“数字渗透”与“参数化主义”

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Digital Infiltration & Parametricism
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黄蔚欣　刘延川　徐卫国　主编
Weixin HUANG　Yanchuan LIU　Weiguo XU

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Knot Making

Zhiwei Liao|廖智威
Richard Meier & Partners Architects LLP, USA
zwliao@gmail.com

Abstract: This paper seeks to explore digital fabrication by addressing the disparity between computational form and physical realization. The proposition of fabricating a knot is explored at three scales: fabric, hand-held and room-sized. Each scale uses a distinct material and fabrication method. It also explores the notion of parametric material, which adds potential that overcomes material limitation and improves assembly precision, in particular for the room/sized knot.
Keywords: Digital fabrication; knot (mathematics); parametric material

建结

摘　要：本文尝试探讨数字建造中数字模型和物理现实之间的差异。在大、中、小三种尺度的实验中，分别运用了独特的材料和方法来进行结的建造。这组实验同时也提出了参数化材料概念，探讨如何在大型结的建造中克服材料局限性和提高组装精确性。
关键词：数字化建造；结；参数化材料

Introduction

The emerging techniques for digital modeling, programming and fabrication ease the process from data to artifact and vice versa. Today, the robotic arms and 3D printers are programmed to build things and to replace human hands to create its mechanized *stereotomics* forms, whereas CNC machines incorporate new scripting software enhance the potential of the *tectonics* assemblies. Paralleling these macroscopic possibilities, it is essential to investigate the fabrication process by microscopic thinking. This paper seeks to explore in this regard building material within the digital fabrication realm.

Inspired by Erwin Hauer`s elegant screen wall built in the 1950s (figure 1), the experiment proposed the design and fabrication of three different scales of knot. The knot is defined as a closed, non-self-intersecting curve which is embedded in three dimensions and cannot be untangled to produce a simple loop. [1]

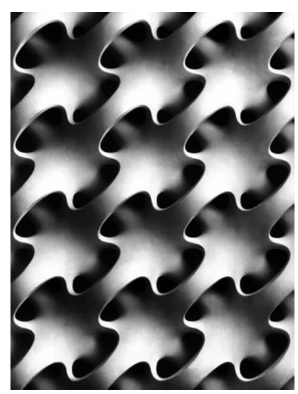

Figure 1　Screen wall by Erwin Hauer

The digital model of the knot as an exquisite virtual entity offers no resistance, while fabricating the knot using physical

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material reveals numerous forms of resistance. To bring this digital form into the physical realm, and still maintain its intrinsic character-a three-dimensional entity without beginning or end-challenges the fabrication methods. The 3D printer translates the digital data into a physical entity, whereas the handmade wooden knot is composed by blocks with inevitable joints (figure 2).

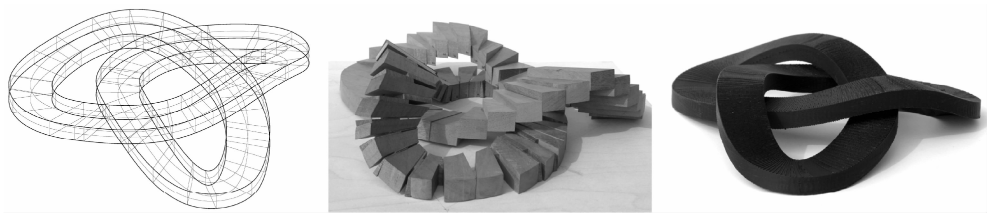

Figure 2 Digital model, wooden model and 3D print knot

Knot prototyping

3D prototype and the handcrafted model demonstrate the disparities between the two fabrication techniques. The fabric project and the hand-held knot are developed in order to discover a fabrication method to precisely present the topological form generated in digital realm.

Fabric

As the 3D printed prototype could be transformed precisely from computational data to physical entity, the fabric project is to further present the topological concept, in other words, the knots are "untangled" and "woven" completely in digital space. The 8 inches by 8 inches 3D printed fabric is consisted of 60 unitized interlocking knots, which are unlikely achievable in the physical realm. The pure 3D-print has more to do with the knot concept but is less relevant to material reality because it is not associated with the real world. (Figure 3)

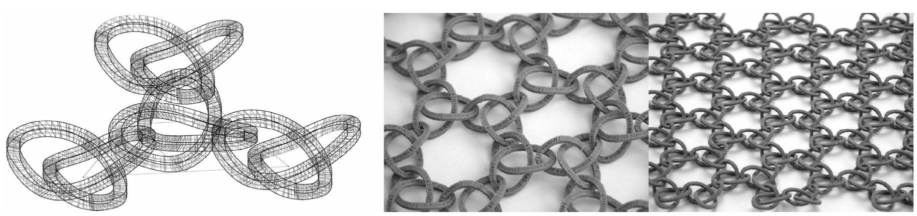

Figure 3 Fabric, physical model, digital model and 3D printed model

Assembly

Since the fabric project is limited in scale in material reality, the material of the hand-held knot experiment is determined to be plaster. As the physical knot has only three points touching a supporting flat surface, most parts are supported by the arch-like shape. Hence, the plaster elements should be designed to address those structural concerns. The scale determines the thickness of the knot which should be lightweight yet strong enough to span and retain its shape. The symmetrical form divides the knot into 6 typical parts which are reproduced by a 3D printed mold. They are connected by six stainless steel fasteners made by wire EDM (Electrical discharge machine), providing the required precision.

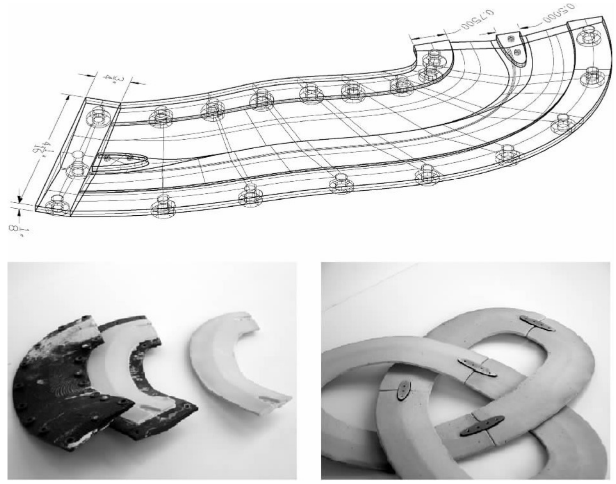

Figure 4 Digital model of the mold, 3d printed mold with the casted component, stainless steel fasteners and the Assembly knot

As precision reduces during the casting process, the 3D printed mold is designed digitally in order to maintain certain tolerance. For the purpose of assembling and striping, the mold is composed of two parts with flanges with 19 holes for bolts. Considering the liquidity of the plaster, openings have to be horizontal. A recess accommodates the metal connector which clamps two parts together. While this assembled knot has more to do with the material reality of plaster, the idea of the knot is compromised.

Digital Stereotomics

The room-sized knot is made of concrete. The formwork parts are fabricated precisely to conjoin. The patterns for the sides and bottom of the form-work are extracted digitally from the rationalized knot geometry. The manufactured plywood material is cut, bent and clamped in order to conform to the required shape.

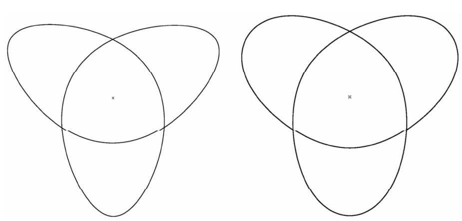

Figure 5 Knot Geometry rationalized process

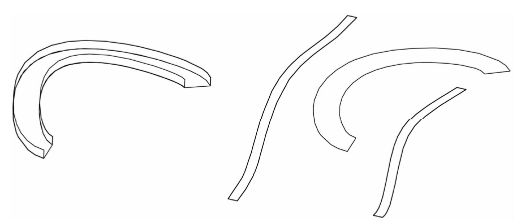

Figure 6 Unfolding surface diagram

The specific modification to the plywood shifts its characteristic and enhances its pliability. Beyond its physical limits, common plywood resists deformation and will bend or tear. Hence, the intentional introduction of discontinuity, the kerfs, into the smoothly continuous 3/4 inch plywoods surface alleviated the material's resistance to the required curvatures. The kerfs used to assist in shaping the plywood are translated from computer-generated sub-divisional lines based on the required curved surface. As a result, the notched plywood becomes flexible, yet remains strong enough to support the considerable weight and fluid pressure of the concrete mixture. The concrete, cast in one pour, eliminates the joint to represent the poetry of the primitive math-defined knot.

Figure 7 Bottom of final formwork, looking to obverse

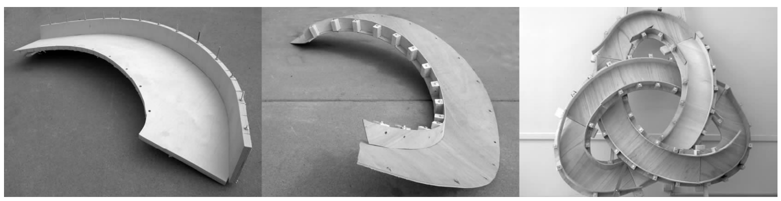

Figure 8 Formwork mockup 1, 2& 3

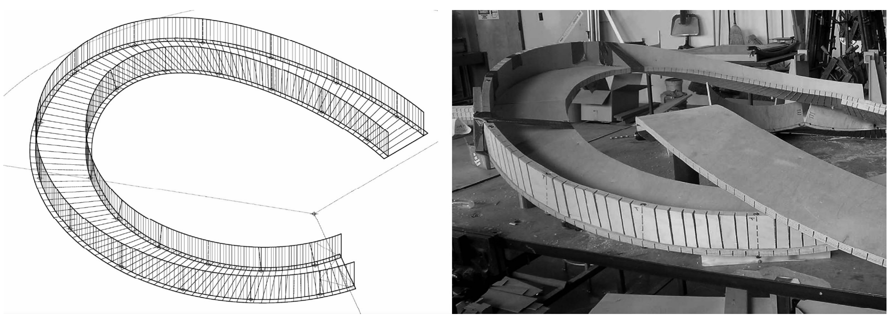

Figure 9 Digital Model and final formwork in progress

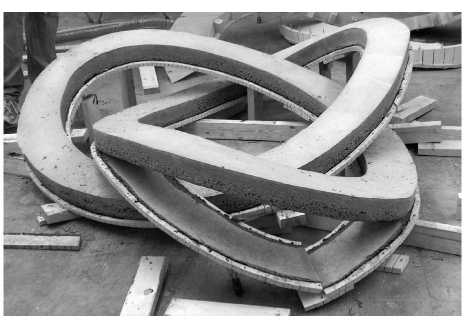

Figure 10 Formwork striping

Figure 11 Concrete knot

Conclusion

This paper seeks to describe the fabrication process of making the knot and rethink digital design and physical fabrication. The exploration investigates the material characteristics and constructability associated with the curve form and the object scale, which include:

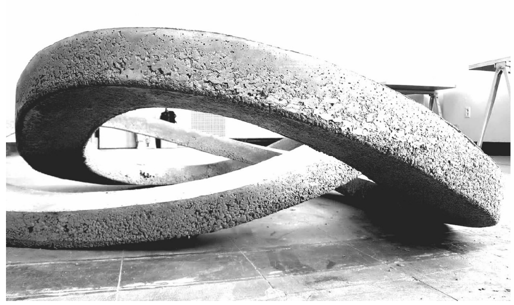

Figure 12 Concrete knot

- The configuration of 3D printed entity was transformed from rigid form to fabric.
- The assembled knot is achieved by the precision of 3d printed mold, the components casted in plaster and the stainless steel fasteners.
- Through evaluating the formwork mockups, the decision of selecting the material is driven not by the original material's pliability, but customized potential.

The fabrication of the curve surface further addresses the notion of parametric material in a microscopic scale, changing the conventional material to customized material, e. g. , parameter such as location, pattern density and depth of the kerfs on the formwork panels are generated and manipulated parametrically, then evaluated and exported to a CNC milling machine to cut the sheet material. Theoretically CNC cut material with parametric enhanced value will contain both an extrinsic profile for joining and an intrinsic feature for bending. As the bending resistance being released, the plywood turns into a fabric-like material. Hence, the performative characteristic of the material are precisely transformed to meet the particular fabrication need.

Figure 13 Concrete knot

References

Hauer, E 2004, *Erwin Hauer: continua-architectural screen and walls*, Princeton Architectural Press, New York.

Kolarevic, B (ed) 2003 *Architecture in the digital age: design and manufacturing*, Spon Press, New York.

Mitchell, WJ and McCullough, M 1995 *Digital design media*, Van Nostrand Reinhold, New York.

Shelden, DR 2002 *Digital Surface Representation and the Constructibility of Gehry's Architecture*, Massachusetts Institute of Technology, Department of Architecture, Boston.

[1] http://mathworld.wolfram.com/Knot.html.