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Biomimetic Interlocking Modules For Rapid Emergency Shelter Fabrication

Kang, Ho-Yeong, Zofia Rybkowski, Matthew Yarnold

T3: TEXAS A&M TRIADS FOR TRANSFORMATION
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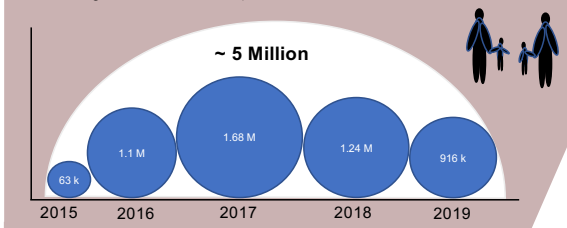
Displacements

- 2019 saw 916,000 estimated new internal displacements in the US by disasters. Globally, across 140 countries, 24.9 million internal displacements were triggered by around 1900 disasters.

New Internal Displacements in US by disasters (Data Source: *Global Report on Internal Displacement 2016-2020).*



Current Industry Approach

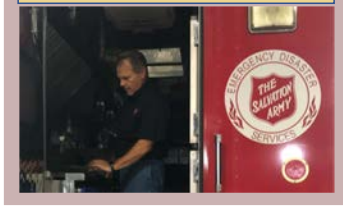
Federal Emergency Management Agency (FEMA)
- Money for Temporary housing and repairs
- FEMA Trailer as a "last resort"

Available Shelter Products
- Better Shelter by Ikea & UNHCR
- Rapid Deployable System (RDS)
- DecaDome Disaster Shelter
- Intershelter SolarDome and Survival Sphere
- Quick Cabin by Quite Lite

Research Approach

Design Brainstorming Sessions and hands-on Modeling Workshop

Warehouse Facility Tour and Interaction with Disaster Response Professionals: The Salvation Army, Texas Division



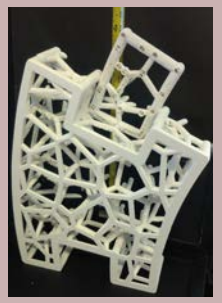
Key Design Criteria
- Modules have built-in storage capabilities
- Assembly tools requirement
- Size and weight of module
- Two person can assemble the structure in 6 hours

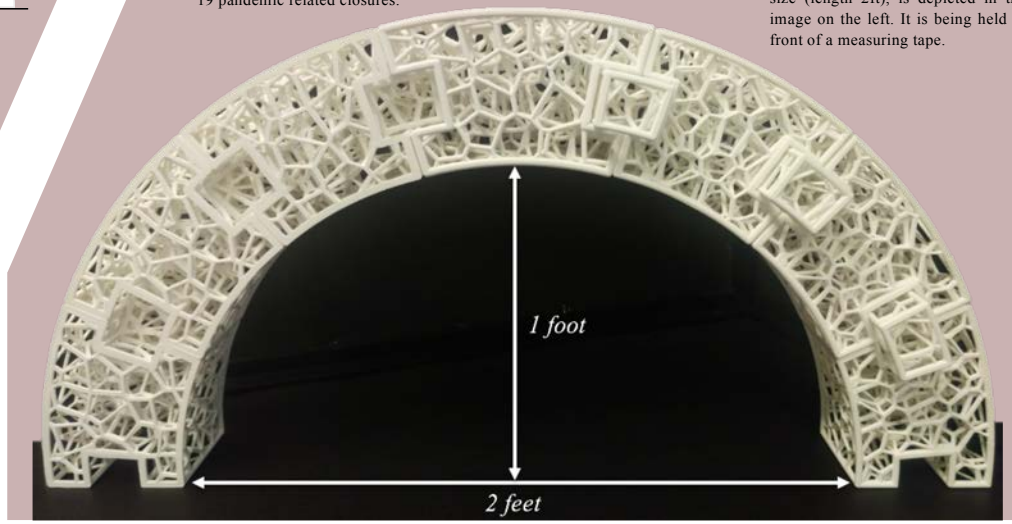
Additional Criteria
- Modules are interchangeable and easy to disassemble/ reuse
- Passive ventilation and Natural sunlight
- Structural durability for ~30 years of use
- Manufacturing ability and production cost

Structural Skeleton

Scaled Structural assembly of barrel vault arch. Both the microscopic geometry and the topological interlocking were achieved using Voronoi tessellation, a pattern widely found in nature.

Constructability of the full-scale arch will be tested upon completed of the module fabrication, delayed in part due to the Covid-19 pandemic related closures.





Module

Modules printed so far display the quality of interlocking in 3 dimension. Barrel Vault modules were 3D Printed.

The Scaled Module, pictured above, next to a standard travel tumbler for reference. The Full-scale Module size (length 2ft), is depicted in the image on the left. It is being held in front of a measuring tape.

Fabrication

For the developed technique, additive manufacturing approach using Fusion Deposition Modeling (FDM) was selected and tested out with Polylactic acid (PLA). The following 3D printers were procured, assembled, calibrated and used for manufacturing.

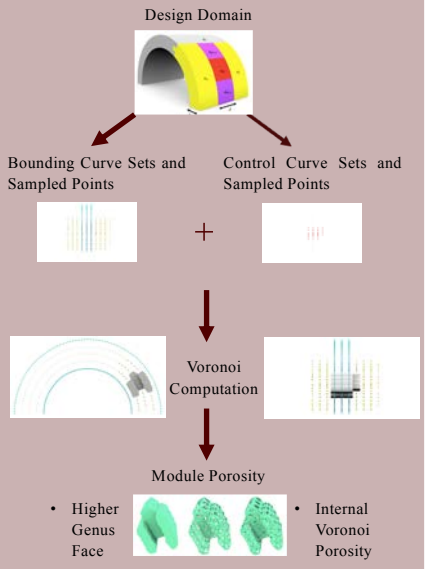
- ✓ Creality Ender 3D for scaled prototypes
- ✓ Modix Big 120X v2 for full scale prototypes

Modix 120X printer (print volume 2ft x 2ft x 4ft) is pictured on right. Standard Formlabs Form 3's can be seen in the background for size reference.

This equipment is a collaboration with IT Division of the College of Architecture helping with crucial maintenance and upgrades.

Parametric Design Tool

Development of a robust design technique to create modular interlocking structures by application of the bioinspired Voronoi tessellation was carried out in Rhinoceros 6 and Grasshopper platform.



Porosity and Interlocking

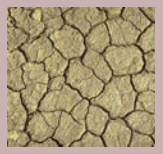
It is crucial to strategically reduce the material weight while maintaining the structural strength. Multiple techniques mentioned below, were utilized to create porous and interlocking prototypes as shown in the figure.

Porosity Patterns
- Regular Tessellation
- Semi Regular Tessellation
- Non-Regular Tessellation

Interlocking Approach
- Weave Pattern based Curves
- Voxel based Boolean Operations

Bioinspiration

A wide range of forms and patterns are found in nature, however, one of the tessellation is noticeable from epithelial cells to metal grains to structural geology. This *Voronoi Tessellation,* partitions the space into regions closest to a given point.



As seen in nature.

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