Door of Return Museum of Senegal

By

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Master of Architecture in Architecture

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Abstract

Door of Return Museum symbolizes a synthesis of environmental building systems (EBS) and extends Senegal's cultural fingerprint along the Atlantic shoreline. Benefits of EBS technologies include ecologic imperatives, coexistence with nature, and transcultural synergies to name a few. Architecturally speaking EBS is the purposeful integration of environmental systems in a harmonious manner that maximizes passive energy solutions to the fullest extent possible. When doing so problems exist both environmental and contextual yet resolutions can be rewarding to the client, community, and most important the end-user. Overcoming problematic challenges maintains sensitivity towards nature, cultural history and vernacular typology. Design methodology mitigates natural systems such as thermal heat transfer, daylight control, natural ventilation and thermal lag prior to incorporating mechanical systems. The paramount result is a contemporary museum that educates via its collection and economized performance systems.

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Acknowledgements

This effort would not be possible without the Creator including support of family and friends.

Overview

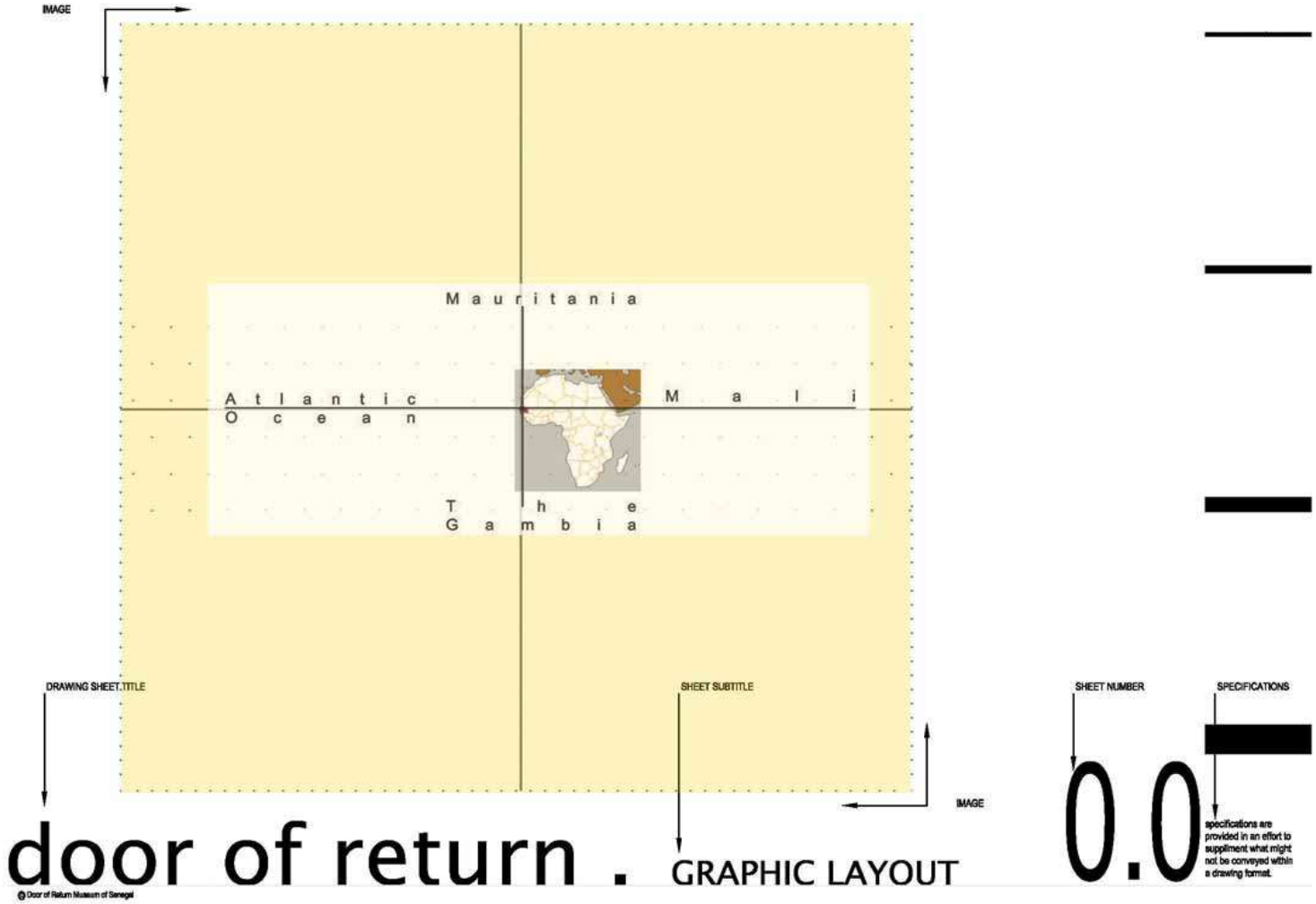


Figure 1 **Vicinity map of Sengal. Original image Courtesy: http://www.researchintouse.com/nrk/RIUinfo/map-img/Maps_Senegal_image001.gif (May 2003)**

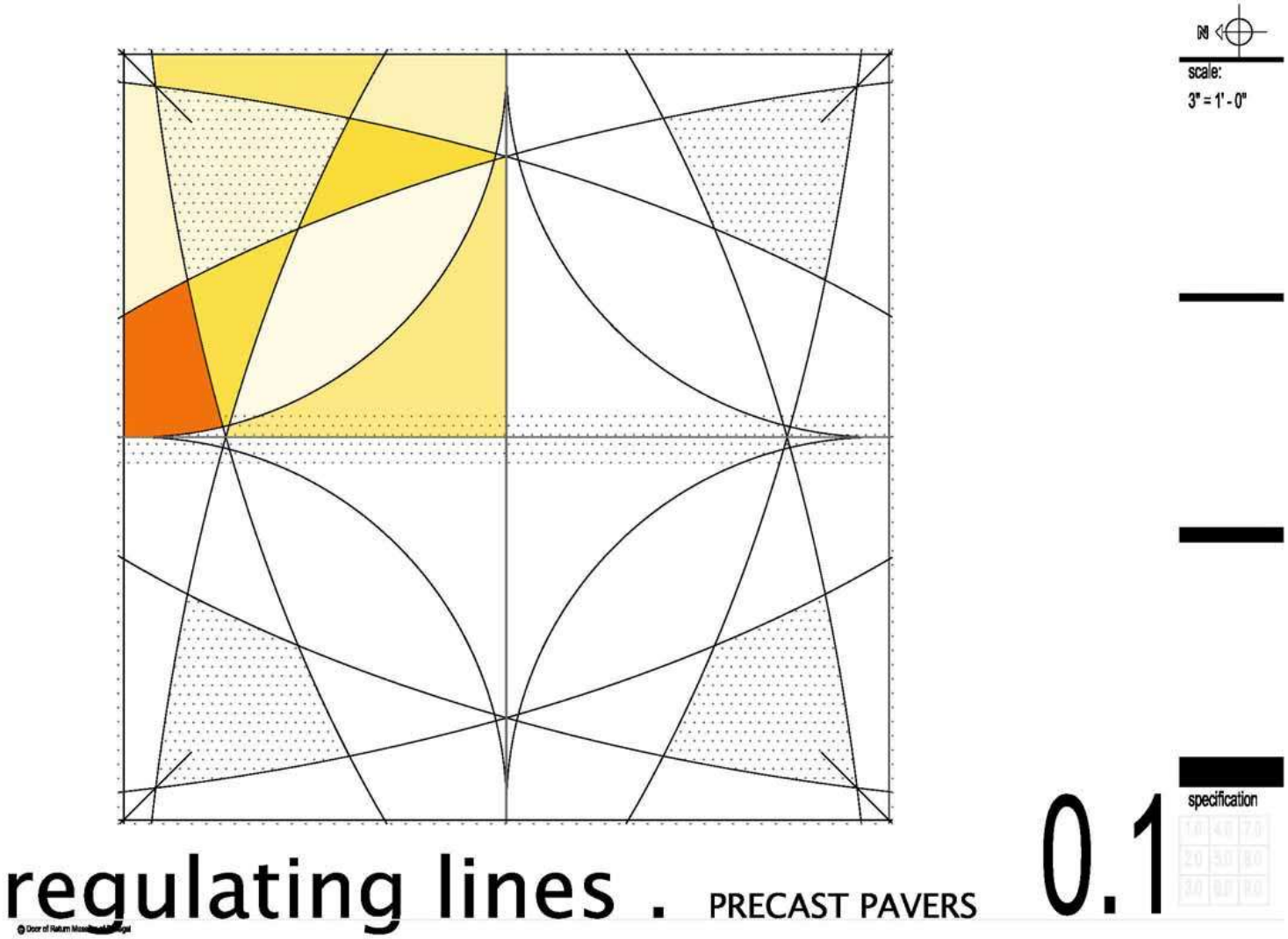


Figure 2 **Paving module and the regulating lines used to construct each paver.**

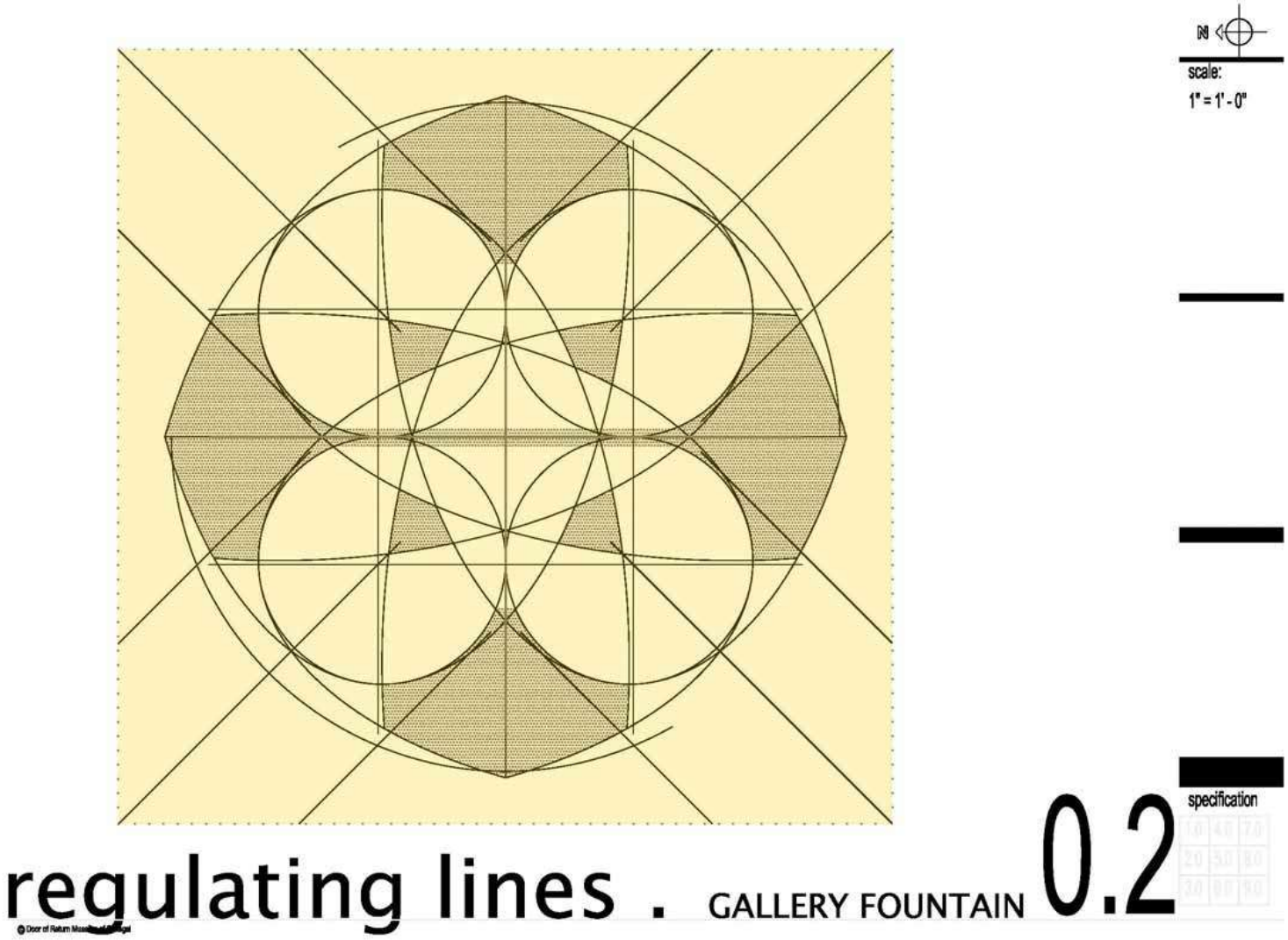
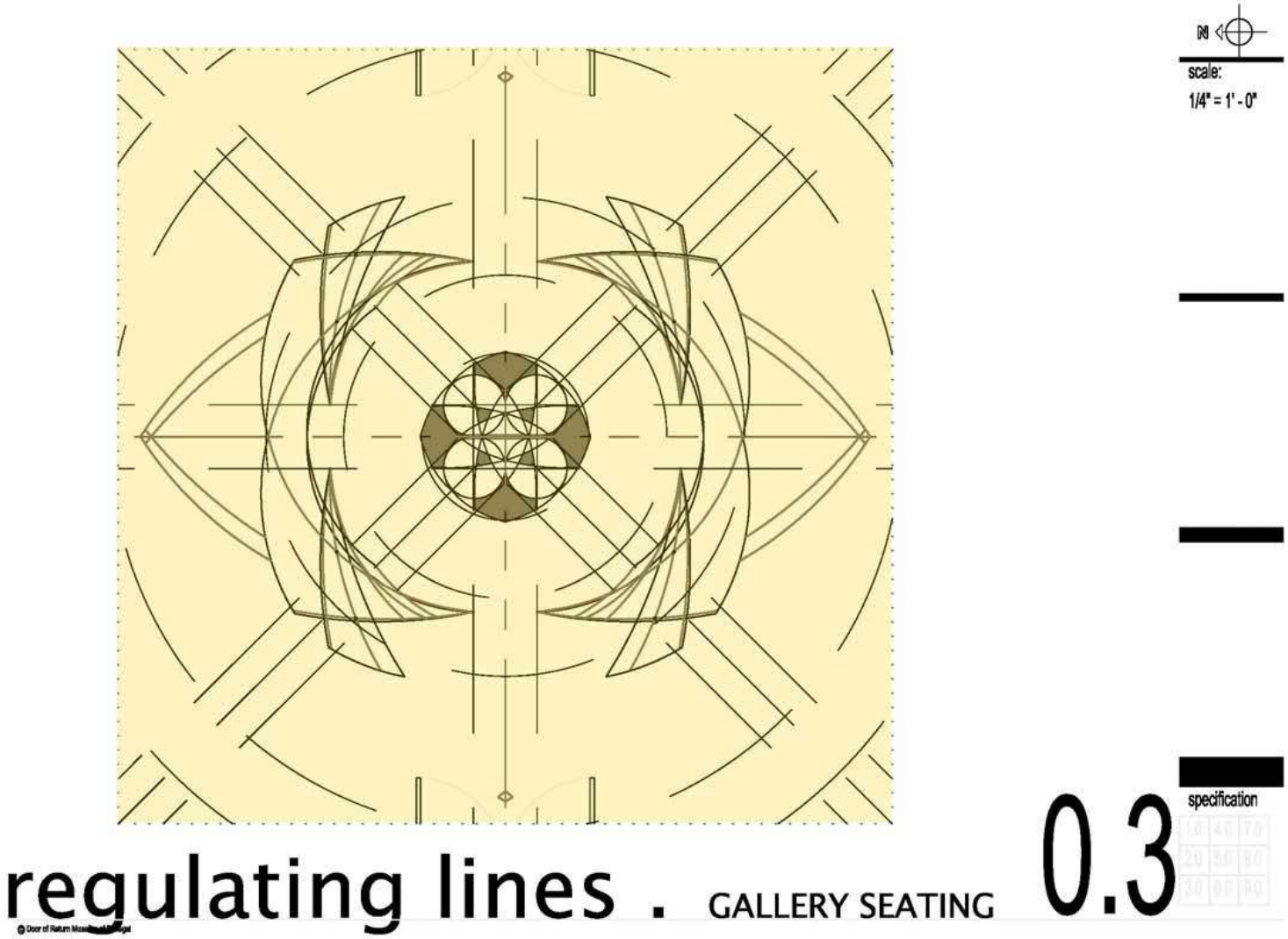


Figure 3 **Diagram of the gallery fountain. This is a centralized water feature in the middle of each art gallery bay.**



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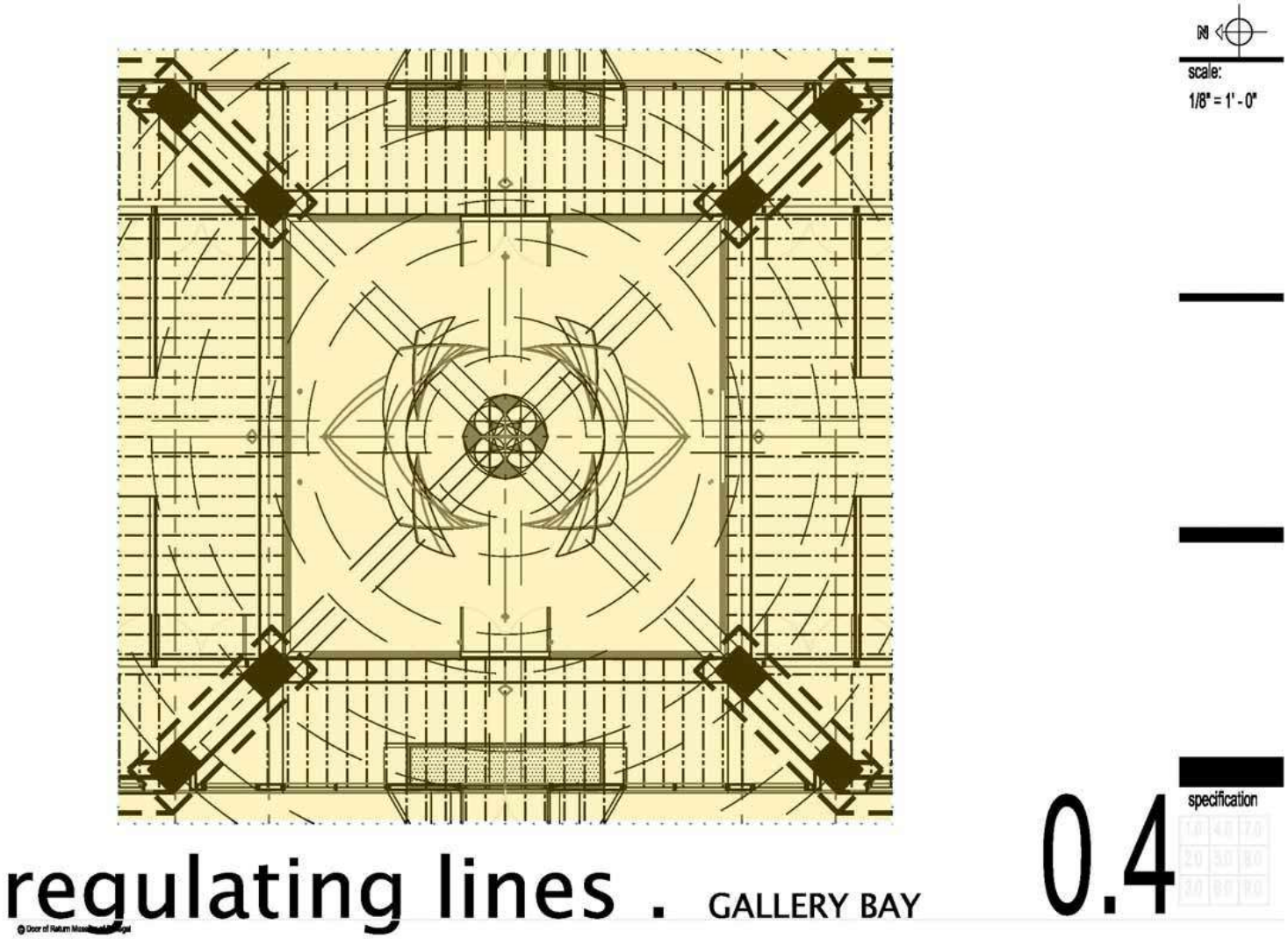

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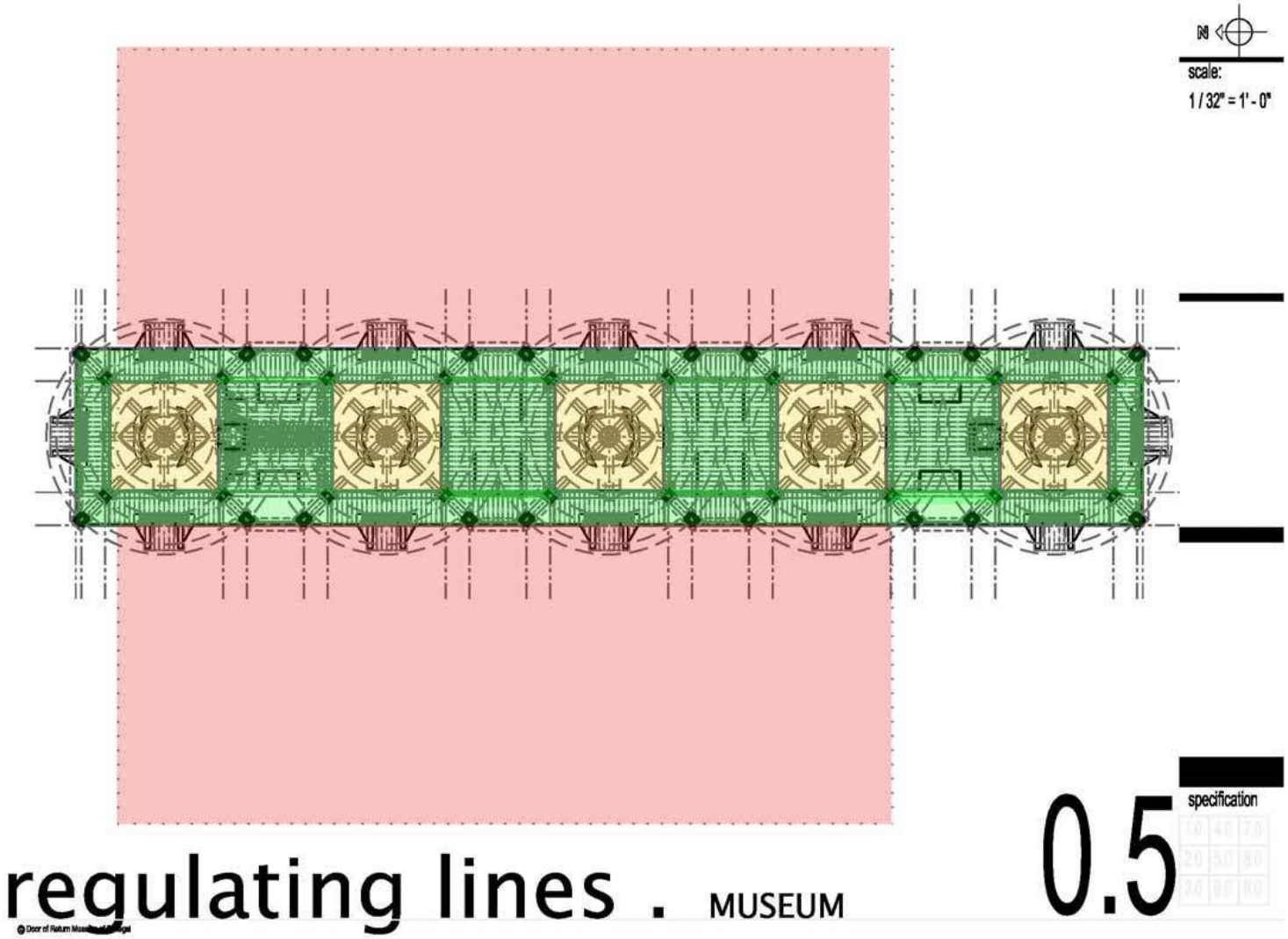

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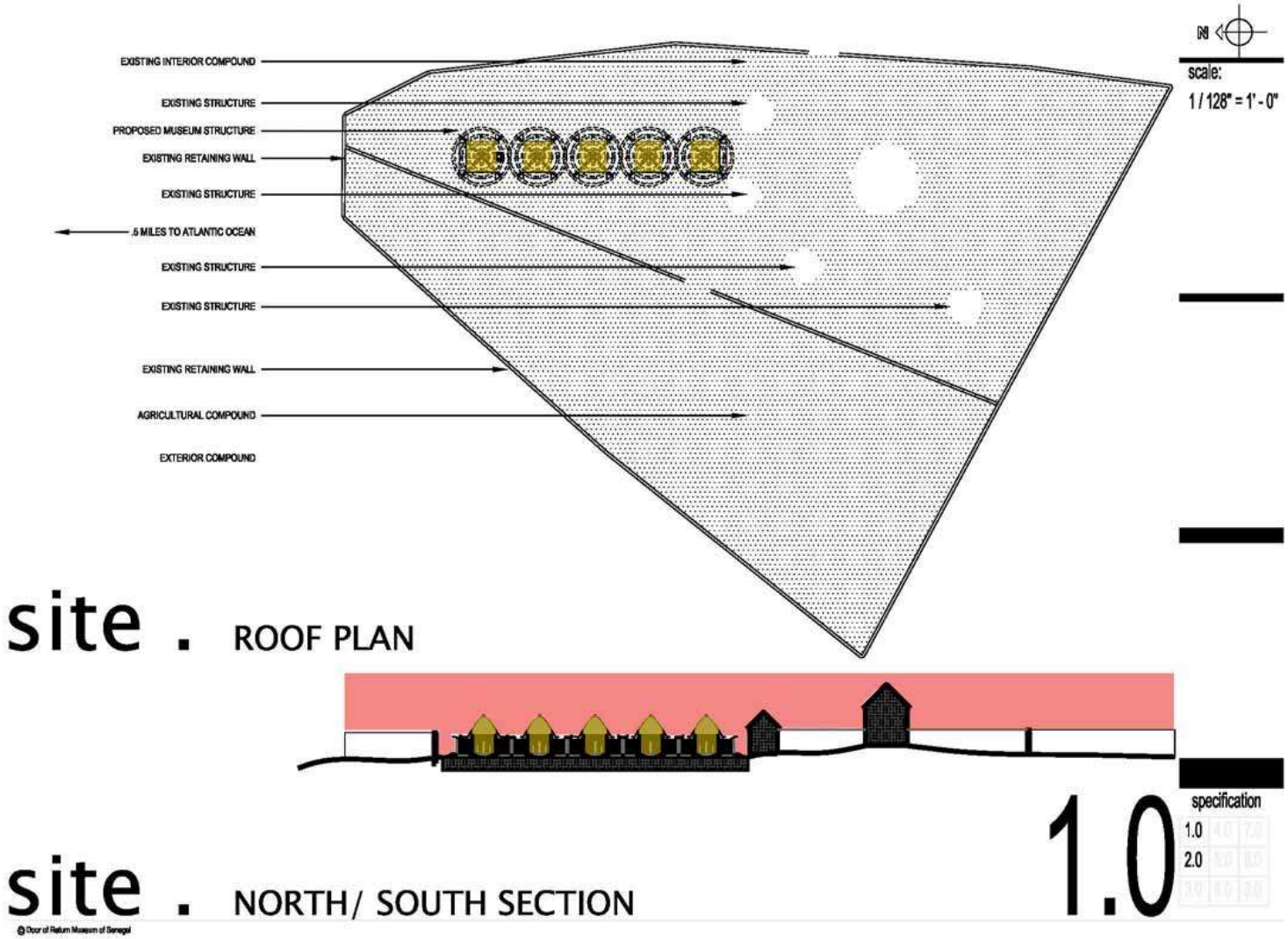

Figure 7 **Overall site plan and site section illustrating relationship between existing buildings and proposed design development**

Chapter 1 - Why Africa and Why Senegal

The practice of African architecture mandates environmental understanding and climatic response. However to blend these powerful issues takes an understanding of each within its own context separately then fusing specific elements in order to create harmony. This design process considers a number of solutions to the climatic problem of latent heat. We find some building standards practiced in Europe are suitable for African vice versa. Research draws from a diversified array of case studies in designing the Door of Return Museum of Senegal.

Environmental Building Systems (EBS) contextualize this thesis inquiry. This means research utilizes passive energy design strategies in order to optimize the structure's heating and cooling performance. What distinguishes this investigation is theoretical design integration such as organizational approach and spatial experience but also practicalities of building. The recipe for optimal building performance may appear simple in theory yet become elusive in practical application given a multitude of variables, albeit scientific, climatic, structural, or experiential phenomena beyond the designers control. Design success hinges on the ability to execute the aforementioned attributes consistently with specific attention towards detailing.

Senegal is a globally interconnected society where EBS capabilities stitch connections between seemingly unrelated archetypes. For example, an artisan pot in Morocco became the motivation for a pottery wall exterior façade in the museum. This idea was only possible after travel, research, documentation and architectural refinement along the building envelope. Inquiry herein articulates a number of different EBS interventions expressed in floors, walls, material modules and adaptation towards Senegal's climate. Some scholars classify EBS as "socially responsible architecture" when in fact this only tells part of the truth. EBS systems underscore technical performance and as well as economic viability qualifying this research for business as well as engineering inquiry. EBS passive designs reduce local and regional energy demand qualifying this investigation for regional planners and government officials alike. Lowering demand on energy needs has significant geo-political implications. EBS solutions create case-specific design integration and enhance air quality perhaps validating ethics as socially responsible.

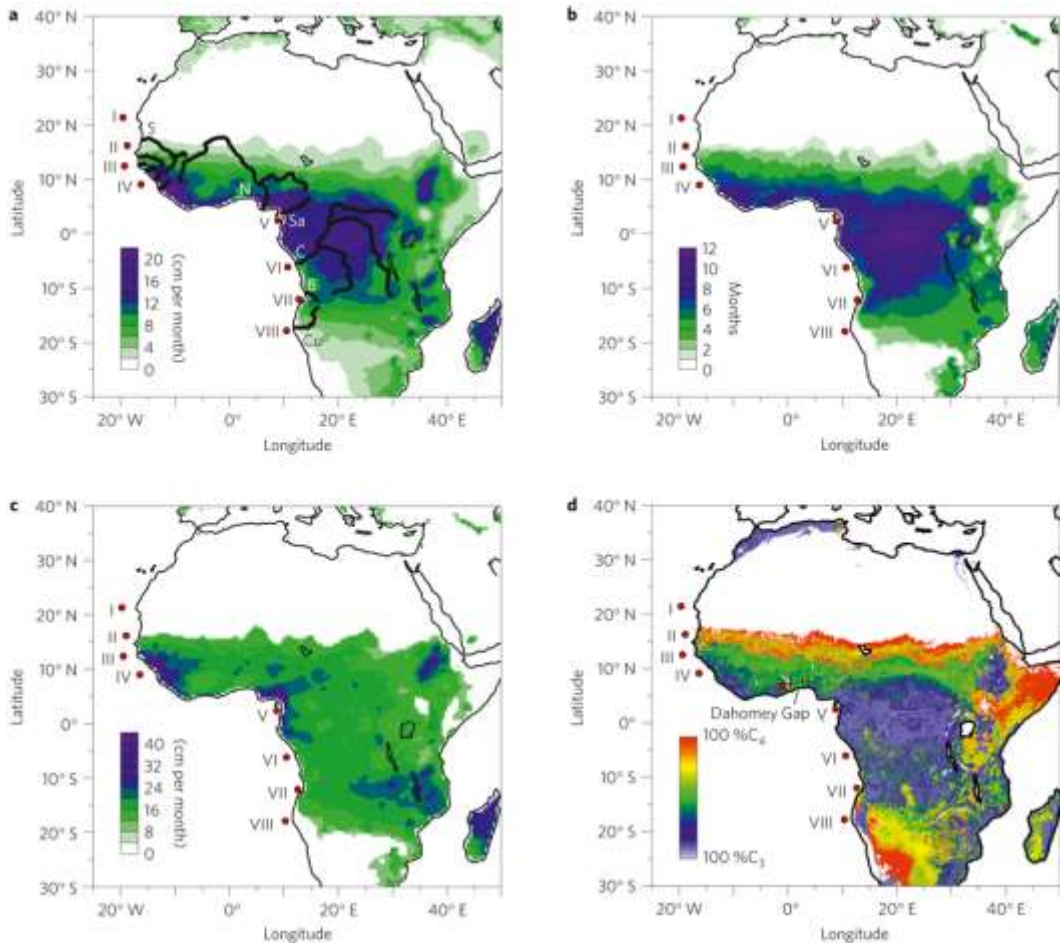

Figure 8 Regional Climatic Data for sub-Saharan Africa (White areas = no data).

(http://www.nature.com/ngeo/journal/v4/n1/fig_tab/ngeo1039_F1.html)

a, Mean annual rainfall (cm month^{-1}) for the period 1950–1999 (University of Delaware data set; http://climate.geog.udel.edu/ climate/). Senegal (S), Niger (N), Sanaga (Sa), Congo (C), Balombo (B) and Cunene (Cu) rivers are marked, as are smaller West African rivers. Red circles (I–VIII) represent the eight core sites (see Table 1).

b, Wet season length (number of months exceeding 10 cm month^{-1} rainfall; ref. 17).

c, Wet season intensity (mean rainfall of months exceeding 10 cm month^{-1} rainfall).

d, Modern-day vegetation type distribution (ref. 29),

Climate and Farming Imperatives

Senegal is located in what is termed the Sahel region. This characterization of the sub-Saharan climate is semi-arid. In recent years there has been a movement to integrate farming techniques of India, China, and Brazil within the Senegalese landscape. There have also been successful attempts to educate farmers particularly with the use of digital technologies that bring education to otherwise remote areas of the country. Environmentally speaking, solar farming has gained in popularity as a method of alleviating an overtaxed electric power system. On the Atlantic shoreline wind farming has been explored but the wide-spread use of this technology remains an untapped but extremely lucrative endeavor. Some architects in Senegal are exploring integrated roof systems in urban settings that allow urban farming. Historically the climate and fertile earth in conjunction with its proximity to the Atlantic Ocean allowed what is known today as Senegal, The Gambia, and Mali nations to thrive as trading enclaves within the western Sahel.

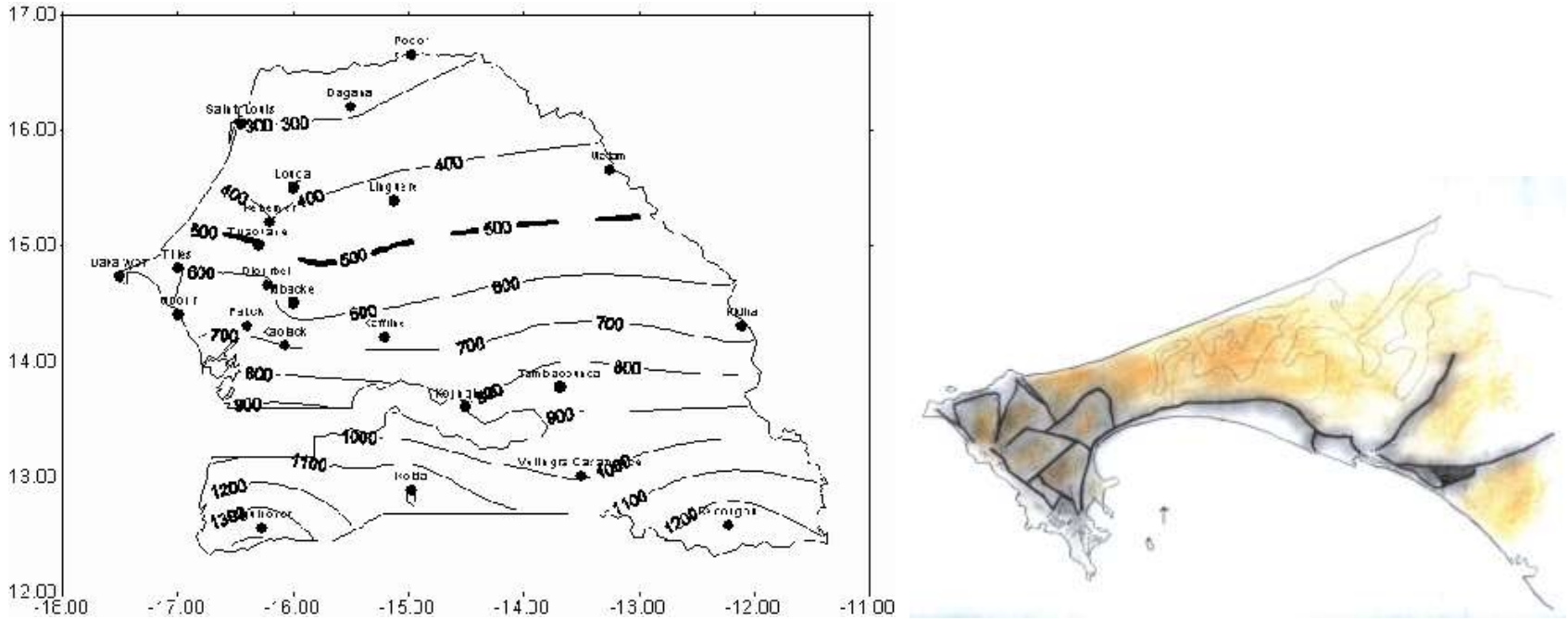

Figure 9 **(Left) Senegal topographic map. (Right) Pastel image of main roadway from Dakar to project site, shaded in black.**

Climate and Farming Imperatives

Month	Activity	Climate	Environmental Qualities	Notes
January	Second Harvest	Dry	Savannah	n/a
February	No data recorded	Dry	Savannah	n/a
March	Spiritual / Cultural Events	Dry	Semi-Arid	n/a
April	Spiritual / Cultural Events	Dry	Semi-Arid	n/a
May	Preparation of Land	Dry	Arid	n/a
June	Preparation of Land	Dry	Arid	n/a
July	Sow the earth	Rain	Tropical	n/a
August	Sow the earth	Rain	Tropical	n/a
September	First Harvest	Rain	Tropical	n/a
October	First Harvest	Rain	Tropical	n/a
November	Second Harvest	Dry	Savannah	Silt Deposit
December	Second Harvest	Dry	Savannah	Silt Deposit

Table 1 **Monthly climatic table illustrating the interrelationship between environment, activity, and climate.**

(http://www.iao.florence.it/training/geomatics/Thies/Senegal_23linkedp14.htm#T1.)

Environmental Problem Statement

The southern environment of Senegal is lush with green vegetation due to the humid weather patterns. The central region is filled with baobab forests a mature tree species which can significantly subdue high wind currents and provide a canopy shield from harsh sunlight. Northern Senegal is semi-arid much of the year with sparse vegetation. Given the expansion of the Sahara estimates cite 47% or roughly half of the available land as unsuitable for agricultural cultivation. Roughly 60% or two-thirds of Senegalese depend on the natural landscape for survival. The numbers may become higher when herdsmen and fishermen are accounted. Naturally this raises significant environmental problems regarding ecology, sustainability, land equity, and particularly building system indicators. This novel research aims to provide some prescriptive measures specific to environmental building systems.

Water induced erosion affects 77% or over three-quarters of Senegalese landscapes. This is a dual process coupling Atlantic Ocean wind currents and moisture with a significantly high saline content. For this reason the Northwest coastline in the Niaye region is most affected by the oceanic winds. After depletion no long-term methods of restoration exist however local scientists pursue engineered irrigation techniques adopted from East Asian and South American technological markets. In addition wind induced erosion problems over the past 30 years Senegal produced increased drought from the expansion of the Sahara Desert. Therefore Sahara wind erosion deteriorates 3% of soil annually. Nonetheless turbines could strategically integrate both high wind scenarios from the ocean as well as the desert in order to produce renewable electricity and modernize the workforce. For instance the approximate wind speed between January and March is typically 3 meters per second. Charcoal is the primary basis for energy in Senegal accounting for 8% of energy and unfortunately accelerating environmental fatigue.

Chemical degradation comes from saline acidification. Some of the surrounding regions affected by saline phenomenology include Casamance, The Gambia, The Sine, Saloum, and Niaye. Biochemical acidification affects about 50% or half of the available farmland in Senegal further devastating agricultural sustenance. In short, the environment appears to be attacking the landscape from the north and west. The two dams in Senegal stem from the River Senegal and provide potable water. Coupled with overpopulation existing forests suffer the devastating taxation of nourishing flora, fauna, and people. Research provides some prescriptive measures.

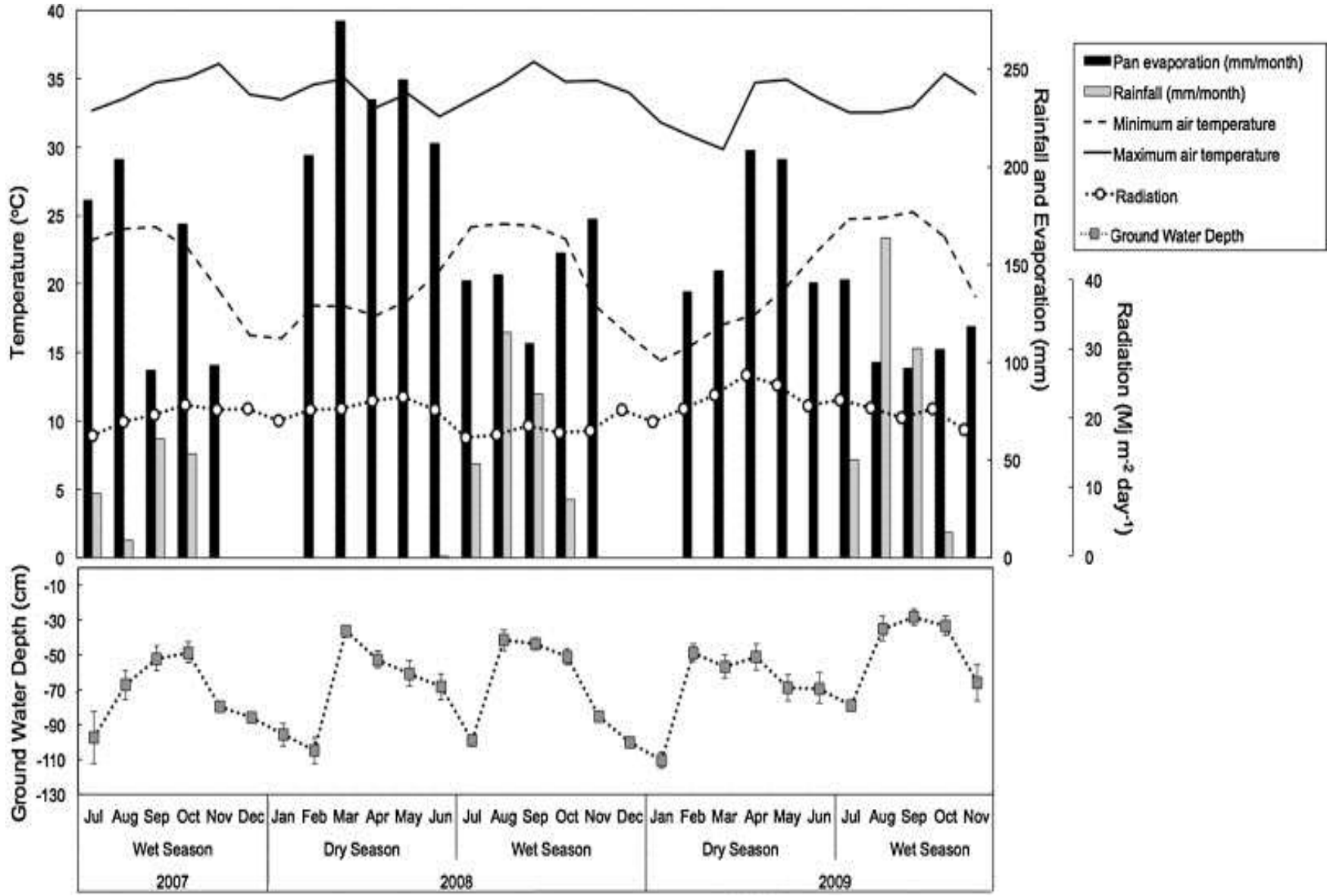

Table 2 **Senegal Climate / Hydrologic conditions (Krupnik, T. J., Shennan, C., & Rodenburg, J. 2012.) Used under fair use, 2013.**

Environmental Building Systems (EBS)

For many African societies their spirituality facilitated interrelationship with nature. This is most evident in their building systems. Comparatively colonial architecture countered indigenous design typology yet today modern computer simulations tell us these ancient cultures were correct in their adaptation to African environment. Environmental balance can preserve nature while providing a modern urban aesthetic. Consider indigenous typologies such as building size and morphology, orientation of apertures, passive ventilation strategies, thermal mass as a resolve for latent heat and other environmental factors including shading principles and material application. Once again modern environmental codes adopt standardizing primal phenomenology considered sacred rule by modest ancient African civilizations. Hence design aesthetic pairs technological advancements with localized typologies honoring EBS principality.

Figure 10 **Early concept of exterior double envelope wall as a "pottery wall".**

Figure 11 **Exterior Elevations**

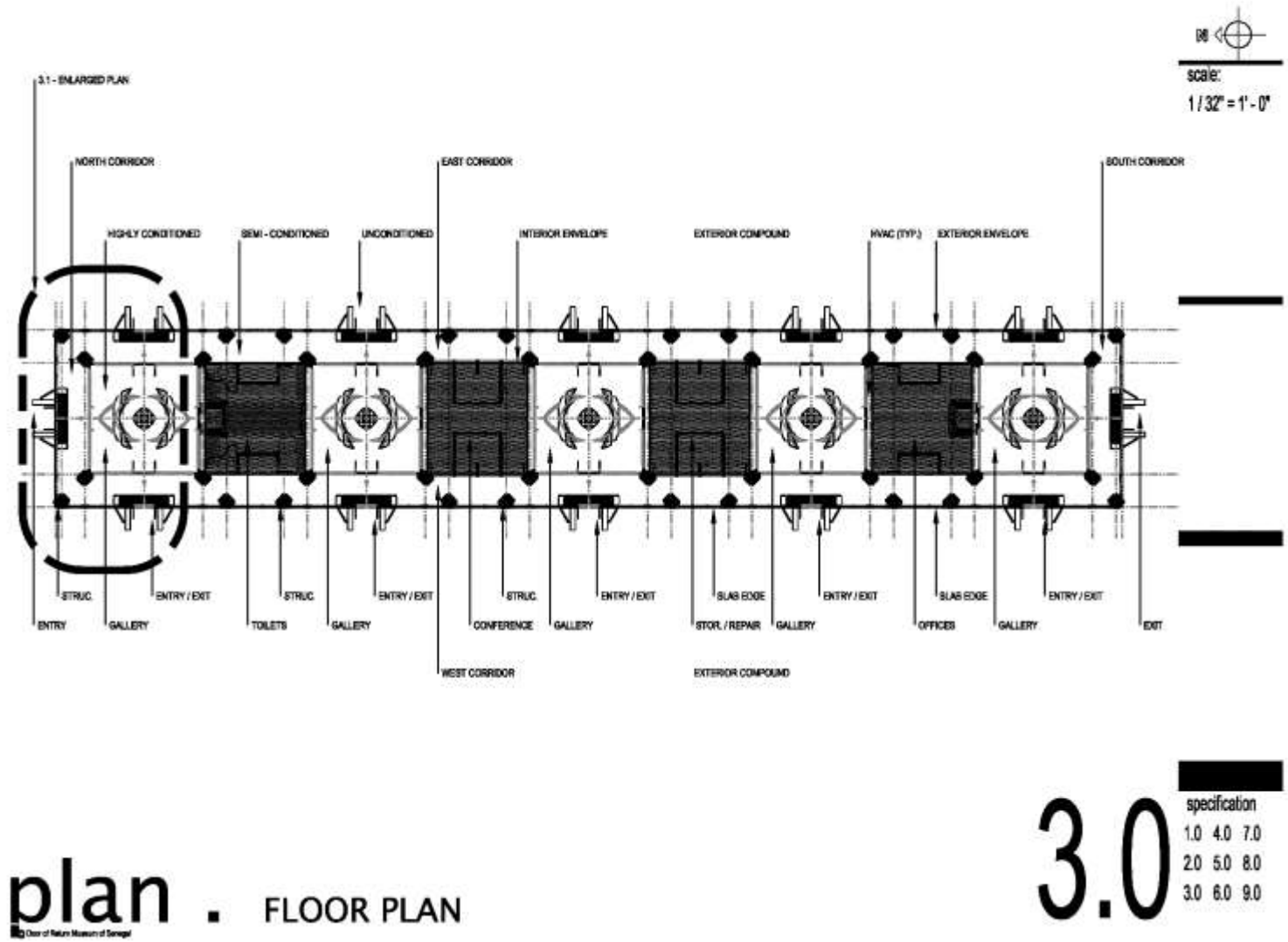

Figure 12 Floor Plan

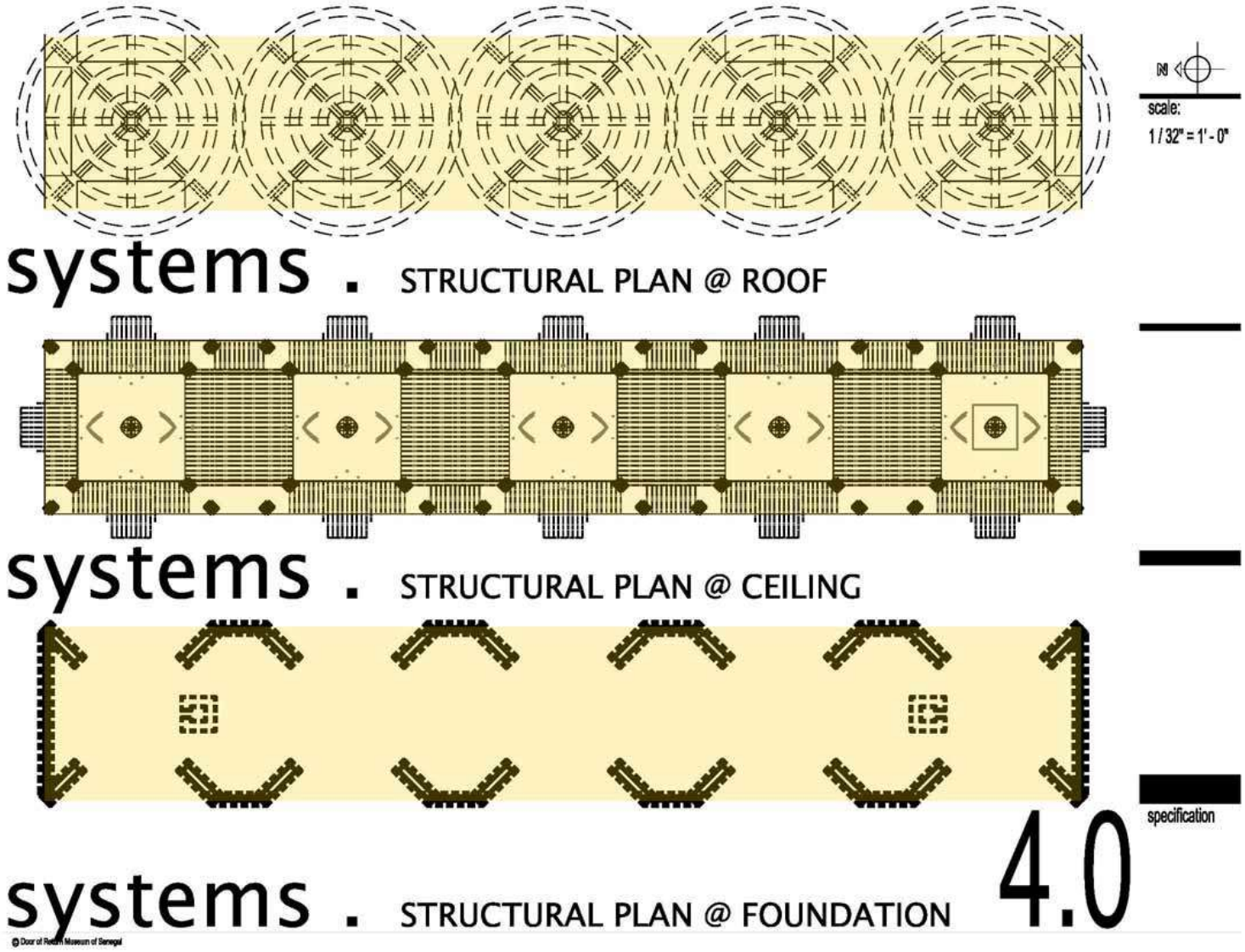

Figure 13 **Structural Systems.**

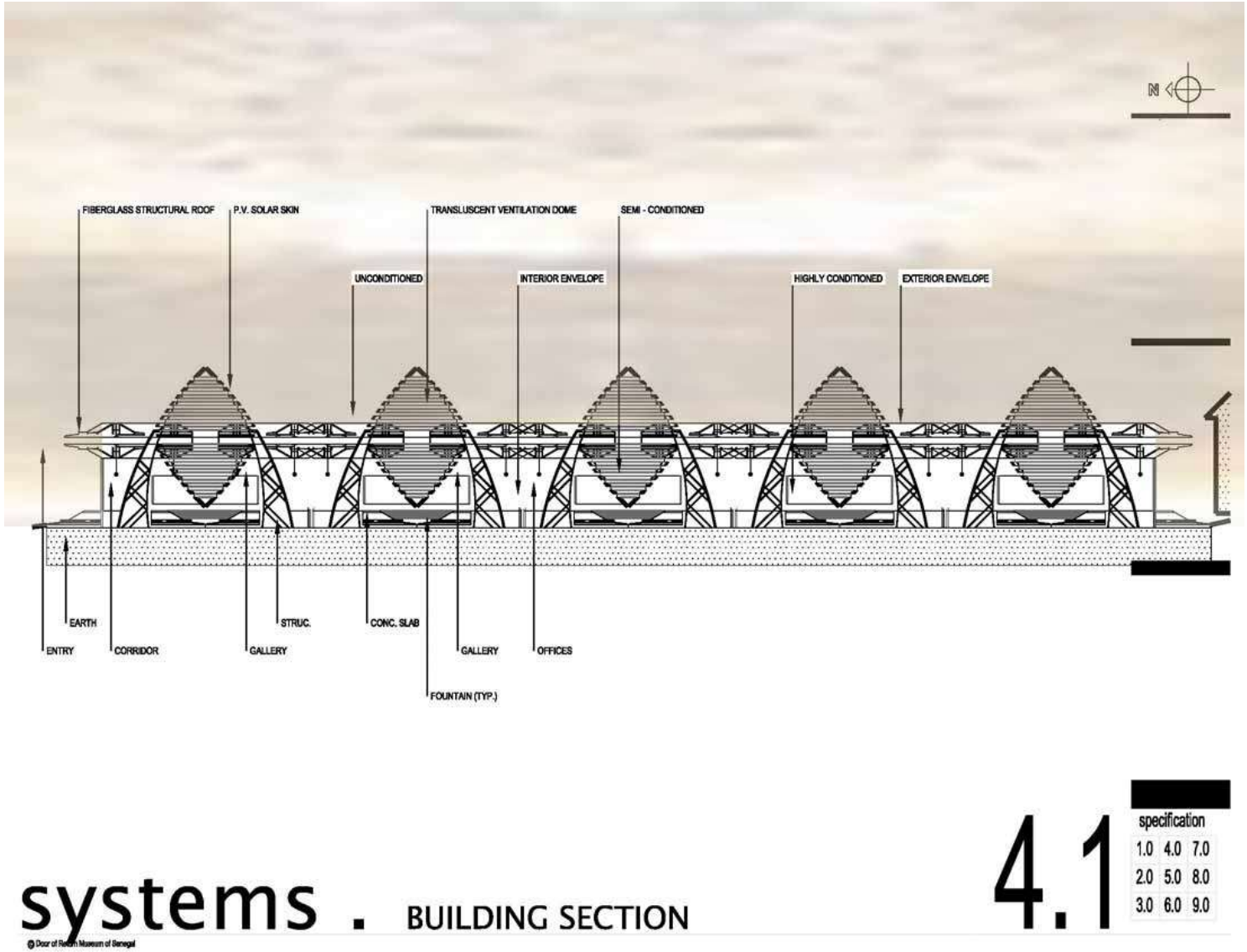

Figure 14 **Building Section**

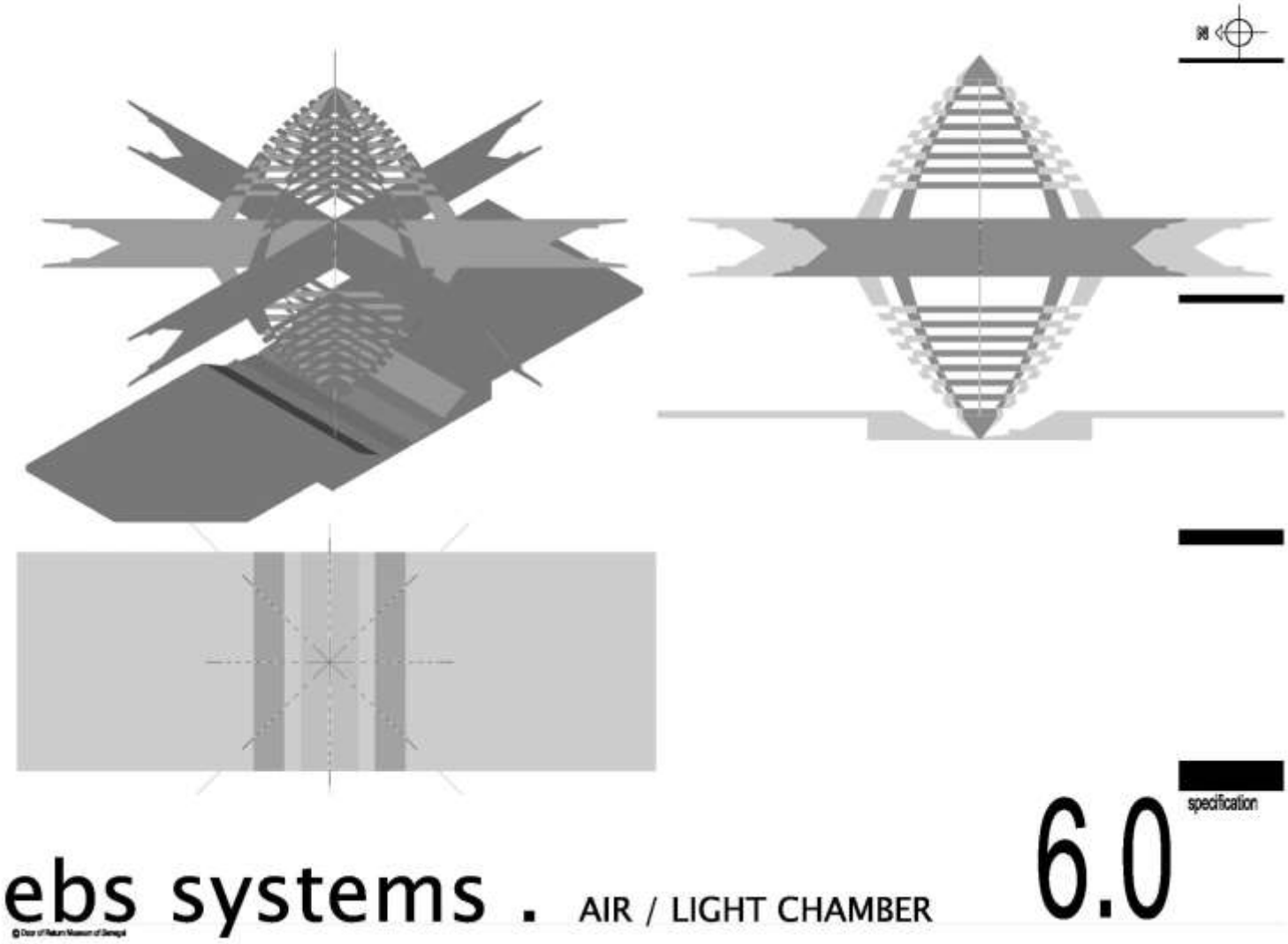

Figure 15 **Translucent dome and integrated ventilation chamber.**

Significance of EBS

Unique restrictions exist when designing in any given landscape. Research investigates the constraints of finance, communication, cultural competence, scientific research, logistics, and art to name a few. Increasingly these skillsets are required if we are to become stewards of the environment via design and planning. Tracing the development of a cultural museum interrelationships are forged between the environmental problems and architectural solutions. Cultural idioms are utilized to enhance the theoretical expression while specifications outlay the practical necessities of construct. The result is an iconic cultural fingerprint.

Purpose of EBS

The primary purpose of designing a museum is not a linear process and requires critical thinking using a concerted approach to integration of sustainable systems. Foremost this research exemplifies design synthesis within a specific geography. Environmental adaptation is what ultimately gives the structure EBS affinities. Therefore EBS qualities illuminate the iconic appearance of the museum. EBS configuration reinforces sustainability, provides useful adaptive exhibition space, and exploits natural ventilation.

Research Tools

The research tools include:

- Notations from physical lectures
- Recorded discussions
- Field Sketches
- Photography
- Computer and graphic documentation
- Analysis of typology

Chapter 2 - Literature Review

African Metropolitan Architecture, by architect David Adjaye, is one of the latest texts to emerge that describes African architecture in pictorial detail. The good news is that Adjaye's publication quenches a parched aspect of non-Western architecture. There are some shortcomings. Because the architecture in Africa is so expansive and diverse this book falls short and is presented as a sketchbook of personal experiences rather than a serious academic periodical with a fair comparative assessment of each environment documented. *Drawing from African Dwellings* (Jean-Paul Boudier) is a more in-depth study of the different spatial delineation that defines African structures. Then there is *Afrocentric Architecture: A Design Primer* (David Hughes) which provides some substantive information and for its time was unlike any other book published on the typological variations that define African architecture. The cultures depicted were selected by David Hughes and thus it is a rather limiting guideline to such a historically stratified continent. *Safari Chic* and *Swahili Chic: The Feng Shui of Africa* (Bibi Jordan) are two books that aim to reveal the natural qualities of space within east Africa that provide serenity and sensual healing akin to the modern spiritual healing design trends. This book does something the previous literature omits which is capture the colors and sense of space in a very tangible manner. One would expect this from the author who is a professional photographer but without architectural training her images are a missed opportunity for didactic spatial analysis. An anecdote would be a sketchbook documentation delineating the two dimensional qualities.

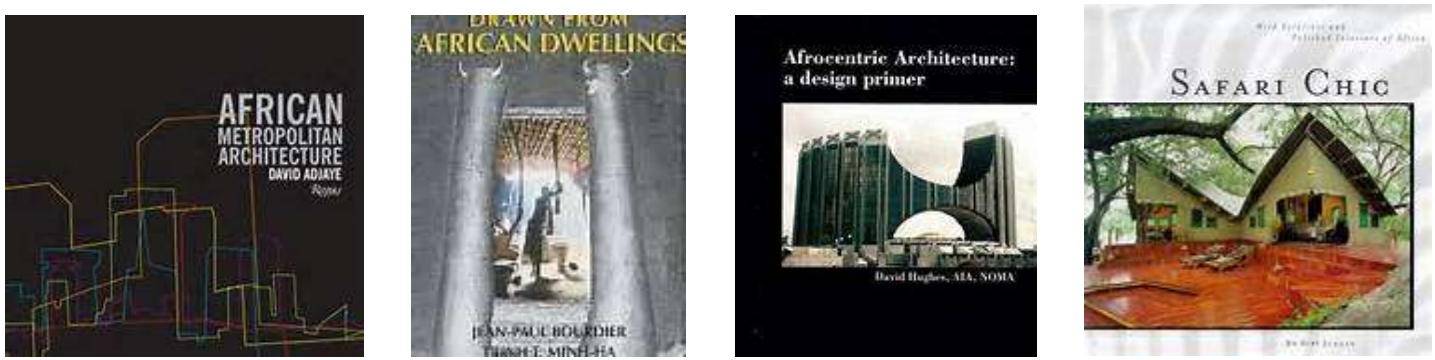

Figure 16 **Publications referenced in the literature review. Used under fair use, 2013.**

Keep the sunshine out

Deflecting sunlight before it enters a building redirects sunrays from penetrating interior spaces placing less demand on mechanical systems and achieving passive control of thermal comfort, one of the key elements of this proposal. Several methods are appropriate to combat direct solar heat gain. One method uses exterior shading devices to obstruct the sun before it strikes the surface of the building. By positioning shading devices above building apertures the design upholds ancient principality coupling shading and cooling. External shading devices are available in various configurations including horizontal, vertical, or a combination of both in various patterns. Therefore horizontally positioned devices combat the altitude of sunrays while vertically positioned shading devices alleviate unwanted solar glare during sunrise and sunset. For this reason horizontal shading devices are typically located on the south or north facade of a structure while vertical shading devices are located on the east or west surfaces. It should be noted the same principality holds true for internal shading devices albeit a tertiary remedy with glazing options as a secondary prescriptive. The work of architect Sym Van Der Ryn serves as a useful case study to underscore these concepts.

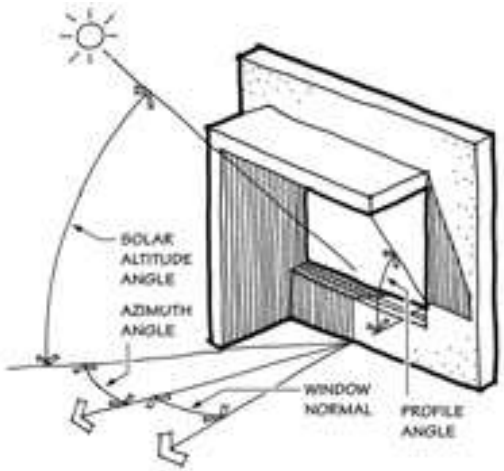

Figure 17 **Solar shading principles depicting horizontal and vertical elements compared to solar angle. (Courtesy: US Army)**

Flatten day to night temperature swings

Conversion from day to night and vice versa poses thermal comfort challenges because the outdoor temperature undulates from one extremity to another. Hence we find traditional construct using large masonry stone walls at least 12 inches in thickness or greater with a plaster finish. Research proves heat will transfer through 1 inch of material for every hour during the day such that 12 inches of thermal mass provides 12 hours of passive protection. The shear mass of the wall creates a condition known as thermal lag meaning the edifice composition moderates temperature by reducing heat transfer from warm to cooler environments. We must foremost understand that heat moves from hot to cooler spaces therefore 'expands'. Given this principality material selection, insulation techniques, double envelope partitioning, and skin thickness are all vital to creating an optimal thermal lag setting. The Door of Return Museum of Senegal utilizes a concept termed a double envelope signifying an interstitial space or 'buffer zone' between conditioned space and the exterior environment. The total dimension between the outdoor temperature and interior gallery space is 10'-0" or 120 inches assuring superior passive thermal control which significantly alleviates mechanical energy requisites.

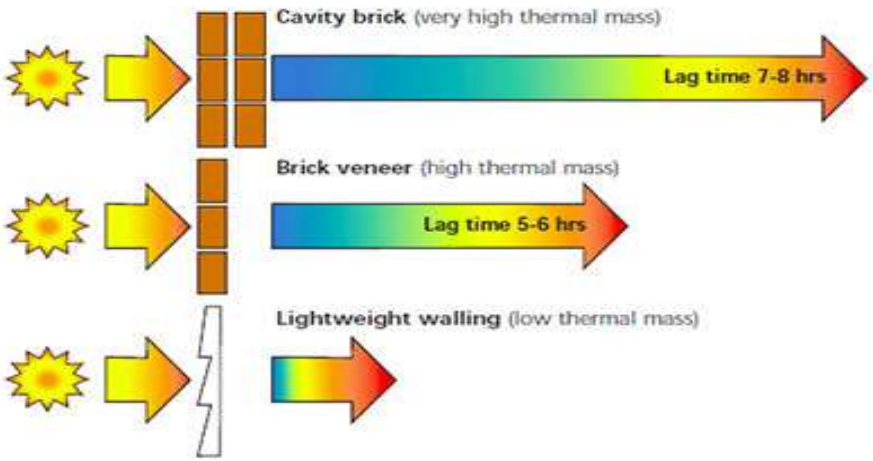

Figure 18 **Thermal lag time assumes brick width is 4" therefore 1 hour of lag or every 1" of material. (Courtesy: http://www.azobuild.com)**

Natural ventilation

Proper natural ventilation provides fresh air in buildings. The aim is to circulate air but the danger is losing conditioned air during the cyclical process. Designers must understand prevailing wind patterns in tandem with nocturnal wind shift and consider obstructions that may prevent proper airflow. Additionally the windward and leeward apertures must be appropriately located and sized to achieve a desired outcome. Stack ventilation is a principal that uses thermal buoyancy to ventilate a tall space. Thermal buoyancy is created by heating air and as it rises it draws cooler air into a space below. A useful example is a hot-air balloon. We can deduce the term 'stack ventilation' as an apt description akin to a chimney stack. A well designed ventilation scheme includes an emersion of all aforementioned conditioned arranged in an architectural manner. For this research this means honoring the needs of a museum.

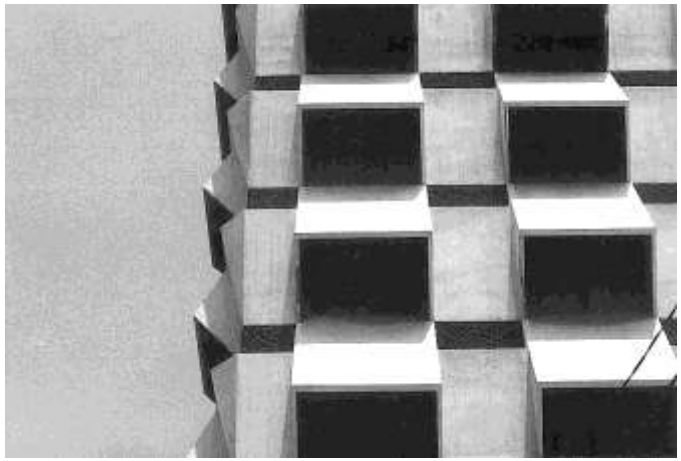

Figure 19 (Left) Ventilation and shading integration. (Center) Water and vegetation as natural cooling strategy for a public park / beach. (Right) Typical ventilation opening on a high-rise tower in Dakar.

Day lighting

Museums require specialized day lighting strategies in order to protect collections, some more than others. This museum incorporates borrowed day lighting. This theory diffuses harsh light in order to subdue potentially damaging qualities then filtering a softer luminance into the gallery space. In doing so a softer or even natural light condition is produced, free of shadows and glare yet ideal for sensitive paint mixtures commonly associated with rare art. Using this technique results in day light zones meaning certain spaces were identified by the light needed at a given time of day. Fenestration apertures in desert regions are typologically narrow and deep which provides both shading and pre-cooling but more significantly subdues harsh light amidst maintaining a view.

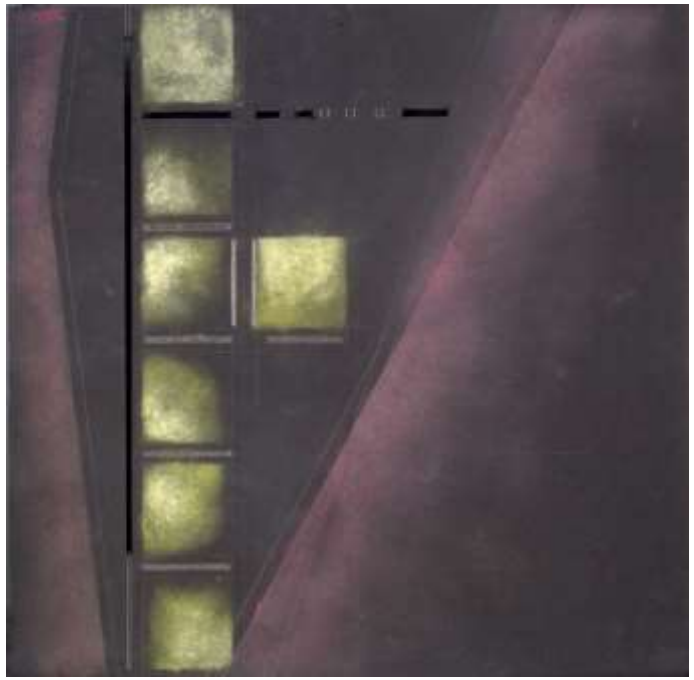

Figure 20 **Pastel images constructed to depict the quality of light in each gallery.**

Water and cooling

Water is perhaps one of the most ancient and widely tested methods of natural cooling. An ideological predecessor to air conditioning, integrating water in conjunction with ventilation strategies lowers ambient temperature of prevailing wind before entering an interior space. Ancient civilizations understood this notion and its use continues to this day although aesthetic expression varies depending on fountain, reflection pool, retention and detention needs. Ponding water then shading a pool of moisture a tranquil heat sink capable of extracting warmth from its surrounding environment displacing the energy into water is created. Although subtle this method is effective and further research could draw relationships to neuroscience advantages. A good example of this principle is the Alajambra complex in Granada, Spain.

Figure 21 (Left) Passive cooling using breezes from the Atlantic Ocean, a colonnade veranda, and shading to help cool interior spaces (Right)

Transitional Enclaves

In Senegal sunlight is abundant throughout the day between the hours of 7am and 7pm. Short sunrises and sunsets and abundance of sunlight during daytime hours are typical for nations that stratify the equatorial belt and general bioclimatic response includes use of shade coupled with ventilation. Architectural mitigation yields transitional exterior zones such as enclosed courtyards and shaded porticos and a double envelope system on the interior of the museum. Locating such quads or piazzas along pedestrian promenades offsets extreme temperature swings and extends spatial use. Exterior piazzas are essentially rooms that act as buffer zones to pre-cool hot air. As such protection from the hot climate is achieved using mitigation methods such as transitional enclaves.

Figure 22 Example of a naturally shaded pedestrian walkway on Goree Island.

Chapter 3 - Environmental Systems

Courtyard

Most communities in this part of the world are centralized around a unifying space. Traditionally courtyards are a mediating space where visitors are greeted and welcomed before entering a home or estate. Each subsequent structure or delineation within the landscape honors the infrastructure to enhance or reinforce prominence of the existing and therefore create harmony. Many of these principles can also be found in East Asian Feng Shui design mainly spirituality and place-making. The Door of Return Museum attempts to re-connect traditional elements that pay homage to culture. The challenge as a foreign designer is to understand which elements of the culture to preserve and what to modify.

Figure 23 View of existing compound.

Figure 24 **Integrated seating and lighting concrete sculpture.**

Roof and Canopy

The roof serves the dual purpose of capturing solar-electricity via photovoltaic panels and producing hot water using integrated piping so that each 'bay' can produce and store its own electricity. This is similar to a micro energy farm and bears affinity to the self-sustaining autonomy of farming communities in rural Senegal. We find again the integration of culture and modernization. Similarly the canopy has two direct functions. The first is to provide shading for pedestrians and the second is to support integrated solar panel arrays which capture the sun's energy and turn it into electricity. Unused energy is stored for off-peak demand. By maximizing passive strategies an energy surplus is created over time given the minimal need for electricity, thermal comfort, or water to name a few.

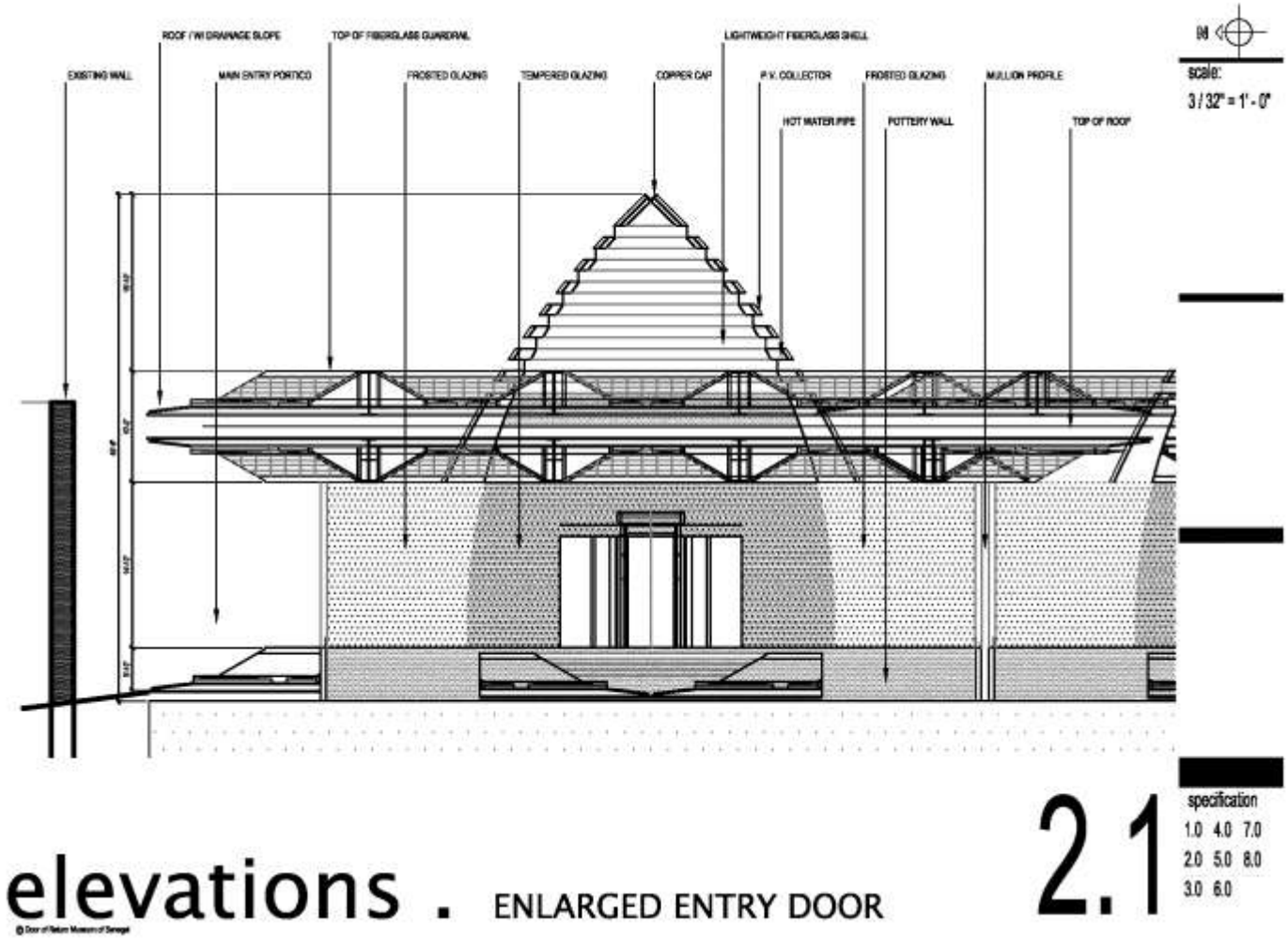

Figure 25 Enlarged elevation

Double Envelope Façade

The term double envelope is an apt characterization of the museum enclosure. There are essentially to formal barriers against the exterior weather condition that act as thermal buffers to help moderate extreme temperature swings. Certain attributes that are controlled include the filtration of light, greater thermal comfort, protection from extreme wind or heat, and acoustic segregation for the gallery spaces. This perimeter ring which surrounds the museum is conceived as a protective barrier and it would be otherwise very challenging to depend on passive systems given the latent heat in Senegal's tropical climate. Double envelope facades significantly reduce the need for immediate mechanical intervention particularly when considering the use of glass. Traditionally exterior walls are constructed of concrete masonry in this climate which has a lower conductivity rate as a material and is cheaper to acquire with less opportunity for liquidated damages during transport. Glass is a much more fragile material, expensive to transport and must be carefully considered for its high maintenance. However glass also provides some dramatic opportunities to subdue natural light and provide a translucent internal pedestrian corridor between the two envelopes. What is sacrificed in thermal transmission with glass is gained by significantly reducing the electricity demand on the total building system with natural daylight and will be discussed further in this chapter. The heat that is captured within the double envelope is addressed with a ventilation scheme also discussed later in this chapter. The double envelope concept is also applied between the roof and ceiling albeit less dramatic.

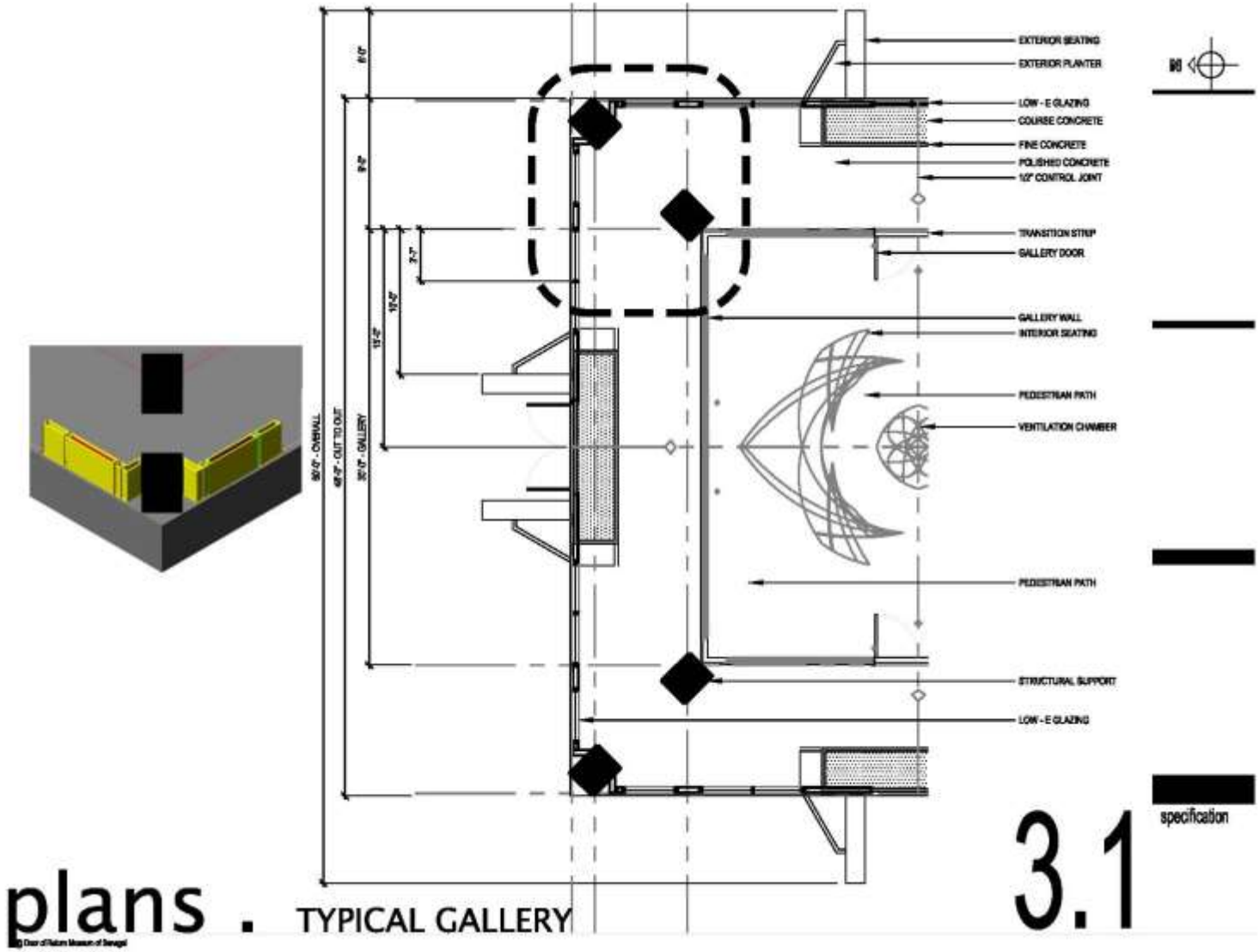

Figure 26 **Plan detail (typical)**

Thermal Detailing

The double envelope concept would not be possible without an associated thermal detailing strategy. The essence of the detailing strategy is to create buffer zones that prevent heat transfer which slows the conductivity between materials. This is where the science of modern technologies aids in the fabrication of structures. Some of the thermal buffers include insulation within floors, walls and ceilings. Argon is another gas used to fill the center of window systems and improve the performance of the glazing. There is also low-E coded glass which comes in a green or blue tint and helps repel direct sunlight. The collective efforts while better explained within the technical specifications all slow the rate of heat transmission into the gallery space. At night the inverse occurs and the slight rise in temperature on the interior is captured therefore moderating the thermal extremities that might otherwise prevail. It is significant to note that thermal detailing also includes moisture protection and therefore specifications provide a standard of efficiency. Therefore integration becomes a more complex synthesis of systems.

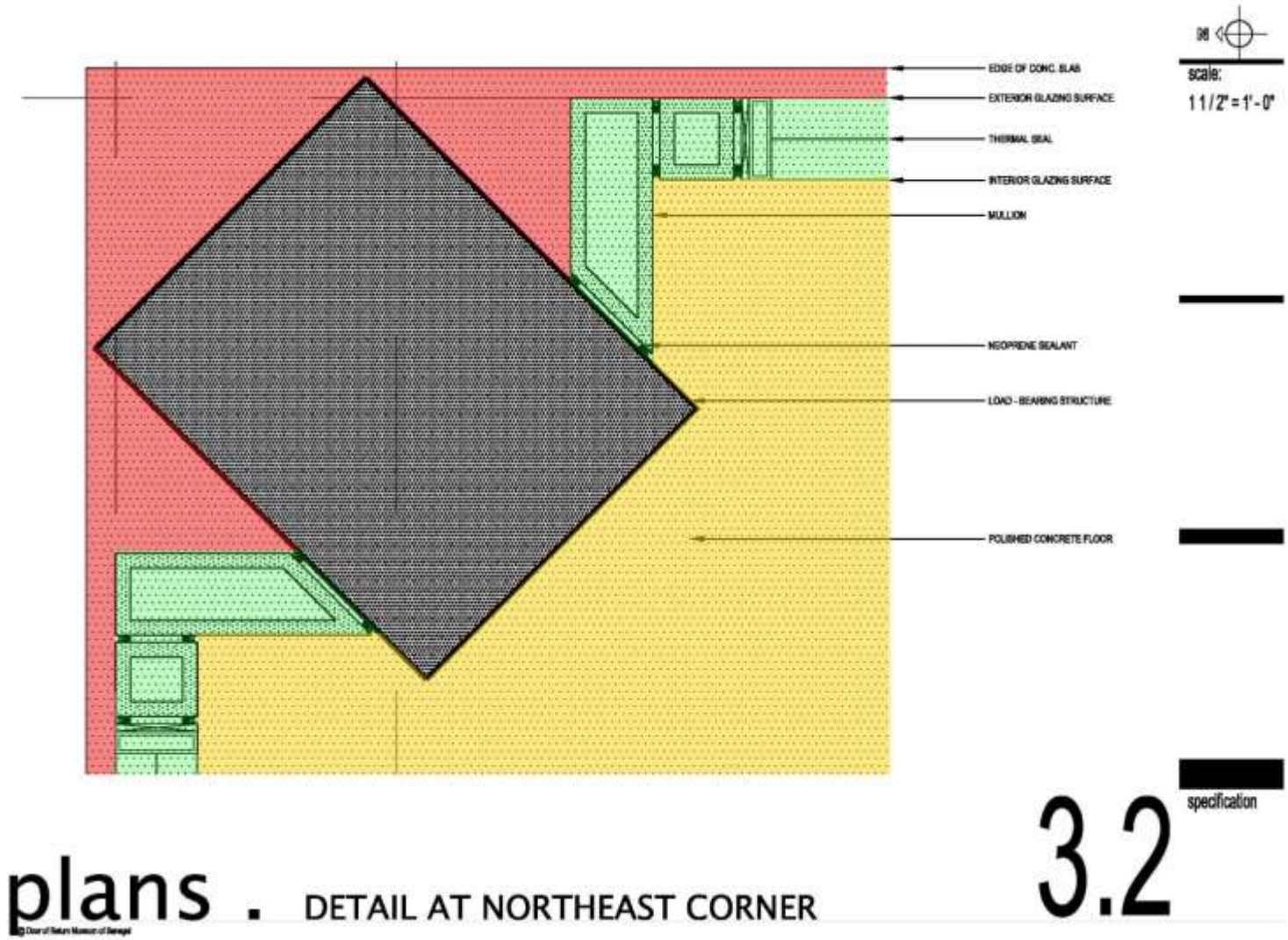

Figure 27 **Plan detail (typical at bay corner)**

Interior

Characterized by ambient light flowing into the spaces, the gallery spaces provide various light conditions creating a different hue and feeling in each space. Even though some spaces are highly luminous, others are more subdued or even light occlusive. The dimension of the gallery spaces has a dimensional correlation with the diameter of the huts on-site. Spatially, it is a familiar feeling which helps connect the site. Organization is linear allowing the pedestrian to move along the sun's north/south axis. Many researchers and design manuals will cite a desired east / west axis orientation however the natural order of the existing compound does not afford that opportunity so it should be noted that this design, as an anomaly, is a novel resolution to EBS. Concrete is used as a massing element on the floors with pools of water strategically located in the structure. The moisture helps cool the concrete while the concrete draws heat from the interior environment and stabilizes lower temperature.

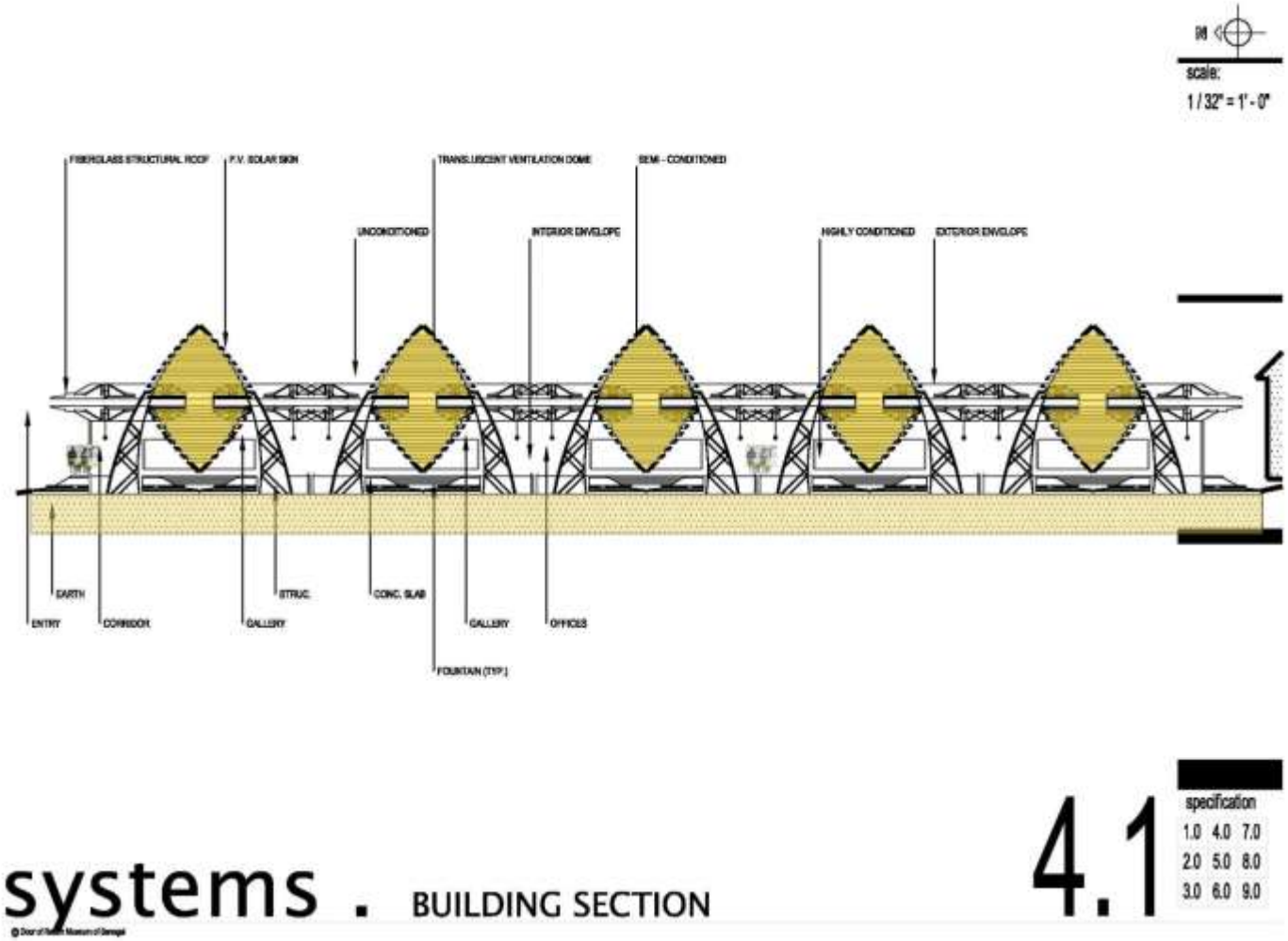

Figure 28 Building section

Figure 29 **Interior lighting demonstrating diffused light within each gallery space.**

Figure 30 **Lighting Studies during design development evaluating filtration, diffusion, and reflectivity.**

Ventilation Chamber

Envisioned as a meditative space, this floating space is covered by a porous wooden shell suspended in the center of each gallery. In plan, the structure is rectilinear, but the order of each 'bay' is aligned with the center of the embryo-like structure, which hovers above. The shell is fabricated from fiberglass. Inscriptions of African proverbs shall create the ambiance for the finished spaced. In its simplicity, the form is derived from the integrated roof system for the entire structure. The form gives energy to the museum. From a visual standpoint one can witness the pedestrian traffic and procession leading to the museum. It is only within the gallery that viewers can understand the connection between their journey to through the site and the museum iconography. Metaphorically speaking the museum itself is a testament to the journey of Africans as a people throughout the Diaspora. The hue of selected museum spaces is an orange / red pigment invoking the feeling of a fiery space. This idea was derived from travels throughout Senegal as Saharan earth tones are found in countless aspects vernacular architecture and art.

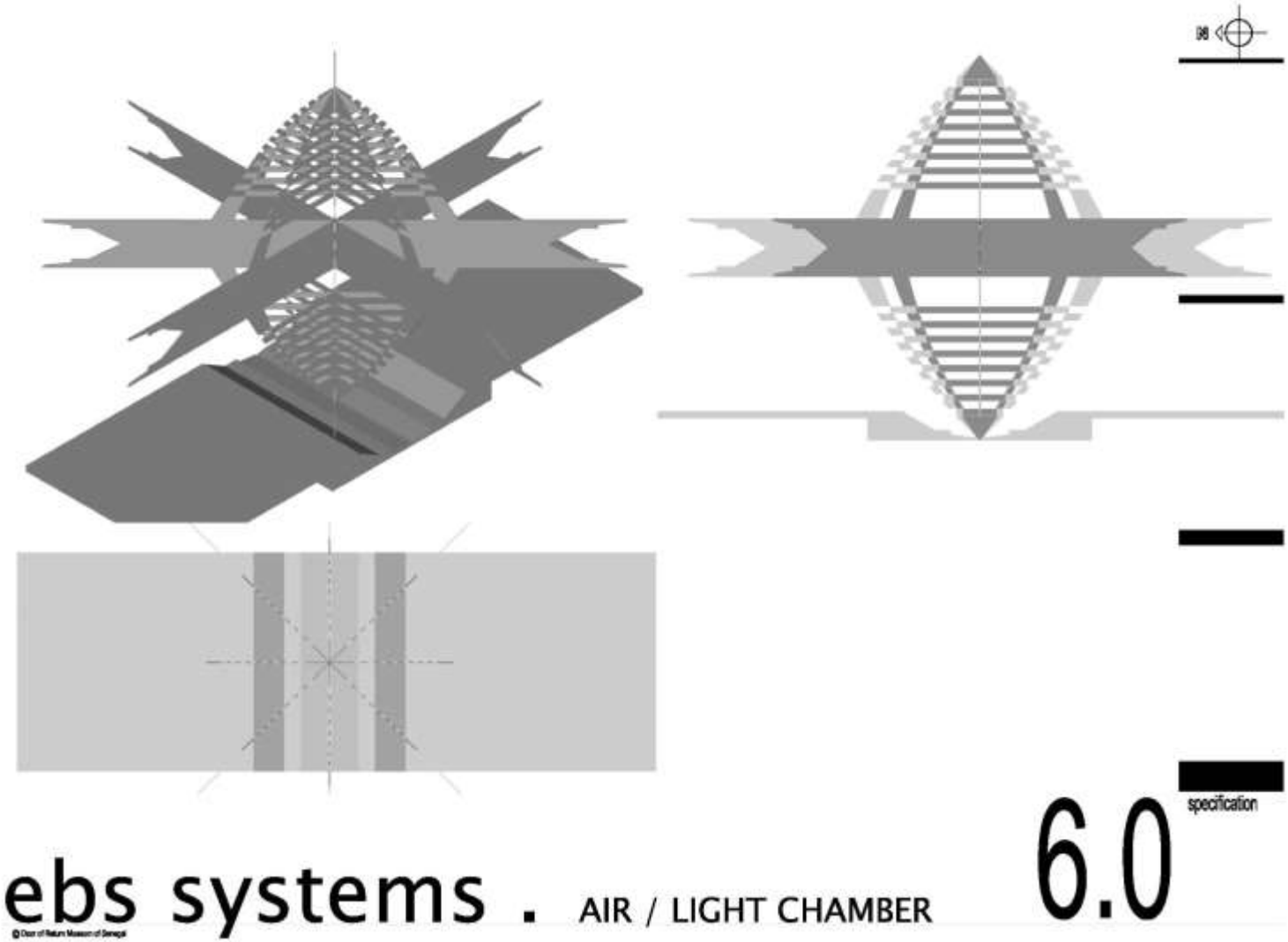

Figure 31 **Translucent dome and integrated ventilation chamber as referenced in Chapter 1.**

Chapter 4 - Closing Discussion

Senegal is an emerging global market and part of a necklace of countries in Africa that are among the fastest growing economies in the world. Many of these countries including cities like Dakar utilize modern technologies, renewable energy sources and conservation techniques that mitigate natural resource depletion. In doing so it is paramount their cultural idioms remain preserved or enhanced but never lost. What this means for architecture students is that sustainability must couple culture and technology indeed but also educate. Many opportunities exist for collaboration including training local masons, providing irrigation techniques for farmers, producing lucrative business ventures in solar and wind systems and generally restoring communities and a sense of independence. The Door of Return Museum is a testament to Dakar's economic ambitions. Countries such as China, India, France, and Russia have joined recent efforts to help develop infrastructure as well as educate the Dakar population. The Qatar Foundation is also present in Senegal and their award-winning education methods make practical use of the local labor force as part of sensible environmental building solutions.

Future architecture research in this demography will explore how architects can better integrate allied economic industries. Therefore when we further assess latent heat we must consider the types of businesses and industries that can emerge from combating this omnipotent environmental condition. Similarly if we consider water as a commodity there are significant industries that emerge which address collection, distribution systems and end-user satisfaction using modern science. Thermal insulation is another industry that is poised to grow in sub-Sahara given the proper investment. Each of the aforementioned elements must be synthesized collectively whenever architects incorporate sustainability amid emerging global markets. The Door of Return Museum is one example that will positively inspire comparable considerations for the environment.

Bibliography

AIA, 1982. *Climate and Life*, American Institute of Architects, Washington, D.C. [P 729 A51]

AIA, 1994. *Environmental Resource Guide*, American Institute of Architects (AIA), Washington, D.C. [R 720.47 E61]

AIA, 1999. *Environmental Resource Guide on CD-ROM* [computer file]: includes 1997 and 1998 updates, American Institute of Architects, John Wiley, New York. [AV 720.47 E61 C]

Alcock, A. E. S. and Richards, H. M., 1960. *How to Build for Climate*, Longmans, London. [P 721.0913 A3]

Argiriou, A. and Santamouris, M., 1995. *Natural Cooling Techniques*, CIENE, University of Athens, Athens, Greece. [697.92 A69]

Baird, G., 2001. *The Architectural Expression of Environmental Control Systems*, Spon Press, London & New York. [696 B163 a]

Baker, N. and Steemers, K., 1999. *Energy and Environment in Architecture: A Technical Design Guide*, E. & FN. Spon, New York. [720.472 B16]

Baker, N. and Steemers, K., 2002. *Daylight Design of Buildings*, James & James, London. [729.28 B16]

Baker, N., Fanchiotti, A. and Steemers, K., 1993. *Daylighting in Architecture: A European Reference Book*, James & James, London, 1993. [729.28 D2]

BCA, 2005. *Green Building Design Guide - Air-Conditioned Buildings*, Building & Construction Authority, Singapore. [website]

BCA, 2008. *Code for Environmental Sustainability of Buildings*, Version 1.0, Building and Construction Authority (BCA), Singapore. [PDF]

Bell, J. and Burt, W., 1995. *Designing Buildings for Daylight*, Professional studies in British architectural practice - lighting, Building Research Establishment, London. [729.28 B4]

Benson, J. F. and Roe, M. H., 2000. *Landscape and Sustainability*, Spon Press, London/New York. [712 L26 B47]

Brookes, A. and Grech, C., 1991. *Building Envelope: Applications of New Technology Cladding = Das Detail in der High-Tech-Architekture: Analyse von 33 Bauten und Ihrer Fassadentechnik*, Birkhäuser, Bäsel. [LB 690.12 B8 b]

Brookes, A. and Grech, C., 1996. *The Building Envelope and Connections*, Architecture Press, Oxford. [LB 690.12 B8 bu]

Brown, G. Z. and DeKay, M., 2000. *Sun, Wind, and Light: Architectural Design Strategies*, 2nd edition, John Wiley & Sons, New York. [720.47 B8 s]

Brown, G. Z., et al., 1982. *Insideout: Design Procedures for Passive Environmental Technologies*, 2nd ed., Wiley, New York. [720.47 I59]

Brown, R. D. and Gillespie, T. J., 1995. *Microclimatic Landscape Design: Creating Thermal Comfort and Energy Efficiency*, J. Wiley & Sons, New York. [712.2 B87]

Carmody, J., et al., 2004. *Window Systems for High-performance Buildings*, Norton, New York. [690.1823 W76 C2]

Carmody, J., et al., 2004. *Window Systems for High-performance Buildings*, Norton, New York. [690.1823 W76 C2]

Carpenter, W. J., 2009. *Modern Sustainable Residential Design: A Guide for Design Professionals*, Wiley, Hoboken, N.J. [728.047 C2]

CIBSE, 1999. *Daylighting and Window Design*, CIBSE lighting guide LG10, Chartered Institution of Building Services Engineers, London. [729.28 D27 C]

City of New York, 1999. *High Performance Building Guidelines*, City of New York Department of Design and Construction, New York, 1999. [720.47 H63][PDF]

Cuito, A. (ed.), 2000. *Ecological Architecture: Bioclimatic Trends and Landscape Architecture in the Year 2001*, English translation: Richard-Lewis Rees, Paco Asensio, Barcelona, Spain. [720.47 E17 C]

CWCT, 1992. *A Comparative Study of the Facade Industry in the UK, Europe, Japan and the USA*, Centre for Window and Cladding Technology, Bath, UK. [690.12 C73 v.1-v.3]

CWCT, 2002. *Guide to Good Practice for Facades*, 2nd ed., Centre for Window and Cladding Technology, Bath, UK. [P 690.12 G9]

de Boer, J. and Erhorn, H., 1999. *Survey Simple Design Tools: Daylight in Buildings*, Fraunhofer Institute for Building Physics, Stuttgart. [P 729.28 S96]

Department for Education, Architects and Building Division, 1994. *Passive Solar Schools: A Design Guide*, H.M.S.O., London. [727.0472 P28]

Dimoudi, A., 1995. *Passive Cooling of Buildings: Case Studies*, CIENE, University of Athens, Athens, Greece. [697.92 D58]

Dimoudi, A., et al., 1996. *Design Source Book on Passive Solar Architecture*, Central Institution for Energy Efficiency Education, National and Kapodistrian University of Athens, Athens, Greece. [697.78 D4 D]

European Commission, Directorate General XVII for Energy, 1999. *A Green Vitruvius: Principles and Practice of Sustainable Architectural Design*, James & James, London. [720.47 G79 E]

Evans, B. H., 1981. *Daylight in Architecture*, Architectural Record, New York. [720.47 E9]

Evans, M. 1980. *Housing, Climate, and Comfort*, Architectural Press, London. [728 E92]

Evans, M. 1980. *Housing, Climate, and Comfort*, Architectural Press, London. [728 E92]

Fathy, H., 1986. *Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates*, University of Chicago Press, Chicago. [728.09174927 F2]

Fontoynont, M., 1998. *Daylight Performance of Buildings*, James & James, London. [720.47 D27]

Frej, A. B. (ed.), 2005. *Green Office Buildings: A Practical Guide to Development*, Urban Land Institute, Washington, D.C. [725.23047 G7]

Fry, M. and Drew, J., 1964. *Tropical Architecture in the Dry and Humid Zones*, Reinhold, New York. [721.0913 F9]

Fuad-Luke, A., 2009. *The Eco-design Handbook: A Complete Sourcebook for the Home and Office*, 3rd ed., Thames & Hudson, London. [745.4 F94]

Gallo, C., Sala, M., Sayigh, A. A. M. (eds.), 1998. *Architecture: Comfort and Energy*, Elsevier, Amsterdam. [720.472 A67 G]

Givoni, B., 1998. *Climate Considerations in Building and Urban Design*, Van Nostrand Reinhold, New York. [720.47 G51]

Goulding, J. R., Lewis, J. O. and Steemers, T. C. (eds.), 1992. *Energy in Architecture: The European Passive Solar Handbook*, B. T. Batsford, London. [720.472 E5]

Greenland, J. and Szokolay, S., 1985. *Passive Solar Design in Australia*, RAIA Education Division, Canberra. [697.780994 G8]

Grosslight, J., 1990. *Light, Light, Light: Effective Use of Daylight and Electric Lighting in Residential and Commercial Spaces*, 2nd ed., updated, Durwood Publishers, Tallahassee, Florida. [729.28 G87]

Design, McGraw-Hill, New York. [720.47 G993 d; CUHK: NA2542.3 .G89 2000]

Halliday, S., 2000. *Green Guide to the Architect's Job Book*, 2nd ed., RIBA Publishing, London. [720.68 H18]

Hermannsson, J., 1997. *Green Building Resource Guide*, Taunton Press, Newtown, CT. [R 691.029473 H552 g]

Herzog, T., 2004. *Facade Construction Manual*, Birkhauser-Publishers for Architecture, Basel & Boston. [on order]

Hutcheon, N. B. and Handegord, G. O.P., 1983. *Building Science for a Cold Climate*, National Research Council of Canada, Toronto. [690.0911 H9]

Hyde, R., 2000. *Climate Responsive Design: A Study of Buildings in Moderate and Hot Humid Climates*, E & FN Spon, London. [720.47 H99]

Ichinowatari, K., 1982. *Climate, Nature and House*, Process Architecture, Tokyo. [728 C6]

IESNA Calculation Procedures Committee, 1984. *Recommended Practice for the Calculation of Daylight Availability*, IES RP-21-1983, Illuminating Engineering Society of North America, New York. [P 621.3211 I2]

IStrutE, 1995. *Aspects of Cladding of Interest to Structural Engineers, Architects, Surveyor, Contractors, Building Owners, Clients, Local Authorities*, Institution of Structural Engineers, London. [698 A9]

Johnson, B. R. and Hill, K. (eds.), 2002. *Ecology and Design: Frameworks for Learning*, Island Press, Washington, D.C. [712.2 E19 J66]

Jones, L. (ed.), 2008. *Environmentally Responsible Design: Green and Sustainable Design for Interior Designers*, Wiley, Hoboken, N.J. [747 E62]

Kibbey, D. (ed.), 2000. *Ecological Architectural Resource Guide: Environmentally Conscious, Resource-efficient, Less Polluting, Sustainable, Recycled, Healthy, Local*, prepared by Members of Northern California, ADPSR, Berkeley, California. [691.025 E19 K]

Kirkwood, N. (ed.), 2001. *Manufactured Sites: Rethinking the Post-Industrial Landscape*, Spon Press, London. [333.7715 M29 K59]

Kodama, Y., Cook, J. and Yannas, S., 1991. *Passive and Low Energy Architecture*, Process Architecture, Tokyo, Japan. [720.472 P2]

Koenigsberger, O. H., et al., 1973. *Manual of Tropical Housing and Building*, Longman, London. [728.0913 K7]

Konya, A., 1980. *Design Primer for Hot Climates*, Architectural Press, London. [721.0913 K8]

Krupnik, T. J., Shennan, C., & Rodenburg, J. (2012). Yield, water productivity and nutrient balances under the System of Rice Intensification and Recommended Management Practices in the Sahel. *Field Crops Research*, *130*, 155-167.

La Roche, P., et al., 2001. *Keeping Cool: Principles to Avoid Overheating in Buildings*, Research, Consulting and Communications, Kangaroo Valley, NSW, Australia. [697.92 K2]

Lam, W. M.C., 1986. *Sunlighting as Formgiver for Architecture*, Van Nostrand Reinhold, New York. [720.47 L2]

Littlefair, P. J. and Aizlewood, M. E., 1998. *Daylight in Atrium Buildings*, Construction Research Communication Ltd., Watford, Herts. [P 729.28 L77 d]

Lstiburek, J. W., 2000. *Builder's Guide to Cold Climates: Details for Design and Construction*, Taunton Press, Newtown, CT. [693.8 L925 b]

Lstiburek, J. W., 2000. *Builder's Guide to Mixed Climates: Details for Design and Construction*, Taunton Press, Newtown, CT. [693.8 L925 bm]

Lyle, J. T., 1994. *Regenerative Design for Sustainable Development*, John Wiley, New York. [333.7315 L98]

Lynes, J. A., 1968. *Principles of Natural Lighting*, Elsevier, Amsterdam. [729.28 L98]

Markus, T. A. and Morris, E. N., 1980. *Buildings, Climate, and Energy*, Pitman, London. [697 M34]

Matus, V., 1988. *Design for Northern Climates: Cold-climate Planning and Environmental Design*, Van Nostrand Reinhold, New York. [696 M44]

Melby, P. and Cathcart, T., 2002. *Applied Regenerative Design Techniques*, John Wiley, New York. [on order]

NPS, 1993. *Guiding Principles of Sustainable Design*, National Park Services (NPS), Denver Service Center, Denver, Colorado. [333.720973 G9][website]

Oesterle, et al., 2001. *Double-skin Facades: Integrated Planning: Building Physics, Construction, Aerophysics, Air-conditioning, Economic Viability*, Prestel, Munich. [LB 690.12 D7]

Olgyay, V., 1963/1992. *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, Van Nostrand Reinhold, New York. [729 O458]

O'Sullivan, P. (ed.), 1988. *Passive Solar Energy in Buildings*, Elsevier Applied Science, London. [720.472 P28]

Ouahrani, D., 1993. *TAGA: Daylighting of Houses in Desert Regions*, Thesis, Dept. of Architecture and Development Studies, Lund University, Lund, Sweden. [CUHK: NA2794 .O924 1993]

PSIC, 199-. *Passive Solar Design Strategies: Guidelines for Home Building*, Passive Solar Industries Council (PSIC), Washington, D.C. [697.9 P28]

PTI, 1996. *Sustainable Building Technical Manual: Green Building Design, Construction and Operations*, Public Technology, Inc. (PTI), Washington, D.C. [721.0467 S964][from WBDG]

RAIA, 1995. *BDP Environment Design Guide*, Royal Australian Institute of Architects (RAIA), Red Hill, A.C.T. [720.47 E61 R v.1 & v.2]

RAIA, 2001+. *BDP Environment Design Guide* [CD-ROM and online], Royal Australian Institute of Architects, Red Hill, A.C.T., Australia. [AVS 720.47 E61 R8][website] (access online)

RMI, 1995. *A Primer on Sustainable Building*, Rocky Mountain Institute (RMI), Snowmass, Colorado. [696 P9]

Robbins, C. L., 1986. *Daylighting: Design and Analysis*, Van Nostrand Reinhold, New York. [729.28 R63]

Robinette, G. O. and McClenon, C. (eds.), 1983. *Landscape Planning for Energy Conservation*, Van Nostrand Reinhold, New York. [712 L2]

Rudlin, D. and Falk, N., 1999.*Building the 21st Century Home: the Sustainable Urban Neighbourhood*, Architectural Press, Oxford. [711.40942 R91]

Salmon, C., 1999. *Architectural Design for Tropical Regions*, Wiley, New York. [720.913 S172 a]

SBIC, 2007. *Green Building Guidelines: Meeting the Demand for Low-energy, Resource-efficient Homes*, 5th ed., Sustainable Buildings Industry Council, Washington, D.C. [696 G79][AV 696 G79 S_CDROM]

Schittich, C. (ed.), 2001. *In Detail: Building Skins: Concepts, Layers, Materials*, Birkhäuser, München & Basel. [721 I35]

Steele, J., 1997. *Sustainable Architecture: Principles, Paradigms, and Case Studies*, McGraw-Hill, New York. [720.47 S81]

Thompson, J. W. and Sorvig, K., 2000. *Sustainable Landscape Construction: A Guide to Green Building Outdoors*, Island Press, Washington, D.C. [712.01 T473 s]

Tzonis, A., Lefaivre, L. and Stagno, B., 2001. *Tropical Architecture: Critical Regionalism in the Age of Globalization*, Wiley, Chichester. [721.0913 T998]

Watts, A., 2005. *Modern Construction Facades*, Springer, Wien & London. [729.1 W34]

Wong, Wah-sang, 1998. *Building Enclosure in Hong Kong*, Hong Kong University Press, Hong Kong. [690.12 W87]

Woolley, T., et al., 1997. *Green Building Handbook: a Guide to Building Products and Their Impact on the Environment*, E & FN Spon, London. [LB 691 G7 v.1 & v.2]

Wright, D., 1978. *Natural Solar Architecture: A Passive Primer*, Van Nostrand Reinhold, New York. [728.047 W9]

Yannas, S., 1994. *Solar Energy and Housing Design*, Architectural Association, London. [720.472 Y24]

Zhou, Y. S., 2002. *An Introduction to the Design of Curtain Walls, Aluminum Windows, Glass Walls, Skylights and Canopies*, Wilson Curtain Wall Consultant (HK) Ltd., Hong Kong. [690.12 Z6]

Zion, R. L., 1995. *Trees for Architecture and Landscape*, Van Nostrand Reinhold, New York. [715.2 Z79]

Appendix A - Specifications

1.0 SITE WORK

- EXCAVATION –
  - Shall be sufficient to provide full design dimensions or to allow for forming as required.
  - No footings shall be placed on frozen earth.
  - No footings shall be placed on soft material.
- BACKFILL AND COMPACTION –
  - Use only clean, well-graded earth containing no organic material, trash, muck, roots, logs, stumps, concrete, asphalt or other deleterious substances.
  - Backfill shall be compacted to 95% of maximum density as determined by the ASTM D698 standard proctor test.
  - Do not backfill against masonry walls until super structure is in place.
  - Prior to placing fill, the existing surface shall be cleared of all refuse or organic materials. Apply backfill in layers of 8" depth.
  - All soil fill material must be approved by soils engineer prior to placement.
  - Equivalent fluid pressure of soil backfill shall not exceed 30 P.C.F. uniform class SM or better.
- FOUNDATIONS –
  - All foundations are to be placed on undisturbed or compacted soil not less than 1'-0" below existing grade or 2'-6" below adjacent finished exterior grade unless otherwise noted on the drawings.
  - Maintain 1:2 slope (vertical to horizontal) from bottom edge of footing to bottom of any adjacent foundation.
  - Soil bearing valued assumed to be 2,000 PSF minimum unless otherwise noted on drawings.
  - Architect/Engineer to be notified immediately should insufficient bearing capacity of high water table be encountered.

- INSPECTIONS –
    - Footing excavation shall be inspected by the building official prior to the placing of any concrete.
    - The building official shall be given notice for this inspection.
- SOIL INVESTIGATION AND REPORT –
    - All earthwork, compaction, and foundation work shall be done in accordance with the soils investigation report which shall be provided by the owner.
    - Notify architect if on-site test bearing indicates lesser values before proceeding with the work.
    - Soil values to be determined by a registered engineer experienced in soils engineering.
- DRAINAGE OF FOOTINGS –
    - Unless otherwise noted, provide perimeter basement walls with 4" diameter drain tile laid on 2" gravel base with 6-8" gravel cover, with joints covered with filter cloth for perforated tile.
    - Slope drain tile as required to drain to storm sewer or outfall.
    - 18" gravel all around foundation.
- DAMP PROOFING FOR CONCRETE AND MASONRY FOUNDATIONS –
    - Exterior foundation walls of masonry construction enclosing basements shall be damp proofed by applying not less than 1/2" of Portland cement parging to the wall from footing to finish grade.
    - The membrane shall consist of 2-ply hot mopped felts, 6-mil polyvinyl chloride, 5-pound roll roofing or equivalent material.
    - The laps in the waterproofing membrane shall be sealed and firmly affixed to the wall, continuously.

2.0 CONCRETE

- CONCRETE –
  - Shall reach minimum compressive strength of (Fc)
  - All concrete to be poured in accordance with ACI 301 specification.
  - Concrete exposed to weather to be air entrained.
    - At 28 days psi
    - Concrete in the locations which may be subject to freezing and thawing during construction shall be air-entrained concrete in accordance with footnote 4
    - Concrete shall be air-entrained. Total Use of additives shall not be permitted unless specifically approved by the structural engineer.
  - Use of additives containing calcium chloride shall not be permitted.
  - Air content (percent by volume or concrete) shall be not less than 5 percent or more than 7 percent
- REINFORCING RODS -
  - Shall conform to ASTM A-615 grade 60 WWF shall conform to ASTM A-185, MESH 6x6 drawings.
  - Furnish support bars and all required accessories in accordance with C.R.S.I. standards.
  - All reinforcing steel marked "continuous" shall be lapped 36 bar diameters at places and around corner or intersection with a standard 90 degree bend on corner bars.
  - Lap welded wire mesh one full mesh at side and end laps.
- SLABS ON GRADE –
  - 4" thick with WWF placed midway in slab thickness, slabs poured on 6 mil poly.
  - Apply film vapor barrier on minimum 4" gravel.
  - Overlap joints of barrier 12".

    - Seal or tape penetrations by plumbing and avoid puncturing of film.
    - Seal edges to foundation walls.
- COMPACTION –
    - Provide 95% compaction at all slabs and footings.
    - All compaction shall be verified through in-place density tests by a qualified soils engineering consultant.
- FORMWORK –
    - To be well braced, true to dimension, level and plumb.
    - Provide clear distance to outermost reinforcing as determined by the structural engineer OR 2” min.

3.0 MASONRY

- CONCRETE MASONRY UNITS (CMU) –
  - To be ASTM C-90, grade A for load bearing masonry.
  - Solid block ASTM C-145 grade B.
  - Minimum net compressive strength 2,000 PSI.
- MORTAR TYPE –
  - To be ASTM C-270 type compressive strength 2,000 PSI.
- MASONRY REINFORCEMENTS
    - Horizontal reinforcements - over wall at 16" O.C. vertically (no reinforcing required on walls less than 4 courses high).
    - Unless otherwise noted. 12" masonry foundation walls shall be reinforced as follows if applicable for 8'-0" from slab to underside of joist (H):
        - Exterior grade = H to .75H.....#4 @ 24
        - Exterior grade = Less than .75H.....None
        - For 9'-0" from slab to underside of joints (H):
        - Exterior grade = H to .75H.....#6 @ 32
        - Exterior grade = .75H to .50H.....#5 @ 48
        - Exterior grade = Less than .5H.....None
        - For 10'-0" From slab to underside of joists (H):
        - Exterior grade = J to .75H.....#5 @ 8
        - Exterior grade = .75 to .50H.....#5 @ 32
        - Exterior grade = Less than .50H.....#4 @ 48*

- Provide dowels from all footings to masonry walls to match size and spacing of all vertical reinforcing. Grout all reinforced cores solid.
- PARGING –
    - 1 coat Portland cement above grade - below grade.
- SOLID MASONRY –
    - Provide minimum 8" deep below all concentrated loading conditions
    - Top Courses of block foundation walls shall be filled or solid including the courses under any steel beam.
- MASONRY LINTELS
- Provide 1 angle for each 4" of wall thickness as follows:
    - Openings to 3'-0" = 3 1/2"x1/4"
    - 3'-1" to 5'-0" = 4"x3 1/2"x5/16", with 3 1/2"
    - Horizontal
    - 5'-1" to 6'-6" = 5"x3 1/2"x5/16, with 3 1/2"
    - Horizontal
    - 6'-6" to 8'-1" = 6"x4"x3/8", with 4" horizontal
    - (Non-rated wall only, 3/8" diameter bolts without wood lintel # 32" O.C. - Type.)
- MASONRY VENEER CONSTRUCTION –
    - To have vertical ties at 16" O.C. and horizontal ties @ 32 O.C. flash at base and provide weep holes at 24" O.C.

4.0 METALS

- FOUNDATION ANCHOR BOLTS –
  - Shall be provided at maximum 6'-0" O.C. intervals and placed 12" from the end of each section with minimum two anchor bolts per section of wall.
  - Anchor bolt shall be minimum 1/2" diameter and shall be embedded in foundation in depth minimum 8" of poured in place concrete and not less than 15" in grouted unit masonry.
- STEEL –
  - All metal anchors, fasteners, joist hangers, etc to be galvanized. All structural steel to conform to ASTM-36.
    - Pipe to be A53.
    - Tube to be A500 or A501.
  - Detailing to be accordance with AISC structural steel detailing manual. Connections shall be capable of supporting allowable uniform load stress of 24 KSL.
  - Bolted field connection shall be 3/4" diameter high strength bolts.
  - Bolted joints to be bearing type using the turn-of-the-nut method of tightening. Except add hardened washer under turned element.
  - Provide galvanized metal-let in bracing at all exterior corners of frame walls
- NAILING SCHEDULE – Per manufacturers recommended standards but not less than that required by local codes.
  - Provide base plate for all structural steel beams bearing on masonry.
  - Holes shall not be cut through beams unless indicated or approved by engineer. Provide standard angle wall anchors for a beam resting on masonry.

5.0 WOOD

- SILL PLATE –
  - Plate treated to meet American Wood Preserves Institute Standard LP-2 or LP-4 where indicated on plans.
  - Bolts shall be 1/2" diameter at 6' O.C., 7" into concrete, not more than 12" from corner.
  - ALL EXPOSED EXTERIOR LUMBER or lumber in contact with masonry or concrete shall be pressure preservative treated in accordance with industry standards.
- MAXIMUM MOISTURE CONTENT –
  - Of all lumber shall be 19%.
  - Lumber may be kiln dried but drying process must be regulated to cause a minimum amount of cheching and kiln dried lumber shall be comparable to air dried stock.
- STRENGTH OF FRAMING MATERIALS –
  - All framing lumber shall be hem fir, grade 2 or better, having the following minimum properties.
    - -Bending stress "Fb" = 850 PSI for single member use
    - -Bending stress "Fb" = 975 PSI for repetitive member use
    - -Horizontal shear "Fv" = 75 PSI
    - -Compression perpendicular to grain "Fc" = 405 PSI
    - -Compression parallel to grain "Fc11" = 875 PSI
    - -Modules of elasticity "E" - 1,400,000 PSI
    - -Bending stress "Fb" = 1200 PSI for single member use
    - -Bending stress "Fb" = 1400 PSI for repetitive member use
  - -Horizontal shear "Fv" = 90 PSI
  - -Compression perpendicular to grain "Fc" = 565 PSI

- -Compression parallel to grain "Fc11" = 1000 PSI
- -Modules of elasticity "E" - 1,600,000 PSI
    - Plywood laminated (LVL) beams shall have the following minimum properties.
    - -Shall be 1-3/4"
    - -Bending stress "Fb" = 2800 PSI
    - -Horizontal shear "Fv" = 285 PSI
- -Modules of elasticity "E" = 2,000,000 PSI
    - -Tension parallel to grain = 1850 PSI
    - -Compression perpendicular to grain = 500 PSI
    - -Compression parallel to grain - 2700 PSI
    - -Prefabricated structural timber beams shall conform to one of the following specifications:

- Cutting and notching of floor joists shall conform to the following, or per manufacturer's specifications.
- -Notch depth in the top or bottom of the joists and beams shall not exceed one-sixth the depth of the members and shall not be located in the middle one-third of the span (including bird mouth cuts).
- -Notch depth at the ends of the member shall not exceed one-fourth the depth of the member.
- -The tension side of beams, joists and rafters of four inches or greater nominal thickness shall not be notched, except at ends of members.
- -Holes bored or cut into joists shall not be closer than two inches to the top or bottom of the joists. The diameter of the hole shall not exceed one-third the depth of the joists.
    - Stress grade lumber shall be clearly stamped with the lumber inspection association seal showing the stress grade. All fabrication, erection and other procedures shall conform to the current "national design specification for stress grade lumber and its fastenings."

    - Prefabricated timber shall be installed and braced per manufacturer's recommendation. Timber member shall not be cut or drilled unless so authorized by the manufacturer.
    - Where double members are indicated on the drawings, mechanically fasten both members in a manner such that both members share the superimposed loads, including loads from headers.
- Manufacturer must be a "TPI" (Truss Plate Institute member).
- WOOD JOISTS - Shall have a minimum bearing of 1 1/2". Wood floor trusses to have minimum bearing as per manufacturers recommendations. All joists and rafters to be bridged midway at intervals of 8'-0" max. All rafters and trusses shall be connected at bearing points with one prefabricated galvanized metal connector, minimum 18 ga., with capacity to resist 450# loading unless shown otherwise on drawings.
    - Prefab joists and beam hangers shall be sized and attached for manufacturer's recommendations. Holes through wood 1's shall not exceed manufacturer's recommendations. No cuts or holes are allowed through top or bottom chord.
    - Wood floor joists shall be per depth and spacing shown on drawings. Supplier shall confirm that members provided can carry the loading designated in Section 1.08.
    - Provide 2-3/4" exterior plywood bands at all perimeter bearing walls. Provided squash block and stiffeners as required to distribute loading and shear reinforcing as required at concentrated loads.
    - Bearing studs should be at 16" O.C. with 2 top plates, and care shall be exercised to ensure locating supported floor joists or roof trusses within 5 inches of the studs beneath.
    - Provide solid blocking at 1'-0" O.C. between band and joist and first interior parallel joist.
    - All prefabricated trusses and truss joists shall be designed for the following loads unless noted otherwise:
- Roof: Live load-30PSF
    - Dead load top chord-7PSF

    - Dead load bottom chord-10PSF
- Floor: Live load-40PSF
    - Dead load-15PSF
    - Prefabricated truss joists shall be designed to resist the loading shown with a maximum live load deflection of 1/480 of the span.
- All lintels over all framed openings to be shown below unless noted otherwise:
    - 2 - 2x8 - Openings up to 4'-6"
    - 2 - 2x10 - Openings up to 5'-6"
    - 2 - 2x12 - Openings up to 7'-0"
- All wood blocking, nailers, etc. shall be attached to steel or concrete framing with power activated fasteners or 3/8" diameter bolts unless noted otherwise. Fasteners shall be spaced at 24" maximum O.C. and shall be staggered. Fasteners shall have a minimum capacity of 100 pounds in shear and pullout unless noted otherwise.
- HANDRAILS - At stair 34" height measured vertically from the nosing of the tread.
- GUARDRAILS - Not less than 42" height measured vertically. Construct such that a sphere with a diameter of 4" cannot pass through any opening.

6.0 THERMAL AND MOISTURE PROTECTION

- SILL SEAL - 1/2"x3-1/2" compressible fiberglass beneath all exterior sill plates.
- INSULATION
  - WALLS - R-13, 3-5/8" batt insulation with draft paper face vapor barrier, min., unless otherwise noted.
  - CEILINGS AT ROOF - R-30 fiberglass batt with draft paper face vapor barrier, or blow insulation, r-30 min.
  - PERIMETER SLAB - insulation to be rigid exterior grade, min. R-7 extending 2'-0" vertically and 2'-0" horizontally, min. perimeter insulation to be extruded polystyrene closed cell.
  - VAPOR BARRIERS - to face warm side of space (interior) unless noted otherwise on drawings.
- ROOFING AND EXTERIOR WALLS
  - RIDGE-FLASHING - Install as per manufacturer's specifications.
  - ROOF EDGE - Provide non-corrosive aluminum drip edge flashing at roof edge.
  - FLASHING - To be non-corrosive aluminum provided at tops and sides of all exterior window and door openings in such a manner to be leak proof.
  - FLASH AND COUNTER FLASH - All roof to wall conditions, minimum No.26 U.S. gauge corrosion resistant aluminum step flashing as required to maintain min. height.
  - FLASH AND CAULK projections through exterior walls or roof surfaces.
  - EXTERIOR SHEATHING - 1/8" thermo ply S.G. sheathings installed per manufacturers specifications unless noted otherwise on drawings.
- FIRESTOPPING - Shall be provided to cut off all concealed draft openings (both vertical and horizontal) in the following locations:
  - In exterior or interior stud walls, at ceiling and floor levels and so placed that the maximum dimensions of any concealed space is not more than 10'.

- Other locations not mentioned above such as holes for pipes, sleeves, behind framing strips and other similar places which could afford a passage for flames.

- DRAFTSTOPPING - Provide draft stopping where required in accordance with applicable codes.
- VENTILATION
- Roof Spaces: Enclosed attics and enclosed rafter spaces formed where ceilings are applied directly to the underside of roof rafters shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain and snow. The openings shall be covered with corrosion resistant mesh not less than 1/2" (6 mm) or more than 1/2" (13mm) in any direction.
- Rough carpentry contractors shall seal with construction adhesive, plates at floor and ceiling, and caulk all window and door flanges/jambs and all panel butt joints prior to and during erection.
- All pipes, ducts, vents, wiring, and chases which penetrate ceilings directly below a truss or roof assembly shall be fire stopped.

7.0 DOORS AND WINDOWS

- EXTERIOR ENTRANCE DOORS - 1-3/4" solid wood core hollow metal - min. 20 gauge filled with solid slab polystyrene insulation permanently bonded to panels or insulted fiberglass floor. Provide 1-1/2 pair hinges for doors up to 7'-2" in height and 2 pair for doors to 8'-0" in height. Frames to be minimum 16 gauge galvanized steel with steel doors and wood otherwise. Provide complete weather stripping and metal threshold.
- INTERIOR DOORS - To be solid core wood.
- WINDOWS
- GENERAL - Glazing in locations subject to human impact shall be fully tempered. Fixed panels with area in excess of 9 sq. Ft. with the lowest edge less than 18" above the finished floor or walking surface within 36" of such glazing unless a horizontal member not less than 1-1/2" width located between 24" and 36" above the walking surface shall be fully tempered.
- WEATHER PROOFING - All sliding, swinging doors, and windows opening to the exterior shall be fully weather-stripped, caulked, gasket or otherwise treated to limit air infiltration. Provide maximum air infiltration as follows:
    - Windows shall have an air infiltration rate of less than 0.5 CFM per foot of such crack.
    - Sliding glass doors shall have an air infiltration rate of less than 0.5 CFM per square foot or door area, or
    - Swinging doors shall have an air infiltration rate of less than 1.25 CFM per square foot of door area.
- ALL OPERABLE WINDOWS - Shall have non corrosive screens and sash locks.

8.0 FINISHES

- GYPSUM WALLBOARD - Provide 5/8" type "X" fire-rated gypsum board at walls & ceilings.
- GYPSUM WALLBOARD - Shall not be installed until weather protection for the installation is provided
    - SUPPORT - All edges and ends of gypsum board shall occur on framing members except those edges perpendicular to framing members.
    - MOISTURE-RESISTANT GYPSUM BOARD - Provide moisture resistant gypsum board in bathrooms and wherever moisture conditions can exist.
- Grout - Waterproof grout cement.
- UNDERLAYMENT - Provide suitable floor under-lay for all ceramic tile and resilient flooring.
- PAINT INTERIOR
    - Ceilings - Latex flat, 2 coats
    - Walls - Latex flat, 2 coats
- PAINT EXTERIOR
    - Trim - Latex (1) coat prime (1) coat finish