inhabit3D

3D printing focused on social housing using the Kit-of-Parts method

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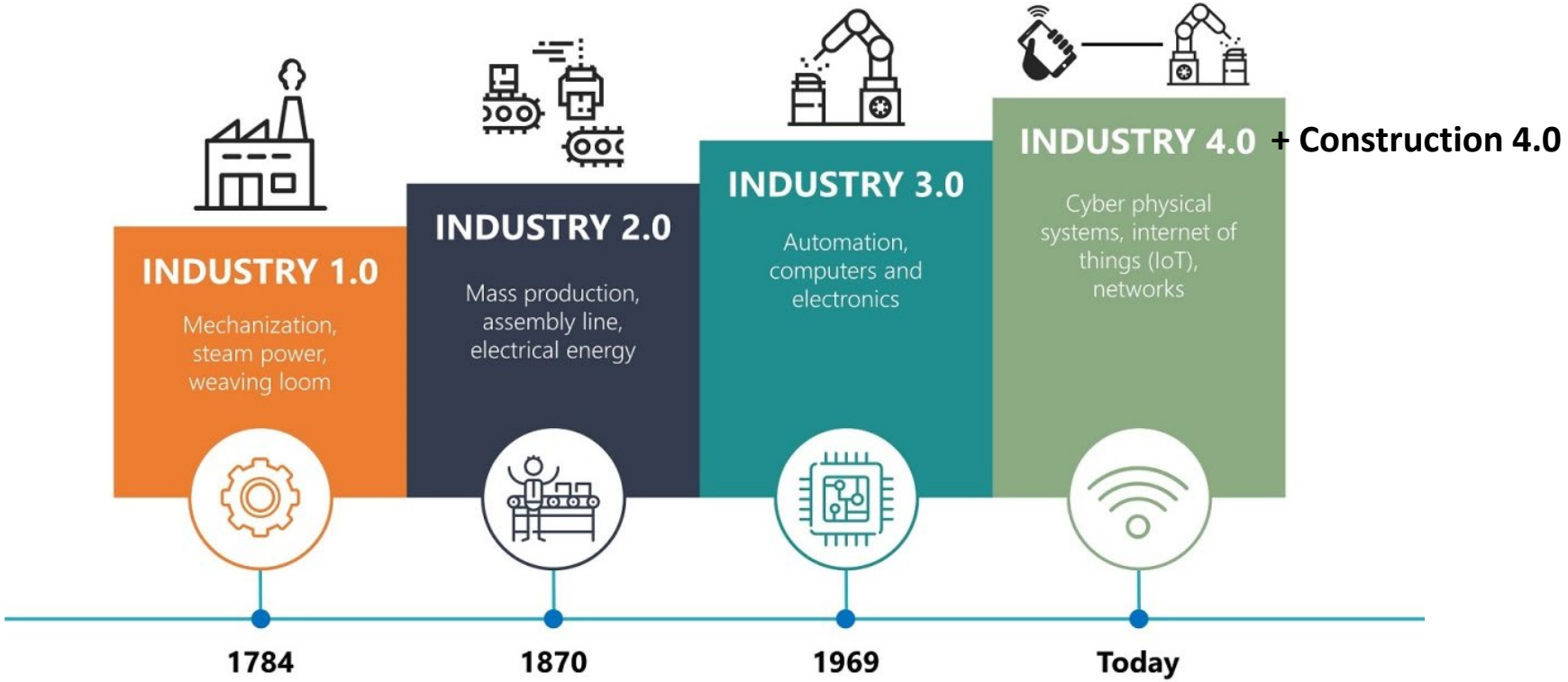
Oscar Rommens

Own photo.

Own photo.

1_BACKGROUND

Industry Revolution 4.0



+ Construction 4.0

Industrial Revolution 4.0 is imparting its impact on our medium of communication and visualisations; therefore, we are adapting to cyber–physical systems.

1_BACKGROUND

3DP benefits

3D concrete printing. All3DP website.

3D printed house. 3M future LAB, UCLA

The speed, automatization and the possibility to address high-volume projects made it one the most economical options. By including an integrated design, other building elements as furniture or plumbing can be fused to walls or columns.

1_BACKGROUND

3D printing explorations

3D printed columns. ETH Zurich.

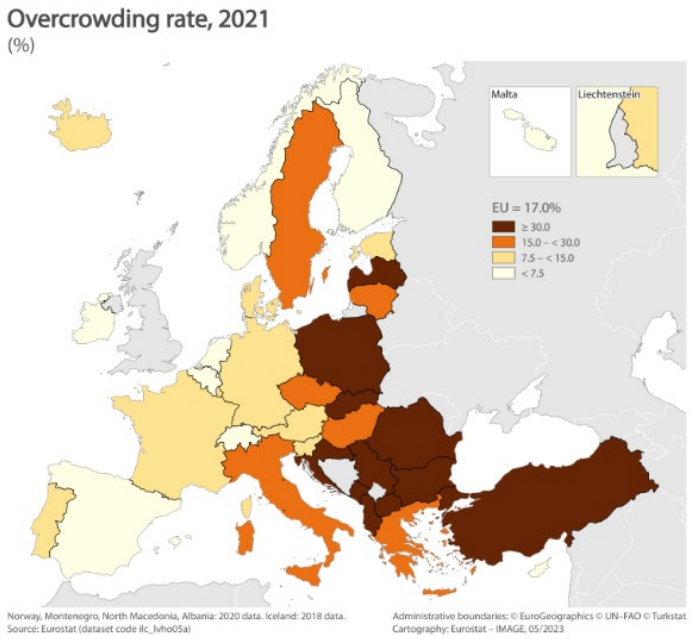
3D printed house, 2021. Mario Cucinella Architects.

The ETH University in Zurich (left) is exploring the 3D printing in concrete for columns. The TECLA -technology + clay- project (right) uses a double dome solution for the proposal.

2_PROBLEM STATEMENT

Lack of housing

South America, 2012



Europe, 2021

The Netherlands, 2023

Lack of housing and decent living conditions are worldwide problems currently affecting South American countries, Europe, and even The Netherlands.

2_PROBLEM STATEMENT

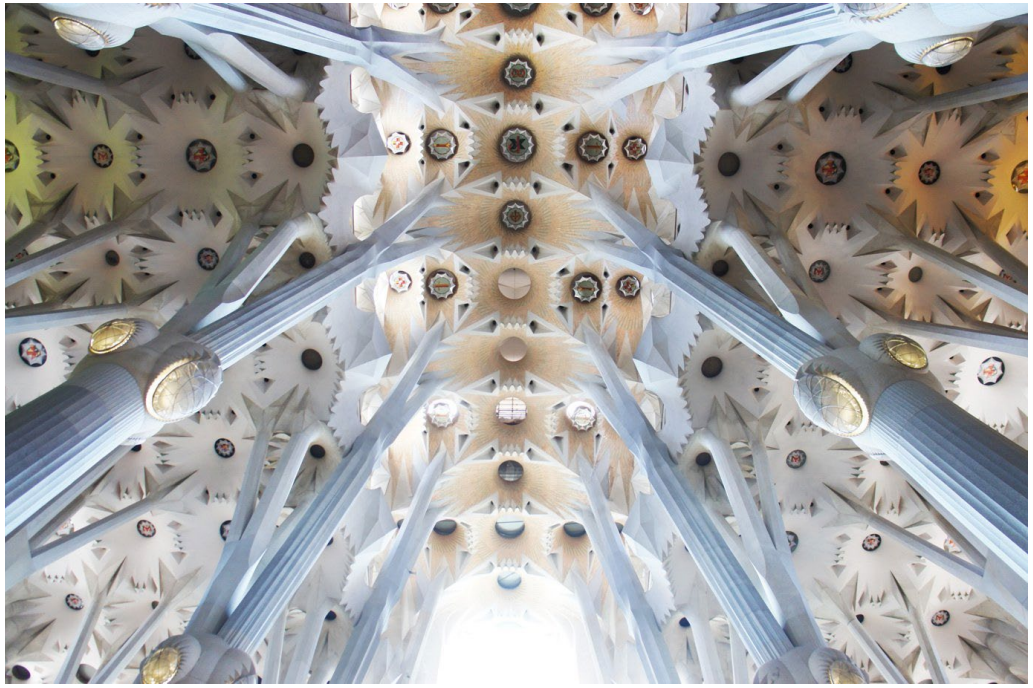
3D printing on housing can go further

3D printed houses, 2021. ICON (left), Milestone (right).

The ICON and the Milestone Project are housing constructions and examples of how the 3D printer size and the crane can limit the design. Also, it only prints in a vertical axe, resulting in an extrusion.

2_PROBLEM STATEMENT

3D printing on housing can go further



Sagrada Familia. Antoni Gaudi

Church of Christ the Worker and Our Lady of Lourdes, 1958. Eladio Dieste.

- Learn from the past and propose better solutions with the available technology. -

3_RESEARCH QUESTIONS

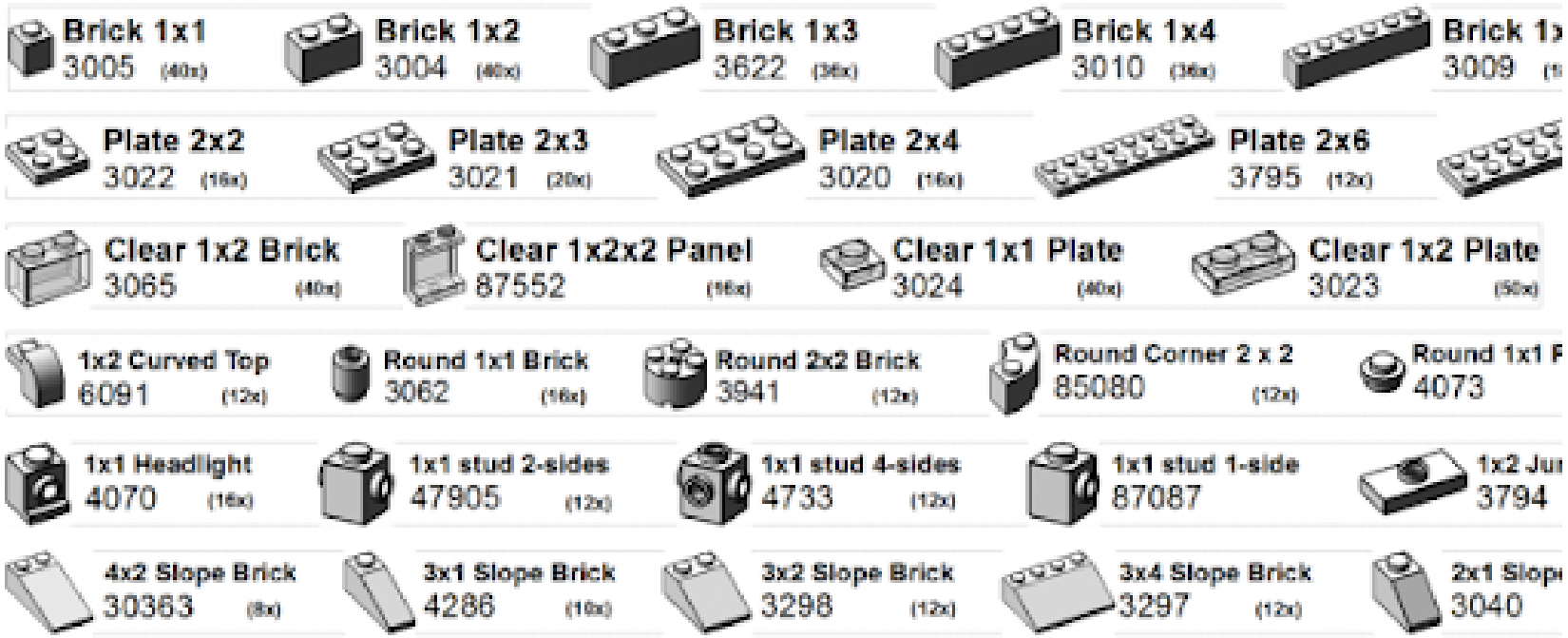
Main research question

How can 3D printing, produce social housing units, and at the same time enhance construction efficiency, architectural adaptability, and encourage innovation in form and shape?

4_LITERATURE REVIEW

Kit-of-Parts (KoP)

Construction method



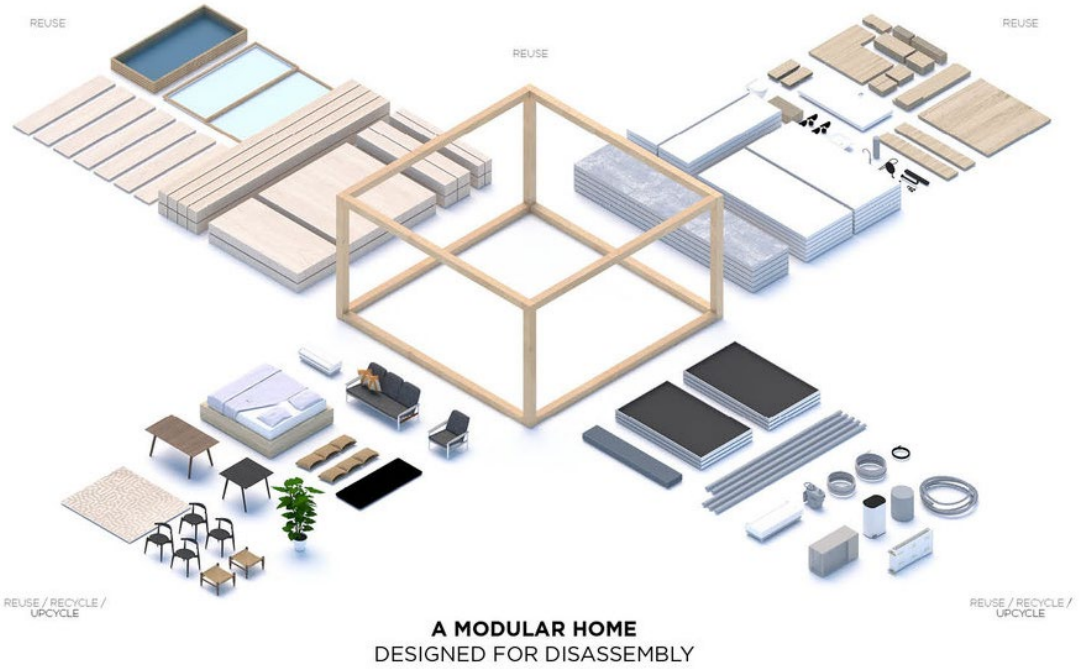
KoP in a lego set.

Its application simplifies manufacturing processes, enhances product consistency, and facilitates customization while reducing production costs and lead times. The structure is broken down into **modular components** that can be **prefabricated, assembled, and reconfigured in various ways**.

4_LITERATURE REVIEW

Kit-of-Parts (KoP)

Construction method



Urban Villa Project, 2018. Kit-of-Parts.

The Kit-of-Parts concept is also an answer to go **against the mass production** and go instead with **mass customization** construction.

4_LITERATURE REVIEW

Housing referents

Construction method

Nakagin Capsule Tower, 1972 – Kisho Kurawa

Habitat 67, 1967 – Moshe Shafdi

Nakagin Capsule Tower aims at **adaptable, growing, and interchangeable building outcomes**. The prefabricated capsules can be connected and combined with increasing spaces between them.
Habitat 67, with an **interlocking of prefabricated concrete** typologies was stacked in multiple configurations.

4_LITERATURE REVIEW

Housing referents

Customer-oriented

La Maison Médicale, 1976 – Lucien Kroll

Quinta Monroy, 2003 – Alejandro Aravena. Chile.

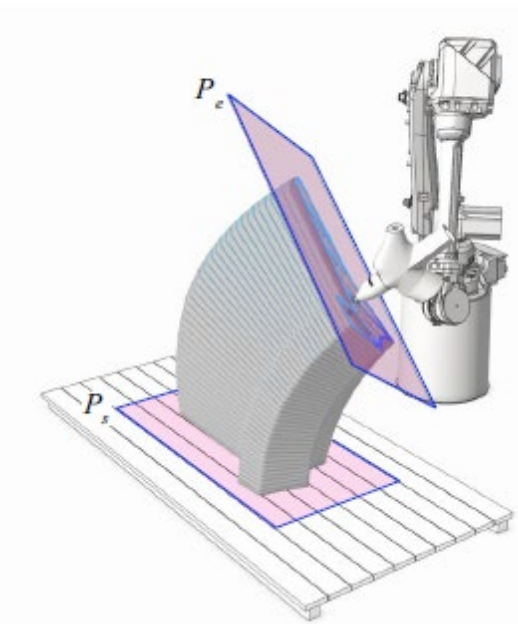
The Maison Médicale facade showcases the user customization possibility in their windows and materials.
Quinta Monroy gives the possibility to the **user to adapt its space** accordingly to its necessities. **Customizable** and **customer-oriented** approach.

4_LITERATURE REVIEW

3D printing technology

Fabrication methodology

Villa Roccia, 2011 - James Gardiner



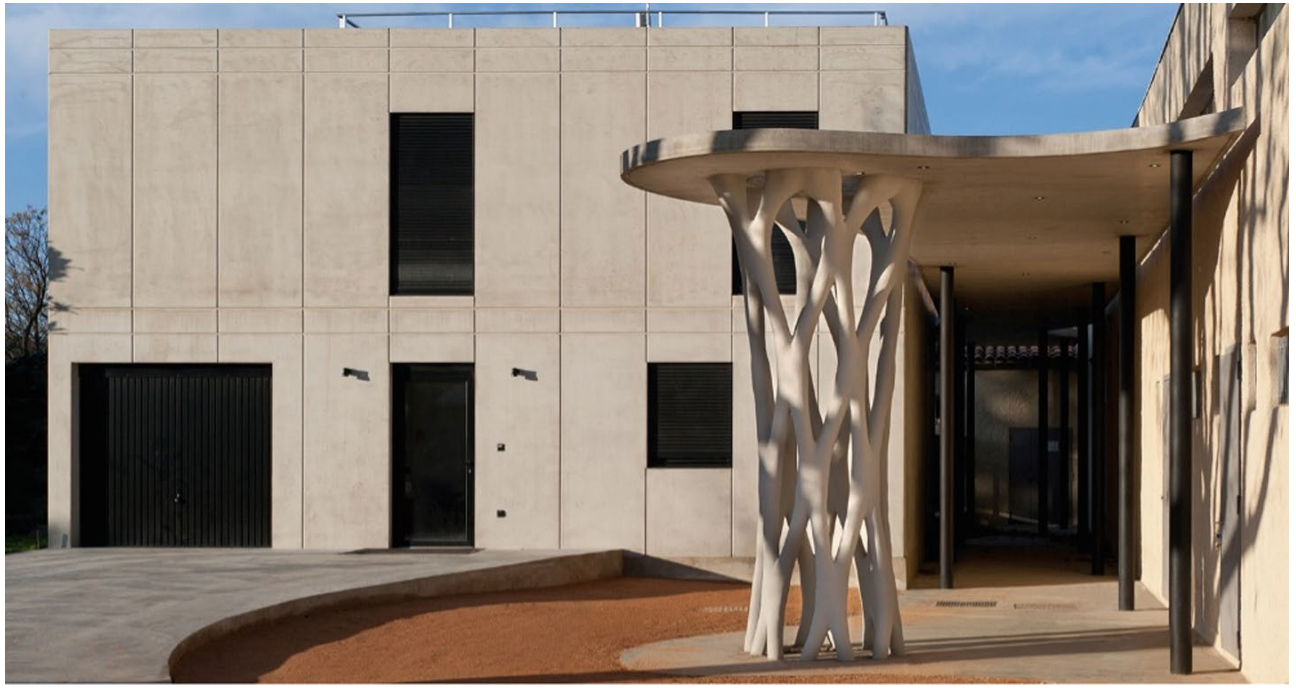
Striatus Bridge, 2021 - Zaha Hadid Architects + Block Research Group

These projects use construction 3D printing techniques to enhance the function and design based on a potential of buildings elements, by flipping the parts or programming the robot's arm. This expression describes the gradual **agglomeration of parts into larger assemblies**, through discreet stages to form the whole.

4_LITERATURE REVIEW

3D printing technology // Fabrication Methodology

Fabrication methodology



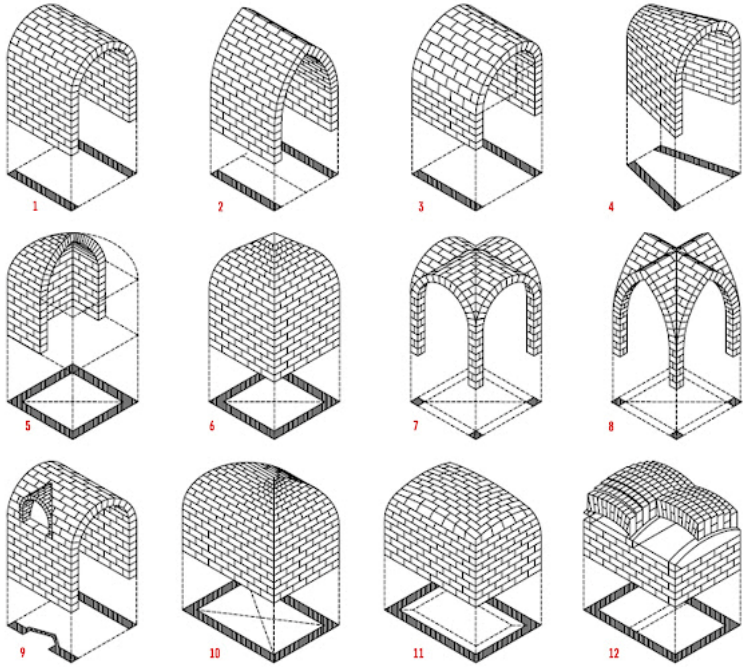
Preschool in Aix-en-Provence, 2018 – XtreeE

Building Architecture Continuity, 2019 – IAAC Barcelona

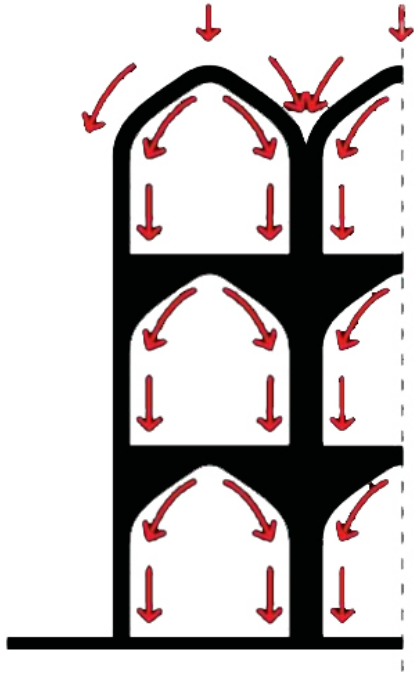
Instead of 3D printing the 4-meter-high column itself, XtreeE **3D-printed a hollow formwork**, or outer layer, for the complex concrete column, which was **then filled with concrete**.
IAACC university explores the **incorporation of stairs into the design and printing**.

4_LITERATURE REVIEW

Architectural geometry // Vault as a starting shape



Form study of a vault.



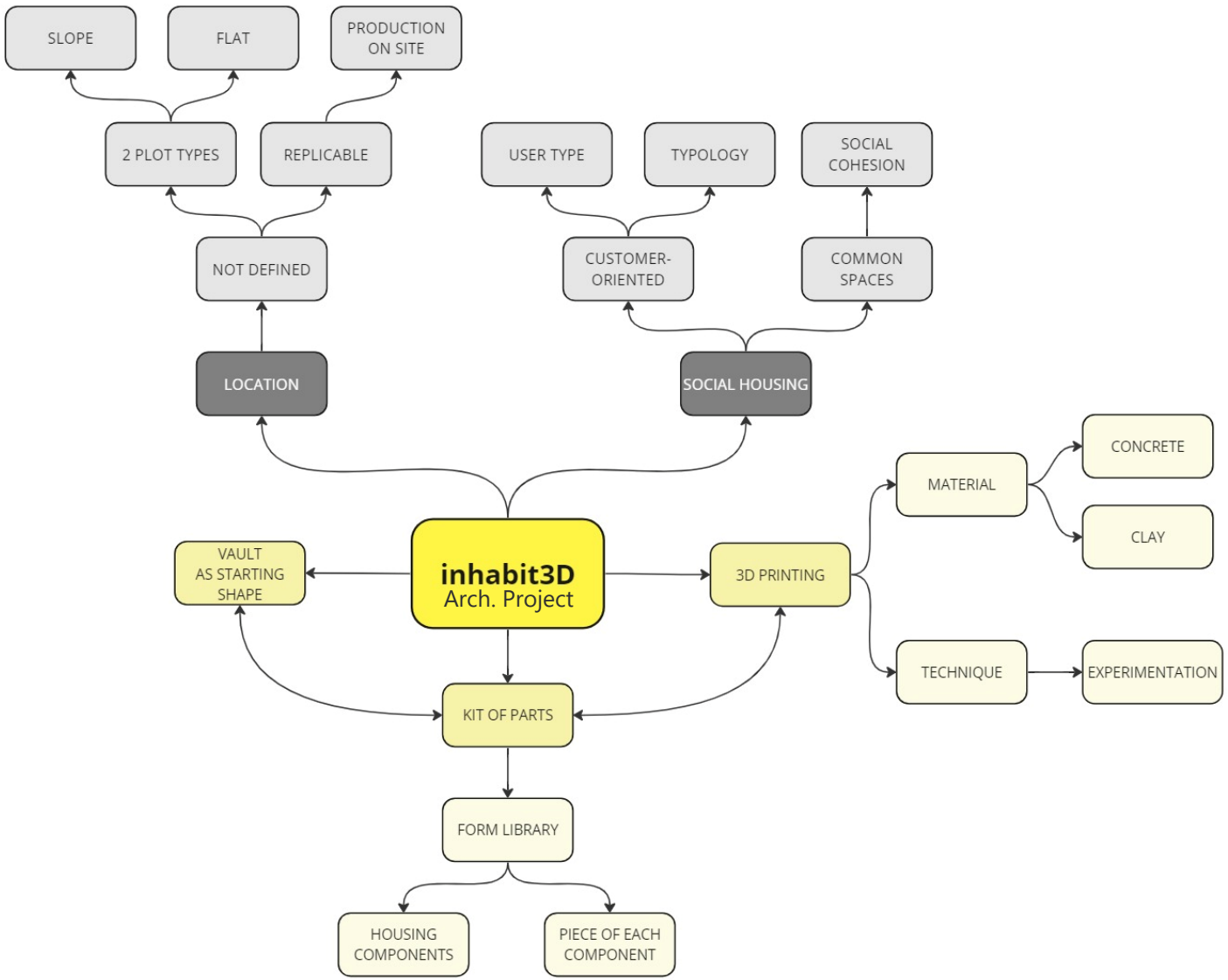
Compressive forces diagram in vaults.

Striatus Bridge, 2021.

As in unreinforced masonry, feasibility can be analysed through the degree of overlap in its layers. These networks of curves are based on the primitive geometry of compressive structures such as **vaults and domes**. This shapes allows a large span without columns and gives the possibility to the user to adapt its space accordingly to its necessities and get.

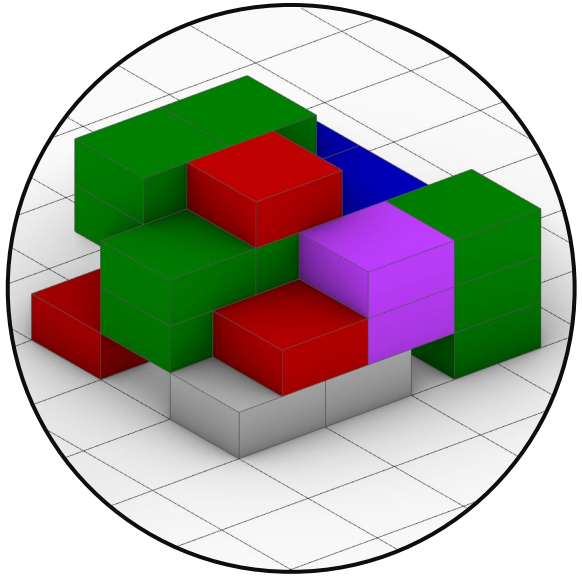
5_DESIGN

Overview

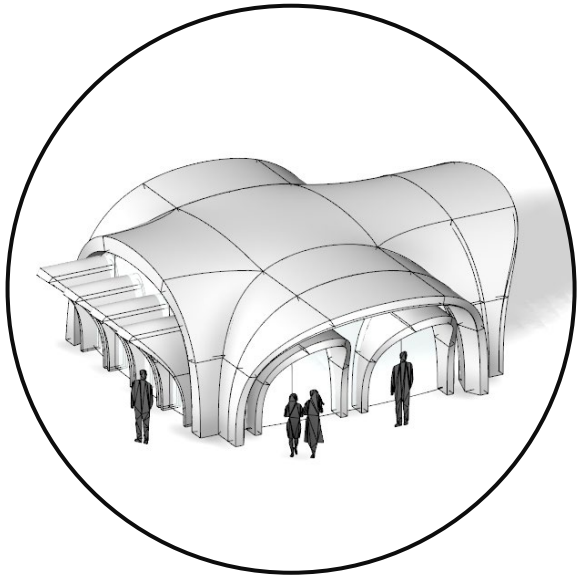


5_DESIGN

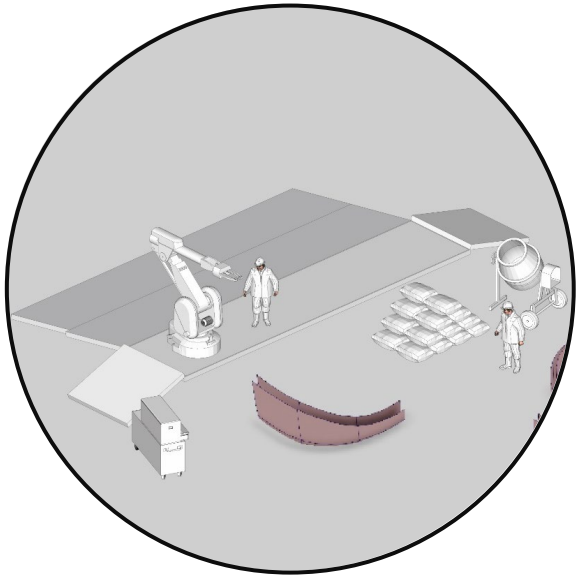
Phase Structure



Organization
Building level



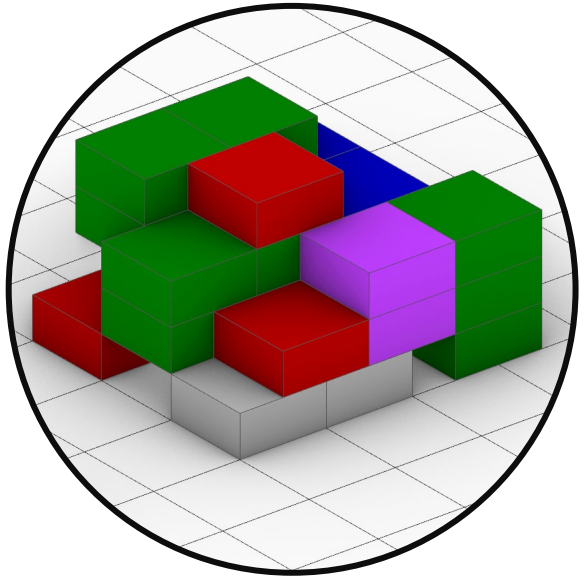
Unit
House level



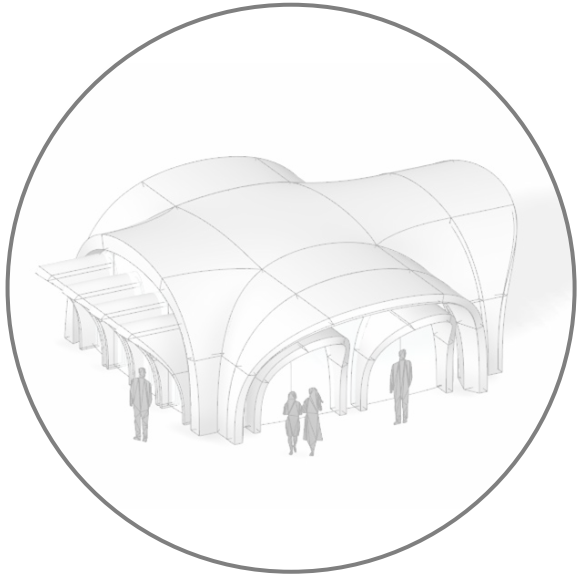
Construction
Structure level

5_DESIGN

Phase Structure



Organization
Building level



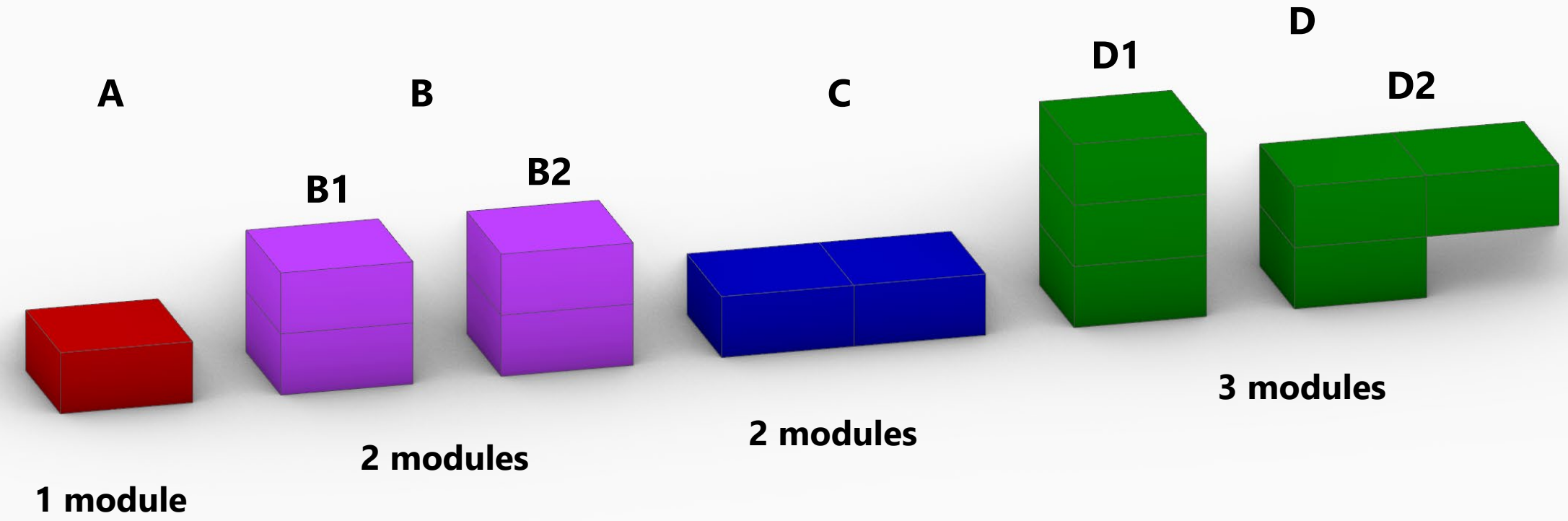
Unit
House level

Construction
Structure level

5_DESIGN

Organization – Building Level

Components



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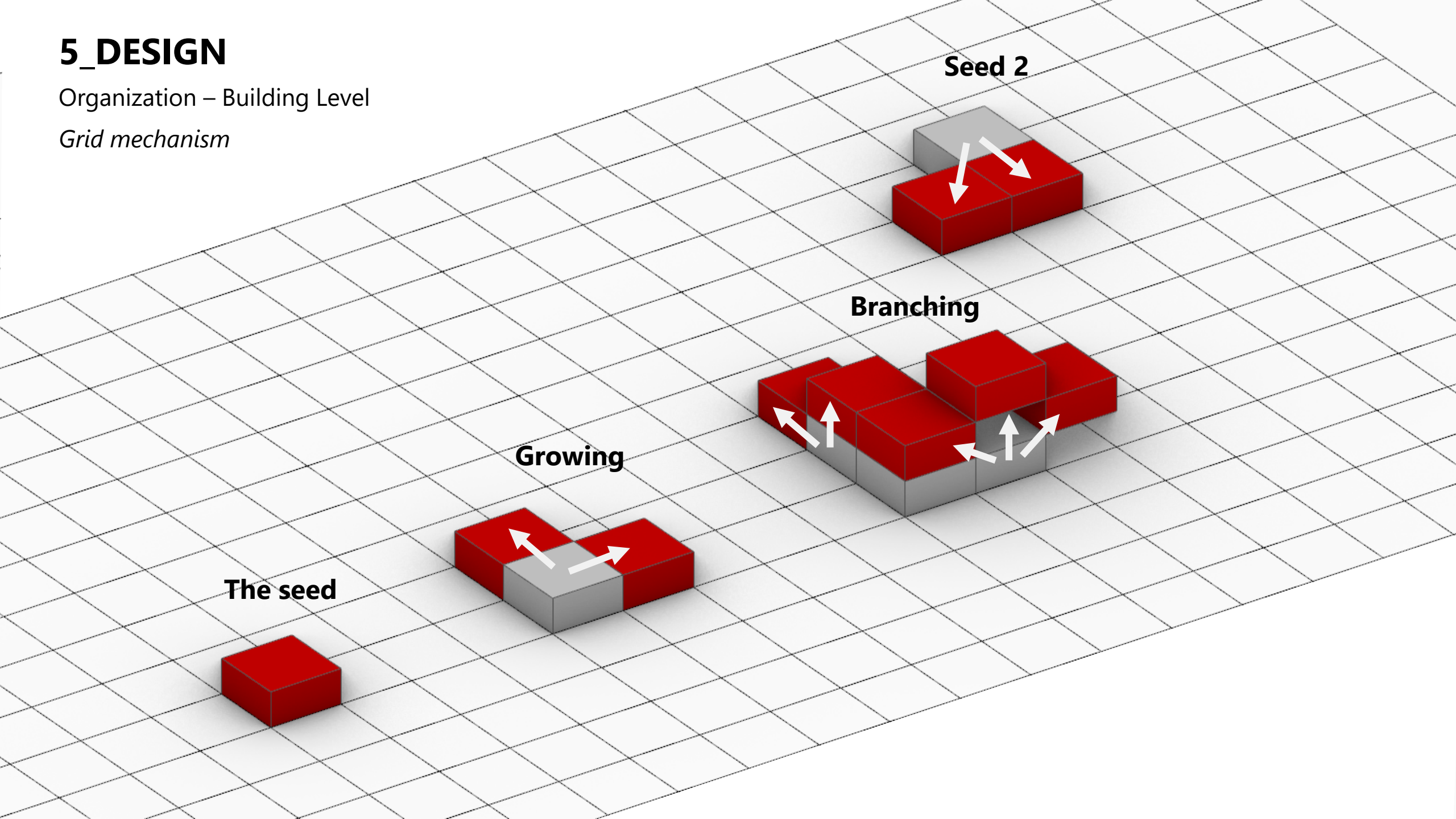
Organization – Building Level

Grid mechanism



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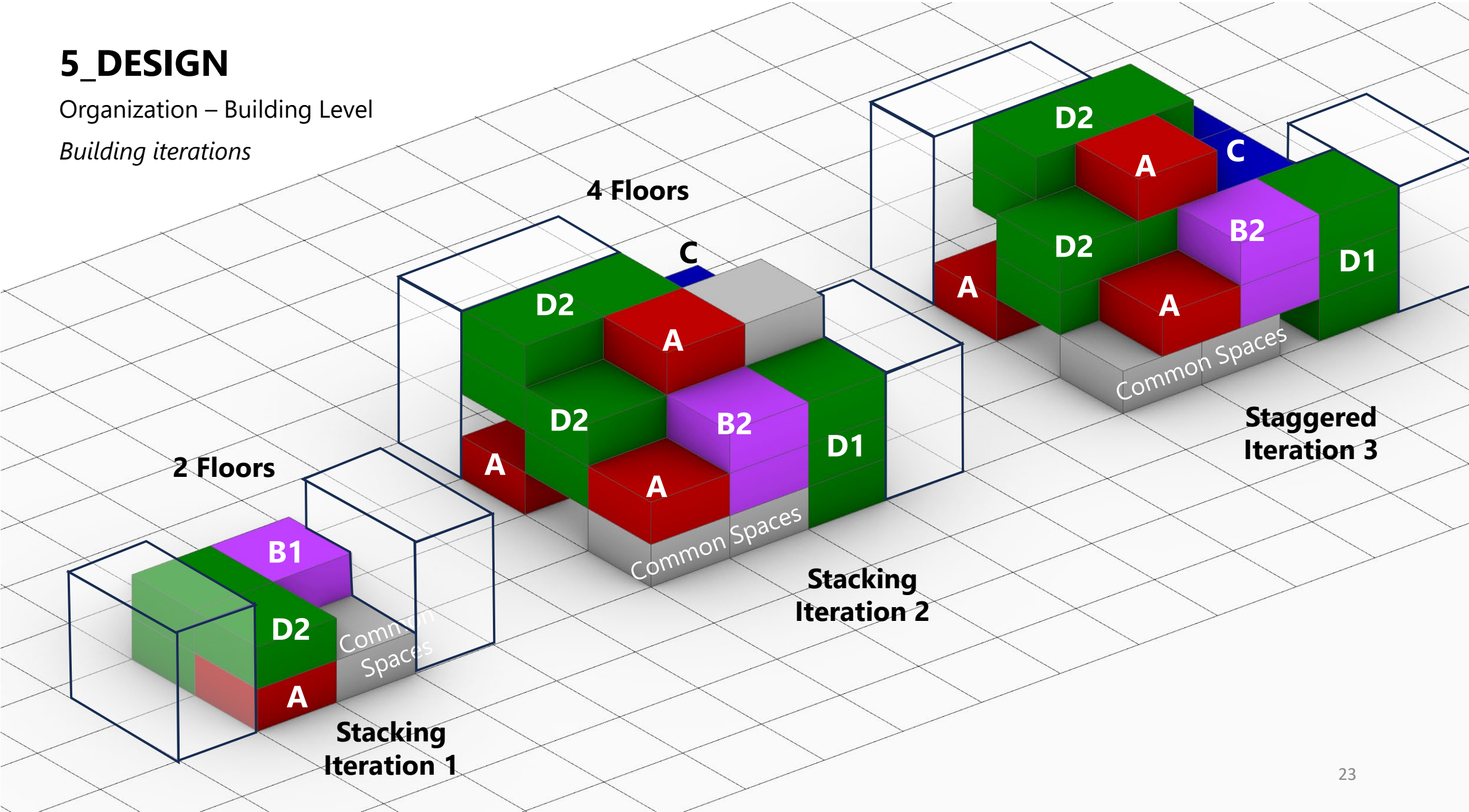
Organization – Building Level

Building iterations



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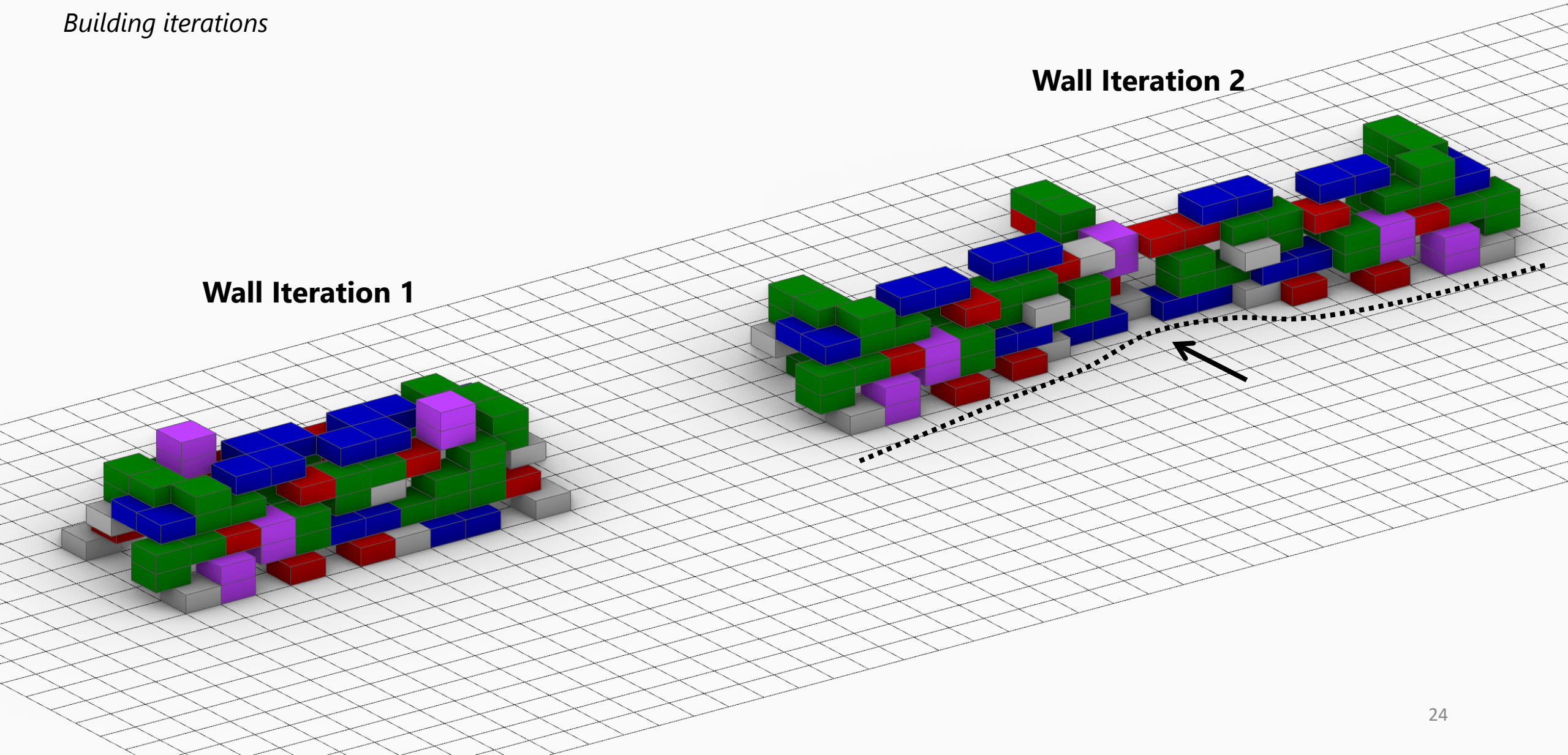
Organization – Building Level

Building iterations



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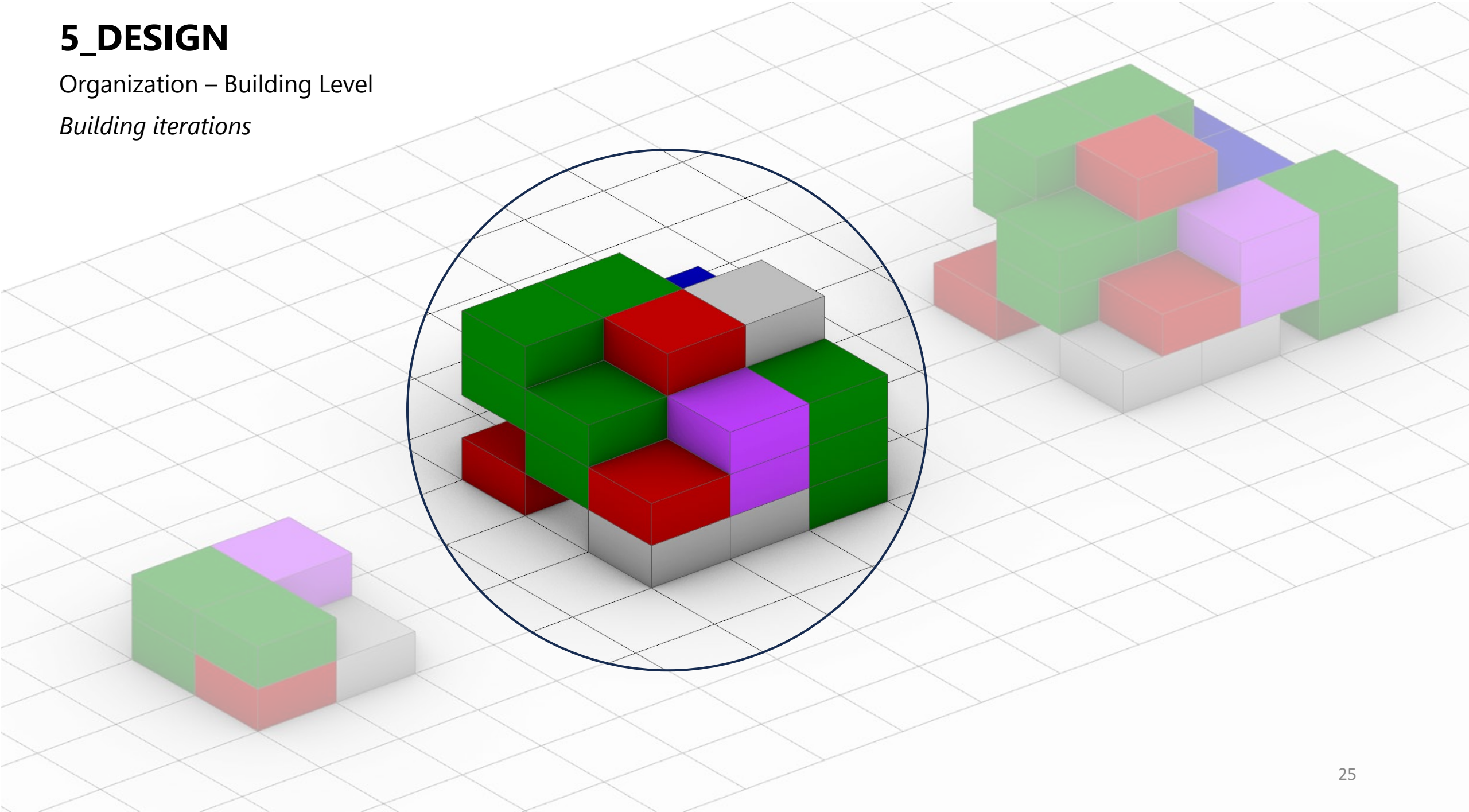
Organization – Building Level

Building iterations



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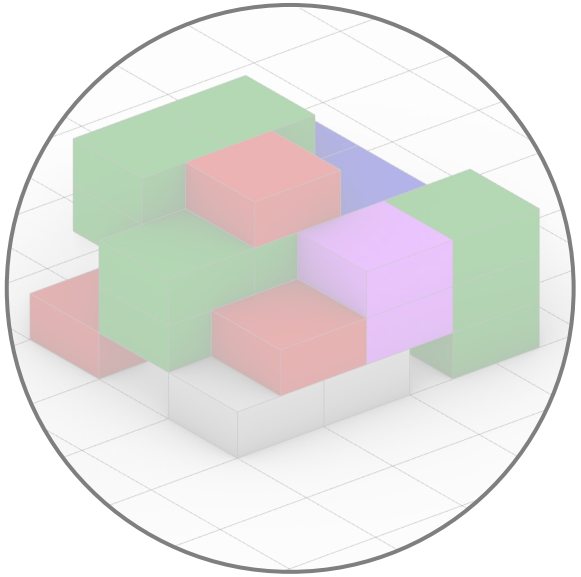
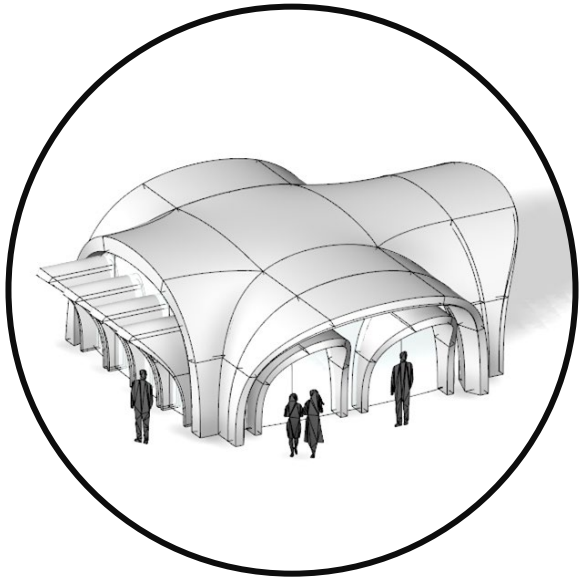
Phase Structure



Organization
Building level



Unit
House level

Construction
Structure level

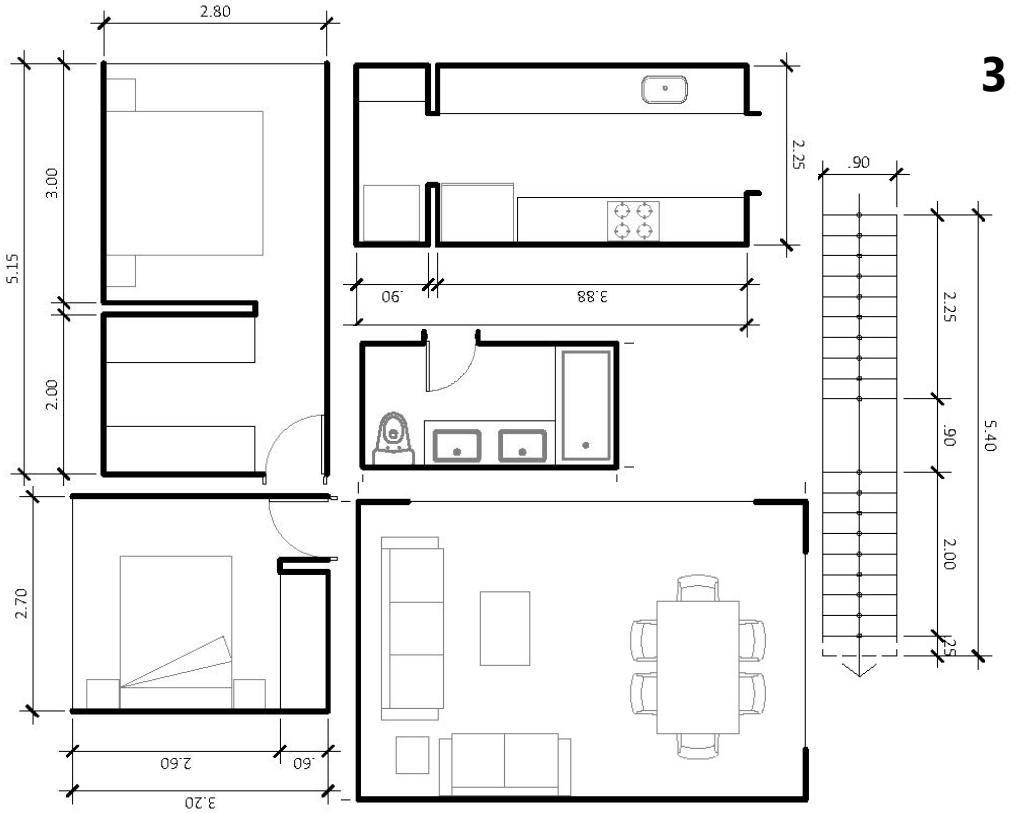
5_DESIGN

Unit – House Level

Housing components

2. Kitchen + laundry

1. bedrooms



3. bathroom

5. circulation

8. terraces

4. social

7. balconies

6. study room

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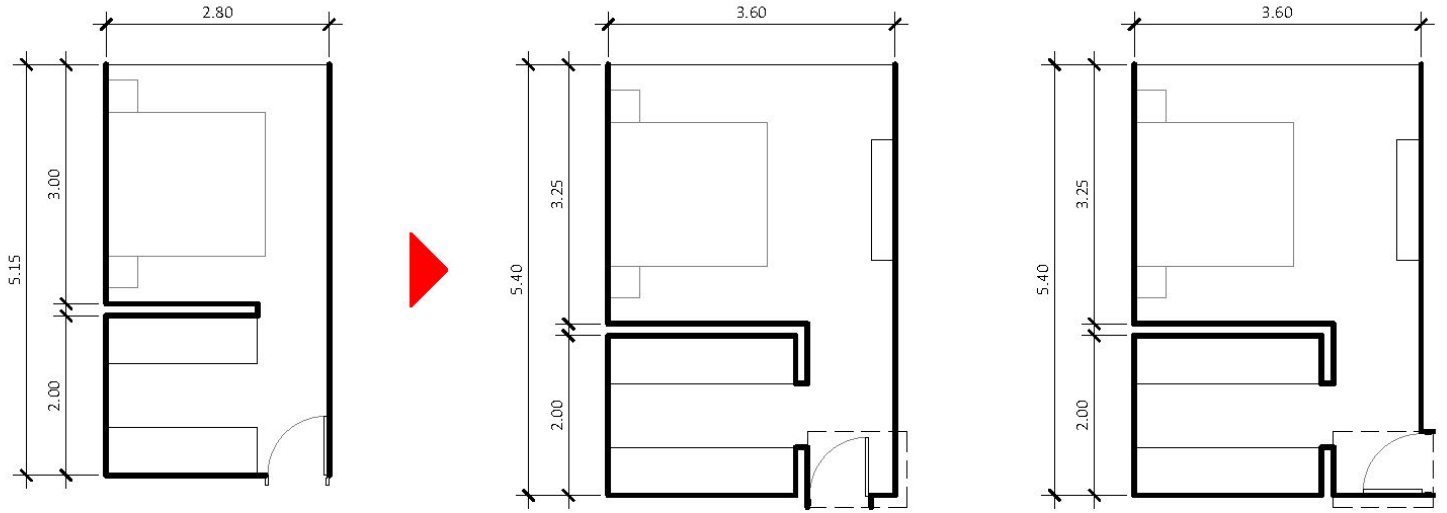
Unit – House Level

1. Bedroom

1a. master bedroom

1aa

1ab

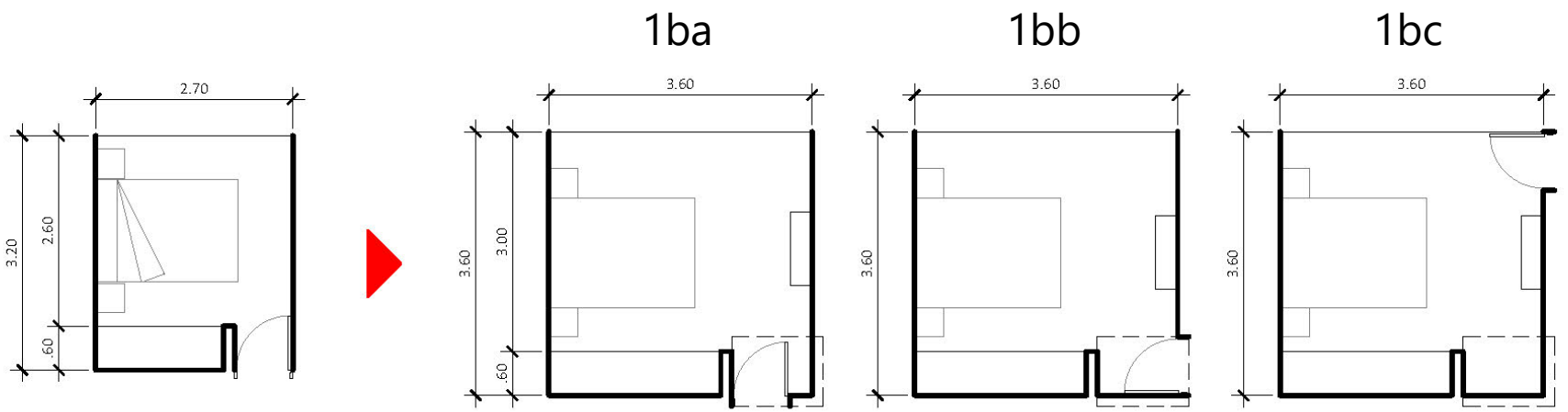


1b. regular bedroom

1ba

1bb

1bc



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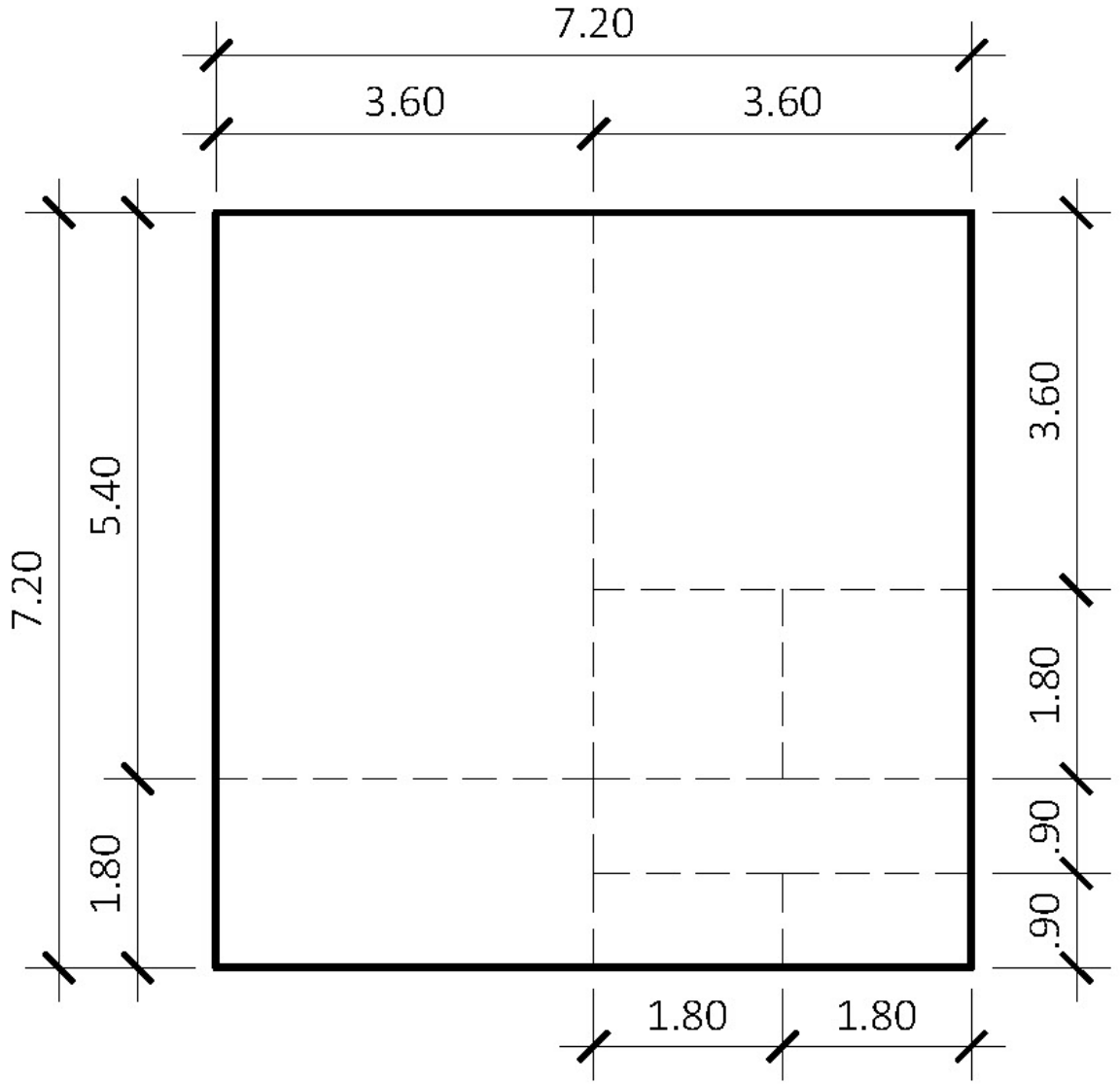
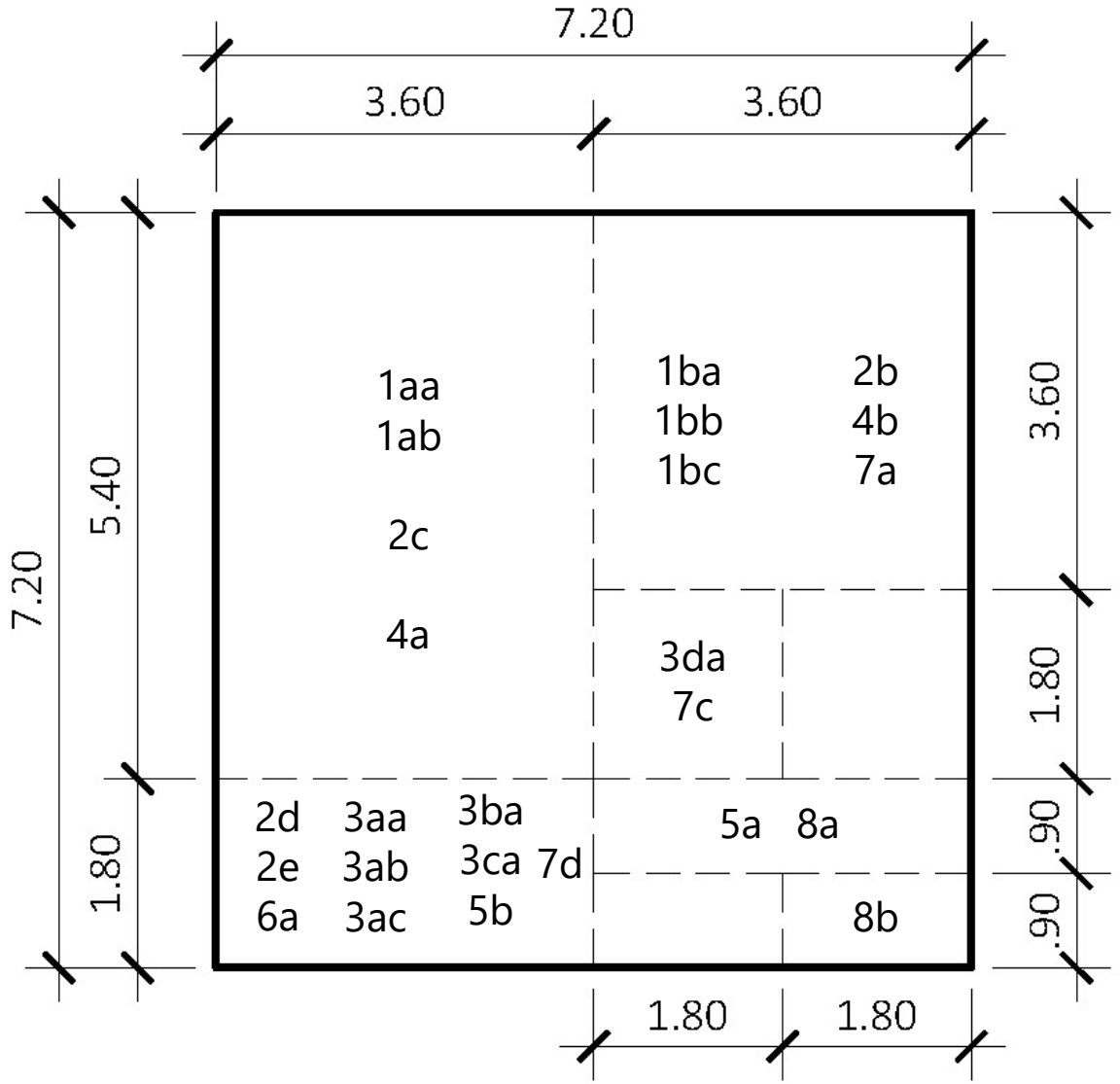
The module



5_DESIGN

The module



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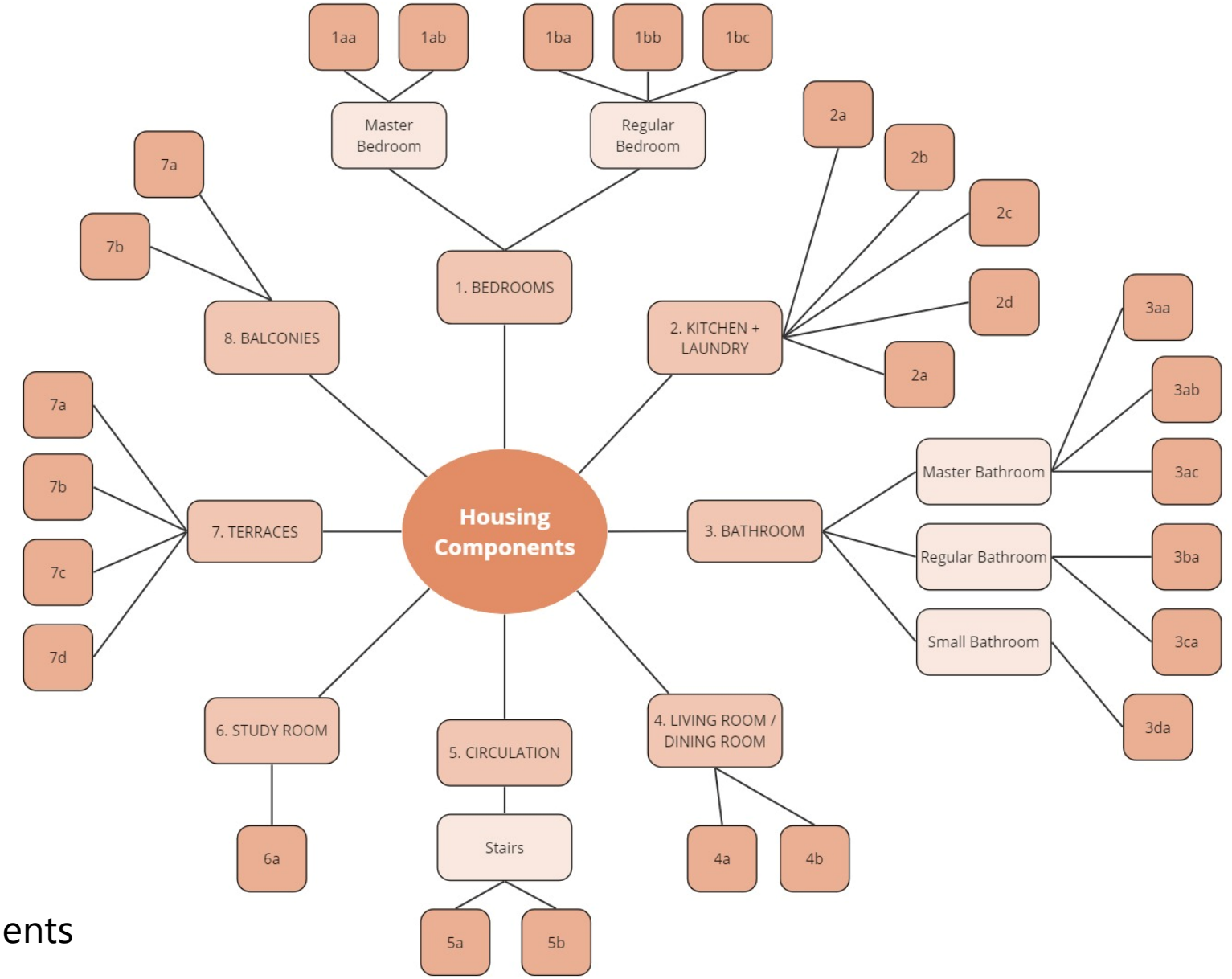
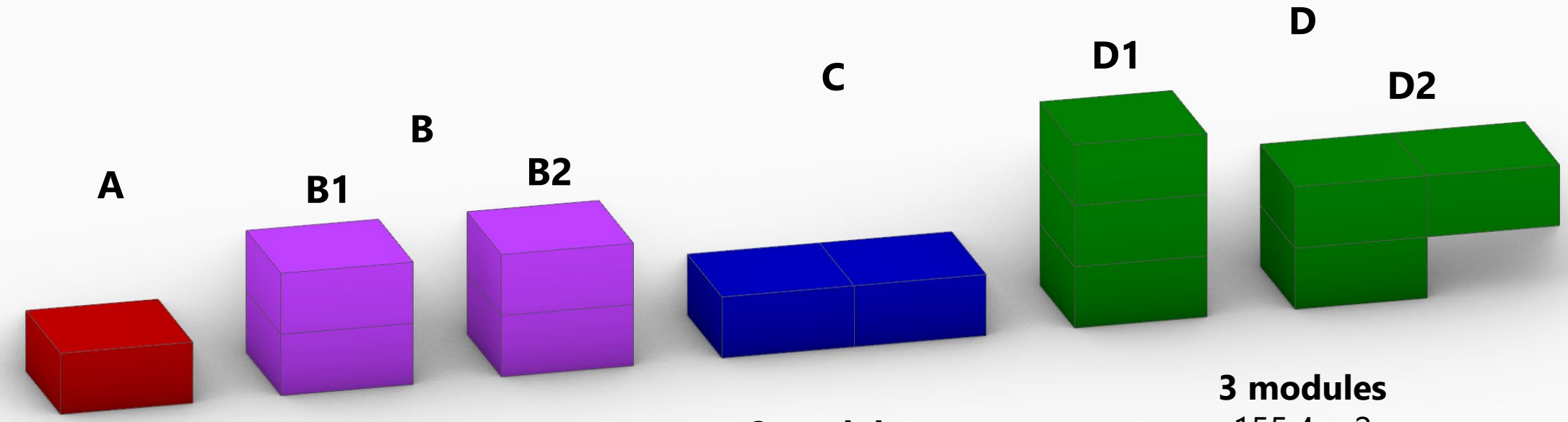
Housing components



27 different components

5_DESIGN

Housing components



5_DESIGN

User Customization

User 2: couple

Diana & Andrew
36 and 35 y.o.
Public prosecutor & Architect

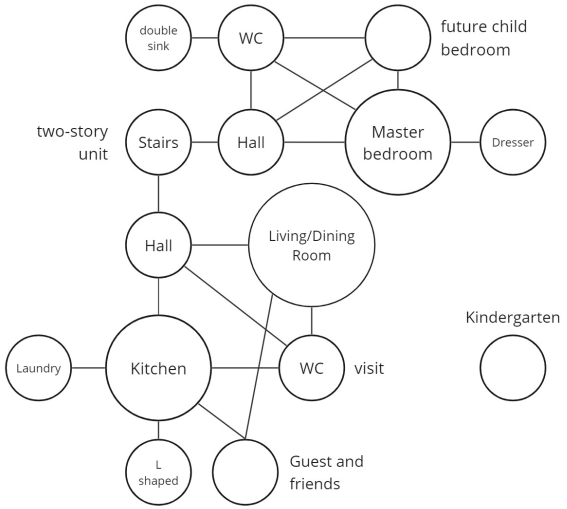
"We would like a bedroom and social part, both connected to a balcony. A medium size living room and integrated kitchen where we can have guest and dinner with friends. Double sink and a bathtub is a must for us. A second room for our future child in the same floor with our bedroom.

In the common spaces I would like to have a kindergarten. And first, I want to invest owning 1 module, but keep the possibility in a short future to add one more."

5_DESIGN

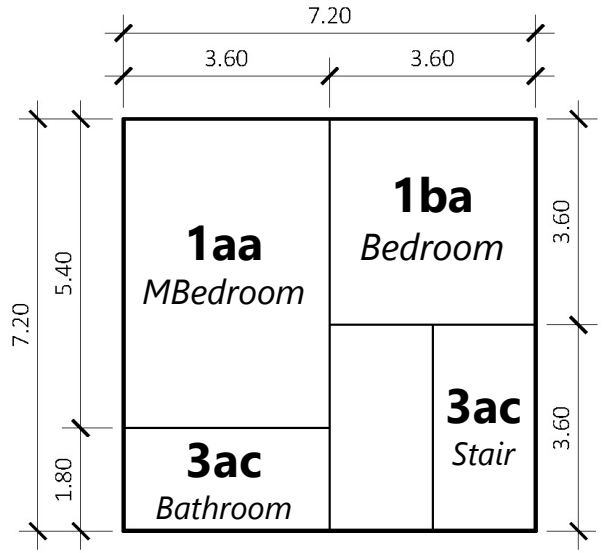
User Customization

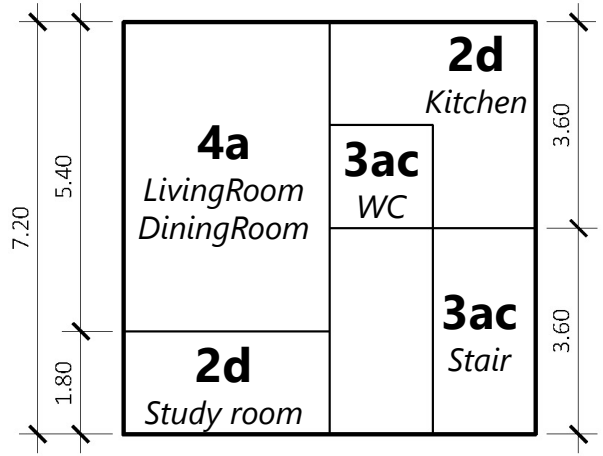
User 2: couple

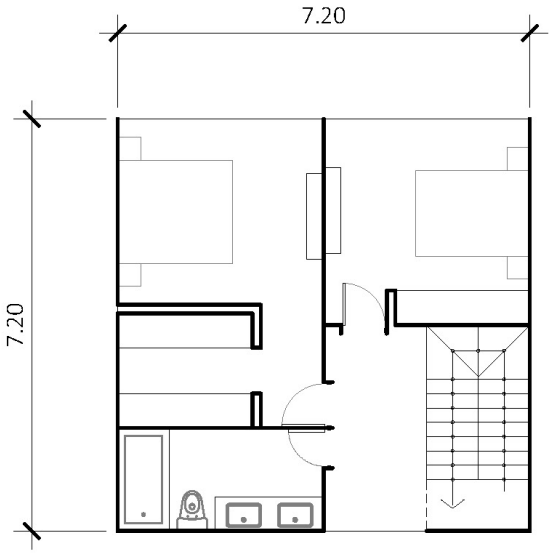


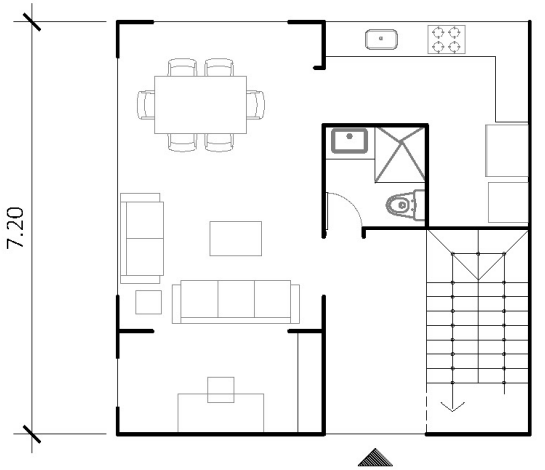
wish-list diagram

2 modules
103.6 m2







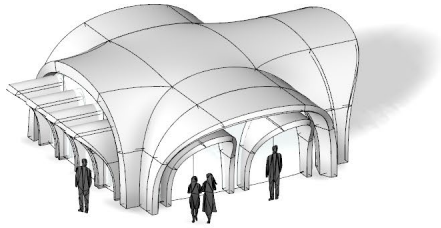


Diana & Andrew
36 and 35 y.o.
Public prosecutor & Architect

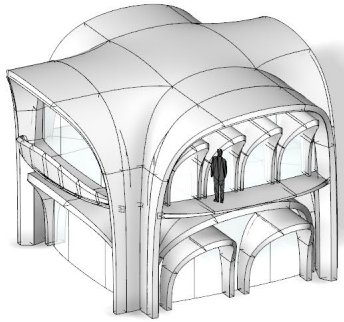
5_DESIGN

Unit – House Level

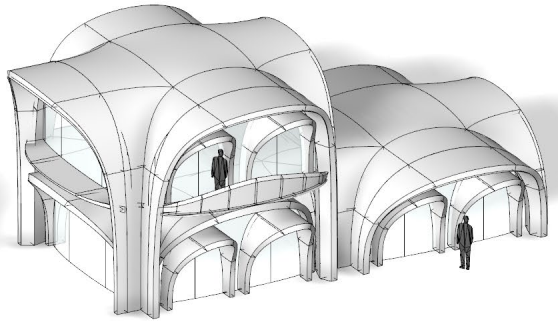
Inhabited modules



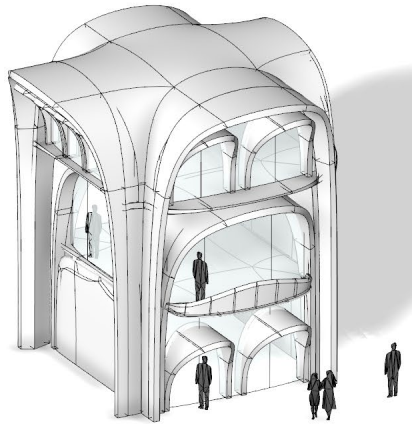
1 module
51.8 m2



2 modules
103.6 m2



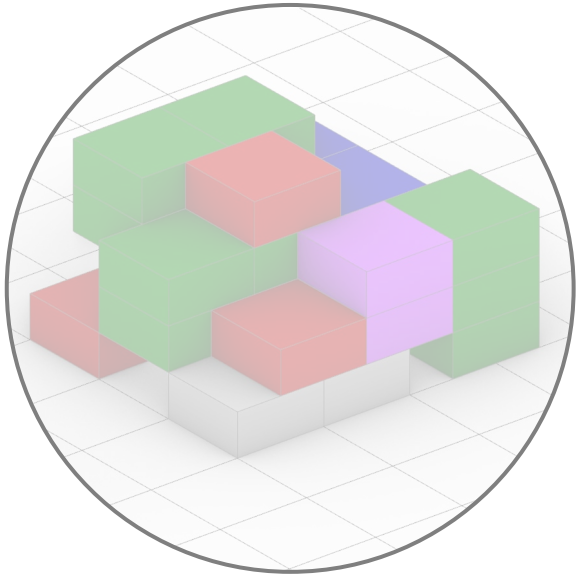
3 modules
155.4 m2



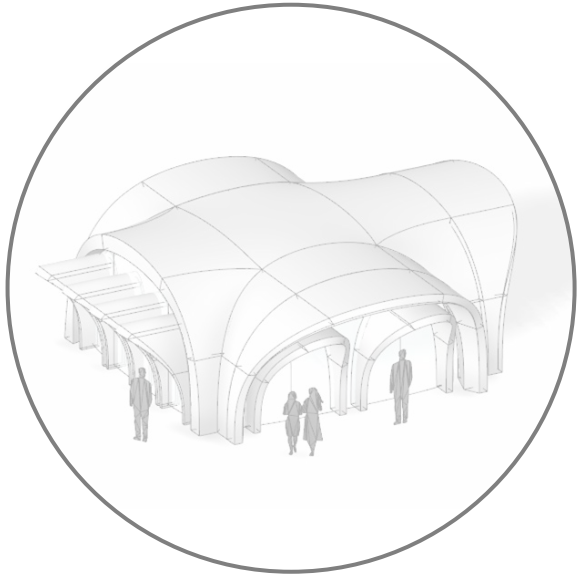
3 modules
155.4 m2

5_DESIGN

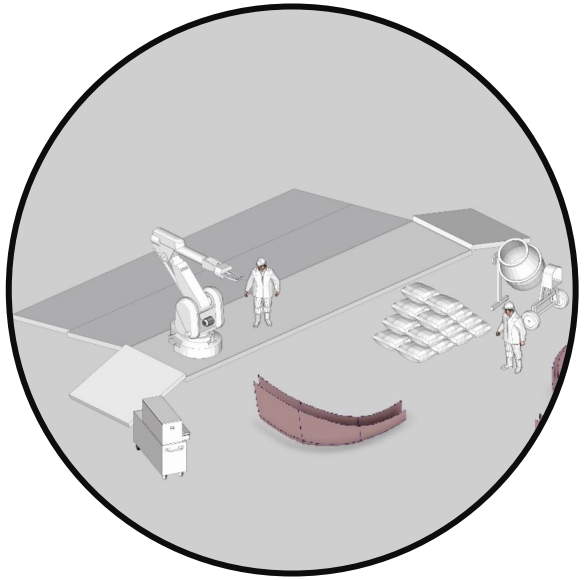
Phase Structure



Organization
Building level



Unit
House level



Construction
Structure level

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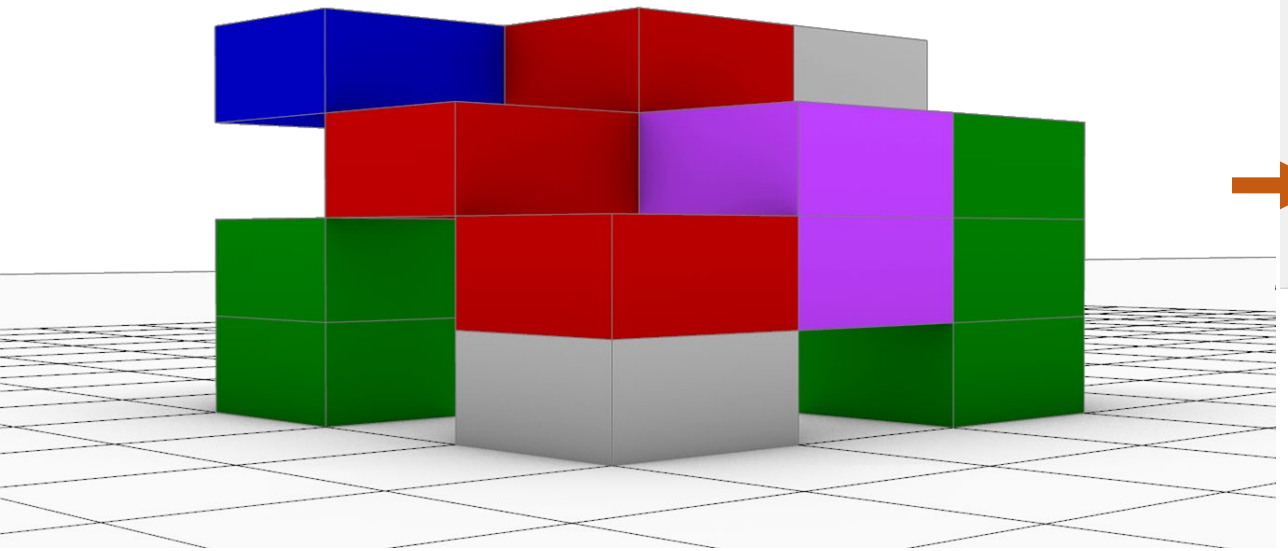
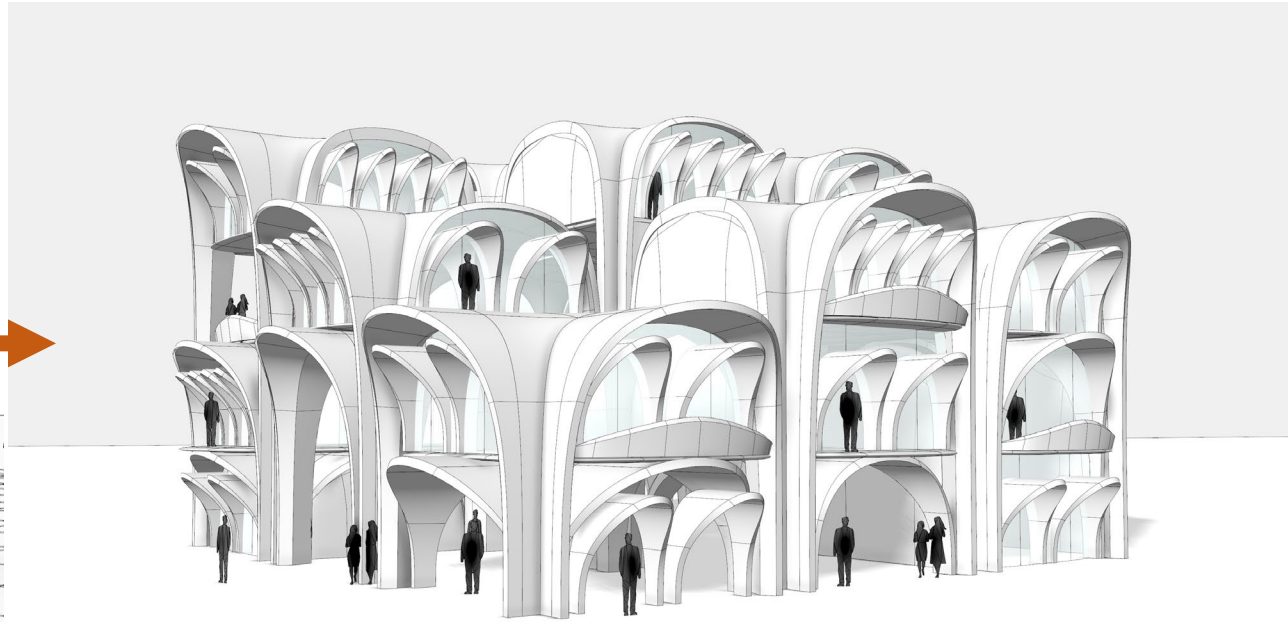
Construction – Structure Level

Aggregation





5_DESIGN

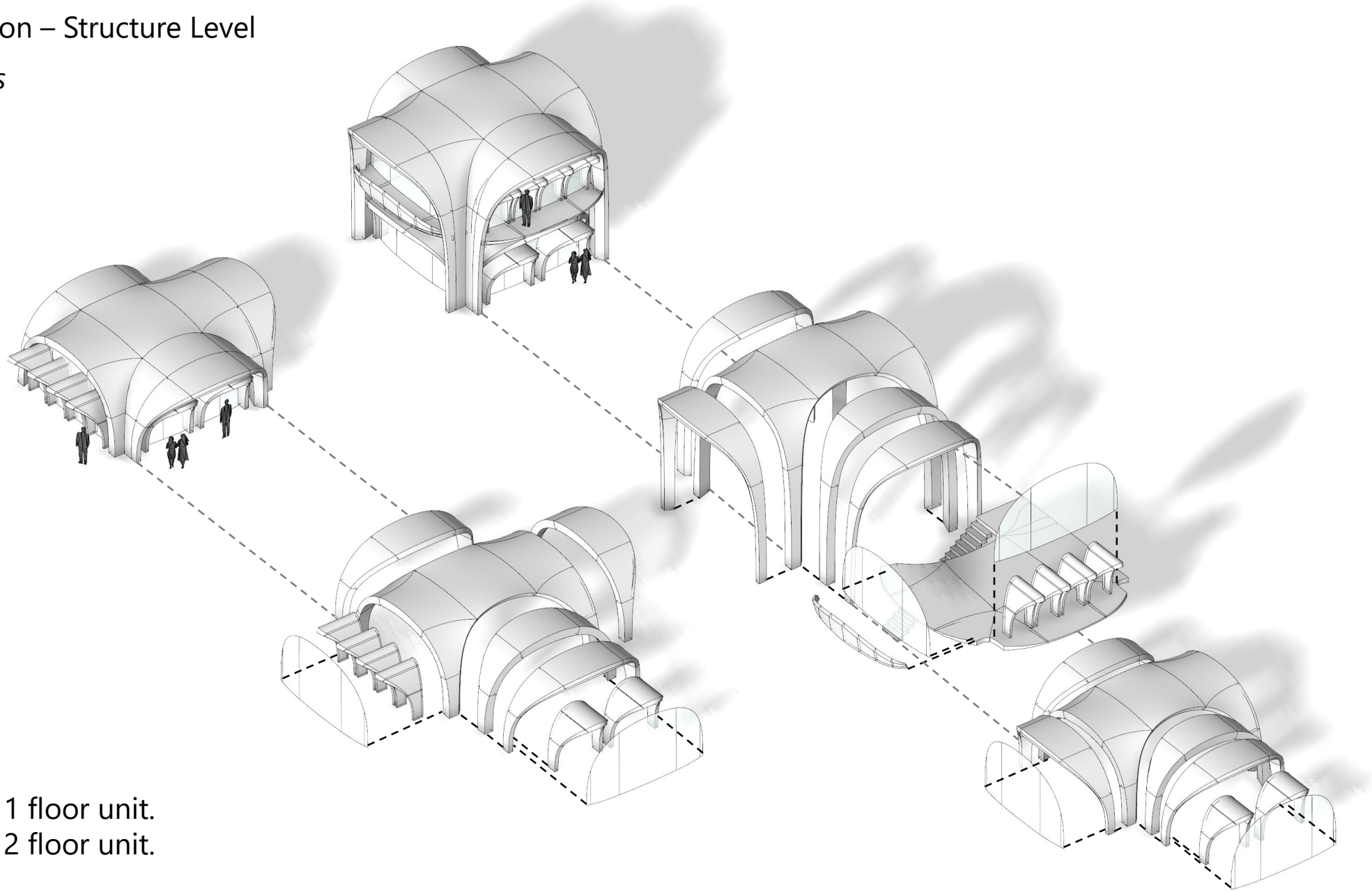
Construction – Structure Level

Aggregation

5_DESIGN

Construction – Structure Level

Kit of Parts



1 module, 1 floor unit.
2 module, 2 floor unit.

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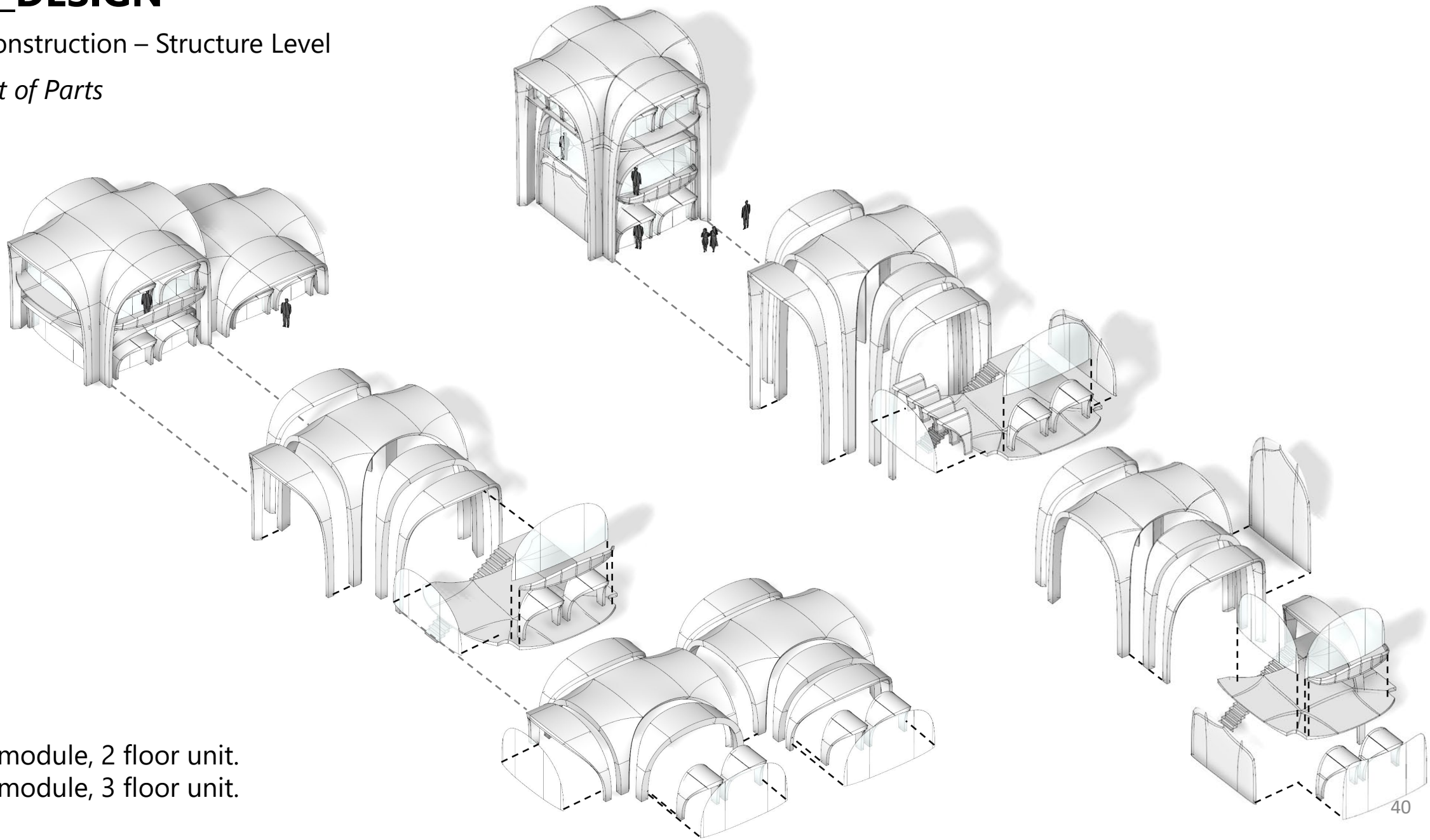
Construction – Structure Level

Kit of Parts



3 module, 2 floor unit.
3 module, 3 floor unit.

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Construction – Structure Level

Kit of Parts

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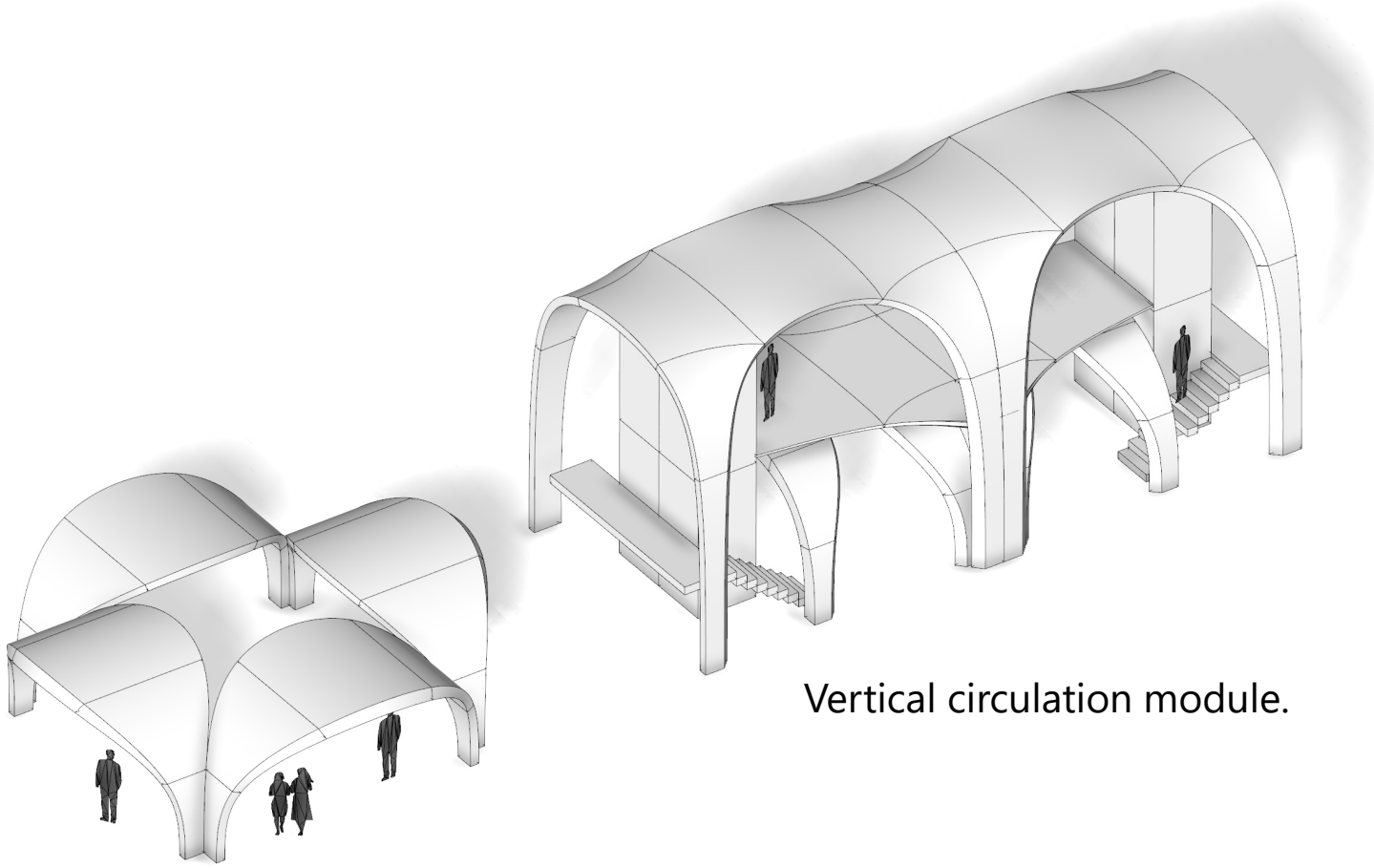
Construction – Structure Level

Kit of Parts



Vertical circulation module.

Public space module

5_DESIGN

Construction – Structure Level

Multi-material approach

Slabs and additional elements 3D-printed in wood.

5_DESIGN

Construction – Structure Level

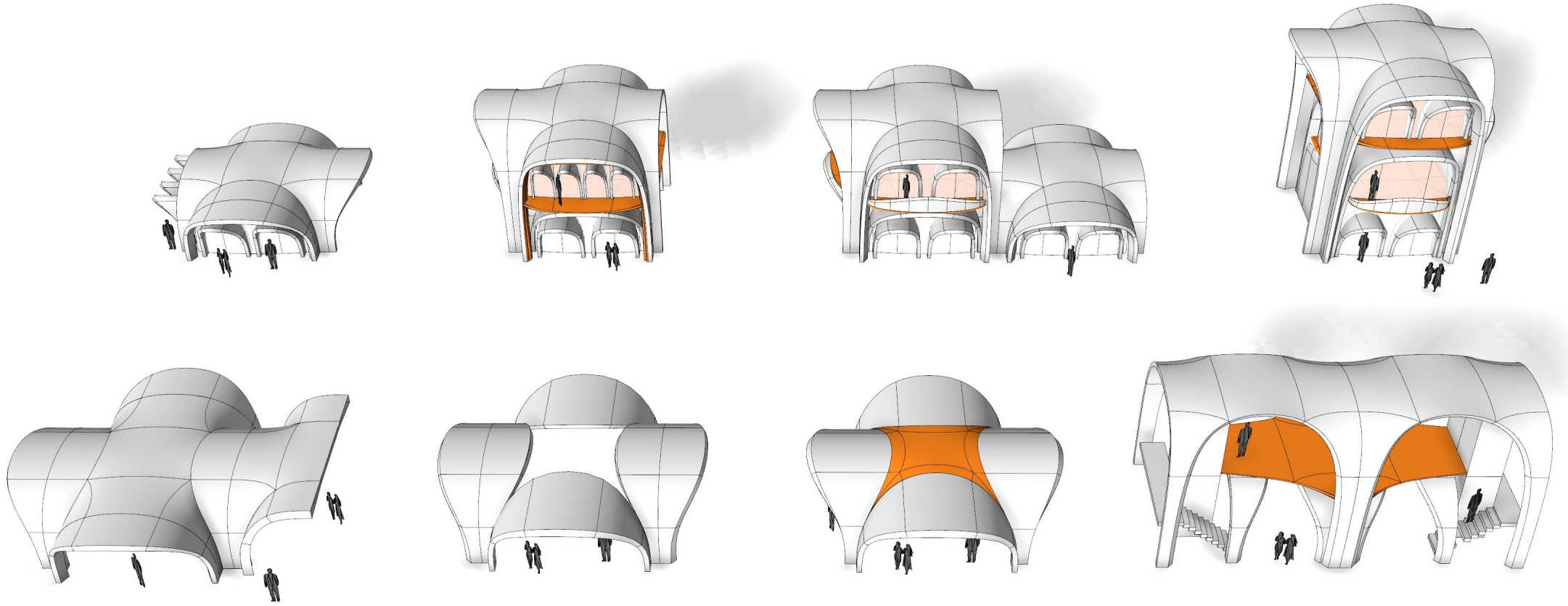
Multi-material approach

Slabs and additional elements 3D-printed in wood.

5_DESIGN

Construction – Structure Level

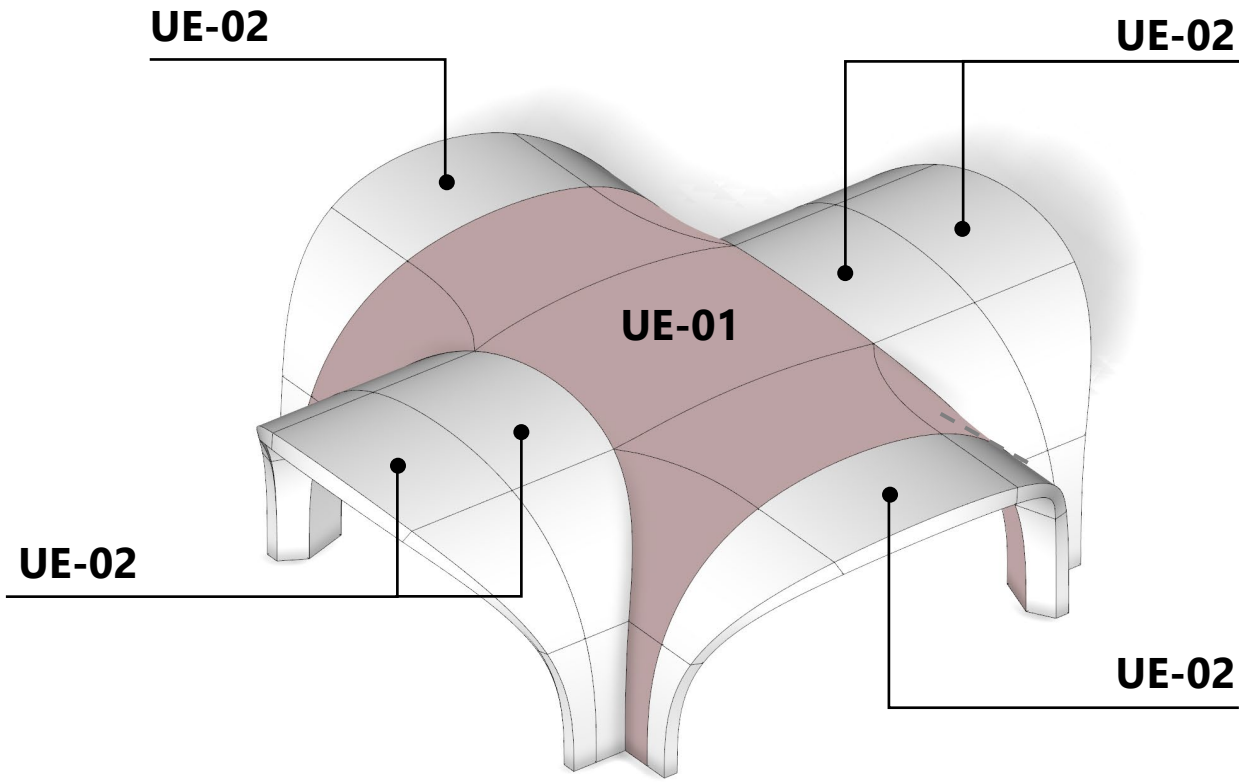
Kit of Parts

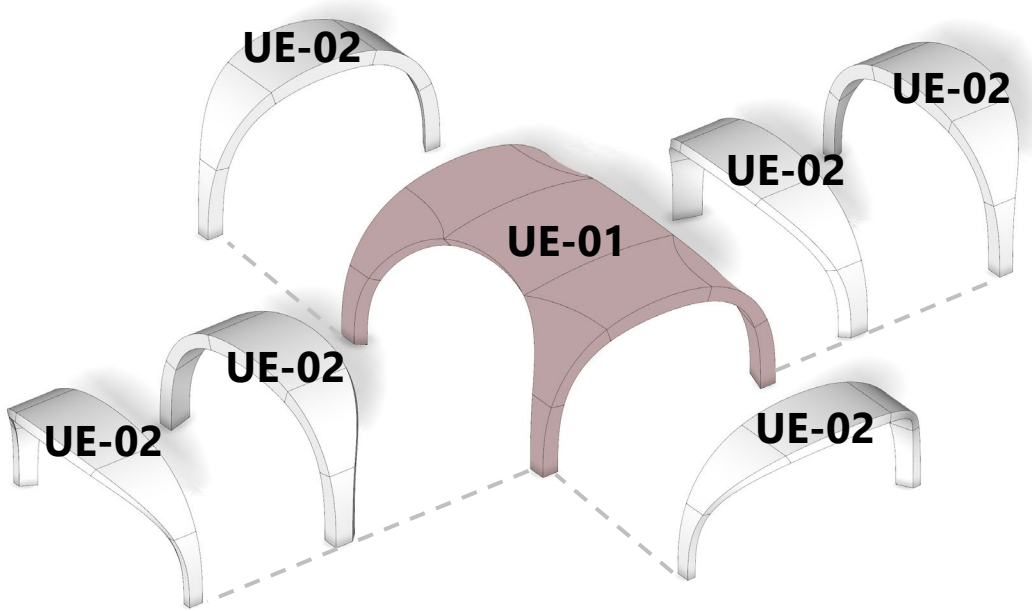


5_DESIGN

Construction – Structure Level

Kit of Parts

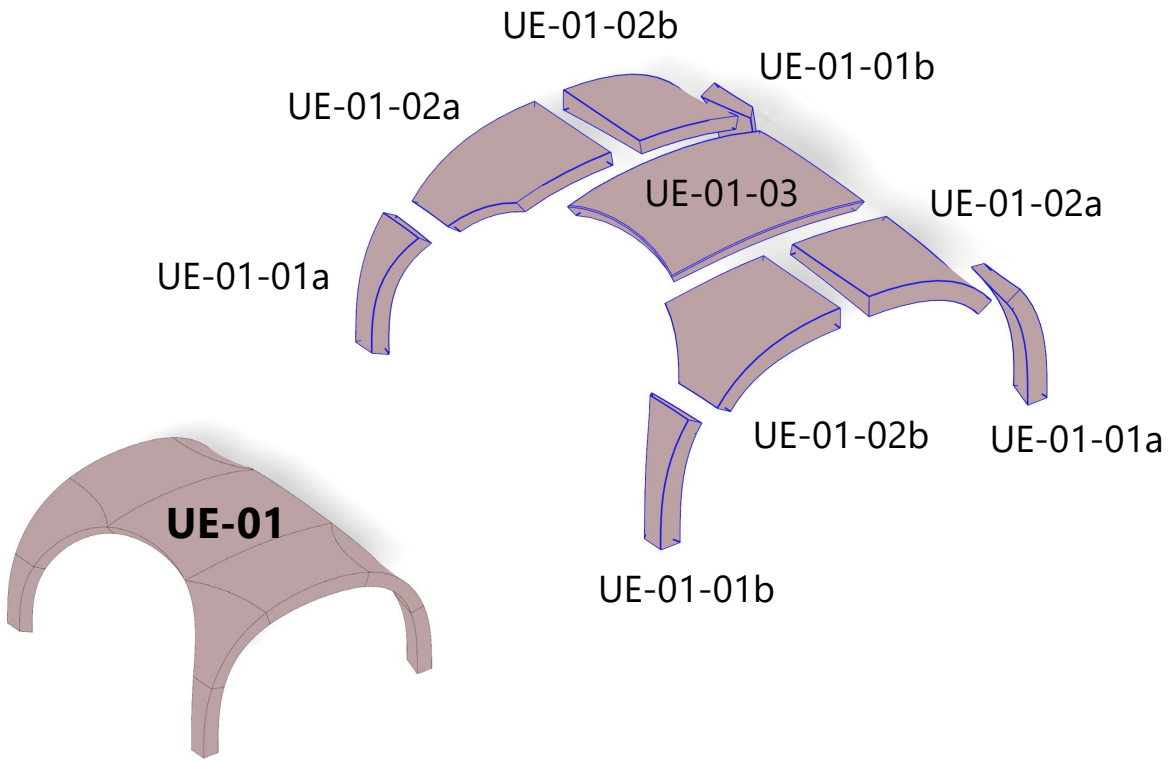


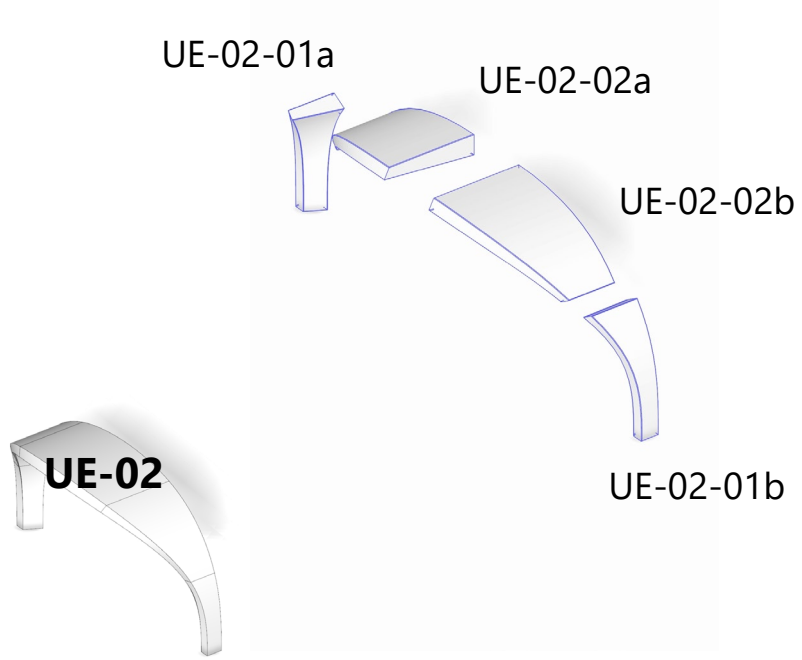


5_DESIGN

Construction – Structure Level

Kit of Parts – UE-01, UE-02

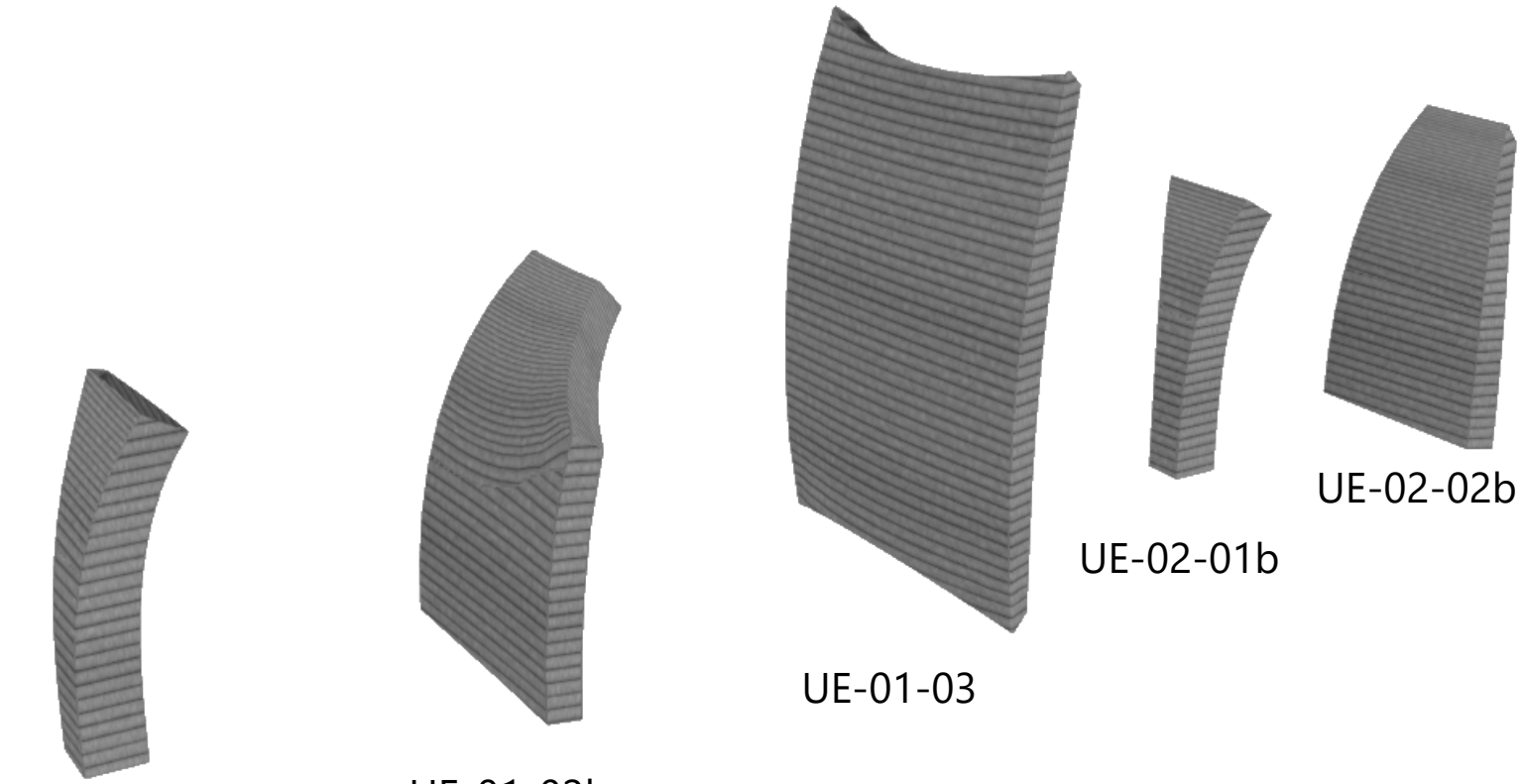




5_DESIGN

Construction – Structure Level

Kit of Parts – printing direction



UE-01-01b

UE-01-02b

UE-01-03

UE-02-01b

UE-02-02b

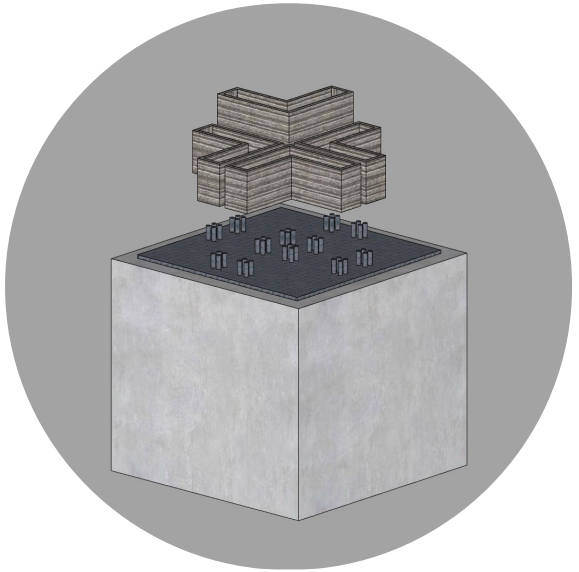
5_DESIGN

Construction – Structure Level

Foundation

Foundations with concrete base and steel bars

Foundations with concrete base and metal panels

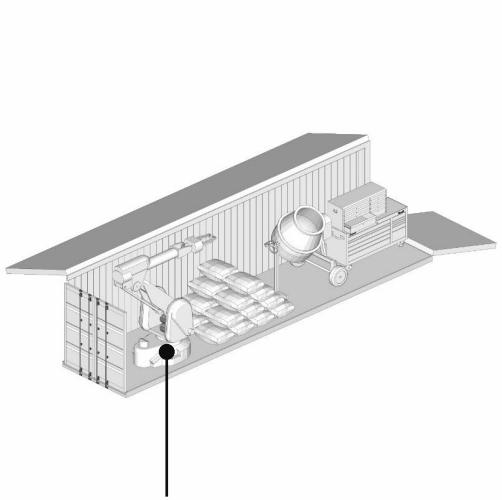


Proposed foundation
Concrete base (1.7x1.7x1.5) + steel plate + steel bars

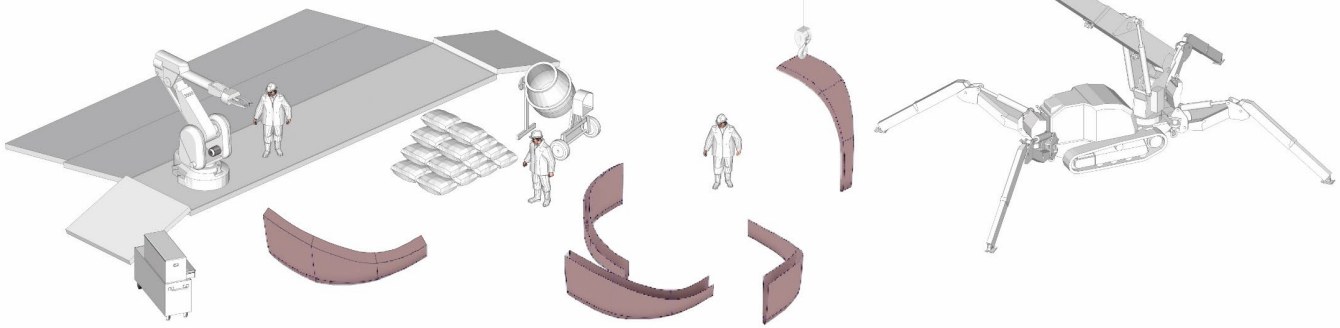
5_DESIGN

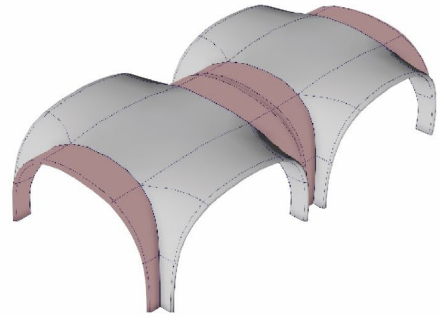
Construction – Structure Level

Construction process



CyBe RT 3DP

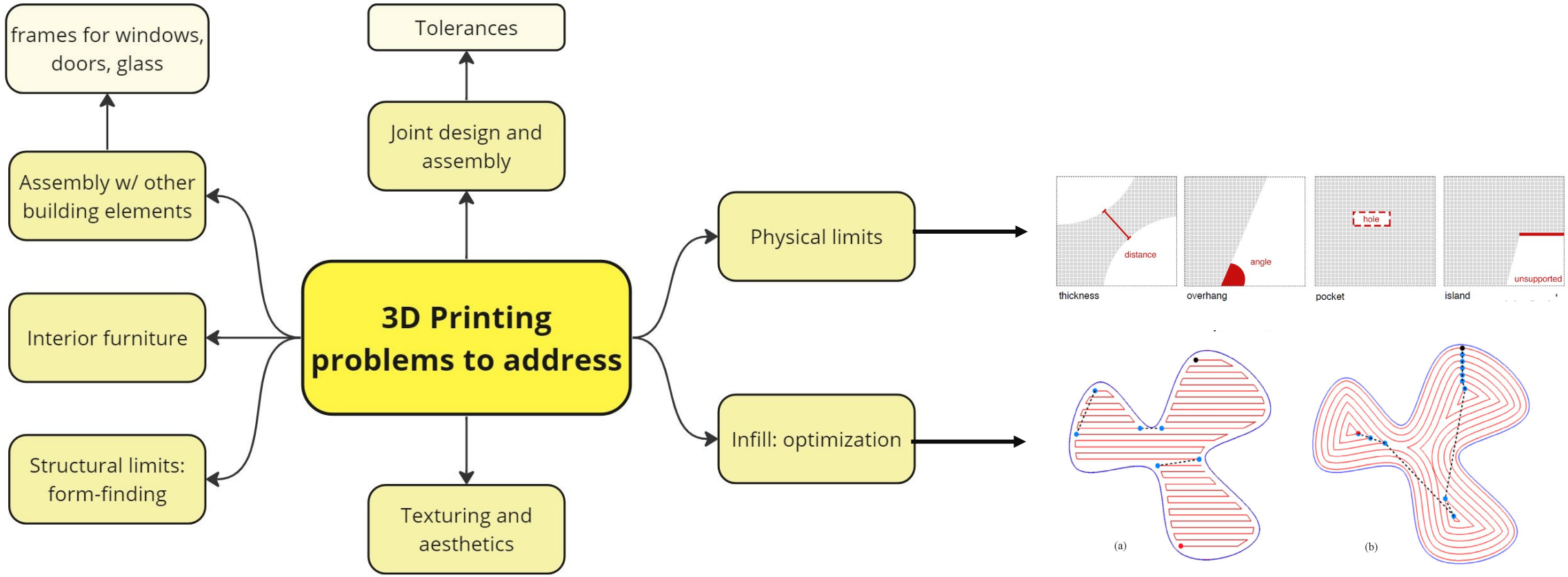




A container will reach the plot with all the materials needed for fabrication. The 3D printer will remain in the base of the container and with a riel will move to print the series of KoP. The printed elements will be placed and assembled by a spider crane. Human assistance will be also needed.

6_EXPERIMENTATION

3DP problems identification



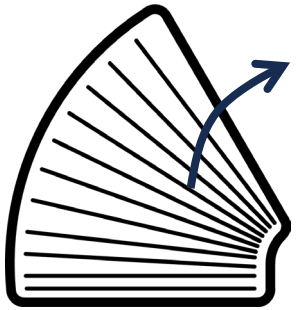
The 3DP process present different problems or constraints to address.

6_EXPERIMENTATION

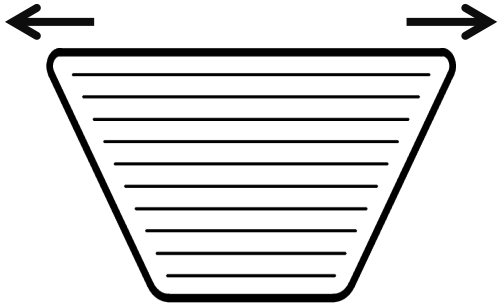
Shape testing

Testing criteria

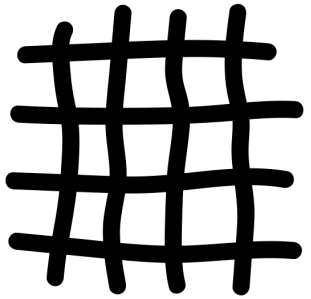
straight



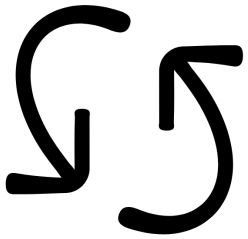
bending



cantilever



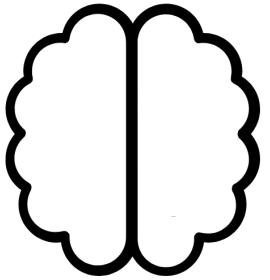
texturing



rotation

corrugation

branching



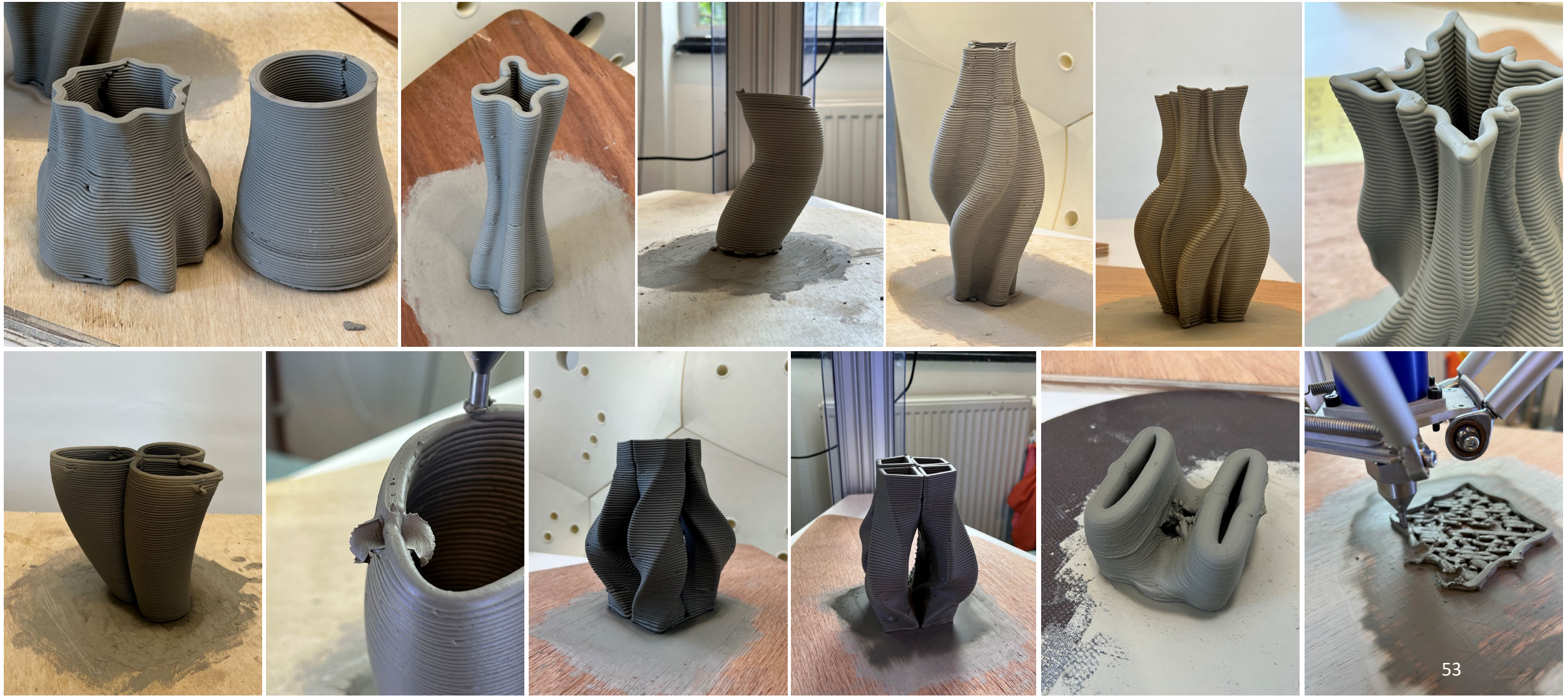
joint

6_EXPERIMENTATION

Shape testing

Physical limits

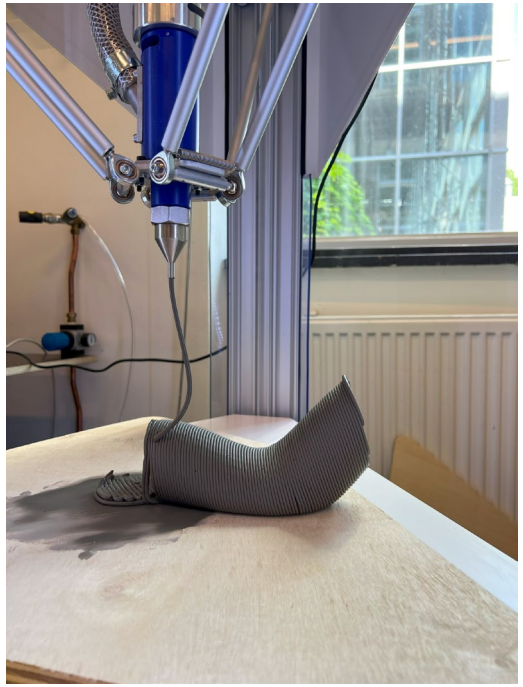
Own work. Materials and tools supplied by the LAMA lab.

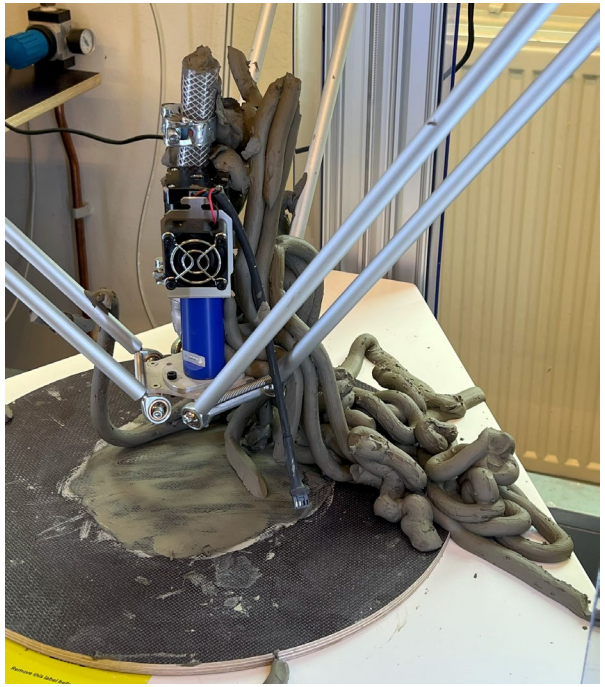


6_EXPERIMENTATION

Shape testing

Failures



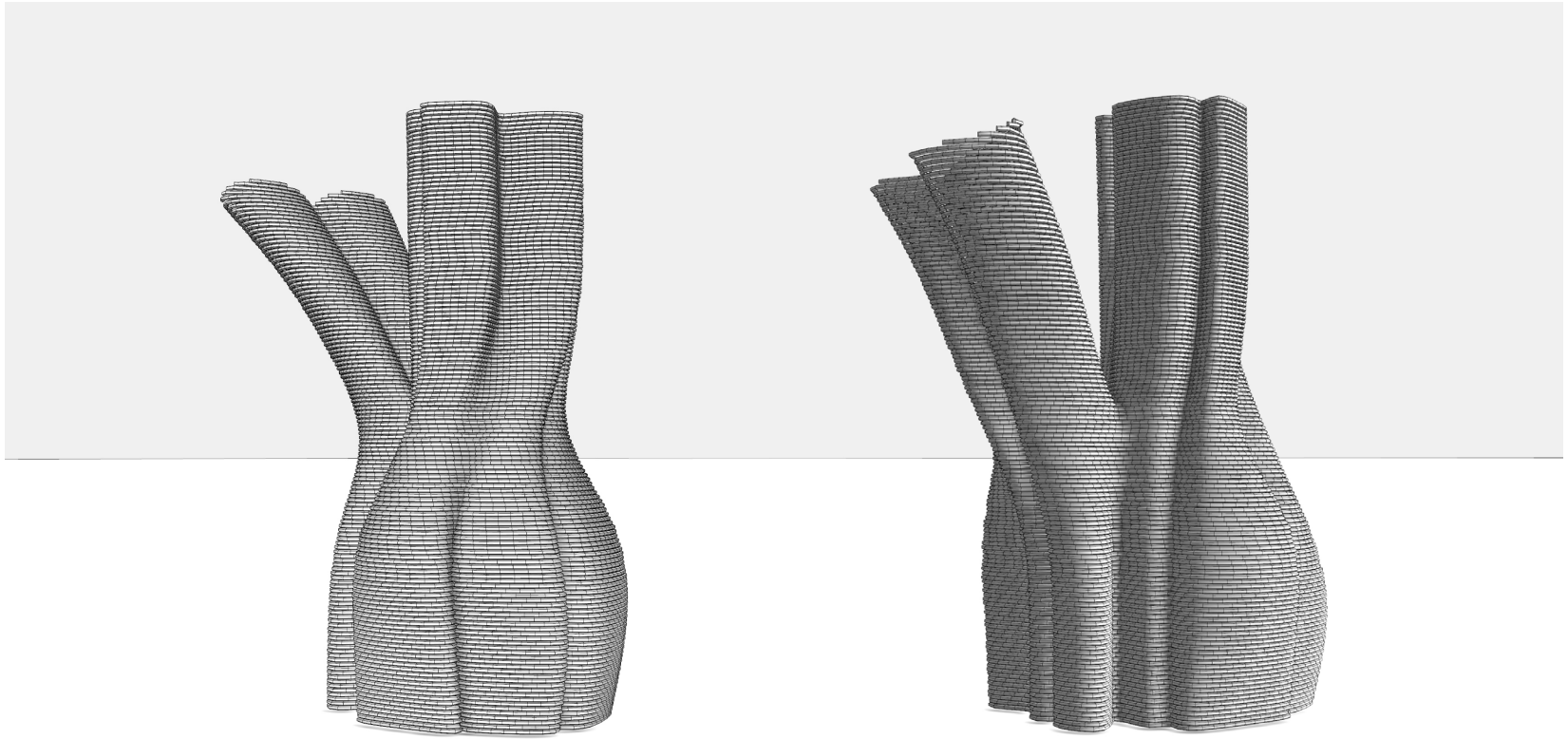


Own work. Materials and tools supplied by the LAMA lab.

7_PROTOTYPING

Column section design

Geometry

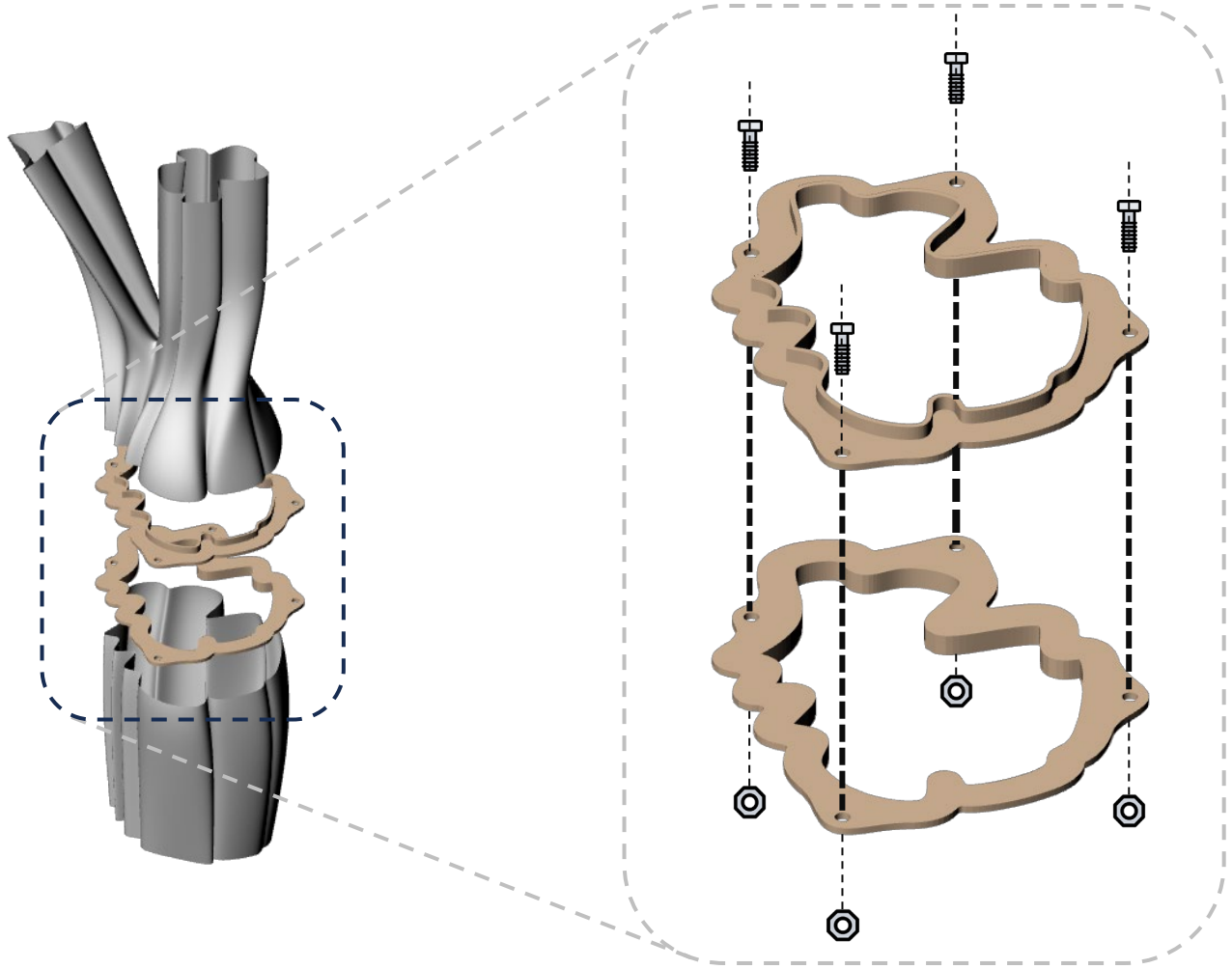


Joint of two column pieces. Model in 1/1 scale.

7_PROTOTYPING

Column section design

Joint



The design of the joint will accommodate every encounter of different pieces. Composed by laser cut metal plate with a flange added, which will be in contact with the concrete piece. The plates will be bolted then.

7_PROTOTYPING

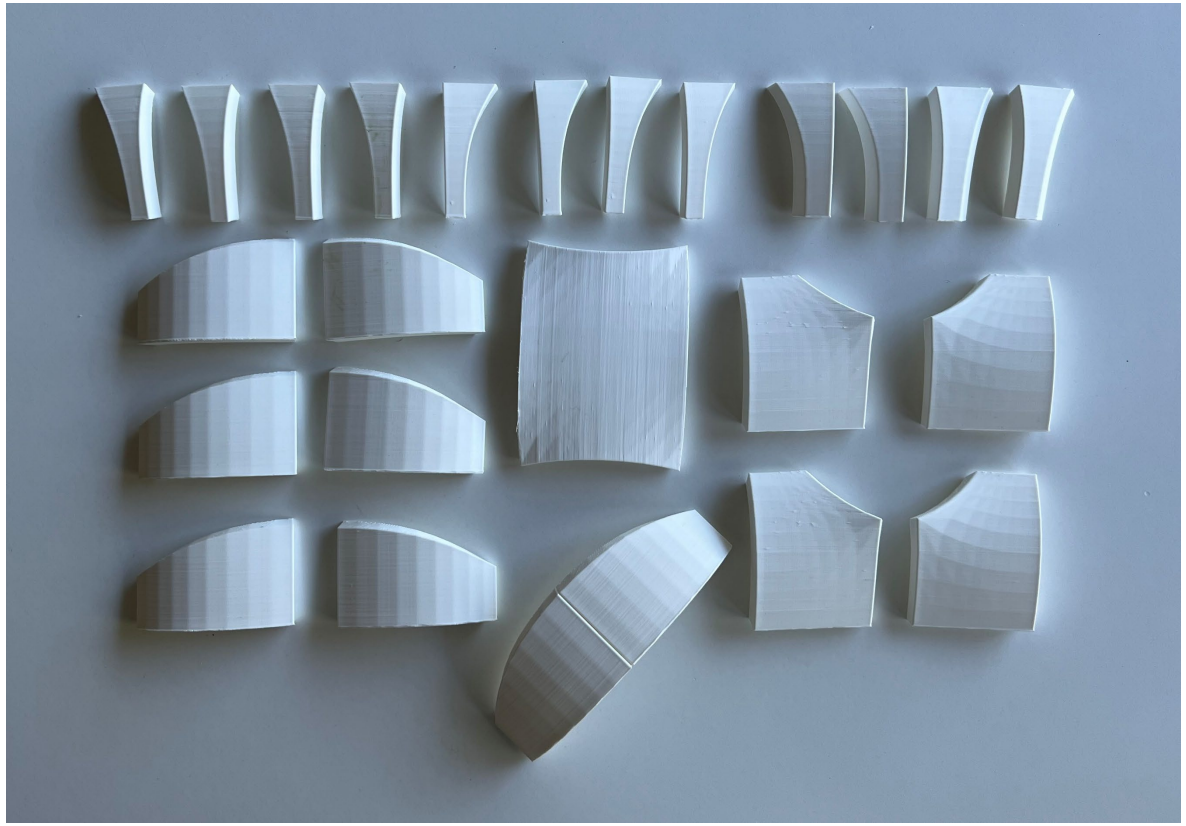
Column section design

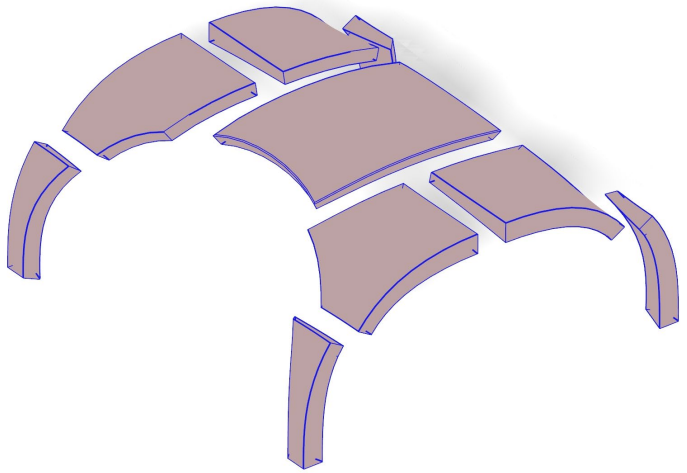
Model

7_PROTOTYPING

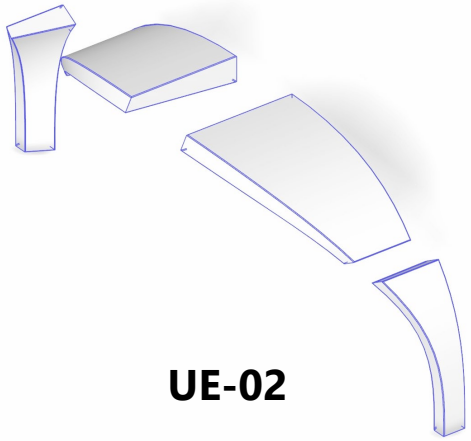
Kit of parts – U-01, U-02

Pieces





UE-01



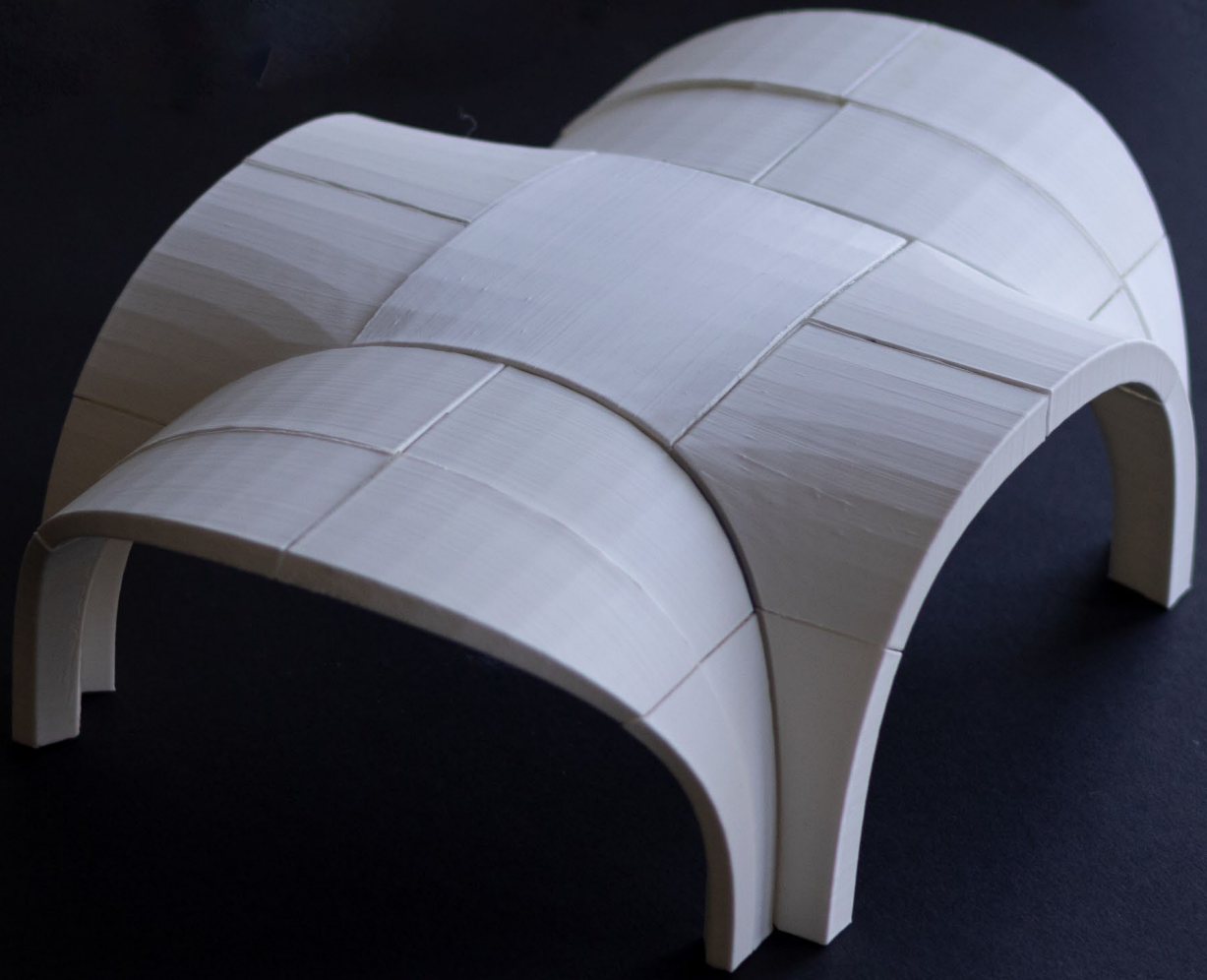
UE-02

The Kit-of-Parts of the UE-01 and UE-02 modules in 1/20 scale

7_PROTOTYPING

Kit of parts – U-01, U-02

Model



7_PROTOTYPING

Kit of parts

Additional iterations

8_CONCLUSIONS

Answering the main research question

How can 3D printing, produce social housing units, and at the same time enhance construction efficiency, architectural adaptability, and encourage innovation in form and shape?

- The results in terms of design and prototyping the expected.
- Combining the kit-of-parts, user-customization and multi-material approaches.
- It is necessary to design specially for the kit-of-parts approach.
- The process was iterative between the design and experimentation phases.

9_FURTHER RESEARCH

- Include the non-planar printing using the robot arm. More control of the G-code to achieve other shapes in 3D printing.
- Automate the aggregation through simple and friendly platforms for the user interaction.
- Automate the interior distribution of the housing units with the library of rooms.
- Interior design. A lot to explore in terms of printing integrated furniture, plumbing, etc.

Q&A