2006-2427: THE IMPORTANCE OF MATERIAL INVESTIGATIONS IN THE CONTEXT OF THE ARCHITECTURAL DESIGN STUDIO - THREE CASE STUDIES

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The Importance of Material Investigations in the Context of the Architectural Design Studio - Three Case Studies.

Abstract

The teaching of architectural design is greatly enriched by a pedagogy which promotes the rigorous apprehension of the knowledge of materials. Students who directly engage the physical, tectonic and constructional limits of a range of building materials are successful in developing advanced designs which demonstrate an understanding of architectural characteristics such as measure, weight, structure and texture. This paper offers as evidence the results of three different design exercises undertaken in the context of a design studio, each of which problematized the issue of architectural materials. The first was concerned with the exclusive use of concrete in the design of a large scale public building; the second was directed at the use of traditional building materials for producing material studies with innovative surficial manipulations and tectonic joints; and the last was defined by the adoption of a single material in the construction of a full scale design-build installation.




Fig 1. Material Study; insertion and compression of a sheet of galvanized metal within the edge of a solid plank of maple.
Fig. 2 Material Study; rolled and polished bent steel plate.
Fig 3 Detail of Paper Tube Installation; horizontally stacked hollow cardboard tubes.
Fig. 4 Detail of Paper Tube Installation: vertically arranged hollow cardboard tubes.

Introduction

This paper is concerned with the use of material fabrications in the teaching of architectural design. It identifies and describes three different methodologies which have been used, in the context of Masters level studios, to organize the conception and construction of architectural projects; most particularly, projects defined by the exigencies of their physical properties. For well over 60 years the design studio has been at the center of architectural education serving as an important venue for exploring the relationship of building to construction. And it is the goal of this paper to critically assess the educational merit of three distinct exercises conceived to promote a paradigm shift in accepted studio procedures. To this end, and by way of a series of descriptive case studies, this paper will evaluate the re-introduction of material constraints within the development of an architectural pedagogy.

The student projects presented herein are the result of creative work. They are works of synthesis which required the elaboration of physical models in order to communicate the results of research. They are not proofs but rather demonstrations of architectural inventions generated by the productive introduction of material limits within the design process. In describing and illustrating the results of a series of architectural studios, this paper will foreground the specific pedagogical strategies which enabled students to acquire a direct knowledge of building materials. The express goal of all exercises was to encourage the immediate acquisition of both qualitative and quantitative measures of architectural matter.

To this end, in each exercise students were asked to build three dimensional material analogues designed to respond to a specific set of physical determinants. Whether associated with the constraints of gravity, with resistances to weathering, or with the manipulation and calibration of light, students acquired first hand familiarity with the performance of materials such as woods, plastics, metals and concrete. And within a highly scripted set of design parameters, pedagogical activities of three distinct types were elaborated.

In the first exercise students were asked to design individual projects entirely generated from the study of a single material; concrete. A rigorous investigation of the properties of both pre-cast and poured in place concrete was central to the design of a public art gallery and performing arts complex. In the second set of exercises students built a series of material objects directed at the invention of new ways of manipulating the surfaces of glass, plaster, wood, fabric, plastics and metals (Fig. 2). And these one to one constructions evidenced a host of news methods of joinery (Fig. 1). In the final exercise, groups of undergraduate and graduate students organized in a week long design charette built 3-dimensional open air enclosures using a structurally sound, sustainable, yet perishable material; hollow paper tubes (Figs. 3 & 4).

Articulating the pedagogical processes which governed these exercises as well as their results is the focus of this paper. And to this end, it is of some consequence to identify the larger disciplinary circumstances which have contributed to this return in the material dimension of architecture.

From “Space” to “Matter”

The decision to structure design studios based primarily on the study of materials was borne, in part, from the following observation; contemporary architectural education privileges near exclusively the spatial, pictorial and cinematographic interpretation of architecture. Implicitly or otherwise, the articulation of "space" with its associated focus on "form," with the proliferation of "images", and with the experience of architecture defined through the lens of a "camera" has had a significant effect on the design process of young architects. Noted architectural historian Kenneth Frampton identified the predominance of this focus on "space" in his seminal work from 1995 entitled *Studies in Tectonic Culture, The Poetics of Construction in Nineteenth and Twentieth Century Architecture*.[1] In the "Introduction", Frampton reminded his readers of the influence of new space/time conceptions, formulated at the turn of the 20th century, and on the "identification of space as the driving principle behind all architectural form."[2] He suggested, moreover, that technological and engineering innovations such as cars, airplanes and trains contributed to this condition by situating physical 'displacement' and 'movement' at the center of the architectural design lexicon. "Space has since become such an integral part of our thinking about architecture that we are practically incapable of thinking about it at all without putting our main emphasis in the spatial displacement of the subject in time."[3] The frequency with which students, architects and engineers use the word "space" when intending to speak about "architecture" is evidence of precisely this condition.

A result of this excessive reliance on "space" has been the over emphasis of "form" in architectural design and an increasing neglect of the material specificity attendant to the practice of architecture. Decisions related to the construction of a building, the selection of particular materials, assessments of available technologies and natural resources, as well the ecological impact of a building are factors which have only sparingly structured student designs; until however, fairly recently. In the past five years a growing number of significant pedagogical initiatives aimed at reversing this condition have been noted.

Important in this regard have been recent publications and exhibitions centered on the role of materials in architecture. The *Journal of Architectural Education* (JAE) has significantly contributed to the dissemination of such information. With the publication of student designs produced in architectural studios organized by educators Cathrine Veikos, Lisa Iwamoto, Nils Gore and Stephen Turk for example, new strategies have been identified that resituate construction at the center of design.[4] All published projects critically engaged the challenge which "matter" affords architecture, whether involved with the construction of full scale installations, digital methods of fabrication, the use of plaster in initiating design methodologies or with the attention to "craft" made possible by material inventions.

Additionally, recent research conducted by architectural educators focused on the engineering processes and properties of materials has furthermore expanded our understanding of the subject. The work of John Fernandez, Michelle Addington and Daniel Schodek has vastly contributed to the re-introduction of engineering measures within the design studio. In his 2006 publication, *Material Architecture, Emergent materials for innovative buildings and ecological construction*, Fernandez developed a methodology for the study of materials which, originating in the sciences, communicates and translates qualitative characteristics into quantifiable measures thereafter applicable in the development of design strategies. The book is equally concerned with identifying innovations in five groups of materials, including polymers, ceramics, composites, metals and natural materials.[5] In *Smart Materials and Technologies for the architecture and design professions,* Addington and Schodek also communicate their familiarity with non-traditional building materials which have emerged from advances in the sciences, particularly nanotechnology, and which offer architectural design the prospect of "smart" technologies.[6] Their analysis of "property –changing" and "energy-exchanging" materials drastically expands the definition of possible building materials. [7] And their introduction of a range of electrical systems and sensors with which these materials will be "controlled" confirms the drastic reinvention of the role which materials will play within the design, construction and operations of a building. [8]

The recent exhibition "Extreme Textiles, Designing for High Performance" held at the Cooper Hewitt, National Design Museum in 2005, furthermore affirms the precipitous increase in innovation which technology and engineering have made possible in the field of textiles.[9] High Performance Fibers with "high modulus and high tenacity" were featured alongside designs for a Carbon Tower designed by the architect Peter Testa.[10] And as such, this exhibition and the recent publications mentioned here above confirm the urgent need to once again undertake a return to the material dimension of architecture.

To this end, the design exercises described here below were directed at increasing the student's capacity to acquire a learned understanding of materials, albeit the materials with which they were involved were neither "emergent, given to high performance or Smart". Rather, the interest in manipulating readily available building materials was the aim of this particular triad of exercises conceived to integrate within the design studio full scale material constructions, digital technology, the rigorous study and application of a single material, and the return to an attention to craft.

Exercise One – "Casting Matter"

The first set of exercises of interest to this paper describes a full studio sequence conducted at the Georgia Institute of Technology in collaboration with Monica Ponce de Leon.[11] The decision to focus the entire studio on the design processes engendered by one material was highly productive. The chosen material was concrete and all designs were developed within the constraints of either pre-cast or poured in place concrete. The entire studio was dedicated to developing a specific skill set attendant to deploying construction details and architectural forms in either modes of concrete fabrication. As a result, the studio was singularly focused on activities which helped identify the difference between cast in place and pre–cast concrete.

It was also structured in three separate parts of which the first two were aimed at developing a more precise understanding of the determinants of poured concrete and the logic of assemblies which accompanies the implementation of pre-cast concrete. Students were asked to develop, by trial and error and by precise design, a quantifiable logic and an array of techniques for the making of concrete profiles and castings. And in the end, whether intended for poured in place or pre-cast concrete, the techniques developed as a result of this early set of exercises became the basis for the entire configuration of a building; the studio's final requirement.

Both initial exercises in pre-cast and poured in place concrete were three weeks long; the final project involving the design of an entire building was nine weeks long. The students worked both individually and in teams during the completion of the final project. And in addition to the conventional measured drawings which students produce in the process of designing buildings, they were expected to cast large scale plaster models for the first exercise, produce 3-dimensional digital "print-outs" for the second investigation, and construct detailed models of their final projects.

In the first assignment, "Casting Spaces – The Concrete/Plaster Pour", students were asked to consider the liquid state of concrete given the observation that, differently than most other building materials, concrete begins its life in a state other than that which it acquires in the curing process. This highly significant determinant makes of concrete extremely dependent on its formwork for shape, volume, and structure and students were asked to research these functional variables with the goal of addressing concrete's unique material exigencies. Via processes of analogical transposition, students produced a series of plaster casts in order to explicitly investigate the logic and constraints of pouring. The average dimension of each poured prototype was two cubic feet and in the production of waffles, thin plates, bent plates and even figures here thereto not yet commercially available, a rigorous set of plaster models were made in order to establish the limits of a tectonic language which thereafter could be used to inform the design process (Figs. 5 – 16).

Fig. 5

Fig. 6

Fig. 7

Fig. 8

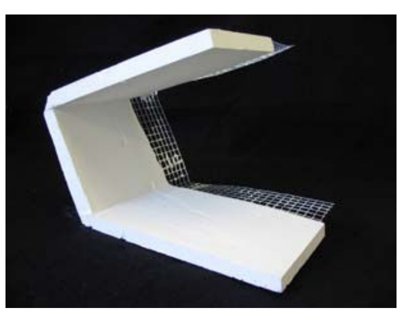


Fig. 9

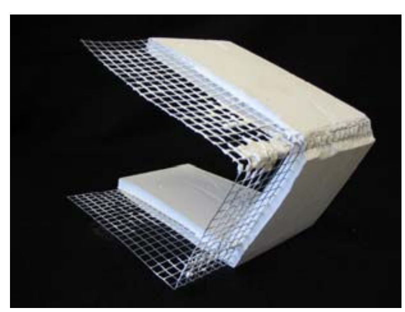


Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 14

Fig.15

Fig.16

Following these initial prototypes, the students were asked to organize significantly larger pours in which the extent of the formwork used was substantially larger than previously employed. Each student was expected to develop a model whose clear geometric logic demonstrated an understanding of the tectonic possibilities of concrete at the scale of a building. The average dimension of the second pour was 10 cubic feet and in the process of constructing these vastly larger plaster casts students were invariably exposed to significant ruptures, if not outright failure, of the formwork (Figs. 20-21). Eventually, and with greater degrees of expertise, leakages and the unexpected bonding of surfaces were identified as positive constraints in the design process. This assuredly more challenging pour was a further demonstration of the degree of skill already acquired by the student in the pouring of his or her first structural proto-type. And it was intended, moreover, that encoded within this second construction was a geometric model of five interconnected volumes whose fluid surfaces defined a building entirely conceived using the logic of concrete pours (Figs. 17-19).

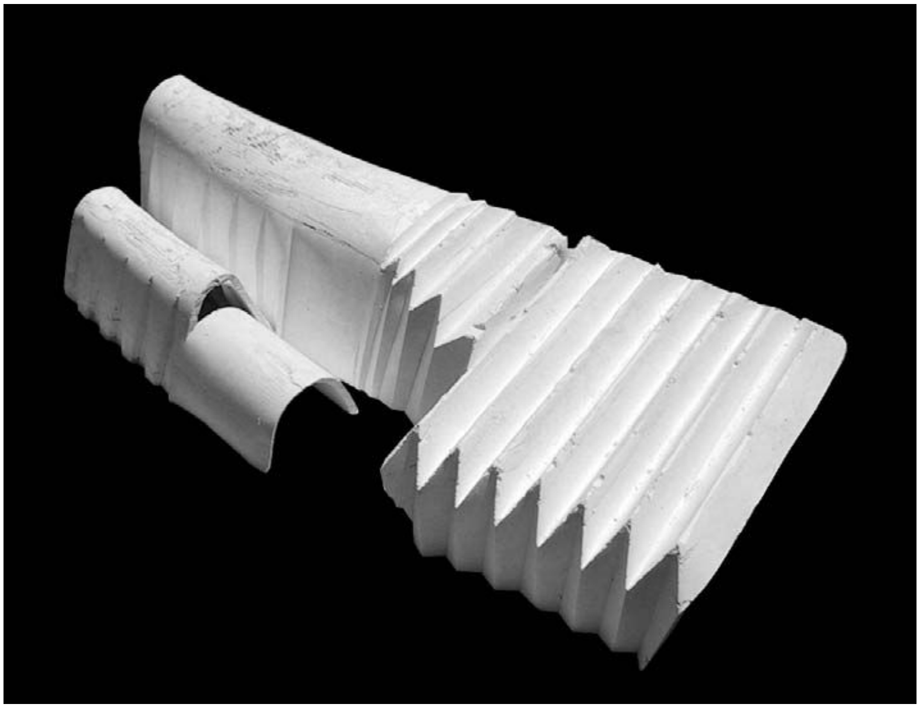


Fig. 17. Large plaster pour of a folded concrete structure (app. 24” x 60” x 12”)

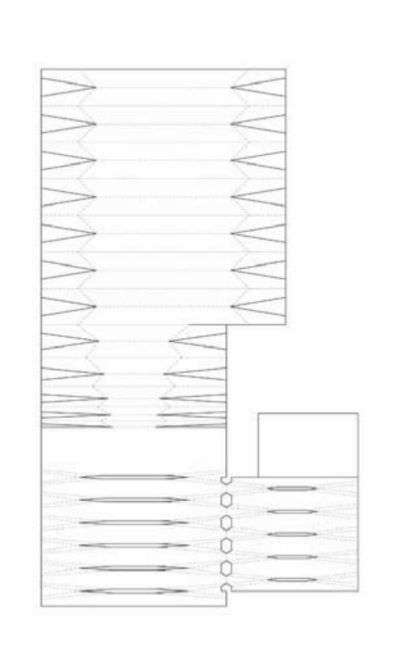
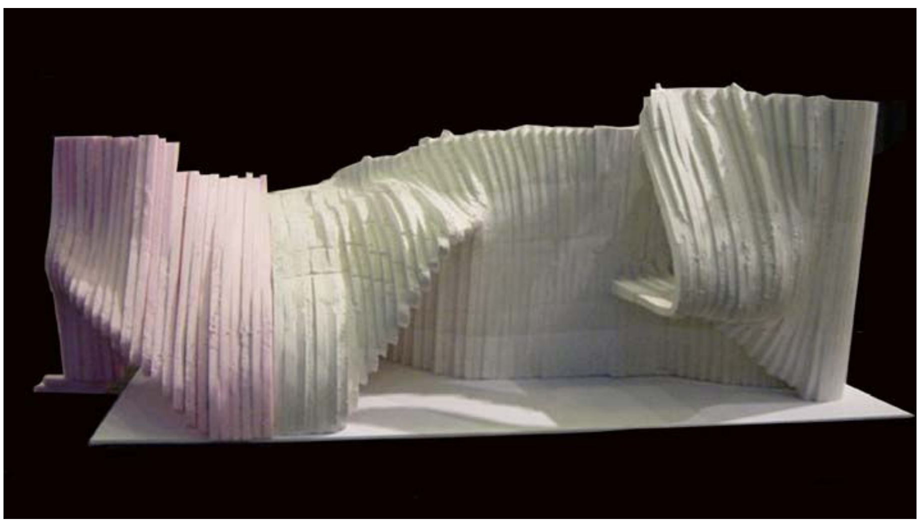


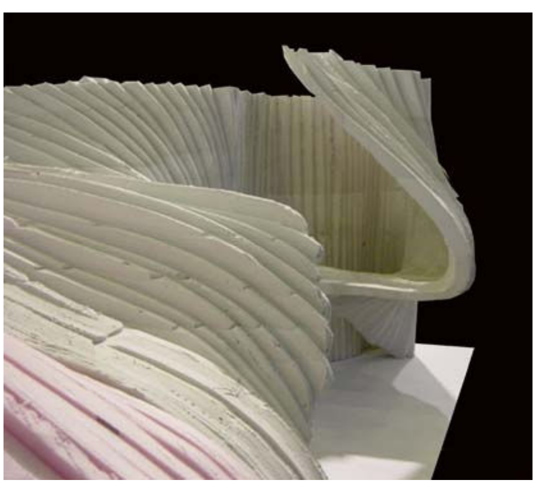
Fig. 18. Plan layout of the plaster pour prior to being folded to make the mold.

Fig.19. Folded paper mock up for the formwork and the final structure.

Fig. 20. Failed plaster pour

Fig. 21. Failed plaster pour





Figs. 22 -23 Plaster pours using Styrofoam molds

In the second exercise, “Part Two – Aggregated Castings – Pre-cast Concrete”, students were asked to research the relationship between pre-cast concrete construction units, methods of their assembly, and a range of volumes which such aggregates rendered possible. To this end, students were required to undertake a highly prescribed design process whose goal was the development of a 3-dimensional structural pattern here thereto never built. While the process began with the consideration of traditional building elements such as beams and columns, the students were thereafter required to invent a language of innovative pre-cast units which relied on gravity and interlocking to achieve an entirely new structural system. The system was to be accommodated to an overall building footprint of 52’ x 104’and the maximum ceiling height of each floor was 7 ‘- 6”.

The design of two new families of structural elements was essential to this end and the process by which new structural members were invented was based in digital manipulations. Using Form Z software, students morphed, lofted and blended a range of sectional profiles and in so doing developed profiles not readily available in the building industry. These alternative structural profiles were then printed in three dimensions at a 1/8” = 1’-0” scale using a 3D printer which interpreted the digital files. The 3D printer combined small scaled particulates (of cornstarch) with adhesives in order to construct the final physical model and in so doing defined a form of making which was very different from that of the original plaster pour. A significantly higher level of precision was thus possible in the execution of this second exercise.

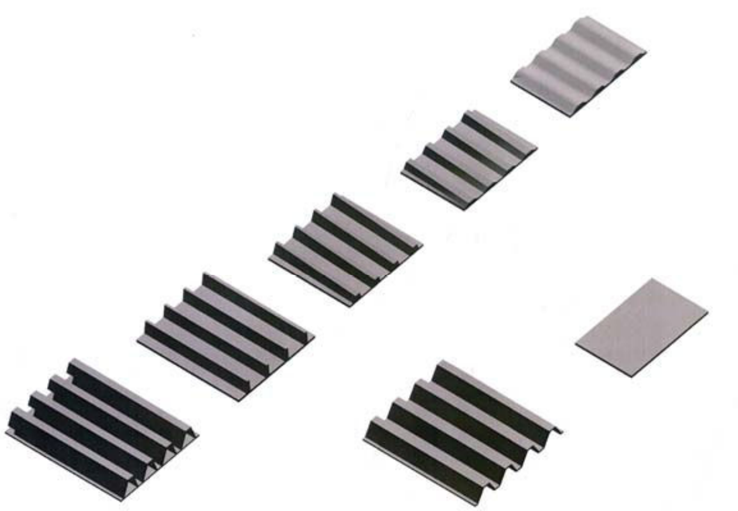


Fig. 24. The individual slab elements as they are morphed from a flat rib profile to a very deep and hollow rib profile.

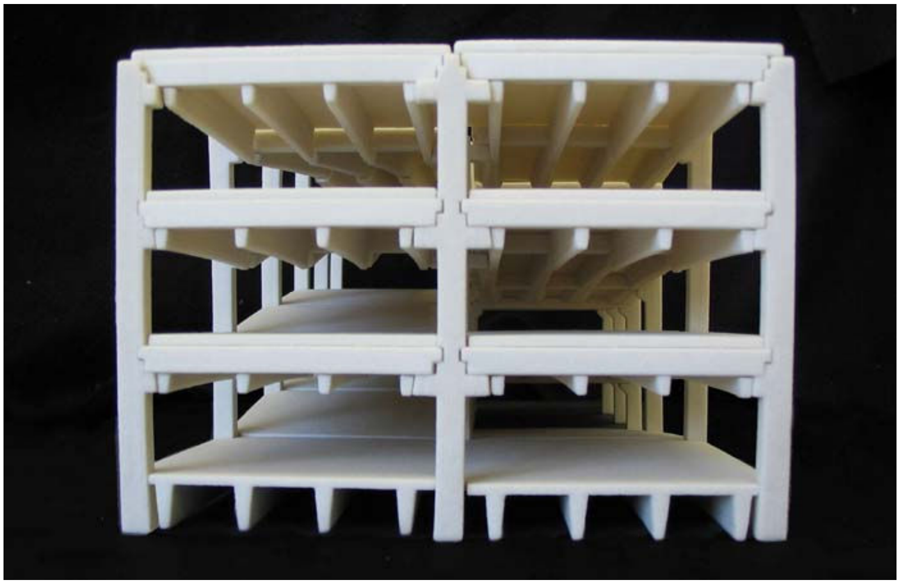


Fig. 25. The 3Dimensional 1/8" scaled model demonstrating the inventive rib and slab configurations which the assignment called for.

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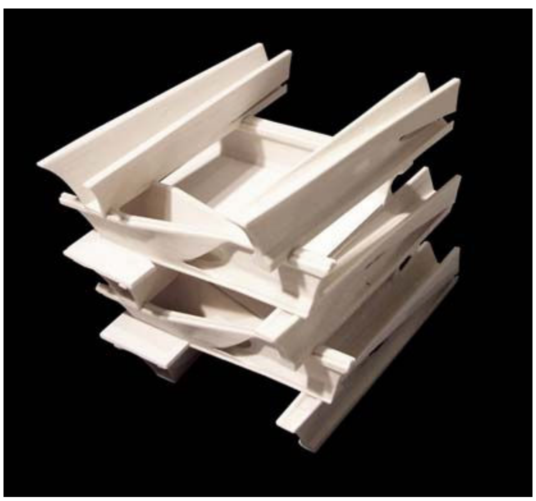
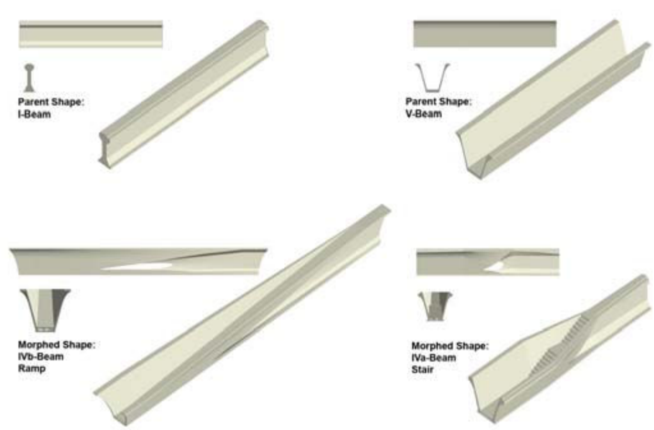




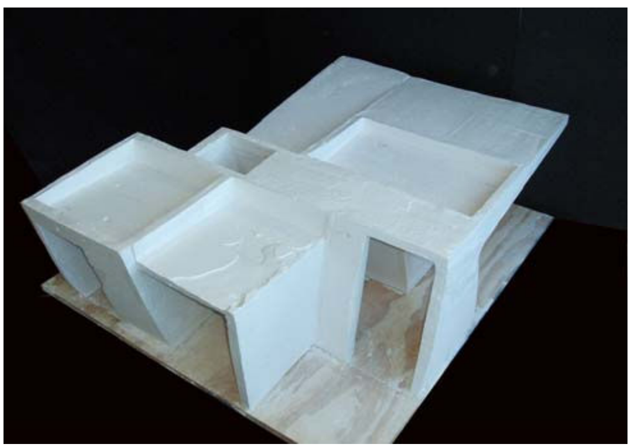
Figs. 26 -27. The alternate stacking of deep, yet hollow, wall/ beams which resulted in a 'house of cards' structural framework. Within the hollow of structural members were situated the stairs necessary to move from one level to another.

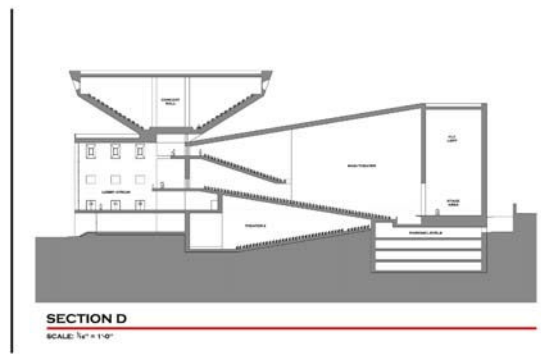
The third and final part of the semester, "Part Three – The Concrete Building - Programming Casts", sought to transfer these structural inventions to the design of an entire building. Students who had succeeded in the poured in place plaster exercise were assigned the design of a Performing Arts Center (Figs. 28-33), whereas students who had excelled in inventing new structural pre-cast elements were assigned the design of a Contemporary Art Gallery (Figs. 34 - 38).

The dimensions and program for each building type was as listed below.

The Performing Arts Center

Theatre A.	Theater with fly loft (seats 3,600)		36,000
Theatre B.	Concert hall (seat 2,000)		20,000
Theatre C.	(seats 1,200)		12,400
Theatre D.	Black Box (seats 450)		4,500
Small Theater	(seats 450)		4,500
Café/Lobby/Box office			13,500
10 Administrative Offices			1,500
Services (Circulation and Building services)			as needed
		Total	92,400





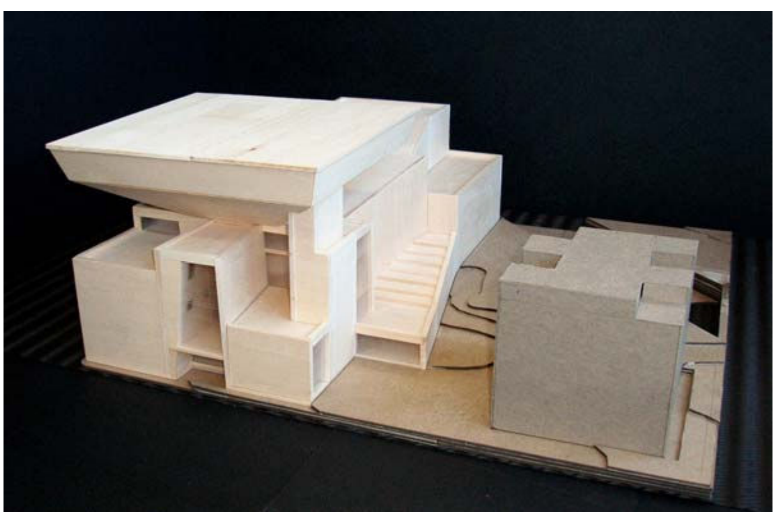


Fig. 28. Plaster cast of the original pour.
Figs. 29 -30. Final Plan and wood model of the Performing Arts Center.

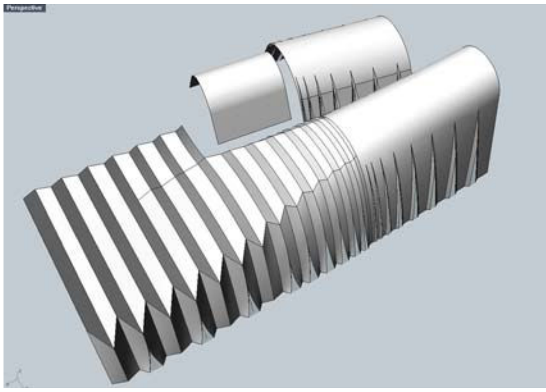


Fig. 31. Rhino software model of the original cast

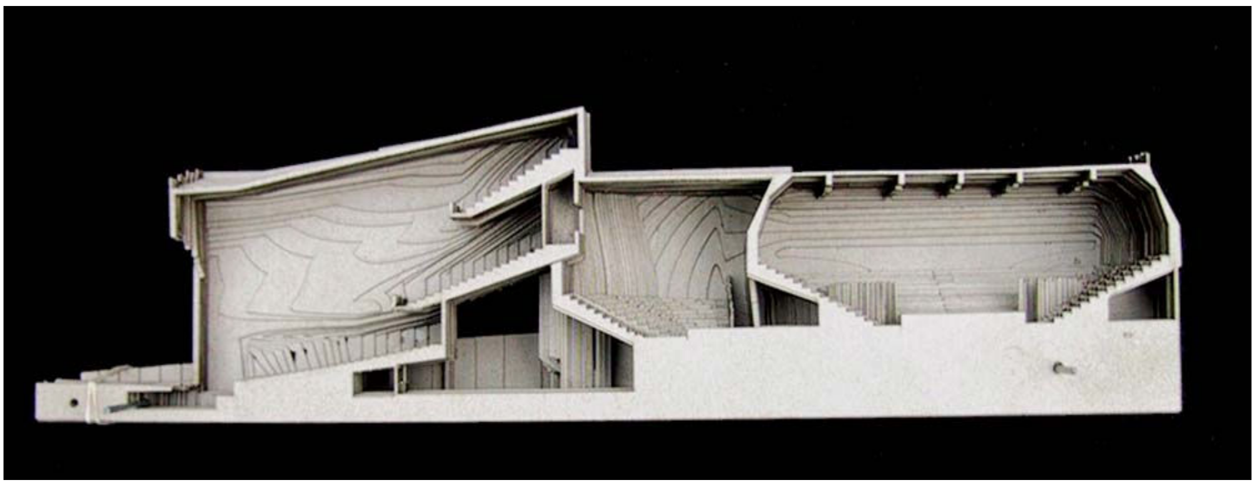


Fig. 32. Laser cut cardboard model of the section of the Perfoming Arts Center

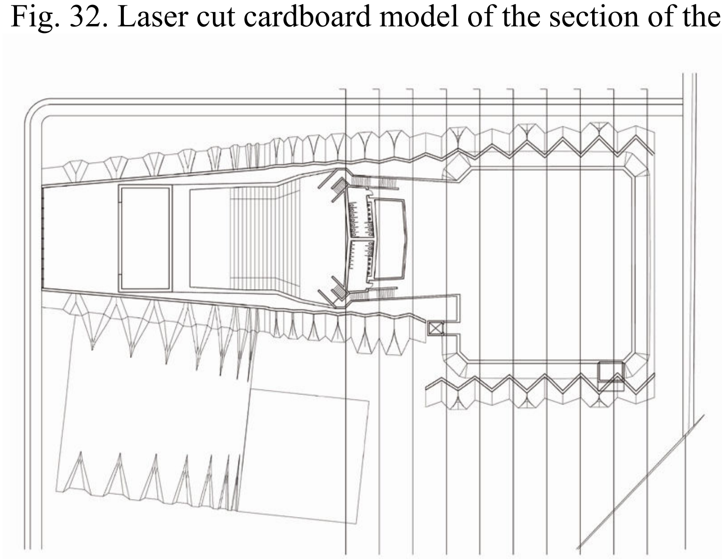


Fig. 33. Final Plan of the Performing Arts Center

The Contemporary Arts Gallery

Temporary Exhibitions – ceiling height @ 8’ min		13,000
Temporary Exhibitions – ceiling height @ 12’ min		13,000
Temporary Exhibitions – ceiling height @ 21’ exactly		13,000
Temporary Exhibitions – ceiling height @ 30’ min		3,000
10 Administrative Offices		1,500
Curatorial labs (prep rooms)		1,500
Temporary Art Storage		3,000
Café/ Lobby		2,000
Services (Circulation and Building Services)		as needed
Outdoor Sculpture Garden		10,000
	Total	60,000

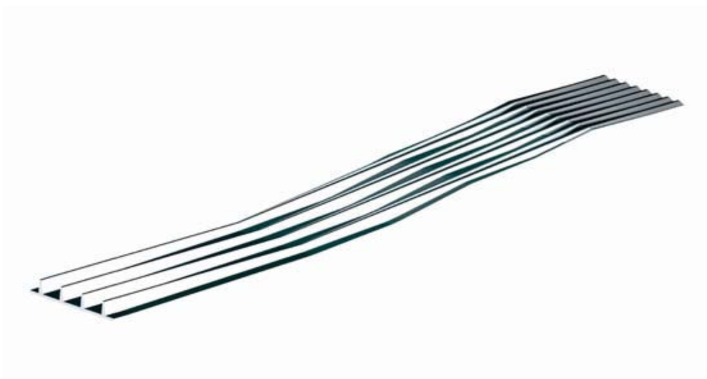


Fig. 34. A continuous slab and rib section of the new structural invention.

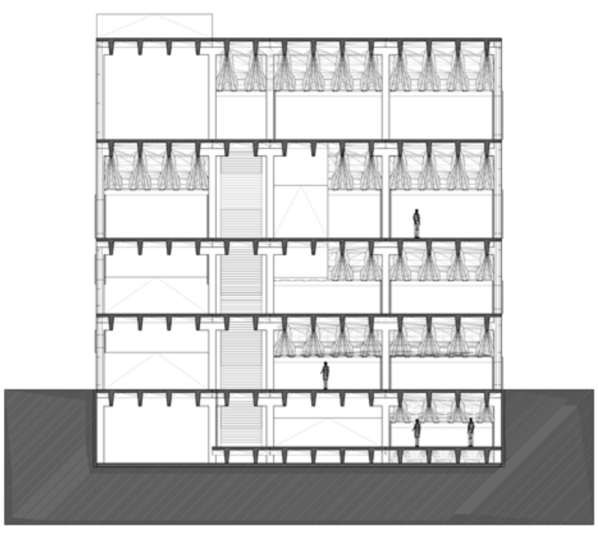


Fig. 35 . Detailed section of the slab and rib profile used in the design of the Contemporary Art Gallery.

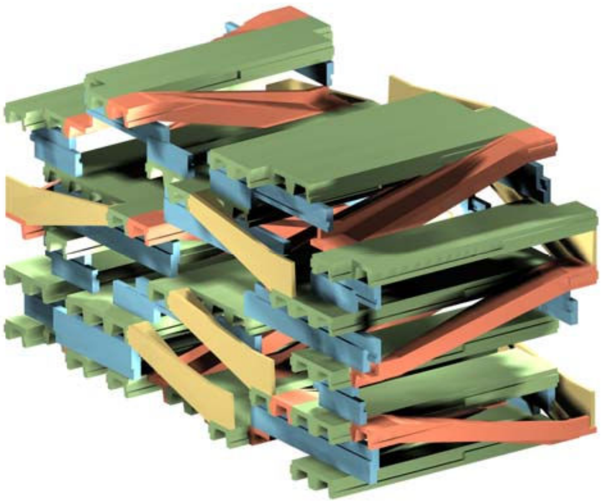


Fig. 36. Pre-cast members vertically stacked to produce the innovative structural principal.

Fig. 37. Detailed section of the art gallery designed using the pre-cast members from above.

Fig. 38. Detailed view of the façade of the art gallery. The cladding references the structural members supporting the building.

Exercise Two – Material Studies and the Construction of Surfaces and Joints

In this particular series of exercises students were asked to build highly elaborate constructions that explored the dimensional, physical and the phenomenal qualities of various materials. These material studies were built throughout the studio sequence in order to study and discover the nature of surfaces, the depth of building sections and the tectonic exigencies associated with both. To begin with, students investigated a full range of surficial manipulations whether using woods, metals, types of glass, plasters, concretes, or fabrics. (Figs. 39- 41)

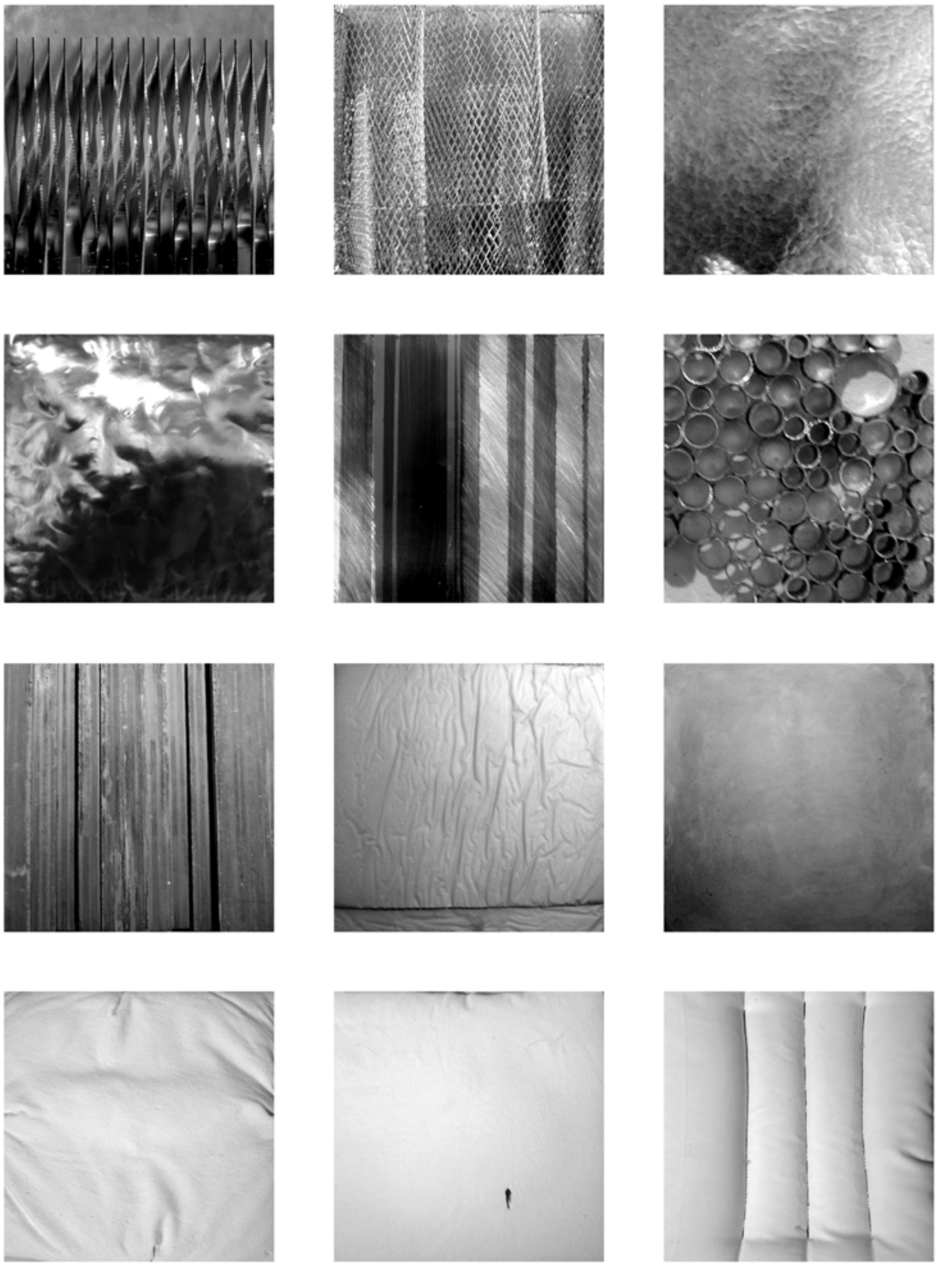


Fig 39. Material studies of metals, plasters and plastics.

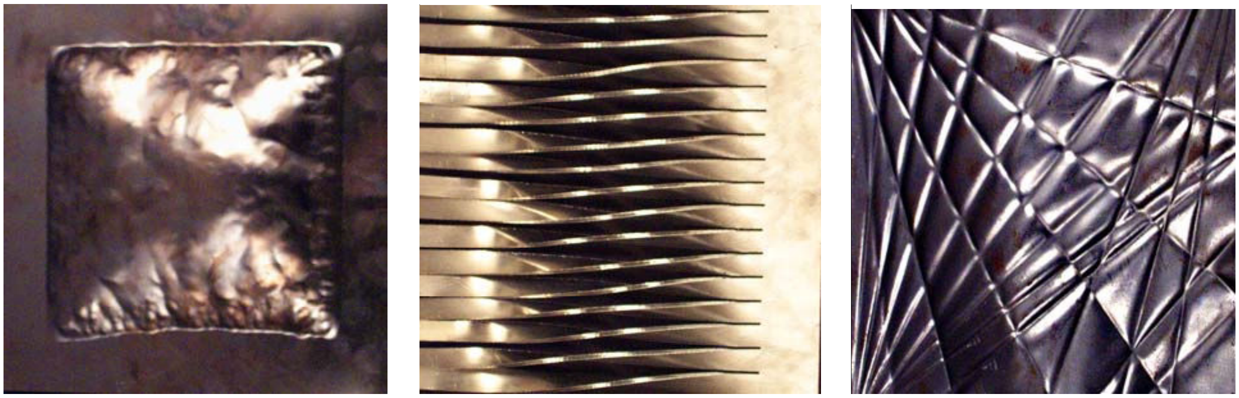


Fig. 40. Material studies demonstrating the effects of various processes; cutting, embossing, and bending.

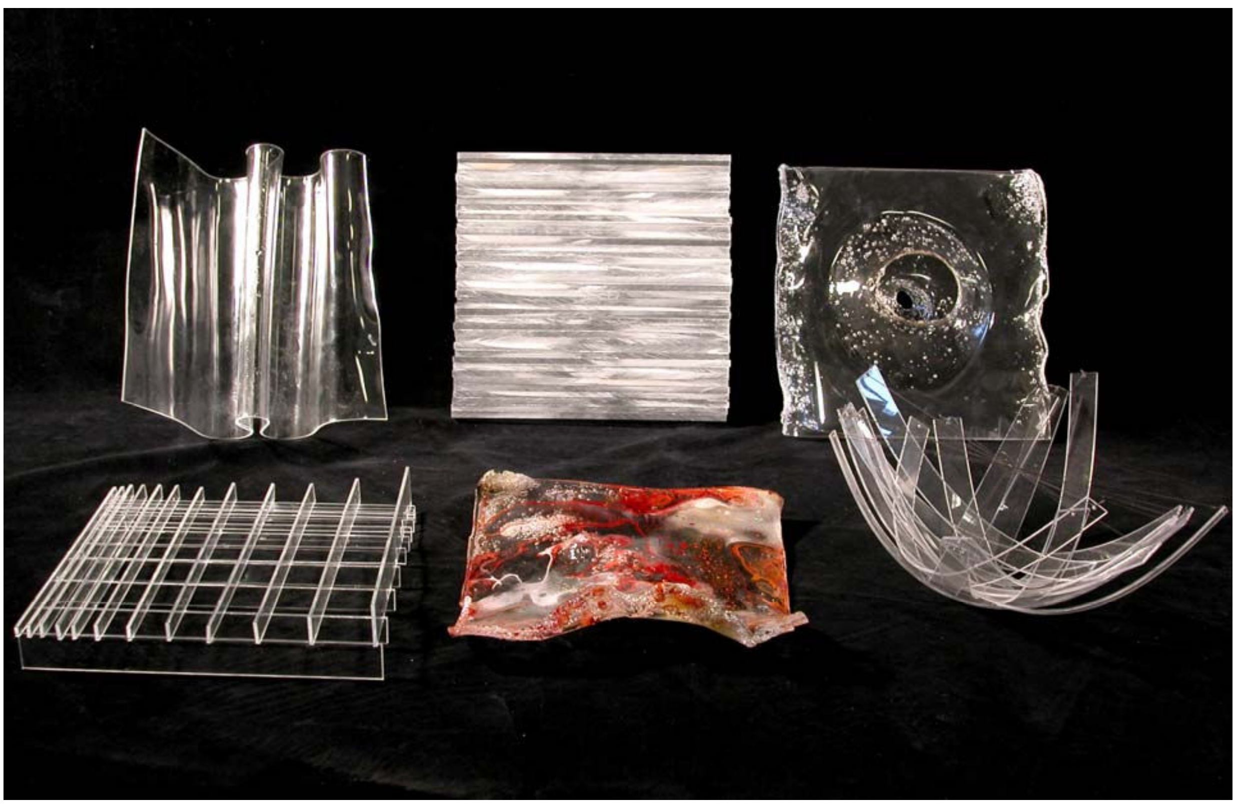


Fig. 41. Material studies in plastic

Students then proceeded to develop material hybrids wherein tectonic negotiations were forged between the different materials. To this end, issues of weight, flexibility, porosity and structural resilience were studied in order to achieve the physical connection of two materials. The construction of such hybrids was also an opportunity for students to directly engage the issue of joinery necessary when any two materials come into contact with each other. (Figs. 42-45)

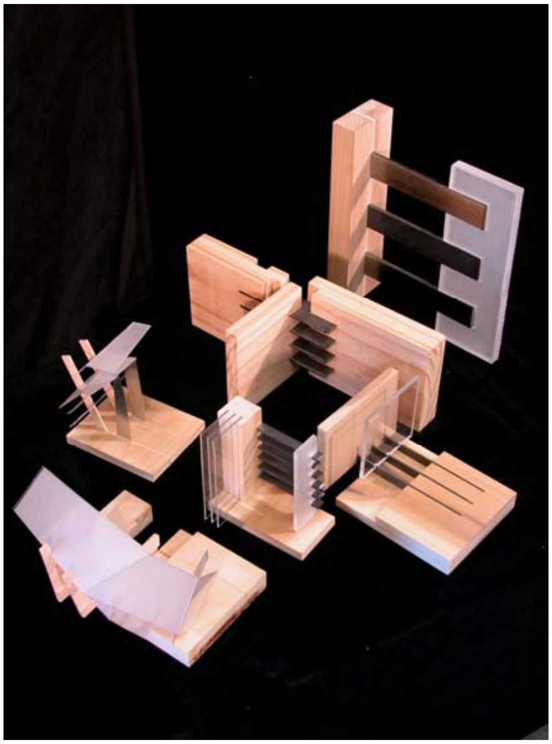
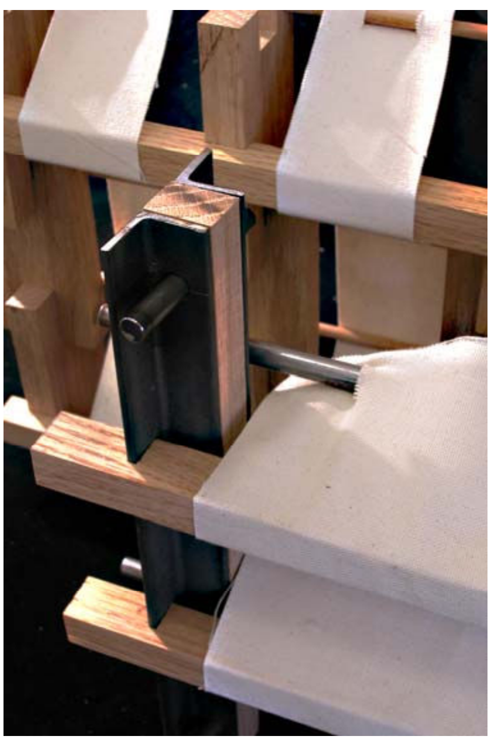


Fig. 42. Material hybrids using wood, metals and plastics
Fig. 43. Material hybrid using galvanized metal and wood



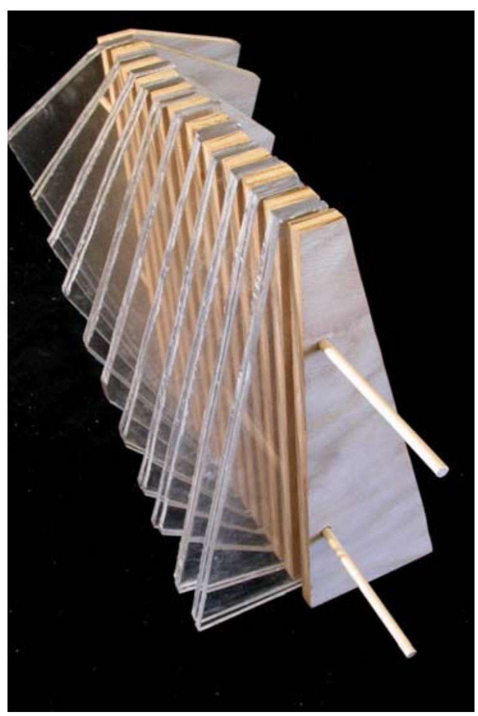


Fig. 44. Material hybrid using wood, metals and fabric
Fig. 45. Material hybrid using wood and plexi

The development of the hybrid, led thereafter to the construction of tectonic models; three dimensional material objects intended as structural and architectural analogues. Challenges faced by gravity, weight, support, anchor and stability were once again re-engaged in this series of constructions. (Figs. 46 -49)

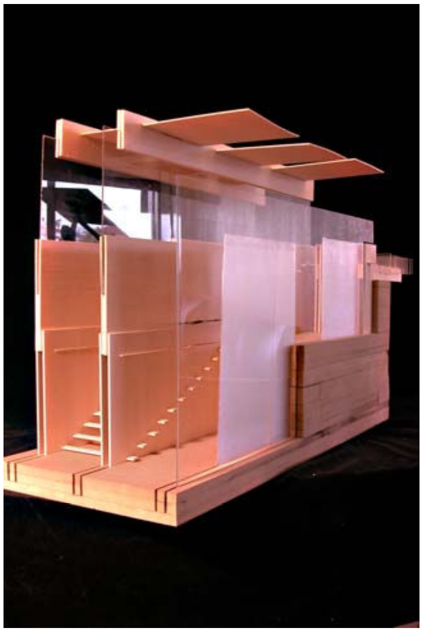


Fig. 46


Fig. 47

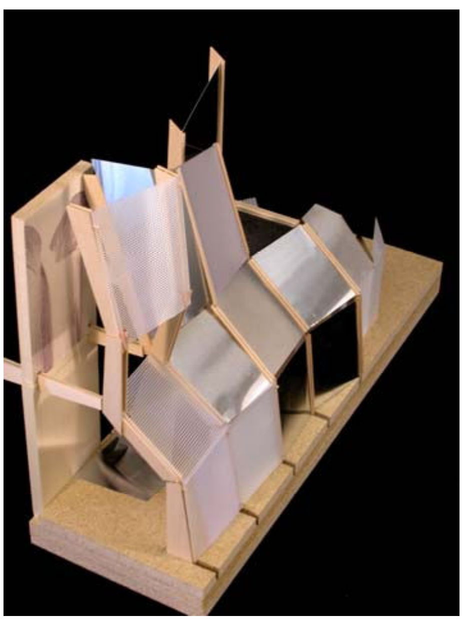


Fig. 48

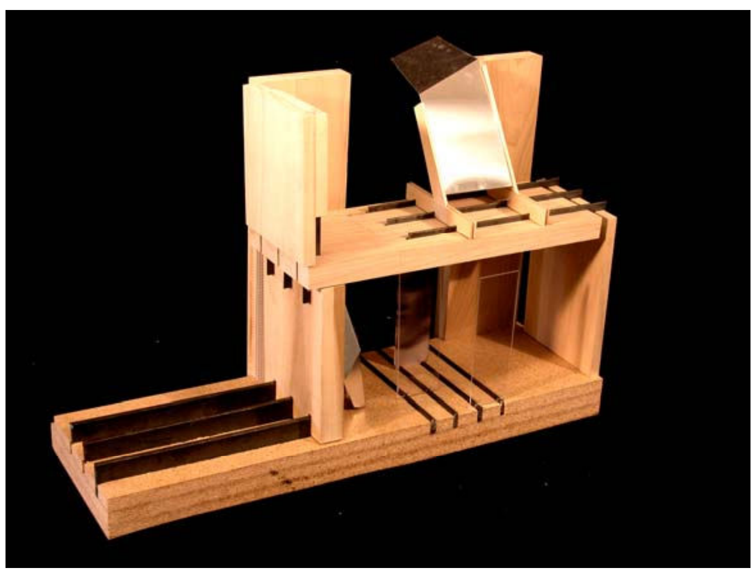


Fig. 49

Tectonic models constructed of woods, plastics and metals.

Exercise Three – Building with Paper Tubes – the SONOCO Charette.

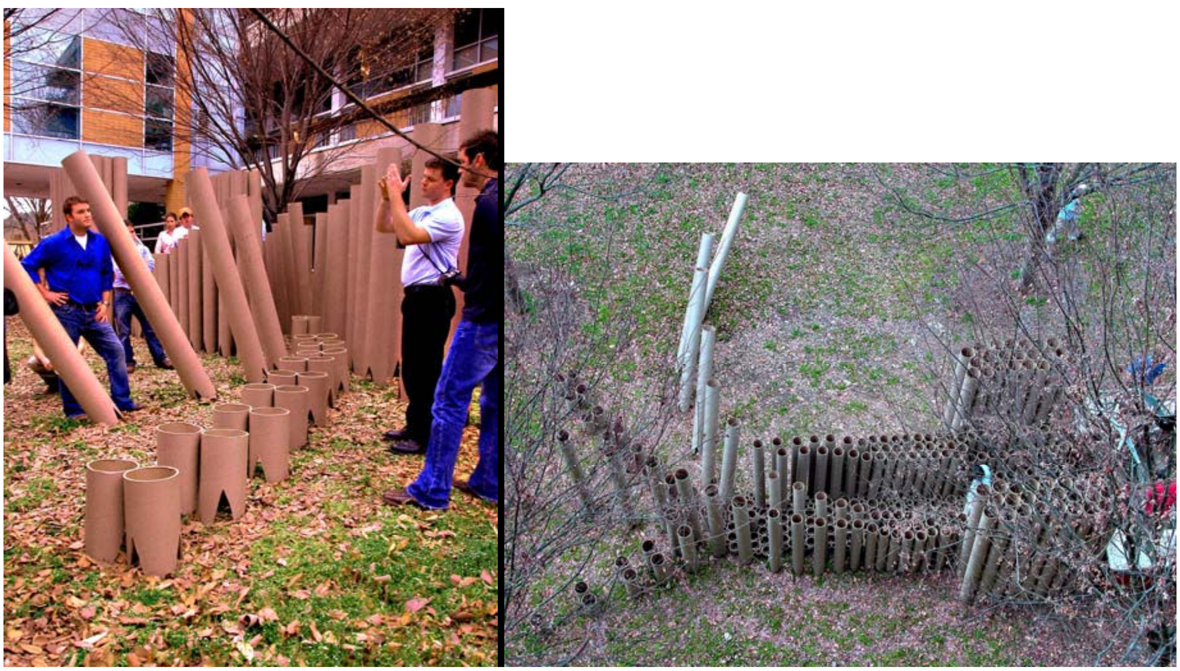
This final exercise described here below is of a design build project which sought to extend material investigations to the scale of one to one constructions; these being, in–situ installations which make possible the immediate acquisition of material experiences at full scale. The one week design charette was organized with and facilitated by the direct collaboration with an industry sponsor. The project was made possible by the generous support of Sonoco Industries of Hartsville, SC; a world wide producer of paper products. [12]

Students were asked to build a temporary open air enclosure using this alternative building material and the paper product selected to this end was that of paper tubes. [13] A total of 700 tubes of varying diameters, thicknesses and lengths were delivered to the University using a 20 meter tracker trailer and students were asked to study their properties before initiating the building process. (Fig. 50)

Fig. 50. Poster announcing the week long building Charette. Students constructed temporary seating from the delivered shipment of paper tubes using cantilevered supports and in so doing tested the bending limit of the paper tubes.

In the past, Sonoco Industries was an important player in the textile industry; as all fabrics were transported and sold wrapped around such paper tubes. Similarly, these are the same tubes which continue to be important for the newspaper industry. Relative to the building industry, they are the producers of SONO Tubes used in the pouring and curing of circular concrete columns and footings. And significant for our purposes was the fact that from an environmental point of view the simple paper tube was produced from recycled materials and it was itself easily recyclable once the construction charette completed.

Three teams of graduate and undergraduate students were mandated to design a structure which would facilitate the dynamic encounter between two individuals, scaled to both the human body and the landscape within which the installation was to be located. The students were asked to challenge the material's structural capacities in both the horizontal and vertical directions in the process of making an enclosure. Testing the possibility of building cantilevers, using the soil as an anchor for the structure and developing a structure which delivers an eloquently patterned skin, were designed guidelines the students undertook in their innovative use of these near structural paper tubes. In fact, the project's success was in large part due to the eagerness with which students sought to work with the tube's immediate physical and material constraints. (Figs. 52 -57)



Figs. 51- 52. Paper Tubes used to construct a vertically oriented structure composing a series of freestanding walls.

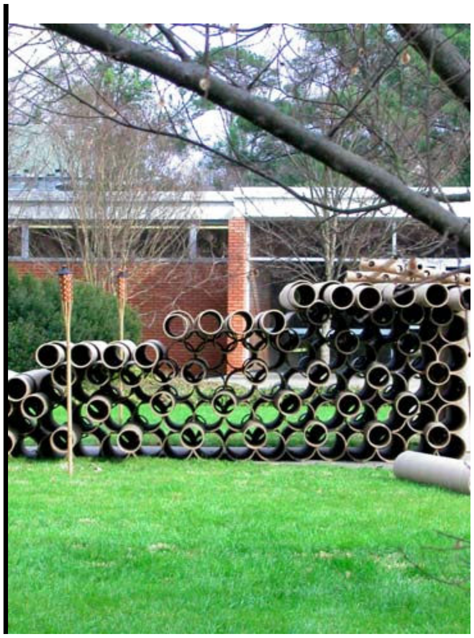


Fig. 53

Fig. 54

Fig. 55

Fig. 56

The use of paper tubes to construct a horizontally loaded structure able to support the weight of more than a dozen students yet entirely transparent in the cross section.[14]

Conclusion

The principal tenet which underlies this paper is the committed belief that the teaching of architectural design is greatly enriched by a pedagogy which promotes the rigorous apprehension of the knowledge of materials. This paper has demonstrated in a number of ways, using a variety of scales and pedagogical questions the benefits accrued in situating material constructions at the center of the design process.

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7. Ibid., pp. 83-108.
8. Ibid., pp. 109- 137.
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10. Ibid., See Alyssa Becker, “ High Performance Fibers”, pp. 72 -75 and Philip Beesley and Sean Hanna, “A Transformed Architecture” , pp. 110-116.
11. This “Concrete” design studio taught at The Georgia Institute of Technology in the Spring of 2005 was co-developed and co-taught with Prof. Monica Ponce de Leon, the 2004-2005 the Distinguished Ventulett Chair in Architectural Design whose vision for the studio assured its success.
12. The author remains indebted to Principal Scientist /Engineer, Wim Van de Camp from Sonoco Industries who graciously worked with the students in developing a design exercise which would permit for the explorative investigation of the paper tubes.
13. For a most accomplished and eloquent use of paper tubes in the construction of architectural enclosures see the work of architect Shigeru Ban.
14. Student Credits .

Fig. 1	Jeremy Tate (Clemson)
Fig. 2	n.a
Fig. 3-4	Clemson University Charette Teams
Fig. 5-7	Kenneth Elsworth (Georgia Tech)
Fig. 8-10	Benjamin Hudgins (Georgia Tech)
Fig. 11-12	Allison Gander (Georgia Tech)
Fig. 13&16	Jason Dooley (Georgia Tech)
Fig. 14-15	Lida Cunningham (Georgia Tech)
Fig. 17-19	Kenneth Elsworth
Fig. 20-21	Benjamin Hudgins
Fig. 22-23	Lida Cunningham
Fig. 24-25	Benjamin Hudgins
Fig. 26-27	Kenneth Elsworth
Fig. 28-30	Jason Dooley
Fig. 31-33	Kenneth Elsworth
Fig. 34-35	Benjamin Elsworth
Fig. 36-38	Nathan Johnson (Georgia Tech)
Fig. 39.	Rachel Johnston (University of Pennsylvania)

Fig. 40	Rachel Johnston and Meaghan Pierce Delaney (U Penn)
Fig. 41	varia
Fig. 42	Peyton Shumate (Clemson)
Fig. 43	Jeremy Tate
Fig. 44	Steve Grogan (Clemson)
Fig. 45	Lindsey Sabo (Clemson)
Fig.46-47	Sean Raboin (Clemson)
Fig. 48-49	Peyton Shumate
Fig. 50-56	Clemson University Charette Teams.