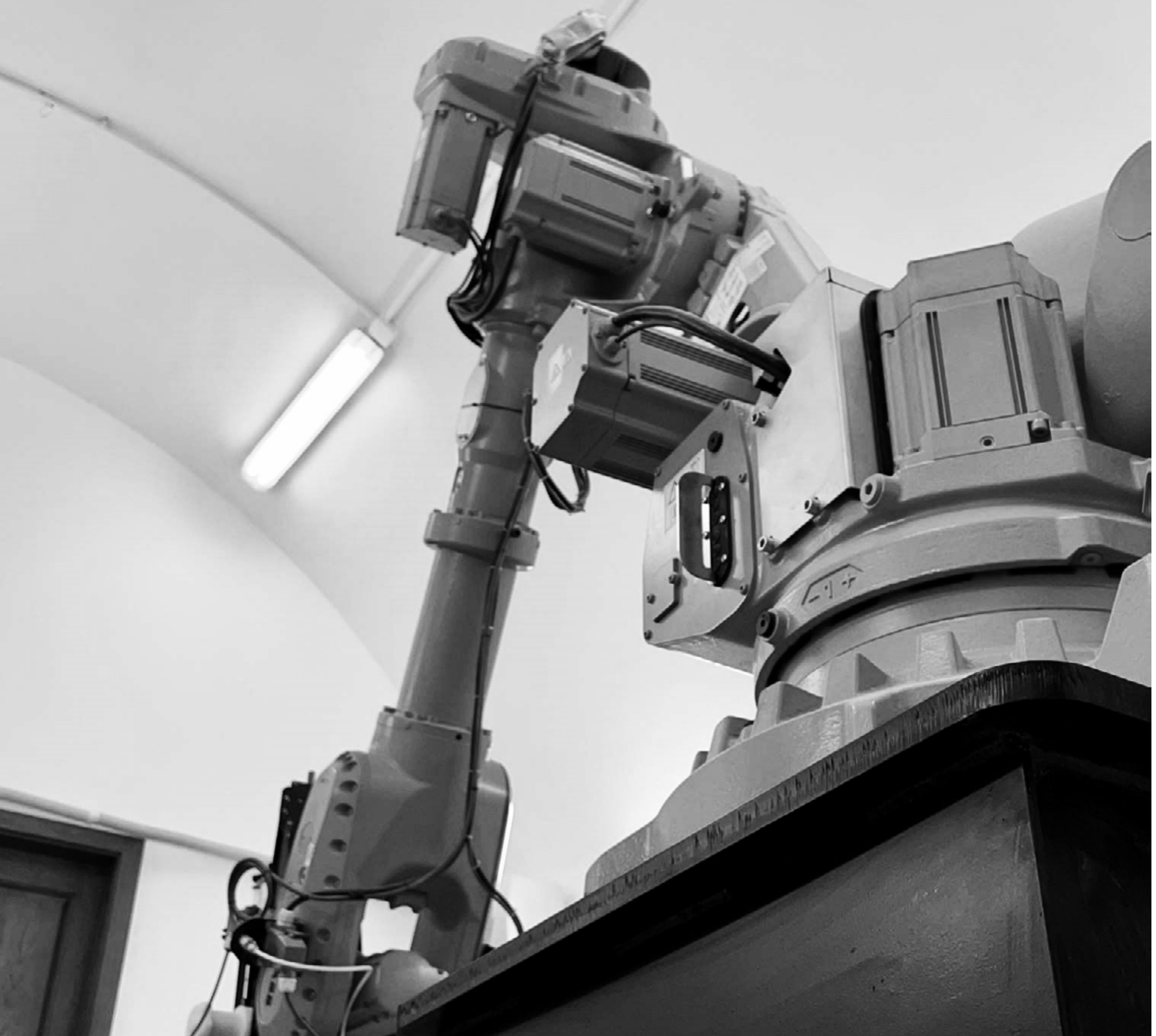
RFL

AUC Robotic Fabrication Lab

Department of Architecture, The American University in Cairo



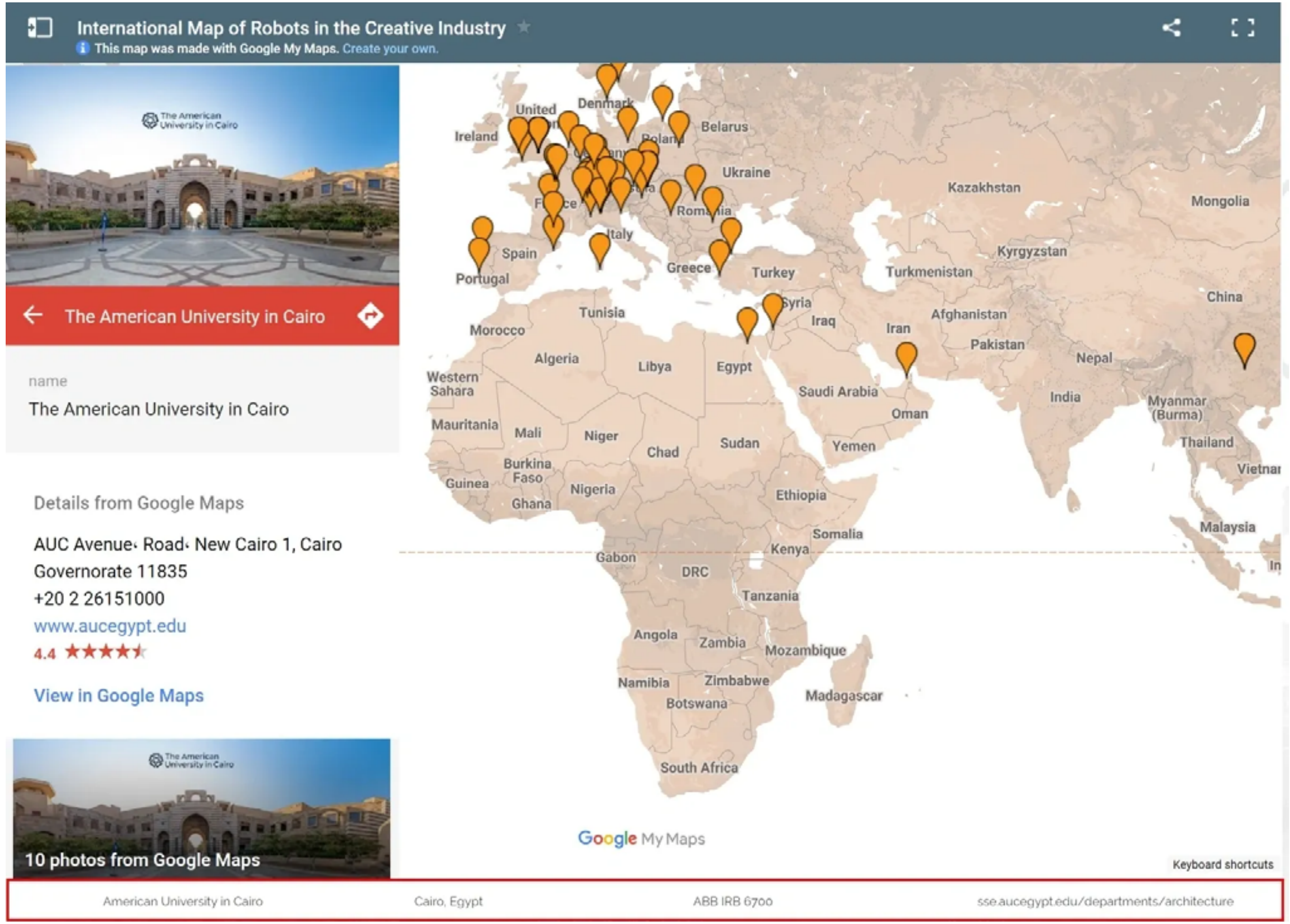
The American University in Cairo (AUC)

School of Sciences and Engineering - Department of Architecture
Robotic Fabrication Lab (RFL)

The Robotic Fabrication Lab (RFL) is hosted at the Department of Architecture at the American University in Cairo (AUC), Cairo, Egypt. The lab was officially launched in February 2022. The lab contains a 6-axes ABB Robotic Arm (IRB 6700 – 175/3.05) adapted for large-scale 3D printing and robotic material deposition, with multiple tool heads for extrusion, milling and gripping, with minimum effective volume of depositing (1.5mx1.5mx1.5m) and capacity to extrude primary clay and plastics. Other parts installed in the lab include an industrial robot controller (IRC 5), pedestal, clay and ceramic extruder, clay tank (5.0L), 3D printer head and plastic extruder (for printing a variety of thermoplastic materials with 80mm/s speed and 10mm3 flow rate), safety fence, and small pneumatic mechanical gripper (to handle objects from 3mm up to 20cm thickness, with rubbery gripping end, and gripping force up to 10kg).

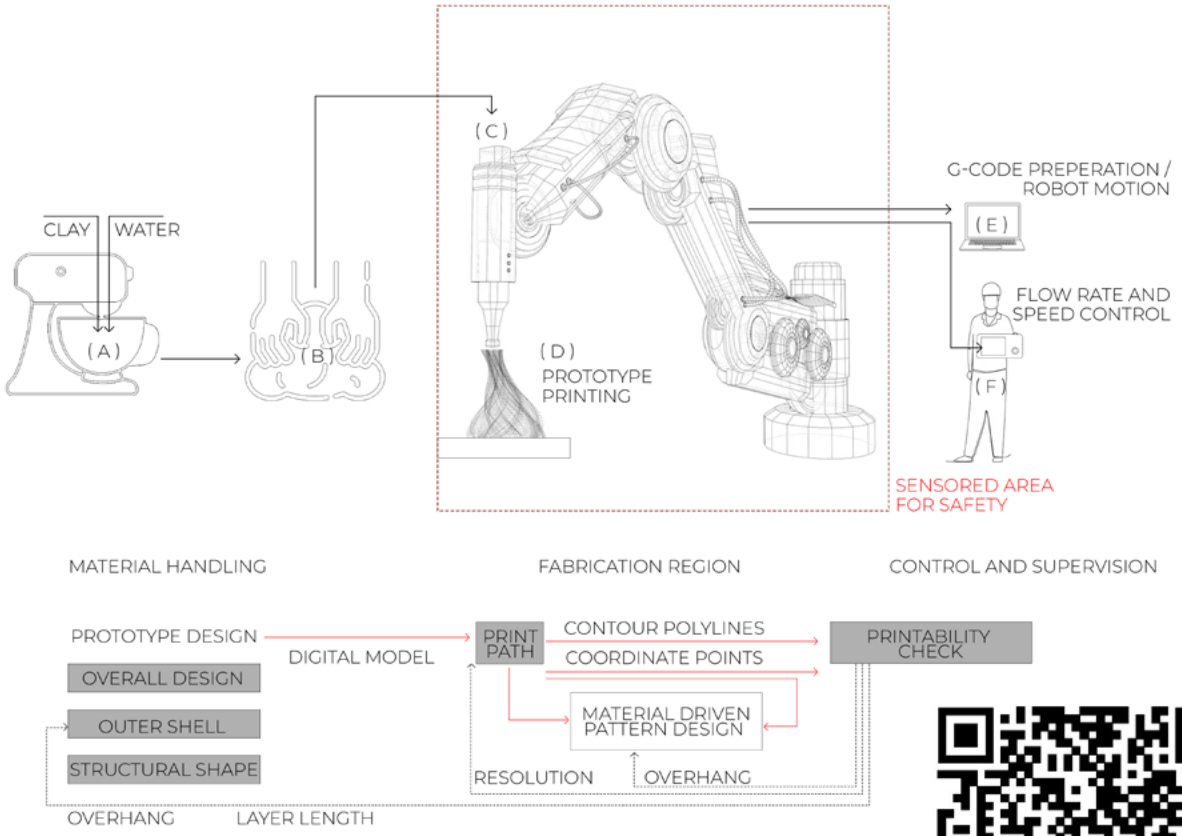
01

Introduction



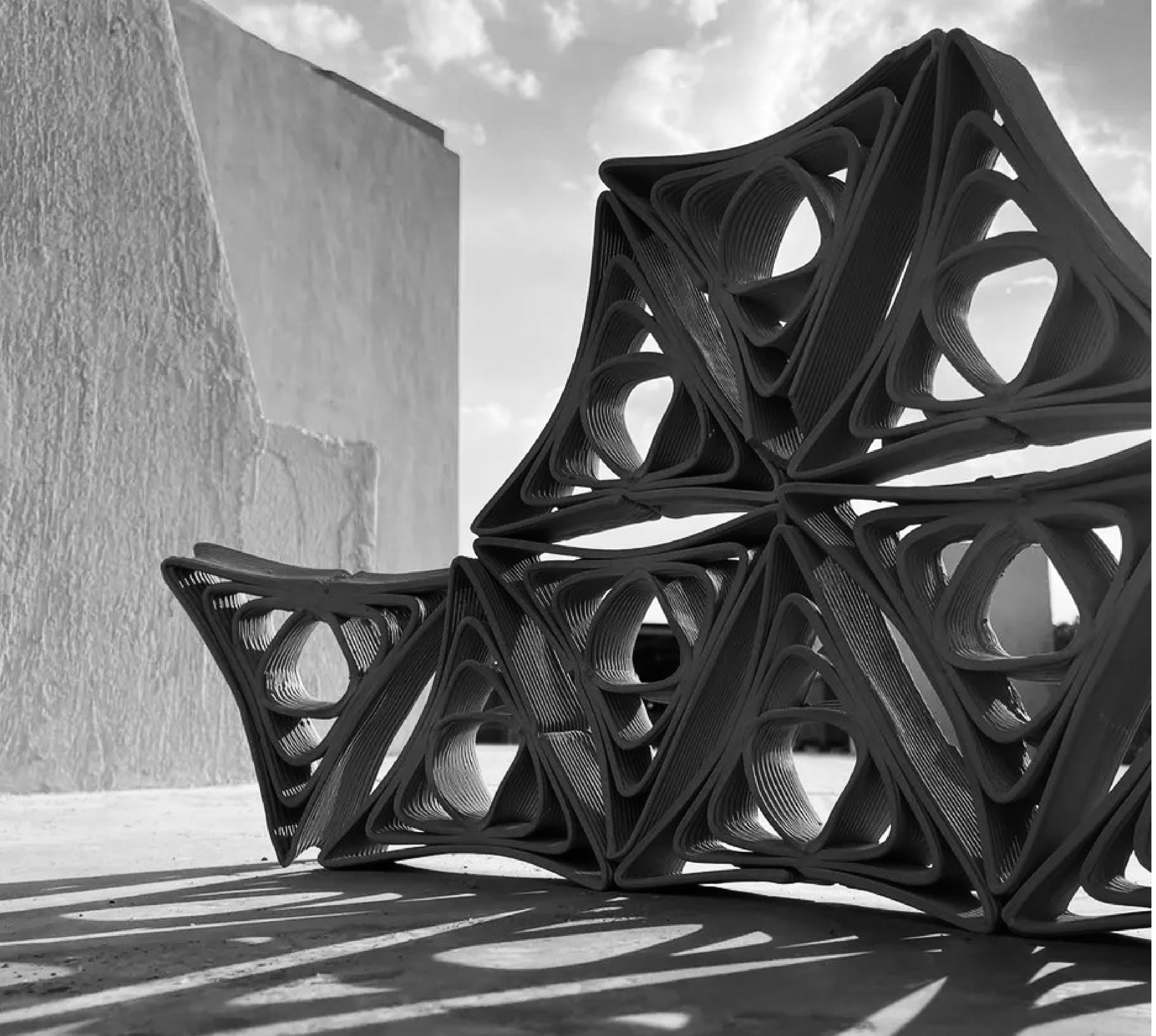
AUC RFL on the Map!

The Robotic Fabrication Lab (RFL) at AUC is officially on the International Map of Robots in the Creative Industry!



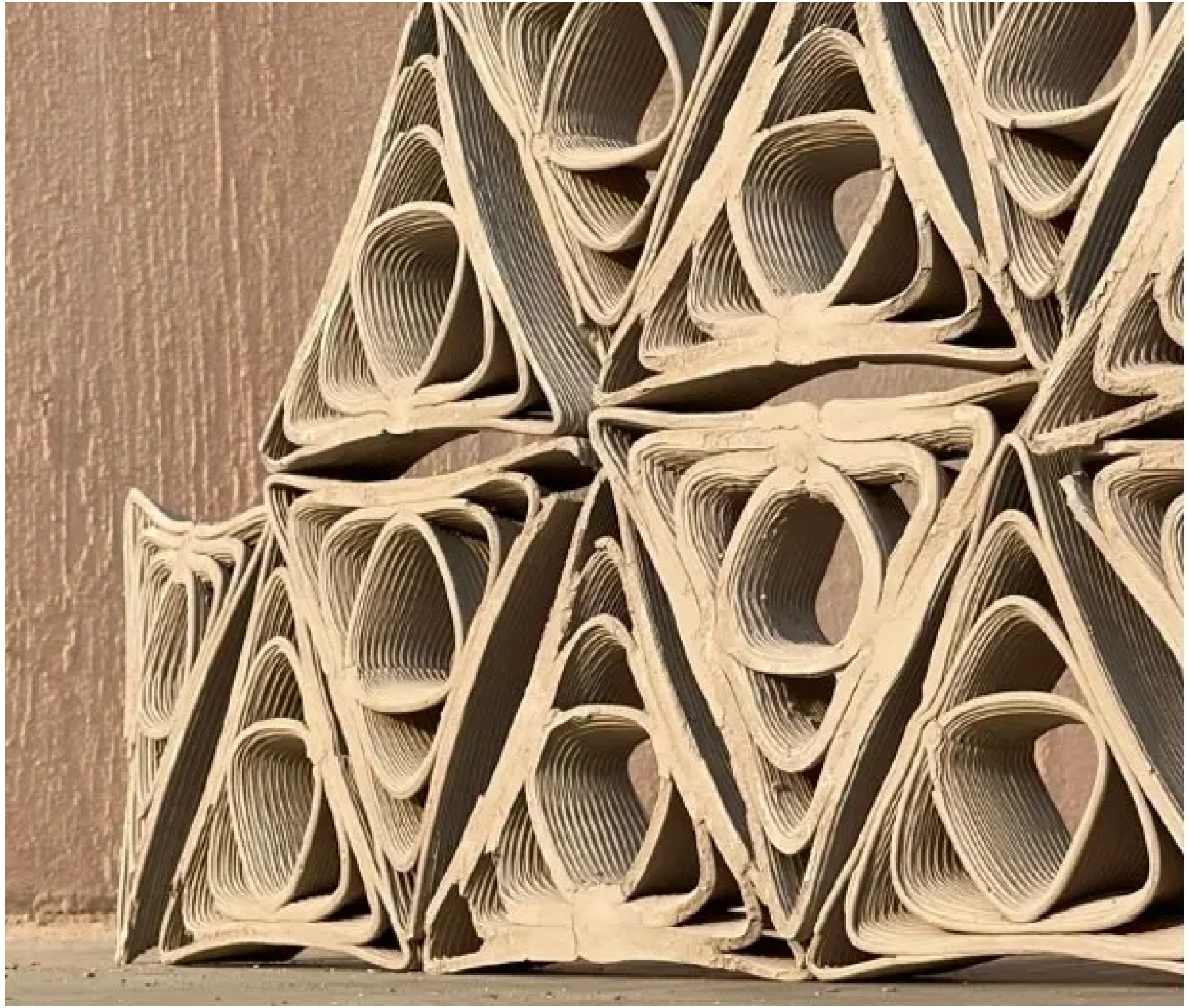
Additive Manufacturing - Robotic Fabrication - Clay

This is simply the process of the RFL process being incorporated in a myriad of research work and eeducational projects and future possible endeavours.



02

RFL Research Projects



Sustainable Green Construction using Robotically-Controlled Additive Manufacturing

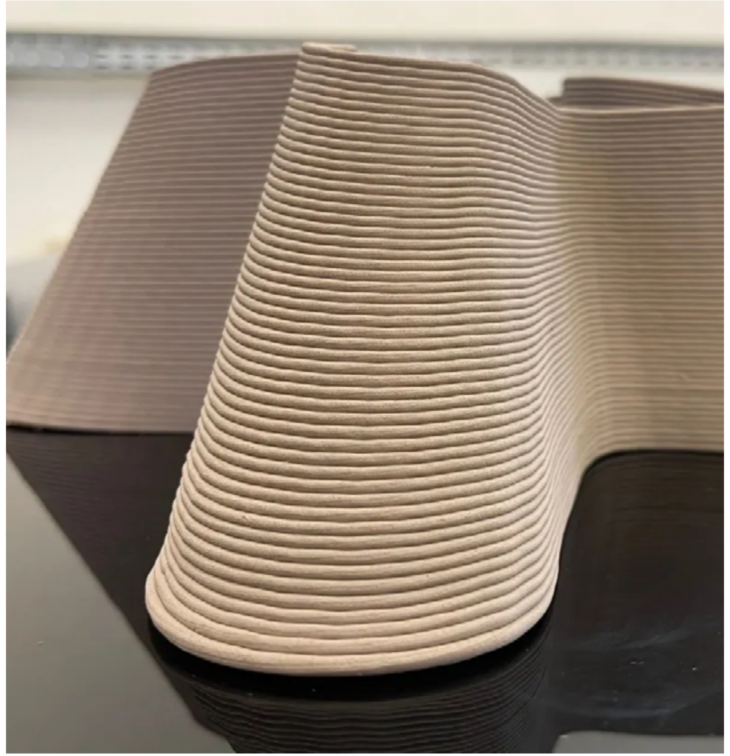
[2022 - Present]

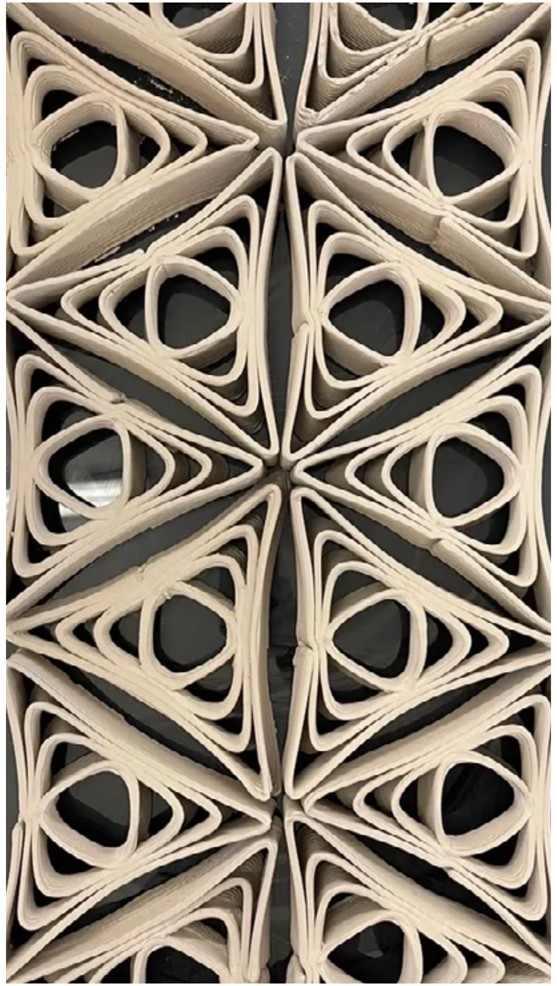
This interdisciplinary project capitalizes on the AMCL lab at the MENG Department and RFL lab at the ARCH Department at AUC, with the objective of expanding the possibilities of both wire arc additive/subtractive manufacturing (WAASM) and clay robotic deposition in the manifestation of architectural applications, specifically building facade envelopes. The project showcases state-of-the-art additive manufacturing facilities that consciously adopt sustainable approaches for a carbon-zero built environment, with the purpose of developing innovative and efficient design-to-fabrication workflows that stretch the boundaries of industries supporting green buildings. In particular, robotically-controlled additive manufacturing (AM) using different building materials facilitates Cleaner Production and a sustainable building construction process without causing emissions and/or pollutants compared to conventional techniques. With the overwhelming growth of AM, scaling up of these processes is revealing potential applications in the construction of green/clean buildings.

Using locally available resources, like clay-based materials instead of traditional bricks that are abundant in Egypt, will help achieve precision and accuracy when adopting the latest technology.

ClayMorphs

ClayMorphs - Design and Fabrication of robotically 3D printed clay panels, at the Robotic Fabrication Lab at the American University in Cairo, Egypt





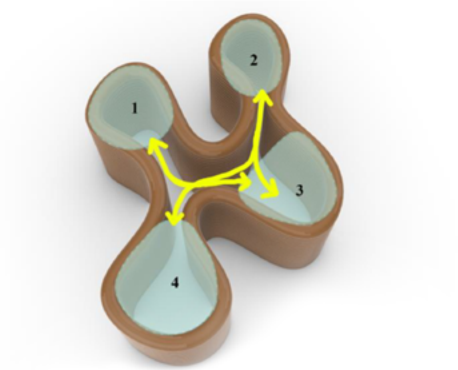
ClayBricks

ClayBricks - Design and Fabrication of robotically 3D printed clay bricks, at the Robotic Fabrication Lab at the American University in Cairo, Egypt

CORA 3D

CORA 3D - Design and Fabrication of robotically 3D printed clay bricks, at the Robotic Fabrication Lab at the American University in Cairo, Egypt

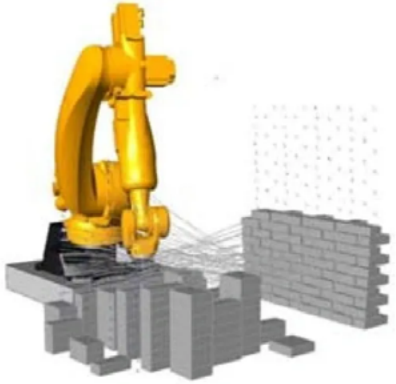
The different modules are designed to be horizontally assemebled, where they behave in this case as panels that could be placed in front of glazed surfaces in the building to protect against
unwanted solar radiation. However, each individual module could also be nested vertically, forming vertical load bearing structures, if the clay mixture affords so. In addition to this, if the scale of the module is increased it could host a cluster of spaces inside it with highlighted circulation paths, which manipulate the movement of the users inside.



Labelling potential space clusters and circulation paths within one module

MODULE NUMBER	MODULE	INNER CURVATURE RELATIONSHIP
1		MAXIMUM DISTANCE (D) = 10 CM
2		MINIMUM DISTANCE BETWEEN OPPOSITE SIDES = 4CM SAME SIDE = 10 CM

MODULE NUMBER	MODULE	INNER CURVATURE RELATIONSHIP
3		EQUAL DISTANCE BETWEEN STRAIGHT OPPOSITE SIDES AND CURVES
4		VARYING MAXIMUM AND MINIMUM DISTANCES (18CM, 4CM, 18 CM) RESPECTIVELY BETWEEN OPPOSITE SIDES



Thermally Responsive Brick Walls using Parametric Modeling and Robotic Assembly

[2017 - Present]

The aim of this project is to design, fabricate, and assemble low-cost thermally responsive masonry walls based on informed solar radiation data addressing the relation between incident thermal radiation and brick texture. Wall thermal responsiveness relates to variation in thermal mass via differences in brick extrusion values in response to shade and shadow from the surrounding context and brick topography. The objective is to set a methodology by which the majority of redbrick construction in growing informal settlements in Egypt can benefit from reductions in solar heat gain and enhanced thermal performance, without disrupting existing mainstream construction practices.

In collaboration with the Building Sciences Lab (BSL) at AUC, our approach involves (1) modeling/simulating thermal performance, construction and assembly for thermally responsive brick walls in hot arid climates; (2) physically testing/monitoring performance of the designed wall prototypes. We couple thermal simulation using parametric design, robotic assembly simulation and solar radiation simulation to allow for unlimited wall texture variation, context responsiveness, and construction efficiency/precision as relates to thermal performance. This is done using computational scripts that automatically translate wall configurations resulting from thermal simulations into robotic assembly simulation using parametric robotic control algorithms. This is done via a case study in Cairo as proof-of-concept using testing in an environmental chamber and in outdoor conditions. Due to the custom nature of the prototypes, structural challenges emerge, in relation to wall depths, heights, brick bonds, and structural robotic assembly process.

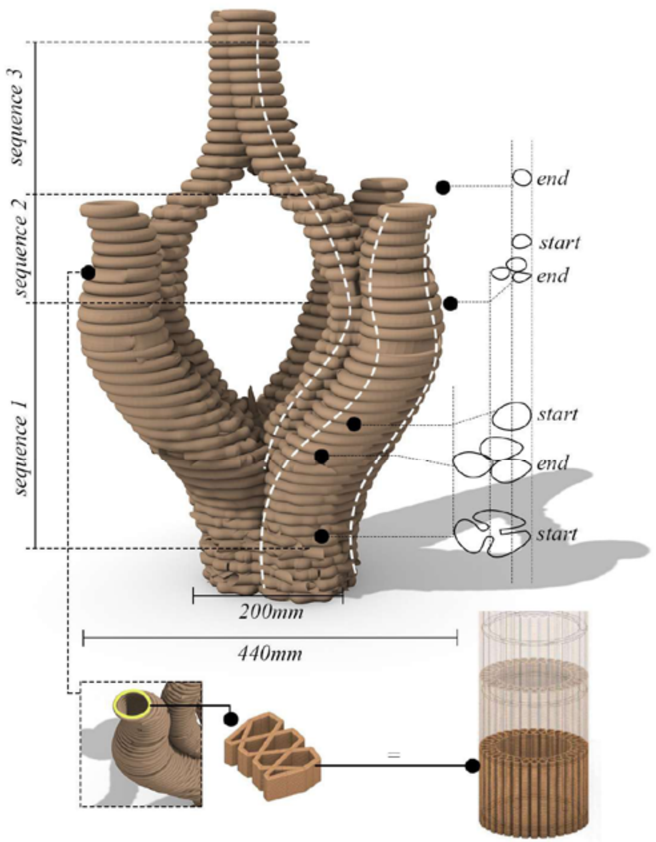
Integrating Robotic Material Deposition and Multipoint Forming in the Mass Customization of Double Curved Facades

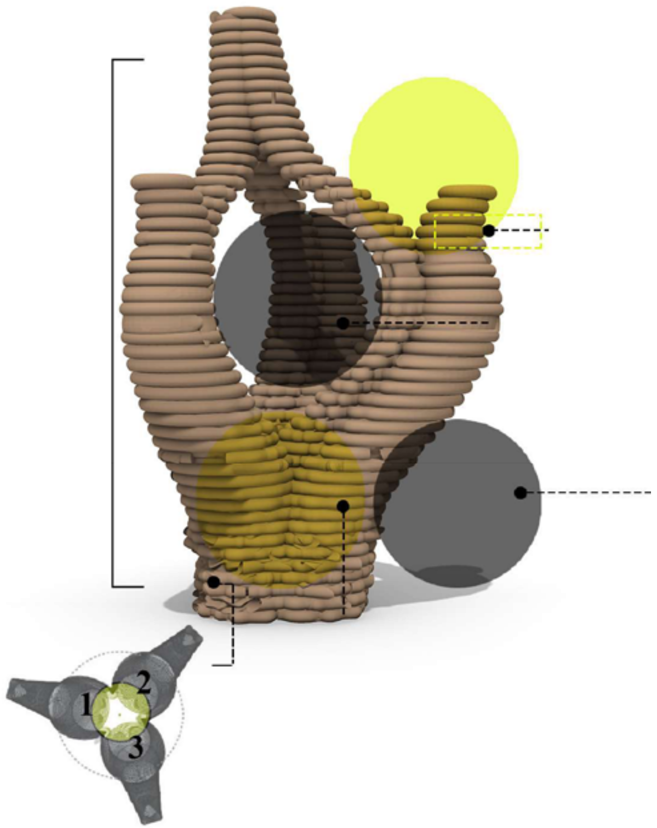
[2017 - Present]

This research introduces an optimized design-to-robotic production approach that integrates multipoint forming and adjustable moulds together with robotic free form material deposition to produce mass customizable double curved façade panels. We argue that our approach generates customizable panels with complex geometry, and optimizes fabrication workflow, with minimum waste and maximum accuracy in representing irregular forms. This optimized workflow capitalizes on two aspects; first, the use of automatically adjustable flexible moulds using multipoint forming, and second, free form material depositing over the moulds using robotic arms for high degrees of precision. The premise in this integration is two-fold: (1) generating customizable double curved panels with complex geometry; and (2) optimizing fabrication workflow, where waste material is minimized in comparison to conventional workflows.

03

RFL - Educational Studio Work





An Exploration of Clay Mixes As An Alternative Building Material

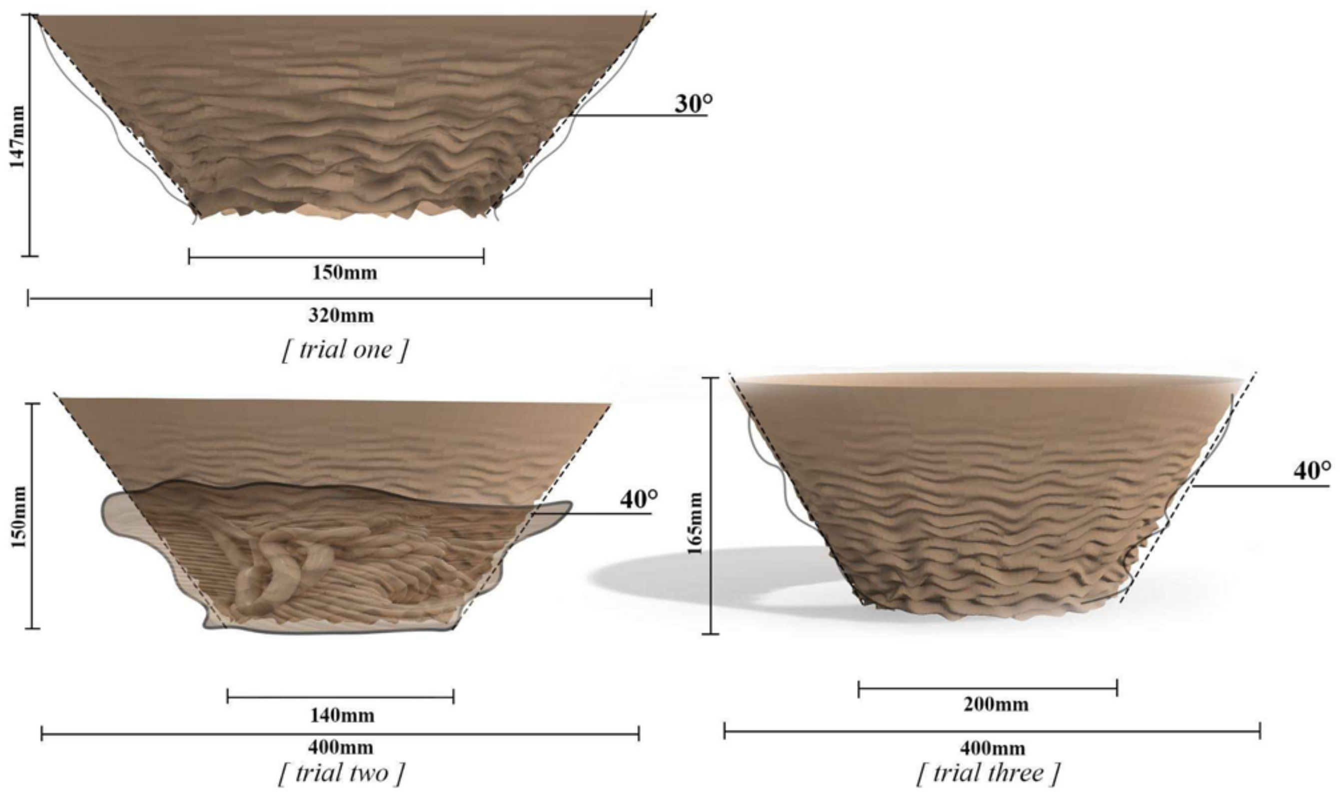
3D Printing With Clay For Form Generation

By: Farah Kamel - Fall 2022
ARCH 4801/2/3 – Tectonics Theory and Dissertation
Advisor: Dr. Aly Gabr

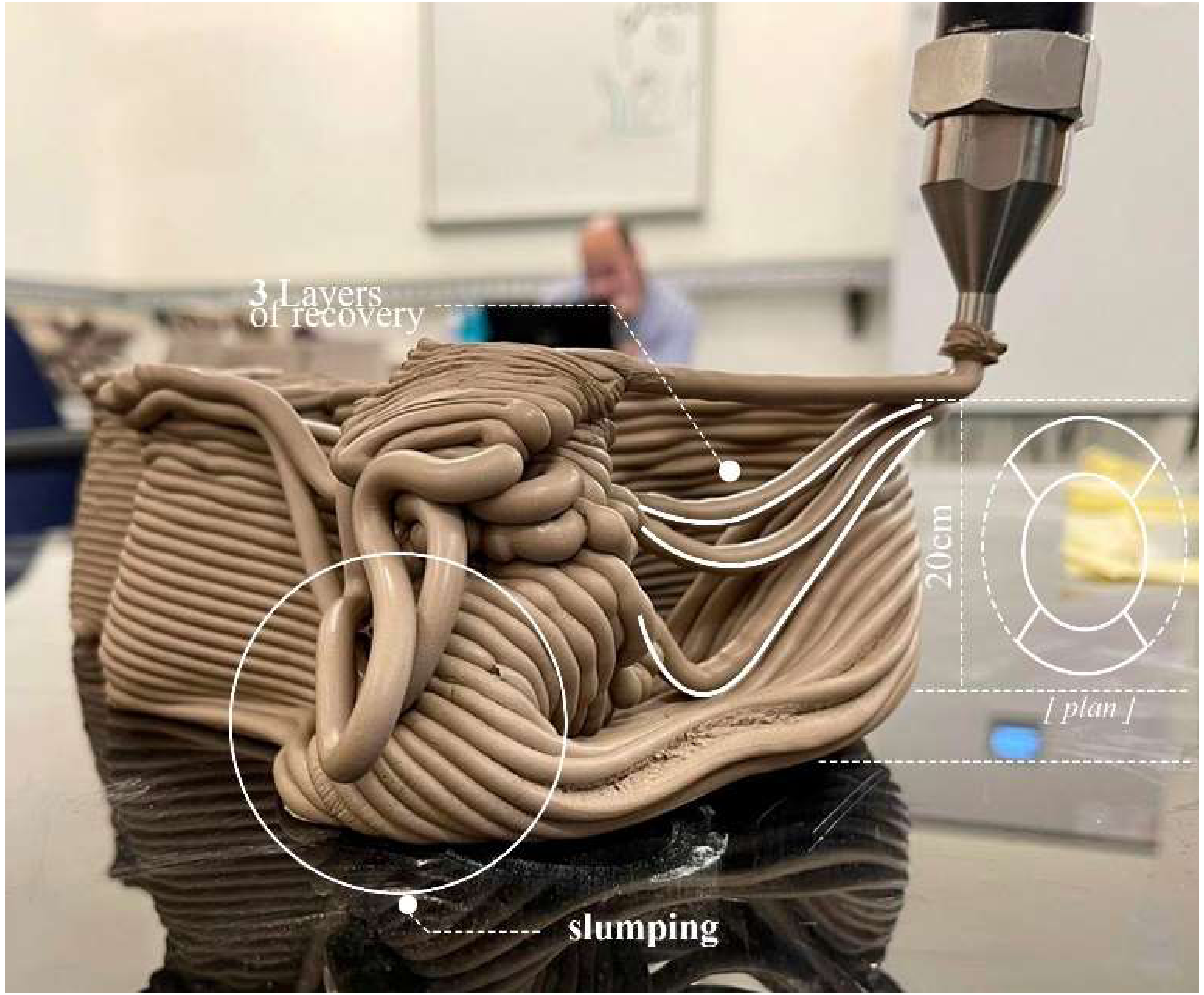
"Centuries ago, ancient Egyptians realized the full potential and power of the mud borne by the Nile and settled on its fertile banks. They manipulated the clay by firing and shaping it, giving it a characteristic tint, darker than the pottery created in nearby regions, imparting a piece of themselves into its making. It was an integral part of ancient life, being used in spiritual contexts such as temples, joining its maker into " the eternity that lies beyond the grave." (El-Batraoui,2016)

The primary problem to be researched in the proposed study, is the current inadequate number of trials investigating the vast room available for clay exploration and testing, which would push the potentials and limits of the material. Consequently, there is a lack of form generative approaches with clay as a building material, except typical models using traditional fired and adobe bricks. Hence, a new suitable building technique, which requires testing, is necessary to develop architecture that constantly inspires its inhabitants and harnesses new technologies.

Thus, the aim of this research paper is to use 3D printing to explore different clay mixes as a building material and form generator of a Clay Research Center. That acts as a container, which is comprehensive and reflective of the users in it, and a source of inspiration for them. To achieve the above mentioned aim, the following objectives have been formulated:
1) To examine the possibilities of clay mixtures supplemented by natural additives.
2) To propose clay as a new building material beyond the vernacular possibilities exhausted
3) Analyzing and adapting the scope of previous works using high tech fabrication methods exploring clay to local abilities.
4) To inspect the application of 3D printed clay modules as walls, and its ability to handle multiple floors and/or different perforations. "



This research delves into the gap in clay exploration and testing within architecture, aiming to develop a form generation process beyond traditional brick stacking by integrating 3D printing techniques to achieve a hybrid form genesis approach. The study encompasses a theoretical exploration of vernacular architecture, critiques of 3D printing processes, and practical experiments in 3D printing to understand and manipulate printing parameters for creating complex geometries that are stable and functional for architectural applications. Ultimately, it proposes a methodology that combines manual and mechanical processes to create a clay research center, focusing on local adaptation and innovation while addressing the challenges of introducing such technologies in low-tech environments.



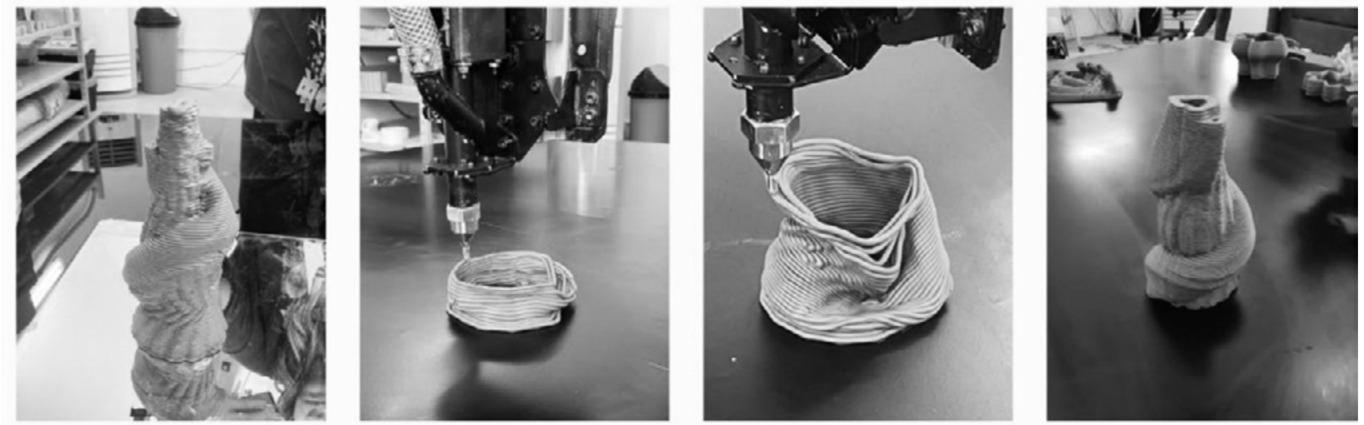
Phase 2: Synthetic Fabrications

Fall 2023 - Spring 2024

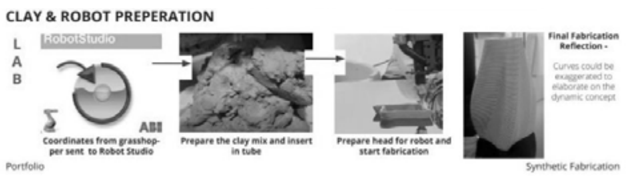
ARCH 3522/473 – Design Studio and Workshop

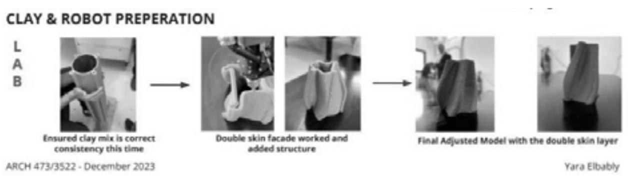
Teaching Team: Dr. Sherif Abdelmohsen - Dr. Passaint Massoud - Aly Magdy - Youstina Eskandar - Farah Yasser - Rowan ElSelmy - Sarah Ashraf - Miyar Kassass - Lina Naguib - Nada Yaakoub - Fatma A. Farrag

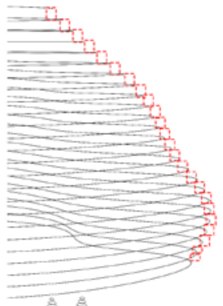
In an attempt to manifest your innovative designs, patterns and compositions into physical artifacts, the theme of this project "Synthetic Fabrications" couples aspects of art and material culture, contextual relevance, and heritage roots, with advances in additive and subtractive manufacturing, 3D printing, digital fabrication and robotic production techniques. The challenge in this project is to translate digital designs into constructible artifacts that can be physically fabricated using state-of-the-art digital fabrication approaches, and to achieve suitable workflows that satisfy both aesthetic and technical requirements of naturally inspired designs. The objective is to appropriate digital models for fabrication using a natural and abundant material in Egypt such as clay which is characterized by its longevity, low heat transfer, aesthetic value, eco-friendly characteristics, distinct technical specifications, plasticity, and its intricate connection to local and traditional knowledge, and its role in preserving cultural heritage and maintaining social identity, therefore adding to the general objective of reviving the character and heritage of our authentic rich context while adopting the latest in digital fabrication methods and approaches.



In this stage of the course, the same student groups established in Project 1 are asked to research digital fabrication techniques and approaches, and develop a workflow for physically transforming a naturally- inspired digital model representing the group to a digitally fabricated outcome using clay. The challenge in this project involves
(1) achieving a workable digital model that can be easily fabricated using robotic production,
(2) developing a clear understanding of the material properties of clay as the suggested deposited material,
(3) developing an understanding of design-to-robotic production workflows and the necessary programming environments that translate digital models to the robotic fabrication code, and
(4) understanding the constraints of the material properties to develop different iterations of a physical artifact. Accordingly, groups are encouraged to assign clear tasks amongst their members to address these challenges.

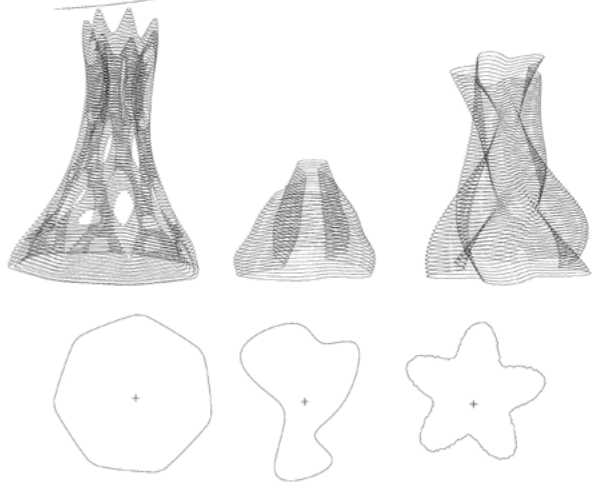






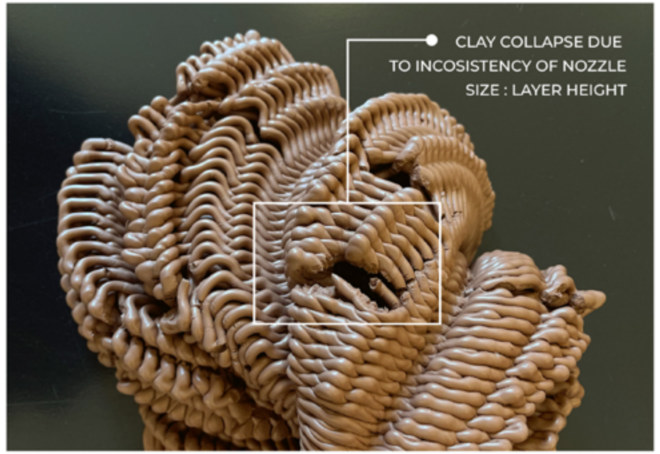
NOZZLE SIZE VS LAYER HEIGHT IN THE RFL

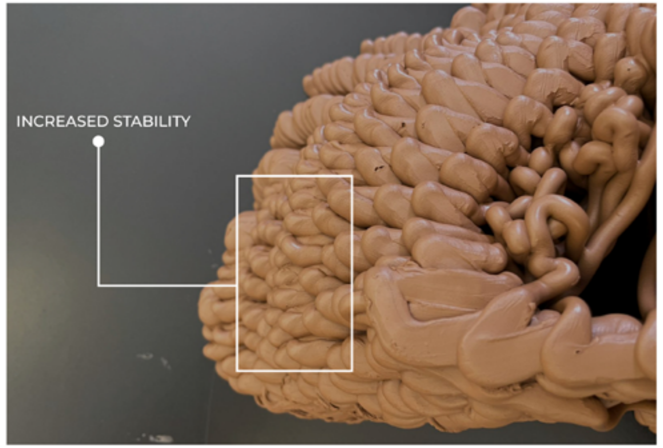
modulating the contour height according to the nozzle size-to-layer height ratio is vital. it may change according to the consistency of the clay mix but the nozzle sizeshould mostly be twice the layer height. if this ratio is reduced, it will result in the slumping of the layers and collapse of the the print.



CONTOUR HEIGHT = 2 CM MINIMUM AMPLITUDE	CONTOUR HEIGHT = 2 CM MEDIUM AMPLITUDE	CONTOUR HEIGHT = 2 CM MAXIMUM AMPLITUDE

while keeping the contour height the same, altering the amplitude in the different prints increases the relative toolpath thickness resulting in a more stable print.





In doing so, you are encouraged to continually ask yourself the following questions:

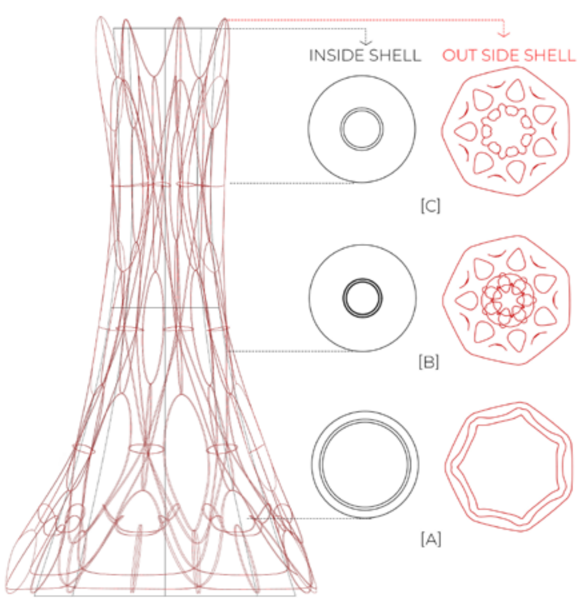
- **What strategies can be developed to extract data from digital models for fabrication?**
- **How can digital fabrication be used to extract parameters for a parametric form finding process?**
- **How can digital fabrication workflows produce designs that satisfy both aesthetic and technical requirements?**

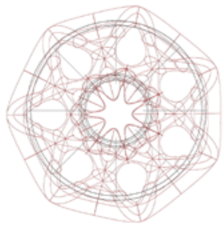
04

Future Potential Upscaled Endeavours

Columns to Towers

We could expand from micro to macro with the correct industrial-level equipment, resources, space and adequate work environment.

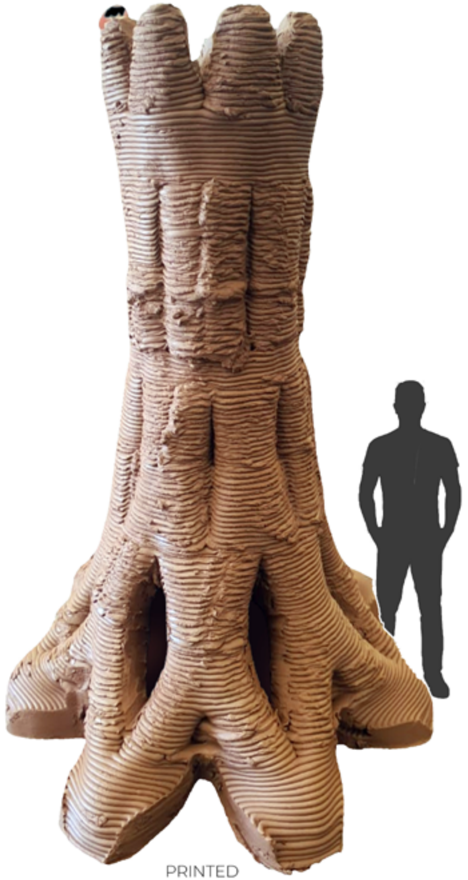




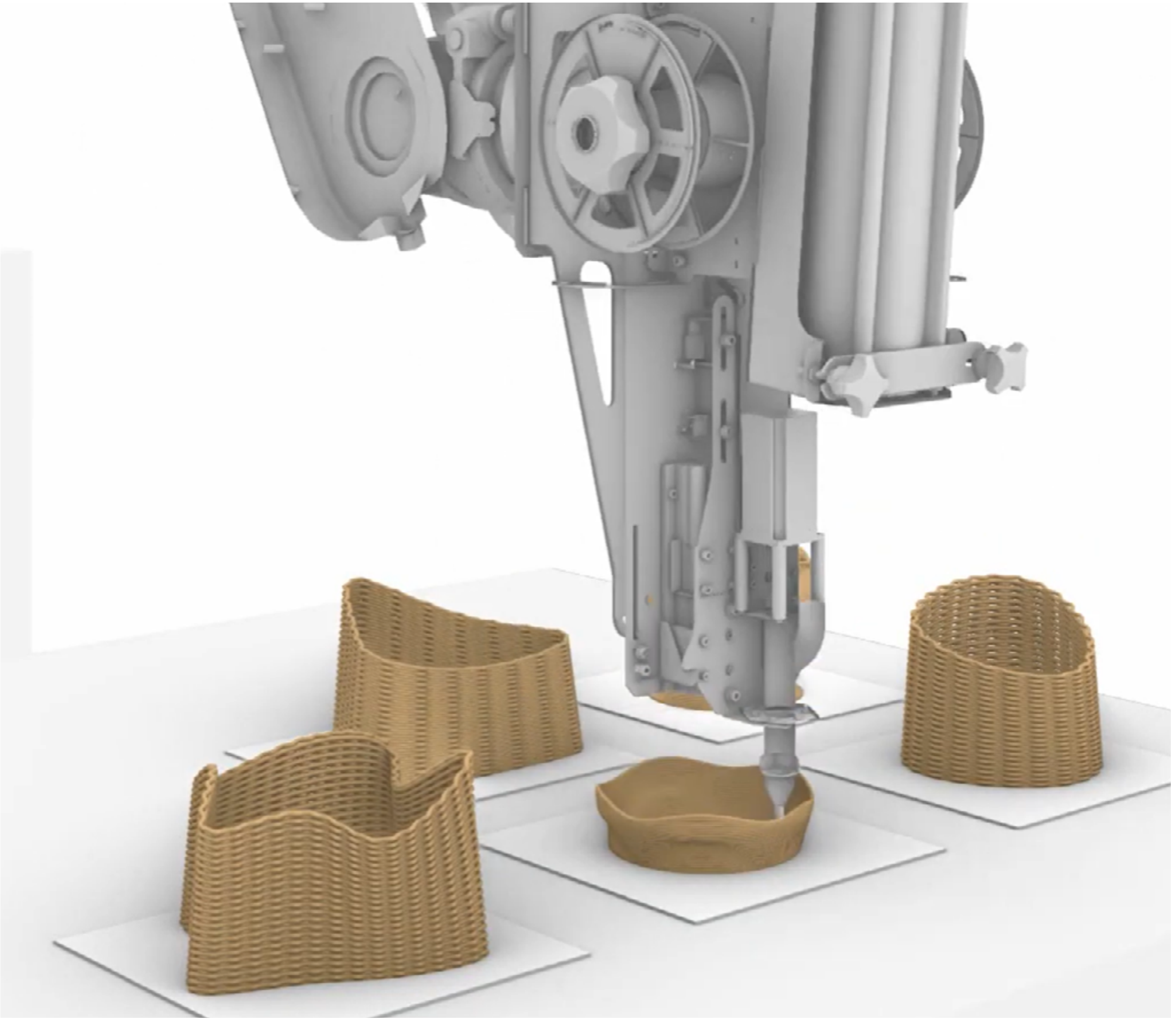
TOP VIEW

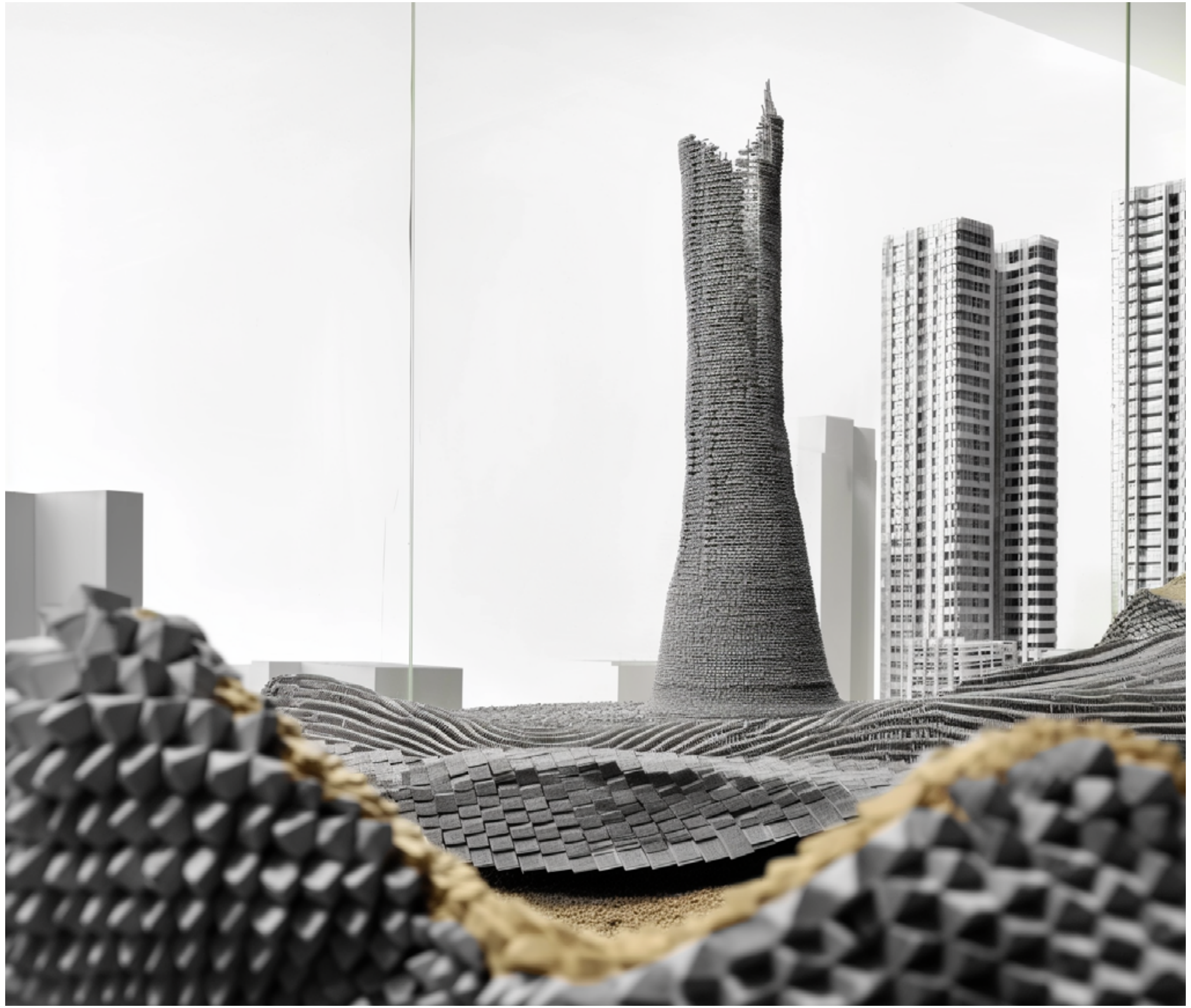
NESTED COLUMN TYPOLOGY

the attempted prototype explores the design space that allows for columns creation in the robotic fabrication lab (RFL). As this is a standalone attempt, further collaborations with other fabrication labs could allow for the **structural testing** of these columns.

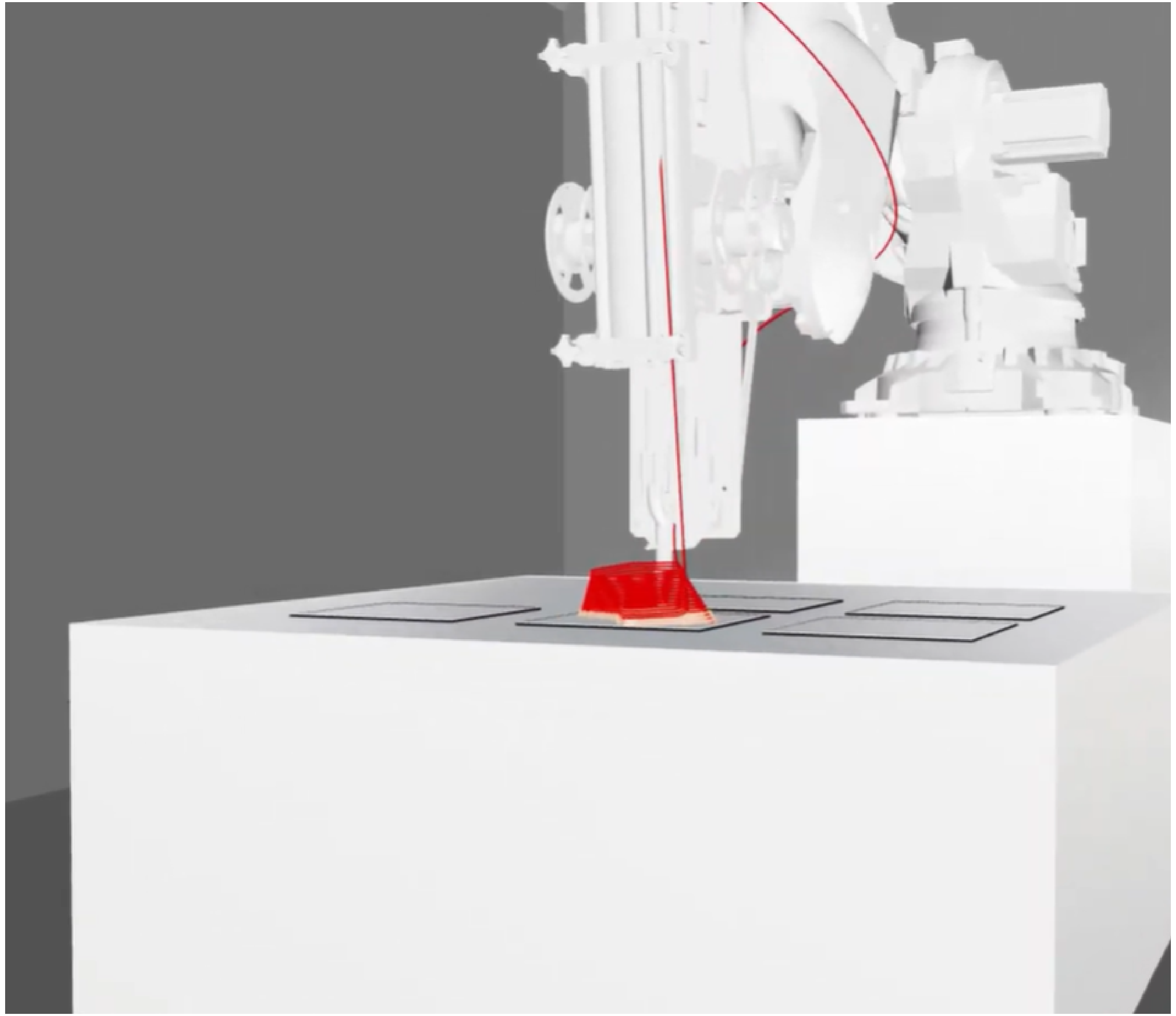


PRINTED PROTOTYPE





Future Potential Upscaled Endeavours

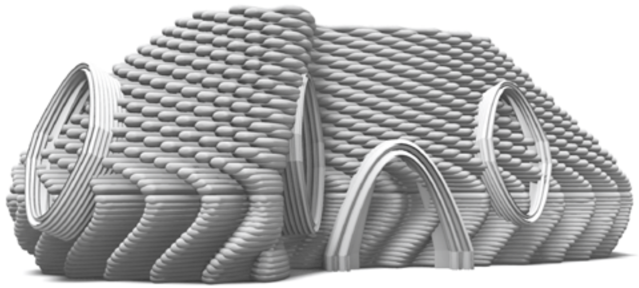


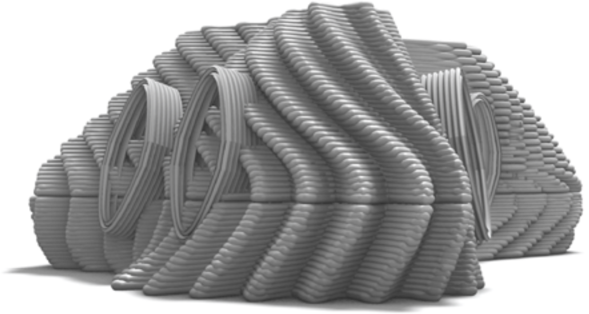
AUC Robotic Fabrication Lab

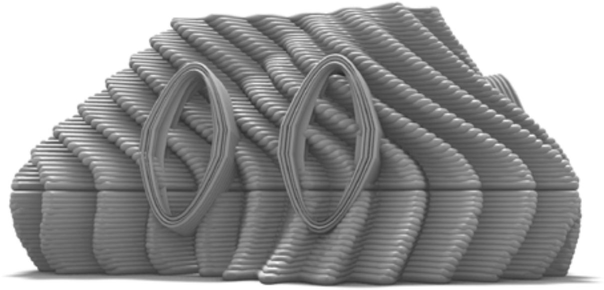
Vernacular Modernism

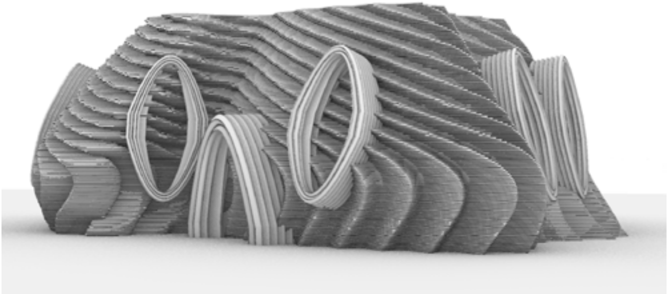
Housing prototypes could be fabricated and mass-customized in a most time-efficient and labour-efficient matter with Robotic Fabrication.

These protoypes and knowledge was established in the multiple research and educational projects produced and conducted in the AUC RFL.









Clay Eco-Compounds

Mass Customization and Rapid Construction with Local Environmentally-Friendly materials is closer than you think.

05

RFL Affiliates and Teams

Dr. Sherif Abdelmohsen
RFL DIrector and Chair, Department of Architecture at AUC, Egypt

Dr. Aly Magdy
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Founder, Aly Magdy Studio
Visiting Researcher, RFL

Dr. Islam Salem
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Assistant Professor at AAST
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Aseel ElAshry
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Salma Ghanem
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BSc, AUC 2022
MSc CAD Cadidate - DesignMorphine

Nada Yaakoub
Research Assistant, RFL
Teaching Assistant, Coventry University, AUC
BSc, AUC 2022

Omar Geneidy
MRAC Holder, IAAC 2019
Founder, JEEZAR
Head of Business Development, CONIX.AI

Rowan ElSelmy
Founder, WeAreDesco
Computational Designer, Illusor
AUC Architecture Teaching Assistant

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