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A MODERNIST APPROACH TO DANISH CITIES

case for building better cities in modern society

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ABSTRACT

During recent years the rent in the inner cities has risen to a level that has made the average and lower-income citizen unable to exist in the city centres. While gentrification is pushing out the newer generations and reserving the inner parts of the city for the wealthy, the less fortunate are left with housing that is not living up to modern standards of living. Sub-par housing at astronomical prices and an impossible dream of owning real estate in the city centre has pushed out the working- and middle class to the suburbs. But the question stands – if the city centre is not for the public, then who is it for?

This thesis investigates the causes and symptoms of modern capitalism on the Danish city with point of departure in Copenhagen. During the investigation of the problem, ideas for a solution to it is laid out and present in a final design for the island of Refshaleøen, a breathing hole arms reach from the inner city of Copenhagen. A modernist approach with point of departure in then contemporary literature and ideas will lay the foundation for the design approach of which the final solution is made. The principles of the modernist movement concerned itself with similar problematics, such as an urgent need for housing in the inner cities with the human and the quality of life in focus.

The final solution culminates in a sprawling addition to the Island of Refshaleøen. Where Copenhageners can co-exist with the historic past of the place. It builds upon the identity of what once was on the island while creating new areas for the inhabitants to enjoy a new addition to the city they love.

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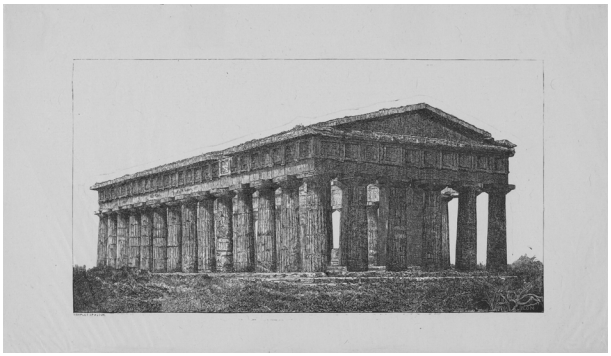

1st PART: PROLOGUE

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1. MOTIVATION

The urban landscape has through a combination of the political and architectural decisions developed into a market where it has become near impossible for younger generations to have access to the city. Copenhagen stands as a prime example of how inaccessible the city is becoming with rent and house prices skyrocketing and the quality of available housing not following modern living standards.

It was not many years ago that you could find a decent apartment for a reasonable price in the city centre of Copenhagen, but these days are no more. Young people, elderly and newly baked families are perpetually stuck between the choice of renting sub-par housing for abnormal prices in the city or move out of the city altogether, while the wealthy profit off the spaces in the city. Growing up in a generation where the city never has been accessible while the necessity for being in the city to get an education, be near friends and enjoy the urban lifestyle that society is pushing in present times, is very difficult. Seeing the rise of mental health problems often attributed to the stress of modern life and fortified by the hardships and conditions that come with living in the city, drives the desire to find solutions to better the life of people living in the city.

So, this thesis is based on a desire to change this course and redefine the city to ensure an inclusive and accessible place to live for all and is therefore not only a scholarly pursuit; it is a plea for change. We imagine the future of Copenhagen where affordable, high-quality housing is not a luxury but a fundamental right for everyone and not a continuation of the prosperity-driven formation happening today.

MODERNISTIC APPROACH

This project is made with a point in departure of the modernistic ideals that were prevalent in through the 19th century. Many of the societal problems that spawned modernism, which modernism was an answer to, are still prevalent in today's society. As authors, architects, and humans we strongly believe that modernism and its ideals can be used as an answer to the increasing housing problems in major European cities. Through this report there will be elaborated on these prevalent problems and a depiction of how modernism has been a primary driver for the solution presented in the end of the report.

2. METHOD

This thesis' methodological approach is the Integrated Design Process (IDP). This method is selected to ensure that the project follows a protocol that can achieve its goals for a holistic final design where factors between aesthetics, functionality and technical design decisions support each other through an iterative process.
The design phases are divided into four, which overlap each other in different stages of the design process for a structure of designing that encourages and iterative approach to find solutions between the different stages of the method. Much of this iterative way of designing is being done subconsciously, especially when one has been through a design process before, therefore there is an element of banality when breaking the design process into a method such as the Integrated Design Process. However, being aware of the tools withing the process and deliberately reaching for its design-approach, especially at crucial design decisions, can help ensure that the particular design solution becomes more holistic and that the inevitable fault of human error happen as rarely as possible.

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Chapters of societal problems: this multilayered phase contains -

- developement of the problem for the thesis
- analysis of buildings, site and context
- theory that helps solving the problem
- cases that highlight a specific solution for a problem

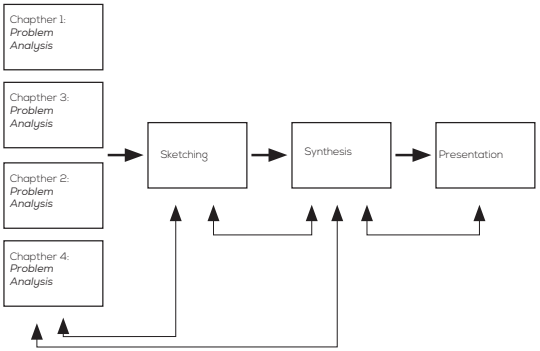
Because the problem subject is so vast and relatively undiscovered for us, this phase and it's layers are iterative in itself and can be characterised as a primarily investegative phase.

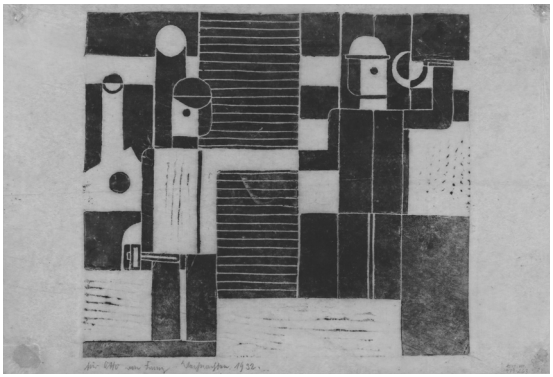
Sketching: the findings from the previous phase is brought onto paper as initial design ideas.

Synthesis: ideas, studies and knowledge from ealier phases are combined into solutions, which can be evaluated for their weaknesses and strengths as a holistic solution

Presentation: the best design solutions are combined into a final design

PHASES OF THE DESIGN PROCES





2nd PART: THE PROBLEM

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    a. theory

Copenhagen has an international reputation for being one of the most liveable cities in the world. Flashy headlines and shallow journalism continuously focus on the overpriced designer's coffee and juice bars, painting a false narrative for what Copenhagen in actuality has presented itself as in recent years.

Copenhagen has for the last two decades been subject to rising house prices, shortage of available housing, bad quality of housing in both older and newer buildings, and a gentrification pushing the working class out of the city centre, while reserving the centre for the rich. This paradigm shift has been coined by several academics as a transformation from a velfærdsby to a velstandsby. This shift has brought changes to the city, which has been the detriment of the common citizen of Copenhagen and the overall quality of the city.

(Kvorning, et al., 2020) (Weiss, 2019) (Jørgensen, 2021)

1.

SHORTAGE OF AVAILABLE HOUSING

It wasn't many years ago that you could find affordable housing in the city centre of Copenhagen. Housing that is desperately needed by the working class and minorities, who are working essential jobs and keeping the city running. These cheap accommodations are disappearing and the cause of this can be attributed to a set of 7 variables:

FIRE-SALE OF THE MUNICIPALITY'S HOUSING

the state ordered the municipality to sell 20.000 public-owned housing during the financial crisis of the 1990's to private investors and owners.

APARTMENTS HAVE BEEN JOINED TOGETHER

during 1980-2005 there was a decrease in overall available housing compared to the amount of newly constructed housing. This happened because several apartments were joined together as a part of sale to private owners or done as a part of renovation. Danish building law state that the municipality cannot intervene if the area of the apartment has a total of 130m2. The municipality of Copenhagen increased this limit to 160m2. A total of 15000 apartments were joined to 7500 apartments, making the apartments more expensive.

THE 25% QUOTA IS NOT MET

the municipality of Copenhagen can demand that 25% of newly built housing in an area to be social housing, but the developers are pushing for a lower rate and building the social housing in the very end of development.

SOCIAL HOUSING IS GETTING PRIVATISED

Ghettoloven has made it possible for the municipality to sell some of the then-social housing as privately owned property or demolish it altogether and build a fewer amount of social housing on the same property.

ANDELSBOLIGER IS GETTING MARKETED

a new law in 2006 made it possible for Andelsboliger to be valued

at market price. The prices on Andelsboliger in Copenhagen saw a massive rise after this. In later years pension funds and investors started to buy these Andelsboliger for the benefit of renting them out to private renters of selling them as private apartments.

a growing part of the housing capacity is getting filled with housing that are advertised and used as accommodation for tourists. The growing influx of tourists from both China and Europe has created a market for home owners to make businesses around viral sites like AirBnb. These apartments remove a part of the housing capacity for native citizen because their rent prices are not suited for long-term renters.

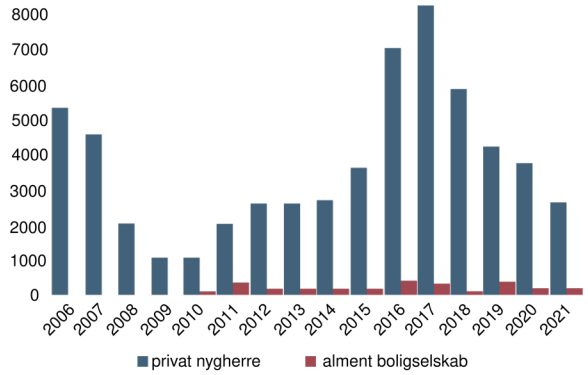
TOURIST APARTMENTS

the most attractive and expensive apartments in Denmark are ironically enough not the ones intended for Danish citizen. Realtors sell apartments without residency requirement like hot cakes. Danish laws assert that newly constructed apartments, can be sold without residency requirement. International oligarchs buy these apartments with residency in Monaco and are free to use them as speculation-objects or as vacation homes without paying tax to the municipality.

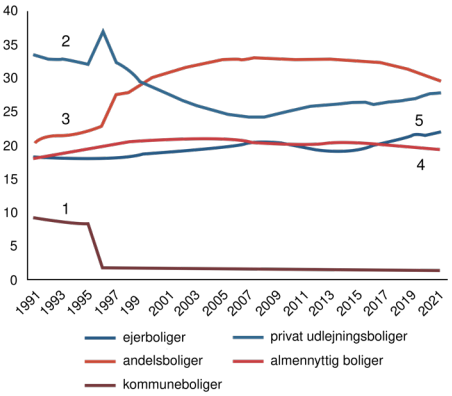
GHOST-APARTMENTS

The effects of these 7 factors mean that an increasing amount of people are forced to find housing through private housing marked, which is more expensive and outside of many people's budget. There is simply not enough social housing the city to supply the average citizen with housing that is affordable on a worker's salary.

(Jørgensen, 2021)



The figure shows residential construction underway as of the first quarter in the Municipality of Copenhagen. The vast majority are privately owned or rented dwellings. Public housing construction remains consistently low. (Jørgensen, 2021).

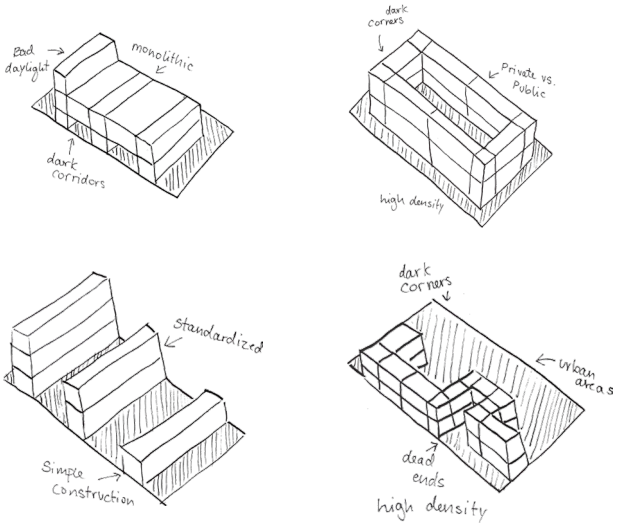


The distribution of housing types in percentage in the Municipality of Copenhagen from 1991 to 2021. 1) The municipality sold its housing. 2) As a consequence, there were more private rental properties. 3) More cooperative housing due to the possibility of converting rental properties into cooperative housing. 4) The share of public housing has been declining. 5) Growth in the share of both privately owned and rental properties. (Jørgensen, 2021).

THEORY

DENSIFICATION

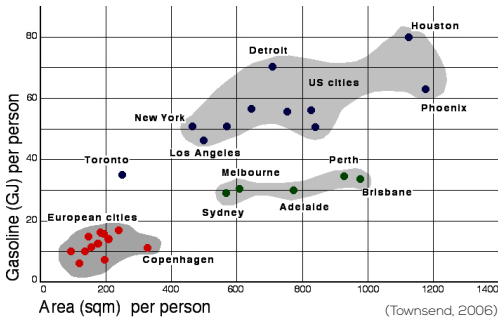
"An ideological vacuum arose when architects and urbanists stopped producing manifestos and urbanist utopias in the 1930s. When this stopped the most powerful tool in linking beauty, morality, idealism and prosperity was lost. These idealistic ideas spawned from manifestos and urban theories are the counterpart to architecture and urban atrocities spawned from the market-driven city" (Weiss, 2019,p.9-11).



"Aarhus and Copenhagen excel art building harbour baths, bike paths and other progressive urban elements, but the architectural imbalance in the city is rarely addressed" (Weiss, 2019,p.9).

(Corbusier, 1933)

SCIENCE & SUSTAINABILITY



(Townsend, 2006)

During the rapid urbanization of the industraliasation the need for more housing in the inner cities rose. The modernist movement concerned itself with this issue and it is then inherent in the modernist ideology, that it occupies itself with the solutions of densification of the city; increasing the amount of populace per hectare. During the industrialsation new techonolgy enabled mankind to reach new numbers of density that were previous unreachable. Increasing density also comes with concerns about scenarios that enables poor living conditions and constructions surrounding the humans which are out of scale in relation to the subject. It is therefore of upmost importance that the population density be treated as a holistic design-variable, where these concerns are accounted for.

Le Corbusier's says the following about a solution for increasing the urban density:

"The present city authorities are trying at all costs to thrust us out into suburban garden-cities. My proposal is that we should pile the city in on top of itself. Intra-muros, and increase its population density to 1000 [...] We must eliminate the surburbs, eliminate and ban these garden-citiess with their mock nature: then we shall hear no more about the transportation crisis. And then, on top of Paris as it is, costive, shut-in and stifling, let us build the GREEN CITY = THE RADIANT CITY." (Corbusier, 1933, p.107)

Le Corbusier emphasizes the design approach of "stacking people" on top of each other to increase the urban density and allow more people access to the city. The plans for the Radiant City clearly builds upon this principle with its pattern-like design of blocks spanning several hectares. Contrary to the corridor-street, this design achieves both more lustrous open spaces but also a much greater urban density than how our city is currently built.

With the principle of stacking people on top of each other in mind and from inspiration of the RADIANT CITY, initial sketching of urban density can be made.

A meta-analysis from 2017 concluded that increase in urban density is linked to a set variables of positive effect; these variables included increase in wages, decrease of taxes and fees pulled from these wages, increased economical welfare, better job accessability, better value of space, better overall energy efficiency, pollution reduction, better access to services and increased amount of economic resources and amenities for its citizen. (Ahlfeldt & Pietrostefani, 2017)

Another meta analysis from 2020 described the link between urban densification and sustainability in reducing travel distances, fuel consumption, encouragement of more fuel-efficient transportation and better willingness to share scarce urban amenities. (Puga & Duranton, 2020)

2. BAD QUALITY OF AVAILABLE AND NEWER BUILDINGS

The modern metropolis has truly become a tarmac for real-estate investment and urban development. Copenhagen has proven itself to be a reliable financial asset as a secure and safe modern city in a well-functioning society. Every vacant plot is purchased as speculative objects for the developers as an investment-machine to secure capital for the wealthy. Private capitalists, such as Blackstone, and pension funds funnel massive amounts of money into city development. This is a problem because the architecture spawned from this developer-driven growth clearly reflect its intended purpose of generating money rather than creating quality architecture and meaningful urban spaces. Municipalities are pressured to compromise their district plan through pressure from the developer and processes are streamlined for development to be swift rather than quality-oriented. This is creating a market-driven city where it rewards quantity, not quality. We see it time again that different developers erect the first inspiration-forsaken complex after another. The interiors of these dwellings more so resemble living instruments designed to squeeze as many occupants into as little space as possible, rather than liveable homes for people to bring out the qualities that make a well-designed home. Likewise cultural nodes are hotlined to international drawing offices that expedite fast architecture with no respect to the surrounding context. This type of architecture thrives in the market-driven city where carefully designed buildings are slowing down development. Instead, buildings are erected that are applauded by international magazines as tomorrow's architecture. Often praised for their contrarian approach to architecture they just boil down to lazy architecture designed to be situated everywhere without respect for its context. (Weiss, 2019) (Kvorning, et al., 2020) (Jørgensen, 2021)

"It's an intentional critique of Danish urbanism. [...] The city has become too calm and beautiful. I miss the cars and the noise."
Ellen Van Loon, Lead Arkitekt (OMA, Rem Koolhaas) behind BLOX.

(Kvorning, et al., 2020)

Architects used to be driven by good intentions. We have placed ourselves in a situation where we in best case support individual ambition and in worst case pure profit objectives

(Kvorning, et al., 2020)

ODE TO GLASS

"The world shall be rebuilt to crystal!", Paul Scheerbart triumphed when he and the architect Bruno Taut presented the manifest "Glas-Architektur".

There are no limits to what the invention of glass could offer humankind; Full transparency, no more secrets, no more sun starved rooms, no more shady business.

Less than a couple decades later Kirsten bernikow Gade and Bremerholm erected the historic Danske Bank building in glass in the middle of 1970s, which didn't avert the biggest launder scandal in Danish history.

BLOX is made of glass. Across from Langebro lays Nykredit's new headquarter made of glass. On Amager Boulevard the glass houses are lined up besides each other. Along havneløbet the first glass building is erected after another. You can too hear the glass houses clink in the new neighborhoods of Ørestaden, Tuborg havn and Nordhavnen. Surely there's no lack of this new glass-architecture presenting buildings as monumental copies of each other with little regard to their context.

The obsession with glass in architecture is clear: "The atrium and the open offices makes it possible to see each other and follow the life inside the buildings.", "This Nordic life is superior" and the architecture reflect a deliberate and Nordic expression only found in the great Nordic society.

By "Nordic" it is understood that there is plentiful amounts of sunlight, fresh air, straight lines, and contrasts. A reflection of a democratic expression. But is this true? Even though glass allegedly can be recognised on their open and democratic expression, it is important to ask: does it resonate with its surroundings?

And if it even tells a story, isn't it the story of the Emporer's new clothes? Does it even have something on?
Glass is smooth, it doesn't collect dust, it doesn't patinate. If it collects marks it can be washed off. If it develops cracks, it is replaced.
Glass is the symbol of modern society with all of its characteristics and flaws alike.
Glass is the modern architectural answer to silicone and botox.
Glass is nothing without silicone; It is silicone that binds the glass to its steel-joists, so the façade gets this smooth, character-forsaken and immortal expression.
Glass is the promise of an eternal present.

(Kvorning, et al., 2020)

THE SITE

"To build houses you must have sites. Are they natural sites? Not at all: they are immediately artificialized. This means that the natural ground is limited to but one function: withstand the strains, the weight of the structure (law of gravity). Once this is done we say "goodbye" to the natural site, for it is the enemy of man. A home on the ground (beaten earth) is frightfully unhealthful." (Corbusier, 1933, p.55)

Le Corbusier argues that no site is ever truly natural, and no truly natural site is inherently good. The intervention of human action on the site will immediately artificialize the site, but this is not a bad thing, for we prepare the site for human inhabitance; we remove the disadvantage and dangers of the site and provide the site with the necessities to harbour human life.

"Vestige of Roman times. Will this aqueduct, on a scale so much larger than that of the houses, destroy the site? Of course not! The aqueduct has created the site." (Corbusier, 1933, p.58)

Le Corbusier presents an important point of man-made sites, in the case of the roman aqueduct; it is immediately apparent that this artificial construction that stands till this day provides (with an incredible size and scale) the foundation for the roman urban spaces surrounding itself. Is this inherently bad? And this poses the question of how our buildings can be used as instruments to create the site itself with great effect on the existing ground. And lastly how does this tie together with the modern obsession with sustainable imagery consisting of wild and (mostly virtue-signaled) untouched nature? He argues that these "natural sites" are inferior to the "artificial site".

(Corbusier, 1933)

FLOWERS

"Living in order to work! This means breaking our backs, driving ourselves mad, mvvoral bewilderment, a prodigious hiatus between us and the realities of nature, plunging into a black abyss of artificiality. So men have grouped themselves together. Why? In order to struggle together for an improvement in their lives? No! In order to suffer. To have gone so far, to have allowed ourselves to drift so far in our cities – all our cities – that the human mechanism has run off the rails, so that we are mere hunted animals! .... Flowers! We must live surrounded by flowers!" (Corbusier, 1933,p.105)

How do we establish a connection to nature? The thing we are supposed to live surrounded by. It will be near impossible to find the arguments against the human right of living with access to nature. Much like the insect man are inherently attracted to the wonderful colours and smells of the flowers. Let's establish this connection in our architecture.

(Corbusier, 1933)

THE SUN

One of the elements of most importance is the amount of sunlight exposure for the inhabitants. Whether you are inside or outside you should be able to feel the rays of the sun. Because we know the psycological and physical benefits of sunlight exposure, be it in architecture or for the the human health.

"Architecture, city planning, our happiness, the state of our consciousness, the equilibrium of our individual lives, the rhythm of our collective duties, are all governed by the 24-hour cycle of the sun. the sun is in control. Of everything: thought, action movement, functions, undertakings, obligations, all these are contained, inevitably, within the exact boundaries established by two sleeps. Each morning life begins afresh and our energies are renewed: every evening our eyelids close, and sleep performs its inexplicable miracle.
24 hours! That is the yardstick and the rhythm of human life; the unit to which everything must conform.
all problems of distance dimension, and distribution have to be solved within those precise limits: 24 hours." (Corbusier, 1933, p.104)

let this be a testament to how all-encompassing the sun is in the lives of human life. In the same vein the sun should also be of upmost importance in the final design of the building. So how do we capture the sun in our buildings?

(Corbusier, 1933)

THE SUN, OUR DICTATOR

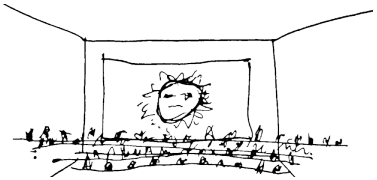
"To our insufficiently sagacious eyes, it appeared that the foliage prolonging the movement of the branches, stems, or trunk of the tree stood as motionless and quiescent around a tree trunk as the petals around a moon daisy, or the scales around an artichoke. But now, the advance of technology (photography and clockwork: slow-motion film) shows us that each of those innumerable leaves is an eye hypnotized by the sun, an eye always wide open, continually turning so as look the great solitary traveler who passes from East to West across our sky once every day always in the face. It is the sun that governs us. That tiny leaf, all those billions of leaves, free to move in the air, but held fast to their stems by the petiole and a stipule, all turn completely on their axes once every day; the stipule produces an intense muscular effort, and on the screen, magnified four hundred times and with its movement speeded up twenty thousand times, we can see it contracting, twisting into painful wrinkles, contorting itself in unremitting obedience to the commands of the sun. This tiny and pathetic adventure, lived out daily by the tiny little leaf, by the billions of tiny leaves that form part of the complex existence of hedgerows or great forests, always obeying and turning their faces to the great warm star, proclaims the fundamental law of this earth we live on: that the sun is our dictator."

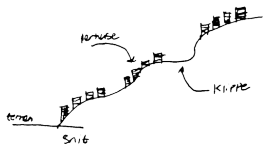
(Corbusier, 1933, p.78)

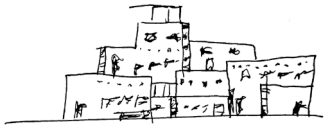
ALGERIA

(istockphoto, Jeremy Patton)

(istockphoto, JacobH)







the sites upon the native people of algeria brings great inspiration for how the landscape enables every home to capture sunlight and retain great view. The slope that the houses are built on enables this, but the way of their ancient cities could surely be an inspiration and asset when trying to capture sunlight and view.

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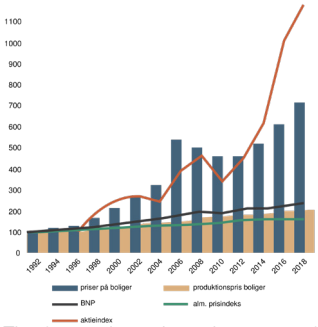
3. RISING HOUSE PRICES

One of the vital things for the working- and middle-class is the possibility of living close to your workplace. This is important for the quality of life of the citizen. Living close to your workplace reduces time spent on work in total, so that more time is freed up for recreational activities or family activities. It also has an important impact on the climate as it reduces emissions from transportation. Being in biking distance from work will cut out the need for carbon-fueled transportation methods and also steer the city in a direction of a walk-able city rather than a car-centric city, feeing up car parking and road space for the inhabitants. There is also a quality to be had in being a part of the cultural community of the inner city, where



The figure shows how the prices of real estate are not following the price of production or the general economy. It is rather artificially inflated by the investment market.
(Jørgensen, 2021).

RENT IS RISING IN PRIVATE HOUSING MARKET

§5 STK. 2 RENOVERINGER

PRIVATELY OWNED APARTMENTS ARE GETTING MORE EXPENSIVE

4. GENTRIFICATION

most activities and social gatherings will be held. To be able to live in the inner city is today a luxury as house prices and rent is rising rapidly. This means that the average citizen no longer has access to the city, which is in direct contrast to the welfare system that we pride ourselves on. The prices can be attributed to the following points:

according to Boligstyrelsen have the amount of rentable housing to under 5000DKK a month fallen from 48000 in 2015 to 36300 in 2019. The rent has on average increased by 25% since 2015.

of the 54700 private rental apartments in Copenhagen and Frederiksberg were 18600 of those renovated till 2019 after this arrangement. After the rules of market priced rent, the the average annual rent increased from 776DKK pr. m^2 to 1456DKK pr. m^2. That's an increase of 87%.

the squaremeter price for the marketed privately owned apartments from February 2020 to 2021 increased from 41937DKK to 49164DKK.

(Jørgensen, 2021)

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The city is a living organism in constant development. Different areas in the city will have different identities belonging to their heritage. Sub-cultures and movements through people's drive to create will be born in these neighbourhoods. In the market-driven society these sub-cultures and neighbourhood-specific identities are under constant threat. The citizens that built the neighbourhood while it was seen as an undesirable place to live are displaced because developers capitalise on what these sub-cultures created for the area. Developers buy the complexes in these neighbourhoods, inflate the value and rent of the apartments through newly constructed concrete blocks or inspiration-forsaken renovations, which forces the people that originally built the neighbourhood out of it. The city loses a huge part of its identity with these changes and a normalisation of the area happens where the original spirit and charm of the area is lost. Instead of businesses driven by passionate people, the streets are reduced to juice bars and overpriced chain-coffee establishments. The quality of the city is dependent on these creative people engaging in the city, but instead they are displaced and they are replaced by upper-middle class citizen and tech-workers, which provide very little to their immediate environment.
When different sub-cultures and passionate people build and create in their neighbourhoods it is for the benefit of the entire society, as it was intended in the welfare-society. When this is lost, the citizens are losing while the developers are the only ones benefiting.
(Kvorning, et al., 2020) (Weiss, 2019) (Jørgensen, 2021)

"It may be worth while to consider the different kinds of inhabitants of a great city. As the seat of power (in the widest meaning of the word; for in it there come together princes of affairs, captains of industry and finance, political leaders, great scientists, teachers, thinkers, the mouthpieces of the human soul, painters, poets, and musicians), the city draws every ambition to itself: it is clothes in a dazzling mirage of unimaginable beauty; the people swarm to it. Great men and our leaders install themselves in the city's centre. There too we find their subordinates of every grade, whose presence there at certain hours is essential, though their destinies are circumscribed within the narrower bounds of family life." (Corbusier, 1987, p.100)

Le Corbusier paints a picturesque representation of the good city. He firmly believes that a city that can accommodate every man in every layer of the social ladder is a superior city and that this will bring qualities to the city itself. This also aligns perfectly with a point of departure in the welfare state, where access to the city is equally dispersed to everyone.

"We have, of course eliminated the "corridor-street" – the street that now exists in all the cities of the world. Our living quarters have nothing to do with the streets. More than that, we have deliberately (though not merely for the sake of it) gone against the present tendency to envisage the pedestrians running to and fro on raised walks in the air and the traffic occupying the ground. We have allotted the ENTIRE GROUND SURFACE of the city to the pedestrian. The earth itself will be occupied by lawns, trees, sports and playgrounds. Almost 100 per cent of the ground surface will be used by the inhabitants of the city. [...] in other words: NO PEDENSTRIAN WILL EVER MEET AN AUTOMOBILE, EVER! [...] SPORTING ACTIVITIES WILL TAKE PLACE DIRECTLY OUTSIDE THE HOUSES. No more courtyards, ever again. Instead, an open view from every window (though there won't be any windows, of course, only walls of glass)." (Corbusier, 1933, p.108)

A way to combat gentrification in modern times would be gifting the city to the pedestrian. Making sure that infrastructure and architecture encourages and sets the foundation for the urban areas around the areas and especially in the city to be used for the inhabitants of the city. So, there should be an emphasis on creating urban areas where the pedestrian is in focus. Furthermore, limiting access of automobiles, which in many cases are a direct enemy to the soft trafficants. The citizens should, despite their ability to pay be able to use the city. This will be a tool to eliminate the gentrification happening in the streets of major cities, where spaces where the man can just exist without spending money or have a specific goal are getting rarer. No more juice bars or hipster coffees.

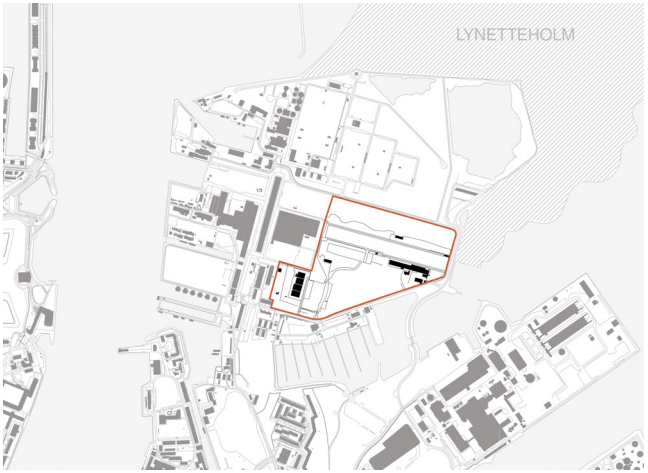
"Liberty!
In Paris, in 1919, the great new religion was founded: Business! Making money, organizing for the purpose of making a lot of money; business lunches, conferences, scientific management. The right man at the right place"

(Corbusier, 1933, p.11)

3rd PART: REFSHALEØEN

1. SITE
2. VISION

1. THE SITE

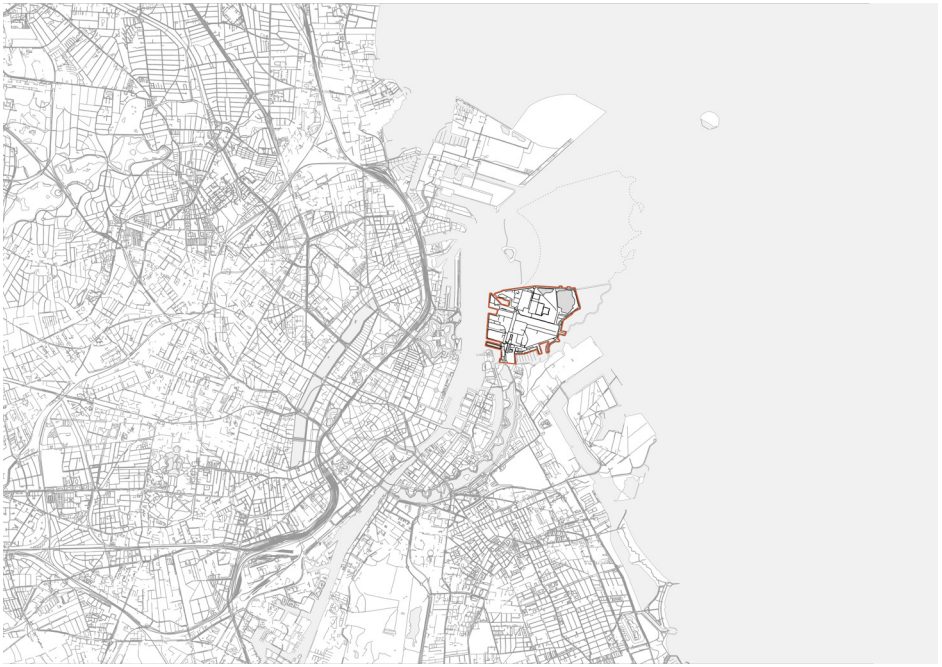


The project site is situated on the artificial island of Refshaleøen. The island is connected with a narrow entry point to the island of Amager. Cyclists have 12 minutes to mainland Zealand. The island was originally built as a manufacturing site for the now defunct B&W shipyard company. The company has now left the island, but many of their buildings still stand till this day. The many historic traces that were left behind has the potential to contribute to the identity of local places in the coming renewal.

In the future the addition of Lynetteholm is going to extend the island to the northeast. Buses and charging stations for electrical vehicles (including public buses) has already been established.

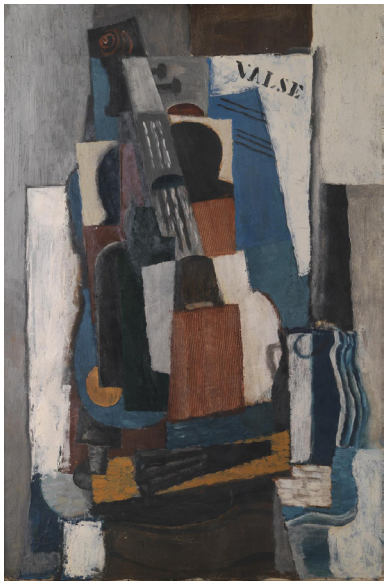
The project site is localized to the south-eastern part of the island. This space stands mostly empty because it for the last couple of years has been used as a festival ground for Copenhell. The festival's contract expires this year and it will be the last year it is held on the site, this means a new plan for the site must be made.

The island is relevant for this thesis because it is situated relatively close to the city centre. It is one of the few largely empty sites around the centre, and with the centre getting more congested the site harbors the potential for a new great urban renewal for the city of Copenhagen.



2. VISION

The island of Refshaleøen is known as the lungs of Copenhagen. It has a historical significance to the city with its industrial buildings and calm atmosphere. This thesis' vision for the new project site for Refshaleøen is to build upon the concept of the place being the lungs of Copenhagen. To build a place where Copenhageners can get out from the congested city and enjoy the city as a vibrant green oasis. The living quarters should stand as an example of how healthy, modern, and quality oriented new housing is still possible in the developer-driven city. The project will respect the existing industrial context and add the to existing activities happening around the island, while providing a safe environment for new inhabitants to start life anew. All this will be achieved through a point of departure in the modernistic architecture design ideals to ensure an ideology-driven design approach. For it is the belief that strong opinion creates architecture with personality.


VALSE

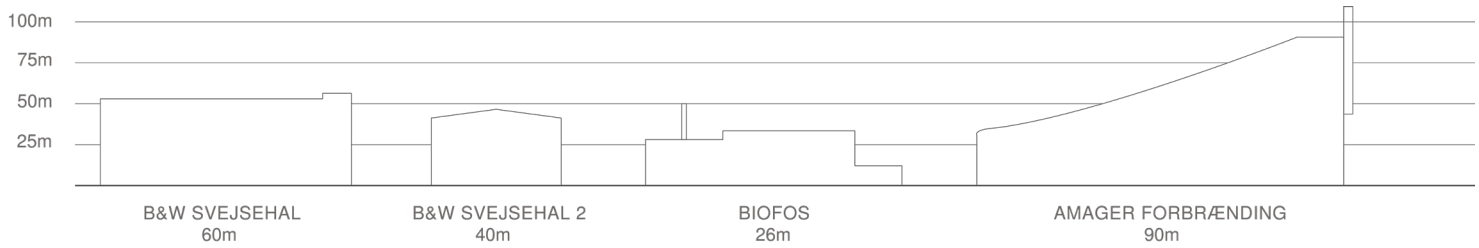
4th PART: STUDIES

1. SCALE
2. B&W
3. GRID
4. THE BUILDINGS
5. THE CULTURE
6. THE NATURE
7. THE MATERIALS


ØSTERBRO
NØRREBRO
REFSHALEØEN
INDRE BY
VESTERBRO
AMAGERBRO

1. SCALE

The scale of the buildings on the island and around the island are characterised by mostly large industrial buildings. These buildings stands wide and tall as almost monoliths when you stand near them. Due to the history of the place around the site, one will also find other industrial buildings outside the site. Namely Amagerforbrænding. The scale and size of these buildings create an atmosphere on the site that is built on the rational concepts of building for the specific function of the building in relation to the industry. Smaller sheds has been established around these bigger structures, which introduces some scale-mixture.

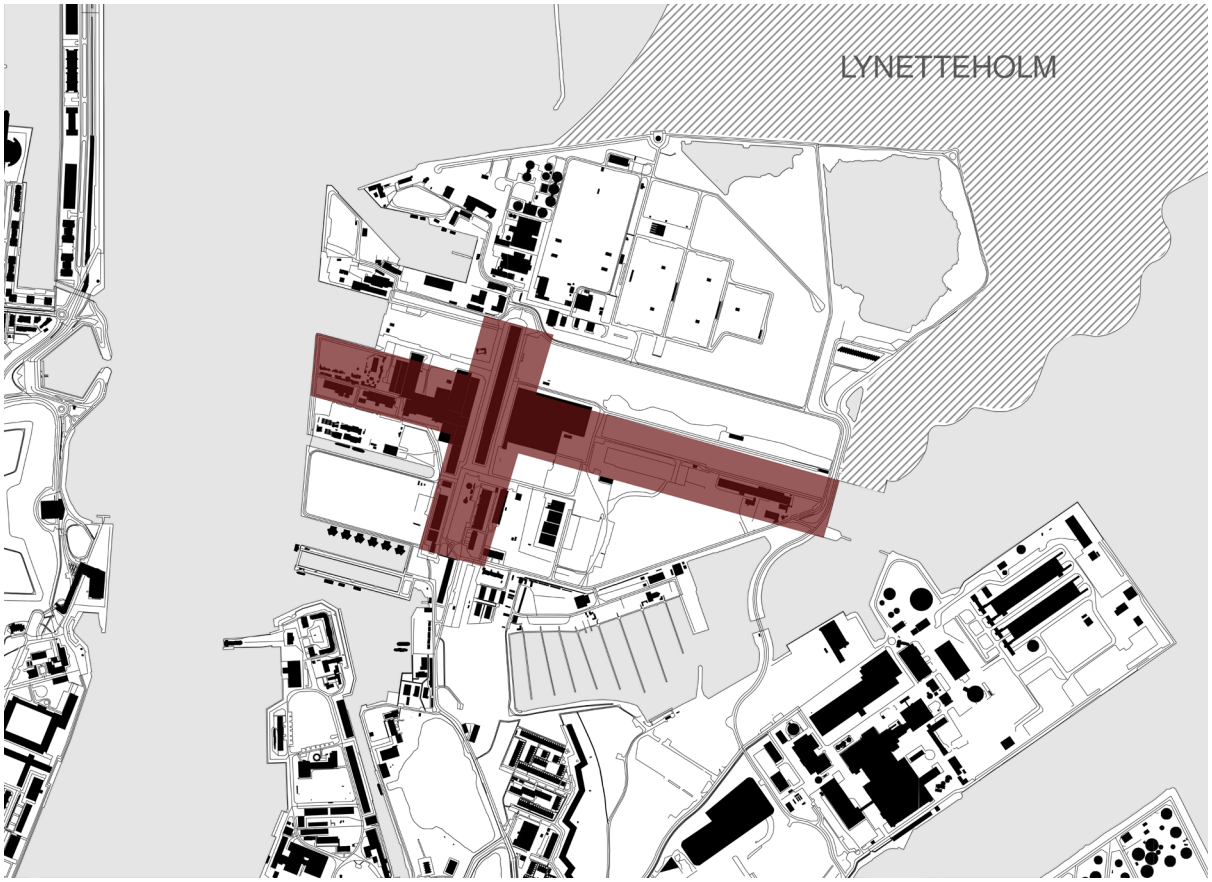


2. B&W

The island was built for the purposes of manufactoring ships and large water-vessels for transportation. This is very apparent both physically and atmospherically on the site. Railways were built for the transport of the industries, and these railways lay the foundation for the cross-like structure on site. This is also reflected on the buildings on the island; they are mostly placed in respect to this already established cross structure.

Because of the very honest architecture, it is somewhat easy to understand the layout and make-up of the place. This also reflects on the outside of the buildings; even though they are mostly heavy and untransparent, the buildings are readible in that they clearly reflect the purpose for what they were built for.

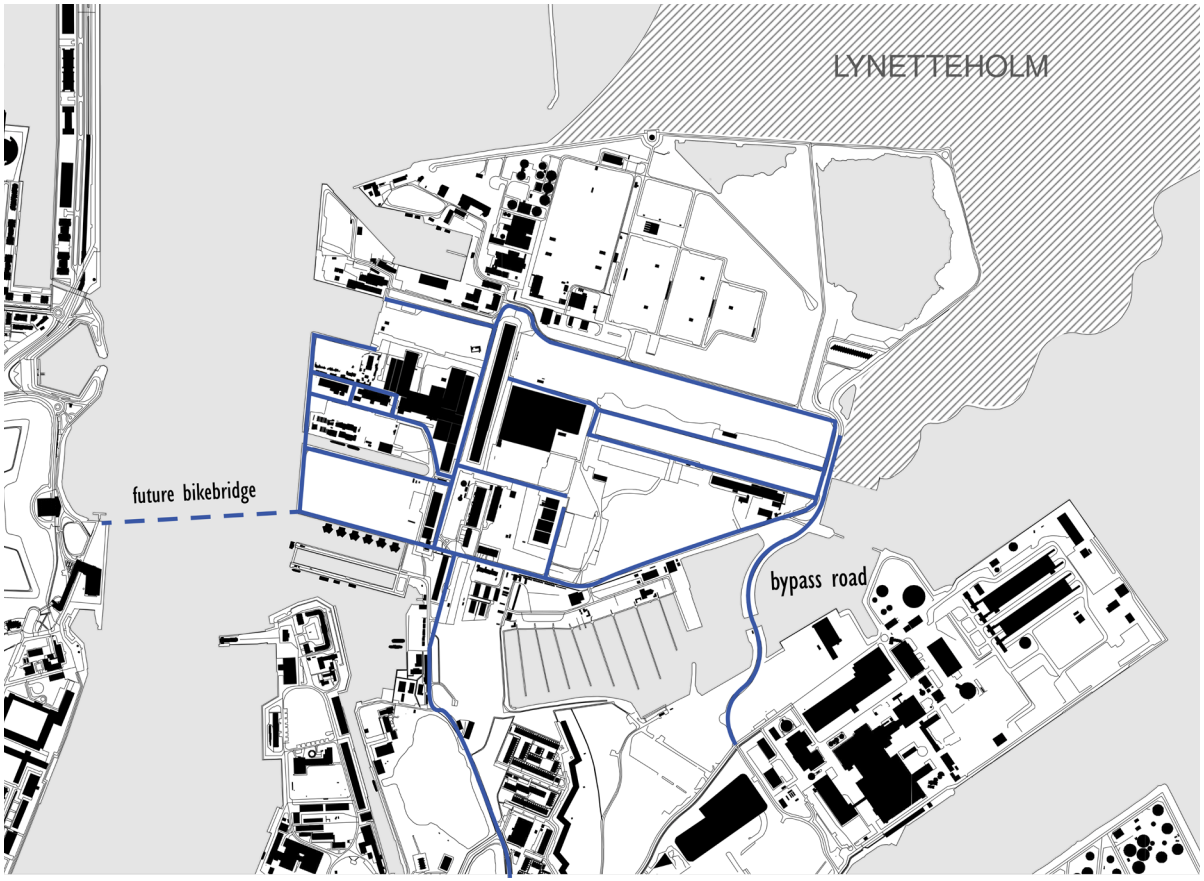
The functionalistic structure and the scale of the buildings has an architectural value that is unique to the island and is a central part of the identity of the place.

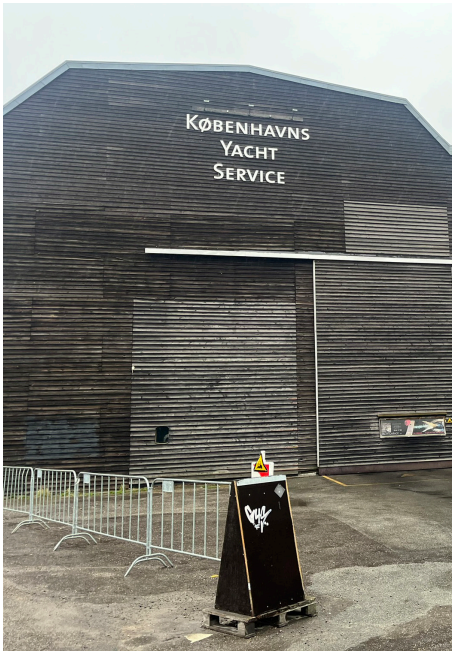


3. GRID

The infrastructure on the site follows a very strict grid structure. This is due to the island's past in industry. The railways and roads were laid to easily transport goods around the different buildings. The grid structure further strengthens the functionalistic and raw atmosphere on the site. Along the coast of the island there are broad bypass-roads, which currently are used for heavy vehicles to transport big loads around the island.

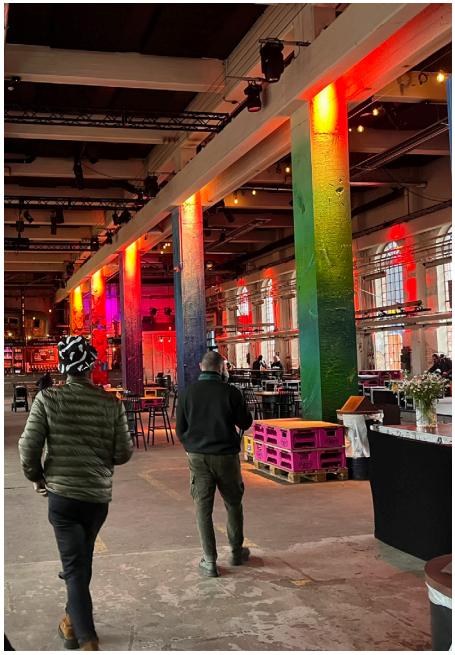
Plans for a bike bridge has been made for easier access to the mainland island. This bike bridge is situated on the west bank of the island and will be an addition for inhabitants of both Refshaleøen and the new Lynetteholm.





4. THE BUILDINGS

The typologies has a wide range on the site. The buildings are generally characterised by being very functionalistic and cheap to build as most of the buildings were built for industrial purposes. This creates a unique feel on the island as a place that presents itself as very unrefined. Renovations has been made to the buildings that has obtained new functions, but these renovations has been made in respect to the existing style, so that the buildings look as they were built.



5. THE CULTURE

The island has for several years been a hotspot for creative minds and cultural gatherings. All year around "Reffen" draws people from all over the country for a selection of food. Once a year during summer the rock-metal festival Copenhell is held on the island. The island is also home to the museum Copenhagen Contemporary. As such the island stands as a tourist hotspot for non-Copenhageners and a breathing hole for Copenhageners, who are looking for an escape from the busy city centre.

6. THE NATURE

The nature is wild and overgrown. There are many different species and types of plants; trees, bushes, stand-alone vegetation and grassy areas. The vegetation does not necessarily outline any areas or create barriers. The most overgrown areas are characterised by the fact that they might be inaccessible.







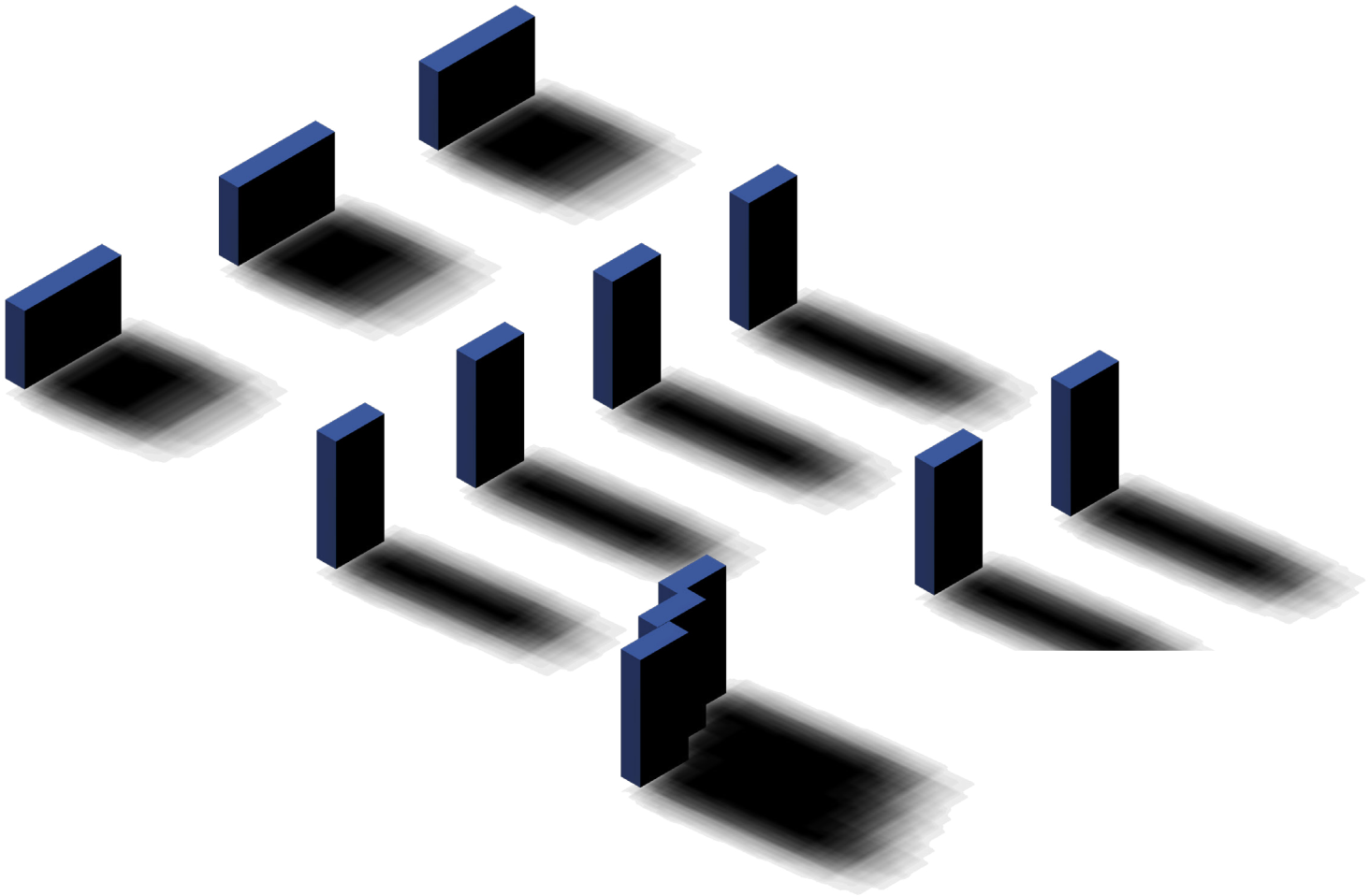


7. THE MATERIALS

The materiality on site are characterised by rough and unprocessed materials. The buildings are mostly constructed with concrete, metal and occasionally some simple wooden constructions. Attempts at decorating the raw facades has been made by painting various planes. The rough materials has a certain style in itself that contributes to the overall atmosphere on the island.

5th PART: DESIGN PROCESS

1. FORM AN SHADOW
    a. understanding shadows
    b. the dimensions
    c. shadows on surfaces
2. BUILT/URBAN AREAS
    a. dense placement
    b. limited placement
    c. equidistand placement
3. URBAN DENSITY AND SHADOWS
    a. fewer buildings
    b. more buildings
    c. more buildings + towers
4. DIMENSIONING OF CONCRETE DECK
    a. load analysis
    b. material properties
        I. prefabricated concrete
        II. rebar
    c. 1st iteration
    d. 2nd iteration
    e. discussion



1. FORM AND SHADOW

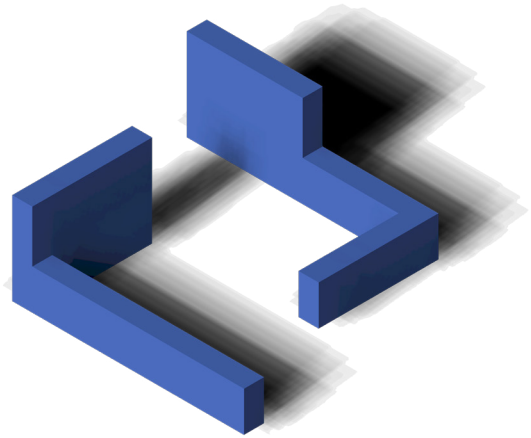
UNDERSTANDING SHADOWS

One important factor when designing a masterplan, the building shadows and understanding how they act on site. This means that it is important to make sure that the shadows do not influence the urban areas negatively. An example of such a case could be an urban area allocated so that it's in shadows constantly because the surrounding buildings either are too close or too bombastic. The shadows can also impact the surrounding buildings and result in dark living spaces. Analyzing shadows is therefore necessary to ensure comfort and wellbeing for the different users of the site.

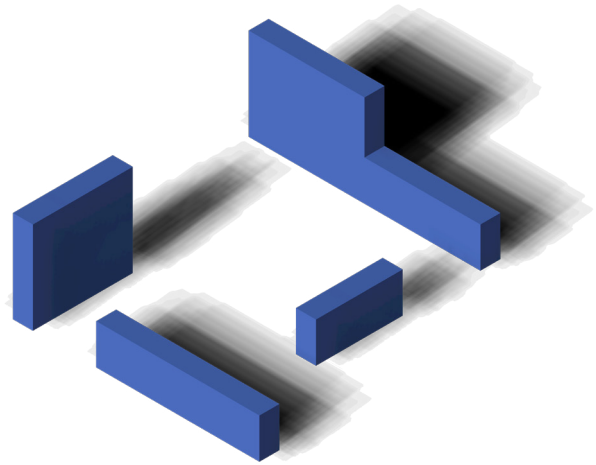
THE DIMENSIONS

When analyzing simple structures such as shown it is extremely straightforward to acknowledge the fact that some of the structures bring a more lightweight than others. Here we for instance see the blocks furthest back, that compared to the ones in front of them, seems way denser and darker. The harshest example is the zig-zag structure, that forms a very distinctive shadow.

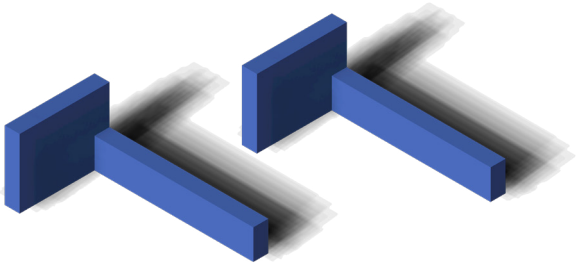
SHADOWS ON SURFACES



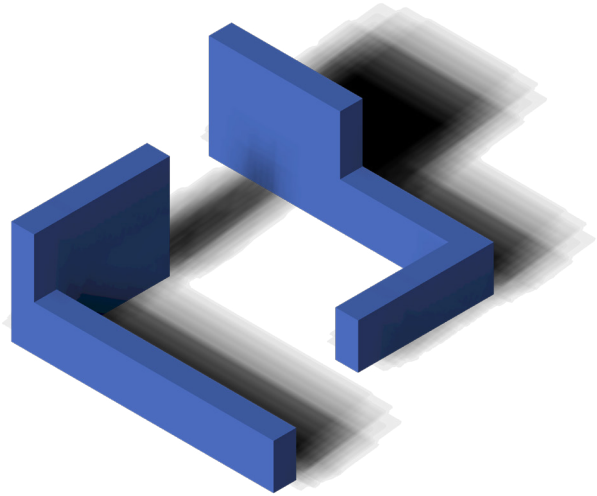
This structure shadows itself, which leads to dark corners and less enjoyable apartments. Otherwise, the urban area does not seem to get obstructed by too many shadows.



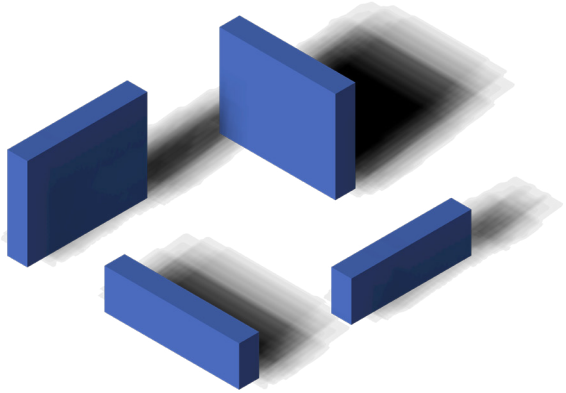
This structure does not shadow itself, thereby all the apartments will be equally enjoyable.The urban area inside the structure get a lot of sun, but there is created some voluminous shadows outside the structure.



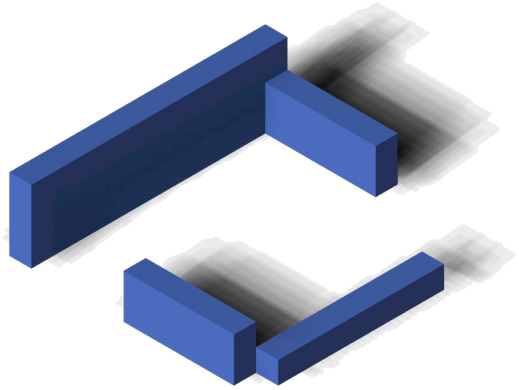
This structure does not shadow itself, thereby all the apartments will be equally enjoyable.The urban area inside the structure get a lot of sun.



This structure shadows itself, which leads to dark corners and less enjoyable apartments. Otherwise, the urban area inside the structure does not seem to get obstructed by too many shadows. on the other hand there is some voluminous shadows outside the structure.

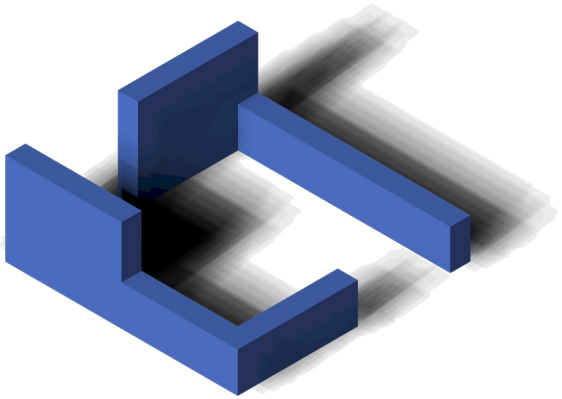


This structure does not shadow itself, thereby all the apartments will be equally enjoyable.The urban area inside the structure get a lot of sun, but there is created some voluminous shadows outside the structure.

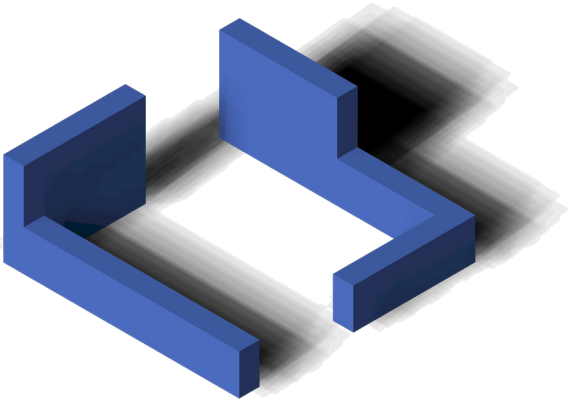


This structure shadows itself, twhich leads to dark corners and less enjoyable apartments. The urban area inside the structure get a lot of sun, but there is created some voluminous shadows outside the structure.

This structure shadows itself, which leads to dark corners and less enjoyable apartments. Furthermore, the urban area does seem to get obstructed by shadows , so overall the shadows dominate.

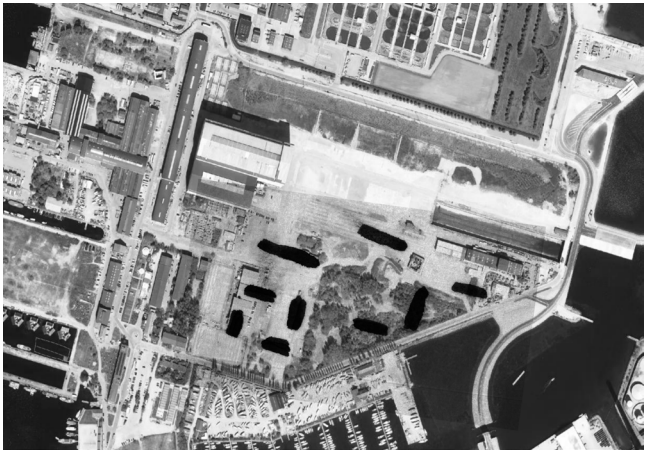


This structure shadows itself, twhich leads to dark corners and less enjoyable apartments. The urban area inside the structure get a lot of sun, but there is created some voluminous shadows outside the structure.



2. BUILT/URBAN AREAS

DENSE PLACEMENT



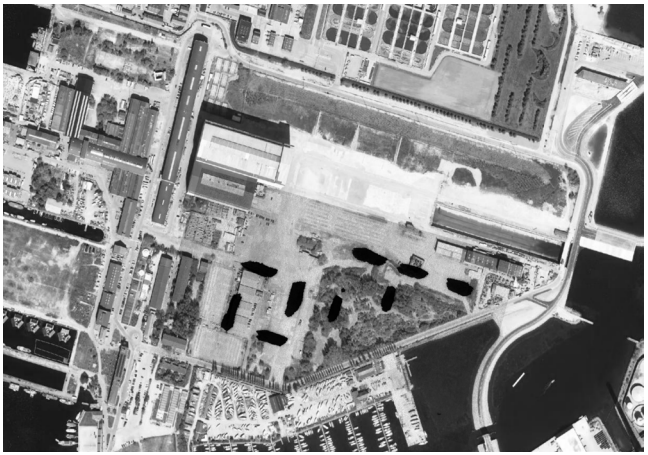
The forms create several inward-pointing urban areas that enhance the possibility to visually exclude heavy traffic from the center of the site. The forms are densely placed and leaves an open area towards the welding hall.

LIMITED PLACEMENT

The forms create several outward-pointing urban areas that diminish the possibility to visually exclude heavy traffic from the center of the site. The limited number of forms necessitates the need for taller buildings. The urban area in front of the welding hall is very open.

EQUIDISTANT PLACEMENT

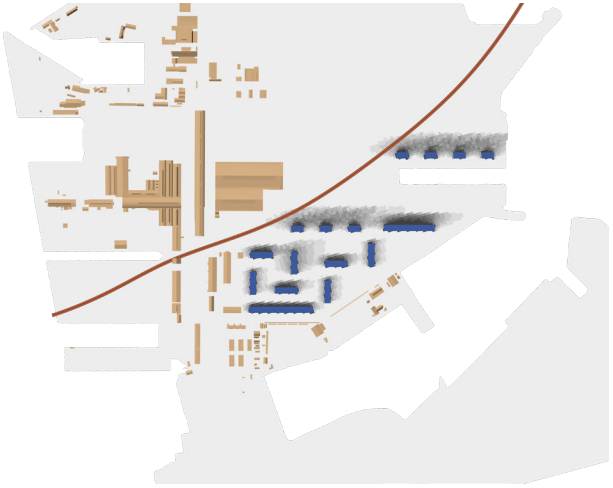
The forms create urban areas that focus inward and away from the traffic, while still creating some urban areas that approach the trafficked part of the site. This layout allows for a shorter building height with this more compressed site.



3. URBAN DENSITY AND SHADOWS

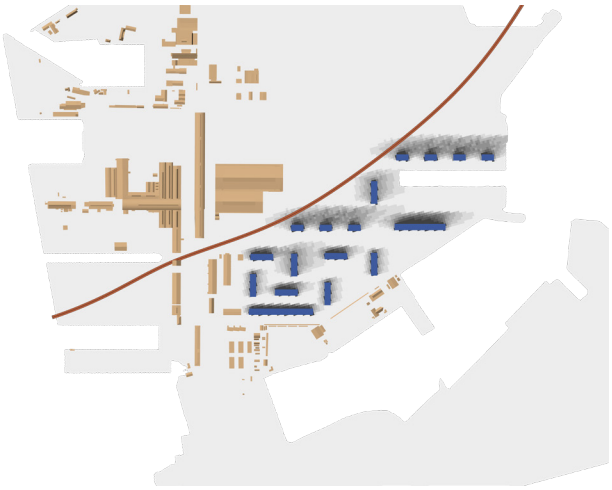
To design with urban density in mind, it is important to analyze different scenarios to ensure that neither the urban area nor the surrounding buildings is bathed in too many shadows throughout the day. In this project it is especially important that the building and the urban areas is sun-filled during the afternoon to allow the users to enjoy the sun during their spare time.

FEWER BUILDINGS



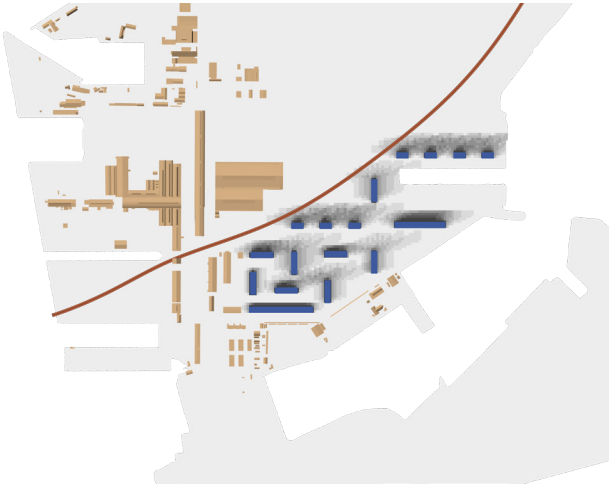
The structure allows for urban areas that is not dominated by shadows during the afternoon and none of the buildings is exposed to shadows from neighboring buildings.

MORE BUILDINGS



The structure allows for a higher urban density, while the urban areas still is not dominated by shadows during the afternoon and none of the buildings is exposed to shadows from neighboring buildings.

MORE BUILDINGS + TOWERS

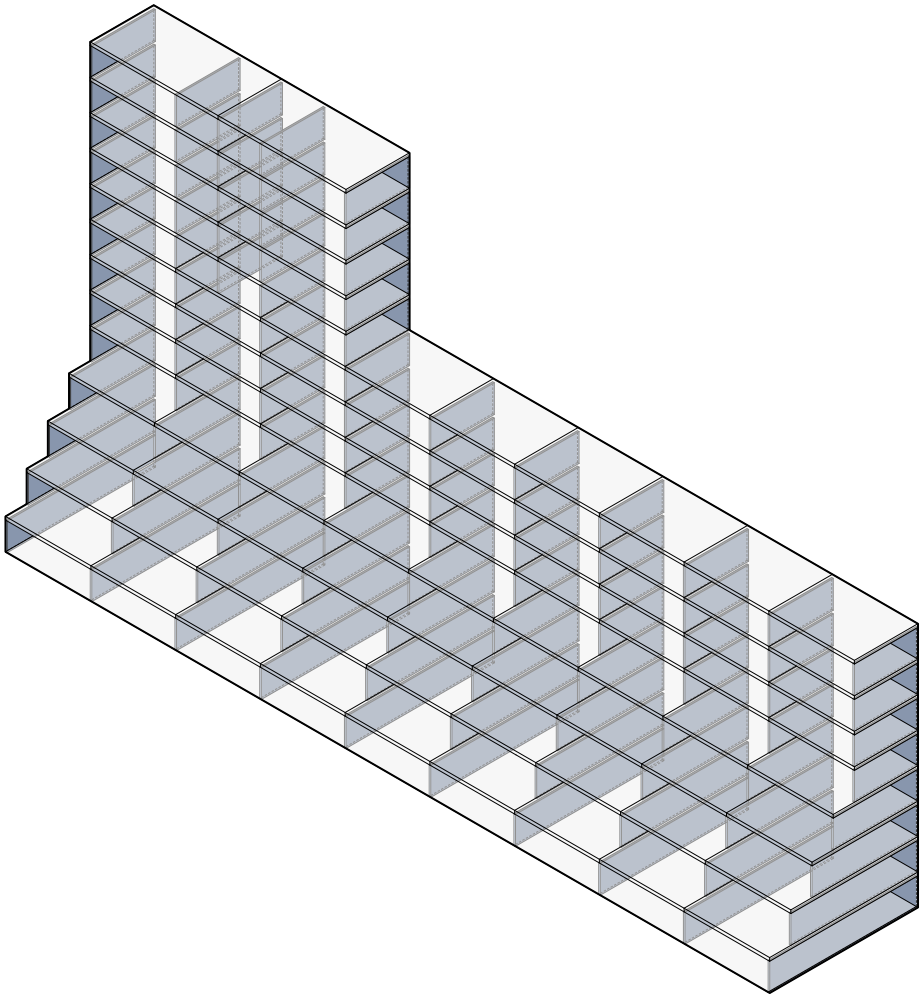


The structure allows for the highest urban density, while the urban areas still is not dominated by shadows during the afternoon and none of the buildings is exposed to shadows from neighboring buildings.

4. DIMENSIONING OF CONCRETE DECK

To ensure the structural integrity of the apartment buildings, a dimensioning of the concrete decks will be conducted. Since the construction only consists of one-way slabs, they will be calculated as a range of beams with a width of one meter. The process involves a definition of the material properties, a load analysis and the showcasing and screening of two different iterations from the process. Other iterations can be found in appendix 1.

The dimensioning is based on a deck in one of the senior apartments, which is wider than the other types of apartment-types and therefore will function as a critical apartment.



LOAD ANALYSIS

Characteristic dead weight: $g_k = 7{,}66\frac{kN}{m^2} * 1 = 7{,}66\frac{kN}{m}$

Flooring structure consists of:

- 22mm floorboard (hardboard): $0{,}022 * 7 = 0{,}15 kN/m^2$
- Mineral wool + joists: $\sim 0{,}05 kN/m^2$
- 400mm reinforced concrete: $0{,}200 * 25 = 5 kN/m^2$
- 13mm plasterboard ceiling: $0{,}013 * 9 + 25\%\ (ophæng) = 0{,}30\ kN/m^2$

Load-baring partitions: $0{,}120 mm * 18 = 2{,}16 kN/m^2$

Characteristic live load: $q_k = 2{,}0\frac{kN}{m^2} * 1 = 2{,}0\frac{kN}{m}$

The live load for a dwelling is $2{,}0\ kN/m^2$

The beams permissible load is:

$$p_d = g_k * 1{,}0 + q_k * 1{,}3 \Rightarrow p_d = 7{,}66\frac{kN}{m} * 1 + 2{,}0\frac{kN}{m} * 1{,}3 = 10{,}26\frac{kN}{m}$$

The beams permissible momentum is:

$$M_{max} = \frac{1}{8} * q * l^2 \Rightarrow M_{max} = \frac{1}{8} * 10{,}26\frac{kN}{m} * 12^2 = 184{,}68\frac{kN}{m}$$

MATERIAL PROPERTIES

PREFABRICATED CONCRETE

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu3} = 0{,}35\%$

REBAR

S550

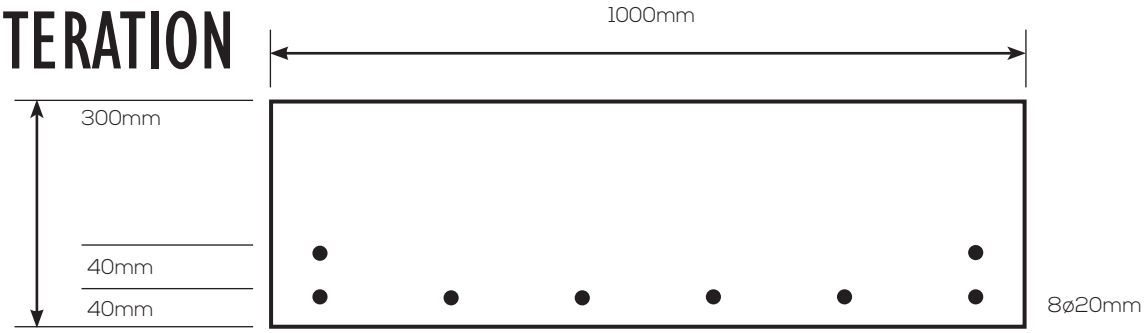
Diameter = 20mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

1ST ITERATION



a = 142mm ≥
- ø = 20MM
- D_G+5MM = 69MM
- 20MM

How much momentum can the beam withstand?

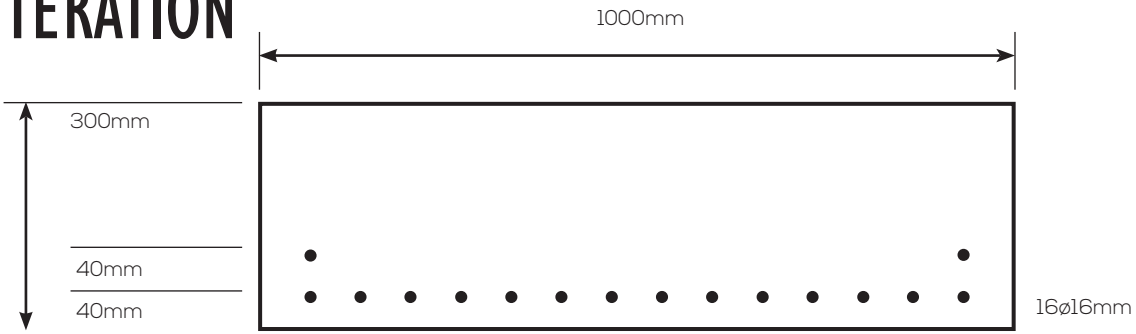
$M = 198kN/m$

The calculated strain on the beam.

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 1{,}4\% < 5\%$

Aggregate type: coarse (singles)
Size: 32-64mm

2ND ITERATION



a = 66mm ≥
- ø = 16mm
- d_g+5mm = 37mm
- 20mm

How much momentum can the beam withstand?

$M = 232kN/m$

The calculated strain on the beam.

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 2{,}4\% < 5\%$

Aggregate type: gravel (nødder)
Size: 16-32mm

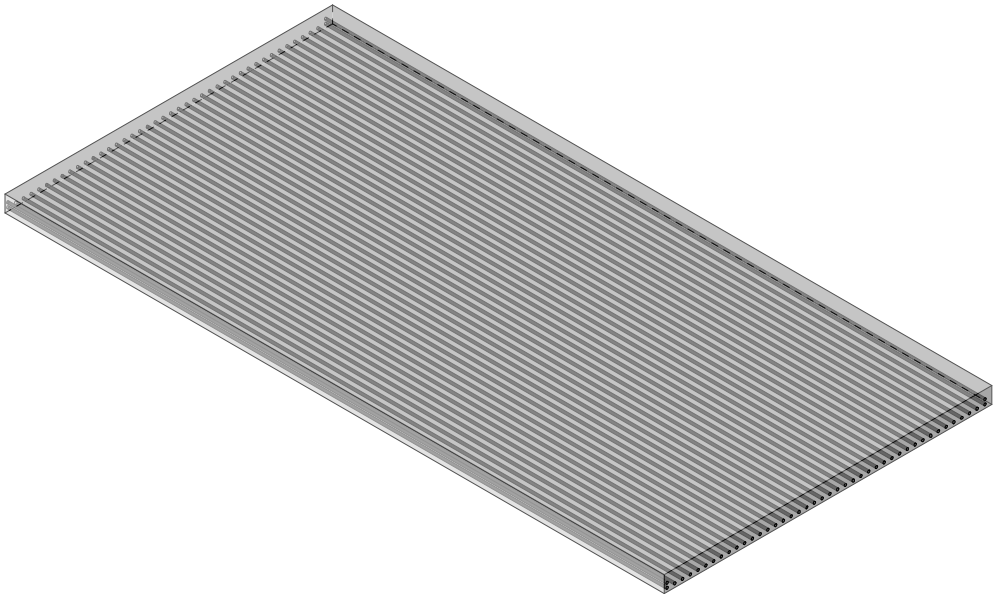
DISCUSSION

To ensure the best possible cross section of the two iterations, they will be evaluated on the basis of sustainability, cost efficiency and overall durability.

Iteration 1 allows for a coarse-sized aggregate which enhances the concentration of recycled material, such as reused concrete or gravel, in the construction and therefore minimizes the overall carbon footprint. This leads to a construction based on moderate sustainability where both structural integrity and material efficiency, especially seen in the limited processing during production, is balanced. Iteration 2 on the other hand, still allows for medium-sized aggregate, but with the smaller distance between the rebar, the concrete will be less sustainable than iteration 1. This is followed by the fact that iteration 2 also contains more rebar than iteration 1, which means that the construction would become more expensive and require more processing during production.

Both cross sections can withstand the beams permissible momentum but one could argue that iteration 2 would allow for a more sustainable and adaptable solution, since the beam can withstand the most amount of momentum, and therefore allow for the building to become more adaptable in the future if needed. On the contrary, if choosing iteration 1, one can argue that the overall construction would be more sustainable with less rebar and larger aggregate. With the amount of momentum, that iteration 1 can withstand, still being far more than the beams permissible momentum, it can still allow for some adaptability in the future.

Based on the evaluation on the two iterations, iteration 1 will be the cross section utilized in the building. This is mainly based on the fact that the cross section allows for a coarser aggregate and less rebar, leading to a more sustainable and cost-efficient construction.



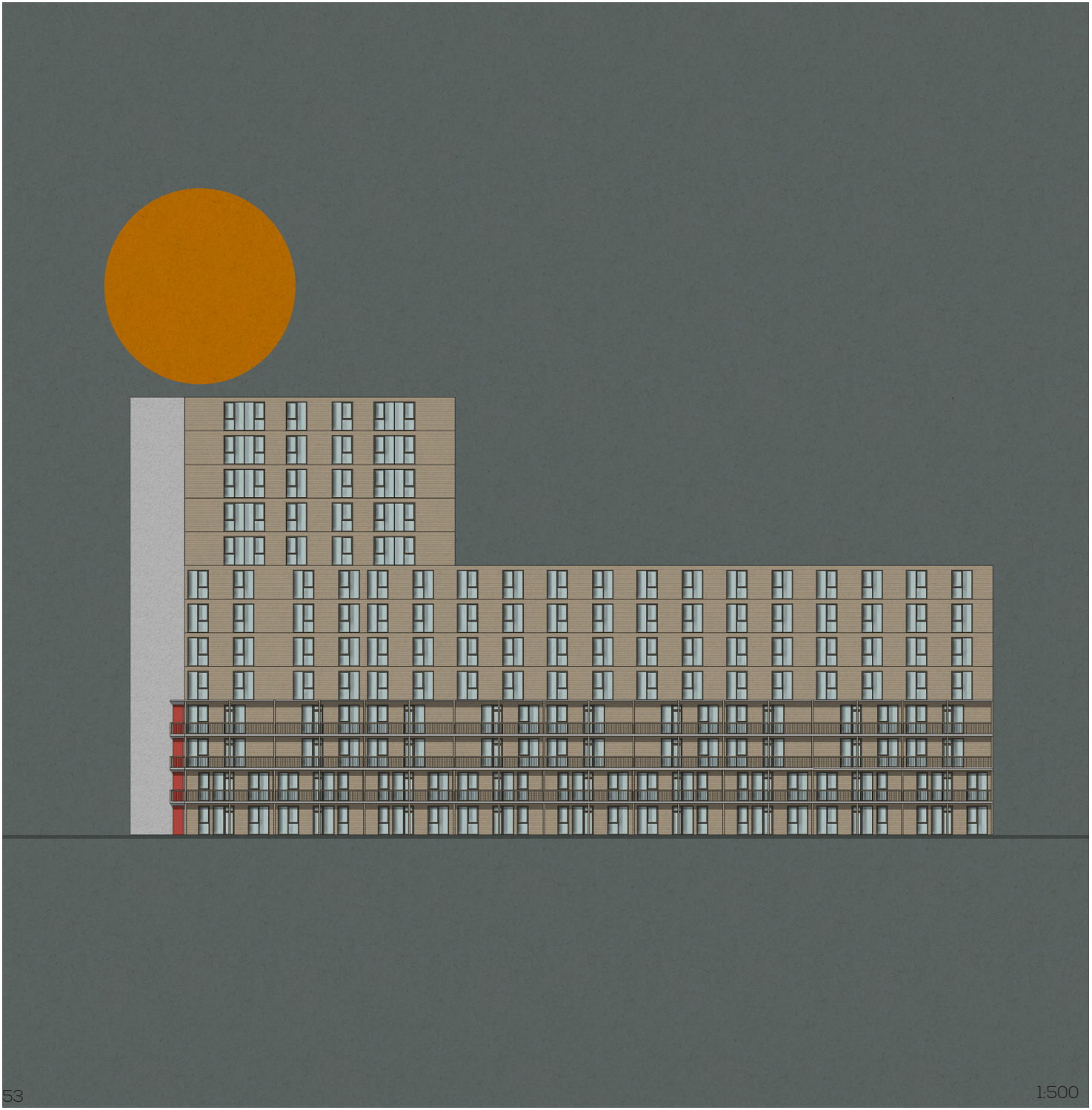
6th PART: PRESENTATION

1. MASTERPLAN
2. BUILDING SCALE
3. OUTDOOR AREAS
4. THE GROUND FLOOR
5. THE FIRST FLOOR
6. THE SECOND FLOOR
7. THE THIRD FLOOR
8. THE FOURTH FLOOR
9. THE EIGHTH FLOOR
10. CONCEPT DIAGRAM
11. DAYLIGHT FACTOR
12. BE18

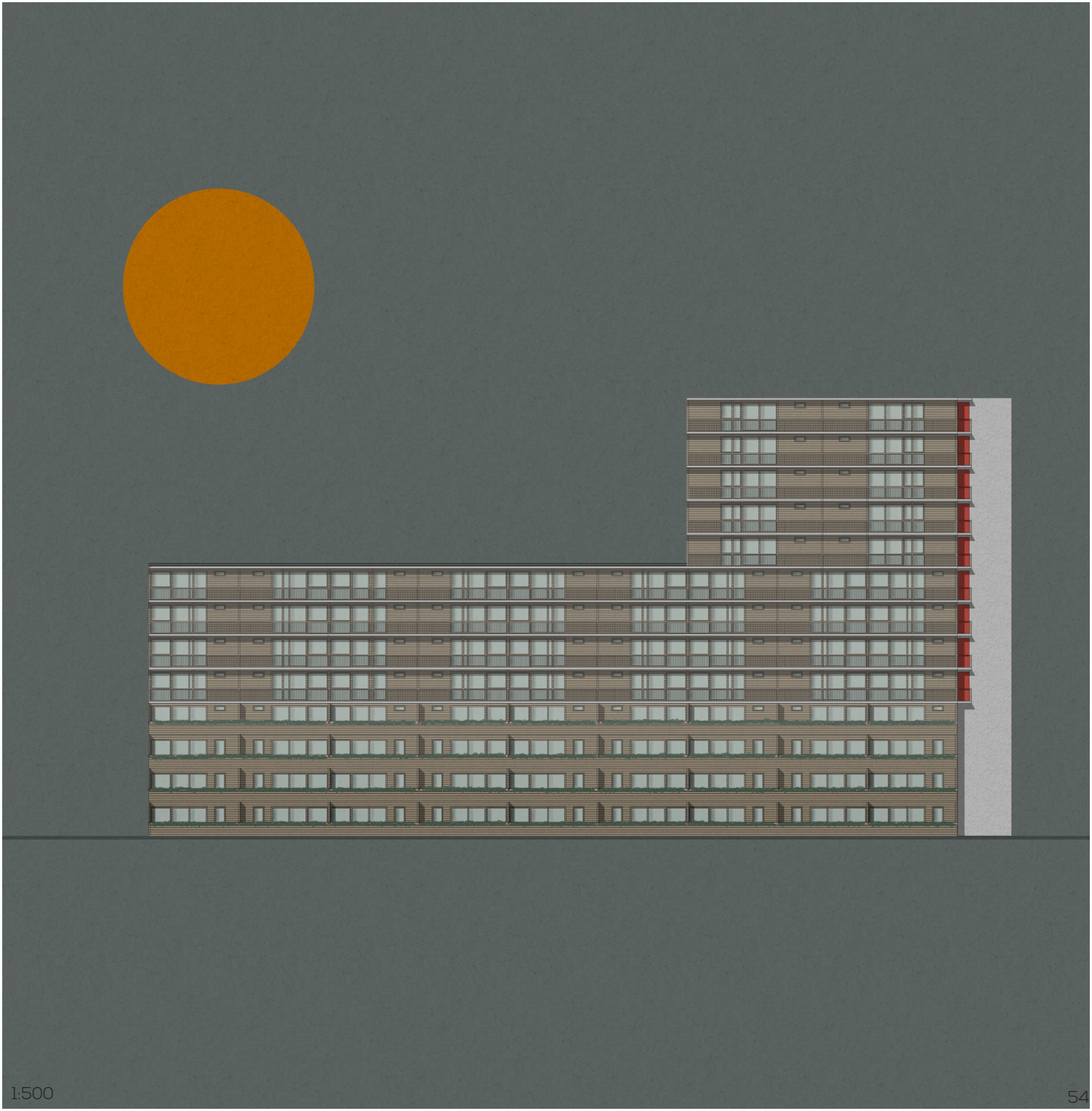

N
1:3000

1. MASTERPLAN

The masterplan showcases the ratio between the built and the green urban spaces. By minimizing the buildings' footprint, the masterplan allows for the integration of large green urban spaces. The different urban spaces consist of an array of different types of stops and activities including large green areas with the possibility to relax and enjoy the nature, sport facilities, plazas in connection to the existing area's cultural activities and swimming facilities.
By excluding cars and other heavy traffic, the infrastructure will allow the pedestrian to fully utilize the area with a direct bike/walking connection to the rest of Copenhagen. Furthermore, the site consists of a web of small twisted paths, that creates different semi-private zones and areas.



1:500



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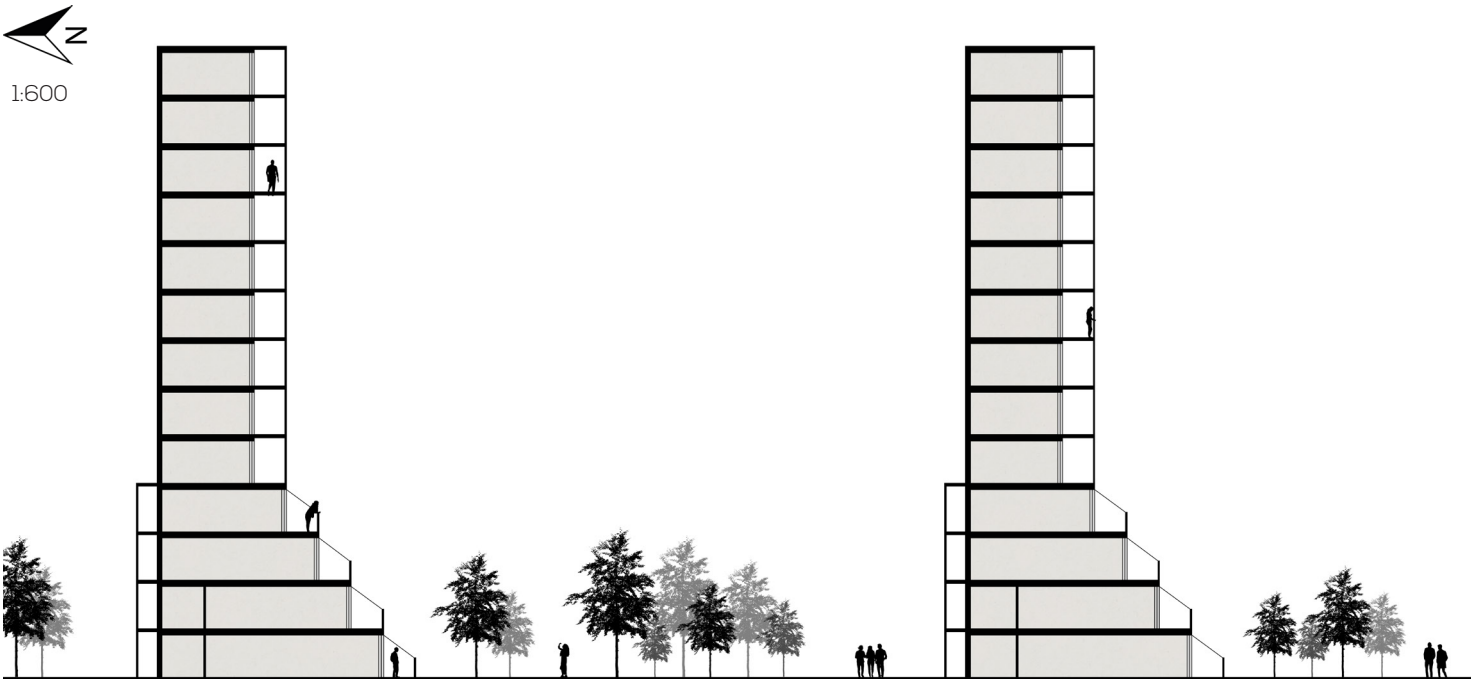
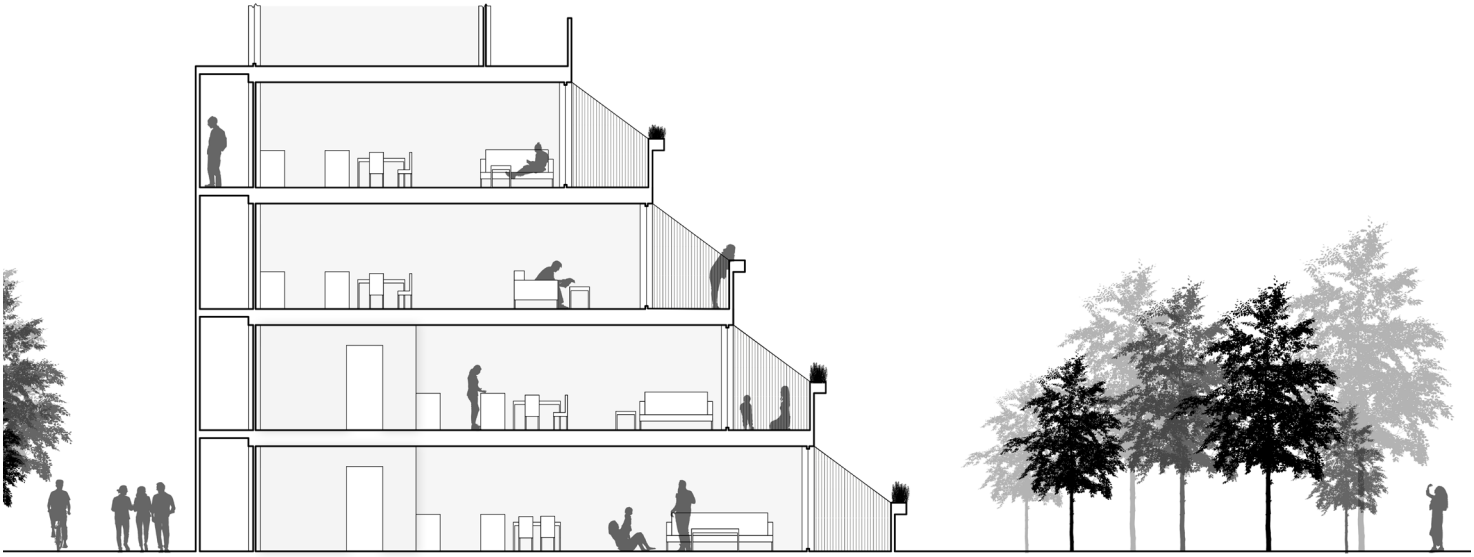


2. BUILDING SCALE

By using a stepped pattern in the shaping of the four bottom stories, the buildings is perceived to be shorter than its factual height and in combination with the trees from the urban areas, it has been possible to achieve a less harsh and monumental expression of the buildings.

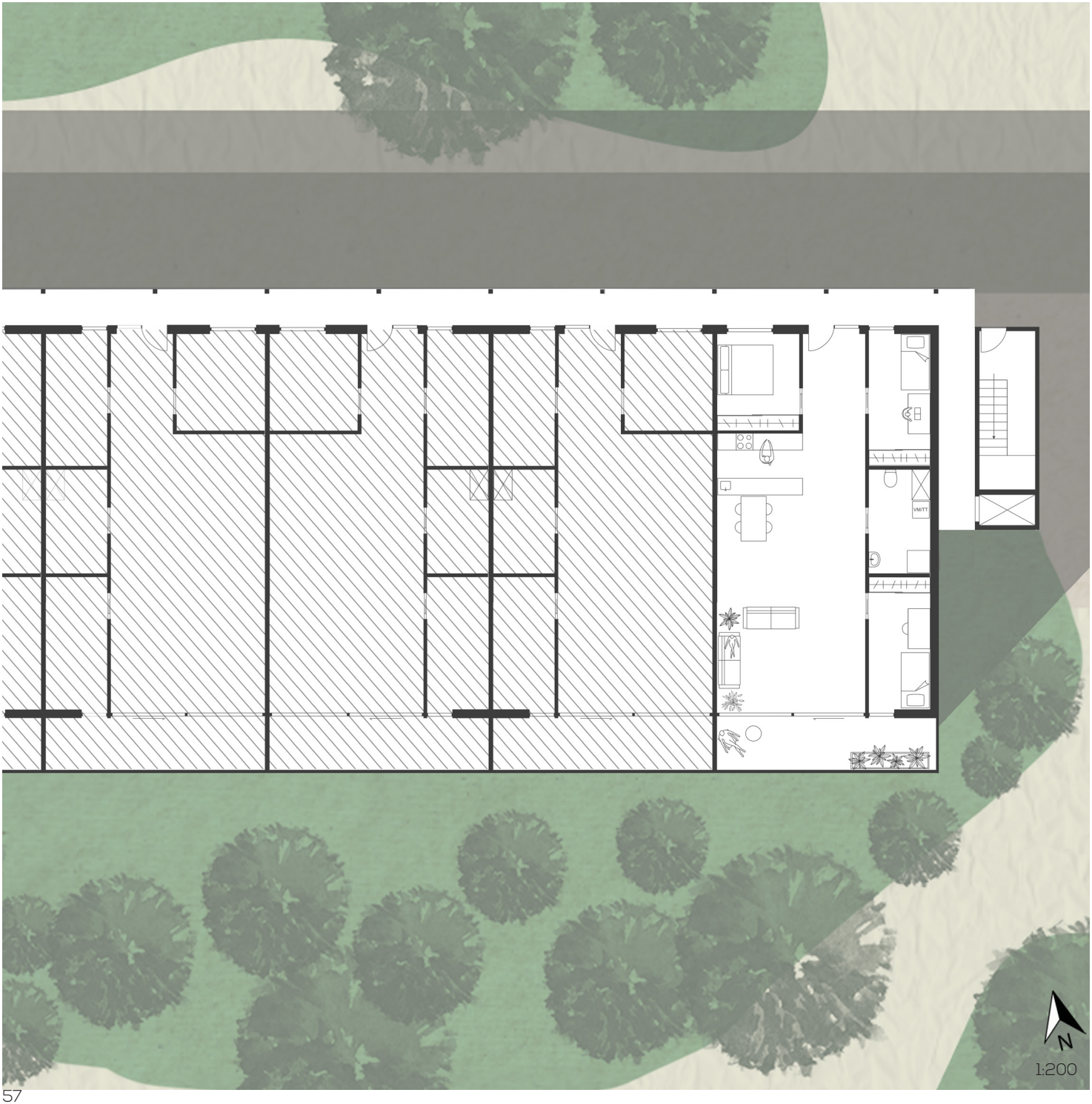
N

1:200



By utilizing the stepped form of the buildings, it is possible to create common areas and private balconies with optimum light conditions. With the purpose of allowing the residencies to privacy in their outdoor areas, the placement of a multiple trees between balconies and the public paths is utilized to minimize the vision.

3. OUTDOOR AREAS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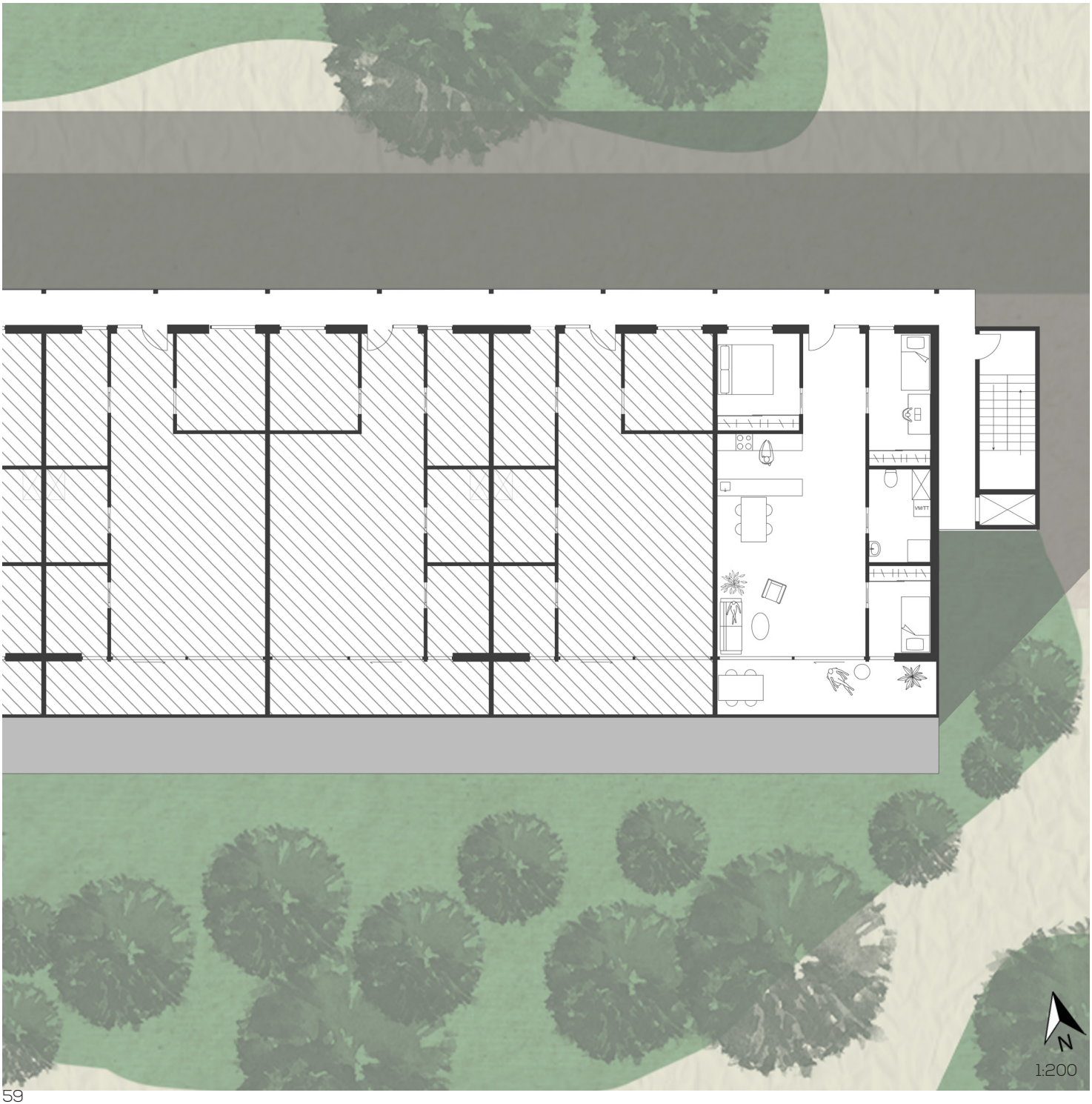
4. THE GROUND FLOOR

FAMILY HOUSING 112 KVM^2

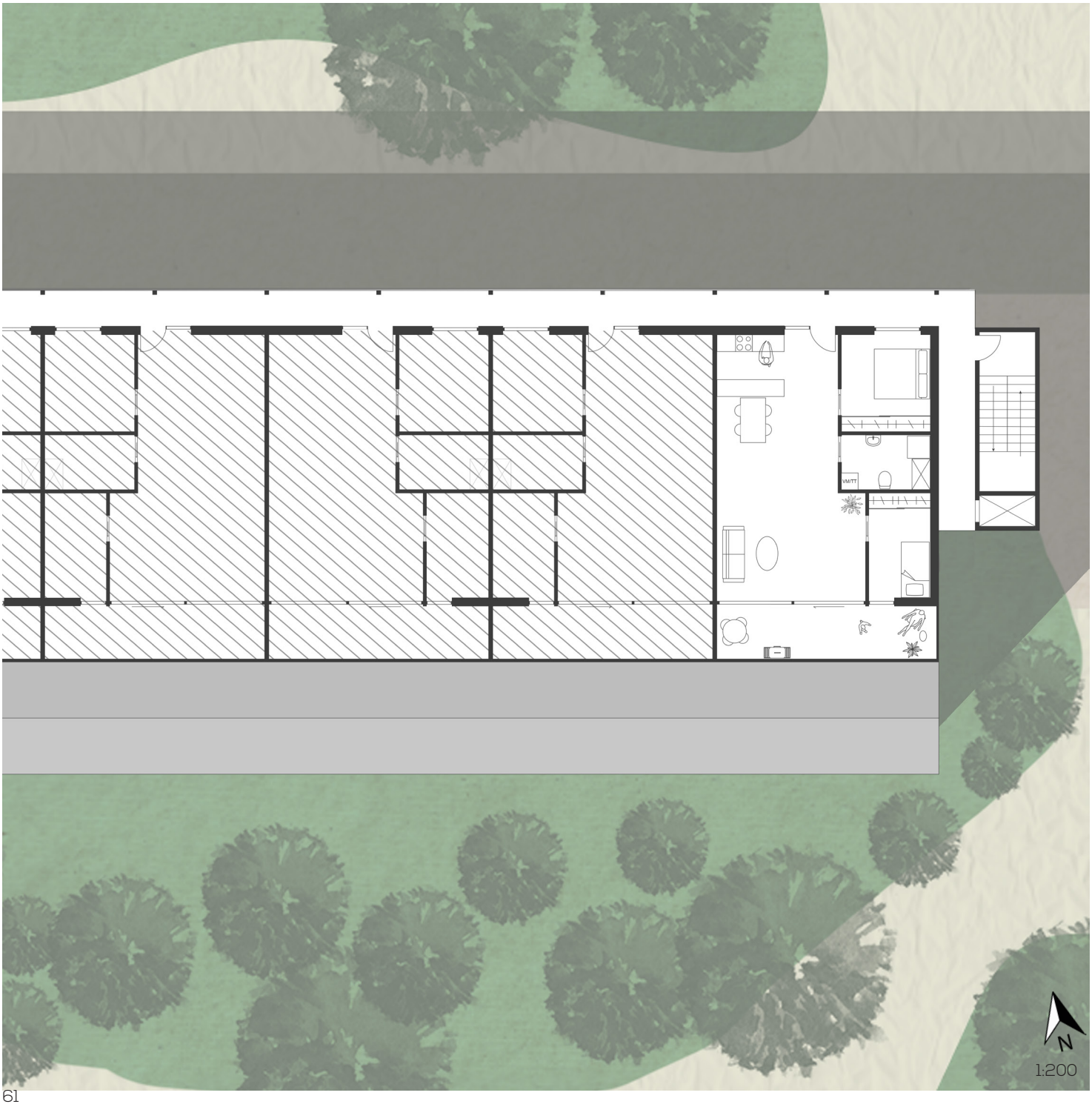
The ground floor consists of a family room, a toilet and three bedrooms. This plan type would be ideal for a family of four, since it consists of a master bedroom and two smaller bedrooms. The apartment has a north/east-facing external gallery and a south/west-faced 16kvm^2 private balcony. An important detail is the large sliding door facing the balcony that enables an elongation of the living spaces outwards.


VM/TT
N
1:200

5. THE FIRST FLOOR

FAMILY HOUSING 96 KVM^2

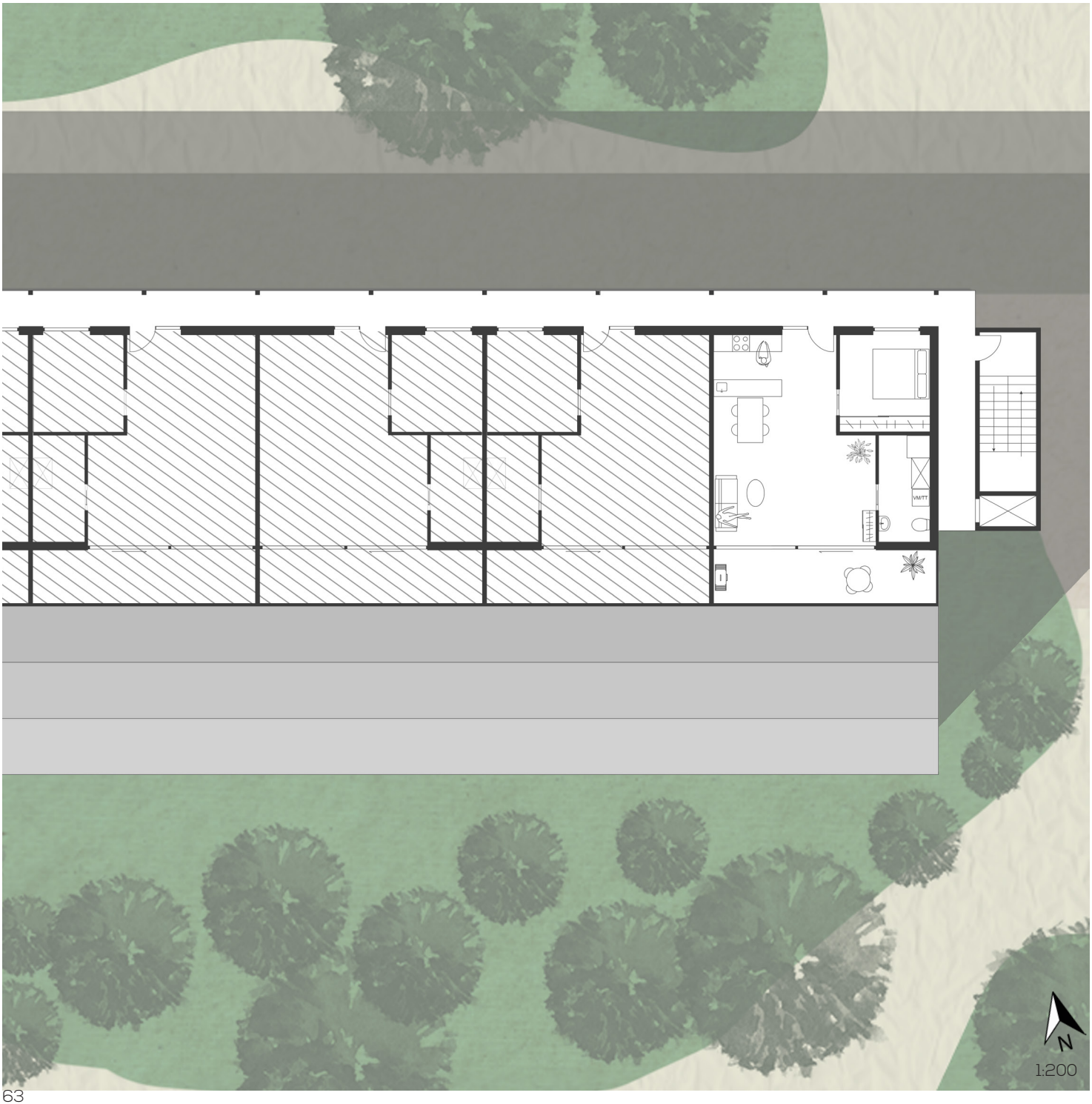
The first floor consists of a family room, a toilet and three bedrooms. This plan type would be ideal for a family of four, since it consists of a master bedroom and two smaller bedrooms. The apartment has a north/east-facing external gallery and a south/west-faced 16kvm^2 private balcony. An important detail is the large sliding door facing the balcony that enables an elongation of the living spaces outwards.


N
1:200

6. THE SECOND FLOOR

FAMILY HOUSING 80 KVM^2

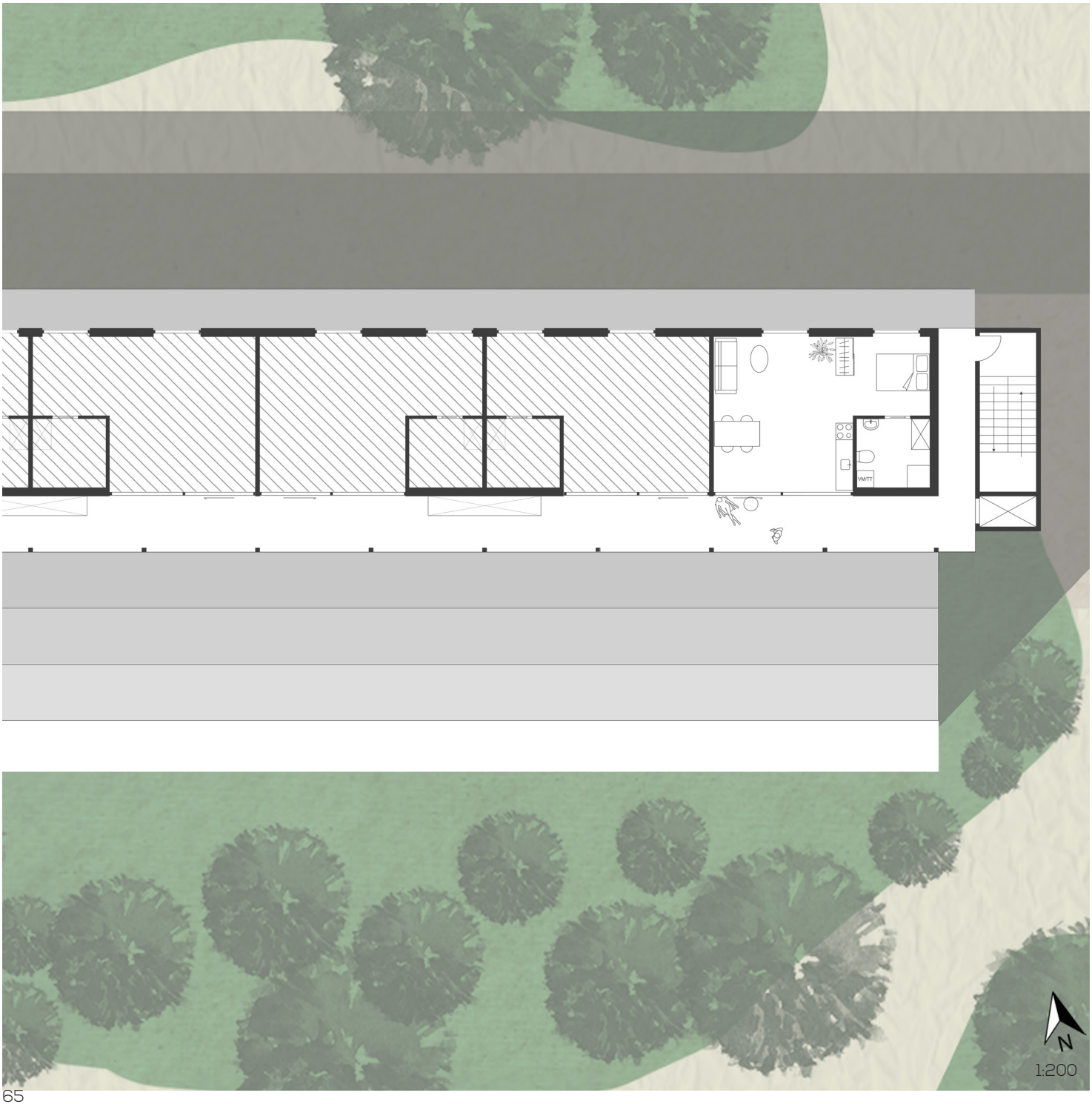
The second floor consists of a family room, a toilet and two bedrooms. This plan type would be ideal for a family of three, since it consists of a master bedroom and one smaller bedroom. The apartment has a north/east-facing external gallery and a south/west-faced 16kvm^2 private balcony. An important detail is the large sliding door facing the balcony that enables an elongation of the living spaces outwards.


VM/TT
N
1:200

7. THE THIRD FLOOR

FAMILY HOUSING 64 KVM^2

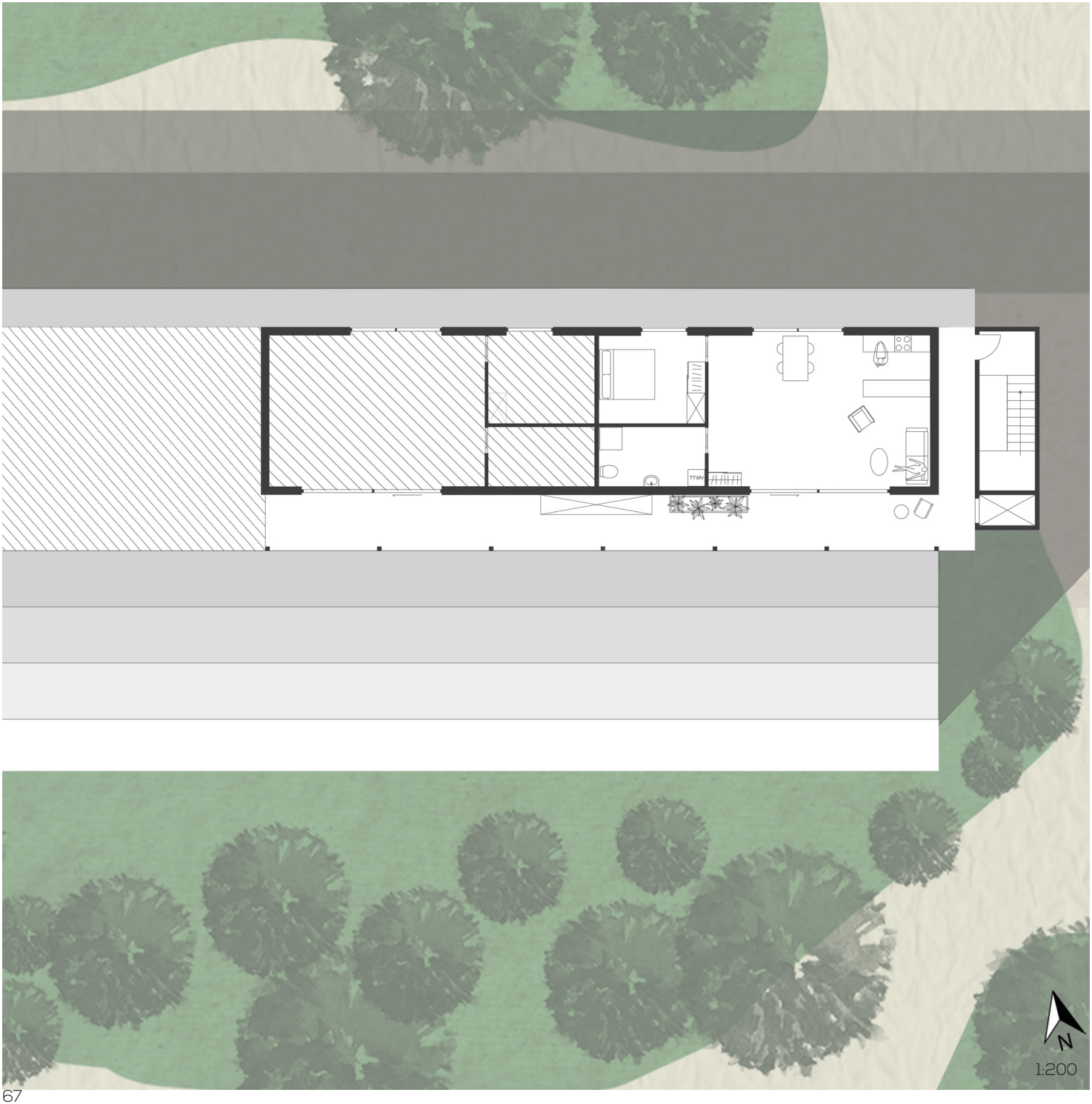
The third floor consists of a family room, a toilet and one bedroom. This plan type would be ideal for a young couple, since it only consists of a master bedroom. The apartment has a north/east-facing external gallery and a south/west-faced 16kvm^2 private balcony. An important detail is the large sliding door facing the balcony that enables an elongation of the living spaces outwards.


VM/TT
N
1:200

8. THE FOURTH FLOOR

STUDENT HOUSING 48 KVM^2

The fourth floor consists of a one-bedroom student apartment. This plan type would be ideal for a single student or a couple. The apartment has a south/west-faced shared external gallery with enough space to also function as a semi-private space for the residents. An important detail is the large sliding door functioning as the front door, that enables an elongation of the living spaces outwards.

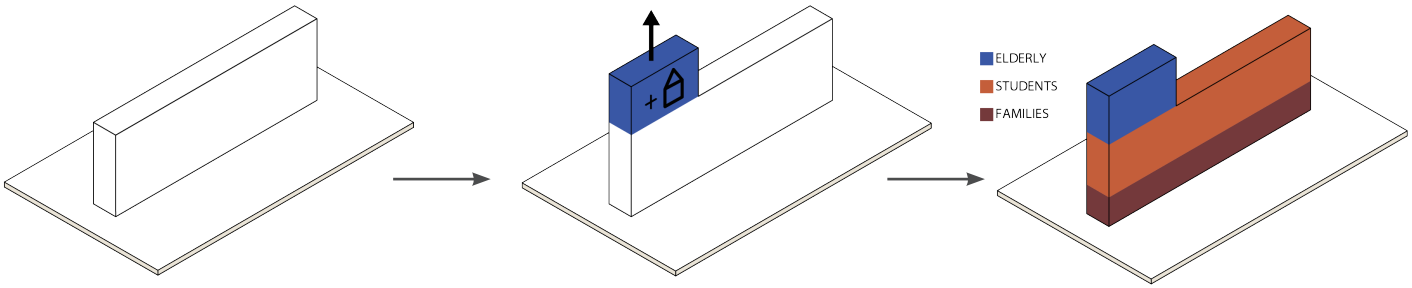

N
1:200

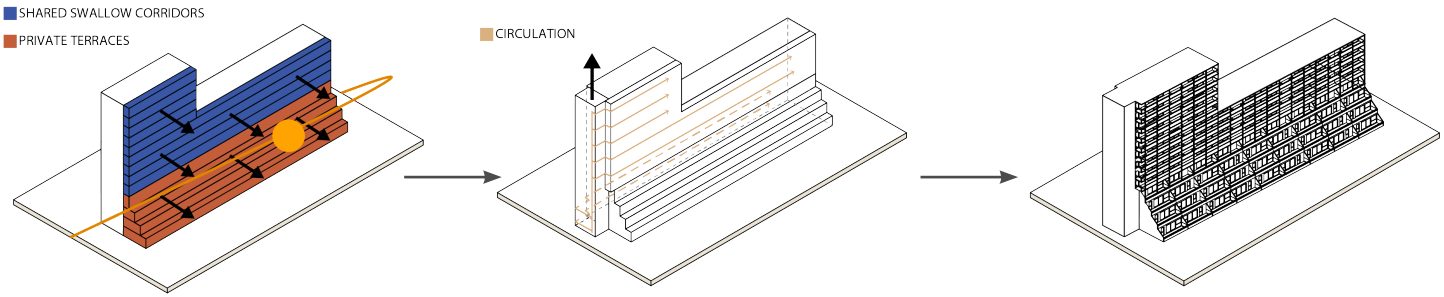
9. THE EIGHTH FLOOR

SENIOR HOUSING 72 KVM^2

The eighth floor consists of a two-bedroom senior apartment. This plan type would be ideal for a single senior or a couple. The apartment has a south/west-faced shared external gallery with enough space to also function as a semi-private space for the residents. An important detail is the large sliding door functioning as the front door, that enables an elongation of the living spaces outwards.

10. CONCEPT DIAGRAM



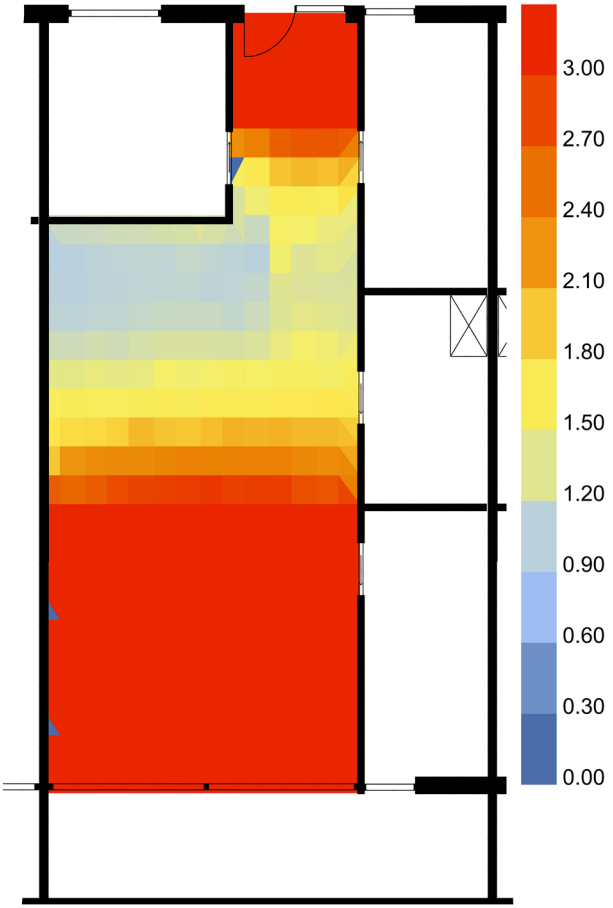

SHARED SWALLOW CORRIDORS
PRIVATE TERRACES
CIRCULATION

11. DAYLIGHT FACTOR

FAMILY HOUSING 112 KVM²

The daylight factor is simulated in the critical apartment which is the family housing apartment on the ground floor since it is the deepest apartment and therefore one with least daylight.

When simulating the daylight factor it is important to state where the daylight factor reaches 3 since this is the desired factor for living quarters. As shown on the illustration, minimum half of the apartment achieves the goal, whereas areas around the kitchen reaches a daylight factor around 1 or so. Since this is in the kitchen and about half of the area is occupied by kitchen tables, most of the area does not necessarily need to achieve the daylight factor of 3.
The conclusion to this is, that the critical apartment reaches the demand of daylight factor, and therefore the rest of the apartments would not meet any challenges regarding daylight.



The apartment buildings total energy requirement is 23,5 kWh/m² per year, which put the building in the energy frame low energy, and with a total electricity consumption of 32,9.
The buildings heat requirement is at 19,1 but is mainly caused by the net requirement of domestic hot water on 12,8, which is an inevitable requirement. As for room heating the building has a demand of 6,3, but it does not have any excessive temperature and therefore no demand for cooling.

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
70.5	0.0	70.5
Total energy requirement		23.5

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
52.9	0.0	52.9
Total energy requirement		23.5

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
30.2	0.0	30.2
Total energy requirement		23.5

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
27.0	0.0	27.0
Total energy requirement		23.5

Contribution to energy requirement

Heat	19.1
El. for operation of bulding	2.3
Excessive in rooms	0.0

Net requirement

Room heating	6.3
Domestic hot water	12.8
Cooling	0.0

Selected electricity requirements

Lighting	0.0
Heating of rooms	0.0
Heating of DHW	0.3
Heat pump	0.0
Ventilators	1.9
Pumps	0.3
Cooling	0.0
Total el. consumption	32.9

Heat loss from installations

Room heating	0.0
Domestic hot water	1.2

Output from special sources

Solar heat	0.0
Heat pump	0.0
Solar cells	0.0
Wind mills	0.0

7th PART: EPILOGUE

1. CONCLUSION
2. REFLECTION
3. APPENDIX
4. REFERENCES

1. CONCLUSION

The aim of this thesis was to reimagine a solution for the upcoming part of Copenhagen on Refshaleøen, while solving the contemporary issues of modern society and city life through a modernist approach; building energy-efficient housing with the intention of improving the quality of life for the average citizen in the city. The approach entails designing with the principles employed through the 1940s and using it as a tool to solve similar problems that was prevalent at that time.

The thesis proposes a solution which combines technical and aesthetic elements through an iterative process to create a new area for the city of Copenhagen on Refshaleøen. The final urban area and blocks reflect a remedy for the symptoms seen in modern society while still accounting for the history and identity of the site. The thesis also proposes a framework for how this design approach, contrary to popular belief, can be used as versatile way to solve modern problems, albeit results of political decisions, through architecture.

The Thesis has been developed through analyses of the target project-site, which aimed to create at foundation for how the solution should relate to its context. Moreover, the thesis is produced through studies of theory and literature that relates itself with contemporary societal issues. Through the process of finding relevant theory, it was important to rely on some that relates itself to several aspects of architecture. Studies on the site and the iterations of the different solutions have been made to ensure an optimal solution for daylight, among other things. Especially the plans for the individual apartments are a center-point for the thesis to argue that a quality home, where the human is in focus, has been met.

Statics with point of departure in a building block has been calculated to ensure a reasonable solution that is founded in a desire to incorporate a technical element into the design at a phase of the process where different outcomes of these calculations could change the direction of the final design. Apart from that it is also implemented from a desire to exemplify the simplicity and functionality of the design, as a versatile construction with many variables that can adapt and change accordingly in relation to scale, function and aesthetics.

By combining these several variables and points of knowledge it was possible to create the design proposal that aims to not only provide the inhabitants with quality housing, but also a monolith that stands as an example of how future housing can be done sustainably and cheap while still exceeding beyond the standard of quality seen in concurrent housing.

2. REFLECTION

OUR POSITION

This thesis has dealt with the renewal of an entire new space on an island with a central position in relation to the biggest city in Denmark. Throughout the project our position on the methods and intentions of the design has been clear, but this also entails the question of whether this position and approach has made the most of the potential of the project site and the framework of the project, and more importantly if it has worked has intended.
One of the reasons for this approach, aside from personal preferences, was the versatile nature of the modernistic approach. Also evident from the many principles that are still used in modern architecture that originate from the modernism, it was possible to investigate this movement and implement its principles and use its tools in a way that made the approach our own in a final design that not necessarily is absolute in modernism. This means that it was possible to draw inspiration and use the literature as a philosophy while still making personal choices that felt grounded in other factors that were made simultaneously with the literature.
New construction today is either very shallowly made with little to no personality or ideology behind it, or an act of power to make a statement often to the demise of functionality. Our approach attempts to combine technical factors with an ideology-driven approach to something that holds strong opinions while simultaneously providing quality housing based on objective measurable variables. In this way the two complement each other and ideally create something greater than the sum of the two.

THE COLLECTION OF KNOWLEDGE

Creating something non-specific on a mostly empty site lays the basis for the opportunity to be creative in the different ways that we could tackle the problem. One consideration could be expanding the scope of literature used in the design process. This will have drawbacks and benefits in relation to the final design, which could benefit in the way it could add more perspective. On the contrary it might also muddy the ideology-driven design and fuel a design without strong opinions playing into the generic architecture that is already being built. Modernism spanned for many years and had a lot of different smaller movements within' itself with varying opinions and contrarian styles. So, in this instance when referring to a modernistic approach it stands to reason to question the scope of that modernism. Due to the scope of the project and the allotted time it was only possible to delve into a selection of literature and contemporary works, but for a more thorough explanation and nuanced interpretation of what the modernistic approach has to offer, more prominent giants of the movement could have been implemented and especially Danish modernists, whom also had a prominent position during the golden age of modernism.

3. APPENDIX

APPENDIX I

An investigation into different cross sections of a reinforced concrete beam.

How much momentum does the beam have to withstand?

Load information:

Characteristic dead weight: $g_k = 7{,}66\frac{kN}{m^2} * 1 = 7{,}66\frac{kN}{m}$

Flooring structure consists of:

- 22mm floorboard (hardboard): $0{,}022 * 7 = 0{,}15 kN/m^2$
- Mineral wool + joists: $\sim 0{,}05 kN/m^2$
- 400mm reinforced concrete: $0{,}200 * 25 = 5 kN/m^2$
- 13mm plasterboard ceiling: $0{,}013 * 9 + 25\%\ (ophæng) = 0{,}30\ kN/m^2$

Load-baring partitions: $0{,}120 mm * 18 = 2{,}16 kN/m^2$

Characteristic live load: $q_k = 2{,}0\frac{kN}{m^2} * 1 = 2{,}0\frac{kN}{m}$

The live load for a dwelling is $2{,}0\ kN/m^2$

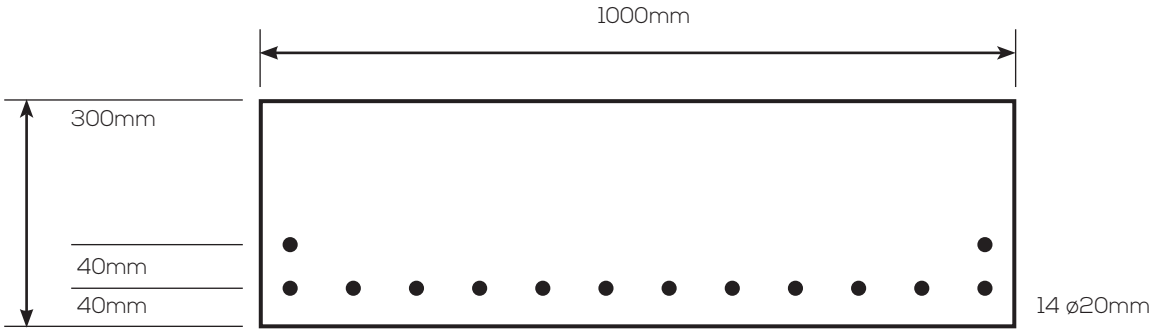
The beams permissible load is:

$$p_d = g_k * 1{,}0 + q_k * 1{,}3 \Rightarrow p_d = 7{,}66\frac{kN}{m} * 1 + 2{,}0\frac{kN}{m} * 1{,}3 = 10{,}26\frac{kN}{m}$$

The beams permissible momentum is:

$$M_{max} = \frac{1}{8} * q * l^2 \Rightarrow M_{max} = \frac{1}{8} * 10{,}26\frac{kN}{m} * 12^2 = 184{,}68\frac{kN}{m}$$

ITERATION I



Prefabricated concrete:

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu3} = 0{,}35\%$

Reinforcement:

S550

Diameter = 20mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

Concrete's tolerable compressive strength:

$$f_{c,d} = \frac{f_{ck}}{y_c} = \frac{30MPa}{1{,}4} = 21{,}4MPa$$

The reinforcement's tolerable yield point:

$$f_{y,d} = \frac{f_{yk}}{y_s} = \frac{550MPa}{1{,}2} = 458{,}3MPa$$

The reinforcement's center of mass:

$$C_s = \frac{12 * 40mm + 2 * 80}{14} = 45{,}7mm$$

The cross section's effective height:

$d = h - C_s = 300mm - 45{,}7mm = 254{,}3mm$

The reinforcement's area:

$A_s = 6 * \pi * r^2 = 6 * \pi * \left(\frac{20}{2}\right)^2 = 1880mm^2$

The force of the tensile reinforcement when floating:

$F_s = A_s * f_{y,d} = 1880mm^2 * 458{,}3MPa$

The force of the concrete when crushed:

$F_c = A_c * f_{c,d} = 0{,}8 * x * 1000mm * 21{,}4MPa$

The forces of the horizontal equilibrium (showcases the height of the neutral axis):

$F_s = F_c \Longrightarrow 0{,}8 * x * b * f_{c,d} = A_s * f_{y,d} \Leftrightarrow x = \frac{A_s * f_{y,d}}{0{,}8 * b * f_{c,d}}$

$\Leftrightarrow x = \frac{862 * 10^3 * N}{0{,}8 * 1000mm * 21{,}4MPa} \Leftrightarrow x = 50{,}3mm$

How much momentum can the beam withstand?

$M = F_s * z \Leftrightarrow M = F_s * (d - 0{,}4 * x) \Longrightarrow 862 * 10^3 * N * (254{,}3mm - 0{,}4 * 50{,}3mm)$

$\Leftrightarrow M = 202 * \frac{10^6 N}{mm} \Leftrightarrow M = 202kN/m$

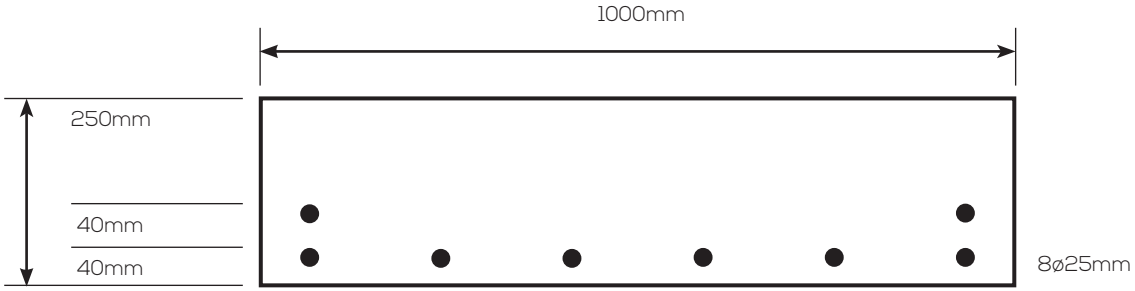
Is the strain of the tensile reinforcement $\boldsymbol{\varepsilon_s}$ larger than the yield stress $\boldsymbol{\varepsilon_y}$ and lower than the breaking strain $\boldsymbol{\varepsilon_u}$:

$\varepsilon_y = \frac{\sigma_s}{E_s} = \frac{458{,}3MPa}{200.00MPa} = 0{,}00229 \approx 0{,}23\%$

$\varepsilon_s = \varepsilon_{cu3} * \frac{d - x}{x} \Longrightarrow \varepsilon_s = 0{,}0035 * \frac{254{,}3mm - 50{,}3mm}{50{,}3mm} = 0{,}0142 \approx 1{,}4\%$

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 1{,}4\% < 5\%$

ITERATION 2



<u>Prefabricated concrete:</u>

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu3} = 0{,}35\%$

<u>Reinforcement</u>:

S550

Diameter = 25mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

Concrete's tolerable compressive strength:

$$f_{c,d} = \frac{f_{ck}}{y_c} = \frac{30MPa}{1{,}4} = 21{,}4MPa$$

The reinforcement's tolerable yield point:

$$f_{y,d} = \frac{f_{yk}}{y_s} = \frac{550MPa}{1{,}2} = 458{,}3MPa$$

The reinforcement's center of mass:

$$C_s = \frac{6 * 40mm + 2 * 80}{8} = 50mm$$

The cross section's effective height:

$d = h - C_s = 250mm - 50mm = 200mm$

The reinforcement's area:

$A_s = 6 * \pi * r^2 = 6 * \pi * \left(\frac{25}{2}\right)^2 = 2945mm^2$

The force of the tensile reinforcement when floating:

$F_s = A_s * f_{y,d} = 2945mm^2 * 458{,}3MPa$

The force of the concrete when crushed:

$F_c = A_c * f_{c,d} = 0{,}8 * x * 1000mm * 21{,}4MPa$

The forces of the horizontal equilibrium (showcases the height of the neutral axis):

$F_s = F_c \Longrightarrow 0{,}8 * x * b * f_{c,d} = A_s * f_{y,d} \Leftrightarrow x = \frac{A_s * f_{y,d}}{0{,}8 * b * f_{c,d}}$

$\Leftrightarrow x = \frac{1350 * 10^3 * N}{0{,}8 * 1000mm * 21{,}4MPa} \Leftrightarrow x = 78.8mm$

How much momentum can the beam withstand?

$M = F_s * z \Leftrightarrow M = F_s * (d - 0{,}4 * x) \Longrightarrow 1350 * 10^3 * N * (200mm - 0{,}4 * 78{,}8mm)$

$\Leftrightarrow M = 227 * \frac{10^6 N}{mm} \Leftrightarrow M = 227kN/m$

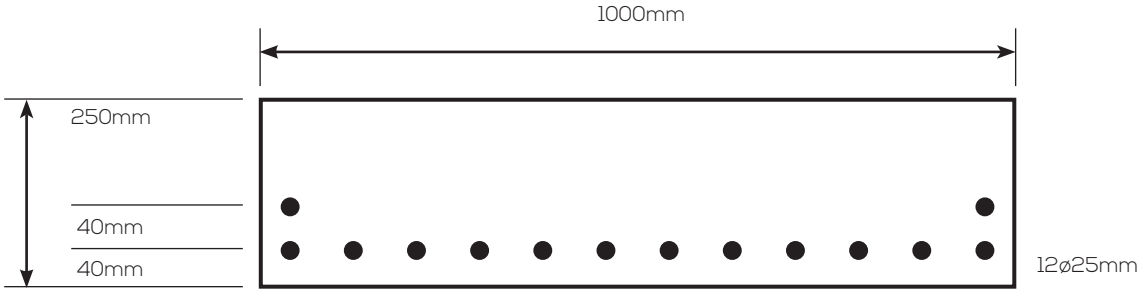
Is the strain of the tensile reinforcement $\boldsymbol{\varepsilon_s}$ larger than the yield stress $\boldsymbol{\varepsilon_y}$ and lower than the breaking strain $\boldsymbol{\varepsilon_u}$:

$\varepsilon_y = \frac{\sigma_s}{E_s} = \frac{458{,}3MPa}{200.00MPa} = 0{,}00229 \approx 0{,}23\%$

$\varepsilon_s = \varepsilon_{cu} * \frac{d - x}{x} \Longrightarrow \varepsilon_s = 0{,}0035 * \frac{200mm - 78{,}8mm}{78{,}8mm} = 0{,}0054 \approx 0.54\%$

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 0{,}54\% < 5\%$

ITERATION 3



Prefabricated concrete:

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu3} = 0{,}35\%$

Reinforcement:

S550

Diameter = 25mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

Concrete's tolerable compressive strength:

$$f_{c,d} = \frac{f_{ck}}{y_c} = \frac{30MPa}{1{,}4} = 21{,}4MPa$$

The reinforcement's tolerable yield point:

$$f_{y,d} = \frac{f_{yk}}{y_s} = \frac{550MPa}{1{,}2} = 458{,}3MPa$$

The reinforcement's center of mass:

$$C_s = \frac{10 * 40mm + 2 * 80}{12} = 46.46mm$$

The cross section's effective height:

$d = h - C_s = 250mm - 46{,}67mm = 203{,}33mm$

The reinforcement's area:

$A_s = 6 * \pi * r^2 = 6 * \pi * \left(\frac{25}{2}\right)^2 = 2945mm^2$

The force of the tensile reinforcement when floating:

$F_s = A_s * f_{y,d} = 2945mm^2 * 458{,}3MPa$

The force of the concrete when crushed:

$F_c = A_c * f_{c,d} = 0{,}8 * x * 1000mm * 21{,}4MPa$

The forces of the horizontal equilibrium (showcases the height of the neutral axis):

$F_s = F_c \Longrightarrow 0{,}8 * x * b * f_{c,d} = A_s * f_{y,d} \Leftrightarrow x = \frac{A_s * f_{y,d}}{0{,}8 * b * f_{c,d}}$

$\Leftrightarrow x = \frac{1350 * 10^3 * N}{0{,}8 * 1000mm * 21{,}4MPa} \Leftrightarrow x = 78.8mm$

How much momentum can the beam withstand?

$M = F_s * z \Leftrightarrow M = F_s * (d - 0{,}4 * x) \Longrightarrow 1350 * 10^3 * N * (203{,}33mm - 0{,}4 * 78{,}8mm)$

$\Leftrightarrow M = 232 * \frac{10^6 N}{mm} \Leftrightarrow M = 232kN/m$

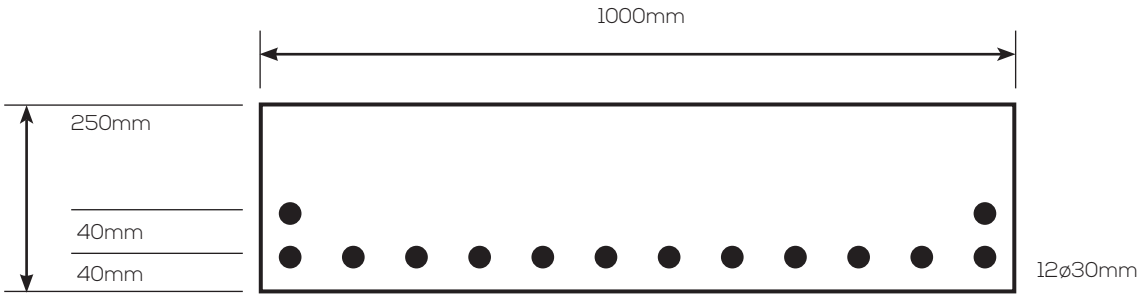
Is the strain of the tensile reinforcement $\boldsymbol{\varepsilon_s}$ larger than the yield stress $\boldsymbol{\varepsilon_y}$ and lower than the breaking strain $\boldsymbol{\varepsilon_u}$:

$\varepsilon_y = \frac{\sigma_s}{E_s} = \frac{458{,}3MPa}{200.00MPa} = 0{,}00229 \approx 0{,}23\%$

$\varepsilon_s = \varepsilon_{cu3} * \frac{d - x}{x} \Longrightarrow \varepsilon_s = 0{,}0035 * \frac{203.33mm - 78.8mm}{78.8mm} = 0{,}0055 \approx 0.55\%$

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 0.55\% < 5\%$

ITERATION 4



Prefabricated concrete:

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu} = 0{,}35\%$

Reinforcement:

S550

Diameter = 30mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

Concrete's tolerable compressive strength:

$$f_{c,d} = \frac{f_{ck}}{y_c} = \frac{30MPa}{1{,}4} = 21{,}4MPa$$

The reinforcement's tolerable yield point:

$$f_{y,d} = \frac{f_{yk}}{y_s} = \frac{550MPa}{1{,}2} = 458{,}3MPa$$

The reinforcement's center of mass:

$$C_s = \frac{10 * 40mm + 2 * 80}{12} = 46.46mm$$

The cross section's effective height:

$d = h - C_s = 250mm - 46{,}67mm = 203{,}33mm$

The reinforcement's area:

$A_s = 6 * \pi * r^2 = 6 * \pi * \left(\frac{30}{2}\right)^2 = 4241mm^2$

The force of the tensile reinforcement when floating:

$F_s = A_s * f_{y,d} = 4241mm^2 * 458{,}3MPa$

The force of the concrete when crushed:

$F_c = A_c * f_{c,d} = 0{,}8 * x * 1000mm * 21{,}4MPa$

The forces of the horizontal equilibrium (showcases the height of the neutral axis):

$F_s = F_c \Longrightarrow 0{,}8 * x * b * f_{c,d} = A_s * f_{y,d} \Leftrightarrow x = \frac{A_s * f_{y,d}}{0{,}8 * b * f_{c,d}}$

$\Leftrightarrow x = \frac{1944 * 10^3 * N}{0{,}8 * 1000mm * 21{,}4MPa} \Leftrightarrow x = 113.55mm$

How much momentum can the beam withstand?

$M = F_s * z \Leftrightarrow M = F_s * (d - 0{,}4 * x) \Longrightarrow 1944 * 10^3 * N * (203{,}33mm - 0{,}4 * 113.55mm)$

$\Leftrightarrow M = 307 * \frac{10^6 N}{mm} \Leftrightarrow M = 307kN/m$

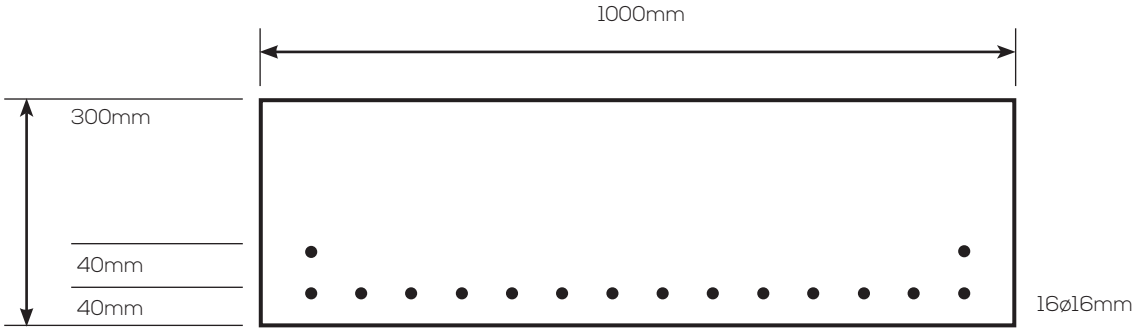
Is the strain of the tensile reinforcement $\boldsymbol{\varepsilon_s}$ larger than the yield stress $\boldsymbol{\varepsilon_y}$ and lower than the breaking strain $\boldsymbol{\varepsilon_u}$:

$\varepsilon_y = \frac{\sigma_s}{E_s} = \frac{458{,}3MPa}{200.00MPa} = 0{,}00229 \approx 0{,}23\%$

$\varepsilon_s = \varepsilon_{cu3} * \frac{d - x}{x} \Longrightarrow \varepsilon_s = 0{,}0035 * \frac{203.33mm - 113.55mm}{113.55mm} = 0{,}0028 \approx 0.28\%$

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 0.2\% < 5\%$

ITERATION 5



Prefabricated concrete:

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu3} = \ 0{,}35\%$

Reinforcement:

S550

Diameter = 16mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

Concrete's tolerable compressive strength:

$$f_{c,d} = \frac{f_{ck}}{y_c} = \frac{30MPa}{1{,}4} = 21{,}4MPa$$

The reinforcement's tolerable yield point:

$$f_{y,d} = \frac{f_{yk}}{y_s} = \frac{550MPa}{1{,}2} = 458{,}3MPa$$

The reinforcement's center of mass:

$$C_s = \frac{14 * 40mm + 2 * 80}{16} = 45mm$$

The cross section's effective height:

$d = h - C_s = 300mm - 45mm = 255mm$

The reinforcement's area:

$A_s = 6 * \pi * r^2 = 6 * \pi * \left(\frac{16}{2}\right)^2 = 1206mm^2$

The force of the tensile reinforcement when floating:

$F_s = A_s * f_{y,d} = 1206mm^2 * 458{,}3MPa$

The force of the concrete when crushed:

$F_c = A_c * f_{c,d} = 0{,}8 * x * 1000mm * 21{,}4MPa$

The forces of the horizontal equilibrium (showcases the height of the neutral axis):

$F_s = F_c \Longrightarrow 0{,}8 * x * b * f_{c,d} = A_s * f_{y,d} \Leftrightarrow x = \frac{A_s * f_{y,d}}{0{,}8 * b * f_{c,d}}$

$\Leftrightarrow x = \frac{552.9 * 10^3 * N}{0{,}8 * 1000mm * 21{,}4MPa} \Leftrightarrow x = 32.3mm$

How much momentum can the beam withstand?

$M = F_s * z \Leftrightarrow M = F_s * (d - 0{,}4 * x) \Longrightarrow 552.9 * 10^3 * N * (203{,}33mm - 0{,}4 * 78{,}8mm)$

$\Leftrightarrow M = 232 * \frac{10^6 N}{mm} \Leftrightarrow M = 232kN/m$

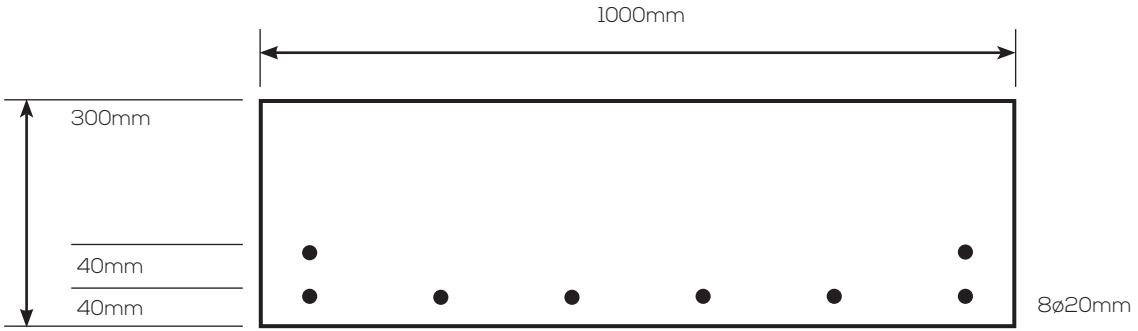
Is the strain of the tensile reinforcement $\boldsymbol{\varepsilon_s}$ larger than the yield stress $\boldsymbol{\varepsilon_y}$ and lower than the breaking strain $\boldsymbol{\varepsilon_u}$:

$\varepsilon_y = \frac{\sigma_s}{E_s} = \frac{458{,}3MPa}{200.00MPa} = 0{,}00229 \approx 0{,}23\%$

$\varepsilon_s = \varepsilon_{cu3} * \frac{d - x}{x} \Longrightarrow \varepsilon_s = 0{,}0035 * \frac{255mm - 32{,}3mm}{32{,}3mm} = 0{,}024 \approx 2{,}4\%$

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 2{,}4\% < 5\%$

ITERATION 6



Prefabricated concrete:

Moderate environment class.

$f_{ck} = 30\ MPa, C30$

$y_c = 1{,}4 \quad y_s = 1{,}2$

$\varepsilon_{cu3} = 0{,}35\%$

Reinforcement:

S550

Diameter = 20mm

$f_{yk} = 550\ MPa$

$E_s = 200.000\ MPa$

$\varepsilon_u = 5\%$

Concrete's tolerable compressive strength:

$$f_{c,d} = \frac{f_{ck}}{y_c} = \frac{30MPa}{1{,}4} = 21{,}4MPa$$

The reinforcement's tolerable yield point:

$$f_{y,d} = \frac{f_{yk}}{y_s} = \frac{550MPa}{1{,}2} = 458{,}3MPa$$

The reinforcement's center of mass:

$$C_s = \frac{6 * 40mm + 2 * 80}{8} = 50mm$$

The cross section's effective height:

$d = h - C_s = 300mm - 50mm = 250mm$

The reinforcement's area:

$A_s = 6 * \pi * r^2 = 6 * \pi * \left(\frac{20}{2}\right)^2 = 1880mm^2$

The force of the tensile reinforcement when floating:

$F_s = A_s * f_{y,d} = 1880mm^2 * 458{,}3MPa$

The force of the concrete when crushed:

$F_c = A_c * f_{c,d} = 0{,}8 * x * 1000mm * 21{,}4MPa$

The forces of the horizontal equilibrium (showcases the height of the neutral axis):

$F_s = F_c \Longrightarrow 0{,}8 * x * b * f_{c,d} = A_s * f_{y,d} \Leftrightarrow x = \frac{A_s * f_{y,d}}{0{,}8 * b * f_{c,d}}$

$\Leftrightarrow x = \frac{862 * 10^3 * N}{0{,}8 * 1000mm * 21{,}4MPa} \Leftrightarrow x = 50{,}3mm$

How much momentum can the beam withstand?

$M = F_s * z \Leftrightarrow M = F_s * (d - 0{,}4 * x) \Longrightarrow 862 * 10^3 * N * (250mm - 0{,}4 * 50{,}3mm)$

$\Leftrightarrow M = 198 * \frac{10^6 N}{mm} \Leftrightarrow M = 198kN/m$

Is the strain of the tensile reinforcement $\boldsymbol{\varepsilon_s}$ larger than the yield stress $\boldsymbol{\varepsilon_y}$ and lower than the breaking strain $\boldsymbol{\varepsilon_u}$:

$\varepsilon_y = \frac{\sigma_s}{E_s} = \frac{458{,}3MPa}{200.00MPa} = 0{,}00229 \approx 0{,}23\%$

$\varepsilon_s = \varepsilon_{cu3} * \frac{d - x}{x} \Longrightarrow \varepsilon_s = 0{,}0035 * \frac{250mm - 50{,}3mm}{50{,}3mm} = 0{,}014 \approx 1{,}4\%$

$\varepsilon_y < \varepsilon_s < \varepsilon_u = 0{,}23\% < 1{,}4\% < 5\%$

3. REFERENCES

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