National Institute of Building Sciences

Provider Number: G168

3D-Printing in the Built Environment: Today and Tomorrow

Course Number: TH2B

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BUILDING INNOVATION 2018
National Institute of BUILDING SCIENCES
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Bjorn Birgisson, PhD

TEES Distinguished Research Professor, Center for Infrastructure Renewal, Department of Civil Engineering

Research interests:

Material science and mechanics for infrastructure materials; Additive manufacturing; life cycle analysis

Zofia Rybkowski, PhD

Associate Professor, Texas A&M University Department of Construction Science

Research interests:

Sustainable construction; Serious games for lean-integrated project delivery; Self-regulated building envelopes; Additive manufacturing

Negar Kalantar, PhD

Assistant Professor, Texas A&M University Department of Architecture

Research interests:

Transformable design principles; Adaptive designs; Additive manufacturing

Manish Dixit, PhD

Assistant Professor, Texas A&M University Department of Construction Science

Research interests:

Life cycle energy modeling; Building Information Modeling (BIM); Additive manufacturing

CONTINUING EDUCATION AIA

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

3D-printing (additive manufacturing) facilitates construction of intricate and previously unexplored building forms. It also enables mass customization of design, low waste, reduced cost, increased precision, reduced time to construction, remote control of the building process, and is potentially ideal for tackling the repair and replacement of aging infrastructure, especially in times of skilled labor shortages, as has been observed in the United States. Recent milestones in additive construction (3D printing) are gaining global attention. In 2015, China unveiled the first multistory 3D-printed apartment building and mansion, and the United Arab Emirates (UAE) announced intentions to print a 2,700 SF museum in Dubai. In 2016, Amsterdam claimed creating a prototype of the world's first 3D-printed steel bridge with robots. In 2016, Spain became the first to complete construction of a 3D-printed pedestrian bridge. In 2017, the UAE revealed plans to print the first 3D-printed skyscraper, and in an article in the same year, *The Economist* discussed the first large 3D-printed commercial building, in progress in northern England. The four-member research team will speak on the current state of 3D-printing in the building industry in the U.S. and abroad, and the challenges and opportunities associated with this exciting and potentially disruptive form of innovative technology.

Learning Objectives

At the end of this course, participants will be able to:

- Identify **global challenges** in the built environment that need to be solved by 2030;
- Envision how 3D-printing offers **opportunities** to address these challenges;
- Understand the **current state** of 3D-printing in construction around the world;
- Understand the **technical capabilities** of existing 3D-printing equipment; and
- Identify **specific opportunities** where 3D-printing can be of assistance to *individual participant needs and goals**

* During an interactive exercise participants will build scenarios of the AEC industry in 2030 and envision how 3D-printing can address these concerns.

Presentation Agenda

1. **Introduction of team**
   a. Who we are as a team
   b. Pre- workshop ”quiz”
   c. Why we are interested in 3D-printing→Opportunity to solve specific global challenges
2. Overview of 3D-printing in the built environment around the world
3. Current state of 3D-printing equipment & examples of what each can do
4. Where TAMU is going with respect to 3D printing
   a. Center for Infrastructure Renewal
   b. NSF workshop on 3D-printing, summer 2017
   c. CIR brainstorming retreat
   d. Post-workshop ”quiz”

Why we are here?

- Create a consortium for leadership in 3-D printing
- Create a forum for dialogue
- Seek collaboration & resources
- We see an opportunity for industry

How we plan to conduct this workshop?

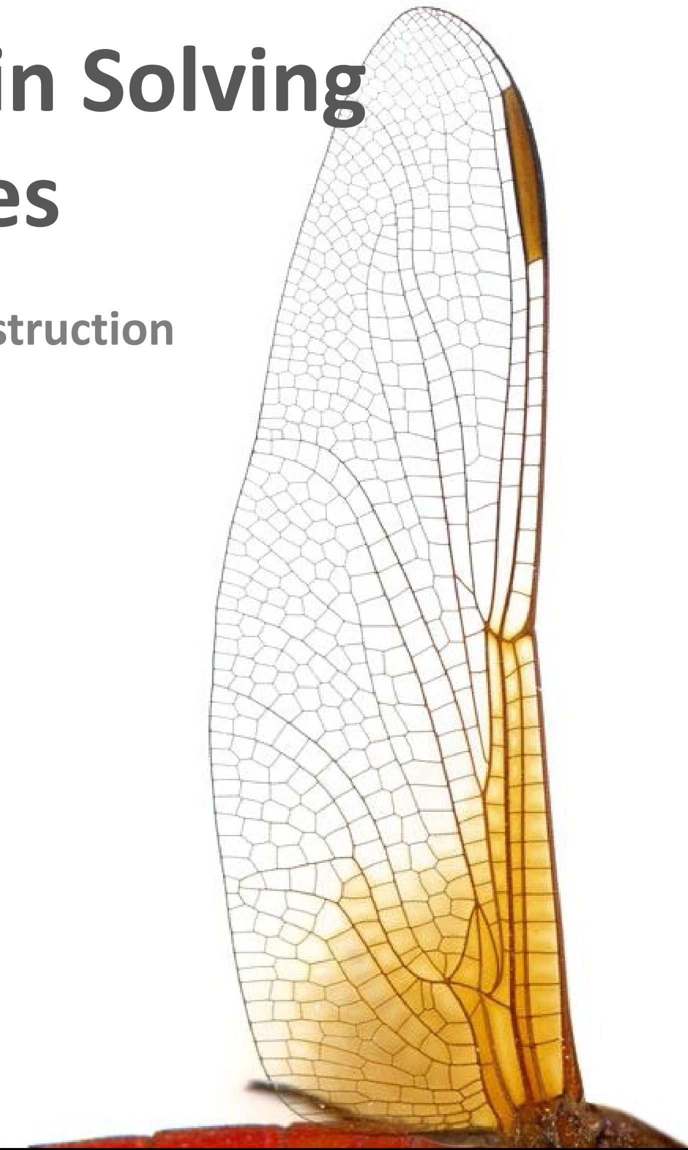
- Pose a workshop question
- Go through the following four sessions, each connected to the five learning objectives:
  - Global challenges & opportunities
  - Overview of 3D-printing in the built environment around the world
  - Current state of 3D-printing equipment & examples of what each can do
  - Interactive participatory exercise
  - Where TAMU is going with respect to 3D printing
- Revisit the workshop question

Workshop Question

- How is 3-D printing technology going to affect you and your business?

The Role of 3D Printing in Solving Global Challenges

Designing & Printing for Sustainable Construction



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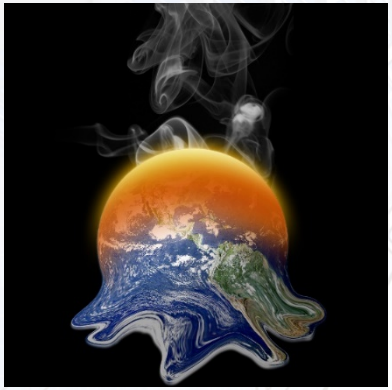
Global Challenges



Climate Change

- Sea level rise
- Radical weather
- Natural disasters

Resource Depletion

- Food security
- Raw material
- Energy & water
- Workforce

Economic Crisis

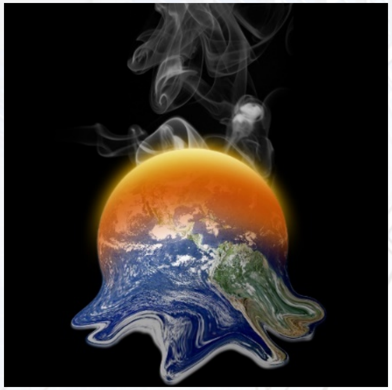
- Profit
- Efficiency
- Value
- Ethics

Quality of Life

- Health
- Comfort & safety
- Personal control

IMAGE CREDITS: https://www.flickr.com/photos/102642344@N02/10080584183; https://pixabay.com/en/workers-construction-site-hardhats-659885; https://pixabay.com/en/financial-crisis-stock-exchange-544944/; https://pixabay.com/en/field-commitment-determination-839827/

Global Challenges



Climate Change

Resource Depletion

Economic Crisis

Quality of Life

PEOPLE

PLANET

PROSPERITY

IMAGE CREDITS: https://pixabay.com/en/human-observer-exhibition-2944064/; https://pixabay.com/en/earth-blue-planet-globe-planet-11015/; https://pixabay.com/en/cash-money-wealth-assets-1169650/

Global Challenges

SUSTAINABILITY

Climate Change

Resource Depletion

Economic Crisis

Quality of Life

PEOPLE

PLANET

PROSPERITY

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Global Challenges

SUSTAINABLE CONSTRUCTION

To enhance the three dimensions of sustainability

Climate Change

Resource Depletion

Economic Crisis

Quality of Life

PEOPLE

PLANET

PROSPERITY

CONTINUING EDUCATION AIA

How to define sustainable construction ?

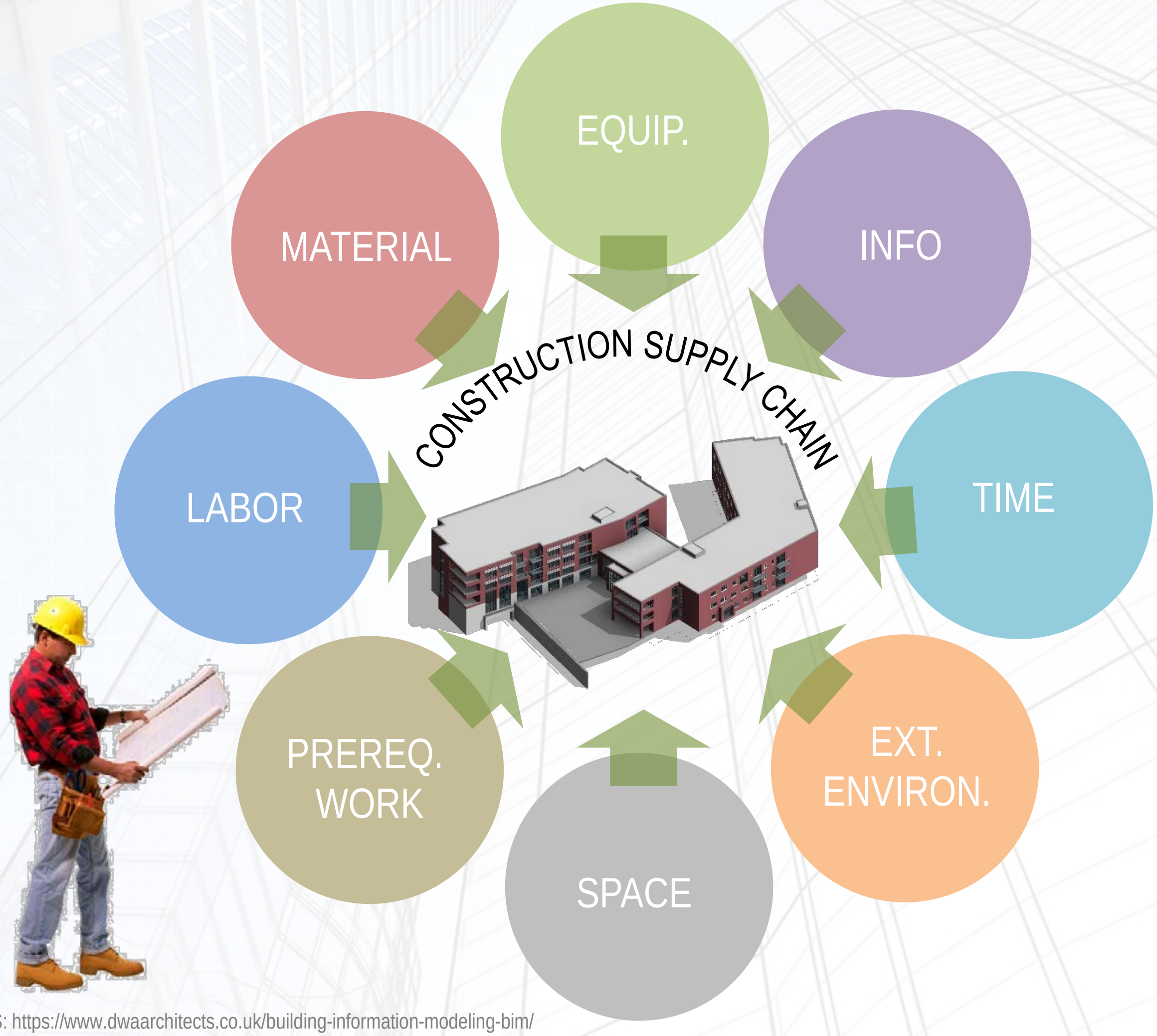
- Using construction resources to enhance
  - profitability,
  - environmental quality, and
  - health & safety of workforce

  of construction supply chain

What resources are used in construction supply chain ?

IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

What resources are used in construction supply chain ?



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How 3-D printing helps make supply chain sustainable?

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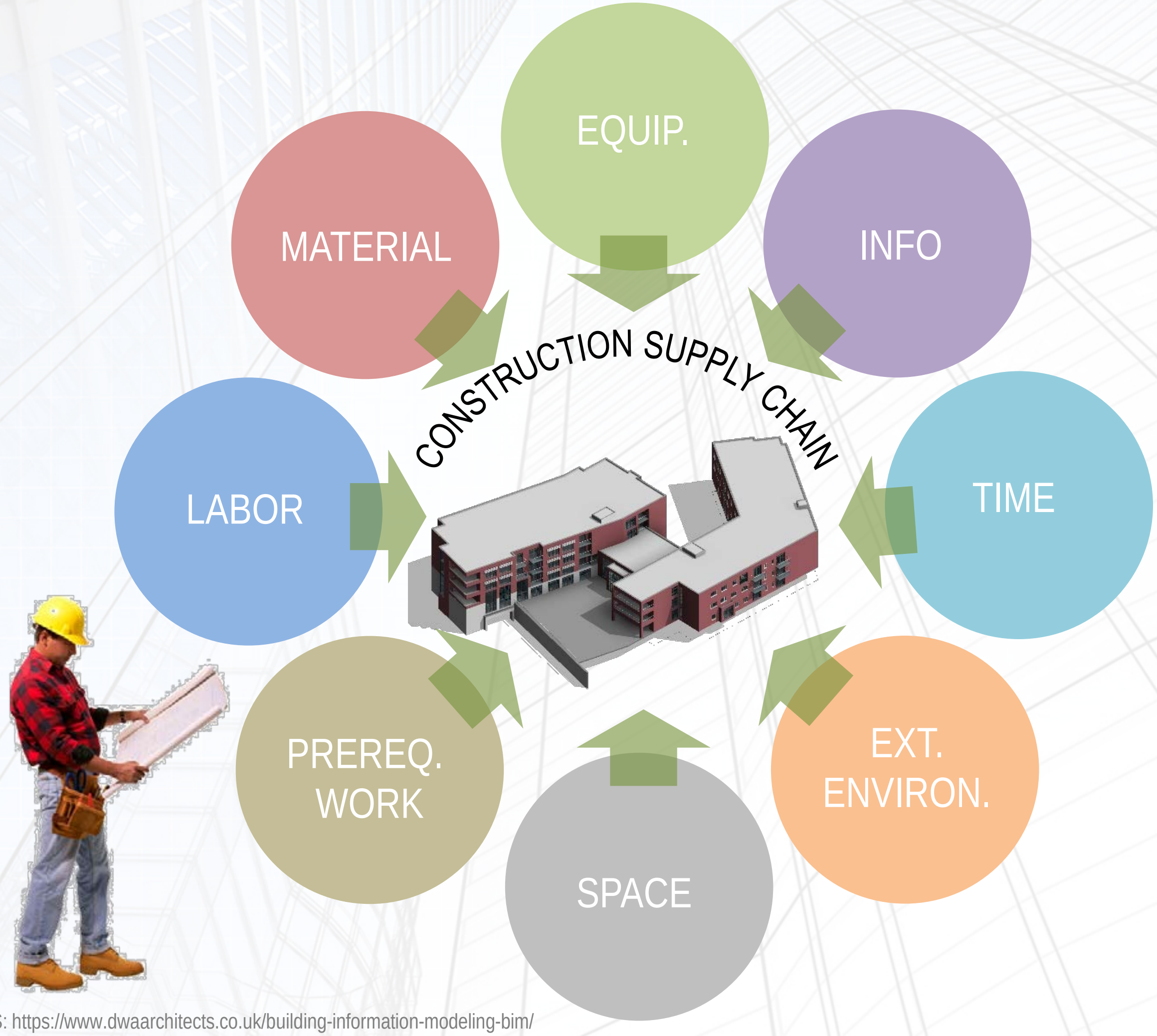


IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

How 3-D printing helps make supply chain sustainable?

Labor shortages in craft workers eased; unsafe activities could be accomplished by 3D-printing

[redacted]

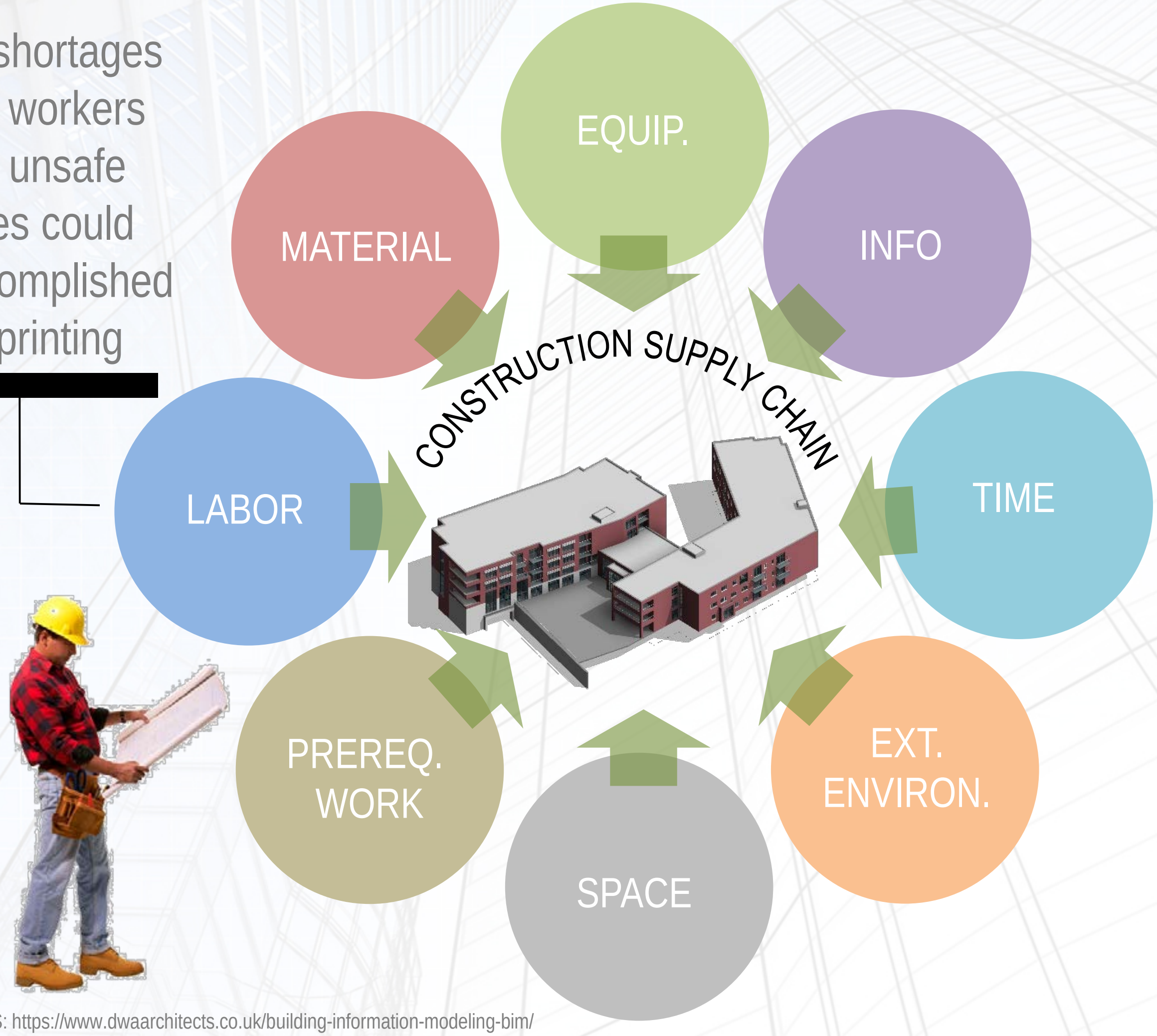
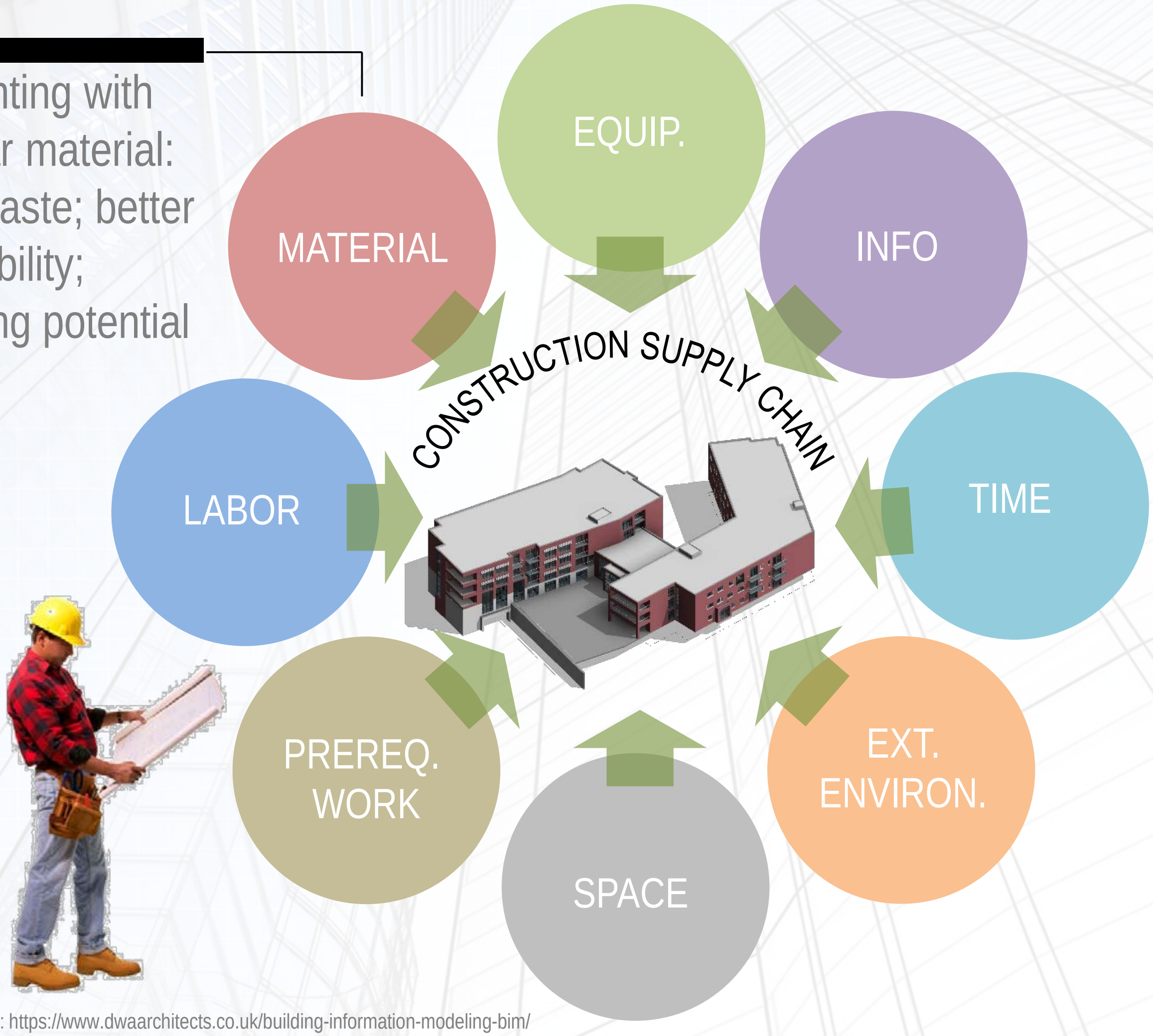


IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

How 3-D printing helps make supply chain sustainable?

[redacted]

3D-Printing with singular material: Less waste; better adaptability; recycling potential



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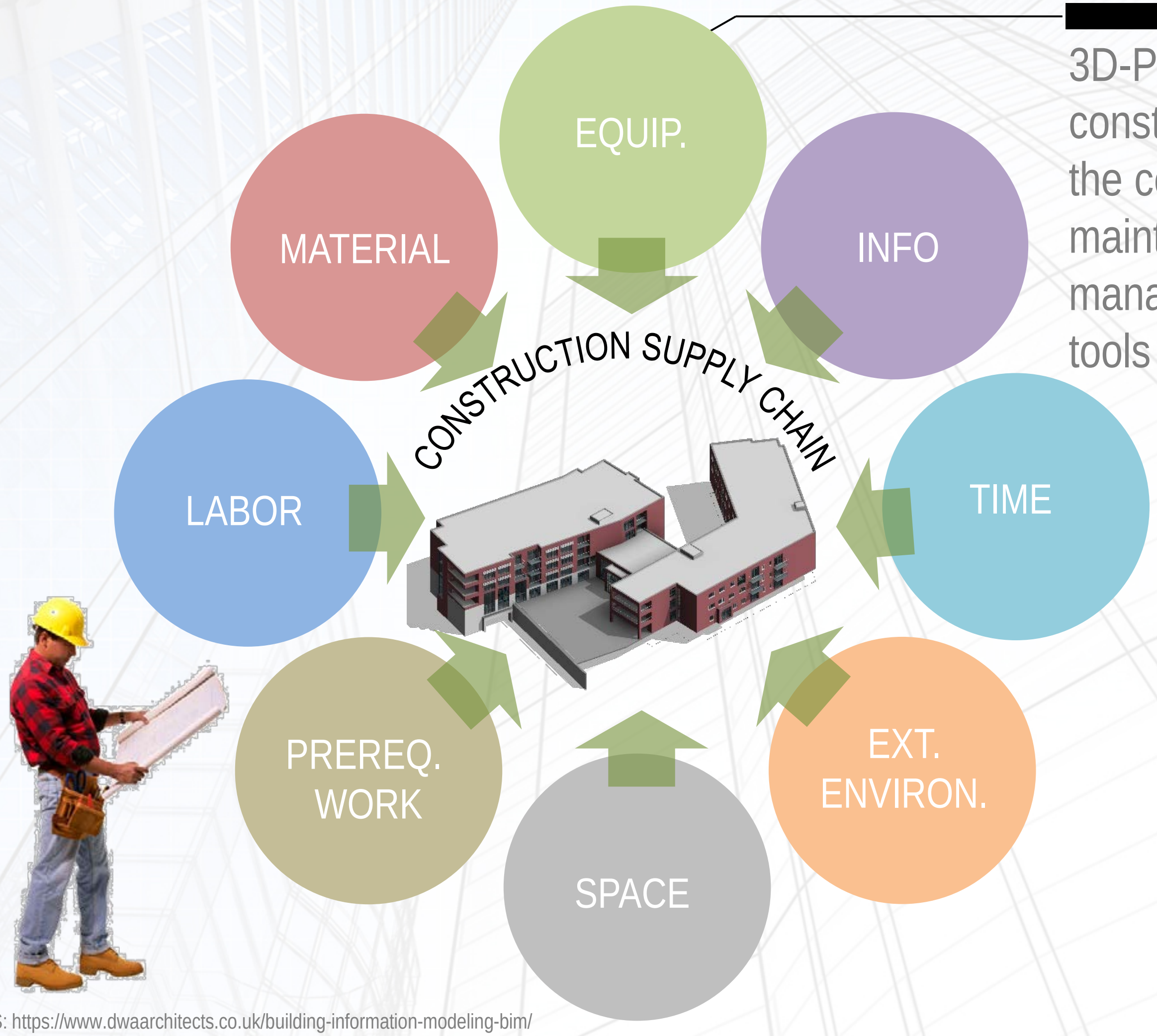
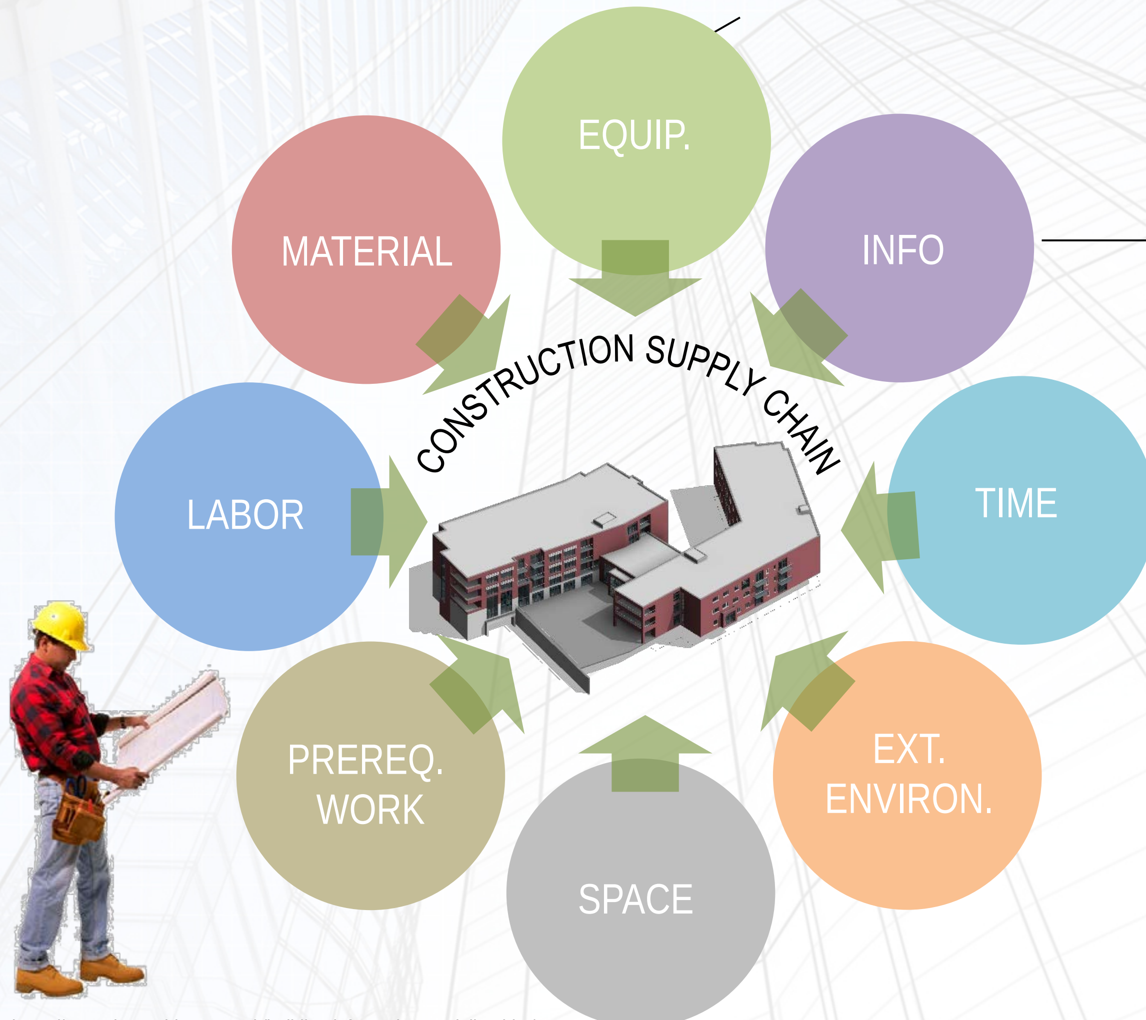


3D-Printing can simplify construction by reducing the cost of buying, maintaining, and managing numerous tools & equipment

IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

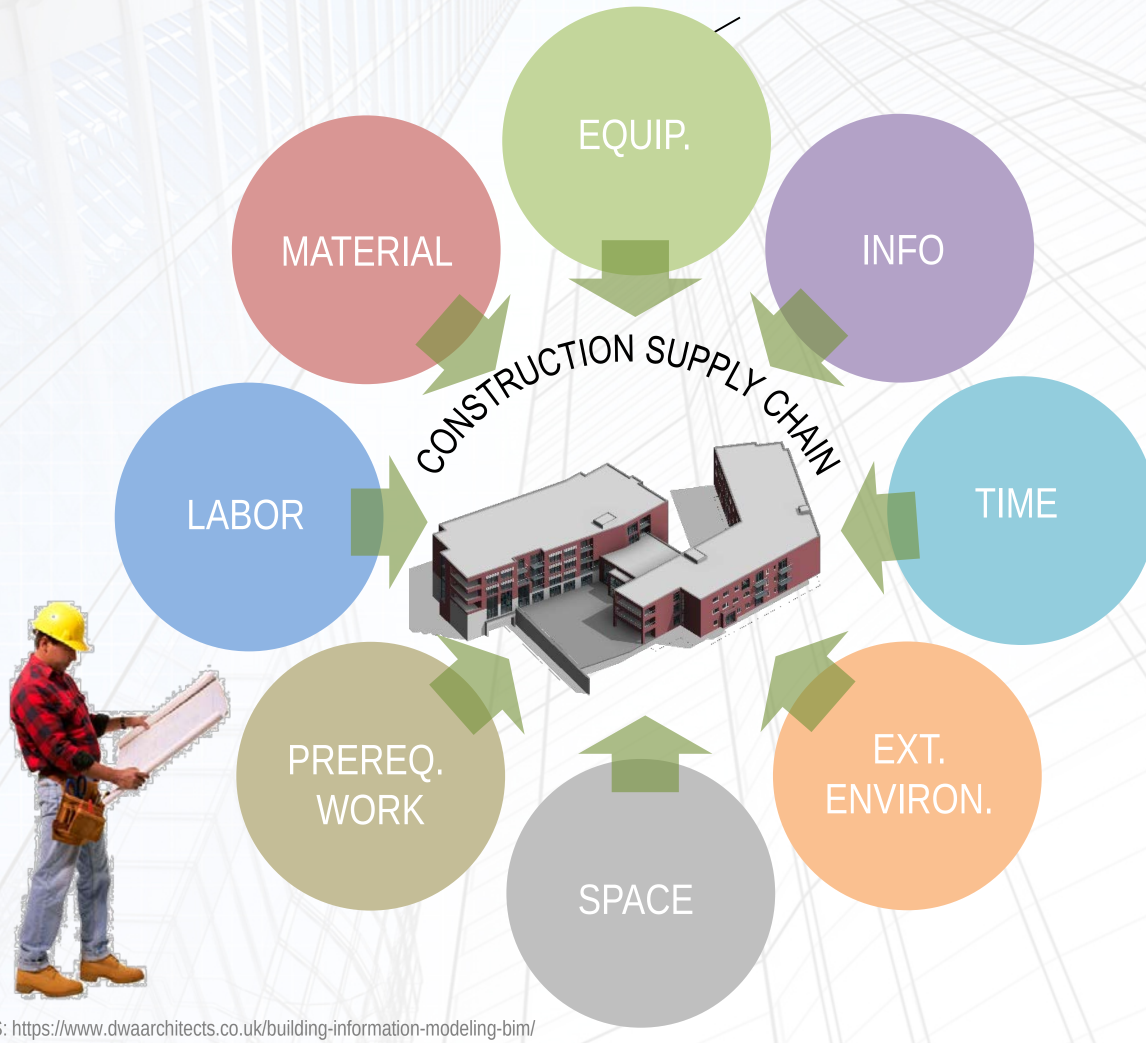
How 3-D printing helps make supply chain sustainable?



3D printing's digitalization of information: Improved accuracy; less error & rework; less or no paperwork.

IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

How 3-D printing helps make supply chain sustainable?



3D-Printing could reduce the time needed to negotiate multiple contracts and manage construction due to automation

[redacted]

IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

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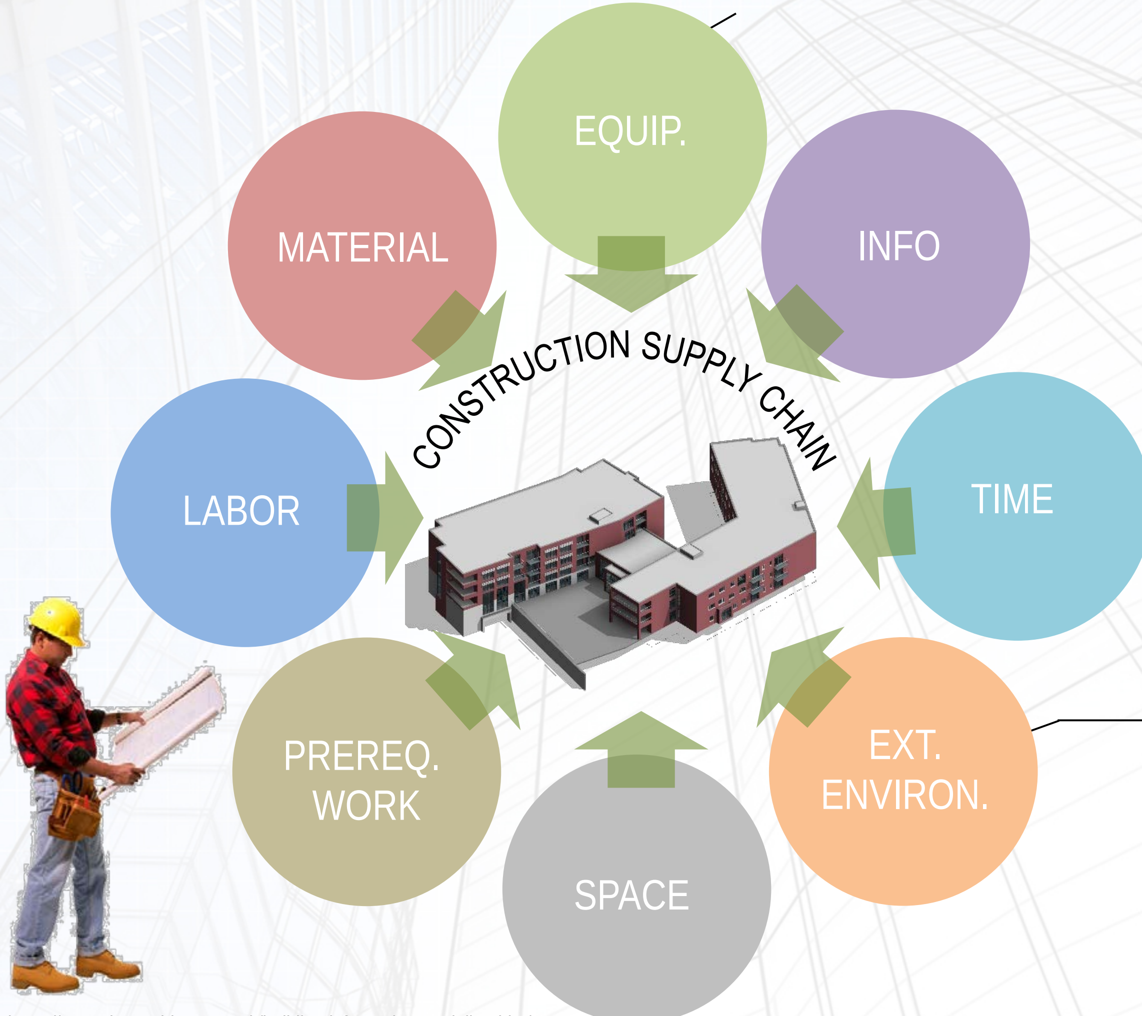

3D printing: Less environmental constraints; construction in difficult locations or conditions (i.e. arctic cold, planet Mars, ebola virus outbreak locations).

[redacted]

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IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

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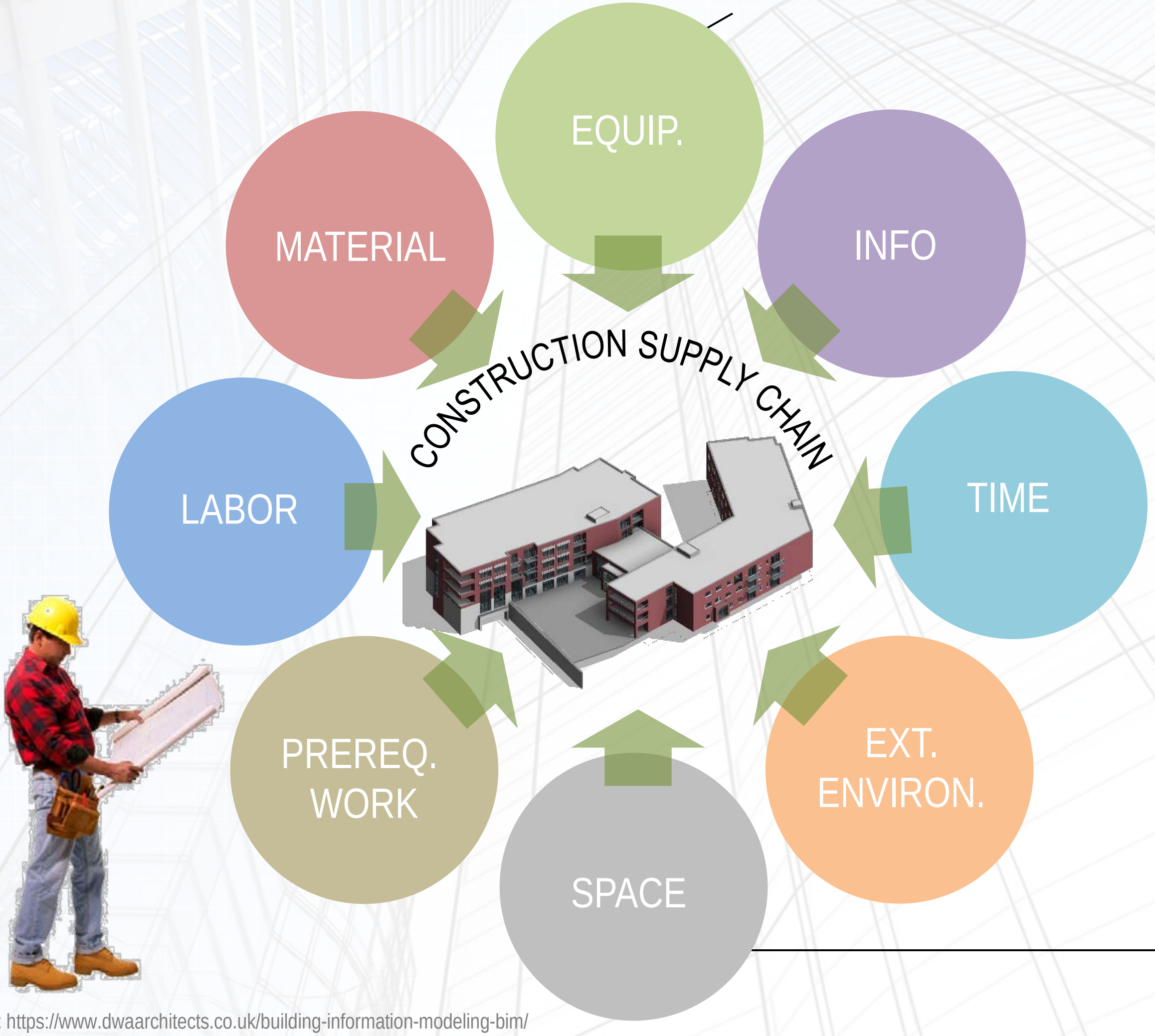
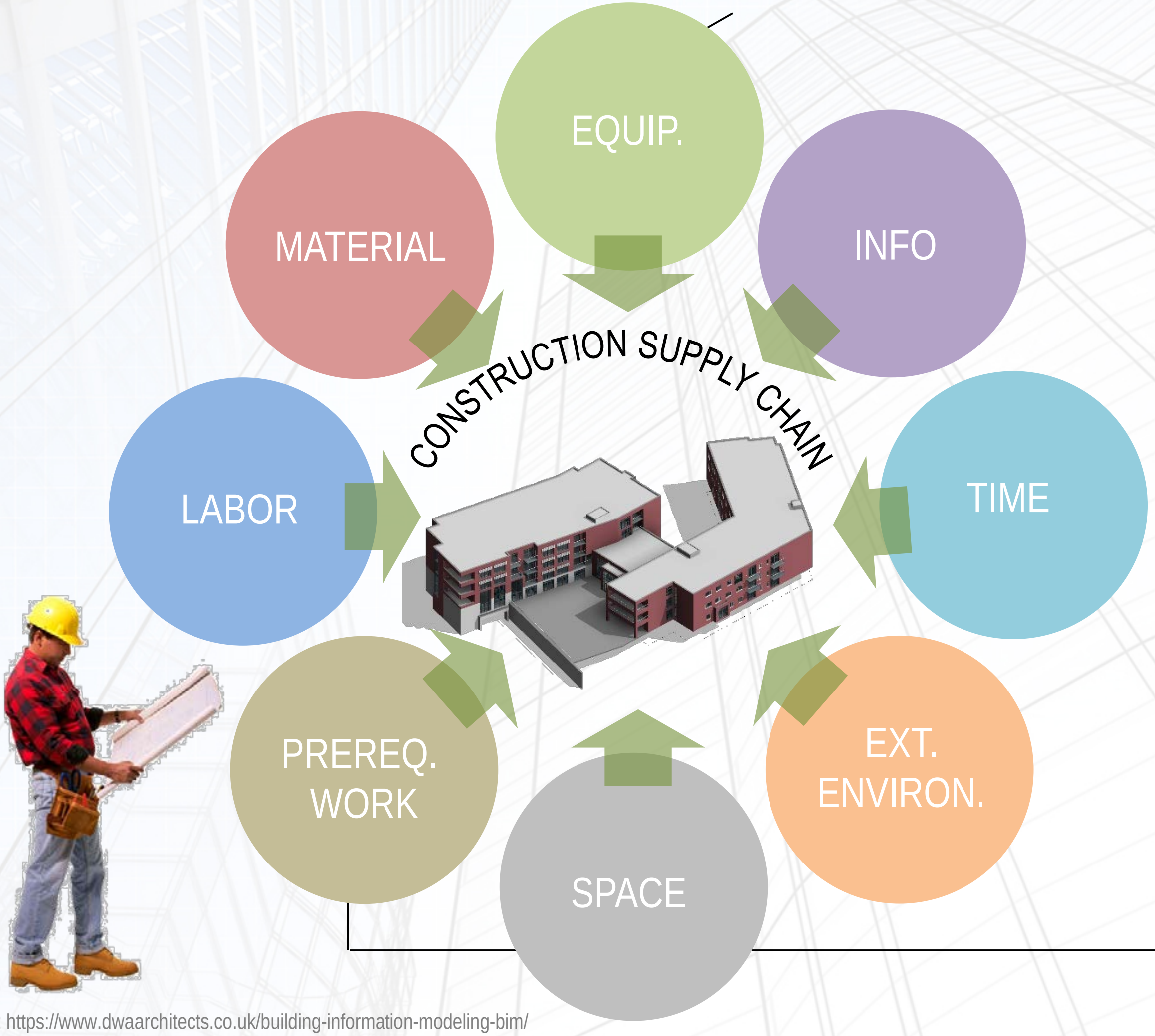


3D-Printing could simplify laydown areas; reduce the need for secured storage facilities maintained by multiple specialty contractors.

IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

How 3-D printing helps make supply chain sustainable?



3D-printing from a common digital model would enhance coordination of dimensions, etc. with pre-requisite work
so there is less rework.

IMAGE CREDITS: https://www.dwaarchitects.co.uk/building-information-modeling-bim/

What are the key challenges?

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- Material
  - Multi-dimensional & dynamic properties
  - Locally available, natural & renewable
  - Intelligent & adaptive

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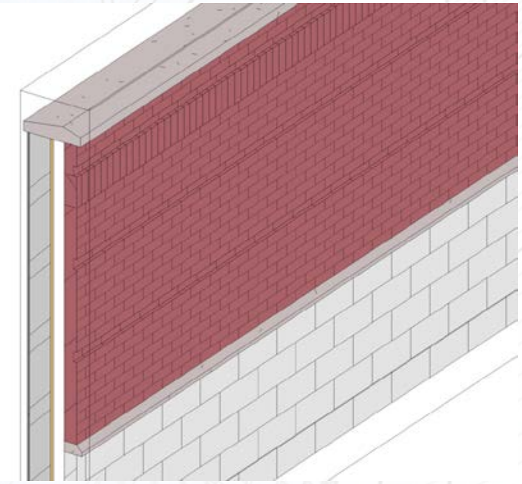

IMAGE CREDITS: Autodesk Revit sample

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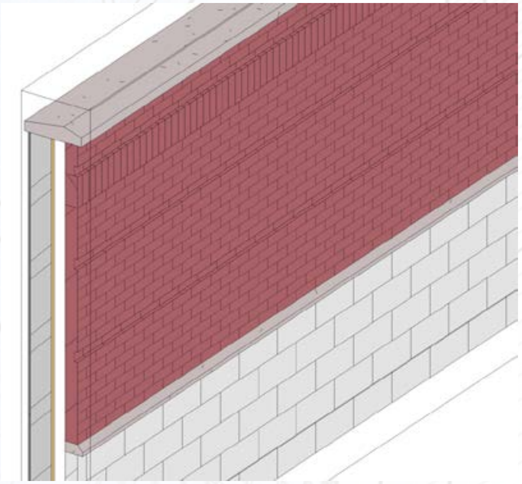

IMAGE CREDITS: https://pixabay.com/en/poison-ivy-on-stone-wall-plant-2219689/

What are the key challenges?

- Material
  - Multi-dimensional & dynamic properties
  - Locally available, natural & renewable
  - Intelligent & adaptive
- Technology
  - Hardware, 3-D printing technology
  - Software, interoperability with other tools

IMAGE CREDITS: arch2o-25-of-dubai-buildings-will-be-3d-; http://money.cnn.com/2017/05/02/technology/3d-printed-building-mit/index.html; https://3druck.com/gastbeitraege/shanghai-10-haeuser-aus-dem-3d-drucker-innerhalb-eines-tages-2616651/

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  - Building design compatible with 3-D printing technology
  - Adaptive & biomimetic designs
  - Customization & social acceptance
  - Regulatory/compliance issues

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IMAGE CREDITS: eluxemagazine.com; es.paperblog.com

What are the key challenges?

- Building Design
  - Building design compatible with 3-D printing technology
  - Adaptive & biomimetic designs
  - Customization & social acceptance
  - Regulatory/compliance issues
- Education
  - Teaching & training future workforce
  - Occupant awareness

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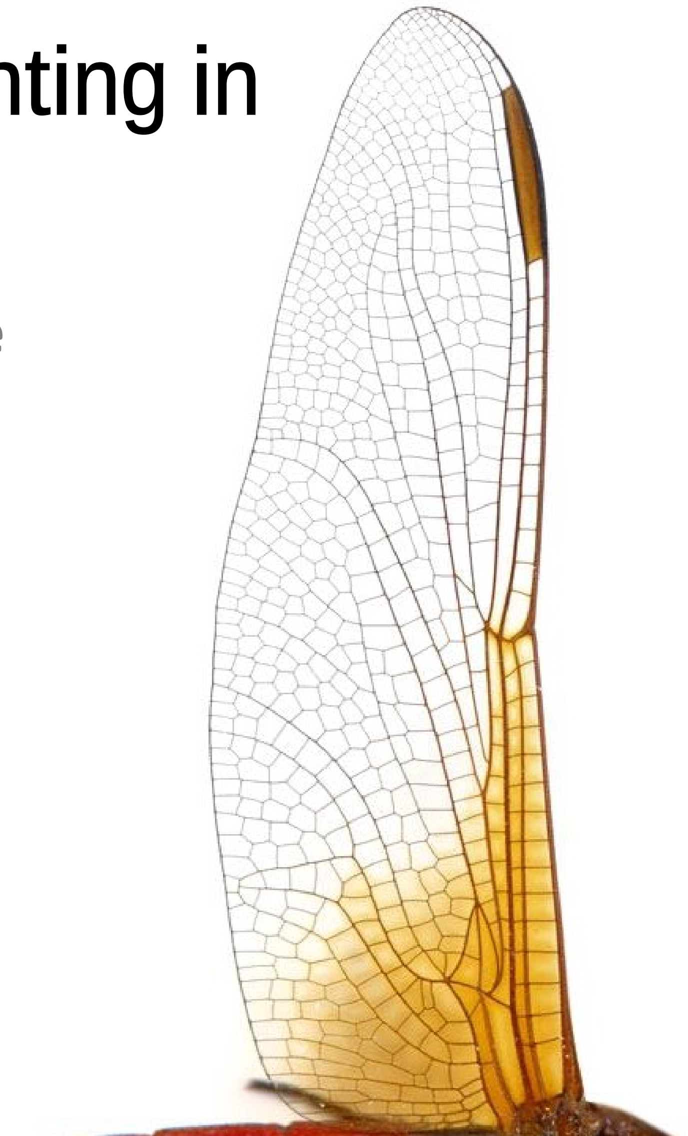
current state of 3D-printing in construction

A Global Perspective



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A Global Perspective

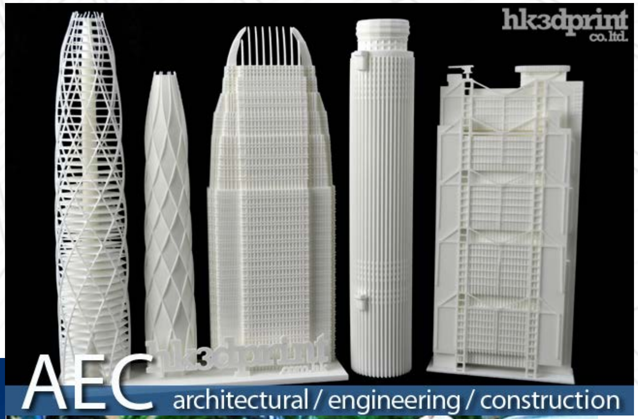
- Additive manufacturing (AM) is the process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtracting manufacturing and formative manufacturing technologies

- Worldwide, since inception in the late 1980’s, AM industry has grown into a $5.165 billion industry in 2015.

- Applications of AM technology include:
  - Aerospace (17%)
  - Industrial/business machines (20%)
  - Motor vehicles (14%)
  - Consumer products/electronics (13%)
  - Medical sectors (12%)
  - Architectural industry (2.1%)

Current 3D printing practice in other industries

- In 2012, 3D printing market was $777 million in sales,
- with predicted 18% annual growth,
- predictions for 2025 are $8.4 billion in sales.
- The auto, aerospace and medical industries are 84% of that market



Europe-America

MAIN TRENDS QUOTED OF EUROPE - AMERICA

90% OF RESPONDENTS FROM AMERICA AND EUROPE CONSIDER 3D PRINTING AS COMPETITIVE ADVANTAGE

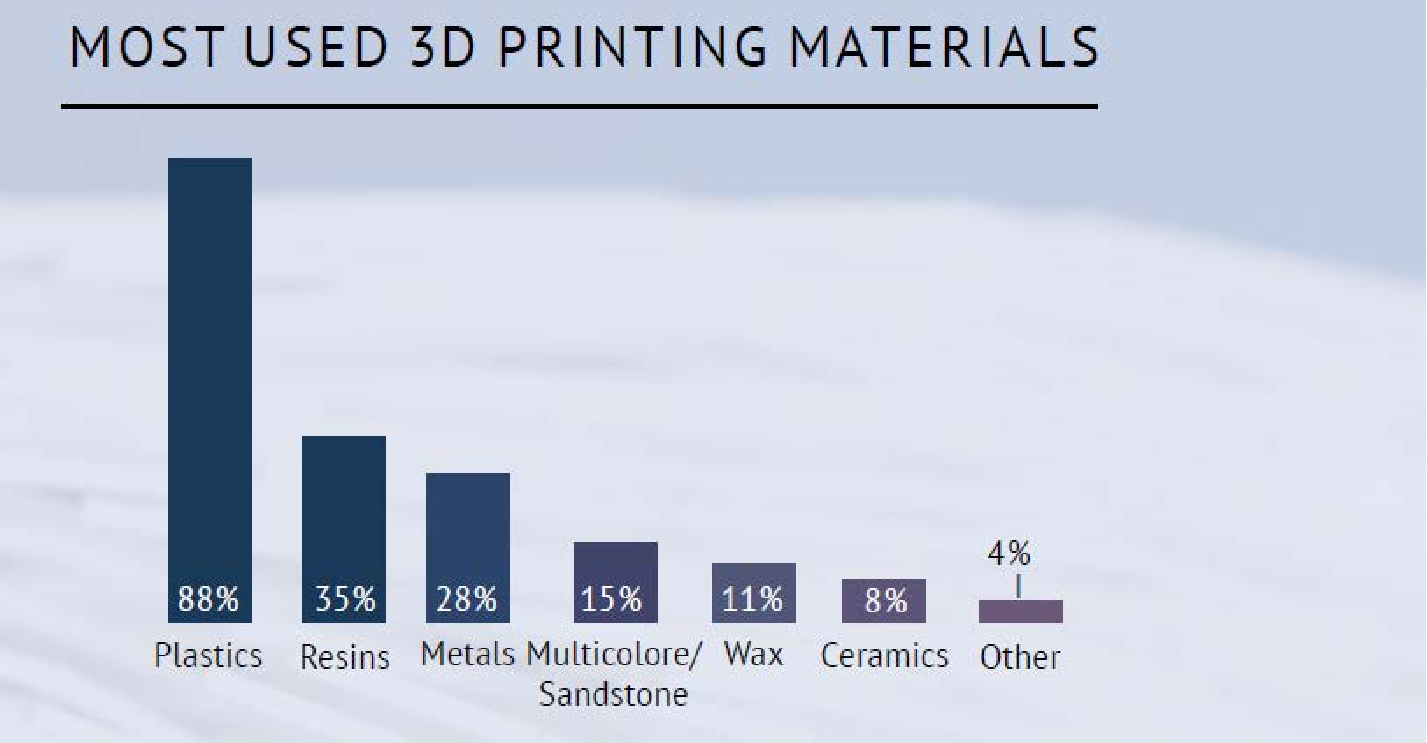
69% EUROPEANS + **59%** AMERICANS ARE SKILLED 3D PRINTING USERS

TOP MATERIALS USED

	EUROPEANS	AMERICANS
Plastic	75%	69%
Metal	23%	23%
Resin	29%	30%

Reference: Sculpteo - The state of 3D printing, 2017

Most Used Materials



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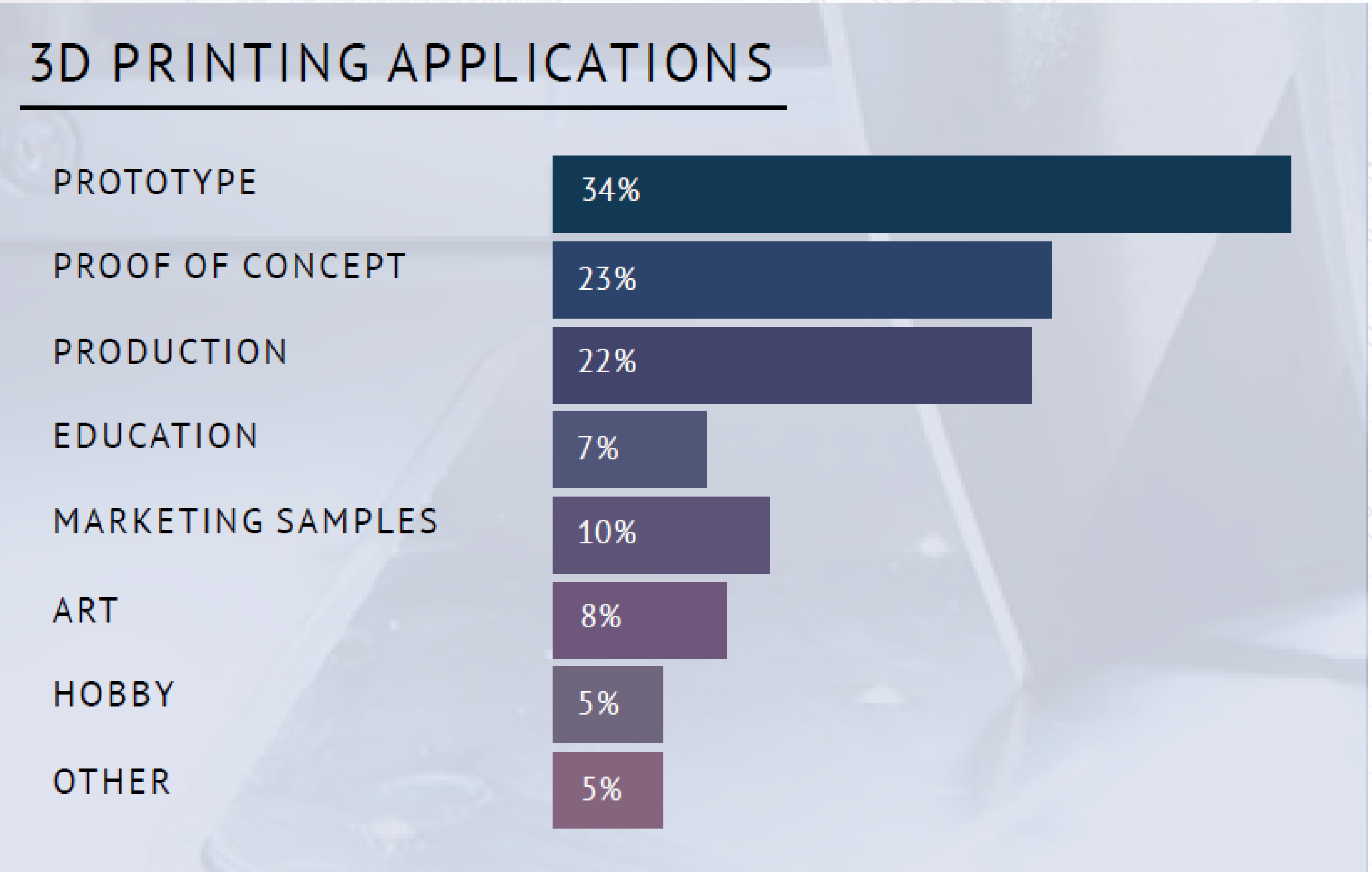
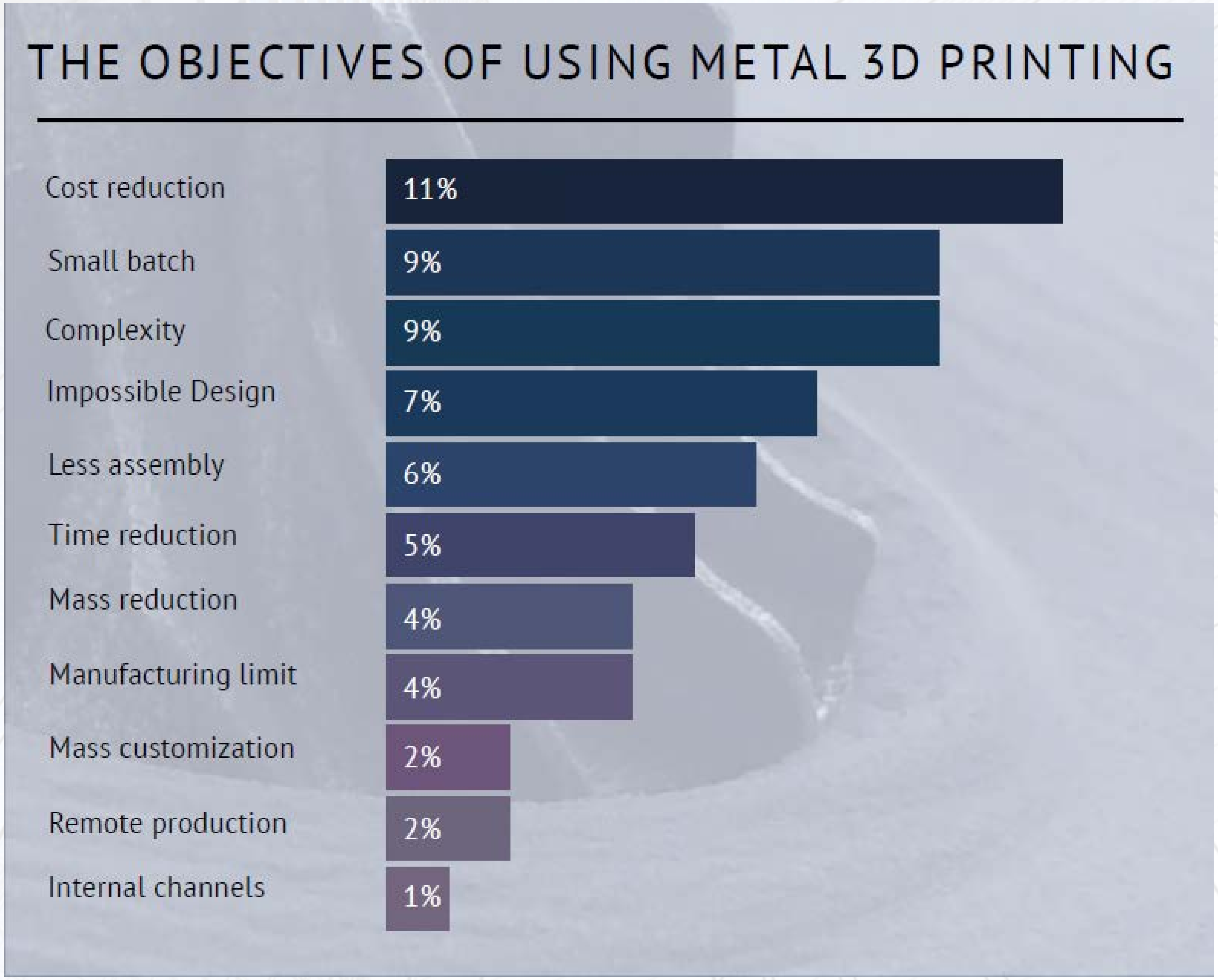
Most Common Application Areas



Reference: Sculpteo - The state of 3D printing, 2017

Objectives with 3D Printing



Reference: Sculpteo - The state of 3D printing, 2017

Sculteo: The State of 3D Printing, 2017

47%
OF OUR RESPONDENTS SAW GREATER RETURN ON INVESTMENT THAN LAST YEAR

3D Printing is showing positive results for companies that use it consistently, delivering an increasing Return on Investment over the years. Our respondents consider this technology a vital part of their business operations.

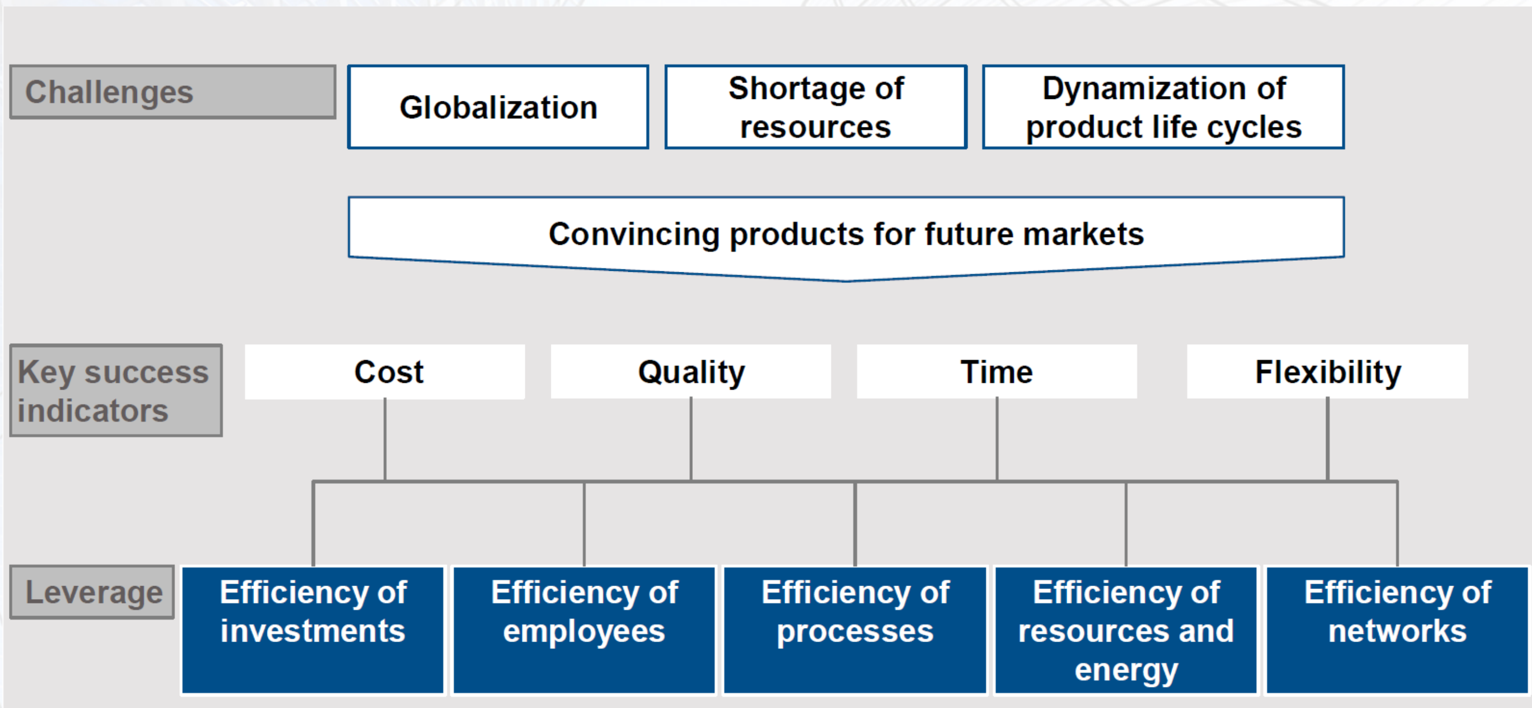
EXPENSES IN 3D PRINTING ARE EXPECTED TO RISE
55% **THIS YEAR**

Respondents expect their investment in 3D Printing to strongly increase this year. The market for additive manufacturing is growing, and growing rapidly.

COST DECLINE
WILL HAVE A MAJOR IMPACT ON 3D PRINTING

Respondents said the declining cost of the technology will have the biggest impact on the continued use and growth of 3D Printing over the next few years.

Benefits & Opportunities for Increasing Efficiency



Specific Benefits to the Building Industry

- Greater design freedom and system integration
- Reduction of material interfaces
- Additional functionalities into structures
  - Custom parts
- Structure as a homogeneous unit
- Better internal and external finishes
- Less human factor related problems due to automation

Typical metrics of success

morale
morale
morale
morale
morale
morale
morale
morale
morale
morale

time

quality

morale
morale
morale
morale
morale
morale
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morale
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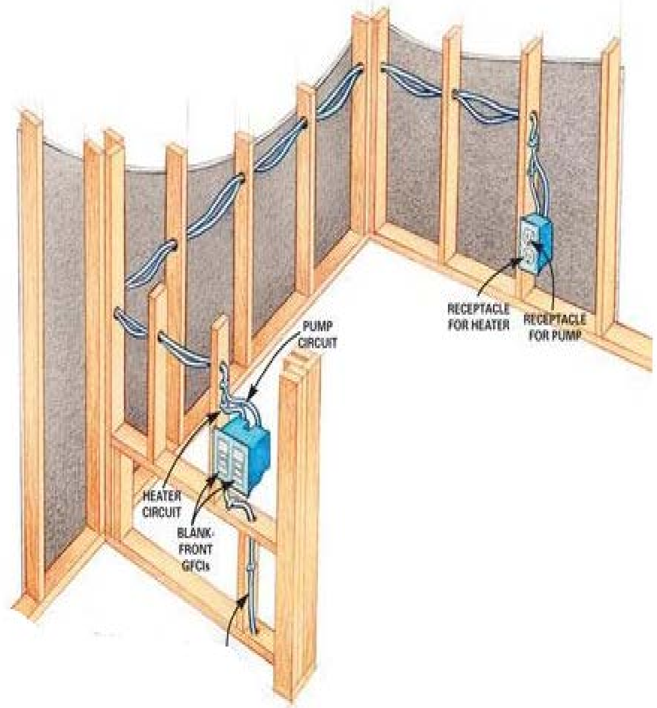
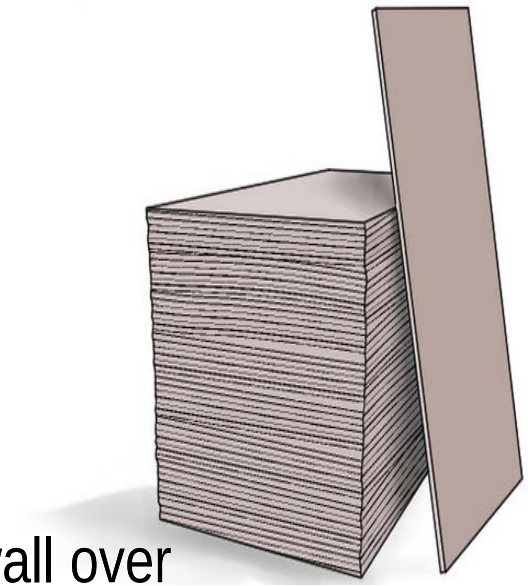
morale
morale

Photo source: http://c12solutions.com/blog1/sustainability-green-business-models-fdu/

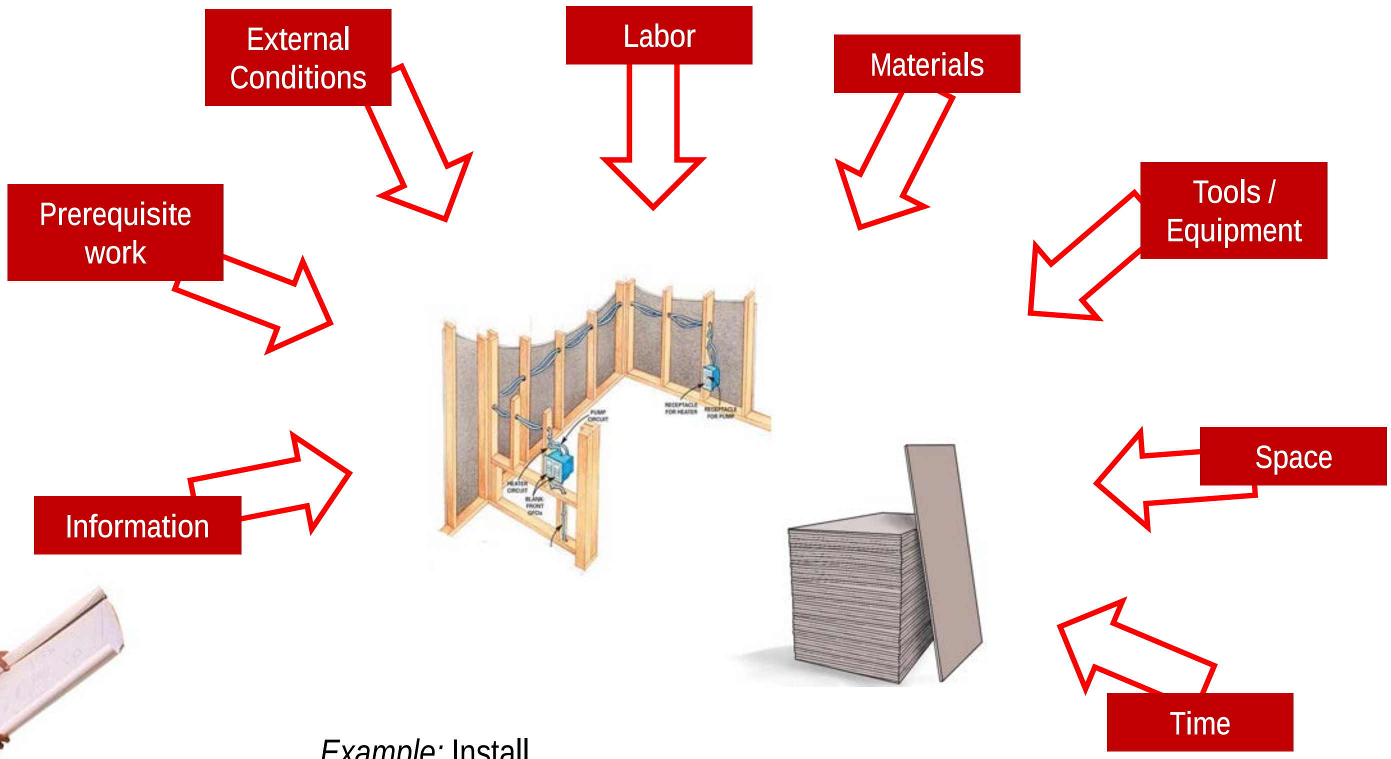




Example task: Install drywall over roughed-in studwall frame

Image sources: Handyman: http://www.ceh18.com/2015/08/hiring-an-electrician-during-your-bathroom-remodel/
Wonkee Donkee tools: https://www.wonkeedonkeetools.co.uk/drywall-t-square/what-is-plasterboard
Touch Wood Constructions: http://touchwoodconstructions.com.au/category/cID/20

Eight (8) RESOURCES needed to complete a task



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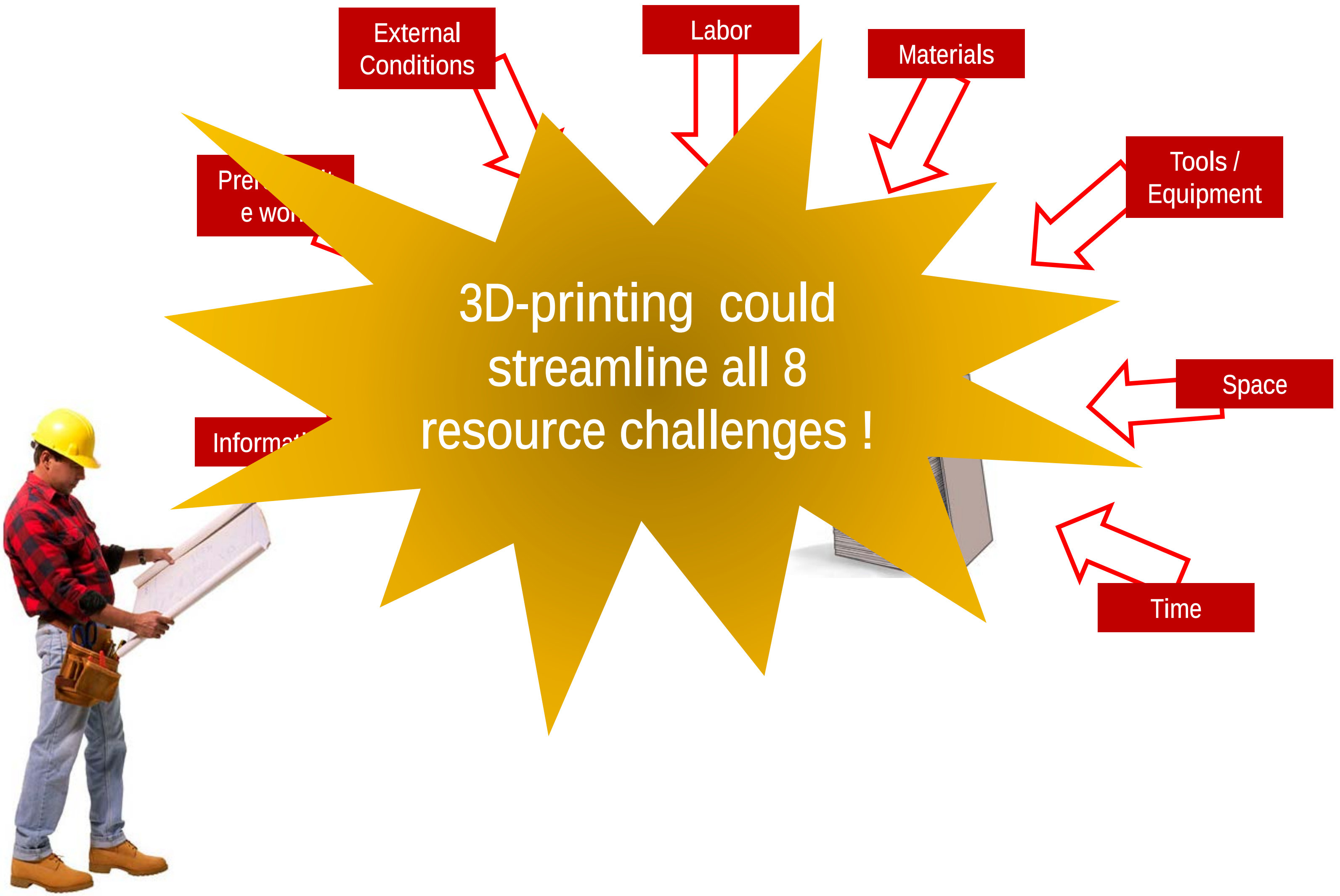
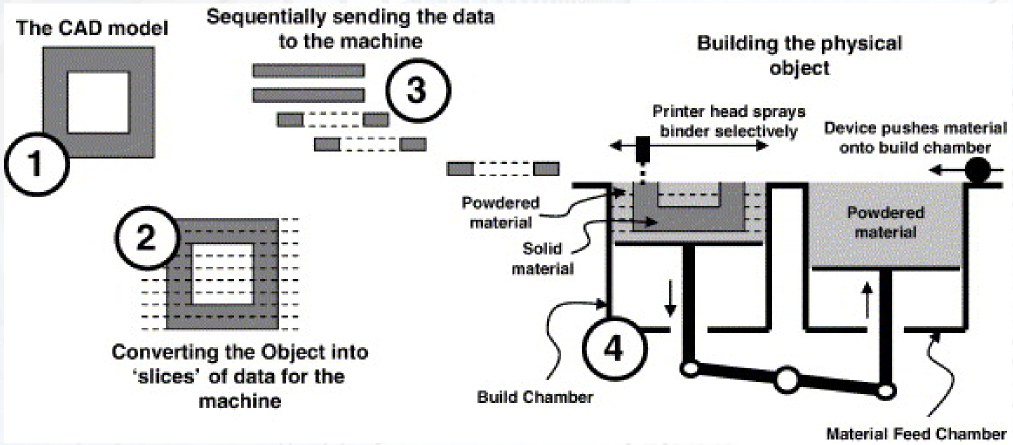
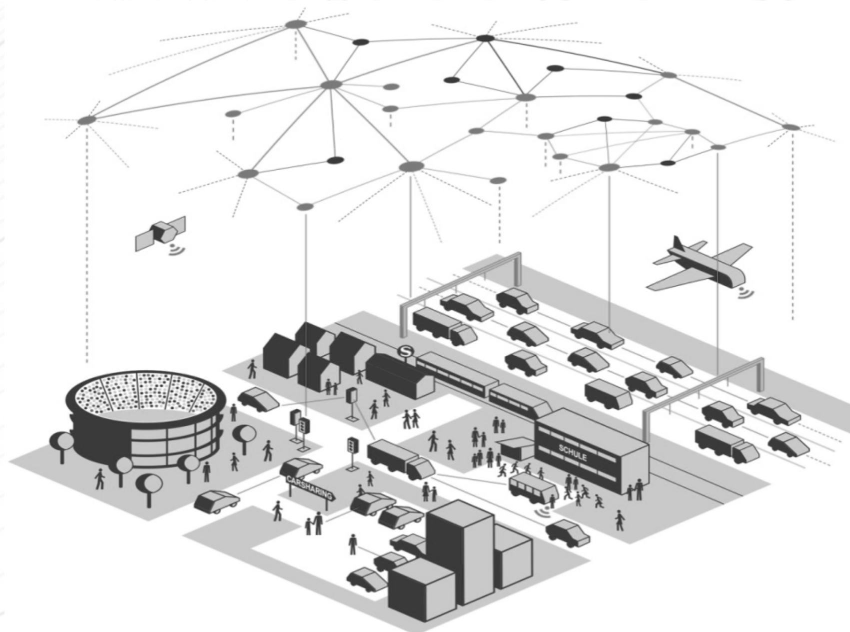

External Conditions
Labor
Materials
Tools / Equipment
3D-printing could streamline all 8 resource challenges !
Space
Time

The 3D Printing Process



Enablers

- Sensors
- Computing power
- Storage capacities
- Data analytics
- Networking ability

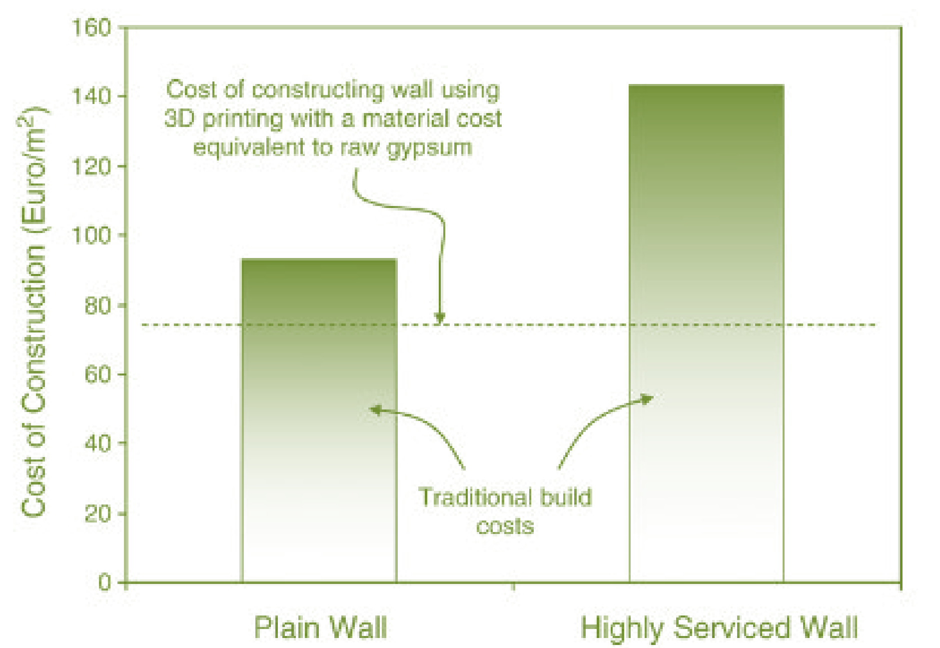


3D Printing in a Connected World

3D printing is cost competitive with traditional processes and products

Pilot studies show three key issues that affect how Freeform Construction impacts traditional methods:

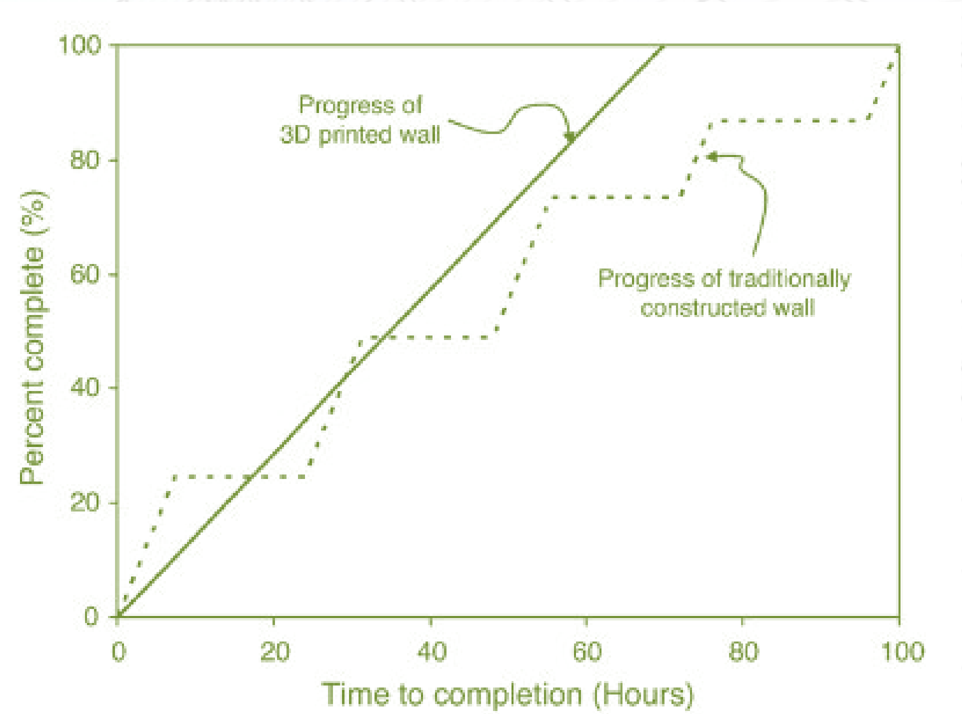
COST



http://www.sciencedirect.com/science/article/pii/S0926580506000227

3D printing can be faster than traditional processes and products

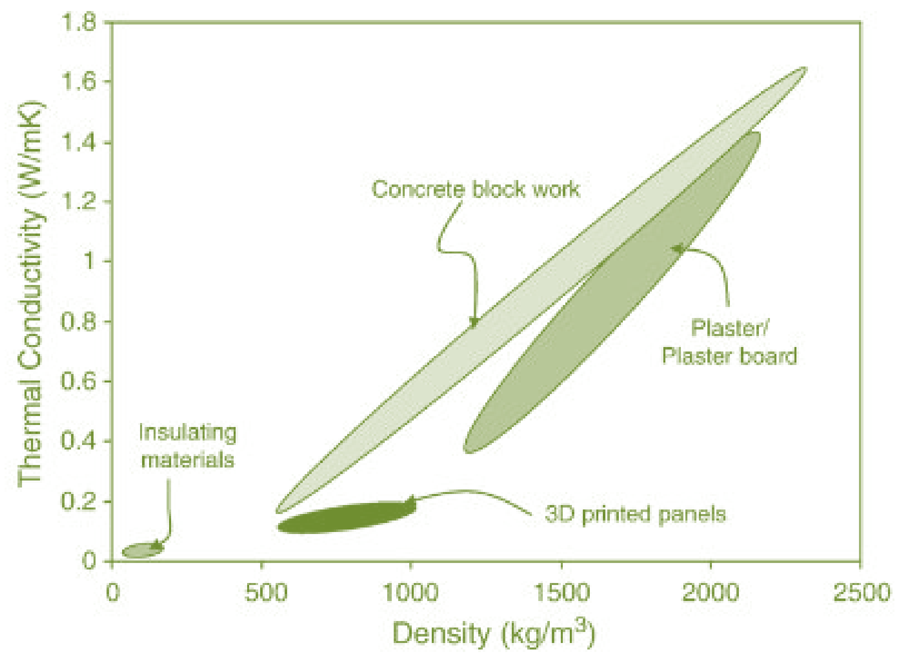
TIME



http://www.sciencedirect.com/science/article/pii/S0926580506000227

3D printing can provide value added over traditional processes and products

VALUE ADDED



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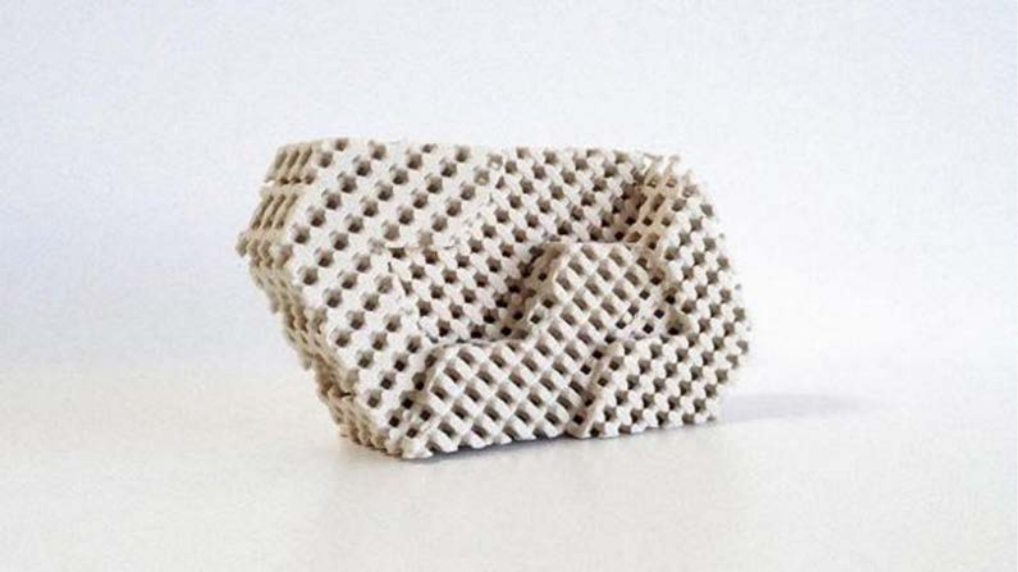
Design for Multifunctionality

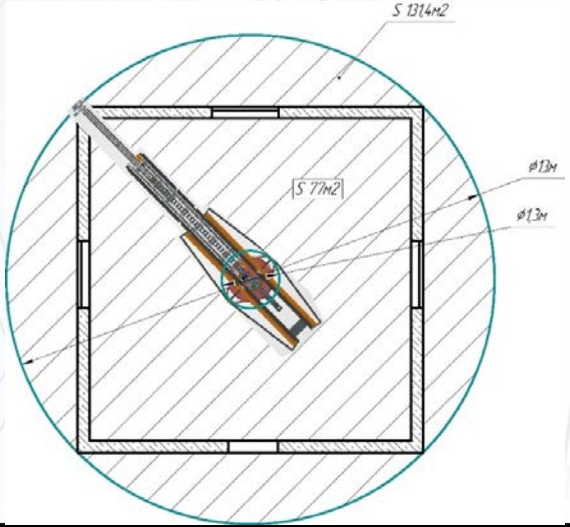
Cool Bricks

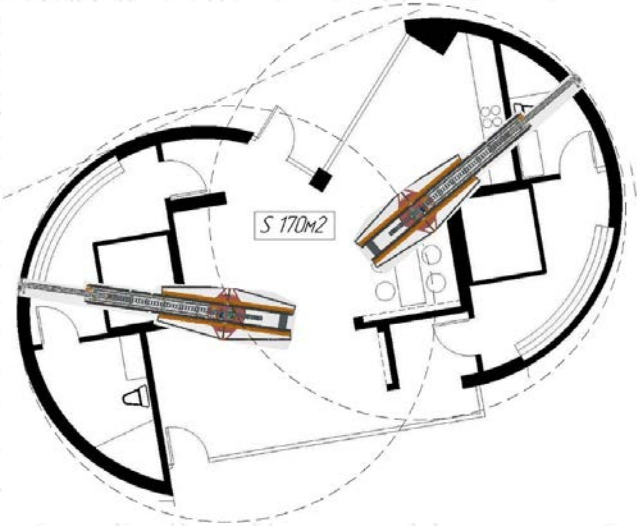


- Design studio Emerging Objects has come up with 3D-printed porous bricks called Cool Bricks that can be filled with water to bring down temperatures.
- Each 3D-printed cool brick, has a three-dimensional ceramic lattice-like structure that can hold water in its pores, like a sponge.
- When air flows through the porous brick it absorbs evaporated water vapour, becoming cooler in the process.

3D Printing Robot

3D Printing in Russia





China

3D Printed Urban Cabin
Amsterdam

United Kingdom
Loughborough University

Using a robotic arm means that the team can print up to 10 times faster and create a huge variety of forms, including curved, hollow and geometrically complex shapes

Bridges in Amsterdam

Bridge In Spain

Automation is Coming Our Way

Bricklaying Robot - Roads

Bricklaying Robot - Walls

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Surveying Drone

The Future Construction Site

- Skycatch drones give a bird's-eye view of a site and provide progress reports, speed up the logistics of construction by monitoring deliveries and offer real-time updates on any changes that may need to be made to the plans.
- Komatsu has gone one step further - using the Skycatch drones to provide the eyes for automated bulldozers. The drones send 3D models of a building site to a computer which then feeds the information to unmanned machinery to plot their course.

Demolition Robots

Other Useful Robots

Gaps and Challenges

- Delivery components not large enough for building structures
  - Printing on site, or
  - Printing components in a factory
  - Need new systems and approaches
- Materials not optimized for 3D printing
  - Ex: Concrete has a slow setting time
- Construction speed not always greater than traditional approaches
  - Need to redesign the automation process

Significant opportunities for innovative designs and multifunctional materials and structural components

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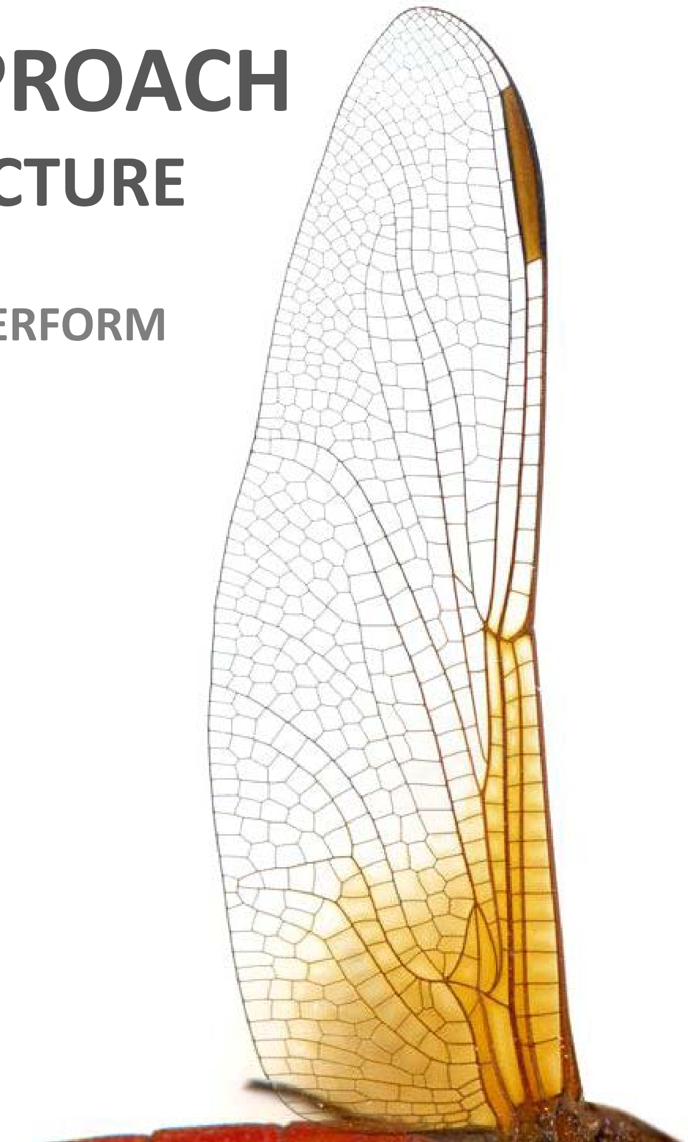
A PERFORMATIVE APPROACH
TO 3D PRINTED ARCHITECTURE

PUSHING THE LIMITS OF FORM TO PERFORM

Negar Kalantar, PhD
kalantar@tamu.edu



- **3D Printed Architecture**
  - 3D Printing **Technique**
  - **Materials** of Printing
  - **Scale/Size** of Printing
  - **Quality** of Printed Surfaces
  - **Precision**

There is **NOT** (yet) a 3D printer for Architects.

- **Integration of 3D printing in Architecture**
  - On the Final **Building Itself**
    - **Joints**
    - **Components**
      - Blocks
    - **Monoliths**
  - On the **Construction Process**
    - **Grids**
    - **Molds**

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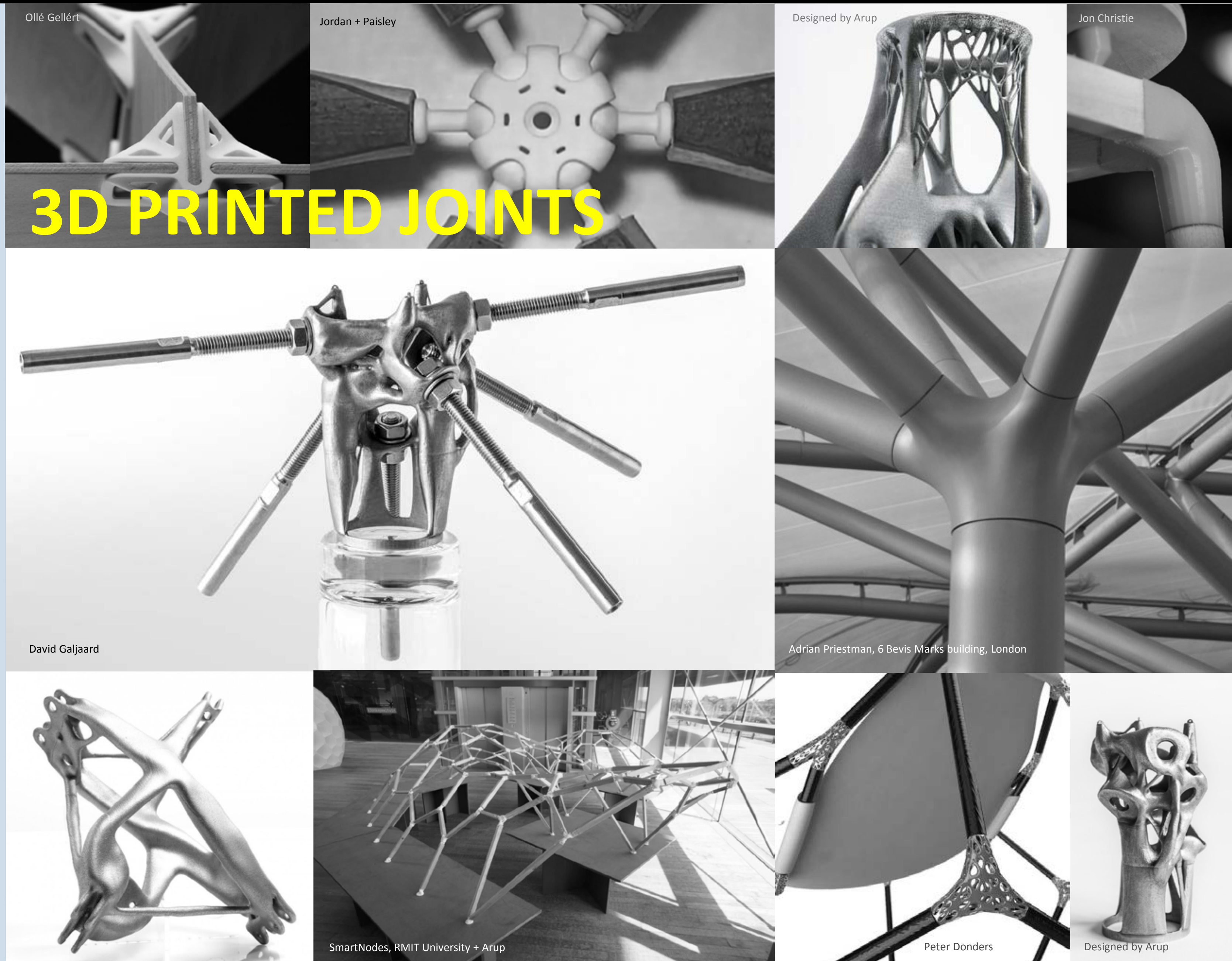
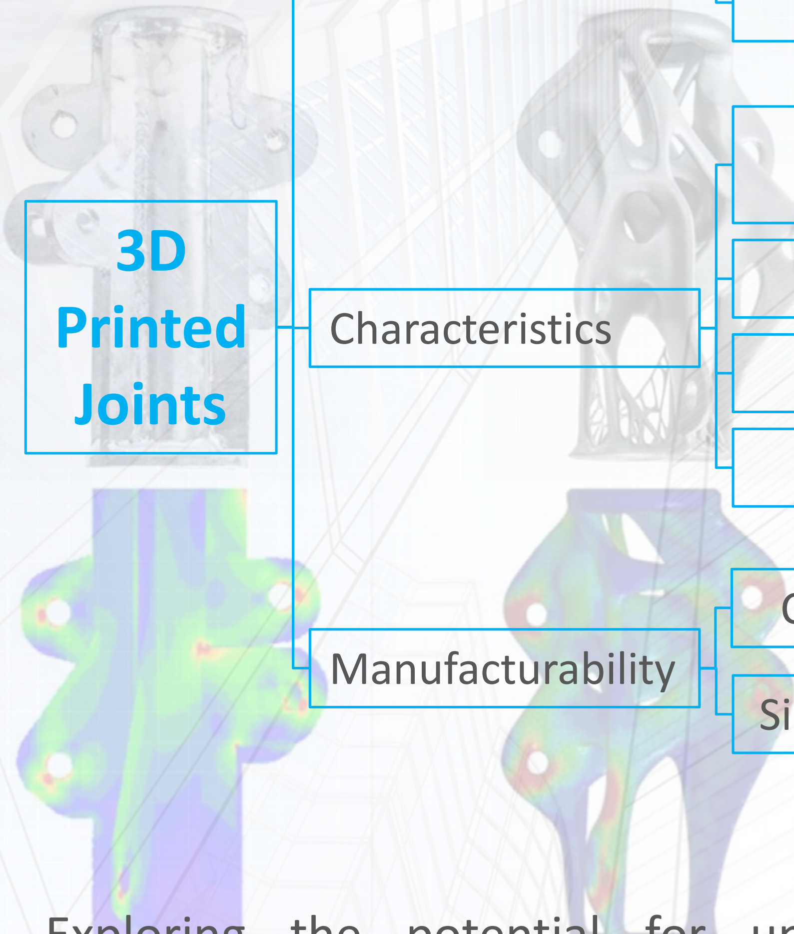
3D PRINTED JOINTS





3D Printed Joints

- Applications
  - Joints for **Building Structures**
  - Joints for **Furniture/Object** Designs
- Characteristics
  - **Removing all Extra Materials**
    Reduction in Weight
  - Relatively Small in Size + Very Precise
  - Suitable for very Complex Structures
  - Customized Design + Geometrical Freedom
- Manufacturability
  - Constructability with existing 3D printers
  - Similar to Aeronautical & Automotive Parts

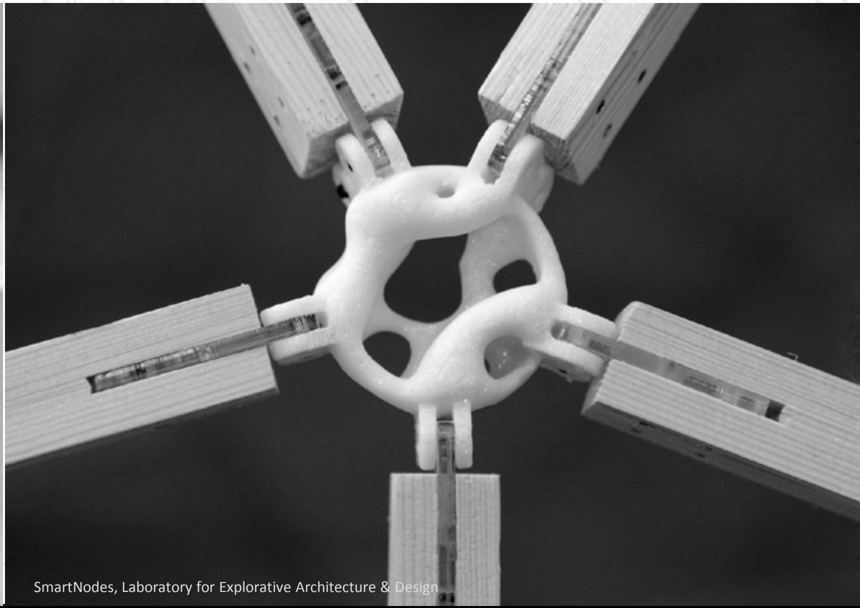
Exploring the potential for unique, and **weight optimal** node components with off-the-shelf, **standard** structural components to achieve complex building form.

Placing matter only where structurally needed

Main barriers of having 3D printed Joints

- The **cost** of production at the **scale of buildings**
- The **uncertainty** of structural & mechanical behavior of materials

Bayu Prayudhi TU Delft - ARUP



SmartNodes, Laboratory for Explorative Architecture & Design

3D PRINTED CONSTRUCTION COMPONENTS


Star Lounge, Emerging Objects


Bloom, Emerging Objects


Bloom, Emerging Objects


Echoviren Pavilion, smith | allen studio


Echoviren Pavilion, smith | allen studio


Canal House, DUS Architects


Project EGG Pavilion, Michiel Van Der Kley


The Saltygloo, Emerging Objects


Canal House, DUS Architects

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3D Printed Construction Components

- Applications
  - Load-bearing elements
  - Non-load-bearing elements
- Characteristics
  - Improving **ASSEMBLY** systems
    Determining the position of each piece within the full scale assembly
  - Producing **Transportable** Pieces
  - Having Infinite Typologies
    A piece is printed with a code, explaining how it should be configured
- Manufacturability
  - Taking Advantage of **Existing** Machines
    Without the need of huge & expensive machines
  - Changing new "Print Head" for standard printers

Rather than 3D printing massive parts, several linked components are printed.

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3D PRINTED MASSIVE MONOLITHIC STRUCTURES

3D Printed Monolithic Structures

- Applications
  - Load-bearing Elements
- Characteristics
  - Good in Compression + **Weak in Tension**
  - Less Homogeneity
  - **Rough** Surface Quality
  - Less Resolution
  - Mainly Thick Layer Deposition
  - Large Fabrication Scale
  - Printing **Simplified Shapes**
    Mainly having 2.5 D geometries rather than 3D freeform elements
  - Less Over-hanged Parts (Less support materials)
- Manufacturability
  - Mainly Extrusion Process of **Paste** Material
    Out of semi-fluid materials such as ceramic, concrete, polymers
  - Longer **Curing** Period
    To resist pressure from the weight of the structure itself
  - Adding Post Tensioned Steel Cable Reinforcement
  - Producing Horizontal Elements Separately

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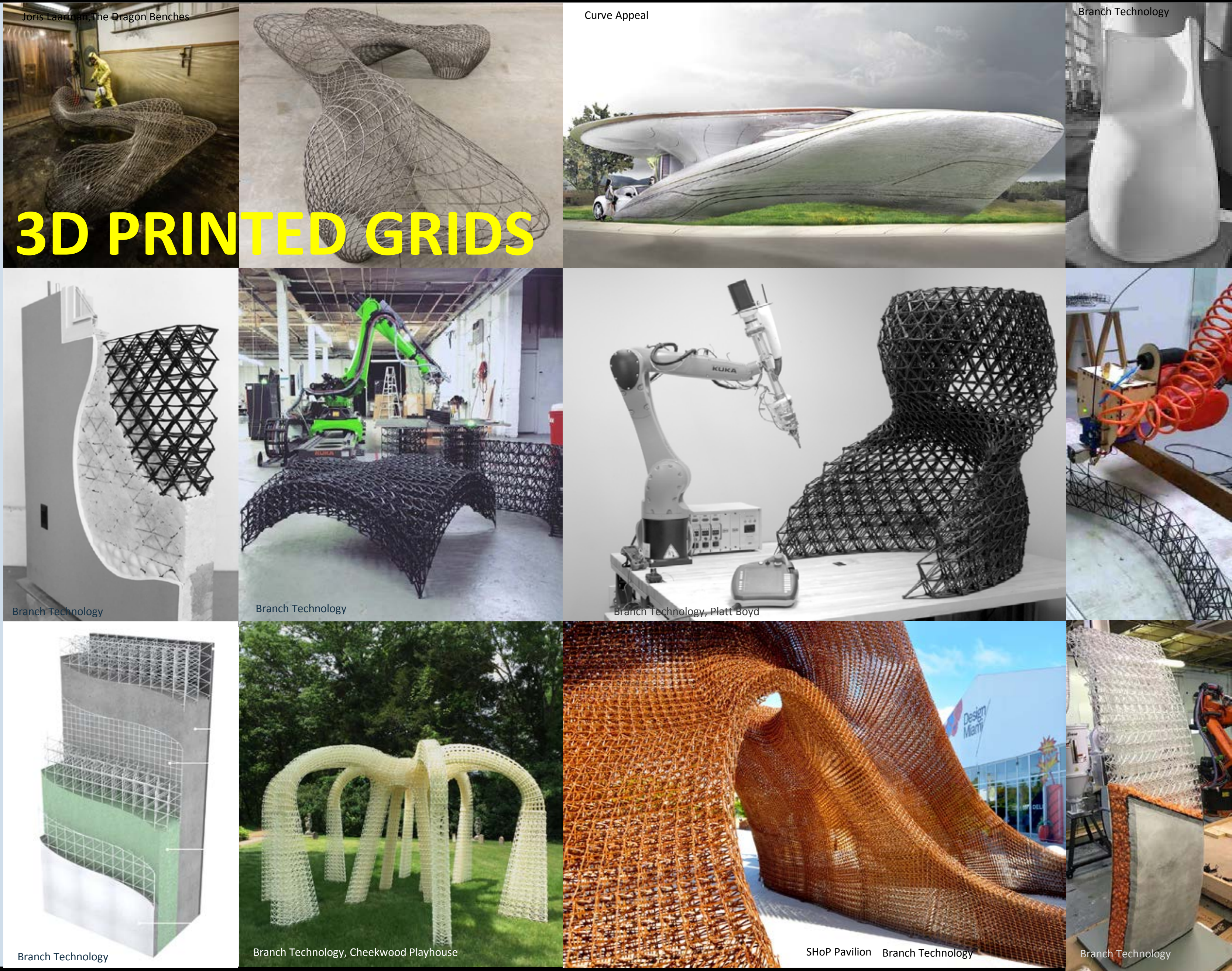
3D PRINTED GRIDS

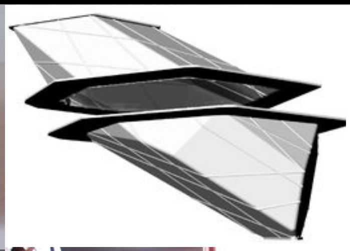
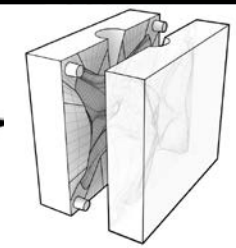


3D Printed Grids

- **Applications**
  - Load-bearing elements
- **Characteristics**
  - **Hybrid** Building Structures
  - Creating a Cell-like Matrix
    - With **different density** to improve strength and reduce material use
  - Scalability of the Process
    - **Parallelization** of Different Working Printers
  - Freedom of Design
    - Less geometric limitations
- **Manufacturability**
  - Combination of 3D Printing + Conventional Building Materials
  - Printing Without any Supporting Material
  - An Inner Grid surrounded by Concrete/Foam

3D Printed Grid: Serving as the **formwork**, **scaffold**, or **core** that integrates common building materials like spray-foam insulation, spray-applied concrete, and cladding.

3D PRINTED MOLDS

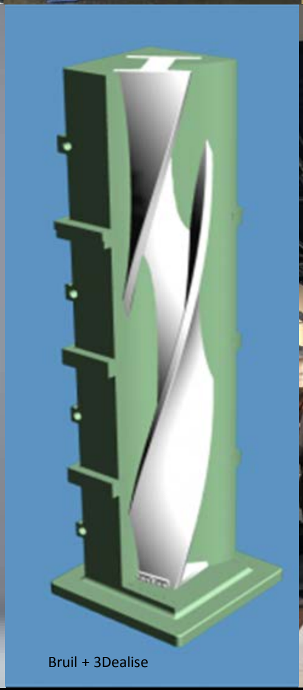
Philippe Morel, Studio EZCT

Philippe Morel, Studio EZCT

OWI-Lab

OWI-Lab

Bruil + 3Dealise

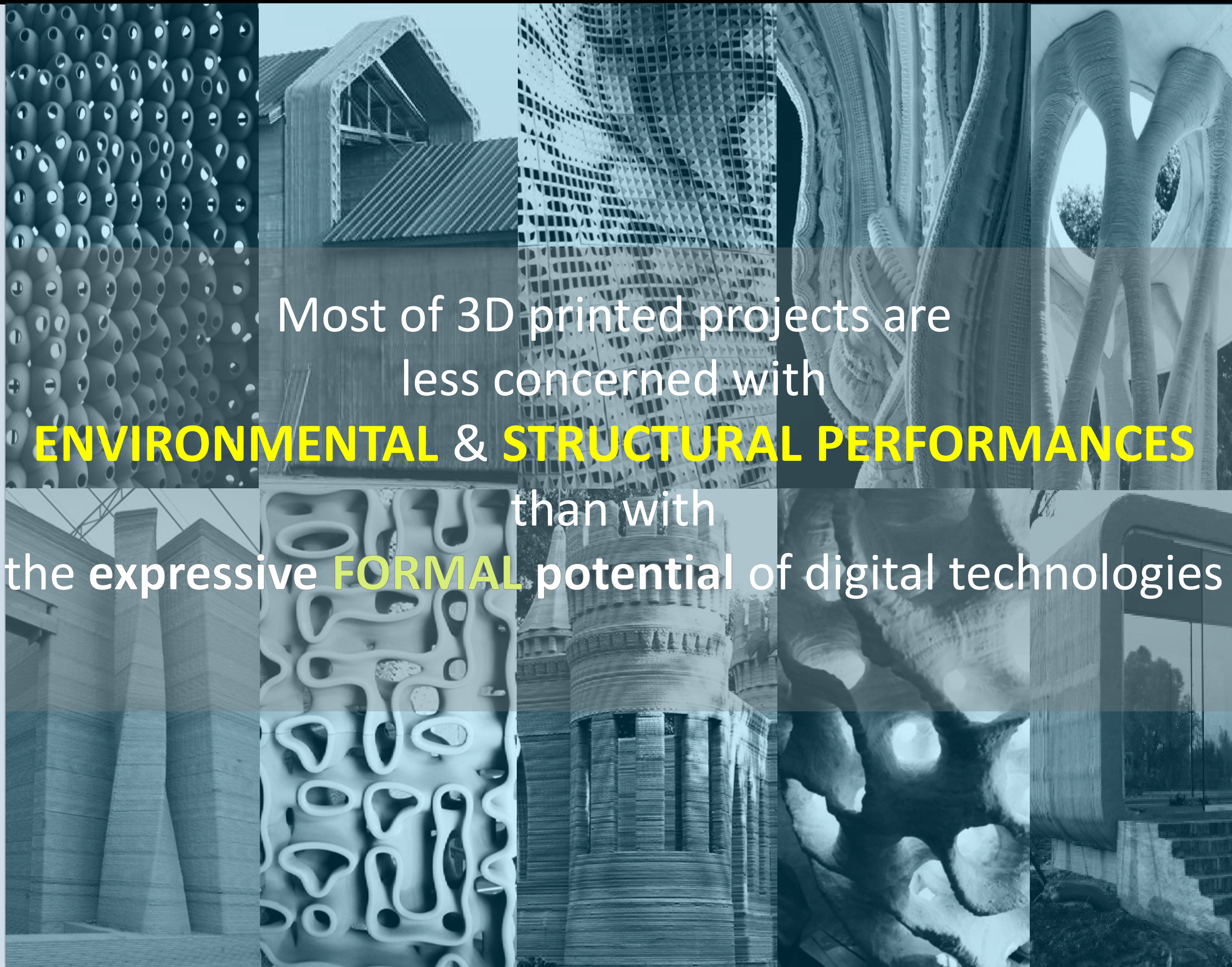


Bruil + 3Dealise

3D Printed Molds

- Applications
  - Small or Big Components
  - Structural or Non-structural Components
- Characteristics
  - Refine Surfaces and Textures
  - Reduction of **Fabrication Time**
  - Fabrication at Larger Scale
  - Using more **variety of materials**
- Manufacturability
  - Printing Smaller Parts by Using **Existing Printers**
  - Using 2 types of Molds
    - Reusable Molds
    - Destroyable Molds

What is the proper combination of
TECHNOLOGY + MATERIAL + APPLICATION
towards the use of 3D printing in architecture?



Most of 3D printed projects are
less concerned with
ENVIRONMENTAL & **STRUCTURAL PERFORMANCES**
than with
the **expressive FORMAL potential** of digital technologies

Adding Performance & Functionality to Printed Parts

The Difference between Natural & Man-made Constructions

Nature

Material is expensive BUT **complexity** is free

↓

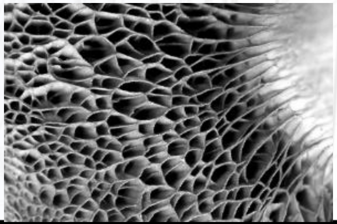
Less material + More complex forms

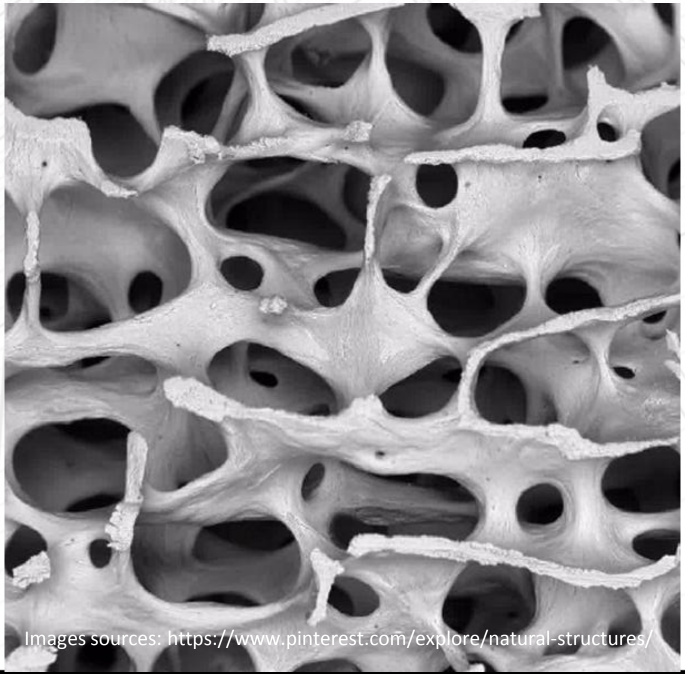
Man-made

Complexity is expensive while **material** is not

↓

More material + Less complex forms





Images sources: https://www.pinterest.com/explore/natural-structures/

Bio-Inspired Approaches

Smart Materials

A New Way to Design Buildings

Additive Manufacturing Techniques

New Computational Design Methods

Designing buildings at the intersection of Additive Manufacturing, new Computational design methods, Smart Materials, and Bio-Inspired Approaches

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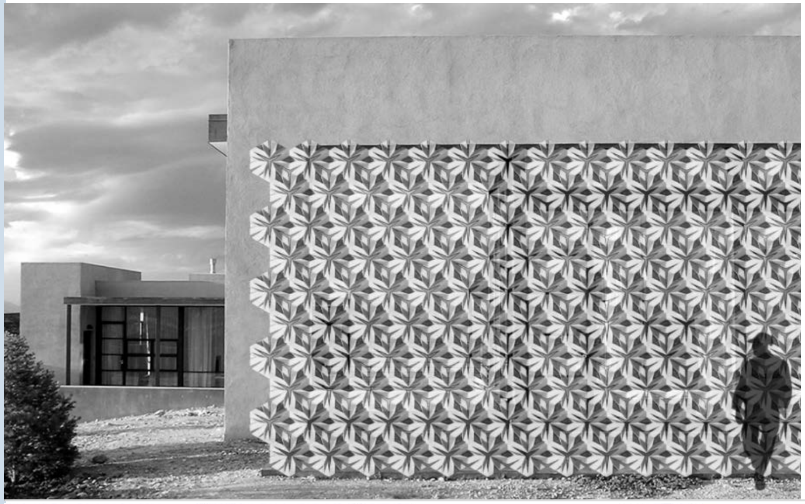
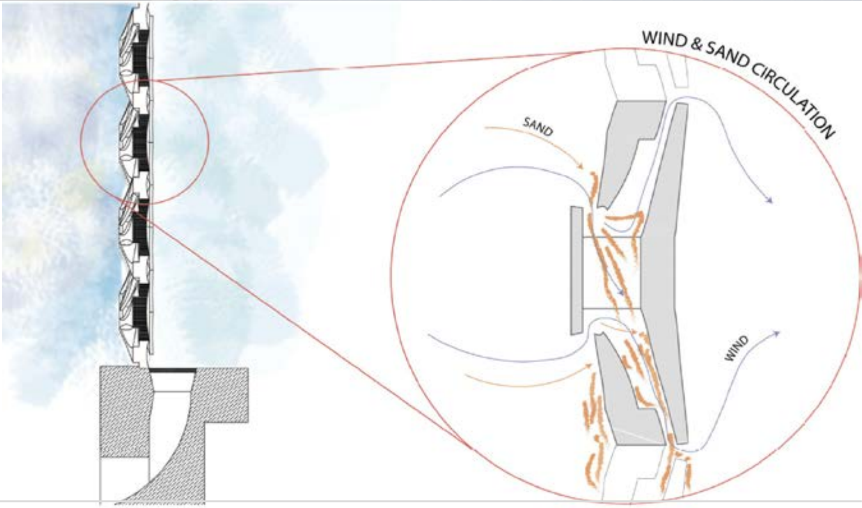
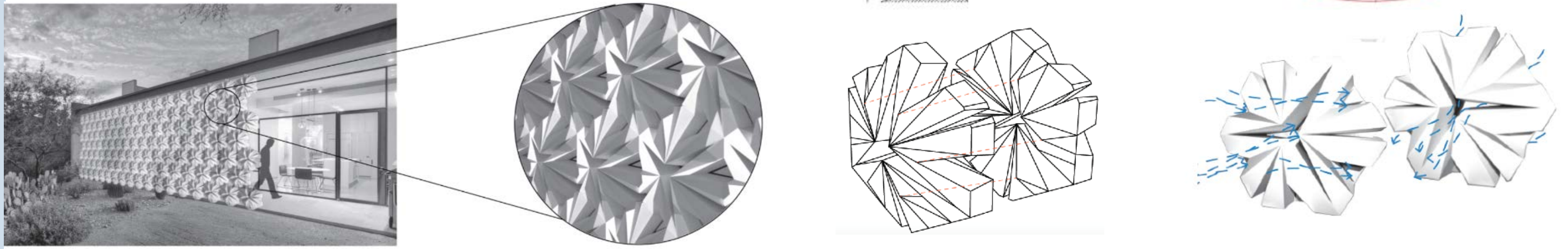
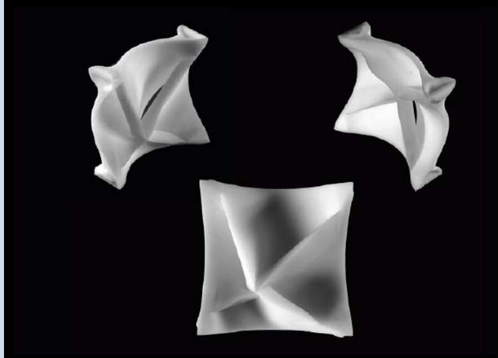
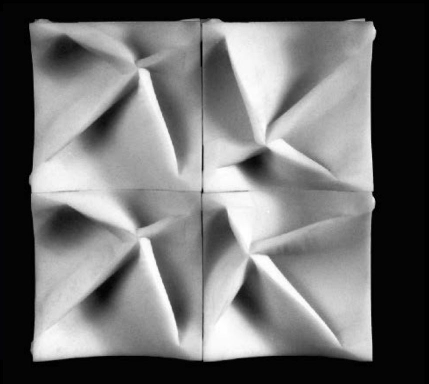
BREATHABLE WALL

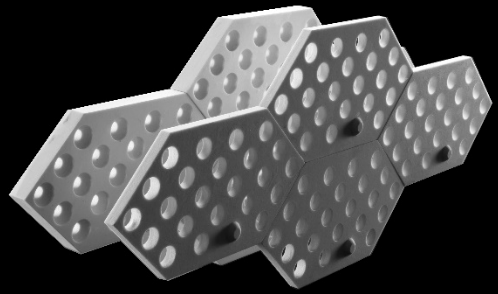


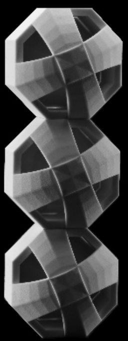












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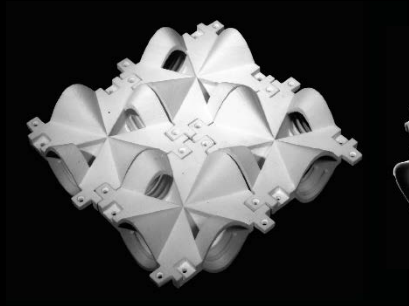
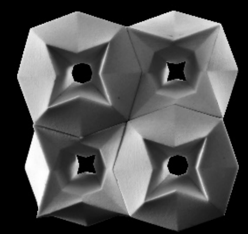
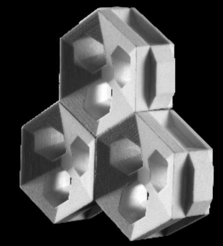
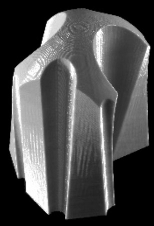
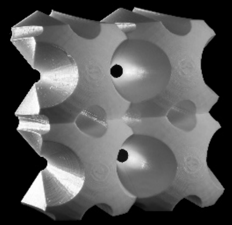
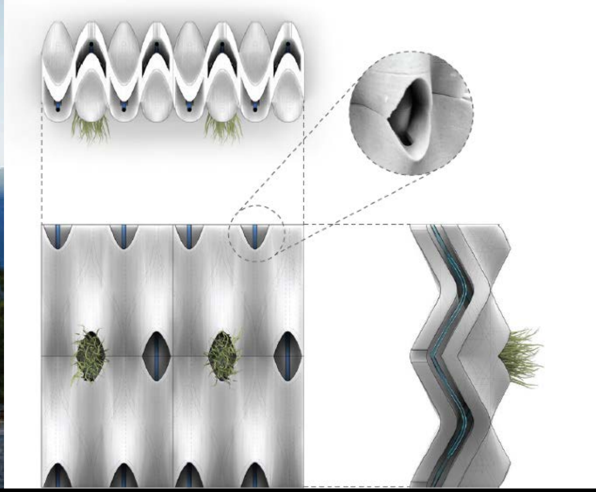
Research Collaborators: Kalantar, Borhani, Schaper, Williams, Newchurch, Doggett, Fuentes, Roose, Bradely & Mengers

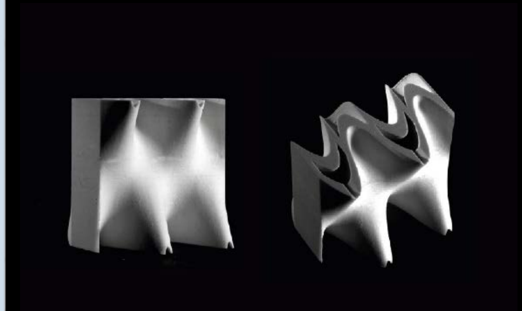
BREATHABLE WALL

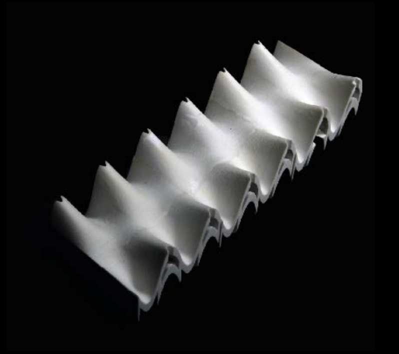


Running water along designated paths is proposed as a means of adding humidity and cooling the air as it passes over the 3D printed blocks





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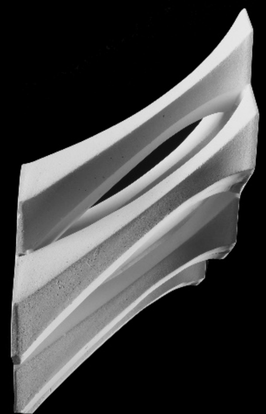
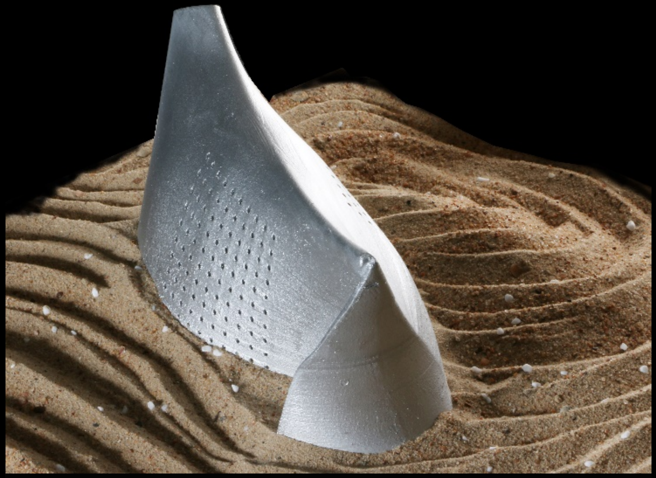
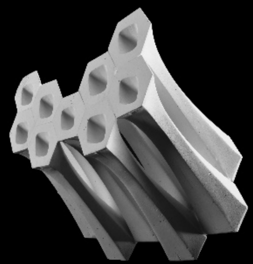
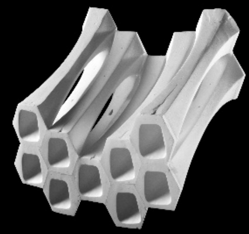
Research Collaborators: Kalantar, Borhani, Callen, bradley, & others – Texas A&M

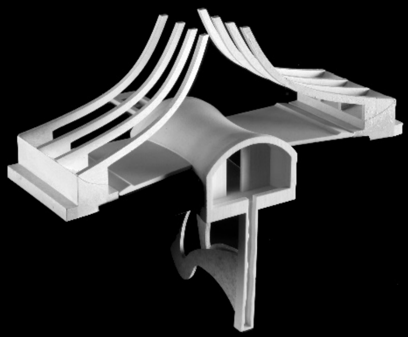
BREATHABLE WALL

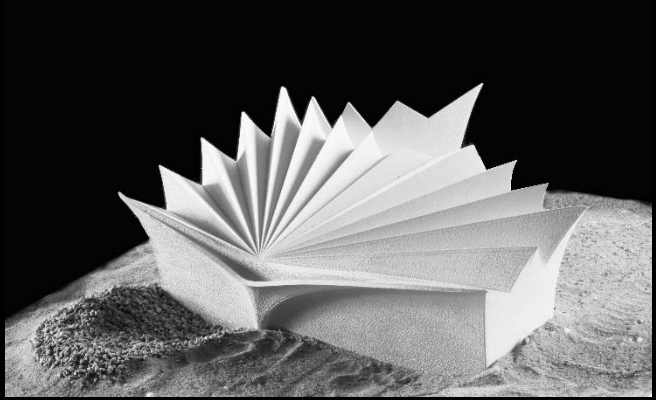


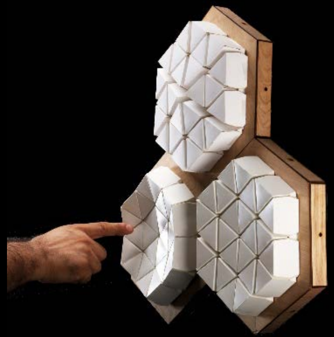


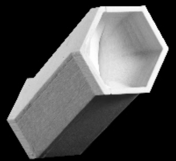












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Research Collaborator: Borhani, Kalantar, Wilt, Armenta, Reyes, Lambeth, Bush, Woodruff & Palmer – Texas A&M

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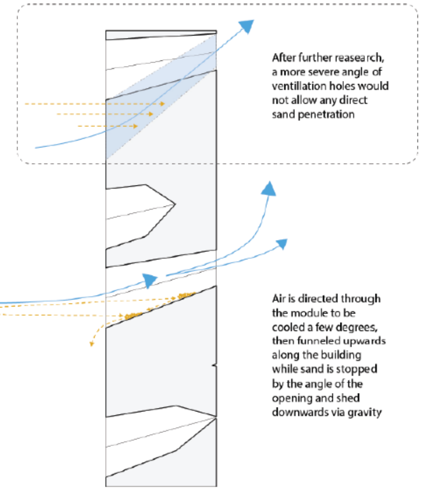
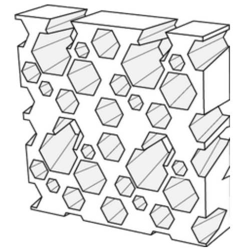
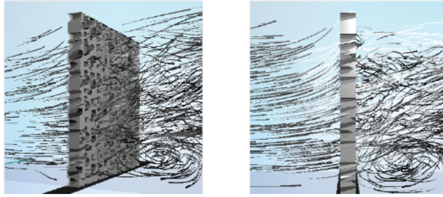
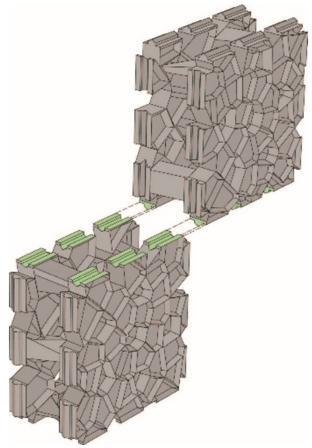
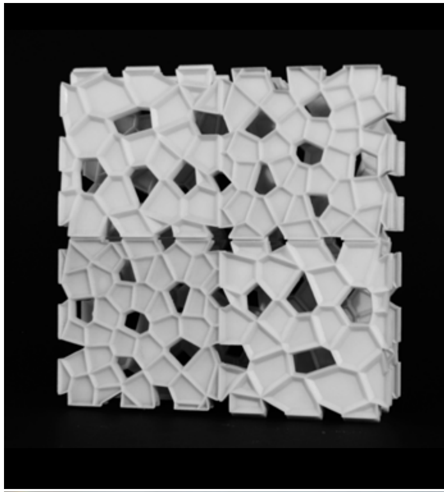
Prevent the transmission of sand via the structure of building, made out of 3D printed porous blocks

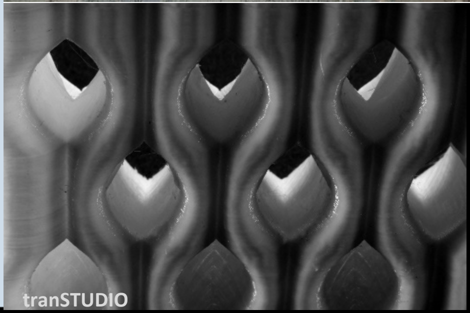


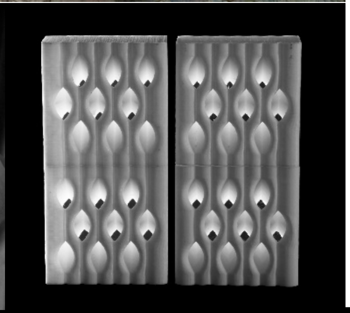


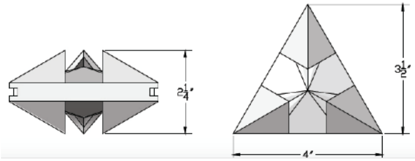




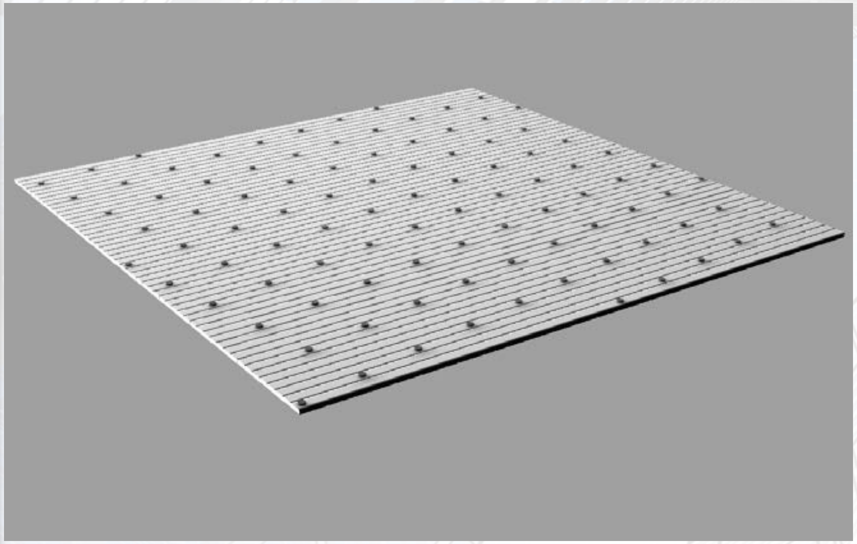


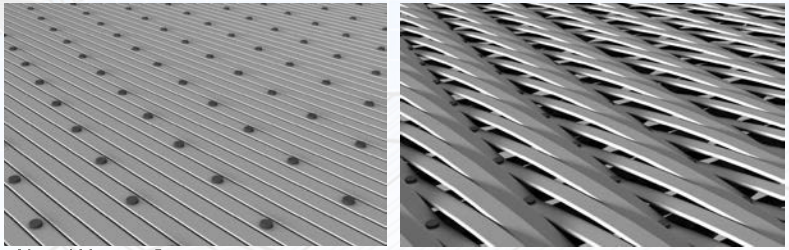




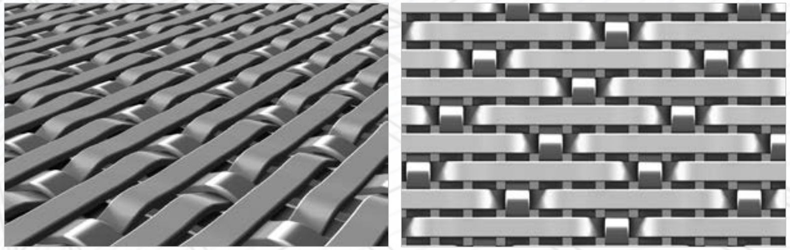


Research Collaborators: Kalantar, Borhani, Ritter, Gilbert & others, Texas A&M

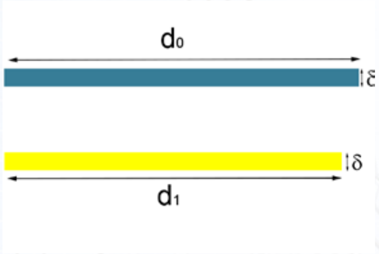


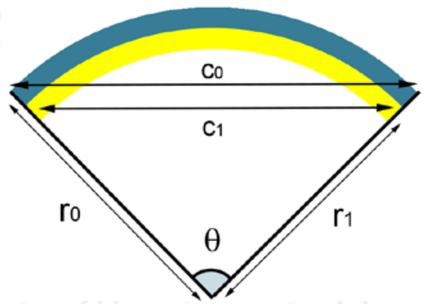


Non-Woven Structure



Woven Structure





Bi-material Strips

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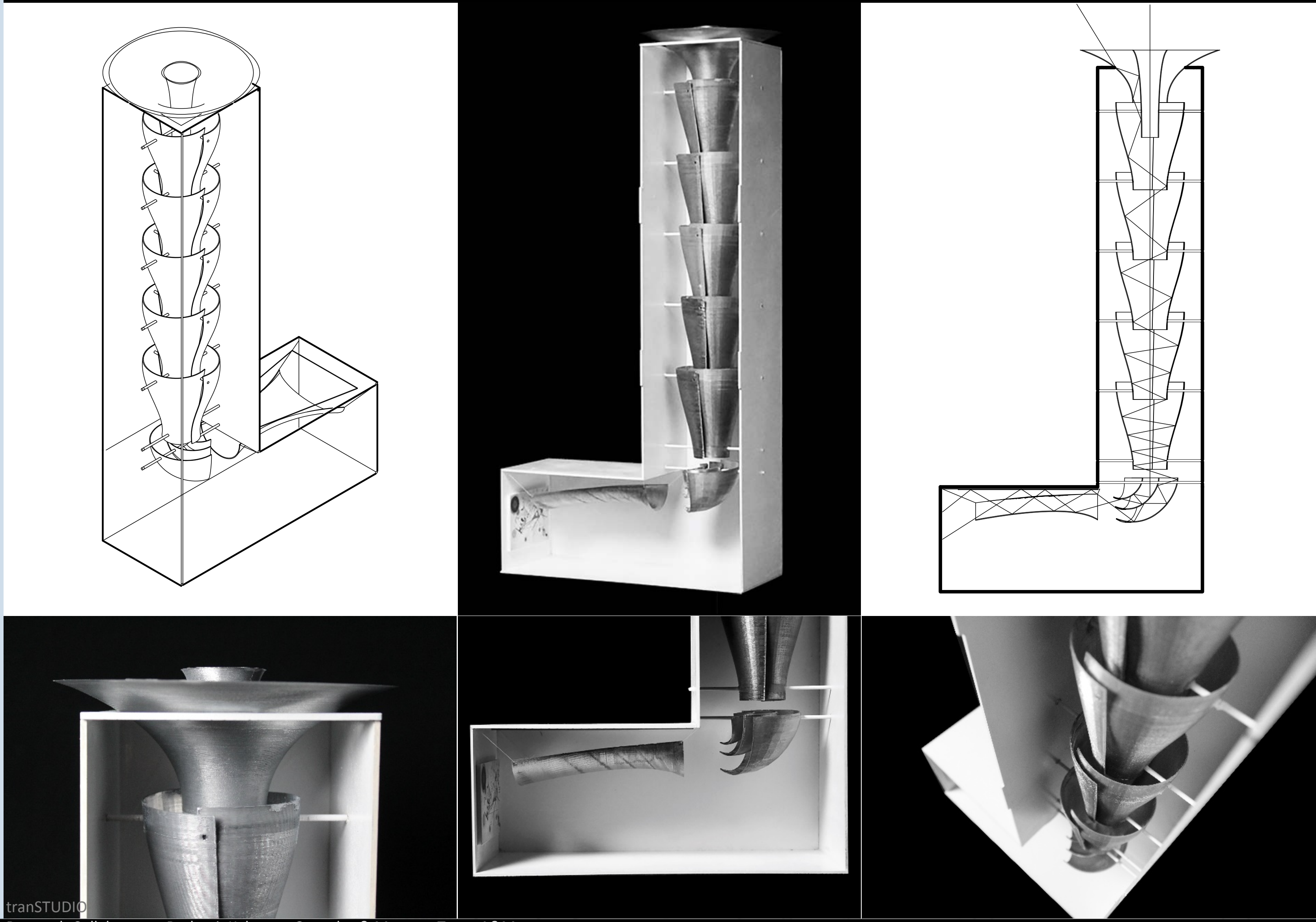
Research Collaborators: Akleman, Zarrinmehr, Cagin, Al Mezrakchi, Kalantar, Creasy & Rybkowski

tranSTUDIO, Adaptive Design, Thought & Fabrication
Texas A&M University, College of Architecture

LIGHT MATTERS

Conducting light into darkness & moving it 90 feet



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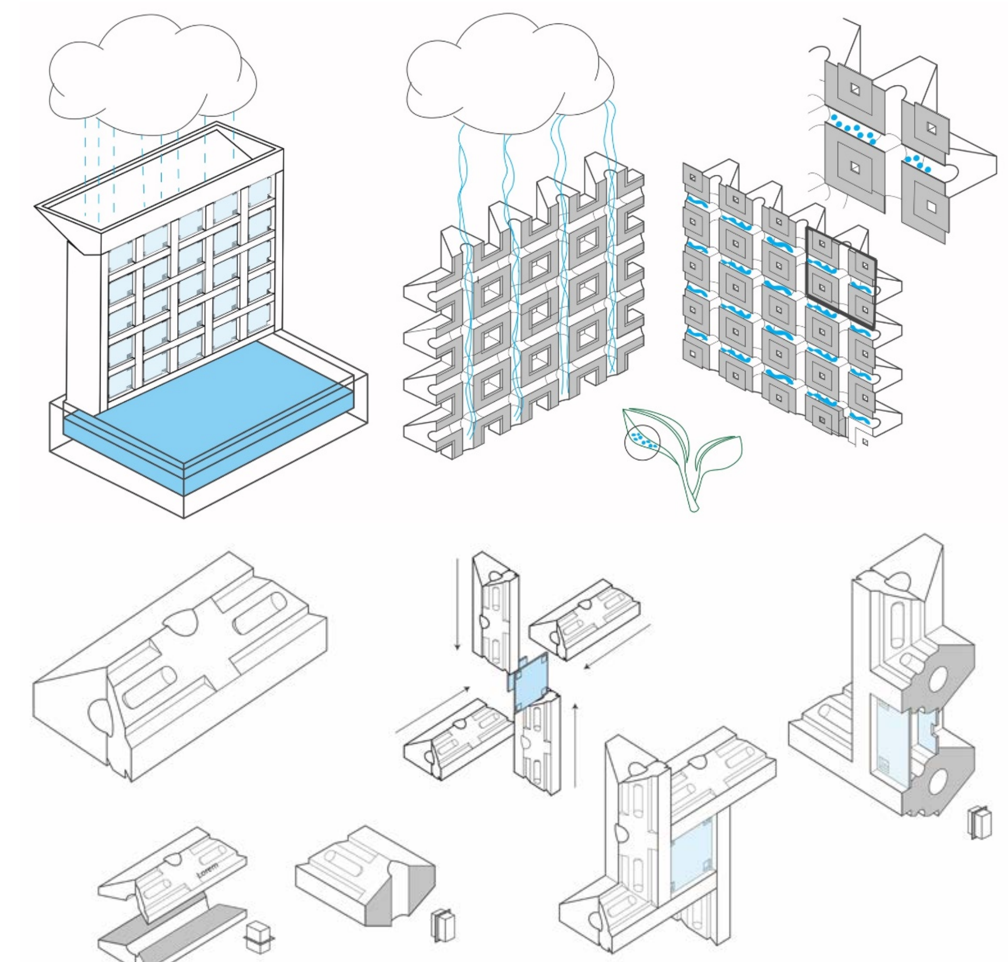
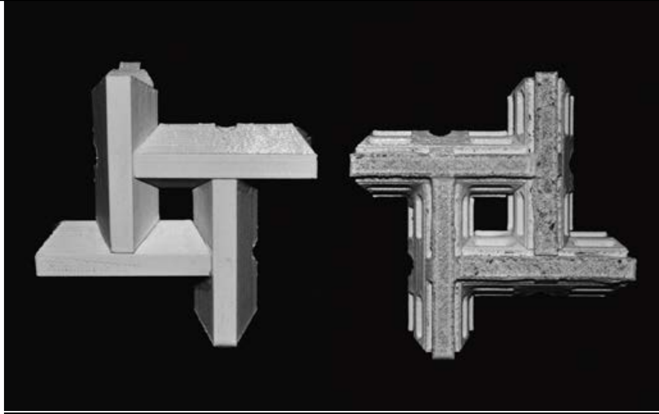
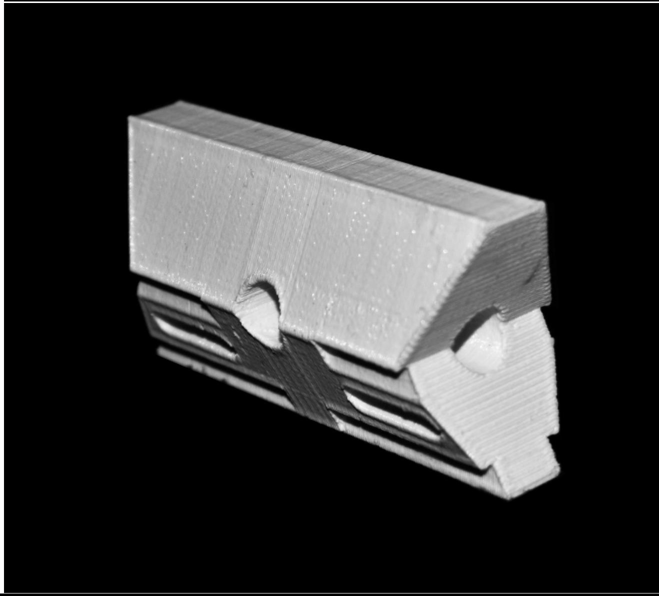
Research Collaborator: Borhani, Kalantar, Gonzalez & Morgan- Texas A&M

HYDRO-WALL

The goal is to not only make interlocking structural elements, but also to integrate environmental performance to **generate water** directly into the entire structure.





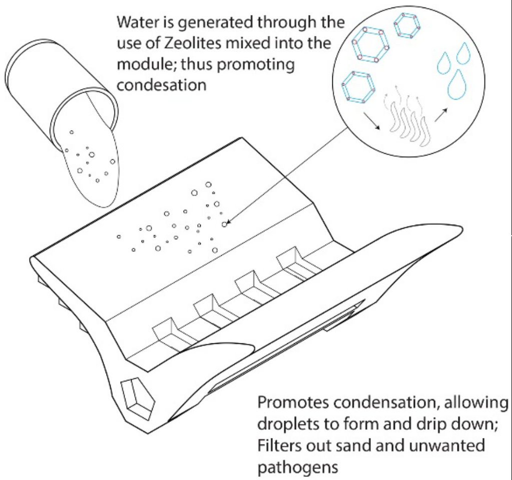


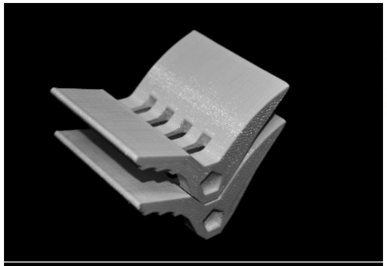
tranSTUDIO

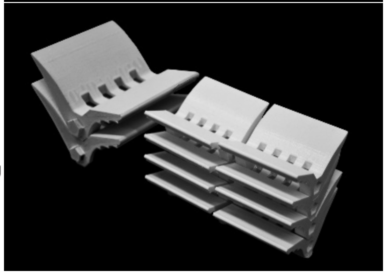
Research Collaborator: Borhani, Kalantar, Fernandez, Robinson & Konopka - Texas A&M

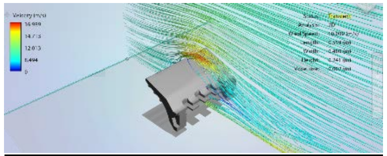
HYDRO-WALL

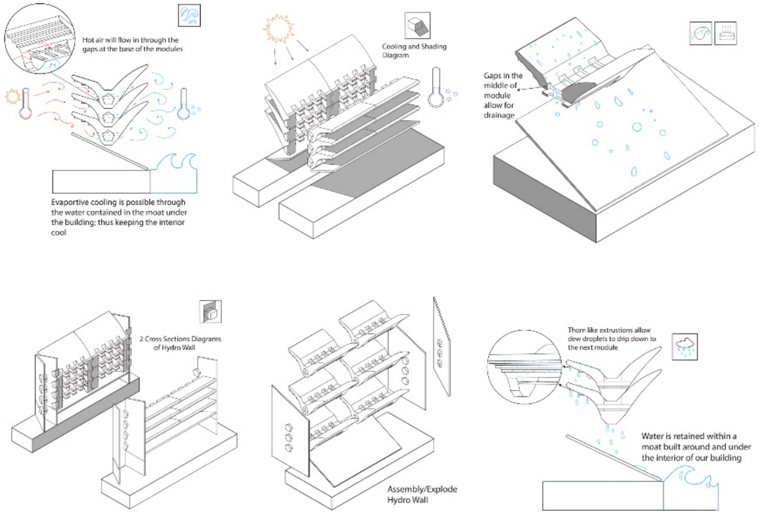
Harnessing the water vapor in in the atmosphere in its natural setting via building structures enabled by 3D printing

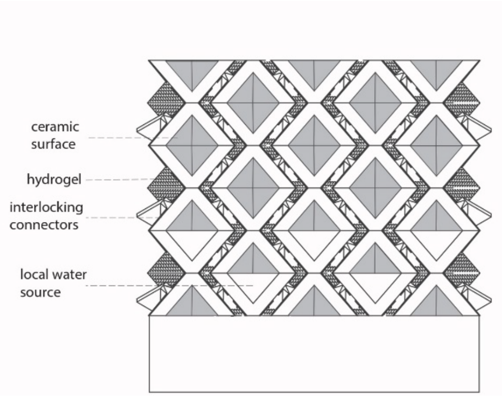


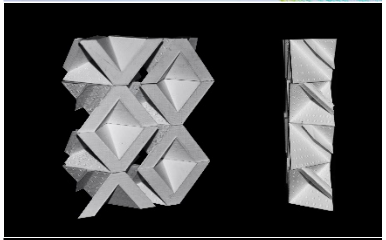


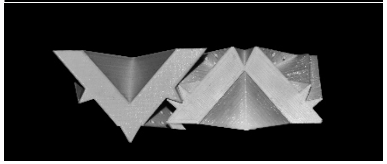


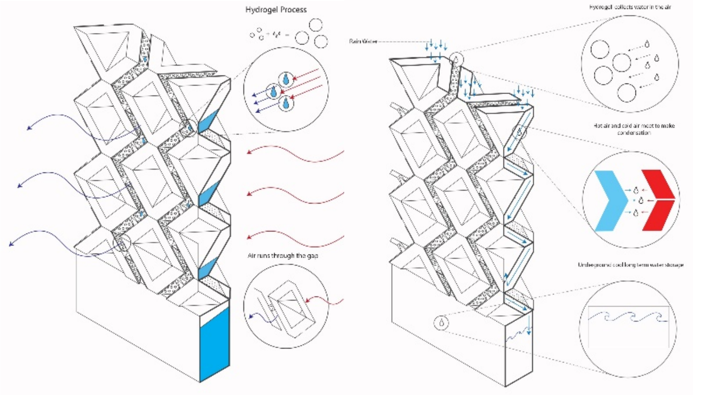




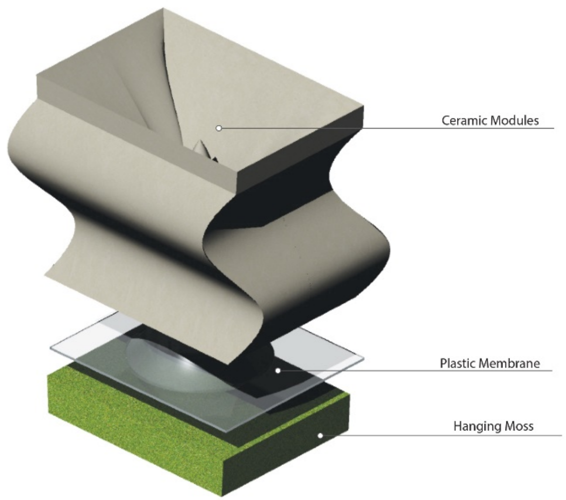


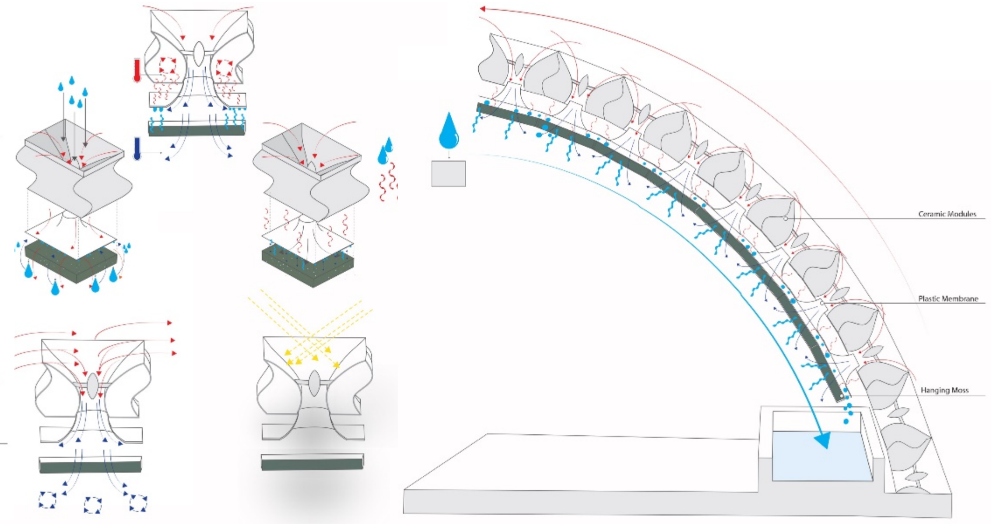


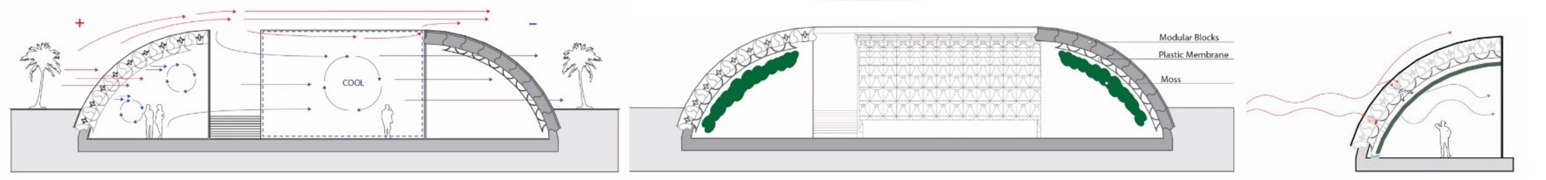




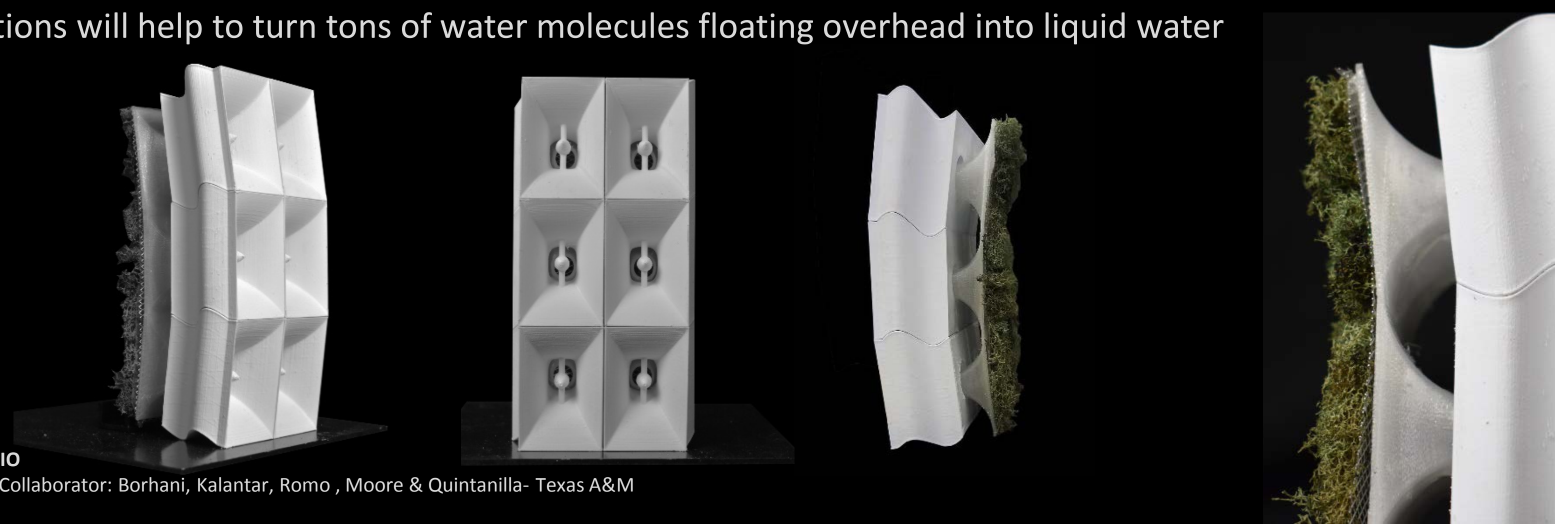
HYDRO-WALL







The exploration of 3D printed construction with simultaneous structural and environmental functions will help to turn tons of water molecules floating overhead into liquid water



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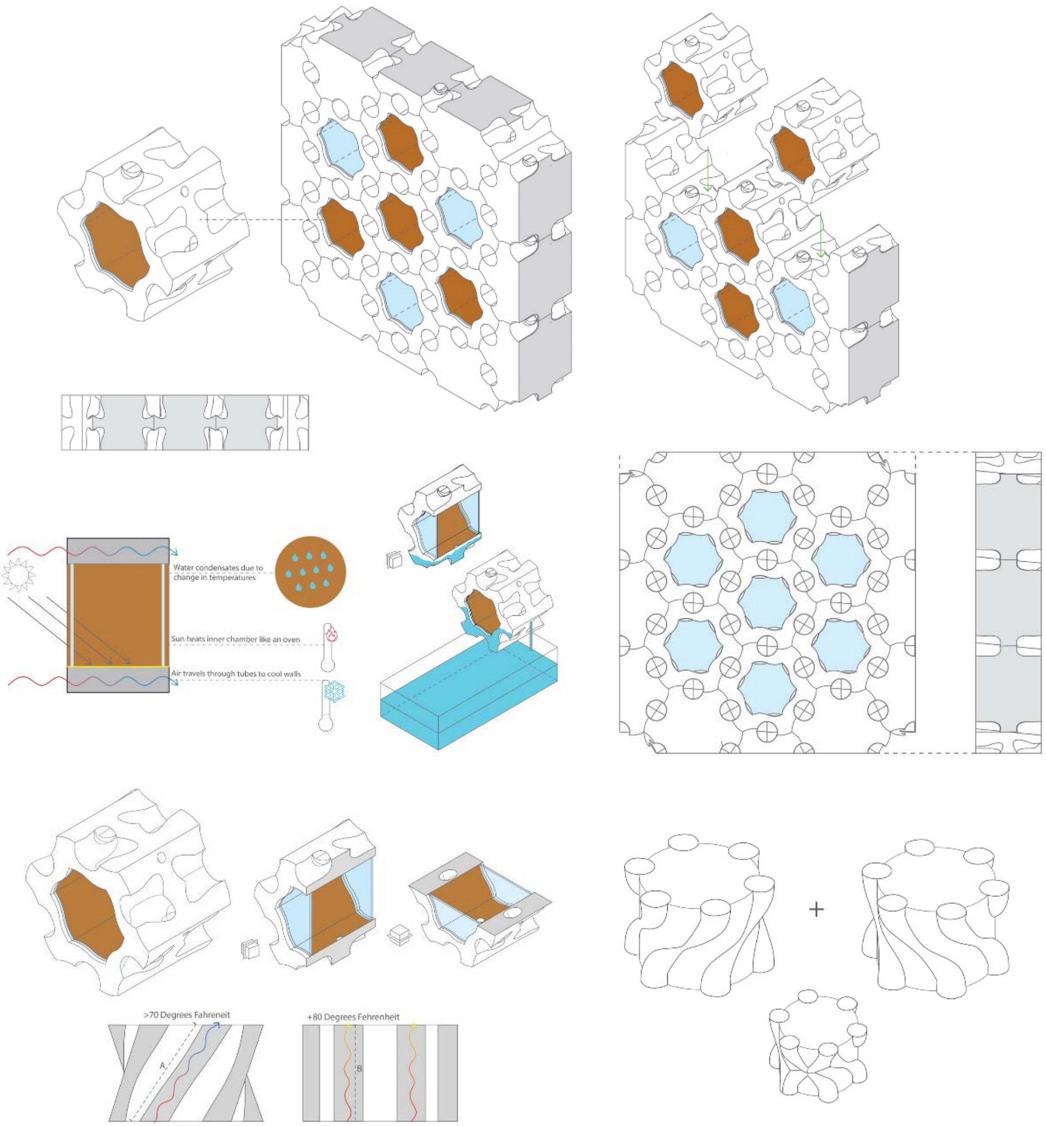
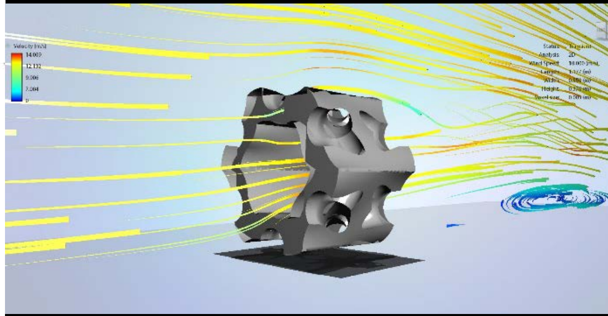
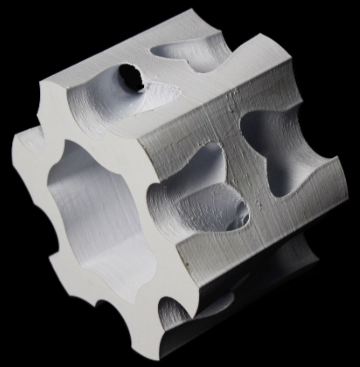
Research Collaborator: Borhani, Kalantar, Romo , Moore & Quintanilla- Texas A&M

Exploiting the concept of night radiative cooling and naturally chilling a porous 3D printed structure below the dew point







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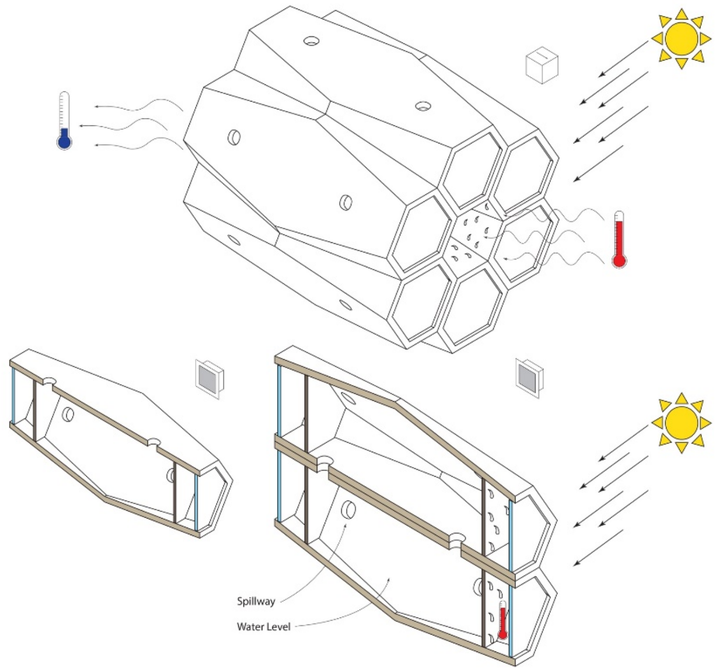
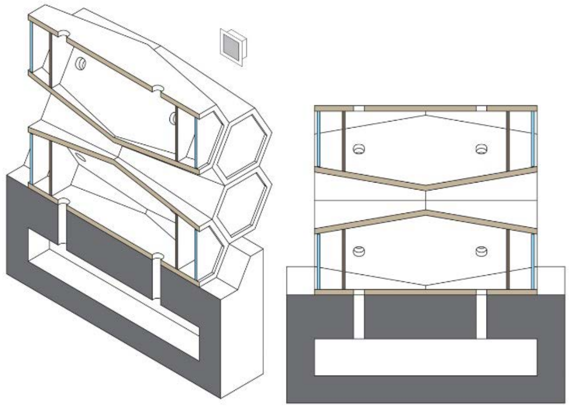
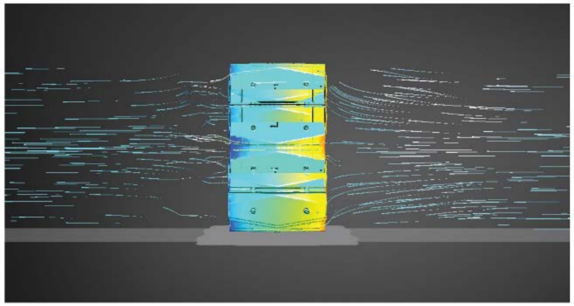
Research Collaborator: Borhani, Kalantar, Brown, Howard &Marcello- Texas A&M

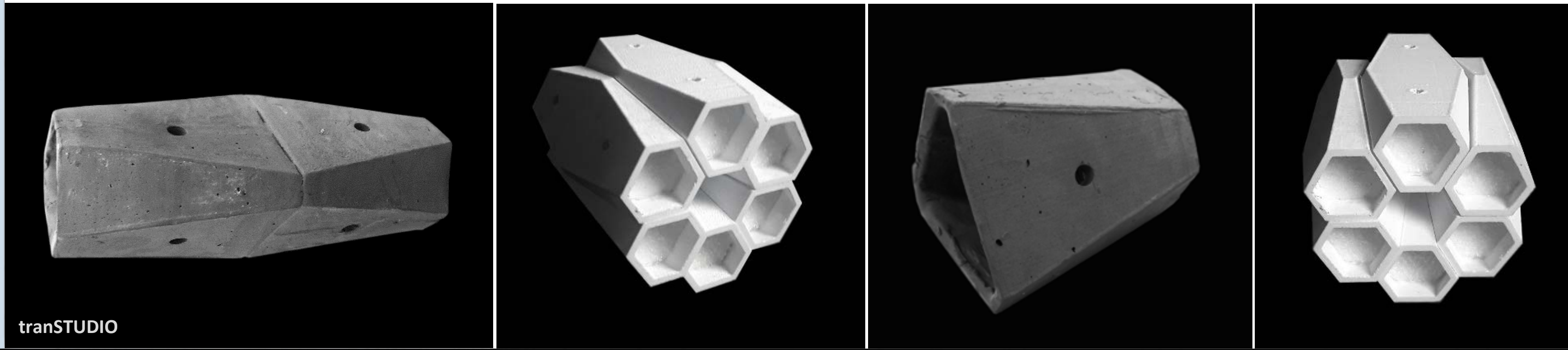
HYDRO-WALL

Different layers of hydrophilic and hydrophobic surfaces, controlled pore structures, and osmotic effects will be investigated as means to attract water from the air.





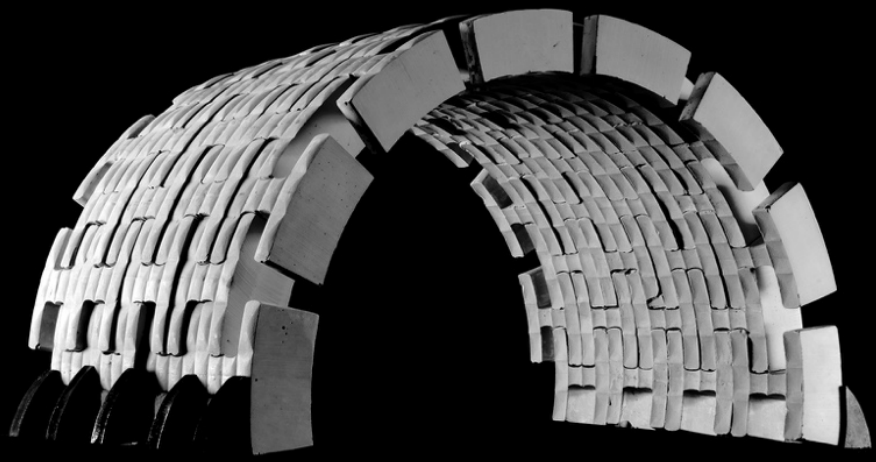


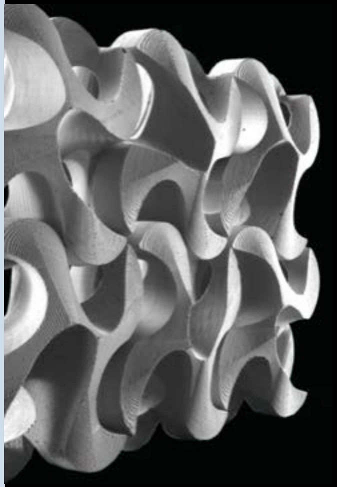


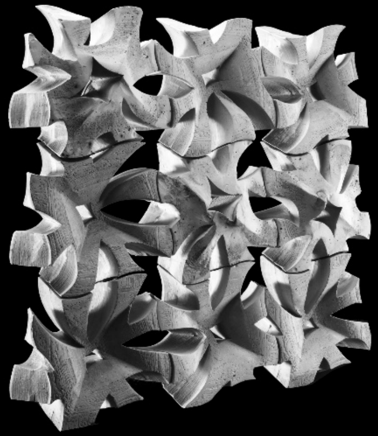
Research Collaborator: Borhani, Kalantar, Hluza, Adame & Springer- Texas A&M

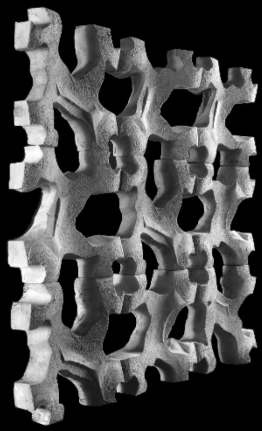
TESSELLATED INTERLOCKING STRUCTURES

The assembly of unreinforced and mortar-less structures, working purely under compressive forces









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Research Collaborator: Borhani, Kalantar, Heger, Allen, Metcalfe, Casto, Kim, Dempsey, Gregory, Morahan & Wilson - Texas A&M

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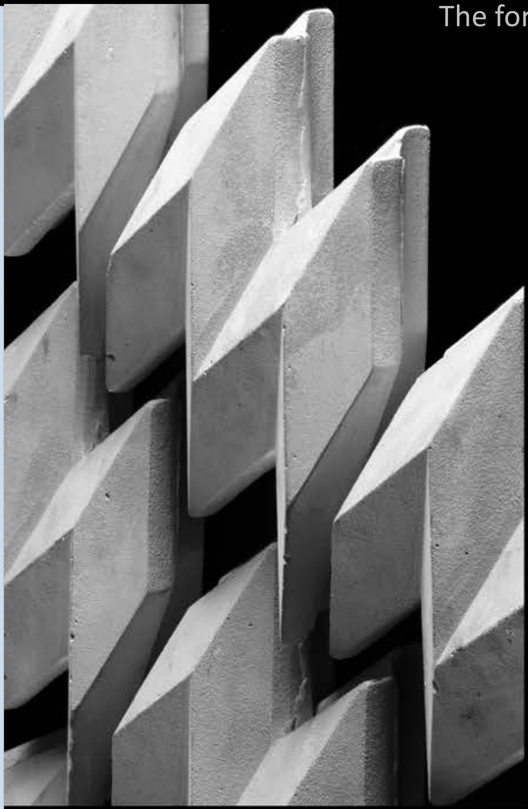
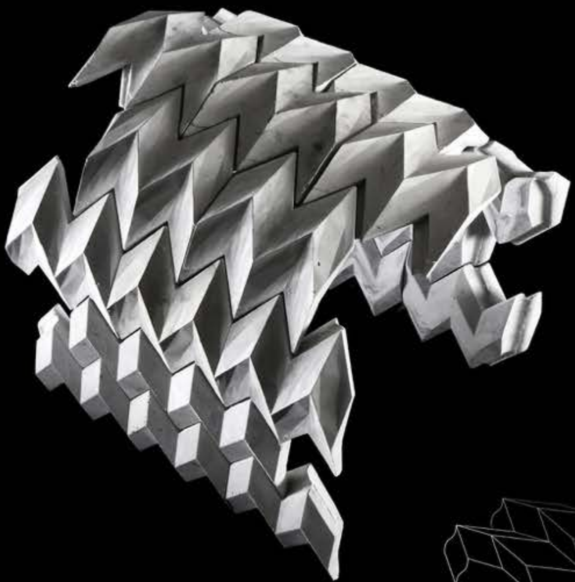
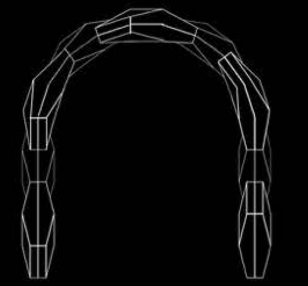
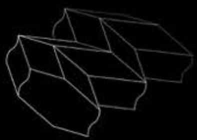
TESSELLATED INTERLOCKING STRUCTURES

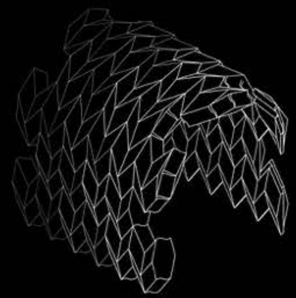
The force of gravity locks adjacent components together: Creating seismically resistant structure to diffuse seismic forces

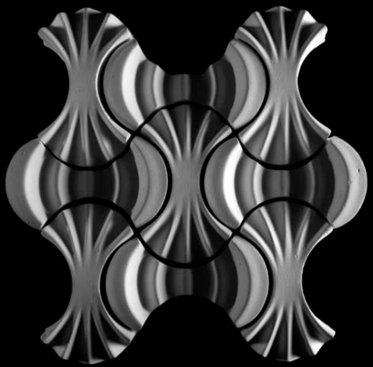












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Research Collaborator: Borhani, Kalantar, Houser, Hergert, , Casto, Kim, Dempsey, Gregory, Morahan, Wilson , Clark & Kolodziej

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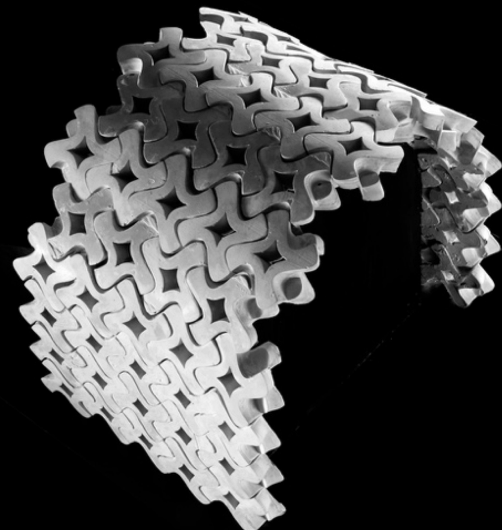
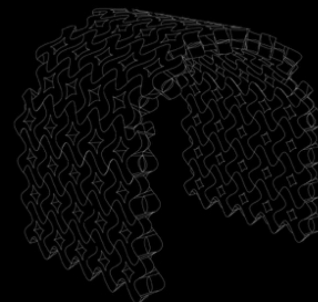
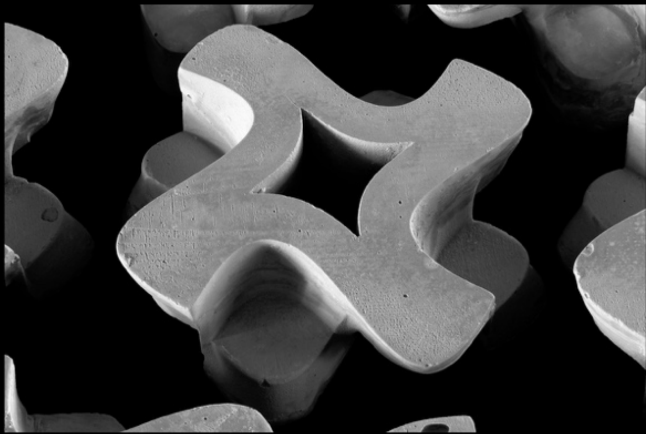
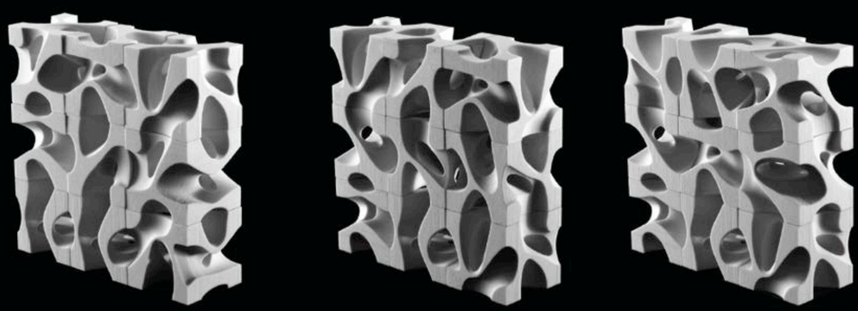
TESSELLATED INTERLOCKING STRUCTURES

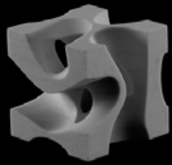






Disassembling the structure and transporting the components to a new site.





tranSTUDIO
Research Collaborator: Borhani, Kalantar, Houser, Hergert, McGilberry, Allen, Burro, Marshall & Loofs – Texas A&M

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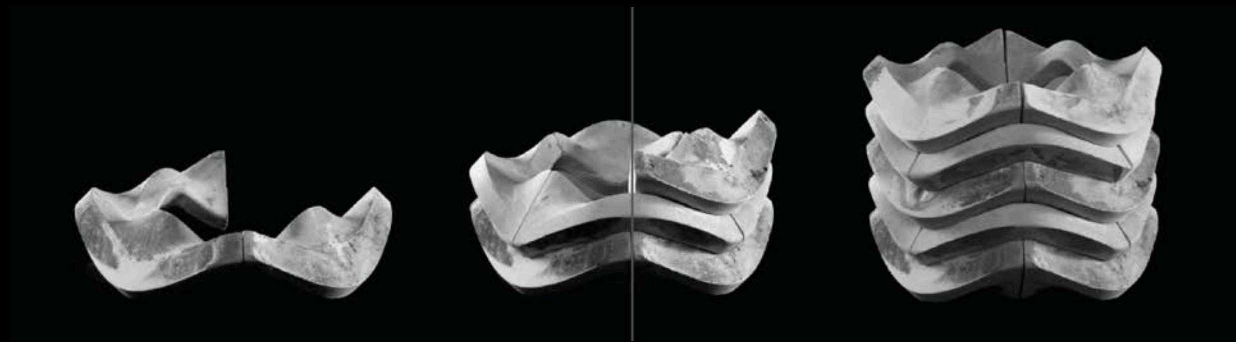
QUAKE COLUMN

Fine-tuning Quake Columns to work with seismic events



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Research Collaborator: Borhani, Kalantar, Wilt, Armenta, Echanove, Espinosa, Preiss, Reyes, Lambeth & Pearson – Texas A&M

TRANSFORMABLE SHADING DEVICE

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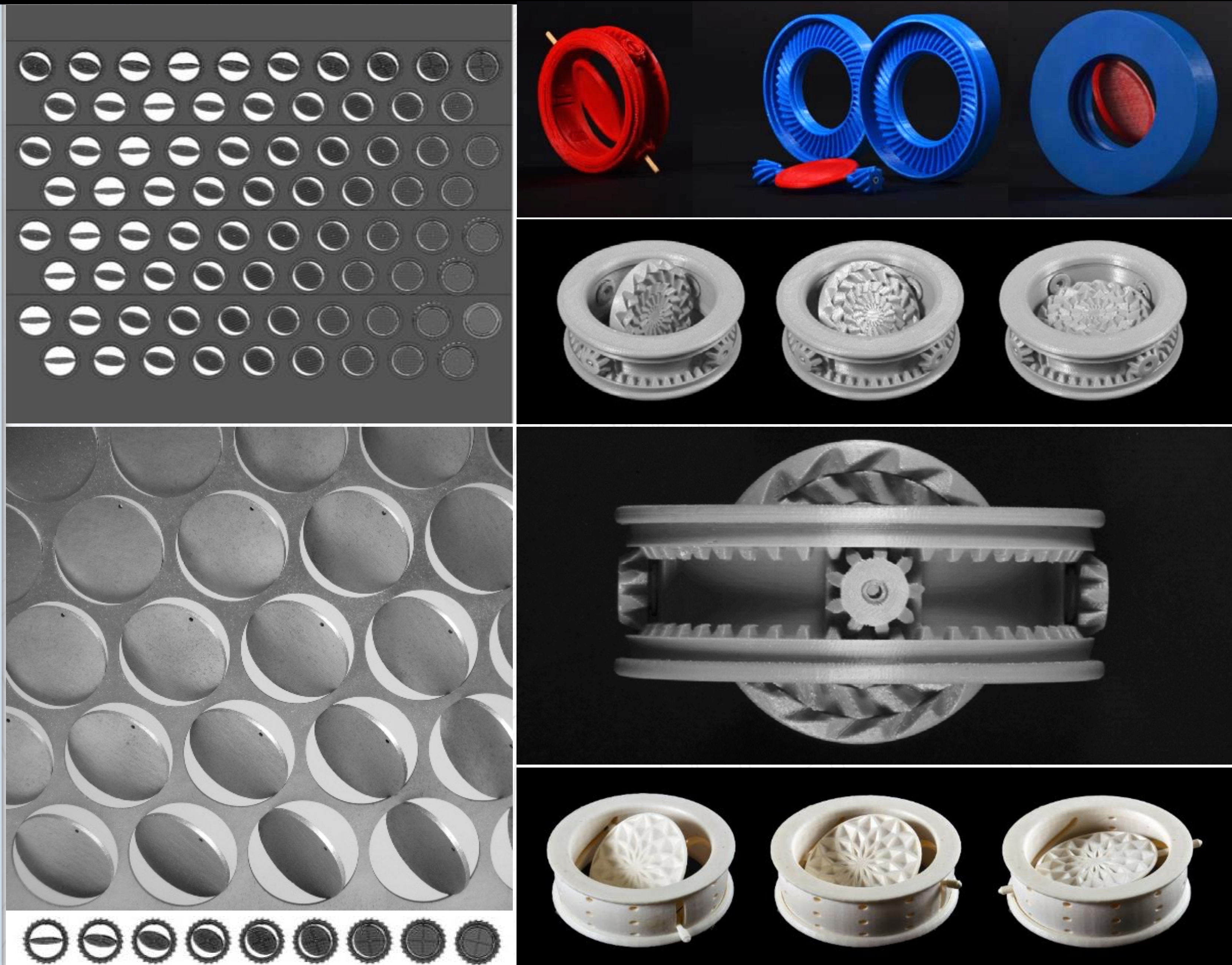
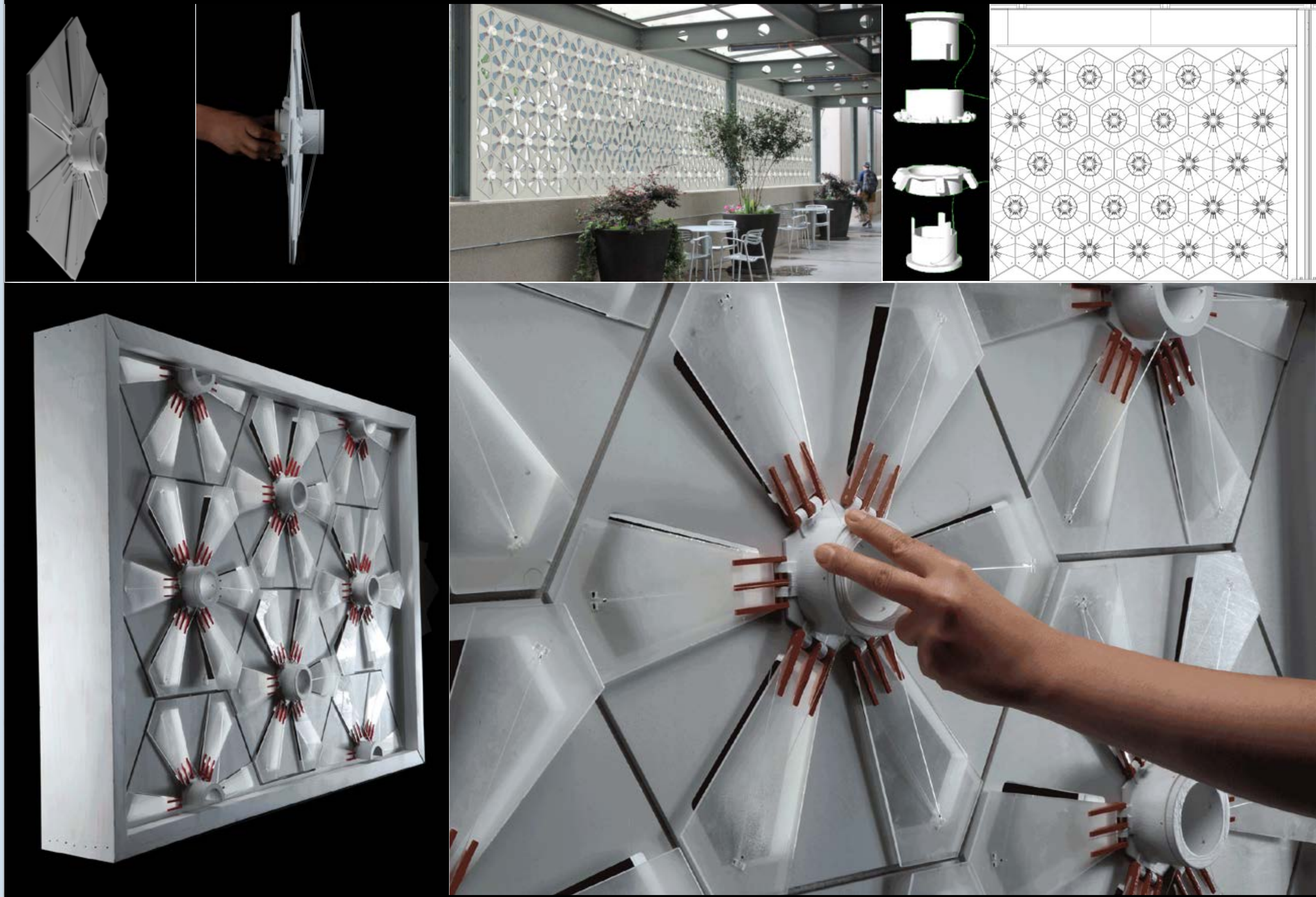


tranLAB- Research Collaborators: Borhani & Kalantar

TRANSFORMABLE SHADING DEVICE



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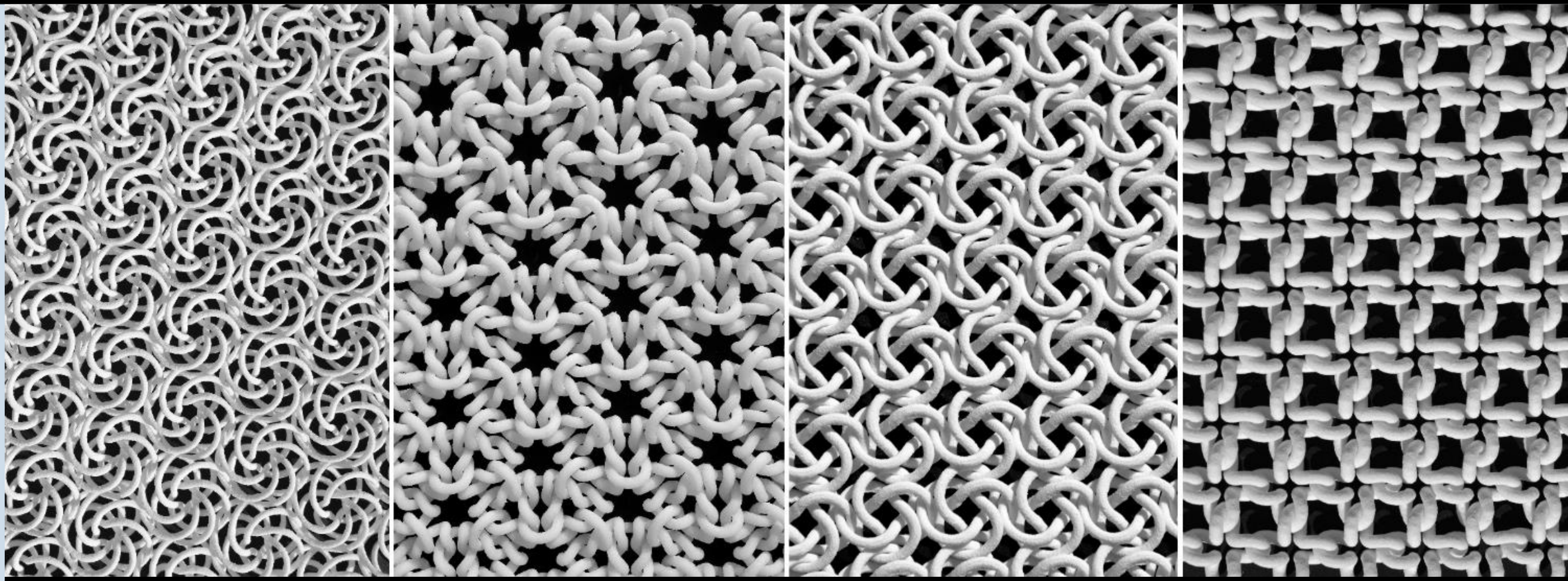
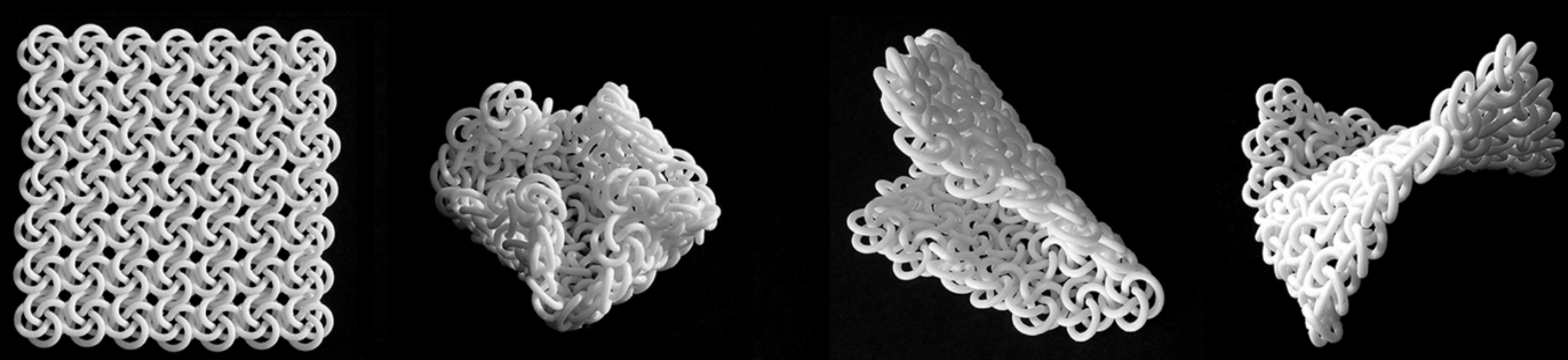
Research Collaborators: Kalantar, Wells, Henry, Yamaya, Al-Sholi & Buckley – Texas A&M

FLEXIBLE YET RIGID

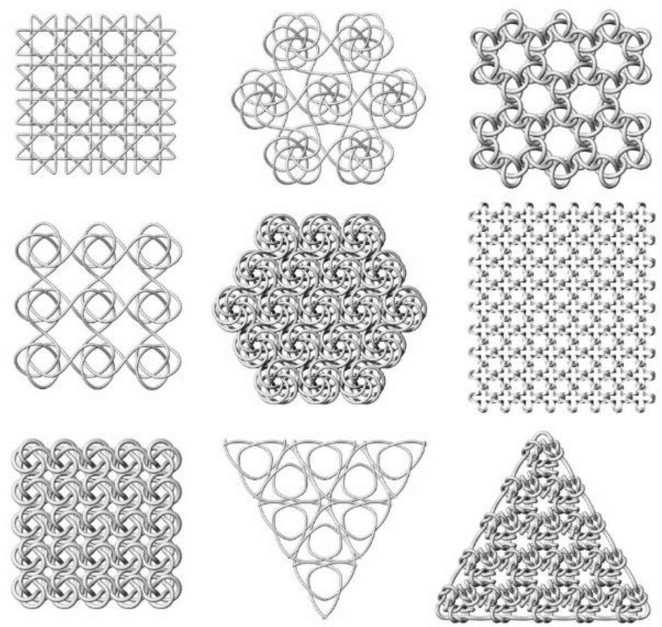


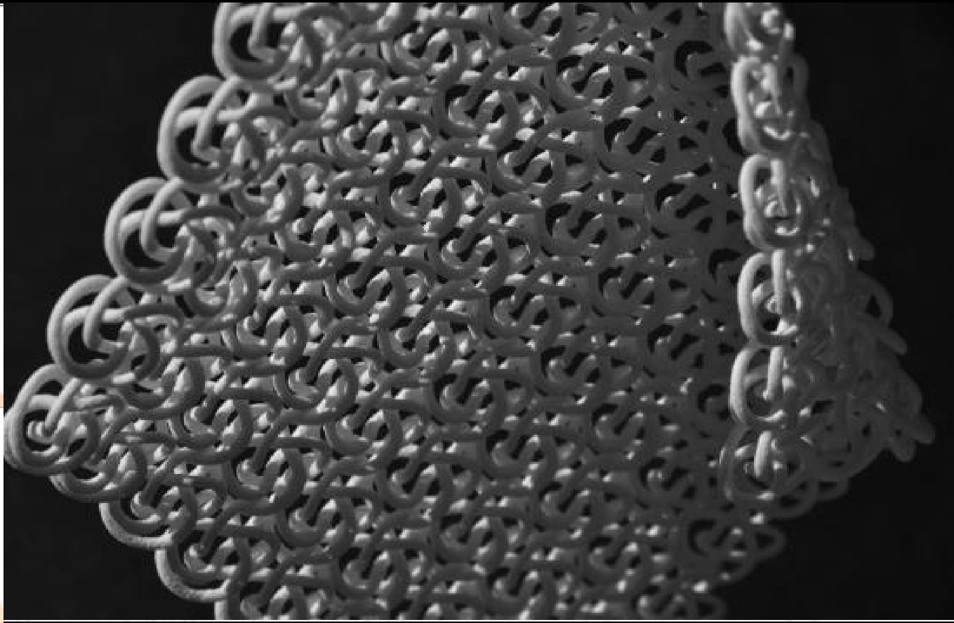
3D Printed Textile Structures

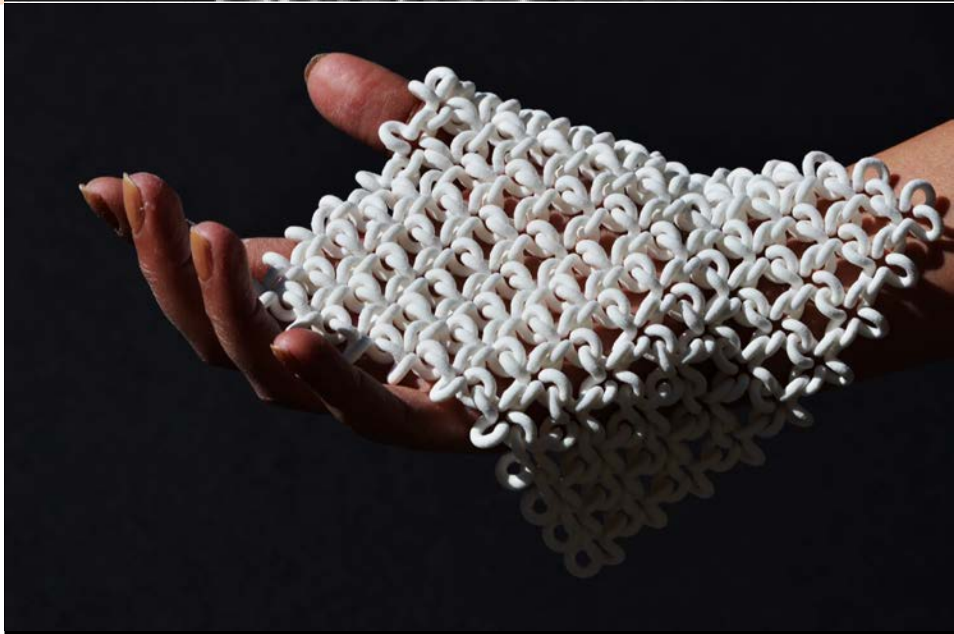


tranLAB
Research Collaborators: Kalantar, Borhani & The Dream LAB at Virginia Tech

FLEXIBLE YET RIGID







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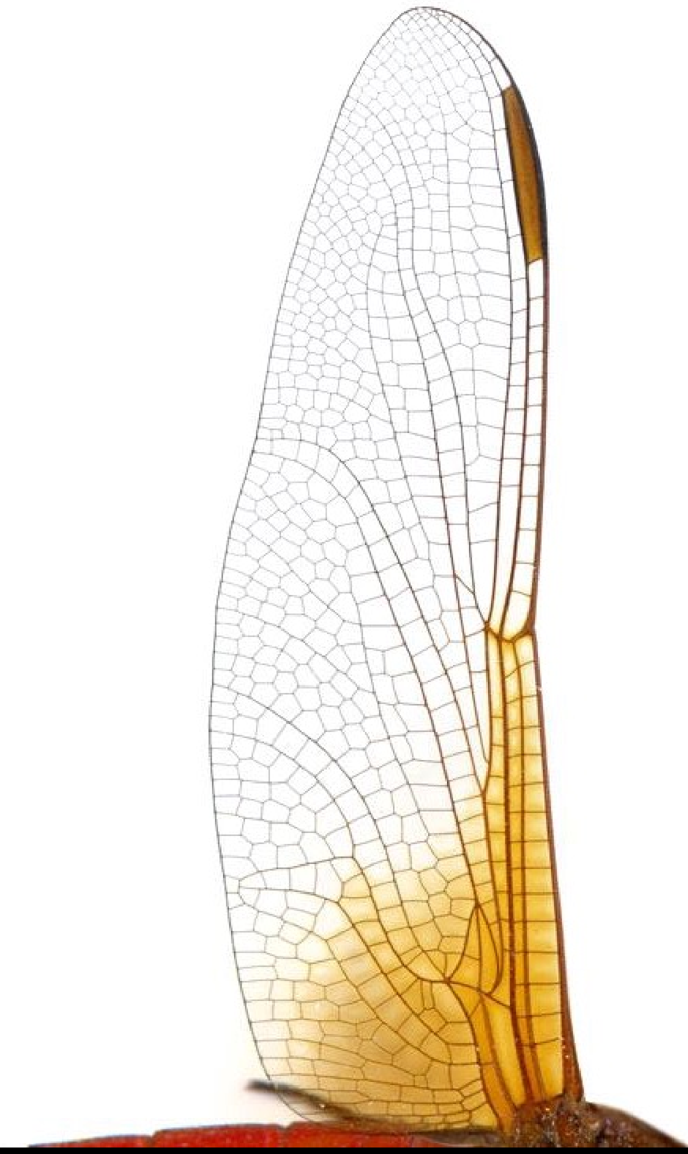
Research Collaborators: Kalantar, Borhani & The Dream LAB at Virginia Tech

Summary



Bjorn Birgisson, PhD, P.E.
Bjorn.Birgisson@tamu.edu

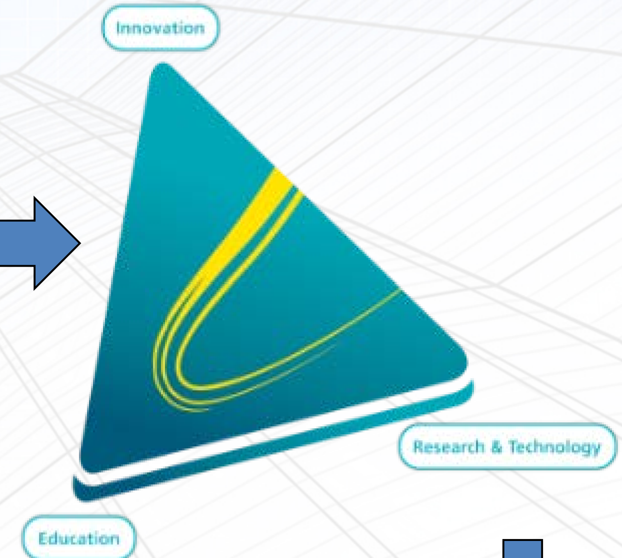
Center for Infrastructure Renewal at Texas A&M

138,000 square feet:

- High-tech, high-impact multi-disciplinary center for supporting research, innovation and workforce development

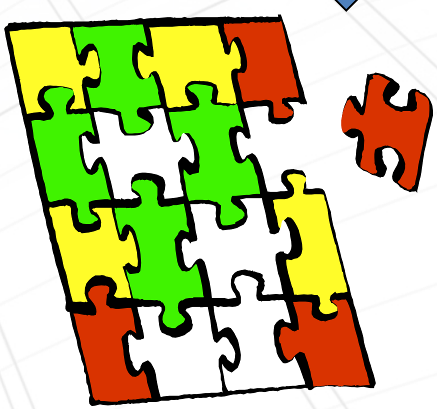
https://vimeo.com/188710268

Accelerating Research into the Marketplace



CIR Knowledge and Innovation Communities (CIR KICs)

A Multidisciplinary, Multi-Stakeholder Systems Approach to Research, Innovation and Workforce Training



Megamanufacturing KIC

- An interdisciplinary group of 27 faculty from architecture, construction science, civil engineering, industrial engineering, mechanical engineering and computer science
  - NSF Workshop, Summer, 2017
  - IDEA LAB, September, 2017
  - Create a consortium for leadership in 3-D printing
    - A forum for dialogue and collaboration
    - Industry Meetings in 2018
    - Joint National Roadmap Planning?

Workshop Question

- How is 3-D printing technology going to affect you and your business?

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Thank You!

This concludes The American Institute of Architects Continuing Education Systems Course

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CONTINUING EDUCATION AIA