Innovation in Practice: Experiment and Improvisation in the Architecture of Henry Chapman Mercer

Charles Lucas Phinney

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Architecture and Design Research

Paul Emmons, Chair
Susan Piedmont-Palladino
Marcia Feuerstein
Jonathan Foote

April 16, 2018
Alexandria, VA

Keywords: Architecture, Ceramics, Henry Chapman Mercer, Improvisation, Innovation, Reinforced Concrete, Tools

Innovation in Practice: Experiment and Improvisation in the Architecture of Henry Chapman Mercer

Charles Lucas Phinney

ABSTRACT

In the opening years of the 20th century, a furor of new and experimental techniques swept the architectural field. The materials and methods of building altered so rapidly that standards of architectural representation and the acts of construction they choreographed appeared for a time to exist without history or precedent. In chaotic times chaos seems all consuming; yet standards are soon established and modes of practice formalized. So it was with the advent of architectural modernity. The beginning of the century was a time of great experimentation and innovation, not only in architectural materials but in the tools and representations of architects, and the methods of building they described.

In this exploration of the relationship between material innovation and architectural representation, we examine the case of the Pennsylvania artisan-scholar Henry Chapman Mercer (1856-1930), and his development of a unique method for construction in reinforced concrete and ceramic tiles of his own design. In the years between 1907 and 1916, Mercer built three buildings of increasing complexity and scale, using methods of fabrication he developed over the course of these constructions. His approach was experimental, innovative, and yet quite different from the prevailing currents in engineering and industry at that time. While Mercer has been studied as a decorator of tiles, as an archaeologist, and as a curator of one the first and finest collections of early American material culture, very little work has been completed on Mercer as architect-builder.

In Mercer's building projects we see a scientific mind and an artistic maker explore and experiment freely, building a bridge between his seemingly disparate worlds: from the Arts and Crafts-inspired Moravian Pottery he founded, to the archaeologically rigorous collection of pre-industrial tools. Mercer focused with great intensity on implements and evidences of traditional craft activities, and it is his particular sensitivity to the traditions and forms of craft activity that renders his architectural activity unique, and pertinent to the question of innovation in method. At the center of his architectural activities, Mercer's construction notebooks, in which he worked out plans, details, and many of his most unique procedural innovations, illustrate a novel comportment of architect to architectural representation, and offer a story of how the making of architecture is, itself, made.

Innovation in Practice: Experiment and Improvisation in the Architecture of Henry Chapman Mercer

Charles Lucas Phinney

GENERAL AUDIENCE ABSTRACT

In the opening years of the 20th century, a furor of new and experimental techniques swept the architectural field. The materials and methods of building altered so rapidly that standards of architectural representation and the acts of construction they choreographed appeared for a time to exist without history or precedent. In chaotic times chaos seems all consuming; yet standards are soon established and modes of practice formalized. So it was with the advent of architectural modernity. The beginning of the century was a time of great experimentation and innovation, not only in architectural materials but in the tools and representations of architects, and the methods of building they described. In this exploration of the relationship between drawing and building, we examine the case of the Pennsylvania artisan-scholar Henry Chapman Mercer (1856-1930), and his development of a unique method for construction in reinforced concrete and ceramic tile of his own design. Mercer has been studied as a decorator of tiles, as an archaeologist, and as a curator of one the first and finest collections of early American tools. Yet very little work has been completed on Mercer as architect-builder. In Mercer's building projects we see a scientific mind and an artistic maker explore and experiment freely, building a bridge between his seemingly disparate loves: from the Arts and Crafts-inspired Moravian Pottery he founded, to the archaeologically rigorous collection of pre-industrial tools. Mercer focused with great intensity on implements and evidences of traditional craft activities, and it is his particular sensitivity to the traditions and forms of making that renders his architectural activity unique, and pertinent to the question of innovation in method. At the center of his architectural activities, Mercer's construction notebooks, in which he drew plans and worked out many of his most unique procedural innovations, illustrate a novel comportment of architect to drawing, and offer a story of how the making of architecture is, itself, made.

Dedication

To my family.

Acknowledgements

With deepest gratitude to the scholar-practitioners of my dissertation committee, Paul Emmons, without whom I would not have found my way to Doylestown, and whose example as a scholar I am continually inspired by; Marcia Feuerstein, who reminded me to find the body in building; Susan Piedmont-Palladino, who helped me to link the literary and architectural hemispheres; and Jon Foote, who set me back on the rock-dust (or rather, concrete-dust) littered path more than once with just the right connection, thank you. To the orbital scholars who have enriched the WAAC with their presence, Amy Kulper, Don Kunze, Elaine Scarry, you altered my trajectory more than you know. With thanks to my colleagues at the Washington Alexandria Architecture Center, Karima Benbih, Jodi La Coe, Francie Hankins, Ezgi Isbilen, Arezou Khalili, Andreea Mihalache, Berrin Terim, and Carolina Dayer, without whom I might not have found my way to the WAAC. Thank you for the many insights and pellucid conversations. To my students at the WAAC and at Johns Hopkins, for everything you have taught me, my warmest thanks.

A project like this one, so indebted to often unpublished sources, would have been impossible to undertake without the knowledge and care of the staff of the Mercer Museum and Research Library, Cory Amsler, Sara Good, Heather Hicks, Rayna Polsky. Your assistance and insights were invaluable. And with thanks to the ceramists at the Moravian Pottery, I'd like to raise a glass (or mug) to you. To the reference librarians and staff at the Johns Hopkins Libraries, thank you for the hundredweight of books portaged on my behalf—and their weightier contents.

To my father, who made the craft of clay a part of my earliest memories; my mother, whose example made me believe in the perennial rebirth of education; and my sister. You formed me. And to Andy and Betty, for the thoughtful notes and references, thank you.

I can't imagine undertaking a project like this without the support and companionship of my family. To Elizabeth, Will, and Andrus, for everything you make possible, thank you for always and ever. We will always have been in this together. I look forward to our next adventures.

Table of Contents

List of Figures

Introduction

The myth of the origin of drawing, as it was handed down to posterity by Pliny the Elder, tells us the story of Diboutades tracing the shadow of her departing lover on a wall. These traditional drawings are merely jigs and templates; they are an intermediary step of a design projection, where the interpreter is the architect. Drawings are then preposterous tools. In the present situation, the drawings must become demonstrations of architecture; they have to be pro-sperous tools for the builder, not a prescription.

- Marco Frascari[1]

Things simply are not 'fit for their purpose.' At one time a flake of flint was fit for the purpose of surgery, and stainless steel is not fit for the purpose yet. Every thing we design and make is an improvisation, a lash-up, something inept and provisional. We live like castaways.

- David Pye[2]

In general the house, like old barns, anthracite coal breakers, old houses in the country before 1800, and, as I believe, like many European castles, was built from the inside, that is to be used first and looked at afterwards, therefore with only a secondary regard for outside construction. The establishment of the height of walls, shape of windows, roof-lines, steeples, chimneys, etc., were finishing touches. The construction was nowhere concealed. From first to last I tried to follow the precept of the architect Pugin. "Decorate construction but never construct decoration." So little was outside appearance considered that we remained in doubt and some fear as to the final result till the forms were removed. The flat towered roof and "Jersey Terrace" were afterthoughts. When the covering of woodwork finally disappeared the general outlines from the east seemed disappointing and out of proportion, but seen from the west the building realized the literary and artistic dreams and memories of travel which had inspired its construction.

- Henry Mercer[3]

PRIOR TO THE OPENING YEARS OF THE 20TH CENTURY, few architects foresaw the furor of new and experimental techniques that would sweep the architectural field. The materials and methods of building altered so rapidly that standards of architectural representation and the acts of construction they choreographed appeared for a time to exist without history or precedent. In chaotic times chaos seems all consuming; and once the dust has settled the new standards of material and organizational practice take on an air of inevitability. So it is with the advent of architectural modernity.

Architectural materials and methods were very much in flux, transforming the nature of practice. New building technologies rose to join established ones, and new habits of practice, both in the architectural office and on the job site, emerged in company with them. This research considers the relationship of material innovation to variant modes of architectural practice by looking at a particular case in which both material and organizational complexity was at a minimum, and in which ad-hoc and improvisational methods took on many of the tasks usually reserved for more formal modes of design and construction documentation. In this setting, free of many of the assumptions underlying standard practice, it may become newly possible to see those enabling constraints with fresh eyes.

The relationship of complexity to innovation, and building technology to the actions and inventions of architects will be at the core of what follows (as it was then.) We might productively begin, then, in a place and at a time prior to the establishment of today's materials and methods; and yet after their invention. This would require a figure uniquely free of preconceptions regarding architectural practice, and of indebtedness to existing modes and mores of building craft.

These questions uniquely figured in the case of the Pennsylvania artisan-scholar Henry Chapman Mercer, and his development of a unique method for reinforced concrete and clay tile construction. At the turn of the 20th century, one material was in its infancy; a second was at the height of its development. A relentless innovator and iconoclast, Mercer did not originate or participate in the architectural conversations of his time. While he worked with many architects in his capacity as a producer of Arts and Crafts tile, he had no formal training in the discipline. And few architects have studied his buildings[4].

Mercer has been studied in some depth as a designer of tiles, as an archaeologist, and as a curator of one the first and finest collections of early American material culture. Mercer focused with great intensity on the tools and products of traditional craft activities, and it is this particular sensitivity to forms of making and the made that renders his architectural activity so different from, yet relevant to, the theories and practices that would shortly follow, particularly in light of the novelty of his material inventions and procedural innovations. From his well-documented, but preponderantly unpublished, explorations, a case can be made for a novel comportment of architect to architectural representation, and through this a re-engagement of the architect with the act of building. The seemingly revanchist products of this eccentric inventor turn out to be surprisingly apropos to new modes of practice and representation.

Mercer was driven by two passions, and given to two engrossing commitments, neither of them architecture. First, he founded the Moravian Pottery and Tileworks, one of the most significant producers of Arts and Crafts tiles of its day. Second, he was one of the first American cultural archaeologists—assembling over his lifetime a collection of nearly 25,000 examples of the tools and implements of early American craft industry.[5] It was precisely these bodies of knowledge, and a method distinguished by free material experimentation and invented craft processes, that enabled Mercer to fuse the mature technology of terra cotta tile to experimental uses of site-cast and precast reinforced concrete construction, and in so doing to pose a fundamental question about the relationship between artifactual, and representational, modes of practice.

From his well-documented, but largely unpublished, experiments and explorations, and from their few but well-cared-for-and-preserved results, a case can be made for a novel comportment of architect to architectural representation, and through this a re-engagement of the architect with the act of building.

A. The Buildings of Henry Chapman Mercer

Beginning at the turn of the twentieth century, the archaeologist-curator and tile-maker Henry Chapman Mercer [Fig. i.1] experimented with structures of reinforced concrete and clay tile, developing a method for construction that was unique in its time. Mercer's experimental buildings demonstrate a road-not-taken in the development of a building technology, featuring hand mixed and placed concrete walls and vaults created with hybrid centerings of wood, earth, sand, and carefully choreographed tile murals.

It is hard to see Mercer's first efforts to build in reinforced concrete as anything but the fumblings of an enthusiastic amateur. In his private communications, Mercer makes no claim to an expertise he does not possess. Even his published and promotional accounts project an aura of crafty disarray; a delight in disorder very much in keeping with the spirit of his times, prior to the age of the modernist manifesto and the machine aesthetic, when the Arts and Crafts movement was at the peak of its influence on the fine and functional arts in England and America. This was a time before the codification of standard practices for building in reinforced concrete, and in Mercer's case we see the invention of a unique method, a portrait of innovation in a time of change. And while Mercer's results were certainly rough-and-ready, the method that produced them increased in sophistication, efficiency, and adaptive capacity with every iteration.

By 1913, Mercer's method was mature, and, with hand tools (many of them invented for the purpose), a gasoline powered concrete mixer, one horse and a crew of roughly a dozen workers, Mercer built a seven-story reinforced concrete museum. [Fig. i.2] Not only was this building intended to house over 30,000 artifacts in more than 50 rooms, but the very collection it housed continued to grow and evolve during the construction of the building—the building, as it rose, adapting to its changing contents. Concrete is rarely employed in architectural processes as flexible or adaptable—as plastic—as their primary material input might suggest. On the contrary, concrete construction often calls for greater attention to tolerances and specifications (that is, for greater control) than alternate materials and methods. Despite many of the claims made in the foment of early modern hyperbole, concrete construction is typically not a free-flowing affair. Every corner, gap, and detail must be drawn and calculated; measured and laid out; and built on site in formwork before the "plastic" material flows in to take its shape. In this the most monolithic, most seemingly-sculptural of materials is in the present configuration of practice one of the least, often requiring more complex carpentry than similar buildings executed in wood, more intricate patterning of metal ties and connectors than similar structures made of steel, and as careful a handling of plumb and level as is required by similar constructions in unit masonry. Concrete may be the most difficult material commonly used in contemporary construction; certainly, it is one in which fine-grain control of built results presents perennial difficulty—commonly accepted tolerances for concrete construction, versus wood or steel, support this observation.[6] And while most treatments of Mercer, and, for that matter, of the early years of reinforced concrete construction more generally, often dwell upon the unskilled nature of the labor involved,[7] in Mercer's builders we see a different condition: of the adaptation of one body of expertise and manual skill (ceramics production) to meet the requirements of a new material condition. This translation of craft technique and technology may provide a unique window onto a birthing of material inventions, and procedural innovations, developed by Mercer and his craftsmen over the course of nearly two decades of intensive research and building production.

Mercer's experiments in the organization of labor and design began in his founding of a ceramics enterprise, the Moravian Pottery and Tileworks, an Arts and Crafts influenced manufacturer of tiles and other architectural specialties. While Mercer had considered adapting established methods of industrial production, or collaborating with experienced tile producers, his Moravian Pottery was in the end an almost entirely novel approach to the manufacture of architectural ceramics. Mercer depended heavily on traditional techniques and local materials, but he also fostered correspondences with modern industrial producers of tile, experts in glaze chemistry, and key cultural figures in the Arts and Crafts movement.[8] As a result of these hybrid influences, Mercer's Moravian Pottery and Tileworks emerged as one of the most successful and long-lived efforts of its kind,[9] and remained in operation from its founding until long after Mercer's death, a tenure of over half a century.

Mercer's first forays into the production of tile occurred in 1897-98. His first use of concrete was in the renovation of a barn into a building for his kilns, sometime between 1899 and 1906.[10] [Fig. i.3.] Very little is recorded about this shed, but in it we can already see some of Mercer's characteristic non-normative uses of concrete: the roof is half concrete, half tile, and those tiles are directly set in mortar.[11] The walls are visibly striated, indicating the concrete was hand-placed in small lifts, and there appears to be a concrete divided-light window—certainly the first of its kind in Mercer's work, as the process of their fabrication was still being worked out in 1908.[12] By 1908, when Mercer began his first major building, a house he would come to call "Fonthill," [fig. i.4] these methods have clearly been considered and developed further. Most of Mercer's experiments in the years between 1897 and 1907 are focused on the development of tiles, primarily for sale to other architects and builders. At Fonthill Mercer uses a dizzying array of different tiles, custom-made for the project and integrated both inside and outside the building; we also see the use of many different mix recipes and forming and shaping methods for concrete, and the first development of one of Mercer's signature techniques, an original forming method for tiled, vaulted, concrete ceilings. His next project was a new and vastly expanded facility for his ceramics manufactory, begun in 1911. [Fig. i.5.] In it Mercer simplified and streamlined some of the more ornate and time-consuming of the methods he developed at Fonthill, while continuing to use the same materials and structural systems. Between 1912 and 1914, Mercer completed two smaller projects, the renovation of a stone farmhouse and the construction of a garage/meeting house adjacent to Fonthill. [Fig. i.6.] Mercer's last building project, built 1913-1916, was a museum for the Bucks County Historical Society (which he seems quite satisfied to note was completed for $38,944.99, almost $1 million in today's dollars,[13] or approximately $40 per square foot, adjusted. [Fig. i.7.] While this sounds extravagantly inexpensive by today's standards, it was relatively typical for large reinforced concrete buildings of its time, as we will discuss further in chapter two.

Figure i.1. Mercer, late portrait, ca. 1927. Image: courtesy of the Mercer Museum Research Library.

Figure i.2. Mercer's crew at the museum. Image: courtesy of the Mercer Museum Research Library.

Figure i.3. Concrete Kiln Shed at Aldie. Image: courtesy of the Mercer Museum Research Library, collection on loan from the Moravian Pottery and Tile Works.

Figure i.4. Fonthill. Image: courtesy of the Mercer Museum Research Library.

Figure i.5. The Moravian Pottery and Tileworks. Image: courtesy of the Mercer Museum Research Library.

Figure i.6. The "garage" at Fonthill. Image: Library of Congress, HABS PA,9-DOYLT.V,7A—1.

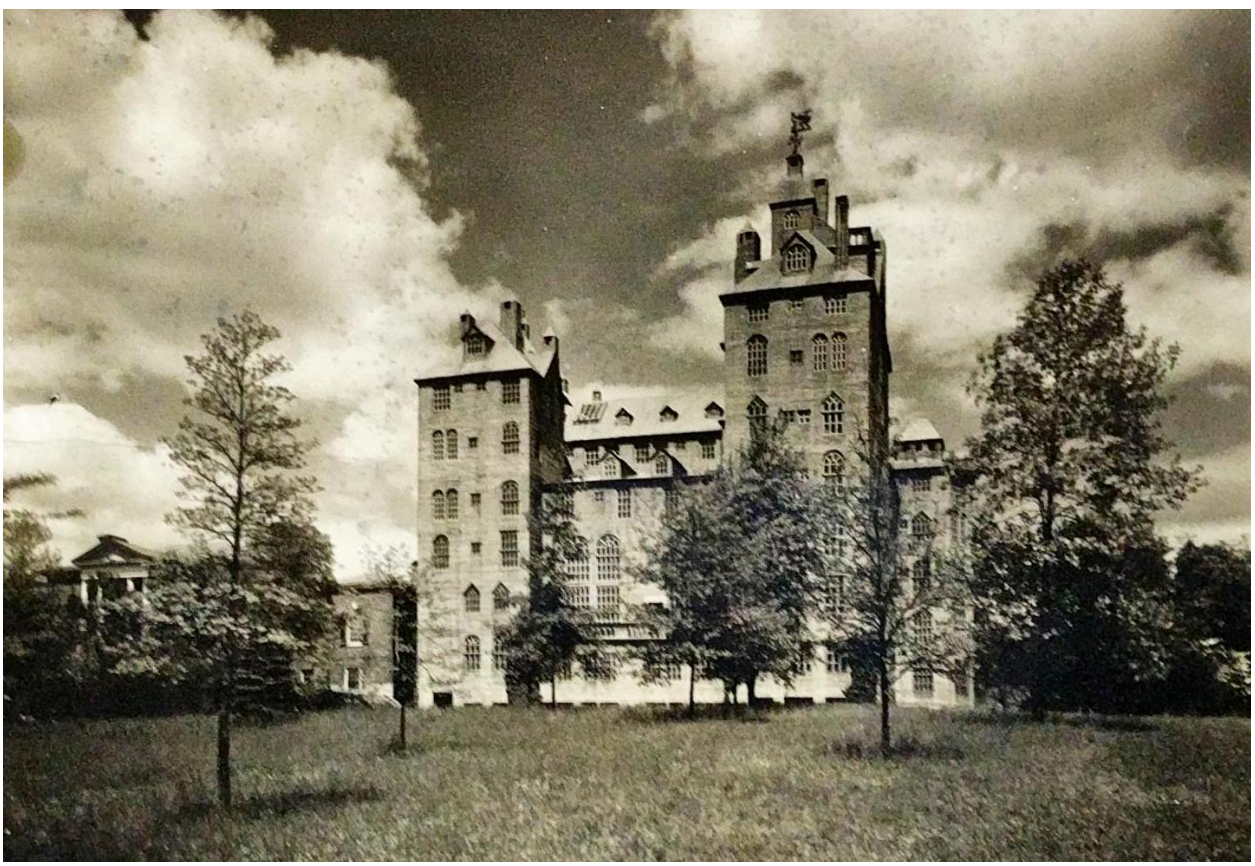


Figure i.7. The Mercer Museum. Image: courtesy of the Mercer Museum Research Library.

B. Justification of Interest

Despite their novelty, and significant position with regards to the historical trajectory of his primary two materials (at the apogee of arts and crafts tile and the beginning of reinforced concrete), Mercer's projects have not been the subject of significant scholarship.[14] This is probably because of two factors. First, the buildings Mercer produced are manifestly not modern, despite their time and materials. This may not have been a revanchist anti-modernism so much as the natural reticence of an artistic temperament which came to maturity in the late Victorian era, and had personal experience of the spirit of the times during Charles Eliot Norton's tenure at Harvard, where Mercer studied art, archaeology, and law[15]. Also, Mercer's wide-ranging travels and professional expertise as an archaeologist would have given him a lens of unusual distance through which to view the trends of his day, and a healthy skepticism regarding Modernism's claims, particularly those of historically significant novelty.[16] The past hundred years of modernism and modern building have changed things, and Mercer's buildings are often received today as eccentric and eclectic[17]—despite their construction only a handful of years before the publication of Le Corbusier's *Vers Une Architecture*. But whether revanchist or merely retrograde, this in itself would not explain the reticence of architectural scholars to take up the questions posed by Mercer's work. The second problem interfering with serious consideration of Mercer's buildings is that they seem to have been built without any of the conceptual or material apparatus of architectural practice—there are no plans, as an architect would draw; they are not possessed of any single identifiable historical "style" or formal order—and so they seem to belong to a narrative of idiosyncrasy and individual craft. This view places Mercer's buildings outside of the main stream of architectural discourse and practice. In a narrow sense, and yet manifestly at first glance, Mercer's buildings are not architecture.

Often those who give the projects a second glance, however, are drawn to them—for their irrational exuberance, their storytelling polychromy, or their dark, moody, labyrinthine spaces [fig. i.8]. Even at their most expansive, Mercer's spaces display a gothic obscurity. [Fig i.9.] And while Mercer certainly evinced many of these personality traits himself, he was also a rigorous, exact, and painstaking planner and scientific mind. It is fortunate that he was, because he kept and preserved copious records of the design and construction of his buildings; and while these records do not look like the typical products of architectural representation, they mediated between Mercer's ideas and experiments, and his work crews engaged in the daily labor of building. Looking closely at these documents, we can trace how the work of building was conceived and choreographed, how this work was differently accomplished by Mercer's methods, and thus how these methods may constitute a reinvention of architectural practice in new terms.

Figure i.8. Labyrinthine passages at Fonthill. Image: author, courtesy of Fonthill Castle.

Figure i.9 The large studio/showroom at the Moravian Pottery. Image: author, courtesy of the Moravian Pottery.

Certainly, Mercer's techniques for working in concrete and tile were unique, and developed without significant influence from extant standards of practice. In the chapters that follow we will look in detail at several of Mercer's most original contributions to building craft. Mercer was responsible for the invention of these practices; and his construction notebooks record the origination, refinement, and communication of particular techniques in great detail. The notebook, in a number of ways, served as Mercer's primary construction document, and includes many of the types of drawing we would expect: plan, elevation, and section drawings (wholly or partially orthographic, and often sketchy and not to scale), details, usually annotated in a manner similar to specification (something we will examine in chapter 6), dimensions, spatial programming diagrams, and materials lists and (partial) schedules; but the notebooks also contain a number of things that don't seem at first to belong: dated accounts of construction progress, illustrations of precedents both historical and local, musings on poetry, philosophy, and family history; and, in the case of the museum notebook, the emerging categories of material culture Mercer was working out in conjunction with the spatial program of the museum. Yet all of these forms of documentation were, in the notebooks, patently partial and informal, often a fusion of image and text, written usually in pencil, and intermingled without apparent order or hierarchy (this last is a misleading semblance, as we will see).

Can architecture be had without drawings? In the present day it is hard to imagine—as a project manager I worked with once quipped, he was afraid he killed more trees with drawings than he ever did with building[18]. Yet today's paper—or post-paper—jobsites[19] are of relatively recent advent, historically speaking. Renaissance architects were more likely to present their patron—and their builder, too—with a large-scale, detailed model than with comprehensive drawings. And, unlike today's presentation models, the renaissance model was vested with full authority to determine subsequent construction dimensions, materials, and assemblies.[20] These models were used much the way architects today use construction documents: to instruct the builder and quantify the work[21]. As we will see, Mercer, at Fonthill, used this same method to supplement the crude and searching plans held in his construction notebook.

Construction representations, whatever their material form, always walk a line between what is made explicit and what remains tacit, and Mercer's detailed notebooks, unlike more traditional representations, often tell both sides of the story, recording both the information communicated to the builder—the exact material components and the procedural sequences of construction—as well as making visible, at least in part, the process of communication itself. Thus these documents stand to tell us a unique story about the origin of a building practice, and the relation of that practice to the conceptualization, representation, and coordination of construction activity.

C. Warrant

This study is at heart neither an investigation of architectural history nor of architectural technology. It is a study of design method and representation; of the tools of building and the tools of architects; of the invention of practice and the nature of the architectural imagination. The materials and methods of construction, and the architectural documents through which they are put in play, form a complex that is often taken as given, forming a context within which innovation in the field is circumscribed; or this larger complex of instrumental means and methods is ignored as irrelevant to whole bodies of research, which draw their warrant instead from related fields such as art history, socio/ethnographic studies, or materials science.

All of these disciplinary lenses and mirrors are of course of great import for architecture; but sacrifice a relevance to practice for what they gain in novelty. On the other hand, researches drawn up on the basis of current architectural practice risk foreclosing on rich possibilities for innovation in method, because of assumed incommensurabilities between what was and what is: and an unwitting trust in the telos of historical precedent, from which their own work holds itself separate, and on which its fabrication is based. We honor architects that 'make it new.' But we would do better to seek the ways they make new practices.

This is the context within which the origin story of a material and method may be told; and in this story I hope to create a telling portrait of the workings of innovation in architectural practice. Like Don Quixote, we may ponder the priority of the path of arms (*praxis*) versus the path of letters (*poiesis*); but in this case we have simultaneously a question of architectural representation, and material practice, those often irreconcilable poles of the discipline. In the false bifurcation of technical and artistic discourse, emerging at this time, we see augured the disciplinary split prevailing within architecture today, which began to assume its seeming inevitability in these very years.

We might productively begin, then, in a place and at a time in which these standards were not as fixed as they are today, and with a builder who worked to invent them anew. Mercer's three major projects, taken together, illustrate the development of a unique method for construction in a then-novel material, from conception, through experimentation and application, to refinement and systematization. As such this subject allows the close examination of the nature and trajectory of material innovation, and the role of architectural representation in methodological innovation in building culture.

We are far more reliant than we think upon improvisation and tacit knowledge in the development of new methods, and that this reliance follows a natural trajectory of diminishment as a technique is refined. Mercer's case provides an extreme example of the minimization of written documentation, and illustrates the necessarily hermeneutical relationship to construction documents adopted by craftspeople. An analysis of the limits and possibilities of construction documents, and an expanded definition of what they are and how they might work, requires an understanding of the nature of craft hermeneutics.

For the architect, this opens the possibility for tacit understandings, mobilized by construction documents, to be taken up into the representational toolkit of the designer. It may be that Mercer's highly economical, site-specific innovations presages present-day reformulations of design practice from the enlightenment ideal of perfect knowledge to a nuanced, nimble, and adaptable practice. It is just such a close look at a 'site of innovation' that is the focus of the present study: to trace and reconstruct the choreography of decision-making that selects, from all the range of possibility, a set of methods for codification and improvement. In short, this is a study of how the making of buildings is itself made.

D. Mercer: A Brief Biography[22]

Henry Mercer was born in 1856 in Doylestown, Pennsylvania, at the home of his maternal grandfather, the former U.S. Senator Henry Chapman. His father, an officer in the U. S. Navy, resigned his commission shortly thereafter and the Mercers moved to rural Claverack, or "clover fields", New York, a town of about 3,500 people, where they attempted to live as farmers. After three years they returned to Doylestown, and young "Harry" was given over to the tutelage of a Scotsman, Thomas Hughes, who raised Mercer on stories of historical adventure and discovery.

At the age of nine Mercer was sent to boarding school, which he attended until it closed in 1869. There he was taught by a Reverend Mahlon Long, one of the school's founders, and Mercer was encouraged to explore, recollecting later that "the whole country side was our play ground."[23] When he was fourteen, Mercer's mother took him with her to Europe, where Mercer's aunt Elizabeth had lived while her husband, the diplomat Bigelow Lawrence, served as Consul General. There Mercer explored the parklike grounds around the villa Torrigiani where the Lawrences were lodged, exploring, among other things, the tower of the Torrigiani Garden. [Fig. i.10.]

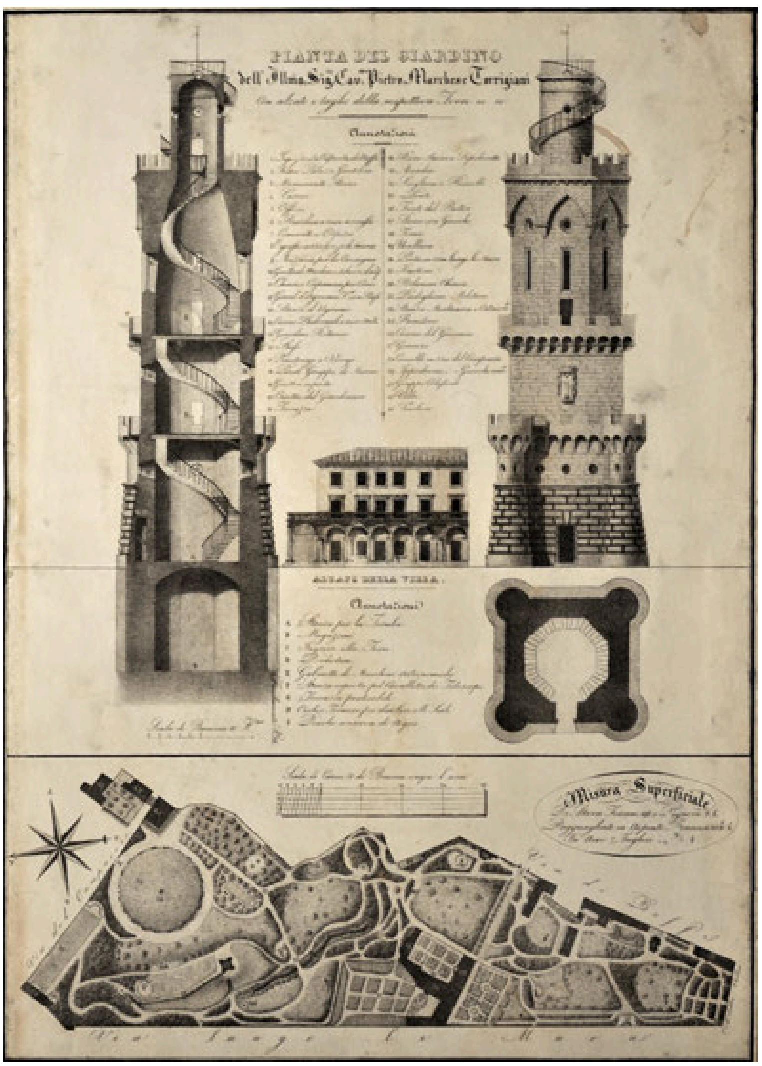


Figure i.10. The Torrigiani tower, built to house a library and a collection of astronomical instruments, included a spiral stair and top floor observatory. Image: SCI-FI/Storie Della Scieza a Firenze / public domain.

Upon the death of her husband, Elizabeth Chapman Lawrence packed up her things in Florence and took her sister and sister's offspring on a tour that lasted the better part of a year and included much of Europe, including Venice, Vienna, Prague, Dresden, Berlin, Amsterdam, The Hague, Cologne, Wiesbaden, Frankfurt, Heidelberg, the castles of the Rhine, Brussels, Ostend, London (where the crystal palace made an impression), Oxford, Edinburgh, and many historic sites between. Mercer completed his secondary schooling at the Mohegan Lake School in New York, and matriculated to Harvard in 1875.

At Harvard Mercer studied Latin, philosophy, and history, including, in his junior year, art history with the noted scholar and proponent of the arts and crafts Charles Eliot Norton. After graduation he spent a year in Doylestown and helped to found the Bucks County Historical Society, after which he relocated to Philadelphia to attend the University of Pennsylvania law school. At the end of 1881 Mercer passed the bar and left for a winter trip to England, France, Italy, Egypt, Corfu, and Austria. It was on this trip that he first experienced repeated symptoms, and was diagnosed with, gonorrhea, and the disease would afflict him recurrently throughout his life. Between 1881 and 1890 Mercer traveled extensively in Europe and especially Germany, Austria, and France, where he lived on and traveled by a series of purpose-built houseboats. [Fig. i.11.] He collected artifacts and investigated key sites of Roman and Medieval history. Stateside, he visited sites of both historical and family significance, and continued to develop his interest in the artifactual evidences of history. In 1885, as an independent scholar, he published *The Lenape Stone*, an investigation into the provenance of a pictorial artifact of purportedly ancient and Native American manufacture. When, in 1890 the University of Pennsylvania formed an Archaeological Association, Mercer was an early member.

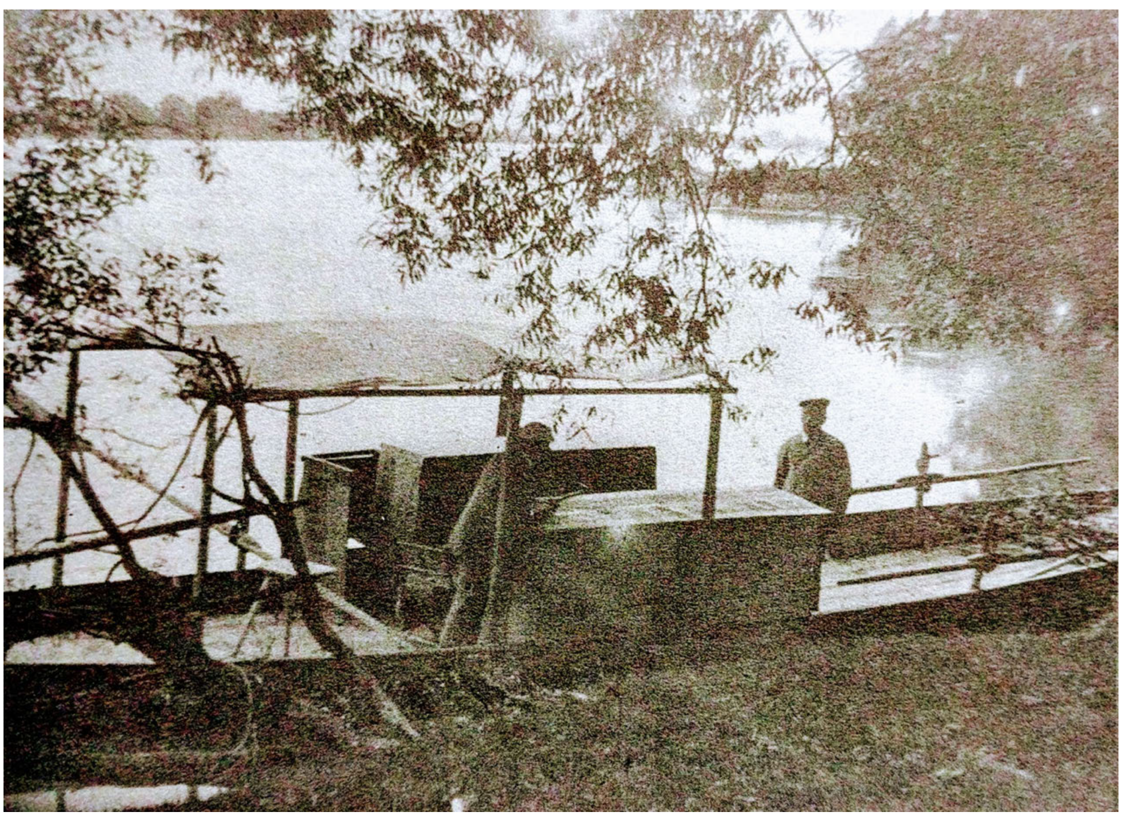


Figure i.11. Mercer's houseboat ca. 1886. Image: Mercer Archive, BCHS.

In these years Mercer occasionally donated some of the various fruits of his collections and investigations to the University Museum[24] [fig. i.12], and when in 1891 the university consolidated its museum collections under the newly formed Department of Archaeology and Paleontology, Mercer was one of ten scholars appointed to positions in the new department. From this point onward Mercer turned his increasingly scholarly attentions to archaeological sites, digging in Europe in 1892-93 and from 1894 onward in the Americas. During these years he was active in the growing community of American archaeology, serving as a member of the U. S. Archaeological Commission at the 1893 Columbian Exposition in Spain, and as an associate editor of *The American Naturalist*, a key scholarly periodical in the field. In 1895 he led a major expedition to the Yucatan Peninsula, which resulted in his second book, *The Hill Caves of the Yucatan.* He also had an archaeological workshop built on the grounds of the family home, Aldie, and hired an assistant, the young Frank Swain, who would become Mercer's closest collaborator in all of the enterprises that followed.

Figure i.12. Several of Mercer's contributions to the university museum: African carrying stick; Neolithic stone hoe head; Native American game. Images: Penn Museum

The book that was to be Mercer's last archaeological treatise, *Researches upon the Antiquity of Man in the Delaware Valley and the Eastern United States,* collected much of his shorter work from the preceding years; but by the time the book was published Mercer was in the process of relocating to Doylestown, having resigned his position due to personal conflicts, lack of "space and 'turf' problems at the burgeoning University Museum."[25] This marked a turning point in Mercer's life.

Beginning in 1897 Mercer turned his attention to the collection of pre-industrial tools. That spring and summer he explored Bucks and surrounding counties for stove plates, ceramics, and other artifacts, and investigated the defunct Pennsylvania-German potteries falling into ruin in the area. In July he exhibited his finds briefly outdoors at the summer meeting of the Bucks County Historical Society, and that fall he staged a more substantial exhibit at the county courthouse (where the historical society held its meetings) entitled "The Tools of the Nation Maker." [Fig. i.13.] By 1899, however, the other leaders of the historical society, adverse to the preservation of what they perceived of as junk, and to several of the ways Mercer proposed to identify and record the provenance of such artifacts (such as allowing the contribution of histories from those Mercer called "intelligent persons who would not write,"[26] and were presumably the makers and users of these tools) obstructed Mercer from admitting these everyday items to the collection of the society, and from publishing about his findings. He would quit his association with the society that year.

Figure i.13. Tools of the Nation Maker. Image: Mercer archive, BCHS.

Beginning also in 1897 Mercer explored the possibility of reconstructing one of the fading potteries he visited, or starting one of his own. This effort, which is described in some detail in the pages that follow, would ultimately lead to the founding of the Moravian Pottery and Tileworks, which was originally housed in the converted archaeological workshop on the grounds of Aldie. There Mercer, with the help of Swain, and with an increasing number of employees recruited from the unskilled labor pool of the Doylestown area, began to fabricate terra cotta tile and other architectural specialties. After copious experimentation into clay bodies and glaze formulae, the Tileworks filled its first order in 1899, and Mercer turned his full energies into the business. In 1900 he traveled to the Paris Exhibition, and exhibited tiles at the Pennsylvania Academy of Fine Arts Club in New York, and was elected to the position of "craftsman" in the Boston Society of Arts and Crafts, an association that would prove long and fruitful for Mercer. Mercer was well known and liked by the society, in which his aunt Elizabeth was active, and whose founder, Charles Eliot Norton, Mercer remembered from his Harvard days. In 1902 he was elevated to "master" in the society.

The Moravian Pottery and Tileworks soon began to fill prestigious commissions, including the private museum of Isabella Stewart Gardner in Boston [fig. i.14], the Pennsylvania State Capitol, and the National Zoo in Washington, D. C. As his operations increased, Mercer expanded the facilities at Aldie, building two more workshops which he called the "upper pottery" and "lower pottery." These outbuildings, which served as workshop and kiln space (only one of them known to be photographed, shown in fig. i.3), served as the occasion for Mercer's first experiments with concrete as a building material. These experiments may have been prompted by Mercer's bother's use of the material in his sculptures and throughout the grounds of Aldie, which we will discuss further in the next section. Mercer's mother died in 1903 and his aunt Elizabeth in 1905, and Mercer turned ever more to his work and his collecting efforts.

Figure i.14. Isabella Stewart Gardener's Fenway Court. Image: Thomas E. Marr / Boston Public Library / Massachusetts Digital Commonwealth / CC BY-NC-ND 3.0.

Mercer soon rejoined the Historical Society, and they accepted his *Tools of the Nation Maker* collection—which continued to grow—into their new building, on a site just south of downtown Doylestown. With the death of his aunt Mercer had received an inheritance, which he used to buy property in the northwest of Doylestown, including the Thierolf farm, including an 18th century farmhouse and barn. Rather than move into the farmhouse, however, Mercer began to plan a home for himself to be built on the site.

In 1907 Mercer's concrete kiln building at Aldie would receive mention in the new magazine *Cement Age*, whose editor, Robert Lesley, took a particular interest in Mercer's projects, featuring them several times in the pages of his magazine. Mercer intensified his planning efforts and in 1908 he began work on the building that would come to be called Fonthill. Mercers architectural output would be limited to the ensuing decade, and consist of three substantial buildings, all of reinforced concrete, and all completed using a consistent suite of invented building methods and technologies. These projects and methods form the core of the discussion that follows.

During these years also the Moravian Pottery operated at peak productivity, and Mercer vastly expanded the range and complexity of the tiles they produced. With the completion of the building now called the Mercer Museum in 1918 Mercer turned his attention wholly to the collection of artifacts and the productive activity of the Moravian Pottery. In 1921 he received a Gold Medal in Allied Arts from the American Institute of Architects for his contributions to architectural ceramics; but no such recognition would follow for his work in reinforced concrete.

In the 1920's Mercer continued these activities, and remained deeply involved with community, contributing both scholarship and materially to the Bucks County Historical Society and sponsoring the Doylestown Nature Club. He also, like a number of architects late in life, turned to the writing of fiction. He died in 1930 at Fonthill.

E. Structure of the Dissertation

The first part of this account describes the materials and methods unique to Mercer's practice. While the focus is on the range of materials he used for building, particular attention will be paid to two of them: concrete, because it formed the structure and enclosure of Mercer's buildings; and clay tile, because it was in the development of unique tiles (a development that altered and was altered by a rich dialogue with building construction) that Mercer's characteristic stance towards experiment and improvisation first emerged; and it was in the context of this body of preexisting craft knowledge that his new practices took shape. Even as he began to find success as a manufacturer of tiles, Mercer continued to see the limits and possibilities of his new field with the eyes of an archaeologist, a lens he never wholly left behind.

Chapter one, which consists of an account of Mercer's primary building materials, begins in the description of this lens: Mercer's time and training as an archaeologist at the University of Pennsylvania formed his unique view of materials as evidential, and inherently cultural, a view not widely shared at the time. When Mercer came to use his first materials, he came to these materials as an archaeologist and collector. His primary ceramic material, an earthenware clay local to his projects, dug and processed primarily by hand, fired and glazed in Mercer's own kilns, and installed, more often than not, by his own expert installers, was the same clay used by his antecedents in ceramics art and production, in a literal sense locally, and in a metaphoric sense globally. His fascination with concrete began not in modern construction technologies but as a family affair. His brother, a sculptor, was an early adopter of the material, exploring its potential both as a unique vehicle for the production of identical copies of classical statuary, and also as a durable material for use in landscape design, everything from reflecting pools to garden structures (as well as a smattering of the aforementioned sculptures). [Fig i.15] William Mercer began using concrete as a setting for glass mosaic work, but soon moved on to the reproduction of historical fragments garnered from his travels in Europe. For Henry Mercer, however, it remained a material that was worthy of respect in and as itself,[27] rather than in sculptural modes, and served primarily as a matrix and neutral background for his tiles.

A ROMAN URN FOR FLOWER GARDEN.

GARDEN ORNAMENT, ITALIAN RENAISSANCE.

ROMANESQUE COLUMN, NATIONAL MUSEUM, MUNICH, SURMOUNTED BY HEAD OF A SATYR.

Figure i.15. Images of William Mercer's castings of historical spoglia, from the magazine Cement Age, Volume 6, 1908: 365. Note particularly the ready combination of architectural fragments with contemporary sculptures, as in the Satyr-headed column. Image: Public domain.

Mercer's formwork also receives an introduction in this chapter, though more extended consideration will follow in later chapters. Chapter one continues with a consideration of the hybrid nature of Mercer's constructions, in which concrete and tile would ultimately form parts of a single, and simultaneous, method. The development of this method is considered in light of historical precedents, from which it may be distinguished. The techniques Mercer invented continued to mature and change over the course of his projects, and this development is part of what suggests that we have, in this case, not merely an approach to building characterized by randomness and willful idiosyncrasy, but a method in which ad-hoc and improvisational solutions were tactics for building in a nuanced, tactile, and site-specific manner. The chapter concludes with a discussion of the systematic uncertainty of Mercer's methods, and how it was orchestrated by a particular form of documentation: the construction notebook.

Chapter two addresses the structure of the construction notebooks which Mercer used in each of his three major projects. All contain a similar variety of drawings—building plans, elevations, sections, and details—though these are always loose pencil drawings, with significant but incomplete dimensions and copious annotation, particularly in the case of building details, which are often described in terms of the sequential steps of their fabrication. Not every detail in Mercer's buildings receives a full description in the notebooks, but the most unique of his details are well illustrated, and these passages are often accompanied by sketches of architectural precedents—for example, in the notebook for Fonthill we find many pages of drawings of historic and contemporary windows, in projects ranging from abbeys to townhouses, followed by a few densely written and illustrated pages exploring an original method for precast concrete window fabrication. When Mercer revisits a detail in a later project, as he does with the precast windows, he reiterates this cycle but dispenses with the copious exploration of precedents. Because of its preponderance of such explorations, the Fonthill notebook is by far the longest, and contains the greatest number of these 'digressions'. Many of these seeming digressions, however, anticipate ensuing passages of a more instrumental bent.

After discussing the various modes of representation in the notebooks, we turn to the model Mercer built as part of the design of Fonthill. This was a far from normative model, with regards to traditions of architectural model-building: it was, rather than a representation of future built form (or 'baby building', as Filarete famously proposed) instead something like a three-dimensional sketch, executed in clay, utilized to explore facets of the design which did not lend themselves to orthographic projection or mercer's narrative detailing sequences. (Such as roof slopes, or the highly variable floor heights and interstitial circulation.) Much has been made of this model by the several authors who have written on Mercer's design process,[28] but a close examination of its details (such as they are) and its considerable distance from the finished building, render such claims of its authority over the design process (claims first articulated by Mercer himself in later reminisces) a natural, if somewhat implausibly romantic, characterization of its role.

Mercer relied on the notebook, the model, ledgers accounting for material and man-and-horse-power, a system he first developed at the pottery and entrusted to his assistant Frank Swain. In addition to the ledgers, the Mercer archive held in the Spruance Library of the Bucks County Historical Society has preserved much of Mercer's correspondence, and many of the incidental notes and paraphernalia of his various occupations and researches. Notable among these are records of experiments which suggest a methodical process of trial and error in the formulation of glazes for tile making, as well as several other related processes. This speaks to Mercer's training, and grounds even his most ephemeral notes in the rigor of archaeological habits of mind, and its ethos of precise and careful documentation, and preservation, of the found. These documents, taken together, tell the story of a concerted approach, scientific in its origin, to the formulation of experimental methods for fabricating increasingly ambitious sequences, narratives, and constellations of tiles, and ultimately of entire buildings. For Mercer, however, it was not so much the invention of architectural products, but of tools and processes, that is, of practice itself, that most distinguishes his contribution to these fields.

Mercer's invention of practice is the subject of chapter three. The chapter begins in a consideration of the site where many of Mercers' techniques had their origin: in his Moravian Pottery. In that setting Mercer fused the primarily unspoken craft practices of traditional Pennsylvania German potters with modern innovations in ceramics production. His development of a functional system for producing durable and colorful tiles from clay local to his region was the fruit of several years' arduous research; and Mercer did not scale back his experiments and innovations once initial success was achieved. Instead, he continued to advance the complexity and adaptability of his tile installations over the years of their production.

Chapter three then turns to a consideration of the nature of experimental practice, beginning in the sciences (where the most notable scholarship on this subject has occurred). Bruno Latour's landmark analysis of biological research, and the schema he developed for understanding the structure of scientific discovery, is, perhaps surprisingly, a useful schema for addressing the possibility of architectural research; and a consideration of architectural fabrication as a research practice suggests the historically central significance of templates and tools in that setting. Mercer's precast windows are then discussed in detail as a key example of how the invention of a product entailed, for Mercer, the invention of new tools or templates; and the ways in which the heritage, and capacities, of these tools were predicated upon the extant craft knowledge of Mercer and his workers. This will return us to a fuller consideration of Mercer's innovative practices in the pottery, and their configuration as the very sort of research practice Latour describes. Mercer's windows are evidence of the inherent materiality of the invention of practice, and a consideration of that materiality raises the question of how tacit craft knowledge in mobilized to shift domains and provide reliable approaches for the handling of novel materials and methods.

This leads us to chapter four, wherein the contextual knowledge of material practices is considered as a key ingredient in Mercer's design process, as evidenced in his notebook passages that record the development of a detail for building cornices. This passage in the notebook is unusually detailed, and so we are provided with an almost play-by-play description of the workings of the architectural imagination, and its free motion between history, theory, art, and material practice. In the development of the cornice detail we find a portrait of the act of architectural detailing; and the various facets of this process, as made visible in Mercer's notebook, are discussed in detail. We arrive back at the same conundrum which confronted us at the end of chapter three, and so we find that, if we want to understand the 'invention of practice,' the subject of the preceding two chapters, we must turn our attention to the way that tacit craft knowledge is activated by the various tools and documents we bring to bear. Understanding the activation of tacit knowledge by templates and tools, and the invention of new tools and templates through the application of such knowledge, allows us to consider the way that knowledge moves in innovative settings, and therefore the aspects of Mercer's operation most responsible for its innovative character. This turns out to have everything to do with his abiding passion for the collection of preindustrial tools.

Chapter five begins in a consideration of those tools, describing the genesis of their collection and the planning and construction of the museum to house them. Mercer's museum is a unique example of a building coming to be in conjunction with its reason for being. While much of the field of architecture is dedicated to what is colloquially called "custom" work (indeed, in the residential sector the work of architects is almost always distinguished by that word) very few of these custom buildings take into account the precise nature of their contents. Instead, the various uses of the building are abstracted as a program document, which can be as simple as a list of square footages or as complex as a highly relational database; they can even come to inform the qualitative, as well as quantitative, aspects of the design.[29] But even at their most nuanced program documents are responses to an external list of categories and purposes. This list is fixed as early as possible, and guides the distribution of rooms and spaces within the building. With Mercer's programming of the museum, as it is drawn up in the construction notebook, we see something different: a system of ethnological classification for the various tools and artifacts of craftwork, with particular emphasis on manual craft, coming into being in conjunction with the spatial distribution of the building. Mercer's schema looks nothing like his building. But it informs his building; and the rooms of the building, as they are planned in the construction notebook, inform the classification system for the collection.

Each room of the museum is devoted to a particular craft, and the display of tools and products in various stages of manufacture tells the story in a particularly holistic way, functioning as both a vignette, and as an encyclopedic array—a display not just of the range of tools belonging to a particular craft, but the range of diversity in each kind of tool. This can be understood, in terms of the psychological theory of affordances, as a way of providing an expanded and polyphonic account of the craft activity at hand. Affordance theory also provides a way of seeing the instrumentality of the tool in a non-reductive manner, and critiques of technology, such as those undertaken from a phenomenological standpoint, can be reconciled with the instrumental use of tools, if we can come to understand the significance of tools in the larger context of their expert use. Chapter four continues with a consideration of what these insights about the nature of tools, provided by Mercer's museum, may offer to the consideration of Mercer's development of specifically architectural tools, and the network of tacit knowledge which they presuppose, activate, and in which they are inextricably entwined. Mercer, maddeningly, did not preserve his own invented tools of building fabrication, despite the construction of a museum for just this purpose. The chapter concludes with a consideration of how the affordance-structure of expert tool use may be expanded to consider the non-manual tools of the architect, linking the patently instrumental artifact with the much-more-ambiguous condition of ephemeral documentation and the oral transmission of building knowledge, particularly as these phenomena are evidenced in Mercer's construction notebooks.

Chapter six takes up the question of ephemeral documentation directly, analyzing the differing grammatical structures employed in Mercer's notebooks and relating them to the characteristic grammars of standard forms of architectural documentation. The relationship of the document to the site of work, and to the daily progress of construction, illustrates a method for nuanced and adaptable construction practices. The flexibility provided by this form of documentation can be seen as one of Mercer's key innovations, and the next part of the chapter examines flexible planning in a historical context, marking its presence in those early Renaissance practices in which the architect was, for the first time, held separate from the site of construction. An argument can be made for seeing the diagram, as the paradigmatically ephemeral architectural representation, to be a corrective element rooted in the origin of formal documents. It may also be analyzed in light of recent developments in information theory, which confirm that even the most inconsequential of architectural doodles may, in the right context, hold meaning. The context-dependent meaning of these communications is a limit, but also a source of great power: the leanest communications can also be seen to have great efficacy. This understanding of architectural ephemera places such representations in the context of the experimental practice first theorized in chapter three, and suggests that they deserve fuller consideration as an essential dimension of architectural practice. Dialogue, naturally, is one of the most evanescent of these 'ephemera', and yet what we find when we examine Mercer's notebooks with the tools of linguistic analysis is that many of his most detailed passages function in the same mode as construction specifications. This lexicological analysis suggests the possibility of an 'archaeology of the specification', and supports the contention forwarded in chapters four and five, of a link between the material tools of construction and a certain kind of projective document. Projection, it is argued, functions as an activation of the stock of instrumental knowledge at hand, that is to say, of the field of affordances created by the nominal conjunction of person-place-thing, the operatory chain of a particular activity. Thus the 'projection' which functions at the core of architectural documentation is not graphical or geometric, but temporal, and hermeneutical. This brings us to a close examination of the way architectural documents work; and the contrast between Mercer's documents and standard practices suggests that formal systems and experimental practices, while often at odds, need not be.

Chapter seven returns to a consideration of Mercer's ceilings in an attempt to understand how Mercer's unique intensity in this regard may illustrate a particular stance with regards to architectural representation and placemaking. The lessons of Mercer's notebooks are counterintuitive, but provocative, and suggest that effective architectural documents may need to be reconsidered as something more than acts of representation. The role of drawing and specification, the provision of broad tolerances, and the improvisational capacity of our documents are all at stake in such a reconsideration. The relationship of innovative practice to improvisation, considered in light of Mercer's approach to detailing and construction tolerances, suggests that we might go about describing, and effecting, buildings on a different basis than the one to which we are accustomed. This puts in play the possibility of a new economy of drawing, in which the unique possibilities of sites, materials, and constellations of craft knowledge stand to enrich the built environment beyond the capacity of its designers to preconceive. The economy of such documentary practices is predicated upon an understanding of craft, and an openness to opportunity we find exemplified in Mercer's architectural works.

PART 1: Materials, Methods, and Documents

Chapter 1: Materials and Methods

"We must go back to Virgil. The real meaning of the poet is in words the motto leaves out,—the idea of final victory. Read out the text: Tendimus in Latium."

"You mean that they went on to Latium, in spite of the shipwreck and the misfortune."

"Yes,—they founded Rome."

"Splendid!" exclaimed Pryor. "I lost that in Virgil. But it reconciles the motto to the vision."

"Exactly," I agreed. "The castle becomes an ideal. That we hold on to, in spite of the Devil and all his angels."

"Just as I thought it was from the first, without knowing why," said Pryor.

"Now that the stone is gone, it is fortunate that I have seen your castle, thunderstorm included," I continued, "or I should never have known what you were talking about. So much for hypnotism. But how wonderful, how astonishing it is, merely as a picture! Don't you think so? Those unearthly pinnacles that pierce the clouds! If I were a painter, as you are, and saw a thing like that, I would feel that I had got hold of my ladder of fortune and only needed to climb up—up—up."

"But the ladder is yours as well as mine."

"Why? I am not a painter, and never could be."

"What are you?"

I got up, seized his hand, and looked deep into his glowing eyes. "I didn't know, till just now," said I. "I thought I was a politician. But I have decided that I am an architect!"

- Henry Chapman Mercer, "Castle Valley", *November Night Tales*

LET US BEGIN WITH MERCER'S MATERIALS, as they were limited, consistent, and characteristic throughout his projects. In discussing their sources and applications, we can begin to mark out the territory Mercer occupied with regards to the past and the future, for him considerations of the widest scope. That he thought like an archaeologist is hardly surprising; that he thought architecture *through* archaeology begins in his materials of building: their origin stories in the taking-up of these 'raw' materials into building process and culture; and their future, and fragmentary, significance.

A. Clay Tile

Earthenware tile was one of Mercer's two primary construction materials; was likely the reason he learned enough about reinforced concrete construction to pursue its use; and was, in its many varieties, the primary product of his ceramics manufactory—an enterprise which served as the premise for one of his key building projects and was the primary source of funding for his architectural activity.[30] Understanding Mercer's relationship to architecture may begin in biography; material sources and properties; or in analysis of the extant buildings; but understanding how he came to uniquely see architecture and choose clay tile from among the range of possible materials might also productively begin before his experiments in building; before even he began his design and manufacture of tiles, in his interests as a scholar and curator at the University of Pennsylvania

The Pursuit of Archaeology

Before he left the university museum and his position as an archaeologist,[31] perhaps even as early as his "vexatious"[32] investigations in the Yucatan, Mercer was considering options and pursuits outside of his scholarly interests. In his academic publications, between 1893 and 1897, we see a marked shift from topics of general interest to the field of archaeology to essays on the artifacts and technologies of craft manufacture and particularly of pottery. [33] These are supplanted beginning in 1898 by essays in the academic and the popular press on the material culture of his region, quite abruptly no longer written for an audience of archaeologists. To understand Mercer's turn from his position as an academic to the production of Arts and Crafts tiles, we should explore this shift.

Years later he would read an account of this transformation of his life's work to the Bucks County Historical Society:

> the pottery came as a very unexpected growth, a thing as it were, suddenly forced upon me by others as a result of a series of disappointments, grievances and contentions, rather than through my own deliberate choice. [...] I had no more intention of giving up Archaeology for the sake of a pottery, than I had of emigrating to Australia, and if I had not been forced out of my position in Philadelphia the summer of 1897, I never would have come to Doylestown and made the collection called the Tools of the Nation Maker for this society, and if I had not made that collection, I would not have become associated with this society as I have been. But the singular part of it is, that if this collection, or myself or some unaccountable faith had not stirred up another hornets nest in this society, almost worse than the University and which drove me out of this building in 1897, I would have put all my efforts into the collection and never turned aside to make pottery.[34]

When Mercer undertook his most ambitious research trip as an archaeologist, to research prehistoric specimens extant in the caves of the Yucatan peninsula, he did so with a particular focus on artifacts of human skill and craft. On his Yucatan trip Mercer witnessed firsthand contemporary potters in the region carrying on their craft in much the same way (he imagined) as their ancestors might have.[35] This was perhaps the most vivid experience on his trip of the experience of a living past. Mercer was moved by these intimations of archaeological significance—it would turn out to be the closest he would come to answering "the question which lies at the bottom of the science, —namely, the question of sequence, which came first and which next? When and where was the beginning, middle, and end of the story[36]?" Ultimately, however, the ambiguous findings of that trip followed upon similar difficulties Mercer encountered in the reception of his first book, a scholarly study of an artifact of particular controversy in late 19th century American archaeological circles.

This was his first academic publication of any kind: *The Lenape stone; or, The Indian and the Mammoth*. In it, Mercer treated a particular, arguably prehistoric, artifact of purported Native American manufacture, with rigor but also with a decidedly effervescent hopefulness. This small stone, found in 1881 in a farmer's field and acquired by an acquaintance of Mercer's, Henry Paxson, was carved with a scene of stick figures firing arrows at a mastodon. The stone, Mercer hoped, would provide unique evidence of the longevity of native tenure and of human coexistence with ice age fauna. (Fig. 1.1.) This was one of the leading archaeological debates of his day.[37] In his book, Mercer examined in detail the stone's imagery and speculated as to its meaning in the mythology of the Lennai-Lenapi tribal culture to which he attributed its fabrication. After reviewing published correspondence concerning the artifact, which was in preponderance of the opinion that the stone was a forgery, Mercer cast doubt upon each of the objections raised in turn, and provided other evidence in support of the stone's possible authenticity. Interestingly, however, Mercer did not make a claim for the stone's demonstrable authenticity, arguing instead for its *possible* authenticity. In his arguments he is careful not to overstep the bounds of rational argument from observed facts; yet he endeavors to systematically disprove the negative,[38] providing enough doubt that it might continue to be considered a possible artifact of archaeological significance. The *Lenape Stone* was, for Mercer, the "simple story of most great archaeological discoveries"[39]: an artifact of compromised provenance but indubitably ancient aspect, shrouded in mystery.

Mystery, for Mercer, was key: the artifact raises 'a hundred questions' and requires the 'strongest evidence'[40]—that is, the significant artifact is not merely evidence of human artifice; it is a forensic provocation. In its decidedly narrative and anthropological digressions, *The Lenape Stone* was an argument with the emerging empiricist orthodoxy of his field's more established figures. Had it been authentic, it would indeed have been the American archaeological find of the decade, if not the century. Yet even before Mercer's study, the artifact's provenance was dubious; and only a few years after the publication of *Lenape Stone*, one of Mercer's superiors in the department, Daniel Brinton, the first anthropologist to hold a position at the University of Pennsylvania,[41] dismissed it (repeatedly) in a few brief paragraphs in the pages of *Science*.[42] (This was probably not a reflection of any larger conflict between the two men, as Brinton was in general one of Mercer's supporters in the department.)[43]

Figure 1.1. Mercer's Lenape Stone. Image: author, courtesy of the Mercer Museum.

In light of the reception of his treatment of the Lenape stone, Mercer's disappointment with the

Yucatan expedition becomes more comprehensible—while there was no shortage of physical remains to be studied, they were on the whole of self-evident purpose and little import to the field. There was no story, simple or otherwise; or rather, no story distinct from the craft practices still extant in the region, and in need of an archaeologist's telling. The expedition concluded that there was no evidence of peoples previous to the ancestors of the Maya in the caves they studied, and that humans had occupied the sites only recently in geological time.

The Discovery of Artifacts

Returned to the University of Pennsylvania, Mercer continued to publish in 1896 and 1897 on archaeological subjects, but his relationship with the head of the department[44] grew increasingly strained, and in the spring of 1897 he left his position at the university. At this time he began his own investigations into the craft traditions and implements of his home region. He designed and built[45] a studio building, first conceived as an archaeological research laboratory, on the grounds of his family property in Doylestown and began collecting the tools and products of early American craft industry. He would come to tell the origin story of these collection efforts in a markedly romantic vein:

> From the sweet scented herb store of the ancient garret to where the mill race washes the mossy machinery of the crumbling mill; from the dark recesses of a bake oven to where a north light wanes through dusty windows upon the granary or wagon house; from the smelter's iron heap to the wood pile, the search for these disused and neglected things has led us. The historian has overlooked them. The antiquary has forgotten them. But when we realize the value of the associations that perish, as they pass away in our midst, we commend them as heirlooms to be saved from destruction and set in a place of honor[46].

Mercer was, in 1884, one of the founding members of the Bucks County Historical Society. Yet when he in 1897 attempted to convince society members to participate in and sponsor his collection of craft artifacts, he ended up in an attenuated and public argument with his fellow Bucks County historians.[47] While roaming the countryside collecting artifacts, Mercer was paying particular attention to one particular handicraft: the rural Pennsylvania German pottery of the 18th and 19th centuries. From 1897 onward Mercer developed an intense interest in pottery, visiting the three remaining potteries near Doylestown that summer, and studying the collection of slip-decorated earthenware collected by Edwin Atlee Barber for the Pennsylvania Academy of Fine Arts.[48] Mercer's first plans and early experiments in the material were pointed toward the rehabilitation of a traditional craft pottery, and the production of functional ware for table service. He hired local potter David Herstine to produce replicas of some of the examples of 18th and 19th century Pennsylvania German redware he had collected, as well as imitations of some of the pieces in the Pennsylvania Academy collection. He undertook some pottery experiments in his archaeological workshop. Soon he would begin producing tile.

Mercer's assistant Frank Swain gives us a clue as to this transition in his own recollections of the founding of the pottery when he writes:

> His first tiles were copied from designs on old stoveplates. He got the idea of making tiles while visiting the old potteries of upper Bucks County, where his first plan was to make pots, dishes, etc. for his collection, but his artist friends discouraged that feature, saying they wanted tiles and not crocks.[49]

These friends may have been academic colleagues from the university, but were rather more likely associates Mercer knew through his Aunt Elizabeth Lawrence and her connections in the Boston Society of Arts and Crafts and in Europe. Mercer had, in 1897, conversed with his aunt regarding his pottery experiments, and she took samples of local clay with her when she returned to Europe and had them tested by the Italian pottery manufacturer Ulisse Cantagalli, whose letter confirming its suitability for use in commercial production of terra cotta wares she forwarded on to Mercer in 1898.[50] Lawrence also proposed to her acquaintance William De Morgan, the English potter, tile designer, and novelist (and lifelong friend of William Morris) that Mercer become his agent in the expansion of his tile production into the United States market. De Morgan wrote to Mercer that they could "quarrel over millions realized, if we preferred to do so, but an ordinary commercial arrangement could be easily made."[51] Mercer met with De Morgan in June 1898, but did not enter into partnership.

It may be that De Morgan's visually arresting tilework [fig. 1.2] exerted an influence on Mercer (though this influence would ultimately seem to be remote); or that Mercer's collection of traditional redware pottery and other artifacts, begun substantially that year, fostered in him the desire to undertake some creative material enterprise of his own. Another possible impetus towards tiles was Mercer's fascination with the cast-iron stove plates commonly used in the 17th through early 19th centuries to make flat-sided stoves in colonial homes, a tradition immigrants brought with them from continental, and predominantly German, sources. [Fig 1.3.] As Swain suggested, here is good reason to believe Mercer found inspiration in these stove plates, as a number of his earliest tile designs are drawn directly from the low relief castings which decorated the plates in his collection. He would go on to feature the stove plates prominently in his museum, as well as write a catalog for them, first completed in 1899, and expanded upon fifteen years later as he began work on the museum. This work would mature into a historical treatise on this particular species of artifact. To open its first chapter, he wrote:

> A large number of remarkable castings in iron have recently come to light in Eastern Pennsylvania, New Jersey and New York. They are heavy, flat rectangular plates, about two feet square, covered with patterns in very low relief, consisting of tulips, flowerpots, leaves of wheat, stars, medallions and pictorial designs, showing human figures, often enclosed in architectural canopies. […] Discovered among the rubbish of old farms, as make-shift chimney tops, stepping-stones, or gutter lids, buried under soot and ashes, as hearth pavements for still existing fireplaces where applebutter is cooked, soap boiled, or hams smoked, or rescued at the last moment in the scrap-heap of the junk dealer, they at once arrest the attention, as perhaps the most interesting and instructive of any of the relics of colonial times which have survived to us[52].

And, in a particularly telling moment, he wrote: "American histories had overlooked them." While these decorative stove plates served as an early source for his tile designs, we should remember that Mercer's first encounter with these stove plates was not as a sourcebook of decorative motifs,[53] nor as a catalogue of historically situated exemplars,[54] but as adumbrative remnants, very much in the vein of the sort of storytelling artifacts he had sought in his time as an archaeologist.


Figure 1.2. De Morgan's Fulham Indigo Ducks, 1871-1882. A 6-inch porcelain tile. Image: Rob Mcrorie / CC BY 3.0; and one of the Moravian Pottery's 4-inch earthenware tiles. Image: courtesy of the Moravian Pottery.

Figure 1.3. Mercer's collection of cast-iron stove plates. Collection of the Mercer museum. Image: author, courtesy of the Mercer Museum.

Sources

The clay used in Mercer's tiles was an iron-rich earthenware dug from a nearby deposit, an old lake bed approximately a mile from the pottery. This was a warm, brick-toned body, what geologists term a secondary clay, meaning its deposition was the result of erosion and transport rather than the slow dissolution and conversion of an unadulterated parent material (such as slate). This meant that, while it was easily accessible, it was an impure clay with a low temperature of maturation and required variable, but likely considerable, processing to render it of use for ceramics manufacture. Mercer supplemented this base body with smaller quantities of a more expensive white-burning clay from New Jersey, about 80 miles from the pottery. One of Mercer's longtime employees wrote an account of his time at the pottery, published in pamphlet form by the Bucks County Historical Society in 1970. It included a brief description of the sourcing of clay:

> We bought two kinds of clay, red and white. The red clay came from the Pierce Buckman property on old route 611, just east of Cross Keys Hotel. The clay was hauled in a horse-drawn cart by Walter Leatherman who worked at the pottery and lived at the hotel. It cost three dollars a load, delivered.[55]

Once the clay was delivered it was cached on site and processed first by hand, and later with a steam powered grinder. Water was added, and a pugmill blended and de-aired the clay. [Fig 1.4.] The clay was stored in a plastic state, because while Mercer used traditional, and developed new, techniques for the fabrication of tiles, these techniques always used plastic clay rather than powdered dry clay, despite the increasing popularity of "dust-pressing" methods in industrial production at the time. Mercer found the results of such methods "oppressively mechanical,"[56] and his tiles and other architectural ceramics are distinguished by their lack of uniformity, muted, earth-toned color palette, and their wide range of finishes, from matte to high-gloss.

Figure 1.4. Historic pugmill, no longer in use, at the current site of the Moravian Pottery. Image: author, courtesy of the Moravian Pottery.

Mercer used a variety of techniques for finishing his ceramics. Traditional lead-based glazes provided glossy finishes, and Mercer made multiple attempts to recover old formulae for these glazes, both through trial and error and through interviews with aging potters. Mercer also undertook experiments to develop new glazes, corresponding with several eminent ceramic artists in Europe and North America.[57] Mercer developed slips made from his clay bodies, with colorants added to widen the chromatic range, and would often leave these surfaces unglazed on finished tiles. He also added pigment integrally to clay bodies.[58]

Mercer often used these finishing techniques in combination, and many of his tiles evince a patina that results from multiple layers of finish. A single tile might, for example, be fabricated from red clay, dipped in a white slip, this white slip to be allowed to harden to a leather-like consistency before being partially removed with a tool Mercer developed for the process [fig. 1.5], after which it would be fired, have a clear glaze applied to some areas, and then be fired again in stacked saggars.[59] Techniques like this made Mercer's tiles unique, and rendered them particularly desirable to architects looking for materials congruent with buildings designed in an Arts and Crafts style.

Figure 1.5. Mosaic floor tiles, showing muted glazing, integral color, and carbon smoking, ca. 1905, at the Hispanic Society Museum, New York. Image: Michael Padwee.

Design and Fabrication

The genesis of Mercer's Moravian Pottery may also go back several years before its founding to when he was still fully immersed in the life of an academic. Before leaving his position at the university museum, Mercer witnessed firsthand the construction of the new University of Pennsylvania Museum of Archaeology and Anthropology [figure 1.6, 1.7], designed by university architecture faculty Wilson Eyre, Walter Cope, John Stewardson, and Frank Miles Day. Eyre was credited with the facade design, and made a particular impression on the young Archeologist and, as of February 1894, curator of American and Prehistoric Archaeology for the museum.[60] The new building was designed in 1892 and construction begun in 1894 (though it would not be completed until 1899, after Mercer had left the department). Eyre, a prominent Arts and Crafts architect based in Philadelphia, would continue in his association with Mercer, and ultimately play a pivotal role in Mercer's decision to produce architectural tile.[61]

Figure 1.6.: Arts and crafts tilework at the soffit and cornices, University of Pennsylvania Museum of Archaeology and Anthropology. Image: Penn Museum.

Figure 1.7 University of Pennsylvania Museum of Archaeology and Anthropology, shortly after construction. Image: Penn Museum.

In April of 1898, Mercer invited Eyre to visit his workshop at Aldie, where Mercer had begun the process of creating an arts and crafts pottery and Tileworks. Eyre suggested Mercer should consider producing tiles rather than functional ware. While Mercer's accounts of the founding of the pottery make little mention of Eyre's visit (only noting in an early draft that he was 'helped by encouraging words of Mr. Wilson Eyre, the architect')[62], It was soon after Eyre's visit that Mercer took the decisive step of transforming his archaeological workshop into a pottery.[63] Eyre remained in communication with Mercer, and featured him in one of the flagship articles in his new magazine, *House and Garden,* founded in 1901. That article began:

> It has been said that a new birth of art is taking place in this twentieth century. Those who have broken away from the beaten tracks of wholesale production, and have sought to create beautiful objects by individual effort of hand and brain, give truth to the statement. Unfortunately these persevering few are still overpowered by a majority whose production is ruled by Quantity and Speed. But the satisfaction remains to us to recognize this individual effort whenever it is found.
>
> The work of Mr. Henry C. Mercer, of Doylestown, Pennsylvania, is of this conscientious and independent kind. In the course of his researches in archaeology and ethnology he has turned to reviving an art long since buried by modern methods: the art of tile-making […] Journeying into the counties of Berks, Lancaster and Bucks three remaining kilns, found in a fitful state of existence and worked by successors of the old craftsmen, were made subjects of study. There were all the primitive tools of shapes and forms tried by the labor of centuries.[64]

This was one of the pivotal moments in Henry Mercer's life. And while Eyre's visit may or may not have had an impact of Mercer's trajectory, it came at a key point in the formation of Mercer's tile making enterprise; and Eyre's own success and authority, as well as his use and advancement of tile as an element in architectural design, would have provided Mercer with a timely corroboration of the viability of his intention to produce, and innovate in the design of, this particular architectural material.

Mercer's enterprise would subsequently receive mention in the New York Times[65] and other mass-market venues, and in these accounts Mercer would see a validation of his idiosyncratic blend of the retrograde and the experimental; of the commercial viability of his enterprise; and, perhaps, a suggestion of the possible connection between such craft activity and a form of proactive archaeological discovery—a discovery through the collection and preservation, but also through the renewal, of the obscure, outmoded, or threatened crafts of his home territory.

Mercer found his first commercial success in late 1899 selling to mostly residential clients. Within a year he had representation by tile dealers and arts societies in Philadelphia and Boston, and had applied for a patent on his multi-layered glazing process. [Fig. 1.8.]

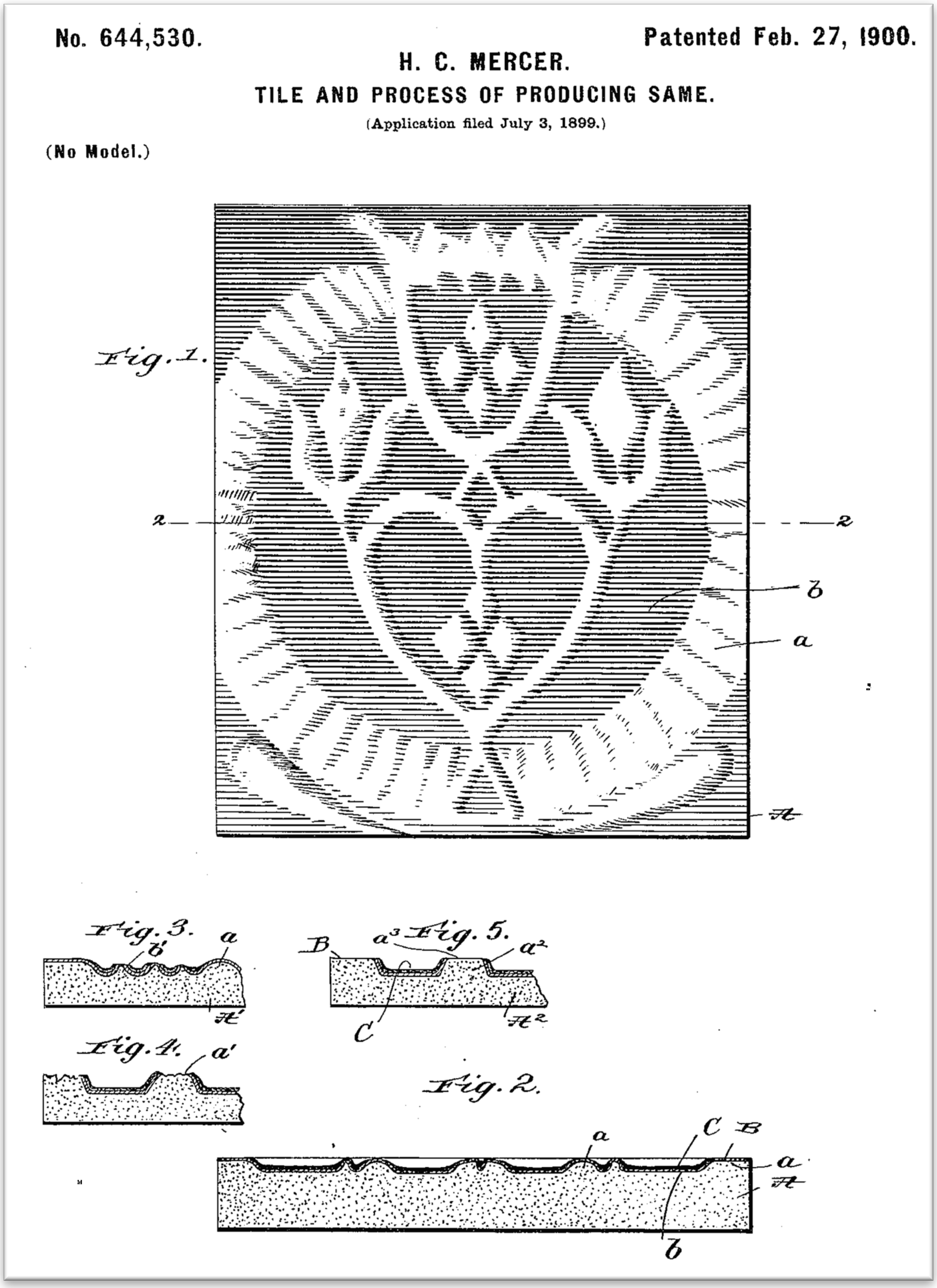


Figure 1.8. Mercer's first patent for a tile-making process. Image: public domain / Google patents.

At least three other distinct patents would follow in the next few years as Mercer expanded his range of products. By his fifth year of operation his tiles—both mosaic and field tiles—would be included in the Pennsylvania state capitol. His Moravian Pottery, balanced carefully (as we will discuss further in chapter 3) between skilled handcraft and industrial innovation, was an excellent fit for the spirit of the times.

How his tiles developed over the next two decades, through free experiment and tireless ceramics research, correspondence, and testing, as well as in conjunction with the needs and possibilities opened by his architectural works, will be the subject of further consideration in ensuing chapters, as we move on from constituent materials to consider the complex choreography of their assembly.

B. Concrete

Knowledge of reinforced concrete as a building technology began in its earliest years as a collection of closely guarded methods, principles, and rules of thumb developed through iterative trial-and-error uses of the material. Despite often-retold stories of how concrete was forgotten,[66] falling in and out of the common knowledge of building trades between the Greco-Roman period and the European Renaissance,[67] lime mortars remained in constant (if not always well-understood) use,[68] and sophisticated and hybrid uses of mortared unit masonry and tile formed a basis for the facility with and ready adoption of concrete technologies.[69] Thus it seems only fitting that reinforced concrete got its start not with high-rise or industrial construction (despite what we might assume from Le Corbusier's powerful, grainy images in *Vers une Architecture*) but with that bastion of clay production, flowerpots.

Various experiments from the mid-1850's to the mid-1860's vie for being recognized as the first use of reinforcement in concrete;[70] with Joseph Monier's exhibition of wire mesh reinforced cement flowerpots at the World's Fair in Paris in 1867 the technology became a subject of wide discussion and experiment.[71] Several innovations in material technology made Monier's flowerpots possible. "Naturally occurring" cement, comprised of kiln-fired limestone contaminated with trace amounts of clay (silica and alumina compounds), or even sourced directly from deposits of lime from volcanic ash or coal seam fires, was until the early 19th century the only source for cement mortars and concrete for the building trades.[72] Quality and availability of these natural cements varied widely, depending on the geologic and chemical peculiarities of the material source, and its ratio of lime to clay; and their final compressive strength was unpredictable and generally low, as little as 10-15% of today's standards.[73] By the latter half of the century, however, the process, and the distinction between 'natural' and what (in Anglophone regions) would come to be called 'Portland' cement, was well understood, in the popular as well as academic press.[74]

While lime kilns had been used for centuries to burn limestone for lime, and cement had been made from lime as early as the 5th century BCE,[75] in the early to mid 19th century the addition of measured quantities of powdered clay to the limestone in the kiln, and the increase of firing temperatures, created the chemically similar, but higher-performing, Portland cement that we use today; the subsequent development of rotary kilns allowed for higher outputs and greater consistency in material production.[76] These innovations increased the prevalence and use of cement in its many applications in 19th century construction, from paint and waterproofing to cement mortar and concrete. By the opening years of the 20th century, Portland cement had almost entirely replaced natural cements in the building industry.[77]

But while Portland cement is generally high-performing—stronger and harder than naturally occurring cement, and perhaps most importantly, more reliable—it is also quicker-setting and more brittle. This would have exacerbated its unsuitability for use in spanning conditions. (To speak of the material's structural performance in tension and compression would be anachronistic prior to this time, as this theoretical framing for the analysis of reinforced concrete was developed contemporary with, and at times as a result of the failures of, the early buildings of reinforced concrete.)[78] Although within the domain of industrial technology, the development of knowledge and practice was local and episodic, closely guarded, and prone to failures and omissions.

Distribution of Skill and Knowledge: Early Tradecraft

In the late 19th century concrete was recommended for use in fire protection and for its economy. Only slowly did an understanding of its considerable structural capacities emerge. Various local experiments lead to proprietary systems of construction, protected by patents in their apposite jurisdictions, and while these patents were often limited in scope, specifying things like the shape of reinforcing bar, they formed the armature for a closely guarded set of practices that allowed for reliable results with this novel and poorly understood material. Knowledge of the behavior of concrete would not be formulated in a systematic way until the turn of the 20th century, though work as early as the American Thaddeus Hyatt's *An Account of Some Experiments with Portland-Cement-Concrete Combined with Iron as a Building Material, with Reference to Economy of Metal in Construction and for Security against Fire in the Making of Roofs, Floors, and Walking Surfaces* in 1877, and similar contemporaneous publications in Europe, allowed for the proliferation of a variety of attempts and experiments, at which point knowledge of a more portable and systematic sort such as Hyatt's pamphlet propagated rapidly.[79]

From Auguste Perret's early concrete work in France to Thomas Edison's cast-iron formed concrete spec houses, the opening years of the 20th century saw a previously stigmatized material find widespread utilization across the spectrum of architectural typologies. This acceptance, at first grudging and much-debated, would within a generation turn to adulation as the material, formerly used only for silos, bridge abutments, and flower pots, became iconic of modern architecture. The development and adoption of standards for reinforced concrete design and construction was paralleled by substantial changes in the organization of architectural practice, so much so that it is hard to say whether it was organizational or material changes that most altered the field. In that time of profound change much of what architects take for granted today, from the structural systems of buildings to the structure of the relationships governed by architectural contracts and representations, was in flux. The origin and codification of architectural practice specifically with regards to reinforced concrete is a telling case of the simultaneous evolution of new practice and theory, in an environment of chaotic and fertile innovation.

In 1898, when Mercer began experimenting with concrete, the technology was entering a time of rapid expansion, driven not so much by architects or builders as by producers of the material. Manufacturers advertised heavily in conventional media and a growing list of trade periodicals. In the waning years of the 19th century Mercer subscribed to several of these publications and corresponded with their editors and other early adopters. Some of his earliest and largest tile commissions were for noted early buildings in reinforced concrete, including the Jacob Reed and Sons Department Store, built in Philadelphia in 1904, and the Marlborough Blenheim Hotel in Atlantic City, by the noted Arts and Crafts architect Will Price, which, when it was built in 1905, was the largest reinforced concrete building in the world.[80] [Fig 1.9.]

Figure 1.9. Marlborough-Blenheim Hotel, Atlantic City, New Jersey; Price & McLanahan, Architects (1905-06). Image: Detroit Publishing Co.; Library of Congress, public domain.

Mix Design and Constituent Elements

Cement

Mercer sourced his cement from various suppliers in the northeast and mid-Atlantic.[81] In his earlier experiments he seems to have closely followed the recipes provided by those suppliers. But with his first large project, begun in 1907, he found the need for several different recipes. Mercer's general use concrete followed the accepted standard practice of 1:3:6, or 1 part cement, three parts sand, and 6 parts aggregate,[82] what Mercer called "govt specification"[83]. As he developed experience with the material, he adjusted his recipe to the proportions 1:2.5:5 recipe. (It is worth noting that current standards for concrete exposed to weather match Mercer's altered formulation.)[84] Mercer used the 1:2.5:5, which he refers to in his notebooks as "our mixture," for walls, beams, and slabs. Ceilings were set in two layers, with a layer of what Mercer called "cinder" concrete topped with a layer of the standard mix.[85]

Mercer had ready access to a continual supply of coal ash residue produced by the firing of the kilns at the Moravian Pottery. Unlike the current practice, going back at least as far as 1914,[86] of using fly ash as a replacement for cement in concrete mix, Mercer would only have had access to what is today called "bottom ash"—that is, he had no system with which to capture fly ash from the exhaust gases of his kilns, and so would have been left only with the coarser, more silicaceous ash left at the bottom of his kilns after firings. This would have been a light, porous material, resembling volcanic gravel or coal-fired boiler cinders, and unlike fly ash would have best served to replace sand or aggregate rather than cement in the mix. More recent studies[87] of the differences in concrete mix performance suggest that this substitution would result in improved workability and lighter weight, but at the expense of overall strength and durability.

Mercer also experimented with a wide variety of cement based recipes for other purposes, such as adhesives, tilesetting, and waterproofing. These recipes included ingredients such as plaster, rosin, linseed oil, sawdust, rye meal, and powdered forms of lead, calcium, alumina, and limestone. Some of these recipes are detailed in Mercer's construction notebook for Fonthill. [Fig. 1.10.]

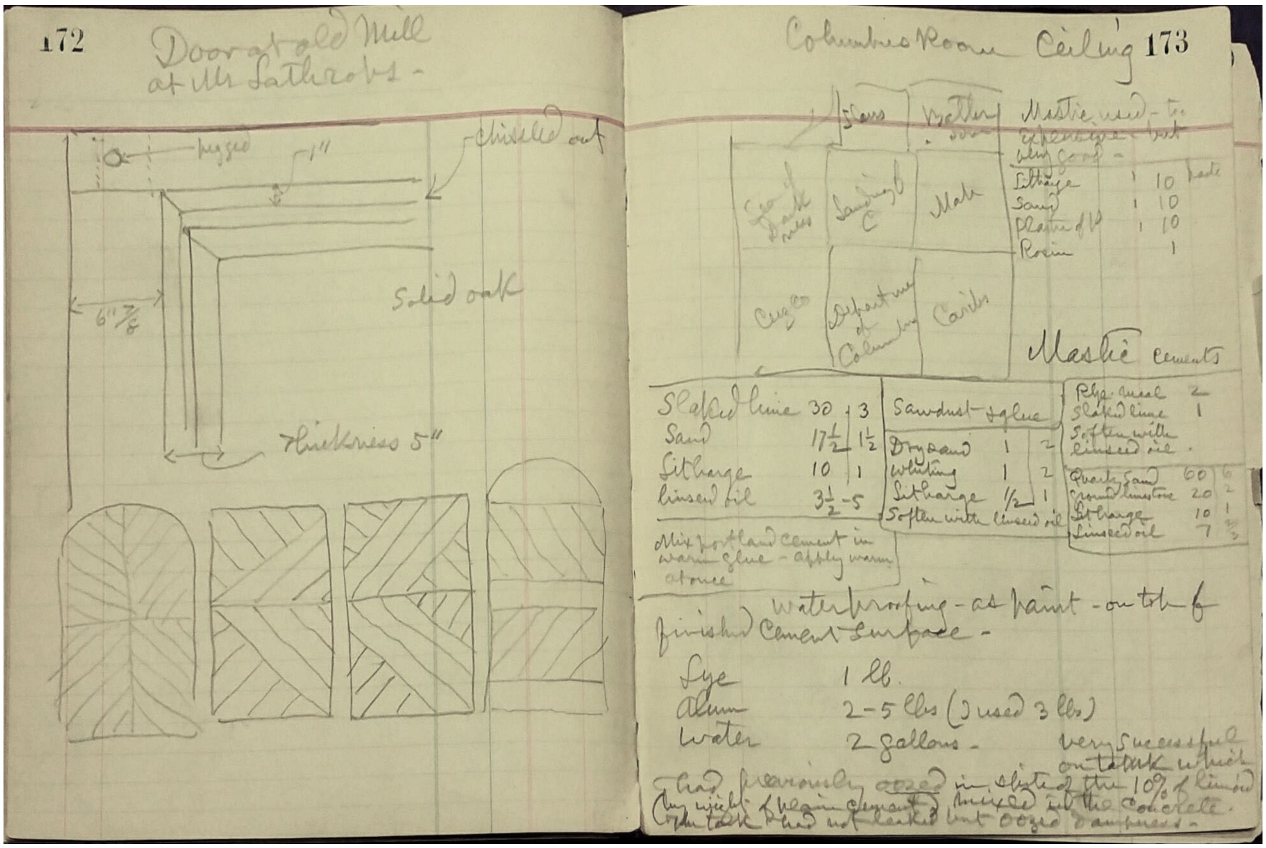


Figure 1.10. Fonthill notebook, ca. 1908-1910, page 172-173, with various recipes used at Fonthill listed on 173. Image: courtesy of the Mercer Museum Research Library.

Sand and Gravel

Mercer bought sand and gravel from a variety of sources, by the cartload for earlier projects, and by the train car for the museum, as the building site was on a terminal railroad spur. The museum jobsite included a jerry-built shed into which a train car of cement, sand, or gravel could be pulled for storage out of the weather. His aggregate was a uniform blue-grey basalt, or "trap," provided by the crushed stone works at Rockhill Station, 15 miles northwest of Doylestown. Mercer sourced his sand in several colors, and remarked in his construction notebooks on the effect of these colors on the underlying tone of his vaulted ceilings. His preferred sand was a yellow fine sand from Defrain Sand Company, in Van Scriver Lake, about 25 miles Southeast of Doylestown. (Mercer notes that the yellow sand has a pleasing effect on tone of the resulting concrete.)

Reinforcing

For reinforcing Mercer used scrap metal, reclaimed fencing, and plumbing pipe. At Fonthill, non-critical areas such as walls and floors, had hollow pipe, while beams and other critical elements received solid rod. At the Museum, Mercer began the project using graded iron rod and progressed to the use of purpose-manufactured reinforcing bar. In certain interior applications he allowed embedded reinforcing to be exposed for decorative or functional purposes [see the discussion in the next chapter, and illustration in fig. 2.12]. Reinforcing would be bent by hand after it was partially embedded in concrete, and was spaced centrally in structural elements, typically 3-6 1/2" or 3/4" bars per column, and 1/2" bars 24" on center horizontally and vertically in walls. Floor, ceiling, and roof assemblies were also typically reinforced with 1/2" bar in a 24" o.c. grid. Mercer also used 1/4" to 3/8" rod in the reinforcing of precast elements such as windows and concrete furniture, which he experimented with throughout his building projects. In addition to reinforcing bar, ceilings received wire mesh, manufactured not for the purpose but rather as farm fencing. This echoed Monier's first experiments with mesh-reinforced flowerpots.

Mercer's Museum ledger shows the delivery beginning in July of 1913 of "Hughes & Patterson _33 Bndl 1/2 round Best Iron,"[88] of which he received five lots total over the next year of construction. This is a great improvement over the random lengths of iron pipe and fencing from local scrapyards with which he began at Fonthill; but a year into construction Mercer makes another improvement, changing out his reinforcing to "Buffalo Steel Co. Tonawanda N.Y. 193 Bars 1/2" sq. twisted bars"[89] (Figure 4). While Ernest Ransome had patented a ferroconcrete construction system featuring twisted square bar in 1893,[90] it was only with the breakdown of the entrenched system of closely guarded patents in the first decade of the 20th century in both America and Europe[91] that the full dissemination of craft knowledge concerning the new material was achieved. Thus it seems reasonable to suppose that Mercer either sought out purpose-manufactured reinforcing in response to performance problems, or encountered it in his reading of trade periodicals dedicated to the diffusion of expertise in the new material. This incremental adoption of improved inputs and methods, sometimes mid-product was typical material practice at the time, as this was prior to the adoption of broad standards or performance criteria for reinforced concrete construction.[92]

C. Formwork

Whether formwork is a material or a method may seem an unnecessary question. Today it certainly seems to belong to a general category of material, like "roofing," or "sheathing," that comes in several varieties, all based on the same principle of surfaced or unsurfaced sheet goods fastened with tension ties.[93] Describing Mercer's formwork as a material is considerably more problematic, as we will see, and this case illustrates how much the categories of material and method overlap.

In a passage from his notebooks, in which Mercer not only jotted ideas for room plans and tile designs, but which also contained reflections on the work, as well as digressions into history, philosophy, and the arts, Mercer described his peculiar techniques for concrete formwork, first worked out in the construction of Fonthill. These methods would subsequently be refined in the building of the Moravian Pottery, and streamlined in the construction of the museum; but at the outset they seem to have consisted of a nearly unbroken string of improvisations:

> Several demolished buildings, followed by car loads of unplaned boards, furnished the wooden material for the forms. These consisted of partitions made by laying the boards horizontally, edge to edge one upon another, with battens nailed wherever convenient against their outer sides. Double lengths of wire were looped around and twisted upon the projecting ends of these battens as we proceeded to keep the forms from bulging. These forms were set vertically with a spirit level, and not by eye, as has been asserted. Where high winds deflected them or where they sagged or where mistakes were made the results were corrected after construction … The concrete was purposely not spaded inside the walls in the hope of making them more porous. Continued suggestions as to dampness, resulting in rheumatism, etc., caused us to cast large vertical holes by means of collapsible wooden boxes invented by me, stove pipes filled with dry sand, pulled upward as we proceeded, and even corn stalks wrapped in paper at intervals of a few feet throughout all the walls. The cornstalk plan was, however, a failure as the leaves flew in all directions into the forms and the wet stalks would not burn out of the holes. Angles in the very irregular chimneys, and the chimneys themselves, were cast upon wooden boxes or boards pounded, pried, or burnt out afterwards.[94]

Mercer tells a story here of an implausibly makeshift construction process: forms were made from cast-offs, from pipes, even cornstalks. Boards were 'pounded, pried, or burnt out.' The mental picture is almost vaudevillian. But this ad-hoc process, he is careful to clarify, is not slap-dash: formwork, though rough in surface, was laid out plumb and square; careful consideration was given to the finish surface of the concrete, which was left "form finish" in most areas, with the general exception of more formal or public interior rooms. Parging on the exterior is irregular and seems to have been used only where necessary to maintain a weathering surface, and concrete is used additively only to repair forming defects and to regularize openings in the building, as well as at occasional details such as chimney caps. [Fig. 1.11, 1.12, 1.13]

Figure 1.11. Exterior parging, Fonthill. Note the abrupt shift from unparged to parged surface half way through the arch in the foreground, and the complete reconstruction of the arched window opening in the right/background. These are areas that would be prone to initial failure (e.g., honeycombing) of the concrete work. Image: author.

Figure 1.12. Interior prior to parging. Saloon room, first floor. Photograph taken during construction. Image: courtesy of the Mercer Museum Research Library.

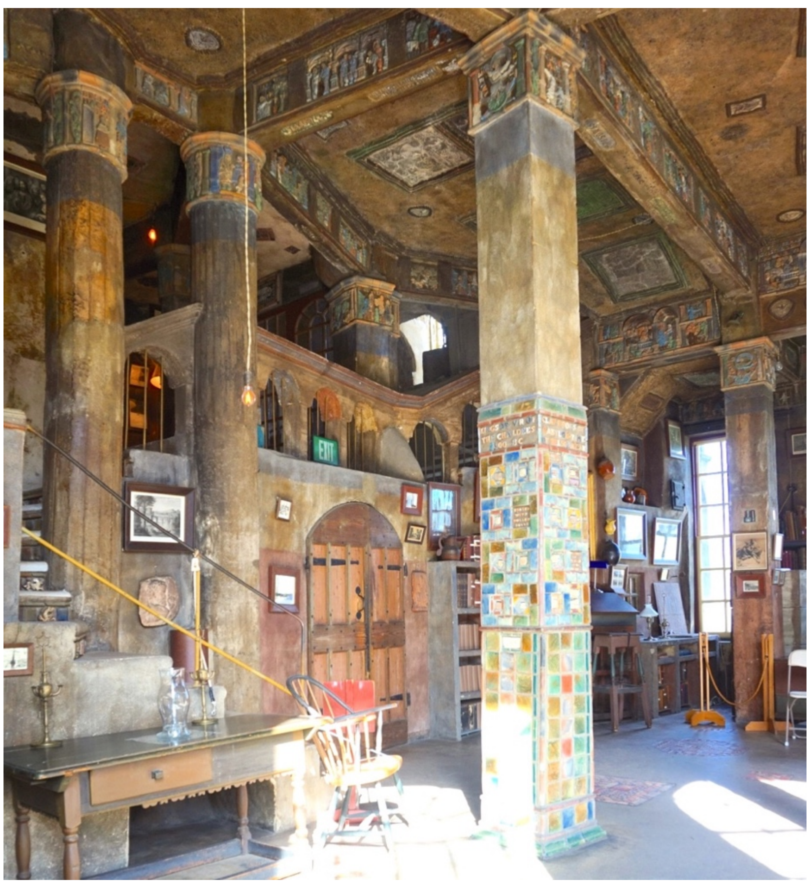


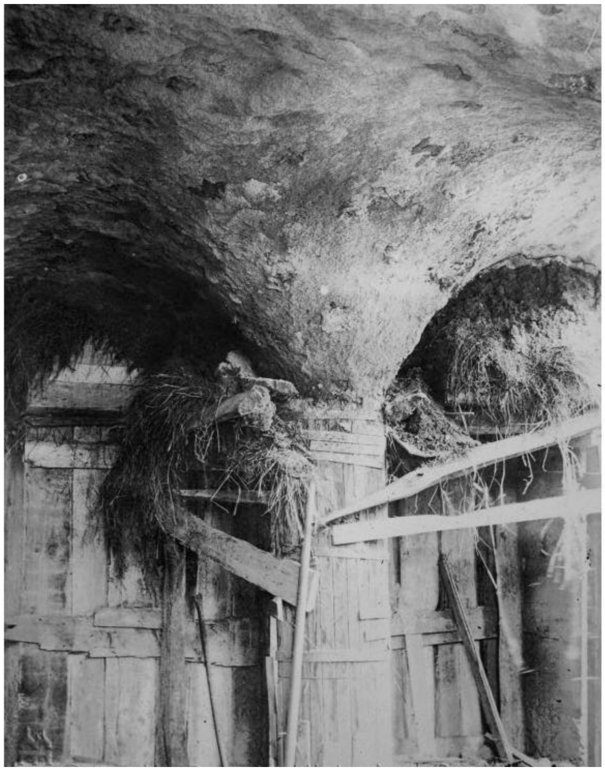
Figure 1.13. Interior Parging. Note particularly the upper surfaces of the rectangular column. Image: author, courtesy of Fonthill Castle.

The process described above details a building growing piecemeal, day-by-day, in nearly impossible-to-anticipate variations on, and adaptations to, the plans for construction. (The plans themselves were perhaps the most non-normative part of Mercer's whole project—a subject we will entertain at length in the next chapter.) In the end it is unclear whether Mercer's forming materials were so irregular that the resulting concrete rarely came out exactly as planned; and whether the plans, shifting from room to room, and column to column, provoked much of the resulting variety or were responding to it.

One way or another Mercer was engaging with a highly variable design process and product: at Fonthill the walls of the finished building vary as much as twelve inches out of plumb;[95] from the tops of these walls vaulted ceilings negotiate the span of rectangular, polygonal, and doglegged or other irregularly-shaped rooms, and are further supported also by beams spanning between multiple irregularly-sided and -placed columns. Building openings are rectangular, arched, or angled, and these shapes, particularly in the case of arches, present a considerable compromise from their geometric ideal. Floor and ceiling heights vary considerably, almost every room different; bed nooks in bedrooms are often lower than the adjacent ceiling, sometimes barely high enough for head clearance (and Mercer was a tall man). Stairs are generally narrow, and run straight, wind, spiral, and overlap into rooms. These manifold variations, combined with a tendency to redesign as construction progressed, created a need for highly flexible and adaptable forming techniques.

D. Concrete and Tile: Material Hybrids

The method of construction Mercer developed for the centerings of his vaults is particularly notable. Mercer writes, "the vault forms were made of heaps of earth spread over piles of boxes and overlaid as before with sand producing a series of carefully graded mounds resting on the platforms." That is, a platform, custom-cut to the profile of the top of the walls, would be built on temporary legs, and the platform would be pulled out later to remove the centering. [Fig. 1.14] On top of this platform earth was piled and sculpted to an approximate partial catenary arch.



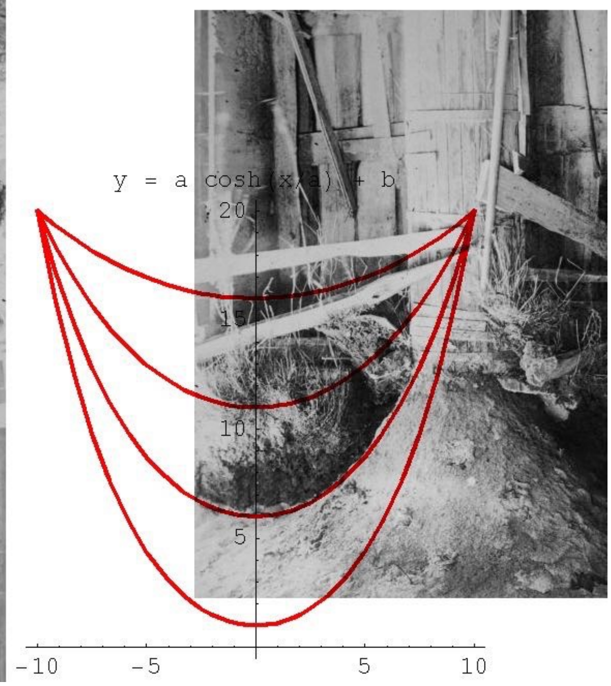


Figure 1.14. Left: Construction photo showing partially disassembled formwork for a vault at Fonthill, with sand and soil still stuck to the surface, and formwork remaining on column and walls; Right: Superimposed graph of a mathematical equation of a catenary curve on the same, inverted, image. Note that the centerline of the column aligns with the base of the catenary, and the spring point of the arch is approximately one-third the distance to the apex, traditionally understood to be the ideal location for bracing a catenary arch.[96] Image: courtesy of the Mercer Museum Research Library; composite by author.

This was very much in keeping with the construction of Mercer's 'bottle' kilns, which employed partial catenaries set atop cylindrical walls. [Fig. 1.15, 1.16.] Unlike the rooms at Fonthill, however, the kilns were freestanding masonry structures and required metal banding to brace their walls and spring points. [Fig. 1.16.] While these 'bonts' complicated access and loading, the kilns endured considerable thermal expansion and contraction, and required such bracing. Mercer, while he used concrete whenever possible, did not construct kilns from the material,[97] and provided space between brick kiln walls and concrete building structure. [Fig 1.18.] The rooms in Fonthill might be considered to be made in the same mold, as catenaries on top of polygons; but unlike the cylindrical kilns, Mercer's ceilings were articulated with groin lines running from corners and columns. Where barrel vaults were used, they were again abridged catenaries, almost never full hemi-circular barrel vaults. Instead, the vaults are based on a structurally sophisticated system of braced shallow catenaries. [Fig 1.15.] This may seem an oddly, even improbably, modern structural solution; but in the context of ceramic kilns, the catenary arch has deep roots in both Asian and European traditions.[98] The adaptation of the kiln-arch to the house and museum may simply have made good sense to Mercer as well as to his craftsmen, at least one of whom, William Labs, had been responsible for the building of many of Mercer's kilns, and who would also go on to act as one of the foremen for Mercer's construction sites. Certainly Mercer could have chosen a more traditional arch shape, either the barrel vault, which he would use elsewhere, or the pointed groin vault—Mercer would have been familiar with these general vault typologies from his European travels. Given the material and the short spans, Mercer could have made his ceilings any shape he wanted; by-and-large, he chose catenary arches. Mercer also used flat and gabled slabs, particularly for his roofs, where his earth-formed vaults would have required far too much filler to create a pitched upper surface to be practicable. These structural solutions, and forming systems, would be utilized in all of his major works.

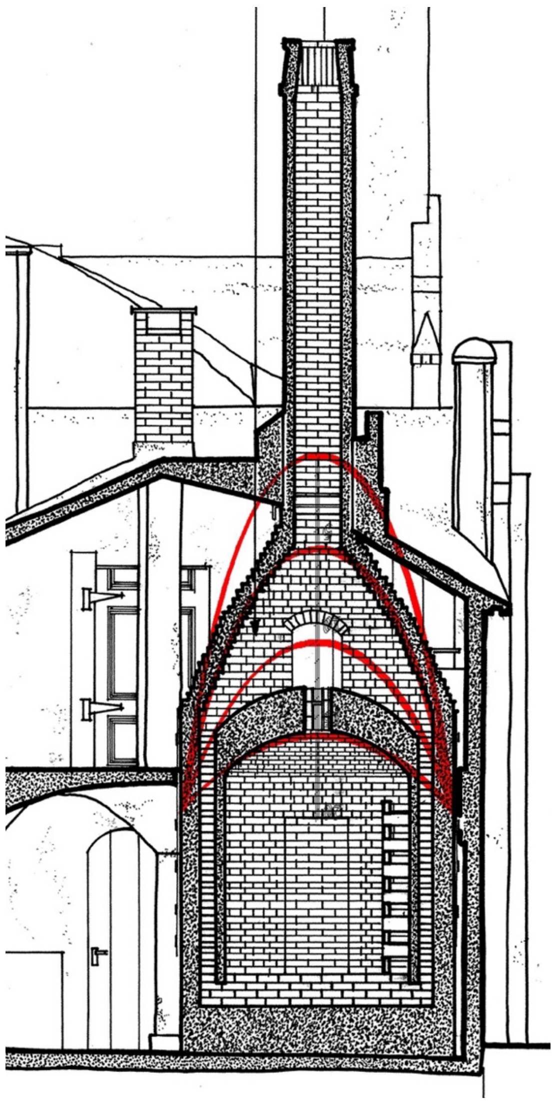


Figure 1.15. Catenary graph superimposed on section of one of Mercer's "glost" kilns. Image: Historic American Engineering Record (Library of Congress), Public Domain. Catenary graph superimposed in red by author.

Figure 1.16. General view of a kiln "built into" the building. Image: Historic American Engineering Record (Library of Congress), HAER-PA-107, public domain.

Figure 1.17. Bonts at one of Mercer's kiln openings. Image: author, courtesy of the Moravian Pottery.

Figure 1.18. Gap between reinforced concrete vault and Bottle Kiln at the Moravian Pottery. This was likely intended to allow for thermal expansion during firing, and to avoid transferring load from the floor slab into the wall of the kiln. Kilns and Building were built separately, yet simultaneously. Image: author, courtesy of the Moravian Pottery.

Each room would have a ceiling of whatever shape or shapes were decided upon; the floor slab for the room above would be built directly over that—often, in the case of the vaults, irregular—surface. Short passages or stairs were added where required for circulation between these spaces. Roofs were formed in a similar manner to floors, built up over the ceilings of the rooms below into, or cast directly as, gable shapes, with hips, crickets, dovecotes, vents, chimneys, and other features added in process. After this sculpting of the roof a final layer of 'waterproof' cement was added.[99] In places this can be seen clearly against the vertical faces of elements such as chimneys. [Fig. 1.19.]

Figure 1.19. Chimney at the Moravian Pottery, with cement render waterproofing. Image: author.

In 1987 a team of surveyors from the Historic American Engineering Record, sponsored by the National Park Service, created a detailed as-built drawing set describing Mercer's second major building project, the Moravian Pottery and Tileworks, and these measured drawings show both the bottle kiln structure in isolation, [fig. 1.20] as well as a speculative reconstruction of the concrete forming methods used to fabricate the building. [Fig 1.21.] According to these documents,

> The coarse-aggregate concrete used for the factory was mixed and cast by hand, yielding a highly textured surface of varied porousness. The roof tiles, as well as the decorative tiles adorning the exterior walls and chimneys, are of Mercer's own manufacture. The structural reinforcing techniques were standard, even somewhat unadvanced for the period, but Mercer's form work departed dramatically from the mainstream practice of the time. Mounded-earth forms were used to cast the building into complex, irregular, vaulted shapes.[100]

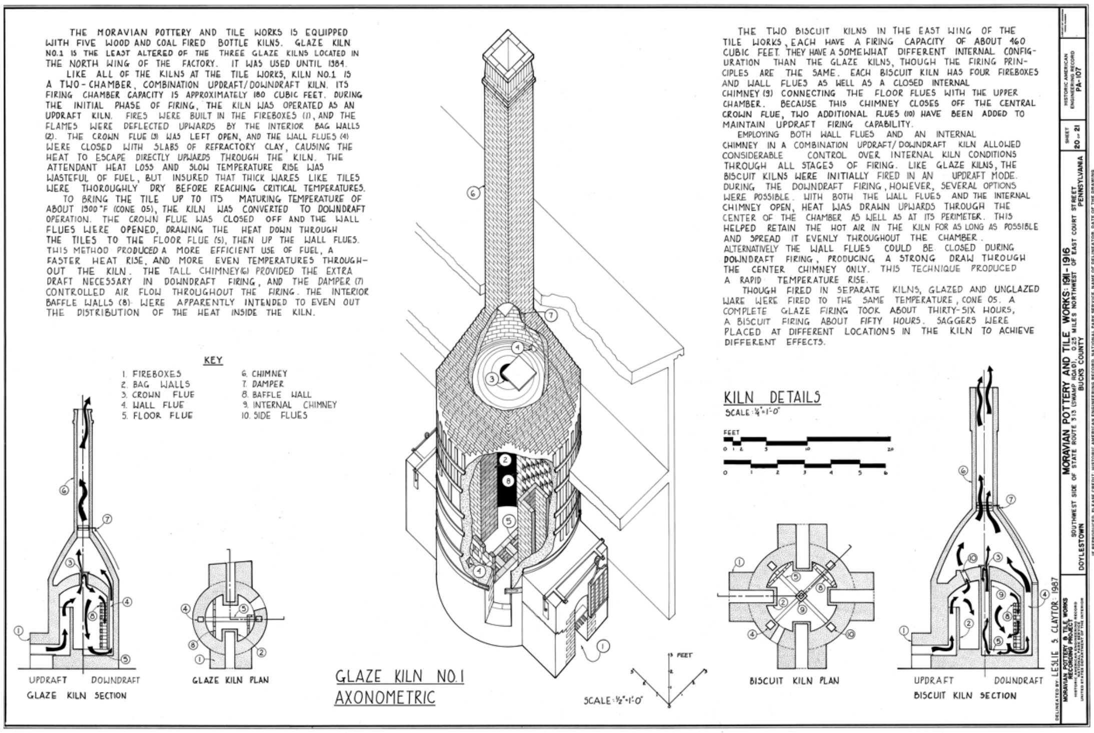


Figure 1.20. Axonometric of Kiln at the Moravian Pottery and Tileworks. HAER Survey Sheet 20. Image: Historic American Engineering Record (Library of Congress), public domain.

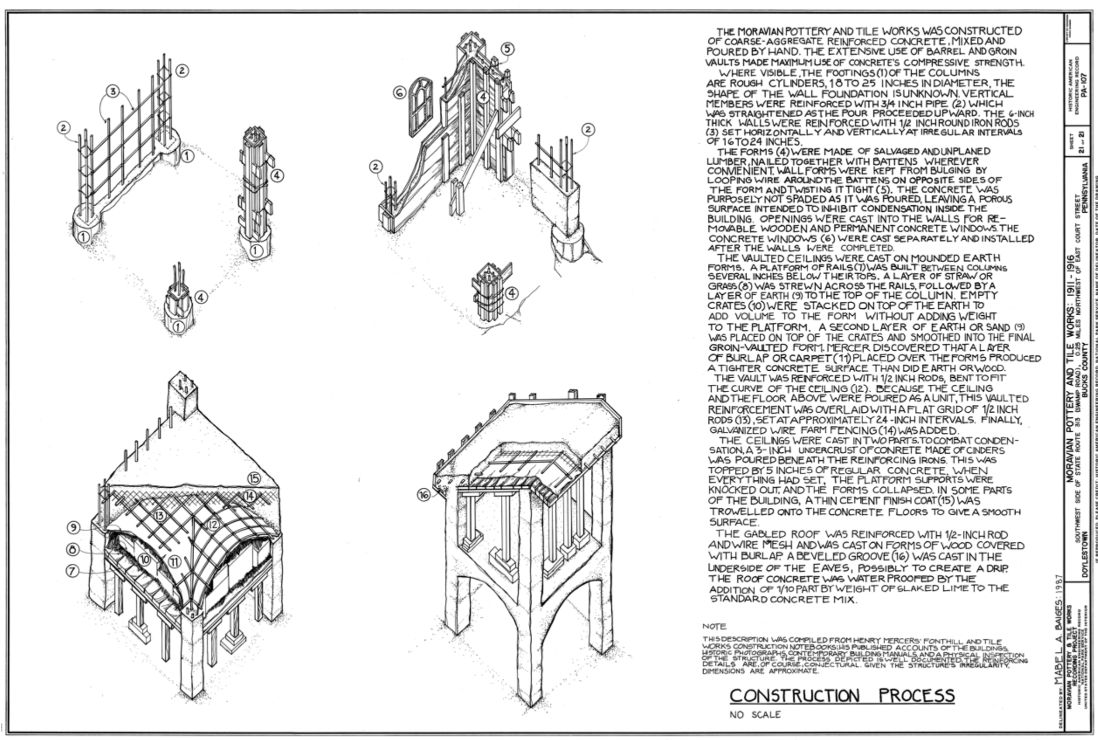


Figure 1.21. Narrative/diagram of the unique forming methods used at the Moravian Pottery and Tileworks. HAER Survey Sheet 21. Image: Historic American Engineering Record (Library of Congress), public domain.

In addition to their structural and formal ambiguity, these complex vaults, used throughout Mercer's architectural works, are characterized by a marked dimensional indeterminacy. Each step in the process was open to renegotiation; and each renegotiation was undertaken as part of the act of, and in response to the vagaries of, previously completed steps in the building process. Neither Mercer's surfaces, nor his shapes, were particularly refined or close to a geometric ideal; yet each was the result of a distinct, apt, and repeated technique: what we might today call a heuristic procedure. They featured a rare fusion of sequential, procedural logic with an improvisational flair, achieved through a dialogic process and the allowance of broad, yet strategic, tolerances. And while nominal operations were carried out to finish the work, Mercer's concrete vaults came out of their forms not only finished, [Fig. 1.22, 1.23] but decorated with convoluted arrangements of tiles, often in interlocked mosaic, decorative, or narrative sequences. [Fig. 1.22, 1.23.] While a number of operations were carried out to finish the ceilings (cleaning, parging, fuming, sealing, etc.,) these were nominal: the vaults were substantially complete direct from the formwork, and the stripping of the form boards would have been an occasion of drama, satisfaction, and potential surprise.[101]

Figure 1.22. Construction photo, Fonthill, after formwork removal and before finishing. Image: "A Concrete House" Cement Age, May 1909 / public domain.

Figure 1.23. The library vaults under construction, after formwork removal and before column capitol tiling was complete. Image: courtesy of the Mercer Museum Research Library.

Figure 1.24. Mercer's tiled vaults at the library, Fonthill. Image: author, courtesy of Fonthill Castle.

Figure 1.25. Mercer's tiled vault, Columbus room. Fonthill. Image: author, courtesy of Fonthill Castle.

Boardformed Walls and Columns, and Tiled Vaults

Mercer's various methods of concrete forming were more indebted to the habits of work and traditional tools of the clay artisan than the carpenter (see chapter 4). This would distinguish him from those few of his contemporaries already working in similar materials and at similar scales. In the pages that follow we will look at several key details and methods Mercer developed in the construction of his various projects, and how these non-normative solutions embody a different view of the material, and the work, of designing and building.[102]

The first major example of this in Mercer's work is his invention of a method for simultaneously tiling and placing the concrete of his ceilings. As he would later describe the process:

> For the flat ceilings in the cellar, platforms of boards, sawed to fit, were placed between the beam troughs, and these levels covered up to the troughs with earth. Later, for upper rooms, the platforms were made very roughly of rails covered with grass upon which the earth layer was spread and then about two inches of yellow Bucks County sand was spread over the earth.[103]

After the walls of a room were formed and the formwork for beams constructed, a frame of salvage lumber was topped with planks of random length and width. On top of this platform unscreened[104] fill dirt from excavation at the job site would be piled and sculpted to create curves that were not calculated; but were regulated by flexible stick guides. This was an approximate technique for deriving curves common in woodworking; perhaps of more relevance, it is also used to create sprung arch vaults in traditional kiln building, and Mercer may have first encountered it in this setting.[105] Mercer continues describing the process:

> The vault forms were made of heaps of earth spread to reduce their weight, over piles of boxes, and overlaid as before with sand, producing a series of carefully graded mounds resting on the platforms as before. This process began in the crypt of the tower, where no sand layer was used. In the Library the earth mounds were raked into semi-circles or ellipses and the sand overlay carefully smoothed.[106]

The mounded earth would be sculpted to the shape of an inverse of a multi-rayed cross vault and dressed with sand. Custom-designed tile mosaics were laid out on full-scale drawings, and then transferred upside-down in (reverse) sequence or narrative order into the sand, and the first layer of "cinder" concrete poured. Reinforcing and a structural concrete layer followed. Where flat ceilings were required, Mercer built platforms and formed the beams first and integrated clay impressions of various articles, such as tiles and stove plates, as bas-relief form liners, then built up to the ceiling, in much the same way as with his vaults. Mercer described the method of tile setting, relief casting, and other integrally decorated formwork techniques, like this:

> In the hall and Saloon clay troughs for groins and borders, and clay impressions of stove-plates, were used in casting the ceilings. Otherwise tiles were pushed face downwards into the sand layer, so as to project about a quarter of an inch on the backs. […] The ceiling tile work pictures, inscriptions, designs, etc., cast, as described, directly during construction, tried first in the crypt, and next in the Library, were very successful. The elaborate and probably overworked pictures in the Columbus and Bow Rooms, which may be called adaptations of our mosaics, with patterns modelled in relief and no background, were designed in August and burnt and set before frost of the same year. These tiles were laid first, with much difficulty from the wind, on large drawings, and then turned upside down and pushed into the sand. We feared sagging of vault forms and the falling of heavy tiles set in this manner, but no such bad results followed. When we pulled out the platform props, and the platforms collapsed, tons of earth and sand fell, exposing the tiles, after which the loose sand was washed off with a hose, and when dry, brushed and shellaced with diluted yellow shellac, between the tiles.[107]

Mercer's account, in combination with a review of his construction notebooks, allows us to understand, step-by-step, his process. [Fig 1.26.]

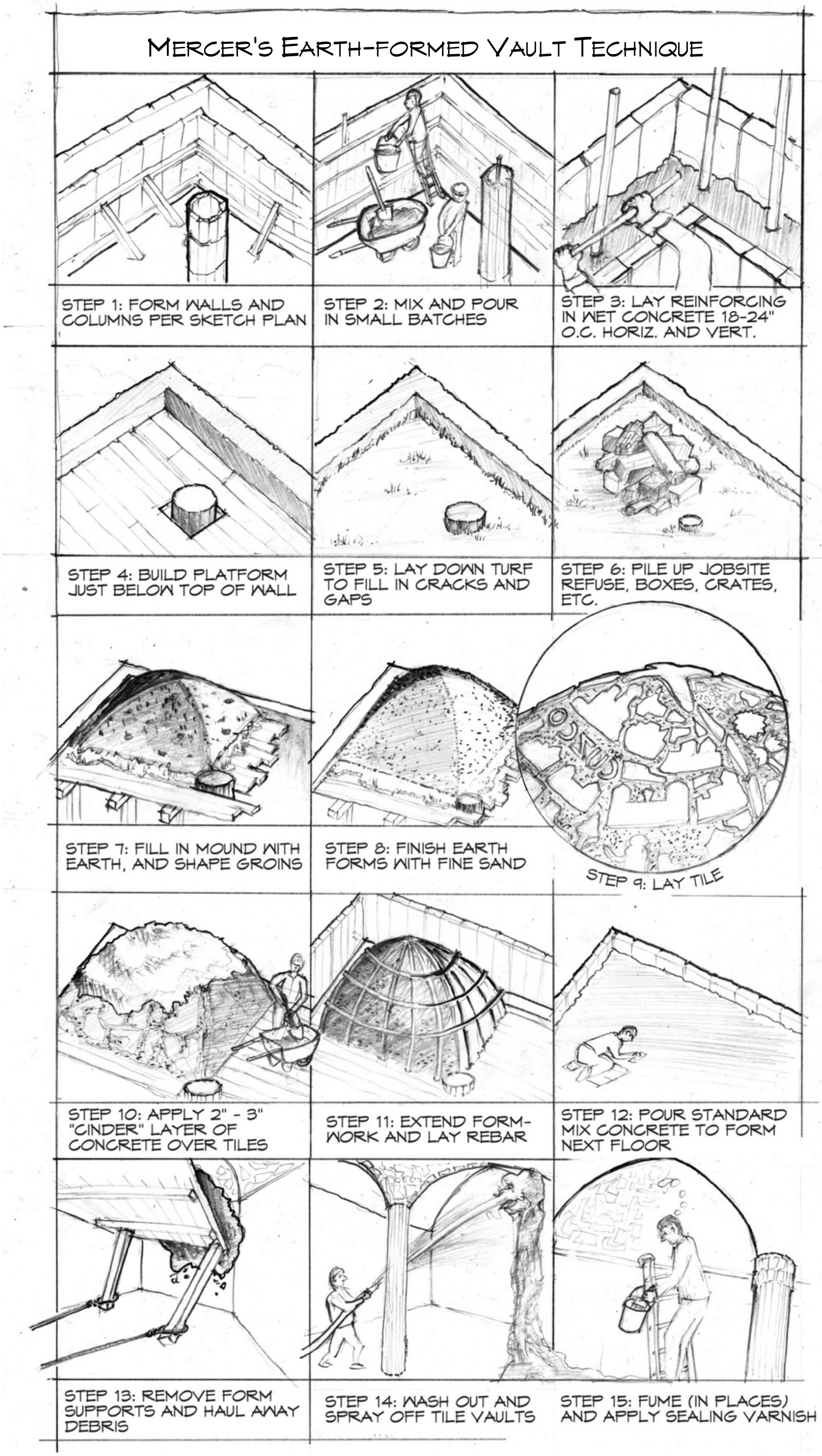


Figure 1.26. Storyboard of the Mercer Technique for hybrid centerings. Image: author.

Mercer describes a method distinguished by its adaptability; but also by a lack of dimensional control or accuracy. In a room with walls built from a plan sketch, but yet-to-be-ceilinged, a wooden platform would be built to fit the walls as-built. Thus using the roughest of carpentry and piled-up surplus materials, bridging the gaps with sod, rounding out the shape with earth, giving it a precise contour with sand, and providing for form release with tiles, carpets, or clay, served two very different purposes simultaneously: the rough methods were highly adaptive; the final methods increasing in precision to whatever degree required by the particulars of the individual room being constructed. These are two functions rarely achieved by the same process—processes are often conceptualized, in fact, by balancing these two things in a 'necessary' tradeoff. Mercer's example shows that this is an assumed, rather than inherent, incommensurability. What distinguishes this particular method is that it moves in graduated steps from flexibility to precision, entailing no more precision that is required at any step in the process. If, then, the same method and materials can be configured to provide gradations of precision, the method may be 'tuned' or 'tempered' to the exact requirements of local conditions. This is a hallmark of economy, which we will discuss in chapter seven.

In the sequence illustrated above, Mercer arrives at several remarkably economical techniques for achieving his desired ends. Mercer poured his walls in small batches.[108] In earlier projects, these batches were hand-mixed in wheelbarrows; and even once Mercer had purchased a portable gasoline-powered mixer, the individual batch of concrete was quite small, and continued to be transported by wheelbarrow. This was not uncommon at the time; but standard practice called for the concrete to be "spaded," or agitated by hand, to both mix individual batches, and to reduce honeycombing and other faults. [Fig. 1.27.] Mercer did not do this, believing the absence of spading would result in a more porous wall, and one thus less susceptible to condensation and damp. Throughout his projects this resulted in a marked striation with horizontal or slightly overlapping curved lines, as the natural variation in batches, and the tendency of fines, unagitated, to settle out, produced patterns on the concrete walls. The copious flaws this produced were repaired where required after the forms were removed; but only where required for building performance, such as at columns or building openings. Presumably such intermittent roughness may even have been considered an advantage when it came to applying tile.

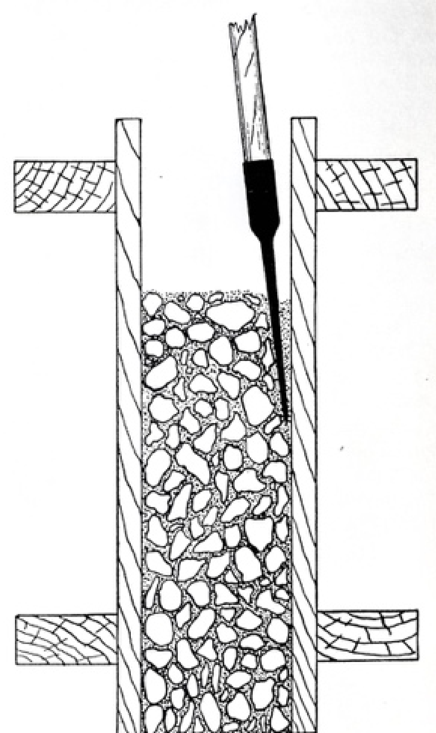


Figure 1.27. Photograph and caption from the 1916 handbook "Proportioning Concrete Mixtures and Mixing and Placing Concrete," published by the Portland Cement Association, describing the spading of concrete. Note the detail hatch indicating the standard use of dimensional lumber for formwork. Image: public domain.

Mercer used the pause between deliveries of each batch to lay horizontal reinforcement into the wall, rather than tying it at predetermined intervals to the vertical reinforcing, as was even then beginning to be standard practice.[109] Rebar cages are time-consuming to construct on site, particularly in high locations; and can be difficult to coordinate with both forming and pouring operations. Mercer's solution, while less than ideal from an engineer's point of view (because of the lack of control over the precise vertical spacing, as well as position within the thickness of the wall), achieved, with perhaps some redundancy, an adequate structural solution which required less division of labor and fewer scheduling dependencies in the planning of the work. This is just one indication that Mercer paid close attention not only to the work-product, but to the work-flow. (It is also important to recognize that Mercer's work comes before the standardization of engineering design principles with regards to concrete reinforcement, so there was not one accepted standard for reinforcement type or spacing.)[110]

The turf depicted in step 5 of figure 1.26 is an unusual solution to the problem of soil and sand slipping through cracks in the platform rails. What today we might call a rapidly renewable or zero-waste strategy was for Mercer merely an ad-hoc solution to an unforeseen problem. (The settling of the vaults as the earth built up on the platform sifted down between platform boards.) By itself, the earth was too porous and irregular to produce an acceptable ceiling, so sand was added to regularize the curves and facilitate tile placement, with the added benefit that its color was taken up into the finished concrete. The tile laid in sand serves not only as a decorated finish surface but also as a form-release. This may have developed in part from Mercer's frustrations with achieving an acceptable form finish specifically on his ceilings. In some of the basement rooms of Fonthill, and of the Pottery, Mercer did without any form release or layer of smoothed sand, and the ceiling still retains the texture (and some of the small stones and debris) from the earth it was poured over. [Fig 1.28.] And where Mercer used wooden formwork, the results required considerable patching and parging, as his lumber was highly irregular, and, even when bought for the purpose, was roughsawn, and so its removal from concrete, once set, would have proved particularly problematic. [Fig. 1.29.]

Figure 1.28. Earth finish in the basement clay storage room of the pottery. Image: author, courtesy of the Moravian Pottery.

Figure 1.29. Boardform finish in the museum. Image: author, courtesy of the Mercer Museum.

In the earth formed vaults, tiles set in sand would have been easy to dislodge during concrete application; the initial layer of lighter, "cinder" concrete could be used to protect the tiles, as the lighter, finer grade of concrete could be packed around the tiles and any errors fixed as they occurred. (This would also require that the tile-setter and the concrete-placer maintain a close working relationship, and dialogue-in-process.) While this two-layer technique almost certainly created a cold joint between the cinder and structural concrete layers, very little separation is evident in any of the projects. The few exceptions that occur are visible primarily in areas where vaults are exposed to outside air and therefore to freeze-thaw cycles, as at the pottery. [Fig 1.30.]

Figure 1.30. Failure at the cold joint between concrete layers, Moravian Pottery. We can conclude that this was a failure between cast-in-place layers rather than between concrete and parging because the surface layer retains the burlap texture characteristic of the exposed cast-in-place ceilings in this area, something that will be discussed later. Image: author.

After the ceiling concrete had set, the legs of the platform were knocked out—allowing for the collapse of the platform and the easy removal (and potential reuse in the next room over) of forming materials. This would have offered considerable time savings over a more painstaking disassembly of typical vaulted centerings made entirely of wood.

Mercer's formwork does not work like conventional concrete formwork, yet it achieves, in its own way, a very similar end to the highest level of concrete craft today: that is, a finish surface direct from the forms. This finished surface, singularly dense with color, pattern, story, and dream [fig. 1.31] was, itself, a considerable design investment, and was only rarely approached in complexity or decorative effect, by installations of Moravian tiles in other buildings. This was due, at least in part, to the uniquely hybrid and simultaneous nature of their conception, fabrication, and installation, and this invented method may be considered one of Mercer's chief contributions to the field.

Figure 1.31. Ceiling of the Columbus Room, Fonthill. Image: author, courtesy of the Mercer Museum.

That these methods were imprecise should not be taken as a failure of method, as precision was not a primary design criteria for Mercer. Rather, the method can be seen to accomplish Mercer's own goals for the material with remarkable economy and dispatch in large part because it does not incorporate or attempt to satisfy extraneous criteria. Mercer used few materials, to a great variety of effects, a variety made possible by the flexibility of his methods of construction. A full consideration of his material practice, then, must include not only Mercer's craft of the materials of building, but his craft of method.

Chapter 2: Methods and Documents

It seems to be really possible to consider concrete as a reconstructed stone, worthy of being exposed in its natural state. It has been said that the appearance of cement is dreary, that is to say that its color is dreary. This is just as false as to say that a color coin be dreary per se, when in fact colors have value only in relation to their surroundings. The Unité at Marseilles was constructed during five difficult years and was constantly upset by a variety of circumstances; co-ordination was lacking, and indifferent workmen, even within the trade, were maladjusted to one another. For example the concretors and the carpenters who made the shuttering, did their work under the impression that the defects (as is usual) would be made good with the trowel, plastered or painted over when the shuttering was struck. The defects shout at one from all parts of the structure! […] I have decided to make beauty by contrast. I will find its complement and establish a play between crudity and finesse, between the dull and the intense, between precision and accident. I will make people think and reflect, this is the reason for the violent, clamorous, triumphant polychromy of the façades of Marseille.

-Le Corbusier, Dedication of the Unité d'habitation, Marseille, 1945[111]

I was getting ready to tell you of a lot of vaults I'm throwing together to call a house in reinforced concrete on a hill nearby—Mercer's Folly—quite the thing. Ceilings, floors, roofs, everything concrete. You stand up a lot of posts—throw rails across them—then grass—then heaps of sand shaped with groined vaults, then lay on a lot of tiles upside down & throw on concrete. When that hardens pull away the props & you think you're in the Borgia room at the Vatican. Quite an experiment but I wasn't going to say much till I had it done. Then astonish people. All the intricacies of Holanby House including the "Priest's Hole." You must come over and see it.

-Henry Chapman Mercer[112]

"Instruct the mason with general orders … and then keep your fingers out of it.";

-Bernard Maybeck

Unlike the architects to whom he supplied tiles, in Mercer's own architectural production the work was orchestrated without formal drawings. Informal sketches, and brief, often verbal, communications took on the primary burden of the transmission of both knowledge of building and the authority to proceed. Where architectural documents were created, they took the form of informal, fragmentary notebooks containing partial plans, details, notes, and other forms of representation. Despite their partiality, Mercer came to rely on these documents, and to pursue the sorts of results their internal narrative and procedural order, and adjacency to construction, made possible. Mercer's use of these construction notebooks, and the various notes, sketches, and financial ledgers which accompanied them, begins to reveal how complex constructions were accomplished without normative architectural documents. In what follows, we can trace out the way each of various forms of work were presaged by an apposite form of documentation; and how these documents were in turn reconfigured by the progressing work. This interwoven structure of document and building activity made certain innovations in the structure of work more possible.

A. The Craft of Method

It is important to remember that these manifestly un-polished, unrefined techniques are being employed by a collector of artifacts and a scholar of craft traditions. While it is common to assume a builder resorts to ad-hoc methods because of a lack of foresight, education, or organization, in Mercer's case such an assumption would prove to be unfounded. Certainly, Mercer's method is characterized by a marked experimental indeterminacy: each step in the process is open to renegotiation; and this renegotiation is undertaken as part of the act of building. In the building of the vaults at the pottery, where there was to be relatively little decoration in the ceilings, the labor-intensive smoothing of sand and laying of tile at Fonthill was replaced by a more direct and conventional pouring of concrete over wood centerings (for barrel vaults) or earth centerings (for cross vaults). He used these simplified methods first in the basement and back rooms of the pottery, and found that, without the smooth sand layer, or tile, to act as a form release, the raw earth created an unacceptably porous and irregular surface, while the raw boards were difficult to remove. In the construction notebook, he wrote, "Find carpet needed over loose earth forms. Find that unsifted cinder casts very porously on ceiling, especially on dry and rough earth forms, but tight on boards where carpet thrown over cracks. Decided to use carpet at all points."[113]

There are a number of fabric patterns on the ceilings of the pottery, left by Mercer's various attempts to improvise a form liner. Raw earth in the lowest levels [see fig 1.28] gives way to carpet and burlap in the primary work spaces [fig 2.1]; in the exterior colonnade it seems burlap was preferred. [Fig 2.2.] In the showroom and office of tileworks manager Frank Swain we see some tiling, and evidence of the sand-finish used at Fonthill. [Fig 2.3.] The entire campus of the pottery is a continuous string of experiments in ceiling-technique.

Figure 2.1. Carpet fragments adhered to concrete ceiling, with iron-band-reinforced brick kiln wall beyond. Moravian Pottery and Tileworks. Image: author, courtesy of the Moravian Pottery and Tileworks.

Figure 2.2. Burlap pattern in the cloister colonnade, Moravian Pottery. Image: author.

Figure 2.3. Sand finish at showroom ceiling, Moravian Pottery. Image: author, courtesy of the Moravian Pottery and Tileworks.

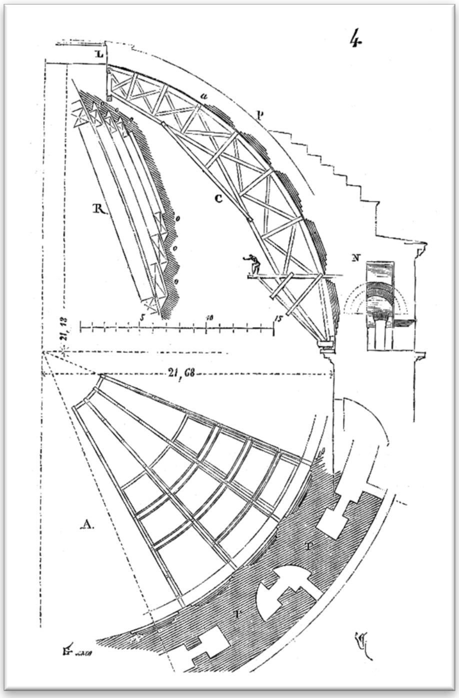
It is at first easy to dismiss this as a method designed merely for speed over formal exactitude. There is some truth to this, particularly at the pottery. But to say that it was ad-hoc, just-good-enough, or even slapdash, is not to say that this impromptu formwork was not also, in its own way, systematic. In his construction notebook for the pottery, Mercer writes, "Barrel vaults made of boards, cross vaults of earth."[114] This is supported by observations of the extant building, in which a stepped profile is visible in some of the barrel vaulted spaces, such as the second floor work room adjacent to his double-height display space (added a few years after the rest of the construction); and conversely by the regular, if coarse, curves that typify groin vaulted spaces.

Precedents

Perhaps, as Mercer often comments in his correspondence, he is motivated by an appreciation for certain grand spaces of European villas and abbeys, which traced their vaulted geometries to Roman precedents;[115] or perhaps he was influenced by his study of kiln building traditions, and his own experience building (and rebuilding) kilns for the pottery.[116]

Whatever his motivation, Mercer invented, or reinvented, a method for working in what was at the time an untested and unpredictable material. Widely traveled in Italy and continental Europe, Mercer was familiar both as a layman and an archaeologist with the masonry vaults of Roman engineers. Mercer did not, however, take over these methods wholesale into his own work. Most significantly, while the authoritative sources Mercer would have had access to, including Viollet-le-

Duc's definitive mid-19th century *Dictionnaire Raisonne de L'Architecture Francaise du XIe au XVIe Siecle,* document Roman formwork and vault centerings, the methods depicted relied on wooden armatures formed to the precise contour of the vault being built. [Fig 2.4.] Mercer eschewed these complex and specialized works of carpentry in favor of hybrid wood-and-earth centerings. Some sources attribute this to a deliberate adaptation, on Mercer's part, of Roman techniques.[117] But archaeological accounts in Mercer's time, with a few exceptions,[118] seldom mention earth centerings (that is, vaults and arches whose shapes are formed using a substructure of shaped earth, rather than wood). Subsequent scholarship[119] has allowed a more complete understanding of Roman uses of formwork and centerings with regards specifically to unreinforced concrete structures. Some of these were even, like Mercer's constructions, lined with tile laid up over their wood centerings, as in the case of the typical barrel vault illustrated in Viollet-le-Duc's *Dictionnaire*. [Fig 2.5.] In Mercer's time, however, Roman vaults were still considered to be essentially masonry in nature[120], with the Pantheon recognized as an extra-ordinary example not so much of structural concrete construction as of an ingenious solution to the problem of weight reduction in the concrete infill of long-span masonry vaults through the control of concrete mix design. In a detail [fig. 2.6], from his *Dictionnaire,* Viollet-le-Duc illustrates the construction of the dome of the Pantheon (shown also in Fig. 2.4). Note the similarity in technique to the typical barrel vault. Viollet-le-Duc illustrates an essentially masonry structure, with concrete used as infill. In his drawing, the grid of brick serves as an armature for the concrete coffers. This low estimation of the capacities of concrete would have been not only because of the lack of tensile reinforcement, but also in part because, prior to the invention of Portland cement in the mid-19th century, naturally occurring cements were far more variable, unpredictable, and generally lower strength, than the material we know today. What seems commonsense in our times—that concrete can be used as structure in the largest buildings—would have been counterintuitive to Mercer and his contemporaries. As Adrian Forty notes in his 2012 cultural history of concrete, "Still in 1914, signs of the imminence of such a revolution [reinforced concrete as the epitome of modern architecture] were scanty: a few stark industrial structures in Europe and the U.S., and some domestic and commercial buildings largely indistinguishable from buildings made from traditional materials."[121]



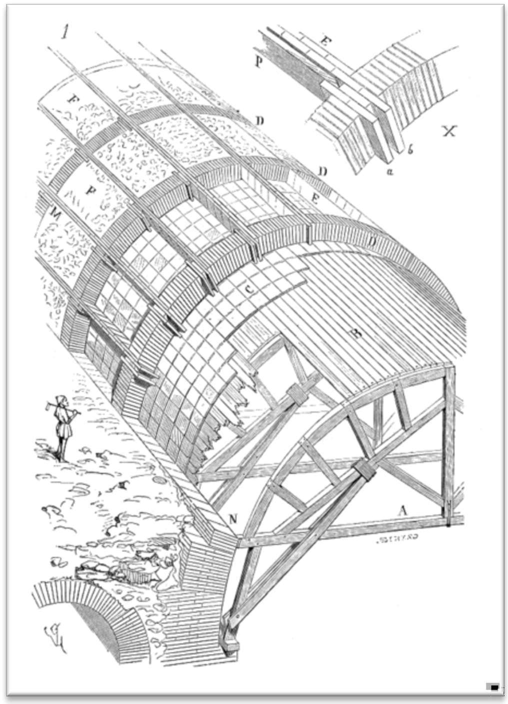


Figure 2.4. Section view of the wooden centering used in the construction of the pantheon. Speculative reconstruction by Viollet-le-Duc, published in his Dictionnaire. Image: public domain.

Figure 2.5. Isometric view of a typical Roman barrel vault. Speculative reconstruction by Viollet-le-Duc, published in his Dictionnaire Raisonne De L'Architecture Francaise Du XIe Au XVIe Siecle. Image: public domain. Note that for Viollet-le-Duc, unlike Choissy, the layer of tile seems to be illustrated purely as a form-release for the concrete, rather than as a structural layer.

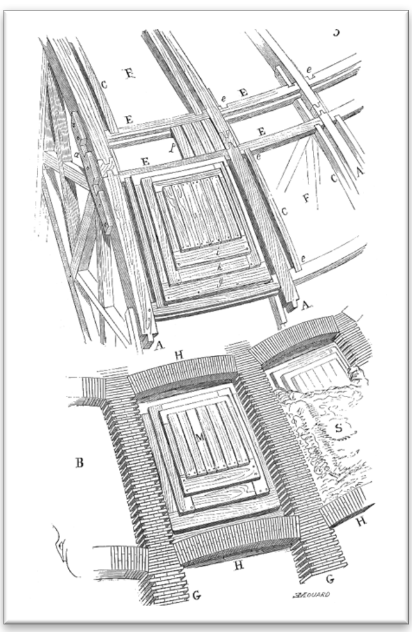


Figure 2.6. Isometric view of coffer construction detail at the Pantheon. Speculative reconstruction by Viollet-le-Duc, published in his Dictionnaire Raisonne De L'Architecture Francaise Du XIe Au XVIe Siecle. Image: public domain.

Even when vaults were entirely comprised of concrete, as at the cisterns of the imperial palace at Trier,[122] scholars attributed their structural performance as much to the layer of tiles placed beneath the concrete (sometimes only one tile thick) as to the concrete itself.[123] Earth centerings were not widely discussed, and where they are mentioned, they were generally relegated to substructures.[124] While it is not impossible that Mercer had come across a few sources that mentioned Roman earth centerings, copies of these works were not in Mercer's personal library, the construction notebooks bear no mention of the practice, and what little contemporaneous academic commentary on the subject there was shows up only in asides and appendices.[125] Therefore, while not impossible, it would seem unlikely that Mercer based his method directly on Roman precedents. It was generally understood that in classical times cement was used in wall and floor/ceiling construction, as mortar, infill, and finishing. Classical sources detail the depth of craft knowledge pertaining to these uses of naturally occurring cements. Yet interior ceilings, particularly when vaulted, were normatively built separately from, and supported by, the floor above. This merited a mention as far back as Vitruvius:

> When arched ceilings are introduced, they must be executed as follows. Parallel ribs are set up, not more than two feet apart: those of cypress are preferable, because fir is soon injured by the rot and age. These ribs being got out to the shape of the curve, they are fixed to the ties of the flooring or roof, as the case may require, with iron nails. The ties should be of wood not liable to injury from rot, nor age nor damp, such as box, juniper, olive, heart of oak, cypress, and the like, common oak always excepted, which, from its liability to warp, causes cracks in the work whereon it is employed. The ribs having been fixed, Greek reeds, previously bruised, are tied to them, in the required form, with cords made of the Spanish broom. On the upper side of the arch a composition of lime and sand is to be laid, so that if any water fall from the floor above or from the roof, it may not penetrate. […] The arches being prepared and interwoven with the reeds, a coat is to be laid on the underside. The sand is afterwards introduced on it, and it is then polished with chalk or marble.[126]

While Mercer kept a copy of Vitruvius in his library, it would seem that he was not drawing directly upon his treatise in the development of his ceilings.

Perhaps of more relevance as a possible inspiration for Mercer's technique was the fascination of 19th Century archaeology with Roman road building, in this case particularly the method for marshy terrain. In these situations, a wood structure of posts, beams, and rails, was used to stabilize the ground before being topped with dressed or rubble stone, then crowned with layers of progressively finer gravel and sand.[127] [Fig 2.7.]

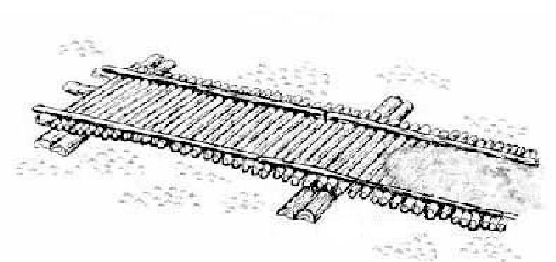


Figure 2.7. Roman road building techniques for marshy terrain. Image: U. S. Forest Service / public domain.

Even considering these possible influences, there is no exact corollary to Mercer's hybrid earth and wood technique for vault construction in antique practice. It was a method uniquely suited to Mercer's decorative tiles, which were distinguished by their irregularity and the complexity of their sequences. Some of his most ambitious tile installations he developed specifically for or in tandem with the building of Fonthill, something we will discuss further in chapter 6. It may be that the house inspired innovations in tile design; or that the tiles themselves, their thickness and polychromy, their allowance of wide and irregular mortar joints, their high-relief, and their scenographic and narrative arrangements, inspired the development of these novel building technologies.

The Maturation of Technique

In his final architectural project, the museum, Mercer used the methods he had developed over the course of his earlier projects. There we see a combination of the rapidity and economy deployed at the pottery, with the attention to detail and careful planning and circuitous pathmaking Mercer used throughout Fonthill. While still maintaining the open-ended and adaptive quality that marked those earlier and less-refined experiments, Mercer observed a stricter and more methodical process both with regards to planning as well as in record-keeping, material supply, and uniformity of construction detail.

In a review of the records of construction for the Mercer museum, a few things stand out. First, the job site was far more structured than Mercer had previously arranged. A rail spur provided access to the site for train car loads of aggregate, sand, and cement, and Mercer bought his raw ingredients in quantity. The cement, vulnerable to weather, would be pulled into a long shed built for the purpose, and delivered by wheelbarrow to a platform set up below the building. There, Mercer's gas-powered mixer was set up and served, providing concrete a wheelbarrow at a time to the work crew on the building. A site-built wooden crane attached to the upper part of the building, powered by a horse, lifted concrete to the floor level under construction, where it was placed, while further on around the building other workers extended the formwork. [Fig 2.8.]

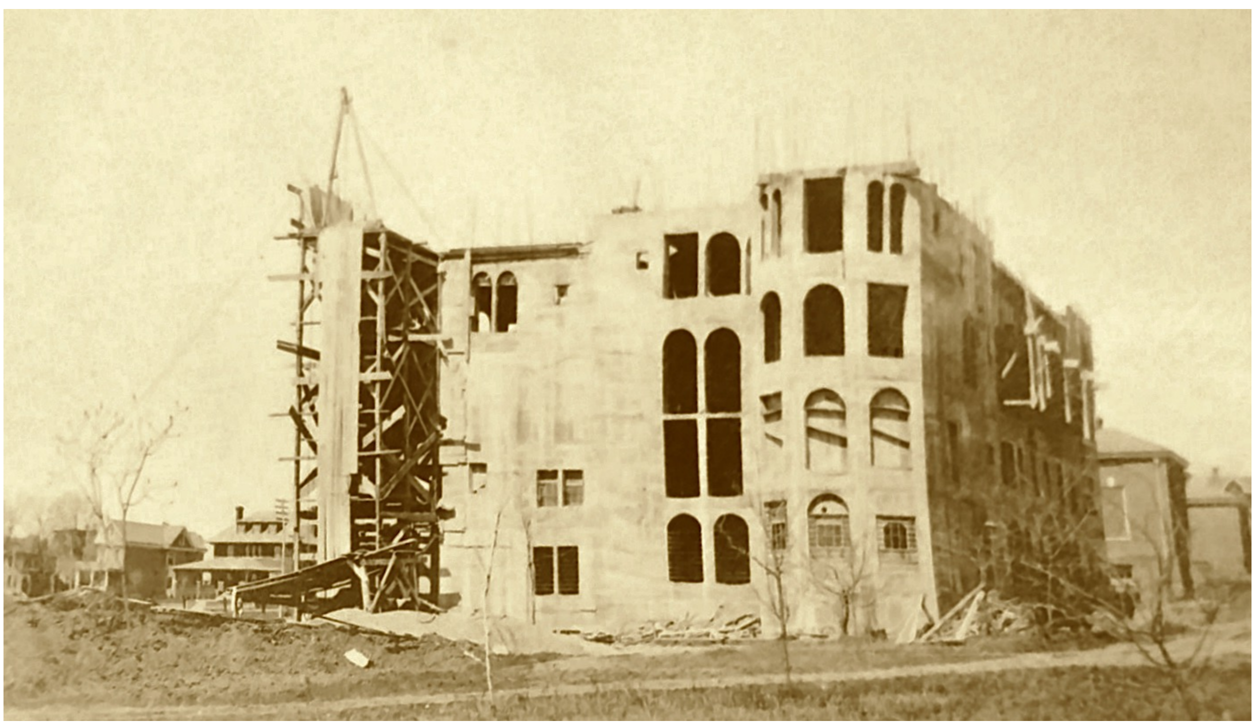


Figure 2.8. The museum, partially complete, with wooden crane to upper left. Note the faint lines of rebar extending vertically from the top level. Image courtesy of the Mercer Museum Research Library.

This construction was labor-intensive, by today's standards, and indeed Mercer's crews would typically put in 6 ten-hour days per week,[128] only slowing as inclement weather demanded. But it was also very well-choreographed, so much so that any one hold up in the chain of actions would have downstream consequences on the overall pace of the job—something that would present a problem for Mercer as the project progressed.

The vaults at the museum were complex formally, with intersecting and overlapping spans; but quite simple decoratively. Only in the museum library did Mercer approach the complex tilework and careful finishes he pursued at Fonthill. [Fig 2.9.] Elsewhere bare concrete is evident, often board-formed and regular, if rough, in appearance. [Fig 2.10.] There is less cosmetic parging at the museum than at Fonthill, both within and without. While this may be a result of Mercer's differing aims for the occupation of these two buildings, the quality of "form finish" is much higher at the Museum, rendering the time-consuming process of parging and refinishing less uniformly necessary.

Figure 2.9. The museum library. Image: author, courtesy of the Mercer Museum.

Figure 2.10. Museum, typical concrete vaults. Image: author, courtesy of the Mercer Museum.

This regularity was made possible by another of Mercer's key shifts: from using reclaimed lumber for formwork to using roughsawn boardfoot pine. This change was made about a year into the project. In the ledger of expenses kept throughout the project, Mercer lists as his very first line item dated May 1, 1913: "Old Lumber Fencing at Base Ball Park".[129] Thirteen months later, on May 1, 1914, he makes an entry for a payment to "C. S. Witherill Lumber".

This is corroborated by notes in his construction notebook. In an entry for 1913 he writes, "bought at sale all boards of fence and stand of ball ground." And later: "1914. By May 20th 1st gallery level with all rooms & alcoves cast". The ballpark boards, then, were used for the foundation and the first floor. The remainder of the Museum—and this is confirmed by observation—was formed with uniform roughsawn boards.

This was quite literally board-foot lumber, unplaned 1"x12"x16-foot planks, and these were used to form walls, columns, and many of the vaults. The workers also sawed or split planks for battens, and used 4x4 roughsawn lumber for posts and bracing.[130] During the course of the project Mercer settled on linseed oil as a release agent, and may have used it to facilitate the release of the roughsawn formwork. (While gasoline is also possible, as the ledger lists it among purchases, it was most likely used to run the concrete mixer—in places it is listed as such explicitly.)[131]

To choreograph these actions Mercer used a construction notebook, as he had in his other projects, supplemented with the accounting ledger listing not only materials and deliveries but also each workman by name, hours worked, and, where applicable, specialized skill. We should consider, then, the ways both the construction notebook and its accompanying ledger provoked, structured, and reflected Mercer's original methods for building—and how we might find, in them, the story of his practice.

Systematic Uncertainty

Day by day, room by room, Mercer would arrive at the museum job site and survey the progress from the day before. He knew approximately, but not exactly what he would find. He would begin with survey and diagnosis of completed work, and proceed to verbal instruction of either the work crew entire, or the crew foreman. In an interview recorded in 1963 with the sole surviving workman from the museum project, William Frankenfield, then-curator of the museum Jack Potter asks,

> What about the construction. Was Dr. Mercer there a great deal of the time when the actual construction was taking place? In other words, did he supervise most of the construction himself, or did he more or less have a foreman who took care of that for him?
>
> F. Well, Mr. Mercer was not here exactly all of the time. I remember he would come in about once in the morning probably about 11 o'clock and probably stay around for an hour or so in the morning. Then about half past three or so or four o'clock he would come back again in the afternoon.

From Frankenfield's account, as well as archival photographs showing formwork in place [fig. 2.11.], we can infer that the work proceeded around the perimeter of the museum, with room layouts, rough openings, columns and interior partitions worked out based on the room function and overall dimensions listed in Mercer's construction notebook. Many of the elements normally added later, including interior details such as handrails and stairs, and exterior details such as cornices and dovecotes, were inserted into the concrete structure as work progressed. [Fig 2.12.]

Figure 2.11. Formwork in place, and stripped formwork at the base of the museum under construction Image: courtesy of the Mercer Museum Research Library.

Figure 2.12. Pipe used as cast-in-place floor to ceiling balusters in the stove plate room balcony. Image: author, courtesy of the Mercer Museum.

In several key rooms, there occurs what would seem to be a failure of planning: in the carpentry room, for example, horizontal boards hung with tools cover several of the window openings. [See figure 5.17, part of the discussion of the rooms in the museum in chapter 5.] This may simply have been a case of Mercer's collection outgrowing the rooms he planned for it. But a second possibility exists—that the tools-hung-on-rough-boards is itself a display of the sorts of buildings carpenters might have used to house their tools: rough, uninsulated sheds, built as needed and often up against more permanent buildings. (While we don't know if this is what Mercer planned, some of his other documented decisions point toward this conclusion, including the purchase, disassembly, and reassembly of a complete log house on the grounds of the Museum in the 1920's.)

While several of the crafts displayed in the museum have been relocated to rooms not designed for them, the carpenter's tools remain in their original location. Mercer intended for the rooms to have whatever natural lighting best suited the collection of that room, and designed his window sizes and layout to that effect. In the speech he would give at the presentation of the finished museum to the Bucks County Historical Society, he said

> In order to allow for the varied size of exhibits the levels of floors and ceilings vary greatly, and there are numerous fireplaces. The windows were placed so as to get the most and best light regardless of outside effect, and when the object of the building was attained, which was entirely a matter of inside arrangement, the pitch of the roof, the position of steeples, dormers and chimneys, and the shape of the mullions of windows, were only then considered from a decorative point of view.[132]

'The most and best light' may suggest itself as hyperbole to the contemporary museum visitor, accustomed as we are to the ubiquity of artificial light in museum settings (as well as seamless, well-integrated lighting design). Certainly, those of Mercers displays which have not been significantly altered by the subsequent installation of lighting appear to the modern eye to be dim and cave-like spaces filled with a dizzying array of implements. The early-20th century eye, however, accustomed to different living and working environments, may have perceived things differently. This question, of the world-view of the museum and its tools, will be addressed in detail in chapter 5.

The process of construction of the Museum, then, was to move from room to adjacent room, erecting the formwork of both outer walls and inner partitions and columns, working from floor to floor (one is reminded of the chambers of a nautilus shell), consulting the construction notebook and directing the placement of window openings and other elements as the room took shape. This followed the general plan diagram in the notebook, and proceeded, room by room, circling the central atrium. The circuit would begin adjacent to the existing Bucks County Historical Society Elkins Building. Frankenfield recounts his own experience of the process:

> F. We laid the concrete from the old building, brick building, and we worked back towards the house, so that they made it one floor all the way through from that house so that when we was done with the scaffold where we pulled up the concrete we poured the last right close. […] If it was good drying weather the time we got to the south end that concrete would be hard enough that we could start to take the shoring out […] working from the north side to the south side the time we got that poured it would take anywheres from six to eight weeks before we got one floor done.[133]

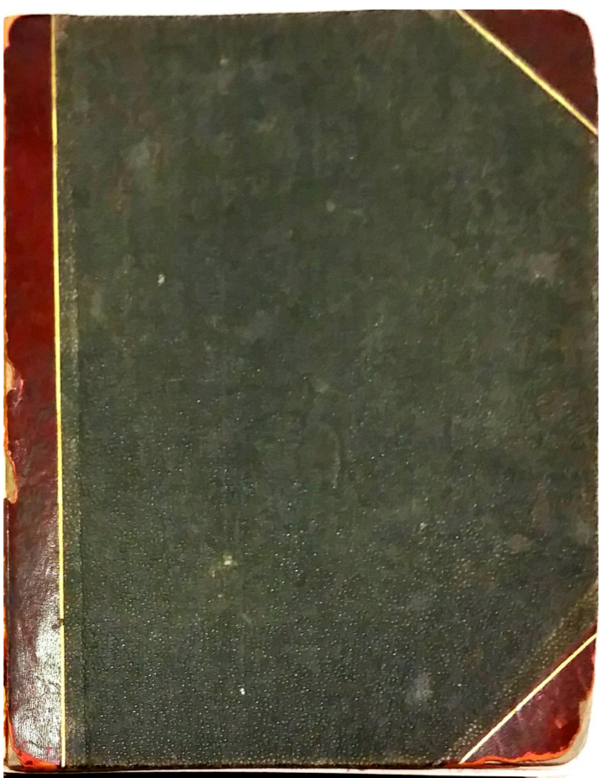
Each construction decision—from the shape of a room to the configuration of its stairs or passages—rather than being spelled out in normative construction drawings, could be generated on site based upon the notes in Mercer's notebook, coupled with an on-the-ground assessment of the completed work directly adjacent. We will come back to the question of improvisation. For now we should observe that this sort of experimental, improvisational method required both structure; and permissiveness. The latter would seem to be a matter of trust, of long association and shared craft practices; the former was almost certainly provided by close collaboration between Mercer and his foremen; and anchored in the construction notebook as an (admittedly unorthodox) construction document.

We should not confuse permissiveness or trust in his workers for a lack of rigor. Mercer set some large decisions is play early on in the building process (the primary materials we have discussed in chapter one were predetermined and remained a constant in his work; room layouts and their coalescence into an approximate outer footprint occur in the opening pages of each construction notebook) but he left others until the activity of construction and the logic of individual room layout required their determination (such as interior partitions, window shapes, and stairs). His daily presence and negotiation of the vicissitudes of construction allowed the development of this flexible approach.

This leaves us with a key question, the question of coordination: how was such regulated flexibility coordinated? Clearly, the oral transmission of architectural technique was a core part of Mercer's process. But what was the role of the construction notebook? How did it work to supplement informal communication and ad-hoc decision making in order to provide the structure necessary to coordinate this incremental, iterative method for clay tile and reinforced concrete construction?

B. The Construction Notebooks

Mercer's construction notebooks are perfectly normal journals, on the one hand: collections of daily miscellany, made up of speculative drawings, wish lists, and notes about found objects, people, and conversations. They are at times diary-like, recording daily happenings (not always related to the construction). And they are sequential planning notebooks for his construction projects. They contain primarily his notes and sketches in graphite pencil in a loose informal hand. Construction notebooks have been preserved for each of his three major projects, though there is no evidence he followed this habit for his smaller projects—to the contrary, occasional pages in the three notebooks are devoted to consideration of these smaller projects, the planning of which overlapped with the building of the major works.[134] The notebook for Fonthill, the first of its kind, begins with jotted plans of various rooms and occasional overall dimensions, proceeds to elevations of windows and doors, and moves on to show details, from the profile for window mullions and their fabrication (also from concrete) to the "soil pipe in N. ~~bathroom~~ closet—".[135] This hierarchy, from plans to elevations and sections to doors and windows and details, to schedules and etc., would be familiar to an architect practicing today. [Fig. 2.13-2.18.]. Yet this order is partial and recursive, ultimately nonlinear, something we will discuss in greater length later in this chapter. And while Mercer created a "revised" sketch plan on loose leaf paper of many of the floors at Fonthill, these seem to have been created after, rather than prior to, the construction activities described in and orchestrated by his construction notebooks.[136]



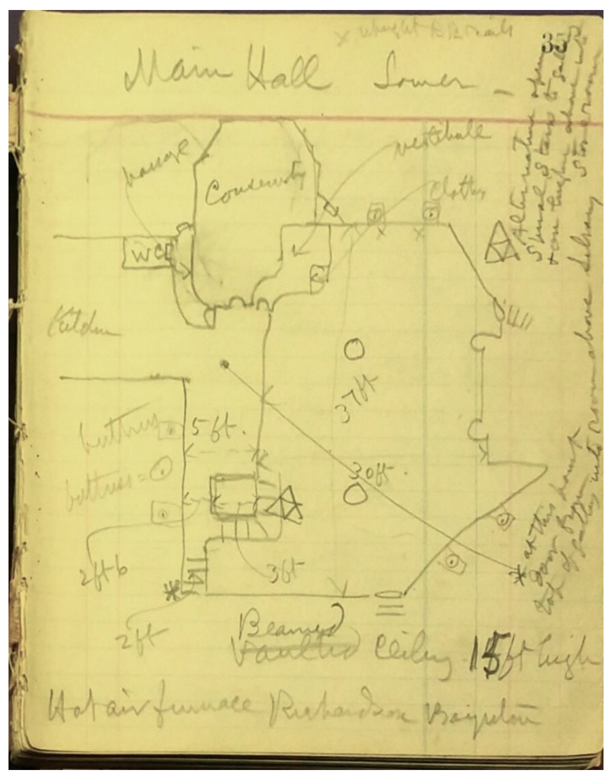


Figure 2.13. Fonthill construction notebook. Image: courtesy of the Mercer Museum Research Library.

Figure 2.14. Early room plans of the building. Image: courtesy of the Mercer Museum Research Library.

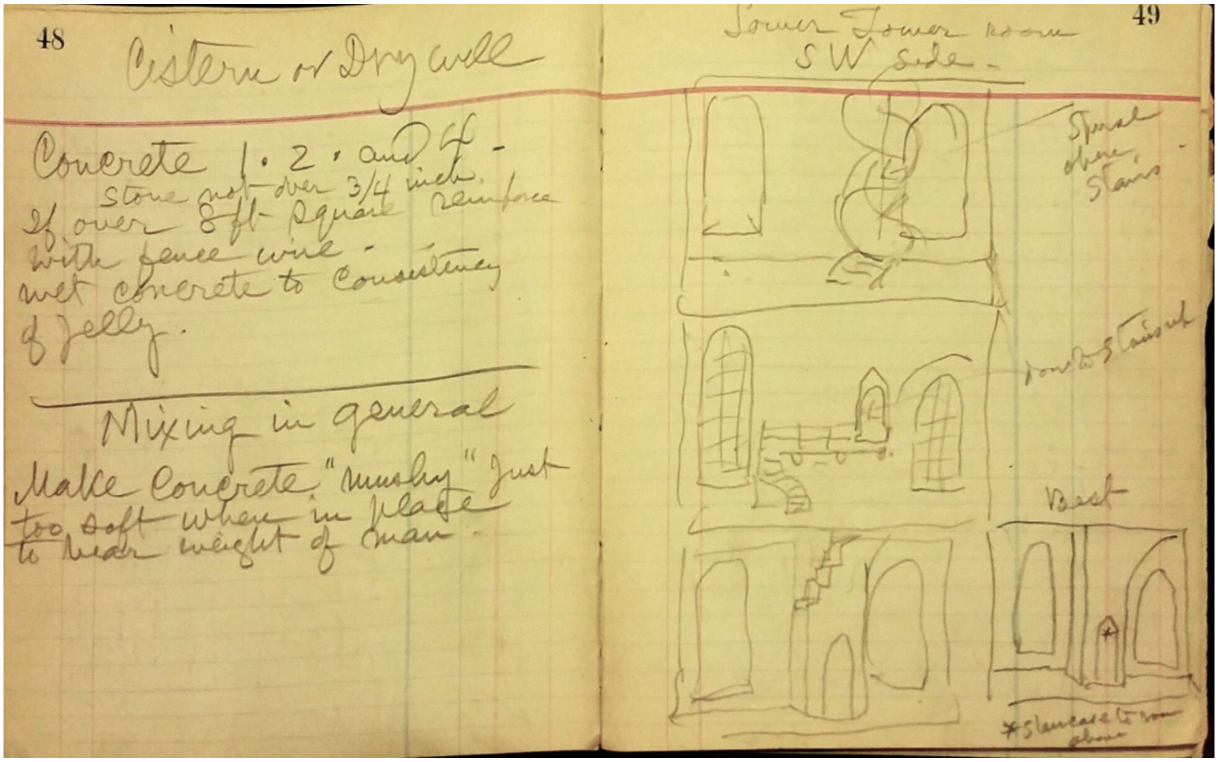


Figure 2.15. Schematic section. On facing page Mercer makes notes for concrete recipes and rules-of-thumb. Image: courtesy of the Mercer Museum Research Library.

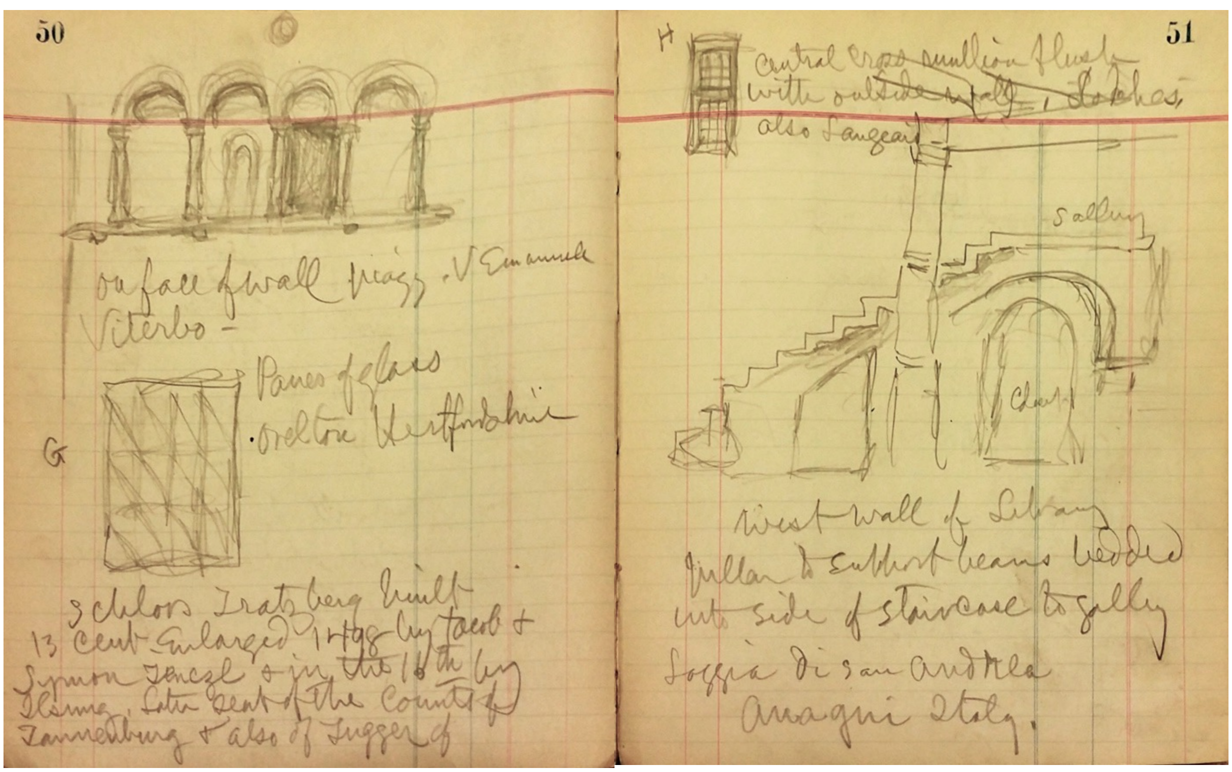


Figure 2.16. Interior elevation: stair in "Saloon" room. Text reads: "West wall of Library pillar to support beams bedded into side of staircase to gallery Loggia di San Andrea Anagni Italy." Image: courtesy of the Mercer Museum Research Library.

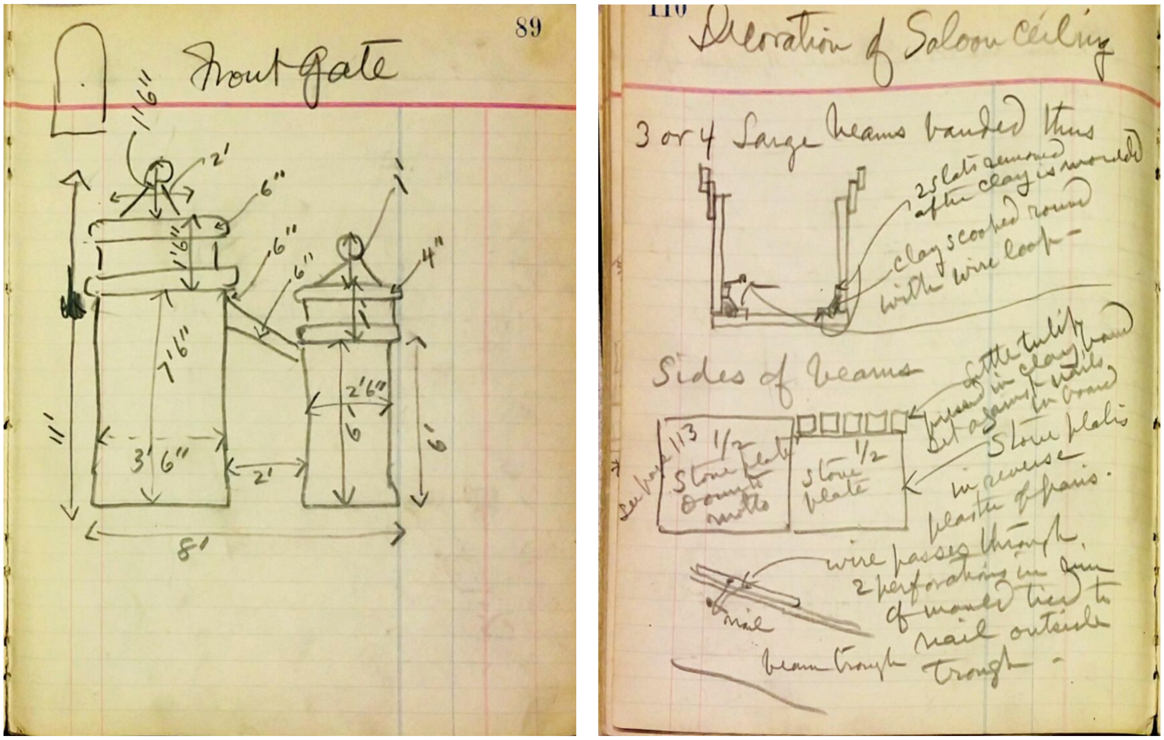


Figure 2.17. Details for front gate, Saloon ceiling. Text reads, "3 or 4 large beams banded thus [2 slats removed after the clay is moulded] [clay scooped round with wire loop—] Sides of beams [see page 113] [1/2 stone plate down to motto][1/2 stone plate][Little tulip pressed in clay, band set against rails in board][Stove plates in reverse plaster of paris.][wire passes through 2 perforations in rim of mould tied to nail outside trough.][nail][beam trough]" Image: courtesy of the Mercer Museum Research Library.

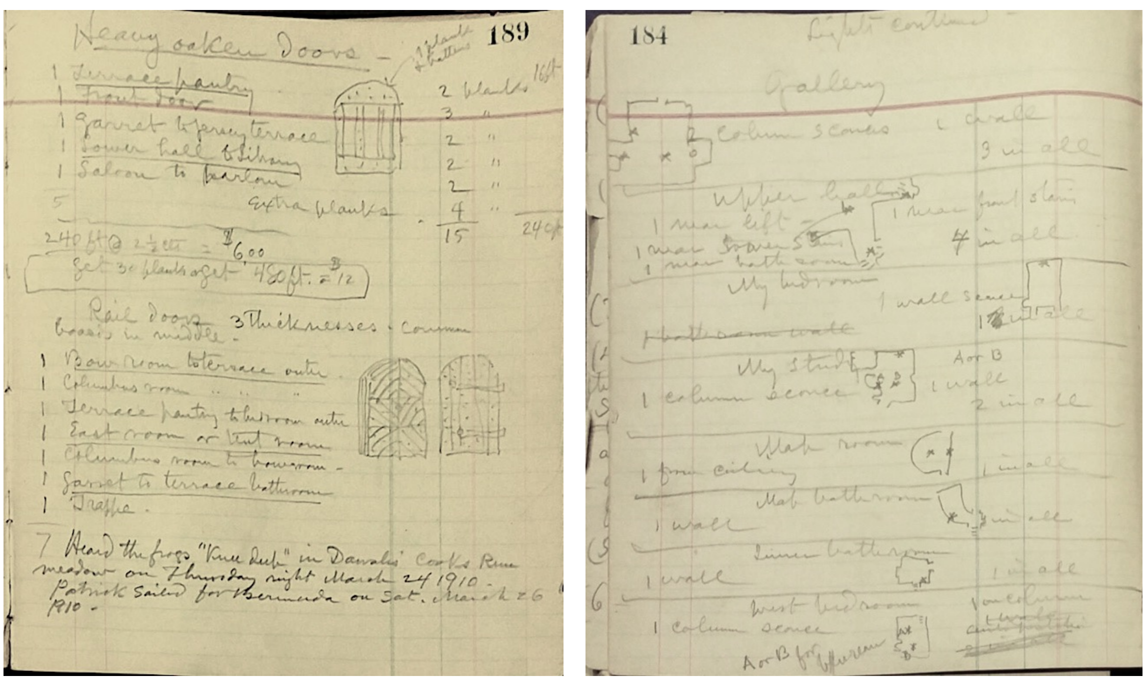


Figure 2.18. Door and lighting schedules. Image: courtesy of the Mercer Museum Research Library.

While much of the early part of the notebook is primarily composed of graphical explorations, as the notebook progresses Mercer begins to adopt a more didactic tone:

> Decoration of Ceilings — Library. Lay out rectangular shores between beams with bands composed of Cluny quarries and red unglazed. In rectangles place small mosaics about two feet apart. Indian making fire, galleon, etc., sowing corn, blowing conch shell etc. Vary these plaques with tile people. Construct these mosaics by laying drawings on earth bonding with clay and pouring on cement colors—.[137]

This shift in tone (in this case and at times subsequently distinguished by the substitution of pen for his customary pencil) suggests he may be using the notebook not merely as a record-keeping device—logbook—or as a place for creative explorations—sketchbook—but also as a place to prepare himself for the instruction of his workmen and/or foreman.

In the 1963 interview, Frankenfield recalled the absence of architectural drawings in Mercer's projects: "I don't remember ever having seen no sketches, no plans of any kind." Absence of documentation required that Mercer be far more present than is typically the case for architects, something made possible by Mercer's insistence on living near his projects and his daily visits to the jobsites. When he was building Fonthill, Mercer lived first at the family home, Aldie, about a mile away. As construction intensified, he moved to a rental house, "Linden House," located a block south from the property.[138] When working on the Museum, Mercer had moved into Fonthill; the Museum was again about a mile from his residence. The other projects were considerably closer. [Fig. 2.19.]

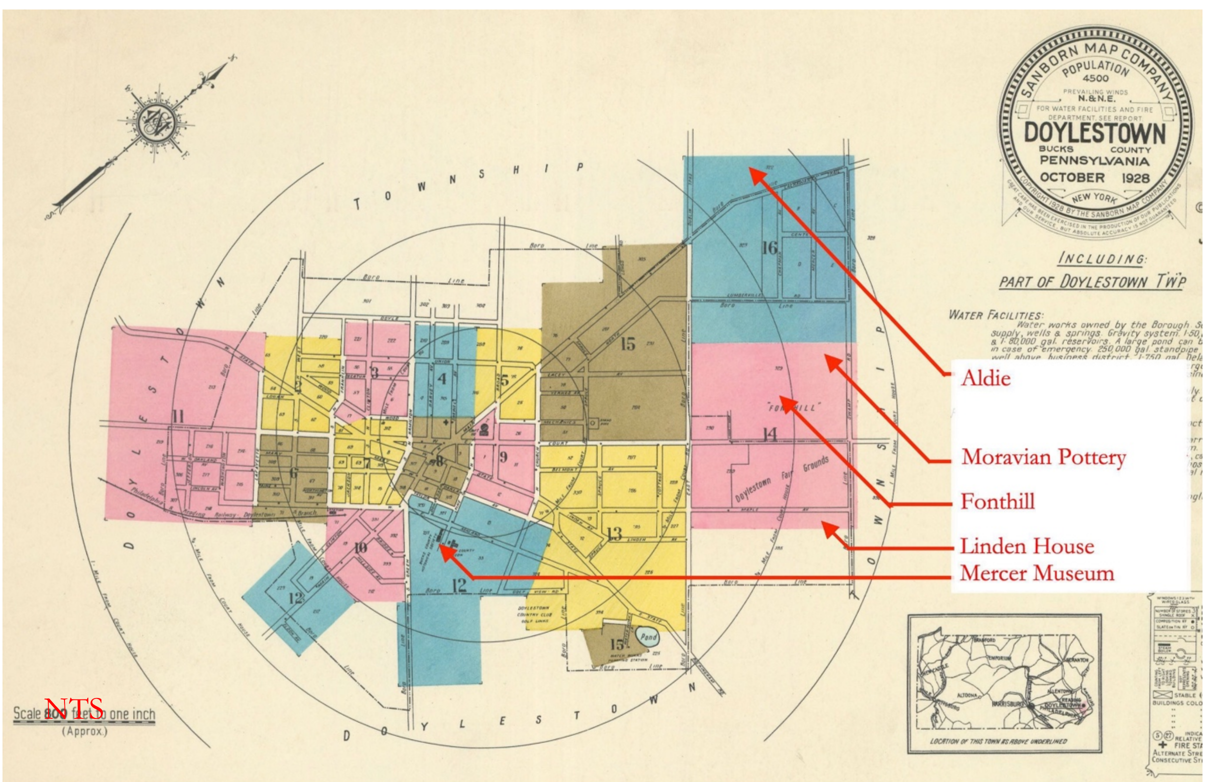


Figure 2.19. Area plan of Mercer's projects. Image: 1929 Sanborn map / public domain; annotations by author.

Mercer's notebooks, then are predicated upon daily presence and verbal, if not manual, participation in construction. They follow a recognizable pattern and use a limited and consistent set of components. The notebooks are bound and the pages numbered, so we may read these documents chronologically, as Mercer does not pre-date his pages, or leave blank pages, moving instead to the next page in sequence to finish his entry. Occasionally, later in the notebooks, we find passages on other subjects or sites, which interrupt the regular chronological flow, but these can be readily discerned by their extraneous subject matter and, often different media and style of penmanship. The notebooks, in their chronological deportment, follow a characteristic pattern: at first the notebook is composed mostly of graphical and lexical explorations pointed at a building yet-to-be-built, functioning thus in the standard mode for architectural design drawings—as a projection of possible-buildings, encompassing speculations and considerations for the building to-be-built. In these pages we see a preponderance of sketchy, searching plans, but also other drawings and notes, both of the building and of fragmentary historical precedents. Before long, these planning pages begin to alternate with dated records of construction progress, and the 'rehearsal' passages described above; these come in sequence just prior to the passages recording the explored work achieved. The Fonthill notebook, for example, begins with graphical exploration in plan, including dimensioning, layout, and circulation in partial and indistinct drawings (pages 25-37), next we see doors, windows, and overall elevations (38-54), and following this he moves on to consider details such mosaics cast into ceilings (97, 105). But here other modes begin to intrude.

The first dated account in the Fonthill notebook appears on page 80, and begins, "April 24, 1908. General house foundation partly filled in." This follows the section devoted to sketch plans of various rooms (the first 24 pages of the notebook have been ripped out, and it is unlikely they contained more complete plans.)[139] The remainder of the first 60 numbered pages are devoted to possible construction details, historical precedents and material technologies and compositional patterns for windows, doors, etc.

Further speculations, primarily of a pragmatic nature and concerning the solution of particular detailing issues, continue up to and after the dated pages recording the progress of the work once it has commenced. These speculations, mostly in graphite pencil with some color for diagrammatic clarity, follow the likely order of questions that would arise as the building emerged from the ground: from the foundation we proceed to sketches working out the walls and ceiling vaults; proceeding from there to cornices, terraces, and chimneys, following the building up out of the ground. Each page, it would seem, is the foundation for the one that follows, coming into being after the work described on previous pages is complete, and before the work on ensuing pages has occurred. This tells us that the initial resemblance to the typical architect's hierarchy of drawings (plans, elevations, sections, details) was only superficial; that this is instead very much a chronological account of a single synthetic process, comprised not only of multiple simultaneous construction acts or methods, but of *design and construction pursued in simultaneity*. While this was not unusual at the time, it was often limited to detail and ornament, rather than extending from space planning through façade design to the placing of mosaics.

The notebooks follow a problem-solving sequence that is both spatial—ground to sky—and chronological—in order of the logic of construction. This spatial-chronological-constructional order is the result of filling one numbered page after another; but the particular order of parts offer some surprising revelations about Mercer's process. These will be explored in chapter 6. Mercer's construction notebook at the Museum, for example, can be pictured as a collage; a call-and-response; or a dialogue with the materials of building. However we characterize the construction notebook, we can analyze its structure as composed of the following types of representation: Drawings such as plans, elevations, sections, and details; programming and space planning; specifications; construction logs; as well as blank pages and notes on unrelated subjects. [Fig. 2.20.]

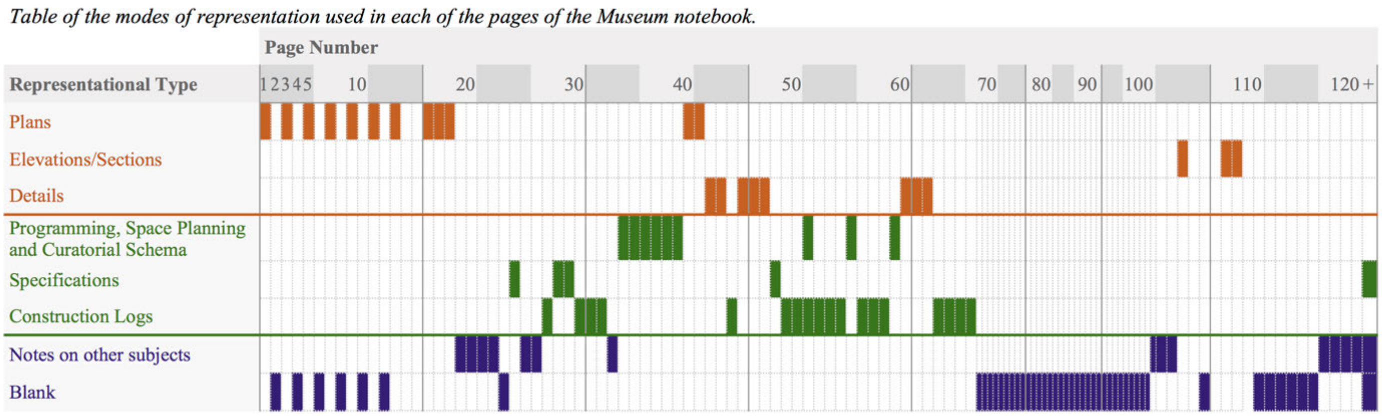


Figure 2.20. Table of the modes of representation used in each of the pages of the Museum notebook.

Rather than following the logic of descriptive geometry and the sequence of increasing scale, the way a conventional set of construction drawings might, Mercer's construction notebooks can be seen to follow the chronological, and fully three-dimensionally spatial, order of building fabrication. Significantly, we can see that, while he began with considerable plan drawing, he followed up with more space planning and plan drawing after construction had commenced. Part of this was a natural consequence of the co-creation of the building and the construction notebook, in its embedment in the act of construction as a tool of the builder. Part of this was presumably also an intentional decision to postpone the decision-making process until he could see the results of earlier steps, using the results of earlier experiments-in-building to inform his decisions about later ones. We will take up the question of experimental practice in the next chapter, then return to Mercer's notebooks as possibly one of his most significant contributions to that practice. This will require the development of a theory of the instrumentality of documents.

C. Fonthill Model

Like the Renaissance architects mentioned in chapter 1, Mercer created a large model as a key step in the design of Fonthill. Beginning on page 60 of the Fonthill notebook, we see reference to a clay model, which confirms its creation early in the trajectory of Fonthill; and, as Mercer recounts elsewhere,[140] it remained very much a part of his design and decision-making process throughout construction. The notebook also contains notes regarding changes associated with observations of the model, which Mercer fabricated in an iterative manner until he was satisfied with its overall massing, at which point he cast the clay model in plaster. [Fig. 2.21.]

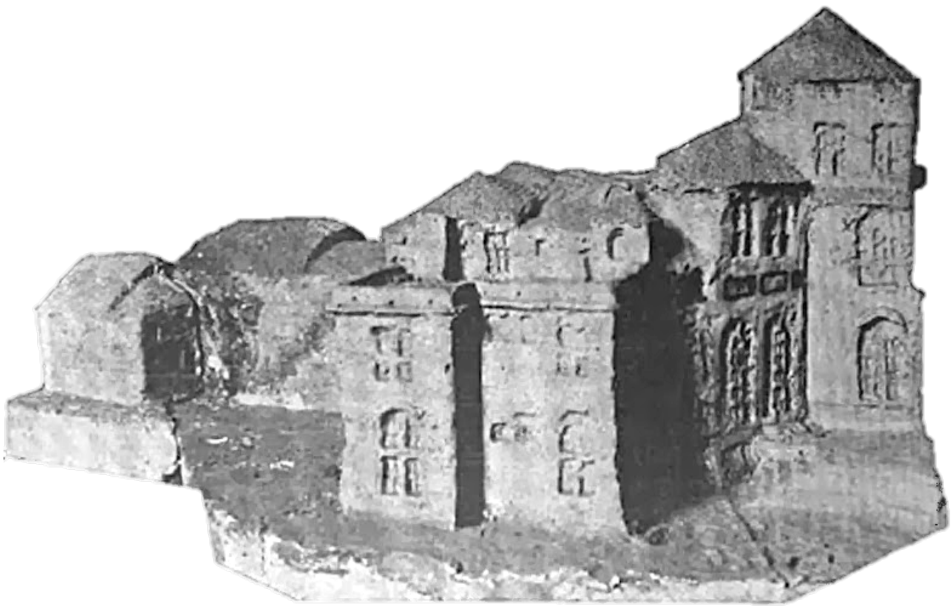


Figure 2.21. Model for Fonthill, ca. 1907. Image: "Bonfire on his housetop," Cement Age, Vol. X, No. 2, Aug. 1910, p. 98. / public domain.

A guidebook to Fonthill contains this rather generalized description

> He designed by first imagining a room and making rough sketches of each wall. He then cut the shape of the room out of a block of clay. […] When all the rooms were modeled in clay, he placed the blocks on a table and assembled them into the interior arrangement he wanted. […] At this point he had a general outline of the house, to which the roof was modeled. Only then did he turn his attention to the exterior, for the outside appearance of the house was of minor importance compared to the interior.[141]

This description sacrifices a bit in the way of accuracy for the sake of its picturesque effect; of more concern is its elevation of the model as the first comprehensive consideration of the building as a whole. The construction notebook tells a different story, as plans of the building floors begin on page 25, and the first elevations occur on page 54. It is more likely that the elevations on page 54, which don't bear much resemblance to the built result, either prompted, or were created in conjunction with, the model described on page 60. Mercer's own description of the use of the model is more limited: "after a good many changes in the profile of the tower, roofs, etc., a plaster-of-Paris model was made to scale, and used (as a working model) till the building was completed."[142] That is to say, Mercer seems to have used the model as a supplement to the notebook and other drawings, for those particular things it better enabled him to visualize: the vertical relationships of rooms (the first building sections do not occur until page 70) and the configuration of the roof and its elements.

Like most other accounts, the Fonthill guidebook seems to displace of the act of design to its more conventional location prior to the construction process. But as we will see, for Mercer they were very much part-and-parcel.

D. Ledgers

The names and wages of every worker were recorded in a construction ledger; it also tracked deliveries of material, specialized labor, and some tools and equipment. [Fig. 2.22.] This allows us to recreate with a great deal of precision the pace and detailed story of construction. While the ledger for Fonthill is spilt between an earlier and later volume, and includes some of Mercer's living and collecting expenses as well as construction information, and the expenses for the pottery are intermixed with other documents, and dwarfed by Frank Swain's much more voluminous recording of the operation of the Moravian Pottery, the construction ledger for the Museum is complete and meticulous. This may be because of the more public nature of the building; because Mercer wanted to quantify the resultant gift; or because he sought some external proof or validation of the efficacy of his methods. In any case, the museum ledger is certainly the most accountable of his account books, and with it we are best able to ask the question of how a construction ledger may have supplemented the planning and constructional logic of the notebooks with a more normative record of the sequencing of materials and labor on the construction site. While this is not something typically in the architect's bailiwick today, we should not discount its role in Mercer's documentary process.

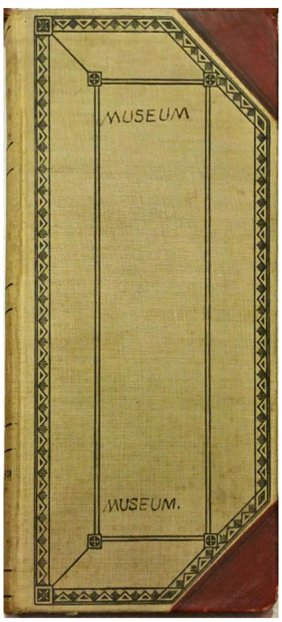
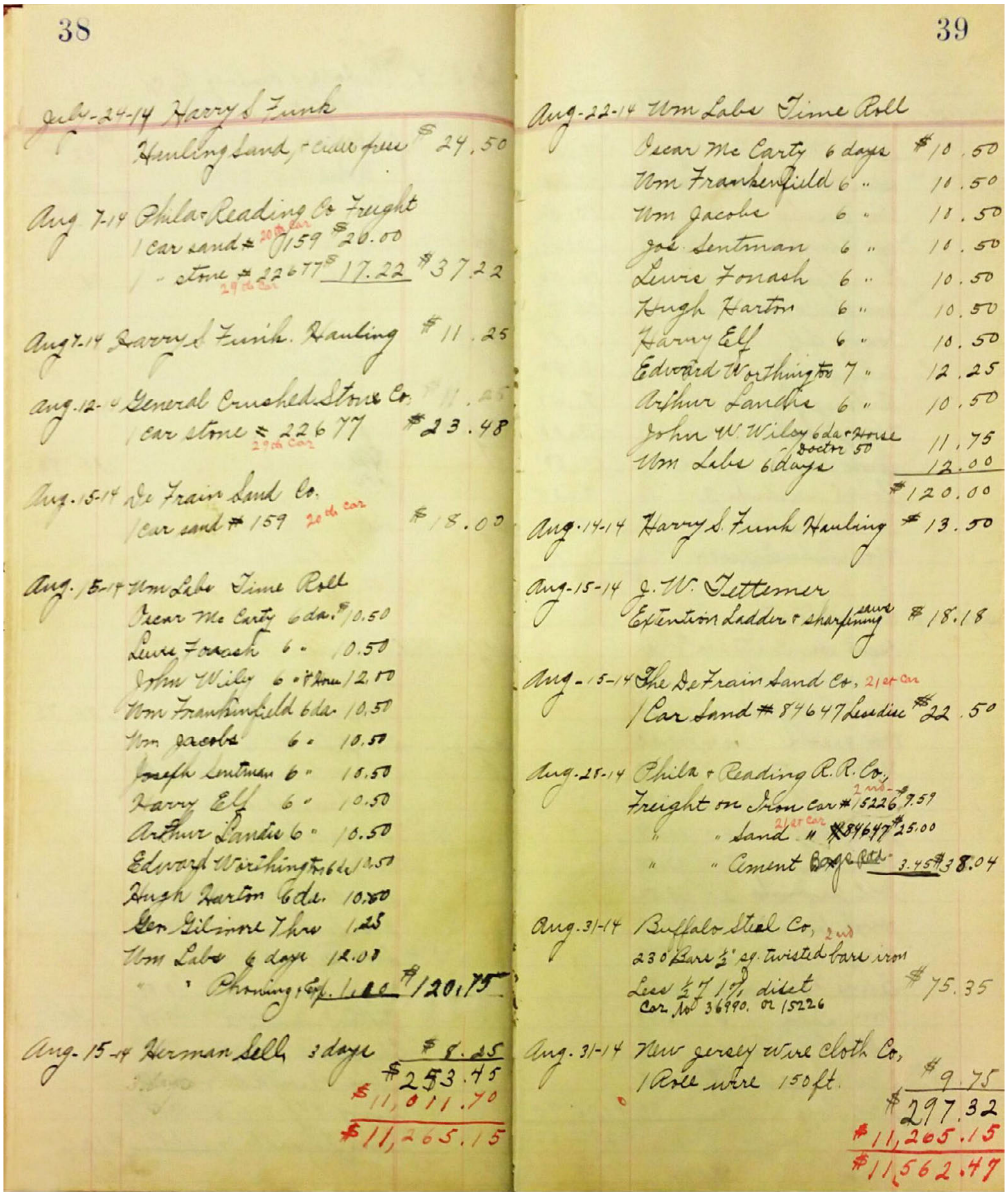


Figure 2.22. Museum construction ledger. Image: courtesy of the Mercer Museum Research Library.

Fig. 2.23 shows a typical series of entries in the museum ledger. These pages cover the weeks of July 14th 1914 to August 31st 1914, and record both labor and material costs. Labor is spelled out by the individual worker, though they were paid the same rate. For these dates, we read: "Aug. 15-14 Wm [William] Labs Time Roll", in which we see 10 workers paid a prevailing wage of $10.50 for the week's work, including both William Frankenfield, from whom we have already heard, and Joseph Senfman, who will also have a role to play in this story. In addition, John Wiley received the higher wage of $12 because he contributed the work of his horse "Lucy", and Labs was also paid the $12 rate, as he was entrusted with the supervision of the work as foreman. Labs was not always foreman; prior to 2014 we see the roll listed under "P. B. Trainor" (Patrick Trainor), and in those entries Trainor receives a wage of $15 for the week. Additionally, as was typical for the time, the workers were only paid for the hours worked, and winter entries often show partial weeks worked, and correspondingly lower pay. Workers not on the concrete crew are called out under separate heading, and often labor and material for these entries are listed as a single item, as these individuals worked more like subcontractors, hired for a specific job such as hauling or masonry. So on July 24th we read "Harry S. Fink, Hauling Sand, & cider press $24.50, and on August 15th we read "J. W. Tettemer | Extension ladder & sharpening saws $18.18. Materials were also listed as net price delivered: on August 7th we read, "Phila & Reading Co. [The Philadelphia and Reading Railway Company] Freight|1 car sand # 159 20th car $20.00 | 1 car stone # 22677 28th car. $17.22 | $37.22".


38

Jul-24-14 Harry S Funk
Hauling Sand, & cider press $24.50

Aug 7-14 Phila & Reading Co Freight
1 car sand # 159 (20th car) $20.00
" stone # 22677 (29th car) 17.22 $37.22

Aug 7-14 Harry S Funk. Hauling $11.25

Aug. 12-14 General Crushed Stone Co.
1 car stone # 22677 (29th car) $23.48

Aug. 15-14 De Frain Sand Co.
1 car sand # 159 (20th car) $18.00

Aug. 15-14 Wm Labs Time Roll
Oscar Mc Carty 6 da. 10.50
Lewis Forash 6 " 10.50
John Wiley 6 " & Horse 12.00
Wm Frankenfield 6 da. 10.50
Wm Jacobs 6 " 10.50
Joseph Sentman 6 " 10.50
Harry Elf 6 " 10.50
Arthur Landis 6 " 10.50
Edward Worthington 6 da. 12.50
Hugh Harton 6 da. 10.50
Geo Gilmore 7 hrs 1.25
Wm Labs 6 days 12.00
" Phoning &c. 1.00 $120.75

Aug. 15-14 Herman Sell 3 days $8.25
$253.45
$11,011.70
$11,265.15

39

Aug. 22-14 Wm Labs Time Roll
Oscar Mc Carty 6 days $10.50
Wm Frankenfield 6 " 10.50
Wm Jacobs 6 " 11.50
Joe Sentman 6 " 11.50
Lewis Forash 6 " 10.50
Hugh Harton 6 " 10.50
Harry Elf 6 " 10.50
Edward Worthington 7 " 12.25
Arthur Landis 6 " 10.50
John W. Wiley 6 da. & Horse, doctor 50 11.75
Wm Labs 6 days 12.00
$120.00

Aug. 14-14 Harry S. Funk Hauling $13.50

Aug. 15-14 J. W. Tettemer
Extention Ladder & sharpening saws $18.18

Aug. 15-14 The DeFrain Sand Co. (21st car)
1 Car Sand # 84647 Lessdise $22.50

Aug. 28-14 Phila & Reading R.R. Co.
Freight on Iron car # 15226 (2nd) 9.59
" Sand " # 84647 (21st car) 25.00
" Cement 3.45 $38.04

Aug. 31-14 Buffalo Steel Co. (2nd)
230 Bars ½" sq. twisted bars iron
Less 47 1% disct $75.35
Car No 36990. or 15226

Aug. 31-14 New Jersey Wire Cloth Co.
1 Roll wire 150 ft. $9.75
$297.32
$11,265.15
$11,562.47

Figure 2.23. Pages 38-39, museum ledger. Image: courtesy of the Mercer Museum Research Library.

The ledger runs from April 1st 1913 to September 19th, 1916. The costs it tracks are very stable. At the time the typical wage for workers in reinforced concrete was 15-25 cents per hour.[143] Mercer paid at the lower end of this scale, 17-20 cents per hour, but given Doylestown's relatively rural condition, this would not have been unusual. Regarding the cost of construction, we can consult the comprehensive 1912 manual of reinforced concrete construction costs, *Concrete Costs: Tables and*

Recommendations for Estimating the Time and Cost of Labor Operations in Concrete Construction and for Introducing Economical Methods of Management, written by Frederick W. Taylor, and published the year after his influential "Scientific Management."[144] In a chart, Taylor and his co-author, the consulting civil engineer Sanford E. Thompson, illustrate the normative range of cost per square foot in a graph with nested curves indicating the size of the building (cost decreasing as size increases). We can add Mercer's museum to this chart given the data in Mercer's ledger. This is shown in Fig. 2.24.

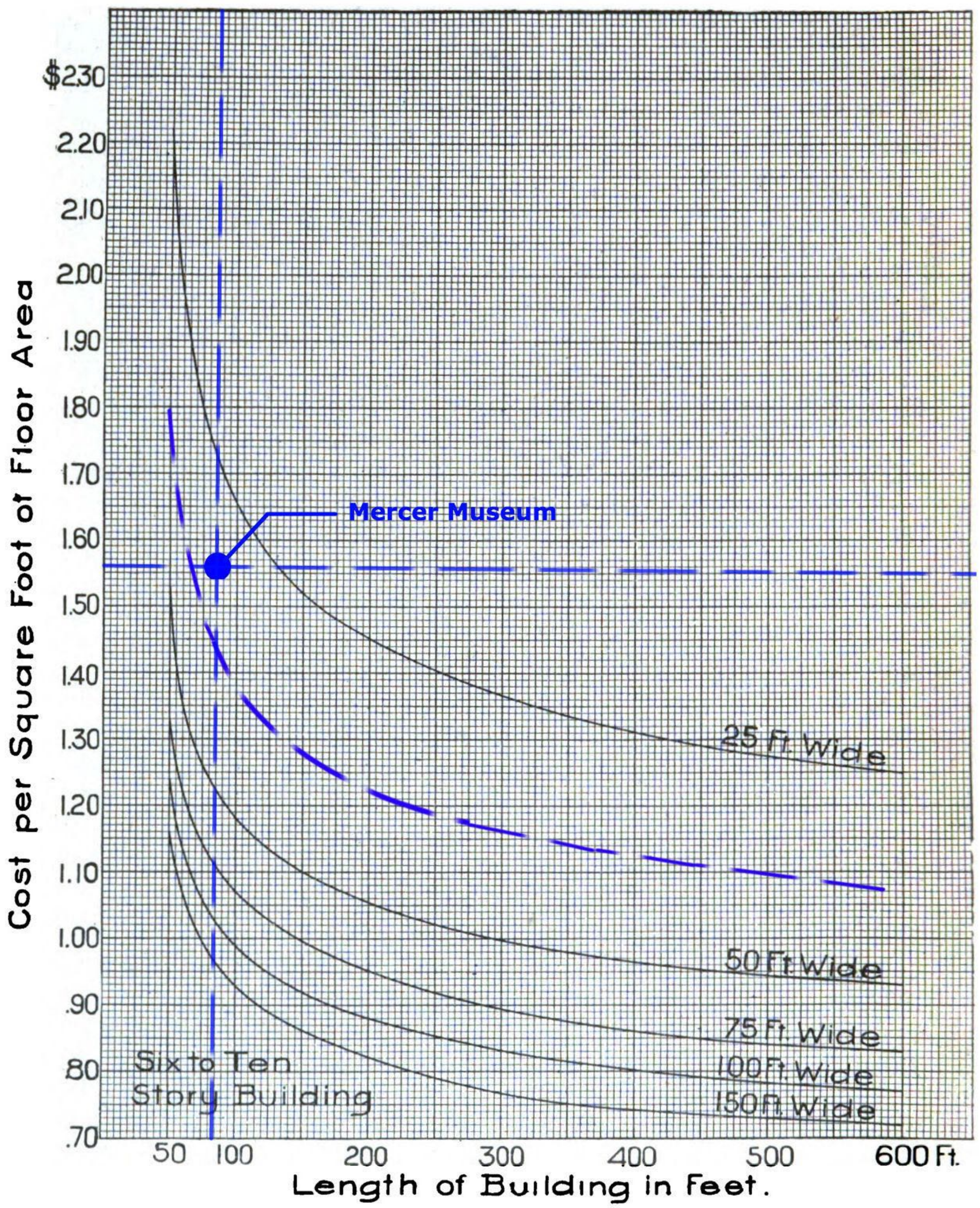


Fig. 7—Curves for Estimating Costs of Six to Ten Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

Figure 2.24. Graph of typical cost of reinforced concrete construction ca. 1912, with Mercer added. Image: Public Domain; Source: Concrete Costs: tables and recommendations for estimating the time and cost of labor operations in concrete construction and for introducing economical methods of management, page 50. Annotation in blue by author.

At first glance, the Mercer Museum would seem to be rather high on the chart, with regards to its overall dimensions—that is to say, its location on the chart looks to be about 10 cents per square foot higher than typical. With a footprint of 82'-9" by 71'-3", according to the survey completed just after it was built, [see fig. X, in chapter 6, p. X] the Museum may not have benefitted to any great degree from the economies of scale so well illustrated in this chart. We should note as well the two small additional spaces at the Library and the Bow Rooms, which slightly increase its overall square footage; but, given their added complexity, this added square footage seems unlikely to work in favor of overall economy. Using the simplified overall footprint of the building, then, we might read the above chart in the following manner:

- vertically along the line closest to 82'-9"

- along the curve at the approximate location of 71'-3"

- horizontally from the cost per square foot of Mercer's museum, or $1.56[145]

Where the curve crosses the vertical line indicates the normative cost of construction for a reinforced concrete building in 1912 the same size as Mercer's, when this chart was produced in 1912. Note that the dot signifying Mercer's actual cost per square foot is a bit above this line. This suggests its methods came at a premium.

However, we should take into account inflation in the years between 1912 and 1916, when Mercer completed the structure. In reviewing the ledger, the increase in material costs was marked, though labor was less so. This suggests that the rapid inflation accompanying World War I, when costs increased as much as 17% annually (1917), was felt in Doylestown. (Labor seems to have followed a similar, but belated, inflationary increase, with Swain noting its effect on the Moravian Pottery in the 1919 pottery expenses book.)

Adding this information to Taylor and Thompson's chart suggests something different concerning the general economy of Mercer's methods. [Fig. 2.25.] With this chart we can see a remarkable congruence between Mercer's method and normative practice circa 1912/1916. Yet this seeming-normativity disguises a remarkable difference.

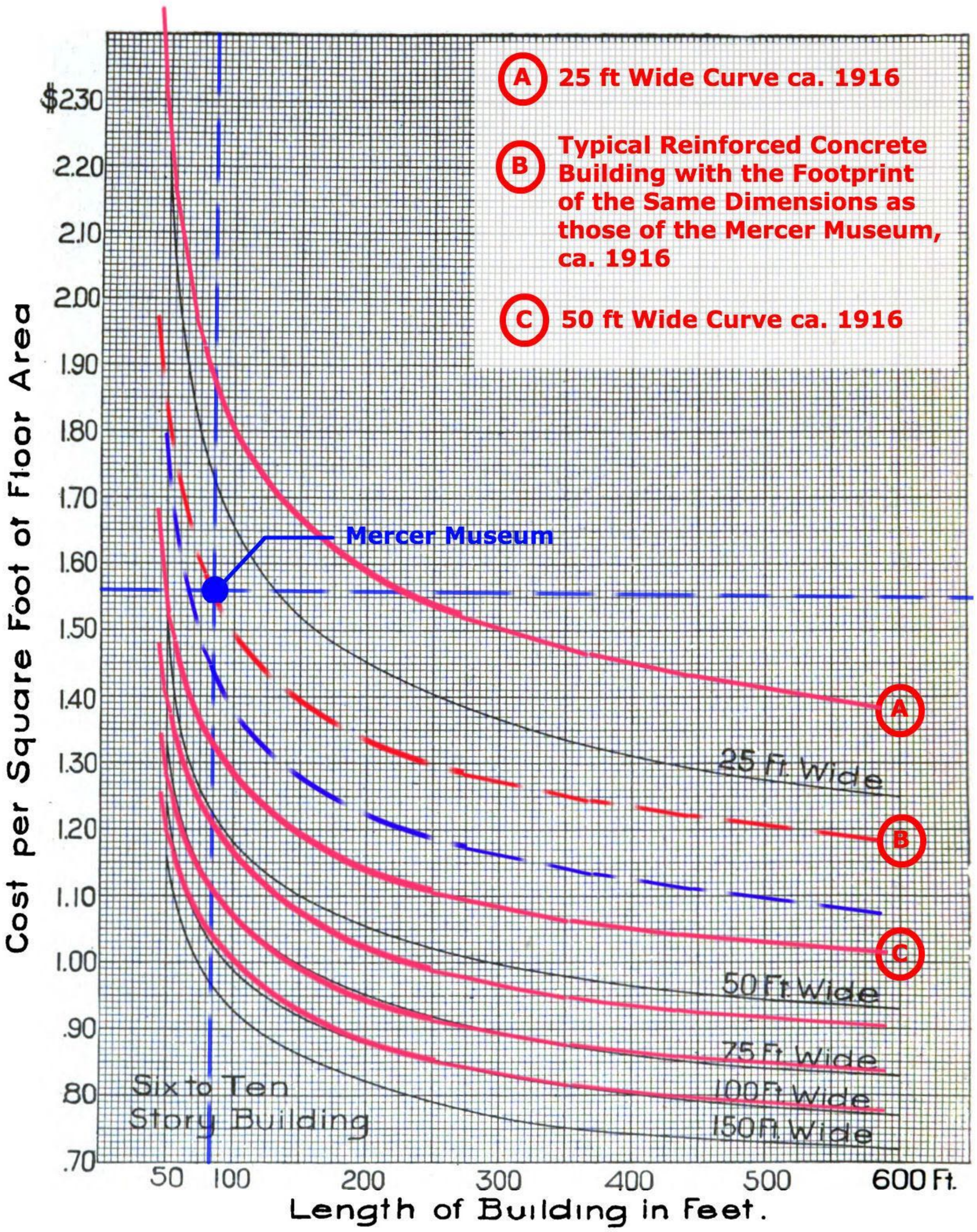


Fig. 7—Curves for Estimating Costs of Six to Ten Story Building per Square Foot of Floor Area for Different Widths and Lengths of Buildings (See p. 36)

Figure 2.25. Graph of typical cost of reinforced concrete construction, with curves accounting for inflation accrued by 1916 depicted in red. Image: public domain / "Concrete Costs…" Annotations by author.

For while the total cost per square foot is quite similar to standard practice, the distribution of costs is quite different. This conundrum only grows more perplexing when we remember that Mercer paid a very similar rate to his contemporaries for labor. For Mercer to have paid prevailing wages and yet spent proportionally more on labor than normative methods may have several explanations:

- His rate of construction was less rapid than normative methods, and so the same built square footage required more labor hours per unit material. As we have discussed, however, Mercer's rate of construction was well suited to the limits of his materials supply infrastructure, so it is not clear that a faster rate would have had any necessarily positive impact of costs.

- His rate of construction was more complex, required more skill, or entailed more repair and revision, than normative methods, and thus required more labor. If this were the case, however, we would expect the cost of materials to remain relatively constant (particularly given the thickness of Mercer's walls, vaults, and floor slabs) and the cost of labor to increase, resulting in a total cost per square foot higher than comparable methods of construction.

- The methods Mercer employed, to some extent, *replaced* the cost of materials with the cost of labor. Taylor tells us that labor typically accounts for one quarter to one third the cost of materials.[146] This suggests that Mercer's method as much as doubled the proportion of building costs occupied by labor, and *reduced* the cost of materials proportionately. It is unlikely that Mercer's costs for stone, sand, or cement were considerably less than his contemporaries. (As mentioned above, they may well have been greater.) This means that the cost of staging, forming, and centering lumber, reinforcing, finishing, and other secondary materials, and the freight, hauling, and organization of these materials, must been, with Mercer's method, considerably less costly than more 'scientifically', or even conventionally, managed projects. (We should remember that, while Taylor's conclusions come from his theoretical position, his data comes from conventional practice.)

What the data suggests, then, is that standard practice privileged material and organizational complexity at the expense of labor; a trend the Taylorization, or "scientific management" of labor would only increase. Despite his evident interest in the production of buildings—his book on concrete construction being published only a year after the publication of his much more well-known work on scientific management—this would seem to be a field in which the Taylorization of labor had rather more of an ideological, than economical, basis.[147]

Taylorization may have had quantifiable positive impacts on efficiency in settings more akin to the laboratory or factory; but on the construction site, Mercer's method, which we might without too much of a stretch call a form of 'anti-Taylorism,' shows that, at least for reinforced concrete construction circa 1916, manual work could be substituted for material cost, and associated organizational complexity, without adverse impact on the 'bottom line.' (We should say that Mercer's practices were "differently organized," rather than "disorganized." This will become a core argument in the pages that follow.)

The data from Mercer's ledger tells us something else as well, beyond that Mercer's labor-intensive methods had no significant impact on the total cost per square foot of construction. What is more remarkable is that his method reversed the trend of the redistribution of value from labor to more expensive and complexly structured materials and assemblies. This can be understood, in the context of its time, as a matter of social rather than scientific engineering, showing Taylor's purportedly scientific revisions of practice to be very much in line with other attempts by industry to disrupt the emerging power of organized labor. Mercer was no great fan of organized labor, or even of the skilled trades—of the total labor costs in his project, only 14% was accounted for by Masons, Blacksmiths, and other 'skilled' artisans.[148] Yet his museum project would be a clear case of the valuation of labor in and as itself, over and against the dubious efficiencies of high-embodied energy materials and hierarchical systems of jobsite organization. In this Mercer was exhibiting an ethos very much in keeping with his contemporaries in the Arts and Crafts movement. *Why* these efficiencies would be dubious on the job site rather moreso than in the factory will be explored in chapter 7.

E. Loose Sketches, Notes, Experiment Records, and other Ephemera

The notebooks, then, can serve as a provocation, offering both a structure for understanding Mercer's work, and a model for how construction documentation might take a different form than the one it has today. The ledgers, in their turn, might seem to suggest that, while Mercer was certainly methodical, he was not scientific. Nothing could be further from the truth. There are many other articles in Mercer's archive, held at the Spruance Library of the Bucks County Historical Society. Many of these are the typical documents held in such a collection, objects made significant only by their adjacency to the person of interest. This includes brochures for pottery equipment, notes on genealogy, local history, and other biographical topics, and newspaper clippings. The archive also contains some of Mercer's own poems and stories, reminisces, personal correspondence, and etc. These will be invaluable to Mercer's first true biographer. (While Reed's study is biographical, its focus remains on the Moravian tiles.) But of more immediate interest are a number of the unbound notes and records Mercer kept of his various studies and experiments. These were not kept in any systematic way, but rather, it would seem, produced on the spot as a part of his research process. An excellent example of this sort of document is a single page dated December 1915 and detailing a series of six experiments and their results. [Fig 2.26.] Mercer often titled such pages "Experiment" or "Experiments", and he seems to have jotted them down on whatever loose paper happened to be at hand.

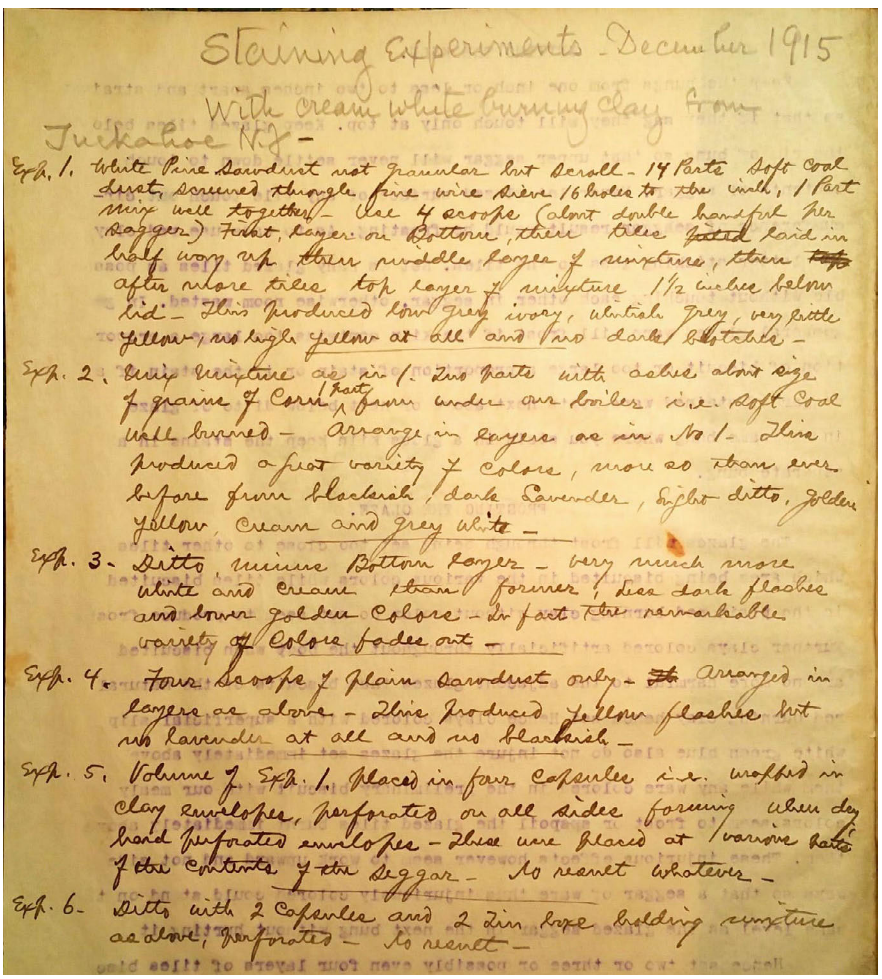

Staining Experiments December 1915
With cream white burning clay from
Tuckahoe N.J. –
Exp. 1. White Pine sawdust not granular but scroll – 14 Parts Soft Coal dust, screened through fine wire sieve 16 holes to the inch, 1 Part mix well together – Use 4 scoops (about double handful per sagger) First, layer on Bottom, then tiles ~~[illegible]~~ laid in half way up then middle layer of mixture, then ~~[illegible]~~ after more tiles top layer of mixture 1½ inches below lid – This produced lower grey ivory, whitish grey, very little yellow, no high yellow at all and no dark blotches –
Exp. 2. Same mixture as in 1. Two parts with ashes about size of grains of Corn ^part from under our boiler i.e. Soft Coal well burned – Arrange in layers as in No 1 – This produced a great variety of colors, more so than ever before from blackish, dark lavender, light ditto, golden yellow, cream and grey white –
Exp. 3. Ditto, minus Bottom layer – very much more white and cream than former; less dark flashes and fewer golden colors – In fact the remarkable variety of colors fades out –
Exp. 4. Four scoops of plain sawdust only – ~~[illegible]~~ arranged in layers as above – This produced yellow flashes but no lavender at all and no blackish –
Exp. 5. Volume of Exp. 1. placed in four capsules i.e. wrapped in clay envelopes, perforated on all sides forming when dry hard perforated envelopes – These were placed at various parts of the contents of the saggar – No result whatever –
Exp. 6. Ditto with 2 capsules and 2 tin box holding mixture as above, perforated – No result –

Figure 2.26. Staining Experiments—December 1915. Single loose page on the verso side of a page from the Moravian Pottery kiln manual. Image: courtesy of the Mercer Museum Research Library.

Unlike Mercer's construction notebooks, such pages are not numbered or otherwise organized, and there is every reason to believe Mercer had no intention of their dissemination. Despite this, such documents help to recreate Mercer's stance towards documentation more generally: as something to be used as an aide-memoire, rather than a self-sufficient vehicle of communication. While this presents problems for the historian, it also ties Mercer to the documentary traditions of construction, for which drawings seem to have had a long history of impermanence. From the tracing floors of late Medieval cathedrals, [fig. 2.27] which were freshly plastered whenever a clean drawing surface was required, to the occasional and illuminating unintentionally preserved wall drawings of antiquity [Fig 2.22-2.23], historical sites are rife with the evidences of ephemeral in-situ drawing.

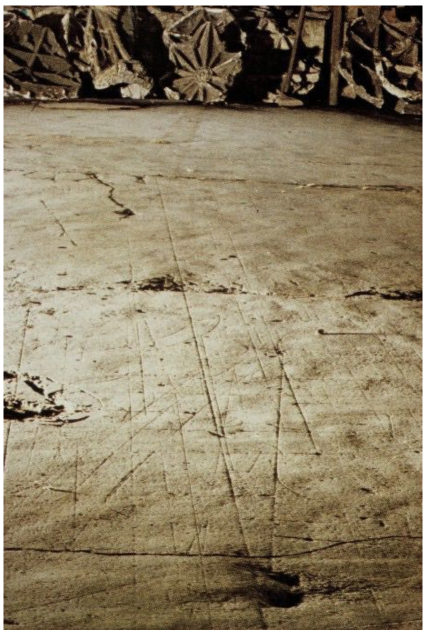


Figure 2.27. Tracing Room Floor at York Cathedral. Note the templates in the rear of the image. Image: University of York, York, UK.

Figure 2.28. Temple of Apollo at Didyma. Damian Entwistle / CC BY-NC 2.0.

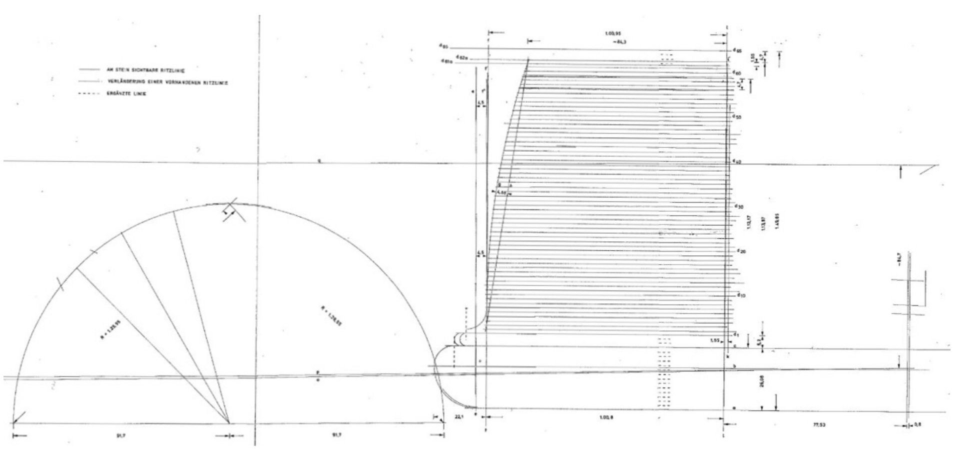


Figure 2.29. Drawing of column with visual calculation of entasis, Temple of Apollo at Didyma. First discovered as a scratched wall drawing (top) and discussed in Lothar Haselberger's 1985 The Construction Plans for the Temple of Apollo at Didyma. *Image: Haselberger.*

Rather than attempt to make comprehensive claims about such materials, we should look to them as traces of the sorts of verbal conversations and transitory documents pervasive throughout the history of building. While much of the craft of building, both traditionally and today, consists of a series of unspoken and unexplicated expert actions, it is clear that at times a temporary drawing, note, or specification is required, and put to use, in the flow of manual action.

In Mercer's case, we are fortunate to have the construction notebooks, which preserve more fully and comprehensively such traces. Mercer's various experiments in ceramics production and building design seem to have occasioned some of the most detailed of these notes and sketches. This suggests a possible link between the deliberate cultivation of an experimental method, and the production of documentary ephemera.

It is also points to the nature of Mercer's action in building as the continuation of an experimental approach generally, which proposes the reinvention of architectural practice as a practice of invention.

PART 2: The Invention of Practice

Chapter 3: Experiment and Tacit Knowledge in Craft Practice

'Study Nature in the language of experiment' is the maxim of the schools of science. That art should be pursued in the same language is shown by the fact that her works are ever created by experiment and experiment alone.

- Wilson Eyre[149]

Much of the world's mechanical ingenuity is devoted to creating robust, reliable, and highly adapted "creole" technologies, an ingenuity that is largely invisible to us only because we happen to live in a low-maintenance, high-throwaway regime.

-Steven Shapin[150]

"Study nature in the language of experiment," advised Mercer's early advisor and tileworks client, the architect Wilson Eyre. While Eyre gave Mercer critical early positive feedback on his ceramics enterprise, this maxim seems to have proved influential on Mercer's architectural work as well. That Mercer's architectural works were almost wholly invented is readily apparent to the casual visitor. That his methods were just as unique as their results will require a great deal more analysis. We might begin in an exploration of the origins of Mercer's construction techniques in a preexisting set of relationships and methods established as part of the productive activity of the Moravian Pottery and Tileworks, and how the inheritance of these craft traditions, both adopted and invented, may illustrate a larger pattern of the heritage of within, or translation of craft knowledge between, allied fields. We will discuss how this experimental mode gives rise to a unique method for building detailing, and explore how a theory of practice might relate to architectural invention at this scale. Finally, a close examination of Mercer's precast concrete windows will serve as a case study through which to test these interpretations.

A. Building the Moravian Pottery

Mercer built his reinforced concrete structures with a crew of workers who, it is often noted, had no experience in reinforced concrete.[151] A number of the workmen, and of particular importance key workmen in superintendence roles, however, had developed considerable experience working with both Mercer and with each other, as they had been employed by Mercer as early as the opening year of his tile manufacturing business. Some of the others were word-of-mouth hires, known by the other men before their association with Mercer.[152] Thus the precise nature of Mercer's ceramics enterprise, and in it his relation to experiment, is of some significance here.

Mercer's experiments in the construction of his residence at Fonthill and other early projects—for they may be called little else—should be understood in the context of his simultaneous engagement in the research and development of ceramic products and production facilities. In 1908, when he built Fonthill, Mercer had for a decade been engaged in the highly experimental process of developing a "craft" pottery.[153] His Moravian Pottery and Tile Works was by that time a thriving business; but ten years before, when Mercer first began his experiments in ceramics, its success was by no means a certainty. Mercer conducted his first tests in 1898 in an abandoned kiln five miles from his house with the help of a local master potter. These tests, of large lots of clay bodies and glaze samples, resulted in almost total failure, with many bodies and glazes failing to mature, or disappearing entirely.[154] Mercer's primary complaint at the time, recounted in his "Notes on the Moravian Pottery at Doylestown" (which is preserved in manuscript copy, and was also published in final form in the *Papers of the Bucks County Historical Society*) was not the expense or loss of time and materials, but that "little was learned", and that he ("the projector of the enterprise"), "still remained in the dark as to some of the most important steps in the process." A manuscript copy with revisions has at this point the summary statement handwritten in the margin: "the effort was a failure."[155]

His response to this failure was to intensify his investigations. Mercer briefly apprenticed himself to a local potter, and cultivated contacts with chemists and manufacturers in the ceramics industry.[156] He used a dentist's kiln, then a larger portable kerosene kiln, and experimented with a kiln of his own design built into the chimney of his workshop.[157] None of these approaches bore fruit. Finally, in 1899 he hired a kiln builder to transform his "archaeological work-room" and its outbuildings into a facility for ceramics testing and production, and build an English bottle kiln.[158] This first kiln of his own allowed a more systematic exploration of glaze formulae, and by the fall of 1899 Mercer began regular firings to produce primarily ceramic tiles. In 1903 Mercer expanded his kiln shed, an old wood barn, with a concrete addition and second kiln for the rapidly expanding production of the Moravian Pottery. This would mark his first use of concrete as a building material. He would expand the "Indian House" facility further in 1906, building two new bisque kilns and a shed to house them. It may be that the only extant pictures of his concrete kiln shed show, in fact, this latter building; but they have been attributed to the former.[159] In any case, his first experiments in concrete construction, like his early experiments in clay, would ultimately meet with failure. "On March 27-1912 at ten oclock in evening," Frank Swain wrote in an unpublished account, "a fire was discovered in the 2nd floor ~~fireproof~~ room of upper pottery—several hundred wooden racks burned, and about 40,000 tiles destroyed—loss about $1200.00"[160] (about $30,000 today).

Fortunately, by this time Mercer was almost finished with the construction of a new home for his pottery, a purpose-built facility arranged around a courtyard "cloister". The original pottery was demolished by Mercer's brother Willie, then in residence at Aldie, after Mercer moved to the new building in 1912. [Fig. 3.1.]

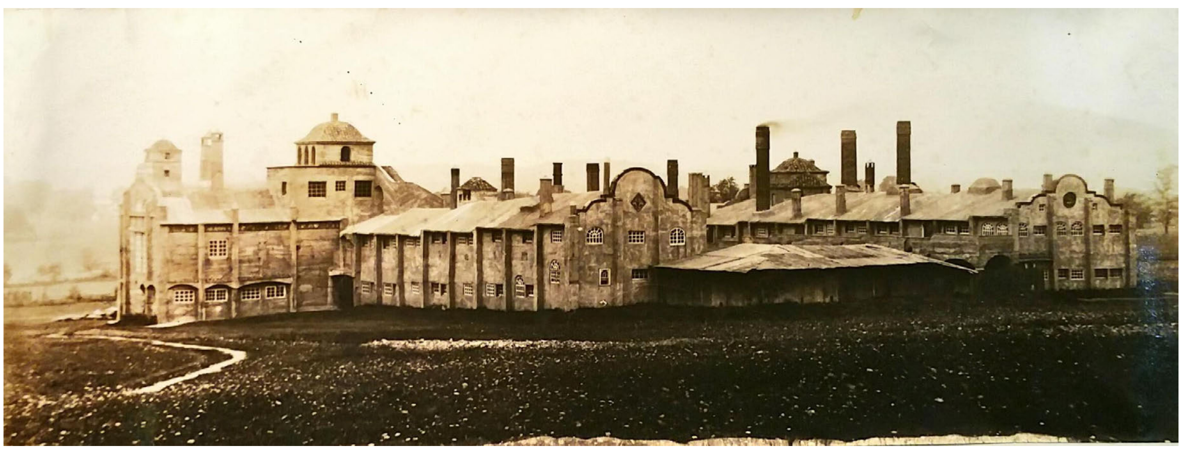


Figure 3.1. Mercer's new home for the Moravian Pottery. Image: courtesy of the Mercer Museum Research Library.

Mercer had begun work on the new pottery in March of 1911, in response to growing demand for his tiles and the need for a larger and more productive workplace. Reed argues that Mercer "configured the pottery as a mission," largely based on sketches later in the construction notebook of several California mission buildings. It seems he may have had this sort of precedent in mind early on, as the first page of the new construction notebook he began for the pottery shows a plan sketch of a u-shaped building with the word "cloister". [Fig 3.2.] Yet following the order of the numbered pages, we can reconstruct a design chronology somewhat at odds with assumptions of the primary influence of style and historical precedent. We read that as of July 14 of 1911 the foundations and basement were finished, and by the end of the month he would have the first story walls formed and work begun on the building of new kilns, which were erected as the building was built. On page 10 of the Notebook, in an entry dated July 30th, we read "main ceiling finished from end to end of N. Side—but not full width over clay mill room."

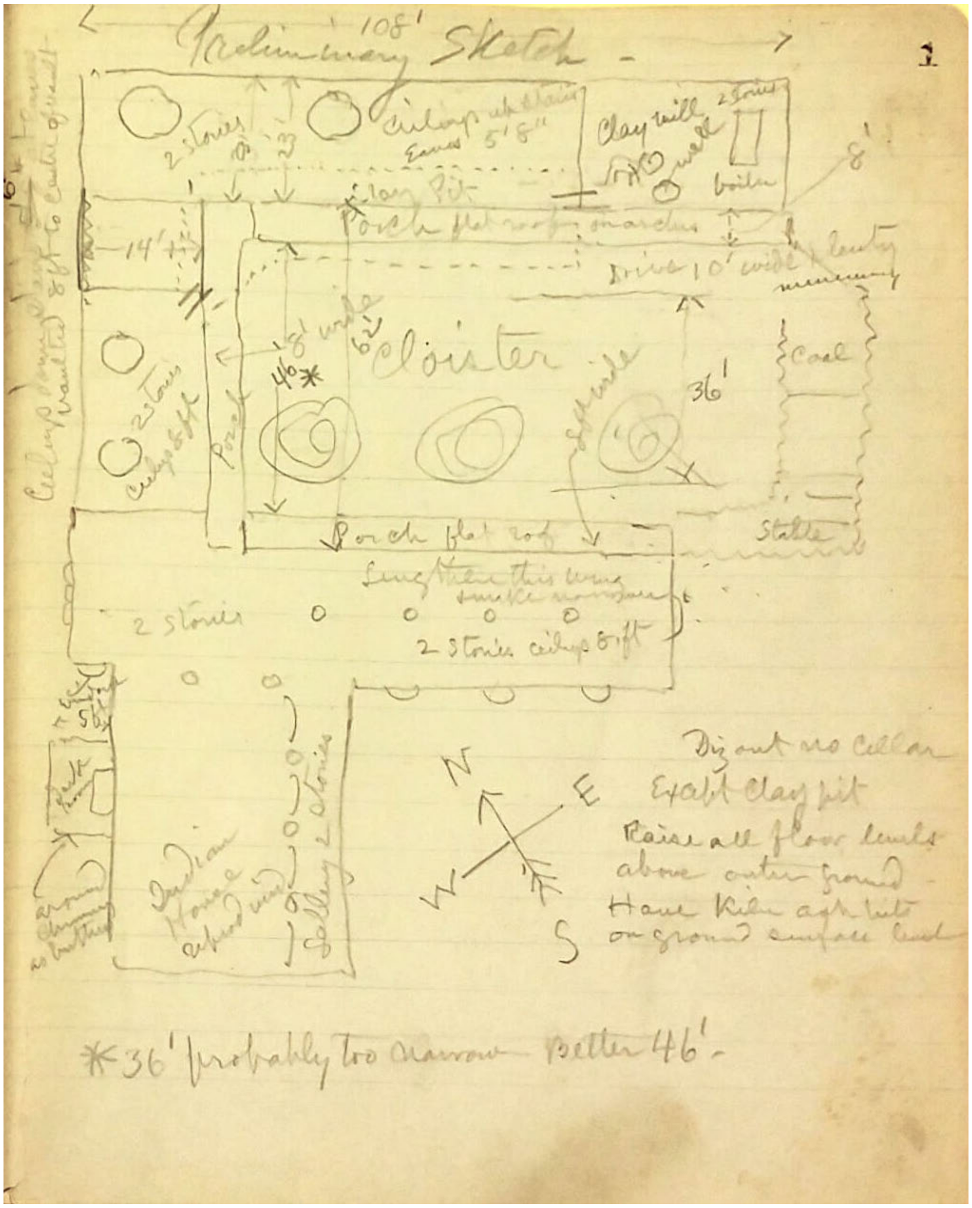


Figure 3.2. Mercer's plan sketch for the pottery. Image: courtesy of the Mercer Museum Research Library.

On page 11 Mercer sketches out a crest and motto [fig 3.3]: *Juvent Probum Aspera*, by which he might have intended something like "Roughness (or difficulty) benefits the just." Below a sketch of the crest, he notes, "see Burke's Encyclopedia of Heraldry."[161]

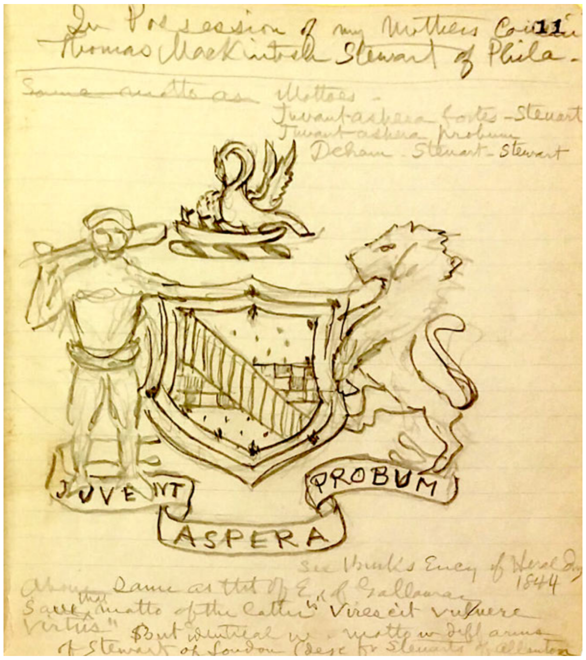


Figure 3.3. Mercer's sketch for an unrealized crest. Image: courtesy of the Mercer Museum Research Library.

This was possibly a family crest on his mother's side, and so may be included merely as a function of Mercer's genealogical interests; more likely, in the context of the construction notebook, this was an exploration of motto or motif to be used with the pottery. ('Virescit vulnere virtus' might be translated as 'courage flourishes at the wound'; or, alternately, 'in roughness', a motto which may have held resonance for him.)

On page 14 we see the first and only building section, specifying very little except for the balcony dimensions and low point of the inside ceiling on the second floor. Pages 16-22 hold the sketches of California missions Mercer may have felt inspired by in his design; but these come after, presumably, the buildings plan had been laid and much of the first floor constructed. Perhaps not coincidentally, many of these sketches show only the parapets of missions. [Fig 3.4.]

Figure 3.4. Several of Mercer's sketches of missions from the pottery construction notebook, pages 18-20. Image: courtesy of the Mercer Museum Research Library.

Perhaps Mercer was motivated by recollections of his travels in the Yucatan, where he saw a mission closely resembling the cloister plan he devised.[162] It is also possible that Mercer undertook these speculations as to architectural style only once the problem of the building facade presented itself; and the plan conception of a 'cloister' may well have been derived from the interior space of his original workshop at Aldie, which was composed of small single height rooms arranged around the perimeter of one large three-story high workshop space. [Fig. 3.5.] That is to say, we should consider the possibility that the building gave rise to its style rather than the other way around: that its decorative motifs and historical affect, such as it they were, emerged from constructional decisions and (newly) extant tectonic necessities, rather than being imposed prior to the process of construction and the requirements of its planned use.

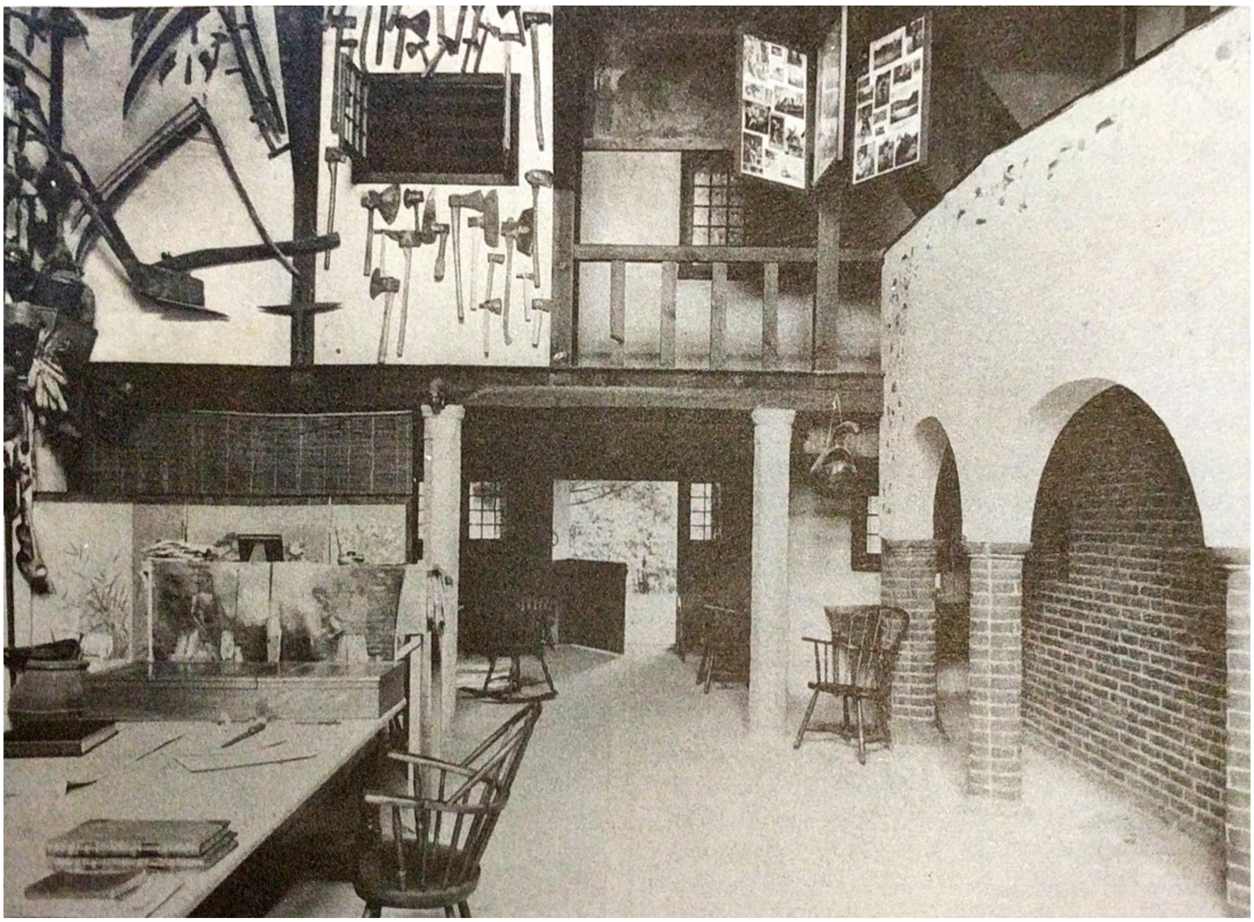


Figure 3.5. Mercer's archaeology-lab-turned-pottery-studio, "Indian House," at the family home. Note the material diversity, ground-floor spatial fluidity and overlooking balconies. Image: courtesy of the Mercer Museum Research Library.

The dated entries resume on page 23, and by the end of that page, on October 12th, Mercer writes that all ceilings are finished on the first level, and walls up to the second story cornice. The next two pages are taken up with a list of the leaks at Fonthill—Mercer had moved in that summer—and other assorted notes follow. Mercer resumes his account on page 31 with an entry titled "New Pottery 1912" and dated April 12th (though he notes, "work begun about April 1st"). On June 1st we read, "Main building done."

B. A Window on Operations

When it was in full swing, Mercer's Moravian Pottery and Tileworks maintained an almost continuous production and firing schedule, summer and winter, for most of the decade preceding Mercer's major concrete works.[163] It is worth considering how the pottery may have served as an incubator and training ground for the men who would be employed in the erection of some of the first reinforced concrete buildings in the region.[164]

Picture a low dark passageway, ceiling blackened with soot, and in it men carrying boards on their shoulders and large saggars (ceramic boxes filled with tiles) in both hands. They weave between each other and detour around the broad curves of kiln walls, which radiate heat while a yellow-white light glints from the chinks in bricks. In the small space between each kiln there is room enough for a coal hopper and a man with a shovel, who loads coal at precisely scheduled intervals into a stoke hole—a "firemouth"—in the side of the kiln. It is a warm spring day and the doors are open onto the central cloister, and conversations can be heard overhead, where workers on the second level press tiles from wet clay with plaster molds, and set them out to dry all around the stepped tops of the bottle kilns, where the heat is unrelenting; on clear days they move out onto the balcony that wraps around the building and connects its rooms. In the yard below, piles of coal and other ingredients rise and fall as they are deposited and consumed, while overhead the cool clouds coil. [Fig 3.6.]

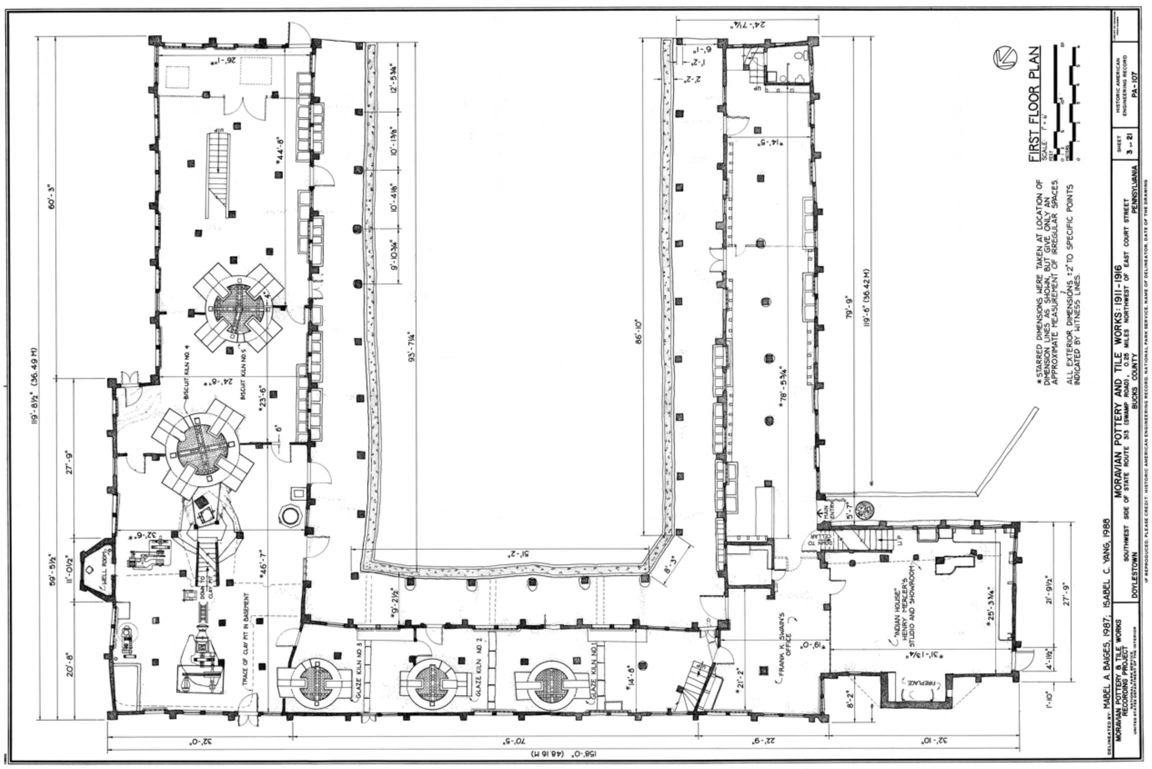


Figure 3.6. Plan of the ground floor of the pottery. Image: Historic American Engineering Record (HAER).

This was the daily life of Mercer's Moravian Tileworks, where as many as eighteen men at once undertook the shared work of tile production.[165] It is a scene that, if not for the narrowness of its confines, might merit its own *Carceri* engraving. [Fig 3.7.] Yet this was a deliberately thought-out, *designed*, process-and-place. The various stages in the workflow were sited to take advantage of things like waste heat from the kilns, the constant cool and damp of subterranean rooms to store and season clay, and the cloister and second floor roof terrace for dustier tasks or benevolent weather. The workstations were small and cellular, arranged with circulation enfilade, allowing for and provoking overlap, shared labor, and an impromptu attribution of tasks quite at odds with what Mercer's contemporary, and sometimes correspondent Henry Ford, might have laid out on his factory floor. [Fig 3.8, 3.9.]

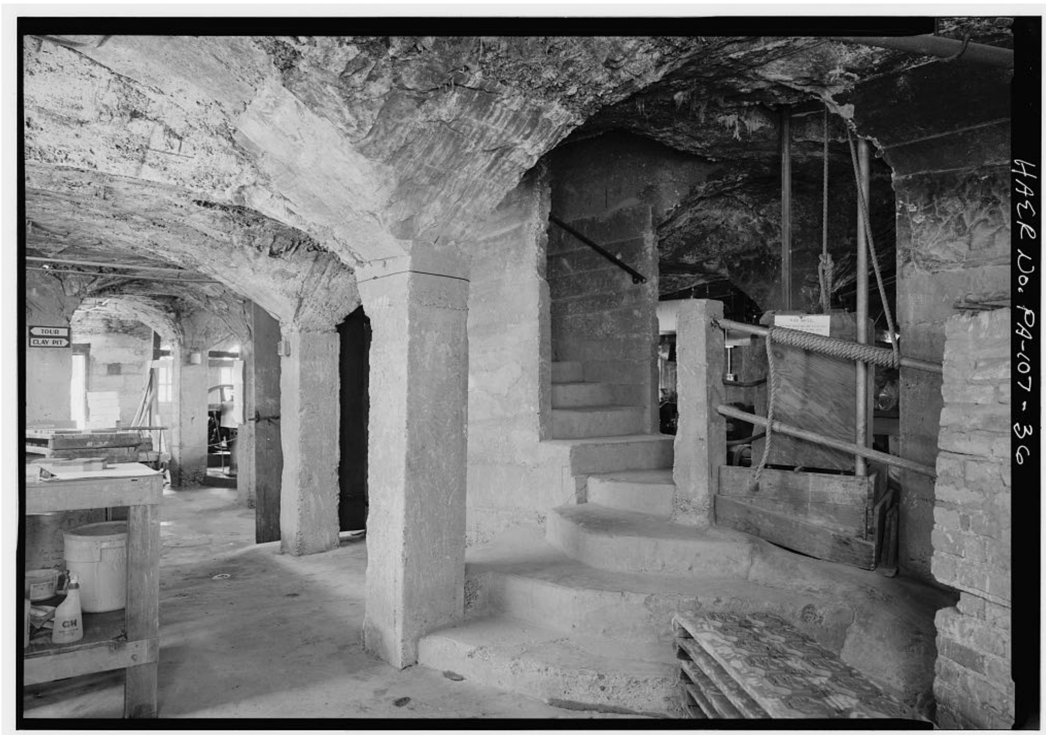


Figure 3.7. Interior view, Moravian Pottery and Tileworks. Image: Historic American Engineering Record (HAER).

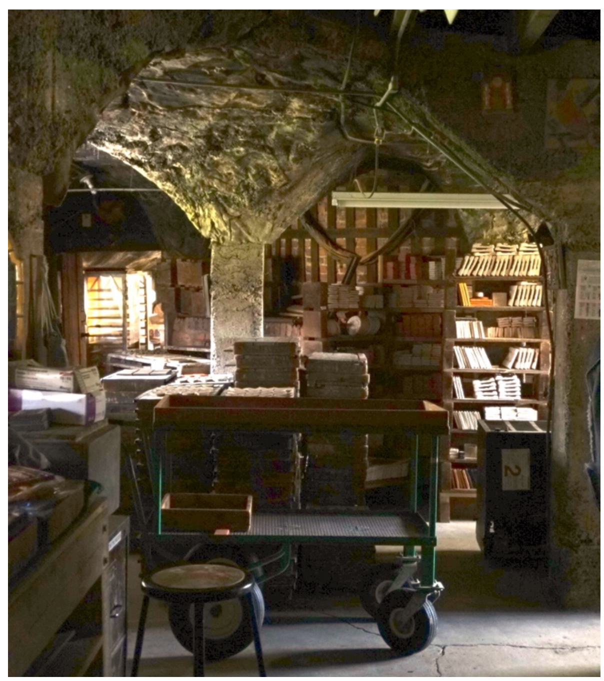


Figure 3.8. Workers on a Ford assembly line ca. 1913. Image: public domain.
Figure 3.9. Workspaces in the Moravian Pottery, fit between kilns. Image: author, courtesy of the Moravian Pottery.

In his recollections of the day to day operation of the Tileworks, collected in an autobiographical account published by the Bucks County Historical Society, longtime employee Benjamin Barnes recounted a flexible division of labor with various workers employed at tile presses, with plaster molds and mallets, at stations for mixing and applying glazes, some with brush and some by dipping and pouring.[166] Workers were rotated between stations as their skills allowed (and the strenuousness of the tasks required); a foreman, in consultation with the pottery manager, apportioned tasks on a daily basis and gave verbal instruction based on past practices and the standards set out in a typewritten handbook, the Moravian Pottery Kiln Manual (Fig 5) which detailed actions directly related to the functioning of the kilns. This written record may have been necessary because of the exacting requirements for successful operation of the kilns. Other tasks in the pottery were not recorded in detailed form, though this is not to say they did not represent a process of trial-and-error and depend upon a working mastery, and daily communication, of specific craft practices. (These various flexible arrangements and habits, structuring a predominantly informal style of collaborative work, would have proved useful in the adaptation of clay craft techniques to, and the development of new methods for, reinforced concrete construction.)

Mercer continued to develop the methods for tile production at the Moravian Pottery over the course of his projects, improving and refining some, and abandoning others, as they proved their worth through application and practice and their commercial marketability. There was, over the tenure of the Moravian Pottery, a steadily increasing level of complexity in both the individual products, their ensemble installations, and the level of expertise that installation presumed.

C. The Development of an Experimental Method in Ceramics Production

Mercer was, through his studies and family connections, influenced by the Anglo-American Arts and Crafts movement. His own background as a scholar and archaeologist, his studies in the fine arts, and his cosmopolitan upbringing and European travels gave him a deep appreciation of the context of, and encyclopedic knowledge of precedents in, architecture and the decorative arts. He was uniquely situated to found and promote his enterprise, and did so at a time when the demand for arts and crafts tile was "very opportune,"[167] as the artists and architects of his time were looking for just such an exemplar of this new way of seeing the role of the arts in culture. "The repulsive colors, decadent designs, mechanical surface and texture, and chilling white background of most of the tiles then on the market, had so thoroughly disgusted modern architects of taste, that many of them refused to ornament fire-places with tiles".[168]

As such Mercer was not merely a producer of ceramics, but an innovator; or perhaps, rather, a hybridizer of the techniques of traditional workshop practice (of great interest to proponents of the Arts and Crafts) with modern researches and methods developed during the industrial revolution, such as using steam-powered pugmills and clay grinders [fig 3.10] (without which his efforts would have been prohibitively costly and labor-intensive). Mercer thus took a hybrid stance between ideologies, and the theories and practices, of his time.

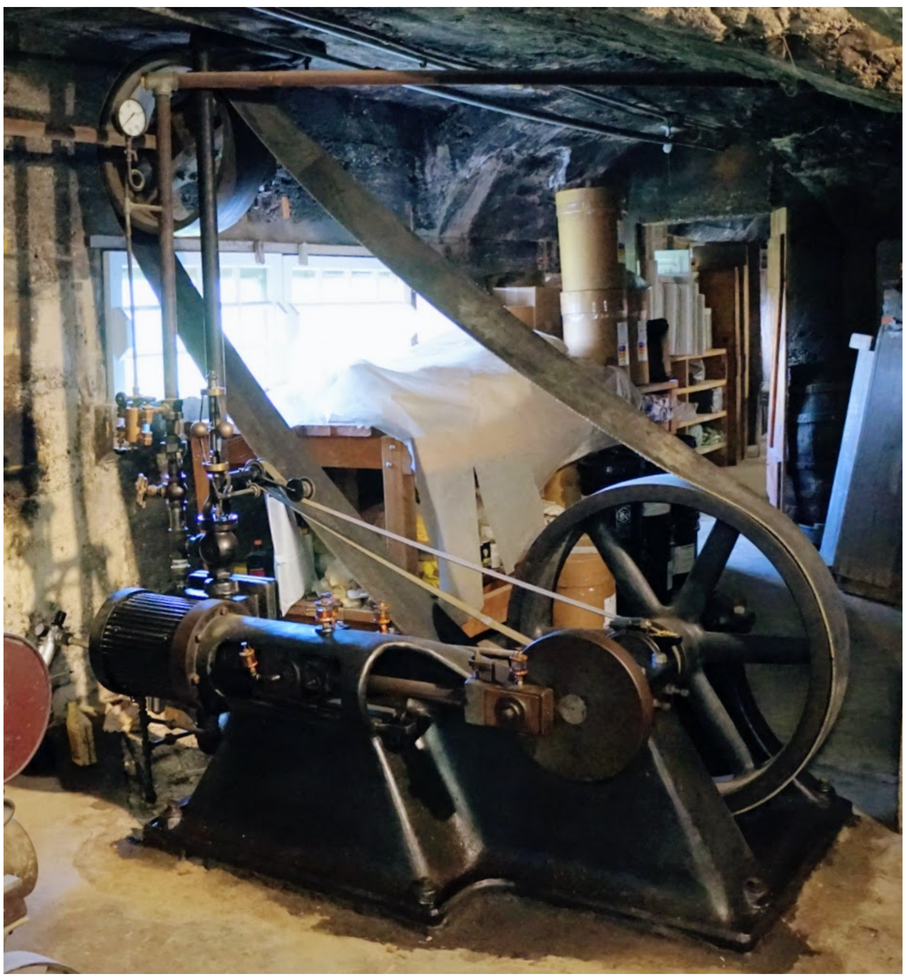


Figure 3.10. 15-horse power "Metropolitan" self-contained steam engine, manufactured by Donegan & Swift of New York, used from 1903 onwards to power belt and shaft-driven pugmills and grinders. Image: author, courtesy of the Moravian Pottery.

In addition to the dated accounts and log books of kiln firings, Mercer's papers and even his construction notebooks are populated with the occasional note or sketch regarding tile design or glaze formulation, and there are also in his archive a collection of loose pages (many of them titled "experiment") describing methodical glaze testing experiments or documenting materials sourcing and processing. Some of these are clearly an account of a received craft practice, for example, a scrap of paper in this archive contains the cryptic note: "Common Glaze. Red lead of Galena. Often add opaque oxyde (sic) of tin."[169] At other times Mercer is more scientific in his approach, and creates an explicit record of each step in a testing regimen. [Fig 3.11.]

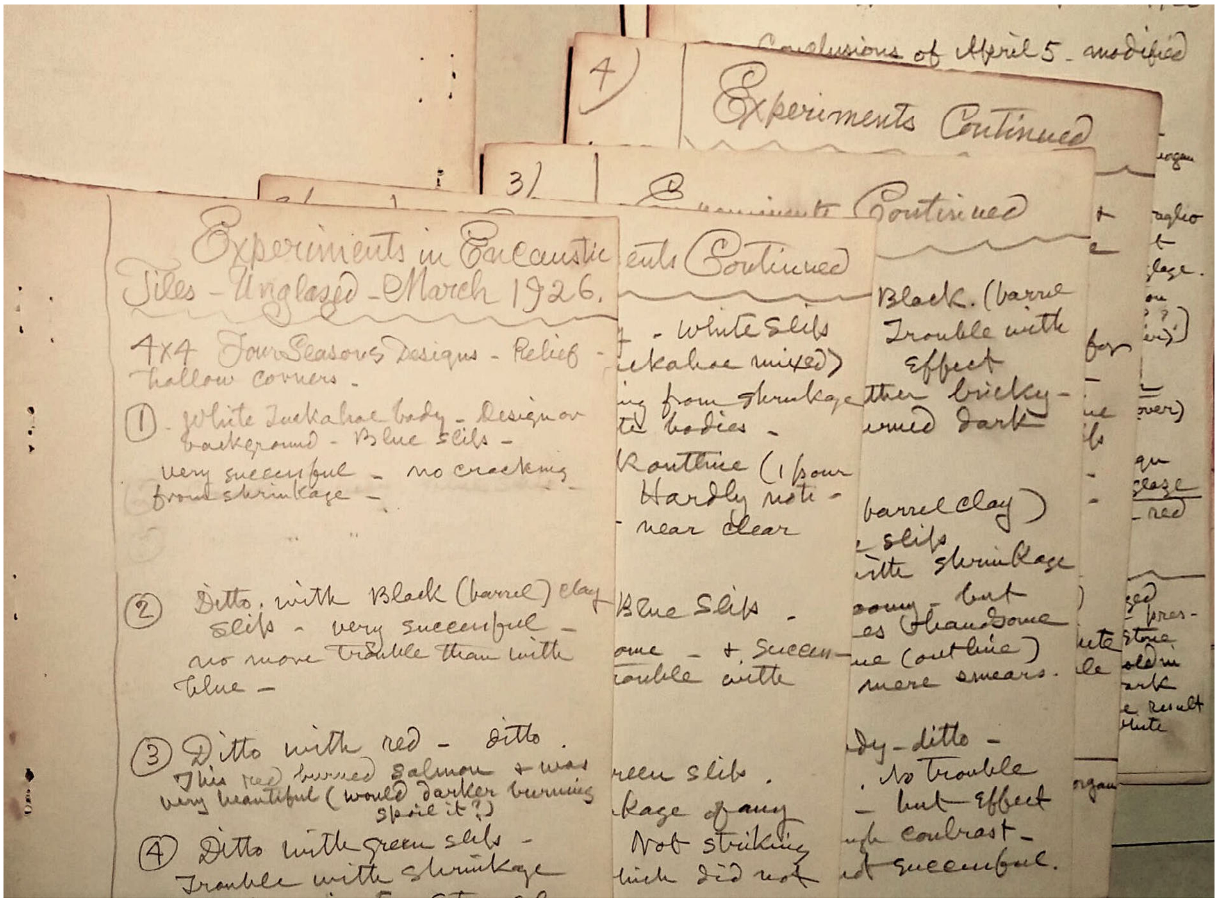


Figure 3.11. Experiments dated March-April 1926. Note the formulation of a series of tests in which Mercer specifies both material and equipment, and lists the results of each trial. Image: courtesy of the Mercer Museum Research Library.

This method of glaze formulation through careful experiment, it should be noted, is not unique to Mercer but is instead common practice among craft potters, and continues to this day.[170]

Traditional ceramic craft practices combine the extreme sensitivity of high temperature chemical reactions—often it is not merely the ingredients in a glaze recipe that determine its color, texture, and finish, but also the amount of available oxygen, intentional additives such as salt or soda, as well as free carbon and other combustion by-products that taken together are described as the 'atmosphere' of the kiln. Because of this sensitivity, and the variability of craft kiln construction, operation, fueling, and chemical sources for glazes, each kiln has its own peculiarities, which relate to both the space of the kiln, and the precise chronology and process of its firing. A craft potter will often, through long experience and careful tracking, come to know the precise variability in an individual kiln, and configure the placement of wares to take advantage of differences in the kiln atmosphere.[171] Mercer, and his trusted workmen, knew their kilns in great detail, and would stack unglazed ware loose, and glazed ware in "saggars" (protective ceramic boxes) in precise locations in each kiln to take best advantage of the variations in temperature throughout the kiln.[172] This variability, the bane of industrialized production, was taken up into the ethos of Mercer's Arts and Crafts pottery. Moreover, Mercer deliberately sought out manufacturing techniques that would highlight variability, making it part of his aesthetic project. In his brief history of the pottery, *Notes on the Moravian Pottery at Doylestown,* Mercer described some of the difficulties that arose.

> At first, although the tiles were favored by architects, there was much objection from tile setters and tile merchants to the novel ideas introduced in the pottery […] such as the reasonably large joints considered desirable in our tile work, or our so called half glazed designs produced on rectangles and polygons of common red clay. Discarding the method known as the dry process, the pottery abandoned all attempt to resist the free shrinkage of clay, and unbounded value was given to the red color of the red burning clay.

Such variability, however, required careful control and detailed knowledge of the local capacities and idiosyncrasies of Moravian Pottery tools and equipment. The *Moravian Pottery Kiln Manual* gives the following instructions:

> Under glaze green can be burned from the third seggar up inclusive to the top of the kiln. Under glaze blue requiring more heat for its development can be preferably worked from the fourth seggar up inclusive. Under glaze black under de Morgan in three lower most seggars not very successful generally running into brown. Yellow under glaze requires a good heat burned from fourth seggar up inclusive very apt to go brown or with pale scum much depends upon application of color which should be fairly thin. Stir color solution continually so as to keep a sort of froth which rises upon it under the surface or out of the way of the face of tile as you dip it.[173]

This is a remarkable series of instructions not only because it is so specific,[174] but because of its performative asides. These make explicit the sort of craft knowledge that is usually held tacitly, and, if expressed at all, is communicated verbally, in the course of a demonstrative act. In this example, one can imagine a nineteenth (or ninth) century master potter instructing his apprentice: 'stir the glaze *like this*, until a froth rises up; no, not quite to the surface; *like this*: just under the surface; now dip the tile—not in the froth! Allow the stirring motion, *like this,* to pull the froth to the sides of the bucket so that you can dip the tile cleanly, quickly, so the glaze stays thin…' and so on, engaged in one of the myriad of communications essentially gestural, and only secondarily lexical, upon which a mastery is achieved.[175] In most craft traditions, and indeed, in much of Mercer's work, these sorts of instructions remain below the surface of any extant text. Yet the texts retain their implicit dependence upon a whole complex of performative acts and expertise; and we may at times read between the text and the built result to find these vanished communications, and reconstruct the forgotten acts.

This small moment of archival evidence is a bit like Blake's grain of sand, in that it opens on many issues of significance to this study. First, that the act of innovation belongs to a set of behaviors that can broadly be considered experimental, and which can be passed on to or inherited by separate—if related—bodies of craft practice. (This is a question we will turn to immediately in this chapter.) Second, that expert tool use, carried out in a tradition of craft technique, relies upon a body of tacit knowledge; and that this tacit knowledge should be taken into consideration when we essay any theory of architectural methods and their documents. It is important to remember that there are always dialogic, ephemeral, precursors to written specifications; and that these precursors underlie construction documentation and make possible its economy and efficacy. As such, it is precisely tacit practice that enables the instrumental relationship between drawing and building. These issues will be the subject of chapter 4. Finally, this archival transcript of a dialogic process reminds us that the performative "like this" that often characterizes ephemeral communications is rendered implicit when these communications are taken up into systems of architectural representation. They are formalized and transmuted into a tacit indication of a projected performance, a translation that can be analyzed grammatically as the evolution from indicative, to imperative, infinitive, and finally subjunctive grammars. We will return to this question of the 'grammar' of construction documents in chapter 6.

D. Experimental Practice in Science

Anthropological studies of experimental practice have to date focused on fields in which experiment is an unambiguous and defining part of disciplinary activity. An argument might be made that architecture, at times, falls into this category; or we can simply undertake an experiment of our own, testing whether the lessons learned regarding the 'production' of scientific knowledge apply fruitfully to the production of architecture. In any case, understanding Mercer's techniques not in isolation or as individual accidents, but as a coherent set of practices, will require an understanding of how experimental practices are characterized, structured, and carried out. This may provide a theoretical grounding for a more systematic understanding of Mercer's novel building practice.

The social scientist Bruno Latour has provoked broad reconsideration of experimental practice in the sciences with regards to a few underlying premises: that it is embedded in technical practices rather than carried out *a priori*; that the knowledge gained in these pursuits is inextricable from practical action; and that this knowledge is transferred, often analogically, to other fields of research, carrying along the baggage of its origins. In the realm of scientific research, this seems so counterintuitive as to be inconceivable, as it controverts one of the founding principles of the discipline: the primacy of apodictic reasoning over pragmatic experimentation[176].

Throughout their writings, Latour and his inheritors argue for a full consideration of the sites of the researches they study, and their conclusions remain both local to these sites and practices and disciplinarily specific. This is at odds with conventional accounts of research and of innovation, which are motivated by universalizing goals.

Latour's first significant treatment of the subject was founded on two years of fieldwork in the late 1970's at the Salk Institute, with which he would arrive at his impeccably observed yet fundamentally 'irrealist'[177] proposal that "scientific activity comprises the construction and sustenance of fictional accounts which are sometimes transformed into stabilised objects."[178] (A claim designedly at odds with the ideology of scientism—if not science itself.)

In *Laboratory Life,* the book that resulted from his research, a work even those belonging to opposed viewpoints consider a 'pioneering study,'[179] Latour and his coauthor Woolgar examine the ways that knowledge is discovered through the practices of the scientists he observed; or rather through the group practice of a small community of scientists working together at the Salk Institute. While these practitioners seemed to conceive of themselves as the producers of positive and quantifiable knowledge, which was followed by the representation of that knowledge to a broader scientific community, in Latour's account instead their productive activity *begins* in various representational acts, which remain local and contingent. Latour synthesizes many of the key thinkers, and diverse fields of study, of the latter 20th century to create a multi-part explication of the characteristic pattern of the scientific practices he observed, proposing six stages in scientific research practice. (And, in the process, he attributes each of his six steps to one of the key figures of 20th century intellectual history[180].) In Latour's analysis the structure of experimental practice consists of:

1. Construction, "the slow, practical craftwork by which inscriptions are superimposed and accounts backed up or dismissed[181]." These behaviors are, on the surface, representational; yet Latour insists that we reverse our usual assumptions about the priority of idea and representation. This is a state of mind he calls:

2. Agonism; that "reality is the consequence, rather than the cause, of this construction[182]". Latour's point here is not merely that our tools condition our truths—but that they create them. In observing the actions of practitioners, he found that the tools, and the representations they were used to create, came into being in advance of their justifications in data or scientific discovery. (This went against the narrative he heard from the scientists he studied, who insisted their tools were created in service of these truths.) Of particular interest to this study is the counterintuitive superordinate category Latour proposes: *tools-and-representations*. Latour's account opens the possibility that the materiality of our tools is not a given but rather the result of acts of:

3. Materialisation: "One cannot take for granted," he writes, "the difference between "material" equipment and "intellectual" components of laboratory activity: the same set of intellectual components can be shown to become incorporated as a piece of furniture a few years later." Here he means 'furniture' broadly, as either the "tacit skills" or "material equipment" of the laboratory[183]. This is akin to the fuzzy line between materials and methods in architectural production. Tools may be manifestly material (like a hammer), putatively material (like a yard stick, which is used in material practice but is configured as an instrumental articulation of the culture, rather than the material, of building—e.g., it serves to propagate standards of measurement), or a materialization of method (such as a drawing, which, while it may take a material form is generally considered to be interchangeable with other materializations of the same 'content') or a purely immaterial method (such as the craft knowledge regarding the use of that hammer which the drawing assumes and depends upon). Tools-and-representations belong to a superordinate category, materializations, which the work of the scientists he observes is pointed toward. Materializations are not 'materialist,' in the sense of a positivist account of stuff versus ideas; quite the opposite. The viability of a materialization of knowledge depends upon:

4. Credibility, which, unlike 'bare facts', consists of their contextualization within the larger economy of human enterprises, blurring the "arbitrary divisions between economic, epistemological, and psychological factors[184]." That is to say, the pursuit of scientific knowledge is contingent with regards to its materializations inasmuch as these materializations are always situated in particular communities and arise from immediate meanings, negotiations, and

5. Circumstances. For Latour circumstances "have generally been considered irrelevant to the practice of science[185]." Yet they are, he argues, instead the *foundation* of scientific knowledge: scientific practice is "entirely fabricated" from contingent and local. In understanding research and discovery as inherently local, Latour must reconcile ideologies of truth and empirical proof with the everyday practices of researchers. He does this through the concept of

6. Noise, a term borrowed from information theory, that "information is measured against a background of equally probable events," and thus that experimental rigor and scientific discovery is no less socially—and materially—constructed than the products of other disciplines: that is, a scientific community, in discovering new knowledge, is using the filter of novelty—registering, in their own familiarity-with (or surprise-at) the new contribution, its value to the field. "New knowledge" is that which stands out against the background; and which is adopted into the *milieu* of shared knowledge—or, we should say, into practice[186].

E. Scientific Practice and Architectural Research

Some of the earliest significant scholarship on innovation in practice focuses on the structure of work in scientific fields.[187] In the second half of the twentieth century, fields such as science and technology studies, sociology of science, and the history of science, have emerged in pursuit of a cultural as well as material understanding of invention, production, and work. Perhaps it is unsurprising that most scholarship in these disciplines critical of a purely positivist paradigm attends to fields of practice in which material artifacts are self-evidently ancillary to the notional objectives of the field—few would attribute advances in HIV research solely to new tools allowing rapid genome sequencing, despite their utilization of such tools to produce new insights, and even the direction of their research toward the capacities of these tools. That is to say: no matter how productive the tool, without the right questions the sea of data will not yield up its answers.[188]

Yet scholars of innovation cleave to research fields, perhaps because if the primary work in field is not material production, but 'knowledge production,'[189] then the conditions of possibility of knowledge (something these fields are well equipped to study) may be studied as the generative principles of innovation (something they wish to understand). Sociologists of science have even, at times, been considered by their subjects—the research scientists they study—to be epistemologists rather than scientists[190], and their recommendations pertinent to how we consider ourselves in theory rather than how we might direct ourselves to the practical pursuit of further innovation. (Unfortunately, the very focus of science and technology studies upon the immaterial aspects of practice often results in a furtherance of the very divide between theory and practice its scholars endeavor to critique.)

For the Anthropologist David Turnbull this conflict is the central argument of his work: "Within the master narrative of modernism," he writes, "local knowledge is an oxymoron."[191] Yet in the historical and cross-cultural examples Turnbull studies, it is precisely situated, local knowledge from which the very ideologies of essentialism and placelessness emerge. Unlike some architecturally trained theorists, however, Turnbull remains nonplussed by issues of anonymity or placelessness—such modern afflictions are not descriptions of dystopian reality, in his view, but rather flawed caricatures arising from socially embedded actors making the fundamental mistake of assuming cultural hegemony, even as they critique the culture at hand. Contrariwise, Turnbull argues for a return to the local as predicating epistemological force. "A particularly perspicuous perspective on the cross-cultural history of knowledge production is provided by a social history of space," he writes, proposing "a history of the contingent processes of making assemblages and linkages". The making of 'assemblages and linkages,' that is, the daily work of knowledge production, whatever the discipline, is, he argues, rather than abstract or apodictic, instead always concrete and local. Effective research entails the creation of "spaces in which knowledge is possible."[192] (What exactly this means, and how productive activity, facilitated by tools, may operate reciprocally with them in the 'creation of space', will be discussed further in chapter five's discussion of affordance theory.

In any case, understanding innovation generally, and scientific research in particular (Turnbull's primary interest) as fundamentally a local enterprise, requires extended argument and evidence. This is a project undertaken to show that the discovery of knowledge has defining characteristics; and that these characteristics do not 'square' with the underlying assumptions practitioners often make about their activities, and with which they inform their planning and evaluation of their own success—a project inherited from Latour.

For these thinkers, there exists in the sciences a fundamental misconception about the relationship of representation and discovery: that former is in service to the later, and is 'transparent' to its findings. As a result of this misconception many enterprises dedicated to research or innovation operate wastefully, and squander the material and human capital with which they are endowed. This is as true in the productive arts (such as ceramics or building) as it is in the research sciences: the process of representation is fundamental, constitutive, and indissociable from both everyday practice and innovation in the field. But in this we must understand "representation" in the terms in which it is used sociological/ethnological theories: rather than 'pictures,' representations most broadly are first artifacts—that is, material fabrications—and thus include the tools of research.[193] This is a much broader and more abstract usage of the term, at odds with how "representation" is traditionally construed within Western cultural discourses of the fine arts as a non-instrumental mimesis of the 'external' world. (Because of its great variety of meanings, we should always note the context of the usage of the term.)

In his essay "Talk, Templates and Tradition: How the Masons Built Chartres Cathedral Without Plans," Turnbull seems to suggest at first that some of the most iconic works of architecture in the Western tradition were built without representations; or rather, as the argument develops, that their representations were in every case local and instrumental, rather than comprehensive and abstract, taking the form of either material tools, such as templates, or the informal communications—verbal and gestural—which are everpresent in organized craft activity. In his essay, Turnbull describes the process by which Chartres cathedral was constructed, and the significance of the tools and representational technologies of its 12th and 13th century masons. Turnbull argues for the social construction of scientific knowledge, underlining local and ad-hoc decisions and actions (what he calls "site specific, contingent, and messy practices"[194]) as constitutive of, rather than ancillary to, innovation in practice and the 'production of knowledge'.

These conclusions regarding the misconceptions of scientific theory and practice do not originate with Turnbull, who for his part readily acknowledges his debts in this matter to Bruno Latour, as well as Shapin and Shaffer's landmark *Leviathan and the Air Pump.*[195]

This makes Turnbull's observation of the historical example of Chartres cathedral unusual in its own field; and particularly apropos to architectural thought. Turnbull's focus is on a series of operations carried out by masons that result in the creation of not just the built environment, but of knowledge of how to build. These are acts of the co-fabrication of building and of knowledge in that they take place not as the rote duplication of craft actions but as practical experimental acts. And this experimental practice is fundamentally, manifestly, manual, consisting in the masons' deployment of the primary "technological component"[196] of their practice: the template. (Leaving aside, though not explicitly excluding, questions regarding the chisel, hammer, hod, hoist, or scaffold.)

The mystery of a cathedral built without any plans, or architect to draw them, has of course long bedeviled architectural historians[197], for whom such a mystery offers little but threat of the coup de grâce for a profession already feared lost to its former glories. Thus it is that the body of historical study has attempted to take up the medieval cathedral into the arena of architectural practice, and attribute its evident order and 'genius' to lost documents, secret traditions, or arcane societies.[198] Turnbull, instead, pursues "a more performative approach," in which "gothic cathedrals are conceived as sites of experimental practice—literally as laboratories."

This brings Turnbull's study very much in line with Latour's principles of scientific action; but it clarifies the meaning of certain of Latour's proposals with regards to the artifacts—the tools—of research in an architectural context. For where Latour stretches his terminology some distance to characterize the various tools of scientific research as 'inscription devices'[199], the template can readily be seen to take its form directly from the tracing of a profile—a direct and unambiguous act of inscription. Yet despite the apparent simplicity of this medieval artifact of construction, all of Latour's six concepts may be mapped in its use.

Templates are (1) constructed representations of building elements, and their fabrication on the job site occurs in just the daily manner Latour uses to describe inscriptions generally. They are (2) agonistic, in that they create the convoluted (or simply voluted) surfaces of cathedral structures without themselves containing a complete description of those elements and surfaces, or any general theory for deriving such formulae. They materialize (3) the constructional logic worked out on the tracing room floor (or elsewhere); they make that knowledge portable, and allow its transport both physically between places of work, and notionally, as it is taken up into the system of knowledge of medieval cathedral construction. This transport is broadly speaking the transmutation of stones into the specialized and speciated materials of building, and of the unprepossessing world into building technology. The work of the tool is, thus, to effect the *socialization* of the building material, its uptake into a technological field of practice. Once this assimilation has been accomplished, the template can be seen to work within that field as (4) a conveyance of authority from the master mason to the stone cutter. Each stone, however, must be cut to fit not merely a predetermined sectional extrusion but the fully three-dimensional reality of its (5) local situation—this is a situation determined at the scale of the detail, the building, the site, and the city, at the various scales in which the branching network of craft expertise flowers in the production of building. The template therefore is not a complete description—a fully prescriptive model—of the stone to be produced, but rather a proximate guide to the act of cutting. It is essential however that we not mistake its sparseness *as* representation for a lack of acuity, or any sort of informational deficit, as its minimal representational content (a single contour line) might be more accurately termed a deliberate and functional economy of representation. Finally, the meaningful use of the template is predicated upon its ability to render clear the 'signal' (6) carried in the template (its profile) which will have become, through this process of localization and adaptation, the singular description of the building as built, and a potential source for further iterations of this cycle.[200]

In addition to templates, Turnbull sees two other factors as forming the basis of medieval cathedral construction practice: "tradition" (inherited craft practices) which we will look at in the specific context of Mercer's work in the remainder of this chapter and the one that follows; and "talk," to which we will turn in the chapters that follow.

In endeavoring to show that Medieval jobsites are like laboratories, and laboratories like jobsites, Turnbull accomplishes a far humbler thing as well, but one of particular relevance to the study at hand: he proposes that the template is a piece of "representational technology," and illustrates the degree to which it served as a basis not only for communication of geometrically derived or "discovered" knowledge, but constituted the discovery itself. The template, then, is a perspicuous instance of representation in and through its instrumentality, rather than in spite of it[201].

It is important to consider that the translational activity at the heart of Latour's consideration of scientific practice, what Turnbull calls the *portability* of knowledge in the artifact, applies not just between participants in a shared enterprise—fellow masons sharing a template—but is readily adapted into other contexts and practices. Knowledge drifts and transforms, adapting to new needs.

Ultimately, Turnbull wants us to consider the way that scientists function a bit like medieval masons. They depend on informal communication, the structuring work of inscriptional tools, and the paradigms and traditions of their field.

Mercer presents a problematic case to these analyses in two ways: first because his methods were influenced by the growth of scientific consciousness in American intellectual life in the latter 19th century that is, they were aspirationally scientific; and second because working as he did in an entirely new suite of materials, tradition was for Mercer a created, rather than received, thing. (Perhaps, for the best of us, it always is.) We can see how the analysis of scientific process explicated by Latour applies in the case of Turnbull's medieval masons. Next I want to explore whether similar structures apply in Mercer's work. This should provide the opportunity to propose several arguments: One, that Mercer's construction notebooks served not merely as private journals but, like the templates of medieval masons, as a core representational technology structured by and structuring his practices. Two, that these notebooks record a process of innovation with great detail and intimacy, shedding light on how innovation happens even in—or especially in—local constellations of building knowledge and practice. Three, that Mercer's construction details, as explored in the notebooks and evident in the finished works, illustrate a process of design which was repeated, internally consistent, and productive: namely, a scientific method. And four, that Mercer's practice included the adaptation of his own form of template: molds of wood and plaster used in ceramics design and production, to forms made from wood, plaster and clay for construction in reinforced concrete.

In the pages that follow we will begin by treating a building detail drawn very directly from clay forming methods (Mercer's precast windows), proceed to one of more hybrid character (his typical cornice detail), and finally examine how these details—themselves inventions—demonstrate the key role of Mercer's notebooks in his invented system of building.

F. Casting Windows

Beginning with the construction of Fonthill in 1908, Mercer developed an approach to designing and fabricating divided light precast concrete windows of a great variety of sizes and shapes, which followed the pattern of wooden fixed or double-hung windows, at times to the extent of having a lower panel recessed below an upper panel, despite the fact that neither panel was operable. The sectional profile of the muntins in these precast windows was a very close approximation of the millwork profile of the muntins of the wood windows used elsewhere in Fonthill; [fig. 3.12-3.14] yet a number of the precast windows were installed prior to the wood windows. Wood windows were used in many of the primary occupied spaces, and wherever operable windows were required. In places Mercer even combined wood and precast panels into a single window. [Fig 3.15, 3.16.] Many of the early pages of his Fonthill notebook, directly following the lowest-level plans, and *prior* to elevations and sections, are devoted to different possibilities for divided light window shapes and patterns. (They are undated, but their sequence in the notebook points to their creation between the fall of 1907 and spring of 1908.) Mercer sketches windows he sees in images published of English manor houses, Italian villas, and other assorted European precedents from periodicals such as *Country Life* (sketches on pages 38 and 39 of Mercer's notebook) and *House and Garden* (page 43), from artworks such as those by the Dutch painter Pieter de Hooch (page 78) and windows he saw in his travels and more local collecting trips, such as "House on Germantown ave, Germantown" (page 79). (One wonders if Mercer may have passed Taylor's childhood home on his walk.) At times he notes windows that may simply be from memory, or for which he did not bother to provide a source, such as with a sketch of a colonnade accompanied by the cryptic note "On face of wall Piazza V. Emanuele Viterbo" (page 50), which refers presumably to a real place, the piazza of that name in Viterbo, Italy (as opposed to the far more renowned one in Rome)[202]. Often these are more musing sketches that begin to transition to a description of Mercer's design criteria, such as a small thumbnail on the next page accompanying the note "Central cross mullion flush with outside walls, Loches, also Langeais" (page 51) (these are castles in the Loire valley in France).

Figure 3.12, 3.13, 3.14. Wood and precast concrete windows, Fonthill. Images: author, courtesy of Fonthill Castle.

Figure 3.15, 3.16. Combination wood and concrete window at Fonthill. Note the 'millwork' profiles of the concrete muntins. In this case the upper concrete sash was installed 'inside-out', as the space behind it was an unfinished elevator shaft. (The lower sash may have been wood to facilitate its removal for summer ventilation.) Images: author, courtesy of Fonthill Castle.

The majority of the windows at Fonthill are wood. But even early on, Mercer is contemplating the possibility of casting his windows. The construction had barely begun when we find the first notes to that effect, and ensuing pages thoroughly explore their fabrication. On page 80 of the notebook we read the following account:

> April 24— 1908 General House foundation partly filled in. Collapsable boxes found to catch, requiring wedges, large flat stones inserted in concrete all along wall — 6 vertical pipes inserted in each pier, several of the columns started at base 15 inches square with four pipes inserted and occasionally three. Cement mixer works very well. 2 carloads crushed stone came yesterday. Terrace wall made under great difficulties with tin and wooden forms using cinders and native sand— 1, 2 and, 5. John Rufe lent pump until Ram finished. Ram pit & Reservoir successfully cast in concrete. Terrace wall well reinforced with fence wire and pipes.

In the pages leading up to this account, we find notes, in a much looser hand, about the various problems that have presented themselves leading up to these actions. This places us at the west end of Fonthill, with the building just emerging out of the ground. The Terrace wall is at the West side of the building, and its small windows would eventually receive precast concrete inserts, though not until after the technique had been refined in other rooms. Construction photos [Fig. 3.17] show other early precast concrete windows. In this image the unfilled rough openings visible would go on to receive wood windows, and this sort of side-by-side placement of wood and concrete windows would be typical throughout the house. [Fig 3.18.]

Figure 3.17. Rear facade of Fonthill, ca. 1908, with first story and part of second complete, showing what may be the first experiments in cast concrete windows. Image: courtesy of the Mercer Museum Research Library.

Figure 3.18. Rear facade of Fonthill, present day. Image: author.

Figure 3.19. Front facade of Fonthill, ca. 1908, cellar and first story complete, showing what is likely the first wood window installed. Image: courtesy of the Mercer Museum Research Library.

Mercer's explorations of possibilities for concrete windows may have begun as early as 1903 or 1906. In the rediscovered photographs of the kiln building at Aldie we see an upper eyebrow dormer with what look to be small cylindrical vents or glazing set in concrete, and the full size window in the photo may be concrete as well. [Fig 3.20; and see fig. i.3.] There is no record of the materials of the windows shown in the few surviving photos, but the muntins appear to be wide and rough, quite similar in general appearance, configuration, and dimension to Mercer's concrete windows at Fonthill. Whether they began in 1903, 1906 or at Fonthill in 1908, Mercer's precast windows continued to evolve throughout his projects.

Figure 3.20. Eyebrow dormer and full window detail view. Archival image of Mercer's first experiments in concrete. Image: courtesy of the Mercer Museum Research Library. Collection on loan from the Moravian Pottery and Tile Works.

However convenient it would be to see the cast concrete windows as a direct mimetic transcription of the wood window into a concrete imitation, this is not indicated by a close observation of Mercer's development of the technique. His earliest windows at Fonthill [fig. 3.21], lack much of the definition exhibited in later versions. [Fig. 3.22.]

Figure 3.21. Window at Fonthill. Image: author, courtesy of Fonthill Castle.

Figure 3.22. Window at the Mercer Museum. Image: author, courtesy of the Mercer Museum.

The precast windows at Fonthill also show a greater preponderance of craft defects, such as failure of coverage of the small diameter reinforcing [fig. 3.23], as well as evidence of greater irregularity in the results and less successful performance (with associated subsequent material failures due to lower quality concrete and/or or water infiltration). [Fig. 3.24.]

Figure 3.23. Muntin in unglazed window at outdoor terrace at Fonthill, showing corroded reinforcing. Freeze-thaw cycles may have exacerbated issues of insufficient coverage in this case. Image: author.

Figure 3.24. Degraded precast window with muntin profiles mostly effaced, Fonthill. Image: author.

These problems, or perhaps others, or simply the desire to find a better, faster, or more reliable method, would cause Mercer to continue exploring forming options for his precast windows, which he would use almost exclusively in his later projects. A careful reconstruction of his process, based on the notes from his notebooks, allow us to trace the evolution of the method. As a further test of these deductions, the author undertook to recreate Mercer's technique, including the fabrication of several of the nonce, purpose-made, tools (now lost) that Mercer's notebook illustrations suggest were used. (Only the results of these tools, and not the tools themselves, are illustrated in the notebook, perhaps because when these initial design sketches were drawn the tools had yet to be invented.)

G. Mercer and Templates

With one hundred years of hindsight, and changes in fundamental assumptions about the role of buildings in energy conservation and the conditioning of interior air, these imitation-wood windows would seem to be an absurd exercise in mimicry. Several things mitigate against this. First, we should hold these window to the standards of their time, in which glass was only beginning to become affordable in larger sizes, and the maintenance and repair of small broken panes was a common household task, requiring no more than putty, knife, and a replacement pane of glass. (If only the modern window was so tractable!) Second, the similarity to the wood window, while acute, is superficial. Unlike a wood window, Mercer's concrete sashes could be fully sealed into their opening with mortar, creating—as unlikely as it may seem by current standards—a *tighter* than typical building envelope. After the windows were shimmed into place with wood shims, mortar was placed throughout the rough opening, and blended with parging on the exterior concrete wall to create a seamless exterior surface, with no additional trim applied to window openings. What resulted was a building facade in which the windows appeared as an unbroken part of the concrete planes of building walls [fig 3.25]; but only seemingly so. As we saw in the discussion of the fabrication of the windows, which were cast on the flat rather than in-situ, Mercer's windows were made to fit their openings after their rough openings were complete. And while the precast window has a visual parallel to its wooden model, it does not function the same way in the context of the building envelope: this sort of seamless fit would present problems for wood windows (differential thermal expansion, moisture uptake from the concrete rough opening) that would not be presented to precast concrete inserts. But the greatest advantage for Mercer may have been the ready customization of the windows to the unique requirements of each room (something he would remark upon in later years) as well as adaptation to variations in as-built conditions. At its heart, this is a story of the details of fabrication, for Mercer's windows had deep roots in the materials and methods of the Moravian Pottery.

Figure 3.25. A large concrete plane with many openings. West wall of the Mercer museum in afternoon sun. Image: author.

The Moravian pottery is still run today as a living history museum by the Bucks County Parks and Recreation Department. Preserved at the site are many of the original master molds Mercer developed to make his tiles. The earliest of these are simply rectangular or square relief molds made from plaster. These were made in the positive, and everyday working molds, also in plaster, would be cast from them to use in tile production. This provided a physical archive of Mercer's designs, and a ready method to replace molds in case of breakage. [Fig. 3.26.] But as Mercer developed his different genera of tiles,[203] the methods of fabrication became more complex, and Mercer (or his workers) invented and refined a number of tools to facilitate their production. In the case of the undecorated hexagonal field tiles installed at the Pennsylvania Capitol building, Mercer invented a press made from wood and sheet metal [fig. 3.27] to facilitate rapid and accurate production. But soon Mercer would move on from regular polygons. And where Mercer's trajectory would seem to be of increasing mechanization, as one might expect in a production environment, this was not mechanization for its own sake, or in pursuit of an abstract ideal of efficiency.

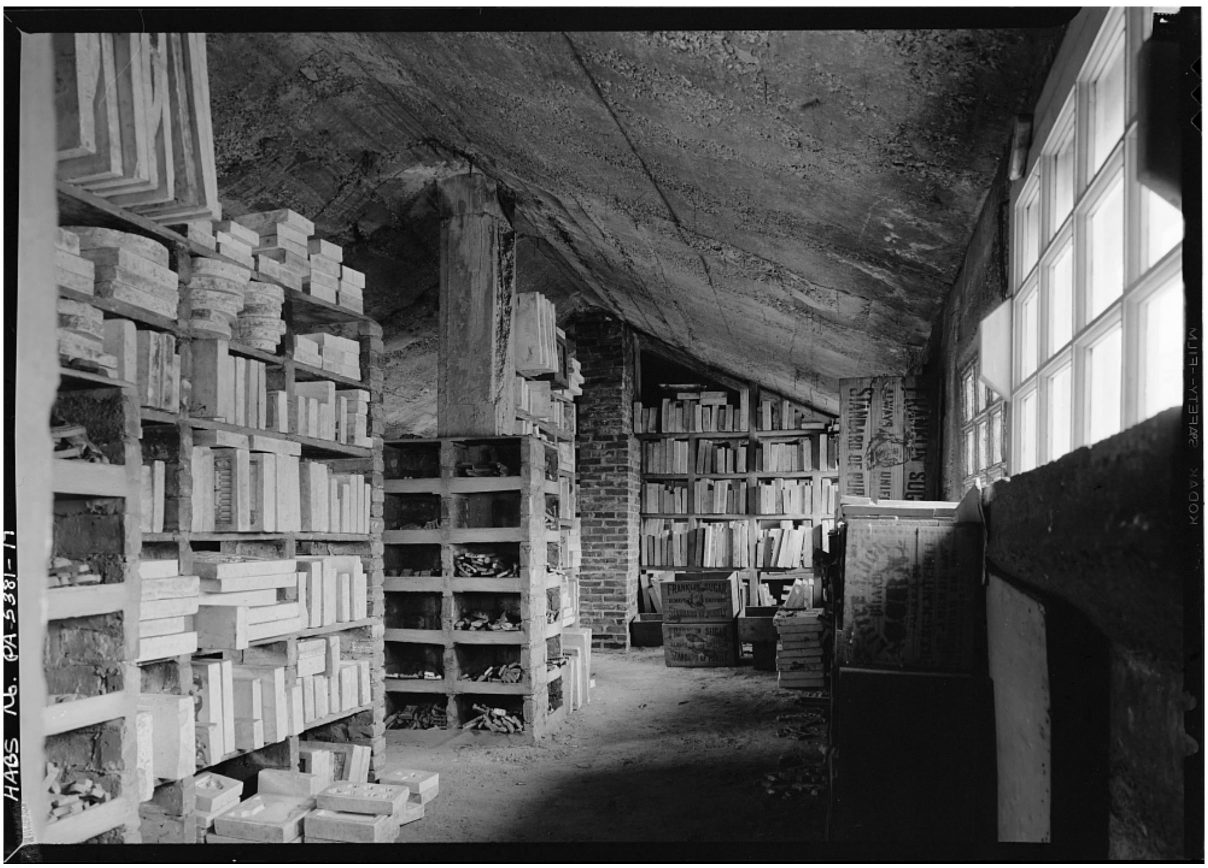


Figure 3.26. Tile molds, Moravian Pottery. Image: Historic Engineering Record (HAER).

Figure 3.27. Hexagonal tile maker, Moravian Pottery. Image: author, courtesy of the Moravian Pottery.

A key example demonstrates the opposite. As Mercer's tile designs developed they became more and more irregular in outline, as well as higher-relief. This was particularly the case with his "brocade" and modular relief panel tiles. [Fig 3.28; fig. 3.29.] When it came to make these high-relief tiles, Mercer attempted to use the tile press he had developed several years earlier for lower relief tile production. [Fig 3.30.] It consisted of a long lever arm with a pressing plate and a frame into which plaster molds could be placed. A slab of clay would be inserted into the frame, and the pressing plate would apply even force to impress the design on the clay slab, the remnant clay being cut off by hand. According to one of the present day interpretive staff, Mercer soon abandoned his device, not because it was cumbersome, but because the deep relief molds could be filled more rapidly and with less error by hand, by pressing loose clay from multiple angles until the deep plaster mold was filled, and then compressing it with a wood tool invented for the purpose, adding clay as required to fill out the shape. This tool is preserved at the pottery, where it is called a "tamper".[204] [Fig. 3.31.]

Figure 3.28. Brocade tiles in the Moravian Pottery showroom. Image: author, courtesy of the Moravian Pottery.

Figure 3.29. High relief mural figure from museum panel. The figure is near-life-size. Image: author, courtesy of the Mercer Museum.

Figure 3.30. Tile press, Moravian Pottery. Image: author, courtesy of the Moravian Pottery.

Figure 3.31. Wooden hand-held clay pressing tool. Image: author, courtesy of the Moravian Pottery.

This shows a willingness to improvise; and to continue to experiment and improve processes of manufacture, even abandoning established methods and the sunk-cost of complex tools, returning to a ground state of ad-hoc problem solving and the reinvention of tools. Many of Mercer's methods were comprised of a sort of hybrid of freehand making and the certainty[205] provided by molds, templates, and improvised, purpose-made tools.

Mercer's mosaic tiles, which were also installed in the Capitol project, were made with a combination of press-molding and had forming methods that demonstrates this hybridity well. These tile mosaics, which were set within large areas of field tiles, are complexly pictorial or even narratively structured, featuring figures, tools, flora, fauna, and architectural settings. [Fig. 3.32.] The capitol project included a total of over 400 unique mosaics.[206] With the Capitol mosaics Mercer began to experiment not just with ceramic glazes but with adding colorant oxides directly to the clay body, resulting in a range of earth-toned hues, from black and grey to green, beige, and red. (Some of these required using his secondary, paler, base clay, as the iron in the red clay would overwhelm the weaker additive pigments.) This was an elegant solution to a fundamental problem encountered by using earthenware clay as a flooring material: even the most durable of glazes, slips, and other surface treatments would rapidly wear through, erasing the polychromy of the mosaic. With integral color, Mercer arrived at a superior solution. Consider, however, the difficulties it presented to fabrication: All the parts of the mosaic had to fit together, yet would need to be made of different clay bodies, each with its own colorant. Colorant oxide and carbonate compounds are more often than not different in raw and fired appearance, sometimes drastically. (Cobalt carbonate, for example, is pink in powdered form, and a rich transparent blue when fired.) What is more, the mosaics were composed of tightly interlocked shapes of different colors, and therefore of different clay bodies. [Fig 3.33; fig 3.34.]

Figure 3.32. Tile mosaic at the Pennsylvania Capitol. Image: Elizabeth Thomsen / CC BY-NC-SA 2.0.

Figure 3.33. Bisque fired small tile mosaic at the Moravian Pottery, present day. Image: author, courtesy of the Moravian Pottery.

Figure 3.34. Finished small tile mosaic at the Moravian Pottery, present day. Image: author, courtesy of the Moravian Pottery.

What was needed was a method to rapidly make copies in different clay bodies, only some parts of each copy to be used in the final mosaic. Mercer arrived at a technique combining the regularity of plaster molds with the flexibility of hand fabrication. The mold used illustrates the method well. First, full scale drawings would be made of the mosaic. The drawing would be inverted and traced on a slab of clay. This tracing would be deepened with a needle tool, and this clay pattern was used to create a "master" mold. [Fig. 3.35.] When the plaster cast is placed on a prepared slab of clay, its raised lines trace, with a few taps of the mallet or the flat of the hand, the entire mosaic onto the clay slab. Individual parts of the correct color can then be cut out by hand, and the unused remainder, still plastic, recycled into the stock of unused colored clay. The clay tile mold, then, is not a mold in the traditional sense, but a template.

Figure 3.35. Plaster mold for bird tile mosaic, Moravian Pottery. Image: author, courtesy of the Moravian Pottery.

This unlocks a key attribute of Mercer's approach to problem-solving in tile manufacture, and ultimately in building detailing. Many of Mercer's tools function not so much to entirely replace hand work as to guide it loosely within broad tolerances, trusting the knowledge of the worker and adapting as required. While Mercer had a general intention with regards to the colors of individual components that was generally lifelike (trees tended to greens, buildings to browns, etc.) iterations of same or similar patterns could vary, indicating this was a loose scheme, what we might call prospective rather than prescriptive. This working method was grounded in the allowance of broad tolerances, something that only became more the case as Mercer continued to invent new forms of tile, from fireplace installations in which he developed his earlier mosaic technique into a more open and narrative use of small relief tiles to tell sequential stories [fig. 3.36], to more open-ended but thematically linked wall and ceiling arrangements [fig. 3.37], to large murals for installation in institutional buildings. As Mercer developed his ever more ambitious tiles, he provided for ever greater tolerance in the joints between them. Ultimately, in some of his later designs, those joints would merge into a field of mortar—or, depending on the method of fabrication, the structural concrete of the building itself—in which small constellations of tile were resolved, then, as a sculptural figure. [Fig 3.38.] We should note, looking ahead to chapter 5, that some of the most ambitious of these bas relief sculptural panels depicted traditional craftspeople at work in an architectural frame.

Figure 3.36. "Pickwick Papers" Fonthill. ca. 1910; and offered in the 1915 catalog of the Moravian Pottery. Note the combination of conventional mortar joints, and the wide areas of untiled "background." Image: author, courtesy of Fonthill Castle.

Figure 3.37. "Four Seasons" mosaic installation, Fonthill. Image: author, courtesy of Fonthill Castle.

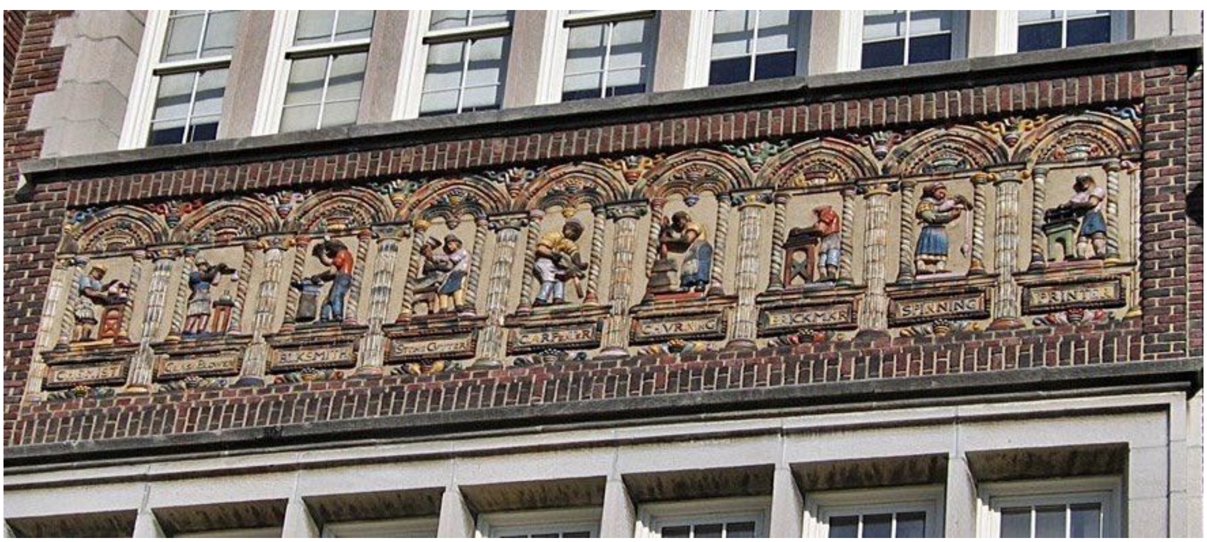


Figure 3.38. Trades mural, installed at Grover Cleveland High School, St. Louis, Missouri, ca. 1913. Image: Toby Weiss.

This approach—using templates to guide free hand forming operations—combined with an adaptable matrix and forgiving tolerances, can be seen to be used not only in the most literal sense of the two-dimensional plaster template marking out a contour profile for cutting. Mercer also took this method into three dimensions, as we have seen with the fabrication of his precast windows.

H. Fabricating Tools for Fabricating

The fabrication of Mercer's precast windows followed the pattern established by his mosaic tiles almost exactly, with one additional step. First, a profile, was determined for the desired window element. This profile was most likely reproduced as a shape of bent wire, a tool which could be drawn through the clay to produce a sectional extrusion of the desired profile. Mercer used wire tools in many facets of his pottery production, from the potter's common loose wire with toggles to a more substantial bowed construction in which a wire was strung from a frame to create a tool like the carpenter's drawknife (see chapter 5) to remove excess clay from tile molds. Variations of this tool, updated with modern materials, is still used by the staff of the pottery today. [Fig. 3.39.] While such tools were not preserved by Mercer, we can speculate that this bent wire profile, affixed to toggles or a bow, could be drawn through clay packed into a wood mold, as Mercer is reported to have done to create his beaded beams at Fonthill. This technique was described by an article on the construction of Fonthill published in *Cement Age*.

> Many interesting and novel structural methods were devised building the house. The plan of constructing the arched ceilings, in which expensive form work was eliminated and much time saved, has already been described. Another short cut to effective results is shown in the method of securing moldings on the concrete beams. In each lower corner of the beam forms two narrow strips of wood were tacked and between them was tamped a long rope clay. With a looped wire attached to a handle the workmen merely slide the handle along the wooden strips, which serve as a guide. The curved wire cuts through the clay throughout the length of the form. The released portion the clay was then lifted away, leaving a clay trough which was stained with any color desired, and into which the concrete settled, forming a beaded beam.[207]

Marianne Bernice Walsh, in her 1998 thesis in Historic Preservation and Conservation on Mercer's finishes, diagrammed a possible configuration of this modified form of the potter's loop tool.[208] [Fig. 3.40, 3.41.] It should be noted that the precise geometry of the tool would determine whether the regulation of the depth and shape of the cut was controlled by hand, or through the use of the guides shown, which are similar to those Mercer depicts in his journal. (Illustrated in Fonthill construction notebook page 110, see figure 2.17 on page 79.) The bow shown in figure 3.39 is used in a way that benefits from the edges of a wood frame into which the clay is packed, and along the top of which it cuts—the wood frame acts as a guide for cutting along. [Fig. 3.42.] It would seem likely that the tools Mercer invented for other, similar, applications likewise made use of guides to regulate hand work wherever possible; and the finished profiles of elements at Fonthill and at the Museum formed in this manner are highly regular, supporting this proposition.

Figure 3.39. Wire "bow" for clay cutting, present day Moravian Pottery and Tileworks. Image: author, courtesy of the Moravian Pottery.

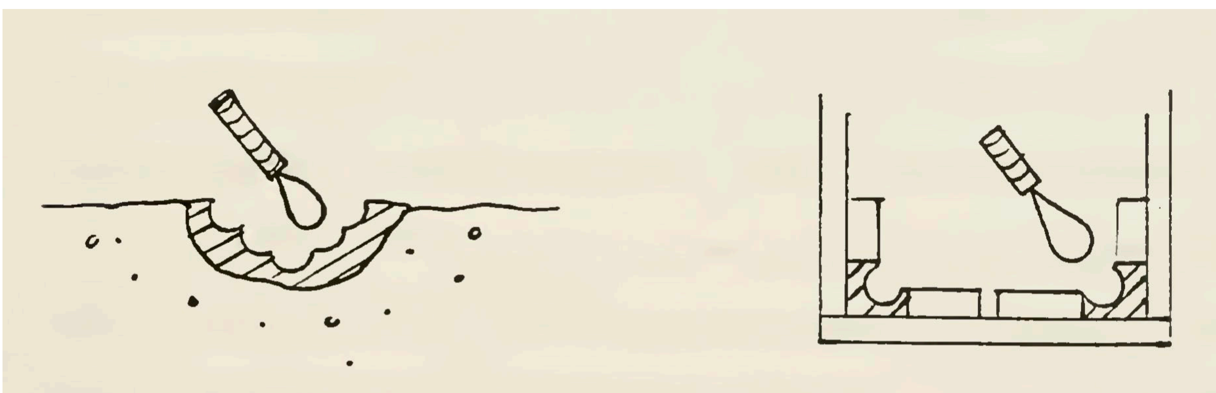


Figure 3.40. Walsh's drawing of the tool used to create the beaded beams in the 'saloon' room at Fonthill. Image: Marianne Walsh, Finishes Analysis in the Saloon, *Fonthill.*

Figure 3.41. Loop tools from the early years of the Moravian Pottery. Image: author, courtesy of the Moravian Pottery.
Figure 3.42. Contemporary wire cutting tool made from a bow saw frame. Note the wood guides built into sides of the cutting table. Image: author, courtesy of the Moravian Pottery.

Once a block of clay had been cut to the profile to be used in window fabrication, this extrusion could be used directly, or, if the same tool was flipped and the extrusion reversed, it could be used to cast a more durable plaster profile, as Mercer describes in his Museum notebook. There, Mercer cast right-angled corner molds in plaster, joining them with clay splices and supplementing them with clay extrusions for fan and peakhead windows. [Fig 3.43.]

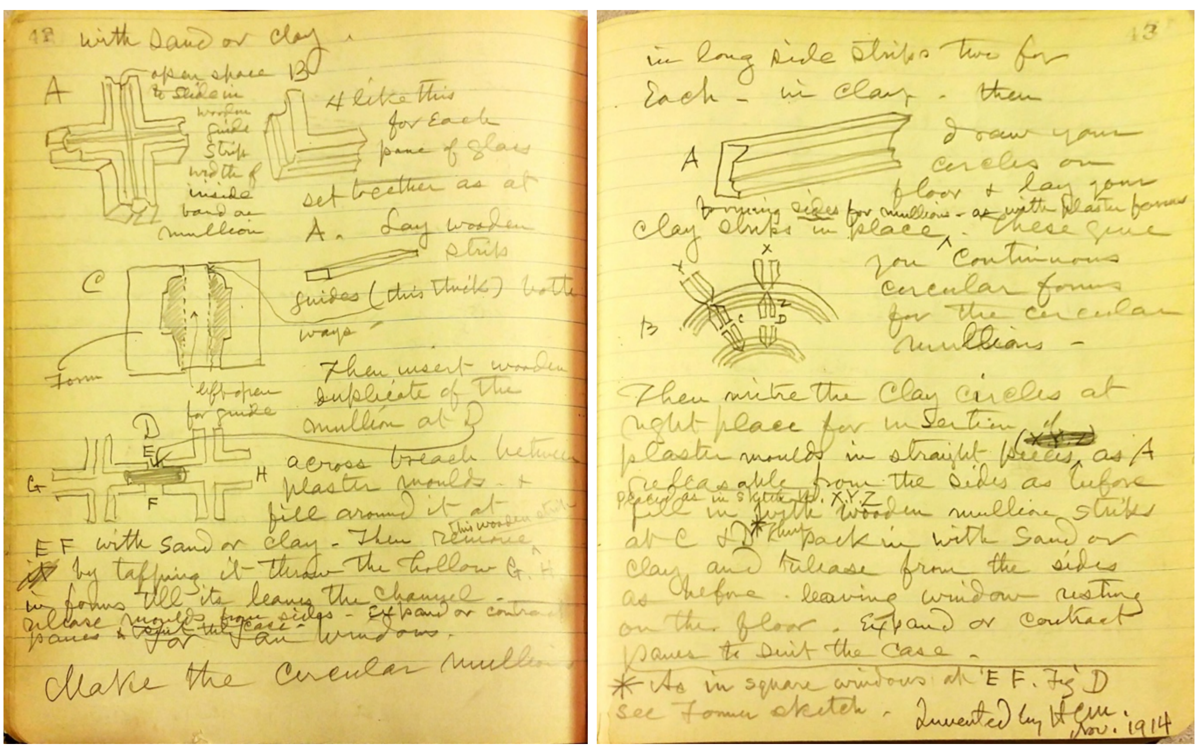


Figure 3.43. Mercer's museum notebook diagrams for the fabrication of molds for precast windows. Image: courtesy of the Mercer Museum Research Library.

This combination of pre-made molds, and clay extrusions to supplement them, took from each mode type of fabrication its relative strength. For example, achieving a consistent right angle, something essential to make consistent divided light windows and perennially difficult in hand-formed clay, could be taken care of with a pre-made shape; and adapting to an as-built curve, something constantly presenting new geometries and therefore onerous to achieve with plaster molds, could be fabricated from the more flexible and easily modified clay.

Mercer's wood and clay forms, like his plaster tile molds, deployed two strategies: a rough, template which allowed for flexibility, such as a 'beam trough' or other structural shape, and the incremental cutting or modeling by hand following the guidance of the template. Chapter four will look at the application of these techniques in the formulation of a similar sectional mold for cornices. Unlike the windows, however, Mercer's cornices were cast monolithically as part of the concrete of the building.

I. Improvisational Tools and Experimental Practice

Before we turn to the case of the cornice in chapter 4; we first should conclude our discussion of whether Mercer's ad-hoc and improvisational methods in the pottery can truly be considered, in the rigorous sense Latour laid out, an experimental practice. Returning, then, to Latour's schema for the practice of research, we can trace the evolution of the precast window as an architectural experiment:

1. *Construction*, the slow, practical craftwork:

As the precast windows illustrate, whatever the particular configuration of Mercer's lost templates, scribes, and tools, some intermediary step or steps between sketch and window would have been required. These steps would have needed to involve an outworking of the original 'inscription' as it took on a fixed set of dimensions and profiles, including a modification of the profile to included sufficient thickness for reinforcing bar; and that the 'slow, practical craftwork' of these problem-solving acts required experiment and refinement of a manual nature.

2. Agonism, that reality is consequence and not cause of this manual work:

Mercer may have had an architectural 'intention' for his windows. We see this in his many sketches and comments concerning window shapes and patterns throughout his construction notebooks. They make up, in fact, a disproportionate percentage of the total pages, and, together with doors, constitute the majority of his notebook drawings of historical and contemporary precedents. There is no direct use of historical precedent to arrive at an initial sketch for the profile of the window muntin, it is rather the normative shape brought over from another material, even if the origin of that shape has no tectonic logic in the new material.[209] (As we will see in the next chapter, when the detail profile was non-standard, Mercer would turn to historical precedent as part of his design process.) However, the development of the composite window mold/form from its original configuration at Fonthill to its more successful incarnation at the Museum indicates that Mercer's successful experiments remained open to renegotiation. Further, this renegotiation could extend to alteration of the original inscriptional premise—as when the museum windows sacrificed the rounded face of its 'millwork' (a non-sensical term in concrete, of course) in order to achieve a smoother and more unvarying finish. Latour's agonism, then, while not a word Mercer might have used, well describes the nature of his process of open-ended tool-and-template-afforded design. More generally, a working method founded in broad tolerances and skilled hand fabrication continually negotiates this terrain—the terrain of agonism.

It is important to note however that Mercer's development of the muntin should not be characterized only as a 'transcription' of wood millwork profiles into concrete, in the way a more conventional architect of his time might have looked to a pattern book for possible profiles. Mercer's method was not encyclopedic in this fashion. Instead, the sketches of desired window precedents were of entire windows, the overall pattern and proportion of frame, mullions, and muntins, and this, combined with a simultaneous imaginative outworking of the practical capacities and material limits of a particular method for forming concrete, was followed directly by related, though not exactly-as-drawn (or even, perhaps, fully preconceived) material experiments, in which Mercer's guiding idea altered and improved in its *agon* with the possibilities afforded, both speculatively and through experiment, by composite clay, plaster and wood forms.

3. *Materialization*, the embodiment of tacit skills in material equipment:

Materialization is readily visible in the process of trial and error that Mercer pursued—a process that was neither predetermined nor characterized by linear development from representation to production. But Latour's point about materialization is rather more profound than merely that our plans are often realized in non-linear fashion. (This much could be said about the contemporary jobsite, with an inbox—or binder—of R.F.I.'s ['Requests for Information'] held up as ready evidence.) The route to knowledge passes through tools and is interwoven with their use; sometimes we, the designers and builders, are in the driver's seat; sometimes our tools drive us. If in Mercer's case there was rather more of the latter than is usually the case, we should take this as no accident, but rather an attribute of his method. As such we might ask whether there is a connection between an improvisational give-and-take between design and its tools, and innovative work in the field. Certainly, both were present in the genesis of Mercer's windows.

Additionally, the skills of working in clay found embodiment in the fabrication of custom tools, not only in the context of the Moravian Pottery, but also as these skills were repurposed for solving problems in reinforced concrete construction. This puts in play a central issue we will take up in the next chapter: materialization of craft skills in tools allows for a crucial step in material innovation: it makes those skills, to use Turnbull's term, *portable*. Another way to say this might be that the artisan at work with a clay tool (or a tool derived from that tradition) *thinks the building* differently than another builder might, equipped with a different awareness of the possibilities opened by his or her tools and disciplinary background.

4. *Credibility*, a marker for the social construction of design and craft intelligence in the collaborations of client, architect, engineer, and builder:

While agonism and materialization find ready parallels in architectural activity, scientific credibility can seem, from the outside, a hermetic system of tacit knowledge, abstruse procedure, and flagrant nepotism. The question of social stature within a scientific field is not, however, Latour's chief concern, but rather how that position functions as a meta-inscriptional marker of reliability—that is, in the degree to which the propagation of scientific knowledge is dependent on source monitoring[210], and the perception of credibility (as opposed, conventionally, to veridical content). Latour, in his study, seems to behave like a latter-day explorer set down upon some terra incognita, exploring the inscrutable behaviors of the odd denizens of the island of Salk. His account is not concerned with the content of these strangers' communications, but rather with the way those communications structure their social interaction. And what he finds, from this view, is that the distinguishing feature of these communications, which have the character of inscriptions made through the use of discipline-specific tools, resided not their truth but in the conjunction of two things: their credibility, and their distinction from other, similar, inscriptions. That is to say, credibility and novelty together result in what Turnbull, in his work, calls 'portability'—that is, the ability of representational technologies to be transferred between the tight-knit groups producing these types of inscriptions.

With the template, Turnbull arrives at the single thing which is for the medieval mason at once inscription and a materialization, a manifestly portable embodiment of the specialized knowledge of building, that conveys not only permission (as in a contract) nor merely descriptive content (as in a drawing) but rather creates an open-ended relationship between conceiver and fabricator in which dialogue and adaptation is part of the configuration of the space of knowledge-and-practice. Significantly, the efficacy of the template is predicated upon future, to-be-determined actions within that field of expertise.

Existing accounts of Mercer's process seem to describe the opposite of this sort of configuration: a situation in which the knowledge of building resides within a single, exceptional, individual mind; and that this person was directly responsible for the work of building. In these accounts Mercer's workmen are invariably characterized as 'laborers' 'farm laborers' or 'local laborers'.[211] Special mention might be made of a worker with a particularly useful skill, such as Herman Sell, who developed an initial knack for fine detail work, over the course of his association with Mercer, into a specialized ability in tile-setting. (Note here that this was a type of tile work unique to Mercer's tiles and building methods, rather than generalized vocational training.) But overall Mercer is characterized as an eclectic, whose drawings were "mere hen scratches on note paper drawn as he sat with his workmen in the midst of construction."[212] In this view it is Mercer's indescribable genius, energy, or force of personality that is the driver of his work. This is an ideologically driven oversimplification, and does particular disservice to his invention of tools-for-making—an activity seemingly of core import given its location at the intersection of his various fields of interest.

In his notebook explorations of window detailing there is a clear progression: precedents viewed generally and from afar; then, close-up, the configuration of the template or system of fabrication. It would seem clear that he is thinking not only about *what* to make but *how* to make it—and, further, how to make the *tools* for making. Even further, the construction notebook shows Mercer rehearsing how to communicate the *making* of tools to his craftsmen. Materialization is in this sense an act of conveying credible inscriptions to an intended audience at work in a particular site and situation.

5. *Circumstances*, the priority of the contingent and local:

This brings us to one of the most puzzling aspects of Mercer's window casting technique: the hybrid of his own premade window molds with the execution of fan curves, peak heads, and other non-rectangular shapes in clay, a method which is seemingly far less efficient than the same mold made entirely of plaster, wood, or metal (today, of course, we would see such molds made from various plastics—latex, urethane, vinyl, etc.). None of these materials, however, from Mercer's time or our own, are quite so readily, or speedily, adapted to custom shapes as is clay.

If Mercer's goal is a perfect replica of a wood window, clay is a bad choice. If his goal is a perfectly consistent building detail, clay is likewise suboptimal. If he desires many copies of the same window, his method is markedly inefficient. However, if Mercer's representational goals are approximate rather than exact; and if his windows are called for in a great many varieties of size and shape; and if its construction detail must adapt to a great many divergences in as-built dimensions and angles, then clay, as it would allow for (and in fact require) continual adaptation to local conditions, provides just the sort of innate flexibility Mercer would have needed. (It should be noted that its ready availability and economy, and its copious uses in the pottery, would have also been contributing factors.) It is tempting to say, why not just make more accurate, permanent forms for window fabrication, and then use them over and over again? Surely each-and-every window does not need to be a different size or shape from the next? This is an assumption, conditioned on our contemporary familiarity with mass-production techniques, which excludes one of Mercer's key resources: the skills of his workmen. This raises a point that will become salient in chapter seven: that effective improvisation presupposes expertise.

This in a nutshell is the distinction between eidetic and experimental practices. Where the engineered mass-production process chooses a quantifiable goal first, and searches for a method second, the experiment chooses its method on the way to its ends. And while Mercer's method was technological, it was not teleological.

6. *Noise*, a discovery's ability to filter, and provide clarity to or meaning for other researches and in other settings:

In Latour's account, a community of researchers is a well-tuned filter for significance. Particular findings, methods, or artifacts are taken up into more general use because their use results in local aggregations, or intensifications, of meaning which extend beyond the fact-at-hand. The window forming method could be seen as an isolated example of problem-solving in architectural detailing, distinguished perhaps only by its unusually apt marrying of available expertise, material, and the requirements of the building at hand. But Mercer's use of clay in concrete formwork was not restricted to only this one case, and in fact its lessons, learned early in his development, were clearly incorporated in other applications over the course of his projects. The complex of actions and directions, shared between Mercer and his workers, were taken up into the tacit knowledge shared by these particular practitioners, their expertise growing by just the degree that this novel solution recommended itself for adoption into their shared technical vocabulary, and thereby adaptation for other uses. That is to say, Mercer's crew engaged in an experimental practice founded on a background expertise in clay fabrication. Problem-solving was carried out *in situ* and resulted in the production of material, portable, often inscriptional instruments: that is to say, tools. We might call this broad process of technical adaptation, in which the tools and techniques of an established practice are brought over (or translated) into a new domain, analogical practice.

Chapter 4: Analogical Practice: The Case of the Commodious Cornice

For the technological system of a coherent and totalizing space that is "linked" and simultaneous, the figures of pedestrian rhetoric substitute trajectories that have a mythical structure, at least if one understands by "myth" a discourse relative to the place/nowhere (or origin) of concrete existence, a story jerry-built out of elements taken from common sayings, an allusive and fragmentary story whose gaps mesh with the social practices it symbolizes. Figures are the acts of this stylistic metamorphosis of space. Or rather, as Rilke puts it, they are moving "trees of gestures." They move even the rigid and contrived territories of the medico-pedagogical institute in which retarded children find a place to play and dance their "spatial stories." These "trees of gestures" are in movement everywhere. Their forests walk through the streets. They transform the scene, but they cannot be fixed in a certain place by images. If in spite of that an illustration were required, we could mention the fleeting images, yellowish-green and metallic blue calligraphies that howl without raising their voices and emblazon themselves on the subterranean passages of the city, "embroideries" composed of letters and numbers, perfect gestures of violence painted with a pistol, Shivas made of written characters, dancing graphics whose fleeting apparitions are accompanied by the rumble of subway trains: New York graffiti. If it is true that forests of gestures are manifest in the streets, their movement cannot be captured in a picture, nor can the meaning of their movements be circumscribed in a text. Their rhetorical transplantation carries away and displaces the analytical, coherent proper meanings of urbanism; it constitutes a "wandering of the semantics" produced by masses that make some parts of the city disappear and exaggerate others, distorting it, fragmenting it, and diverting it from its immobile order.

- Michel de Certeau[213]

Just as mosaics preserve their majesty despite their fragmentation into capricious particles, so philosophical contemplation is not lacking in momentum. Both are made up of the distinct and the disparate; and nothing could bear more powerful testimony to the transcendent force of the sacred image and the truth itself. The value of fragments of thought is all the greater the less direct their relationship to the underlying idea, and the brilliance of the representation depend as much on this value as the brilliance of the mosaic does on the glass plate. The relationship between the minute precision of the work and the proportions of the sculptural or intellectual whole demonstrates that truth content is only to be grasped through immersion in the most minute details of subject-matter.

- Walter Benjamin[214]

Unlike many architects working at the time, Mercer did not design his details in a particular style or inspired by a particular period. He did, however, consider precedent. If we look at the passage in Mercer's Fonthill construction notebook in which he is working out cornice details, we can see that his exploration of possible construction techniques for the novel material of reinforced concrete is grounded in a consideration of personally significant historic buildings. Yet in thinking about good ways to detail the cornice, he does not ask merely what material, form, style, or period a cornice should be derived from, but also what sort of tool, formwork, and process would best effect that result, and marry his aesthetic goals with material economy and procedural flexibility. His was a constructive rather than formal imagination.

A. From Materials to Material Experiments: Patterns of Innovation

Mercer engaged in a number of material experiments that had only remote precedents, and displayed little connection to existing norms of architectural and construction practice, where these existed—with reinforced concrete, as we have seen, such norms had only begun the transition from hearsay and trial-and-error to systematization. Material experiments that found failure, such as his attempt to cast cornstalks into the columns at Fonthill and later burn them out (to create air spaces to reduce damp and lighten the overall build; and which failed because the vegetable matter would not burn) were replaced by other techniques. At the museum, for example, he used sheet metal pipes for vents in the walls, pursuing the same goal without the cornstalks. Material experiments that found success, such as the precast windows, were improved upon—not primarily in their outward form but in their execution as material technology.

These improvements in process, far from being those of a solitary tinkerer, were often carried out as a result of a lively discourse with other architects and builders working in reinforced concrete, though Mercer often did not record his source of information. Page 107 in the Fonthill notebook contains a cryptic note: [fig. 4.1]

> C. R. Knapp & Co Builders Exc - Philad Bill Telt Waln. 34 0 [unclear—Probably the name of a contact, or address of the business, 3rd and Walnut St.]
>
> Beams - Experimented in Harlem River Park Casino - 126 st. & 2nd ave N.Y.

Span	~~Thic~~ Depth	
15'	14"	} below 6" slab
30'	20"	
60'	48"	

> slabs - 6" thick span 14 ft. 6 in.

These notes refer to Sulzer's Harlem River Park Casino [fig 4.2.], a large building and one of the earliest (ca 1880's) American examples of reinforced concrete architecture. The building is listed in some sources as having been demolished, probably because of misleading contemporaneous accounts;[215] but it was instead made over into a prominent movie studio.[216] Mercer's notebook lists it as built by C. R. Knapp and Co. Builders of Philadelphia, and transcribes a short chart for span and depth of concrete beams and slabs. [Fig 4.1.] There is no record of how Mercer came by this information, whether in correspondence with the builder or in person. What it reveals, particularly situated so early in the Fonthill notebook, is that Mercer was well aware of the structural capacities of concrete, and could have put them to work in creating the spaces at Fonthill. The rooms—small in proportion to their structure—are not limited by the inherent structural capacity of the material, or by Mercer's knowledge of that capacity. It is likely, then, that they are exactly the size and shape he intended.

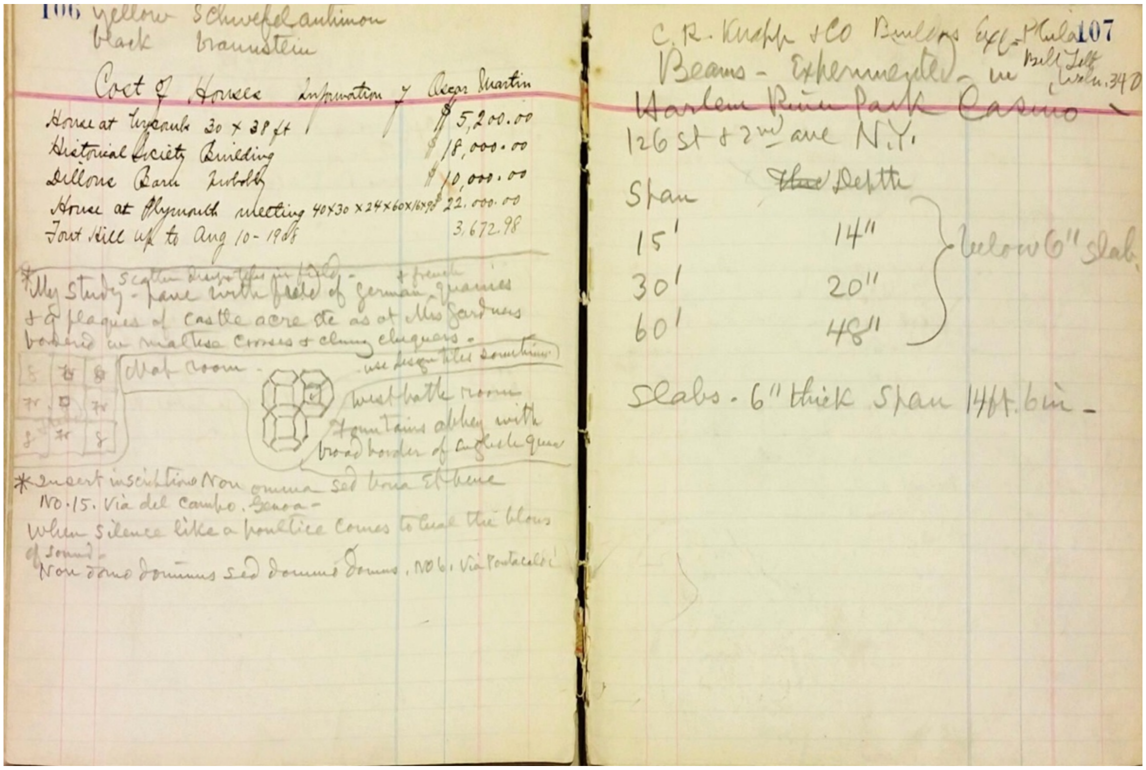


Figure 4.1. Page 107 of Mercer's Fonthill Journal. Image: courtesy of the Mercer Museum Research Library.

Figure 4.2. Sulzer's Harlem River Park Casino. Image: postcard ca. 1900 / public domain.

But where the dark and labyrinthine interior of a residential 'castle' would seem to fit well with the spaces he created at Fonthill, this only makes the question more pointed when we turn to the Moravian Pottery building. Surely, clear spans like those at the Harlem Casino would have been more efficient in such a building? Yet if we look at the long sections through the building, we can see that Mercer configured the primary work spaces as a series of rooms enfilade, arranged around the cloister space, each room with a relatively short span from wall to wall, with columns used to mark off a circulation space typically 6' from the cloister-facing wall. [See plan of pottery, fig.3.6.] Additional columns are semi-irregularly spaced in the larger rooms, further breaking up the rooms into small pockets of interlinked space. Surely it would have been simpler, even given the flexibility of Mercer's earth-form centering technique, to lay out a grid of columns?

The same question proposes itself with regards to the Museum. Mercer, well aware of the economy and efficiency of reinforced concrete frames—the span table he transcribed listed spans up to 60 feet—used hybrid structures of earth-formed centerings in some places, and wholly timber centerings in others; even when spanning the largest spaces in the building, he used a combination of arched beams and pitched platforms, similar to the construction of the largest space he had previously built, the studio/showroom at the pottery. At the museum, this primary structure was intersected in places with clerestories and the groin vault structure typical elsewhere in the museum. [Fig 4.3.] This structural variability suggests Mercer was not thinking about his building as a structural system; not planning its frame so much as resolving the intersections of its various rooms and systems and scales opportunistically, as these intersections presented the possibility of bringing light in, framing space, or providing avenues of circulation. The building structure, then, is not a system so much as a network, a fabric of fragments or details, arrived at through a weaving-together of design solutions in microcosm. We should examine in depth, then, Mercer's paradigmatic process for arriving at the architectural detail, which is best illustrated in the documentary exploration and the evolution in fabrication of his prototypical cornice.

Figure 4.3. Complicated intersections of structure on the fifth level of the museum. Image: author, courtesy of the Mercer Museum.

B. The Case of the Commodious Cornice

Another seemingly seamless detail, the cornice, also began in the adaptation of techniques and technologies from the skilled handling of clay. On pages 108-109 of his construction notebook for Fonthill, Mercer explores for the first time how to execute the cornices of his building. (We should remember that this follows his earliest entries recording the progress of construction.) In these pages he sketches how to create "good" and "better" roof cornices. He begins with a precedent. On a page titled "Roof Cornices" he writes "Monte Cassino," presumably Montecassino Abbey, a mountaintop Benedictine abbey about 80 miles south of Rome. [Fig 4.4.] Indeed, Montecassino Abbey has a graceful, uncomplicated cornice, and Mercer draws a sketch of one, possibly from memory, on the right, and an abstracted outline of its profile to the left. [Fig. 4.5.] Below this he describes the gutters at the Abbey of Sassovivo outside Foligno, Italy. [Fig 4.6.] He notes, "St. Sassovivo-Foligno Tin or lead gutter troughs like ours. Under the tiles". Then he draws an elevation sketch of the cornice of San Biagio, Montepulciano, with the caption, "S. Biagio Montepulciano" and, with arrows to various parts of the sketch: "thick brackets", "this cornice overhang about 5 in.", and "tile ends overhanging by about 3 inches". [Fig 4.7.]

Figure 4.4. Montecassino Abbey. Note the cornices' resemblance to Mercer's sketch. Image: CC0 / Pixabay.

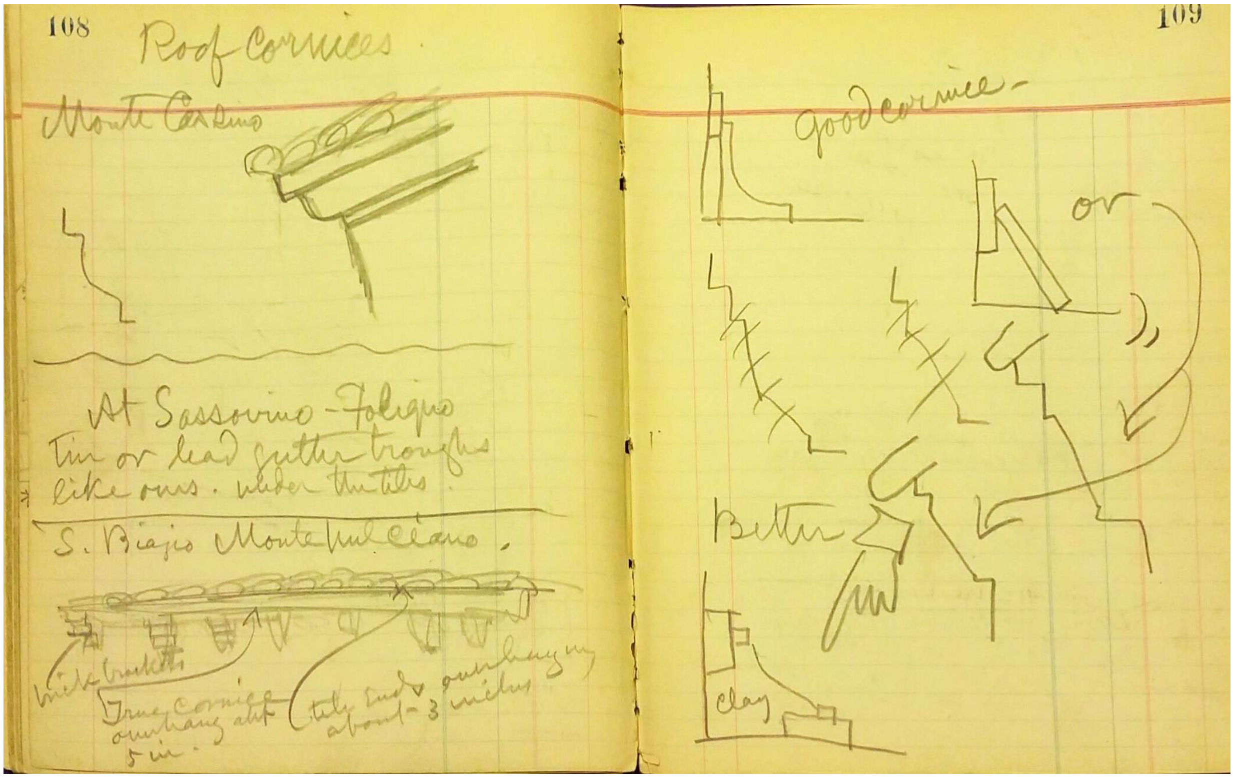


Figure 4.5. Mercer's cornice drawings. Image: courtesy of the Mercer Museum Research Library.

Figure 4.6. The Abbey of Sassovivo at Folingo, ca. 1895. Oddly, in the present-day these gutters have been removed. Presumably this was in the service of some historical imperative—though not one of benefit to Mercer or his occasional scholars. Image: public domain / William Henry Goodyear.

Figure 4.7. The church of San Biagio, Montepulciano, detail. Image: Geobia / CC BY-SA 3.0.

On the facing page [shown in fig 4.4, right] we see a section drawing of an assembly of parts that at first glance appears to be a cornice upside-down or sideways, labeled, "good cornice—". Below this are several profiles, scratched out, and beside them what appears to be two blocks of wood, one vertical and one at a 60 degree angle, set in a corner. Below this diagram is the first sketch of what looks like a cornice, crossed out; its profile matches the blocks of wood directly above, and we can see now that the first sketch was not an upside-down cornice itself, but the negative of one: the formwork with which to cast a concrete cornice. An arrow leads from this diagram to an improved version, and below this a stylized hand points us to a design for the form which might be used to cast it. Several things are of note here. First, the evolution of Mercer's design departs from, and returns to, the method of its fabrication. But where the first drawing shows what might be a difficult-to-fabricate mold of unspecified makeup, the final drawing is materially specific, drawing closely on Mercer's experience with using combinations of wood and clay to create tiles, and molds for making tiles, in his pottery.

But we should also note that as Mercer refines his idea, elements from his study of historical precedents make their way into the design: where in the first two, scratched out, outlines, there is no indication of separate materials, in the next two, more acceptable alternatives, Mercer distinguishes between a top layer of what may be tile, drawing on his observations of San Biagio, and the remainder shown as monolithic. It may also be that Mercer already had in mind a top coat of concrete, applied separately from the primary fabrication of the cornice; or it may be he was thinking about manufacturing his own roofing tiles and applying them directly to the concrete roof, a technique we saw tested in his very first concrete kiln shed, and used on a number of the roofs at Fonthill, and occasionally afterward. While uncommon then or since, this technique would be independently echoed in the 1930's in Bernard Maybeck's experimentation with concrete versus tile roofs at Principia College beginning with his "mistake house," (an on-site cottage built solely for experimenting with materials and techniques) the roof of which was half tile and half concrete, just as with Mercer's initial kiln shed experiment.[217] [Fig. 4.7.] These roofs were not particularly successful, then or since. (On an undated page of the pottery notebook, likely written in 1913 not long after Mercer moved into Fonthill, Mercer made a list of roof leaks.)[218] And while problems with water infiltration at roofs would continue at other projects, there is surprisingly little evidence of similar problems on the vertical surfaces of the buildings, despite the most readily apparent idiosyncrasy of Mercer's cornice detail: it contains no gutter, groove, or other system for water management. Because of this, rainwater runs from the top edge of the cornice, and often sheets down the face of the building, requiring Mercer's windows to be very well sealed, and door openings to be protected (as they often were by overhangs or recesses. (This is a detail that would only work in tandem with Mercer's seamless windows.)

And, with some minor revisions which we will discuss shortly, we see even at the Mercer Museum, built ten years after this sketch was made, not only the myriad chimneys, dovecotes, and elaborate roof lines of Fonthill reprised, but the same cornices of Montecassino Abbey, cast monolithically in concrete.

Figure 4.8. Maybeck's 'Mistake House'. See fig i.3 for Mercer's Kiln Shed at Aldie. Robert Craig, in his nearly 800 page 1973 dissertation on Maybeck's work at Principia, makes no mention of Mercer as an influence. While he was born in New York, Maybeck, a noted Arts and Crafts architect, spent his professional life in California. It is certainly possible he never encountered Mercer's work. Image: Principia Archives / Principia College.

The cornice at the Mercer Museum [fig. 4.11] is similar but not identical to its predecessor at Fonthill [fig 4.9], and these differences are, evidently, both practical and aesthetic.[219] The profile of the earlier cornice is more evenly divided between rectangular profiles and the primary curve [fig. 4.10]; while at the Museum the curve is more dominant and refined in appearance, and the fillets smaller and more precisely cut. [Fig. 4.12.] This may be in part because the concrete mix itself, or the builder's skill at placing it, was improved, producing a smoother and more predictable surface. The placement of reinforcing at Fonthill, while generally successful, at times is evidently too close to the surface of the finished concrete. [Fig. 4.13.] At the Museum this issue seems to be resolved. Perhaps the larger curve of the cornice at the museum was an aesthetic refinement, a larger overall cornice because it was to be built higher off the ground; or perhaps it was practical, to give more room for reinforcing steel. With Mercer these two motivations often seem to dovetail.

Figure 4.9. Cornices at Fonthill. Image: author.

Figure 4.10. Cornice at Fonthill, detail. Image: author.

Figure 4.11. Cornice at the Mercer Museum. Image: author.

Figure 4.12. Cornice at the Mercer Museum, Detail. Image: author.

Figure 4.13. Cornice reinforcing visible at the spring house at Fonthill. Image: author.

All of this suggests a permanence to this particular notebook drawing, and the process of fabrication it describes, disproportionate to its sketchy, improvisational affect. Also, it should be noted that this is the only documentary record of Mercer's cornice design. There is no construction document, measured architectural detail, further, refining, doodle, or written specification, and if Mercer's construction crew made any tools or templates for use in construction those ephemera have not been preserved. It is clear from his notebooks and from his buildings, taken together, that Mercer deployed a number of custom-made techniques in forming the concrete and placing the tile of which his buildings were made. This brings us to perhaps the single greatest mystery that presents itself to the study of Mercer's buildings: where are these tools? The mystery only grows more puzzling in light of the program of Mercer's last building, and his driving passion to collect and catalogue implements of hand craft. Despite the obvious means and opportunity to preserve his tools and templates, there is no evidence Mercer did so. The tools at the Moravian Pottery were retained in use because the pottery remained in operation after Mercer's death, rather than through any concerted preservation effort. (That situation has since been altered, and the Moravian Pottery is a careful conservator of Mercer's craft artifacts.)

Like the windows, the cornice would become a subject of continual, incremental, refinement; yet these refinements were only visible under the closest scrutiny. Thus this should not be considered aesthetic refinement or the evolution of design in the formal or even tectonic sense. Instead, Mercer's details seem to evolve primarily in terms of their means of fabrication—that is, what we see is an evolution of product as a result of process. Mercer's innovations are primarily innovations in tools for the fabrication of architectural details, rather than in the details themselves as purposive deployments of architectural artifice. That is to say, the construction notebooks paint a picture of a design process that does not follow the habits or norms of normative architectural training, judgement, or practice.

C. Analogical Practice

Mercer's sequence of design decisions regarding the building cornice is a remarkable window into the mind of the designer. Scholars have attributed the inspiration for Fonthill on the English abbey of the same name.[220] This claim, while attractive because of the many parallels between the buildings, is contradicted by Mercer's Fonthill notebook, in which he fills two pages with possible names for the house.[221] "Fonthill" is right at the top, but Mercer notes "abandoned because of similar names in England and America". [Fig. 4.14.] After listing some 44 others, Mercer must have felt "Fonthill" worth forgiving the obvious parallels. More nuanced speculations have been made about other singular precedents for his buildings.[222] It would seem, however, that the designer is engaged in something altogether more synthetic; but also categorically different, than the discovery of mere visual parallels: he is being driven by needs of the building, and the questions it asks as it is being made.

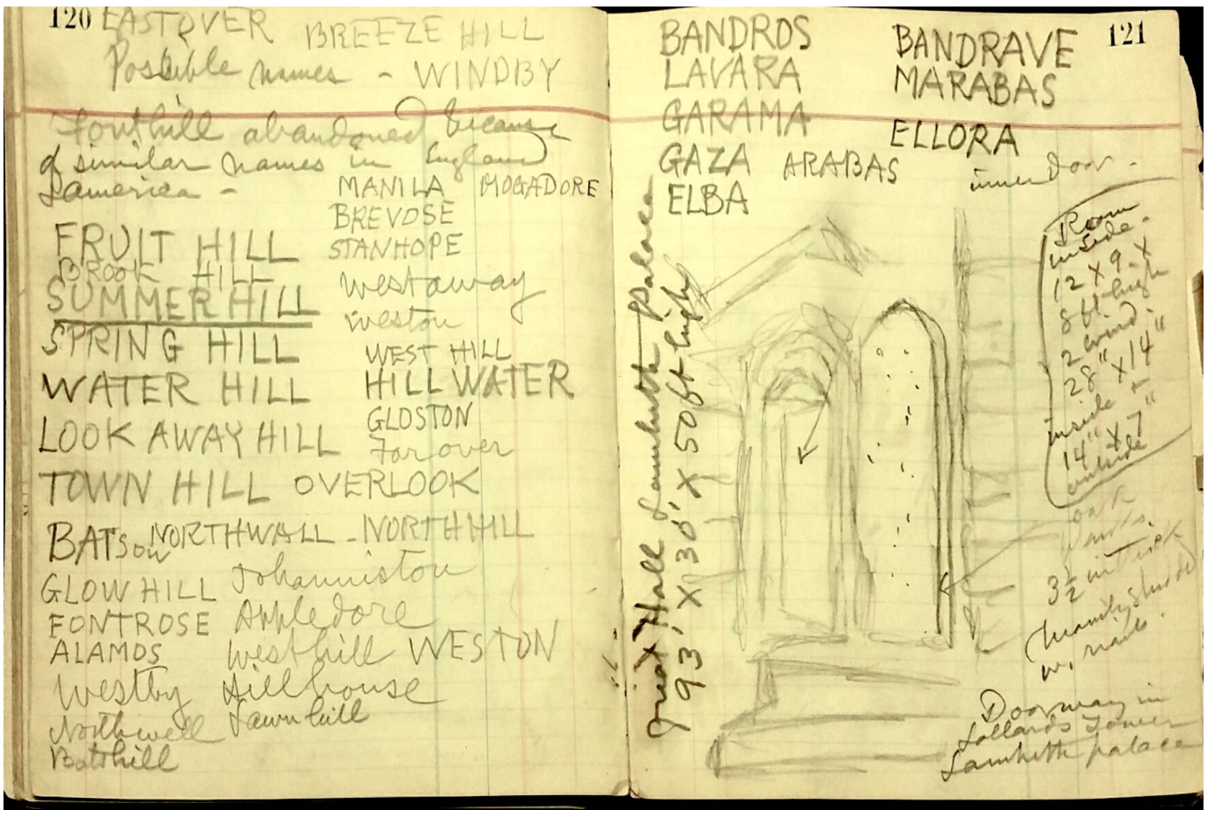


Figure 4.14. Names for Fonthill. Pages 120-121 of the Fonthill notebook. Image: courtesy of the Mercer Museum Research Library.

This is a question of what we might today call the building detail. That is, it is a small, but telling, part of a complex whole. Its relation to that complexity is not merely that of part to whole, or even species to genus. As we see from its genesis in the limits and capacities of clay forming techniques and fond memories of being young and abroad in Italy, the detail's inspiration arises from the deep emotional wellspring of the embodied human psyche, and is linked to its sources both technically and symbolically, a dual linkage which mediates between capacity and constraint, memory and projection, through analogy.

"It seems inevitable," the scholar of the modern detail Ed Ford writes, "that we use analogy to understand this arrangement of parts as something more than what it is. Evidently, we project a great deal more than our own bodies into a building. […] How are we to define the relation of part to whole, except as a consequence of the building being assembled, however fictive that interpretation might be?"[223] The formulation of the detail occurs, Ford argues, on two levels simultaneously: what might be called the symbolic or stylistic, and the tectonic. That is, Mercer thinks back to his experience of memorable cornices. The first that comes to mind is an abbey he likely visited in 1882, more than 20 years prior to the drawing of these sketches.[224] The other precedents he draws upon are buildings whose similarity lie not so much in their cornice profile as their geographical and typological situation. Mercer here is not merely recalling one cornice after another, as if turning pages in an encyclopedia of architectural elements. The first memory triggers others of like kind, and their likeness is not primarily stylistic, in an encyclopedic sense, but a matter of an associational and highly personal logic. Mercer's cornice exemplars belong to a family of shared experience, linked in the brain by the arbitrary saliences of personal experience and intuition. Presumably the precise structure of such intuition is different for each individual designer; in Mercer we see a linkage of the cornice to a very specific subset of material and historical instances: stone and tile church buildings of 10th to 15th century Italy. Despite this family resemblance, Fonthill is, on the whole, not an outworking of any particular (or, it must be said, coherent) historical style.

The structure of Mercer's design intuition is, if not irrational, certainly not systematic in any traditional sense. The questions it answers are small and local, pertinent to one moment in the building, in which multiple precedents are brought to bear upon a single decision among the thousands that compose the process of construction. This decision, once made, will become the rule for the remainder of the project; but it is not by nature, or in its coming-to-be, rule-like.[225] (We might take this as a description of the process of architectural detailing more generally.) Rather than a specification, the detail is a provocation, in the oldest sense of the word. The Latin roots "to call" and "forward" suggest that in calling-forward, the detail projects not merely its rules but its worldview into the world of the building as a whole, and in that serves as a materialization, however partial, of that world-under-construction. The detail puts in play a set of symbolic, tectonic, and haptic associations that alter the meaning of the building-to-be in a very particular way—*as-if* it already was, complete and whole, a world unto itself. The detail is thus a foreshadowing of the meaning of building. Mercer's method, then, is well positioned to read these auguries.

Ad-Hoc Categories and Collage

These prolepses are, for Mercer, carried out in the constant improvisational space of the task-at-hand. They are manifested in what Douglas Hofstadter and Emmanual Sander, in their study of the role of analogy in creative thought, call "incessant mental sparkling":[226] the rapid-fire formation of possible-actions seen in the light of past actions. This analogical mode makes up the ongoing process of invention and refinement that form the trajectory, the scintillant trail, of innovative practice.

In the case of the cornice it was clear that Mercer's architectural imagination was always already a material imagination, and that it functioned in a non-linear collage-like mode.[227] The sketches we have been observing occurred relatively early in Mercer's construction notebook; yet after he began construction. Mercer's explorations of the cornice appear in the notebook following the likely order of questions that would arise as the building was built. The cornice passage, on page 80, appears after some of the earliest diagrams of wall and vault details, and doors and windows. This is in keeping with the spatial-and-chronological organization of the notebook as a whole: The lowest cornices in the building occur on the wall of basement level, just above the windows to the basement, and make the transition to a roof terrace which opens out from the first floor library. Just after the cornice notes, we find copious design sketches for possible ornate tilework column capitals, which would first occur in the library, on the same level as the earliest cornices. Then, on page 139, we see a multi-layered and technically difficult solution for the concrete roof deck over the ceilings of the basement bedrooms, drawn in section. [Fig 4.15.] This would have been built as the first level was completed, after the cornice and columns were built.

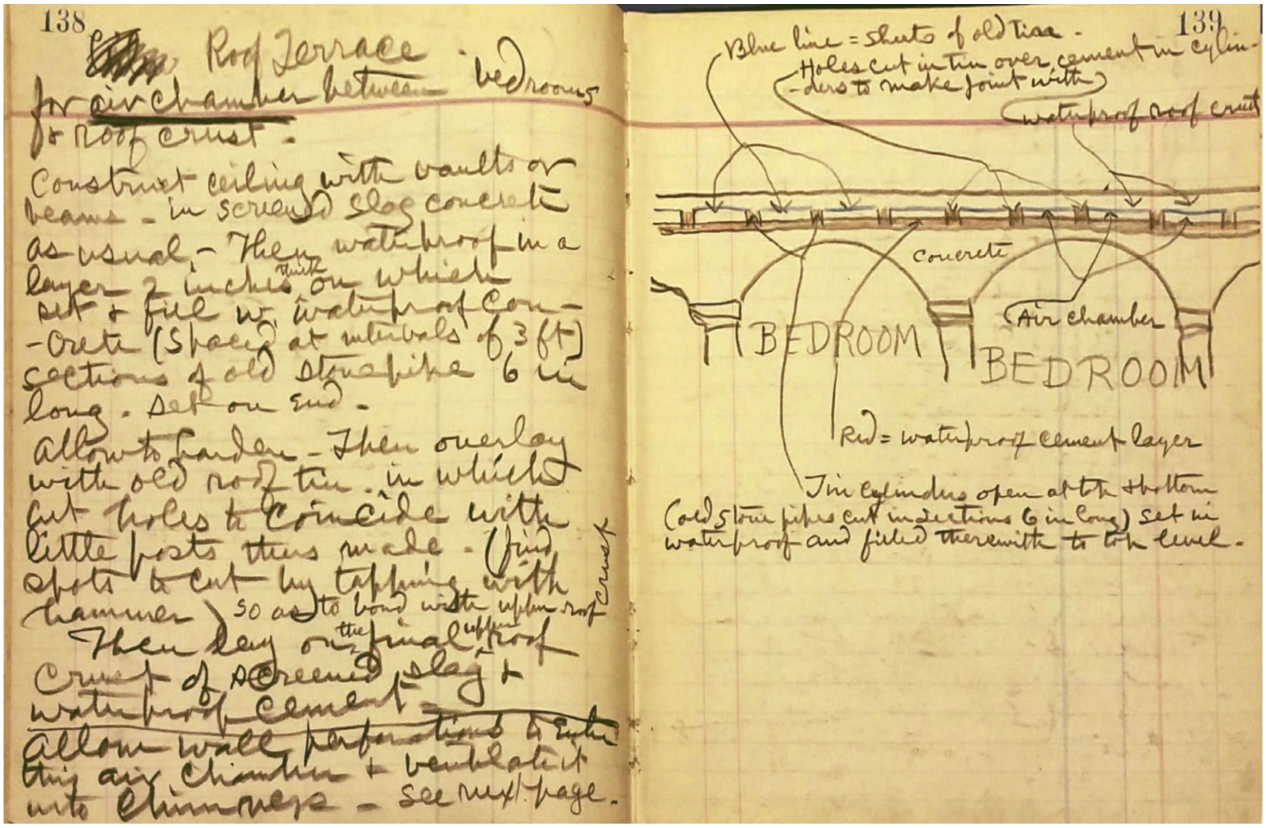


Figure 4.15. Section of roof terrace construction.

After page 80, when Mercer records that construction has commenced, the progress reports are interspersed regularly with these digressions, or rather explorations, detailings, and rehearsals. These drawings belong to a number of different representational categories; what holds them together is that they all would seem to be variations of testing—of tentative ideas, possible methods, and potential dialogues—all patently incomplete. Rather than separate sections of specifications, depictions, and research reports, they are notes for future action: a form of shorthand—for what Turnbull might, with deliberate anachronism, call "experiment design."[228] The notebook functions as a container for all these conjunctions of record-keeping, technical planning, troubleshooting, and anticipatory sketching; moreover, it brings them into juxtaposition, serving not merely as a "space in which knowledge is possible,"[229] but as a particular sort of device, a synthesis or collage of categories.

To understand Mercer's notebooks as a collage of categories, we must first undertake a brief digression into the theory of categories in the orchestration of knowledge. Cognitive psychologist Lawrence Barsalou, whose experimental research is focused on category formation, has proposed that categorization is a fundamental attribute of human knowledge.[230] Traditionally, categories have been construed as collections of fixed feature sets or properties, which can be understood as the components of that category (whether abstract, such as "geometric forms, or concrete, such as "hammers"). Gilbert Ryle, in his 1945 *The Concept of Mind*, illustrated the now classic pitfalls of thinking in categories with the example of a visitor to Oxford who, after touring the library and walking through several colleges, asks when he will get to the university. Ryle's illustration of the unlifelike rigidity of categories as an epistemological model was taken up by subsequent theorists, who critiqued assumptions of a theory of categories reducible to feature sets and properties. Barsalou summed this up this countercurrent in the 1980's: "Numerous theories in psychology and linguistics assume that representations contain more than feature lists. In many cases, however, the additional structure—which tends to be frame-like—remains implicit theoretically and receives little attention empirically."[231] His critique of the reductive "feature lists" of empirical studies in cognitive science led Barsalou to propose a theory of 'ad hoc categories,' or 'frames.'[232] Barsalou contrasts 'natural,'[233] or 'taxonomic',[234] categories such as [dogs] or [furniture] to the contextual categories that form as a part of human social interaction, such as [places to look for antique tools]. Barsalou argues that the graded superstructure of natural categories (their tendency to have exemplary, and marginal, members) applies also to ad-hoc categories: for example, in experiments on category formation, he found that ephemeral categories had what he termed 'typicality gradients' no less salient than those in permanent categories. That is to say, in cognitive terms an ad-hoc category is just as organized, and organizing, as a long-established one. Further, these categories tend to emerge when existing categories are conceptually inadequate to the circumstances at-hand: that is, they are the natural result of categorical thinking in unfamiliar domains, and possess the same efficacy as more permanent systems of conceptualization.

In subsequent work Barsalou argues for the ubiquity of these ad-hoc categories, as what he comes to call "frames": "A frame includes a co-occurring set of abstract attributes that adapt different values across exemplars."[235] A frame, then, is what happens when existing categories fail us; and particularly in complex and unprecedented work, categories tend to fail us. Frames, then, are the space of analogical thought, in which dissimilar domains are brought into juxtaposition by the need for new categories. We might speak colloquially of 'frames of reference'; Barsalou's insight is that our frames are made as well as found—often with such facility that we do not know where 'tacit craft knowledge' ends and invention begins.

Detail—Fragment—Analogy

In the notebook, Mercer's many sketches seem less like architectural drawings than reveries—about ways of building and about past exemplars. The sources on which Mercer is drawing as he explores how a particular detail, presenting itself as a problem to be solved, was solved, lie either in his own past experiences of buildings he regards as worthy or successful (and which are generally old, and of masonry construction), or in the present "modern" day constructions of fellow builders in concrete, with whom Mercer corresponded, as well as contributing occasional articles to trade periodicals.[236] Each detail seems to strike Mercer as a new question; there is no carrying-over of style or motif from detail to detail or even page to page, and little internal reference to previously worked-out solutions. In some cases there is a clear historical precedent for the detail at hand,[237] listed by name (or cryptic abbreviation); in others Mercer proceeds directly to sketches exploring how to solve the technical problems presented. The only gesture toward a comprehensive consideration of the building is an index at the end of the notebook, which itself only illustrates the collagic construction of the volume, moving directly from "Monte Casino Cornice" to "Sand idea not grasped in 1908", (probably indicating that the finish layer of sand on vaults' earth centerings was not worked out in advance of the construction of Fonthill, but rather developed during the construction) and from writing out all the possible names for the house that would come to be called "Fonthill" to a passage on the detailing of spiral stairs. [Fig 4.16.]

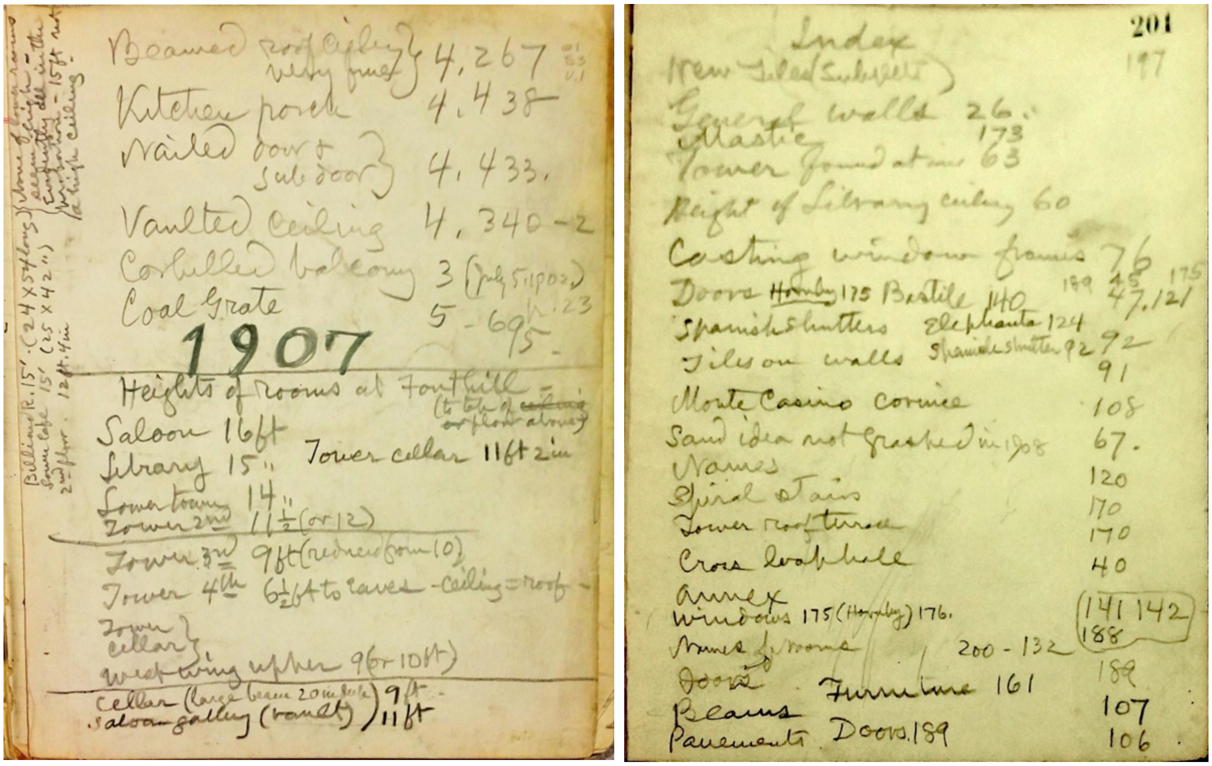


Figure 4.16. Index of ceiling heights at the front, and topics at the back, of the construction notebook. Image: courtesy of the Mercer Museum Research Library.

We have every reason to believe, looking at the notebook, that this is an intimate portrait of the mind of the designer, engaged in an act of simultaneous design-and-building.[238] What is more, the associative logic of Mercer's decision making is revealed anew with each improvisational detail-fragment-analogy.

Each detail is a question, then; one that is asked by the building as its builders arrive at a joint, a moment of necessary connection between dissimilar parts. The logic of the joint may be material, tectonic, symbolic, stylistic, or thematic;[239] but it is always immanent. Each of these details, once derived and constructed, *remains a fragment*[240] within the larger whole, which is ordered by some inscrutable drive—some sense of affect or "atmosphere" rather than architectural style or formal *parti*.

"Atmosphere," however, is one of those darlings of architectural theory beloved precisely because it is abstract. We can do better. When Mercer draws upon historical precedent, he is undertaking a particular sort of design thinking, what Douglas Hofstadter and Emmanuel Sander call "interdomain analogies,"[241] which function not so much as a statement of equivalence as a pointing hand, a projective "like that—"[242] a discovery of affinity enacted as a rehearsal for a demonstration. The structure of analogy, then, is that of a performative representation that is gestural, extralinguistic;[243] these are analogies constructed, naturally, on the fly in a moment of embodied problem-solving.[244]

The interdomain analogy follows these steps: an ad-hoc category, such as [cast-in-place cornice], is suggested by the need to build formwork for the next lift of concrete, the one that must negotiate the joint between roof and wall. The category [cornice] receives an initial materialization achieved through a process of design sketching (in the notebook), probably in advance of (given Frankenfield's testimony regarding standard practice on the jobsite), or possibly in conjunction with, trial-and-error *toolmaking* efforts—that is to say, in the terms of the previous chapter, templating. The divide between representation and making is mooted in this crucial intermediary step, the fabrication of artifacts that do not suit the category [representations] any better than [tools], but are best characterized by their belonging to a new category, some hybrid of the previous two, which we might call [template-ness]. They are a particular kind of tool—in Mercer's case, an experimental, material representation of the design idea. These tools are utilized in a constructive context characterized by the allowance of broad tolerances and the juxtaposition of dissimilar materials; materials not merely of building but also of building—and tool—fabrication. Further, these tolerant templates are iterated and improved upon, and thus belong to a larger trajectory of material innovation: what we might see as, in some small part, participation in the anonymous age-old evolution of the tool.

The relationship between tacit knowledge and material production in this setting might be termed *analogical*, in that portable, material representations allow for the transfer of craft techniques to analogous materials; this result in a viable, and certainly original, form of building practice.

In the location described in the previous section, one of the lowest (and hence presumably earliest, as I have discussed) cornices at Fonthill, the cornice began mid-wall, aligning with the edge of the roof terrace, so this particular detailing problem was, from the outset, one requiring several different technical solutions. [Fig 4.17.] (This would, in a more normative practice, require multiple different drawings.)

Figure 4.17. At Fonthill: cornice transitioning from wall surface, to flat roof condition. Image: author.

We should not, I think, evaluate the detail from the *post-hoc* position of knowing how the story works out: that is, we may take pleasure in holding in our minds the memory of the totality of details in a particular project, or particular architect's work, and finding in this sum-of-details thematic reflections and stylistic cohesions, whether local or global; but this pleasure is distinctly different from the logic and process of an immanent, problem-solving approach.

Such an approach is, to be sure, a far cry from standard practice with regards to architectural detailing, in which the detail drawing is created as a correlate of its material result—an assumption reflective of a deep bias towards a descriptive characterization of representation that pervades the Western tradition, one which is not limited to architects but pervades our understanding of creative thought, extending even to neuroscientific accounts of design thinking, technical innovation, and the creation of architecture of profound and lasting originality.

Analogy versus Correlation: Embodied Problem-Solving

A number of architectural historians and theorists have been influenced by the insights of neuroscientists, notably Harry Francis Mallgrave, whose 2010 monograph recasts the scope of architectural theory through the lens of the brain sciences. Of particular interest to this group of architects and theorists are neural correlates. Neural correlates belong to a theory, most notably advocated beginning in the 1980's by Francis Crick and Christof Koch, that 'subjective' events in consciousness have distinct, repeated, and identifiable brain states; Crick and Koch explored these states in direct relation to visual perception, and attributed memory formation to distinct visual impressions.[245] Notably, Crick and Koch in their research were careful to distinguish visual and iconic memory, a nuance sometimes lost in the conversations that ensue.

In the 1990's the first direct experiential evidence for this theory was presented by Italian neurophysiologists Giuseppe di Pellegrino and Giacomo Rizzolatti. In their studies of monkeys, di Pellegrino and Rizzolatti found evidence of particular neurons which fired both when an action was performed, and when a similar action was passively observed. This sparked a great deal of interest in the design fields, as it began to suggest an alternative theory for the relation between representation and reality, and between perceiving and imagining, based on these "mirror neurons". For these theorists, a neurobiological understanding of consciousness and particularly of creativity offered new justification for a return to an anthropocentric theory of architecture.

But to say that certain mental events such as the experience of beauty or love have 'neural correlates';[246] to work from the experimental demonstration of mirror neurons to broader claims about the 'mirroring' of reality in art;[247] to discover that tool use is localized in certain areas of the brain (such as the left inferior parietal lobe);[248] that mirror neurons together with canonical neurons (both categories of neurons that activate in response to the anticipation of motor action) are instrumental in tool-use;[249] and somehow in all of this to infer that our appreciation of the artful results of tool-use "is based on the biological platform" is rather beside the point.[250] All of these, argues cognitive scientist Alva Noë, are just "chapter[s] in neuroscience's attempt to come up with a brain-based theory of everything."[251] He, along with a growing number of cognitive psychologists, offer various rebuttals to the 'intellectual imperialism'[252] of the empirical brain sciences.

Whether or not these arguments are persuasive, however, can be safely set aside here, as they fall short of providing an account of Mercer's particular case. Analogy, whether or not it is localizable to particular regions of the brain, is at work here; but *how* it works remains to be explored—it is the way that analogies are taken up into, and alter, craft practice, rather than their direct physiological evidence, that offers us a new filter for understanding cases like Mercer's.

In one view, Mercer's notebook would seem merely disorganized: a single volume used where multiple—one for construction progress reports, one for the architectural sources for and drawings of building details, one for space planning, and one for specifications, recipes, material sources, and the like—would better have served. Yet what we have in the notebook is something altogether different from this sort of lateral movement between divergent categories of knowledge and action, and the wide spaces between disciplines and ways of knowing that such rigorously organized habits of documentation tend to create (precisely the spaces interdomain analogies must bridge.) As a product of the construction process, the notebook is a record of design thinking—something that includes all of these categories in adjacency, juxtaposition, and fusion. The rapid shift between types of representation and categories of knowledge is not so much ir-rational, then, as differently rational, and this rationality—which etymology tells us comes from ratio, or reckoning, recounting—is a different sort of telling. Understanding the notebook's structure in terms of these analogical shifts and linkages may propose a different account of how innovation develops in practice.

In the notebook, each detail-fragment is an analogy built on past expertise, a response to a possibility-for-building newly afforded by the evolving material reality of the project. As a transcription of this dialogue between builder and built thing the notebook illustrates the way analogy is often bound up in material action and culture. Hofstadter and Sander note, significantly, that analogies become both more frequent and more complex in expert communities.[253] This observation is borne out by field research on the topic, which has shown not only that experts use analogies in design problem-solving[254], but that their use is local and discipline-specific. If we consider, then, that in creating his Tileworks Mercer founded a body of expertise, and a community of experts, and that in his reinforced concrete buildings he was often able to draw upon this reservoir of expertise, we have a situation in which an analogical method of design development and documentation would be well suited to its local community of practice, and thus more than usually likely to result in robust and reliable outcomes. The notebook acts as a by-product rather than end-product, a mark or inscription of the larger process. This is a process of collage—of the ramification of analogies—related through affinity and concrete action rather than visual, typological or categorical similarity. Marco Frascari, writing on the subject, looks forward from analogy to the possibility of analogical drawings, which he labels 'graphic prognostications';[255] representation not so much *of*, but *by*, the fact and process of building.

Imagination as an Emergent Property of Practice

How analogy works to structure human psychological and social life is the subject of a book, mentioned above, by American polymath Douglas Hofstadter and French cognitive psychologist Emmanuel Sander. Sander has pursued extensive empirical research on the role of analogy in conceptual thought, as well as in perception. Sander and Hofstadter make a more ambitious claim, that analogy is 'the heart of thought' (Sander), the 'fuel and fire of thinking' (Hofstadter): nothing less than the underlying architecture of conscious (and even preconscious) experience. Analogy, in their account, is not merely one way of thinking among many, as it has been understood since antiquity,[256] but fundamental to the way the brain responds to—and anticipates—events. It is the lens, the matrix, the fiber, on which and of which imagination is built. (Such metaphors are a delightful undercurrent throughout the book.) But it is not primarily in or of the mind.

Instead, analogy, which we might provisionally define as the logic of particulars,[257] is always at work within a field of action; in the case of interest to us here, this a field of tacit knowledge and local expertise[258], possessed of a characteristic structure. Gian Paolo Caprettini, in his essay on Sherlock Holmes, makes an interesting observation: "as others have already stated, the inferential procedure of a detective for his hypothetical reconstruction cannot be correctly called "deduction."

Regis Messac reminds us that deduction consists in reaching particular conclusions from general premises, whereas induction refers to the opposite process and that *Holmes's reasonings are based on a particular fact and lead to another particular fact*."[259] He then goes on to link 'Holmes's deduction and Pierce's abduction' as processes of reasoning which abandon the customary directionality of one↔ many. (Or, as Yves Bonnefoy said about English and French Poetry, one moves from God to the detail, while the other moves from the detail to God.)[260] Abduction, in this view, moves instead through the detail's alteration of the world, to the detail made new. Caprettini clarifies this motion:

> Facing mysterious cases, abduction can be so described: 'x is extraordinary, however, if y would be true, x would not be extraordinary anymore; so x is possibly true.' […] The heuristic character of this power, which is not a vague one, is reconfirmed in the following passage: '"See the value of imagination,' said Holmes. 'It is the quality which Gregory lacks. We imagined what might have happened, acted upon the supposition and find ourselves justified. Let us proceed."'[261]

Abduction, as a formal logic, moves from the detail, through the possible-world-within-the-detail, to the second detail; this possible-world is of immense diagnostic value and requires, as Doyle, through Holmes, puts it, 'imagination.' To say that it is a heuristic procedure is only half-correct. Abductive logic proceeds through the case-by-case creation of possible-worlds, what the early-twentieth century philosopher of science Hans Vaihinger called 'heuristic fictions.' In his treatise*, The Philosophy of As-If,* Vaihinger posits the structure of scientific thought as dependent upon 'scaffoldings'[262] of conditional statements and thought experiments. The abductive structure, then, depends on fiction. He writes:

> The case is posited but, at the same time, its impossibility is frankly stated. This impossible case is, however, in a conditional sentence of this sort, assumed or posited for the moment as possible or real. But now the whole hypothetical combination is brought into a new connection. The main clause—the apodosis or 'then' clause—is given a new twist; a second knot is added to the first. […] This new connection has already been discussed; it is the equating of another case with this consequence. […] Thus an impossible case is here imagined, the necessary consequences are drawn from it and, with these consequences, which must also be impossible, demands are equated that do not follow from existing reality.[263]

Vaihinger directs this critique at a positivist view of scientific experiment: "Logically considered, these psychical structures are fictions and not hypotheses"—that[264] is to say, the heuristic detail proceeds through the deliberate deployment of the as-if, the conditional enframing of the possible world. In Vaihinger's account, scientific theories are described as essentially unreal, dependent upon intuition, or the Holmsian imagination, which moves from particular to particular through the construction of possible wholes.

This may be the 'mental sparkling' Hofstadter and Sander refer to; but such a characterization, while accurately depicting its speed and ephemerality, belies the degree to which it is a constructed, rigorous method. Holmes is a good figure here for the forensic character of the heuristic fiction; its unique economy, and its rarity. The heuristic fiction is associational rather than representation, and thus contingent upon local conditions, and embedded in a field of expertise and a community of practice. This clarifies the relationship of Mercer's notebooks to the processes in which they were embedded, and what they have to tell us about the unique structure of these hybrid methods. The notebooks are not descriptions of that method, but rather traces, fragments-that-were-preserved, of a much larger complex of knowledge-and-action, and, in our shared reading of them we should attempt to envision the larger context of expert action and daily fabrication in which they were embedded.

Relying, then, on the evidence of the notebooks, we can speculate as to the elements of practice that leave no trace by looking at other cases in which tacit practices, gestural vocabularies, and the interrelationship between communication and action have been studied. Scholars of expert practice have arrived at a number of interesting conclusions regarding verbal dialogue and gesture in productive activity:

- The more expertise a person has, the greater the frequency and complexity of their nonverbal gestures.[265]
- This is because they act within a social environment of presupposed shared tacit knowledge, and because gestures, as performative actions, serve as just the sort of shorthand for larger complexes of action that words do; or rather, as more exact and economical descriptions than words—in these particular situations—could provide.[266]
- Nonverbal communication, if we accept craft activity as predicated upon shared tacit knowledge, provides for a more direct transfer of certain types of knowledge, particularly manual actions. As we saw in the Moravian Pottery Kiln Manual, many expert actions are most efficiently communicated through gestural analogy, in which a shared familiarity with craft actions held in common is taken as a backdrop for communication. In expert settings, nonverbal communication is often, in addition to demonstrative and exact, indirect and analogical. These gestural analogies are highly efficient. As the French information theorist and computer scientist Antoine Cornuéjols argues, analogy is a principle of economy within the algorithmic complexity of specialized knowledge.[267] Gestural analogies in the context of craft activity are, in the sense discussed in chapter 3, very "low noise".
- Thus as a person develops expertise, their lexicon of specialized terms—their technical vocabulary— grows; but alongside this lexicon they come to understand an entire secondary body of non-lexical "terms", and deploy these specialized gestures in informal modes of communication.

The Finnish communication and educational theorists Yrjö and Ritva Engeström observed the collaborative practices of modern day tile setters, and found that

> verbal dialogue was intricately interwoven with the collaborative use of body movements and physical artifacts of the environment. As observers, we doubt that the knowledge that emerged was characterized by "a sense of interiority"; our strong impression is that the knowledge had much more an emergent and interactive quality, as if it were hanging in the air between the actors and their artifacts, waiting to be further tested, modified, and discussed."[268]

Several things emerge from this brief passage. First, that the knowledge of what to do in a material, problem-solving setting is not characterized by interiority[269], a 'figuring out in the head' that is then communicated to other parties. Second, that gesture and talk—often accompanied, at the site of work, by sketches of (or on) material or building fragments—are indissociable parts of a single system; and that more formal modes of communication reify and privilege the latter at the expense of the former. Third, that successful problem solving often emerges not from a watershed "eureka!" moment, but rather, as the Engeströms transcribe at length in their study, from collaboration and knowledge exchange between representatives of different knowledge domains and fields of action. Communications between these parties necessarily involve the nonce construction of interdomain analogies; these analogies are not, essentially, linguistic but rather multi-modal. They presuppose a substrate of shared tacit knowledge, and rely on this common ground for their efficacy and economy.

Collaborative work, then, has the capacity to materialize knowledge even when—or especially when—it cannot be easily put into words. It is, instead, 'in the air between the actors and their artifacts.'

Shortly we will turn to affordance theory and Mercer's understanding of tools to try to understand just what this "in the air" might mean. First, however, we need to understand just how tools and templates—or [template-ness]—facilitates the translation of craft knowledge between allied fields by making that knowledge—and the tacit practices embedded therein—portable.

D. Tacit Knowledge and Tools

In his discussion of templates, David Turnbull considers the role of representational technologies in building culture, and traces their origin to cathedral templates.

> the beginnings of the technology of representation that is involved in the modern system of architectural drawings may have come about in conjunction with the development of cathedral building. […] The use of plans in the modern sense is only possible with a standardised system of measurement; in the thirteenth century masons had no such common measure. Moreover, of 5,000 medieval drawings that have been examined only ten have measurements on them at all. Drawings were used, but at full scale, like those still extant incised into the stone in the ambulatory at Clermont Ferrand. More commonly they would have been laid out on sheets of plaster or wood. But regardless of whether there were 'plans in the modern sense or full-scale drawings, a key device is the template, a pattern or mold that permits both the accurate cutting and replication of shaped stone and the transmission of knowledge between workers.[270]

Turnbull's account of the social and organizational significance of templates is deeply indebted to John James' long study of, and monograph on, the 12th and 13th century French cathedral builders of the Paris basin.[271] In his study, James proposes templates as the primary form of construction document for that period: "On them were encapsulated every design decision that had to be passed down to the men doing the carving in shop and quarry. Through them the work of all the masons on the site was controlled and coordinated. With them dozens, and in some cases hundreds, of men were guided to a common purpose. They were the "primary instruments" of the trade."[272]

To understand the primacy of the template as an artifact of representational technology in the way Turnbull proposes, requires the use of certain terms in their specific meaning in the lexicon of social science. Perhaps the most ambiguous of these terms is "tacit knowledge". As the sociologist Harry Collins has noted, "the idea of the tacit only seems hard because, mistakenly, the explicit has been taken to be easy. The pioneers of the idea of tacit knowledge […] made it into something mysterious[273]." Collins argues that the basis of the term—and likely the reason it is active in so many fields—is simply that, from a pragmatic point of view, "we want to know the most efficient ways to get people to be competent at doing *new* things[274]." This extends to the study of past innovations: more than competence, we want to know how people become, in the advent of a new field, tradition, or tool, the *first* expert in its use.

Collins draws heavily on the pioneering work of the mathematician-turned-philosopher Michael Polanyi, perhaps the most significant of those mid-twentieth century 'pioneers.' Polanyi's books in the 1960's and 1970's established a critical basis for the study of 'tacit knowledge,' characterizing explicit knowledge—knowledge that is specifiable, or can be put into propositional form—as "distal," that is, as knowledge that "can be constructed only by relying on *prior* tacit knowing and can function as a theory only *within* an act of tacit knowing[275]." Underlying explicit knowledge, then, is a form of knowledge he calls *tacit* and characterizes as "proximal[276]." This framing in terms connoting physical, bodily, distance has had the unfortunate effect of overlapping with the terms and metaphors of phenomenological thought, and subsequent theorists often conflate the embodiment claims of phenomenology with the epistemological claims of the sociology of knowledge. This is an unresolved problem for Collins, who characterizes these two different contextual meanings of "tacit" as *varieties* of tacit knowledge: "strong" being the unuttered and at times unutterable knowing inhering in social groups; and "medium" being that form of tacit knowledge that finds its outworking in the body's analog figurings. There is (naturally) a third term in his analysis, the "weak" tacit knowledge of processes we simply haven't gotten around to spelling out yet.

But all of this seems perhaps an unnecessarily abstruse (and Hegelian) superstructure. Collins plants the seeds for simpler, more economical account of tacit knowledge with his discussion of how tacit knowledge functions in practice, and for which he adopts the metaphor (remarkably) of templates. "Imagine the brain has a mechanism that works a bit like a set of templates so that there is an area of tolerance around what will fall through a particular 'analogy template.' When two slightly different items can fall through the same complexly shaped 'hole,' we call it an analogy." He continues later in the same passage, discussing why this process is best described as 'tacit': "It just happens, however, that we don't know how to construct these templates artificially—there they are in the human brain but we don't know how to make them."[277]

This hearkens back to Polanyi's first articulation of tacit knowledge in his 1966 *The Tacit Dimension*, in which he reviews then-recent experiments performed by psychologists on the ability of electrical shocks to condition even unconscious behavior. (Of all the places for the discussion of tacit knowledge to begin, it may not be an accident that it begins in pain[278].) The idea that 'tacit knowledge' has something to do with what-we-don't-know-how-we-know-how-to-do has been continual thorn in the side of its theorists—unless, perhaps, the *doing* of tacit knowing is the heart of the matter.

Perhaps Collins' 'analogy template' is not 'in the brain' at all, but rather in the material template itself. Collins considers the possibility that craftsperson and template may be part of a larger system:

> We can visualize the body *and the tools* as material scaffolding within which the brain and body work, and even the brain itself, as components belonging to an analogue string-driven device. Because analogue string-driven devices have special properties that turn on the materials of which they are made and the shape in which they are formed, it may be very difficult to reproduce the outcomes they produce by other means for logistical if not for logical reasons.[279]

What Collins' argument means, here, for the material template engaged in expert practice, is that it may well produce results that would be very difficult to reproduce by explicit means. That is to say, templates may produce architectural results unavailable to architectural drawings.

The 'analogue systems' of skilled, tool-afforded work, achieve their ends with unique economy—much as the human chess master, another of Collins' examples, achieves his victory without significant 'brute force' calculation[280]. "If we were to stop talking and just get on with things—that is, if the tacit was not made mysterious by its tension with the explicit—there would be no puzzle at all about the body, per se[281]." But Collins here is engaging in a perhaps too-easy reduction, not dissimilar from Wittgenstein's dismissal of explicit rule-sets through the paradox of infinite regress[282]. 'If we were to stop talking and just get on with it' is precisely the romantic fiction that would have us treat Mercer as some sort of ur-builder, fabricating his primitive hut in splendid isolation. Nothing could be further from the awkward, thorny, intersubjective truth: that productive action, particularly in architectural settings, depends upon the collaboration of and fruitful communication between diverse groups and disciplinary domains. To make buildings we must make groups; and to make groups is to alter or enlarge the context of operative knowledge, and to engage in the translations from which analogy, and through it the possibility of innovative practice, is born.

We should be careful however not to confuse this 'translation' for a linguistic phenomenon. This is instead about the portability of meaning in the tools of work; and the translation, or extension, of human perception and/or cognition into the tool. On this subject, Collins takes issue with Maurice Merleu-Ponty's iconic walking-stick-as-extension-of-the-body: "The stick may extend the 'scope and radius of touch' but it is not true that 'to get used to a hat, a car, or a stick is to be translated into them.' We are not transplanted into them—they only are transplanted into us. The relationship is always asymmetrical[283]." It is a shame that Collins does not extend his argument in this instance through his own earlier example of the template, because if he did so the possibility of reciprocity might be harder to dismiss.

If we consider the template as both tool and representation, as an emblematic form of the 'portable inscription' suggested by the confluence of Latour and Turnbull's work, it becomes much more plausible to say something like: 'the mason has ceased to be an object for the template, he has now become transplanted into it'—transplanted, that is, into its contained, portable, milieu of expertise—thus extending the *template's* sensitivity to engagement with the full richness of the human world[284]. Here Merleu-Ponty's 'human world' takes on a much more specific meaning: it is the world of expertise of the master mason, enlarged in and through the community of expertise of fellow masons engaged in the project. The portable inscription of the template or other, template-like tool, provides not merely for the transmission of explicit information between parties but for the translation of both the non-verbalized, and the non-verbalizeable, knowledge of craft practices. Collins' conclusion that 'we can use the stick as an extension but the stick cannot use us' seems to preclude the very thing that makes a template work: its very ability to 'use us.'

Ultimately, the template functions as a means for the conveyance of "logistically demanding knowledge[285]" in a format of unique economy. The question of whether this 'knowledge' is wholly, or partially, untranslatable is rather beside the point. Some tacit knowledge can be rendered explicit; but we act as-if *all* of it (related to a certain task) can be; and it is precisely this acting as-if that is activated by the unique instrumental/inscriptional configuration of template-ness: we 'get on with it,' in this setting, not so much randomly or hap-hazardly, but in a designedly-provisional manner. The template allows the mason putting it to use to 'get on with it' in absence of the master mason's guiding hand; it is thus the proxy hand of the master in-corporated in the hand of the journeyman. It is Merleu-Ponty's walking stick; and the human world opens out from both ends of the cane. This is not *despite* the template's explicit and instrumental function (as the conventional opposition of tacit and explicit would have it) but in and through them: the template is explicit and verbose about certain things, and in certain ways; but its silence speaks volumes. And while it appears at first glance to be an inscription, merely an imperative—"copy this profile in stone"—the three dimensional geometry of columns and vaults requires a coordination much larger than the profile of any individual template. The template-system, as a whole, never 'speaks' but in fragments; yet these fragments enact three-dimensional complexities. We might call them 'instrumental fragments', and note that they have a characteristic configuration, what we might call (to continue the grammatical analogy) subjunctive rather than imperative. We use subjunctive forms, and narrative structures, to evoke behavior we cannot describe. Trial and error, in a craft situation, is thus the repeated attempt to evoke a desired behavior, an abductive process that puts-into-representation the tacit knowledge of building without ever making it explicit; yet which is understood as-if it were explicit. We might say this another way: the template *evokes* the specification of the tacit.

This raises two distinct questions. First, if these 'template-networks', these constellations of representing artifacts (or artifactual representations), are the vehicle of a translation, what is their epistemological nature? Are they portable knowledge? Conveyable practice? Are they Marco Frascari's white whale, the "angelic technography[286]"? What chance do we have of accounting for them, if they are by nature tacit, ephemeral, and contingent upon site and builder? Second, while it seems relatively straightforward to propose a network of templates as a core part of the practice of the mason, does the same hold true for the tools of the tile fabricator repurposed for concrete, new and strange in the hands of the concretor? This question, as I have discussed, hinges on the efficacy of a sort of irreducibly material analogy. The lack of formal documents, in Mercer's practice, means that a far-more-than-usually-tacit transfer of practice was required. Thus this knowledge transfer, this adaptive practice, may hinge not so much on the sharing of tools as on the availability, and advantage, of knowing what to do with them: that is, on *surplus expertise*.

E. Skills Translation in Innovative Systems

The migration of tacit and craft knowledge through the creation and use of tools and templates presupposes a common ground of shared experience, something we might term a *reservoir of craft experience.*

This reservoir is a set of craft practices, and their apposite artifacts—and possible artifacts—held in common by a community of work: this can mean a single, isolated community of heterogeneously skilled members, such as the crew of a deep sea fishing boat[287]; or the much more uniformly trained and disciplined members of a certain professional class, school, or training regimen, such as the crew of the navigation room of a naval vessel, which is composed of an efficient distribution of expertise, a clear hierarchy of roles, and designed redundancy in critical skill-systems.[288] On a construction site, we might see these skill-systems as the various trades involved in building construction, which are a hybrid of both of these types of groups (homogenous vs. heterogeneous expert groups). Often a crew of carpenters or roofers will remain relatively cohesive, staffed by many of the same personnel as they move from job to job. This was true in Mercer's time and has only become more prevalent in the ensuing years. Today we might readily speak of 'professionals' in the 'building industry', whatever their trade.

Mercer's work crews, however, would not be a good illustration of this type of expert group. This suggests that while Turnbull's discussion of templates raises interesting questions regarding Mercer's organization, Medieval masonic traditions may not be an accurate model with which to describe Mercer's system. Despite his interest in and collection of the tools of diverse trades, in his architectural work Mercer eschewed the use of established tradespeople whenever possible. This is a contradiction based entirely upon the gap between the material tools of a particular craft and the much more complex and constraining set of established practices, norms, and methods which belong to any given well-established trade.[289] Mercer, it would seem, wanted nothing to do with the very traditional occupations he so assiduously studied. It is often suggested that this was because he was a skinflint, constitutionally unable to pay the high wages required for expert craftspeople.[290] As we have explored through analysis the Museum ledger, however, Mercer's labor practices were normative for his place and time.

This understanding of Mercer's affinity for concrete as attributable to penury may arise from a common association of exposed concrete with unskilled labor. The architectural historian Adrian Forty comments on Concrete's early association with cheap labor, and explores at length the socio-political implications of this view. "To make things out of concrete," he writes, "has, since its 19th century beginnings, customarily been seen as needing little or no skill."[291] Forty argues that this is a mistaken assumption, as "there are degrees of excellence, and quality, just as much as in any other building trade," and that the key question for concrete, given the degree to which it preserves the evidence of the skill of its fabrication, is "where this skill comes from, who holds it, and how it is transmitted."[292] As Forty goes on to discuss, the issue of concrete with regards to labor was, in the late 19th and early 20th centuries, not so much a question of the expense of skilled labor, but rather the degree to which it was self-organized—"in this respect, the attraction of concrete was not so much that it used unskilled labor, but more that it employed men from outside the unionized trades."[293] And this, while it may not have been of particular social concern to Mercer,[294] would likely have had methodological significance. That is, in pursuing a construction material without its own history, and accompanying body of 'traditional craft labor', Mercer was freed from the accompanying norms and practices of carpentry, masonry, and etc. Just as in his invention of tiles, Mercer sought creative autonomy in the methods of building. And while Mercer used various trades freely as their expertise was warranted, he used concrete from the beginning as an unknown, and undetermined, type of building fabrication; and he took into its domain many building components—roofs, chimneys, fireplaces, windows, and even furniture—ordinarily the domain of externally organized labor and production. This allowed him to maximize opportunities for the invention of method.

Unlike the cadres of trained, even at times unionized, masons or carpenters with whom Mercer had to negotiate when he supplied tiles to the architectural projects in which his tiles had been specified, in his own work Mercer seems to have sought out deliberately a group of workers who were not trained in or members of any sort of larger craft organization.

Forty, in his study, is careful to distinguish 'formwork carpentry' from general concrete labor: "In America in the early 1900's it was reckoned that in any elaborate construction the costs of the formwork exceeded the costs of the concrete, and was generally the largest single item of expense on a concrete building."[295] If this was true in the typical usage of wood and iron forms, we can only imagine the degree to which Mercer's tiled vaults would have exceeded the baseline condition. While Mercer's ledger calls out the skilled laborer of individual trades separately, it is perhaps significant that 'formwork carpentry' was not such an item. Two factors may account for this. First, with regards to rough carpentry, Mercer's particular approach to formwork would have provided for a great deal of latitude in the accuracy of carpentry work. Particularly at Fonthill much of the 'skilled labor' required for a finished interior space would have been shifted from the domain of wood carpentry to the skill sets of the clay modeler, plasterer, and tile setter. As the workers gained more experience in formwork carpentry, we see a corresponding increase in form-finish results—this is true from ground to sky at Fonthill, as well as across the sequence of Mercer's architectural works—though the overall level of finish is still quite rough. This trajectory was also present in the attribution of tasks to individual workers, as we see recounted by William Frankenfield in his description of his own assigned tasks at the museum.[296] And while secondary sources tend to emphasize the unskilled nature of Mercer's workers (Reed calls them, without attribution, 'farm laborers,'[297] and Forty, in his description of Mercer's projects, merely attributes the work to "local labour."[298] This supposition goes back at least to the 1950's, when an article in *Pennsylvania Archaeologist* described Fonthill as "built entirely by unskilled labor."[299]

Mercer's own account in not exactly at odds with these suppositions, but presents a different picture when taken in conjunction with the earlier development of methods and techniques at the Moravian Pottery, where, from the beginning, Mercer and his workers were inventing new tools and methods for tile fabrication. In his manuscript notes on the history of the pottery, Mercer writes,

> Without the efficient help of collaborating hands and hearts, the success achieved could not have been looked for. Mr. Swain, old companion and assistant in Archaeological days, invaluable helper and master of every detail, has been business manager from the start. The foreman have been John Bartleman, John Briddes, Wilson Wismer, Oscar Rosenberger, and now Clarence Rosenberger, whose economic, untiring, and efficient management, has produced results far exceeding anything ever reached before. With devoted skill and interest, George Jacob Frank has carried out all our later elaborate designs, having not only modelled but also arranged and set all the ceiling and many of the mural tiles at Fonthill. Herman Sell, though not regularly employed at the pottery, has set innumerable pavements, particularly those at Mrs. Jardner's, Fenway Court in Boston, and many mural tiles by *various new methods,* besides building all the kilns ever constructed at the pottery.[300]

Mercer's workers, then, developed their expertise in conjunction with the development of new methods; these methods, in their novelty, requiring an approach both experimental and didactic; and this invention of method was recognized and valued by Mercer, and cultivated in his workers. (At Fonthill, we even see the installation of a mural designed to honor their contributions. [Fig. 4.18.])

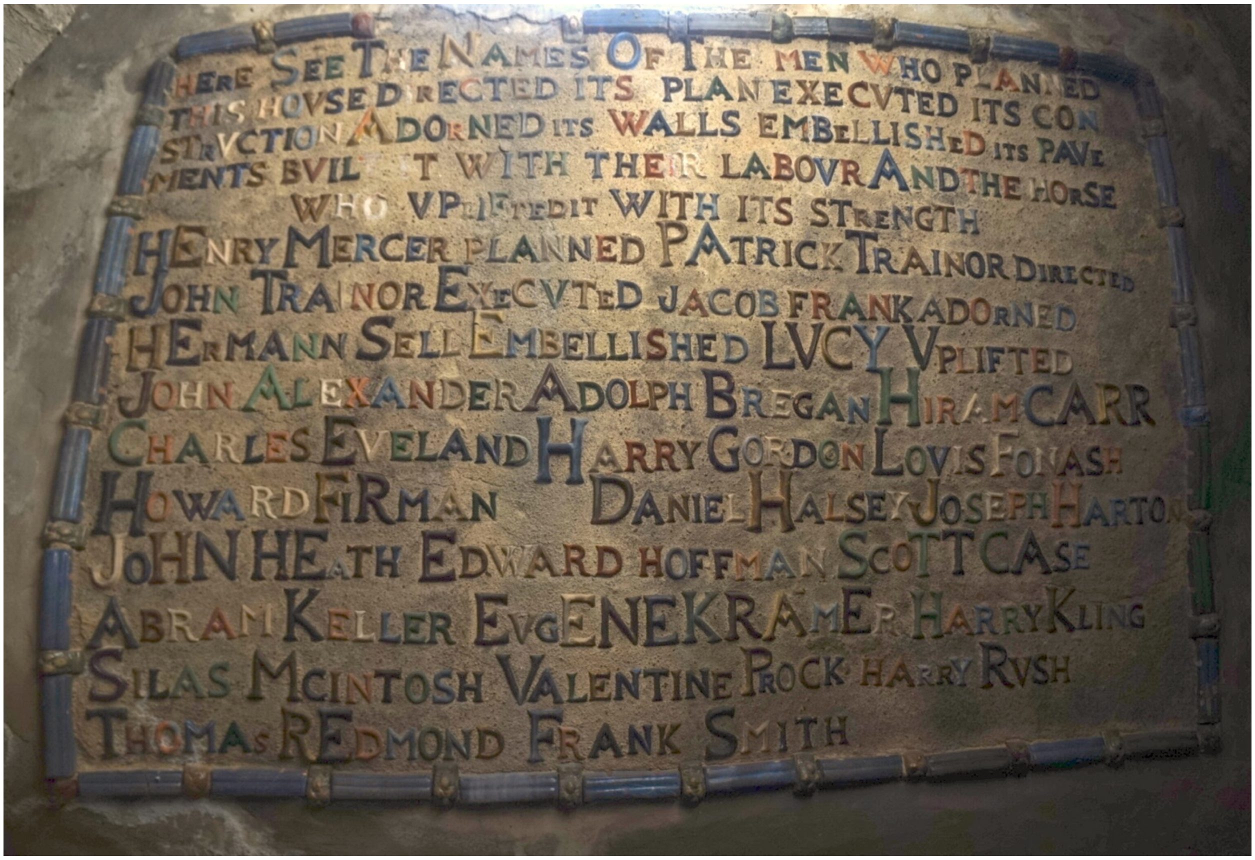


Figure 4.18. A mural commemorating the building of Fonthill, at Fonthill. Image: Bucks County Historical Society. Image: author, courtesy of Fonthill Castle.

Ultimately, with Mercer's crews, we see the case of a group of 'untrained' craftsmen forming, over the course of years of work, an organized practice complete with its own norms, tools, and standards—a unique and local reservoir of craft experience. These were the people, systems, and infrastructures Mercer developed for his Moravian Pottery, and from which he drew material, methods, tools, and as we will see, expertise, to be repurposed in architectural fabrication.

Surplus Expertise

Mercer's methodological innovations illustrate the development of a cohesive set of craft practices and the adaptation of those practices, to use the terminology of the psychologists and philosophers who study analogy, from their 'source' domain (ceramics production) to an adjacent, 'target' domain (reinforced concrete construction.)[301] Given a "source domain," what we might in these more manual settings call a reservoir of craft experience, the analogical practice functions by construing the reservoir expertise of the source domain *as-if* it were that of the target. *If* concrete were clay, we might make concrete windows much like Mercer did. And *if* concrete were clay we might also expect to see it used as a plastic material rather moreso than we customarily do, accustomed as we are to the dichotomy of the pump truck and the concrete block.[302] Thus, as we saw with abductive logic generally, the world-view of the source domain sets in play the limits and possibilities open to the target domain. The richer the analogy, presumably, the more apt the result.

In Mercer's case, several types of adjacency facilitated a rich analogical practice. As mentioned in chapter 2, Fonthill and the Moravian Pottery Facility were directly adjacent; and geographical proximity certainly provided the opportunity for overlapping work. Even the Museum was only a 10 minute bike ride—Mercer's preferred form of travel—from his residence at Fonthill. [Fig 4.19.]

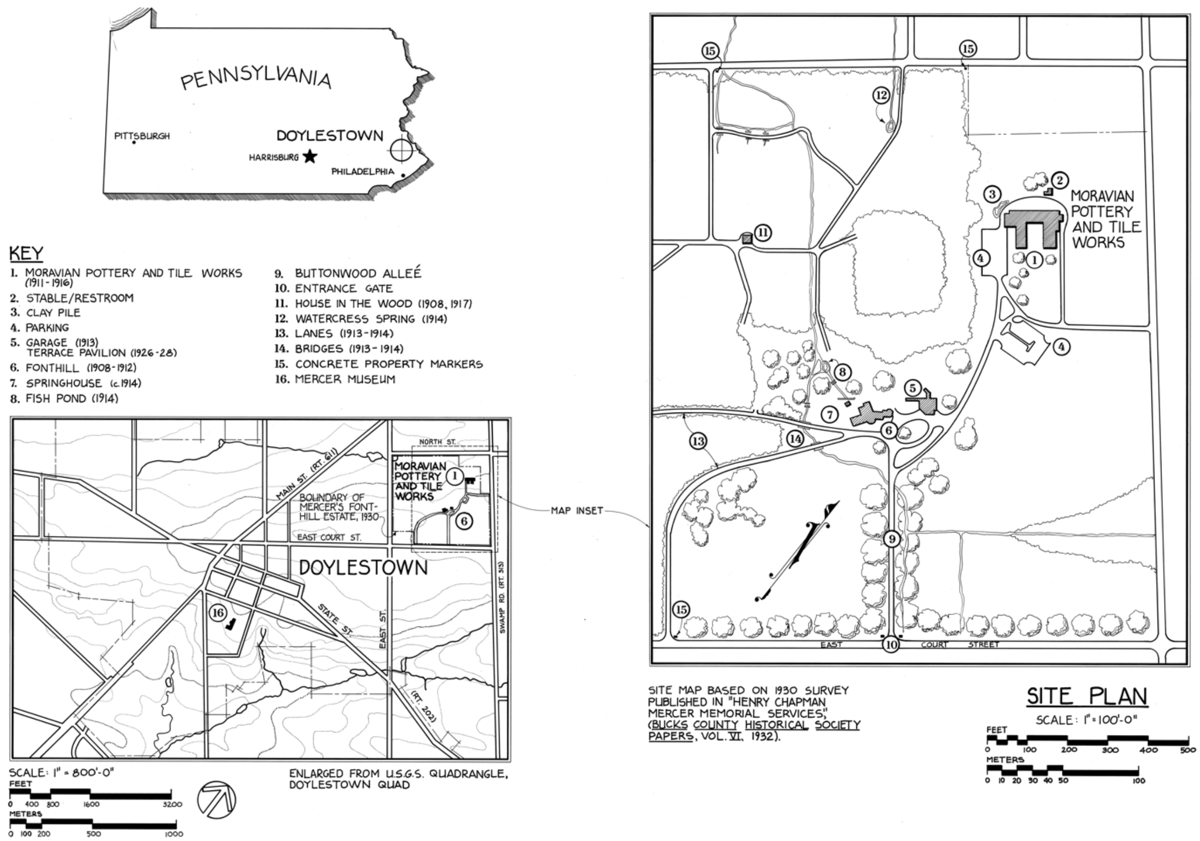


Figure 4.19. Area plan showing location of Mercer's projects, from sheet 2 of the 1988 Historic American Engineering Record Survey of the Moravian Pottery.

While we don't know the precise background of Mercer's workers, we do know that many of Mercer's hires were young men, without training or qualifications in particular building trades. Others were trained in a particular craft related to the area of expertise he required. When it came time to build kilns for his pottery, Mercer hired a recent transplant from England who had been part of a family of potters there. Of John Briddes, this "expert kiln builder,"[303] we know very little.[304] What we do know is that Mercer had been considering traveling to Germany to study "one of the ancestral potteries of the Black Forest" on the advice of his acquaintance, Philadelphia artist Joseph Willman.[305] In January of 1899 Mercer met the English potter John Briddes, recently emigrated from England to Philadelphia, who offered his expertise. Mercer hired him that spring, cancelling his German trip. The kiln Briddes constructed is of the classic English "bottle" type, such as were built by the thousands in the pottery-manufacturing region of 19th century England, now known collectively as Stoke-on-Trent. [Fig. 4.20.]

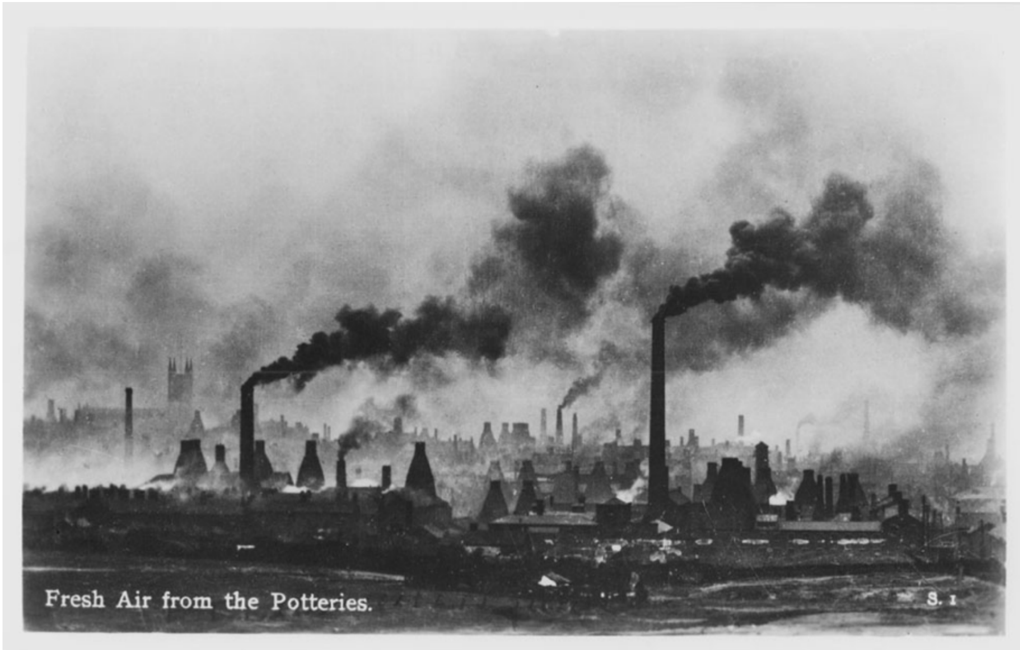


Figure 4.20. Photo of bottle kilns in Stoke-on-Trent, the center of ceramics production in England; and, for a few decades earlier in the 19th century, in the world.[306] *Image: courtesy of The Potteries Museum & Art Gallery, Stoke-on-Trent.*

Mercer also hired Herman Sell, a local mason, to assist Briddes, and Sell would take over the task and ultimately become a regular part of Mercer's workforce, supervising many of Mercer's tile installations and building eight more kilns at the two locations of the pottery. Subsequent study of the kilns[307] show that, while they were modified slightly into two types, one for "bisquit", or bisque, firings and a smaller, more tightly constructed version for "glost", or glaze, firings,[308] they followed the general pattern Briddes had devised. While it has been argued that Mercer significantly improved the design of the kilns,[309] there is no direct evidence that he made changes as significant as subsequent scholars have suggested, such as the transition from an updraft to downdraft configuration inside the kiln. The Historic American Engineering Record completed a study of Mercer's extant kilns in 1987 and determined the kilns functioned as a hybrid downdraft-updraft.

> During the initial phase of firing, the kiln was operated as an updraft kiln. Fires were built in the fireboxes (1), and the flames were deflected upwards by the interior bag walls (2) […] To bring the tile up to its maturing temperature of about 1900°F (cone 05), the kiln was converted to downdraft operation. The crown flue was closed off and the wall flues were opened, drawing the heat down through the tiles to the floor flue (5), then up the wall flues. This method produced a more efficient use of fuel, a faster heat rise, and more even temperatures throughout the kiln.[310]

Rather than representing an innovation, this was the current "state of the art" in kiln design, with the first patents for this particular variation filed in 1863 and 1867 in England and the United States by kiln builder Thomas Minton,[311] who was based in Stoke-on-Trent. By the turn of the century this knowledge was general, and many updraft kilns had been or were in the process of being converted to hybrid updraft/downdraft bottle kilns; and new bottle kilns began to be built upon the pattern of this makeshift solution. What we have here is a case of a "systematized ad-hoc process."[312]

Archaeologists David Dawson and Oliver Kent write that

> the impact and cost of conversion were minimized by retaining as much of the original structure as possible and by avoiding reduction in the capacity of the ware chamber. Most of the original perforations in the vault of the ware

chamber were blocked. Baffles were added to the springing of the vault to give protection from the concentrated blast of flame channelled from the firemouths. The realigned system of flues under the floor focused on a central aperture, from which an exit tunnel led to a new external square chimney. Kilns of this type are thus a hybrid between the updraught bottle kiln and the standard beehive downdraught kiln with its free-standing chimney. Ad hoc solutions of this sort may well have been applied to achieve the same end in other kilns, but the evidence for these may be less easy to interpret.[313]

Mercer's first kiln is no longer extant, having been demolished when Mercer's original pottery on the grounds of Aldie was "dynamited," and, while it is certainly possible, there is no direct evidence (material, or in his notebooks) that Mercer first built and then independently arrived at the modification of an older, updraft design to the hybrid design current at the time.

However, the bisque kilns in the pottery are further modified from the general hybrid updraft/downdraft type, but this modification is additive: an additional, central, internal chimney provides a more even distribution of combustion gases when the kiln is functioning in downdraft mode, and likely allowed a denser packing of bisqueware while maintaining even heatwork throughout. The central chimney modification was only included in the final large kilns built at the pottery in 1912, and so were most likely made long after Briddes was associated with the new pottery, but when Sell was serving as principle kiln builder. Thus we see the continued evolution and systematization of fundamentally ad-hoc processes, based in the transfer of expertise between expert and assistant, and subsequent impromptu and problem-solving actions which demand modification of received methods.[314]

This traditional form of side-by-side work of master, journeyman, and apprentice, or more generally and recently of expert and assistant, and the future independent work of the assistant as new circumstances present themselves, is another case of the building-up, and drawing-upon of a reservoir of craft experience. This is not always intended or understood as an experimental practice, serving instead as a normal part of premodern tradecraft. But at Mercer's pottery we see a variation upon the typical master-apprentice relationship, and a resultant acceleration and intensification of experimental practice: the assistant is not a long-term subjugate of the master, but rather an experienced tradesperson possessed of closely related skills, assigned to assist, and to learn while doing so, the methods of the principal actor—it is significant here that Mercer hired a qualified mason to assist his kiln-builder. (If it had been feasible for Mercer to use one of his younger, less-experienced general laborers for the task, he likely would have.) Mercer saw two benefits from this: first, his kiln-builder was able to complete the first kiln quite rapidly, between January and February of 1899.[315] Second, the mason's preexisting experience allowed him to rapidly pick up the techniques specific to kiln building, which utilize minimal, high-temperature mortar, firebrick, and steel tension rings to prevent bowing; in these and many other technical details diverging from standard mason's craft knowledge.[316]

An analogical practice in the vein of Mercer's tileworks is configured to provide for a colocation not primarily of master and apprentice in the traditional sense, but of a more horizontal arrangement of craftspeople, in which allied trades work side by side and contribute, as well as learn, tradecraft, techniques, and norms. Such a juxtaposition would seem to be counter to efficiency, both in terms of wages, and in terms of the distribution of expertise. This brings us to the third factor in analogical practice: surplus expertise.

By the early 1880's the construction of bottle kilns in England had reached its peak. It is perhaps then no accident that Mercer was able to hire an out-of-work expert in their construction by 1899, as this was a time of rapid contraction in the market for kiln-building expertise.[317] It may have been good fortune that Mercer hired Briddes. But it was also likely a boon to Briddes, who may well have emigrated in the first place because of decreased opportunities to use his expertise in his home country. In any case, Mercer saved himself a long and costly apprenticeship in Germany; and was able to make use of this surplus kiln-building expertise. Expertise-surpluses like this are common in building trades, as materials are used up or supplanted, as tastes and standards and local availabilities change. The late 19th century was, generally speaking, a good time for masons and a bad time for carpenters, as a series of city-altering fires swept through the dense and still predominantly timber cores of the cities of North America (Chicago, Seattle, etc.) and these cities rebuilt themselves in stone or brick or other less flammable materials.

Surplus expert labor would also, on a much smaller scale, play a role Mercer's last project. The years surrounding World War I occasioned a reduction in business for the pottery, as there were far fewer than normal projects under construction and in need of tiles. In 1914, Mercer's assistant Frank Swain noted the decreasing demand in his meticulous records of the Moravian Pottery and Tileworks sales and expenses: "Business dull. European War." By the end of the war, he would reflect on the overall impact: "War restrictive, costs of labor and building materials stopped most work. Government allowed no new building started and none finished except by permit."

A review of the job files for the pottery indicates that the tiles were installed in every variety of architectural project. [Fig. 4.21]

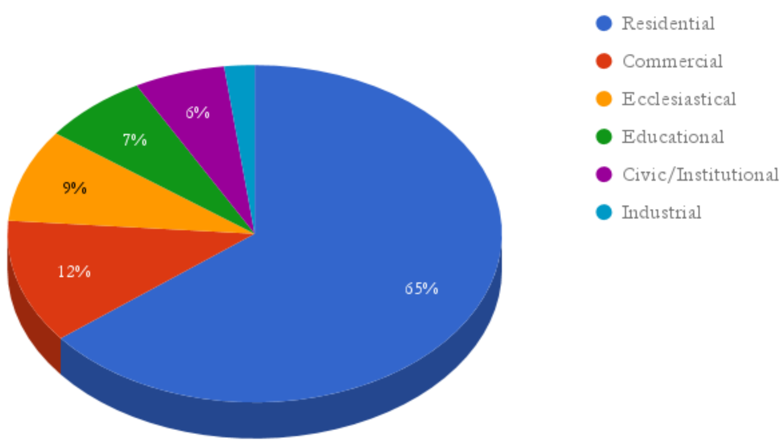


Figure 4.21 Chart of building types and their distribution within the Moravian Pottery and Tileworks Archive, listed by number of total unique project records. Between 1902, when formal records were first kept, and Mercer's death in 1930, nearly 1400 clients are recorded in both the archived correspondence and the plan file (some appear only in one or the other). For a complete list of project and client name, location, and architect, contractor, and agent/dealer where available, see the Guide to the Records. While the total number of installations heavily favored residential projects, the overall distribution is reflective of the overall distribution of architectural commissions in contemporary practice, with the exception of industrial buildings. Just as in architectural billings generally, however, the civic and institutional projects were for Mercer by far the largest commissions, and often laid claim to a substantial part of the pottery's production in any given year. From the Pennsylvania capitol building in 1904, to the Nebraska state capitol in 1930, Mercer's tiles were used in high-profile projects throughout the United States and Canada, in scores of churches and schools, as well as at a few sites in places as distant as Cuba, Egypt, and the United Kingdom. Figures abstracted from a review of the Guide to the Records of the Moravian Pottery and Tileworks; categories, and categorizations of particular projects, are my own. Image: Author.

Swain's records indicate that, during the war years, the Moravian Pottery relied heavily on their existing stock, so much so that, when business picked up again in 1919, Swain wrote of "demand beyond the supply"[318], of cancelled orders and "no back stock."[319] This presents a bit of a mystery. The mystery deepens when we look at the total commissions in the nineteen-teens. [Fig. 4.22.] With the exception of the dip in 1918, the records tell the story of a thriving and remarkably stable business. The reason for the dip in stock is not, it would seem, either due to a long recession nor a sudden surge in demand. Quite the opposite. This decade was in fact the high-watermark for Mercer's pottery, and despite the widespread prosperity and building boom of the 1920's, the pottery would not reach these levels again. Many of the architects listed in the records are repeat customers; and a number of them disappear from the books after 1919. The Twenties saw markedly lower productivity than that of the Teens (averaging 47 projects per year versus 72). It may be that the damage to customer loyalty was irreparable; or that architecture had moved on to other modes and materials less in keeping with Mercer's tiles. It may also be that Mercer was more comfortable with a smaller operation.

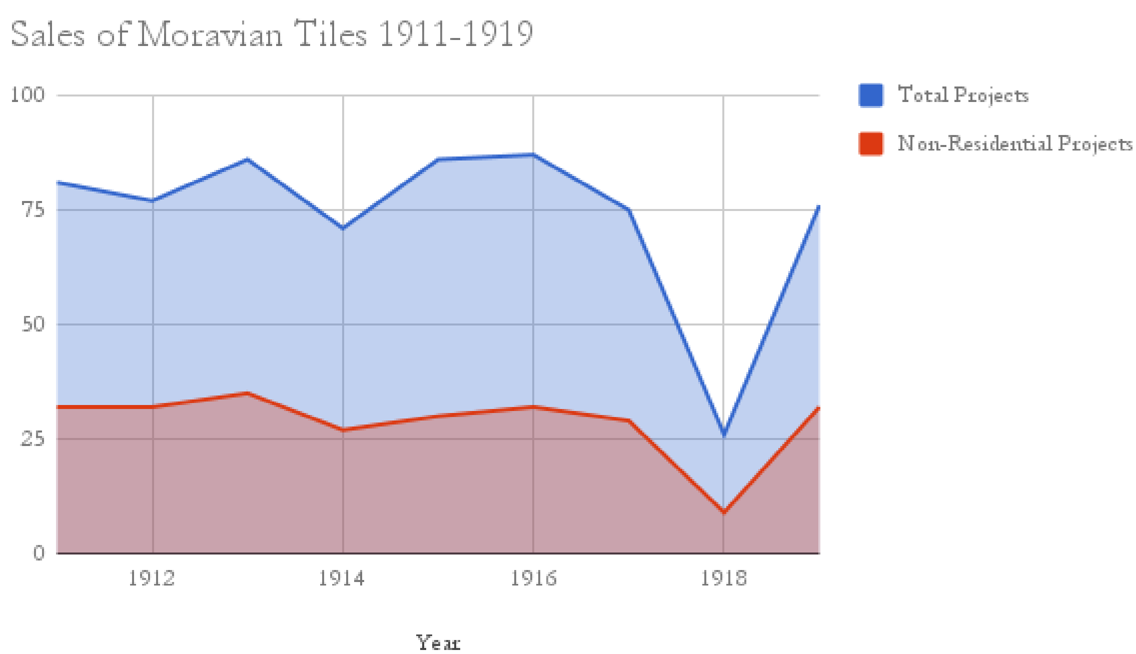


Figure 4.22. Total commissions for the years 1911-1919. Source: Guide to the Records of the Moravian Pottery and Tileworks. Image: Author. The dip in sales in 1918 accompanies the most dire of Swain's complaints about wartime reductions in demand.

The mystery, then is this: it was not that Mercer suddenly had a bad year. It was rather that the years leading up to 1918 provoked a change in the overall productivity of the pottery, in which Mercer and Swain brought the level of output into line with the wartime demand for tiles. When the war ended and more normative construction resumed, they were unprepared for the level of demand, resulting in the cancelled orders and general scramble of 1919. Clearly, then, Mercer's pottery, in the war years, was not producing tiles at its previous capacity.

World events would have changed the economics of tile production as early as 1914. If the pottery reduced its output, and yet saw a relatively brief dip in demand, they may have relied more than was prudent on back stock from 1914-1918, such that 1919 caught them depleted and unready to fulfill new orders. Meanwhile, Mercer's years-long construction of Fonthill was substantially complete by May of 1912. Mercer had a crew of workers by now well trained—some in tile-making; others in his particular method of reinforced concrete construction; a number in both[320]—and a sudden drop in productive work for those skilled hands.

This frames for us the third factor in the analogical transfer of expertise: surplus expertise. Just as larger economic conditions in England may have contributed to the availability to Mercer of skilled knowledge of kiln-building, Mercer was faced as early as 1912 with just such a surplus of his own. This was a surplus he did not put to waste. From 1912 to 1913 he built an elaborate "garage" structure,[321] with upstairs meeting rooms. [Illustrated in figure i.6.]

Sometime between 1913 and 1917,[322] Mercer employed some of his workers in renovating a stone cottage in the wooded land between Fonthill and Aldie, on land that was part of the tract he had purchased for Fonthill but which was, and is still today, undeveloped with the exception of that farmhouse. [Fig 4.23.]

Figure 4.23. Stone farmhouse in the Fonthill woods. Note the concrete roof, still serviceable despite showing no signs of regular maintenance. Image: author.

As at Fonthill, Mercer inserted his new materials directly into existing built fabric; unlike at Fonthill he left the stone walls mostly intact and untreated. He replaced the roof with a concrete roof like those on his other projects. Tiles on the eve of the gable roof spell out a motto, “Who learns will love and not destroy the creatures life the flowers joy”, which he first developed likely (in smaller format) for a residential fireplace commission. There is also a mosaic which includes the Latin phrase *Silva Vocat,* “the forest calls.” [Fig. 4.24.] A tilework medallion is inserted into the structure of the end wall. Other small changes were made, but the overall effect is of a very light renovation, a harmonious blend of old and new.

Figure 4.24. Silva Vocat mural. Image: author.

Also in 1913, Mercer began the design for what would be his largest and most ambitious project, the which would house and to which he would donate his substantial collection of early-American tools and artifacts. To understand how Mercer’s unique view of his materials set in play unique processes of building—which may well be his most significant contribution to the architectural field—we must turn to how these views were formed by, and are articulated in, his rooms of tools.

PART 3: The Tools of the Architect

Chapter 5: The Tools in and of the Museum: How Affordances and Feedback Structure Tool Use

The symptoms of accelerated crisis are widely recognized. Multiple attempts have been made to explain them. I believe that this crisis is rooted in a major twofold experiment which has failed, and I claim that the resolution of the crisis begins with a recognition of the failure. For a hundred years we have tried to make machines work for men and to school men for life in their service. Now it turns out that machines do not "work" and that people cannot be schooled for a life at the service of machines. […] The crisis can be solved only if we learn to *invert the present deep structure of tools*; if we give people tools that guarantee their right to work with high, independent efficiency[.]

-Ivan Ilich[323]

Human ingenuity seems to have no boundaries in trying a different, often ad hoc tool to get the job done so that several tools may be applied for the same effect. We only need to think about the different items we tend to use as screwdrivers if we do not have a proper one to hand. […] Moreover, Ingold, who carried out several craft tasks and described them in great detail, indicated that movements and actions with the same tool that would be considered repetitive to the outsider are, in the hands of the executor, a dynamic flow of actions that change as movements are made; the tool fulfills different roles throughout the entire job and makes the executor change position. Moreover, the changing position or the movement of the executor may be detected through careful study of preserved tool marks. This is a clear example of how interlinked people (e.g. the carpenter), materials and objects (the saw and wooden plank) and spaces (workspace needed in which the carpenter needs to adjust his or her position) all dynamically form but also restrict each other.

-Ann Brysbaert[324]

LESS THAN A GENERATION SAW THE LANDSCAPE OF WORK AND LIVELIHOOD in Philadelphia and its environs utterly transformed by the industrial revolution. It was in this setting that University of Pennsylvania archaeologist and soon-to-be former-academic Henry Mercer began to discover throughout the countryside fragments of a culture unstudied by the archaeologists of his time: the artifacts of their own immediate forbearers. These evidences included the abandoned tools, jigs, templates, material stockpiles, and unfinished craft objects of the myriad cottage industries pushed to extinction in the closing decades of the 19th century. Mercer would recall this time in a 1915 introduction to his book on cast iron stove plates:

> An immense mass of objects became obsolete about 1860 to 1880 and were destroyed, or sold in the so-called 'penny lots,' at innumerable sales to native junk dealers, who, impelled by a desire to find scrap iron, or discover new uses for old things, saved thousands of cast off utensils, and piled up what they did not destroy, in scattered heaps upon their premises.[325]

In 1897, as his relationships at university became strained (his primary advocate in the department, Daniel Brinton, having died the year before), Mercer began to collect these 'obsolete objects,' rescuing them from the junkheaps and iron dealers to which they would otherwise be lost.

A. An Archaeologist-of-Tools

Mercer often retold the story of how he came to discover the myriad objects in his collection as a story of good fortune and sudden insight, of being out in the countryside and happening upon a jumble of discarded tools; of seeing them as worthy of preservation; of recognizing them, in an eye-blink, as archaeological relics.

> It was then probably one day in February or March of the Spring of 1897 that I went to the premises of one of our fellow-citizens, who had been in the habit of going to country sales and at the last moment buying what they called "penny lots," that is to say valueless masses of obsolete utensils or objects which were regarded as useless, or valuable only as old iron or kindling wood, things which fortunately have been preserved among us for two noteworthy reasons, first because of the existence in our country of several of these unthanked and non-mercenary hoarders, and second because of the abundance of wood and consequently of outbuildings, such as are lacking in Europe, adapted to the preservation of perishable heirlooms. The particular object of the visit above mentioned, was to buy a pair of tongs for an old fashioned fire place, but when I came to hunt out the tongs from the midst of a disordered pile of old wagons, gum-tree salt-boxes, flax-brakes, straw beehives, tin dinner-horns, rope-machines and spinning-wheels, things that I had heard of but never collectively saw before, the idea occurred to me that the history of Pennsylvania was here profusely illustrated and from a new point of view.[326]

Over time, Mercer built up a collection of tens of thousands of these abandoned tools and implements, until, in 1913, he began work on the museum to house them. This was a far cry from his first exhibit of the collection, in the Bucks County courthouse in 1897, which consisted of a room of artifacts and implements and a catalogue published through the historical society titled *Tools of the Nationmaker*. In that catalogue he would write:

> From the sweet scented herb store of the ancient garret to where the mill race washes the mossy machinery of the crumbling mill; from the dark recesses of a bake oven to where a north light wanes through dusty windows upon the granary or wagon house; from the smelter's iron heap to the wood pile, the search for these disused and neglected things has led us. The historian has overlooked them. The antiquary has forgotten them. But when we realize the value of the associations that perish, as they pass away in our midst, we commend them as heirlooms to be saved from destruction and set in a place of honor.[327]

Mercer's comportment toward these objects was, from the first, that of the archaeologist or conservator. Perhaps, frustrated with the attempt to find significant potsherds in the middens and firepits of vanished civilizations[328], Mercer set himself the task of collecting the ruins of his own civilization before they were lost to time. As Reed would write in her biography, Mercer "was among the earliest of serious scholars to recognize the value of the seemingly mundane artifacts of recent history for cultural studies of many kinds."[329] And museum historian Steven Conn proposes that Mercer "applied an anthropological model of cultural change to the process of American historical change."[330] Sadly, Conn deemed the museum Mercer built to house his collection was merely "a bizarre seven-story pile of his own design and made entirely of reinforced concrete" rather than an integral part of Mercer's project. This bias, seeing the museum as a mere container and the tools as the contained, is widespread.

A Museum of Rooms

While the museum—still extant and actively pursuing its mission—is often described in impressive, if reductive terms, as a collection of 30,000 items,[331] it might better be described as upwards of 60 distinct vignettes:[332] carefully staged rooms in which Mercer organized his collection in an attempt to depict, in each room, the range of artifacts and craft operations utilized in a single trade. This is where the insights of the architectural scholar may perhaps supplement that of the museum historian. When we pay attention to the building itself, along with the items it houses, a clear, and quite prescient, curatorial warrant becomes evident.

The taxonomical scheme for the display of Mercer's tools first took shape when he displayed the incipient collection at the county courthouse in 1897. [Fig 5.1; see also figure i.13.] The schema continued to develop over the intervening years, but it would not be until the construction of the museum that it would be solidified into its final form, a hierarchy or family tree of the constituent elements of early-American material culture, which Mercer published as a broadsheet in 1921.[333] [Fig 5.2.] There may well be a profound statement about material culture embodied in the layout of the rooms; or it may simply be how it appears at first glance: a concretion of hap-hazard invention. It may also be that the message of Mercer's museum, like the purloined letter hiding in plain sight, requires an abductive circulation to bring to the fore what is concealed. We should begin, then, in good forensic fashion, with a close examination of the room.

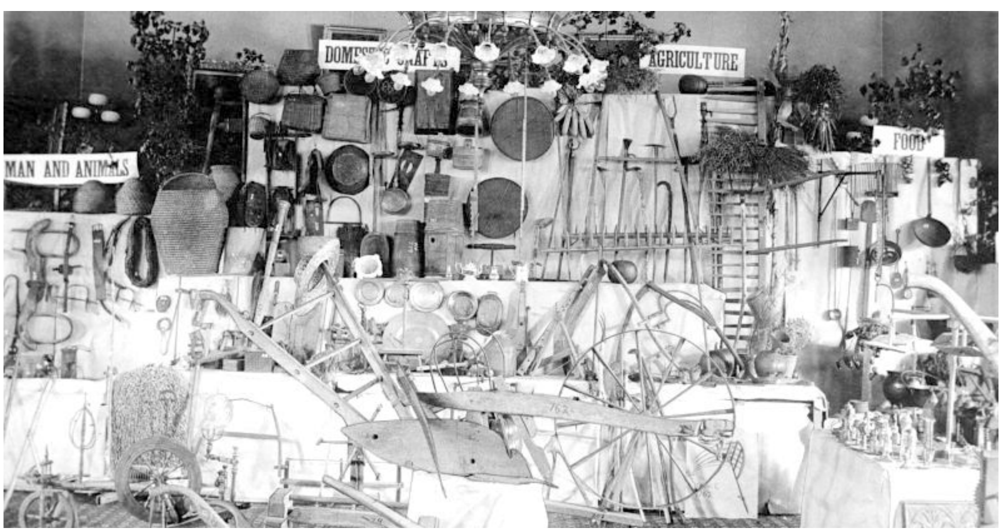


Figure 5.1. Tools of the Nation Maker, ca. 1897. Note the early broad categories indicated by signage. Image: courtesy of the Mercer Museum Research Library.

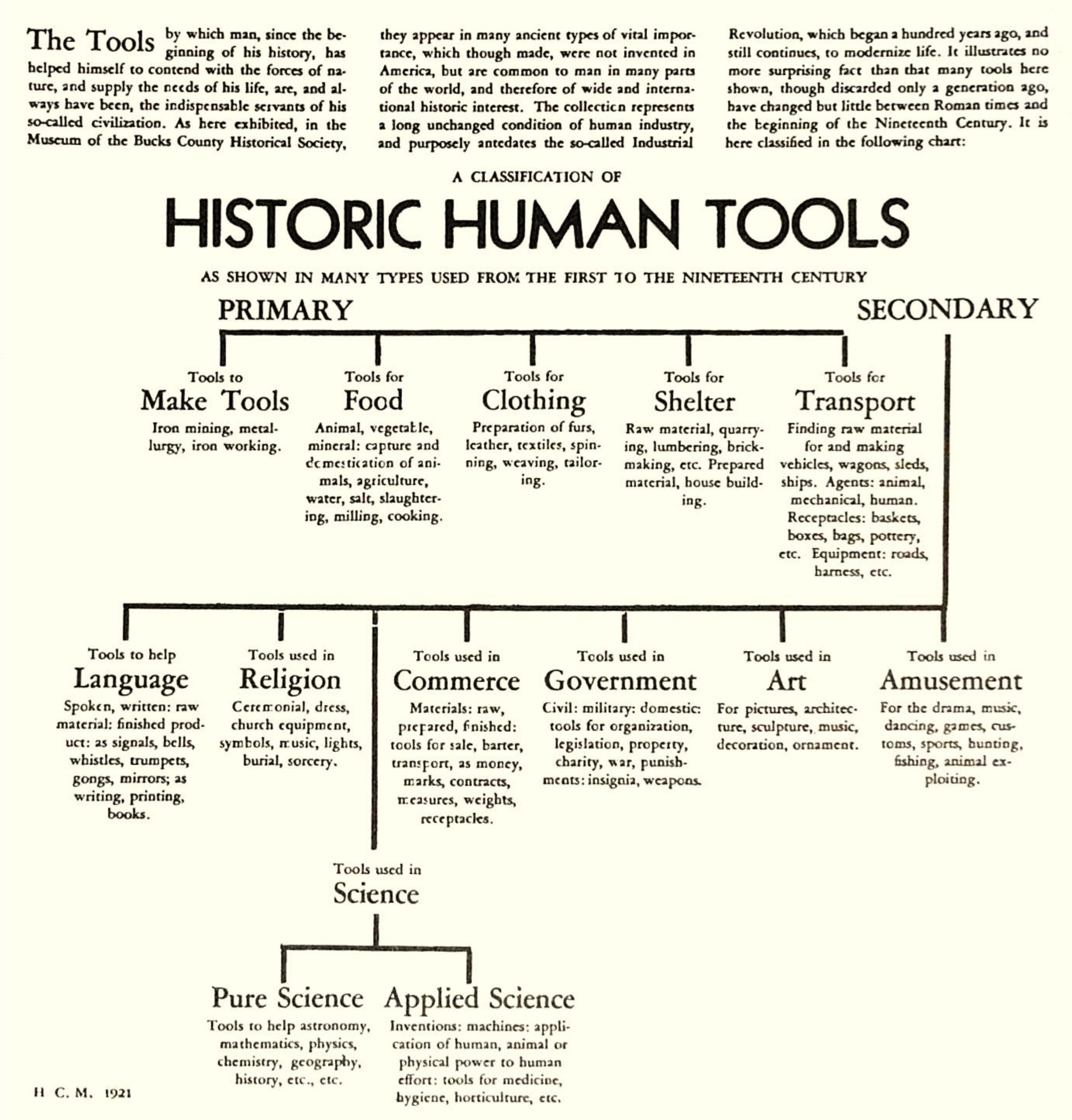


Figure 5.2. Diagram for the collection of the Mercer Museum. Image: courtesy of the Mercer Museum Research Library.

Each room in the museum contains the tools associated with a particular trade. Yet this is not a particularly encyclopedic effort. A file-maker's room has many files, including a shelf of "shoemaker's files". The shoemaker's room has rasps and a few files; there are files in other rooms as well. Likewise, a range of drawknives appear in the carpentry, lumbering, and wheelwrighting rooms. Often these tools are arranged around a work bench, table, or some other primary tool-furniture. [Fig. 5.3.] These tools are accompanied by examples of the sorts of work they produced. But as Conn notes in his study, neither are these rooms dioramas, because Mercer displays many of the same type of tool, often mounted side by side on the walls of the museum room.[334] [Fig. 5.4.] The array of tools is not comprehensive, in that it is even today primarily composed of items collected by Mercer in the immediate environs of Doylestown, Pennsylvania in the years between 1897 and his death; nor is it presented encyclopedically. (Originally, Mercer intended the visitor to view, or even step into, the room of each craft uncluttered with the visual presence of signage or description; though present-day interpretive signage has been added in most cases.)[335] But neither is it a diorama—though it likely owes its origin to that tradition.

Figure 5.3. An interpretive arrangement of tools and workbench, complete with wood shavings. Image: author, courtesy of the Mercer Museum.

Figure 5.4. Many iterations of the same tool, on the wall of the "Harvesting" room. Image: author, courtesy of the Mercer Museum.

Mercer's arrangements harken back to a tradition far older that the enlightenment project of the encyclopedia (or its most idiosyncratic and anti-mundane materialization in the cabinet of curiosities, into which, it must be said, the occasional visitor to Mercer's museum may believe he has stepped). In late Medieval engravings, commonly used as sources for 19th century children's primers (and likely where Mercer would have first encountered them, both in his own youth and in later collecting efforts), we often see depicted a craftsperson in a small room, surrounded by the tools of their trade. [Fig 5.5.] This tendency, to depict trades in vignettes of craft activity carried out in a confined but architecturally articulated space crowded with tools, was a cultural norm in Europe from the late Middle Ages onwards, utilized not only in engravings and other pictorial arts but also making its way into the decorative arts, as in the ornament of buildings. [Fig 5.6.] 'Vignette', however, may be a misleading term, as it implies the creation of a scene-of-work. In these engravings the intent is certainly to an extent scenographic: here is the artisan at work. Yet there is also an analytic element. Even at first glance these depictions do not show just those tools than might be visible in any purely representational depiction of a workshop. These are not photographic depictions of the place of work so much as assemblages of the tools-to-work-with; not so much workplace stagings as narrative framings of the various possibilities for tool-enabled work.

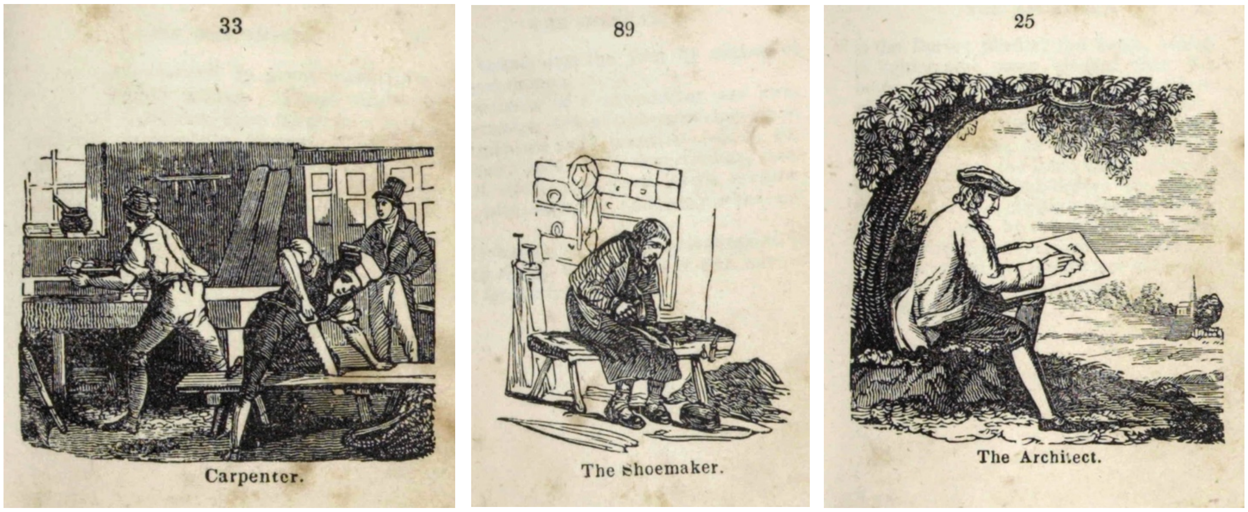


Figure 5.5. Depictions from the 19th century children's primer The Book of Trades, *first printed in 1847 in Philadelphia. Images: Edward W. Miller,* The Book of Trades *(Philadelphia: T. K. & P. G. Collins, Printers, 1847) / public domain.*

Figure 5.6. Nanni di Banco. Detail from The Four Crowned Saints, 1408. Orsanmichele, Florence. Image: Dan Philpott CC 2.0 Attribution.

A 1568 woodcut attributed to Hans Sachs shows a potter in his pottery. [Fig 5.7.] In it, the story of the potter's craft is told in chronological order from the right background to the left foreground. In the distance a woodsman cuts wood, which is in the next moment fed into the open mouth of a kiln. Closer, but still outside the workshop window, a man digs clay, the folded earth beginning to pile up beside him. Inside to the potter's right a pile of clay sits on the floor, while the potter sits facing left with his hands on an unfinished vessel and his foot turning the kickwheel below. Extending from a shelf next to the wheel to the front of the frame are vessels increasing in decoration and variety as they crowd into the foreground. (There are also, inscrutably, what look to be cosmological, or perhaps alchemical, books in the potter's direct line of sight.)[336] In this image we see a clear narrative development, laid out in the non-perspectival three-dimensional space of the illustration.

Figure 5.7. Der Hafner. Hans Sachs, in Jost Amman's 1568 Eygentliche Beschreibung aller Stände auff Erden, hoher und nidriger, geistlicher und weltlicher, aller Künsten, Handwercken und Händeln. [Daily Description of all Occupations on Earth, High and Low, Spiritual and Secular, All Arts, Handcrafts, and Trades.] Image: public domain.

The rooms of Mercer's museum possess a similar narratively structured disposition of materials. As one of the museum curators described the original arrangement of the pottery room: [Fig. 5.8.]

> In the room devoted to pottery craft there are two potters' wheels—one an XVIII Century type, in the background. One of these wheels has a very complete set of the hand tools used in the "throwing" of jars or pitchers or bowls etc. At the left is a pug mill, with extra irons, used for grinding and mixing clay. In the foreground are two querns, mainly for grinding glaze materials. There is also a miscellany of moulds, materials used in firing the kilns, also finished and partly finished pottery.[337]

In the current pottery room, as in the original, all of these items are displayed in close proximity. Sadly, this room is one of several of the trades that are not housed in their original rooms, having been relocated by earlier generations of museum curators.[338] On the table surface of the potter's wheel, ribs and jigs sit adjacent to finished pots, whose curves reflect but are not identical to those of the forming tools, suggesting the causal relationship without making a specific claim about *this* bowl and *this* rib. Their arrangement moves from the potters wheels and tools on the right to the partially finished ware directly adjacent to them. To the left, shelves of finished glazed ware show the range of possibilities open to the traditional redware potter. [Fig 5.9.] This storytelling arrangement is repeated in the various rooms of the museum. The result, then, is a material synopsis of the world of work, a broad range of the craftsperson's actions at various sites with various tools. All of Mercer's primary rooms participate in this sort of narrative summation. Even the smaller alcoves demonstrate both the range, and variation, in the tools of a particular variety of work.

Figure 5.8. Original pottery room, Mercer Museum. Image: courtesy of the Mercer Museum Research Library.

Figure 5.9. Pottery wheel with ribs and other tools, and finished vessels. Mercer Museum, present day. Image: author, courtesy of the Mercer Museum.

In Mercer's museum, then, as in his tile mosaics, we see this tradition of the narrative vignette reprised. The vignettes in Mercer's museum rooms, however, do something more. Unlike the above engravings, rather than showing one representative tool for each type of craft activity Mercer shows us at times 10 or 20 variations on the same implement. It seems as if he wants to display not one tool's singular use, but rather the larger context within which that tool is situated, revealing the trajectory of innovation and refinement, the cosmogony of a particular tool, [fig 5.10] in the context of other, related, tools and their overlapping trajectories of refinement. [Fig 5.11.] Perhaps this is Mercer's attempt to hybridize a perennial storytelling impulse with an enlightenment desire for totality. Mercer collects not just one representative artifact for each trade; but also not multiple copies of the same tool. (If the word "copy" can be used in a pre-industrial setting.) Rather, he gathers exemplars of many possible related-but-distinct tool forms. Mercer, it would seem, unlike so many of his Arts and Crafts contemporaries, is interested not just in idealized craft activity, but in the techniques and tools of particular craft tasks, and their evolution as recorded in a chain of purposive artifacts. The story he seeks to tell is one not merely of a sum of 'craft knowledge' but of the process of innovation and invention. These are the stories of the lives of tool users; but also of the generations—and speciations—of their tools. Mercer's rooms begin in vignettes of craft activity, but go on to illustrate variations of type and task, and, rather than depicting a settled and incontestable aporia of tacit craft knowledge, demonstrate a range of possibility.

Figure 5.10, 5.11. Carpentry room, Mercer Museum. Images: author, courtesy of the Mercer Museum.

This is not so much a story about vignettes of tool use, then, as a story of the lives of craftwork. It is a story that could only be told from an archaeological point of view, in which the iterations of tools make visible an evolution of practice. Mercer's rooms do not show the design of one tool or tool-type; but rather a constellation of tools, co-evolving together as the needs of the work grow and change. Further, these vignettes reveal the degree to which we take as axiomatic the materiality of our tools. Yet they point to an underlying nature that is not abstract; and yet not merely, or even primarily, material. To understand this underlying nature we will need to consider the ways that tools, in the context of skilled use, afford the user their uses.[339]

B. Affordance Theory

It is perhaps unsurprising that architects are not overly persuaded by the insights of much of the early work on the psychology of perception, which "was, and is, about phenomena that occur when an observer is stationary."[340] The presuppositions, or framing assumptions, underlying classical psychological research are not a good fit for a discipline which occupies itself with the fabrication of edifices. It is not merely that buildings demand a mobile and engaged perception of and in the messy and immeasurable everydayness of the un-lab-like world;[341] additionally, the architect does not so much engage with buildings as extant facts (as might the conservator, assessor, or real estate agent) as they do as possibilities, and as purposive acts. This undermines the relevance of many of the early findings of the psychology of perception with regards to the practice of architecture. Fortunately, by the middle of the 20th century, psychologists, in what is often called a 'cognitive turn',[342] began to explore alternatives to the jejune empiricism of their field. Foremost among them were the Charles-and-Ray-Eames-of-midcentury-psychology, J. J., and E. J., Gibson.

After a number of articles in the 1950's and 60's exploring the topic of 'environmentally situated,' or 'ecological,' perception, J.J. Gibson in 1973 presented a paper entitled *The Theory of Affordances* at a conference held by the Center for Research in Human Learning at the University of Minnesota. In it, and in the book that would follow in 1979, Gibson formulated what has become one of the most influential theories of perception of the 20th century.[343] In that paper Gibson introduced the theory he and his wife had been developing for over a decade, coining the term "affordances" to describe ways we engage with what we perceive. He began by defining this new term.

> The affordances of the environment are what it offers the animal, what it provides or furnishes, for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment."[344]

Many of the psychologists who took up Gibson's challenge to alter the framing assumptions of their research did so by looking specifically at the effects of being in motion on perception and cognition, replacing the usual laboratory experiments with studies of jugglers,[345] baseball and hockey players,[346] and martial artists.[347] These new research subjects were distinguished by their status as relative experts, as compared to the typical participant in a blind study. Experiments of this type can be difficult to fit in a typical research laboratory, and while attempts have been made to duplicate these findings in a more traditional setting,[348] the result is often a kinematic study absent the factor of expertise.[349] Many of Gibson's inheritors, while expanding the empirical justification and broadening the application of his claims, echo his studied reticence regarding ways in which the faculties of perception might be altered by a deep knowledge of or familiarity with tools and their environments.

Since at least the mid-1990's researchers have attempted to address this omission by designing experiments involving multiple actors in complex, life-like situations. In related disciplines ethnologists and cultural anthropologists have come at this from the other side, performing deep studies of expertise-in-practice, both in the case of literal hammers and anvils,[350] as well as the more immaterial pursuits of scientific disciplines such as biological research, explored by Bruno Latour in *Laboratory Life*. Perhaps as a result, the findings of these lines of inquiry have been increasingly influential on other fields. In 1988, the academic and former Apple vice president Donald Norman popularized affordance theory in his bestselling *The Design of Everyday Things*, the first book to bring these ideas to a broader audience in the design professions.

Affordances, appropriated by Norman from Gibson's work (and the subject of some argument between them),[351] would be central to his argument for user-centered design, as "affordances provide strong clues to the operations of things."[352] As Norman revised it, the idea of affordance was not so much an ontological shift, replacing the primacy of objects' empirical properties with their behavioral connotations, as it was a layer of depth added on top of these material properties. For Norman, as for many designers since, questions of ontology were extraneous, and his pragmatism found a ready audience in the design fields. He critiqued the stylistic excesses of modernism, arguing for a more nuanced, behavioral understanding of the designed object. In his follow up book on the topic, *Emotional Design,* Norman argued that "the best products today, from a behavioral point of view, are often those that come from the athletic, sports, and craft industries, because these products do get designed, purchased, and used by people who put behavior above everything else. Go to a good hardware store and examine the hand tools used by gardeners, woodworkers, and machinists. These tools, developed over centuries of use, are carefully designed to feel good, to be balanced, to give precise feedback, and to perform well."[353] (We will return to this tetrad.)

This is where the question of affordances dovetails with instrumentality, and expertise with the topic of tool-use. The best tools are themselves not only objects of design, but designs produced by expert users. Yet many of these designs are old and anonymous, making it difficult to understand how a consideration of their affordances might enrich the projective work of design, and what a room full of old tools has to offer the forward-looking designer.

C. The Affordances of Tools

We might ask what the tool-room (the figured workbench, workshop, work-space) of the carpenter has to tell us about that common philosophical protagonist, the hammer. Placing the hammer in the carpenter's room, and widening the scope of what we understand as its context of affordances, may allow us to visualize a field of affordances that is structured by the carpenter's past experience, and articulated by his/her moment-to-moment intuition and problem-solving intelligence, a backwards-and-forwards-ness belonging at once to the hammer and the hammerer. These tracks or traces, it may be argued, belong to the carpenter-hammer pairing, forming a 'field' of affordances engendered by the task-at-hand. Some cognitive psychologists even argue that these affordances are material properties of the hammer;[354] but this is rather beside the point. The ontological status of the hammer in itself may be a significant philosophical question; but are external to the context and questions of instrumental use, in which the hammer and the hammerer are joined.

Asking after the nature of the hammer in the moment of its use may remind the reader of Martin Heidegger's perennially inscrutable claim that the hammer only becomes visible when it breaks.[355] Certainly, this is one of his designedly counterintuitive claims. Yet if we consider this claim with the room of affordances in mind, rather than as pertaining to an object alone, the tool-in-use, in the rhythm of expert practice, might seem to disappear: that is, when we are engaged in a skilled, repetitive, task, we begin to see the work through the tool; only when the tool breaks do we fall out of that room-of-affordances and into a place in which the tool presents itself as an object, as that-which-is-indicated-by the symbol (whether phonetic or graphical) "hammer". Heidegger's critique of our naive relationship to equipment is not a metaphysical project, as is sometimes assumed.[356] It is instead—as it would have been originally received, given the context of its time—a phenomenological project.

In this Heidegger was following very much in the footsteps of his mentor at the University of Freiburg, Edmund Husserl, for whom metaphysical claims were "precisely—nonsense."[357] Husserl was also deeply influential on Maurice Merleu-Ponty, and a close reading of his then still unpublished work would provoke Merleu-Ponty's dual critique of idealism and materialism, which, he felt, mistakenly posited the qualities of an item as prior to the item itself, and treated that item in isolation from its context of use. Much of his *Phenomenology of Perception* would be devoted to the correction of this mistaken assumption regarding the priority of objects and their properties. For Heidegger, as for Merleu-Ponty, the cosmogenic properties of the tool are inherently human in their focus and bent. Rather than being concerned with the inauthenticities of technology and production, a question native to the post-World-War-II period, Heidegger's consideration of "equipment" concerns the way the use of the tool alters the perception of work and the nature of embodied human engagement in the world. The invisibility of the tool is in no way a negative judgement. Instead, it is an analysis of the way the tool gets absorbed, in use, into the perceptive filed and action potential of the user. Heidegger's "invisibility," then, is a species of Merleu-Ponty's *haecceity,* an "abductive," "existential rhythm"[358] which unifies sensation and action. Either philosopher might here be describing the "flow"[359] Michael Jordan demonstrated so clearly as a basketball player: that is, to be so immersed in the action at hand we are of a piece with the object, in a moment of reciprocal action and feedback.[360]

In accounts of Heidegger's critique of technology,[361] tools often take a central role, and seem to illustrate a dysfunctional modern relationship to technology and its artifacts. This is often attributed to the dehumanizing ethos of industrial production and the enervating effects of an instrumental outlook. For theorists in this tradition 'instrumentality' may be contrasted in some places to 'poetic', and in others to 'ethical', language-and-making.[362] Even the most prominent of architectural theorists occasionally will occasionally read Heidegger in aggregate rather than distinguishing the vastly different context of his pre- and post-war periods. Such is the case with much of the critique of instrumentality in architecture, from Dalibor Vesely's capable analysis of our "surprisingly limited" understanding of the nature of technology, founded in "our inability to discuss technological problems from a non-instrumental point of view,"[363] to rather more histrionic treatments of the loss of architectural "authenticity" that don't need enumeration here.

We should be careful to place the development of these ideas in the context of their time; and to read our original source without prejudging the work in light of later conclusions. In his early, and broadly influential *Being and Time* Heidegger writes not about instrumentality but about 'equipmentality.'[364] His discussion of equipment[365] in 1927 reads remarkably similarly to the discussions of affordances that would flower in later 20th century philosophy and psychology.

> In our dealings we come across equipment for writing, sewing, working, transportation, measurement. Taken strictly, there 'is' no such thing as an equipment. To the Being of any equipment there always belongs a totality of equipment, in which it can be this equipment that it its Equipment is essentially 'something in order to…' […] Provisionally, it is enough to take a look phenomenally at a manifold of such assignments. Equipment—in accordance with its equipmentality—always is in terms of [aus] its belonging to other equipment: ink-stand, pen, ink, paper, blotting pad, table, lamp, furniture, windows, doors, room. […] Out of this the 'arrangement' emerges, and it is in this that any individual item of equipment shows itself. Before it does so, a totality of equipment has already been discovered.[366]

Treating the tool as object entirely obviates a key distinction: the difference between the hammer of the novice and that of the expert. While it is the same object, with it in hand the expert steps into a vastly different room. This is not a metaphysical statement but and performative and cognitive one: the hammer is a room to think with; to work with the hammer is to enframe the world in its motions, histories, and potentialities.

To begin with, the hammer in the hand of the expert may provide a greater range of use in its designated function—though not always a greater degree of control. In the case of the hammer one need only consider how it is held by the amateur: thumb extended along the haft, hand "choked up" midway to the hammer head. This allows the motion of the hammer head to be controlled with care; but very little force to be exerted on the nail. The amateur then takes a very many short, precise swings from the elbow to drive in the nail. Consider now the handhold of the expert user: thumb wrapping the haft, hand positioned near its base. Much more force can be brought to bear, and the motion is a far more ergonomic one, swinging from the shoulder as well as the elbow, suited to repetition. Significantly, however, the expert has given up some apparent control over the hammer head, to the extent that, once the motion is begun, it will not be arrested until the hammer head meets some resistance. (Yet some small corrections to angle or direction may be made mid-swing.) Each swing of the arm takes into account feedback from the previous action: a tap (or a tap-tap) to set the nail head conveys some information about the density of the wood; confirming or altering expectations set in place by the previous nail. The first full swing buries the nail well into the wood, and any unexpected shift (as from a knot hidden in the wood) can be corrected for as the second swing progresses, the hammer able to shift slightly in its path to meet any slight digression from the expected, adapting on the fly to drive the nail cleanly home. All of this occurs in far less time than it takes to describe it. (Though this may not be said for the novice.)

For while the expert gives up a certain degree of absolute control of the position of the hammer head in three-dimensional space, she/he has gained a smaller, more structured form of control, congruent with efficiency. Expertise thus fuses the demands of control and efficiency, which are commonly thought to be trade-offs, a fusion predicated upon feedback and good judgement. The tool and the material together provide this feedback, which is a source of further affordances perceived by the skilled user, who operates in the unified experience-space of the nail-hammer.

Additionally, an expert is also often more ready to use the hammer outside of its range of designed use, either because of a fund of possible-misuses the expert may recall in response to situational cues; or because, in the confident use of the tool, the expert may improvise a new use on the spot. To an expert, the everyday hammer seems to offer 101 different possibilities[367]—driving nails, certainly, but also pulling them, knocking other objects together or free of each other, levering things apart, leveling doors and windows and driving shims, opening and closing cans, splitting lumber, making rough measurements, straightening saw blades, digging holes, breaking ice, etc. Further, we can see the speciation of the tool into its myriad forms as an exploration of the field of affordances germane to that particular tool. The hammer's uses are primarily constellated around the exertion of force on other material objects, foremost to drive or to remove the nail. [Fig. 5.12.] A mechanical engineer might see a hammer in just these terms, describing the tool as, in essence, one of the seven simple machines (the lever), and determining the functional requirements of its design in relation to that mechanical essence. But other uses of the hammer are more ambiguous, such as tapping a wall to find a stud, transferring a measurement from floor to lumber, or driving the claw down into a pitched roof, mid-slide, to keep from falling off. Not only is the expert more various in his or her uses of the hammer as-designed, she/he is more ready to use the hammer in a way that modifies its designed configuration.

This is reflected in the evolution of the tool and in its present, refined, state, as an exemplar of the sort of incremental design Norman praises and Heidegger assumes as fundamental to human engagement with the world, which is not always reflective of purpose-driven design.

Figure 5.12 Two common types of carpenter's hammer, the rip claw or "framing" hammer, and the curved claw, or "finish" hammer. Despite their common names, both types of hammers are used, at times interchangeably, in the work of both rough and finish carpenters. The differences between the two relate to the overall weight of the hammer—a framing hammer is heavier, between 22 and 24 ounces, versus the finish hammer's 16-20 ounces—and the curvature of the claw. Image: author.

For example, the framing, or "rip claw," hammer compromises on one of its primary design imperatives. As force is applied and the nail pulled, the point of rotation moves toward the head of the hammer, decreasing the tool's mechanical advantage. Compared to the finish hammer, the geometry of which is configured to maintain maximum leverage as long as possible, the rip claw hammer, despite its often longer handle, requires more force to pull the same nail. We can speculate, given the incremental nature of the evolution of the tool, that secondary uses must have made a sufficiently significant claim on the design of the tool to affect its morphology. To put it simply: why is it so hard to pull nails with a framing hammer? [Fig. 5.13, 5.14.]

Figure 5.13 Diagram of the pulling of a nail with a framing hammer, which can be accomplished with the same motion used with the finish hammer, rocking the head along its primary axis, or by moving the handle of the hammer perpendicular to the axis of the head. In neither of these cases is the tool as well configured for the task as is the case with the finish hammer. Image: author.

Figure 5.14 Diagram of the pulling of a nail with the finish hammer, which might be considered the paradigmatic case of the geometry of the tool optimized to provide for a primary design function. Note that the geometry of the curved claw provides for a stable point of rotation of the hammer, such that the user can maintain a high ratio of mechanical advantage throughout the process of pulling the nail. Image: author.

Perhaps the rough carpenter simply makes fewer mistakes than the finish carpenter. Perhaps, conversely, only the finish carpenter cares about protecting the work rather than hacking it apart. But these (dangerous, in certain company) suppositions fail to take into account the range of other activities the framing hammer is used for, which exert their own pull on the morphology of the hammer head. Moreover, the experienced carpenter may improvise to improve the leverage of the tool, as, for example, classic first lesson of the carpenter's apprentice, in which the carpenter interposes a block of wood to change the point of leverage of the tool, effectively recovering the mechanical advantage enjoyed by the curved-claw hammer. [Fig. 5.15.]

Figure 5.15 Use of a block of wood to alter the leverage for pulling nails with a rip claw hammer. Image: author.

Yet it makes very little sense to talk about collecting all the hammers in Mercer's Museum to map the entirety of their affordances, because the affordance is a function of the material, and the expert, as much as the tool. And there are few experts indeed who wield the watchmaker's hammer, the blacksmith's hammer, and the judge's gavel with the same expertise. The constant modifications to a tool's range of possibility is deeply imbedded in not only the particular expertise of its user but with all the other tools in her/his particular room, as these tools manifest their possibilities related to the work at hand. The morphology of a particular tool, then, is a map of (or analogy for) the metamorphosis of a particular consciousness in the locale of a particular task.

Like the mechanical engineer, the contemporary architect understands her/his tools as designed to fulfill certain functions; like the carpenter, she/he often employs these tools in ways that expand or entirely controvert designed use. The tools themselves speciate and evolve in response to this full range of uses: all tools ramify in the field of affordances.

D. An Architect-Without-Tools

This is no less true of the tools of the architect than those of the carpenter. Mercer's organizational chart for the museum (illustrated in figure 5.2) included provisions for the 'tools' of the lawyer, surveyor, and school teacher. His notebook also lists rooms for the Botanist ("West Room 4th"), the Archaeologist ("West room 3rd"), and, indeed, the Architect. Very few of these trades, unfortunately, have received vigorous curatorial treatment in his museum; nor do their artifacts and documents figure substantially in Mercer's original collection. This may have been because these 'trades' were not in the process of wholesale transformation when he undertook his collection efforts; or rather, that their changes were rather more re-organizational than existential.

And while Mercer's museum does provide a room for the tools of the architect, it features not the tools of fabricating drawings, but particularly those parts of buildings, it would seem, least often designed by the architect. [Fig. 5.16.] The room Mercer planned for the tools of the architect's trade is filled not with the implements of drawing but fragments of building, architectural hardware for doors and windows, mouldings, etc., those items today called 'architectural specialties," and only on the rarest of occasions designed by architects.[368]

Figure 5.16. The architect's implements, present day, Mercer Museum. This particular display has been significantly reconfigured, and considerable interpretive signage and lighting added to supplement the relatively meager collection of material artifacts. While the museum does have in its collection several types of graphical tools, such as drawing sets in shagreen cases, parallel rules, protractors, etc., as well as a considerable collection of 19^{th} century surveyors tools, these items are held in the surveyors, schoolteachers, and other rooms, rather than with the "tools" of the architect. It should be noted that in Mercer's museum notebook the planned room for architectural implements was described as "Architecture" rather than "Architectural Hardware."[369] Image: author, courtesy of the Mercer Museum.

Mercer's extensive library included a number of architectural treatises, including several editions of Vitruvius, Ruskin, Morris, and the then-immensely popular 8-volume set titled *The Builder's Dictionary: Or, Gentleman and Architect's Companion, Explaining Not Only the Terms of Art in All the Several Parts of Architecture, But Also Containing the Theory and Practice of the various branches of that Useful and Noble Art requisite to be known by Masons, Plaisterers, Turners, Carpenters, Painters, Carvers, Joiners, Glaziers, Statuaries, Bricklayers, Smiths, Plumbers, &c. Also necessary Problems in Arithmetic, Geometry, Mechanics, Perspective, Hydraulics, and other Mathematical Sciences. Together with The Quantities, Proportions, and Prices of all Kinds of Materials used in Building; with Directions for Chusing, Preparing, and Using them: The several Proportions of the Five Orders of Architecture, and all their Members, according to Vitruvius, Palladio, Scamozzi, Vignola, M. Le Clerc, &c. and also by Proportions of Equal Parts.*[370]

Far more prevalent in Mercer's library than treatises, however, were practical manuals on carpentry, ironworking, and various other trades. The closest Mercer came to such a manual for current architectural practice circa the late 19th century was the 1853 manual *The Builder's and Workman's New Director: Comprising explanations of the general principles of architecture, of the practice of building, and of the several mechanical arts connected therewith; also the elements and practice of geometry in its application to the building art.* Its author, Scottish architect and inventor of 'draughtsman's instruments' [fig. 5.17] Peter Nicholson not only lays out all of the practical, theoretical, and geometrical knowledge of his discipline which we would expect of a treatise in the Vitruvian tradition, he also provides detailed drawings of a number of the instruments to be used in architectural drawing; as well as a highly unusual (and one of the earliest of its kind) pictorial depiction of concrete formwork in an architectural treatise.[371] [Fig. 5.18.] The book is illustrated throughout with examples of both geometric calculation and construction representation, and includes a lengthy section of practical instruction on drawing in both orthographic projection and perspective. Laid out in this one volume, quite explicitly, are the tools of the Architect's trade circa 1850.

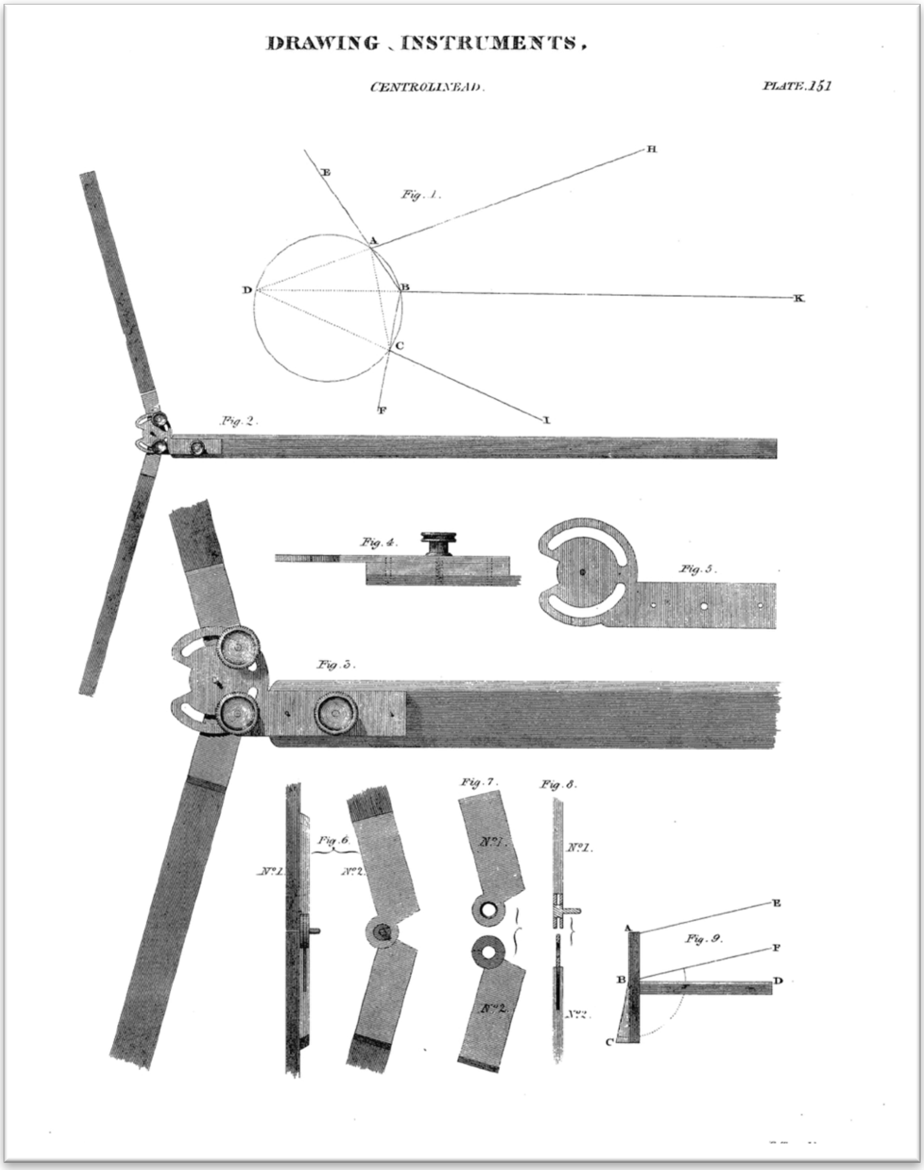


Figure 5.17. The centrolinead, a drafting tool designed by Peter Nicholson. There is something stirringly, steampunkily beautiful about Nicholson's centrolinead. Like a saber-tooth tiger of architectural tools, it belongs to a whole class of drawing implements now extinct, with which, in the 19th and 20th centuries, architects regulated their drawings and through which they altered the affordances of their workplace. Image: Nicholson, plate 151, p411, public domain.

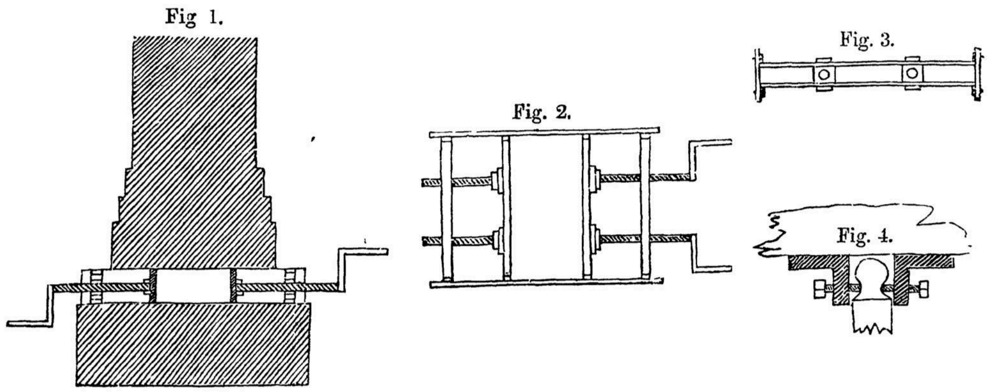


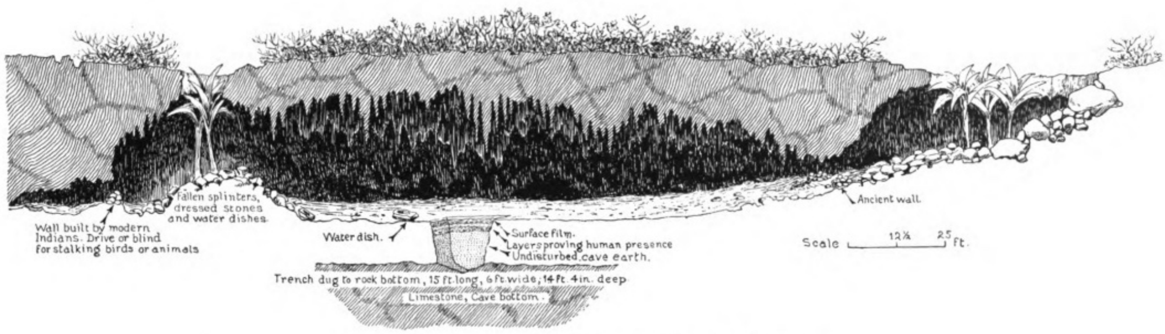
Figure 5.18. Concrete formwork used for underpinning/stabilizing existing structure, described and illustrated in Nicholson's treatise. Image: Nicholson, fig 1, p445, public domain.

In his collection of surveyor's instruments located on the fourth floor of his museum (and grouped with the tools of navigation), Mercer has several surveyor's compasses; in the carpenter's crowded room he displays not only planes and saws but also a caliper rule and several parallel and folding rulers. Elsewhere in the museum there are slide rules, kits of art supplies, inkwells and pounce boxes and other 19th century writing and drawing implements. Notably absent is the workplace of the architect, or any display with reference to the site of work, as is the rule with more manual crafts. Given Mercer's acquaintance with some of the most eminent practitioners in, and exposure to the standards books and reference materials for, the field of architecture, his elision of the space of architectural practice and the minimal collection of its representational technologies must either indicate an unvarnished faith in the unchanging perpetuation of these instruments (a point of view which Mercer did not evince in any of his other craft-collections) or something more critical and circumspect.

We could attribute this omission from the museum-of-all-tools to a preference for the artifacts of manual labor (a warrant subsequent curators of the museum may have inferred and perpetuated, given how the collection has developed) but the examples listed above mitigate against this reading. We could attribute the missing tools to Mercer's unfamiliarity with their use or diversity—yet books such as the one described above would have certainly suggested the latter; and as for the former, we should remember that Mercer was an archaeologist, and created numerous technical drawings to accompany his publications.

It is not that Mercer was incapable of producing scaled, orthographic drawings. His earlier archaeological studies included detailed drawings at both the scale of the site and the detail; [fig. 5.19] and his studies of tools often included technical—even, at times, multi-view orthographic projections. [Fig. 5.20.] While none of these drawings approach the expertise exhibited by the most eminent architect-authors of his time, they are clear and technically correct.

Fig. 16.



Water-cave at the ruins of Oxkintok, ten miles east of Maxcanu.

Fig. 5.19. A section drawing from Mercer's Hill Caves of the Yucatan. *Image: public domain.*

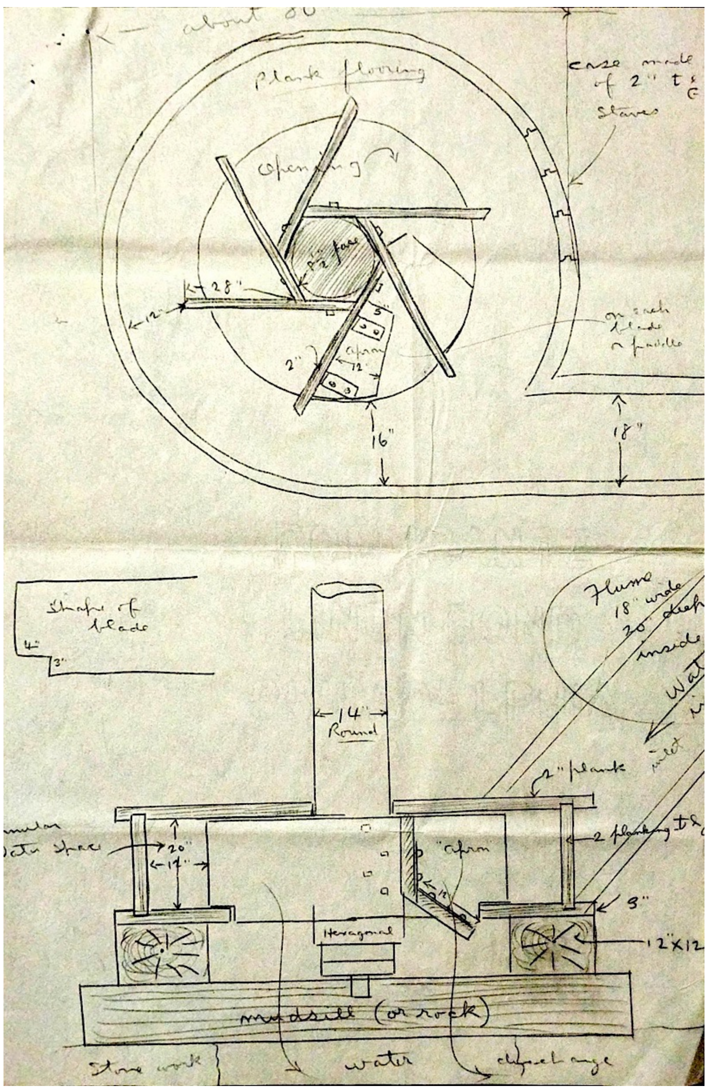


Fig 5.20. Sketch accompanying manuscript copy of "Notes on the Norse Mill." Unpublished. Image: courtesy of the Mercer Museum Research Library.

Mercer was familiar with the fabrication of technical drawings; yet in his own architectural work, while he may have sketched in the various standard orthographic projections, he did not create measured drawings with drafting instruments. This leaves us with the unenlightening prospect of a wholly tacit criticism of architectural representation—unless, for Mercer, the tools of the draughtsman are simply not the tools of the architect.

The Tools of the Architect

In his time supplying tiles to projects in the full range of building typologies, Mercer engaged with a great many architects, every one of whom, presumably, produced a set of construction drawings for their project. For these projects Mercer supplied prefabricated, or made-to-order, suites of tiles designed for complex decorative and illustrative installations. Often, for the more complex installations, he would also supply full scale drawings to coordinate the installation of these complex mosaics or brocades. In no case would Mercer have accepted a situation in which the tile was initially designed by the architect, to be refined and manufactured by the Moravian Pottery. (In fact, Mercer's most significant falling-out with his lifelong friend and chief assistant Frank Swain occurred when, not long after the move into the new pottery, Mercer found laid out to dry a tile design not his own. This resulted in a heated argument and Swain leaving for a three-week sojourn in Philadelphia.[372])

These full scale drawings, then, should not be confused for 'shop drawings'. They were not intended to be used as a device for the securing of 'approval to proceed' from the architect or client. Rather, they were a means to facilitate the assembly of the complex, puzzle-like arrangements of tiles. This may seem to leave aside much of the architect's work—and thus many of his/her tools. Yet from the point of view of the affordances of these drawings, it may be fair to argue, in Mercer's defense: if a verbal conversation suffices for approval-to-proceed, what use any further drawing? If a collection of sample tiles, a profusely illustrated catalog, or a showroom visit combined with the exercise of the imagination, can paint a picture of the future building fitted out with Moravian tiles, why belabor the point with a constructed perspective or *analytique*?

Only the drawings that provide affordances which cannot be provided by more economical means are necessary; yet this question of 'necessary drawings' is a thorny one, subject to the unique affordances of graphical depictions. If, as Gibson proposed, "time and space are not empty receptacles to be filled; instead they are simply the ghosts of events and surfaces,"[373] then, in a Gibsonian view, symbolic representation of information is never carried out on a blank slate, but rather in relation to shared experience or information. If indexical at all, the sign references not the encyclopedia but the job site. It is not the blank page or the infinite perspectival recession of three dimensional space upon which graphical communication is built but rather the common ground of the work it either anticipates or, after-the-fact, describes. Gibson's insights decouple time and space from their long-held primacy in the cosmology of architectural fabrication. If abstract and undifferentiated space can only be had through the deletion of preexisting sites, and the empty anticipation of unplotted time comes always at the expense of the perpetually retrograde amnesia of "the new", where do we begin?

Perhaps, with the handle. More than anything else, the Mercer Museum is a museum of handles. It may be only in juxtaposition to collections of more recent material culture, but room-to-room, the remarkable recurrence of well-made handles reinforces one of Mercer's key claims, which he articulated most clearly in his final book, *Ancient Carpenters' Tools*.

> Yet, when the specimens here shown are compared with what ancient tools of like character remain to us in museums, an important oversight appears. Attention is again called to the fact that the evidence of these tools of the eighteenth century has been overlooked by archaeologists, who, concerned only with the past, often fail to

> account for the interval between it and the present, since many tools, once existing and very necessary to explain human effort, because made of or mounted with perishable materials, cannot be found or recognized in the excavations of Assyria, Italy, Greece and Egypt. If, therefore, in these specimens, the past has survived into the present, the more we study them the more certain it becomes that a gap of two thousand years can often be filled with implements in perfect condition, comparatively modern in date, but very old in type, not excavated or studied by the archaeologist, yet none the less the master-tools of ancient and extinct peoples.

If in Mercer's evocation of a historical telos we hear echoes of the cultural imperialism common in the 19th century, we should take it in the context of its own time; the process of technical innovation, Mercer is arguing, is both evident, and proceeds in the smallest of increments, and these incremental advances are anonymous and cumulative, gradually rising to an apogee of functional appropriateness.

To put it in Gibson's terms, while the primary affordance of the tool may be achieved early on (a good rock will drive a nail) many other affordances may be gradually sedimented in the tool (its comfort in the hand, durability, accuracy, ability to pull as well as drive nails, or split shingles) and the tool may speciate into a thousand closely allied forms, each providing one of a thousand infinitesimally different affordances. The aporia of the tool, then, is no one Platonic idea of the hammer, but rather a contextual perfection, a hammer belonging to one craftsperson, particular school, or tradition of making, each exemplar winnowed uniquely by the engine of expert use and its economies, and necessities.

This, then, is why it is worth displaying multiple iterations of the same tool—not to celebrate difference for itself, but as illustration of the variety in necessity, and the necessity of variety. If the nature of design perfection is incremental and anonymous, proceeding without plan or lasting trace, then, for Mercer, the architect must be horribly confused about the object of his or her discipline. If we look at buildings archaeologically, the *individuality* of the individual building is not significant, and therefore neither is the drawing that celebrates such individuality. Rather, the building is significant as an embodiment of the life-stories it contains. This may be why Mercer designed his buildings 'from the inside out;' and why the pursuit of fixed and final representations would have seemed to him wholly extraneous to the core purposes and activities of the architect. For Mercer, in this sense, the real work of architecture is to provide ever-evolving rooms for ever-changing lives. Even as Mercer built the museum, his collection was expanding, and altering. Some of the last rooms built at the top of the structure are built precisely to fit their contents. When we reach the highest room, we look up—and see a gallows armature and the rough concrete ceiling through the trapdoor in the gallows floor. In that moment we join Mercer where he is, in the subterranean labyrinth of the material past.

E. Inventing New Tools

Despite Gibson's direct treatment of the making of tools as an exemplar of affordances at work, and Norman's elevation of the tools of gardeners and machinists—of expert manual work—as being particularly well designed, neither of these thinkers treats tools particularly like those Mercer developed in the construction of his buildings. Gibson's discussion of factors like graspability would seem to apply to the category of 'tools' generally; in Norman's account tools are a subset of the category 'products' or perhaps 'objects of design'.[374] These accounts share a presupposition of the locus of affordances inhering in a particular, present-to-hand, object or tool. Yet if I need to hammer a nail and a hammer is not nearby, I may try with the back of a hatchet; and when I need to split a piece of kindling without my hatchet, the hammer's claw will suffice (provided it is a rip claw hammer). These improvised solutions, to use the hatchet *as if* it were a hammer, seem to be aberrations, perhaps design failures (or opportunities, thinks the inventor searching for a next patent). Yet tools often come about in just this fashion: some new purpose calls for an affordance that is not well provided by an existing or available tool; a new tool is improvised in response to this affordance-call.

In creating the curved wire tool for beam, and presumably cornice, fabrication, Mercer is facing the need to do something with speed and accuracy that has not, in just this way, been done before. This calls not merely for skilled work of the hands: it calls for a tool shaped to the desired outcome. He casts about for such a tool (he need not be physically in a workroom, but he acts as-if he is), for something that will facilitate the desired outcome with best speed and accuracy, discovers that such a tool does not exist for the fabrication of profiles in concrete. He determines that the time and effort required to fabricate such a tool will be more than made up for in either the time it saves down the road; or the accuracy it provides in accomplishing the desired result.

At this point, the work of analogy begins. He thinks back over other, similar problems, and allows his rich reservoir of craft experience in the fabrication of clay at the pottery to suggest an answer. Perhaps he thinks of other, similarly vexing, problems of translating "millwork" into a foreign material. At the pottery, as Reed explains,

> From the start, Mercer designed three-dimensional architectural elements for use with his other tiles. He produced ceramic moldings, brackets, cornices, shelf elements, engaged columns, and other shapes to frame and accent his tile installations. Most of these molding tiles never appeared in his tile catalogues, although molds and templates for over a hundred designs exist. He cast a few of these shapes from clay models; most he made by dragging metal templates based on typical molding styles over wet plaster.[375]

All of this, of course, may flash through the mind in a moment, the hands already at work reaching for a scrap of wood or roll of baling wire even as the sequence of thoughts is completed.

We should examine each of these steps in turn to better understand how improvisation, catalyzing affordance, gives rise to innovation. It begins with the opening of the field of affordances.

This is the moment in which anything can become a hammer: between the task at hand and the tools in the room, a network of affordances forms. Some of these might be almost always ready to hand, depending on the trade, the setting, and the individual craftsperson. Each worker might keep a slightly different 'kit'; this applies to factory-made tools as well as hand-made ones—every electrician will have her own best wire pliers; every illustrator his own particular color range of AD Markers. Other tools are held in common—the table saw, the gene sequencer. Some may be so distant their unique affordances are not considered a part of the place-of-work; yet even the astronomer who, after months of waiting in the queue, is afforded five minutes on the Hubble, has for that brief time the sharpest eyes in the world.

Remoteness or irregularity of use is no disqualifier. (Indeed, given the scale of their work, the eyes of the astronomer may be proportionately closer to her tool, floating serenely overhead in low earth orbit, than the jeweler ever comes to his loupe.) Yet all of these tools stretch out their net of affordances: to the potential user; and, indeed, to each other, inasmuch as, without a moment's hesitation, the carpenter's square might be used in tandem with her Skillsaw; or the dentist's mirror with his drill.

The affordance call, then, is the moment after the hand begins moving toward a tool, and before that tool is pictured in the mind[376]: the moment our expertise most purely uses us.[377] However, something else happens when the hammer is missing from its hook, the beaker from its shelf, the knob from the microwave dial. The affordance-call stretches; and as it stretches out in time, it broadens in category, searching for hammerness, beakerness, (or knobbedity) in other objects.[378]

This is a remarkable moment, of plasticity, of sympathy. In the case of the missing tool, this moment of openness collapses rapidly, as either something-will-do, or we turn, in frustration, to search out the missing tool. But this is not what happens in every case, because sometimes—in the right setting, with the right infrastructure of regulated craft action—that moment continues to stretch, and a new tool is invented to fill the gap in the network of affordances. A new node forms in the larger system of skilled work.

F. Networks of Affordance

As was the case with Mercer's curved wires, the new tool often belongs to a family of similar objects, those tools which, as the net of affordances of stretched, were closest to serving the purpose. Often this family is clearly—morphologically—akin. We see this on the wall of Mercer's carpenter's room, where hatchet hangs next to hatchet, each hatchet haft and head only slightly different in shape and profile from the next. [Fig 5.21.] Yet each is different, forged, presumably, by a different smith in a different time to a slightly different internalized performance criteria or explicit request. And while we may tend to see these differences as merely the quaint evidence of hand crafted variety unavoidable before the advent of mass production, the differences negligible in each category of tool, such a view occludes how, in a room full of such tools, the network of affordances is broader, and richer, and more complex, than when we stand before a single iteration of the type.

Figure 5.21. Axes, hatchets and drawknives in Mercer's carpenter's room. Image: author.

And when those enlarged networks of affordance reach out and overlap—as they often do in Mercer's rooms—they begin to suggest the interpenetration of even visually dissimilar tools. Next to the hatchets, for example, an array of drawknives hang. These are very different tool-forms; yet for the traditional carpenter familiar in their use, the drawknife and the hatchet hold entangled affordances. With both tools the carpenter shapes raw material, such as a log, and readies it for the further craft actions that will render it a beam. [Fig 5.22, Fig. 5.23.] Using both tools the carpenter stands alongside, or even astride, the log, reading the grain of the wood and working 'with the grain' (to the craftsperson this is a directional indicator) to facilitate efficient work. In Donald Norman's terms, there is a high degree of feedback between tool and user in these cases, each swing of the hatchet or pull of the knife giving more information about the density of the wood, direction of the grain, location of knots, and other irregularities. The skilled user reacts to all these irregularities in his/her next motion, incorporating that momentary knowledge of the topology and composition of the log into precise bodily motion; and the tool, as it is repaired, upgraded, or replaced, incorporates this haptic field in its own formal evolution. [Fig. 5.24.]

Figure 5.22. Use of the drawknife to plane timber. The carpenter in the foreground is at work with a medieval frame saw; the carpenter in the background is planing a beam or plank (the image is unclear) with a drawknife. Image: Der Schreiner. Hans Sachs, in Jost Amman's 1568 Daily Description of all Occupations on Earth…. / public domain.

Figure 5.23. Use of the broadaxe to square a log (foreground—it should be noted that the head of the axe is shaped more like a traditional hewing axe, which may indicate this particular illustration was made early in the evolution of this particular genus of tool). Proceeding into the background we see the use of other tools of timber framing. While the German "Zimmermann" (this figure) and "Schreiner" (previous figure) are both translated commonly as 'carpenter,' the distinction is similar to what we would call in the United States the 'rough carpenter' and the 'finish carpenter' or even 'cabinet maker.' (Mercer used the term 'joiner' for the finish carpenter, and British English retains the term to this day.) Image: Der Zimmermann. Hans Sachs, in Jost Amman's 1568 Daily Description of all Occupations on Earth…. / public domain.

Fig. 79—The Chisel-Edged Broad Axe with Bent Handle

As described in the text, these axes differ importantly in construction from those illustrated under Figure 82. The photograph does not clearly show that, unlike the latter, all are sharpened on the right side of the blade and that the handles, as in broad axes of this type, are all bent to the right, except one abnormal axe, No. 7656, here imperfectly shown in the photograph, basilled, eye-swollen, and handled in reverse, which has been made for a left-handed man.

According to Mr. Wilson Woodman, who, at the building of his barn near Wycombe, Bucks County, Pa., in *c.* 1860, helped hew the timbers, the fresh-felled tree, laid about knee high above the ground on underplaced cross strips, was first pared to the brown under-bark with the draw knife, then white chalk-lined on the brown for the hewing line. Thereupon, the workman standing on the log "scored it in," preferably for ease and speed, with a common felling axe, *i. e.*, hacked into the log side with a succession of deep cuts, and split off the intervals nearly to the chalk line. Standing then on the ground with the log on his left hand and close to his left knee, he held the axe right-hand foremost with its flat side against the vertical log face, and hewed with both hands, not longways with the grain but diagonally downward across it.

Figure 5.24. An illustration from Mercer's Ancient Carpenters' Tools, with his caption describing drawknife and hatchet use. Image: Ancient Carpenters Tools / public domain. The caption indicates that 19th century timber shaping took three steps: "the fresh-felled tree, laid about knee high above the ground on underplaced cross strips, was first pared to the brown under-bark with the draw knife." Second, "the workman standing on the log 'scored it in,' preferably for ease and speed, with a common felling axe, i. e., hacked into the log side with a succession of deep cuts, and split off the intervals nearly to the chalk line." Third, the log was "hewed with both hands, not longways with the grain but diagonally downward across it."

There is considerable overlap between this bodily knowledge of grain, resistance, and other feedback between the hatchet and the drawknife (as there is indeed between the planes, chisels, and mallets closer to hand in the vicinity). These haptic forms of knowledge are held very much in overlap in the expert user, for the ability to 'read the log'—that is, assimilate and act on the complex feedback of the tool, given limited cues and a rapid pace of work—is an essential faculty in the use of both hatchet and drawknife.

This bodily knowledge of the range of possibilities a certain material or work-piece provides is not so much an index of possible uses as it is a familiarity with the way a material characteristically behaves. The characteristic behaviors of the material are known through the touch of its apposite tools; these tools form a constellation of possible use; and the task at hand activates this constellation.

All of this is taken up into expert practice, and transformed into a sort of anticipatory-feedback. The drawknife user knows to 'follow the grain' around knots of a certain size or density, because of how they would feel, of how the tool would behave, were the tool pulled straight through.

Let us return then to the moment of the act of design, with Mercer reaching out as-if he is in the workroom. This *reaching-out-as-if* is dependent upon the individual expertise, the craft-past, of the reacher. In Mercer's case the design of formwork for cornices calls for the affordances of unknown tools, a call that propagates into a constellation of possible-tools, which is not necessarily the room of work immediately at hand but is rather the room as-if it held the full range of tool-afforded possibilities suggested to the worker by the work. Mercer's as-if room is filled with tools that shape clay. So it is only natural that further tools that evolve in his practice, even if their ultimate end is the shaping of materials other than clay, owe their heritage to the family of potters' tools. This also explains why Mercer would turn so readily to the use of clay in the fabrication of concrete forms: the inclusion of clay in the process afforded him many more tools.

G. Propositional Affordances

Mercer's rooms show tools not merely as individual objects or evolving types, but in their broader context of affordances and interrelationships. The Dutch psychologist Julian Kiverstein has written on this same topic—the question of a larger field, a context or 'landscape' of affordances.[379] With collaborator Erik Rietveld he has extended this analysis to specifically architectural settings.[380] Architects, they argue in a 2014 essay, use affordances (knowingly or not) to solve design problems. This is a significant expansion of Gibson's original premise, which held affordances to belong to the realm of perception (prior, that is, to deliberative decision-making). The object-oriented affordances of Donald Norman may have attributed purpose to affordances, but did not alter their order in the act of perception and action. Rietveld and Kiverstein, following on recent work in this field,[381] want to propose that immaterial things create affordances too, such as uses of language or representations. "Language," they write,

> opens up the possibility to be held to account by other people in our community for what we say and do. We argue that these practices of giving and asking for reasons can also be made sense of in terms of skilled engagement with affordances. Abilities and practices like these typically have not been recognized as within the scope of investigation in ecological psychology. It is a virtue of our framework for understanding affordances that it can also be applied to allegedly "higher" human abilities, such as the capacity to make correct perceptual judgments, an ability that is fundamental to propositionally articulable forms of knowledge. For instance, when we are out looking for mint leaves to make mint tea and a friend incorrectly reaches for a nettle we can stop him or her by making the judgment, "That is not a mint leaf; that is a nettle." In doing so we are skillfully engaging with the affordances the nettle leaf has in our form of life[.][382]

Rietveld and Kiverstein's insight here is that the affordances of nettle leafs, teapots, and hammers are inextricably bound up in the social net of using and making. But their claim is more specific than merely that human communication is integral to the affordances of objects. Human communication, or more specifically "propositionally articulable forms of knowledge" are, by this argument, no less materially instrumental than the tool-in-hand. For these thinkers, *propositional* affordances—that is, affordances produced by linguistic structures—are not dissimilar to the affordances provided by material tools.

The problem with 'propositional affordances' as a conceptual framework is that it threatens to return us to the very dichotomy between tacit and explicit which proved problematic at the outset. This is not so much a flaw in Kiverstein's theory as a byproduct of his chosen terminology. The language-use studied and theorized in psychological fields are too often taken to be paradigmatically propositional.

This tendency persists, even in those theorists most attentive to the implicit. Michael Polanyi's development of the theory of tacit knowledge sprang from this dichotomy. As he originally laid out his theory, what he called the 'functional structure' of tacit knowledge consisted of "muscular acts" and "elementary movements":[383] in this context the tacit is that *from which* we begin to specify the unspecified. Contrasted to this, he called the 'phenomenal structure' of tacit knowledge that which consists of the 'performance to which our attention is directed,':[384] the tacit, then, is that *to which* the explicit is pointed. Tacit knowing, in both of these cases (Polanyi explains) is the sense of meaning from which, and to which, our actions are directed, the inchoate chaos from which the sensible universe is formed. This dichotomy of from-to, and to-from, maintains an arms-length distance between language and tacit knowledge. Like Merleu-Ponty, Polanyi illustrates this meaning-at-a-distance with the metaphor of the blind man's stick.[385] "We become aware," he notes, "of the feelings in our hand in terms of their meaning located at the tip of the pole or stick to which we are attending. This is so also when we use a tool."[386] From this observation of 'meaning at a distance'

Polanyi derives his terminology for the bifold nature of tacit knowledge: the 'proximal' and the 'distal'.[387] The proximal is muscular and manual and immediate; the distal is performative and semantic and mediated. He calls this the 'semantic aspect' of tacit knowledge. Both are tacit; yet they are distinct forms of knowing.

Yet if the past two chapters have shown us anything, it is that the seemingly proximal is part of a system of contextual meaning; and that this network of affordances does not distinguish between the in-hand and the ready-to-hand. Perhaps more surprisingly, the affordances of our tools do not privilege fact over fiction—quite the opposite: the affordance call reaches out into the ramifications of our tools, and follows the branches of their evolutionary tree *as if* they were all in the room with us.

This is a magisterial act of the imagination: but we should remember that the imagination is often clue-driven, and that tools hold in themselves, and open for us, many more affordances than we can entertain unprompted. The more manual and 'proximal' our acts, the more they are connected to the 'distal' infrastructures of socially embedded meaning and tacit craft knowledge.

James Greeno, one of Gibson's inheritors, writes of the difficulty of designing psychological experiments with a manual component: "Symbolic representations of information in these situations are very tangible, and the theoretical analyses that turn out to be productive are at the level of functions that are accomplished by groups of people interacting with each other rather than of hypothetical mental representations constructed by and operated on by individuals."[388] That is to say, researches presuming cognition on the model of the human mind as a 'black box' in which 'representations' are made, and from which an individual draws her/his innovative practices, don't 'turn out to be productive' for the analysis of collaborative manual production and tool use. This is because, as we found with Turnbull and Latour, that while our tools may be 'portable inscriptions,' their meanings are not primarily lexical; nor are their uses simply material.

This suggests that dichotomies of near and far, of 'lower' and 'higher' functions; of *instrumental* and *poetic* making, remain with us not for their accuracy or descriptive power but rather as the last vestiges of a positivist tradition that, in the foment of experiment and improvisation, melts into air, and we, engaged in the work at hand, enter upon a seamless interwoven state which encompasses both worker and work, individual and social group, explicit and tacit knowledge—everything in the room; and quite a bit beyond. (*Plus Ultra,* as Mercer was fond of inscribing on buildings. [Fig 5.25.]) And just as our tools may function as inscriptions and documents, our documents may function as tools. How they function as such is the subject of the next chapter.

Fig 5.25. Plus Ultra *mosaic, embedded in the wall in several permutations at the Moravian Pottery. Image: author.*

Chapter 6: Architectural Ephemera and Ad-Hoc Tactics: the Semantics of Construction Documents

…a radical change in our understanding of the role of drawings in architecture…

-Marco Frascari

Technologies are artificial, but–paradox again–artificiality is natural to human beings. Technology, properly interiorized, does not degrade human life but on the contrary enhances it. The modern orchestra, for example, is the result of high technology. A violin is an instrument, which is to say a tool. An organ is a huge machine, with sources of power–pumps, bellows, electric generators–totally outside its operator. Beethoven's score for his Fifth Symphony consists of very careful directions to highly trained technicians, specifying exactly how to use their tools. Legato: do not take your finger off one key until you have hit the next. Staccato: hit the key and take your finger off immediately. […] To achieve such expression of course the violinist or organist has to have interiorized the technology, made the tool or machine a second nature, a psychological part of himself or herself. This calls for years of 'practice', learning how to make the tool do what it can do. Such shaping of a tool to oneself, learning a technological skill, is hardly dehumanizing. The use of a technology can enrich the human psyche, enlarge the human spirit, intensify its interior life. Writing is an even more deeply interiorized technology than instrumental musical performance is. But to understand what it is, which means to understand it in relation to its past, to orality, the fact that it is a technology must be honestly faced.

- Walter Ong[389]

The tools of early American industry that Mercer amassed reside today in the rooms of the museum he built to house them, as much a museum of trade-rooms as of their apposite tools. In the room of the horn-worker, we see the knives and awls of the trade; we see work half completed and raw material dressed for future tasks. But more than that we see into (dimly, briefly) the life of the horn-worker. The room the school teacher calls up the pedagogy of the late 19th century; even the engraver's alcove illustrates the ethos of that solitary art in and through the evocation of the affordances of its many tools and tasks. It is one thing to see a collection of engravings; quite another to see the world as the engraver does, full of graven objects and their facture. But the museum has many hallways, stairways, vaults and columns, doors and windows, and other non-rooms. It is in these spaces that we may, perhaps, begin to see into the world of its builders, and in so doing to move past caricatures of architect and builder to understand the living dialogue that moves from 'lines in the mind' to material fact, and back again, in an act of weaving that well may be (with apologies to Semper) the most primordial form of human craft. In Mercer's museum we find an example of a building built without reference to permanent drawings of any kind, though there are copious records of a more informal sort. It is from these carefully preserved sources that we must try to reconstruct the fabric of an architectural process carried on predominately through "gesture and talk."

In chapter 4 we discussed how craft knowledge, embedded in tacit practices, structured Mercer's work; in chapter 5 we moved from a discussion of the tools held in the museum to the tools used in the creation *of* the museum. Chapter 6 will bring these two threads together to examine how the craft knowledge accumulated in his processes found its outworking in a highly informal, yet reliable and efficient, system of documentation. While at first glance it may seem that Mercer *had no* system of documentation, close attention to the interface between his planning for, and implementation of, innovative practices on the job site will reveal a sequence of exploration, development, instruction, troubleshooting, and record keeping that is very similar to the arrangement of project phases typical in architectural offices to this day (schematic design leading to design development, followed by construction drawings and specifications and construction administration).

Just as the tools collected in the museum shed light on how the tools used in the making of the museum came to be and functioned, Mercer's documentary process will be seen to possess similar properties, in themselves broadly instrumental but connected to a larger context of affordances. In this way the role of documentation, in construction, is broadly similar to the role of tools generally, and particularly to the nonce and ad-hoc tools invented for each project and specific to the needs of site, expertise, available materials, and the community of building.

If, for Mercer, the tools of his architecture were not the T-square and the drafting desk; and not, concomitantly, the set of construction drawings that would result from their use, we should look closely at what took the place of these things. This will require, first, a close look at the documentary evidence for the museum, as it is the most mature, systematic, and ambitious of Mercer's projects; and second, a reconsideration of the nature of documentation.

That a certain subset of the passages in Mercer's notebook may be distinguished from the others through textual analysis, and that these passages form a sort of ur-specification, and indeed have a more than passing resemblance to what has become the standard language of architectural specification, will allow us in part 1 of this chapter to consider an archaeology of the language of specification.

In the second part of the chapter we will consider how drawings work, and the ways in which Mercer's notebooks challenge conventional theories of architectural representation, and offer an expanded sense of how drawings might structure the act of building.

A. An Archaeology of the Language of Specification

Several things recommend the museum construction notebook as the best example of its kind, and the most clear and concise summary of Mercer's unique process. Certainly, the Museum building it is the most rigorous and complex of Mercer's three major works, both spatially and technically (if not always decoratively) and, as a part of the larger fabric of Doylestown and a programmatically diverse cultural institution, it comes the closest to having relevance for today's complex buildings and sites. It is also the most fully documented. For while the notebook for the Museum occupies fewer pages than that of Fonthill, it is more concerted and balanced (in terms of the modes discussed in chapter 2). It is also accompanied by a detailed ledger recording dates, materials, and labor on the project. This is similar to Mercer's standard procedure at the Moravian Pottery. The primary written document at the pottery was the sales and expense ledger, which ran to 8 volumes over the years between 1899 and 1945. While Mercer died in 1930, the pottery remained in production and Swain continued to keep the ledger. Mercer also kept detailed kiln logs between 1900 and 1927, as well as records of orders, large format drawings of tile designs, printed catalogues, and various correspondences and other ephemera. The records of the building's construction are considerably more sparse. And Mercer's more speculative explorations, which filled the Fonthill notebook, in the Museum notebook find a balance with his other modes of representation, as many of his characteristic details have been worked out, and are revisited only as necessary to explore improvements in their process of fabrication. Yet the explorations of building precedent, detailing, and sequence undertaken in the Fonthill notebook are continued in the Museum notebook. Thus these experimentations and explorations were evidently a necessary part of the chain of operations involved in making the building. That is to say, the documentary process Mercer arrived at in his most mature project—the construction of a multistory reinforced concrete institutional building built without measured plans or comprehensive specifications—included not only record-keeping, but a multi-modal development and refinement of architectural precedents, details, and methods of building, sustaining an underlying experimental process.

In 1910 Mercer began keeping his planning notebook for the museum, working through floor layouts, details, and material specifications. By 1913 Mercer had broken ground on the building, and continued writing in the same notebook, keeping notes on the progress of the project. In 1913, supplementing the notebook, Mercer began a ledger of the project costs, detailing both materials and labor on a daily basis. Each worker is listed by name under the crew foreman, with the days and fractional days per week worked and in some cases the specialized task they were hired to complete. In addition to materials' sources and costs, staging, hauling, and other "soft" costs are included. The only scaled drawing in the archive is a 1917 plat completed by the local surveyor W. O. Weisel dated after the new museum building was complete. [Fig. 6.1.]

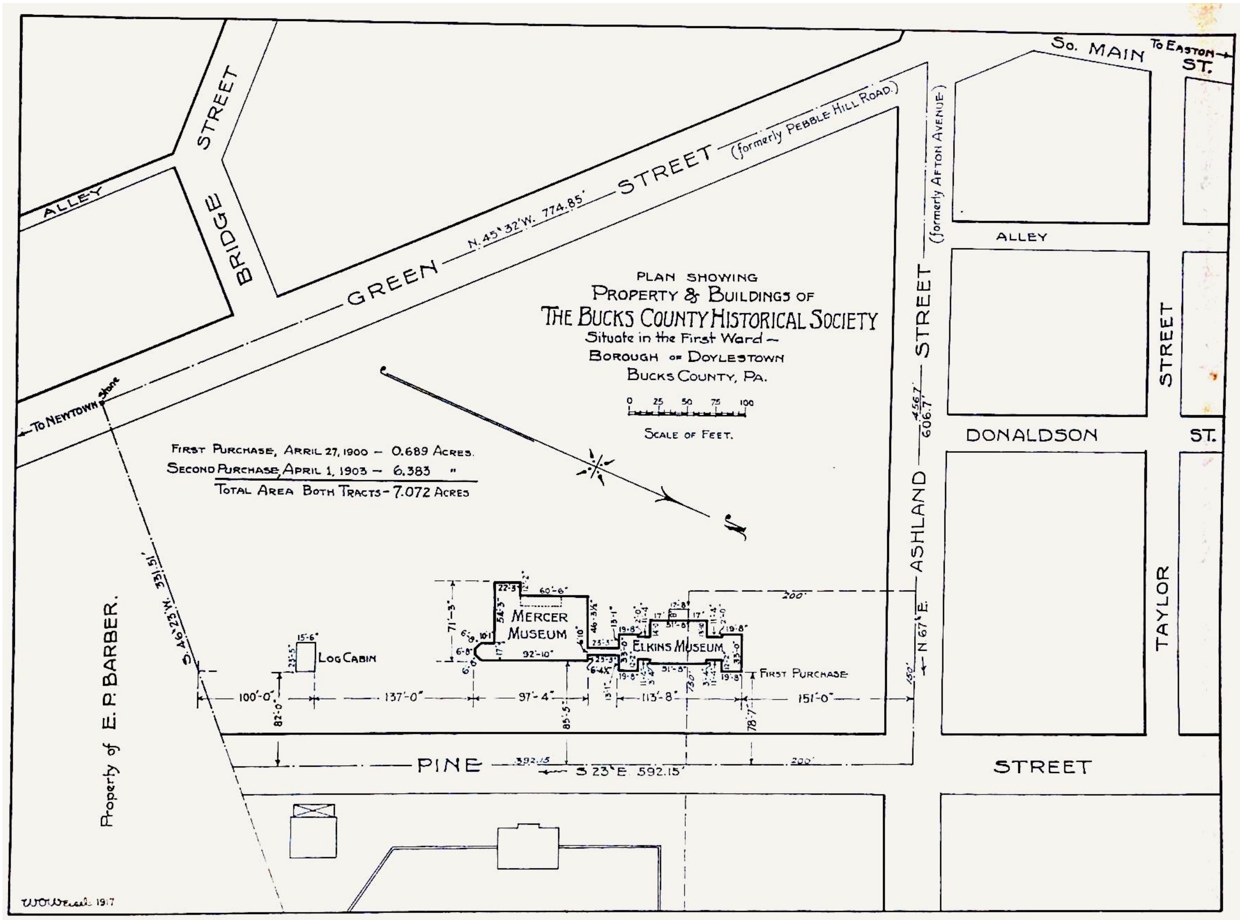


Figure 6.1. First survey of the Mercer Museum. W. O. Weisel, surveyor, ca. 1917. Image: courtesy of the Mercer Museum Research Library.

Flexible Planning and Corrective Action

Fortunately Mercer's construction notebooks and ledgers are detailed, and show the evolution and refinement of his method of building, illustrating the relationship between his own role as designer and director of construction, and the expanding practical knowledge of his workmen. It should be noted in this context that, counter to what is commonly asserted about Mercer, he did not, himself, play a large role in the manual acts of building of any of his projects, particularly the museum. His role was rather more similar to that of the traditional architect, planning and communicating the plans for construction to a building crew. Yet unlike the traditional architect, at least in Mercer's time, this communication was primarily oral, and founded upon a deep collaboration between Mercer and those of his workers who were held over from project to project, developing a deep familiarity and even expertise with the unique methods they used.

Secondary sources such as the published and unpublished work of subsequent scholars (some of this preserved only in the Mercer archive), testaments of Mercer's contemporaries recorded in the papers of the Bucks County Historical Society, and other documents, such as the oral history with William Frankenfield discussed previously, further illustrate the nature of this lasting and productive collaboration between Mercer and his workers.

These discursive, collaborative relationships between parties evolved over the course of ten years of concerted construction activity, a decade which saw the metamorphosis of a primarily experimental and improvisational approach into a body of craft knowledge which was drawn upon to flesh out the minimal formal representations produced by Mercer (and in rare instances his foremen). Despite the fact that, with the museum, Mercer had transitioned to a project in which he had a budget (under $40,000) and, at least nominally, a client (the Bucks County Historical Society), his production of construction-orchestrating documents followed almost exactly the pattern set out at Fonthill and confirmed at the pottery: no hardline drawings of any kind; and a sequence of different modes in the construction notebook, beginning (after a few unnumbered pages listing contact information and serving as title page and frontispiece) with space planning diagrams in plan and proceeding to details and daily progress logs. [Fig. 6.2.]

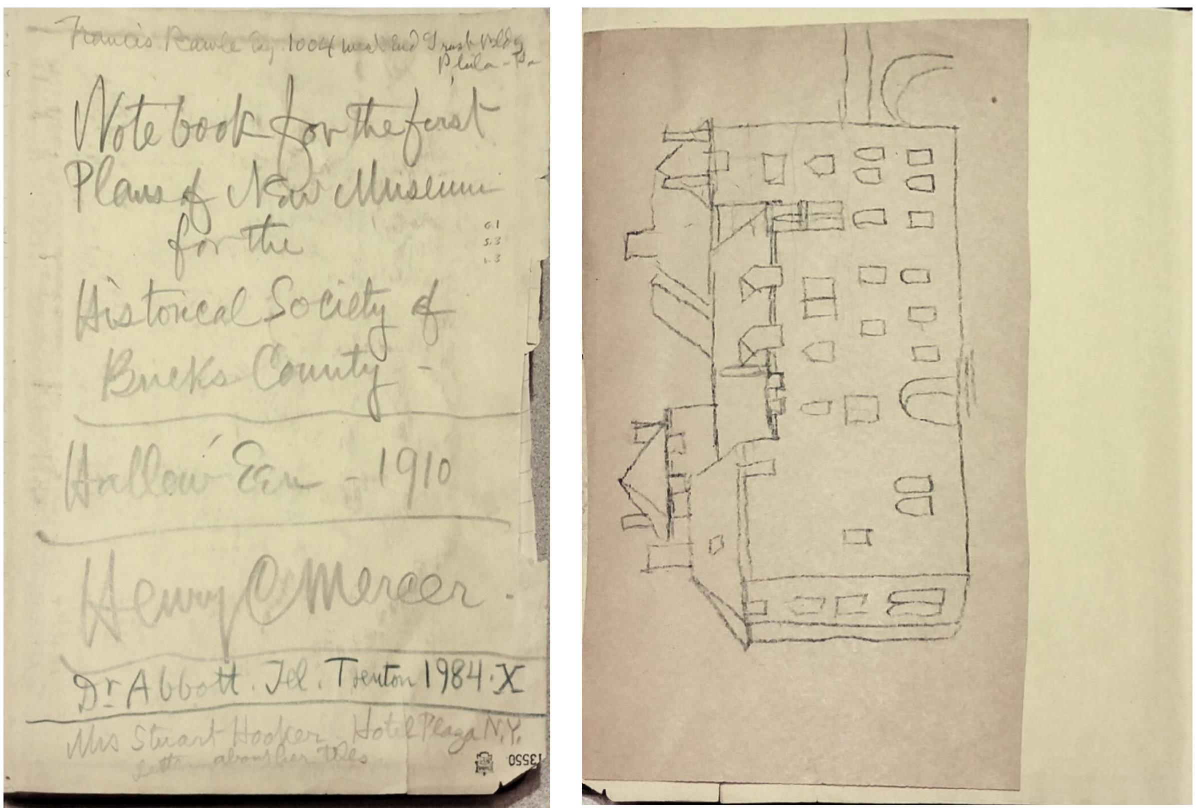
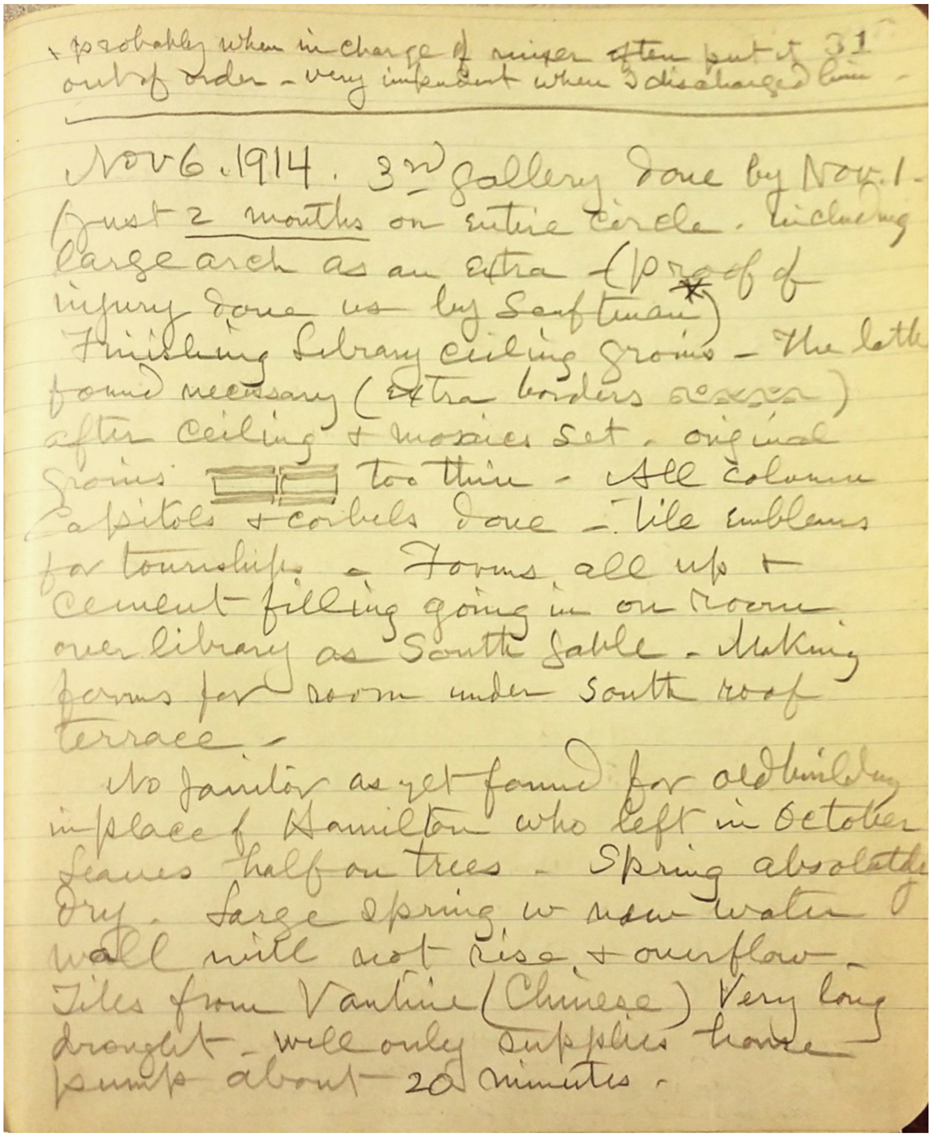


Figure 6.2. Title page and 'frontispiece', in a most informal vein, from the museum notebook. Image: courtesy of the Mercer Museum Research Library.

Unlike the sometimes daily logs in the Fonthill notebook, many of the dated entries in the Museum notebook tend towards a more summary mode, recording several weeks of progress at a time. The months of October and November of 1914, for example, are recorded in the ledger as a series of weekly rolls, with each of worker tallied in terms of full and part days worked (dated Oct. 10th, 17th, 24th, and 31st, and November 7th, 14th, 21st, and 28th), along with various line items such as "Frank J. Gerlitzki, Lumber … $31.42" and "General Crushed Stone Co. 1 car stone # 23296 … 35th … $26.34" (both dated Nov. 6th), and comprise a total of 39 entries running for 8 pages. The notebook entries covering the same period run for two pages and comprise 3 brief entries. The entry dated Nov. 6 1914 [Fig. 6.3.] is typical:

> […] Finishing library ceiling groins—the lath [or "latter"] found necessary (Extra borders [diagram]) after ceiling and mosaics set—original groins [diagram] too thin—all column capitols and corbels done—tile emblems for townships—Forms all up and cement filling going in on room over library at South gable—Making forms for room

under South roof terrace. […]


+ probably when in charge of mixer often put it 31
out of order – very impudent when I discharged him –

Nov 6. 1914. 3rd gallery done by Nov. 1 –
just 2 months on entire circle. including
large arch as an extra (proof of
injury done us by Saeftman*)
Finishing Library ceiling groins – the latter
found necessary (extra borders)
after ceiling + mosaics set. original
groins too thin – All column
capitols + corbels done – Tile emblems
for townships – Forms all up +
cement filling going in on room
over library as South Gable – Making
forms for room under South roof
terrace –
No janitor as yet found for old building
in place of Hamilton who left in October
Leaves half on trees – Spring absolutely
dry. Large spring w new water
wall will not rise + overflow –
Tiles from Vantine (Chinese) Very long
drought – well only supplies house
pumps about 20 minutes.

Figure 6.3. Nov. 6 entry in the museum construction notebook. Image: courtesy of the Mercer Museum Research Library.

The sketches that show these rooms occur on page 15 and 17 of the notebook [fig 6.4], and, while some few critical dimensions are present, the library (in the upper-right corner of the sketch) shows only overall dimensions. Moreover, we should take these dimensions to be approximate, as the overall dimension string on the south wall reads *42'*, which is equivalent to the sum of the internal dimensions (leaving wall thicknesses, which were variable but considerable, unaccounted for. Moreover, the as-built dimensions of the room are not 19' x 20' but rather 20' x 28', an increase particularly notable because it resulted in the library room projecting out from the perimeter of the building. [Fig 6.5.] This indicates the degree to which Mercer planned his building sequentially and determined the sizes and shapes of his rooms, as at Fonthill, from the inside out. Supporting columns are shown only in places, and generally not dimensioned. This suggests the ceilings, too, were planned in-situ. The vaulting geometry and decorative tilework on ceilings is never indicated, and the only note as to ceilings occurs in the passage just quoted, indicating that the original plan for the groined ceiling in the library needed revision, and the planned groin lines (diagram) were too thin and required widening with a second pattern (diagram). A reflected ceiling plan, which even the most recent set of construction documents for the museum's 2009 addition and renovation did not complete in any detail [fig. 6.6], indicates the degree to which this design evolved in an improvisational manner, the groin lines shifting to mediate between irregularly placed supports. (The only thing more remarkable than the production of this ceiling without plans is perhaps its continued evasion of such documentation.) Despite these variabilities, the library in the Museum [fig. 6.7] is clearly modeled on the one Mercer built at Fonthill [fig. 6.8], and it may well have been by reference to this, or to their own personal previous experience of its construction, that his workers were instructed, rather than by any close consideration of plan geometry or guiding document.

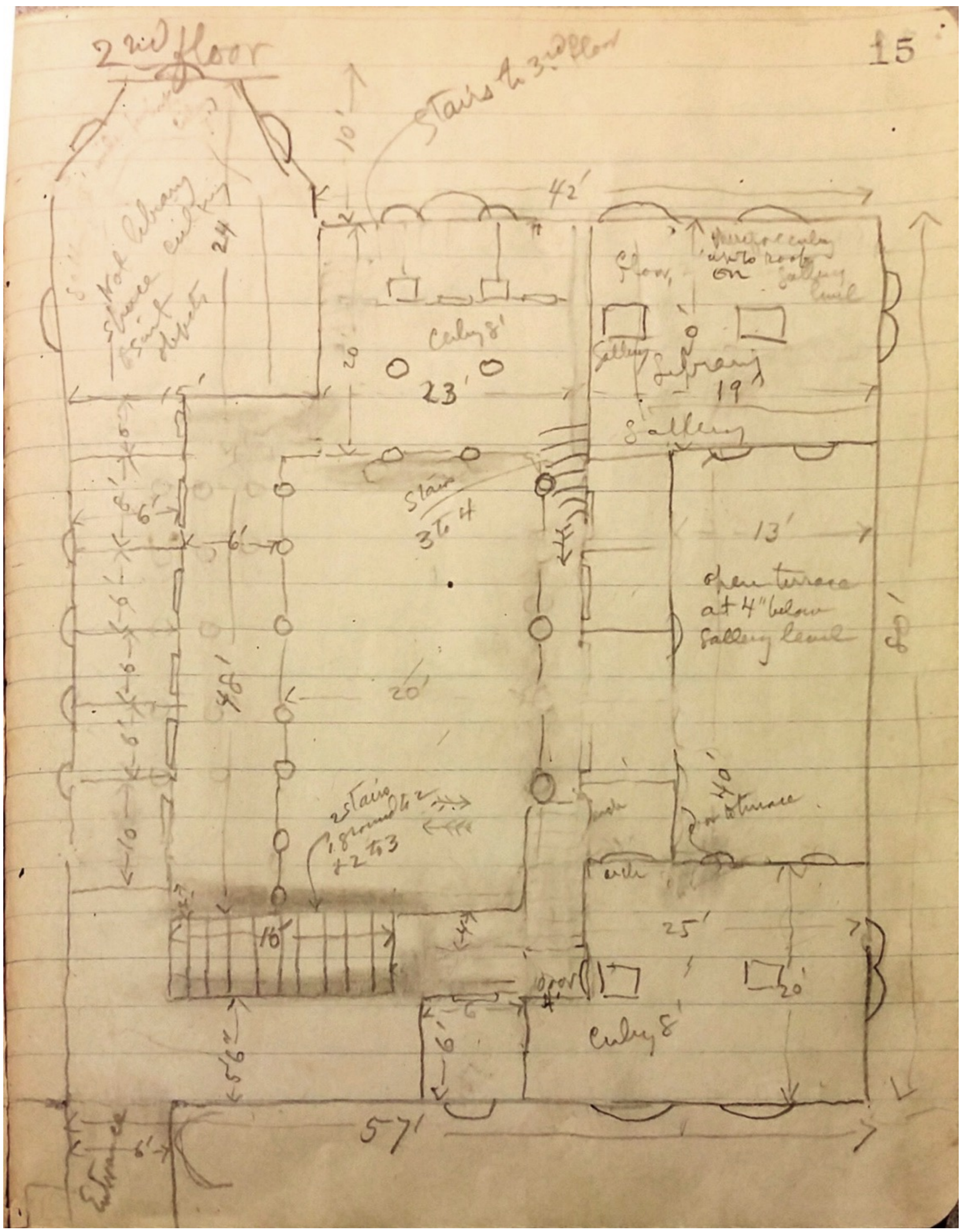
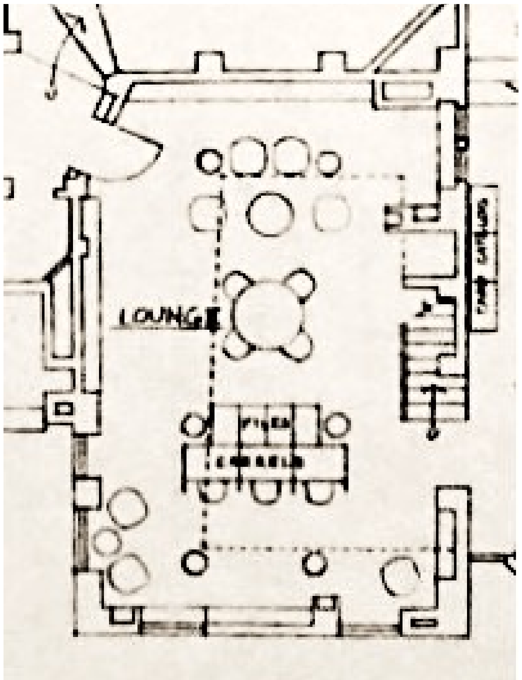


Figure 6.4. Library level plan in the museum construction notebook, page 15. Image: courtesy of the Mercer Museum Research Library.



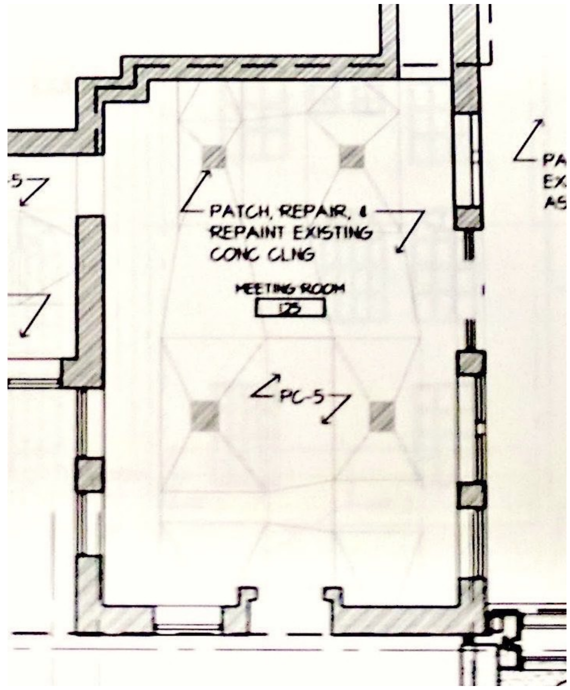


Figure 6.5. Floor plan of the original museum library from the 1974 drawings by Chappelle & Crothers Architects. Image: courtesy of the Mercer Museum Research Library.
Figure 6.6. Reflected ceiling plan of the original museum library from the 2009 drawings by Voith & Mactavish Architects. Image: courtesy of the Mercer Museum Research Library.

Figure 6.7. Museum library ceiling. Image: author, courtesy of the Mercer Museum.

Figure 6.8. Fonthill library ceiling. Image: author, courtesy of Fonthill Castle.

As we have seen previously, Mercer's tendency was to set up flexible systems; then adapt within the provided flexibility as conditions warranted. We may never know exactly what "too thin" meant as a reaction to the tiling on the groin vaults in the library—perhaps the narrow rectangular tiles did not align well with the column capitol tiling. Or perhaps the alignment was satisfactory, but the result insufficiently decorative or regular for Mercer's tastes (though the opposite would seem to be the case, with the secondary layer of tiles (diagram) in some places needing to be reduced to a single row or omitted to fit between the rectangular tiles.) It is also possible that the ceiling came out of the forms with enough flaws in curvature or tilework to cause Mercer to add the second course of tiles after-the-fact as a corrective measure, much as he used parging on the more formal rooms in Fonthill to unify and regularize the exposed concrete surfaces. Several observations support this possibility. First, the surface of the untiled parts of the ceiling is visibly different from Mercers' concrete finish at other locations in the museum. The vast majority of exposed concrete in the museum, including most of its ceilings, has a form-finish surface, in which impressions of woodgrain and board lines from formwork are readily evident. [Fig 6.9.]

Figure 6.9. Boardform groin vaults in the stove plate room at the museum. Image: author, courtesy of the Mercer Museum.

But the library ceiling texture is also different from the sand-form finish visible at Fonthill and in a few places at the pottery. [Fig 6.10.] The library ceiling, in fact, looks more like an applied cement render such as achieved by sprayed concrete (gunnite) or splattered troweling, than any formed concrete finish (though sprayed concrete is not mentioned in Mercer's notebooks.)

Figure 6.10. Typical sand-form finish, with embedded tiles, at the Fonthill library ceiling. Image: author, courtesy of Fonthill Castle.

The second indicator of the corrective nature of the finish work in the library is a mention made by Frankenfield in his 1953 interview, in which he recalled workers on scaffolding in the library, and asserts that the tile was applied from below. While this is secondary evidence and circumstantial, it supports the possibility that at least some of the tiling was applied after the ceiling had been cast and the formwork removed. All of the tile may have been applied this way, as Frankenfield asserted, though this would have been counter to Mercer's methods elsewhere. Mercer's comment, "extra borders after ceilings and mosaics set" also mitigates against this possibility. It is most likely, then, that Mercer completed the ceiling with rectangular tiles, and the resulting tiling was "too thin" to cover whatever flaws in the geometry or finish of the vaults had occurred.

What we do know is that neither the initial scheme [fig. 6.11] nor the modified one [fig. 6.12] were documented projectively—only retrospectively after the decision was made. This is in keeping with the way Frankenfield described Mercer's process in his recollections: "I don't remember ever having seen no sketches, no plans of any kind. And I asked the foreman if he had any plans to go by and he said, "No he [Mercer] wanted the building just to be put up and he described it and that's the way the foreman got his information and he ordered the workmen just the way Mr. Mercer wanted it done."[390] And this is very much in keeping with the pattern described by Frankenfield for his own interactions with Mercer—Mercer would allow considerable latitude to his workers, and repair or reconstruct if the results were unacceptable. Frankenfield describes one such occasion:

> Potter: I understand sir, that you also did a great deal of work on the stairs in the building, particularly the circular stairs on the second and third gallery levels. What is the story behind that?
>
> Frankenfield: Well, those steps were supposed to be easy walking up and down, so that they had the right height for the tread, they wouldn't be too high a step, or too narrow. Of course I was shoring up at that time and Mr. Mercer used to come down and he would look at it, some other fellows had shored it up, and he would look at it, and if it didn't suit him he would tell the foreman Mr. Labs that, not to pour them but to tear them down, and he would like to have them put up a little different. So, he had those steps set up for about three different times, and had them torn down, finally Mr. Labs didn't know what to do about it and he said to Mr. Mercer, I don't seem to get them, to get them exactly like you want them, but he said, I'll tell you what I'll do he said, I got a man that I think could give you just what you want. So Mr. Mercer wanted to know what man that was, so that happened to be myself and he come over and told me to come over and talk to Mr. Mercer and Mr. Labs and between the two of them they explained exactly what he wanted, and asked me if I thought I could do it, and I said well there is nothing like trying and I would try to do my best to please them. Mr. Mercer seemed satisfied and he put me on the steps and then he come and looked at them, and it seemed he was pleased with them and he told me to go ahead and leave them just like that. They were fine.[391]

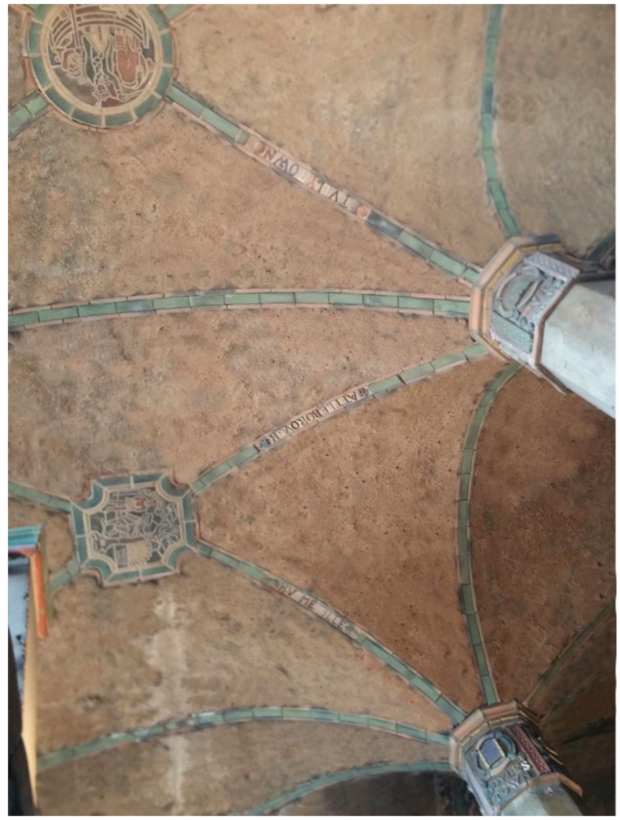



Figure 6.11. The library ceiling. Image: author.

Figure 6.12. Digitally altered image showing the original design for the library ceiling, as it might have looked after the centerings were struck. Image: author.

Flexible Planning in Historical Context

Far from being invented by Mercer or a unique attribute of his practices, this sort of latitude often characterized pre-modern building. If we look at the synthesis of actions and actors on the job site, we see a delegation of authority in which each worker's semi- or unregulated craft actions make a non-trivial contribution to the building as a whole, and in which free-hand and tool- or machine-assisted operations add their distinctive patterns and forms to the larger coherence of the details of the building.

Such was the case with Frank Furness's Pennsylvania Academy of the Fine Arts, [fig. 6.13] where Mercer studied and lectured on the collection of early American ceramics, as his interest in that medium blossomed in the closing years of the 19th century. Every time he entered the building he would have walked past the rusticated brownstone masonry, in which the tool marks on the pitch-faced and rough-pointed stone contrast against the machined finishes of the other building materials, figuring the hand of the mason in the texture of the façade. Free and unregulated manual actions are implicated in decorative effects, which may be prescribed but are rarely depicted in any accuracy by the architect's drawings. That is to say, the mason's judgement is assumed to be in play in the specification of 'pitch-faced', 'reticulated,' or 'coarse-pointed' facings, and the drawings designedly avoid a duplicate (and potentially contradictory) description of that particular aspect of the building.

Figure 6.13. Pennsylvania Academy of the Fine Arts, Frank Furness, ca. 1871-1876. Image: public domain / Library of Congress.

The manual actions of building construction are necessarily interwoven with constant exercises of judgement;[392] and these judgements are not generally recorded or transcribed. This is true wherever an established practice, such as the dressing of stone, is relied upon. And in cases falling between established practice and formal documentary convention, informal documentary practices spring up to fill the gap.

It is particularly these ephemera of searching and experimental architectural fabrications, the drawings created as the builder and architect attempt to determine just how to proceed (what we might call "architectural ephemera"), that are most likely to be excluded from the mainstream of architectural history and theory.

This tendency to suppress the tentative or indeterminate is often attributed to the earliest and most influential figures in the formation of the discipline. The treatise of Leon Battista Alberti becomes a point of origin for this narrative, in which the role of the architect is taken to be the creation of drawings owing more to ideal geometries than site-specific knowledge. In this neo-platonic account, Alberti's formulation of the primary faculty of the architect as the drafting of *lineamenti*,[393] or "lines in the mind" recommends architectural activity as "a clear and effective prescription (*preordinatione*) conceived in the mind, made of lines and angles, and realized by a good mind and intellect."[394] That is to say: the creation of proportionate and predictive drawings.

Despite this predisposition to see architectural activity as a sequence of mental events (a characterization likely formed by antecedent enlightenment revisionings of the Albertian project)[395] Alberti carried on many more pragmatic conversations his patrons and builders.

In the letters between Alberti and his site manager at the Tempio Malatestiano, Matteo de' Pasti, we find a curious case. In a letter from architect to construction manager, in the midst of a passage of otherwise normative description, Alberti reaches a point at which lexical description in too cumbersome to communicate his meaning, and, rather than create an elaborate description in prose, he draws a small interlineal doodle, not considerably more extensive or ornate than the letters of his script. (Fig. 6.14.) Yet this doodle is not a word, and functions not merely as a shift from rhetorical to graphic communication, but as a shift from the syntactic redundancy of descriptive language to an altogether different sort of insistence: that of authority by demonstration. *Do it like this,* the diagram says.[396]

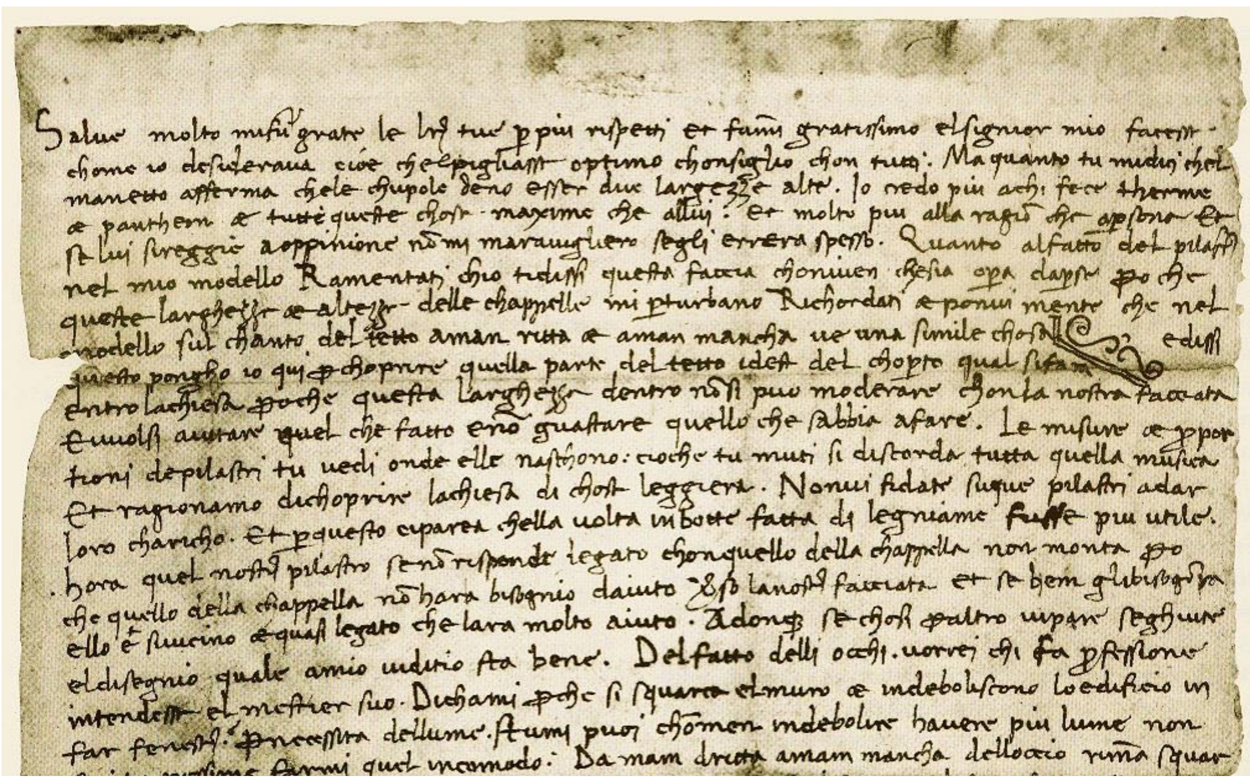


Figure 6.14. Alberti's doodle. Letter to Matteo de' Pasti, ca. 1545. Image: public domain.

Architectural drawings such as these relate to the future states they describe in a primarily predictive and fictional capacity: that is to say, they are not factual descriptions of the built world, but rather of a fictional world, in that, as representations, they depict the results of the material action they are created to provoke. That this fiction has a heuristic structure, per Vaihinger, arises from what he called its 'useful falsehood': each part of the building is dependent on many others not shown, and on many actions not depicted, *as if* it were all already existing, and had taken-place.[397]

Two things distinguish Alberti's doodle as this sort of fiction; and this sort of fiction as paradigmatic of the architectural document. The first is its *locality,* the second its *economy*. These are functions of its *gestural quality*. Situated between one word and the next, it only shows one small moment of the building, depending for its significance not on syntax or symbology but on a shared backdrop of previous experience: it is enough like the model of the building previously created and held as a guiding representation of the building-to-be, and also, presumably, enough like a previous conversation, that it may be presented merely as a reminder to de' Pasti; but as such it serves to recreate the entirety of, and so to activate, the sum of those communications.

In this letter if not elsewhere, Alberti is not interested merely in setting down the lineaments of architecture, but rather in activating the network of communications that will provoke material action. Ultimately, Alberti's doodle relies not on redundancy, in the informational sense, but on what Elaine Scarry would call "vivacity."[398] Its gestural quality is a spur to the imagination.

This brings us to the second attribute of Alberti's doodle: its economy. The doodle is not representational, in that it does not participate in the mimesis of the drawing, either pictorial or scalar. If it is mimetic in function, this is mimesis as Elaine Scarry proposes to modify the term in her *Dreaming by the Book*: rather than a visual mirroring, this is an orchestration of reenactment, in which mimesis is the imitation of an action rather than a strictly pictorial event. "Desire is mimetic,"[399] she tells us, revising the traditional, and originally Platonic, formulation of mimesis-as-resemblance: in art, the correspondence between depiction and depicted. For Scarry, "the imagination produces a mimesis of sensation by miming the deep structure that brings the sensation about."[400] In this reading Mimesis is not the description of a particular sense-perception, such as a visual description of the facade of a building, but the mirroring of the 'structure of production' of the building. This is the purpose of architectural drawings.

Alberti's doodle can be understood in just this light: not as the description of a desired-future material reality, but as an instruction for the recreation of the gestural action that can give rise to the intended constructional process. Just like a bodily gesture between master and apprentice, the doodle is the imitation of an action.

How is it possible that such a small gesture, such a minimal communication, can have any assurance of successful execution? Almost lost in the curves of Alberti's cursive letters, how can its non-lexical, non-representational curve communicate anything approaching the curve Alberti intends?

Understanding the structure that allows for the efficacy of this architectural communication, and by extension other similarly structured ephemera, will require us to temper the neo-platonic ideal of the architect, who, disembodied from the construction site, works in insomniac abstraction from the brute facts of building, and who claims as his prerogative and force a privileged knowledge of the ideal. This was the only the Palladio for generations of architects. But these same generations of architects struggled, ad-libbed, adapted, and engaged in fruitful dialogue with builders to get buildings built, and they used the (often simultaneous) rhetorical and graphical act of improvisational architectural communication to extend the affordances of their formal documents. Sadly, the ad-hoc communications of architects, whether verbal, written, or graphic, do not partake of the longevity of the treatise; and yet they persist in practice, like the subliminal mutterings of an architectural madman. It was Mercer's unique worldview as archaeologist, collector, and inventor, that allowed him to move such ephemera from a minor to a major role—and to function neither as planning nor production (that original, Taylorist, split), but as a fusion of the two, a form of representational practice possessed of both economy and openness.

B. Architectural Ephemera and Information Theory

The nature of reader-generated meaning in the arts is the subject of Umberto Eco's *Open Work*. He explores the various ways "the author offers the interpreter, the performer, the addressee a work to be completed."[401] And if this premise sounds indebted to the hermeneutic thought of the 20th century, Eco remains well aware that meaningful communications cannot help but be characterized by their historical period, medium, and audience. He is careful to situate his analysis historiographically,[402] and spends much of the first part of *The Open Work* distinguishing the subject of his exploration (openness) from the various experiments in indeterminate composition, often also called "open", prevalent in the 1960's when he wrote his work. By his third chapter, however, Eco has turned his attention to the question of information density in communication, and thus laid groundwork for the question at hand.

Influenced by classical information theory, which operates on the assumption of the possibility of communication without ambiguity,[403] Eco proposes a reciprocal relationship between "noise"—which he generalizes as any barrier to communication,[404] and redundancy—which is what compensates for noise and increases the likelihood of successful communication in a noisy environment. (A construction site, as we well know, is ever a noisy environment.) Steven Pinker offers this now-classic example:

> Thanks to the redundancy of language, yxx cxn xndxrstxnd whxt x xm wrxtxng xvxn xf x rxplxcx xll thx vxwxls wxth xn "x" (t gts lttl hrdr f y dn't vn kn whr th vwls r). In the comprehension of speech, the redundancy conferred by phonological rules can compensate for some of the ambiguity in the sound wave. For example, a listener can know that "thisrip" must be *this rip* and not *the srip* because the English consonant cluster *sr* is illegal.[405]

We can understand the evolution of the modern standards of construction drawings as an effort to provide just the sort of redundancy Eco, and Pinker, attribute to language. Where the syntax and phonology provide us with the ability to verify possible miscommunications in words, the scalar progression of orthographic drawings, in its careful progression from plans, to elevations, sections, large scale views, details, schedules, and diagrams,[406] balances the needs of redundancy with the desire that a project not be 'overdescribed'—that is, possessed of more than one description of critical information, and thus potentially of contradiction if the drawings are not well coordinated. (Indeed, much of the touted progress in systems of design representation boil down to the automation of such coordination efforts.) Many of these changes in pursuit of efficiency, however, amount to alterations in semantic redundancy, without decreasing the structural redundancy of the drawing system. This is because the system as a whole requires a degree of redundancy to offset noise and assure the communication of valid information.

We should distinguish, however, between the redundancy imparted by phonology and morphological structure, as is the case in most linguistic communication,[407] and the redundancy offered by illustration, as it is often the case in architectural demonstrations that both are required. *That* both are required may have something to do with the unusual noise and extreme complexity of the site of construction, or rather moreso with the range of meanings conveyed and their intractability at being well-translated into words. To be sure, the interplay of text and image is fragmented and formulaic in much of contemporary architectural documentation. This fragmentation undermines the agency of architects, builders, craftsmen, and the communications that carry their intentions and provoke their actions; and formulaic drawings serve some purposes and starve others, to the ultimate impoverishment of the built environment.

Thus we need clarify the nature of the relationship between information and communication. Given a context like the building of buildings, in which communication is intended to result in action, that an information-rich communication provokes action unrelated to its semantic content illustrates for us the problem inherent in theories of comprehensive description: the descriptions contained in a construction document cannot account for its successful implementation; moreover, nothing in the content of an articulate, exact, and comprehensive communication can reliably predict the efficacy of that communication in a 'noisy' setting, which Eco defines in terms of information theory: "In its analysis of communications, information theory considers messages as organized systems governed by fixed laws of probability, and likely to be disturbed either from without or from within […] by a certain increase in entropy commonly known as 'noise.'" Communication in construction enterprises is particularly susceptible to failure, then, not because of insufficient documentation or planning, or the overall complexity of documentation required by modern high performance buildings, but because of the semantic disorder entailed by overlapping disciplinary bodies of knowledge and tacit practice. To understand how this might be the case—that *noise* could be due to the *tacit*—we need to understand a bit more about how information theory treats acts of communication, whatever their venue. Eco asks us to picture a string of phonemes or graphemes, which make up a series of events—the unity of meaning (or possible meaning) to be carried by the communication.

> The relationship between the number of possible events in a series and the series of probabilities connected to each of them is the same as that between an arithmetic progression and a geometric progression, and can be expressed by a logarithm, since the second series is the logarithm of the first. The simplest expression for a given quantity of information is the following:

$$\text{Information} = \log \frac{\text{odds that addressee will know content of message after receiving it}}{\text{odds that addressee will know content of message before receiving it}}$$

> […] the quantity of information conveyed by a given message is equal to the binary logarithm of the number of possibilities necessary to define the message without ambiguity.

The format of this equation tells us something important about the nature of communication: that the density of information in a message is proportional to the likelihood of that message making sense, and thus relative to the body of knowledge held by its audience. Another ratio suggested by the form of this equation might be:

$$\text{Information} = \log \frac{\text{explicit knowledge}}{\text{tacit knowledge}}$$

We tend to focus on the numerator, and forget the denominator. But what this ratio tells us is that information density in communication is not absolute, but proportional; and what the denominator tells us is that the larger the set of possible meanings and contexts and the wider its relevance, perversely, the smaller the informational value of a given message. We can see this regressional ratio at work in contemporary architectural practice in the case of the big database that attempts to hold and specify all information of relevance to a particular a construction project or typology. The result is often a large quantity of information, but also a large amount of possible meanings and categories of relevance, resulting in the common complaint that unless we know the right question to ask, the model tells us nothing.[408]

Conversely, Alberti's doodle is able to carry meaning, despite the noise of the job site, because it is operating within a vastly reduced sphere of possible meanings. (So much for the argument of the log.) The logarithmic function itself tells us something else. Without the log we would have a geometric progression, like this: [fig 6.15.]

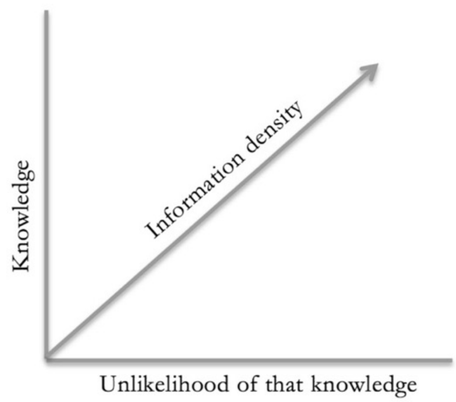


Figure 6.15: Information density in communication: a linear progression? Chart: author.

In the above graph, adding more knowledge to a system of communication is always a good thing. As we expand total knowledge, at worst we also expand the total possible meaning and referents and so the unlikelihood of that knowledge. At best we increase the ratio of the former to the latter. At worst we merely need to increase redundancy in proportion to complexity to assure successful communication. "To protect the message against consumption so that no matter how much noise interferes with its reception the gist of the meaning (of its order) will not be altered," Eco writes, "it is necessary to 'wrap' it in a number of conventional reiterations".[409] And Eco repeats the claim, adduced originally in the 1950's by C. E. Shannon, that the English language is 50% redundant.[410] However, not each and every sentence is equally, that is to say, equivalently, redundant. As Shannon demonstrated, longer strings have greater entropy, with a predictably logarithmic increase in redundancy over string length. This function implies that we would expect to see a substantially different graph than the one described above. Instead: [Fig. 6.16.]

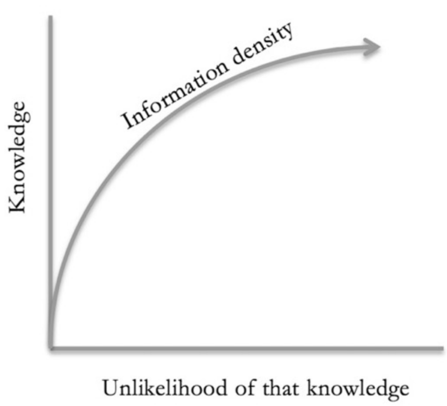


Figure 6.16: Information density in communication: logarithmic progression. If we substitute the terms tacit and explicit on the above graph, we find that it predicts the common observation that the more we know about something, the less we need to say. Chart: author.

Here we see a falling-off of information density as overall complexity increases. And this has the frequently observed practical result that the more complex the information, the more redundancy is required to assure its communication. Redundancy and efficacy are not friends. Yet with music, and with everyday speech, Eco observes a marked tendency to abridge and elide many of the normative syntactic structures of redundancy. He takes this as a critique of the orthodox view of the relationship between entropy and information proposed by information theory, pointing out that information and meaning are not the same thing. And while redundancy preserves informational content, it may in fact inhibit meaning.

> On reflection, one sees that this is precisely the case with everyday speech, whose very power of communication and information seems to be directly proportional to the grammatical and syntactic rules it constantly eludes—the very same rules deemed necessary to the transmission of meaning. It often happens that in a language (here taken to mean a system of probability), certain elements of disorder may in fact increase the level of information conveyed by a message.[411]

To say that art makes more sense as it departs from syntax is nothing particularly new. Even as Mercer was building his museum, Gertrude Stein was reinventing modern English poetry with some *Rooms* of her own:

> The time when there is not the question is only seen when there is a shower. Any little thing is water.
>
> There was a whole collection made. A damp cloth, an oyster, a single mirror, a manikin, a student, a silent star, a single spark, a little movement and the bed is made. This shows the disorder, it does, it shows more likeness than anything else, it shows the single mind that directs an apple. All the coats have a different shape, that does not mean that they differ in color, it means a union between use and exercise and a house.[412]

Eco goes on in his *Open Work* to discuss the many misprisonings of syntax in art, and illustrates how they offer a richer explanation of human creativity than is available to a formulaic information-processing model of human communication. In the words of the novelist Glenn Blake, 'If it doesn't say more than it says, it's not a story.'

But shouldn't we distinguish between the cultivated contravention of the rules of syntax—what has been called in another context "cognitive play with pattern"[413]—and the momentary elisions and inversions of 'everyday speech'?

In his later work *Six Walks in the Fictional Woods,* a book that came of his Charles Eliot Norton lectures, Eco takes great pains to separate 'fictional worlds' and the 'actual world'[414]; yet he wrote *Open Work* to propose, and to advocate for, works that "strive to be as ambiguous as life." These 'open' works, he argues, often succeed through a "radical, irredeemable disjointedness," a play that is not merely the mirroring of life in art, but something else. We should pay careful attention to Eco's caveat, "*organized* disorder." This is not the imitation of perceived-disorder, but rather something that happens much earlier, and which requires far greater rigor. Eco reminds us that our perceptions work because we "trust prior stories. We could not fully perceive a tree if we did not know (because others have told us) that it is the product of a long growth process and that it does not grow overnight."[415]

This proposal, that culture underlies nature, does not originate in Eco. It is a keystone of phenomenological thought. But we should be careful to understand this, as its original formulators did, as a statement of indissociability, rather than one of priority. The poet and translator Robert Bringhurst writes about the task of translation:

> Translators, lawyers, doctors, teachers, and engineers, like bakers, potters, and carpenters, all have to be poets in their way. When they are not, things are apt to go awry. And they do go awry, because professions become institutions, and institutions close their doors and windows, leaving poetry outside.

> That does no harm to poetry, of course; it only harms the institutions. Outside—meaning outside human management—is the place where poetry lives: in the mountains, in the forest, in the body, in the mind. […] So why do we meet poetry so often in the guise of managed language? Because that's where we officially permit it to exist. Poetry, like alcohol and sex, is subjected to rules and invested with ritual because of the threat it represents. Like sex, it breaks those rules, and when it doesn't break them, it often makes them dance. The translator, trafficking in poetry, trafficking in meaning, must smuggle *that which makes and breaks and twists the rules* from one set of rules to the next.[416]

Eco and Bringhurst are speaking from two very different domains, but talking about the same subject; and crucially, locating the question of interpretation *prior* to judgement, as part of the complex act of perception-and-action.

While we can readily see how the artist or the poet uses organized disorder to provoke "the possibility of conveying a piece of information that is not a common "meaning" by using conventional linguistic structures to violate the laws of probability that govern language from within,"[417] the achieve-of, the mastery of the thing, has little to do with 'art' as a cultural product or judgement, and everything to do with what is of particular interest to us here: 'trades, their gear and tackle and trim. All things counter, original, spare—' and how that words make them.

Because, in terms of structure, high art and artifice, and everyday speech, are not categorically different. This is what we learn from Eco's analysis: that the same interplay of explicit and implicit that obtains in everyday speech lies at the heart of the poet's dancing, twisting rules. And so we might speak of the 'violation of the laws of probability' by everyday speech and by the ephemeral documents of architectural production process; and rather than reify the poetic, concretize it.

In his close reading of the extant medieval texts, Joseph Rykwert critiques the neglect of the "vast expanse of gesture and talk"[418] underpinning medieval architecture. Conversations, he argues, make up a continuous stream within Medieval European building practice, and constitute an undercurrent no less significant in architectural theory.

Yet despite their subliminal influence on theory, these architectural ephemera, considered collectively, have no coherent theory of their own. What is the structure of episodic and ad-hoc communication? How might it, deliberately conceived and deployed, alter the capabilities of architectural representations, and ultimately the architecture they set in motion?

According to Eco's logarithm of intelligibility, the more reduced a set of possible meanings in a communication, the greater its information density. Compact, contextual communications need less structural redundancy, and less reiteration, and so gain in efficiency. That is to say, more building can be described with less drawing the closer one comes to the act of construction.

The Vast Expanse of Gesture and Talk

The release of formal specification of action to the apparent chaos of unspecified craft practice may seem like a release of control; and in the time that gave rise to Eco's Open Work, musicians and artists flirted with every form of randomness. But this was not merely the abandonment of artistic agency (despite how prevalent this trope sometimes seems in contemporary art). The composer releases decision-making to the performer;[419] the artist creates works that depend on its participants. Ultimately, however, the giving up of agency means nothing if it is wholesale, and arbitrary. Eco foresaw this natural limit to the artful pursuit of randomness for its own sake:

> If, for instance, on August 4 the weather forecaster says, "Tomorrow, no snow," the amount of information I get is very limited; my own experience would have easily allowed me to reach that conclusion. On the other hand, if on August 4 the forecaster says, "Tomorrow, snow," then the amount of information I get is considerable, given the

improbability of the event. The quantity of information contained in a particular message is also generally conditioned by the confidence I have in my sources."[420]

Thus confidence, or credibility (in Latour's terminology) plays a role in informational value, and a rich communication is characterized by two things: it tells me something I did not know before; and it comes from a trusted source. But credibility is not an absolute value; nor is it inherent in charisma, expertise, social position, or occupational hierarchy. Rather, or in addition to the extra-diegetic nature of its source, authority depends upon the conveyance of agency via the communicative act. (This may be why architectural communications still occasionally fail despite the manifest authority of their originator.) This suggests that one of the essential functions of the architectural document is the conveyance of agency. Alberti, in using a gesture to activate the complex of talk and memory, engages his site architect in an interpretive process, and in so doing he not only conveys new information, but makes his own credibility or authority, *portable.* In this context the openness of the work consists of both its open-ended, gestural quality (an example of the 'efficacious disorder' of everyday talk), and in its interconnection in a larger field of dialogue, shared experience, and expertise. It functions as a call to action, which only grows more meaningful—more rich in information—as the ambiguity of that interaction is given structure and limit, and directed toward a procedural or instrumental outcome.[421]

A decade before Eco wrote The Open Work, the American modern poet Charles Olson described an "open" poetics: "every element in a modern poem must be taken up as participant in the kinetic of the poem just as solidly as we are accustomed to take what we call the objects of reality."[422] What Eco, and Olson before him, have called 'open' work is not merely Avant-garde poetics but also an apt description of the potential of architectural drawing in an increasingly "kinetic" world: to carry on a conversation in which what is known and what is not-yet-known are put into in a reciprocal dialogue that does not merely describe a building, but sets a construction process in motion. This setting-in-motion is an enabling, a giving-over of agency, not from one designer to another but from the determined past to the indeterminate future actor, whether architect, craftsperson, or inhabitant. A viable theory of architectural ephemera requires a form of drawing—of communication—characterized by an interweaving of lexical and graphical structures, and by an economy of description with regards to action that utilizes local, specific, and limited knowledge-sets, rather than engaging in systematized and predictive representations. As the literary theorist Guillemette Bolens reminds us, kinesic gestures cannot be reduced to typologies—they are context dependent.[423] The "open" drawing originates from, and points to the site, and describes a building not merely *as if* it were real, but as if it were in the act of being built.

C. Instruction and Dialogue

Often, historians of Mercer's art and architecture describe a craftsman-builder, and suggest a question-and-answer, manual intimacy in which Mercer was involved personally and continually in the momentary decision-making at the site. Indeed, if this was a typical story of the craftsman-builder we would expect to see, if not an archetypal primitive figure building a tower like Robinson Jeffers dwelling poetically at Carmel-by-the-Sea [fig 6.17.] (contemporaneous with Mercer's projects, but 3000 miles distant), then at least a constant manual engagement of the craftsman with the stuff of building and his workmen. This is a particularly American evolution of the ideology of the Arts and Crafts movement, in which Mercer would come to play a not-insignificant role, and so perhaps it is unsurprising that Mercer, and his aficionados, would lean toward this sort of interpretation.

Figure 6.17. Robinson Jeffers' Tor House / Hawk Tower. Self-built by poet Robinson Jeffers, ca. 1919. Image: Harvey Barrison / Creative Commons Attribution-Share Alike 2.0 Generic.

It is clear from the interview with Mercer's workman, William Frankenfield, however, that Mercer was far more "hands off" than is generally assumed. Frankenfield describes a pattern in which Mercer would stop by twice a day to give direction, and otherwise not be present at the site;

and this is supported by archival evidence such as ledgers kept interchangeably in the hand of Mercer and of his chief assistant Frank Swain.[424] In the ledger entries pertaining to labor, each worker is called out by name, but summed under the heading, "[Forman], Roll", suggesting that it was the crew leader's responsibility to account for the time of individual workers in any given week. As discussed in chapter 2, Mercer entrusted a number of his workers in such supervisory roles, but the ledger indicates a marked constancy: at the Museum only two men were entrusted as foremen, Patrick Trainor until the end of 2013, and William Labs thereafter.

By today's lights, this seems a much *less* remarkable (if also less romantic) situation, in which a designer communicates a vision to a builder responsible for on-site management of construction; under this foreman is a group of some half dozen to a dozen workers, some skilled and some less so, who do the actual constructing. Within this "crew" there is further division of labor as tasks and skills permit. This was as true in 1910 as it is today.[425]

Mercer's foreman, then, would act as his deputy, taking on the responsibility for the daily oversight of particular processes, and oversight of and accounting for the crew of workers. This required on the part of these deputies autonomy and willingness to improvise. It also required the conveyance of authority necessary to do so.

The informal division of labor and specialization, and overlapping authority between Mercer and his foreman, was not without conflict:

> Sept 3 1914 Placing mosaics & tile groins in ceiling of Library. By evening of Sept. 5. cement floor above all done Except about 10 Sq feet on S corner and most of it finished with smooth top coat. Thus since June 2 or 3 we had constructed 2nd gallery & reached this point several weeks later than I had hoped.* About July 28 or 9 we discharged Joseph Senfman at the mixture for drinking demoralizing the men & holding back the output of the machine.
>
> *Probably because of unfaithful work on the mixer of Joseph Senftman who had "struck" without grievance at the garage in 1913, and asked for reemployment in following winter. He was frequently drunk, very jealous of interference—profane probably when in charge of mixer often put it out of order—very impudent when I discharged him.

This passage, an intimate record of Mercer's frustration and discomfort, raises a useful point precisely because it illustrates a moment of failure in the transference authority in Mercer's rather informal system. This is perhaps most common when a worker has the least craft knowledge, and therefore autonomy, as was the case with the unskilled laborer running the mixer. In the informal systems of authority governing construction acts, a worker is given a degree of authority; but this authority is limited, and constrained within the formal systems of decision making and control. When Senfman, either through ineptitude or malice, created a series of delays, he was fired. That he was fired from his position for reasons of inefficiency is understandable; the degree of Mercer's anger is far more comprehensible, however, in light of Senfman's having transgressed beyond individual infringement upon the authority Mercer granted him. Senfman may not have known what to do next; or not been invested enough in the outcome to seek out answers. But it was apparently his waywardness and intractability, his disruption of the social practice of the jobsite, rather than mere lack of expertise with the mixer, that culminated in his termination. In any case, we should note that it was at the interface between formal and informal systems that the error occurred; and it was in the tacit and social practices implied but not regulated, rather than the quantity or quality of representational content, that the system of formalities (and informalities) failed.

This is quite clear in Mercer's case because there were so few formal structures of communication.[426] Mercer's workmen were not predominantly skilled tradesmen, and so their familiarity, and facility, with architectural drawings would have been negligible, as is evidenced in the interview with Frankenfield. Even had he desired to produce a set of drawings for his buildings, Mercer would not have wanted to take the time to teach his workmen how to read them. This is not to say that he did not have an established system of communication upon which to base his collaborations. Drawing, as he did, many of his laborers directly from his staff at the Moravian pottery, Mercer, and they, would have been accustomed to a more performative conveyance of information, as we explored in chapter 4, as was typical at the Moravian pottery. Yet, unlike the pottery, the construction of the museum entailed a higher proportions of unknowns to knows—that is, even if the colors and shapes of Mercer's tiles varied, Mercer's workers in that setting could draw directly on past experience to implement new designs. Innovation in that setting was primarily in product, secondarily in process. With the museum, while there was certainly repetition, even the most repetitive tasks (such as the precast windows) presented, by design, constant variation, and required a greater degree of flexibility and judgement on a daily basis.

When these tasks were sufficiently complex, Mercer's notebook took on the role described in the general discussion of his notebooks in chapter 2 as 'rehearsal' for jobsite instruction. We should clarify now the nature of this 'rehearsal.' In these passages, the notebook shifts from a description of overall conditions and progress generally to a detailed written description of how to fabricate key details of the building. The transition can be quite abrupt, such as:

> Saturday night turns cold—rain and sleet—by Sunday Dec 6 morning thin snow and sleet and ice—1914 stopped sleeting—New forms (invented Nov 1914 by HCM.) for square and fan windows in plaster of Paris [diagram] and intervals filled with sand or clay.

This is followed directly by a page full of diagrams and descriptions [see fig 3.36, page X] of the window forming method used at the museum, including: "Lay wooden strips guides (this thick) both ways—then insert wooden duplicate of the mullion at D across breach between plaster moulds and fill around it at EF with sand or clay".

D. An Archaeology of Specification

These pages would seem to be a transcription of instructions conveyed, to be conveyed, verbally to the workers. These passages are distinct from others in the notebooks for the reasons mentioned above; and also in that they have a distinct grammatical configuration, often written in the imperative mood.

The imperative mood is a familiar one for architects, as it has become the de facto standard for specifications: the linguist Steven Pinker describes our use of the imperative mood in a natural language setting as carefully calibrated to the possibility for voluntary action. Verbs that tend to describe actions "outside the sphere of voluntary control" or that announce a "momentaneous culmination" of accomplishment—something requiring, perhaps, a bit of luck—don't, Pinker argues, "harmonize well" with the imperative mood.[427] He is also careful to point out that grammatical mood is about more than verb tense; it can also function as a remarkably nuanced marker of social hierarchy and tacit meaning.

In Mercer's case it would seem to be quite natural to practice or rehearse the giving of instructions in the same grammatical mood in which they will be uttered. For where the foreman giving direction to a worker uses the imperative in its conventional sense, e.g., "*backbutter* the tiles, then *place* them in the mortar bed," (these are verbs conjugated in the imperative) the standard language of specification undergoes a slight permutation when it undertakes the same instruction, e.g., "tiles to be backbuttered prior to installation.") This sentence appears to be modeled upon the prior one; yet the shift to the infinitive in verb conjugation marks a subtle but significant difference—the specification seeks to be taken to apply to all instances of tile installation; yet it also maintains a polite distance from the voice of command, which is the traditional role of the imperative mood.

Despite the shift to the infinitive in the conjugation of the verb, the specification is not written in the indicative. For where the indicative describes, and the imperative commands, the subjunctive dictates, proposes, suggests, or stipulates.[428] In traditional grammatical analysis the subjunctive is identified by specific trigger words and altered verb conjugation.[429] In the expanded sense of mood (as opposed to mere verb conjugation), the subjunctive may be triggered by tacit or implied conditionals rather than explicit ones. Together with the imperative, the subjunctive belongs to the category of *irrealis* moods, while the indicative is the primary form of the *realis*—that is, while the indicative describes actuality, the imperative and subjunctive describe forms of the imaginary. The language of architectural specification is just such a case: the specification states a hypothetical condition, describing the building *as-if* it were built. It is, in Vaihinger's terms, a heuristic fiction. And where we might adequately describe a craft action in the indicative ("the tiles were backbuttered"), the use of the subjunctive suggests that these formalizations of tacit craft practice are not descriptive, the way a pictorial illustration might be, but rather are closely linked to, and have their origins in, verbal instruction on the job site, where a master might say to an apprentice, in the imperative, "backbutter the tiles."

To be sure, this is an enlarged sense of these grammatical terms; but it is not without precedent. According to Kasper Boye, who reviewed the state of linguistic scholarship on the subjunctive for the *Oxford Handbook of Modality and Mood* (2016), "the definition of subjunctive has been formulated in both structural and functional terms, but it is hard to find agreement in the literature."[430] For some scholars it is a "semantically vacuous" and culturally variable aspect of language use.[431] For others its meaning lies in the opposition of indicative and subjunctive as significant of *realis* and *irrealis* moods. Notably, in this broader view the infinitive and the subjunctive conjugation of verbs are both considered uses of the subjunctive mood, as "both forms express the same irrealis future situations."[432] The following chart may clarify the relationship between realis and irrealis moods and the various conjugations discussed. (Fig 6.18.)

Mood (category)	Mood (type)	Verb conjugation	Example
Realis	Indicative	Indicative	"The tiles were backbuttered."
	Interrogative	Indicative	"Will you backbutter the tiles please?"
Irrealis	Imperative	Imperative	"Backbutter the tiles."
	Subjunctive	Subjunctive	"It is necessary that the tiles be backbuttered."
		Infinitive	"Tiles to be backbuttered."

Figure 6.18. The Various Moods of the Tilesetter. Chart: author.

Such a description, of course, belies the complexity of many of Mercer's invented methods. And so his construction notebook ranges from description, to command, to possibility, interspersing lexical and graphical modes where he reaches the limits of each form of transcription the variable process of the invention of building, and of the tools for building. Robert Bringhurst insists that we distinguish "writing," as we know it, from "self-transcription." While this might seem a specious distinction in a society built upon universal public literacy, he reminds us that past societies did not share this lexical privilege, and certain disciplines within modern Western societies continue to operate in this way.

> There is no hard line between these two, yet there is a salient difference. It is not that one is audible, one silent. (Good writing in its way is just as audible as speech.) The distinction has to do with tangibility and time. The oral poet never meets a deadline by delivering a script; instead, he must start when occasion demands and work from there at concert speed. His vocabulary consists from words and phrases and of many large units: lines and stanzas, scenes and motifs, episodes and themes. There is no first draft in oral composition. Intensive editing goes on, but it ends with the speaking of the work—and starts again with preparation for the next performance. Writers also have to improvise, as oral poets to, but the writer begins by making a text; his revisions and his tinkering come after.[433]

Mercer's notebooks, then, are self-transcriptions rather than written documents. They are byproducts, rather than end-products, of his building process, and as such may be considered, neither informally formal, or formally informal*,* because they do not participate in the distinction between formalities, but rather come before such distinctions pertain. They fill the gap between simple, off-the-cuff instruction and formal specification, and as such they are not so much representational technologies as transcripts for the performance of building.

Mercer's notebooks remind us of the origin of specifications in the passing on of craft knowledge from master to apprentice. It is as if his archaeological mind naturally turned to the oldest form of architectural documentation. But it may be that it also marks the beginning of modern construction practice, in that the movement from imperative to infinitive/subjunctive negotiates a different social relationship and hierarchy. If this is the case, the difference between instruction and specification is a real one: the instruction accompanies a demonstration ("here—these tiles—install them like so"); while the specification may potentially imply something quite different, a movement of externalization and thus a separation of design and responsible action.

In any case, a construction document is not the frozen music of a conversation, and any account of Mercer's documentation as such must first clarify this distinction.

Tools for making buildings

Unlike a verbal conversation, the construction document does not rely upon external and often tacit gesture or demonstration. It does, however, assume and require a context of knowledgeable and expert practice; or at very least the supervision of someone possessed of such knowledge, and able to act as an interpreter or demonstrator, supplementing the explicit information with implicit suppositions or improvisations. This implicit demonstration and interpretation, which is bound up in (and revealed by) the grammar of specifications, will necessarily be made explicit in the construction document wherever that document describes operations which do not belong to standard practice or preexisting professional competence.[434] We see this occur quite literally in the case of Mercer's templating wires and jigs.

The user must know how to shape clay; but given this background, the shaping of concrete formwork is only a small step. Likewise the patterns for mosaic installations transfer the drawing to the building in a very direct process. Unlike the template, the construction document does not itself materialize a profile, or other inscription intended for direct application to the material of building. This distinction, between the patently material tool, template, or pattern, and the more abstract delineation of the drawing, tends to occlude their shared origin in the instruction for and fabrication of building components. For while a construction document does not itself exert physical force on, or transfer a profile or layout directly to the building, it affords their inscription on the building. Affordance theory tells us two important things about the nature of our tools. First, that a good construction document functions just like a hand tool, by populating the site of the work with affordances. This is its essential function; and if we look at the way a construction set is used on a typical job site—as a reference, authority, and sub-dividable instruction set—it is clear that it functions as a primary tool in the building's realization. Together, the architect and the contractor fabricate and use this tool in a nonce collaboration and improvisation. Second, seen in light of Mercer's museum of tools, affordance theory suggests that when designing our tools we should remember that there is a historical trajectory in which the tool at hand has evolved, and that its affordances are conditioned upon past iterations of the same tool, and expanded through material analogy with other related tools.[435] Even tools vastly different in appearance may afford very similar things; yet a new tool is adopted as such, whatever its superficial resemblance to other similar tools, when it expands the affordances available to the user. Thus, whether it is the 21st century CAD workstation or the 19th century centrolinead, the tools of the architect are only proximally these material objects; distally they are the construction documents themselves.

If we suppose the construction document may act as the "chief tool" of the architect in the making of buildings, bridging between the disciplinary nexus of the office and the craft actions of the jobsite, then much of the recent innovation in the tools of our representational technology, driven as it is by advances in information technology, and located wholly within the office of the architect, would seem to be in service of ends extraneous to those of economical and effective construction documentation. BIM may suit some buildings, and some firms, better than others, not because of any flaw in the firm or the design but rather because it, as presently constituted, provides some affordances with dizzying facility (product specification, for example), and renders others wholly inaccessible to the designer. (Often these privileged affordances carry external baggage.) As information technology continues to move us from mice to touchscreens and from desktops to "augmented" reality, we may see alterations to the standards of practice far more substantial than those that have occurred between Mercer's time and our own. This is because, as we see with Mercer's tools, so few of our graphical innovations, aimed as they are at producing the same old construction drawings, offer truly new affordances. Instead, we labor with circumscribed tools to make available the same context of affordances provided by the maylined and Mylar drawings of generations past. If we recall Norman's tetrad—that our designs are "pleasurable," "functional," "balanced," and "responsive," we can see how poorly the contemporary construction document functions as an object, itself, of design. It is not so much that it lacks the Vitruvian virtues—and here we might read pleasure as *Venustas*, functionality as *Utilitas,* and balance as *Firmitas*—as that they so poorly provide Norman's fourth virtue, *feedback*. Perhaps it is time to ask what our new technologies might newly afford; and how the instruments of representational activity might interpenetrate with those of building—and ultimately engage with the building of the building itself.

We should not be persuaded by the superficial resemblance between the drawing of the face of a building and the elevation of its facade—the elevation drawing may be *theorized* as an orthographic projection;[436] yet if we trace its historical development we may find it has as much to do with full scale (and proportional) floor and wall drawings—the jobsite ephemera from which templates were born—as it does idealized Cartesian geometry and the projection of the building within that "space." If the more pictorial of construction drawings can be taken together with the more analytic, and understood as springing from a common source in practical matters of construction, the role of these documents can be seen to be instrumental in the fabrication of the building, and very much akin to the material templates, and indeed tools taken generally, by which builders effect the building. Plans are instruments.

The sociologist Alfred Schutz describes this as the act of 'projecting', or making anticipatory plans,[437] an action that activates "the stock of knowledge actually at hand, which is, thus, the sedimentation of previous experiencing acts together with their generalizations, formalizations, and idealizations. *It is at hand*, actually or potentially recollected or retained, and as such the ground of all our protentions and anticipations."[438]

That is to say, we can call the construction document a tool in the hands of an expert because it, like the material artifacts we are more wont to imagine, is activated by and activates the stock of craft knowledge relevant to the tasks it describes. The tool engages the tool user in a context of affordances (a 'room') belonging to a particular trade; the document engages its expert user in just the same way; and the building is made in and through these devices.

We thus need to understand what Schutz, and sociologists more generally, mean by the term "formalizations," and why understanding construction documents as representations is an inadequate and ultimately misleading characterization of the nature of these architectural tools. Because ultimately, the work of the architect is the invention of tools.

E. Representations and other Instruments

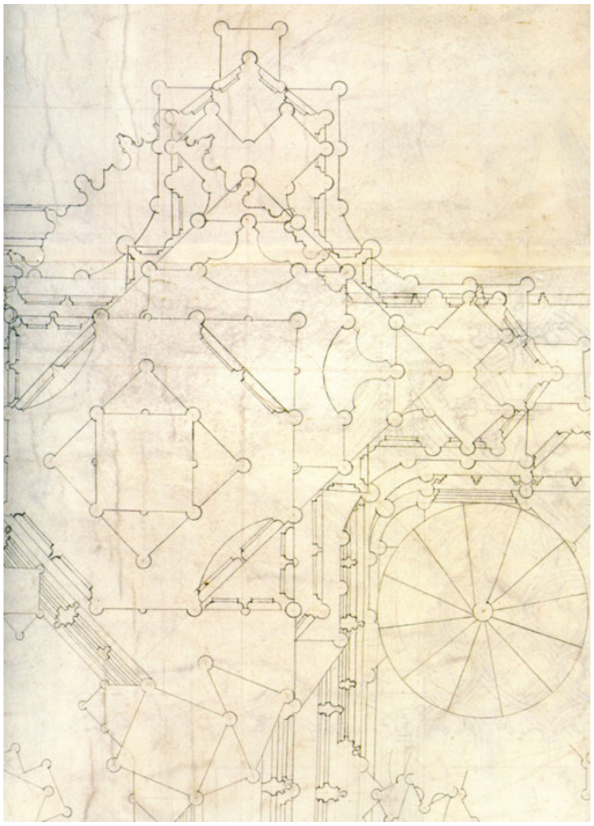
Architects tend to see drawings from the point of view of the architect, and so understand them as relatively comprehensive depictions—skinny models, as it were, of the built-thing. To each individual involved in the materialization of a set of plans, however, the drawings look different. First, because the plumber or the painting contractor might receive only some small excerpt of the entire drawing set. But more significantly because each trade will look into the drawings only for some subset of the information those drawings contain, missing much of the redundancy that makes formal systems reliable. This is the underlying reason why plumbers saw holes in structural timbers, concrete workers form curbs over manholes (or construct concrete walls with revision clouds formed in them, as is rumored to have taken place in the construction of the Helsinki subway station). These are mistakes that seem impossible, given the inclusion of all relevant information in the drawings, and the implicit assumption of professional expertise. Yet even if both of these things are in place, the former may not always activate the latter.

Critics of recent advances in the technologies of architectural representation like to point out that far more information goes into a building model than comes out of it in the form of actual, transferrable, documents. But this was the case long before the advent of Sutherland's electronic doodles.[439] It may be that each tradesperson reads a different story from a single set of plans; and it may be that the architect should be, above all, a chief-storyteller; but before any such claim can be made we need to understand the story each maker of the building needs to hear, and how that story, however partial, arises from the conjunction of the knowhow of the builder and the descriptions of the plans.

In his 2001 study of organizational systems, Arthur Stinchcombe takes as one of his primary examples the representation of external (plumbing, electrical, etc.) systems of knowledge and practice in architectural drawings. He distinguishes, as most sociologists after Max Weber do, between formal and informal systems, though his is a particularly detailed treatment, as the 'formality' of formal systems is the primary concern of his work. In sociology a formal system, like law, or the game of chess, is a structure for social interaction which prescribes certain behaviors and proscribes others. The construction drawing is a formality, per Stinchcombe, that governs the action of building with remarkable accuracy, cognitive economy, and robustness. The representational system of construction documentation works (when it works) by transferring the fiscal authority of the client through the structuring representation of the architect, to the material fabrication of the building. This translation requires a shared language. To make use of a set of drawings, "One has to know how a notation of "Finished Floor Elevation 1919.00'," is turned into practical measurements on the ground for building forms to pour concrete into."[440] But Stinchcombe wants to differentiate his analysis from the more orthodox view of formal systems, in which the translations from law to everyday life are described as negotiations between *formal* and *informal* systems of action. Instead, he sees the informal as merely the intervention of and accommodation to other formal systems external to the one at hand.

> Just as a cookbook recipe for bread relies on one knowing what "smooth and elastic" bread dough feels like (though if designed for beginners, the cookbook may include an extended essay on the craft of bread making at the beginning of the series of recipes), the blueprint relies on a plumber knowing how to fit a 1 percent grade of a waste pipe into a wall as that wall has been actually built (up to 0.2 percent out of plumb). The semantics of the abstractions in the first instance are given by craft knowledge, quite often craft knowledge that the architects or engineers themselves do not have." (59-60)

That is, "the informal competence of craftspeople is part of the semantic system that tells us what the blueprints mean."[441] Stinchcombe's liberal understanding of formal systems is especially pertinent to architectural representation, because so much of what is described by a set of contract documents depends upon a tacit assumption of competence in craft knowledge; and the architect's job is to coordinate an ever-increasing, and increasingly specialized, array of agents, each of which (necessarily) knows more than the architect. While it may once have been possible to, like the Medieval architect, build the tower of a cathedral with a single drawing, [fig. 6.19, fig. 6.20] that possibility seems remote today.



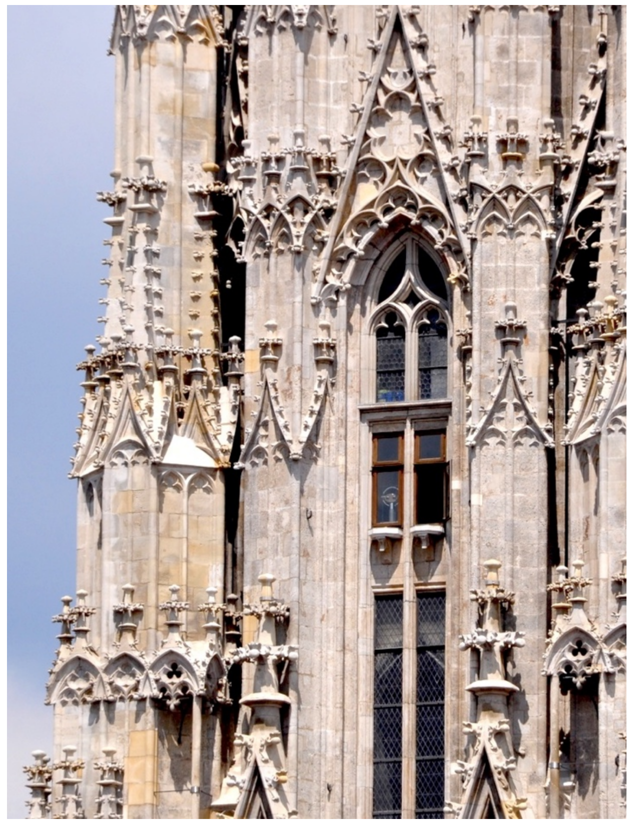


Figure 6.19. St. Stephan Wien north tower c. 1465, Gregor Hauser Master Mason (Detail). In this Medieval plan of a cathedral steeple, there are as many as 27 different levels of plan view collaged into a single image. It is left to the historian's imagination to consider the dialogues which were engendered—and necessitated—by this minimal representation. Image: Archives of the Metropolitan and Cathedral Church of St. Stephen's in Vienna. Image: Wien Museum / public domain.

Figure 6.20. St Stephen's Cathedral. Detail of North Tower. Image: Robin Stevens / CC BY-NC-ND 2.0.

To a certain extent the contemporary apparatus of construction documentation, from AIA contracts to Master Spec to the ready exchange of pre-drawn details from manufacturer to designer, and project to project, exists to support the architect in this vertiginously complex coordination. While it may have once been possible to orchestrate, with a single drawing such as the one above, much of the construction of a cathedral tower, the multiplication of trades and techniques (to say nothing of materials and products) has necessarily demanded a corresponding increase in the quantity, and diversity (if not always the information density), of architectural drawings.

It may be that Mercer's methods are permitted, in part, by the almost Medieval simplicity of the trades involved in his buildings, though we should be careful to note that his buildings were not technologically retrograde for their time—quite the opposite—Mercer's myriad attempts to combat condensation and damp in his concrete walls is only one example of his continual attempts to improve the performance of the building technologies he appropriated. He also integrated a number of recent innovations, including electric lighting and central heat. (Though his implementation of central heating was aspirational at best, as museum staff, and Fonthill docents, often attest.)

We should also consider that the simplicity with regards to the integration of skilled trades was for Mercer very much by design—wherever he could assimilate a preexisting craft tradition into the skill-set of his everyday employees, as in the case of window fabrication or kiln building, he did so. A key feature of Mercer's method, then, was its *hunger* for other bodies of knowledge, other tools, and other skills. (We might call this an analogical hunger.)

This analogical hunger has implications for what is made explicit in drawings, and what remains tacit. The most articulate and exact passages in Mercer's construction notebooks correlate with the exercise of this analogical hunger—that is to say, his representations are most verbose just when we might, in a conventional drawing set, those lacunae that point to a lack of technical knowledge or a failure of the architectural imagination. It is not that Mercer always possessed this knowledge in advance—with the notebook in hand he may proceed as-if he did.

The goal of a good construction set, then, might be reviewed in light of Mercer's notebooks. It is not necessarily the most complete description of the building to be built; rather, it is the clearest prescription of that building, the one most readily followed to a successful outcome. And often, as we endeavor to describe with perfect fidelity the complex reality of building, we end up mirroring that complexity. We task ourselves with the creation of a perfect mirror, and when we find it has lapsed, either during the drawing or during the building, we patch it. This makes for a recursive, and problematic, complexity.

Formal Systems, or Materializations of Experiential Practice

For Stinchcombe, formal systems are distinguished by three properties: cognitive adequacy, transmissibility, and feedback.[442] If we hear echoes in this triad of the criteria established in previous chapters of *low-noise*, *portability*, and *feedback*, this is no accident. The sorts of materializations of experimental practice Latour and Turnbull are concerned with, and those efflorescences of the arts Eco analyzes, are a certain type of inscriptional instrument, or instrumental document, sociologists call a formality. The sociologists we have reviewed point back to Max Weber's analysis of law and society as the origin of this term.[443] Construction drawings, I would like to argue, belong to this same category, not despite their instrumentality, but in and through it. That is, they function as adaptive distributed formal systems, 'open' in the way Eco describes. Stinchcombe, describing the way construction drawings work, writes:

> The formalities of blueprints, then, have to be good enough abstractions of the substance of a building not yet built so that concrete foundations poured in accordance of them will hold up the building and its contents, so that the partitions into which plumbing and electrical wiring are to be put are wider on the inside than the pipes and conduits that go into them, so that the windows ordered in advance can be fitted into the rough enclosures left by the bricklayers, so that the furnaces fit between the relevant part of the floor and ceiling of the basement, and so on. The argument here is that the function of the formality of blueprints is to reduce the variance in the meaning of technical facts (and the corresponding technological acts that cost money) between what the client transmits to the contractors and what the contractors understand, and that one can tell which technical facts matter most by which ones are most formalized in the prints.[444]

In this sense, then, construction documents provide a structure and system for organizing the parties in a construction project; and, precisely in the *economy* of what they formalize, communicate hierarchy of craft actions, and open the possibility of a context of affordances, larger than the task-at-hand. The architect is uniquely able to offer these coordinating economies and fabricate these heuristic fictions because of their placement with regards to the other parties in building practice: as a central node in the network of relationships. A typical arrangement of parties is shown in figure 6.21.

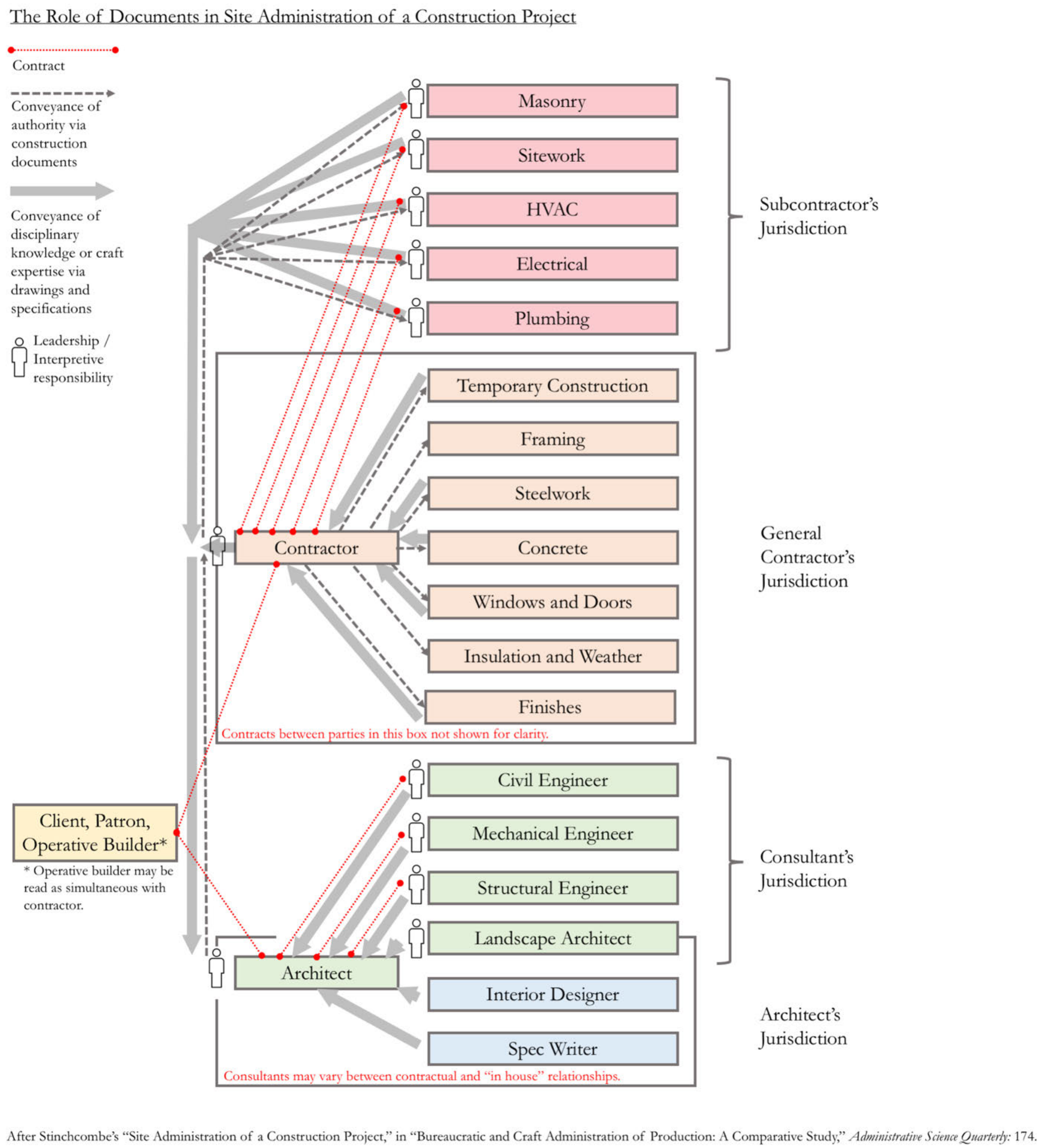


Figure 6.21. Chart of the relationships structured through the use of construction documents. This is of course a massive simplification, and is intended to serve as an illustration only of the role of documents, rather than a comprehensive depiction of the parties involved in construction. It is interesting to note that, while the prevalence of hybrid models and integrated design has increased in recent years, standard contractual relationships are relatively unchanged since Stinchcombe explored these issues in the late 1950's. Chart: author.

According to a sociological account, such as Stinchcombe's, the construction documents created by the architect provide a vehicle for the conveyance of authority from client, via architect, to builder; and the associated responses by various consultants and subcontractors provide a conduit for the flow of information from disciplinary domains and craft knowledge sources outside of the architect's ken. Given this model, it would seem that greater specification would only be to the good—and indeed, the writing of specifications has become a highly specialized discipline within the profession, with the result that even a relatively humble project can expect to see a 'spec book' running to hundreds of pages, much to the chagrin of the typical builder.

Many contemporary accounts of architectural progress feature grandiloquent claims for the ever-increasing accuracy and mobility of representation. Implicit in these claims is an assumed apotheosis of technological mastery of the formal systems of representation, in which the representation of the thing and the thing-itself grow more and more alike until they become (virtually) identical. If the goal of architectural drawing is to create descriptions of buildings, it is only natural to want these descriptions to be as comprehensive as possible.

However, as Stinchcombe points out, architectural drawings don't tell a builder what to do; they give a builder what is necessary to know about the rest of the building.[445] For example, he writes,

> the size and location of foundations (foundation walls, piers, footings, and piles) need to be calculated from the loads of the building they will have to bear and from the qualities of the soil and subsoil on which the building will rest. The results of these calculations are designed into the drawings of foundations and the reinforcing steel specifications for those foundations. The concrete contractor needs to know also how much space to excavate so that its workers can build forms, how to support and brace the forms, how much concrete it will take to fill the space, which parts have to be vibrated so as not to leave unfilled spaces, what lifting and pumping capacities will be needed place the concrete, and so on. None of the latter will be in the drawings, though occasionally, for very crucial aspects of the structure, the contractor may be required to supply its own drawings for how it expects to achieve the purposes built into the abstractions.[446]

What is necessary to know, even within any given trade, may vary greatly depending on the building materials, techniques, and design of the building. The mason may need to know quite a bit about the plumbing of the building, or nothing at all, depending on the location of that work; and a drawing full of plumbing information unnecessary for the mason would be, for the mason, at best an inefficient drawing and at worst the source of expensive mistakes. In this view the best representations may be those most closely tied to the questions of the particular builder or tradesperson they are used by, rendering their efficacy a function of their adjacency to the act of making—their pertinence, rather than their comprehensiveness.

Generally speaking, we tend to see the most economical forms of communication, like Alberti's doodle, reserved for a very privileged, and restricted, set of relationships. (We see this play out in contemporary practice when a client may require from a trusted architect of long association only a rough sketch for approval to proceed; while a relationship of greater formality and anonymity might demand an elaborate sequence of presentation drawings or models. And so we find that trust is inversely proportional to the gloss and comprehensiveness of a firm's renderings—a challenge, it would seem, to the conventions of architectural education.)

As the designer and the builder of reinforced concrete buildings at a time when and in a place where such a practice was not established, codified, or well understood, both formal *and informal* structures of communication-and-action were required to be invented. It is the latter of these structures which is particularly difficult to study, because it is the nature of tacit knowledge to leave only secondary traces.

F. Formality and Invention

So much of much of Mercer's method lies outside of the spectrum of normal architectural documentation that it appears to be entirely informal, in sociological terms. However, observing the conveyance of authority in Mercer's projects, and comparing this delegation to more normative architectural documents, reveals their underlying similarity. As Stinchcombe puts it, authority in architectural drawings "is embedded and not formally governed by the architect because it is specialized, and can be better embedded correctly in the design of the building by letting the electrical contractor and electrical engineer, and ultimately the electrician, manage the details".[447] That is to say, even the most explicit of architectural drawings performs some of its most significant functions tacitly, functioning not merely as a description of physical form but as provocation of physical acts, and as the conveyor of authority to engage in both specified—and unspecified—action. This sort of delegated authority, which Stinchcombe calls 'informally embedded formality' is not, he will eventually argue, different from formality, but rather is the way formalities function in adapting to change, particularly in the context of complex systems of delegated or non-hierarchical authority. Construction, he argues, is just such a system.[448] This is particularly the case when formal systems must engage with manifold uncertainty.

What makes Mercer interesting from this point of view is the degree to which unknowns and uncertainties are appropriated by his methods and (such as they were) formal systems. This is not unique to Mercer's construction projects; only, perhaps, uniquely visible in them.

There is a layeredness, a nested structure that obtains whenever formal systems adapt to real life situations. Such networks of action can be mapped predictively, and described algorithmically in long chains of if-then statements, but these sorts of representations of uncertainty are often ponderous precisely when dexterity is required, and prescriptive in the face of patent evidence of a misfit between prediction and reality. Yet successful formal systems must behave adaptively to sustain themselves, as there are always other systems, formal and informal, with which they must engage. In Stinchcombe's account, this adaptation is provided for by tacit knowledge and informal communication, "embedded" within the larger formal matrix. But this adaptive capacity need not be relegated to the oppositional and imponderable territory of 'informality'. Just because something appears to be informal, or remains unspoken, does not mean that it is not systematic; only that its ruleset or mode of articulation is outside of the syntax of the superordinate formal system. Whatever the drawing shows, it provokes far more, both in terms of action on the basis of tacit knowledge, and in terms of the conversations which it engenders in the tension between formal and informal systems. What is more, that which appears, when viewed from within a formal system, to be just the sort of syntactical controversion Eco describes as particularly fruitful, may make perfect and logical sense in an external context. This is not merely the case for communications intended to provoke, through novelty, fresh consideration. It also applies, as we have seen, to the sort of everyday speech aimed at effective and apt communication put to the purpose of solving a novel problem, particularly when the parties involved share a body of expertise in a related discipline.

This may be counterintuitive; but only because we have come to see novelty, and the interpretational difficulties it provokes, as paradigmatically artful. If we place ourselves in a moment of meaningful everyday conversation, we find, as Eco suggested, that it exhibits many of these same properties—so it should come as no surprise that Mercer's systems of representation and action depended deeply on dialogue.

On Mercer's jobsite, information would flow both ways, with overall performance capacities and design criteria passing as often from the installer to the designer as the other way around. Even in

Mercer's case, despite his incessant researches in ceramics fabrication and experiments in novel architectural applications, we can see evidence of this sort of bilateral knowledge transfer. In one of the few preserved notes in the Mercer archives not in the hand of Mercer or Frank Swain,[449] we find a "Receipt for Pointing and Finishing Moravian Pavements":

> Where trowel pointing is not desired, upon a pavement set with unglazed tiles previously oiled (their faces immersed in boiled linseed oil, in oil pans of tin or metal, two inches deep by twenty or more inches in rectangular diameter, for at least a minute) after the lapse of at least one day, pour over the whole pavement a grouting made of Portland cement fine sharp sand and color if desired, mixed to the consistency of molasses […] Let the grouting run and push it well into the joints, so as to fill them everywhere to overflowing. The sand may be omitted from the above cement mixtures A, B, C, and D,. Where particular smoothness is desired upon the finished surface of the joints, as the presence of the sand in the cement, after the rubbing of the pavement with saw dust, as described below, leaves a roughened surface upon the joints. Allow this to harden over the pavement in the form of a crust, for five six or seven hours according to warmth and dryness of the atmosphere and consequent rapidity of setting, or at most overnight. Then, after scraping with a trowel the surface crust off the surface of the tiles without scratching the joints, and sweeping The Dust away, rub on the pavement with the hands a mass of clean fine sawdust (not of chestnut wood, because of its staining property) free of lumps and sticks, and moistened with [omitted][…] When in two or more weeks after setting and cleaning with oiled sawdust as above described the pavement has dried and become dingey and grey in places and upon the cemented joints through the distillations of the cement, clean the floor as above described if it has not been already cleaned, but if previously cleaned as directed, then simply sweep a pile of the sawdust oiled as above over the whole pavement.[450]

This sort of description of best practices in the installation of Moravian tile floors reads not unlike that most formal of architectural documents, the "prescriptive" or "proprietary" specification. And like many such specifications today, it is a document created by the product manufacturer, to help guide the work of the architect in the use of a particular product. With this particular specification or "receipt", however, the ad-hoc nature of the process remains readily evident, not merely in the informality of the language, but in the accommodating and variable specification of its particulars. Moreover, it is handwritten, and may not have been meant for use outside a circle of select few pottery employees. It may in fact have been, like the technical passages in Mercer's notebooks, intended as an aide-memoire or rehearsal for verbal instruction, to be given by Sell or Mercer on the various jobsites where his tiles were being installed.

In any case, this is a specification with notably broad tolerances: "mixed to the consistency of molasses," "for five six or seven hours according to warmth and dryness of the atmosphere and consequent rapidity of setting, or at most overnight." If it is formal, it is a particularly forgiving and practical formality. Yet Stinchcombe's clarification of how formality works has the potential to validate the methodical nature of Mercer's construction communications as no less instrumental than more traditional (and comprehensive) architectural formalities. A formal system either assimilates the unpredicted into itself or is deviated from—something Stinchcombe non-pejoratively calls "deviant action".[451] In construction, the system of communication is necessarily explicit and predictive. But this does not mean it is always need be envisioned as comprehensive, or designed to be prescriptive.

For whereas a prescriptive drawing attempts to regulate informal behavior through formal means, a more open documentary system must find an altogether more nuanced, concrete, and dialogic shape—beginning, perhaps, in the perennially open-ended configuration of an experimental practice. As Marco Frascari wrote,

> My proposal is that a productive approach to critical research in architecture is possible only if the complexity of the technological image is preserved. This is possible only through a radical change in our understanding of the role of drawings in architecture. Drawings must become technographies. These are graphic representations analogously

> related to the built world through a corporeal dimension and embodying in themselves the Janus-like presence of technology in architecture, where the *techne* of *logos* cannot be separated from the *logos* of *techne*. As specific acts of demonstration, these technographies are based on an architectural encyclopedia, which is a thesaurus of technological images.[452]

Technography, used here neologically by Marco Frascari, is a word coined originally by 19th century statisticians to describe the cultural study of technological artifacts.[453] It is, in this, a fitting description of Mercer's warrant in the collection and housing of his tools: it would seem that Mercer is, over and over in his works, seeking to write the story of technology. This argues with Frascari's metaphor of a "thesaurus of technological images," by which he may mean a theorist's practical pattern-book; an encyclopedia of pregnant fragments; or perhaps a memory palace of architectural praxis. What it does not mean, we can be sure, is the preservation of the "complexity of the technological image" through some sort of comprehensive database infrastructure for architectural representations. (Even if such a heaven were possible, it would be barren without revision clouds.)

A close reading of Mercer's works proposes another possibility: that the informal systems and tacit practices which together form the semantics of construction documents may be—and perhaps must be—invented anew in the prefiguration and fabrication of each building. Certainly, such was the case with Mercer's museum. This proposal—that a set of construction drawings should be unremittingly local to their site and project—might seem a recipe for unnecessary complexity. Yet like Fonthill or the Museum, an architectonic complexity may belie some few simple and economical processes that, when repeated, provide endless variety. If this were music, we would call it improvisation.

Chapter 7: Improvisation, Complexity, and Economy

Conventional "lump sum" construction contracts only serve to exacerbate the *ideological hostility to change and improvisation*. Much of the animosity that arises between architects. The heavily financed nature of modern construction means that the speed of completion will also be the owner's primary concern.

- Dan Willis[454]

The ancient Greeks had a better term for this alignment of skill and 'favorable occasion.' They called it kairos, which they distinguished from kronos (time as sheer duration). In contrast to opportunity, kairos has a network of meanings emphasizing both human skill and the ephemeral window for its expression. This network includes measure, proportion, timing, and season, as well as advantage and profit. When the ancient sculptor Lysippos gave Kairos human form, he did so in the form of an athletic, naked young man, walking on a razor's edge and balancing fine scales on a fingertip. Lysippos endowed Kairos with the muscular feet needed for poise on such a precarious blade. The wings on his heels and back ensure speed, flowing locks frame his face and his skull is bald. Underneath one copy of this statue, an epigram explains: Kairos can be grasped as he comes towards you, but no one can seize him once he has passed by. […] To cite the Greek classicists Marcel Détienne and Jean-Pierre Vernant, environments harboring kairos are characterized by "multiplicity and… ambiguity… fluid situations which are constantly changing and which at every moment combine contrary features and forces that are opposed to each other." […] For athletes, doctors, orators, navigators, and all who strive to excel or simply to survive through what might be called the arts of action, the ability to grasp kairos is a practical necessity.

- Margaret Cohen[455]

Regarding improvisation, the musician-philosopher Stephen Nachmanovitch proposes that the finished character of an improvised work is distinct from that of a more conventionally scripted one. "Finished artworks that we see and may love deeply," he writes, "are in a sense the relics or traces of a journey that has come and gone. What we reach through improvisation is the feel of the journey itself."[456] Later, talking about a literal journey, he writes, "the trip, like an improvised piece of music, reveals its own inner structure and rhythm. Thus you set the stage for fateful encounters."[457] Mercer delighted in 'fateful encounters.' His system of documentation, though informal, can be seen in Stinchcombe's terms as 'formally embedded informality,' in that it relied on the body of craft practices developed at his Moravian Pottery and over the course of his building projects, and that its formalizations depended upon the assumption of an elaborate body of shared tacit knowledge. Many of these practices were themselves techniques invented to provide broad tolerances; and their translation, through analogical adaptation to new materials and requirements, preserved or even enhanced the breadth and inter-domain applicability of these tolerances. What may have begun as merely dimensional tolerance in the spacing of the elements of a tile mosaic became, once fully integrated into a larger sequence of construction operations, a dialogue between the surface, form, proportion, and experiential sequence of the building. This dialogue was carried out even as the building took shape.

Nachmanovitch makes this point with regards to the history of music, which aligns remarkably with that of the documentary practices of architects. The sweep of musical history across cultures, Nachmanovitch explains, is one of structured improvisation, from the baroque practice of playing over a prearranged ("figured") bass line, to the use of scales and keys to anchor flights of invention in jazz. The convention of 'note-for-note' playing, and the view of sheet music as (in our terms) a specification for performance, was not standard practice until the 19th century.[458] Instead, as Bringhurst noted in the last chapter, practice came before work, and work was structured to encompass, and admit, the opportunities and accidents of site and circumstance.

A. Structure, Stories, and Stuff

There exists a rich literature on accident in architecture, stretching from the iconography of *Fortūna*[459] [fig. 7.1], a figure of particular meaning to Mercer [fig. 7.2], to the celebrated crack in the gymnasium ceiling of the Unité d'habitation Marseille. [Fig. 7.3.] Ceilings were important to Mercer as well—as canvasses for the storytelling imagination, as primordial, labyrinthine caves, and, perhaps entirely pragmatically, as the underutilized 'fifth wall' of every room.

Figure 7.1. Fortuna, depicted blindfolded on a winged ball, with the implements of navigation. In the classic iconography of this figure we find an image of the perennial conflict between the tools of measurement and the unknowable future. Image: La mythologia explicada para la inteligencia de todos : obra elemental indispensable á los jovenes de uno y otro sexo, y útil á toda clase de lectores, y adornada con cien láminas, Traducida del francés por Pedro Chico de Guzmán y Salcedo / public domain.

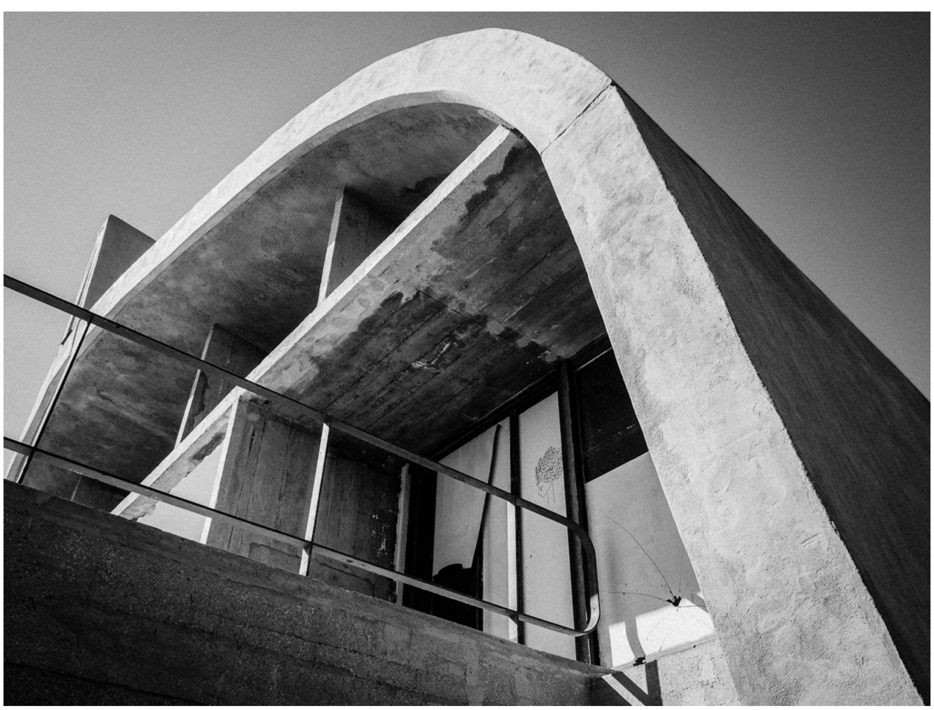


Figure 7.2. The gymnasium at the Unité d'habitation Marseille, today renovated as an art museum. Image: Pascal Jappy.

Figure 7.3. Fireplace in the Morning room at Fonthill, with the motto Ardet Fortuna*, "fortune ablaze." Image: author, courtesy of Fonthill Castle.*

In each of his major projects, Mercer used his ceilings in diverse and characteristic ways; but in almost every case he used them to a far greater degree than is customary, with the possible exception of the medieval church or the renaissance palace. (Perhaps not coincidentally, these were the buildings he was most influenced by, and many of his most notable rooms are visibly indebted to these precedents.)

Structure

We see echoes in his work of the architectonic vault in which structure and ornament intertwine [fig. 7.4], as at the Roman baths turned Medieval abbey of Cluny (which Mercer visited as a young man). And in the mosaics and brocade murals he created for Fonthill, we encounter Mercer's own reconfiguration of some of the great ceilings of Europe. [Fig 7.5., Fig 7.6.] Like the ceilings of those buildings, Mercer's ceilings were populated with structure and stories; and the decoration of his ceilings followed similar patterns, such as the highlighting of groin lines in intersecting vaults with tile, and the telling of myriad stories within the 'frames' marked out by these, and other, outlines of building structure. Column capitals were often intensely decorated, in line with his precedents; and their tiles, installed after everything else around them had been installed or finished, [fig. 1.25] allowed for the mediation between his often board-formed and faceted concrete columns and the smooth curves of ceiling vaults. But in other ways he diverged from the norms of the buildings he was inspired by.

Figure 7.4. A chapel at Cluny, Paris. Note the placement of a single column in the center of the room, typical for a chapter house. Mercer may have been influenced by this particular idea, as many of his rooms feature a single, central, column. In the pottery, for example, the workspaces are configured as a series of rectangular rooms side-loaded along a colonnade, with a column roughly centered in each space. Image: author.

Figure 7.5. Columbus room, Fonthill. Image: author, courtesy of Fonthill Castle.

Figure 7.6. Ceiling mosaic above the presbytery, Basilica of San Vitale, Ravenna, Italy. Note the tiled block capitals. Image: Tango7174 / CC BY-SA 4.0.

Perhaps the most unusual characteristic of Mercer's ceilings, particularly in comparison to these sorts of grand and often public buildings, is their closeness. This is perhaps most striking at Fonthill, where constant alterations in floor level, and nearly 30 stairways (some of them hidden), force a constant awareness of the scale of the room in relation to the body. It is a building that no doubt makes some people uncomfortable, because it is impossible to move cleanly and separately through its spaces—one is constantly brushing up against narrow doorways and halls, taking care about headroom on the various stairs, entering rooms obliquely and often at corners, and leaving by a different door than one entered. In the rooms themselves, varied and irregular outlines would at times provoke multiple different ceiling configurations, and these configurations might respond to the program of the rooms below. Bednooks in bedrooms could have ceilings tangibly adjacent to the bed [fig. 7.7], and windows, unusually large for the size of their rooms, often enhance by contrast this sense of smallness. Departing a room through narrow doors and passages might lead directly to and through another intimate space, or into hallways connecting nodally as well as room to room Fonthill is a complex and recursive concatenation of many small rooms; and we know from Mercer's own accounts that this was very much by design. It is also one of the most fully three-dimensional of buildings—that is to say, there are no "floor plates" as we might expect to see in a more typical multi-story building. The spatial diversity includes an inordinate amount of up and down, as well as side to side, and this vertical complexity activates the ceiling and makes it present; the tiled and textural complexity of the ceilings make them in turn more tangible than we are used to; they become a central and even focal part of the experience of the building. (This may also explain Mercer's unusual predilection for placing a column in the center of the room: it draws the eye up and into the story of the ceiling; or draws the ceiling down to join the haptic surfaces of the room.) Tangible ceilings were of great importance to Mercer—they were also, often, enriched with complex and interwoven stories.

Figure 7.7. Bed nook, Dormer Room. Often Mercer's preferred bedroom. Image: author, courtesy of Fonthill Castle.

Stories

The vaulted ceilings Mercer developed at Fonthill also provoked innovations in tile design at the Moravian Pottery. The building contains a history of these innovations, read vertically. (As we have discussed, the tiles were cast integrally, such that the level of a room may be read as a chronology of the development of its tiles.) The ceilings of the lowest rooms such as the library and the conservatory use decorative motifs in tiles to outline building elements and geometries. [See figure 6.7.] Beams and groins are outlined with geometric shapes, and other simple tiles; and between these outlines only occasional individual tiles break up the unadorned concrete of the ceiling surface. Half a story up, in the Saloon, Mercer experiments with using some of his collection of stove plates to create impressions in clay, which are then cast in relief on the flat concrete ceiling and beams. [Fig. 7.8.] In this room we find the 'beaded' beams discussed earlier. The Saloon has elaborate tile friezes along the top of its walls, but its ceiling is simple in comparison to what follows. These lower, public rooms have tiles from other makers and other parts of the world on their walls, each marked with a catalog number, as Mercer intended his house to be a demonstration of the history and contemporary variety of the world's tiles as well as of the diverse output of his own pottery. (Here again we encounter Mercer as a collector and curator. [Fig 7.9.] As the guidebook to Fonthill explains, "The origins of Mercer's foreign tiles span the globe, including Mexican, European, Asian, and Middle Eastern examples dating from the 13th to the 19th century. […] From the first, Fonthill served as a kind of an advertisement for Mercer's tiles, since Mercer installed most of the different kinds of tiles he produced."[460]

Figure 7.8. Saloon ceiling. Image: author, courtesy of Fonthill Castle.

Figure 7.9. Tiles in the "Chinese stair." Image: author, courtesy of Fonthill Castle.

His ceilings, however, were reserved almost exclusively for his own tiles. Moving upwards through the house, the variety of tile increases, and we begin to see medallions and mosaics, such as the ones Mercer had developed for the Pennsylvania state capitol in the years immediately prior to the construction of Fonthill. These increase in complexity until, on the fourth level, in the rooms he called the Columbus Room and the Bow Room, we see the first evidence of a new family of tiles, a style Mercer would come to call "brocade" or "relief" tiles and which he developed, according to Reed,[461] specifically for application in tiled vaults, following the method he first developed at Fonthill. There is a clear connection between the mosaic installations and those of the brocade tiles: both depict figures, flora and fauna, artifacts and buildings; but where the mosaics do this in a manner traditional for mosaics—through the assembly of many small, multicolored pieces—the relief tiles tend to have a much simpler relationship between figure and tile. This means that the Columbus Room and others in its style tend to look dizzyingly complex, a collection of myriad individual things, rather than presenting a single coherent theme or themes. In other, less central rooms, Mercer uses such complexity to tell a linear story, such as in the "Bluebeard" tiles in the Yellow Room, which retell Charles Perrault's gruesome fairy tale of murder, intrigue, and good fortune, and the revenge of the many wives of the pirate Bluebeard. [Fig. 7.10.]

Figure 7.10. Bluebeard tiles. Image: author, courtesy of Fonthill Castle.

Perhaps unsurprisingly, these storytelling sequences would go on to become a popular seller in the catalog of the Moravian Pottery[462], and Mercer planned a great many of them, though he produced far fewer than he planned.[463] Ultimately, however, Mercer's tiles developed in other directions. We can see this clearly in his most ambitious installations at Fonthill, which show us a diverse population of figures, places, and ideas, and tell us, in this polyphonic vein, the European exploration and colonization of the Americas.

This was a subject of longstanding interest to Mercer, as it formed the core of his archaeological studies. It was also central to his pursuit of original work in the art of architectural tile. In a 1925 letter to the architect William Graves, Mercer described his thinking with regards to the design of tiles, which he saw as a project unique not only in its Arts and Crafts inspirations but in its connection to a particularly American identity, writing that

> if tiles are to be considered as decorative art, no one should make them without first reverently and faithfully studying the great decorative art of the past. In a high estimate of the aesthetic value of these ancient works, namely their mastery of color, conventionalism, balance of pattern, splendid decorative effect, I agree with my artistic friends, but in the best of these masterpieces I find a story, a sermon, that my friends care nothing about. Yet to me, this so called "literary" side of the craft, this story telling, which I understand has been said to "contaminate" painting, has been my primary impulse or inspiration. I agree with them that the design must be an aesthetic success in color, pattern, conventionalism, balance, etc., and further that it may be such a success without any meaning at all. But if tiles could tell no story, inspire or teach nobody, and only serve to produce aesthetic thrills, I would have stopped making them long ago. To explain this more clearly, I would say that to me the ancient designs have seemed more and more inspiring as they rose from the geometrical forms of the Western Mohammedans, through the flowers, birds and animals of the Persians, Chinese Buddhists, or Byzantines, none the

less decorative none the less aesthetic, none the less constrained to constructive laws, but interwoven with human figures expressing in legends and stories sincerely felt and told. […] [T]he modern American maker of tiles might well find his best and most inspiring and appropriate theme in the dramatic story of the discovery and first exploration of America.[464]

But this passage, often reproduced in studies of Mercer, is retrospective, summary, and can lead to the impression that Mercer wanted to merely to tell a story in the manner of his illustrated fairy tales. What we see in the ceilings of the Columbus Room, and the Bow Room, however, is that when it came time to tell this "best and most inspiring" story, Mercer created something completely different from a fairy tale, or even the sort of linear historical account common in his time.

Reed's analysis of these ceilings is excellent, and she traces the direct influence of maps[465] and codices[466] on Mercer's development of these tiles, both thematically, and graphically. And, to be sure, there are striking visual resemblances between these sources and Mercer's ceilings. Of particular importance is the presence in these influences of text integrated into pictorial representations, a tendency we see expressed in Mercer' ceilings if anything more pervasively than in the models he drew from. But where the text on maps tends toward an annotative function, the tile letters in Mercer's ceilings are self-sufficient graphical elements, variably shaped and patterned, rendering them difficult to decipher. The letters spell out mottoes, names, locations, actions, and historical figures, and feature famous lines from poetry and mythology, such as Virgil's description of the cyclops Polyphemus in the Aeneid: "Monstrum horrendum, informe, ingens, cui lumen ademptum." A monster both horrible and marvelous. Many of the phrases on the ceilings are in Latin, others are in English. Like a good scholar, Mercer even cites a source: "Vide la Crónica del Perú de Pedro Cieza de León," the first account, published in 1553, of the European encounter ("conquest") of and role in the larger history of the Andean world. All of these textual elements intermingle with the pictorial, in a bedlam of shapes and colors.

The ceilings are divided into parts, and different parts suggest different stories and depict different scenes, from "Peruvians worshipping the sun," to the bridges and urban form of pre-contact Mexico City. Rather than telling any story, these ceilings suggest the many stories archaeology can tell; and present the cacophony of all possible stories rather than selecting any one narrative thread. These are not storylines, or the carefully triangular structures of classical drama, or even the condensed flashes of modern fiction, but the inchoate maelstrom of the endlessly fecund storytelling dream.

In the end it is worth noting that Mercer may have been a far more sophisticated designer of tile ceilings than of individual tiles. For while the move from mosaic to brocade would seem a simplification of the decorative range of tile groupings (shrinking the unit of meaning from dozens or even hundreds of tiles to small groupings of standalone figures), it may instead represent the enlargement of the unit of meaning to encompass the low, tangible ceilings of entire rooms, and the intricate, highly textured figures who freely populate them.

We should keep this in mind when we look to Mercer's seemingly pragmatic use of the ceiling to expand the useful surfaces of his buildings, and to hang stuff from.

Stuff

This is in fact the earliest of Mercer's uses of ceilings, going back to his first workshop, the 'archaeological laboratory' at Aldie that would become the nascent Moravian Pottery. As Mercer began to develop his collection of tools, he hung them from the exposed timbers of the walls and ceiling, categorized by type. [Fig. 7.11.] We can take this as a strategy for display, rather than merely a matter for convenience, for when Mercer first came to show his collection of tools, in the fall of

1897, and when he exhibited the collection again in the new Historical Society building in 1907, he followed a similar practice of increasing the density of objects as he moved up the wall and toward the ceiling. [Fig. 7.12.]

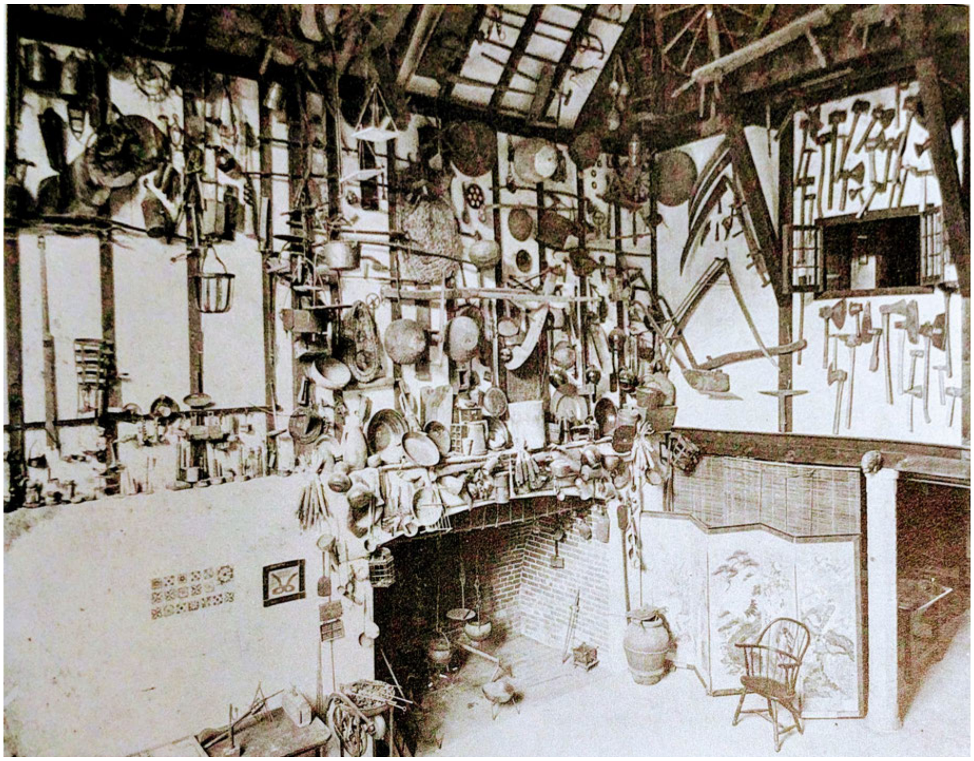


Figure 7.11. Mercer's studio at Aldie, ca. 1897, with early collection of tools. Image: courtesy of the Mercer Museum Research Library.

Figure 7.12. Mercer's 1907 exhibit in the Elkins building of the Bucks County Historical Society. Image: courtesy of the Mercer Museum Research Library.

When it came time to build the museum, Mercer adapted a technique he had used at Fonthill and the pottery, casting loops of wire into the concrete ceilings [fig. 7.13] as a place to hang lanterns.[467] (While Mercer included electrical lighting in his projects, areas of sleep or study were provisioned with these loops in strategic places for supplementary light.) There is evidence Mercer used this technique from the very beginning. [Fig. 7.14.] At the museum, Mercer used these loops to suspend many of his largest and most irregular artifacts from the ceilings. [Fig. 7.15.]

Figure 7.13. Lantern, Morning Room, Fonthill. Image: author, courtesy of Fonthill Castle.

Figure 7.14. Hanging loop in the "crypt" at Fonthill. This room, below the Saloon and Morning rooms, was one of the first built by Mercer, and its various elements contain a record of a great many roads-not-taken in the development of his architectural details. Image: author, courtesy of Fonthill Castle.

Figure 7.15. Typical hanging loop, Mercer Museum. Image: author, courtesy of the Mercer Museum.

The hooks also play a more monumental role. In addition to the individual rooms in which the hooks serve as convenient furniture for hanging objects in the collection, Mercer also provided a large open atrium in the center of the Museum, proportioned like the nave of a church; yet without even the most rudimentary of tiling or decoration. Instead, hanging from the various columns and balconies that ring the atrium are modes of transport—carriages and boats, a sleigh, handcarts and hoppers, even a charcoal burner's ladder. (Fig. 7.16.) These means of transit, seen from below, fill the air with their paths, and draw the eye up to the ceiling itself, hung with baby carriages and cribs with chairs beside them, baskets and bicycles and boxes. [Fig 7.17.] At first glance this seems an odd collection of items, their affordances diverse and incommensurable. Yet at the level of the metaphorical imagination, these objects are tools to hold and transport things—and people.

Figure 7.16. Charcoal burner's ladder. Image: author, courtesy of the Mercer Museum.

Figure 7.17. Ceiling of the museum atrium. It should be noted that these objects were not lit as they are today: they may have been lost in the shadows of the ceiling rather than featured as prominently and individually as they seem to be presently. Image: author, courtesy of the Mercer Museum.

It would be possible to read too much into the possible meanings of these objects. Certainly, various accounts could be made of the symbolism of cribs, scaffolds, and musical instruments that occupy the highest parts of the museum. But we should remember that Mercer's arrangement of circulation is not linear or particularly hierarchical; and, while the collection follows the broadly upwards-rising schema discussed in chapter 5, this is a schema based on Mercer's understanding of the cultural complexity of the various crafts and professions, rather than any existential or psychoanalytic semiology of individual items in the collection. Besides this, it is hard to say what superordinate category "baskets, bicycles, and baby carriages" belongs to.

Despite the inevitability of our seeing these things from below, the baskets are generally displayed upright, chests are closed, and other objects are situated such that whatever they might hold is concealed. A number of these things, particularly the chairs and cribs, are clearly empty; but their adjacency seems to suggest an only momentary absence; and many of the other items which in modern lighting show as empty may have, in their original shadows, provided some ambiguity. We look up, ultimately, to see the possibility of *more*—of contents yet to be discovered, of lives lived just beyond our view—*Plus Ultra,* "more beyond." This, then, may help to explain why it is hooks that figure the ceiling of the museum, rather than tile murals (which Mercer could easily have produced and installed, as we have seen, as a seamless part of the construction process). This also explains why there are so many hooks in Mercer's museum that *don't* have items hanging from them [fig. 7.18]: the hooks are not an exhibit strategy merely, but a way of configuring the building to be open to change, to have *more, beyond* what it has at any given moment. This sense of open-ended possibility is what brought Mercer to his collection, and, in the end, what he hoped to have its visitors take away.

Figure 7.18. Far more hooks than are necessary. Image: author, courtesy of the Mercer Museum.

B. Drawing More … Beyond: Allowance and Improvisation

The unused hooks in the museum ceiling seem like just the sort of accident architects try to avoid: in the seamless idiom of machine-age modernism, there is no tolerance for the leftover, the purposeful object misplaced or misappropriated. Yet it seems Mercer made little attempt to develop a regular (or irregular) strategy for their placement. In some areas they are thickly present; in others absent entirely or merely occasional. They also vary in gauge and overall size. Frankenfield, in his interview, describes their installation:

> Now those staples that are hanging was put in for to hang different things on in the ceilings. There may be a few around somewheres on the side wall. They had to be put in when the forms were made and they made them good and secure the same as the reinforcement was, so the concrete would go underneath of them, make a good tie in with the concrete and wouldn't pull out. So when we pulled the shorings out the concrete was all finished and the hook would be there for what ever purpose they wanted to hang on it. If it was heavy stuff it would be heavy hooks or staples like hooks to hold whatever may be hung on it.

This helps explain why there is little regularity to the frequency or location of the hooks: they were placed at the joints in the boards used to form the ceilings, and these joints did not follow a regular grid. It is clear from the construction notebook that Mercer developed ideas for the suspension of objects (the more substantial objects are listed on page 35) in conjunction with the planning of individual rooms (pages 34-39, as well as some notes on the plan sketches). And yet despite this advance planning, there are many more hooks in place than there are items to hang from them, even today. This suggests that, whatever preservational impulses we have to the contrary, Mercer intended his collection to continue to grow (as it has) and his museum to continue to change.

This proposes that we see our buildings as capable of more than we can conceive of for them; yet this sort of anticipatory ambiguity requires a different way of seeing the building, challenging our tendency to view buildings as 'projects'[468], and our role as artists *or* as technicians producing a finite and material result. Certainly this is a challenge to how we think as architects, and what we generally accept as the limits of design; but such a discussion is beyond the scope of this work. Here we can ask a smaller and more specific question: how might our *drawings* provoke more…beyond what they describe?

Draw Less

If we attend to the way Mercer used drawings, our first answer to this question must be: "draw less." This is not an admonition that may ever gain traction in schools of architecture. And it should not be taken too literally. Mercer created a great number of drawings, including etchings and other representations belonging to the domain of the fine arts. What he did not create very many of were technical drawings. As we have seen, many of his drawings describe, in great detail, techniques and technical matters. Yet few of them obey fully the conventions of technical drawing. We might call such drawings non-technical; we should not call them non-instrumental. And we should recognize that theirs was a technicality tuned to the precise audience and context of work.

Where he published articles and books for an audience of archaeologists, Mercer used the conventions of archaeological representation. When he produced large tile murals, he used full-scale pattern drawings to prototype and to transfer the precise arrangement of parts. But when it came time to do the work of the architect, he departed wholly from the conventions of that field. These conventions, however, should be understood in a historical context, as arising from the desire for professional separation between architect and builder, and the not unconnected rise in status of the position of architect. As the sociologist David Brain has explored, in the United Stated the consolidation of the tasks of the architect into a coherent and self-perpetuating disciplinary tradition occurred between 1800 and 1860. (While there were certainly architects before this time, there were not, in Brain's account, professionals.)[469] A large part of the process of professionalization, Brain argues, resided in the establishment what he calls the "rhetorical dimension"[470] of professional action, similar to what we have been discussing above as "formal systems". He writes:

> The practical side of this development is apparent in the introduction of new drawing techniques during this period. In addition to the standard schematic delineation of plan, elevation, and section, architectural practice incorporated the techniques of geometric perspective […] techniques of drawing [that] were elaborated and stylized in architectural practice. This craft relationship with the fine arts gave new practical manifestation to the traditional association of architecture with elite culture.[471]

Formal systems, as Stinchcombe begins to suggest, and as Ivan Illich has explored in great detail throughout his *oeuvre*, are not impartial, and often serve purposes extraneous to their purported aims. From this point of view, the technical drawing of the architect has as its primary function not so much the description of building, but the elevation of the architect to a position of authority as privileged holder of the abstract and hermetic knowledge of building; and as agent and conveyor of the authority of the client or patron.

This is why, in the treatise Mercer kept as a reference (Nicholson's *The Builder's and Workman's New Director…,* discussed in chapter 5) of the total of 625 pages and plates, nearly 300 treat geometry and drawing, while under 200 treat all practical matters, from site selection to painting, with the remainder devoted to history, theory, and 'style.' With the advent of professional organizations such as the *Brethren of the Workshop of Vitruvius* in 1803,[472] and the *American Institute of Architects in* 1836, the profession changed rapidly until, in the latter half of the 19th century, the role of the architect swung toward its present, fully professionalized configuration. This ultimately resulted in the bifurcation of construction practice into the roles of architect and builder, and the emergence of a second profession, the general contractor.

The architectural scholar George Johnston has pursued the question of this bifurcation, and locates it in the opening years of the twentieth century, with the first AIA contracts spelling out the separate roles of architect and general contractor appearing in the opening years of the century, and occasioning much remonstration in the pages of architectural periodicals about the crisis of the profession.

This was the fruition of trends begun decades before. "As early as 1859," Brain writes, "the AIA debated the issue of the ownership of drawings. Drawings were to be considered analogous to the tools of the carpenter, as instruments of service rather than commodities."[473] And by the turn of the 20th century the AIA had positioned itself as the source for standard contracts specifying the relationship between the architect and general contractor. This separation of powers confirmed the success and dominance of the professional model.

For Illich, however, professionalizations of expertise, such as occurred in the architectural field in these years, represent a pernicious, dehumanizing trend:

> Today's domineering professionals, of whom physicians provide the most striking and painful example, go further: They decide what shall be made, for whom, and how it shall be administered. They claim special, incommunicable knowledge, not just about the way things are and are to be made, but also about the reasons why their services ought to be needed. […] A guild, a union, or a gang forces respect for its interest and rights by a strike, blackmail, or overt violence. In contrast, a profession, like a priesthood, holds power by concession from an elite whose interests

> it props up. As a priesthood offers the way to salvation in the train of an anointed king, so a profession interprets, protects, and supplies a special this-worldly interest to the constituency of modern rulers. Professional power is a specialized form of the privilege to prescribe what is right for others and what they therefore need.[474]

For Illich it is then no accident that, with the rise of 'professional practice,' we have seen a consequent rise in the quantity of specifications, and the proportion of the specifiable in construction documents. This trend, unameliorated, will tend toward a state of affairs in which architects become product specifiers, and the practice of architecture one of 'service' to the proper coordination and installation of these products.

Mercer, as we have seen, resisted 'specification' at every turn, often to an alarming degree. (Such as avoiding, until the last half of his last project, the use of purpose-manufactured reinforcing bar, despite its negligible difference in cost (30 cents per rod in 1913 versus approximately 37 cents per twisted bar in 1914[475]) and greatly increased performance and reliability.)

In a system as open-ended as Mercer's, however, specification might not have the efficacy it does in a more prescriptive setting; it might also entail sacrifices not described by or registered within the range of the specified. With rebar, for example, when Mercer repurposed bar for other purposes, such as handrails or shelving, smooth or twisted bar might be preferable to stamped or textured rebar for these purposes; and while different bar might be purchased for each use, such increases in complexity, factored across an entire building, naturally require a much higher degree of tracking and specification; such specification presents its own difficulties (coordination, specialized knowledge, cost, performance criteria, finishing, etc.) And while Mercer's construction notebooks contain a great many drawings that treat technical subjects, in them we see an avoidance of the specifiable; or rather, specification of remarkably broad tolerances, and a reliance on prudence, or opportunistic judgement.

It is not, then, that Mercer would have us draw less, as draw differently. Rather than describing products, and specifying performances, our drawings might focus on processes, and, wherever possible signify, like Alberti's doodle, the critical gestures of craft action. This is only possible if we can accept some variety in our outcomes; if such variety can be seen as opportunity rather than flaw; and if we consider the reconfiguration of our *allowances*, as *affordances*.

Provide Affordances

It is this latitude, or 'play', this lack of control in the conventional sense, that makes Mercer's projects seem so individual, and also so unprofessional. But to call Mercer's buildings 'unprofessional' is not so much a critique of Mercer's projects as it is a critique of the ideology of professionalism. Illich makes a related appraisal of the mid-20th Century American housing industry:

> The building trades are another example of an industry that modern nation-states impose on their societies, thereby modernizing the poverty of their citizens. The legal protection and financial support granted the industry reduces and cancels opportunities for the otherwise much more efficient self-builder. […] [in] 1945, 32 percent of all one-family housing units in Massachusetts were still self-built: either built by their owners from foundation to roof or constructed under the full responsibility of the owner. By 1970 the proportion had gone down to 11 percent. Meanwhile, housing had been discovered as a major problem. The technological capability to produce tools and materials that favor self-building had increased in the intervening decades, but social arrangements—like unions, codes, mortgage rules, and markets—had turned against this choice. […] Our present tools are engineered to deliver professional energies.[476]

Documents that orchestrate 'professional energies' rely upon the authority of the contract and the threat of fiduciary penalty for noncompliance. The contracts preferred by architects shade the balance of these threats and penalties towards other parties; those preferred by contractors shift the balance in their own favor. Even the client must offer a sacrifice: that of the sovereign right to change one's mind, which is signed away as the ink on the contract dries.

Such an arrangement was, as Brain, Johnston,[477] and Larson have explored, new in Mercer's time; and, as Illich observed, 'self-building' was a far more normative occupation.[478] (Though we should be careful with the term 'self-building', as it presupposes a dichotomy which many of the thinkers we are engaging with call into question.) In the intervening years, however, the role of architect has come to be increasingly defined (even statutorily)[479] in opposition to the owner-builder.

This may partly explain Mercer's antipathy toward the encroachments of the professionalized trades, which he would have felt acutely, and first, in his tile production. (The very variability of his tiles, conceived as an aesthetic and perhaps social project, would, as the years progressed, fall more and more afoul of emerging trends towards comprehensive drawings and specifications, and the prerogative of design aesthetics, reserved more and more for the architect, would exclude Mercer's larger and more ambitious installations from consideration, as they were often created by Mercer fully customized for their location.)[480] When it came time to undertake his buildings, his experiences of the dictates (and dictators) of professional practice may have provoked him to reexamine the necessity of the conventions of the field; and his archaeological background and tendency to see tools in the larger frame of reference of their invention and evolution would have equipped him with the ability to maintain a critical distance from the commonly accepted tools of the trade.

Mercer would never become a participant in the historical and theoretical trajectory of the discipline of architecture; and his buildings have not to date been elevated to such august company. As such he does not share the presuppositions of the discourse, and its hylomorphic bent. There is, certainly, a guiding "design idea" in Mercer's work. But it is an idea about method more than form or style, a hylozoic rather than hylomorphic conceit.[481] The arts of representation bear no special ontological privilege, and so, for Mercer, the practices of design and building do not participate in many of the founding myths of architectural idealism. This makes his projects dissonant when viewed from an idealist perspective: they do not subscribe to a formal or stylistic teleology; their formal and stylistic attributes are emergent rather than prescribed.

Magali Larson, whose analysis of professionalism in general and its permutation in architectural circles particularly, is a key source for both Brain and Johnston, and her analysis of the architect's role as that of intermediary between the "*telos* and *techne*" of building[482] grounds an abiding pessimism about the scope of architectural practice. This is a pessimism that afflicts much of the profession today, and finds its expression in laments of the reduced role or even the irrelevance of the architect. (The only problem with this apocalyptic view of architectural practice is the mistaken assumption that architects were ever intrinsically relevant in the first place.)

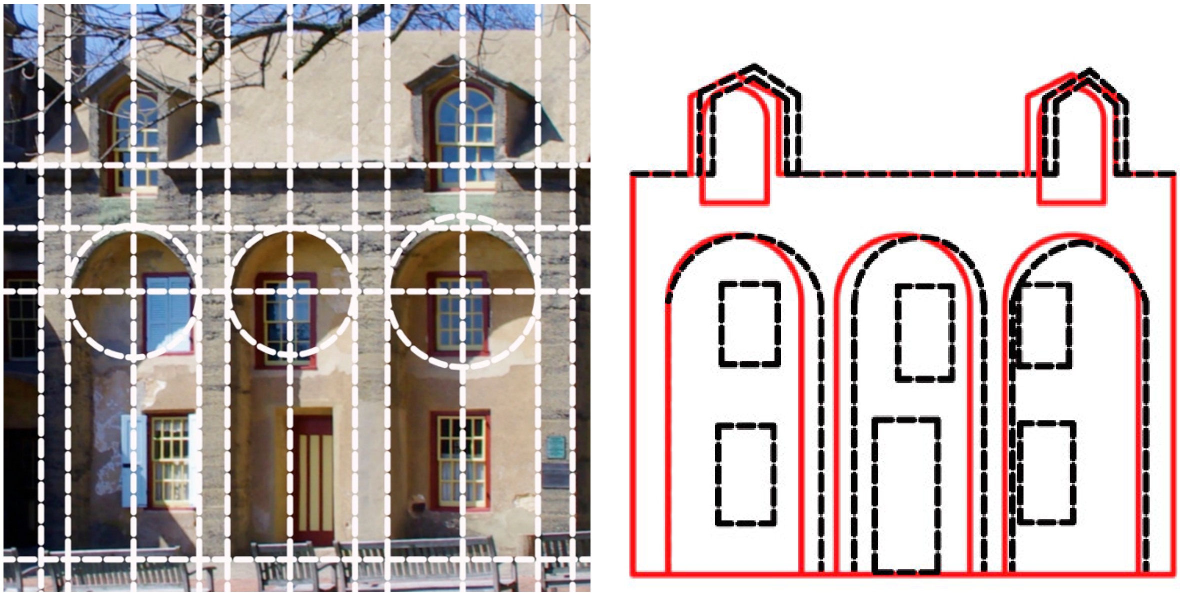
The comprehensive verisimilitude of the prescriptions of the architect, then, are instruments of the perpetuation of occupational hegemony, and a protection of that privilege, rather than something directly pertinent to, or derived from, the needs of construction. The elevation of construction documents to the status of "instruments of service" is a fallacy. Unless and until construction documents convey privileged knowledge of building practices, their instrumentality is illusion, and their authority that of fiat. In this arrangement, the drawings of the architect have no force. This underlying anxiety (what we might call 'the anxiety of inexpertise') is what fuels Larson's account: architecture "is an exceptional profession because it cannot, by definition, establish a monopoly; unlike other professions, it does not succeed in establishing jurisdiction against either professional competitors or lay resistance."[483] On the one side the expertise of the engineer must be consulted in matters of structure and function; on the other the expertise of the contractor must be respected with regards to the means and methods of building. But by vesting the role of architect in the realm of aesthetics, and abandoning claim to these other realms, the professional forecloses on the possibility of the invention of meaningful practice. This foreclosure is written in the exacting language of the specification, for if the architect cannot lay claim to the privilege of translation from lines in the mind to the stuff of building, there is no role left. Larson writes: "Of the Vitruvian definition—architecture is the combination of 'firmness, commodity, and delight'—only delight was not claimed by credentialed or otherwise expert rivals. To concentrate on the aesthetic dimension of building was therefore an inevitable strategic choice."[484]

Yet Larson's account of the fate of architectural practice is not complete. In chapter 6, we discussed the possible expansion of the Vitruvian triad to include a fourth virtue: feedback. Buildings change, even (or especially) while under construction. There is no inherent reason why drawings should not change as well. This calls for a sort of drawing that is not produced today; or rather, a process of drawing much closer to the conversational give-and-take of the pre-professional jobsite. Mercer models one way this might be achieved in a limited and simplified way; but the assumptions underlying his methods are more broadly applicable.

For Mercer there is, in the act of building-craft, little point in approaching architecture as a reconciliation of the material reality of the building with its platonic ideal. Both are subject to change. Certainly, there is a loose connection between idea and thing; and this in no way diminishes the act of realization. Seen from an archaeological distance, the building is only ever more or less a realization of the architectural idea; and this relationship of idea to thing may continue to grow long after the building has been constructed, or reconstructed. For example, in perhaps his very first act of architectural composition, Mercer (echoing Alberti's Tempio Malatestiano in Rimini) re-faced the existing building with a two story concrete arcade.

This was not his first concrete work at Fonthill, but it was one of the earliest finished facades, and the encapsulation of the existing farmhouse in a concrete shell was one of the few primarily cosmetic actions he took at Fonthill—that is to say, while the rooms in the existing house provided for secondary (or quite literally "servant") spaces, the concrete work undertaken around the original building envelope did not add space or improve the soundness of the building. It would seem likely, then, that the three-arched façade was an attempt on Mercer's part to alter the materiality and geometry of the existing building, bringing it more in line with the rest of the project.

Yet if we look closely at this arcade, we can see its distance from a corresponding geometrical ideal. (Figs 7.19, 7.20.)



Figures 7.19, 7.20. Partial front façade of Fonthill. The three arches were built directly against the wall of the extant stone farmhouse. Overlaid with dashed lines for closest ideal geometry aligned with the building as built. Also shown: dashed lines of actual (black) in relation to a fully symmetrical and equally proportioned layout (red). Images: author.

Surely, this is in part due to the novelty of the material, and Mercer's inexperience as a builder. But this does not mean the irregularity of the facade was an omission or mistake, because these sorts of digressionary geometries occur throughout his works. For Mercer the translation from idea to thing was always and invariably only approximate; and many of his formative experiences of architecture would have supported the idea of maintaining a comfortable, even productive, distance between the ideal and the real.

This willingness to accept 'digressionary geometries' is evident not only in Mercer's compositional decisions (which were, by all accounts, a secondary matter for him) but also in his invention of the various unique details and processes of fabrication. As we have explored, these techniques capitalized upon the adaptive capacities inherent (though often unrecognized) in their constituent materials, methods and makers. (That concrete was a new and relatively untested material, and so would have seemed full of possibility and protean, would only have made it more attractive to Mercer.) His specifications left room for 'flex,' and in places even provoked much broader improvisations.

Provoke Evolution

Mercer's precast windows are a perfect example of the evolution of a design idea through iterative improvisation. It would be quite possible to decide, even as the forms went up, that the windows planned were too short, their lights too large, or in need of a fan or triangular head. The existing process for window fabrication could adapt, without lost time or wasted material, to the changing requirements of building. While this is not categorically different from the way custom windows are produced today—shop drawings for window fabrication created by the window manufacturer from architectural drawings, then 'verified in field' from constructed rough openings by the contractor, after which the entirety of the window 'package' is fabricated by the manufacturer, delivered to and verified by the general contractor, and installed by the installer or carpenter—it is far more open to alterations in design, rather than merely marginal dimensional change to rough openings. The allowable "plus or minus" on Mercer's rough openings was not measured in inches, but in shape, and pattern, and scale. Thus elements of architectural design normally off-limits were brought into 'play', and thus into the arena of craft judgement and intuitions of the material imagination.

Mercer's plans show approximate window locations. His elevations suggest window shapes. But the buildings that result from these drawings are only in the most general sense described by them. Rather than describing the building, Mercer's plans and elevations serve as placeholders for a decision to be made…later—and illustrate just so much as needs to be known to proceed. This is an approach to drawing-as-hypothesis.

Like Mercer, Ivan Illich saw tools broadly, as a category that included

> not only simple hardware such as drills, pots, syringes, brooms, building elements, or motors, and not just large machines like cars or power stations; I also include among tools productive institutions such as factories that produce tangible commodities like corn flakes or electric current, and productive systems for intangible commodities such as those which produce "education," "health," "knowledge," or "decisions. "[…] all these planned and engineered instrumentalities[.][485]

Illich's writings on tools were not merely a jeremiad against the dehumanizing aspects of professionalism and its tools, but a call to recognize the possibility of what he called 'convivial tools'—tools that "give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision."[486] He thought that most hand tools fit this description.

But here Mercer might propose a more nuanced understanding of the particular qualities of "hand" tools. Tiles, he found, could be made a part of a larger system of construction; or they could be applied after-the-fact as decoration. But where decoration after the fact required a reliable product, integrated production benefited from broad margins and allowances and 'reliably' imperfect tiles (the better to disguise any digressions in geometry). Ivan Illich's convivial tools are a proposal directed towards the larger systems and infrastructures of modern life. But there is no reason we cannot bring the metaphor back to its concrete origin, and ask that the instruments of 'architectural service' partake of a little conviviality of their own. This means more than merely doing more with hand tools. (As Illich notes, "in principle the distinction between convivial and manipulatory tools is independent of the level of technology of the tool."[487]) It means holding tools to account as components of larger processes, and attempting to not only utilize, but to represent, those processes in ways that provoke improvisation, and allow for happy accident.

For a rational man of science, child of the latter half of the 19th Century, Mercer held an unusual reverence for the serendipitous. In his late book of short stories, *November Night Tales,* Mercer's protagonists often come up against the seemingly-supernatural; and while their credulous companions may be swayed by such demonstrations of the more-than-human-world, Mercer's alter-egos (which they so clearly are) remain skeptical. Despite their rationalism, however, many of these stories turn on some moment of unexplained or uncanny mystery, or unanticipated fortune.

Openness to "happy accident" was, for Mercer, a value in itself, the guiding logic of his collection of old tools, and a recurrent motif in his building practice. Thus the conviviality of Mercer's tools was not so much about the 'enrichment of the environment with the 'vision' of the tool user' as it was a matter of the ability of the tool to multiply affordances, and provoke the unexpected—to allow, or provoke, not merely randomness but structured improvisation in an iterative frame.

Over time, the tool may afford more than its user can intend.

C. The Structure of Improvisation

We can return now to Nachmanovitch's careful explication of the structure of musical improvisation. Structured improvisation, he tells us, requires *long practice, productive limits*, and *openness to circumstance.*[488] 'Long practice' is something entailed by the development of expertise. Nachmanovitch writes: "Prepare the tools. From buying the tools to cleaning and maintaining and repairing them, develop an intimate, living, years-long relationship with them. The tools need to work not only individually, but together."[489] 'Productive limits,' he proposes, "yield intensity. When we play in the *temenos* defined by our self-chosen rules, we find that containment of strength amplifies strength."[490] And finally, by 'openness to circumstance' Nachmanovitch means both the 'power of mistakes' ("if the oyster had hands, there would be no pearl"[491]), and the ability to see value in them. But this is about more than merely waiting for good fortune to strike. Instead, Nachmanovitch describes a creative method that serves as a cultivation of productive accident through hybridizing domains of knowledge and an open and hands-on approach to making.

This last factor—immersion of the act of design in the process of making—is a possibility that normative contemporary methods often minimize or eliminate completely (with some significant exceptions[492]), as its results would seem to be impossible to quantify, predict, or control. Mercer suggests otherwise. What we gain, in the use of design tolerances, and other tools of structured improvisation, is an open and collaborative arrangement of work, a configuration of practice that benefits the architect in at least three ways:

1. The possibility for the affordances of the actual, partly-built building to engage with those of the other tools of design to expand the range of what is available to the design process, allowing for buildings that could not have been (or merely were not) conceived of in advance in the abstract and representational practices of design.

2. The capacity of the 'happy accident' to register or evoke something of the spontaneity of its coming-to-be, and in this make possible a category of experience otherwise unavailable to the designer. Nachmanovitch tells the story of Leonardo da Vinci, who "was one of the great pioneers of improvisation on the viola da braccio, and with his friends put on entire operas in which the poetry and the music were made up on the spot."[493] Maurice Merleu-Ponty writes that our perceptions are characterized by an "open series of possible experiences."[494] That is to say, improvisation is an everyday part of perception, of tool use, and, as Nachmanovitch points out, of conversation.[495] The challenge, then, is not so much to 'put improvisation on display' (as Alva Noë might say,[496]) as it is to protect, and to provide space for, what is already very much a part of our creative intelligence and everyday lives.

3. Ramification of the affordances of our tools. Tools, in their affordances, structure and direct our improvisations: when these tools are responsive to change, and deeply contextualized in practice, we find ourselves engaging with the manual possibilities of building as a branching network of paths, a 'tree of gestures.' This possibility is predicated on the ability of our tools to offer feedback, not merely in terms of vibration, force, or material texture, but in a more inferential manner, a form of inference we might call 'Bayesian' because its attempts at prediction are iterative, scalable, and feed back into future predictions and representations.

The Evolution of Drawings

To this we need to turn to consider for a moment one of the most elegant (and now, with advancements in computation, common) tools for the management of prediction: Bayesian inference. Science journalist Derek Muller describes how "Bayes saw the world: It wasn't that he thought the world wasn't determined, that reality didn't quite exist; it was that we couldn't know it perfectly, and all we could hope to do was update our understanding as more and more evidence became available."[497] Bayesian inference is not inherently computational—Bayes lived in the 18^{th} century—but its most common applications today, such as epidemiological research, investment risk analysis, and spam filtering, are all computationally intensive. Bayesian inference is the general term for predictions which take into account the iterative revision of statistical projections modeled by Bayes' theorem, which describes conditional probability mathematically—that is, the likelihood that an event A occurs given an event B. In the orthography of statistical analysis this is written $P(A|B)$. If we take the probabilities of these events independently, $P(A)$ and $P(B)$, Bayes theorem tells us that: $P(A|B)=P(A|B)P(A) / P(B)$, in other words, that the likelihood of the possibility of A increases with regards to new evidence only insomuch as the likelihood of B is relevant to A. (This is what is represented mathematically as $P(B|A) / P(B)$. Bayesian inference describes what happens when we use this understanding of the revision of probabilities iteratively. This is why contemporary uses of the theorem tend to be computationally intensive: additional iterations increase the accuracy of prediction.

Now, a drawing that tries to get absolutely everything right at the very outset and is absolutely binding we might describe as contained within a single iteration, or quanta, of the relationship between representation and reality. A spec house in a large development on a flat site might come quite close to this ideal, as might the suites in a multi-story office building. Other building typologies may demand a shorter cycle, or refresh rate, between prediction and revision, and we might say that the quanta of representation-to-reality in these cases are much smaller. One might even consider the templating practices of Medieval masons an example of very-low-comprehensiveness coupled with very-high-refresh-rate, as each newly produced template might take into account changes necessitated by the building that has gone before, alterations to material or expertise availability, as well as design modification in light of these and other changes.

This points to a key limit on the proposition that we might describe architectural representation as 'quantized prediction.' The more elaborate and comprehensive a prediction (the larger its quanta of representation), the longer and/or more resource intensive its refresh rate.

Mercer's construction notebooks generally contain very small and non-comprehensive representational quanta: the revised detail for precast windows shows both the limits, and opportunities, provided by such a configuration of representational technology. But the notebook also contains much larger, more comprehensive, and infrequent quanta: the room layouts of the museum, which are explored first in the lower half of the building, are revisited significantly only after construction has progressed sufficiently to make that revisitation both possible, and necessary.

Such a system of a small-quanta/high-refresh-rate relations between documentation and fabrication may require organizational and representational tools which don't yet exist. Recalling Stinchcombe's observation that the 'blueprint' is well adapted to the conveyance of only that information that needs to be communicated explains why efforts to reinvent construction documents[498] so seldom find success or adoption in a larger building industry built upon the model of a singular, controlling set of drawings (and the contracts written in the image of that idea). That is to say: normative construction documentation is quite poorly adapted to the support of dialogic, experiment-based, and narrative modes.

Even Stinchcombe retains the bias of the established and partitioned trades, and with it the assumption of craft knowledge as an established and even age-old thing, and "passed from one generation of craftspeople to the next",[499] rather than made up on the fly in a constantly shifting network of alternately skilled work, and skilled improvisation. Mercer's example begs the question of how a system of representation, "embedded in a system that fills in the blanks in the blueprint with formalities or informal competencies worked out elsewhere, especially in the institutions of separate crafts",[500] can account for, and indeed engender, assimilate, and evolve in the context of innovations that occur in the process of its own use.

Because not all bodies of craft knowledge are equally vast, unchanging, or applicable, not all formalities can make the same demands. Where a well-established body of expertise might allow for the externalization of technological requirements to the competency of external systems of formalization and action, novel materials and methods cannot make such demands. Drawings in these conditions may productively be structured with small quanta and a high refresh-rate—to rely, that is, on many iterations of inference. These inferences are built upon highly networked, experimental, and recursive domains of knowledge.

It is easy to be sympathetic to the value of improvisation in music; perhaps less so in architecture. For where the cultural significance of jazz in undisputed, the role of improvisational building practices in architectural history and theory is far less well recognized. Yet we might consider how tools for structured improvisation might take their place among the 'instruments of service' of the prudent architect. "There is a French word," Nachmanovitch writes,

> *bricolage,* which means making do with the material at hand: a *bricoleur* is a kind of jack-of-all-trades or handyman who can fix anything. […] We see *bricolage* in small children, who will incorporate anything into their play—whatever piece of stuff is lying on the ground, whatever piece of information they picked up at breakfast. Dreams and myths work the same way; in dream-time we take whatever happened that day, bits and pieces of material and events, and transform them into the deep symbolism of personal mythology. These magical acts of creation are analogous to pulling a large amount of rabbit from a small amount of hat. […] *Bricolage* implies what mathematicians like to call "elegance," that is, such economy of statement that a single line of thought has a great many implications and outcomes."[501]

D. Economy

The *bricolage* of Mercer's invented tools served more than one purpose. Despite the non-prescriptive nature of so many of Mercer's working methods, whether in his pottery or on his jobsites, he took great pride in the profitability of his enterprises, and the degree to which his constructions came in under budget and were built for less than those of his contemporaries. (His notebooks contain occasional self-congratulatory mention of the net or per-unit cost of other, contemporaneous, constructions, particularly those in concrete.)

Mercer's economy was not an idiosyncrasy of his character so much as an attribute of his design method: succeeding at the challenge to do more with less served as a confirmation of the value to be found in allowing for, and engaging with, unceasing variability and improvisational process. At times (and in the right light) the evidence of unexpected results might even seem beautiful. Mercer, in his account of the building of Fonthill, described the results, and the cultivation, of such improvisations.

> Owing to the color of the Jersey gravel, gray cement and bluish trap, the outer walls show soft gray-yellow with faint greenish reflections and, owing to the roughness of the forms, board welts, and porous spots not retouched, the texture is very rich as seen at a distance. In experimenting upon smoothing down these outer surfaces for weather protection with cement plaster, when a mason working upon a hanging platform did the work, we found that the plastering had been carried too far on the east upper wall of the tower and thereafter proceeded by retouching only the very porous spots.[502]

The walls at Fonthill are occasionally consistent, and occasionally haphazard, with overmuch parging in some places and substantial defects in others. [Fig. 7.21.] When it came time to build the pottery, it is clear this roughness and variability had been incorporated into wall forming as a design objective [fig. 7.22], and at the museum there is a remarkable consistency, as it were, of variability. [Fig. 7.23.]

Figure 7.21. Occasional variability at Fonthill. Image: author

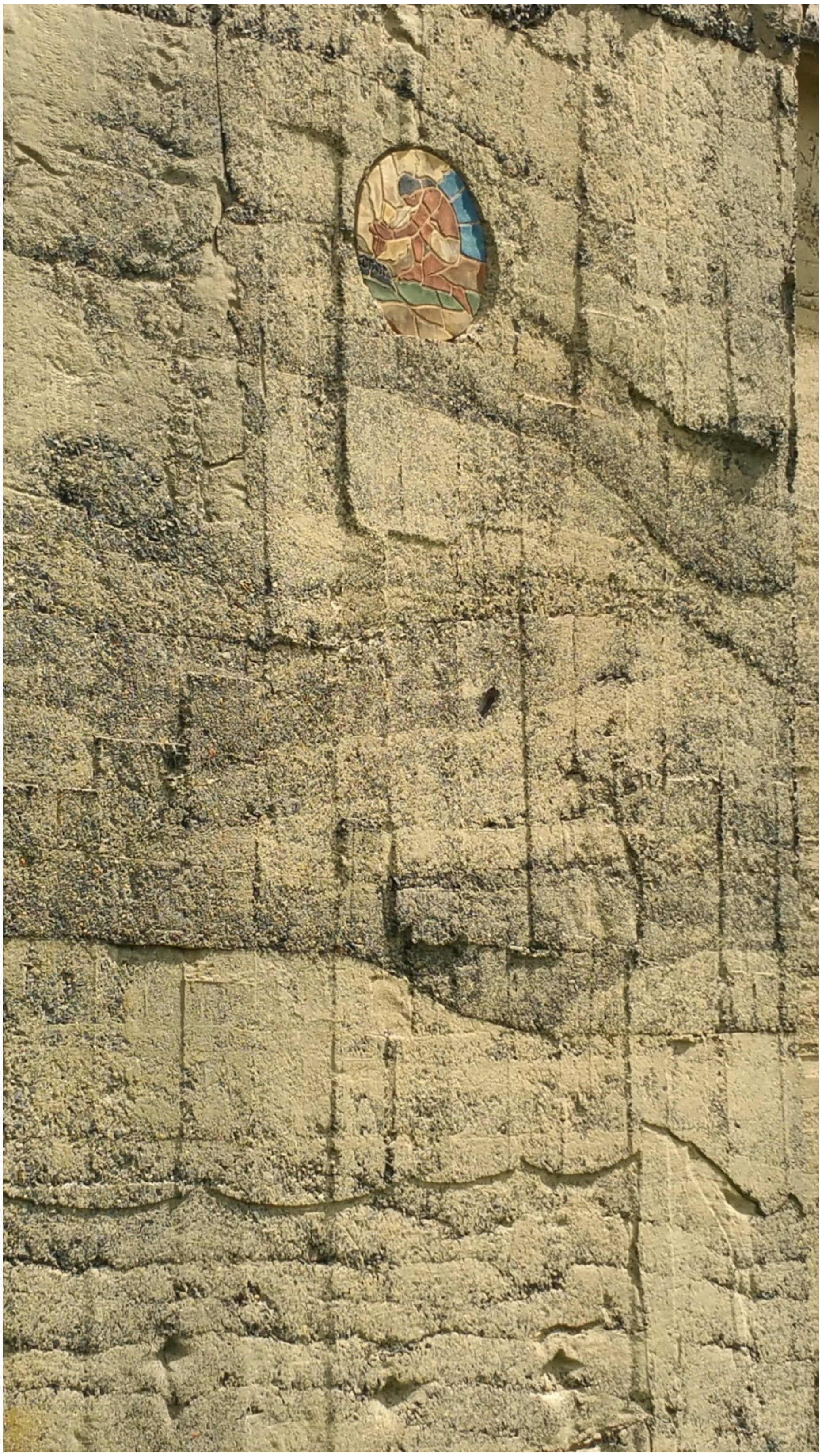


Figure 7.22. Deliberate variability at the pottery. Image: author.

Figure 7.23. Consistent variability at the museum. Image: author.

The use of twisted bar reinforcing at the Museum also serves as an example of the way Mercer made improvisational use of his materials. On the top level of the museum, a walkway runs along a series of windows that extend down nearly to the floor. Mercer allowed the reinforcing bar in the walls adjacent to the window to run through the window opening so that when the forms were removed the rebar remained as a guardrail. As we can see from an enlarged view, this is not a case of bars being mortared into pockets in the concrete wall after the fact, but rather being cast in-situ during the original pour (note the lack of any seam or circle at the point of embedment, while the seam where the window was mortared into place is clearly visible). [Fig 7.24.] Mercer also used twisted bar to fabricate furniture for his installations, as in the collection of stove plates, where a steel angle, topped with twisted bar, served as a shelf for the heavy iron artifacts. [Fig. 7.25.]

Figure 7.24. Twisted bar reinforcing passing through a window opening, finding economical use as a guardrail in Mercer's museum. Image: author, courtesy of the Mercer Museum.

Figure 7.25. Twisted bar used as shelving. Image: author, courtesy of the Mercer Museum.

These improvisations might be recommended for their architectural interest (such as making the building reinforcing legible), as well as for their economy, both in terms of the cost of materials, and in the minimization of complexity in sourcing and coordination on the job site. Minimal complexity is often a feature of improvised solutions, and Mercer's methods are often distinguished by their economy in a procedural sense. Economy as a goal of design would seem to be a self-evident good. But unlike the contractor's old chestnut, "cheap, fast, and good—pick two," economy in this sense is not equivalent to 'cheap'. Nachmanovitch's "elegance", which he attributes to the language of mathematical proof, does better to suggest the procedural nature of the economy in question; but carries its own baggage with suggestions of visual appearance or class status—it is not until we get four definitions down the list in the O. E. D., that elegance refers to "pleasing or ingenious simplicity of a scientific or mathematical theorem, process, invention, etc."[503]

Economy in this sense acts as a heuristic for decision making in the absence of critical information, something David Fleming explored under the heading, "lean logic."[504] This is on the one hand the everyday efficiency of normative construction documents,[505] which, when they function well, serve as efficient and apt tools in the realization of building. This is also, however, a criteria by which we might judge our improvements upon normative systems, a form of Occam's Razor[506] for the architect.

A lean prescription should be accurate, concise, and adaptable. A good plan is not, for example, lacking accuracy or completeness in its dimensions; it is not over-dimensioned (this occurs when multiple dimension strings locate the same objects in space, resulting in redundancy or even contradicting measurements); and it anticipates and accommodates-in-advance divergence within accepted tolerances.

Let us return to Stinchcombe's claim that 'craft activities are the semantics of abstractions' (61). Semantics is "the meaning of signs," or the "system of meanings" in a communication.[507] To parse this, note the plural: the system itself, the structure of that system, would more rightly be called syntax; Stinchcombe's use of 'semantics' maintains the bifurcation of informal craft actions from the formal or explicit—the specifiable. According to Stinchcombe it is the tacit acts and practices, rather than the explicit, that constitute the *meaning* of the formal system of architectural drawing—it is not what the drawings tell the builder to do, but what she or he does over and above what is described, that is the heart of the matter. This is not to say these actions are not triggered by the communication between architect and builder; but rather that not all of these actions may be explicitly described; and that the relationship is structured *as-if* they were so described.

Architectural modernism is filled with stories of significant communication by informal means. From Louis Kahn on the job site with trowel in hand, to Lawrence Halprin's architectural choreography, architects find ways to connect with the intangible attributes of their materials and sites. We should begin to notice how often these moments are accompanied by significant, and ephemeral, architectural representations. They run as a consistent undercurrent in the high-watermarks of modern architecture. Peter Latz tells the story of renting a trailer and going out to live at Duisburg Nord, amid the rusted truck heaps and piles of old clinker. About how beautiful it was in the morning light there.[508] Scarpa is said to have rehearsed, the night before an important meeting, the impromptu sketches he would employ in that meeting;[509] and Gaudi is famous for having moved into the Sagrada Familia in the last years of his life, where he would wake up every morning and walk through the site, determining what needed to be said to the builders when they arrived.

Now a lean drawing set would find a way to say only those things that need saying, to only those people who need to hear it. And the principal of economy, understood as Occam's razor, says the best instruction set will be the leanest. That is to say, our representations should invoke the maximum tacit knowledge available with the minimum representational content possible. Economy, then, is pulling a large rabbit out of a small hat. But Mercer's economy had a few discrete attributes, and we can look back to his treatment of ceilings to see how he goes about getting 'more rabbit.'

1. Structure and Space: the tendencies described above, to create close, low-ceilinged passages and small rooms, often with expressly omnidirectional ceiling structures and multiple ingresses and egresses, and to arrange these rooms with as much variety in the vertical dimension as the constraints of circulation allow, is not merely a spatial or tectonic strategy. The smallness of the rooms, and their material restraint, are direct economies; and the use of reinforced concrete to fabricate these sorts of interlocked spaces provided a ready "flow" not merely of spatial experience once the building was complete, but of the work tasks as it was built. As we discussed in chapter 2, in building the museum, Mercer choreographed the construction of his formwork in a continuous progression, wrapping around the footprint of the building in a clockwise circuit that would last 6-8 weeks per floor.[510] As work progressed the concrete would harden sufficiently to remove the formwork—this occurred typically when work had progressed to the opposite side of the building,[511] and the boards would be reused, and supplemented, to extend the formwork. (Inclement weather would be taken as an opportunity to go inside rooms already finished and complete the work of form removal.) Thus, similar to contemporaneous developments in the fabrication of concrete grain elevators,[512] Mercer had developed a what might be considered a particular variety of slip-forming (the first patent for which, specific to grain elevator fabrication, would not be issued until two years after Mercer began work on the museum).[513] Unlike the simple vertical lift from which "slip" forming takes its name, Mercer's pattern took a spiral, rather than cylindrical, path. But even "spiral" may give the wrong impression: everything from interior walls and columns, to ventilation ducts and dovecotes, were cast as part of one continuous pour. (Fractal symmetry might be more appropriate image than helical.) The pace of construction resulted in many more cold joints than is the case in typical slip-forming; but as these cold joints wrap the building discontinuously, they would not be as disruptive as a cold joint in a simple cylindrical pour. Instead, the pattern of short lifts of concrete was transformed into an advantage in the building process: rather than using rebar-bending equipment on the ground, Mercer's crew would bend their reinforcing after it was fixed in hardened concrete, adapting it to fit the next level of formwork. These methods display an 'economy of means' that is as much about flexibility as rapidity, and prioritizes preexisting or reusable resources. We might call this the economy of adaptational practice—or an evolutionary *praxis*.

2. History and story: To get more story from less prose has been one of the dearest ambitions of modern fiction since Baudelaire walked the streets of the first modern city. To judge by his literary tastes, Mercer was more persuaded by psychological depth (Poe) than psychological realism (Hemingway). Mercer's own literary works were written very much in the vein of Poe's sometimes macabre but always intricately crafted tales; but Mercer's designs for tile-rooms, particularly as evidenced in the upper rooms at Fonthill, suggest a more fragmentary approach to the telling of stories in tiles. These are not graphical novels (nor collections of short stories). Nonetheless, particularly in the development of the brocade relief tiles, we see a shift from the careful choreography required by mosaics, in which each and every piece fits together, puzzle-like, to compose a specified whole, to a much more open and spontaneous collection of thematically related, but geometrically independent,

elements—characters, that is, in a story yet to be told. Should the characters desire a different story, they might just have the capacity to rearrange themselves in the process of construction—or even, perhaps, afterwards, in the dim and flickering light of a November evening, when a story that had been lost amid the myriad others might come to be found. (Surely, it had been there all along.) This, then, is the economy of the dreaming mind: from fragments and feelings, in the inscape of a unique architectural room, stories come to be in an eyeblink, in reverie, and they may tell us more than we know. We might call this an oneiric economy—economy as *poiesis*.

3. Mysterious stuff: from the very first time Mercer put his collection of tools on display, hung in the trees and set out in groupings in a field at the summer 1897 meeting of the local Bucks County historical society (at "Galloway's Ford" a site outside Doylestown[514], Mercer used the ceiling (or the sky) as a site for population by artifacts. This represents, as we discuss elsewhere, a typically 20% increase in the surface of building available for use. That he built his ceilings not only with stuff, but with the equipment for holding more than was programmed, indicates that he was thinking ahead to the life of the building, rather than merely executing the program immediately at hand. This might better be termed elegance than economy, because it often flies in the face of a fiduciary economy: Mercer's ceiling hooks cost some nominal amount, but more importantly required an increase in coordination. These costs were small, however, compared to drilling holes in concrete later to attach more hooks. This is the original meaning of Vitruvius's 'commodity'—the unnecessary extra that lays the groundwork for future opportunity. We might call this the building-of-fortune—or the fortune of building, a.k.a., *Kairos*.

Economy as a principle of architectural innovation is exactly that: a design principle that serves as a spur to the invention of new tools and innovation of new techniques. In the company of old tools, Mercer made a great many new inventions. While this juxtaposition may seem counterintuitive, it is firmly grounded in economic theory.

The economist Willy Shih, in a 2009 article in the Harvard Business Review that (with the book that followed) helped to shift the conversation on 'outsourcing' in the United States, proposed that we consider the systemic effects of technological production, coining the term 'the industrial commons' to describe this essential aspect of maintaining a competitive industrial base.

> Centuries ago, "the commons" referred to the land where animals belonging to people in the community would graze. As the name implies, the commons did not belong to any one farmer. All were better off for having access to it. Industries also have commons. A foundation for innovation and competitiveness, a commons can include R&D know-how, advanced process development and engineering skills, and manufacturing competencies related to a specific technology. […] An engineer in Silicon Valley, for instance, is more likely to exchange ideas with other engineers in Silicon Valley than with engineers in Boston. When you think about it, this is not surprising, given that much technical knowledge, even in hard sciences, is highly tacit and therefore far more effectively transmitted face-to-face.[515]

Shih went on to argue that the loss of productive capacity to outsourcing—he cites the specific examples of solar cell technology and personal computers—was soon followed by the loss of design innovation in these particular areas. As the day-to-day manufacture of these items ceased in particular locales, the industrial commons was impoverished, and the capacity for new invention decreased until it was outpaced by other groups working in other geographical locales—often places to which production had relocated.

Shih and his co-author Pisano focus on the macroeconomic trends of national productivity and technology development, and so their examples tend to be drawn from the largest and most recognizably technological industries. Certainly, it is easy to see the 'erosion of the commons' in such industries as auto manufacturing and mobile technology. But these trends occur at every scale of fabrication and every level of technology, and were, in fact, something Mercer observed in his own place and time, and was motivated to repair. Reed describes a relevant example:

> In the early decades of the nineteenth century, with the introduction of more durable grades of white factory-made crockery, the products of the German potters gradually ceased to be in demand. They could not compete with factory production methods. […] Without demand for their products, they lost their skills as potters."[516]

What Mercer found, when he first surveyed the decaying potteries of Bucks County, were the ruins of an industrial commons. It is not so much that the resources of the redware potter had failed (as Mercer's own later success demonstrates) but that the complex of skills and infrastructures, both of material supply, and of end product distribution and sale, had found other inputs and outputs; and the formerly essential components of the process situated in the craft expertise and enterprise of the Pennsylvania German potters had been excluded from the larger system of production. The question of an industrial commons, then, is not merely one of 'high-tech' or macroeconomic inputs or industries, but something that touches on local idiosyncrasies and regionally specific crafts, resources, infrastructures, and social groups. (This is something Shih touches on in his discussion of centers of expertise.) The key insight from Shih's economic analysis, however, is that centers of expertise, and thus nurseries of innovative practice, cannot long survive the departure of more mundane productive capacities, or the decay of their industrial commons—though perhaps "material commons" is a more appropriate term in this context, as it does not presuppose a certain arrangement of capital and work. This calls for a site-specific economy.

Consider Mercer's own invented process for building in reinforced concrete, then, in terms of the material commons of his own time and place: if your concrete arrives not from a readymix plant but as train cars of separate cement, sand, and gravel; if your mixing apparatus is a portable gasoline powered mixer, and your "crane" a wooden jib jury-built on the top level of the building, powered by a solitary horse lifting one wheelbarrow load at a time; if your formwork is made from roughsawn yellow pine arriving green and sappy from the mill and quite literally by the board foot,[517] then the method Mercer arrives at is well suited to the available flow of material; and the resulting building a record and re-presentation of that method. [Fig 7.26.] The building is legible: it tells its own story.

Figure 7.26. Archival photo from the construction of Mercer's museum. Image: courtesy of the Mercer Museum Research Library.

Mercer's method was not exact, it was not prescribed (except loosely, with notes and jotted plans and details in his construction notebook), and it did not rely on a sophisticated material or informational infrastructure. But that it is not a technical method does not mean that it is non-methodological. It is characterized by having no more technical acuity than is required at any given moment or in any given operation. We can now see that its aptness consists of more than a good fit between material supply and rate of construction. This is a method distinguished throughout by its use of minimal effective complexity. Columns in the museum are often formed one foot square because of the supply of board-foot lumber; materials were stored in the train cars in which they are delivered; voids and honeycombing, rather than requiring complex admixtures, vibration, and short lifts, are simply parged over after the formwork has been removed—or left as deliberate textural patterning. In these and other ways, Mercer structured his method to allow for minimal, and flexible, inputs; and to take as further input the evidences generated by its own process: that is, to learn.

Adopting and capitalizing on existing and inherited infrastructures, rather than imposing preconceived structures and methods developed for other sites and construction problems, then, is the core elegance of Mercer's method. It is configured to the limit conditions of its site and community of skilled labor, such that organizational complexity is minimized. These are the sources of its frequent, and fluid, innovation.

E. Complexity

Economists and anthropologists who study complexity have identified a problem in the economics of complex systems that obtains at every scale, from project teams to institutions, and in society as a whole: that as complexity increases the maintenance cost of that complexity rises in turn, such that each individual takes on a proportionally larger burden of maintenance, as opposed to engaging in wholly productive activity. The anthropologist Joseph Tainter has argued "that return on investment in complexity varies, and that this variation follows a characteristic curve. […] After a certain point, increased investments in complexity fail to yield proportionately increasing returns. Marginal returns decline and marginal costs rise. Complexity as a strategy becomes increasingly costly".[518] Tainter is not talking about architectural production. His concern is larger institutions and the economy of modern industrial society; yet his analysis is applicable to the management of project teams. We see it evidenced in "Brooks' law," which every project architect knows implicitly if not explicitly: that 'adding staff to a late project will invariably make it later.'[519]

According to the trajectory of a complexity curve (often created through statistical analysis of occupational demographics, patents, or economic data), the greatest amount of innovation happens at the advent of a material technology, process, or body of research. This is in part because early adopters often pick the low-hanging fruit; and in part because these early applications and experiments define the limits and outline the possibilities of the material, method, etc. That is, the way we see a new material or process, in terms of its capacities and possible applications, are at the outset open, Promethean. As the material is developed and assimilated into technical culture, and its capacities become known quantities, it becomes more and more predictable, until it is fully taken up into standard practice. In the process of assimilation and dissemination, some branches of possible practice are inevitably pruned; others grow, develop, and ramify. It is this ramification, this efflorescence of possibilities, that opens a field for innovation; and, indeed, is plausibly responsible for the surge in productivity we see so reliably charted in complexity curves.[520]

We find ourselves in positions low on a complexity curve, and thus positions of manifold opportunity for innovation, through a number of the methods discussed in earlier chapters on Mercer's invented practices:

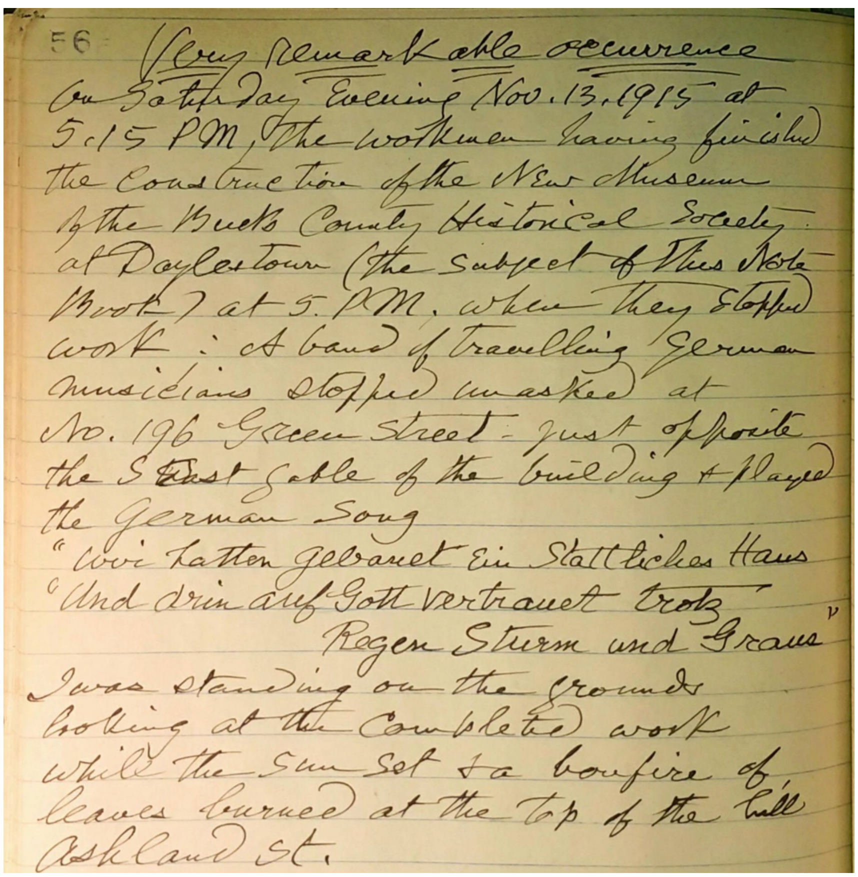
Analogy shifts domain-specific knowledge into a new context. In this new register much of what is taken for granted as predictable has unforeseen effects; and the very tendency towards prediction is undermined. The adaptation of old techniques to new ends demands alteration and improvisation; and while many of these improvisations will fail, some few may provoke a new and improved result. The trial… and error… and re-trial process, while more expensive than a proven and habitual method, often results in a whole series of crude uncomplicated solutions. If many of these simple solutions fail, one may succeed, and the result is an overall reduction in complexity—and a new beginning to the complexity curve.

A *context of affordances,* critically considered, offers to expand the range of possibilities for our tools. The multiplication of affordances provides a way to provoke creative thought through material experiment, and the historical or archaeological consideration of the lineage of tool may provoke us to see the kinship in dissimilar tools, and the potential interoperability of tools normally belonging to different technological paradigms or historical periods. Such expansions of tool use may expand the capacities for well-understood materials and methods.

An awareness of *tacit craft knowledge,* and the way it is implicitly described in formal representations, may provide a closer interlock between what is intended by our representations, and what results from them. But such an awareness may also allow us to see the value in results we did not foresee or intend. Such a consciousness engenders a closer relationship between the instruments of architectural practice and the construction actions they must ultimately be translated into, fostering a deeper understanding of craft practice on the part of the architect, and a more expert and empowered reading of formal documents on the part of the builder.

In these and other ways the iterative, improvisational tactics demonstrated in Mercer's buildings suggest ways we might place ourselves in new or altered domains of knowledge and practice, in which the arc of the complexity curve rises up before us, full of possibility. In an entry in his notebook, dated Nov. 13. 1915, originally written in pen (and the only passage later typewritten and pasted into the notebook) Mercer wrote: [Fig. 7.27]

> Very Remarkable Occurrence.
>
> On Saturday evening, Nov. 13. 1915 at 5.15 PM, The workmen having finished the Construction of the New Museum of the Bucks County Historical Society at Doylestown (the subject of this Note Book) at 5. PM. when they stopped work: A band of traveling German musicians stopped unasked at No.196 Green Street—just opposite the S East gable of the building and played the German song
> "Wir hatten Gebauet Ein Stattliches Haus
> "Und drin auf Gott vertrauet trotz Regen Sturm und Graus"
> I was standing on the grounds looking at the Completed work while the sun set and a bonfire of leaves burned at the top of the hill Ashland St.



56 Very Remarkable occurrence
On Saturday Evening Nov. 13. 1915 at
5.15 PM, The workmen having finished
the Construction of the New Museum
of the Bucks County Historical Society
at Doylestown (the subject of this Note
Book) at 5. PM. when they stopped
work: A band of travelling German
musicians stopped unasked at
No. 196 Green Street - just opposite
the S East gable of the building + played
the German Song
"Wir hatten Gebauet Ein Stattliches Haus
"Und drin auf Gott vertrauet trotz
Regen Sturm und Graus"
I was standing on the grounds
looking at the Completed work
while the sun set + a bonfire of
leaves burned at the top of the hill
Ashland St.

Figure 7.27. A fortunate occurrence. Image: courtesy of the Mercer Museum Research Library.

Afterword: Building a Story

Any history is an interpretation, and in these explorations of the architecture of Henry Chapman Mercer I have tried to balance a vision of Mercer seen through the eyes of architecture with one of architecture, seen, as best as we might, through the eyes of Mercer. This has entailed the discussion of a great many disciplinary lenses, often more recent to our time than Mercer's. In these voyages I have hoped the reader might join me in asking "what if": how might architecture have changed, if Mercer's works had exerted more pull upon it? Looking back to that key moment of change in the opening decades of the 20th century, a hinge-point in the discipline, we should consider what was lost as well as what was gained. Mercer is one small avenue for such considerations.

Mercer's invented practice shows evidence not merely of an insistence on job site economy, nor an antique man given to antiquated pastimes, but a mind motivated by finding value in the cast-off (an appropriate and understandable tendency in one trained as an archaeologist) and creating from that fortunate *spoglia* an architectural narrative. While much has been claimed for narrative in architecture, Mercer's myriad labyrinthine rooms illustrate a novel relationship to the telling of stories-in-building, one predicated on the interrelationship of technical action and historical meaning.

Far from being a series of impromptu and unplanned actions (as they are often interpreted), Mercer's methods of construction were a collection of well-timed choices and strategic responses to uncertainty. These methods may have had their origin in Mercer's longtime and daily association with the techniques of ceramic fabrication and archaeology. Mercer worked with concrete as if it were not a new material at all, but rather as something with which he as intimately familiar, adapting to and accommodating its inaccuracies and idiosyncrasies as if the material were no more permanent than clay. Sadly, many of his methods for working in this new material were lost, too local, and too counter to the spirit of the times that directly followed his. Whatever we see in his buildings, however, we should recognize them as the products of methods of remarkable ingenuity and originality. These new methods were not only those of the material trades, but those most apropos to the work of architects: systems for the organization and communication of design, uniquely able to preserve and profit from ambiguity and improvisation.

Architectural representation is not often grouped with scat singing or the subtle permutations of the tea bowl; yet it is, like these more esoteric and individual art forms, a pursuit improved by long practice; by iterative and reflective process; and by the support of a diverse and collaborative creative community. With these structures and supports, the activity of the architect, like that of the jazz vocalist or the potter, may take on a free and gestural quality rarely equaled by a more deliberate and predictable process. Improvisation is also evident in the deliberate lacunae by which an architect leaves room for the work of associated disciplines, or for his or her own projected (future) activity—that grey area where "construction observation" may become a more active participant in the process, and where the capriciousness of concrete or clay, coupled with a parsimonious representation, make room for happy accident.

However much we may want to avoid it, the site of construction, and the systems it entails, have grown so intertwined with the overarching interwoven infrastructures of modern life that the architectural project, in the fullness of its time, is no longer merely complicated, it is complex. This means that our inherited tools for guiding and shaping that complexity will soon be, if they have not already become, insufficient to the task of designing reliably nimble, adaptable, and generative building processes, and buildings. How to deal with complexity is the leading challenge of our time.

The dark side of the story of complexity is told by collapse theorists who, unlike most other scholars, don't want to be proven right. Typically, the downward spiral envisaged in collapse discourse goes something like this: "new capital falls short of maintenance needs, [society] enters a maintenance crisis in which capital of all kinds cannot be maintained and is converted to waste: physical capital is destroyed or spoiled, human populations decline in number, large-scale social organizations disintegrate into smaller and more economical forms, and information is lost."[521] The further we go along a complexity curve, the more capital is consumed in maintenance, resulting in diminishing returns that may be observed by tracking the increasing complexity in every field: in agricultural production, in health care, in the ever-increasing specialization of education, and throughout quantifiable human action and enterprise. All these complexity-curves rise, and crest, and plummet, tracking not only the way that the rate of production per capita decreases as overall system complexity increases, but predicting the point at which we can no longer maintain an organizational superstructure, and begin to eat our seed corn. These are the times to which economists give the bloodless term, "contractions."

Such times may well come. If they do, we will need new methods (and old tools) more than ever.

Notes

1. Marco Frascari, *Monsters of Architecture: Anthropomorphism in Architectural Theory* (Savage, Md.: Rowman & Littlefield, 1991), 94.
2. David Pye, *The Nature and Aesthetics of Design* (New York: Van Nostrand Reinhold, 1978), 14.
3. Henry Chapman Mercer, "The Building of 'Fonthill' at Doylestown, Pennsylvania, in 1908, 1909 and 1910," manuscript copy, held at the Mercer archive of the Spruance Library at the Mercer Museum maintained by the Bucks County Historical Society, a.k.a., the Mercer Museum Research Library.
4. With the notable recent exceptions of Dan Willis at Penn State and William Kleinsasser at the University of Oregon. See Daniel Willis, *The Emerald City: And Other Essays on the Architectural Imagination* (New York: Princeton Architectural Press, 1999) and William Kleinsasser, "Synthesis 9: A Theory Base for Architecture," *Unpublished Course Manuscript, Department of Architecture* (Eugene: University of Oregon, 1999). Fonthill was also featured shortly after it was built in architectural periodicals and the popular press, but only rarely in the intervening century. See "Architectural Expression in a New Material," *Architectural Record* 23 (April 1908); "Personal Architecture," *Architectural Record* 33 (March 1913).
5. "At the time of its dedication in 1916, this museum had 14,428 historic implements, in addition to a library of 8,000 volumes. At the time of Mercer's death in 1930, the museum had 24,800 historic objects; by 1945 it boasted a collection of 25,668 speciments and a library of more than 45,000 volumes; and by the mid-1980s the historic tool collection had more than 30,000 specimens" David L. Browman and Stephen Williams, *New Perspectives on the Origins of Americanist Archaeology* (Tuscaloosa, AL: University of Alabama Press, 2002). The Museum website currently numbers the collection at 40,000.
6. Construction tolerances are a complex body of knowledge in current practice, with standards groups for each construction type and region producing guidance documentation, such as the American Institute of Steel Construction's *Code of Standard Practice for Steel Buildings and Bridges* or the American Concrete Institute's *Formwork for Concrete (Publication SP-4)* as well as the guidelines produced by general standards and testing bodies, such as ASTM (American Section of the International Association for Testing Materials), and model building codes, such as the IBC (International Building Code) as adopted and amended by jurisdictions. As a rule of thumb, the 1/4" or 1/2" standard tolerance for concrete (depending on condition) is far larger than similar rules of thumb for wood or steel, which tend to be 1/16" and less.
7. Adrian Forty's recent cultural history of the material emphasizes the degree to which early adopters of reinforced concrete building technologies assumed (or cultivated) an association with low-skill labor, and speculates as to the social and/or economic motivations for such associations. He is careful to note, however, there were (and remain) widely varying degrees of skill in concrete construction, a variation readily evident in the resulting buildings. See Adrian Forty, *Concrete and Culture: A Material History* (London: Reaktion Books, 2012).
8. Mercer's correspondences concerning the development of the pottery are held at the Mercer Museum Research Library, including letters from Charles Smith, a New Jersey chemist and manufacturer of glaze materials, and from his Aunt Elizabeth reporting on her various European contacts which she undertook on Mercer's behalf, including William De Morgan and Ulisse Cantigalli.
9. Cleota Reed, *Henry Chapman Mercer and the Moravian Pottery and Tile Works* (Philadelphia: University of Pennsylvania Press, 1987).
10. Reed claims the few remaining photos of a kiln shed at Mercer's first site for the Moravian Pottery, a workshop built on his family property, called "Aldie," are of what Mercer called the "Upper Pottery" (51). It may be that when the two kilns in this shed were built, in 1899 and 1903, the "wood shed" was modified to make it more fireproof, resulting in the odd assemblage depicted in those photographs. It is also possible that Reed has incorrectly identified the photographs, and that they in fact show Mercer's "Lower Pottery", built in 1906, which Mercer described as "a fireproof shed, constructed of tin, clay, and cement". Both of these structures were torn down by Mercer's brother, who resided at Aldie, in 1912 not long after Mercer moved to his new pottery facility. For Mercer's description of the upper and lower pottery, see Henry Chapman Mercer, "Notes on the Moravian Pottery at Doylestown," held in several

drafts in manuscript copy at the Mercer Museum Research Library, and printed in *Papers of the Bucks County Historical Society* 4 (1917): 482. In addition, Mercer's annual financial summary for 1905-06 lists an improvement of "1 cement Bldg. Around Kiln," which would support the latter conclusion.

11. While the application of roof tile in mortar is so rare as to be unheard-of today, it was not uncommon practice at the time. A number of prominent buildings in the region used this building detail, including Gilman Hall, the building adjacent to the Baltimore Homewood House, which the Bucks County Historical Society's first building was modeled upon. Mercer's use of the tile as a cover for a reinforced concrete roof, however, was unusual, and would not find a notable revisitation until Bernard Maybeck's experiments at Principia College in the 1930's.
12. This can be seen in the Fonthill construction notebook, page 76, in an entry titled "Casting window frame or mullions". The unpublished construction notebooks for Fonthill, the Moravian Pottery, and the Mercer Museum are held in the Mercer archive at the Mercer Museum Research Library.
13. This calculation is based on the purchasing power of the dollar in 2018 divided by the same value in 2013. It should be noted that the calculation is considerably different if we use 1916 as a starting point, because of the rapid inflation that accompanied World I ($885,612.65 versus $975,068.47).
14. Recently, William Kleinsasser at Oregon and Dan Willis at Penn State have both used Mercer extensively in their teaching, and art and museum historians have looked at various aspects of Mercer's work, focusing on his engagement with their own disciplines. Mercer's tiles have been considered in the context of his biography in Cleota Reed's *Henry Chapman Mercer and the Moravian Pottery and Tile Works,* and this remains the preeminent scholarly consideration of Mercer; but its focus in very much on the development of his tile designs. The best source for Mercer related scholarship, besides the copious archive itself, may be the prolific publication of Newsletter content by the Mercer Museum itself.
15. Dyke, Linda, Assistant Curator, Mercer Museum, and the Bucks County Historical Society, *Henry Chapman Mercer (1856-1930): An Annotated Chronology* (Bucks County Historical Society, Doylestown, PA: 1989; 1996; 2009), 6-7.
16. Mercer was unconvinced by what he saw of the flowering of modern art and painting, annotating his copy of Hemingway with highly critical marginalia. Mercer's often annotated volumes remain at Fonthill, where they are conserved by the staff of Fonthill and the Mercer Museum.
17. A 1999 Washington Post article is typical. See Marty Barrick, "A Visionary in Concrete: One Man's Eclectic View of Technological Progress," *Washington Post* (March 11, 1998), https://www.washingtonpost.com/archive/1998/03/11/a-visionary-in-concrete-one-mans-eclectic-view-of-technological-progress/76ce4602-a396-4469-914f-84a558109f7f/. Accessed 3/21/2018.
18. Conversation on the job site of a private residence between author and project manager Tom Marsten, Jerry Fulks Company (1999: Woodway, Washington).
19. In this context it is the spreadsheet, rather than the cellulose sheet, that is significant.
20. For example, Michelangelo made a clay model of his design for the dome of St. Peters so that the work could be continued after his own death. The wood model, which still exists at the Vatican and is often attributed to Michelangelo, was made later by Giovanni Franzese, from Michelangelo's original model. This is described contemporaneously by Vasari, whose *Lives* was first published in 1550, while the construction of the Dome of St. Peters was still underway, and in which he discusses the project in progress, writing of Michelangelo that "at length he made a beginning, and by degrees and by the aid of the plans and sections which he had likewise prepared, there might eventually be made a much larger one in wood. Such a model was accordingly constructed in somewhat less than a year, and under Michelangelo's guidance, by Maestro Giovanni Franzese, who worked at the same with much zeal and care. The dimensions and minute proportions of this smaller structure, measured by the ancient Roman palm, corresponded in every particular with those of the great Cupola, all the parts being executed with extreme nicety; the members of the columns, the bases, capitals, doors, windows, cornices, ressaults, and every other minutia, being represented in such sort that no better work of the kind could be effected. […] Up to this point Michelangelo has finished the masonry of the building, it now remains that we commence the vaulting of the Cupola, of which, since we have the model, we will continue to describe the arrangement as he has left it to us." Giorgio Vasari and Jonathan Foster, *Lives of the most Eminent Painters, Sculptors, and Architects:*, Bohn's Standard Library, (London: George Bell & Sons, 1878), 317-318,

321.

21. This is still, very occasionally, practiced today. When the author was an intern, working for Greg Kearly/Inscape Studio, he built a large, fully disassemblable model—and a substantial case to transport it in—as part of a project to develop a series of women's' centers in small towns and remote regions in Afghanistan. The model was intended to be used by the builder in place of paper drawings, to determine quantities, spans, and materials, as we anticipated some difficulty in communicating through traditional construction documents. While the author never personally saw the built results, the first of this series of courtyard buildings was completed successfully in 2004, and there were a number of interesting substitutions, such as round, stripped, logs used for joists, rather than dimensional lumber. See
22. Sources for dates and destinations in this section include: Henry Chapman Mercer: An Annotated Chronology, published by the Bucks County Historical Society, Reed's Henry Chapman Mercer and the Moravian Pottery and Tileworks.
23. Mercer, Henry Chapman. "Recollections of the Tennent School," *Papers of the Bucks County Historical Society,* 5, (1926): 634.
24. The current catalog of the Penn museum lists over 2000 entries related to Henry C. Mercer, about half of them European artifacts dating from Neolithic to modern periods. Everything from gunflints to tribal fetishes, stone axes to ceramic dishes were objects deemed worthy of collection by Mercer. See the catalog of the collection of the Penn Museum, https://www.penn.museum/.
25. *Chronology*, 14.
26. *Chronology*, 15.
27. See Mercer's essay "Where Concrete Stands for Concrete," published in a 1908 issue of *Cement Age.* These sentiments, while seemingly in anticipation of those of Loos or Le Corbusier with regards to the architectural potential of reinforced concrete, likely co-evolved from shared theoretical precedents, such as Pugin's insistence on the tectonic derivation of ornament. Henry Chapman Mercer, "Where Concrete Stands for Concrete," *Cement Age 6* (January 1908): 9-20.
28. The model receives mention in the publications of the Mercer Museum and the Bucks County Historical Society, in Cleota Reed's biography, and in the guidebook: Thomas G. Poos and Henry Chapman Mercer, *Fonthill: The Home of Henry Chapman Mercer: An American Architectural Treasure [in Historic Bucks County, Pennsylvania]* (Feasterville, PA: Manor House Publishing Company, 2000).
29. As was perhaps too literally explored in Rem Koolhaas's Seattle Public Library, where the building program, diagrammed as a collection of irregular polygonal volumes, came to describe the form of the building.
30. This is a point generally overlooked in other accounts, which tend to emphasize Mercer's family background of wealth and privilege. While these elements of his background were of key significance in providing Mercer with both the education, and the freedom for exploration and collection, that would become essential to all of his later projects, his Moravian Pottery was from the beginning a successful enterprise, and provided him typically, with a personal profit of $13,000 per year, or over $300,000 in today's dollars. He invested these profits and the return on those investments provided him as much as $30,000 in annual dividends. See Reed, 74.
31. At this time the field was in its infancy, and Mercer was one of the first managers of the University Museum, appointed to that position despite lack of academic credentials in the field because of his fieldwork and publication, and his association with Edward Cope, one of the key figures in the new department (and one of the leading American paleontologists of his time). See Reed, 12-14.
32. "Vexatious" is Mercer's word. See Henry C. Mercer, *Hill-Caves of Yucatan: A Search for Evidence of Man's Antiquity in the Caverns of Central America. being an Account of the Corwith Expedition of the Department of Archæology and Palæontology of the University of Pennsylvania* (Philædelphia: J. M. Lippincott company, 1895), 30.
33. See: Henry Chapman Mercer, "The Kabal, Or Potter's Wheel of Yucatan, by Henry C. Mercer ..." *Bulletin of the Free Museum of Science and Art of the University of Pennsylvania* 1, (December, 1897b): 63-70.
34. Mercer's statement that he was 'forced out' of the University Museum is a bit extreme; at other times in his accounts he seems to indicate he left the position voluntarily. The language about being forced out appears in the first draft of "Notes on the Moravian Pottery". See also Reed, 176-177.

35. Mercer, "The Kabal, Or Potter's Wheel," 63.
36. Mercer, *Hill-Caves of Yucatan,* 10.
37. James B. Griffin, David J. Meltzer, Bruce D. Smith, and William C. Sturtevant, "A Mammoth Fraud in Science," *American Antiquity* 53, no. 3 (1988): 578-582.
38. "Nobody is interested in negative evidences," he later commented. Mercer, quoted in: Helen H. Gemmell, *The Mercer Mile: The Story of Dr. Henry Chapman Mercer and His Concrete Buildings* (Doylestown, PA: Bucks County Historical Society, 1972), 3.
39. Mercer, *Lenape Stone,* 3.
40. Ibid.
41. Daniel Brinton was by this time a well-established figure at the University of Pennsylvania, whose career spanned archaeology and anthropology. Brinton was the first anthropologist appointed to faculty not just at the University of Pennsylvania, but at any major U. S. university. See Lee D. Baker, "Daniel G. Brinton's success on the road to obscurity, 1890-99," *Cultural Anthropology* (Aug 2000: 15, 3; Research Library): 394-423, 395.
42. Daniel Brinton, "Current Notes in Anthropology-12," Science 20 (1892): 90-91; and "Current Notes in Anthropology-22," *Science* 22 (1893): 75.
43. Ruth Anna Cary, "The Mercer Museum and the Landis Valley Farm Museum: Exhibitions of Typology and Ethnicity in Pennsylvania," *The Folklore Historian* Vol. 6, No. 2 (Fall 1989): 43.
44. Stewart Culin, Director of the University Museum Department of Archaeology, argued repeatedly with Mercer concerning jurisdiction over display cases, specimens, taxonomy, and materials. In one of these arguments, early in 1897, he asked Mercer to leave the Museum. Mercer left—and ended his association with the museum. Reed quotes an uncatalogued note in Mercer's hand: "Ordered out of my own Museum at the University". Reed 171, note 47.
45. Reed, 16.
46. Henry C. Mercer, *Tools of the Nation Maker. A Descriptive Catalogue of Objects in the Museum of the Historical Society of Bucks County, Pennsylvania*, Vol. 1 (Doylestown, Pa.: Printed for the Bucks County Historical Society at the office of the Bucks County Intelligencer, 1897), 3.
47. "Davis, and another founder named Alfred Paschall, protested against Mercer's collection, fearing that heaps of old tools in and around the BCHS grounds would detract from their own work with written history. Mercer and Davis fought each other for years, with Mercer emphasizing the need for visual history, and the Davis-Paschall faction believing that his collection was worthless. They eventually excluded Mercer from BCHS." Kathleen Ryan, "Implements of Change: Henry Chapman Mercer and the Bucks County Historical Society," *Thesis in History, Lehigh University* (2002): 1-2.
48. Mercer would give two papers on the Pennsylvania Academy collection. Though these talks do not appear in the archive, they are referenced in Mercer's notes for his history of the pottery. Reed describes Mercer's reaction to the Pennsylvania Academy collection as a pivotal one: "When Mercer saw Barber's pieces, his interest intensified. He believed he had found in them the basis for a hitherto untold story". See Reed, 37-38, and footnote 5 on 176.
49. Frank Swain, "Memorial Services for Henry Chapman Mercer," Papers of the Bucks County Historical Society (Doylestown, PA: 1930), 312.
50. Reed, 42.
51. Ibid. This occurs in the De Morgan correspondence.
52. Henry C. Mercer, Horace Michener Mann, and The Bucks County Historical Society, Doylestown, *The Bible in Iron; Or, Pictured Stoves and Stove Plates of the Pennsylvania Germans* (Doylestown, Pa.: the Bucks County Historical Society, 1941), 1.
53. That he would go on to use them in the development of tile design motifs has received a thorough treatment in Cleota Reed's art historical biography, the most comprehensive scholarly treatment of Mercer produced to date, and a key resource for this study. It particularly concerns the pictorial derivation of Mercer's tile designs, which is not something duplicated here.
54. He would later write one of his most thorough studies as just such a catalogue. See Henry Mercer, *The Bible in Iron.*
55. Benjamin H. Barnes, *The Moravian Pottery: Memories of Forty-Six Years* (Doylestown, Pa.: Bucks County

Historical Society, 1970), 5-6.
56. Mercer, “Notes on the Moravian Pottery at Doylestown,” 2.
57. *Chronology*, 15.
58. Barnes makes note of this; Reed describes integrally colored clay bodies as belonging to a recent 20th century innovation in ceramic art; but it goes back at least 5000 years to the Egyptian practice of combining colorant oxides with clay, silica, feldspar, and soda with colorant—usually copper oxide—to create richly hued ceramic beads and sculptures.
59. A saggar is a fireclay box used to protect glazed ware, and has been a part of craft ceramics in both Asian and European traditions since ancient times. Unlike the traditional use of the saggar, however, which is merely protective (wood or coal fired kilns would otherwise deposit ash on the pottery), Mercer also used his saggars in a fashion prescient of their use in craft pottery today: he would include combustibles within some saggars to “smoke”, or introduce carbon, into the body of unglazed clay, providing a mottled or dusky finish.
60. *Chronology*, 12.
61. Eyre was named Fellow of the American Institute of Architects in 1893 and would receive their Gold Medal in 1917.
62. Quoted in Reed, 43.
63. Ibid. According to Reed, “soon after Eyre’s visit, Mercer called in carpenters, plumbers, masons, plasterers, painters, and other workers to convert [his studio] Indian House into a full-fledged pottery.” Reed makes this deduction from a review of Mercer’s cancelled checks.
64. Wilson Eyre, “An American Potter,” *House and Garden* Volume 1 No. 3 (August 1901).
65. "Indian House: An Antiquarian's Studio with Indian and Colonial Relics: A New Brand of Industrial Art." *New York Times* (Mar 30, 1901): BR35.
66. See, for example, Carl W. Condit, *American Building Art: The Nineteenth Century* (New York: Oxford University Press, 1960)*, 223*.
67. Reese Palley, *Concrete: A Seven-Thousand-Year History* (New York: The Quantuck Lane Press, 2010), 42.
68. More recently, the Russian historian Igor Znachko-Iavorskii has undertaken a historicoetymological study of technical terms regarding craft traditions of cementing materials and methods, tracing how “tenacious ideas, technical processes, and standards” were forgotten and rediscovered between the 4th century B.C.E. and the present. Despite regionally distinct practices (such as differing casein sources for water resistance, e.g., sour camel cream in central Asia, Cheshire cheese in England, and Egg White in Slavic regions) the overall trajectory of knowledge was one of ‘chance and serendipity’. The knowledge cement practices would not be systematized until the 19th century. See Igor Znachko-Iavorskii, "New Methods for the Study and Contemporary Aspects of the History of Cementing Materials," *Technology & Culture* 18, (1977): 25-42; 26, 27, 38.
69. John J. Hughes and Jan Vlek, *Mortars in Historic Buildings: A Review of the Conservation, Technical and Scientific Literature* Historic Scotland Edinburgh,, Scotland, 2003).
70. William B. Wilkinson patented a system for iron reinforcing in concrete slabs in England in 1854; in France François Coignet patented ferroconcrete floor and roof slabs in a house in 1855; also in 1855 J. L. Lambot used hydraulic lime and mesh reinforcing to create a rowboat exhibited at that year’s Paris exhibition.
71. As the French Wikipedia page recounts: “Despite the contributions of engineers, the invention of reinforced concrete originates with a policeman and a gardener.” Translation my own. See https://fr.wikipedia.org/wiki/Histoire_du_b%C3%A9ton_de_ciment.
72. We should remember that a modern understanding of the chemistry involved in burning limestone for lime was not in place before the French chemist Joseph Louis Gay-Lussac’s experiments in the 1830’s. See Znachko-Iavorskii, 38.
73. Paul Livesey, quoted in Andrew Wright, "Early Portland Cement: Its Use and Influence on Architectural Design," *Architectural Heritage* 22, no. 1 (July 2011), 99-114: 99.
74. La Roy Freese Griffin, "Natural and Artificial Cements," *Popular Science Monthly* 37, no. 2; 6 (June, 1890): 253-257.
75. Znachko-Iavorskii, 25.

76. One of the most efficient designs of the late 19th century was patented and put into production by Thomas Edison, and served as one of the primary instigations of his experiments in reinforced concrete housing.
77. In 1910, as reinforced concrete exploded in popularity and use, the USGS released a survey of concrete use in the United States showing a 10-fold *decrease* in the production of naturally occurring cement. See the unattributed "Natural Cement Versus Portland Cement," *Journal of Industrial & Engineering Chemistry* 4, no. 5 (1912): 388.
78. The first methods of numerical analysis of statics were pioneered in the late 19th century, primarily concerning mathematical models of deflection. In the mid 1880's the German company Wayss & Freytag pioneered the use of calculation to determine spans and reinforcing, and Hennebique's was the first practical system, in 1897, to arrive at a deliberate and systematic provision for shear forces. Analysis of tensile and compressive forces would become formalized over the course of the next decade, certainly by the 1904 publication of Charles Fleming Marsh's *Reinforced Concrete* (New York: D. Van Nostrand Co. 1904). For a discussion of the priority of empirical over theoretical origins of statics analysis, see "Structural engineering," *New World Encyclopedia*, http://tinyurl.com/hyvu9de (accessed July 29, 2016). "The profession of structural engineer only really took shape with the Industrial Revolution and the re-invention of concrete."
79. Thaddeus Hyatt, *An Account of some Experiments with Portland-Cement-Concrete Combined with Iron: As a Building Material, with Reference to Economy of Metal in Construction, and for Security Against Fire in the Making of Roofs, Floors, and Walking Surfaces* (Private circulation, at the Chiswick Press, 1877).
80. Terry A. McNealy and The Bucks County Historical Society, *Guide to the Microfilm of the Papers of Henry C. Mercer and the Records of the Moravian Pottery and Tileworks* (Doylestown, PA: Bucks County Historical Society, 1985), 9.
81. In his construction notebook Mercer notes six major suppliers of concrete, the "Big Six": Alpha, Atlas, Lehigh, Vulcanite, Saylors, and Edison. See *Fonthill Notebook,* 66. Each of these suppliers had a proprietary suite of recipes, and locally available sands and aggregates would have required some adaptation. In her 1998 Master's Thesis on Mercer's finishes, historic preservationist Marianne Walsh notes that Mercer had several notable contacts in the rapidly growing field of concrete manufacture, including the ASTM vice president and founding editor of the magazine *Cement Age* Robert Lesley. She writes: "Other acquaintances of Mercer's who undoubtedly counseled and advised during the construction of Fonthill included Albert Moyer, civil engineer and a writer for Cement Age, and associated with the Vulcanite Portland Cement Company […] [and] George Elkins, a director of Vulcanite Portland Cement Company [who] was also a board member of the Bucks County Historical Society". See Marianne Bernice Walsh, *Finishes Analysis in the Saloon, Fonthill,* Thesis, Historic Preservation, University of Pennsylvania (Philadelphia, PA: 1998).
82. Mercer, *Museum Notebook,* 28.
83. Mercer, *Fonthill Notebook*, 66.
84. "Concrete Mixtures," *Engineering ToolBox*, (website, 2009): https://www.engineeringtoolbox.com/concrete-sand-cement-gravel-mixtures-d_1547.html. Accessed 3/27/2018.
85. Two of the best authorities on Mercer, both the Historic American Engineering Record survey and the Reed biography, do not explicate what Mercer meant by "cinder" concrete. It is likely that this was a concrete mix design including powdered coal and/or coal ash as a replacement for cement or sand. (Unfortunately, though Mercer wrote down many of his recipes, there seems to be no record of his "cinder" recipe.) While the practice of using coal cinders to replace aggregates became widespread in the early decades of the 20th century, the first experiments with what is commonly called "cinder concrete" did not occur until 1907 and 1913 in New York, contemporaneous with Mercer's own use of the material. Mercer's "cinder concrete", then, represents the use of an invented material rather than an established one, and we should not assume his "cinder concrete" is necessarily the same formulation as that which would go on to become widely used in low-cost concrete construction in the 1920's through 1940's. See Ciro Cuono, "Cinder Concrete Slab Construction," *STRUCTURE magazine* (April 2015): http://www.structuremag.org/?p=8405.

86. W. Halstead, "Use of Fly Ash in Concrete". *National Cooperative Highway Research Project.* (October 1986): 127.
87. Malkit Singh and Rafat Siddique, *Effect of Coal Bottom Ash as Partial Replacement of Sand on Properties of Concrete*. Vol. 72 (2013).
88. Henry C. Mercer and Frank K. Swain. *Museum Construction Ledger.* Unpublished (Bucks County Historical Society Henry Mercer Archive, Doylestown, PA): Manuscript page 9.
89. Ibid., Manuscript page 33.
90. Ernest Leslie, "Mold for Concrete Construction." (Patent, United States: US516113 A 1893). https://www.google.com/patents/US516113 (accessed July 29th 2013).
91. Rosa Grima López, de Cea Aguado, and Josep Gómez Serrano, "Gaudí and Reinforced Concrete in Construction," *International Journal of Architectural Heritage* 7, no. 4 (2013): 375-402, 380.
92. Ransome's 1912 *Reinforced concrete buildings* was the first significant American reference book, and the first broadly adopted code did not appear until the 1927 UBC (Uniform Building Code). See Ernest L. Ransome, *Reinforced Concrete Buildings* (New York: McGraw-Hill Book Company, 1912).
93. The author can still remember vividly his own astonishment when, as an emerging practitioner, he was told by a contractor that the boardform concrete he had specified would naturally consist of modular steel forms with thin boards applied as a liner. Would he prefer cedar fence boards or something with a tighter grain?) (This occurred in practice in Missoula, Montana ca. 2005. At that time, like many architects, he accepted the false choice presented rather than proposing an alternate method to the contractor. The author was totally comfortable insisting on a certain species and texture of wood; but less so asking the contractor to consider alternate methods of fabrication. Yet in doing so he accepted considerable restriction on the full range of architectural possibilities available to the material—this may serve as an illustration of how architects might benefit from being taught methods as well as materials.)
94. Mercer, Henry C. "The Building of Fonthill, at Doylestown Pennsylvania, in 1908, 1909, and 1910." *Bucks County Historical Society Papers*, 6 (1926): 321-31.
95. Eichenberger, Kurt Frederick. 1982. *Design and construction techniques of an American vernacular architect : the work of Dr. Henry Chapman Mercer. Master's Thesis,* Massachusetts Institute of Technology. Dept. of Architecture. Cambridge: DSpace MIT. (Publication 09343398-MIT), 105.
96. Samuel Y. Harris, *Building pathology: deterioration, diagnostics, and intervention.* (New York, NY [u.a.]: Wiley, 2001), 261.
97. Portland cement loses strength rapidly at high temperature. By 900 degrees Fahrenheit (500 Celsius, a temperature considerably exceeded in the production of earthenware ceramics) its compressive strength is cut in half, 1 and explosive spalling begins to occur. While more recent experiments have been successful in the fabrication of "castable" kilns, there is no indication Mercer attempted any such experiments. See Izabela Hager, "Behaviour of Cement Concrete at High Temperature," *Bulletin of the Polish Academy of Sciences* 61, no. 1 (2013); William E. Lee and Robert E. Moore, "Evolution of in Situ Refractories in the 20th Century," *Journal of the American Ceramic Society* 81, no. 6 (1998): 1385-1410; and John Britt, "Solid Arch Kiln," *Ceramics Monthly* 60, no. 3 (2012): 14.
98. Kevin Grealy describes three examples of 'essentially' catenary kilns built on a type going back several thousand years. See Kevin Grealy, "Three Old Kilns from the Jingdezhen Region: Jiangxi Province, P R China." *Ceramics Technical* no. 21 (November 2005): 25-29.
99. Mercer's ledgers show the repeated purchace of "Limoid", a proprietary dolomitic hydrated lime, often used for this purpose.
100. "Written Historical and Descriptive Data," Historic American Engineering Record (Washington, D.C.: Library of Congress, Survey No. PA-107), 2.
101. This is not too distant, in its uncertainty and theater, from the potter's kiln-opening.
102. Ultimately, by looking at the way skills give rise to methods we can, perhaps, trace the lineage of novel practices back through their genesis in the generative misprisioning of preexisting bodies of knowledge and practice.
103. Henry C. Mercer, "The Building of Fonthill," 191.
104. In places, particularly at the pottery where Mercer in some places placed concrete directly over mounded earth, sizeable stones can be seen still embedded in the ceiling. Mercer used a jury-rigged screening

system for his raw clay materials processing, but not, evidently, for the earth used in his forms.

105. It is still used today in architectural design research. Tile vault fabrication using bent-stick guides has recently been incorporated in the Guastavino vault research undertaken by the Block Research Group at ETH Zurich. See in particular their SUDU project, written up in: "López López, D., Van Mele, T., AND Block, P.. "Tile Vaulting in the 21st Century" Informes De La Construcción, Volume 68 Number 544 (9 December 2016).
106. Mercer, Henry C. "The Building of Fonthill," 192.
107. Note: "modelled" and "shellaced" are sic. Mercer, "The Building of Fonthill," 193.
108. William Frankenfield, Jack C. Potter, and Elizabeth H. Sias, *Transcript of Taped Interview with William Frankenfield, Only Known Survivor of the Workmen Who Built the Mercer Museum* (Doylestown, PA: Bucks County Historical Society, August 21, 1963).
109. In the United States, the formwork for Thomas Edison's reinforced concrete houses (1907-1917) were assembled with not only reinforcing but also electrical conduit and plumbing pipes integrated in the complex iron formwork, which consisted of over 2300-2500 distinct parts. See Michael Peterson, "Thomas Edison's Concrete Houses," *American Heritage of Invention & Technology* 11, no. 3 (1996): 50.
110. Homer A. Reid, *Concrete and Reinforced Concrete Construction* (New York: Clark, 1908), 531. This widely circulated handbook lists for walls the rather broad range of 1/4"-1/2" rod, vertical 1'-6" to 3'-0", horizontal 1'-0" to 2'-0". Mercer's spacing fell within these ranges, but varied within each project and likely within each wall.
111. Full text published on the website of the Fondation Le Corbusier, http://www.fondationlecorbusier.fr/corbuweb/morpheus.aspx?sysId=13&IrisObjectId=5234&sysLanguage=en-en&itemPos=58&itemCount=78&sysParentId=64&sysParentName=home.
112. Mercer, in a letter to Sir Hercules Read, *BCHS Journal*, v2, 1980, 272-290; also quoted in Reed, 120.
113. Mercer, *Pottery Notebook,* entry July 12th, 5.
114. Mercer, *Pottery Notebook,* entry June 27th, 4.
115. His travel journals record visits to many of the key Roman sites in Western Europe. Mercer papers, Mercer Museum Research Library, BCHS.
116. When Mercer moved his tileworks from its original location to the purpose-built facility near Fonthill, he built his new kilns and the building around them simultaneously. Reed, 56.
117. Reed, 118.
118. Delbruck, 1921, is one of only a few examples. See: Jean Pierre Adam, *Roman Building : Materials and Techniques* [Construction romaine. English] (London: Batsford, 1994).
119. For a treatment of Roman uses of concrete in vaulted structures, see: Lynne C. Lancaster, *Concrete Vaulted Construction in Imperial Rome : Innovations in Context* (Cambridge: Cambridge University Press, 2009).
120. For a summary of Roman building technology as understood in the late 19th century, see Auguste Choisy, *L'Art de Batir Chez les Romans* (Paris: Ducher et al, 1873); and Alfred Léger*, Les travaux publics les mines et la métallurgie aux temps des Romains la tradition Romaine jusqu'à nos jours* (Atlas. Paris: J. Dejey, 1875).
121. Forty, *Concrete and Culture,* 22.
122. The German archaeologist Heinz Lamprecht, in his 1984 review of current scholarship on concrete in Ancient Roman building technology, finds few examples of concrete used without stone facing. One of the few examples he shows is that of the subterranean cisterns at the imperial palace in Trier, ca 400 C.E., in which can be seen the segmented impression of the original board formwork. See Heinz-Otto Lamprecht and the Romisch-Germanisches Museum. *Opus Caementitium: Bautechnik Der Romer*. 2 Aufl ed. (Dusseldorf: Beton, 1984), 19.
123. Choissy, referenced in Lancaster, 29.
124. "Delbreck (1921) noted that the vaults of some rooms, which he specifies only as 'unzuganglichen Raumen,' [inaccessible rooms] were constructed using an earth centering and that traces of fine sand, bricks, and lime were found along the intrados as well as impressions of horizontal floor planks, which must have formed the surface holding the earth centering." Lancaster, 188.
125. Delbruck's description occurs in a caption to an image, rather than in the text of his treatise.
126. Vitruvius Pollio, Ingrid D. Rowland, Thomas Noble Howe, and Michael Dewar, *Vitruvius: Ten Books of Architecture* [De architectura. English], New ed., (New York: Cambridge University Press, 1999), 7.3.1-3.

127. “Two rows of timbers, approximately 2m apart, were laid on regularly-spaced cross-pieces, 'nailed' into the ground with stakes. These supported a roadway made up of poles, limestone slabs, then gravel and compressed pebbles." Adam, 76. See also Léger, 158.
128. For which the pay was typically ten to twelve dollars. See Frankenfield interview; This is confirmed by the pay rates listed in the Museum construction ledger, though the week’s foreman received a wage of $12.50 to $15.00.
129. Mercer, *Museum Construction Ledger*, 2.
130. Interview with William Frankenfield, unpaginated (11).
131. Mercer, *Museum Construction Ledger:* September 1st 1913, 14.
132. Mercer’s dedication speech was reproduced in the *Papers of the Bucks County Historical Society,* 3, (191): 629.
133. Interview with William Frankenfield, unpaginated (6-7).
134. There are notes in the Moravian Pottery journal about the garage/carriage house, and in the museum journal about the spring house. There seems to be no written record of his plans for the stone house renovation; but this is not remarkable given the minimal nature of his interventions there.
135. “Bathroom” is written and crossed out. Mercer, *Fonthill Notebook,* 96.
136. These sketch plans are drawn usually in a combination of media (pencil, crayon and/or charcoal) on a thin paper Mercer called ‘foolscap’ resembling architectural trace. The plans are loose and undimensioned (with the exception of ceiling heights) and may have been used only later to coordinate windows, which construction photos show were fabricated and installed after much of the building was complete. These plans are published in *Fonthill, The Home of Henry Chapman Mercer.* The publisher was unfortunately unreachable with regards to reprint rights for these drawings.
137. Mercer, Fonthill Notebook, 107.
138. Linden house was a converted boarding school. See Barnes, 23.
139. Fragments of the ripped pages remain bound into the journal, and these pages appear to have contained words written in pen, though too little remains to discern full words or the likely content of these pages. It may simply have been that Mercer repurposed an existing journal for use as a construction notebook, ripping out the irrelevant pages to begin his account. In any case, there is no evidence in these ripped page-ends of the graphite pencil Mercer used in drawing his plans.
140. This is a claim Mercer repeats in his “The Building of Fonthill at Doylestown,” 20.
141. Poos, *Fonthill,* 29.
142. Mercer, “The Building of Fonthill,” 20.
143. Frederick Winslow Taylor and Sanford Eleazer Thompson, *Concrete Costs: Tables and Recommendations for Estimating the Time and Cost of Labor Operations in Concrete Construction and for Introducing Economical Methods of Management* (New York: Wiley, 1912), 4.
144. Taylor’s “scientific management” has since come to be commonly known as ‘Taylorization’, and pursues the purported goal of increased worker productivity through the quantification of work processes. This was first carried out through “motion studies” conducted by Taylor and others. “In practice, to make time studies that will place the work on the most economical basis, the labor of laying a single brick should be divided into its elementary motions, so as to see whether any of these motions can be left out and the brick be laid just as well. By studying the motions of laying one brick, for example, Mr. Frank B. Gilbreth has been able to reduce the number of motions in ordinary work from 18 to 5.” Taylor and Thompson, *Concrete Costs*, 54.
145. To arrive at this figure I have made the following assumptions: first, that the cost of the building is as Mercer reported it. While his ledger shows a final cost of $38944.99, a figure Mercer repeated in several other settings, the sum of all the line items in the ledger is a bit higher, just over $40,000. This discrepancy may be because of cumulative errors in addition; or because Mercer discounted several of the more personal costs itemized in the ledger, such as a Bicycle (page 63). Because these figures are relatively close, I have used Mercer’s published figure for the calculations that follow. The second assumption I have made is an approximate total square footage for the original Museum of 25,000 s.f., discounting crawlspaces and other utility areas, and subtracting areas on each level lost to double-height space. Because of its many additions, this is considerably smaller than the current square footage of the Museum.

146. Taylor and Thompson, *Concrete Costs*, 54.

147. For a treatment of the influence of 'scientific management' on the discipline of Architecture, see Mauro Guillén's *The Taylorized Beauty of the Mechanical: Scientific Management and the Rise of Modernist Architecture* [Princeton Studies in Cultural Sociology] (Princeton: Princeton University Press, 2006).

148. This, and other figures related directly to the ledger are drawn from the author's own tabulation of the data in the ledger. (Raw data available on request.)

149. Eyre, "An American Potter," 12-19.

150. Steven Shapin, "What Else is New? how Uses, Not Innovations, Drive Human Technology," *New Yorker* 14, (2007b): 144-148.

151. Many of the names of the workers, enumerated in the construction ledger for the museum, can also be found in the Moravian Pottery and Tileworks sales and expense records. Both of these documents were maintained primarily by Frank Swain, though Mercer's hand predominates in the ledger.

152. Barnes, *Memories*.

153. The idea of a craft pottery would not have even been conceivable 50 years before. The trajectory of ceramics production was, for most of the 18th and 19th centuries, a continuous development towards mechanization and standardization, caused as much by market conditions as by the development of technological solutions in the field. Only with the advent of the Arts and Crafts movement in the writings of William Morris did the recovery of traditional ceramics practices become possible as a socially progressive undertaking.

154. Reed, 43.

155. Mercer, "Notes on the Moravian Pottery," 3.

156. Reed discusses this period in Mercer's life in detail. See the second and third chapters of her *Henry Chapman Mercer and the Moravian Pottery and Tileworks.*

157. Reed, 178 n42.

158. Mercer, "Notes on the Moravian Pottery," 3-4.

159. Reed proposes this reading; but it may be contradicted by a passage in Mercer's notes for his history of the pottery, where he writes, "The first two kilns were constructed in a woodshed adjoining the Indian house, after which two larger kilns were built in a fireproof shed, constructed of tin, clay, and cement". See Reed, 51, 178. Reed includes this in her notes, but does not discuss the possibility that the pictured building is the 1906, rather than the 1903, construction; other sources are also ambiguous.

160. Here "fireproof" is written and emphatically crossed out. Swain, in unpublished account dated Sept. 19-16. Swain, Frank K. Mercer Papers, Series 8:13 (Doylestown, Pa.: The Bucks County Historical Society).

161. This is likely a reference for the iconography, though it also prescribes a motto that echoes in spirit, if not in detail, Mercer's own. The passage Mercer is likely referring to reads: "Stewart *(Earl of Galloway).* Or, a fesse echequy, ar. and az. surmounted of a bend engr. gu. within a double tressure, flory, counterflory, of the last. *Crest*—A pelican ar. winged or, in her nest, feeding her young, ppr. *Supporters*—Dexter, a savage, wreathed about the head and loins with laurel, holding a club over his dexter shoulder, all ppr.; sinister, a lion gu. *Motto*—Virescit vulnere virtus." See John Bernard Burke, *Encyclopædia of Heraldry, Or General Armory of England, Scotland and Ireland: Comprising a Registry of all Armorial Bearings from the Earliest to the Present Time, Including the Late Grants by the College of Arms* (London: H. G. Bohn, 1844), 924.

162. Reed, 34.

163. Reed, 73.

164. Mercer's first experiments with the material in the construction of the kiln building for his Aldie pottery and of Fonthill are approximately contemporaneous with Ransome's 1903-1904 construction of the Kelly and Jones Machine Shop in nearby Greensburg, Pennsylvania, is claimed by historian R.E. Shaeffer as one of the earliest monolithic reinforced concrete frame structures of its kind in North America. See R. E. Shaeffer, *Reinforced Concrete : Preliminary Design for Architects and Builders* (New York: McGraw-Hill, 1992).

165. See Barnes, *Memories,* 8.

166. Barnes, *Memories*, 16.

167. Henry Chapman Mercer to William Hagerman Graves, November 14, 1925. Mercer Papers, Mercer Museum Research Library, BCHS.

168. Mercer, "Notes on the Moravian Pottery," 2.

169. Unpublished loose page in the Mercer archive (folder 8:16) "Notes on Making Tiles" Undated, ca. 1903. Mercer had great difficulties finding glazes that were both predictable, and varied in their surface coloration, a particular goal of the arts and crafts approach. The lead glaze here is probably something he learned from the potter with whom he briefly apprenticed in 1897. Galena is a particular mineral form of lead; but here Mercer is probably indicating a source, the nearby village of New Galena which was named after its primary industry, lead mining. "Red" lead here probably indicates lead oxide, which is red in color, and a compound of far more use to the potter than straight mineral lead. Thus the note would be indicating a glaze composed primarily of lead oxide and tin dioxide ($Pb0+SnO2$). Small amounts of clay and silica were likely added to improve the performance of the glaze.

170. A note here on sources. Much of my knowledge of ceramic craft practices is the result of family tradition and personal experience. Where a specific, disputable, claim needs to be made, I provide a particular source in the literature; but much of what I relate in the proceeding passages, while it is not "common knowledge" in the general population, can be characterized as such in the context of the practitioners of craft ceramics. (Certainly, much of what I know I learned in dialogue, rather than from attributable sources.) As such, I will present this information without individual citation; though much of this information is also present in authoritative sources. These works are based on and share the same background of craft knowledge, conversational learning, and teaching. Some key references for 20th (and 21st) century studio potters have been:
   - Bernard Leach, *A Potter's Book;* (London: Faber and Faber, 1940).
   - Michael Cardew, *Pioneer Pottery* (New York: St. Martin's Press, 1969).
   - Daniel Rhodes, *Clay and Glazes for the Potter*, Rev ed., (Philadelphia: Chilton Book Co, 1973).
   - Anton Reijnders, *The Ceramic Process : A Manual and Source of Inspiration for Ceramic Art and Design/ Anton Reijnders; European Ceramic Work Centre.* (London: A. & C. Black, 2005).

171. This is not merely the observation of 'hot spots' or 'cold spots', where the maximum temperature is irregular, but also factors in the total amount of 'heat work' each pot receives, as well as local variation in oxygen (caused by adjacency to flues or the perimeter of the kiln, which may have areas of fresh-air leakage) and combustion by-products (caused by adjacency to the firebox or flue). The amount of oxidation or reduction experienced by glazes when they are molten can be quite variable, and greatly affects the final performance of glaze colorants. (Copper, for example may range from green to magenta across the surface of a single vessel.) Crystallization is also affected, altering the visual depth and gloss of a glaze. These variables tend to be known and mapped quantities in an established pottery operation, either held explicitly in a kiln manual, as we see at the Moravian Pottery, or simply maintained 'in the head' of an experienced craftsperson.

172. Barnes, *Memories,* 8.

173. Henry Mercer, *Kiln Manual for the Moravian Pottery,* unpublished: Mercer Papers (folder 8:37) (Doylestown, Pa.: The Bucks County Historical Society), 3.

174. The kiln manual goes on in this vein for several pages: "Enamels in general fired from fourth seggar upward to top of kiln inclusive greens in four whites and browns in fifth and sixth and blues in sixth and seventh not doing well below the sixth seggar, yellows in sixth and seventh, whites and browns ditto, green enamels occasionally burnt below the fifth seggar namely in fourth but preferably burn them all in fifth sixth and seventh…"

175. In the traditional pottery village of Onta in Ōita Prefecture, Japan, the familial handing-down of technique occurs without any verbal instruction, proceeding only through observation and imitation. Despite this, the village has developed a consistent and iconic style of pottery, "Onta ware," and an associated specific set of craft practices, that date to the 13th century. See "Ceramic Treasures - Onta-yaki, Oita Prefecture," (Video: NHK World, Japan) https://www.youtube.com/watch?v=KFOotlIz9xs; see also Richard L. Wilson, *Inside Japanese Ceramics: A Primer of Materials, Techniques, and Traditions*, (Trumble, CT: Weatherhill, 1995), 108.

176. Or "apodeictic". Latour uses the word in the context of his discussion of Archimedes' demonstration of sufficient leverage. Apodiectic reasoning (reasoning from demonstrated facts) was for Aristotle the noblest of three categories of reasoning, the lower two being dialectical (reasoning from generally accepted opinions) and contentious (reasoning from erroneous opinions). See Joseph Childers, *The*

Columbia Dictionary of Modern Literary and Cultural Criticism Columbia University Press, 1995), 15. Latour expands the range of the term and sites it within the history of technology as the origin of the privileging of abstract knowledge over the knowledge of material or technical processes.

177. As it was characterized by one of his critics, Ian Hacking. This is not, I think, a characterization that would bother Latour in the slightest. See Ian Hacking, "The Participant Irrealist at Large in the Laboratory," *British Journal for the Philosophy of Science* (1988): 277.
178. Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton, N.J.: Princeton University Press, 1979), 235.
179. Hacking, "The Participant Irrealist," 278.
180. Knorr, Lyotard, Sartre, Bourdieu, Serres, and Brillouin, respectively, in the order of the list of concepts. *Laboratory Life,* 236-240.
181. Ibid., 236.
182. Ibid., 237.
183. Ibid., 238.
184. Ibid., 238.
185. Ibid., 239.
186. Ibid., 240.
187. This has been true since the beginnings of the field, nominally in Thomas Kuhn's *Structure of Scientific Revolutions.* Indeed, the field that has developed since that time is often called "Science and Technology Studies." See Thomas S. Kuhn, *The Structure of Scientific Revolutions*, International Encyclopedia of Unified Science : Foundations of the Unity of Science ; V. 2, no. 2, 2d enl ed., (Chicago: University of Chicago Press, 1970); Sergio Sismondo, *An Introduction to Science and Technology Studies* (Chichester, West Sussex, U.K.; Malden, MA: Wiley-Blackwell, 2010).
188. Conversation between author and Eli Boritz, M.D. Ph.D., NIH research scientist, Oct 2016.
189. The term "Knowledge production," while a phrase of inscrutable popularity among researches in the social sciences who study the 'hard' sciences, and critique their uncritical positivism, would seem to be possessed of considerable ideological baggage of its own.
190. Latour reports in his postscript to the second edition of *Laboratory Life* that Guillemin, in originally allowing him access to the Salk Institute to undertake his researches, took him to belong to the philosophical, rather than scientific, category of thinker, seeming to assume that the "epistemologist" was concerned primarily with scientific reasoning rather than social processes. *Laboratory Life* (1986), 274.
191. David Turnbull, *Masons, Tricksters and Cartographers : Comparative Studies in the Sociology of Scientific and Indigenous Knowledge* (Amsterdam: Harwood Academic, 2000), 39.
192. Ibid.
193. This includes—perhaps is often centrally occupied with—imitations and adaptations of preexisting tools; 'materialization', in Turnbull's sense, is only rarely invention-from-whole-cloth.
194. Turnbull, *Masons,* 82.
195. Turnbull, *Masons,* 41.
196. Turnbull, *Masons,* 55.
197. See for example Spiro Kostof, *A History of Architecture : Settings and Rituals* (New York: Oxford University Press, 1985).
198. The early Twentieth century architect and mystic Claude Bragdon was far from alone in attributing the inscrutable mysteries of the cathedral builders to the society of freemasons. "In Mediaeval Europe, as in ancient Egypt, fragments of the Secret Doctrine—transmitted in the symbols and secrets of the cathedral builders—determined much of Gothic architecture." See Claude Bragdon, *The Beautiful Necessity : Seven Essays on Theosophy and Architecture* (Rochester, N.Y.: Manas Press, 1910), 18.
199. Latour clarifies: "This notion of inscription device is sociological by nature. It allows one to describe a whole set of occupations in the laboratory, without being disturbed by their material shapes. For example, a "bioassay for TRF" counts as *one* inscription device even though it takes five individuals three weeks to operate and occupies several rooms in the laboratory. Its salient feature is the final production of a figure." *Laboratory Life*, 51 fn 5; 89.
200. It is not algorithmic so much as it is iterative. Turnbull explicitly makes this point in his essay, offering a

remarkably prescient critique of the current fad of algorithmic formalism in architectural representation.

201. Some recent works have begun to recognize this function in contemporary construction documents. See Annette Spiro, *The Working Drawing - the Architect's Tool.* (Zurich: Park Books, 2014).

202. Unfortunately, Mercer's annotation cannot be verified in the field, as the buildings on that piazza have all been replaced by 20th century apartments; but the piazza is called out for mention in guidebooks of Mercer's time, such as the 1909 *Brochure Series of Architectural Illustration, Volume 9,* particularly for the virtues of its central fountain.

203. A detailed discussion of Mercer's plaster molds for tiles can be found in Reed; the complete annual catalogs produced by the Moravian Pottery, as well as Mercer's original design and shop drawings for tiles are preserved in the Mercer archive held by the Bucks County Historical Society.

204. This is perhaps a temporary term for an extemporized tool, as it is described by the present day Moravian Pottery as a tool that "may have been used to press or tamp wet clay into press molds or onto mosaic molds." (Collection of the Moravian Pottery, interpretive signage.) Reed is more certain: she describes it as a "plaster and wood tool for pressing brocade tiles." Reed, 66.

205. David Pye's observations regarding the 'workmanship of risk' and the 'workmanship of certainty' are relevant here, but would be anachronistic in this discussion, belonging to a period and a polemic the causes of which had not yet, in Mercer's time, fully emerged. See David Pye, *The Nature and Art of Workmanship* (London: Cambridge U.P., 1968).

206. Barnes's *Memories* claims the total was 398; but Mercer's own catalog, published the year after the capitol project was complete, lists 420 mosaics.

207. Robert Lesley, "A Concrete House," *Cement Age* 6, no. 1 (May, 1908): 331.

208. Marianne Bernice Walsh, *Finishes Analysis, 14.*

209. The borrowing of forms across materials has happened throughout architectural history, perhaps most famously in the context of the Greek appropriation of timber construction details into stone, discussed by Vitrivius (Book IV) and echoed in Laugier's *Essay* and Semper's *Four Elements.* Marc-Antoine Laugier, *An Essay on the Study and Practice of Architecture* [Essai sur l'architecture. English] (London: printed for Stanley Crowder and Henry Woodgate, 1756); Gottfried Semper, *The Four Elements of Architecture and Other Writings*, RES Monographs in Anthropology and Aesthetics, [Selections. English. 1989] (Cambridge England ;New York, NY, USA: Cambridge University Press, 1989).

210. For more on source monitoring see Lisa Zunshine, *Why we Read Fiction: Theory of Mind and the Novel* (Columbus, Ohio: Ohio State University Press, 2006).

211. Poos, 43; Reed, 72; Forty, 315. Mercer himself, at the beginning of his projects, called them "unskilled day laborers." See Mercer, *The Building of Fonthill,* 186. This should not, however, be taken as a description of their state throughout their association with Mercer. Instead, it seems Mercer employed the same men for as long as they were willing and available—this is attested to by the recurrence of names in the ledgers.

212. Paley, 216.

213. Michel de Certeau, *The Practice of Everyday Life* [Arts de faire. English] (Berkeley: University of California Press, 1984), 103.

214. Walter Benjamin, *The Origin of German Tragic Drama*, Radical Thinkers, [Ursprung des deutschen Trauerspiels. English] (London ;New York: Verso, 2009), 28-29.

215. "Sulzer's Harlem river park and casino, a noted resort on the harlem river, north of One Hundred and Twenty-ninth street, fronting on Second avenue, was wiped out by fire today." See "Sulzer's Casino Burned," The Kingston Daily Freeman, Volume XXXVII, Number 30, 21 November 1907.

216. Other historical accounts only mention it as the structure replaced by William Randolph Hurst's movie studio in the 1920's. As we can see from photographs of Hurst's studio, the buildings are one and the same. See Jonathan Gill, *Harlem: The Four Hundred Year History from Dutch Village to Capital of Black America* (New York: Grove/Atlantic, Inc., 2011), 122.

217. Robert Michael Craig, *Maybeck at Principia: A Study in an Architect-Client Relationship,* Dissertation, Fine Arts, (Cornell NY: Cornell University, 1973).

218. See page 25 of the pottery construction notebook. For information on recent repair efforts, see Dale H. Frens, "Restoration of the Concrete Roof of the Mercer Museum in Doylestown, Pennsylvania," *APT*

Bulletin 33, no. 1 (2002): 13-19.

219. It is unclear whether the differences were also procedural. While the cornice takes the same form as at previous projects, a note in a secondary source mentions the possibility that Mercer had the cornice forms for the Museum made in advance offsite. See the Frankenfield interview, Mercer Archive, BCHS.
220. Kerry Dean Carso, *American Gothic Art and Architecture in the Age of Romantic Literature*, Gothic Literary Studies, (Cardiff: University of Wales Press, 2014), 206.
221. Mercer, *Fonthill Notebook,* 120.
222. Reed, 53.
223. Ford, Edward R. *The Architectural Detail*. New York: Princeton Architectural Press, 2011. 307-308.
224. Reed, 10.
225. This suggests algorithms may always be better at explaining buildings than designing them.
226. Douglas Hofstadter and Emmanuel Sander, *Surfaces and Essences: Analogy as the Fuel and Fire of Thinking* Basic Books, 2013), 18.
227. "There are minds for which certain images retain absolute priority. Bernard Palissy's was one of these and, for him, shell images were of enduring interest. If one had to designate Palissy by the dominating element of his material imagination, he would fall quite naturally into an "earthly" group. But since the material imagination is a matter of nuances, Palissy's imagination would have to be specified as that of an earthly being in quest of a hard earth that must be further hardened by fire, but which also has the possibility of attaining natural hardness through the action of a solidifying, self-containing salt." Gaston Bachelard and M. Jolas, *The Poetics of Space* [Poetique de l'espace. English] (Boston: Beacon Press, 1994), 127.
228. To borrow Turnbull's deliberate anachronism.
229. Turnbull, *Masons,* 39. While this remark was discussed in chapter 2 as a material proposition—the workplae as a 'space' of knowledge production—it may also be applied to the 'space' of the construction notebook, an account of building which, as we have seen, is configured primarily in time. For a discussion of the interdependence of plots and plans, see: Paul Ricoeur, "Architecture and Narrative," in Pietro Derossi, Identita, Differenze, Triennale Di Milano, XIX Esposizione Internazionale (Milano: Electa, 1996), Pp. 64-72; and "Architecture Et Narrativité," Arquitectonics 4 (2002): 9–29.
230. Lawrence W. Barsalou, "Frames, Concepts, and Conceptual Fields," *Frames, Fields, and Contrasts: New Essays in Semantic and Lexical Organization.* (1992): 21.
231. Barsalou, "Frames," 23.
232. "Ad hoc categories" is his term in earlier works; "Frames," in later.
233. Lawrence W. Barsalou, "Ad Hoc Categories," *Memory & Cognition* 11, no. 3 (1983): 211.
234. Ibid., 224.
235. Barsalou, "Frames," 23.
236. These publications are concentrated in the first decade of the 20th century. By 1909, when Mercer published his first draft of *Tools of the Nation Maker*, he seems to have moved on to subjects pertaining to the collection and classification of tools; with the exception of several review articles describing the building of Fonthill or the museum in general, his publications from this date onward concern tools and trades almost exclusively. Concrete industry trade publications from the early 20th century have been sporadically digitized but never to my knowledge comprehensively indexed, so finding Mercer's publications, which likely did not amount to more than several per year, can prove difficult. Some good examples of his combination of artistic polemic, technical description, and historical study, include: "The Decoration of Concrete with Colored Clays," Paper read at the annual meeting of the Association of American Portland Cement Manufacturers. Bulletin No. 10., issued by the Association of American Portland Cement Manufacturers, Land Title Building, Philadelphia, PA: 1905.; and the aforementioned "Where concrete stands for concrete."
237. "At hand" is more than a figure of speech here. We might consider at-handedness a central question in the philosophy of technology (if only we could agree on whether it is an instrumental, or ontological, term.)
238. As any jobsite binder of RFI's will attest, every building project is a simultaneous building-and-designing; but the opposite is, certainly for architects, far more rare. (This may begin to explain the enduring

fascination of Sam Mockbee's work.)

239. Ed Ford's *The Detail* explores just this question, arriving at five basic categories of detail: seamless, motific, representational, tectonic, and autonomous. Ford, *The Detail,* 18-45.

240. Dalibor Vesley, in his essay on the nature of the 'modern fragment,' gives Hannah Arendt the final word on the subject: "only when things [fragments or elements] can be seen by many in a variety of aspects without changing their identity, so that those who are gathered around them know they see sameness in utter diversity, can worldly reality truly and reliably appear." Arendt, quoted in Vesley, Dalibor Vesely, *The Nature of the Modern Fragment and the Sense of Wholeness*, Fragments: Architecture and the Unfinished: Essays Presented to Robin Middleton, edited by Werner Oechslin, Barry Bergdoll (London: Thames & Hudson, 2006), 53. Vesley's point, in concluding with this Delphic call, is not so much that such a state of grace is waiting to arrive, always just around the corner and into tomorrow, but rather that is already here, in the uncategorizeable entire of fragments. This returns us to the question of comportment presently at hand: how to act in, and fabricate, such worlds.

241. Hofstadter and Sander*, Surfaces and Essences,* 17.

242. Ibid., 30.

243. In characterizing this moment of demonstration as 'extralinguistic' it would seem we are at odds with Pierce, who describes such elements in discourse—like the perfect example of Mercer's drawing of a hand pointing to his "best cornice"—as 'indexical signs'. Yet this pointing hand stands in for a larger complex of action, to be carried out on the jobsite, and in that context functions in a different way. Pierce characterizes the index as an empty placeholder; but his description of the icon can be recognized as equally applicable to the moment of the transfer of tacit knowledge. He describes an indexical sign as follows: "I call such a sign an index, a pointing finger being the type of the class. The index asserts nothing; it only says "There!" It takes hold of our eyes, as it were, and forcibly directs them to a particular object, and there it stops. Demonstrative and relative pronouns are nearly pure indices, because they denote things without describing them; so are the letters on a geometrical diagram, and the subscript numbers which in algebra distinguish one value from another without saying what those values are." His description of the icon follows some pages later, and suggests resemblance as a mode of relationship. Yet in the moment of translation, something beyond resemblance occurs. He writes: "I call a sign which stands for something merely because it resembles it, an icon. Icons are so completely substituted for their objects as hardly to be distinguished from them. Such are the diagrams of geometry. A diagram, indeed, so far as it has a general signification, is not a pure icon; but in the middle part of our reasonings we forget that abstractness in great measure, and the diagram is for us the very thing. So in contemplating a painting, there is a moment when we lose the consciousness that it is not the thing, the distinction of the real and the copy disappears, and it is for the moment a pure dream,—not any particular existence, and yet not general. At that moment we are contemplating an icon." While the gesture may have been a sign, this is the moment that the sign becomes a gesture. See C. S. Pierce, "On the Algebra of Logic: A Contribution to the Philosophy of Notation," *American Journal of Mathematics,* Vol. 7, No. 2 (Jan., 1885): 180; 196.

244. Pierce, "On the Algebra of Logic," 137.

245. Francis Crick and Christof Koch, *Towards a Neurobiological Theory of Consciousness*, *Seminars in the Neurosciences, Vol.* 2 (Saunders Scientific Publications, 1990), 263-275.

246. Andreas Bartels and Semir Zeki, "The Neural Correlates of Maternal and Romantic Love," *NeuroImage* 21, no. 3 (2004): 1155-1166; Hideaki Kawabata and Semir Zeki, "Neural Correlates of Beauty," *Journal of Neurophysiology* 91, no. 4 (2004): 1699-1705.

247. This is an 'extrapolation' rather than something provided by direct experimental observation of individual neurons in the human brain, as discussed in Carr, Richard., Hass-Cohen, Noah., Findlay, Joanna Clyde., Masterson,Jessica Tress., *Art Therapy and Clinical Neuroscience.* (London: Jessica Kingsley Publishers, 2008).

248. C. B. Boronat, L. J. Buxbaum, H. B. Coslett, K. Tang, E. M. Saffran, D. Y. Kimberg, and J. A. Detre, "Distinctions between Manipulation and Function Knowledge of Objects: Evidence from Functional Magnetic Resonance Imaging," *Brain Research.Cognitive Brain Research* 23, no. 2-3 (2005): 361.

249. Bartlomiej Piechowski-Jozwiak, François Boller, and Julien Bogousslavsky, "Universal Connection

through Art: Role of Mirror Neurons in Art Production and Reception," *Behavioral Sciences* 7, no. 2 (2017): 29.

250. This "cartesian vertigo" is particularly indelible in neuroscientific approaches to "lower order" perceptive faculties; it persists, however, as an ideological bias even in the analysis of higher order functions. See Alva Noë, *Strange Tools : Art and Human Nature*, First ed., (New York: Hill and Wang, a division of Farrar, Straus and Giroux, 2015), 123.
251. Ibid., 125.
252. Ibid.
253. Hofstadter and Sander*, Surfaces and Essences,* 342-246.
254. Kretz, Donald R. and Daniel C. Krawczyk. "Expert Analogy use in a Naturalistic Setting." *Frontiers in Psychology* 5, (2014): 1333. doi:10.3389/fpsyg.2014.01333.
255. Dreamhouse, 98. <>
256. Euclid uses the term 'analogy' to describe proportional relationships in numbers, but it is only with Plato that the term comes to be used to describe similarities in broader conceptual domains such as between things and ideas.
257. This 'logic of particulars' might be opposed to the conventional part-to-whole, and whole-to-part, logics of investigation—that is to say, induction and deduction.
258. Hofstadter and Sander write that while no one has a complete chart of all professional expertise in their head, "being a specialist in some domain inevitably means that one has internalized some local portion of this complexly structured knowledge." Hofstadter and Sander*, Surfaces and Essences,* 243.
259. Gian Paolo Caprettini, *Peirce, Holmes, Popper*, The Sign of Three: Dupin, Holmes, Peirce, edited by Umberto Eco, Thomas Albert Sebeok 1991), 141. Emphasis mine.
260. Yves Bonnefoy and Richard Stamelman, in classroom discussion, Williams College, Fall 1996.
261. Caprettini, 155.
262. Hans Vaihinger and C. K. Ogden, *The Philosophy of "as if" : A System of the Theoretical, Practical and Religious Fictions of Mankind*, The International Library of Philosophy. Epistemology and Metaphysics, [Philosophie des als Ob. English], Vol. 5 (London: Routledge, 1924), 354.
263. Ibid., 258-259.
264. Vaihinger, 177.
265. Peter Murray and Deborah Blackman, "Managing Innovation through Social Architecture, Learning, and Competencies: A New Conceptual Approach," *Knowledge & Process Management* 13, no. 3 (2006): 132, 253.
266. Or as Adam Kendon argues in his monograph on the semiotics of gestures, "Whenever speakers give descriptions of objects, gesture is almost always employed as an integral component of such descriptions. Gestures used in this fashion undoubtedly serve to provide important information for recipients. However, they may be useful also because they make possible a much more economical account than any that could be accomplished by words alone." See: Adam Kendon, *Gesture: Visible action as utterance* (Cambridge: Cambridge University Press, 2004), 1934.
267. Antoine Cornuéjols, "Analogie, principe d'économie et complexité algorithmique." *Actes des 11èmes Journées Françaises de l'Apprentissage* (1996).
268. Their conclusions from these observations included the following: "In their work, experts operate in and move between multiple parallel activity contexts. These multiple contexts demand and afford different, complementary but also conflicting cognitive tools, rules, and patterns of social interaction. The criteria of expert knowledge and skill arc different in the various contexts. Experts face the challenge of negotiating and combining ingredients from different contexts to achieve hybrid solutions. The vertical master-novice relationship, and with it, in some cases, the professional monopoly on expertise. is problematizcd as demands for dialogical problem solving increase." See Yrjö Engeström, Ritva Engeström, and Merja Kärkkäinen, *Polycontextuality and Boundary Crossing in Expert Cognition: Learning and Problem Solving in Complex Work Activities*, Vol. 5 1995): 319-336, 331.
269. This is a challenge to the representation, in literature, of those parts of life structured by informal communication, such as collaborative craft work. For whereas the metarepresentational project of fiction as fiction (see Zunshine, *Why we Read Fiction*) or art as art (see Noe, *Strange Tools*).
270. Turnbull, *Masons,* 66.

271. John James, *The Template-Makers of the Paris Basin: Toichological Techniques for Identifying the Pioneers of the Gothic Movement with an Examination of Art-Historical Methodology* Boydell & Brewer, 1989).

272. James, *The Template-Makers,* 2.
273. H. M. Collins, *Tacit and Explicit Knowledge* (Chicago: The University of Chicago Press, 2010), 7.
274. Collins, *Tacit and Explicit,* 8. Emphasis mine.
275. Michael Polanyi, *The Tacit Dimension*, Terry Lectures, Vol. 1962 (Garden City, N.Y.: Doubleday, 1966), 21.
276. Ibid., 10.
277. Collins, *Tacit and Explicit,* 110.
278. As Elaine Scarry has proposed in her *The Body in Pain,* "Whatever pain achieves, it achieves in part through its unsharability, and it ensures this unsharability through its resistance to language. "English," writes Virginia Woolf, "which can express the thoughts of Hamlet and the tragedy of Lear has no words for the shiver or the headache. . . . The merest schoolgirl when she falls in love has Shakespeare or Keats to speak her mind for her, but let a sufferer try to describe a pain in his head to a doctor and language at once runs dry." True of the headache, Woolf's account is of course more radically true of the severe and prolonged pain that may accompany cancer or burns or phantom limb or stroke, as well as of the severe and prolonged pain that may occur unaccompanied by any nameable disease. Physical pain does not simply resist language but actively destroys it, bringing about an immediate reversion to a state anterior to language, to the sounds and cries a human being makes before language is learned." See Elaine Scarry, *The Body in Pain : The Making and Unmaking of the World* (New York: Oxford University Press, 1985), 11.
279. Collins, *Tacit and Explicit,* 112. Emphasis mine.
280. He makes this point on 107, in reference to Hubert Dreyfus's much more extended argument on the same topic.
281. Collins, *Tacit and Explicit,* 105.
282. "This was our paradox: no course of action could be determined by a rule, because any course of action can be made out to accord with the rule". PI 201. Also see the discussion of color chips in PI 258. Ludwig Wittgenstein, *Philosophical Investigations* [Philosophische Untersuchungen. German & English] (New York: Macmillan, 1953).
283. Collins, *Tacit and Explicit,* 114.
284. This is, Collins proposes, the heart of Merleu-Ponty's claim about the walking stick. He glosses Merleu-Ponty's argument with the following words, in quotes: "the blind man has ceased to be an object for the stick, he has now become transplanted into it, extending the stick's area of sensitivity to engagement with the full richness of the human world." But Merleu-Ponty's claim is, I think, slightly different. Not only does he not use the term 'transplanted', Merleu-Ponty's emphasis is not on the change of the stick's ontological status and the in-corporation of the tool so much as on the indissociably corporeal realm of human action and the extensibility of his ontological condition, particularly in routine action. Later in the passage Collins is referring to, he writes, "Places in space are not defined as objective positions in relation to the objective position of our body, but rather they inscribe around us the variable reach of our intentions and our gestures. To habituate oneself to a hat, an automobile, or a cane is to take up residence in them, or inversely, to make them participate within the voluminosity of one's own body. Habit expresses the power we have of dilating our being in the world, or of altering our existence through incorporating new instruments." Maurice Merleau-Ponty and Donald A. Landes, *Phenomenology of Perception* [Phénoménologie de la perception. English] (Abingdon, Oxon ;New York: Routledge, 2012), 145. See also Collins, *Tacit and Explicit,* 114.
285. Collins, *Tacit and Explicit,* 97. Collins by this means knowledge that could be made explicit, had we world-enough-and-time, but is, practically speaking, unavailable to explication.
286. Marco Frascari, "A New Angel/Angle in Architectural Research: The Ideas of Demonstration," *Journal of Architectural Education* 44, (1990): 11.
287. As a fisherman-turned-framer one put it, 'everyone on the crew has to be a jack-of-all-trades.' Conversation between author and the former crew of a deep sea vessel, which stayed together and

formed a carpentry crew, Spring 2004, Camano Island, WA. With thanks to Jimmy S. and the Horizon Home crew.
288. See Edwin Hutchins, *Cognition in the Wild* (Cambridge, Mass.: MIT Press, 1995).
289. Indeed, the latter half of 20th century modernism is filled with examples of architects who struggled to overcome or productively engage with the norms of many of the trades involved in their buildings.
290. Reed, 72. Reed mentions this in passing; tour guides at Fonthill tend to emphasize the point with more insistence, though this may reflect the informal culture of these volunteer associates rather than an institutional position.
291. Forty, *Concrete and Culture,* 225.
292. Ibid., 226.
293. Ibid., 227.
294. Forty explores how the attraction of reinforced concrete due to its perceived openness to unskilled labor was not confined to the persons of factory owners and titans of industry. For some early proponents of the technology, such as François Coignet in France, the material had a decidedly utopian resonance, and could be "to construction what printing is to writing, and tends like engraving, lithography, and photography to the popularization of the art, putting it within the reach of people of all fortunes." Coignet, quoted in ibid., 227.
295. Ibid., 235.
296. In the Frankenfield interview discussed in chapter 2, Frankenfield recalls Mercer rotating workers between jobs (as does Barnes in his memoir of the Moravian Pottery operations) and recounts his work initially in unskilled labor tasks, and his later engagement with complex formwork carpentry.
297. Reed, 72.
298. Forty, *Concrete and Culture,* note 8, 315.
299. Society for Pennsylvania Archaeology., "Henry Chapman Mercer," *Pennsylvania Archaeologist: Bulletin of the Society for Pennsylvania Archaeology* 26, (1956): 160.
300. Mercer, *Notes on the Moravian Pottery at Doyelstown,* manuscript copy, 6-7. Emphasis mine.
301. George Lakoff and Mark Johnson, *Metaphors we Live By* (Chicago: University of Chicago Press, 1980).
See also George Lakoff, "The Contemporary Theory of Metaphor," *Metaphor and Thought.* (1993): 202.
302. This dichotomy of the liquid and the solid may well go back to the powerful influence of Auguste Perret on the generation of architects that followed him. Karla Britton, in her essay echoing the midcentury critique of Perret offered by Reyner Banham, writes: "The unique position of respect that he held among the younger generation as a *constructeur* was such that, had Perret chosen to use the material according to its paste-like nature, architectural design could have developed far more imaginatively." While one might have reservations with a characterization of imagination as having a particular aesthetic configuration, Britton and Banham's shared regret for the plastic potential lost to Perret's ortho-doxy is best summed up by a question the French poet Paul Valery, a contemporary and acquaintance of Perret, wrote in a note to that architect: "Since concrete is above all a paste, why don't you more often use the curve in your works?" See Karla Britton, "The Poetic Economy of the Frame: The Critical Stance of Auguste Perret," Journal Of Architectural Education 54, no. 3 (February 2001): 176-184, 177.
303. Reed, 45 (178). Reed's footnote on this matter is unclear, suggesting that Briddes came from a family of potters but offering no direct evidence for his expertise.
304. There seems to be no genealogical record for a John Briddes of Philadelphia matching this time frame. Mercer's notes only record him as being from England; it is certainly possible however that he was part of the English ceramics industry centered in Stoke-on-Trent, as Briddes is an uncommon surname in Northwest England—this area, centered to the East of Stoke-on-Trent in Derby and Sheffield, is the only one where the surname root "Bridden" was recorded in the Great Britain Census of 1881. See http://gbnames.publicprofiler.org/ Briddes may be derived from the Old English word for 'birds' or from 'Brigantes', which was a Celtic tribe native to this same region.
305. Mercer, *Notes on the Moravian Pottery at Doyelstown,* manuscript copy, 4.
306. Birks, Steve. "Timeline of Stoke-on-Trent," *ThePotteries.org, the local history of Stoke-on-Trent, England*, www.thepotteries.org. Accessed 2/11/2018.
307. Historic American Engineering Record Survey HAER PA-107.

308. “Bisquit” and “glost” are terms used in traditional English, rather than American, practice, and these are the terms found in Mercer’s notes.

309. Reed, 72.

310. HAER PA-107, Sheet 20.

311. For English patent, see the Minton archive at http://www.themintonarchive.org.uk/. For the U.S. Patent, see: William Minton, T. *Improvement in Ovens for Firing Pottery* Google Patents, 1875. http://www.google.ca/patents/US165856.

312. “Systematized ad-hoc process” might be a good description of much of the innovation in this particular field; and, for that matter, of Mercer’s practice.

David Dawson and Oliver Kent, "The Development of the Bottle Kiln in Pottery Manufacture in Britain," *Post-Medieval Archaeology* 42, no. 1 (2008): 201, 205.

314. The central chimney variant was documented as early as 1865 in English bottle kiln design by the French scholar Guillaume Lambert, and so may have been part of the craft knowledge conveyed by Briddes either directly in his work or in discussions accompanying it, rather than an innovation arrived at by Mercer or Sell. See ibid., 206.

315. Moravian Pottery Kiln Records, quoted in Reed, 45. The Kiln records show test firings of the new kiln in March 1899. By early summer Mercer and his workmen were carrying out their first production firings.

316. Birks, Steve. "Bottle Kilns,” *ThePotteries.org, the local history of Stoke-on-Trent, England,* http://www.thepotteries.org/bottle_kiln/bottle_kiln_two.htm. Accessed 2/11/2018.

317. Moore, Dylan. "Early Kilns," *Cement Plants and Kilns in Britain and Ireland,* http://www.cementkilns.co.uk/early_kilns.html. Accessed 2/11/2018.

318. Moravian Pottery and Tileworks Sales and Expense Records, quoted in Reed, 73.

319. By 1922 the cost of materials had ballooned; and Swain reports labor costs doubled from 1918. It was the beginning of the ‘roaring’ Twenties.

320. Mercer carried over a number of workers from Fonthill through other projects and into work at the Museum. The passage in the museum journal discussing the “unfortunate situation” of the firing of one his more difficult and unproductive workers (discussed further in chapter 4) notes that he was originally brought on at Fonthill. See Museum Journal; and Pottery Expense Records. Mercer archive, BCHS.

321. Reed assures us it is a “carriage house”, though Mercer calls it a “garage” throughout his notebooks.

322. Different sources give different dates. The Fonthill Museum’s own guide to the grounds of Fonthill, produced by the Bucks County Historical Society, lists 1917 as the date of renovations. A recent article on planned rehabilitation of the house places it in 1916. There are notes in the pottery journal that may refer to the garage or to the stone house, which date to 1913-1914. See: *Fonthill Castle Park Walk,* Bucks County Historical Society, 2016. Also see Carl LaVO, "Little House in the Woods. Plans Hatch to Restore a Precious Relic Defaced by Vandals Behind Fonthill Castle in Doylestown," The Intelligencer (Doylestown, PA: Dec 18, 2017). Accessed 1/19/18.

323. Ivan Illich, *Tools for Conviviality*, World Perspectives., Vol. 47 (New York: Harper & Row, 1973), 10. [Emphasis my own.]

324. Ann Brysbaert, "Talking Shop. Multicraft Workshop Materials and Architecture in Prehistoric Tiryns, Greece," *Material Crossovers: Knowledge Networks and the Movement of Technological Knowledge between Craft Traditions* (2014): 37-61, 54.

325. Henry C. Mercer, Horace Michener Mann, and the Bucks County Historical Society, Doylestown, *The Bible in Iron; Or, Pictured Stoves and Stove Plates of the Pennsylvania Germans* (Doylestown, Pa.: The Bucks County Historical Society, 1941), 182 (note 36).

326. Henry Chapman Mercer, and The Bucks County Historical Society, “Tools of the Nation Maker," *Papers of the Bucks County Historical Society*, vol. 3, (1909): 471. This is a talk based on Mercer’s Tools of the Nation Maker catalog from 1897.

327. Mercer, Henry C. 1897. *Tools of the Nation Maker. A Descriptive Catalogue of Objects in the Museum of the Historical Society of Bucks County, Penna*. Vol. 1. (Doylestown, Pa.: Printed for the Society at the office of the Bucks County intelligencer), 3.

328. As discussed previously, his earlier research trips to more traditional archaeological sites bore little fruit; and his publications often disputed the findings of his peers at the University of Pennsylvania, despite

their daily collaboration on their university work as well as the running of the new museum. It may well be that Mercer's firsthand view of the building of the new museum for the university gave him an enlarged sense of what a "place of honor" might look like; as well as confirming his own lack of serious contribution of artifacts to such a venue.

329. Reed, 17.

330. Steve Conn, *Museums and American Intellectual Life, 1876-1926* (Chicago: The University of Chicago Press, 1998), 173.

331. "About." Mercer Museum website. Accessed March 22, 2017.

332. Kleinsasser counts as many as 70, but this includes a number of small alcoves and interpretive displays. See Kleinsasser, *Synthesis 9,* 297.

333. While Mercer's curatorial project bears comparison to Semper's schema for the ideal museum, articulated in his 1850's treatise, it is unlikely Mercer had seen the work. While Semper's text was written in English, it had not been published at the time, and was held in the collection of the Austrian Museum of Applied Arts, where Semper had donated the manuscript in 1867. Gottfried Semper; Peter Noever, ed., *Gottfried Semper-The ideal museum: practical art in metals and hard materials* (Wien: Schlebrügge, 2007).

334. Conn, *Museums, 172*.

335. Mercer was not opposed to signage; in his dedication of the museum, he wrote that he would leave it to later generations. He did not, however, find it necessary to supply such signage himself, leaving it to the interpretive work of future scholars.

336. This might suggest the potter is lost in deep consideration of the mysteries of the universe as he works. In the author's own experience, however, the act of throwing is one of being 'in the hands,' rather than high above the clouds. Perhaps then these books suggest the underlying forces at work—the centripetal pressure of the clay to open into form, the balance of strength and tension in the plastic mass, the play of friction and frictionlessness, interpreted and internalized though small cues and signals that pass through the hands, and yet are wholly, in the moment, abstract.

337. John Cummings (Curator of Mercer Museum) "First Draft for Mercer Museum book," dated Aug 17th 1957, papers of BCHS. 24-25. Unpublished. This can be found in manuscript in Mercer's papers held at the Mercer Museum Research Library.

338. Rearranged by an early curator of the Mercer Museum due to concerns about theft.

339. While Mercer was not a participant in the academic discourse of the psychological or social theorists of his time, some of the earliest seeds of these theories may have been planted in Mercer's mind, such as John Dewey's bridging of philosophy and anthropology that would find fruit in his seminal 1915 *Democracy and Education.* Mercer pursued his efforts relatively independent of these converging strains of intellectual history, but he may have been exposed to the theories of John Dewey through his friend and client Queene Ferry Coonley, an educator and proponent of Dewey's ideas who would commission works not only from Mercer but some years later from Frank Lloyd Wright. Mercer, however, did not keep any of Dewey's works in his library and does not directly reference Dewey's aesthetics or ethical thought in his journals. Still, the congruence between these two thinkers is remarkable, and may well have been part of their participation in a larger *zeitgeist* or intellectual community. It would seem the two were fascinated by many of the same problems: as Theodora Polito wrote in her study of Dewey and Vico, "Instead of looking for the origins of the modern mind in the aesthetic, more precisely the myth, Dewey looks for the origins of the modern mind in the original occupations and industries of ancient people." See Theodora Polito, "Educational Theory as Theory of Culture: A Vichian Perspective on the Educational Theories of John Dewey and Kieran Egan," *Educational Philosophy & Theory 37, no. 4* (2005): 475-494.

340. James G. Greeno, "Gibson's Affordances," in *Psychological Review* 101, no. 2 (1994): 336-342, 336.

341. Turnbull does not address the 'messy vitality' of the workshop versus the cleanliness and order of the lab.

342. Joseph F. Porac, Marc J. Ventresca, and Yuri Mishina, *Interorganizational Cognition and Interpretation*, The Blackwell Companion to Organizations, Blackwell Publishing Ltd, 2017).

343. See James Jerome Gibson, *The Ecological Approach to Visual Perception* (Boston: Houghton Mifflin, 1979). Gibson's influence was particularly evident in the 1990's, as the 1986 republication of his 1979 work

found a wide audience. Psychological Review published a 1994 special issue dedicated to his Affordances theory, and while none of its exponents have to date received a Nobel prize for their work, one did receive an IgNobel for his work on Hula-Hooping. (Michael Turvey in 2004.)

344. Gibso, *The Ecological Approach*, 127. Gibson's work is of course presaged by Merleu-Ponty's 1945 *Phenomenology of Perception.*
345. Michael T. Turvey, Richard C. Schmidt and Peter J. Beek. "Fluctuations in Interlimb Rhythmic Coordination." In Karl M Newell, Daniel M Corcos, *Variability and Motor Control* (Champaign IL: Human Kinetics Publishers, 1993), 381-411.
346. Claire F. Michaels and Raul R. D. Oudejans, "The Optics and Actions of Catching Fly Balls: Zeroing Out Optical Acceleration," *Ecological Psychology* 4, no. 4 (1992): 199.
347. Motoki Okumura, Akifumi Kijima, and Yuji Yamamoto, "Perception of Affordances for Striking Regulates Interpersonal Distance Maneuvers of Intermediate and Expert Players in Kendo Matches," *Ecological Psychology* 29, no. 1 (Jan, 2017): 1-22.
348. Jeffrey B. Wagman and Claudia Carello, "Affordances and Inertial Constraints on Tool Use," *Ecological Psychology* 13, no. 3 (2001): 173.
349. It is interesting to note the degree to which psychologists able to overcome the subject-object dichotomy with regard to kinematic experience retain a materialist skepticism regarding differing levels of past experience with regards to the task at hand. Perception and memory would seem to be difficult to reconcile in the stricter variations of the empiricist worldview. Or perhaps the methodological norms of their discipline make such a subject hard to test and verify.
350. Charles M. Keller and Janet Dixon Keller, *Cognition and Tool Use: The Blacksmith at Work. Learning in Doing* (Cambridge England; New York: Cambridge University Press, 1996).
351. See the introduction to Norman's later book revisiting the topic, *Emotional Design.* In Donald A. Norman, *Emotional Design: Why we Love (Or Hate) Everyday Things* (New York: Basic Books, 2004).
352. Donald A. Norman, *The Design of Everyday Things* [Psychology of everyday things] (Basic pbk ed. New York: Basic Books, 1988), 9.
353. Norman, *Emotional Design*, 82.
354. See the "expanded mind" theories of Andy Clarke and David Chalmers. Andy Clark, *Supersizing the Mind : Embodiment, Action, and Cognitive Extension*, Philosophy of Mind, (Oxford; New York: Oxford University Press, 2008). See also David John Chalmers, *The Character of Consciousness*, Philosophy of Mind, (Oxford; New York: Oxford University Press, 2010).
355. Martin Heidegger, John Macquarrie, and Edward Robinson, *Being and Time* [Sein und Zeit. English] (Oxford: Blackwell, 1962), 105 (1.3.16).
356. Reading Heidegger backwards might leave us with the impression that he was always a metaphysician, his project one of formulating an ontology of objects. See the recent book by Graham Harman, *Tool-being: Heidegger and the Metaphysics of Objects* (Chicago: Open Court, 2002) as an example of this sort of construal of early Heideggerian thought as a metaphysical project. A review of Heidegger's scholarship on early Greek thinking undercuts this assumption; and while a case could be made for the presence of a metaphysical bent in his post-World War Two essays, *Being and Time* is held largely—and carefully—distinct from its tropes. As Heidegger writes in the opening sentences of Being and Time: "Even though in our time we deem it progressive to give our approval to 'metaphysics' again, it is held that we have been exempted from the exertions of a newly rekindled γιγαντομαχία περὶ της ουσίας." Literally, "battle of the gods and the giants," by which Heidegger means 'the materialists and the idealists'. From the outset Heidegger exempts himself from the traditional arguments of the metaphysicians.
357. Edmund Husserl, *Cartesian Meditations; an Introduction to Phenomenology. Translated by Dorion Cairns* (The Hague: M. Nijhoff, 1960), 84.
358. Merleu-Ponty, §259 (221) Here Ponty may be riffing on Pierce.
359. Erik Shonstrom, *Wild Curiosity: How to Unleash Creativity and Encourage Lifelong Wondering* (Lanham, MD: Rowman & Littlefield, 2015), 148. Researchers in the psychological fields have studied the "flow state" in expert performance in music (William J. Wrigley and Stephen B. Emmerson, "The Experience of the Flow State in Live Music Performance," *Psychology of Music* 41, no. 3 (2013): 292), sports (Susan A. Jackson, "Joy, Fun, and Flow State in Sport," *Emotions in Sport.* (2000): 135), and the visual arts (Gioia

Chilton, "Art Therapy and Flow: A Review of the Literature and Applications," *Art Therapy* 30, no. 2 (2013): 64). Outside of a vernacular context, the term was first given serious scrutiny in the work of Jeanne Nakamura and Mihaly Csikszentmihalyi, see Nakamura and Csikszentmihalyi, *The Concept of Flow*, *Flow and the Foundations of Positive Psychology* (Berlin: Springer, 2014).

360. This serves as an excellent illustration of the arts functioning as a form of embodied philosophy, a point made in great detail by the cognitive scientist Alva Noë. However, in an unexpected turn of academic privilege Noë specifically excludes sport—though not any form of dancing—from art-as-embodied philosophy. This is perhaps because it is goal-oriented, and the telos of the score sheet inhibits whatever metarepresentational capacity the activity might otherwise possess. Such a conclusion, however, would not seem a valid distinction regarding the immersivity of these practices, whatever their superordinate category: even the enthusiastic amateur basketball player has moments—occasional and bright—of "flow". See Noë, *Strange Tools,* 74-76.

361. See particularly Heidegger, Martin. *The Question Concerning Technology, and Other Essays*. Harper Torchbooks. Vol. TB1969. New York: Harper & Row, 1977. 6.

362. At times these approbations follow one-upon-the-other. See for example Perez-Gomez, Alberto. "Hermeneutics as Discourse in Design," *Design Issues 15*, no. 2 (1999): 71-79, 72, 73.

363. Dalibor Vesely, *Architecture in the Age of Divided Representation : The Question of Creativity in the Shadow of Production* (Cambridge, Mass.: MIT Press, 2004), 284.

364. Heigegger's terms are "das Zeug" versus "das Instrumentale"; and in the next passage the term "totality of equipment is the accepted translation for Heidegger's coinage "Zeugganzheit."

365. *Being and Time,* 97-107 (I.3.15-16).

366. *Being and Time,* 97 (I.3.15). The Macquarrie and Robinson translation has the following explanation of the term, "equipment," in a footnote at its first significant use: "'das *Zeug*'. The word 'Zeug' has no precise English equivalent. While it may mean any implement, instrument, or tool, Heidegger uses it for the most part as a collective noun which is analogous to our relatively specific 'gear' (as in 'gear for fishing') or the more elaborate 'paraphernalia', or the still more general 'equipment', which we shall employ throughout this translation. In this collective sense 'Zeug' can sometimes be used in a way which is comparable to the use of 'stuff' in such sentences as 'there is plenty of stuff lying around'. (See H. 74.) In general, however, this pejorative connotation is lacking. For the most part Heidegger uses the term as a collective noun, so that he can say there is no such thing as '*an* equipment'; but he still uses it occasionally with an indefinite article to refer to some specific tool or instrument—some item or bit of equipment." In later works Heidegger uses the latinate "das Instrumentale" where the reader in English translation finds the term "instrumentality" This can be found for example in "Die Frage nach der Technik," the original German language version of the essay referenced above in translation as "The Question Concerning Technology." See Martin Heidegger, *Die Technik Und Die Kehre*, Opuscula Aus Wissenschaft Und Dichtung, Vol. 1 (Pfullingen: Neske, 1962), 8.

367. Editorial Staff, "Hammers Aren't Just for Nails: 101 Ways to Use a Rip Hammer," *Family Handyman Magazine:* https://www.familyhandyman.com/tools/hammers-aren-t-just-for-nails-101-ways-to-use-a-rip-hammer/view-all/. Accessed September 25, 2017. It is worth noting that the expert writing this particular article for a DIY audience only enumerates the first nine possibilities, assuring his readers that there are "lots more".

368. One might think of Tom Kundig on the one hand; and Michael Graves on the other.

369. This occurs on page 36 of the museum construction notebook, titled "Special Consideration." "Botany" is also included, and "Archaeology" appears at the top of the page, crossed out.

370. Despite the presence of these books in Mercer's library, Kleinsasser proposes that Mercer was not overly influenced by the influential architectural treatises of past generations, even those thinkers closest to Mercer's own involvements in the Arts and Crafts. Kleinsasser, in reviewing Mercer's library in the 1980's, found that Mercer's "copies of Ruskin's *Modern Painters* contain handwritten margin notes calling Ruskin "the hater" and "the mannerist" who attacked Lorraine [a favorite painter of Mercer's] "unfairly" and "unknowingly" […] and the Kelmscott Press copy of Ruskin's "The Nature of Gothic" was not – when I found it in 1986 – blade-opened beyond the beginning of the chapter, "Changefulness," less than half way through." See Kleinsasser, *Synthesis 9*, 336.

371. What is depicted is cast-iron formwork for use in unreinforced foundation footings. The accompanying text seems to describe a concrete made from lime rather than Portland cement, and contains an interesting if historically dubious aside about its 'discovery' at Buckingham Palace. See pages 444-446. While this is not the first treatise to treat concrete footings (that honor, of course, going all the way back to Vitruvius), it may be the first architectural treatise to detail purpose-made reusable formwork.

372. Reed, in one of her footnotes, points us to longtime employee Benjamin Barnes's recollection the result, if not the occurrence, of this argument: Mercer "came into the office and asked, 'Why are we making these bracket tiles? They are not my design.' This led to a hot argument. Dr. Mercer went back to Fonthill. The first thing I knew Frank Swain got his topcoat and lunch kettle. I was outlining a fireplace facing on the drawing board in the studio when Frank said goodbye. He was gone for about three weeks. When surmising where he would be, Dr. Mercer sent Laura Long, the housekeeper, and me to go to Philadelphia, treat him to a dinner and show, and bring Frank back to Fonthill". See Barnes: *Memories,* 11-12.

373. Gibson 1979, 101.

374. To understand the degree to which, in Norman's account, the use of the tool is subjugated to its design and manufacture, one need only consider his characterization of those 'rare' cases in which we do not purchase the product of an industrial design-and-manufacture process. In the epilogue of his *Emotional Design,* he characterizes such cases as hopelessly retrograde: "In 'the good old days,' so it is said, we either made all our own things or went to the local craftsperson who would make something to our specifications, often as we watched. Some people still cherish those old days of folk arts—see, for example, John Seymour's wonderful description of them in his Forgotten Arts and Crafts. But as our needs get more complex and specialized in this ever-more technological, information-rich age, it is an impossible dream that many of us would possess the skills and time required to design and construct the objects required in everyday life. Nonetheless, it is not totally impossible to follow this route, and those who do reap many benefits. Some make their own clothing and construct furniture. Many people create and maintain gardens. Some even build their own airplanes or boats." Certainly, the phenomena Norman describes here are real; yet his characterization leaves out the manifold everyday improvisations and adaptations that are part of skilled tool use in expert settings. By setting the object of industrial design as his criteria for what constitutes an object, Norman risks missing the degree to which objects are altered, repaired, and repurposed; and invented wholesale; in even the most contemporary settings of high-tech tool-afforded research and fabrication. To be sure, this sort of improvisation is excluded from the assembly line. But we should be careful about visualizing the making of products from within the metaphor of assembly line production, particularly in fields (such as architecture) to which the assembly line is so poorly suited.

375. Reed, 62.

376. This is of course only a seeming-contradiction, as recent psychological studies have shown. These laboratory demonstrations contradicting our popular assumptions about decision and action have been popular since Benjamin Libet's experiments in the 1980's showing that the electrical impulse towards movement in the hand (the "Bereitschaftspotential") preceded subjects' conscious decision to move their hand. See Benjamin Libet, Curtis A. Gleason, Elwood W. Wright, and Dennis K. Pearl, "Time of Conscious Intention to Act in Relation to Onset of Cerebral Activity (Readiness-Potential) the Unconscious Initiation of a Freely Voluntary Act," *Brain* 106, no. 3 (1983): 623-642. For a more comprehensive treatment of the topic, see Alan D. Baddeley, *Working Memory, Thought, and Action*, Oxford Psychology Series, Vol. 45 (Oxford; New York: Oxford University Press, 2007).

377. As we have just discussed, to call this a moment of the tool's invisibility, with Heidegger, is specious. The tool is no more or less invisible than the hand is, or the piece of work. The biomechanics of the hand (or any other out-of-context truth, such as Heideggerian ontology) is plainly not 'visible' to us as we swing the hammer, and drive the nail sweetly into the wood—even the most experienced of carpenters would not carry out this task eyes-closed; and we are rarely so blinded by other considerations that a mashed thumb does not offer its corrective. The point here about expertise 'using us' is not one of free will or ontological priority (whether for objects or beings or Being) but rather one of our embeddedness in systems of knowledge-and-action. The norms of these expert systems structure behavior even—or

especially—at the level of the hammer's swing. Inasmuch as the tool, taken up into use, merges into this larger system, it might be said to be 'invisible' as-itself. But such a statement simply creates a false metaphysics of the as-itself, and distracts us from consideration of the larger system of action, to which the question of the objective (or subjective) materiality of the tool is merely a footnote.

378. This is only true in a subset of cases—on a cloudy night the astronomer does not go looking for another telescope. There are perhaps certain tools that are so situation-, or purpose-, specific, that the idea of finding a replacement is dismissed out-of-hand. Yet these frustrations give rise to their own inventions, sometimes of the most ambitious kind—such as lifting the telescope and setting it above the clouds.

379. See Andy Clark, Julian Kiverstein, and Tillmann Vierkant, *Decomposing the Will*, edited by Andy Clark, Julian Kiverstein and Tillmann Vierkant (New York, NY, US: Oxford University Press, 2013).

380. Erik Rietveld and Julian Kiverstein, "A Rich Landscape of Affordances," *Ecological Psychology* 26, no. 4 (2014): 325-352.

381. Hubert Dreyfus, Andy Clark, and Stanley Cavell are all prominent voices who have expanded the discussion. Relevant works are listed in the bibliography.

382. Rietveld and Kiverstein, "A Rich Landscape," 343.

383. Polanyi, *Tacit Dimension,* 10.

384. Ibid., 11.

385. Ibid., 12.

386. Ibid., 13.

387. Ibid., 10, 14.

388. Greeno, *Gibson's Affordances*, 337

389. Walter J. Ong, *Orality and Literacy: The Technologizing of the Word*, New Accents, (London; New York: Routledge, 1982), 81.

390. Interview with William Frankenfield, unpaginated (3-4).

391. Ibid., unpaginated (10-11).

392. Except in cases, such as the manufacture of mobile homes, where such judgements are reduced to the minimum necessary—usually in pursuit of an idealized efficiency.

393. "It is the function and duty of lineaments, then, to prescribe an appropriate place, exact numbers, a proper scale, and a graceful order for whole buildings" Leon Battista Alberti, *On the Art of Building in Ten Books* [De re aedificatoria.] (Cambridge, Mass.: MIT Press, 1988). (I, I).

394. Alberti, translated by Cosimo Bartoli and quoted in Howard Burns, "Between the lines: Palladio's project and Palladio's drawings," in Charles Hind and Irena Žantovská Murray, *Palladio and His Legacy: A Transatlantic Journey* (Venice: Marsilio, 2010).

395. John S. Hendrix argues for the profound influence of Ficino on Alberti in his "Alberti and Ficino," *School of Architecture, Art, and Historic Preservation Faculty Publications. Paper 25.* http://docs.rwu.edu/saahp_fp/25 (2012). Accessed 3/2/2018.

396. What is remarkable about Alberti's letter is just how efficient is the interplay of graphical and lexical redundancy; this interplay of redundancy may well be a function of the complementary way these genres of communication carry meaning.

397. "We are operating here with unrealities and not with realities; but they are useful and indispensible unrealities." Vaihinger, 236.

398. "We shall find that imaginary vivacity comes about by reproducing the deep structure of perception. On one level this is wholly unsurprising: if imagining is a mimesis of perception, then successful imagining will of course come about through the accuracy or acuity of the mimesis. Still, it seems amazing that what in perception comes to be imitated is not only the sensory outcome (the way something looks or sounds or feels beneath the hands) but the actual structure of production that gave rise to the perception" Elaine Scarry, *Dreaming by the Book* (New York: Farrar, Straus, Giroux, 1999), 12.

399. Ibid., 161.

400. Ibid., 196 note 6.

401. Umberto Eco, *The Open Work* [Essays. English. Selections.] (Cambridge, Mass.: Harvard University Press, 1989), 19.

402. Eco writes, "In every century, the way that artistic forms are structured reflects the way in which science

or contemporary culture views reality. The closed, single conception in a work by a medieval artist reflected the conception of the cosmos as a hierarchy of fixed, preordained orders. The work as a pedagogical vehicle, as a monocentric and necessary apparatus (incorporating a rigid internal pattern of meter and rhymes) simply reflects the syllogistic system, a logic of necessity, a deductive consciousness by means of which reality could be made manifest step by step without unforeseen interruptions, moving forward in a single direction, proceeding from first principles of science which were seen as one and the same with the first principles of reality. The openness and dynamism of the Baroque mark, in fact, the advent of a new scientific awareness: the *tactile is* replaced by the *visual* (meaning that the subjective element comes to prevail) and attention is shifted from the *essence* to the *appearance* of architectural and pictorial products. It reflects the rising interest in a psychology of impression and sensation". Ibid*.,* 13.

403. Ibid., 46.
404. Ibid., 51.
405. Steven Pinker, *The Stuff of Thought : Language as a Window into Human Nature* (New York: Viking, 2007), 178.
406. As is now enshrined in the United States National CAD Standard, V.6.
407. Eco, *Open Work,* 52.
408. This is the well-recognized Achilles heel of big data approaches.
409. Eco, *Open Work,* 50-51.
410. C. E. Shannon, "Prediction and Entropy of Printed English," *Bell System Technical Journal* 30, no. 1 (1951): 50.
411. Eco, *Open Work,* 53.
412. Stein, "Rooms," from *Tender Buttons,* 1914. (These really must be read aloud.) Gertrude Stein and Seth Perlow, *Tender Buttons*, The correct centennial; First City Lights ed., (San Francisco: City Lights Books, 2014).
413. "Fiction, like art in general, can be explained in terms of cognitive play with pattern—in this case, with patterns of social information—and in terms of the unique importance of human shared attention. Music and visual art each appeal directly to one of our main sense, and therefore have antecedents in other animals, in the song of humpback whales or nightingales, in the bodily or architectural displays of paradise or bowerbirds. But since fiction appeals to our craving for higher-order information, it has slighter precursors in other species. Even more than other social species, we depend on information about others' capacities, dispositions, intentions, actions, and reactions. Such 'strategic information' catches our attention so forcefully that fiction can hold our interest, unlike almost anything else, for hours at a stretch." See Brian Boyd, *On the Origin of Stories* Harvard University Press, 2009), 130.
414. Umberto Eco, *Six Walks in the Fictional Woods*, Charles Eliot Norton Lectures, Vol. 1993 (Cambridge, Mass.: Harvard University Press, 1994), 85.
415. Quotations in this paragraph are from Eco, *Six Walks,* pages 85, 117, 128, 60, 130, in sequential order.
416. Robert Bringhurst, *Everywhere being is Dancing: Twenty Pieces of Thinking* (Kentville: Gaspereau, 2007), 74-75.
417. Eco, *Open Work*, 55.
418. See the final paragraph of Rykwert's seminal essay "On the oral transmission of architectural theory," *AA files* 6 (1984): 14-27. He writes: "This vast expanse of gesture and talk is the ground on which mediaeval architecture was built. To neglect it, to make no attempt at conjuring it up, at divining its outline is to estrange yourself from those builders, and misconceive their motives." Here Rykwert may suggest the intimate connection between architectural ephemera and motive force. But an earlier version of the essay is more metaphoric, and not nearly so provocative. The same paragraph reads: "Yet the clouds of Euclidian talk have not blown away; they pervade the monuments of medieval architecture. They are only perceptible to those who acknowledge the continuing value of the talk and its enormous importance to the makers of the monuments." Joseph Rykwert, "On the Oral Transmission of Architectural Theory," *RES: Anthropology and Aesthetics* 3, no. 1 (1982): 68-81, 79.
419. The same year Eco published his *Open Work,* John Cage's performed his composition *0'-0".* The score of the work, and the entirety of its first performance, consisted of the writing of a single sentence: "In a situation provided with maximum amplification, perform a disciplined action."
420. Eco, *Open Work,* 45.

421. Perhaps, then, the anti-instrumentality of 20th century theory may well be merely the unwitting inheritance of 19th century romanticism.
422. Olson, Charles, "Projective Verse," Poetry Foundation–Essays on Poetic Theory (1950): http://www.poetryfoundation.org/resources/learning/essays/detail/69406. Accessed May 11 2016.
423. Guillemette Bolens, *The Style of Gestures : Embodiment and Cognition in Literary Narrative*, Rethinking Theory, [Style des gestes. English] (Baltimore: Johns Hopkins University Press, 2012), 42.
424. This was not only the case with the ledgers for the pottery. Swain's hand is also evident throughout the museum construction ledger. While Mercer's and Swain's penmanship is similar, Swain's letters tend to be shorter and rounder, Mercer's more fluid and graceful. See page 124-125 of the museum ledger for a side-by-side example of the same letters. In this analysis, the author has used Mercer's correspondence and Swain's handwritten history of the Moravian Pottery as a basis for lexicographical comparison.
425. In their 1999 study of crew design in various construction fields including reinforced concrete construction and masonry, Hassanein and Melin found that 12 or fewer crew members tended to be common practice; and that: "Productivity, in general, due to less control, decreases with the increase in the crew size. Decreasing the crew size to the minimum possible for each job is therefore an objective in most cases." See A. Hassanein and J. Melin, "Crew Design Methodology for Construction Contractors," *Journal of Construction Engineering and Management* 123, no. 3 (1997): 203-207, 204.
426. We should, however, treat this lack of documentation in historical context. Even experienced builders at this time would not have known what to do with a modern "construction set." The drawings conveyed to a mason or carpenter might consist of a single or several sheets, annnotated with dimensions.
427. Pinker, *The Stuff of Thought*,106.
428. Justine Brehm Cripps, *Targeting the Source Text: A Coursebook in English for Translator Trainees*, Vol. 1 Publicacions de la Universitat Jaume I, 2004), 265.
429. According to Anita Auer, whose "survey of meta-linguistic comments during the Early and Late Modern English periods revealed that between the publication of the earliest English grammars and the end of the eighteenth century, grammarians recognized a connection between certain conjunctions and the use of the inflectional subjunctive." See "Chapter 8: Lest the situation deteriorates – A study of lest as trigger of the inflectional subjunctive" in: Miriam A. Locher and Jürg Strässler, *Standards and Norms in the English Language*, Vol. 95 Walter de Gruyter, 2008), 165.
430. See Kasper Boye's "The Expression of Epistemic Modality," in: Jan Nuyts and Johan van der Auwera, *The Oxford Handbook of Modality and Mood* Oxford University Press, 2016), 115.
431. Ibid.
432. Ibid, 122.
433. Bringhurst, *Everywhere Being is Dancing,* 81.
434. A number of the errors in the detailing of early modern architecture might have been avoided had this necessity been understood.
435. Fascinating, in this context, is Mercer's predilection for reinforced concrete construction, a building technology which at that time had no established craft practice—and indeed, received no room in his museum.
436. Orthographic projection was theorized as early as Albrecht Dürer's 1525 *Underweysung der Messung mit dem Zirckel, und Richtscheyt,* though it wasn't until the work of René Descartes and Gaspard Monge in the 17th and 18th Centuries that the theory became comprehensive, and began to rewrite architectural theory in its own image.
437. Anticipatory plans can here be read as a homologue for the construction document in its subjunctive construal by the architect (rather than in its nominative use by the builder).
438. Alfred Schutz, *Collected Papers 1 the Problem of Social Reality*, Phaenomenologica, 11, (The Hague: Nijhoff, 1962), 146. Emphasis mine.
439. For a novel revisitation of Sutherland's role in the origins of CAD, see Daniel Cardoso Llach, "Algorithmic Tectonics: How Cold War Era Research Shaped our Imagination of Design," *Architectural Design,* Vol. 83 (2013): 16-21.
440. Arthur L. Stinchcombe, *When Formality Works: Authority and Abstraction in Law and Organizations* (Chicago: University of Chicago Press, 2001), 57.

441. Ibid., 61.
442. Frank Dobbin puts this very clearly in his review of Stinchcombe's book for the American Journal of Sociology: "Stinchcombe identifies three characteristics. First, formalization must be based on abstractions that are useful representations of the problems and solutions in question—that achieve "cognitive adequacy." If abstractions do not map well to real situations, they will not be useful guides to action. Second, formalization must be communicable. It helps if rules are transparent, and if they are written in the lingua franca of those subject to them (lawyerese for lawyers, physicsese for physicists). Finally, rules must have feedback systems (a "trajectory of improvement") that allow them to be updated. See: Dobbin, Frank. "When Formality Works: Authority and Abstraction in Law and Organizations by Arthur L. Stinchcombe." American Journal of Sociology 109, no. 5 (2004): 1244-1246, 1244.
443. Though both also express reservations about the currency of his work. See David Turnbull, *Knowledge Systems: Local Knowledge*, Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures, edited by Helaine Selin (Dordrecht: Springer Netherlands, 2016a). Stinchcombe is of much the same opinion. see Arthur L. Stinchcombe, "The Preconditions of World Capitalism: Weber Updated," *Journal of Political Philosophy* 11, no. 4 (2003): 411.
444. Stinchcombe, *When Formality Works:* 12.
445. Ibid., 58.
446. Ibid., 59.
447. Ibid., 6.
448. "Building appears to be one of the many industries where vertical disintegration increases efficiency and lowers costs without lessening stability. […] Operative decisions are still very important at the work level, rather than being concentrated in production engineering and cost-accounting departments. Modification of tools for special purposes is done by workers (e.g., the making of templates which provide guides for standardized cutting operations, or the construction of special scaffolds fot the crew.) There is no large element in the administration with the specialized task of planning technological innovation in the work process." Arthur L. Stinchcombe, "Bureaucratic and Craft Administration of Production: A Comparative Study," *Administrative Science Quarterly* (1959): 168-187, 181. Recent developments in management theory, particularly in the administration of software development, have pushed even the largest of high-tech firms in the direction of the sorts of decentralized design innovation Stinchcombe describes as a daily part of the work of building. See Craig Larman and Bas Vodde, *Scaling Lean & Agile Development : Thinking and Organizational Tools for Large-Scale Scrum* (Upper Saddle River, NJ: Addison-Wesley, 2009).
449. While it is unattributed, the note is likely to have been written by Mercer's preferred tile installer, Herman Sell. Sell would have developed the relevant expertise over the course of his work with Mercer at the Moravian Pottery, as he was often sent out to the jobsite to help with the installation of tiles at the various projects to which the Moravian Pottery supplied tiles. See Reed, 99.
450. The original title of the note, "Receipt for Pointing and Finishing Moravian Pavements," has carroted additions, which altogether would read, "Receipt for Rapid Pointing and Finishing Moravian Pavements Rapid Pointing by Grouting". In the passages quoted, the spellings "dingey" and "omited" are sic. See loose note in the Moravian Pottery folio of the Mercer Archives, Mercer Museum Research Library, BCHS.
451. Though this is a difficult term to consider in a non-pejorative light. See Stinchcombe, *When Formality Works*, 7.
452. Frascari, "A New Angel," 13.
453. "technography, n.," OED Online (Oxford University Press: March 2017) http://www.oed.com/view/Entry/272313. Accessed March 22, 2017.
454. Willis, *Emerald City,* 205. [Emphasis mine.]
455. Margaret Cohen, "On Time: Kairos and the Arts of Action," *Wax* no. 5 [On Immediacy] (Summer, 2014): 116-121, 118.
456. Stephen Nachmanovitch, *Free Play : Improvisation in Life and Art* (Los Angeles; New York: J.P. Tarcher, Inc., 1990), 6.
457. Nachmanovitch, 19.
458. Nachmanovitch, 8.

459. “Medieval representations of Fortune emphasize her duality and instability. She often displays two faces, either side-by-side, or back-to-back like Janus; with one black face and one white, or one smiling and one lowering. Sometimes one eye is beaming and one weeping. She may appear blindfolded, like Justice, but without the scale: she is, so to speak, impartial in injustice. Sometimes her head is bald behind but has a long forelock for seizing, like Opportunity.” Richard Leighton Greene, s.v., "Fortune," *Dictionary of the Middle Ages,* Vol.3, Joseph R Strayer, ed., (New York: Scribner's, 1983) 145-147. See also Malcolm Bull, *The Mirror of the Gods: How Renaissance Artists Rediscovered the Pagan Gods* (Oxford: Oxford University Press, 2005), 2: “Horace made Fortune ‘mistress of the ocean’, for, as Cicero said, when we enjoy a favorable breeze we reach a haven, and when she blows against us we are shipwrecked. Petrarch and many others picked up the image, and from the mid-fifteenth century onwards Fortune is often personified as a nude woman on the sea. She looks rather like the goddess Venus herself, but she stands precariously on a boat, a ball, or even a dolphin, and holds a sail.”
460. Poos, 65.
461. Reed, 131. He would go on to adapt the brocade tiles for more normative installation in wall panels and building facades.
462. Poos, 65.
463. In addition to the Bluebeard sequence, he produced story sequences from *Rip Van Winkle, The Pickwick Papers, Arkansas Traveler,* and *Cornstalk Fiddles.* For a list of further planned but not completed sequences, see Reed, 143.
464. Henry Chapman Mercer to William Hagerman Graves, November 14, 1925. Mercer papers, Mercer Museum Research Library, BCHS.
465. Reed, 133.
466. Reed, 131.
467. I am indebted to Heather Hicks, Site Administrator at Fonthill, who suggested this rationale for the ceiling hooks.
468. Something critiqued by Dalibor Vesely and Dan Wills in their writings. See Vesely, *Divided Representation,* 240; Willis, *Emerald City,* 104.
469. David Brain, "Practical Knowledge and Occupational Control: The Professionalization of Architecture in the United States," *Sociological Forum* 6, no. 2 (1991): 239-267, 240.
470. Brain, 261.
471. Brain, 246.
472. Mentioned in Everard Upjohn’s 1939 biography of his great grandfather, Richard, quoted in Brain, 254.
473. Brain, 255.
474. Ivan Illich, *Disabling Professions*, Ideas in Progress, (London; Salem, N.H.: M. Boyars, 1977), 18.
475. Mercer, *Museum Ledger,* pages 3 and 33, respectively.
476. Illich, *Tools*, 48-50. One can’t help but wonder if, despite the vast hopes engendered by such new tools as maker spaces and the ecology of online how-to videos, a similar statement could be made today.
477. Johnston writes about the split personality of the 20th century architect: on the one hand “vocational and the other professional. The vocational identity reflects the division of labor within architectural practice, the manner in which the work is instrumentalized through tools, manuals, handbooks, and various architectural representations, and the means by which the knowledge of practice is reproduced through practice. The professional identity of the architect, on the other hand, is publicly projected and embraces the social contract that all professionals enter into as a basis of their public trust and esteem. In its social orientation, the architect’s professional identity is discursive, and the reproduction of that knowledge about architecture is formalized through academic theory.” Johnston, *Drafting Culture,* 6.
478. Illich, *Tools*, 50.
479. In Canadian law, the Architect’s Act defines the architect as someone who "is engaged in the planning or supervision of the erection or alteration of buildings for persons other than himself". Article 57 of the Canadian Architects’ Act. Quoted in Bristol, Graeme Leslie. "Architecture and Shelter: The Roles and Responsibilities of Architects in Meeting Basic Needs.” Ph.D. Dissertation, University of British Columbia, 1992.
480. Reed notes the gradual diminution in the popularity of Mercer’s tiles, but attributes it to changing tastes

rather than changing methods. While the advent of modernism as architectural style may be part of the story, we should be careful that the lens of architectural history does not predispose us to seek for the causes of events only in the preexisting schema of period, style, or school. See Reed, 74.

481. See Ingold, Tim. *Making*. Hoboken: Taylor and Francis, 2013.
482. Magali Sarfatti Larson, "Emblem and Exception: The Historical Definition of the Architect's Professional Role," *Professionals and Urban Form* (1983): 49-86, 54.
483. Larson, 75.
484. Larson, 72.
485. Illich, *Tools,* 28.
486. Illich, *Tools,* 29.
487. Illich, *Tools,* 30.
488. Nachmanovitch, 196.
489. Nachamanovitch, 76.
490. Nachmanovitch, 84.
491. Nachmanovitch, 88.
492. This exception is the case of 'motific' architects, such as Frank Lloyd Wright or Jim Cutler, who design a large number of buildings that share a consistent range of material and tectonic patterns. With these architects, while each project may be contractually separate, the knowledge gained in the building of one project may be readily applied to another still "on the boards." While this is true of any experienced practitioner, the consistency of the work may make it more possible to determine a trajectory of incremental improvement. Ultimately, however, this sort of motifically embedded construction knowledge falls short of what a study of Mercer's practices may propose, as it is unavoidably retrospective, rather than dynamically embedded in the construction process.
493. Nachmanovitch, 6-7.
494. Merelu-Ponty, 220.
495. Nachmanovitch, 95.
496. See Noë's 2015 *Strange Tools,* in which he argues at length that the role of the arts is to put the various spontaneous forms of cultural practice 'on display'. *Post hoc ergo prompter hoc.* This would seem to invert the structure of experience in favor of a contemporary Western conception of the role of the 'arts' in society.
497. Derek Muller "The Bayesian Trap," *YouTube: Veritasium* (April 5, 2017: https://youtu.be/R13BD8qKeTg). Accessed February 2, 2018.
498. Such as the construction documents and materials handling innovations explored by SHoP architects. See Elite Kedan, Jon Dreyfous, and Craig Mutter, *Provisional: Emerging Modes of Architectural Practice USA* (Princeton, NJ: Princeton Architectural Press, 2010).
499. Stinchcombe, *When Formality Works*, 70.
500. Ibid., 180.
501. Nachmanovitch, 86.
502. Mercer, "The Building of Fonthill," 321.
503. "elegance, n.," 4a., *Oxford English Dictionary* (Oxford, England: Oxford University Press, 2000).
504. Fleming is careful to distinguish conventional economic theory from this sense of the term 'economics': "The starting point for this is the principle that, although people are aware of what they value, and alert to the opportunities and constraints which surround them, the consequences of what they do may be transformed by what others do, or intend to do". Counterintuitively, he distinguishes 'lean' from conventional economics precisely in its provision of "intentionally imperfect competition" and "organisational slack." See David Fleming, *Lean Logic: A Dictionary for the Future and how to Survive It* (White River Junction, VT: Chelsea Green Publishing, 2016), 115, 238.
505. "The system of abstraction and the corresponding semantic system for translating it into a building is nicely adapted to what needs to be communicated. Nothing about the path of conduit through the walls needs to be said, so the electrical symbols and drafting conventions have no way to say it." Stinchcombe, *When Formality Works*, 69.
506. Bertrand Russel writes, "The above extrusion of permanent things affords as an example of the maxim which inspires all scientific philosophizing, namely, Ockham's razor': Entities must not be multiplied

without necessity. In other words, in dealing with any subject matter, find out what entities are undeniably involved and state everything in terms of these entities." Bertrand Russell, Our Knowledge of the External World, George Allen & Unwin Ltd. (London: 1924), quoted in abridged form in: "Occam's razor, n.", *Oxford English Dictionary,* OED Online (March 2018: Oxford University Press, https://bit.ly/2vyYBte, accessed April 20, 2018).

507. "Semantics, n." Definitions 1 and 3. *Oxford English Dictionary,* OED Online (March 2018: Oxford University Press, https://bit.ly/2vyYBte, accessed April 20, 2018).
508. Conversation between author and Latz, Charlottesville, VA, spring 2002.
509. Carolina Dayer, "Material Intuitions: Tracing Carlo Scarpa's Nose," in Matthew Mindrup, *The Material Imagination: Reveries on Architecture and Matter* (Farnham, Surrey, England ; Burlington: Ashgate, 2015).
510. Frankenfield interview, page 7 of the unpaginated manuscript.
511. Ibid., 6.
512. Milo Smith Ketchum, *The Design of Walls, Bins and Grain Elevators* (New York: McGraw-Hill Book Company, 1919), 394.
513. James Macdonald, "Patent for a device to move and elevate a concrete form in a vertical plane," Official gazette of the United States Patent Office (United States Patent Office, Volume CCXXXVII April 24, 1917): 943.
514. Reed, 18.
515. Gary P. Pisano and Willy C. Shih, "Restoring American Competitiveness," *Harvard Business Review* 87, no. 7 (2009): 114, 116-117.
516. Reed, 38.
517. Frankenfield interview, page 7 of the unpaginated manuscript.
518. Joseph A. Tainter, *The Collapse of Complex Societies*, New Studies in Archaeology, (Cambridge, Cambridgeshire; New York: Cambridge University Press, 1988), 92-93.
519. Fredrick Brooks, father of Brook's law, found in his work managing software development for IBM that the 'man hours' used to quantify productive capacity had very little correlation to actual project delivery, and that the cost of adding staff, in terms of increased complexity, often absorbed more net productive capacity than it created. See Frederick P. Brooks, *The Mythical Man-Month: Essays On Software Engineering* (Reading, MA: Addison-Wesley, 1982).
520. Thomas Kuhn's influential *The Structure of Scientific Revolutions* introduced the idea of paradigm shifts, or discontinuous advances, into the mainstream. After a long, slow, accumulative process of incremental improvement, Kuhn argued, the history of science exhibits again and again the radical disjunction of a new way of understanding its material. Thomas S. Kuhn, *The Structure of Scientific Revolutions.* 2d ed. enl. (Chicago: University of Chicago Press, 1970).
521. John Michael Greer, "How Civilizations Fall: A Theory of Catabolic Collapse," (Essay released in conjunction with radio interview: Radio Ecoshock, 2005). http://ecoshock.org/transcripts/greer_on_collapse.pdf. Accessed July 31st 2016. 6.

Bibliography

"Indian House: An Antiquarian's Studio with Indian and Colonial Relics: A New Brand of Industrial Art." *New York Times* (Mar 30, 1901): BR35.

"Natural Cement Versus Portland Cement." *Journal of Industrial & Engineering Chemistry* 4, no. 5 (1912): 388.

Abel, Chris. *The Extended Self: Architecture, Memes and Minds*. Manchester: Manchester University Press, 2015.

Adam, Jean Pierre. *Roman Building: Materials and Techniques* [Construction romaine. English]. London: Batsford, 1994.

Adee, Sally. "Zen and the Art of Genius." *New Scientist* 213, no. 2850 (2012): 32.

Aicher, Otl and Wilhelm Vossenkuhl. *Analogous and Digital* [Analog und Digital. English]. Berlin: Ernst & Sohn, 1994.

Akera, Atsushi. "Constructing a Representation for an Ecology of Knowledge." *Soc Stud Sci* 37, no. 3 (2007): 413-441.

Alberti, Leon Battista. *On the Art of Building in Ten Books* [De re aedificatoria]. Cambridge, Mass.: MIT Press, 1988.

Alexander, Christopher, *The Production of Houses*. New York: Oxford University Press, 1985.

Allen, Stan. *Practice*. Hoboken: Taylor and Francis, 2012.

Allwood, R. J. *Techniques and Applications of Expert Systems in the Construction Industry*. Chichester, West Sussex, England; New York: E. Horwood; Halsted Press, 1989.

American Concrete Institute., National Association of Cement Users (U.S.), National Association of Cement Users (U.S.), American Concrete Institute. "Proceedings - American Concrete Institute."American Concrete Institute, 1905.

Aristotle and Gerald Frank Else. *Aristotle: Poetics* [Poetics. English]. Ann Arbor: University of Michigan Press, 1967.

Ashby, Holdon M. *How to Analyze Clay; Practical Methods for Practical Men*. Chicago: Windsor & Kenfield publishing company, 1898.

Atcin, P. C. *High-Performance Concrete*. Modern Concrete Technology. Vol. 5. London; New York: E. & F.N. Son, 1998.

Auerbach, Erich. *Literary Language & its Public in Late Latin Antiquity and in the Middle Ages*. Bollingen Series. Vol. 74. New York: Pantheon Books, 1965.

Auerbach, Erich. *Mimesis : The Representation of Reality in Western Literature* [Mimesis. English]. 50th anniversary ed. Princeton, N.J.: Princeton University Press, 2003. http://www.loc.gov/catdir/description/prin031/2002044721.html.

Aull, Laura L. and Zak Lancaster. "Linguistic Markers of Stance in Early and Advanced Academic Writing." *Written Communication* 31, no. 2 (2014): 151-183.

Bachelard, Gaston and M. Jolas. *The Poetics of Space* [Poetique de l'espace. English]. Boston: Beacon Press, 1994.

Bachelard, Jerome. *Towards an Articulated Phenomenological Interpretation of Architecture*. Florence: Taylor and Francis, 2013.

Baddeley, Alan D. and Alan D. Baddeley. *Working Memory, Thought, and Action*. Oxford Psychology Series. Vol. 45. Oxford; New York: Oxford University Press, 2007.

Bakacsy, Judith, A. V. Munch, A. -L Sommer, and Forschungsinstitut Brenner-Archiv. *Architecture, Language, Critique: Around Paul Engelmann*. Studien Zur Sterreichischen Philosophie. Vol. Bd. 31. Amsterdam; Atlanta, Ga.: Rodopi, 2000.

Baker, Lee D. "Road to Obscurity, 1890-99." *Cultural Anthropology* 15, (2000): 3.

Bar, Moshe. *Predictions in the Brain: Using our Past to Generate a Future*. New York: Oxford University Press, 2011.

Bardi, Lina Bo and Cathrine Veikos. *Lina Bo Bardi : The Theory of Architectural Practice.* [Contribuio propedeutica ao ensino da teoria da arquitetura. English]. First ed. London; New York: Routledge, 2014.

Barnes, Benjamin H.,Bucks County Historical Society. *The Moravian Pottery: Memories of Forty-Six Years*. Doylestown, PA: Bucks County Historical Society, 1970.

Barrett, Peter, Martin Sexton, and Angela Lee. *Innovation in Small Construction Firms*. London; New York: Taylor & Francis, 2008.

Barrick, Marty. "A Visionary in Concrete: One Man's Eclectic View of Technological Progress." *Washington Post* (March 11, 1998).

Barsalou, Lawrence W. "Ad Hoc Categories." *Memory & Cognition* 11, no. 3 (1983): 211.

Barsalou, Lawrence W. "Deriving Categories to Achieve Goals." *Psychology of Learning & Motivation* 27, (1991).

Barsalou, Lawrence W. "Frames, Concepts, and Conceptual Fields." *Frames, Fields, and Contrasts: New Essays in Semantic and Lexical Organization.* (1992).

Barsalou, Lawrence W. and Daniel R. Sewell. "Contrasting the Representation of Scripts and Categories." *Journal of Memory & Language* 24, (1985): 646.

Bartels, Andreas and Semir Zeki. "The Neural Correlates of Maternal and Romantic Love." *NeuroImage* 21, no. 3 (2004): 1155-1166.

Baudrillard, Jean and Jean Nouvel. *The Singular Objects of Architecture* [Objets singuliers. English]. Minneapolis: University of Minnesota Press, 2002.

Beal, Wesley. *Networks of Modernism: Reorganizing American Narrative*. Iowa City: University of Iowa Press, 2015.

Belardi, Paolo and Zachary Nowak. *Why Architects Still Draw*. Cambridge: The MIT Press, 2014.

Benjamin, Andrew E. *Architectural Philosophy*. London; New Brunswick, NJ: Athlone Press, 2000.

Benjamin, Asher. *Practice of Architecture*. 4th ed. Boston; Philadelphia: Perkins and Marvin, 1840.

Benjamin, Walter. *The Origin of German Tragic Drama*. Radical Thinkers. [Ursprung des deutschen Trauerspiels. English]. London; New York: Verso, 2009.

Benjamin, Walter, E. F. N. Jephcott, and Kingsley Shorter. *One-Way Street, and Other Writings*. Verso Classics. [Gesammelt schriften. Selections. English. 1997]. Vol. 8. London; New York: Verso, 1997.

Bentley, R. A. and Herbert D. G. Maschner. "Stylistic Change as a Self-Organized Critical Phenomenon: An Archaeological Study in Complexity." *Journal of Archaeological Method & Theory* 8, no. 1 (2001): 35.

Bloomer, Jennifer. *Architecture and the Text: The Scrypts of Joyce and Piranesi*. Theoretical Perspectives in Architectural History and Criticism. New Haven: Yale University Press, 1993.

Bloomer, Kent C. and Charles Willard Moore. *Body, Memory, and Architecture*. A Yale Paperbound. New Haven: Yale University Press, 1977.

Bolens, Guillemette. *The Style of Gestures: Embodiment and Cognition in Literary Narrative*. Rethinking Theory. [Style des gestes. English]. Baltimore: Johns Hopkins University Press, 2012.

Bond, Ruskin. *The Lamp is Lit: Leaves from a Journal*. New Delhi, India; New York, USA: Penguin Books, 1998.

Boronat, C. B., L. J. Buxbaum, H. B. Coslett, K. Tang, E. M. Saffran, D. Y. Kimberg, and J. A. Detre. "Distinctions between Manipulation and Function Knowledge of Objects: Evidence from Functional Magnetic Resonance Imaging." *Brain Research.Cognitive Brain Research* 23, no. 2-3 (2005): 361.

Boyd, Brian. *On the Origin of Stories*. Harvard, MA: Harvard University Press, 2009.

Bragdon, Claude Fayette. *The Beautiful Necessity : Seven Essays on Theosophy and Architecture*. Rochester, N.Y.: Manas Press, 1910.

Brain, David. "Practical Knowledge and Occupational Control: The Professionalization of Architecture in the United States." *Sociological Forum* 6, no. 2 (1991): 239.

Brand, Stewart. *How Buildings Learn: What Happens After they'Re Built*. London: Penguin Books, 2012.

Breivik, Gunnar. "Skillful Coping in Everyday Life and in Sport: A Critical Examination of the Views of Heidegger and Dreyfus." *Journal of the Philosophy of Sport* 34, no. 2 (2007): 116.

Bringhurst, Robert. *Everywhere being is Dancing: Twenty Pieces of Thinking*. Kentville: Gaspereau, 2007.

Bristol, Graeme Leslie. *Architecture and Shelter: The Roles and Responsibilities of Architects in Meeting Basic Needs*. Ph.D. Dissertation. University of British Columbia, 1992.

Britt, John. "Solid Arch Kiln." *Ceramics Monthly* 60, no. 3 (2012): 14.

Browman, David L. and Stephen Williams. *New Perspectives on the Origins of Americanist Archaeology*. Tuscaloosa, AL: University of Alabama Press, 2002.

Brown, Nathan. *The Limits of Fabrication: Materials Science, Materialist Poetics*. Idiom: Inventing Writing Theory. First ed. New York: Fordham University Press, 2017.

Brysbaert, Ann. "Talking Shop. Multicraft Workshop Materials and Architecture in Prehistoric Tiryns, Greece." *Material Crossovers: Knowledge Networks and the Movement of Technological Knowledge between Craft Traditions* (2014): 37-61.

Bukdahl, Else Marie. *The Re-Enchantment of Nature and Urban Space: Michael Singer Projects in Art, Design and Environmental Regeneration*. Aalborg: Utzon Center, 2011.

Burke, John Bernard. *Encyclopædia of Heraldry, Or General Armory of England, Scotland and Ireland: Comprising a Registry of all Armorial Bearings from the Earliest to the Present Time, Including the Late Grants by the College of Arms*. London: H. G. Bohn, 1844.

Bush, George S., James A Michener Art Museum, and Pennsylvania State University Press. *The Genius Belt: The Story of the Arts in Bucks County, Pennsylvania*. Doylestown, PA: James A. Michener Art Museum in association with the Pennsylvania State University Press, 1996.

Buttram, Virginia, Dora Fink, and Joanne Lemley. *The Doylestown Nature Club History 1907 – 2015*. Doylestown, PA: The Doylestown Nature Club, 2016.

Cage, John. *Silence: Lectures and Writings.* Wesleyan University Press, 2011.

Caprettini, Gian Paolo. "Peirce, Holmes, Popper." In *The Sign of Three: Dupin, Holmes, Peirce*, edited by Eco, Umberto and Thomas Albert Sebeok, 149-169, 1991.

Cardew, Michael. *Pioneer Pottery*. New York: St. Martin's Press, 1969.

Carpo, Mario. *The Alphabet and the Algorithm*. Cambridge, Mass.: MIT Press, 2011.

Carr, Richard., Hass-Cohen, Noah., Findlay, Joanna Clyde., Masterson,Jessica Tress.,. *Art Therapy and Clinical Neuroscience.* London: Jessica Kingsley Publishers, 2008.

Cavell, Stanley. *Must we Mean what we Say?: A Book of Essays.* Cambridge: Cambridge University Press, 2015.

Cetina, Karin Knorr. "Metaphors in the Scientific Laboratory: Why are they there and what do they do?" In *From a Metaphorical Point of View: A Multidisciplinary Approach to the Cognitive Content of Metaphor*. Berlin; Boston: Walter: de Gruyter, 1995.

Cetina, Karin Knorr. "Primitive Classification and Postmodernity: Towards a Sociological Notion of Fiction." *Theory, Culture & Society* 11, no. 3 (1994): 1.

Chaigneau, Sergio E., Lawrence W. Barsalou, and Steven A. Sloman. "Assessing the Causal Structure of Function." *Journal of Experimental Psychology. General* 133, no. 4 (2004).

Chalmers, David John. *The Character of Consciousness*. Philosophy of Mind. Oxford; New York: Oxford University Press, 2010.

Chalmers, David John, David Manley, and Ryan Wasserman. *Metametaphysics: New Essays on the Foundations of Ontology*. Oxford: Clarendon Press; New York, 2009.

Chambers, David Wade and Richard Gillespie. "Locality in the History of Science: Colonial Science, Technoscience, and Indigenous Knowledge." *Osiris* 15, (2000): 221-240.

Champigneulle, Bernard. *Perret.* Paris: Arts et Metiers Graphiques, 1959.

Chappell, James. *The Potter's Complete Book of Clay and Glazes*. Rev ed. New York: Watson-Guptill Publications, 1991.

Chemero, Anthony. *Radical Embodied Cognitive Science*. Vol. 648 MIT press Cambridge, MA, 2009.

Childers, Joseph. *The Columbia Dictionary of Modern Literary and Cultural Criticism.* Columbia University Press, 1995.

Chilton, Gioia. "Art Therapy and Flow: A Review of the Literature and Applications." *Art Therapy* 30, no. 2 (2013): 64.

Choisy, Auguste. *L'Art De Btir Chez Les Romains*. Paris: Ducher et cie, 1873.

Christensen, Bo T. and Christian D. Schunn. "The Relationship of Analogical Distance to Analogical Function and Preinventive Structure: The Case of Engineering Design." *Memory & Cognition* 35, no. 1 (2007): 29.

Cilliers, Paul and Rika Preiser. *Critical Complexity: Collected Essays*. Categories. [Essays. Selections.]. Vol. Volume 6. Berlin; Boston: Walter de Gruyter GmbH, 2016.

Clark, Andy. *Supersizing the Mind: Embodiment, Action, and Cognitive Extension.* Philosophy of Mind. Oxford; New York: Oxford University Press, 2008.

Clark, Andy, Julian Kiverstein, and Tillmann Vierkant. *Decomposing the Will*, edited by Clark, Andy, Julian Kiverstein and Tillmann Vierkant. New York, NY, US: Oxford University Press, 2013.

Clark, Andy and Josefa Toribio. "Doing without Representing?" *Synthese: An International Journal for Epistemology, Methodology and Philosophy of Science* 101, no. 3 (1994): 401.

Cobb, Charles G. *Making Sense of Agile Project Management : Balancing Control and Agility*. Hoboken, N.J.: Wiley, 2011.

Cohen, Margaret. "On Time: Kairos and the Arts of Action." *Wax* no. 5 (On Immediacy) (Summer, 2014): 116-121.

Collins, H. M. *Tacit and Explicit Knowledge.* Chicago: The University of Chicago Press, 2010.

Collins, Peter. *Concrete: The Vision of a New Architecture; a Study of Augusto Perret and His Precursors*. New York: Horizon Press, 1959.

Condit, Carl W. *American Building Art: The Nineteenth Century*. New York: Oxford University Press, 1960.

Conn, Steven. *Do Museums Still Need Objects?* The Arts and Intellectual Life in Modern America. Philadelphia: University of Pennsylvania Press, 2010.

Conn, Steven. "Henry Chapman Mercer and the Search for American History. *Pennsylvania Magazine of History & Biography* 116, no. 3 (1992): 323.

Conn, Steven. *Museums and American Intellectual Life, 1876-1926*. Chicago: The University of Chicago Press, 1998.

Coopmans, Catelijne, Janet Vertesi, and Michael Lynch. "Representation in Scientific Practice Revisited." *British Journal for the History of Science* 48:4, no. 179 (2015): 722.

Cornuejlos, A. "Analogy as Minimization of Description Length." *Machine Learning and Statistics. The Interface* (1997): 321-335.

Cotton, J. Randall. "Who they were: Henry Mercer Valued most the Everyday Objects." *Old-House Journal* 23, no. 1 (1995): 26-28.

Craig, Robert M. *Bernard Maybeck at Principia College: The Art and Craft of Building*. Layton, Utah: Gibbs Smith, 2004.

Craig, Robert Michael. "Maybeck at Principia: A Study in an Architect-Client Relationship."Cornell University, 1973.

Crick, Francis and Christof Koch. "Towards a Neurobiological Theory of Consciousness."Saunders Scientific Publications, 1990.

Cridge, Nerma. *Drawing the Unbuildable*. Routledge Research in Architecture. Florence: Taylor and Francis, 2015.

Cripps, Justine Brehm. *Targeting the Source Text: A Coursebook in English for Translator Trainees*. Vol. 1 Publicacions de la Universitat Jaume I, 2004.

Cross, Dorothy. "The Effect of the Abbott Farm on Eastern Chronology." *Proceedings of the American Philosophical Society* 86, no. 2 (1943): 315-319. http://www.jstor.org/stable/985110.

Crysler, Greig Greig, Stephen Cairns, and Hilde Heynen. *The SAGE Handbook of Architectural Theory*. London: SAGE Publications, 2012.

Dürer, Albrecht. "Underweysung Der Messung Mit Dem Zirckel, Und Richtscheyt." *Linien, Ebnen Und Gantzen Corporen.Hieronymus Andreas Formschneider, Nuremberg,* 1525.

Dawson, David and Oliver Kent. "The Development of the Bottle Kiln in Pottery Manufacture in Britain." *Post-Medieval Archaeology* 42, no. 1 (2008): 201.

de Certeau, Michel. *The Practice of Everyday Life* [Arts de faire. English]. Berkeley: University of California Press, 1984.

Dean Carso, Kerry. *American Gothic Art and Architecture in the Age of Romantic Literature*. Gothic Literary Studies. Cardiff: University of Wales Press, 2014.

Delbrück, Hans. *Geschichte Der Kriegskunst Im Rahmen Der Politischen Geschichte*. Vol. 3 G. Stilke, 1920.

Dent-Read, Cathy Ed and Patricia Ed Zukow-Goldring. *Evolving Explanations of Development: Ecological Approaches to Organism–environment Systems.* American Psychological Association, 1997.

Dewey, John. *Art as Experience*. New York: Perigee Books, 1934.

Di Pellegrino, Giuseppe, Luciano Fadiga, Leonardo Fogassi, Vittorio Gallese, and Giacomo Rizzolatti. "Understanding Motor Events: A Neurophysiological Study." *Experimental Brain Research* 91, no. 1 (1992): 176-180.

Dobbin, Frank. "When Formality Works: Authority and Abstraction in Law and Organizations by Arthur L. Stinchcombe." *American Journal of Sociology* 109, no. 5 (2004): 1244-1246.

Dodds, George, Robert Tavernor, and Joseph Rykwert. *Body and Building: Essays on the Changing Relation of Body and Architecture*. Cambridge, Mass.: MIT Press, 2002.

Dotov, Dobromir G., Lin Nie, and Anthony Chemero. "A Demonstration of the Transition from Ready-to-Hand to Unready-to-Hand." *PLoS ONE* 5, no. 3 (2010): 1-9.

Dreyfus, Hubert L. "Intelligence without Representation–Merleau-Ponty's Critique of Mental Representation the Relevance of Phenomenology to Scientific Explanation." *Phenomenology and the Cognitive Sciences* 1, no. 4 (2002): 367-383.

Dreyfus, Hubert and Sean D. Kelly. "Heterophenomenology: Heavy-Handed Sleight-of-Hand." *Phenomenology and the Cognitive Sciences* 6, no. 1-2 (2007): 45-55.

Duuglas-Ittu, Kevin V. "Checking Heidegger's Hammer: The Pleasure and Direction of the Whirr." Accessed Accessed September 12, 2017. https://kvond.wordpress.com/2009/02/18/heideggers-hammer-the-pleasure-and-direction-of-the-whirr/.

Dyke, Linda, Assistant Curator, Mercer Museum. "Henry Chapman Mercer (1856-1930): An Annotated Chronology." Bucks County Historical Society, Doylestown, PA.

Eco, Umberto. *The Open Work* [Essays. English. Selections.]. Cambridge, Mass.: Harvard University Press, 1989.

Eco, Umberto. *Six Walks in the Fictional Woods*. Charles Eliot Norton Lectures. Vol. 1993. Cambridge, Mass.: Harvard University Press, 1994.

Eco, Umberto and Thomas A. Sebeok. *The Sign of Three: Dupin, Holmes, Peirce*. Advances in Semiotics. Bloomington: Indiana University Press, 1983.

Edgerton, David. *The Shock of the Old: Technology and Global History since 1900*. Oxford; New York: Oxford University Press, 2007.

Edwards, Sarah and Jonathan Charley. *Writing the Modern City: Literature, Architecture, Modernity*. London; New York, NY: Routledge, 2012.

Ehresmann, Donald L. *Architecture: A Bibliographic Guide to Basic Reference Works, Histories, and Handbooks*. Littleton, CO: Libraries Unlimited, 1984.

Emmons, Paul. "Demiurgic Lines: Line-Making and the Architectural Imagination." *Journal of Architecture* 19, no. 4 (2014a): 536-559.

Emmons, Paul. "Embodying Networks: Bubble Diagrams and the Image of Modern Organicism." *Journal of Architecture* 11, no. 4 (2006): 441-461.

Emmons, Paul Frederick. "The Image of Function: Architectural Diagrams in Handbooks and Normative Practices in the Twentieth Century." Ph.D. Thesis, Architecture: University of Pennsylvania, 2003.

Engeström, Yrjö, Ritva Engeström, and Merja Kärkkäinen. *Polycontextuality and Boundary Crossing in Expert Cognition: Learning and Problem Solving in Complex Work Activities*. Vol. 5 1995.

Ericsson, K. Anders. *The Cambridge Handbook of Expertise and Expert Performance*. Cambridge ;New York: Cambridge University Press, 2006.

Eyre, Wilson. "An American Potter." *House & Garden* 1, no. 3 (1901): 12-19.

Ferguson, Eugene S. "Toward a Discipline of the History of Technology." *Technology & Culture* 15, (1974): 13-30.

Fleming, David. *Lean Logic: A Dictionary for the Future and how to Survive It* Chelsea Green Publishing, 2016.

Forrest, Neil. "Reclaiming the Role of Craft in Architecture." *Making and Metaphor: A Discussion of Meaning in Contemporary Craft* (1994): 114.

Forty, Adrian. *Concrete and Culture: A Material History*. London: Reaktion, 2012.

Forty, Adrian. *Objects of Desire: Design and Society, 1750 - 1980; with 272 Illustr*. London: 1987.

Forty, Adrian. *Words and Buildings: A Vocabulary of Modern Architecture*. London: Thames & Hudson, 2013.

Frankenfield, William, Jack C. Potter, and Elizabeth H. Sias. "Transcript of Taped Interview with William Frankenfield, Only Known Survivor of the Workmen Who Built the Mercer Museum." Bucks County Historical Society, August 21, 1963.

Frascari, Marco. *Eleven Exercises in the Art of Architectural Drawing: Slow Food for the Architect's Imagination*. London; New York: Routledge, 2011.

Frascari, Marco. *Monsters of Architecture: Anthropomorphism in Architectural Theory*. Savage, Md.: Rowman & Littlefield, 1991.

Frascari, Marco. "A New Angel/Angle in Architectural Research: The Ideas of Demonstration." *Journal of Architectural Education* 44, (1990): 11.

Frascari, Marco and Federica Goffi. *Marco Frascari's Dream House: A Theory of Imagination*. New York: Routledge, 2017.

Frascari, Marco, Jonathan Hale, and Bradley Starkey. *From Models to Drawings: Imagination and Representation in Architecture*. London ; New York: Routledge, 2007.

Art House. Directed by Freeman, Don, Gordon, Alastair, Rudolph, Jaime, Gotkin, Michael. Oneiric House Productions, First-Run Features (Film). 2016.

Frens, Dale H. "Restoration of the Concrete Roof of the Mercer Museum in Doylestown, Pennsylvania." *APT Bulletin* 33, no. 1 (2002): 13-19.

Fuller, Steve, Marc De Mey, Terry Shinn, and Steve Woolgar. "The Cognitive Turn." *Sociological and Psychological Perspectives on Science. Sociology of the Sciences Yearbook* (1989).

Gadamer, Hans-Georg, Joel Weinsheimer, and Donald G. Marshall. *Truth and Method* [Wahrheit und Methode.]. First paperback translation revis by Joel Weinsheimer and Donald G Marshall ed. London: Bloomsbury, 2013.

The Eccentrics. Directed by Galloway, Scott, Beaton, Gary, Case, Robert G, Stuart, Nancy Rubin, Van Riper, Joe, Arts and Entertainment Network, Cinetel Productions, A & E Home Video (Firm), New Video Group. [New York]: A & E Home Video: Distributed in the U.S. by New Video, 2010.

Geddes, Robert. *Fit*. Princeton: Princeton University Press, 2012.

Gemmell, Helen H. "The Mercer Mile: The Story of Dr." *Henry Chapman Mercer and His Concrete Buildings*. Doylestown, Pa.: 1972.

Giard, Jacques. *Contextual Nature of Design and Everyday Things*. Dubuque, IA: Kendall Hunt, 2016.

Gibson, Chris. "Material Inheritances: How Place, Materiality, and Labor Process Underpin the Path-Dependent Evolution of Contemporary Craft Production." *Economic Geography* 92, no. 1 (2016): 61-86.

Gibson, James J. *The Ecological Approach to Visual Perception*. Psychology Press Classic Editions. New York: Psychology Press, 2015.

Gibson, James Jerome. *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin, 1979.

Gibson, Kathleen Rita and Tim Ingold. *Tools, Language, and Cognition in Human Evolution*. Cambridge England; New York, NY, USA: Cambridge University Press, 1993.

Giedion, S. *Building in France, Building in Iron, Building in Ferroconcrete*. Texts & Documents. [Bauen in Frankreich, bauen in Eisen, bauen in Eisenbeton. English]. Santa Monica, CA: Getty Center for the History of Art and the Humanities, 1995.

Giere, Ronald N. "No Representation without Representation." *Biology and Philosophy* 9, no. 1 (1994): 113-120.

Gill, Jonathan. "Harlem: The Four Hundred Year History from Dutch Village to Capital of Black America."

Gillette, Halbert Powers, Hill, Charles Shattuck. *Concrete Construction, Methods and Cost*. New York; Chicago: The M.C. Clark Pub. Co., 1908.

Gillette, Halbert Powers and Charles S. Hill. *Concrete Construction*. New York; Chicago: The M. C. Clark publishing co., 1908.

Gotkin, Michael and Don Freeman. *Artists' Handmade Houses*. New York, NY: Abrams, 2011.

Greeno, James G. "Gibson's Affordances." *Psychological Review* 101, no. 2 (1994): 336-342.

Griffin, James B., David J. Meltzer, Bruce D. Smith, and William C. Sturtevant. "A Mammoth Fraud in Science." *American Antiquity* 53, no. 3 (1988): 578-582.

Griffin, La Roy Freese. "Natural and Artificial Cements." *Popular Science Monthly* 37, no. 2; 6 (June, 1890): 253-257.

Grima López, Rosa, de Cea Aguado, and Josep Gómez Serrano. "Gaudí and Reinforced Concrete in Construction." *International Journal of Architectural Heritage* 7, no. 4 (2013): 375-402.

Grimmer, Anne E. and Kimberly A. Konrad. *Preserving Historic Ceramic Tile Floors*. Vol. 40 US Department of the Interior, National Park Service, Cultural Resources, Heritage Preservation Services, 1996.

Guillen, Mauro F. *The Taylorized Beauty of the Mechanical : Scientific Management and the Rise of Modernist Architecture*. [Princeton Studies in Cultural Sociology]. Princeton: Princeton University Press, 2006.

Habermas, Jrgen. *Knowledge and Human Interests* [Erkenntnis und Interesse. English]. Boston: Beacon Press, 1971.

Hacking, Ian. "The Participant Irrealist at Large in the Laboratory." *British Journal for the Philosophy of Science* (1988): 277.

Hager, Izabela. "Behaviour of Cement Concrete at High Temperature." *Bulletin of the Polish Academy of Sciences* 61, no. 1 (2013).

Hajdu, Mikls. *Network Scheduling Techniques for Construction Project Management*. Nonconvex Optimization and its Applications. Vol. 16. Dordrecht; Boston, Mass: Kluwer Academic, 1997.

Halbwachs, Maurice. *The Collective Memory*. Harper Colophon Books; CN/800. [Mmoire collective. English]. New York: Harper & Row, 1980.

Hall, Bronwyn H. and Nathan Rosenberg. *Handbook of the Economics of Innovation*. Handbooks in Economics. Vol. 1-2. Amsterdam; Boston: Elsevier,2010.

Hallam, Elizabeth and Tim Ingold. *Creativity and Cultural Improvisation*. A.S.A. Monographs. Vol. 44. Oxford; New York: Berg, 2007.

Halprin, Lawrence. *The RSVP Cycles: Creative Processes in the Human Environment.* New York: George Braziller, 1970.

Harbison, Robert. *The Built, the Unbuilt and the Unbuildable: In Pursuit of Architectural Meaning*. London: Thames and Hudson, 1991.

Harman, Graham. *Tool-being : Heidegger and the Metaphysics of Objects*. Chicago: Open Court, 2002.

Harmat, Lszl, Frans rsted Andersen, Fredrik Ulln, Jon Wright, Gaynor Sadlo, and SpringerLink. *Flow Experience*. Cham: Springer International Publishing, 2016.

Harre, Rom. "The Structure of Tacit Knowledge." *Journal of the British Society for Phenomenology* 8, no. 3 (1977): 172-177.

Harvey, John. *The Master Builders; Architecture in the Middle Ages*. Library of Medieval Civilization. New York: McGraw-Hill, 1971.

Haselberger, Lothar. "Bericht uber Die Arbeit Am Jingeren Apollontempel Von Didyma: Zwischenbericht." *Istanbuler Mitteilungen* 33, (1983): 90-123.

Haselberger, Lothar. "Werkzeichnungen Am Jingeren Dydimeion: Vorbericht." *Istanbuler Mitteilungen* 30, (1980): 191-215.

Hassanein, A. and J. Melin. "Crew Design Methodology for Construction Contractors." *Journal of Construction Engineering and Management* 123, no. 3 (1997): 203-207.

Hass-Cohen, Noah. "CREATE: Art Therapy Relational Neuroscience Principles (ATR-N)." *Art Therapy and Clinical Neuroscience* (2008): 283-309.

Heidegger, Martin. *The Question Concerning Technology, and Other Essays*. Harper Torchbooks. Vol. TB1969. New York: Harper & Row, 1977.

Heidegger, Martin. *Die Technik Und Die Kehre*. Opuscula Aus Wissenschaft Und Dichtung. Vol. 1. Pfullingen: Neske, 1962.

Heidegger, Martin, John Macquarrie, and Edward Robinson. *Being and Time* [Sein und Zeit. English]. Oxford: Blackwell, 1962.

Heller, Agnes. "From Hermeneutics in Social Science Toward a Hermeneutics of Social Science." *Theory & Society* 18, no. 3 (1989): 291.

Hendrix, John Shannon, Holm, Lorens Eyan. *Architecture and the Unconscious*. Farnham, Surrey: Ashgate, 2016.

Henry, Edward, C. *Clay Technology in Ceramics*. Vol. 1. (1952).

Hind, Charles, Irena Žantovská Murray, Pierpont Morgan Library, Milwaukee Art Museum, Heinz Architectural Center, Royal Institute of British Architects, and Centro internazionale di studi di architettura "Andrea Palladio" di Vicenza. *Palladio and His Legacy: A Transatlantic Journey*. Venice: Marsilio, 2010.

Hindle, Brooke. *Emulation and Invention*. The Anson G. Phelps Lectureship Series on Early American History. New York: New York University Press, 1981.

Hofstadter, Douglas and Emmanuel Sander. *Surfaces and Essences: Analogy as the Fuel and Fire of Thinking*. New York: Basic Books, 2013.

Holland, John H. *Hidden Order: How Adaptation Builds Complexity*. Helix Books. Reading, MA: Addison-Wesley, 1995.

Holyoak, Keith James and Paul Thagard. *Mental Leaps: Analogy in Creative Thought*. Cambridge, Mass.: MIT Press, 1995.

Hove, Philip, Michael A. Riley, and Kevin Shockley. "Perceiving Affordances of Hockey Sticks by Dynamic Touch." *Ecological Psychology* 18, no. 3 (2006): 163-189.

Hovind, Jacob. "Figural Interpretation as Modernist Hermeneutics: The Rhetoric of Erich Auerbach's Mimesis." *Comparative Literature* 64, no. 3 (2012): 257.

Hubbard, Bill. *A Theory for Practice: Architecture in Three Discourses*. Cambridge, Mass.: MIT Press, 1995.

Hughes, John J. and Jan Vlek. *Mortars in Historic Buildings: A Review of the Conservation, Technical and Scientific Literature* Historic Scotland Edinburgh, Scotland, 2003.

Hunt, Alice M. W. *The Oxford Handbook of Archaeological Ceramic Analysis*. Oxford: Oxford University Press, 2017.

Hurd, Mary Krumboltz. "Formwork for Concrete." American Concrete Institute, 2005.

Husserl, Edmund. *Cartesian Meditations; an Introduction to Phenomenology.* Translated by Dorion Cairns. The Hague: M. Nijhoff, 1960.

Hutchins, Edwin. *Cognition in the Wild*. Cambridge, Mass.: MIT Press, 1995.

Hvattum, Mari. *Gottfried Semper and the Problem of Historicism*. Cambridge, UK; New York: Cambridge University Press, 2004.

Hyatt, Thaddeus. *An Account of some Experiments with Portland-Cement-Concrete Combined with Iron: As a Building Material, with Reference to Economy of Metal in Construction, and for Security Against Fire in the Making of Roofs, Floors, and Walking Surfaces.* Private circulation, at the Chiswick Press, 1877.

Hyde, Rory. *Future Practice*. Hoboken: Taylor and Francis, 2012.

Iliescu, Sanda. *The Hand and the Soul: Aesthetics and Ethics in Architecture and Art.* Charlottesville: University of Virginia Press, 2009.

Illich, Ivan. *Disabling Professions*. Ideas in Progress. London; Salem, N.H.: M. Boyars, 1977.

Illich, Ivan. *Tools for Conviviality*. World Perspectives. Vol. 47. New York: Harper & Row, 1973.

Ingold, Tim. *The Appropriation of Nature: Essays on Human Ecology and Social Relations*. Iowa City: University of Iowa Press, 1987.

Ingold, Tim. *Being Alive: Essays on Movement, Knowledge and Description*. London; New York: Routledge, 2011.

Ingold, Tim. *Making*. Hoboken: Taylor and Francis, 2013.

Ingold, Tim. *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*. London; New York: Routledge, 2000.

Jackson, Susan A. "Joy, Fun, and Flow State in Sport." *Emotions in Sport.* (2000): 135.

Jakubowska, Honorata. *Skill Transmission, Sport and Tacit Knowledge: A Sociological Perspective.* Abingdon: Routledge an imprint of the Taylor & Francis Group, 2017.

James, John. *The Template-Makers of the Paris Basin: Toichological Techniques for Identifying the Pioneers of the Gothic Movement with an Examination of Art-Historical Methodology.* Woodbridge, United Kingdom: Boydell & Brewer, 1989.

Jencks, Charles. *The Architecture of the Jumping Universe: A Polemic: How Complexity Science is Changing Architecture and Culture*. Rev ed. London: Academy Editions, 1997.

Johnson, Christopher D. *Memory, Metaphor, and Aby Warburg's Atlas of Images*. Signale: Modern German Letters, Cultures, and Thought. Ithaca, N.Y.: Cornell University Press, 2012.

Johnson, Neil F., Johnson, Neil F. *Simply Complexity: A Clear Guide to Complexity Theory*. Oxford: Oneworld, 2009.

Johnston, George Barnett. *Drafting Culture: A Social History of Architectural Graphic Standards*. Cambridge, Mass.: MIT Press, 2008.

Kanekar, Aarati. *Architecture's Pretexts: Spaces of Translation*. London; New York: Routledge, Taylor & Francis Group, 2015.

Karatani, Kojin and Michael Speaks. *Architecture as Metaphor: Language, Number, Money*. Writing Architecture. [In'yu to shite no kenchiku. English]. Cambridge, Mass.: MIT Press, 1995.

Kawabata, Hideaki and Semir Zeki. "Neural Correlates of Beauty." *Journal of Neurophysiology* 91, no. 4 (2004): 1699-1705.

Kedan, Elite, Jon Dreyfous, and Craig Mutter. *Provisional: Emerging Modes of Architectural Practice USA* Princeton Architectural Press, 2010.

Keller, Charles M. and Janet Dixon Keller. *Cognition and Tool use: The Blacksmith at Work*. Learning in Doing. Cambridge England; New York: Cambridge University Press, 1996.

Kendon, Adam. *Gesture: Visible Action as Utterance* Cambridge University Press, 2004.

Ketchum, Milo Smith. *The Design of Walls, Bins and Grain Elevators* McGraw-Hill Book Company, 1919.

Kittredge, William. *The Nature of Generosity*. New York: Knopf, 2000.

Kleinsasser, William. "Synthesis 9: A Theory Base for Architecture." *Unpublished Course Manuscript,* Department of Architecture. Eugene: University of Oregon (1999).

Knorr, Karin D. "Tinkering Toward Success: Prelude to a Theory of Scientific Practice." *Theory & Society* 8, no. 3 (1979): 347.

Kocatrk, Tuba, Benachir Medjdoub, and Mediated Intelligence in Design. *Distributed Intelligence in Design*. Chichester, West Sussex, U.K.; Ames, Iowa: Wiley-Blackwell, 2011.

Kossmann, Herman, Suzanne Mulder, Frank den Oudsten, and Pieter Kiewiet de Jonge. *Narrative Spaces: On the Art of Exhibiting*. Rotterdam: 010 Publishers, 2012.

Kostka, Alexandre and Irving Wohlfarth. *Nietzsche and "an Architecture of our Minds"*. Issues & Debates. Los Angeles, Calif.: Getty Research Institute for the History of Art and the Humanities, 1999.

Kostof, Spiro. *A History of Architecture: Settings and Rituals*. New York: Oxford University Press, 1985.

Kraft, John C. and Ronald A. Thomas. "Early Man at Holly Oak, Delaware." *Science* 192, no. 4241 (1976): 756-761.

Kretz, Donald R. and Daniel C. Krawczyk. "Expert Analogy use in a Naturalistic Setting." *Frontiers in Psychology* 5, (2014): 1333.

Kubler, George. *The Shape of Time; Remarks on the History of Things*. New Haven: Yale Universit Press, 1963.

Kuhn, Thomas S. *The Structure of Scientific Revolutions*. International Encyclopedia of Unified Science : Foundations of the Unity of Science ; V. 2, no. 2. 2d enl ed. Chicago: University of Chicago Press, 1970.

Kumar, Krishan. *Public and Private in Thought and Practice: Perspectives on a Grand Dichotomy*. Chicago, IL: University of Chicago Press, 1997.

Lakoff, George. "The Contemporary Theory of Metaphor." *Metaphor and Thought.* (1993): 202.

Lakoff, George and Mark Johnson. *Metaphors we Live By*. Chicago: University of Chicago Press, 1980.

Lamprecht, Heinz-Otto and Rmisch-Germanisches Museum. *Opus Caementitium: Bautechnik Der Rmer*. 2 Aufl ed. Dsseldorf: Beton, 1984.

Lancaster, Lynne C. *Concrete Vaulted Construction in Imperial Rome: Innovations in Context*. Cambridge, UK; New York, NY: Cambridge University Press, 2005.

Larman, Craig and Bas Vodde. *Scaling Lean & Agile Development: Thinking and Organizational Tools for Large-Scale Scrum*. Upper Saddle River, NJ: Addison-Wesley, 2009.

Larson, Magali Sarfatti. "Emblem and Exception: The Historical Definition of the Architect's Professional Role." *Professionals and Urban Form* (1983): 49-86.

Latour, Bruno. "The Force and the Reason of Experiment." In *Experimental Inquiries: Historical, Philosophical and Social Studies of Experimentation in Science*, edited by Le Grand, H. E., 49-80. Dordrecht: Springer Netherlands, 1990.

Latour, Bruno. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Clarendon Lectures in Management Studies. Oxford; New York: Oxford University Press, 2005.

Latour, Bruno and Steve Woolgar. *Laboratory Life: The Construction of Scientific Facts*. Princeton, N.J.: Princeton University Press, 1979.

Laugier, Marc-Antoine. *An Essay on the Study and Practice of Architecture* [Essai sur l'architecture. English]. London: printed for Stanley Crowder and Henry Woodgate, 1756.

LaVO, Carl. "Little House in the Woods: Plans Hatch to Restore a Precious Relic Defaced by Vandals Behind Fonthill Castle in Doylestown." *The Intelligencer,* Dec 18, 2017. http://www.theintell.com/news/20171218/lavo-little-house-in-woods.

Le Camus de Mzires, Nicolas. *The Genius of Architecture, Or, the Analogy of that Art with our Sensations*. Texts & Documents. [Gnie de l'architecture. English]. Santa Monica, CA: Getty Center for the History of Art and the Humanities; Chicago, 1992.

Le Clerc, Sbastien and Ephraim Chambers. *A Treatise of Architecture, with Remarks and Observations* [Trait d'architecture. English]. London: Printed and sold by R. Ware, 1724.

Le Corbusier. *Towards a New Architecture* [Vers une architecture. English]. New York: Dover Publications, 1931.

Le Grand, H. E. "Is a Picture Worth a Thousand Experiments?" In *Experimental Inquiries: Historical, Philosophical and Social Studies of Experimentation in Science*, edited by Le Grand, H. E., 241-270. Dordrecht: Springer Netherlands, 1990.

Leach, Bernard. *A Potter's Book*. London: Faber and Faber, 1940.

Leach, Neil. *Rethinking Architecture: A Reader in Cultural Theory*. New York: Routledge, 1997.

Leatherbarrow, David. *Architecture Oriented Otherwise*. Writing Matters. New York: Princeton Architectural Press, 2009.

Lee, Doohwang and Robert LaRose. "The Impact of Flow Experience on Self-Regulation and Usage in Video Game Play." *Conference Papers -- International Communication Association* (2005): 1. http://search.ebscohost.com/login.aspx?direct=true&db=ufh&AN=18655840&site=ehost-live&scope=site.

Lee, William E. and Robert E. Moore. "Evolution of in Situ Refractories in the 20th Century." *Journal of the American Ceramic Society* 81, no. 6 (1998): 1385-1410.

Léger, Alfred. *Les Travaux Publics Les Mines Et La Métallurgie Aux Temps Des Romains La Tradition Romaine Jusqu'À Nos Jours. 0tlas. 0tlas.* Paris: J. Dejey, 1875.

Legh, Peter. *The Music of the Eye; Or, Essays on the Principles of the Beauty and Perfection of Architecture, as Founded on and Deduced from Reason and Analogy, and Adapted to what may be Traced of the Ancient Theories of Taste, in the Three First Chapters of Vitruvius*. London: W. Walker etc., 1831.

Lengen, Johan van. *The Barefoot Architect: A Handbook for Green Building*. Bolinas, Calif: Shelter Publications, 2011.

Leonard-Barton, Dorothy. "The factory as a learning laboratory." In *Strategic Learning in a Knowledge Economy* (London: Routledge, 2000): 91-118.

Leonard, Dorothy and Sylvia Sensiper. "The Role of Tacit Knowledge in Group Innovation." *California Management Review* 40, no. 3 (1998): 112-132.

Leslie, Thomas and Louis I. Kahn. *Louis I. Kahn: Building Art, Building Science*. New York: George Braziller, 2005.

Lethaby, W. R. *Architecture, Mysticism and Myth*. New York: G. Braziller, 1891.

Libet, Benjamin, Curtis A. Gleason, Elwood W. Wright, and Dennis K. Pearl. "Time of Conscious Intention to Act in Relation to Onset of Cerebral Activity (Readiness-Potential) the Unconscious Initiation of a Freely Voluntary Act." *Brain* 106, no. 3 (1983): 623-642.

Llach, Daniel Cardoso. *Algorithmic Tectonics: How Cold War Era Research Shaped our Imagination of Design*. Vol. 83 2013.

Locher, Miriam A. and Jürg Strässler. *Standards and Norms in the English Language*. Vol. 95. Berlin: Walter de Gruyter, 2008.

López, D., Van Mele, T., and Block, P. "Tile Vaulting in the 21st Century," *Informes De La Construcción*, Volume 68 Number 544 (9 December 2016).

Löschke, Sandra Karina. *Materiality and Architecture*. New York: Routledge, 2016.

Lovejoy, Ellis. *Fundamentals and Economies in the Clay Industries*. Wellsville, N.Y.: Randall, 1935.

Lupacchini, Rossella and Annarita Angelini. *The Art of Science: From Perspective Drawing to Quantum Randomness*. Cham: Springer, 2014.

Mäckler, Christoph. *Material Stone: Constructions and Technologies for Contemporary Architecture*. Basel; Boston: Birkhäuser-Publishers for Architecture, 2004.

MacMichael, R. F. "Tests to Determine Uses for Clay." *Brick and Clay Record.* (1919): 762-767.

Mallgrave, Harry Francis. *The Architect's Brain: Neuroscience, Creativity, and Architecture*. Chichester, West Sussex, U.K.; Malden, MA: Wiley-Blackwell, 2010.

Mallgrave, Harry Francis. *Architectural Theory*. Malden, MA: Blackwell, 2008.

Manolopoulou, Yeoryia. *Architectures of Chance*. Design Research in Architecture. Farnham, Surrey: Ashgate Publishing Limited, 2013.

Martin, Nathaniel. *The Properties and Design of Reinforced Concrete; Instructions, Authorized Methods of Calculation, Experimental Results and Reports by the French Government Commissions on Reinforced Concrete*. New York: French Commission du Ciment Arme, 1912.

Masheck, Joseph. *Building-Art: Modern Architecture Under Cultural Construction*. Contemporary Artists and their Critics. Cambridge England; New York: Cambridge University Press, 1993.

Mason, Ralph S. *Native Clays and Glazes for North American Potters: A Manual for the Utilization of Local Clay and Glaze Materials*. Beaverton, OR: Timber Press, 1981.

Maxwell, Robert. *Ancient Wisdom and Modern Knowhow: Learning to Live with Uncertainty*. London: Artifice Books on Architecture, 2013.

May, John, Reid, Anthony, A. *Buildings without Architects: A Global Guide to Everyday Architecture*. New York: Ivy Press; Rizzoli; Lewes, 2013.

McEwen, Indra Kagis. *Socrates' Ancestor: An Essay on Architectural Beginnings.* Cambridge, Mass.: MIT Press, 1993.

McGovern, Patrick E., Kingery, W. D. *Cross-Craft and Cross-Cultural Interactions in Ceramics.* American Ceramic Society, 1989.

McInerny, Ralph. *Studies in Analogy*. The Hague: Martinus Nijhoff, 1969.

McNealy, Terry A. and The Bucks County Historical Society. *Guide to the Microfilm of the Papers of Henry C. Mercer and the Records of the Moravian Pottery and Tileworks*. Doylestown, PA: Bucks County Historical Society, 1985.

Mercer, Henry C. *Ancient Carpenters' Tools, Illustrated and Explained, Together with the Implements of the Lumberman, Joiner and Cabinet Maker, in use in the Eighteenth Century*. Doylestown, Pa.: The Bucks County Historical Society, 1929.

Mercer, Henry C. *The Dating of Old Houses*. Reprint of a paper first read before the Society in 1923. Doylestown, PA: Bucks County Historical Society, 1973.

Mercer, Henry C. *The Hill-Caves of Yucatan.: A Search for Evidence of Man's Antiquity in the Caverns of Central America. being an Account of the Corwith Expedition of the Department of Archæology and Palæontology of the University of Pennsylvania*. Philædelphia: J. M. Lippincott company, 1895.

Mercer, Henry C. "The Kabal, Or Potter's Wheel of Yucatan." *Bulletin of the Free Museum of Science and Art of the University of Pennsylvania* 1, (December, 1897b): 63-70.

Mercer, Henry C. *The Origin of Log Houses in the United States*. Doylestown, Pa.: Bucks County Historical Society, 1967.

Mercer, Henry C. *The Survival of the Mediæval Art of Illuminative Writing among Pennsylvania Germans*. Doylestown, Pa.: Bucks County Historical Society, 1897.

Mercer, Henry C. *Tools of the Nation Maker. A Descriptive Catalogue of Objects in the Museum of the Historical Society of Bucks County, Penna*. Vol. 1. Doylestown, Pa.: Printed for the Society at the office of the Bucks County intelligencer, 1897.

Mercer, Henry C. *Unpublished Papers, Including Construction Notebooks, Ledgers, Photos, and Construction Ephemera from the Construction of Fonthill, the Moravian Pottery and Tileworks, and the Mercer Museum*. Doylestown, Pa.: (Unpublished) Mercer Museum Research Library, Bucks County Historical Society.

Mercer, Henry C. "Where Concrete Stands for Concrete." *Cement Age* 6, no. 1 (May, 1908): 9.

Mercer, Henry C., E. D. Cope, and Richard H. Harte. *Researches upon the Antiquity of Man in the Delaware Valley and the Eastern United States*. Publications of the University of Pennsylvania. Series in Philology, Literature and Archaeology. Vol. ol.VI. Boston: Ginn & company;Halle a. S., 1897.

Mercer, Henry C., Horace Michener Mann, and The Bucks County Historical Society, Doylestown. *The Bible in Iron; Or, Pictured Stoves and Stove Plates of the Pennsylvania Germans*. Doylestown, Pa.: The Bucks County Historical Society, 1941.

Merleau-Ponty, Maurice and Donald A. Landes. *Phenomenology of Perception* [Phénoménologie de la perception. English]. Abingdon, Oxon ;New York: Routledge, 2012.

Michaels, Claire F. and Raul R. D. Oudejans. "The Optics and Actions of Catching Fly Balls: Zeroing Out Optical Acceleration." *Ecological Psychology* 4, no. 4 (1992): 199.

Miller, Edward W. *The Book of Trades*. Philadelphia: T. K. & P. G. Collins, Printers, 1847.

Mindrup, Matthew. *The Material Imagination: Reveries on Architecture and Matter*. Farnham, Surrey, England; Burlington: Ashgate, 2015.

Moholy-Nagy, Sibyl. *Native Genius in Anonymous Architecture, by Sibyl Moholy-Nagy*. New York: Horizon Press, 1957.

Morris, William. *Architecture, Industry, and Wealth: Collected Papers*. Connoisseurship, Criticism, and Art History in the Nineteenth Century. New York: Garland Pub., 1902.

Morson, Gary Saul. *Prosaics and Other Provocations: Empathy, Open Time, and the Novel*. Boston, Mass.: Acad. Studies Press, 2013.

Moss, Jean Dietz. "Aristotle's Four Causes: Forgotten Topos of Renaissance Rhetoric." *RSQ: Rhetoric Society Quarterly* 17, no. 1 (1987): 71.

Moy, Stuart S. J. *Plastic Methods for Steel and Concrete Structures*. New York: Wiley, 1981.

Muller, Derek. "The Bayesian Trap." Accessed February 2, 2018. https://youtu.be/R13BD8qKeTg.

Murray, Peter and Deborah Blackman. "Managing Innovation through Social Architecture, Learning, and Competencies: A New Conceptual Approach." *Knowledge & Process Management* 13, no. 3 (2006): 132.

Muthesius, Hermann. *Style-Architecture and Building-Art: Transformations of Architecture in the Nineteenth Century and its Present Condition*. Texts & Documents. [Stilarchitektur und Baukunst. English]. Santa Monica, Calif.: Getty Center for the History of Art and the Humanities; Chicago, 1994.

Nachmanovitch, Stephen. *Free Play: Improvisation in Life and Art*. Los Angeles; New York: J.P. Tarcher, Inc., 1990.

Nakamura, Jeanne and Mihaly Csikszentmihalyi. "The Concept of Flow." In *Flow and the Foundations of Positive Psychology*, 239-263: Springer, 2014.

Neville, Adam M. and J. J. Brooks. *Concrete Technology*. Rev reprint ed. Harlow, Essex, UK: Longman Scientific & Technical; New York, 1987.

Newell, Karl M. and Daniel M. Corcos. *Variability and Motor Control*. Champaign IL: Human Kinetics Publishers, 1993.

Noë, Alva. *Strange Tools: Art and Human Nature*. First ed. New York: Hill and Wang, a division of Farrar, Straus and Giroux, 2015.

Noever, Peter. *Gottfried Semper-the Ideal Museum: Practical Art in Metals and Hard Materials*. Wien: Schlebrugge, 2007.

Norberg-Schulz, Christian. *The Concept of Dwelling: On the Way to Figurative Architecture*. Architectural Documents. New York; Milan: Electa, 1985.

Norman, Donald A. *The Design of Everyday Things* [Psychology of everyday things]. Basic pbk ed. New York: Basic Books, 1988.

Norman, Donald A. *Emotional Design : Why we Love (Or Hate) Everyday Things*. New York: Basic Books, 2004.

Nuyts, Jan and Johan van der Auwera. *The Oxford Handbook of Modality and Mood*. Oxford: Oxford University Press, 2016.

Okumura, Motoki, Akifumi Kijima, and Yuji Yamamoto. "Perception of Affordances for Striking Regulates Interpersonal Distance Maneuvers of Intermediate and Expert Players in Kendo Matches." *Ecological Psychology* 29, no. 1 (Jan, 2017): 1-22.

Ong, Walter J. *Orality and Literacy: The Technologizing of the Word*. New Accents. London; New York: Routledge, 1982.

Ochsendorf, John Allen and Michael Freeman. *Guastavino Vaulting: The Art of Structural Tile*. New York: Princeton Architectural Press, 2010.

Osinga, Frans P. B. *Science, Strategy and War: The Strategic Theory of John Boyd*. Strategy and History. Vol. 18. London; New York: Routledge,

Osiurak, Franois and Arnaud Badets. "Tool use and Affordance: Manipulation-Based Versus Reasoning-Based Approaches." *Psychological Review* 123, no. 5 (2016): 534-568.

Otero-Pailos, Jorge. *Architecture's Historical Turn: Phenomenology and the Rise of the Postmodern*. Minneapolis: University of Minnesota Press, 2010.

Palladio, Andrea. *The Four Books on Architecture* [Quattro libri dell'architettura.]. Cambridge, Mass.: MIT Press, 1997.

Palladio, Andrea, Guido Beltramini, Howard Burns, Centro internazionale di studi di architettura "Andrea Palladio" di Vicenza, and Royal Academy of Arts. *Palladio*. London: Royal Academy of Arts, 2008.

Pallasmaa, Juhani. *The Eyes of the Skin*. New York: John Wiley & Sons, 2012.

Palley, Reese. *Concrete: A Seven-Thousand-Year History*. New York: The Quantuck Lane Press, 2010.

Perez-Gomez, Alberto. "Hermeneutics as Discourse in Design." *Design Issues* 15, no. 2 (1999): 71-79. http://search.ebscohost.com/login.aspx?direct=true&db=f5h&AN=1950173&site=ehost-live&scope=site.

Pérez-Gómez, Alberto. *Architecture and the Crisis of Modern Science*. Cambridge, MA: MIT Press, 1983.

Pérez-Gómez, Alberto and Stephen Parcell. *Chora*. CHORA: Intervals in the Philosophy of Architecture. Vol. 6. Montreal: Mqup, 2014.

Peterson, Michael. "Thomas Edison's Concrete Houses." *American Heritage of Invention & Technology* 11, no. 3 (1996): 50.

Piechowski-Jozwiak, Bartlomiej, François Boller, and Julien Bogousslavsky. "Universal Connection through Art: Role of Mirror Neurons in Art Production and Reception." *Behavioral Sciences* 7, no. 2 (2017): 29.

Pinch, Trevor J. and Wiebe E. Bijker. "The Social Construction of Facts and Artifacts: Or how the Sociology of Science and the Sociology of Technology might Benefit each Other." In *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, 11: Anniversary edition. Foreword by Deborah G. Douglas. Cambridge and London: MIT Press, 2012.

Pinker, Steven. *The Stuff of Thought: Language as a Window into Human Nature*. New York: Viking, 2007.

Pisano, Gary P. and Willy C. Shih. *Producing Prosperity : Why America Needs a Manufacturing Renaissance*. Boston: Harvard Business Review Press, 2012.

Pisano, Gary P. and Willy C. Shih. "Restoring American Competitiveness." *Harvard Business Review* 87, no. 7 (2009): 114.

Polanyi, Michael. *The Tacit Dimension*. Terry Lectures. Vol. 1962. Garden City, N.Y.: Doubleday, 1966.

Polito, Theodora. "Educational Theory as Theory of Culture: A Vichian Perspective on the Educational Theories of John Dewey and Kieran Egan." *Educational Philosophy & Theory* 37, no. 4 (2005): 475-494.

Poos, Thomas G., Mercer, Henry C.,,Fonthill Museum.,. *Fonthill, the Home of Henry Chapman Mercer: An American Architectural Treasure*. Feasterville, Pa.: Manor House Pub. Co., 2000.

Poos, Thomas G., Henry C. Mercer, and Fonthill Museum. *Fonthill, the Home of Henry Chapman Mercer: An American Architectural Treasure*. Rev and expand ed. Feasterville, PA: Manor House Pub. Co., 2000.

Porac, Joseph F., Marc J. Ventresca, and Yuri Mishina. "Interorganizational Cognition and Interpretation." In *The Blackwell Companion to Organizations*, 579-598: Blackwell Publishing Ltd, 2017.

Port, Robert F. and Timothy Van Gelder. *Mind as Motion: Explorations in the Dynamics of Cognition*. Cambridge, Massachusetts: The MIT Press, 1995.

Portland Cement Association. *Proportioning Concrete Mixtures and Mixing and Placing Concrete*. Chicago: Portland cement association, 1916.

Possati, Luca M. *Ricoeur Face L'Analogie : Entre Thologie Et Dconstruction*. Ouverture Philosophique. Paris: L'Harmattan, 2012.

Pritchard, Duncan. *Epistemic Luck*. Oxford: Clarendon, 2005.

Puig-Boada, Isidre. *El Pensamiento De Gaudí: Compilación De Textos Y Comentarios*. Barcelona: Duxelm editorial, 2015.

Pye, David. *The Nature and Aesthetics of Design*. New York: Van Nostrand Reinhold, 1978.

Pye, David. *The Nature and Art of Workmanship*. London: Cambridge U.P., 1968.

Radding, Charles and William W. Clark. *Medieval Architecture, Medieval Learning: Builders and Masters in the Age of Romanesque and Gothic*. New Haven, CT: Yale University Press, 1992.

Rahmani, Ayad B. *Kafka's Architectures: Doors, Rooms, Stairs and Windows of an Intricate Literary Edifice*. Jefferson, North Carolina: McFarland & Company, Inc., Publishers, 2015.

Ransome, Ernest L. *Reinforced Concrete Buildings* McGraw-Hill Book Company, 1912.

Reed, Cleota. *Henry Chapman Mercer and the Moravian Pottery and Tile Works*. Philadelphia: University of Pennsylvania Press, 1987.

Reid, Homer A. *Concrete and Reinforced Concrete Construction*. New York: Clark, 1908.

Reijnders, Anton. *The Ceramic Process: A Manual and Source of Inspiration for Ceramic Art and Design/ Anton Reijnders; European Ceramic Work Centre*. London: A. & C. Black, 2005.

Reith, Reinhold. *Lexikon Des Alten Handwerks : Vom Sptmittelalter Bis Ins 20. Jahrhundert*. Mnchen: C.H. Beck, 1990.

Renfrew, Colin and Ezra B. W. Zubrow. *The Ancient Mind: Elements of Cognitive Archaeology*. New Directions in Archaeology. Cambridge England; New York: Cambridge University Press, 1994.

Rheinberg, F. "Intrinsic Motivation and Flow." *Motivation and Action, 2nd Ed.* (2008): 323.

Rhodes, Daniel. *Clay and Glazes for the Potter*. Rev ed. Philadelphia: Chilton Book Co, 1973.

Ricco, John Paul. *The Logic of the Lure*. Chicago: University of Chicago Press, 2002.

Rice, Prudence M. *Pottery Analysis: A Sourcebook*. Second ed. Chicago; London: University of Chicago Press, 2015.

Ricoeur, Paul. "Architecture and Narrative," in *Pietro Derossi, Identita, Differenze, Triennale Di Milano, XIX Esposizione Internazionale* (Milano: Electa, 1996), Pp. 64-72; and "Architecture Et Narrativité," Arquitectonics 4 (2002): 9–29.

Ricoeur, Paul. *Time and Narrative* [Temps et recit. English]. Chicago: University of Chicago Press, 1988.

Ridgway, Sam. *Architectural Projects of Marco Frascari: The Pleasure of a Demonstration*. Farnham Surrey, England ; Burlington, VT: Ashgate, 2015.

Rietveld, Erik and Julian Kiverstein. "A Rich Landscape of Affordances." *Ecological Psychology* 26, no. 4 (2014): 325.

Rizzolatti, Giacomo, Luciano Fadiga, Vittorio Gallese, and Leonardo Fogassi. "Premotor Cortex and the Recognition of Motor Actions." *Cognitive Brain Research* 3, no. 2 (1996): 131-141.

Rosenstein, Donna Gail. "Historic Human Tools: Henry Chapman Mercer and His Collection, 1897-1930." MA Thesis, University of Delaware: 1977.

Ross, James F. *Portraying Analogy*. Cambridge Studies in Philosophy. Cambridge England; New York: Cambridge University Press, 1981.

Rudofsky, Bernard. *The Prodigious Builders: Notes Toward a Natural History of Architecture with Special Regard to those Species that are Traditionally Neglected Or Downright Ignored*. New York: Harcourt Brace Jovanovich, 1977.

Rudofsky, Bernard, Rudofsky, Bernard,Rudofsky, Bernard,. *Architecture without Architects: A Short Introduction to Non-Pedigreed Architecture*. Albuquerque, NM: University of New Mexico Press, 1988.

Rudofsky, Bernard and Museum of Modern Art. *Architecture without Architects, an Introduction to Nonpedigreed Architecture*. New York: Museum of Modern Art, 1964.

Ruskin, John. *The Elements of Drawing. In Three Letters to Beginners*. 14th ed. London: G. Allen, Sunnyside, 1900.

Ruskin, John. *The Seven Lamps of Architecture*. New York: J. Wiley, 1849.

Ruskin, John. *The Stones of Venice*. New York: Garland Pub., 1851.

Ruskin, John, Charles Eliot Norton, John Lewis Bradley, and Ian Ousby. *The Correspondence of John Ruskin and Charles Eliot Norton*. Cambridge Cambridgeshire; New York: Cambridge University Press, 1987.

Russell, Bertrand. *Our Knowledge of the External World*. New York: W. W. Norton & Company, 1929.

Ryan, Kathleen. "Implements of Change: Henry Chapman Mercer and the Bucks County Historical Society." MA Thesis, Lehigh University: 2002.

Rykwert, Joseph. *The Dancing Column: On Order of Architecture*. Cambridge, Mass.: MIT Press, 1996.

Rykwert, Joseph. *The First Moderns: The Architects of the Eighteenth Century*. Cambridge, Mass.: MIT Press, 1980.

Rykwert, Joseph. "On the Oral Transmission of Architectural Theory." *RES: Anthropology and Aesthetics* 3, no. 1 (1982): 68-81.

Rykwert, Joseph. "On the Oral Transmission of Architectural Theory." *AA Files* no. 6 (1984): 14-27.

Sanchez Vibk, Kasper. *Architectural System Structures*. Routledge Research in Architecture. Hoboken: Taylor and Francis, 2014.

Sandford, Joseph E.,Bucks County Historical Society.,. *Henry Chapman Mercer, a Study*. Doylestown, Pa.: Bucks County Historical Society, 1966.

Scamozzi, Vincenzo, John Brown, William Leybourn, and Henry Wotton. *The Mirror of Architecture: Or, the Ground-Rules of the Art of Building* [Idea dell'architettura universale. English]. 6th ed. London: Printed for J. and B. Sprint, 1721.

Scarry, Elaine. *The Body in Pain: The Making and Unmaking of the World*. New York: Oxford University Press, 1985.

Scarry, Elaine. *Dreaming by the Book*. New York: Farrar, Straus, Giroux, 1999.

Schmitt, Richard. "Heidegger's Analysis of 'Tool'." *Monist: An International Quarterly Journal of General Philosophical Inquiry* 49, (1965): 70.

Schumacher, Patrik. *The Autopoiesis of Architecture, Volume II*. Hoboken: John Wiley & Sons, 2012.

Schutz, Alfred. *Collected Papers 1 the Problem of Social Reality*. Phaenomenologica, 11. The Hague: Nijhoff, 1962.

Searle, John R. "Minds, Brains, and Programs." *Behavioral and Brain Sciences* 3, no. 3 (1980): 417-424.

Semper, Gottfried. *The Four Elements of Architecture and Other Writings*. RES Monographs in Anthropology and Aesthetics. [Selections. English. 1989]. Cambridge England; New York, NY, USA: Cambridge University Press, 1989.

Semper, Gottfried, Harry Francis Mallgrave, Michael Robinson, and Getty Research Institute. *Style in the Technical and Tectonic Arts, Or, Practical Aesthetics*. Texts & Documents. [Stil in den technischen und tektonischen Knsten, oder, Praktische esthetik. English]. Los Angeles: Getty Research Institute, 2004.

Sennett, Richard. *The Craftsman* Yale University Press, 2008.

Serlio, Sebastiano, Vaughan Hart, and Peter Hicks. *Sebastiano Serlio on Architecture* [Tutte l'opere d'architettura. English]. New Haven, Conn: Yale University Press, 1996.

Shaeffer, R. E. *Reinforced Concrete: Preliminary Design for Architects and Builders*. New York: McGraw-Hill, 1992.

Shannon, C. E. "Prediction and Entropy of Printed English." *Bell System Technical Journal* 30, no. 1 (1951): 50-64.

Shapin, Steven. "Invisible Science." *Hedgehog Review* 18, no. 3 (2016): 34.

Shapin, Steven. "Never Pure: Historical Studies of Science as if it was Produced by People with Bodies: Situated in Time, Space, Culture, and Society and Struggling for Credibility and Authority." *Universitas Philosophica* 30, no. 60 (2013): 279.

Shapin, Steven. "What Else is New? how Uses, Not Innovations, Drive Human Technology." *New Yorker* 14, (2007): 144-148.

Shapin, Steven, Simon Schaffer, and Thomas Hobbes. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life : Including a Translation of Thomas Hobbes, Dialogus Physicus De Natura Aeris by Simon Schaffer*. Princeton, N.J.: Princeton University Press, 1985.

Shelley, Cameron. *Multiple Analogies in Science and Philosophy*. Human Cognitive Processing. Vol. 11. Amsterdam; Philadelphia: John Benjamins Pub. Co., 2003.

Shennan, Stephen. *Pattern and Process in Cultural Evolution*. Origins of Human Behavior and Culture. Vol. 2. Berkeley: University of California Press, 2009.

Shonstrom, Erik. *Wild Curiosity: How to Unleash Creativity and Encourage Lifelong Wondering*. Lanham, MD: Rowman & Littlefield, 2015.

Singh, Malkit and Rafat Siddique. *Effect of Coal Bottom Ash as Partial Replacement of Sand on Properties of Concrete*. Vol. 72. (2013).

Sinha, Sumita. *Architecture for Rapid Change and Scarce Resources*. Hoboken: Taylor & Francis, 2012.

Sismondo, Sergio. *An Introduction to Science and Technology Studies*. Chichester, West Sussex, U.K.; Malden, MA: Wiley-Blackwell, 2010.

Slaton, Amy E. *Reinforced Concrete and the Modernization of American Building, 1900-1930*. Johns Hopkins Studies in the History of Technology. Baltimore, MD: Johns Hopkins University Press, 2001.

Sloterdijk, Peter. *In the World Interior of Capital.* Oxford: Wiley, 2014.

Sloterdijk, Peter. *You must Change Your Life*. Oxford: Wiley, 2014.

Small, William J. and Robert H. Rodgers. *Cooperative Apprentice Training in the Building Trades at Niagara Falls, New York*. University of the State of New York Bulletin. Vol. 797. Feb. 1, 1924. Albany: The University of the State of New York, 1924.

Smith, Korydon. *Introducing Architectural Theory*. Hoboken: Taylor and Francis, 2012.

Sober, Elliott. *Ockham's Razors: A User's Manual.* Cambridge: Cambridge University Press, 2015.

Society for Pennsylvania Archaeology. "Henry Chapman Mercer." *Pennsylvania Archaeologist: Bulletin of the Society for Pennsylvania Archaeology* 26, (1956): 160.

Sorli, Mikel and D. Stokic. *Innovating in Product Process Development: Gaining Pace in New Product Development*. Dordrecht; New York: Springer, 2009.

Spiro, Annette. *The Working Drawing - the Architect's Tool.* Zurich: Park Books, 2014.

Spurr, David. *Architecture and Modern Literature*. Ann Arbor: University of Michigan Press, 2012.

Star, Susan Leigh. "Scientific Work and Uncertainty." *Social Studies of Science (Sage Publications, Ltd.)* 15, no. 3 (1985): 391-427.

Steadman, Philip. *The Evolution of Designs: Biological Analogy in Architecture and the Applied Arts*. Cambridge Urban and Architectural Studies. Vol. 5. Cambridge; New York: Cambridge University Press, 1979.

Stein, Gertrude and Seth Perlow. *Tender Buttons*. The correct centennial; First City Lights ed. San Francisco: City Lights Books, 2014.

Stinchcombe, Arthur L. "Bureaucratic and Craft Administration of Production: A Comparative Study." *Administrative Science Quarterly* (1959): 168-187.

Stinchcombe, Arthur L. *Information and Organizations*. California Series on Social Choice and Political Economy. Vol. 19. Berkeley: University of California Press, 1990.

Stinchcombe, Arthur L. *The Logic of Social Research*. Chicago: University of Chicago Press, 2005.

Stinchcombe, Arthur L. *When Formality Works: Authority and Abstraction in Law and Organizations*. Chicago: University of Chicago Press, 2001.

Stinchcombe, Arthur L. and Carol Anne Heimer. *Organization Theory and Project Management: Administering Uncertainty in Norwegian Offshore Oil*. Oslo: Norwegian University Press; Oxford, 1985.

Styhre, Alexander. "Tinkering with Material Resources: Operating Under Ambiguous Conditions in Rock Construction Work." *Learning Organization* 16, no. 5 (2009): 386.

Sullivan, Louis H. and Isabella Athey. *Kindergarten Chats (Revised 1918) and Other Writings*. The Documents of Modern Arts. Vol. 4. New York: Writtenborn, 1965.

Tainter, Joseph A. *The Collapse of Complex Societies*. New Studies in Archaeology. Cambridge, Cambridgeshire; New York: Cambridge University Press, 1988.

Tavernor, Robert. *On Alberti and the Art of Building*. New Haven CT: Yale University Press, 1998.

Taylor, Frederick Winslow and Sanford Eleazer Thompson. *Concrete Costs: Tables and Recommendations for Estimating the Time and Cost of Labor Operations in Concrete Construction and for Introducing Economical Methods of Management. New York:* Wiley, 1912.

Taylor, Rabun M. *Roman Builder: A Study in Architectural Process*. Cambridge, U.K.; New York: Cambridge University Press, 2003.

Thomas, George E. *First Modern: Pennsylvania Academy of the Fine Arts*. Philadelphia; Philadelphia: Pennsylvania Academy of the Fine Arts; University of Pennsylvania Press, 2017.

Thoreau, Henry David and Walter Roy Harding. *Walden: An Annotated Edition*. Boston: Houghton Mifflin, 1995

Todd, Robert B. "Four Causes: Aristotle's Exposition and the Ancients." *Journal of the History of Ideas* 37, (1976): 319.

Trachtenberg, Marvin. *Building-in-Time: From Giotto to Alberti and Modern Oblivion*. New Haven, CT: Yale University Press, 2010.

Turnbull, David. "The Ad Hoc Collective Work of Building Gothic Cathedrals with Templates, String, and Geometry." *Science, Technology, & Human Values* 18, no. 3 (1993): 315-340.

Turnbull, David. "Knowledge Systems: Local Knowledge." In *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, edited by Selin, Helaine, 2495-2501. Dordrecht: Springer Netherlands, 2016.

Turnbull, David. "Local Knowledge and Comparative Scientific Traditions." *Knowledge & Policy* 6, no. 3 (1993c): 29.

Turnbull, David. *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge*. Amsterdam: Harwood Academic, 2000.

Turnbull, David and Wade Chambers. "8 Assembling Diverse Knowledges: Trails and Storied Spaces in Time." *Subversion, Conversion, Development: Cross-Cultural Knowledge Exchange and the Politics of Design* (2014): 153.

Turner, Victor W. *Process, Performance and Pilgrimage: A Study in Comparative Symbology*. Ranchi Anthropology Series. Vol. 1. New Delhi: Concept, 1979.

Turvey, M. T. "Affordances and Prospective Control: An Outline of the Ontology." *Ecological Psychology* 4, no. 3 (1992): 173.

Ulmer, Gregory L. *Heuretics: The Logic of Invention*. Baltimore: John Hopkins University Press, 1994.

Usher, John M., Utpal Roy, and H. R. Parsaei. *Integrated Product and Process Development: Methods, Tools, and Technologies*. Wiley Series in Engineering Design and Automation. New York: John Wiley, 1998.

Vaihinger, Hans and C. K. Ogden. *The Philosophy of "as if": A System of the Theoretical, Practical and Religious Fictions of Mankind*. The International Library of Philosophy. Epistemology and Metaphysics. [Philosophie des als Ob. English]. Vol. 5. London: Routledge, 1924.

van Dijk, Ludger and Raoul M. Bongers. "The Emergence of an Action System: The Organization of Gaze in Creating Novel Tools." *Ecological Psychology* 26, no. 3 (2014): 177-197.

van Pelt, R. J. and Carroll William Westfall. *Architectural Principles in the Age of Historicism*. New Haven: Yale University Press, 1991.

Van Schaik, Leon. *Practical Poetics in Architecture*. Architectural Design Primer. Somerset: Wiley, 2015.

Vasari, Giorgio and Jonathan Foster. *Lives of the most Eminent Painters, Sculptors, and Architects*. Bohn's Standard Library. London: George Bell & Sons, 1878.

Verstijnen, I. M., C. Van Leeuwen, R. Hamel, and J. M. Hennessey. "What Imagery can't do and Why Sketching might Help." *Empirical Studies of the Arts* 18, no. 2 (2000): 167-182.

Vesely, Dalibor. *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production*. Cambridge, Mass.: MIT Press, 2004.

Vesely, Dalibor. "The Nature of the Modern Fragment and the Sense of Wholeness." In *Fragments: Architecture and the Unfinished: Essays Presented to Robin Middleton*, edited by Oechslin, Werner and Barry Bergdoll, 43-56. London: Thames & Hudson, 2006.

Viollet-le-Duc, Eugène-Emmanuel. *Dictionnaire Raisonne De L'Architecture Francaise Du XIe Au XVIe Siecle*. Paris: F. de Nobele, 1967.

Viollet-le-Duc, Eugne-Emmanuel and Benjamin Bucknall. *Lectures on Architecture*. London: S. Low, Marston, Searle and Rivington, 1881.

Vitruvius Pollio, Ingrid D. Rowland, Thomas Noble Howe, and Michael Dewar. *Vitruvius: Ten Books of Architecture* [De architectura. English]. New ed. New York: Cambridge University Press, 1999.

Vitruvius Pollio, Vignola, Joseph Moxon, Abel Boyer, and Claude Perrault. *The Theory and Practice of Architecture; Or, Vitruvius and Vignola Abridg'D* [De architectura. English. Selections]. And now accurately publish'd the fifth time ed. London: Printed for R. Wellington, 1703.

Wagman, Jeffrey B. and Claudia Carello. "Affordances and Inertial Constraints on Tool Use." *Ecological Psychology* 13, no. 3 (2001): 173.

Wagman, Jeffrey B., Kevin Shockley, Michael A. Riley, and M. T. Turvey. "Attunement, Calibration, and Exploration in Fast Haptic Perceptual Learning." *Journal of Motor Behavior* 33, no. 4 (2001): 323.

Walsh, Marianne Bernice. "Finishes Analysis in the Saloon, Fonthill." MA Thesis, Historic Preservation. Philadelphia, PA: University of Pennsylvania, 1998.

Wammes, Jeffrey D., Melissa E. Meade, and Myra A. Fernandes. "The Drawing Effect: Evidence for Reliable and Robust Memory Benefits in Free Recall." *The Quarterly Journal of Experimental Psychology*69, no. 9 (2016): 1752-1776.

Ware, Isaac. *A Complete Body of Architecture*. London: Printed for J. Rivington, L. Davis and C. Reymers, R. Baldwin, W. Owen, H. Woodfall, W. Strahan, and B. Collins, 1767.

Wells, A. J. "Gibson's Affordances and Turing's Theory of Computation." *Ecological Psychology* 14, no. 3 (2002): 140-180.

Welton, J. Michael. *Drawing from Practice*. Hoboken: Taylor and Francis, 2015.

Wiebenson, Dora. *Architectural Theory and Practice from Alberti to Ledoux* Architectural Publications Chicago, Ill., 1982.

Williams, Tod and Billie Tsien. "On Slowness." *2G International Architecture Review* 9, (1999).

Willis, Daniel. *The Emerald City: And Other Essays on the Architectural Imagination*. New York: Princeton Architectural Press, 1999.

Wilson-Mendenhall, Christine, W. K. Simmons, Alex Martin, and Lawrence W. Barsalou. "Contextual Processing of Abstract Concepts Reveals Neural Representations of Nonlinguistic Semantic Content." *Journal of Cognitive Neuroscience* 25, no. 6 (2013): 920.

Wingham, Ivana. *Mobility of the Line: Art, Architecture, Design*. Basel: Birkhäuser, 2013.

Wittgenstein, Ludwig. *Philosophical Investigations* [Philosophische Untersuchungen. German & English]. New York: Macmillan, 1953.

Wrigley, William J. and Stephen B. Emmerson. "The Experience of the Flow State in Live Music Performance." *Psychology of Music* 41, no. 3 (2013): 292.

Wynn, Thomas and Frederick L. Coolidge. "Technical Cognition, Working Memory and Creativity." *Pragmatics and Cognition* 22, no. 1 (2014): 45.

Znachko-Iavorskii, Igor. "New Methods for the Study and Contemporary Aspects of the History of Cementing Materials." *Technology & Culture* 18, (1977): 25.

Zunshine, Lisa. *Why we Read Fiction: Theory of Mind and the Novel.* Columbus, OH: Ohio State University Press, 2006.