# In Pursuit of Depth: an analysis into textural patterning and structural layering as a strategy for formal continuity.

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## ABSTRACT

To make a product that could be manufactured anywhere, the designer is usually faced with the common constraint of the local tools and the global standard of fabrication. At this point in time complex milling machines with 3-axis robotic arms and the ability to shape parametric surfaces are not mainstream tools. Thus designers are limited to a means of production that happens in 2D, creating works that often appear flat and dynamic only in their ability to change in profile. Our interest was to push these limitations and create depth and variety in the building envelope. We began by looking at the envelope as a layered system, capable of responding to different interior and exterior conditions. As we investigated the layering of the façade, the density and aesthetic identity of the façade pattern became a central to our study.

## AUTHOR KEY WORDS
Rhino, Autocad, Illustrator, OMAX, ZPrint, MAYA, 3D Studio Max, Laser Cutter, 3D Rapid Prototyping Machine, MDF, Bead Blaster, Hobby Shop, SHOP, Fab Lab, Water Jet, Table Saw, Table Press, Gypsum Powder, Fabrication

## INTRODUCTION

Another reason we were inclined to study layering and its effect on the skin of the coffee shop was the visual effect it could have on a site. The pavilion is an iconic object – capable of appropriating a parcel of land, a spot in a park or an urban street corner. For a commercial property the envelope is the best way to attract interest and suspense. Our investigation centers on creating different possible dynamic interactions between public and private components of the coffee shop through layering and façade patterning.

## RESEARCH
We decided to build a series of models that would allow us to investigate and parse the conflicts between the façade and structure when trying to sublimate each for the other. Additionally we researched timber construction buildings by Bonte & Migozzi Architects, to inform our use of post and beam construction in how to creatively frame the coffee house. We

looked at wall penalization in projects by Wiel Arets Architect and KHR Arkitekter. We also researched examples of prefabricated insulated wall sections and found relevant precedents for the coffee shop in Volume 6, 2009 of Detail Magazine.

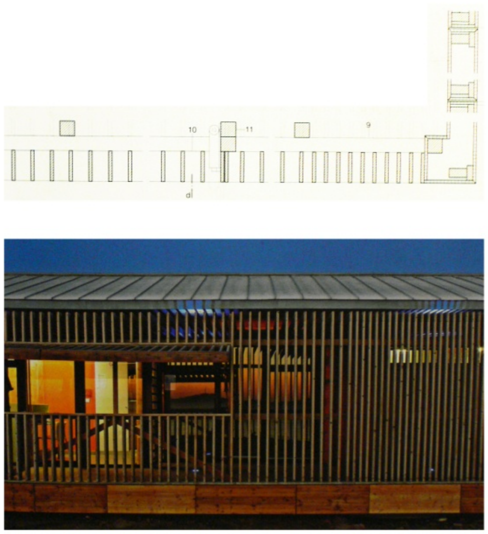


FIGURE 1 . Example of Timber Construction.Bonte & Migozzi Architects. 2008.

## HYPOTHESIS

The objective of our research is to create a panel and structural system that acts in tandem and works as one. Our hope is that we will be able to have the skin and structure influencing each other, each with a logic that compliments the other. Is it possible for the skin and structure to be visually indistinguishable, given the tool constraints mentioned? Given the need for multiple layers, the structure plays with a vertical and a horizontal beam system that varies in width and distance of engagement, producing a flexible space for multiple panels to come together.
At the same time, our hope was that the panelized system could adapt to the connection points provided by the structure and would start to deform and vary giving each individual panel a high degree of aesthetic freedom, thus meeting the visual and technical demands of our thesis.

## DESIGN IMPLEMENTATATION

Our initial investigation into form and massing was done with a series of sketch models in Rhino, but as the design grew to be more complex and we began to develop the panels, it became obvious that we needed to use a variety of programs and models to study different iterations of the structure and the façade.

### COMPUTER MODELS

The primary computer models used were Rhino and Autocad, but we also used Illustrator, OMAX, 3D Studio Max, Maya, and ZPRINT to execute patterning, analysis and production.

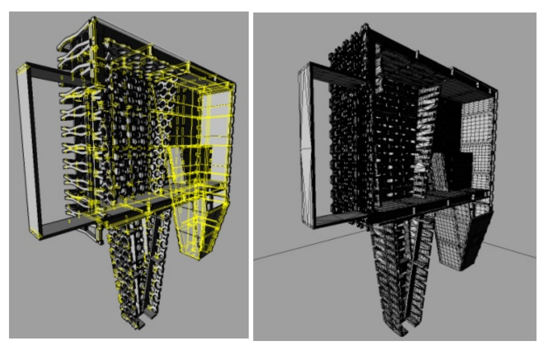

FIGURE 2 . Example of Rhino model showing intersections of panels and a Rhino nurbs model after mesh command.

### 1. RHINO surface modeling

Using Rhino, which is a surface modeling program, we were able to successfully study the coffee shop's massing and the production of individual components. Surprisingly, Rhino worked well as a tool for the beginning and end of the study, but was less successful at producing fast patterning iterations in the middle of the process. When it came to being able to see how the panels fit together and detecting intersections and modeling flaws, we returned to Rhino which allowed us to see in a more spatial way how the structure and skin were fitting together.

2. Autocad vector drafting program
We found that there were distinct advantages to using a lighter program such as Autocad to draw numerous profiles and different iterations of the façade. At this stage, it wasn't absolutely necessary for us to be working in 3D to analyze the pattern, and when attempted in Rhino the files became unworkable and too slow due to the complexity and detail of the fenestration. Thus Autocad was the best tool for working with patterning.

APPARATUS
1. 3D Rapid Prototyping Print A
4"x4.5"x4" Baked Gypsum
The first model we made was a 3D rapid prototyping print where we looked at the overall mass of the coffee shop and analyzed the potential for panelization of the interior and exterior skin. This is the first skin iteration where we investigated using a skin which would reinforce the massing, structure and façade as a complete, monolithic system.

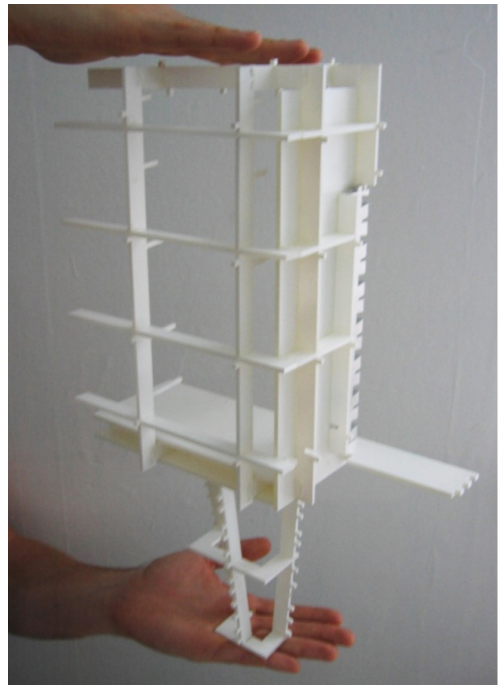

FIGURE 3 . Structural model showing faceted structure and the frames response to the architectural form.

2. Laser/ Water Jet Cut Model A
17"x8"x4" Aluminum, Sanded and Painted Plexiglass
This model was the first example of us working with the structure and skin as systems in relationship with each other. We used materials for this model that would to allow us to play with the notion of material weight (aluminum) and depth of light which passing through the coffee shop (sanded and spray painted plexiglass). What was most successful about this model was the structural system and the connective joints which developed in relationship to itself. However, because this was the first time we had developed the skin and structure to be modular components, they were aesthetically independent and conceptually at cross purposes.

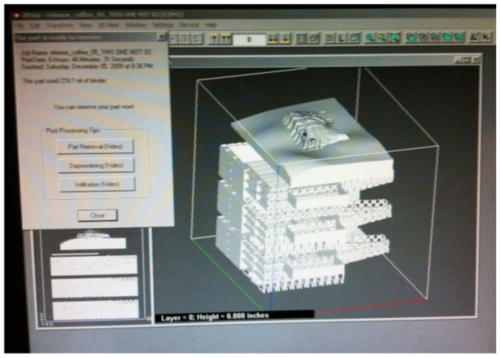

FIGURE 4 . Image of ZPrint interface and stacking of models inside powder suspension.

**3. 3D Rapid Prototyping Print B**
(3) 7"x2"x7" Baked Gypsum
Because we wanted to look at the mass in more opaque, spatial way we made several sectional studies with the 3d printing machine which allowed us to see the affect of the skin in relationship to the depth of the curtain wall. Here we were studying layering different patterns against each other to reinforce different architectural elements of the form. Plus layering the different textures reinforced our initial intent to create depth with planar elements.

FIGURE 5 . Water Jet cutter with garnet powder

**4. Laser / Water Jet Model B**
24"x3"x10" Aluminum, Sanded & Painted Plexiglass
After making several models with standard 3'x4' panels, we realized that there were inherent flaws and that there was a potential for innovation in the individual panelization structure. We sought to play with varying the datum of the façade's depth and playfully blurring the lines of each panel making them individually indistinguishable.

## DESIGN

We considered the skin depth an independent variable that is the main tool for investigation; it is the most flexible element of this project. It can change. Whereas, the dependent variable became the panelization size - which can change in relationship to the individual patterning and skin design to increase performance. The attachment locations in relationship to the structure are fixed, controlled variables that do not change.

### CONNECTION DETAILING
After playing with small studies of patterning in Illustrator, it appeared that there were two ways of visually sublimating the connections: one would create a field condition the other would weave the panels, obscuring individual seams. How the panels fit together would thus appear more fluid allowing for the structure and skin to appear connected and monolithic.

**1. Field Skin:** creating a hidden connection to the structure using dense patterning.

After building the first model we realized that the visual appearance of the connection between the skin and structure was visually overwhelming and created a pattern which didn't reinforce the overall skin pattern. This realization that the two systems of structure and skin were at odds with each other and were creating their own separate visual patterns lead us to our thesis. We wanted to revisit the initial pattern of the first 3D printed model, and find opportunities to use the structural pegs as a visual component of the pointillist pattern of the skin.

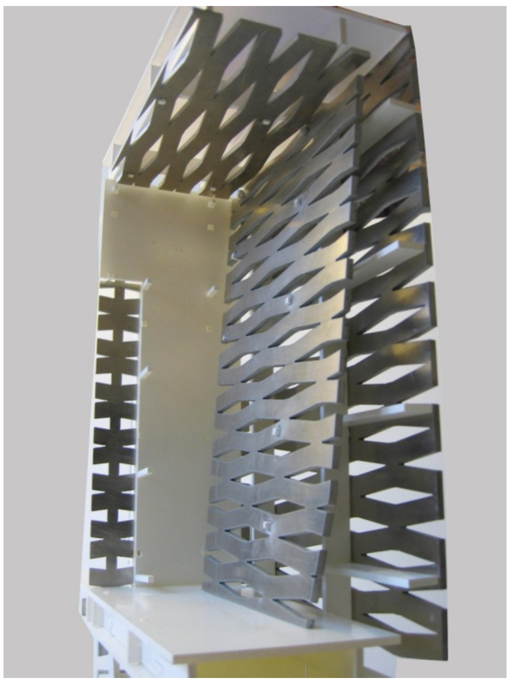
FIGURE 6 . Model showing weaving potential and layering of façade with water jet cut aluminum panels

**2. Weaving:** rethinking the rectangular shape of the façade panel.

In tandem with investigating the field pattern, we wanted to see if there was a way to design a pattern that was not entirely dictated by the aesthetic of the connection to the structure. The intent was to produce a panel that interlaced and was connected back to the structure in moments of shear, or solid locations. The field pattern was successful in hiding the connection to the structure, but lacked variety of pattern and was overly repetitious from panel to panel. We proposed that if we could create a panelized system that fit together as more of a jigsaw then there would be great difference from panel to panel and the module of production would be obscured, reinforcing our initial thesis.

PROCEDURE

We broke down our study into three distinct trial groups: A, B, and C which we used to test and experiment with certain elements and test the thesis of the design.

**Trial 1:** Massing

The first test was to see if the massing worked with a structural system that could be broken down into components and made in a modular, economic fashion. Using Rhino we sketched out the form and the basic façade without any consideration for panels. Then we created a mesh model of nurbs from the surface model which we sent to print using ZPrint. Then, we went back to Rhino and investigated the structure and façade penalization. After looking at the number of panels and density of studs needed for the coffee shop we decided that the form was economically efficient and also provided an extra outdoor functional space for little added construction cost.  Then we built Water Jet / Laser Cut Model A to see how the components that we built in Rhino fit together and where it was hardest to fit the panels together.

**Trial 2:** Structure + Skin = Layering?
We wanted to know if we could create depth by layering the structure and the façade. Thus we worked in Illustrator to create multi-layered panels, which we imported to Rhino and modeled the 3 sectional studies to make sure that the spatial effect of density and depth was achieved and that we were going in the right direction with our investigation. After turning this digital model into nurbs to create a 3D Prototype Print we had 3 physical artifacts that allowed us to spatially test our theories. Additionally we built another model in Autocad which studied pushing the layers of the model in section and disrupting the continuity of the surface. This was cut and fabricated with a laser cutter.

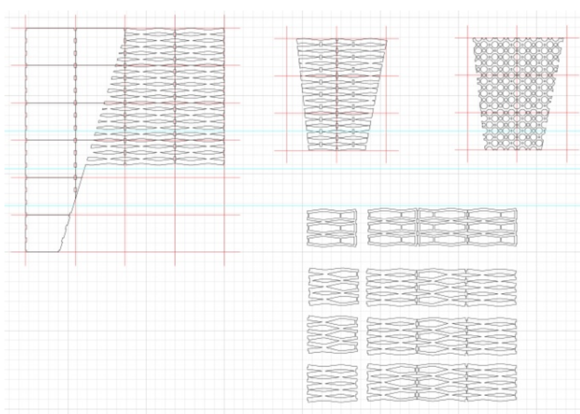

FIGURE 7 . Screenshot of Illustrator model showing façade iterations

**Trial 3:** tool/medium as design driver
After tallying our time using various computer programs and digital fabrication tools we were interested to know which programs gave us the most product for our time. When comparing the different programs, it was clear that we spent the most time using Rhino, and Autocad. However, Rhino was a larger generator of product because we were able to use the same digital model to produce laser files and 3D prototyping models. We also looked at which fabrication tools we used the most: the Water Jet, Laser Cutter, or the 3D Prototyping Machine.
The least efficient was the Laser Jet, giving us only a fraction of the model's façade for a great output of time. This mostly was due to using multiple terminals with scale control issues that had to be accounted for. The most productive and efficient tool was the 3D Prototyping tool. No assembly was required with the product of the 3D print, also no oversight was needed when printing which allowed for multi-tasking and cut our personal time spent by more than half, including the excavation of the model, when compared to the water jet. The laser cutter tool was helpful, and more accessible than the water jet, however all the parts outputted required assembly. Because of the imminent hazard of fire and combustion of materials, the laser cutter needed moderate, physical oversight – a detriment to productivity.

All in all, the most productive rapid prototyping tool is the tool that requires the least oversight and human input after the file's initial transfer.

## ANALYSIS

### DATA
We looked at 5 different relationships and graphed their prospective hierarchies.

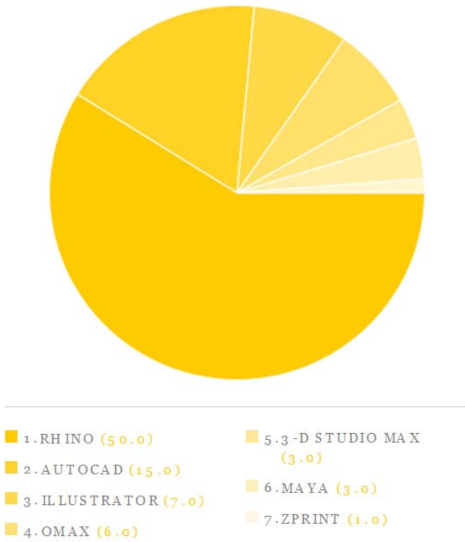


FIGURE 10 . Pie chart showing time spent in each individual program

1. Software Used for Fabrication

Because we each used a wide variety of tools for visualizing, modeling, and fabricating the coffee shop, we wanted to see which programs were used the most frequently and why. After creating this chart, it became clear that it was Rhino, because it could exported, rendered and iterated the most options for us to study.

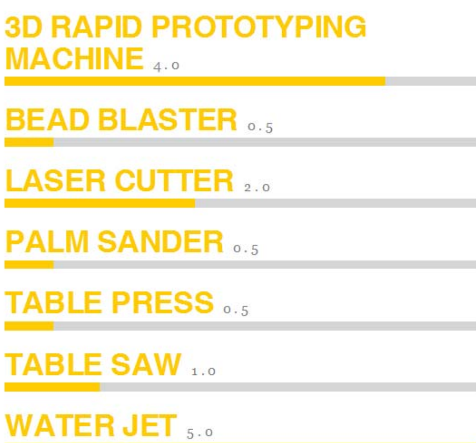


FIGURE 9 . Bar graph of tools used to fabricate various physical models.

2. Tools Used

Since we made the models with several different materials and methods, we were interested in seeing how we spent most of our time fabricating our physical models and list the different tools used. We were surprised to find we had spent the most time with the water jet fabricator when the material it produced was only a small percentage of our total material output.

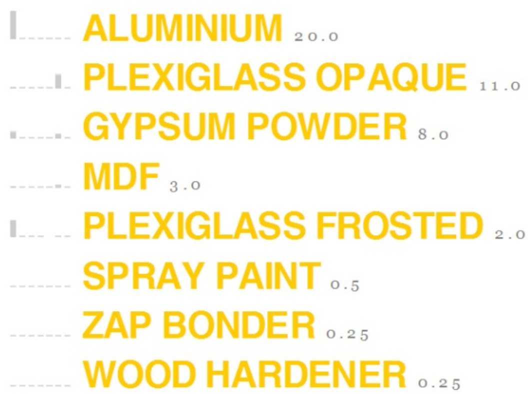


FIGURE 10 . Spike bars showing materials most used in production with their material totals tallied to the right.

3. Material Weight Used

When doing a study of this scope it became necessary to see the amount of material consumed to create and convey our thesis. Because we were interested in using metal as the primary component for the skin, we used the aluminum material more than any other material. The material's density and weight was nearly double that of plexiglass or gypsum powder.

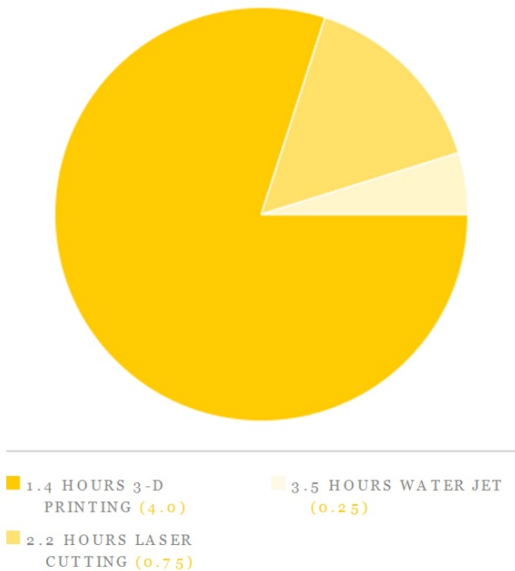


FIGURE 11 . Pie chart showing the time spent using certain tools in production versus the total material they produced in that amount of time.

4. Tool Used VS Material Produced

After working with the various prototyping machines and brute force equipment, it was interesting to us to catalog our hours and determine which machines were the most successful in producing the most material in the least time with the least oversight.

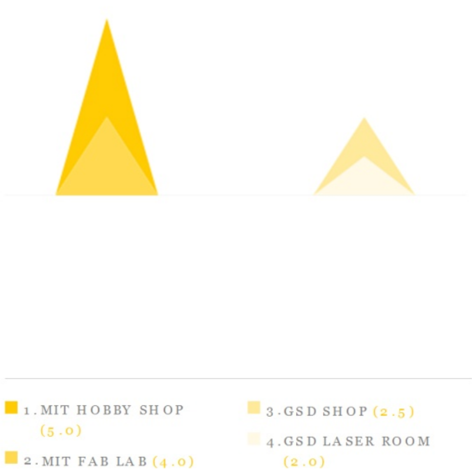


FIGURE 12 . Graph showing proportion of material fabrication work completed at the GSD versus MIT.

5. Time Spent at MIT VS GSD

Due to the fact that we are both Harvard Graduate students taking classes at MIT, we have access to both MIT and GSD facilities. We wanted to list the hours we spent between the two schools and see if we were pushing ourselves to use the facilities at MIT more than those of the more familiar, accessible amenities at the GSD. We were please to see that we spent more than double the amount of time at MIT, this was due in large part to the amount of time we spent at water jet cutting at the Hobby shop and the free 3D prototyping offered at MIT, with a considerably less crowded print queue.

## RESULTS

After reviewing the information we had compiled on the different tools it was clear that the laser cutter worked best as a tool for understanding the fabrication and assembly of the structure. However, using sectional and massing prints made with the 3D Rapid Prototyping machine allowed us to better investigate the spatial and volumetric affect of our thesis.

Through all our tests and studies, we feel that our research conclusively proves that by manipulating façade density and texture one can circumvent the planar visual affects when using 2D prototyping tools.

## PURPOSE

It is imperative for a designer to have autonomous artistic and creative visualization separate, albeit interdependent, from methods of production and mediums of representation. Too often in this digital age of rapid prototyping and computer modeling, where parametric modeling is no longer avant-garde but commonplace, the designer designs well within the constraints dictated by the medium. The medium becomes the entire message. For us, it was important to prove that a designer can have creative autonomy from the primary method of fabrication, and to use the method of fabrication as an informer for design but not the dictator of a visual aesthetic language.

## ACKNOWLEDGEMENTS

We would like to thank Larry Sass, specifically for providing the intellectual background without which we could not have done this project let alone assembled the smallest or most basic parts. We would also like to thank the MIT FAB LAB, HOBBY SHOP and Ken Stone for graciously providing materials and helping us with fabrication and time scheduling.

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