Framing Space

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INTRODUCTION

The Framing Space installation is composed of a differential three-dimensional space truss: a network of linear elements (struts) connected at centralized locations (nodes) where load is transferred axially from node to node through each of the struts. This lightweight and rigid system employs a degree of resilience and redundancy enabling it to span considerable distances proportional to its diminished depth. The triangulation and differential configuration are implemented as geometric means of stiffening, resulting in the slender members experiencing axial loads, creating a more efficient system.

Framing Space consists of two repetitive structural components: stainless steel nodes and extruded aluminum struts, both of which vary in configuration or length according to their position in the system. The Trusset Structural System used in this construction was invented by Phillip Anzalone and Cory Clarke at Columbia's, Digital Fabrication Lab in the Graduate School of Architecture, Planning and Preservation (GSAPP). The Trusset system combines parametric computer modeling, intelligently programmed analytic and algorithmic software processing, and a patented fabrication and assembly method. The materials are cut with simple computer numerically controlled (CNC) machinery such as a two-axis laser cutter, and assembled through methods that can be implemented with semi-skilled labor.

The design integrates spanning panels of varying materials: translucent foamed aluminum, composite polycarbonate, CNC milled high-density polyurethane foam, and incised stainless steel finished sheet. The type and placement of the panels is based on the concept of rethinking the fabrication and detailing of the materials as contemporary versions of traditional pre-computational wall system components (siding, glazing, insulation and cladding).

Theoretical and historic trends and implications of this exploration, as it involves wall systems that become lighter, utilize CAD/CAM and CNC manufacturing techniques and develop into complex forms. Notions of lightness and translucency apparent in the cladding materials are made possible by the confluence of novel design processes and traditional material use. The respective geometry and proportions of the three wall systems trace the evolution of building construction from the stability and modular scale of a brick masonry wall to the integrity of infill construction, ultimately terminating with the paradoxical ethereality and monumentality inherent in most modern day curtain wall systems. The installation explores this lineage of building practices while simultaneously challenging traditional characteristics of all three standard construction types through translucency, digital fabrication and programmatic application.

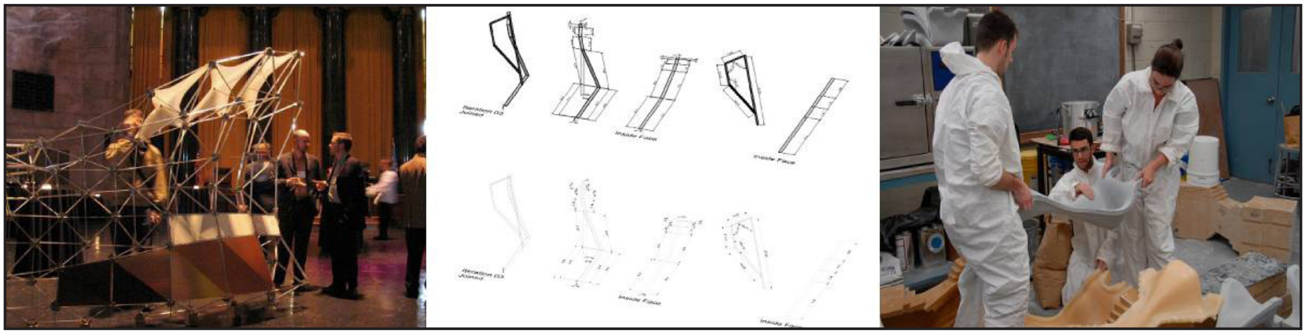

Fig. 1: Precedents at the GSAPP

PRECEDENTS

The Framing Space project serves as a continuation of precedents involving work done by Atelier Architecture 64 (AA64) and the GSAPP. These experiments helped to establish a foundation for building methodologies and logistical trials while also providing a means for the actualization of the construction. In collaboration with the GSAPP, the author's architecture practice, AA64, performed the role as designer and fabricator of the project. AA64's work involves the conjunction of design and construction using new materials and processes, and was therefore an excellent partner to the School of Architecture.

PROJECT / CLIENT / SPONSORS

Crucial to the conception and realization of the installation was a dynamic dialogue with the client, though which the means of assembly and how such processes would help to frame the overarching intent of the exhibition were candidly discussed. This, in conjunction with the generous support of our sponsors, was critical to the success of the Framing Space installation.

Project Initiation

The first site visit was October 1st, 2008, and the contract with AA64 was subsequently signed on November 7th, approximately one month later. With the exhibition set to open on January 23rd, 2009, we were left with only ten weeks for design, fabrication, assembly and installation; we knew from past experience that 60% of the time allotted would be for design and computation involving fabrication prep work, with the remaining 40% involving fabrication and assembly.

Client

The Framing Space installation was designed as part of a larger exhibition entitled "Make it Work: Engineering Possibilities," put together by the Center for Architecture to showcase current technological advances in the field of architectural engineering. Established in 2003, it has been the mission of the Center for Architecture Foundation to promote a broader awareness of the impact of architecture in transforming the social, economic and historical landscape of New York. Through its revolving exhibits on architecture, urban planning, urban design, and engineering, the center has become an increasingly significant cultural institution. The design parameters were relatively open-ended for the Framing Space installation, as we were presented with only two stipulations: that we work within the allocated exhibition space, and that our budget for the project be entirely self-generated.

Sponsors

Once there was a firm guarantee that the installation would be exhibited we approached sponsors, all of whom were incredibly enthusiastic to participate and offered their services and assistance at no or partial charge. The sponsors primary consisted of material suppliers including Contrarian Metal Resources, General Plastics Manufacturing, Panelite, Indalex Aluminum Solutions Group, and Cymat Technologies, Ltd. as well as off-site fabricators such as Mayola Laser, Inc.; and academic institutions such as the GSAPP at Columbia University, and Graduate School of Architecture at Pratt.

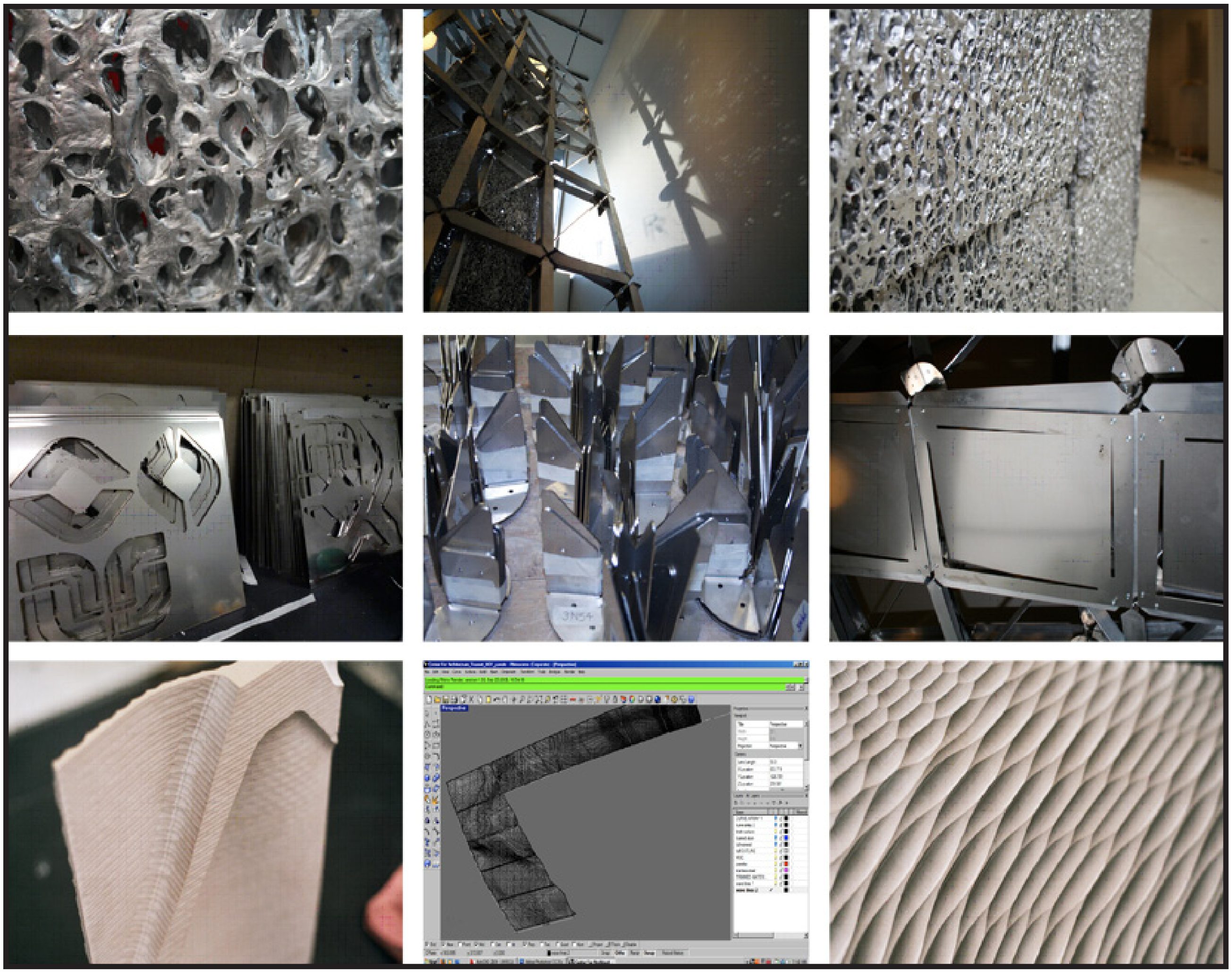

Fig. 2: Alusion foamed aluminum cladding on the Framing Space installation; Invarilux Stainless steel was used for the fabrication of the nodes as well as cladding; General Plastic's high-density polyurethane foam was CNC flip-milled to create additional panels

DESIGN CONCEPTS

The Framing Space installation incorporated a number of innovative materials, fabrication processes, and construction techniques that allowed for experimentation into theoretical and applied building components and systems. The design process and design itself were driven by the concept of applying innovative methods of fabrication and assembly to traditional building materials. This exploration also taught abstract concepts of performative detailing to students—one of the purposes of the project—as the authors believe that the act of constructing is an excellent means of teaching and detailing.

Foamed Aluminum

As the most abundant metallic element known to man, aluminum is highly malleable, is capable of resisting corrosion, and has an incredibly low density. It is the most widely used non-ferrous metal and its alloys are used in the aerospace, automotive and construction industries. In architecture, aluminum is most commonly found in the forms of metal cladding panels as well as window and door framing extrusions.

The panels used in Framing Space are made of 0.5" foamed aluminum, a material condition achieved when gas is injected into molten aluminum, creating open or closed cells similar to other foams. The process creates a lightweight and rigid three-dimensional substructure that is used for the support of thin-shelled constructions and extrusions. In this installation we are exploring the use of foamed aluminum as a critique and reinterpretation of traditional siding, often a ubiquitous application of aluminum in domestic building construction that superficially embraces the material for its aesthetic value and resistance. Rather than simply cladding the structure, we are using the rigidity of the aluminum to provide external bracing to the system, taking advantage of the structural qualities and ductility to act as a diaphragm. Given that the foamed aluminum panels could not be bent or mitered, they were attached at two diagonally opposing edges, allowing for a scale-like overlap and an exposed edge condition, while triangulating the rectilinear units.

Stainless Steel

Stainless steel was originally used for domestic items such as kitchen cutlery, but it quickly spread to other applications once its value was recognized. The use of stainless steel in architecture has not only supported its aesthetic purity as a brilliant, non-staining material, but also its corrosive resistance in hardware and other connection details. These qualities of strength, precision and utility make stainless steel an ideal candidate for visible high performance curtain wall components such as glass point supports and exposed fasteners.

Typically a decorative material, in this installation we are exploring the structural potential of stainless steel as a self-supporting panel system. Traditionally rigid panels would need to be triangularly folded at a specific angle in order to span the warped rectilinear surface of a differential space-truss. Through the use of precisely executed cuts, however, manipulations of the truss masterfully exploit the ductility of steel, resulting in the non coplanar aggregation of flat panels.

Polyurethane

Polyurethane is a traditional component of Structural Insulating Panels (SIPS) in which rigid foam is sandwiched between structural boards, performing as the web of the panel. SIPs are a major component in pre-fabricated construction because they replace studs, sheathing, insulation, vapor barrier, and air barrier, all in one manufactured component that provides structural rigidity as well as thermal insulation.

Framing Space incorporates high-density polyurethane foam detailed to allow for the simultaneous expression of its structural properties as well as the potential for decorative application, merging the two aspects of SIPS into one material. HD Foam Panels (2.75”) were flip-milled to create a rigid double curved panel with a connection detail incorporated into the milling process. The front of the panels were CNC milled with a decorative double curvature pattern, while material has been removed the back of the panels in a process similar to coffering to reduce mass and provide rigidity. Both patterns can be controlled by finite element analysis and CNC production methods to be completely customizable according to site conditions and design intent, transforming the homogeneous nature of the raw material.

Polycarbonate

Polycarbonate is a thermoplastic polymer that is thermally insulating, impact resistant and most

Fig. 3: Red Panelite composite polycarbonate panels used as cladding

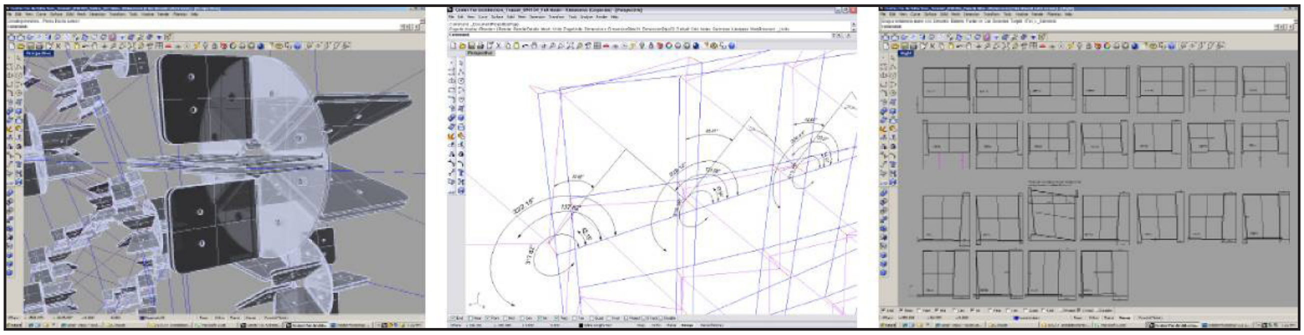

Fig. 4: A variety of different computational software was used throughout design and construction

importantly, transparent. In the composite panels used in Framing Space, stiff exterior polycarbonate plates distribute tension and compression across the surface of the material while in between, a dense cellular matrix of thin plastic tubes provide spacing and internal rigidity, also making the panel resistant to bending. The orientation of the circular tubes also provides an interesting optical effect by being transparent when viewed in axis and translucent when viewed off axis, diffusing the planarity of the rigid panels.

The polycarbonate panels used in the Framing Space installation are a contemporary alternative to glass panel systems such as curtain walls. Like glass, the material is thermally resistant and transparent. Moreover the polycarbonate panels have a hollow, double plate configuration akin to an insulated glazing unit. The panels are cold-formed into warped surfaces on the structural system taking advantage of the rigidity of the space-truss while simultaneously stressing the surface as the panels have a tendency to contract to their original form. This procedure is a relatively nascent method of construction and has been used on buildings to form complex curvature with units of non-coplanar geometry. It required considerable analysis and advanced digital fabrication techniques during production for precise fit of the elements in their bent configuration.

PRODUCTION

Once design was complete, the physical production of the Framing Space installation consisted of three distinct phases: fabrication of components, assembly of space frame into manageable units for transportation to the site, and installation of each wall system in the exhibition space at the Center for Architecture. The final phase of installation also included the cladding of the steel and aluminum structural skeleton with the diverse array of materials previously featured.

Computational Work

Prior to the commencement of fabrication and assembly, as well as during the design and construction processes, extensive computational work and comprehensive material research facilitated the development of this project. Each of the wall systems was first modeled in Rhino, establishing the lengths of the struts and the geometry of how each of the parametric systems would deflect. This model was then exported to Solid Works, where a soft "model" of the node geometry had been created as a referent. The node referent was then moved along the skeletal model of the structural system, stopping at each of the designated node locations and orienting the flanges around the centroid according to the position of the adjoining struts. For each node, a new Solid Work soft model was created and a stainless steel laser cut sheet prepared. After the geometry for all two hundred and fifty nodes had been derived, designers returned to the original Rhino model to take an inventory of the number, position and lengths of the flat and tee struts and to determine the geometry of the cladding panels. SAP 2000 was used to test the internal forces and structural integrity of the individual nodes against the global load conditions.

Fabrication

The fabrication of the primary structural components was the first step in the construction sequence. To fabricate the two hundred and fifty

Fig. 5: A combination of digital (lasercut at Maloya Laser) and analogue (cutting structural aluminum extrusions) fabrication techniques were used to produce the nodes and struts; a majority of the production was done at the GSAPP

nodes, specific information regarding the angle of rotation around which the four top flanges and four bottom orbited about the centroid, as well as the angle at which they connected to the struts, was obtained particular to the location of each node in the space frame system. After determining these pertinent geometric parameters that differentiated the nodes from one another, each node was separated into its eight constituent parts and laser cut off site out of sixteen 4′ x 10′ sheets of .059″ thick polished stainless steel. Programmed into the node components were a series of didactic codes that facilitated their fabrication and enabled those unfamiliar with previous phases of the design and construction sequence to assemble them with no difficulty. In addition to a number identifying each of the nodes, the code also included a series of geometric shapes that were cut into the corner of each flange component as a tab. When organized in the correct clockwise sequence (i.e. square, triangle, circle) this system assured that orientation of the eight flange components corresponded to the position that particular node in the space frame. Score lines were also cut into each of the flange components indicating the angle at which to fold the steel. The flanges were bent in a combination of analogue and digital processes, using a hand press and CNC brake. After being grouped and bent properly the components were blind riveted together connecting the top flange to its bottom counterpart at the base of the component; eight total unique pieces creating one unique node. Simultaneous to this effort, fabricators were cutting down flat aluminum bars and tee extrusions, (2″ x .125″) and (2″ x 2″ x .125″) respectively, according to the predetermined length of the struts that would eventually connect each of the nodes.

Assembly

Once the fabrication of the nodes and struts had been completed the next phase of the construction sequence was initiated; the assembly of the three space frame wall systems. Using blind rivets, each node was connected to its assigned struts with the flat aluminum extrusions connecting the interior top flanges to the interior bottom flanges of the diagonally adjacent node. Along the exterior top and bottom flanges of these nodes, aluminum tee extrusions were connected, providing a flat surface that would ultimately be clad with a diverse array of materials in the last sequence of construction. Given that the majority of the construction was conducted off site, each of three pieces contained

Fig. 6: Assembly of units at GSAPP

within the installation were assembled as a series of parts for the purpose of manageability and transport. Upon arriving on site, each wall system was assembled in totality and fastened according to its respective means of exhibition. The concept of assembly and installation was to have one frame hung from the ceiling in tension, one frame bearing on the ground in compression, and one frame suspended from a wall in bending.

Install

The final phase of the construction sequence consisted of attaching the disparate cladding materials to the faces of each of the three space frame wall systems. A three-dimensional model of the space frame was used as a reference for deriving the dimensions of the rectilinear panels. With the exception of the stainless steel which was laser cut off site, the majority of the materials were hand cut to match these specifications and transported to the site whereupon they were affixed to the flanges of the aluminum tee extrusions at opposing diagonal edges using self-tapping screws. The arrangement of the panels is sequential corresponding to the inherent ability of each material to transmit light. The result is a calculated and calibrated gradient that oscillates between transparent and opaque, reflective and translucent, and regulates the movement of light as it passes from one side of the space frame to the other.

RESULTS

The Framing Space exhibit attracted one of the largest opening day events at the AIA-NY Center for Architecture, in part due to the highly visible nature of the installation location in the storefront window of a heavily trafficked street. Crowds would often gather during the construction and erection anticipating the popularity of the opening. The exhibit was well received by the engineering community who attended the opening, and was extended by the Center due to popularity with local schools that took classes on excursions to the space. For the architecture students working on the project, the chance to not only design but also build an installation that has a high-profile public showing was

Fig. 8: Finished pieces and images of the Opening

Fig. 7: Assembly at Center for Architecture

quite valuable, adding an unconventional didactic element to the creation process.

CONCLUSIONS

The installation was used pedagogically as well and professionally as a means to explore new ways of integrating engineering into architecture and design, a dynamic dialogue between traditional and innovative methods of construction and material use, as well as an alternative mode of professional creativity. The piece simultaneously inhabited the realms of architectural design, art installation, and building system, encouraging a dialog appropriate to the mission of the Center for Architecture, the academic institutions involved, industry partners, and the architecture practice at large. The process was highly successful in all facets of experimentation and has inspired ideas for the continuation of similar research in the academic environment at the universities involved.