A WALL BUILDING

Gabriel J Oliver

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Gabriel J Oliver
August 5, 2011
Blacksburg, Virginia

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

William U Galloway, Chair
Steven R Thompson
Frank H Weiner

Allometric Construction Convention Design-Build Masonry Parametric Research

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ABSTRACT

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This thesis investigates a constructive technique, within the materials and methods of conventional practice, which allows for a common building material such as concrete block to carry form and beauty. Furthermore, this project seeks to demonstrate the role human ingenuity, patience, attention, and perception can continue to play in architecture and construction.

The project focuses on an experimental wall type consisting of regular eight inch concrete half-block masonry units, stack-bonded in elevation and subtly transformed in plan to reveal a gradual shift of the exposed faces of the units. A wall was constructed at the Building Research and Demonstration Facility to investigate one example of this wall type.

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To my Aunt Sue

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ACKNOWLEDGMENTS

For affording dedication and
contributions without which
there would be no wall building,

Thank you Bill

For imparting the wisdom that
human activity is one of dignity,

Thank you Steve

For exhibiting confidence in
and enthusiasm for
the pursuit of this project,

Thank you Frank

For the challenge to become a better
thinker, designer, and builder,

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Richard Jamison at Structural Steel Co., Inc

And finally,

To all the family and friends that support this path, often in the absence of understanding it, thank you

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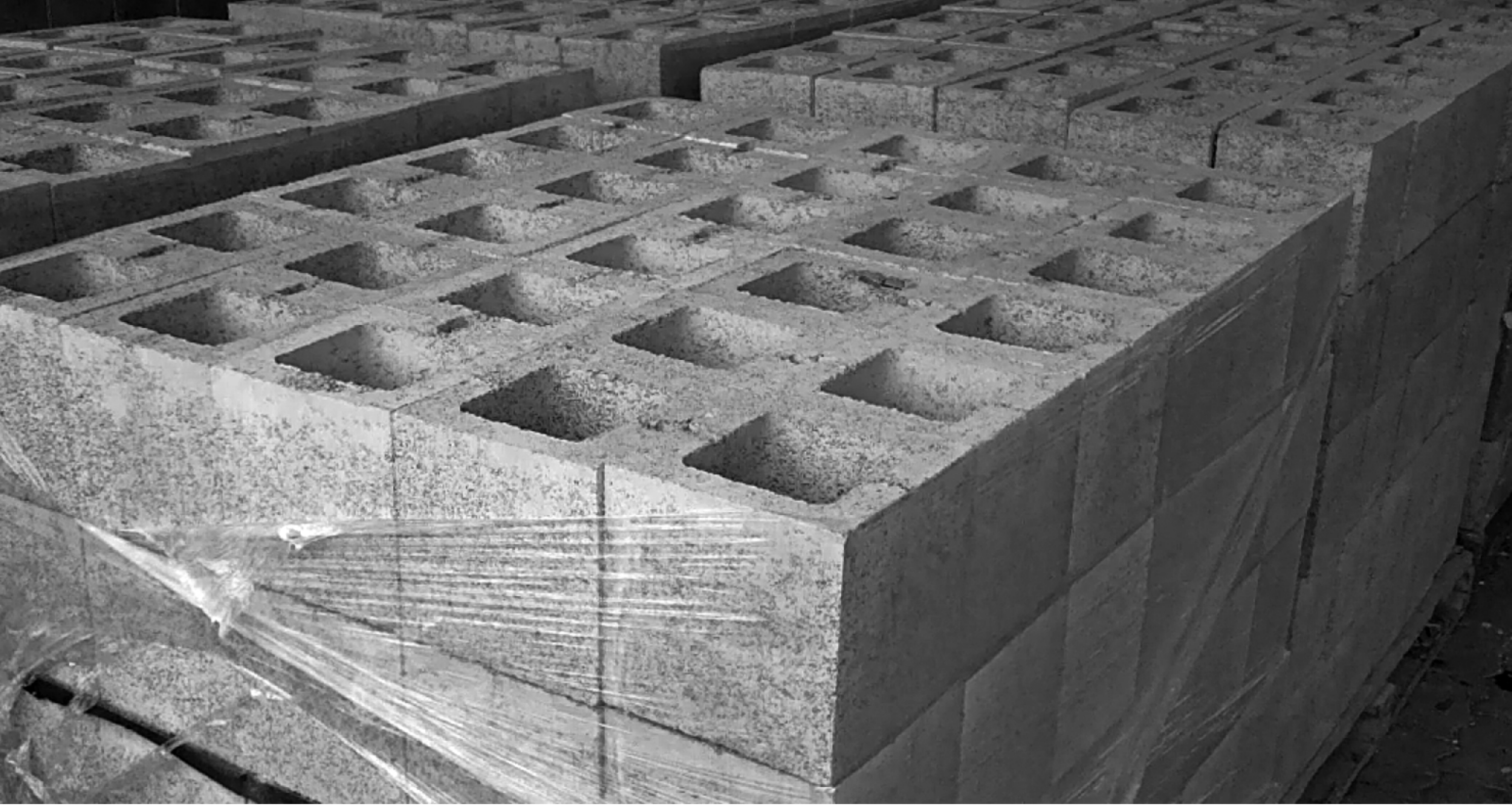
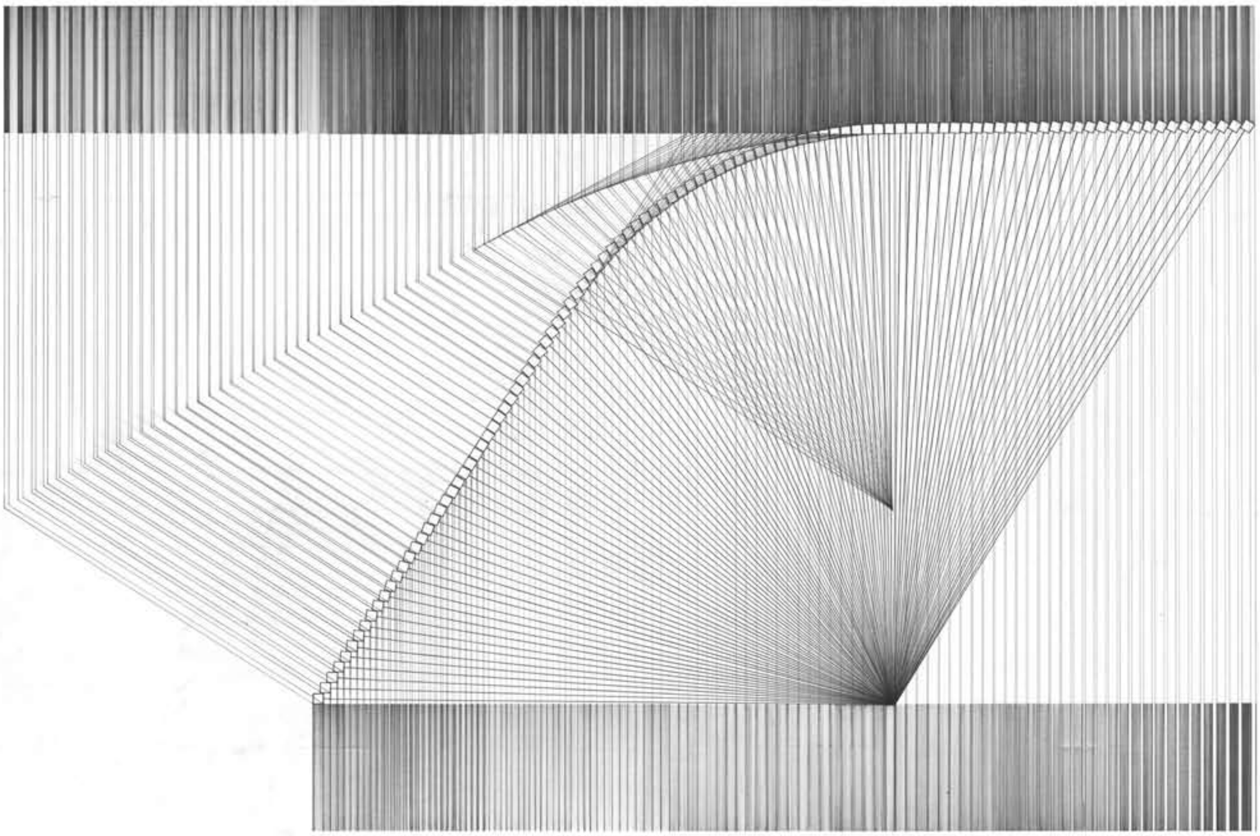
CONTENTS



A THIRD PATH

A third path exists that moderates Tradition and Progress, Idealism and Pragmatism, and Architecture and Construction. While many architects emphasize the Image and the Creative, relying on the power of technology to encode and decode human endeavor, this thesis redirects these energies of the age toward the inertia of the history of building and the humanity it maintains.

This project investigates a constructive technique, within the materials and methods of conventional practice, which allows for a common building material such as concrete block to carry form and beauty. Furthermore, given advances in technology such as drafting and mathematical software, this project seeks to demonstrate an alternative to technologically-driven forms and outcomes, instead highlighting the role human ingenuity, patience, attention, and perception can continue to play in architecture and construction.



Parametric construction holds particular appeal for the contemporary digital designer; modules operate as predictable and manipulatable pixels for the discretized approximations output by software. Culling from industrial developments, masonry laying robots represent the final operator in a series of mathematical and computological operations that begin as fields of data in a matrix regulating the design and continue through interfaces both digital and mechanical. The resulting forms represent successful permeable communication as much as they communicate a human idea.

This project focuses on a wall type consisting of regular eight-inch concrete half-block masonry units, stack-bonded in elevation and subtly transformed in plan to reveal a gradual shift in extent and shadow of the exposed faces of the units. This wall type can be altered for changing effect and use by applying different systematic transformations to the block. However, unlike the algorithmically located and robotically placed projects, this wall relies on its own construction to inform the design and the construction is managed and conducted by manual means.

Above images from *DIGITAL MATERIALITY IN ARCHITECTURE: GRAMAZIO AND KOHLER*
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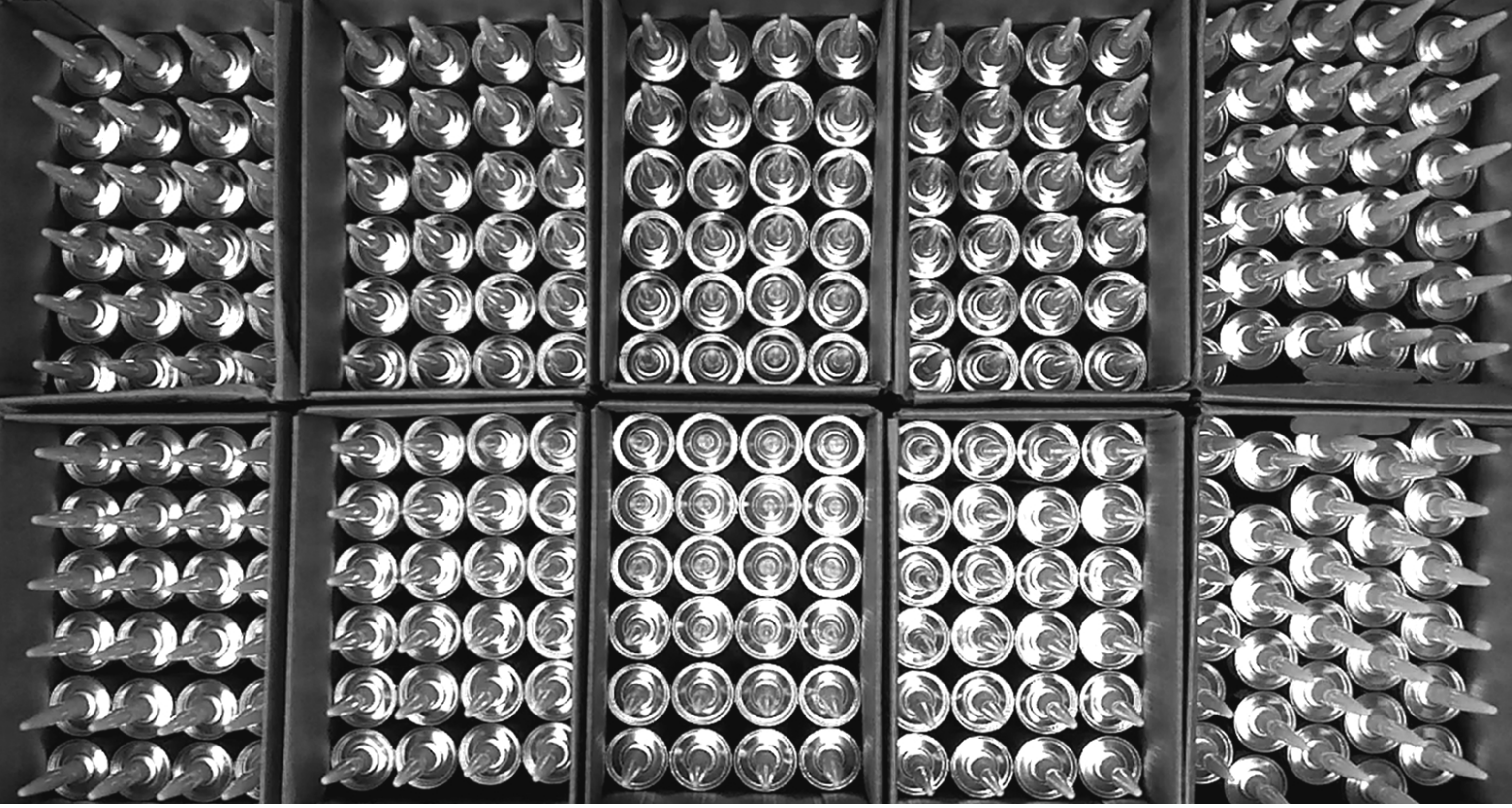
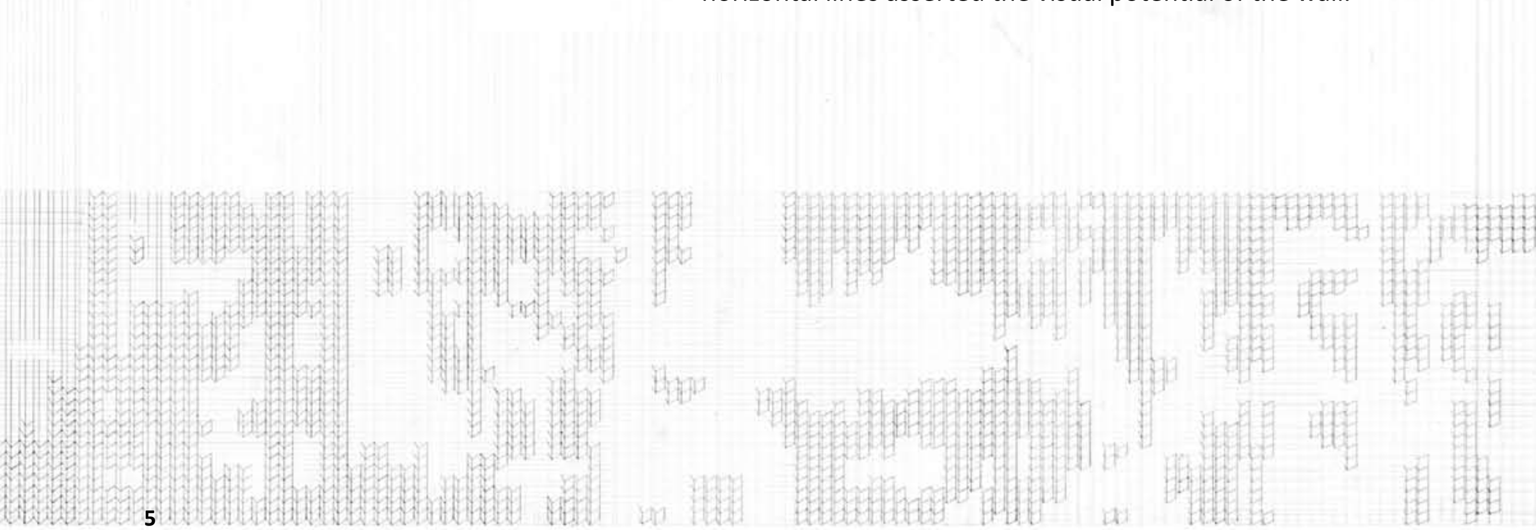
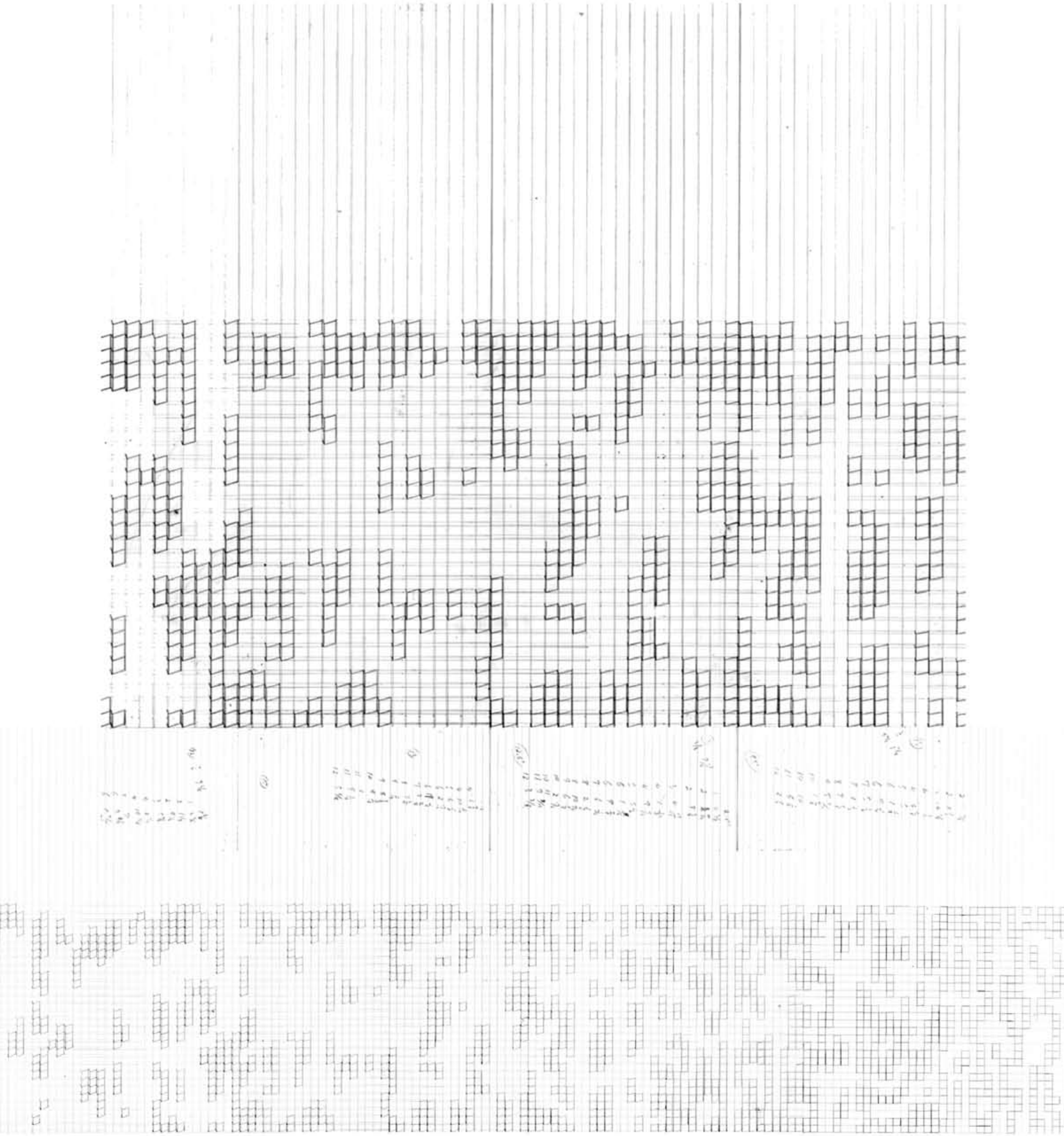


The wall type was first investigated while designing a wall for a synagogue project to be built on a long, narrow plot in Blacksburg, Virginia. The plot's linear shape led to a linear wall design, with each stack of blocks rotating a fraction of a degree to total forty-five degrees of rotation over nearly three hundred stacks. The subtlety of the rotation coupled with the relentless organization of the vertical and horizontal lines asserted the visual potential of the wall.

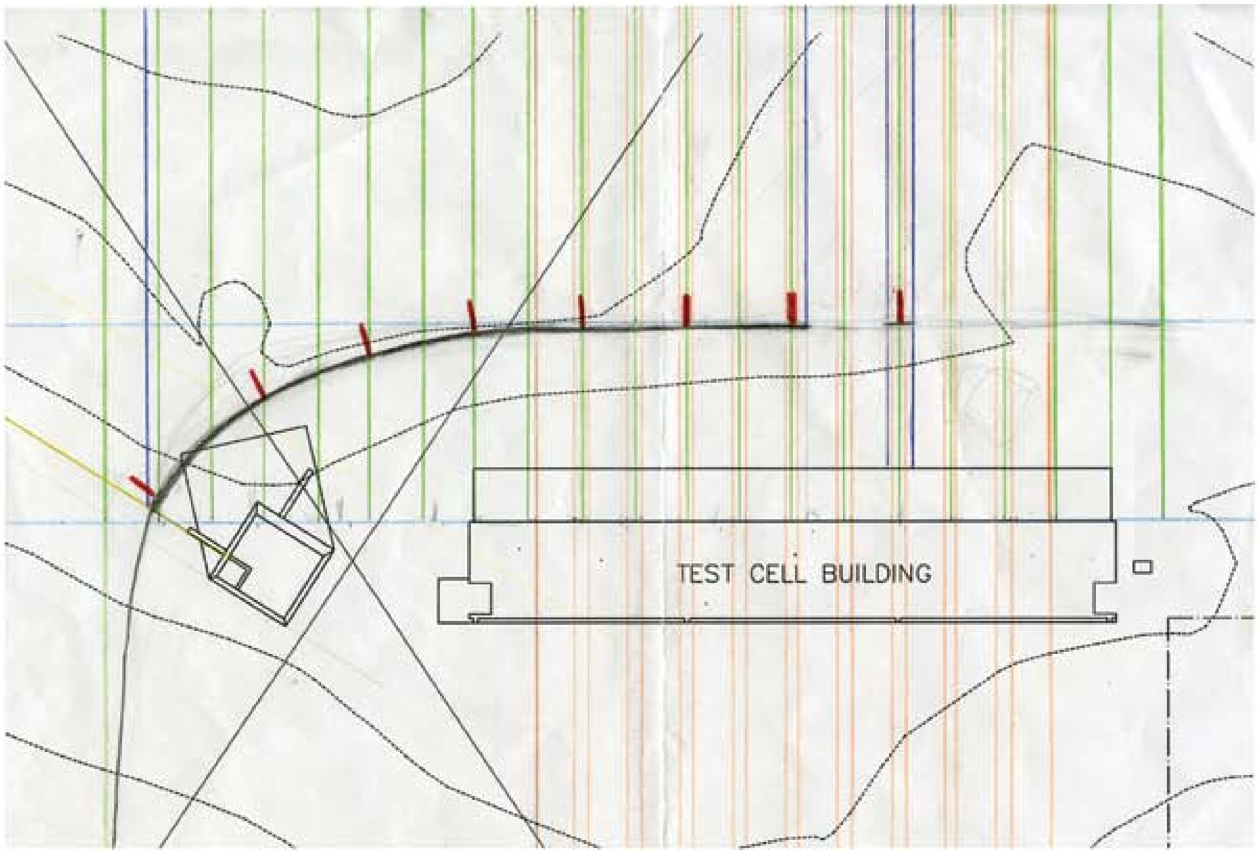




METHOD AND TECHNIQUE

The homogeneity of modern buildings is antonymous to the typological similarities found in past buildings. A built-up tradition of craft, steeped in convention and methodologies developed over time and technological change, has devolved into standard practices designating efficiency as primary to all other concerns. Technology's ability to facilitate, expedite, and often generate results exacerbates the condition, leaving little authority for the passive contemporary architect.

Study of the synagogue wall showed that the human eye's ability to distinguish a small change between two adjacent stacks decreases significantly as the absolute angle of rotation increases: a one degree shift between two stacks rotated forty-five degrees from the plane of view is imperceptible whereas a half-degree shift between two stacks lying nearly in the viewing plane is readily visible. As such, a linear rule determining the transformation leaves much of the wall's transformation inconspicuous.


TEST CELL BUILDING

To examine this property of the wall type, a non-linear alternative was adopted for the wall project's plan. Initially, the wall assumed the shape of a hyperbolic curve, which by its very geometry provides an exponential change in the ratio of its coordinates. As a consequence, the shifting of the blocks would be visible over the entire length of the wall. Additionally, the hyperbola allows for a simple translation of the stacks to provide the shift in plan while maintaining the visual effect. However, utilizing a non-linear shape presents the challenge of finding a mathematical expression that describes the desired curve so as to reliably provide the means to construct the plan at full scale and to render it in discrete units.

To aid in the process of description, a spreadsheet was developed that provided an output graph of the curve generated by the values. The strategy was to use this information to draft a rectilinear grid whose coordinates would be superimposed on the site. By manipulating the input values and the location of the origin, the curve's shape could be altered to one approximating the desired architectural form.

y	X	Theta	y	x				
-30.0	1	88.09	-30	18.95	57.72	-26	16.42	57.73
-15.0	2	82.41	-27.13604	20.95	52.33	-23.17698	18.42	51.52
-10.0	3	73.30	-24.77124	22.95	47.19	-20.90695	20.42	45.68
-7.5	4	61.93	-22.78557	24.95	42.40	-19.04193	22.42	40.34
-6.0	5	50.19	-21.09462	26.95	38.05	-17.48239	24.42	35.60
-5.0	6	39.81	-19.63731	28.95	34.15	-16.15897	26.42	31.45
-4.3	7	31.48	-18.36834	30.95	30.69	-15.02182	28.42	27.86
-3.8	8	25.11	-17.25341	32.95	27.64	-14.03419	30.42	24.77
-3.3	9	20.32	-16.26609	34.95	24.96	-13.16841	32.42	22.11
-3.0	10	16.70	-15.38566	36.95	22.61	-12.40325	34.42	19.82
-2.7	11	13.92	-14.59564	38.95	20.54	-11.72213	36.42	17.84
-2.5	12	11.77	-13.88278	40.95	18.73	-11.11192	38.42	16.13
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-1.9	16	6.68	-11.61389	48.95	13.35	-9.196898	46.42	11.21
-1.8	17	5.93	-11.158	50.95	12.35	-8.817018	48.42	10.32
-1.7	18	5.29	-10.73654	52.95	11.46	-8.467275	50.42	9.53
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-1.4	21	3.89	-9.643766	58.95	9.29	-7.56682	56.42	7.64
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-1.2	25	2.75	-8.491412	66.95	7.23	-6.627134	64.42	5.87
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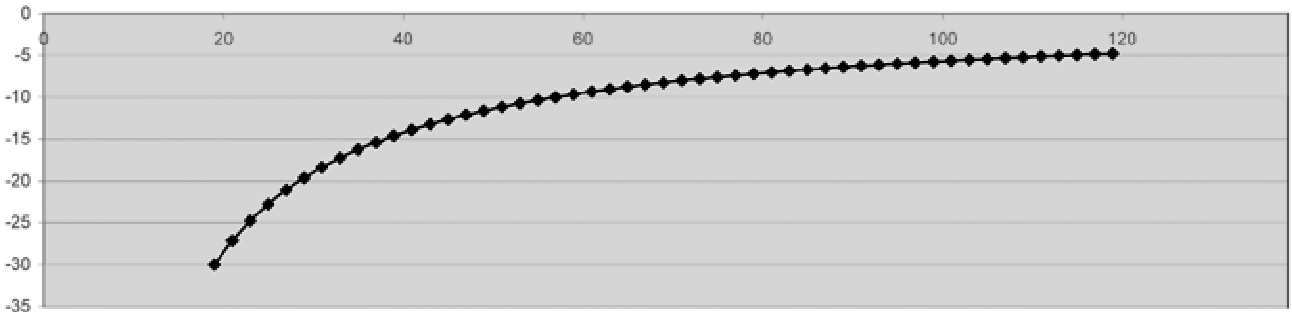
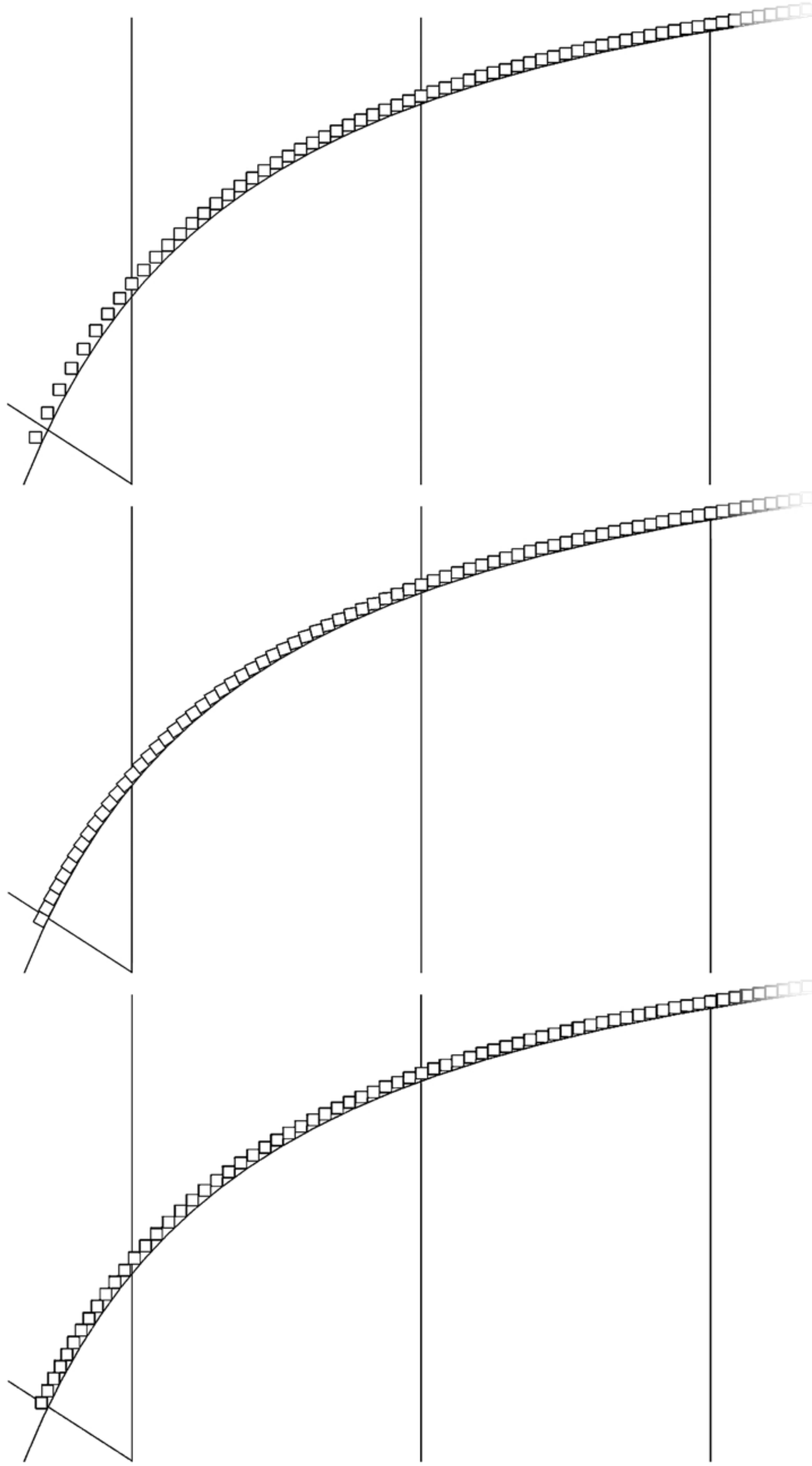
-0.9	35	1.40	-6.53824	86.95	4.30	-5.057095	84.42	3.43
-0.8	36	1.33	-6.391231	88.95	4.11	-4.94006	86.42	3.27



An additional challenge presented by the use of the hyperbola is evident at the curve near the focus. As the blocks translate to meet the curve, the stacks no longer overlap one another and the wall becomes discontinuous. By applying additional transformations to the stacks such as rotation or additional translation, workable solutions to this constructive problem were found. However, a methodological problem remained.

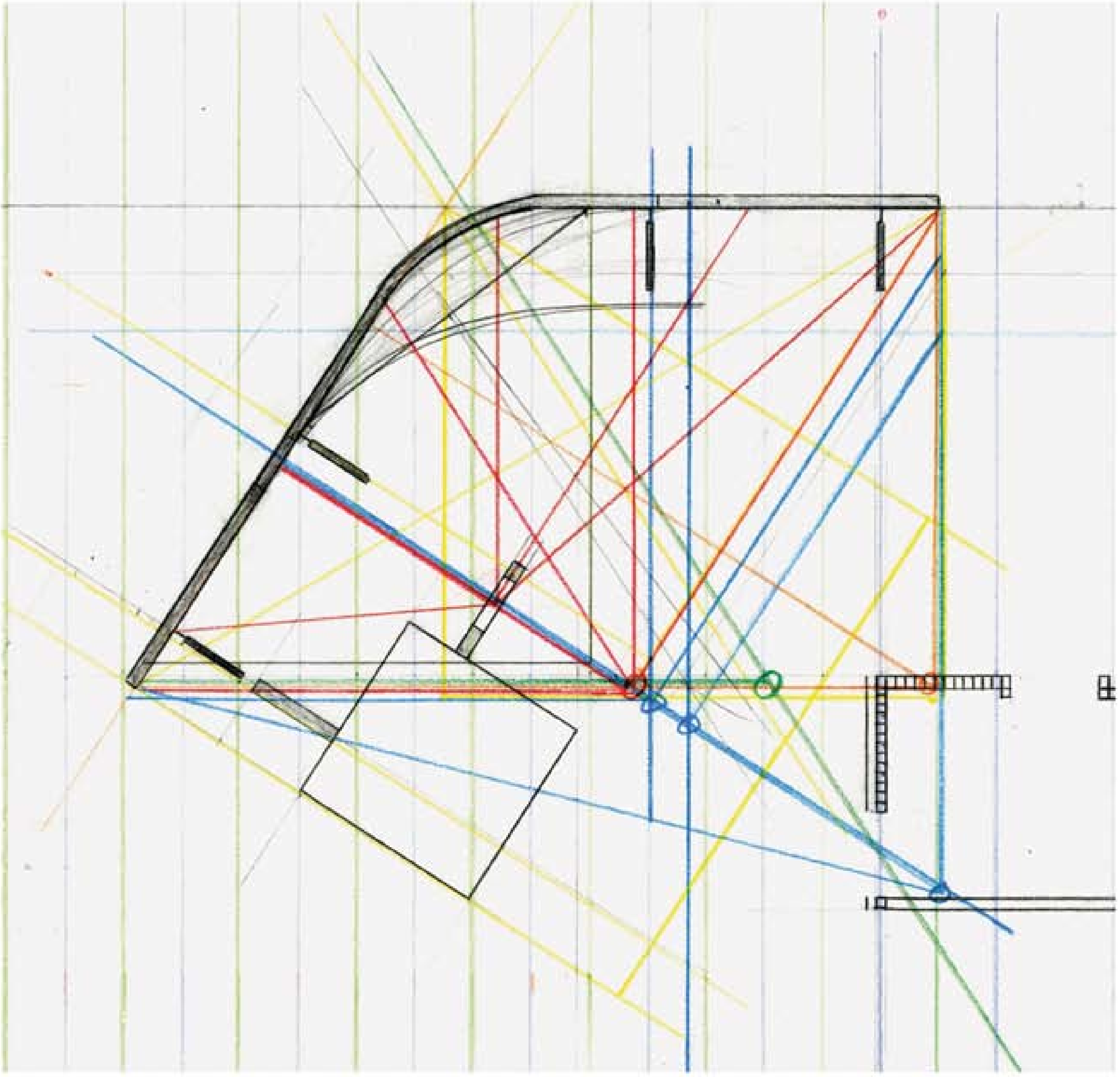
While the desired form began as a sketch, it had been reduced to an iteration. The sketch contained the evolution of the transforming wall, the acknowledgment of the site conditions, and the curiosity of the architect. On the other hand, the graphed solution and all of its derivations were the outcome of a series of algebraic and quasi-geometric gymnastics, lacking the embodiment of an architectural and constructive idea. To reclaim the qualities lost since the original sketch, a new plan was developed.



After reconsidering the existing Test Cell building and the nearby Concrete Cube building under construction, a simplified approach for designing the plan was adopted that structures the outdoor space between these buildings. The revised plan became two straight sections, each parallel to a face of the other buildings, joined by a curve.

The most effective conception of this wall is one where the plan and the rule governing the blocks' transformation exist simply and symbiotically; form and construction depend on and demand of one another. The blocks transform by aligning their faces normal to lines radiating from a common focus point. By moving the location of the focus, the 'flat' areas in each straight section move and the frequency and extent of the rotation can be altered. For constructive reasons*, a minimum block overlap of two and one-half inches was established. Interestingly, the angle between the two straight sections provided an angle that, at certain focus locations, provided the required overlap at desirable termination points for the wall.

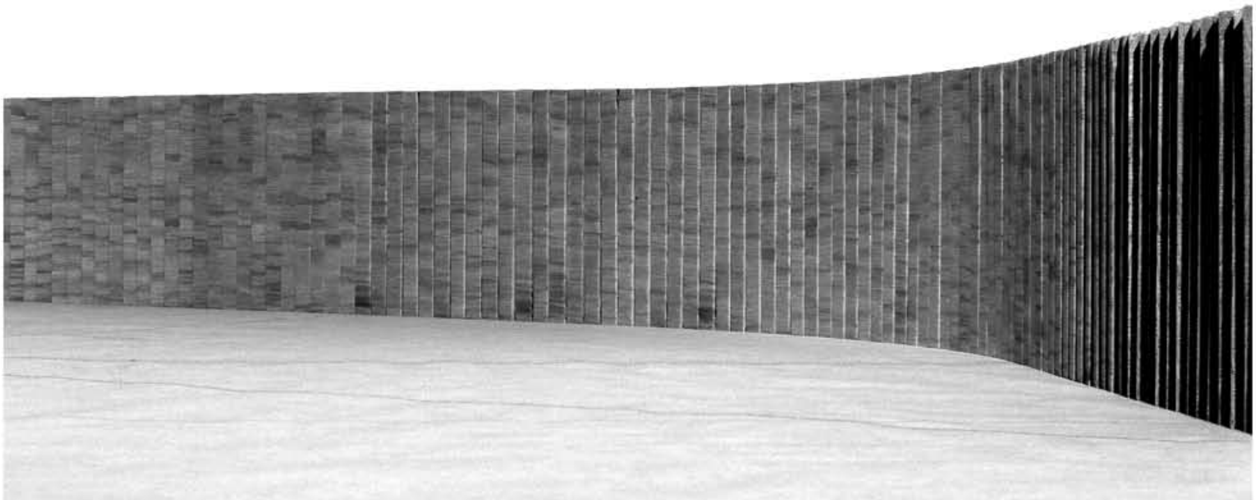
*The block has a wall thickness of 1-1/4 inches, therefore the minimum material on either side of any notch was set to this amount corresponding to a minimum overlap of 2-1/2 inches



Despite starting this plan with a renewed architectural claim, once again the apparent strength of digital technology to rationalize the complex appealed to this process of refinement. Drafting software provided the ability to accurately 'sketch' alternative focus locations and consequent block transformations, but again the process soon devolved into iteration, an especially time-consuming process as each stack must be rotated then aligned to the previous stack using several computer operations.

To improve this process, a large physical model was constructed that allowed for considered changes to be made quickly and the effects able to be analyzed qualitatively, without the hindrance of digital-decimal accuracy. To provide control and semi-permanence to the model, each wooden stack had small but powerful magnets inserted into its base and the model was assembled on a ferrous surface.

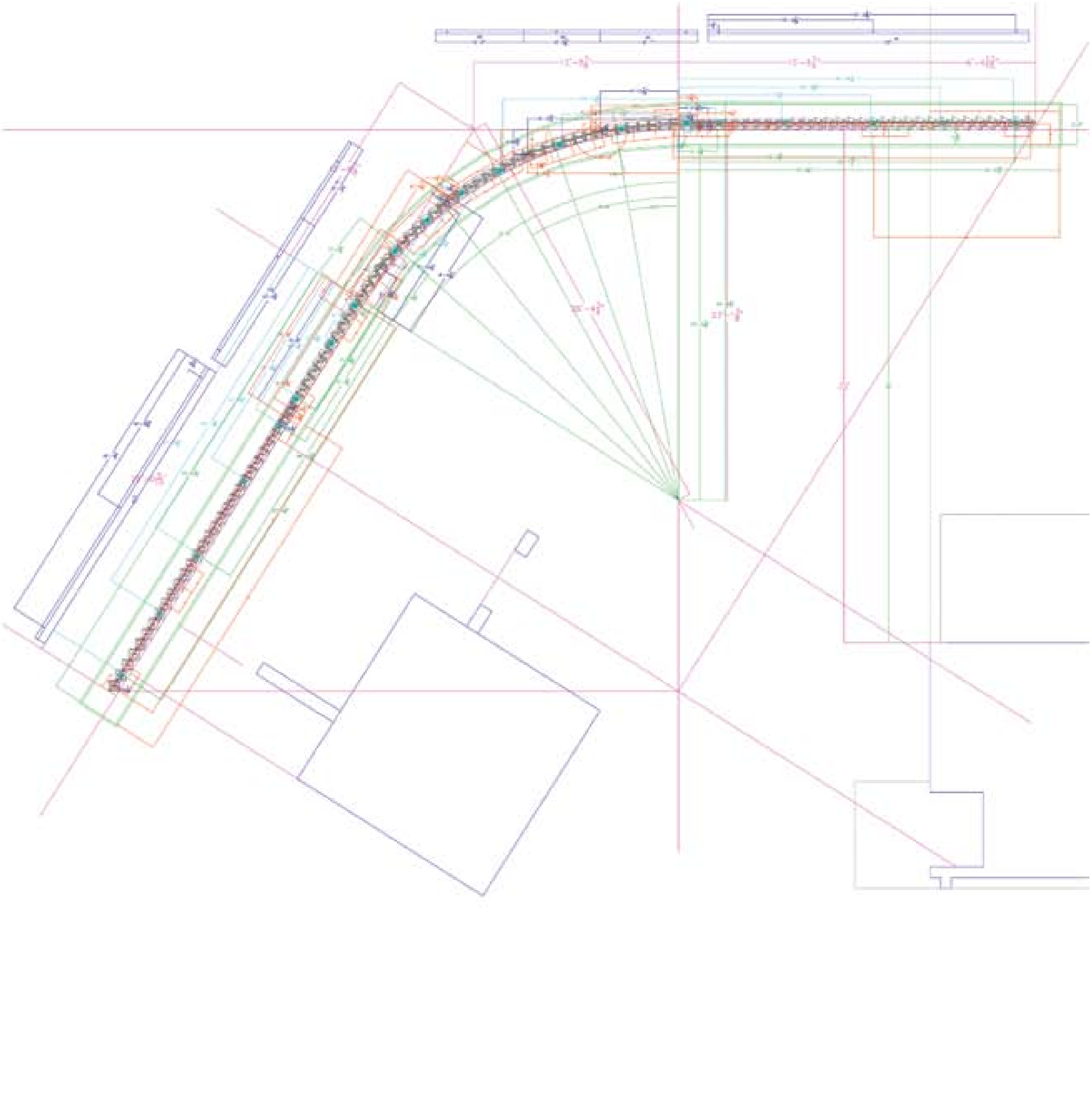




THE POWER/PERIL OF PLANNING

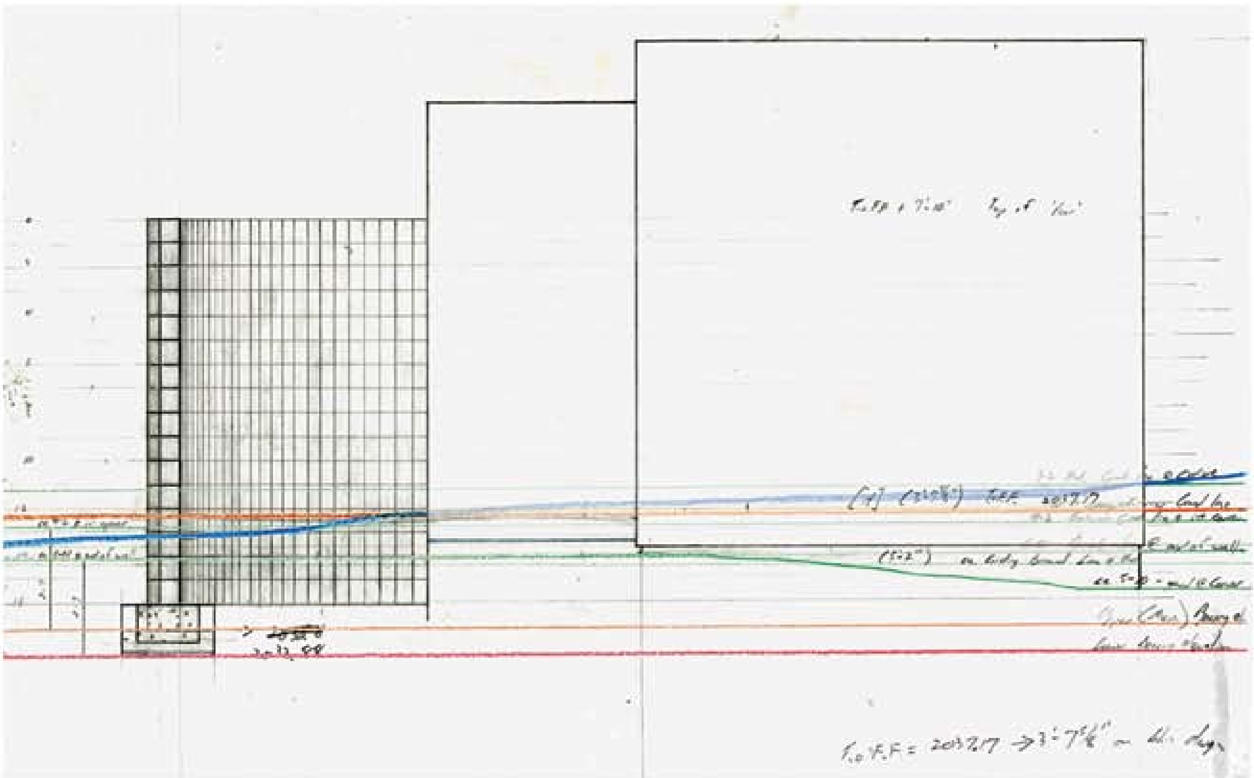
A combination of innate capability and experience-wrought ability enables the architect to effectively anticipate problems and propose solutions. Implementing sound practices and reasoned procedures to govern design work minimizes the dependence on good fortune determining the outcome of building activity. However, no amount of advance planning can save the architect from the frailty of material, the myopia of human intention, and the unpredictability of nature. To rely on contingent successful outcomes is as perilous as leaving success to chance alone.

Once the plan's design was finalized, the idealization present in the model was rationalized for construction. For the first time in the course of the project, software proved legitimately indispensable. Whereas earlier in the design programs were being used as Computer Aided *Design* tools - a tenuous path - now, more appropriately, software was used as a Computer Aided *Drafting* tool. The tedious rotation and alignment of each stack, critical to obtaining the accurate dimensions required to locate the notch and essential to the success of the construction, is only realistically made possible with software.



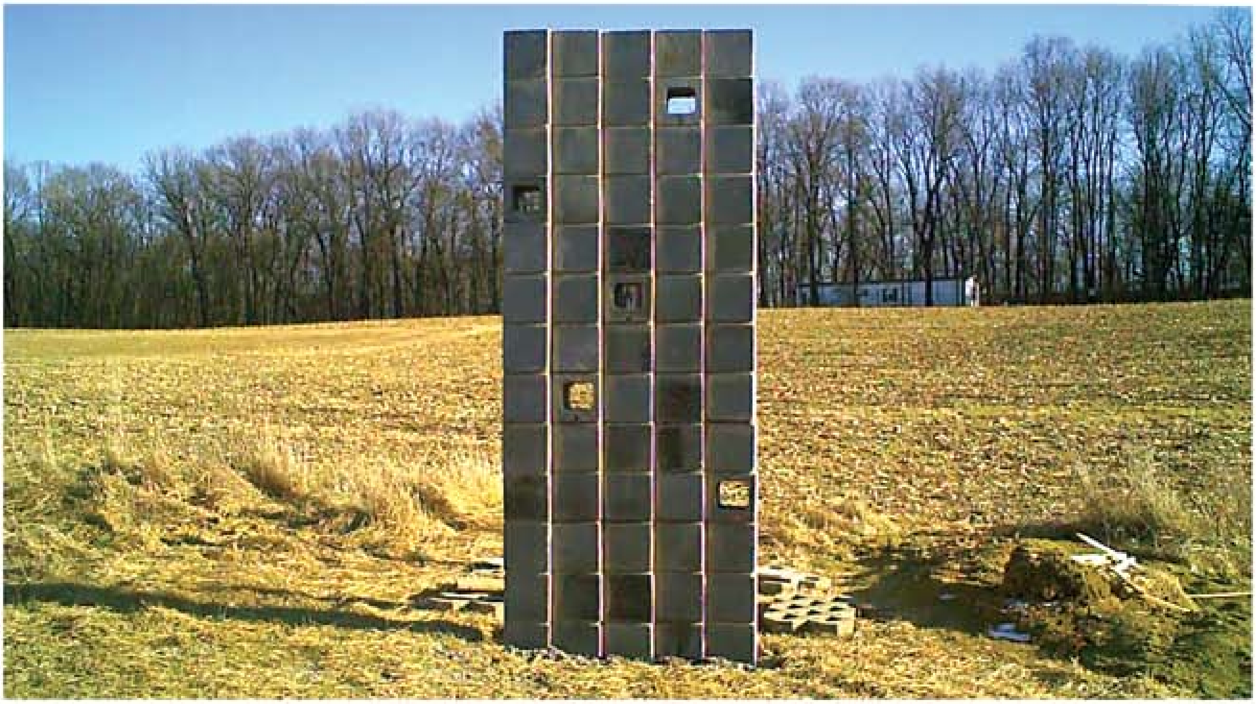
Although the design had achieved some degree of simplicity in its organizing logic, it remained a fairly complex system of construction sequence and tolerance. To this end, the technical drawings required to realize the wall were extensive, though not exhaustive. Several unique layers of information were drawn, approximating the sequence and extent of construction activities. Separate drawings for each stack, 107 total, were drawn for use during the notching process.

The site conditions were analyzed to determine the bearing elevation of the foundation and the finished height of the wall. Based on several spot elevation measurements, a site section was drawn and target finished grade elevations ensuring both adequate soil cover for the foundation and drainage for water runoff were established. Additionally, these section drawings provided a means for determining a finished wall height appropriate to the Concrete Cube and Test Cell buildings.


T.o.F.F = 2037.17

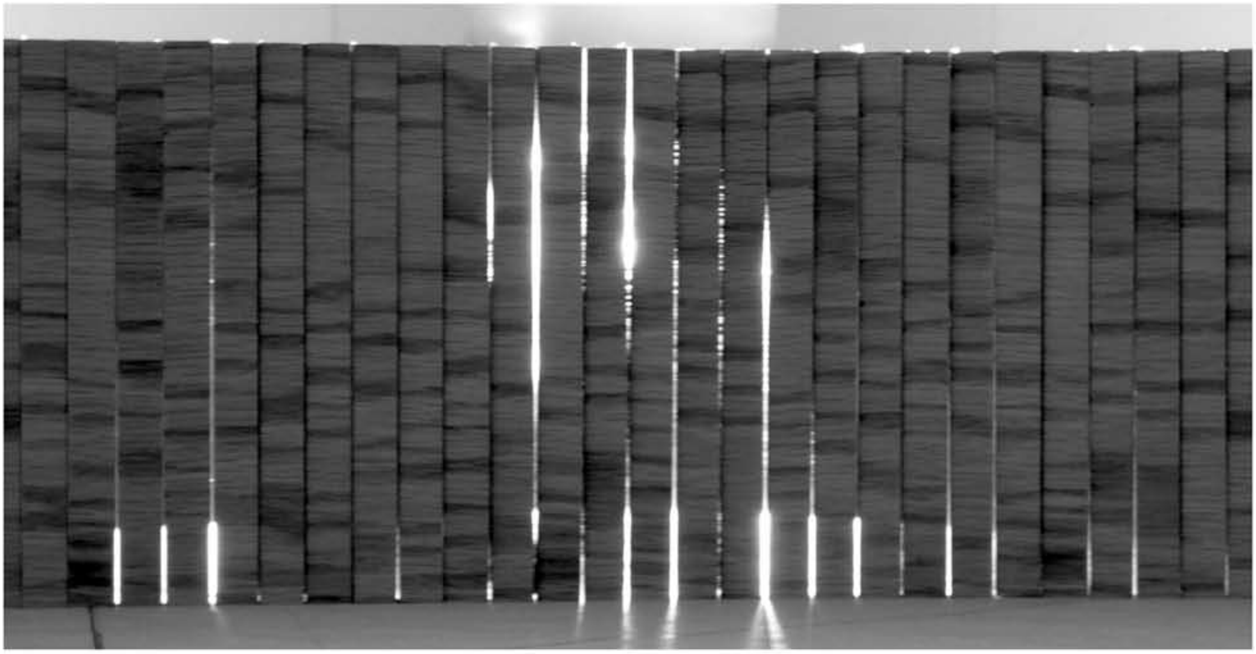
Parallel to the development of the wall plan and site section, several studies were assembled to investigate the material and constructive nature of the built wall itself. The first study was built using a traditional block and mortar assembly, built to a height approximating the finished height of the project. This study highlighted the effectiveness of the proposed notch-and-strap method, as the units required little measurement during lay-up and the completed network performed as expected. However, the first study also highlighted the temperamental nature of the assembly process.

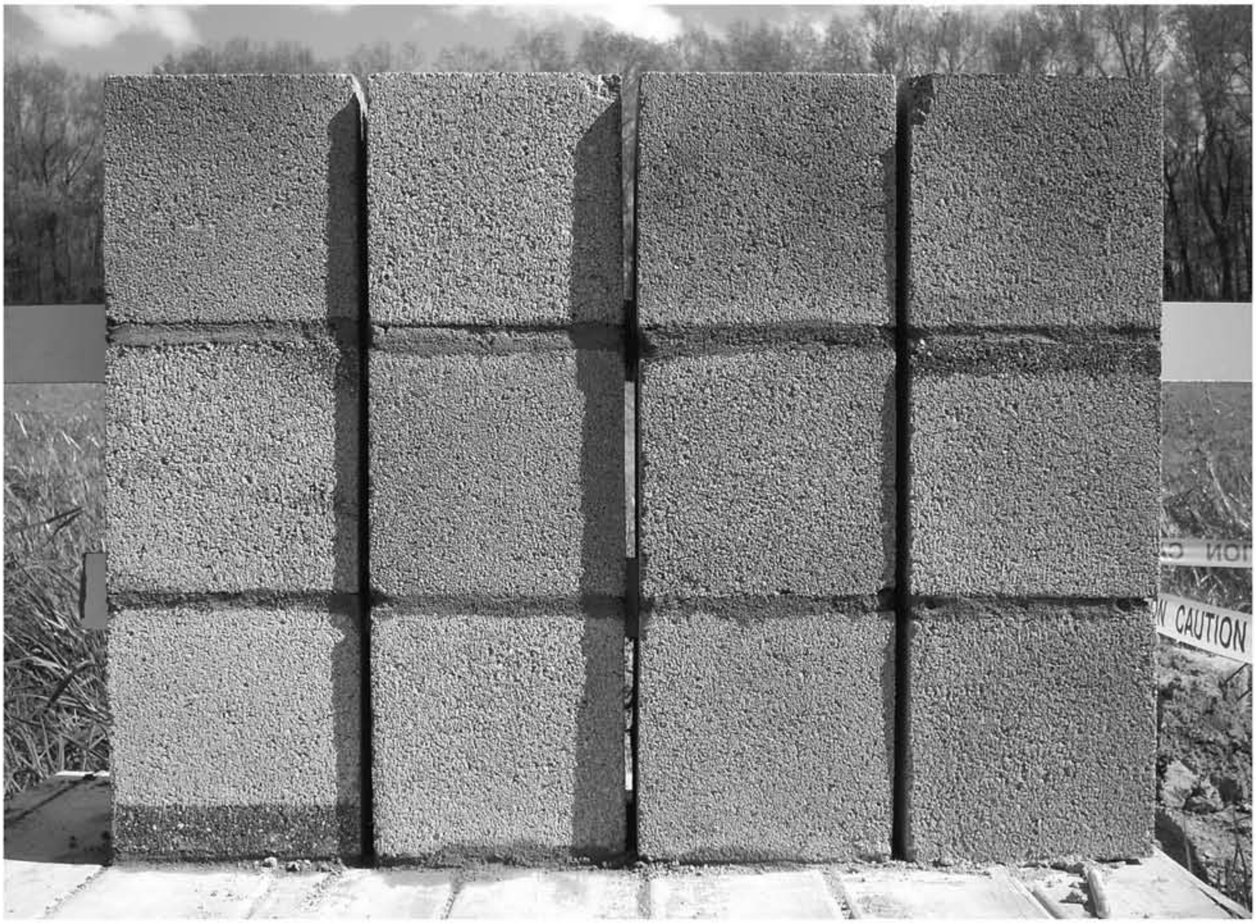
The same devices and strategies employed to provide the wall's fineness also ran the risk of causing substantial, potentially catastrophic failure of the system. Even with a limited width of five stacks, poor diligence in maintaining properly spaced and leveled units led to the mock-up being out of plumb by over in inch over its eight foot height. While the system incorporates compensatory options at each step along the way to correct such deviations, they proved insufficient in reclaiming the work when left unattended.



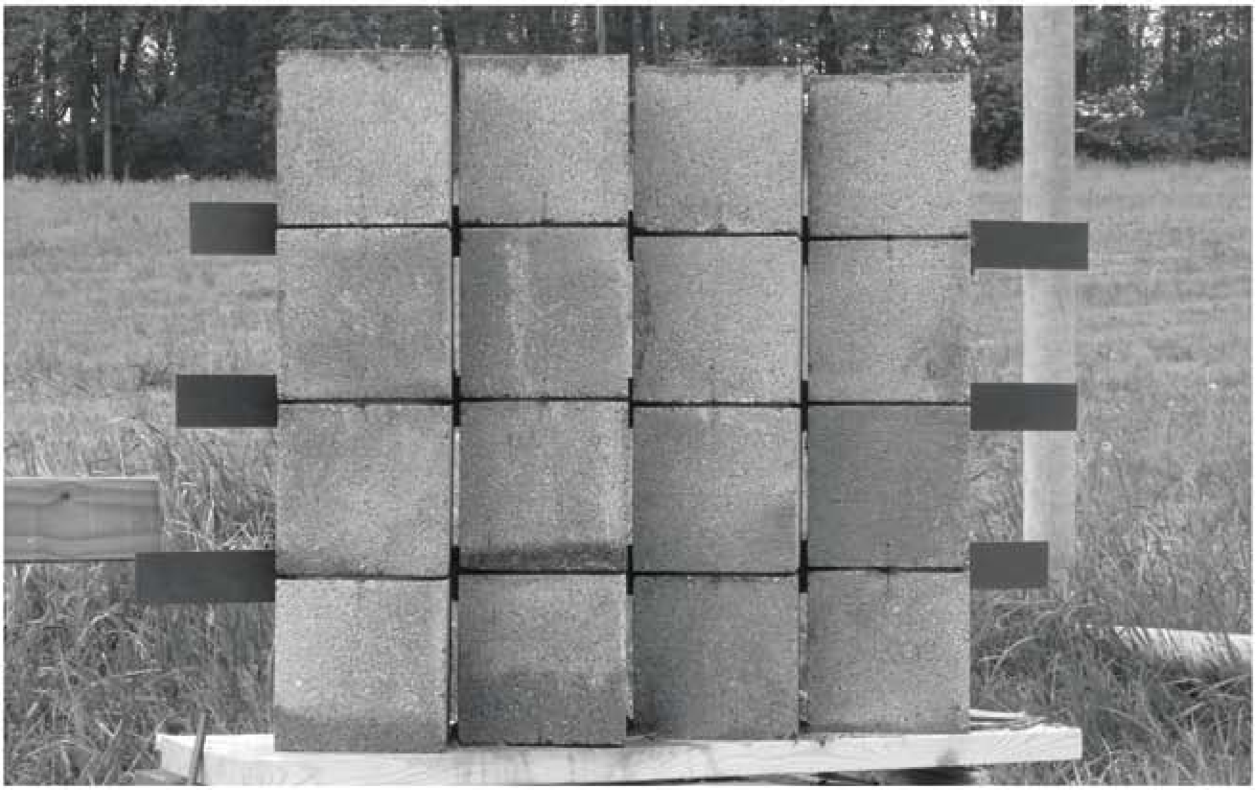
While photographing the wooden model, slivers of light were captured penetrating the stacks at their imperfect joints, leading to a second study. Technically the head mortar joints perform no meaningful work in the assembly and, as such, their removal highlights the unconventional nature of this wall type by revealing the straps integral to the construction. Simultaneously, removing the head joints brings the design and the object one step closer to the clarity and symbiosis being sought throughout the process.

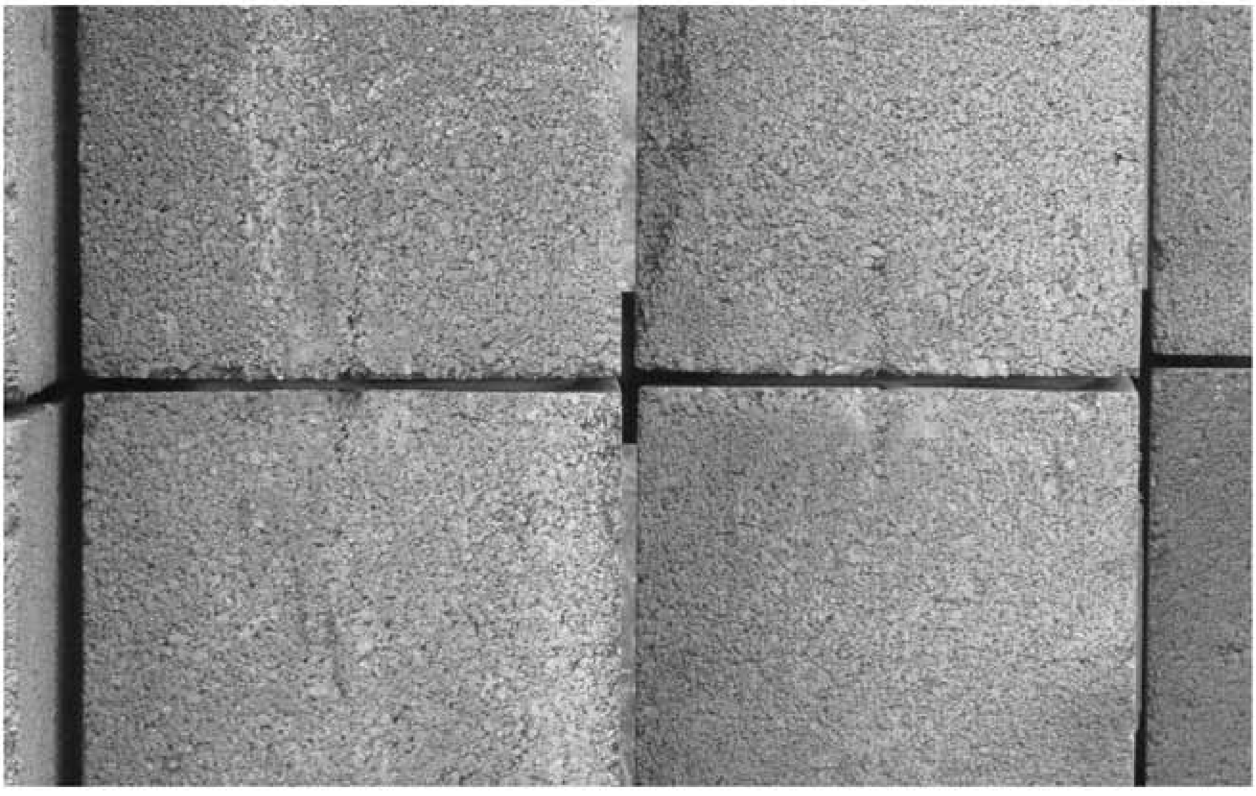
Examination of the second study revealed that the wall type had, at least for this particular application and as a consequence of decisions made to this point, moved completely away from conventional masonry and mortar construction. The absence of a head joint posed the question of whether mortar was required anywhere in the assembly. Technically it was not required, as its function had been reduced to sealing the continuous vertical core to contain the grout that would eventually fill the core.




CAUTION

Removing the bed joint fundamentally changed the qualities and properties of the wall, as what was in the first study a range of individually placed units set in an imperfect mortar matrix was now a precise system of shadowy vertical columns and revealed horizontal lines. The third study offered both the promise of a refined object and the potential for an exceedingly demanding project.





COMPULSION AND PERSEVERANCE

A spider is given no training in web making, nor is it given a mandate to make them. By its very nature, it is compelled to spin webs. If through weather or intervention its web is destroyed, the spider will craft a new one without instruction or hesitation. The first incidence of poor weather or failed planning will quickly remove the luster from construction for the elective builder. The impetus to undertake, continue, and ultimately complete a voluntary project must come from the builder's own resolution.

Nothing worth doing comes easily
Nothing challenging goes according to plan
Therefore,
Nothing worth doing goes according to plan

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Please see Art & Architecture Library copy of *A Wall Building*
for additional photographs of project

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Please see Art & Architecture Library copy of *A Wall Building*
for additional photographs of project

LEFT All images are stills taken from video footage captured by the author on a pocket video camera.

1 The blocks are normal weight concrete masonry half-units, 8” x 8” in nominal size. They include an integrated sash notch on one face, typical of half-units. The notch provides a facile visual reference for keeping the units sorted and oriented correctly.

3 The wall type utilizes a notch-and-strap method to regulate the blocks’ transformation and provide stability to the stacks. A modified table saw and notching jig provide the builder with the requisite control and efficiency necessary to accurately cut the notches into the units.

5 To provide a seal in the stack assembly during the grouting process, a ring of sealant is applied to the top of the unit in the preceding course prior to setting block in the current course. The sealant is applied recessed within the joint to provide a reveal at the surface of the wall.

7 The existing site is composed of mounded earth excavated from the construction of a nearby research complex to the North. To the South, a cornfield rises to meet the bounding edge of Hoot Owl Woods. The North/South wall of the project is aligned to the Concrete Cube project (under construction), the other straight section is parallel to the long dimension of the Test Cell building.

9 An initial layout of the site was performed, establishing the lines governing construction and those to which the blocks will ultimately be aligned.

11 The site was graded to establish the rough elevation of the interior (i.e. Cube) side of the wall.

13 To give the wall a degree of permanence and reliability, the foundation was excavated below the local frost depth.

15 #5 bent reinforcing dowels were placed in the footing at every other stack. Due to the accuracy required for their placement, pre-drilled 2 x 4’s were fixed to the formwork to locate the dowels during casting.

17 Based on the loading conditions of the wall, a suitable foundation was designed and placed. To aid in the location of the dowels and embed plates, the foundation was board formed rather than earth formed.

19 Embed plates were cast into the foundation to provide a weldable fixing point for the first course strap.

21 Three steel columns carry each roughly twenty foot strap, acting as storey poles for setting the units.

23 Setting the first course is critical to the speed and accuracy of all subsequent block placement. The units are leveled and aligned temporarily using shims before the cores are grouted solid and the shims removed.

25 The notch-and-strap system provides controlled repeatability of action and variability of outcome, but requires significant patience, planning, and attention during design and construction.

27 Inclement weather, material delays, and other unforeseen adversities conspire to challenge the builder’s resolve and highlight the difference between intention and realization. This difference *is* building.

RIGHT

All images are the work and property of the author unless otherwise noted.

2	Dual projection drawing from plan. ca. 7,000 individual lines. Ink on Velum.
4	Gramazio, Fabio. *DIGITAL MATERIALITY IN ARCHITECTURE: GRAMAZIO & KOHLER*. Lars Muller Publishers, Baden, Switzerland, 2008. Used with permission of Fabio Gramazio, 2011.
6	Drawing of isometric projection of synagogue project. 12 feet in length. Pencil on bond.
8	Plan sketch of hyperbolic wall scheme. First drawing of thesis project. Note location of Concrete Cube and Test Cell buildings. Colored pencil on printer paper.
10	Screen captures of portion of Excel spreadsheet used to generate hyperbolic scheme. JPEG.
12	Screen captures of various Sketch-Up models. The top image illustrates the discontinuity of the units under a strictly translational scheme. The middle image adds rotation to the translation and the bottom image adds transverse translation to the units near the focus of the curve. JPEG.
14	Sketch of various focus location studies to be translated to wooden model. At certain focus locations, the minimum block overlap was not maintained at the extreme ends of the wall. At other focus locations, the degree of rotation was too subtle to be readily perceived over the length of the wall. Colored pencil on printer paper.
16	Photographic study of sun's travel over the wall. This sequence occurs daily over a short span of a few hours.
18	Overlay of all layers used for construction documents simultaneously. PDF from AutoCAD.
20	Site section from spot elevations superimposed on section drawing at end of wall and Cube. Pencil on velum.
22	First mock-up completed January, 2011. Block salvaged from disused materials from construction of nearby research complex. First mock-up shows one block in each stack turned on its side. This additional layer of visual information was discarded in the final design.
24	Second mock-up completed April, 2011. Mortar bed joint, removed head joint.
26	Third mock-up completed May, 2011. Mortarless construction.
32	Construction of the wall project began June, 2011 and is ongoing as of the defense date of August, 2011. The project is 107 stacks wide (ca. 80' in length), 16 courses tall for a total of 1,712 units.

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PERUSALS

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