

3D Printing Ceramics – An Introduction

Leslie Forehand



I'm Leslie Forehand

Architect. Designer. Educator. Creator.

3D Printing Ceramics – An Introduction

*qualifies for HSW

Ceramics, which is an advanced technology with a long history, is currently being integrated to 3D printing with robotics and other digital fabrication techniques. Of all commercially available 3D printers, ceramic 3D printers offer the most relevant applications to architecture because of its ability to scale and its existing material tradition. This presentation will review the technology and required equipment, existing workflows for product production, current applications of this technology, near future applications, material performance and benefits, as well as an overview of projects being completed at Iowa State University.

Learning Objective 1

The learner will be able to summarize the traditional and current uses of ceramics in architecture.

Learning Objective 2

The learner will be able to summarize the necessary equipment to set up a ceramic printer production, as well as tested workflows for translating digital designs to physical artifacts.

Learning Objective 3

The learner will be able to describe the benefits and limitations of 3D printing as a fabrication methodology.

Learning Objective 4

The learner will be able to describe multiple initiatives in 3D printed applications in architecture.

What is 3D Printing?

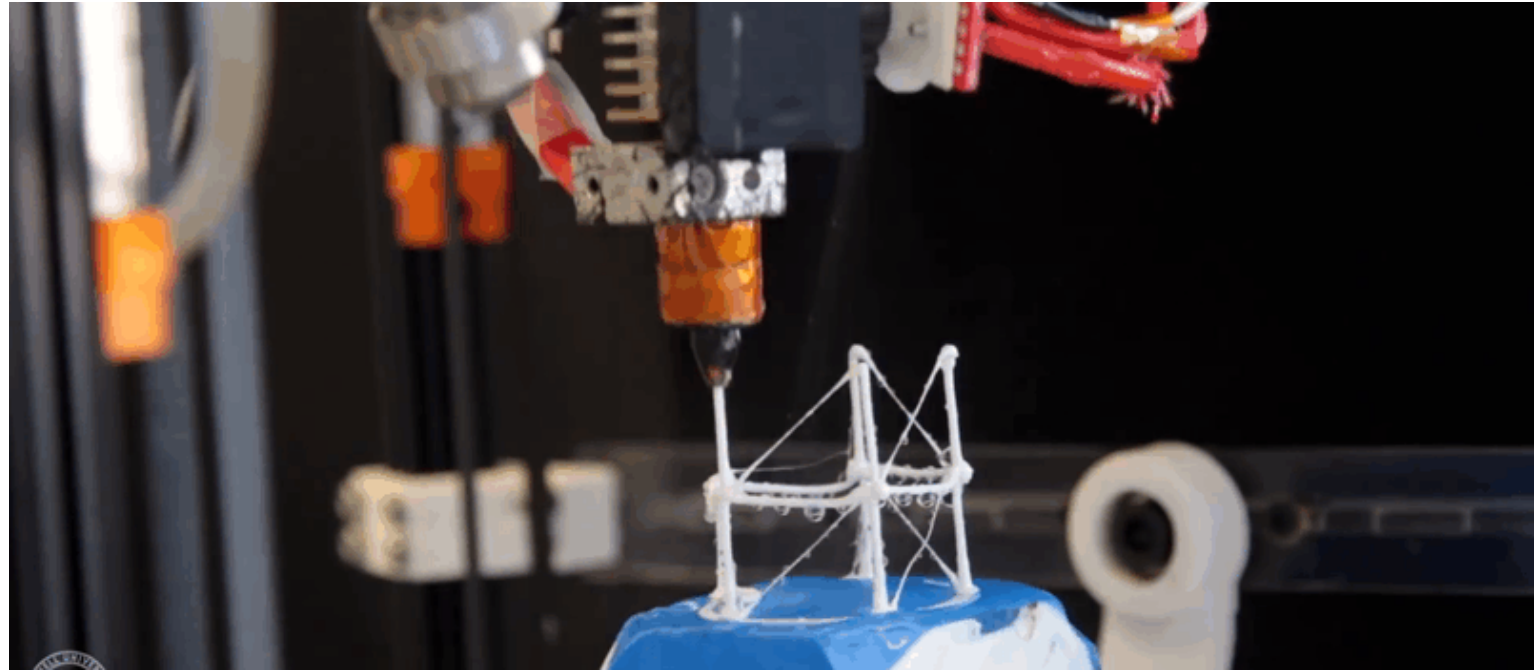
3D Printers

Create 3D objects one layer at a time

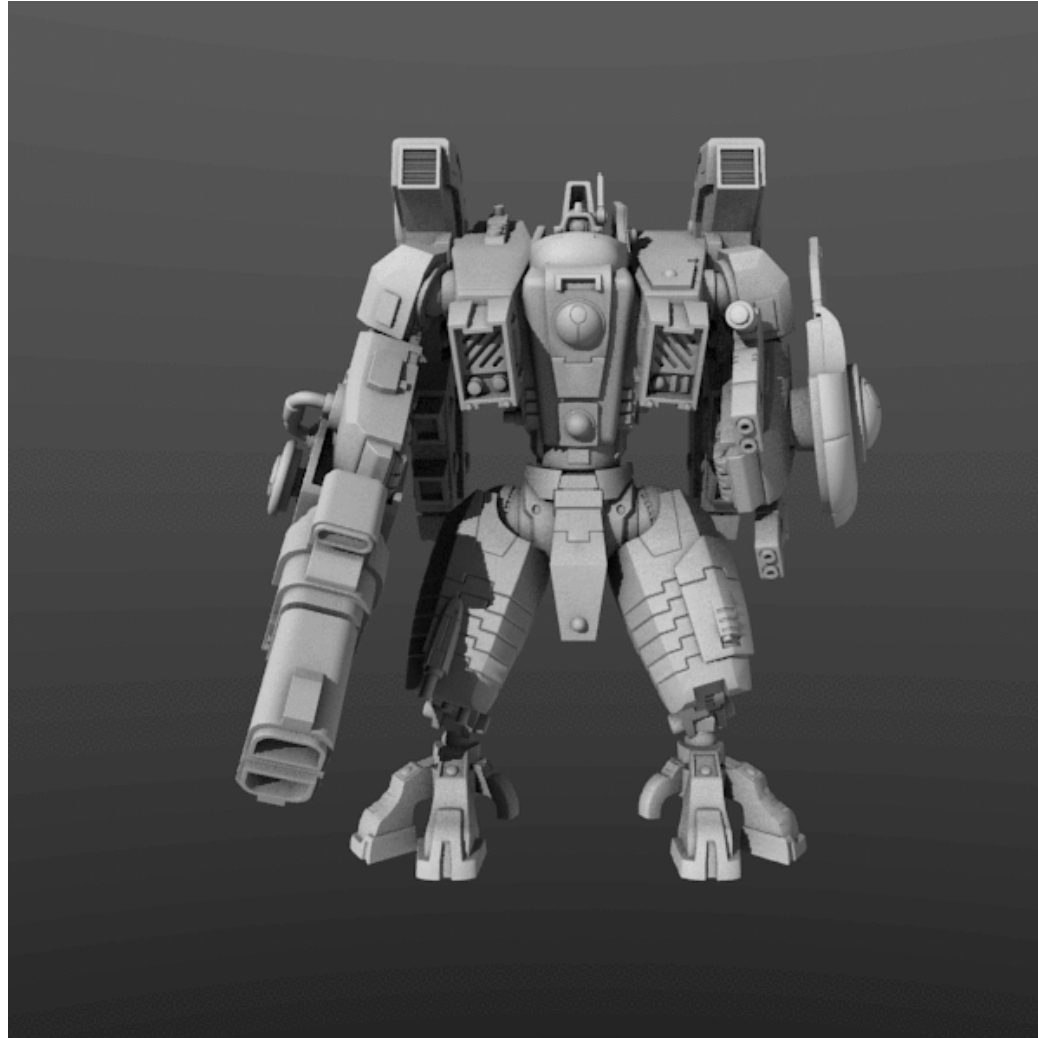


What is 3D Printing?

- “Additive manufacturing” where you create a 3D object one layer at a time
- Requires a 3D design created by tool such as auto-CAD
- Requires material such as plastic that can be melted then put on one layer at a time
- Moving build platform that draws each layer of a 3D design



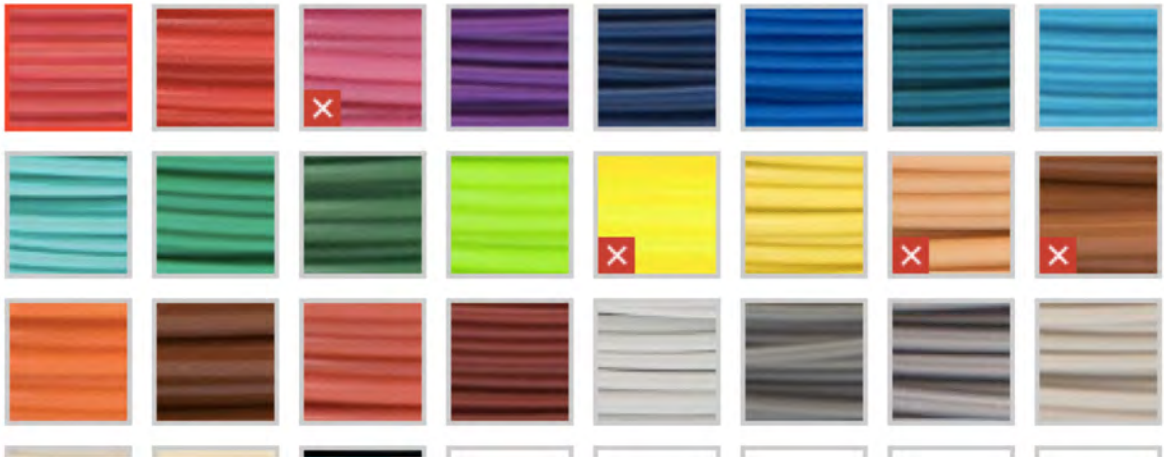
Step One:
Create Digital Design



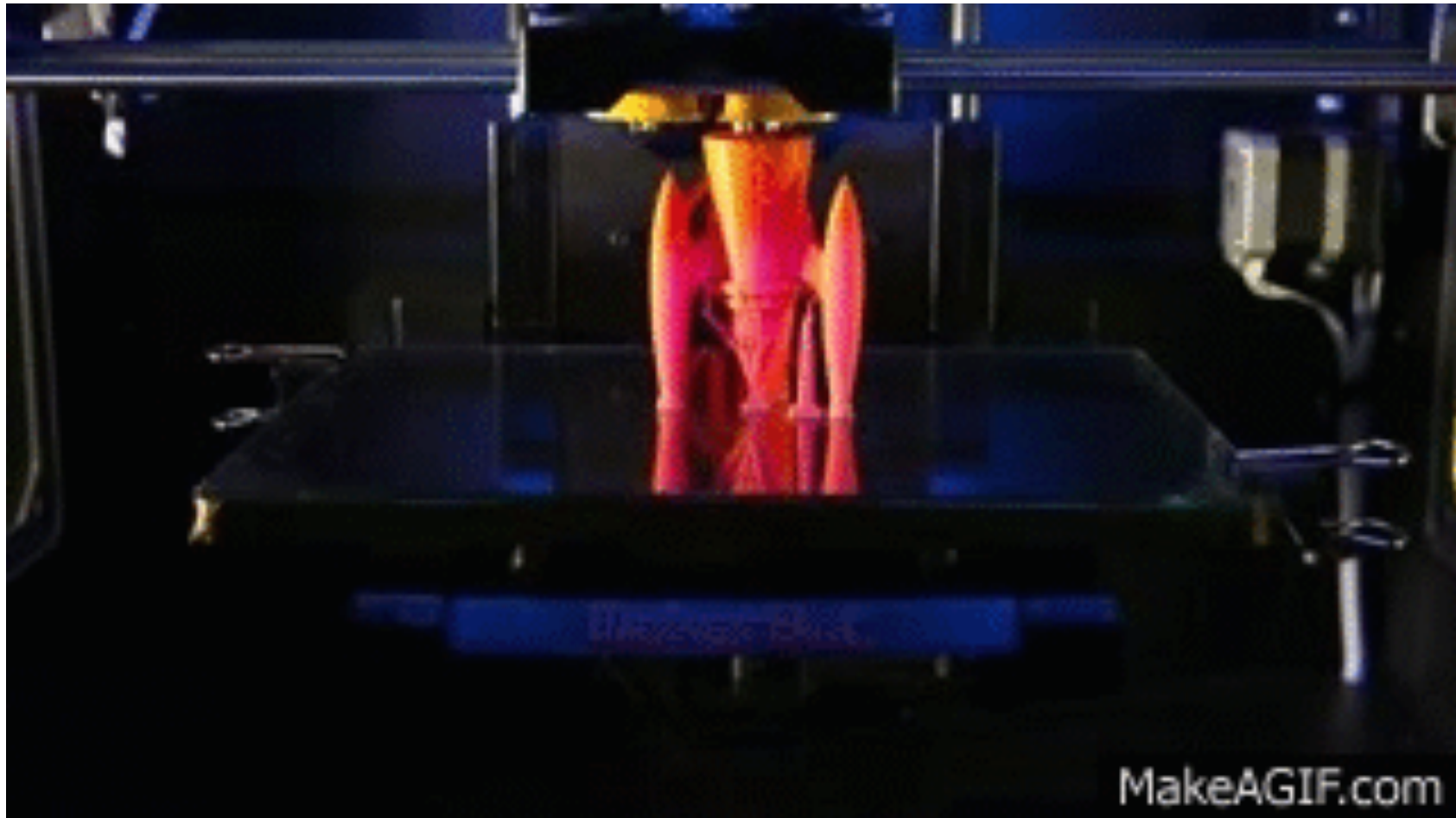
Step Two:
Pick A Material



ABS | 1kg ▼



Step 3:
Print it!



How do people use 3D Printing?

- Prototyping
- Low volume manufacturing
- Tooling
- Consumer products
- Customization + personalization
- Art/design
- Education
- Medical





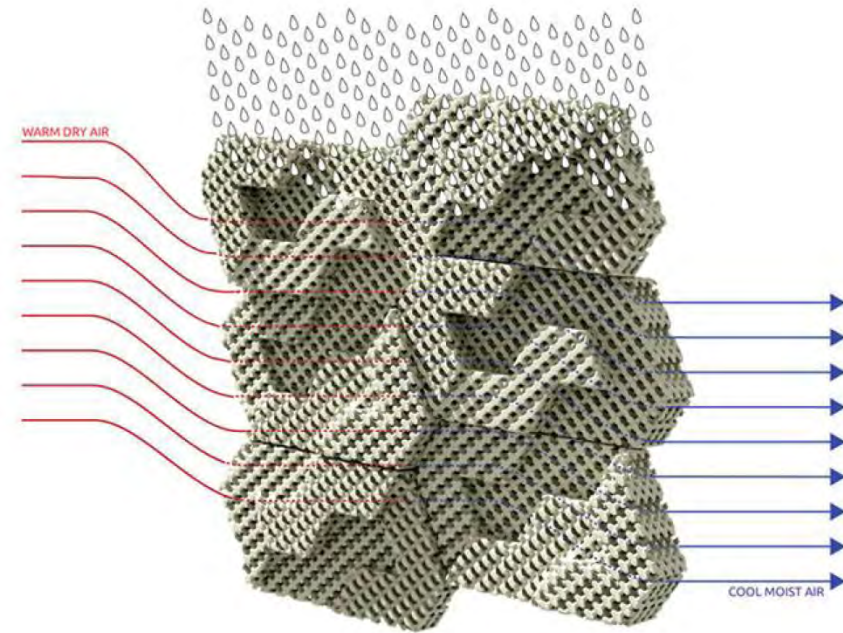
Case Studies

Current Applications of 3D Printed Ceramics

Cool Brick

Project Team: Ronald Rael and Virginia San Fratello
2015

California-based Emerging Objects have been exploring how 3D printing -- when combined with innovative and sustainable materials like salt, clay and wood pulp -- could herald a new age of sustainable building. They printed the world's first salt structure, and now, one of their latest experiments is the 3D printed Cool Brick, which would allow homes to be cooled naturally without the need for air conditioning. Designers Ronald Rael and Virginia San Fratello were inspired by the ages-old technique of evaporative cooling used in hot, dry climates (such as the use of porous, ceramic vessels to keep things cool), for making their digitally fabricated brick. Created using a mixture of clay and organic materials, the 3D printed, porous ceramic bricks are set in mortar, and are made to soak up water like a sponge. The idea is that the modular, interlocking bricks would act like an intricate lattice that allows air -- which is cooled by the water contained in the small pores of the ceramic -- to flow through and cool the inside of the building through the process of evaporation. The particular form of the bricks also increases the amount of shading for the building's facade, thus also helping to keep the interior cooler.



Seed Stitch

Emerging Objects

Project Team: Ronald Rael, Virginia San Fratello, Kent Wilson, Alex Schofield

2016

The Seed Stitch Wall is a prototype for a 3D printed ceramic wall cladding system. Whereas most applications of 3D printing demonstrate how 3D printing allows for mass difference, Seed Stitch is an exercise in mass complexity and allows the influence of the hand, gravity, temperature, and the attempts of a machine to print an unstable shape, to produce difference. The project is inspired by our earlier experiments in manipulating goode to produce clay surfaces that possess the texture of knitted surfaces. In knitting, the seed stitch consists of single knits and purls that alternate horizontally and vertically. Seed stitch gets its name from the texture of the knitted fabric — the little purl bumps look like scattered seeds. At another scale, the knitted ceramic tiles, appear to have the dynamic quality of peeling, both an intentional design element and an attribute of the 3D printer pulling away at the unstable end of each ceramic tile. The machine direction, suggests another influence is shaping each tile — the wind, shrinking, or some other dynamic force, giving each type the quality of a flexible material, despite it being a very rigid, strong, low porosity ceramic building material. Each tile has a curve that allows it to be hung on the surface of a building. The Seed Stitch Wall employs bent galvanized metal J molding to hang the light-weight ceramic tiles. 64 square feet of surface can be hung in just minutes. Alternatively, a 3D printed backing (above) of various translucency or colors was also tested to achieve different functional and aesthetic outcomes. A translucent backing allows for backlighting of the ceramic wall for dramatic night-time effects, and can also be filled with expanded foam to create an insulated wall system. “In each object, texture, pattern, and surface make the objects tactile, and gather light and shadow in beautiful ways,” the Emerging Objects team explained. “Architecture, lighting, and pottery all come to mind when considering the objects through several scales. Ceramic becomes soft to the eye, dynamic, with detail that could not be achieved by hand — yet the hand of the digital designer is present in every artifact.”



Harvard Robot Whiz Invents a Way to Weave Facades Out of Clay

Jared Friedman

Project Location: Harvard University

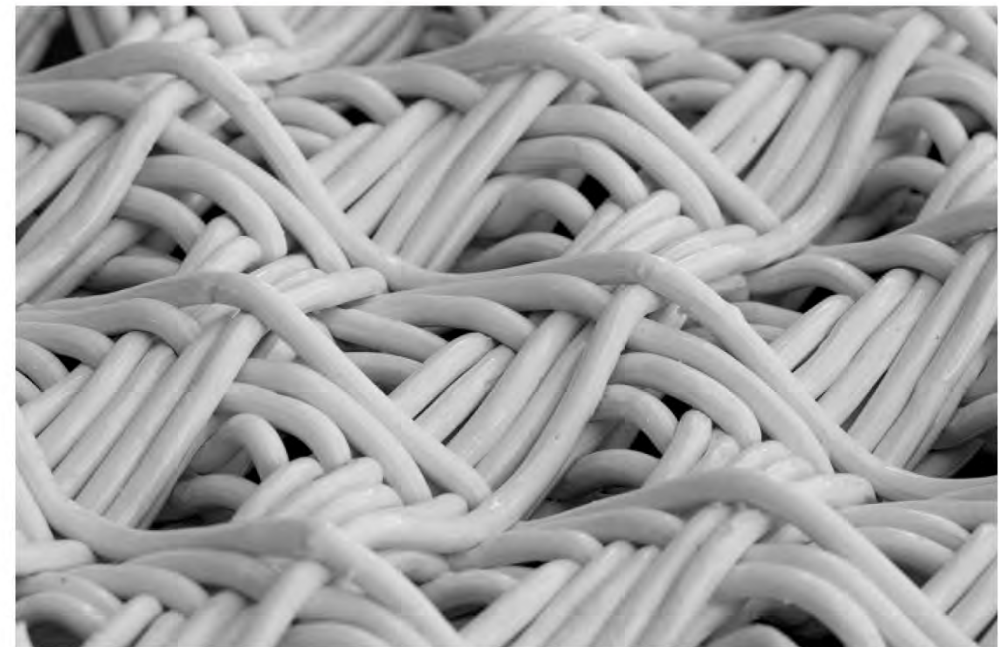
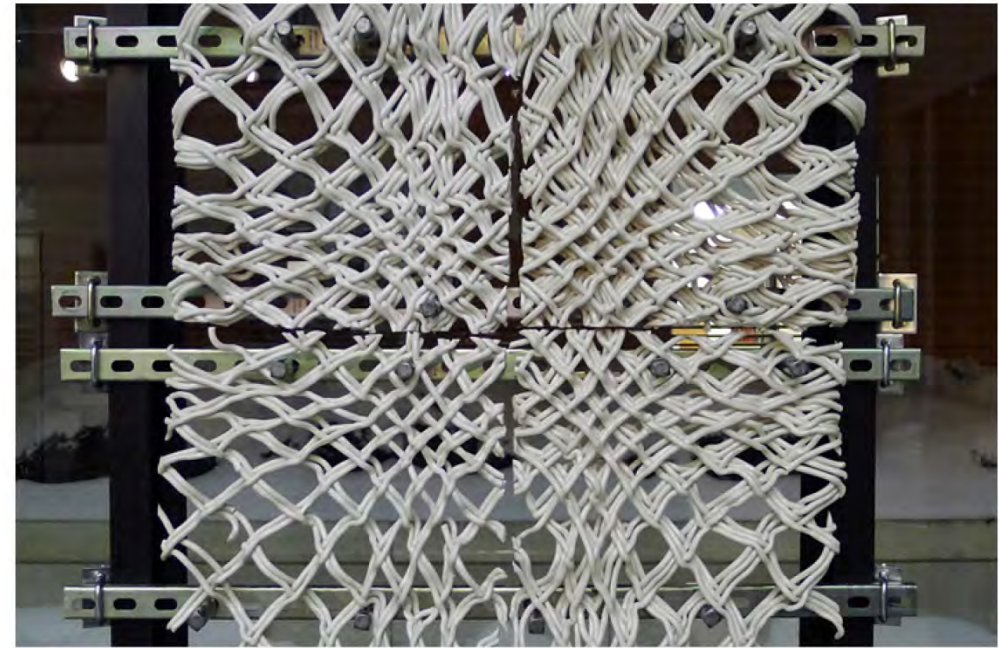
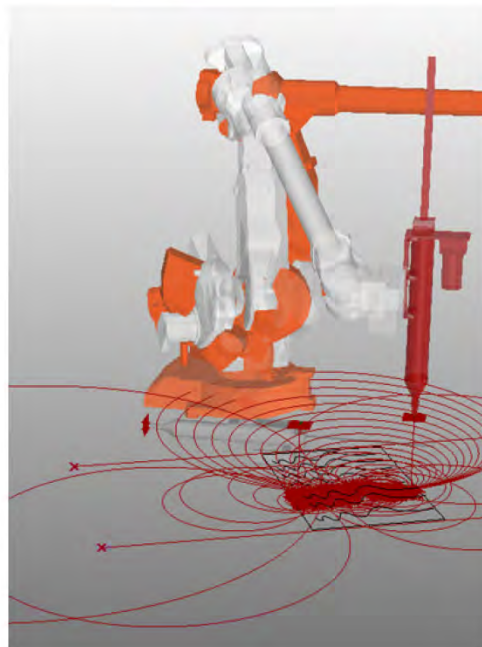
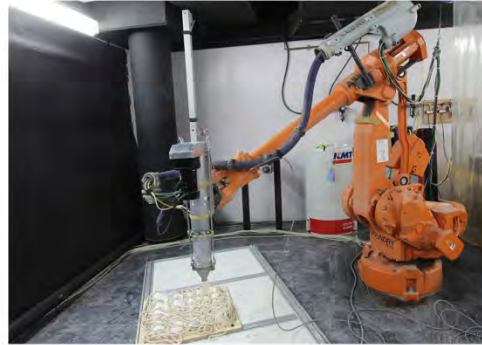
2014

"HARVARD GRAD STUDENT Jared Friedman is a designer who is trying to use one of the most precise industrial tools on the planet to produce architectural facades with the earthy charm of your grandmother's macramé. The budding architect, and his classmates Olga Mesa and Hea Min Kim, were tired of the smooth glass and concrete skins of modern buildings and wanted to create a new architectural style by employing 3-D printing technology.

Low-cost 3-D printers that produce tchotchkes made of melted plastic wouldn't satisfy Friedman's architectural ambitions, so his team decided to build their own machine. "We were tired of seeing the same things over and over being 3-D printed within the design community," he says. "The scale was always very small due to the size of standard 3-D printing machines and everything relies on a 'layer upon layer' process."

"Tools such as the industrial robot can allow for designers to revisit techniques such as weaving, and leverage the abilities granted by the robot to produce new and unique products," says Friedman. "We wanted to have enough control to print a panel with a fair degree of accuracy to the initial design, but we also wanted to allow for some of the irregularities to occur that make each panel unique."

Combining dozens of these panels provides architects with an opportunity to create architectural facades that have the warmth of handwoven fabrics while stretching for hundreds of square feet. Friedman and company have no plans to commercialize their creations, but are excited to have wrung new possibilities out of old hardware."



GCODE.Clay Collection

Emerging Objects

Project Team: Ronald Rael, Virginia San Fratello, Kent Wilson, Alex Schofield
2016

"In this case," they explain, "the 3D printer is pushed outside the boundaries of what would typically define the printed object, creating a series of controlled errors that create a new expressions in clay defined by the plasticity of the material, gravity and machine behavior."

The GCODE.Clay collection, designed by Ronald Rael, Virginia San Fratello, Kent Wilson and Alex Schofield, was first exhibited at Space 2214, in Berkeley, California. The space's inaugural exhibition investigating Pattern, Predictability, and Repetition explored the themes of repetition, and rote action — a defining peril of modernity. In this project, the unpredictability is the fundamental aspiration of the object making. Patterns emerge and disappear in the variations of the experiments explored. It is basically the exact opposite of what digital manufacturing usually does and the irony is that it was achieved by designing in machine language.



ELstudio

Architecture & Research
Cove Park's residencies
Project Location: Scotland
2016

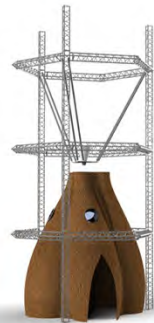
"Cove Park's residencies actively respond to the diversity of contemporary artistic practice in all the art forms, whether performing or visual arts, crafts, literature or music. Our interdisciplinary programmes, for both individuals and collaborating groups, offer time, space and freedom to make new work and to find new ways of working."



3D Printed Village of Shamballa

WASP

2016

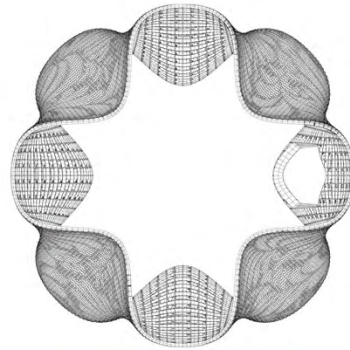


It's Rising up a technological village dedicated to 3D printing, the heart of this project is the 12-metres-high printer BigDelta WASP, a 3D printer resulted from a research project in the field of sustainable housing construction with locally available materials and low costs. This has been WASP's primary objective since the very start. It happens in Massa Lombarda (Ravenna) thanks to a partnership between CSP srl (Centro Sviluppo Progetti – WASProject) and the Municipality that has made available a green area in the industrial zone of the town, in Cooperazione road. WASP, leader in 3D printing technology, with the goal to disseminate the current state of its technology wants to build an eco-friendly village with low energy consumption. Therefore, Massa Lombarda is going to become an important Technology Experimentation Centre dedicated to 3D printing, a unique case in Italy and maybe in the World.



Bloom

Project Team: Ronald Rael, Virginia San Fratello, Kent Wilson, Alex Schofield, Sofia Anastassiou, Yina Dong, Dr. Stephan Adams, Alex Niemeyer, Ari Oppenheimer, Reem Makkawi, Steven Huang
2015



Bloom is a 9 foot tall freestanding tempietto with a footprint that measures approximately 12 feet by 12 feet and is composed of 840 customized 3D printed blocks. The experimental pavilion represents a new paradigm in building construction methods. A pattern derived from traditional Thai flower patterns is mapped onto the surface of the structure that creates a figural pattern and stunning visual effect of light, shade and shadow on the exterior and interior. From the exterior the pattern is most striking from a distance or when viewed through the screen of a digital camera, which creates a surprise upon photographing the structure from up close.



ISU CCL

Computation and Construction Lab

ISU Computation + Construction Lab

The Computation + Construction Lab (CCL) is an initiative of the Department of Architecture at Iowa State University and was co-founded by Shelby Doyle, Leslie Forehand, and Nick Senske.

The CCL works to connect developments in computation to the challenges of construction: through teaching, research, and outreach. As ISU is a land-grant institution in the very first state to adopt the Morrill Act, the CCL works to share knowledge beyond campus borders by leveraging design and construction as tools of public engagement with non-profits and small towns in Iowa.

A primary tenet of this work is the democratization of access to and knowledge about technology in architecture, specifically creating opportunities for our students to learn and create with technology.

People



Shelby Doyle AIA
Assistant Professor

MArch Harvard
BS Architecture UVA



Leslie Forehand
Lecturer

MArch Pratt
BS Architecture UVA



Nick Senske
Assistant Professor

MSArch Michigan
SMArchS MIT
BArch ISU



Erin Hunt
CCL Associate

BArch ISU

Student Researchers

The work of the CCL is made possible by the dedicated work of our Graduate and Undergraduate Research Assistants:

Nick Loughrey, BArch '18
Sarah Schneider, BArch '18
Rahul Attraya, BArch '17
Melissa Brooks, MArch '17
Nakisa Dhpanah, MArch '18
Erin Hunt, BArch '17

Andrew Meyer, MArch '17
Makayla Natrop, BArch '18
Atalie Rhunke, BArch '19
Sirina Reed, BArch '19
Nasar (Tony) Saghafi, MArch '17
Anna Kroll MArch '16
Zhenhua Yin MArch '16
Graham Hanson, MArch '18

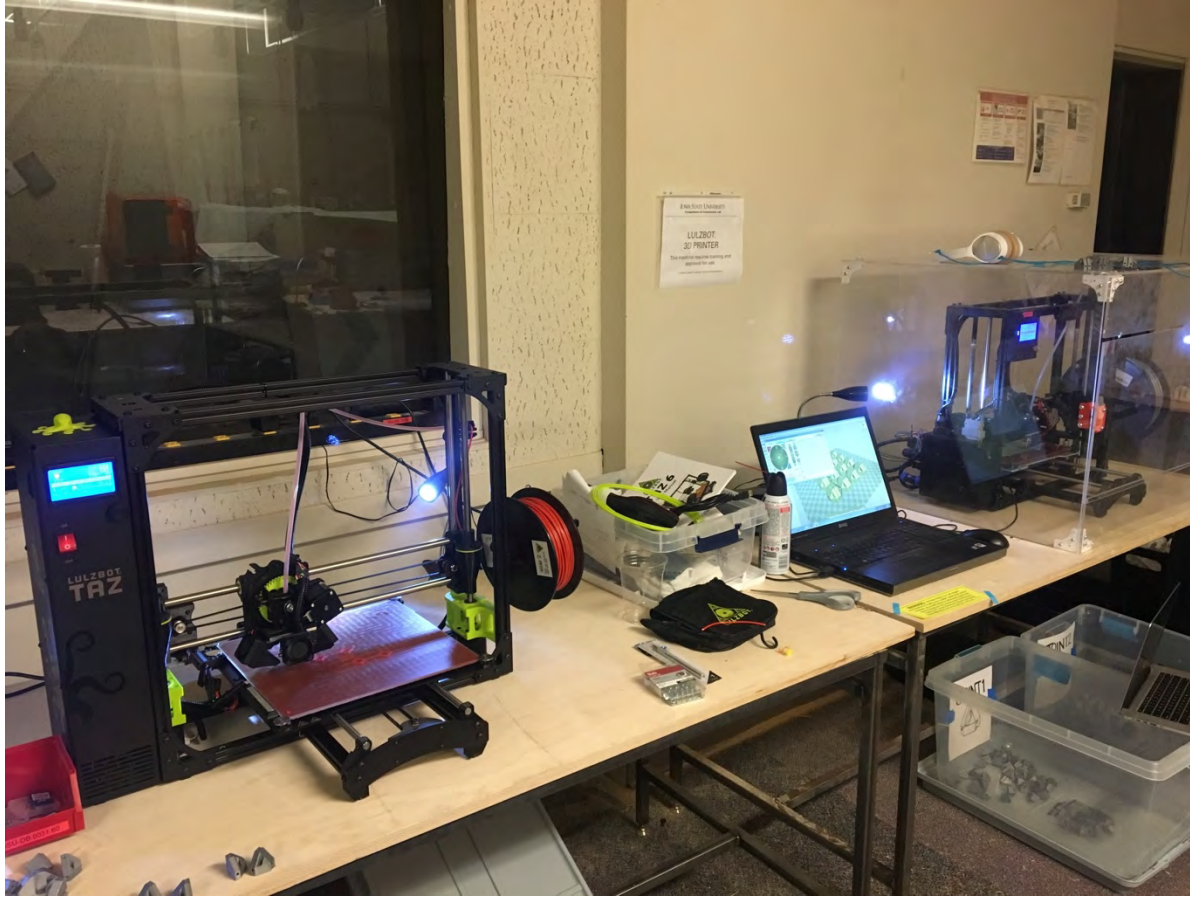
Past CCL Faculty Fellows

Reinaldo Correa, Lecturer in
Architecture

Communications Building – WOI Radio Station



Radio Control Rooms - 3D Printing



Radio Control Rooms - 3D Printing

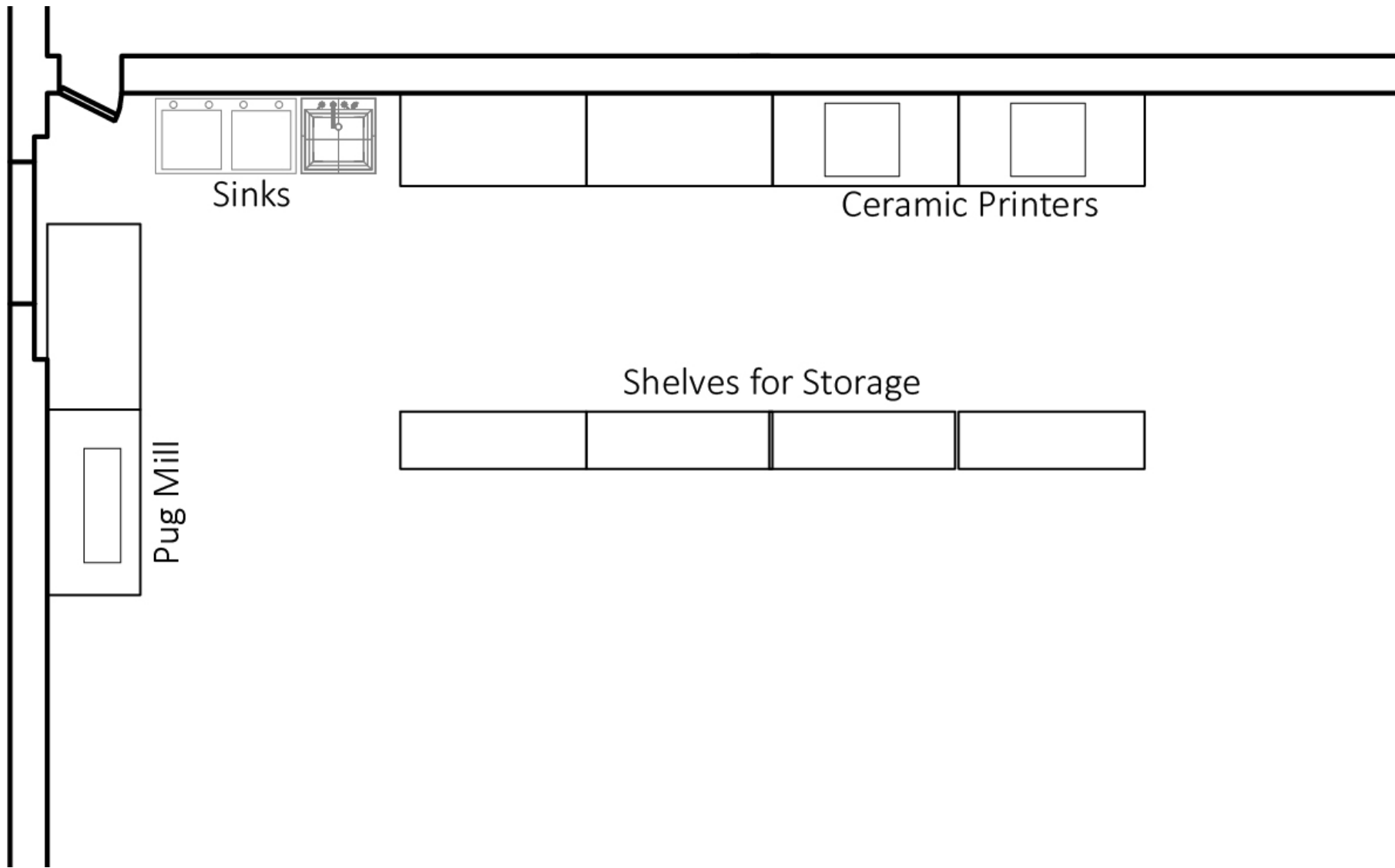


Recognition



The Best
Student Design-Build
Projects Worldwide
2016

Current Set Up - Plan



Current Set up – Pug Mill Station



3D Printed Pug Mill

Nozzle Holder

Masks and Gloves (Safety First!)

Tubes for Clay

Pug Mill

Current Set up – Clay prep - Sinks



Current Set up – Clay prep - Sinks



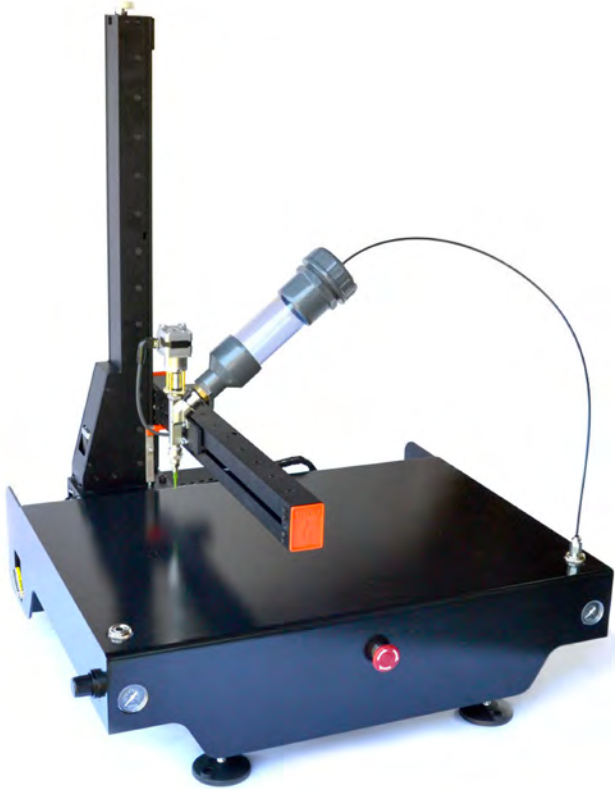
Current Set up – Printers in CCL



Potterbot - \$4,850.00

Made by Danny in Florida

Other Printers on the Market



LITHIUM - \$7,500.00

Made in the
Netherlands



WASP - \$4,000.00

Made in Italy



DIY - \$800.00

Made by you! Parts
from all over.

Current Set up – Shelves



Current Set up – Ceramic Studio Kilns



Process

Step by Step Guide to 3D Printing Ceramics

Step 1 – Software requirements (Grasshopper, Rhinoceros, Grasshopper Plugin)



Rhinoceros 3D

Rhinoceros is a commercial 3D computer graphics and computer-aided design application.



Grasshopper 3D

Grasshopper is a visual programming language and environment



Xylinus

Xylinus allows for novel control of 3D printers, generating G code directly from native Rhino and Grasshopper geometries.

Step 2 – Prepare clay

1. Cut purchased clay into smaller sections, put in micro fiber towel or felt in the plastic bag add 10 -15 oz of water, close. The moisture from the cloth will penetrate into the clay in a day or so.
2. Manual wedging with adding extra water until the consistency is right.
3. Use pug mill and add small amounts of water while cycling the clay through the pug mill several times to get the right consistency. Then the tubes can be loaded directly from the pug mill.



Step 3 – Load clay in tubes

There are several ways to load the cylinders. The easiest way by far is with the use of a pug mill. It's necessary to machine a small transitional flange from the nozzle of the pug mill to hold the polycarbonate tube in place. For best results you should use a De-airing pug mill and a double auger will give you better performance than a single auger. Although a single auger is adequate the consistency of the clays is more critical when it comes to loading the tubes. The consistency of the clay should be similar to a standard throwing clay but wetter.



Step 4 – Set Up Printer

Step 5 – Remove Print

- If Print is good, set it out to dry (Consider a plastic cover)
- Once bone dry, the print can be fired in a kiln
- After it is bone dry, and you do not want it it can be recycled back into soft clay

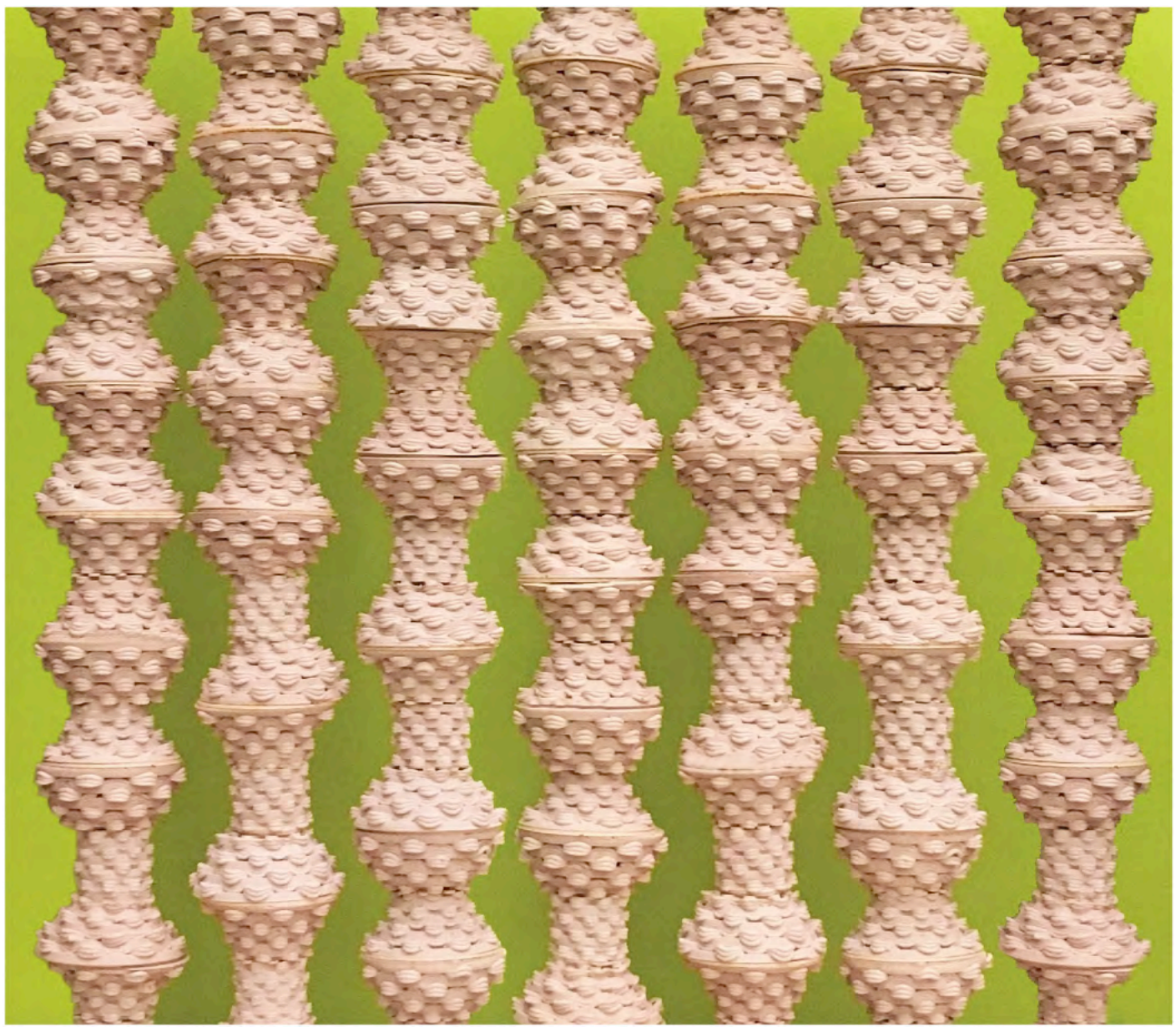


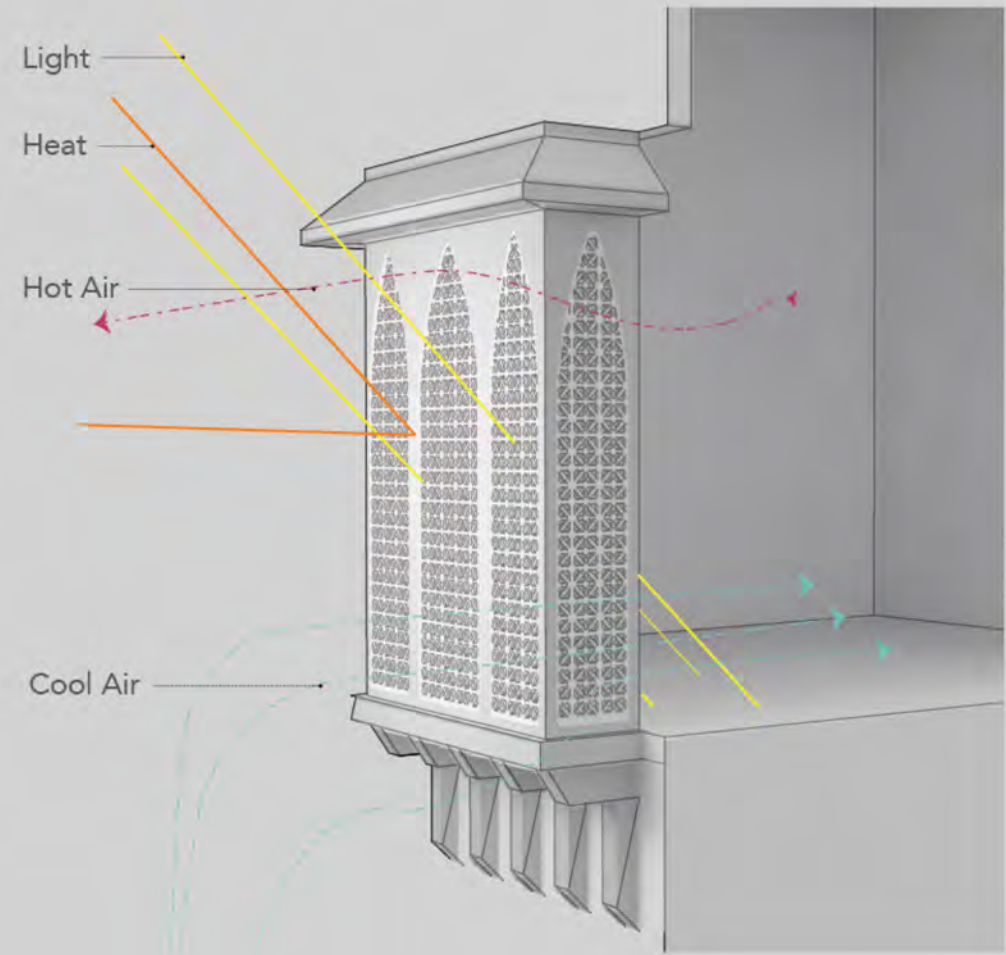
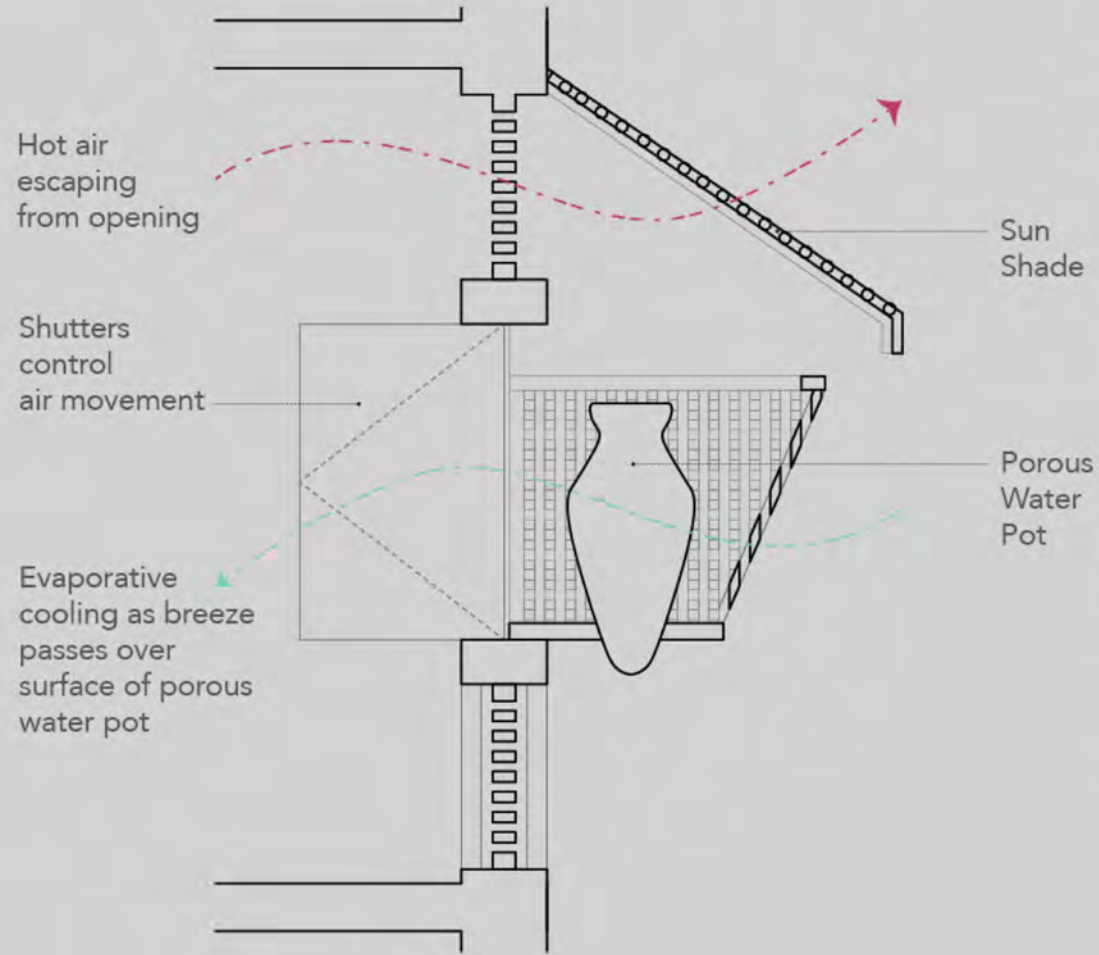
Mashrabiya 2.0

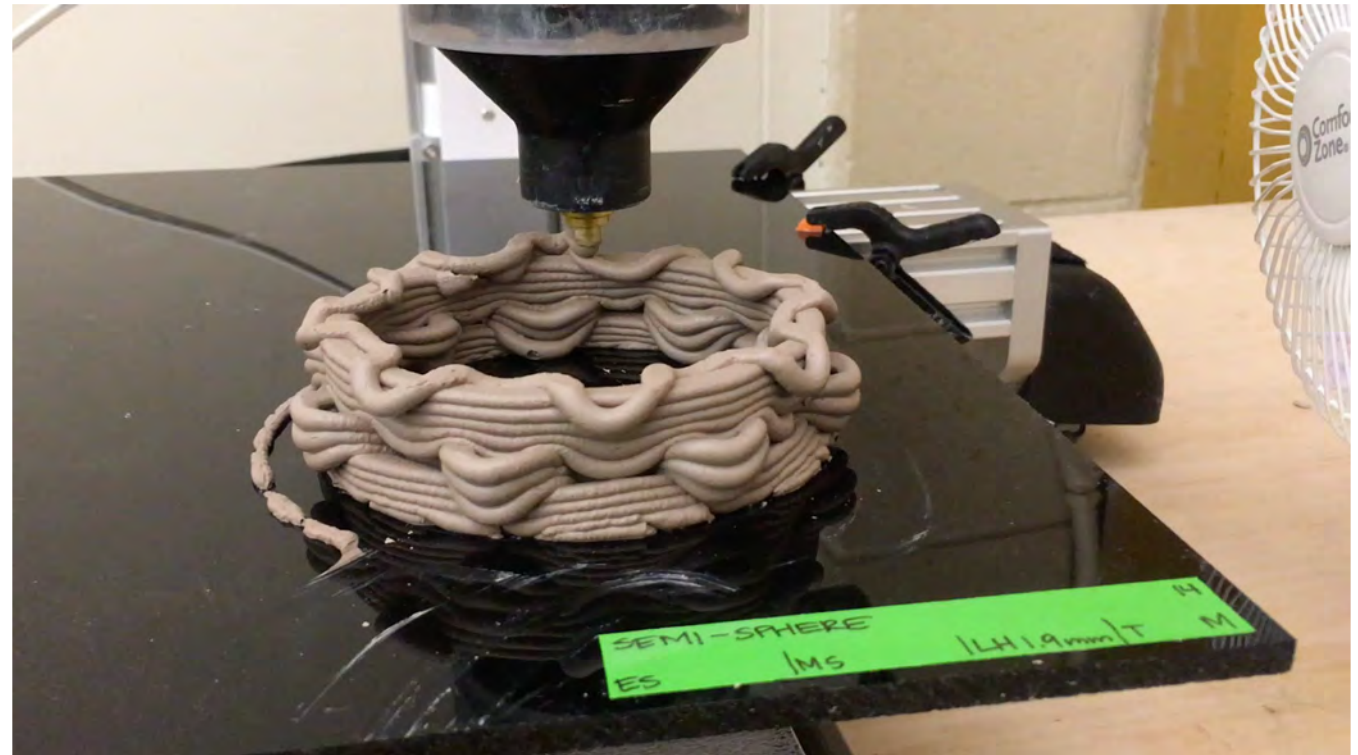
3D Printed Ceramic Evaporative Facade

Joan B. Calambokidis Innovation in Masonry Award Young Designers Category

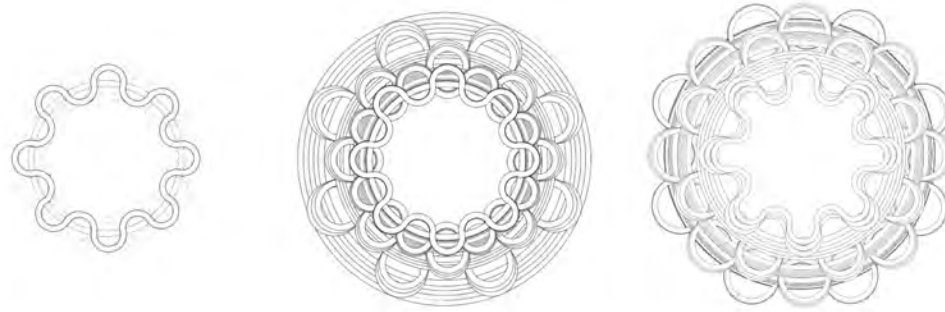








Plan

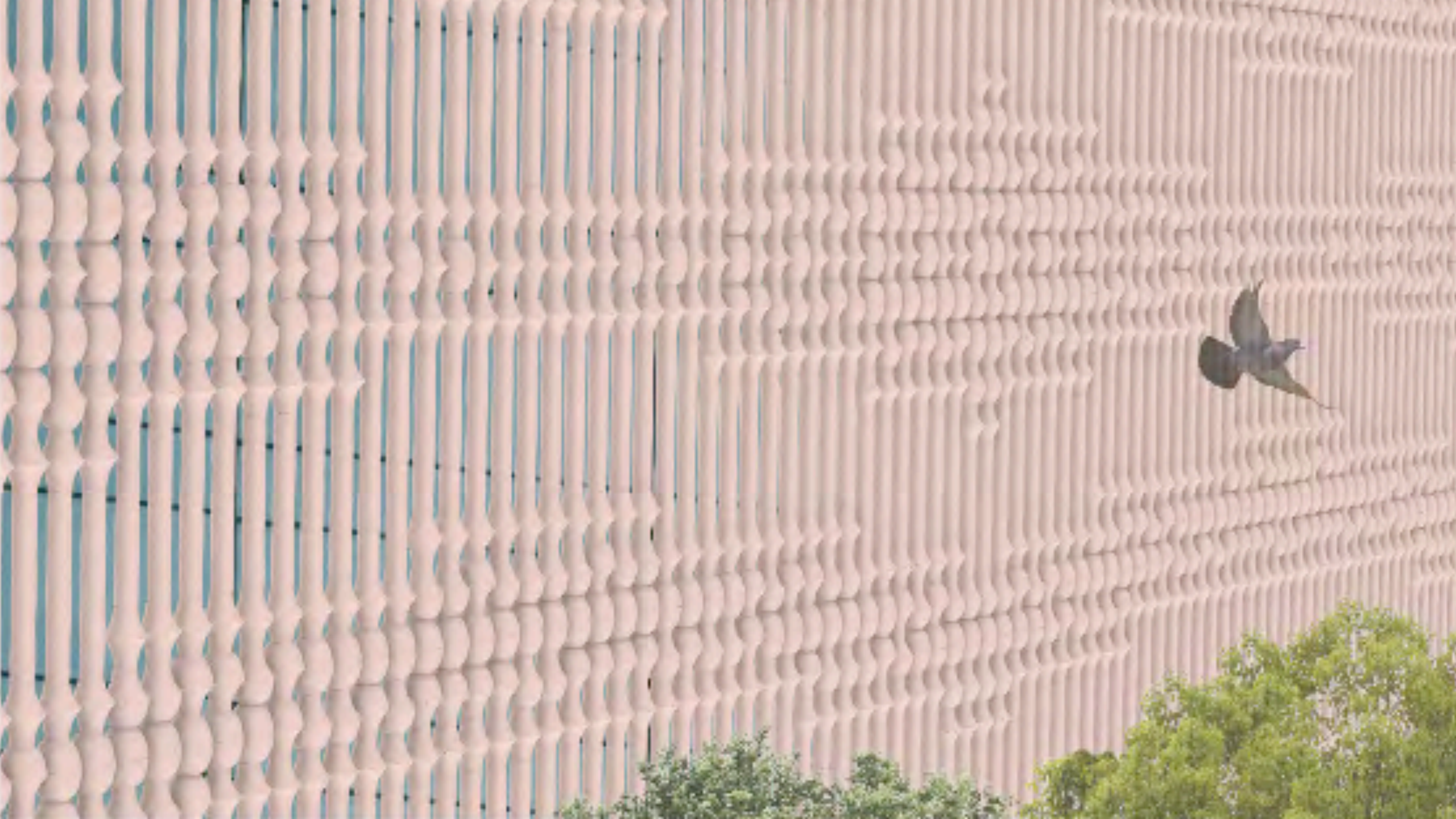


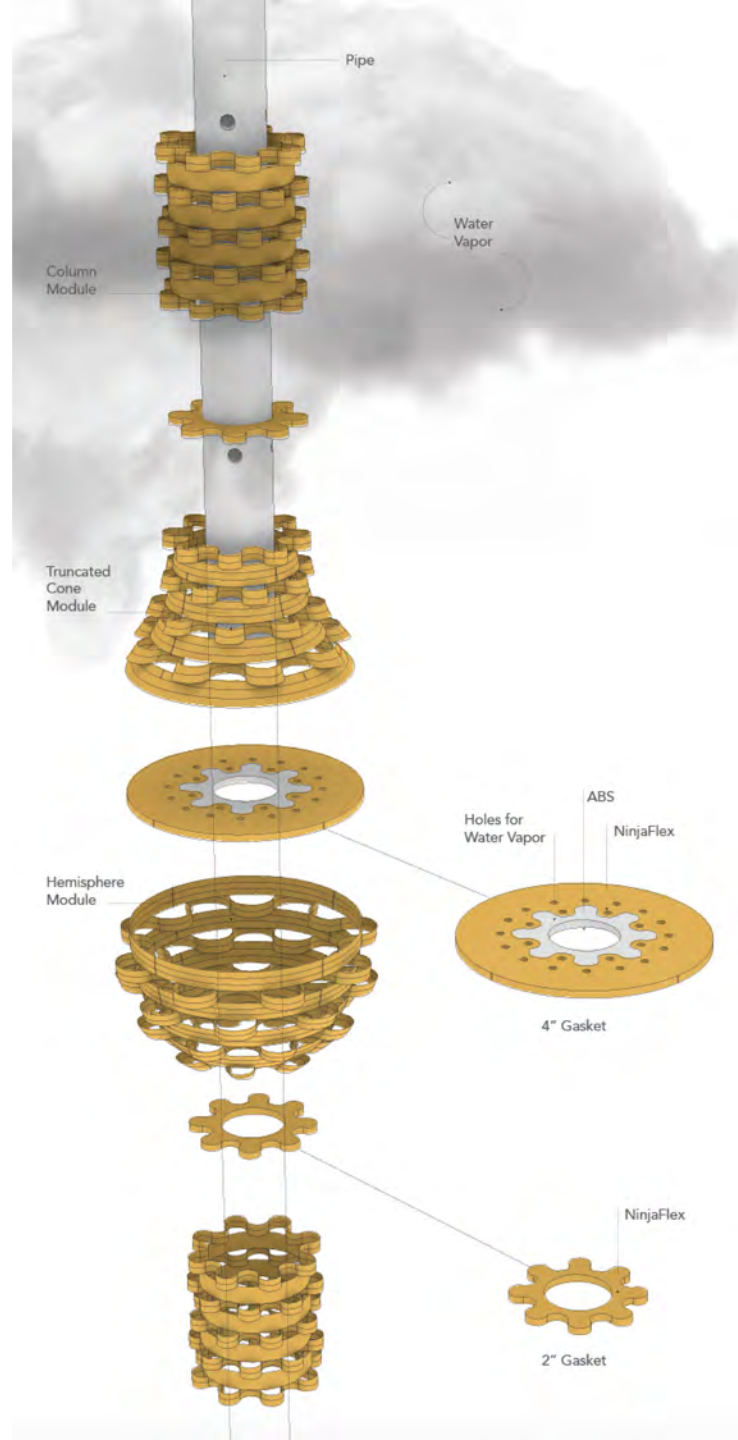
Elevation

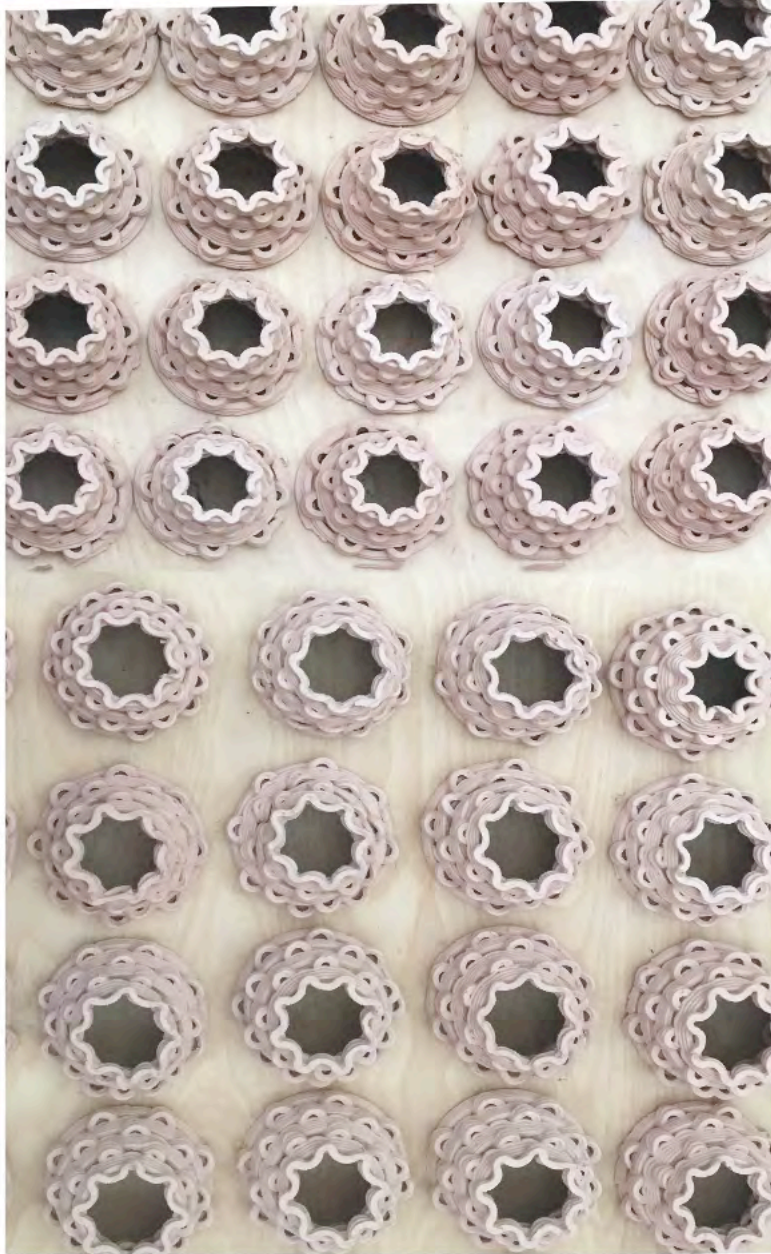


Axonometric

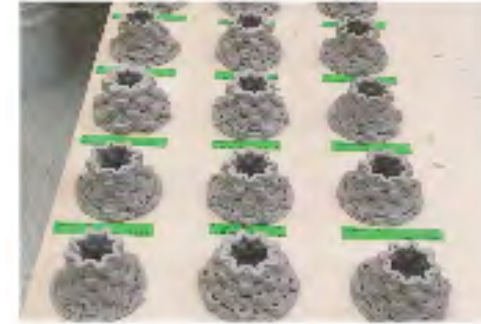








Each module was printed on a Potterbot 2.0 ceramic 3D printer and labeled for extruder speed, movement speed, layer height, and print time.



Print variables were documented and adjusted throughout the process. Upon completion, units were air-dried.



The dried units were bisque fired in a Skutt KM-1018-3 electric kiln in collaboration with the Department of Art & Visual Culture Ceramics.



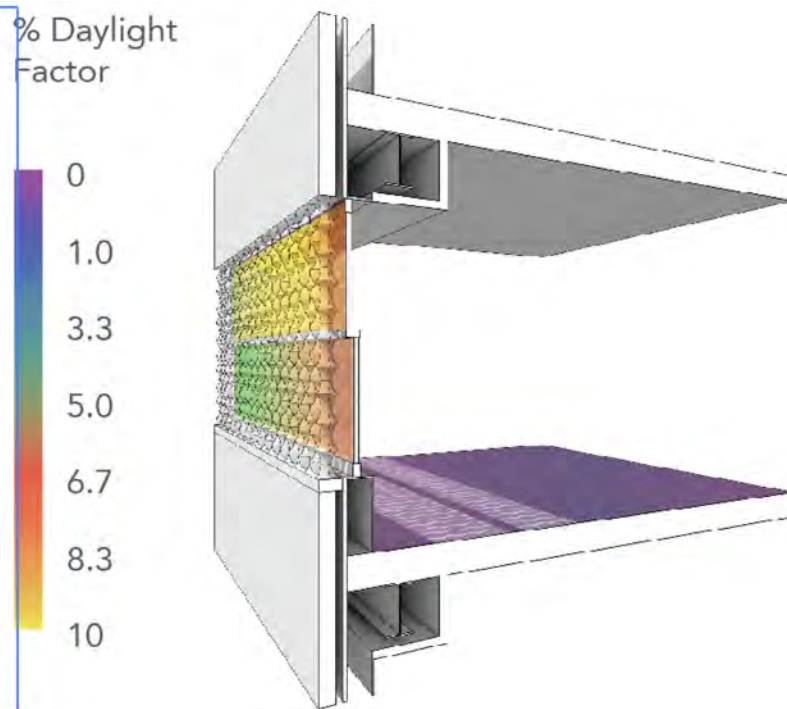
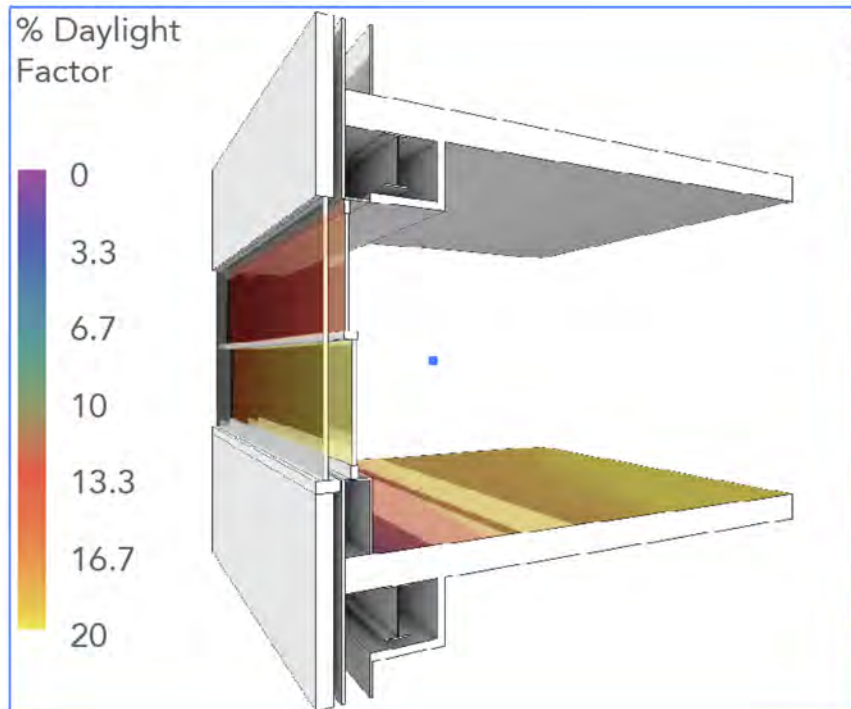
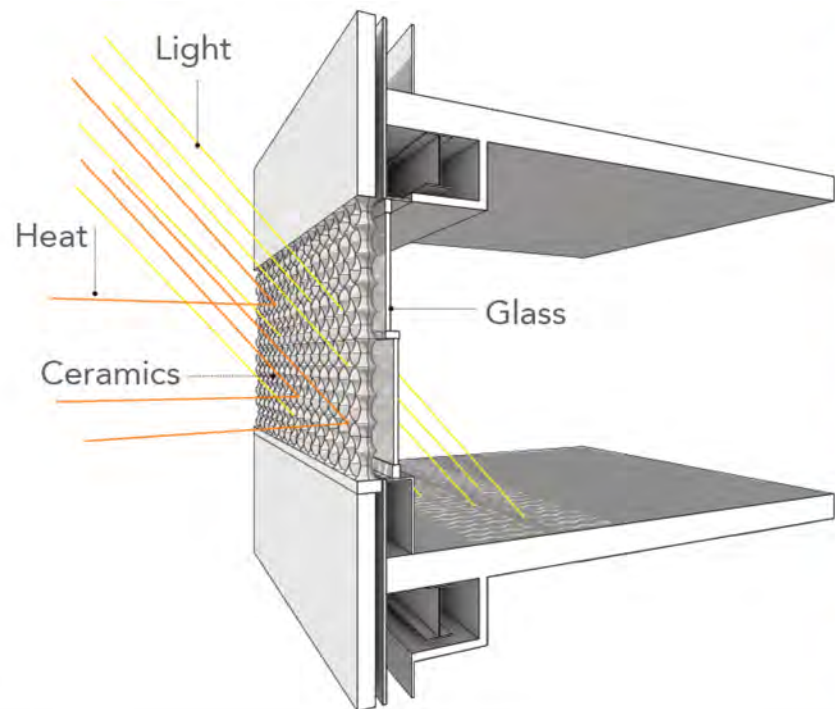
A detail photo of the micro-pores between layers of clay.

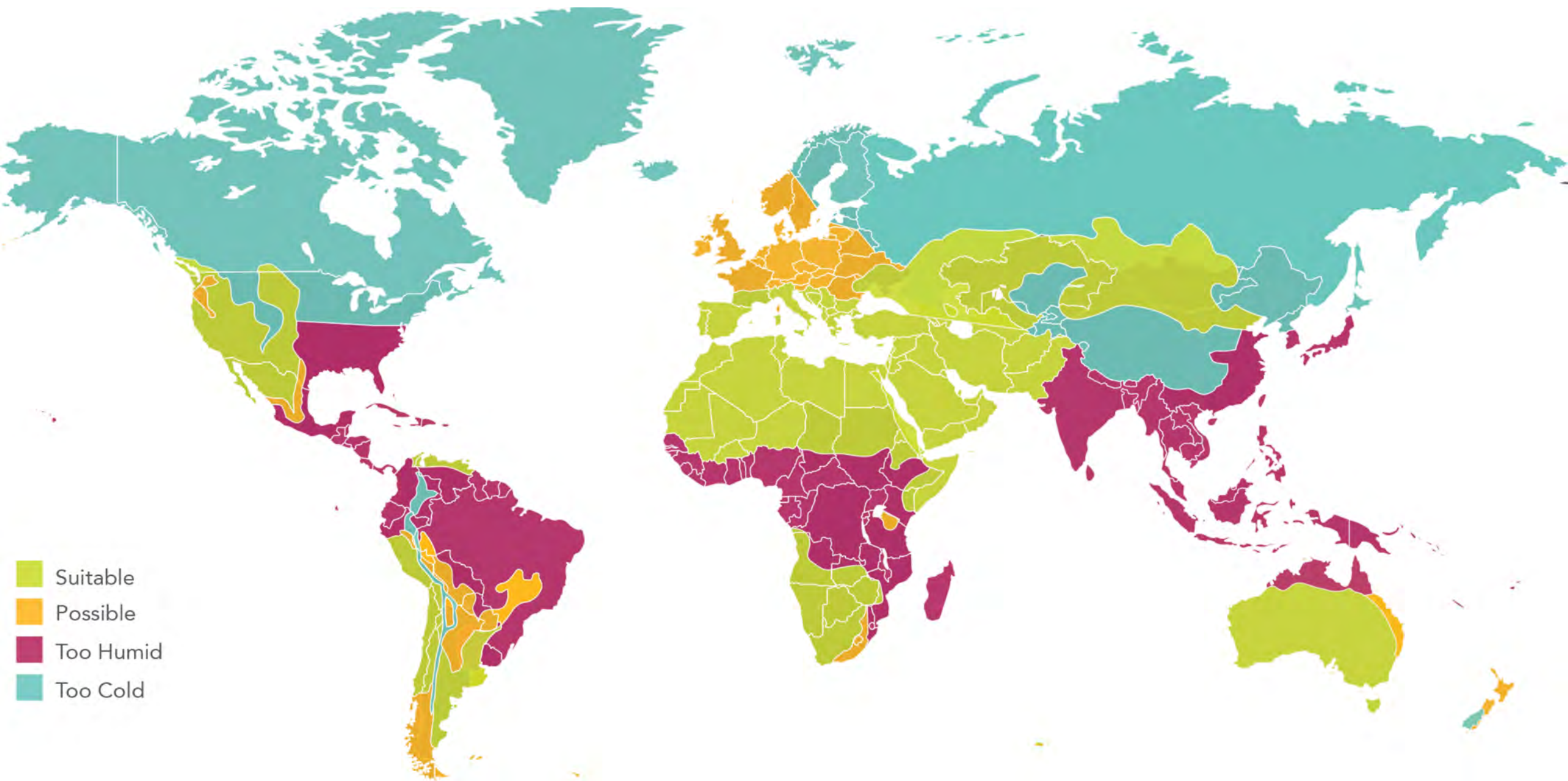


Mock-up assembly using flexible 3D printed gaskets and standard 1" PVC piping.



Mock-up shadow study.







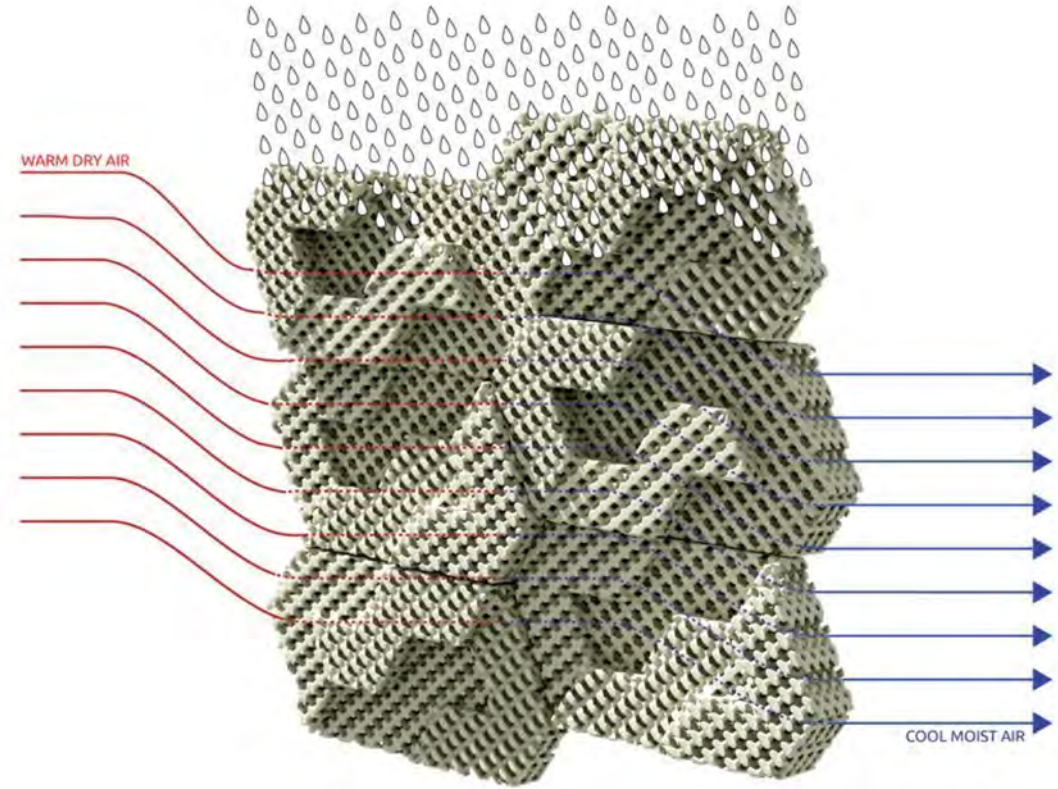
Doha Tower by Jean Nouvel – Doha, Qatar



Institut du Monde Arabe by Jean Nouvel – Paris, France

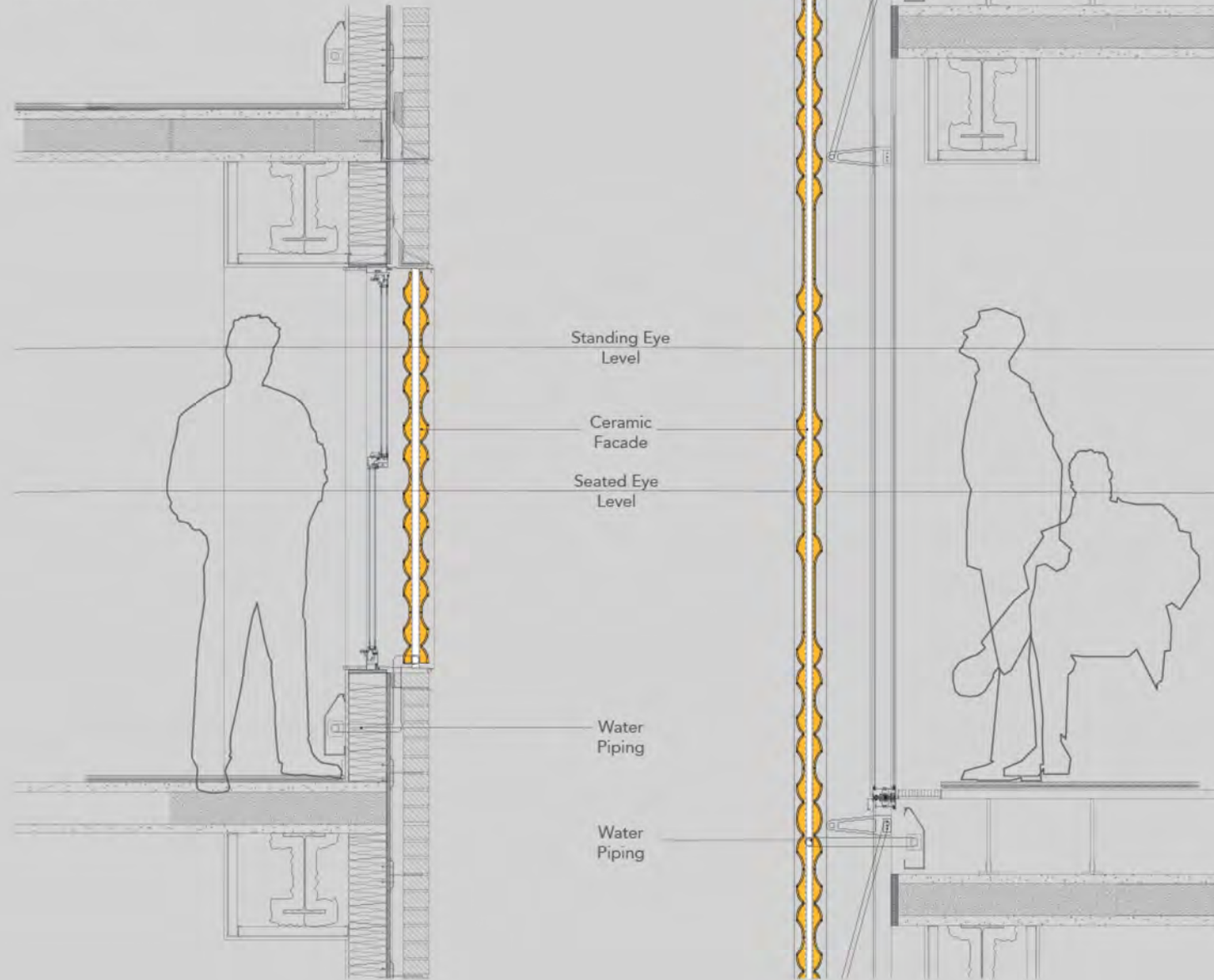


Cool Brick by Emerging Objects



At left, ceramic facade shading applied to a standard double-hung window.

At right, ceramic facade shading applied to a curtain wall section.







I'm Leslie Forehand

Architect. Designer. Educator. Creator.

THANK YOU FOR YOUR TIME!

For more info:

www.leslieforehand.com
www.ccl.design.iastate.edu

Email:

forehand@iastate.edu