



Reconsidering Façade Culture

Graduation Project

A study into a modular facade system
for ecological architectural tectonics

Niels Teunissen
5068541

2024-2025

Architectural Engineering Graduation Studio
Research tutor: Mo Smit
Design tutor: Stephan Verkuijlen
Building technology tutor: Lex van Deudekom
Delegate of the board of examiners: Stefano Corbo

00 | Table of contents

01 | Problem statement & relevance

**02 | The research: towards sustainable
facade culture**

**03 | The design: transforming the Beatrix-
gebouw Utrecht**

04 | Reflection

00 | Table of contents

01 | Problem statement & relevance

02 | The research: towards sustainable
facade culture

03 | The design: transforming the Beatrix-
gebouw Utrecht

04 | Looking back and ahead

The current facade culture:



We use linear economy principles...



to seal us off from
the natural world...



...and to create our own world.

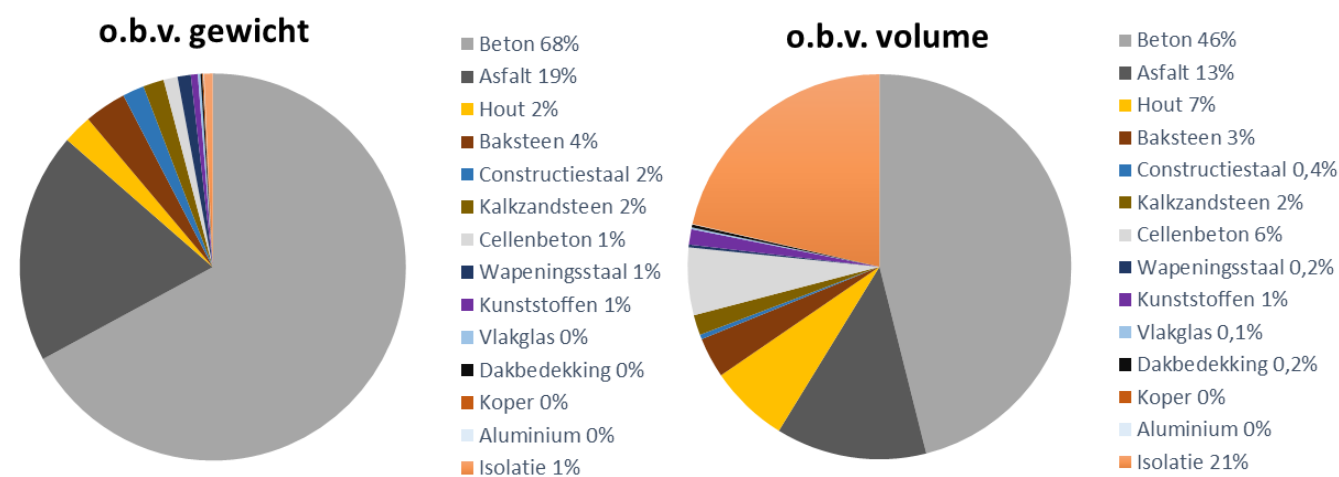
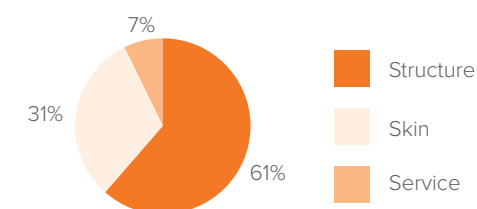
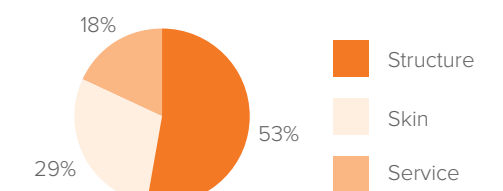


Fig 1: Shares of construction materials used in the Netherlands. Biobased materials are 0,1% (NIBE Research, 2019).

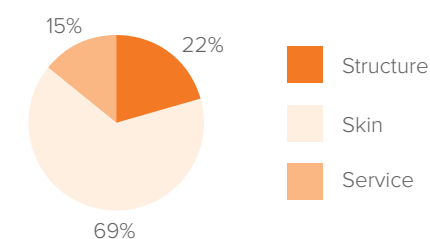
Woningen nieuwbouw



Utiliteit nieuwbouw



Woningen renovatie



Utiliteit renovatie

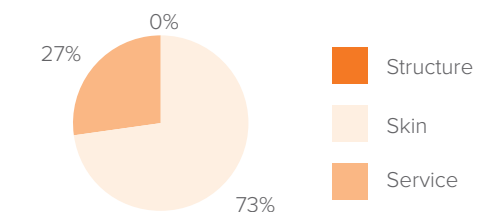


Fig 2: Impact of material related emissions per building layer in the Netherlands, divided in housing-utility and new construction-renovation (DGBC, 2021).

Type gezondheidsklachten binnenmilieu

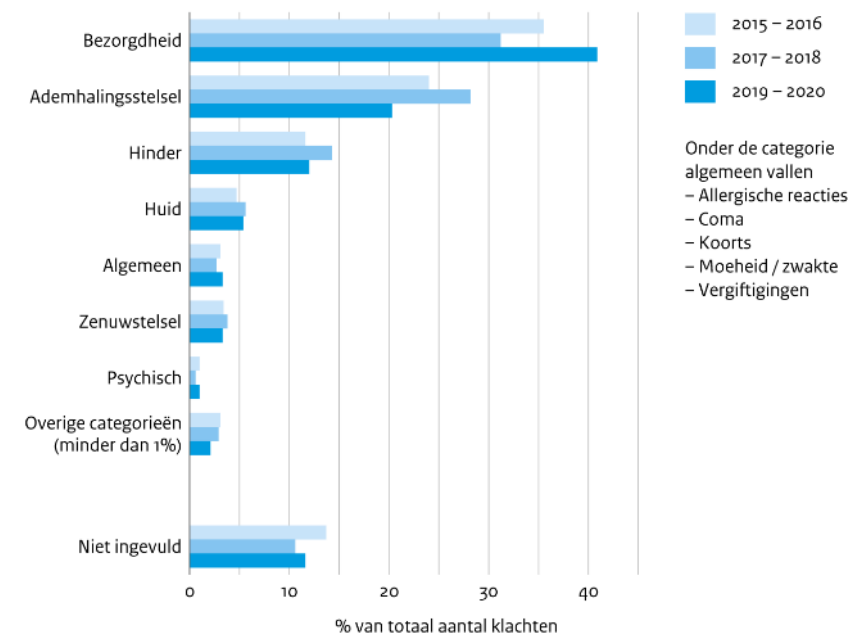
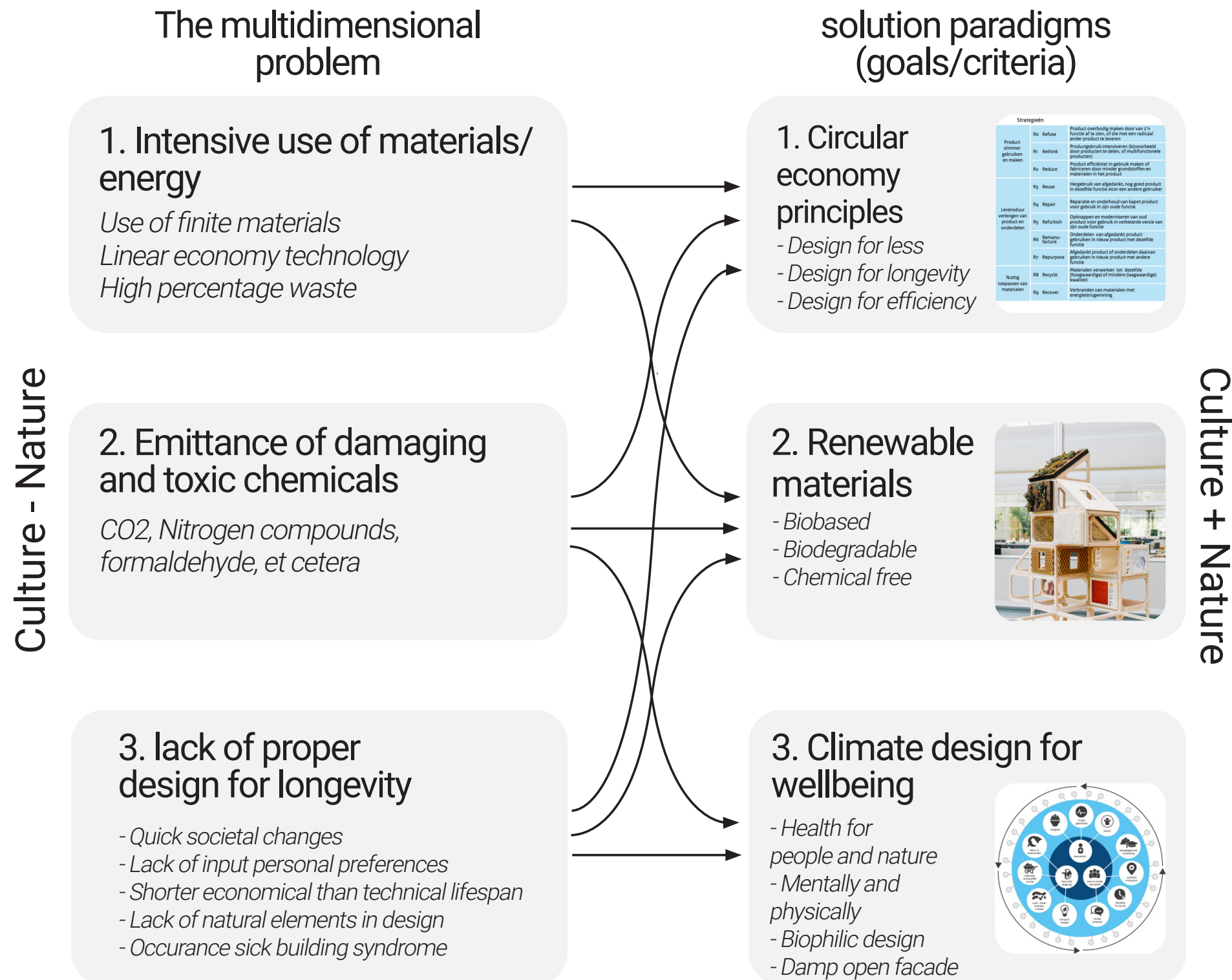


Fig 3: 75% of environment related symptoms reported to the GGD in 2019 and 2020 concern the indoor climate (RIVM, 2022).

A three-piece sustainability goal:



Thematic research objective

Research question:

How can a modular facade be developed with Ecological Architectural Tectonics (EAT) theory?

Part A: Investigation

What are the requirements for:

1. the facade's **structure** and how can it be standardized for the circular economy?
2. the facade's **materials** and how can it consist of as much renewable materials as possible?
3. the facade's projected **climate** and how can it be customized for wellbeing?

Methods: Literature studies, database analysis (edupack).

Part B: Experimentation (iterative process)

How can the insights of 1-3 be combined for an integral facade system?

Methods: Research by design (sketching, CAD), prototyping

Theoretical framework

Ecological Architectural tectonics:
The combination of architectural tectonics and the three-piece sustainability goal

Modularity:
A tool to balance standardization and customization

1. Circular economy principles

- Design for less
- Design for longevity
- Design for efficiency

Strategieën	
Product afbreken en hergebruiken	- R1 Refuse: Product overbodig maken door van zijn functie af te zien, of die met een radicaal ander product te vervangen - R2 Reduce: Product efficiënter in gebruik maken of afbreken door minder grondstoffen en materialen in het product - R3 Repair: Herstel van afgeleide, nog goed product in dezelfde functie door een andere gebruiker - R4 Repurpose: Reparatie en onderhoud van kapot product voor gebruik in de oude functie - R5 Refurbish: Opknappen en moderniseren van oud product voor gebruik in dezelfde functie - R6 Renew: Overbrengen van afgeleide product, gebruiken in nieuw product met dezelfde functie - R7 Reuse: Algemeen product of onderdeel daarvan gebruiken in nieuw product met andere functie - R8 Recycle: Materialen verwerken tot dezelfde grondstoffen (niet of minder laagwaardige kwaliteit) - R9 Recover: Verbranden van materialen met energiegeneratie

2. Renewable materials

- Biobased
- Biodegradable
- Chemical free

3. Climate design for wellbeing

- Health for people and nature
- Mentally and physically
- Biophilic design
- Damp open facade

Three pillars of architectural tectonics

Structure

- Self supporting
- Spatial ordering: layouts composition open - closed Shape
- Standardized per: building owner room person ...

Materials

- Has both structural and climatological properties
- Aesthetic: Texture Tactility
- Exposed to nature (or not)
- Finite or infinite

Climate

- Passive and active climatization
- Indoor climate, protected against natural elements
- support in complex climate processes: temperature ventilation shading humidity
- Tailored per: building owner room person ...

Standardization

Modular Spectrum

Customization

00 | Table of contents

01 | Problem statement & relevance

02 | The research: towards sustainable
facade culture

03 | The design: transforming the Beatrix-
gebouw Utrecht

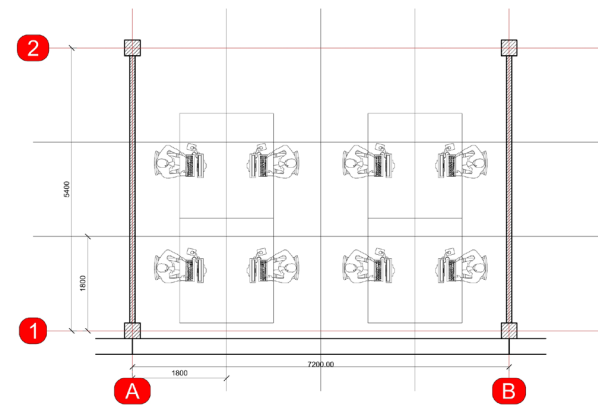
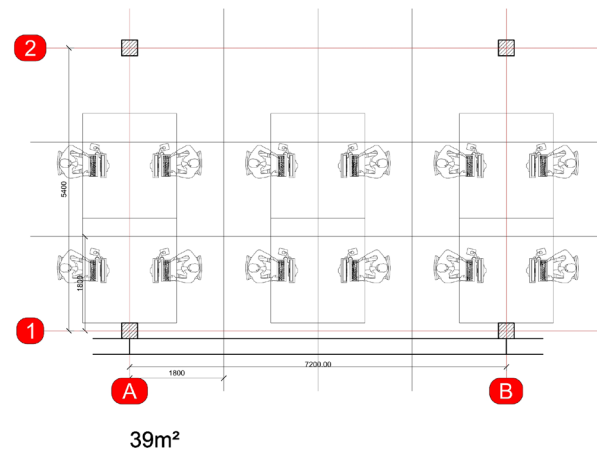
04 | Reflection

Structure

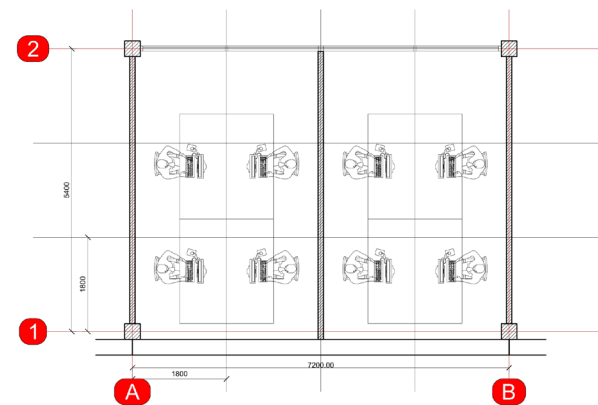
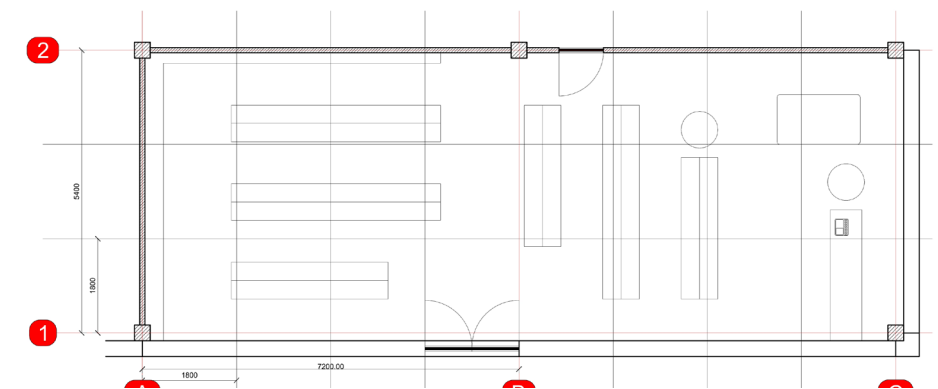
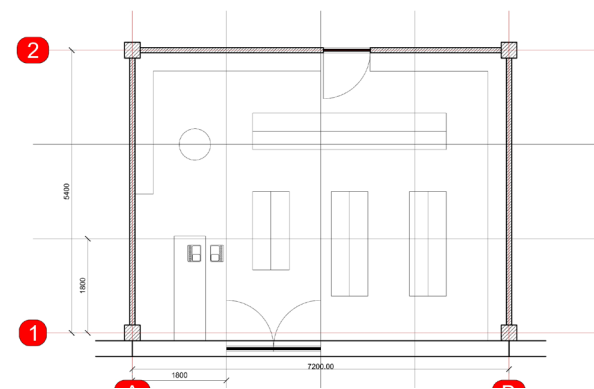
Structure
- Reduce, reuse, repair, remanufacture, refurbish, recycle. - Components approach - Open building/ shearing layers stewart brand - Demountable, universal connections - As independent as possible: when cassette a is removed, b can stay - Casette system - Hoisting equipment - Low tech - Prefabrication - Standardization

Floorplan possibilities

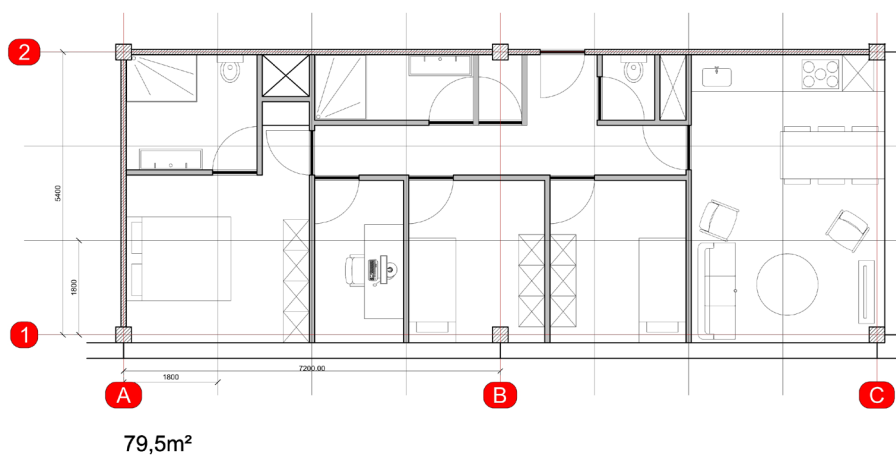
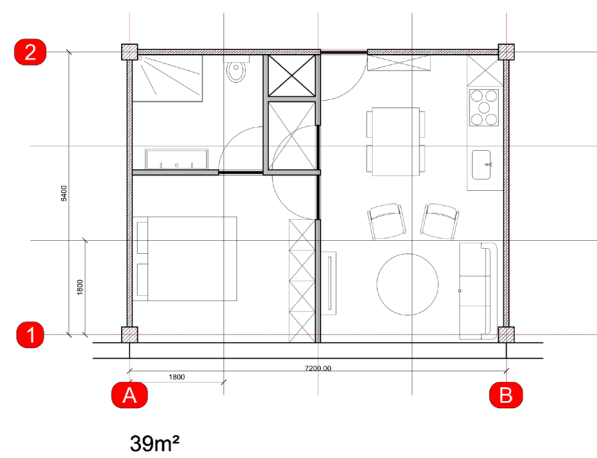
office layouts



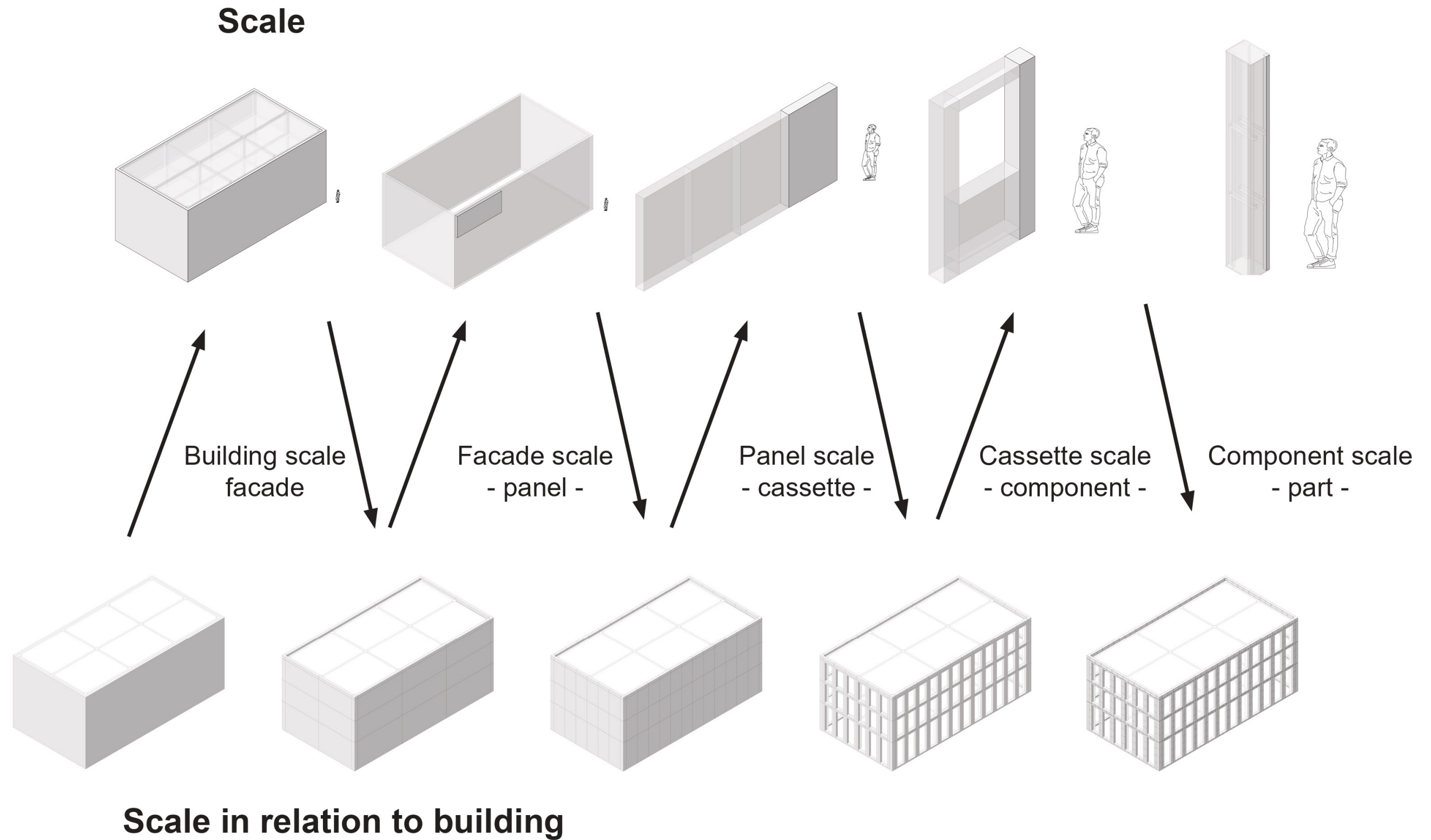
commercial layouts



dwelling layouts

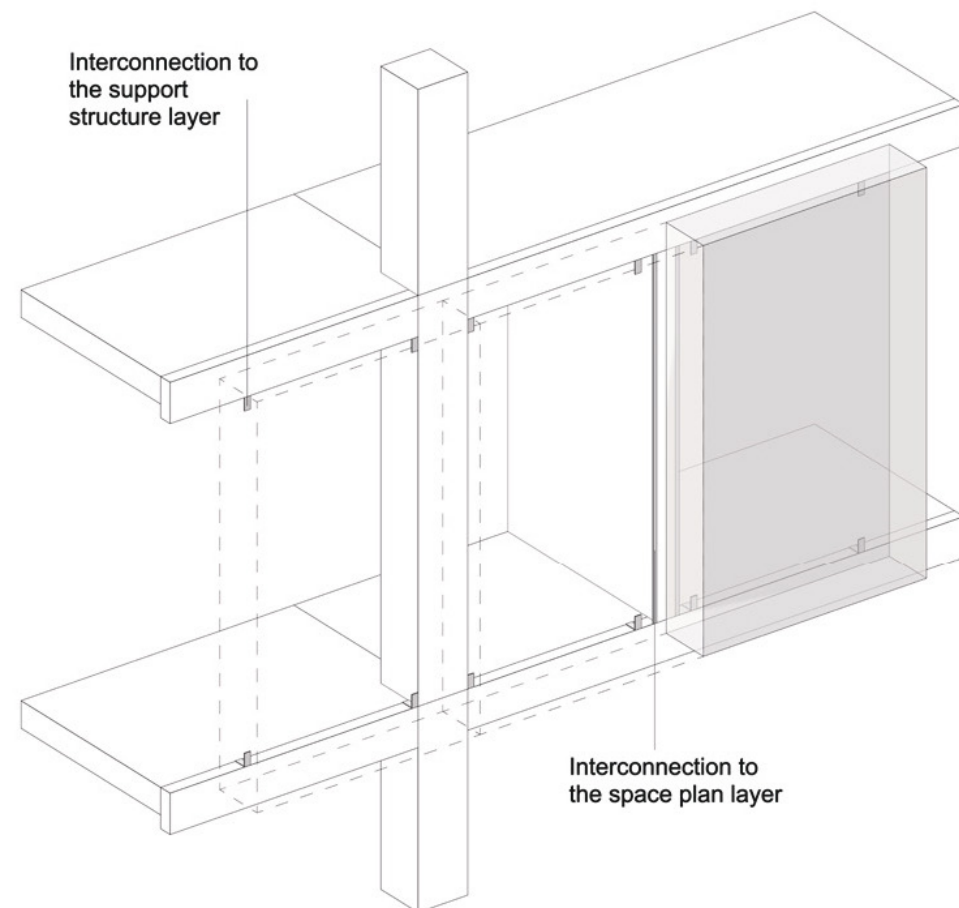


The interscale approach

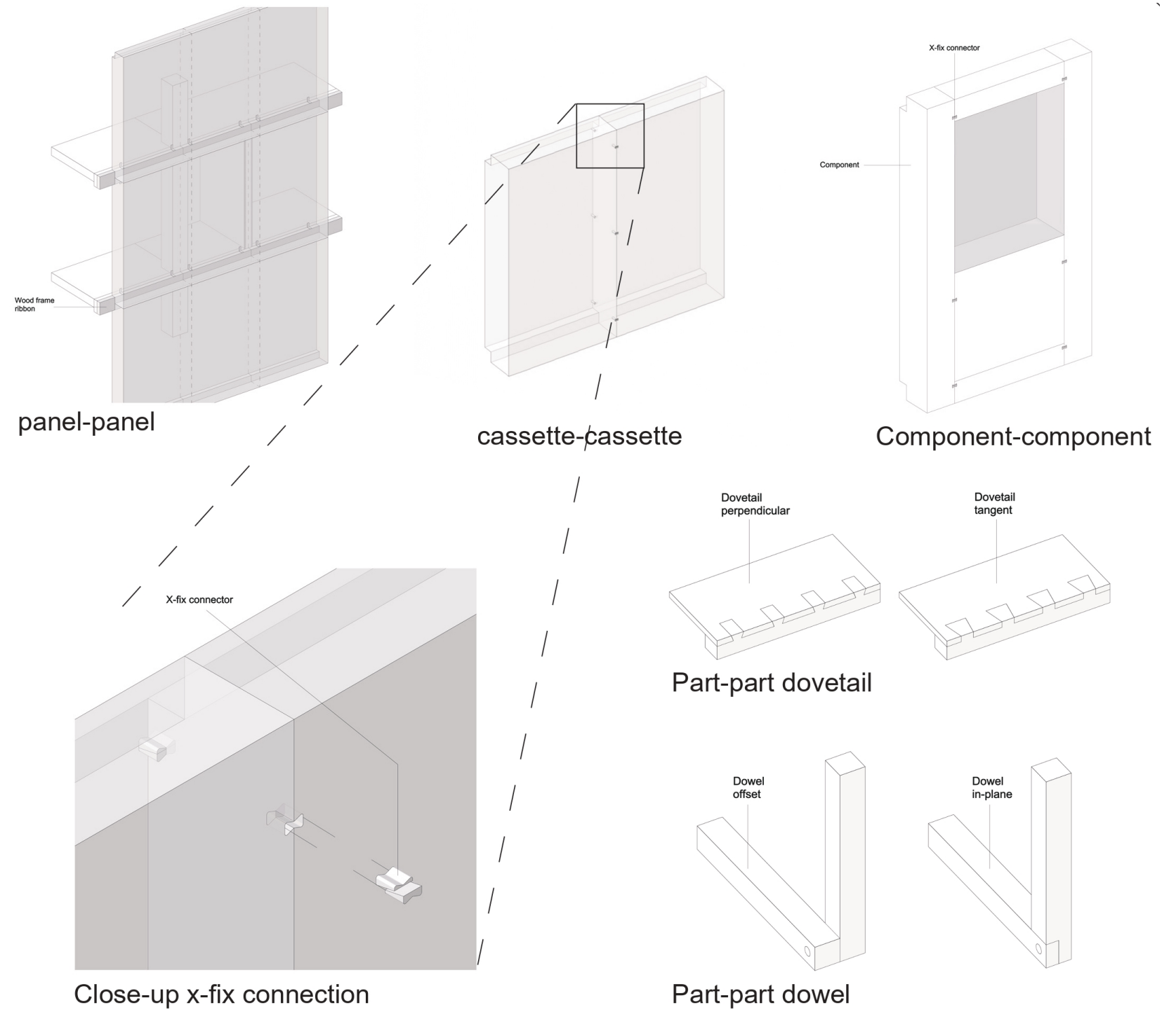


Connections

Interlayer connections



Intralayer connections

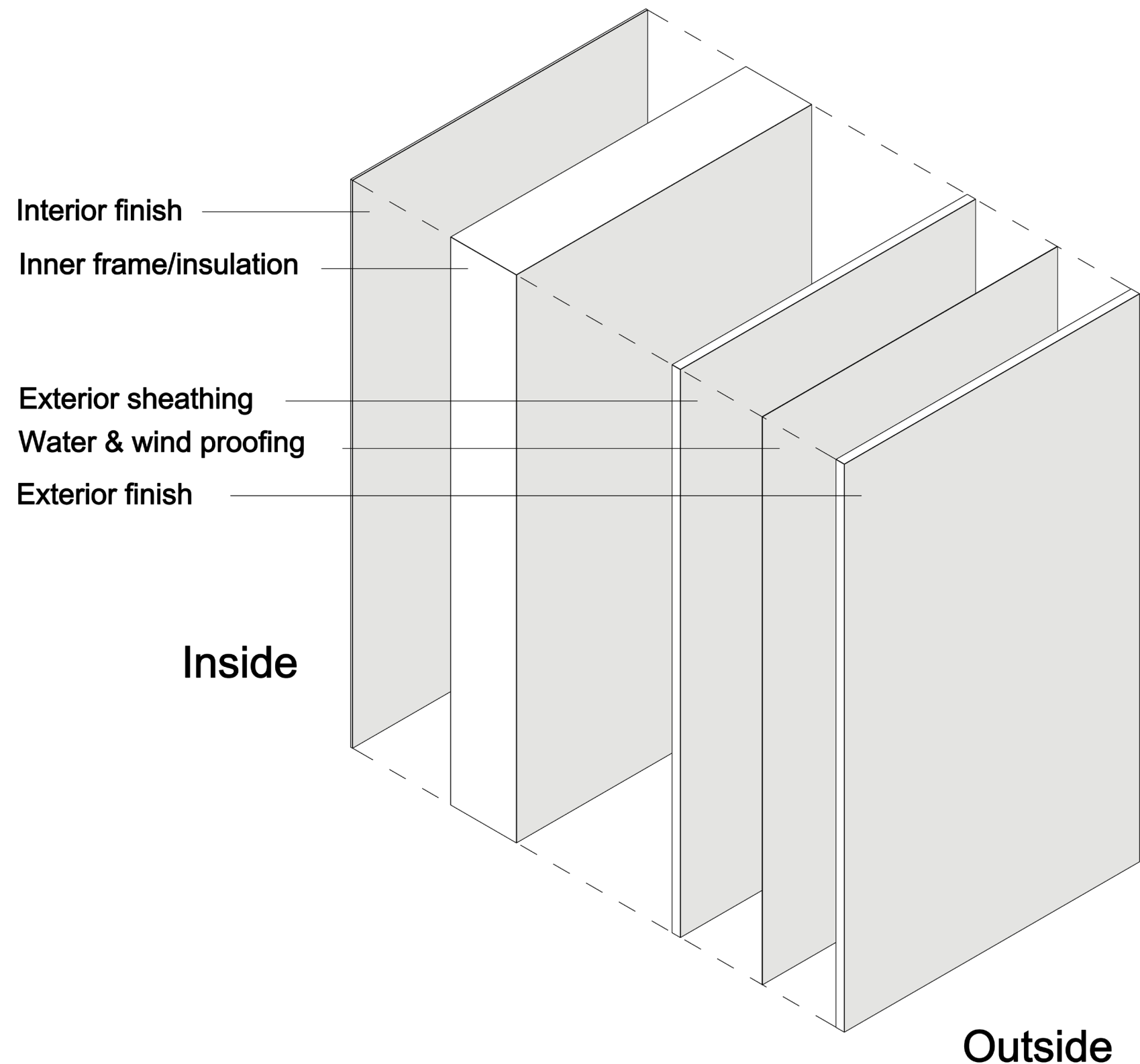


Materials

Materials
- Physical properties - Mechanical properties - Fire proof - Rule: use biobased materials, only a finite (but 100% recyclable) material substitute if necessary - Manufacturing properties (embodied carbon) - Local availability materials - LCA - No or limited amount of toxics chemicals or VOCs

Standard layers in facade design

- Bio-based (renewable)
- Vapor open
- fire resistant
- Local availability
- No (or limited) toxic or damaging compounds



Used materials

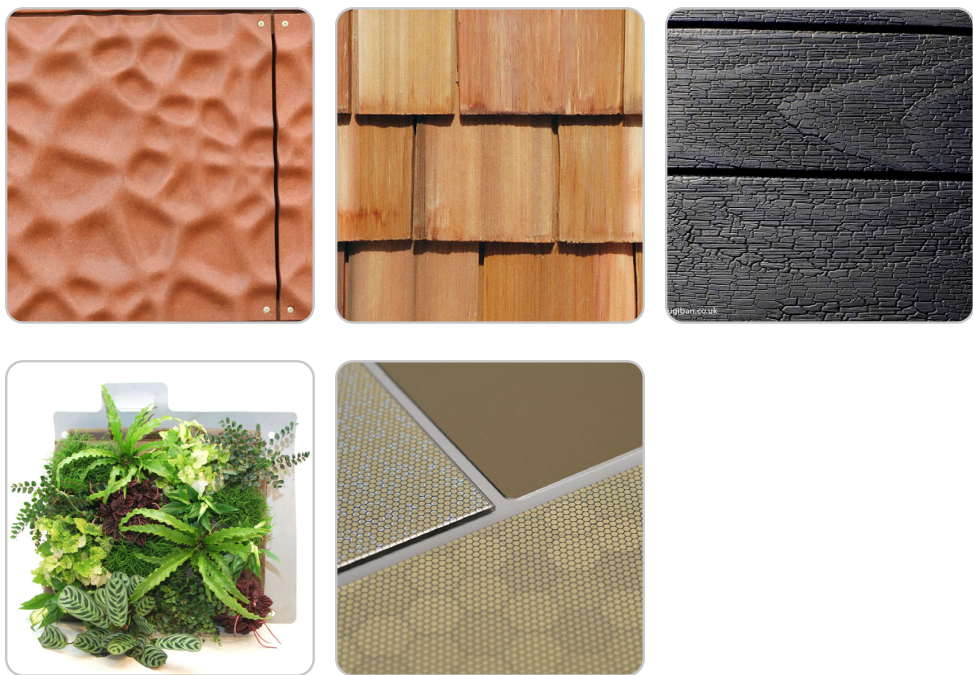
1. Interior finish



3. Exterior sheathing



5. Exterior finish



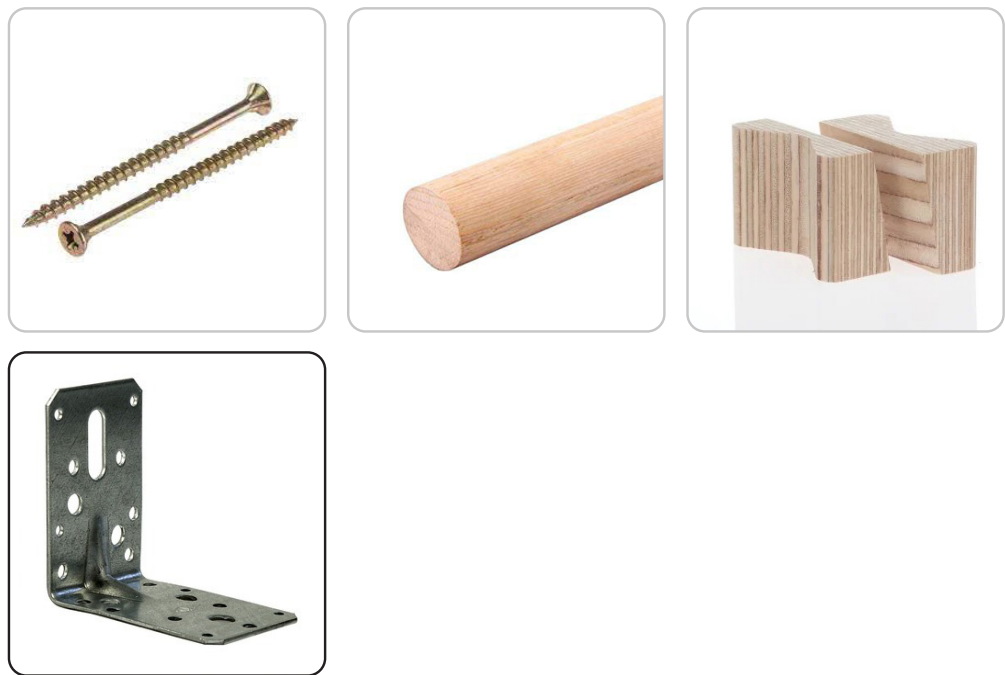
2. Inner frame / insulation



4. Water & wind proofing



6. Connectors

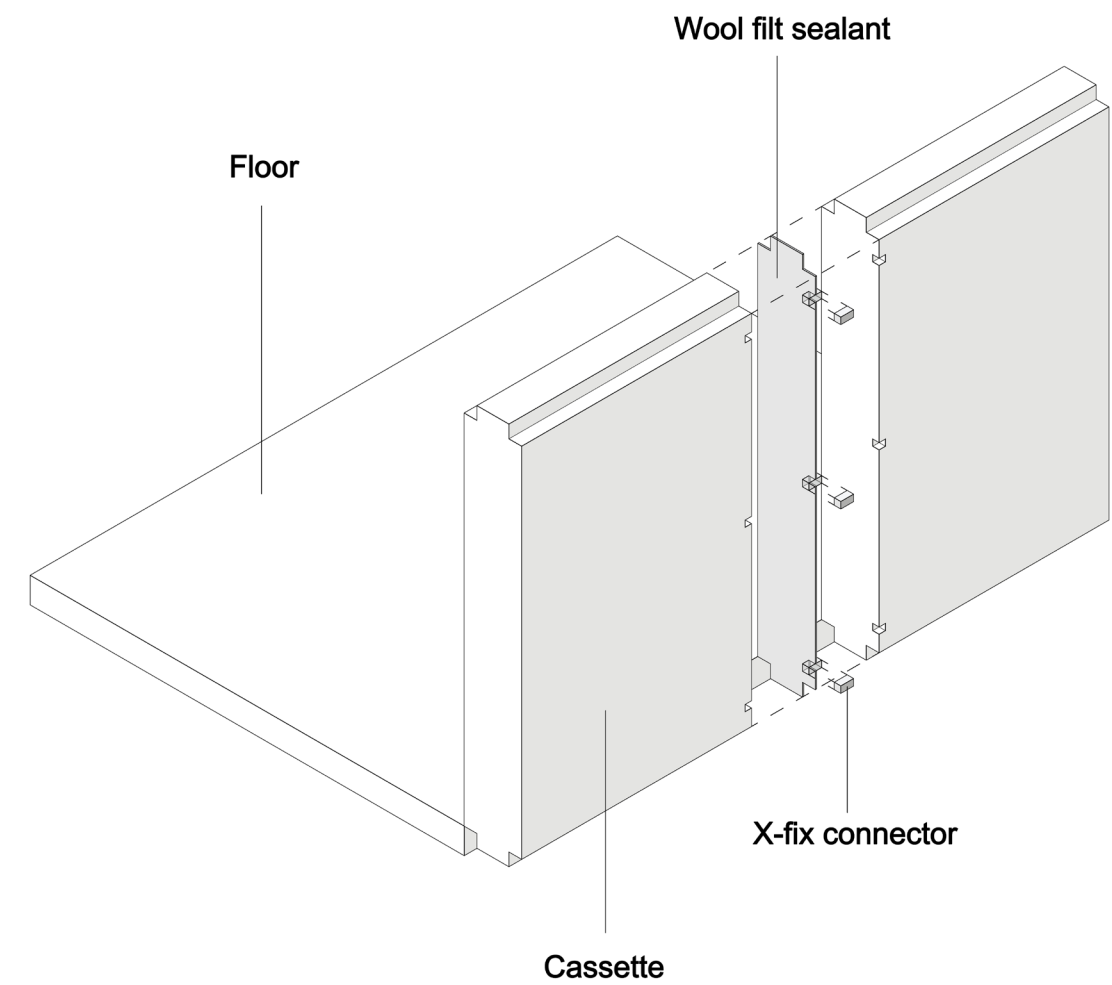
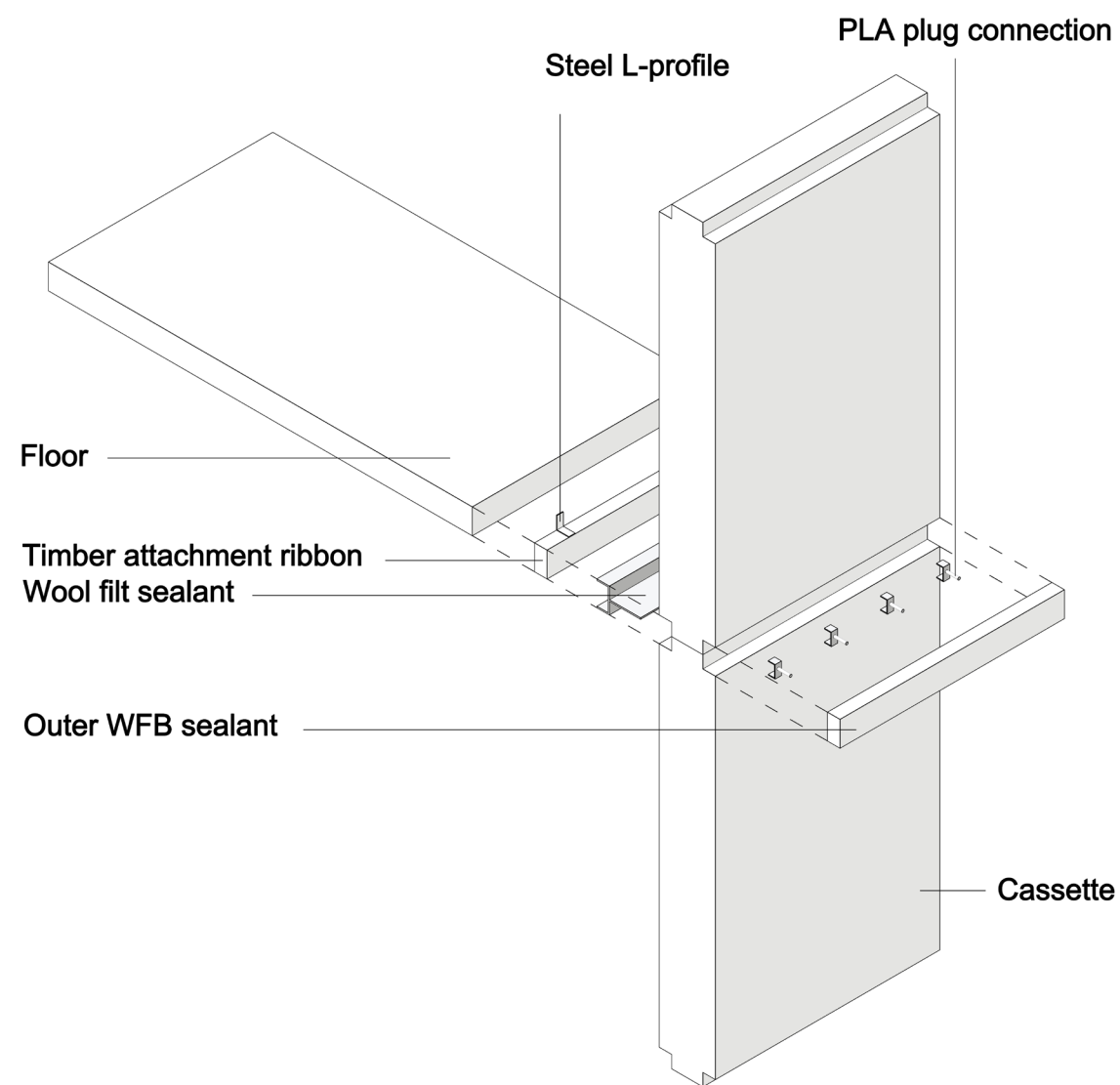


Climate

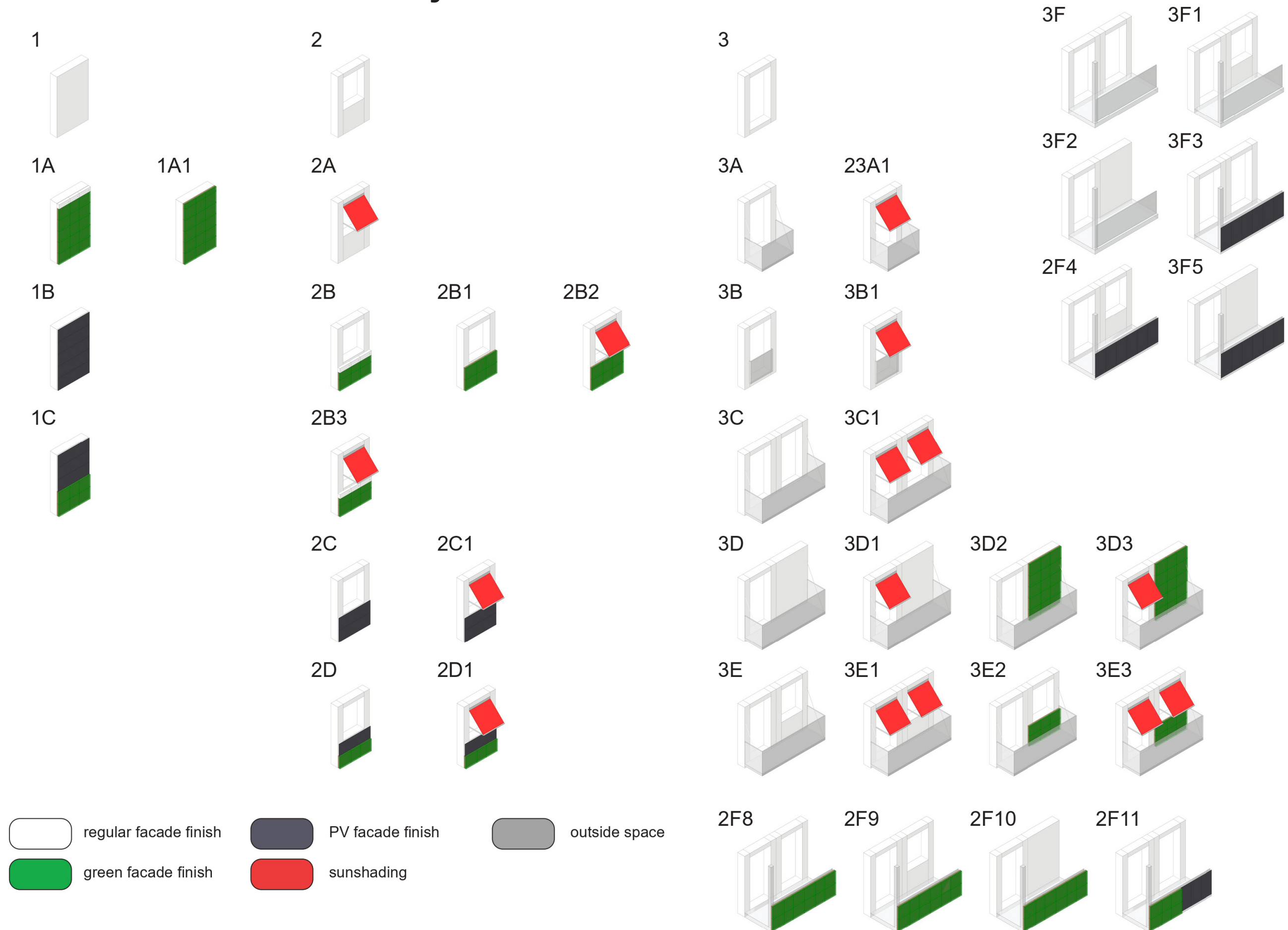
Climate and experience

- Thermal insulation
- Sound insulation
- Water and wind tight
- (direct or indirect) Daylight entry/ % glass and shading
- Rainwater drainage
- Heating/cooling
- Vapor regulation (vapor open)
- Integration of vegetation
- integration of animal habitats (insects, nesting boxes)
- Water buffering
- Outside space (French balcony, balcony, loggia, entrance gallery)
- Thermal accumulative capacity/phase shifting
- Ventilation/openable facade elements

Sealing

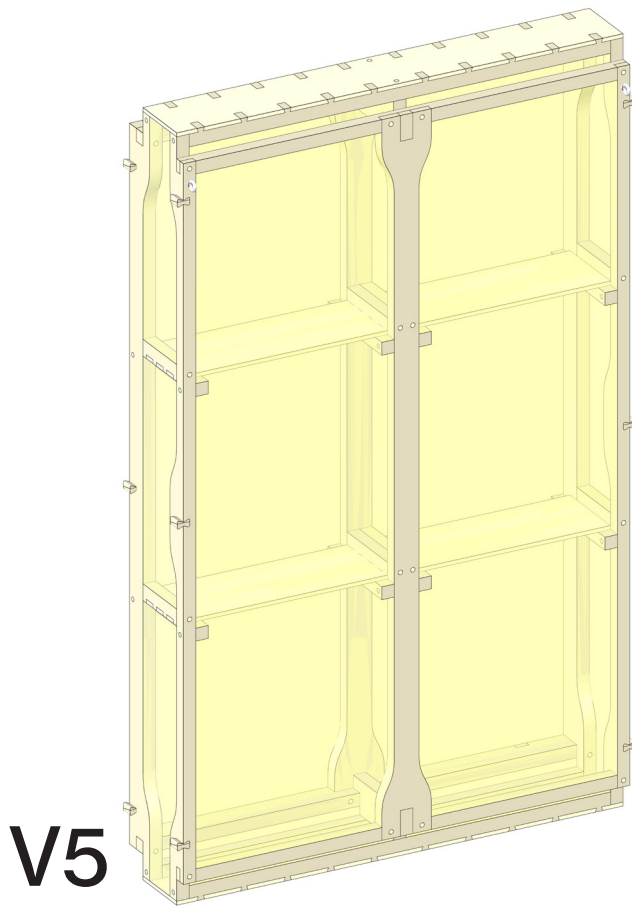
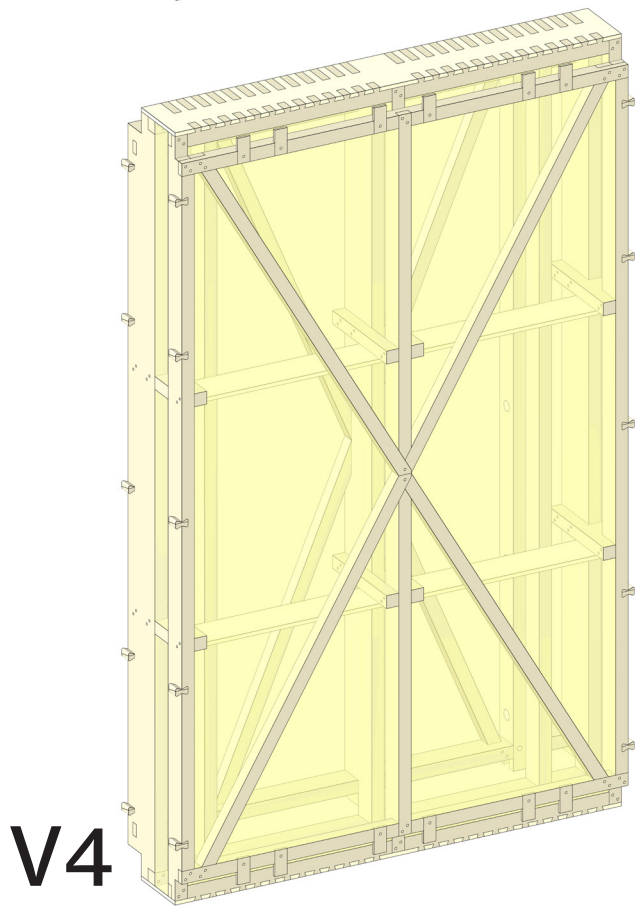
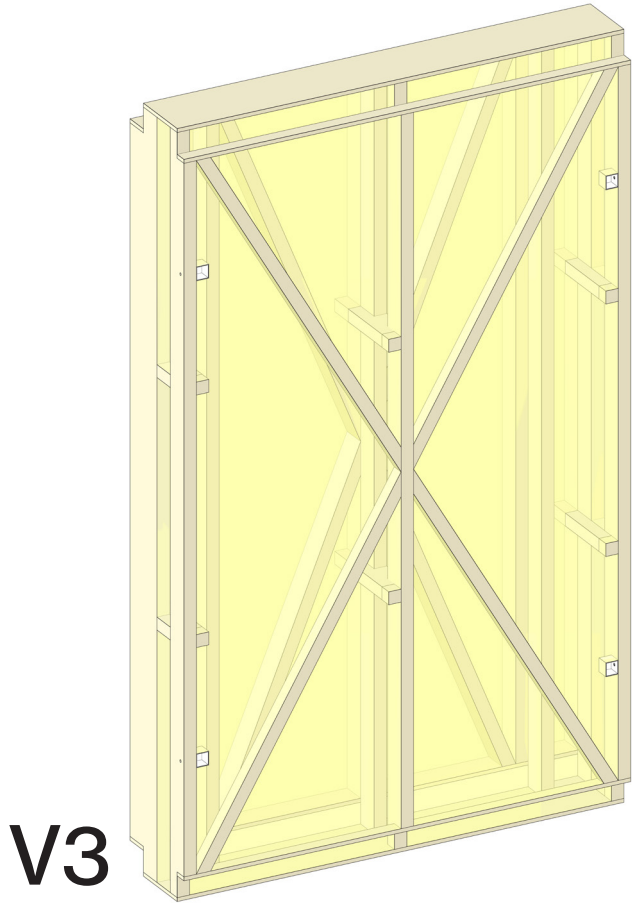
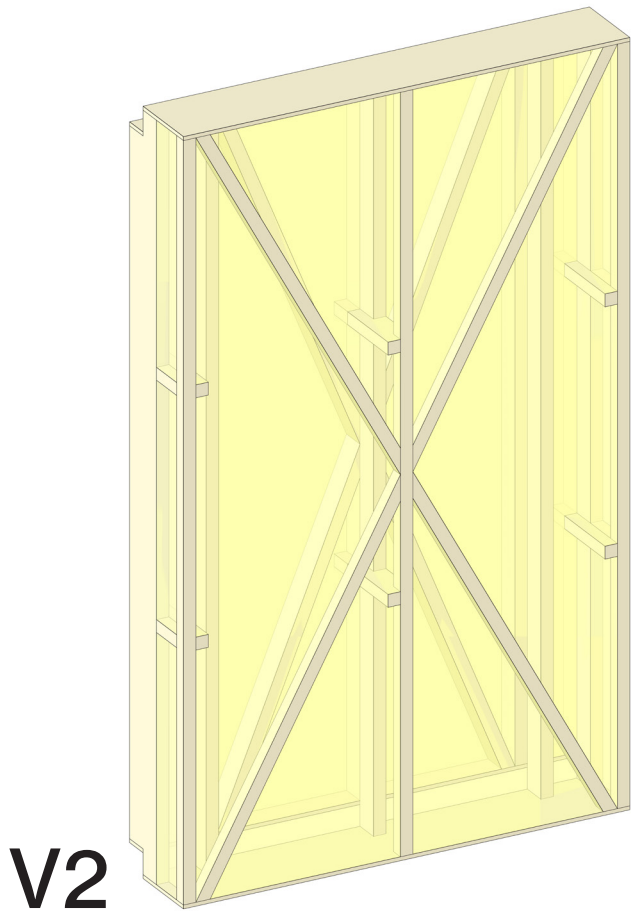
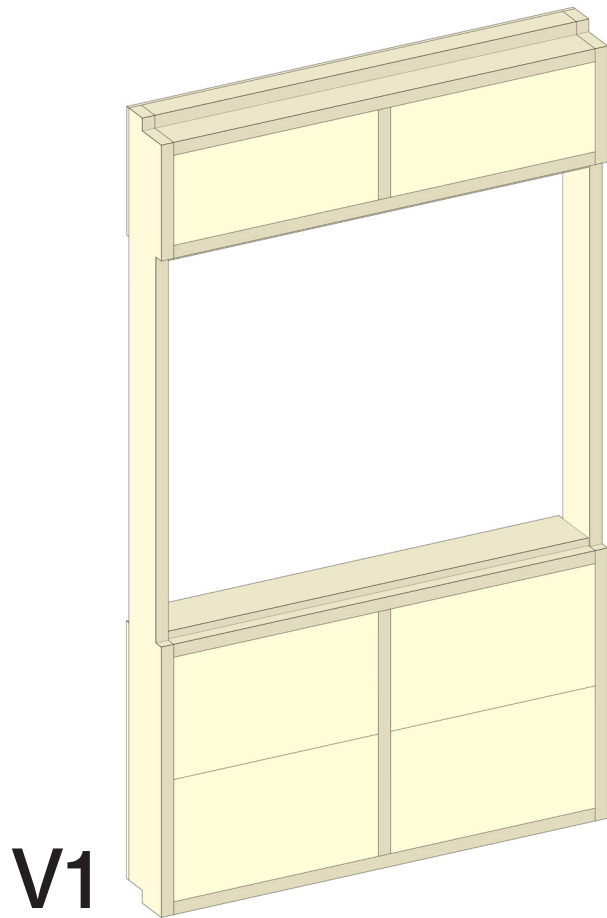


Possible facade 'accessory' combinations:

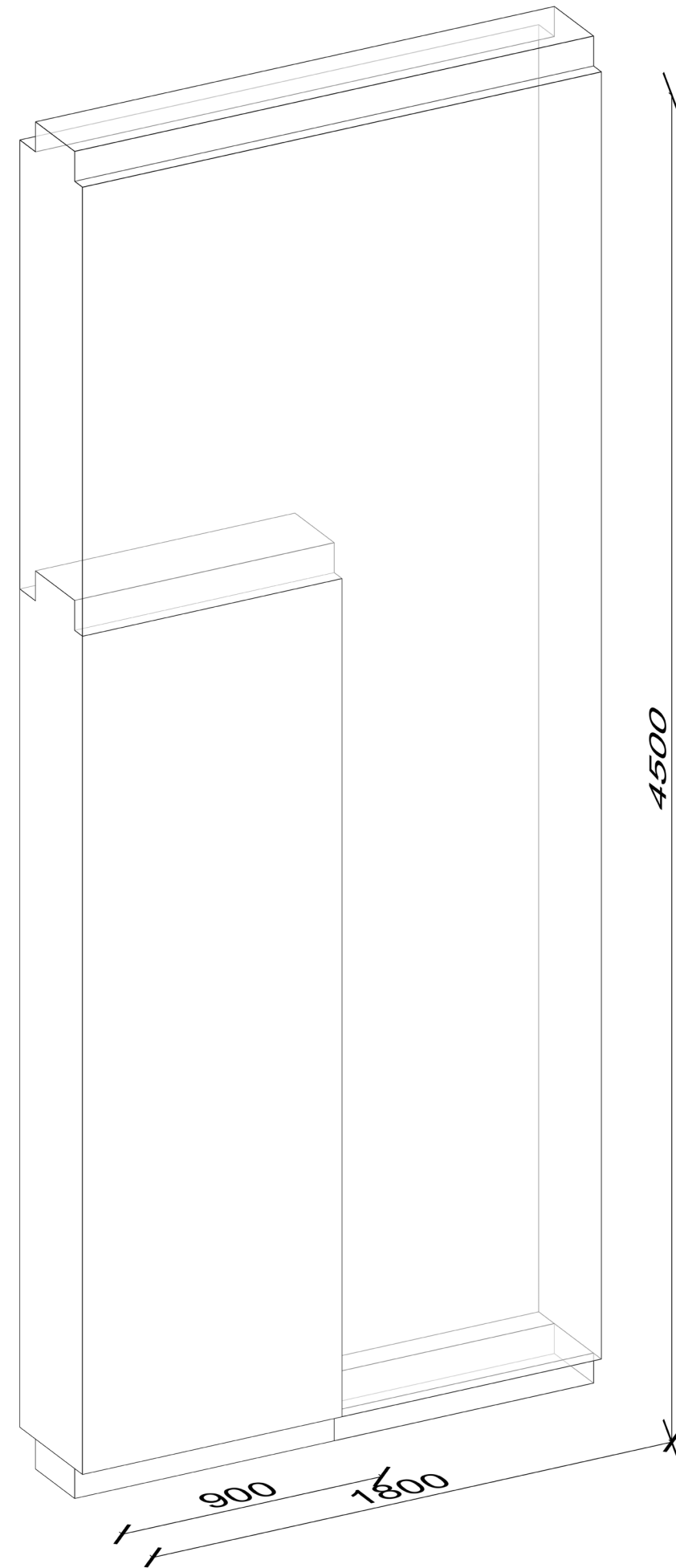


The Facade Design

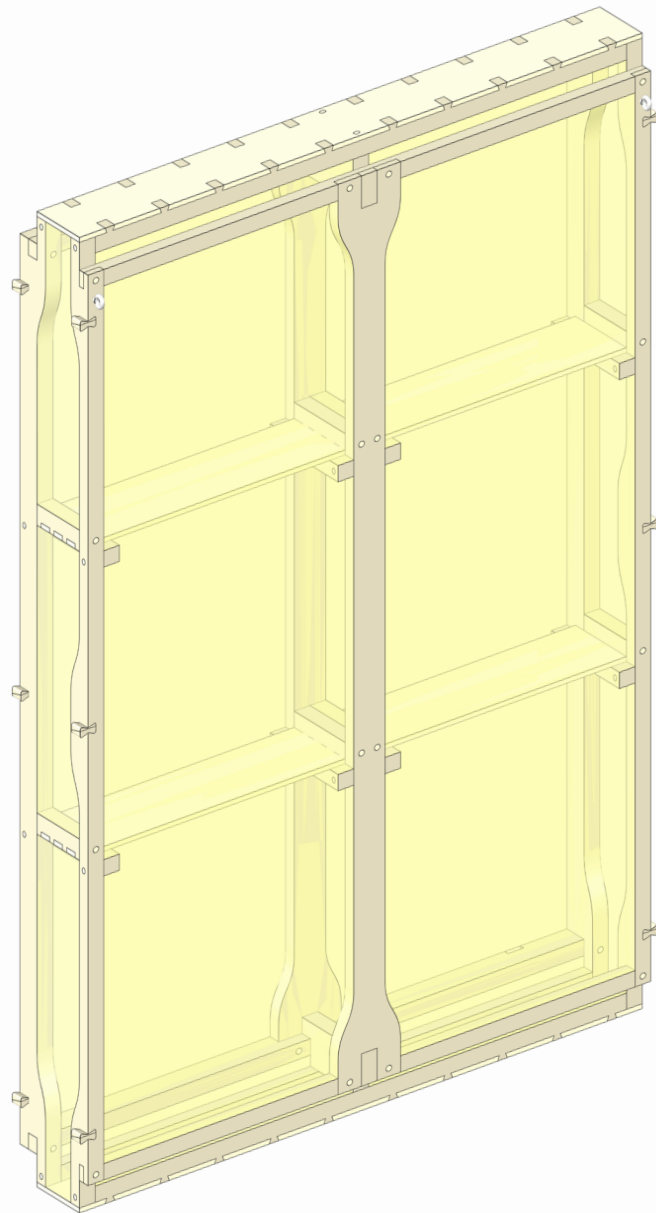
Design Iterations



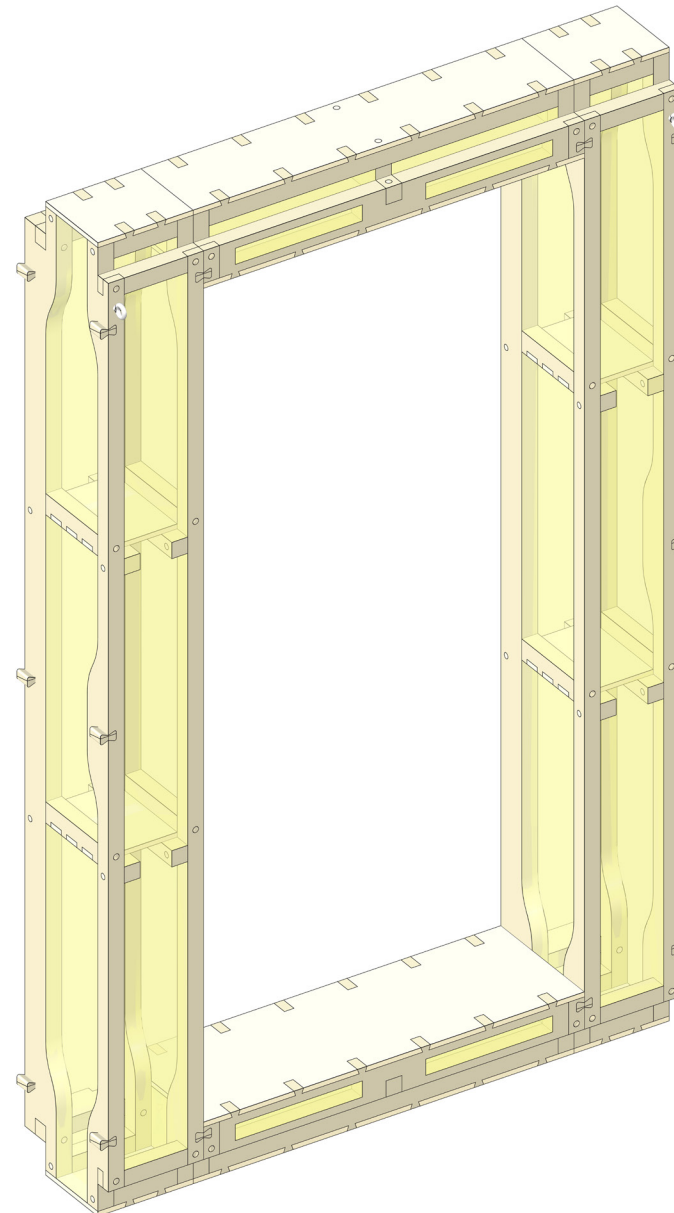
Possible dimensions cassette



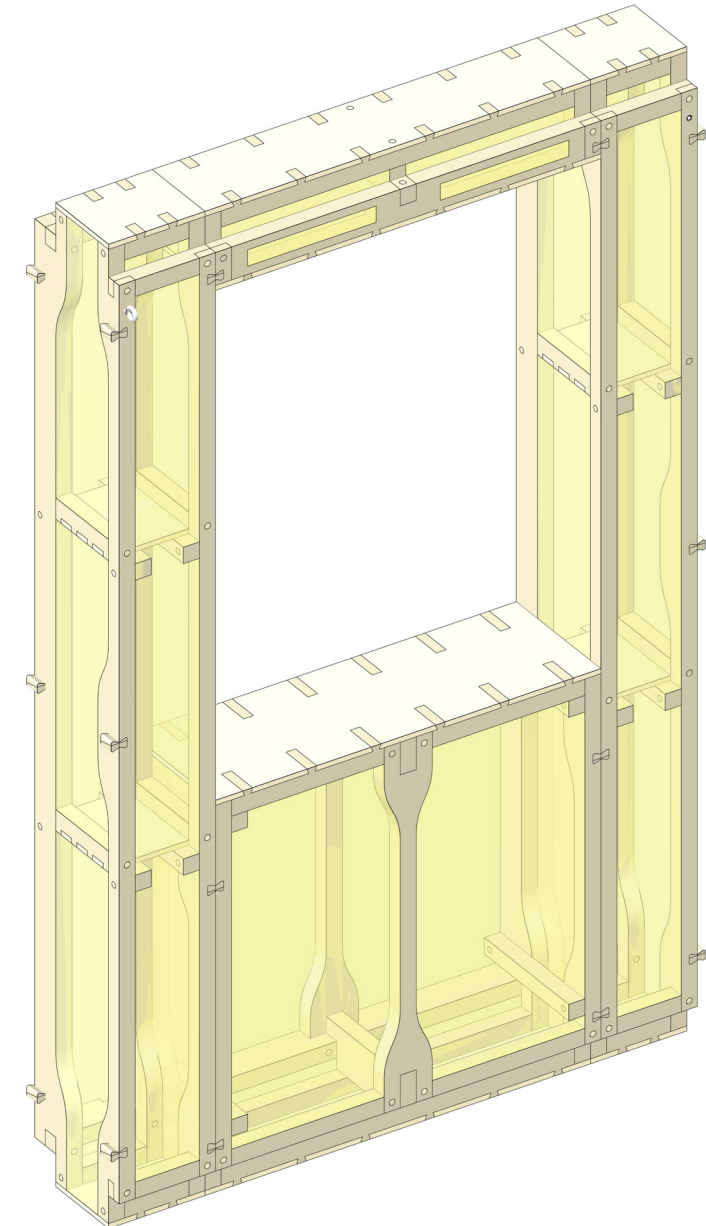
Cassette types



1. Enclosed

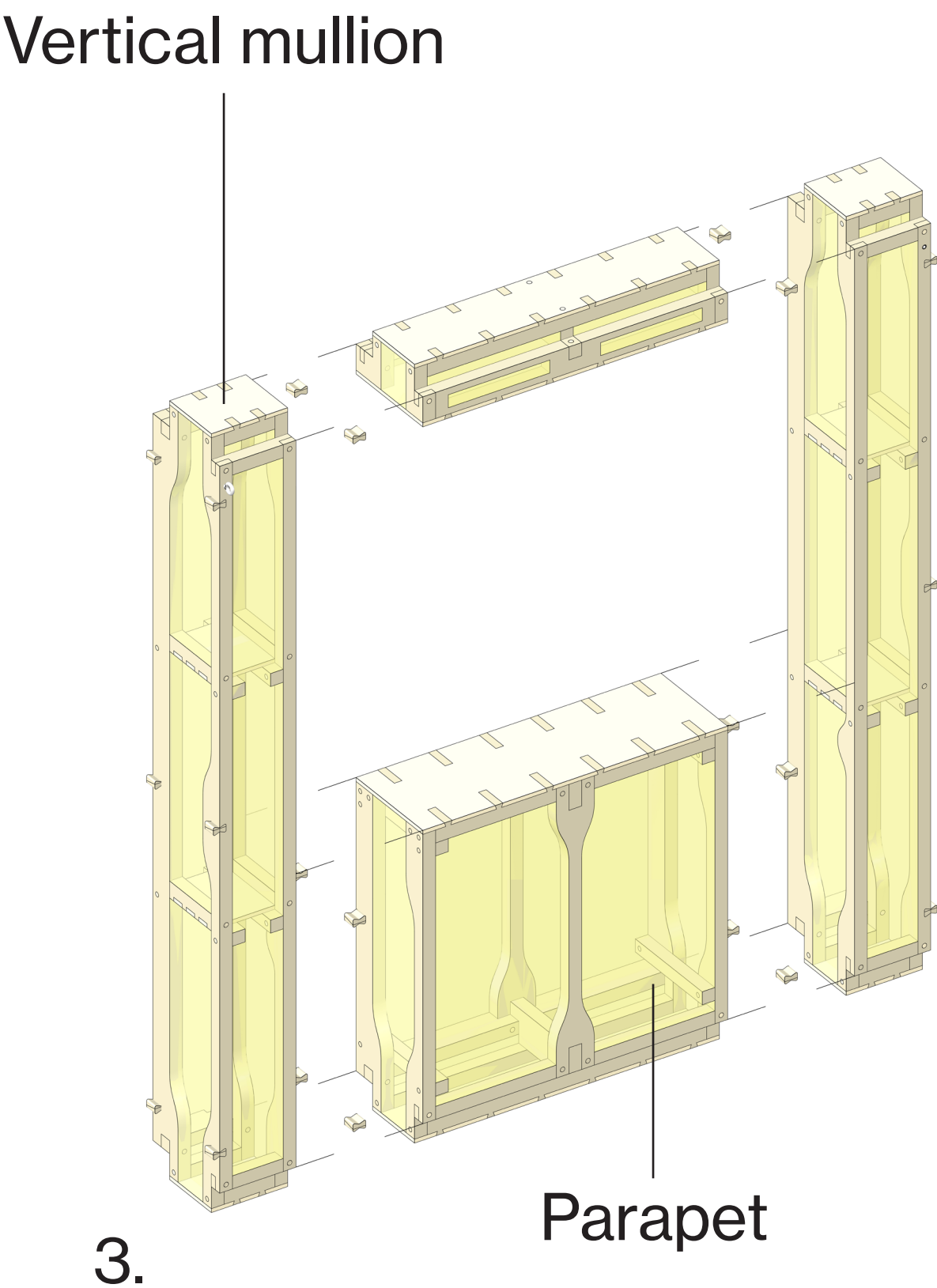
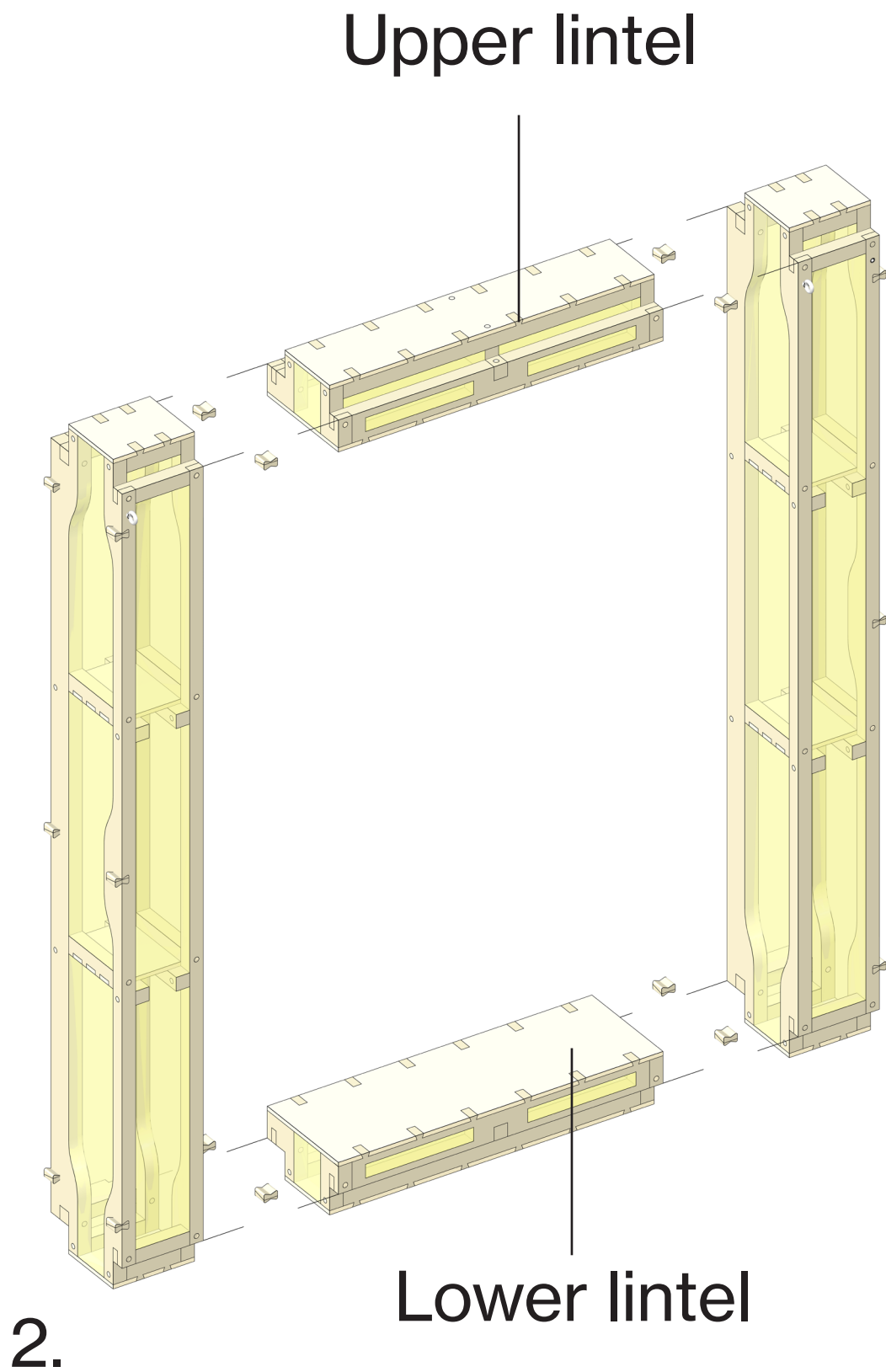


2. Floor-ceiling opening

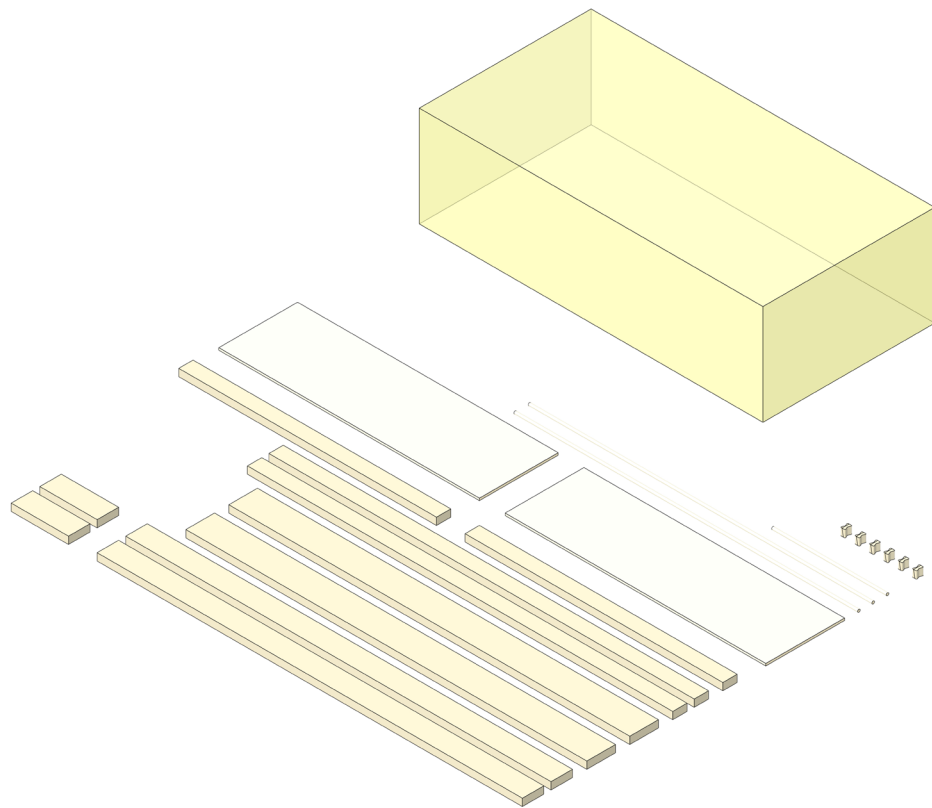


3. Window with parapet

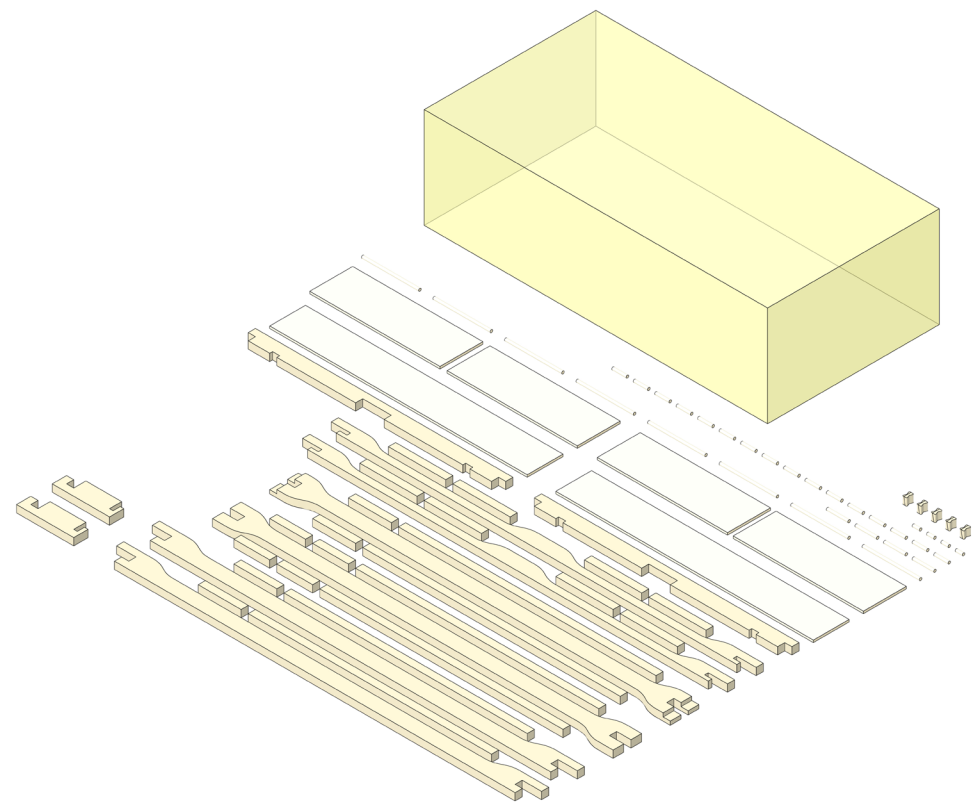
Components in a cassette



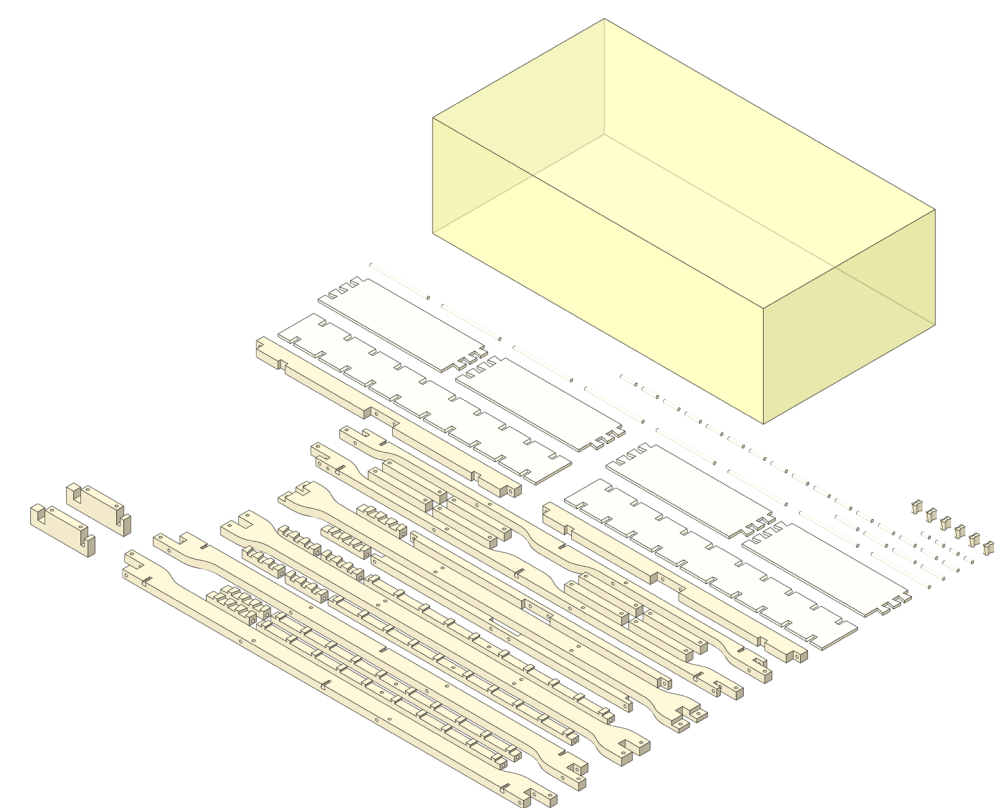
Kit of parts cassette



1. Acquisition



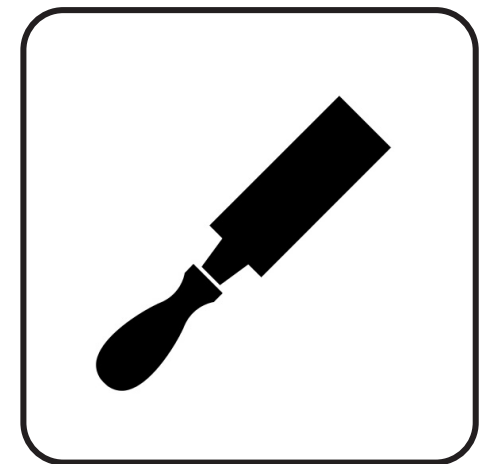
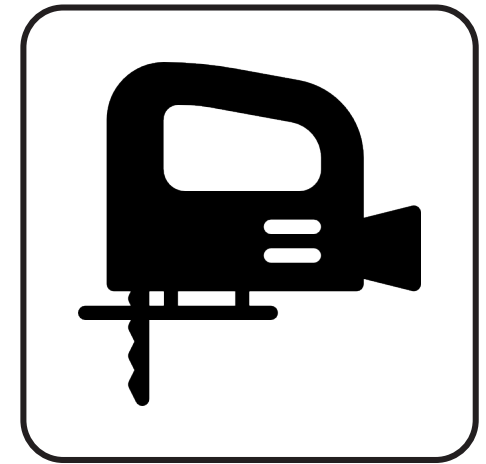
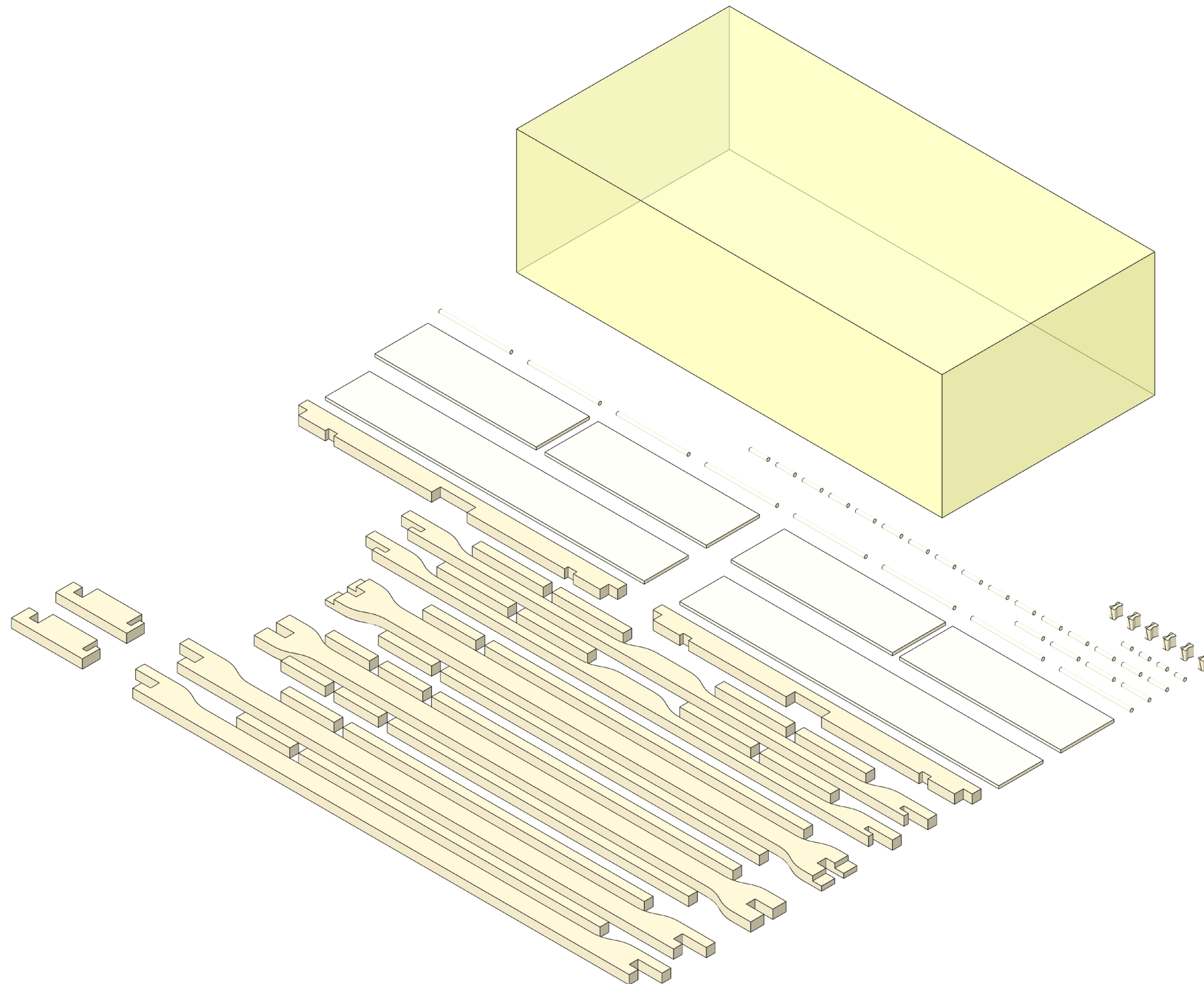
2. Rough processing



3. Fine processing

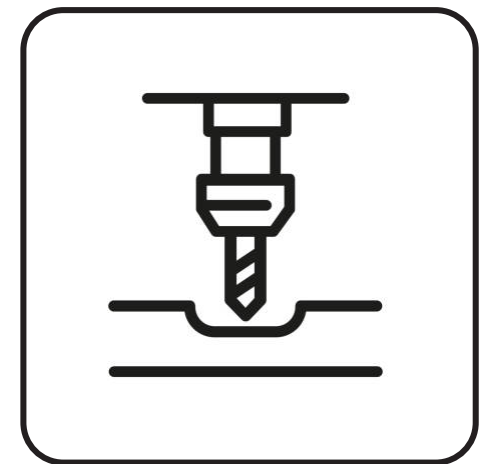
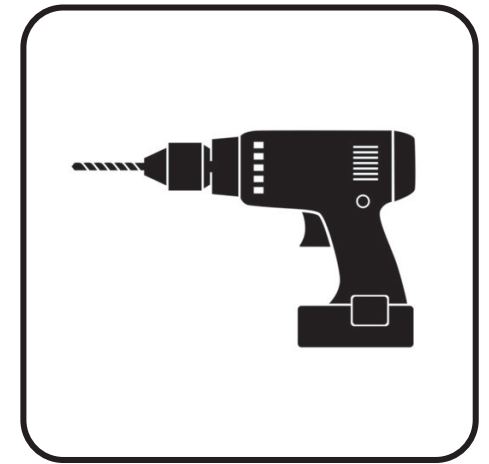
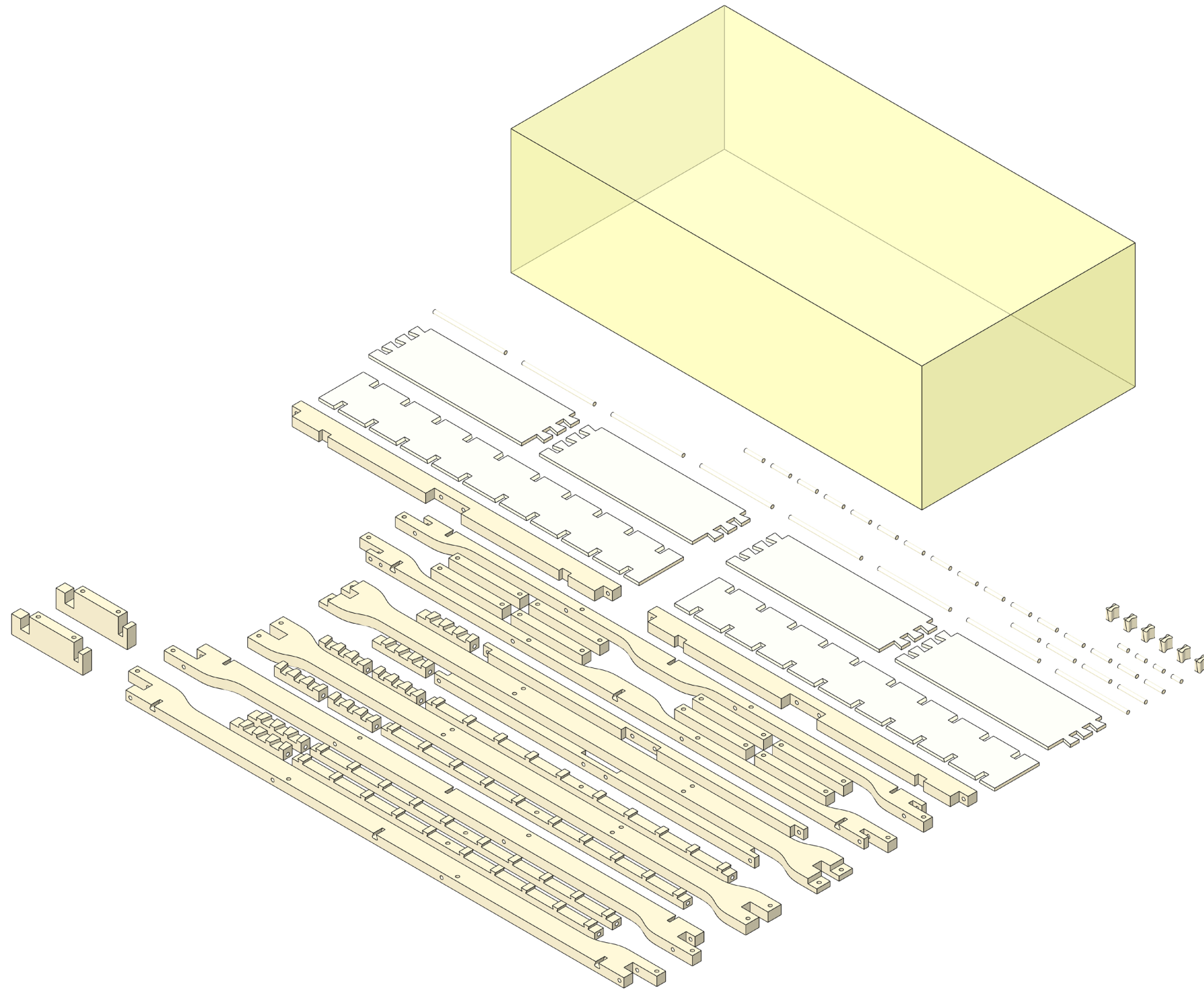
- 99,99% biobased materials
- Only 0,1 m³ materials waste: mostly straw suitable for reuse
- Wooden snippets, shavings and sawdust can all be recycled

Kit of parts cassette



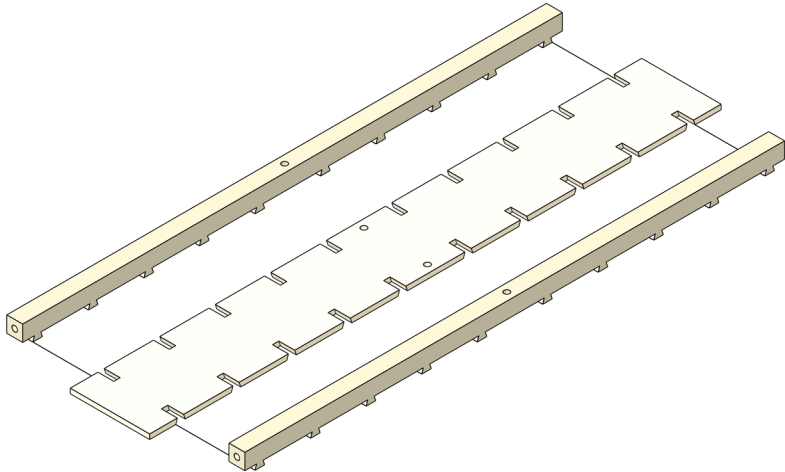
Rough processing

Kit of parts cassette

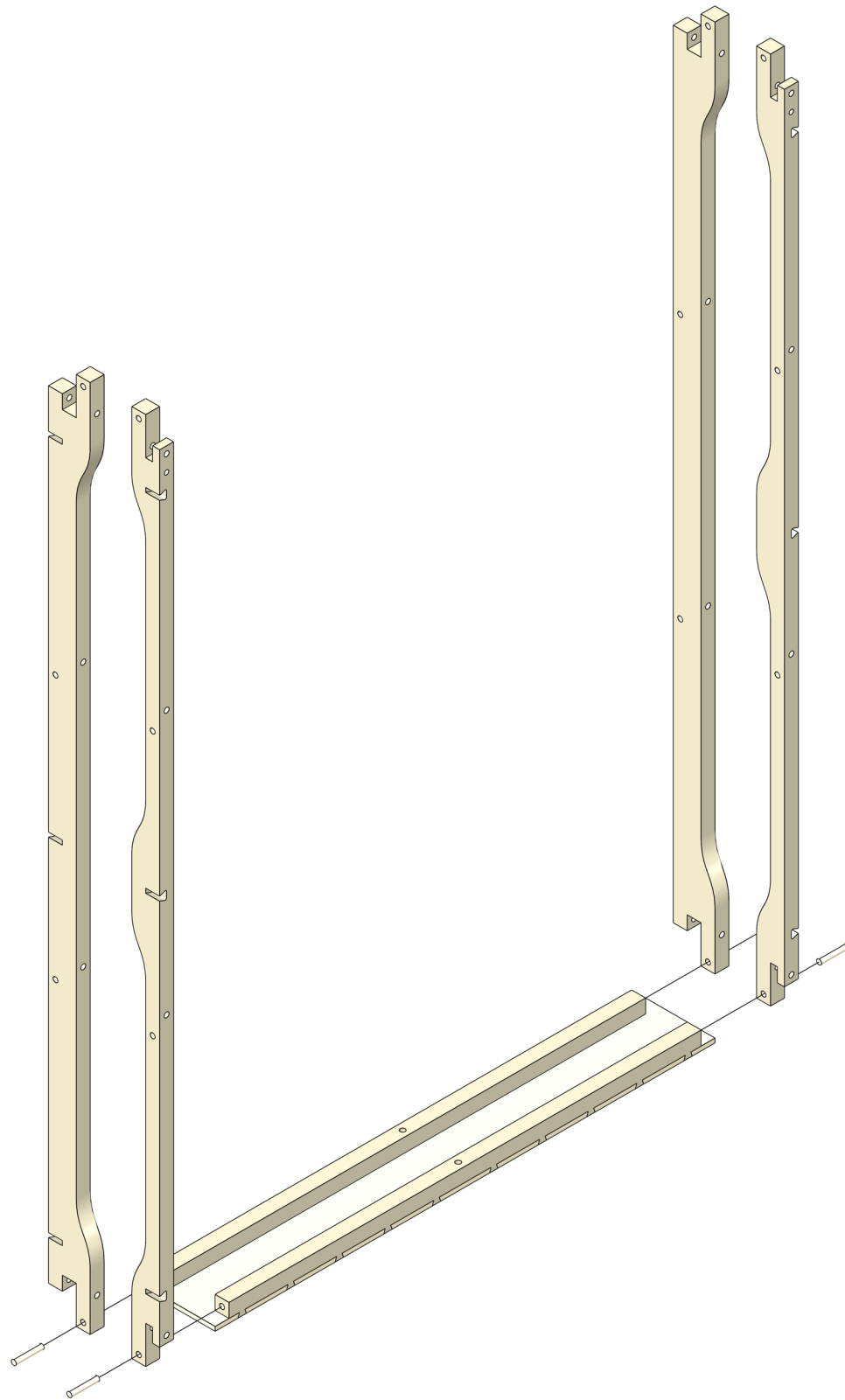


Fine processing

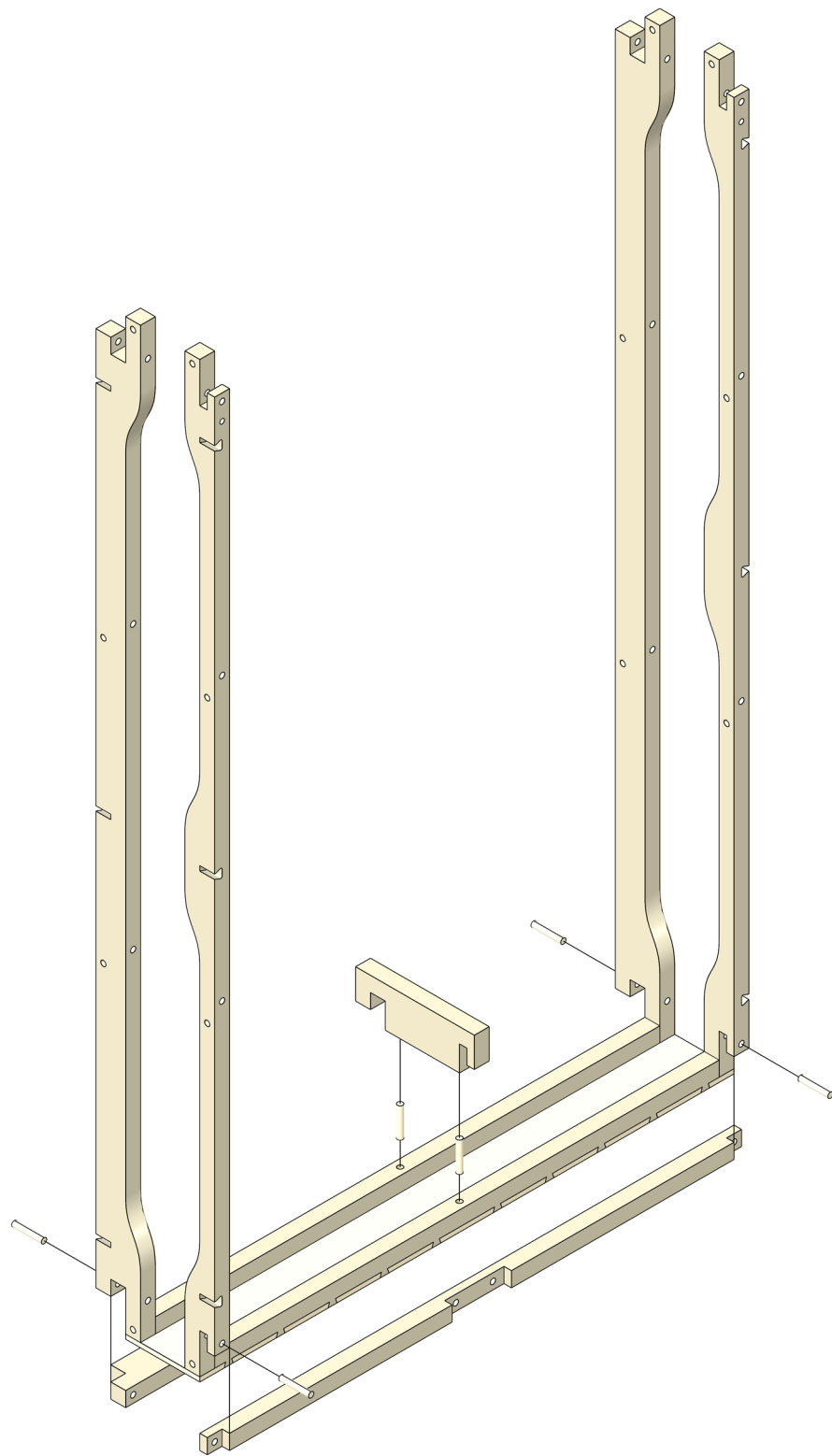
Assembly cassette



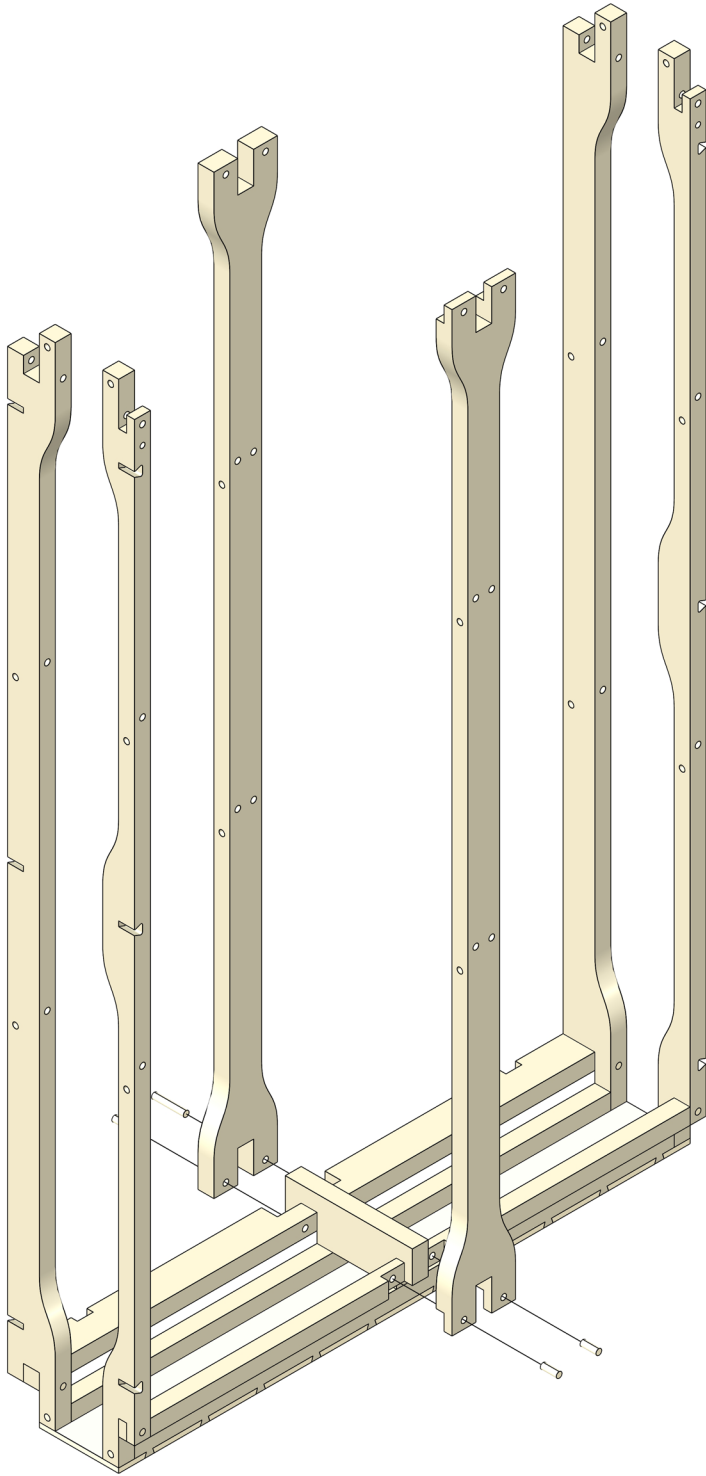
Assembly cassette



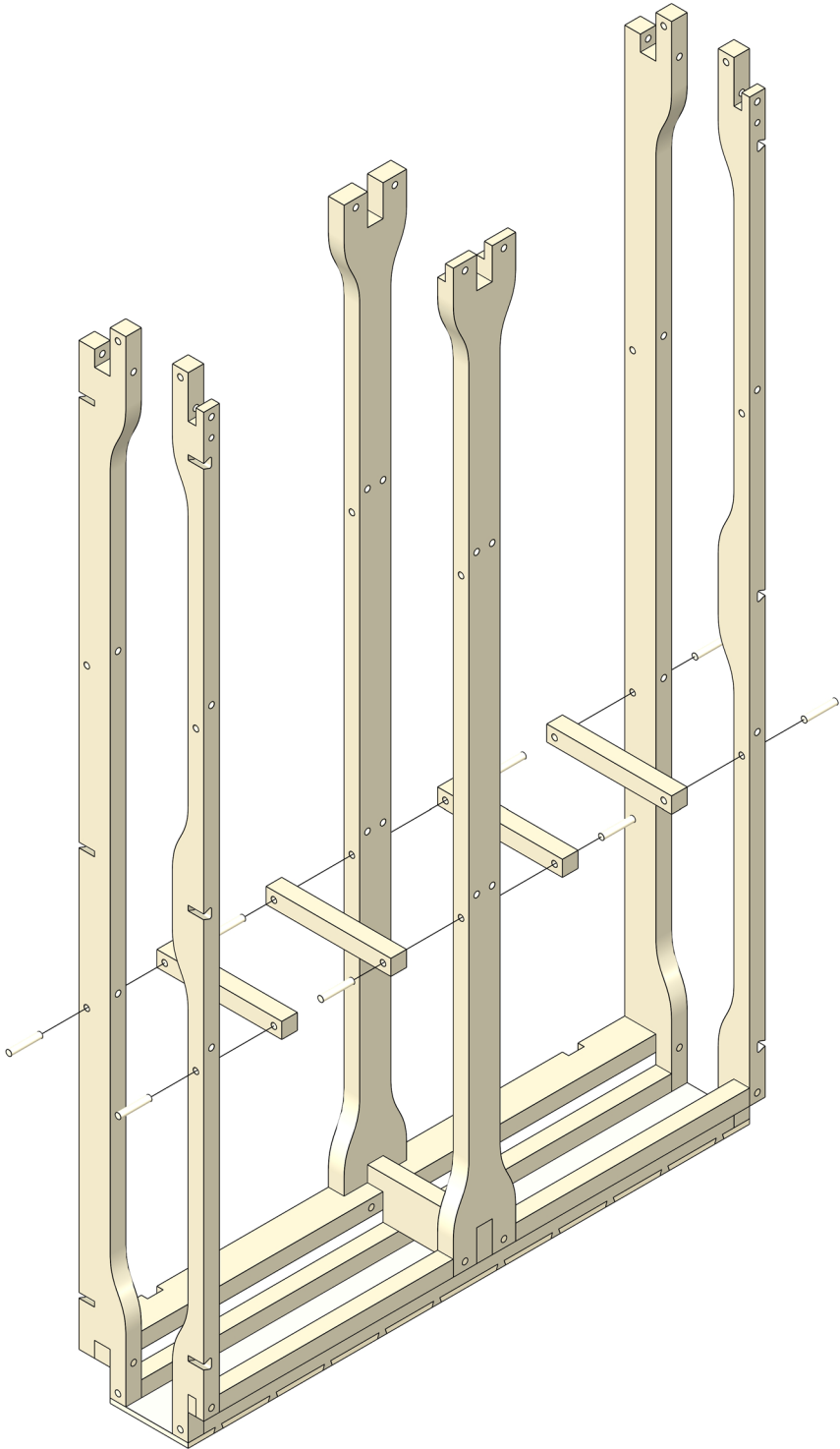
Assembly cassette



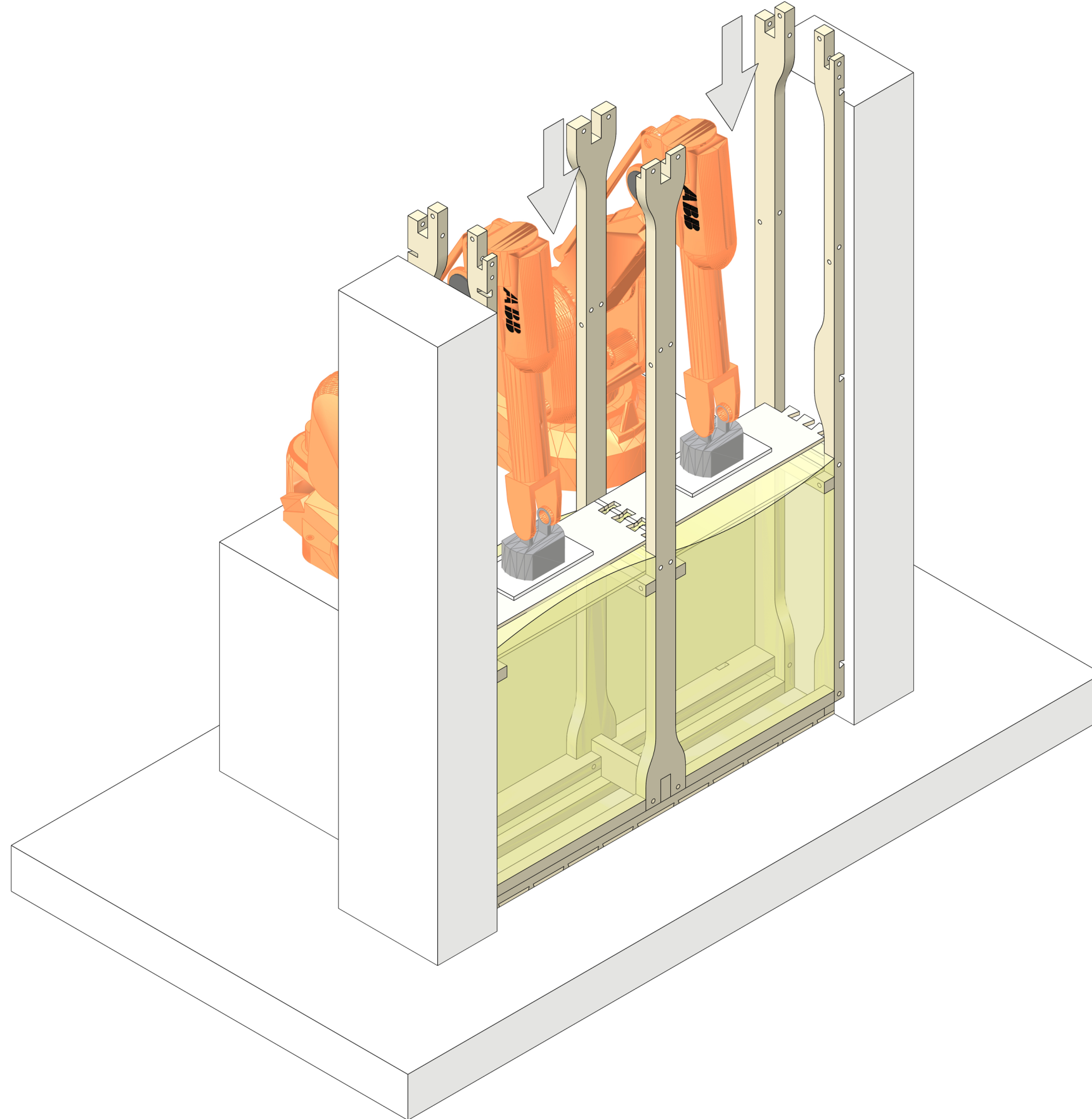
Assembly cassette



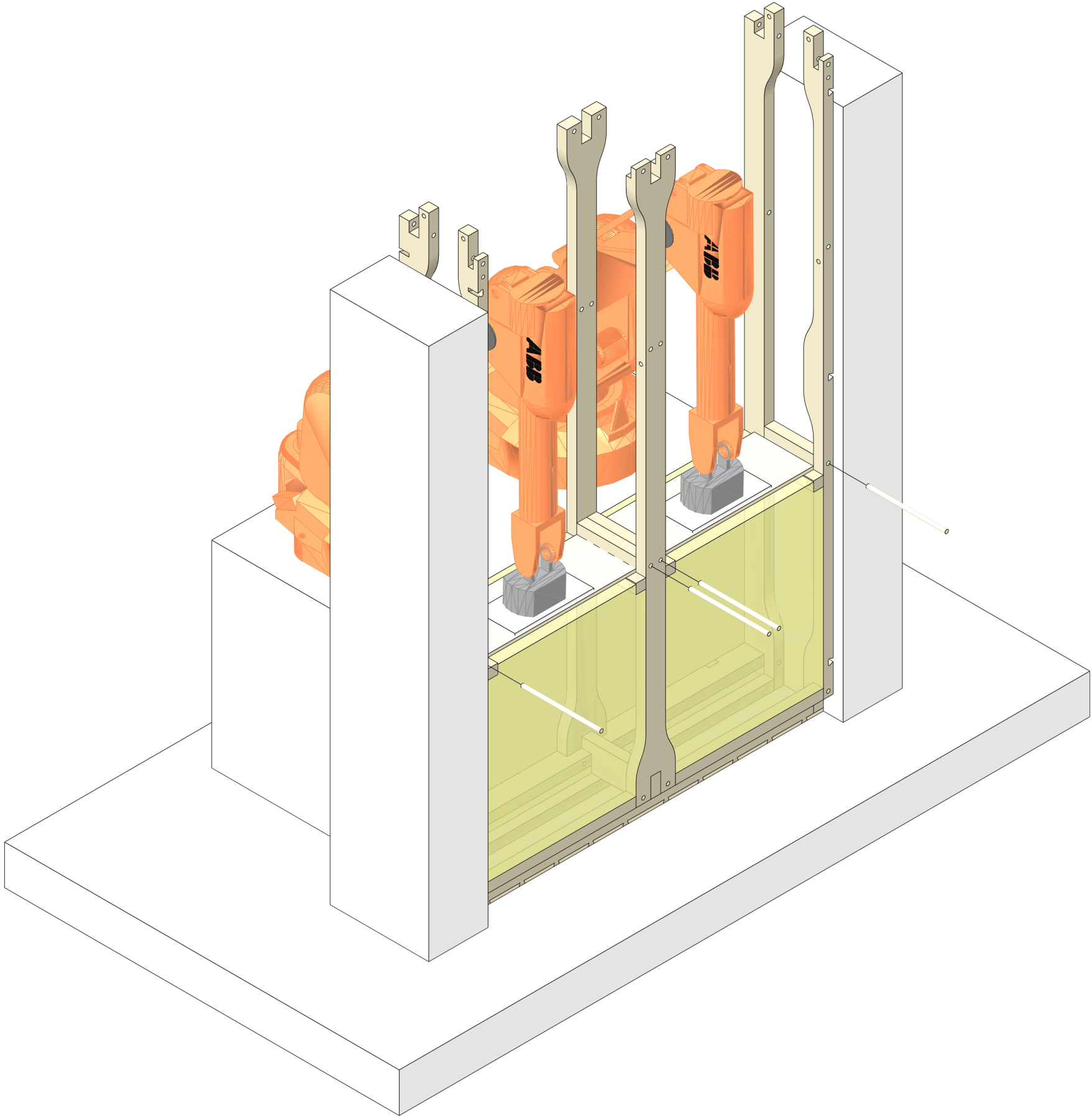
Assembly cassette



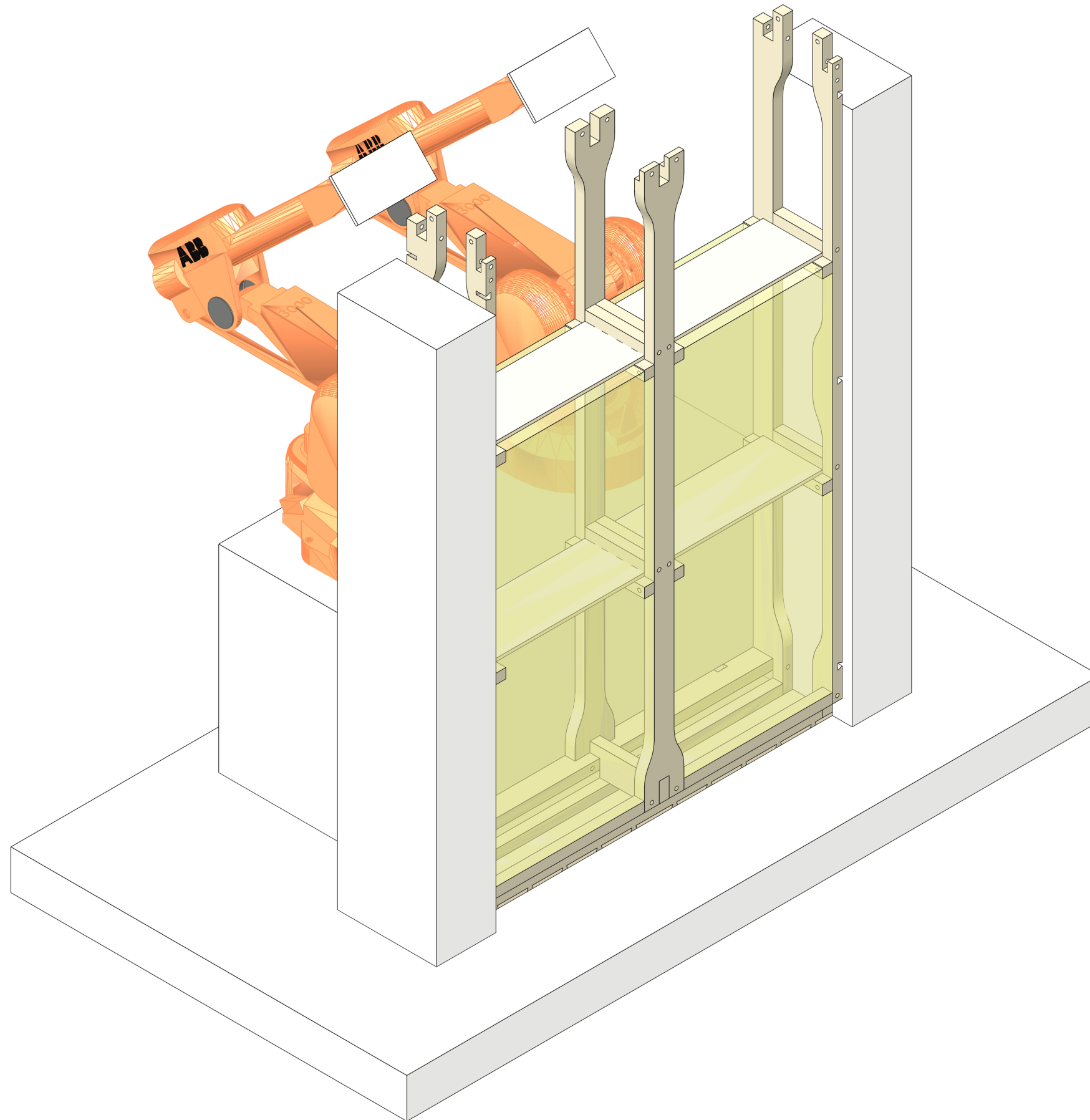
Assembly cassette



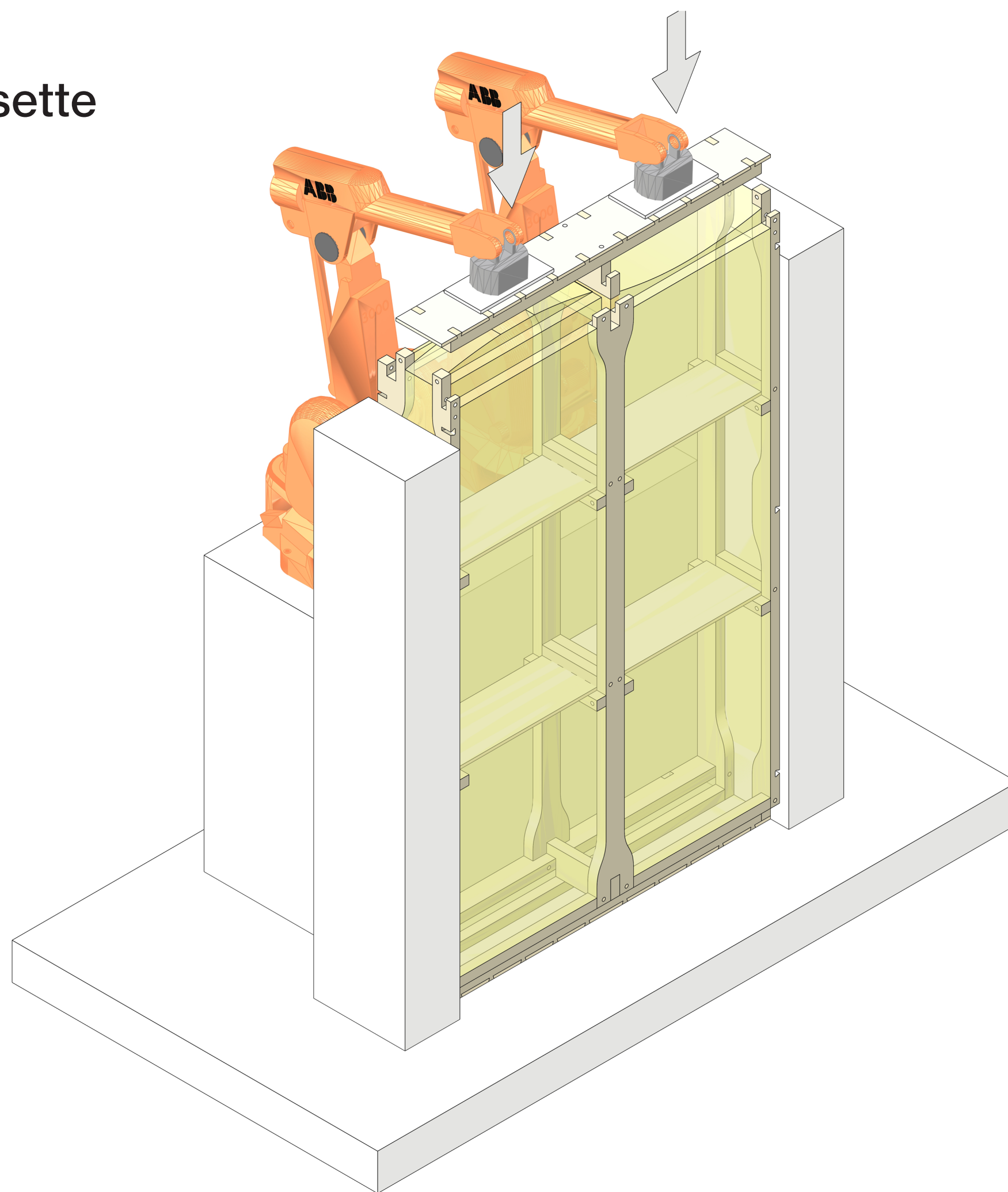
Assembly cassette



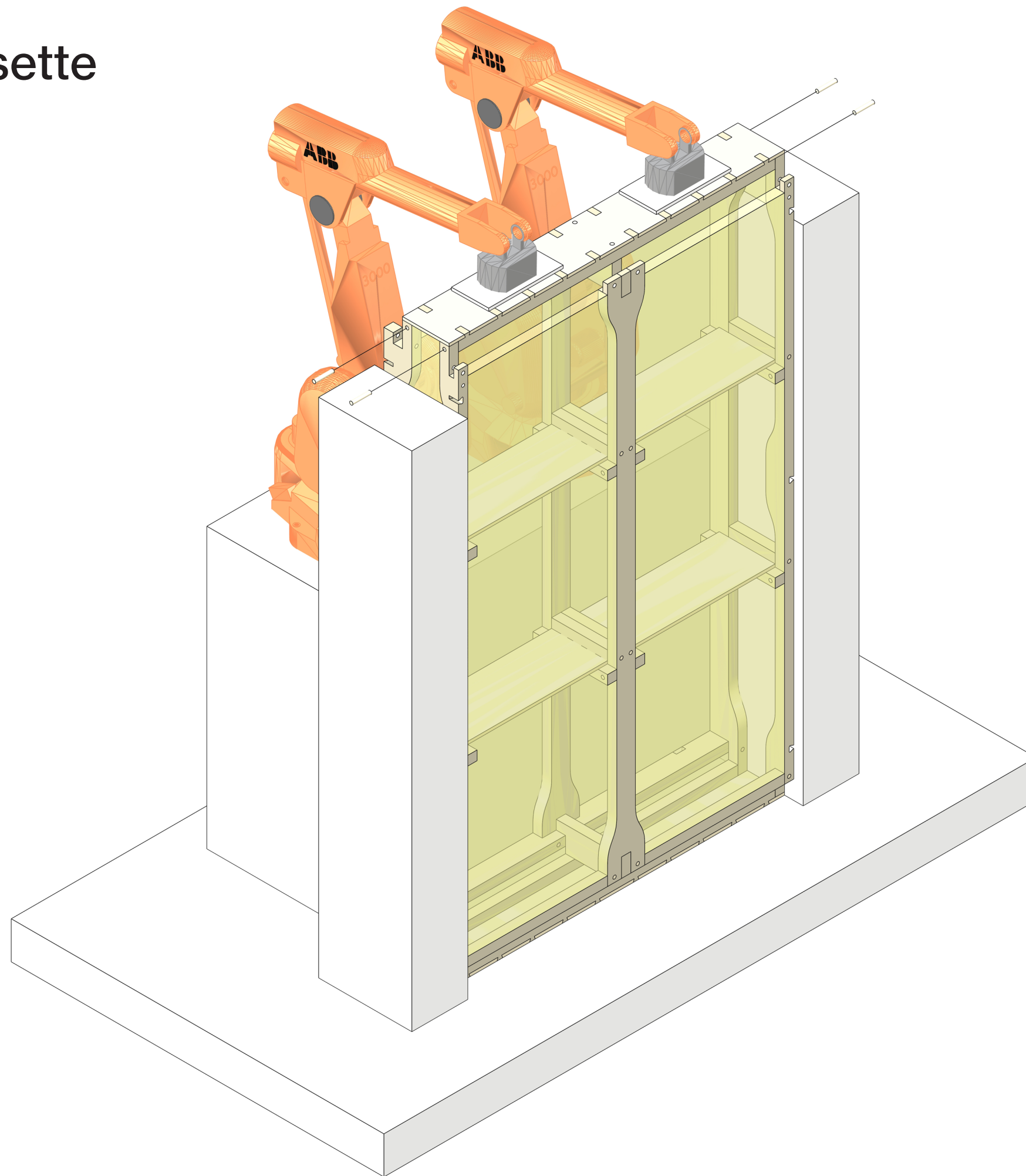
Assembly cassette



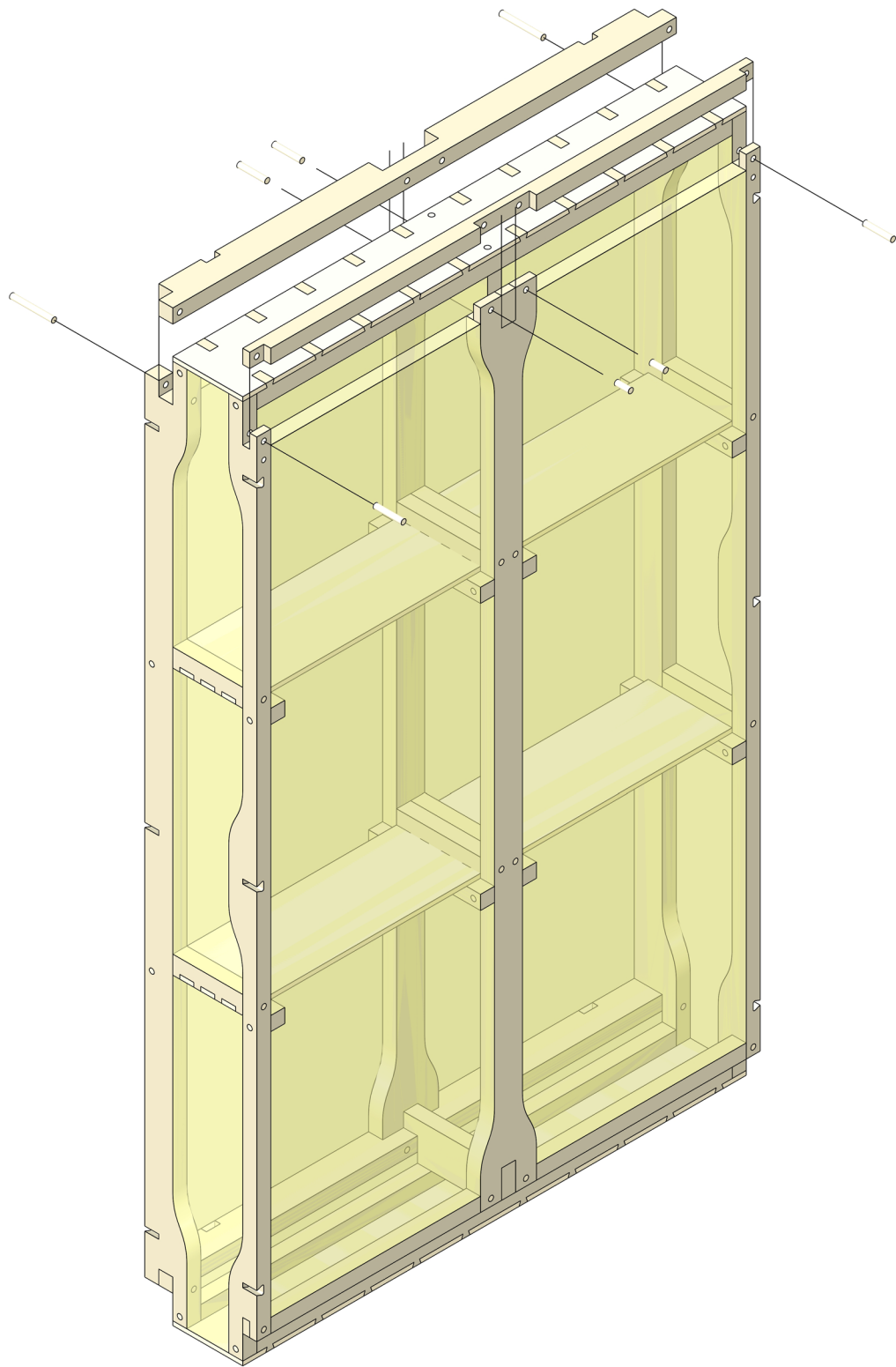
Assembly cassette



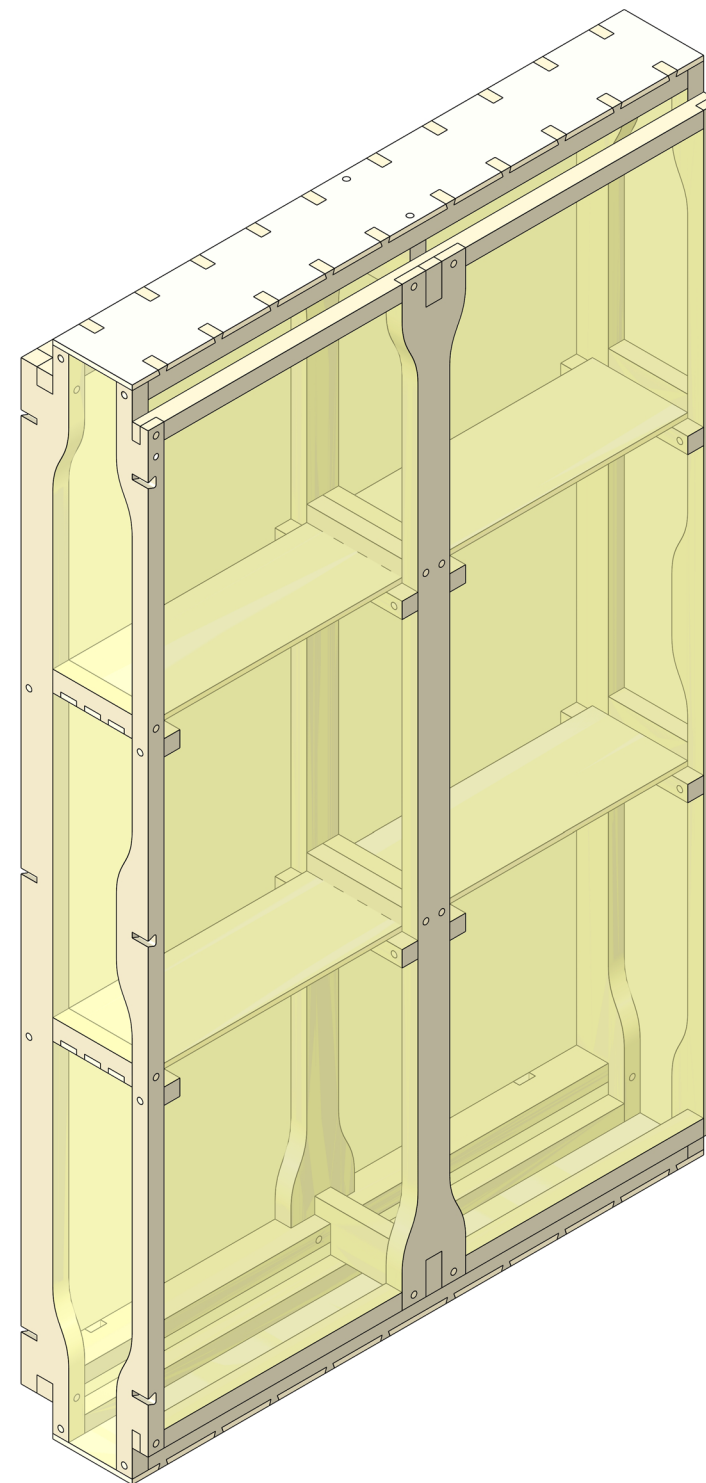
Assembly cassette



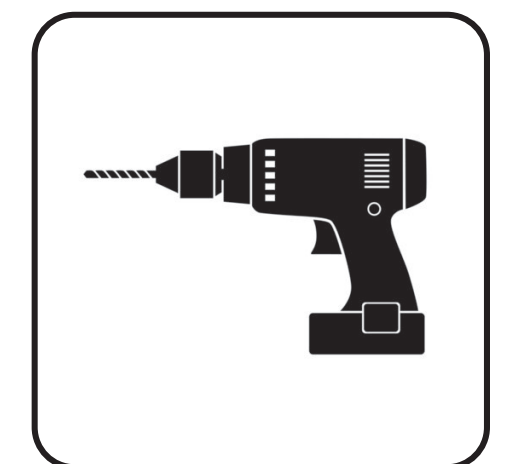
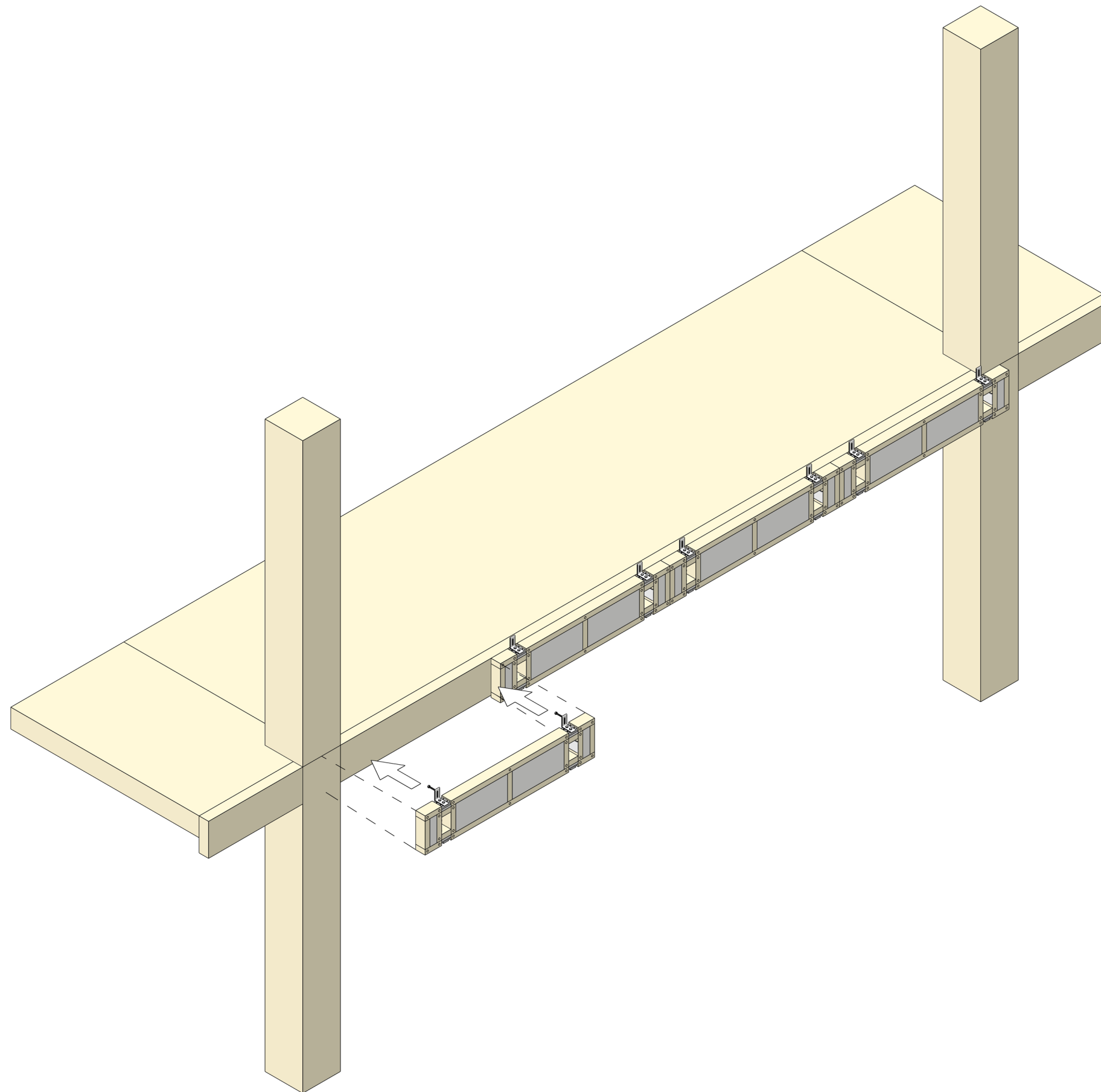
Assembly cassette



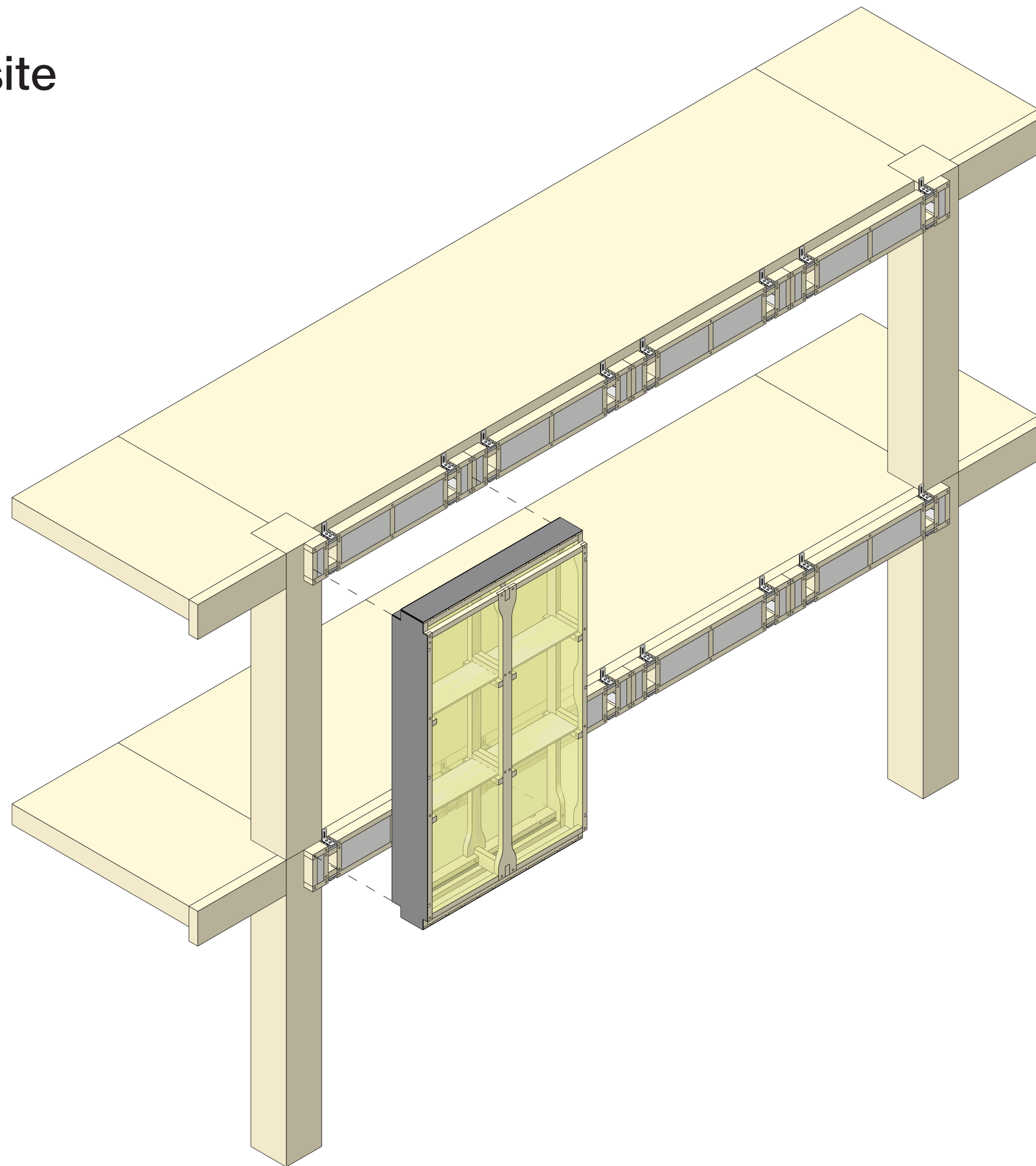
Assembly cassette



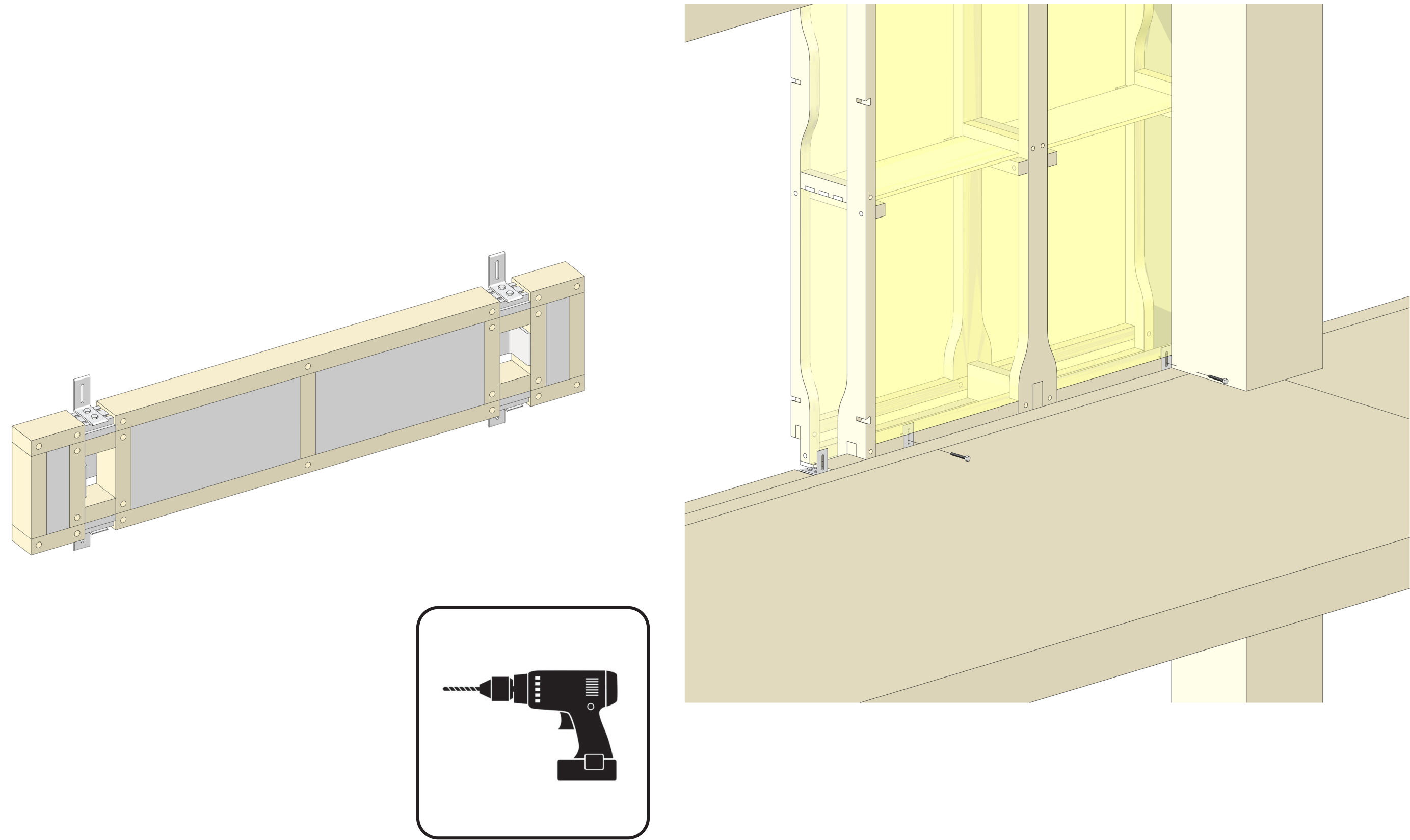
Assembly on-site



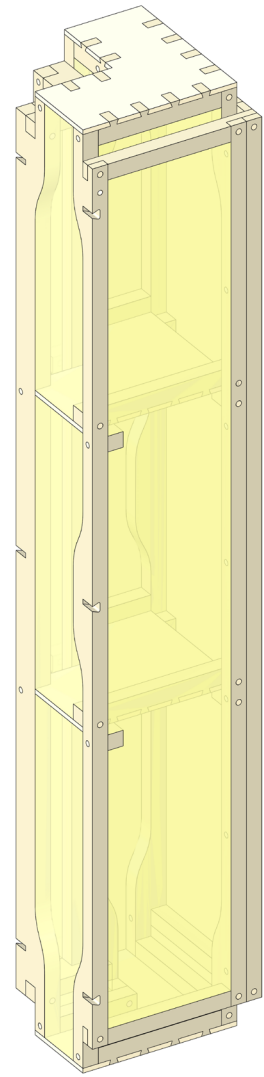
Assembly on-site



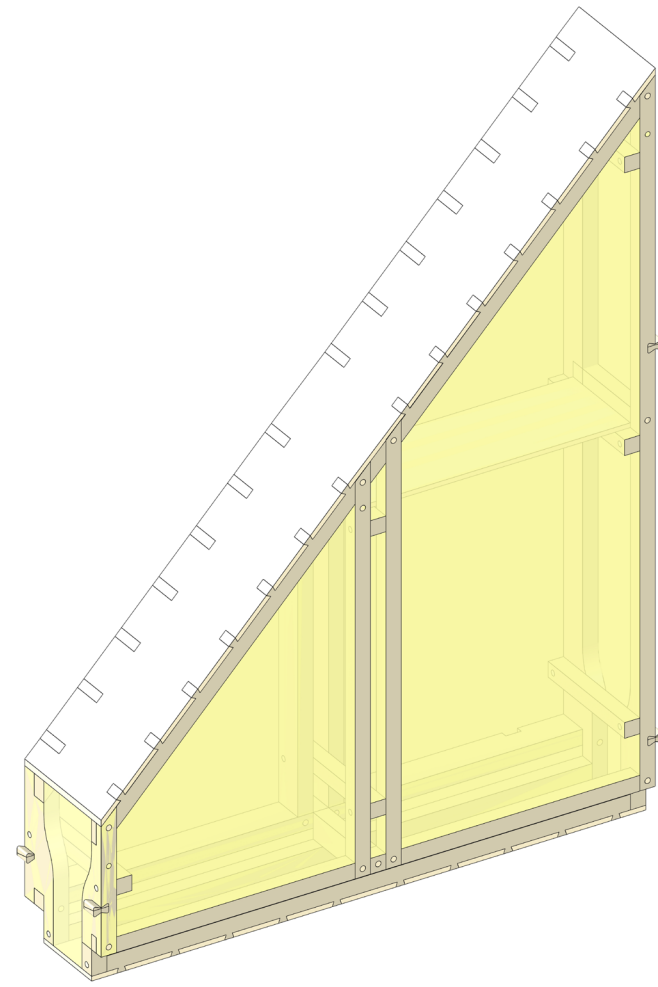
Assembly on-site



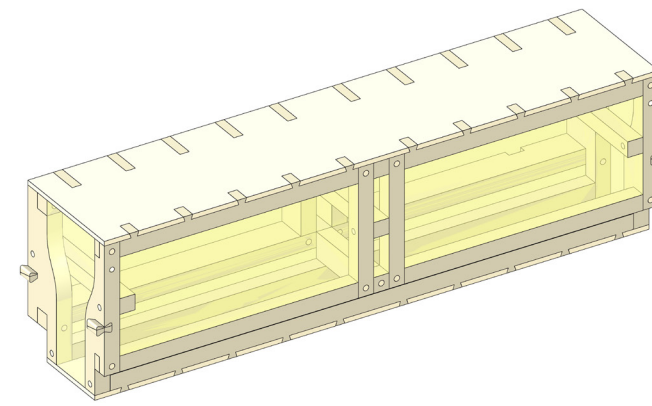
Exceptions in facade system



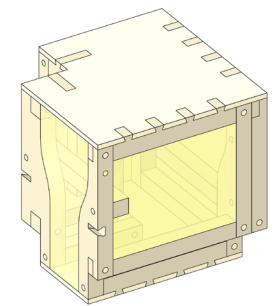
Corner



Inclined roof edge

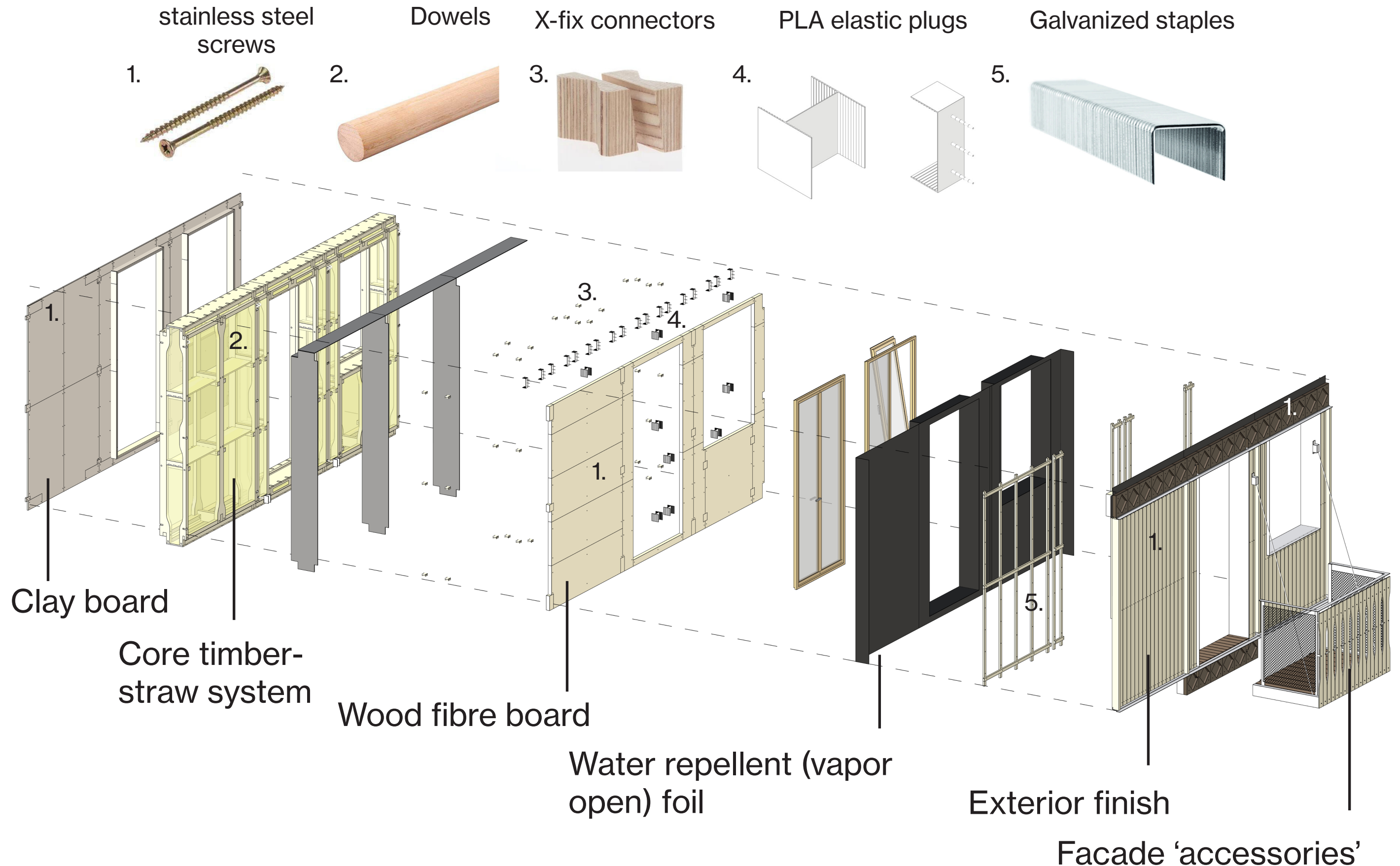


Flat roof edge

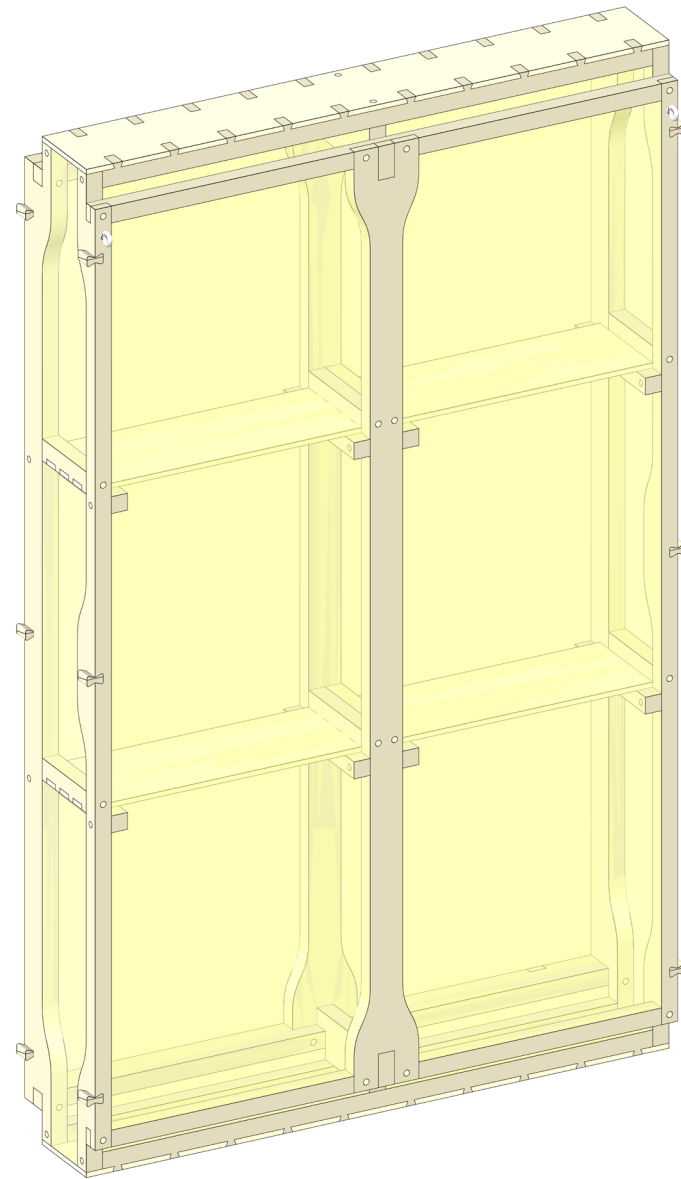


Roof corner

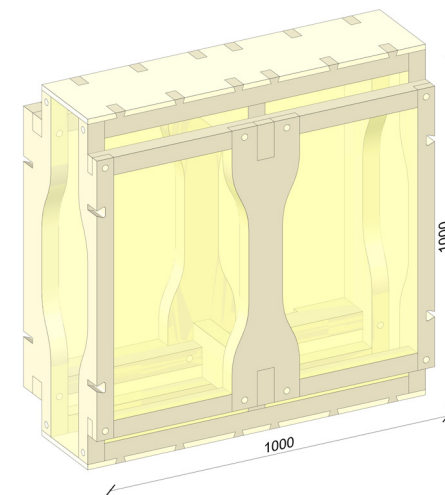
Exploded axonometry complete facade construction with connections



Research Conclusion: the prototype

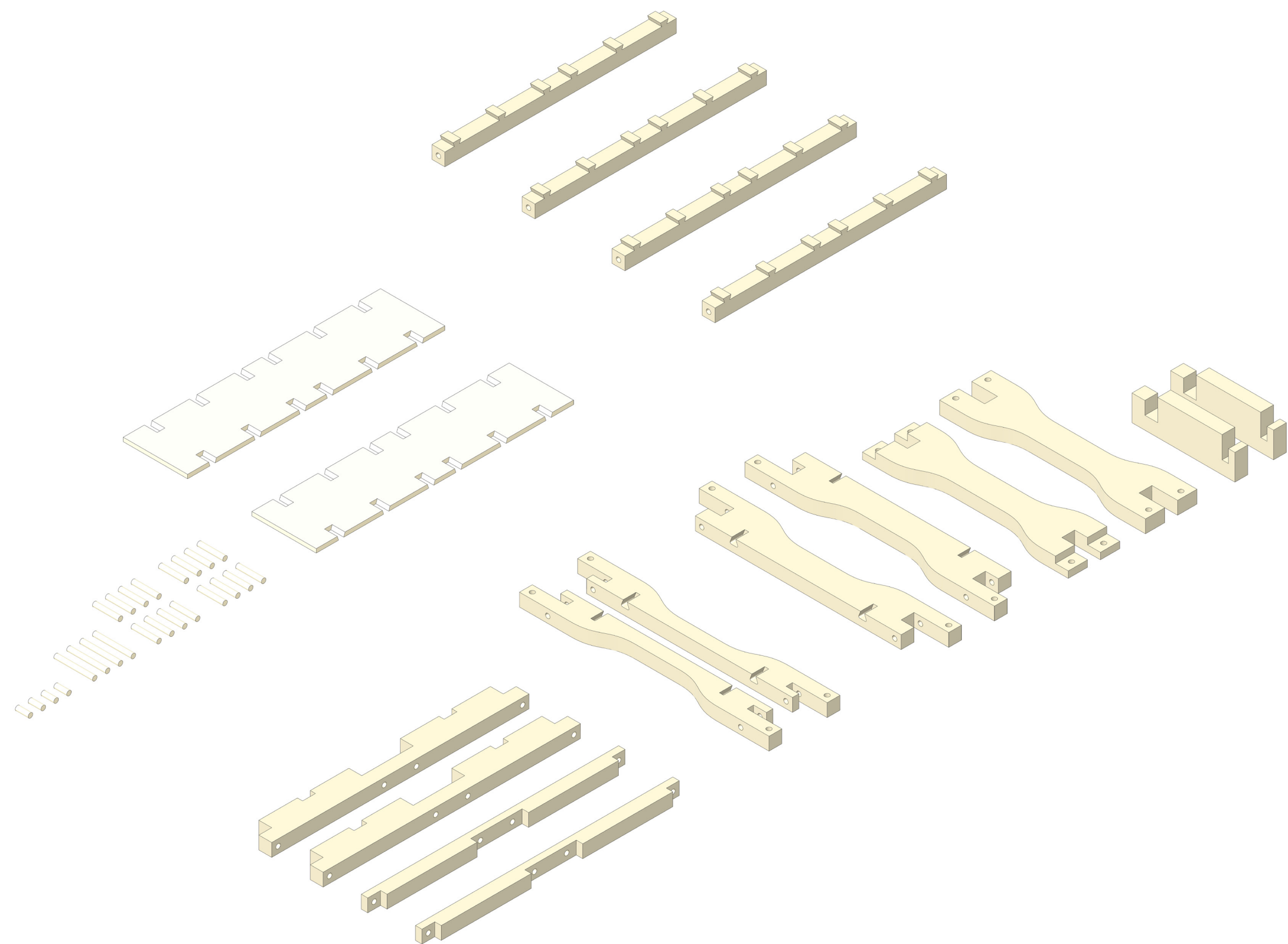


Cassette



The prototype

The digital kit of parts



The real kit of parts





































00 | Table of contents

01 | Problem statement & relevance

02 | The research: towards sustainable
facade culture

03 | The design: transforming the Beatrix-
gebouw Utrecht

04 | Reflection

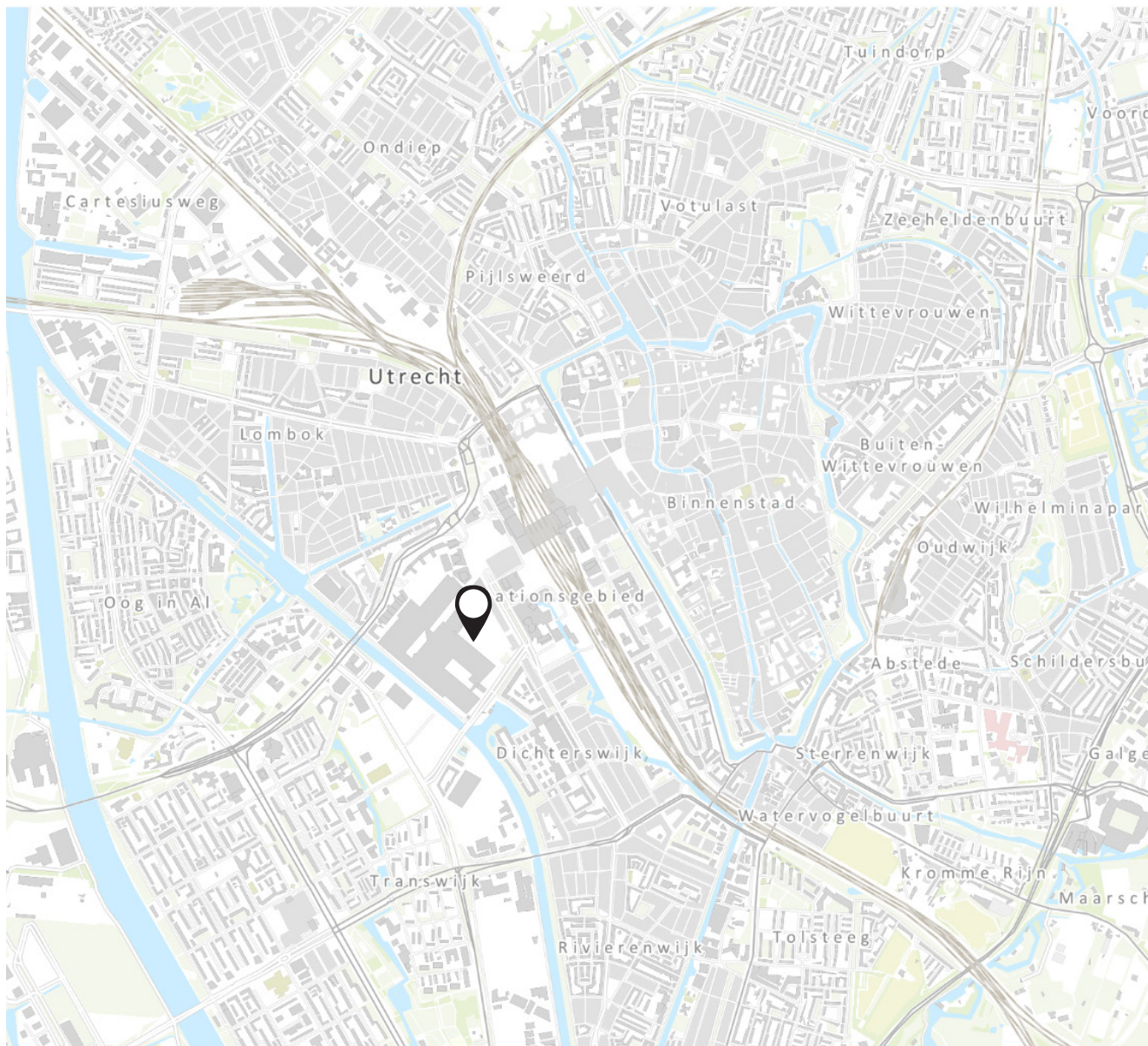
Location requirements

- Within the Netherlands
- New construction and renovation
- Renovation building suited for facade system
- Dwellings, offices and commercial space

Location requirements

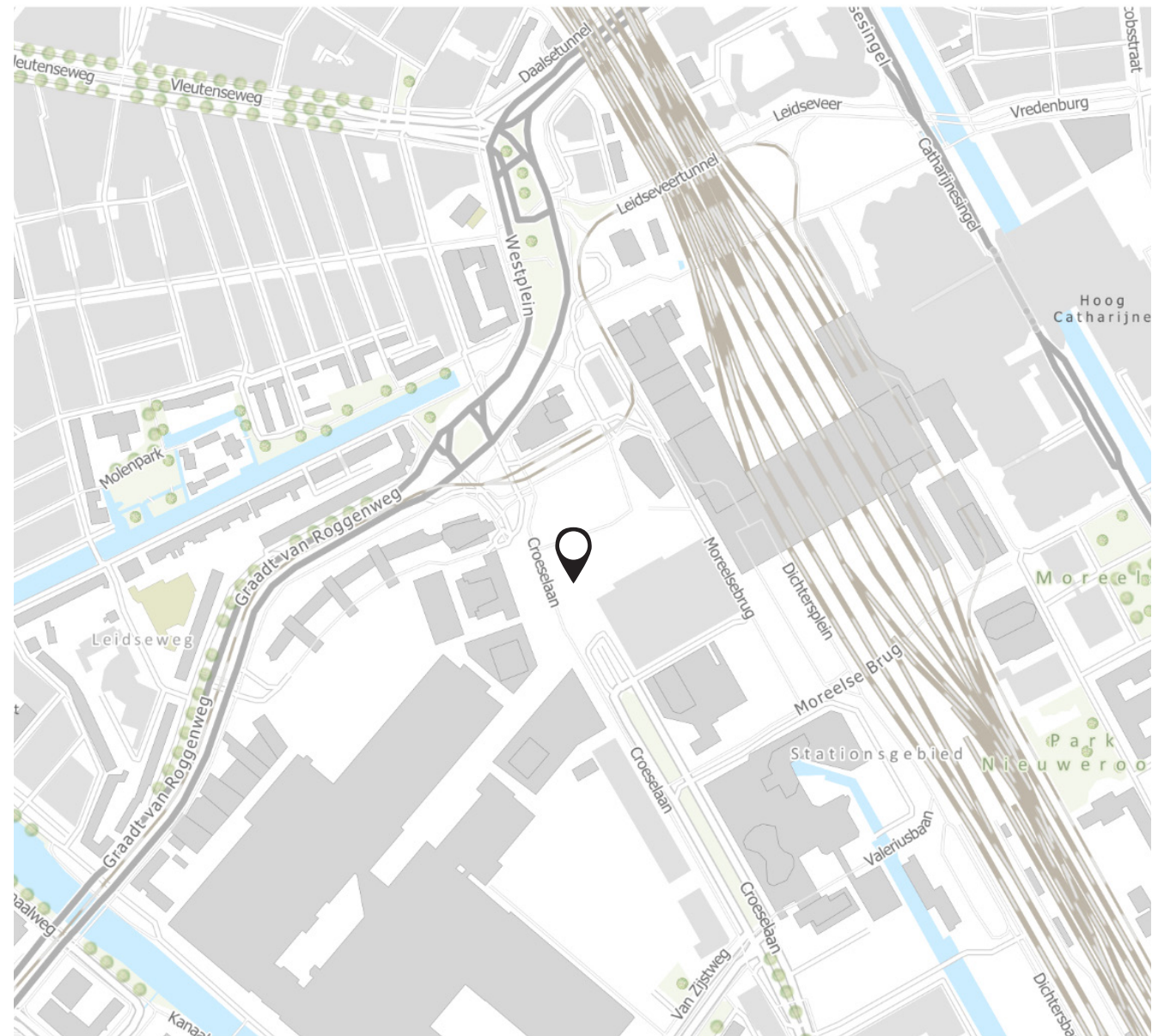
- Within the Netherlands
- New construction and renovation
- Renovation building suited for facade system
- Dwellings, offices and commercial space

Jaarbeursplein



Source: Gemeente Utrecht

Scale 1 : 30.000



Source: Gemeente Utrecht

Scale 1 : 10.000

The near future of Jaarbeursplein and Beatrixgebouw



Source: Nudus & Studio Heatherwick

Jaarbeurs overweegt verkoop Beatrixgebouw na 2028

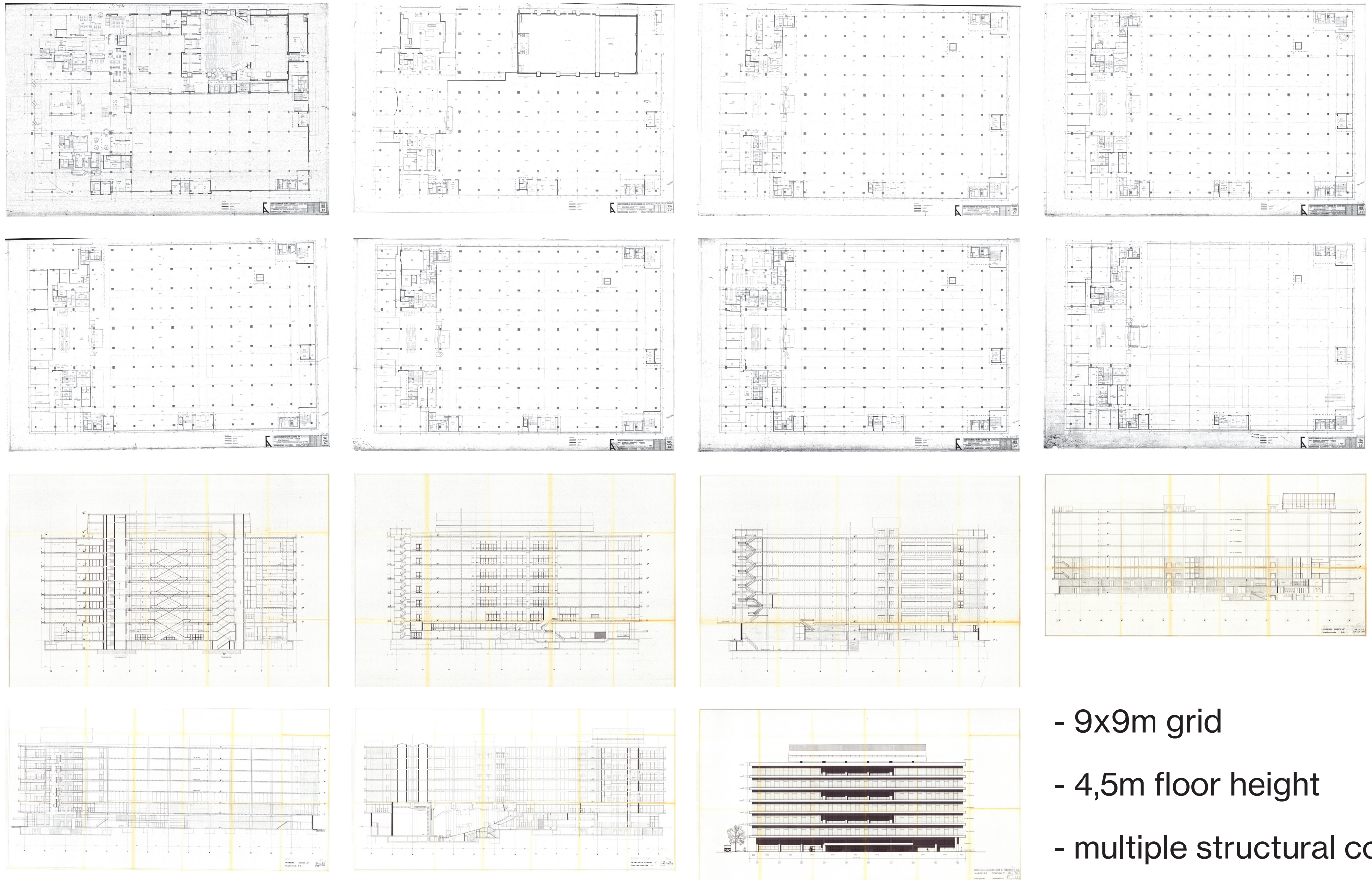
ALGEMEEN 6/4/2020 - 12:28

– Redactie



Source: <https://cu2030.nl/project/jaarbeursplein>

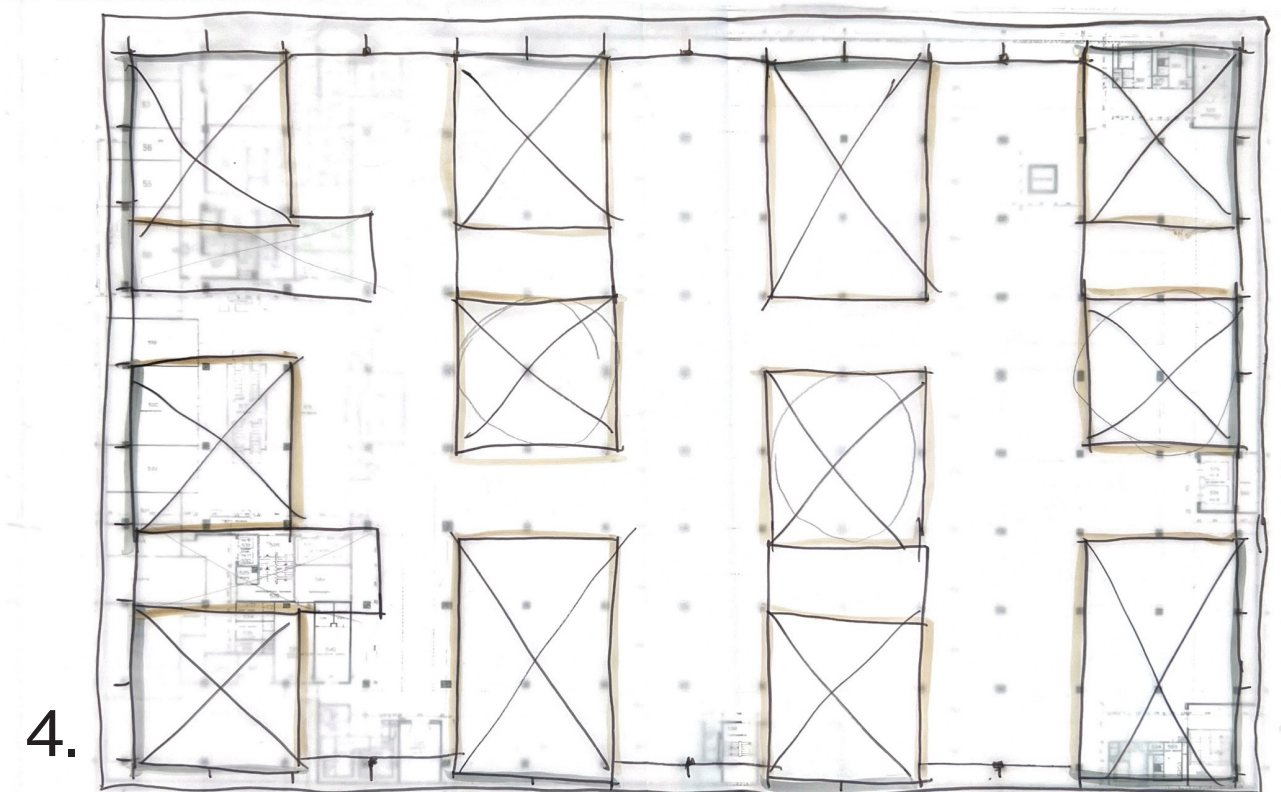
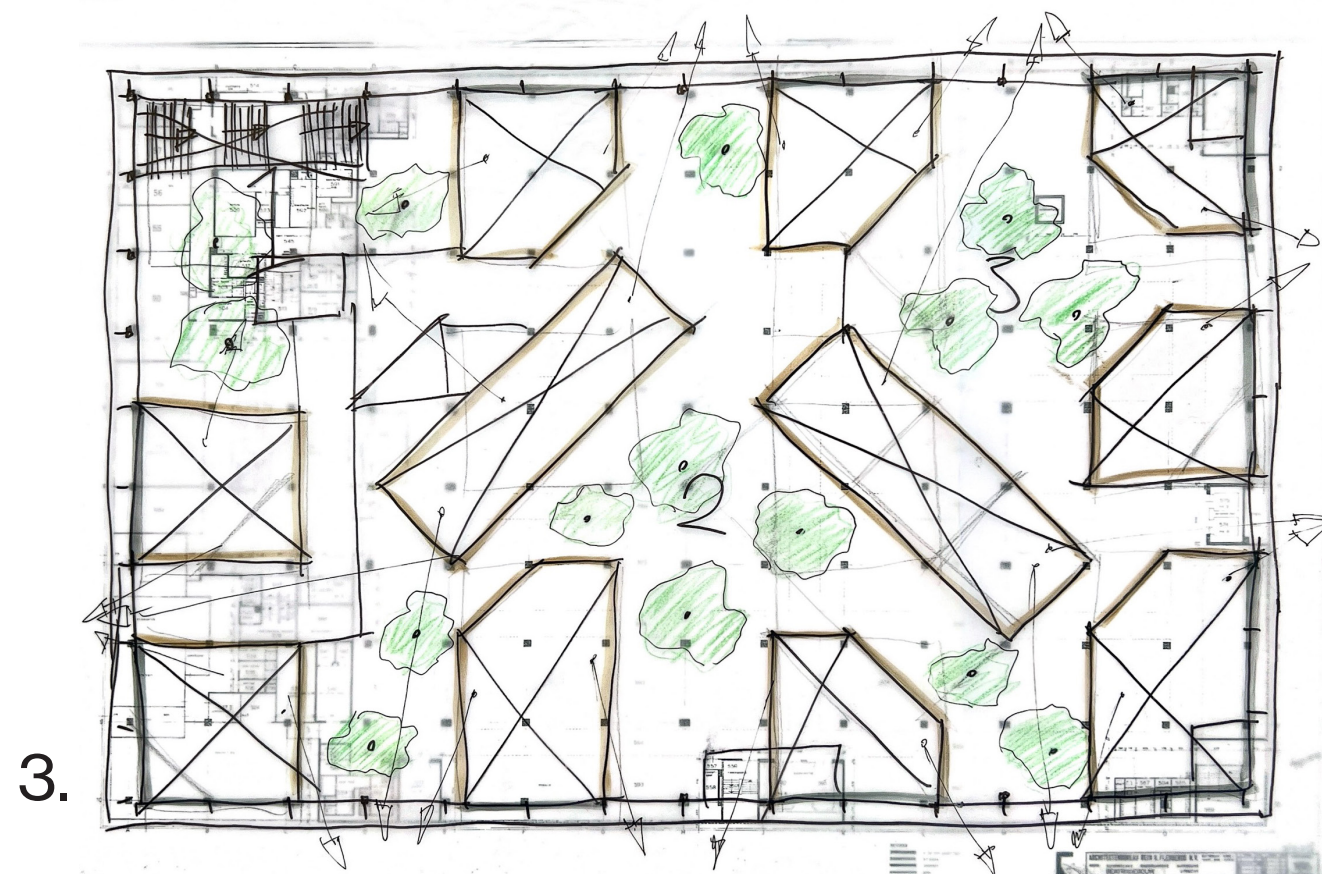
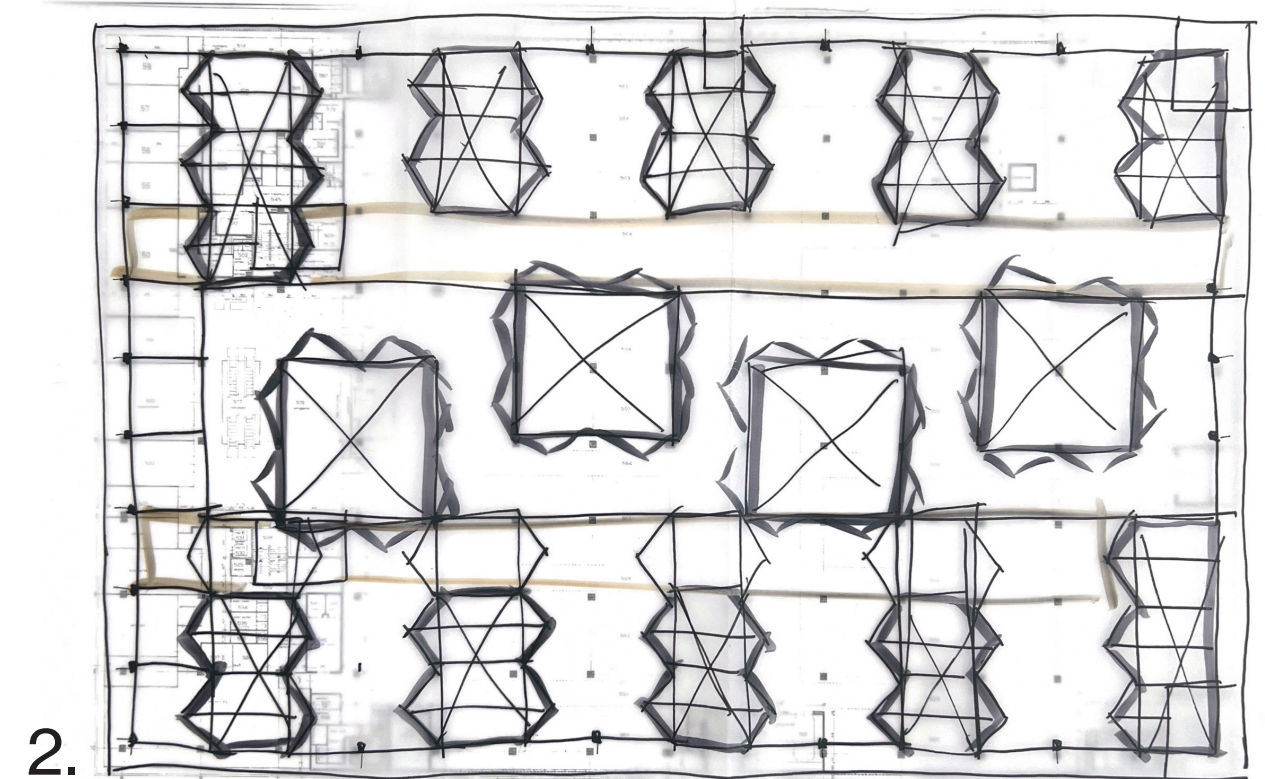
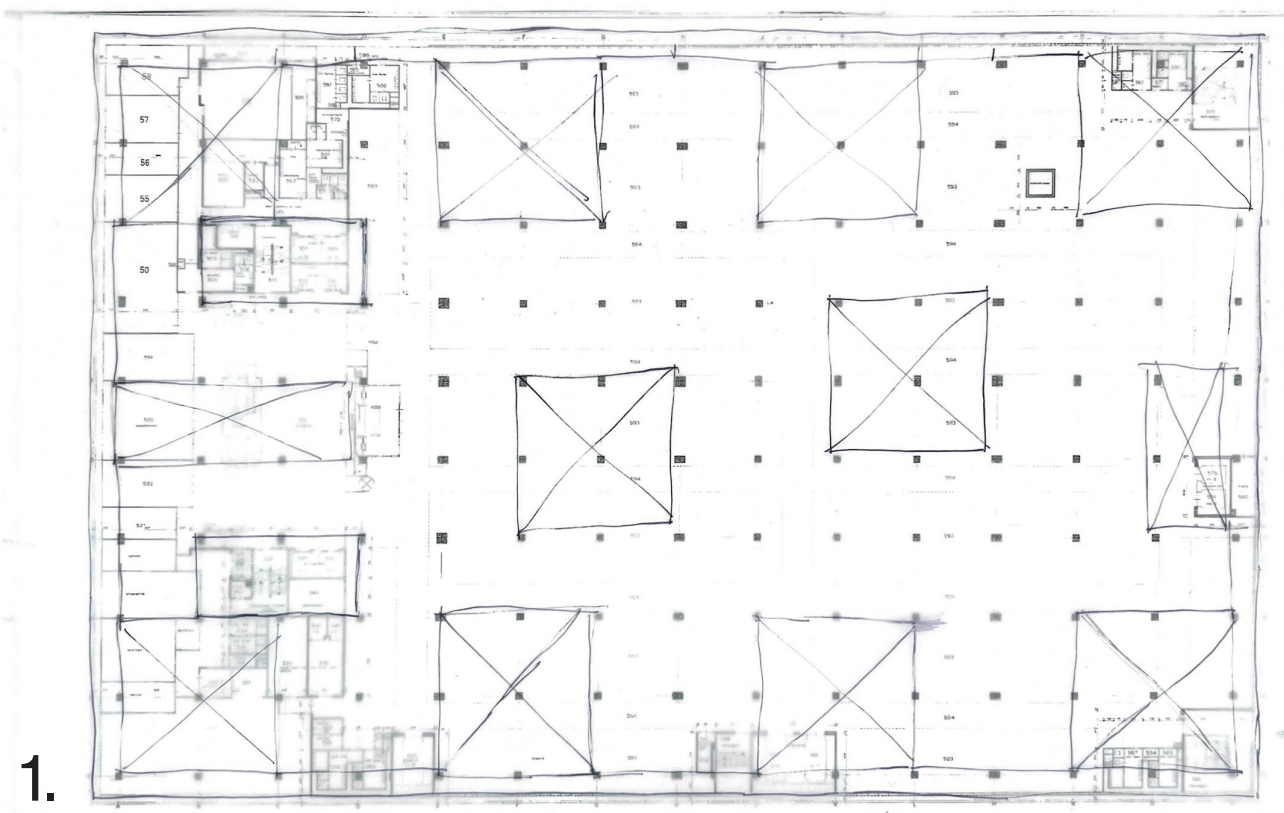
Collecting archival documents of the Beatrixgebouw



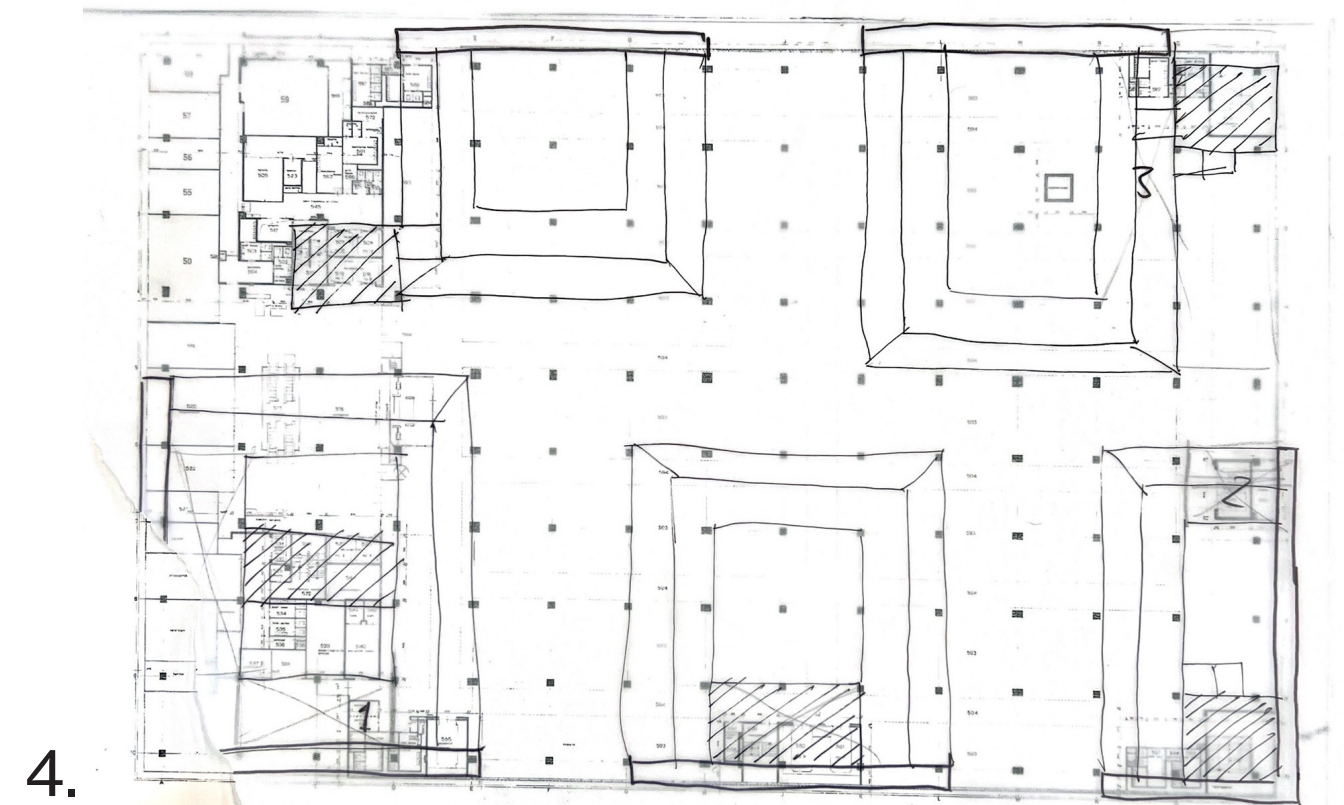
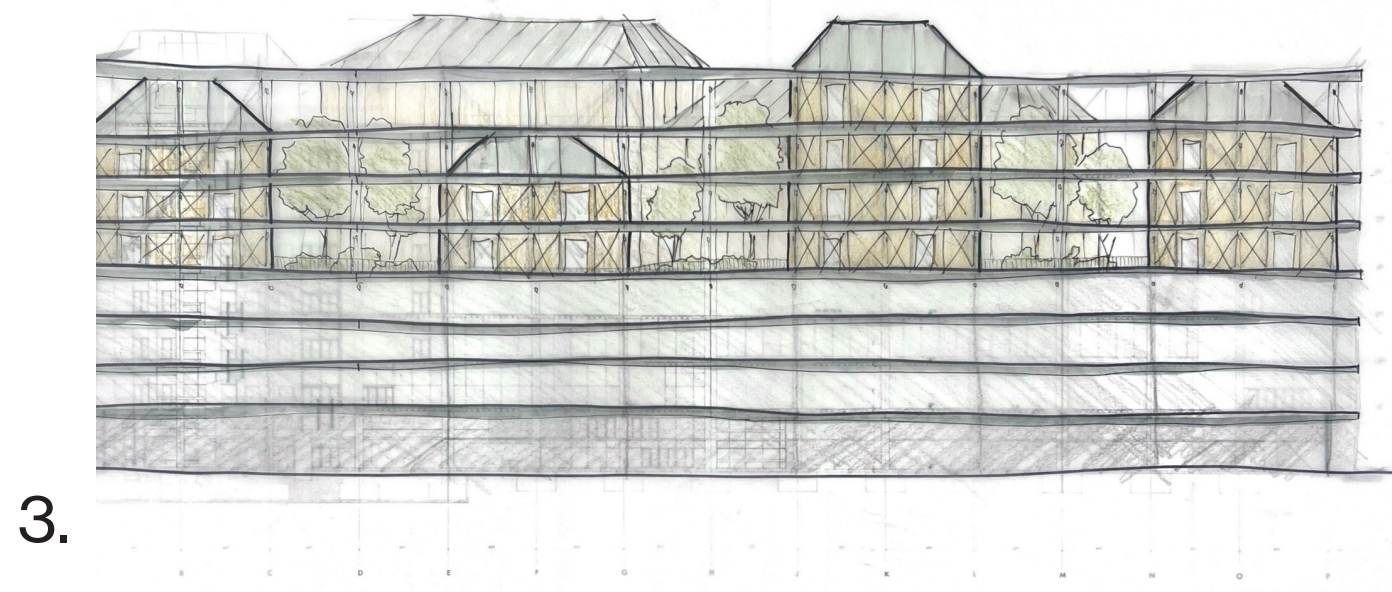
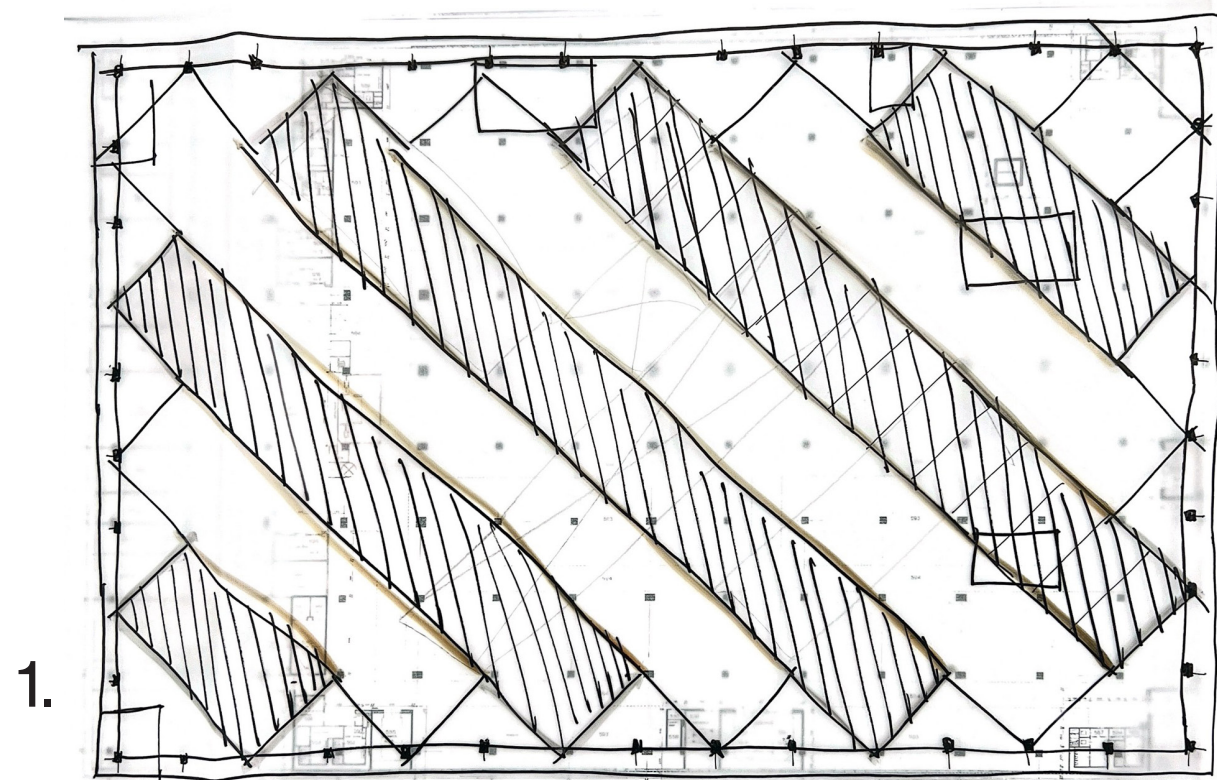
- 9x9m grid
- 4,5m floor height
- multiple structural cores

[illegible]

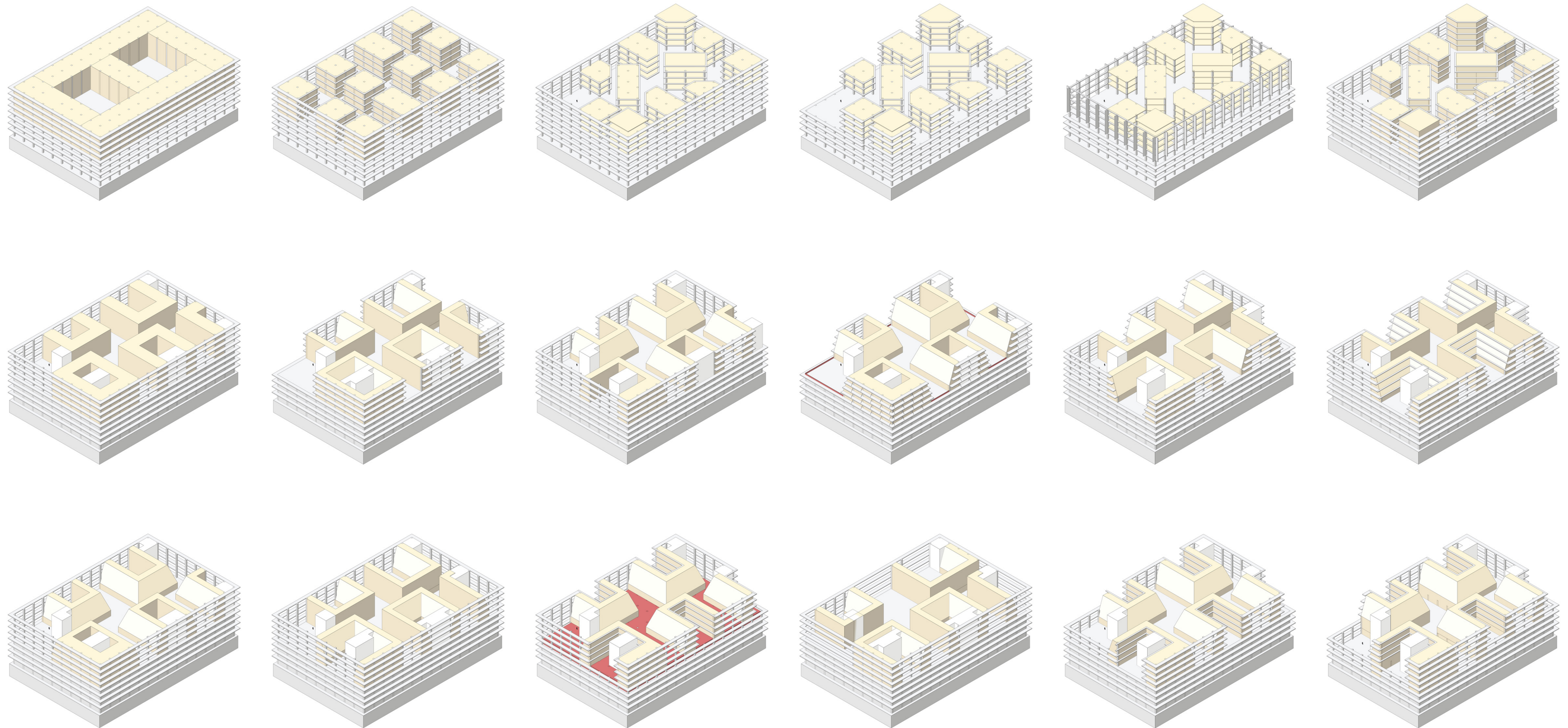
First sketches: introducing daylight and views



Shifting concept: exploration of larger city blocks



Testing possible volumes



concrete

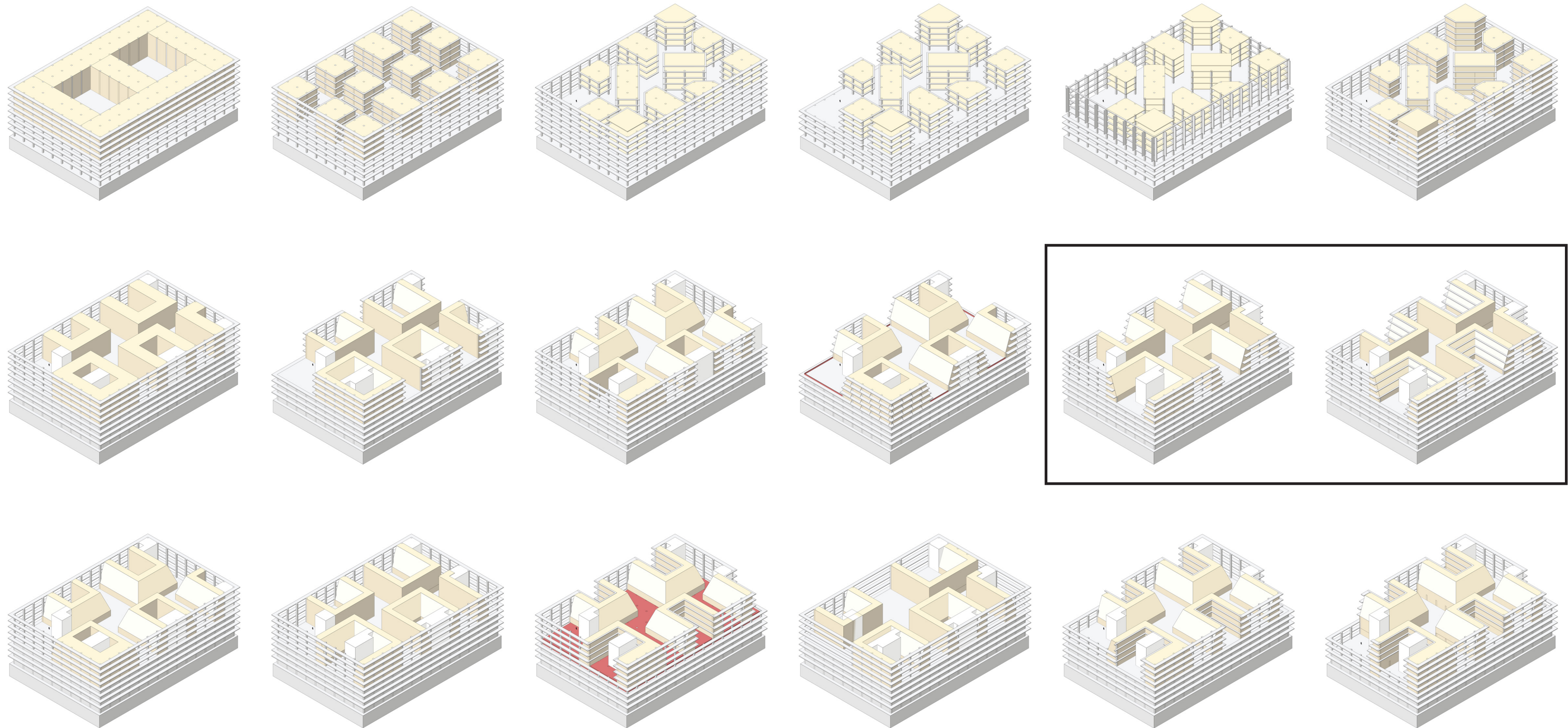


wood



steel

Testing possible volumes



concrete

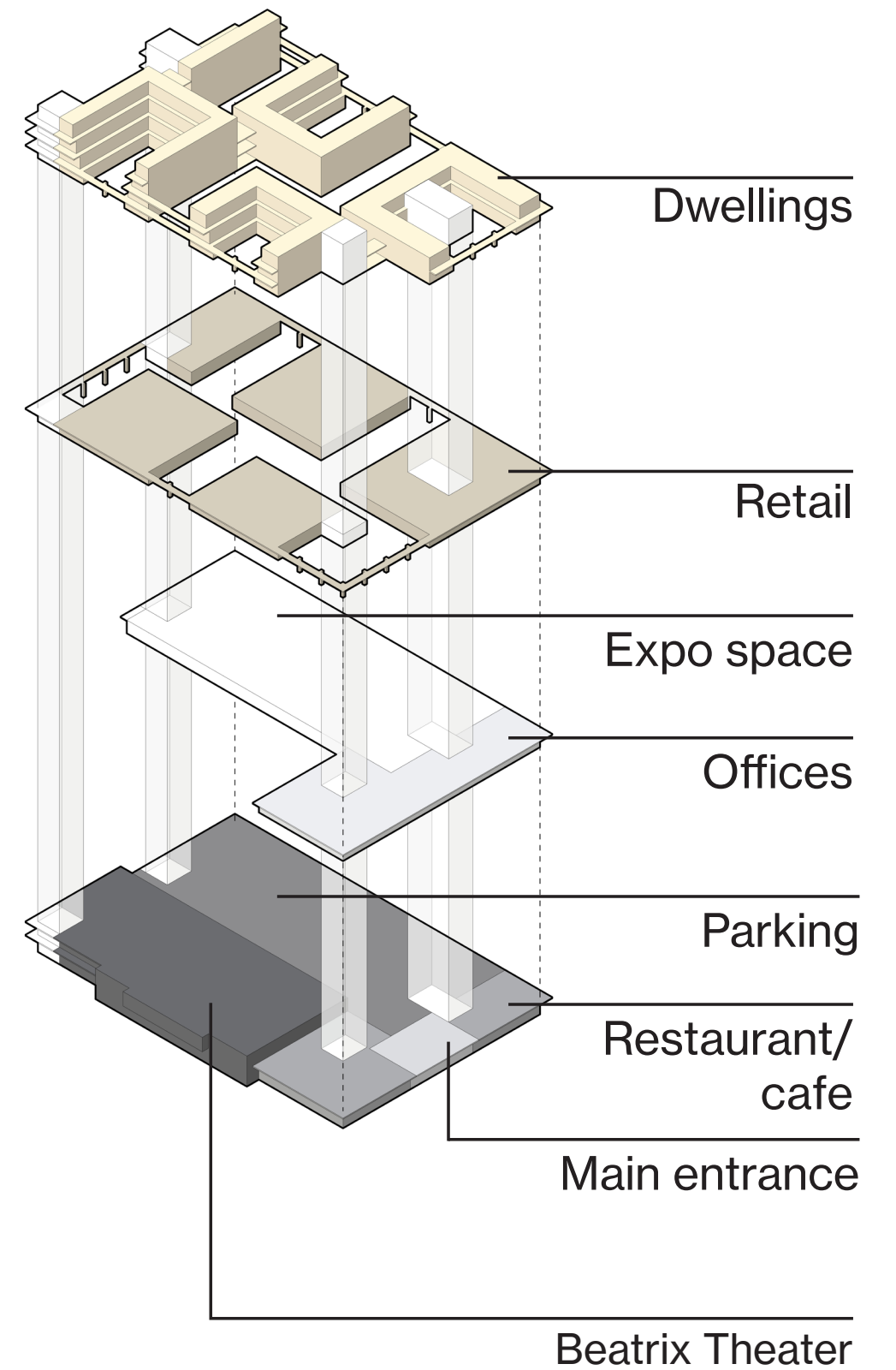
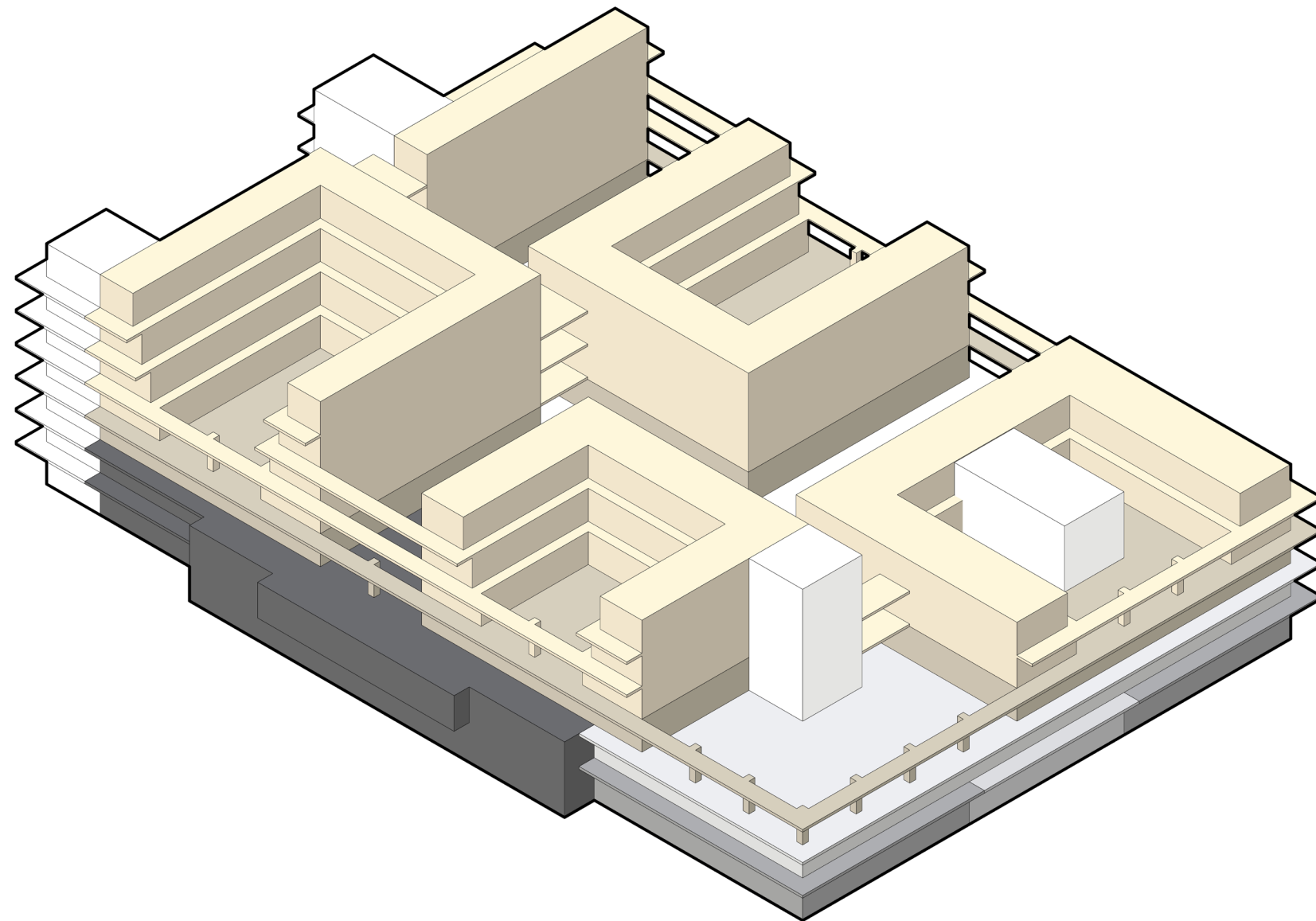


wood

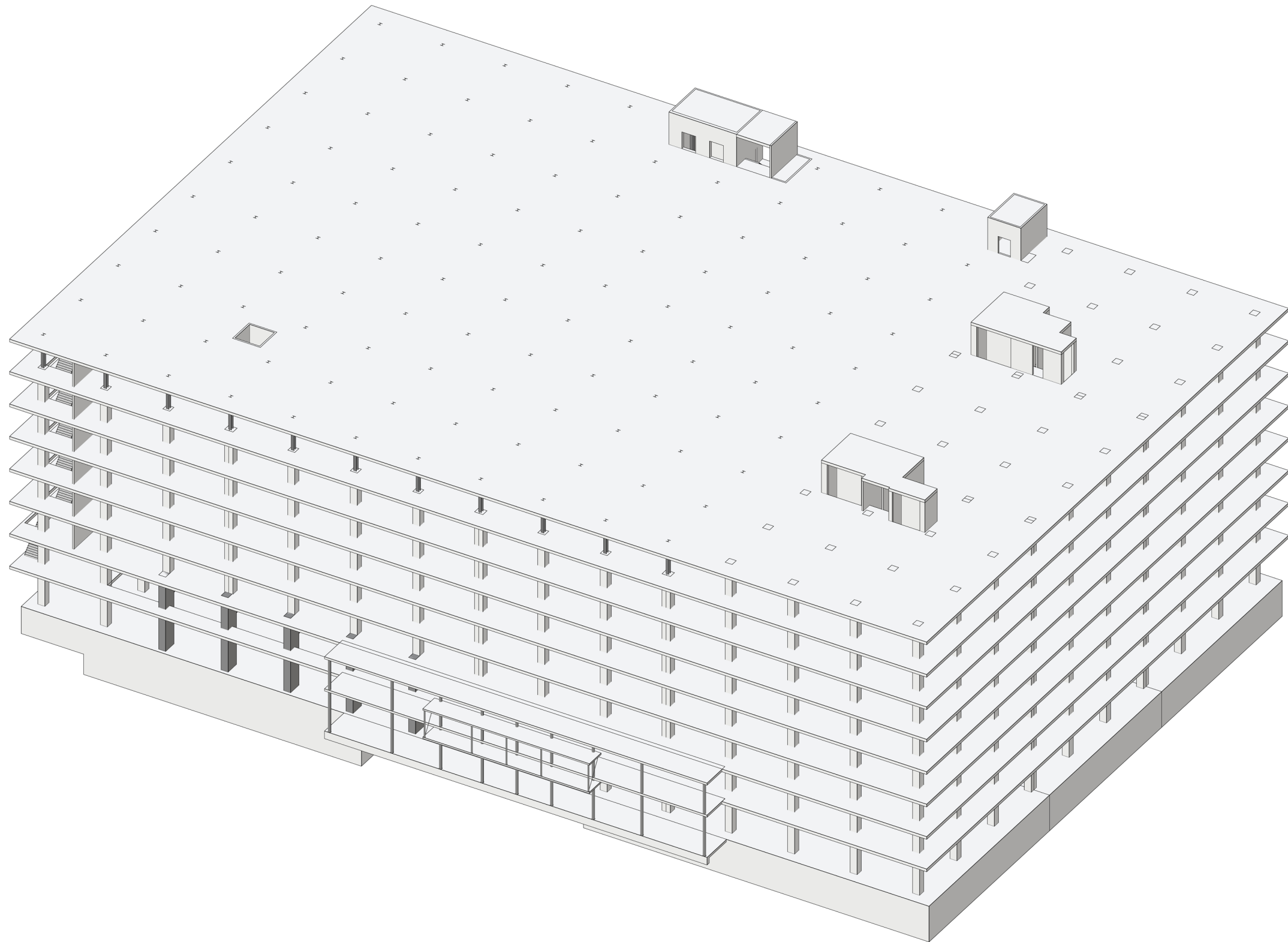


steel

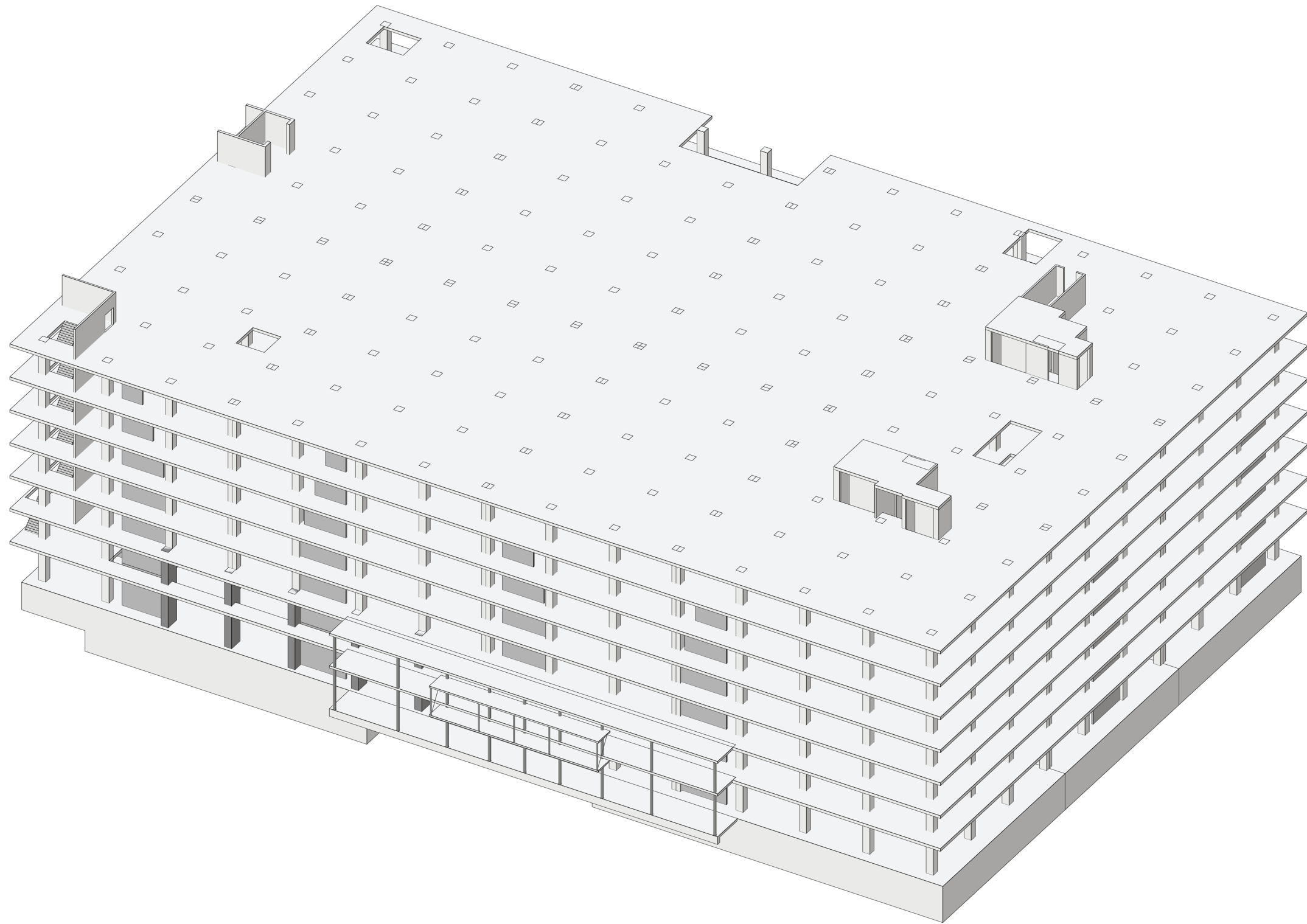
Final volume



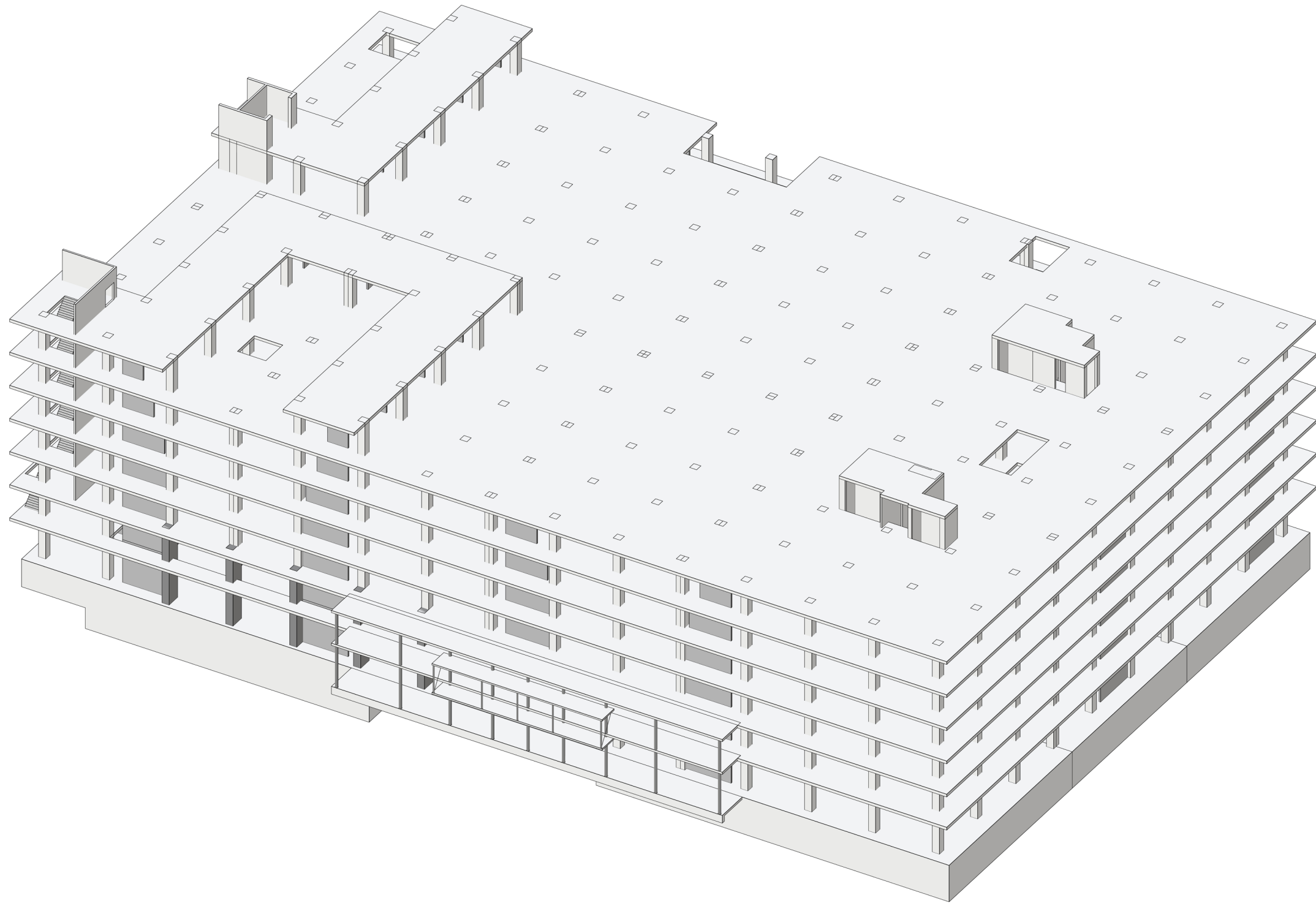
The current structure



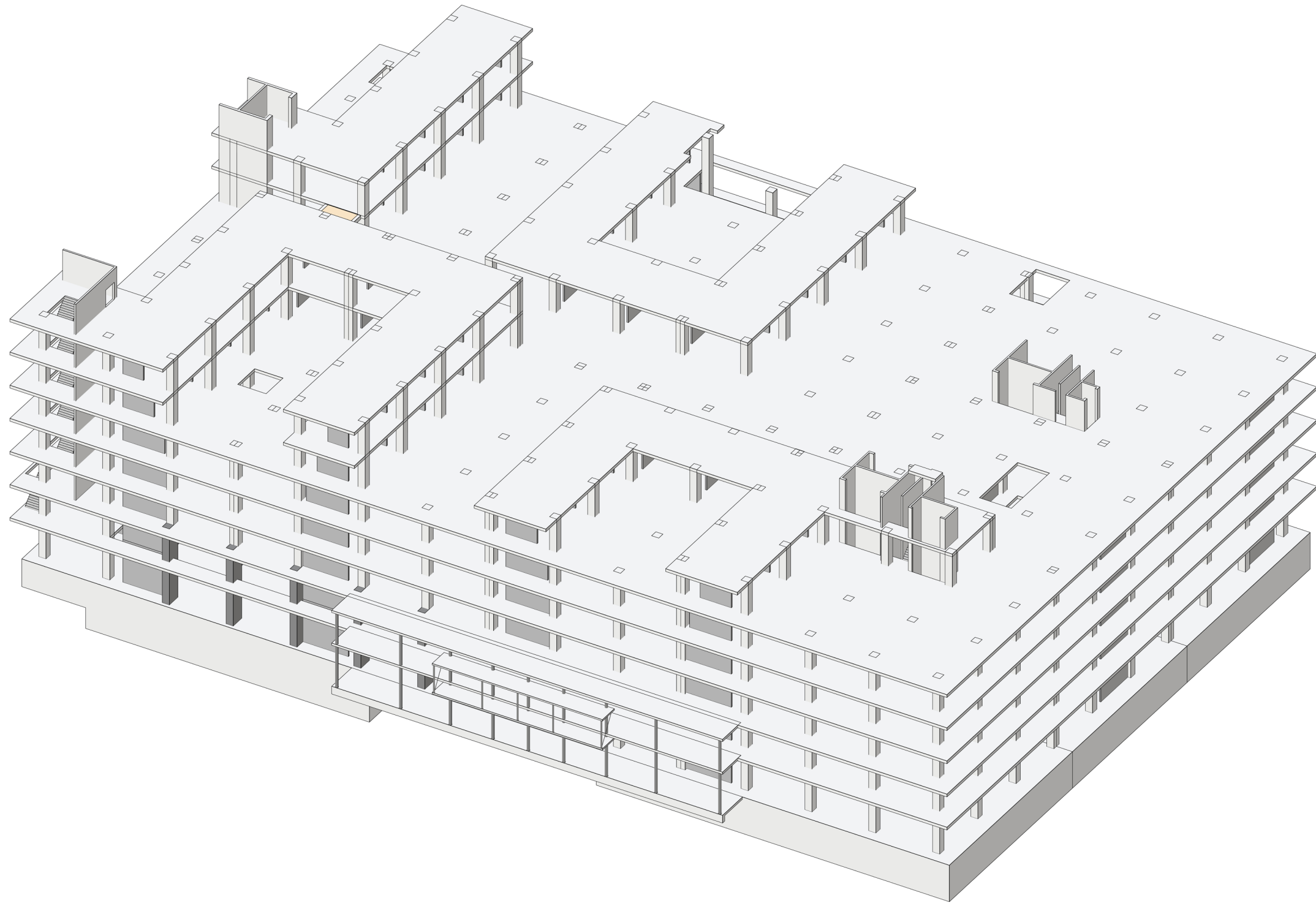
Step 1



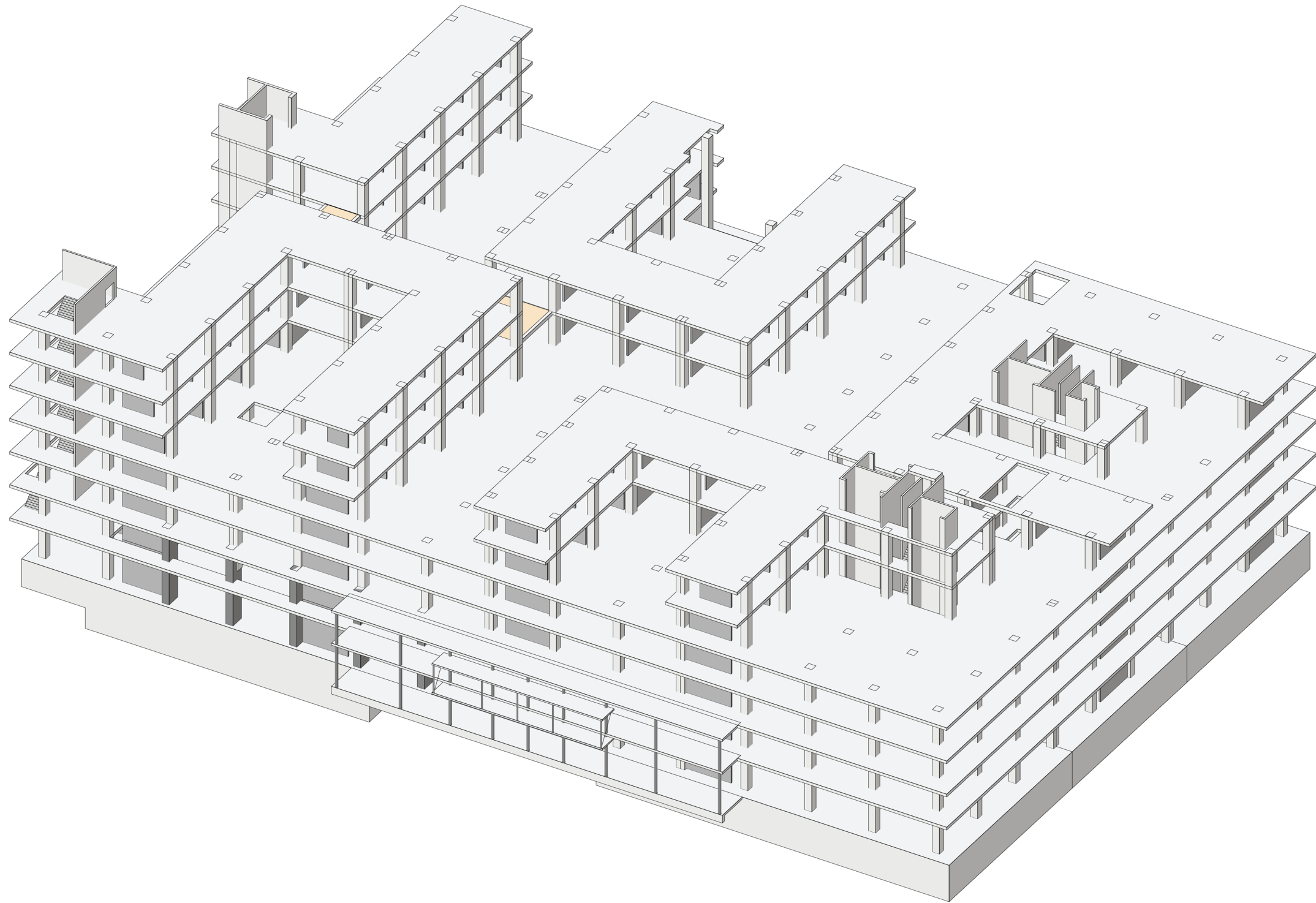
Step 2



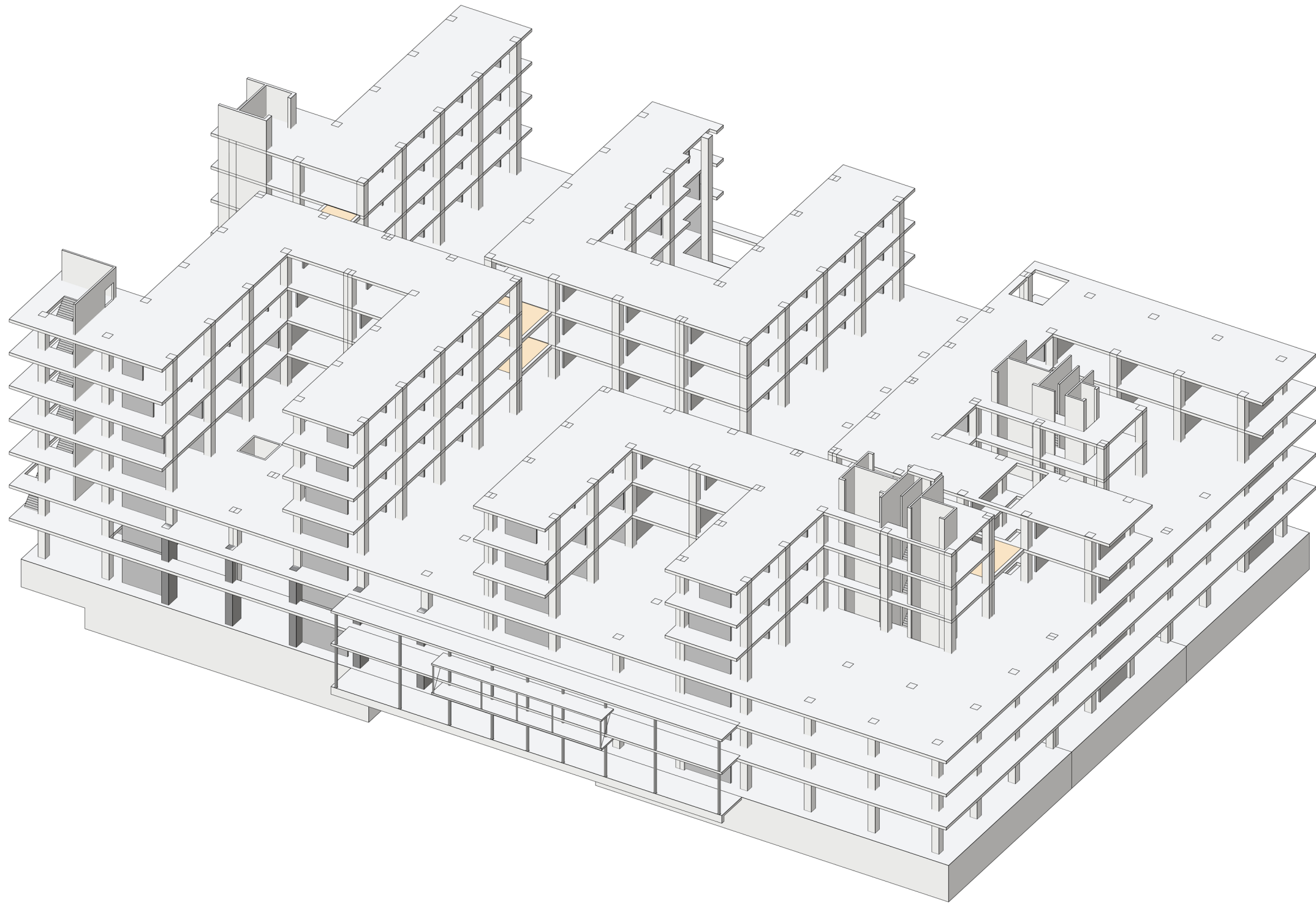
Step 3



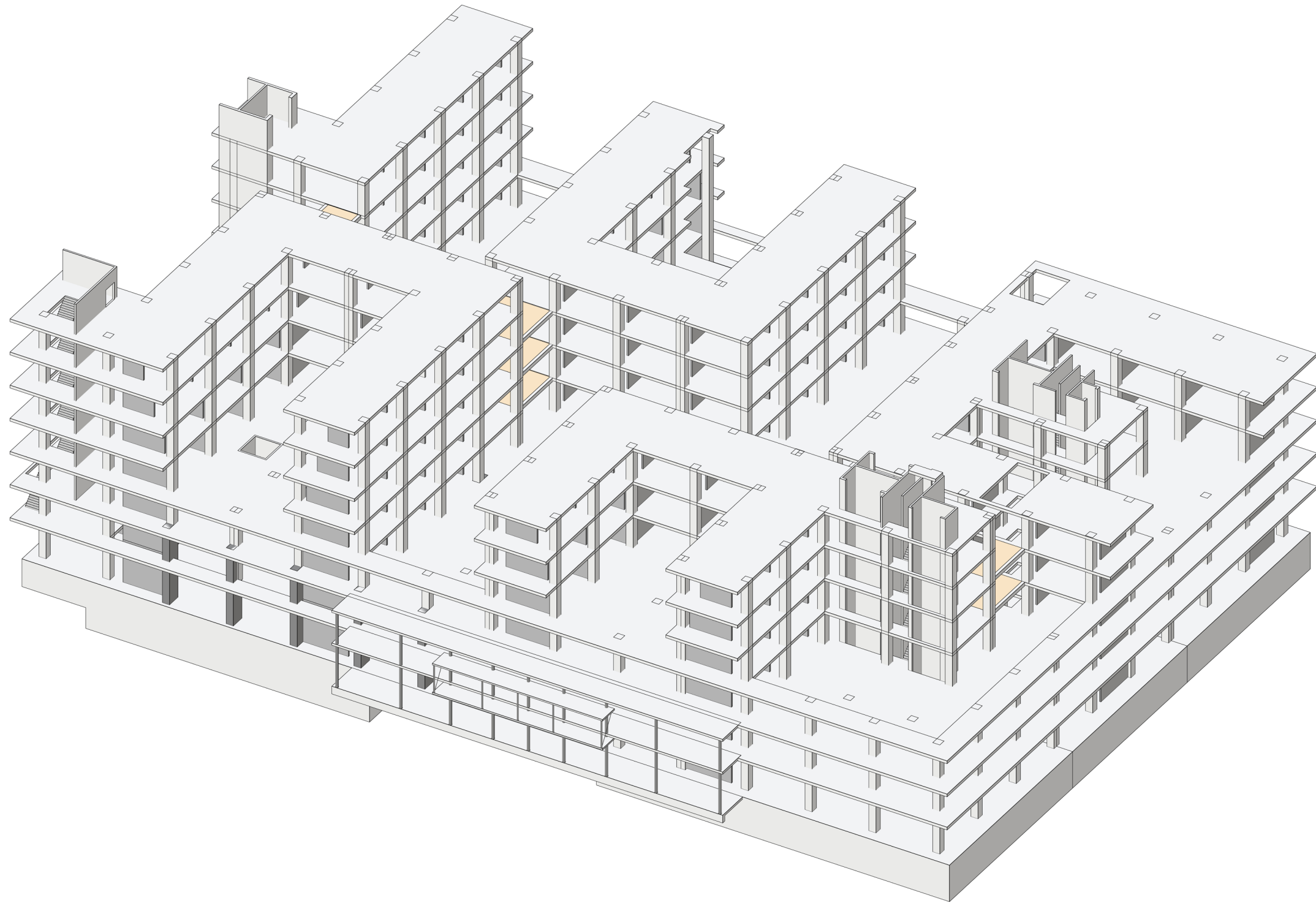
Step 4



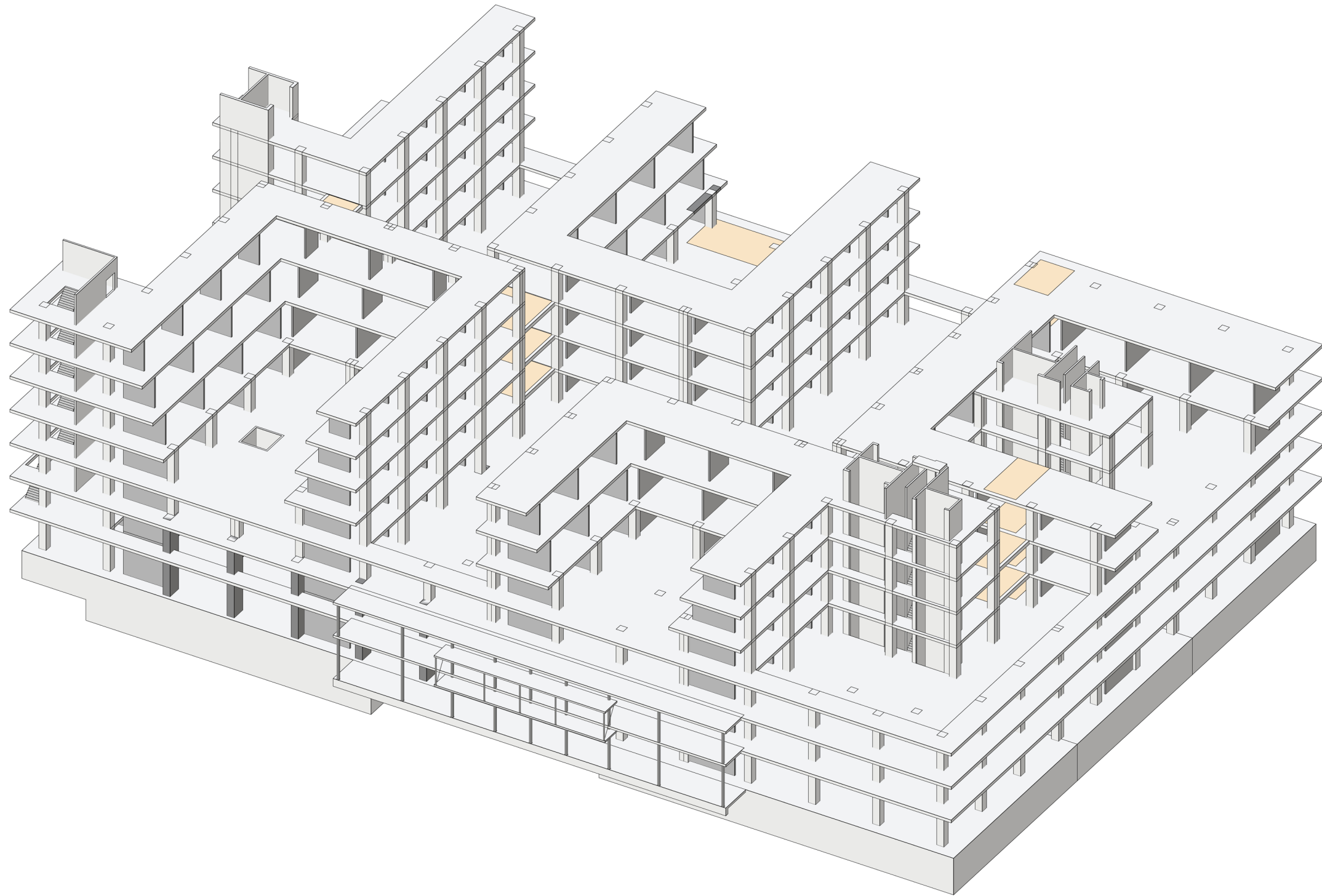
Step 5



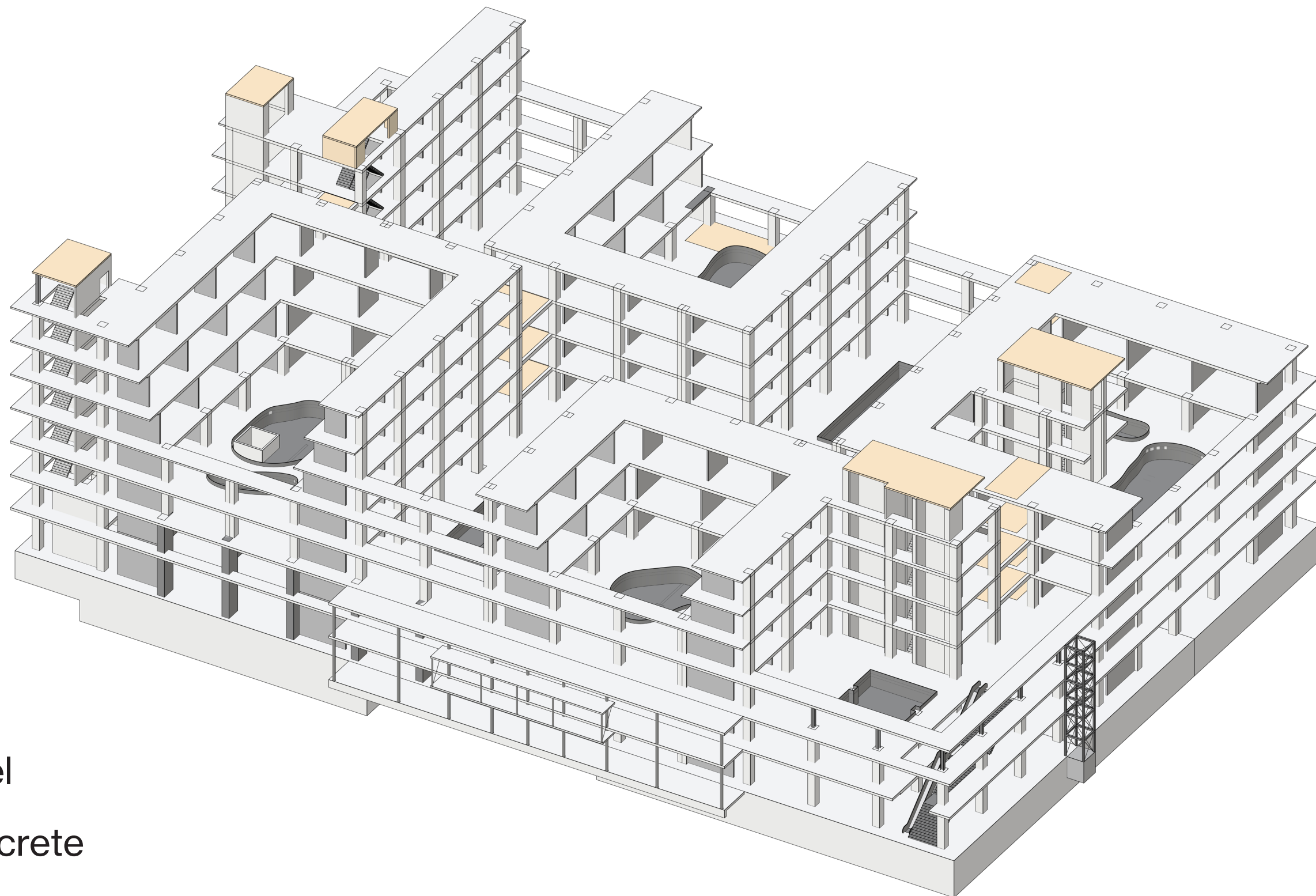
Step 6



Step 7

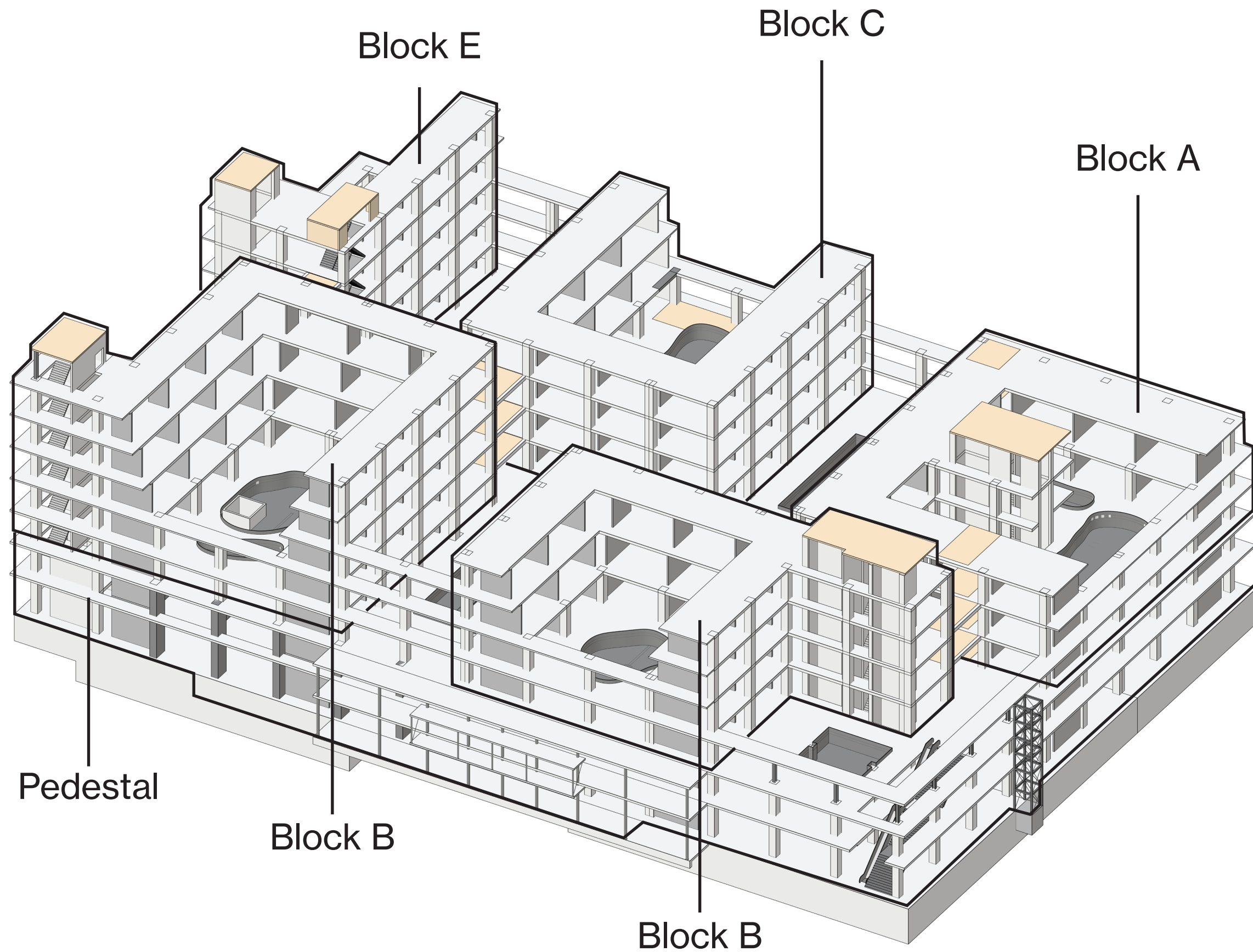


Final transformed structure



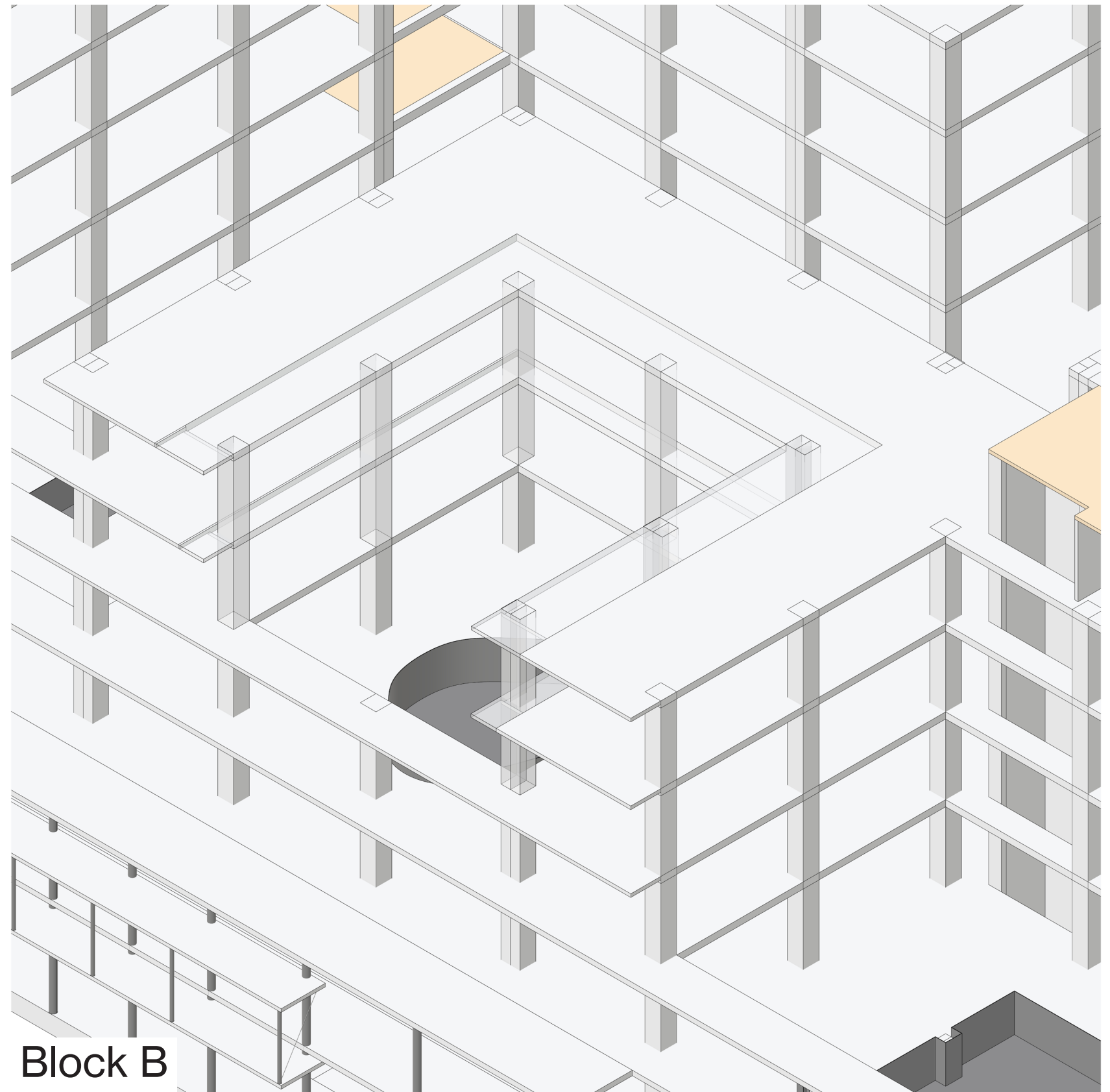
- Steel
- Concrete
- Mass timber

Final transformed structure

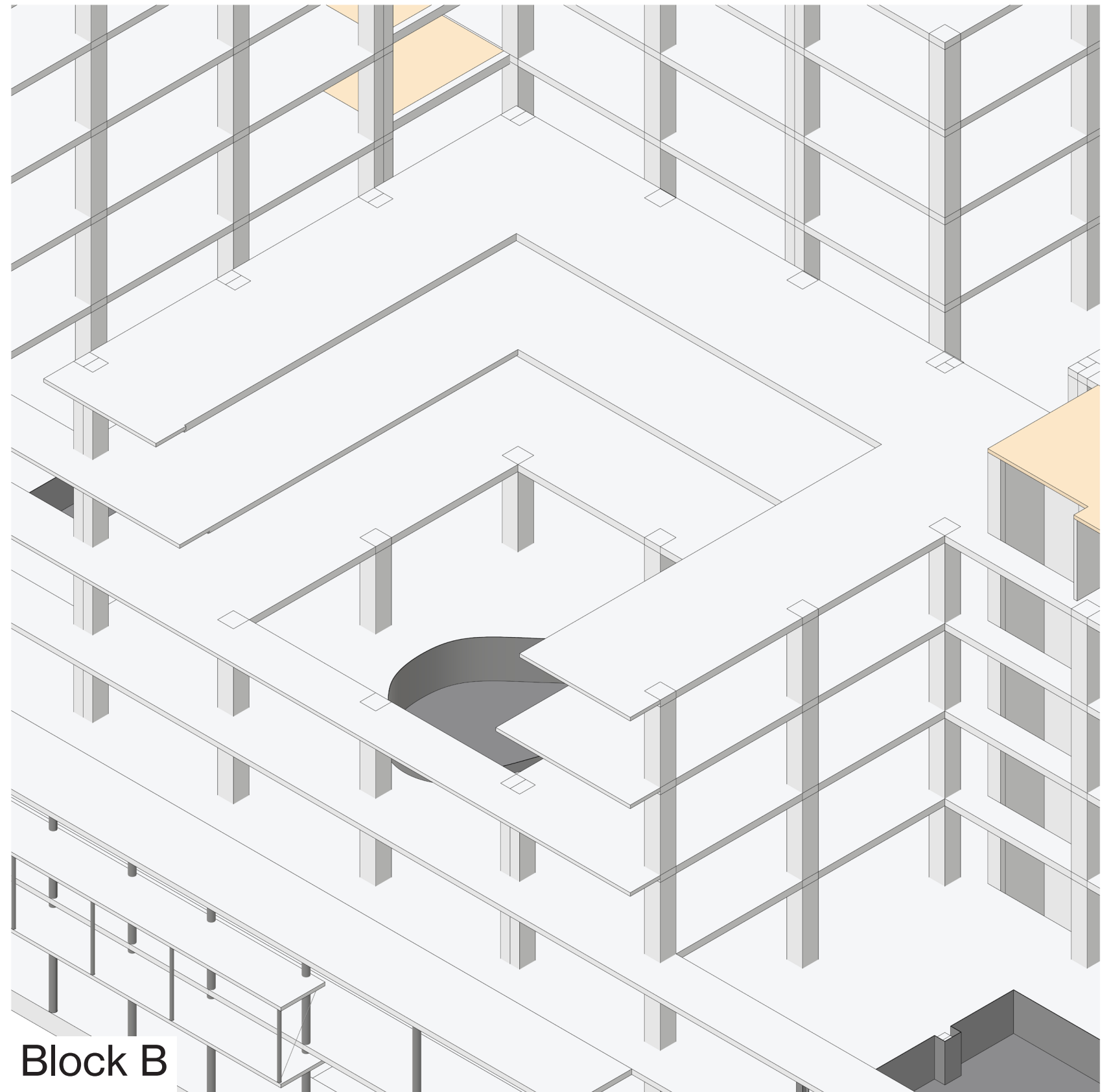


Structural interventions

- U-shape
- setbacks

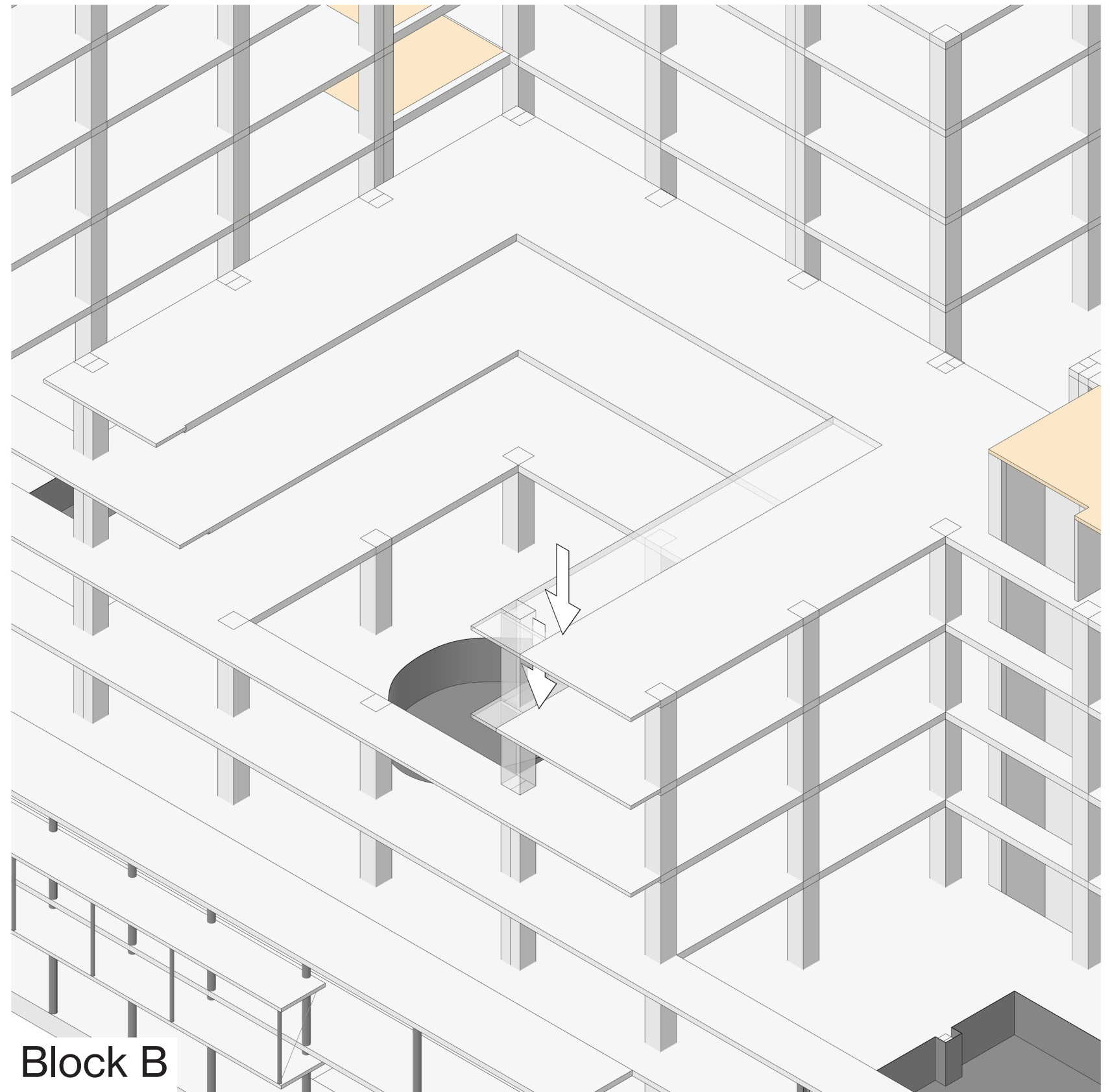


Structural interventions



Structural interventions

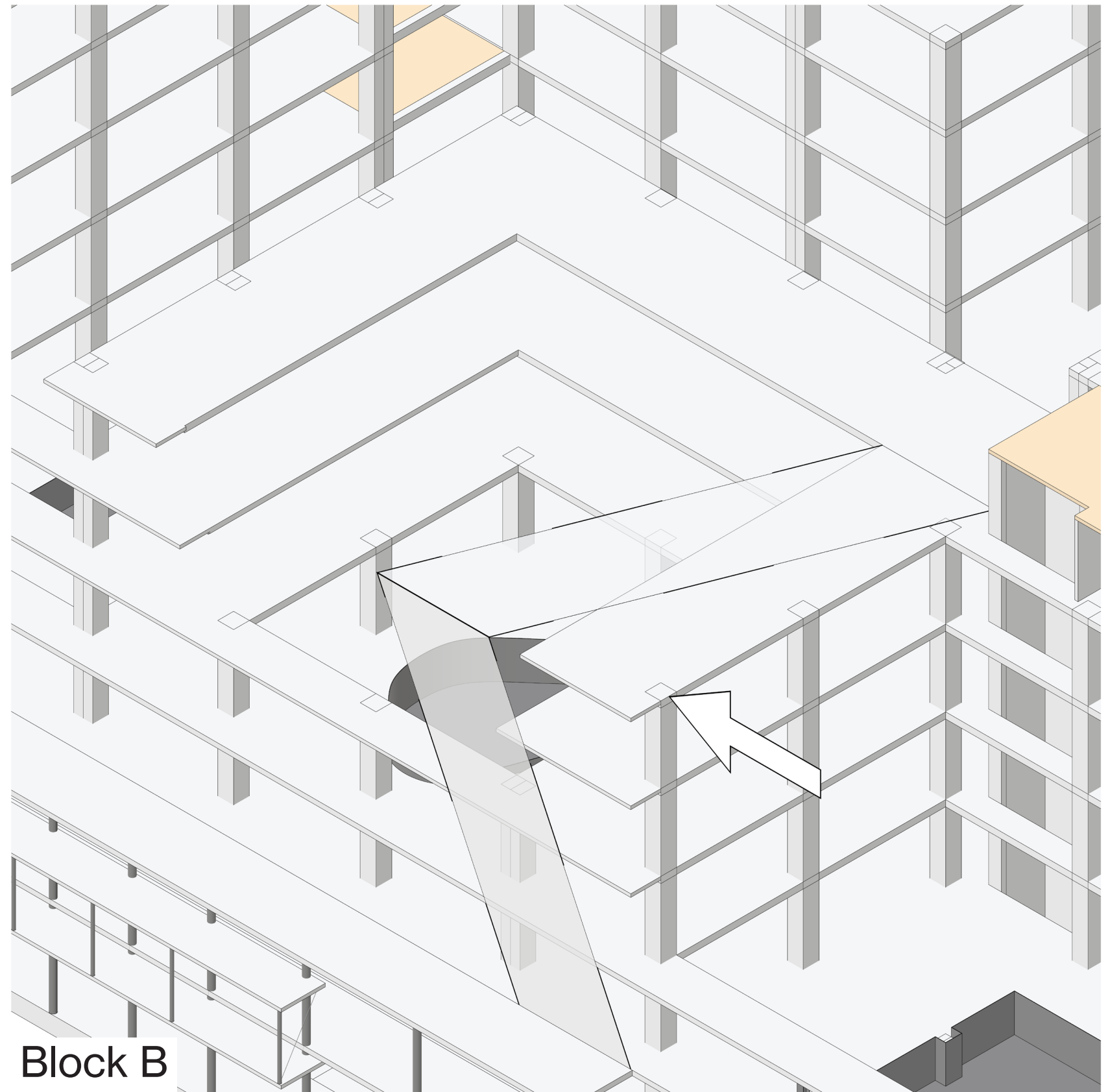
- Present forces:
- Normal force



Structural interventions

Present forces:

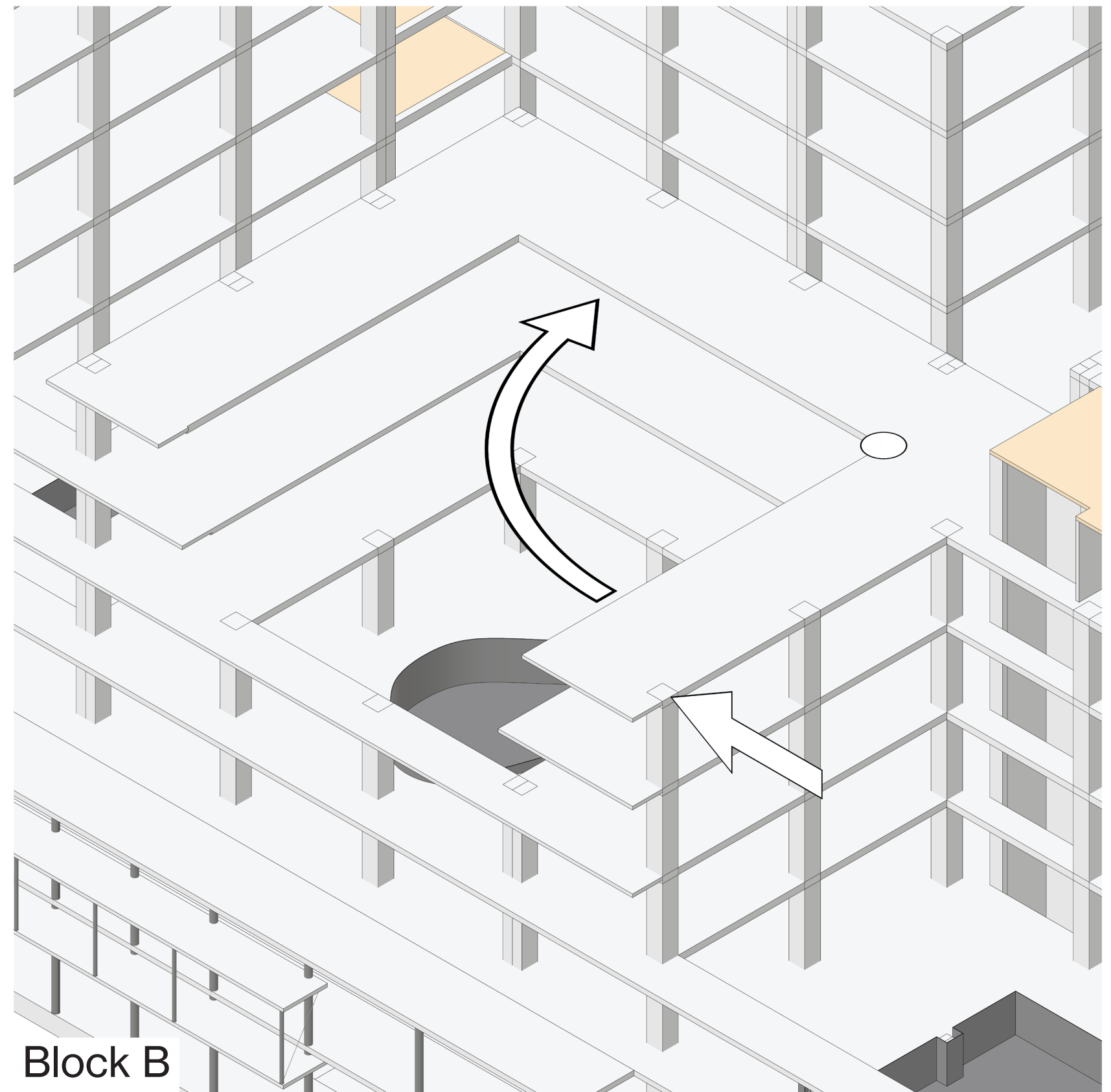
- Normal force
- Shearing force



Structural interventions

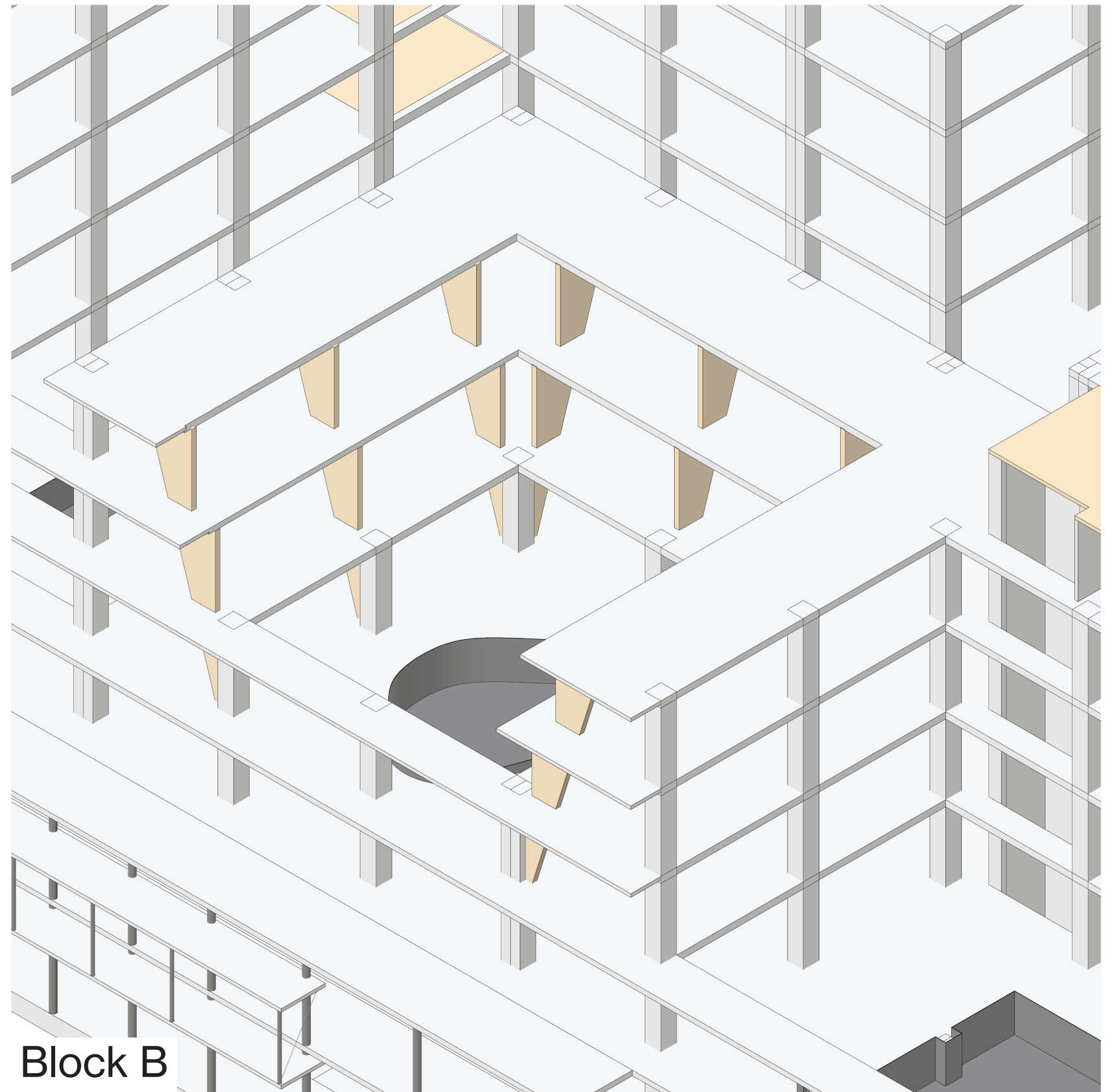
Present forces:

- Normal force
- Shearing force
- Torsion



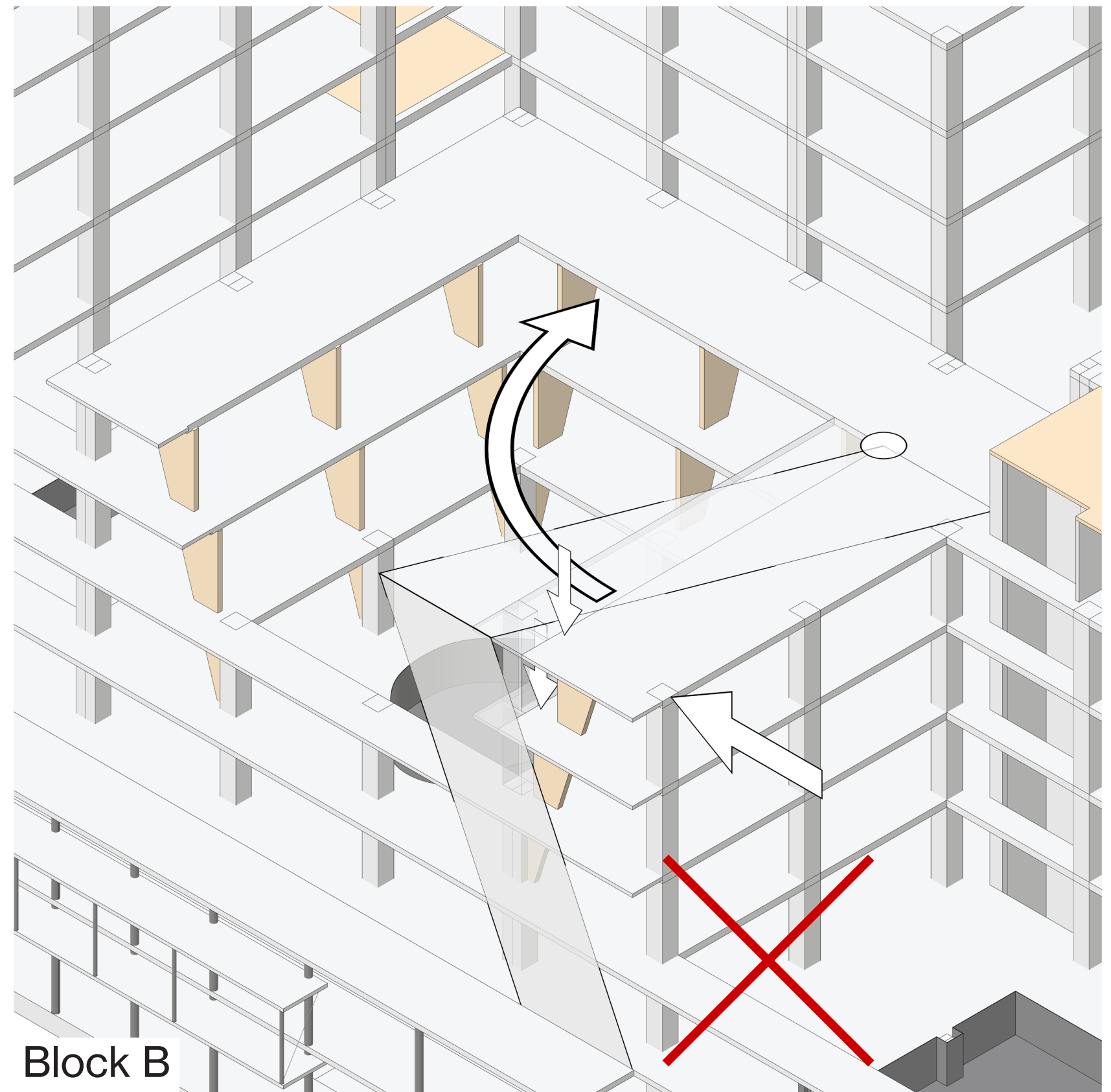
Structural interventions

Introducing mass timber
slanted columns



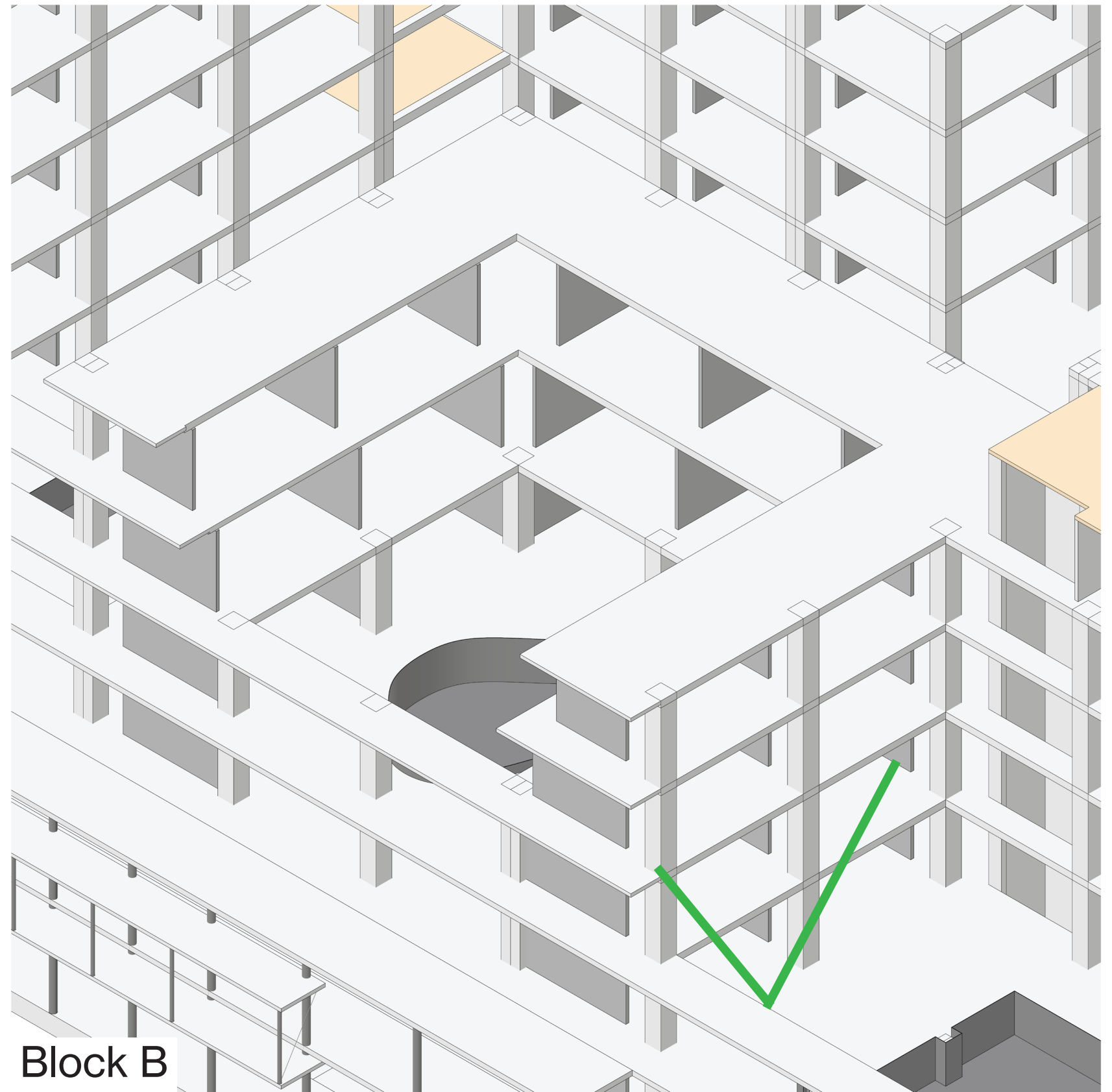
Structural interventions

Introducing mass timber
slanted columns



Structural interventions

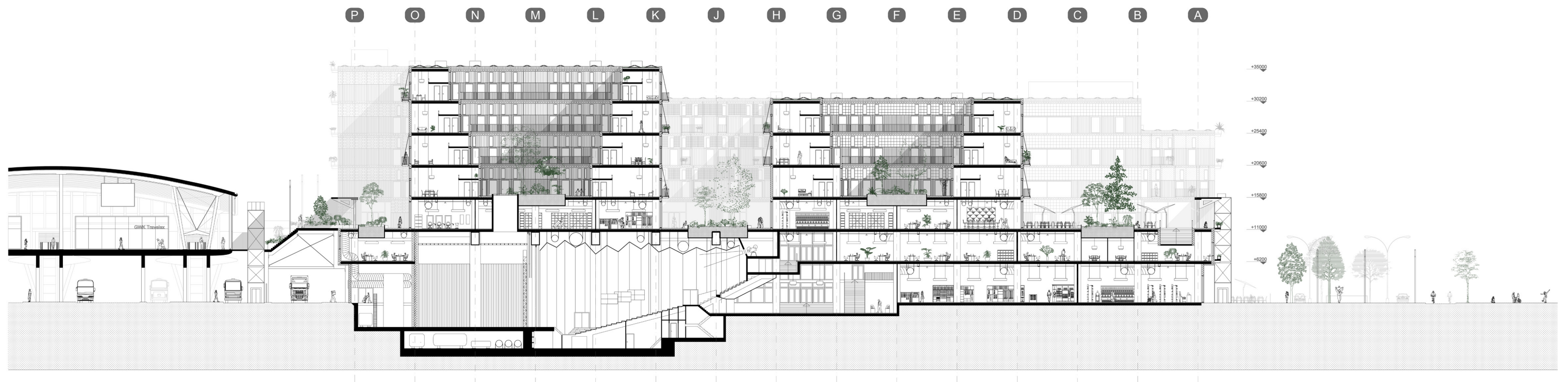
New solution: stability from concrete slabs



Design in the urban context



Longitudinal section A-A'



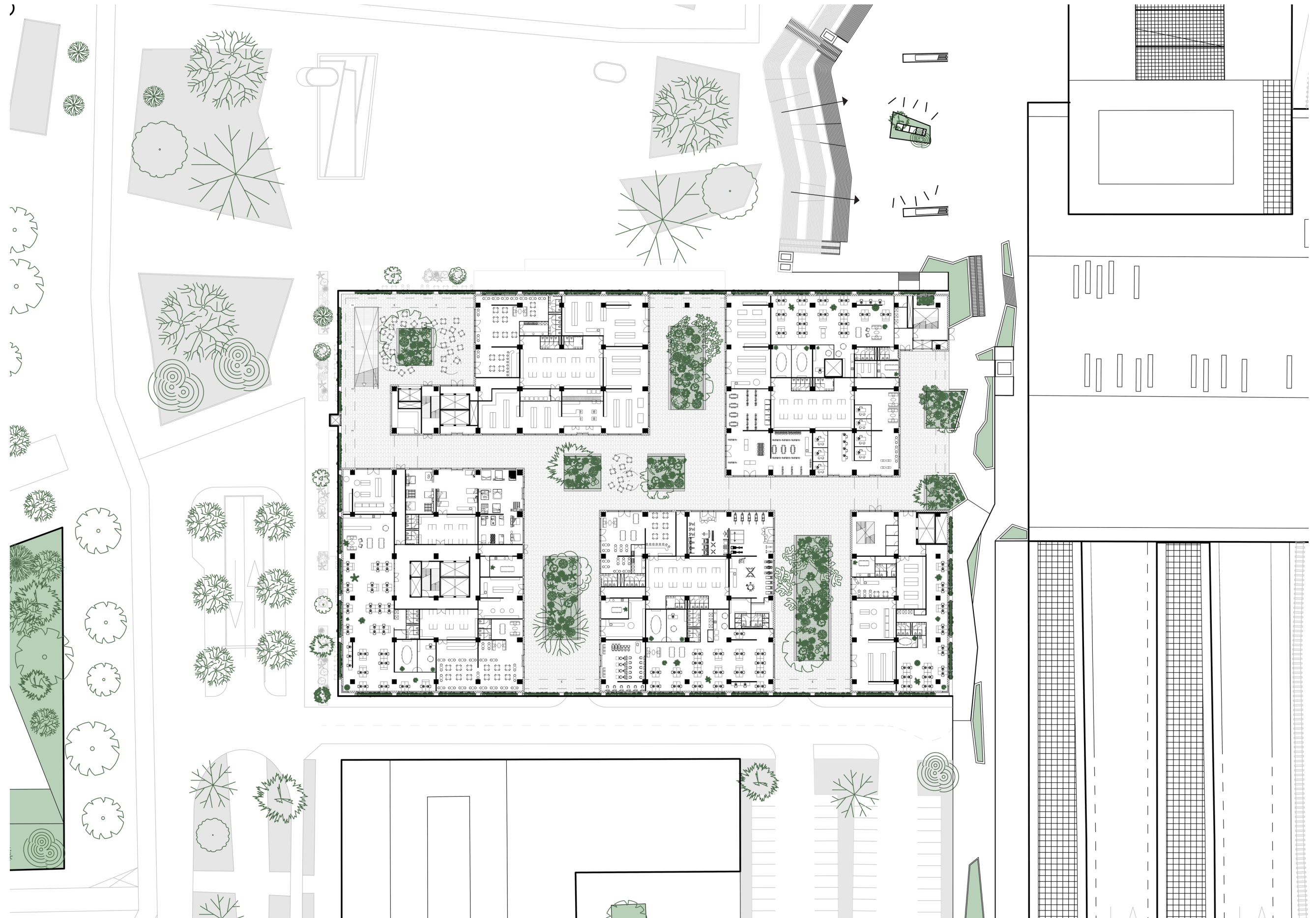
Scale 1 : 200

Floorplan of the ground floor



Scale 1 : 500

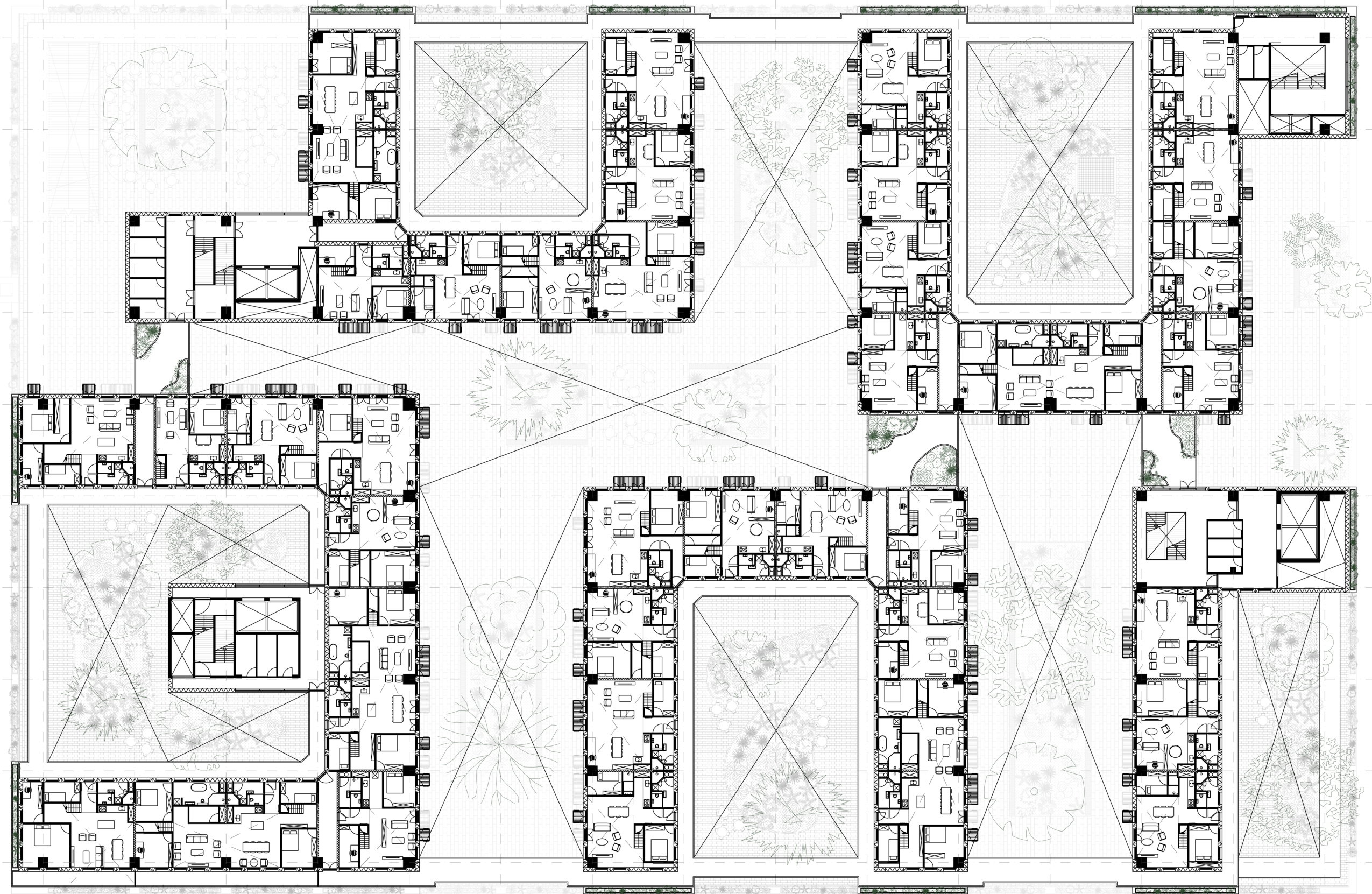
Floorplan of the raised urban level



Scale 1 : 500



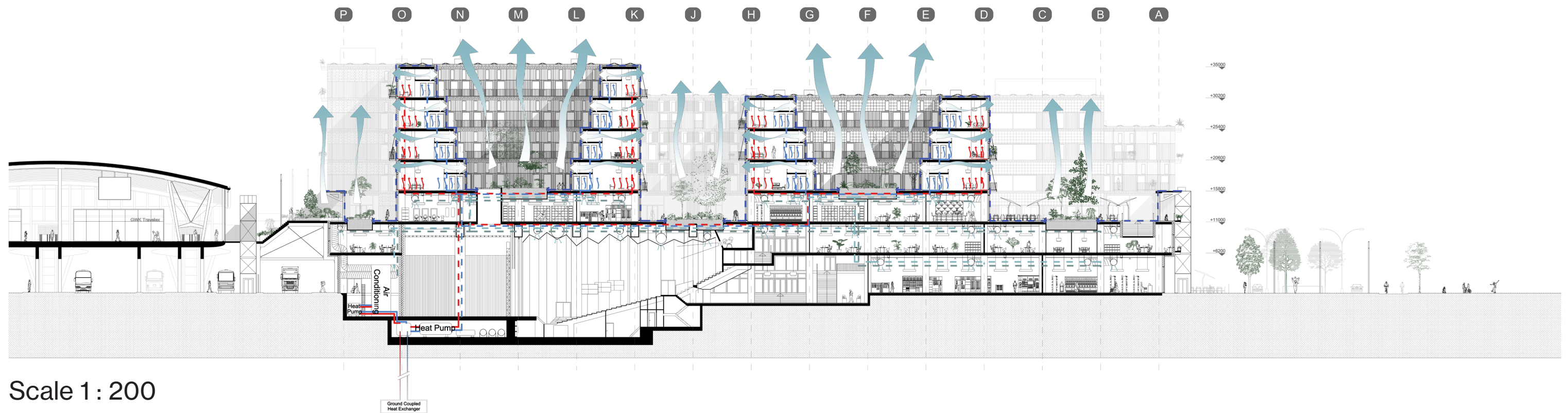
Floorplan of dwellings



Scale 1 : 200

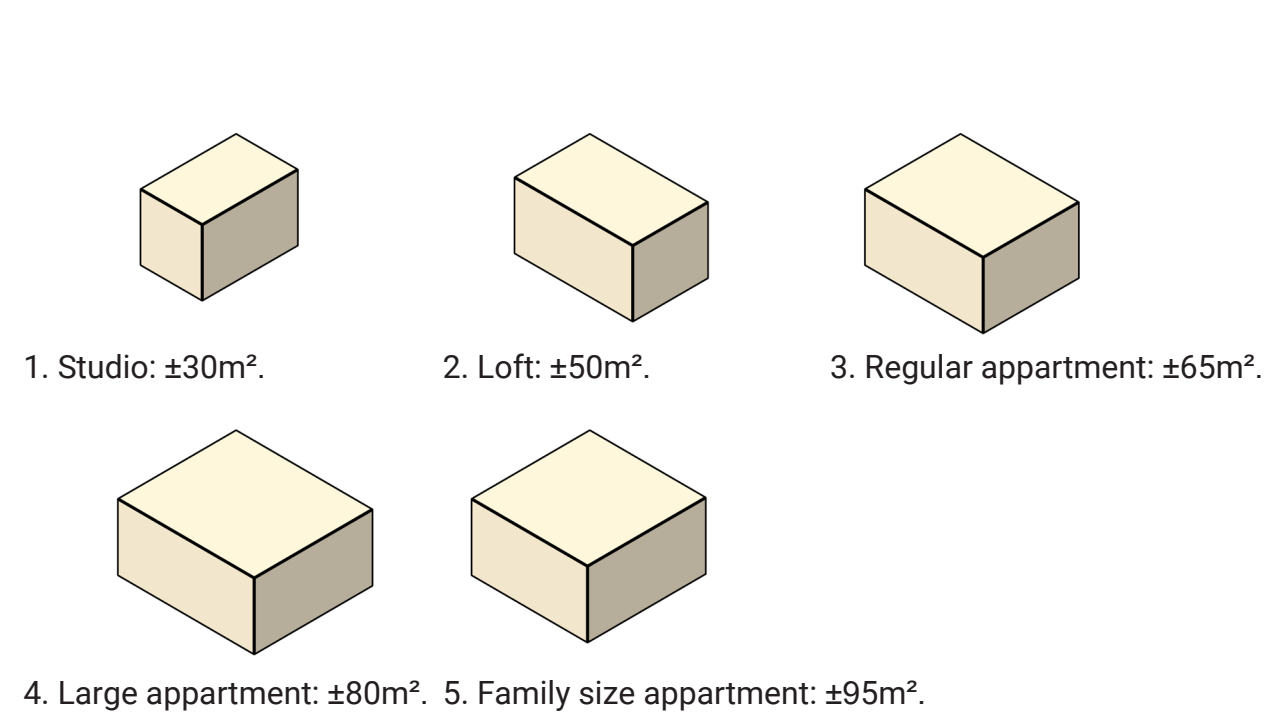


Climate design

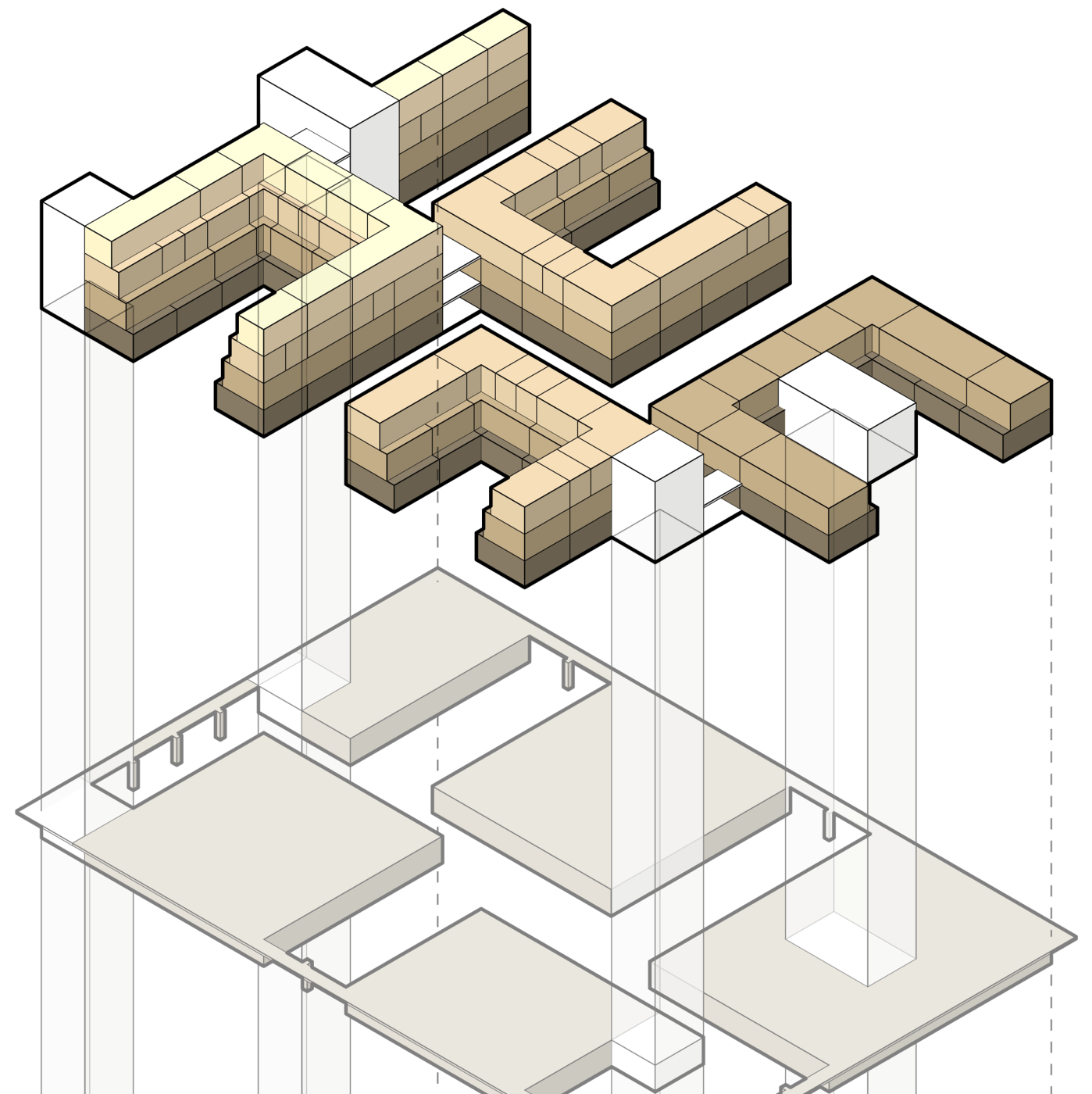


Ventilation Rainwater retention Heating Cooling

Dwelling typology and distribution



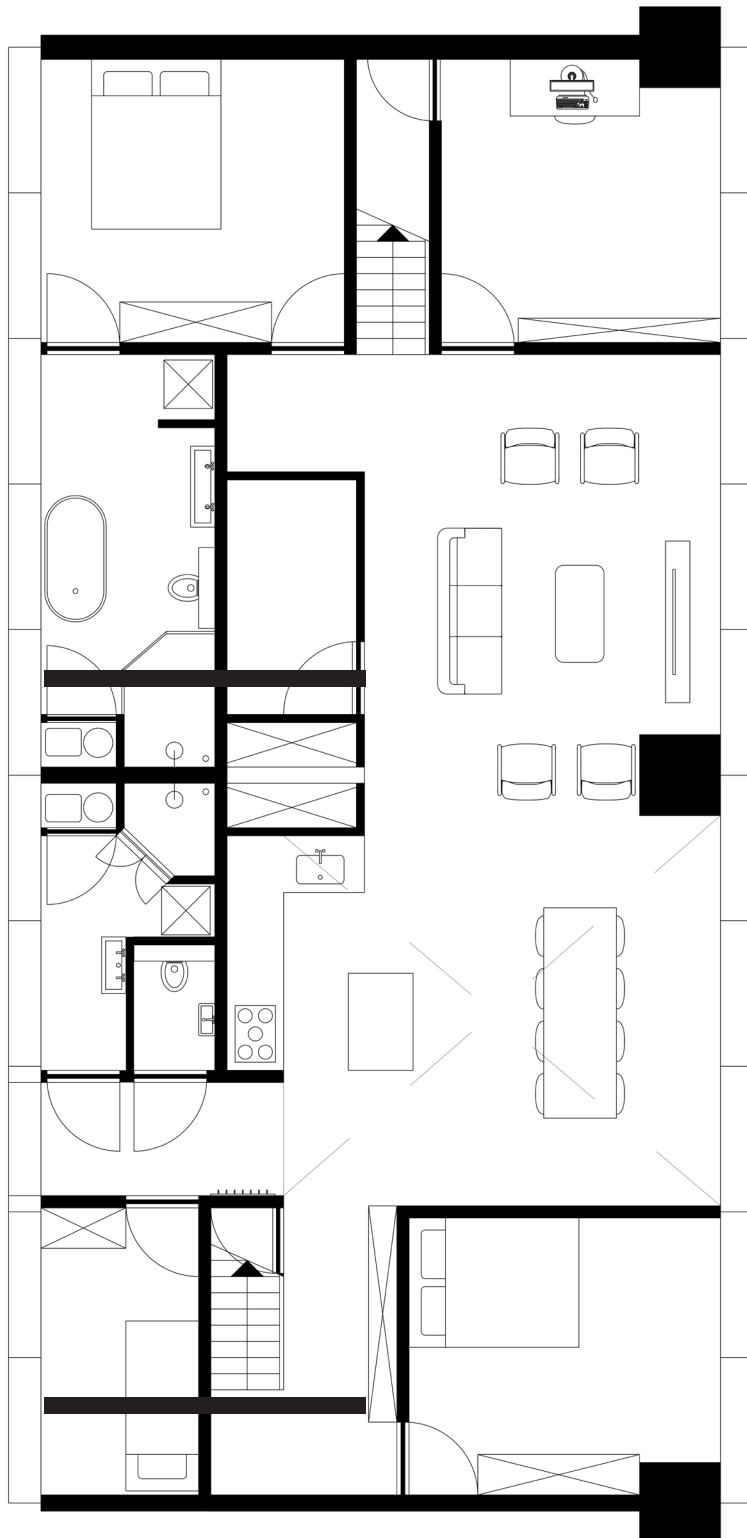
40% social housing,
30% middle segment,
30% high segment.



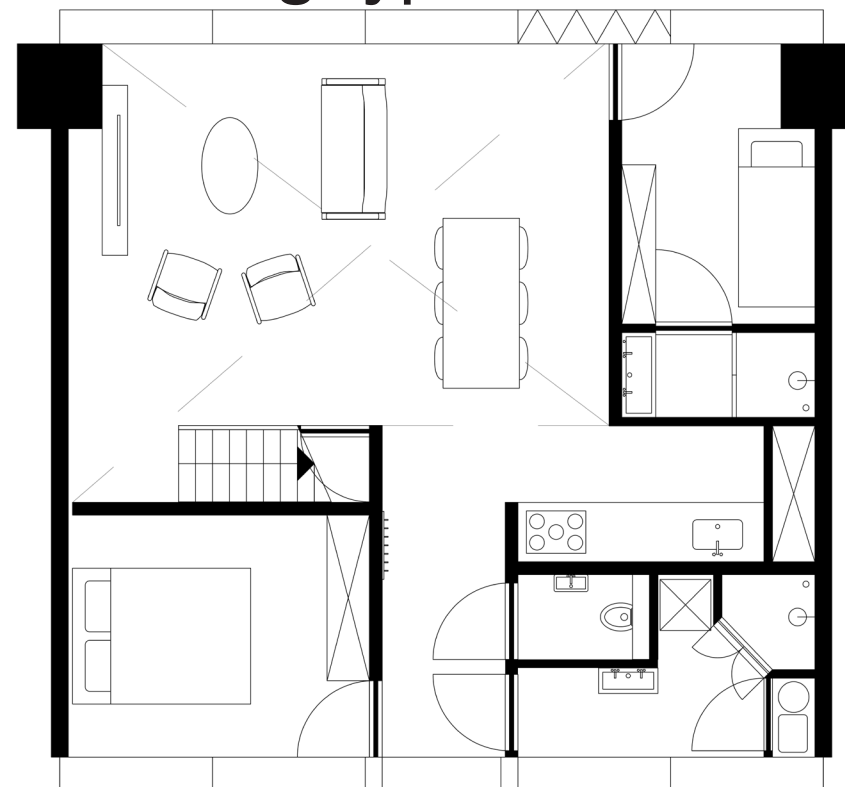
Floor plan typology

Dwelling type 5

Scale 1 : 100

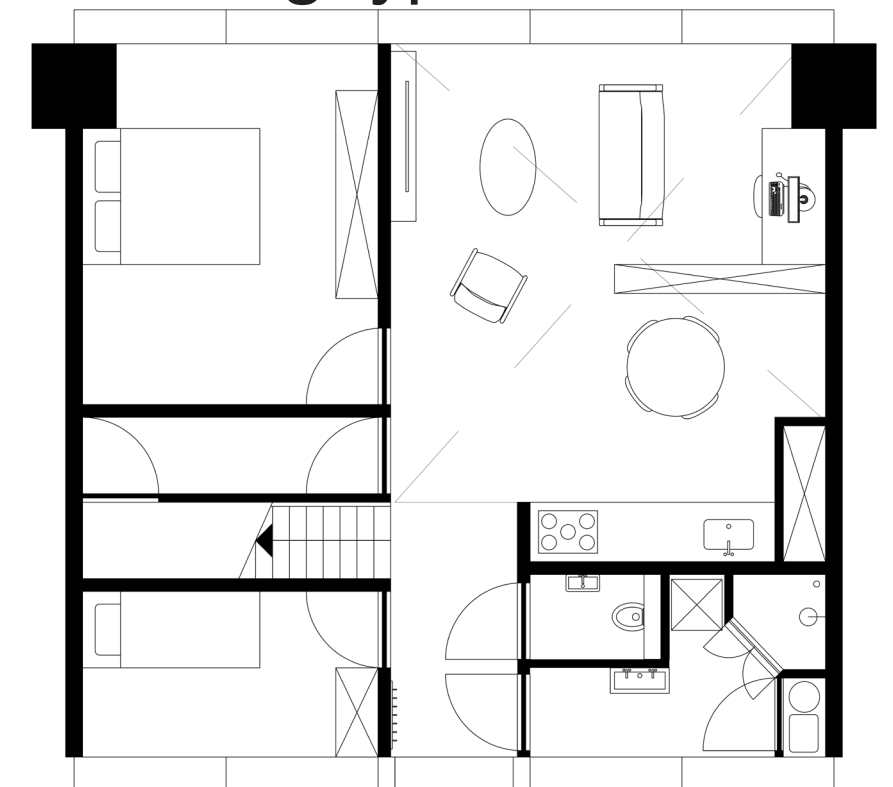


Dwelling type 1



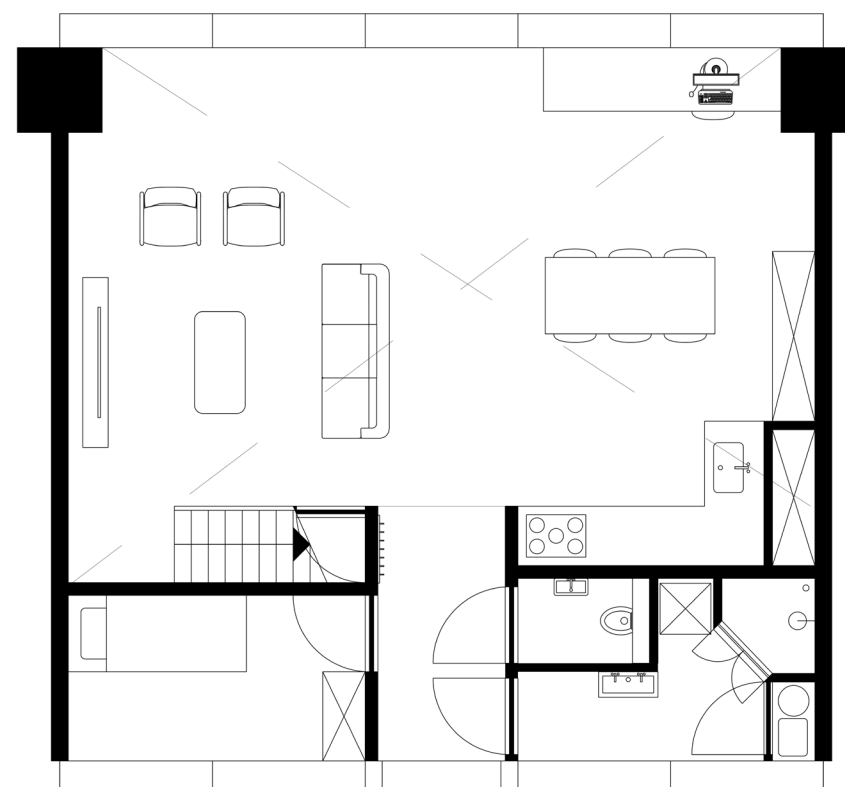
Scale 1 : 100

Dwelling type 2



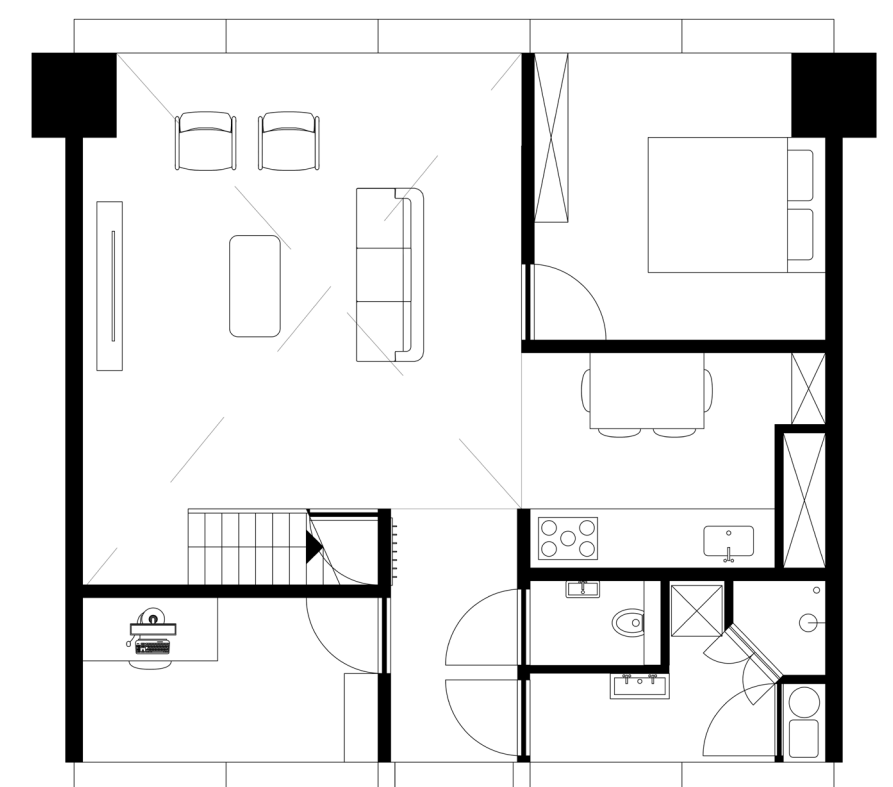
Scale 1 : 100

Dwelling type 3



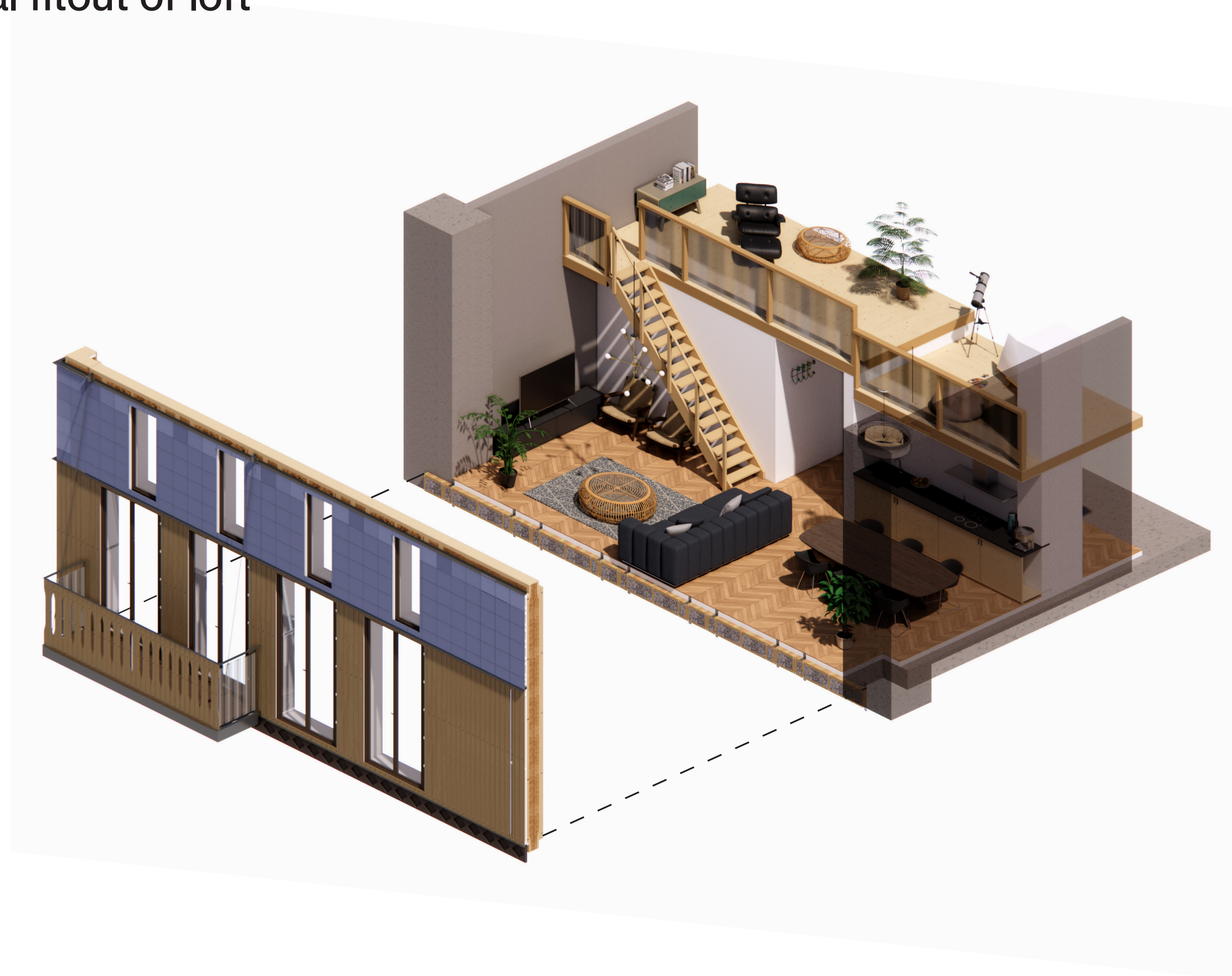
Scale 1 : 100

Dwelling type 4

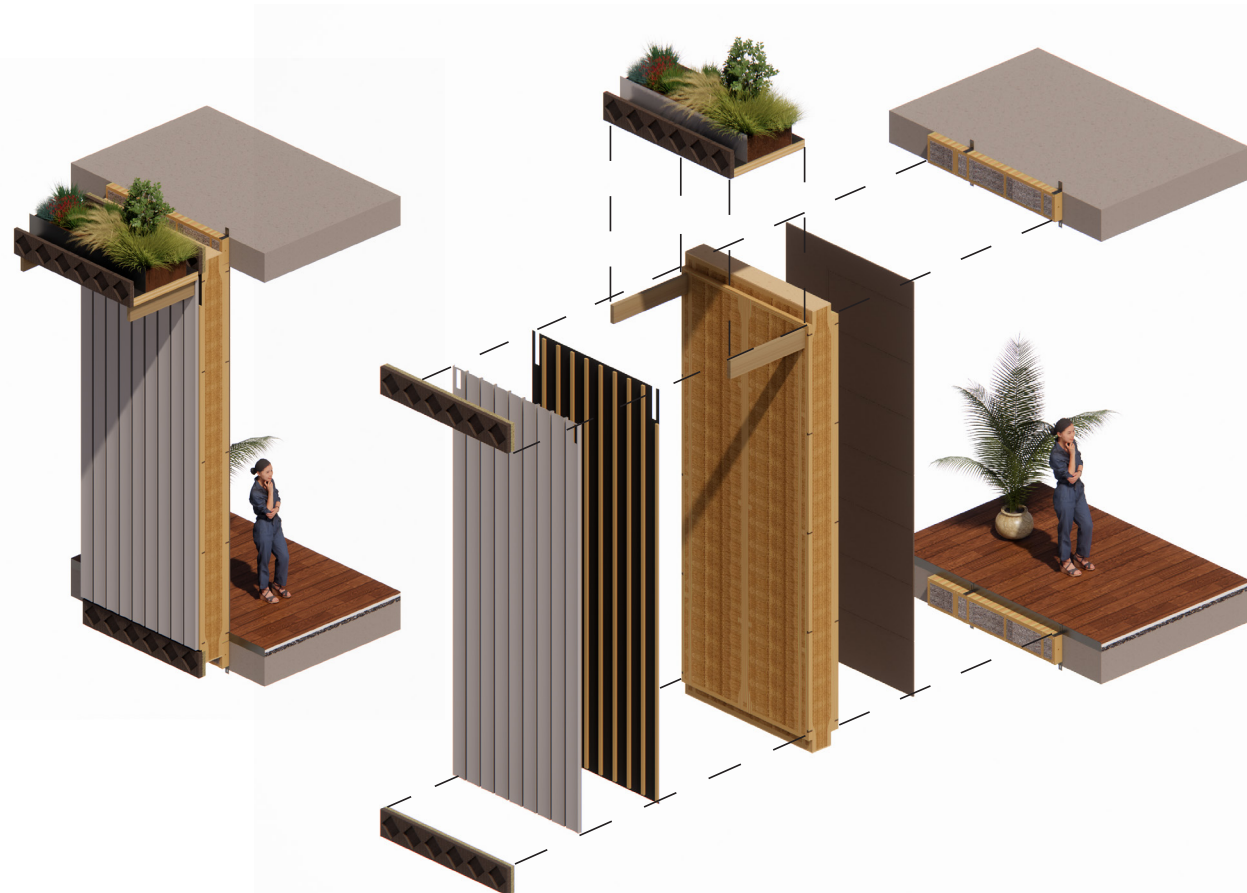


Scale 1 : 100

Typical fitout of loft



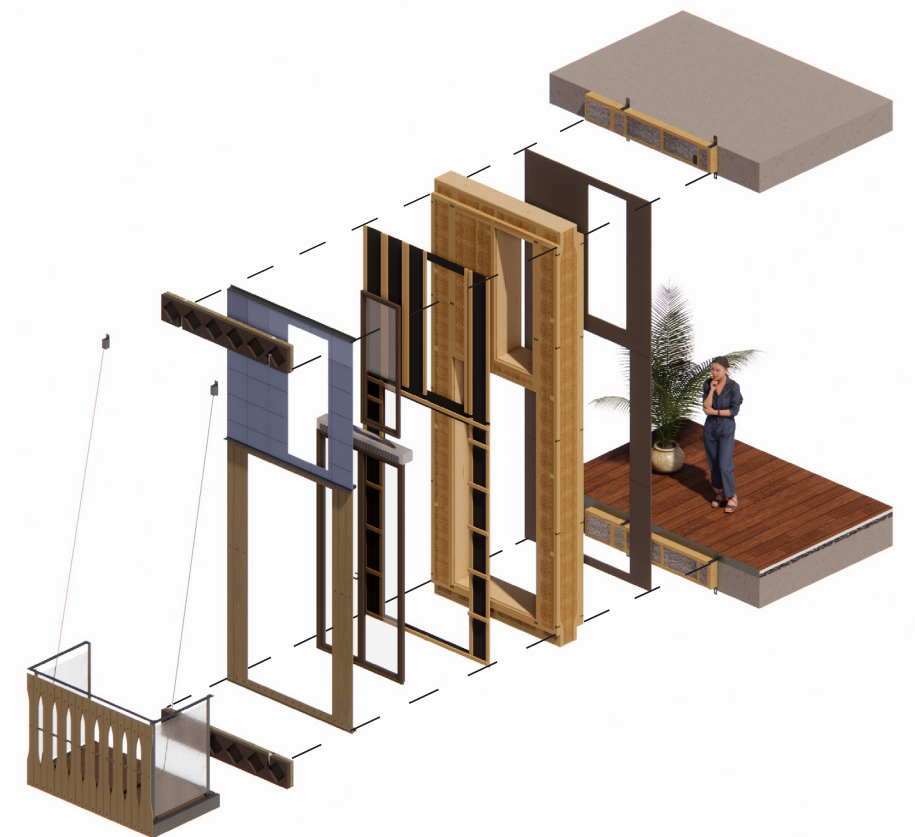
Facade typology



Type 1: outward facade

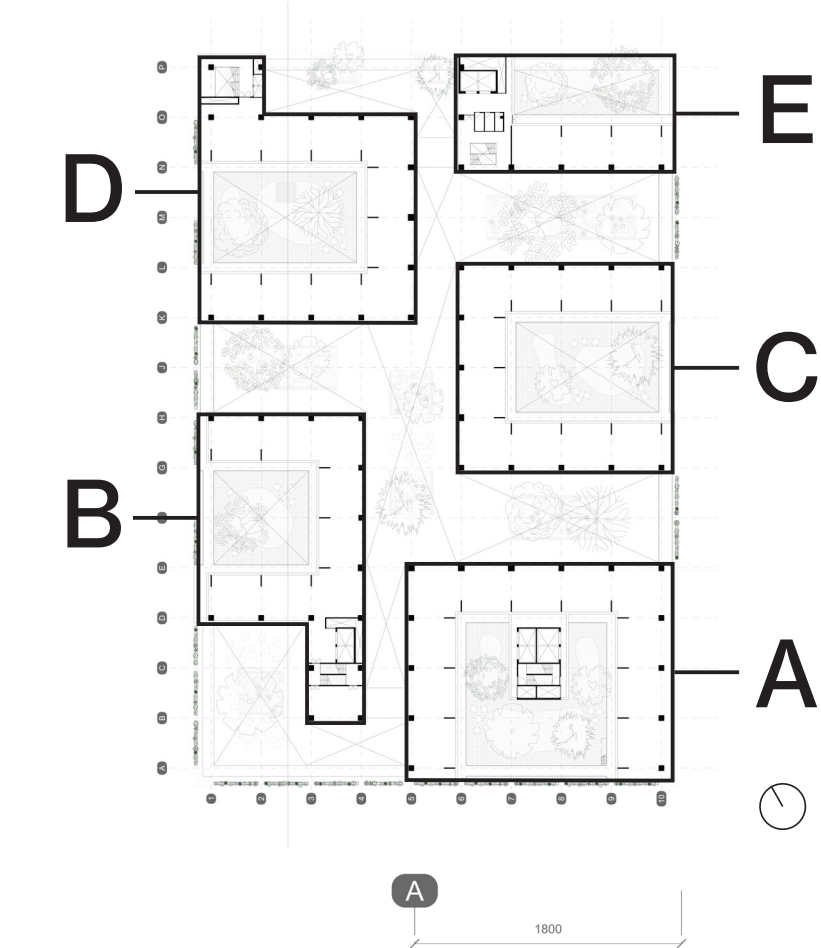


Type 2: french balcony facade inward surfaces

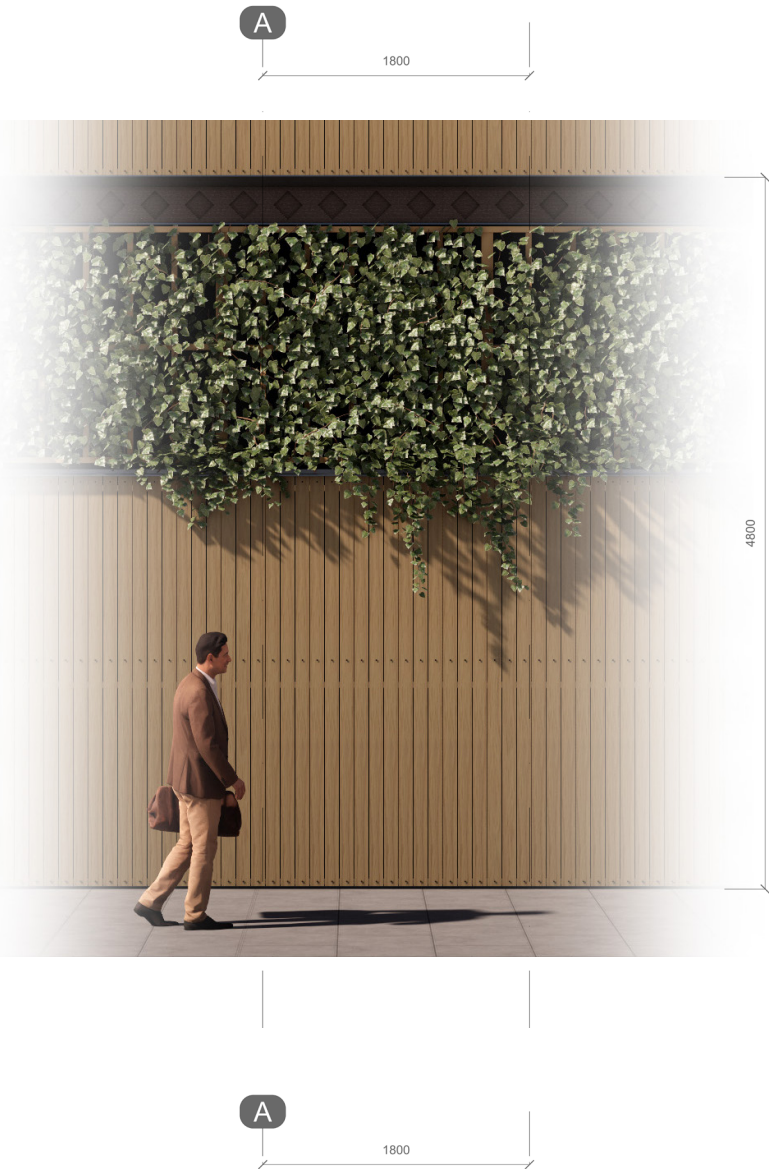


Type 3: balcony facade inward surfaces

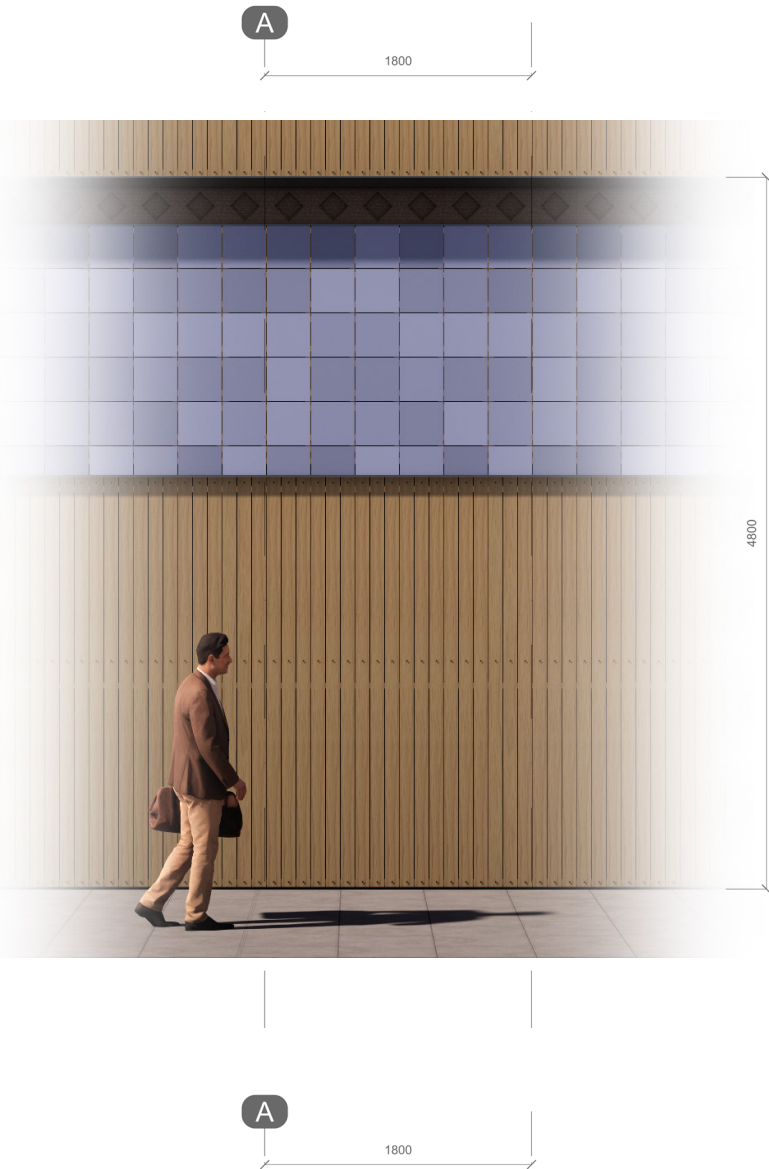
Facade types per block



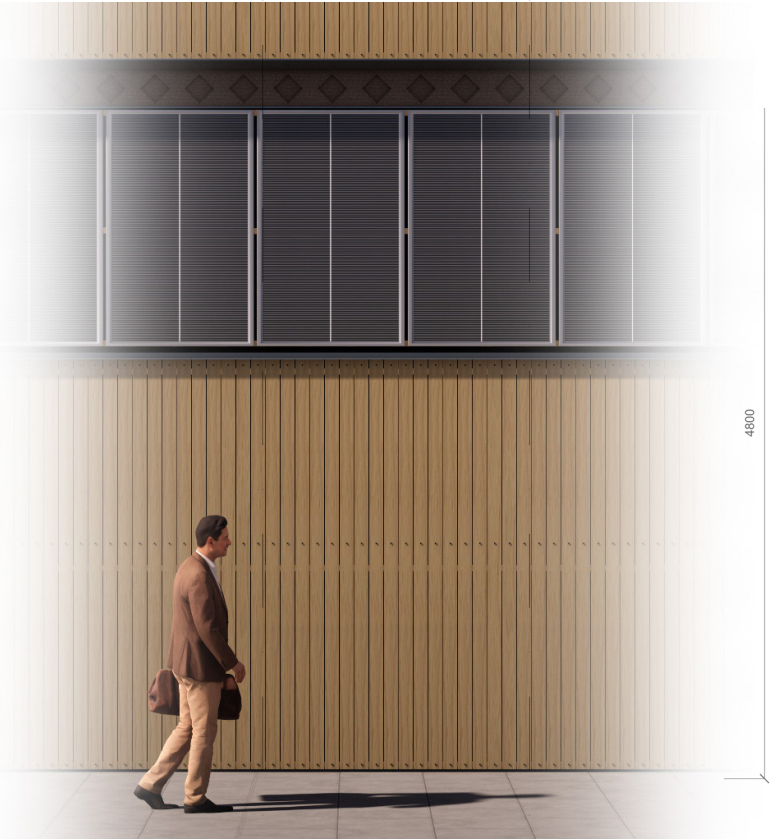
Facade type block A
Vertical garden



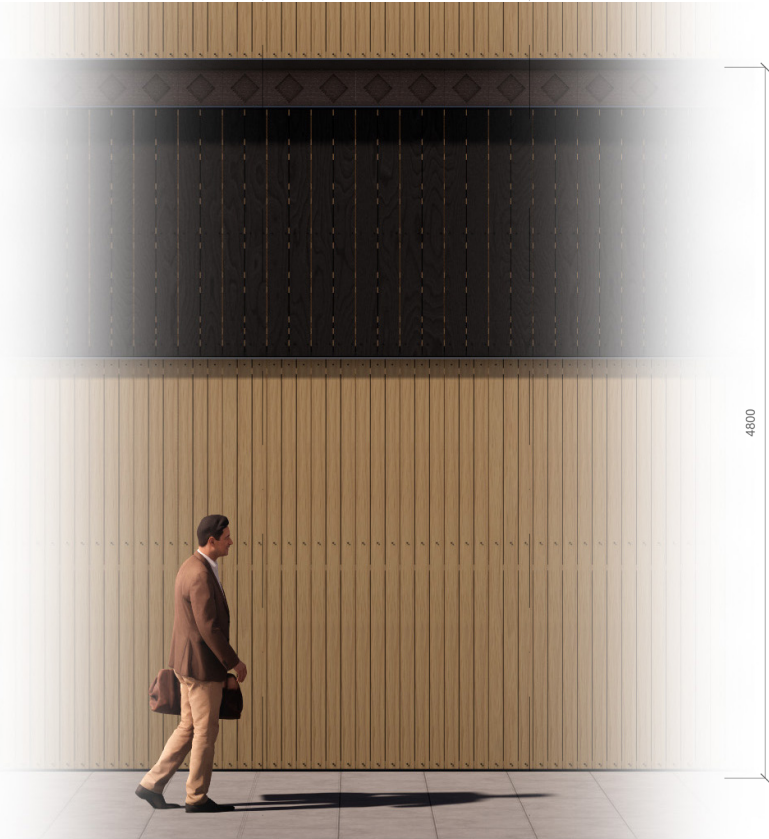
Facade type block B
Biocomposite tiling



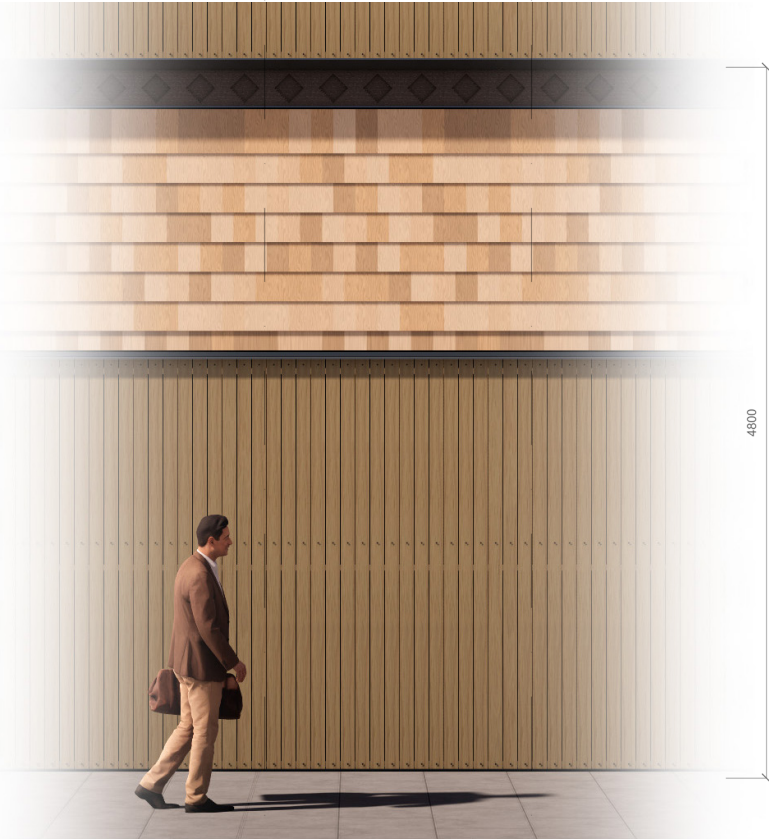
Facade type block C
PV-panels



Facade type block D
Shou Sugi Ban



Facade type block E
Chestnut shingles



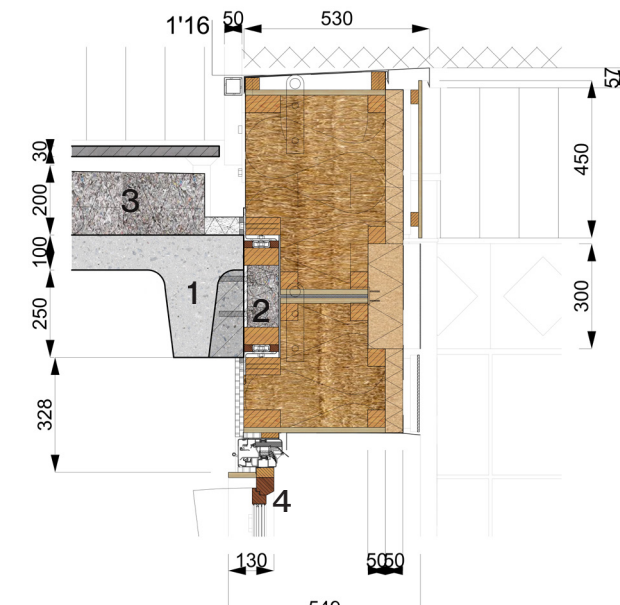


Facade Fragment

Scale 1 : 20

Details of connections

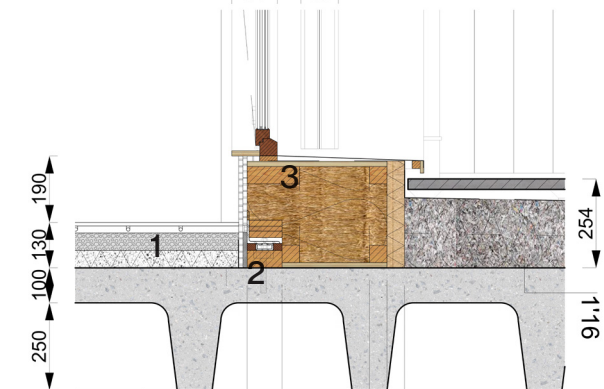
Scale 1 : 5



Detail 1

Gallery edge connection with facade opening:

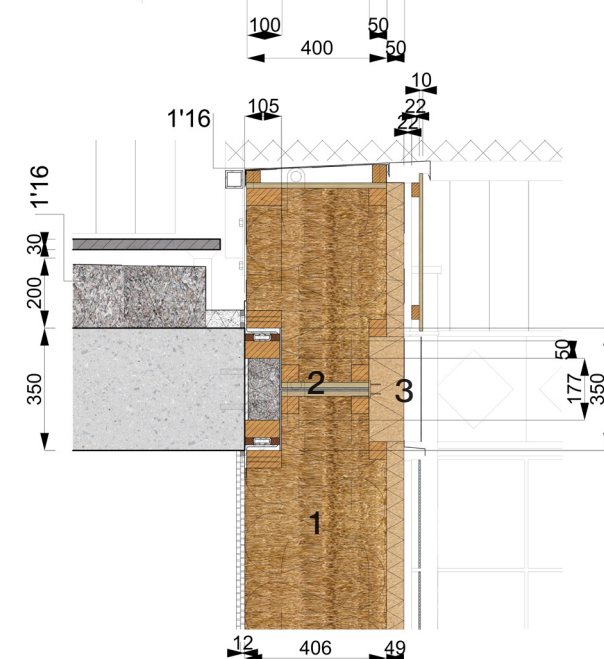
1. concrete cassette floor with healed concrete floor edge
2. Double timber frame floor edge ribbon with cellulose fiber insulation for cassette attachment
3. Hightened reused pavement for gallery slabs with cellulose insulation
4. Timber-straw cassette with operable window and ventilation grille



Detail 2

Dwelling facade connection to gallery with facade opening:

1. Concrete cassette floor with Biofoam EPS and gravel in carboard honeycomb structure, with floor heating and cooling
2. Single timber frame floor edge ribbon for cassette attachment
3. Pressed timber-straw cassette with operable triple pained window frame of teak and aluminium sill

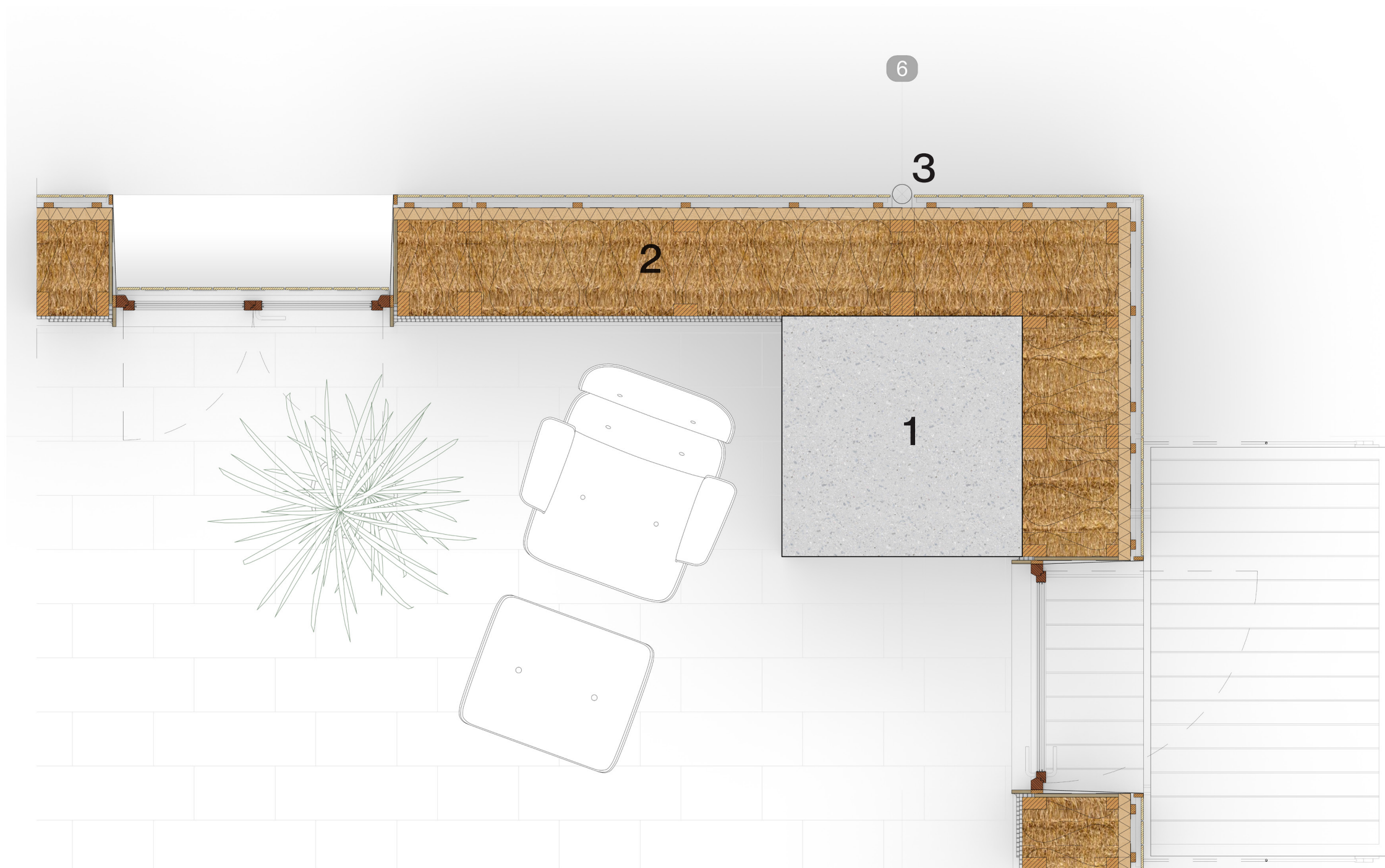


Detail 3

Gallery edge connection with enclosed facade:

1. Enclosed pressed timber-straw cassette with wood fibre board. Vertical timber cladding and Nabasco biocomposite as facade finish
2. Wool felt between cassette for wind and water proofing
3. Wood fibre board ribbon with nabasvo biocomposite finish on outside as secondary sealant

Horizontal detail of facade (connections)



Corner dwelling with balcony and french balcony:

1. existing concrete column
2. Enclsd pressed timber-straw cassette with interior clay board and exterior wood fibre board and wooden cladding
3. rain pipe
4. Pressed timber-straw cassette with facade opening and balcony. Teak, single door, triple glazed window frame. steel and wooden balustrade
5. Pressed timber-straw cassette with facade opening and french balcony. Teak, double door, triple glazed window frame. Steel and wooden balustrade

Scale 1 : 5

Interior impression of loft



Impression of courtyard



Impression from Jaarbeursplein



00 | Table of contents

01 | Problem statement & relevance

02 | The research: towards sustainable
facade culture

03 | The design: transforming the Beatrix-
gebouw Utrecht

04 | Reflection

Looking back: what was the process?

How do you assess the value of your way of working?

- Prototyping is fun.
- The planning is more difficult than the making.
- Unfortunately no time for climate testing.



Are there any specific things you would have done differently?

- Q2 time period was underestimated: too much planned in too little time.

Semester 1																																						
Site analysis	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	2.1	2.2	2.3	2.4	2.5	2.6		2.7	2.8	2.9	2.10																	
Month	September				October				November				December				January																					
Date	2/9 - 6/9	9/9 - 13/9	16/9 - 20/9	23/9 - 27/9	30/9 - 4/10	7/10 - 11/10	14/10 - 18/10	21/10 - 25/10	28/10 - 1/11	4/11 - 8/11	11/11 - 15/11	18/11 - 22/11	25/11 - 29/11	2/12 - 5/12	9/12 - 13/12	16/12 - 20/12	23/12 - 27/12	30/12 - 3/1	6/1 - 10/1	13/1 - 17/1	20/1 - 24/1	27/1 - 31/1																
Delivery	Design tutoring every Tuesday									P1	Design tutoring every Tuesday						Christmas Holidays	Design tutoring		P2																		
	Research tutoring every Wednesday										Research tutoring every Wednesday							Research tutoring																				
01 Introduction																																						
	Composing research plan																																					
02 The research: towards sustainable facade culture																																						
Part A	Collecting relevant case studies						Analyze facade climate				Analyze biobased materials			Analyze structures				Experimentation & facade design				Experimentation & facade design																
Part B																																						
03 The design: transforming the Beatrix gebouw Utrecht																																						
Site analysis														Site selection						Site selection																		

Thank you for listening

Questions?

