HORIZONTAL THIN CASTING

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

OBJECTIVE & DESIGN INTENT

Today's architects are able to push discipline boundaries both in form and performance by advancements in computing capacity, advanced 3D modeling software and new fabrication technologies. Concurrently, today's technology is powerfully accurate and allows for rapid building in virtual form well before it is constructed. Material advancements and innovation in fabrication processes provide higher levels of performance as well.

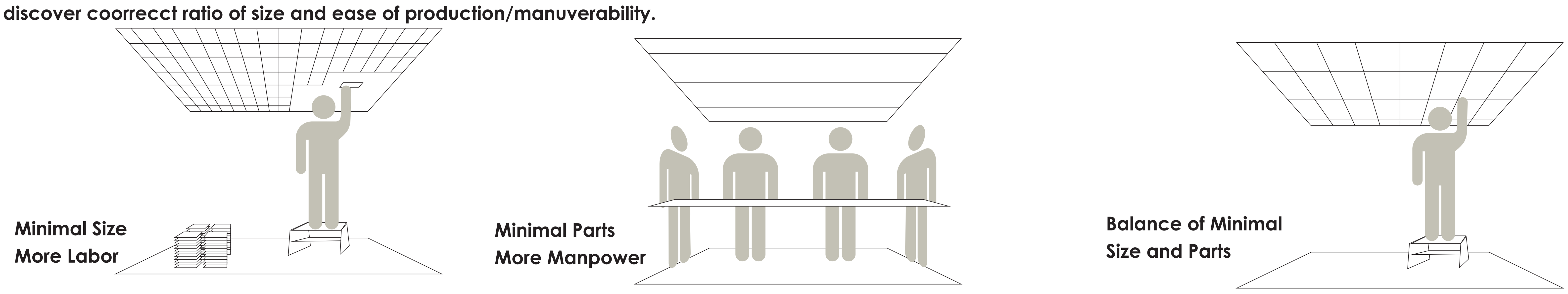
Consequently, how can parametric design help develop a thin horizontal cladding system that iterates upon current architectural trends of emphasizing non-Euclidean forms that display mass-customization with mass-efficiency available via CAD-CAM design-build processes?

Horizontal elements, particularly interior elevated surfaces have great potential to be contextually responsive due to the minimal number of obstructions and the minimal activity or interaction with other objects. This gives multi-variant opportunities to experiment with the elements and customize according to the program. The research will be driven by three phases- testing, demonstrating and prototyping.

Phase one will consist of the testing materials performance. Concrete is a popular material in the building industry due to its durability, strength and shaping capacity. Experimentation with concrete mixtures and aggregates will allow for lightweight, strong and thin material, suitable for fabricating a horizontal cladding system.

Phase two, will demonstrate the information derived from the testing by casting thin elements that become a structurally independent system. Casting provides greater customization potential and improved contextual responsiveness. This research will use a combined method of pre-rationalization and post rationalization to design and test the parametric design of the horizontal cladding system. Geometric form-rationalization will be fabricated to allow us to perform test on the panel geometry. Design will be of high importance in this research as it can inform the decisions made on the acoustical performance, contextual responsiveness, structural system and panel tessellation.

Phase three, prototyping, will deliver a refined horizontal cladding system by introducing anomalies and systems integration at a 1:1 scale. This Phase includes the use of digital tools to create a form, followed by the required mold for the form. This mold would then be robotically CNCed and prepared to be used as a mold for concrete casting. Resulting forms would test the materials ability to span large distances as well as being able to incorporate singularities. REsearch also involves differeing scales of protottypes to discover coorrecct ratio of size and ease of production/manuverability.

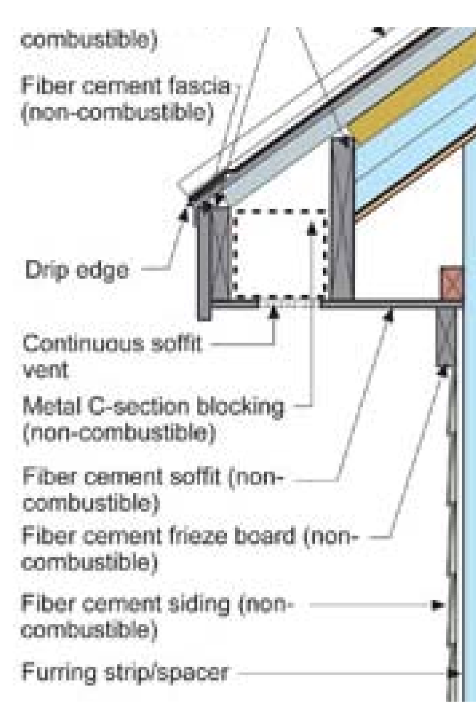


PRECEDENTS

MATERIAL

Fiber Cement | Thinness & Horizontal Application

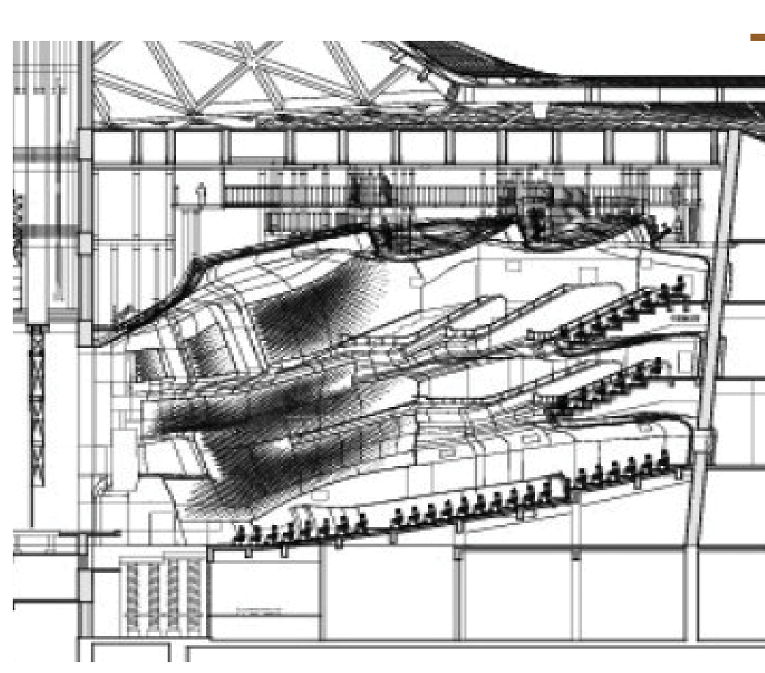
Composed of Cement and Cellulose fibers it is produced by various manufacuters as a siding for commercial and residential projects. It is also used in horizontal applications as a soffit in areas where there is a fire danger or as a substrate for tile in wet areas where mold can be an issue. It is produced in a wide variety of thicknesses and densities.

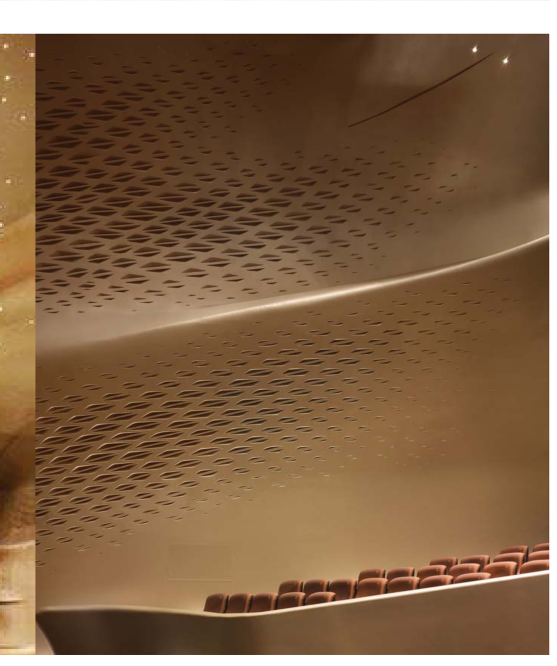


GEOMETRY

Guangzhou Opera House: Form and acoustics

The interior of the theater has both sound diffracting properties as well as sound diffusion properties in a seamless manner through the design of smooth and indented surfaces. The ceiling and wall are also curved to distribute sound to the required spaces. This idea can be incorporated into the ceiling system to address the different sound requirements within a space.

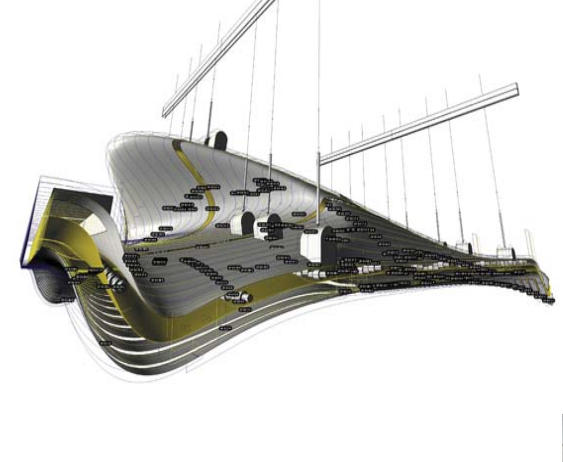


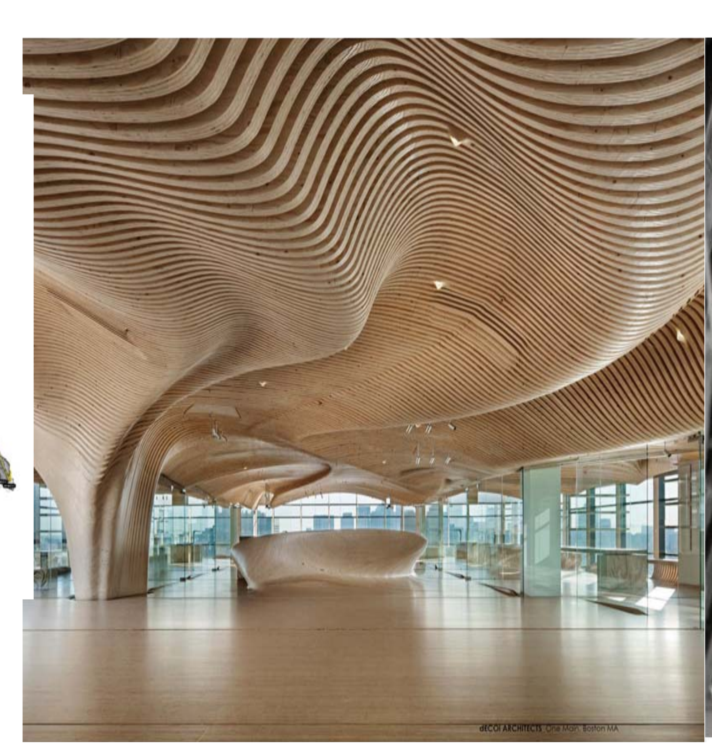


HORIZONTAL SYSTEMS

One Main | Decoi Architects

An office space design using machining of plywood, displaying the versatility and efficiency of CAD design-build process. The project uses ready-made components, typical of late industrial proocesses, providing customized fabrication. The design provides a curvilinear continuity.The floor and ceiling elements are designed as continuous surfaces and influenced by the function. The curvilinearity expresses both the digital genesis and the seamless fabrication logic, with the architect providing machining files to the fabricator.





HORIZONTAL THIN CASTING

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAZVEZ | MARZIA KHATUN

MATERIAL PROPERTIES

MATERIAL	Setting Speed	Compressive Strength, PSI	Span Ratio	Weight/lb/cu.ft	Typical Use	Notes
Hydro-Stone Gypsum Cement	17-20 minutes	Ultimate | 10,000	1:24	108	High quality art and Statuary Castings	Quick drying and simple casting process
Concrete	25-35 minutes	Ultimate | 5,000	1:24	90	Solid & hollow Casting figurines	Very fragile in thin elements
Ductal	27-37 minutes	Ultimate | 18,000-22,000	1:24	72.5	Ultra High Strength Concrete	Proprietary materials, Difficult mixing process, must be kept moist
Forton MG VF-812	20-30 minutes	Ultimate | 6,000-9,000	1:192	95-100	Architectural ornamentation, sculpture, flower pots	Requires 2 coats, face & structural, uses gypsum concrete and fiberglass
Vinyl Concrete Patcher	30 minutes	Ultimate | 5,000	1:24	128	Making thin repairs to cracked horizontal concrete surfaces	Will shink, must be applied in thin layers. Surprisingly supple

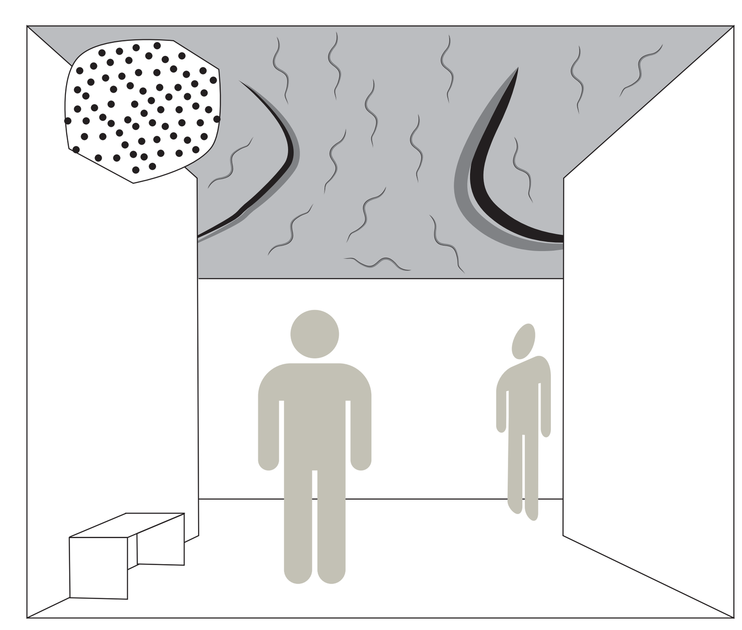
ADDITIVES	What is it?	Typical use	Expected outcome
Poraver	Expanded glass aggregate	As an addative to building products to make them lighter, more yielding, easier to use.	Make the tiles lighter while maintaining a relatively high strength.
Grace MicroFiber	Polypropylene Microfilaments	Reducing formation of early cracking, multidimensional crack prevention, increasing concrete durability	Strengthen tiles and prevent formation of cracks while still in molds.
Glassfiber Mesh	Synthetic woven fibers	Multiple, varied uses. Typically formed into a composite to take advantage of its tensile strength and insulative properties.	Strengthen tiles, help prevent formation of cracks, keep tile in place if breakage occurs.
Carbon fiber mesh	Tiny, high tensile strength fibers composed of carbon atoms	Usually combined with material to form a composite to create thin, strong, high performance elements.	Combined with resin, expected it to strengthen tiles.
Bondo Fiberglass Resin	Polyester resin works in a endothermic reaction with a catalyst	Typically combined with other elements with high tensile strength to form thin, lightweight composites.	Combined with carbon fiber, expected it to strengthen tiles.

Tested Mixture	Water	Hydrostone	Poraver	Microfiber	Fiberglass mesh	Carbon fiber	Resin	Portland Cement	Polyblend Grout	Sand	Ductal	Prema150	Optima100	PVA Fiber	VF-812 Polymer	MF-415 Resin	Hardener
Hydrostone Baseline	12oz	32oz															
Hydrostone + Poraver	12oz	32oz	2.5oz														
Hydrostone + Poraver X2	12oz	32oz	8oz														
Hydrostone + Microfiber	12oz	32oz		.5 in³													
Hydrostone + Poraver + Microfiber	12oz	32oz	2.5oz	.5 in³													
Hydrostone + Fiberglass Mesh	12oz	32oz	2.5oz		11.5" x 11.5" Square												
Hydrostone + Carbon Fiber + Resin	9oz	24oz	6oz	.375 in³		11.75" x 11.75" Square	1/8" Layer										
Concrete + Carbon Fiber + Resin	8oz	24oz	8oz	.5 in³		11.75" x 11.75" Square	1/8" Layer	12oz	3oz	4oz							
Concrete Baseline	10oz							7oz	21oz	14oz							
Concrete + Poraver + Microfiber	10.45oz		8oz	.5 in³				6oz	18oz	12oz							
Ductal	6.6oz (as ice)										38oz	1.8oz	1.8oz	6.1oz			
Forton MG VF-812		27oz													14oz	2.7oz	.13oz

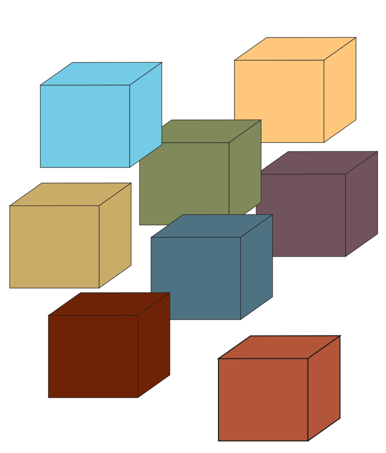
PANEL QUALITIES

CAST HORIZONTAL ELEMENTS HAVE THE BENIFIT OF BEING ABLE TO INCORPORATE QUALITATIVE WAYFINDING ELEMENTS AS WELL AS QUANTITATIVE ACOUSTIC DAMPENING PROPERTIES. THESE ELEMENTS ARE ONLY POSSIBLE ON A RAISED HORIZONTAL SURFACE BECAUSE OF THE LACK OF CIRCULATION DISTRUBING IT. CASTING ALSO ALLOWS FOR INOVATIVE PLACEMENT OF TYPICAL CEILING ELEMENTS, SUCH AS FIRE SUPPRESSION SYSTEM, LIGHTING, AND VENTS.

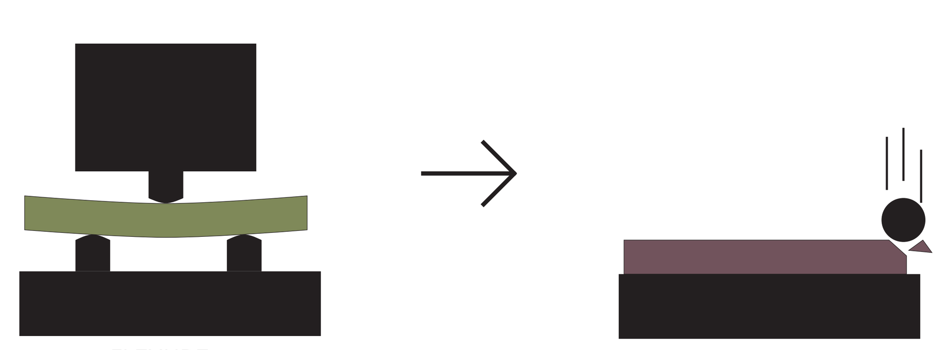
Cast Ceiling Elements
Way finding curves
Acoustic dampening perforations



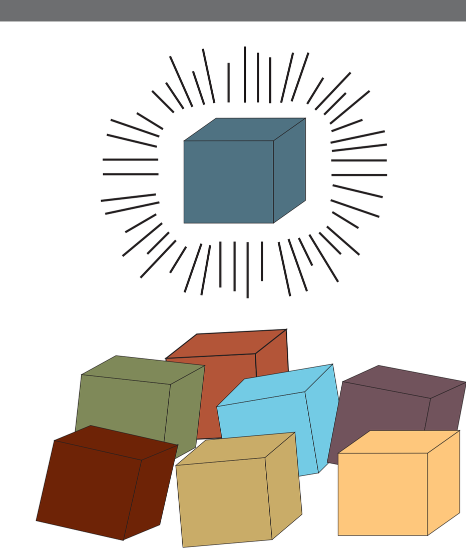
TESTING CHRONOLOGY



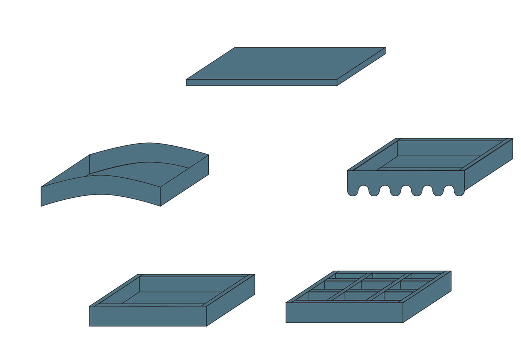
SELECTION OF MATERIALS



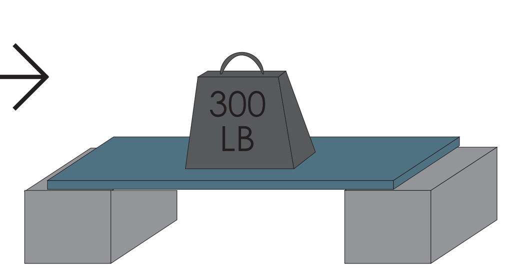
MATERIAL TESTING



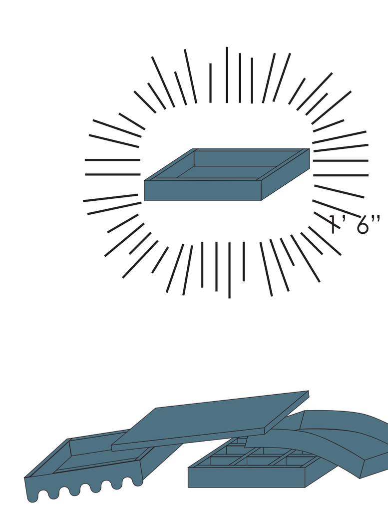
SELECTION OF MATERIAL TESTING FINALISTS



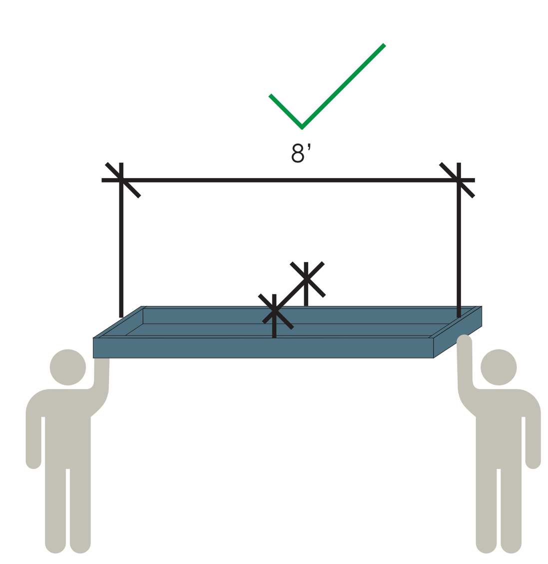
PROFILE SELECTION



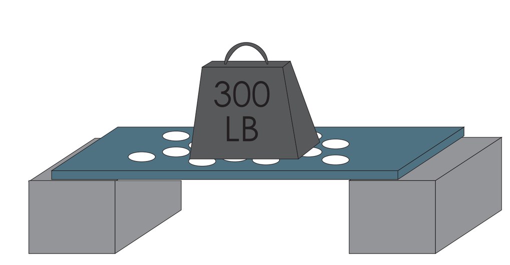
PROFILE TESTING



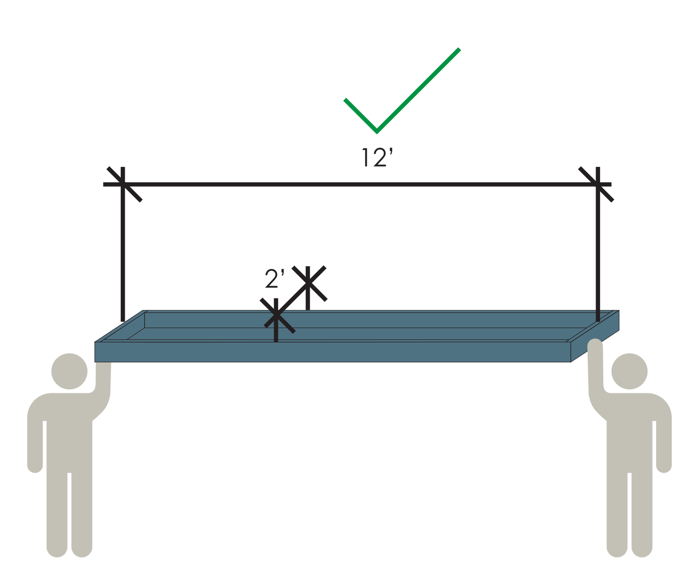
PROFILE SELECTION



SPAN TEST 1



PERFORATION TESTING



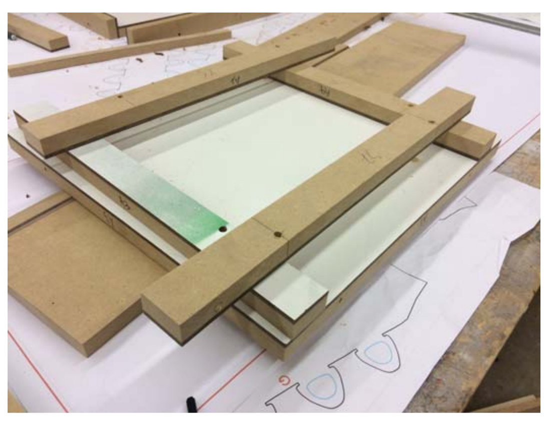
SPAN TEST 2 INCLUDING PERFORATIONS

INITIAL CASTING

The first casting stage is aimed at casting 12in x 12in x 0.5in panels to test the weight, strength and impact resistance of the materials selected.

The materials selected were based on the weight, workability and strength.

Six molds were made from MDF and melamine sheets that are reusable to reduce waste during the testing procedure.



MDF was backed up with melamine to prevent MDF from asorbing moisture and for easy removal of the casted panels.

The pieces were bolted together to form the mold. Mold dimension: 12in (W) x 12in (L) x 0.5in (H)

Mixture formed for each mold and mixed thoroughly

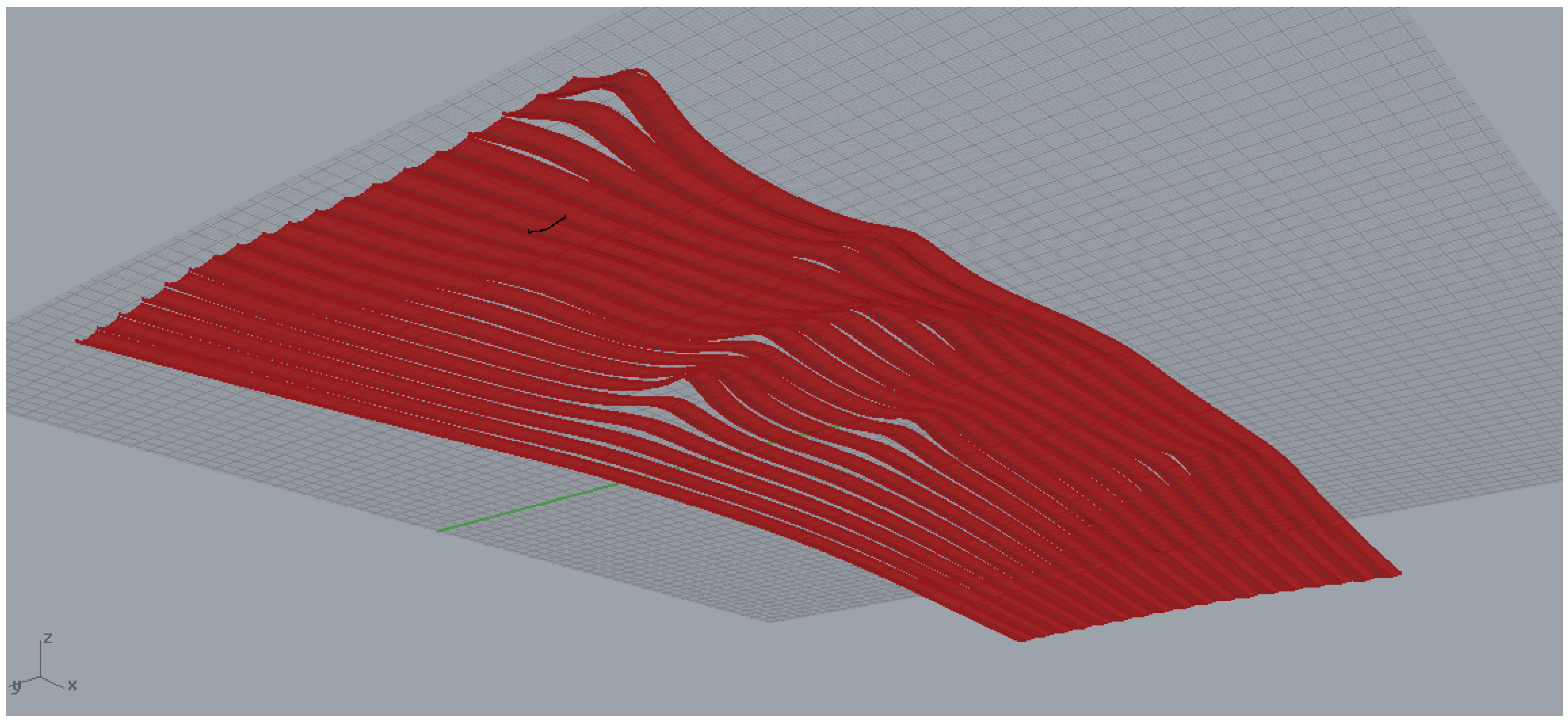
Mixture was vibrated on the vibrating table to level the mixture and release air bulbles.

THIN CASTING **DESIGN**

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

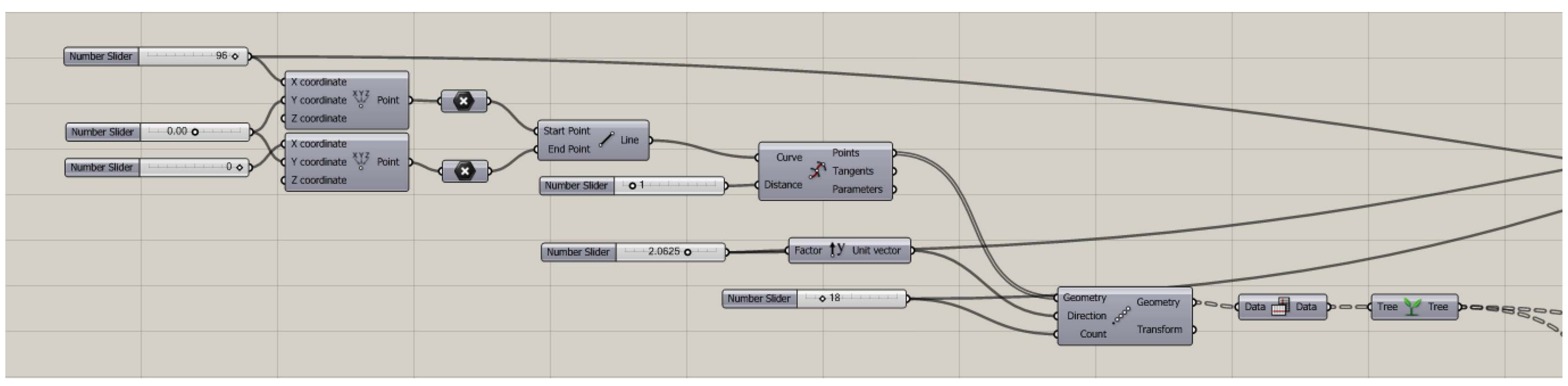
Horizontal Surface

The Grasshopper definition is design to create an editble surface based on paramaters derived from the material testing. It also follows the rule of less parts with minimal material

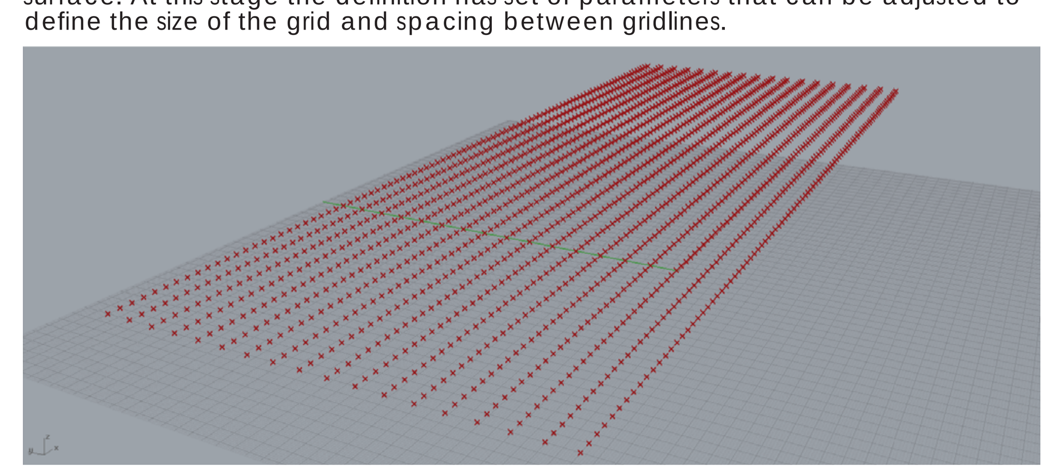


Grasshopper Definitions

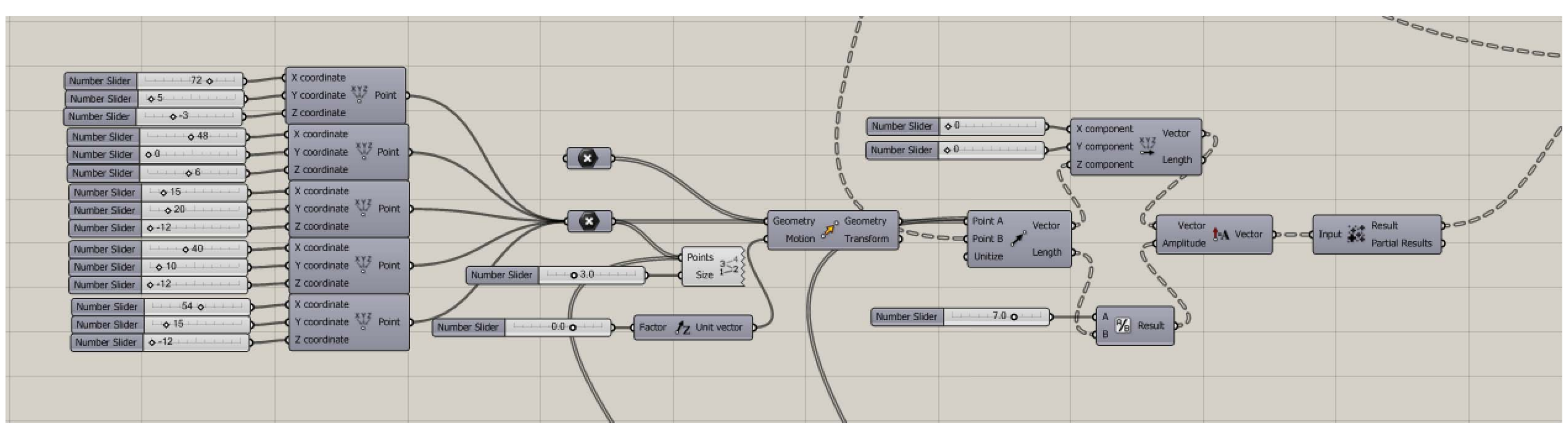
Part A



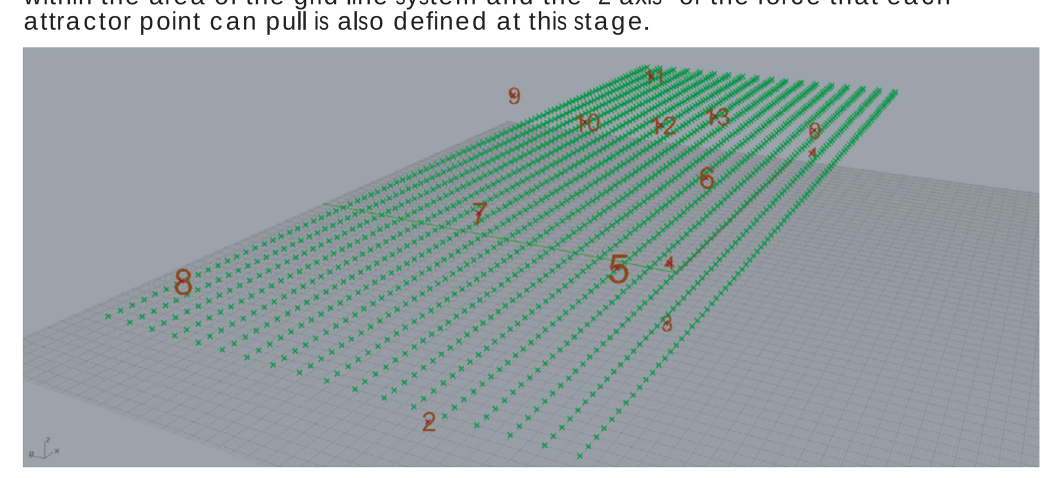
Definition Part A: Creates an array of lines that are the base grid line system of the surface. At this stage the definition has set of parameters that can be adjusted to define the size of the grid and spacing between gridlines.



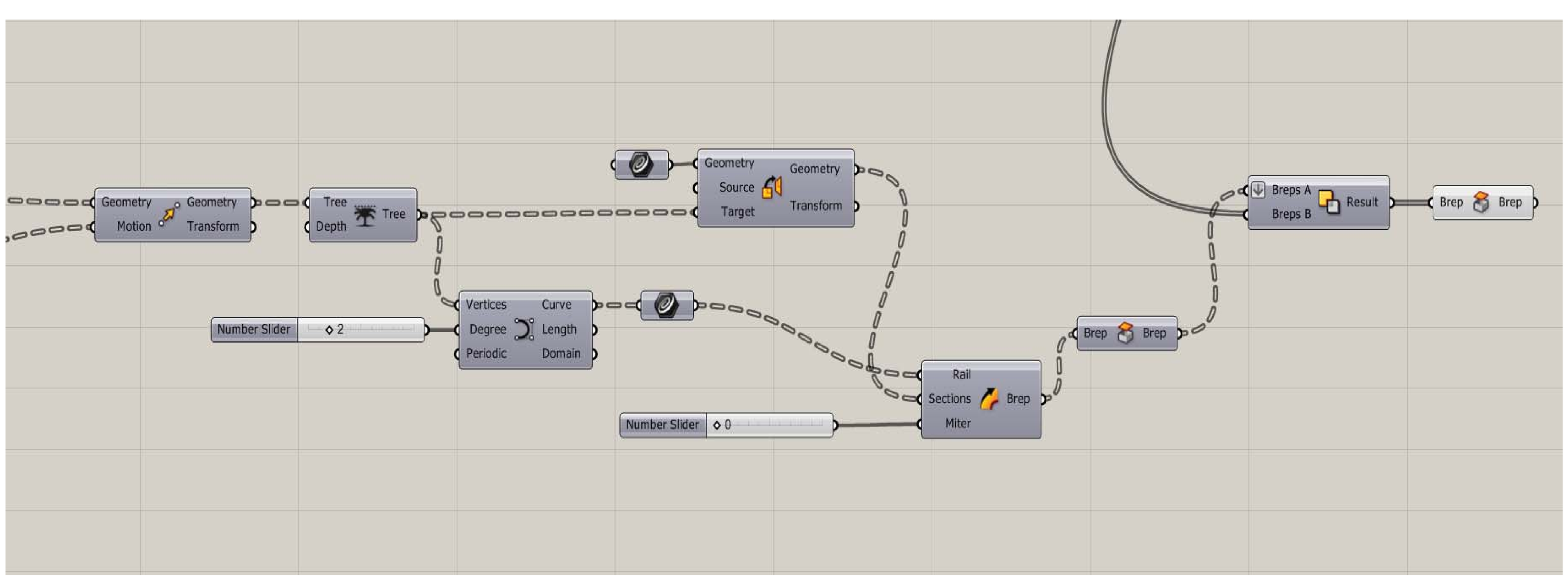
Part B



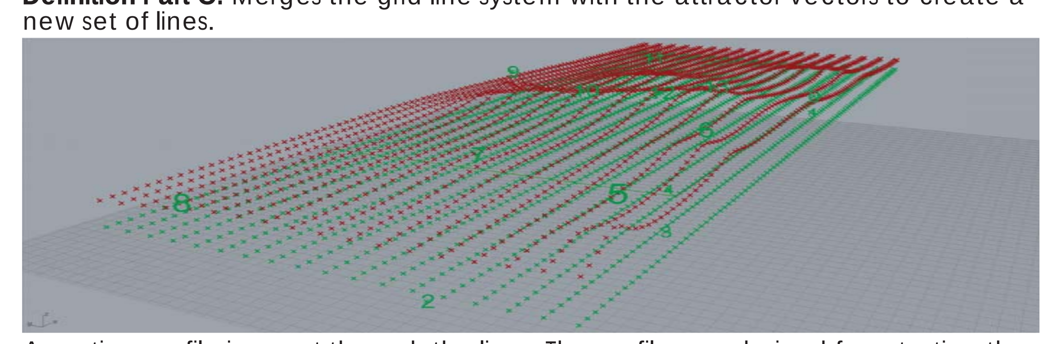
Definition Part B: Creates sets of attractor points that will define the geometry by pushing and pulling the base grid line system. At this stage the definition has a set of parameters that can be adjusted to define the location of the attractor point within the area of the grid line system and the 'Z axis' or the force that each attractor point can pull is also defined at this stage.



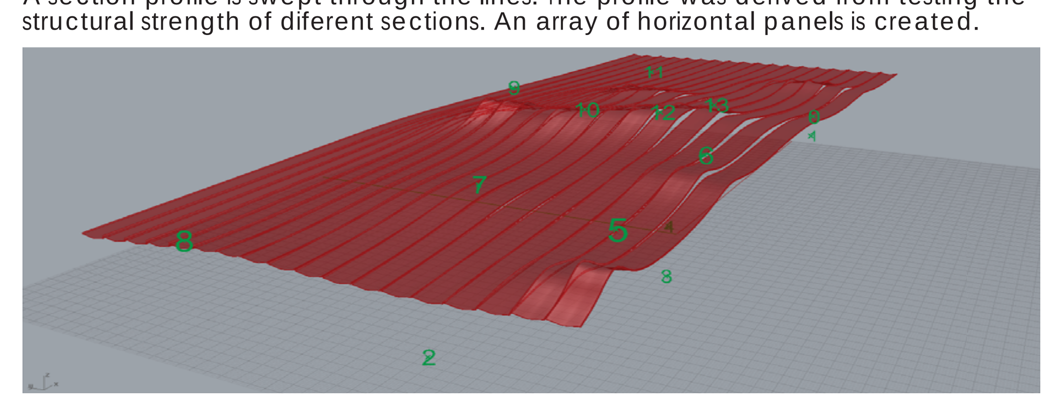
Part C



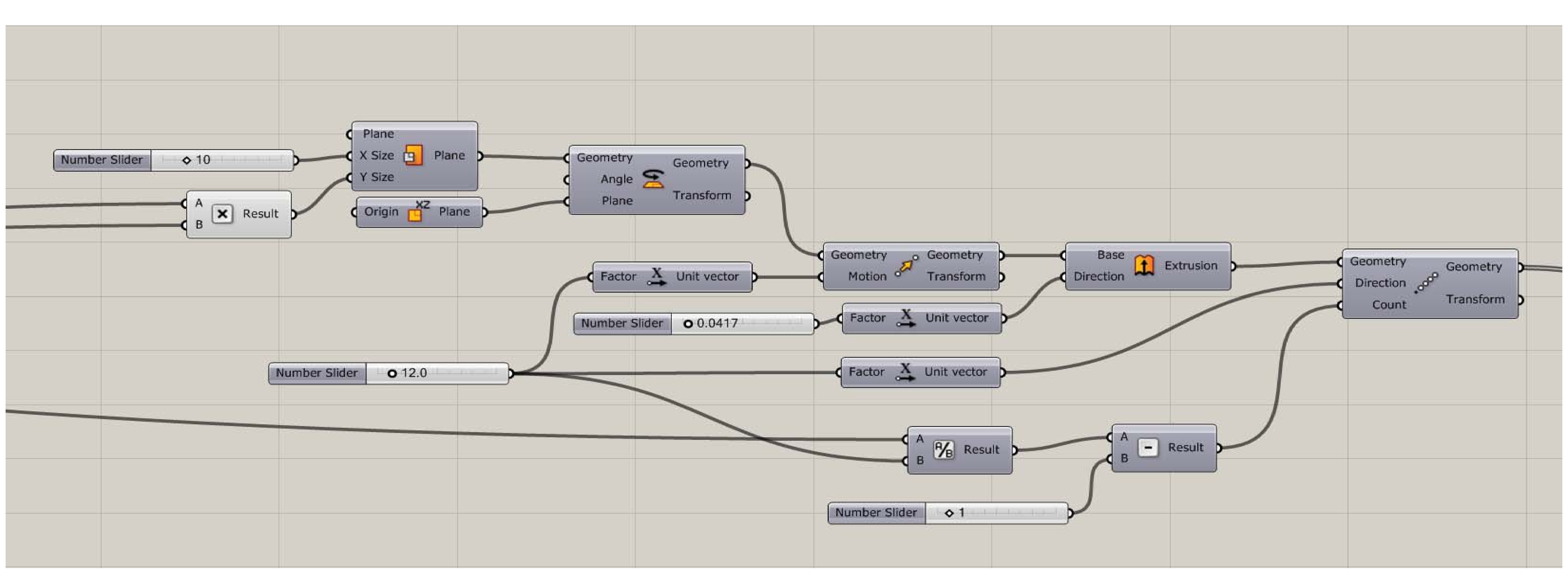
Definition Part C: Merges the grid line system with the attractor vectors to create a new set of lines.



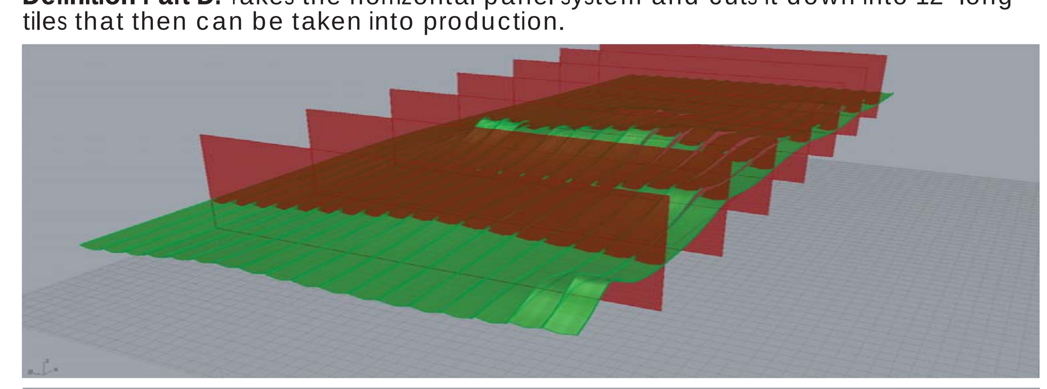
A section profile is swept through the lines. The profile was derived from testing the structural strength of diferent sections. An array of horizontal panels is created.

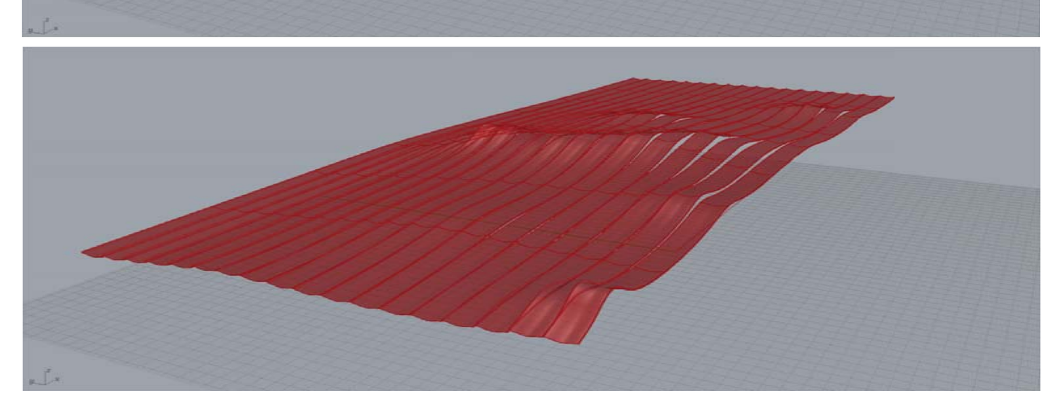


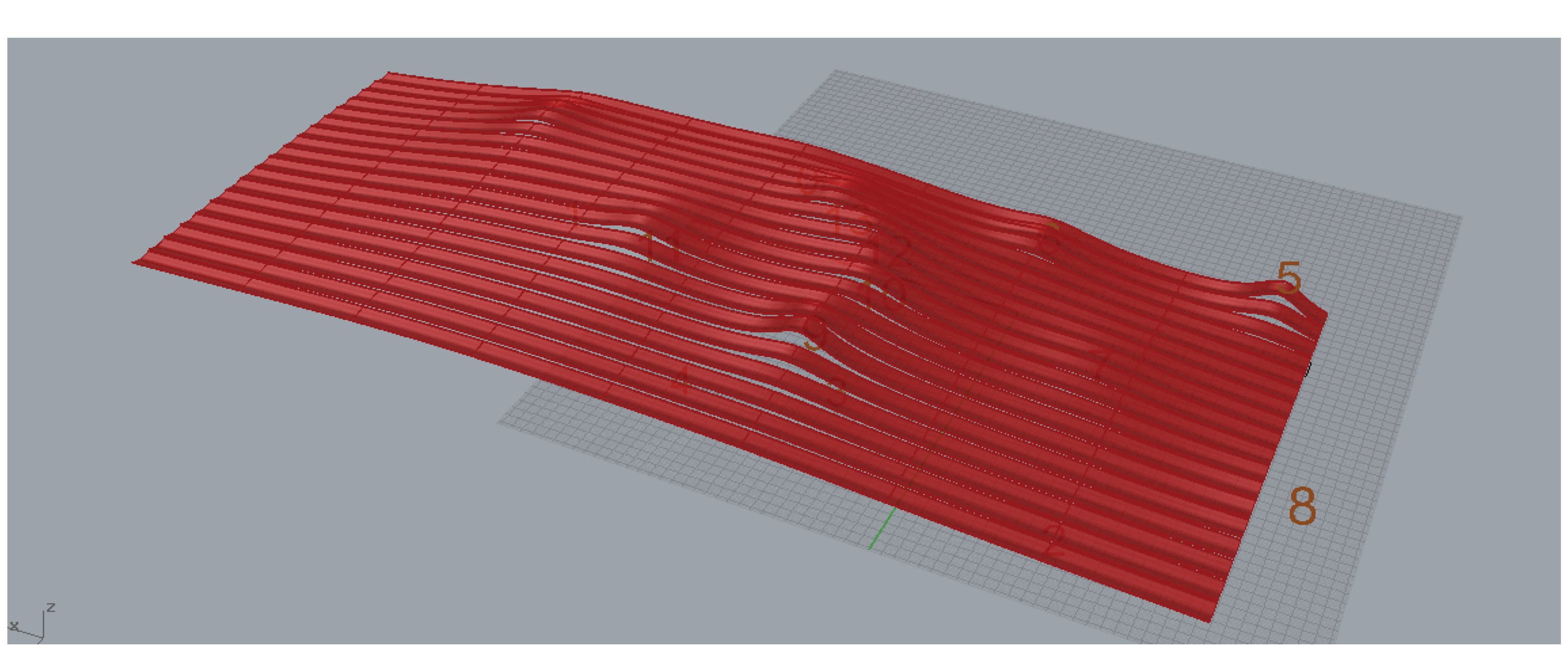
Part D

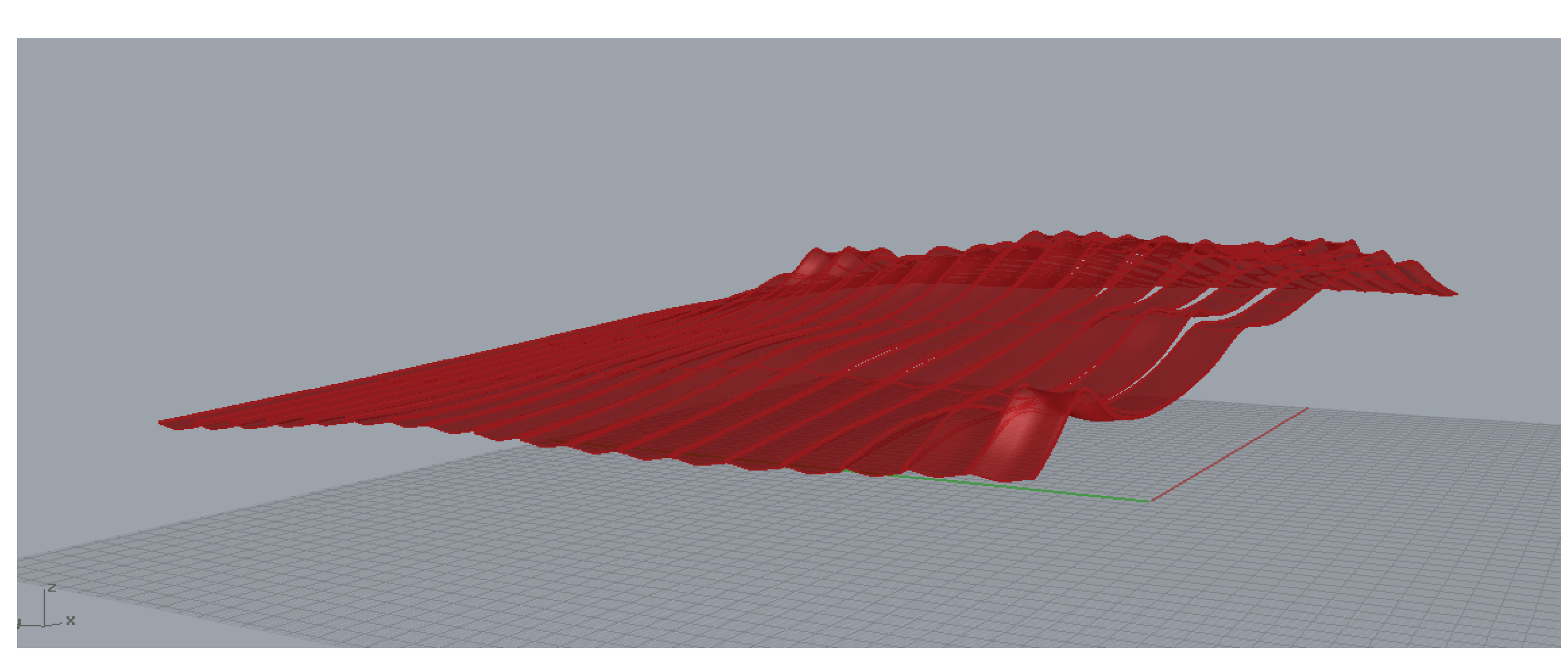


Definition Part D: Takes the horrizontal panel system and cuts it down into 12' long tiles that then can be taken into production.









THIN CASTING PANEL TEST

FALL 2015 ARCH 5670 BRAD BELL

SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

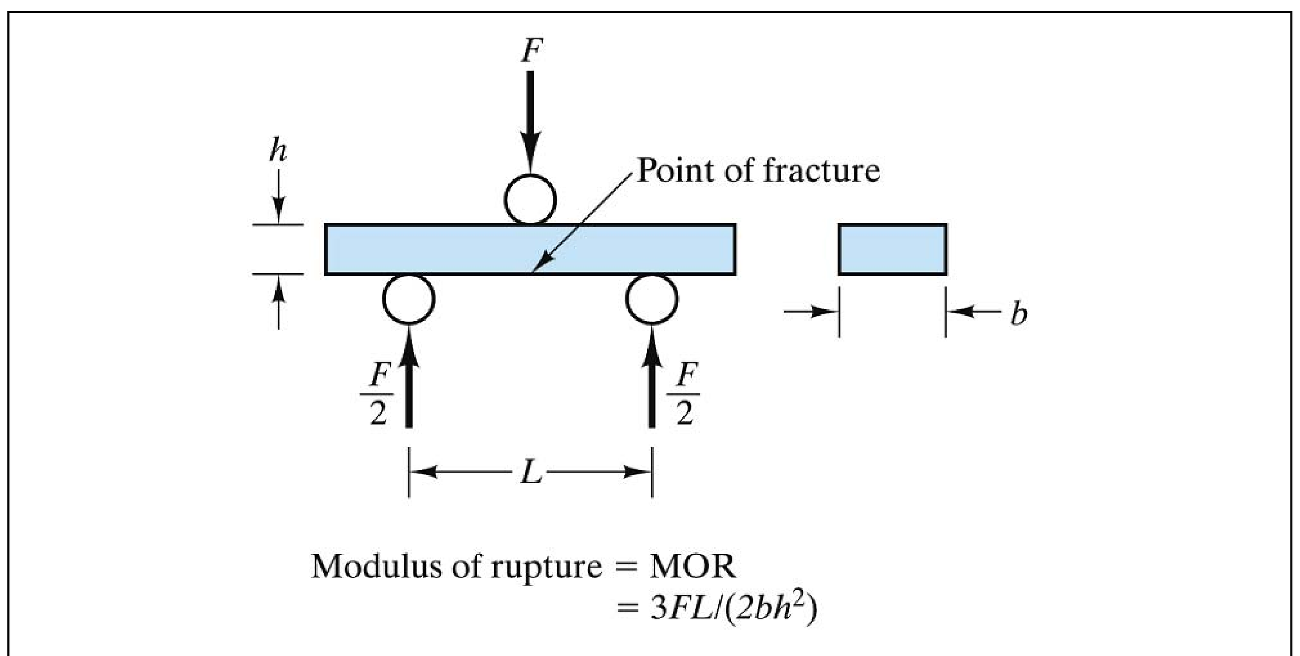
STRENGHT TEST PROCEDURE

Flexure STrenght Test:

This method is similar to ASTM "AASHTO T 177" and covers the procedure for determining the flexural strength of concrete by the use of a simple beam with centerpoint loading.

Setup:

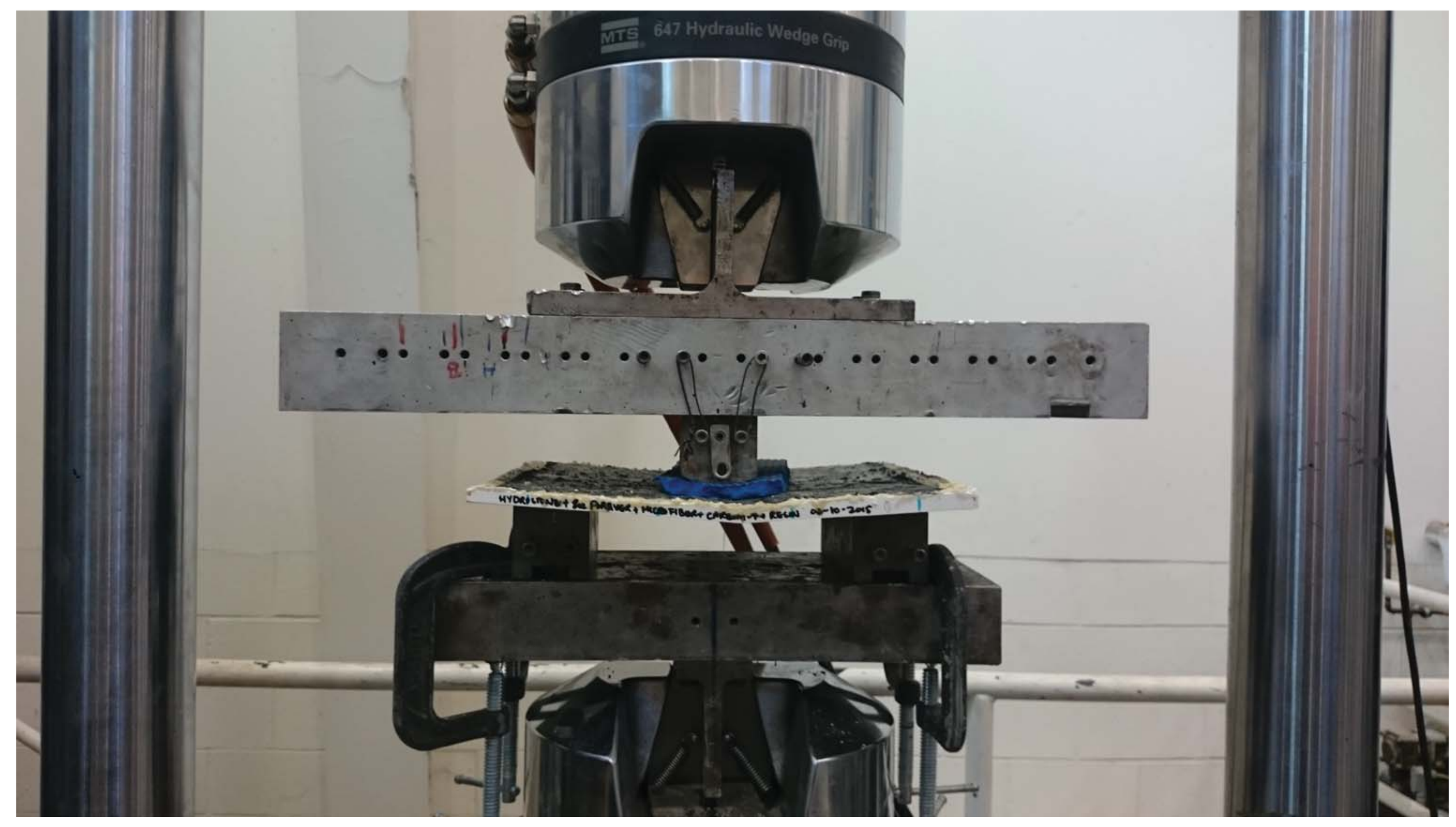
The center-point loading method shall be used in the laboratory. The testing machine shall conform to the requirements of Sections 15, 16, and 17 of the MetHods of Verification of Testing Machines (AASHTO T 67). In the field, a manually operated calibrated jack shall be used in conjunction with the field testing machine supplied by the Regional Materials Engineer. The apparatus shall incorporate the following requirements. The load shall be applied at the center point of the span, normal to the loaded surface of the beam, employing bearing blocks designed to ensure that forces applied to the beam will be vertical only and applied without eccentricity. The direction of the reactions shall be parallel to the direction of the applied load at all times during the test. The load shall be applied at a uniform rate and in such a manner as to avoid shock. The edges of the load-applying block and of the supports shall not depart from a plane by more than .002 in. (0.051 mm).



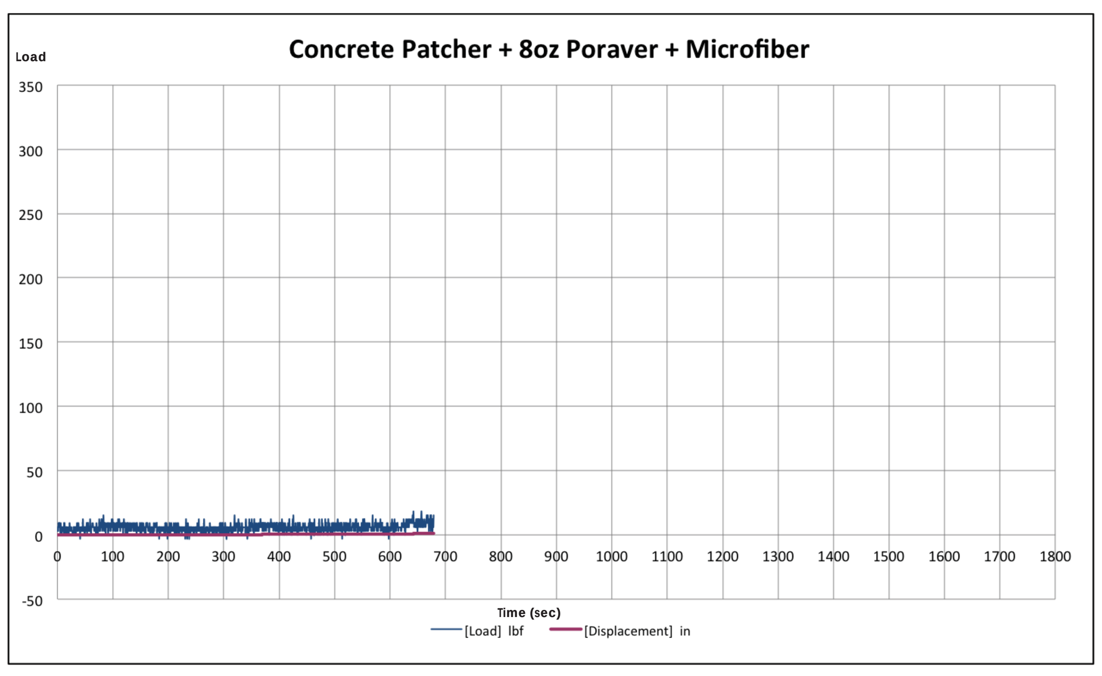
Modulus of rupture = MOR

$$= 3FL/(2bh^2)$$

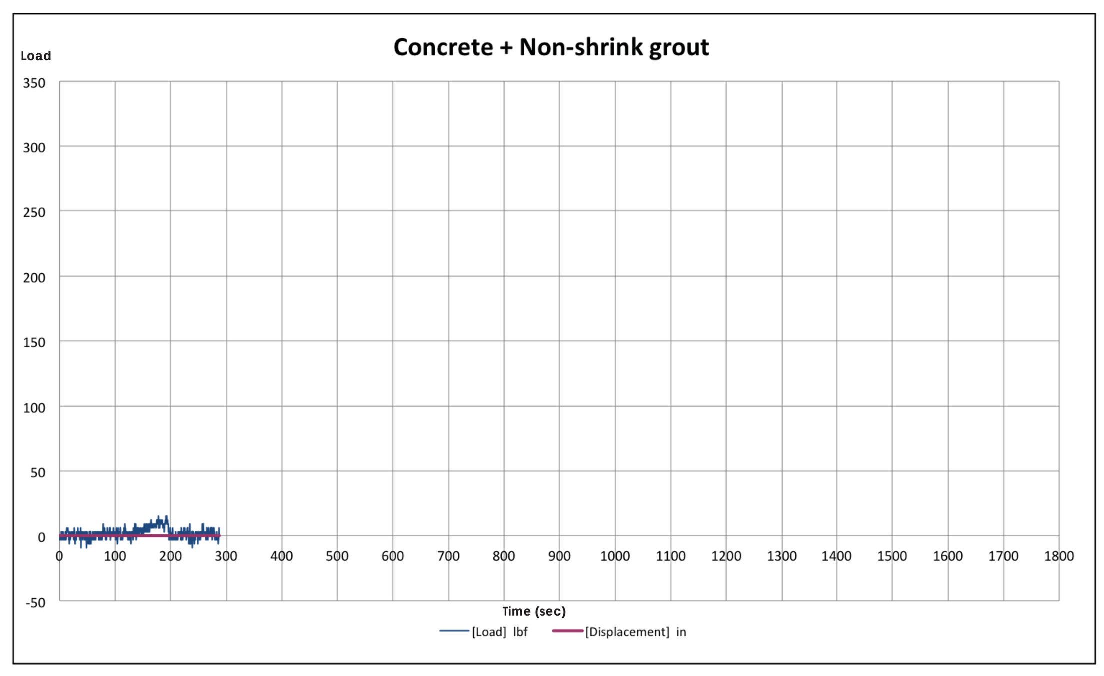
The bending test that generates a modulus of rupture.
This strength parameter is similar in magnitude to a tensile strength.
Fracture occurs along the outermost sample edge, which is under a tensile load.



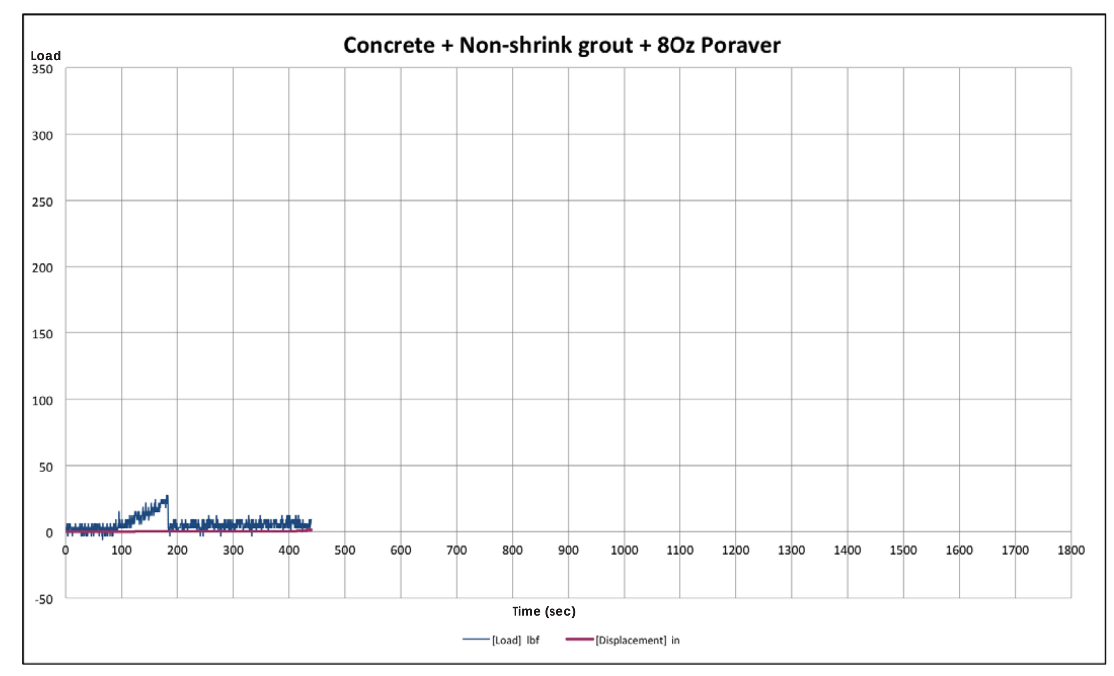
STRENGTH TEST RESULTS



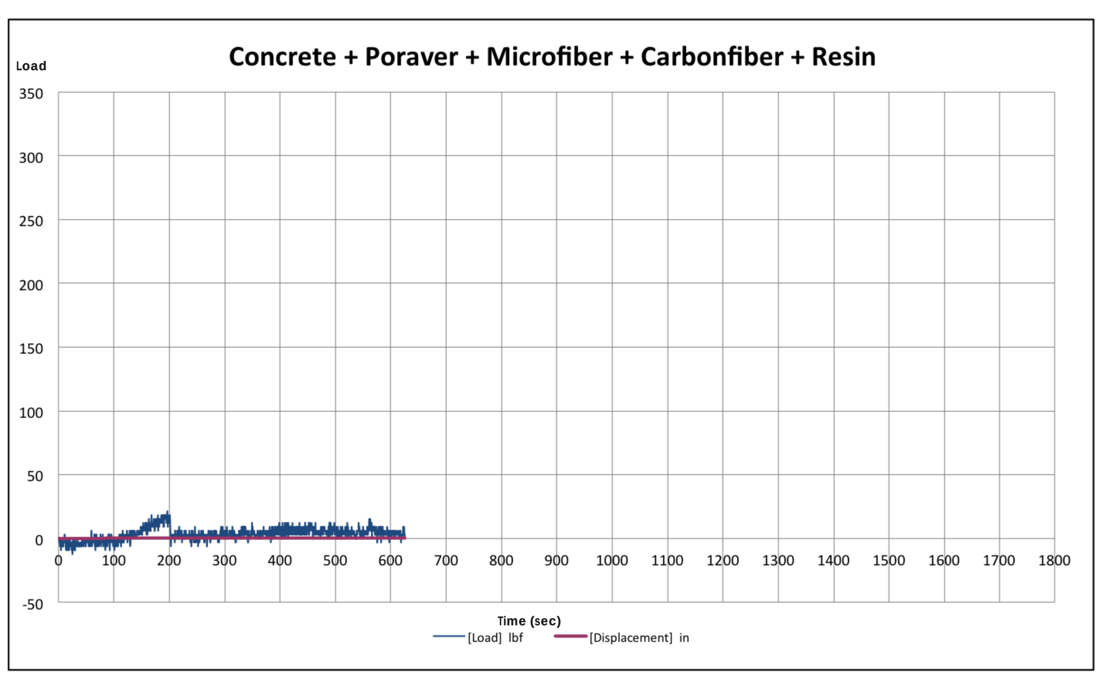
Weight: 1.93 lb



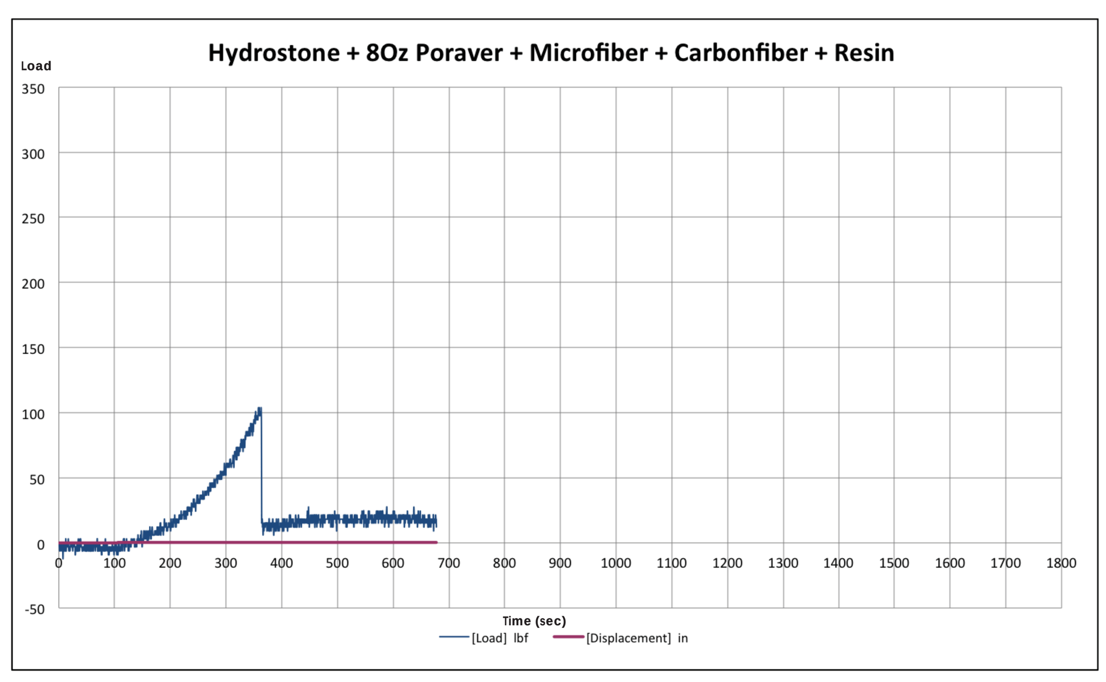
Weight: 3.04 lb



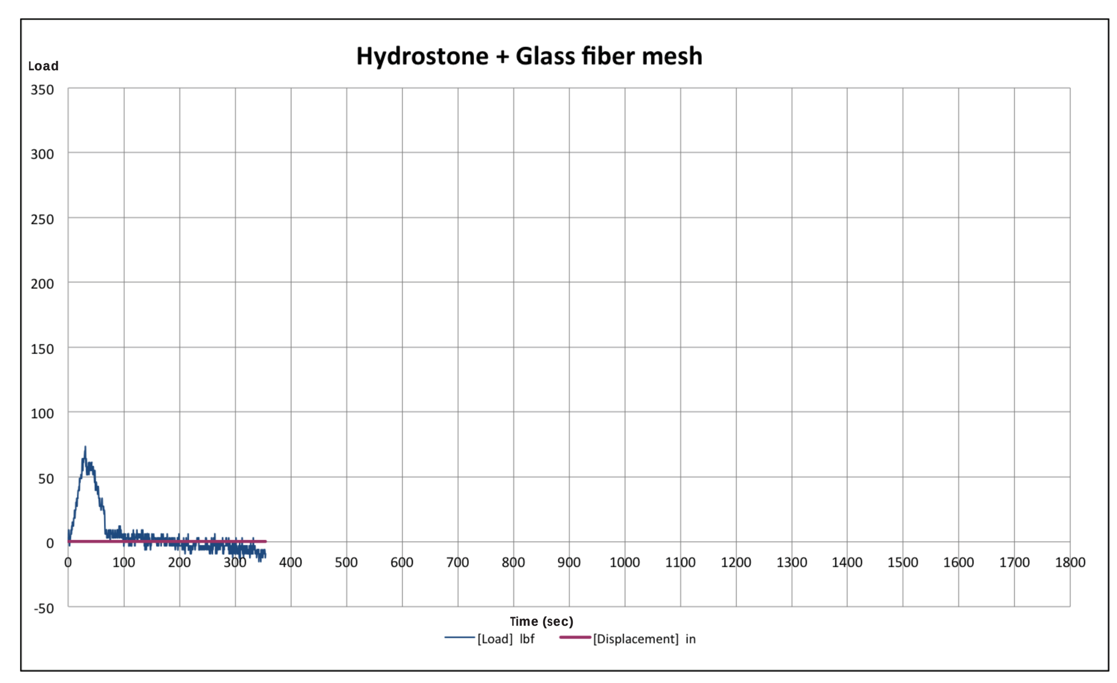
Weight: 2.83 lb



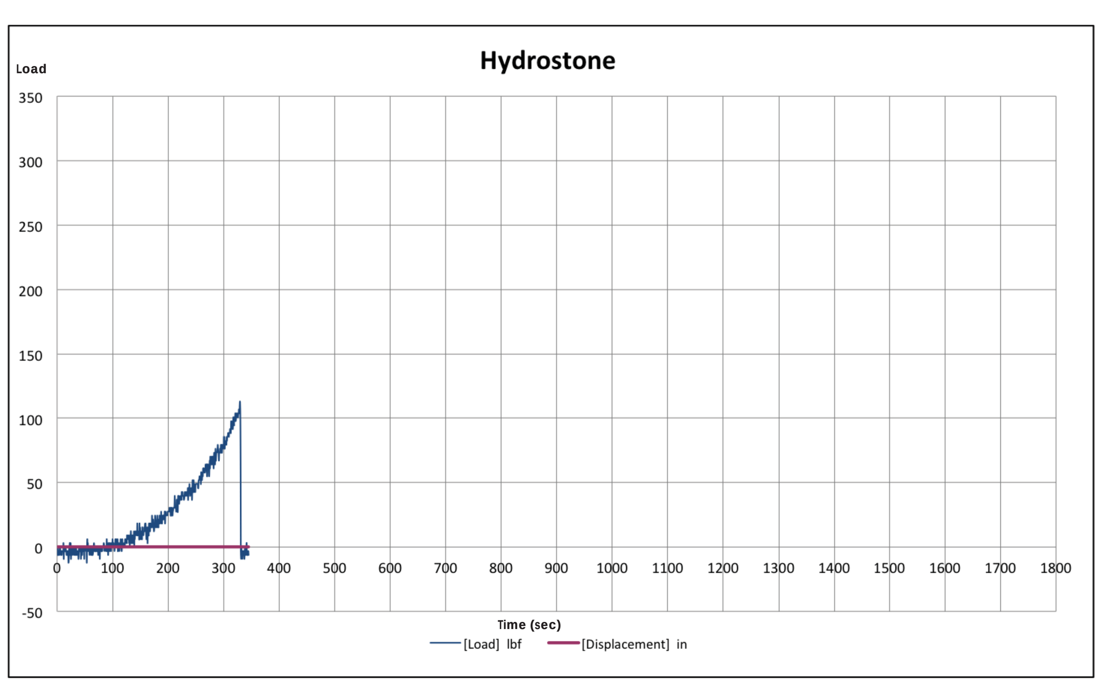
Weight: 2.25 lb



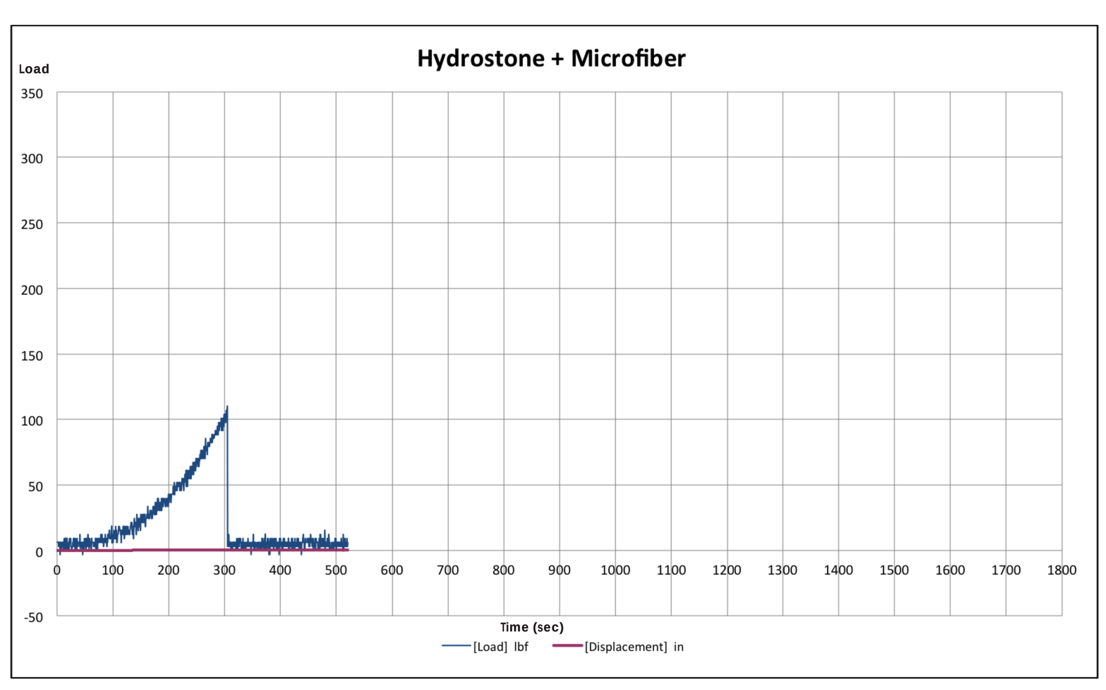
Weight: 2.48 lb



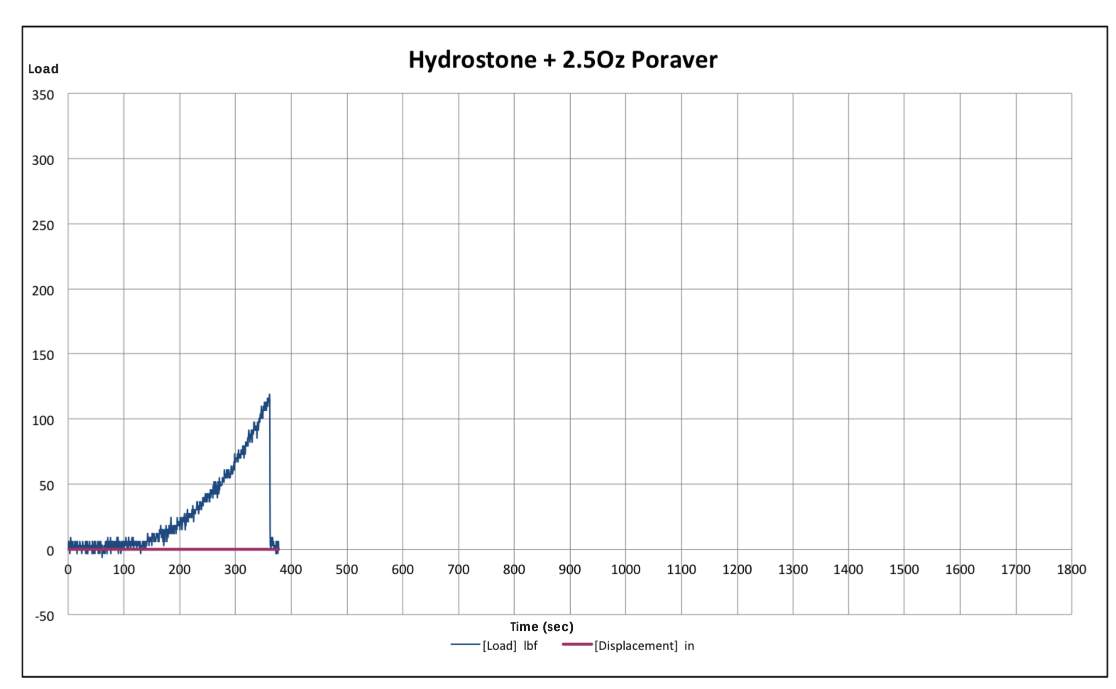
Weight: 2.7 lb



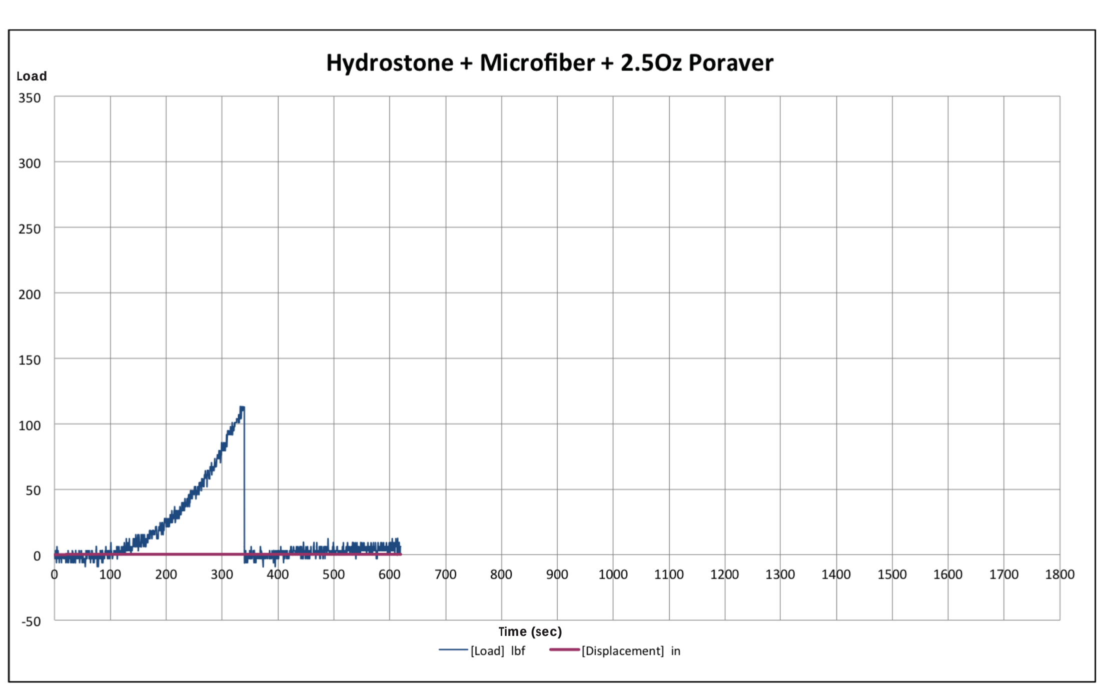
Weight: 3 lb



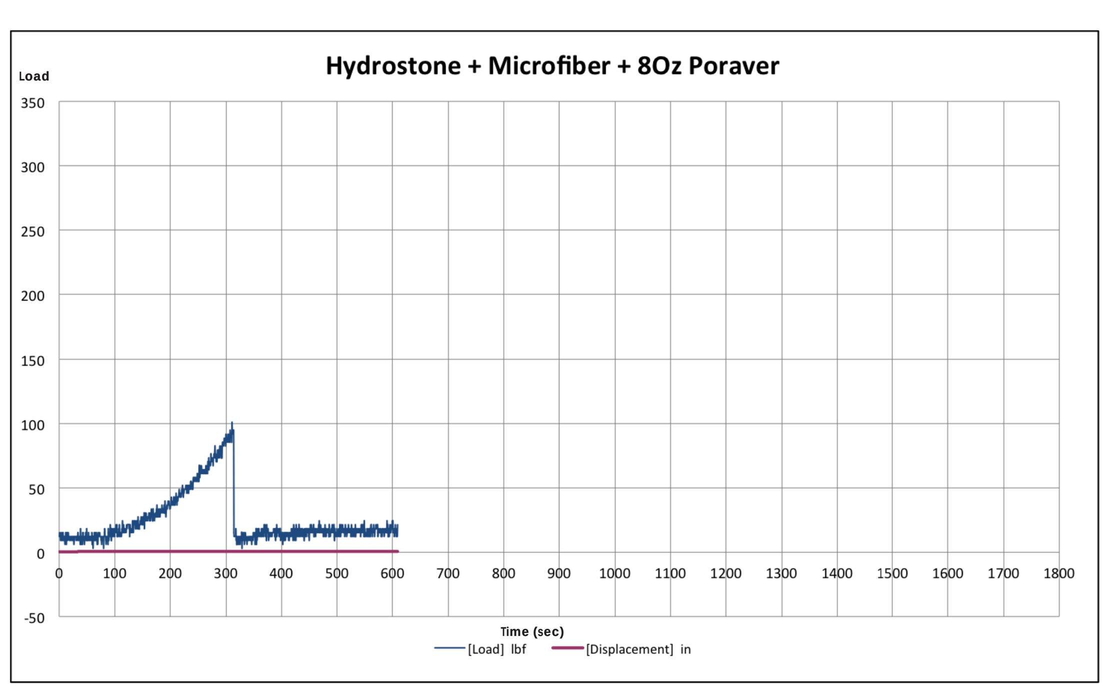
Weight: 2.74 lb



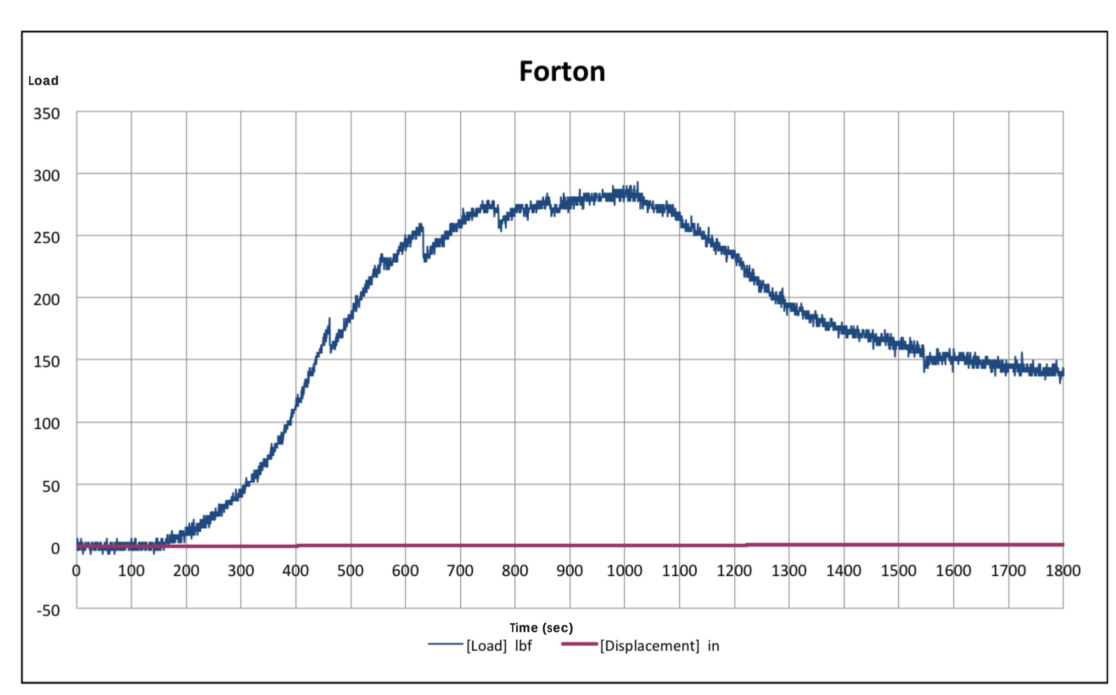
Weight: 2.86 lb



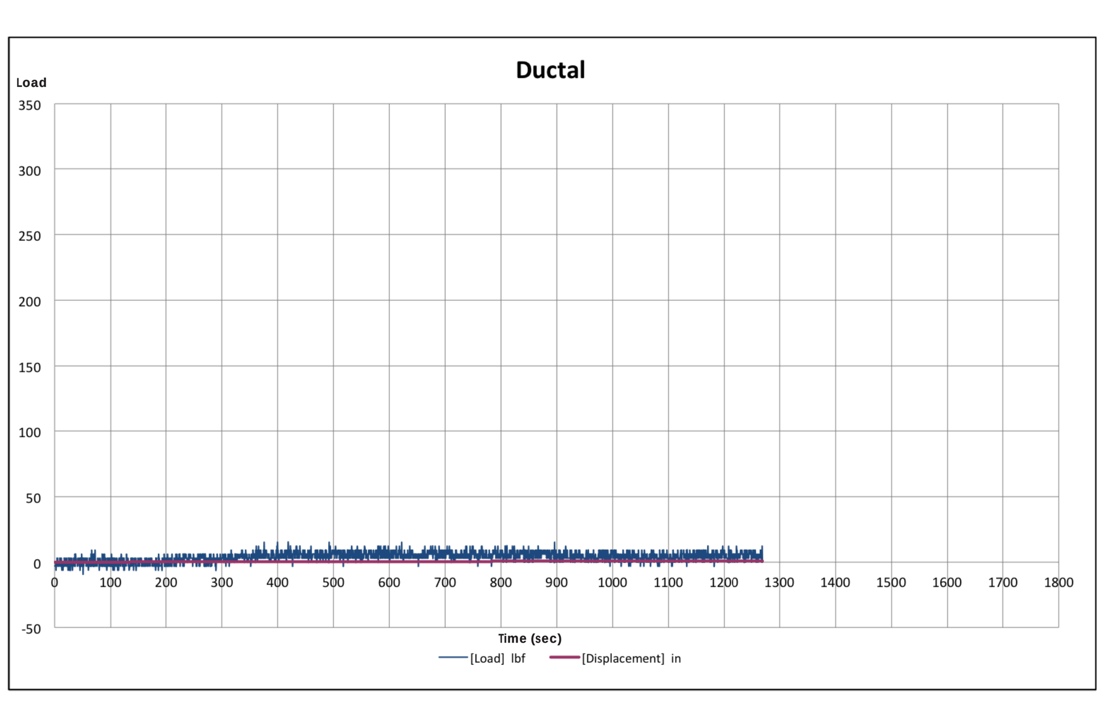
Weight: 2.82 lb



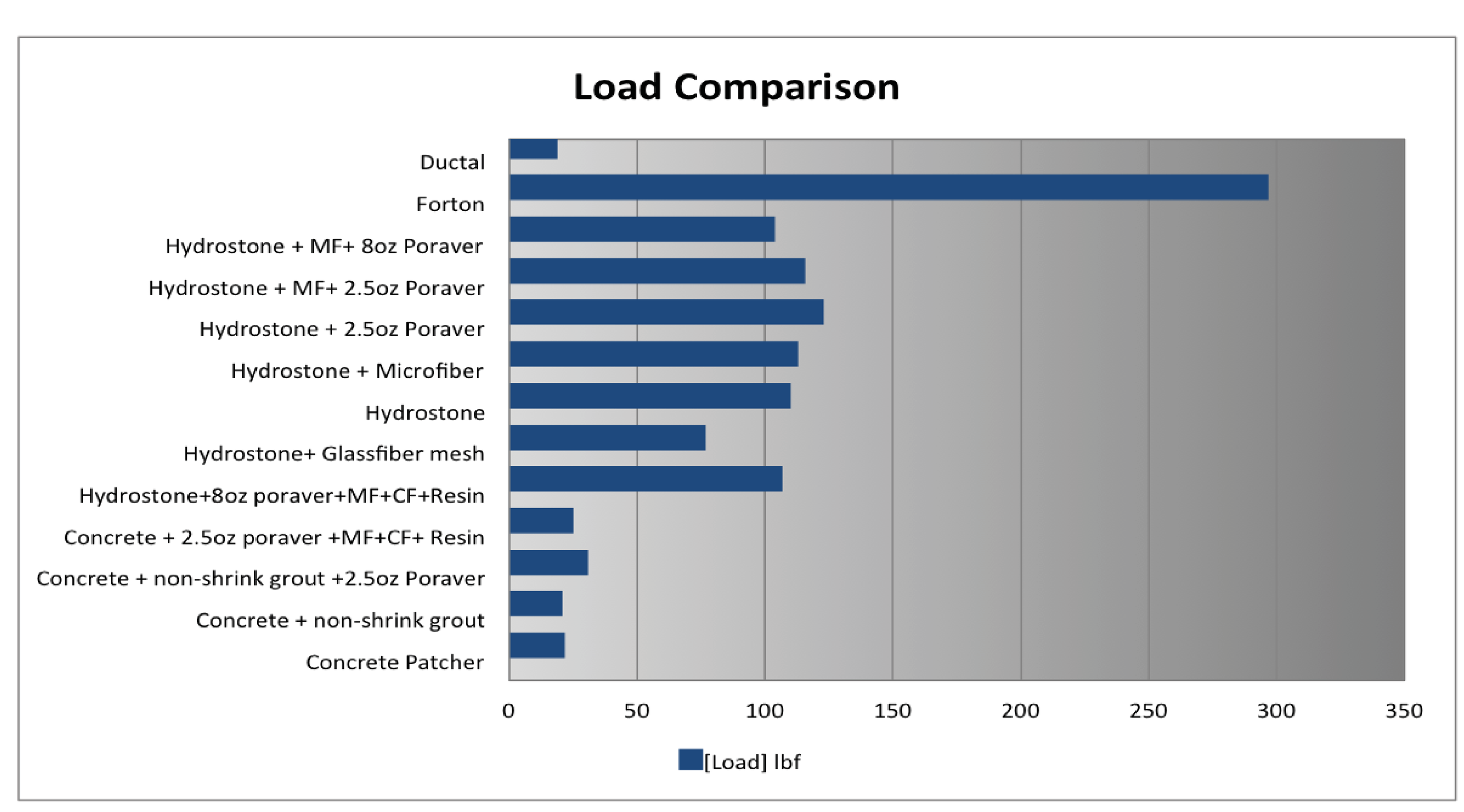
Weight: 2.4 lb



Weight: 3 lb



Weight: 2.89 lb



THIN CASTING PANEL TEST

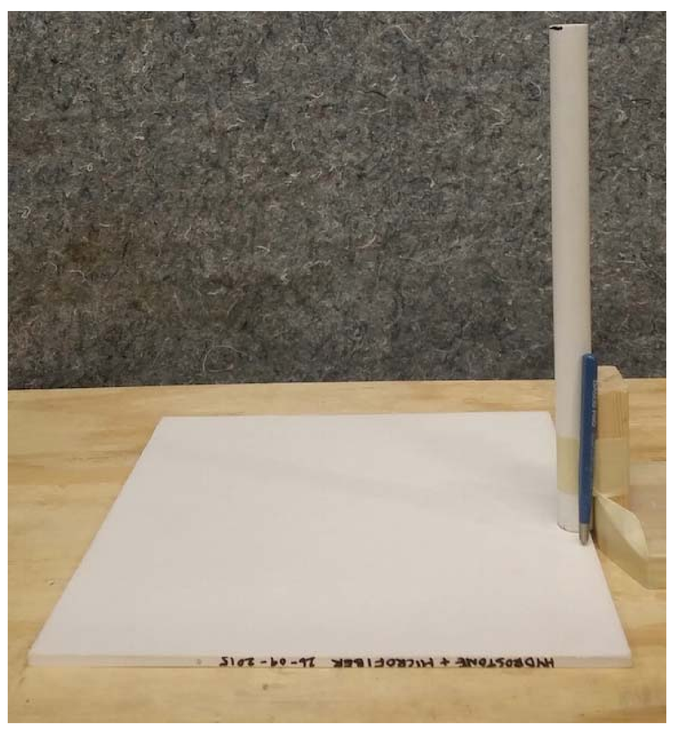
FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

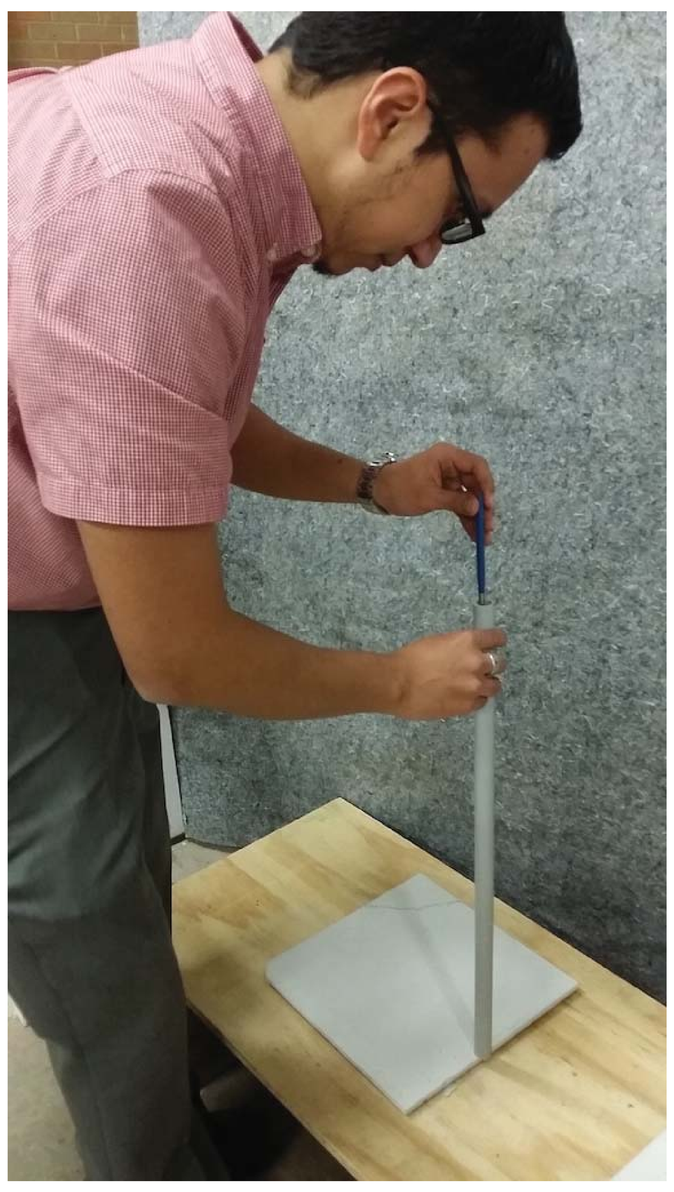
IMPACT TEST PROCEDURE

Impact resistance test:

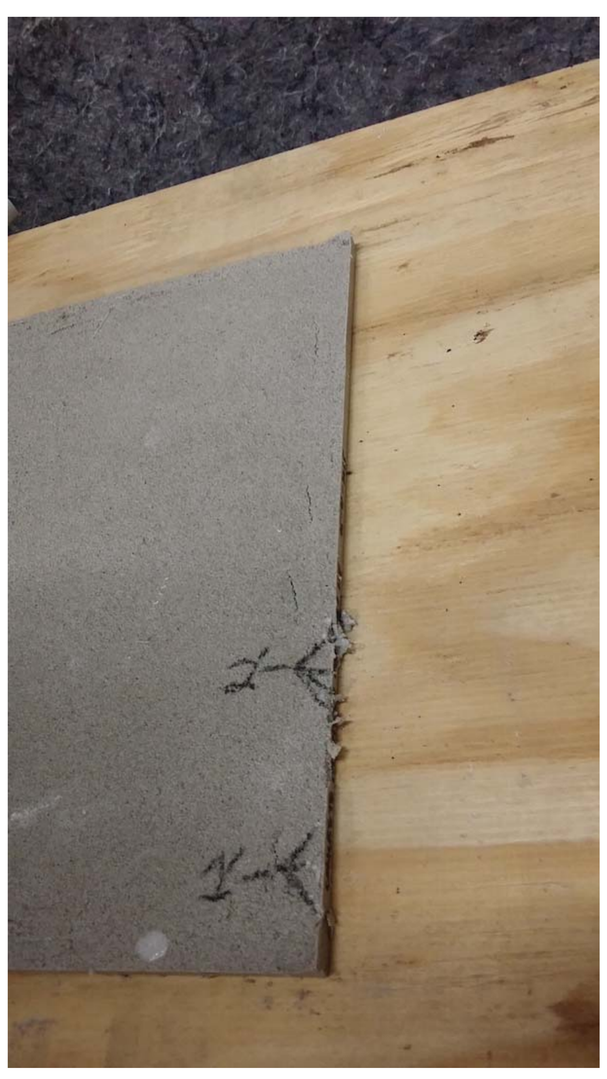
The impact test was based on the “Falling Ball Impact Test ASTM D 1037”. The procedure and setup was improvised for our 12x12 in panels to test the edge brittleness. This test was important to varify how well the panels can be handeled while installing or maintenance; whether their edges would chip off easily or not.

The setup consisted of heights ranging form 1ft to 5ft from which a heavy point was dropped to the edge of the panels until it chipped. The heavy point was dropped 5 times maximum for each height.

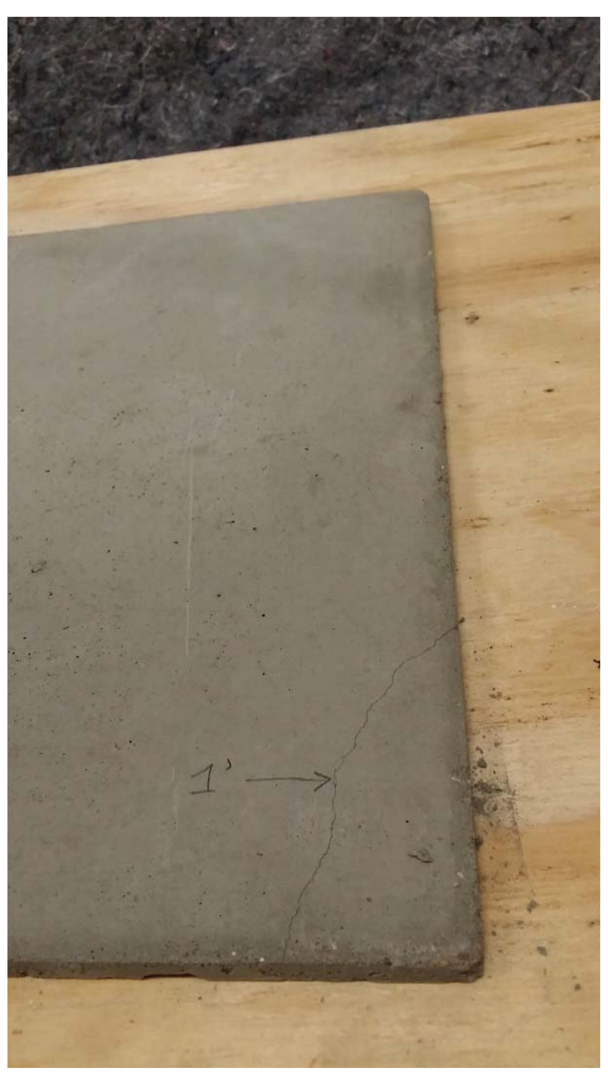




IMPACT TEST RESULTS



Concrete Patcher: 2 ft

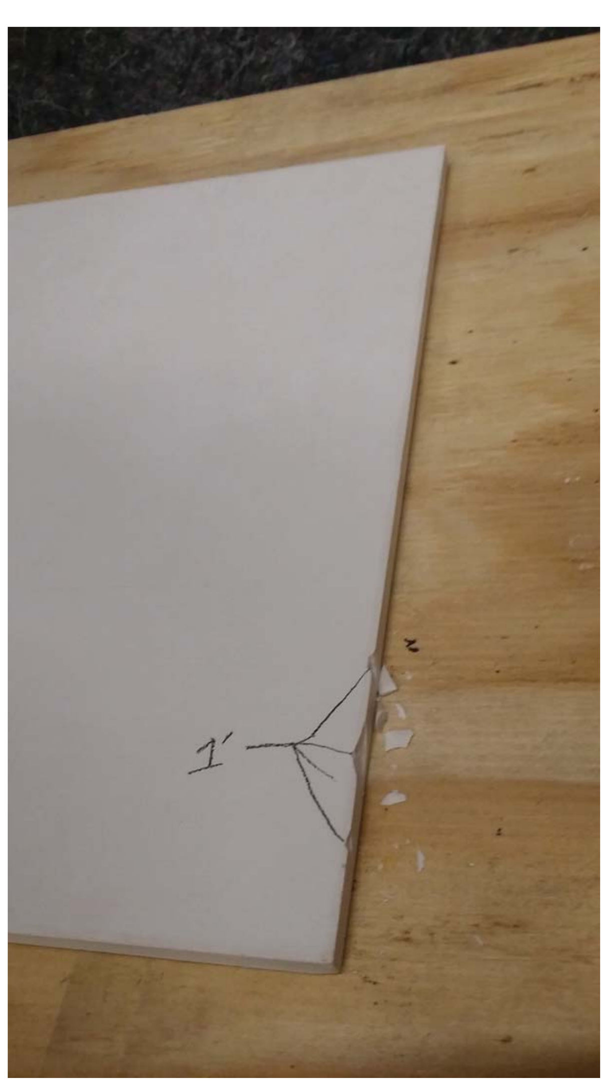


Concrete + Non-shrink Grout: 1 ft

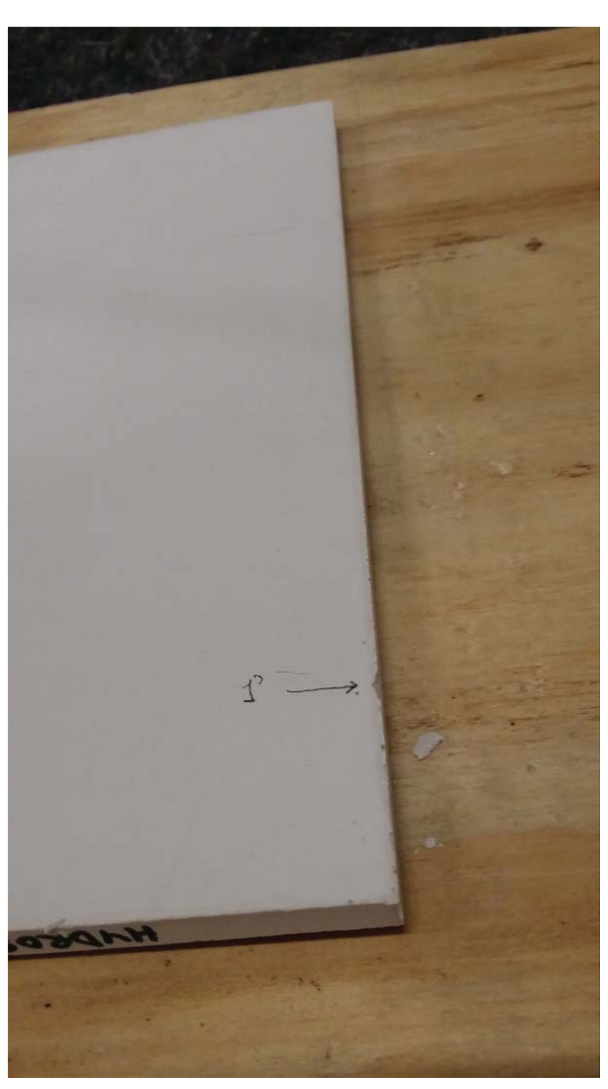
Concrete + Non-shrink Grout + 8Oz Poraver: 1 ft

Concrete + Poraver + Microfiber + Carbonfiber: 2 ft

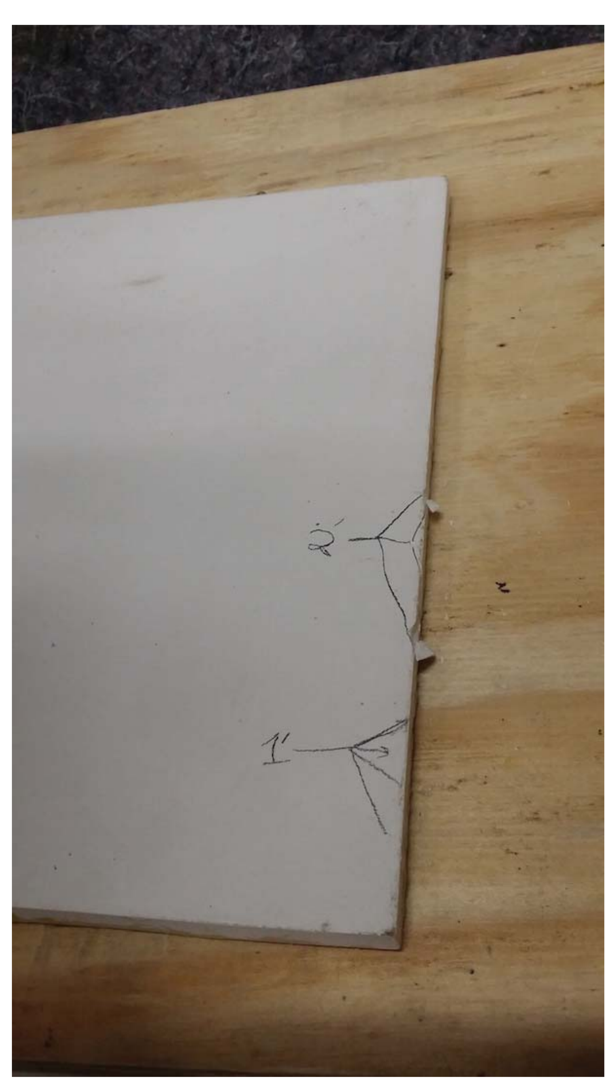
Hydrostone + Carbonfiber: 2 ft



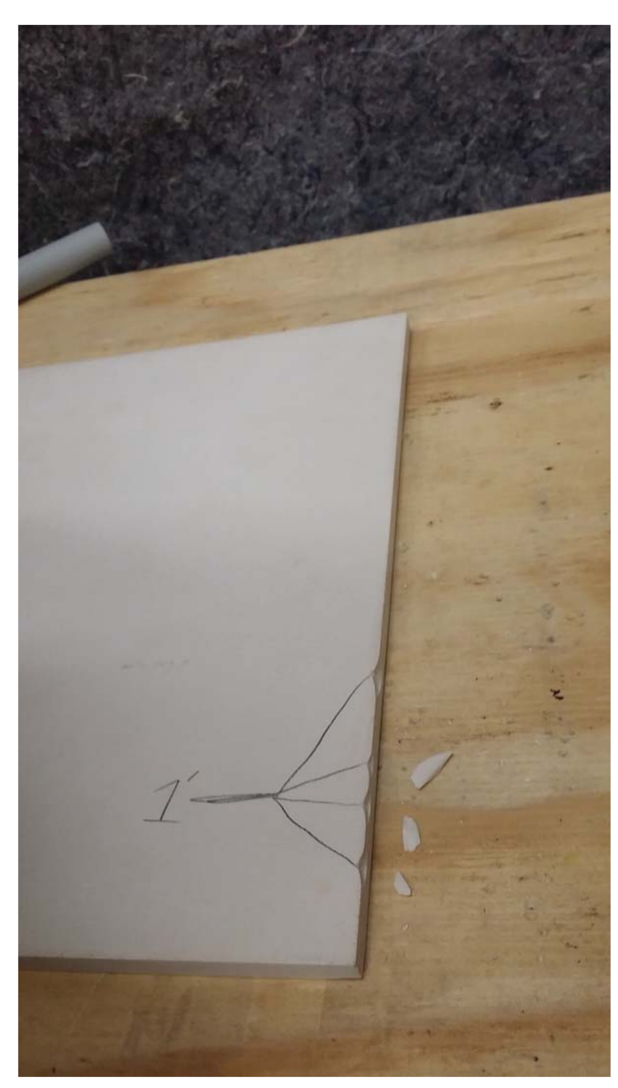
Hydrostone + Glass fiber mesh: 1 ft



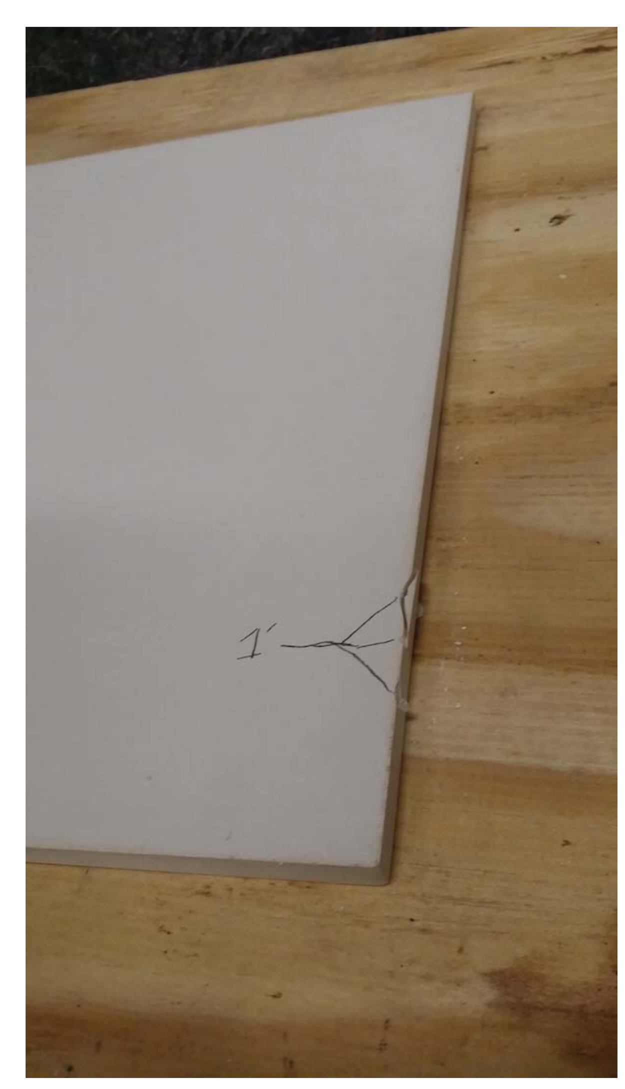
Hydrostone: 1 ft



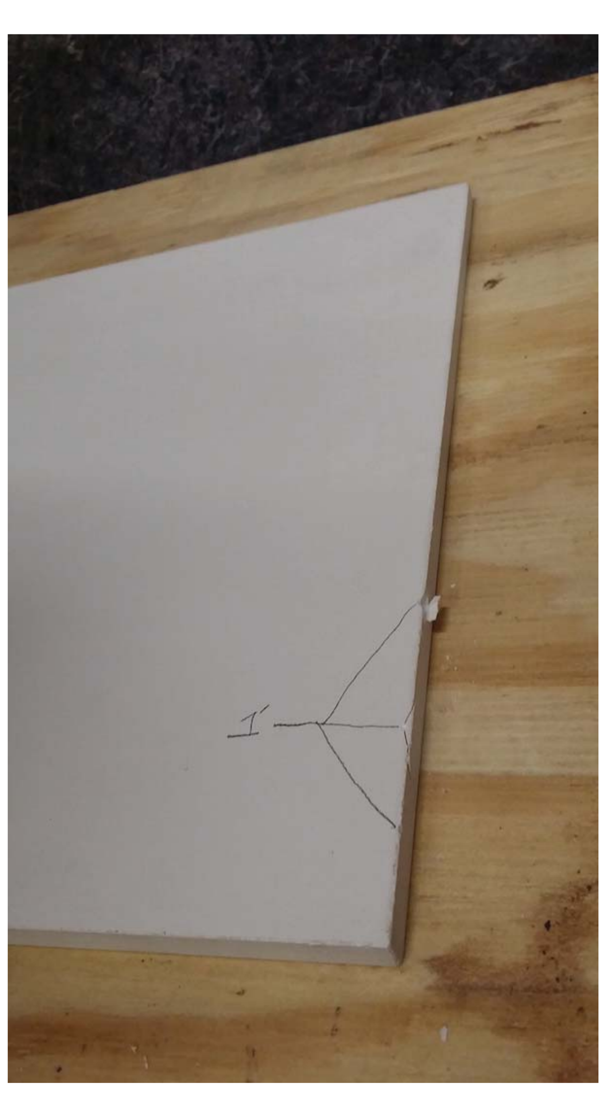
Hydrostone + Microfiber: 2 ft



Hydrostone + 2.5Oz Poraver: 1 ft



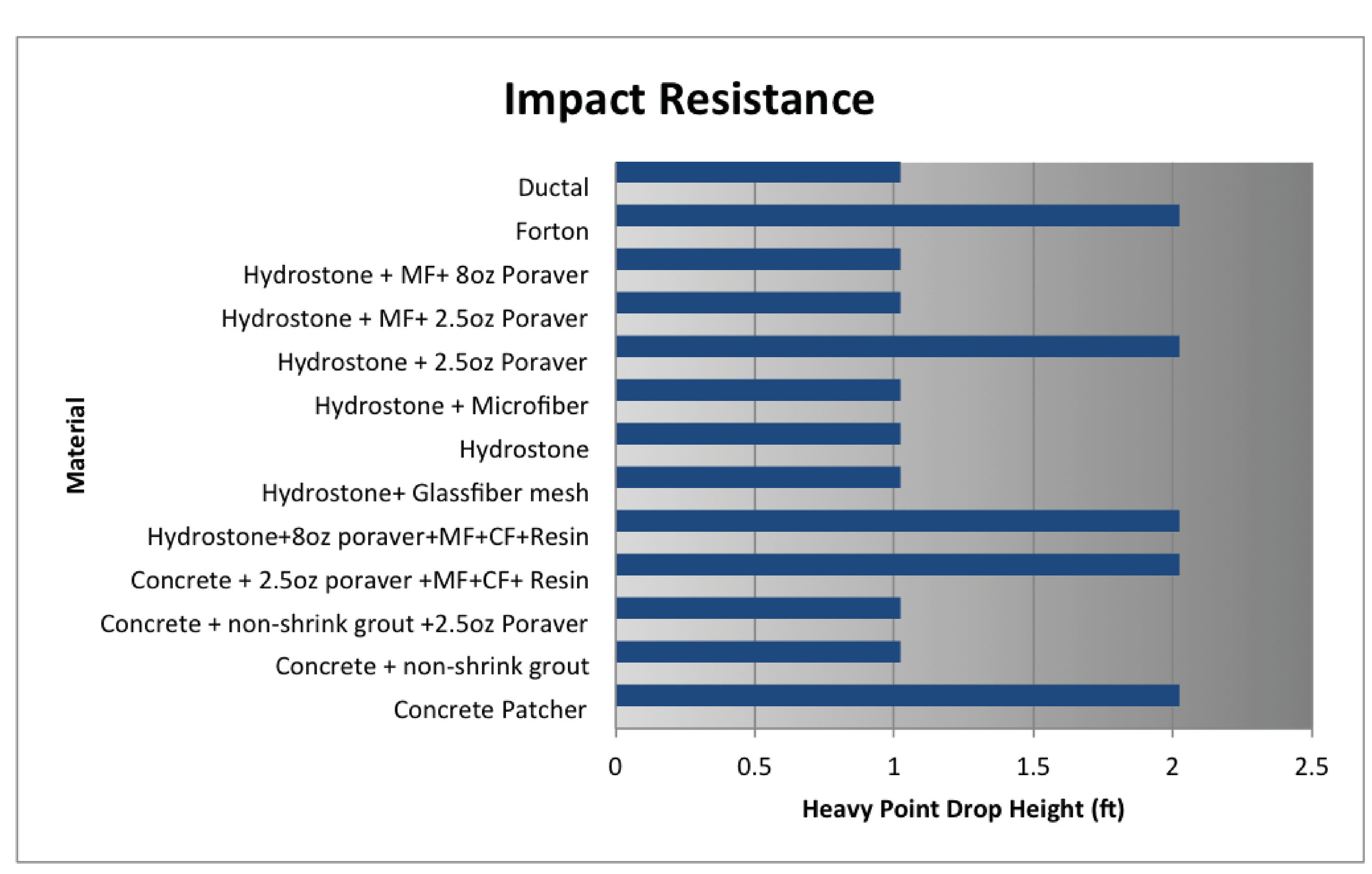
Hydrostone + Microfiber + 2.5Oz Poraver: 1 ft



Hydrostone + Microfiber + 8Oz Poraver: 1 ft

Forton: 2 ft

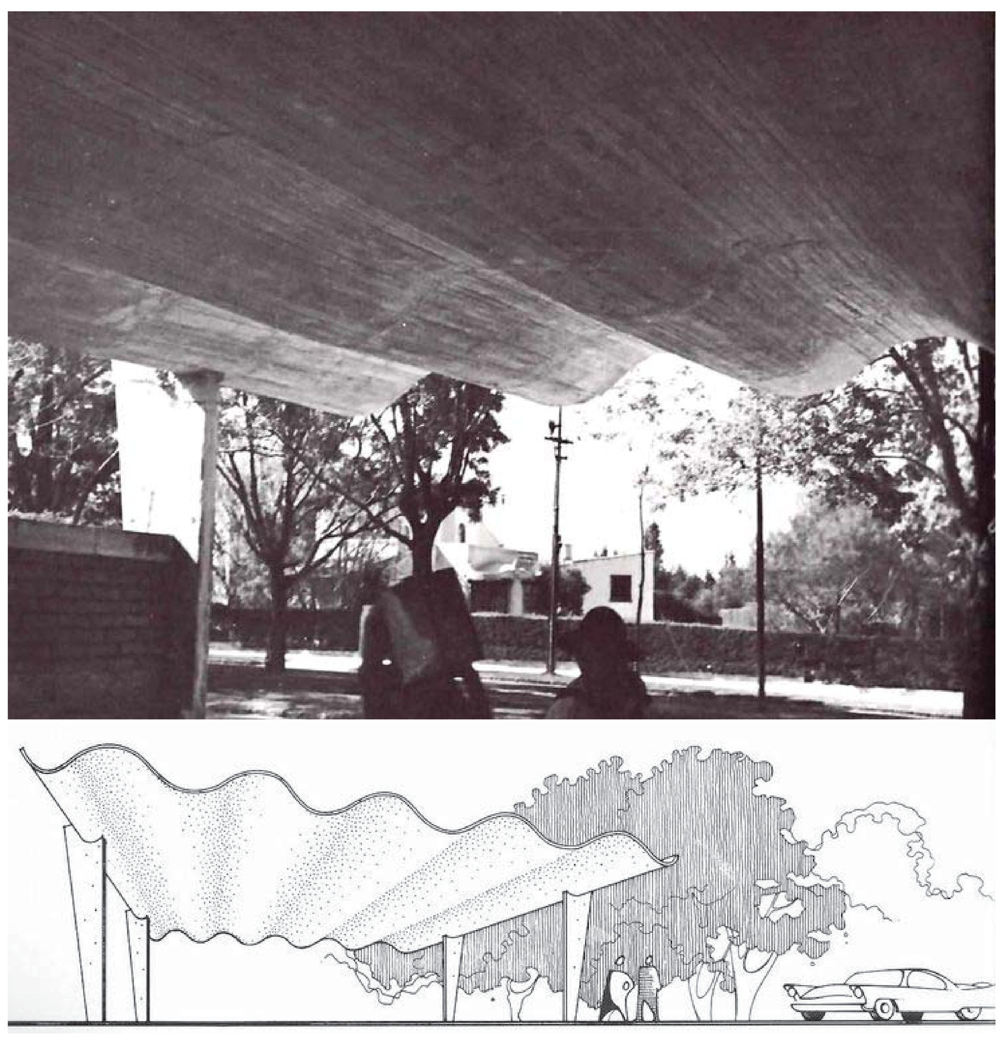
Ductal: 1 ft



THIN CASTING PANEL PROFILES

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

Profile Precidents

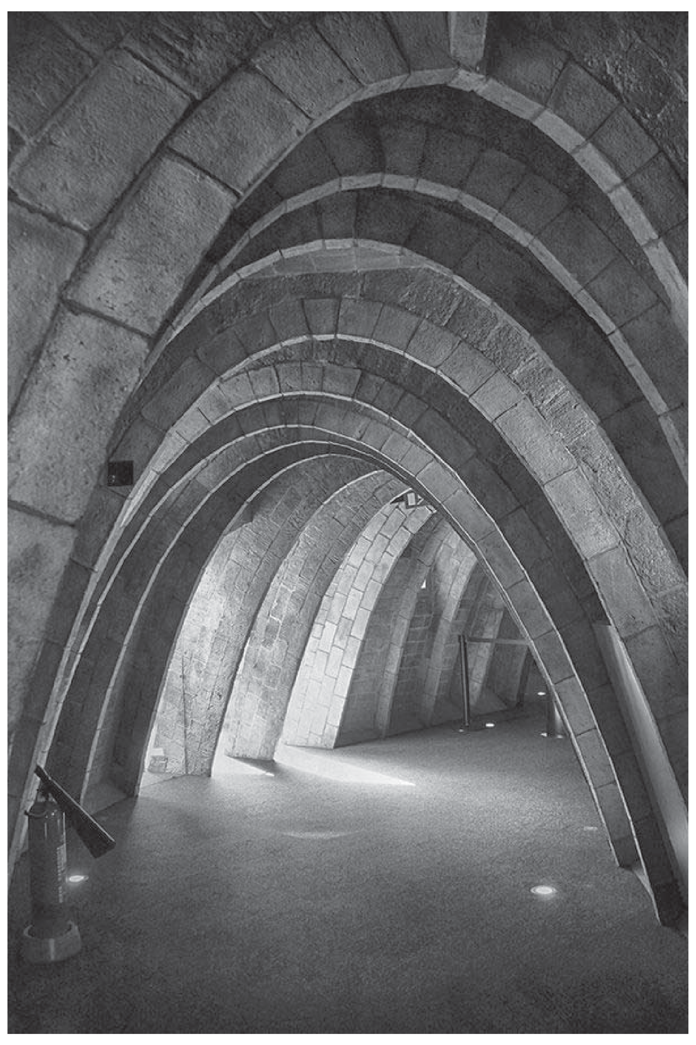


Candela Felix - 1951

Ras-Martin Flower Shop - Sinusodial slab

Luigi Nervi

Gatti Wool Factory, Rome - Ribs following the isostatic lines of the principal bending moments.

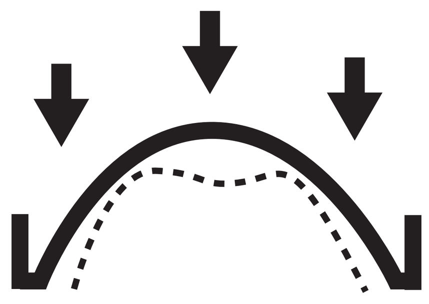


Antoni Gaudi

Casa Mila - Parabolic arch

PANEL PROFILING

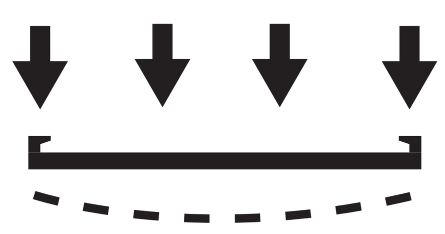
As a horizontal clading system it is a neccesity that every panel should use minimal material. In order to accomplish this a variety of profiles were tested in order to find the performance capacities of each geometry.



Parabolic Panel:

Benefits: Increases stiffness due to better load transfer through the arch.

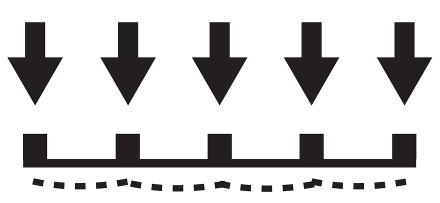
Drawbacks: Increasing the height of the arch will increase the chance of buckling therefore precise calculation is required.



Flat Panel with Edge Channel:

Benefits: The channel provides stiffness to the edges as well as suspension supports.

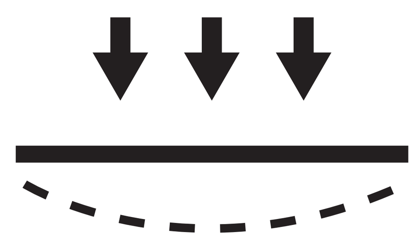
Drawbacks: The center of the panel is still prone to bending moment.



Ribbed / Joist Panel:

Benefits: Shape draws upon concept behind t-beams by useing combined strenght of flange and beams to ultimately minimize volume.

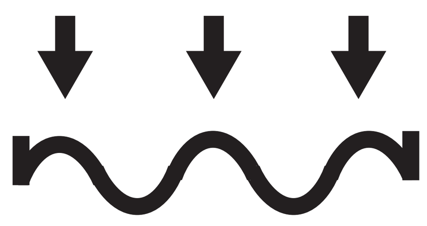
Drawbacks: Increased surface area increases the difficulty of removal from mold.



Flat Panel:

Benefits: Minimal volume cuts down on amount of material needed.

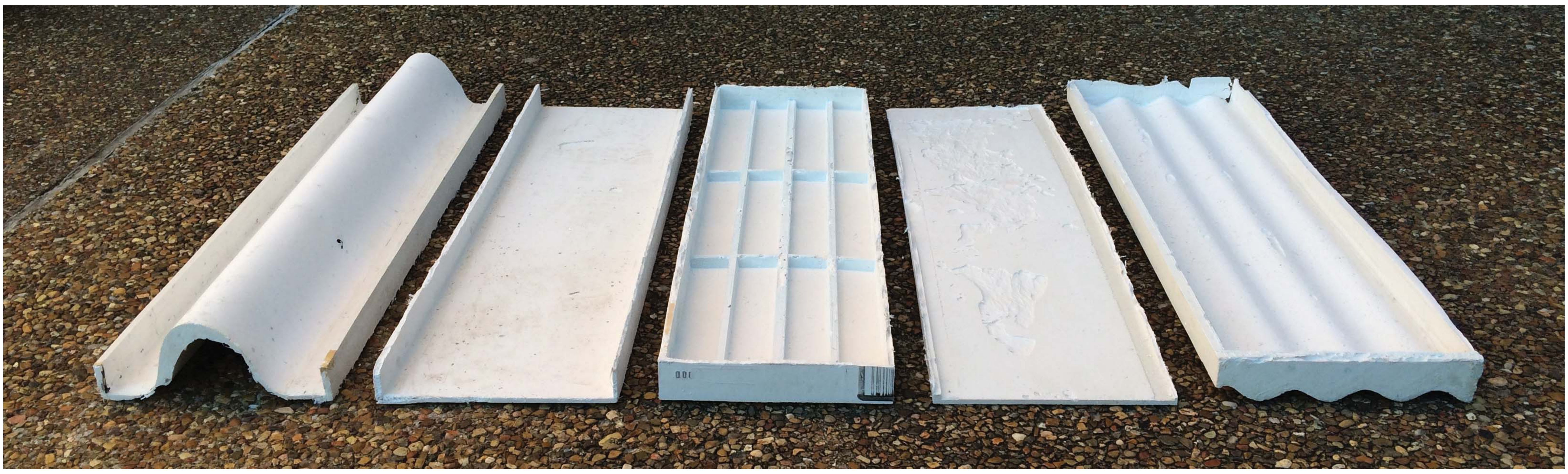
Drawbacks: Homogonus shape does nothing to maximize performance.



Sinusodial Panel:

Benefits: Increases stiffness by transferring load through the curves. Due to small arch-like curves, the risk of buckling decreases.

Drawbacks: Increased surface area therefore increasing weight per panel.



THIN CASTING **PROFILE TEST**

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

PROFILE TEST PROCEDURE

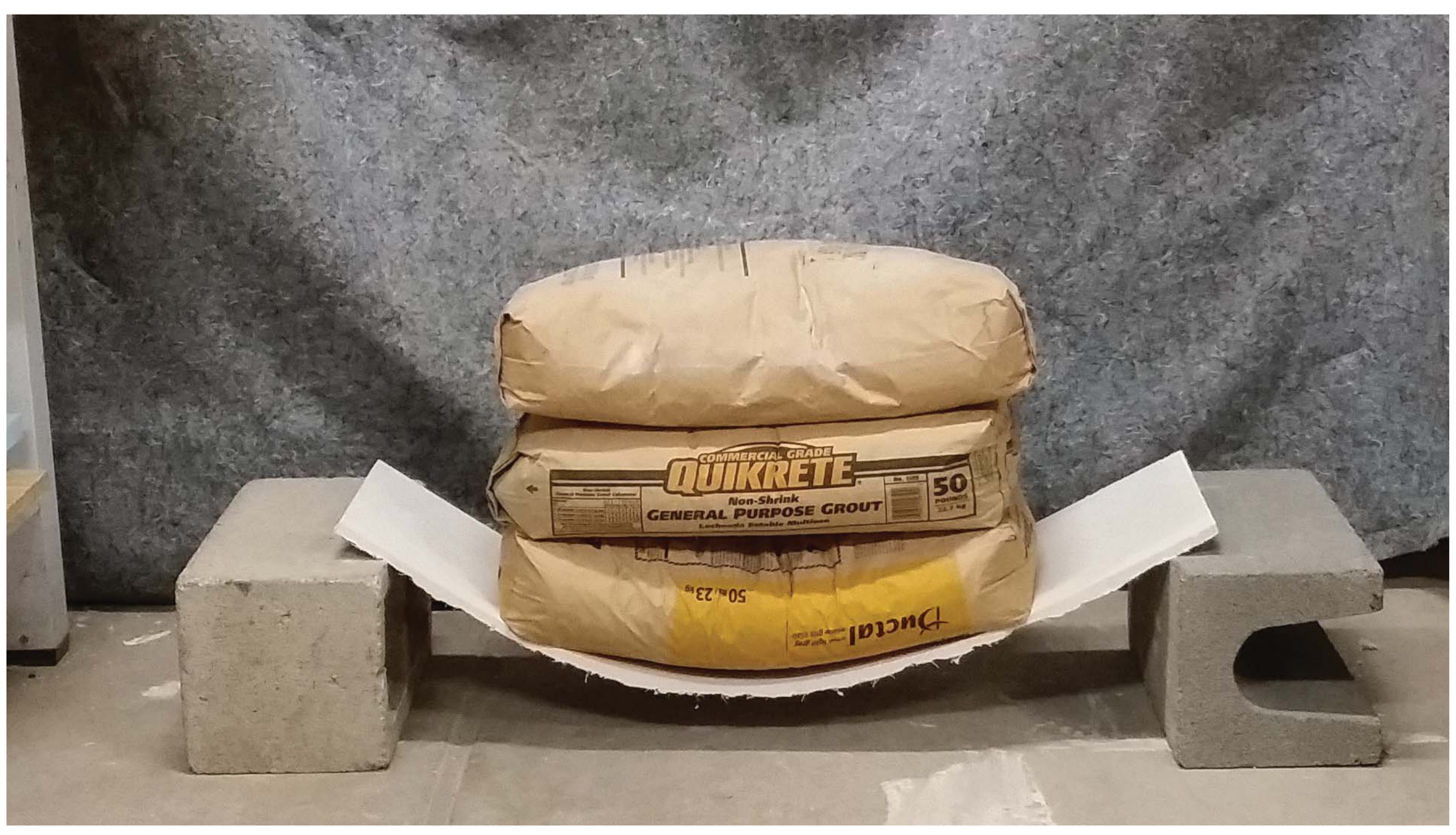
Profile & Span Test:

The profile and span performance was tested by improvising a setup that is similar to the three point flexure streght that was previously done to test the strength of the materials.

Setup:

The 3x1ft panels were placed on two points and loads were put on the center of the panels until the panels cracked or were broken. The Displacement of the panels were also recorded to check how much the panels will deflect before cracking.

PROFILE TEST RESULTS



Flat Panel:

Weight: 8 lb
Load: 150 lb
Displacement: 1.88 in

Flat Panel with Edge Channel:

Weight: 8.88 lb
Load: 473.66 lb
Displacement: 0.38 in

Ribbed / Joist Panel:

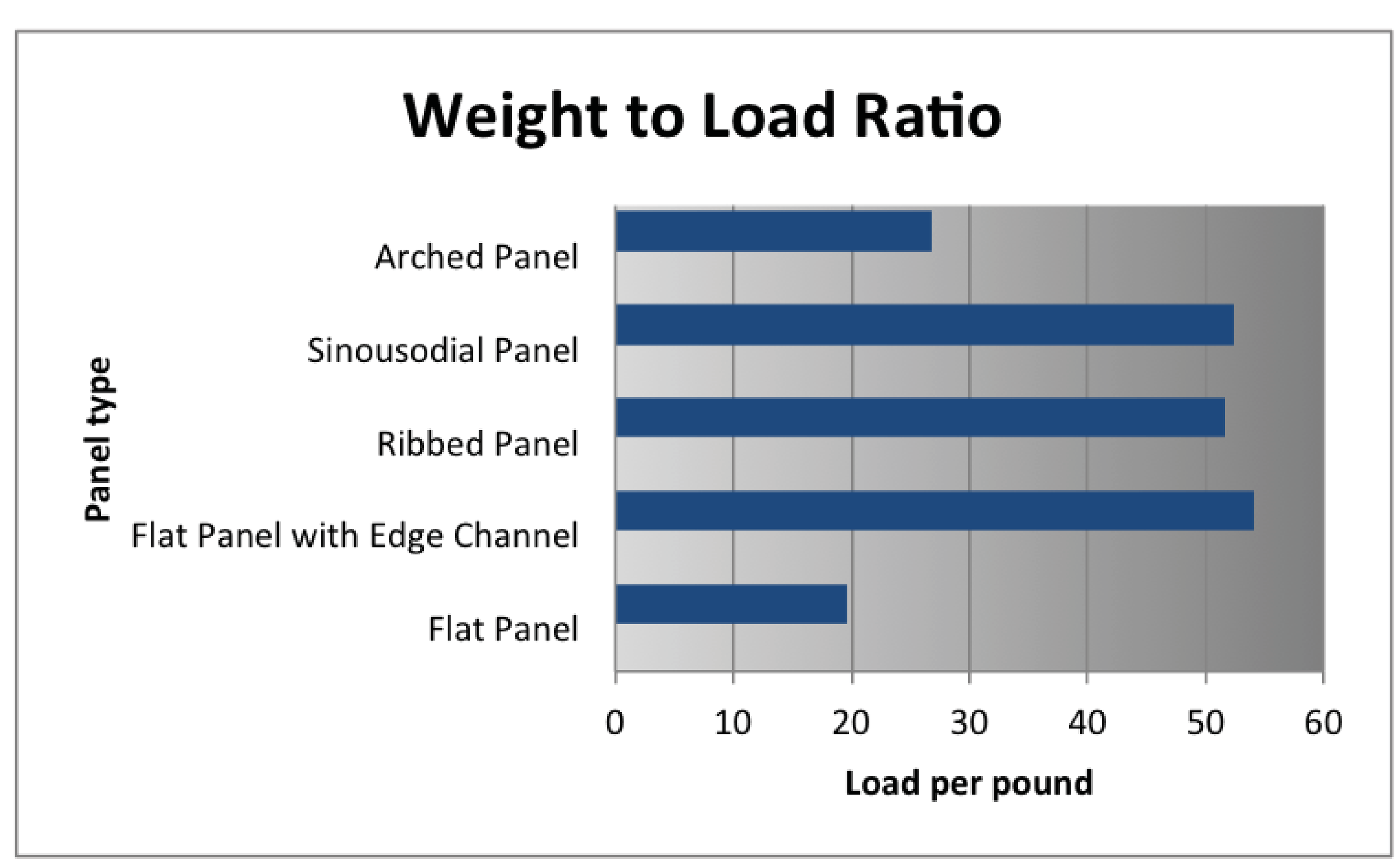
Weight: 11.88 lb
Load: 603.66 lb
Displacement: 0.13 in

Sinusodial Panel:

Weight: 10.75 lb
Load: 553.66 lb
Displacement: 0.31 in

Parabolic Panel:

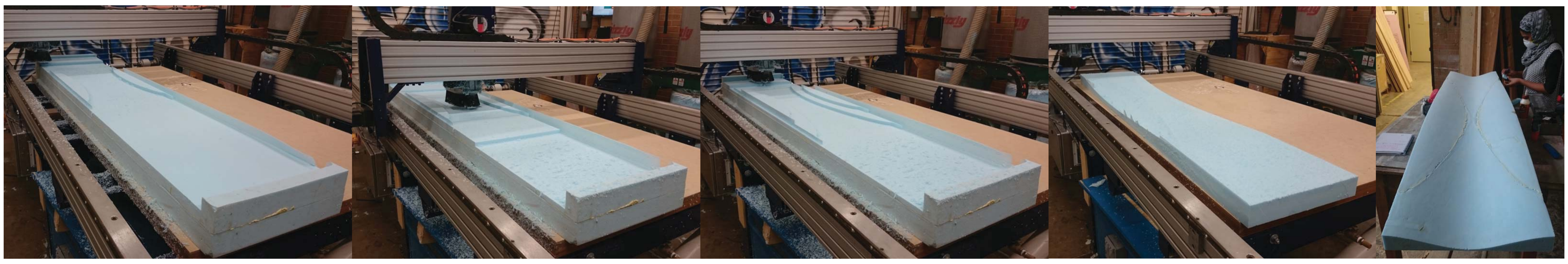
Weight: 12.46 lb
Load: 323.4 lb
Displacement: 0.19 in

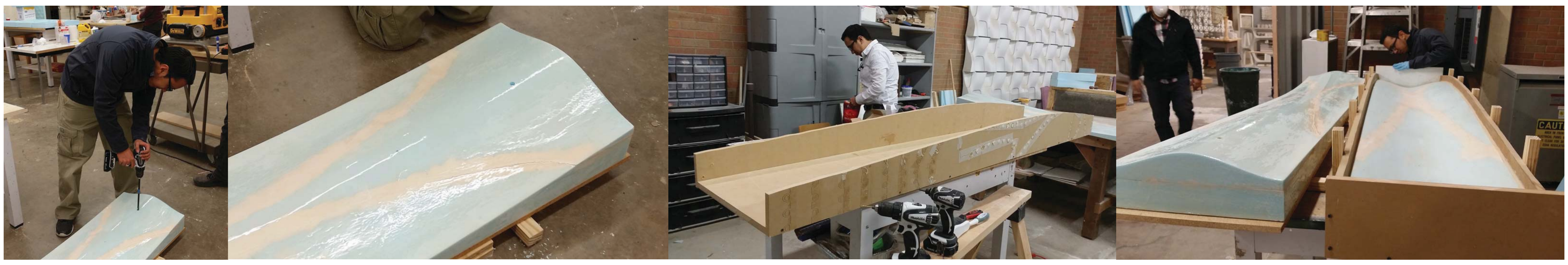


HORIZONTAL THIN CASTING

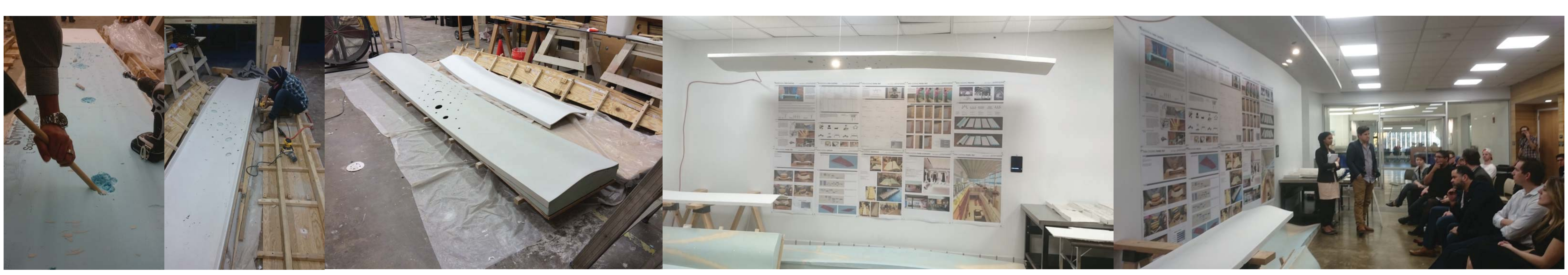
FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAZVEZ | MARZIA KHATUN

8' MOLD PRODUCTION PROCESS





12' MOLD PRODUCTION PROCESS



THIN CASTING PANEL SCENARIO

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

PANEL INSTALLATIONS

The thin casted panels could be used in different architectural spaces such as boutique ceiling, apartments, reception areas, as well as restaurants among many other spaces.

These panels will act as a space defying and acoustically performaitve medium. As mentioned perviously, they may act

Panels can be used in a variety of programms. Their modular and customizable properties allow them to be used singularly or on a system.

Cost estimation:

CNC MILLING: 16 HOURS X $100 = $1600

MAN HOURS: 3 WORKERS X 4-8 HOUR DAYS = 96 HOURS OF PRODUCTION X $15 AN HOUR = $1440

XPS FOAM: 3 4'X8' SHEETS @ $60 A SHEET + $50 DELIVERY CHARGES = $230

FORTON : 1/2 KIT TO CREATE 24SQ-FT @ $263 A KIT = $132

EPSION : $153

WOOD: 2 4"X8" PLYWOOD SHEETS @ $16, 4 2"X4" @ $3, 6 1"X1" @ $2 = $56

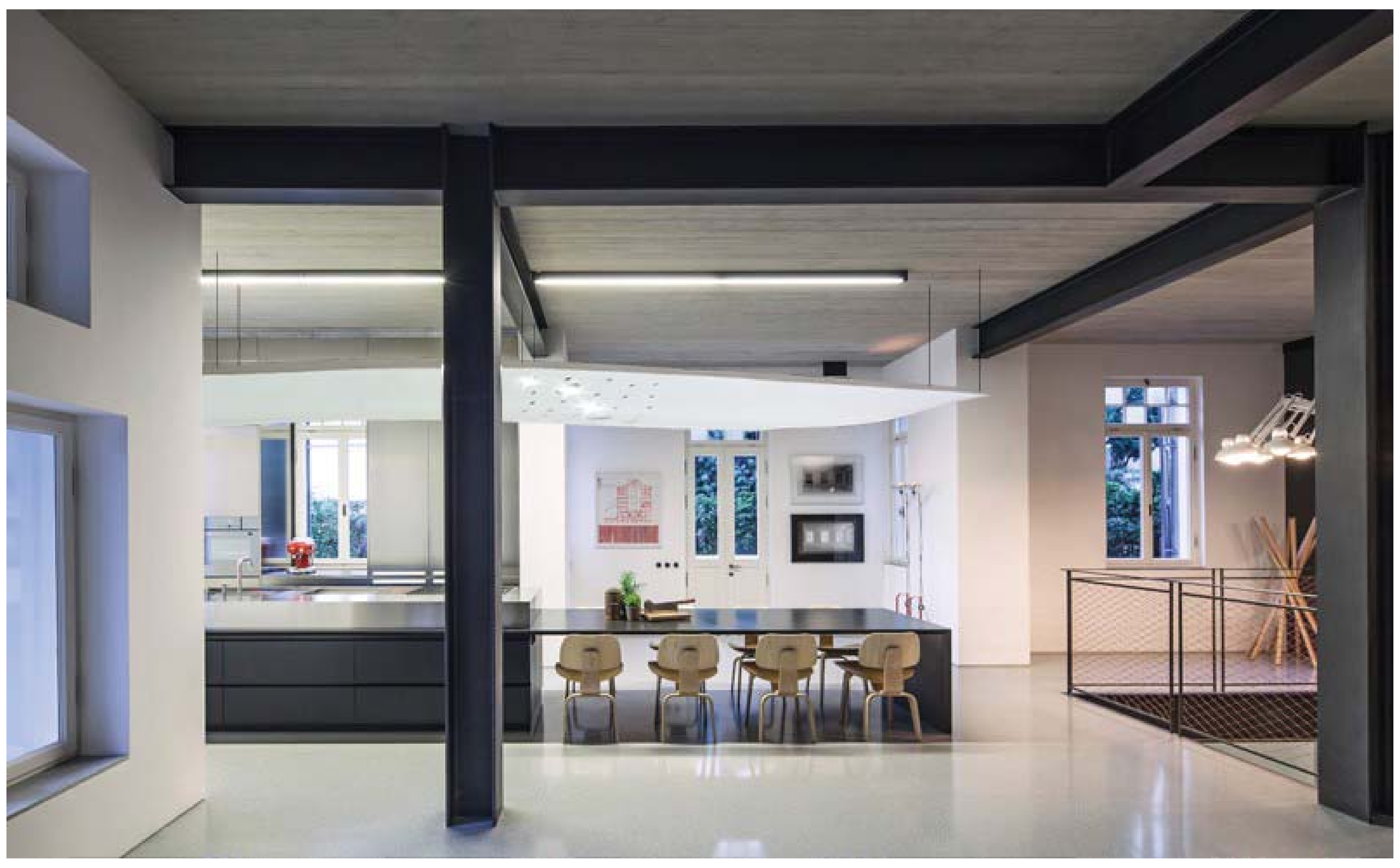
MISC:(WASHERS, WAX, SCREWS, SPACKLE) = $50

TOTAL: $3661| COST PER SQUARE FOOT : 24 SQ-FT = $152

IF USED IN CAFE @ 300 SF X $152 = $45,600

Restaurants

Reception area



Apartment focal ceiling

Boutique ceiling

THIN CASTING RENDERING

FALL 2015 ARCH 5670 BRAD BELL
SIDNEY CARRASCO | ARTURO CHAVEZ | MARZIA KHATUN

CAFE INSTALLATION