Amorphous Stacks: A Low-tech Construction Method for Jointless Cast Structure

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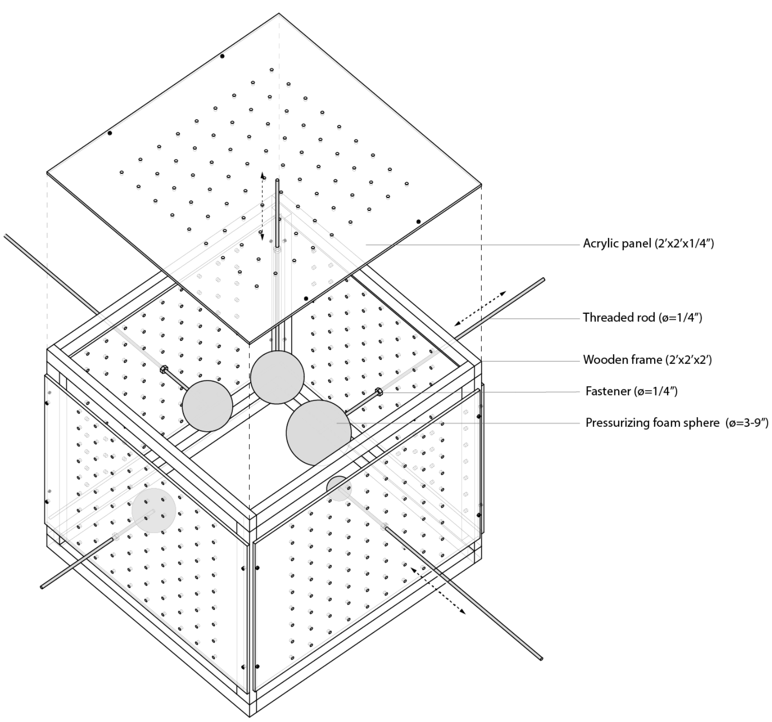
INTRODUCTION

A significant amount of research were done after Philibert de l'Orme's theory on stereotomy (stonemasonry) in the 16th century to reinterpret the masonry tradition by means of innovative materials and advanced technology. A few of the most recent advanced technology include digital and robotic fabrication methods adopted in the project *Cyclopean Cannibalism,* led by Brandon Clifford and Wes McGee (2017), and The *Sean Collier Memorial* designed by Höweler + Yoon (2015). However, although these projects suggest the great potential of technology and digital computation in contemporary masonry construction, they inevitably traded in the traditional value of craftsmanship. How can we rethink the value of making to challenge mass production and high-tech oriented construction in contemporary architecture? Utilizing the liquid-cast material's fluid property, this paper explores a low-tech and hand-crafted fabrication method that returns to the value of craftsmanship and suggests the opportunities in fabrication to challenge accessible means of construction.

FLUID-CAST MASONRY CONSTRUCTION

The fabrication method explores creating a new dry-stacked system of an interlocking family of distinct amorphous units cast in a fluid material. It uses surface geometry of stacking units manipulated by a flexible scaffold system to create a self-supported stacking structure without mortar, such as cement and metal components. This method adopted wet casting as the primary fabrication technique and used plaster as the casting material. Latex balloons were used as flexible molds to hold a controlled mass of the liquid plaster, which was manipulated by external forces generated by a pressure-driven scaffold system (Figure 1) to create organic forms with concave and convex surfaces. The plasticity of the fluid



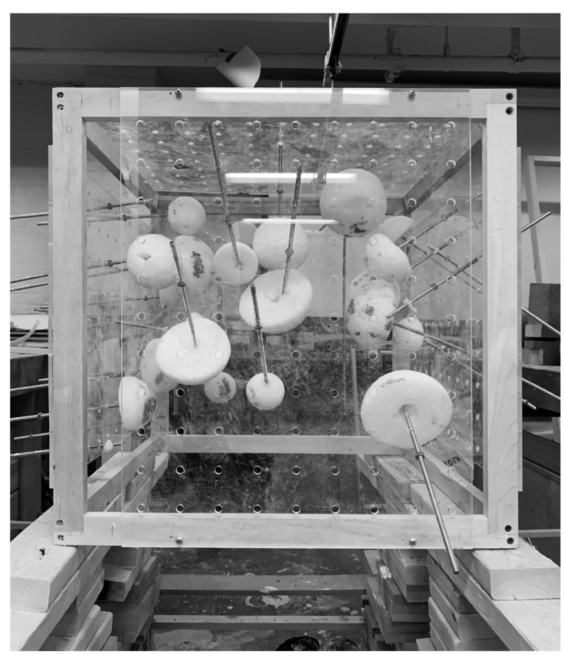


Figure 1. Pressure-driven scaffold system.

Figure 2. Prototype of the 6 feet vertical column.

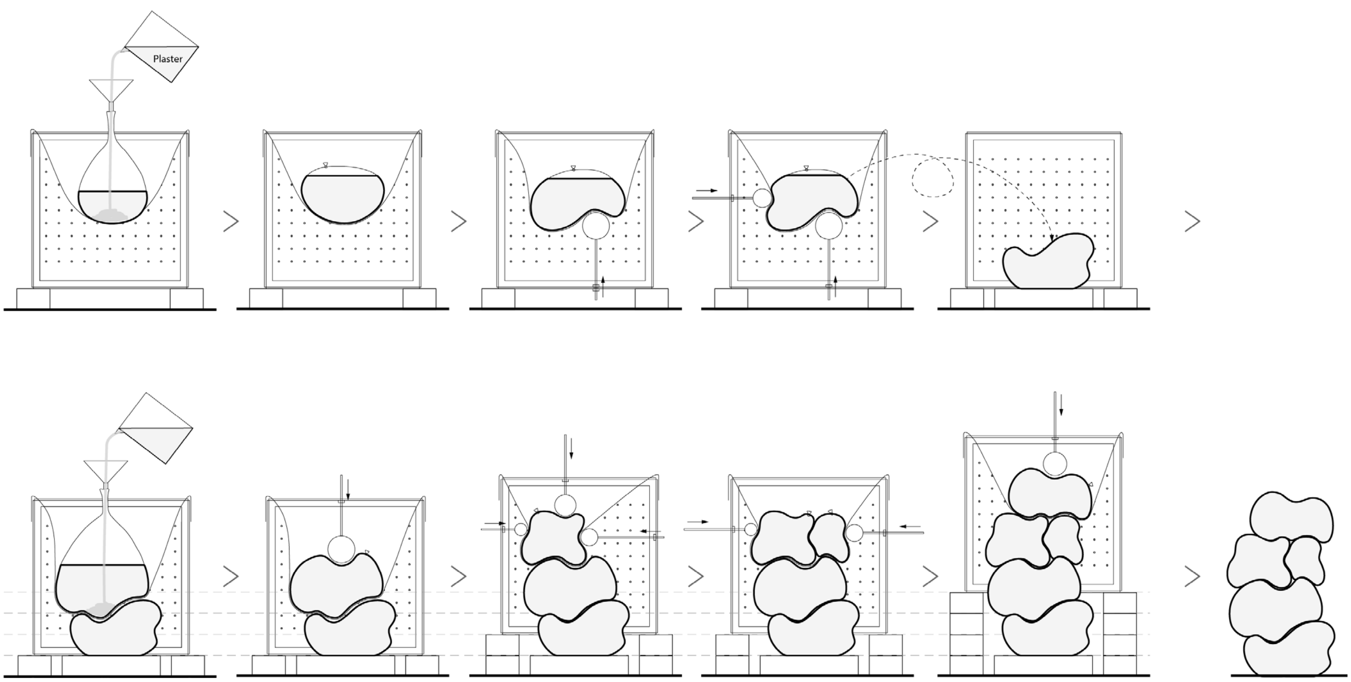


Figure 3. Fabrication sequence of stacking units.

material, in this case, plaster, facilitates the primary subject of this study. The casting material's transitional phase between liquid and solid allows the manipulation of its volumetric geometry. Its fluid nature implies a self-activated form-finding process that responds to the surroundings, during which the materials "actively seek the shape of their own stability in the gravitational field" and arrive at the final geometry in a kinetic way, engaging in "a kind of formal self-invention in real time"[1]. The formwork also utilized a heavy-duty sheet as a temporary fabric support to prevent collapsing in the course of construction (Figure 3). Between the amorphous units, the seamless fitting of concave and convex surfaces behaved as joinery that interlocked the individual units together. In other words, a concave surface on the previous unit would yield a convex surface on the succeeding one, and vice versa. Consequently, the surface curvature degree serves as a determining factor in forming a stable structure: the larger degree of the surface curvatures, the stronger the anchoring function they perform; and the weight of the upper unit helps to stabilize the structure when the curvature is insufficient to achieve static equilibrium (Figure 4). With this incremental process, each unique stacking unit became a part of the scaffolding system for the next one, providing sufficient friction for structural stability.

FOUR ARCHETYPAL STRUCTURES

The architectural applicability of this fabrication method was tested through prototyping four archetypal structures: a vertical column, inclined columns, an inclined wall, and finally, an inclined curved wall. The study first investigated a 6 feet stacked column (Figure 2) to examine the application of the new method. The global static equilibrium was achieved when the final keystone was set in place. Finding the global equilibrium was one of trial and error, a course that relied on empirical studies without structural calculation. The study then examined one-foot tall column structures at two different inclining angles: one at 20 degrees (Figure 5) and the other at 45 degrees (Figure 6), and a half-foot tall inclining wall structure at 30 degrees. In these inclined structures, small knobs were added to the scaffolding frames to prevent blocks from sliding and rotating. The three structures maintained a static equilibrium after all blocks were cast and the fabric removed. The study proceeded to fabricate a larger scale prototype in a highly complex geometry of an inclined curved wall to address problems when facing large-scale construction. The prototype was constructed by a 3'x1.5'x3' scaffold and consisted of 114 stacking units of 1/2'x1/4'x1/4' block, with a 20 degrees of inclination (Figure 8). The structure successfully hold itself up; however, it collapsed after the supporting fabric was removed, due to the disproportionate relation between the total unit count and the scale of the structure. Another contributor was the deformation of the fabric caused by the increasing weight of the structure during the course of fabrication.

The prototype testing results prove the validity and applicability of this innovative fabrication technique and suggest its potential in constructing a structure of greater complexity. During the prototyping process, several variables emerge to be crucial for the effectiveness of the construction: the surface curvatures of the concave and the convex, the inclination degree, the relationship between the total number of

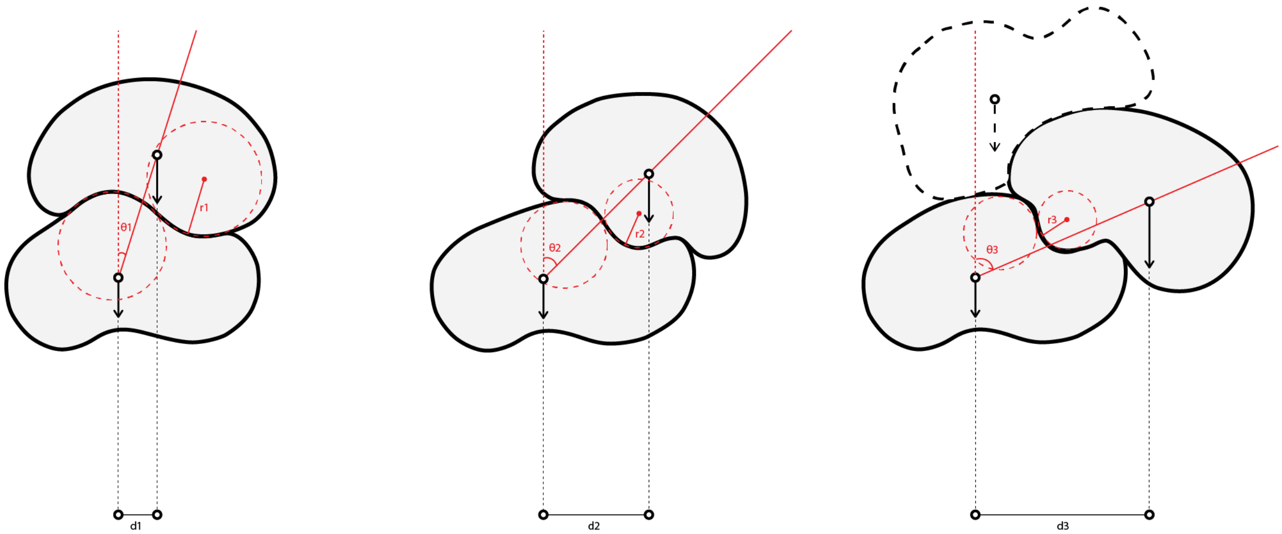


Figure 4. Interlocked convex and concave surfaces as joinery (d1<d2<d3, θ1<θ2< θ3, r1>r2>r3).

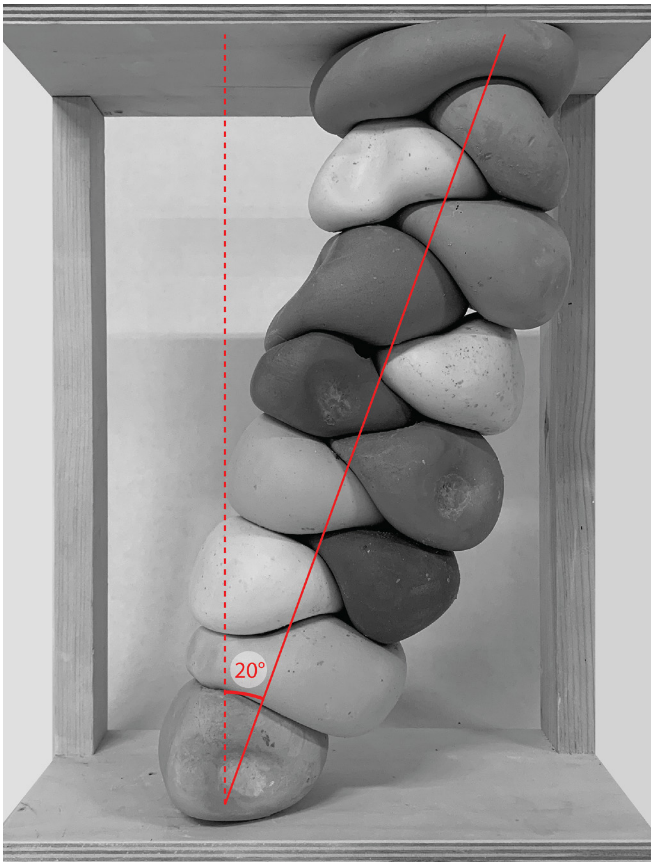


Figure 5. Prototype of the inclined column structure at 20°.

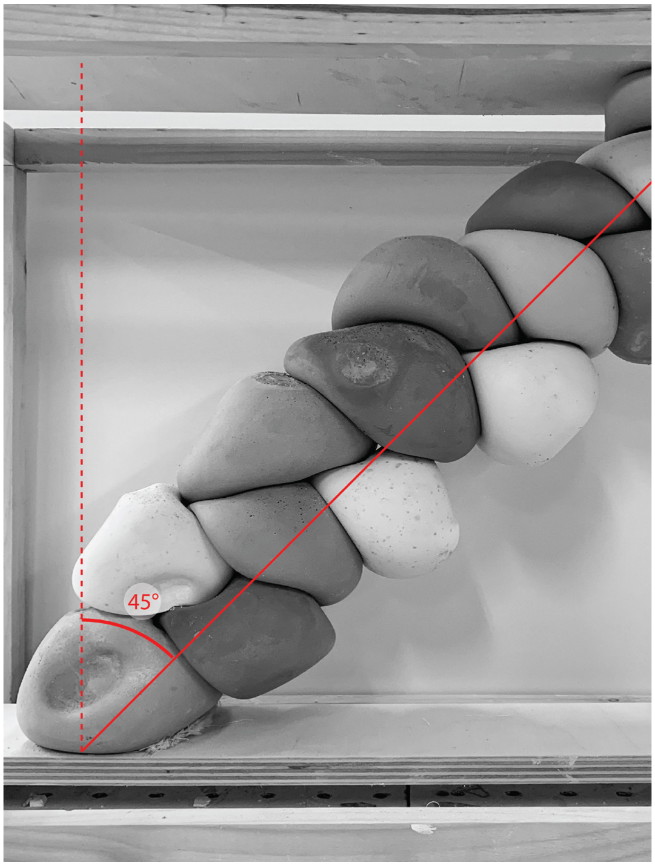


Figure 6. Prototype of the inclined column structure at 45°.

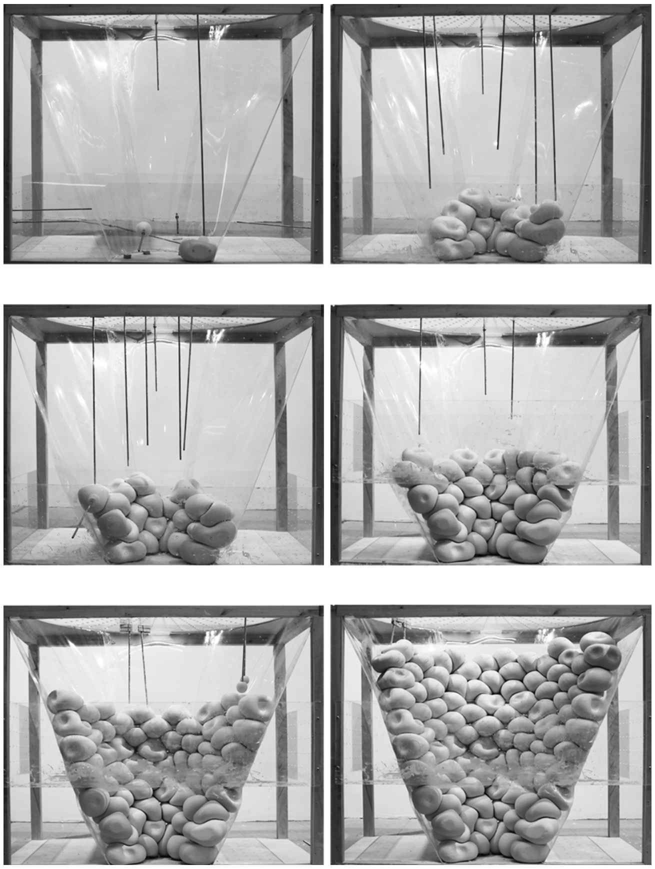


Figure 7. Stacking process of the inclined curved wall structure.

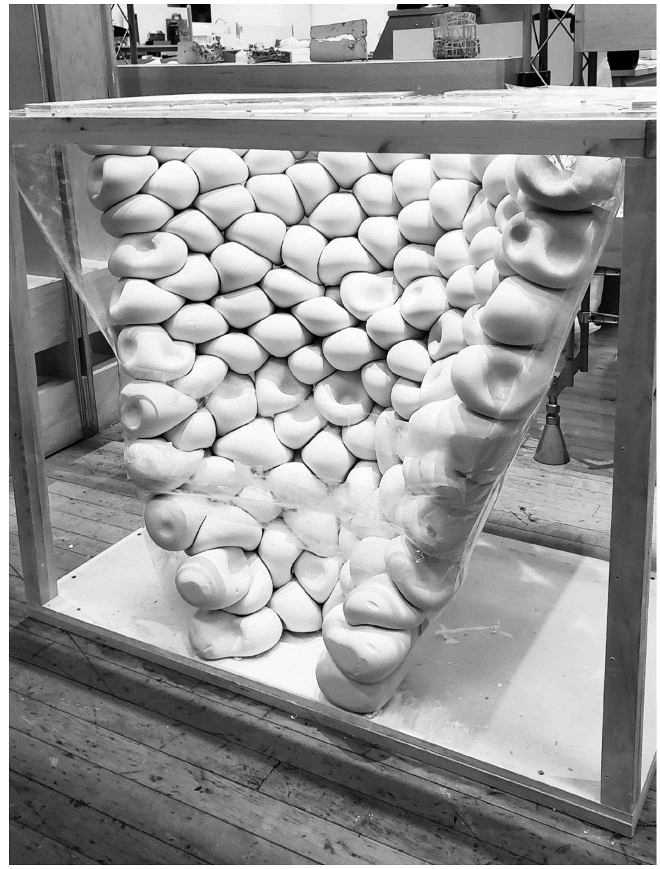


Figure 8. Prototype of the inclined curved wall structure at 20°.

units within each self-standing structure, and the structural capacity of the scaffold system when facing the challenge of large scale construction. A conjecture can be drawn from the testing result of the four archetypal structures that there exists a right domain of ratio between the structure's total volume and its unit count for the practicability of the construction method.

CONCLUSION

The design and the prototype examination of this fluid-cast and pressure-driven fabrication method rethink the potential of liquid-casting materials and the curing process in constructing organic forms and structure. Its low-tech and crafts-based attributes inform itself of a non-standardized and self-explanatory construction method that could be adopted in areas of limited resources, technology, and skilled-builders. The widely accessible casting materials, including concrete and plaster, allow users to build structures in places with difficulties in transportation, such as high mountains or remote islands. The DIY aspect of this technique blurred the boundary between users and builders by lowering the prerequisites and skill demands. With the support of computational parametricism and algorithms, the hand-built approach gradually abolishes in favor of robotic arms. By utilizing the virtue of the fluid material, the flexibility and plasticity of this fabrication method challenge the standardization of mass production and the prescriptive design, offering greater freedom of creation and accessibility. This exploration presents an alternative approach to masonry construction, inheriting the legacy of past knowledge to imbue the making tradition with greater accessibility.

ENDNOTES

1. Mark West, *The Fabric Formwork Book: Methods for Building New Architectural and Structural Forms in Concrete* (Oxon and New York: Routledge, 2017), 6.

Figure 9. Detail images of the 6-feet tall vertical column.

Figure 10. Interior of the inclined curved wall structure.