

# “The beginning of building coincides with the beginning of textiles.”<sup>2</sup>

- Gottfreid Semper

## Potential in Textiles: Space, Surface and Structure of Crochet

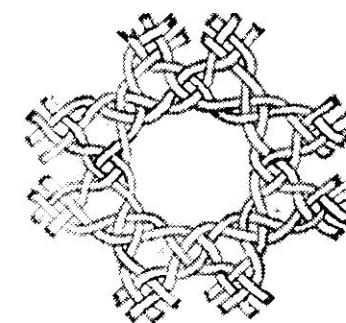
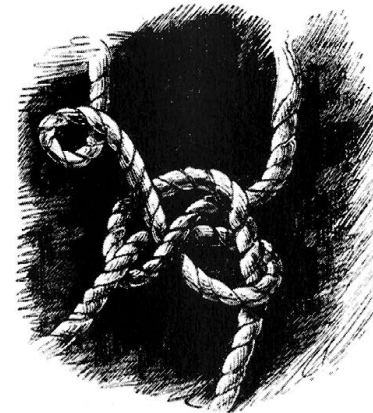
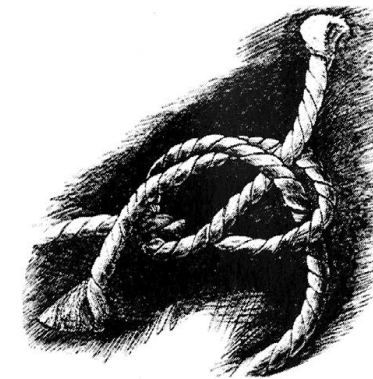
Alex Worden

Excepts from the thesis publication *Emergent  
Explorations: Analog and Digital Scripting*

In *The Four Elements of Architecture*, Gottfried Semper proposed that textiles, or hanging rugs, were the first dividers of space. In its earliest stages, the wall was constructed from branches and plant fibers, woven together into a surface and pulled over inner supports. Though many cultures covered the woven surface with clay or mud, the textile was still the very essence of the wall.

Semper understood the historical use of textiles in defining space, writing, “All operations in the textile arts seek to transform raw materials with the appropriate properties into products, whose common features are great pliancy and considerable absolute strength, sometimes used as pliant surface to cover, to hold, to dress, to enclose, and so forth.” In *The Four Elements of Architecture*, Semper catalogs a number of textile techniques employed to develop, fasten and enclose space: weaving, braiding, pleating. But to Semper, it was the knot that promoted the greatest degree of exploration.

A knot is a means of joining. Its strength is based on both friction and by the method in which the cable was constructed. When pulled, the lateral friction exerts pressure on itself, making the knot stronger when in tension. Sailors and rope makers have developed thousands of different knots tailored for specific purposes. The combination of ropes secured to one another by knots give rise to simple nets, while the knotting techniques of garment making result in beautifully articulated surfaces to cover the human body.



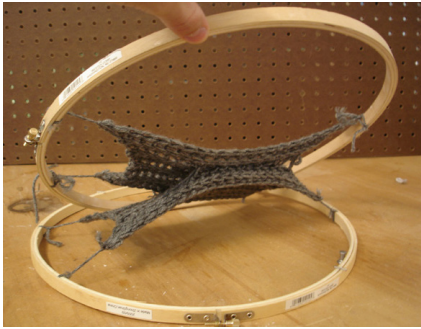
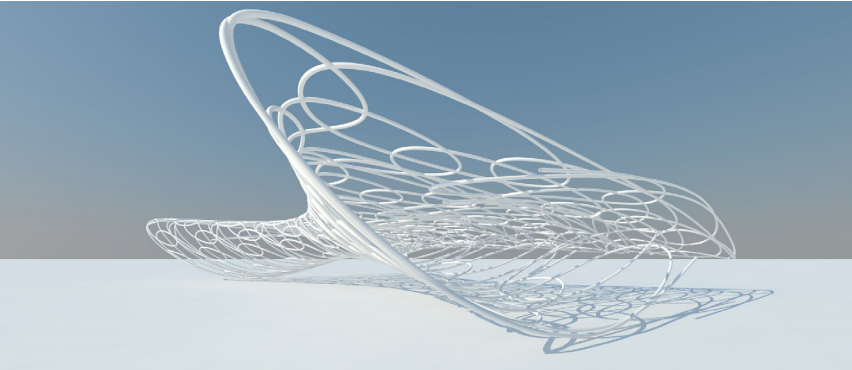
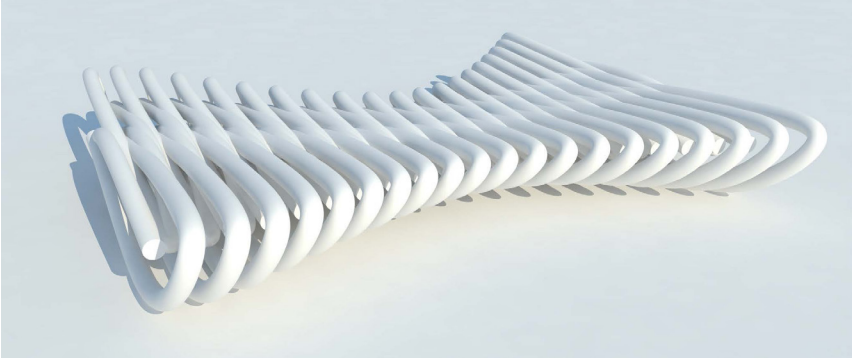
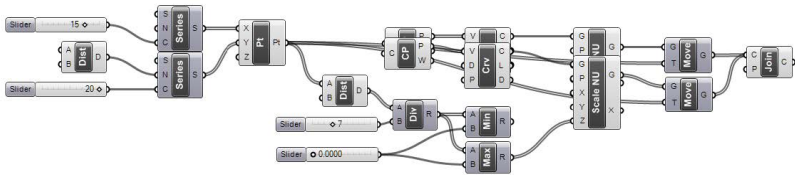
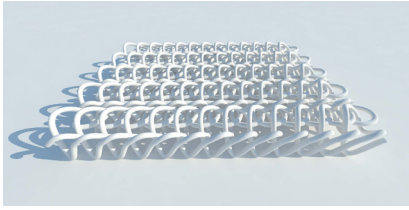
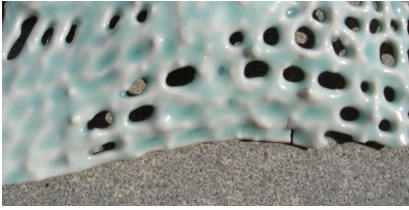




More commonly known as the slipknot, the “loop stitch” is a knot whose loosening can lead to the unraveling of the entire system. Mostly for use in garments, the loop stitch is employed in the textile techniques of knitting and crochet. The technique can be used to create many different articles of clothing from sweaters to delicate lace.

Both knitting and crochet are simple loop techniques that give rise to a great detail of variation, articulation, and ornament. Textile techniques employ a wonderful balance between bottom-up and top-down. Knitting and crocheting require a constant feedback loop of part (stitch) to whole (product). But beyond its commonly known roles, crochet has become a technique used to model complex mathematical models such as hyperbolic geometry (Daina Taimina), the Lorenz manifold (Dr. Hinke Osinka) and the Crochet Pattern Generator (Matt Gilbert). Mathematicians and designers have realized that because of its serial process in fabrication, complex formulas developed with the aid of digital computation can be executed physically in crochet to develop the physical embodiment of mathematical theories.

To learn more about what a technique can achieve, one must begin to play with and explore the technique. Explorations can lead to greater discoveries and otherwise previously unknown insights. Through exploration one begins to realize that the material employed is not defined by the technique. Any material with similar properties to thread can be used in weaving, macramé, braiding, and especially crochet. Crocheting different types and sizes of material gives rise to unexpected results.



Emergent explorations in media lead to questions of application and validity in a programmatic capacity. However, such studies are purposefully qualitative, void of any final goal or outcome. This leads to various experiments in solidifying the crochet system through the addition of hardening agents such as porcelain slip, but also the translation of the physical crochet stitch into the digital model.

The addition and firing of the porcelain crochet model stiffens the crochet threads into a hardened, static geometry. Similarly, by carefully crafting the crochet stitch digitally through the use of NURBS modeling, the digital crochet is a simulacrum of the physical textile. Through the employment of generative modeling tools such as Grasshopper for Rhino, the digital crochet model can be developed parametrically, translating certain qualities of the physical crochet system into the digital model. By adjusting the parameters of the model, one can begin to explore quickly and efficiently. A simple change or adjustment – such as gauge of thread – can completely change the qualities of the model.

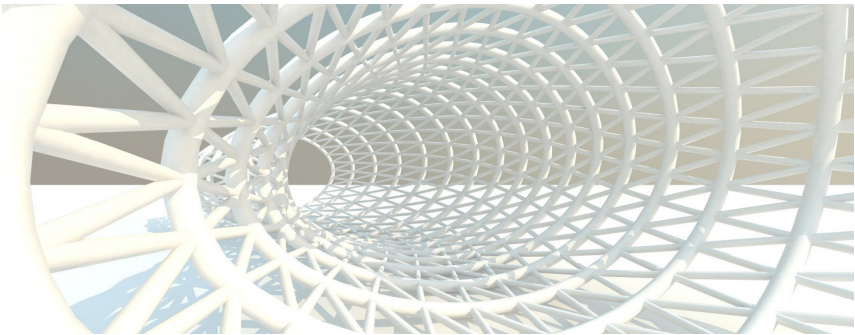
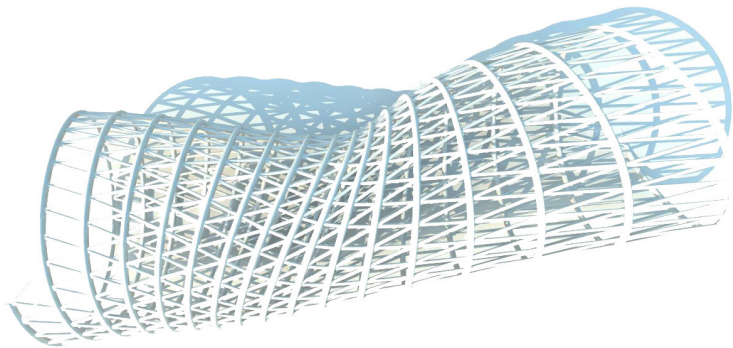
In continuing to explore the ability crochet has to stretch around most any form, a simple wooden cylinder is used in order to see the maximum elasticity of a wool thread tube using a slip stitch. Once the sleeve is stretched over the cylinder, the sleeve is pulled at both ends. This overstretching pulls the crochet to its maximum dimension. The wooden cylinder becomes visible through the openings defined by the crochet. Though the tube is overstretching in its length and diameter, the length of the tube can be also be compressed in discrete sections.

This results in a gradient change in porosity of the openings along the length of the tube. Still overstretching in its diameter, the tube remains affectual; the stitches and thread can renegotiate based on manipulations. When the tube is overstretching in its diameter and length, the process of its construction is clearly visible. A tube is constructed by the use of a single chain that is continually hooked into itself by a slip stitch. The crochet tube’s internal structure is a helix.

When pulled over the wooden cylinder, the tube is overstretching and must reconfigure to maximize its stretching ability. By doing this, the slip stitch is reconfigured into diagonal restraints connecting each revolution of the optimized structure. The experiment clarifies how the looped structure of crochet can reconfigure itself into an easily recognizable structure of diagonal restraints between each helical revolution.

This discovery becomes a critical point in using crochet to execute an architectural idea. A helical structure with diagonal bracing, found within a crochet tube, becomes the base for translating crochet from a textile product into a built structure. In translating the structure of the optimized crochet tube, action, process and method deeply influence the structure. Through a difference in method and execution, this translation exemplifies Semper’s statement that “the beginning of building starts with the beginning of textiles.” Through the explorations in stretching, the crochet model was reconfigured into an optimized structure; a single helical beam with diagonal restraints between each revolution.





This discovery enabled the further exploration of form and space through the use of the analog model. Each crochet model secured into a jig, connecting various portions of model to nodes of the jig, resulting in an analog machine. With these analog machines, one can quickly test the variation of form and space in the physical crochet model. Each model becomes an analog computer where one force begins to affect the whole. Though the analog machine is an optimized tool in defining and visualizing an architectural space, the question of scale and construction come into play. The digital then becomes a realm for exploration where the computer aids in the process of visualization, fabrication and testing.

The digital model of the crochet tube is developed through the use of NURBS modeling in Rhino and the generative modeling tool, Grasshopper. In Grasshopper the helical path, formed by the crochet path, is constructed digitally by the series of relationships defined within the mathematical formula for a helix.

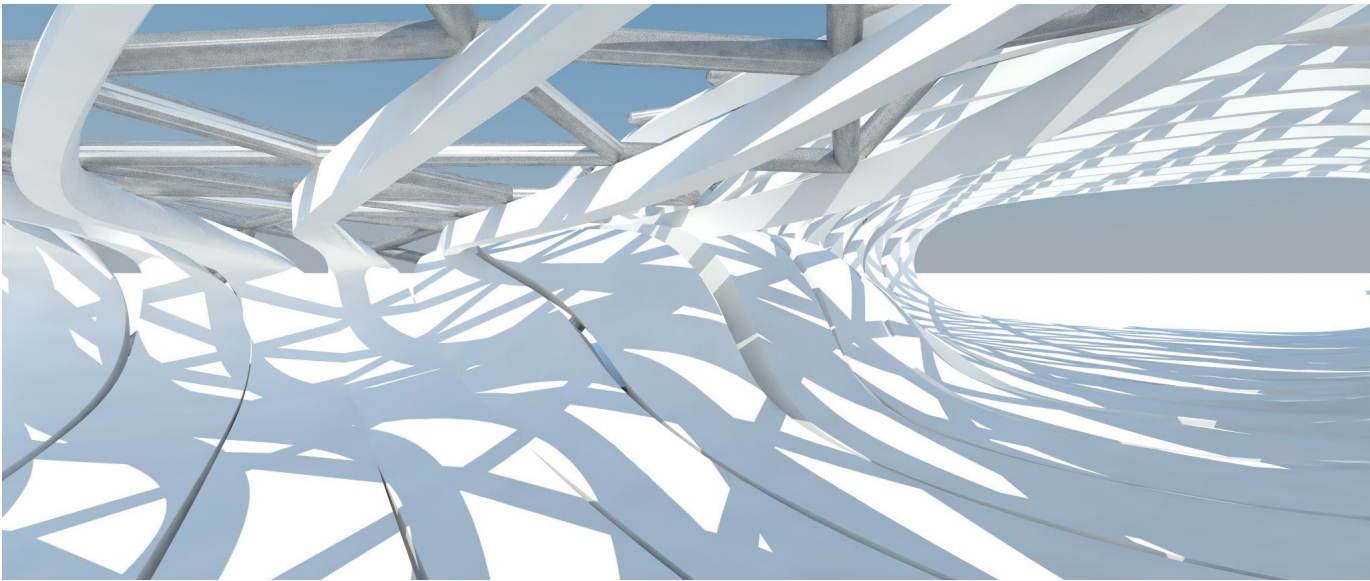
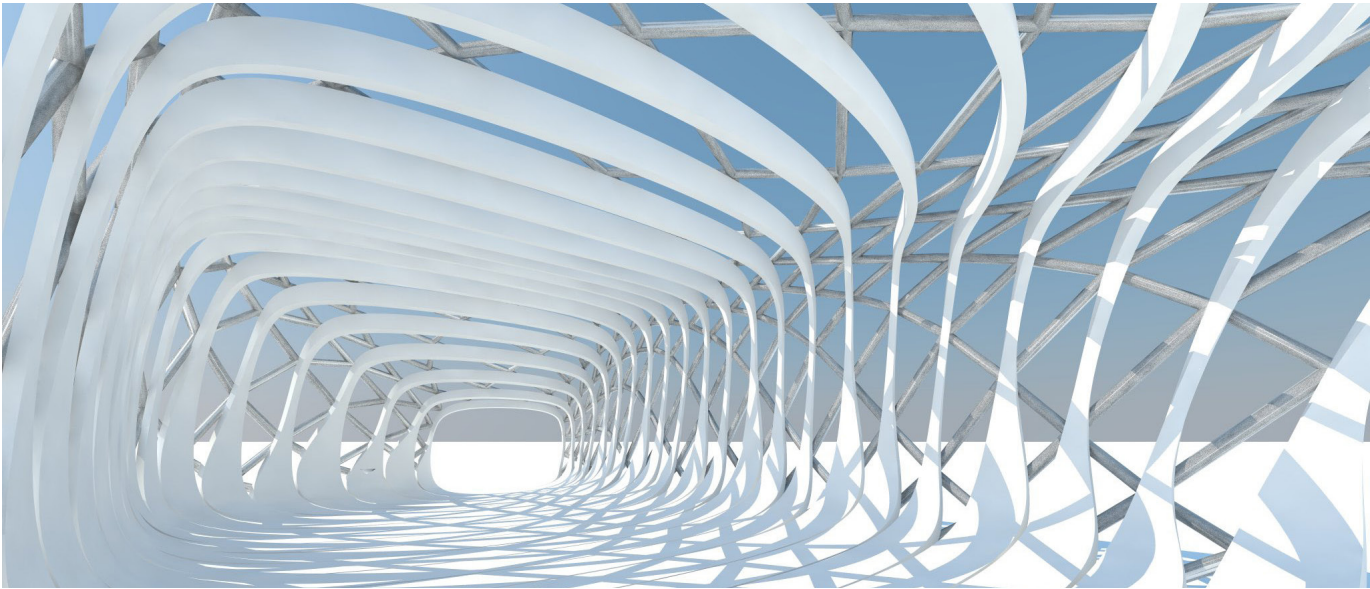
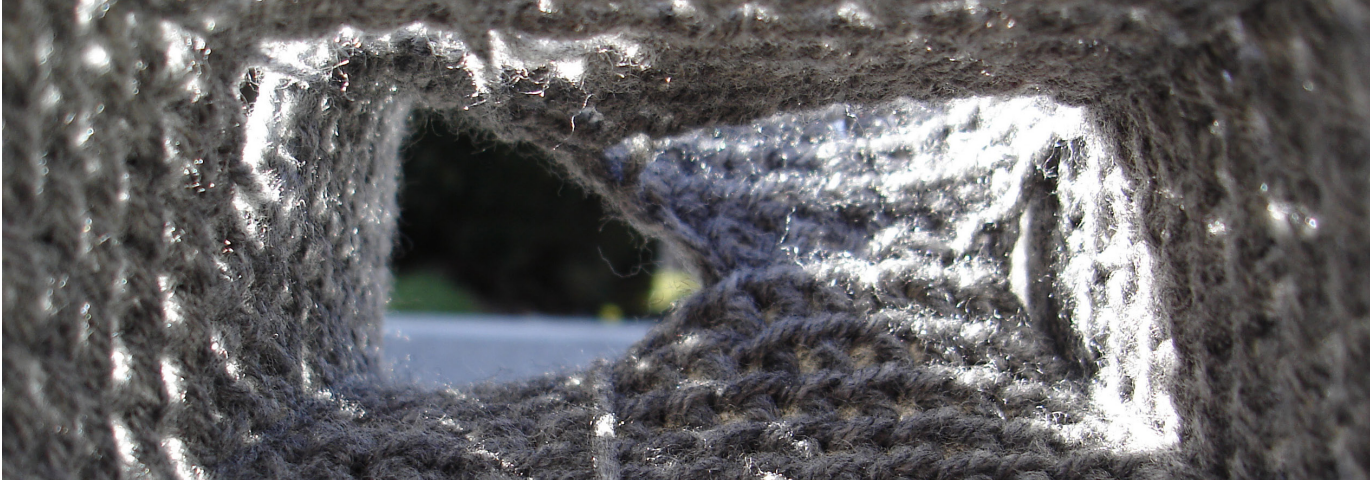
Once it is defined parametrically, the next step in reconstructing the analog tube structure is to connect each revolution of the helix with triangular bracing. This can be done manually by drafting the bracing between each helical revolution. However, if the helix is altered in any way, the bracing will have to be rebuilt. To eliminate the redundancy of reconstruction, the bracing is defined by a set of relationships within Grasshopper.

Grasshopper enables the mapping of the helix and bracing to a target surface. This allows for the manipulation of the target surface, which results in the corresponding deformation of the helically braced structure. The map to surface component takes the relationship of the base curve to the base surface and applies it to the mapped surface. The result is a curve that is modified based on the mapped surface. Any alterations to the mapped surface directly affects the resulting curve. This eliminates reconstruction of the bracing when the helical curve is altered.

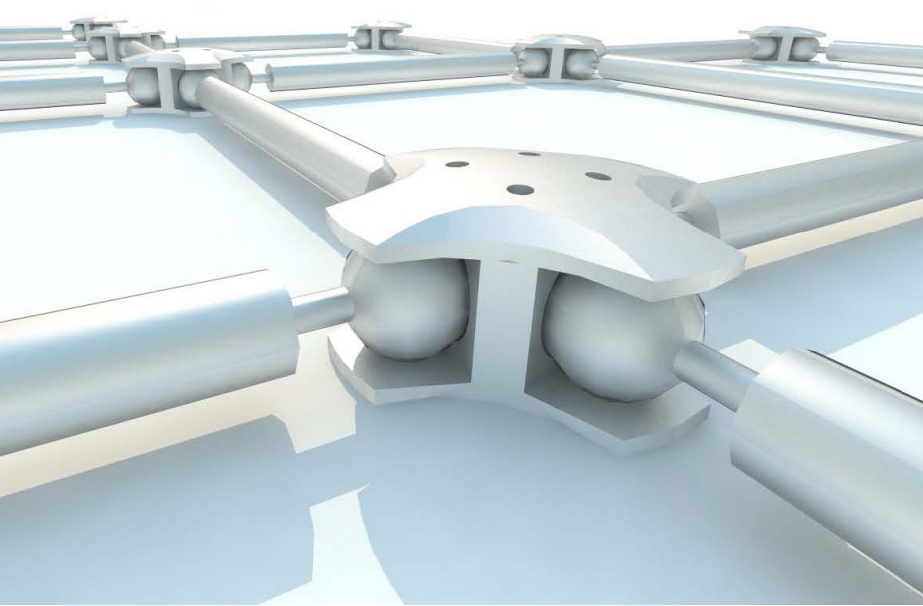
The successful completion and translation of the analog to digital model results in a digital

surface. Though only the form of the crochet model is translated, the articulation occurs when the Grasshopper definition is applied to the digital surface. This digital model becomes a way to fully explore the design by refining and executing the concept. The analog model is the generator of form. The definition of an analog model is indicative of its form, structure, and its articulation of each loop. The digital model, reconstructed through the use of photography and digitized points, is not the same, but rather a translation of the analog crochet. The digital becomes a tool for visualization, exploration and fabrication.

Visualization is one of the digital model's greatest tools. It enables the objective and critical observation of space and structure. After the digital reconstruction of the analog crochet model, questions arise regarding the realistic usability of the structure. The entire structure is porous and open. In its current state, the structure is not occupiable as there is no surface to walk. This is mediated through the employment of digital tools. The helix is deformed, resulting in a surface that is walkable.



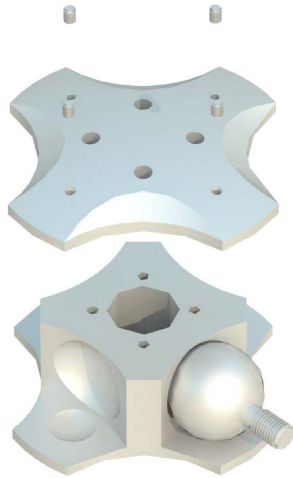




The use of prototyping and digital design through modeling can be used to illustrate relationships and aid in design decisions. A model cannot represent all details and features of the original. Models can only contain the specific features that are deemed relevant for an evaluation or test. By reducing the model to select features, this abstraction can make it easier to gain information. The selection of the represented features is important in its evaluation as their selection can lead to unforeseen opportunities. In fabricating the digital model, desired features can be determined by the method of rapid prototyping. Each prototyping technique will yield a different result and begin to influence the overall design of the digital model. The method of fabrication will define or omit details. By working with these technologies, rapid prototyping machines can lead to decisions in the overall execution of the design.

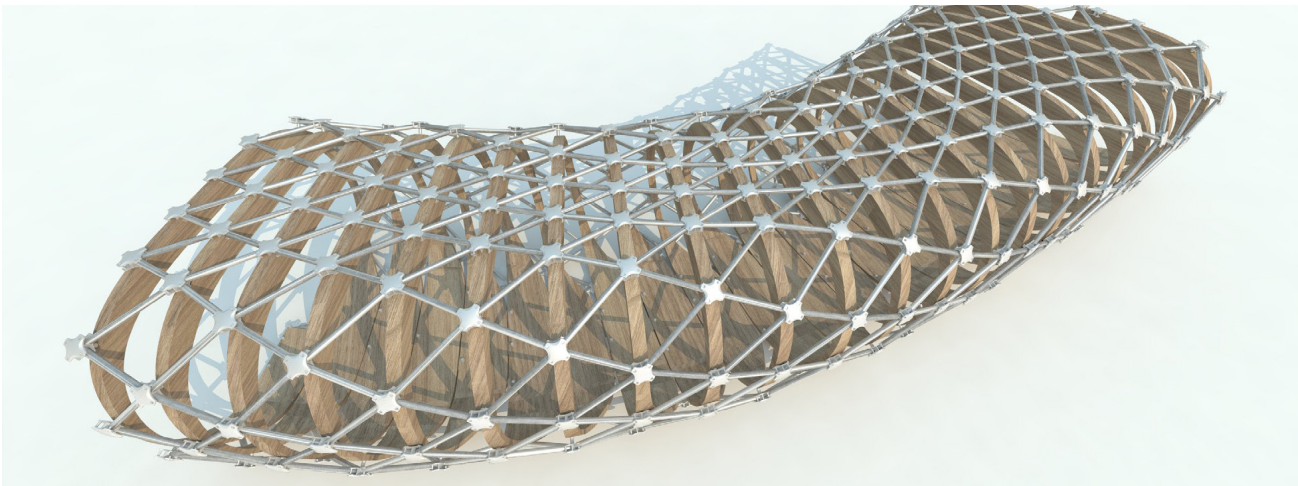


In the fabrication of the digital model through rapid prototyping, the method used directly influences the design. In fabrication, the digital never operates independently from actual reality. The dialog between the two must be constant to achieve a refined result. The testing of a design concept follows the same rules as rapid prototyping. The methods of fabrication, engineering, construction, and standardization of materials all inform the outcome.



Modeling and testing the design of the bracing system is crucial to the integrity of the structure. Though the helical beam is self supporting, the bracing aids in the stability of the system. In order to construct and fabricate these connections, it is important to identify the role that these bracing members play and how the system can be successful in its role. In the scaled physical model, simple nodes are used to connect the bracing members between the helical revolutions. There is no need to design a customized node for each discrete connection so long as the bracing member has a range of motion.

Instead of defining a static geometry that is specific for each individual connection along



the helical path, the connection allows for the bracing to adjust based on its end points between each revolution. By doing this, the standardization of the connection piece becomes an effective solution where the only customization occurs in the length of each bracing membrane. This length can be calculated through the use of digital software and then manufactured to its specific length. Unlike the analog crochet model, emergence doesn't occur within the construction process, it occurs within the connection of the bracing members. The connection configures within the designed range of motion just as its analog crochet counterpart.

The first iteration of the connection node is designed to use simple "i"-bolts to secure the bracing members. Though the "i"-bolts enable the range of motion required for the bracing, these connections can only work if the whole system is in tension.

The second iteration of the bracing connection is constructed of a ball joint. Each bracing member has a ball located at the ends, the ball fits within the connection node secured to the helical beam. This connection is loose, however, and within each node the ball joint can be tightened to result in a static and solid bracing connection. By designing the node with the ball joint connection, it allows for each bracing member within the system to have

a wide range of motion. This removes the requirement for a custom connection along the helix and results in a highly efficient and effective structure. In addition to the bracing connection, each member works towards stiffening the structure. This is achieved by using pneumatic bracing members. Each member can be designed to be in tension or compression by the addition or subtraction of compressed argon. In certain segments of the structure, it is important that the bracing members be in tension and others in compression to achieve the designed result.

The helical beam, connection nodes, and the pneumatic bracing members work in unison to create a beautiful structure that can be applied to a variety of forms without mass customization. The diagonal restraints of the crochet tube have been translated into an engineered system that is a crucial component to the overall structure.

This structure, though influenced by crochet, is an abstraction. The analog crochet model is the medium to generate form, and is then translated into a static structure. This abstraction is born out of a necessity to use the analog model and digital tools to conceive and fabricate a physical structure through the use of current construction technologies. The future development of materials, techniques and technologies could remove the necessity for abstraction.

REFERENCES

[1-5] Gottfried, Semper. "The Four Elements of Architecture." New York: Cambridge University Press, 1989. 215 & 245.

This publication can be read in its entirety at <http://www.lulu.com/spotlight/alexworden>

