

# TALL TIMBER RESIDENCE

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# Title sheet

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Asta Therese Brene Nielsen

# Abstract

Copenhagen is facing a growing housing shortage, making it increasingly difficult for first-time buyers to enter the housing market. At the same time, the construction sector must reduce its environmental impact through more sustainable building methods. This thesis investigates how a timber high-rise residential building in Ørestad, Copenhagen, can provide attractive and efficient housing for first-time buyers while meeting requirements for daylight, fire safety, structural stability, and local planning regulations.

Using the Integrated Design Process (IDP), the project combines site analysis, user studies, case studies, and technical investigations to develop a mixed-use timber high-rise proposal. The design employs CLT and glulam as primary structural materials supported by a concrete core, while optimizing apartment layouts, daylight access, and residential quality.

The project demonstrates that timber high-rise construction can provide sustainable, high-density housing while maintaining architectural quality and technical feasibility. The findings indicate that timber high-rises can contribute to addressing Copenhagen's future housing demand and support the transition toward a more sustainable built environment.

# Use of AI

This thesis has made use of AI in regard to editing text, to limit spelling and grammatical errors.

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# PROLOUGE

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# Introduction

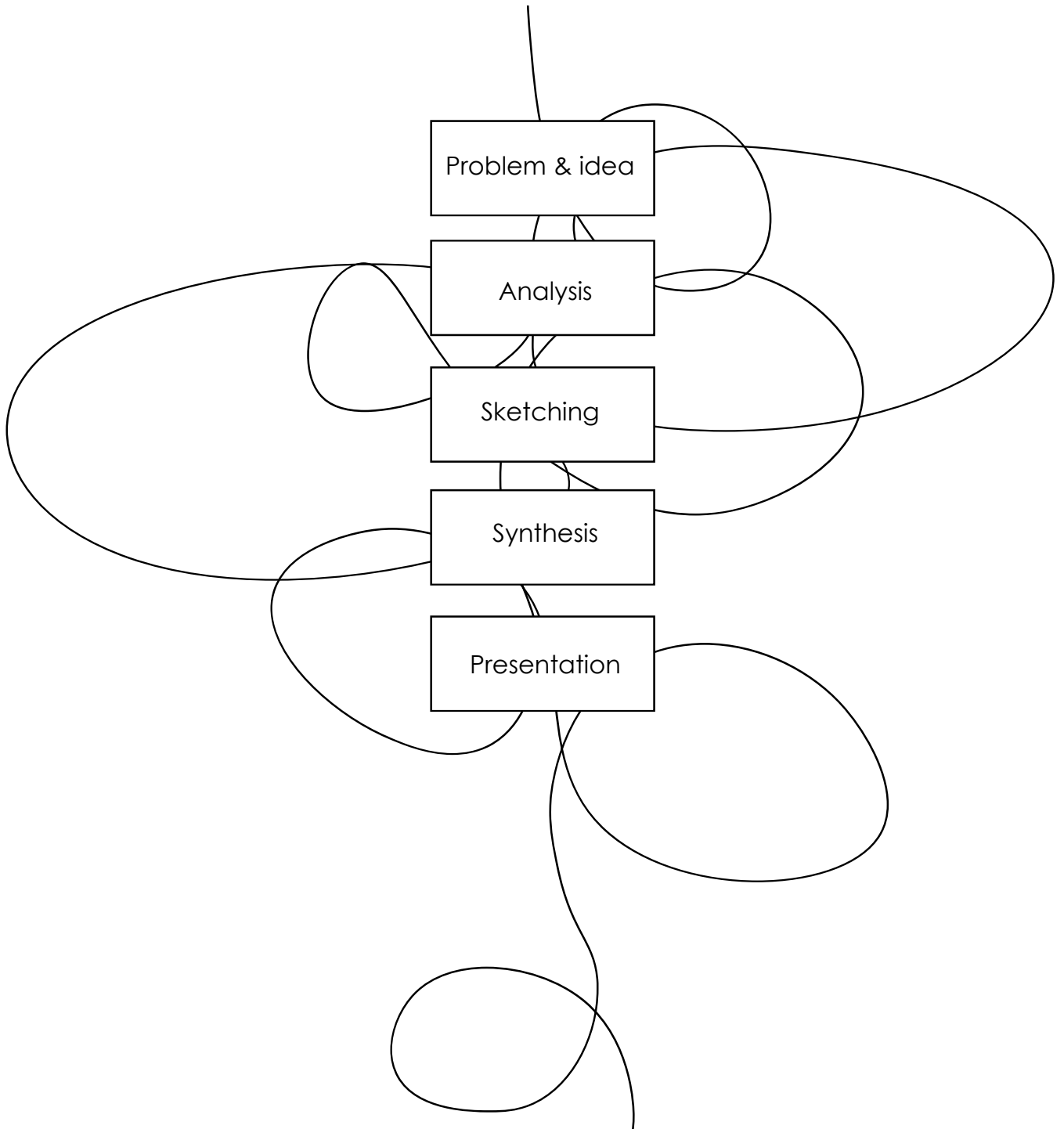
Copenhagen is currently facing a significant housing shortage driven by continuous population growth and increasing demand for affordable homes. According to municipal projections, the city will require approximately 77,000 new dwellings by 2060 in order to accommodate future residents. At the same time, rising housing prices and limited availability have made it increasingly difficult for first-time buyers to enter the housing market, particularly within the capital region.

To address this challenge, new housing developments must make efficient use of limited urban land while maintaining high standards of livability, sustainability, and architectural quality. High-rise residential buildings offer one potential solution by increasing housing density near existing infrastructure and public transportation networks. In Copenhagen, such developments are concentrated in designated growth areas, including Ørestad, where local planning strategies encourage dense, mixed-use urban environments.

Simultaneously, the construction industry faces increasing pressure to reduce its environmental impact. Engineered timber systems such as Cross-Laminated Timber (CLT) and Glulam have emerged as promising alternatives to conventional concrete and steel structures due to their lower embodied carbon and renewable material properties. Recent Scandinavian timber high-rise projects, including TRÆ

in Aarhus and Mjøstårnet in Norway, demonstrate the growing feasibility of tall timber construction while highlighting the importance of structural design and fire safety considerations.

This thesis explores the design of a residential timber high-rise located in Ørestad, Copenhagen. The project focuses on creating attractive and sustainable housing for first-time buyers through careful consideration of apartment layouts, daylight access, structural systems, fire safety, and urban integration. By combining architectural design with technical investigations, the project aims to demonstrate how timber high-rise construction can contribute to addressing Copenhagen's housing challenges while supporting a more sustainable built environment.



Illu. 1

Methodology

# Methodology

This Master thesis is based in the Integrated Design Process (IDP) method in its development. the design has gone through many iterations and stages.

## Problem and ideas

The development of the project started with research to understand the scope of the project and how it would be completed. This research includes gathering knowledge on the history of high rises and their contextual impact, and research into the user group and its needs.

## Analysis

The analysis stage of the project consisted of a wide variety of analyses including site analysis, material studies and case studies.

## Sketching

Most of the sketching for this project was done in Rhino3D as it made it easy to understand sizes and do small adjustments. this was supported by hand sketching as a means to quickly transfer thoughts and ideas onto paper. digital sketching also allowed for technical simulations to be done alongside the sketching to further show the impact of design choices.

# PROJECT FRAMEWORK

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# Copenhagen housing crisis

Just like many other major cities around the world Copenhagen is experiencing a housing shortage. It is expected that before 2060 the population of Copenhagen will increase by 113,000. This means that around 77,000 new homes will need to be constructed to accommodate all incoming families. (Økonomiforvaltningen, Center for Byudvikling, Kontor for Analyse og Klima, 2025)

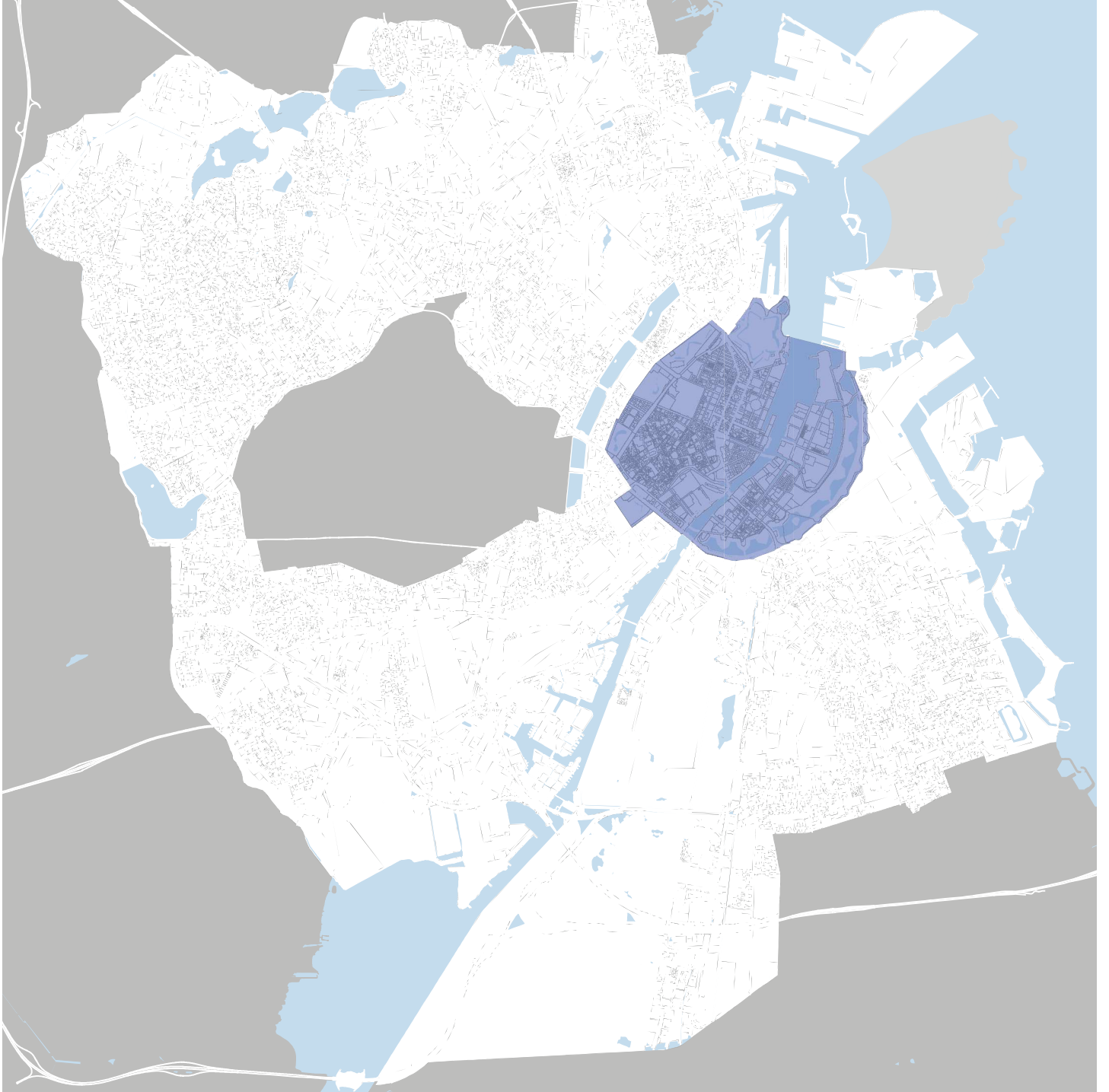
In addition to the rising population the housing market has become harder to access and navigate. Waiting list for social housing has in some instances reached over 30 years (ritzau, 2015) whilst privately owned rental homes and apartments has risen to almost four times the cost in 2010. Today a person would need almost double the average yearly salary to be able to take out a mortgage for a 60 square meter apartment in Copenhagen. Additionally, the upkeep cost of an apartment in Copenhagen is almost double the national average. (Økonomiforvaltningen, Center for Byudvikling, Kontor for Analyse og Klima, 2025) This in turn has made it a lot harder for first time buyers in Copenhagen.

Reasons to the housing shortage can be traced back to the 1980s. Back then, Copenhagen was experiencing a decline in population due to a decline in industrialization and the city being worn and crowded. This resulted in families leaving the city leaving only the poor and the single who would or had to live in the small units.

To reverse this exodus, the municipality enforced a 95 square meter size average requirement to all new apartments. (Eliassen, 2025) This along with other factors has resulted in the average size of owner-occupied homes in Copenhagen being over 100 square meters. (Økonomiforvaltningen, Center for Byudvikling, Kontor for Analyse og Klima, 2025)

Copenhagen municipality is aiming for an 82 square meter average for the 77,000 new homes being built in the coming years. This is influenced by the predicted demand being greatest for smaller apartments, especially in the 60 to 80 square meter range. (Økonomiforvaltningen, Center for Byudvikling, Kontor for Analyse og Klima, 2025)

Before 2040, around 4 million residential square meters are expected to be constructed in Copenhagen to meet the demand. Though if the aim is to reduce housing prices, an additional 70% extra square meters would be needed, meaning closer to 7 million square meters. (Økonomiforvaltningen, Center for Byudvikling, Kontor for Analyse og Klima, 2025)



**Illu. 2** Overordnet byudvikling: Højhuse (Københavns kommune, 2024)

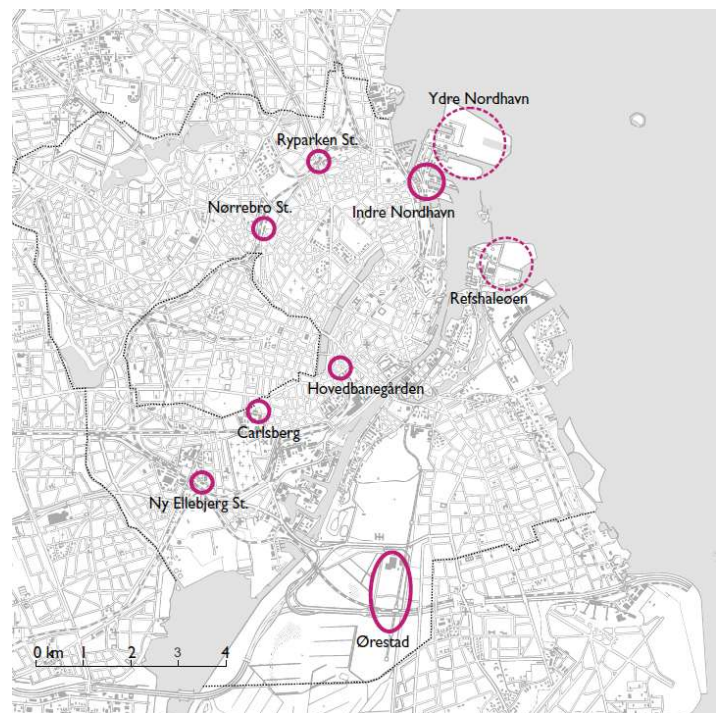
# Copenhagen high rise policy

The municipality of Copenhagen has a set of strategies and regulations that must be followed when constructing new high rises. Certain neighborhoods has been designated as areas for new high rise development. This includes Ørestad, Nordhavn, Carlsberg-byen and more. (Økonomiforvaltningen ved Center for Byudvikling, Teknik- og Miljøforvaltningen ved Plan & Arkitektur)

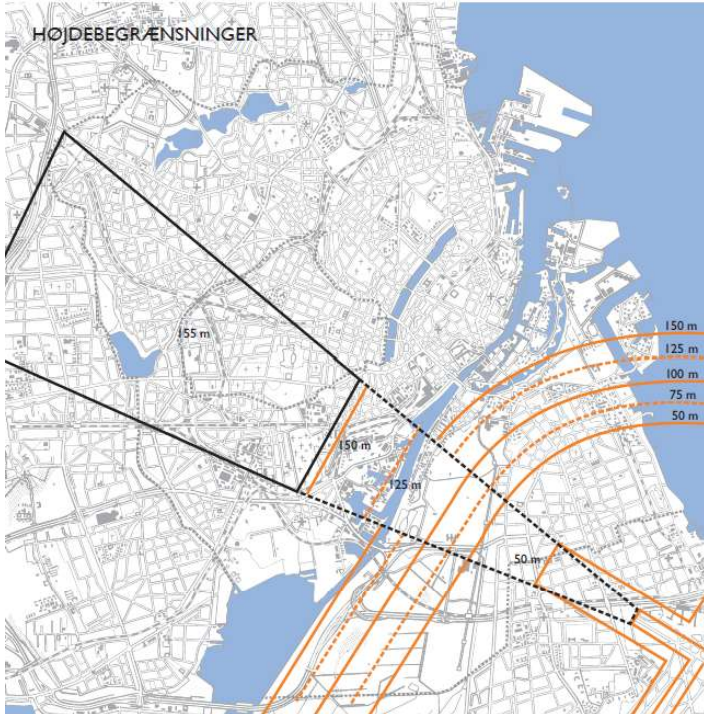
Copenhagen's high-rise policy states that new high-rise buildings must be located near train stations to ensure access to public transportation. This supports the integration of higher densities with existing infrastructure. High-rise buildings may also function as landmarks for specific areas, contributing to local identity and orientation within the city. (Center for Byudvikling, Økonomiforvaltningen, 2024)

No new high-rises are permitted within the old city, marked in blue on illustrations. In this zone, buildings must be kept at six floors or lower in order to maintain the existing urban scale and character. (Københavns kommune, 2024) All new high-rise proposals must be considered in relation to the surrounding city, existing landmarks, and their visual impact—particularly how they are perceived from Copenhagen's coastlines and open areas. (Center for Byudvikling, Økonomiforvaltningen, 2024)

*There is no one definition for what constitutes a high rise, but the consensus in Denmark is a building with a minimum of 12-15 floors. The municipality of Copenhagen defines a high rise as 13 floors and above or taller than 40 meter.*



**Illu. 3** Highrise areas, Copenhagen (Københavns Kommunes Økonomiforvaltning ved Center for Byudvikling, Teknik- og Miljøforvaltningen ved Plan og Arkitektur, 2006)



Building height is further restricted due to the proximity of Copenhagen Airport and must be approved by Statens Luftfartsvæsen. An exemption to the standard height restrictions allows buildings in Ørestad to reach up to 85 meters, as Ørestad is designated as one of Copenhagen's high-rise development areas. (Københavns Kommunes Økonomiforvaltning ved Center for Byudvikling, Teknik- og Miljøforvaltningen ved Plan og Arkitektur, 2006)

**Illu. 4** Building height restriction due to Copenhagen airport (Københavns Kommunes Økonomiforvaltning ved Center for Byudvikling, Teknik- og Miljøforvaltningen ved Plan og Arkitektur, 2006)

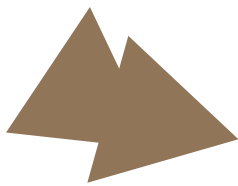
# Existing high rise design



Illu. 5 Tower (punkthuse)



Illu. 6 Block (stokbebyggelse)



Illu. 7 Sculptural



Illu. 8 Clusters (grupper af punktbebyggelser)



Illu. 9 PerimeterBlock (karrébebyggelse)

## Typologies

Tall and slender are some of the words used to describe a tower high rise. These have a relatively small footprint compared to their height. These are often associated with more modern high rises but also encompasses older ones like the SAS royal hotel in Copenhagen.

In quite the contrast there is the Blocks. These long, rectangular, uniform buildings are often associated with modernism. An example of these is Høje Gladsaxe in Søborg.

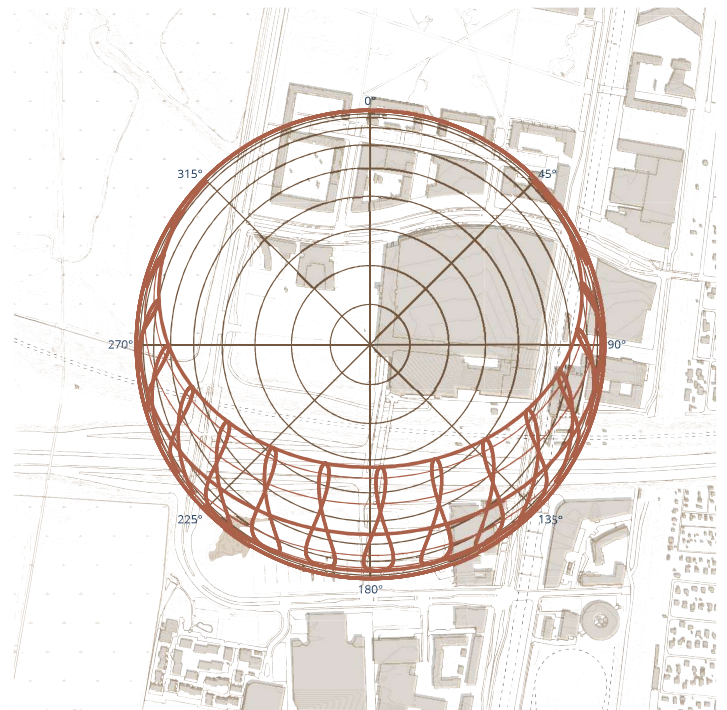
The most recent style is the sculptural high rise. This style questions the classic square shape and challenges what is possible. They can be a tower but are not always. Examples of sculptural high rises are Hotel Bella sky in Copenhagen or turning torso in Malmø.

The forementioned high rise styles are often seen in combination with the more mid rise clusters and perimeter blocks. Clusters are several tower, block or point block buildings, placed in some sort of orderly formation. Perimeter blocks are the most common style in Copenhagen. These are often combined with towers this is seen in Carlsbergbyen where all the towers are placed in one corner of a perimeter block.

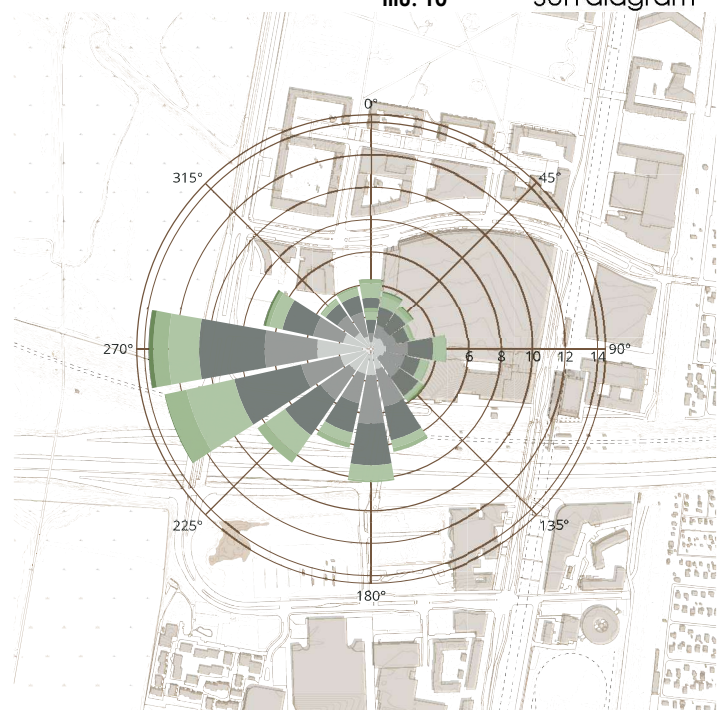
# Site analysis

When designing a high rise, it is important to consider how the building's shadows will affect its surroundings. Furthermore, the rotation of the building is conclusive to how the sun will enter each residential unit. This has a big impact on the indoor climate and comfort level.

In Denmark the sun only reaches around 10 degrees in winter casting very long shadows for the few hours the sun is up. In summer, the sun is up for a large percentage of the day, reaching around 57 degrees in the sky.

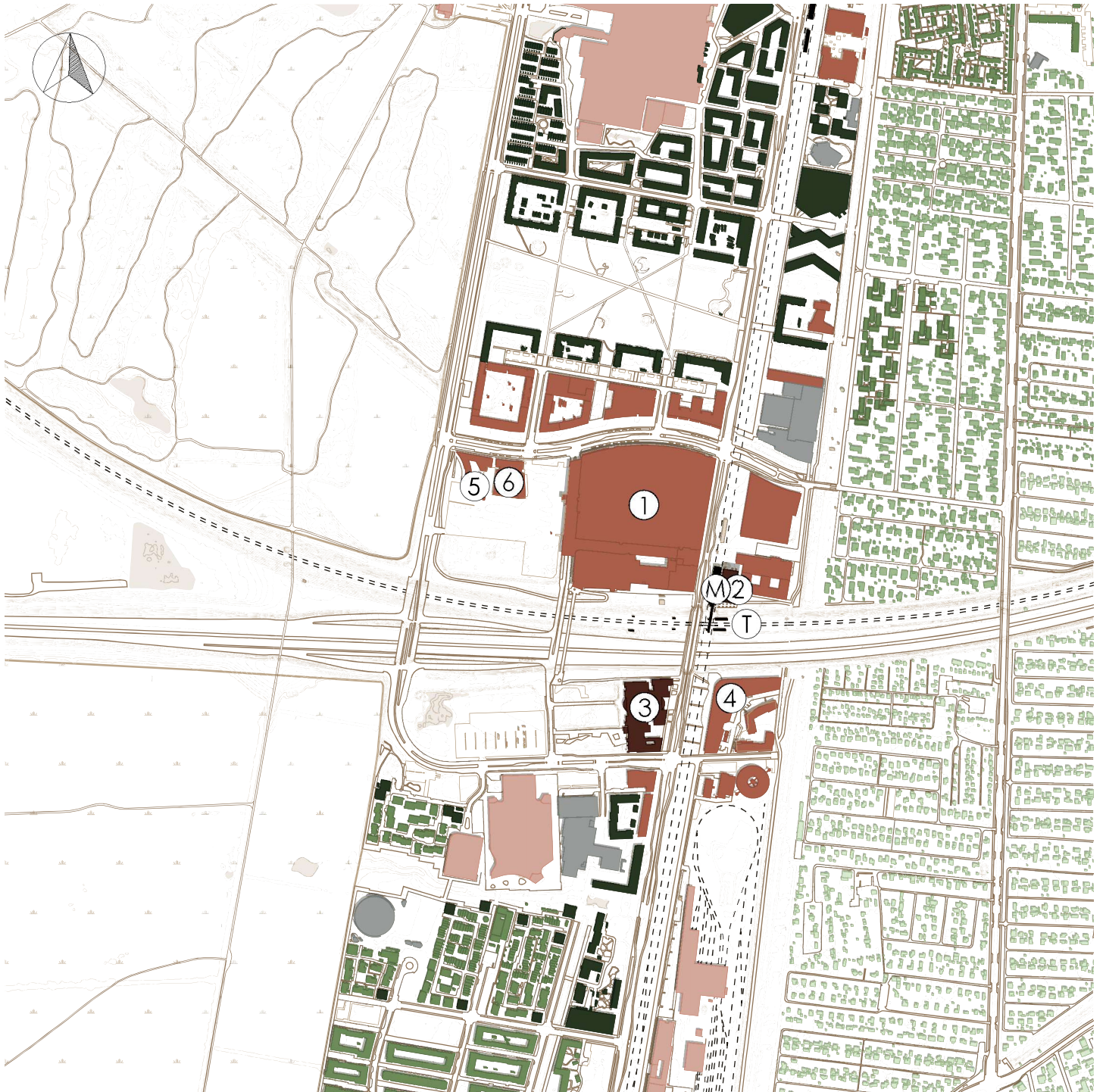


Illu. 10 Sun diagram



Illu. 11 Windrose diagram

Wind has a big impact on natural ventilation, but it is also important to keep in mind in regard to how it flows around the building impacting the surrounding urban space. The most occurring wind direction in Ørestad is for west and south west.












Illu. 12 Ørestad Building typologies 1:10.000

# Ørestad - a new city district

Ørestad is a new city district officially established in 2004 in close connection with the construction of Copenhagen's first metro lines. Shortly before the metro line connecting Ørestad to central Copenhagen was finished in 2002, the pharmaceutical company Ferring built an 81 meter tall office building that even today acts as a landmark along with the newer build Copenhagen Towers which reaches the height of 85 meters. Today, Ørestad has become home to many international businesses, multiple levels of education and one of Denmark's biggest shopping malls, fields.

The district is designed with a high building density. It is a mix of commercial and residential buildings all within the 6 – 12 floor range with a few. It has two high rises at the time of writing with more being planned in the respective local plans.

Just east of the district is a big residential neighborhood consisting of detached and attached houses. Just south from these are several allotment associations. All of these exist in quite the contrast to the towers of Ørestad.

Typologies	Name	Height
 Residential 6 - 12 floors	① field's	approx. 30m
 Residential 2 - 5 floors	② Ferring-tårnet	81m
 Residential detached houses	③ Copenhagen towers	85m
 Residential allotment houses	④ Rambøll head office	approx. 35m
 Commercial 13+ floors	⑤ Hotel Cabinn Metro	approx. 45m
 Residential 6 -12 floors	⑥ Cabinn apartments	approx. 30m
 Residential 1 - 5 floors		
 Educational institutions	Ⓜ Ørestad metro station	
 Train / Metro stations	Ⓣ Ørestad train station	



III. 13 Local plan boundaries 1:5000

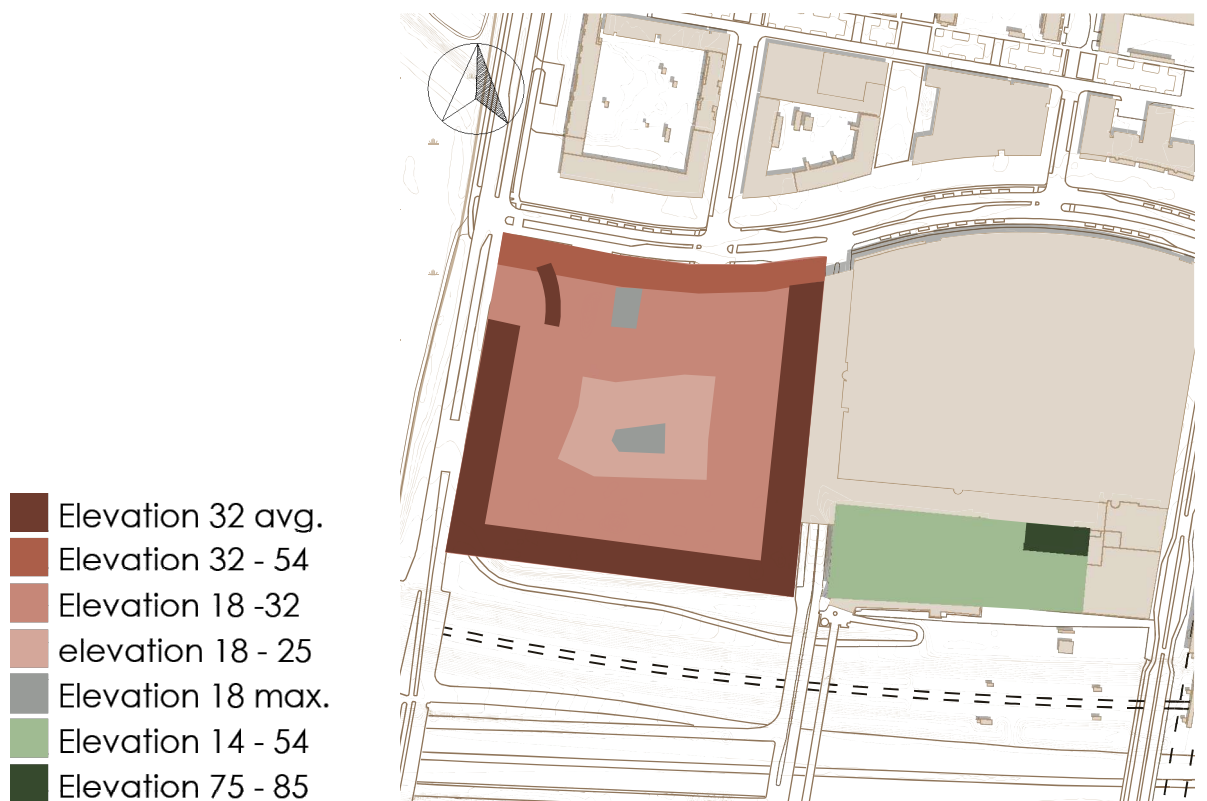
# Ørestad City Center Lokalplan

When looking at the local plans, Ørestad is expected to keep expanding and filling in the gaps. As mentioned, more high rises are in the plans, mainly facing the highway that crosses just south and south-west of field's. This includes the extension to Ørestad city center located west and south of the shopping mall.

The plans for this are a mixed residential and commercial neighborhood built in varying heights spanning from 18 to 85 meters. The local plan intends for the buildings to be laid out in a specific way, with the tallest buildings at the perimeter and the shortest at the middle, forming a bowl shape.

The local plan divides the space into three subareas, I, II and IIA (illustration the left). This project focuses on subarea II where the site is located.

For subarea II, the local plan intends for the buildings to be laid out in a specific way, with the tallest buildings at the perimeter and the shortest at the middle, forming a bowl shape. Residences should be placed the top floors of the building with the bottom floors intended for commercial use. Each building should have its own distinct facades, visually separating them from each other. Ground floor facades have to be open and active to ensure a lively urban space between the buildings.



Illu. 14

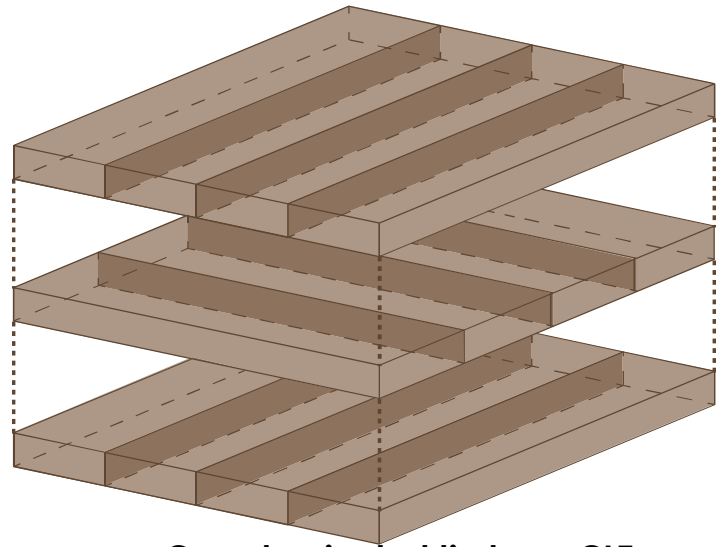
Local plan building heights 1:5000

# Timber Buildings - fire Safety and sustainability

When constructing timber building the most common building materials are engineered wood products such as CLT or Glulam. The forementioned consist of multiple lumber pieces glued together to improve strength and reach desired dimensions. This kind of timber allows for more of the tree to be utilized as they require smaller individual pieces compared to the classic solid lumber. During the processing the wood is often kiln dried, which minimizes warping, prolongs longevity and strengthens the wood. (Michael Green, 2017)

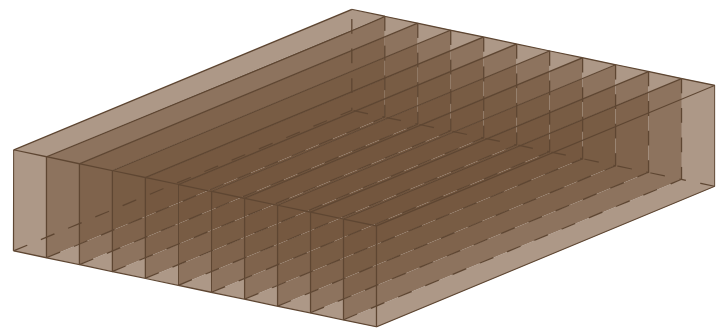
When building tall timber building implementing a concrete staircase and elevator shaft as a core can help transfer lateral loads between floors though it is not necessary. A CLT core is also a viable option if connected properly. Vertical loads are best transferred through continuous columns. CLT and especially glulam is well suited for this in taller structures as it is less susceptible to warping and are not limited by the height of the tree form which the wood is sourced from. (Michael Green, 2017)

A concrete core can also be beneficial in case of fire safety, due to it being incombustible. It is possible to build entirely out of timber each element would need larger in dimension to keep its loadbearing properties in case of fire. According to Danish regulations, a building should be able to maintain its loadbearing properties for the amount of time needed to evacuate the building and for fire rescue services to work.



Illu. 15 **Cross laminated timber - CLT**

Lengths of lumber glued together in multiple layers, each layer perpendicular to the next. Able to withstand loads in multiple directions. Commonly used for walls, floors and roofs.



Illu. 16 **Glue laminated timber - glulam**

Lengths of lumber glued together in the same direction, able to span long distances. Commonly used for beams and columns.

For buildings with the top floor sitting between 12 and 45 meters from ground level, the building should be able to withstand 120 minutes. There's no standard for buildings with a top floor higher than 45 meters. (Trafik-, bygge- og boligstyrelsen, 2021)

Timber can be and is produced in some amount in Denmark. But our neighbors Norway and Sweden are big exporters of timber along with big parts of the rest of Europe. It is beneficial to source timber locally as transportation can be a big source of CO<sub>2</sub> emissions.

Wood is one of the most sustainable building materials there is. Especially compared to some of the most commonly used building materials like steel and concrete. When trees grow, carbon dioxide is stored inside the wood, which makes it carbon negative. When using wood for construction, the CO<sub>2</sub> keeps being stored within. This allows new trees to be sown so that they can store more CO<sub>2</sub>. The stored CO<sub>2</sub> will only be released back into the atmosphere if burned or decomposed when the structure is demolished.

It is also a very durable material. Some wood types can last 50 to 100 years without any kind of treatment. Wood used for building in a way where it's exposed to the elements can be treated to improve durability and make it more resistant to moisture, sun damage, fungi or bugs. This is done by kiln drying or some sort of surface treatment. Though some treatments can counteract the sustainability because of it releasing toxic substances when burned or washed out. (Bæredygtigt byggeri dk, n.d.)

# TRÆ - Case study

*Aarhus, Denmark*

*Lendager Arkitekter*

*2025*

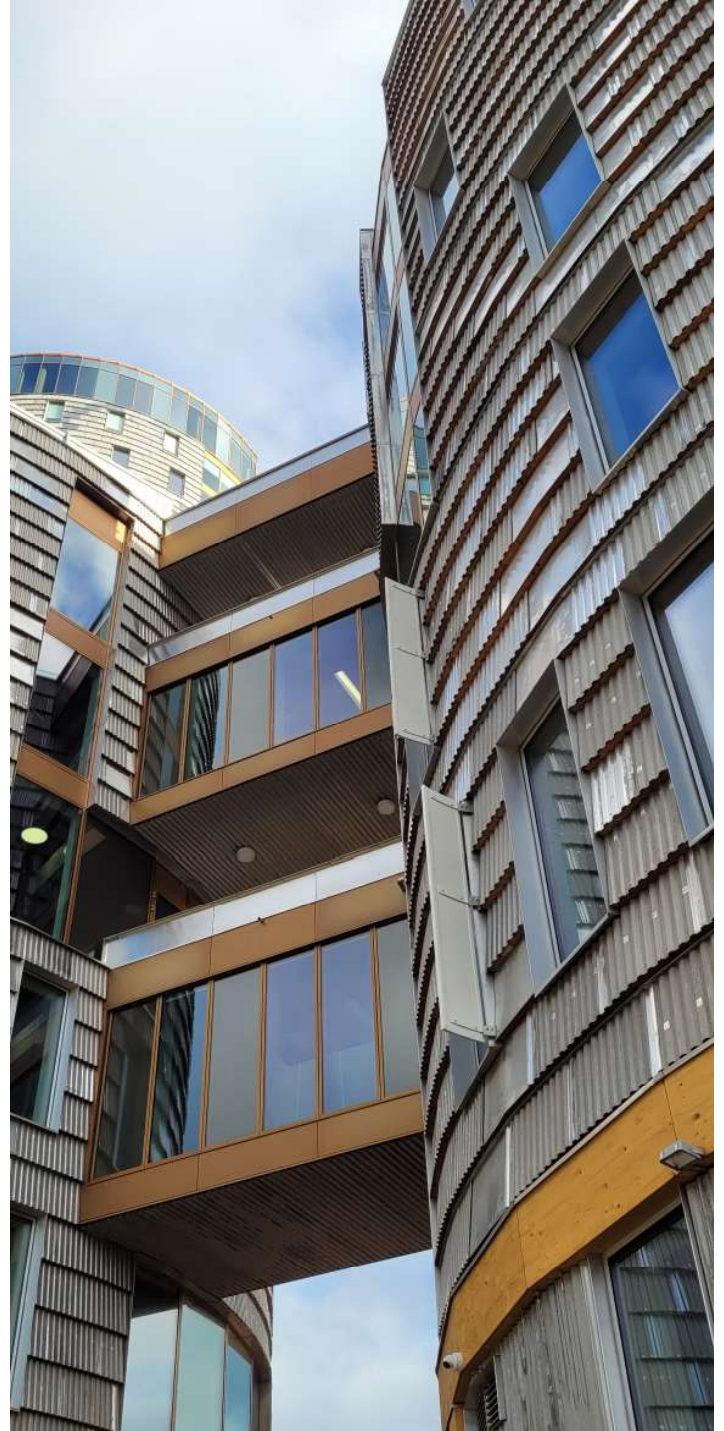
*78 meters and 20 floors tall*

TRÆ is the tallest timber building in the country. Besides being a timber building, the aim of this building was to use as many reused materials as possible. Consisting of three rounded towers, the building has a very specific shape, formed by the pedestrian flow through it. It is an office building owned by PFA Pension who has committed to lowering their carbon output for investment properties.

## Construction

The building is constructed as a hybrid building with timber as the primary material, supplemented by steel and concrete to meet structural and regulatory demands. A large portion of the loadbearing system consists of CLT, which is used for the floor, beams, and columns. A large share of the building is constructed from prefabricated elements which allows for more precise and efficient construction.

Due to its height, the building is classified within a high consequence and construction class, which imposes strict requirements for structural performance, stability, and detailing. The tallest tower is therefore designed to meet enhanced standards of



Illu. 17 TRÆ, Aarhus

robustness, including the dimensioning of the loadbearing system. While timber forms the main structural system, concrete is used on the foundation and cores to provide sufficient stiffness and resistance to horizontal forces like wind. Steel elements are integrated into the structure where additional strength or reduced construction depth is needed or desired, particularly in the beam system and in connection points. The curved shape of the towers also further the need for steel in the construction as timber typically is produced in straight elements, especially loadbearing elements.

## Fire safety

Fire safety is a central aspect of the building's design and is held to stringent regulations due to its height. During the design of TRÆ, the team was working closely with fire safety engineers to ensure that the building live up to the Danish fire regulations. Due to it being the first timber building, taller than 15 floors, some aspects did not have any pre-accepted solutions, requiring new custom solutions to be developed and approved.

Due to its height, exceeding 22 meters, the building is classified in Brandklasse 4 (BK4), which applies to complex and high-rise buildings where a fire safety strategy must be documented and verified by certified fire consultants. This includes verification of fire performance, classification according to relevant standards, and, where necessary, full-scale testing. The fire safety design is

based on a combination of passive and active measures, ensuring that the building meets the functional requirements related to evacuation, structural stability during fire, and limitation of fire and smoke spread.

A central requirement in BR18 is that buildings must be designed so that persons can evacuate safely and that rescue operations can be carried out effectively. This is addressed through the incorporation of protected escape routes located within fire-resistant concrete cores. These cores function as independent fire compartments and provide safe vertical evacuation paths.

Although timber is the primary structural material, only 20 percent of the interior surfaces are allowed to be exposed, untreated wood. The remaining 80 percent are protected by fire-resistant layers. In line with the aforementioned Mjøstårnet, the loadbearing elements are dimensioned to account for charring during a fire which in this instance means an additional 100mm of material as added on each side of the elements. This additional material ensures that the structural elements remain loadbearing for at least 120 minutes (R120) during a fire to ensure safe evacuation of the occupants. Concrete cores provide additional robustness and ensure that critical structural elements maintain their load-bearing function during fire exposure. The building is equipped with a full sprinkler system, which reduces fire growth and allows for design trade-offs in material use.

# Mjøstårnet - Case study

*Brumunddal, Norway*

*Voll Arkitekter*

*2019*

*85,4 meters and 18 floors*

Mjøstårnet was the world's tallest timber building, surpassed by Ascend in Milwaukee in 2022, though some argue that it is still the tallest as Ascend's first 7 floors are fully concrete. It is an 18-storey building that demonstrates how tall structures can be built using timber.

## Construction

The building primarily uses glulam for the main loadbearing elements and CLT panels for the elevator and stair shafts. The structural system consists of large glulam columns, beams, and diagonal trusses placed along the facades. These elements transfer vertical loads to the foundation and provide lateral stability against wind forces. The diagonal elements form truss systems that stiffen the building and limit horizontal movement. The structure has two different floor systems. The lower floors use light weight CLT elements while the upper floors use concrete. The concrete has a higher mass, which helps improve the building's stability and reduces vibrations caused by wind.

A key aspect of the construction process is the extensive use of prefabrication. Structural components were produced in factories using CNC machines, ensuring a high level of precision. Elements were delivered to the construction site pre-cut and pre-drilled, which allowed the structure to be assembled efficiently using cranes, reducing construction time, and improving quality.

The connections between structural elements are made using steel plates and dowels embedded within the timber elements. This protects against exposure to the elements and improves performance in case of a fire.

## Fire safety

Fire safety is a critical aspect of the design due to the use of timber as the primary structural material. For this building, the fire strategy requires that the main loadbearing structure must remain loadbearing for at least 120 minutes of fire exposure, while secondary structural elements such as floors must resist fire for at least 90 minutes.

One of the main fire protection aspects relies on the predictable charring behavior of large glulam elements. When exposed to fire, the outer surface forms a charred layer that protects the inner material from burning rapidly. The design calculates the charring rate as approx. 0,7mm per minute. Structural elements are therefore designed with extra thickness so that even after charring during a fire, the remaining cross section can still support the loads of the building.

Another important precaution involves protecting the steel connections, as steel can lose strength rapidly at high temperatures. As mentioned, the steel plates and dowels are embedded deep within the timber to protect it. Additionally, gaps between elements are lined with a material that expands when heated, sealing openings and preventing fire from reaching the steel components.

Several additional fire safety measures are also incorporated into the building. The entire structure is protected by a sprinkler system, and exposed timber surfaces in public areas are treated with fire-retardant coatings. Escape staircases are protected with fire-resistant gypsum boards, and fire stops are installed in the façade at each floor level to prevent fire from spreading vertically between floors.

# Usergroup

First time buyers are the ones experiencing the most difficulties in the housing market due to high interest rates and not having any home equity to help making the purchase (Stephensen, 2025). First time buyers are defined by Danmarks Statistik as someone who has not own any real estate within the last three years of purchasing a home. The number of first time buyers was in 2022 the lowest since 2014.

The average age of first time buyers are different across Denmark. The national average age is 35,5. The average age of first-time buyers in Copenhagen is 32,6. That is the second lowest in Denmark, only succeeded by the municipality of Frederiksberg. On a national level almost 40 percent of first-time buyers are between the ages of 18 and 29, whilst the 30- to 39-year-olds make up 36 percent.

It is common for couples to be first time buyers. In 2022, 67 percent of home purchases with at least one first-time buyer, were made by two people. Though the number of families with and without children living at home is roughly the same for first time buyers.

One third of homes bought by first time buyers in the capital area were smaller than 75 square meters in 2022. This is a significant difference from the rest of the county where most were over 150 square meters. (Jakob Holmgaard, 2024)

This means that if designing for first time buyers in Copenhagen, the user group is young couples aged 18- 39, both with and without kids. To accommodate these, the apartments should be designed with a range of 2-4 rooms.

# Design criteria

## *Tower typology*

*Timber has to be used as primary construction material*

*Concrete central core to house elevator and staircase*

## *Concrete foundation*

*Top floor must be placed at no higher than at 45 meters*

*The building has to visually reflect the lightness of the construction material, both in the facade and inside the units*

*loadbearing elements should be visible within the building*

*Minimum 3 units per floor*

*minimum 300 lux avg. in each unit*

*Units, 60- 120m<sup>2</sup> bruto*

*Square metres prioritized toward the common rooms of the unit*

*Balconies should be half or fully recessed*

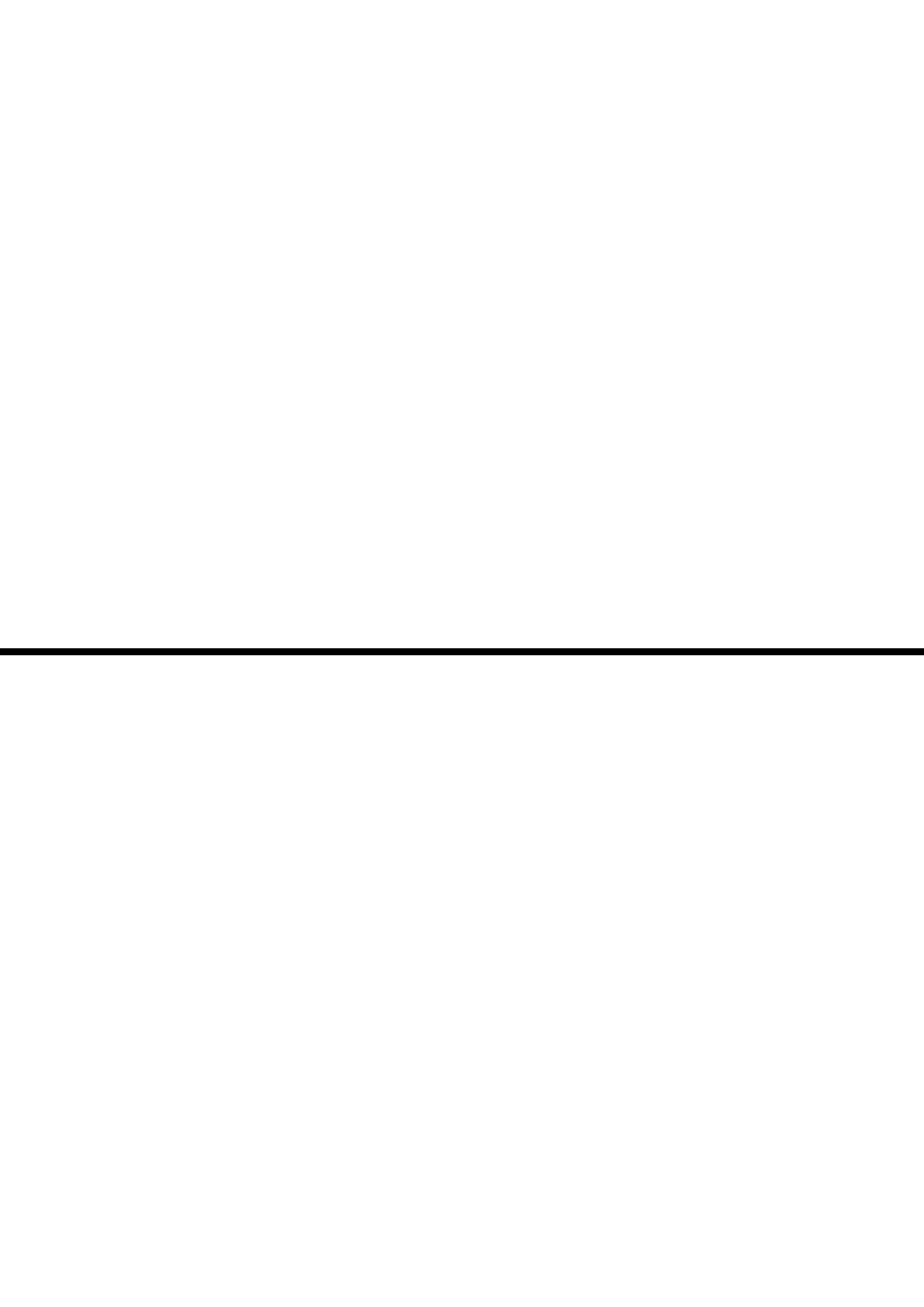


# Problem statement

*How can a timber high-rise residential building in Ørestad, Copenhagen, be designed to provide attractive and spatially efficient housing for first-time buyers while meeting requirements for daylight performance, fire safety, structural stability?*

PROCESS

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# Site location

The site is located on the south-eastern most corner of area II of the local plan. this area provides direct access to the shopping mall as well as easy access to public transportation by foot. the location of the site ensure that the building will not get blocked by future construction in regard to sunlight and views.



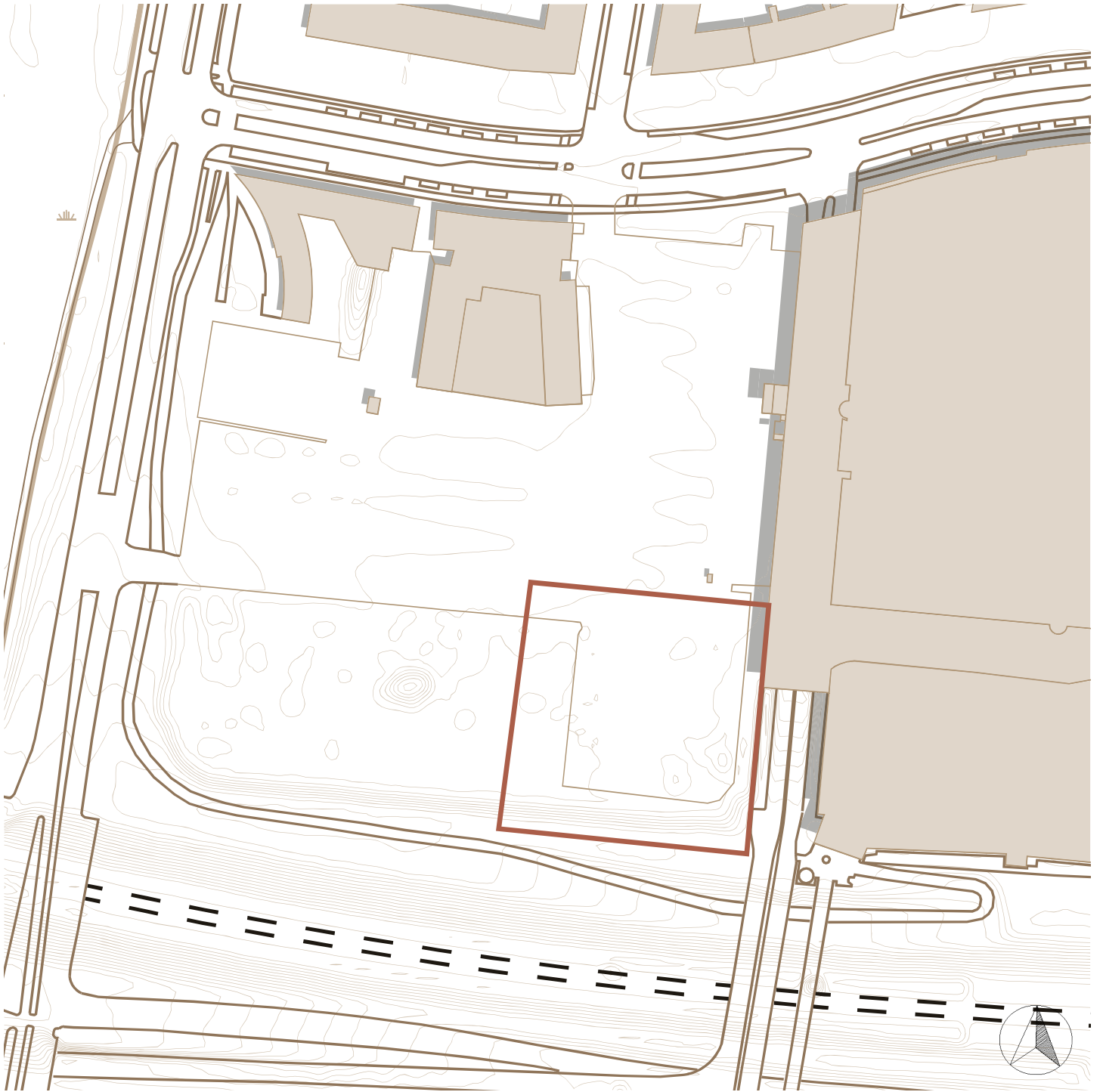
**Illu. 19** Site viewed from south-west



**Illu. 18** Site viewed from west



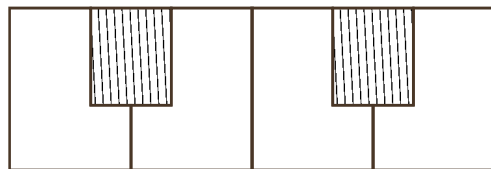
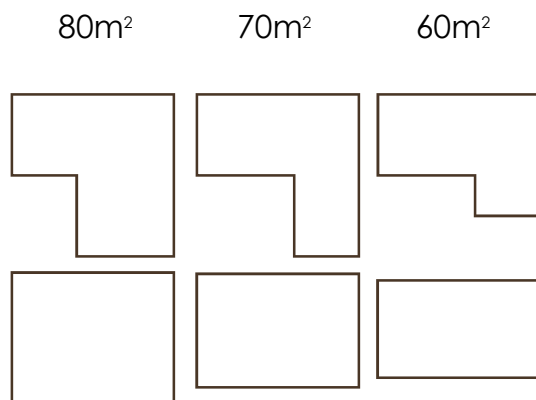
**Illu. 20** Site viewed from the entrance to fields mall north-east of site



III. 21 Building site 1:2000

# Shaping the building

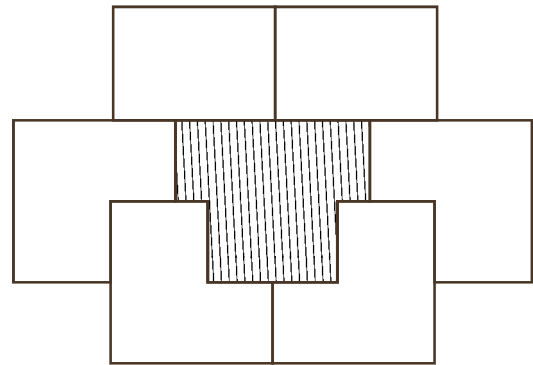
First step of designing an apartment building was to figure out how many units each floor should house. To do this, generic apartment shapes in selected sizes were placed in different formations.



Illu. 22 First building shape

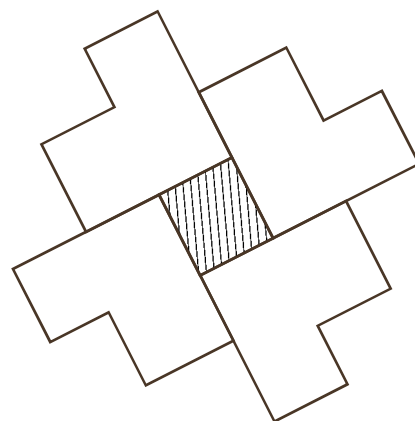
This iteration was deemed inefficient and too small

It was quickly decided that the building should only contain one circulation space with the units surrounding it. This was to minimize the circulations space to unit ratio.

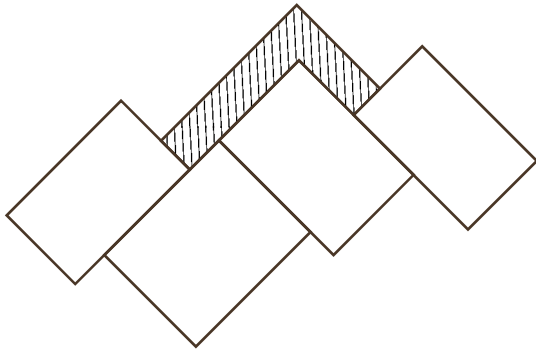


Illu. 23 Maximum number of units

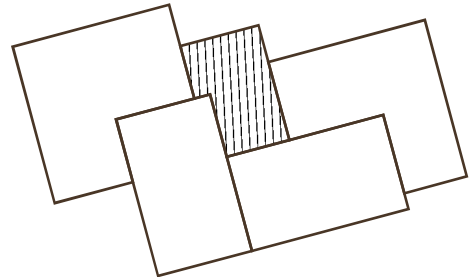
It was found that more than 6 units to a circulation space was unrealistic due to the access to daylight would become too limited or the size of the circulation space would become too large to allow access to all units.



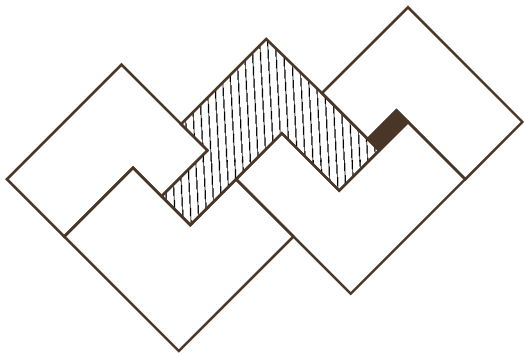
Illu. 24 Shape experiment 1



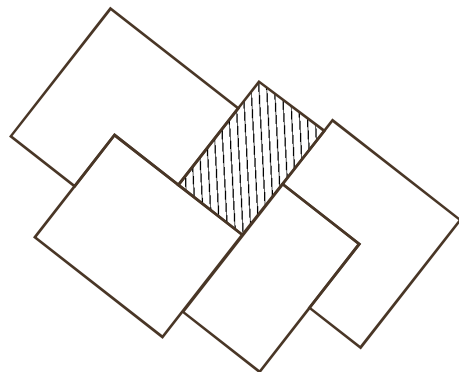
Illu. 25 Shape experiment 2



Illu. 27 Shape experiment 4



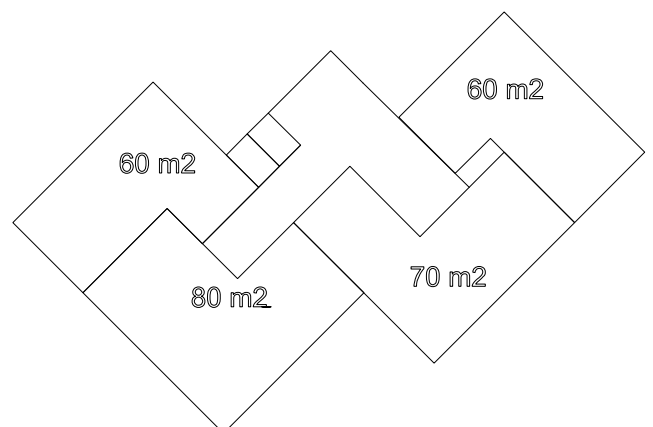
Illu. 26 Shape experiment 3



Illu. 28 Shape experiment 5

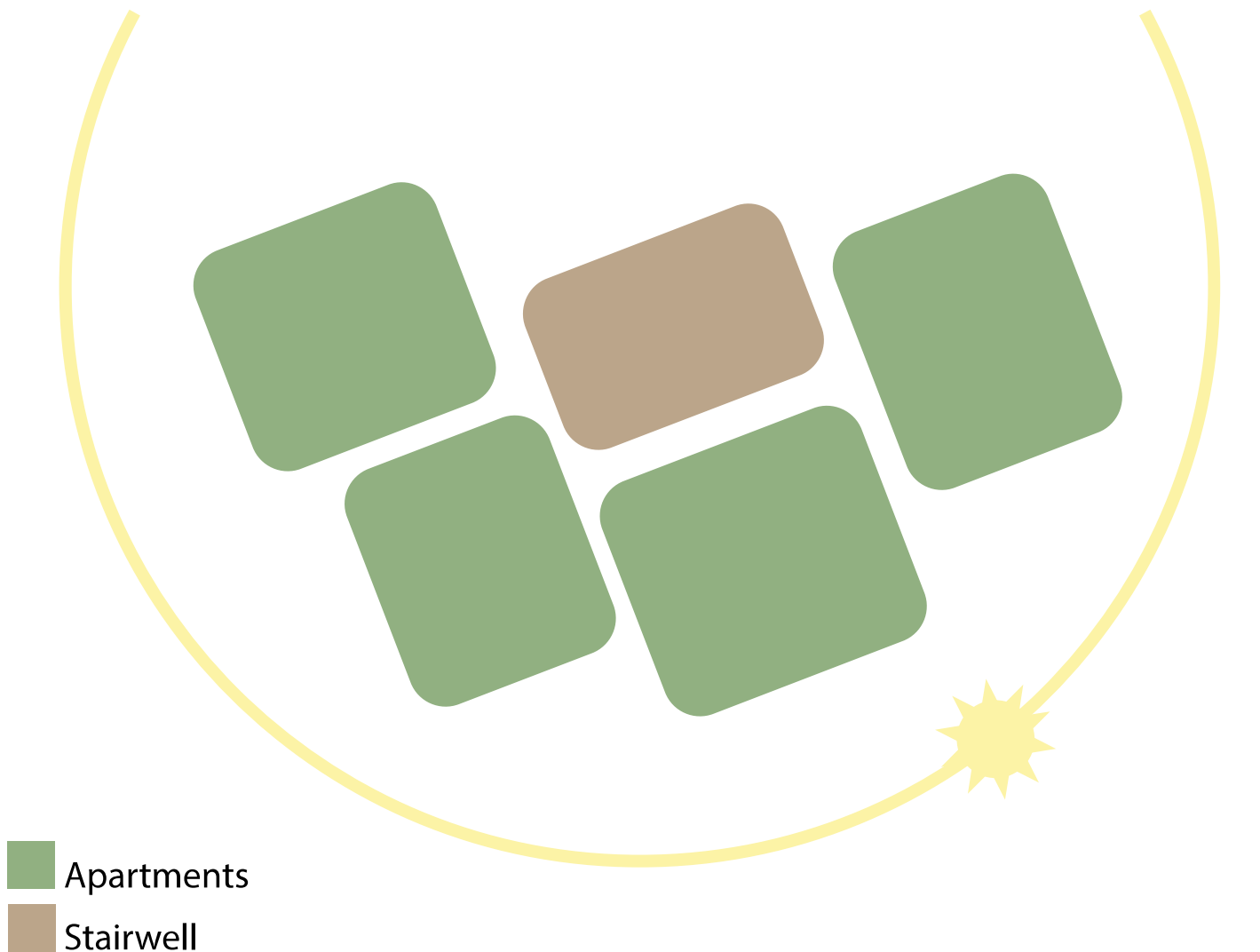
Further exploration and iterations through basic knowledge on the movement of the sun, looking at how it and the shape of the building would impact the experience inside the apartments.

This led to iterations looking at the rotation of the building and its significance on shadows cast by one unit onto the other



Illu. 29 Distribution of unit sizes

# Design concept

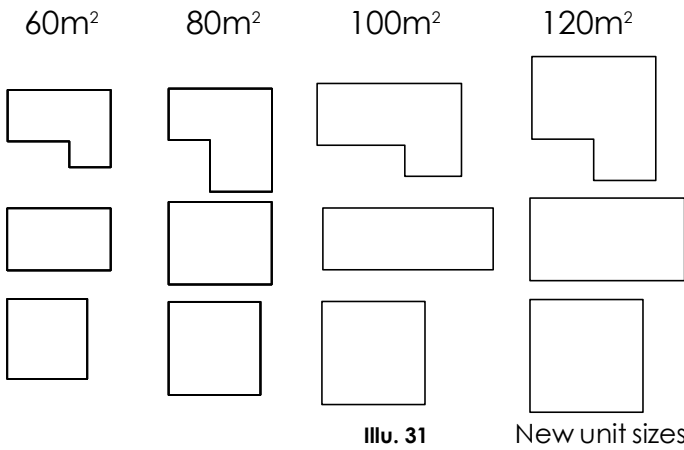


Illu. 30

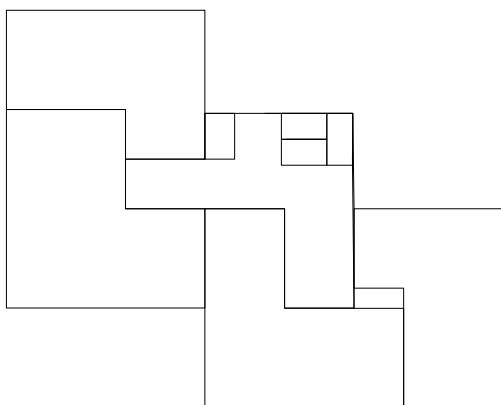
Design concept

No units should be directly or exclusively facing north but face the sun as much as possible while surrounding the circulation space.

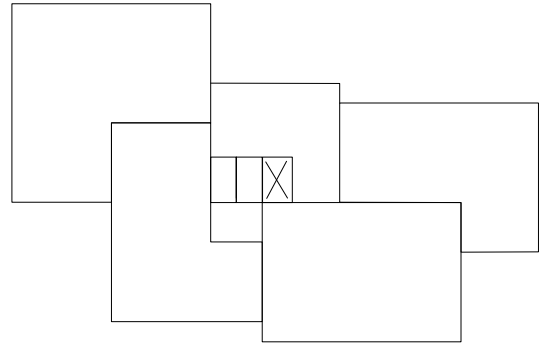
After consideration and further research, it was decided that the variation in unit size should be larger to cater to a larger range of life stages within the user group.



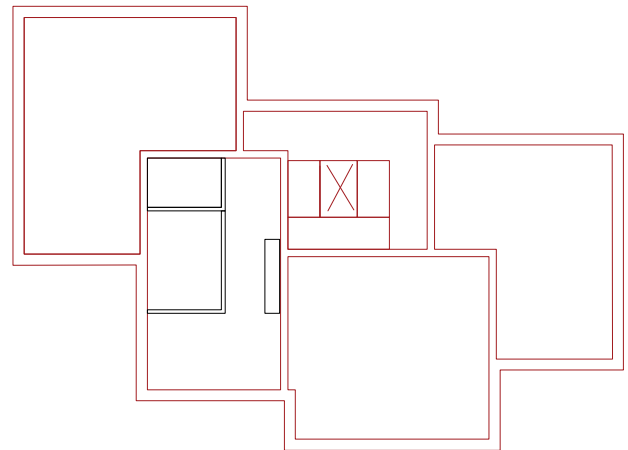
This led to the following iterations, exploring placements of shapes and sizes in reference to each other, prioritizing smaller units and limited the number of big units.



**Illu. 32**      Unit layout iteration 1



**Illu. 33**      Unit layout iteration 2



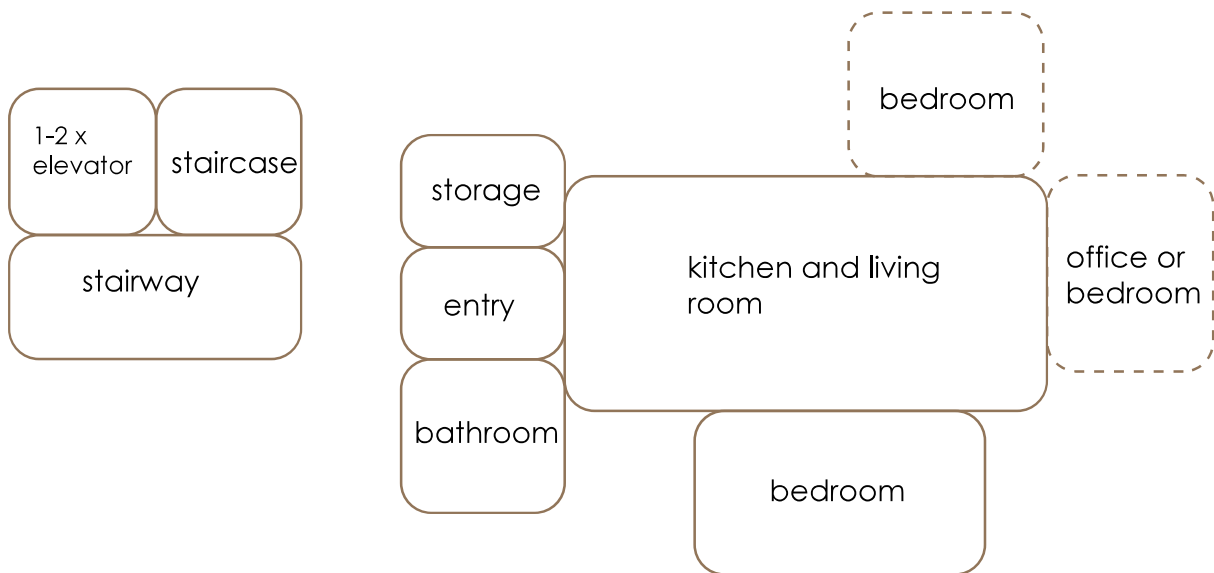
**Illu. 34**      Unit layout iteration 3

# Initial room program

This initial room program was made to guide the further design of the floor plans, the prioritization of square meters within the units and orientation of different rooms.

Area	Room	Size	Lighting	Orientation
Apartment type 1		60 m <sup>2</sup>		
	Entry	4 m <sup>2</sup>	Artificial	N/A
	Livingroom	20 m <sup>2</sup>	Daylight	South or west
	Kitchen	15 m <sup>2</sup>	Artificial	N/A
	Bathroom	4 m <sup>2</sup>	Artificial	N/A
	Storage	2 m <sup>2</sup>	Artificial	N/A
	Bedroom	15 m <sup>2</sup>	Daylight	North or East
		<b>60 m<sup>2</sup></b>		
Apartment type 2		70 m <sup>2</sup>		
	Entry	4 m <sup>2</sup>	Artificial	N/A
	Livingroom	20 m <sup>2</sup>	Daylight	South or west
	Kitchen	15 m <sup>2</sup>	Artificial	N/A
	Bathroom	4 m <sup>2</sup>	Artificial	N/A
	Storage	2 m <sup>2</sup>	Artificial	N/A
	Bedroom	15 m <sup>2</sup>	Daylight	North or East
	Bedroom/office	10 m <sup>2</sup>	Daylight	North or East
		<b>70 m<sup>2</sup></b>		
Apartment type 3		80 m <sup>2</sup>		
	Entry	4 m <sup>2</sup>	Artificial	N/A
	Livingroom	20 m <sup>2</sup>	Daylight	South or west
	Kitchen	15 m <sup>2</sup>	Artificial	N/A
	Bathroom	4 m <sup>2</sup>	Artificial	N/A
	Storage	2 m <sup>2</sup>	Artificial	N/A
	Bedroom	15 m <sup>2</sup>	Daylight	North or East
	Bedroom/office	10 m <sup>2</sup>	Daylight	North or East
	Bedroom/office	10 m <sup>2</sup>	Daylight	North or East
		<b>80 m<sup>2</sup></b>		

Area	Room	Size	Lighting	Orientation
Entry, residential				N/A
	Entry		N/A	
Entry, commercial				N/A
	Entry		N/A	
Stairway				N/A
	Elevator		N/A	
	Staircase Platau		Artificial Artificial	

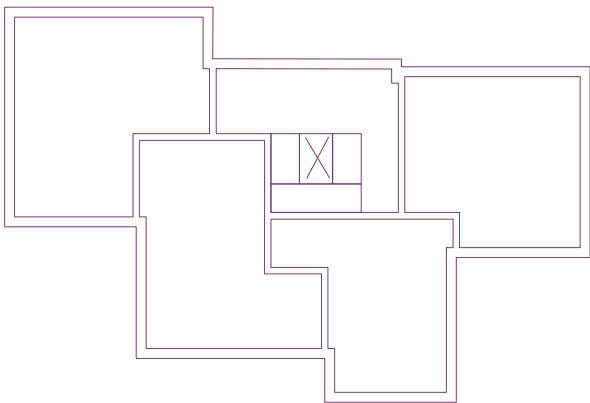


only in selected units

**Illu. 35** Room diagram

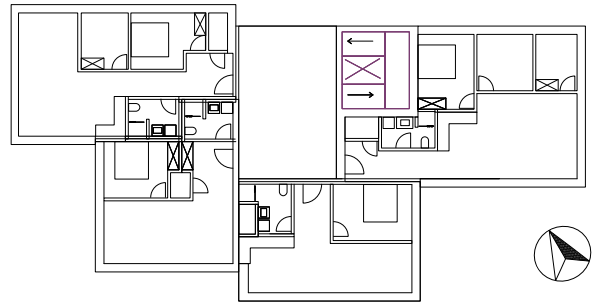
# Designing the floor plan

After achieving an acceptable footprint, the work on the floor plan commenced. Using the initial room program as a guide, each unit was planned whilst trying to optimize the usage of the space available.



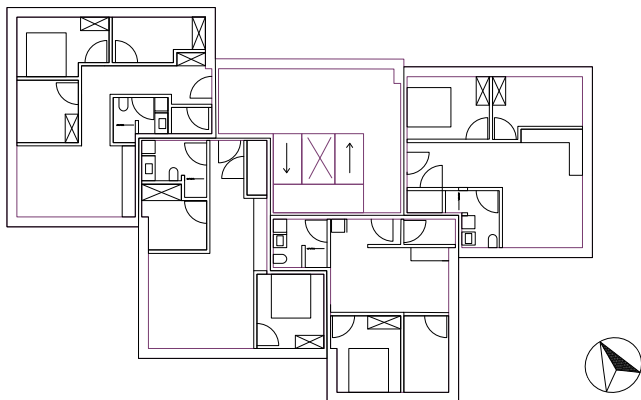
**Illu. 36** Floor plan 1st iteration

The first iteration of the floor plan had some difficulties with allowing proper window access to all rooms requiring it whilst keeping the rooms in the orientation. Furthermore, too much space was wasted on hallways.



**Illu. 37** Floor plan 2nd iteration

To solve some of the issues in the first iteration, the size requirements were loosened to allow for adjustments to be made with a stronger focus on the optimal layout, though this iteration still had some issues with excessive hallway space.



**Illu. 38** Floor plan 3rd iteration

in almost all previous iterations, the stairwell designated to be in concrete for stability and fire safety, was placed in the middle of the building as this is traditionally how it is done. by moving the stairwell to one side, a central room leading to all units in a way that allows for interaction between tenants became possible.



**Illu. 39** Floor plan 4th iteration

When a satisfying floor plan was found, the idea of creating larger units of approximately 120 m<sup>2</sup> was explored through combining two 60m<sup>2</sup> units laterally. This allowed for a few bigger units within the building without having to alter the building envelope. The solution of combining units laterally was found to be unbeneficial due to the large amount of space need to be allocated to circulation space. Instead, a horizontal merging of units was proposed eliminating the need for internal stair within the units. This solution is seen in the final floor plan.

# Balconies



Illu. 40 Balcony floor plan iterations

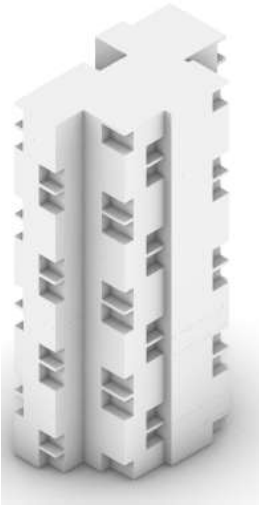
The design of the balconies started on a floor plan level.

Iterations exploring the location and number of balconies in each unit were made along with adjusting the existing floor plan to allow for one balcony location to work with different unit layout.

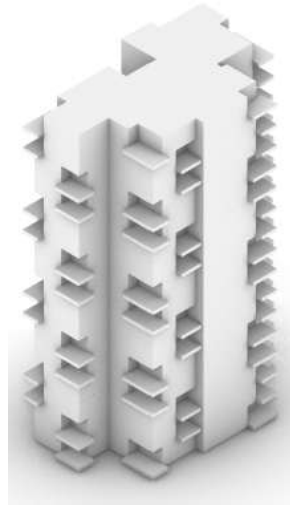


Illu. 41 Recession of balconies

After deciding on the placement of the balconies, iterations exploring the effect of recessing the balconies and the effect that has on the sunlight availability were created. Along with these, closing off the sides of the balconies to block wind was considered but it was found to block too much of the sunlight limiting the usable hours of the space.



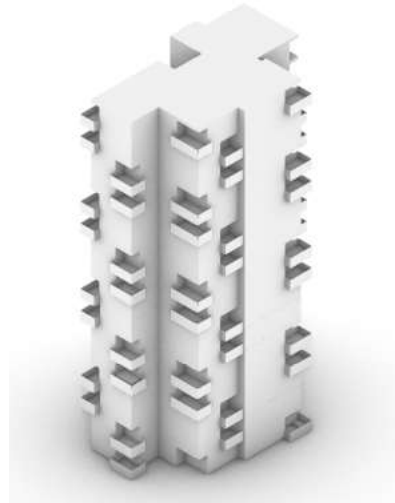
**Illu. 44** Fully recessed balconies



**Illu. 45** Half recessed balconies



**Illu. 42** Fully recessed balconies with walls closing off the sides.



**Illu. 43** Half recessed balconies with railing

# Column placement

The design of the static system is crucial for any construction, but maybe even more impactful when designing a high rise. There are many factors to take into account and designing it in timber only add to the task as not many pre-accepted solutions exist.

To make that task feasible withing the scope of the project, the calculation is performed on a representative cross section of the static system.

The design of the static system is based on the case studies of Mjøstårnet and TRÆ, referencing the layout, material choice and dimensions of the static system of the those buildings.

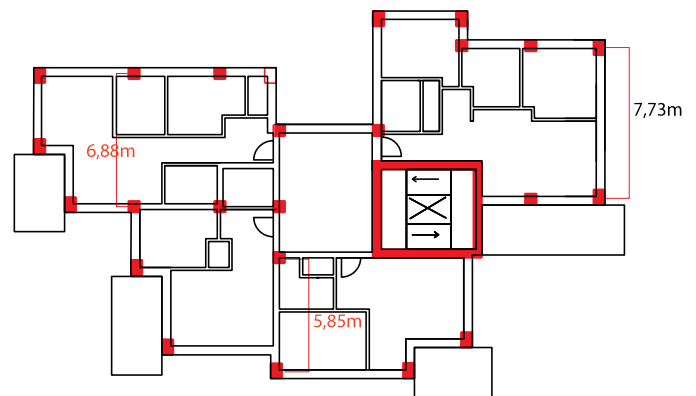
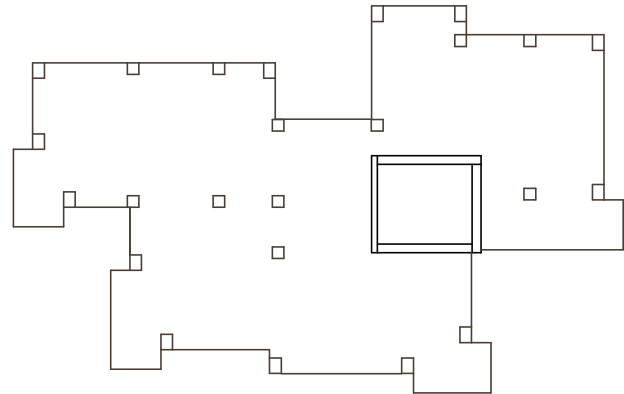
like TRÆ, this building includes a concrete "core" housing the stairway and elevator, proving stability and establishing a fire escape route in one.

The columns has, like Mjøstårnet, been designed with larger GLT columns at the corners of the building with smaller GLT columns in between.

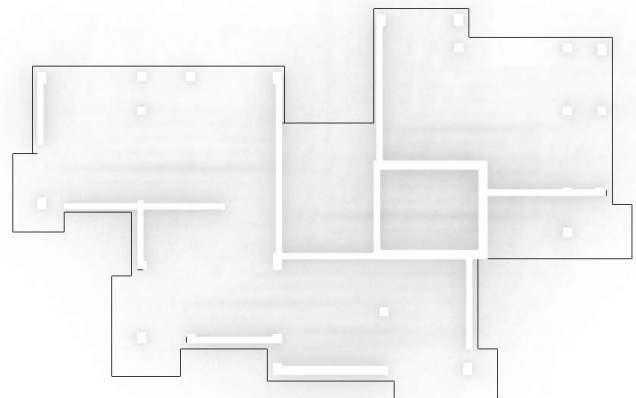
Loadbearing CLT walls has been added the provide resistance to horizontal forces.

The benefit of CLT is that openings for windows and doors can be cut into the wall without compromising the loadbearing capabilities as mush at they would in other more traditional building methods.

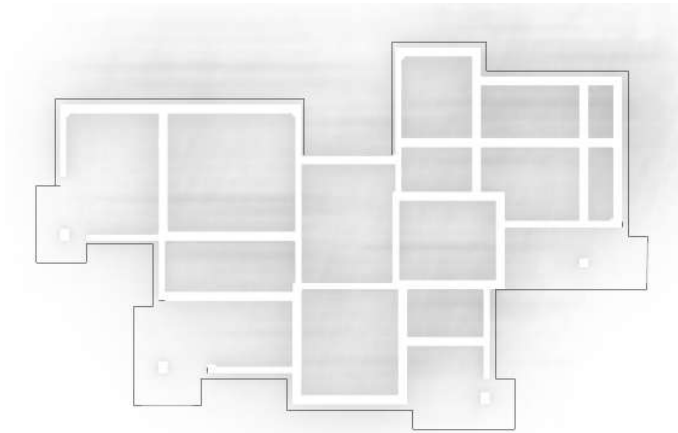
The floors are CLT slabs, these helps distribute forces through the building and like the walls, brace against horizontal forces.



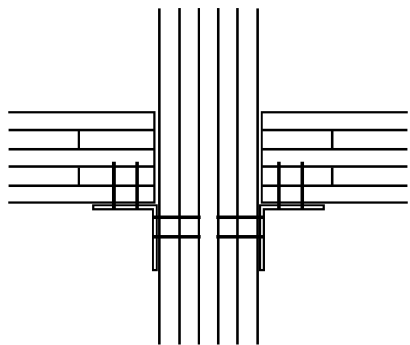
Illu. 47 Placement of Walls and columns  
Illu. 48



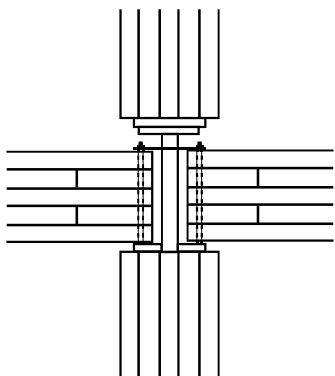
Illu. 46 Placement of Walls and columns



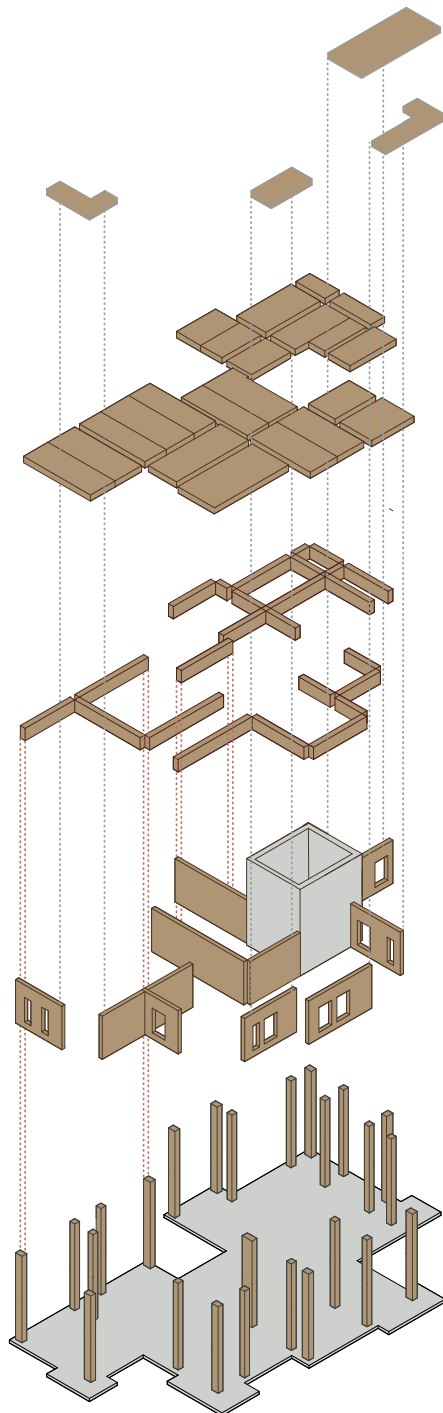
**Illu. 49** Beam placement



**Illu. 51** Joint between columns and beams and walls and beams



**Illu. 52** Joint between columns between floors

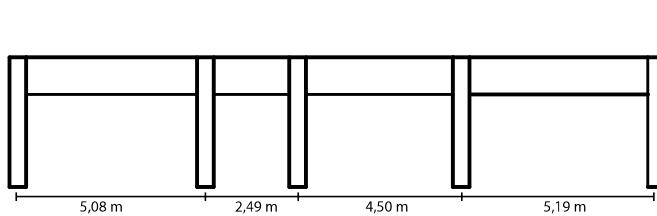


**Illu. 50** Exploded axonometri 1:500

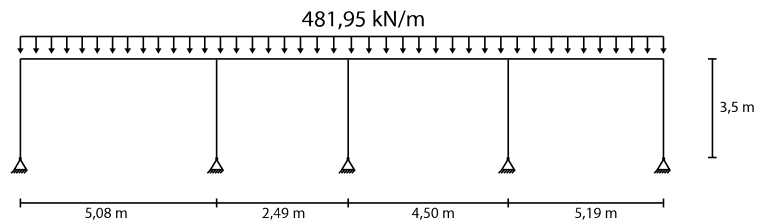
# Dimensioning the columns

Glulam(GLT) GL30	13 floors
Design line load $q_d$	$31,85 \text{ kN/m} \times 15 \text{ floors}$ $477,75 \text{ kN/m} + 4,20 \text{ kN/m}$ $481,95 \text{ kN/m}$
Self-weight	5,2740
Imposed load	978
Snow load	0,19
$k_{mod}$	0,8
$\lambda_M$	1,25
$f_{c,0,k}$	24,0 MPa

These calculations were made without considering the additional material added for fire resistance though this can also be achieved by treating the timber instead of adding material.



Illu. 53 Selected representative cross section of the static system



Illu. 54 Loads and dimensions

Column	A	B	C	D	E
Section (mm)	600 x 450	450 x 450	450 x 450	600 x 450	11720 x 450
Area (m <sup>2</sup> )	0,2700	0,2025	0,2025	0,2700	5,2740
Design load $N_{Ed}$ (kN)	870	2059	952	2459	855
Comprehensive stress $\sigma_{c,0,d}$	3,22	10,17	4,70	9,11	0,162
Buckling					
Buckling factor $k_c$	1,0	1,0	1,0	1,0	1,0
Effective compressive strength $k_c f_{c,0,d}$	15,36	15,36	15,36	15,36	15,36
Utilisation $\eta$	21%	66%	31%	59%	1%

# Calculation of critical column

## Column B

Comprehensive stress  $\sigma_{c,0,d}$

$$A = 0,45 * 0,45 = 0,2250\text{m}^2$$
$$\sigma_{c,0,d} = N_{Ed} / A$$
$$\sigma_{c,0,d} = 2059 / 0,2025 = 10,17\text{x MPa}$$

Utilisation including buckling  $\eta$

$$\eta = \sigma_{c,0,d} / (k_c f_{c,0,d})$$
$$\eta = 10,17 / 15,36 = 0,662 = 66,2\%$$

Buckling

$$L_{cr} = 0,5 * L$$
$$L_{cr} = 0,5 * 3,5 = 1,75\text{m} = 1750\text{mm}$$

Radius of gyration

$$i = 450 / \sqrt{12} = 129,9\text{mm}$$

Slenderness

$$\lambda = 1750 / 129,9 = 13,47$$

Relative slenderness

$$\lambda_{rel} = (13,47 / \pi) \sqrt{(24 / 9600)} = 0,214$$

Buckling factor  $k_c$

$$\text{For } \lambda \leq 0,30 \rightarrow k_c = 1,0$$
$$\text{For } 0,30 > \lambda \leq 0,30 \rightarrow k_c = 1,0$$
$$\text{For } \lambda < 1,0 \rightarrow k_c = 1 / (k_c + \lambda^2)$$
$$\text{where } k = 1,0 \quad k_c = 1 / (1,70^2) = 1,0$$

Effective compressive strength  $k_c f_{c,0,d}$

$$k_c f_{c,0,d} = 1,0 * 15,36 = 15,36\text{MPa}$$
$$f_{c,0,d} = (k_{mod} * f_{c,0,k}) / \lambda_M = (0,8 * 24,0) / 1,25 = 15,36$$

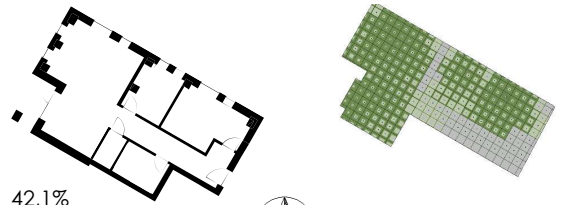
# Windows

The placement of the windows was determined through the design of the floorplan.

The windows are design to let in plenty of daylight while framing the view from the inside of the apartments.

The large fenestrations allows for plenty of sunlight to enter the building resulting in all of the units achieving an average on at least 300 lux within the units.

Unit B2



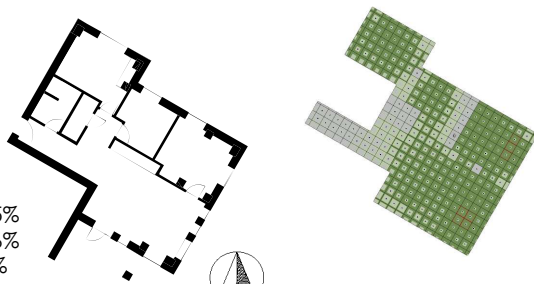
avg UDla 42,1%  
 sDA<sub>300/50%</sub> 53,1%  
 ASE<sub>1000,250</sub> 0,0%  
 avg lux 300

Illu. 57



Daylight analysis unit B2

Unit A2



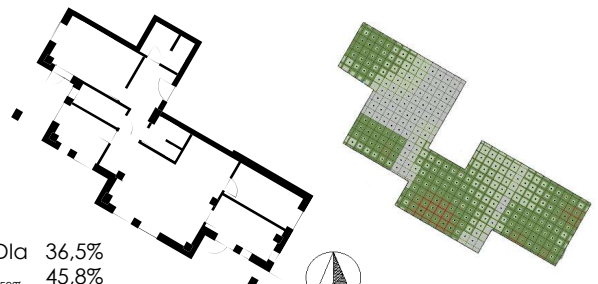
avg UDla 45,5%  
 sDA<sub>300/50%</sub> 61,6%  
 ASE<sub>1000,250</sub> 3,9%  
 avg lux 630

Illu. 55



Daylight analysis unit A2

Unit C2

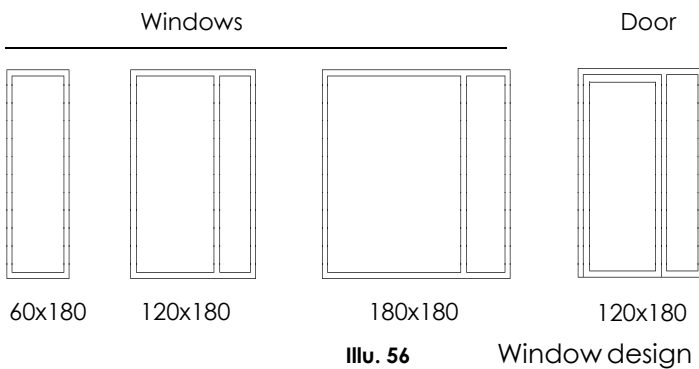


avg UDla 36,5%  
 sDA<sub>300/50%</sub> 45,8%  
 ASE<sub>1000,250</sub> 10,5%  
 avg lux 714

Illu. 58



Daylight analysis unit C2

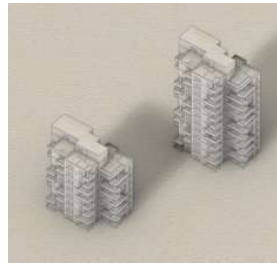


# Building placement

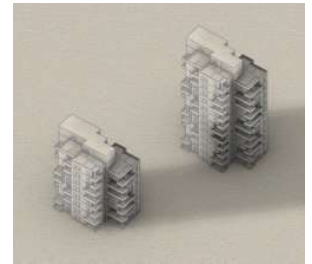
It was decided that two buildings would be placed on site to better utilize the space and improve the relation the surrounding buildings and landscape. these building are to be connected by a subterranean parking garage on the ground floor. The second building was reduced in height and place south-west of the first.

To ensure that the previous efforts to optimize daylight access within the building was not squandered, a sun analysis was performed to look at the shadows cast by the second building onto the first. The placement of the second building was a balancing act of not placing the buildings so close together that the second building would cast large shadows onto the first and the building not being so far apart that they would become visually disconnected from each other.

The final building placement was found to not be casing shadows onto the first except for a limited number of hours in darker months of the year.



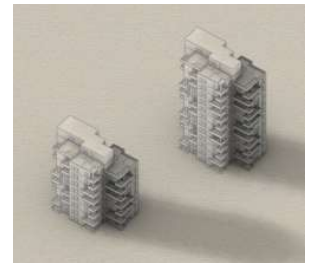
Illu. 59 21/3 15:00



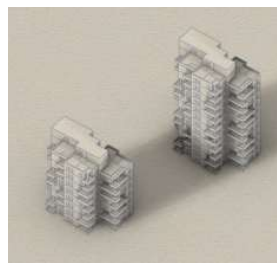
Illu. 60 21/3 18:00



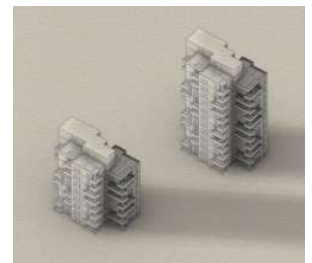
Illu. 64 21/6 15:00



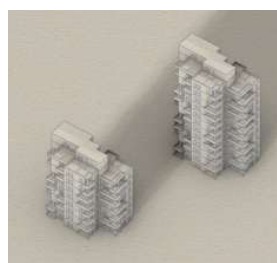
Illu. 66 21/6 18:00



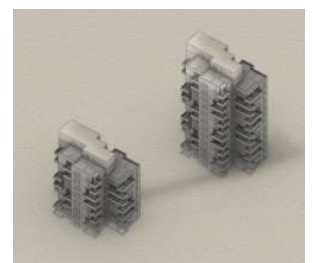
Illu. 63 21/9 15:00



Illu. 65 21/9 18:00

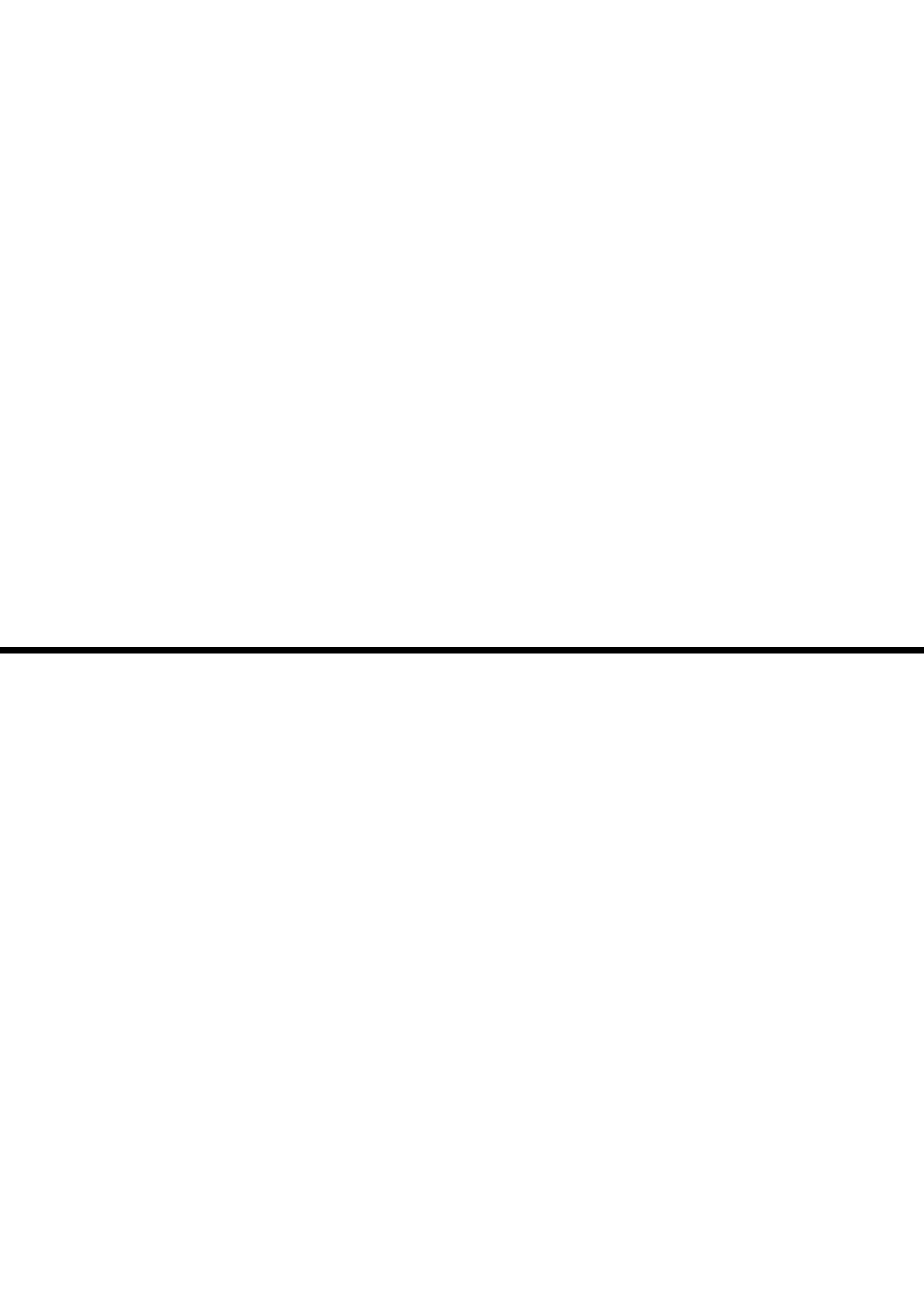


Illu. 61 21/12 15:00



Illu. 62 21/12 18:00

PRESENTATION

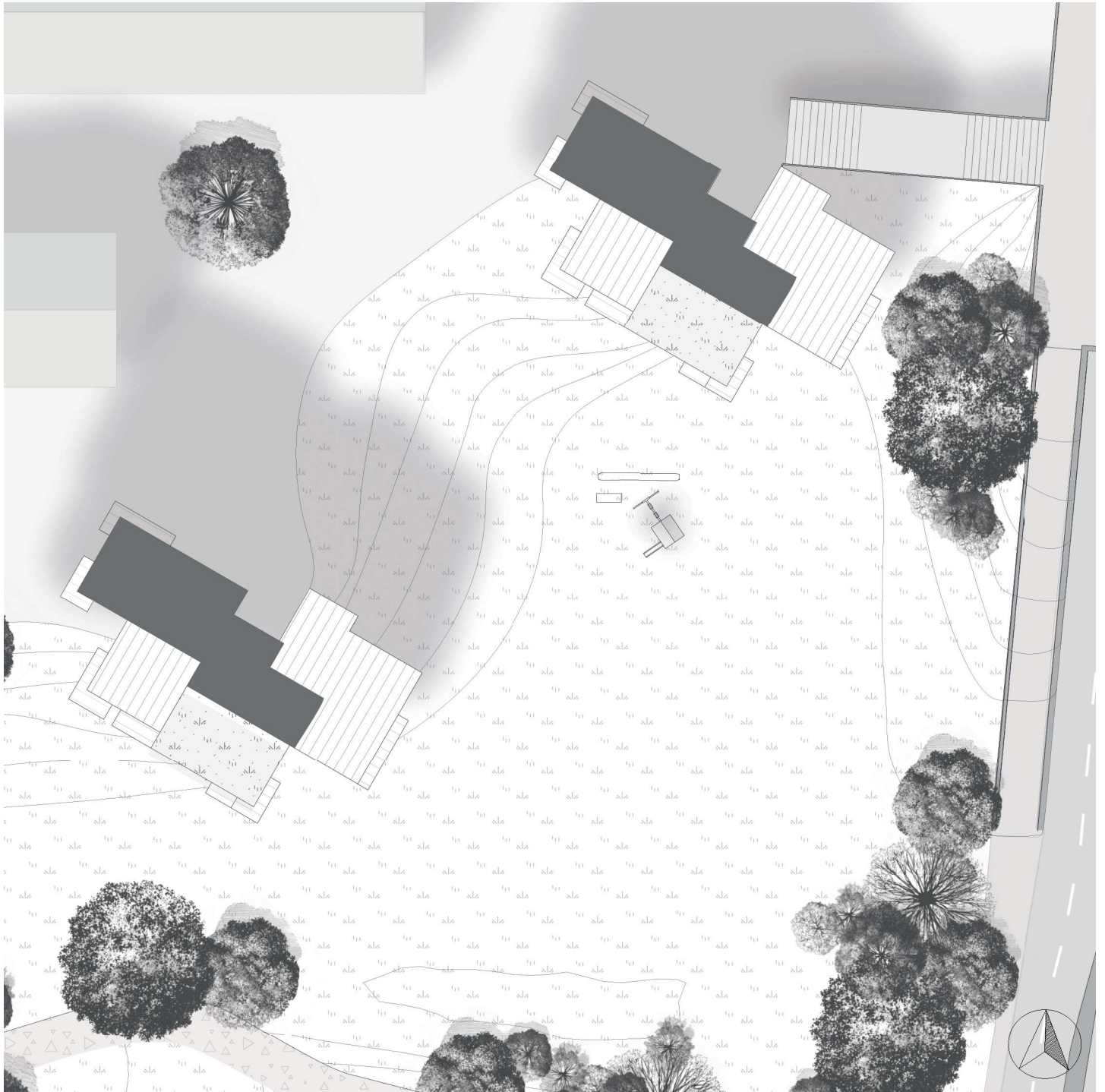




Illu. 67 Outside rendering from south

# Master plan

1:500

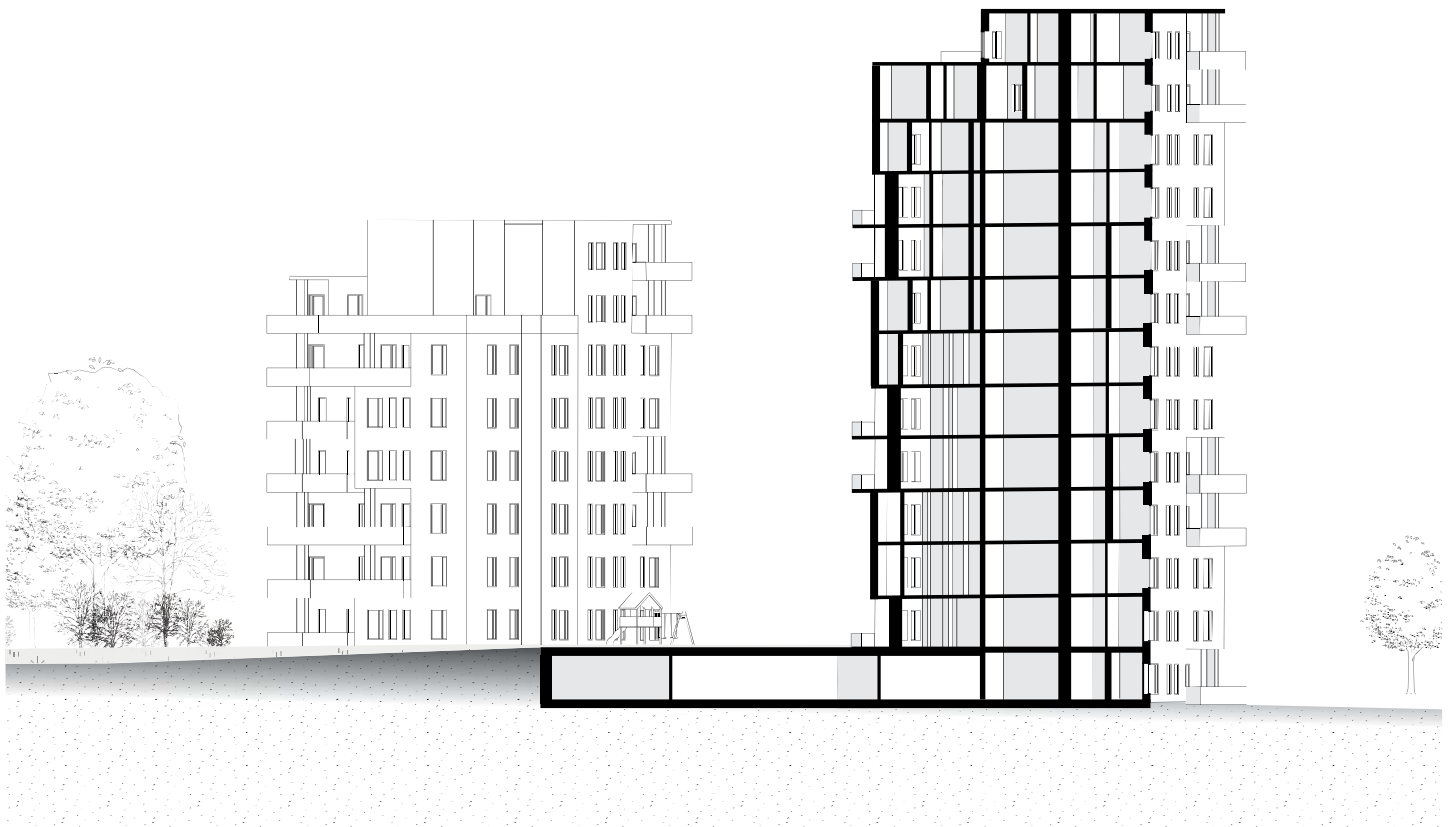
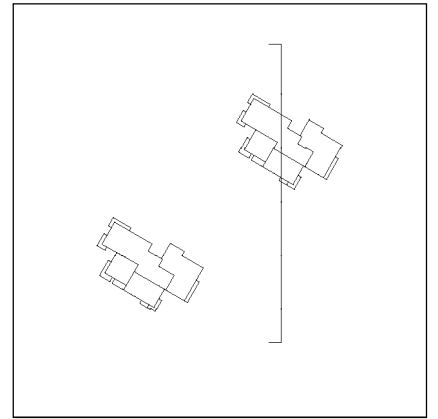


Illu. 68

Masterplan 1:500

# Cross section AA

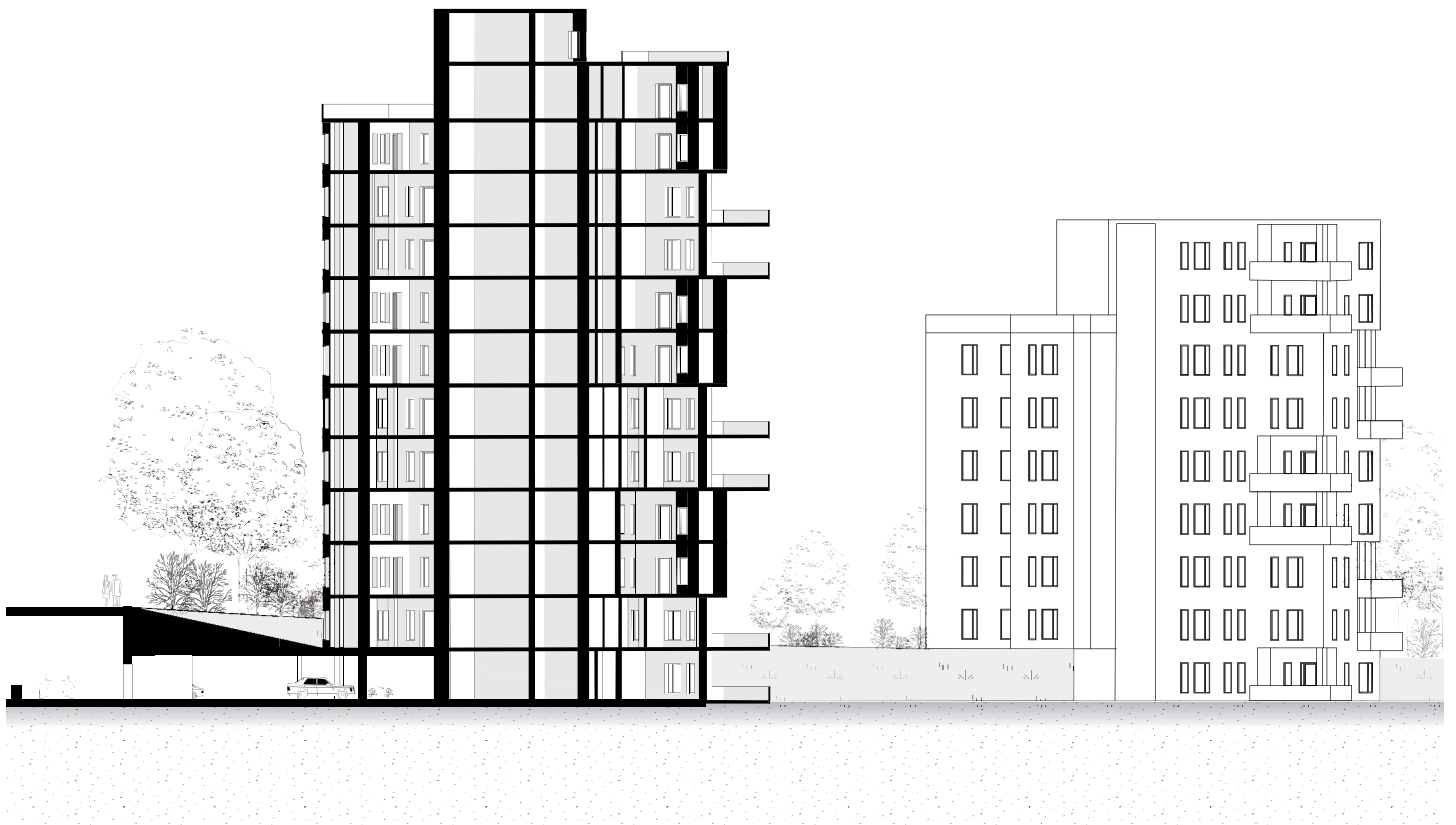
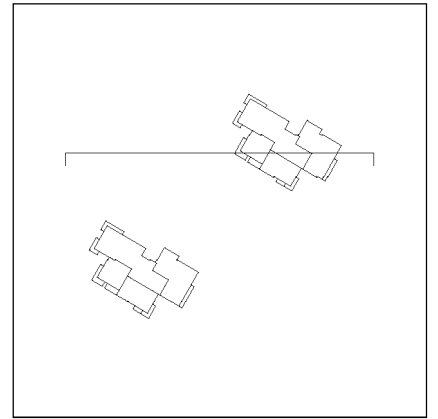
1:500



Illu. 69 Cross section AA 1:500

# Cross section BB

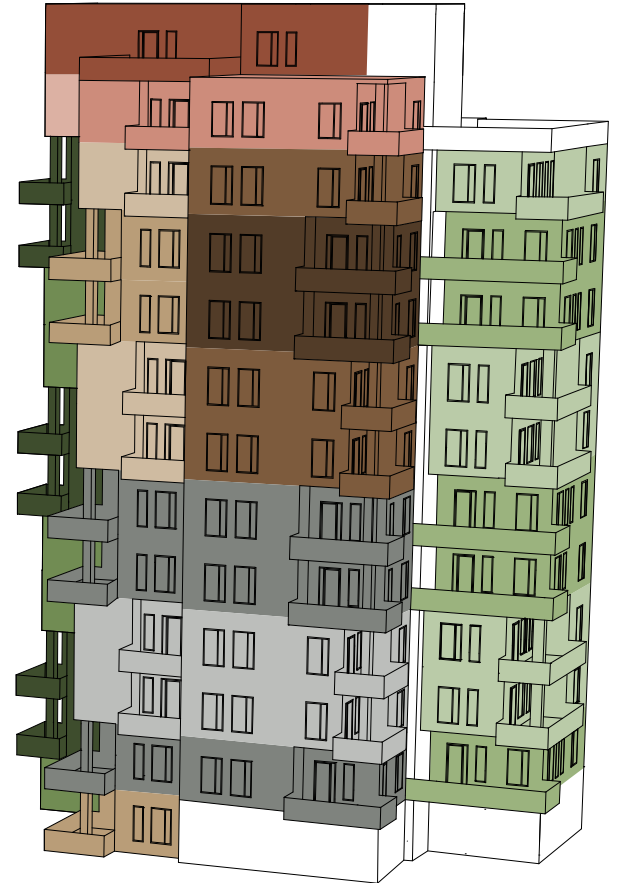
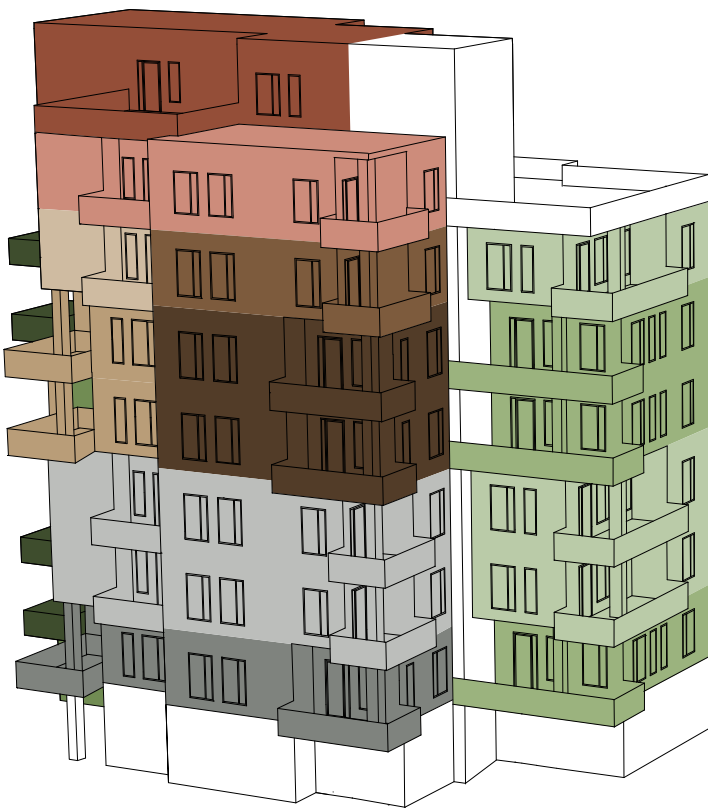
1:500



Illu. 70 Cross section BB 1:500

# Unit placement overview

1:500



Illu. 71

Unit placement overview

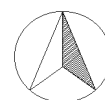
- Unit A1
- Unit A2
- Unit B1
- Unit B2

- Unit C1
- Unit C2
- Unit D1
- Unit D2

- Unit E1
- Unit E2
- Unit F
- Unit G
- Unit P

# Plan - 3rd floor

1:200



Illu. 72

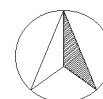
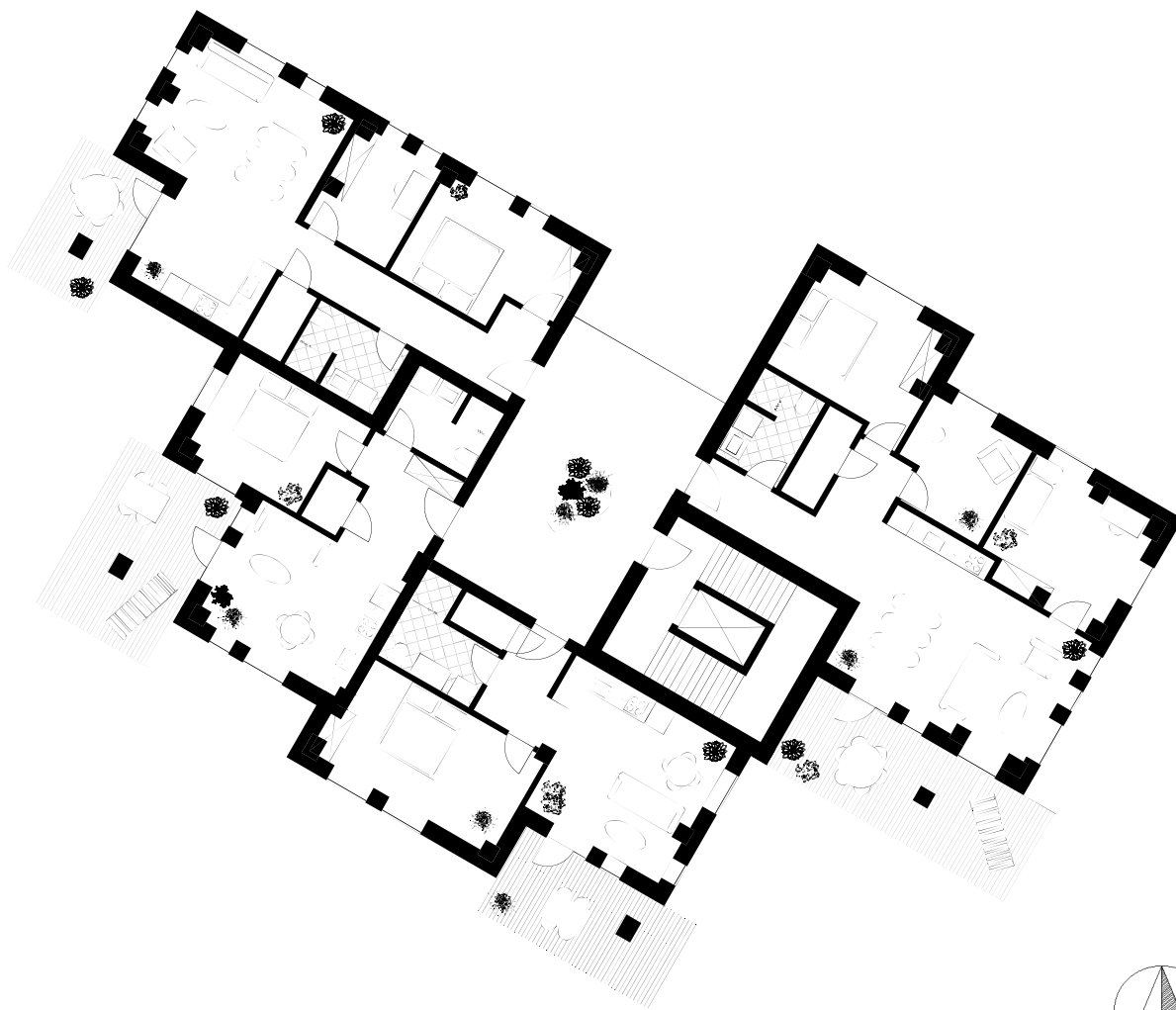
Plan - 3rd floor 1:200



Illu. 73      Rendering inside unit A2

# Plan - 9th floor

1:200



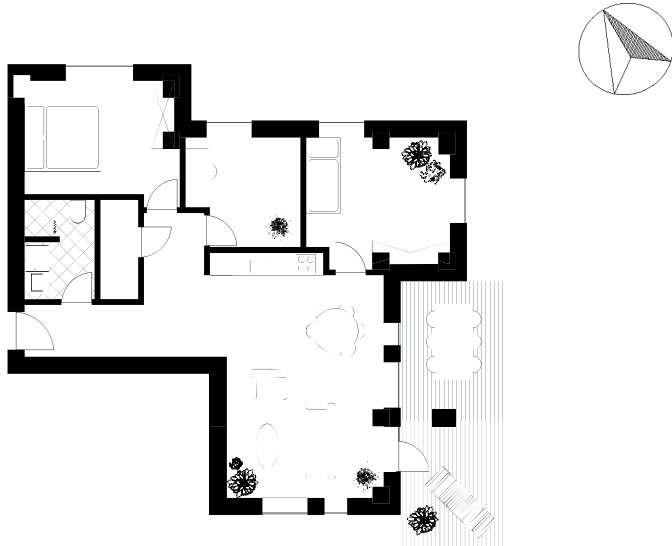
Illu. 74

Plan - 9th floor 1:200

# Unit floor plans

## Unit A1

99m<sup>2</sup>, 3 Bedrooms, 1 Bathroom



Illu. 75 Plan unit A1 1:200

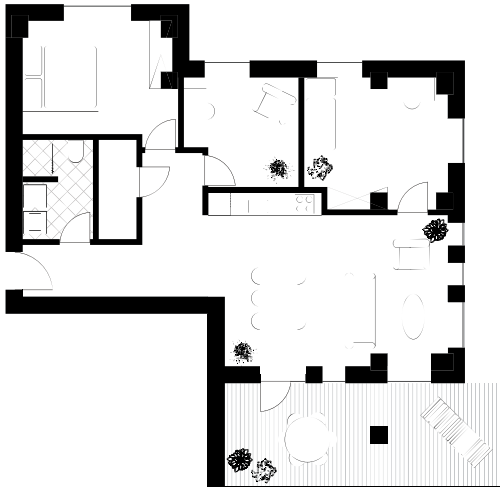
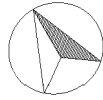


Illu. 76 Plan location indicator unit A1

Room	Size	Lighting	Orientation
Living area	37,5 m <sup>2</sup>	Daylight	South
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	2,5 m <sup>2</sup>	Artificial	N/A
Bedroom	13 m <sup>2</sup>	Daylight	North - east
Bedroom	12,5 m <sup>2</sup>	Daylight	North - east
Bedroom	8 m <sup>2</sup>	Daylight	East
	<b>78,5 m<sup>2</sup></b>		
Balcony	19 m <sup>2</sup>	Daylight	South - west

# Unit A2

98 m<sup>2</sup>, 3 Bedrooms, 1 Bathroom



Illu. 77 Plan unit A2 1:200

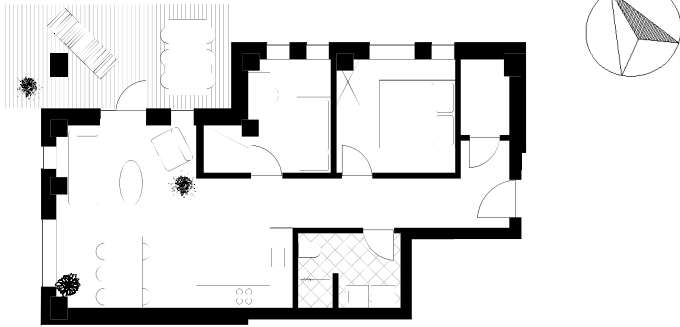


Illu. 78 Plan location indicator unit A2

Room	Size	Lighting	Orientation
Living area	36,5 m <sup>2</sup>	Daylight	South
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	2,5 m <sup>2</sup>	Artificial	N/A
Bedroom	13 m <sup>2</sup>	Daylight	North - east
Bedroom	12,5 m <sup>2</sup>	Daylight	North - east
Bedroom	8 m <sup>2</sup>	Daylight	East
	<b>77,5 m<sup>2</sup></b>		
Balcony	20 m <sup>2</sup>	Daylight	South - west

# Unit B1

77m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



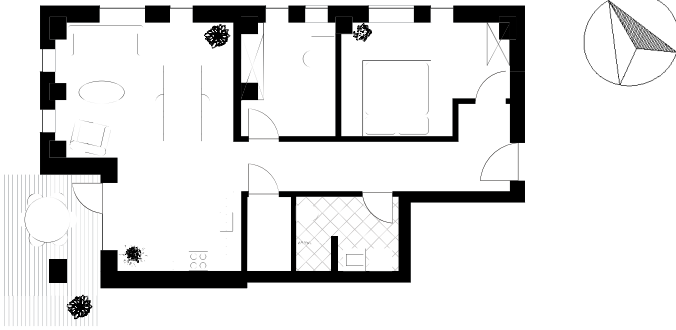
Illu. 80 Plan location indicator unit B1

Illu. 79 Plan unit B1 1:200

Room	Size	Lighting	Orientation
Living area	35,5 m <sup>2</sup>	Daylight	West
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	2,5 m <sup>2</sup>	Artificial	N/A
Bedroom	9,5 m <sup>2</sup>	Daylight	North
Bedroom/office	8 m <sup>2</sup>	Daylight	North
	<b>60,5 m<sup>2</sup></b>		
Balcony	16,5 m <sup>2</sup>	Daylight	North

# Unit B2

80 m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



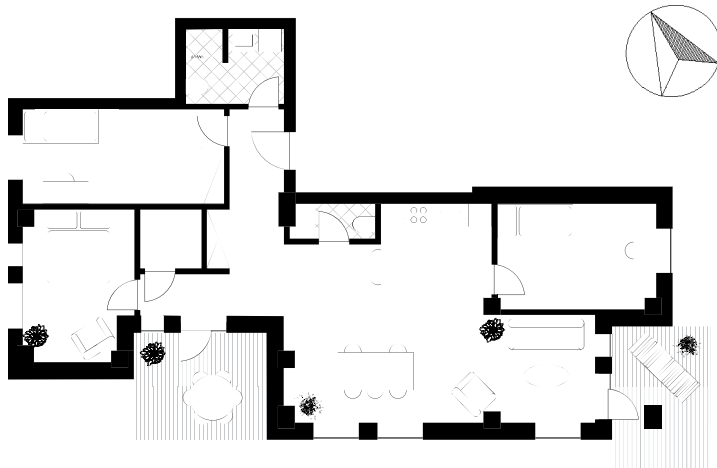
**Illu. 82** Plan location indicator unit B2

**Illu. 81** Plan unit B2 1:200

Room	Size	Lighting	Orientation
Living area	37 m <sup>2</sup>	Daylight	North - west
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	2 m <sup>2</sup>	Artificial	N/A
Bedroom	11,5 m <sup>2</sup>	Daylight	North
Bedroom/office	7,5 m <sup>2</sup>	Daylight	North
	<b>63 m<sup>2</sup></b>		
Balcony	10,5 m <sup>2</sup>	Daylight	West

# Unit C1

117m<sup>2</sup>, 3 Bedrooms, 1 Bathroom



Illu. 83 Plan unit C1 1:200

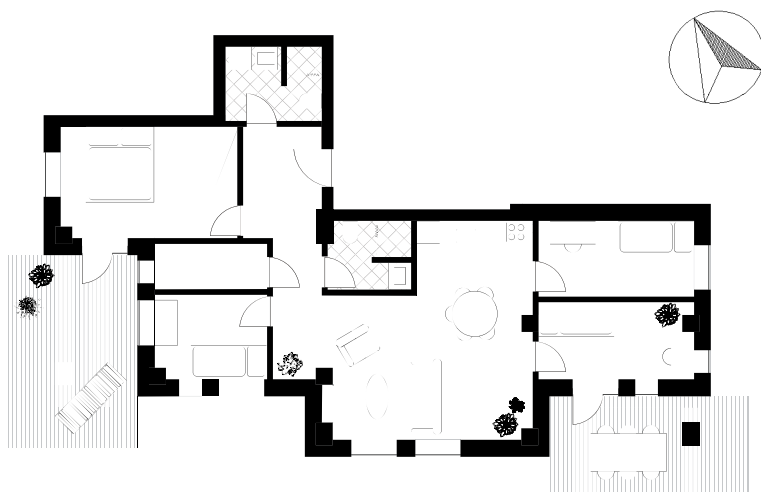


Illu. 84 Plan location indicator unit C1

Room	Size	Lighting	Orientation
Living area	47 m <sup>2</sup>	Daylight	South - west
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Bathroom	2 m <sup>2</sup>	Artificial	N/A
Storage	4 m <sup>2</sup>	Artificial	N/A
Bedroom	12,5 m <sup>2</sup>	Daylight	North - west
Bedroom	11,5 m <sup>2</sup>	Daylight	North - west
Bedroom	11,5 m <sup>2</sup>	Daylight	South - east
	<b>93,5 m<sup>2</sup></b>		
Balcony	10 m <sup>2</sup>	Daylight	South - west
Balcony	10,5 m <sup>2</sup>	Daylight	South

# Unit C2

110m<sup>2</sup>, 3 Bedrooms, 1 Bathroom



Illu. 85 Plan unit C2 1:200



Illu. 86 Plan location indicator unit C2

Room	Size	Lighting	Orientation
Living area	38 m <sup>2</sup>	Daylight	South or west
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Bathroom	4 m <sup>2</sup>	Artificial	N/A
Storage	3 m <sup>2</sup>	Artificial	N/A
Bedroom	14,5 m <sup>2</sup>	Daylight	North - west
Bedroom	8 m <sup>2</sup>	Daylight	South - east
Bedroom	8 m <sup>2</sup>	Daylight	South - east
Bedroom	6,5 m <sup>2</sup>	Daylight	West
	<b>87 m<sup>2</sup></b>		
Balcony	17,5 m <sup>2</sup>	Daylight	West
Balcony	13,5 m <sup>2</sup>	Daylight	South



Illu. 87 Rendering inside unit B2

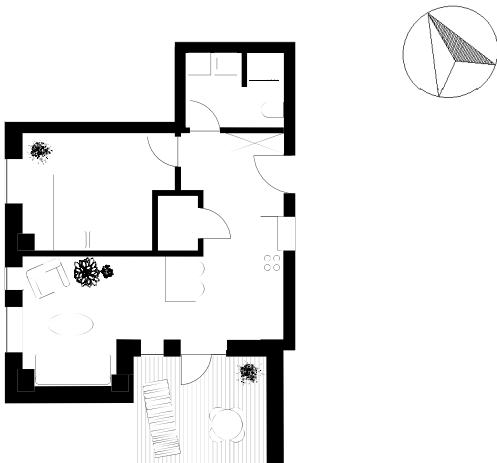


illu. 88

Rendering inside unit A2, bedroom

# Unit D1

56m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



Illu. 89 Plan unit D1 1:200

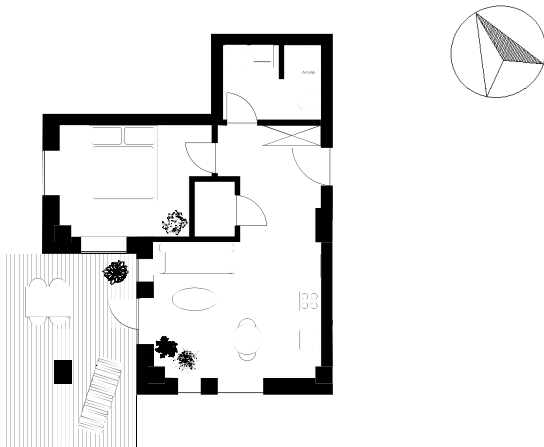
Room	Size	Lighting	Orientation
Living area	26 m <sup>2</sup>	Daylight	South - west
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	1,5 m <sup>2</sup>	Artificial	N/A
Bedroom	11,5 m <sup>2</sup>	Daylight	West
	<b>44 m<sup>2</sup></b>		
Balcony	10 m <sup>2</sup>	Daylight	South -west



Illu. 90 Plan location indicator unit D1

# Unit D2

52 m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



Illu. 91 Plan unit D2 1:200

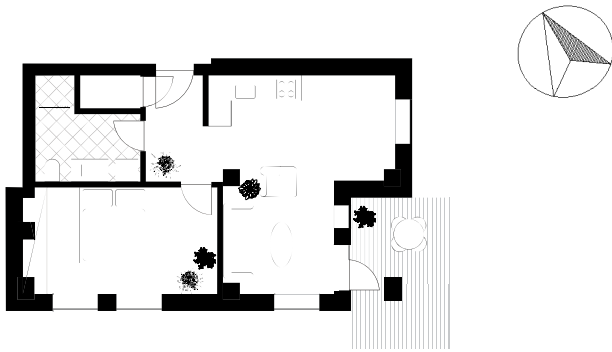
Room	Size	Lighting	Orientation
Living area	23 m <sup>2</sup>	Daylight	South - west
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	1,5 m <sup>2</sup>	Artificial	N/A
Bedroom	11,5 m <sup>2</sup>	Daylight	West
	<b>44 m<sup>2</sup></b>		
Balcony	17,5 m <sup>2</sup>	Daylight	South - west



Illu. 92 Plan location indicator unit D2

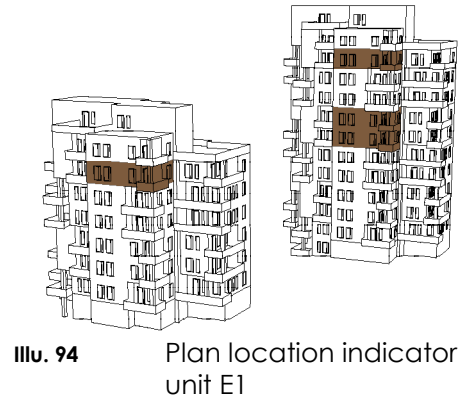
# Unit E1

61m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



Illu. 93 Plan unit E1 1:200

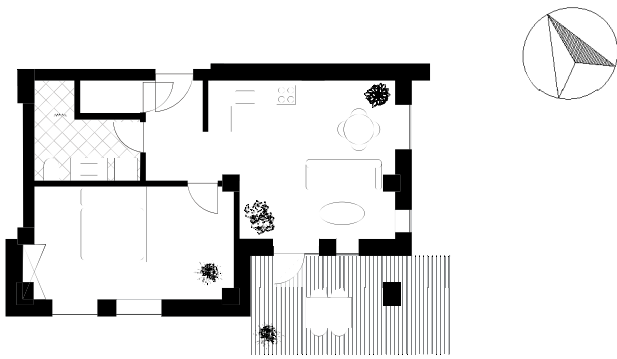
Room	Size	Lighting	Orientation
Living area	28 m <sup>2</sup>	Daylight	South
Bathroom	6 m <sup>2</sup>	Artificial	N/A
Storage	1,5 m <sup>2</sup>	Artificial	N/A
Bedroom	13,5 m <sup>2</sup>	Daylight	South - west
	<b>49 m<sup>2</sup></b>		
Balcony	10,5 m <sup>2</sup>	Daylight	South



Illu. 94 Plan location indicator unit E1

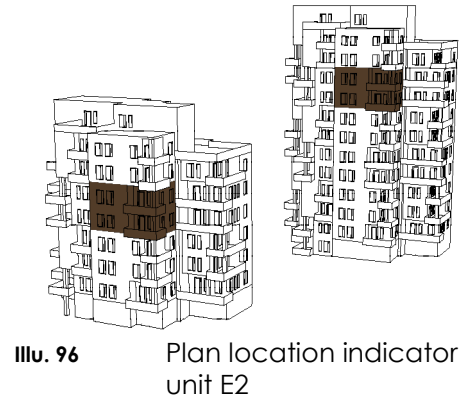
# Unit E2

58m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



Illu. 95 Plan unit E2 1:200

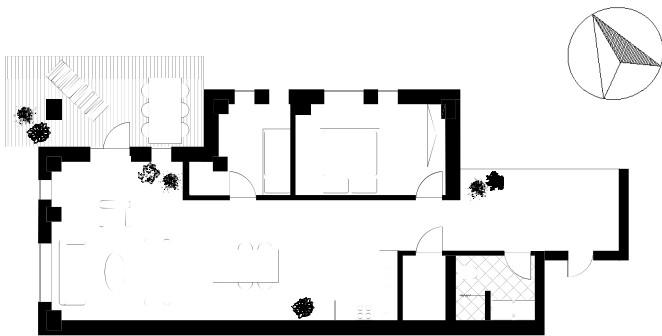
Room	Size	Lighting	Orientation
Living area	23,5 m <sup>2</sup>	Daylight	South - east
Bathroom	6 m <sup>2</sup>	Artificial	N/A
Storage	1,5 m <sup>2</sup>	Artificial	N/A
Bedroom	13,5 m <sup>2</sup>	Daylight	South - west
	<b>44 m<sup>2</sup></b>		
Balcony	13,5 m <sup>2</sup>	Daylight	South



Illu. 96 Plan location indicator unit E2

# Unit F

52 m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



Illu. 97 Plan unit F 1:200

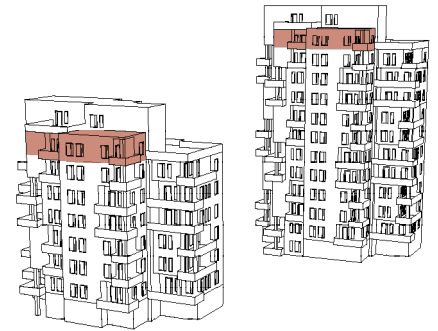
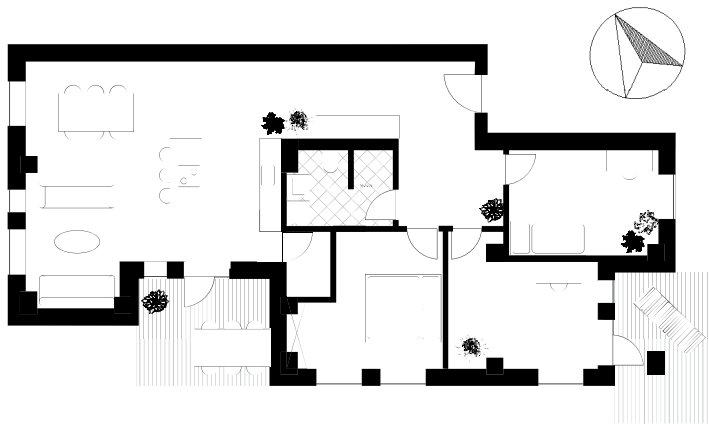
Room	Size	Lighting	Orientation
	97 m <sup>2</sup>		
Living area	52,5 m <sup>2</sup>	Daylight	West
Bathroom	5 m <sup>2</sup>	Artificial	N/A
Storage	2,5 m <sup>2</sup>	Artificial	N/A
Bedroom	12,5 m <sup>2</sup>	Daylight	North
Bedroom	7 m <sup>2</sup>	Daylight	North
	<b>76 m<sup>2</sup></b>		
Balcony	16,5 m <sup>2</sup>	Daylight	North



Illu. 98 Plan location indicator unit F

# Unit G

58m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



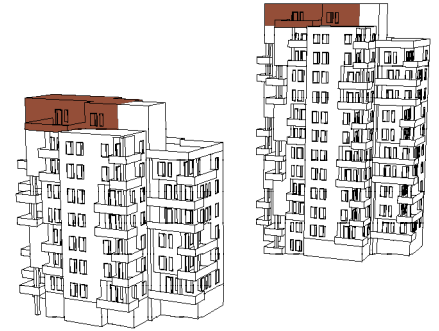
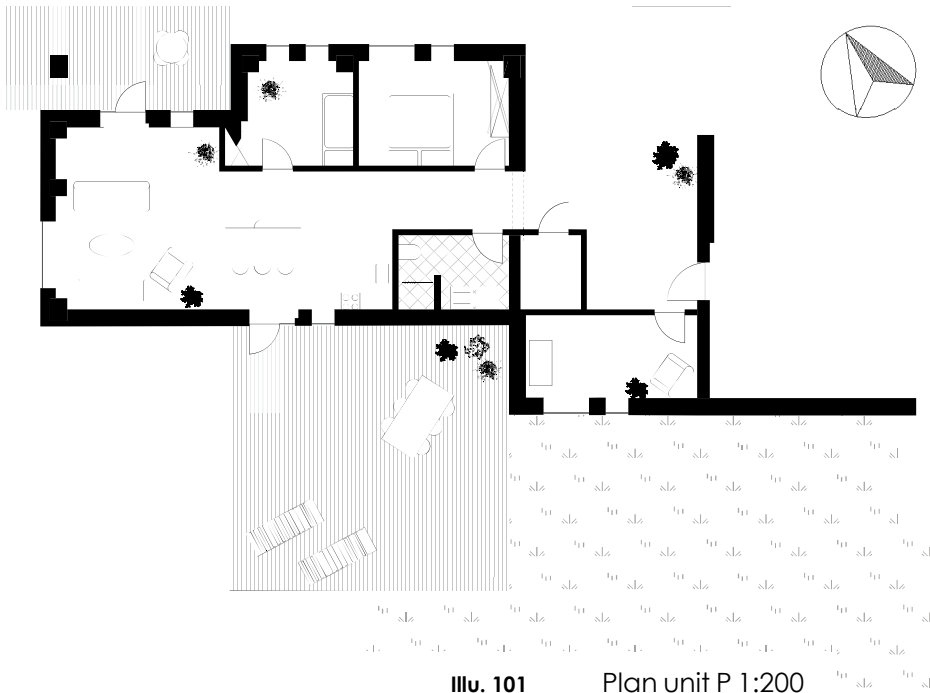
Illu. 100 Plan location indicator unit G

Illu. 99 Plan unit G 1:200

Room	Size	Lighting	Orientation
	122 m <sup>2</sup>		
Living area	55,5 m <sup>2</sup>	Daylight	South or west
Bathroom	5,5 m <sup>2</sup>	Artificial	N/A
Storage	2 m <sup>2</sup>	Artificial	N/A
Bedroom	13 m <sup>2</sup>	Daylight	South west
Bedroom	12,5 m <sup>2</sup>	Daylight	South west
Bedroom	10,5 m <sup>2</sup>	Daylight	South
	<b>99 m<sup>2</sup></b>		
Balcony	10,5 m <sup>2</sup>	Daylight	South
Balcony	10 m <sup>2</sup>	Daylight	South - west

# Unit P

122 m<sup>2</sup>, 2 Bedrooms, 1 Bathroom



Illu. 102 Plan location indicator unit P

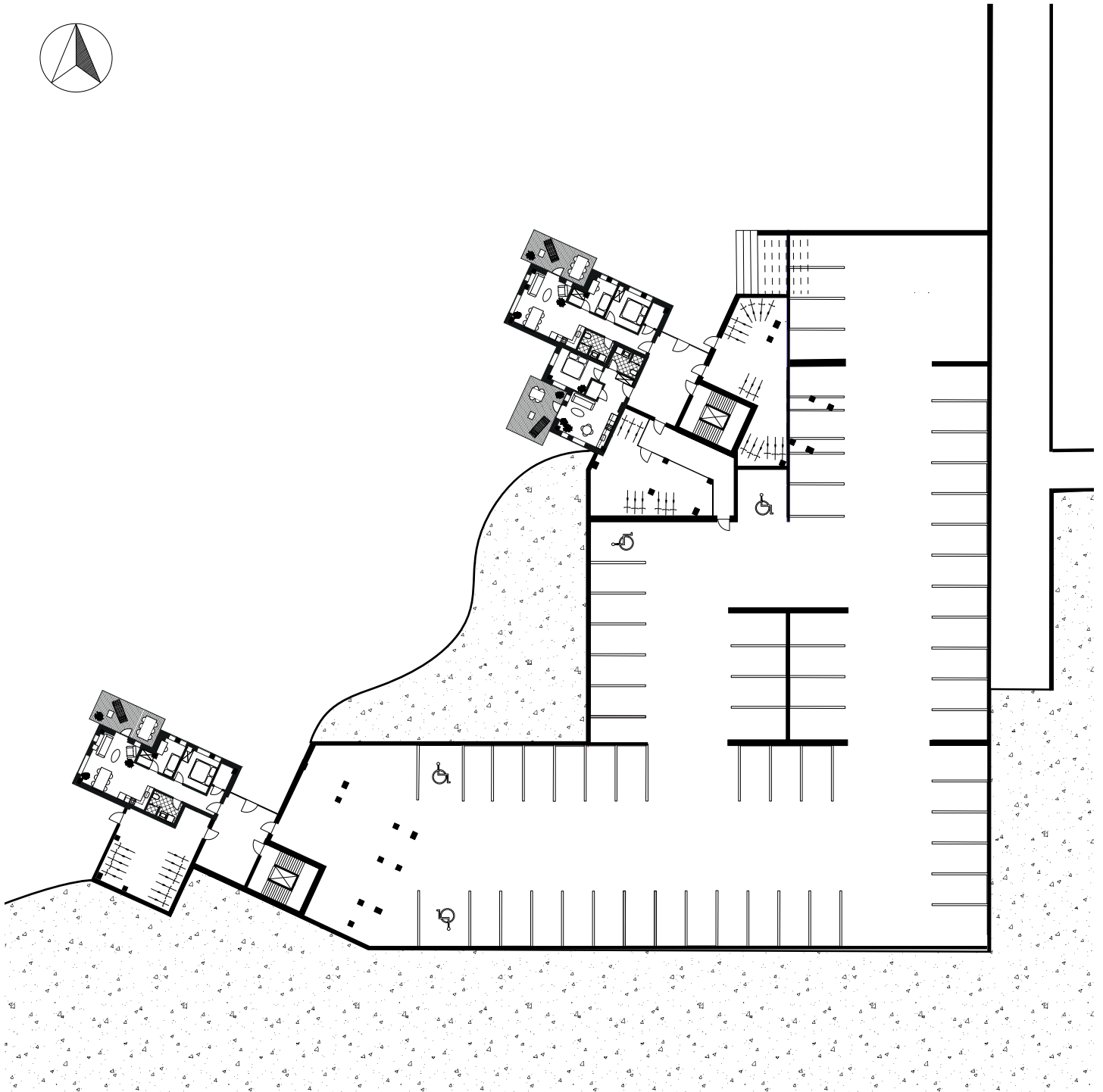
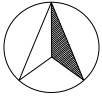
Room	Size	Illu. 101 Lighting	Plan unit P 1:200 Orientation
Living area	56 m <sup>2</sup>	Daylight	South or west
Bathroom	5,5 m <sup>2</sup>	Artificial	N/A
Storage	3 m <sup>2</sup>	Artificial	N/A
Bedroom	11 m <sup>2</sup>	Daylight	North
Bedroom	10,5 m <sup>2</sup>	Daylight	South
Bedroom	8 m <sup>2</sup>	Daylight	Noth
<b>94 m<sup>2</sup></b>			
Balcony	51,5 m <sup>2</sup>	Daylight	South
Balcony	16,5 m <sup>2</sup>	Daylight	North



Illu. 103      Rendering balcony

# Plan - ground floor

1:500

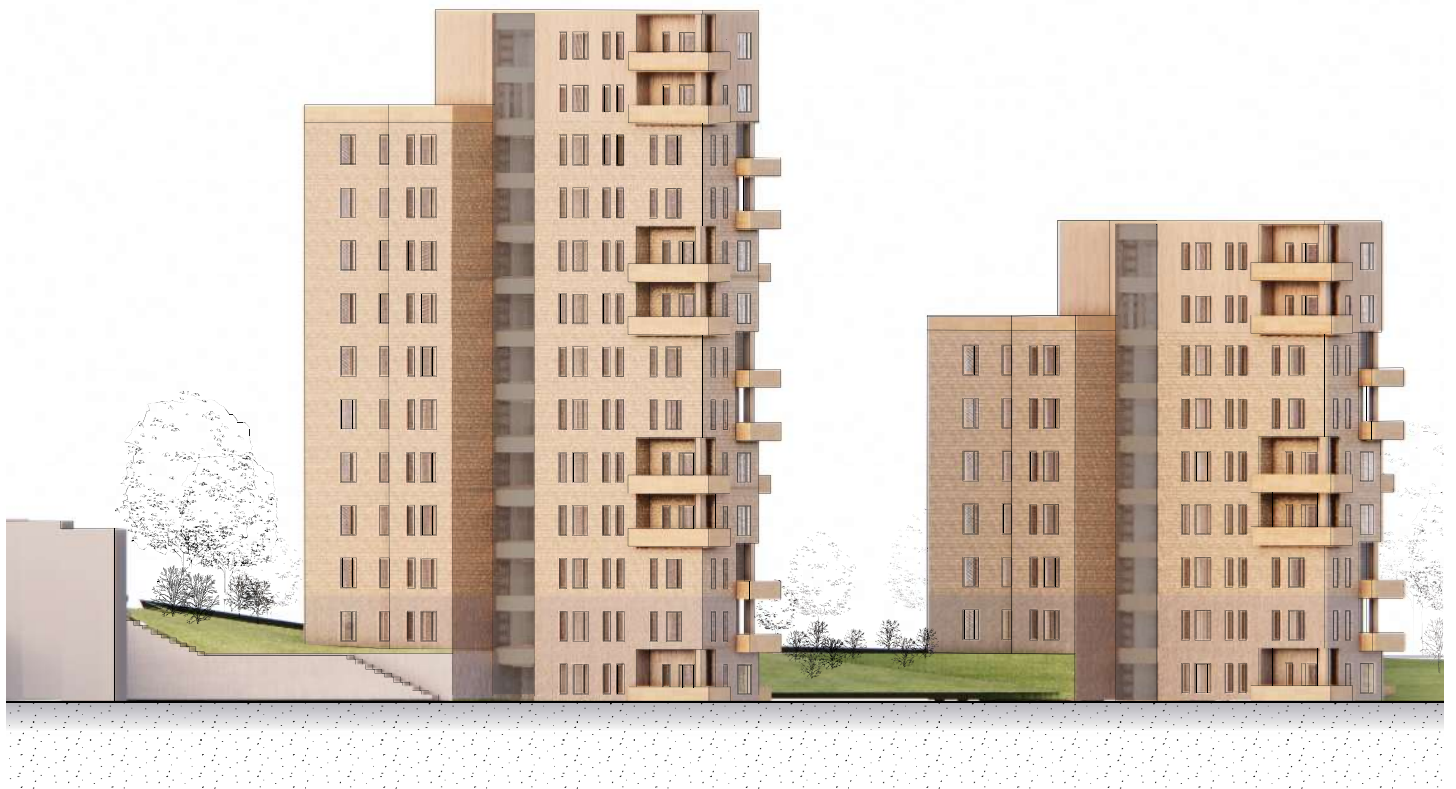


illu. 104

Plan ground floor 1:500

# North elevation

1:500



illu. 105 North elevation 1:500

# West elevation

1:500

Illu. 106 North elevation 1:500



Illu. 107 West elevation 1:500

# South elevation

1:500



Illu. 108

South elevation 1:500

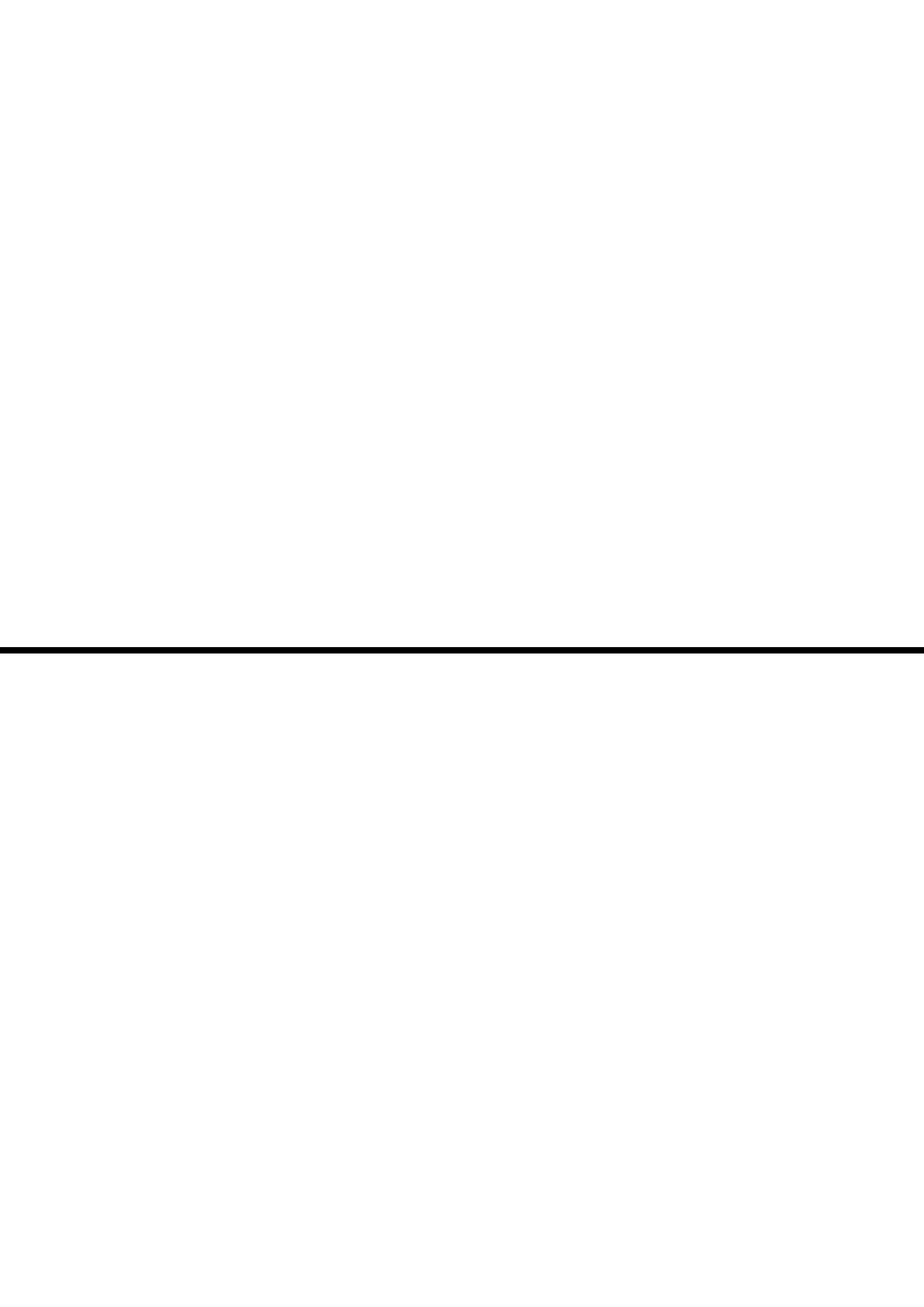


Illu. 109 Rendering outside



# EPILOUGE

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# Reflection

Designing a high-rise building for this master's thesis has been both challenging and rewarding. Due to the limited timeframe, it was necessary to balance the depth of investigation across different aspects of the design process. This required prioritizing certain areas while accepting that others could only be explored to a limited extent.

Completing the project individually has provided valuable insight into the collaborative nature of architectural practice. Throughout the process, the absence of colleagues and interdisciplinary discussions highlighted the importance of collaboration when developing and evaluating design solutions. In professional practice, projects benefit from the combined expertise of architects, engineers, consultants, and specialists, each contributing knowledge within their field. Working alone required assuming all of these roles simultaneously, which broadened my understanding of the design process but also revealed the limitations of individual expertise. As a result, some aspects of the project received more attention than others, reflecting the practical challenges of managing a complex project independently.

Looking back on the project, several areas offer opportunities for further development. A greater focus on materiality would have strengthened the architectural expression of the proposal. While significant effort was dedicated to optimizing apartment layouts and developing the structural concept,

less attention was given to the detailed selection and exploration of materials that define the building's aesthetic character and user experience. A more thorough investigation of façade materials, surface treatments, and construction details could have enhanced the overall architectural quality of the design.

The structural calculations conducted in this thesis primarily served to verify the feasibility of the proposed load-bearing system. However, the analyses remain relatively simplified and focus mainly on utilization rates of selected structural elements. For the project to progress towards realization, more comprehensive calculations and simulations would be required. In professional practice, advanced structural software forms an integral part of the design process, enabling a more detailed assessment of stability, connections, wind loads, fire performance, and overall structural behavior.

Finally, the design could have benefited from a more detailed study of window design and façade openings. Since maximizing daylight access was one of the central design objectives, a deeper investigation into window proportions, placement, glazing types, and shading strategies would have provided a stronger foundation for evaluating indoor environmental quality. Such studies could further optimize daylight performance while balancing thermal comfort, energy efficiency, and architectural expression.

Despite these limitations, the project has provided valuable experience in integrating architectural design with technical and environmental considerations. It has strengthened my understanding of the opportunities and challenges associated with timber high rise construction and highlighted the importance of collaboration, specialization, and iterative development within the architectural profession.

# Conclusion

This thesis set out to investigate how a timber high-rise residential building in Ørestad, Copenhagen, can be designed to provide attractive and spatially efficient housing for first-time buyers while meeting requirements for daylight performance, fire safety, structural stability.

Through site analysis, user studies, precedent studies, and an iterative design process, a residential tower proposal was developed that addresses the needs of young households entering the housing market. The design incorporates a variety of apartment typologies ranging from compact units for couples to larger family-oriented dwellings, creating flexibility for different life stages while maintaining an efficient use of space.

A key objective of the project was to maximize residential quality through daylight optimization. Building orientation, apartment placement, window sizing, and balcony design were continuously evaluated throughout the design process. The resulting apartments achieve satisfactory daylight conditions while avoiding exclusively north-facing units, demonstrating that high-density housing can maintain a high level of indoor comfort and livability.

Finally, the project further demonstrates the feasibility of timber as the primary structural material in a high-rise residential building. A structural system consisting of glulam columns and beams, CLT walls and floor slabs, and a concrete core provides the

necessary stability while addressing fire-safety requirements through protected escape routes, structural redundancy, and fire-resistant detailing. Lessons learned from the case studies of TRÆ and Mjøstårnet informed the development of these solutions and illustrate the growing potential of engineered timber construction for tall buildings.

It can therefore be concluded that a timber high-rise residential building in Ørestad can provide attractive housing for first-time buyers while simultaneously fulfilling requirements for daylight, fire safety, structural stability, sustainability, and urban integration. Although further engineering development would be required before construction, the project demonstrates that timber high-rise architecture represents a viable and sustainable strategy for accommodating Copenhagen's future housing demand.



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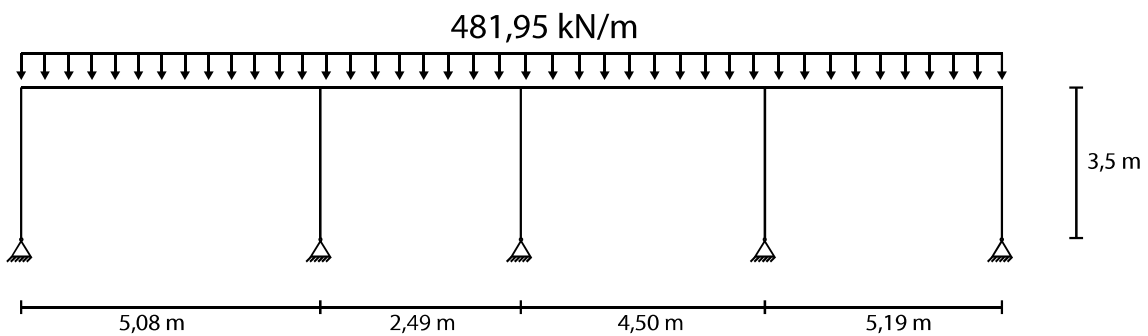
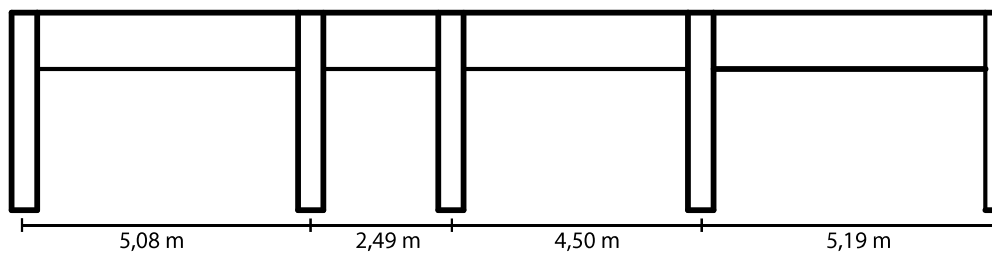
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# Appendix

## Calculations

Glulam(GLT) GL30	13 floors
Design line load $q_d$	
Self-weight	6,1
Imposed load	2,0
Snow load	1,0
	31,85 kN/m x 13 floors
	414,05 kN/m + 4,20kN/m
	418,25 kN/m
$k_{mod}$	0,8
$\lambda_M$	1,25
$f_{c,0,k}$	24,0 MPa



Column	A	B	C	D	E
Section (mm)	600 x 450	450 x 450	450 x 450	600 x 450	11720 x 450
Area (m <sup>2</sup> )	0,2700	0,2025	0,2025	0,2700	5,2740
Design load $N_{Ed}$ (kN)	870	2059	952	2459	855

## Column A

Comprehensive stress  $\sigma_{c,0,d}$

$$A = 0,60 * 0,45 = 0,2700\text{m}^2$$

$$\sigma_{c,0,d} = N_{Ed} / A$$

$$\sigma_{c,0,d} = 870 / 0,2700 = 3,22\text{MPa}$$

Buckling

$$L_{cr} = 0,5 * L$$

$$L_{cr} = 0,5 * 3,5 = 1,75\text{m} = 1750\text{mm}$$

Radius of gyration

$$i = 450 / \sqrt{12} = 129,9\text{mm}$$

Slenderness

$$\lambda = 1750 / 129,9 = 13,47$$

Relative slenderness

$$\lambda_{rel} = (13,47 / \pi) \sqrt{(24 / 9600)} = 0,214$$

Buckling factor  $k_c$

$$\text{For } \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } 0,30 > \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } \lambda < 1,0 \rightarrow k_c = 1 / (k_c + \lambda^2)$$

$$\text{where } k = 1,0 \quad k_c = 1 / (1,70^2) = 1,0$$

Effective compressive strength  $k_c f_{c,0,d}$

$$k_c f_{c,0,d} = 1,0 * 15,36 = 15,36\text{MPa}$$

$$f_{c,0,d} = (k_{mod} * f_{c,0,k}) / \lambda_M = (0,8 * 24,0) / 1,25 = 15,36$$

Utilisation including buckling  $\eta$

$$\eta = \sigma_{c,0,d} / (k_c f_{c,0,d})$$

$$\eta = 3,22 / 15,36 = 0,209 = 20,9\%$$

## Column B

Comprehensive stress  $\sigma_{c,0,d}$

$$A = 0,45 * 0,45 = 0,2250\text{m}^2$$

$$\sigma_{c,0,d} = N_{Ed} / A$$

$$\sigma_{c,0,d} = 2059 / 0,2025 = 10,17\text{x MPa}$$

Buckling

$$L_{cr} = 0,5 * L$$

$$L_{cr} = 0,5 * 3,5 = 1,75\text{m} = 1750\text{mm}$$

Radius of gyration

$$i = 450 / \sqrt{12} = 129,9\text{mm}$$

Slenderness

$$\lambda = 1750 / 129,9 = 13,47$$

Relative slenderness

$$\lambda_{rel} = (13,47 / \pi) \sqrt{(24 / 9600)} = 0,214$$

Buckling factor  $k_c$

$$\text{For } \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } 0,30 > \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } \lambda < 1,0 \rightarrow k_c = 1 / (k_c + \lambda^2)$$

$$\text{where } k = 1,0 \quad k_c = 1 / (1,70^2) = 1,0$$

Effective compressive strength  $k_c f_{c,0,d}$

$$k_c f_{c,0,d} = 1,0 * 15,36 = 15,36\text{MPa}$$

$$f_{c,0,d} = (k_{mod} * f_{c,0,k}) / \lambda_M = (0,8 * 24,0) / 1,25 = 15,36$$

Utilisation including buckling  $\eta$

$$\eta = \sigma_{c,0,d} / (k_c f_{c,0,d})$$

$$\eta = 10,17 / 15,36 = 0,662 = 66,2\%$$

## Column C

Comprehensive stress  $\sigma_{c,0,d}$

$$A = 0,45 * 0,45 = 0,2250\text{m}^2$$

$$\sigma_{c,0,d} = N_{Ed} / A$$

$$\sigma_{c,0,d} = 952 / 0,225 = 4,231\text{MPa}$$

Buckling

$$L_{cr} = 0,5 * L$$

$$L_{cr} = 0,5 * 3,5 = 1,75\text{m} = 1750\text{mm}$$

Radius of gyration

$$i = 450 / \sqrt{12} = 129,9\text{mm}$$

Slenderness

$$\lambda = 1750 / 129,9 = 13,47$$

Relative slenderness

$$\lambda_{rel} = (13,47 / \pi) \sqrt{(24 / 9600)} = 0,214$$

Buckling factor  $k_c$

$$\text{For } \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } 0,30 > \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } \lambda < 1,0 \rightarrow k_c = 1 / (k_c + \lambda^2)$$

$$\text{where } k = 1,0 \quad k_c = 1 / (1,70^2) = 1,0$$

Effective compressive strength  $k_c f_{c,0,d}$

$$k_c f_{c,0,d} = 1,0 * 15,36 = 15,36\text{MPa}$$

$$f_{c,0,d} = (k_{mod} * f_{c,0,k}) / \lambda_M = (0,8 * 24,0) / 1,25 = 15,36$$

Utilisation including buckling  $\eta$

$$\eta = \sigma_{c,0,d} / (k_c f_{c,0,d})$$

$$\eta = 4,70 / 15,36 = 0,306 = 30,6\%$$

## Column D

Comprehensive stress  $\sigma_{c,0,d}$

$$A = 0,60 * 0,45 = 0,2700\text{m}^2$$

$$\sigma_{c,0,d} = N_{Ed} / A$$

$$\sigma_{c,0,d} = 2459 / 0,2700 = 9,11\text{MPa}$$

Buckling

$$L_{cr} = 0,5 * L$$

$$L_{cr} = 0,5 * 3,5 = 1,75\text{m} = 1750\text{mm}$$

Radius of gyration

$$i = 450 / \sqrt{12} = 129,9\text{mm}$$

Slenderness

$$\lambda = 1750 / 129,9 = 13,47$$

Relative slenderness

$$\lambda_{rel} = (13,47 / \pi) \sqrt{(24 / 9600)} = 0,214$$

Buckling factor  $k_c$

$$\text{For } \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } 0,30 > \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } \lambda < 1,0 \rightarrow k_c = 1 / (k_c + \lambda^2)$$

$$\text{where } k = 1,0 \quad k_c = 1 / (1,70^2) = 1,0$$

Effective compressive strength  $k_c f_{c,0,d}$

$$k_c f_{c,0,d} = 1,0 * 15,36 = 15,36\text{MPa}$$

$$f_{c,0,d} = (k_{mod} * f_{c,0,k}) / \lambda_M = (0,8 * 24,0) / 1,25 = 15,36$$

Utilisation including buckling  $\eta$

$$\eta = \sigma_{c,0,d} / (k_c f_{c,0,d})$$

$$\eta = 9,11 / 15,36 = 0,593 = 59,3\%$$

Column E (wall)

Comprehensive stress  $\sigma_{c,0,d}$

$$A = 11,720 * 0,45 = 52740\text{m}^2$$

$$\sigma_{c,0,d} = N_{Ed} / A$$

$$\sigma_{c,0,d} = 855 / 5,2740 = 0,162\text{MPa}$$

Buckling

$$L_{cr} = 0,5 * L$$

$$L_{cr} = 0,5 * 3,5 = 1,75\text{m} = 1750\text{mm}$$

Radius of gyration

$$i = 450 / \sqrt{12} = 129,9\text{mm}$$

Slenderness

$$\lambda = 1750 / 129,9 = 13,47$$

Relative slenderness

$$\lambda_{rel} = (13,47 / \pi) \sqrt{(24 / 9600)} = 0,214$$

Buckling factor  $k_c$

$$\text{For } \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } 0,30 > \lambda \leq 0,30 \rightarrow k_c = 1,0$$

$$\text{For } \lambda < 1,0 \rightarrow k_c = 1 / (k_c + \lambda^2)$$

$$\text{where } k = 1,0 \quad k_c = 1 / (1,70^2) = 1,0$$

Effective compressive strength  $k_c f_{c,0,d}$

$$k_c f_{c,0,d} = 1,0 * 15,36 = 15,36\text{MPa}$$

$$f_{c,0,d} = (k_{mod} * f_{c,0,k}) / \lambda_M = (0,8 * 24,0) / 1,25 = 15,36$$

Utilisation including buckling  $\eta$

$$\eta = \sigma_{c,0,d} / (k_c f_{c,0,d})$$

$$\eta = 0,162 / 15,36 = 0,011 = 1,1\%$$