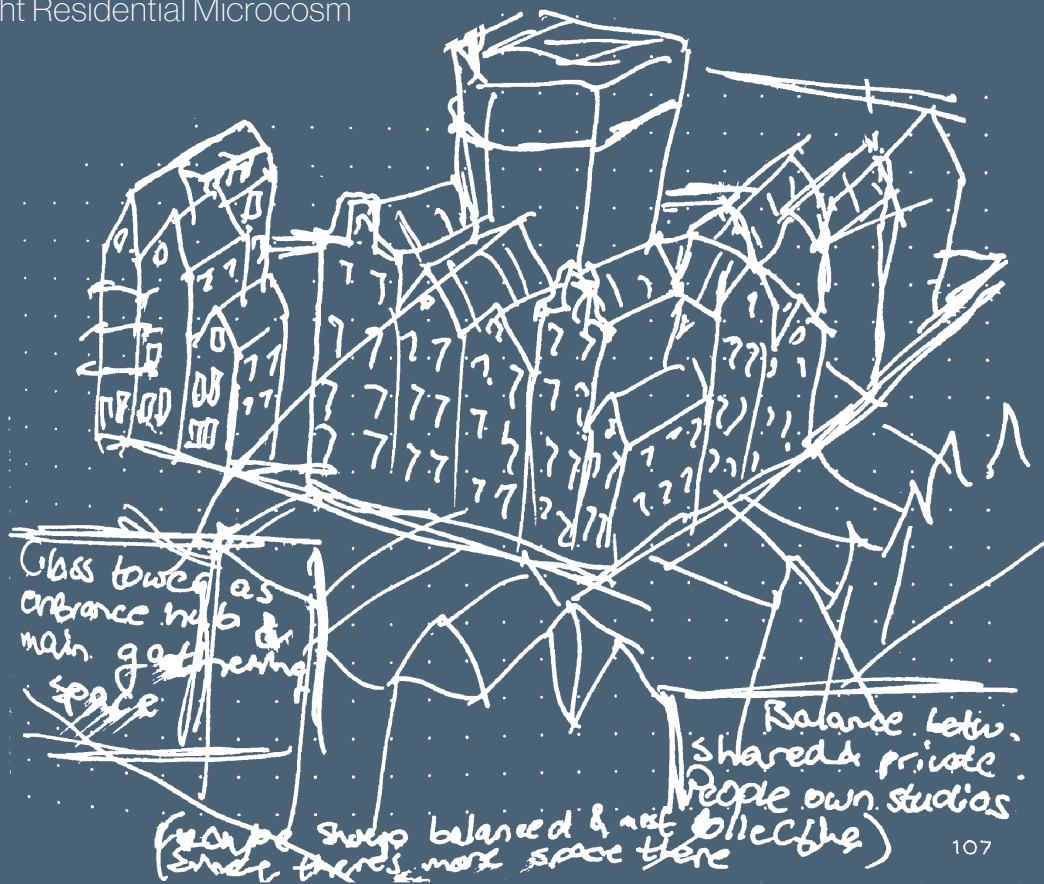


The lightweight revolution

Reimagining the Kalverpassage's roof as a
Lightweight Residential Microcosm



Colophon

Title The lightweight revolution
Subtitle Reimagining the Kalverpassage's roof as a Lightweight Residential Microcosm

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Abstract

As urban housing demand increases and available land becomes increasingly scarce, vertical densification offers an important strategy for adding dwellings within the existing city. This research investigates how the reduction of building mass can redefine architectural expression in residential timber top-ups, using the Kalverpassage in Amsterdam as a case study.

The project explores lightweighting as both a technical and architectural design method. Through comparative material studies, parametric structural evaluation, building-physics research, and iterative dwelling design, the study examines how mass can be minimized while maintaining spatial, structural, and environmental quality. The research focuses on four interrelated dimensions: load-bearing structure, building physics, dwelling allocation, and interior floor plan optimization.

The design proposes a lightweight timber top-up that responds to the existing structural grid, using optimized floors, columns, beams, and transfer trusses to reduce added load. Collective and private dwelling types are allocated according to structural capacity, while compact floor plans use vertical stacking, multifunctional space, integrated storage, and long sightlines to reduce required floor area. Building-physics performance is achieved through layered façade systems, acoustic decoupling, fire protection, solar shading, ventilation, and localized material mass.

The thesis concludes that lightweight architecture is not defined by thinness alone, but by the strategic organization of structure, space, climate, and detail.

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INTRODUCTION

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Problem statement

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Research objective

Research question

Research scope

BACKGROUND

The emerging Timber revolution

Throughout history, humankind has improved their habitat through the use of reliable materials that were available. Through technological advancements, a paradigm shift from traditional materials to steel and concrete was made, dominating the construction industry throughout the 20th century. Yet, with a growing awareness of the consequences of exploitation of earth's resources and boundaries, a reverse shift from these conventional materials has started towards environmentally friendly and renewable materials. This has been sparked by a paradigm shift from anthropocentric to ecocentric thinking, taking into consideration the influences on the planet as a holistic system (De Figueiredo & Marquesan, 2022). With the recent advancements and cost-viability in timber, the construction industry is drawn towards timber as viable construction material (Huang et al., 2024).

Engineered mass-timber products and modular timber systems have seen rapid market growth and adoption in mid- and high-rise projects over the last decade. Recent reviews and market analyses highlight mass-timber's rising share in new construction worldwide, revealing an emerging 'timber-revolution' (Abed et al., 2022).

Necessity to densify vertically

Earth is ever more urbanised, and people are flocking towards cities for economic opportunities and shared prosperities (Ritchie et al., 2024). On top of that, the human population keeps increasing above 10 billion in the coming decades (Lam, 2024). To accommodate for this growth in times of a pressing housing crisis, which is particularly present in cities like Amsterdam (Het Parool, 2024), vertically extending existing built footprints in urban areas to lower the burden on the planet is imperative. This provides more space for people to dwell, while maintaining space for nature to flourish.

Difference between timber and conventional construction materials

Structurally, timber differs from conventional materials, primarily in density and stiffness. This means that timber buildings can be substantially lighter for similar size. Whereas the public's perception of the light characteristics of wood limited the size and height of timber buildings in the 20th century (Huang et al., 2024), more recently, lightweighting is viewed as a strength. This has many advantages, especially in vertical densification cases (Foster & Reynolds, 2018).

Although it is both possible and desirable to design a building in such a way that its structural mass is put to good use in supporting other aspects of the building's function (the thermal and acoustic capacity for example), in many cases the structure's own weight is simply an additional cost. Lightweight structures minimize these additional costs by using materials with higher specific strength and stiffness (Foster & Reynolds, 2018).

Potential of densifying vertically

Many load-bearing structures and foundations of existing buildings work under their potential load-bearing capacity. Research states that: "for typical UK 1960s reinforced-concrete flats, columns may be working at only about 15% of their potential capacity" (Mei et al., 2024). This example may be extreme, but it does indicate that building structures work with margins, however extreme that may be. On top of that, long-term loads densify the soils underneath buildings, which increase the load-bearing capacity beyond the designed assumptions, which may allow for higher loads without taking strengthening measures (Glushkov & Glushko, 2018).

However, due to advancements in BIM technology, building structures have been optimized to reduce structural mass in the design process. "Optimised modern Eurocode steel designs indeed show smaller average reserve (~10%) than more conservative or older-code designs (~20–30%+)" (Gillott et al., 2024).

Several papers stress the drive to reduce material use and cost via more accurate modelling and code calibration, implying designs closer to true capacity while still safe (Eslami et al., 2025).

Problem statement

Emergence of a new lightweight architecture

As Foster and Reynolds (2018) put: *“Although cost-effective use of materials is generally recognized as desirable, a deliberate strategy of mass reduction through material substitution is not widespread in the building sector”*. Thus, stating a mismatch between the sector’s desirability and common practice, despite the value of mass reduction. They continue: *“using less material to provide the same service is a matter of good design”*.

When weight is considered a constraint, new types of architecture emerge of which timber takes an important role. With the removal of the presence of mass, buildings must rely on other systems to control their performance to not compromise on quality. Where weight was a contributing factor to acoustics, thermal functioning and load-bearing capacities, the removal of this factor means there should be alternate systems to make up for this loss (Foster & Reynolds, 2018). As Allwood et al. (2011) state: *“There appear to be many options for reducing the mass of material required to deliver material services, but this area has had little exploration”*. Thus, as of today, exploring these systems is deemed architectural pioneering.

Once the possibilities of structural lightweighting have been conveyed, and the constraints related to minimising weight have been addressed, lightweight architecture has the potential of striking a revolution in the building sector. In terms of topping up, minimising weight enables maximising space on an existing host structure. Hence the philosophy: less weight is more space.

Problem statement

The housing crisis and increasing scarcity of urban land create an urgent need for vertical densification within planetary boundaries. Building top-ups offer a way to add housing without occupying additional ground. To maximise this potential space that can be added on the existing foundations, the added mass of the top-up must be minimised. However, as weight-constrained design remains an uncommon architectural practice, its structural, spatial, and expressive implications require further exploration.

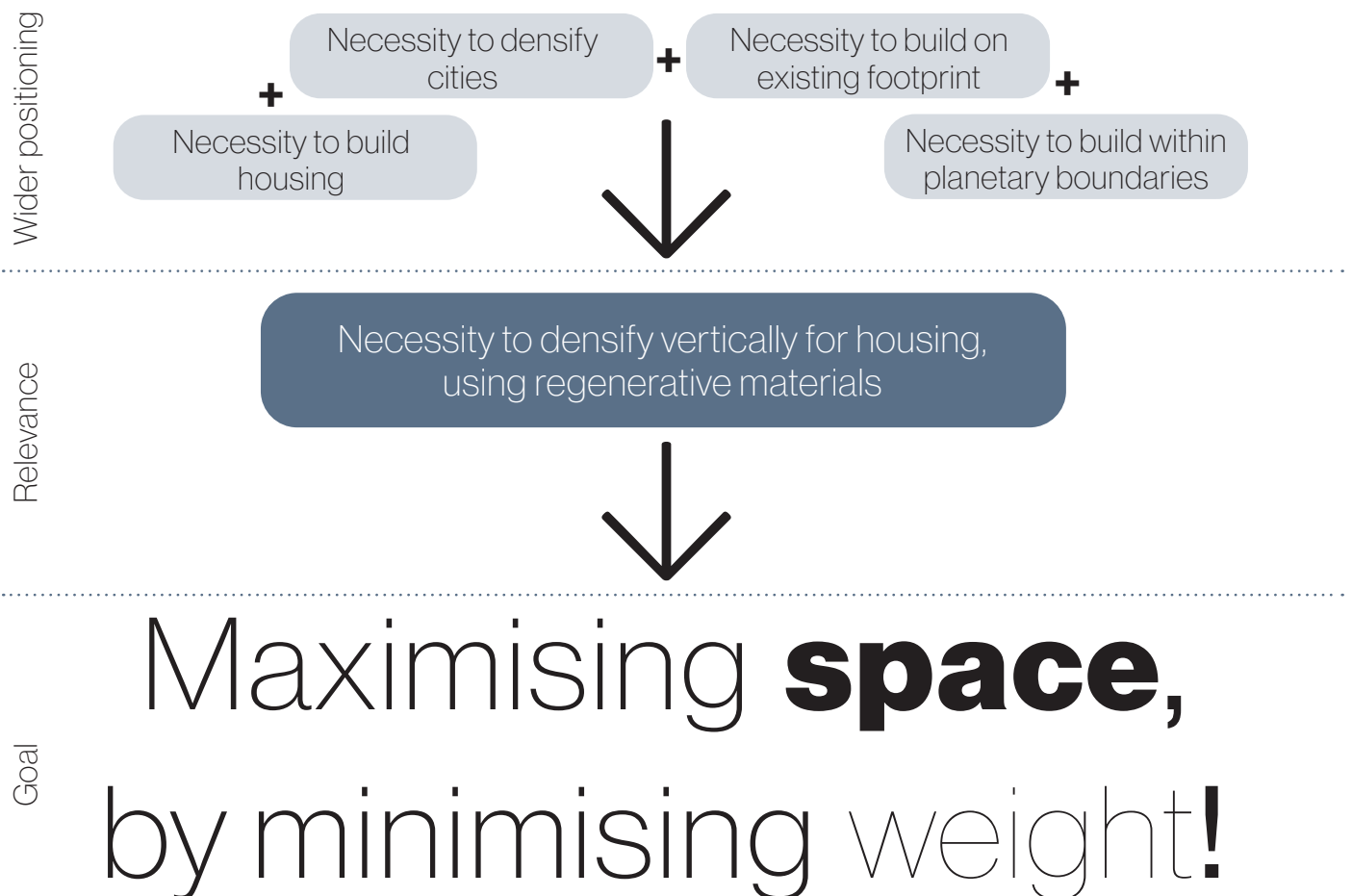


Figure 1. Research aim scheme ▲

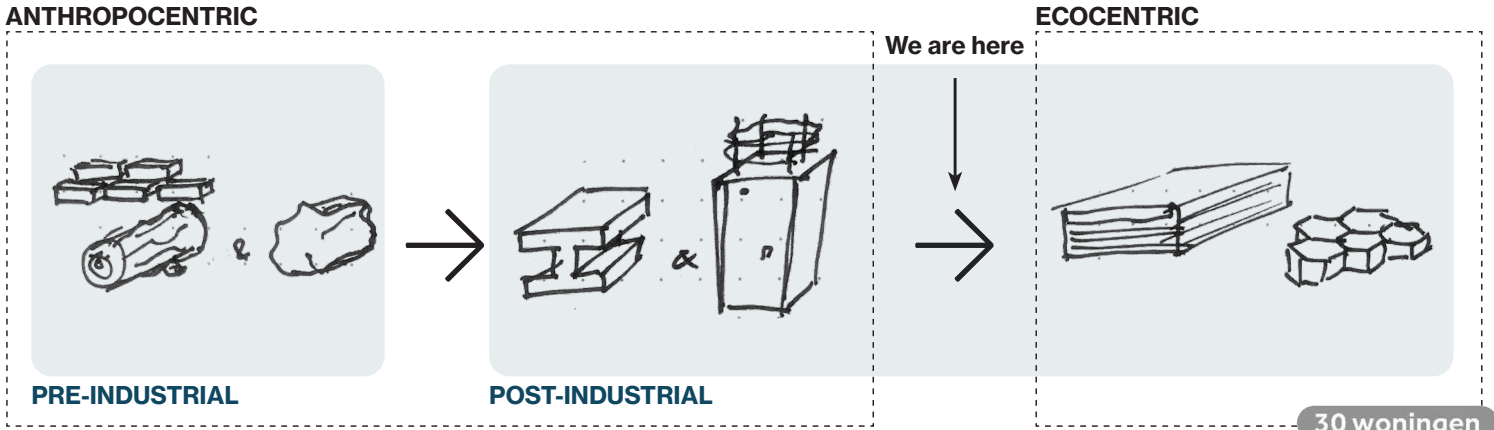


Figure 2. Material use discourse ▲

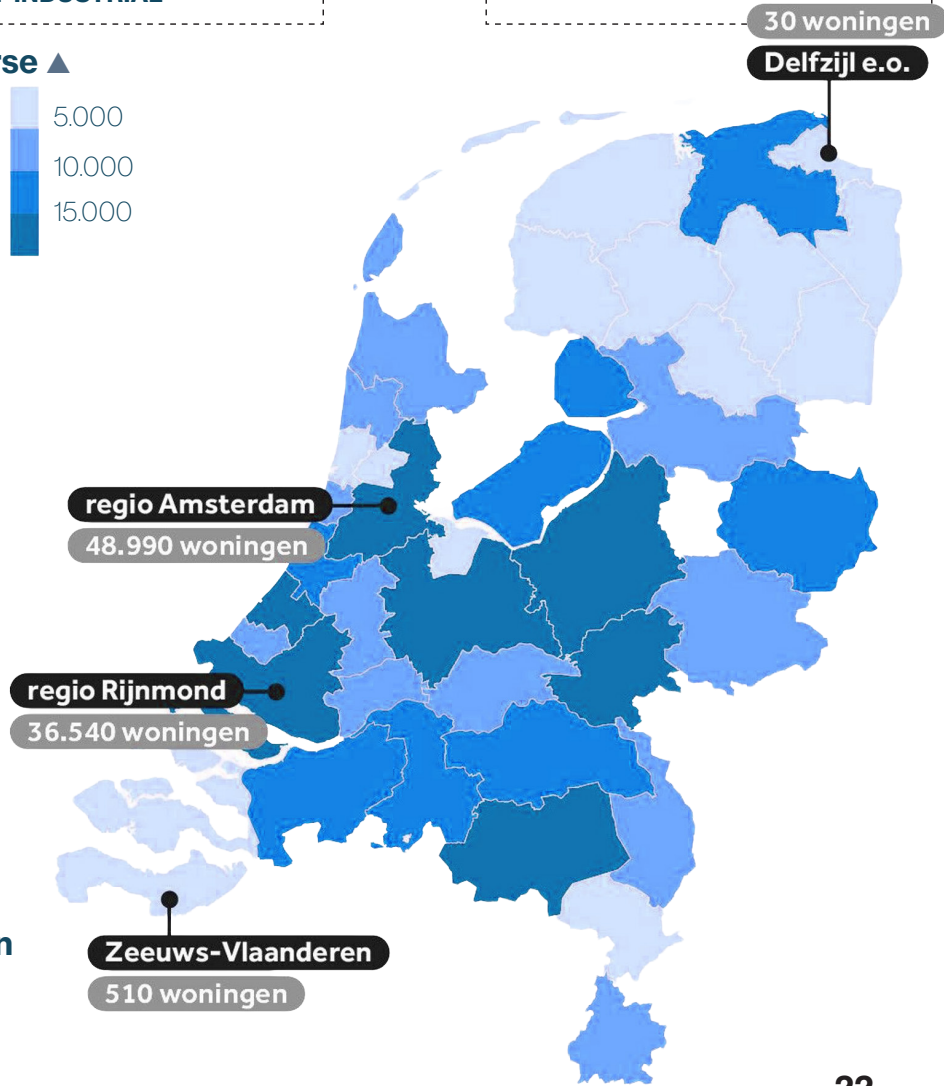
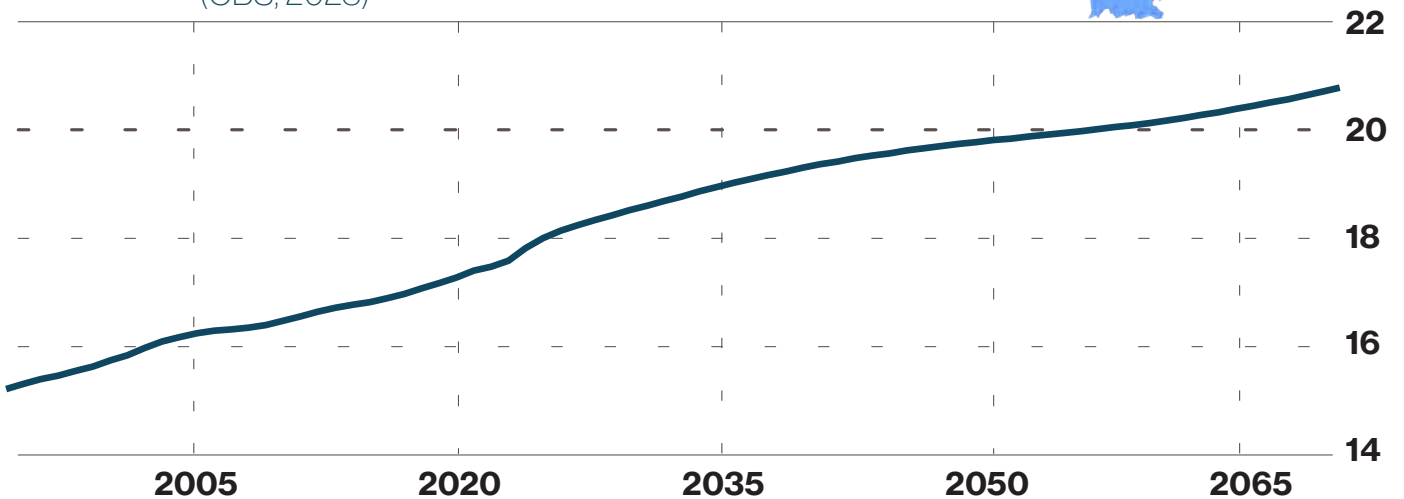


Figure 3. Housing shortage as of 2023 ▶
(NOS, 2023)

Figure 4. Projected population growth in the Netherlands ▼
(CBS, 2023)



Project setup

Research objective

The aim of this research and design project is to understand how lightweighting in architecture results in different architectural expression. The purpose of implementing lightweight principles in a building is to minimise the self-weight and thereafter to enable the maximization of the addition of housing on top of an existing built footprint. Therefore it is imperative to investigate the relations between material properties, timber systems, and building performance regarding their weight. This gives insight into lightweighting in the construction industry. In turn, lightweighting strategies in timber construction can enable the maximisation of residential floors added to existing buildings, without compromising on living quality.

Research question

Contemporary challenges lie in the ongoing trends of housing scarcity and population growth, for which there is an urgency to densify within the existing urban fabric and within planetary boundaries. Within this discourse, vertical densification emerges as a spatially efficient strategy. Yet, conventional building methods for vertical densification are challenged by their embodied carbon and the structural limitations of existing buildings. This raises the question of how alternative lightweight construction methods, particularly mass timber, may offer new possibilities for vertical densification within planetary and urban limits. This leads into the main research question:

Research scope

The project adopts a research-for-design methodology, combining technical measurements with architectural experimentation. With the limited understanding to lightweighting in multi-storey structures, it is deemed a project of pioneering. Within a defined urban context, the scope is limited to vertical densification using a post-and-beam timber system. Structural behaviour and material properties are studied through parametric modelling, allowing to explore the building's weight systematically on a large scale. In doing so, the research does not aim to deliver a fully engineered structural design, nor to optimise a single building solution in detail. Instead, it focuses on comparative evaluation and conceptual optimisation of timber systems to inform architectural decision-making throughout the design stages. Parametric modelling is therefore used as tool to test and refine relations between structure and material which directly informs the architectural design. For uniform comparison, the unit of kg/m^2 is used for quantifying the effectivity of the lightweighting strategies in the parametric research environment.



How does the reduction of building mass redefine architectural expression in residential timber top-ups?

The sub-research questions:

1. How can the load-bearing structure of residential timber top-ups be designed to minimize structural mass through optimized grids and structural components?
2. How can lightweight timber top-ups achieve comparable building-physics performance to conventional high-mass construction?
3. How do dwelling configurations influence the structural mass of lightweight timber top-ups?
4. How can interior space optimization contribute to the reduction of residential floor area in lightweight housing?

2.

RESEARCH- FOR-DESIGN METHODOLOGY

Methods

Project timeline

Theoretical framework

Methodology

In line with principles of material efficiency, the method focusses on minimizing self-weight as main objective, since this is an important factor in vertical extension of existing buildings (Foster & Reynolds, 2018).

This approach is situated within a 'research for design'-framework, in which quantitative research is computationally put together to generate insights that inform architectural reasoning. This is subsequently translated into architectural design proposals, forming a technical, spatial, and material foundation to be articulated.

This methodology is divided into three parts, which are spread across three chapters. For each chapter, the introduction includes a flowchart of the methods used. These are also explained in text form here.

Data gathering & Comparative studies

When dealing with lightweighting, a material choice is always based on density and performance. Therefore, it is imperative to be deliberate about material choice. This method encompasses both the gathering of data, and the comparing based on performance. The gathering happens in a similar way:

- Materials are enumerated, and quantitative data on their performance is traced. Data is collected from manufacturer datasheets, technical handbooks, and relevant literature, focusing on properties of which most importantly: density.
- Materials are compared through comparative studies, which are set up based on the purpose that the material is intended to serve. This study happens on multiple scales, for different purposes, and thus may take different approaches.

The collected data is translated into comparable units, such as kg/m², which allows different materials to be evaluated quantitatively. The aim is to establish a hierarchy of strategies showing where mass can be reduced in the most efficient way.

Parametric workflow

The parametric workflow is part of the comparative study, going in-depth using parametric. The main here is to address the research question by systematically investigating how lightweighting in timber construction can maximise structural capability. Parametric modelling enables to explicitly identify relations between material properties, geometric parameters, and building performance, allowing architectural and structural behaviour to be explored simultaneously (Oxman, 2006). The parametric model is structured to incorporate material properties and structural rules derived from Eurocode standards, enabling performance-based comparison.

In the context of this research, the model enables the direct coupling of timber structural configurations with quantitative outputs of self-weight and dimensions. By fixating a multitude of parameters (like span dimensions, loads and structural system) and varying a set of parameters (like structural system and wood type) the model allows a wide range of timber configurations to be evaluated on weight and load-bearing capacity under similar circumstances. The capability of creating 'associative geometry' allows to "experiment with many different design scenarios and dynamically assess the structural impact of alternative global forms" (Shea et al., 2004).

The aim of the parametric workflow is the comparative evaluation of design variants, of which the parametric model functions as a structural optimization tool, identifying configurations that maximize load-bearing capacity relative to weight.

Building physics desk research

Building-physics desk research was used to establish the technical principles that inform the design of the lightweight timber top-up. The research consisted of literature review and product-oriented market analysis. Literature sources, including *Architectuur als klimaatmachine* and *Bouwfysica*, were used to identify the diverse principles related to building physics.

This theoretical knowledge is complemented by the data gatherings for different building materials. The aim was to translate building-physics principles into applicable material choices, detail packages, and overall climatic interventions. The findings serve as design input for the development of lightweight building systems that help in reducing building mass, as well as make up for it.

Iterative floor plan exploration

An exploration in lightweighting floor plans is conducted through an iterative process of research-for-design and research-by-design methods.

This involved going to a 'small living' exhibition and studying reference cases. Spatial principles were sought and tested through the making of repeated floor plan iterations.

The aim of this exploration is to identify the relation between living and lightweight units, and come up with dwelling units that integrate these principles.

How does the reduction redefine architectural in residential

Load bearing structure

Post & Beam-structure

1. Floor elements
2. Beams
3. Columns
4. Truss

Housing configuration

1. Degree of collectivity
2. Unit form factor

of **building mass** **expression** timber top-ups?

Building physics

1. Acoustics
2. Sun protection
3. Temperature
4. Ventilation
5. Facade tectonics

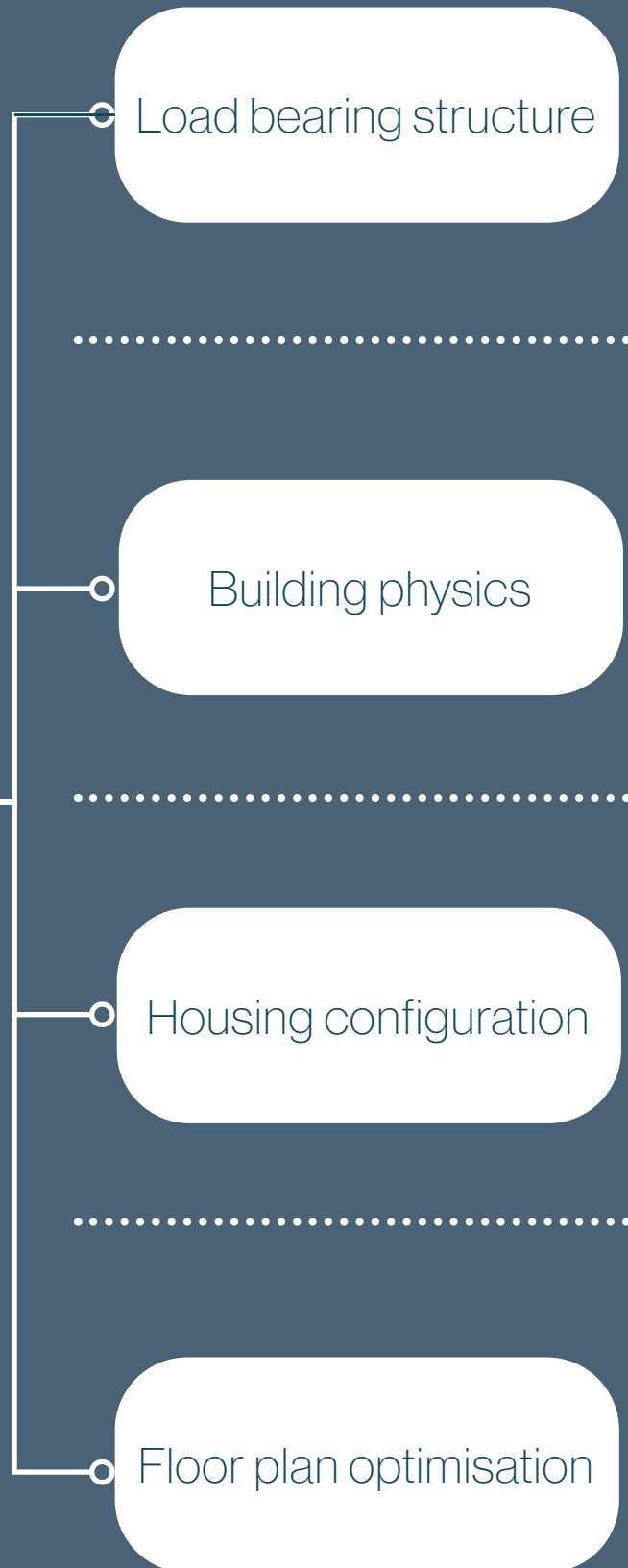
Floor plan optimisation

1. Space saving layouts

Lightweighting

Problem statement

The housing crisis and increasing scarcity of urban land create an urgent need for vertical densification within planetary boundaries. Building top-ups offer a way to add housing without occupying additional ground. To maximise this potential space that can be added on the existing foundations, the added mass of the top-up must be minimised. However, as weight-constrained design remains an uncommon architectural practice, its structural, spatial, and expressive implications require further exploration.



Relevance	Aim	Research questions	Method	Intended outcome
The primary structure is one of the largest contributors to added building mass and determines the feasibility of topping-up existing buildings.	To identify structural strategies and principles that reduce the mass of the load-bearing structure.	How can the load-bearing structure of residential timber top-ups be designed to minimize structural mass through optimized grids and structural components?	Comparative timber product study, parametric Grasshopper evaluation, Eurocode-based checks, structural grid comparison, transfer truss exploration.	A set of lightweight structural principles and component choices for floors, beams, columns, and transfer structures.
High-mass construction often provides acoustic comfort, thermal buffering, and fire resistance through material weight. Lightweight construction must achieve these qualities through alternative strategies.	To understand how comfort, safety, and environmental quality can be maintained without relying on mass.	How can lightweight timber top-ups achieve comparable building-physics performance to conventional high-mass construction?	Desk research, material comparison, façade and detail studies, acoustic/fire/thermal strategy analysis, evaluation of passive and active environmental systems.	A layered building-physics strategy based on acoustic decoupling, fire encapsulation, cavity barriers, solar protection, ventilation, and localized mass.
Housing typology affects imposed loads, span requirements, structural transfer, and the relationship between collective and private space.	To determine how different dwelling arrangements can reduce structural demand while supporting domestic and collective life.	How do dwelling configurations influence the structural mass of lightweight timber top-ups?	Typological comparison, collective/private load analysis, parametric dwelling allocation, relation to existing structural grid and transfer zones.	A load-responsive dwelling allocation strategy that positions heavier collective spaces above stronger structural zones and lighter private dwellings where transfer is required.
Reducing dwelling area reduces the amount of structure, façade, roof, and services required, but must not compromise spatial quality.	To explore how compact dwellings can remain spacious, usable, and comfortable through intelligent spatial organization.	How can interior space optimization contribute to the reduction of residential floor area in lightweight housing?	Floor plan studies, compact living precedents, spatial efficiency analysis, furniture integration, vertical stacking, sightline and storage strategies.	A set of spatial design principles for compact lightweight dwellings, including multifunctional rooms, integrated storage, vertical layering, and long sightlines.

3.

INTRODUCTION TO THE KALVERPASSAGE

Site location: the Kalverpassage

Strategic urban analysis: Amsterdam

Site history

Existing building

Existing context

Design objective

Design challenges

Design questions

Design concepts and criteria



Strategic urban analysis of Amsterdam

The purpose of this analysis is to obtain a general overview of potential locations where adding additional living space through rooftop could create added value on a larger scale. The type of rooftop addition envisioned is therefore intended for residential use. These are, in other words, places where additional people will live. The community aspect of residential use is a key priority.

The area analysis takes the following points into consideration:

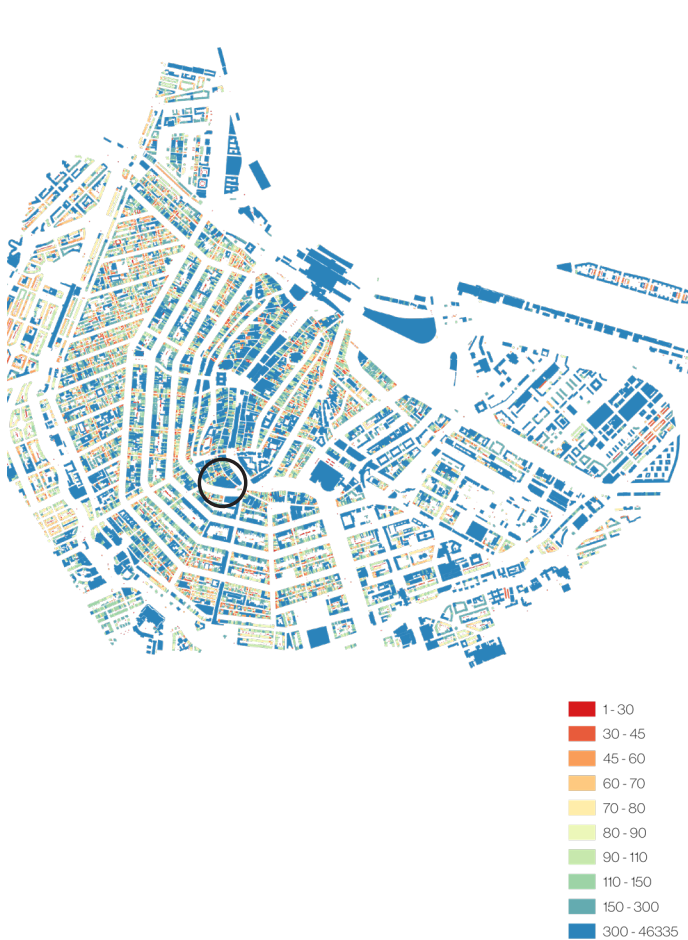


Figure 5. Building footprint

In order to maximize the number of housing units in a challenging, densely built-up location, a larger footprint offers more potential for rooftop.

Blue indicates large building footprint.

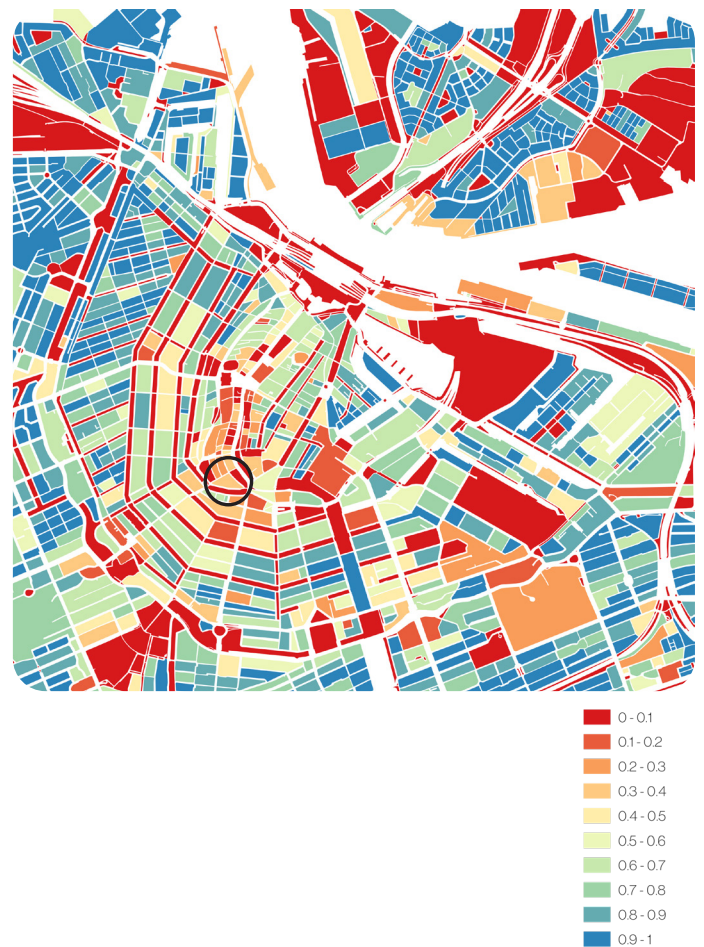


Figure 6. MXI (Mixed-use index)

The MXI indicates either a high, low or balanced housing - not-housing division. The center of Amsterdam, in particular, has areas with many non-residential functions. It is attractive to add residential space there.

Blue indicates high housing allocation.

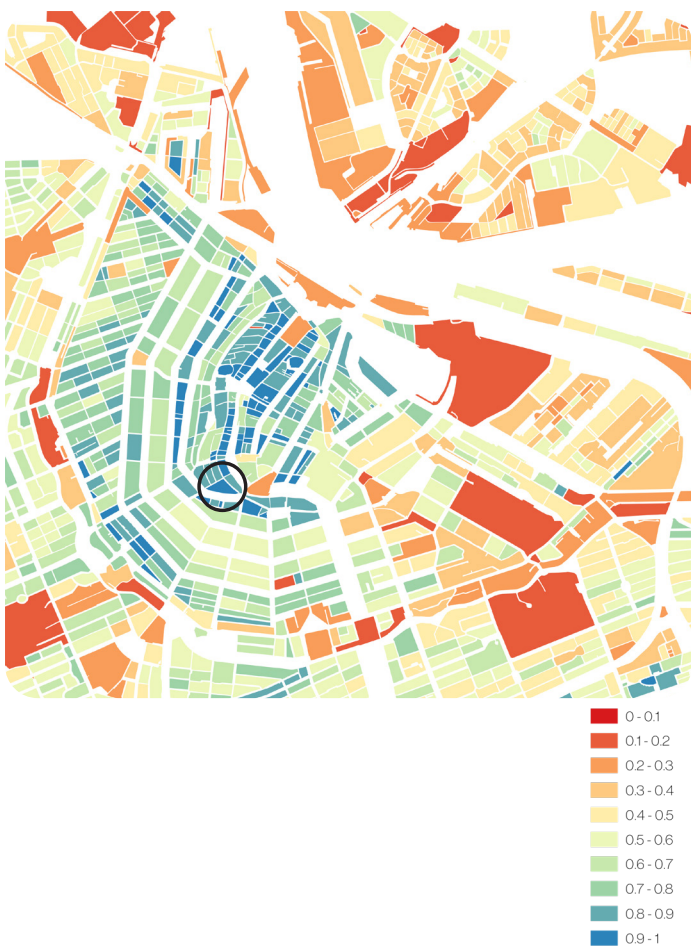


Figure 7. GSI (Ground-space index)

The GSI indicates where space is more limited than available. That makes it a more potential method for densification in some locations than others.

Blue indicates where space is limited.

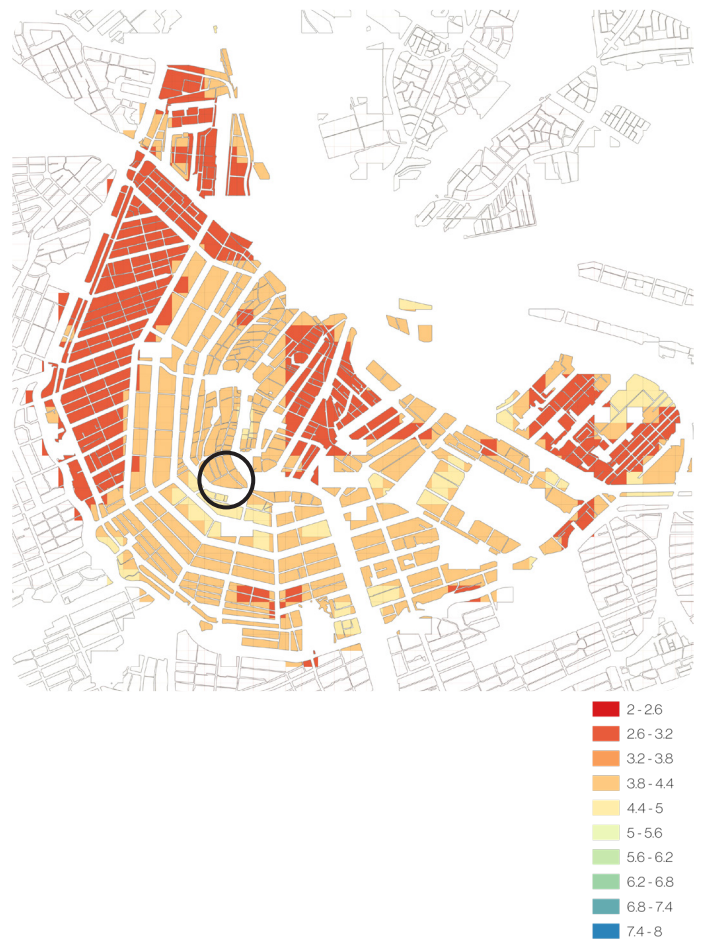


Figure 8. Social cohesion

With the aim of creating a residential complex that prioritizes the community aspect, it is advantageous to select a location where social cohesion is low. This is low throughout Amsterdam, and is particularly low in the Jordaan, the Red Light District, and the Eastern Harbor Islands.

Blue indicates high social cohesion

Based on the above criteria, a composite index has been calculated to indicate the potential for housing. This index aims to quantify where the addition of housing could bring value on the urban scale in terms of social cohesion, locally mixed-use neighbourhoods, and liveliness. It is a socio-spatial index which is different to the optop-potential map of Gemeente Amsterdam, as shown in the appendix.

The chosen spot is the Kalverpassage, because of its strategic situation in the broader urban fabric.

Optop index for housing

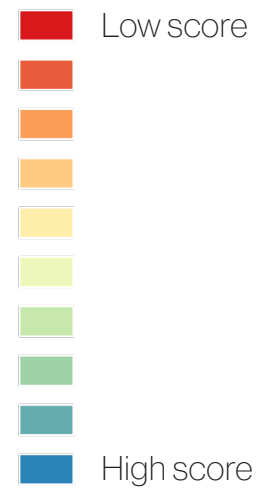


Figure 10. Composite optop index for housing in central Amsterdam



Figure 11. Birds-eye view of the Kalverpassage

Urban analysis of local context

The Kalverpassage is located in the centre of Amsterdam, between the Singel, the Kalverstraat and the Heiligeweg. The latter two are major shopping streets in Amsterdam, and well known nationally.

The site is historically layered, being just a stone's throw from Dam Square. The buildings date back as far as from the 16th century. Due to the historical streetscape, it is at the edge of a UNESCO world heritage site: de Grachtengordel. This edge location is in the buffer zone, where strict rules apply to the modification of the the current streetscape and its visual quality.

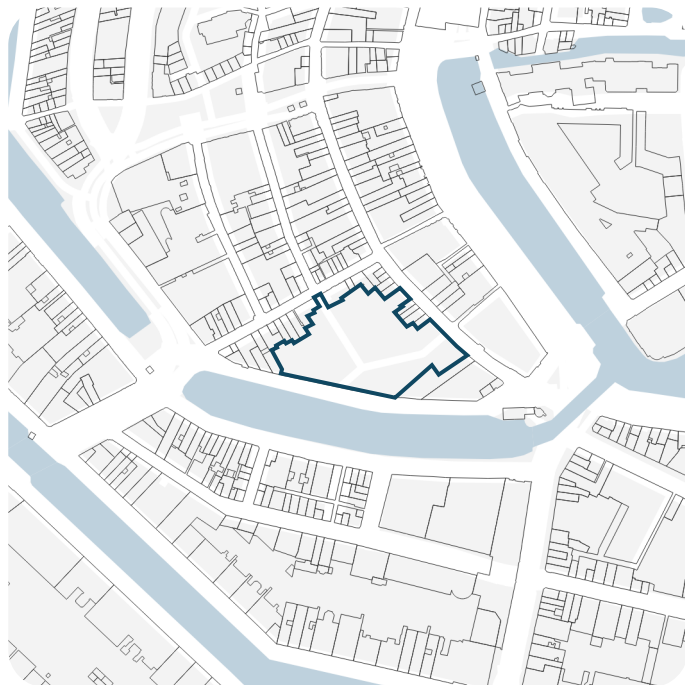


Figure 12. Kalverpassage 1:500

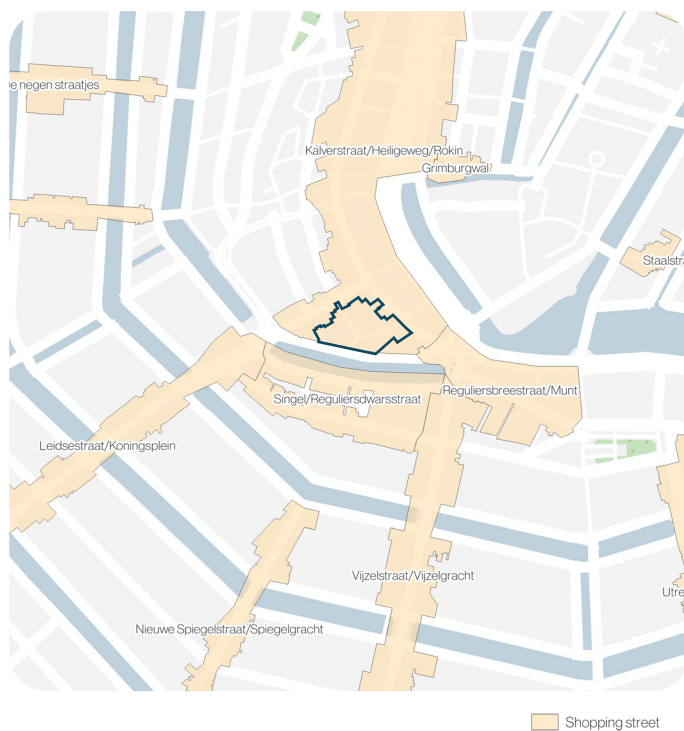


Figure 15. Shopping street network 1:1000

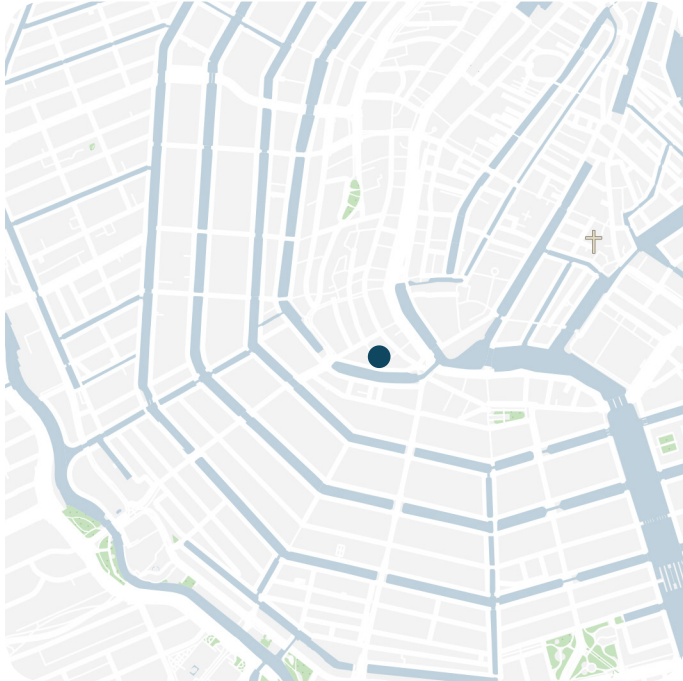


Figure 13. Neighbourhood 1:2500

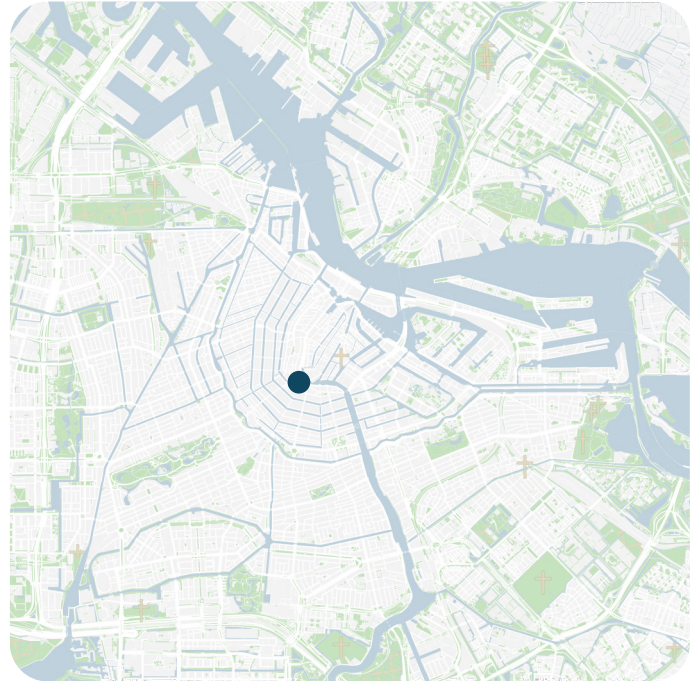


Figure 14. City 1:10000

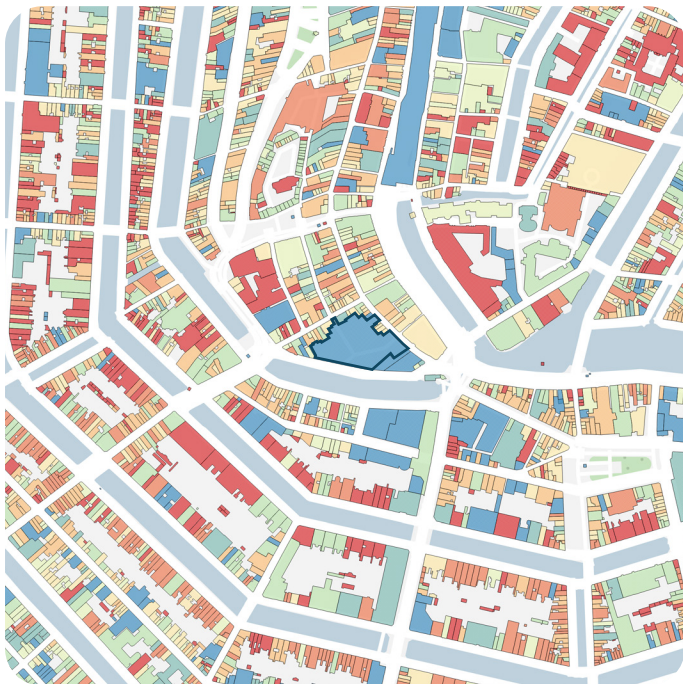


Figure 16. Building ages 1:1000

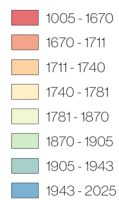


Figure 17. Heritage sites 1:1000



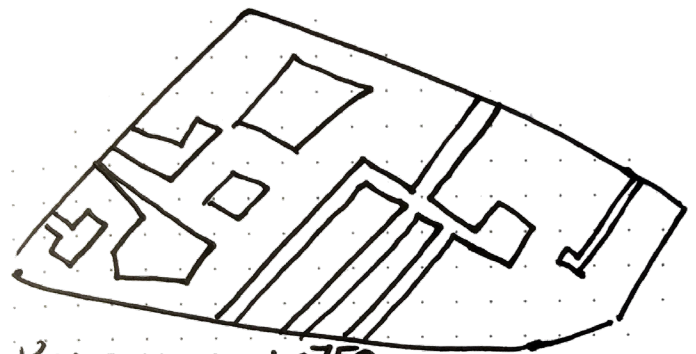
Historic analysis: Kalverblock

The earliest records of the current block in which the present-day Kalverpassage is located was being a monastery since the 16th century.

After that, it served as prison, commonly known as '*Het Rasphuis*', in the 18th and 19th century. Prisoners used to grate wood for the production of paint here. The entry gate on the Heiligeweg dates back to that period.

In 1892, the prison was demolished to make way for the construction of a swimming pool: the *Heiligewegbad*, which was the largest in Europe at the time. This pool stood here until 1990, when it was demolished due to its poor state.

Already from early 1800 the building blocks were consolidated and outer street layout has not changed since. Yet, within the block, parcels changed a lot through time. The Kalverblock used to be porous, but through time, streets and buildings merged leaving a fully built footprint since the arrival of the Kalverpassage.



Kalverblock ± 1750
A dense but porous building block.

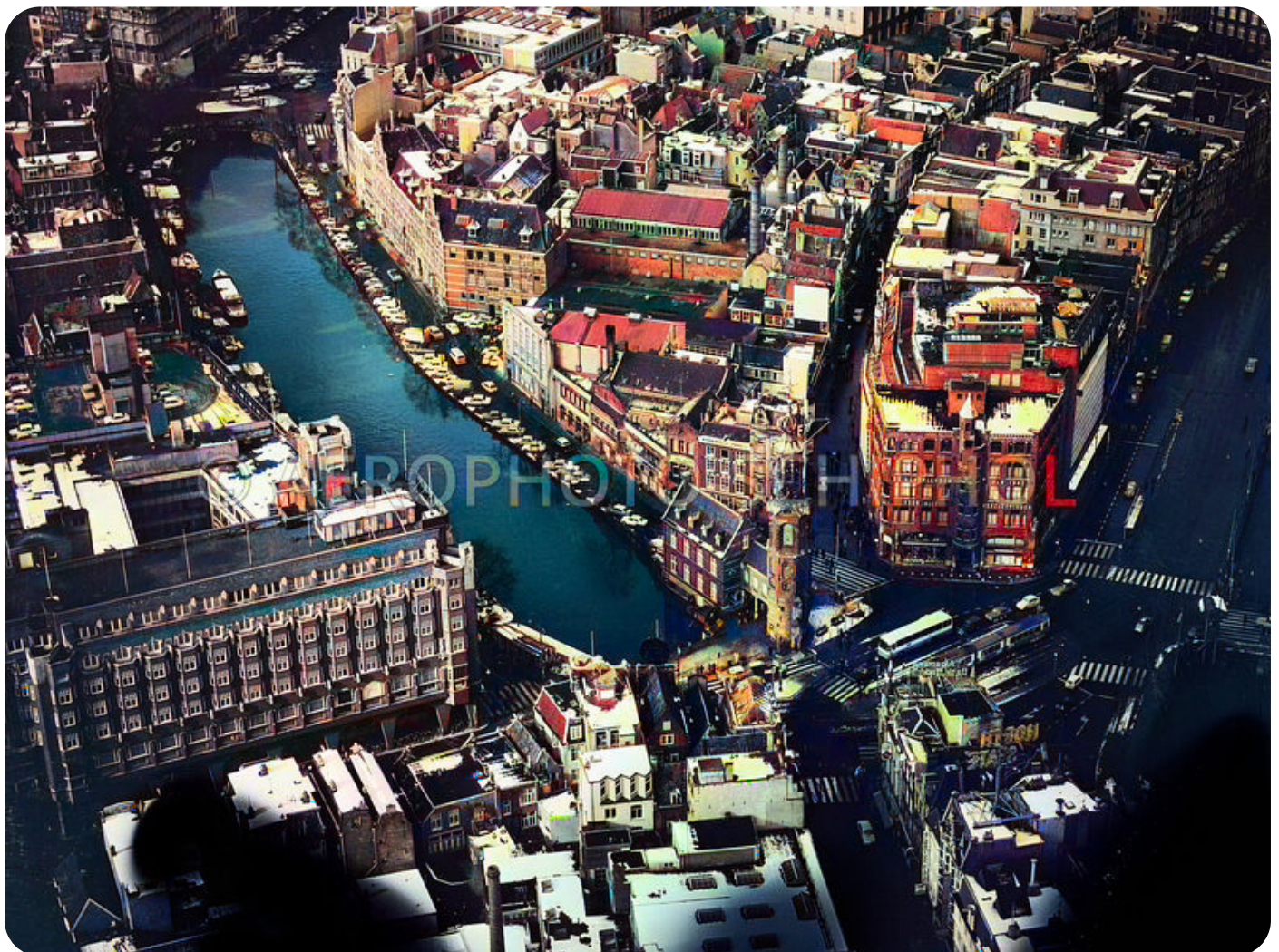


Figure 18. Aerial view of Kalverblock in 1960
(Gemeente Amsterdam)



Figure 19. Historic map from 1840
(Topotijdreis)



Figure 20. Historic map from 1900
(Topotijdreis)

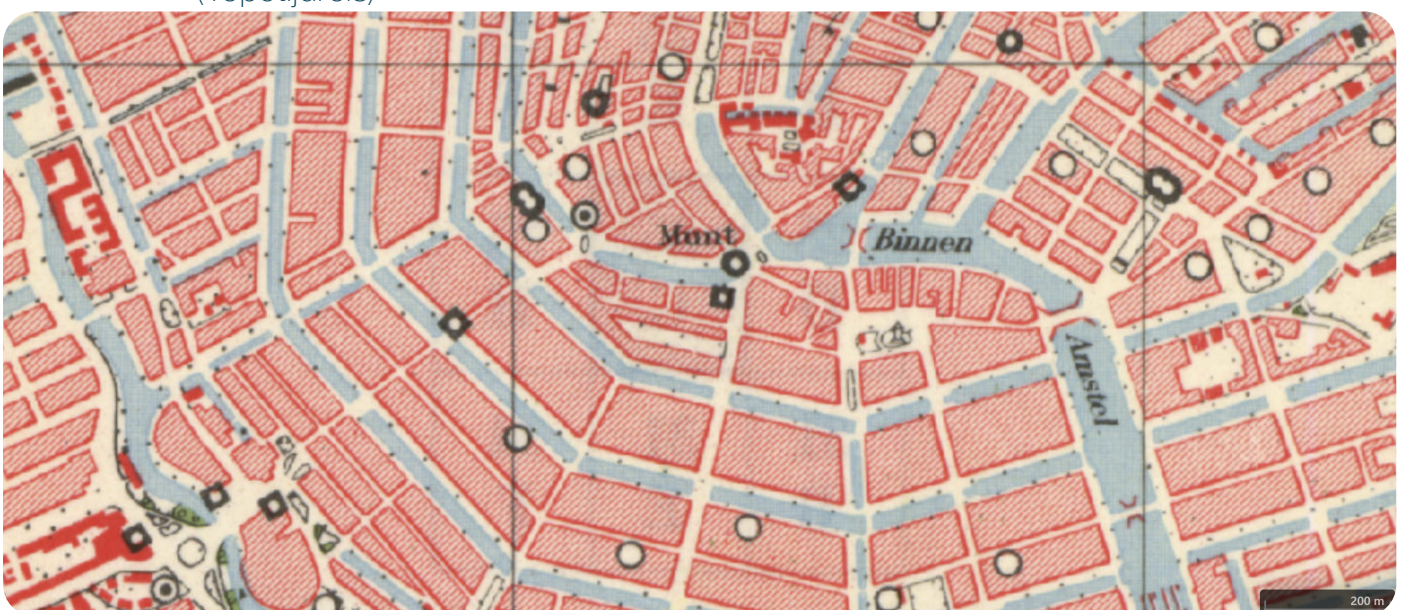


Figure 21. Historic map from 1960
(Topotijdreis)

Historic analysis: Kalverpassage

In 1992, Pi de Bruijn and George de Jong of the Amsterdam-based firm Architecten Cie were commissioned to design a shopping center with 26 residential units above it at the location. The shopping center, named Kalvertoren, comprised four floors with 30 retail stores and 6 restaurants, one of which was located in the 30-meter-tall glass tower at the center of the complex. In total there is 14,750 m² of commercial space, and 500 m² of cultural space. Underneath is a parking garage with 100 spaces. The construction (1995 to 1997) gave a boost to Kalverstraat, where new construction was considered virtually impossible at the time.

In 2014, the shopping center changed ownership and was redeveloped into a shopping arcade. During this renovation, the entrance was given a more open character, and the ground-floor stores were provided with their own access to the floor above.

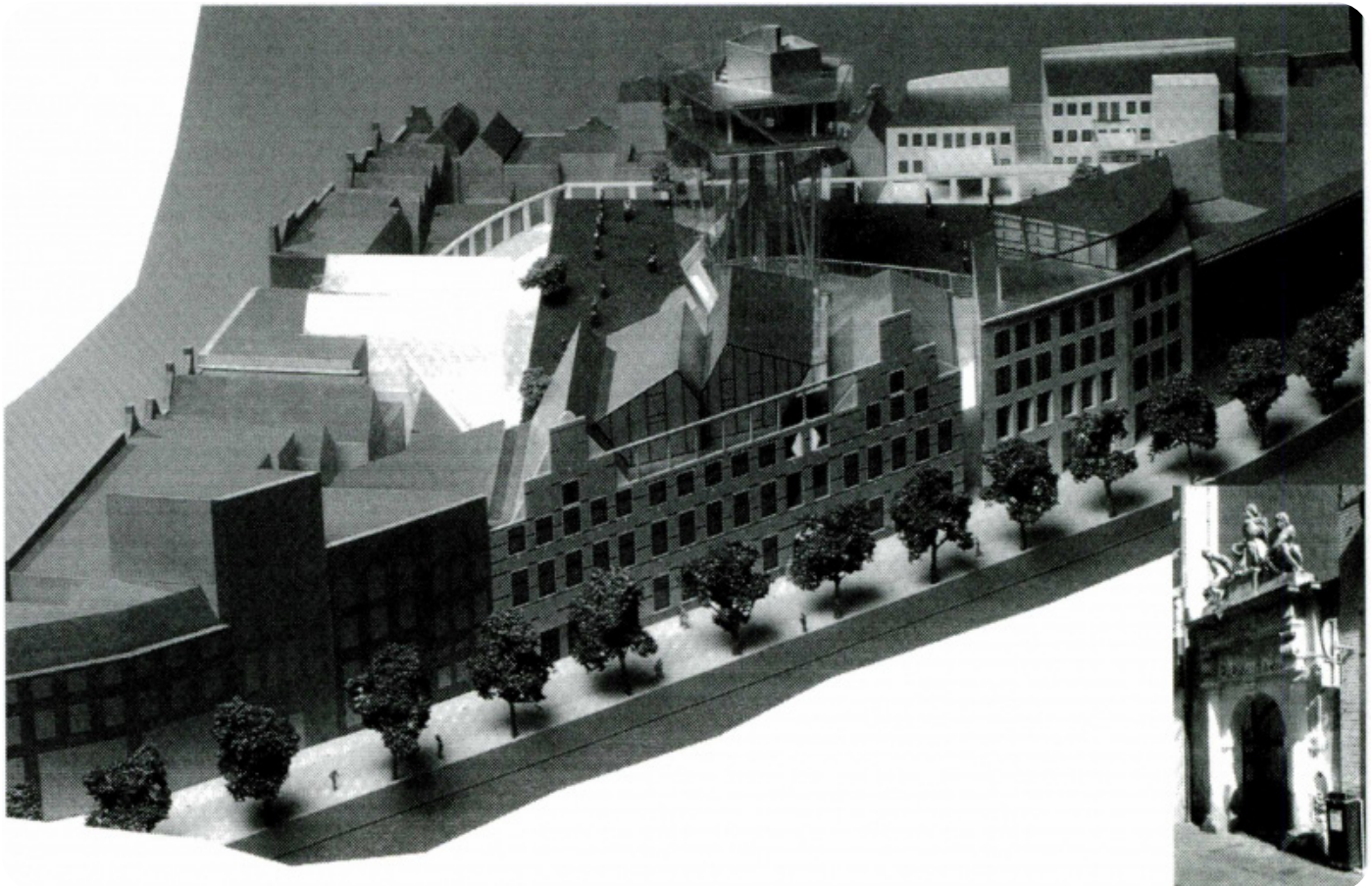


Figure 22. Scale model of Kalvertoren proposal

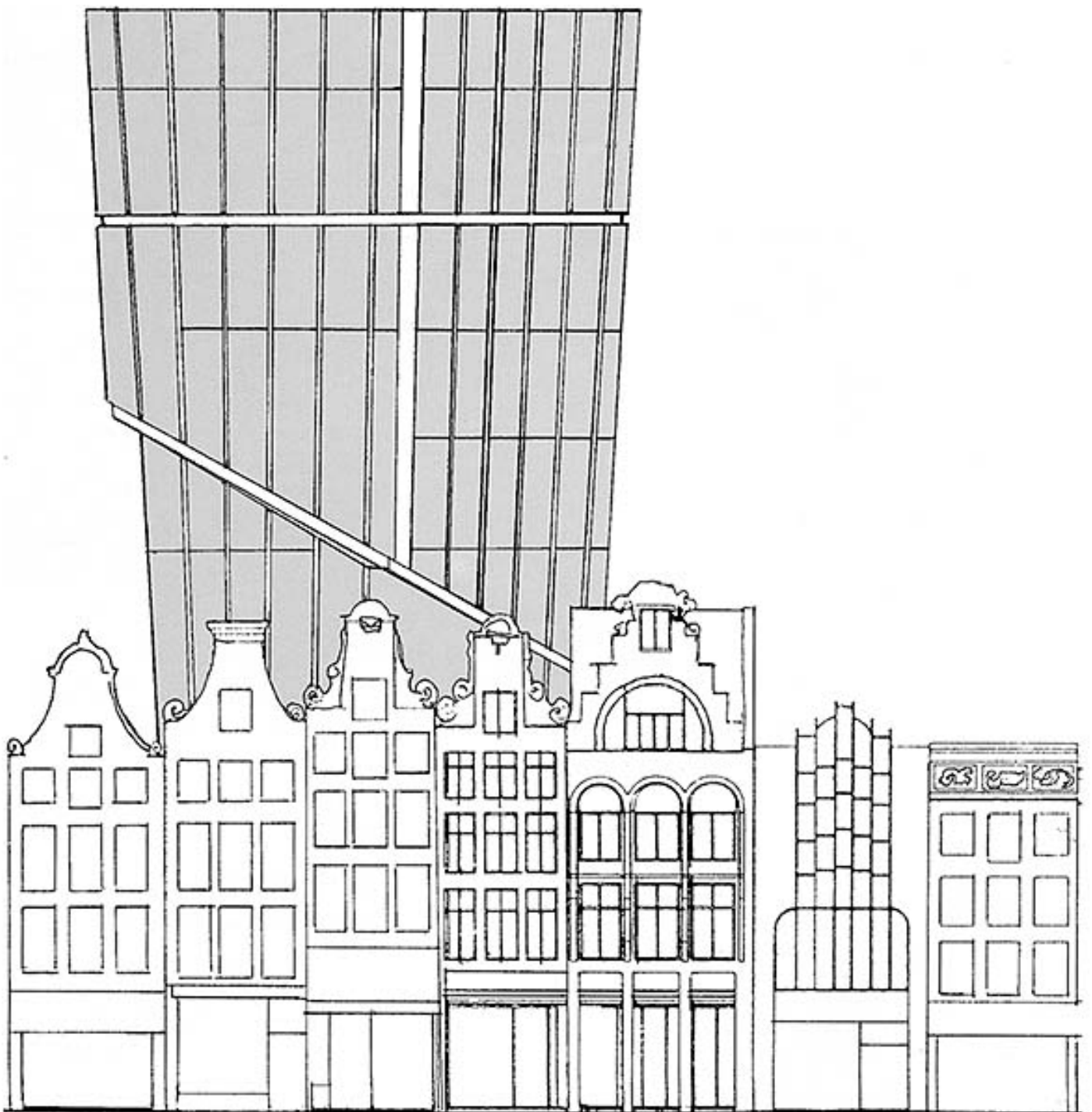


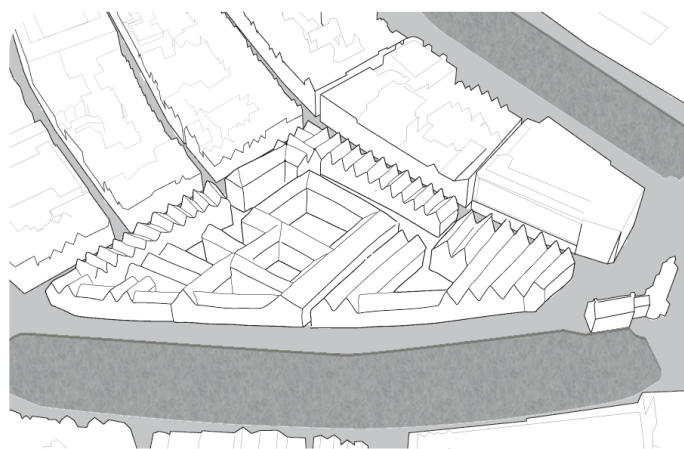
Figure 23. First proposal by Pi de Bruijn, which was controversial and got rejected because of the height

Existing building

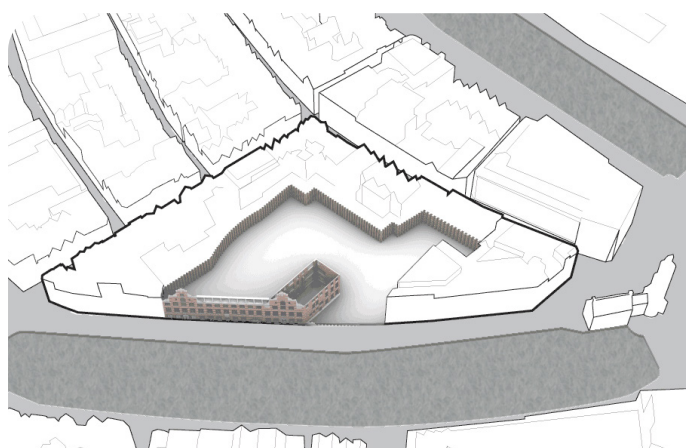
Programming of Kalverpassage

The building is part of a larger triangular urban block of which the outer edge forms a ribbon of historical houses. The inside is merged to form the Kalverpassage.

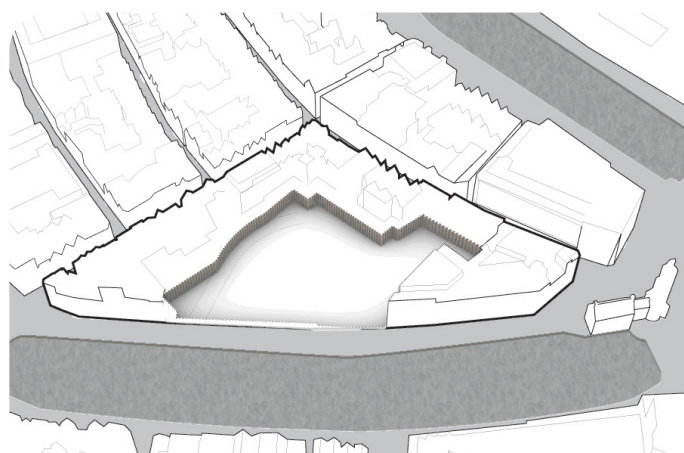
The building serves as shopping mall and car park. And despite being in the heart of the city, the first floor is dysfunctional as shopping mall, and has remained empty for many years already. The roof on the second floor is mostly flat and inaccessible, despite having a large surface area. And on the roof sits a hollow tower with a restaurant on the top floor.



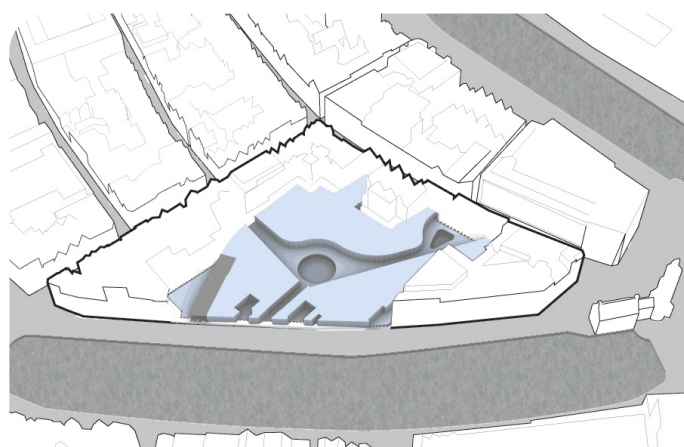
Historic fabric



Historical elements

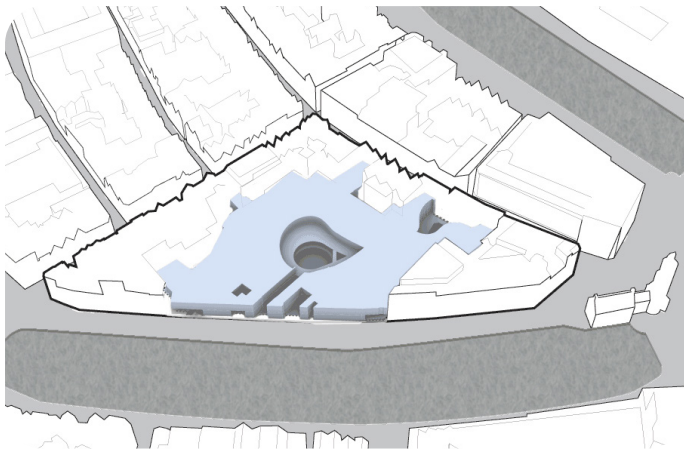


Underground parking

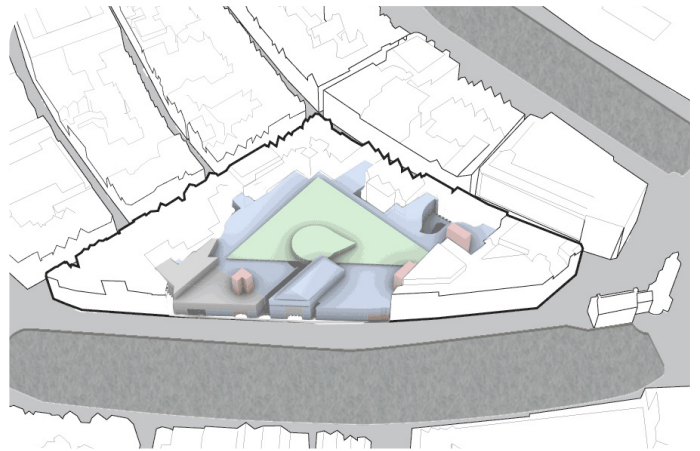


Ground floor

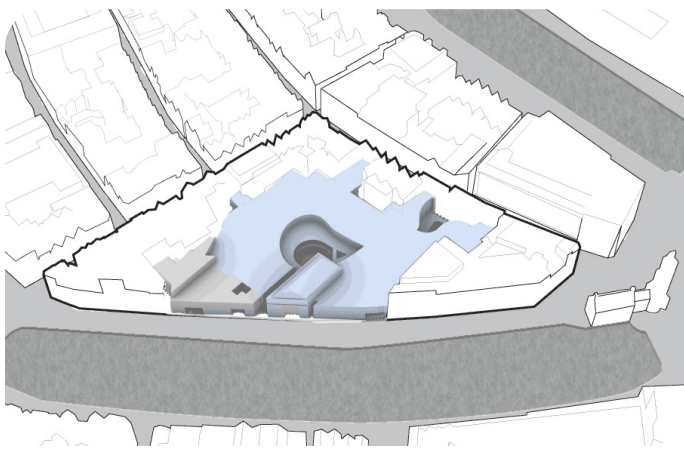
Figure 24. Programmatic diagrams of Kalverpassage
(Architecten Cie)



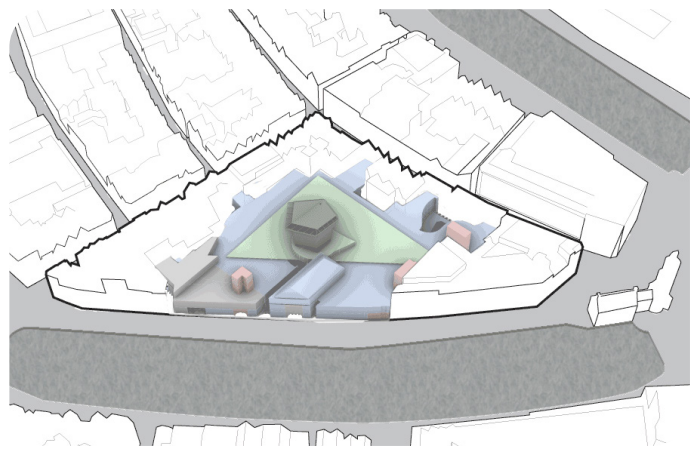
2nd commercial floor



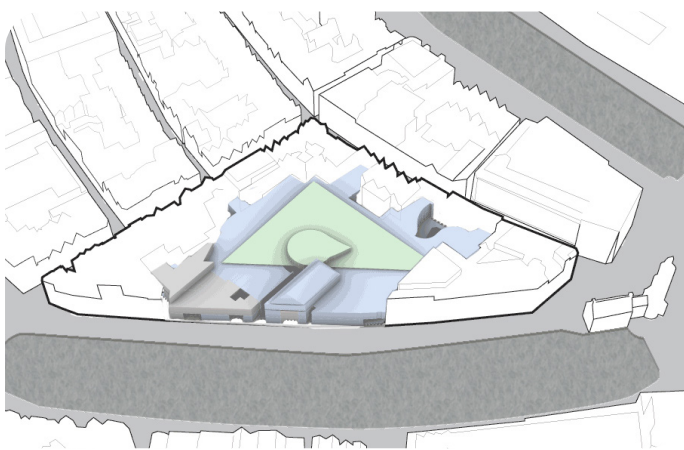
Vertical transport



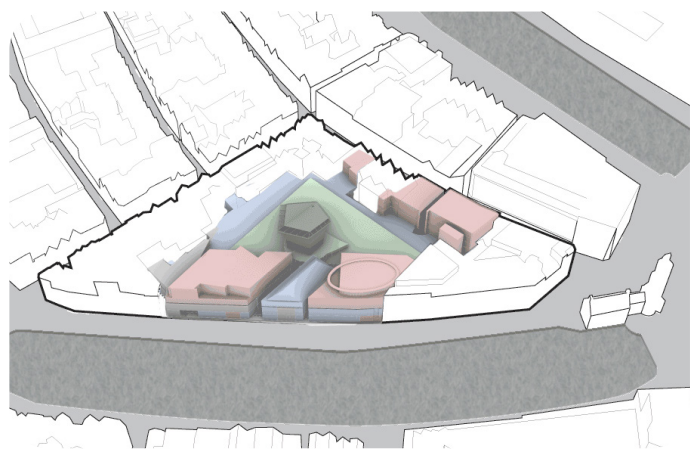
Office layer



Tower



Green roof



Residential units

Existing structure of Kalverpassage

The load bearing structure is irregular shaped, has a grid of 9.6 by 7.8 meters, is built of reinforced concrete slab floors and concrete columns, and together with most columns not conforming the grid, Despite the potential of this roof, the existing structure brings challenges for optopping, since exceptions seems to be the rule here.

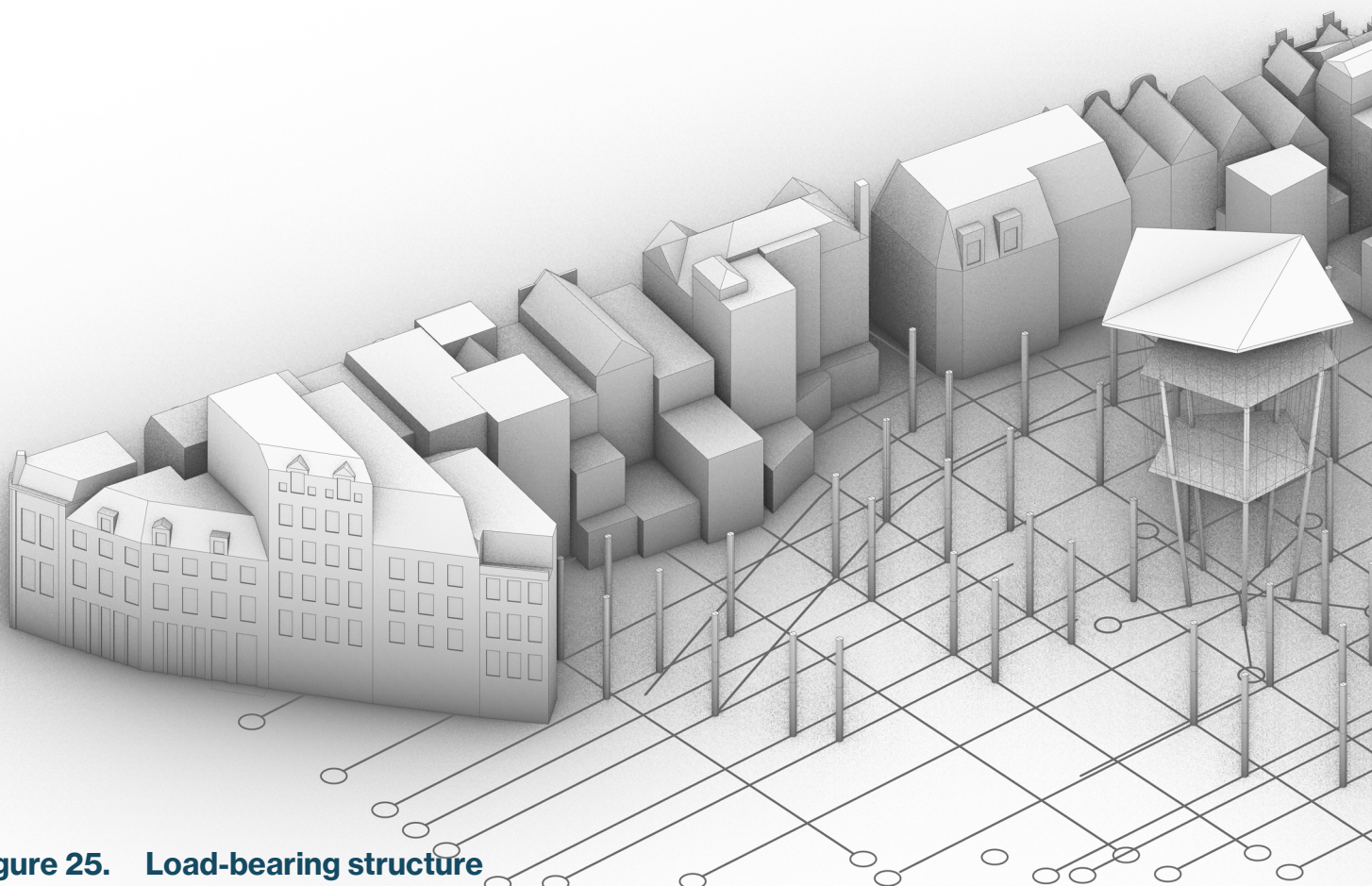


Figure 25. Load-bearing structure of Kalverpassage in its context

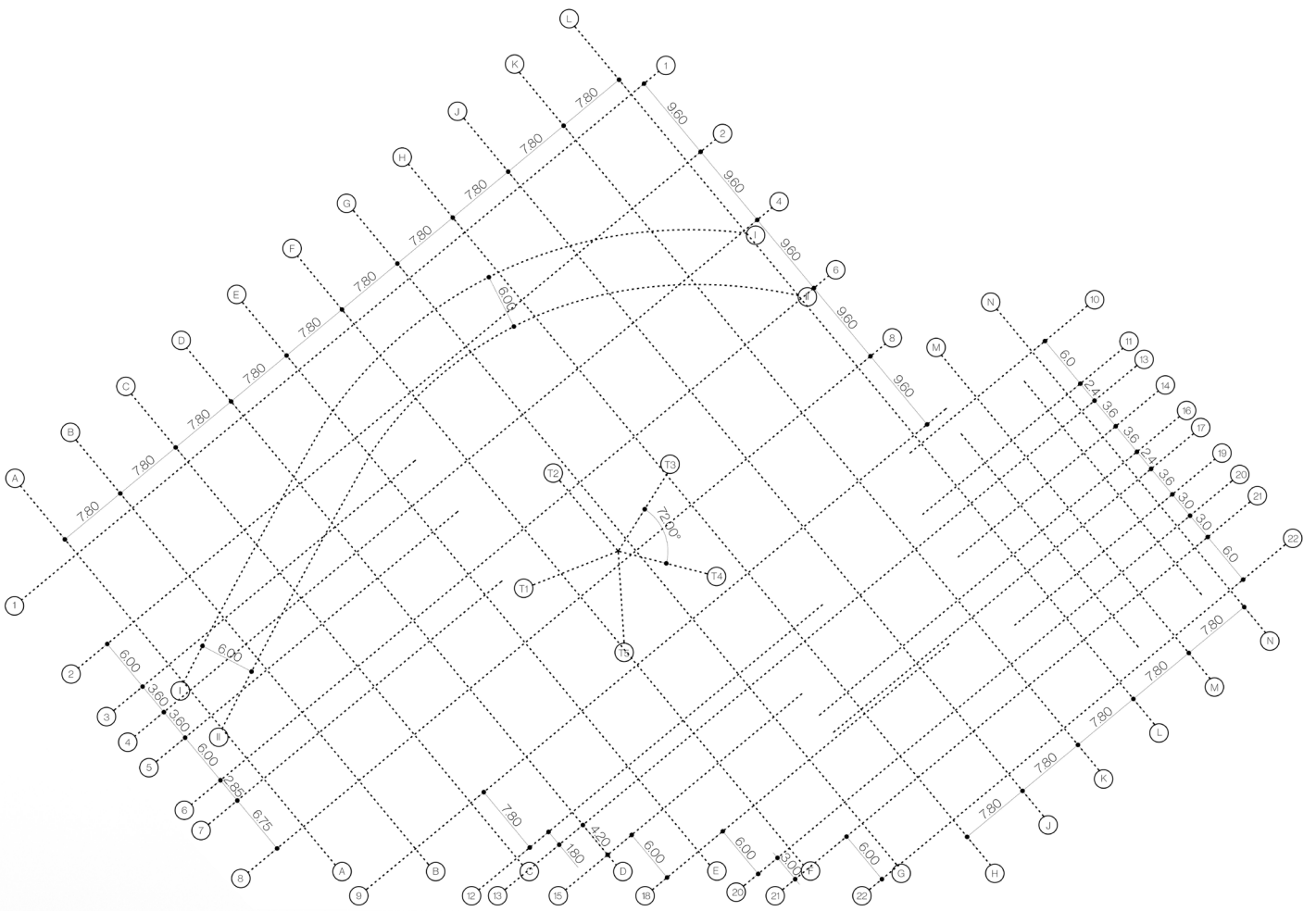
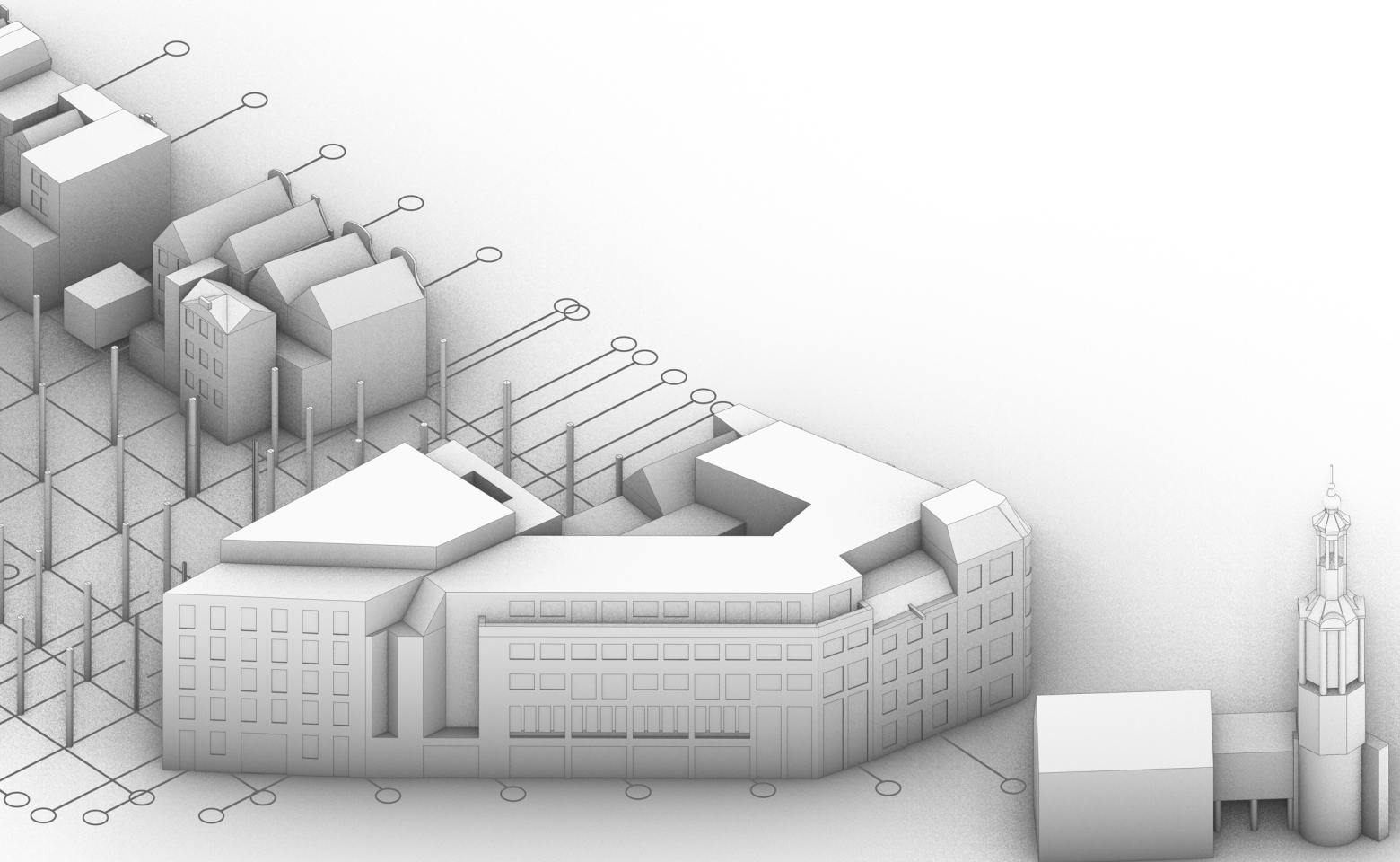


Figure 26. Structural grid with column position ▲



Impressions of Kalverpassage





4. DESIGN BRIEF

Design objective
Design challenges
Design questions
Design concepts



Design objective

The aim of this design project is to create a dense urban habitat of collective micro-apartments. To maximize the space that can be added, a lightweight timber structure will be put on top of the existing structure to enable vertical densification without overburdening the existing structure. With the addition of masses on the roof, the surrounding heritage, daylight and privacy will be taken into consideration and treated with respect.

The Kalverpassage occupies a highly central and historically layered location, yet functions primarily as an anonymous and commercial environment. At the same time, Amsterdam faces a severe housing shortage and limited opportunities for densification within the historic core. Adding residential volume above this complex introduces tensions between daylight, privacy, heritage, and locals.

To sum up important location-related factors that may influence the decision-taking process throughout the project, a concise SWOT is shown below:

Strengths

- Prominent location
- Many facilities in proximity
- Rich history
- Lively streets Heiligeweg & Kalverstraat
- Calm street at Singel

Weaknesses

- Anonymous environment (because of the dynamic crowds that pass daily)
- Difficult and irregular building footprint
- High chance of depriving sunlight to existing apartments/dwellings
- Kalvertoren's intrusive presence regarding privacy
- Many mechanical installations on the roof

Opportunities

- Flat roof
- Relatively large foundations
- Appropriable Singel profile
- Possibility to use the Singel canal in the building process
- Tightness (krapte) in the housing market

Threats

- Public resistance (like with the first iteration of Kalvertoren in 1993)
- Taller structures unintentionally compete with Munttoren

Tabel 1: SWOT-analysis for topping-up in existing context Kalverpassage

Design challenges

In the broad sense of topping up, the Kalverpassage and its surrounding context also provide different challenges. These are untngled into different categories and described below:

Heritage

- How to densify without competing with Munttoren
- How to position new architecture within Amsterdam's historic silhouette

Social

- How to create housing that does not feel anonymous despite anonymous crowds below
- How to introduce collectivity and calmness above a chaotic urban environment

Spatial & Environmental

- How to deal with Kalverpassage's irregular footprint
- How to mitigate risk of overshadowing existing dwellings
- How to ensure privacy between existing housing and the topping-up

Technical

- Existing roof cluttered with installations
- Structural constraints
- Difficult to reach site for large scale construction, in dense inner city

Tabel 2: Design challenges for topping-up in existing context Kalverpassage

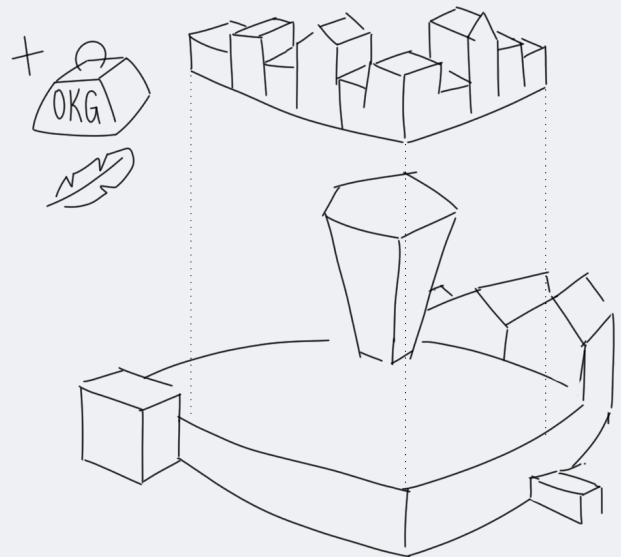
Design questions

Whereas the research question pushes the theoretical limits, the design question is more subdued due to environmental factors. This is due to the positioning of the Kalverpassage, right in the historic centre of Amsterdam with a dense urban fabric.

It is important to treat the existing context with respect, while carefully adding value. Therefore, the design question is intended to create a respectful dialogue between the existing and the new. The question goes:

So, to create a dense urban habitat of community-oriented micro-apartments on the Kalverpassage, the following design sub-questions are taken into consideration:

1. How can the existing structural grid of the Kalverpassage be used as basis for a lightweight timber structure (that minimizes added mass while enabling new residential density)?



The design aims are described as the following:

Create a lightweight timber construction to enable vertical densification on the existing structure

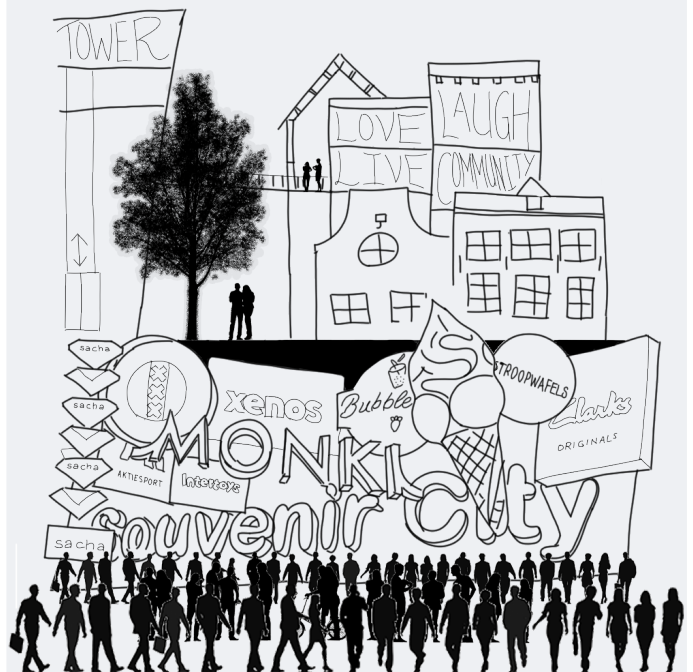
How can Kalverpassage's rooftop be transformed into a dense habitat where lightweighting influences its structural logic, domestic quality and architectural expression?

2. How can dwelling configurations create a sense of community (above the commercial environment of the Kalverpassage) while limiting structural and imposed loads?



Create a respectful volume to preserve daylight, privacy, and the historic skyline

3. How can the volume and façade expression of the top-up preserve daylight, privacy, and Amsterdam's historic roovescape while expressing the lightness of the added structure?



Create a sense of domesticity and community above an anonymous, hyper-commercial environment

Design concepts

The architectural concept regarding maximizing dwelling space is to create respectful volumes on the now inaccessible flat roof. These volumes are arranged in a way to create their own urban fabric composed of plazas, alleys and houses.

This street pattern and the volumes are composed of sightlines that provide views of monumental towers and interesting roofscapes. It gives the awareness of being in the sky. In a rooftop village.

This village is composed of three distinct fracture-shaped structures which each have their own take on co-living and lightweighting. One of these structures is more collectively oriented with more shared facilities and less dedicated private space, whereas another is more privately oriented with less dedicated collective space, and one is an in-between structure. With these different purposes, the Eurocode prescribes different loads which in turn may lead to different load-bearing structures, of which one might be lighter than the other. This influences the kg/m² and kg/inhabitant units.

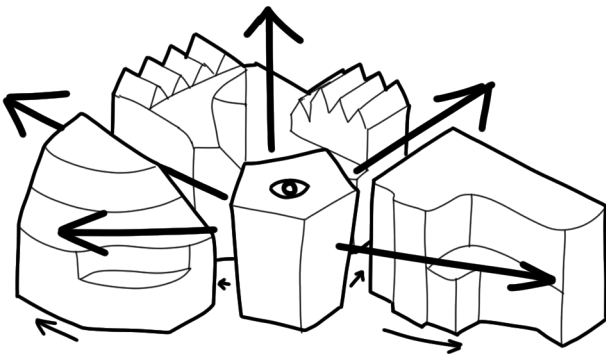
The following are design strategies leading to certain design directions:

- Kalverpassage's roof will be treated as a raised ground floor
- The building structures and layout configurations are informed by the parametric model's deemed most lightweight interventions.
- Form will be employed to allow for setbacks, terraces, and stepping volumes to ensure daylight and maintaining a cohesive skyline
- Housing will be organized around semi-collective spaces and acting as ownership gradient

Programmatic intent

The programming revolves around co-living and uses all the space that the Kalverpassage has to offer. Since the first floor and the entrance at the Singel are underutilized, this will be converted into entrance hall with all addresses and a bicycle ramp going to the first floor. The first floor will be bicycle parking, and storage for the dwellers as well as a storage magazine for the shopkeepers.

Depending on the target groups, a number of facilities will be integrated into the neighbourhood clusters (the entire ground and top floors), per building, per floor and per dwelling itself. The collective functions are accustomed to the personality types which are deemed suited for the specific form of housing that the Kalverpassage-optopping will become: collective micro-housing in the heart of Amsterdam.



▲ Creating volumetric fractures to provide sightlines

Whole optop-community:	Social cohesion	Audience based	Practical
Polyvalent event space	x		
Co-working-ruimte		x	
Board game / games / video game room	x		
Bicycle parking			x
Bike repair place			x
Atelier space	x	x	
Religieuze kamer		x	
Pakjeskamer (brievenbussen)			x
Storage units			x
Werkplaatsen / DIY workshop	x	x	x
Tuin en Kas complex	x	x	
Guest room			x
Sportruimte ?	x	x	
De "nu-even-niet-route"!	x		x

Tabel 3: Collective functions for the whole optop neighbourhood community

Per building	Per community	Per dwelling:
<ul style="list-style-type: none"> • Rooftop garden • Laundry rooms • Waste collection points 	<ul style="list-style-type: none"> • Shared living room • Kitchen and dining area • Social corridors (as transitional spaces, serving as circulation to backdoor space, fire compartmentalisation, and front door spaces) 	<ul style="list-style-type: none"> • Bathroom • Bedroom

Tabel 4: Private and collective functions for the different community gradients

Room / Function	Structure I	Structure II	Structure III	
Entrance zone	PS	PS	PS	
Bedroom	P	P	P	
Bathroom	P	P	P	
Living room	S	PS	P	
Kitchen	S	PS	P	
Dining	S	S	P	
Workspace / study	S	S	PS	
Storage	PS	PS	P	
Laundry	S	S	S	
Circulation corridors	S	S	S	
Collective lounge	S	S	S	
Roof garden	S	S	S	
Guest room	S	S	S	
Mobility / bike storage	S	S	S	
				S = shared P = private PS = both private and shared

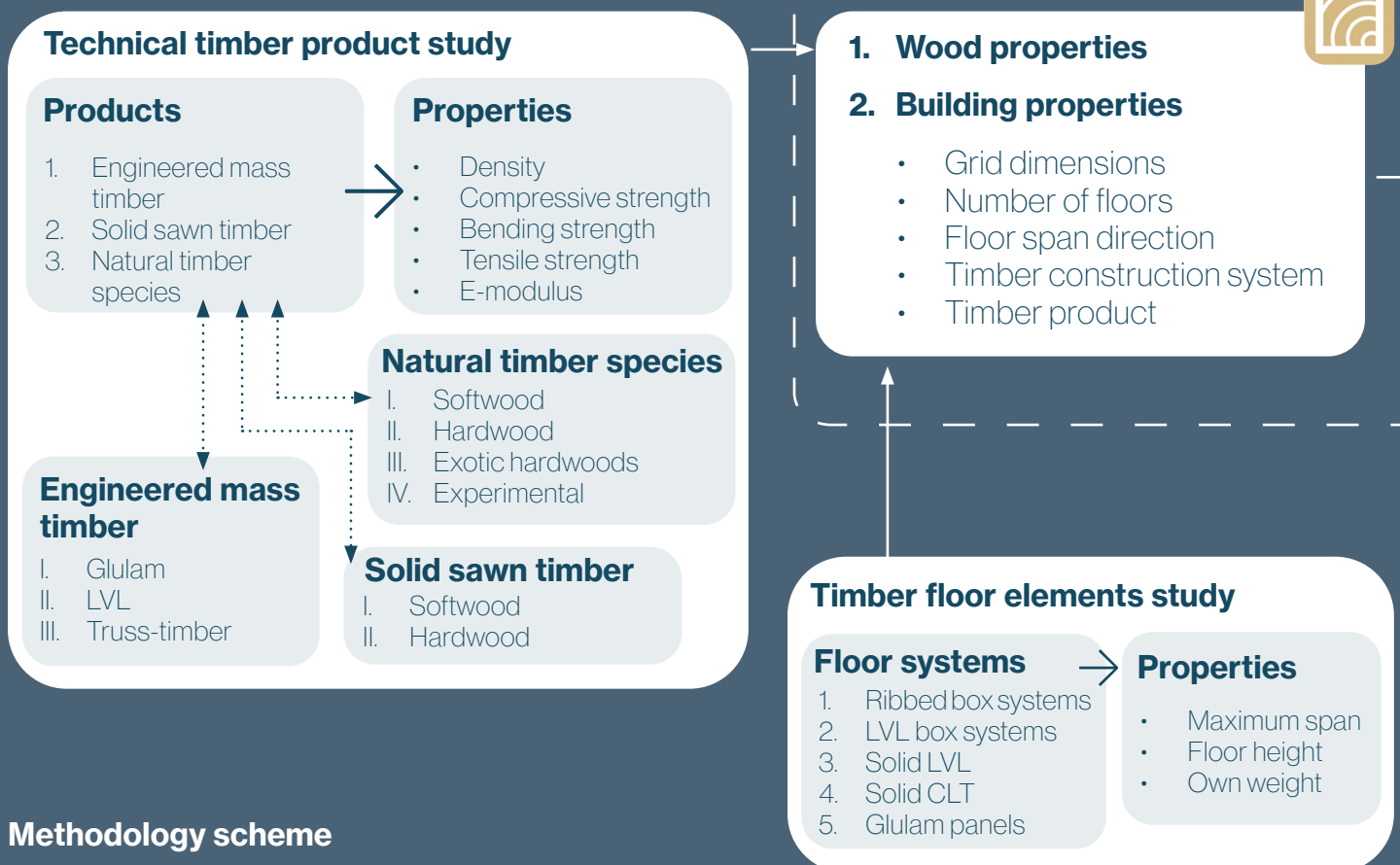
Tabel 5: Private and collective functions for the different optopping structures

5.

STRUCTURAL LIGHTWEIGHTING OPTIMISATION

PARAMETRIC MODEL

INPUT



Methodology scheme

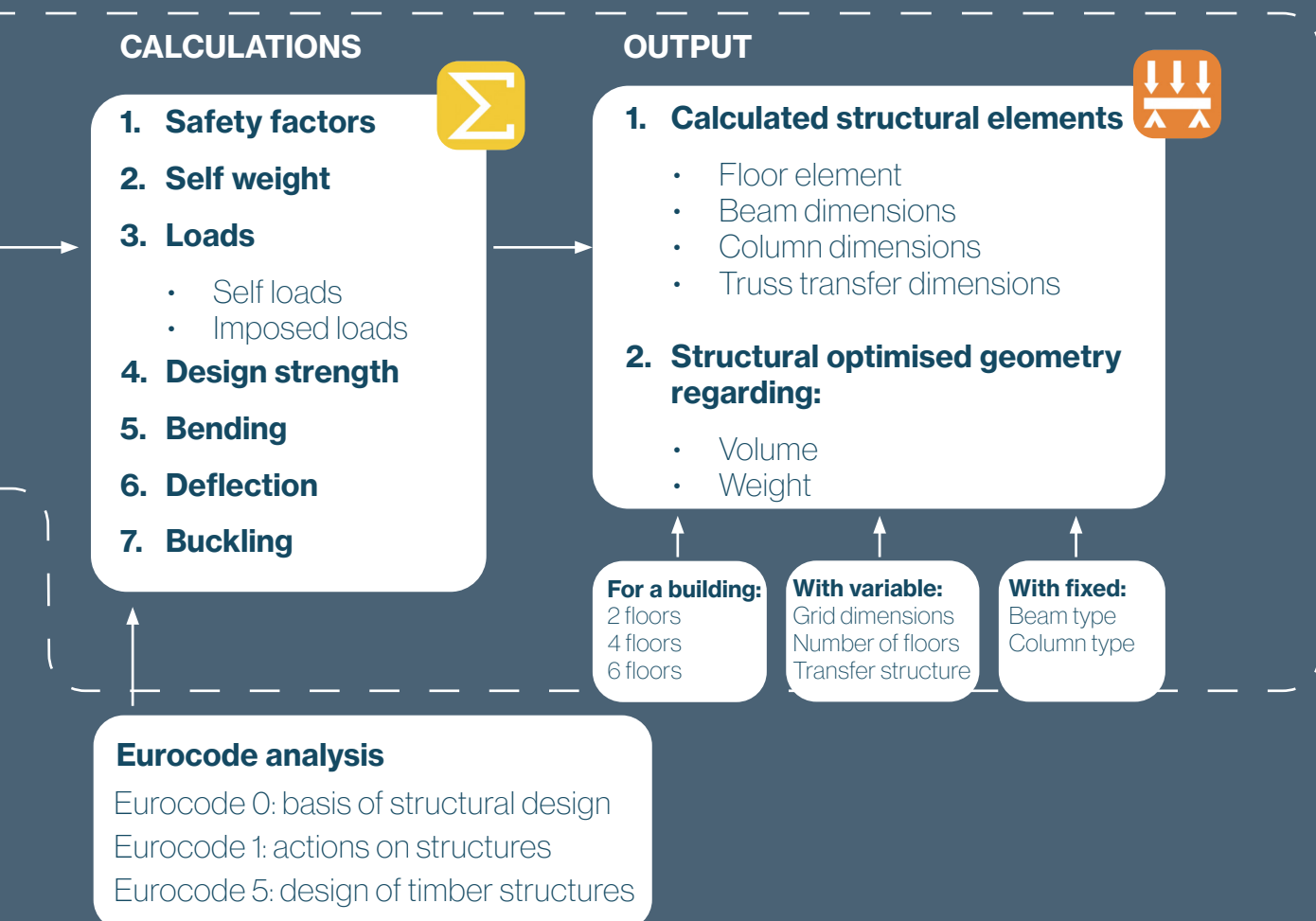
Comparative timber product study

- Structural floor elements
- Structural beams
- Structural columns
- Structural transfer trusses

Eurocode calculation study

Structural optimisation principles

- Structural floor elements
- Structural beams
- Structural columns
- Structural transfer trusses
- Lightweight grid principles



Methods

The aim of this chapter is to establish structural design principles regarding lightweighting of different structural components within a post-and-beam system and transfer truss strategy. These principles can be integrated into the Kalverpassage top-up design proposal. By comparing different sawn timber, engineered timber, and mass timber products, the study identifies how material properties influence the performance of structural components

The study is conducted in two stages. Firstly, performative data is gathered for a selection of timber products and wood species, from European manufacturers. Secondly, this data serves as input for a parametric evaluation model, where structural dimensions and material performance are assessed according to Eurocode norms such as compression, buckling, bending, and deflection. The gathered material properties include:

- density
- Young's modulus
- compressive strength
- tensile strength
- shear strength

The parametric evaluation makes use of these properties and assesses the suitability of different timber products as different structural elements. The comparison is limited to post-and-beam structures and truss-based transfer systems, as these are the primary structural typologies investigated in the design proposal. These elements are:

- structural floor elements
- structural beams
- structural columns
- structural transfer trusses

The intended outcome is a numerical datasheet that captures the structural performance of different timber products regarding lightweighting. This datasheet results from the Grasshopper model and allows relationships between material choice, component dimensions, and structural mass to be identified.

Timber floor elements study

Floor systems

1. Ribbed box systems
2. LVL box systems
3. Solid LVL
4. Solid CLT
5. Glulam panels



Properties

- Maximum span
- Floor height
- Own weight



Technical timber product study

Products

1. Engineered mass timber
2. Solid sawn timber
3. Natural timber species



Properties

- Density
- Compressive strength
- Bending strength
- Tensile strength
- E-modulus

Engineered mass timber

- I. Glulam
- II. LVL
- III. Truss-timber

- I
- GL24h
 - GL28h
 - GL32h
 - GL36h
 - BauBuche GL75

- II
- Spruce LVL-s
 - BauBuche S
 - BauBuche Q
 - Beech LVL-s

- III
- TR26

Solid sawn timber

- I. Softwood
- II. Hardwood

- I
- C14
 - C16
 - C18
 - C20
 - C22
 - C24
 - C27
 - C30
 - C35
 - C40
 - C45
 - C50

- II
- D18
 - D24
 - D30
 - D35
 - D40
 - D50
 - D60
 - D70

Natural timber species

- I. Softwood
- II. Hardwood
- III. Exotic hardwoods
- IV. Experimental

- I
- Spruce
 - Pine
 - (Redwood)

- II
- Ash
 - Beech
 - Birch
 - Elm
 - Maple
 - Oak
 - Poplar
 - Willow

- III
- Teak
 - Mahogany
 - Lignum vitae
 - Walnut
 - Cherry
 - Pear

- IV
- Bamboo
 - Cork
 - Palm
 - Balsa
 - Paper & cardboard

Eurocode calculation study

Eurocodes 0, 1, and 5 were consulted to compile the strength calculations. Each of these was used for the various structural elements: floors, beams, and columns. Rules of thumb were used for the trusses. These calculations are covered in this section.

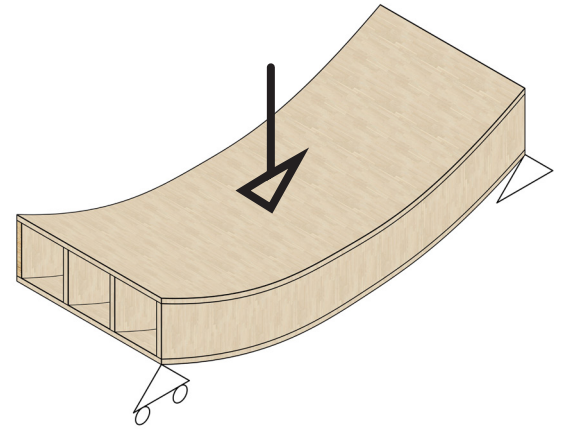
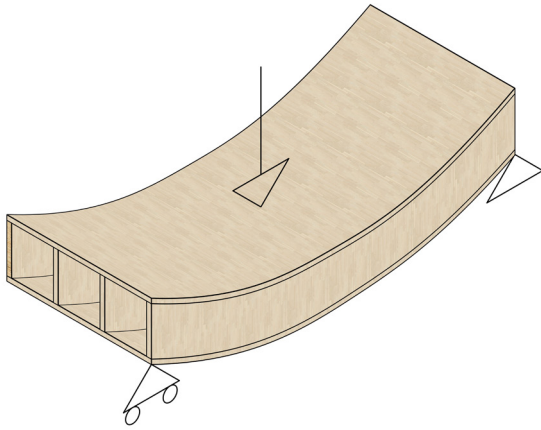
Floor elements

Because the manufacturers did all the span calculations and provided all the span information, it is a matter of using Grasshopper for the selection filtering process in obtaining the most lightweight floor per span.

Beam elements

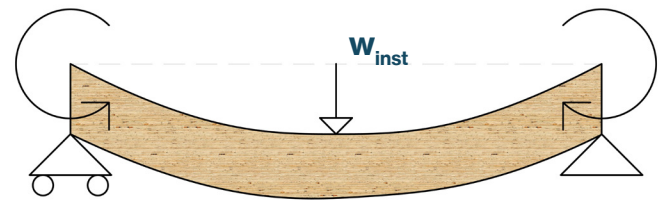
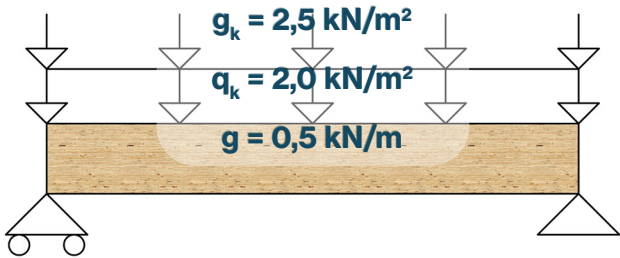
In total, 52 different timber types and species have been taken into account for the beam element calculations. These have been subjected to bending and deflection calculations, as shown on the right.

Note that for collective spaces, the variable loads of q_k are higher as opposed to private spaces.



For private residential space
 $q_k = 2,0 \text{ kN/m}^2$

For collective residential space
 $q_k = 3,0 \text{ kN/m}^2$



$$M_{Rd} = \text{Bending capacity} \left[\frac{\text{N}}{\text{mm}^2} \right]$$

$$M_{Rd} = W \times \sigma_{m,d}$$

$$W = \frac{b \times h^2}{6} \left[\text{mm}^3 \right]$$

$$w_{inst} = \frac{5qL^4}{384EI} \left[\text{mm} \right]$$

$$350 \geq \frac{L}{w_{final}}$$



Based on bending and deflection

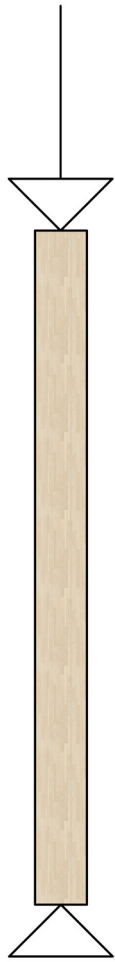
Column elements

Like with the beams, 52 different timber types and species have been taken into account for the beam element calculations. These have been subjected to compressive strength by the imposed loads, as well as the building's own weight. Also the minimum dimensions for buckling have been applied here.

Truss elements

For trusses, the diagonals and upper beam are subjected to compressive forces, whilst the lower beam is subjected to tensile forces.

Therefore, the upper beam and diagonals have been subjected to the same compressive force calculations as the columns, whilst the lower beam is subjected to tensile calculations.

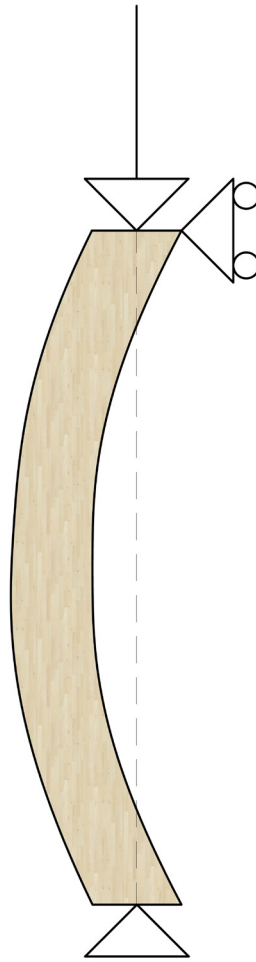


Compressive strength

$$N_{Ed} \leq N_{Rd}$$

$$N_{Rd} = A \cdot f_{c,0,d}$$

$$f_{c,0,d} = \frac{k_{mod} \cdot f_{c,0,k}}{\gamma_M}$$



$$\text{Buckling check : } \sigma_{c,0,d} \leq k_c \times f_{c,0,d}$$

All column materials

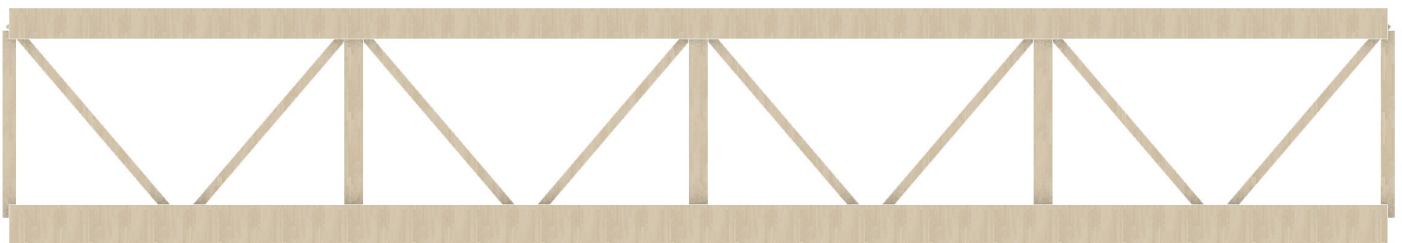


Minimum required dimensions per column material type

Based on compression and buckling



Most lightweight beam material



All column materials



Minimum required dimensions per diagonal and upper beam material type

Based on compression



Most lightweight truss materials

Minimum required dimensions per lower beam material type

Based on tensile forces

$$M = q \cdot L^2 / 8$$

$$N_{Chord} = M / h$$

$$A_{lower} = N_{Chord} / f_t$$

STRUCTURAL OPTIMISATION PRINCIPLES

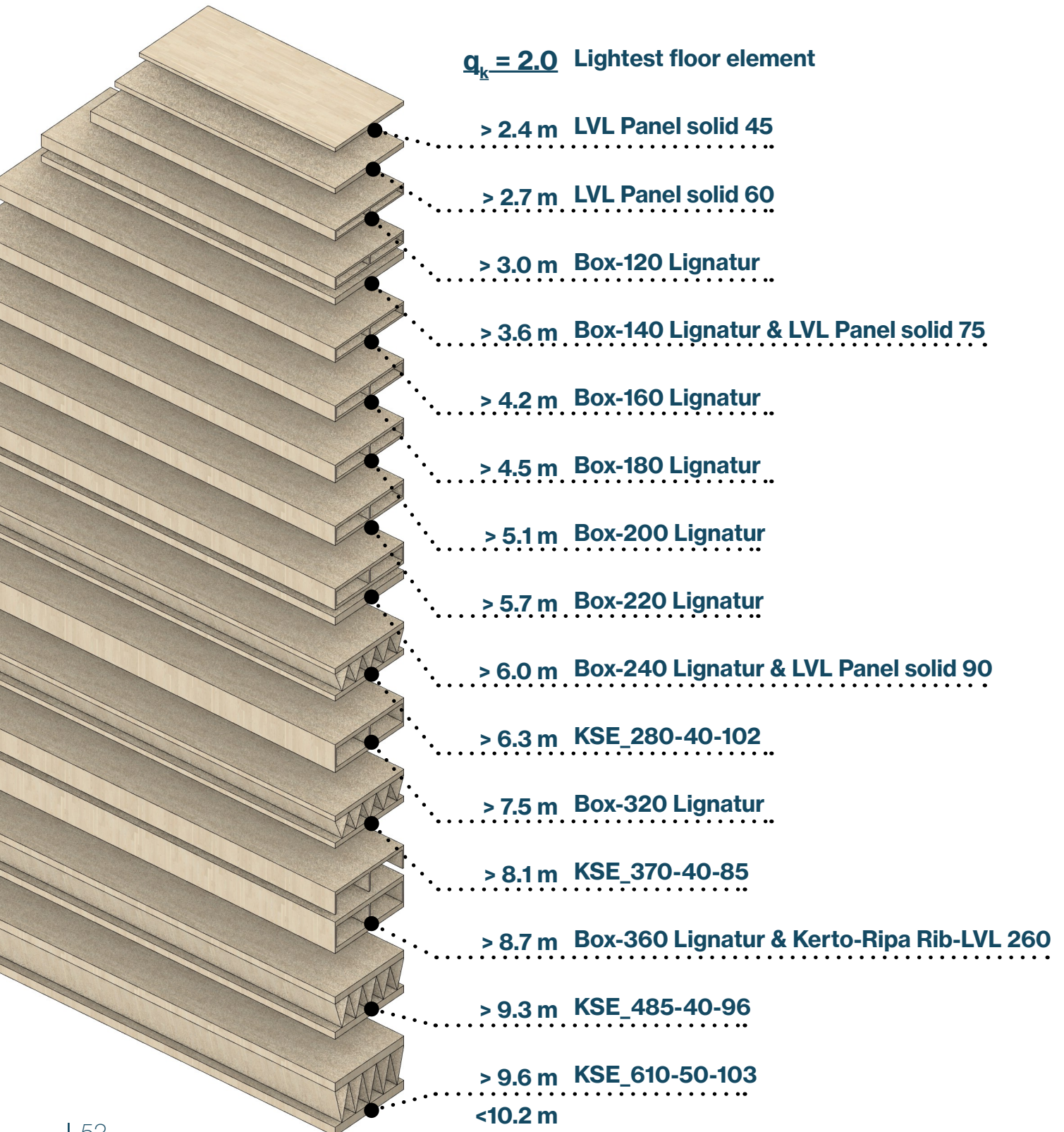
Optimised floor elements

Below it shows a list per floor span what the lightest floor element is, from the list of 51 different floor types. This is done for both the imposed load value of $q_k = 2.0$ (private floor area) and $q_k = 3.0$ (shared space).

The overall contribution to total building weight of floors is high.

Depends on:

- Maximum span [m]
- Imposed loads [kN/m²]
- Density [kg/m²]



Conclusion:

- The bigger the floor span, the bigger the floor's contribution to overall building weight
- Floors contribute most to building weight, in in comparison to beams and columns

$q_k = 3.0$ Lightest floor element

> 2.4 m **Box-120 Lignatur**

> 3.0 m **Box-140 Lignatur & LVL Panel solid 75**

> 3.3 m **Box-160 Lignatur**

> 3.9 m **Box-180 Lignatur**

> 4.2 m **Box-200 Lignatur**

> 4.5 m **Box-220 Lignatur**

> 4.8 m **Box-240 Lignatur & LVL Panel solid 90**

> 5.1 m **KSE_280-40-102**

> 6.0 m **Box-320 Lignatur**

> 6.6 m **KSE_370-40-85**

> 7.2 m **Box-360 Lignatur & Kerto-Ripa Rib-LVL 260**

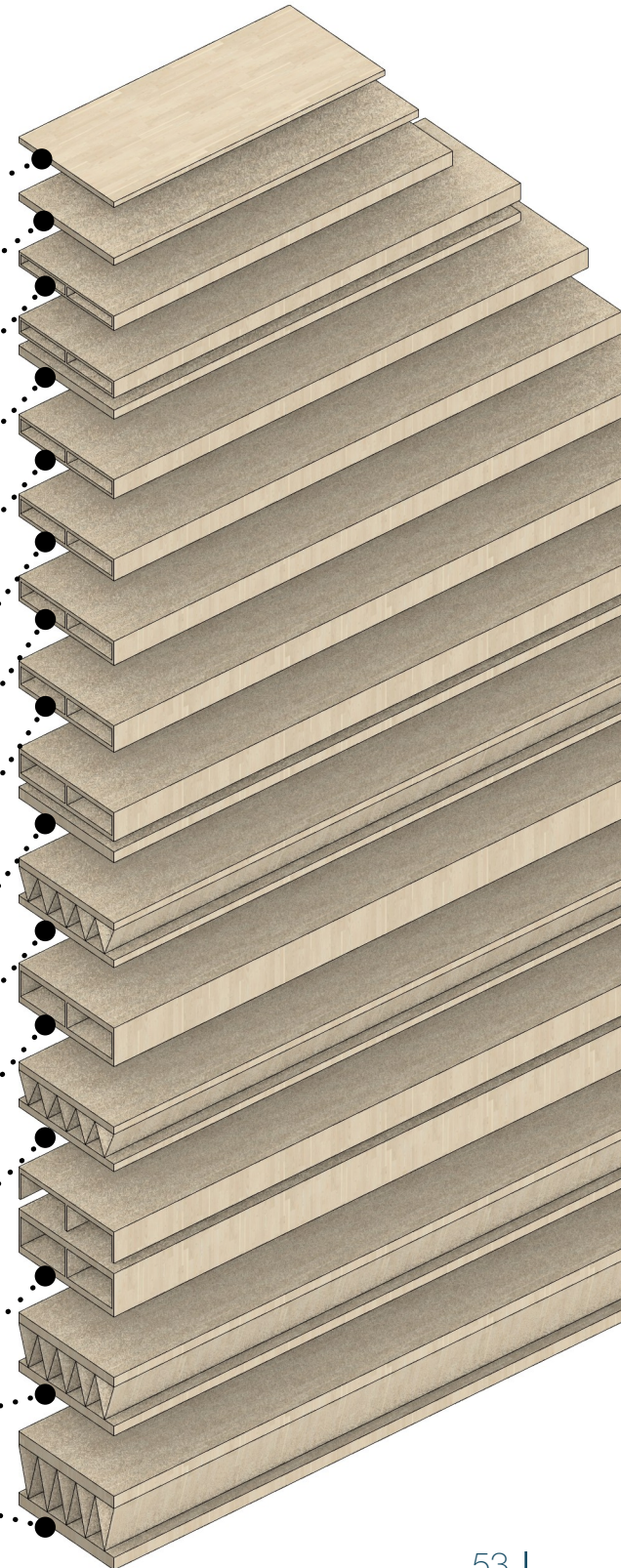
> 7.5 m **KSE_485-40-96**

> 7.8 m **KSE_610-50-103**

> 9.0 m **KSE_610-60-103**

> 9.3 m **KSE_730-80-134**

<10.2 m



Optimised beam elements

For lightweight beams, the following principle apply:

- **Always put beams on the long span**
- **Floors contribute most to building weight,**
in comparison to beams and columns
- **Always put floors in the short span**

The bigger the floor span, the bigger the floor's contribution to overall building weight



Most optimal beam: GL36h, given its:

- **Density [kg/m³]**
- **Bending strength [MPa]**
- **E-modulus [MPa]**

Optimised column elements

For lightweight columns, the following principle apply:

- **The more floors the building has, the lighter the weight per square meter**
- **Columns contribute a fraction to building weight,**
in comparison to beams and columns (not more than 3%)
- **The bigger the floor span, the smaller the column's contribution to overall building weight**



Most optimal column: Spruce LVL, given its:

- **Density [kg/m³]**
- **Compressive strength [MPa]**
- **E-modulus [MPa]**

Optimised truss elements

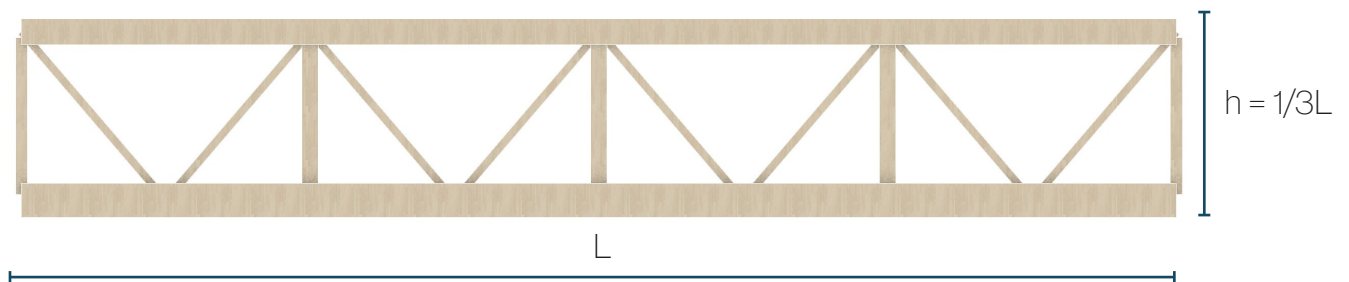
For lightweight trusses, the following principle apply:

- **Truss transfer = heavy!**
So using the existing 7.8m and dividing the 9.6m into a multiplier (veelvoud) of the existing grid length is the most light weight
- **But above 4 floors the total construction becomes lighter!**
- **Around a third of the length of the truss is the optimum height-length ratio**

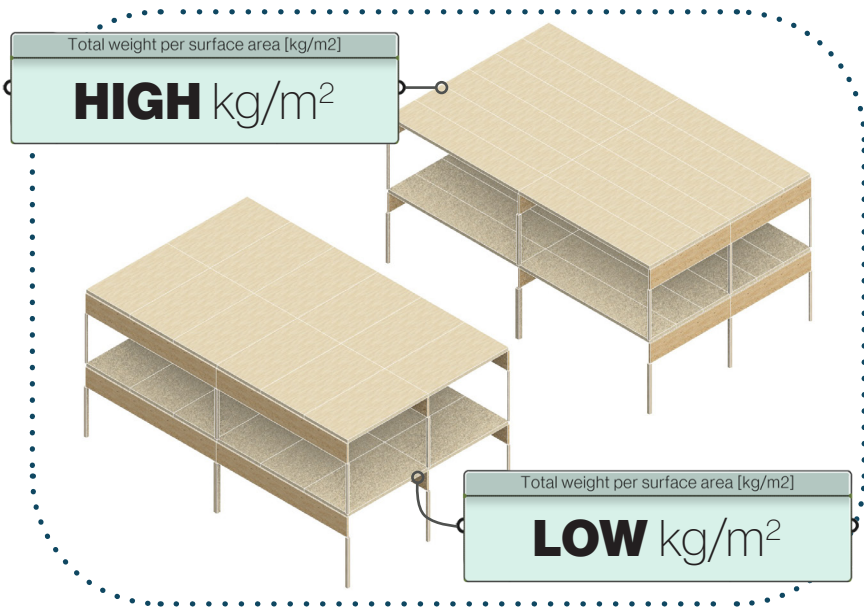


Most optimal lower beam: Bamboo, given its:

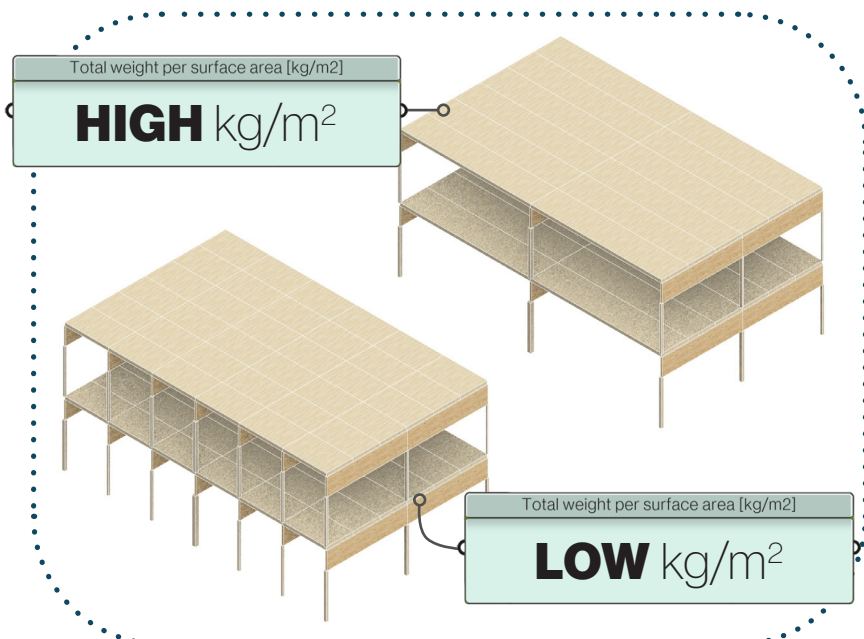
- **Density [kg/m³]**
- **Tensile strength [MPa]**



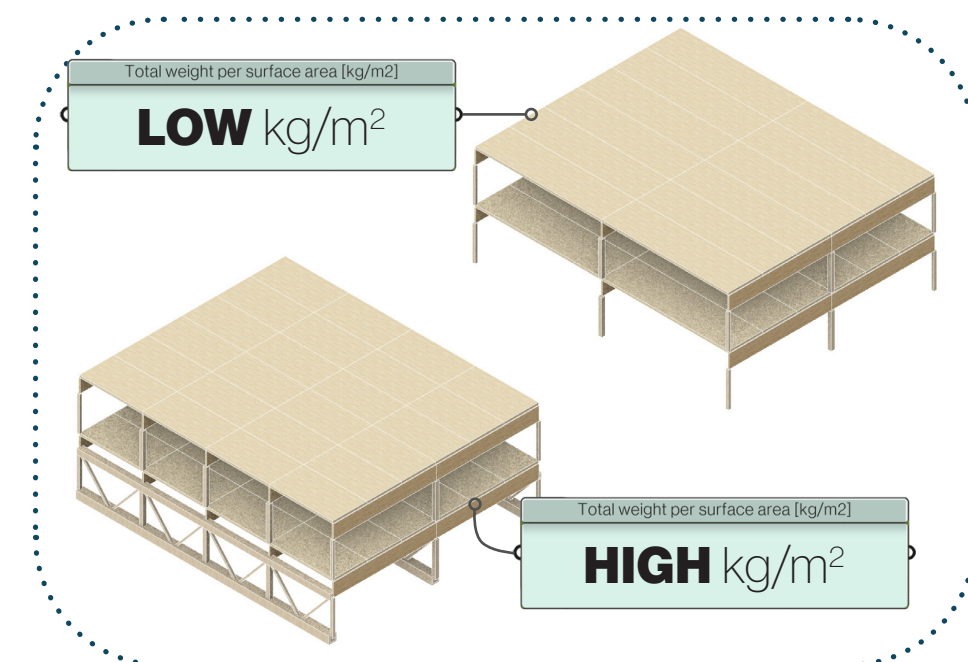
Lightweight grid principles



Always put floors in the short span

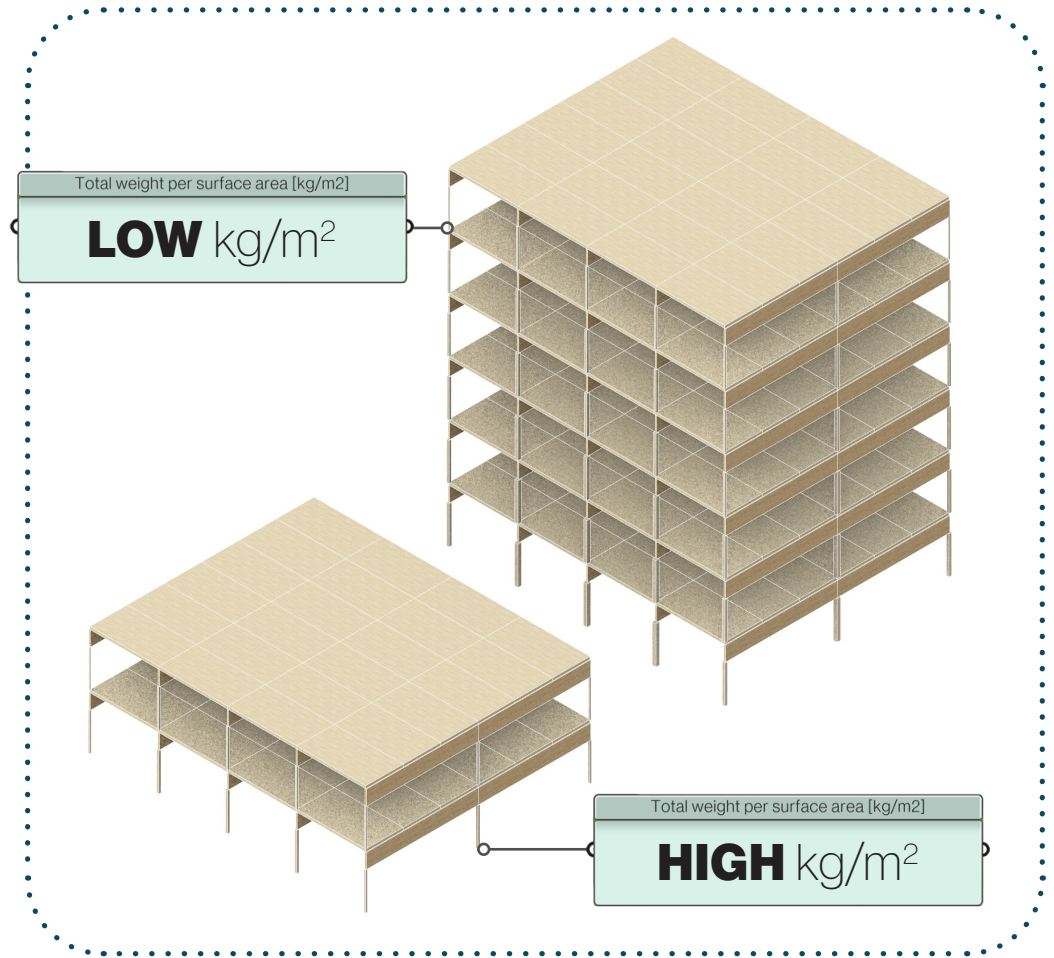


Work with a small grid, rather than a large one

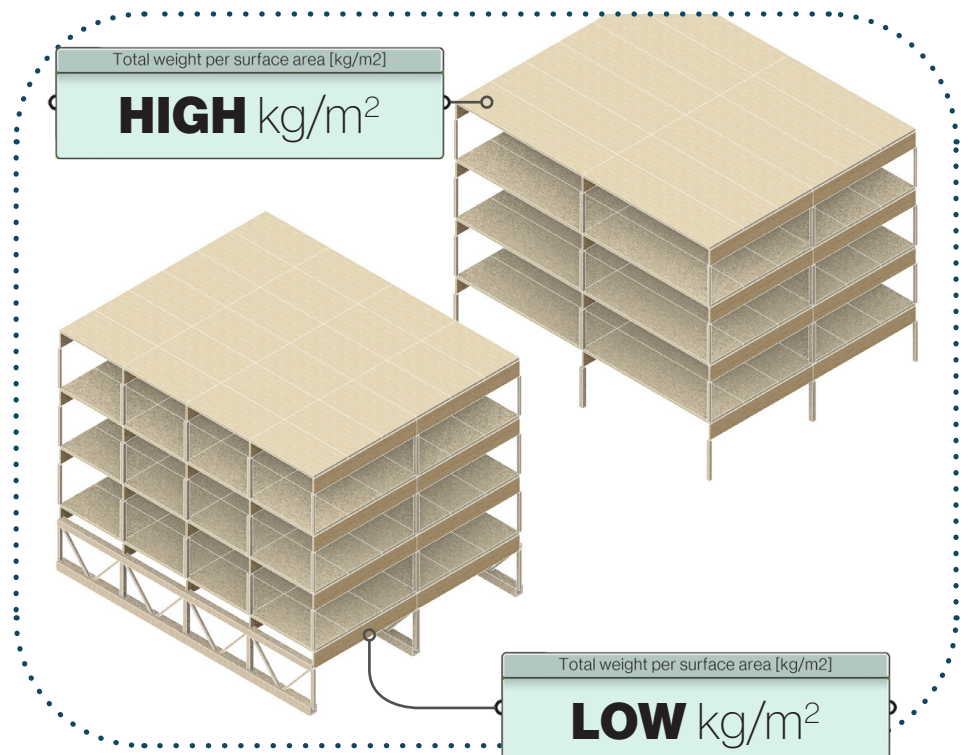


Truss transfer is heavy

The more floors the building has, the lighter the weight per square meter



From 4+ floors, the truss is outweighed by the smaller grid



6.

LIGHTWEIGHTING IN BUILDING PHYSICS

Solar ray protection

Ventilation and Temperature control

Acoustics

Fire safety

Façade performance and detailing

The purpose of this chapter is to examine certain essential elements in order to identify the most lightweight options for ensuring quality of life. This is because an extremely lightweight building can present challenges related to building physics (fire safety, noise and acoustics, solar gain, and thermal regulation), spatial layout, and building systems.

All options are presented in isolation. The aim is to assess the ratio between the weight of the building and that of the material being tested.

SOLAR RAY PROTECTION

The solar strategy of **low solar heat gain** is about passively reducing the heat load from the sun, which is deemed more important than any cooling system. The interventions entail:

Stacked balconies

Besides the high improvement in living quality that is paired with having a balcony, the physical element blocks the sun rays from entering the open parts of the façade. In small, single-oriented homes, it is important to have a large window area to enhance living comfort. Balconies are particularly of value on the south-facing side, since the solar geometry is most predictable here with

- high sun in summer
- low sun in winter

In an east-west direction, eaves are of little use given the low position of the sun throughout the year, even in summer. The sun penetrates deep into the building here, meaning that cantilevers are of little use. Thus, a west-facing façade can cause more overheating than a large south-facing façade. For this reason, a south-facing façade is the best option, and south-west or south-east facing façades are also quite suitable.

There are multiple configurations of attaching a balcony to a façade, of which a non-cantilevering balcony, supported by its own structure, is considered most lightweight since it does not have to withstand a heavy moment.

External sun shades

By placing the sunshades externally, solar heat is massively dissipated before entering the building. Screens are typically lightweight and can withstand wind speeds, which can be a challenge on taller buildings.

Vacuum glass

With its sheer lightness, thinness and effectiveness in terms of insulation, vacuum glass is considered the best pick in terms of glazing, despite its high cost (Milieu Centraal, n.d.). This has been compared to single, double, triple and HR++ glazing.

Louvres

There where balconies and external sunshades don't reach, louvres with green elements are attached to provide the same blocking mechanism as balconies do.

- **Stacking of balcony is most lightweight**

Requires its own column as load-bearing structure. But not as cantilever, because a high moment leads to big dimensioning!

- **Open balcony flooring is most lightweight**

Since there is no acoustic requirements, but intervention towards water collection is necessary

- **On the southern side, the balcony has most effect as sun shading system**

VENTILATION AND TEMPERATURE CONTROL

This section covers measures relating to air circulation and temperature control. These aspects have been combined because, within the building's lightweight design concept, these systems work together and cannot be viewed in isolation. In line with the principle of lightweight construction, warm and cool air are

Ventilation and temperature control per dwelling

At the level of the apartment, the following concepts are used:

1. Radiant cooling and heating

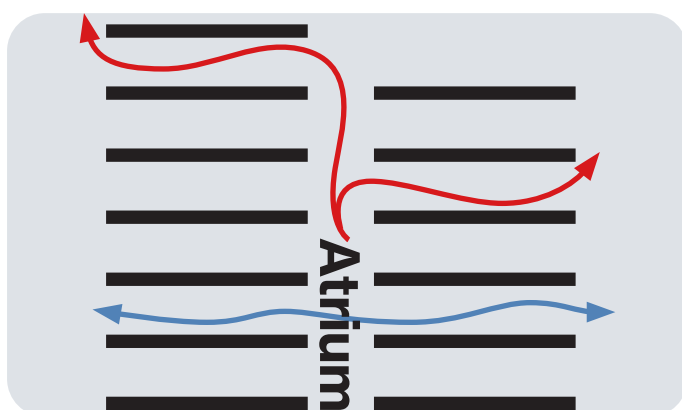
This is achieved through a low-temperature floor heating/cooling system (LTV). This system is energy-efficient, lightweight, and quickly transfers heat to the floor due to its limited mass. The system can be controlled individually per apartment, giving residents control over the temperature.

2. Latent heat storage

Since lightweight buildings contain far less thermal mass than a conventional building, peak temperatures during heat waves can cause a hazard. The latent heat storage principle relies on heat storage through a material phase transition: from solid to liquid. It is thus able to mimic the thermal mass of a heavy building without the mass and volume of conventional building materials (Zhang et al., 2013). This allows it to buffer temperature peaks around the melting temperature of 21 to 23°C, rather than 28°C. It is essential however, to change back to solid during the night, to work effectively over multiple days.

3. Purge ventilation (spui)

Openable windows and mechanical exhaust at the bathroom level create natural ventilation through positive pressure (window surface) and negative pressure (ventilation exhaust). This ventilation flow is complemented by air currents on the scale of the entire building. This system is adjustable to the occupant's preferences, as opening the windows requires manual action.



distributed throughout the building by means of pressure differences. These pressure differences enable ventilation. These systems operate at two system levels: per dwelling unit and per building, for which different concepts are applied.

Ventilation and temperature control per building

At the level of the building, the following concepts are used:

1. Stacking effect

The stacking effect works by creating an uninterrupted chimney structure through which air from areas of high pressure can move to areas of low pressure. In doing so, the system naturally distributes a temperature difference that moves passively throughout the building. The effectiveness of this system is enhanced by:

- Reserving a minimum floor area of 3% of the total floor area
- Open windows to allow air to flow into the north side of the building (in the cooler, shaded side)
- Large openings at the roof
- Installing fans at the bottom and top. These move the air more quickly, create a greater pressure difference, and thus drawing in cold or warm air from outside more rapidly. This significantly enhances the effect with just a small mechanical addition

2. Evaporative cooling

This system works by moistening the walls of the atrium, causing evaporation droplets to move using the stacking effect. The optimal position is at the bottom of the atrium, to humidify the incoming cooler air. Its operation lies in the details, which are structured as follows:

- Water barrier
- Porous material (cellulose / wood fiber mat)
- Water film / droplet system
- Air that transmits the vapor particles

3. Heat pump cycle

A reversible heat pump uses mechanical intervention to ensure a supply of cool or warm air during extreme weather conditions. These heat pumps are energy-efficient, and by implementing this solution centrally, we avoid the risk of individuals purchasing an energy-inefficient but effective solution (such as an AC unit) on their own. The heat pumps are installed on a shock-absorbing base to minimize vibration and noise. The optimal location is on the roof to maximize effectiveness.

ACOUSTICS

Given that mass is generally regarded as essential for ensuring adequate acoustic performance between partitioning walls and floors, it is a challenge to meet these requirements without adding unnecessary weight. Whereas impact sound is often solved through absorption, airborne sound is often solved

through adding mass. This is contrary to this research. To compensate for not adding mass, there are workaround solutions. These will be introduced in the form of principles which will be translated into the section details.

Acoustic Principles

The principles used in the walls and floors to improve acoustic quality are (Van der Linden

1. Mass-spring systems
2. Decoupling and layering
3. Asymmetry and misalignment
4. Absorption
5. Sealing of all gaps, especially in the node sections

Despite its low-weight significance, active noise cancelling technology nor anti-sound wave transmission have been considered as viable. Yet, with the development of this technology, it may pose a promising solution to lightweight architecture in the near future.



Wood fibre board



Cellulose insulation

FIRE PROTECTION

The main principle of fire protection is to **encase** fire-sensitive elements and **delay** the spreading of potential fire. This applies to both the load-bearing structure and combustible materials in the walls or floors, and is manifested in the detail sections.

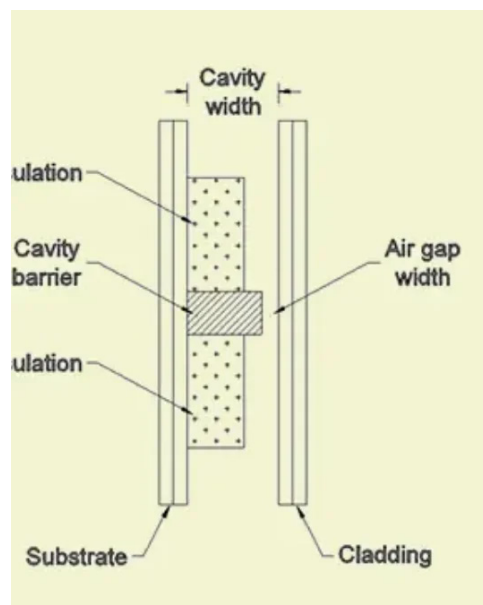
Encasing

The encasing of vulnerable elements:

- Flammable materials
- Load-bearing structure

Fire stops

Adding fire stops to hinder the spread of fire alongside the facade is important. Yet, hard to reach with only biobased materials. Stops are made through open state cavity barriers, which hinder smoke and fire from spreading vertically. This is combined with non-flammable clayboards every floor, which further hinder the upward spreading of fire in the facade.



Cork



Clay board

FACADE PERFORMANCE

The performance of the facade is divided into multiple elements:

- Cladding
- Assemblage
- Insulation
- Window frames
- Drainage system

All these systems deliver different performances for which the mass is an important factor.

Cladding

For cladding, different cladding materials have been taken into account. These include:

- Extremely light, non-biobased metallic sheet cladding,
- Lightweight biobased claddings
- Conventional stony materials

It seems the case that in terms of density, the metallic sheets are lightest, followed by biobased timber claddings, and lastly the stony materials. Listed have been the lightest of these stony materials. Conventional materials (brick) would have been even heavier.

Thermally modified fir and poplar score similarly: both biobased and low weight per square meter. The fir is from manufacturer ModiWood®, which is provided in different colours, whereas the poplar by Platowood and comes with different coatings.

For exterior parts which are exposed to water (roofs and drainage elements), it is suitable to go for a thin sheet of aluminium cladding.



Thermally modified fir



Thermally modified poplar



Aluminium cladding with green patina

Lightweight assembly

When dealing with timber claddings, ventilation is important, hence the exclusion of glue. A lightweight assembly is a ventilated timber façade with horizontally non-overlapping timber cladding, fixed with screws to vertical battens over a vapour-permeable membrane.

This system is lightweight, easy to assemble and allows continuous vertical ventilation behind the cladding. Through the use of horizontal timber cladding elements, the battens behind can be standing in a vertical position. This mitigates the need for a double battens system, reducing the amount of structure required, making it the most weight-efficient option while still ensuring moisture safety.

Insulation

For insulation, biobased and experimental systems have been tested on thickness, weight and performance. This input has been shown in the appendix.

In short, with different densities, weights and performances, some materials require high thickness for an R-value of 7.5 m²K/w, but are extremely lightweight.

One such material is recycled textile, which requires 330 mm of thickness to achieve passive R-values. This is the lightest of all materials enumerated. With the addition of fire retardants recycled textile achieves fire class B. This materials needs to be kept ventilated and dry in order to function properly.

Window frames

Some window frames are more exposed to the elements than others. Some are openable and others are closed. Therefore, some frames require stricter performance than others.

For the exposed frames, accoya is a lightweight option. This can withstand movement and exposure to rain.

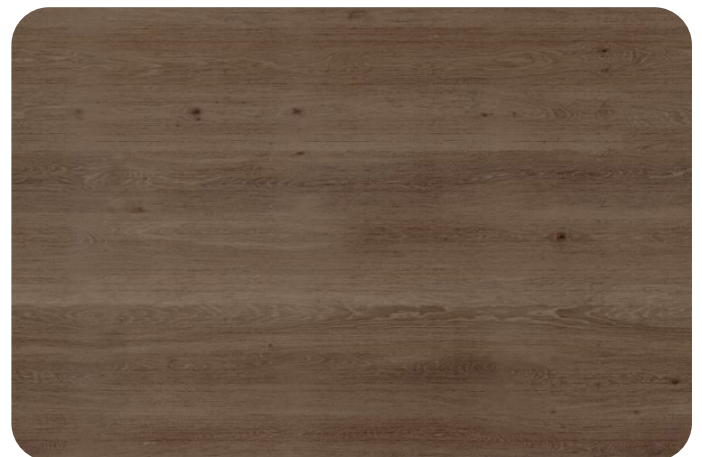
For the sheltered frames, thermally modified pine wood is suitable. This would be in loggias or underpasses. This is even lighter than accoya, but more vulnerable.



Accoya window frame



Recycled textile insulation



Thermally modified western red cedar frame

Drainage system

Since water is heavy, it is beneficial to buffer as little as possible, and drain as much as possible.

Therefore, drainage pipes, water sills (waterslagen) and sloped surfaces are important architectural features that serve in the water drainage system.

Although green roofs and planting offer many qualities, it can also be considered large water buffers. Rather than large green roofs, it is more lightweight to install a lightweight timber deck constructions that can be used as the primary walking surface. Adding vegetation in pots in strategic locations, directly above a column or beam, structural transfer lines can be efficiently followed.

7.

LIGHTWEIGHTING IN DWELLING CONFIGURATION

Collective and private load patterns

Dwelling type allocation

Dwelling scale: spatial efficiency

Collective and private load patterns

Given that collective floor areas result in a higher live load, this also means that the dead weight of the load-bearing floors, beams, and columns increases. At first glance, this seems counterproductive in terms of lightweighting. However, if we consider the number of people and weigh that against the structural weight, a different perspective emerges. While the goal of the research is to keep the structural weight as low as possible to maximize usable space, shared spaces actually have the potential to deliver the same quality while requiring less floor area.

The following study uses deduction to arrive at an answer using three examples.

- The building on the left is highly community-oriented, with many small dwellings and a great deal of shared space.
- The building on the right is primarily private-oriented, with few but large dwellings, and the fewest shared amenities.
- The middle building is equally oriented toward both the collective and the private. Key data include the number of residents per dwelling, which can vary and has a direct impact on the result.

Dwelling configuration (number of floors and floor area) is also an important factor, which is discussed in the following section. The layout of the common areas in the private block is advantageous, given that the floor area is very limited by the building's three-story height, rather than having a shared floor on each level in the collective block.

The comparison shows that the structural efficiency of collective living depends not only on the amount of shared space, but also on how that space is organized. Shared areas become advantageous when they are concentrated, multifunctional, and used intensively by a large number of residents. Conversely, when collective spaces are distributed too generously or repeated too frequently, they may increase structural mass without providing equivalent spatial benefits.

It is advantageous to limit collective areas by allocating them strategically. Collective space should be concentrated where it can align with the strongest zones of the existing structure. Through this, shared space can contribute to domestic quality and community formation without unnecessarily increasing the structural weight of the top-up. The most lightweight dwelling configuration is therefore not necessarily the one with the least collective space, but the one in which collective space achieves the highest utility per square metre and per kilogram of added structure.

- **Private units with little common space is most lightweight**
- **There where the column density is highest: most suitable for collectively oriented housing**
- **There where the column density is lowest: most suitable for privately-oriented housing**

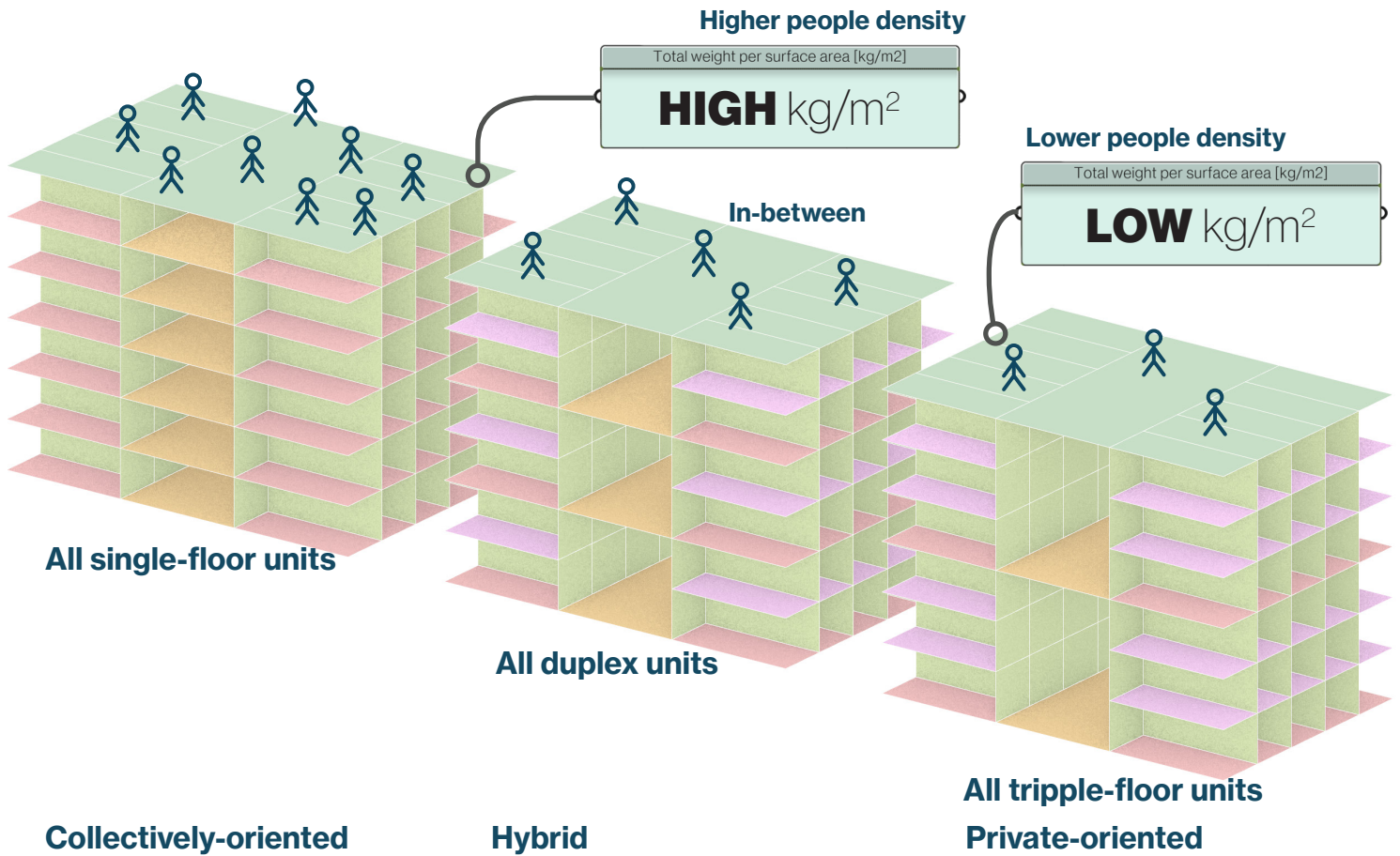


Image [x]. Abstract floor space comparison between collectively-oriented and privately-oriented housing block

	All collective	Hybrid	All private
Partitioning walls [m2]	1700	1700	1700
Partitioning floor [m2]	1500	750	500
Dwelling floor [m2]	0	750	1000
Collective floor space [m2]	750	375	250
Apartments amount	60	30	20
Average inhabitants per apartment	1	1.5	2
Inhabitants per building	60	45	40
Collective floors	6	3	2
Total floor area [m2]	2250	1875	1750
Floor area per inhabitant	37.5	41.7	43.8

Tabel 6: Quantitative floor space comparison between collectively-oriented and privately-oriented housing block

Dwelling type allocation

Community-oriented housing generally requires higher floor loads than private-oriented dwellings, resulting in greater structural demand on the existing load-bearing structure and foundation. Private-oriented housing, by contrast has lower imposed loads, making it more suitable for structurally constrained areas.

This distinction has direct consequences for the allocation of dwelling types within the top-up. In zones where the existing structural grid is larger (and where transfer trusses are required to mediate between the existing grid and the new timber structure) it is more efficient to place lighter private-oriented dwellings. These units reduce the demand on transfer structures and limit additional loading on the existing building.

On the other hand, areas with a denser existing column grid or more direct load paths are better suited to collective-oriented housing. In these zones, higher floor loads can be transferred more efficiently into the existing structure, without requiring transition elements. This allows collective spaces to support higher population densities.

Through this, dwelling allocation becomes a strategy for lightweighting. The housing programme is organized according to the structural capacity of the existing building. Heavier collective functions are concentrated where load transfer is most direct, while lighter private dwellings occupy areas where structural capacity is more limited or where additional transfer systems are needed.

- **The less floor elements, the lighter the building**
- **The less partitioning floors, the lighter the building**
- **Optimal unit: small footprint, many storeys**

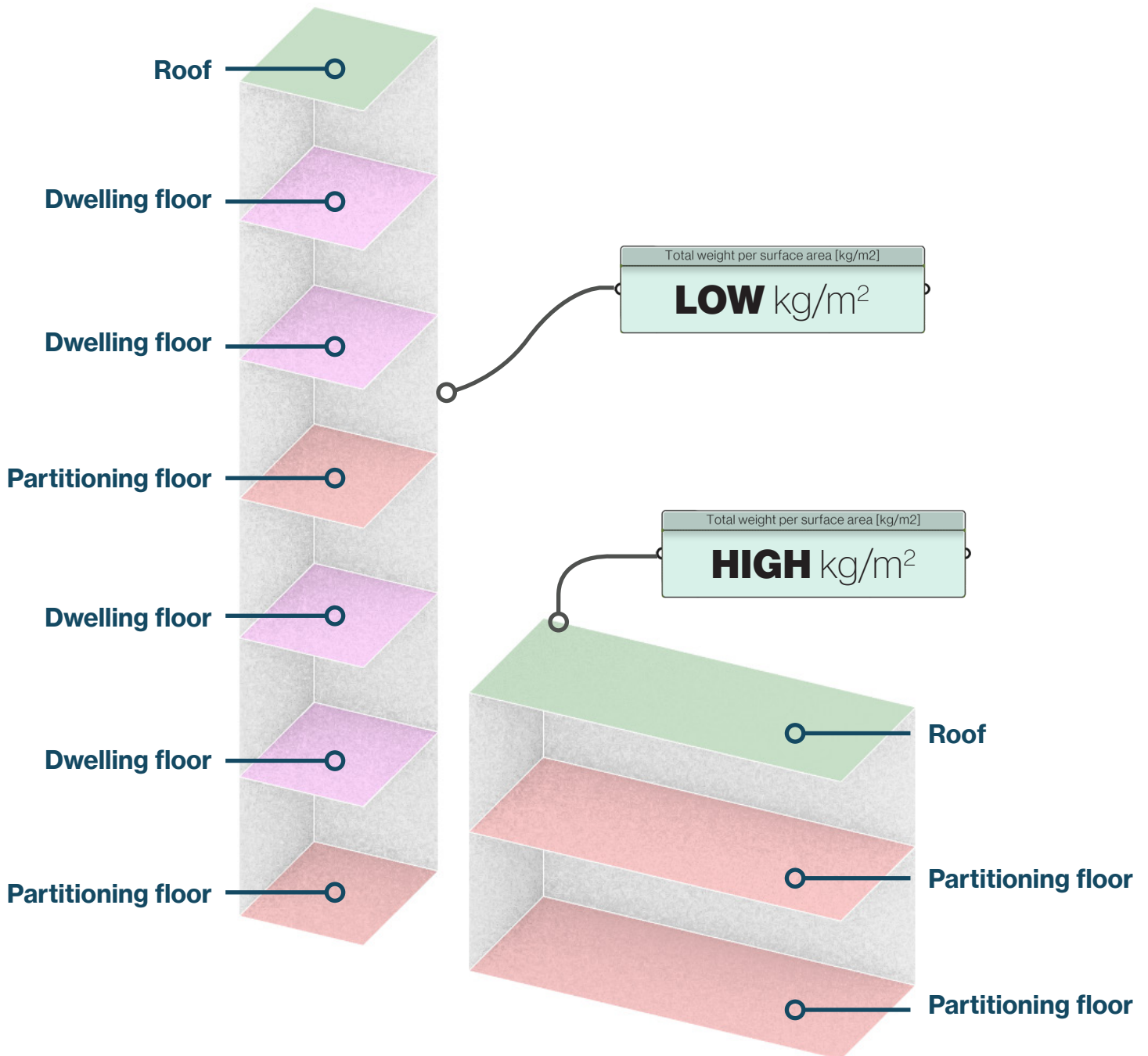


Image [x]. Abstract dwelling type comparison:
 Left: Tall and small footprint
 Right: Single-floor and large footprint

Dwelling scale: spatial efficiency

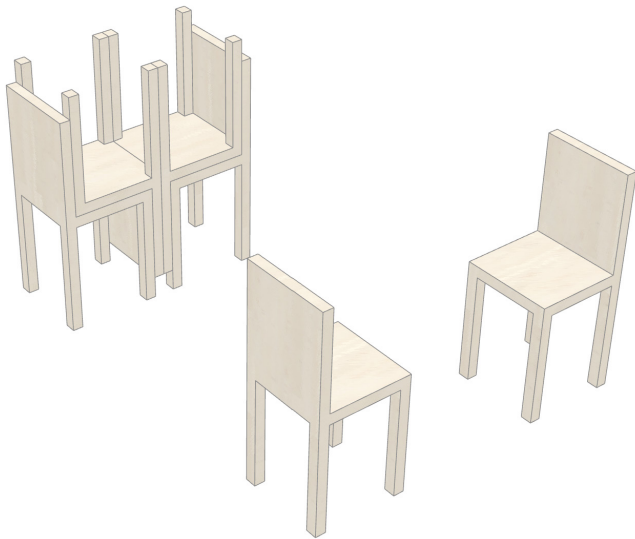
At the dwelling scale, lightweighting is approached through spatial efficiency. The underlying principle is that reducing the required floor area of each dwelling also reduces the amount of structure and materials needed for the top-up. In this sense, compact living becomes a direct lightweighting strategy: smaller dwellings require less building mass, while ensuring that domestic quality is maintained.

The aim is therefore to make each square metre perform more effectively. Spatial optimization allows a dwelling to support multiple activities within a reduced footprint, limiting circulation space and underused areas.

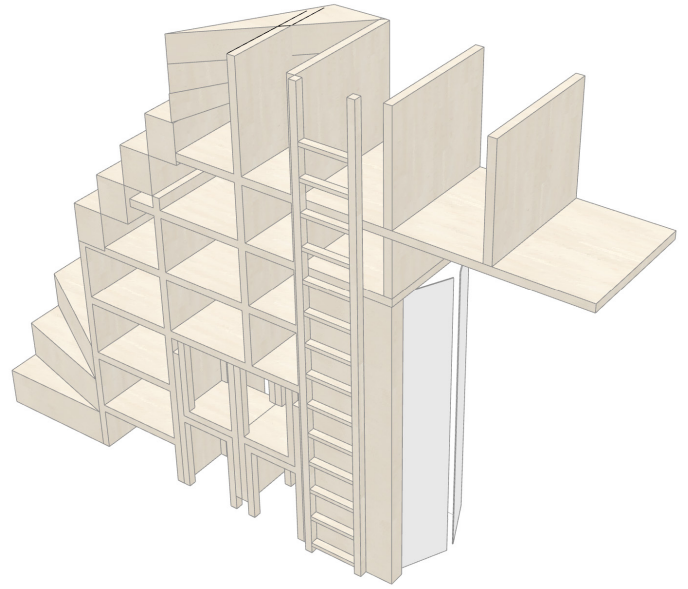
Four key principles are used to guide the floor plan design:

- **Vertical stacking**
Functions are layered vertically through high ceilings, stackable furniture and storage walls. Hereby not only the surface area, but also the volume is utilised, without increasing floor area.
- **Multifunctional space**
Rooms are designed to support different uses at different moments, such as dining, working, relaxing, and sleeping. This reduces the need for separate dedicated rooms.
- **Integrated storage and furniture**
Storage function is added into beds, stairs, walls, and built-in furniture. This reduces clutter and allows compact rooms to remain usable.
- **Perceived spaciousness**
Long sightlines, sufficient daylight and visual continuity are used to make compact dwellings feel larger.

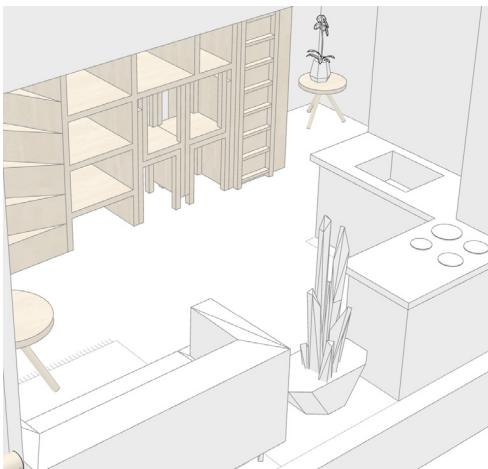
Together, these principles show that by reducing floor area while maintaining comfort and perceived spaciousness, the dwelling layout contributes directly to the reduction of the overall building mass.



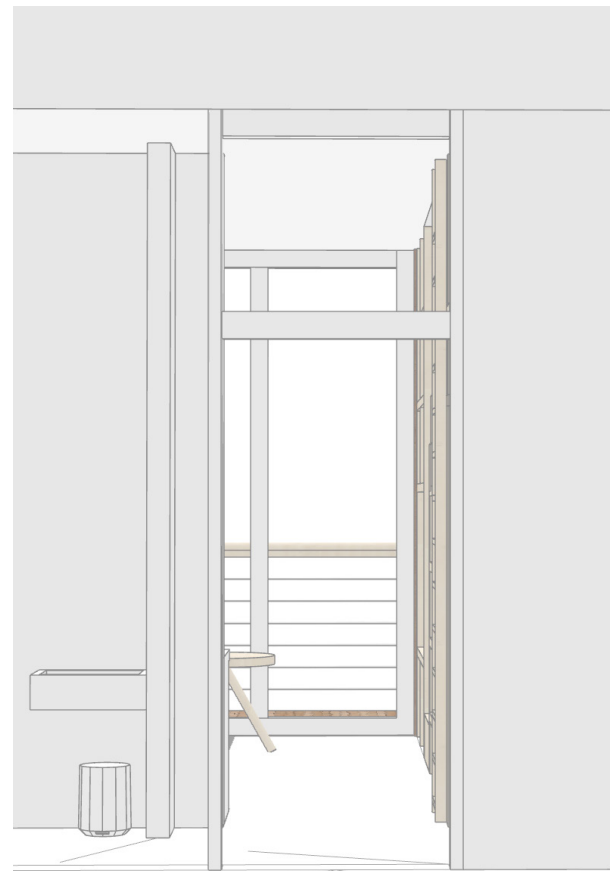
Vertical stacking



Integrated storage



Multi-purpose space



Perceived spaciousness

8 ■

ARCHITECTURAL EXPRESSION OF LIGHTWEIGHTING

KALVER TOP-UP LIGHTWEIGHTING SYNTHESIS

Structure as design generator

Dwelling floor plans

Plan drawings

Climatic concept

Sections and fragments

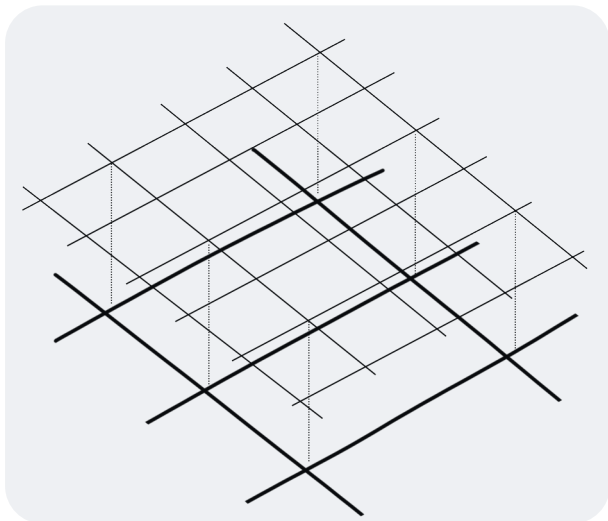
Details

Answer to the design questions

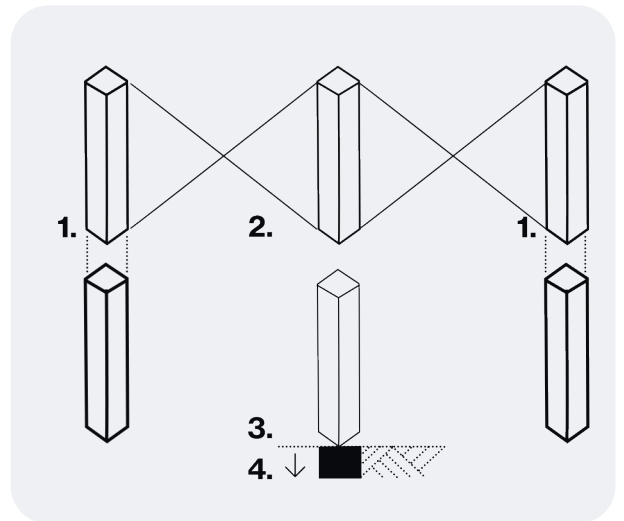


STRUCTURE AS DESIGN GENERATOR

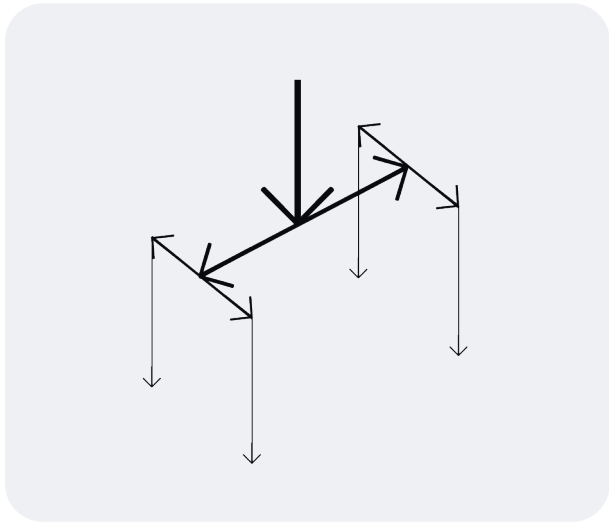
Structural principles



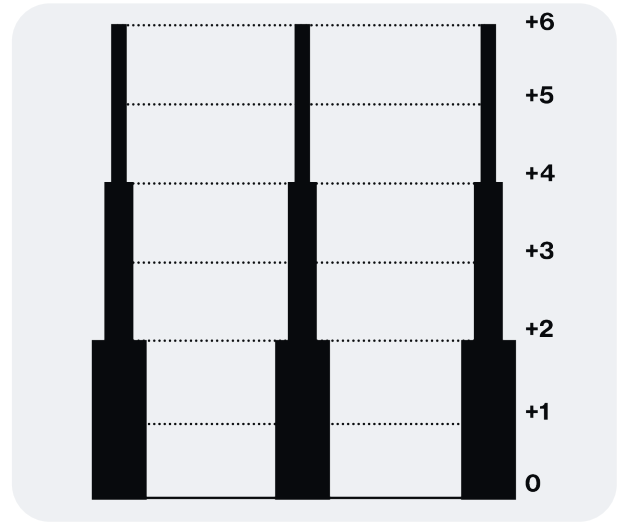
A fine sub-grid



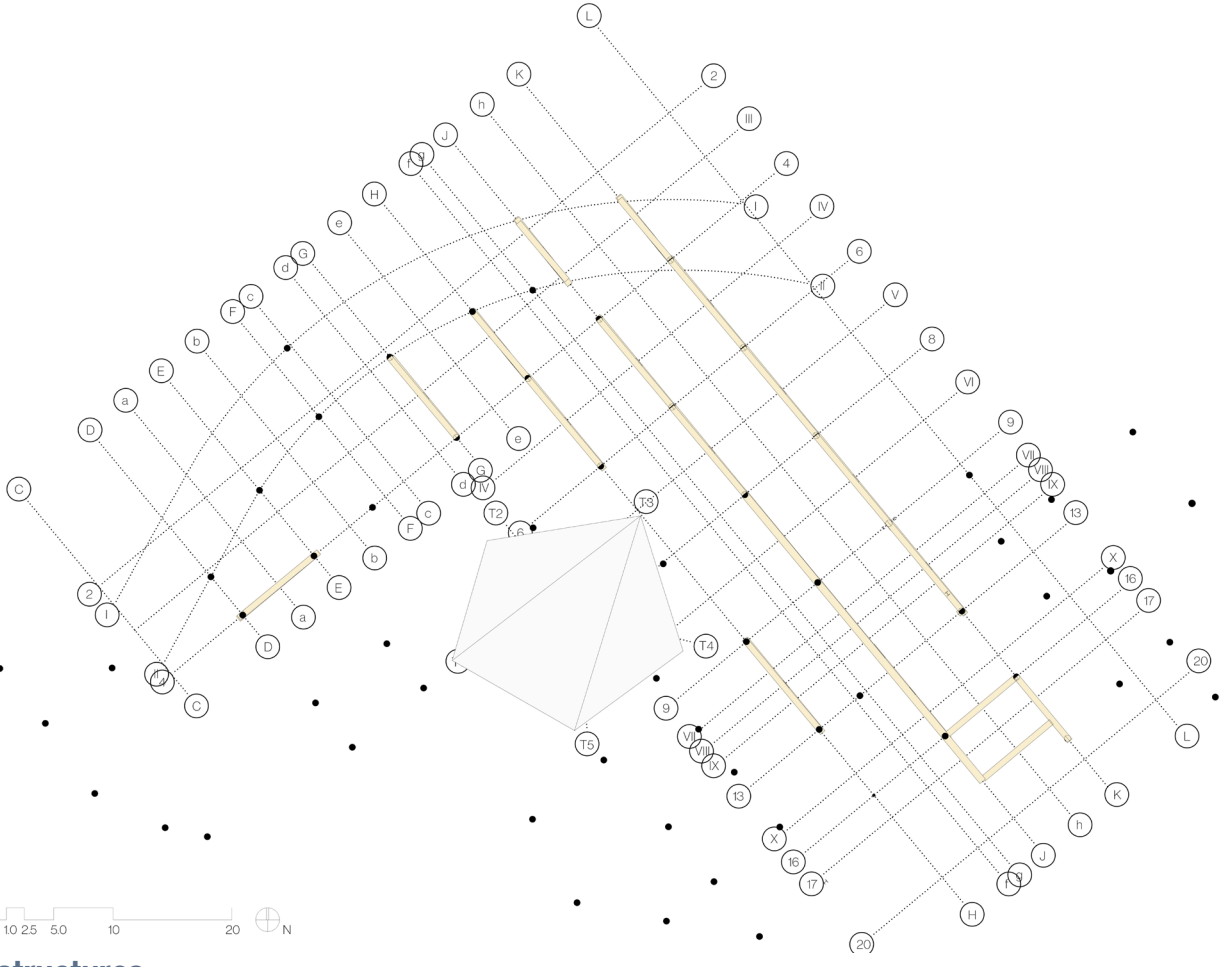
A hierarchy of new load-bearing nodes



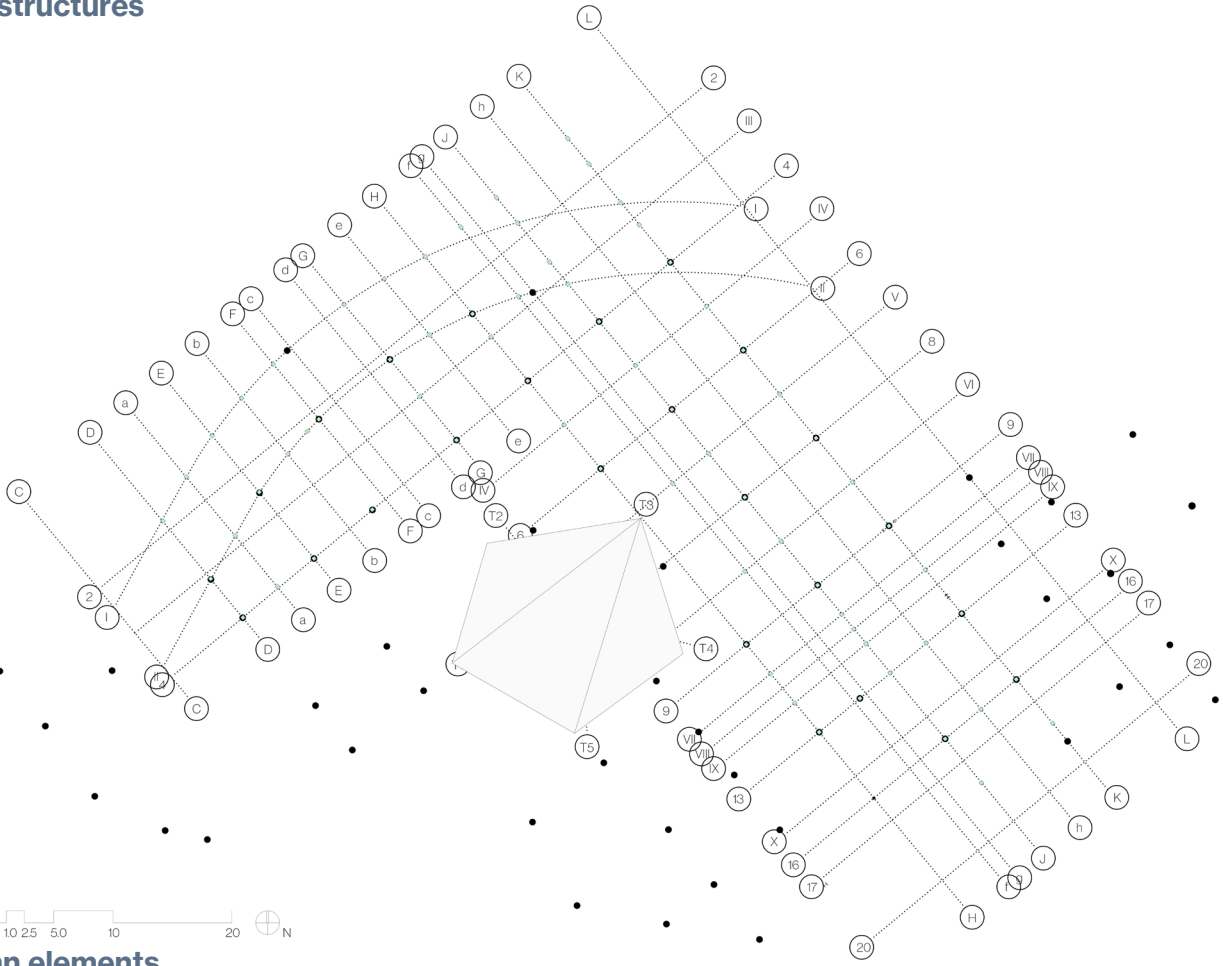
A load-path system



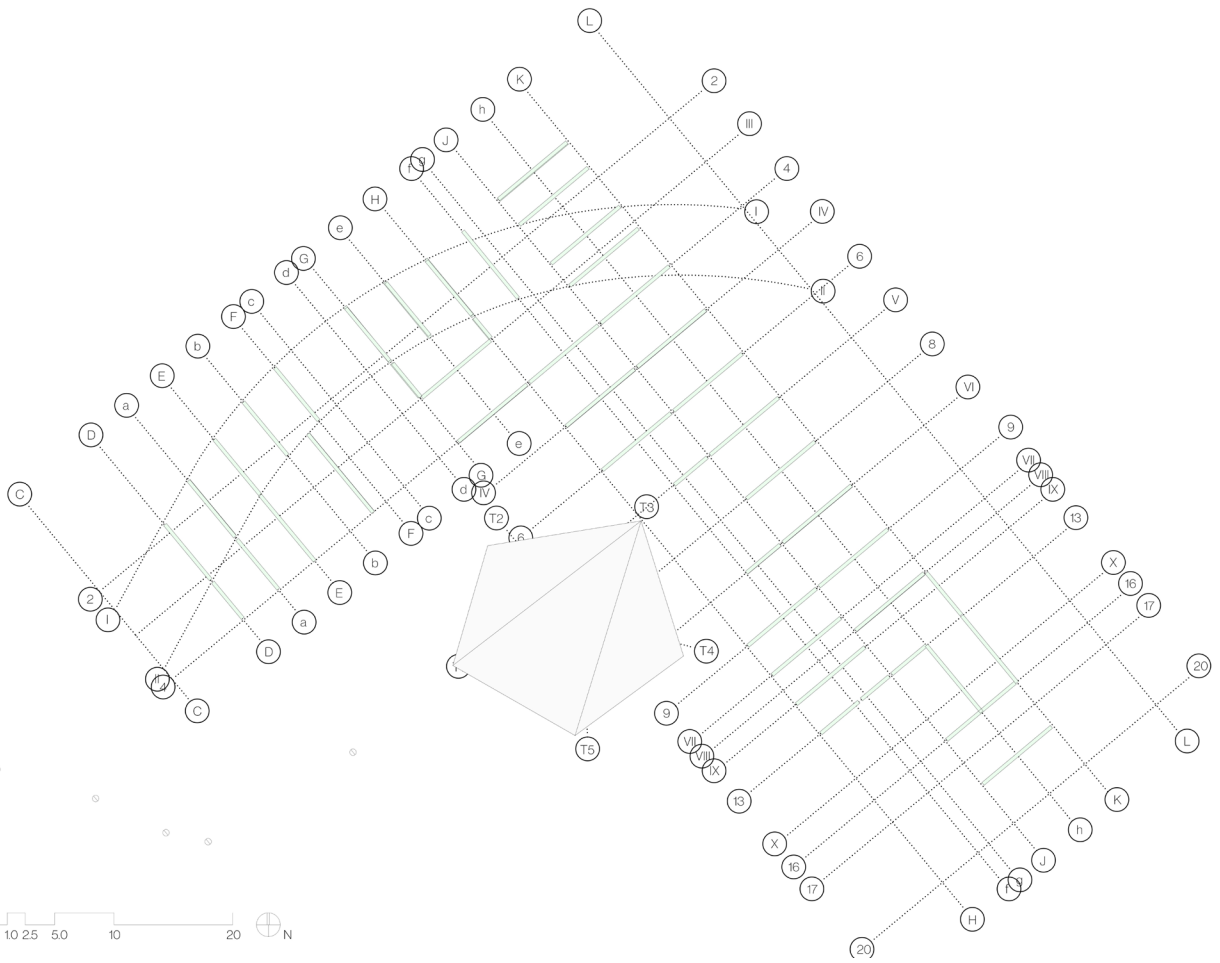
Localised mass density



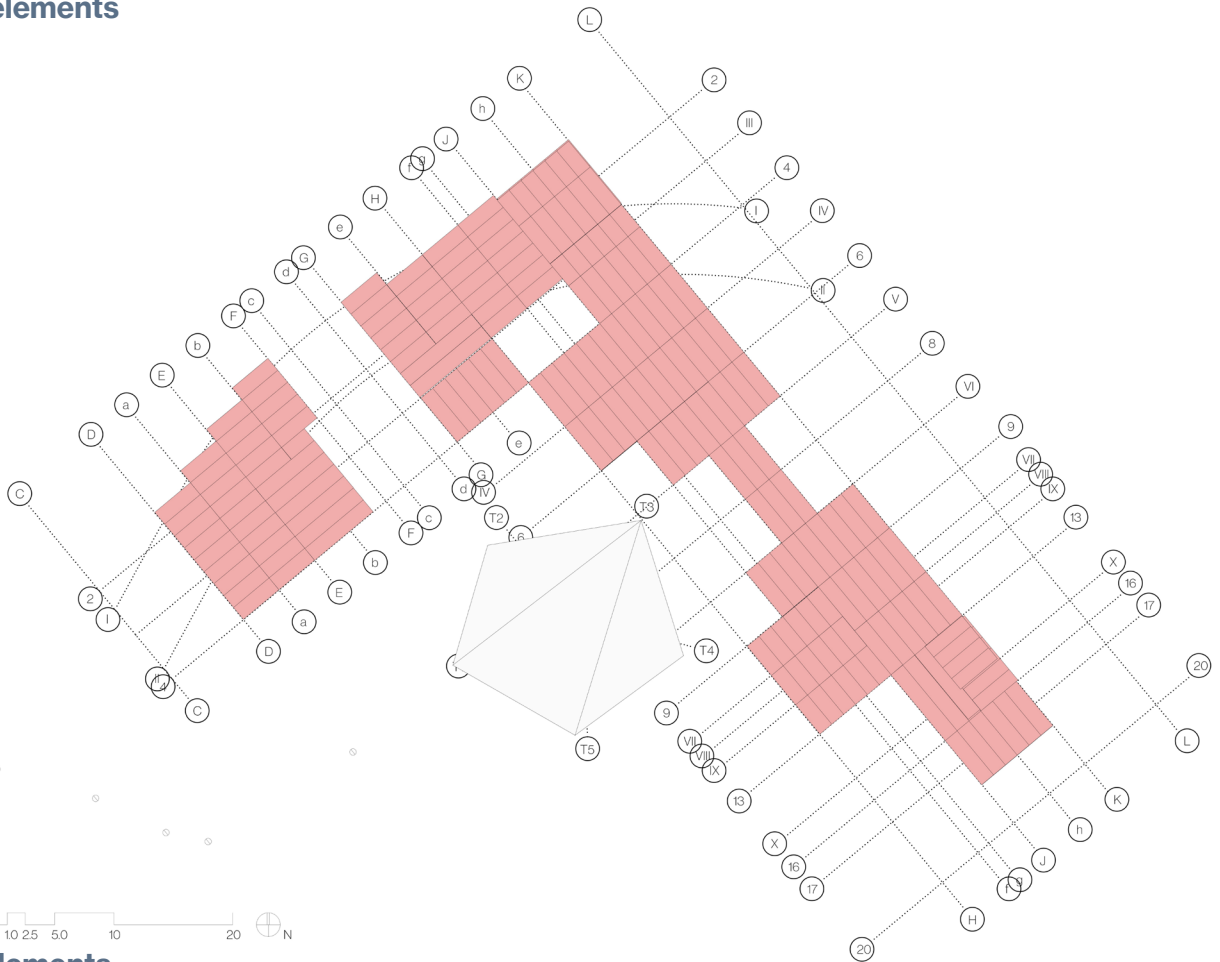
Truss structures



Column elements

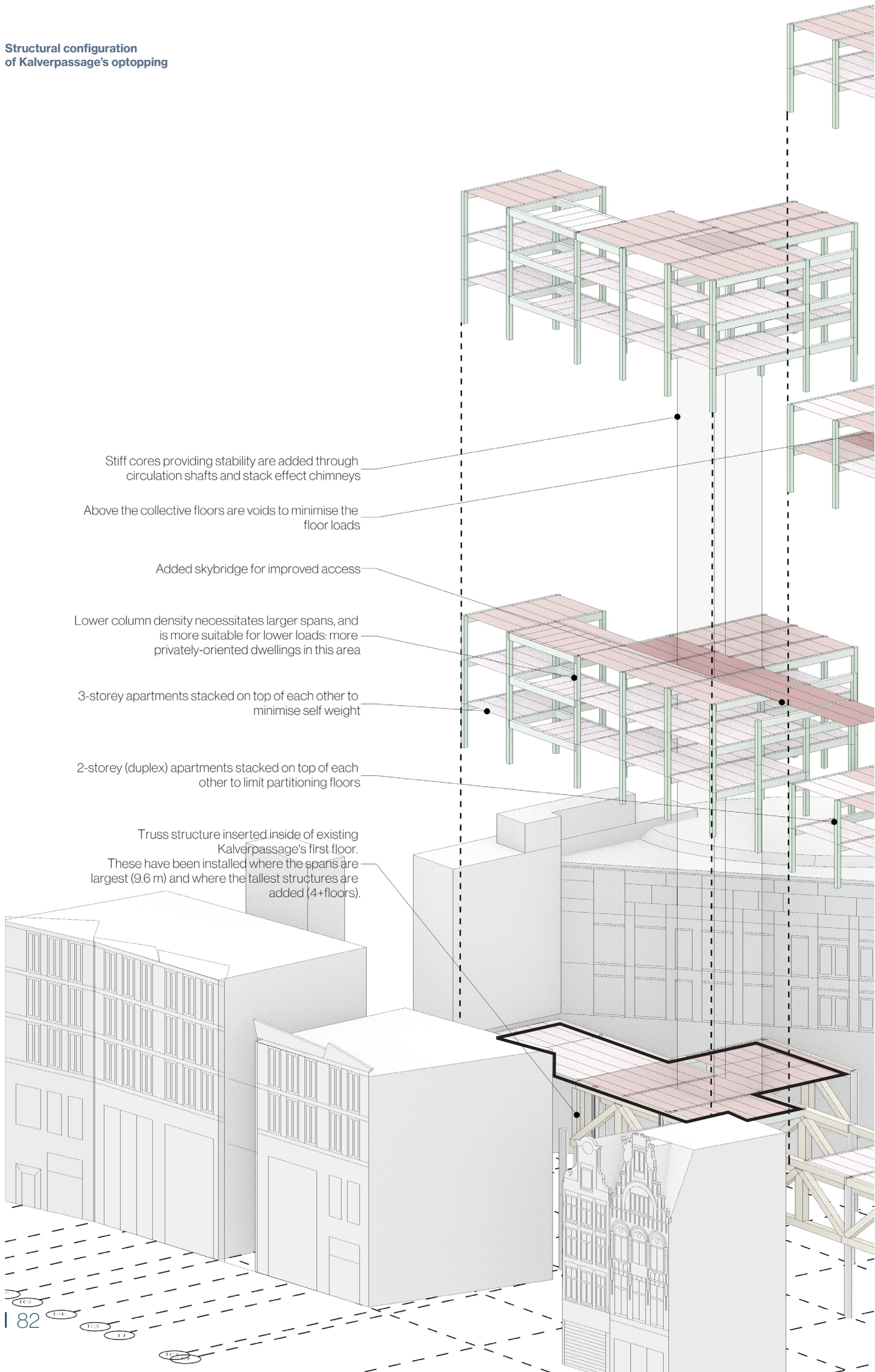


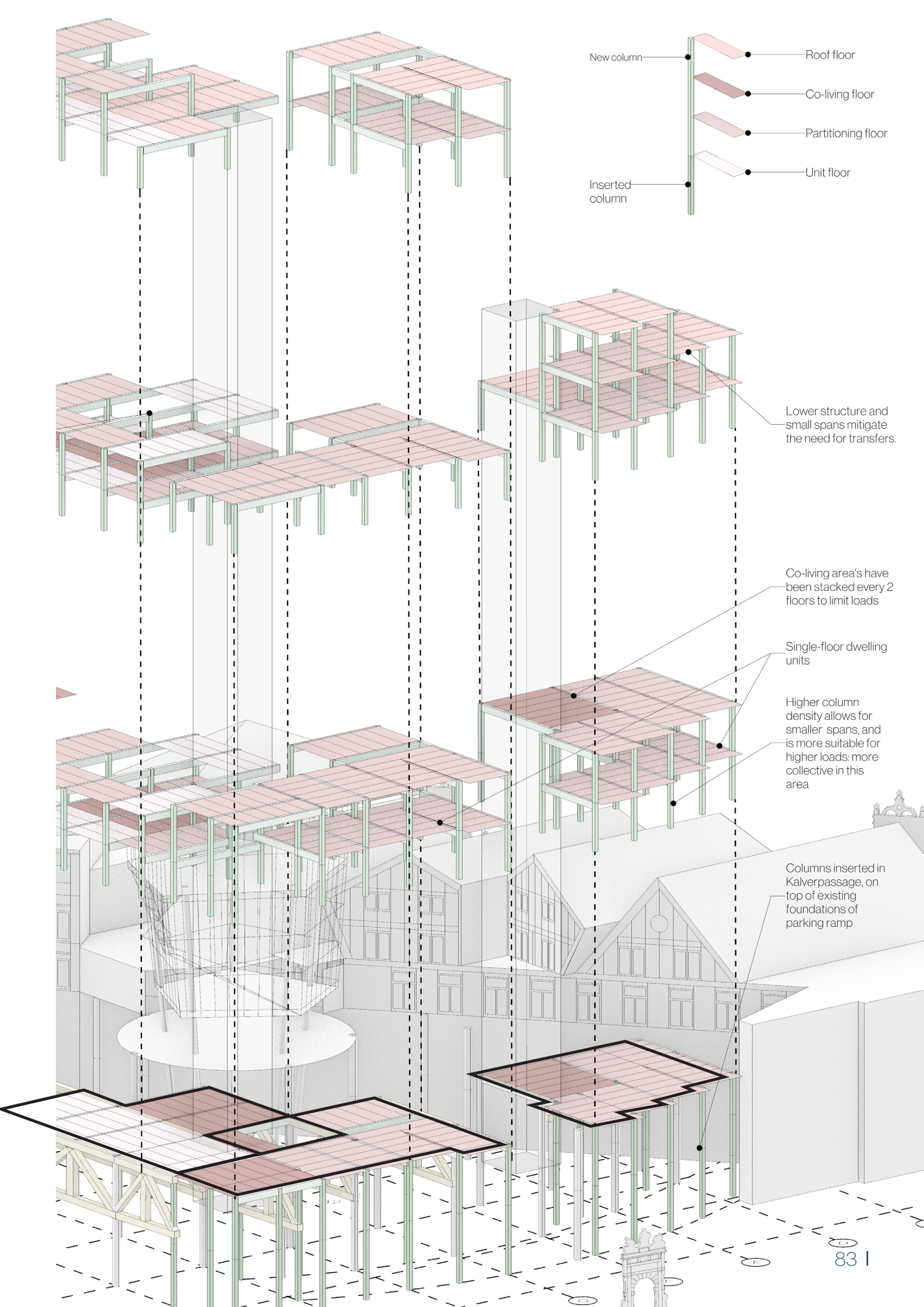
Beam elements



Floor elements

**Structural configuration
of Kalverpassage's optopping**





New column

Roof floor

Co-living floor

Partitioning floor

Unit floor

Inserted column

Lower structure and small spans mitigate the need for transfers.

Co-living area's have been stacked every 2 floors to limit loads

Single-floor dwelling units

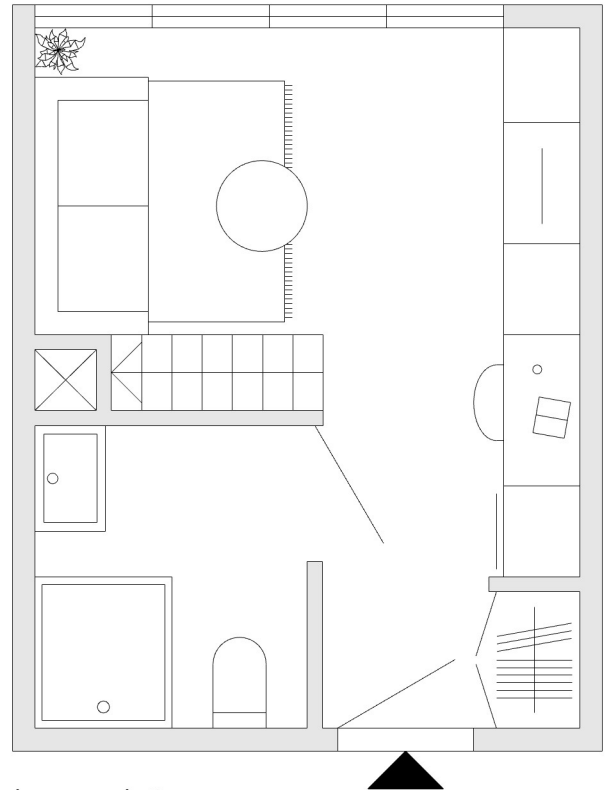
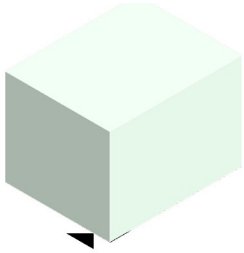
Higher column density allows for smaller spans, and is more suitable for higher loads: more collective in this area

Columns inserted in Kalverpassage, on top of existing foundations of parking ramp

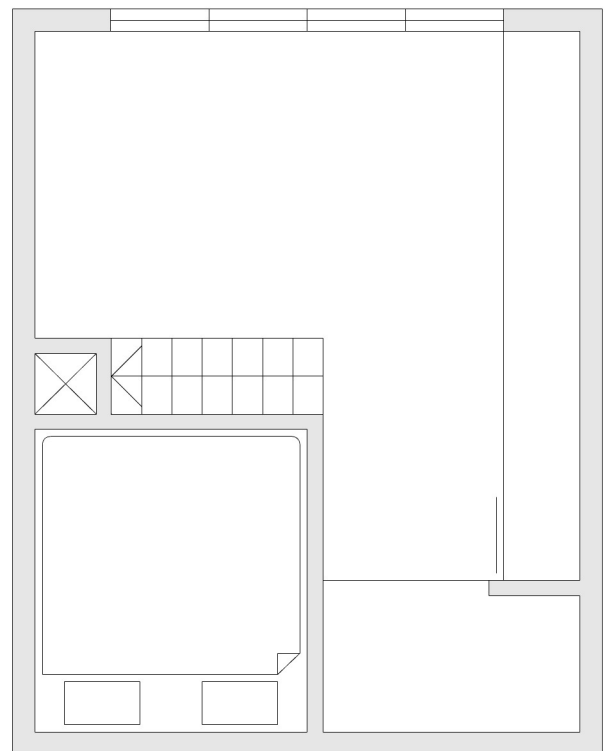
DWELLING PLANS

The crate

Area bruto:	19.2 m ²
Area netto:	16.7 m ²
Height:	3.4 m
Floors:	1
n Units:	52



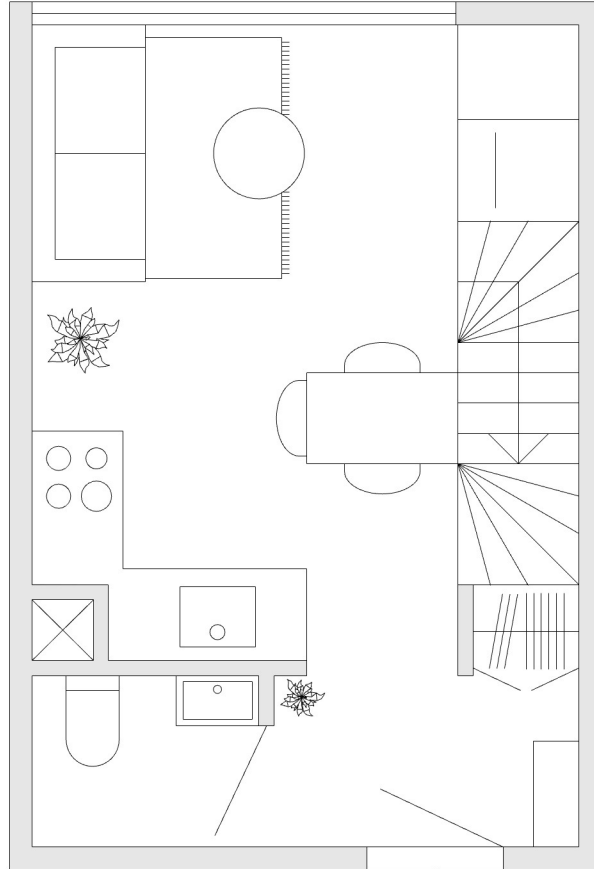
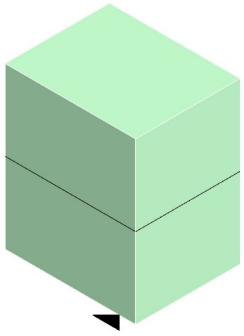
Level 0
Height: 2100 mm



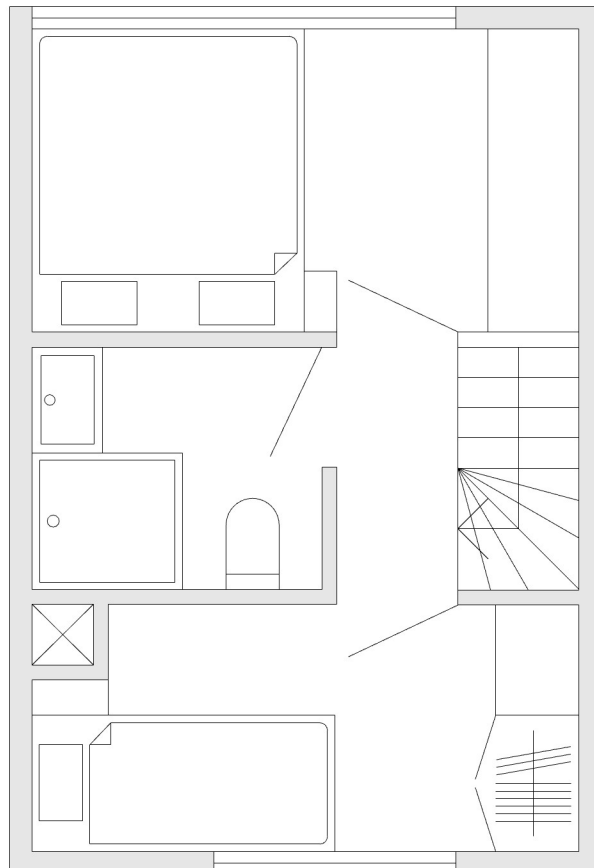
Mezzanine (+2200)
Height: 1200 mm

The chest

Area bruto:	38.0 m ²
Area netto:	34.8 m ²
Height:	6 m
Floors:	2
n Units:	10



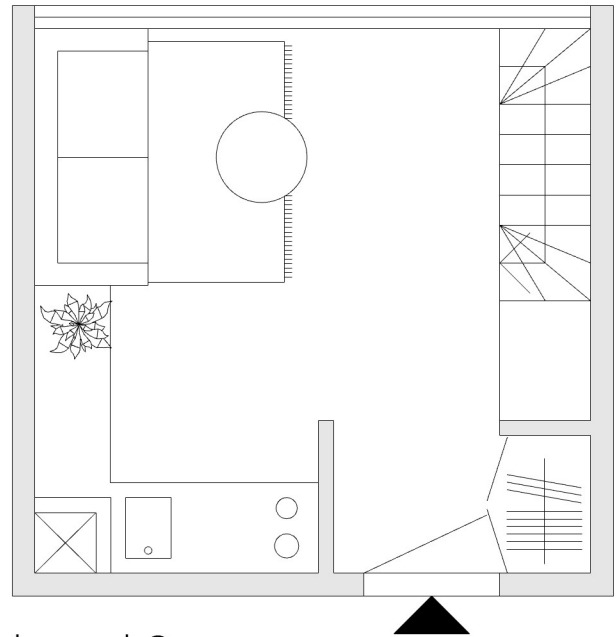
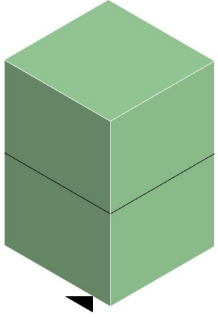
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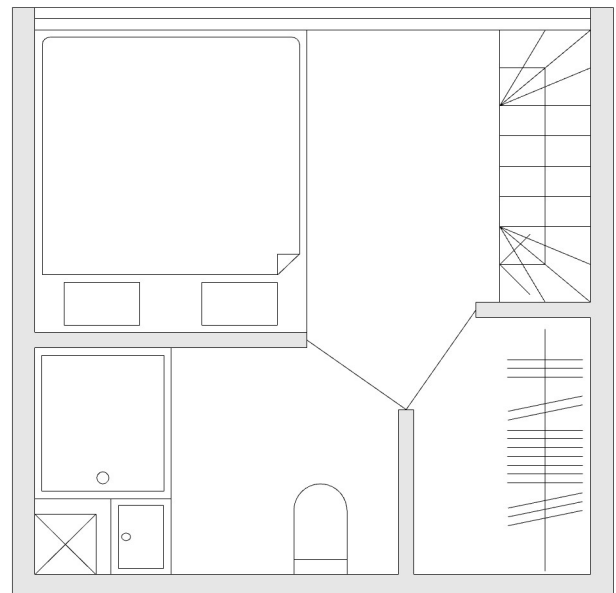
Level 1

The duplex

Area bruto:	31.0 m ²
Area netto:	26.4 m ²
Height:	6.0 m
Floors:	2
n Units:	16



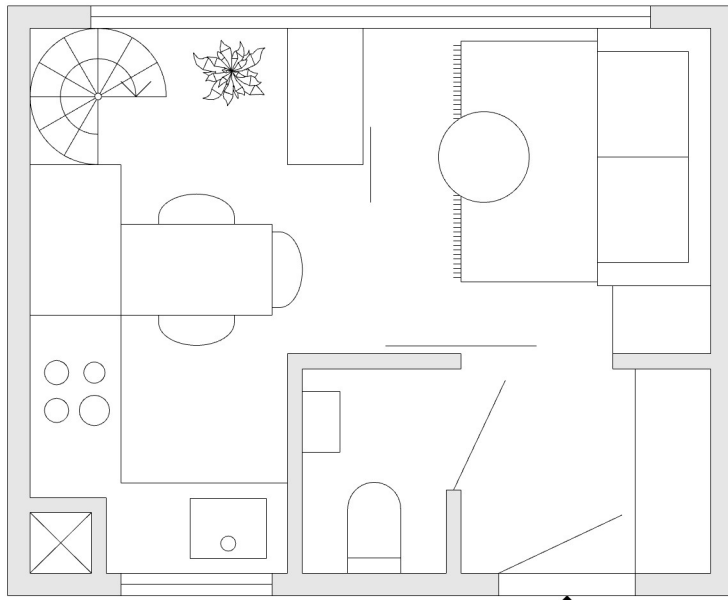
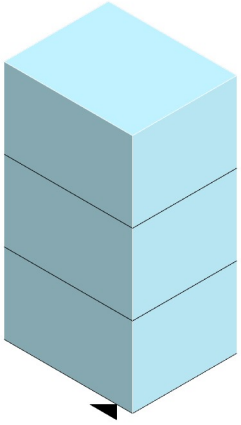
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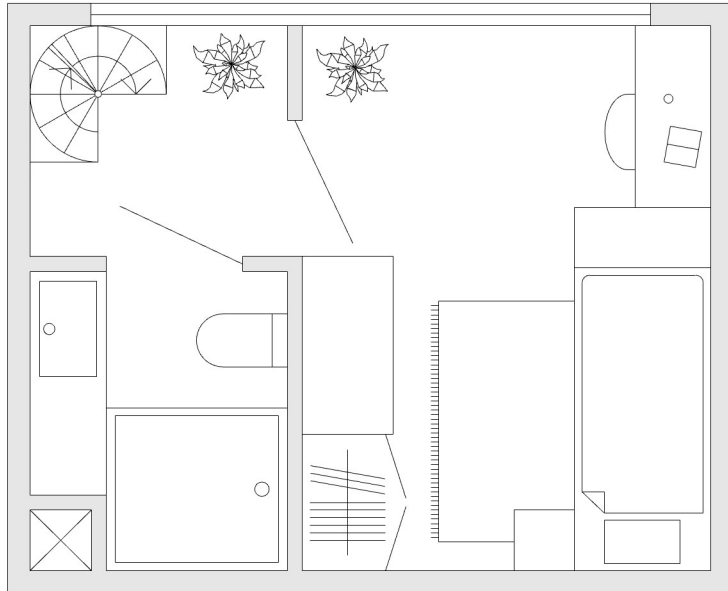
Level 1

The triplex

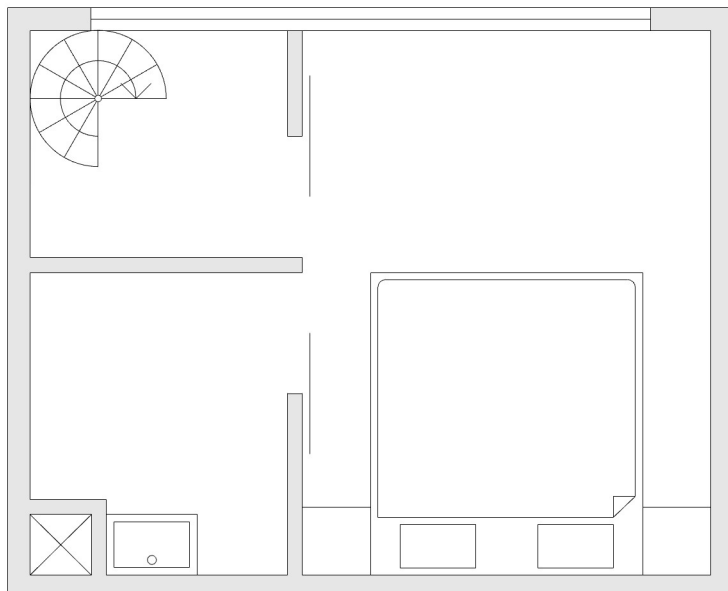
Area bruto:	56.2 m ²
Area netto:	48.6 m ²
Height:	9.0 m
Floors:	3
n Units:	14



Level 0



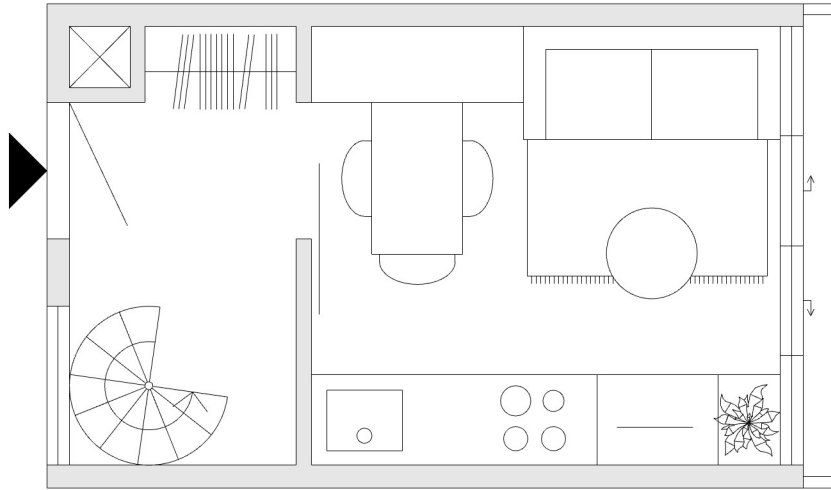
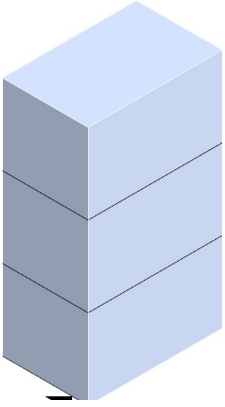
Level 1



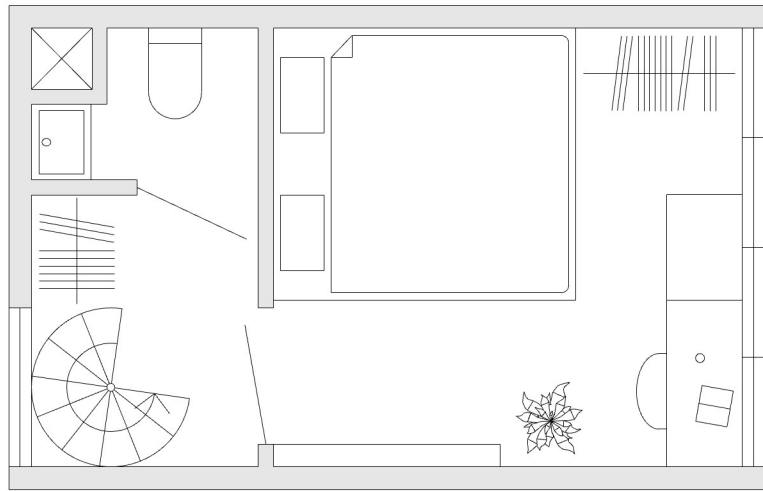
Level 2

The multiplex

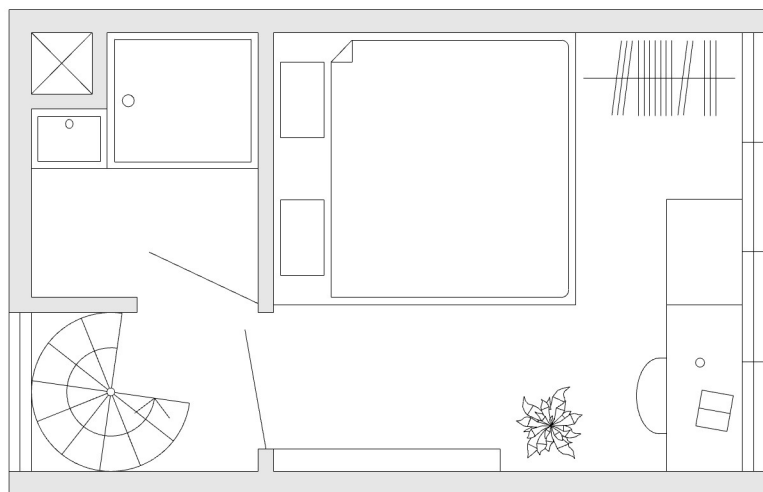
Area bruto:	48.0 m ²
Area netto:	40.9 m ²
Height:	9.0 m
Floors:	3
n Units:	5



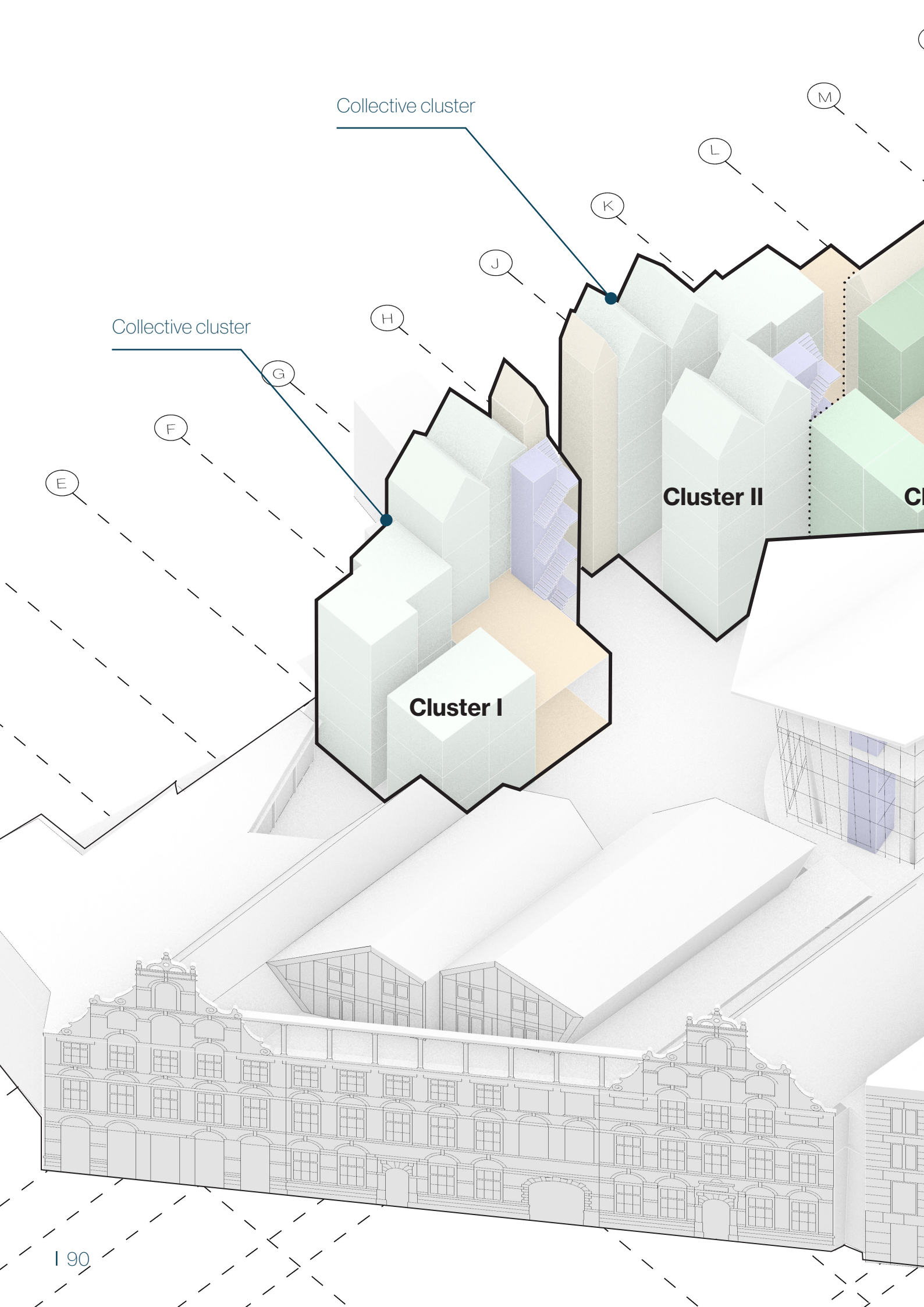
Level 0



Level 1



Level 2

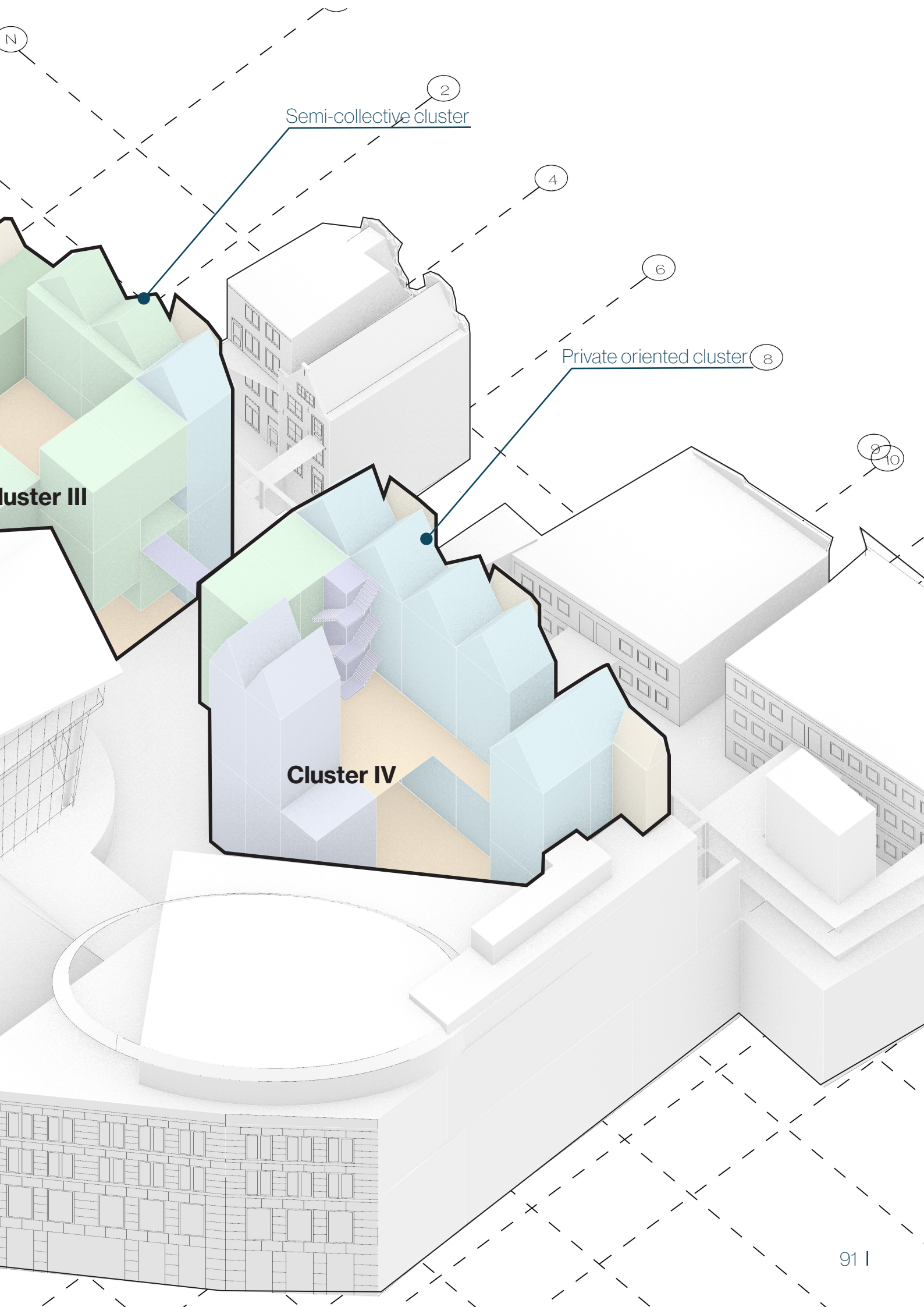


Collective cluster

Collective cluster

Cluster I

Cluster II



Semi-collective cluster

2

4

6

Private oriented cluster

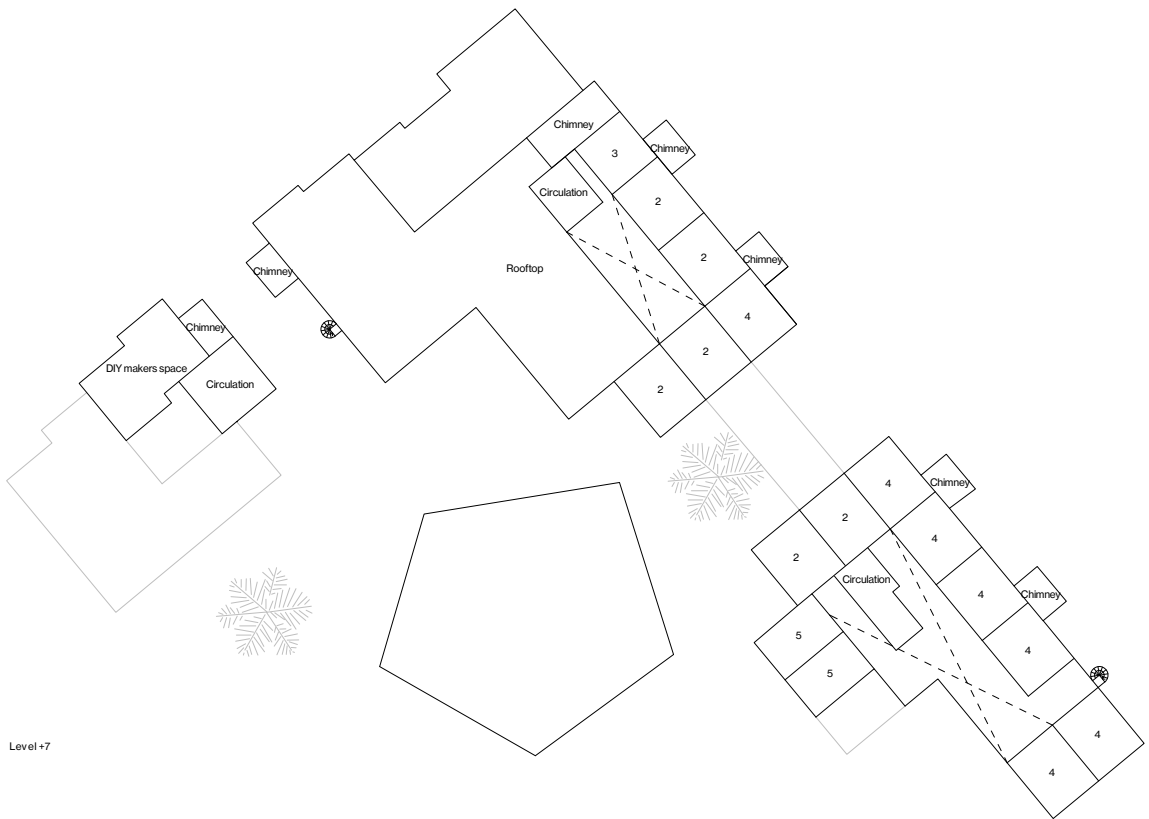
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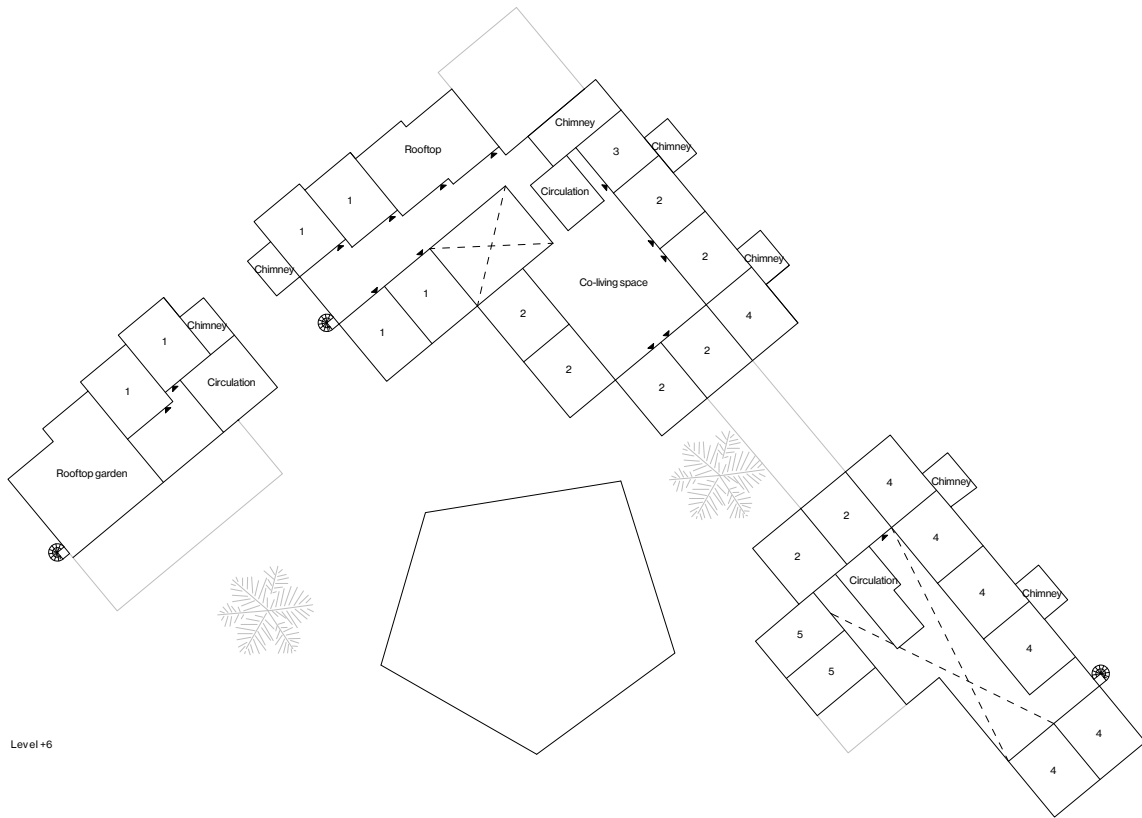
10

Cluster III

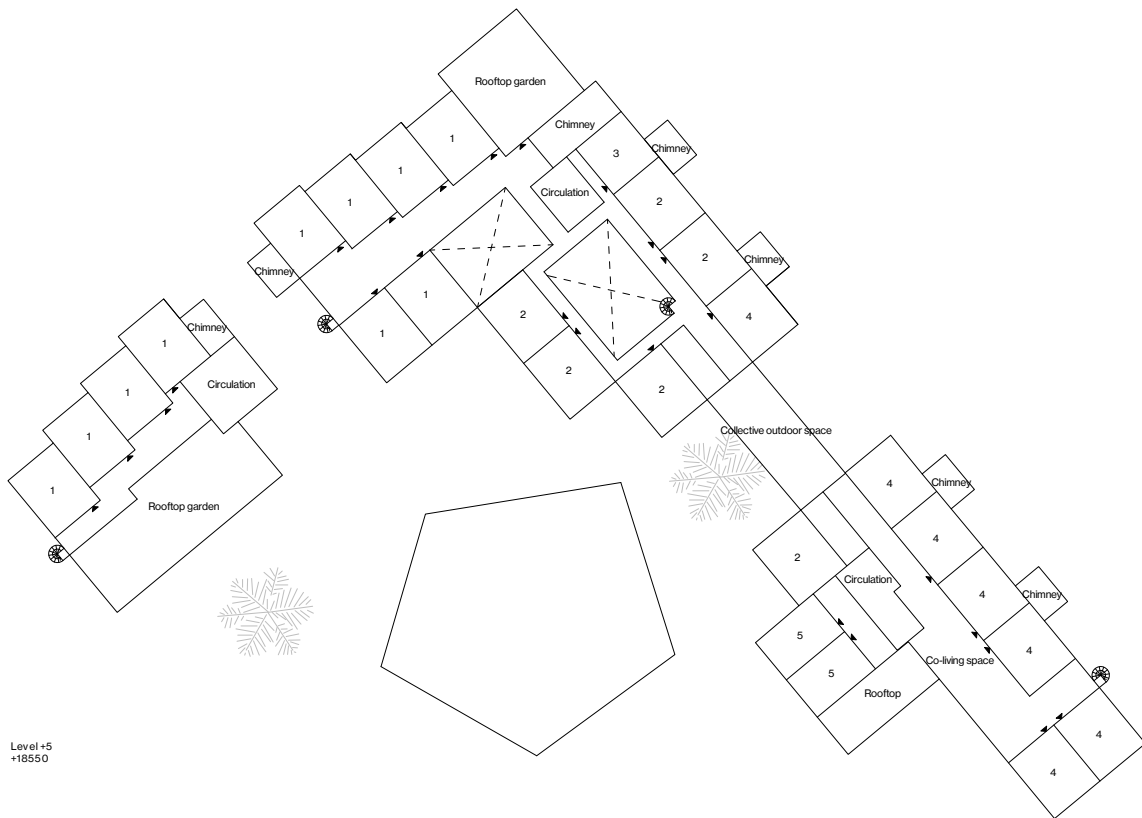
Cluster IV

PLAN DRAWINGS

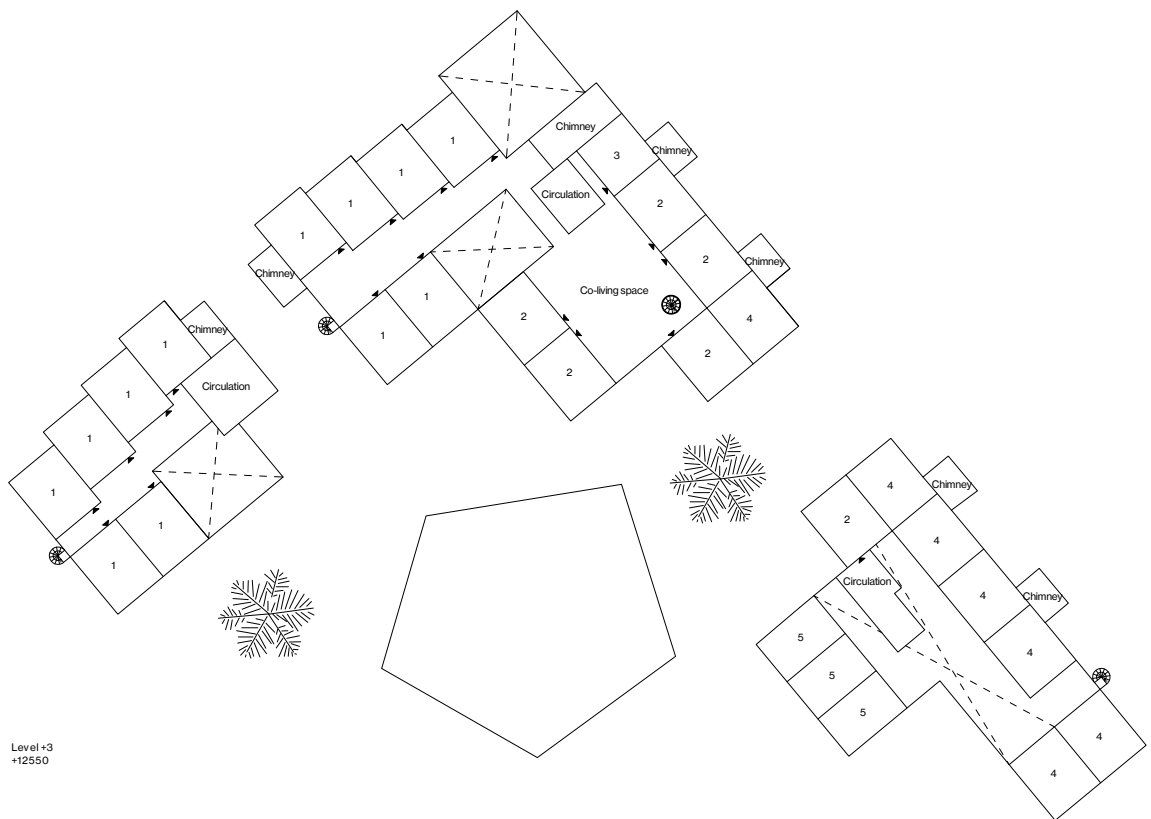
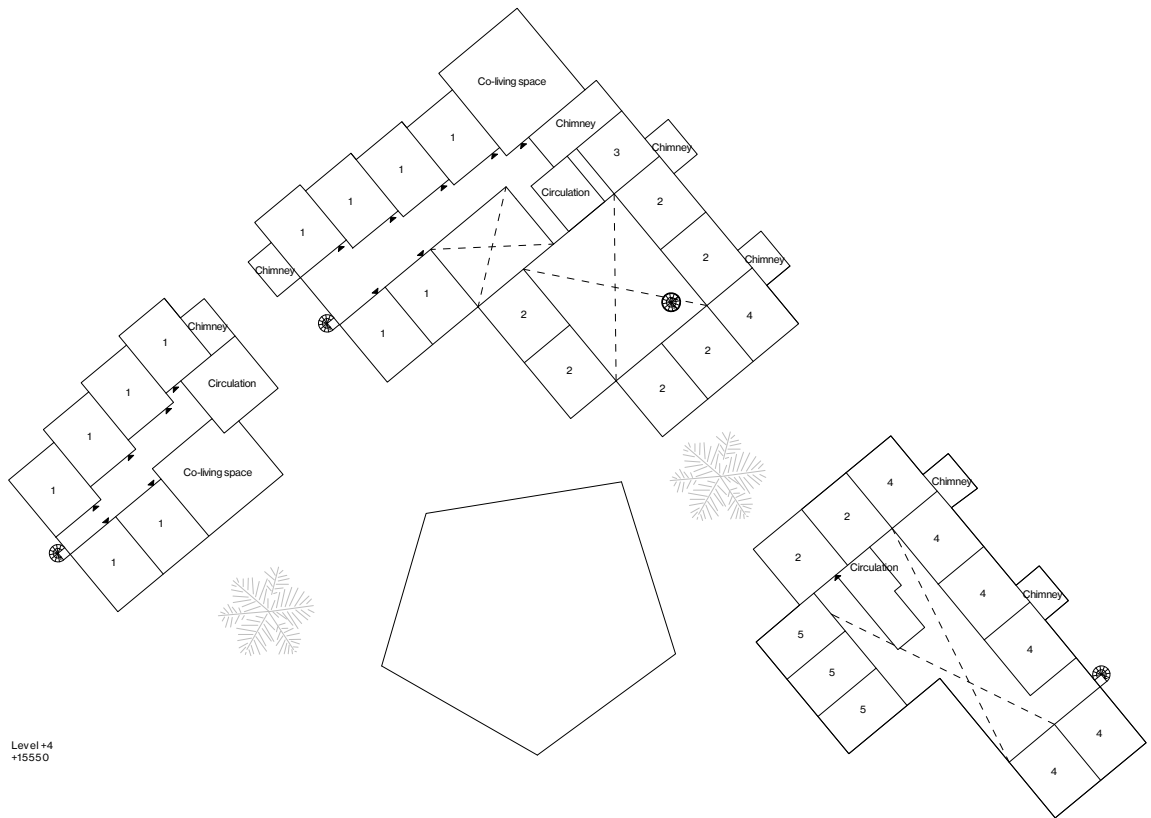




Level +6



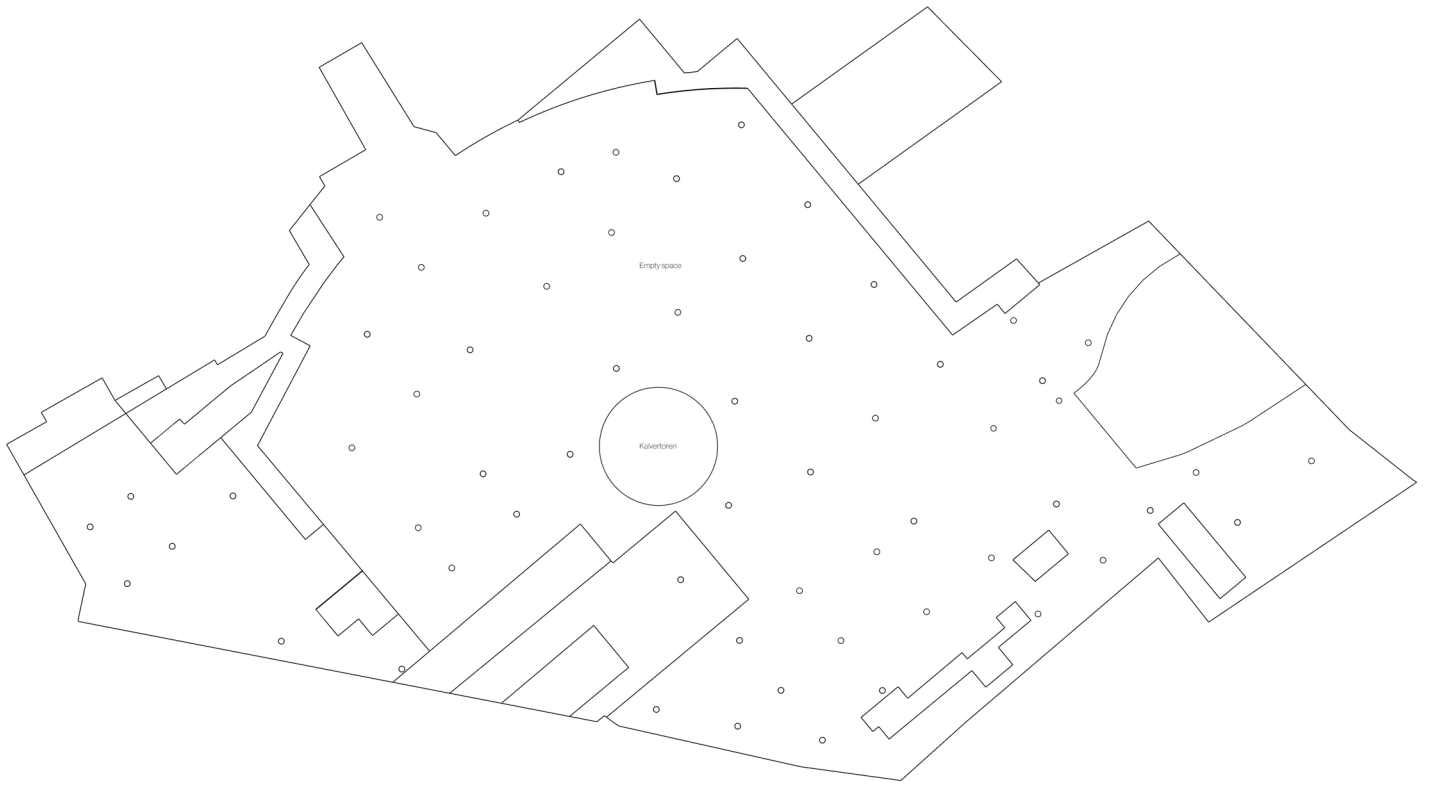
Level +5
+18550



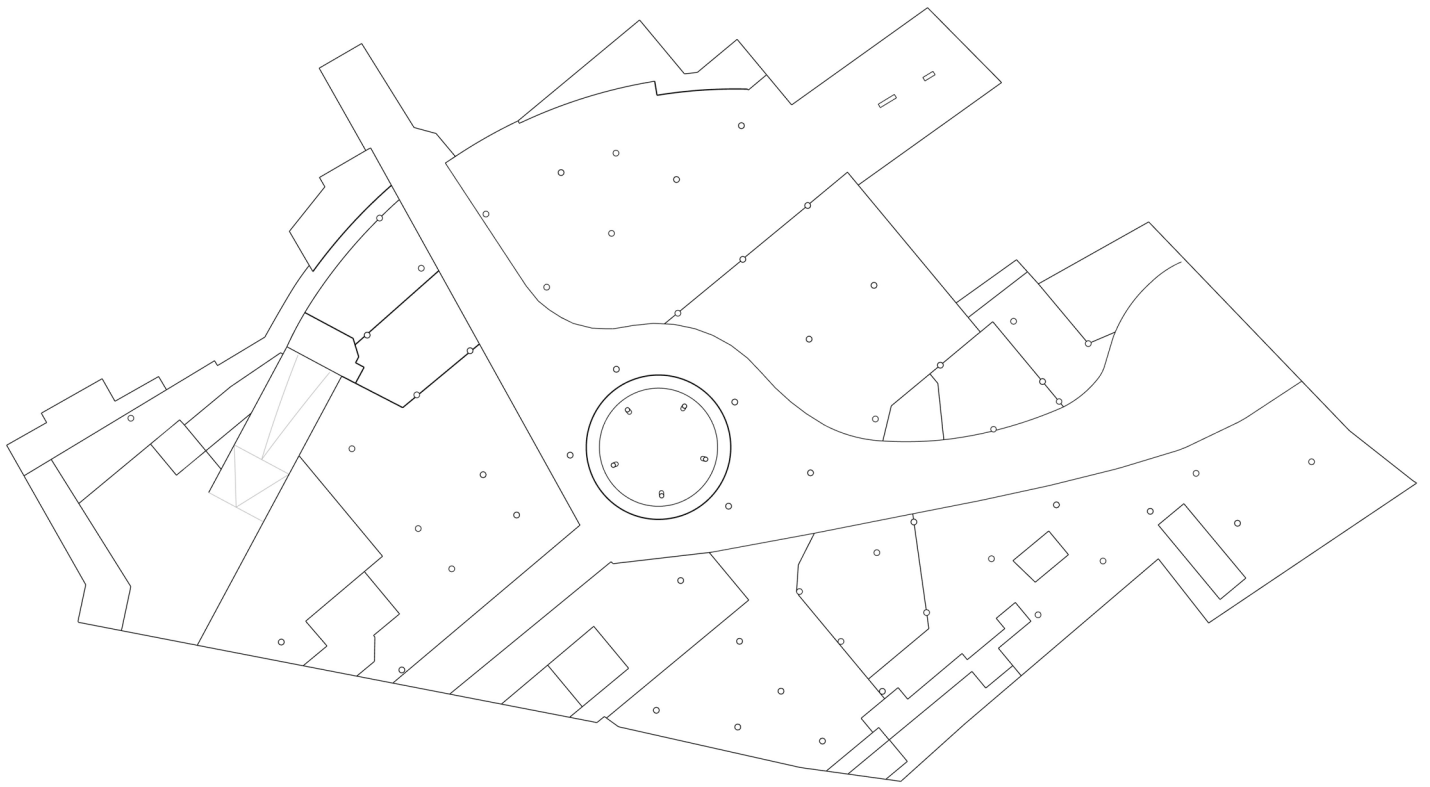
Second floor of the Kalverpassage
Or the Ground floor of the topping-up



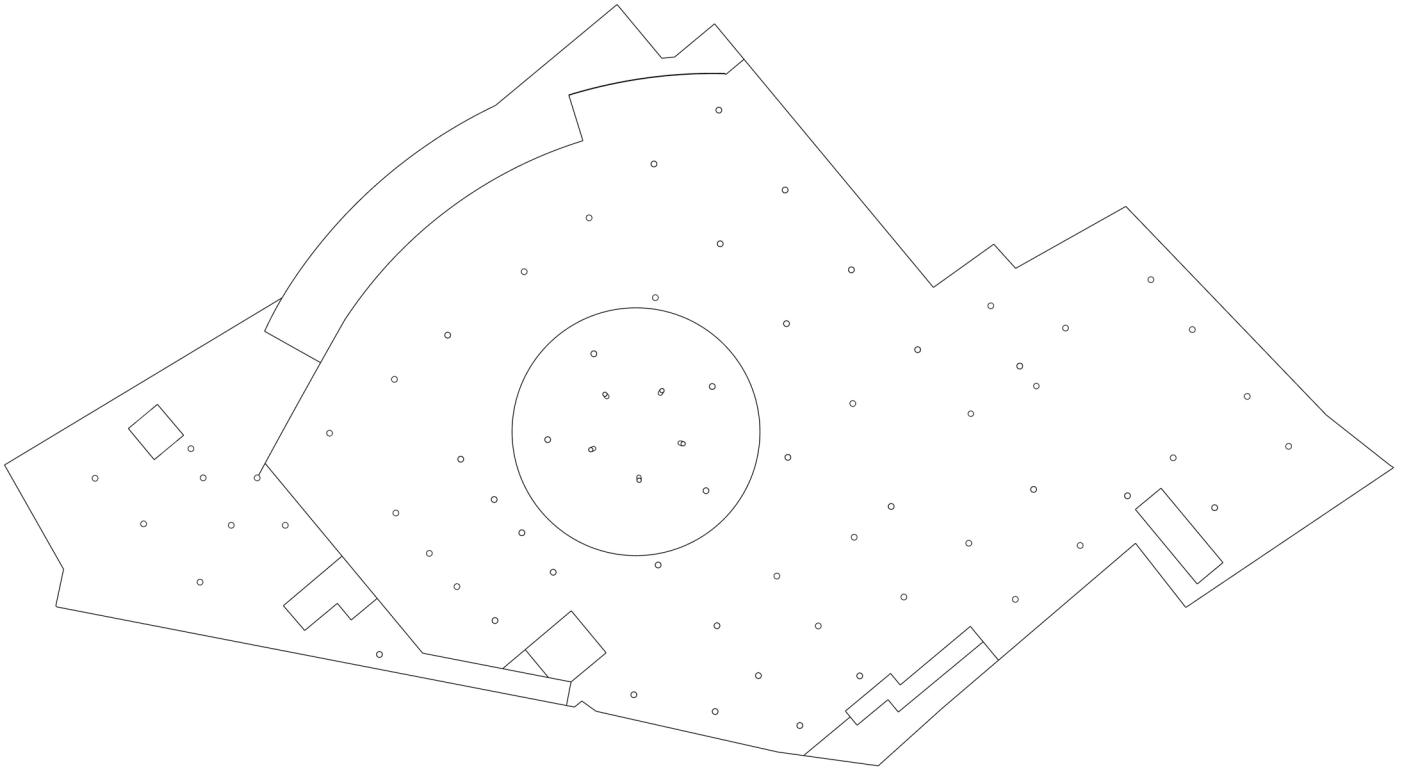




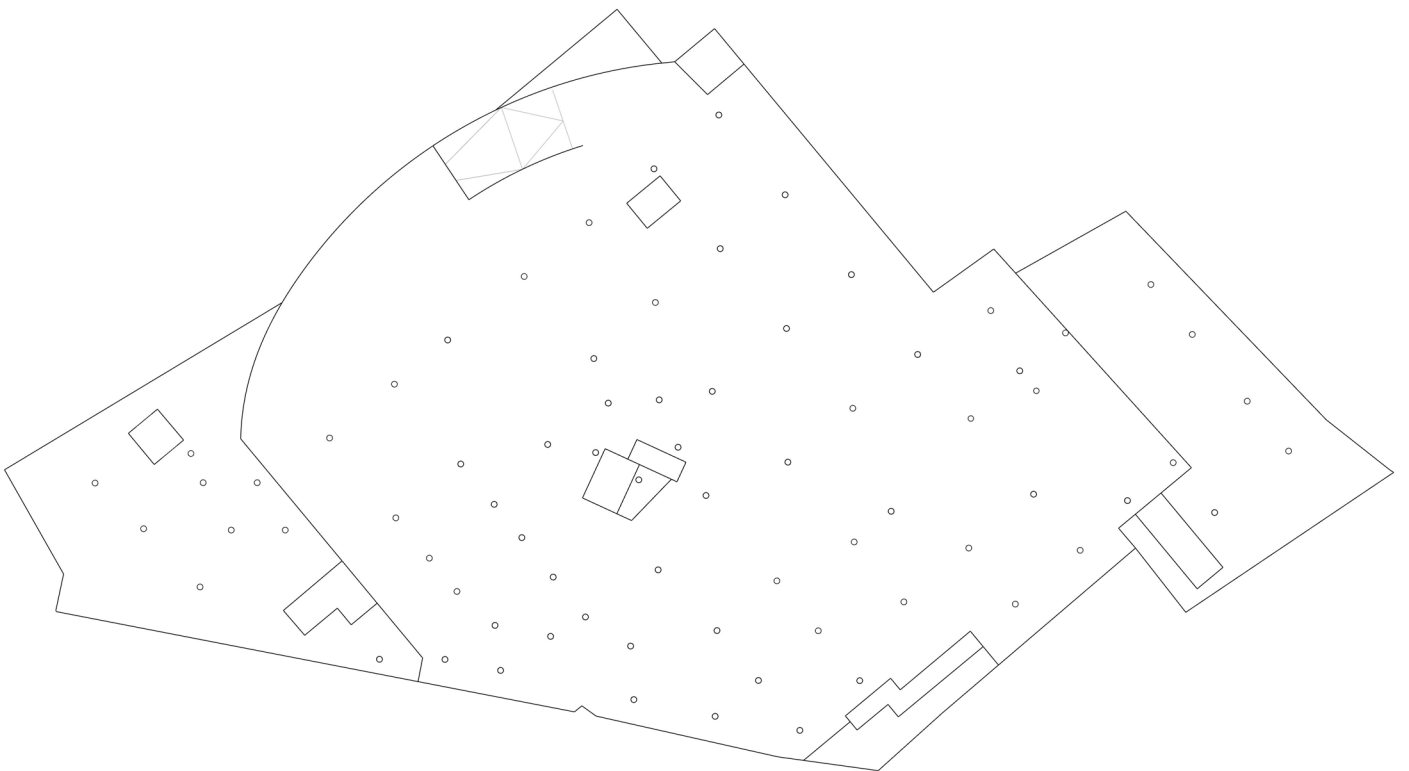
Level +1
+5100m



Level 0 (GF)
0m



Level-1

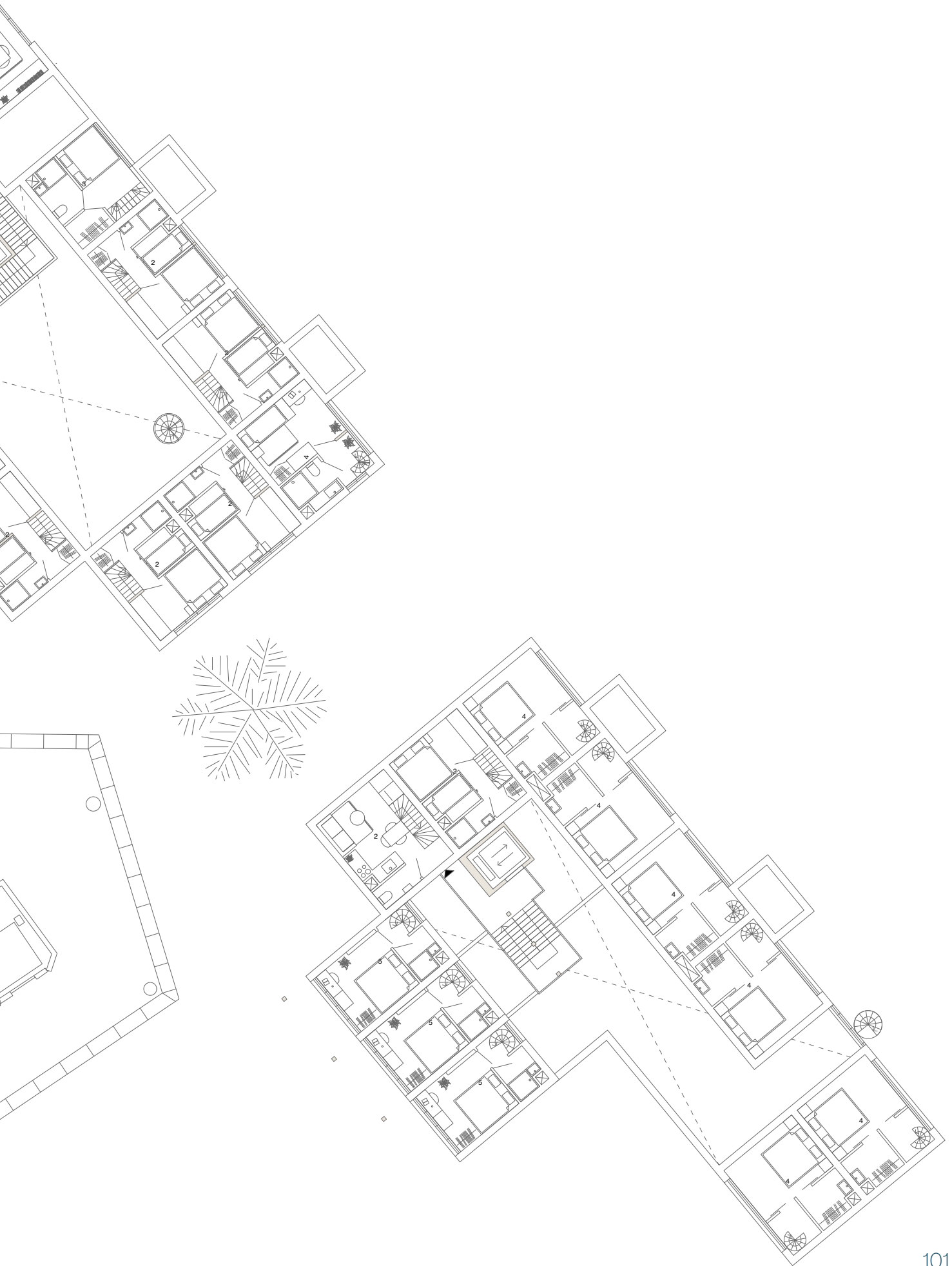


Level-2

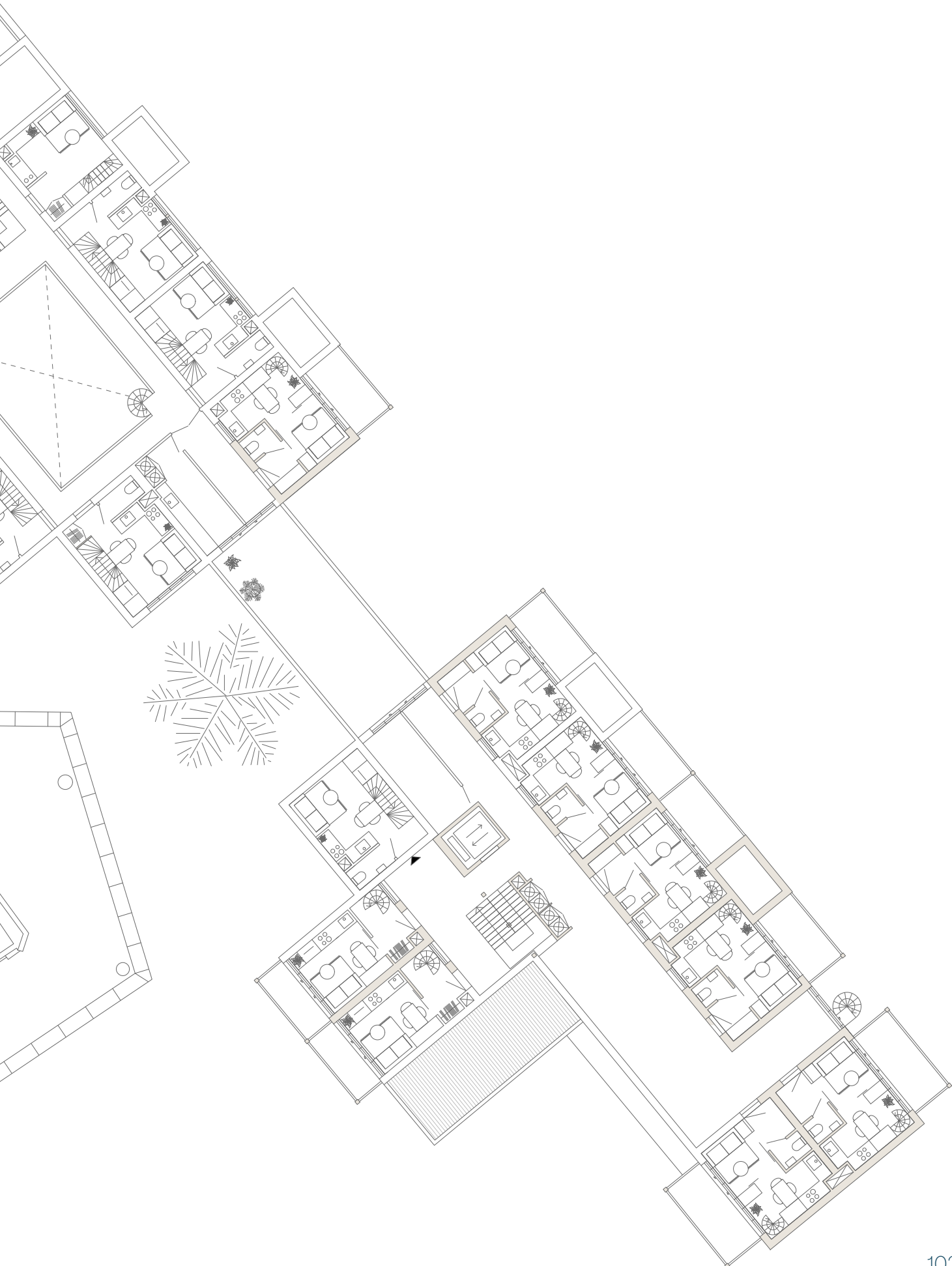




Level +4
+15550





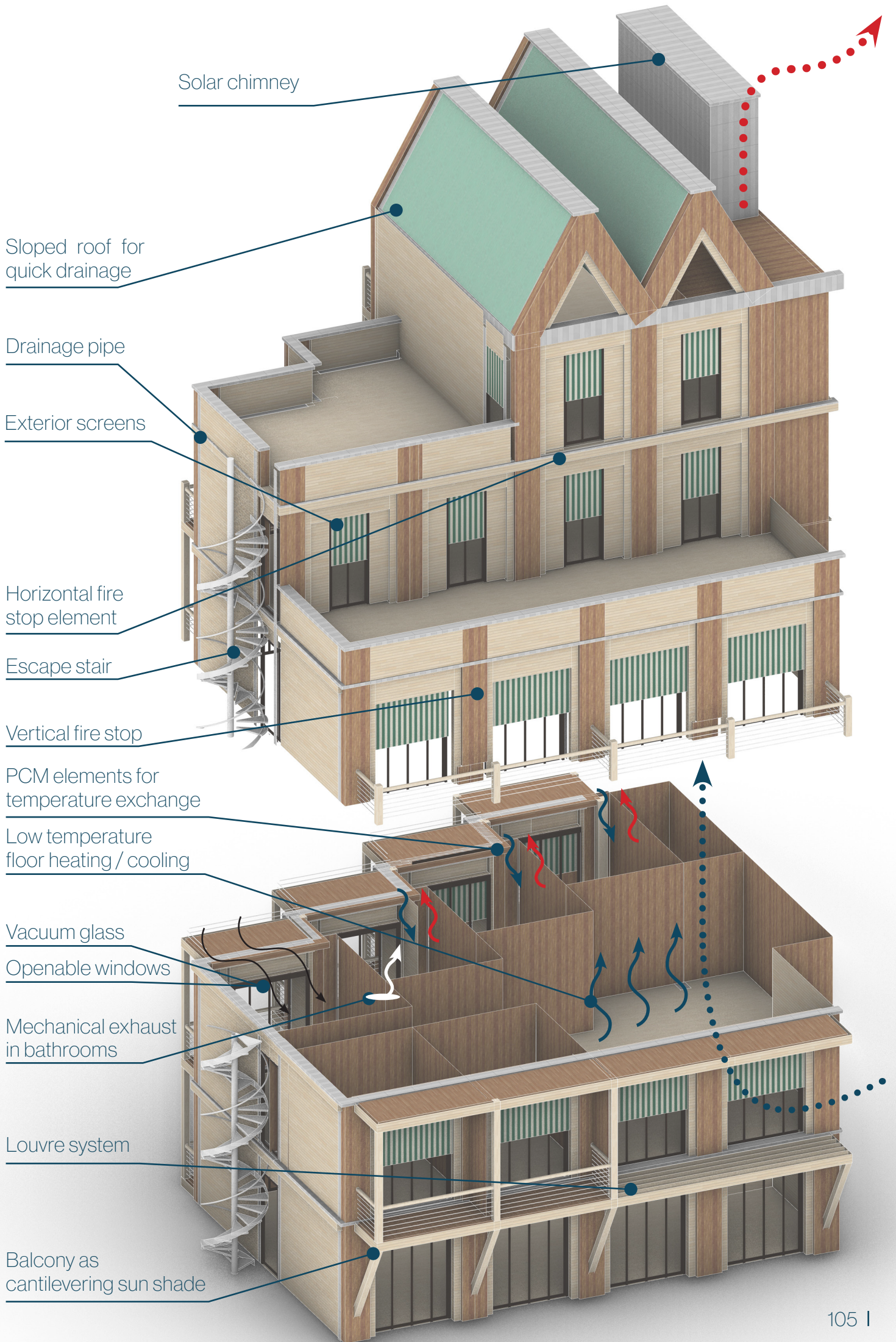


BUILDING PHYSICS

Climatic interventions

The right page shows the climate axonometry in which the building physics interventions are summarised with the use of Cluster I.

This serves as exemplary for the clusters II, III and IV, since these structures make use of the same principles.



Solar chimney

Sloped roof for quick drainage

Drainage pipe

Exterior screens

Horizontal fire stop element

Escape stair

Vertical fire stop

PCM elements for temperature exchange

Low temperature floor heating / cooling

Vacuum glass

Openable windows

Mechanical exhaust in bathrooms

Louvre system

Balcony as cantilevering sun shade

SECTIONS AND FRAGMENTS

Cluster I fragments

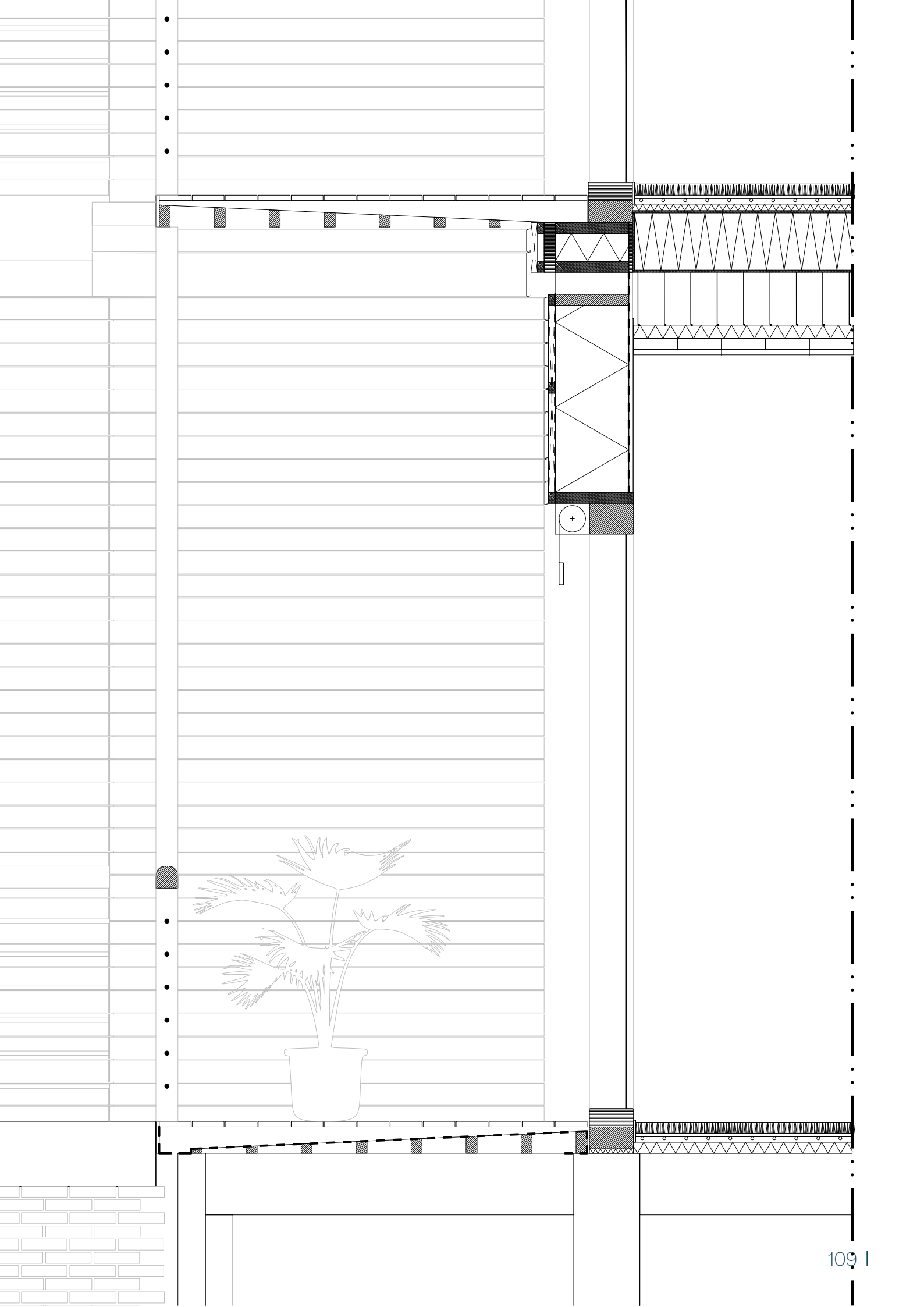
The southwesternmost structure can be identified through the green expression.





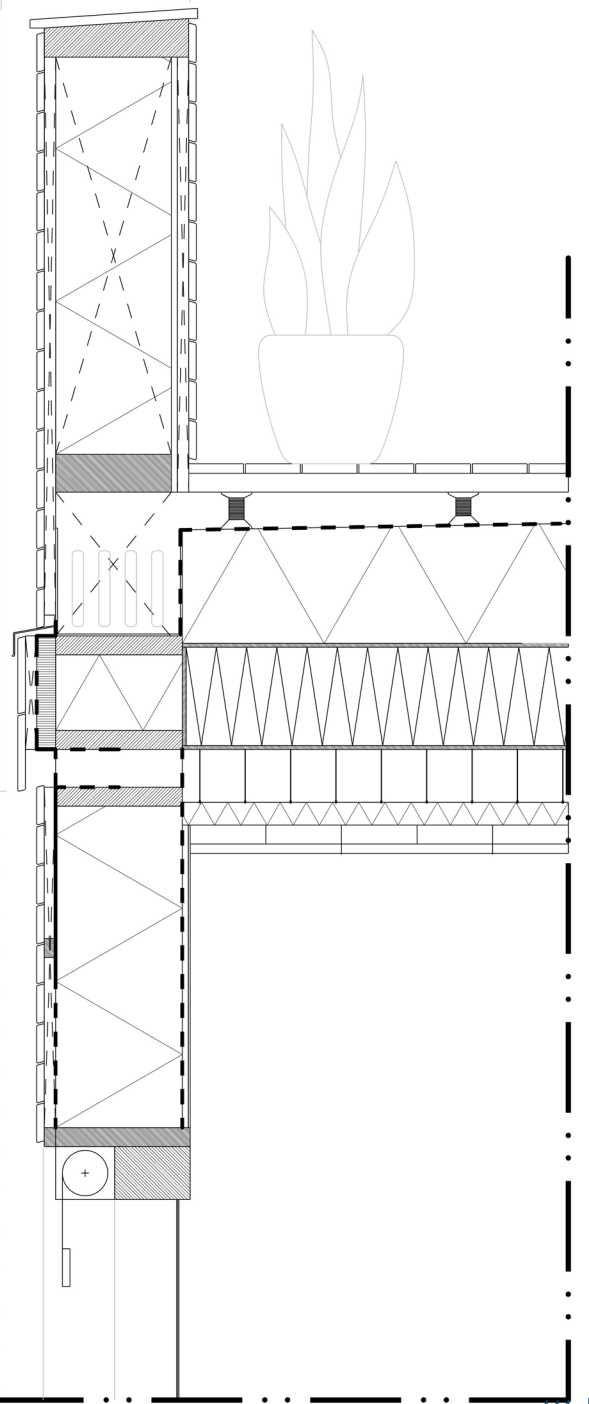
Vertical section facade

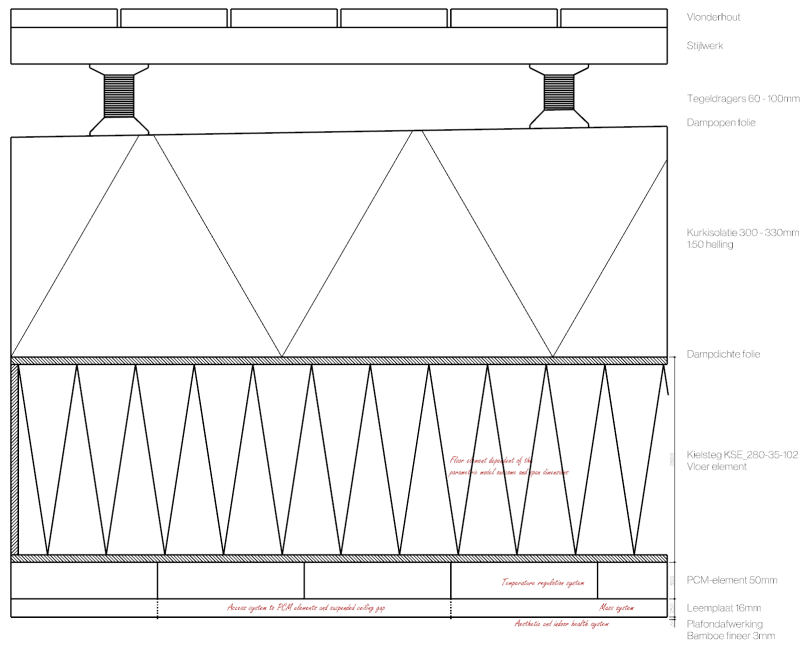




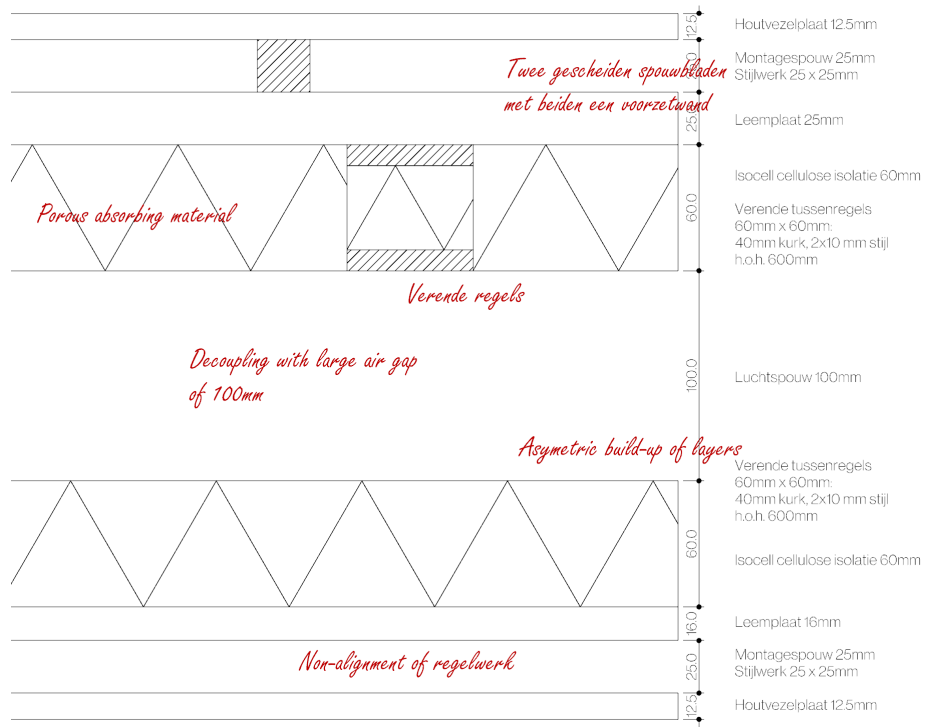
Vertical section facade - roof edge







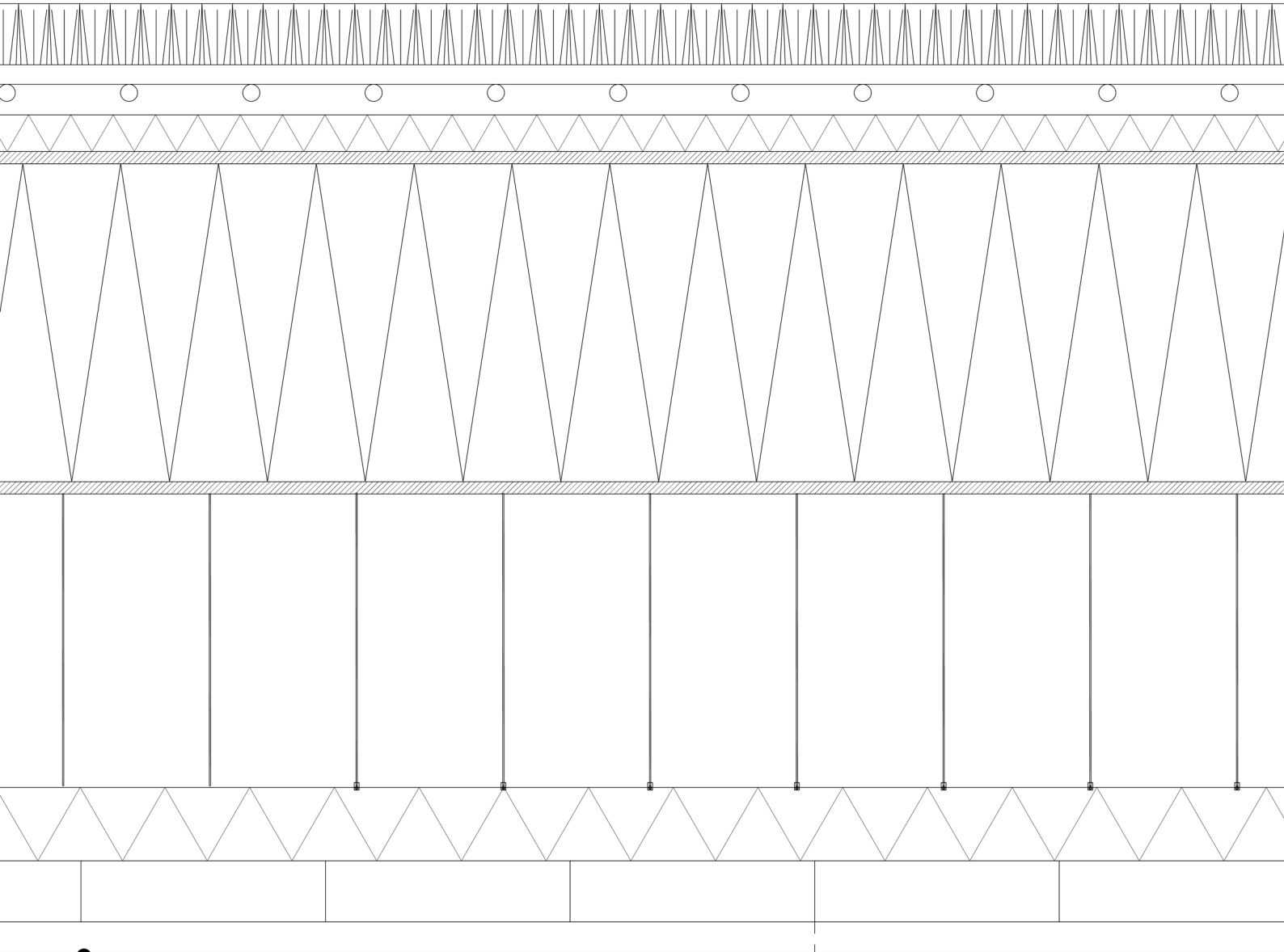
Roof vertical section



Wall horizontal section

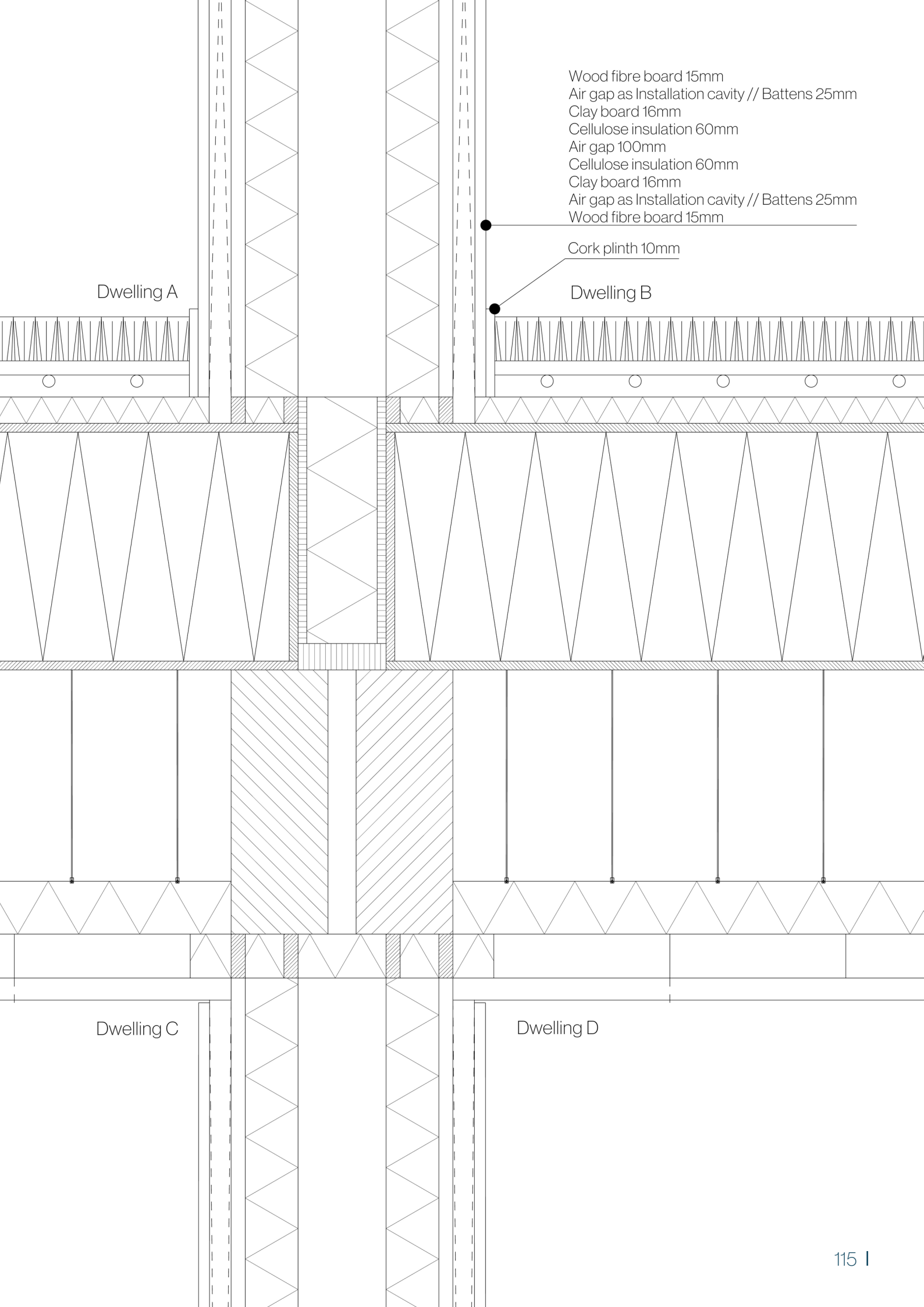
Acoustic interior wall and floor detail

This page contains a vertical detail section through a floor and wall element, in which multiple acoustic principles are translated into building design.



Van ceiling (lower) to floor (upper):

Ceiling furnishing 5mm
Clay board 16mm
PCM-elements 50mm
Cellulose insulation 60mm
Air gap with hanger 300mm
Kielsteg floor KSE_280_40_102: 280mm
Expanded cork floor board 30mm
Fermacell Therm25 underfloor heating / cooling 25mm
Wood fibre board 16mm
Biobased lyocell shag carpet ~50mm



Wood fibre board 15mm
 Air gap as Installation cavity // Battens 25mm
 Clay board 16mm
 Cellulose insulation 60mm
 Air gap 100mm
 Cellulose insulation 60mm
 Clay board 16mm
 Air gap as Installation cavity // Battens 25mm
 Wood fibre board 15mm

Cork plinth 10mm

Dwelling A

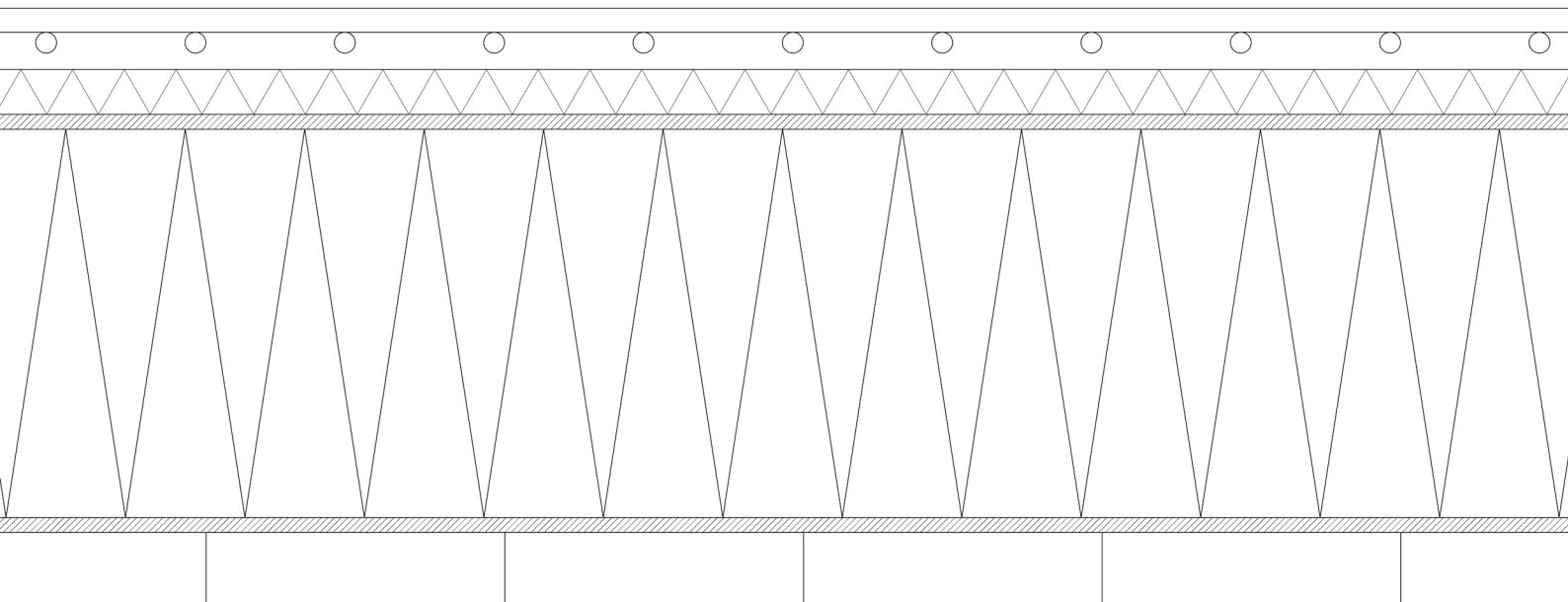
Dwelling B

Dwelling C

Dwelling D

Acoustic interior wall and dwelling floor detail

Without the strict acoustic measures for partitioning floors, the floors inside a dwelling can be much thinner, as shown here.



Dwelling floor
From ceiling (lower) to floor (upper):

Ceiling furnishing 5mm

Clay board 16mm

PCM-elements 50mm

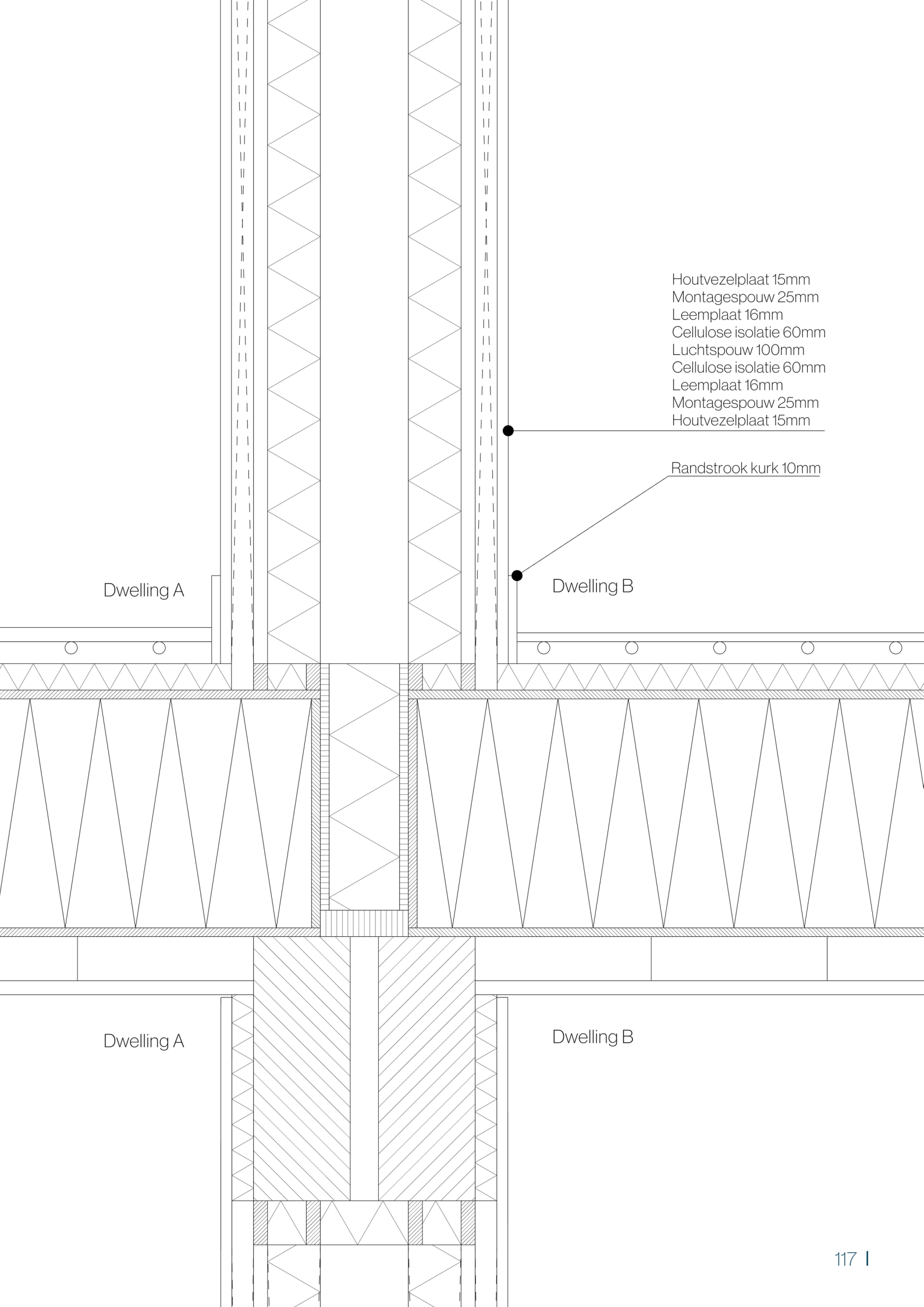
Kielsteg floor KSE_280_40_102: 280mm

Expanded cork floor board 30mm

Fermacell Therm25 underfloor heating / cooling 25mm

Wood fibre board 16mm

Floor screed



Dwelling A

Dwelling B

Houtvezelplaat 15mm
Montagespouw 25mm
Leemplaat 16mm
Cellulose isolatie 60mm
Luchtspouw 100mm
Cellulose isolatie 60mm
Leemplaat 16mm
Montagespouw 25mm
Houtvezelplaat 15mm

Randstrook kurk 10mm

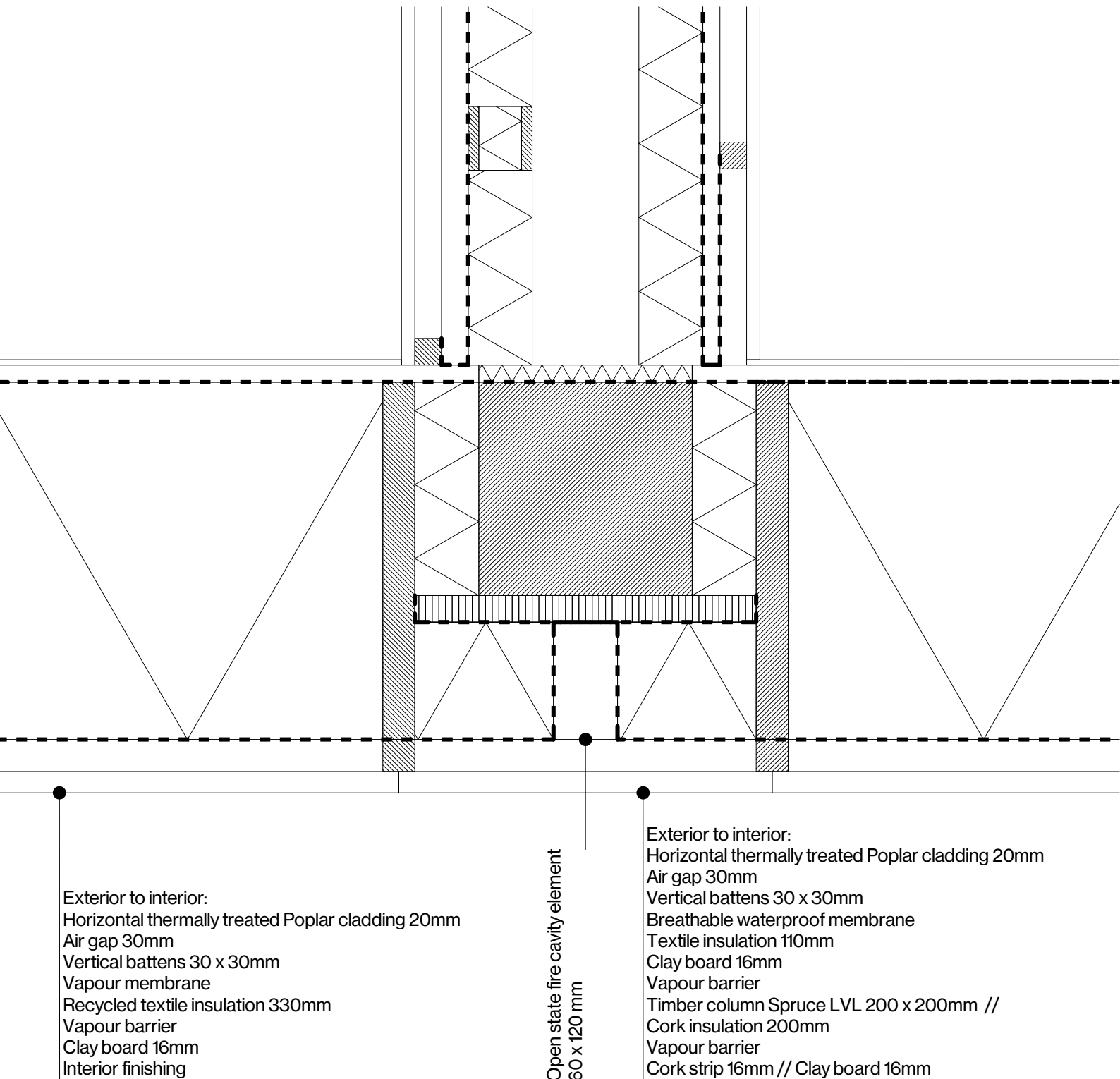
Dwelling A

Dwelling B

Fireproofing facade detail

On this page (left): a 1:5 horizontal section of the facade at a partitioning wall.

On the right page: a 1:5 vertical section of the facade at the partitioning floor.



Vapour barrier

Textile insulation 335mm
Fire class: B-s1

Breather membrane

Vertical timber battens // Air gap
3000 x 30 x 30 mm

Horizontal timber cladding
Thermally treated Poplar
100 x 20mm

Aluminium drip edge profile

Cork insulation 200 x 335mm
Capable of withstanding compression

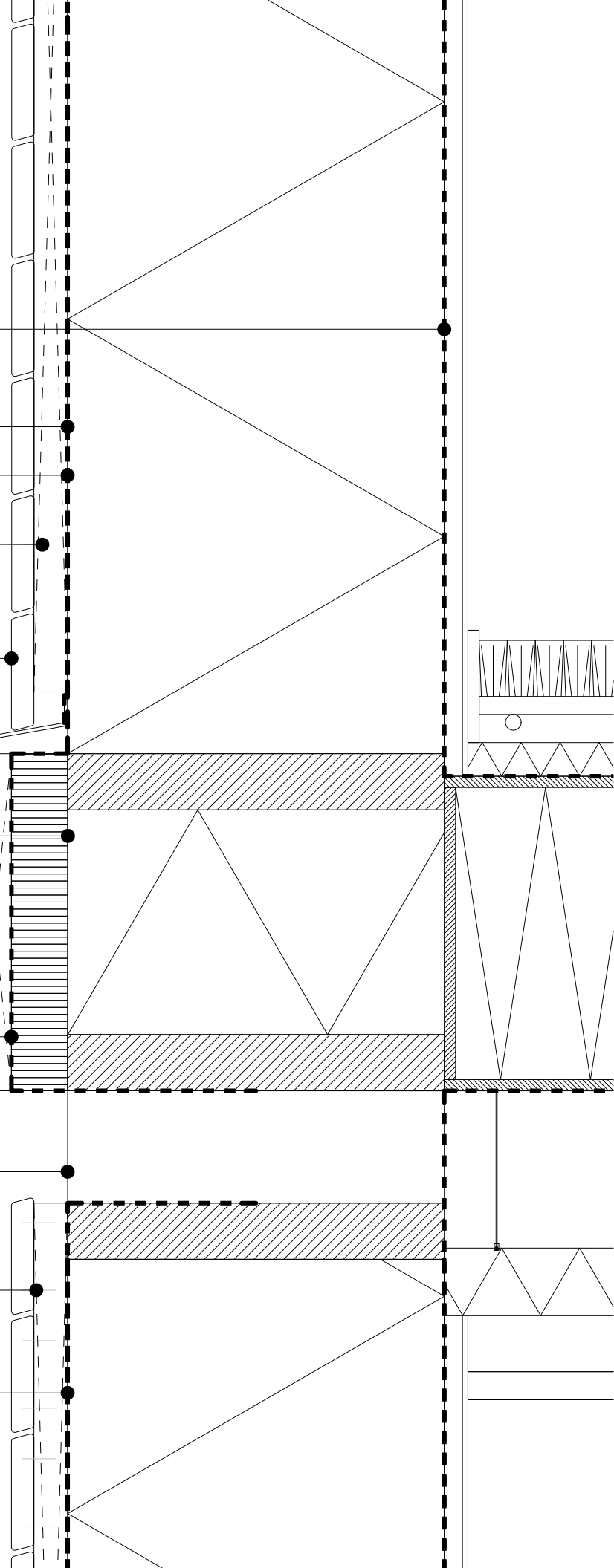
Horizontal timber cladding
Fireproof coating

Clayboard 100 x 300mm
Fire class: A1

Open state fire cavity element
330 x 100 mm

Mechanical assembly:
Screws connecting battens and cladding

Textile insulation 335mm
Fire class: B-s1



How can Kalverpassage's rooftop be transformed into a dense habitat where lightweighting influences its structural logic, domestic quality and architectural expression?

Design question 1: How can the existing structural grid be used as a basis for a lightweight timber structure?

All existing columns will be extended vertically. Where columns are missing but foundations are already in place, columns will be installed within the existing structure. Where there are no existing foundations, a transfer beam will be installed to divide the large grid. These interventions allow for a smaller sub-grid to be created, with floors spanning shorter distances. This significantly reduces the total weight compared to maintaining the existing grid. The column dimensions are directly linked to the required load-bearing capacity, resulting in smaller columns as the storey height increases. Regarding material selection:

- Columns are made of Spruce LVL-s
- Beams are made of GL36h
- Floors are made of dependent on the span, according to the selection on page x

By connecting new timber load-bearing members to existing columns, applying transfer trusses only where the grid does not match, and selecting floors based on minimum mass per span.

Design question 2: How can dwelling typologies support community while responding to load capacity?

Since the first floor is empty for the most part, this gives the opportunity to add heavier programs here (bike storage, entrance and storage units). The building volumes are arranged in a way to make use of the existing load-bearing structure underneath. The new ground floor (2nd floor) houses mostly collective space, which is both socially and structurally logical. Heavier loads are closer to the foundations, meaning that less structural mass needs to go down the columns above.

The shared cluster spaces are 2 floors tall, and the dwelling units are stacked on top of each other. This allows for the space to feel spacious, while mitigating the need for in-between floors, majorly limiting the structural space.

In addition, the collectively oriented clusters have a higher column density, which are positioned above the Kalverpassage where this is possible. The privately-oriented clusters make use of truss structures, which are heavy, but limited in size since the privately oriented clusters provide more lightweight dwelling units.

The single-floor dwelling units are generally heavier per m² than a three-floor dwelling unit. This is because of strict acoustic performance for partitioning floors and walls. Interior dwelling floors are more lenient and thus require less material weight.

The Kalverpassage can be topped-up into a dense urban habitat by using lightweighting as an organizing principle for structure, dwelling configuration, and architectural expression. For this, the design uses the capacity of the existing structure to determine where and how new housing can be added.

Structurally, the existing column grid forms the basis of the new timber load-bearing system. Existing columns are extended vertically, while additional columns are introduced where foundations are already present. Where support is missing, transfer trusses are used selectively to subdivide the span into a smaller sub-grid. This reduces floor spans and allows lighter floor systems to be used. Through both material choices and the alignment of new loads with existing load paths, mass can be minimised.

The dwelling configuration responds to this structural logic. Heavier programmes are placed on the lower levels or in zones with greater structural capacity. Since collective clusters are generally heavier, these positioned where column density is higher, while lighter private-oriented dwelling clusters are placed where fewer load paths are present. In this way, housing typology becomes a structural lightweighting strategy: collective life is supported where the existing building can carry it most efficiently, while private dwellings reduce loads in structurally constrained zones.

Lightweight living quality is achieved through compact, yet spacious dwellings. Multi-storey units reduce the need for acoustically demanding partition floors between separate dwellings, as internal floors can be lighter than partitioning floors. This allows density to increase while limiting the total amount of structure required.

The volume and façade translate this lightweighting logic into architectural expression. The top-up is fragmented into slender, vertically oriented volumes that relate to the fine grain of Amsterdam's historic urban fabric. The façade is a layered timber assembly in which building-physics requirements become visible. Thickened floors and partitioning walls provide acoustic separation, clay boards and cavity barriers support fire safety, balconies and louvres provide passive solar protection, and ventilated cavities allow moisture control and drying.

As a result, the Kalverpassage top-up becomes a dense habitat in which lightweighting is achieved through selective structure, strategic dwelling allocation, compact spatial organization, and performative façade layering. The architectural expression emerges from this logic: the building reveals where it carries, protects, ventilates, shades, and thickens. Lightweighting therefore becomes both a technical strategy and an architectural language.

Design question 3: How can the volume and façade preserve daylight, privacy and roovescape while expressing lightness?

The volume and façade preserve daylight, privacy, and the historic roovescape by fragmenting the top-up into slender, vertically oriented volumes that relate to the fine grain of Amsterdam. This reduces the perceived mass of the extension while supporting a lightweight dwelling strategy, in which compact footprints and vertical living minimize the amount of structural floor area required.

The façade expresses this reduction of mass through a layered timber construction rather than a monolithic envelope. Building-physics requirements are integrated into the architectural language: thickened floors and party walls provide acoustic separation through mass-spring assemblies, clay boards and cavity barriers ensure fire safety, and balconies and louvres act as passive solar-control devices. Ventilating façade cavities support moisture control and drying, while shading and ventilation reduce the dependence on thermal mass.

In this way, the façade becomes a performative layer in which acoustic, fire-safe, thermal, solar, and ventilation strategies are made architecturally legible. Lightness is therefore not expressed through thinness alone, but through the selective thickening, layering, and articulation of the envelope where performance requires it.

9.

CONCLUSIONS

Answer to research questions

Limitations

Reflection

Research question:

How does the reduction of building mass redefine architectural expression in residential timber top-ups?

The reduction of building mass redefines architectural expression in residential timber top-ups by shifting architecture from a logic of mass, which provides structure, acoustics and thermal qualities, toward one without. The building expresses the lightweight qualities through visible systems which make up for this loss in weight: optimized timber structures, transfer trusses, lightweight façades, shading devices, ventilated cavities, acoustic build-ups, and fire-protective layers. It depends therefore on the size of the existing grid, and the building requirements of the top-up, making use of high performance to weight materials.

In this way, lightweight architecture is not expressed simply by making elements thinner. Rather, it is expressed through the strategic organization of material only where it is needed. Therefore, it is not only about removing mass but also reintroducing it strategically where performance requires it. With this, the structure becomes intertwined with its host, façades become more layered, and technical details such as balconies, louvres, fire stops, floor voids, and thick partitioning floors and walls become part of the lightweight architectural expression.

For residential timber top-ups, architectural expression is shaped by the relying on what the existing structure provides and building upon it in a spatially efficient way. Small dwellings with multifunctional space, and interior which is inextricably linked to the area, making use of the whole volume, while also sharing services with neighbours where load-bearing capacity allows it, is what ensures domestic quality in a light manner. The resulting architecture is therefore defined by intelligent assembly and selective density.

Design question 1:
How can the load-bearing structure of residential timber top-ups be designed to minimize structural mass through optimized grids and structural components?

Structural mass can be minimized by aligning the new timber structure with the existing load-bearing grid, reducing unnecessary transfer structures, and selecting lightweight floor, beam, and column systems with high strength-to-weight ratios. Parametric optimization allows structural spans, grids, and component dimensions to be adjusted according to load demand and structural efficiency.

Design question 2:
How can lightweight timber top-ups achieve comparable building-physics performance to conventional high-mass construction?

Lightweight timber top-ups can achieve comparable building-physics performance through layered and multifunctional systems rather than continuous mass. Acoustic decoupling, fire encapsulation, cavity barriers, solar shading, ventilation, and localized mass are strategically combined to provide thermal comfort, fire safety, and acoustic quality.

**Design question 3:
How do dwelling configurations influence the structural mass of lightweight timber top-ups?**

Dwelling configurations directly affect imposed loads, structural spans, and the efficiency of load transfer. Collective-oriented housing generally increases structural demand, while private-oriented dwellings produce lower loads. Strategically allocating heavier collective spaces above structurally stronger zones and lighter dwellings above transfer zones reduces the overall structural mass.

**Design question 4:
How can interior space optimization contribute to the reduction of residential floor area in lightweight housing?**

Interior space optimization reduces required floor area by increasing the efficiency of each square metre. Strategies such as multifunctional rooms, vertical stacking, integrated storage, and long sightlines maintain domestic quality within compact dwellings, thereby reducing the amount of structure, façade, roof, and material required for the building.

Limitations

Limited material selection

The method of comparing materials and their relative performance as different building elements forms the foundation of this research. These have been included in the evaluation process, in which performance relative to weight is the key criterion. Therefore, material selection is important and has direct influence on the outcome. Needless to say, the materials enumerated are not endless, but are limited to a selection of locally available materials, for which biobased properties have priority. Non-biobased materials with good performance factors and lightweight properties are also taken into consideration. It has not been an aim to provide a list ranging from mainstream to most obscure or state-of-the-art materials, with no regard of performance beforehand. Rather, the aim has been to design and operationalize a process which is able to select optimal materials regarding lightweighting and use.

To dive deeper into the floor element input: a list has been made of box elements and panels of LVL, CLT and GLT. Timber floors go beyond these elements, with PSL (Parallel strand lumber), NLT (nail laminated timber) and DLT (dowel laminated timber) also being on the market as alternatives. These types use wooden dowels and nails to bond the layers and are thus free of adhesives (Chen et al., 2026). Because of this, they are considered even cleaner than GLT and CLT.

Despite the material selection being limited, the process is capable of functioning with any given input. Therefore, the selection can be expanded to meet the project's objectives.

Lightweighting has been limited to own weight

Binnen het onderzoek is puur gekeken naar het eigen gewicht van de constructie, en niet gekeken naar de gebruikswaardes (2 en 3 kN/m²), dit is per definitie overgedimensioneerd, sinds het nooit tot die grens zit. Wellicht dat met het interieur kan worden gekwantificeerd, en hedendaagse gebruikerspatronen, screenen van nieuwe bewoners kan worden meegewogen om ook deze waardes laag te houden. Tegenwoordig hebben mensen überhaupt minder spullen, en jonge mensen ook omdat ze nog niet zoveel materiele eigendommen hebben opgebouwd.

Limited parametric calculations

The calculations have been limited to buckling, deflection, compressive, tensile and bending forces.

Wind resistance has not been taken into account. Stability has been assumed based on the rule that one-fifth of the total length and width is a fixed connection.

Ontbreken van bestaande funderingscapaciteit

An important argument in the narrative of this project is that every building foundation has a margin for bearing a greater weight, and that compaction can be maximized by topping it with the lightest possible structure. One limitation, however, is the lack of residual load-bearing capacity in the Kalverpassage. The goal of this study is not to recalculate the existing structure, but to focus on the new structure and keep it as light as possible. In doing so, we examined which architectural interventions are important for keeping the weight of the new structure as low as possible, rather than what the existing structure can handle.

Likewise, the added weight of the topping up has also not been traced to an accumulated representative number for the building.

Reflection

Could the structure be more lightweight?

Reflecting on the process, and where I ended, I think there is still underexplored potential in absolutely lightweighting the optopping to a minimum. Nearing the end of the project I read a newspaper article in which a structural engineer mentioned diagonals being the strongest structural element.

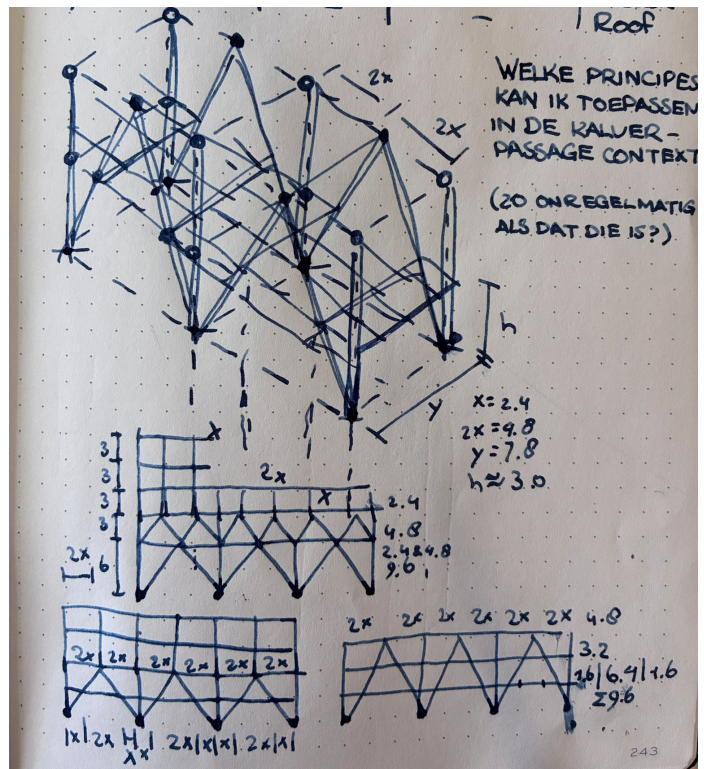
What I found out as a result of my research is that columns contribute a fraction of the weight of the total load bearing structure. If to put these under an angle, they provide stability, but, depending on the angle, are less capable of carrying loads. However, with this given, I think that a truss as transfer is not necessarily the way to go in making a sub-grid from a larger grid: one of the main challenges of the Kalverpassage.

I think there is lots of potential in using diagonals as multi-floor transfer elements.

Personal view on the Kalverpassage

Despite always believing in the potential of the Kalverpassage, it has also been a heavy burden to me in this project. The Kalverpassage has been chosen for strategic reasons, bringing high value to its direct vicinity by introducing a large amount of collectively oriented housing. However, through time, I learned how complex the building was, posing a great number of challenges which impeded the research by not being an optimal test site. Replicating the existing structure in Grasshopper was deemed too complex within the timeframe of this graduation project. I think a building with clear structural logic and repetition would have had the potential to be perfectly replicated and traced in Grasshopper. To work around this, I translated the findings from the parametric model into principles, which would then be brought into the context of the Kalverpassage.

Yet, the more time I invested in trying to understand the place, the less I wanted to change to a different building. Partly because of the knowledge investment in this building, but also because I always kept my vision in mind: a small village on the roof in the heart of Amsterdam. Something I would want to have proudly standing on the first page of my portfolio.



10.

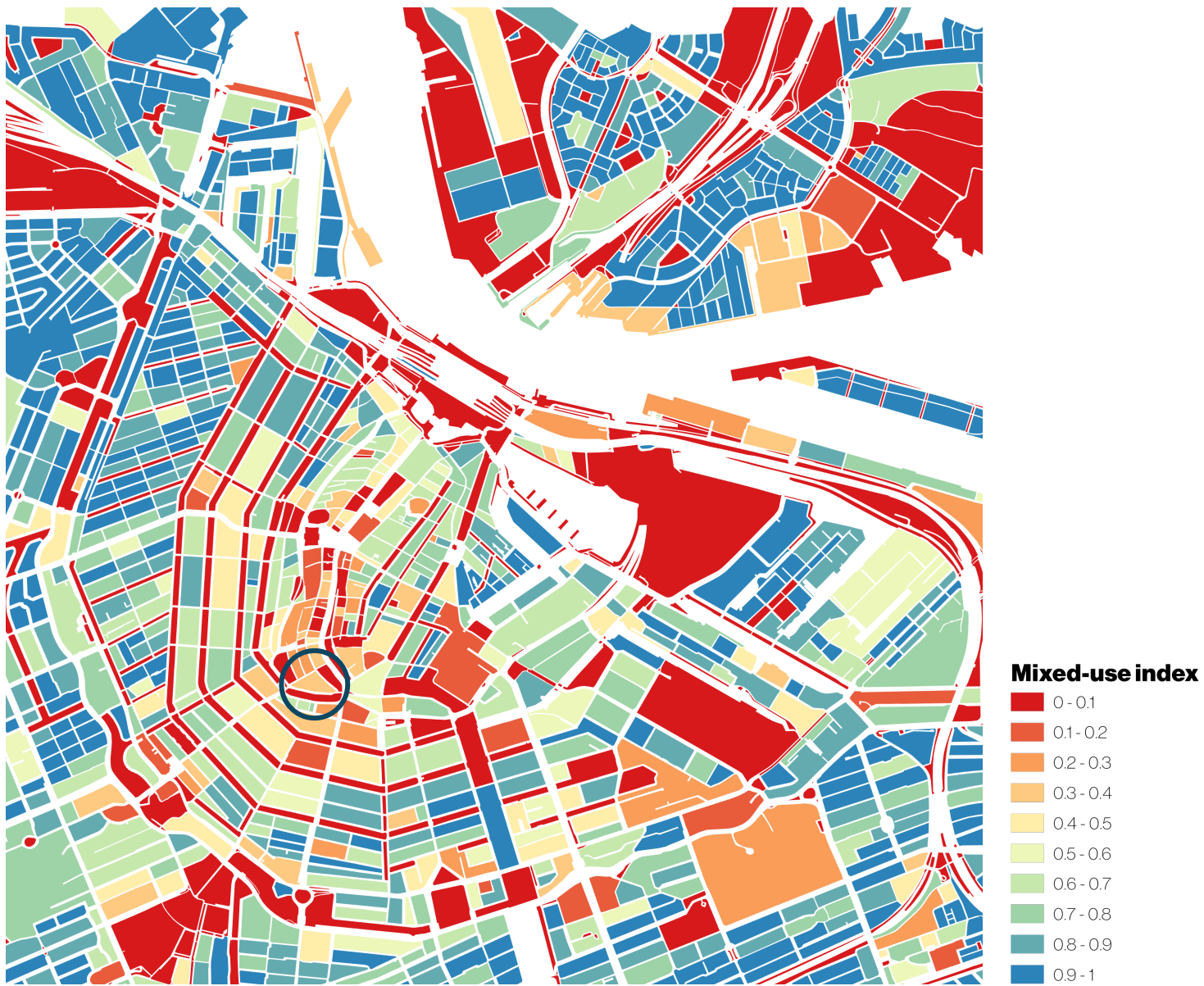
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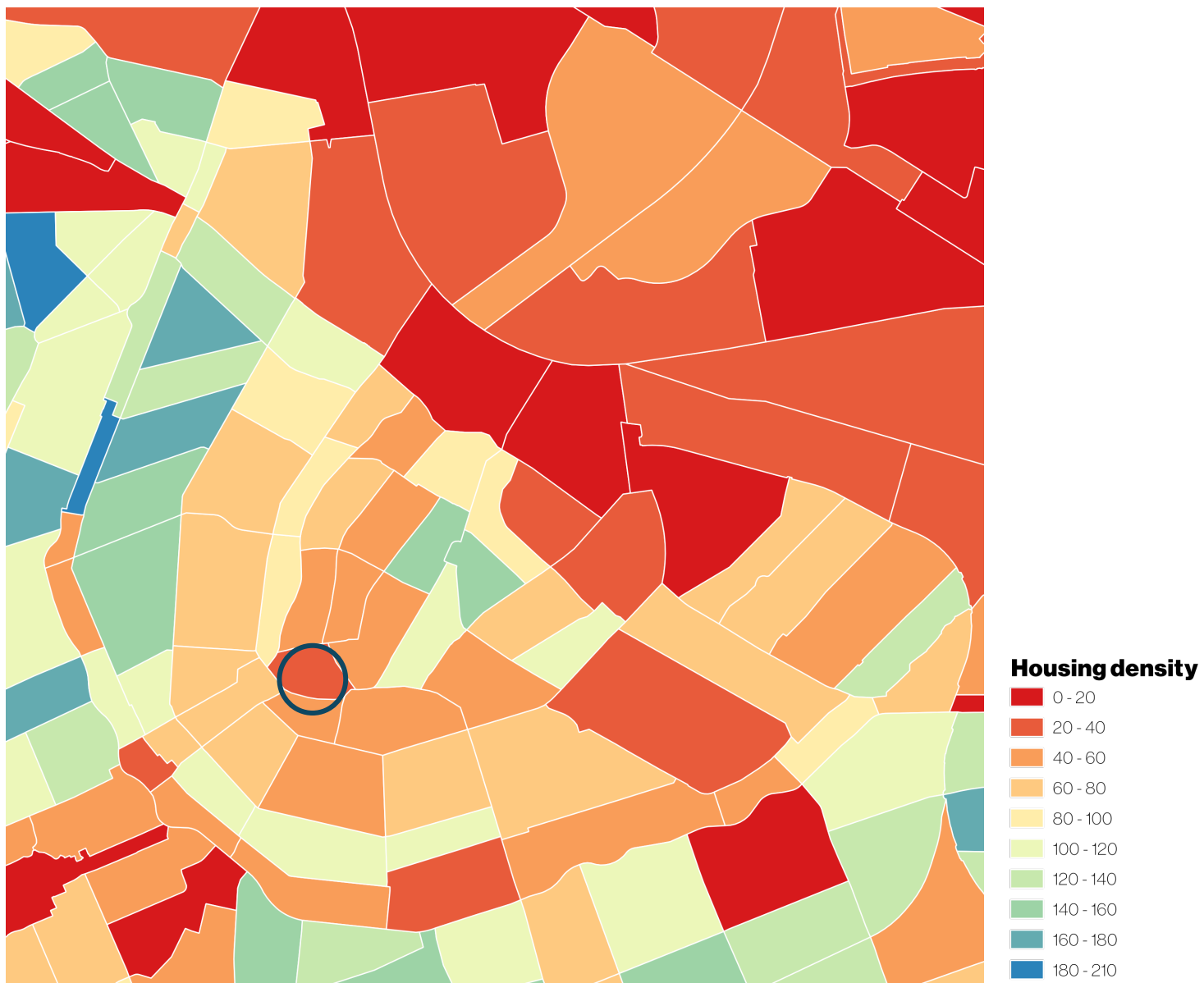
11.

APPENDICES

- Appendix A.** **Urban scale maps**
- Appendix B.** **Numerical material input sheets .csv**
- Appendix C.** **Parametric processing steps**
- Appendix D.** **Parametric output sheets and graphs**

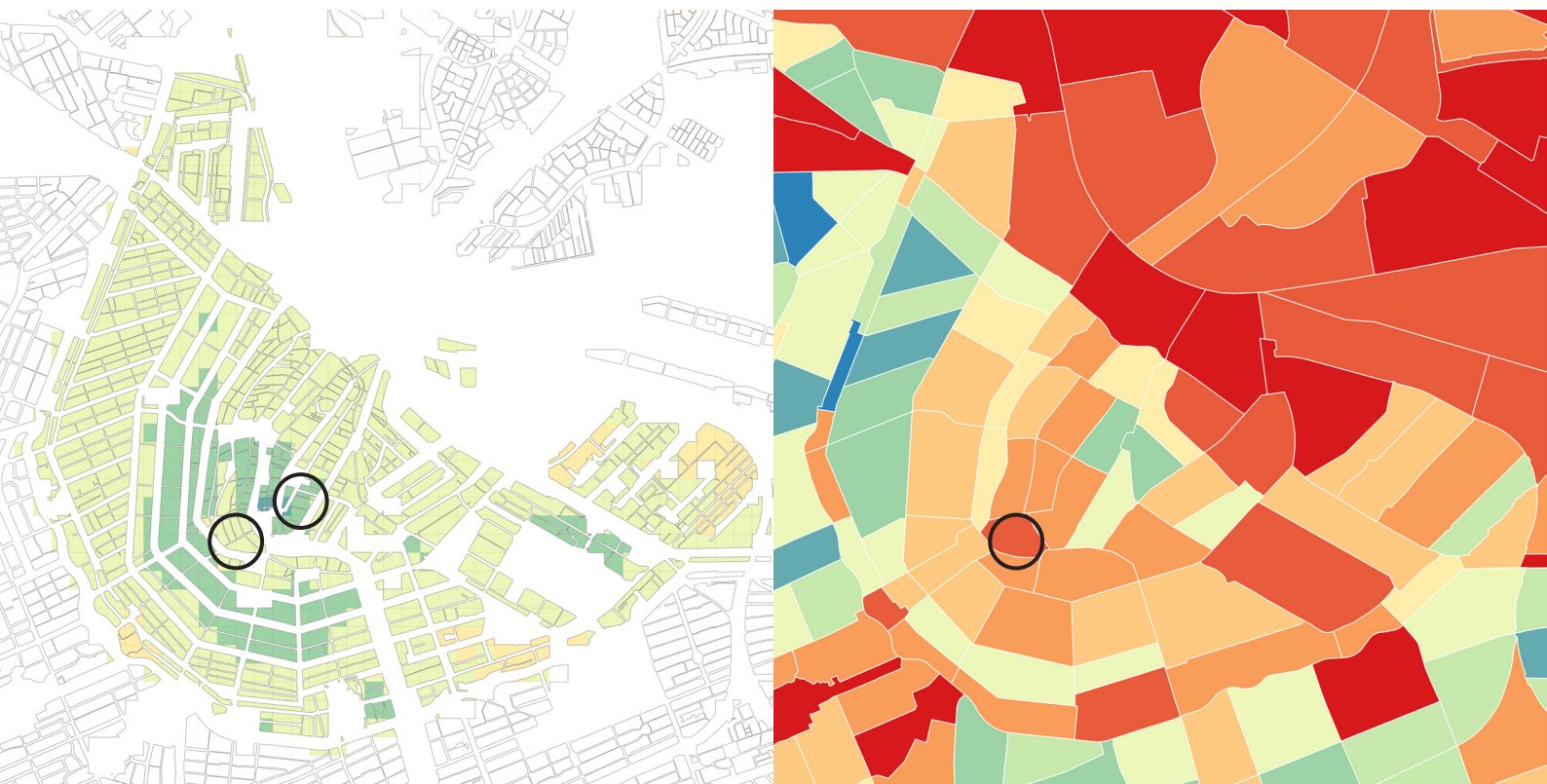


Mixed-use index



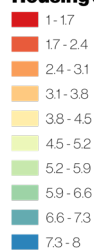
Housing density (dwellings per hectare)

- Housing stock index (HSI): Deze index is een conglomeratie van leegstand, onderhoud, funderingsproblemen, energetische kwaliteit en de grootte van woningen. Waar deze index laag is, kan het waardevol zijn om kwaliteit toe te voegen aan de gebouwde omgeving, door een hshotgebouw met optopping te transformeren.
- Housing density: Door woningen toe te voegen op locaties waar nu weinig woningen zijn, wordt de stad gevarieerder en meer leefbaar. Om deze reden is het meer waardevol om woningen toe te voegen op plekken waar de woningdichtheid nog relatief laag is.



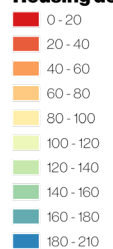
Housing stock index

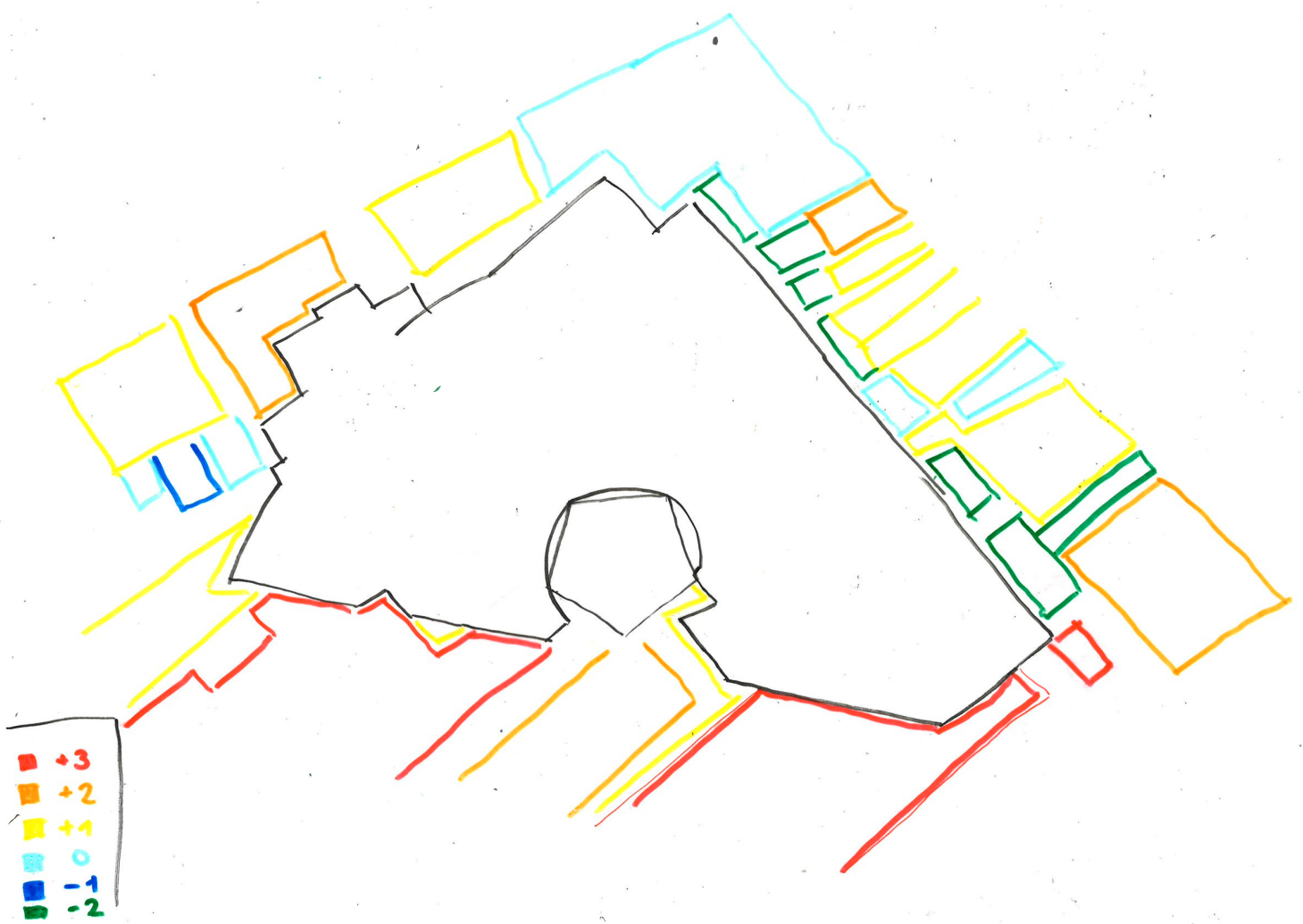
Housing stock



Housing density (dwellings per hectare)

Housing density





Building height relative to Kalverpassage

Historical analysis



1868

The block was fine-grained with a monastery located here



1993

Mix of different building types and functions.



1995

Plans for the Kalverpassage (then Kalvertoren) was made, and the interior of the triangle was removed.

3-12-25
 Site Analysis
 Kalverpassage

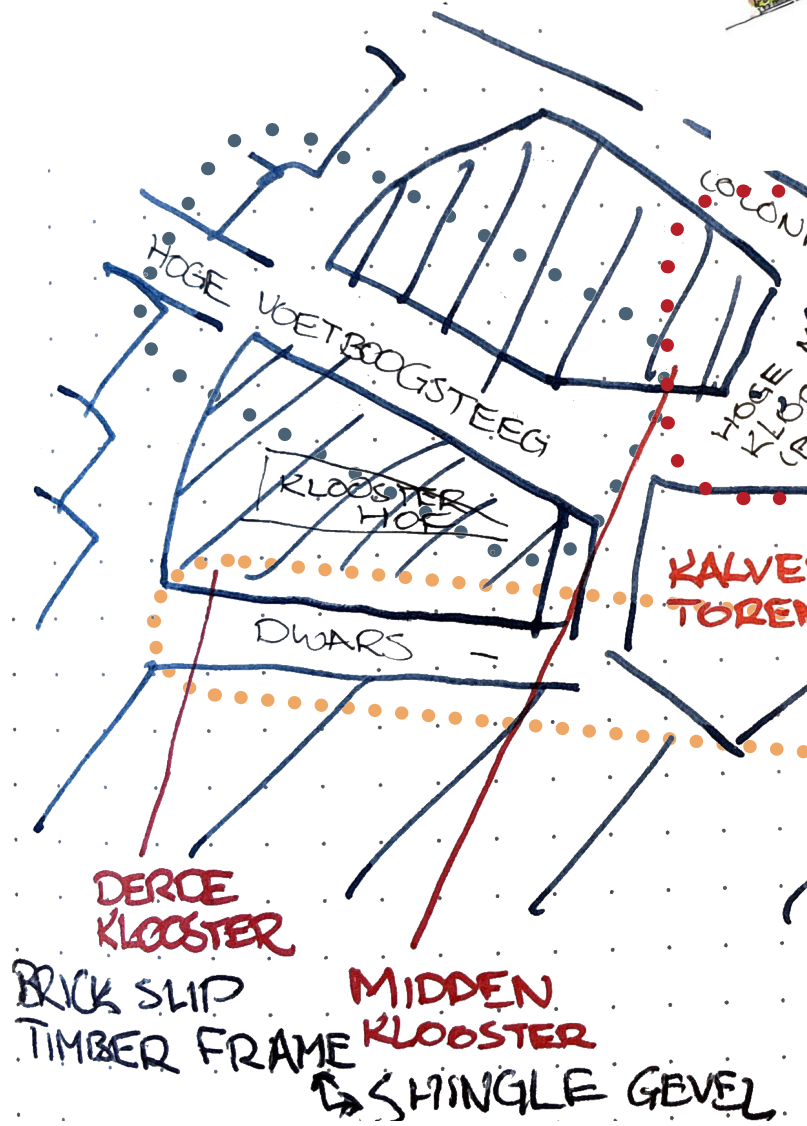


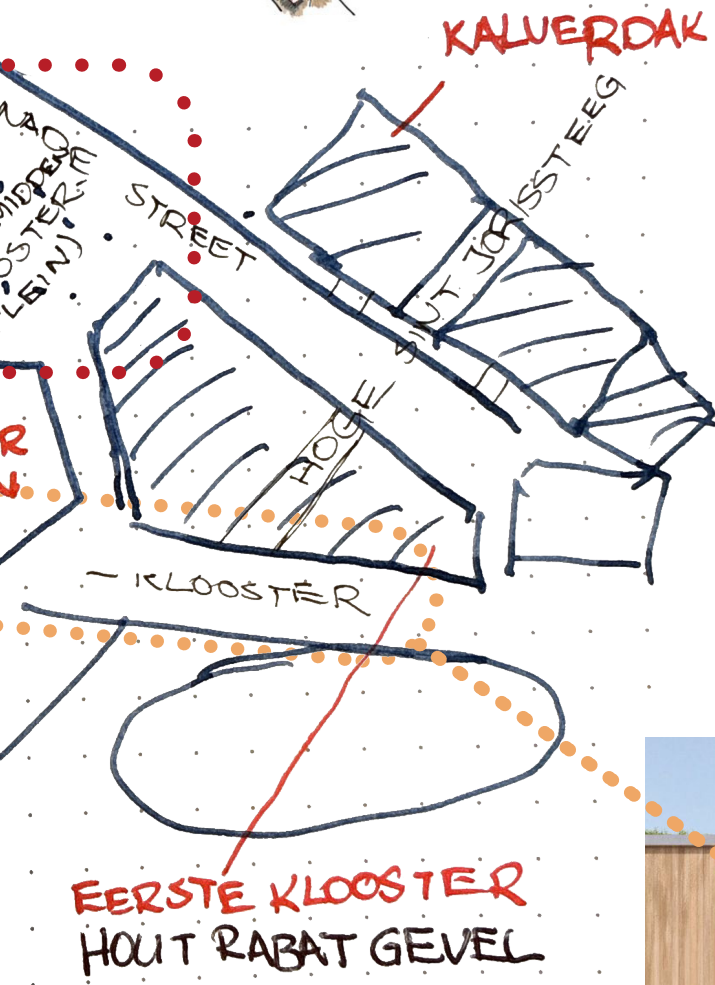
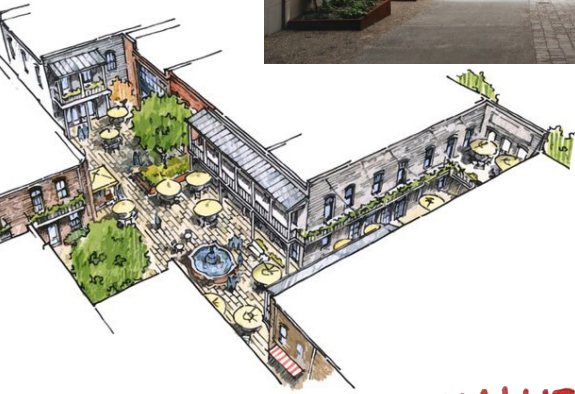
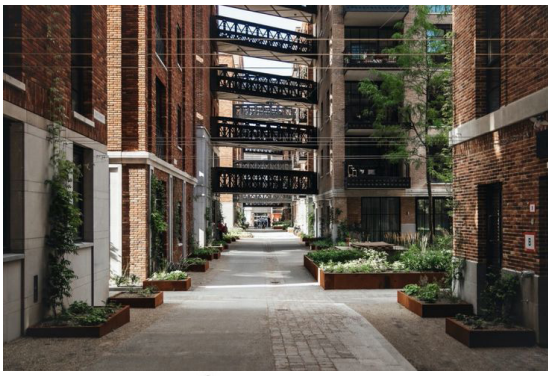
Key take-aways

- Along Kalverstraat, the busiest shopping street in NL
- Triangular block in pedestrian streets and calm back street (Singel) with motorised access
- Two paved squares on outer ends (Koningsplein & Muntplein)
- Very paved environment with little green (mostly tree canopies)
- Block in between the Rekin & Singel waterways
- High pressure on public spaces around Kalverblock, mainly used by tourists and shoppers

1:1250









CLOSED MASS



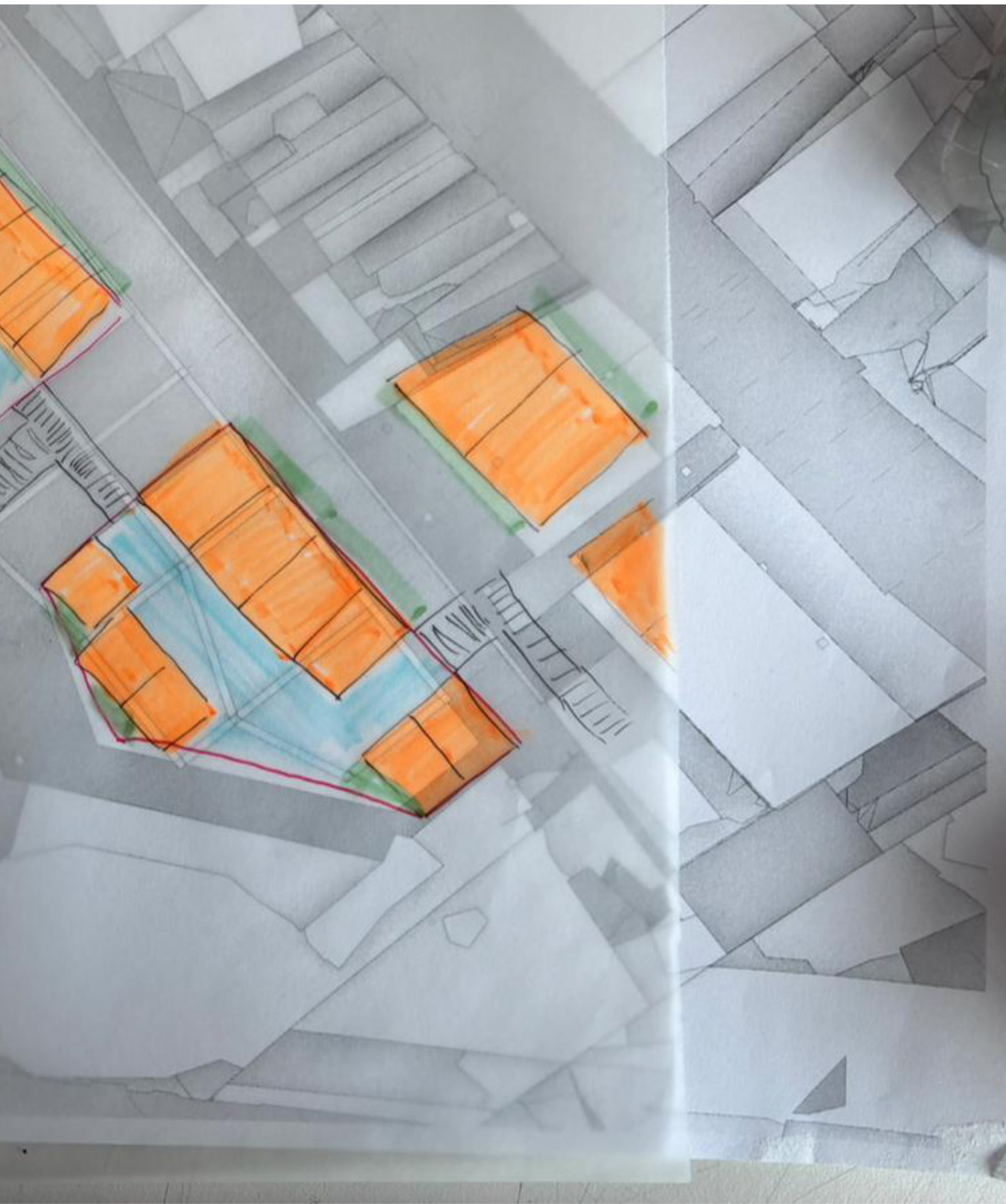
OPEN MASS (ATRIUM /VIDE)



OUTSIDE SPACE (BALCONIES)



SKY BRIDGE CONNECTORS



Principles masses & voids:

- Porous open neighbourhood
- Street viewpoints provide views of surrounding roofscapes (to attain awareness of being 'in the sky')
- Three distinct masses
 - Materiality / Colour
 - Size
 - Private / collective - ratio
- Masses follow the structural logic of Kalverpassage
 - XL Grid
 - Driveway (parking)
- Offset from surrounding buildings
- Apartments as subdivisions from the grid
- All masses contain an atrium/courtyard element as central collective space
- Kalvertoren acts as main connector to all surrounding masses



DERDE KLOOSTER

BRICK SLIP
TIMBER FRAME

MIDDEN KLOOSTER

SHINGLE GEVEL

EERSTE KLOOSTER
HOUT RABAT GEVEL

Think in structures
Think in spatial qualities

Appendix C: numerical input Grasshopper

System	Type	Max span [m] with $q_k = 2,0 \text{ kN/m}^2$	Max span [m] with $q_k = 3,0 \text{ kN/m}^2$	Height [mm]	Weight [kg/m ²]	Fire class
Kielsteg	KSE_280-40-102	7.3	6.0	280	44.83	REI 60
Kielsteg	KSE_330-40-93	8	6.5	330	49.01	REI 60
Kielsteg	KSE_330-50-93	8.2	6.7	330	56.93	REI 60
Kielsteg	KSE_370-40-85	8.6	7.0	370	51.13	REI 60
Kielsteg	KSE_370-60-85	8.9	7.3	370	66	REI 60
Kielsteg	KSE_485-40-96	9.4	7.7	485	73.27	REI 60
Kielsteg	KSE_610-50-103	10.8	8.8	610	104.04	REI 60
Kielsteg	KSE_610-60-103	11.1	9.1	610	112.09	REI 60
Kielsteg	KSE_730-80-134	12.7	10.4	730	116.41	REI 60
Kielsteg	KSE_800-80-113	13	10.6	800	143.29	REI 60
Lignatur	Box-120 Lignatur	3.52	2.9	120	33	REI 30
Lignatur	Box-140 Lignatur	4.02	3.3	140	35	REI 30
Lignatur	Box-160 Lignatur	4.5	3.7	160	36	REI 30
Lignatur	Box-180 Lignatur	4.97	4.1	180	38	REI 30
Lignatur	Box-200 Lignatur	5.42	4.4	200	39	REI 30
Lignatur	Box-220 Lignatur	5.85	4.8	220	41	REI 30
Lignatur	Box-240 Lignatur	6.28	5.1	240	42	REI 30
Lignatur	Box-260 Lignatur	6.88	5.6	260	59	REI 30
Lignatur	Box-280 Lignatur	7.11	5.8	280	45	REI 30
Lignatur	Box-300 Lignatur	7.76	6.3	300	65	REI 30
Lignatur	Box-320 Lignatur	7.9	6.4	320	48	REI 30
Lignatur	Box-360 Lignatur	9.07	7.4	360	58	REI 30
Metsa Wood	Kerto Box LVL 160	4	3.3	160	45	REI30
Metsa Wood	Kerto Box LVL 180	4.5	3.7	180	50	REI60
Metsa Wood	Kerto Box LVL 230	5.4	4.4	230	60	REI30
Metsa Wood	Kerto Box LVL 260	6	4.9	260	64	REI60
Metsa Wood	Kerto Box LVL 300	6.8	5.5	300	68	REI60
Metsa Wood	Kerto-Ripa Rib LVL 200	4.5	3.7	200	50	REI30
Metsa Wood	Kerto-Ripa Rib-LVL 225	5.2	4.2	225	53	REI30
Metsa Wood	Kerto-Ripa Rib-LVL 260	6	4.9	260	58	REI30
Metsa Wood	Kerto-Ripa Rib-LVL 300	6.8	5.5	300	62	REI60
Metsa Wood	Kerto-Ripa Rib-LVL 320	7.4	6.0	320	65	REI60
Stora Enso	LVL Panel solid 45	2.5	2.0	45	22	REI30
Stora Enso	LVL Panel solid 60	3	2.4	60	28	REI30
Stora Enso	LVL Panel solid 75	3	2.4	75	35	REI30
Stora Enso	LVL Panel solid 90	4	3.3	90	42	REI60
Stora Enso	LVL Panel solid 100	3.8	3.1	100	45	REI30
Stora Enso	LVL Panel solid 120	4.5	3.7	120	55	REI60
Massivholz	CLT panel 100	3	2.4	100	50	REI30
Massivholz	CLT panel 120	3.5	2.9	120	60	REI60
Massivholz	CLT panel 140	4	3.3	140	70	REI60
Massivholz	CLT panel 140	4	3.3	140	70	REI60
Massivholz	CLT panel 180	5	4.1	180	90	REI60
Massivholz	CLT panel 220	6	4.9	220	110	REI90
Massivholz	CLT panel 260	6.8	5.5	260	130	REI90
146 Schilliger	Glulam Panel 80	3	2.4	80	40	REI30
Schilliger	Glulam Panel 100	3.5	2.9	100	50	REI60

Type	Compressive strength [MPa]	Bending strength [Mpa]	Tensile strength [Mpa]	E-modulus [Mpa]	Volume Density [kg/m3]
GL24h	24	24	15.6	11600	460
GL28h	26.5	28	18.2	12600	490
GL32h	29	32	20.8	13700	520
GL36h	31	36	23.4	14700	540
TR26	22.9	28.3	17	11000	444
Spruce LVL-s	40	50	31	14000	540
BauBuche S	57.5	80	60	16800	800
BauBuche Q	62	75	49	12800	800
BauBuche GL75	59.4	75	60	16800	800
C14	16	14	8	7000	350
C16	17	16	10	8000	370
C18	18	18	11	9000	380
C20	19	20	12	9500	390
C22	20	22	13	10000	410
C24	21	24	14	11000	420
C27	22	27	16	11500	450
C30	23	30	18	12000	460
C35	25	35	21	13000	480
C40	26	40	24	14000	500
C45	26	45	27	15000	520
C50	29	50	30	16000	550
D18	18	18	11	9500	570
D24	21	24	14	10000	580
D30	23	30	18	11000	640
D35	25	35	21	12000	650
D40	26	40	24	13000	660
D50	29	50	30	14000	750
D60	32	60	36	17000	840
D70	34	70	42	20000	1080
Ash	511	62	96.3	13200	670
Balsa	10.5	12	20.5	4700	190
Bamboo	79.95	68.7	239.5	17500	699.5
Beech	55	64.8	118	15750	755
Birch	39.25	50.9	78.85	12100	615
Cedar	41.55	36.4	56.45	6650	525
Cherry	50	58.2	98.1	11350	610
Cork	1.5	1.65	1.75	37.5	200
Elm	48.6	61.2	94.7	11650	710
Lignum Vitae	78.6	95.6	148	13450	1230
Mahogany	46.75	47.6	73.75	11350	515
Maple	54	65.3	101.1	13900	710
Oak	75.75	95.1	147.5	22900	940
Palm	38	44.5	33	9000	600
Paper	48	38.6	24.5	5950	925
Pear	51	55.8	100.95	8800	740
Pine	39	42	80	9350	520
Poplar	38	38.4	91.9	10000	480
Redwood	42.4	41.4	64.15	10150	445
Spruce	50	46.8	85	15850	510
Teak	58	60.4	93.6	11750	680
Walnut	68	85.2	110	13100	690
Willow	26	15	59	7900	345

PARAMETRIC CALCULATION SHEET

Permanent G
Variable Q
Partial safety γ
Combination ψ

Loads $\left\{ \begin{array}{l} \text{Permanent G} \\ \text{Variable Q} \\ \text{Partial safety } \gamma \\ \text{Combination } \psi \end{array} \right.$

- Self loads (ULS)

- Imposed Loads (ULS)

A floors: $q_k = 1,5 - 2,0 \text{ kN/m}^2$
A stairs: $q_k = 2,0 - 4,0 \text{ kN/m}^2$
A balconies: $q_k = 2,5 - 4,0 \text{ kN/m}^2$

Reduction factor for SLS**

$$\alpha_n = \frac{5}{7} \psi_0 + \frac{A_0}{A} \leq 1,0$$

$A_0 = 10 \text{ m}^2$
 $A = \text{loaded area}$
 $\psi_0 = 0,7$

$$\alpha_n = \frac{2 + (n - 2) \psi_0}{n}$$

$n = \text{nr. of storeys}$
 $\psi = 0,7$

Permanent loads $\gamma_G \cdot G_k$ Characteristic imposed loads $\gamma_Q \cdot Q_k$

$$E_d = \sum \gamma_G \cdot G_k + \gamma_Q \cdot Q_k = 7,05 \text{ kN/m}^2$$

with $G_k = 3,0 \text{ kN/m}^2$
 $Q_k = 2,0 \text{ kN/m}^2$
 $\gamma_G = 1,35$
 $\gamma_Q = 1,50$

$E_d = 10,73 \text{ kN/m}^2$ (Res. balcony)

* ULS = uiterste grens toestand

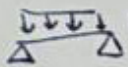
Structural Calculations:

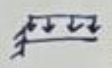
- Bending (ULS)
design bending moment \leq des. bending resistance
 $M_d \leq M_{Rd}$

Glulam: $k_h = \min \left\{ \left(\frac{600}{h} \right)^{0,1} \right.$
 $\left. 1,1 \right.$

$k_h = \text{Depth factor}$
 $h = \text{depth for bending member}$

Solid timber: $k_h = \min \left\{ \left(\frac{150}{h} \right)^{0,2} \right.$
 $\left. 1,3 \right.$

$M_d = q_d \frac{L^2}{8}$  Uniform load

$= q_d L^2 / 2$  cantilever uniform load

with $q_d = \text{design load kN/m}$
 $L = \text{span}$

Bending check:

$$\sigma_{m,d} \leq f_{m,d}$$

\downarrow
 $\sigma_{m,d} = M_d / W$

with $W = \text{section modulus (weers)}$
 $M_d = \text{design bending moment}$

Bending Res

$$M_{R,d} = f_{m,d} \cdot W$$

$$\sigma_{m,d} = M_d / W$$

$$\sigma_{m,d} \leq f_{m,d}$$

Residential $f_{m,d} = \frac{k_{mod} \cdot f_{m,k}}{\gamma_M}$

Collective corridor $\frac{\sigma_{m,d}}{f_{m,d}} + \frac{\sigma_{cd}}{f_{cd}} \leq 1$

$E_d = 10,05 \text{ kN/m}^2$

when combining • bending • compression

** SLS = bruikbaarheidsgrenstoestand

24.02.26

Partial factors γ_M for material properties and resistances

Solid timber	1.3
Glulam	1.25
LVL, plywood, OSB	1.2
Particleboards	1.3

- Design resistances

$$R_d = k_{mod} \cdot R_k / \gamma_M$$

with R_d = Resistance design value

k_{mod} = modif. factor

γ_M = part. factor material

R_k = characteristic load-b. capacity value

Load-duration class	Order of accumulated duration of characteristic load
Permanent	more than 10 years
Long-term	6 months - 10 years
Medium-term	1 week - 6 months
Short-term	less than one week
Instantaneous	

E) Table 3.1 - Values of k_{mod}

Material	Standard	Service class	Load-duration class				
			Permanent action	Long term action	Medium term action	Short term action	Instantaneous action
Solid timber	EN 14081-1	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
Glued laminated timber	EN 14080	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
LVL	EN 14374, EN 14279	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
Plywood	EN 636 Type EN 636-1 Type EN 636-2 Type EN 636-3	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
OSB	EN 300 OSB/2 OSB/3, OSB/4 OSB/3, OSB/4	1	0,30	0,45	0,65	0,85	1,10
		1	0,40	0,50	0,70	0,90	1,10
		2	0,30	0,40	0,55	0,70	0,90
Particleboard	EN 312 Type P4, Type P5 Type P5 Type P6, Type P7 Type P7	1	0,30	0,45	0,65	0,85	1,10
		2	0,20	0,30	0,45	0,60	0,80
		1	0,40	0,50	0,70	0,90	1,10
Fibreboard, hard	EN 622-2 HB LA, HB HLA 1 or 2 HB HLA1 or 2	1	0,30	0,45	0,65	0,85	1,10
		2	0,20	0,30	0,45	0,60	0,80
Fibreboard, medium	EN 622-3 MBH LA1 or 2 MBH HLS1 or 2 MBH HLS1 or 2	1	0,20	0,40	0,60	0,80	1,10
		1	0,20	0,40	0,60	0,80	1,10
Fibreboard, MDF	EN 622-5 MDF LA, MDF HLS MDF HLS	1	0,20	0,40	0,60	0,80	1,10
		2	-	-	-	0,45	0,80

Vibrations

$$\frac{W}{F} \leq a \text{ (mm/kN)}$$

- Deflection (SLS)

$$w = 5 q L^4 / 384 EI$$

with q = line load (N/mm)

L = span (mm)

E = e-module (N/mm²)

I = Massatraagheidsmoment (mm⁴)

TIMBER CREEP

$$w_{final} = w_{inst} \cdot (1 + k_{creep})$$

- w_{inst} is the instantaneous deflection;
- w_{creep} is the creep deflection;
- w_{fin} is the final deflection;
- w_{net} is the net final deflection.

E) Table 3.2 - Values of k_{creep} for timber and wood-based materials

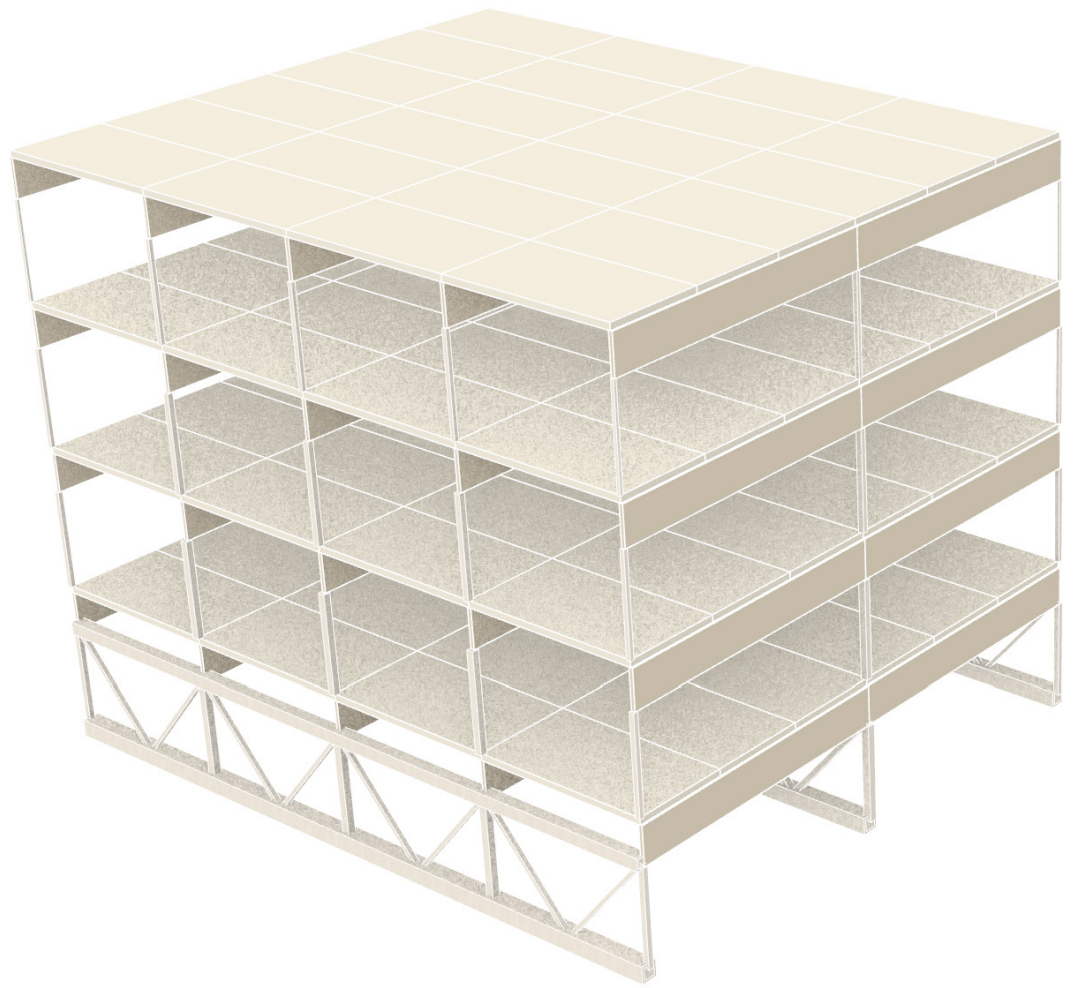
Material	Standard	Service class		
		1	2	3
Solid timber	EN 14081-1	0,60	0,80	2,00
Glued Laminated timber	EN 14080	0,60	0,80	2,00
LVL	EN 14374, EN 14279	0,60	0,80	2,50
Plywood	EN 636 Type EN 636-1 Type EN 636-2 Type EN 636-3	0,80	-	-
		0,80	1,00	-
		0,80	1,00	2,50
OSB	EN 300 OSB/2 OSB/3, OSB/4	2,25	-	-
		1,50	2,25	-
Particleboard	EN 312 Type P4 Type P5 Type P6 Type P7	2,25	-	-
		2,25	3,00	-
		1,50	-	-
Fibreboard, hard	EN 622-2 HB LA HB HLA1, HB HLA2	2,25	-	-
		2,25	3,00	-
Fibreboard, medium	EN 622-3 MBH LA1, MBH LA2 MBH HLS1, MBH HLS2	3,00	-	-
		3,00	4,00	-
Fibreboard, MDF	EN 622-5 MDF LA MDF HLS	2,25	-	-
		2,25	3,00	-

(4) For timber which is installed at or near its fibre saturation point, and which is likely to dry out under load, the values of k_{mod} , given in Table 3.2, should be increased by 1,0.

(5) P Finger joints shall comply with EN 385.

Table 7.2 - Examples of limiting values for deflections of beams

Beam on two supports	w_{lim}	w_{lim}	w_{lim}
Beam on two supports	/100 to /150	/250 to /350	/150 to /300
Overhanging beams	/150 to /250	/125 to /175	/75 to /150



Total weight per surface area [kg/m²]
53.90 kg/m²

n Floors 4

Y (beam span)

Grid length 9.600

n Rows 4

X (floor span)

Grid width 7.800

n Columns 3

Longest floor span? True

Value List

Grid type Truss calc.

Height column 2.600

Panel 8.0

EUROCODE RESIDENTIAL
0 8

Total weight per surface area [kg/m²]
53.50 kg/m²

n Floors 4

Y (beam span)

Grid length 9.600

n Rows 4

X (floor span)

Grid width 7.800

n Columns 3

Longest floor span? True

Value List

Grid type Manual

Height column 2.600

Panel 8.0

EUROCODE RESIDENTIAL (kN/m²)
0 8

Stream Filter

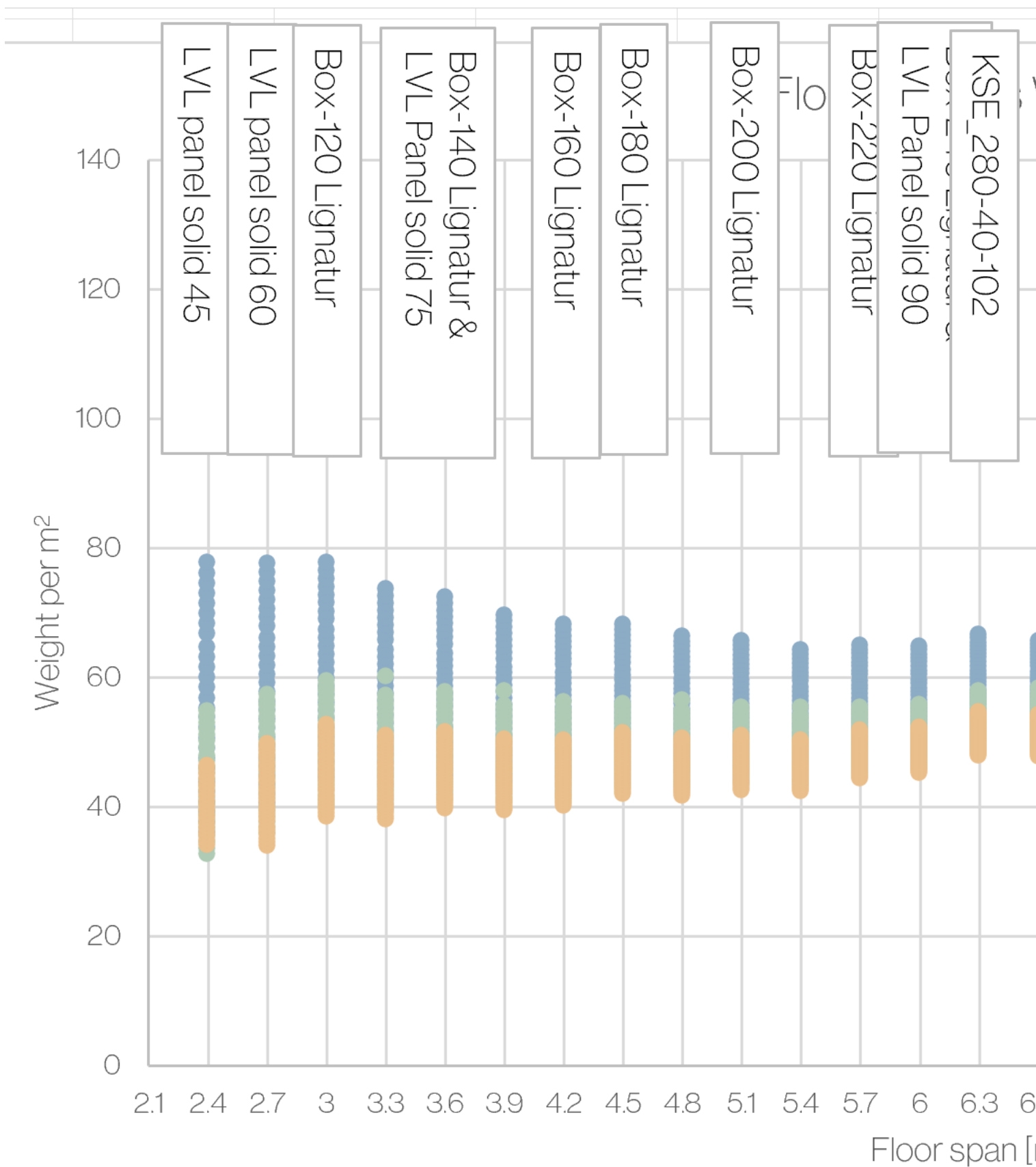
Beam span
0
1 S(0)
2
3

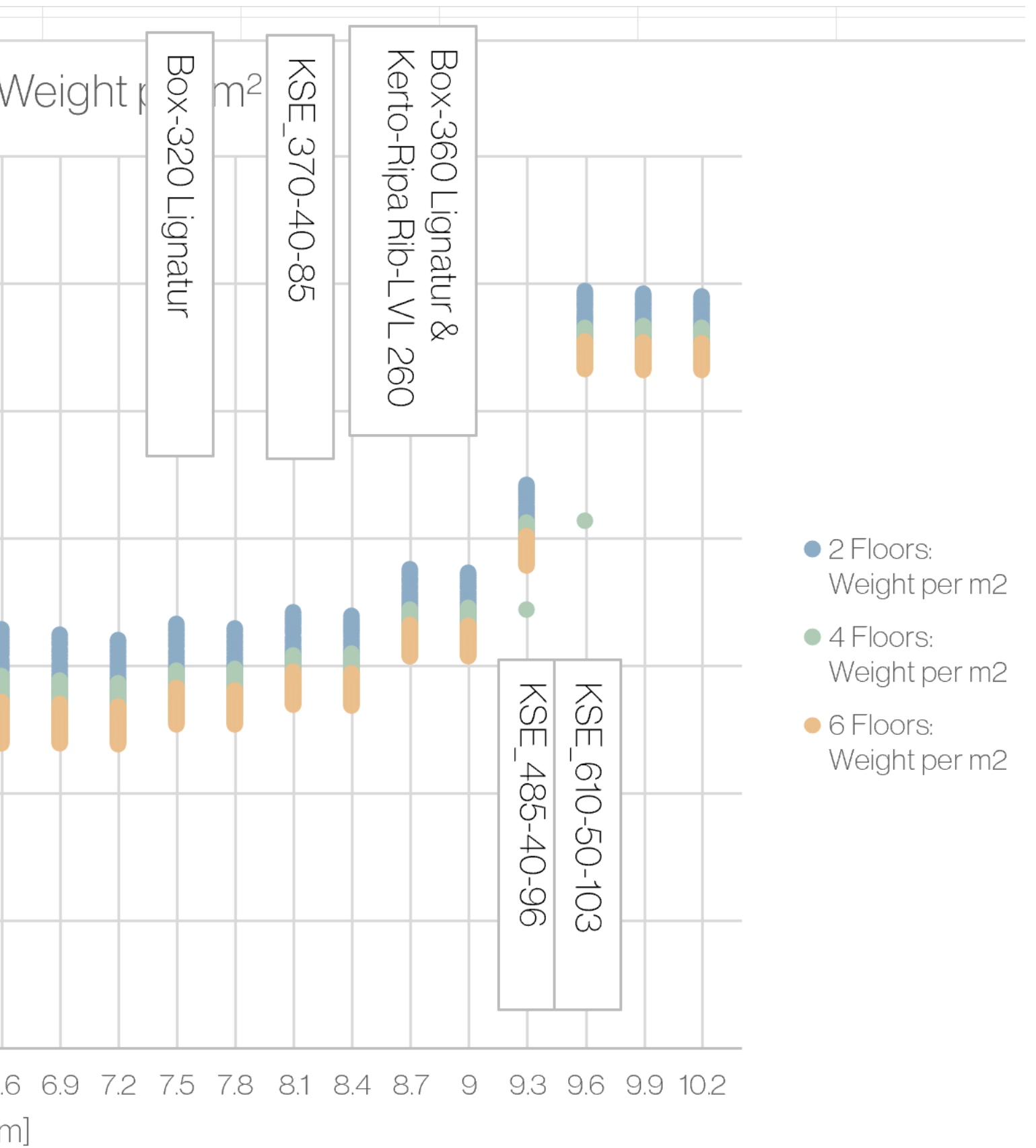
Floor span
0
1 S(0)
2
3

A R
B x
fims

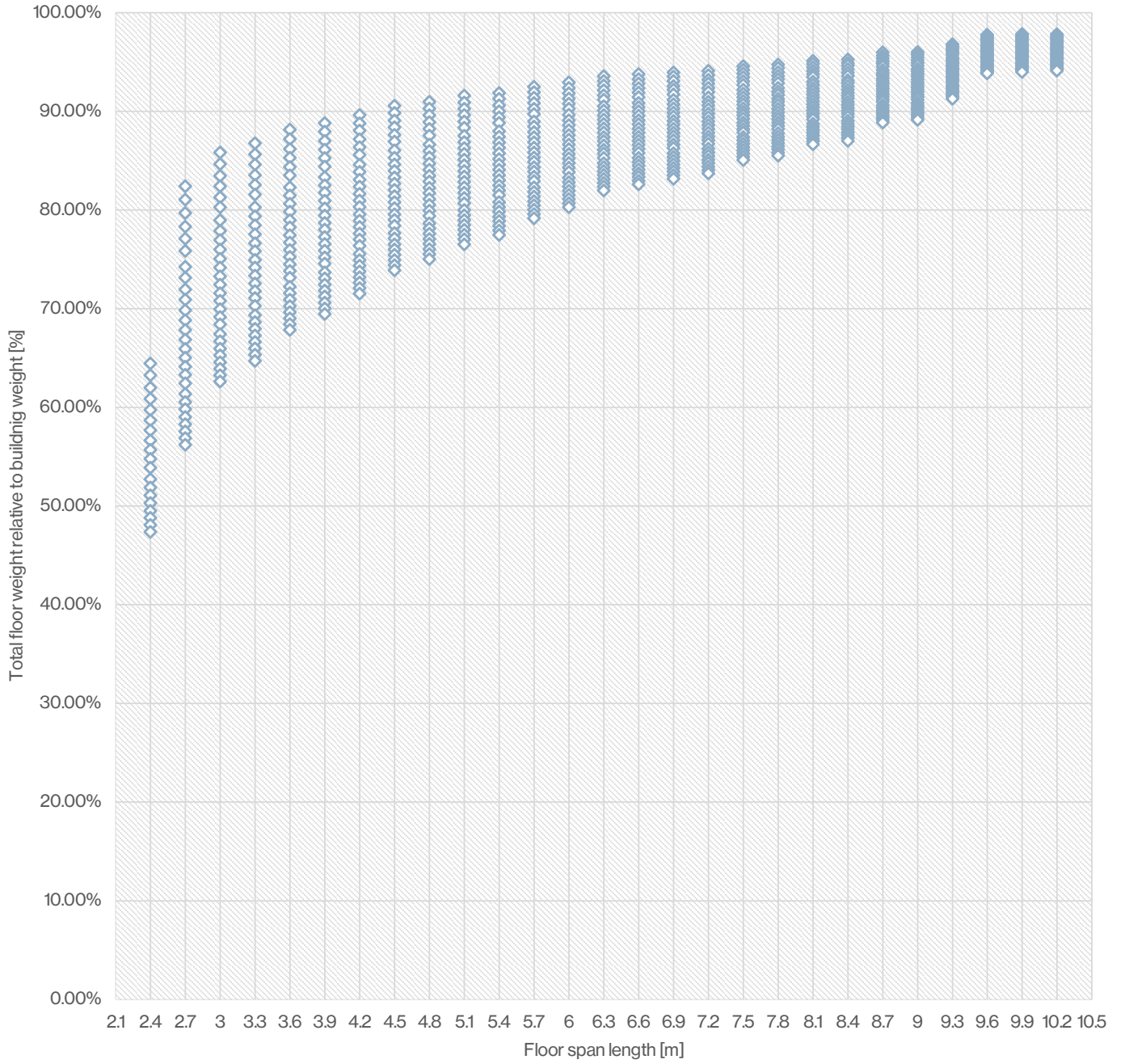
F z V

Appendix C: numerical results Grasshopper

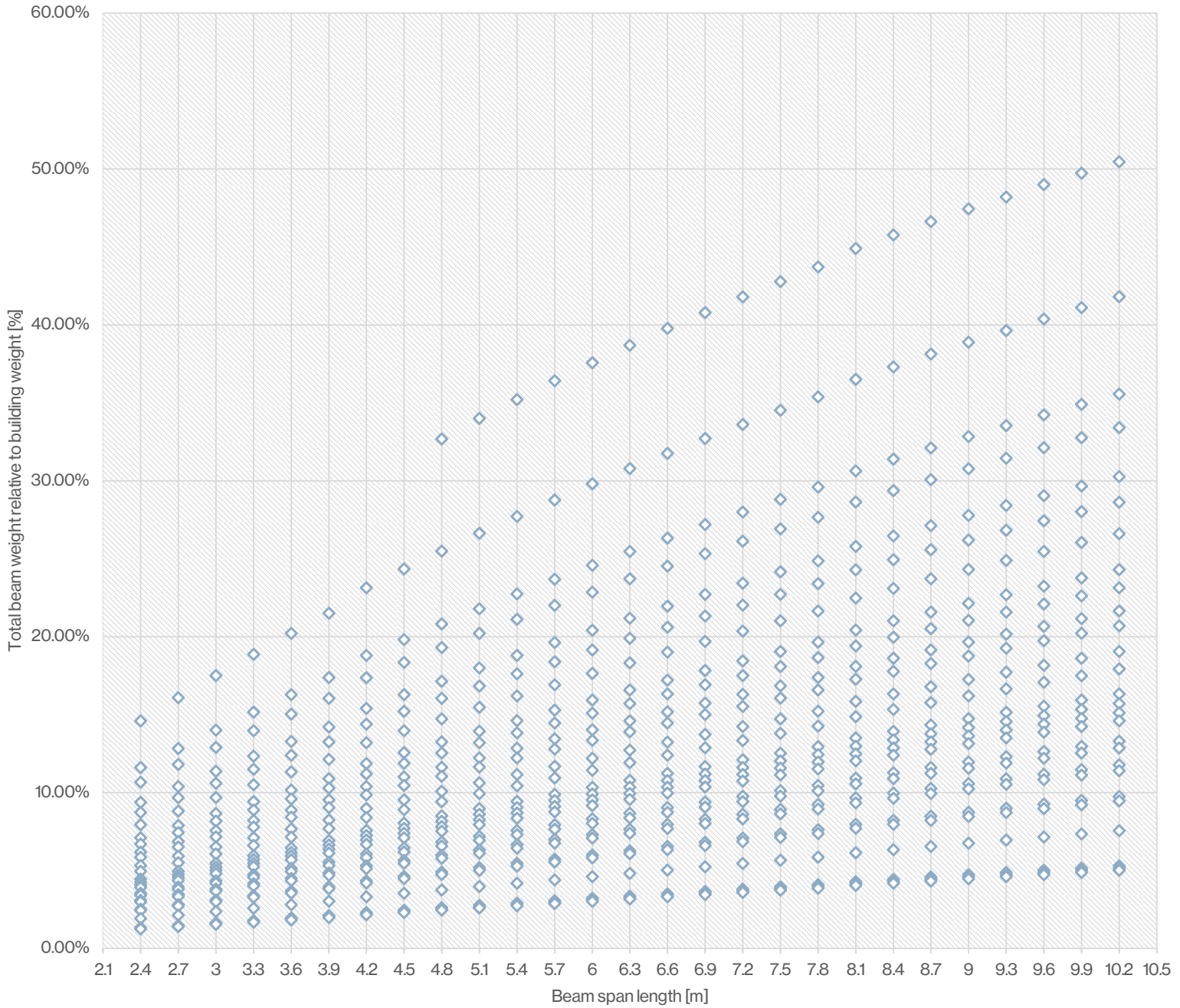




Relation floor span & weight per m²



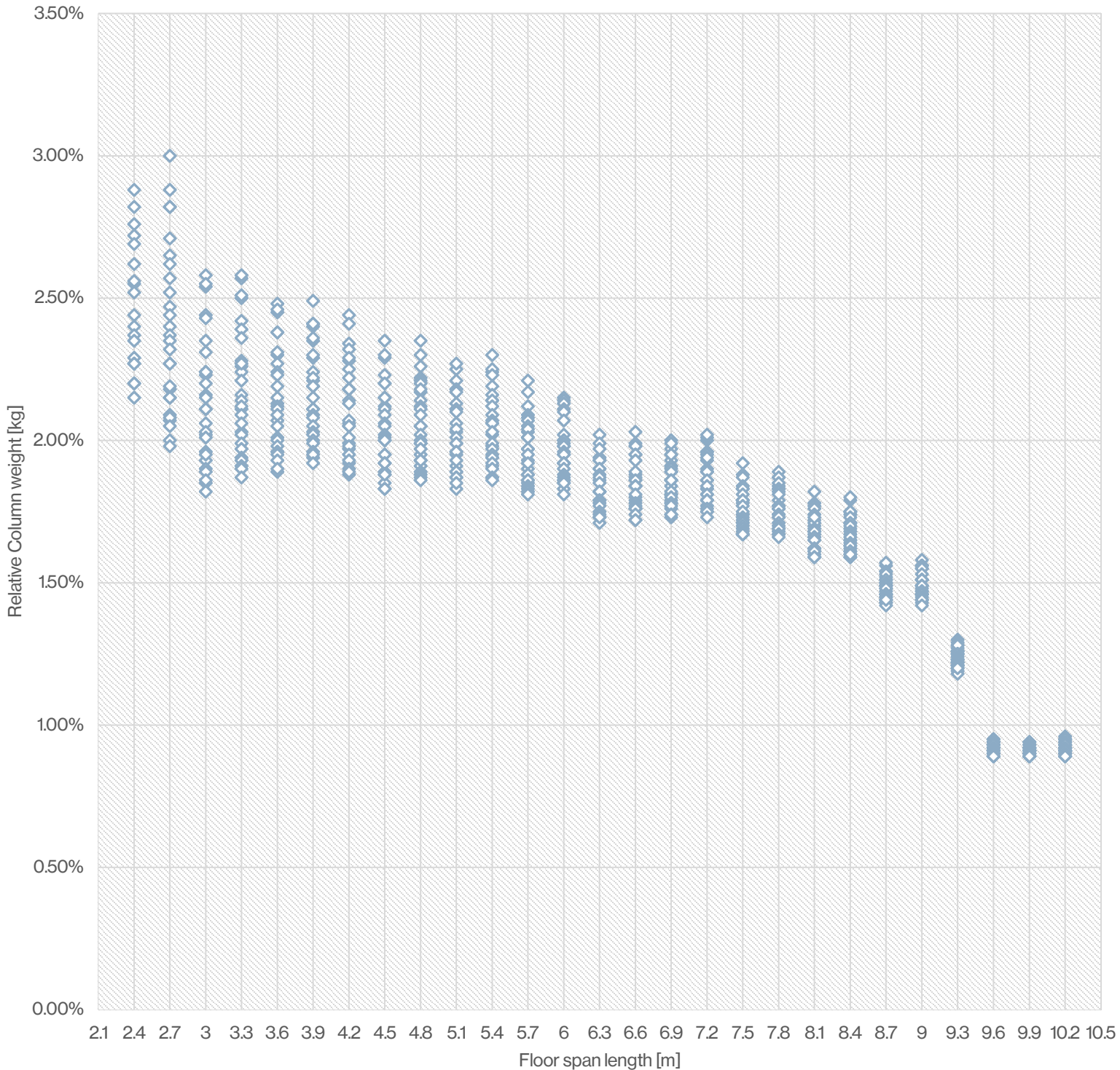
Relation beam span & beam weight % of total building structure



Most optimal beam: GL36h, given its:

- **Density [kg/m³]**
- **Compressive strength [MPa]**
- **E-modulus [MPa]**

Floor span per relative column weight



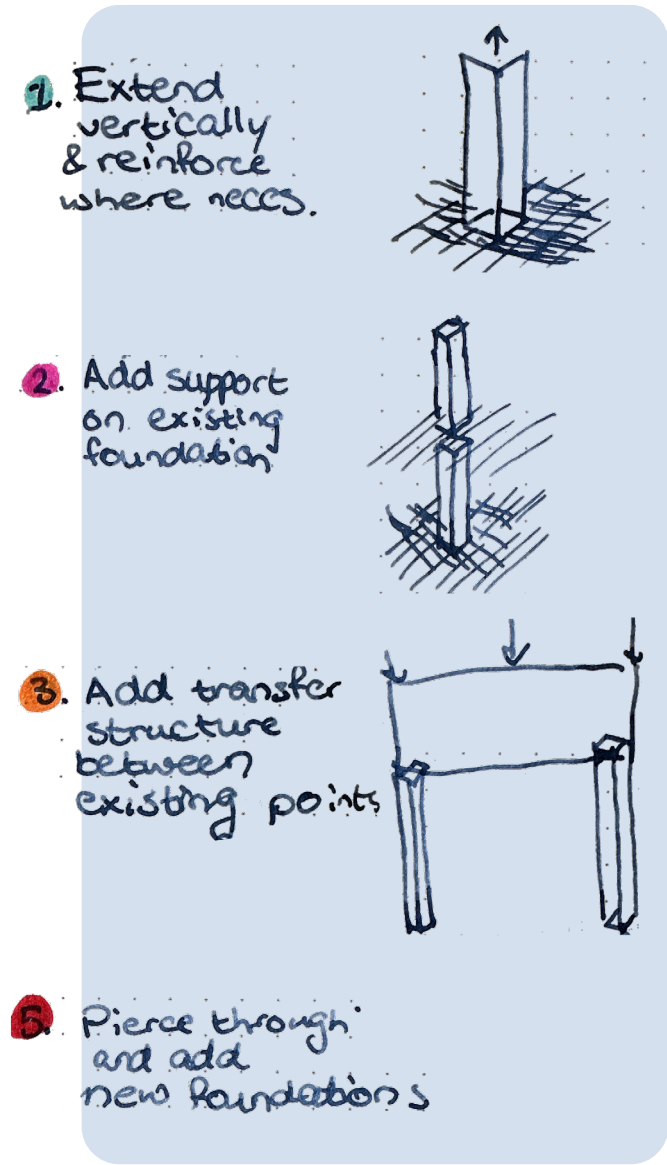
Conclusion:

- **The bigger the floor span, the smaller the column's contribution to overall building weight**
- **Columns contribute a fraction to building weight, in comparison to beams and columns (not more than 3%)**

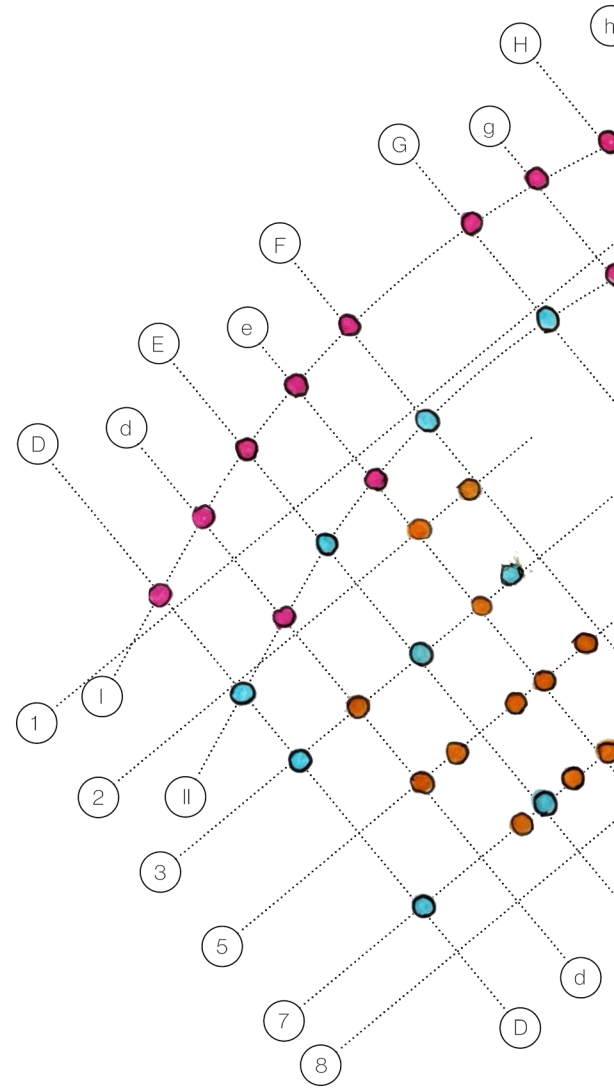
Most optimal column: Spruce LVL, given its:

- **Density [kg/m³]**
- **Bending strength [MPa]**
- **E-modulus [MPa]**

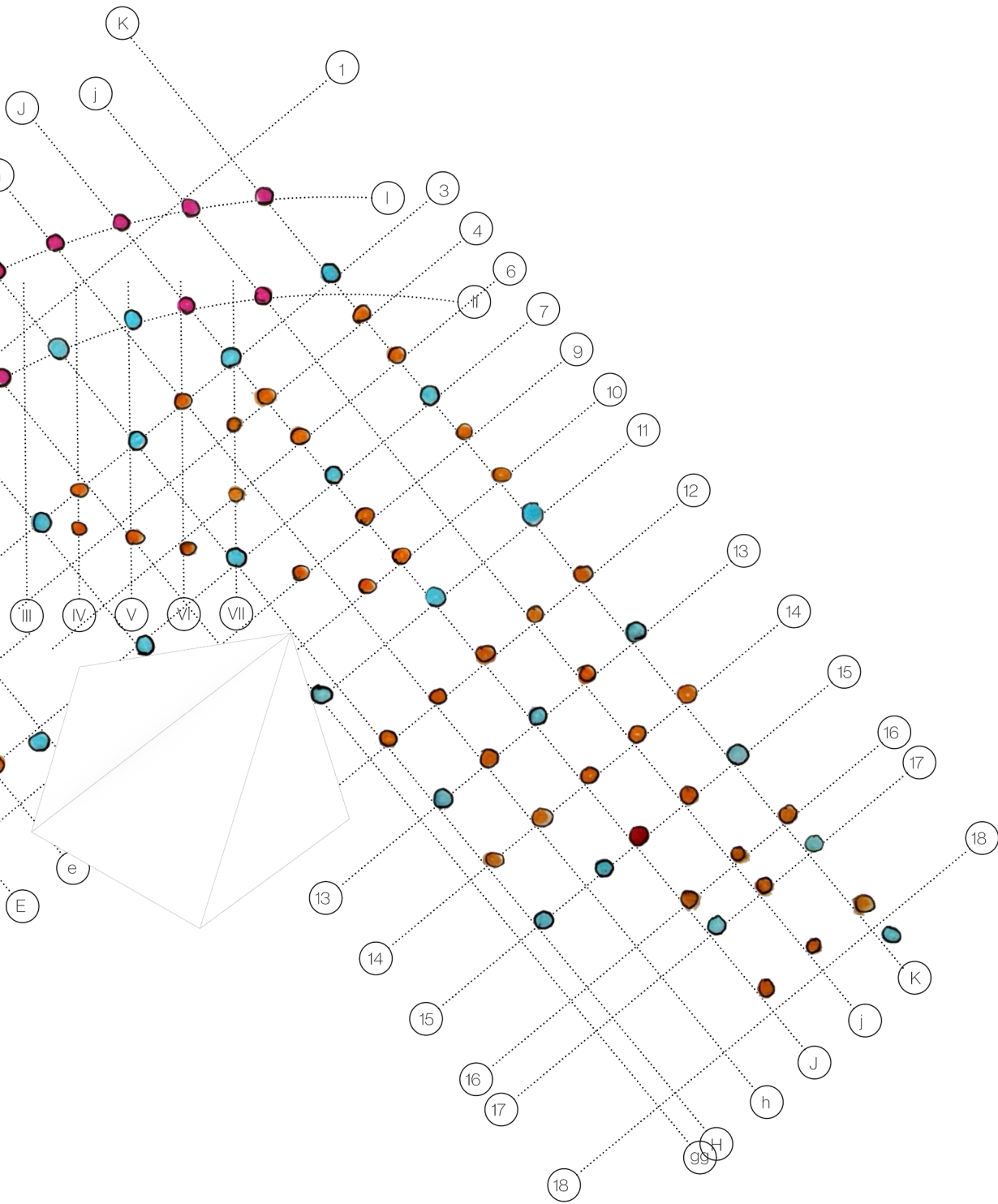
Structural configuration



▲ Hierarchy of structural principles for nodal load transfers



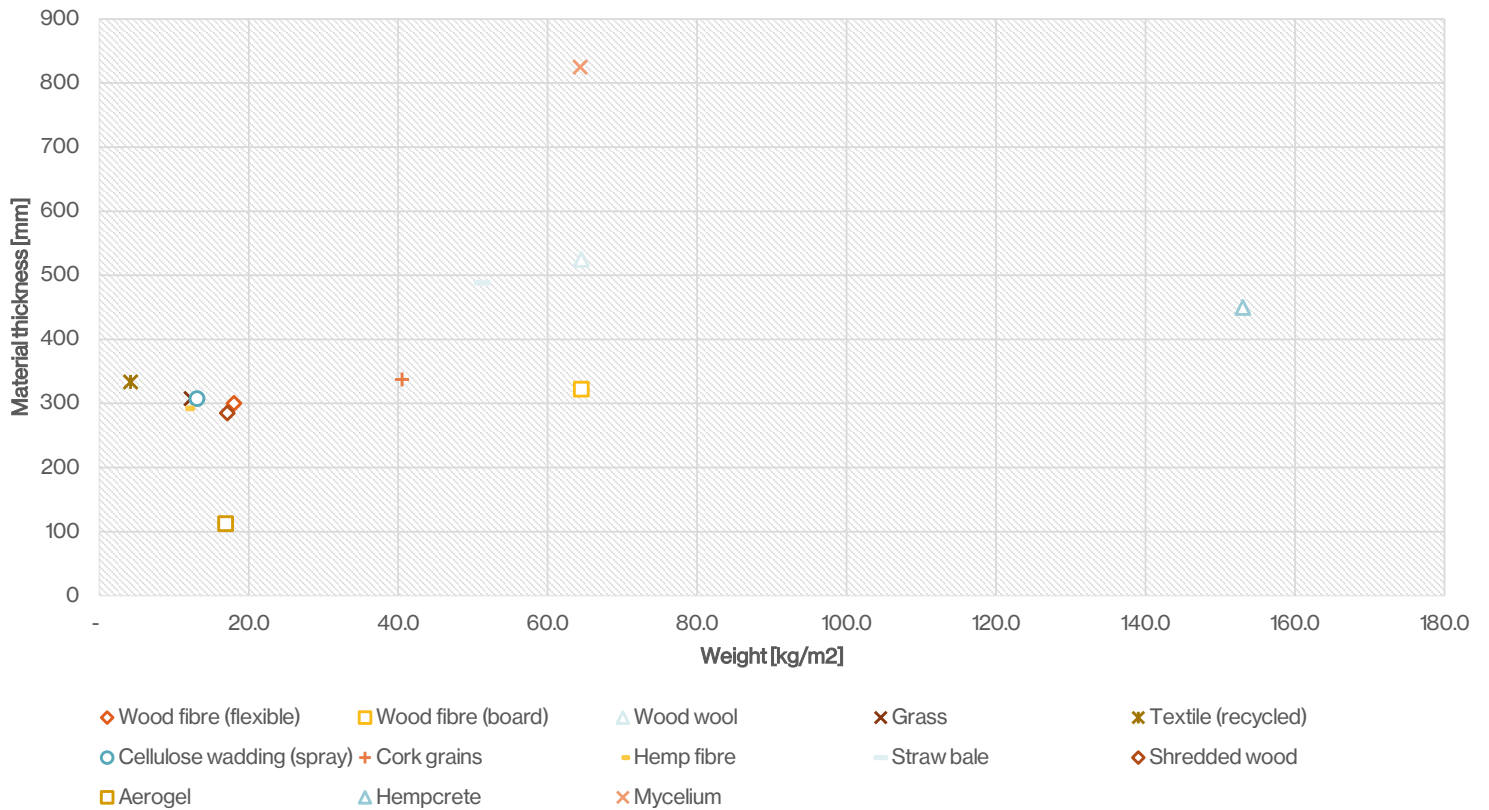
▲ Structural sub-grid with nodal load



transfer types - 1 : 300

Appendix D: numerical sheets building materials

Insulation material performance for R-value 7.5



Material	Minimum Thickness (mm)	Weight (kg/m ²)	Bio-based?	Water-tight?	Colour	Fire class
Aluminium façade panels	0.7	1.89	No	Yes	Diverse	A1
Aluminium composiet	3	3.1	No	Yes	Diverse	B-s1,d0
Powder coated aluminium sheet	1.5	4.2	No	Yes	Diverse	B-s1,d0
Aluminium sandwich panel	6	4.7	No	Yes	Metallic	A2/B
Zinc façade panels	0.6	4.68	No	Yes	Patina grey	A1
Thermally modified fir	18	7.2	Yes	No	Diverse	D-s1,d0
Fir Timber cladding	18	7.45	Yes	No	Timber	D-s2,d0
Thermally modified timber	19	7.98	Yes	No	Dark wood	D-s1,d0
HPL façade panel	6	8.1	Partially	No	Diverse	B-s2,d0
Compressed stone wool panel	8	9.36	No	Yes	Diverse	A2-s1,d0
Accoya cladding	25	10.4	Yes	No	Light wood	B-s1,d0
ETICS stucco system	30	15	No	Yes	Light stucco	A2/B
Fibre cement façade	8	15	No	Yes	Mineral	A2-s1,d0
Ecoline steenstrips	15	17.5	No	Yes	Brick	A1

Material	λ (W/mK)	R-value (100mm)	Density (kg/m ³)	Weight [kg/m ²]	Fire class
Wood fibre (flexible)	0.04	2.5	60	18.0	B
Wood fibre (board)	0.043	2.2	200	64.5	B
Wood wool	0.07	1.4	165	86.6	A
Grass	0.041	2.4	40	12.3	E
Textile (recycled)	0.0445	2.5	12.5	4.2	B-s2,d0
Cellulose wadding (spray)	0.041	2.6	42.5	13.1	B-s2,d0
Cork grains	0.045	2.4	120	40.5	B2
Hemp fibre	0.039	2.3	40	11.7	B
Straw bale	0.0651	1.5	105	51.3	B
Shredded wood	0.038	2	60	17.1	E
Aerogel	0.015	7	150	16.9	A2-s1,d0
Hempcrete	0.06	2.3	340	153.0	B-s1,d0
Mycelium	0.11	2.3	78	64.4	A2

