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EndlessColumns

Variable 3D-Printed Ceramic Molds for Cast Architectural Elements

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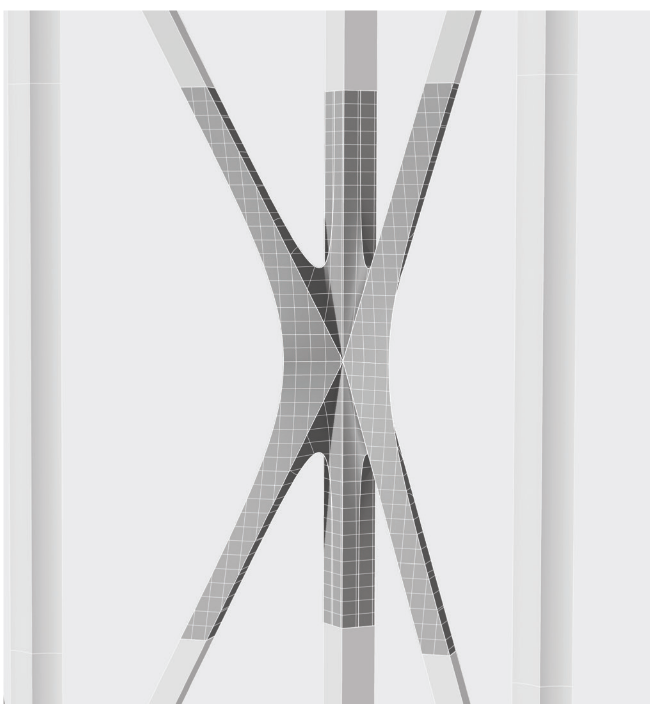
1 Lattice system cast from 3D-printed ceramic molds (Authors 2018).

Abstract
This ongoing project examines the potential to utilize 3D-printed ceramic technologies to produce variable, positive-less molds for the production of architectural elements in cast metal. The research addresses the formal limits and fidelity issues of gel extrusion; computationally assesses the variable infidelities involved in the drying, vitrification, and casting process; and assesses the technical limits of cold-mold, gravity-cast metal. The examples produced show the potential for this process to realize architecture which simultaneously achieves both structural gracility and ornamental complexity efficiently and with a constrained capacity for serial variability.

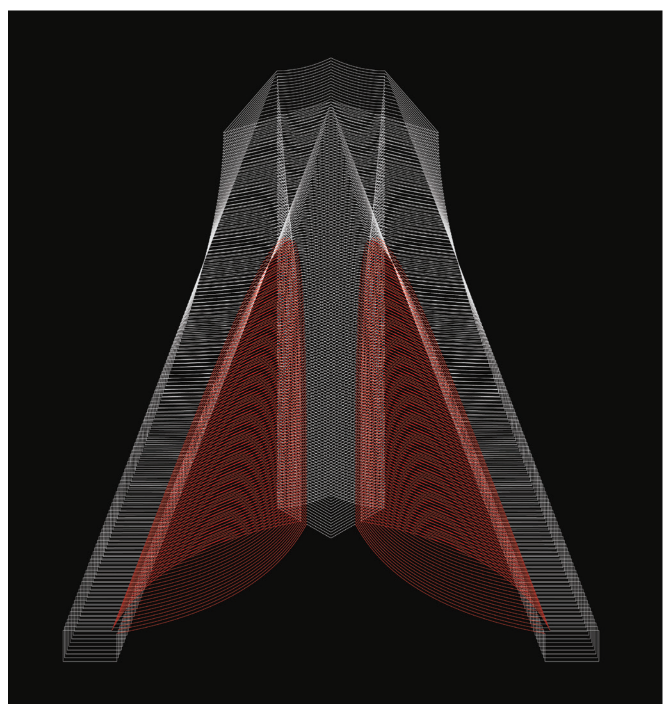
History
Ceramic molds have been used for the past 5700 years for the production of bespoke metal objects. Though capable of achieving both scale and accuracy, traditional slip-painted, "lost wax" methods of ceramic shell casting are unsuitable for the mass production of architectural elements because of the time and materials involved in destructed positive mold production. In comparison, cast metal elements were employed in many exquisite architectural works during the Art Nouveau and Neo-Gothic periods. These larger works used reusable green sand (sand mixed with bituminous clay and water) as a mold medium, and a durable, reusable wood positive. The method was adopted from the industrial arts of the day, and was suitable for serial production of single parts in the ornate yet repetitive style of the era.

2 Two piece 3D-printed ceramic mold (Authors 2018).

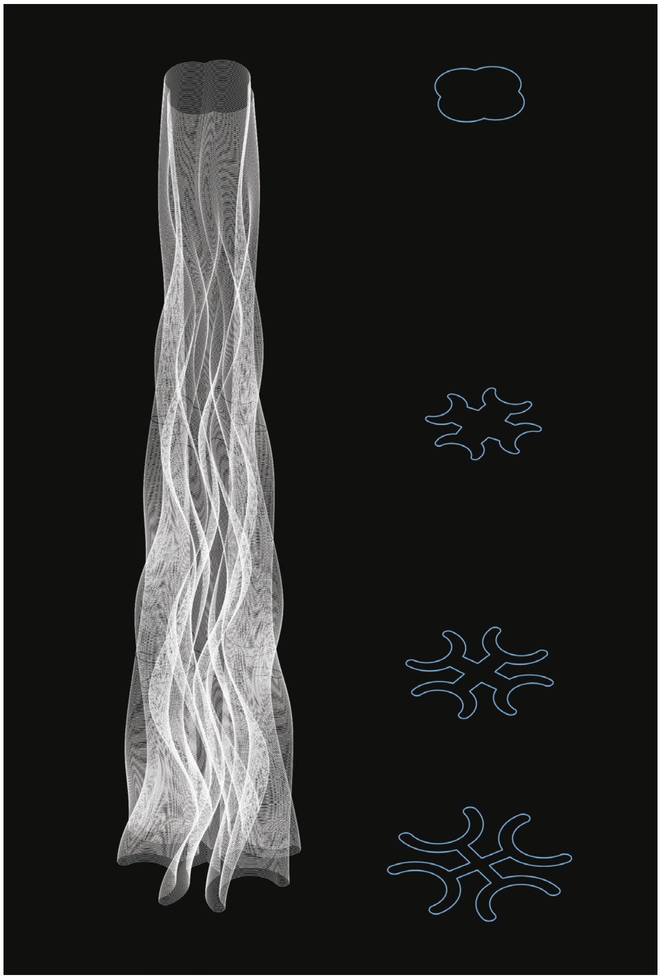
3 Cast aluminum module (Authors 2018).



4 Module geometry (Authors 2018).

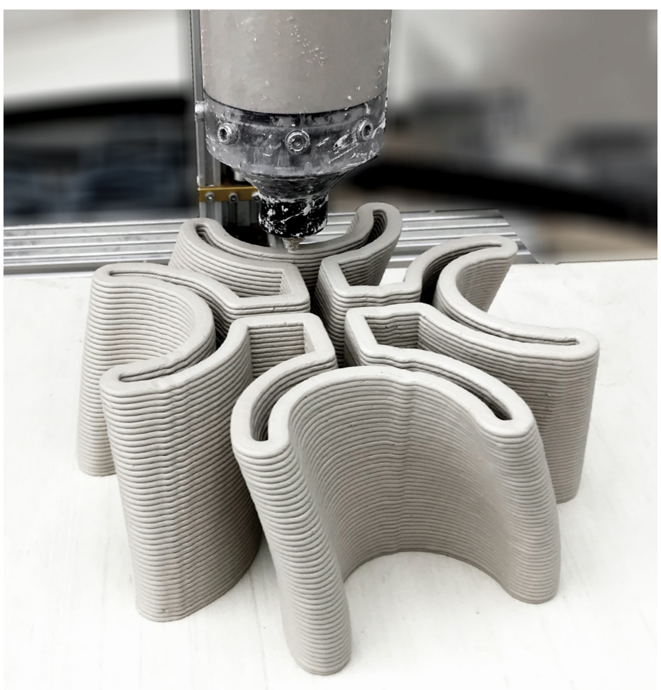


5 3D printer toolpath (white=mold, red=printed support) (Authors 2018).



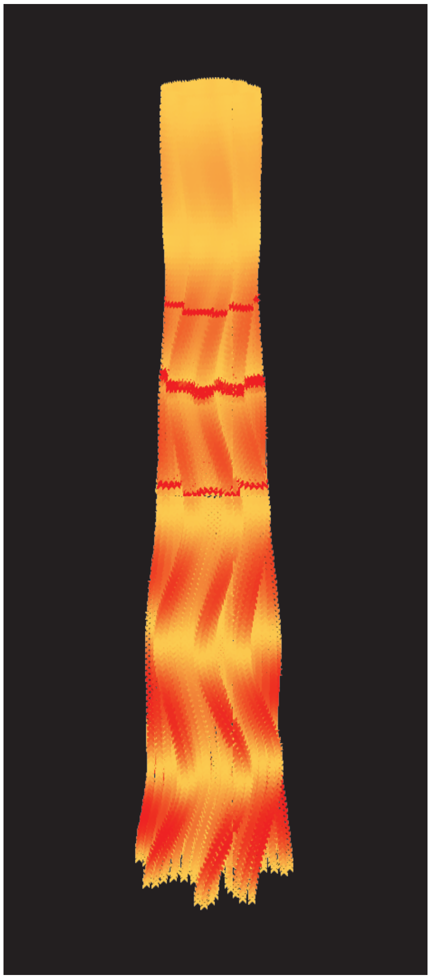
6 Change in moments of inertia at various cross sections of Column (Authors 2018).

7 3D-printed ceramic mold for Column (Authors 2018).

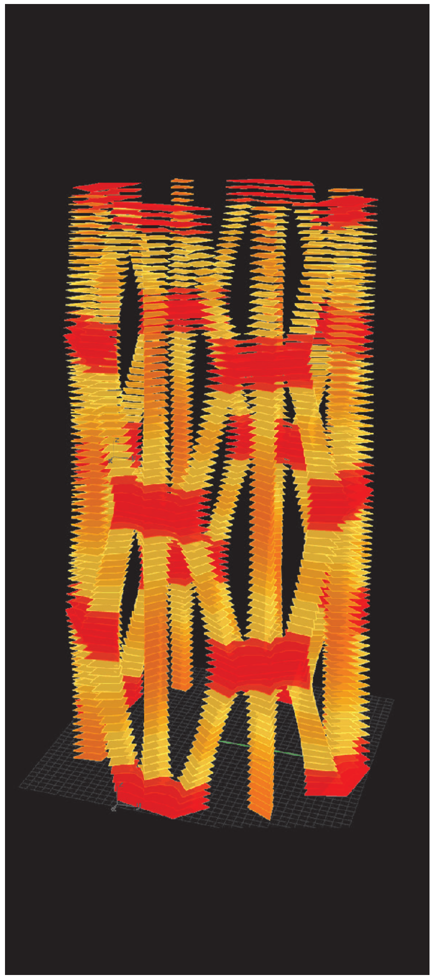


8 Molds are printed from one continuous line of clay using a Potterbot 3D ceramic extruder (Authors 2018).

9 Pouring aluminum into 3D-printed ceramic mold (Authors 2018).



10 Material overhang analysis (Authors 2018).



11 Cross sectional chilling analysis (Authors 2018).

12 Material deflection analysis (Authors 2018).

Materials and Methods

Our technique represents a hybrid of green sand and ceramic shell casting, which circumvents the need for a destructible or reusable positive. The use of a thin-shelled (4–8 mm) printed ceramic void packed into a reusable, thermally resistant green sand mold allows for a serial, efficient casting method with a capacity for the rapid production of unique or variable parts.

The ceramic shells were printed using a Potterbot 3D Ceramic extruder and stoneware. The printer and media combination proved effective when printing simple cylindrical forms with low degrees of overhang and limited traversing. To overcome the process limitations, and to explore non-cylindrical formal typologies, we developed methods for modeling integrated support systems and controlled traverse paths (Figure 5).

Individual part size was relatively small, compelling us to explore the aggregation of several part molds. Although this process allowed for greater variability between each part, serial modular parts were produced to assess the predictability and fidelity of the process for different geometric forms.

Computation

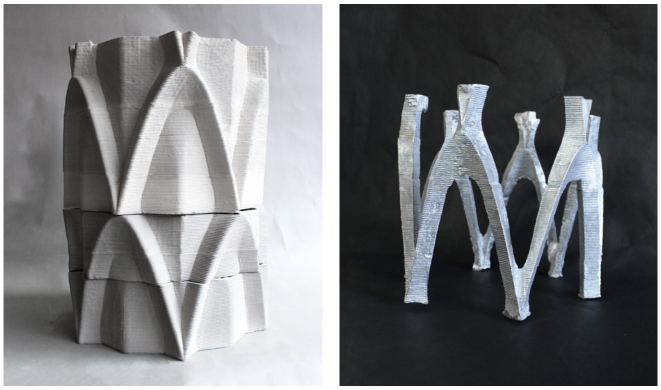
In addition to using a standard Rhino 3DM-to-Cura slicer, We used Grasshopper to assess the printability, castability, and fidelity of the mold and cast. We developed methods to qualitatively analyze the cross-sectional areas of all members showing forms that are likely to chill during casting (Figure 10). Finally, we assessed cross-sectional areas of a final scan of the cast object in relation to the original model to evaluate shrinkage and torsion (Figure 11).

13 Lattice column multi-piece stacked ceramic molds (Authors 2018).

14 Lattice column aluminum cast (Authors 2018).

15 X module system ceramic mold (Authors 2018).

16 X module system iron casts (Authors 2018).



17 Arch column ceramic mold (left) and aluminum cast (right) (Authors 2018).

18 Perferated column ceramic mold (left) and bronze cast (right) (Authors 2018).

19 Iron pour (Authors 2018).

Conclusions

There are many obstacles to overcome before thin-shell 3D printed molds can provide a viable, predictable method for building component production. Significantly, it is necessary to control moisture and temperature at every step in the production process. Even with extensive precaution, rates of shrinkage and predictable patterns of warping must be accounted for in order for parts to be produced in a sufficiently predictable manner for complex aggregations (Figure 1). We feel that the inherent variability of the amorphous material can be overcome with technical rigor, while the predictable changes to the geometry inherent to the process can be overcome with accurate data collection and increasingly sophisticated computational modeling.

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