From Digital to Physical: Best Practices for Large Scale Sand 3D Printing.

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Abstract

Different technologies can be used to create physical models from digital files from CNC routing to 3D Printing.

3D Printing or Additive Manufacturing can convert a digital model to a physical one in plastic, metal, or other materials.

Large Format 3D Printed Silica Sand can be used for sculptural, architectural, and engineering applications after a process of infiltration using epoxy resin or cyanoacrylate. 3D Printing helped by specific postprocessing practices can quickly be scaled up, producing parts up to 13 feet (4 meters) and can help artists, architects, and engineers move from prototyping to large-scale production.

Introduction

Since the beginning of AM in the 80s, several different technologies and materials have been developed to convert digital models to physical ones.

Models created with different software can be converted to specific files (STL / Standard Tessellation Language, OBJ /

Object, VRML / Virtual Reality Modeling Language, etc.) that can be sliced and sent to 3D printers as GCode or proprietary input file formats containing special instructions compatible only with specific printers. Restricted building size has been a limitation for years. Recently, emerging technologies such as Additive Manufacturing of Concrete (AMoC), Big Area Additive Manufacturing (BAAM), Large Scale Additive Manufacturing (LSAM), Electron Beam Additive Manufacturing (EBAM) are making large-scale 3D printing more cost-effective and a possible alternative solution for architectural, artistic and engineering applications. Additive manufacturing of concrete and sand printing can provide a solution for specific large-size fabrication problems.

Objective/Hypothesis:

The research has the objective to determine if large-format sand 3D printing with cyanoacrylate or epoxy resin for infiltration has mechanical and physical characteristics to be used to print digital models for large architectural, sculptural, and engineering applications.

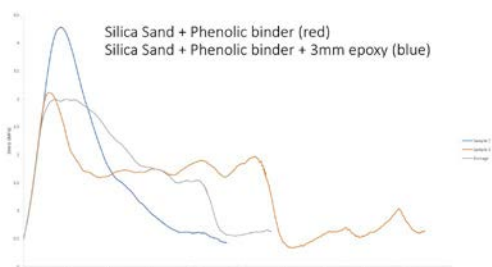
Methods:

The research uses mechanical testing on samples with different internal structure (from solid to gyroid) with different methods (tensile strength, compression strength, fracture toughness, fatigue, etc.). It also uses large model testing to analyze the feasibility of varying infiltration techniques (under vacuum, by immersion, etc.).

Results:

The research started with a collaboration with the foundry Danko Arlington Inc. that provided small printed "beans" we tested after different postprocessing infiltration techniques had been applied. The beans were printed with a Voxeljet VX1000. The VX1000 PDB uses a Phenolic Direct Binding system for printed sand molds and cores, a process which, in addition to increased mold strength and lower gas burst, can also reuse both unprinted sand and printed sand. We compared the non-infiltrated models to infiltrated models with Cyanoacrylate and Epoxy Resin by changing the timing of infiltration and obtaining different depths of external infiltration.

We tested tensile strength first to analyze the difference between the model printed with silica sand + Phenolic Binder and the one with additional infiltration of epoxy resin.

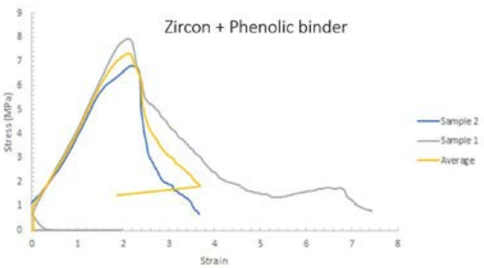


A stress-strain curve for a material gives the relationship between stress and strain.

It is obtained by gradually applying load to a test coupon and measuring the deformation, from which the strain can be determined. The applied load determines the stress.

From our tests, it appears that the silica sand specimen without infiltration has a compression resistance of 3 Megapascal (450 PSI circa)

With additional infiltration with epoxy applied only on one side up to 3 mm-depth, the compression resistance increases to 4.5 Megapascal (650 PSI).



3D printed zircon with Phenolic binder without infiltration tested near 8 Megapascal (1160 Psi).

Additional standard compressive strength tests provided information on the performance of partially infiltrated or deep infiltrated parts with measured values for the compression resistance up to 6500 Psi. Typical residential or commercial concrete work values vary between 2500 Psi and 4000 Psi.

The material created has properties similar to polymer concrete to be used for architectural and sculptural applications after defined infiltration procedures.

A second test was made in collaboration with Freshmade 3D with a model printed with an ExOne S-Max Pro and silica sand + Furan Binder with the patented material called AMClad.

Conclusions:

3D Printing with infiltrated silica sand can be a game-changer in producing highly complex shapes for architectural, sculptural, and engineering applications.

New 3D printers like the Voxeljet VX 4000 can print parts up to 4,000 x 2,000 x 1,000 mm with resolution up to 300 dpi. The 3D printer ExOne S-Max Pro can print up to 1,800 x 1,000 x 700 mm.

Additional postprocessing by infiltrating the 3D printed silica sand can reinforce parts used for tooling and finished models.

Model Examples:

The sculptures prepared by using these technologies are "The Blue Bird" and "Across the sands of Times" (2,000 x 250 x 250 mm and 300x300x1000 mm). They both present mechanical characteristics that prove that sand printing is feasible for fabricating large 3D sculptures from digital models.

Parts of the sculpture "Across the Sands of Time" in green state before infiltration.

After connecting the parts with epoxy resin, the sculpture was finished with a layer of epoxy resin and aluminum powder. A finishing with black cold patina was selected to highlight the structure.

Sculpture Across the sands of Times

Detail of the sculpture Across the sands of Times

Detail of the infiltration process of the sculpture The Blue Bird with epoxy resin and bronze powder.

Detail of the blue patina of the sculpture

Sculpture The Blue Bird.

Keywords:

Generative design, additive manufacturing, 3D Printing, computational design.