VERTICAL HABITAT IN CBD, SINGAPORE

FINAL THESIS

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CITATIONS

Public housing is the main type of residence in Singapore, being over 80% in the total housing market. It is managed and built with governmental programs; a housing unit can be either leased ("sold") to the user on a 99-year lease, or rented out. The system of management for public housing is complex and distinguishes various categories of possible residents: from citizens to foreigners, youth to elderly, there are different conditions set in the rules.

Contrary to the popular impression, public housing in Singapore is not aimed at the poorer categories of people. Starting as an emergency measure for solving the country-wide crisis of housing in the 1950s, it now covers all sorts of income brackets, apartment types including what most would call luxurious. "Executive" apartments could easily span over 130, 150 square meters in area, which is rare, especially by the standards of the most eastern countries.

ABSTRACT

Singapore is considered to be a unique, almost miraculous, country. After ages of being pushed back by colonization, it reached the levels of development well beyond most of the modern countries in half a century. A very limited land area is one of the challenges in managing the country – with the population steadily growing, it gets more obvious that the building heights grow as well.

Following up to the previous point, the land's cherished natural resources, unique flora and fauna play an increasing role in the national image and are included in more and more ambitious projects. After being disconnected with their nature for so long, the people of Singapore now strive to include as much of it into their cities and spaces as possible.

This study aims to design a contemporary building that would be able to satisfy the needs of a rapidly developing, highly technological city, with its' main focus on the younger generation. It takes into consideration all the specific historical and cultural aspects of the country. While going along with the nation's active pursuit of its' image in the futuristic way, it also acts with respect to the established culture of the past.

An example of this conflict of past and future is the growing desire of the younger population to separate from their families and live on their own. It contradicts the years-long accepted way to share large apartments with multiple bedrooms with a large family. The affordability of the new housing is also an important aspect for the newest generation, and is also one of the goals to reach in this design. In addition, affordability should not decrease the life quality or transform a living block into a crammed ghetto.

Another aspect to regard is the international fame that Singapore has achieved in the field of modern architecture. The capital flourishes with landmarks, which at this point start to overshadow each other with their sheer numbers. While this should be viewed as something to celebrate, it also presents another challenge when designing a new build.

As such, the building that this thesis work proposes is attempting to combine all of these points and present suitable offers for the demand of the market. Even when being restricted to a very small, valuable plot of land, surrounded by equally tall buildings, it aims to free up that land to the public, not only providing decent conditions for the potential tenants, but also to any other person passing by. It also contributes to the official urban design direction of today of creating greener connections within the city by providing a pleasant and obvious passage through its own territory.

Structurally, the building uses a known, but rarely used arrangement – instead of following the standard practice of building a central core with supporting columns and/or outer skin, letting the load to flow from top to bottom, it reverts the direction of loads by adopting a suspended system. This allows it to have clear, free openings in the common areas of the buildings, which would let the lights to shine through and decrease the perceived density of the building as seen from the outside.

CH.1 THEORY & METHODOLOGY

SINGAPORE: CULTURAL CONTEXT

When we design a building, we first need to take into account the place that it is being designed for. In our case, it is Singapore – one of the smallest countries in the world with a distinct history, an island city-state found in Southeast Asia. Singapore nowadays serves as an impressive example of overcoming national trauma of colonization and rapid development towards a thriving economy and technical advancement.

Pre-colonial era

There is not much concise information on the state of the island before the age of being colonized by the British empire. We see it on the maps charted by Ptolemy, a greko-roman astronomer, in the 2nd century, under a name "Sabana", or "Sabara"; several records describe a settlement in the area as "Temasek", or "Tumasik", deriving from Malay word for sea, "tasik"; there is excavational evidence of Singapore being a trading port in the 14th century between Malay and Chinese people, and at some point in that time the name "Singapura" appeared, possibly relating to visitors' impression of "lions" that they saw (which were most probably tigers).

Afterwards, apart from mentions of Singapore as a part of a now dead Malacca Empire, and a couple of conflicts of Portuguese navy with the Dutch forces on the territory of the island in the 17th century, there is little information of importance in historical records.

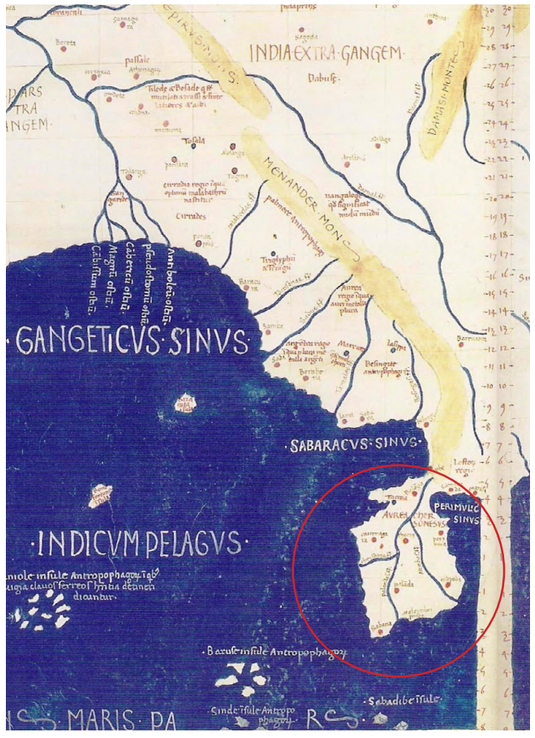


Fig.1. The 11th Map of Asia, Ptolemy's Geography
Fig.2. 15th century

Fig.3. Records of the area during early colony time

Colonial era

The era started with a British trading post established on the island in 1819. Even prior to that, the Malay Archipelago was used as a prominent source of spices by European colonial powers, mainly the Dutch.

Sir Stamford Raffles, the newly appointed Lieutenant Governor of the British colony, was seeking to create a stable presence for the British Empire in the archipelago, as well as a profitable trading route. The island of Singapore was chosen as the most suitable area. By interfering with local power balance of a settlement of 150 people, he put forward an appointed leader - Tengku Long, already known in the area. The new leader received a title of Sultan Hussein and monetary supplements, all in return for a granted right to open a trading port.

By that time, the entire island had a population of about 1000 people. After the trade route appearance, it started to grow rapidly: by 1871, the island's population had reached nearly 100,000. Workers from Malaya, China, India and other parts of Asia took the opportunity to earn money for their families; a notable percentage of these also chose to stay.

As with many countries that have been colonized for ages, there had been multiple administrative interventions, such as the Raffles Town Plan, 1822. Its goal was to segregate ethnic residential areas: The European Town, Chinatown, Chulia Kampong for ethnic Indians, and Kampong Gelam for Muslims, Malays and Arabs.

Fig.6. Restoration of British control in 1945

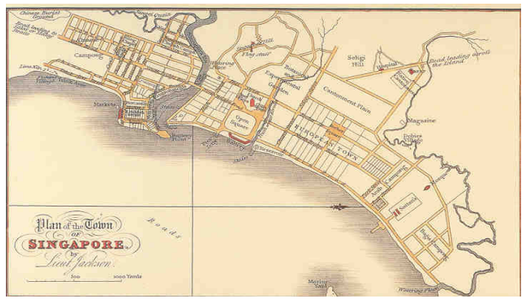


Fig.4. The Raffles Town Plan, 1822

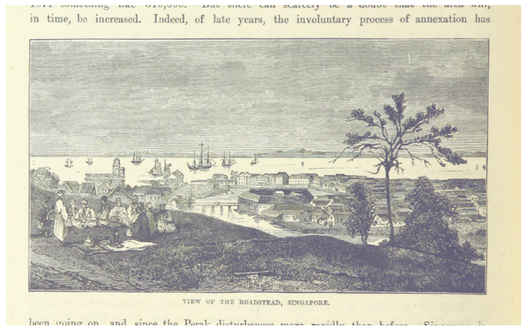


Fig.5. View of the roadstead

During the World War II period, the island was under control of Japanese forces, which had heavy negative effect on it's prosperity, reaching the apex in 1945 with a state of complete disorder and anarchy, massively destroyed infrastructure, unemployment and shortage of essential resources. Although Singapore regained status as a British colony once again after the end of war in 1946, Britain had lost all credibility for local population by failing to defend them against an invading power. It lead to a gradual political awakening under a common slogan for independence. Over the next two decades Singapore saw several elections for members of the Legislative council, increasing the local weight in decision-making, all the way to having full internal self-government in 1959.

The official declaration of independence from the United Kingdom happened in the same year, 1963, with Singapore merging with neighboring states to form Malaysia. This union, however, only lasted until 1965, which is the final date of Singapore becoming a fully sovereign country.

Republic of Singapore (post-colonial)

First steps

The first 15 years of Republic's existence it faced many challenges. The overall situation was shaky, with high unemployment rates, mass problems with housing, education, natural resources, not to mention the lack of actual land; additionally, its sovereignty was also under risk of forced reintegration to Malaysia. However, Singapore immediately started taking measures, joining the UN and strengthening international relationships.

National economic strategies were already in process of implementation since 1961, focusing on manufacturing and industrial sectors, increasing the quality and value of goods and attracting foreign investors. Aside from that, Singapore established oil refinement plants for large companies on its territory; both of these measures worked towards mitigating the unemployment. Singapore's education system received massive investment, adopted English as its language of instruction and promoted importance of practical training.

Further development

1980s showed the overall success of the initial measures, solving the immediate crises on hand. That allowed the young country to strive forward in higher technological industries, opening its own airline and taking a spot among the world's busiest ports. Public housing apartments expanded in area and comfort, and new towns were constructed from scratch. Mass Rapid Transit (MRT) system of public trains opened for public in 1987, allowing efficient commute.

The social issues, mainly a shortage of housing, posed a huge hazard at the moment. Squatter settlements, unregulated and overcrowded, often burned down and spread diseases. The well-known Bukit Ho Swee Fire of 1961 left 16 thousand people without shelter in a day. To solve this crisis, an autonomous government agency, The Housing Development Board (HDB), was rapidly constructing affordable public housing projects, resettling population within the first decade of action.

Fig.7. Squatter settlements

Fig.8. Opening of the MRT system

Fig.9. View in circa 1980

21st century - beginnings

The first decade of the new age did not go without a crisis. After discovering a terrorist attack plan in 2001, Singapore had to take numerous counter-terrorist measures, and put more focus on social integration and intercommunal relations. In addition to this, the country was affected by the global SARS pandemic of 2003.

International image of Singapore popularized thanks to hosting major public events, such as the Singapore Grand Prix, 2008, and Summer Youth Olympics of 2010.

Fig.10. Singapore skyline by 2006; Grand Prix in 2008; Olympics in 2010.

Recent times

In the past decade, Singapore had seen an unprecedented rise of ultra-modern builds, starting with opening the Universal Studios building and the iconic Marina Bay Sands in 2010 – the most expensive casino property in the world. Economical growth in the same year hit a record of 14.7%. Fittingly, the Golden Jubilee of 50 years of independence arrived in 2015.

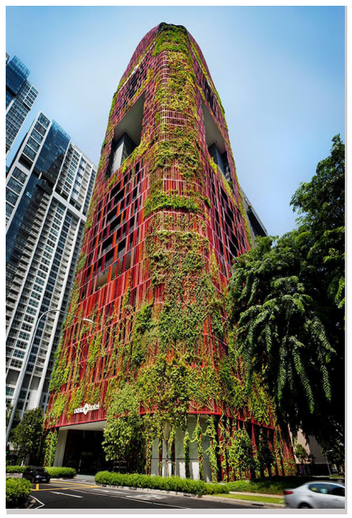


Fig.11.Oasia Hotel Downtown

Fig.12. Marina Bay Sands

Modern Singapore

The Singapore of today could be described as the best advertisement for **technocraty.** The political and expert components of the governing system there seem to have merged completely. Rapid development and efficient management has lead to an international image of a country on the frontiers of progress. The central business district attracts visitors from all over the world, and its' distinct skyline is instantly recognisable.

The value of education is all-times high, and so is the pace of life. It, unfortunately, leads to heightened stress levels of both adults and children, decreased leisure time and work weeks with more hours than most countries. Speed in the eyes of modern city dweller allows for economic and social advancement, while slowness is a threat to sovereignity and progress.

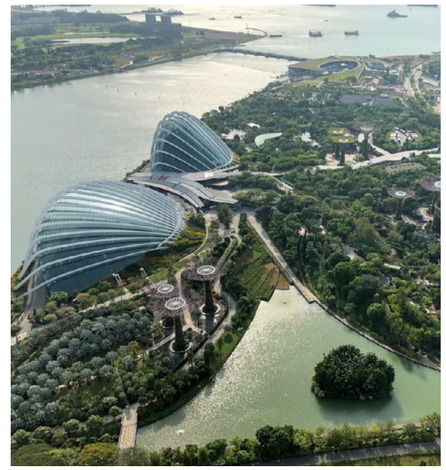


Fig.13. The Gardens by the Bay

In 2013, The Economist Intelligence Unit ranked Singapore as having the best quality of life in Asia and sixth overall in the world.

Future challenges for Singapore are most likely to be external. There are at least three particular phenomena: climate change and its' various consequences; external threats to public health and environment; and the risks posed by civilian nuclear proliferation within the region. Among these, the effects of climate change seems the most extreme, although the other two still stand.

Fig.15. The Interlace

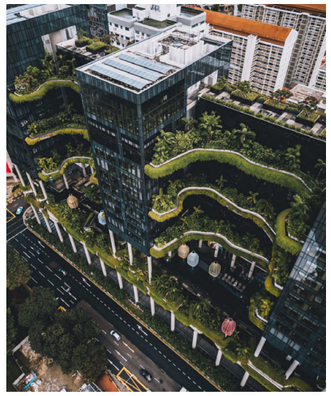


Fig.14. Park Royal

Fig.16. The Hive

Singapore's contemporary architecture is a result of its varied influences, and it does not forget the strong background of cultural and ethnic diversity. There is a strong focus on sustainability, with many examples of vegetative landscapes being introduced into high-rise buildings. Green architecture and ventilation is particularly important for the architecture in Singapore due to its humid climate.

A young nation with a traditional colonial past pushing towards its own unique style of architecture.

SPECIFICS OF ARCHITECTURAL BACKGROUND

The architecture of Singapore is influenced and stylistically diverse. For example, the colonial architecture of the early 1800s is eclectic and hybrid, incorporating various styles from the region. Contemporary architecture often incorporates trends from around the world. Singapore architecture of today can be divided into two main periods: pre-WWII colonial and post-WWII pre-colonial.

Traditional architecture of the country is present in a diverse range, including Malay vernacular houses and shophouses, various places of worship that reflect the ethnic and religious diversity of the country, and a mixture of european styles.

Modern architecture in Singapore began with the Art Deco style, and simultaneous popularity of concrete for structural use. In the 50s, Modernist architecture became popular, and in the 70s the Brutalist style took over. This coincided with a period of urban renewal and building boom, so these styles are still dominating the island's views.

One architectural trend in the 1980s was post-modernism, which experimented with both historic and deconstructivist styles. Preservation of architectural heritage has also been a trend in Singapore for the past few decades, kickstarting a whole industry for this cause.

An example of Singaporean innovation has been seeking to develop a type of architecture appropriate for the tropics. This approach is rooted in the vernacular Malay houses and British colonial architects who used modern construction methods to create an authentically Singaporean architecture. At the same time, in the 1980s, it led to a proliferation of what could be called 'modern tropical' architecture, or neo-tropical architecture. This involves a return to clean and simple modernist forms, coupled with an emphasis on lush landscaping and sleek sun-shading panels made of metal or wood, which replace glass curtain walls of modernism. These architectural efforts are especially important now, as air conditioning in buildings consumes a major percentage of electricity in Singapore, and, in a cycle, contributes to global warming too.

The 1990s saw many global cities and aspiring global cities commit to building iconic landmarks to enhance their country's brand and attract tourism and investment more efficiently. Some of the projects that were launched include the Esplanade Theatres on the Bay Arts Centre, the Supreme Court of Singapore, the new National Library, Singapore, the Marina Bay Sands Integrated Resort and the Singapore Flyer.

Fig.17. Malay vernacular house

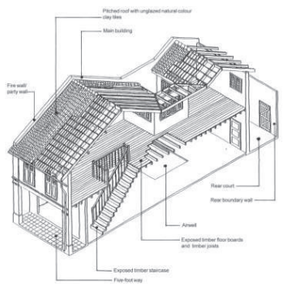


Fig.18. Shophouse

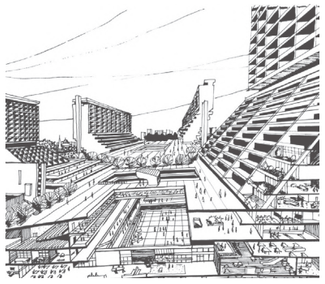


Fig.19. Golden Mile Complex

Fig.20. OCBC Centre

WHAT DOES A TALL BUILDING ENTAIL

In the beginnings of known history, building tall was not out of need but rather created a monument, a symbol of social status. Being visible to all and impressing onlookers with scale and complexity could be seen as ascending above mere mortality.

In relatively modern times, the focus shifted to usability. As living in the city became more desirable, and the flow of people moving from rural areas grew exponentially, it became clear that in order to manage dense population there needs to be appropriate architecture. By shrinking the physical footprint on the ground, not only it allows to provide more area for living and working in the same space, but also gives an opportunity to expand communal ares of the city and provide a healthier environment within cities.

In different times constructing tall buildings had waves of different limitations. The most obvious one would be structural restrictions - it took time to come up with a working concept of reinforced concrete or a proper steel frame, and then progress was halted once again by the shortcomings of a classic steel cable, as elevators were unable to cover enough floors without the cable deforming. Economical conditions could also be seen as a limitation, as every tall building is a large project demanding attention and investment. With the height of structures growing, engineers faced the issues of wind and seismic risks. Last but not least, following contemporary trends, the newest concern for designing the monuments of new age is energy efficiency. Taking into account all these and more, we can conclude that overcoming all of these obstacles could be a statement in itself, a way to demostrate how humanity conquers another dimension.

Naturally, the role of appearance and status did not lose importance either, as a tall building is also an excellent advertisement opportunity. What else would attract attention better than a giant monument growing among modest houses of the past? Once the economic and structural conditions caught up to the demand, the competition started on its own. The architectural race to stand out inadvertedly leads to appearance of unique city skylines, shaping distinct international images.

WHAT IS A TALL BUILDING FOR SINGAPORE

The meaning of a tall building for Singapore specifically is a completely different question. While all the previous general points still stand, with Singapore we need to take into account the uniqueness of the place. The most obvious would be a drastic lack of land to build on - after all, the country is really small. It can barely allot any area for farmlands already, and with a steadily growing population, the need to build vertically is undisputable. Furthermore, there had been discussions of even expanding downwards, underground - but of course, it can not be applied to human dwellings and workplaces. The demand for land is so extreme that the country resorted to land reclamation - a process of constructing artificial land stretches on the former ocean surface. In a nutshell, for Singapore building tall is no less than a need.

However, it must be taken into account that defining "tall" heavily depends on the context. On a world scale, the tallest project spans a full kilometer upward; in many megacities people would not consider a building of 100 or 200 meters that tall at all. For Singapore, the size of the country brings forward unexpected restriction of height - in order to allow for a safe landing of aircraft, there can not be any buildings taller than 280 meters anywhere in the country at all. Despite that, evidence shows that impressive architecture is perfectly possible in these conditions as well.

In addition, since a tall building is an exceptional opportunity to make a statement in a form of architecture, or a visual monument, it fits perfectly with Singapore's ongoing self-discovery for a national image. After being denied self-governance for so long and only being able to follow the lead, Singapore is now rapidly developing its own appearance, in architecture as well. The country already has dozens of impressive examples that are instantly recognised as icons all over the world. The exploration continues.

CLIMATIC CONTEXT

By the Koppen Classification Scheme Singapore belongs to the tropical rainforest climate.

There are no distinctive seasons.

Relative humidity is around 90% in the morning and 60% in the afternoon. During prolonged heavy rain, relative humidity often reaches 100%.

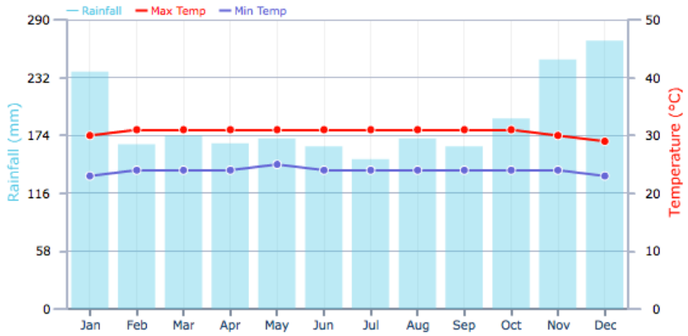


Fig.22. Temperature and rainfall annual distribution

Despite the fact that climatic conditions do not change noticeably throughout the year, they change a lot depeding on the time of the day. As seen in the diagrams provided by the Changi Climate Station of Singapore, the temperature can vary by a margin of up to 15 degrees in one day.

Humidity is reported to be one of the most troublesome factors for daily life outside buildings.

Basic properties of local climate:

Constant high temperatures (average monthly temperatures 18°C (64°F); intense sunlight

Average monthly rainfall	60.0 mm
Warmest month	June: 27.8°C
Coolest months	January, December: 26.0°C
Wettest month	December: 288.4 mm
Driest month	July: 158.6 mm
Average annual rainfall	2,344.0 mm

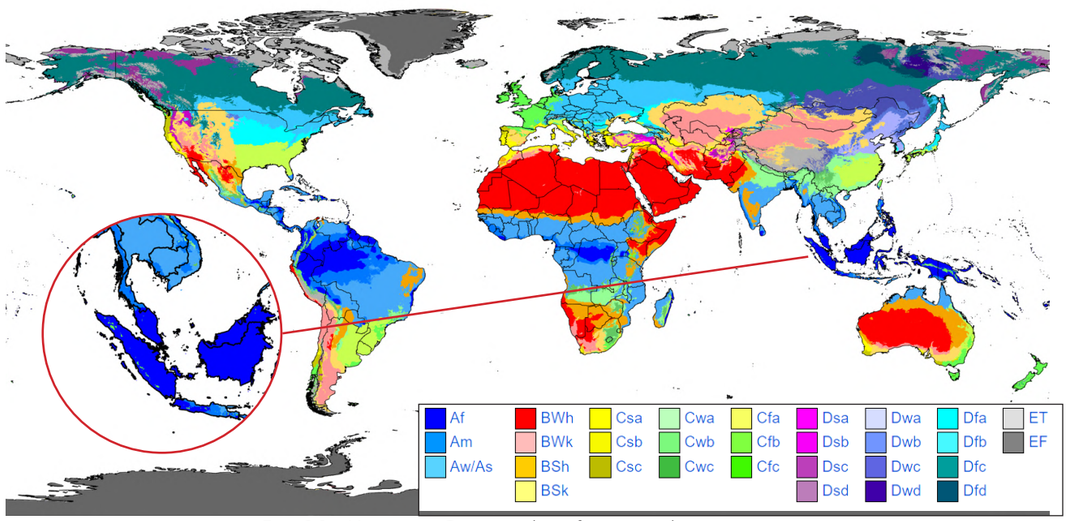


Fig.21. Köppen–Geiger classification climate map

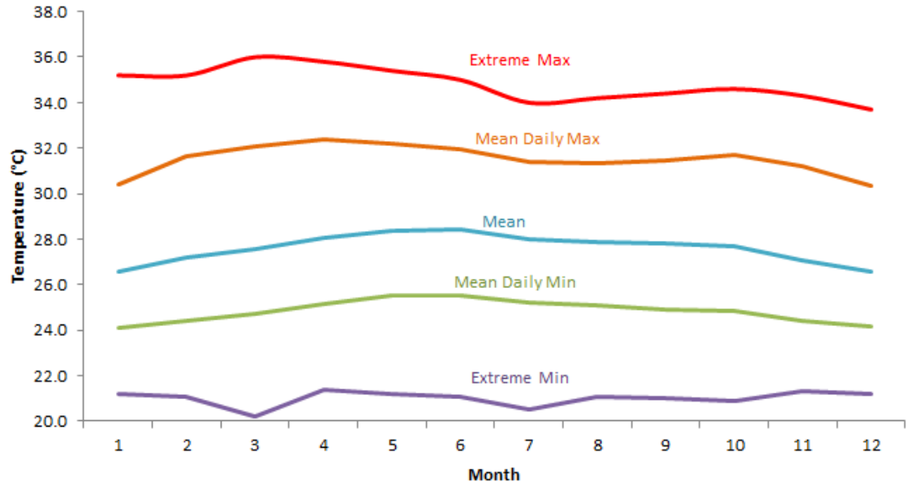


Fig.23. Temperatures by month and daily variations

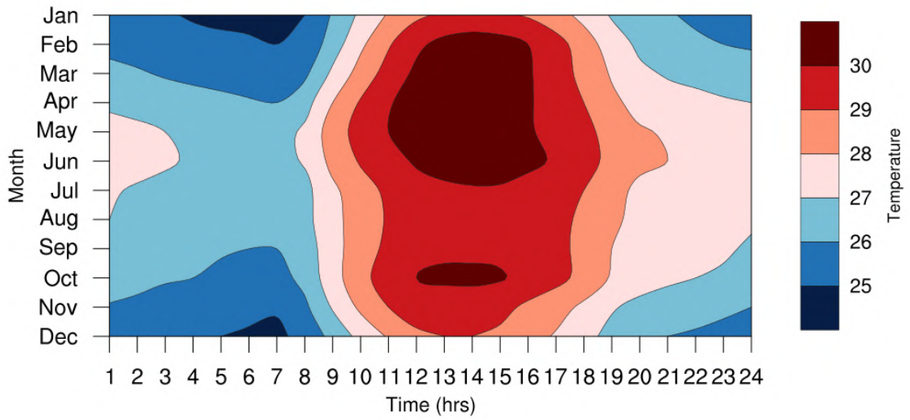


Fig.24. Temperature distribution by time of the day and month

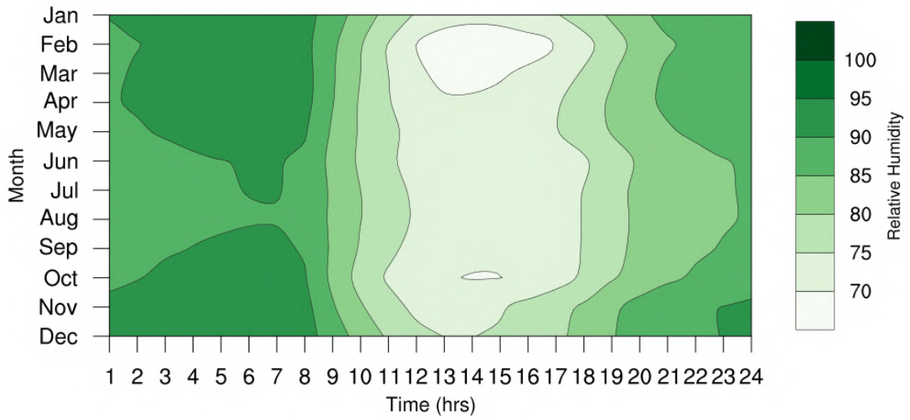


Fig.25. Humidity distribution by time of the day and month

URBAN DEVELOPMENT STRATEGIES

Even from the beginnings of Singapore's modern history it is known to focus on land use planning with great intensity. Starting with the Raffles Town Plan introduced all the way back in 1822, which only covered the initial port settlement, it was already a point of importance to allocate land for green zones inside the town for recreation and "impression of prosperity". Back then, the plan mainly focused on segregating residents into districts according to their role and race - appropriate for a colonial government. Nowadays, fortunately, priorities are shifted.

Master Plans proposed and followed over the years are such:

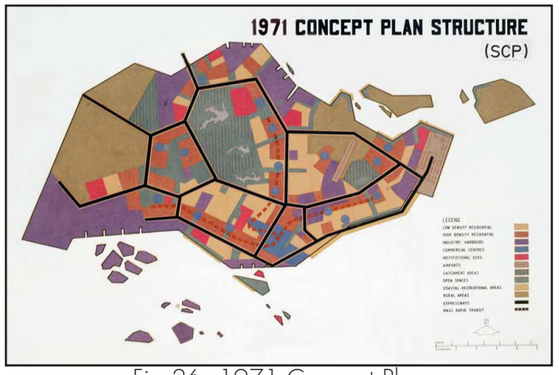


Fig.26. 1971 Concept Plan

1971 Concept Plan

The first long-term plan in 1971 proposed a "Ring Plan" that allocated housing, industrial and transport networks in optimal ways, addressing pressing housing and economic challenges. High-density satellite towns were built around central water catchment area.

It also defined key transport connections for the future development.

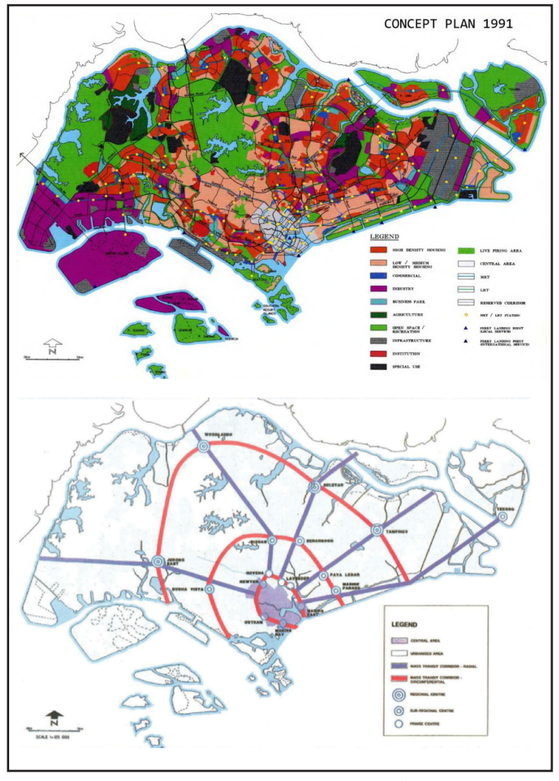


Fig.27. 1991 Concept Plan

1991 Concept Plan

Focused on enhancing the quality of life, creating a "tropical city of excellence". Following a strategy of decentralization, more commercial hubs were proposed outside the city centre.

The plan contained more green and blue spaces, trying to connect them when possible. Infrastructure improved and became more sustainable; also the foundation for Marina Bay Financial Centre was laid out.

2001 Concept Plan

The 2001 Concept Plan focused on working towards shaping a thriving world class city with rich character and diversity. A key focus was on deepening efforts in protecting and enhancing local and natural heritage and identities. It also envisioned greater flexibility for industrial and business land uses and needs.

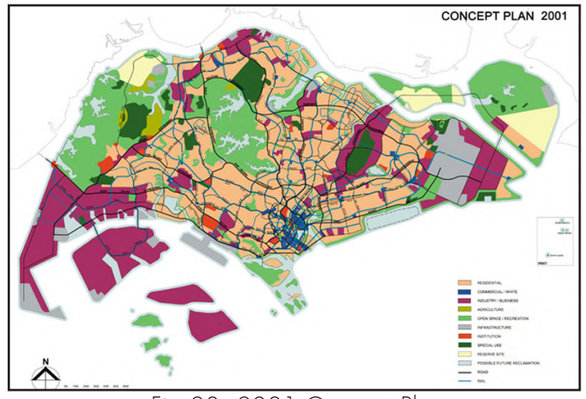


Fig.28. 2001 Concept Plan

2011 Concept Plan

This iteration deepened visions and efforts for live, work and play, making greater provisions for more diversified growth, more integrated green and blue spaces and a wider range of mobility networks, with more walking and cycling options. A wider range of homes and sustainable towns were also planned, with more inclusive spaces.

A special focus was given to parks and park connector networks (PCN) for the future across the island. The "green corridors" are supposed to cover the majority of urbanized area, as a way to reconnect the population with nature, battle urban heat island effect and increase physical activity.

Taking into account the issue of overcrowded central area, the plan proposes further decentralization by introducing new major employment centres in the areas mainly serving for housing now. The proposal has the potential to drastically decrease commute times and transportation emissions, and, by extension, the overall quality of life.

This Concept Plan was further revised and integrated into the Land Use Plan 2013 by the Ministry of National Development (MND). It is now used as the baseline for 2030 plan.

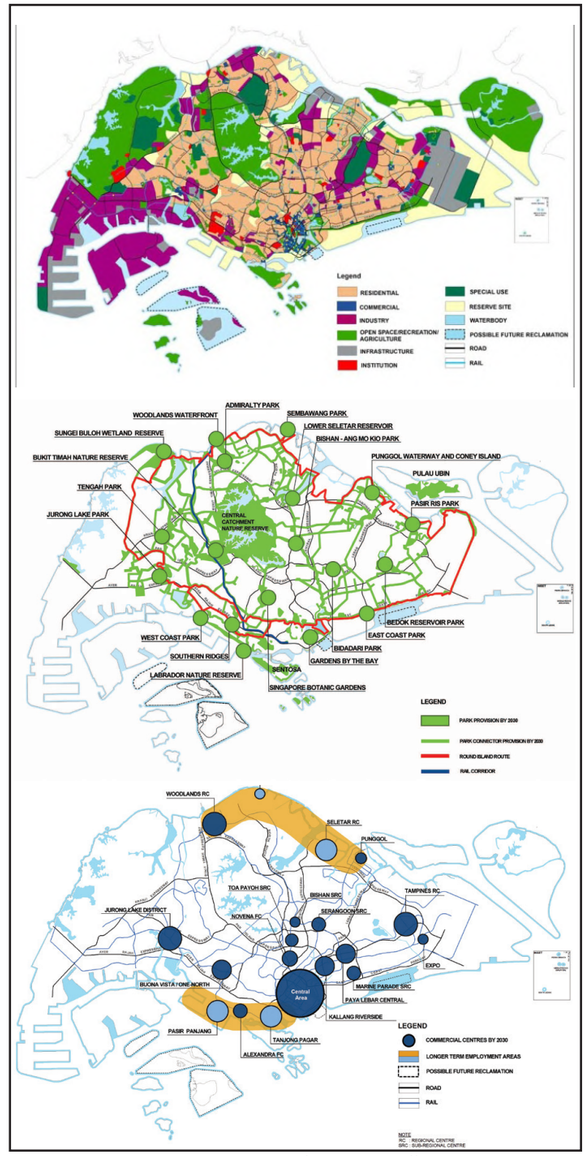


Fig.29. 2011 Concept Plan: overall, greenery, business hubs

“GARDEN CITY” to “CITY IN NATURE“

The Garden City Movement: Origins

In 1898, a method of urban planning under a name “the Garden City Movement” emerged in the United Kingdom. It was somewhat inspired by utopian image of future living common for the time period. The author, Sir Ebenezer Howard, imagined a perfect city to be home to roughly 30 to 35 thousands people, and to consist of layers of concentric circles interconnecting with radial main streets spreading from the center. On later stages of development, these settlements would be linked to each other, forming a network of satellites (seen on Fig.X).

The Garden Cities were planned as a solution to then topical issue of overcrowding and decadence of industrial cities, which were seen as toxic environments for human nature.

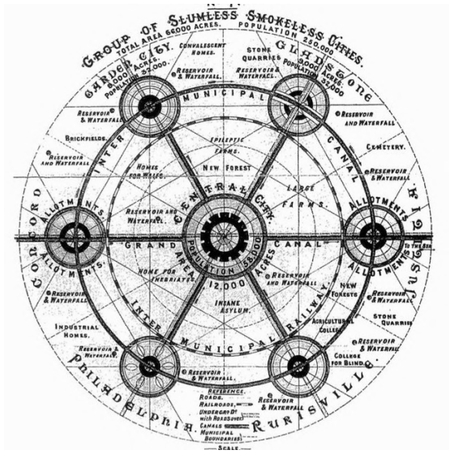


Fig.30. The original Garden City Concept, 1902

The method attracted attention and popularity in many parts of the world, both positive and negative. Singapore had adopted many points of this system in the initial Concept Plan of 1971. Starting from then, inclusion of adequate greenery in all the following land use plans had been prominent as well. The main distinction of Singapore’s planning strategies from the original method is high density of development. This, consequently, solved one of the major downsides of the Garden City - a lack of convenience and movement freedom.

In 1967, Prime Minister Lee Kuan Yew introduced the concept, aiming to transform Singapore into a city with abundant lush greenery and a clean environment. Besides creating a pleasant environment for the inhabitants of the island, the increase of greenery combined with a clean, well-mantained urban environment would add to the international image, attracting more tourism and investments. The original program focused intensely on planting new trees, which had impressive results even before developing the plan: by the end on 1970, 55 thousands new trees were planted.

Furthermore, in 1975 the Parks and Trees Act was enacted, which controlled the percentage of greened land in all new construction works from both public and private developers. These included every project from housing to roads or parkings. As a result of the policy, the new trees amount was reported to increase from 158 thousands in 1974 to 1.4 million in 2014.

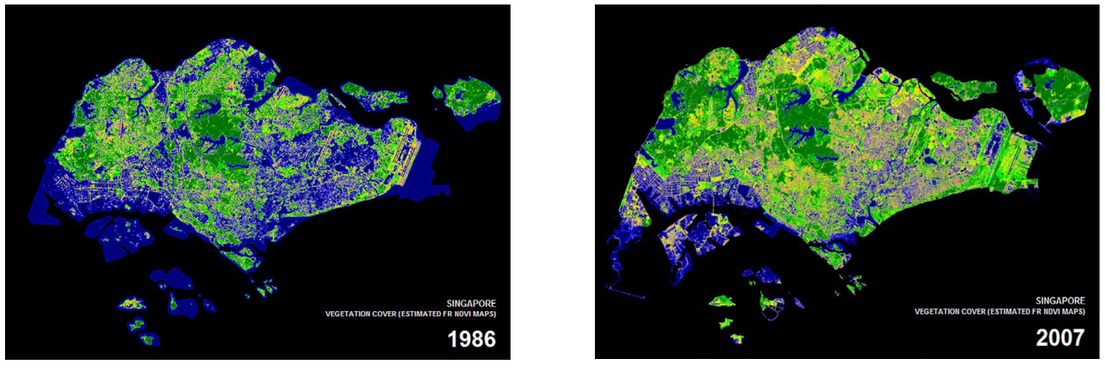


Fig.31. Comparison of vegetation maps of Singapore of 1986 and 2007. An increase of green areas from 36% to 47%, with a population growth from 2.7 to 4.6 million people.

City in a Garden

The inital “Garden City” concept transformed and was formally defined in Singapore as a “City in a Garden” in 2004, going along with the successes in previous greening initiatives. It gave more attention to urban environments and their integration with green landscaped areas; not only the quantity of landscaped areas mattered but also their quality. From then on, a major percentage of newly developed land use plans included extensive networks of green spaces, in contrast with the previously accepted way of planning small patches without connections. Overall, with this new strategy, Singapore adopted a definitive “blue-green” plan: blue representing various water bodies and green standing for anything to do with vegetation.

The strategy defined six important goals:

- establishing world-class gardens;
- rejuvenating urban parks and enlivening the streetscape;
- optimizing urban spaces for greenery and recreation;
- enriching biodiversity in an urban environment;
- enchancing competencies of the landscape and horticultural industries;
- engaging and inspiring communities to co-create a greener Singapore.

City of Gardens and Waters

An intermediate stage of development, presented at an exhibition in 2011. It is defined by a complex of programmes that include considerations for water reserves and water presence in the urban environment. It distinguishes water sources of Singapore in four categories, described as Four National Taps.

These include local catchment water, imported water, NEWater and desalinated water. 17 reservoirs across the country are collecting excess rainwater. Imported water comes from Malaysia; the programs strive to decrease that percentage of import to gain more independance. The NEWater purification system is able to reclaim wastewater, bringing it to extremely clean state, and it is currently providing 30% of water supply in the country. As for desalination, there is no shortage of source material, as the island in surrounded by sea water, but the process is highly energy-intensive.

In addition, a topic of huge importance was put into light as well: management of floods and pollution with innovative solutions.

Singapore National Water Agency PUB is also managing an ABC Waters programme, established in 2006, which stands for Active Beautiful Clean Waters. It manages the state of the water network of Singapore. The ABC Waters Design Guidelines mandate the construction and renovation projects, encouraging the public and private sectors to adopt ABC Waters design features. These features such as rain gardens, bioretention swales, and wetlands, are environmentally-friendly features consisting of plants and soil media that capture and treat rainwater where it falls. As a result, the quality of water arriving to reservoirs is upgraded, while also improving the surrounding areas.

The latest development to strategic approaches to Singapore's planning is the "City in Nature" vision, introduced by NParks in March 2020. With the arrival of colonisation, the primeval forests of Singapore underwent global erasure - the efforts to leave some nature reserves did not prevent forests' decline by 90% by year 1900. The nation's strive to fix this throughout years of independance is fully understandable and fair.

The "City in Nature" concept is more about reintroducing that primal character that was lost in the past. The vegetation is seen as more tropical, representative of the natural forests of the region. Landscapes are less restricted and given more space. As follows, the urban transit is also being partially consumed by greenery, providing more pedestrian connection under tree shade and lessening the rule of roads.

Naturally, with natural "forests" come not only pleasant views of trees and flowers, but also the remainder of wildlife - that includes insects, birds and larger animals. The idea here is for citizens to learn to coexist with all that in their day-to-day life and be able to reconnect with the natural world in a setting that is less artificial and zoo-like.

If this ambitious transformation realizes fully, it could be an example of a real-life biophilic yet highly developed city, where the character is present in every way.

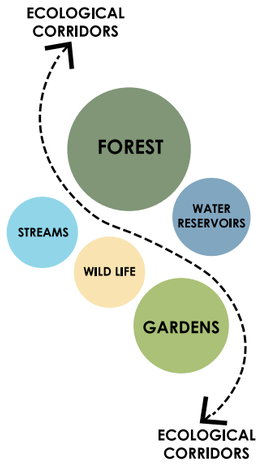


Fig.33. Integration of biodiversity into the city

Fig.32. Stages of development

PUBLIC HOUSING

Singapore is widely known for its successful public housing programs. In fact, the overwhelming majority of all housing in the country is public, and it is constructed under the authority of Housing Develpment Board (HDB). While it strives to respond to people's changing demands with time, we can still see overall simularities in apartments constructed in the same decade.

Researching into the historical context of housing in Singapore is essential for understanding the general population's values and needs and to design an environment fitting a particular time and space.

1950-s

SOLVING THE CRISIS

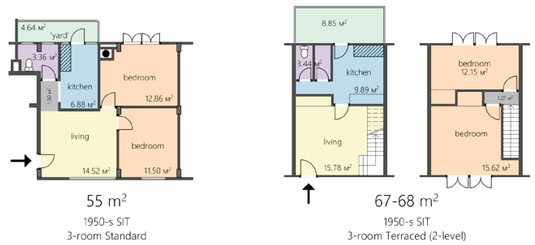


Fig.34. *

Right after obtaining independance, the flats had minimal floor area. At the time the point was to solve the housing crisis on hand, to resettle people from destroyed slums and burned wooden districts. Most of these buildings served their purpose and are already demolished.

1960-s

EXPANSION

Fig.35. *

Apartments start to be built for longer use. We can see the classic local way to make a large common area that opens directly from the entrance. The role of a kitchen is purely functuonal - it is made as a service space, often placed next to the bathroom and sharing a door with it.

A notable part that is present in all of apartments designed from 1960-s to 1990-s is a trash chute with access directly from the kitchen.

In many apartments blocks there are terraces, mostly covering the building from the shared corridor. Some apartments feature a personal balcony.

1970-s

NEW GEN IMPROVED

Fig.36. *

1980-s

+ EXECUTIVE

Fig.37. *

A new type of apartment appears in the classification - "Executive". They are larger than other types and often have separated kitchen for tenants and their house servants.

Larger apartments feature an additional bathroom attached directly to the master bedroom.

In later plans, kitchens started to be incorporated into the living rooms as a uniform space for recreation and socialising. Dining area was also included in the same space.

1990-s

MODERNISATION

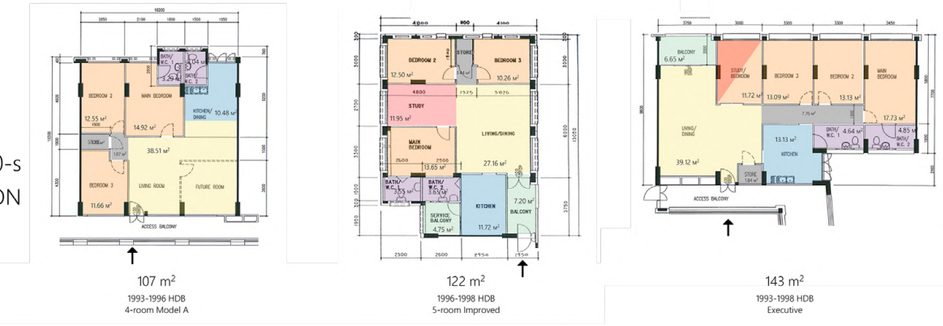


Fig.38. *

After 1990-s, a separated "storage" room appeared in plans, which was surrounded by thick reinforced walls and was supposed to double as a shelter in case of an explosion. This planning decision is still widely debated by the public.

Western influence starts to show in adding corridors that separate bedrooms from the living area. Kitchens are given more space and sometimes are separated. Some plans feature "study areas".

Late 1990-s to Modern

NEW TRENDS DOWNSIZING

Fig.39. *

After 1990-s, a separated "storage" room appeared in plans, which was surrounded by thick reinforced walls and was supposed to double as a shelter in case of an explosion. This planning decision is still widely debated by the public.

Most importantly, the last two decades show a turnover in planning. After half a century of adding more area to apartments, the trend now goes the other way; land becomes more expensive and people want separated smaller homes.

*Figures 24 to 29 - comparisons of typical apartment plans of Singapore through the years.

CH.2 SITE & CONTEXT

MORPHOLOGICAL ANALYSIS

The architecture of Singapore is influenced and stylistically diverse. For example, the colonial architecture of the early 1800s is eclectic and hybrid, incorporating various styles from the region. Contemporary architecture often incorporates trends from around the world. Singapore architecture of today can be divided into two main periods: pre-WWII colonial and post-WWII pre-colonial.

Traditional architecture of the country is present in a diverse range, including Malay vernacular houses and shophouses, various places of worship that reflect the ethnic and religious diversity of the country, and a mixture of european styles.

Modern architecture in Singapore began with the Art Deco style, and simultaneous popularity of concrete for structural use. In the 50s, Modernist architecture became popular, and in the 70s the Brutalist style took over. This coincided with a period of urban renewal and building boom, so these styles are still dominating the island's views.

One architectural trend in the 1980s was post-modernism, which experimented with both historic and deconstructivist styles. Preservation of architectural heritage has also been a trend in Singapore for the past few decades, kickstarting a whole industry for this cause.

An example of Singaporean innovation has been seeking to develop a type of architecture appropriate for the tropics. This approach is rooted in the vernacular Malay houses and British colonial architects who used modern construction methods to create an authentically Singaporean architecture. At the same time, in the 1980s, it led to a proliferation of what could be called 'modern tropical' architecture, or neo-tropical architecture. This involves a return to clean and simple modernist forms, coupled with an emphasis on lush landscaping and sleek sun-shading panels made of metal or wood, which replace glass curtain walls of modernism. These architectural efforts are especially important now, as air conditioning in buildings consumes a major percentage of electricity in Singapore, and, in a cycle, contributes to global warming too.

The 1990s saw many global cities and aspiring global cities commit to building iconic landmarks to enhance their country's brand and attract tourism and investment more efficiently. Some of the projects that were launched include the Esplanade Theatres on the Bay Arts Centre, the Supreme Court of Singapore, the new National Library, Singapore, the Marina Bay Sands Integrated Resort and the Singapore Flyer.

Fig.40. Malay vernacular house

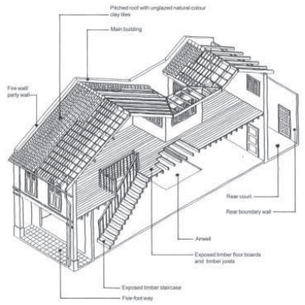


Fig.41. Shophouse

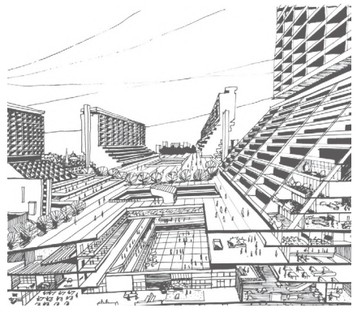


Fig.42. The Golden Mile Complex

Fig.43. OCBC Centre

Fig.44. The Schwartzplan of Singapore

Fig.45. The Schwartzplan of Central region

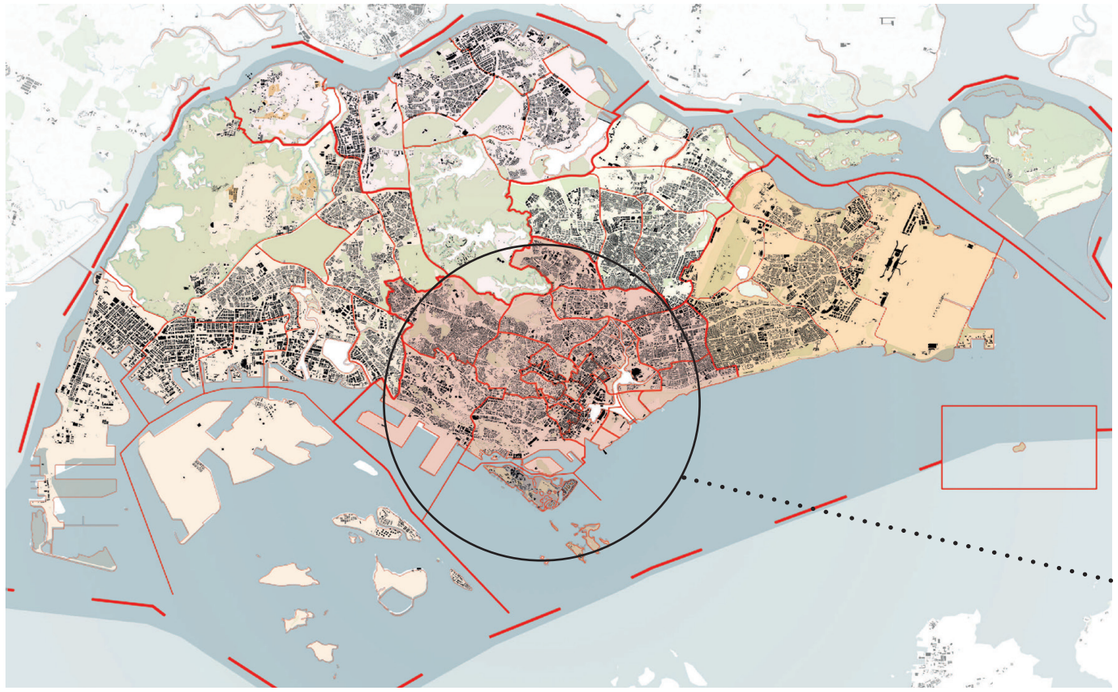


Fig.46. Planning regions of Singapore

Singapore is divided into five regions for urban planning, demarcated by the Urban Redevelopment Authority. The regions are further sub-divided into 55 planning areas, and the largest region in terms of area is the West Region (201.3 km2 or 77.7 sq mi). The Central Region is the most populous, with an estimated population of 922,980 citizens in 2019.

These regions are not administrative subdivisions, but they are used by some governmental organizations. For administrative purposes, Singapore is divided into five districts, each governed by a Council and headed by a Mayor, and that system is not matching the one for urban planning - it is constantly changing along with electoral vote, while the urban planning division stays the same.`

Every region is subdivided into planning areas. Since 1990s, there is a total of 55 of them. Thanks to their stability, they gained even more popularity than the official boundaries.

The Central region is divided to planning areas more densely, as seen on the analysis. Within it, each area is fairly distinct in the layout of districts, and in the prevalence of architectural styles and scales. Some of them are packed with high-rise public housing, while the others are completely occupied by smaller private condominiums. Some are known primarily for public sport arenas, and some feature a notable percentage of historical shophouses.

The Marina Bay area, being the busiest business and tourism hub of the state, demonstates an abundance of skyscrapers, both ultra-modern and of modernist age.

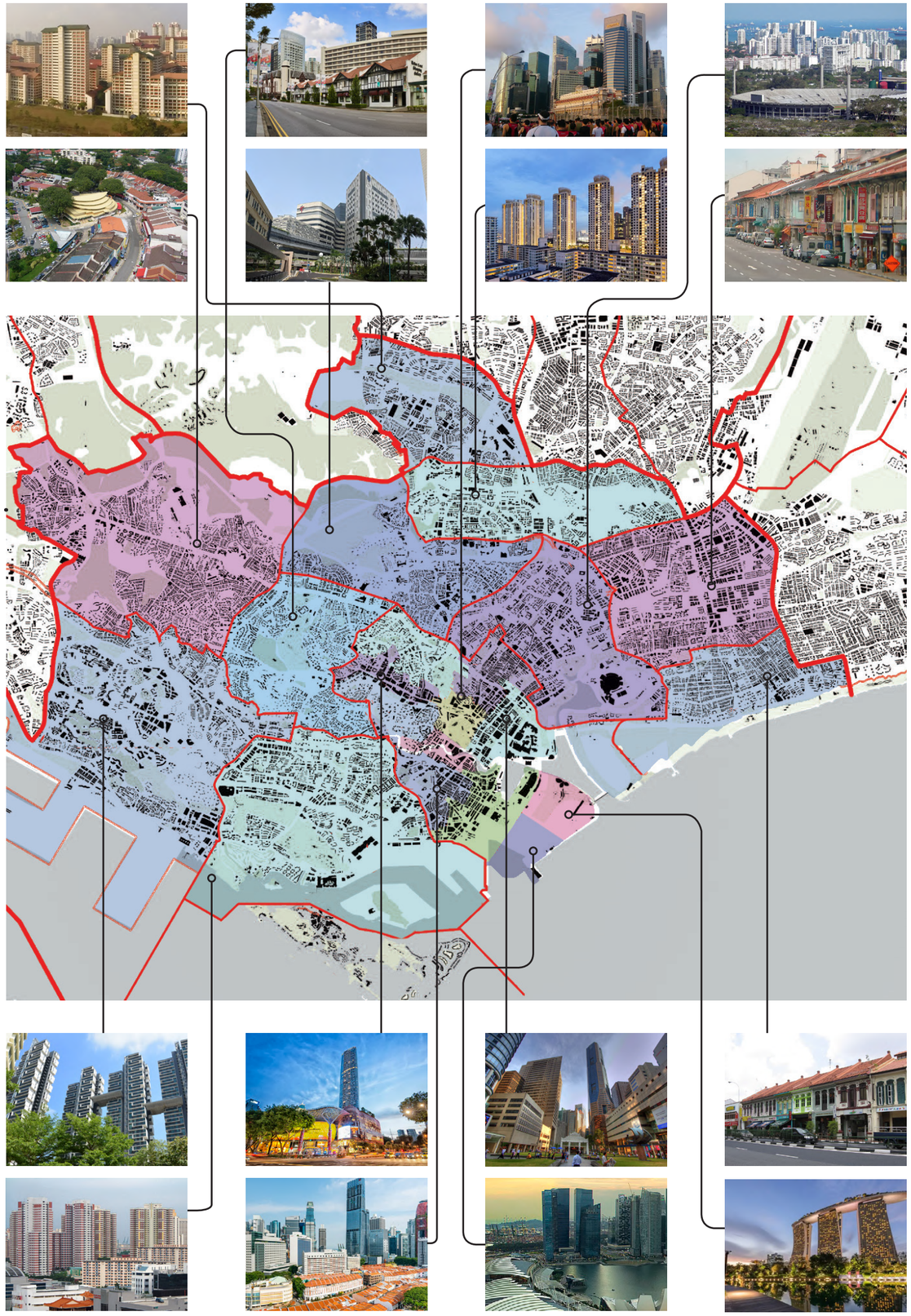
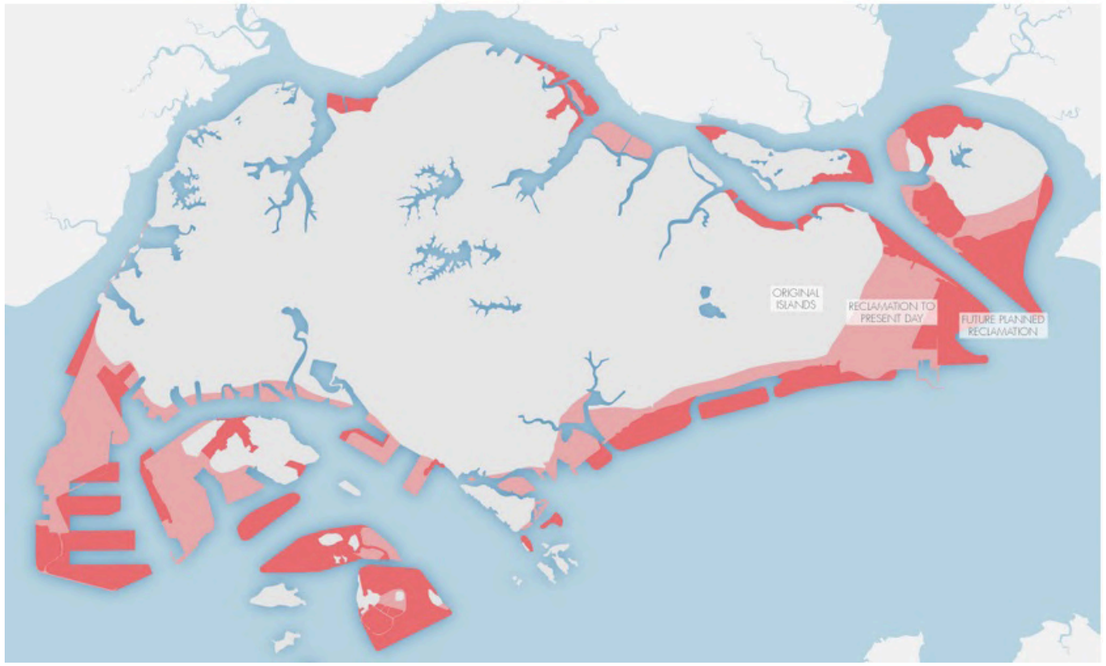


Fig.47. Planning areas of Central region

LAND RECLAMATION



original land reclaimed land future reclamation plans

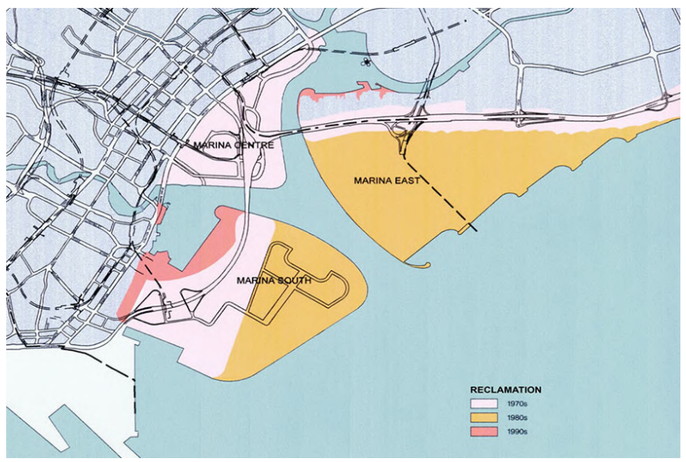
Fig.48. Map of reclaimed land areas of Singapore

When introducing the sites of Singapore, we can not go without mention of land reclamation projects - these produced as much as 17% of all land in the country today.

In fact, a significant portion of Marina Bay, the central port and home to the most iconic points of Singapore, stands on reclaimed land. The process of expanding into the oceans is debated and controversial - after all, not only it is economically demanding and requires extensive engineering work, but it also destroys any coastal ecosystems in the affected ocean parts. Singapore is as ecologically aware as it is possible for a state today, but it is a tough choice between conserving nature and simply having space to exist themselves.

A a point of compromise, in order to accommodate and restore damaged environments, environmental impact assessments (EIAs) are being done since 1990-s before approval of any such project. Restoration efforts had been done by both authorities and public activists.

Land-related projects are being held open and transparent, accepting feedback of the general public as well.



MARINA BAY DEVELOPMENT STRATEGIES

The newly reclaimed territories at the time of their creation were not explicitly dedicated to a particular use, but it was universally agreed on the fact that they are needed there. In today's Land Use Plan, these territories are marked up as mostly White or Reserved (yellow color). Both of these are described as open for interpretation:

These are areas the specific use of which has yet to be determined. Interim uses that are compatible with the uses in the locality may be allowed subject to evaluation by the competent authority.

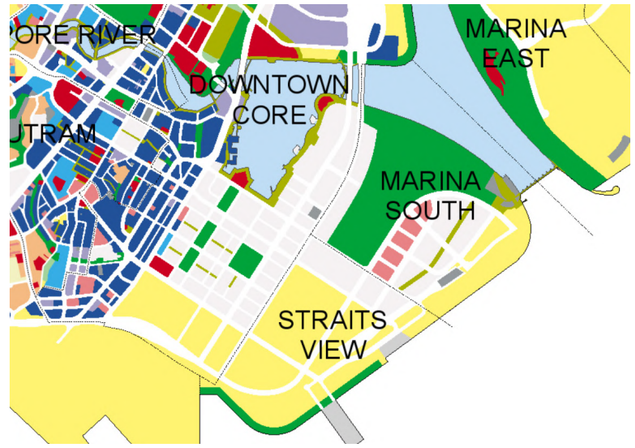


Fig.49. Current Master Plan for land use

However, as seen in the proposal of Urban Redevelopment Authority in 2014, and taking into account the value of land both in the area and in the country, the territories are planned to join the urban fabric of the nearby Central Business District. Despite the density, the project seems to lessen the overall heights of buildings and add more variety, intertwining low- and mid-rise blocks with relatively tall buildings.

Fig.50. 2014 proposal

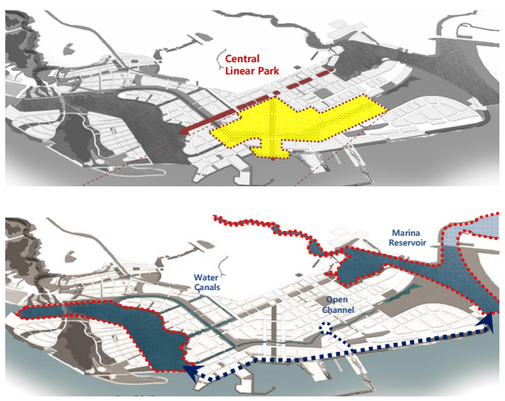
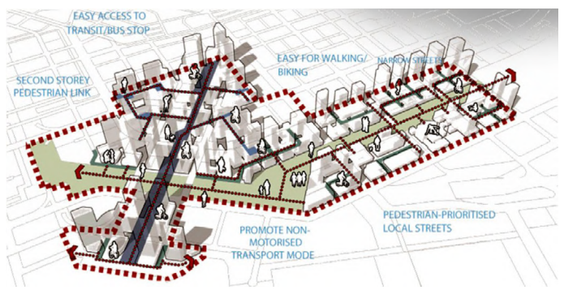


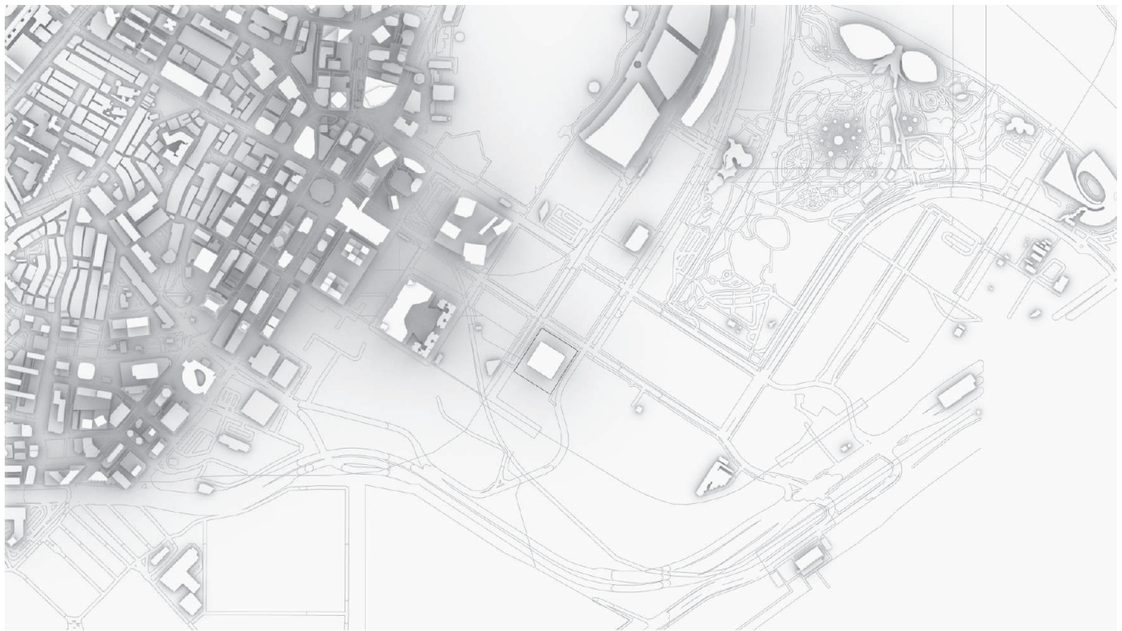
Fig.51. Linear park area and water bodies planned development



Network of public spaces extended;

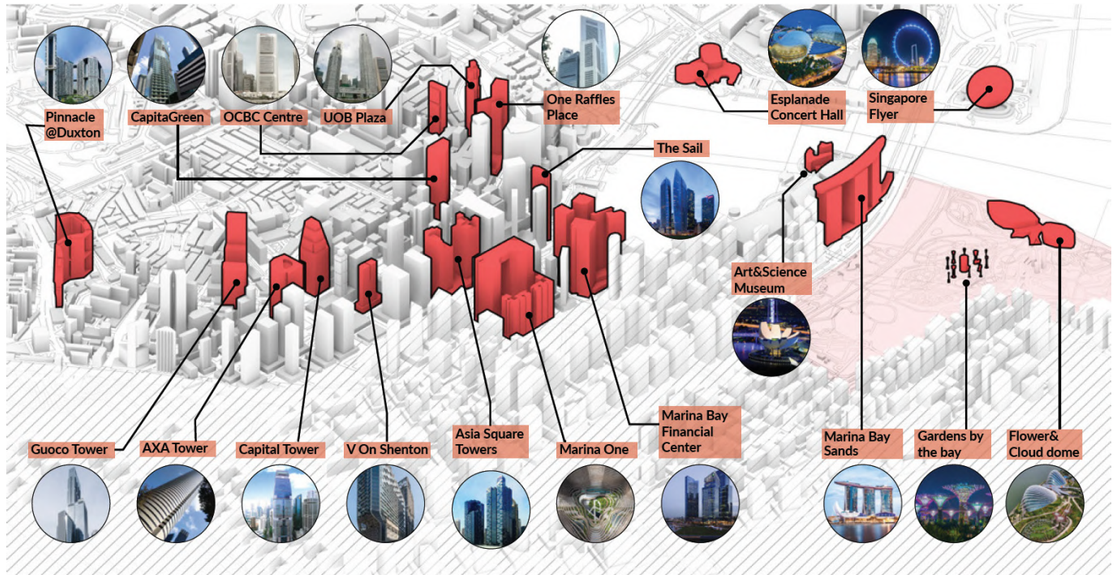
Break through a mass of high-rise with a linear green area, serving as a public park and as a pedestrian street alike. A broad connection to the waterfront.

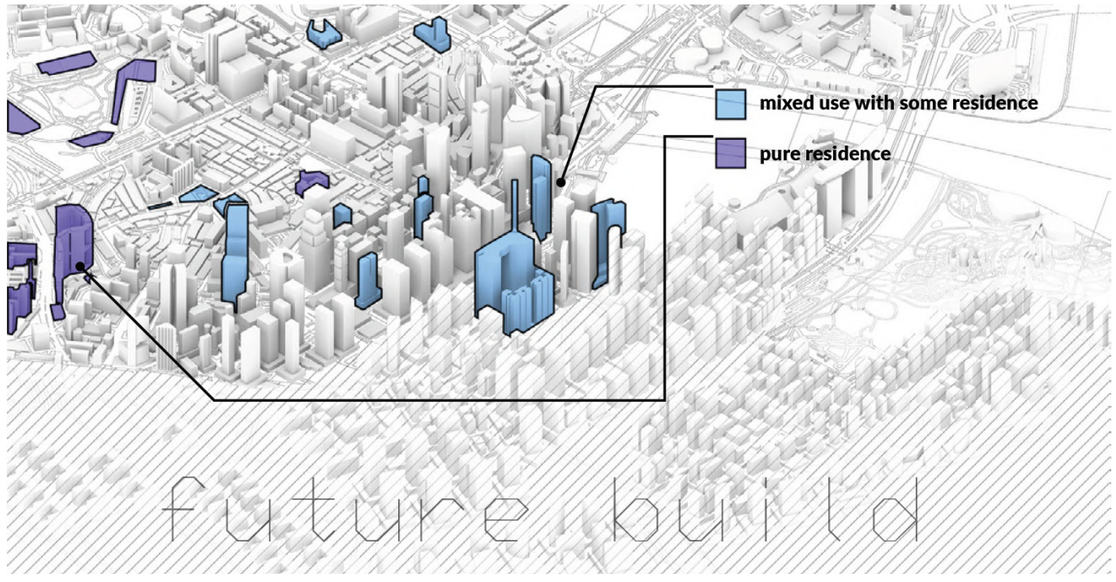
Present-day state of the reclaimed peninsula



Maximal proposed density of a new district

Comparison of functional use in Marina Bay area

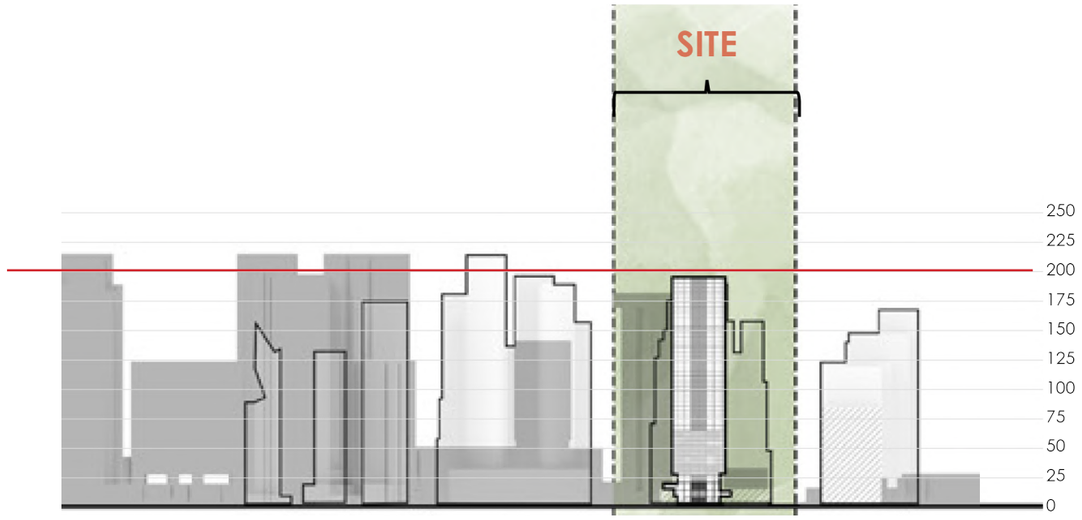




URBAN SECTIONS

Continuing from the previous comparison of existing business center of Singapore and planned districts, we can logically place a potential building in this context.

Keeping with the heights of the surroundings, we fit the building into the downwards curve of heights, making it roughly 200 meters. It is situated at the border of old and new.



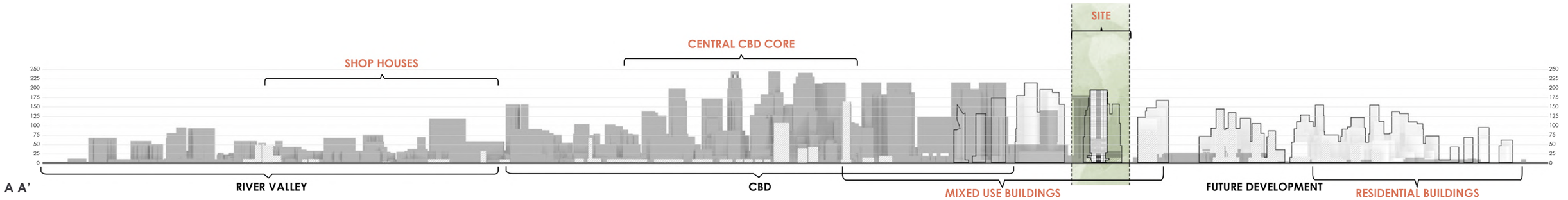


Fig.52. Urban section (NW to SE)

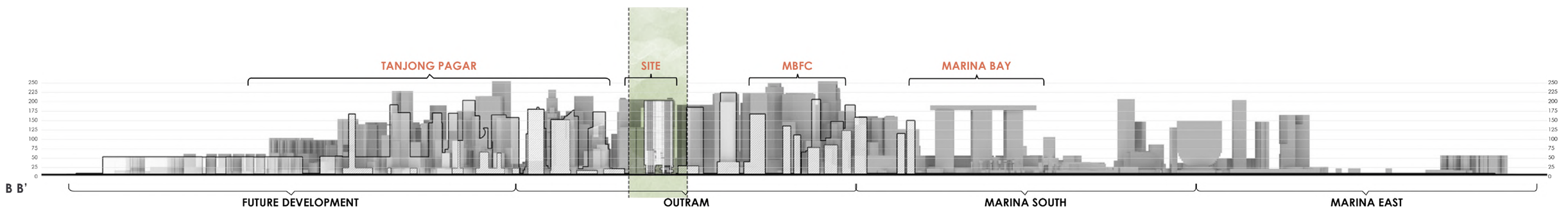


Fig.53. Urban section (SW to NE)

PROBLEM AND SOLUTION

Summarizing all of the aspects described in previous chapters, we can pick out several prominent aspects that need to be considered when planning for a building.

First of all, taking into account the shortage of land, the project needs to be carefully adjusted in scale to the surroundings and make the most use out of the land allocated.

Next, following the current development strategies of the state, that we deem logical and modern, we want to do our part in the overall increase of green connectors in the city. As the site is close to one of the major green streets planned for the future, it can become an extension to it - another branch from a tree, metaphorically. This way, the project not only betters life for the inhabitants, but also improves the areas around it.

There is also the prominent strategy to decentralize business hubs, which works from two directions. New business hubs are planned to be made away from the existing center, to attract life to calmer regions; however, at the same time residence and smaller-scale architecture is introduced into the normally dense and busy urban areas, in order to dilute them.

We need to address the social aspects as well. As seen from the analysis of standard apartment plans through the years, it was considered normal for families to live together as different generations. Nobody expected a young person to move out anywhere when reaching adulthood. While it could be seen as heartwarming and healthy to keep familial ties close - the roots of the traditions, as with many others, lie in scarcity. In modern times, after being influenced by “western values” and with growing economical capacities, the younger generation increasingly desires to live independently. When presented with an inability to separate, they view it as great discomfort. In other words, there is a demand for separation.

In addition, a notable part of modern young people of Singapore does not add creating their own families to their priority list either. The busy central areas of Marina Bay attract a lot of young people striving to build their own careers in the fast paced and competition-heavy environment. They do not prioritize excessive space and luxury when looking for a place to live in. On the contrary, the important aspects are optimal access to work and/or convenience of working from home, after the global digitalization of many jobs. Financial accessibility is also important here.

Another point is that building tall and dense usually has a poor effect on interpersonal connections. The larger the building, the less the tenants know and trust each other. Therefore, there is a need to find a solution that would balance out affordability, height and keep social ties within the community intact.

In conclusion, going with the overall development directions of Singapore and needs of a selected target group, we arrive to a rough idea of a residential building, meant to dilute a former purely business hub, interacting closely with the surrounding land and providing pedestrian-friendly greened areas, which would also encourage the formation of a “good neighbourhood” within itself.

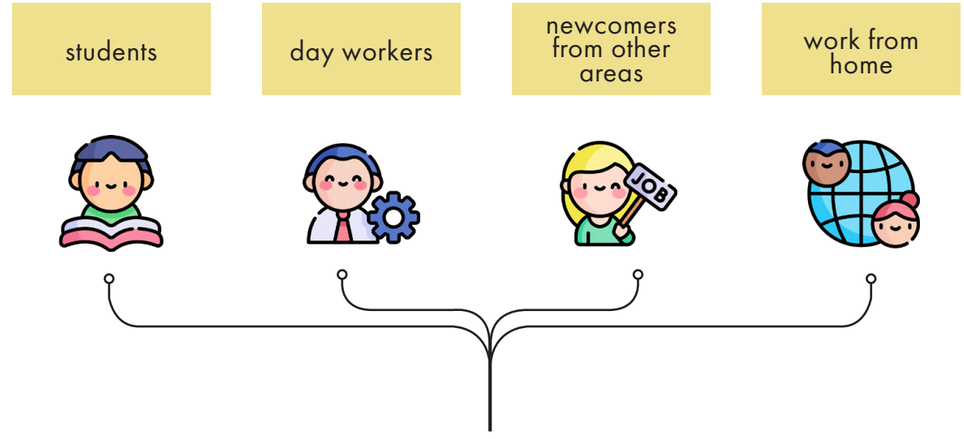
CH.3 ARCHITECTURE

USER ANALYSIS

What are the reasons to live in the center?

close to work	close to university	faster pace of life	public transport	developed infrastructure
The area is still considered the largest business hub and offers more job opportunities than elsewhere.	The overwhelming majority of higher education institution of Singapore is concentrated in this part of the country.	For modern Singaporeans, living fast and competitive became the norm of life.	The transport system is more developed, giving more options to travel both to further parts of the country and around the area.	More services and entertainment are available in a short distance - more comfort of life.

Who are the average users of the building?



Combined special needs:

feeling of personality

services availability

comfortable personal living space

socially healthy neighbourhood

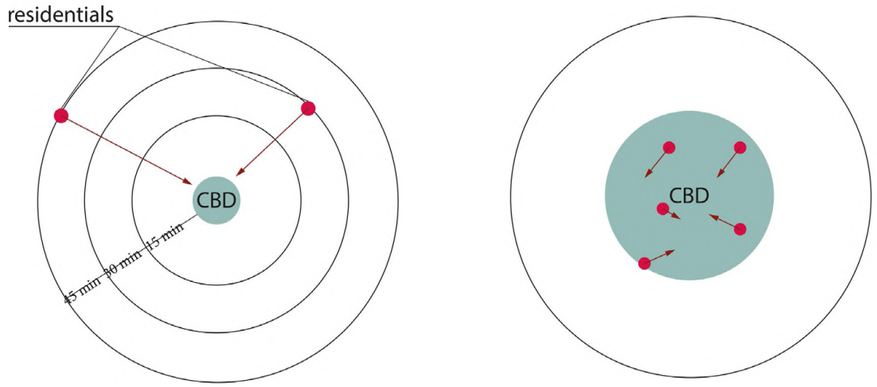
recreation

affordability

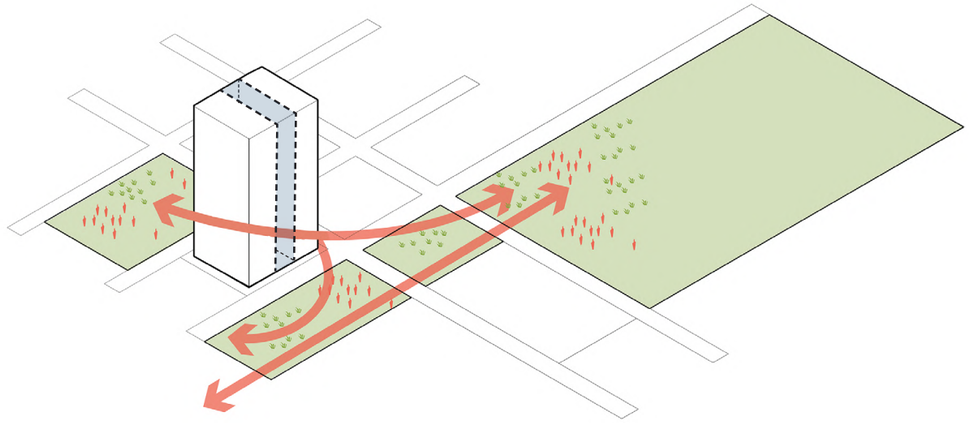
escape from monotony

CONCEPT

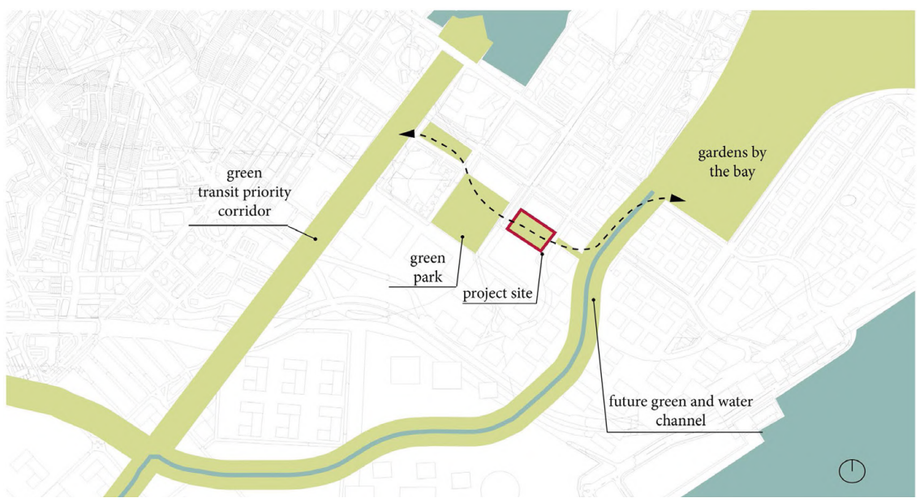
Strategic location closen to meet the needs of residents who work in the business district and want to live in the vicinity



The site provides free access through it from the parks to the metro station.



The project becomes part of a green corridor connecting the future green and water channels. Provides green pedestrian access through its own park.



THE GREEN CONNECTOR CONCEPT

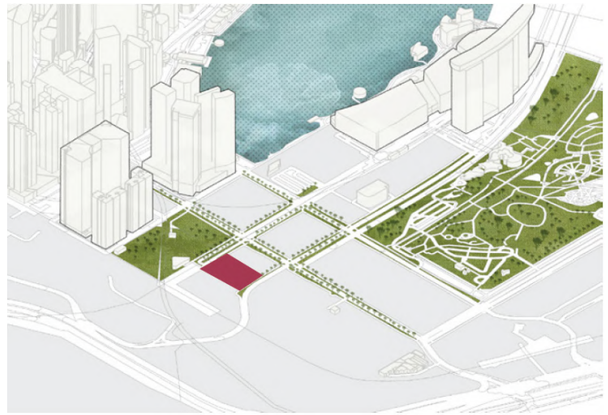


Fig.54. Study of existing and future urban development (plan)

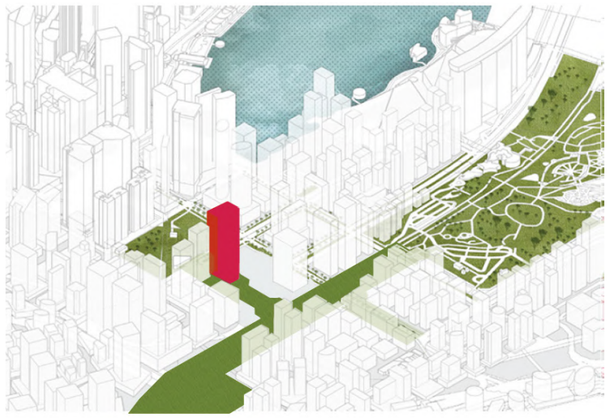
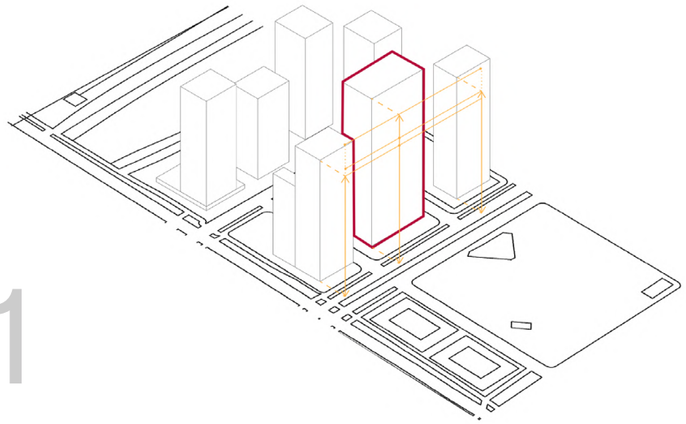


Fig.55. Study of existing and future urban development (axonometry)

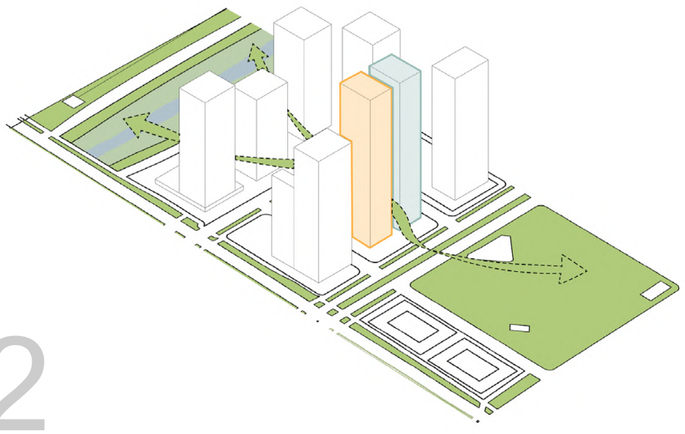
SHAPING ALGORHYTM



1

Placing the main volume in urban context. Potential density of the surrounding area is taken into account.

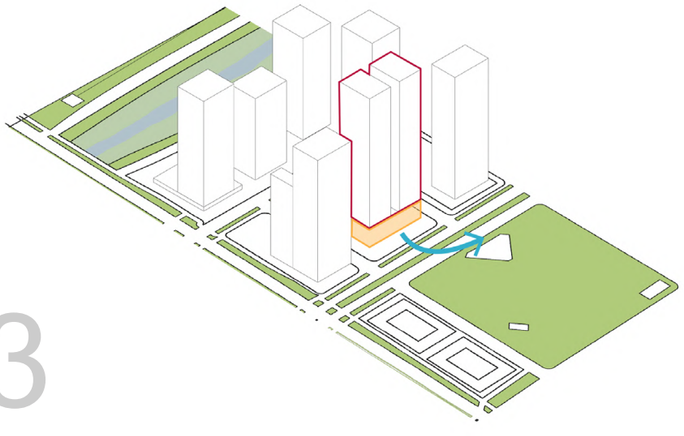
The height of the building is adjusted to the context and to the regulations of Singapore.



2

Creating a passage = "green corridor" through the tight land plot and the building to aid in connecting the city's green zones together.

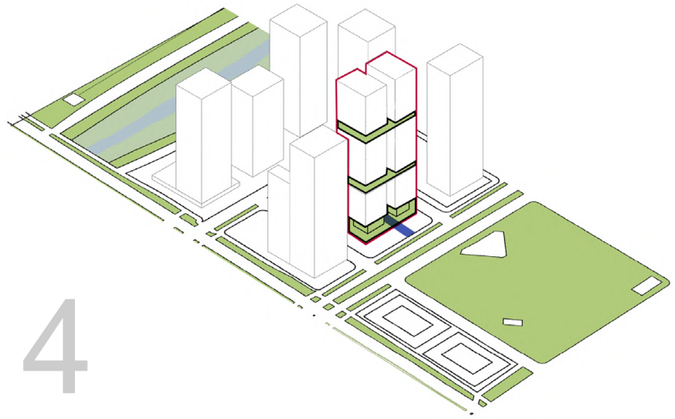
The volume is split in two halves.



3

The building is lifted off the ground in order to free ground floor space to the city and allow for a more free public space.

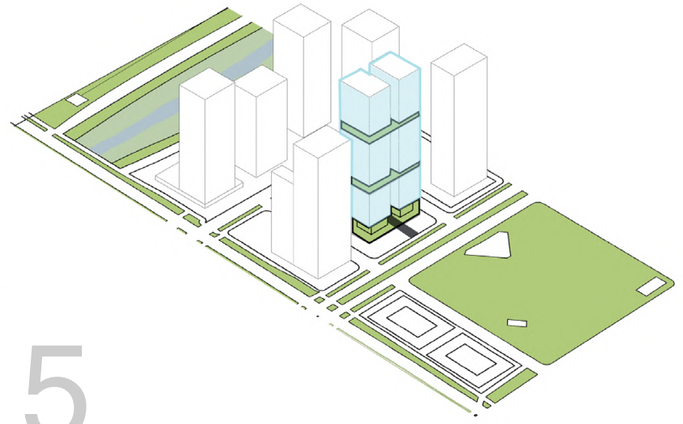
Through the underground, a passage to the adjoining metro station is created.



4

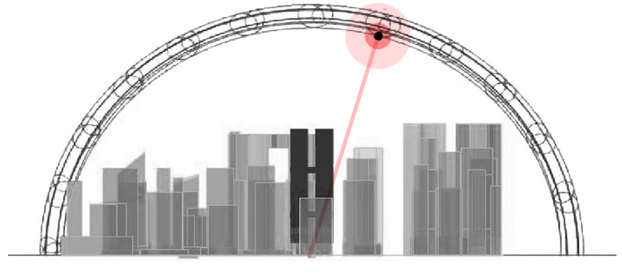
The two volumes of the building are additionally cut on two levels, forming two "gardens".

They are connecting the towers together visually and act as internal recreational space for the tenants, as well as giving the project a distinctive look.



5

Finally, the building is wrapped in a skin, adding shading in areas where sun is not wanted (typical floors) and leaving the glass free of shade where it is required (in garden floors).



Additionally, we need to remember about the local sunlight prevalence on the equator - during the day it is staying high.

BASIC DIMENSIONS

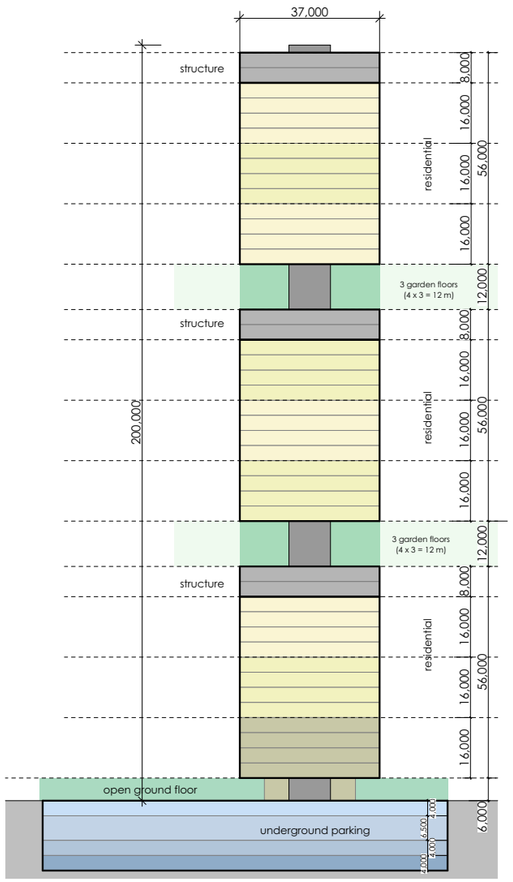
After choosing the plot, approximating the general height and justifying the shaping algorhytm, we are adding more definition to the project.

As seen before, it is evenly split in two towers to create a clear “door“ through the plot; we label them as tower A and tower B. We add two more cuts, this time horisontally, to connect the towers via two gardens. We end up with a structure of six identical blocks stacked above each other, each being 32 by 37 meters in plan and 56 meters in height.

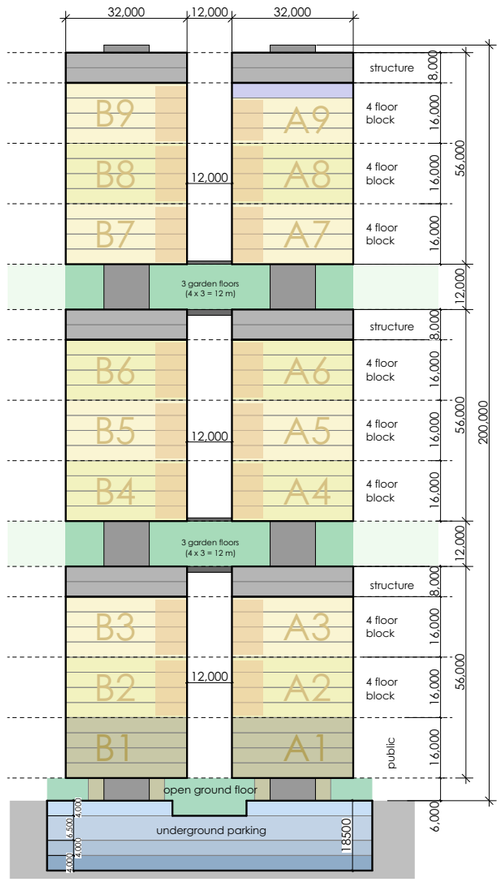
Each of the 6 blocks is, in turn, comprised out of 3 enclosed residential blocks (modules), topped by a primary structure of 8 meters high. The modules are assigned labels according to level and tower (A1, B2, etc.) They are also varied on the inside in plan and organisation, but are identical to one another. The exceptions are the two block on the bottom (A1 and B1), which are left for commercial use, and the A9 block, that leaves out space for a restaurant floor.

The two gardens both span three typical floors in height - 12 meters total, and are supported by a “bridge“ inbetween towers.

The typical floor height is taken as 4 meters to accomodate for all the slab layers and other services, while leaving sufficient ceiling height for inhabitants. The total height of the building from the ground is 200 meters.

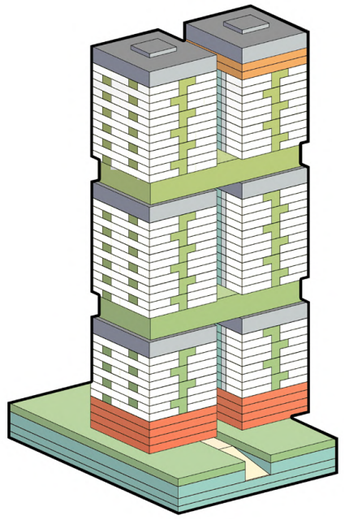


Side view



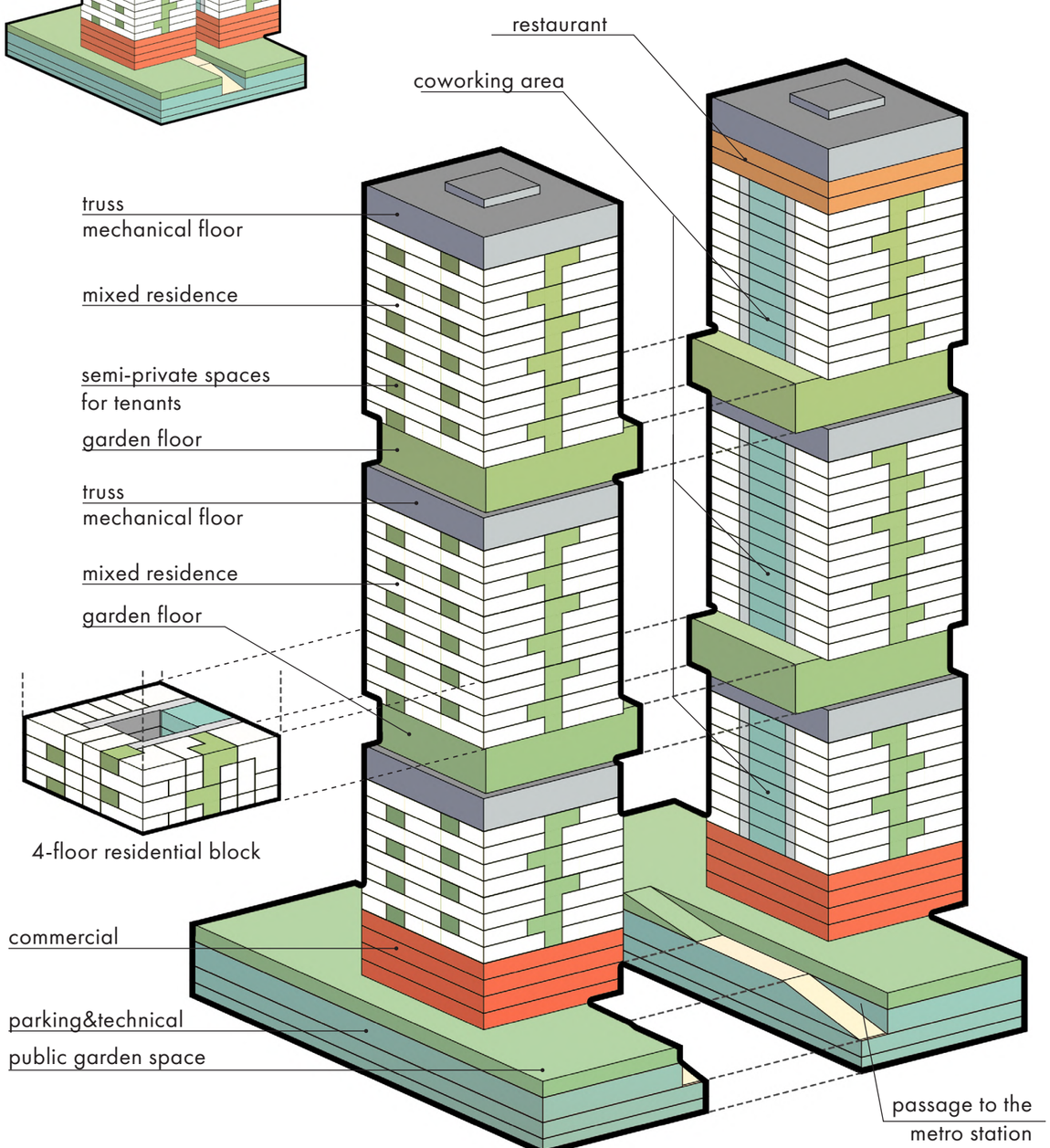
Front view

BUILDING PROGRAM: OVERALL VOLUMES

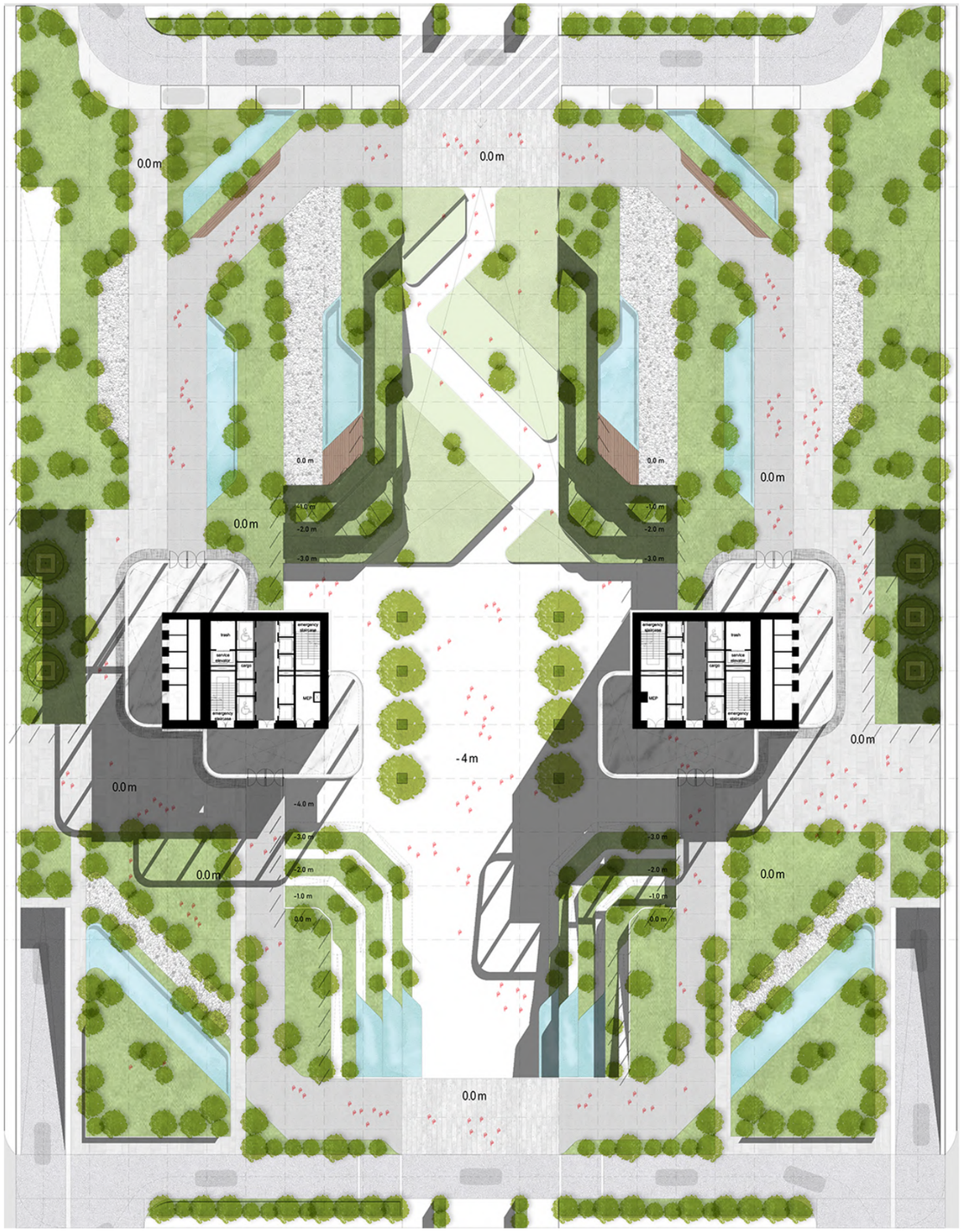


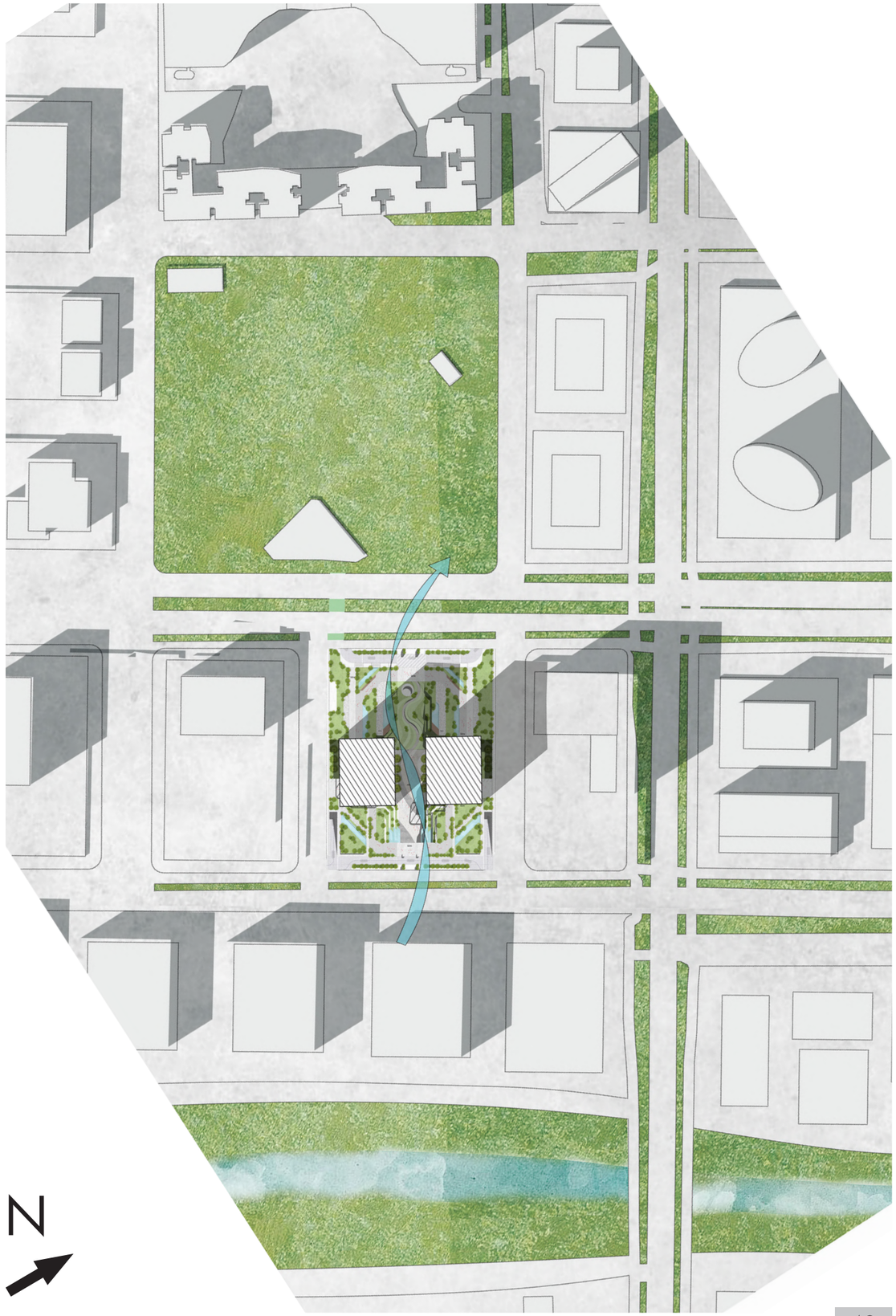
Actual volume

Split view

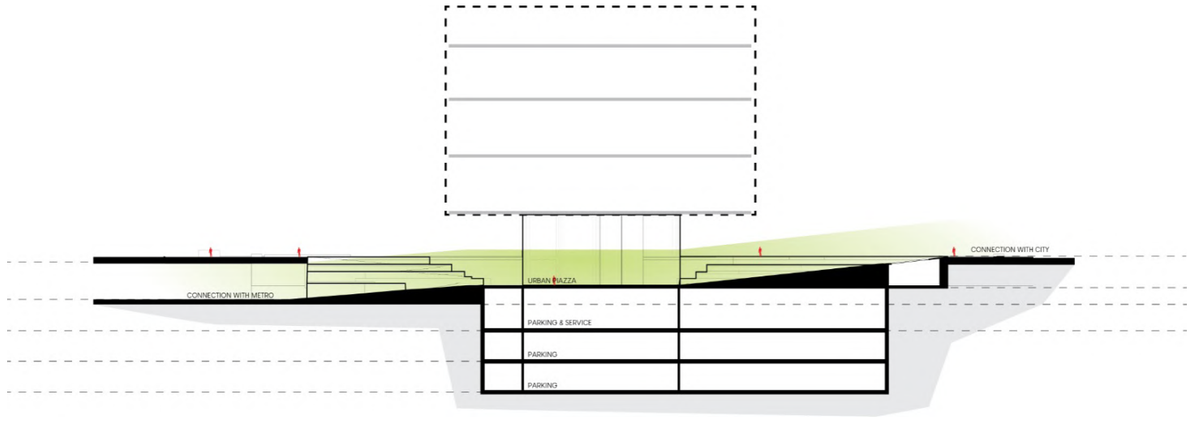


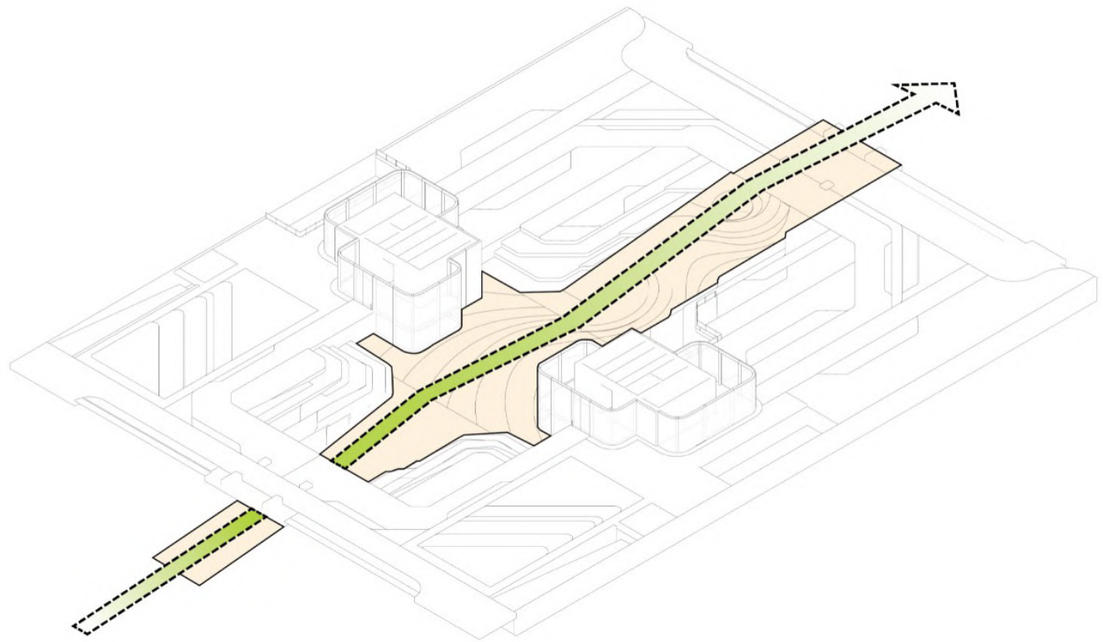
GROUND FLOOR PLAN / SITE MASTER PLAN



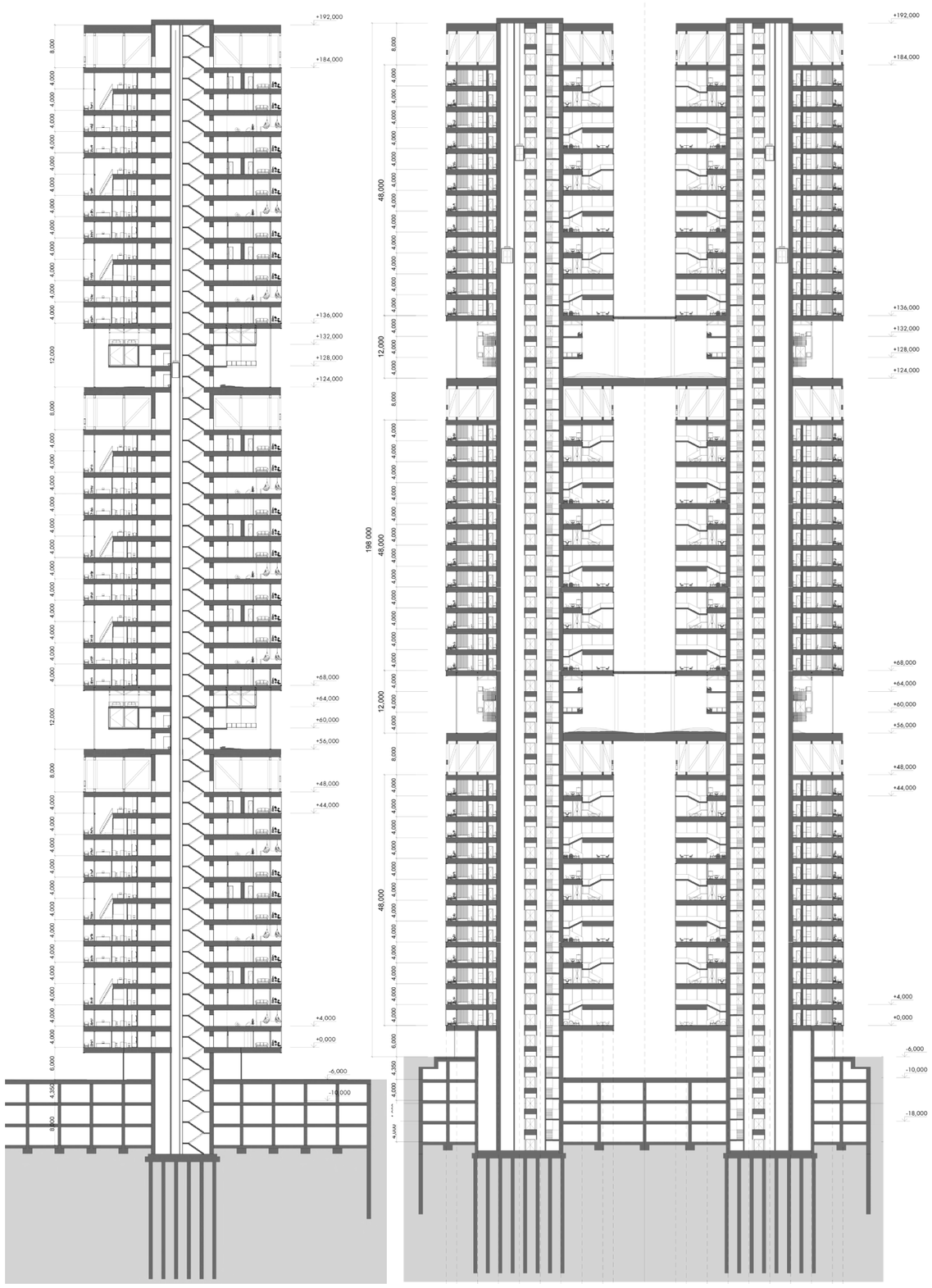


ACCESS TO THE METRO STATION UNDERGROUND



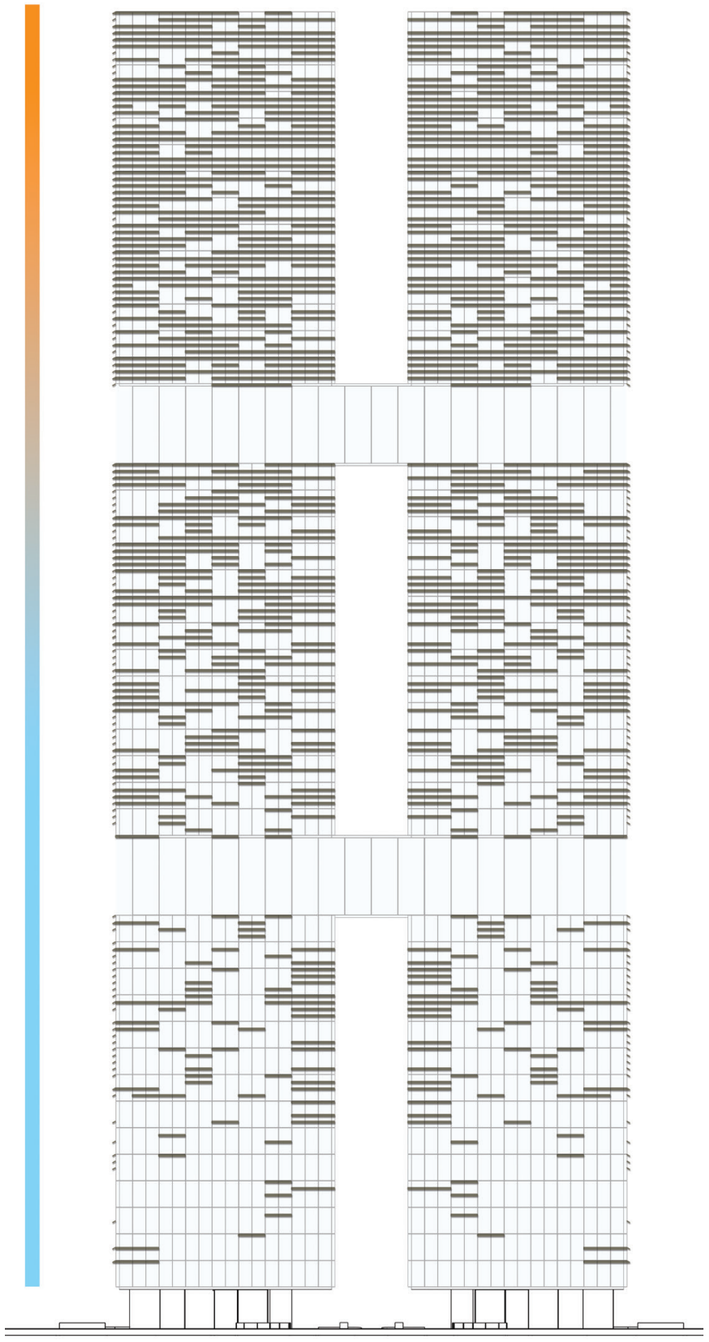


SECTION

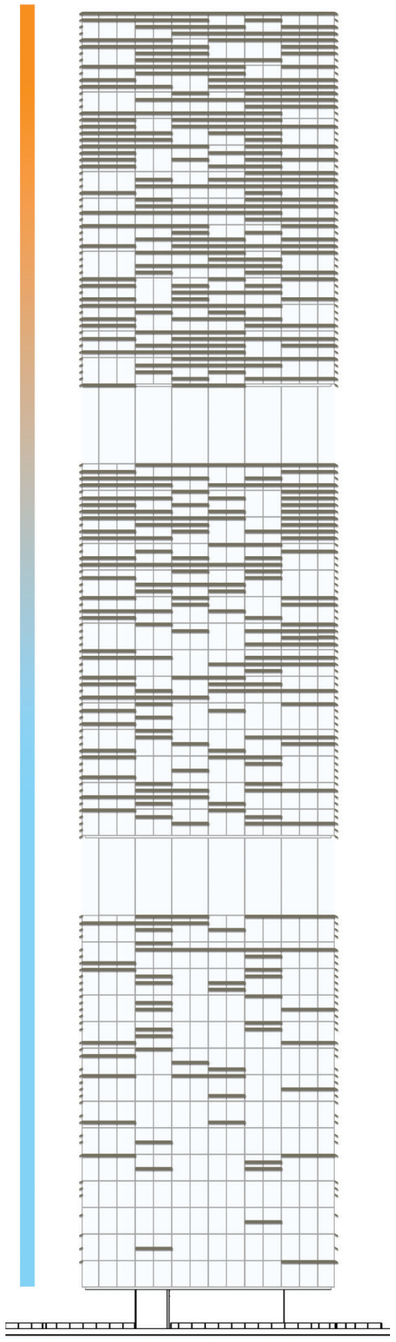


ELEVATIONS

The outermost skin of the building includes a shading system, which is distributed in a pattern derived from sunlight intensity on the building's surfaces. The distribution is represented through a color gradient. The shading system is viewed in more detail in Ch.5.



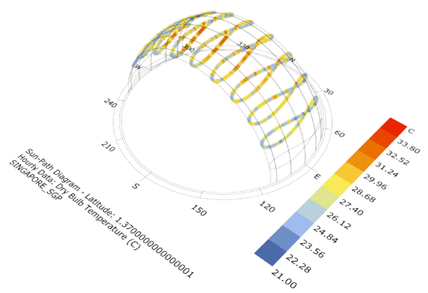
Front view, both towers



Side view

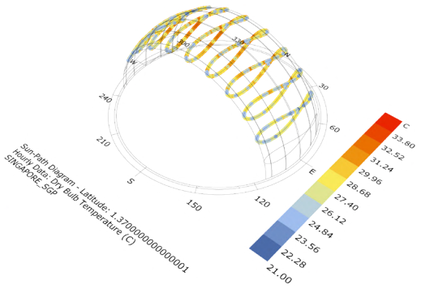
TYPICAL FLOOR PLAN: LEVEL 1

12 meter gap

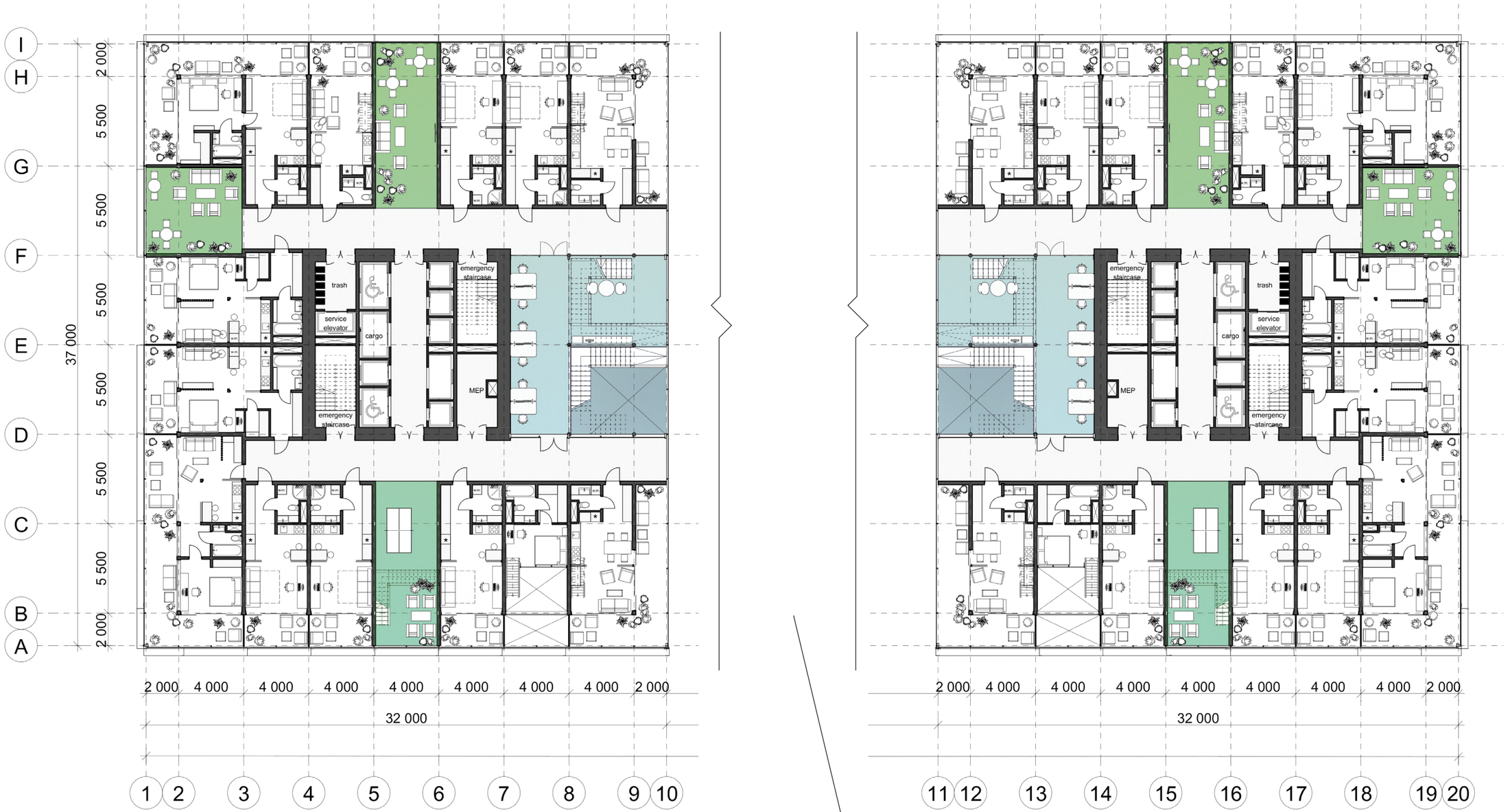


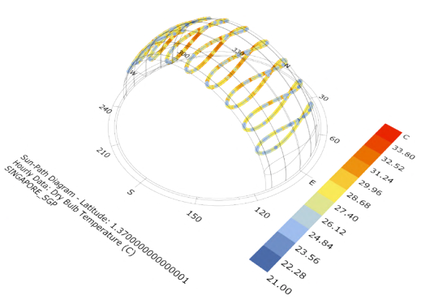
TYPICAL FLOOR PLAN: LEVEL 2

12 meter gap



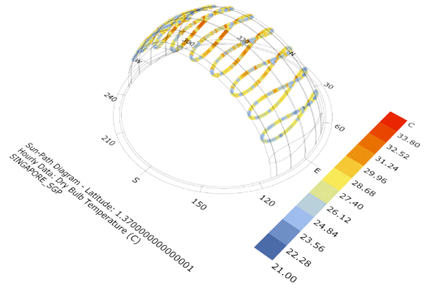
TYPICAL FLOOR PLAN: LEVEL 3



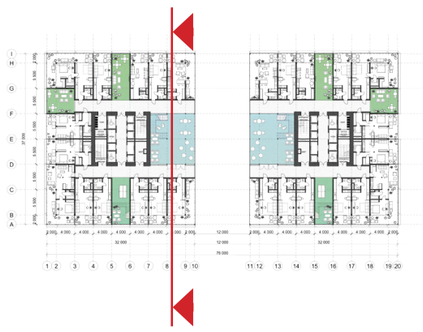


TYPICAL FLOOR PLAN: LEVEL 4

12 meter gap

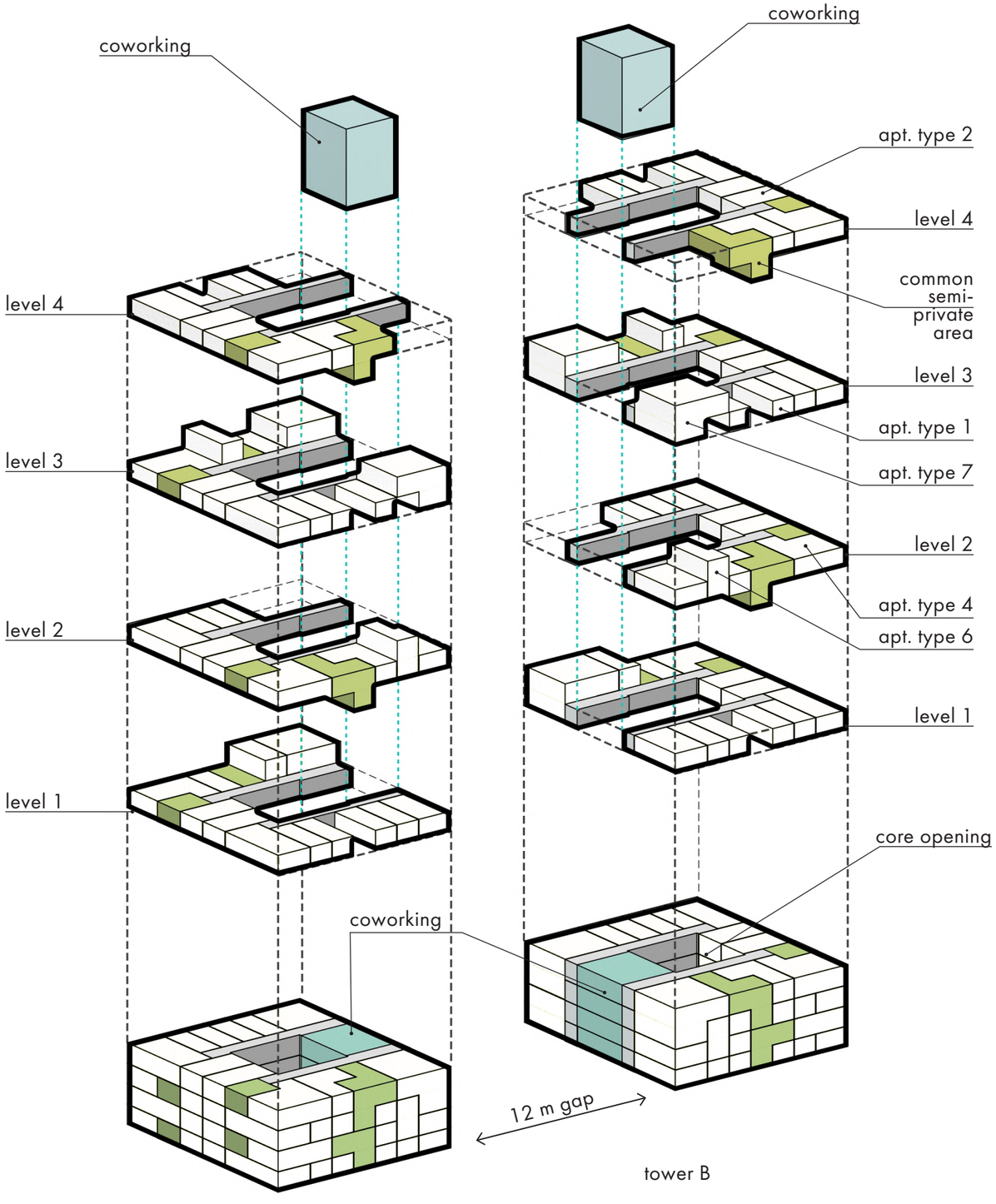


RESIDENTIAL SECTION



RESIDENTIAL SECTION

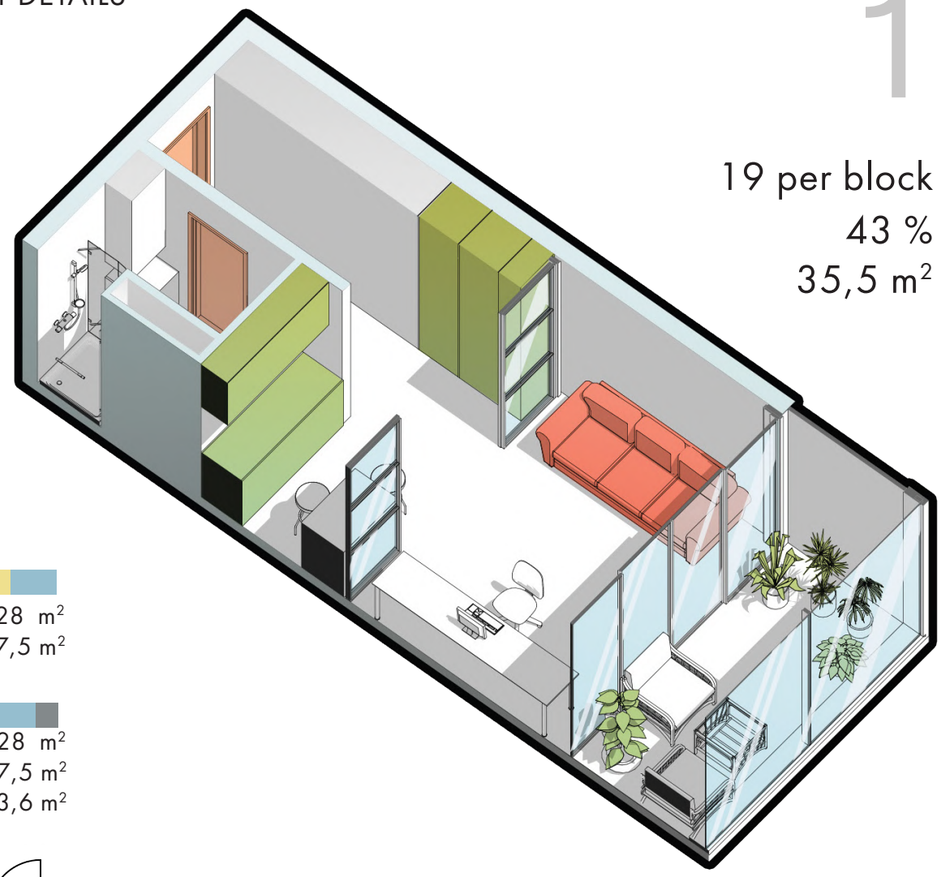
BUILDING PROGRAM: EXPLODED RESIDENTIAL 4-FLOOR BLOCK



APARTMENT DETAILS

1

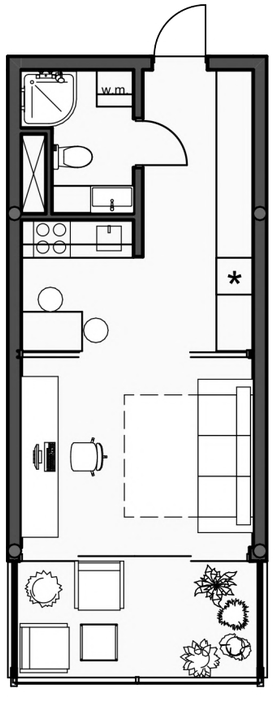
19 per block
43 %
35,5 m²



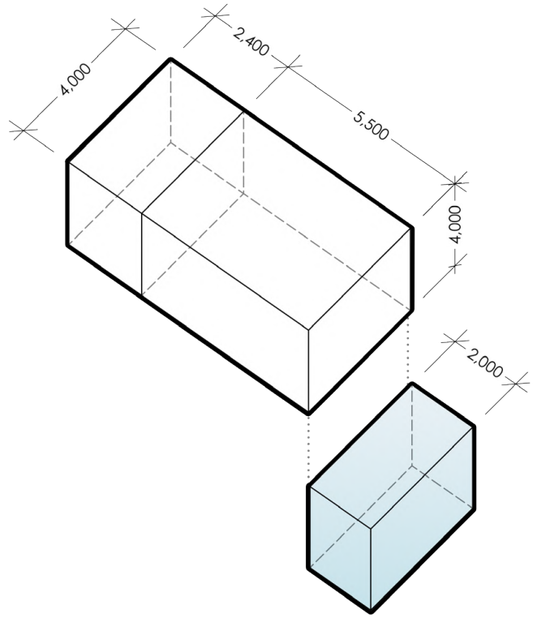
Residents:

Apartment: 28 m²
Balcony: 7,5 m²

Living+kitchen: 28 m²
Balcony: 7,5 m²
W/c: 3,6 m²

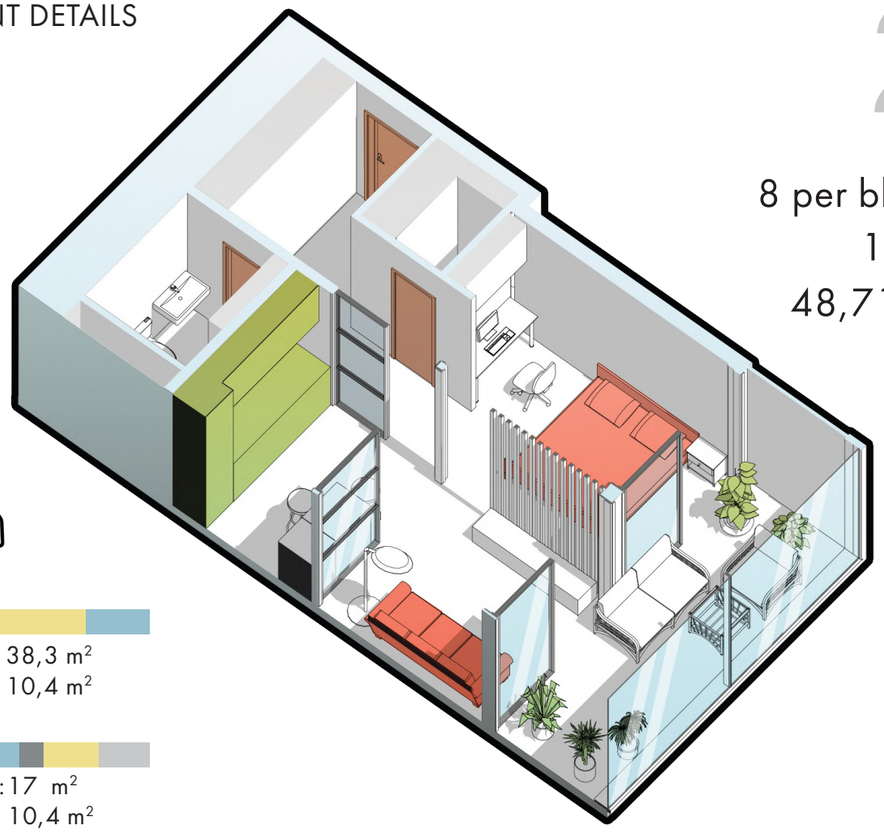


Apartment plan (1) 1:100



2

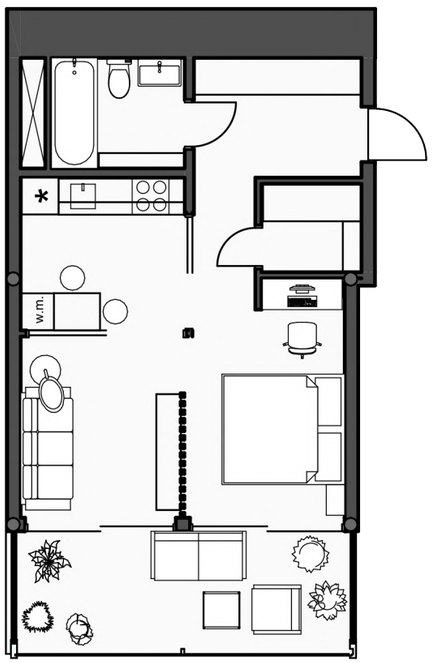
8 per block
18 %
48,71 m²



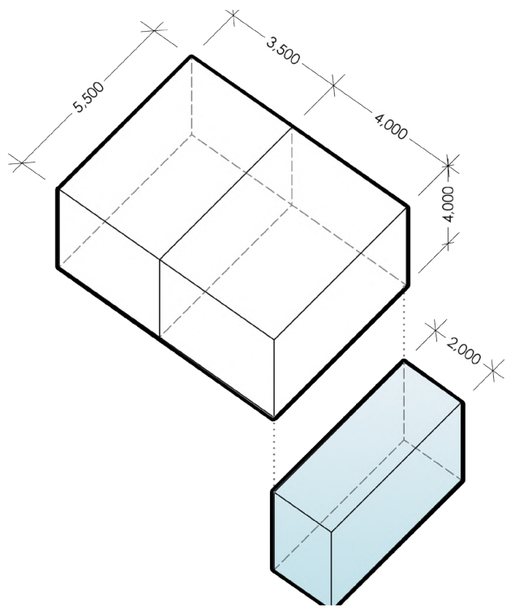
Residents:

Apartment: 38,3 m²
Balcony: 10,4 m²

Living+kitchen: 17 m²
Balcony: 10,4 m²
W/c: 3,9 m²
Bedroom: 9,0 m²



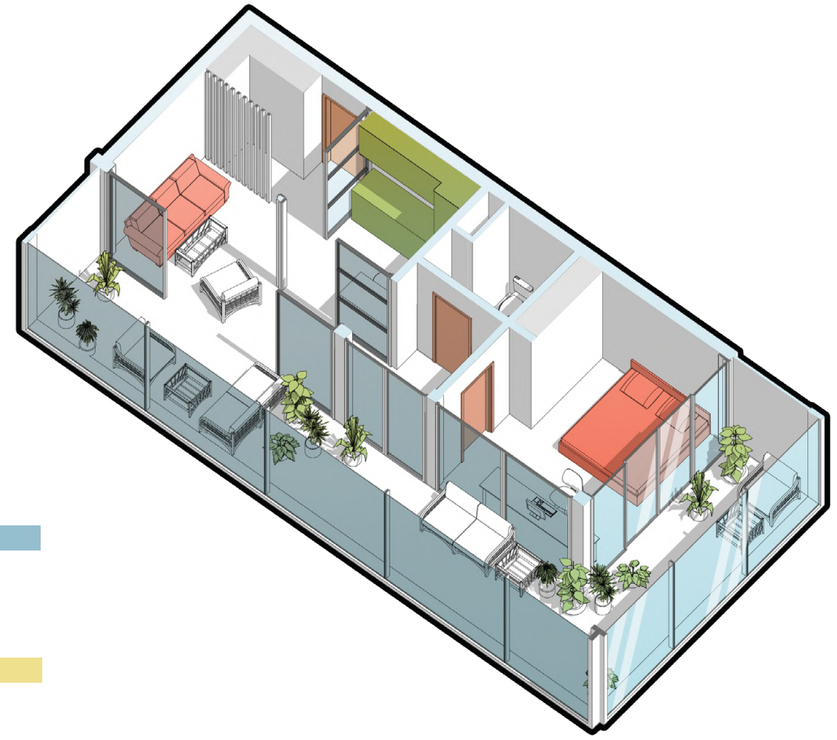
Apartment plan



Apartment in blocks

3

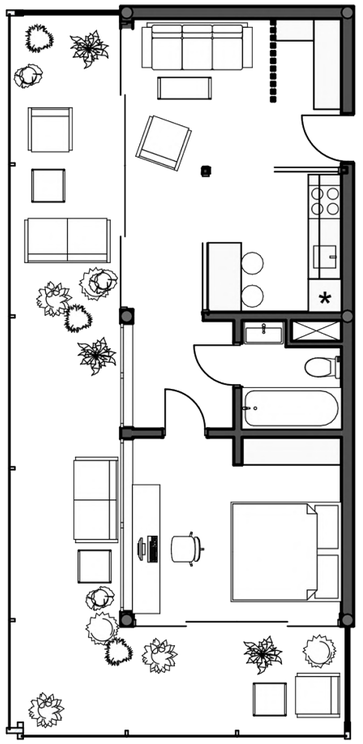
4 per block
9 %
71,75 m²



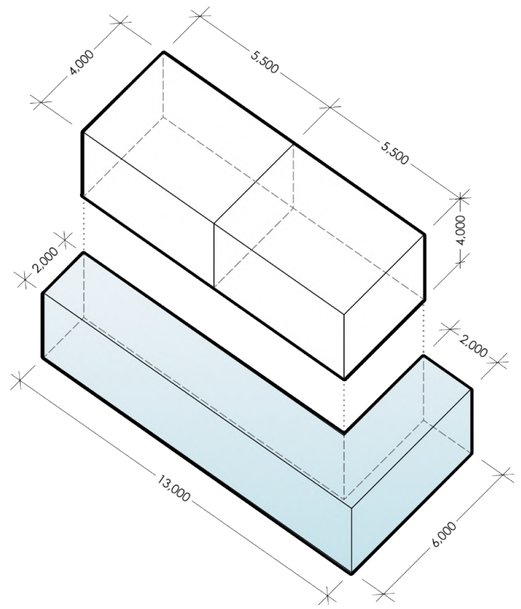
Residents:

Apartment: 39 m²
Balcony: 32,5 m²

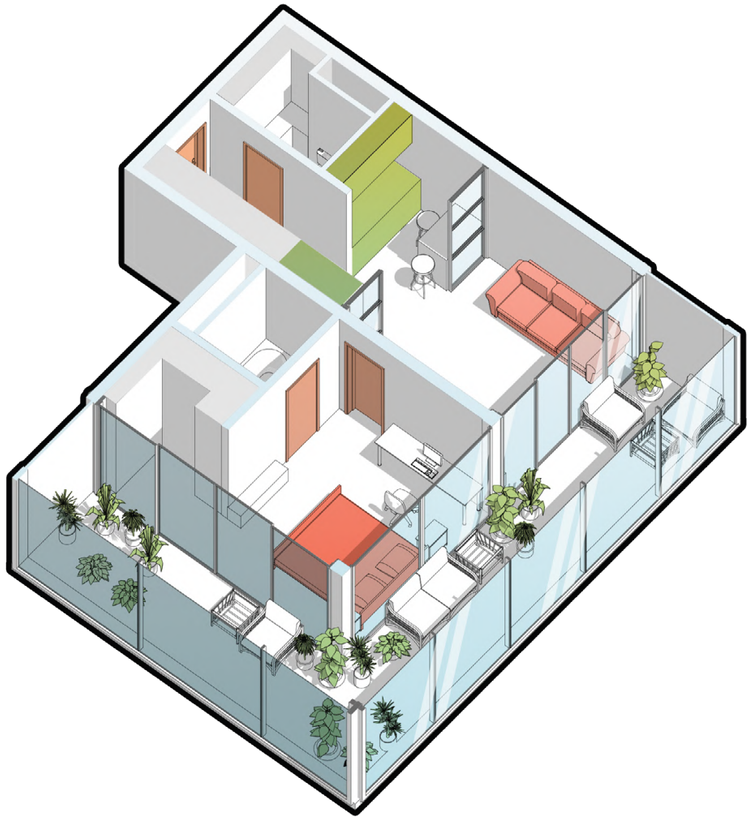
Living+kitchen: 24 m²
Balcony: 32,5 m²
W/c: 3,1 m²
Bedroom: 12,3 m²



Apartment plan



Apartment in blocks



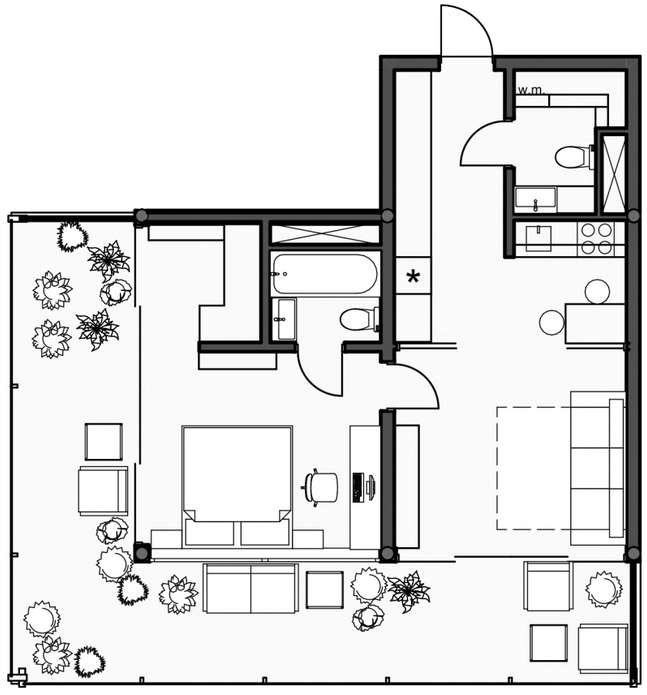
4

4 per block
9 %
75,44 m²

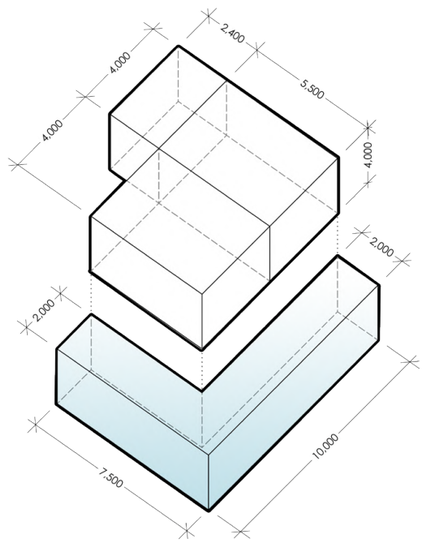
Residents: 1 / 2

Apartment:	46,5 m²
Balcony:	29 m²

Living+kitchen:	19 m²
Balcony:	29 m²
W/c:	6,3 m²
Bedroom:	15,8 m²



Apartment plan



Apartment in blocks

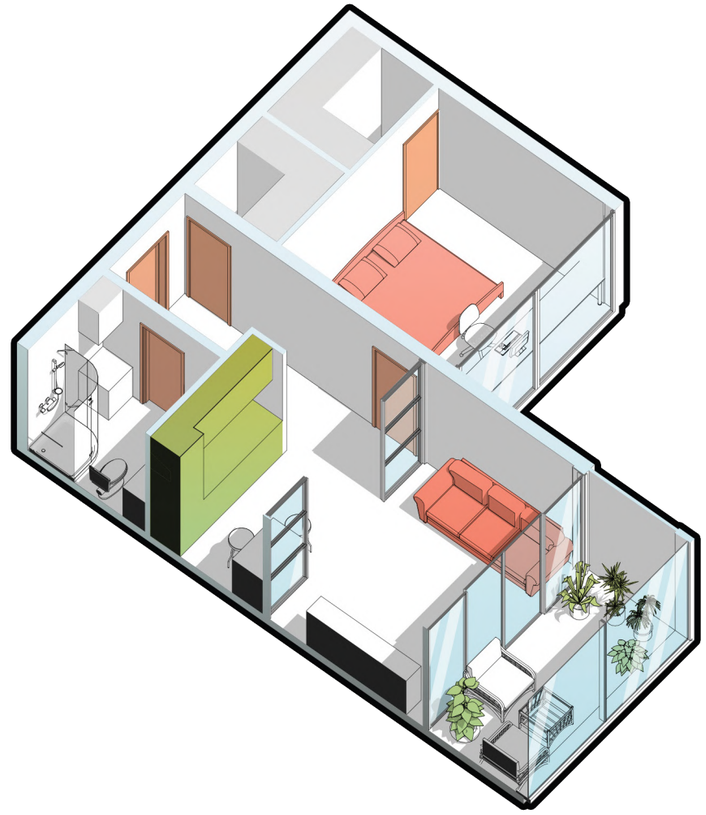
5

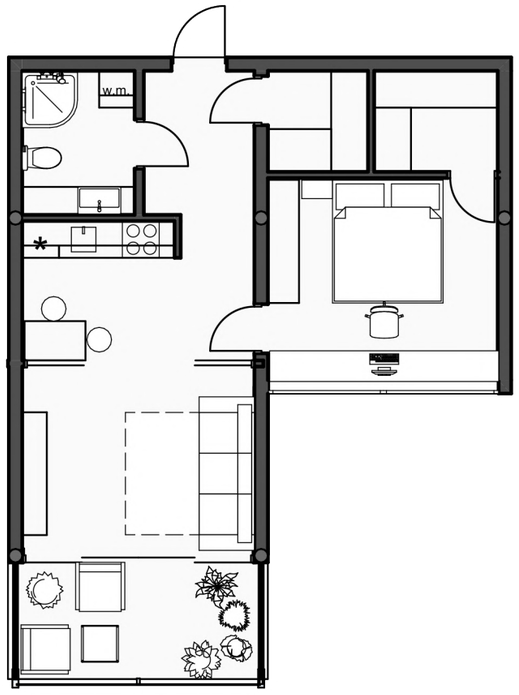
3 per block
6 %
54,72 m²

Residents: 1 / 2

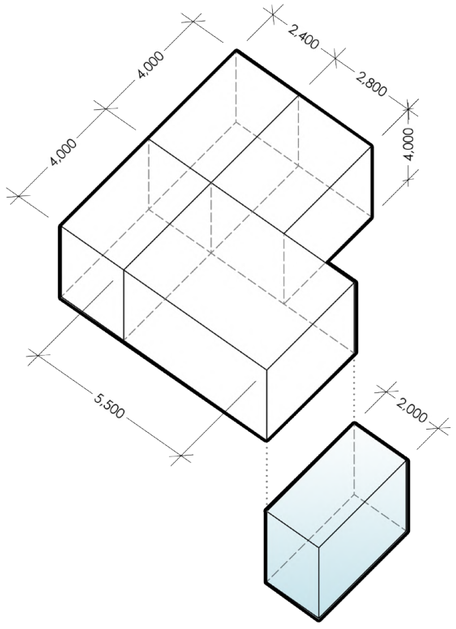
Apartment:	47,25 m²
Balcony:	7,47 m²

Living+kitchen:	20,25 m²
Balcony:	7,47 m²
W/c:	4,29 m²
Bedroom:	12,31 m²

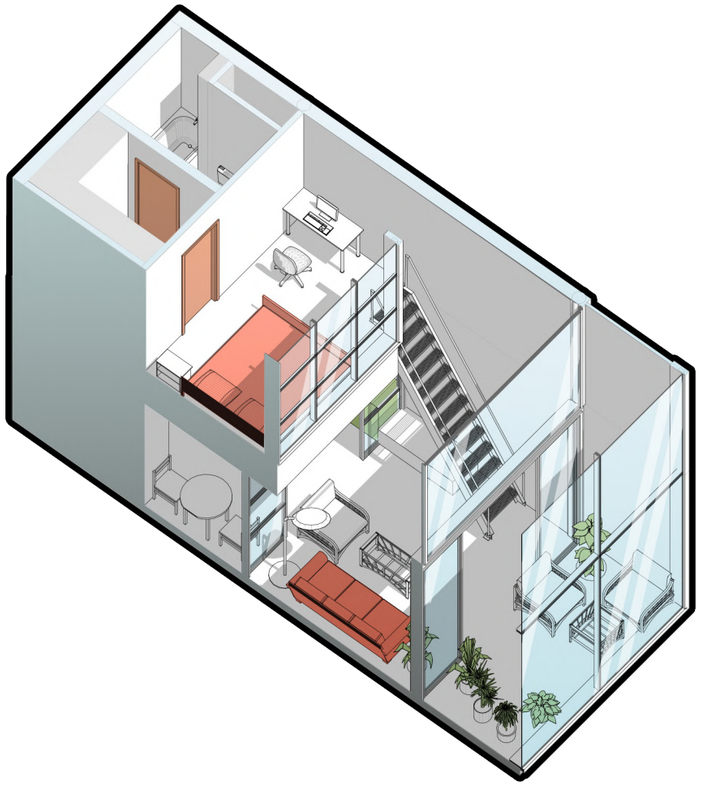




Apartment plan



Apartment in blocks



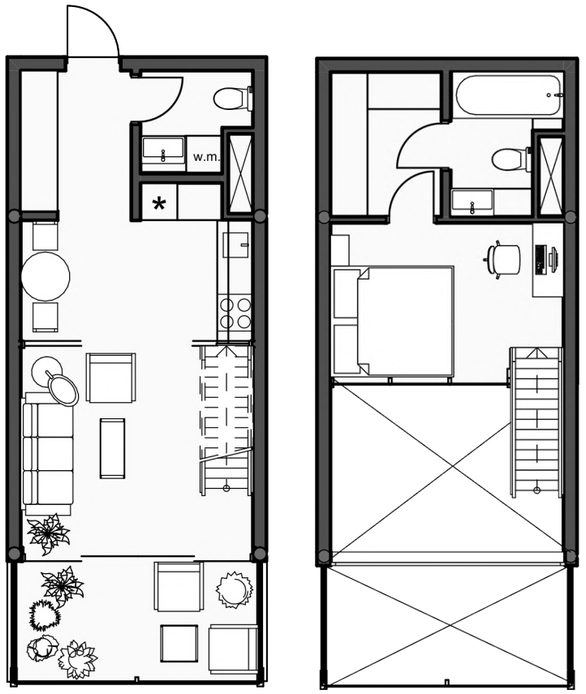
6

8 per block
18 %
52,35 m²

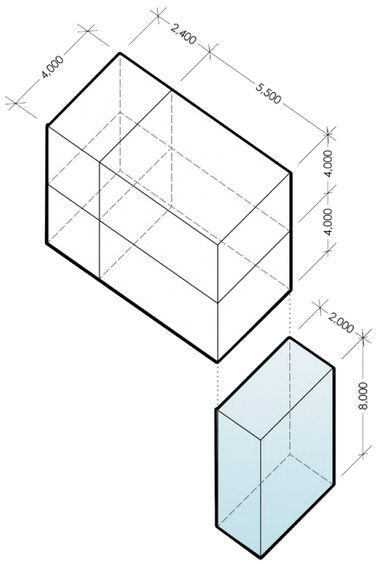
Residents: 1 / 2

Apartment: 44,88 m²
Balcony: 7,47 m²

Living+kitchen: 21,15 m²
Balcony: 7,47 m²
W/c: 6,3 m²
Bedroom: 9,11 m²



Apartment plan (two floors)



Apartment in blocks

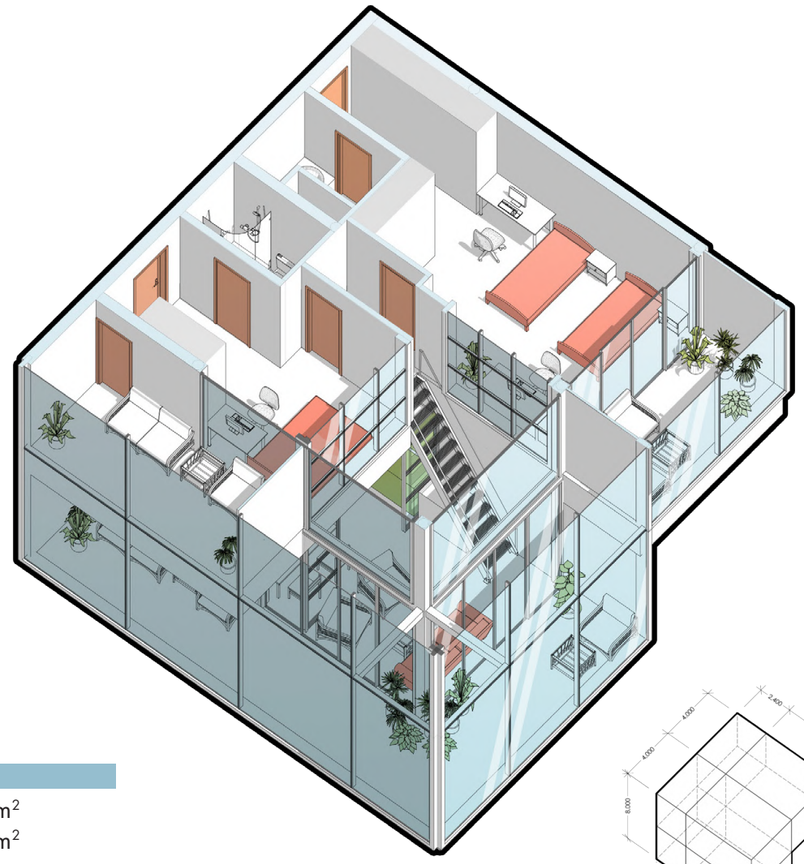
7

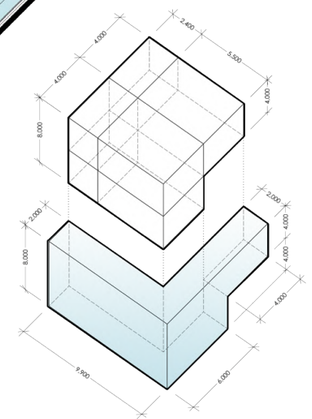
4 per block
9 %
116,63 m²

Residents: 3 / 4

Apartment: 73,26 m²
Balcony: 43,37 m²

Living+kitchen: 26,49 m²
Balcony: 43,37 m²
W/c: 9,7 m²
Bedrooms: 37,07 m²

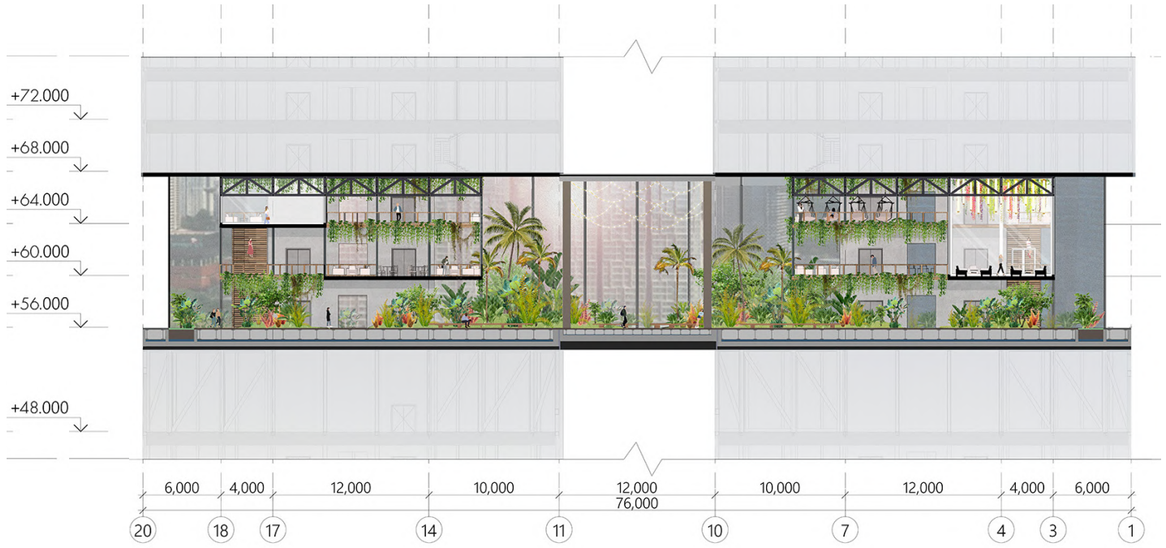


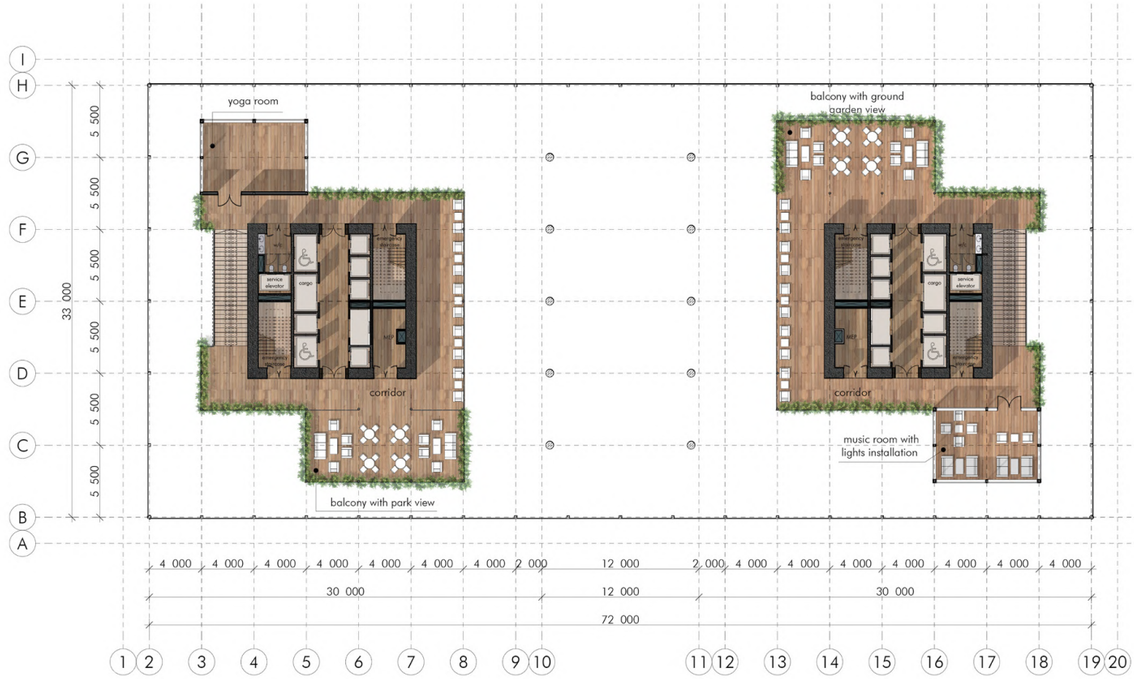


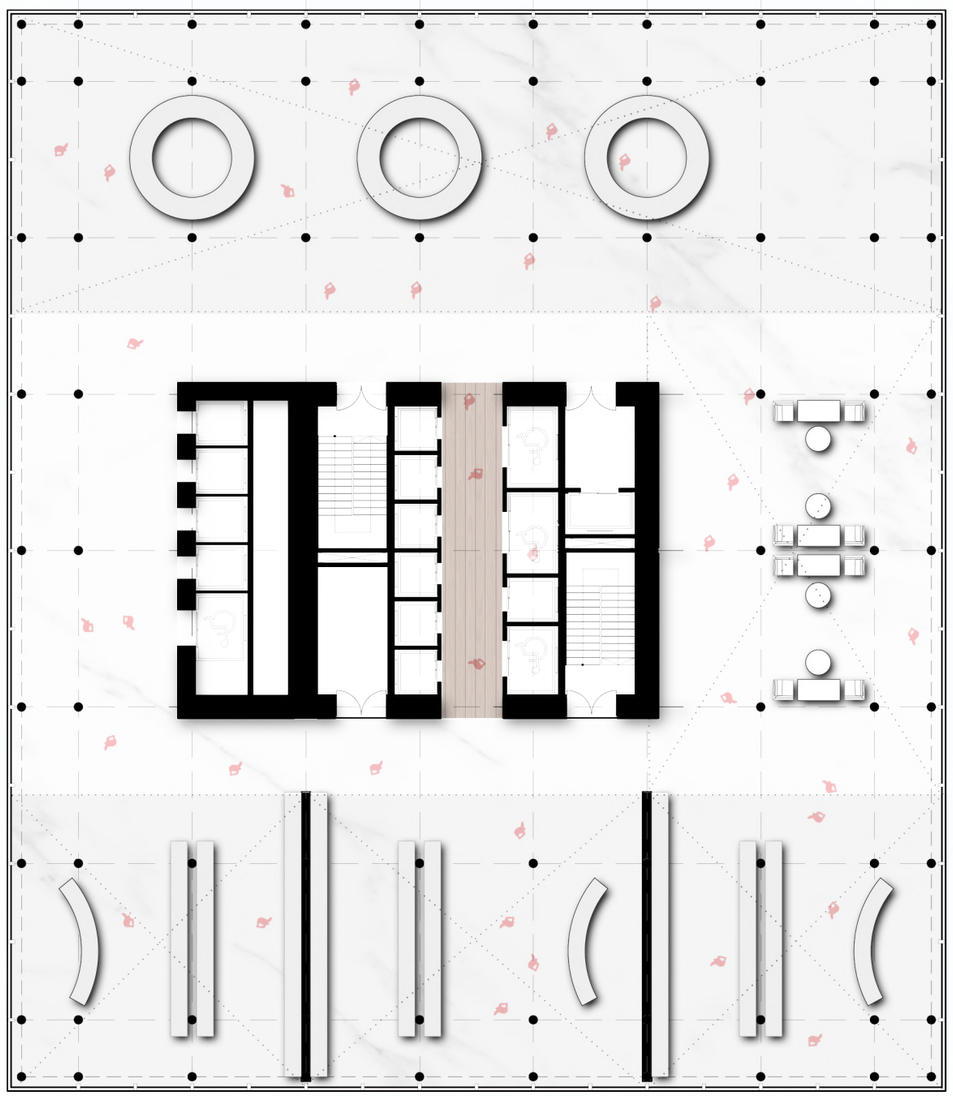
Apartment in blocks

Apartment plan (two floors)

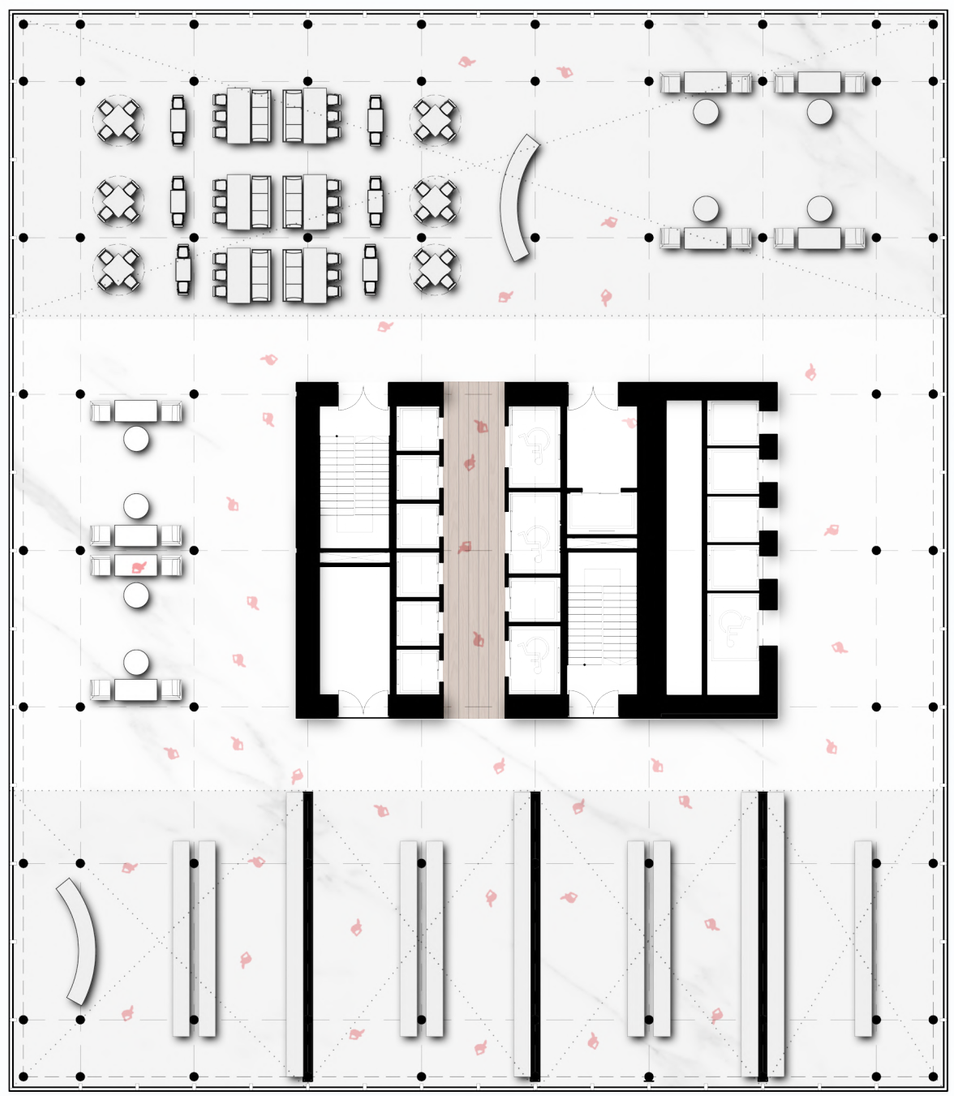
GARDEN FLOORS

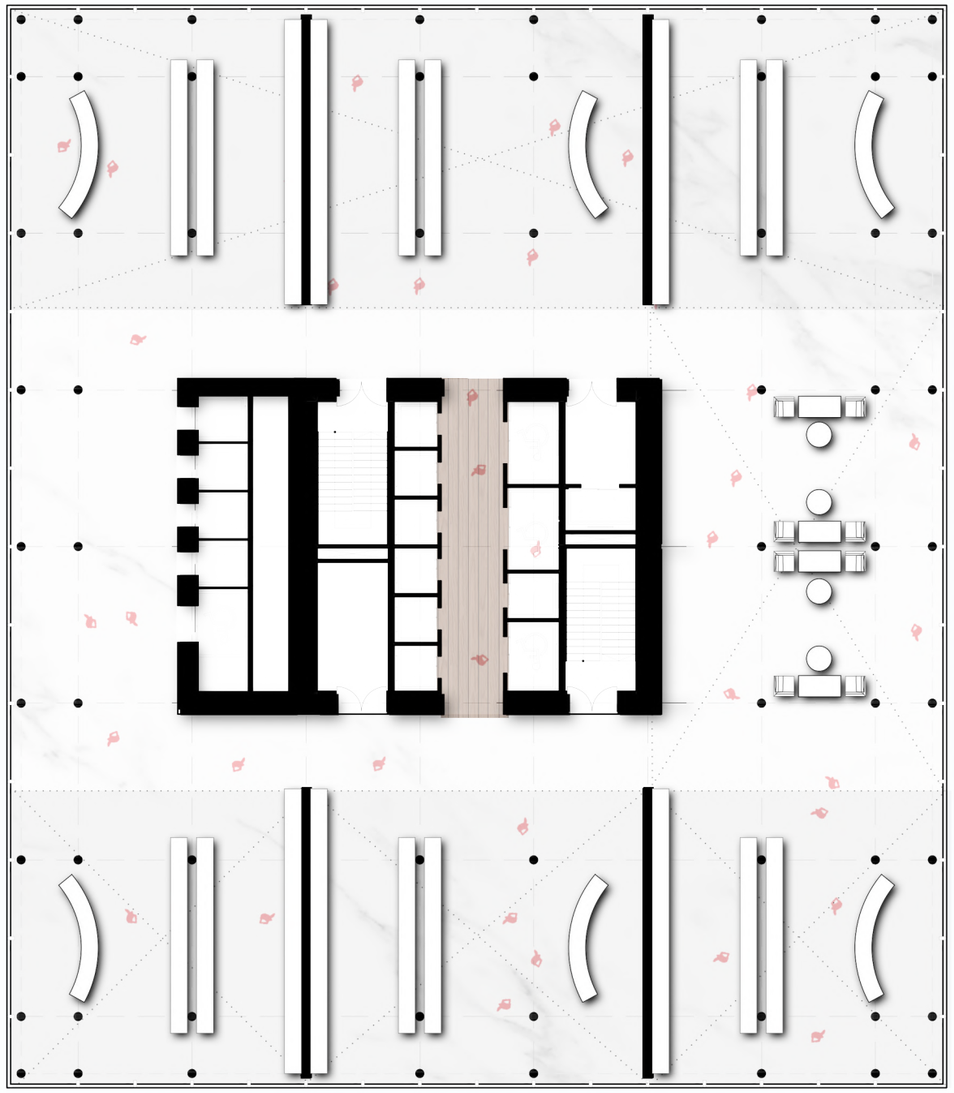




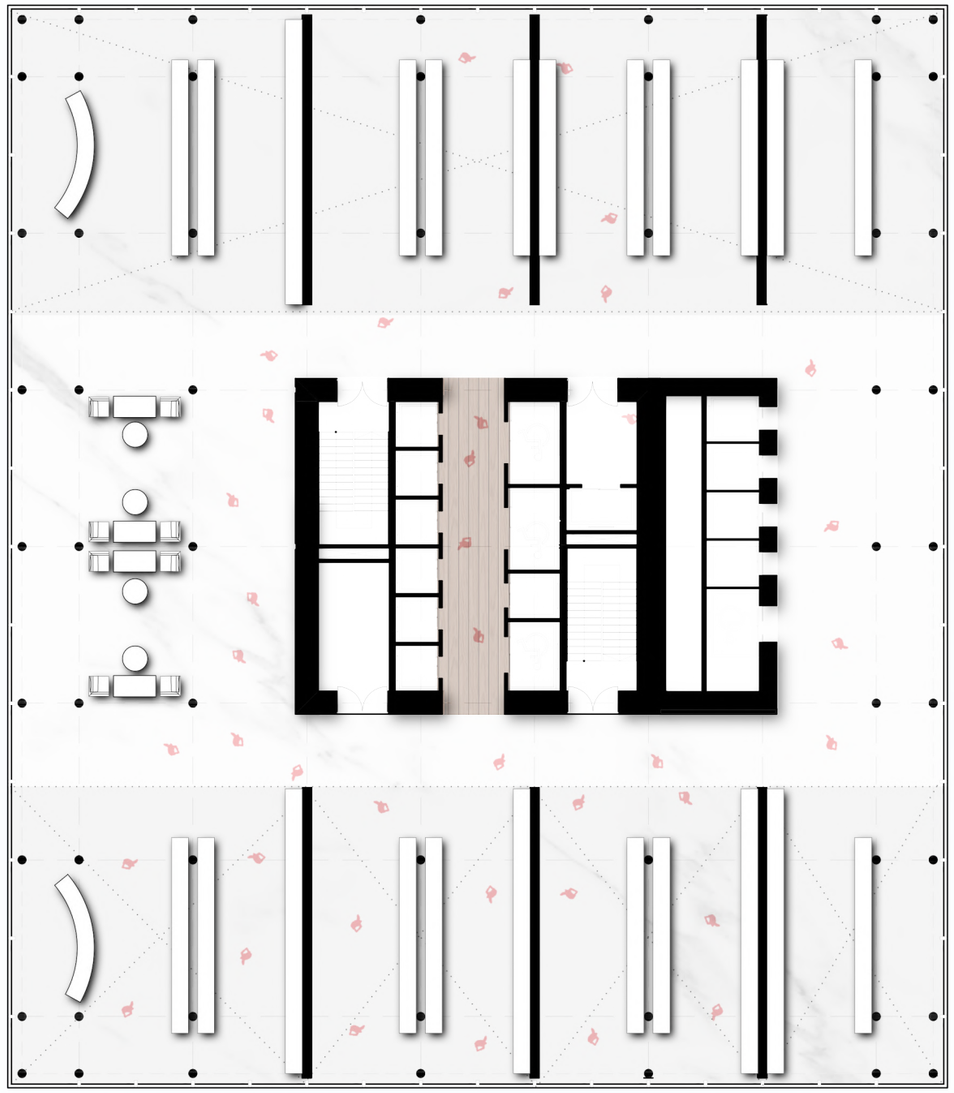


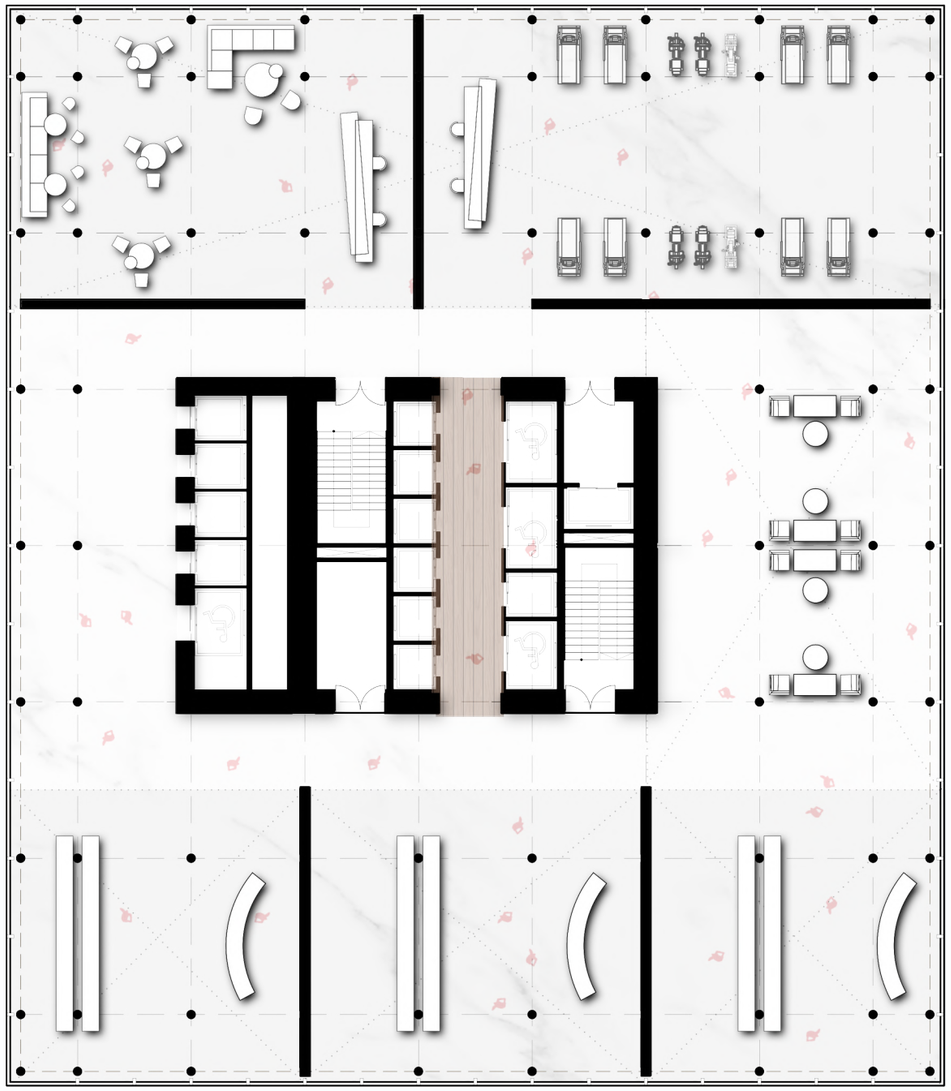
COMMERCIAL LEVEL PLANS - level 1



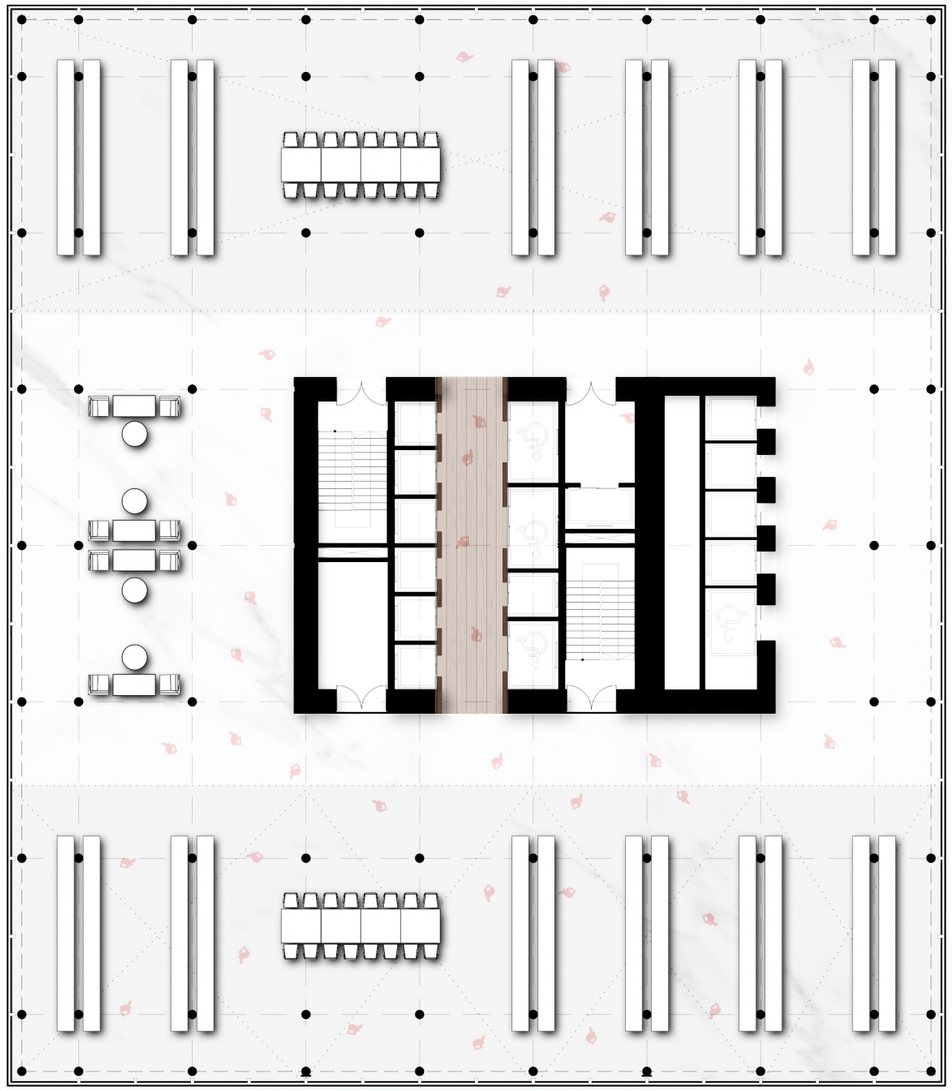


COMMERCIAL LEVEL PLANS - level 2

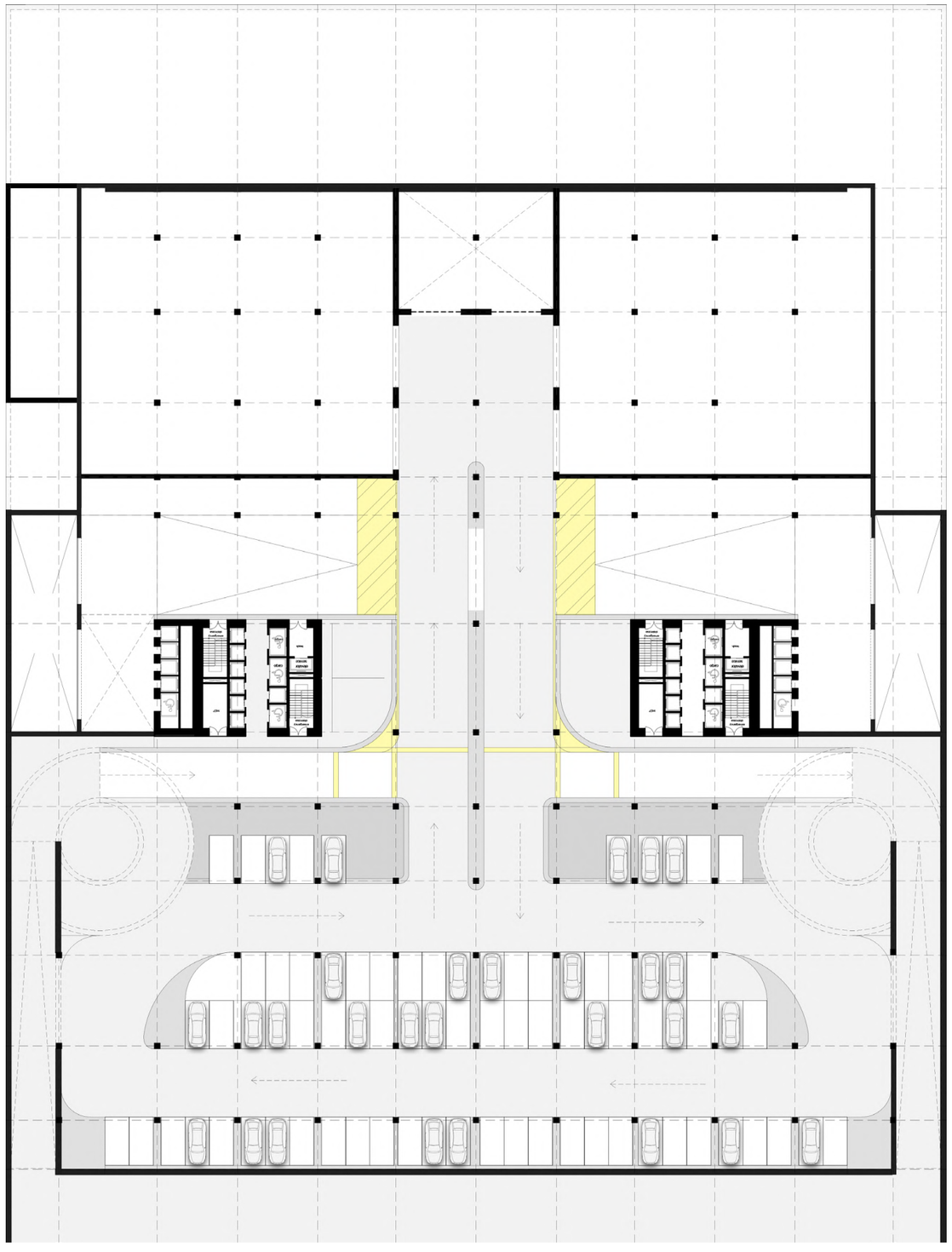




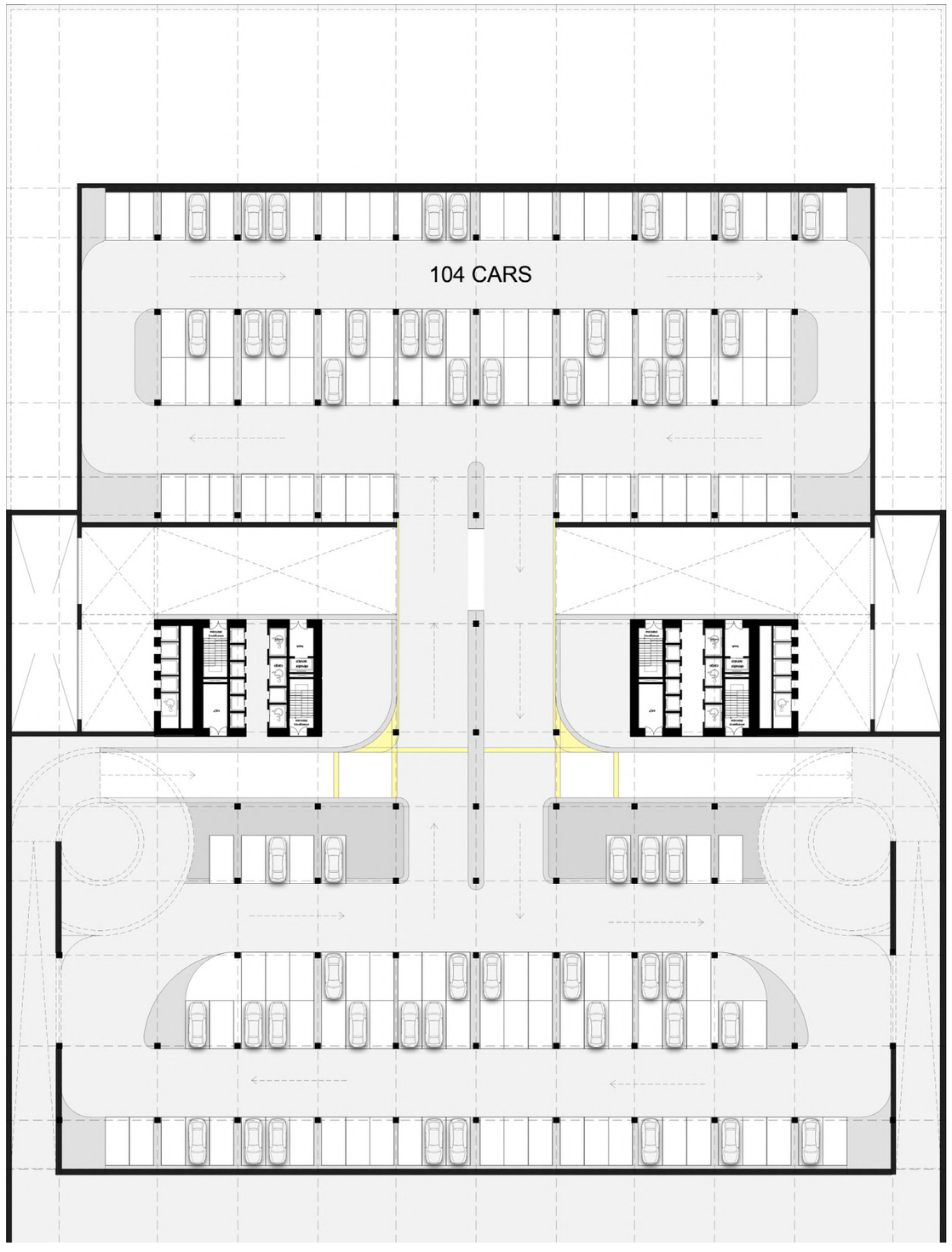
COMMERCIAL LEVEL PLANS - level 3



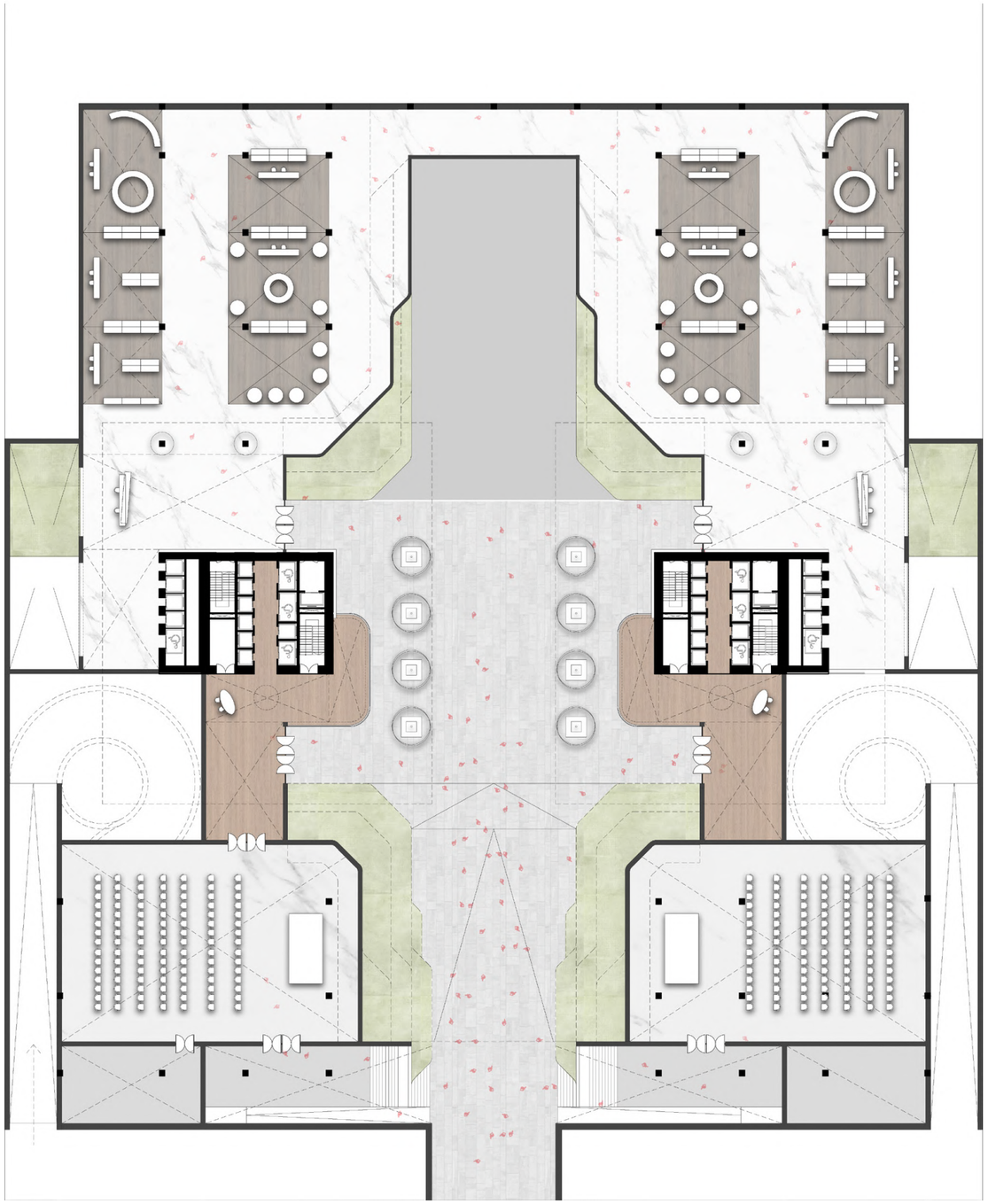
UNDERGROUND LEVEL PLANS - level 1



UNDERGROUND LEVEL PLANS - level 2



UNDERGROUND LEVEL PLANS - podium



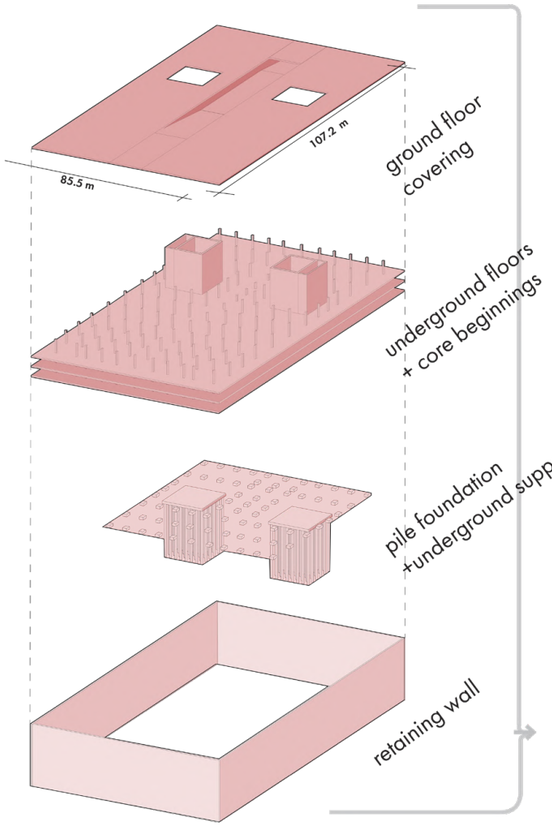
CH.4 STRUCTURE

OVERVIEW

From a structural point of view, the project consists of two rouglhy symmetrical towers, independant from each other. They are being linked together on two levels, where two bridges are attached to the towers via flexible joints, and share a common underground complex.

The following diagram set looks into 8 different groups of elements comprising the structure.

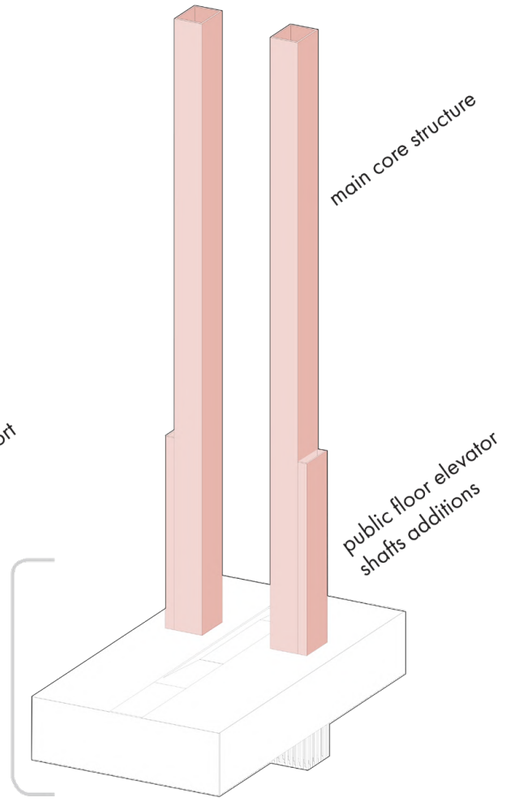
1



1. FOUNDATION + UNDERGROUND

Outline of the underground is excavated and secured by a retaining wall; the pile foundations that are holding the cores are then installed among with the raft supports for underground floors. Cores as the main structural elements are beginning constructions as soon as their foundations are finished.

2

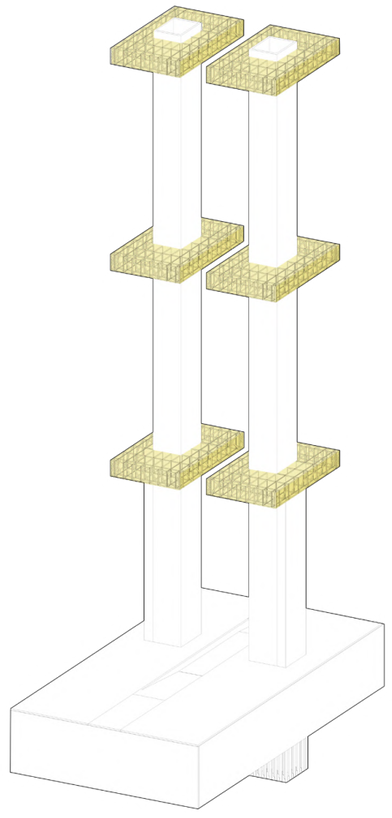


2. CORES

Cores of the building are symmetrical to each other.

The first third of the building from the ground has wider cores to account for extra elevator shafts in the areas open to public.

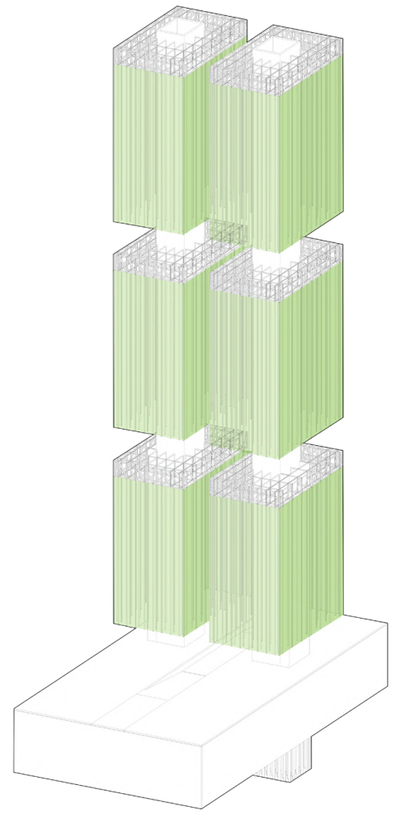
3



3. TRUSSES

Six two-way steel “hat” trusses are attached to the cores, evenly distributed along the height and mirroring each other. Each truss follows the grid of the typical floors, with additional reinforcements in diagonal directions, and is 32 by 37 meters in total dimensions.

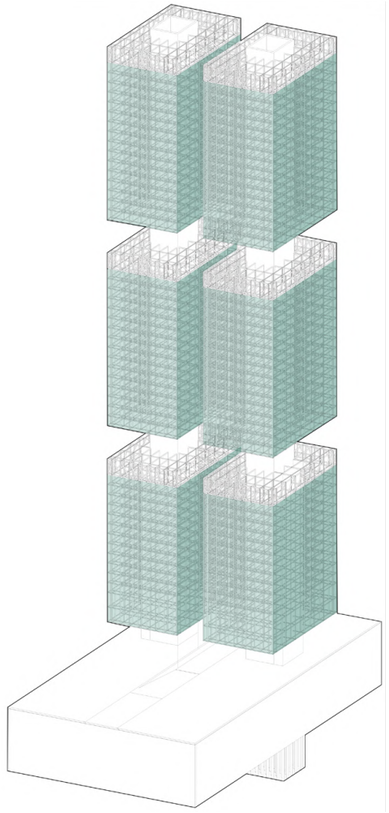
4



4. SUSPENDED COLUMNS

The floors are suspended on a system of balanced steel tubes, working in tension (in contrast to a standard scheme with columns working in compression and putting their load on the structure below). Suspended columns are all attached to the trusses in an upside-down manner.

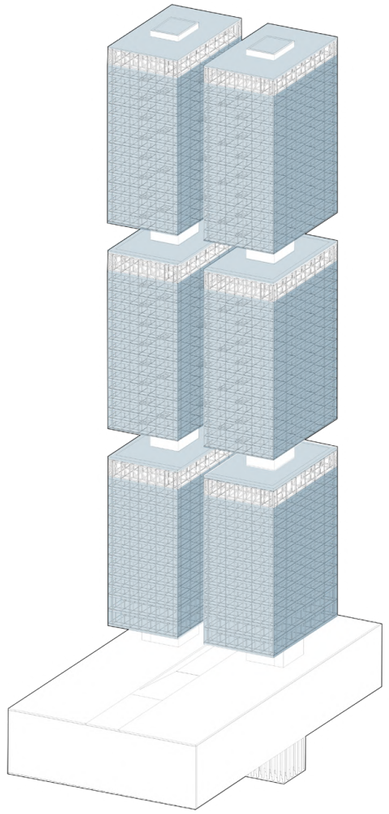
5



5. BEAMS

A rectangulat grid of beams is attached to the suspended columns, identical and symmetrical in all floors and dimensions. It is done in that manner in order to avoin the uneven elongation of vertical elements.

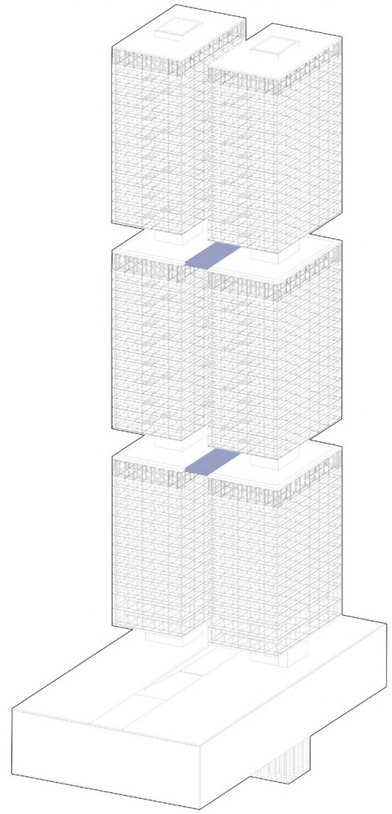
6



6. FLOOR SLABS

Lightweight floor slabs on metal deck are constructed on beams in a one-way directions. A system is chosen that allows them to incorporate the floor beams in the slab height and increase usable space in the building.

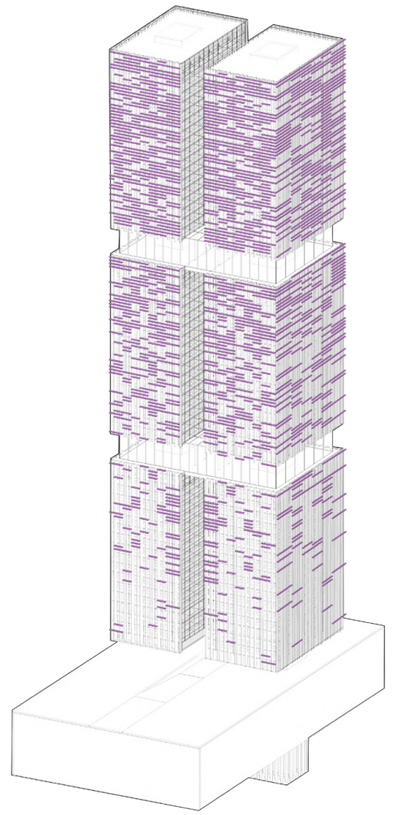
7



7. BRIDGES

The towers are functionally connected throught two “bridges” - at two levels, we have “garden floors”. Structurally, the gardens are independant, only transferring vertical load to the towers’ trusses. Horisontally, we design an connection through flexible rubber joints, so two towers do not transmit any lateral loads among themselves.

8



8. SKIN + SHADING

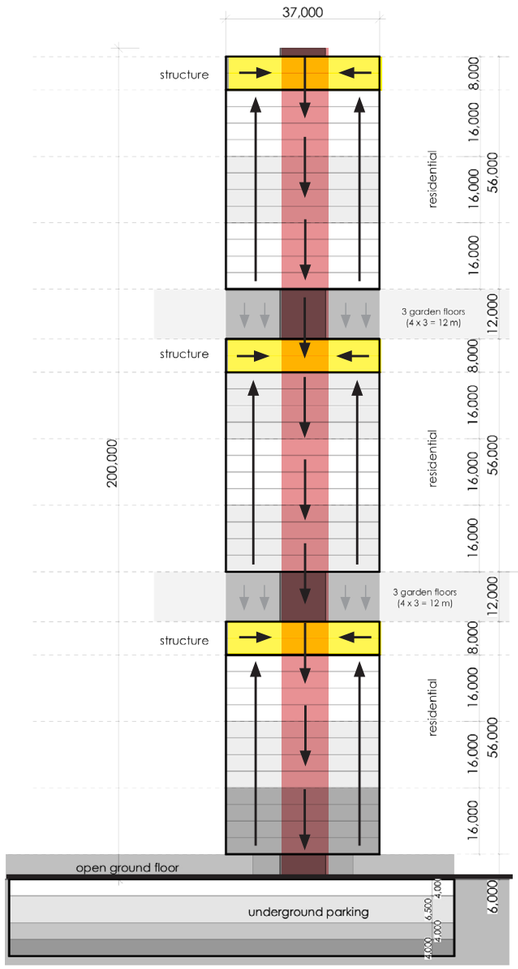
The two contrasting types of finishing facades are supposed to control the amount of incoming sunlight, allowing it in garden floors and partially blocking or diffusing it in residential floors. The shaded facade is organised through a system of horisontal fin-like extrusions perpendicular to the facade, which are organised in a procedurally generated manner. The transparent facades of gardens need their own support grid, being rather tall (12 meters).

BASIC DIMENSIONS AND LOAD DISTRIBUTION SCHEME

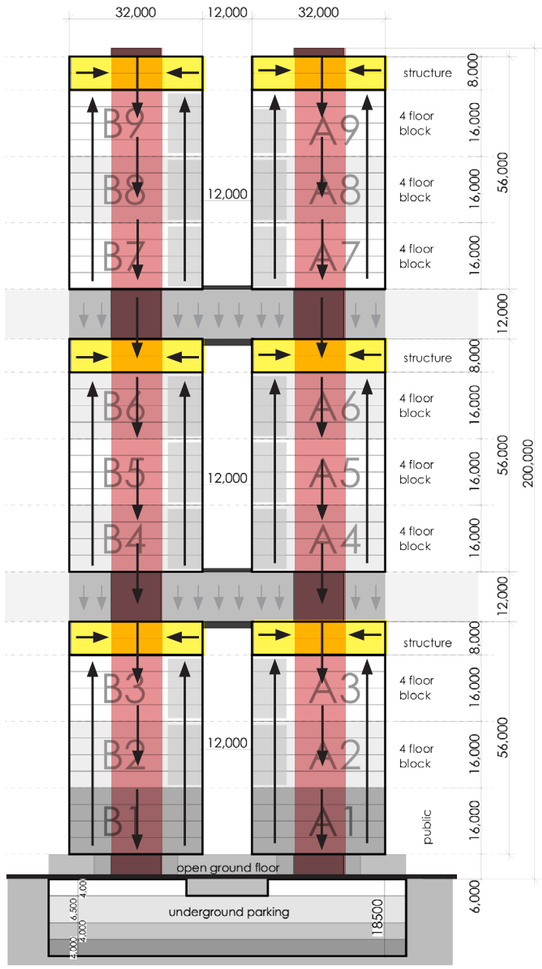
12 typical floors are suspended from a major structural truss, which is in turn cantilevered from a central core. The project has 6 of these modules, distributed evenly among two independant towers. The typical floor and the structural truss share the same grid, and have the dimensions of 32 by 37 meters.

The core is placed in the center of each tower and is 12 by11 meters in horizontal size. The core holds all the communications and transmits all the loads from three suspended modules to the foundation.

In additiion, on two levels the trusses are loaded by the bridges that connect the towers.

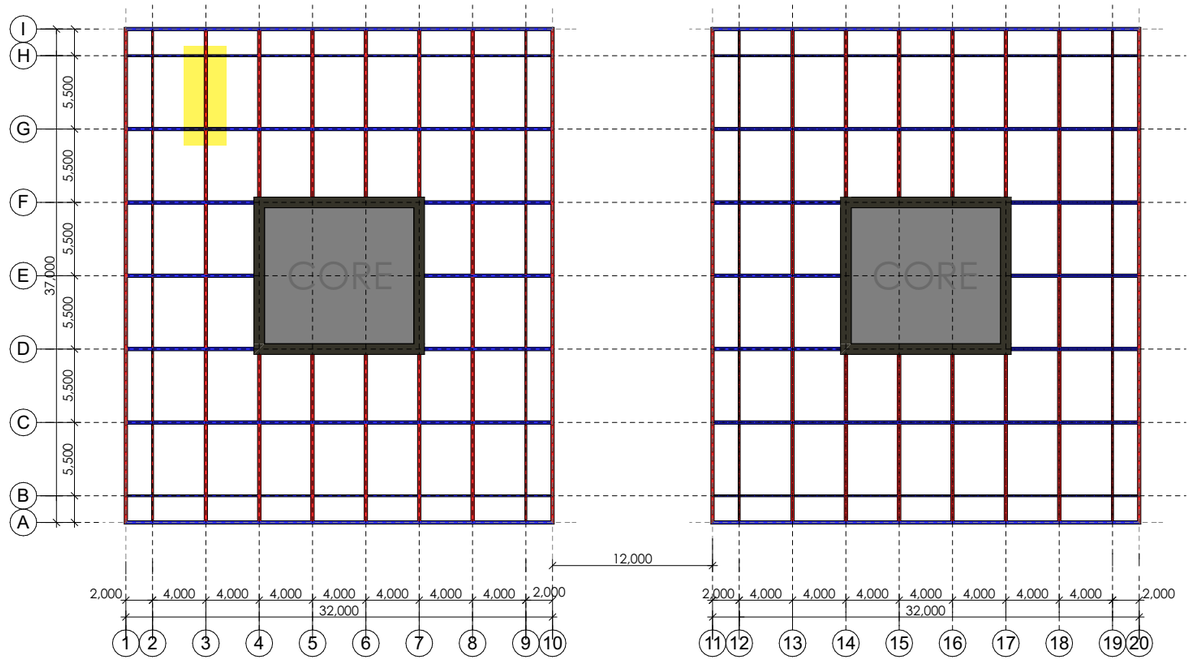


side view



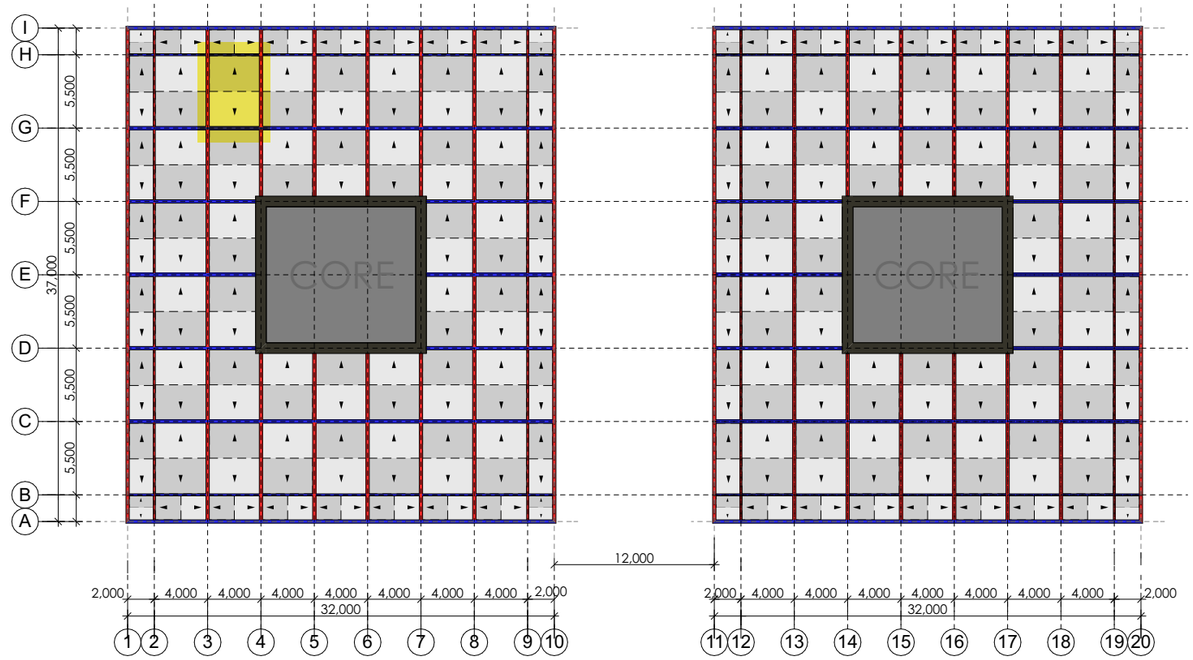
front view

BEAM PLAN



Floor beam plan layout follows the grid of the building.
The system is made to be symmetrical to the core.

SLAB PLAN



Concrete slabs of the floors are constructed in one-way pattern.
Directions of load application are depicted with arrows.

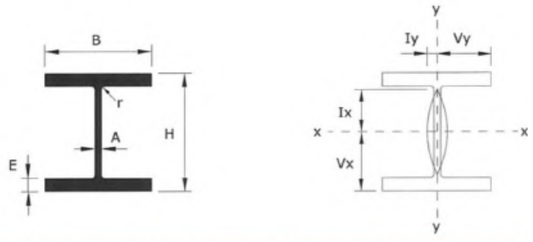
BEAM IN TYPICAL FLOOR

Calculations for the Beam in Typical Floor									
		Values	Units	Area of Loading			Live Load Calculations		
Weight of the Floor	w_f	**4.42**	KN/m^2	Length	4	m	Live Load	2	KN/m^2
Live Load (class A = 2,0 or B = 3,0)	q_f	**2**	KN/m^2	Width L_T	5.5	m	Snow Load	0	KN/m^2
Formula for Reaction forces at point A				Tributary length			Wind load	0	KN/m^2
W_d ($w_f + q_f$)*L^T		**35.31**	KN/m						
q_d (1.3 x wf + 1.5 x qf) * L_T		48.103	**KN/m**						
R_A = 1/2 x q_d x L (span)		96.206	*KN*						
REACTION FORCE **R_A**		**96206**	***N***	**Area A1**	**22**	m^2	**q_f**	**2**	KN/m^2
Calculations for Bending Moment M									
Reaction force	q_d	48.103		Wpl = M/fyd			We choose **HEA 260** Section (Wpl = 919.8 cm3)		
Width of the loading area	L	4		f_{yd} for steel	338	N/mm^2			
Moment	L^2	16							
$M = 1/8 \times q_d \times L^2$	M	96.206	*KNm*	w_{pl}	284633.14	mm^3			
	M	**96206000**	*Nmm*	**w_{pl}**	284.63314	cm^3			
Calculations for Deflection δ									
HEA 260							**δ**	**19.17130473**	**mm**
wpl	w_{pl}	**919.8**	***cm^3***						
Area moment of Inertia	***I***	10450	cm^4						
		104500000	**mm^4**						
Youngs Modulus	***E***	210	*Gpa*				Check	δ<L/250	
		210000	***N/mm***	**δ = 5 / 384 x $q_d L^4$ / EJ <= L/250**			**L/250**	**22**	**mm**
Reaction force	**W_d**	35.31	*KN/m*						
		35.31	***N/mm***						
Length of Beam	**L**	5.5	*m*				δ < L / 250	**FULLFILLED**	
		5500	**mm**						

HEA BEAMS

Parallel wide flange

Light weight series UNI 5397-64

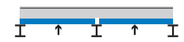


Designation	Weight kg/m	SIZES						Properties related to the neutral axis					
								x - x			y - y		
		section	h	b	a	e	r	Jx	Wx	Ix	Iy	Wy	Iy
		cm^2	mm	mm	mm	mm	mm	cm^4	cm^3	cm	cm^4	cm^3	cm
100	16,7	21,2	96	100	5,0	8,0	12,0	349	72,8	4,06	134	26,8	2,51
120	19,9	25,3	114	120	5,0	8,0	12,0	606	106	4,89	231	38,5	3,02
140	24,7	31,4	133	140	5,5	8,5	12,0	1030	155	5,73	389	55,6	3,52
160	30,4	38,8	152	160	6,0	9,0	15,0	1670	220	6,57	616	76,9	3,98
180	35,5	45,3	171	180	6,0	9,5	15,0	2510	294	7,45	925	103	4,52
200	42,3	53,8	190	200	6,5	10,0	18,0	3690	389	8,28	1340	134	4,98
220	50,5	64,3	210	220	7,0	11,0	18,0	5410	515	9,17	1950	178	5,51
240	60,3	76,8	230	240	7,5	12,0	21,0	7760	675	10,1	2770	231	6,00
260	68,2	86,8	250	260	7,5	12,5	24,0	10450	836	11,0	3670	282	6,50
280	76,4	97,3	270	280	8,0	13,0	24,0	13670	1010	11,9	4760	340	7,00

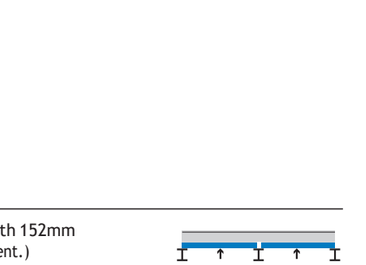
SLAB IN TYPICAL FLOOR

ComFlor® 46 / Bar Fire Method / Propped

Propped deck, single or continuous slab (m) - Normal weight concrete - British Standard - Beam width 152mm
(Note: For Simple Mesh and Deck Fire Method) load/span tables, please refer to the Technical Department.)



Props	Fire period	Slab depth (mm)	Mesh 0.1% min.reqd.	Total applied load (kN/m²)					
				5.00	7.50	10.00	5.00	7.50	10.00
				0.90mm			1.20mm		
1 line	60 minutes	120	A142	4.79 (32)	4.40 (32)	4.05 (32)	4.85 (32)	4.46 (32)	4.18 (32)
		130	A142	4.80 (16)	4.66 (32)	4.28 (25)	5.20 (32)	4.79 (32)	4.49 (32)
		140	A142	4.68 (12)	4.66 (16)	4.47 (20)	5.50 (32)	5.11 (32)	4.79 (32)
		150	A142	4.53 (12)	4.51 (16)	4.51 (16)	5.49 (16)	5.35 (32)	5.09 (32)
		160	A142	4.39 (12)	4.39 (12)	4.37 (16)	5.35 (16)	5.33 (16)	5.22 (25)
		170	A193	4.26 (10)	4.26 (12)	4.24 (16)	5.22 (16)	5.20 (16)	5.20 (16)
		180	A13	4.15 (10)	4.14 (12)	4.14 (12)	5.18 (16)	5.16 (16)	5.16 (16)
		190	A193	4.04 (10)	4.04 (10)	4.03 (12)	5.25 (16)	5.22 (16)	5.20 (16)
		200	A193	3.93 (10)	3.93 (10)	3.93 (12)	5.32 (16)	5.31 (16)	5.28 (16)
1 line	90 minutes	130	A142	4.80 (16)	4.66 (32)	4.28 (25)	5.20 (32)	4.79 (32)	4.49 (32)
		140	A142	4.66 (16)	4.63 (20)	4.47 (20)	5.50 (32)	5.11 (32)	4.79 (32)
		150	A142	4.51 (16)	4.51 (16)	4.48 (20)	5.47 (20)	5.35 (32)	5.09 (32)
		160	A142	4.37 (16)	4.37 (16)	4.35 (20)	5.35 (16)	5.32 (20)	5.22 (25)
		170	A193	4.24 (16)	4.24 (16)	4.24 (16)	5.20 (16)	5.17 (20)	5.17 (20)
		180	A193	4.14 (12)	4.12 (16)	4.12 (16)	5.08 (16)	5.03 (20)	5.03 (20)
		190	A193	4.03 (12)	4.02 (16)	4.02 (16)	4.93 (16)	4.93 (16)	4.91 (20)
		200	A193	3.93 (12)	3.93 (12)	3.91 (16)	4.81 (16)	4.81 (16)	4.79 (20)
1 line	120 minutes	140	A142	4.63 (20)	4.59 (25)	4.47 (25)	5.50 (32)	5.11 (32)	4.79 (32)
		150	A142	4.48 (20)	4.48 (20)	4.44 (25)	5.43 (25)	5.35 (32)	5.09 (32)
		160	A142	4.37 (16)	4.35 (20)	4.35 (20)	5.32 (20)	5.27 (25)	5.22 (25)
		170	A193	4.24 (16)	4.22 (20)	4.22 (20)	5.17 (20)	5.13 (25)	5.13 (25)
		180	A193	4.12 (16)	4.12 (16)	4.10 (20)	5.03 (20)	5.03 (20)	5.00 (25)
		190	A193	4.02 (16)	4.02 (16)	4.00 (20)	4.91 (20)	4.91 (20)	4.87 (25)
		200	A193	3.91 (16)	3.91 (16)	3.91 (16)	4.80 (16)	4.79 (20)	4.79 (20)



ComFlor® 46 Composite slab - volume and weight (BS values)

Slab depth (mm)	Concrete volume (m^3/m^2)	Weight of concrete (kN/m²)			
		Normal weight concrete		Lightweight concrete	
		Wet	Dry	Wet	Dry
96	0.077	–	–	1.43	1.35
106	0.087	2.04	2.00	1.61	1.53
110	0.091	2.13	2.09	1.69	1.60
120	0.101	2.37	2.32	1.88	1.78
130	0.111	2.60	2.55	2.06	1.95
140	0.121	2.84	2.78	2.25	2.13
150	0.131	3.08	3.01	2.43	2.31
160	0.141	3.31	3.24	2.62	2.48
170	0.151	3.55	3.47	2.81	2.66
180	0.161	3.78	3.70	2.99	2.84
190	0.171	4.02	3.93	3.18	3.01
200	0.181	4.25	4.16	3.37	3.19
250	0.231	5.43	5.32	4.30	4.07

Notes

1. Deck and beam deflection (ie, ponding) is not included in the table.
2. Deck and mesh weight is not included in the weight of concrete figures.
3. British Standard density of concrete is taken as:

   Normal weight (wet) 2400kg/m³
   Normal weight (dry) 2350kg/m³
   Lightweight (wet) 1900kg/m³
   Lightweight (dry) 1800kg/m³

ComFlor® 46 (S280) Section properties (per metre width)

Nominal thickness (mm)	Design thickness (mm)	Cross section area (mm^2/m)	Profile weight (kN/m^2)	Height to neutral axis (mm)	Moment of inertia (cm^4/m)		Ultimate moment capacity (kNm/m)	
					Sagging	Hogging	Sagging	Hogging
0.90	0.86	1137	0.09	20.38	41.50	–	4.63	4.67
1.20	1.16	1534	0.13	20.44	53.00	–	5.99	6.23

Section properties in the above table conform to BS 5950

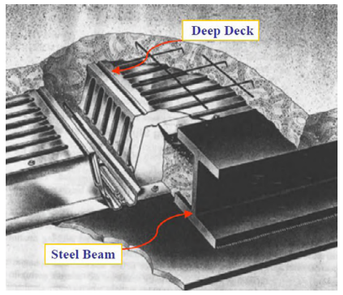
iTECH floor system

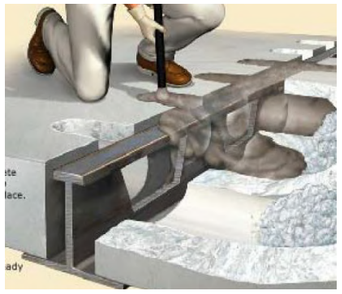
The iTECH system is proposed in a publication at the CTBUH 2004 Seoul Conference. It takes three systems as the basis for development.

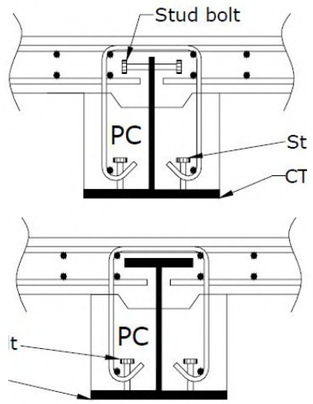
First example is the modern slim floor system. The concrete slab is formed directly on site using a steel deck as both reinforcement and mold; the deck is in turn propped up on the grid of structural beams. The steel deck is secured on the bottom flange of the beam, allowing for a smaller overall height of the floor.

Second example is the girder-slab system. It uses asymmetrical steel beams with a web opening. The pre-case concrete slab is also placed on the lower flange of the beam. The slabs are then interconnected through the openings in the beam by reinforced concrete.

Third example are the TEC beam and A-TEC composite beams. They consist of a structural T-section, or an asymmetrical I-beam, combined with precast concrete and in situ concrete slab.







The iTECH system allows for improvement and combining of the previous solutions. The basis is an asymmetrical steel H beam with a smaller top flange, with openings along the vertical plate in a "honeycomb" style. A C-channel is placed at the bottom flange and supports the deck during the construction stage. It is not a structural member and may be removed afterwards. The reinforcements of the slab are put through the openings in the beam, integrating the entire floor in one large slab.

The advantages of this composite system listed in the research are such:

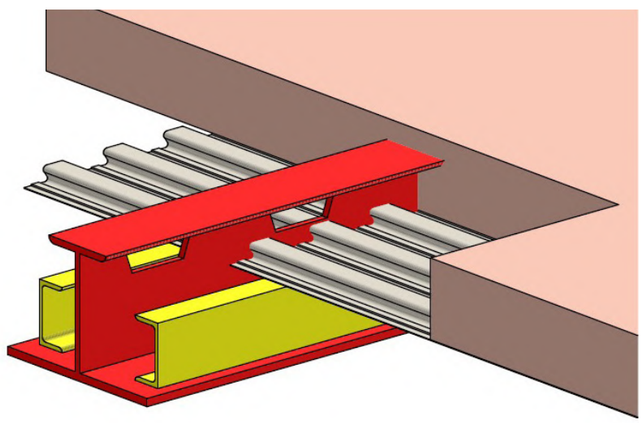
1. lower construction costs compared to reinforced concrete or steel frame structures;

2. shorter construction time compared to the reinforced concrete structure;

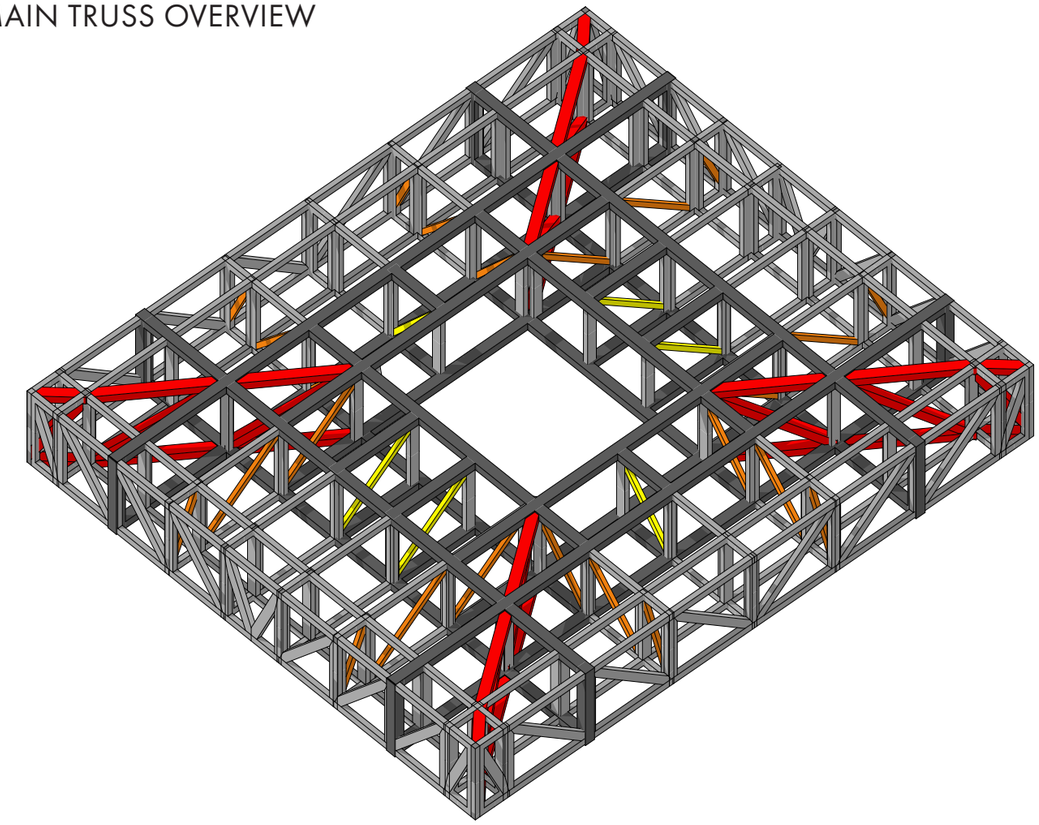
3. better construction quality control and management;

4. flexibility in planning

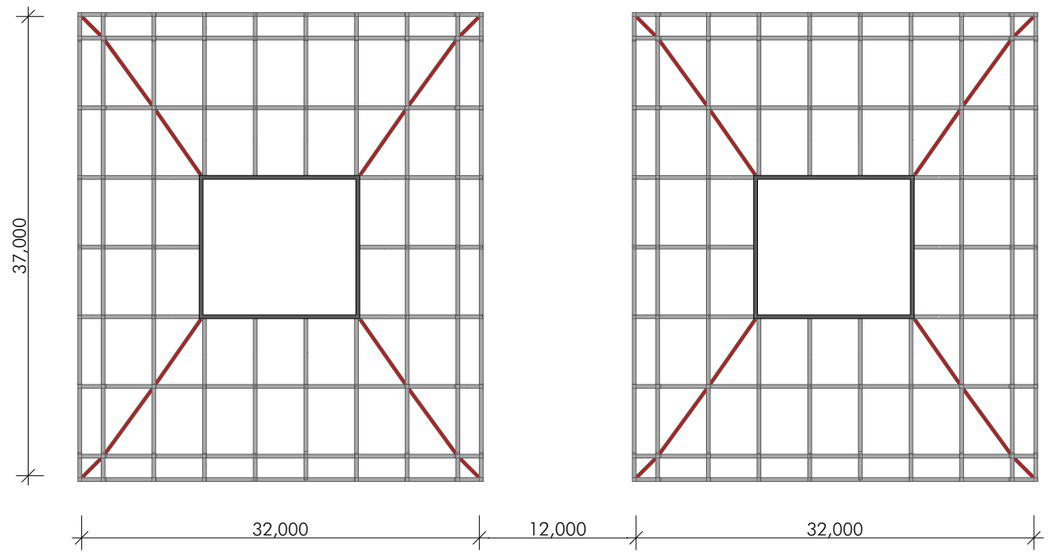
5. lower story height due to shallower beam depth.



MAIN TRUSS OVERVIEW



Each truss is cantilevered off the main core. The main elements (grey) follow the orthogonal grid. The ones sharing a gridline with core walls are additionally reinforced with diagonal bracing on the inside (orange). Secondary bracing is present in other elements attached to the core (yellow). Finally, a set of braces connects the corners of the truss with the core (red).



Trusses of two towers in plan

TYPICAL FLOOR LOAD VARIATION BY FUNCTION

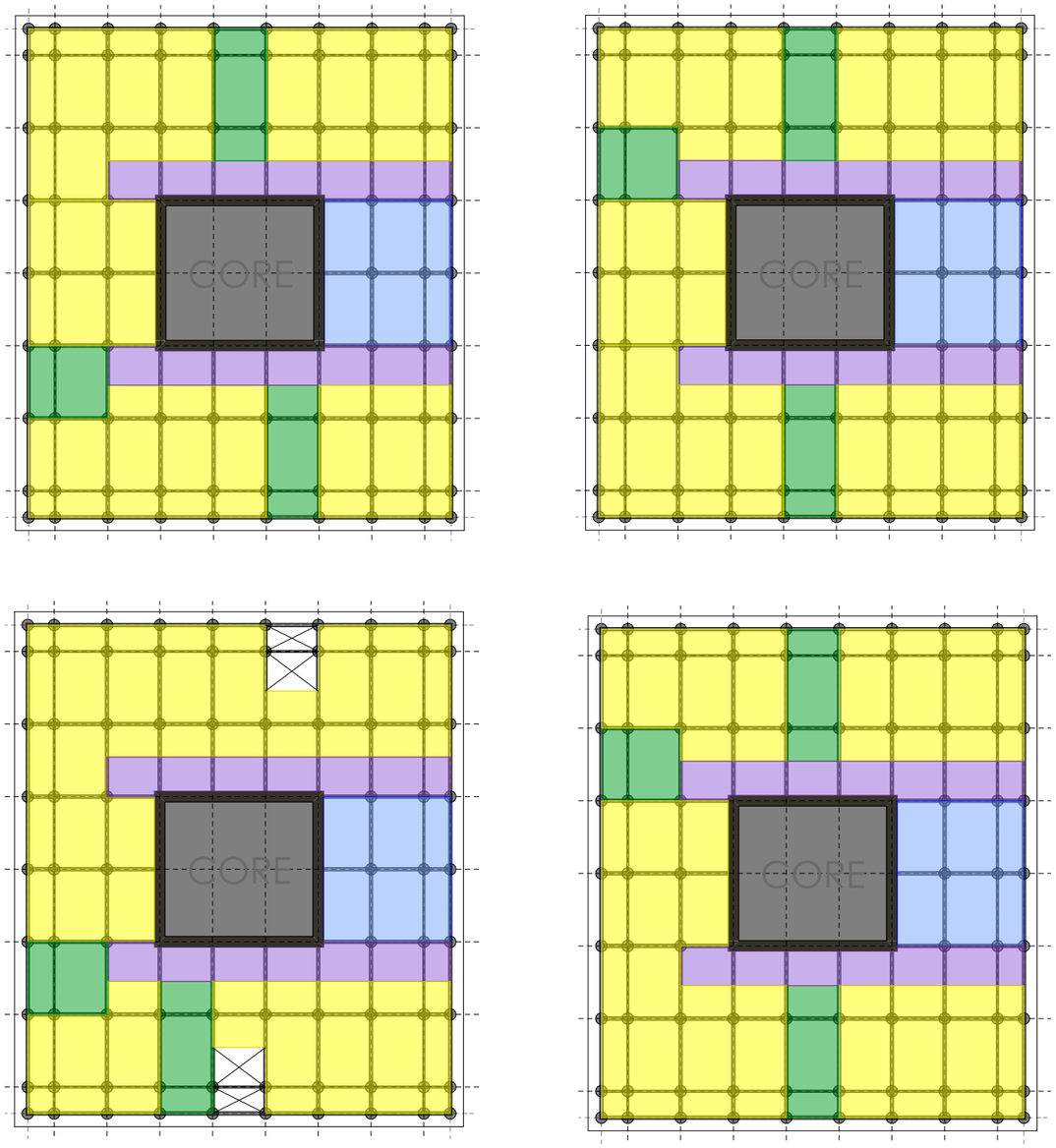


Fig.56. Analysing varying distribution of floor loads between four types of typical floors

The floor loads on each floor vary depending on the purpose of the area. In the half-plans above, we see a comparison of four different typical floors by load distribution. That data is further taken into account in total load combinations.

To properly collect all the load data for the main structural element - the truss, we divide all the loads applied to it into four types. In the diagram we see three of them, excluding the self-weight of the structure.

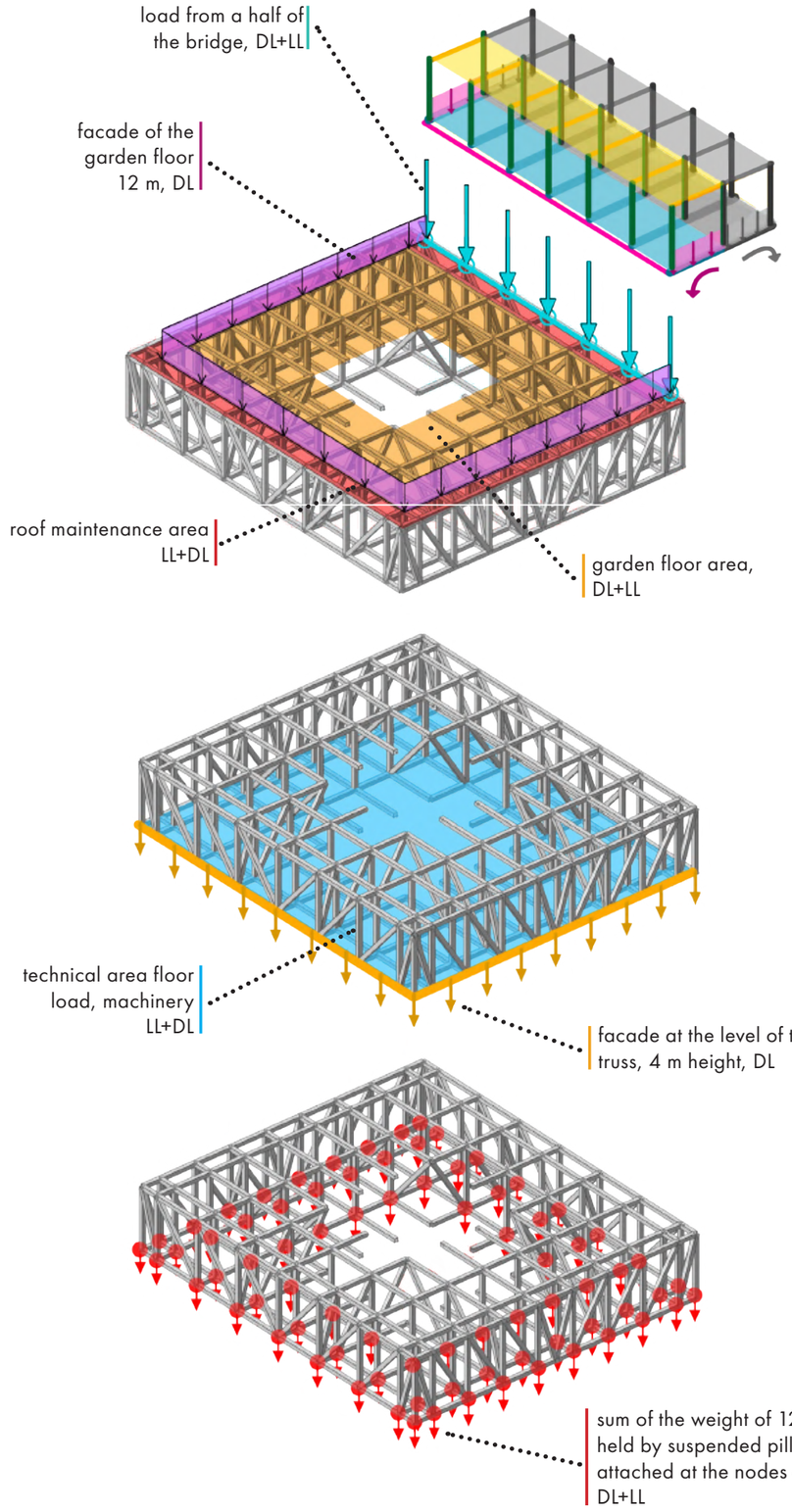


Fig.57. Load distribution applied on various parts of the selected truss

COLUMN PLAN

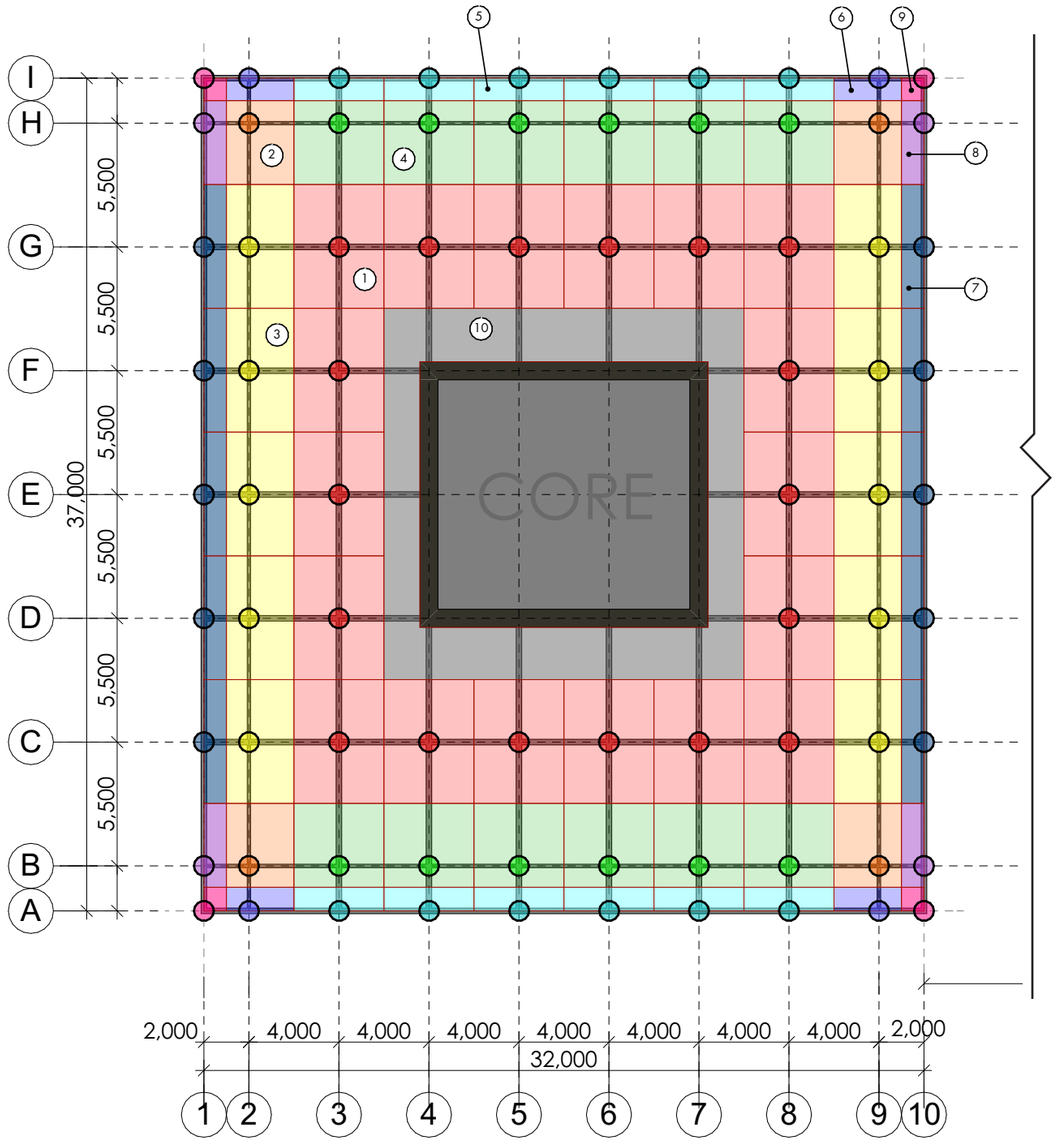


Fig.58. 10 types of floor loads for different columns

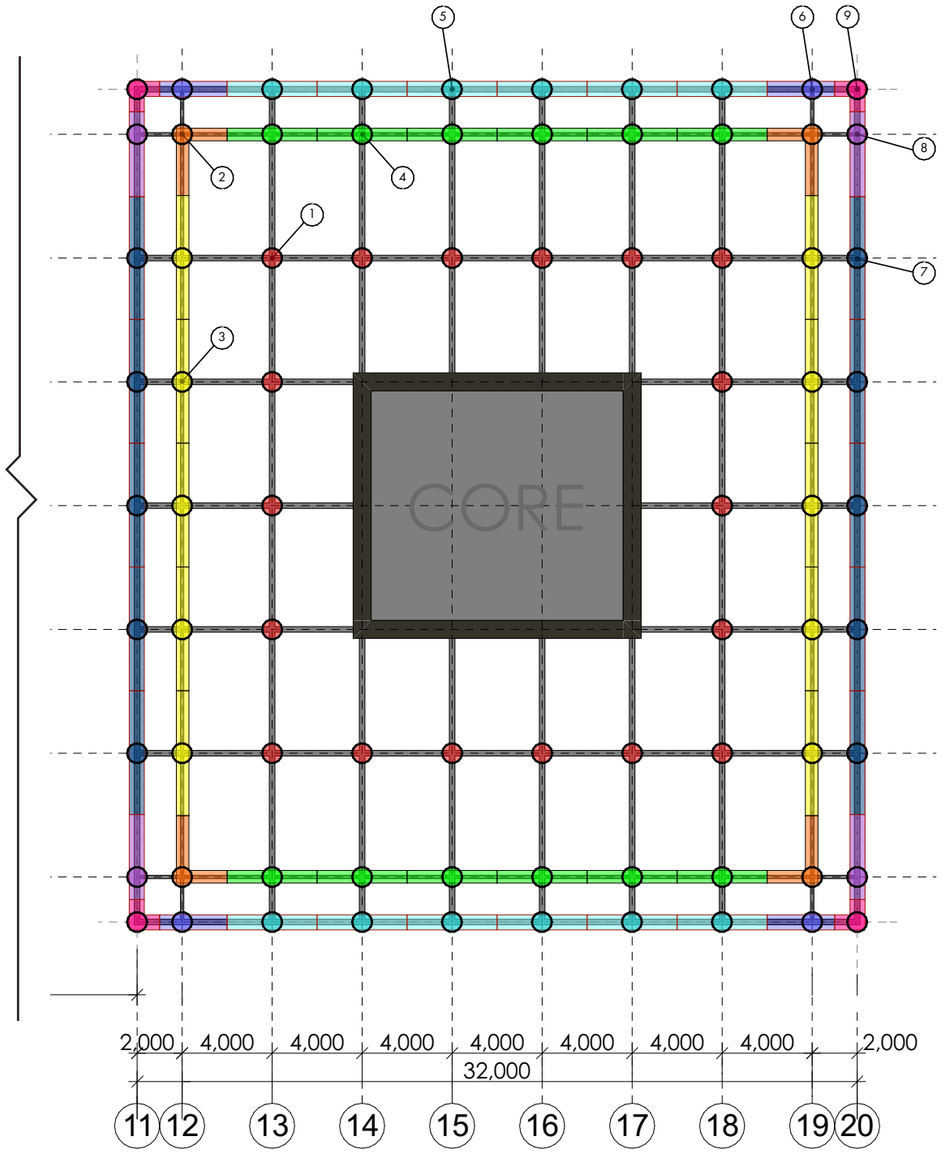


Fig.59. 9 types of wall/facade loads for different columns

As described above, the vertical elements of the building are elements in tension. For the ease of speech, we will still describe them as columns. Elements in tension face different problems from the classic compressed columns. In our case there is a need to account for imminent elongation of the suspended elements.

For this reason, the grid of the buildings is kept simple and symmetrical, to allow minimal differences in column loads. The diagram set above divides all columns in 9 types by the load that they have to carry, highlighted by colors. The diagram on the left separated 10 possible floor areas depending on one column, where grey area loads arrive to the core and are not important.

The diagram on the left adds linear loads from external facade walls to the combination. These are assigned the same color as the column and area load.

Every column except type 1 carries facade loads to some extent.

The weight of the facade is calculated for one meter on the floor for four meters of height.

1	**DL (Self-weight of the structure)**	Calculated by MidasGEN				kN/m2 kN/m						
2	**Loads to the top of the structure**	Area 1 (border, only maintenance access)	DL (Weight of the floors)	slab + layers	**3.15**	kN/m2						
			LL (maintenance)	H	**1**	kN/m2						
		Area 2 (people access and plant cultivation, taken as max possible)	DL (Weight of the floors / soil)	slab + layers	**11.06**	kN/m2						
			LL (Garden floor, people)	C3	***5***	kN/m2						
		Area 3 (half of the bridge)	DL (Weight of bridge)	beams slabs soil plants façade pillars roof beams roof glass	**79.9**	kN/m	(applied as a linear load)					
			LL (Human activity)	C3	***5***	kN/m2						
		Façade loads	DL (Linear load by inner perimeter of tower)		**0.92**	kN/m						
3	**Loads inside the structure**	Technical areas for machinery placement (water supply, heating, trash accumulation/disposal, ventilation, etc.)	DL (Weight of the floors)		***5***	kN/m2						
			LL (maintenance)	H	**1**	kN/m2						
			LL (machinery)	eurocode says calculate the load yourself	**20**	kN/m2						
		Façade loads	DL (Linear load by outer perimeter of tower on lower beam)		**0.92**	kN/m						
4	**Loads from suspended floors (12 living floors, 3 identical blocks of 4 different floors);** **Combinations differ in the amounts of different areas on each floor**	Combination 1	Area 1 (apartments)	DL	**4.42**	kN/m2	**668.8**	m2	**2956.096**	kN/area	**DL total:**	
				LL = A	**2**	kN/m2	**668.8**	m2	**1337.6**	kN/area		
			Area 2 (hallways)	DL	**4.42**	kN/m2	**145.8**	m2	**644.436**	kN/area	**4485.384**	
				LL = C3	***5***	kN/m2	**145.8**	m2	**729**	kN/area		
			Area 3 (office areas coworking)	DL	**4.42**	kN/m2	**105.6**	m2	**466.752**	kN/area	**LL total:**	
				LL = B	**3**	kN/m2	**105.6**	m2	**316.8**	kN/area		
			Area 4 (light green areas)	DL	**3.7**	kN/m2	**113**	m2	**418.1**	kN/area	**2722.4**	
				LL = C1	**3**	kN/m2	**113**	m2	**339**	kN/area		
		Combination 2	Area 1 (apartments)	DL	**4.42**	kN/m2	**668.8**	m2	**2956.096**	kN/area	**DL total:**	
				LL = A	**2**	kN/m2	**668.8**	m2	**1337.6**	kN/area		
			Area 2 (hallways)	DL	**4.42**	kN/m2	**145.8**	m2	**644.436**	kN/area	**4337.384**	
				LL = C3	***5***	kN/m2	**145.8**	m2	**729**	kN/area		
			Area 3 (office areas coworking)	DL	**4.42**	kN/m2	**105.6**	m2	**466.752**	kN/area	**LL total:**	
				LL = B	**3**	kN/m2	**105.6**	m2	**316.8**	kN/area		
			Area 4 (light green areas)	DL	**3.7**	kN/m2	**73**	m2	**270.1**	kN/area	**2602.4**	
				LL = C1	**3**	kN/m2	**73**	m2	**219**	kN/area		
		Combination 3	Area 1 (apartments)	DL	**4.42**	kN/m2	**668.8**	m2	**2956.096**	kN/area	**DL total:**	
				LL = A	**2**	kN/m2	**668.8**	m2	**1337.6**	kN/area		
			Area 2 (hallways)	DL	**4.42**	kN/m2	**145.8**	m2	**644.436**	kN/area	**4485.384**	
				LL = C3	***5***	kN/m2	**145.8**	m2	**729**	kN/area		
			Area 3 (office areas coworking)	DL	**4.42**	kN/m2	**105.6**	m2	**466.752**	kN/area	**LL total:**	
				LL = B	**3**	kN/m2	**105.6**	m2	**316.8**	kN/area		
			Area 4 (light green areas)	DL	**3.7**	kN/m2	**113**	m2	**418.1**	kN/area	**2722.4**	
				LL = C1	**3**	kN/m2	**113**	m2	**339**	kN/area		
		Combination 4	Area 1 (apartments)	DL	**4.42**	kN/m2	**668.8**	m2	**2956.096**	kN/area	**DL total:**	
				LL = A	**2**	kN/m2	**668.8**	m2	**1337.6**	kN/area		
			Area 2 (hallways)	DL	**4.42**	kN/m2	**145.8**	m2	**644.436**	kN/area	**4485.384**	
				LL = C3	***5***	kN/m2	**145.8**	m2	**729**	kN/area		
			Area 3 (office areas coworking)	DL	**4.42**	kN/m2	**105.6**	m2	**466.752**	kN/area	**LL total:**	
				LL = B	**3**	kN/m2	**105.6**	m2	**316.8**	kN/area		
			Area 4 (light green areas)	DL	**3.7**	kN/m2	**113**	m2	**418.1**	kN/area	**2722.4**	
				LL = C1	**3**	kN/m2	**113**	m2	**339**	kN/area		
		Cables self-weight	Length of 1 cable multiplied by 78 cables; chosen section has outer diameter of 323.9mm and wall thickness of 6 mm. Mass = 47 kg/m, each cable is 12*4=48m, 48*47 = 2,256 kg	DL	**2256** **22.1238** **78** **175,968** **1725.66**	kg / cable kN / cable cables kg / tower kN / tower						
		Beam self-weight	HEA 260, mass = 68.2 kg/m 578 m of beam per floor 578*68.2 = 39,419.6 kg/floor 12 floors	DL	**39419.6** **386.57** **12** **473,035.2** **4638.89**	kg/floor kN/floor floors kg/tower kN/tower						
		Façade loads multiplied by 12 floors as well	3/4 walls - with shading	DL		kN/m2						
			1/4 walls - no shading	DL		kN/m2						

Fig.60. Load combination table

The combined table of loads is divided in four parts as well.

First part (red) is left empty, as software will take care of self-weight of the structure depending on the changes in element section. Second part (green)describes loads applied to the top of the structure. Third pard (blue) lists the loads applied from the inside of the truss, plus the facades that attach to it directly from the sides. Fourth part (yellow) details everything attached to the bottom of the truss, which ultimately all comes down to the suspended columns. In it we look into 4 types of typical floors separately depending on their floor load distribution, plus calculate self-weight of the columns, beams and attached facades.

The following table calculates the 9 different loading variations for suspended columns. We acquired the data from previous analyses, comparing floor areas, facade length and differences in typical plans. The last two columns of the table show, respectively, the total ultimate dead loads and combined deal and live loads for each type of column.

				kN		loads at one cable of a certain type while it passes one floor, kN								4 floors	
type	1 area m2	%	amount	all areas	%	DL C1	LL C1	DL C2	LL C2	DL C3	LL C3	DL C4	LL C4	DL C 1 floor	LL C 1 floor
1	22	2.13%	18	396	38.33%	95.53	57.98	92.37	55.42	95.53	57.98	95.53	57.98	378.95	229.36
2	11.18	1.08%	4	44.72	4.33%	48.54	29.46	46.94	28.17	48.54	29.46	48.54	29.46	192.58	116.56
3	16.5	1.60%	10	165	15.97%	71.64	43.48	69.28	41.57	71.64	43.48	71.64	43.48	284.21	172.02
4	14.9	1.44%	12	178.8	17.31%	64.70	39.27	62.56	37.54	64.70	39.27	64.70	39.27	256.65	155.34
5	4.1	0.40%	12	49.2	4.76%	17.80	10.81	17.22	10.33	17.80	10.81	17.80	10.81	70.62	42.74
6	3	0.29%	4	12	1.16%	13.03	7.91	12.60	7.56	13.03	7.91	13.03	7.91	51.68	31.28
7	5.5	0.53%	10	55	5.32%	23.88	14.49	23.09	13.86	23.88	14.49	23.88	14.49	94.74	57.34
8	3.72	0.36%	4	14.88	1.44%	16.15	9.80	15.62	9.37	16.15	9.80	16.15	9.80	64.08	38.78
9	1	0.10%	4	4	0.39%	4.34	2.64	4.20	2.52	4.34	2.64	4.34	2.64	17.23	10.43
10	-	-	-	113	10.94%										

4*3 = 12 floors		Length of the Façade per 1 cable m	Load of the Façade per 1 m (linear) kN	DL façade kN on 12 floors	Beam length per 1 cable m	Beam % per 1 cable	DL beam 1 floor kN	DL beams total (12 floors) kN	every cable weights the same, kN		
DL C TOTAL	LL C TOTAL								DL cable	**DL total ultimate**	LL+DL
1136.86	688.09				9.5	1.64%	6.35	76.24	22.1238	**1235.22**	1923.31
577.73	349.67	4.75	0.92	52.44	6.725	1.16%	4.50	53.97	22.1238	**706.27**	1055.94
852.64	516.07	5.50	0.92	60.72	8.5	1.47%	5.68	68.22	22.1238	**1003.70**	1519.77
769.96	466.02	4.00	0.92	44.16	7.725	1.34%	5.17	62.00	22.1238	**898.24**	1364.27
211.87	128.23	4.00	0.92	44.16	5	0.87%	3.34	40.13	22.1238	**318.28**	446.52
155.03	93.83	4.00	0.92	44.16	4	0.69%	2.68	32.10	22.1238	**253.41**	347.24
284.21	172.02	5.50	0.92	60.72	6.5	1.12%	4.35	52.17	22.1238	**419.22**	591.25
192.23	116.35	4.75	0.92	52.44	4.725	0.82%	3.16	37.92	22.1238	**304.72**	421.07
51.68	31.28	2.00	0.92	22.08	2	0.35%	1.34	16.05	22.1238	**111.93**	143.21
					34	5.88%	22.74	272.87			

Fig.61. Table comparing 10 different types of load at columns

type	E, N/mm	F, kN	F, N	l, mm	A, cm^2	A, mm^2	Δl, mm
1	200000	1910.79	1910787.74	4000	26.04	2604	14.67578909
2		1043.42	1043415.936		26.04	2604	8.013947281
3		1507.25	1507246.108		26.04	2604	11.57639099
4		1351.74	1351743.022		26.04	2604	10.38205086
5		433.99	433991.542		26.04	2604	3.333268371
6		334.72	334718.6757		26.04	2604	2.570803961
7		578.72	578722.8432		26.04	2604	4.444875908
8		408.54	408542.7243		26.04	2604	3.137808943
9		130.68	130683.3417		26.04	2604	1.003712302

type	E, N/mm	F, kN	F, N	l, mm	A, cm^2	A, mm^2	Δl, mm
1	200000	1910.79	1910787.74	4000	13.86	1386	27.57269466
2		1043.42	1043415.94		13.86	1386	15.05650701
3		1507.25	1507246.11		13.86	1386	21.74958308
4		1351.74	1351743.02		13.86	1386	19.50567131
5		433.99	433991.54		13.86	1386	6.262504213
6		334.72	334718.68		13.86	1386	4.829995321
7		578.72	578722.84		13.86	1386	8.350978979
8		408.54	408542.72		13.86	1386	5.895277407
9		130.68	130683.34		13.86	1386	1.885762507

$\Delta\ell = F\ell/EA$

Elongation check for **HEB section** in columns:

With a section of HEB100, max.elongation is 14.67 mm > 30 mm, success;

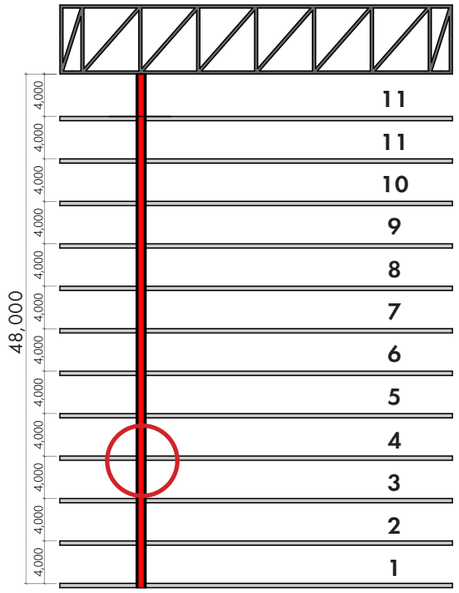
Weight of a column in 12 floors = 20.4 kg/m, 20.4*48 = 979.2 kg

Elongation check for **tube section** in columns:

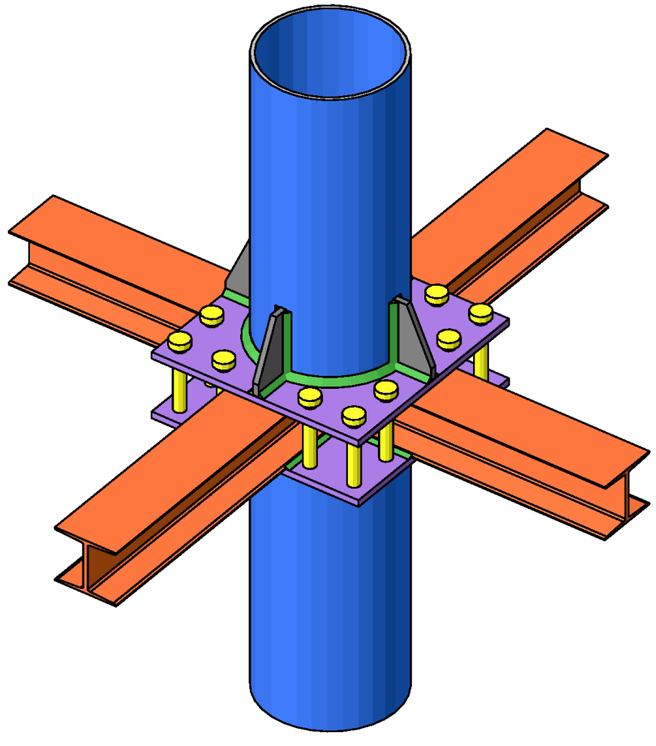
With a section of CHS 114.3/4, max. elongation is 27.5 mm > 30 mm, success;

Weight of a column in 12 floors = 10.9 kg/m, 10.9*48 = 523.2 kg

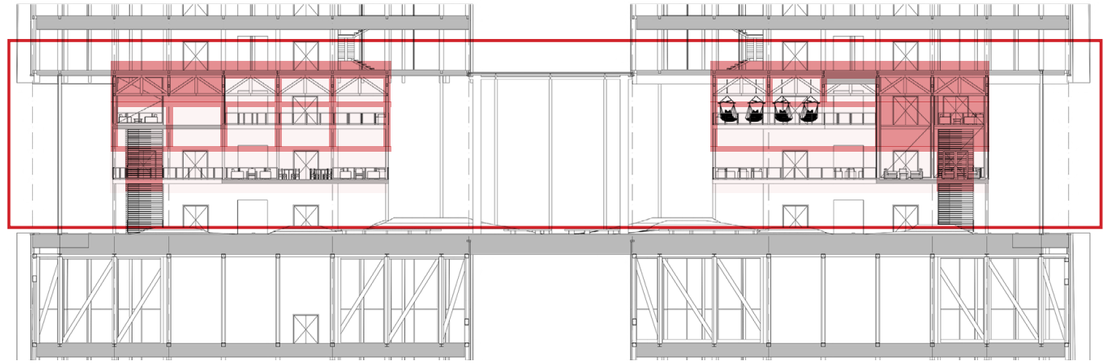
Column in tension supporting 12 floors, suspended from the upper structure

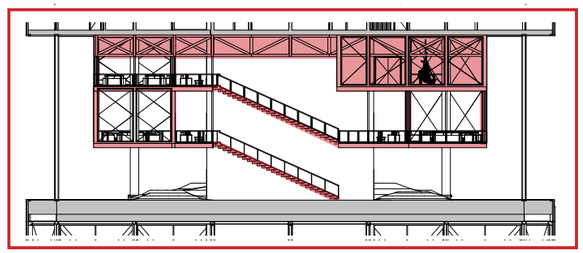


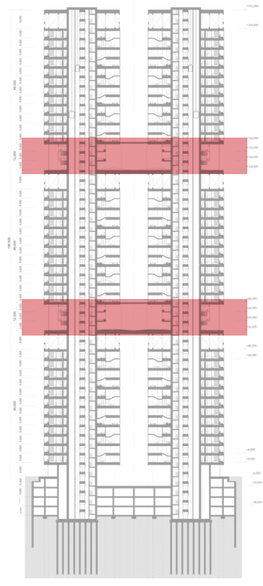
A detailed view of the column intersection with floor beams



GARDEN FLOOR STRUCTURES

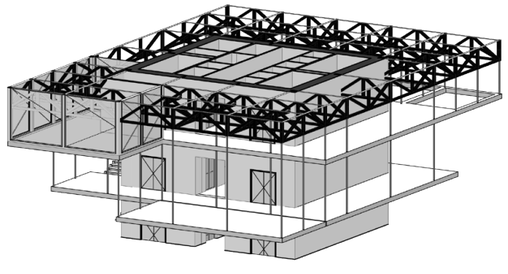


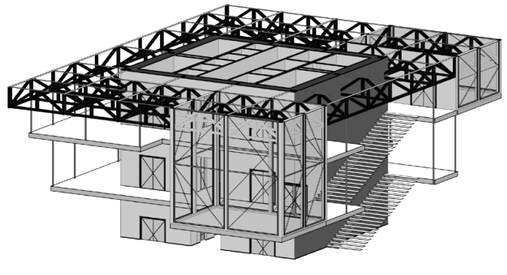




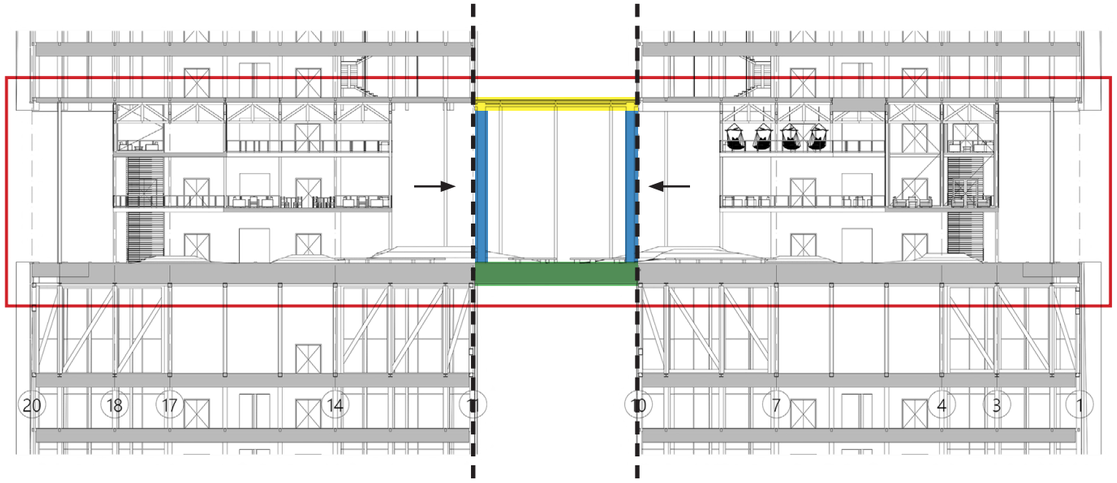
The garden floor is 12 meters high, and is divided in three sub-floors of 4 meters each. It is not possible to add the loads from the gardens to any of the main structural trusses, as the garden plans are not symmetrical and would offset the loads for different suspended columns (if attached from above) or introduce uneven loads to the truss below.

Instead, we introduce a smaller truss, cantilevered from the core in the same manner as the major trusses. The sole purpose of it is to support two levels that are suspended above the main garden surface. This system is essentially a smaller version of the primary structural system.

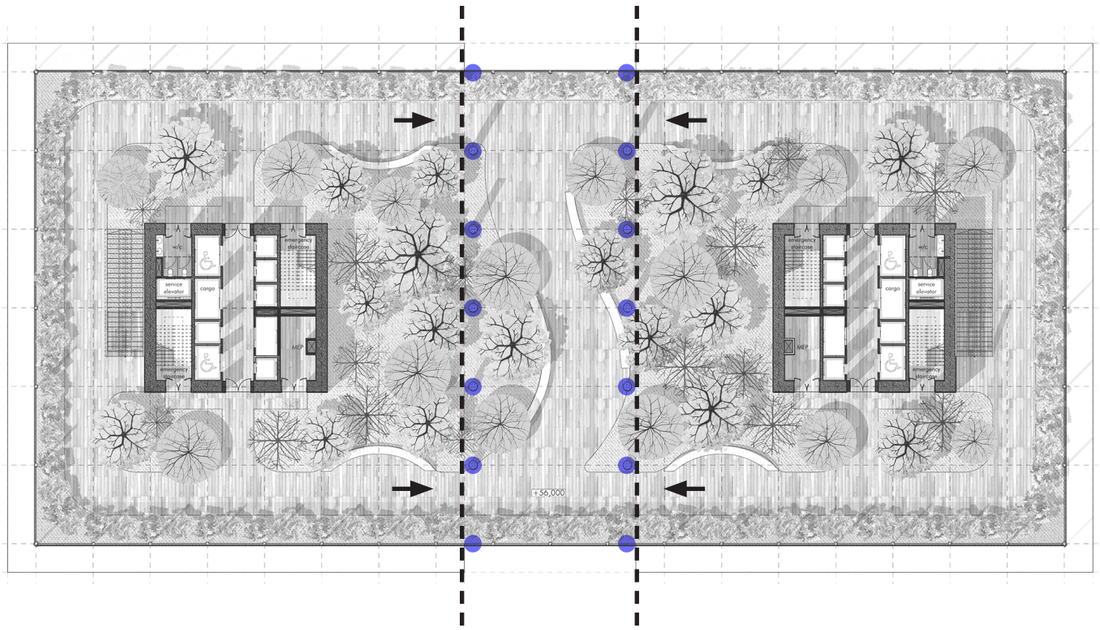




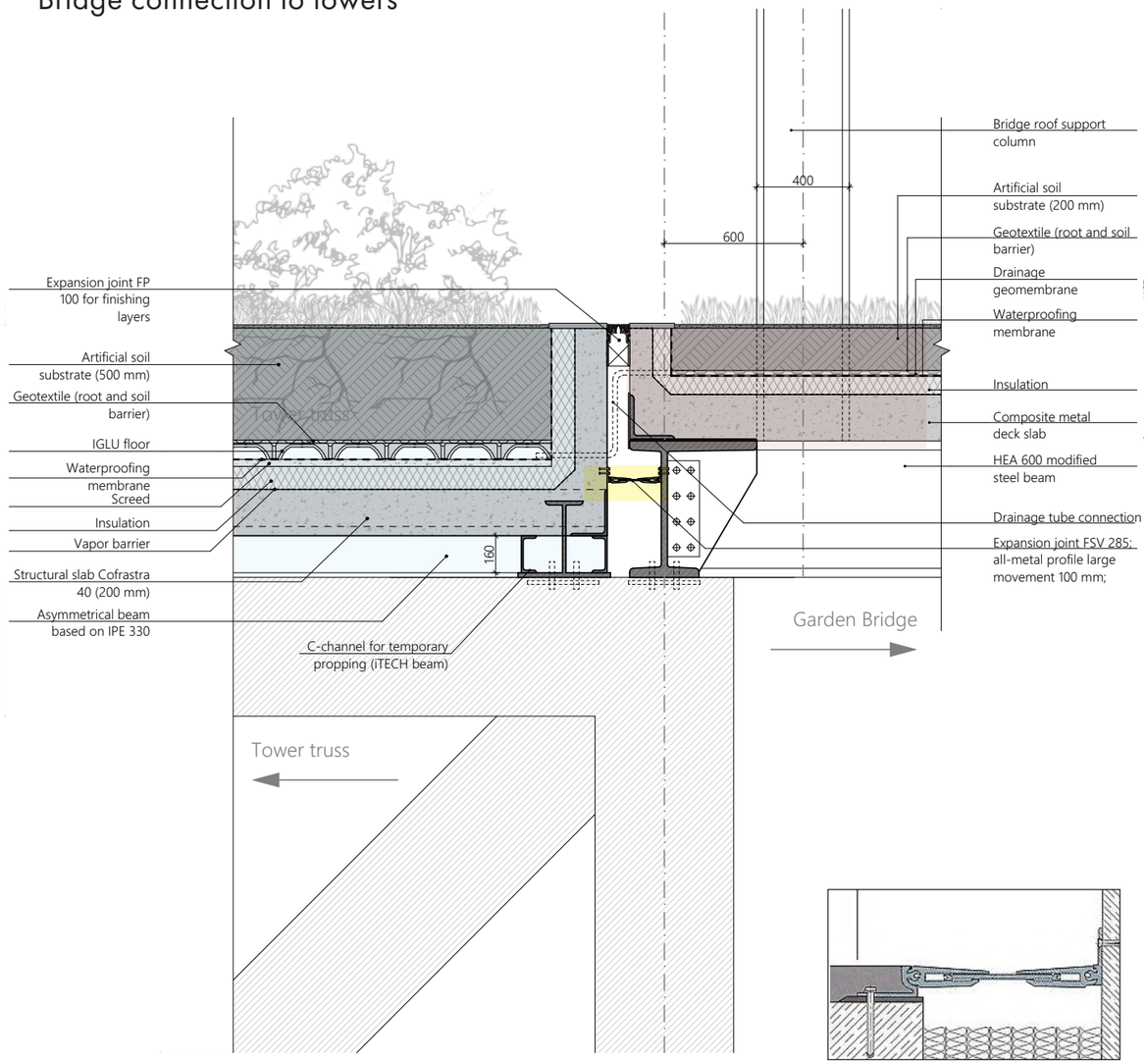
GARDEN FLOOR STRUCTURES - BRIDGE



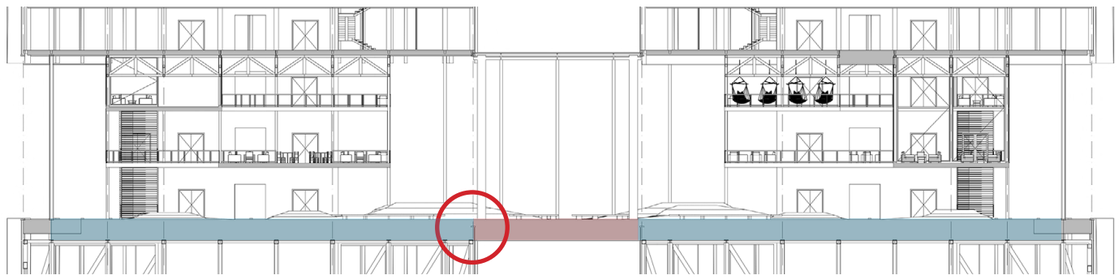
The bridge is essentially an independant structure, and therefore needs to have its own supports (blue) for the roof (yellow). These supports can not interfere with the main structural trusses of towers directly, and are shifted inwards from the towers. The outermost gridlines of the towers do not overlap with the supports.



Bridge connection to towers



The bridges are secured to the towers through structural expansion joints. The goal is to avoid transmitting any horisontal loads from one tower to another, and keep only vertical load.



Highlighted detail in the garden floor

CH.5 TECHNOLOGY & MATERIALS

SUSTAINABILITY

Overview

Both the developed world and Singapore as a state are moving towards a more sustainable future. That is reflected in development plans of the country and in general approach to construction. Our project needs to comply with this strategy and take appropriate measures in the building's design.

Sunlight

We take steps to make use of Singapore's intense sunlight to compensate at least part of the building energy consumption. Although the overall roof area that could be used for solar energy is comparatively small, it could still be useful. The calculations are explained in more detail further in the chapter.

The sun is present in Singapore without a clear advantage on either side. Throughout the day it is illuminating the city from all sides. Thus, we do not have to give any focus to a particular direction, as we do in northern regions for the south.

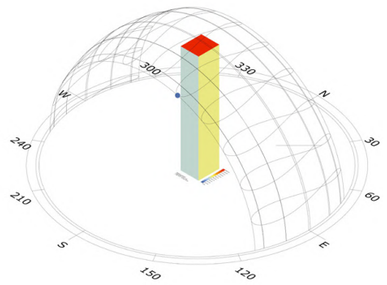
As for the effect of sunlight on the users of the building, we take control of it by designing a shading facade for different parts of the building. By decreasing excessive light and heat we also decrease the energy wasted on air conditioning.

1 - the gardens (green) receive the maximum possible light; no shading;

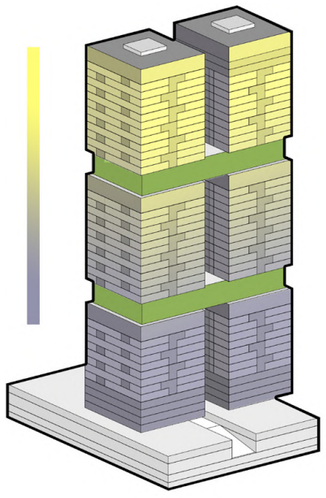
2 - apartments are protected from incoming sunlight by a gradient facade, designed on the basis of light intensity (the less light, the less dense the shading gets);

3 - the two inner surfaces of towers facing each other have no shading at all, since the light there is low;

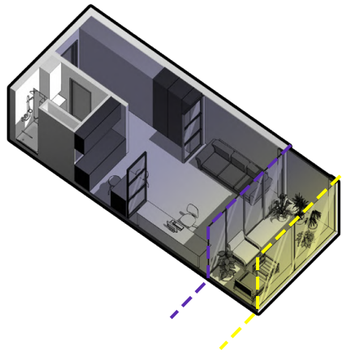
4 - apartments are completely surrounded by a balcony belt of 2 meters deep, which gives tenants an additional level of protection from sunlight.



Sunlight direction in Singapore



Different surfaces of facades by shading type



Shading the apartment with a wide balcony

Smart material selection

The majority of materials picked out for the construction are found in local assortments. We pay attention to their location and availability, as well as being certified for quality by Singapore authorities and being in line with moder ecological requirements. The detailed material selection is shown further in the chapter.

SUSTAINABILITY

Solar energy

Taking into account the high levels of solar radiation in Singapore, it would make sense to use that factor to offset energy consumption of the building at least to some extent.

With an average annual solar irradiance of 1,600 kWh/m2, solar energy is currently the most viable renewable energy source for Singapore. Solar Photovoltaics (PV) also generate less emissions than fossil fuels, which contributes to environmental sustainability.

Sunshine hours in Singapore range from 4:32 daily in November to 6:26 daily in July. The longest day of the year is 12:04 long and the shortest day is 11:55 long.

There is an average of 2064 hours of sunlight per year (of a possible 4383) with an average of 5:39 of sunlight per day. At midday the sun is on average 75° above the horizon at Singapore.

5 hours 39 minutes of sunlight per day (5.65 hrs in value); 2064 hours of sunlight per year.

A 10kW solar system consists of 31 to 40 solar panels. With standard size of 1.6m x 1m in size, it will require at least 50 square metres to place.

50 sq m = 10 kW (per hour of sunlight)

The area of each of two roofs, that could be used for solar energy, equals to 1000 square meters;

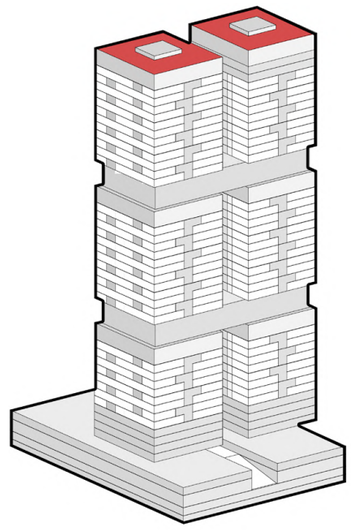
At 1000 m2, we can fit 20 systems of 10 kW output each. Therefore, **one roof is able to output 200 kW per hour of sunlight.**

As stated above, per year we have 2064 hours of sunlight:

2064 h * 200 kW = **412,800 kW/year.**

5:39 of sunlight per day average = 5.65 hours in plain numbers.

5.65 h * 200 kW = **1130 kW/day from one roof.**



Roof area available for solar energy

Now, to figure out the energy consumption of the tower:

The absolute maximum capacity of one residential block of **4 floors is 84 tenants**. That number is only true if every apartment reaches maximum occupancy at the same time.

One tower is comprised of 9 blocks; however, the bottom block is dedicated to commerce. We accept 8 blocks per one tower.

8 * 84 = 672 tenants in one tower (maximum).

Energy Market Authority (EMA) data of 2019 states that the average studio apartment consumes arounf 11-12 kWh per day. If we count one person as 11 kW, which is already generous, then :

11*672 = 7392 kW per tower daily is consumed.

While solar energy from the roof does not cover the demands of the tower, it can still provide **1130/7392 = 15.2%** of energy needed for apartment blocks.

MATERIALITY

SGBP Scheme

Singapore Green Building Product (SGBP) Scheme - certification scheme designed to evaluate and benchmark products in the industry for their notable qualities.

Regarded as one of the key standard and benchmarks for green building products in the building and construction industry, the SGBP Scheme is recognised under the Green Mark Scheme, Singapore's national green building rating tool administered by the Building and Construction Authority (BCA).

The producers chosen in the project were chosen according to the current evaluations by SGBP, with preference given to the Excellent and Leader groups.

Lightweight concrete

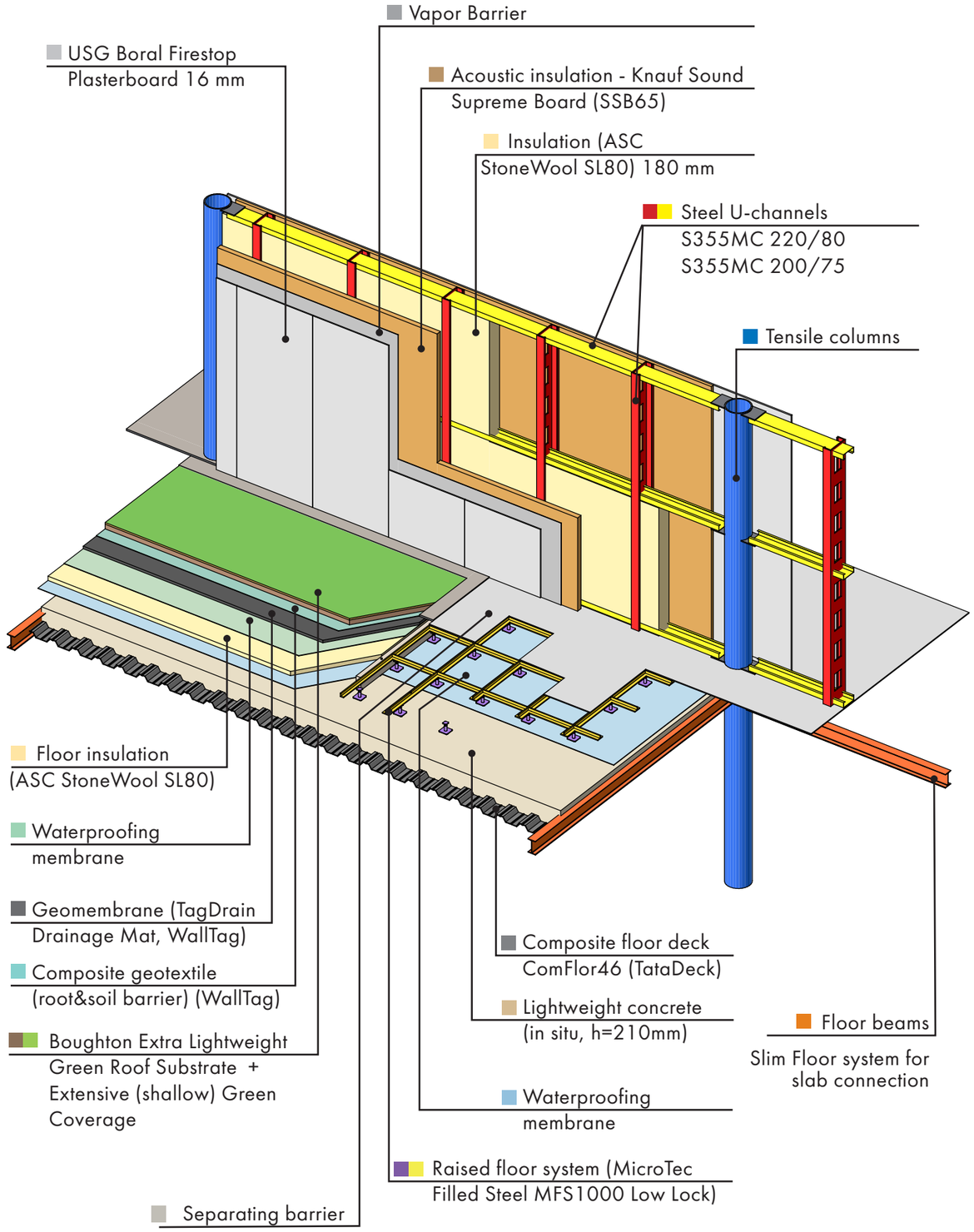
ALLIANCE Concrete Singapore PTE LTD is the highest-ranking company in the official ranking and their production plants are present in 9 locations in Singapore. That includes Marina East area, which is very close to the site.

Alliance also offers a very wide range of ready-mix concrete types, which include eco-friendly options in wide selection.

ALLIANCE CONCRETE SINGAPORE

SINGAPORE GREEN BUILDING PRODUCT SGBC LEADER

COMPOSITIONS OF TYPICAL FLOOR TYPES AND INTERIOR WALLS



Boughton Extra Lightweight Green Roof Substrate

This mixture is an ideal growing media for green roofs where weight loading is an issue. Its low bulk density, even at field capacity, allows it to be installed to a much deeper depth than conventional extensive substrates, improving the growing environment for plants.

Boughton Extra Lightweight would normally be applied at depths between 80 and 150mm.

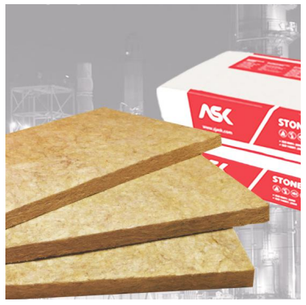
Properties

Bulk density oven dried (g cm-3)	0.70
Bulk density at 10% VMC (g cm-3)	0.83
Bulk density at field capacity (g cm-3)	1.13
Field Capacity (% v/v)	41.0
Particle Density (g cm-3)	0.98
Total Porosity (%)	71.8
Porosity at Field Capacity (%)	28.9
Effective Porosity (%)	42.9
Saturated Hydraulic Conductivity (mm min-1)	213

Boughton

Floor insulation (ASC StoneWool SL80)

ASC Stonewool slabs are stone fibre-based products that deliver excellent thermal and acoustic performance. It is an inorganic spun fibre made from molten minerals. Products comply with the requirement as set by internationally recognized standard European standard.



ASC STONEWOOL

Properties		Unit	SL60	SL80	SL100	SL120	SL140	Standard
Thermal Conductivity	50℃	W/（m·k）	≤0.040	≤0.038	≤0.038	≤0.038	≤0.038	GB/T 10295 ASTM C518 ASTM C177
	100℃		≤0.046	≤0.045	≤0.045	≤0.045	≤0.045	
	150℃		≤0.060	≤0.058	≤0.056	≤0.055	≤0.055	
	200℃		≤0.077	≤0.071	≤0.067	≤0.064	≤0.062	
	250℃		≤0.09	≤0.085	≤0.080	≤0.074	≤0.070	
	300℃		≤0.120	≤0.099	≤0.095	≤0.090	≤0.085	
Max Service Temperature		℃	450	650	750	750	750	ASTM C411
Linear Shrinkage		%	≤2	≤2	≤2	≤2	≤2	ASTM C356
Noise Absorption Co-efficient at 50mm (NRC)]			—	0.95	—	—	—	ISO 354
Water vapor absorption		vol %	⩽0.02	⩽0.02	⩽0.02	⩽0.02	⩽0.02	GB/T 5480 ASTM C1104M
Water leachable chloride content		ppm	≤10	≤10	≤10	≤10	≤10	ASTM C871
Reaction to Fire:		Classification A1 Non-combustible Surface burning characteristics: Smoke development ≤50, Flame Spread≤25						EN13501-1 GB 8624 ASTM E136 ASTM E84

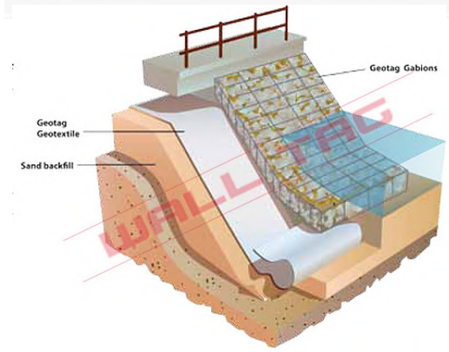
Composite geotextile (root&soil barrier) (WallTag)

Composite geotextile is made of high strength polyester woven fabric and non-woven polyester or polypropylene geotextile.

It is suitable for reinforcement of fine-grain soil and it also works as a separator and filter for water and materials, e.g. soil, sand and gravels. It has a high tensile strength at a low elongation and has a high level of microbiological resistance.

Geotag Composite Geotextile is a combination of advantages of high-strength reinforced woven geotextile with filtration, drainage and protective properties of non-woven geotextiles.

WALL TAG



Geomembrane (TagDrain Drainage Mat, WallTag)

Tag-Drain Dimple Mat is designed as a flexible subsoil drainage mat for roof gardens, landscape decks or plazas and planter boxes.

Weighing less than 1kg/m2 Tag-Drain Dimple Mat reduces the loading on concrete decks as compared with gravel drainage layers. This lightweight material also eases transportation and handling.

Tag-Drain Dimple Mat has a free surface that is at least 90% permeable to water, and has a high flow rate of 60 lit/min/m at 1% hydraulic gradient, allowing it to efficiently drain off seepage water.

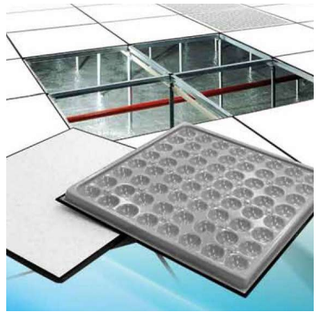
Tag-Drain Dimple Mat has a compressive strength of 200kN/m2 and can withstand instaallation loads and soil loadings. Its 1.0 metre width saves installation time and can be cut to fit any shapes or profile

WALL TAG

Microtac Filled Steel (MFS) Access Floor System

MFS panels are resilient, durable epoxy coated steel panels with a unitized shell construction.

The panel shell is constructed from a at steel sheet resistance wielded to a die-formed bottom pan, with hemispherical reinforcing pockets. Internally, the steel shells are filled with a non-combustible light weight, high compressive strength cementitious mixture. The resultant product is a panel that delivers excellent and uniform load bearing results.



Microtac

USG Boral Firestop Plasterboard 16 mm

USG Boral Firestop™ plasterboard is a high-performance fire-rated interior plasterboard, composed of fire-resistant gypsum core encased in 100% recycled face and back papers that form a high strength composite design.

The panels have tapered long edges for easy finishing, when used with USG Boral's Jointing compounds.

Property	USG Boral Firestop™ 12.5 / 16 mm
Weight (kg/m²)	11.50 / 13.60
Thickness (mm)	12.5 / 16.0 mm
Width (mm)	1220
Length (mm)*	1830, 2440, 2745
Edges	Square and Tapered
Face Paper Color	Pink

USG BORAL
INNOVATION INSPIRED BY YOU.™

Acoustic Knauf Sound Supreme Board (SSB65)

Insulation board, based on a composition of rock mineral wool and other ecologically oriented materials. Sound insulation up to 43 dB, fire resistance (EI 30 – EI 60) and thermal insulation. Could be applied with thickness of 8 – 50 mm.

Vapour permeable, water repellent, stable dimensions, resistant to microorganisms.

The materials used are non hazardous for both personal health and for the environment.

KNAUF INSULATION
OEM Solutions

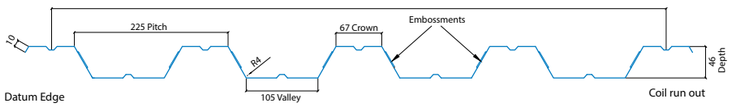
Technical properties of DRS Sound Supreme Board

	SSB 65	SSB 50/50	SSB 65/65	SSB 50/90	SSB 90/90	
Density	650	500	650	700	900	kg/m³
Sound insulation	39	35	40	42	43	dB
Thermal conductivity – declared	0.092	0.077	0.092	0.100	0.120	W/mk
Fire resistance			EI 30 / EI 60			min
Compression strength	–	290	630	–	1700	

Composite floor deck ComFlor46 (TataDeck)

TATA STEEL

TATA



ComFlor® 46 Composite slab - volume and weight (BS values)

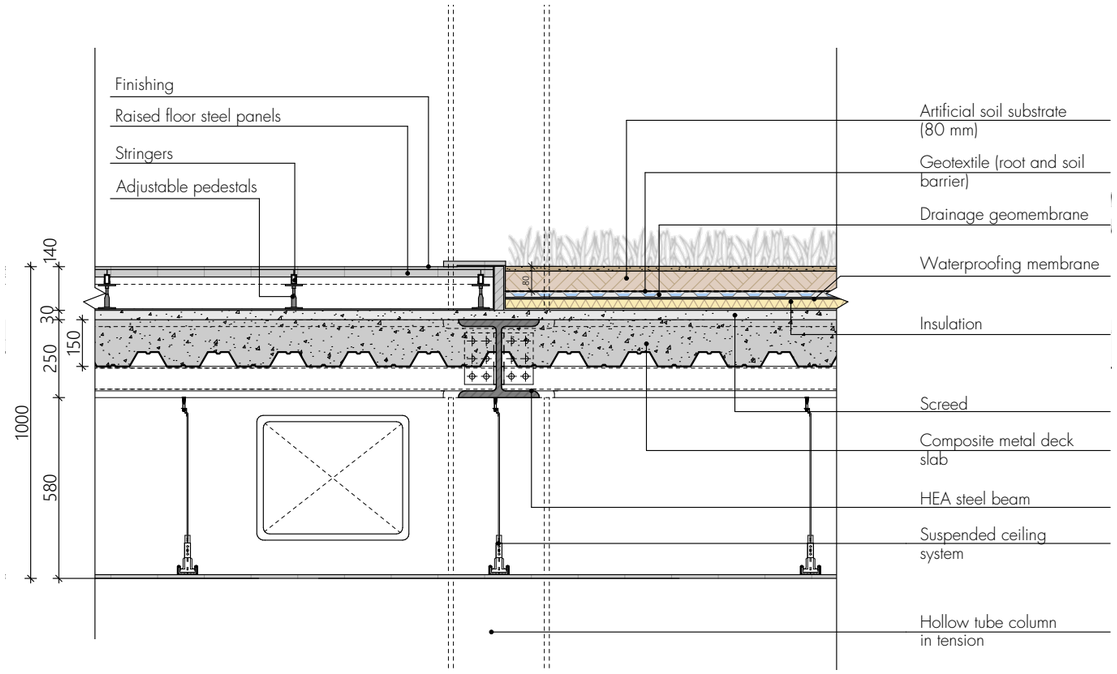
Slab depth (mm)	Concrete volume (m³/m²)	Weight of concrete (kN/m²)			
		Normal weight concrete		Lightweight concrete	
		Wet	Dry	Wet	Dry
96	0.077	–	–	1.43	1.35
106	0.087	2.04	2.00	1.61	1.53
110	0.091	2.13	2.09	1.69	1.60
120	0.101	2.37	2.32	1.88	1.78
130	0.111	2.60	2.55	2.06	1.95
140	0.121	2.84	2.78	2.25	2.13
150	0.131	3.08	3.01	2.43	2.31
160	0.141	3.31	3.24	2.62	2.48
170	0.151	3.55	3.47	2.81	2.66
180	0.161	3.78	3.70	2.99	2.84
190	0.171	4.02	3.93	3.18	3.01
200	0.181	4.25	4.16	3.37	3.19
250	0.231	5.43	5.32	4.30	4.07

Notes

1. Deck and beam deflection (ie, ponding) is not included in the table.
2. Deck and mesh weight is not included in the weight of concrete figures.
3. British Standard density of concrete is taken as:

   Normal weight (wet) 2400kg/m³
   Normal weight (dry) 2350kg/m³
   Lightweight (wet) 1900kg/m³
   Lightweight (dry) 1800kg/m³

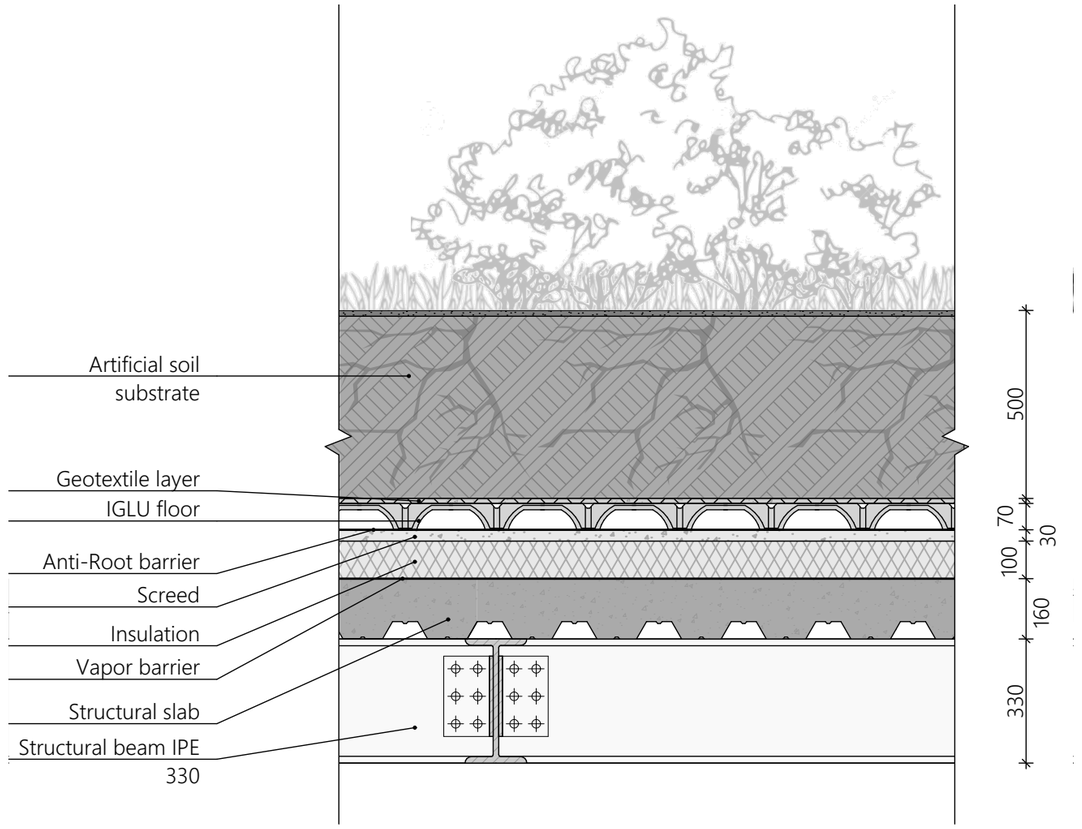
BASIC STRATIGRAPHIES
Typical floors



Typical Floor Slab Detail							
	Material	Height (mm)	Height (m)	Width (m)	Length (m)	Unit Weight r (KN/m3)	Total Weight of the Material KN/m^2
1	Partition Walls (approx.)	3000	3	1	1	-	1.2
2	Flooring (Raised Floor Decking; MicroTac Filled Steel Panel MFS1000)	150	0.15	1	1	-	0.41
3	Insulation (ASC StoneWool SL80)	100	0.1	1	1	0.8	0.08
4	Waterproofing membrane	2	0.002	1	1	0.01	0.00002
5	Vapor Barrier	0.2	0.0002	1	1	0.15	0.00003
6	Composite floor deck ComFlor46, Lightweight concrete (TataDeck)	150	0.15	1	1	0	2.43
7	Mechanical Plans	-	-	-	-	-	0.2
8	Ceiling	60	0.06	1	1	-	0.1
9						TOTAL WEIGHT	4.42005

Typical Floor Slab Detail (green areas)							
	Material	Height (mm)	Height (m)	Width (m)	Length (m)	Unit Weight r (KN/m3)	Total Weight of the Material KN/m^2
1	Boughton Extra Lightweight Green Roof Substrate	80	0.08	1	1	11.8	0.944
2	Composite geotextile (root&soil barrier) (WallTag)	10	0.01	1	1	0.01	0.0001
3	Geomembrane (TagDrain Drainage Mat, WallTag)	30	0.03	1	1	-	0.01
4	Waterproofing membrane	2	0.002	1	1	0.01	0.00002
5	Insulation (ASC StoneWool SL80)	30	0.03	1	1	0.8	0.024
6	Composite floor deck ComFlor46, Lightweight concrete (TataDeck)	150	0.15	1	1	0	2.43
7	Mechanical Plans	-	-	-	-	-	0.2
8	Ceiling	-	-	-	-	-	0.1
						TOTAL WEIGHT	3.70812

BASIC STRATIGRAPHIES
Garden floors



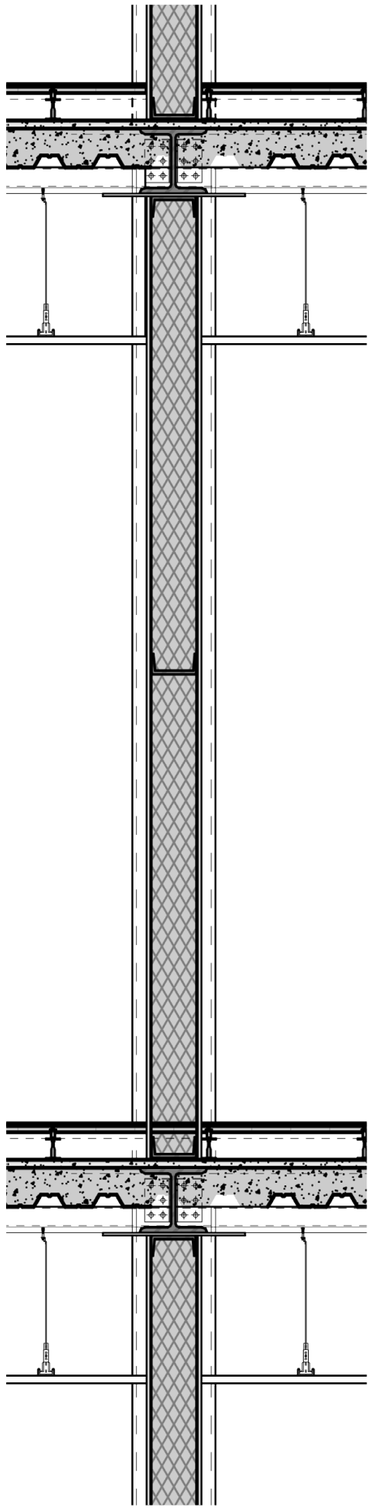
Garden Floor							
	Material	*Height (mm)*	*Height (m)*	*Width (m)*	*Length (m)*	*Unit Weight r (KN/m3)*	*Total Weight of the Material KN/m^2*
1	Pavement (12 mm Tile) + 6mm Adhesive	*9*	*0.009*	*1*	*1*	-	*0.1398*
2	Plant coverage (average, avoid thick trunks)	-	-	-	-	-	*2*
3	Boughton Extra Lightweight Green Roof Substrate (height = average by floor)	*500*	*0.5*	*1*	*1*	*11.08*	*5.54*
4	Geotextile layer	*5*	*0.005*	*1*	*1*	*0.003*	*0.000015*
5	IGLU Floor	*42*	*0.042*	*1*	*1*	*1.56*	*0.06552*
6	Protective Layer/Anti-Root barrier	*0.2*	*0.0002*	*1*	*1*	*0*	*0*
7	Screed Construction	*50*	*0.05*	*1*	*1*	*8*	*0.4*
8	Thermal Insulation	*100*	*0.1*	*1*	*1*	*0.45*	*0.045*
9	Vapor Barrier	*0.2*	*0.0002*	*1*	*1*	*0*	*0*
10	Metal Deck with Concrete Cover	*295*	*0.295*	*1*	*1*	*0*	*2.57*
11	Mechanical Plans	-	-	-	-	-	*0.198*
12	Ceiling	*60*	*0.06*	*1*	*1*	-	*0.1*
						Total Weight	11.058335

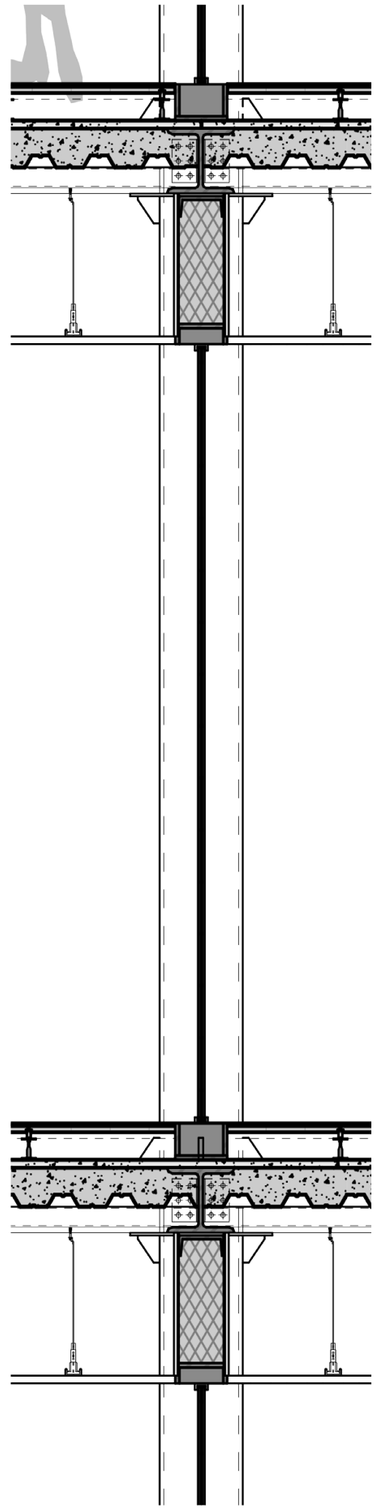
BASIC STRATIGRAPHIES

Internal walls

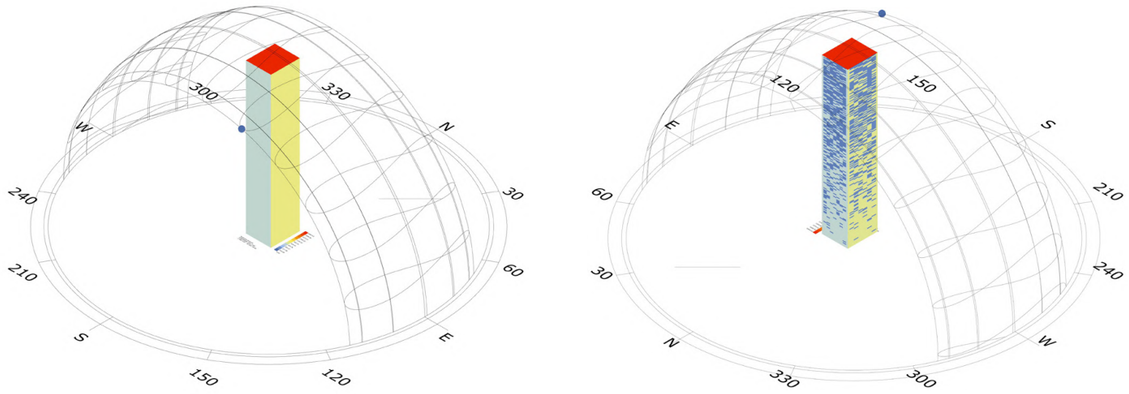
Typical Partition Wall (inside apartment)							
	Material	Thickness (mm)	Thickness (m)	Width (m)	Length (m)	Unit Weight r (KN/m2)	Total Weight of the Material KN/m
1	Insulation (ASC StoneWool SL80)	100	0.1	1	1	0.8	0.08
2	Steel cold-formed punched U-Channel S355MC 65/42, 1 m = 4 kg	65/42	-	-	4.5	-	0.18
3	Steel cold-formed punched U-Channel S355MC 50/38, 1 m = 3.5 kg	50/38	-	-	3	-	0.105
4	Acoustic insulation - Knauf Sound Supreme Board (SSB65)	20 * 2	0.04	1	1	0.26	0.78
5	Vapor Barrier	0.2	0.0002	1	1	0.003	0.009
6	USG Boral Firestop Plasterboard 16 mm	16 * 2	0.032	1	1	0.272	0.816
						TOTAL WEIGHT	1.97

Typical Partition Wall (between apartments)							
	Material	Thickness (mm)	Thickness (m)	Width (m)	Length (m)	Unit Weight r (KN/m2)	Total Weight of the Material KN/m
1	Insulation (ASC StoneWool SL80)	180	0.18	1	1	0.8	0.144
2	Steel cold-formed punched U-Channel S355MC 220/80, 1 m = 17.77 kg	220/80	-	-	3	-	0.5333
3	Steel cold-formed punched U-Channel S355MC 200/75, 1 m = 14.145 kg	200/75	-	-	3	-	0.4525
4	Acoustic insulation - Knauf Sound Supreme Board (SSB65)	20 * 2	0.04	1	1	0.26	0.78
5	Vapor Barrier	0.2	0.0002	1	1	0.003	0.009
6	USG Boral Firestop Plasterboard 16 mm	16 * 2	0.032	1	1	0.272	0.816
7							
8							
						TOTAL WEIGHT	2.7348

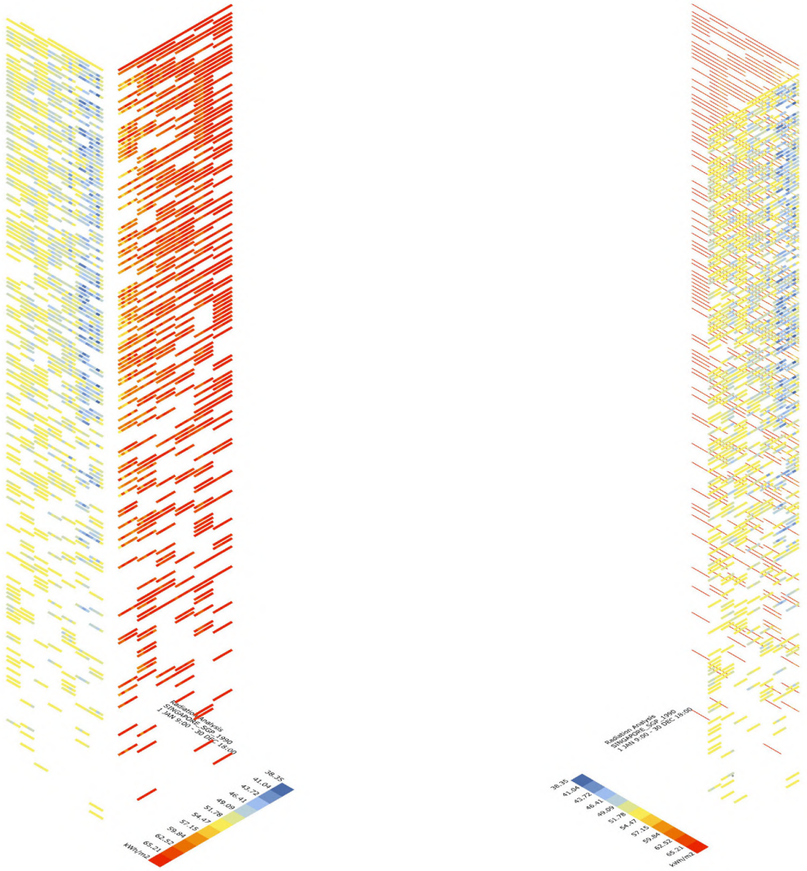




FACADE SYSTEM

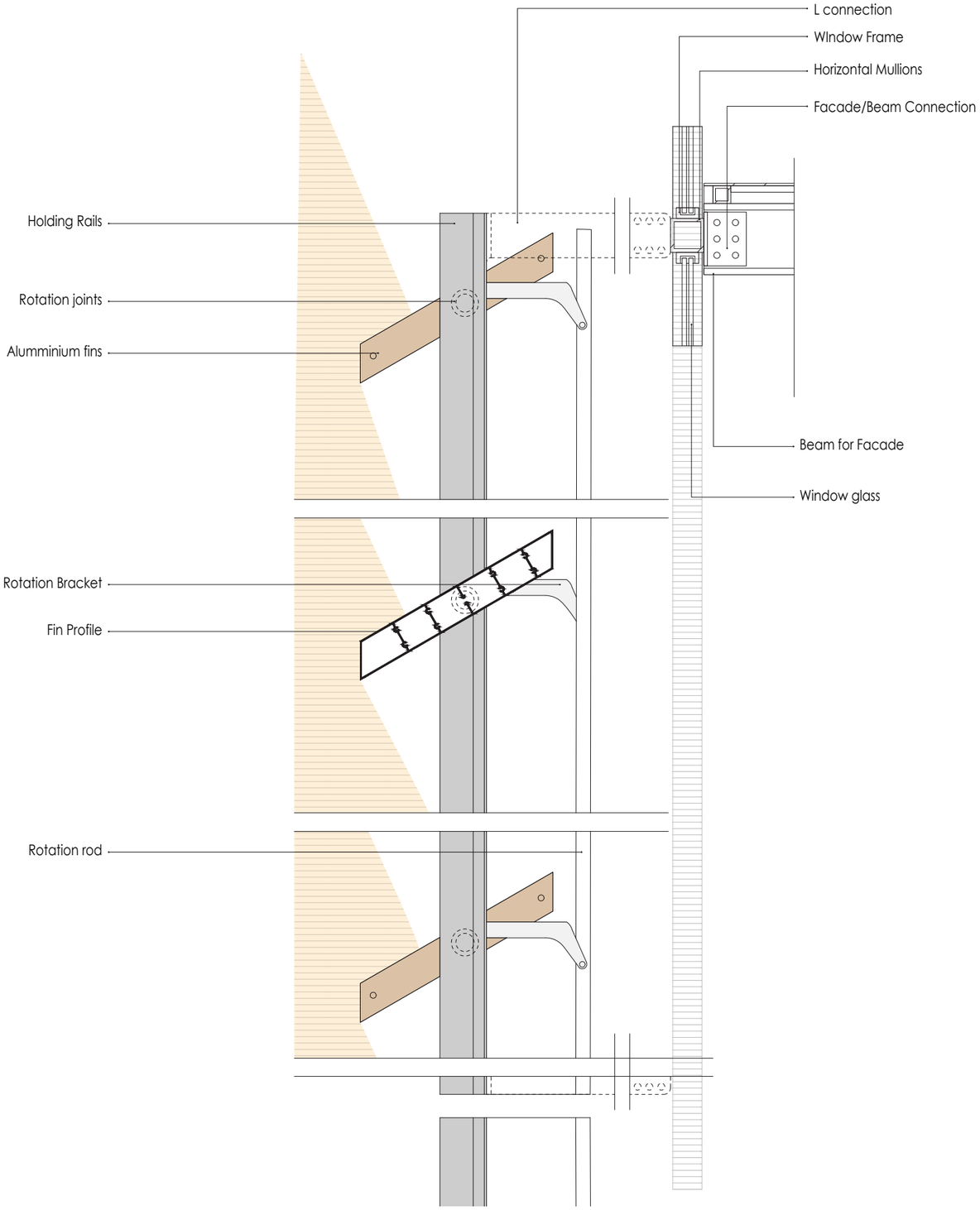


Sunlight intensity on different facade surfaces with sun path



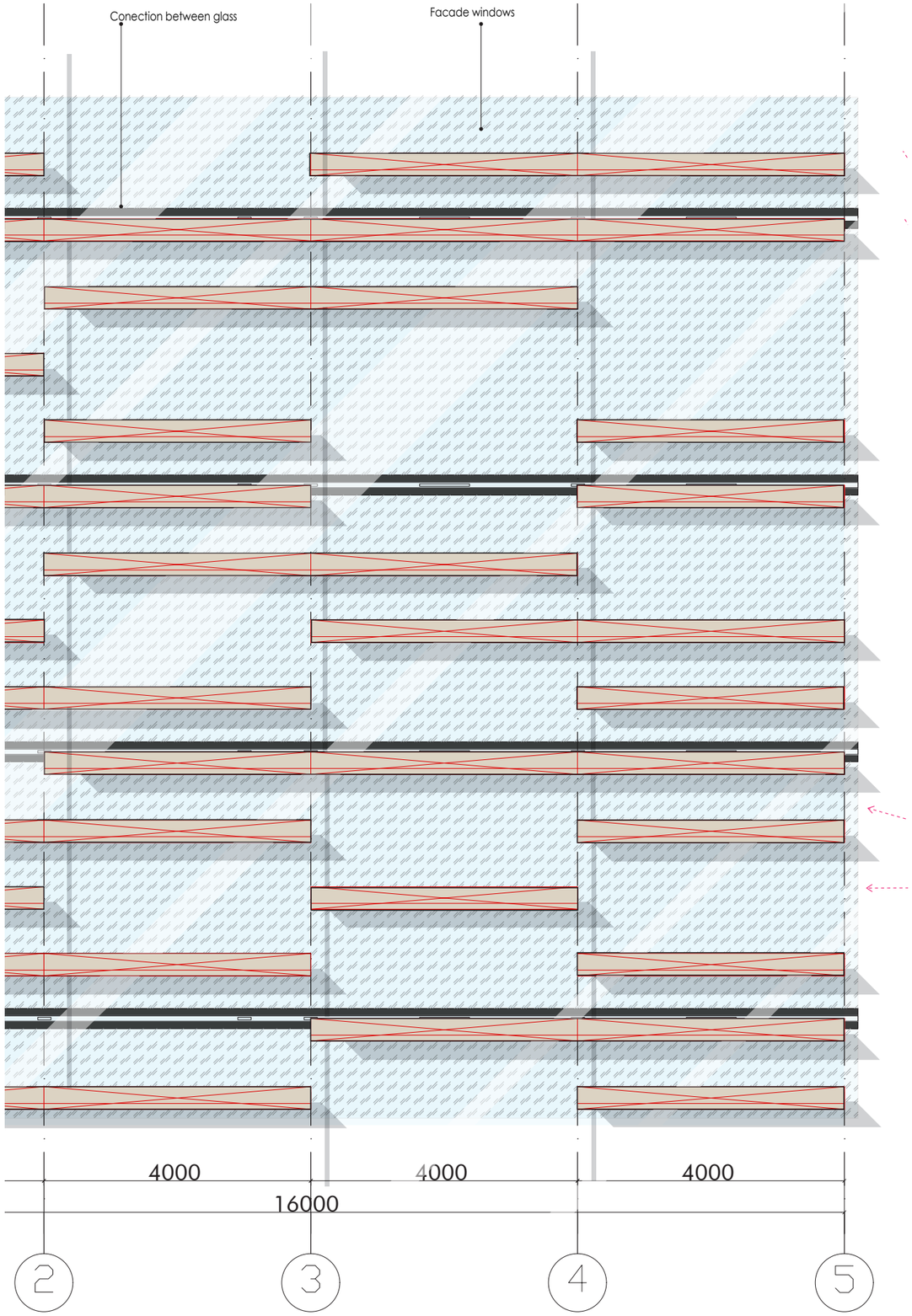
Sunlight intensity on different facade surfaces

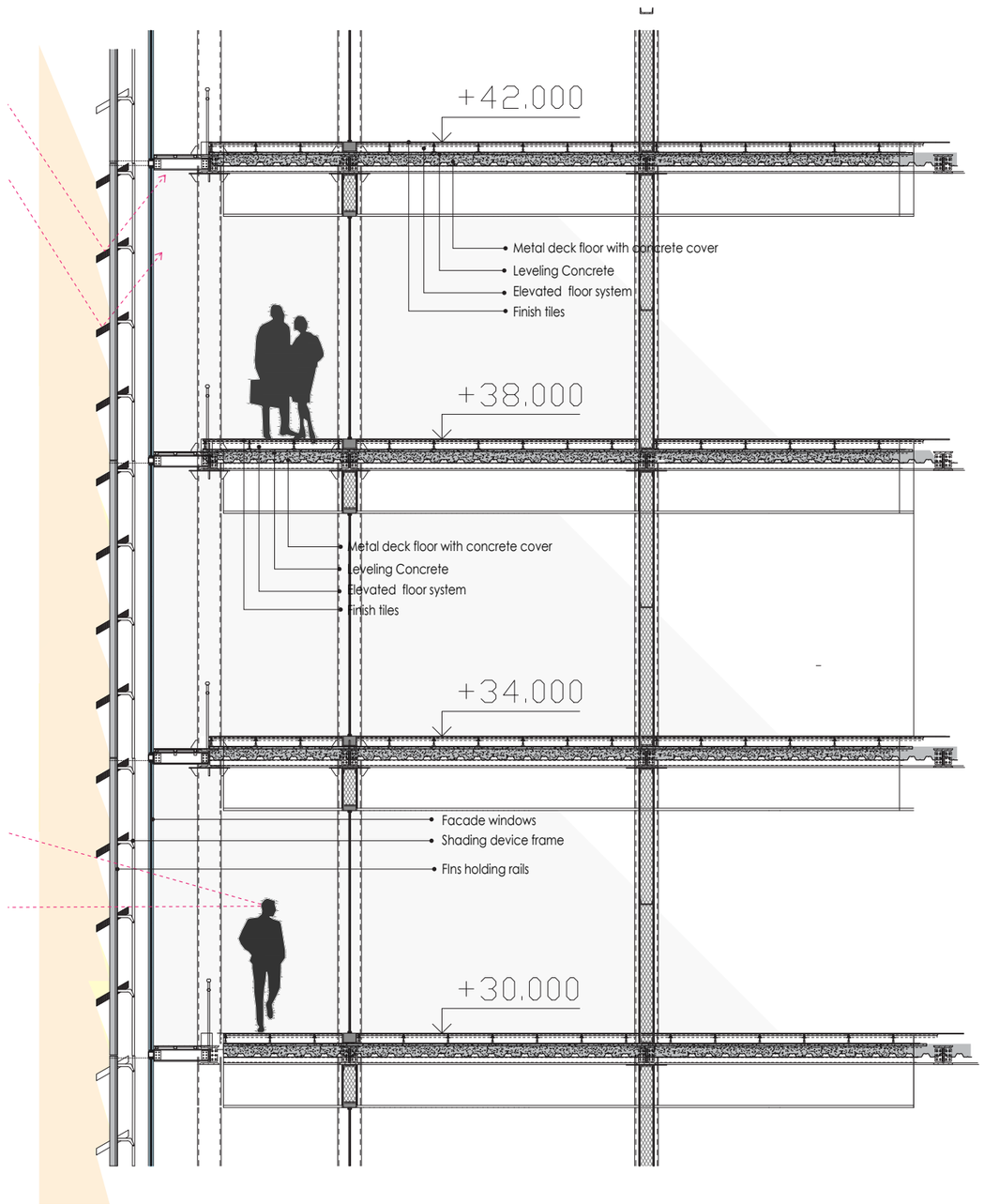
FACADE SYSTEM: DETAILS

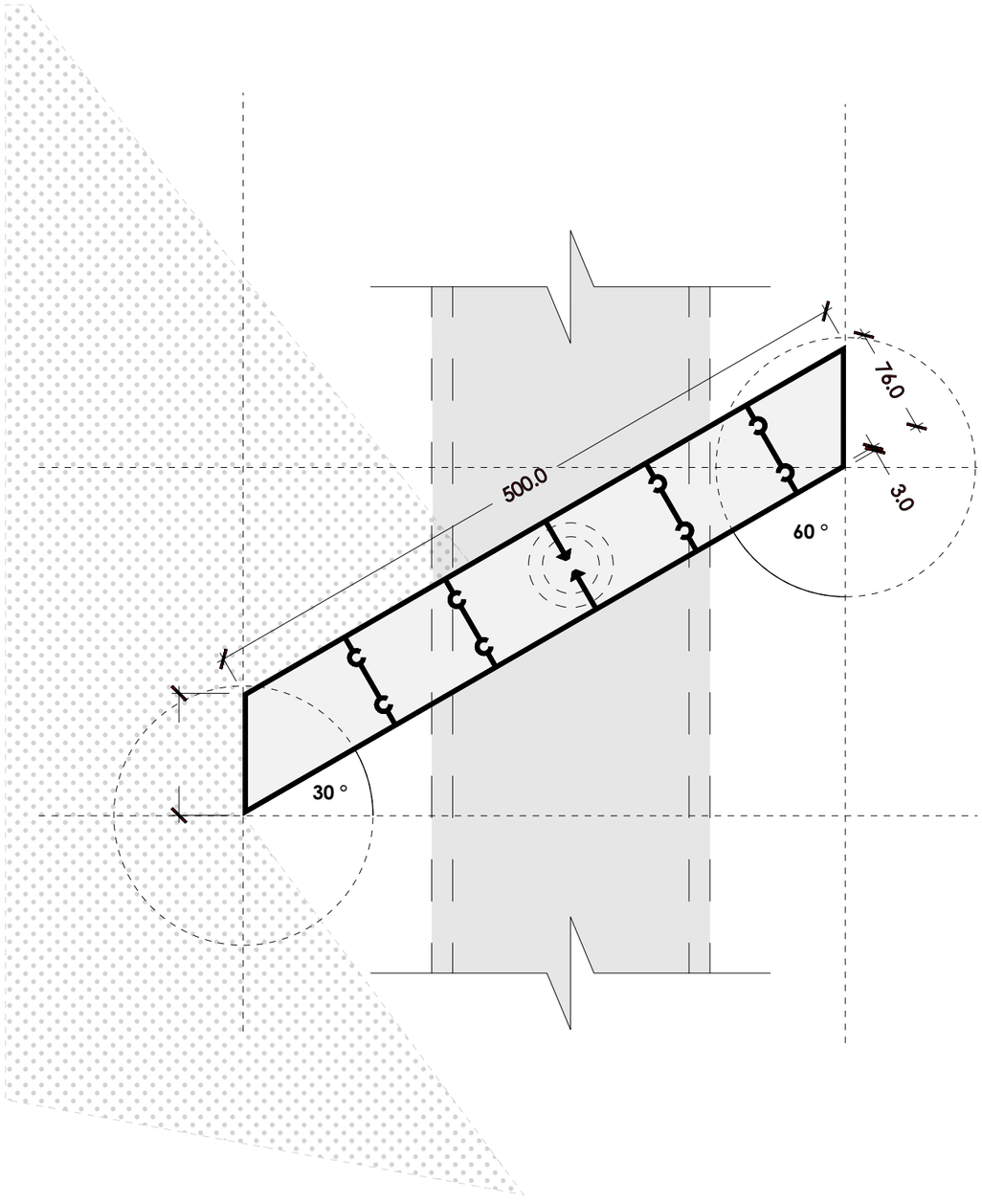


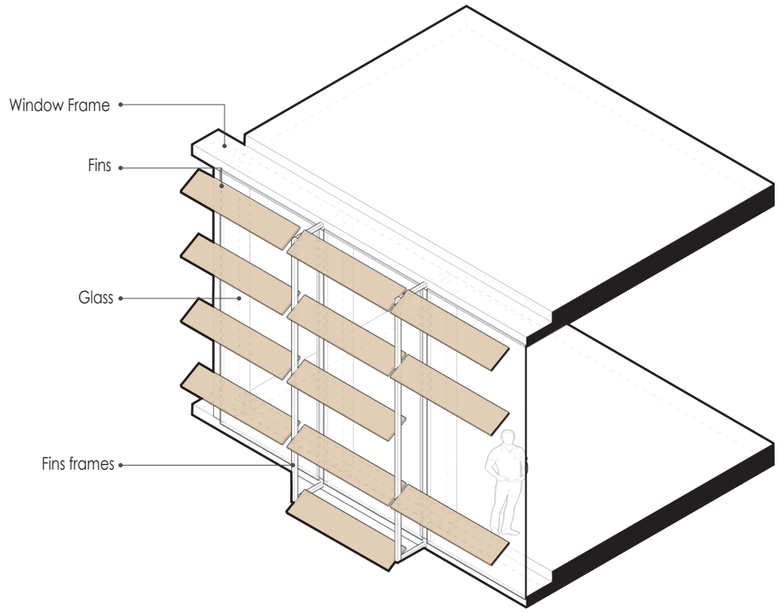
Detail of tilted horisontal fin facade system

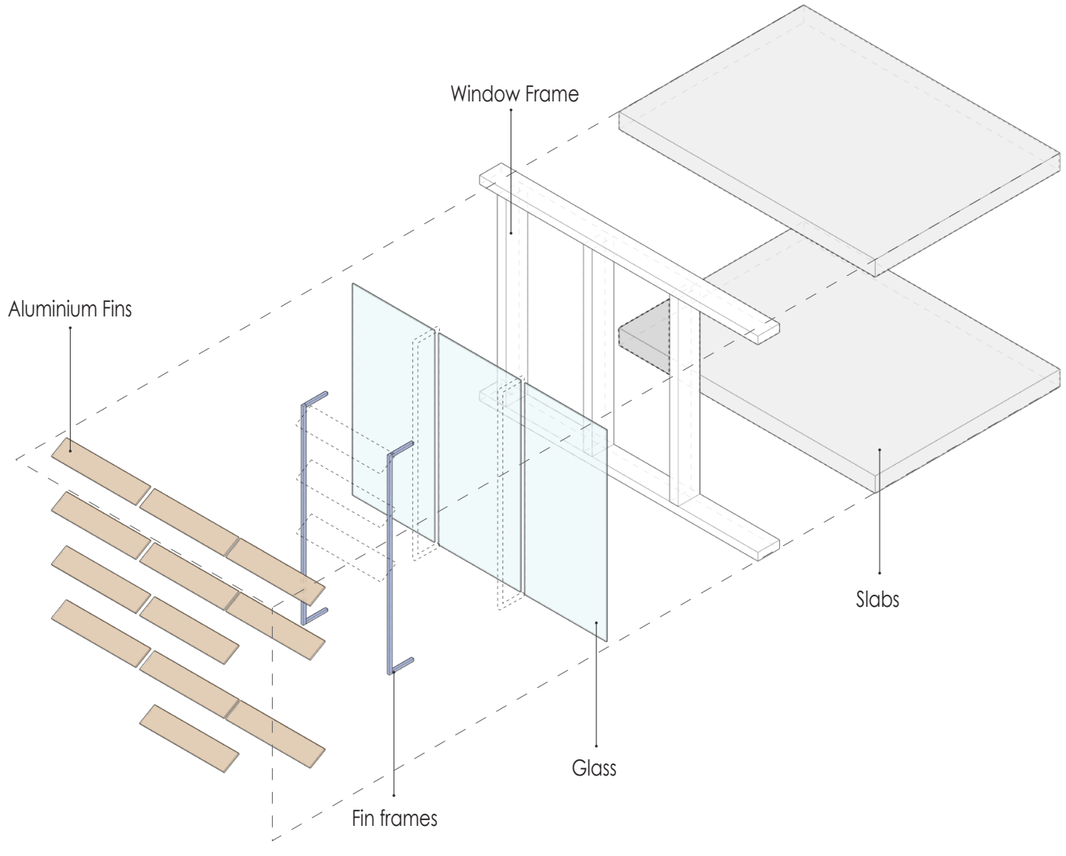
FACADE SYSTEM: EXTERIOR & INTERIOR






76.0
500.0
3.0
60 °
30 °


Window Frame
Fins
Glass
Fins frames


Window Frame
Aluminium Fins
Slabs
Glass
Fin frames

SELECTION OF FLORA SPECIES

Greenery plays an important role both for Singapore of today and for our building's message. We need to plan for a suitable selection of plant species both in the site of the building, which serves as public territory, and inside the building - in the enclosed gardens. These two areas have their own requirements for the plant sets depending on the conditions.

GENERAL REQUIREMENTS:

In both areas, there are common properties expected from plants. For gardens set inside a building, there is an obvious limitation of soil depth sue to the weight of it and structural restrictions. As such, preference is given to plants with roots not developing downwards. Also, soil is replaced with substrate which has more potential and less volumetric weight.

- Ability to grow on artificial soil substrate
- Roots need to extend horisontally, not downwards
- Non-toxic for human contact
- Native to Singapore
- Not an allergy trigger

EXTERIOR

Suitable for local weather conditions:

- high temperatures
- strong sun
- high humidity

low grass

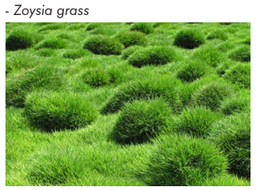
Qualities:

able to grow on shallow soil (8-10 cm)

soft to the touch

resilient to stepping on

- Zoysia grass



- Festuca arundinacea

shrubs

Qualities:

knee height/ /chest height

ornamental

safe (no spikes)

- Cyrtostachys renda

- Colocasia

trees

Qualities:

canopy-forming

not a thick trunk

shallow root network

- Bougainvillea arborea Glaz.

- Bougainvillea glabra

- Millettia pinnata (L.) Panigrahi

- Syzygium zeylanicum (L.) DC

- Bougainvillea × buttiana 'Poultonii'

SELECTION OF FLORA SPECIES: INTERIOR

Suitable for indoor growing (able to tolerate air conditioning):

- lower temperatures
- lower humidity

vines

either hangs from root point or crawls up a surface

thick foliage as to cover green wall structure

- Dischidia oiantha

- Tradescantia pallida (Rose) D.R.Hunt

- Axonopus compressus

- Cynodon dactylon (L.) Pers.

low grass

able to grow on shallow soil (8-10 cm)

soft to the touch

resilient to stepping on

- Phlegmariurus phlegmaria

- Rhynchospora colorata (L.) H. Pfeiffer

shrubs

knee height/chest height

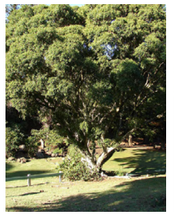
ornamental

safe (no spikes)

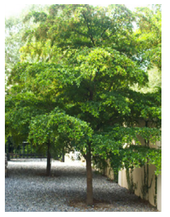
- Schismatoglottis calyptrata

- Licuala spinosa

- Ficus microcarpa



- Terminalia buceras



trees

canopy-forming

not a thick trunk

shallow root network

- Microsorum punctatum (L.) Copel

- Ficus nitida

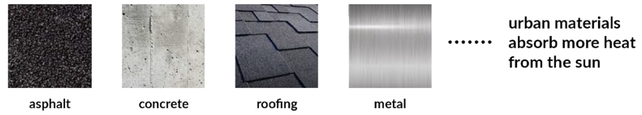
- Kentia palm

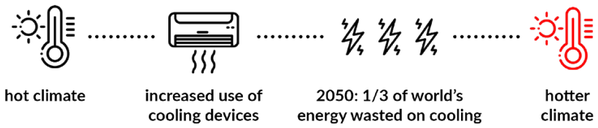
URBAN HEAT ISLAND EFFECT

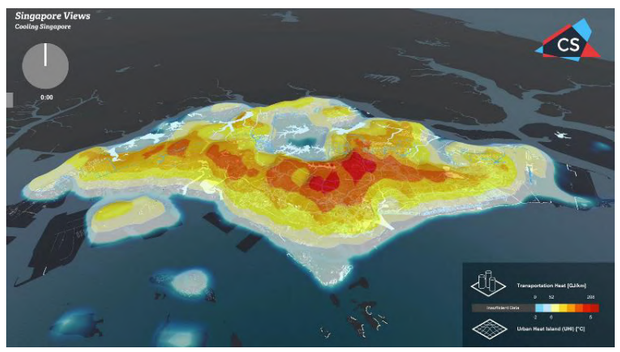
UHI Effect normally occurs in heavily urbanized areas, as they require higher energy input in electricity and fuel, have less vegetation to provide shade and cooling, and are built of materials that absorb and store energy from the sun.

The urban heat island effect over much of Singapore averages about 4°C, though it can exceed 7°C at certain times of the day. This warming reduces thermal comfort, discourages people from walking or cycling, and increases the energy used for air conditioning. In an ironic way, the increase of air conditioning use contributes to temperatures rising - a vicious cycle.

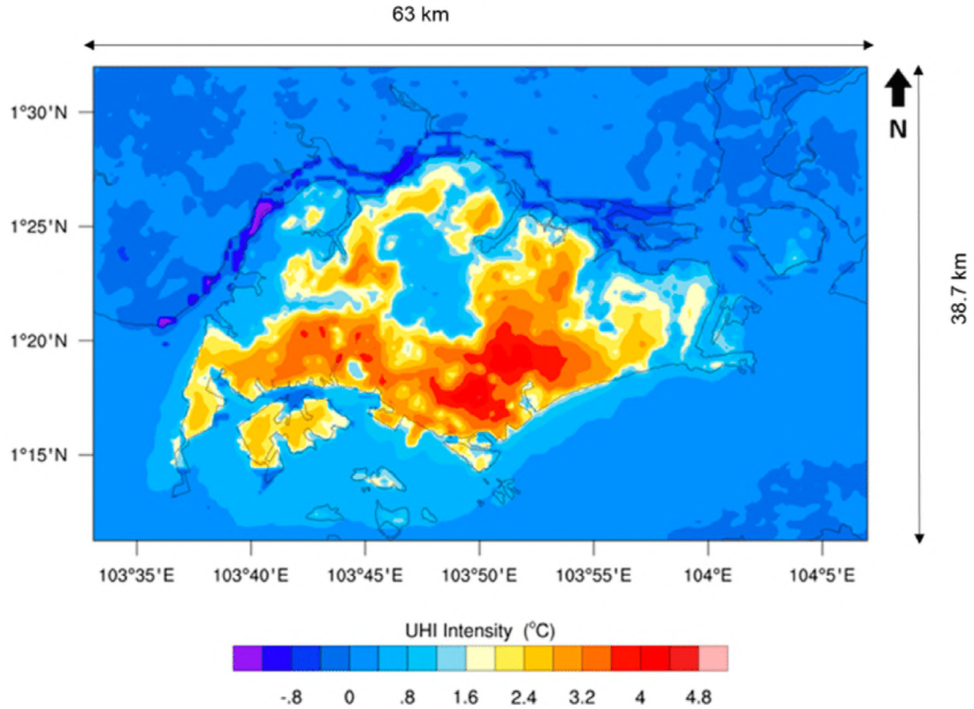
It is also responsible for more intense storms, which sometimes lead to flooding. And as the economy develops Singapore's urban heat island effect will only grow larger, unless mitigating action is taken.







UHI 3D map of Singapore

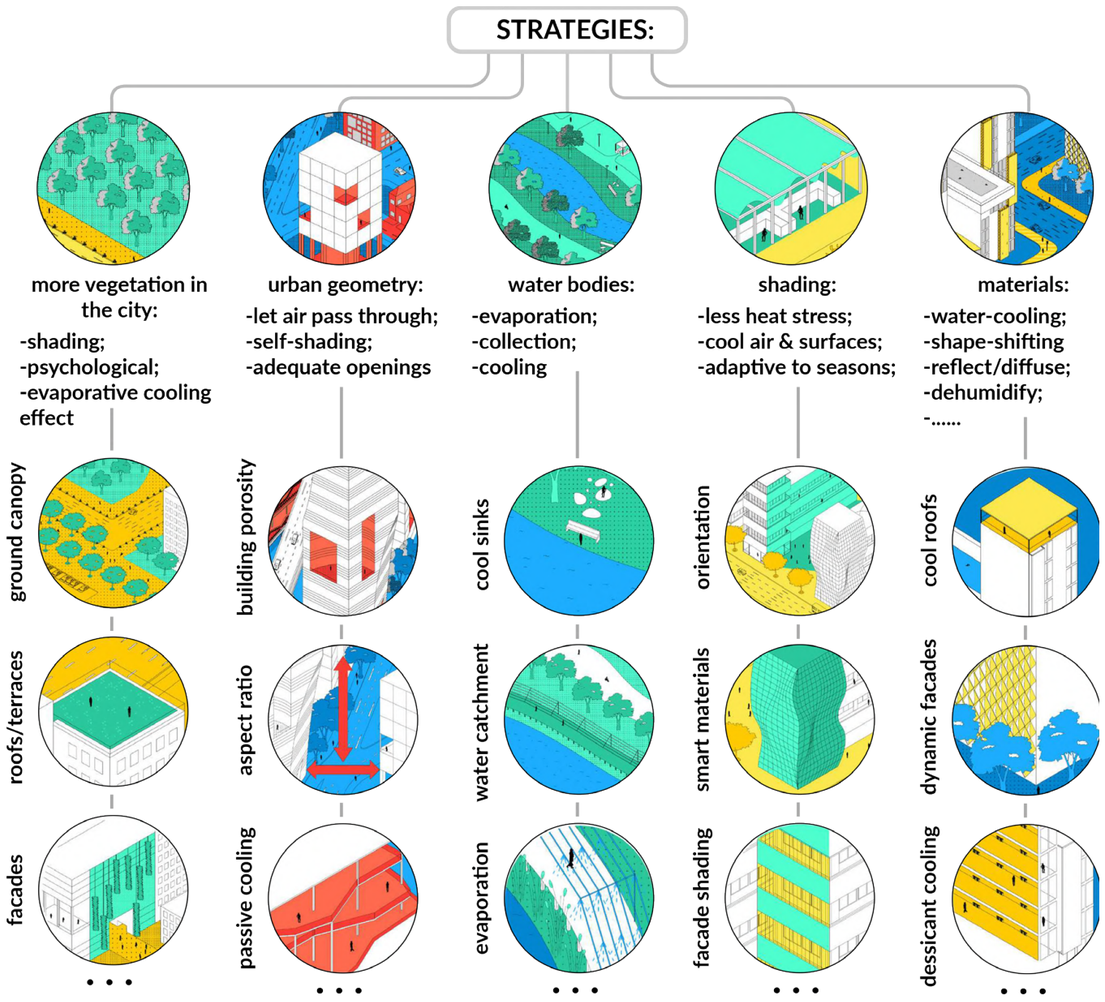


UHI intensity map of Singapore

UHI MITIGATION

In the 2017 work "Cooling Singapore", a team of researchers proposed 86 strategies for mitigating the problem in Singapore. These strategies are subdivided in 7 groups, out of which we can apply 5 to our project. The last 2 are referring to efficient transport system and energy distribution, which we have less control over on a scale of a single building.

The following strategies were taken into consideration from the start of designing process. Vegetation increase is provided by freeing up the entire ground surface of the site to a park area, and is further expanded by adding two gardens in the building itself. Urban geometry is represented through creating a gap inbetween two towers. Shading system is generated on the entire surface of the building, except for the gardens, as they need more light; also, an array of shading covers is provided in the ground floor park. As for the water bodies, we can not form any on the very limited plot, but the project follows the large-scale development plan for having free access to the nearby stream.



CH.6 BUILDING SERVICES

INTRODUCTION

The building comprises of two towers, which are connected at three levels: ground floor, 17th floor, 35th floor. Both towers have the same function in general, but structurally they are separate buildings. Consequentally, they are not connected in terms of building services as well. The only point of common mechanical areas is the basement of the buildings.

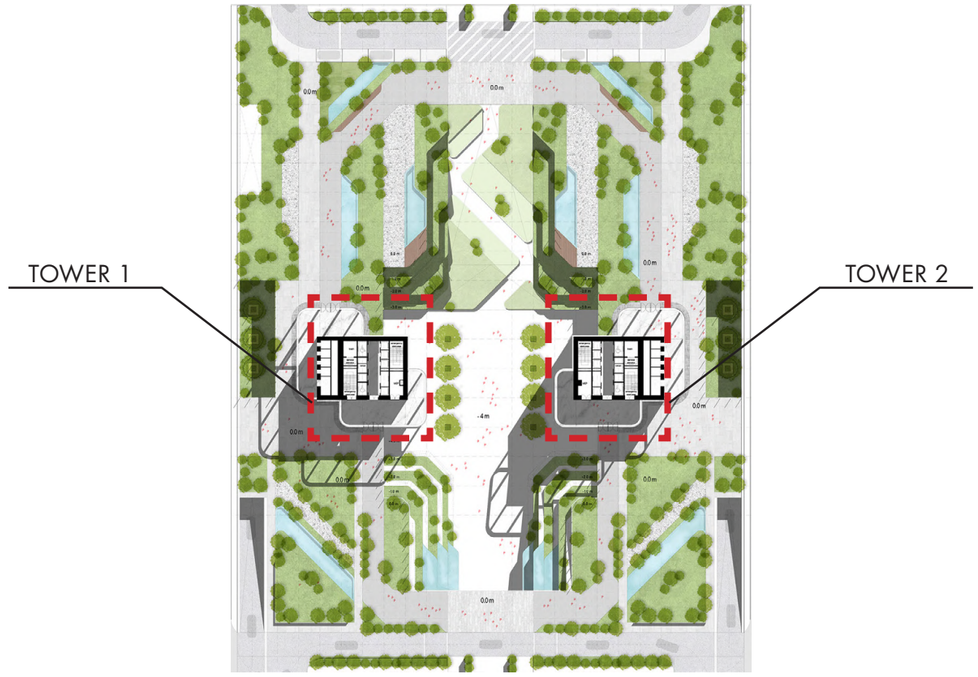


Fig.62. Master plan. Location of towers

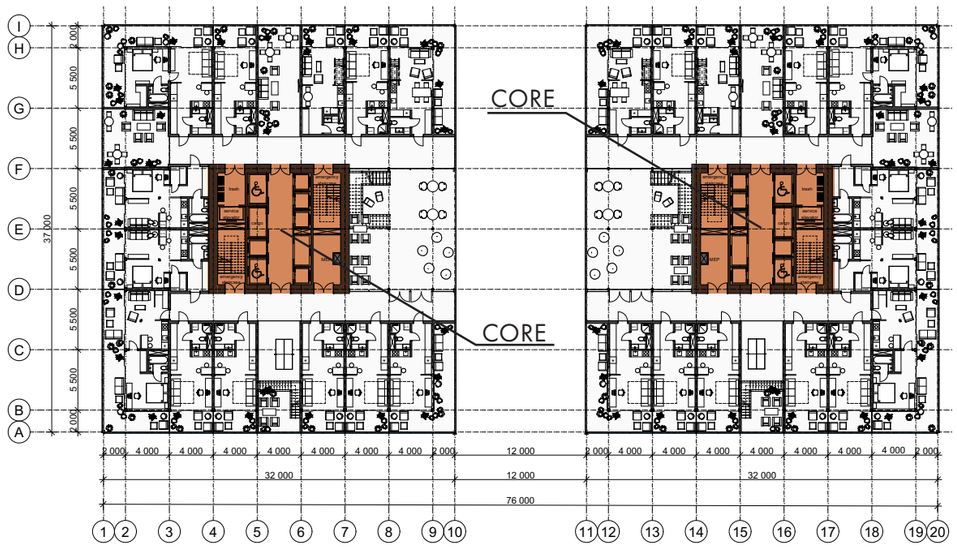


Fig.63. Typical plan of the towers

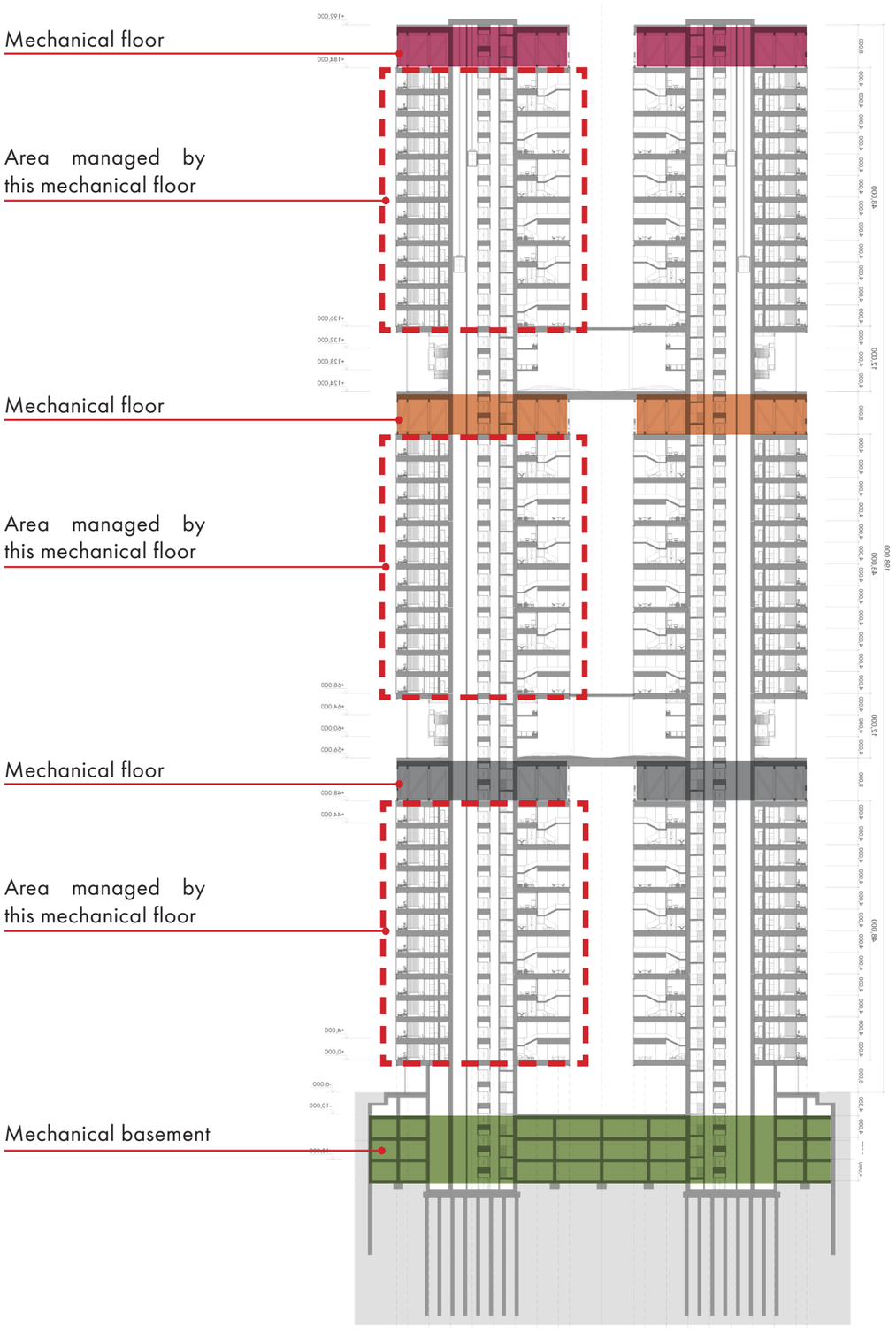
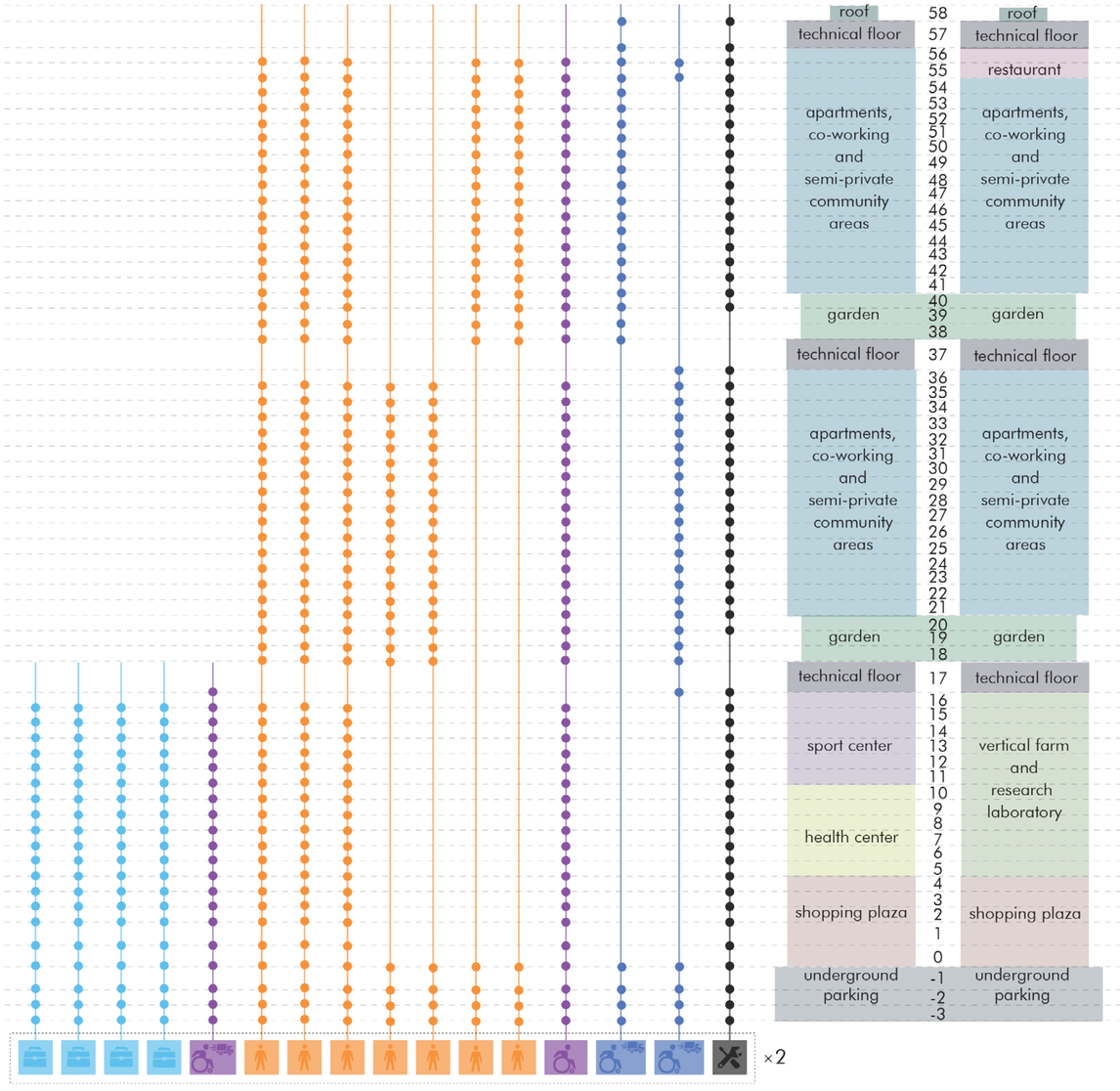


Fig.64. General layout of mechanical areas

ELEVATOR SCHEME

Vertical connections



DISTRIBUTION OF SYSTEMS IN THE TOWER

General layout of the plants

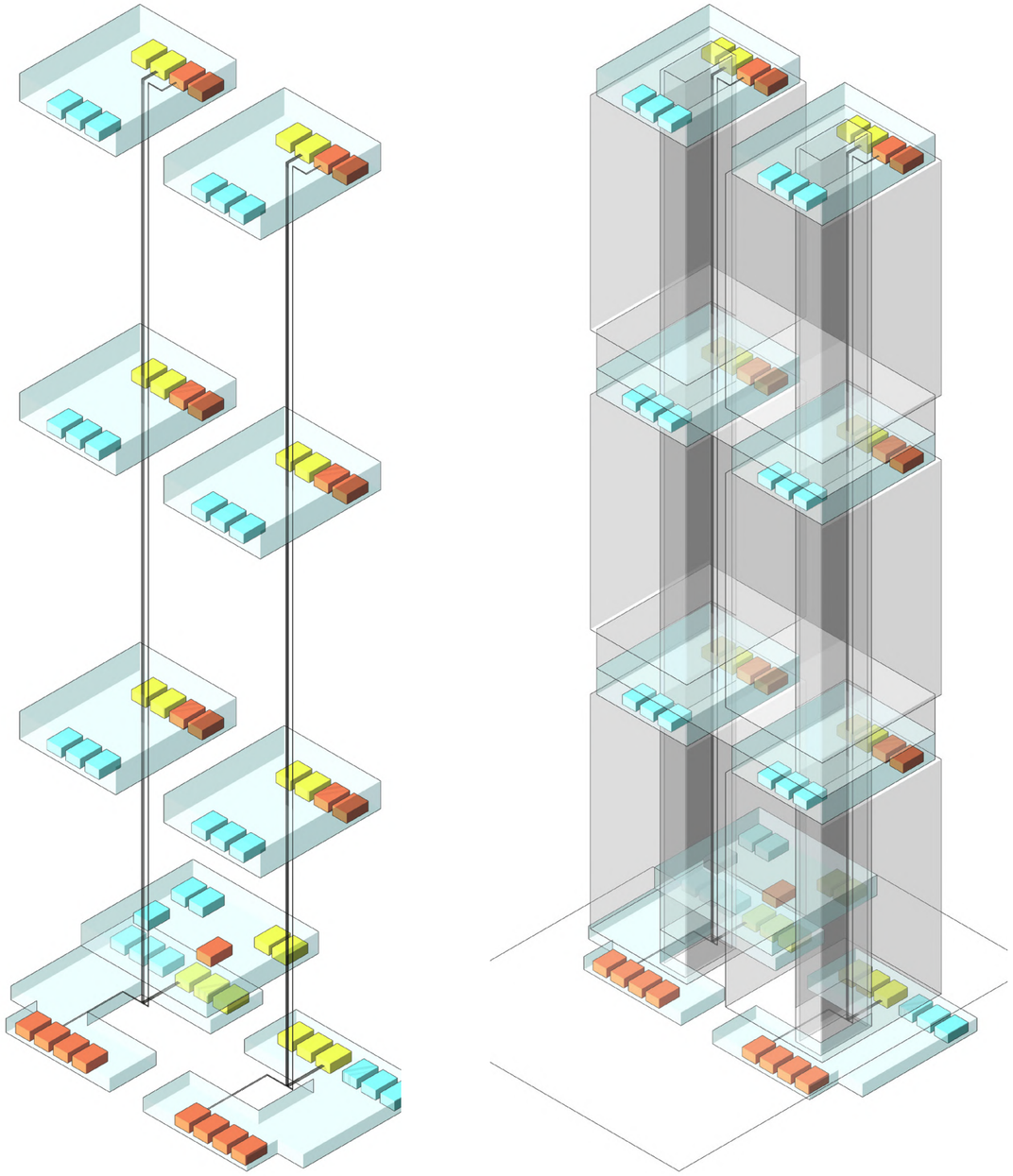


Fig.65. General layout of the plants

SECTION CONSIDERED FOR THE CALCULATIONS

Section of 12 floors managed by one mechanical floor inside a structural truss

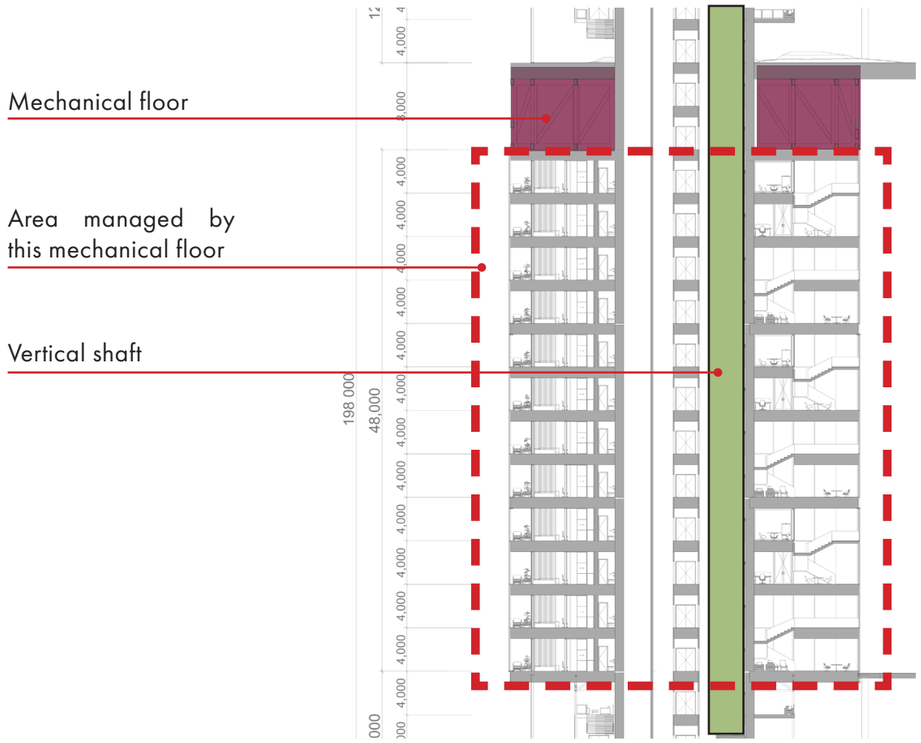


Fig.66. Section chosen for the checks

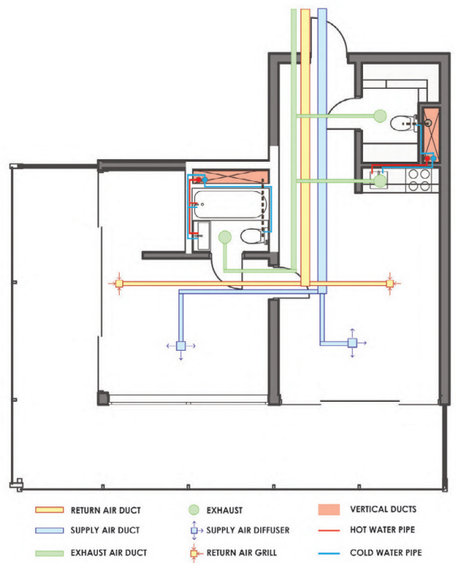


Fig.67. Typical apartment considered for the calculations

BASEMENT PLANS
General layout of the plants

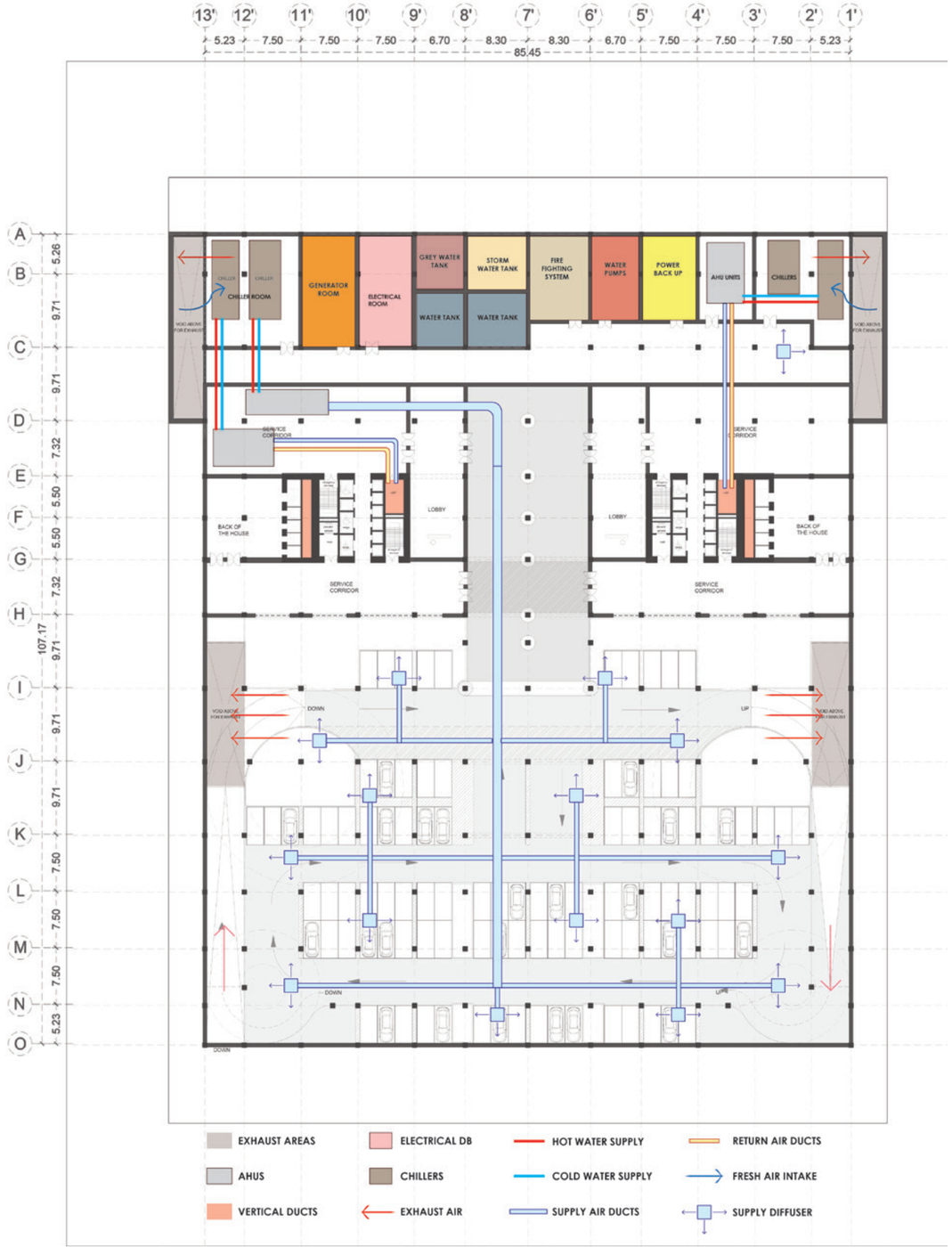


Fig.68. Distribution of HVAC system in the basement 1

Fig.69. Distribution of HVAC system in the basement 2

BASEMENT PLANS
Layout of mechanical floors

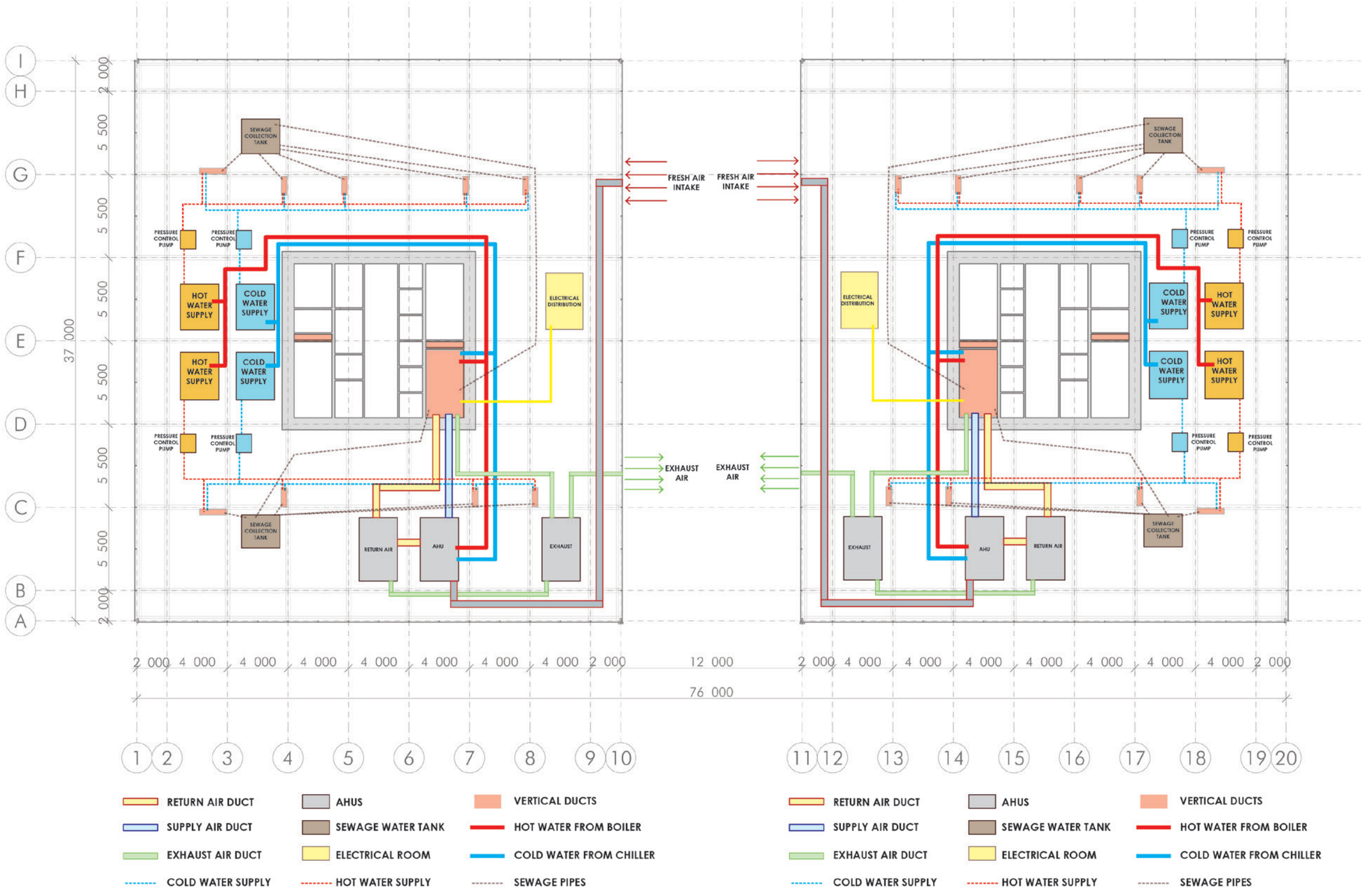


Fig.70. Mechanical floor distribution

Heat Load Calculation

Fig.71. Exterior rendering of the building

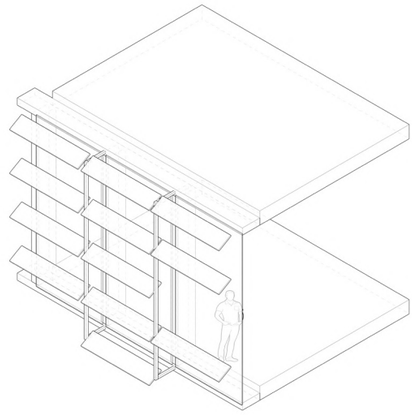


Fig.72. Double glazed glass facade shaded with aluminium fins

General data for the location taken from online sources:

Dati Generali				Note
Località		Milano	-	
Temperatura esterna progetto	T_e	31	°C	*Valore compreso fra 5 e 17 °C
Escursione termica giornaliera*	ΔT_e	6	°C	**Valore compreso fra:
Umidità assoluta esterna massima	X_e	25	g/kg	pareti verticali: 100 e 700 kg/mq
Latitudine		1	°	orizzontale sole: 50 e 400 kg/mq
		17	'	orizzontale ombra: 100 e 300 kg/mq
Temperatura ambiente progetto	T_a	27	°C	***Valore compreso fra 150 e 730 kg/mq
Umidità ambiente progetto	X_a	12.7	g/kg	
Massa in pianta***	M_a	500	kg/mq	**RIEMPIRE CAMPI CON BORDO ARANCIONE**
Portata aria esterna di rinnovo	V	54,939	mc/h	

Ventilation loads:

Ventilation Loads								
Areas description	Area (m²)	Floors	Total Area (m²)	Ns (people/m²)	Total people	Air supply (l/s/person)	Simultaneity (%)	Total (m³/h)
Area of the Apartments	424	16	6784	0.5	3392	5.5	60%	40,297
Area of Circulation	132	16	2112	0.2	422.4	4.8	60%	4,379
Area of co working areas	214	16	3424	0.12	410.88	8	40%	4,733
Bathroom	50	16	800		Extraction		50%	0
Area of Balconies	200	16	3200	0.2	640	4.8	50%	5,530
		0	0	0	0	0	0%	0
Total								54,939

Some of the references used for heat load calculations

Classificazione degli edifici per categorie	n_s
EDIFICI ADIBITI A RESIDENZA E ASSIMILABILI	
- abitazioni civili:	
soggiorni, camere letto	0,04
- collegi, luoghi di ricovero, case di pena, caserme, conventi:	
• soggiorni	0,20
• sale riunioni	0,60
• dormitori	0,10
• camere letto	0,05
- alberghi, pensioni:	
• ingresso, soggiorni	0,20
• sale conferenze (piccole)	0,60
• camere letto	0,05
EDIFICI PER UFFICI E ASSIMILABILI	
• uffici singoli	0,06
• uffici open space	0,12
• locali riunione	0,60
• centri elaborazione dati	0,08
OSPEDALI, CLINICHE, CASE DI CURA E ASSIMILABILI	
• degenze (2-3 letti)	0,08
• corsie	0,12
• camere sterili e infettive	0,08
• visita medica	0,05
• soggiorni, terapie fisiche	0,20
EDIFICI ADIBITI AD ATTIVITÀ RICREATIVE, ASSOCIATIVE, DI CULTO	
- cinematografi, teatri, sale congressi	
• sale in genere	1,50
• biglietterie, ingressi	0,20 (medio)
• borse titoli e simili	0,50
• sale attesa stazioni e metropolitane, ecc.	1,00
(segue prospetto)	

(seguito del prospetto)	
Classificazione degli edifici per categorie	n_s
EDIFICI ADIBITI AD ATTIVITÀ RICREATIVE, ASSOCIATIVE, DI CULTO (segue)	
- musei, biblioteche, luoghi di culto	
• sale in genere	0,30
• luoghi culto	0,80
- bar, ristoranti, sale da ballo	
• bar in genere	0,80
• sale pranzo ristoranti	0,60
• sale da ballo	1,00
ATTIVITÀ COMMERCIALI E ASSIMILABILI	
- grandi magazzini	0,25
- negozi o reparti di grandi magazzini:	
• alimentari, abbigliamento, calzature, mobili, ottici, fioristi, fotografi	0,10
• barbieri, saloni di bellezza, lavasecco, farmacie, zona pubblico banche	0,20
- quartieri fieristici	0,20
EDIFICI ADIBITI AD ATTIVITÀ SPORTIVA	
- piscine, saune e assimilabili	
• piscine (sala vasca)	0,30
• saune	0,50
• ingressi	0,20
- palestre e assimilabili	
• campi gioco	0,20
• zone spettatori	1,50
• bowling	0,60
• ingressi	0,20
EDIFICI ADIBITI AD ATTIVITÀ SCOLASTICHE	
- asili nido e scuole materne	0,40
- aule scuole elementari, medie inferiori e superiori	0,45
- aule universitarie	0,60
- altri locali:	
• aule musica e lingue	0,50
• laboratori	0,30
• sale insegnanti	0,30

Internal loads

Internal Loads						
Areas description	Total people	Qint,S,pp (W)	Total int,S (kW)	Qint,L,pp (W)	Total int,L (kW)	Total int (W)
Apartments	3392	5	17.0	65	220.5	
Circulation	422.4	110	46.5	265	111.9	
Co working	410.88	5	2.1	65	26.7	
Bathrooms	0	5	0.0	80	0.0	
Balconies	640	5	3.2	65	41.6	
Total			68.7		400.7	469.4
Equipment		Qint,S,app neglegible			Qint,L,app neglegible	

Opaque surfaces on different facades

Dati Involucro							
	Superfici Opache					Finestre	
Esposizione	U_p W/(mq K)	$M_{f,p}$** kg/mq	S_p mq	U_F W/(mq K)	f -	F=SC F_{vs} -	S_F mq
NORD	1.03	500	436.7	1.5	0.9	0.6	528.5
EST	1.03	500	614.2	1.5	0.9	0.6	708.5
OVEST	1.03	500	614.2	1.5	0.9	0.6	196.528
SUD	1.03	500	436.7	1.5	0.9	0.6	512
ORIZZONTALE OMBRA	0.25	500	19644				
ORIZZONTALE SOLE	2.2	500	4499				

Opaque and transparent surfaces on different facades

Opaque/translucent façade		
Façade	**Areas (m^2)**	**U value (W/m^2k)**
North	436.65	1.03
South	436.65	1.03
East	614.15	1.03
West	614.15	1.03

Transparent area		
Façade	**Areas (m^2)**	**U value (W/m^2k)**
North	1764.35	0.5
South	1764.35	0.5
East	1941.85	0.5
West	1941.85	0.5

Roof	**Area (m^2)**	**U value (W/m^2k)**
Opaque + translucent	3285.6	0.95

Total Sensible load	630333	
Total Latent load	390148	
Summer heat load	1020481	W
	1020.481263	KW

Adding variantion in the loads

Carichi Interni			
Carico interno sensibile costante	$Q_{int,s,cost}$	68678.4	W
Carico interno latente costante	$Q_{int,l,cost}$	400723.2	W

Carichi interni totali	Ora H h	Costante $Q_{int,s,cost}$ W	Variabile $Q_{int,s,var}$ W	Costante $Q_{int,l,cost}$ W	Variabile $Q_{int,l,var}$ W
	8	68678.4	69000	400723.2	390000
	9	68678.4	69000	400723.2	390000
	10	68678.4	40000	400723.2	300000
	11	68678.4	40000	400723.2	300000
	12	68678.4	30000	400723.2	250000
	13	68678.4	30000	400723.2	250000
	14	68678.4	30000	400723.2	250000
	15	68678.4	30000	400723.2	250000
	16	68678.4	30000	400723.2	250000
	17	68678.4	50000	400723.2	300000
	18	68678.4	69000	400723.2	390000
	19	68678.4	69000	400723.2	390000
	20	68678.4	69000	400723.2	390000
	21	68678.4	69000	400723.2	390000
	22	68678.4	69000	400723.2	390000
	23	68678.4	50000	400723.2	300000
	24	68678.4	50000	400723.2	300000

Sensible load

CARICO SENSIBILE (POTENZA IN W)

Ora del giorno			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
NORD	Pareti	Trasmissione	3,598.0	4,047.7	4,497.5	4,947.2	5,397.0	5,846.7	6,296.5	6,746.2	7,196.0	7,645.7	8,095.5	8,545.2	8,995.0	9,444.7	9,894.5	10,344.2	10,794.0
	Finestre	Trasmissione	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0	3,171.0
	Finestre	Irraggiamento	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EST	Pareti	Trasmissione	5,060.6	5,693.2	6,325.7	6,958.3	7,590.9	8,223.5	8,856.0	9,488.6	10,121.2	10,753.8	11,386.3	12,018.9	12,651.5	13,284.1	13,916.6	14,549.2	15,181.8
	Finestre	Trasmissione	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0	4,251.0
	Finestre	Irraggiamento	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVEST	Pareti	Trasmissione	5,060.6	5,693.2	6,325.7	6,958.3	7,590.9	8,223.5	8,856.0	9,488.6	10,121.2	10,753.8	11,386.3	12,018.9	12,651.5	13,284.1	13,916.6	14,549.2	15,181.8
	Finestre	Trasmissione	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2	1,179.2
	Finestre	Irraggiamento	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUD	Pareti	Trasmissione	3,598.0	4,047.7	4,497.5	4,947.2	5,397.0	5,846.7	6,296.5	6,746.2	7,196.0	7,645.7	8,095.5	8,545.2	8,995.0	9,444.7	9,894.5	10,344.2	10,794.0
	Finestre	Trasmissione	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0	3,072.0
	Finestre	Irraggiamento	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OR. OMBR	Pareti	Trasmissione	39,288.0	44,199.0	49,110.0	54,021.0	58,932.0	63,843.0	68,754.0	73,665.0	78,576.0	83,487.0	88,398.0	93,309.0	98,220.0	103,131.0	108,042.0	112,953.0	117,864.0
OR. SOLE	Pareti	Trasmissione	79,182.4	89,080.2	98,978.0	108,875.8	118,773.6	128,671.4	138,569.2	148,467.0	158,364.8	168,262.6	178,160.4	188,058.2	197,956.0	207,853.8	217,751.6	227,649.4	237,547.2
INFILTRAZIONI			73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7	73,618.7
CARICHI INTERNI	Costanti	Qint,s,cost W			68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4	68,678.4
	Variabili	Qint,s,var W			69,000.0	69,000.0	40,000.0	40,000.0	30,000.0	30,000.0	30,000.0	30,000.0	30,000.0	50,000.0	69,000.0	69,000.0	69,000.0	69,000.0	69,000.0
Totale			221,079	238,053	392,705	409,678	397,652	414,625	421,599	438,572	455,545	472,519	489,492	526,466	562,439	579,413	596,386	613,360	630,333
MASSIMO CARICO SENSIBILE			630333																

Sensible load = **63,0333 W**

Latent load

CARICO LATENTE (POTENZA IN W)

Ora del giorno			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
INFILTRAZIONI			148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2	148.2
CARICHI INTERNI	Costanti		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Variabili		390000.0	390000.0	300000.0	300000.0	250000.0	250000.0	250000.0	250000.0	250000.0	300000.0	0.0	390000.0	390000.0	390000.0	390000.0	300000.0	300000.0
Totale			390148.2	390148.2	300148.2	300148.2	250148.2	250148.2	250148.2	250148.2	250148.2	300148.2	148.2	390148.2	390148.2	390148.2	390148.2	300148.2	300148.2
MASSIMO CARICO LATENTE			390148																

Latent load = **390148 W**

Calculation of duct size for 12 floors in one block of tower

Qsensible (W)	m air (kg/s)	Airflow rate (m^3/s)	c p,air	T air,amb,sp	T air,in	Air speed (m/s)	Cross section (m^2)
630,333	18	15.3	1000	27	61.4	6	2.54

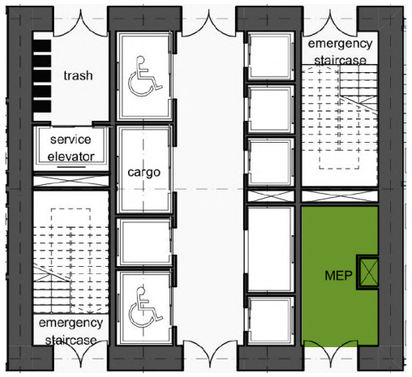
Dividing the cross section required by the number of AHUs to get the required cross section for each duct	0.635872

Qlatent(W) ?
390,148

Qtotal(W)
1,020,481

Cross section of Duct comes out to be **2.54 m^2.**

Number of AHU units for these 12 floors considered is 4, so the duct size comes out to be 2.54/4 = **0.65 m^2.**



The duct given for one tower is **11.63 m2**.

Water Supply Pipe Calculation

Calculation for hot and cold water supply

Cold Water					
	Units	**Loading Units**	**Max. LU**	**Pipe Sizes**	
Bath Room Sink	1	1	1	16 X 2	
WC	1	4	4	16 X 2.5	**26 X 3**
Shower/Bath Tub	1	2	2	16 X 2	
Hand held Shower spray	1	1	1	16 X 2	
Kitchen Sink	1	2	2	16 X 2	
Washing machine	1	2	2	16 X 2	
Total Units	6	12	12	26 X 3	

Hot Water					
	Units	**Loading Units**	**Max. LU**	**Pipe Sizes**	
Bath Room Sink	1	1	1	16 X 2	**18 X 2**
Shower/Bath Tub	1	2	2	16 X 2	
Hand held Shower spray	1	1	1	16 X 2	
Kitchen Sink	1	2	2	16 X 2	
Total Units	4	6	6	18 X 2	

Reference for Water Supply System

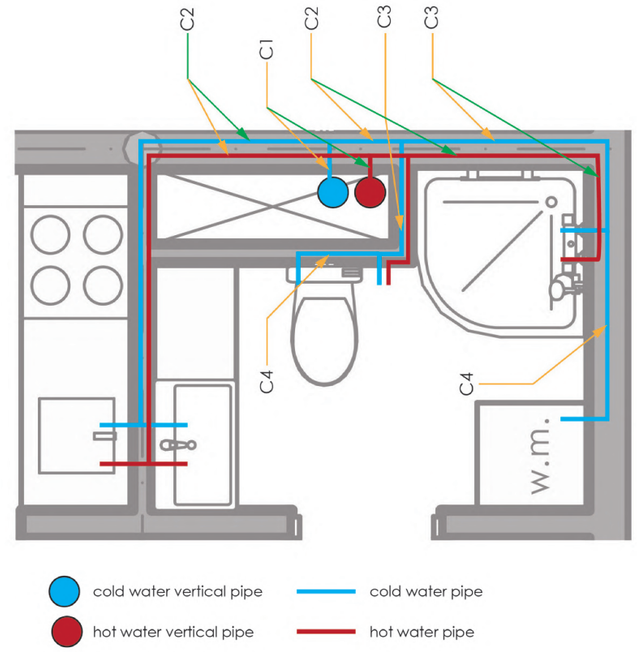
Table 1 —Draw-off flow-rates Q_A , minimum flow-rates at draw-off points Q_{min} and loading units for draw-off points, from EN UNI 806-3.

Draw-off point	Q_A	Q_{min}	Loading units
	l/s	l/s	
Washbasin, handbasin, bidet, WC-cistern	0,1	0,1	1
Domestic kitchen sink, - washing machine [a], dish washing machine, sink, shower head	0,2	0,15	2
Urinal flush valve	0,3	0,15	3
Bath domestic	0,4	0,3	4
Taps /garden/garage)	0,5	0,4	5
Non domestic kitchen sink DN 20, bath non domestic	0,8	0,8	8
Flush valve DN 20	1,5	1,0	15
[a] For non domestic appliances check with manufacturer.			

Table 2— Loading units for determination of pipe diameters from EN UNI 806-3.

Table 3.8 — PEX/AL/PE-HD resp. PE-MD/AL/PE-HD											
Max. load	**LU**	**3**	**4**	**5**	**6**	**10**	**20**	**55**	**180**	**540**	**1 300**
Highest value	LU			4	5	5	8				
d_a x s	mm	**16** x 2,25/**16** x 2,0			**18** x 2	**20** x 2,5	**26** x 3	**32** x 3	**40** x 3,5	**50** x 4	**63** x 4,5
d_i	mm	11,5/12,0			14	15	20	26	33	42	54
Max length of pipe	m	9	5	4							

One Apartment Water supply layout



Cold water supply calculation

C1	Units	Loading Units	Max. LU
Bath Room Sink	1	1	1
WC	1	4	4
Shower/Bath Tub	1	2	2
Hand held Shower spray	1	1	1
Kitchen Sink	1	2	2
Washing machine	1	2	2
Total Units	6	12	12
Pipe Size			26 X 3

C2 Right	Units	Loading Units	Max. LU
Bath Room Sink	1	1	1
Total Units	1	1	1
Pipe Size			16 X2.25

C2 Left	Units	Loading Units	Max. LU
WC	1	1	1
Shower/Bath Tub	1	2	2
Hand held Shower spray	1	1	1
Washing machine	1	2	2
Total Units	4	6	6
Pipe Size			18 X2

C3 Right	Units	Loading Units	Max. LU
WC	1	1	1
Hand held Shower spray	1	1	1
Total Units	2	2	2
Pipe Size			16 X2

C3 Left	Units	Loading Units	Max. LU
Shower/Bath Tub	1	2	2
Washing machine	1	2	2
Total Units	2	4	4
Pipe Size			16 X2

C4 Right	Units	Loading Units	Max. LU
WC	1	1	1
Total Units	1	1	1
Pipe Size			16 X2

C4 Left	Units	Loading Units	Max. LU
Washing machine	1	2	2
Total Units	1	2	2
Pipe Size			16 X2

Hot water supply calculation

Hot water C1	Units	Loading Units	Max. LU
Bath Room Sink	1	1	1
Shower/Bath Tub	1	2	2
Hand held Shower spray	1	1	1
Kitchen Sink	1	2	2
Total Units	4	6	6
Pipe Size			18 X2

Hot water C2 Right	Units	Loading Units	Max. LU
Bath Room Sink	1	1	1
Kitchen Sink	1	2	2
Total Units	2	3	3
Pipe Size			16 X2

Hot water C2 Left	Units	Loading Units	Max. LU
Shower/Bath Tub	1	2	2
Hand held Shower spray	1	1	1
Total Units	2	3	3
Pipe Size			16 X2

DRAINAGE SYSTEM

Calculation for grey and black drainage

Discharge Branches - General Calculations

Grey Water - Drainage					
	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
Pantry Sink	3	0.5	1.5	0.5	0.61
Washbasin	10	0.3	3	0.5	0.87
Total Units	13	0.8	4.5	0.5	1.06
DN					**60**

Black Water - Drainage					
	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
WC	14	2	28	0.5	2.65
Total Units	14	2	28	0.5	2.65
DN					**100**

Reference for Drainage

Table 3: Discharge units (DU) from EN UNI 12056-2.

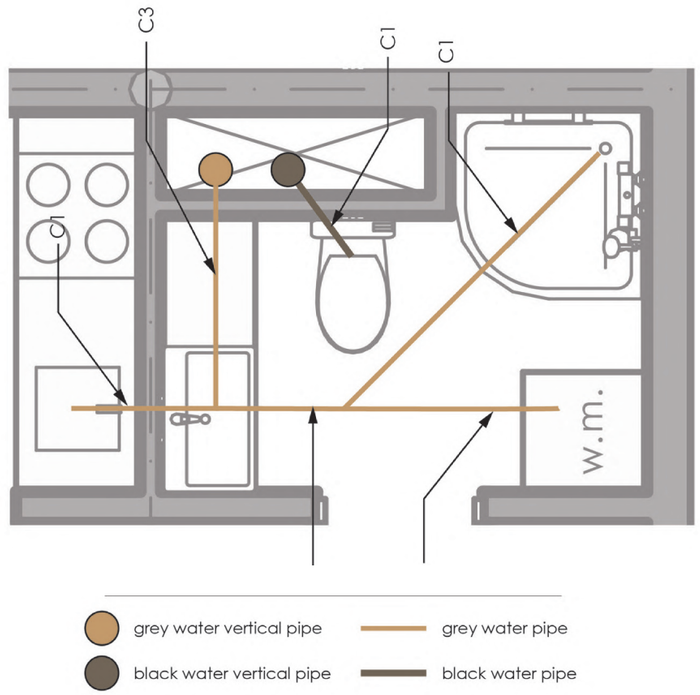
Appliance	System I	System II	System III	System IV
	DU l/s	DU l/s	DU l/s	DU l/s
Wash Basin, Bidet	0,5	0,3	0,3	0,3
Shower without Plug	0,6	0,4	0,4	0,4
Shower with Plug	0,8	0,5	1,3	0,5
Single Urinal with Cistern	0,8	0,5	0,4	0,5
Urinal with Flushing Valve	0,5	0,3	-	0,3
Slab Urinal	0,2*	0,2*	0,2*	0,2*
Bath	0,8	0,6	1,3	0,5
Kitchen Sink	0,8	0,6	1,3	0,5
Dishwasher (Household)	0,8	0,6	0,2	0,5
Washing Machine up to 6 kg	0,8	0,6	0,6	0,5
Washing Machine up to 12 kg	1,5	1,2	1,2	1,0
WC with 4,0 l Cistern	**	1,8	**	**
WC with 6,0 l Cistern	2,0	1,8	1,2 to 1,7***	2,0
WC with 7,5 l Cistern	2,0	1,8	1,4 to 1,8***	2,0
WC with 9,0 l Cistern	2,5	2,0	1,6 to 2,0***	2,5
Floor Gully DN 50	0,8	0,9	-	0,6
Floor Gully DN 70	1,5	0,9	-	1,0
Floor Gully DN 100	2,0	1,2	-	1,3

* per person
** not permitted
*** depending upon type (valid for WC's with siphon flush cistern only)
\- not used or no data

Table 4: Typical frequency factor (K) from EN UNI 12056-2.

Usage of appliances	K
intermittent use e.g. in Dwelling, Guesthouse, Office	0,5
frequent use e.g. in Hospital, School, Restaurant, Hotel	0,7
congested use e.g. in Toilets and/or Showers open to Public	1,0
special use e.g. Laboratory	1,2

One Apartment drain pipes layout



Grey and black water drain calculation

Grey Water - Drainage					
	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
Bath Room Sink	1	0.3	0.3	0.5	0.27
Shower/Bath Tub	1	0.5	0.5	0.5	0.35
Kitchen Sink	1	0.5	0.5	0.5	0.35
Washing machine	1	0.5	0.5	0.5	0.35
Total Units	4	1.8	1.8	0.5	0.67
DN					**DN 50**

Black Water - Drainage					
	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
WC	1	2	2	0.5	0.71
Hand held Shower spray	1	0.3	0.3	0.5	0.27
Total Units	2	2.3	2.3	0.5	0.76
DN					**DN 50**

Grey and black water drain calculation

Grey Water C1 Right	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
Washing machine	1	0.5	0.5	0.5	0.35
Total Units	1	0.5	0.5	0.5	0.35
DN					DN 30

Grey Water C1 Leftt	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
Kitchen Sink	1	0.5	0.5	0.5	0.35
Total Units	1	0.5	0.5	0.5	0.35
DN					DN 30

Grey Water C2	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
Washing machine	1	0.5	0.5	0.5	0.35
Shower/Bath Tub	1	0.5	0.5	0.5	0.35
Total Units	2	1	1	0.5	0.50
DN					DN 40

Grey Water C2	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
Washing machine	1	0.3	0.3	0.5	0.27
Shower/Bath Tub	1	0.5	0.5	0.5	0.35
Kitchen Sink	1	0.5	0.5	0.5	0.35
Bath Room Sink	1	0.3	0.3	0.5	0.27
Total Units	4	1.6	1.6	0.5	0.63
DN					DN 50

B1	Units	Discharge Units	Max. DU	Frequency factor (K)	Qmax
WC	1	2	2	0.5	0.71
Hand held Shower spray	1	0.3	0.3	0.5	0.27
Total Units	2	2.3	2.3	0.5	0.76
DN					DN 50

Pipe size for vertical stacking

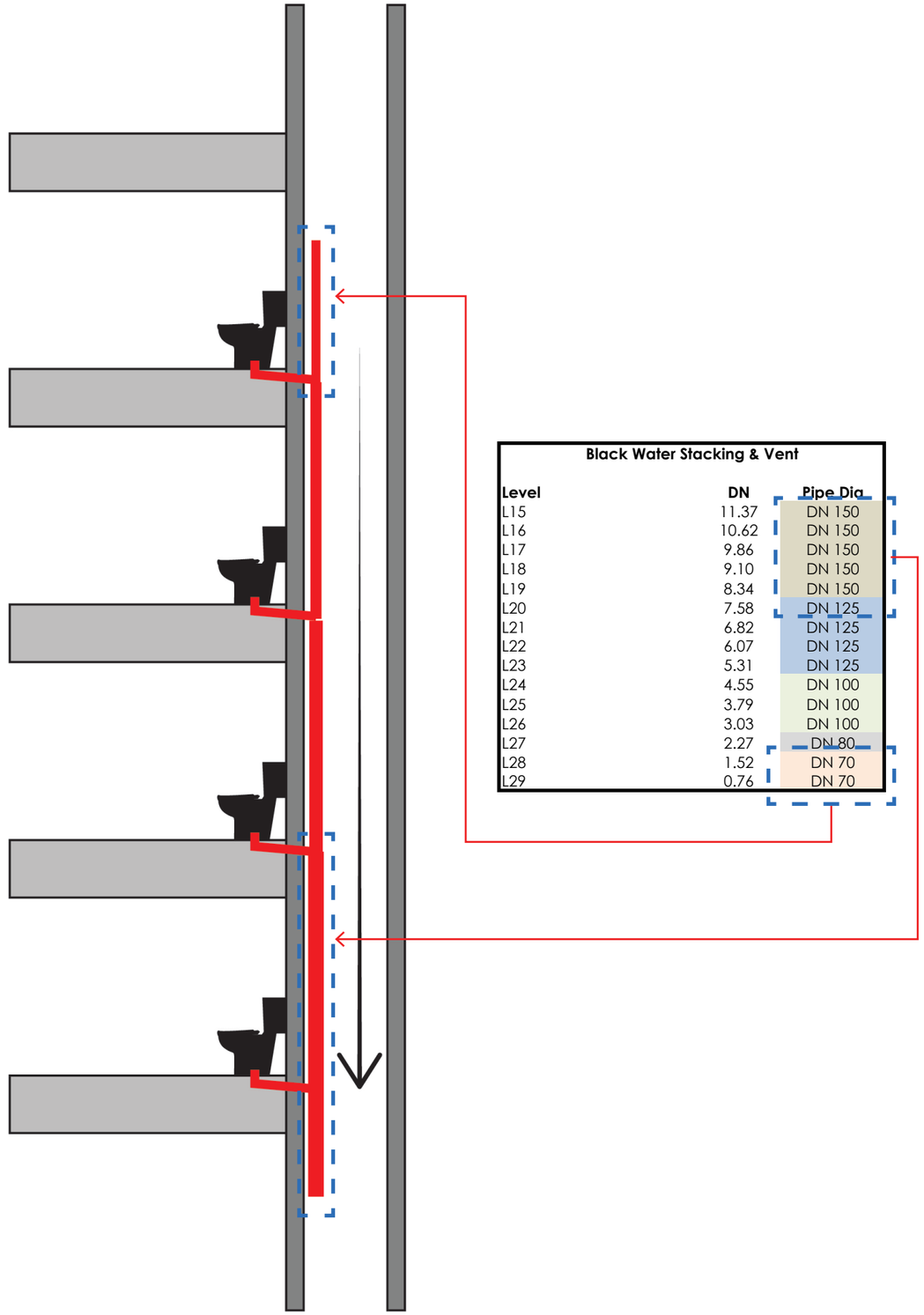
Gray Water Stacking & Vent

Level	DN	Pipe Dia
L15	10.06	DN 150
L16	9.39	DN 150
L17	8.72	DN 150
L18	8.05	DN 150
L19	7.38	DN 125
L20	6.71	DN 125
L21	6.04	DN 125
L22	5.37	DN 125
L23	4.70	DN 100
L24	4.02	DN 100
L25	3.35	DN 80
L26	2.68	DN 80
L27	2.01	DN 80
L28	1.34	DN 60
L29	0.67	DN 60

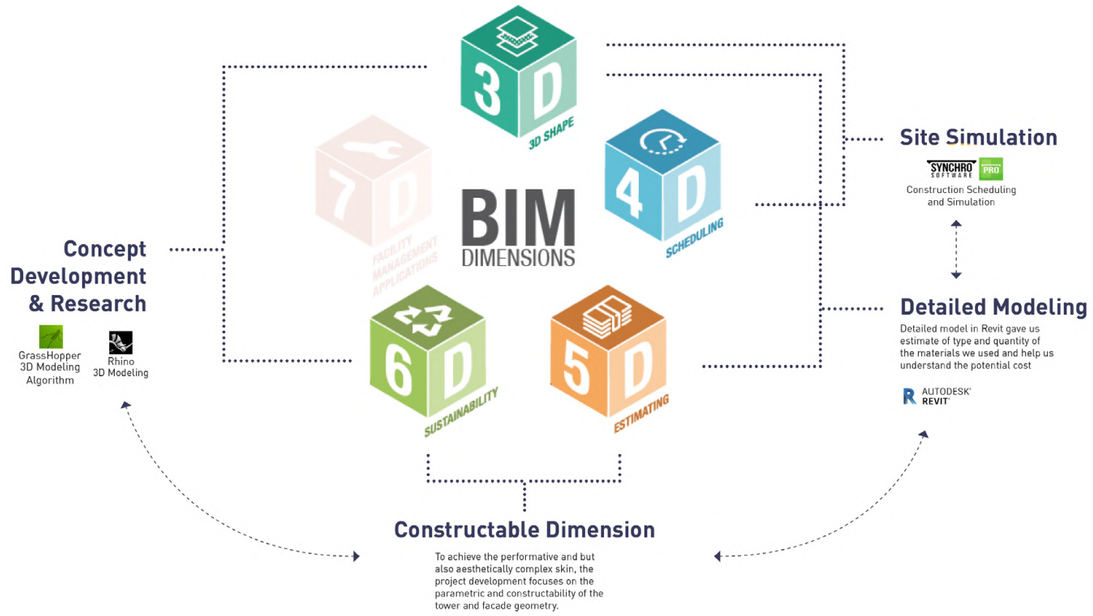
Black Water Stacking & Vent

Level	DN	Pipe Dia
L15	11.37	DN 150
L16	10.62	DN 150
L17	9.86	DN 150
L18	9.10	DN 150
L19	8.34	DN 150
L20	7.58	DN 125
L21	6.82	DN 125
L22	6.07	DN 125
L23	5.31	DN 125
L24	4.55	DN 100
L25	3.79	DN 100
L26	3.03	DN 100
L27	2.27	DN 80
L28	1.52	DN 70
L29	0.76	DN 70

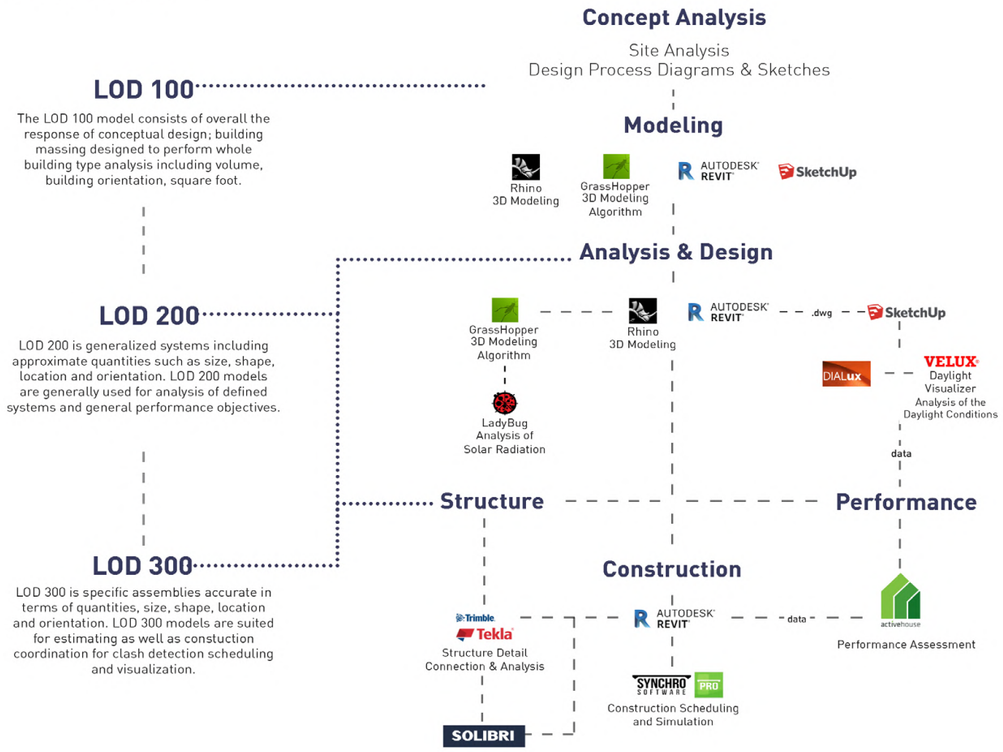
Increasing drain pipe in elevation



BIM 6D CONCEPT



BIM & LOD WORKFLOW



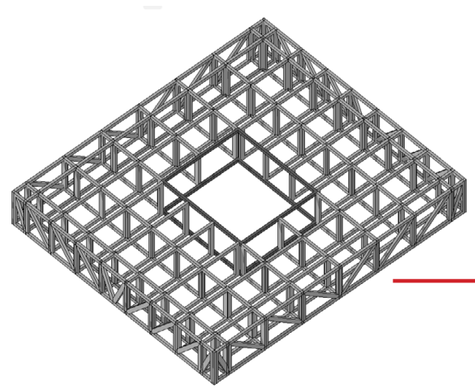
MIDAS GEN

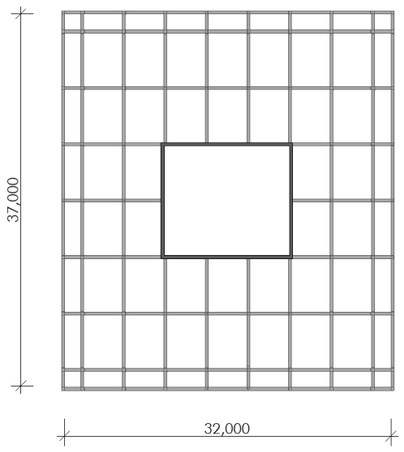
Main structural truss design & check

MidasGEN is a BIM tool used in this work to verify properties and sections of one of the more complicated parts of the building - the spatial steel truss, designed to hold 12 floors below it via an array of "suspended pillars". It also contains the technical floor within itself, and on top of it it bears the loads of the gar den floor.

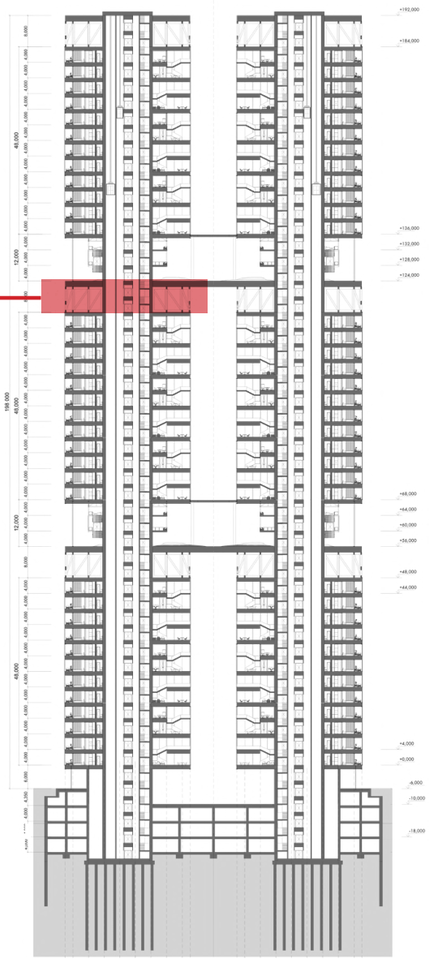
The building in total contains 6 of trusses like this, with the top 4 holding residential floors and the bottom 2 - mixed residential and commercial areas. The chosen truss is highlighted in red in the diagram seen below.

We start the check by defining all of the loads to the truss in the table. Appropriate Eurocodes were applied in calculating live loads; dead loads were calculated according to our previous floor and wall layer combinations. As most of the vertical element in the building are elements in tension, as opposed to the standard columns in compression in most buildings, we need to pay more attention to the deformations on these elements. As such, we define 10 different area types within a typical floor, and separate the columns into 9 types by their applied load. This information will be used in the future calculation of the elongation of individual columns, making sure the entire system stays in balance and no pillar is deformed more significatly than others.





Initial truss estimation



LOAD APPLICATION

Static Load Cases

	Name	Type	Description
▶	DL self weigh	Dead Load (D)	Self weight of the truss
	DL1	Dead Load (D)	Weight of the floors , border roof
	LL1	Live Load (L)	Maintenance of the border roof
	DL2	Dead Load (D)	Weight of the floors + soil, Garden
	LL2	Live Load (L)	People , Garden floor
	DL3	Dead Load (D)	Weight of the bridge (half of it)
	LL3	Live Load (L)	People of the bridge
	Fac1	Dead Load (D)	Facade of the garden
	DLTA	Dead Load (D)	Weight of the floors inside the trus
	LLTA1	Live Load (L)	Maintenance inside the truss
	LLTA2	Live Load (L)	Machinery inside the truss
	Fac2	Dead Load (D)	Facade of the tower
	DLS1	Dead Load (D)	Dead load suspended type 1
	DLS2	Dead Load (D)	Dead load suspended type 2
	DLS3	Dead Load (D)	Dead load suspended type 3
	DLS4	Dead Load (D)	Dead load suspended type 4
	DLS5	Dead Load (D)	Dead load suspended type 5
	DLS6	Dead Load (D)	Dead load suspended type 6
	DLS7	Dead Load (D)	Dead load suspended type 7
	DLS8	Dead Load (D)	Dead load suspended type 8
	DLS9	Dead Load (D)	Dead load suspended type 9
	LLS1	Live Load (L)	Live load suspended type 1
	LLS2	Live Load (L)	Live load suspended type 2
	LLS3	Live Load (L)	Live load suspended type 3
	LLS4	Live Load (L)	Live load suspended type 4
	LLS5	Live Load (L)	Live load suspended type 5
	LLS6	Live Load (L)	Live load suspended type 6
	LLS7	Live Load (L)	Live load suspended type 7
	LLS8	Live Load (L)	Live load suspended type 8
	LLS9	Live Load (L)	Live load suspended type 9
*			

Close

The loads collected in the main table in Chapter 4 were subsequently applied to the model in MidasGEN. From them we define the following load combinations, such as: "ALL", which contains all live loads and dead loads combined, and is the largest possible load to the structure.

The combinations are shown in the list below.

Steel grade chosen is S355, and the initial estimated section is taken as rectangular hollow section, hot rolled, dimensions 400x400mm, wall thickness 10 mm.

The list of loads defined in the software

Load Combinations

General | Steel Design | Concrete Design | SRC Design | Cold Formed Steel Design | Footing Design | Aluminum Design

Load Combination List

	No	Name	Active	Type	Description
	1	DL	Strengt	Add	DL+DL1+DL2+DL3+Fac
	2	Top	Strengt	Add	DL+(DL1+LL1)+(DL2+LL
	3	Inside	Strengt	Add	DL+(DLTA+LLTA1+LLT
	4	Suspend	Strengt	Add	DL+LLS+DLS
	5	LL	Strengt	Add	LL1+LL2+LL3+LLTA1+L
▶	6	All	Strengt	Add	DL+LL
	7	S1	Strengt	Add	DLS1+LLS1
	8	S2	Strengt	Add	DLS2+LLS2
	9	S3	Strengt	Add	DLS3+LLS3
	10	S4	Strengt	Add	DLS4+LLS4
	11	S5	Strengt	Add	DLS5+LLS5
	12	S6	Strengt	Add	DLS6+LLS6
	13	S7	Strengt	Add	DLS7+LLS7
	14	S8	Strengt	Add	DLS8+LLS8
	15	S9	Strengt	Add	DLS9+LLS9
*					

Load Cases and Factors

	LoadCase	Factor
▶	DL(CBS)	1.0000
	LL(CBS)	1.0000
*		

Copy | Import... | Auto Generation... | Spread Sheet Form

File Name: D:\MY STUDY\2021\ARCHITECTURAL DESIGN STUDIO F(| Browse | Make Load Combination Sheet | Close

Fig.LLL Load combinations defined in the software

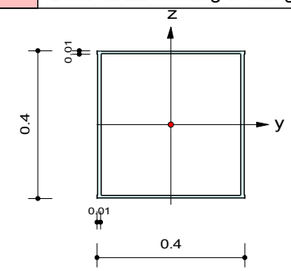
midas Gen

Steel Checking Result

MIDAS	Company		Project Title	
	Author	perkova.kristina@mail.ru	File Name	D:\... 02 22 working working 1.mgb

1. Design Information

Design Code Eurocode3:05 & SGP
Unit System kN, m
Member No 348
Material S355 (No:1)
(Fy = 355000, Es = 210000000)
Section Name RHS-HF 400X400X10 UNI780 (No:1)
(Rolled : RHS-HF 400X400X10 UNI780).
Member Length : 4.00000



2. Member Forces

Axial Force Fxx = 5092.66 (LCB: 1, POS:3/4)
Bending Moments My = -615.24, Mz = -8.7689
End Moments Myi = 531.338, Myj = -1121.5 (for Lb)
Myi = 531.338, Myj = -1121.5 (for Ly)
Mzi = -11.074, Mzj = -8.0004 (for Lz)
Shear Forces Fyy = -2.7636 (LCB: 2, POS:1/2)
Fzz = 900.133 (LCB: 6, POS:J)

Depth	0.40000	Web Thick	0.01000
Flg Width	0.40000	Top F Thick	0.01000
Web Center	0.39000	Bot.F Thick	0.01000
Area	0.01540	Asz	0.00800
Qyb	0.05705	Qzb	0.05705
Iyy	0.00039	Izz	0.00039
Ybar	0.20000	Zbar	0.20000
Wely	0.00195	Welz	0.00195
ry	0.15900	rz	0.15900

3. Design Parameters

Unbraced Lengths Ly = 4.00000, Lz = 4.00000, Lb = 4.00000
Effective Length Factors Ky = 1.00, Kz = 1.00
Equivalent Uniform Moment Factors Cmy = 1.00, Cmz = 1.00, CmLT = 1.00

4. Checking Result

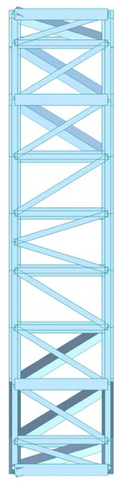
Slenderness Ratio
KL/r = 53.6 < 200.0 (Memb:58, LCB: 14)..... O.K
Axial Resistance
N_Ed/Nt_Rd = 5092.66/5467.00 = 0.932 < 1.000 ..... O.K
Bending Resistance
M_Edy/M_Rdy = 615.239/810.110 = 0.759 < 1.000 ..... O.K
M_Edz/M_Rdz = 8.769/810.110 = 0.011 < 1.000 ..... O.K
Combined Resistance
R.MNRd = MAX[M_Edy/Mny_Rd, M_Edz/Mnz_Rd]
R.BiM = (M_Edy/Mny_Rd)^Alpha + (M_Edz/Mnz_Rd)^Beta
R.byN = N_Ed/(A*fy/Gamma_M0), R.byM = M_Edy/My_Rd + M_Edz/Mz_Rd
Rmax = MAX[R.MNRd, R.BiM, (R.byN+R.byM)] = 358032.203 > 1.000 ..... N.G !
Torsion Strength
T_Ed/T_Rd = 69.699/593.429 = 0.117 < 1.000 ..... O.K
Shear Resistance
V_Edy/Vy_Rd = 0.002 < 1.000 ..... O.K
V_Edz/Vz_Rd = 0.646 < 1.000 ..... O.K

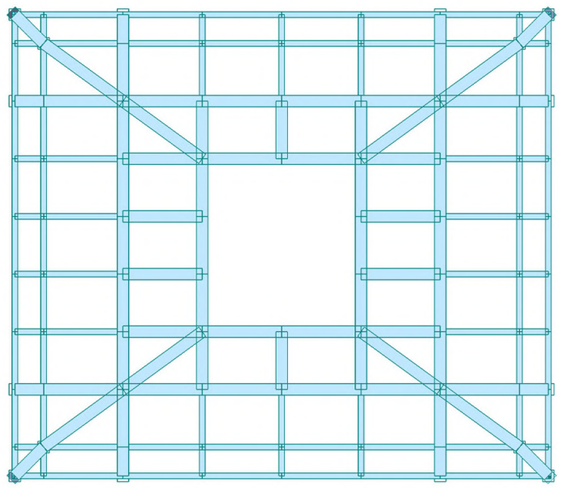
The first attempt of checking the element resistance is **unsuccessful.** Rmax is not satisfying the limit. It follows that the section parameters need to be adjusted.

MODEL ADJUSTMENT

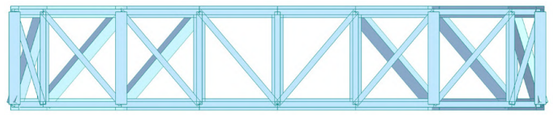
In the following attempt we need not only to adjust the section, but to also rethink the truss logic in itself. We add diagonal bracing to elements that are connecting to the core, and add new bracings that connect the corners of the truss to the core and go beyond the original grid.

Updated side view



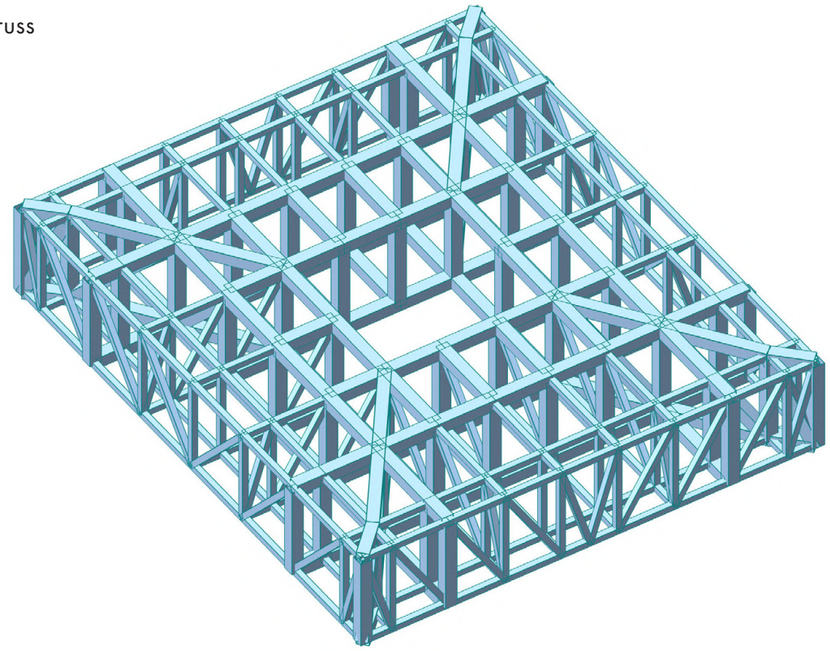


Updated top view



Updated side view

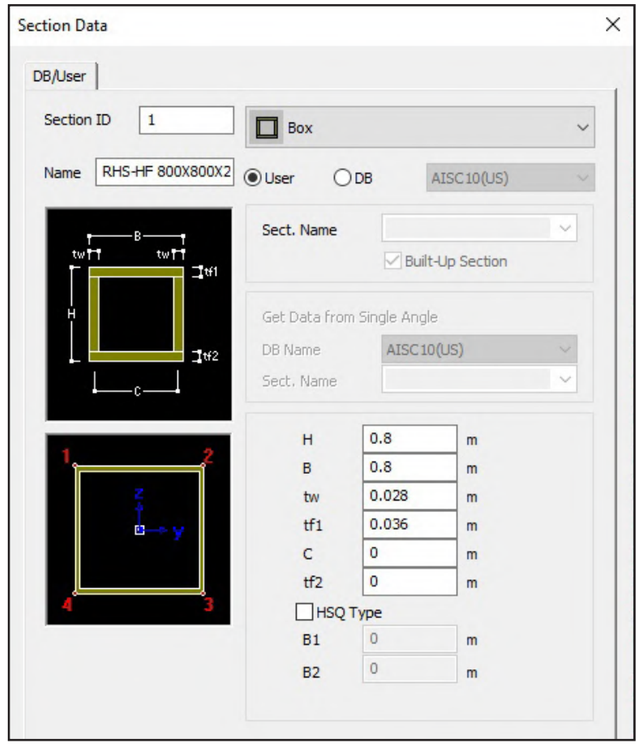
Updated structure of the truss



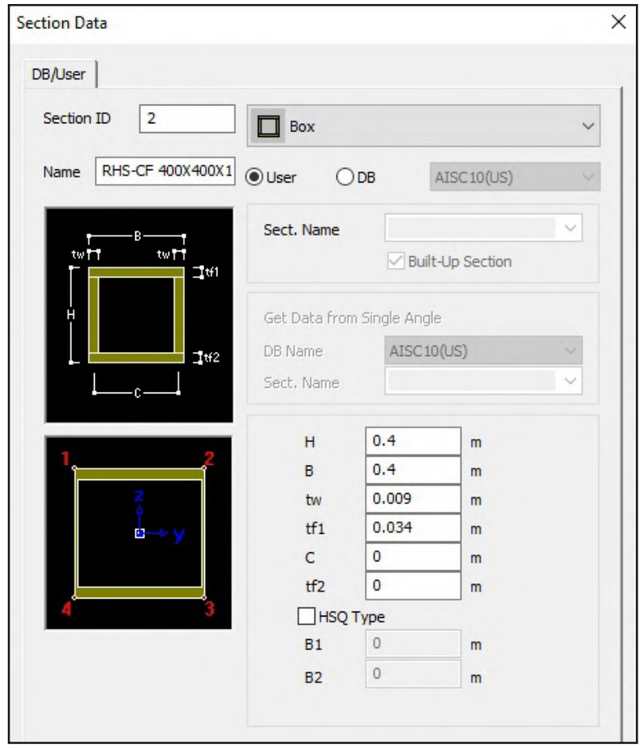
New sections:

There are now two types of section used in the truss. A larger section is used in more essential elements.

These dimensions are suggested by a MidasGEN tool "Steel Optimal Design", which analyses the structure and provides the closest optimal dimensions to fit the requirements. The section is produced by several companies available in Singapore, so we accept it for the next check.



Section 1 properties



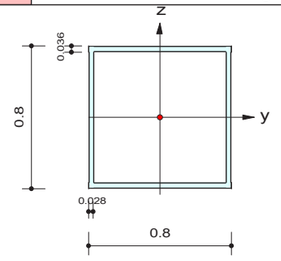
Section 2 properties

midas Gen **Steel Checking Result**

MIDAS	Company		Project Title	
	Author	perkova.kristina@mail.ru	File Name	D:\...\Midas file 6 03 22.mgb

1. Design Information

Design Code Eurocode3:05 & SGP
Unit System kN, m
Member No 153
Material S355 (No:1)
(Fy = 355000, Es = 210000000)
Section Name RHS-HF 800X800X28/36 (No:1)
(Built-up Section).
Member Length : 4.00000



2. Member Forces

Axial Force Fxx = -9536.2 (LCB: 6, POS:I)
Bending Moments My = -4752.2, Mz = -859.70
End Moments Myi = -4752.2, Myj = 2171.92 (for Lb)
Myi = -4752.2, Myj = 2171.92 (for Ly)
Mzi = -859.70, Mzj = 859.700 (for Lz)
Shear Forces Fyy = -429.85 (LCB: 6, POS:1/2)
Fzz = -2046.8 (LCB: 6, POS:I)

Depth	0.80000	Web Thick	0.02800
Flg Width	0.80000	Top F Thick	0.03600
Web Center	0.77200	Bot.F Thick	0.03600
Area	0.09837	Asz	0.04480
Qyb	0.26271	Qzb	0.18928
Iyy	0.01021	Izz	0.00915
Ybar	0.40000	Zbar	0.40000
Wely	0.02553	Welz	0.02287
ry	0.32220	rz	0.30497

3. Design Parameters

Unbraced Lengths Ly = 4.00000, Lz = 4.00000, Lb = 4.00000
Effective Length Factors Ky = 1.00, Kz = 1.00
Equivalent Uniform Moment Factors Cmy = 1.00, Cmz = 1.00, CmLT = 1.00

4. Checking Result

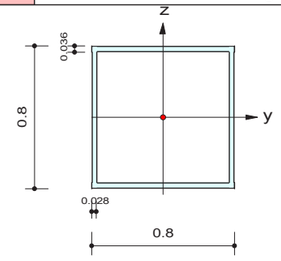
Slenderness Ratio
KL/r = 23.2 < 200.0 (Memb:519, LCB: 8)..... O.K
Axial Resistance
N_Ed/MIN[Nc_Rd, Nb_Rd] = 9536.2/34920.6 = 0.273 < 1.000 ..... O.K
Bending Resistance
M_Edy/M_Rdy = 4752.2/10445.2 = 0.455 < 1.000 ..... O.K
M_Edz/M_Rdz = 859.70/9676.04 = 0.089 < 1.000 ..... O.K
Combined Resistance
R.MNRd = MAX[M_Edy/Mny_Rd, M_Edz/Mnz_Rd]
R.BiM = (M_Edy/Mny_Rd)^Alpha + (M_Edz/Mnz_Rd)^Beta
R.byN = N_Ed/(A*fy/Gamma_M0), R.byM = M_Edy/My_Rd + M_Edz/Mz_Rd
Rc.LT1 = N_Ed/(Xiy*A*fy/Gamma_M1)
Rb.LT1 = (kyy*M_Edy)/(Xi_LT*Wply*fy/Gamma_M1) + (kyz*M_Edz)/(Wplz*fy/Gamma_M1)
Rc.LT2 = N_Ed/(Xiz*A*fy/Gamma_M1)
Rb.LT2 = (Kzy*M_Edy)/(Xi_LT*Wply*fy/Gamma_M1) + (Kzz*M_Edz)/(Wplz*fy/Gamma_M1)
Rmax = MAX[R.MNRd, R.BiM, (R.byN+R.byM), MAX(Rc.LT1+Rb.LT1, Rc.LT2+Rb.LT2)] = 0.817 < 1.000 .. O.K
Shear Resistance
V_Edy/Vy_Rd = 0.036 < 1.000 ..... O.K
V_Edz/Vz_Rd = 0.223 < 1.000 ..... O.K

midas Gen **Steel Checking Result**

MIDAS	Company		Project Title	
	Author	perkova.kristina@mail.ru	File Name	D:\...\Midas file 6 03 22.mgb

1. Design Information

Design Code Eurocode3:05 & SGP
Unit System kN, m
Member No 153
Material S355 (No:1)
(Fy = 355000, Es = 210000000)
Section Name RHS-HF 800X800X28/36 (No:1)
(Built-up Section).
Member Length : 4.00000



2. Member Forces

Axial Force Fxx = -9536.2 (LCB: 6, POS:I)
Bending Moments My = -4752.2, Mz = -859.70
End Moments Myi = -4752.2, Myj = 2171.92 (for Lb)
Myi = -4752.2, Myj = 2171.92 (for Ly)
Mzi = -859.70, Mzj = 859.700 (for Lz)
Shear Forces Fyy = -429.85 (LCB: 6, POS:1/2)
Fzz = -2046.8 (LCB: 6, POS:I)

Depth	0.80000	Web Thick	0.02800
Flg Width	0.80000	Top F Thick	0.03600
Web Center	0.77200	Bot.F Thick	0.03600
Area	0.09837	Asz	0.04480
Qyb	0.26271	Qzb	0.18928
Iyy	0.01021	Izz	0.00915
Ybar	0.40000	Zbar	0.40000
Wely	0.02553	Welz	0.02287
ry	0.32220	rz	0.30497

3. Design Parameters

Unbraced Lengths Ly = 4.00000, Lz = 4.00000, Lb = 4.00000
Effective Length Factors Ky = 1.00, Kz = 1.00
Equivalent Uniform Moment Factors Cmy = 1.00, Cmz = 1.00, CmLT = 1.00

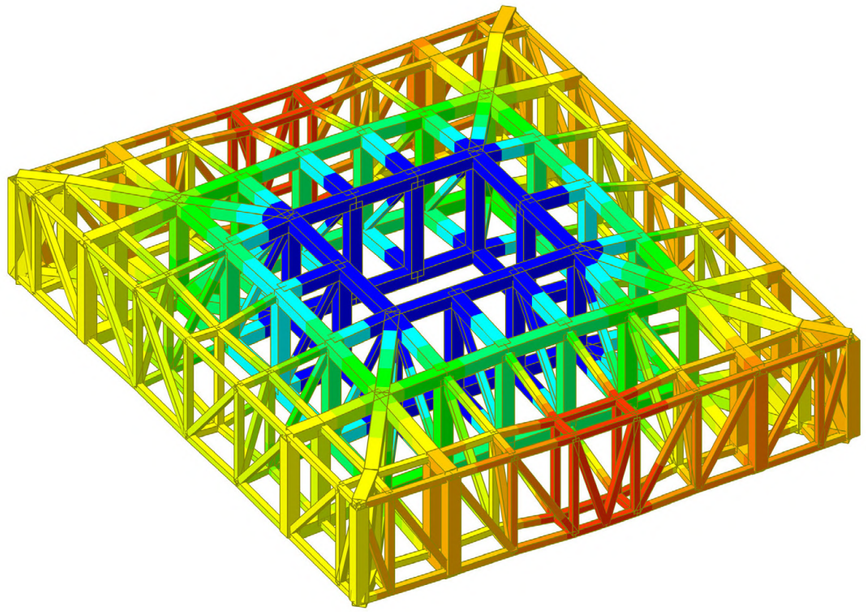
4. Checking Result

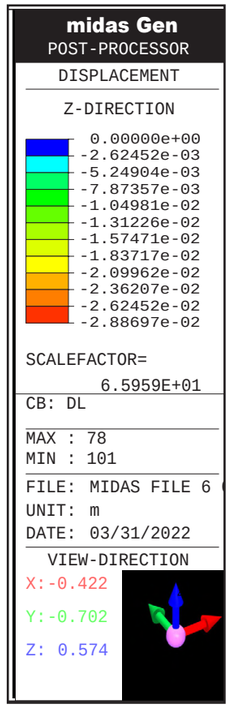
Slenderness Ratio
KL/r = 23.2 < 200.0 (Memb:519, LCB: 8)..... O.K
Axial Resistance
N_Ed/MIN[Nc_Rd, Nb_Rd] = 9536.2/34920.6 = 0.273 < 1.000 ..... O.K
Bending Resistance
M_Edy/M_Rdy = 4752.2/10445.2 = 0.455 < 1.000 ..... O.K
M_Edz/M_Rdz = 859.70/9676.04 = 0.089 < 1.000 ..... O.K
Combined Resistance
R.MNRd = MAX[M_Edy/Mny_Rd, M_Edz/Mnz_Rd]
R.BiM = (M_Edy/Mny_Rd)^Alpha + (M_Edz/Mnz_Rd)^Beta
R.byN = N_Ed/(A*fy/Gamma_M0), R.byM = M_Edy/My_Rd + M_Edz/Mz_Rd
Rc.LT1 = N_Ed/(Xiy*A*fy/Gamma_M1)
Rb.LT1 = (kyy*M_Edy)/(Xi_LT*Wply*fy/Gamma_M1) + (kyz*M_Edz)/(Wplz*fy/Gamma_M1)
Rc.LT2 = N_Ed/(Xiz*A*fy/Gamma_M1)
Rb.LT2 = (Kzy*M_Edy)/(Xi_LT*Wply*fy/Gamma_M1) + (Kzz*M_Edz)/(Wplz*fy/Gamma_M1)
Rmax = MAX[R.MNRd, R.BiM, (R.byN+R.byM), MAX(Rc.LT1+Rb.LT1, Rc.LT2+Rb.LT2)] = 0.817 < 1.000 .. O.K
Shear Resistance
V_Edy/Vy_Rd = 0.036 < 1.000 ..... O.K
V_Edz/Vz_Rd = 0.223 < 1.000 ..... O.K

The second attempt passes the steel check successfully for both sections.

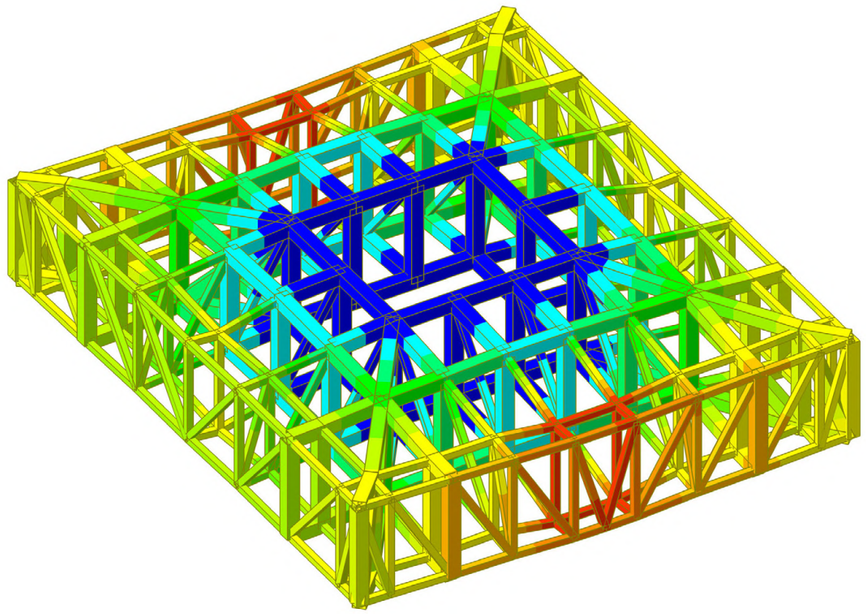
We now need to perform all the other checks.

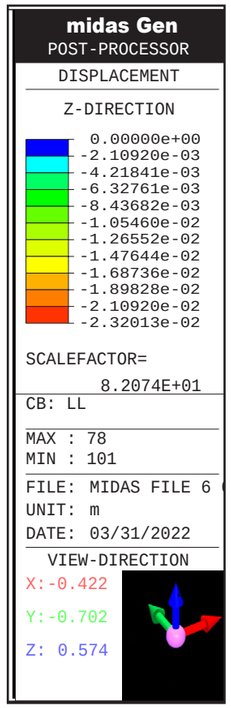
VERTICAL DISPLACEMENT





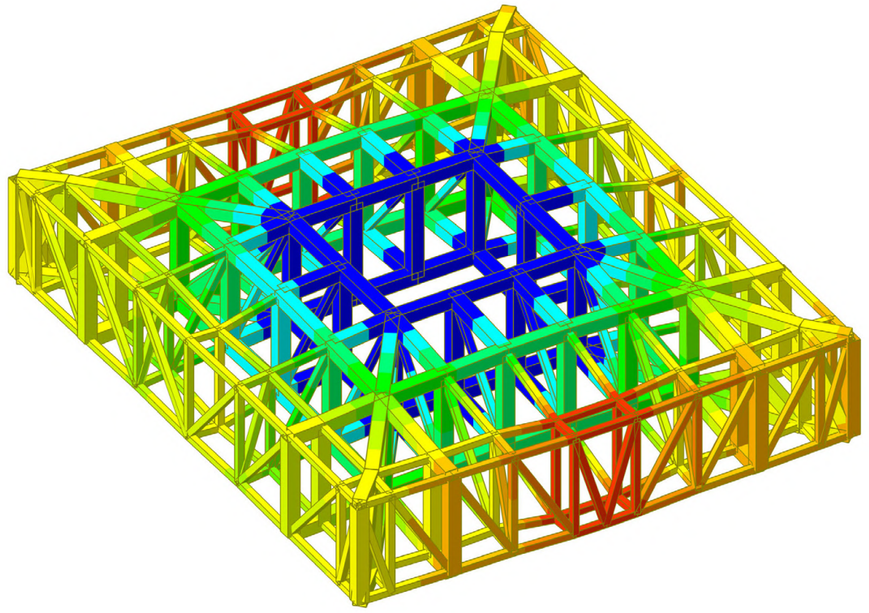
Dead load displacement check

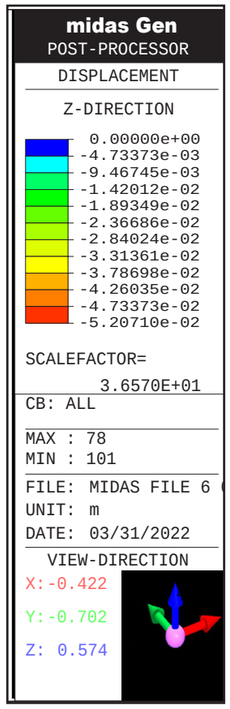




Live load displacement check

VERTICAL DISPLACEMENT





Total displacement check

The displacement check shows the largest displacement value as 0.052 m = 52 mm. We need to make sure that it is less than the maximum vertical displacement for this structure.

According to the Eurocode 3, a structure which is essential to the behavior of other elements, such as columns (which are in our case suspended from the bottom plane of the truss), needs to satisfy the maximum vertical displacement of max/L = 1/400. However, the truss in question is a structure cantilevered from the central core, which makes the L in the ratio twice the actual physical length of it: 2L/400 = max.

The largest distance from the core to the edge of the truss is taken diagonally and equals 16.4 meters.

2*16,4 / 400 = 0.082 m = 82 mm.

52 mm < 82 mm, displacement passes the check.

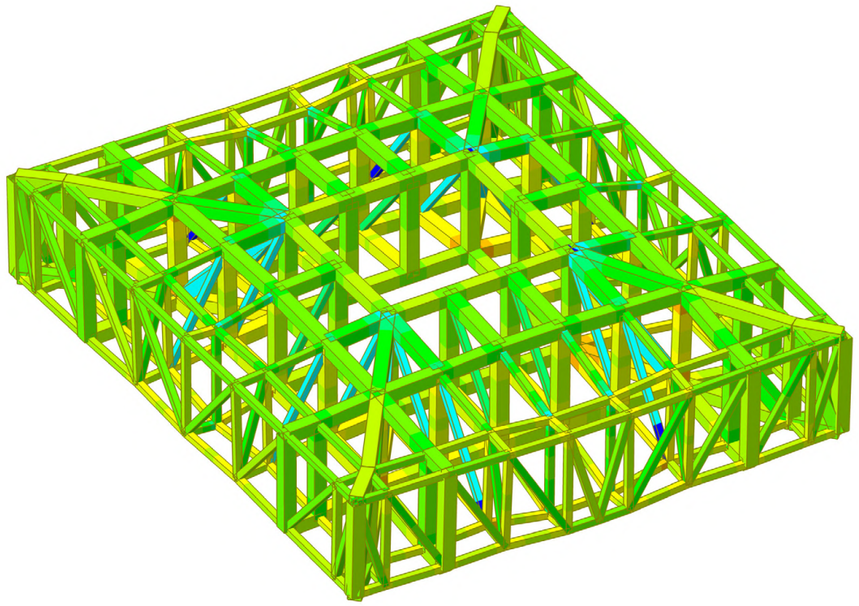
✓

Live load max displacement

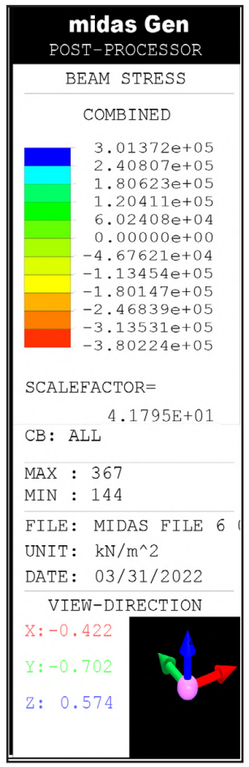
23 mm < L/300 = 55 mm, verified

✓

STRESS CHECK



Beam stress check



A stress check was performed with a load combination "All" (LL+DL).

The graph showed that the maximum stress on a beam is 301372 kN/m2.

Ft allowable = Fyield / γ

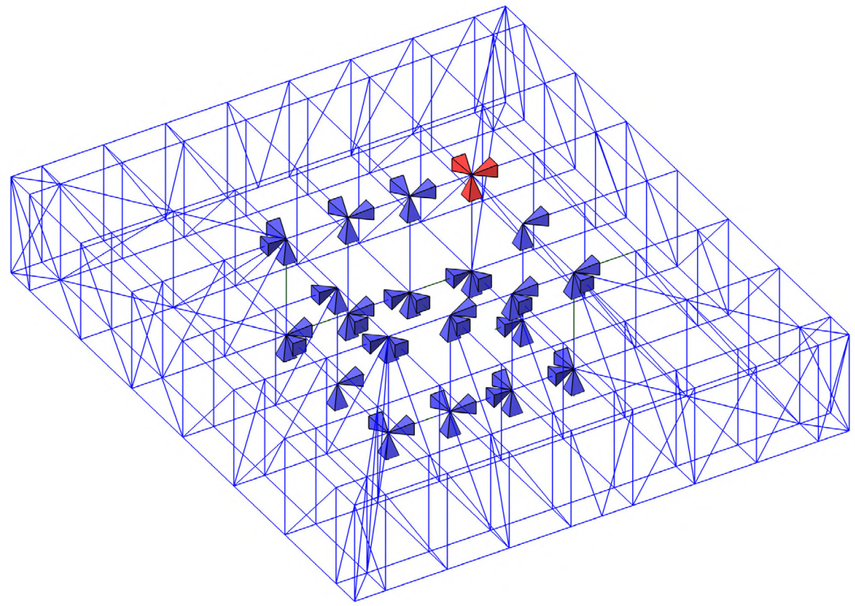
Fyield = 355000 kN/m2

γM = safety factor = 1.15

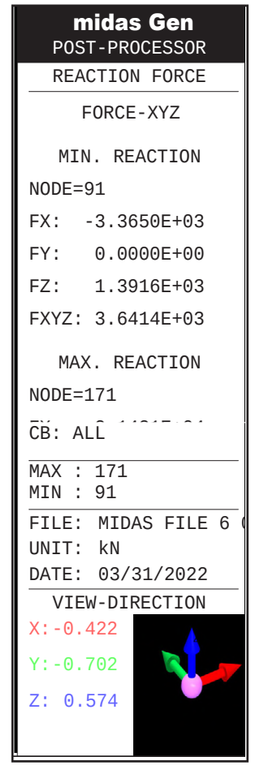
Ft allowable = 355000 kN/m2 / 1.15 = 308695.65 kN/m2

301372 kN/m2 < 308695.65 kN/m2

REACTION FORCES

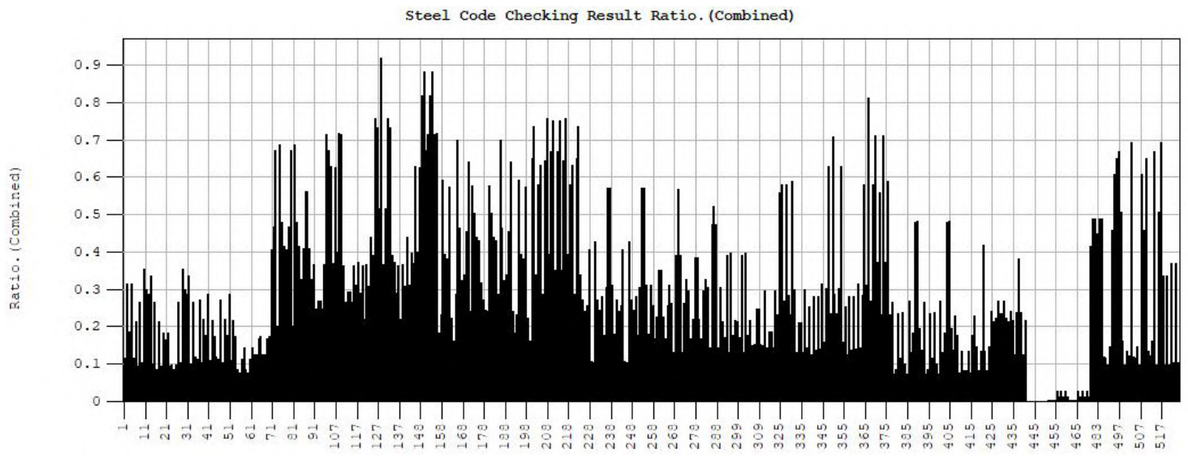


Reaction force diagram of the model



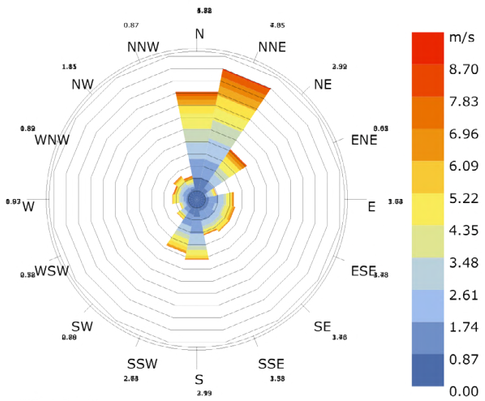
As part of the checks, a reaction force diagram was exported as well, with the same load combination ("all") at FZ. It is clear how the structure is secured in the middle to the core of the building.
Minimum reaction force was determined at node 91, and the maximum force - at node 171.

The diagram shows how all the loads are ultimately transferred to the core. There are no anomalies in the direction of the reaction force. Since the entire structure is secured as a cantilever, there are other reaction forces besides vertical.

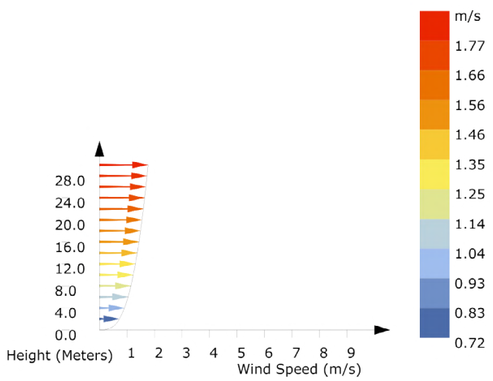


Bar graph (Checking result ratio)

Site conditions check

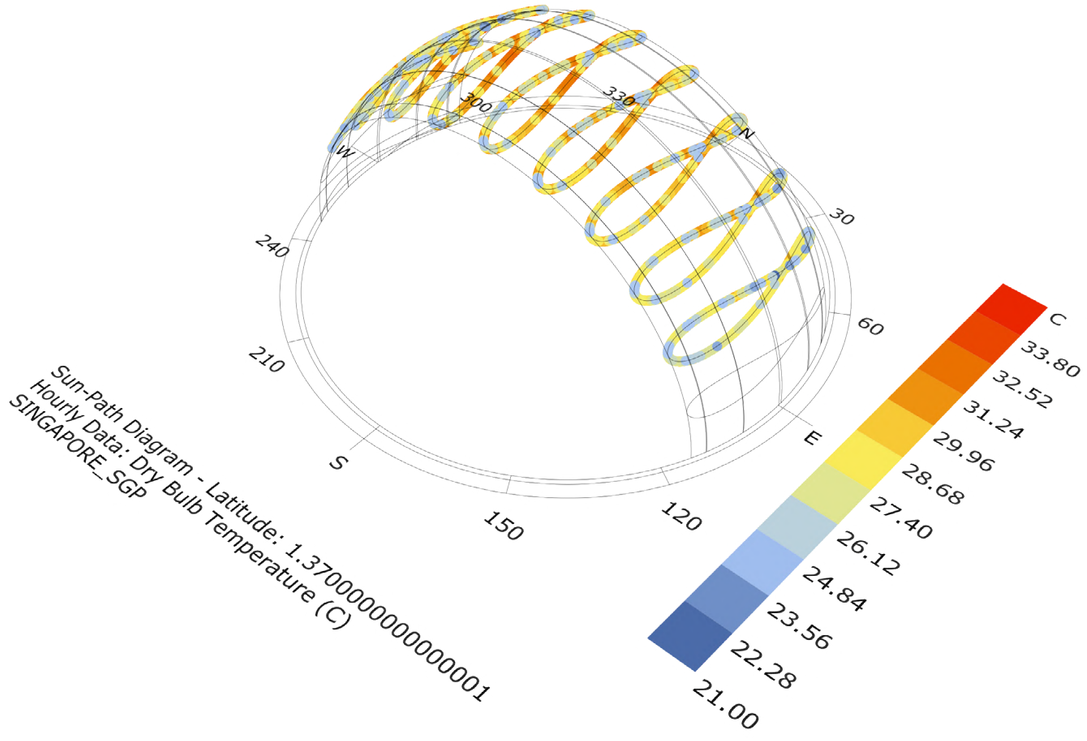


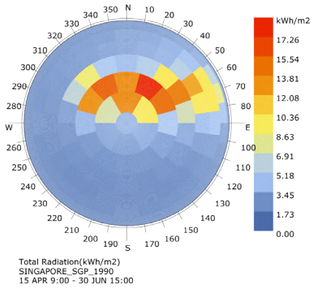
Wind-Rose
SINGAPORE_SGP
1 JAN 9:00 - 30 DEC 18:00
Hourly Data: Wind Speed (m/s)
Calm for 7.87% of the time = 686 hours.
Each closed polyline shows frequency of 0.7%. = 61 hours.



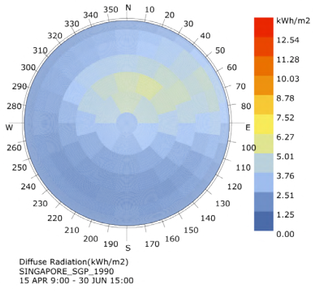
Wind Profile - Average Velocity In Time Period
SINGAPORE_SGP - City Terrain
15 APR 9:00 - 30 JUN 15:00

Site conditions check

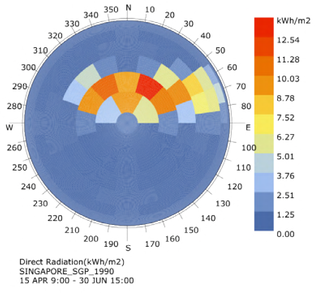




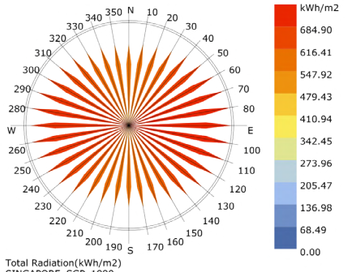
Total Radiation(kWh/m2)
SINGAPORE_SGP_1990
15 APR 9:00 - 30 JUN 15:00



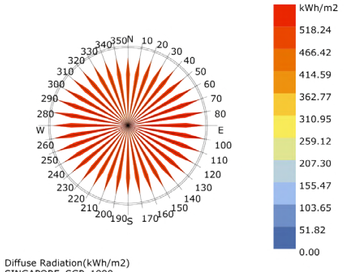
Diffuse Radiation(kWh/m2)
SINGAPORE_SGP_1990
15 APR 9:00 - 30 JUN 15:00



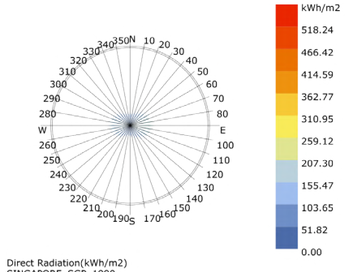
Direct Radiation(kWh/m2)
SINGAPORE_SGP_1990
15 APR 9:00 - 30 JUN 15:00



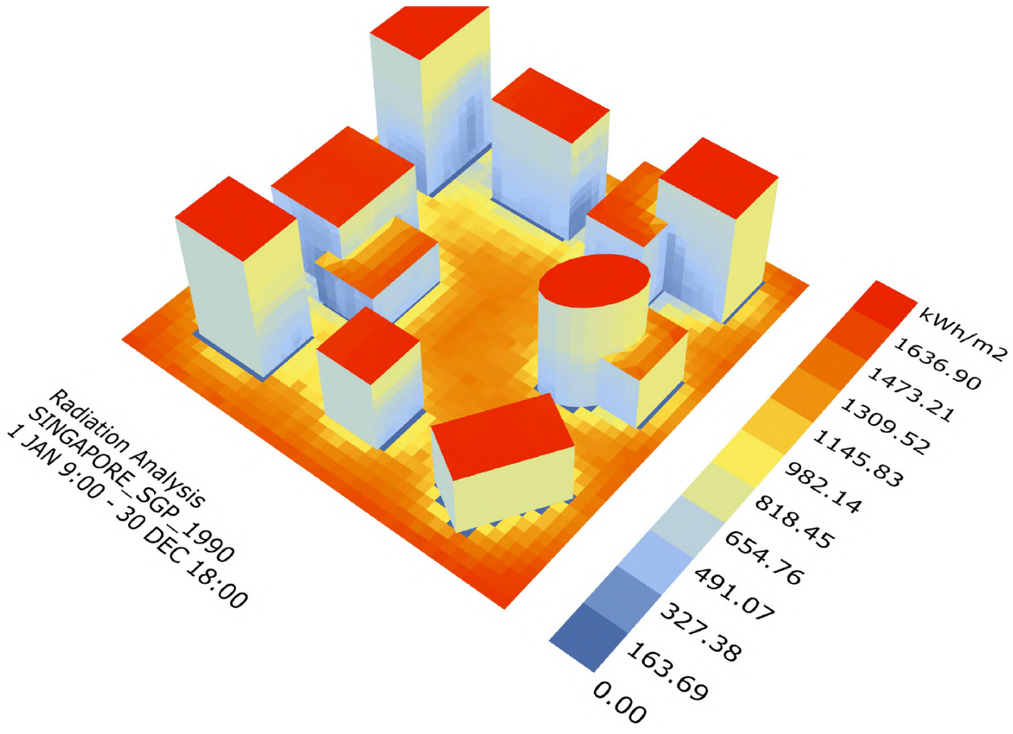
Total Radiation(kWh/m2)
SINGAPORE_SGP_1990
1 JAN 9:00 - 30 DEC 18:00



Diffuse Radiation(kWh/m2)
SINGAPORE_SGP_1990
1 JAN 9:00 - 30 DEC 18:00

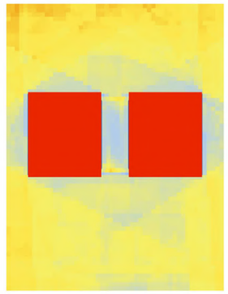


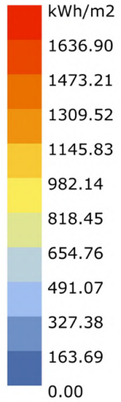
Direct Radiation(kWh/m2)
SINGAPORE_SGP_1990
1 JAN 9:00 - 30 DEC 18:00



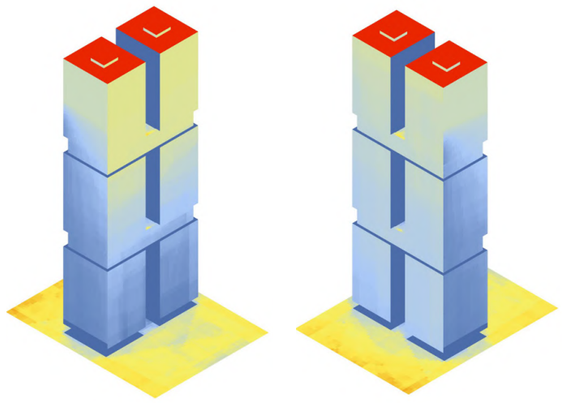
SUNLIGHT EVALUATION

Surfaces of buildings check

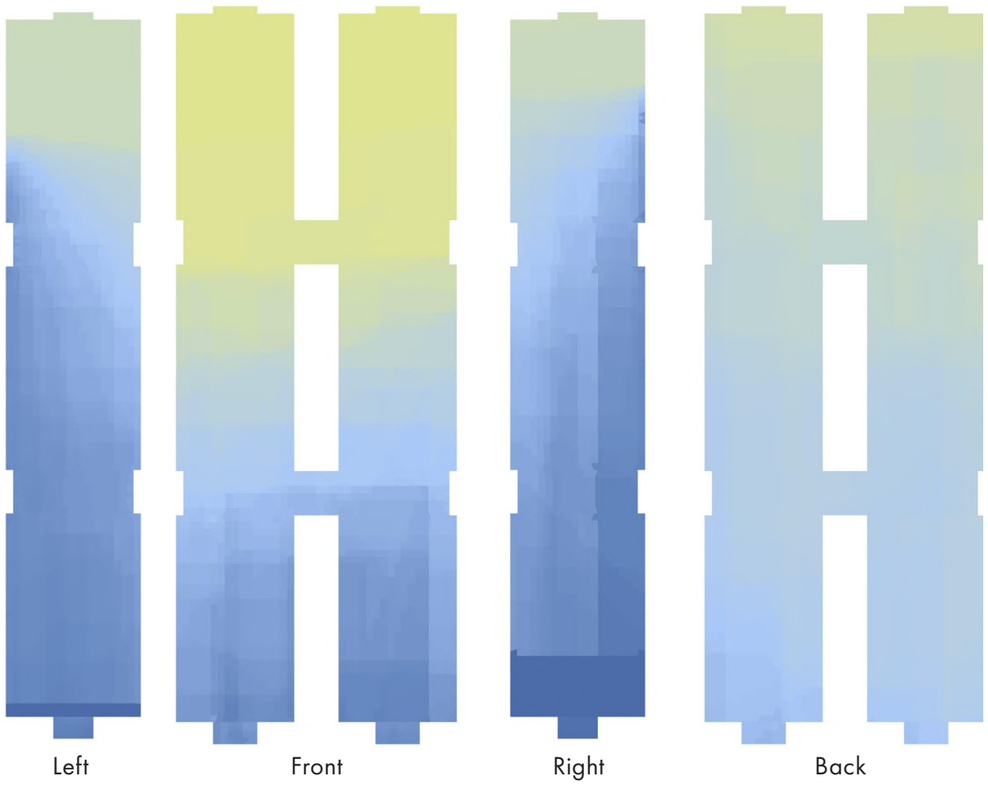




Radiation Analysis
SINGAPORE_SGP_1990
1 JAN 9:00 - 30 DEC 18:00



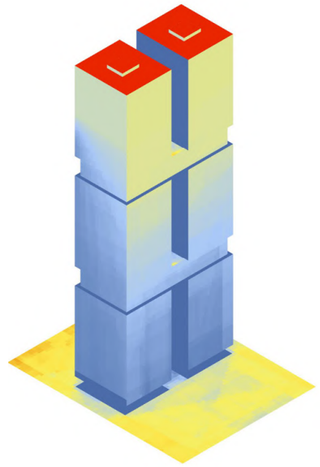
Resulting solar irradiation on building surfaces



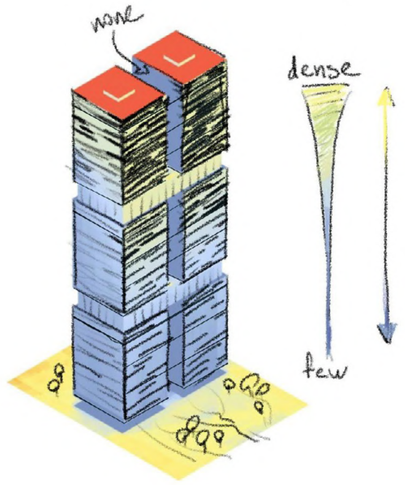
Resulting solar irradiation on four sides of the building, used for facade shading generation

LADYBUG

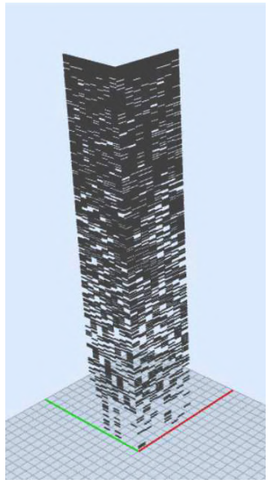
FACADE PANEL DISTRIBUTION ALGORHYTM

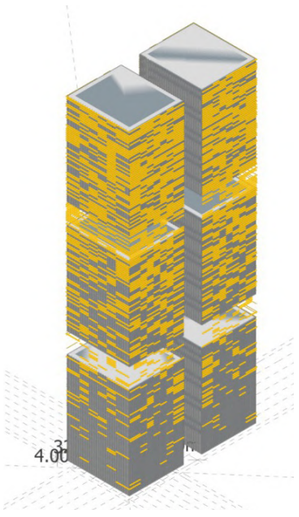


Sunlight distribution on surfaces

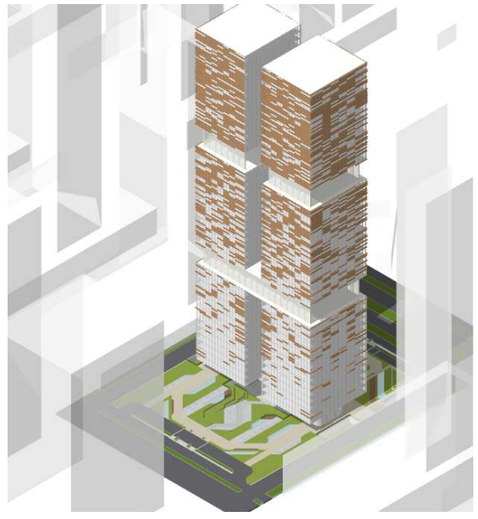


Initial concept

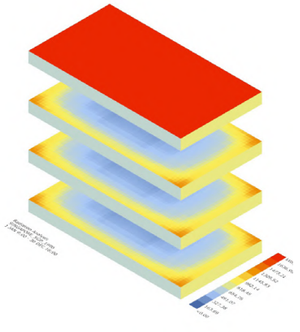


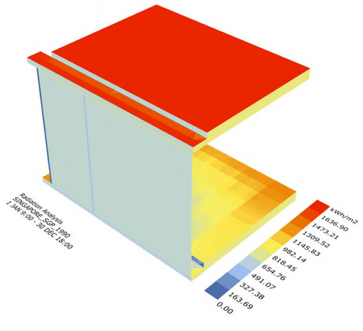


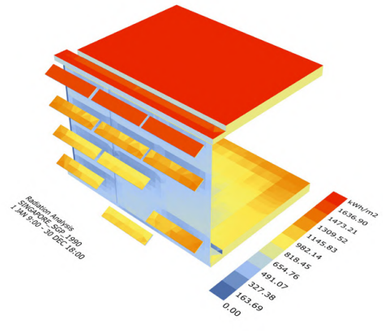
Facade pattern generation process



Result





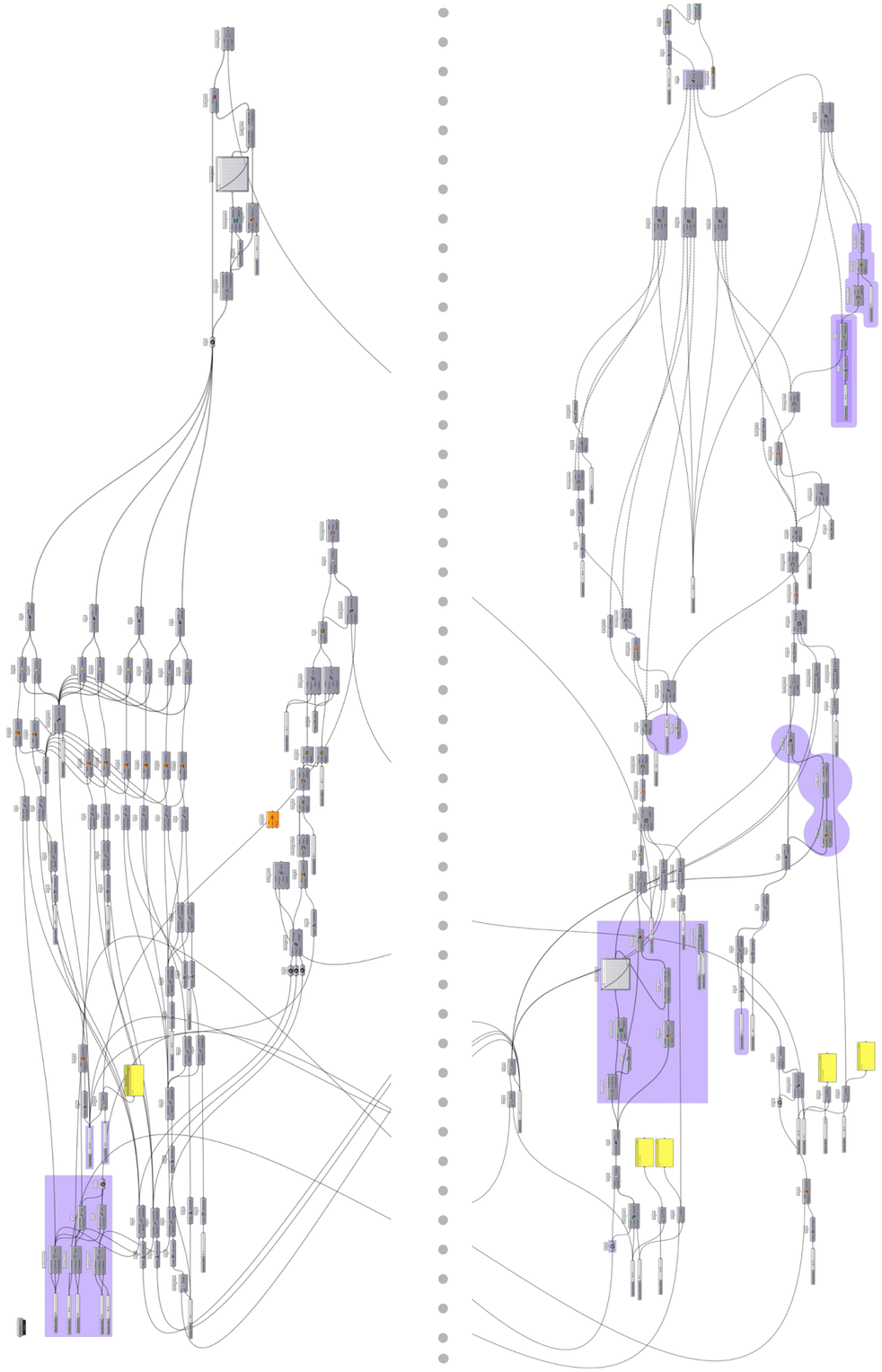


Sun radiation effect: no facade, glass curtain wall and shading panels

FACADE PANEL DISTRIBUTION ALGORHYTM

Adapting the light to facade panels pattern

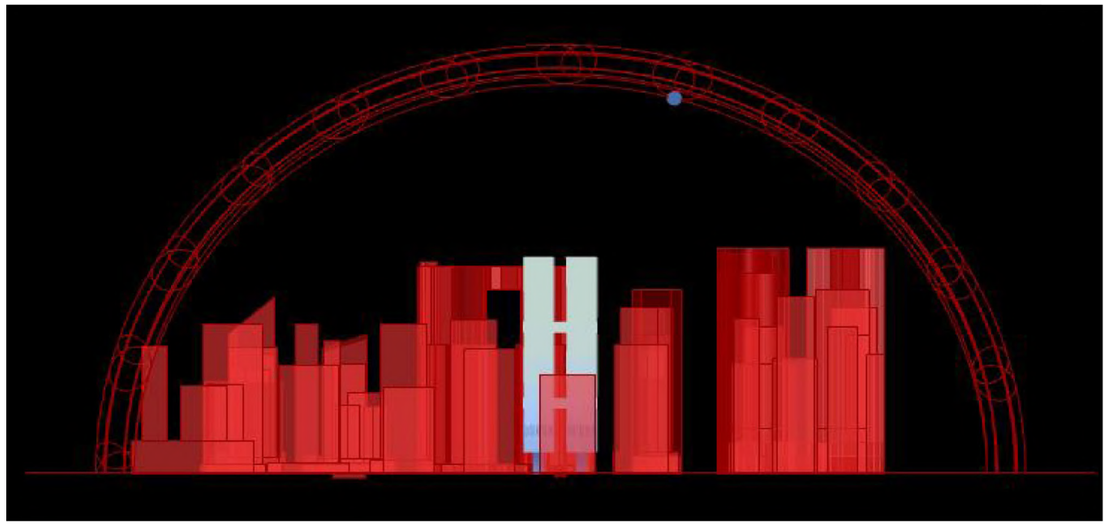
GRASSHOPPER

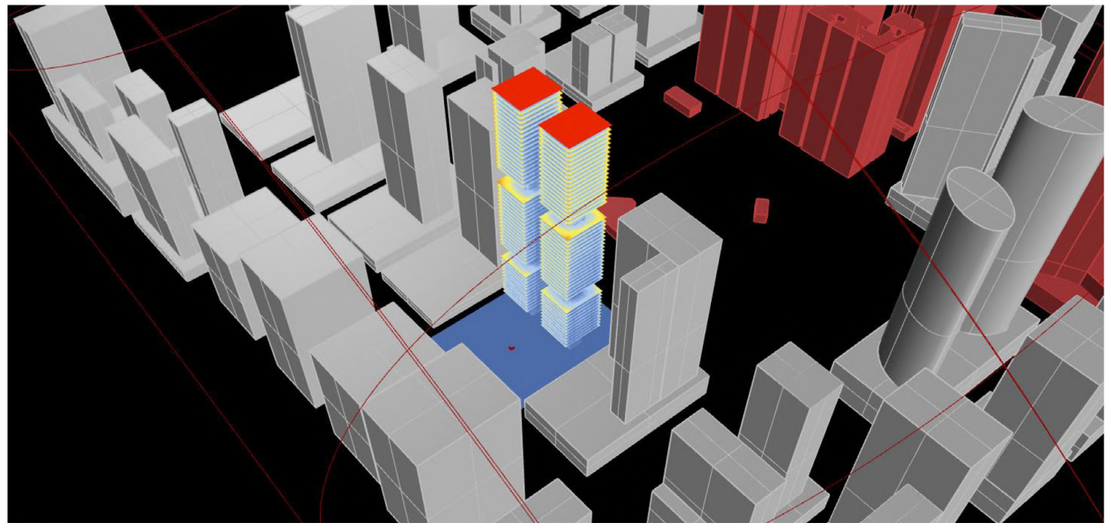


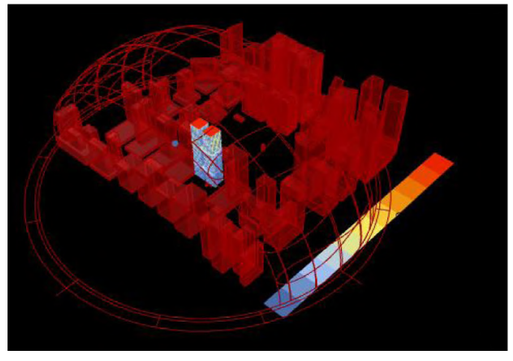
SUNLIGHT EVALUATION

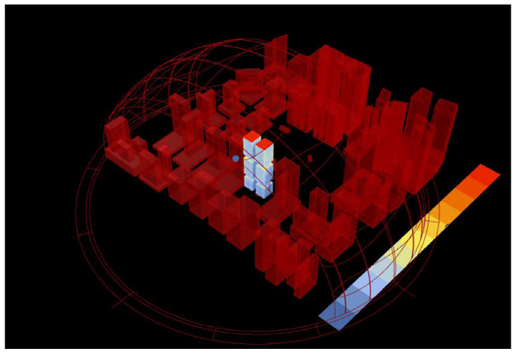
VELUX

Environment check

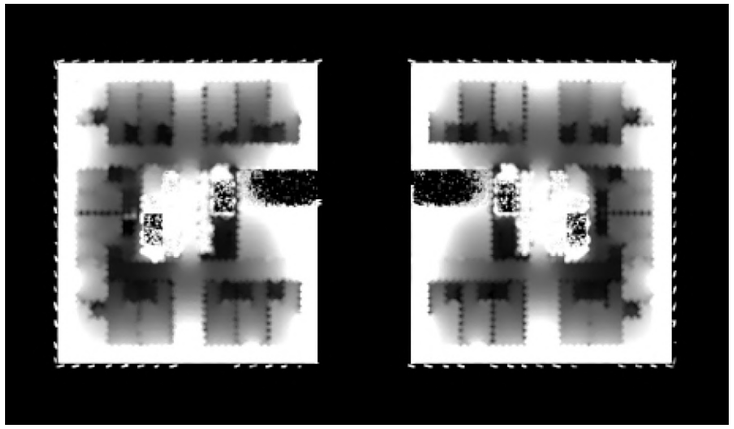


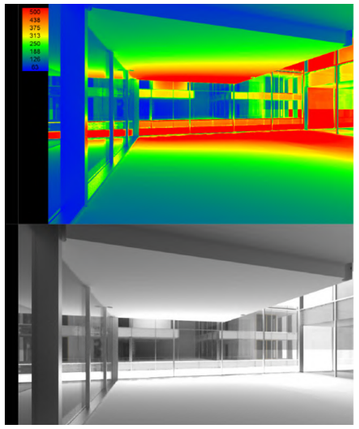


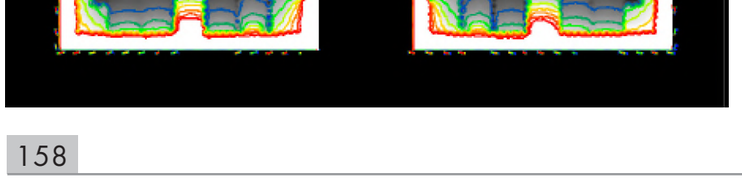


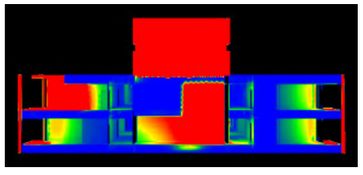


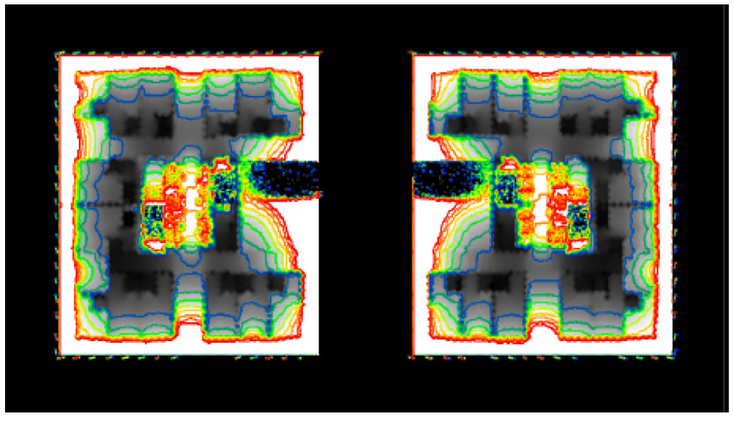
Typical plan check

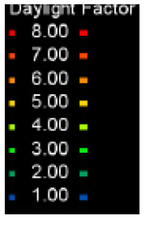






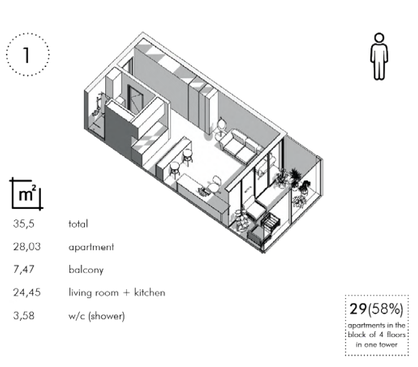


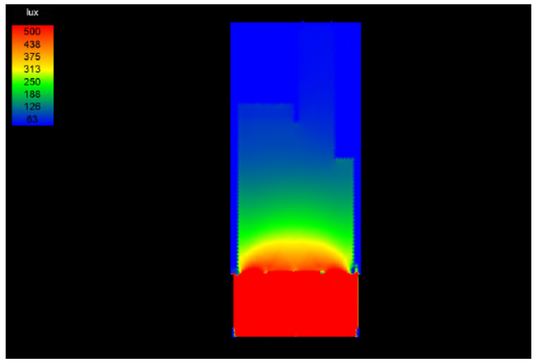


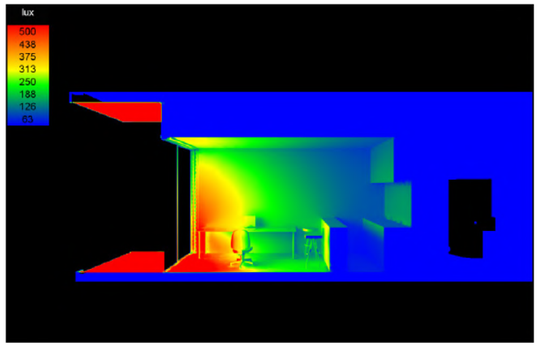


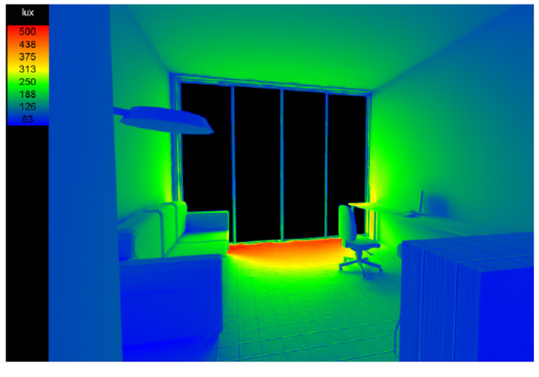
Apartment solar illumination check

Type 1



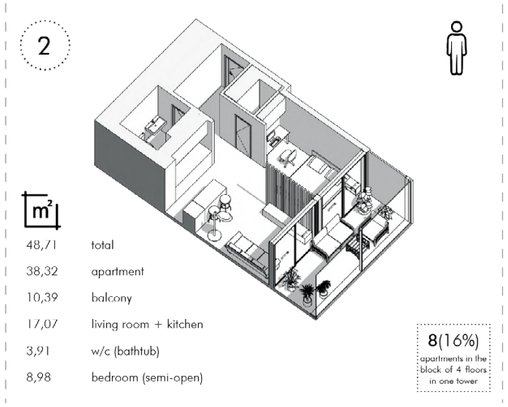


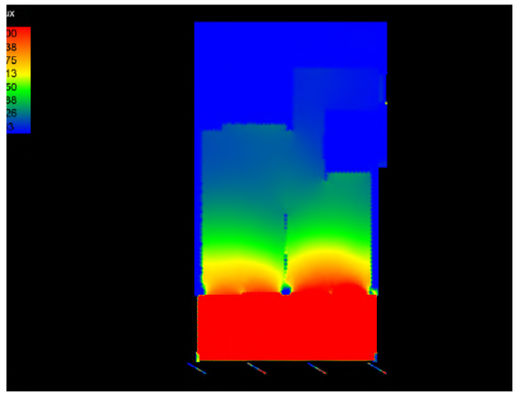


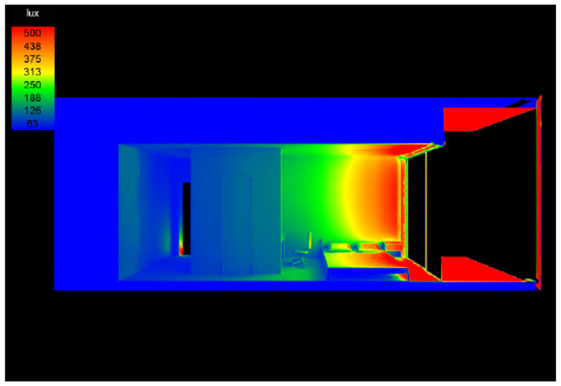


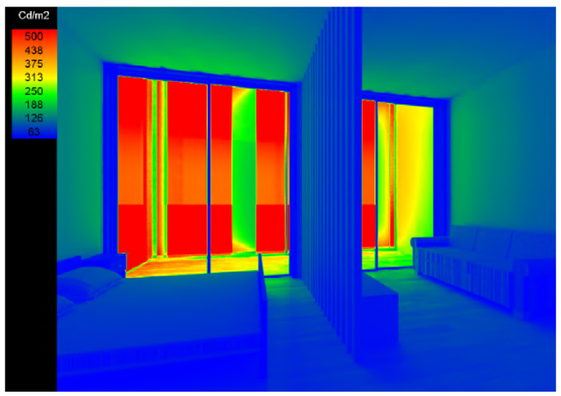
Apartment solar illumination check

Type 2



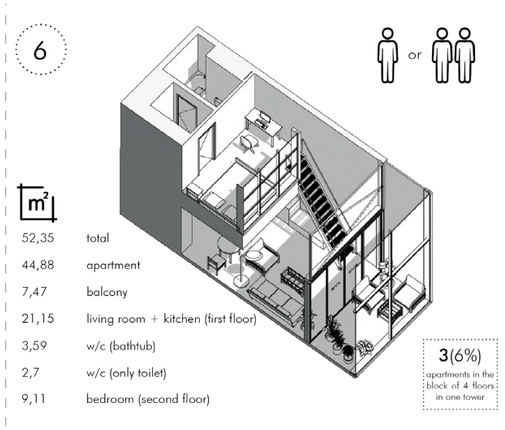


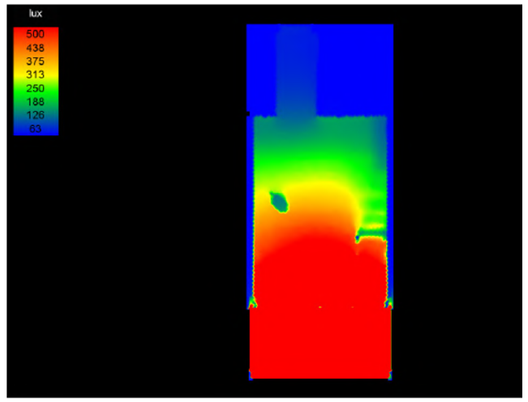


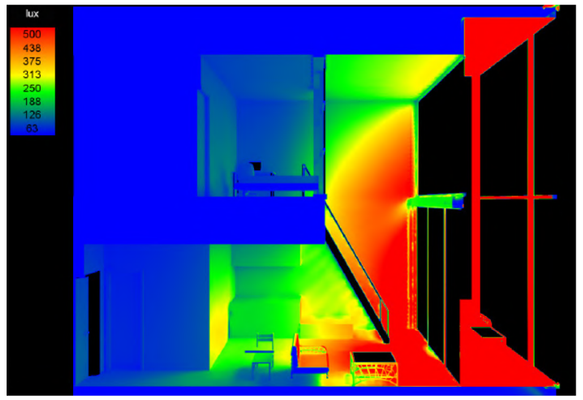


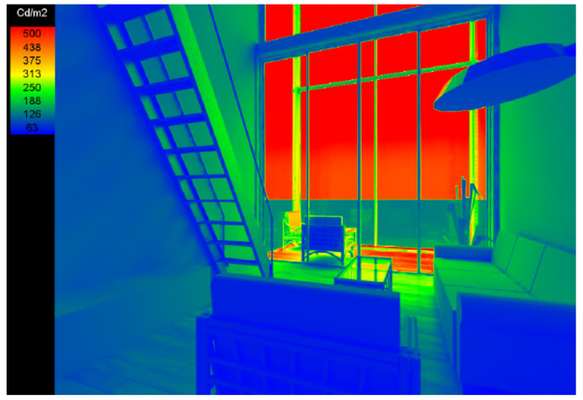
Apartment solar illumination check

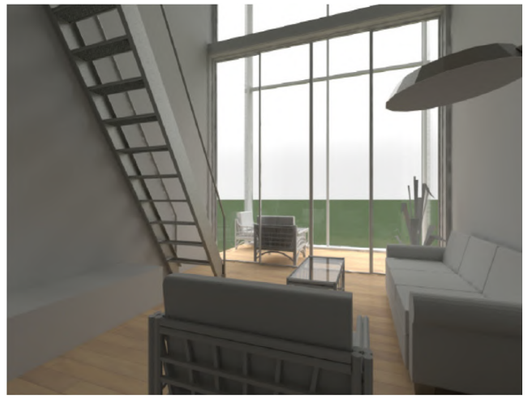
Type 6



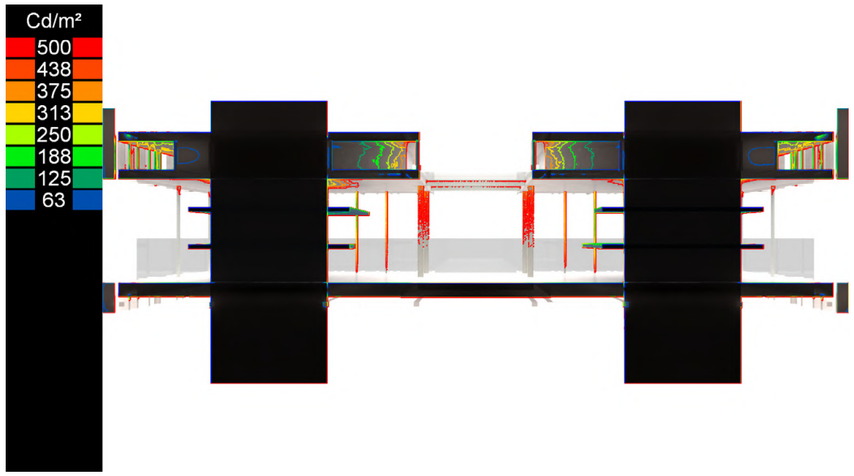




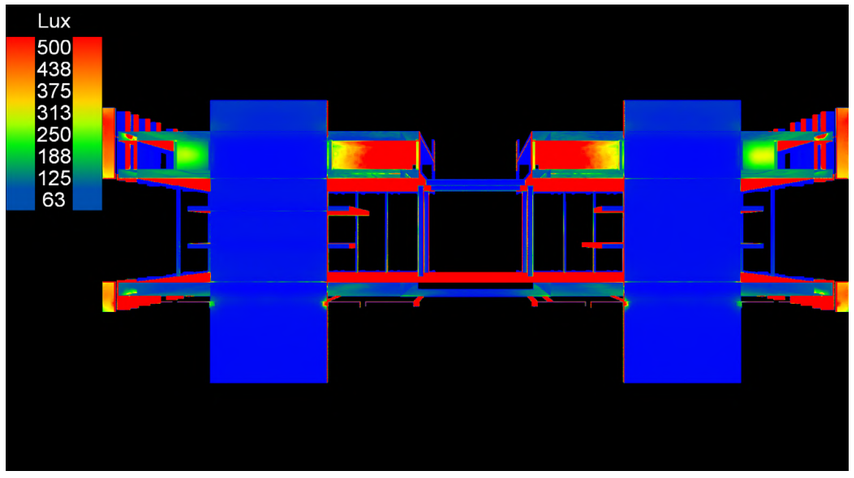




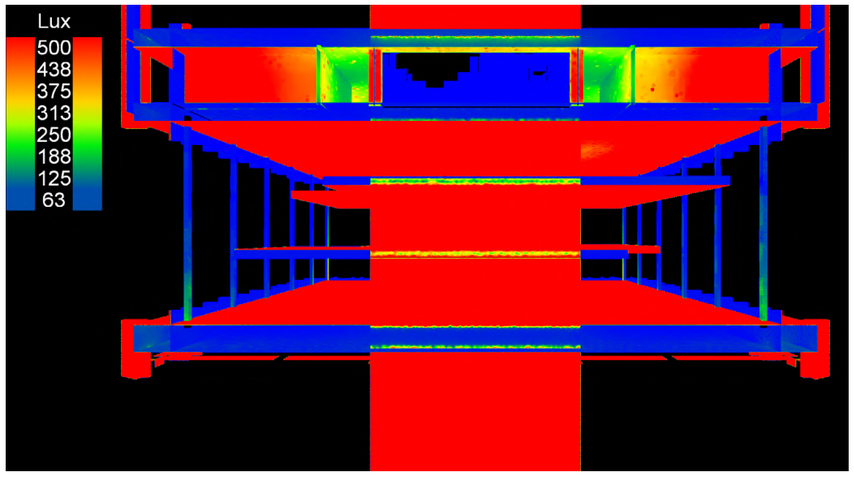
Garden floor illumination check



Primary section - luminance

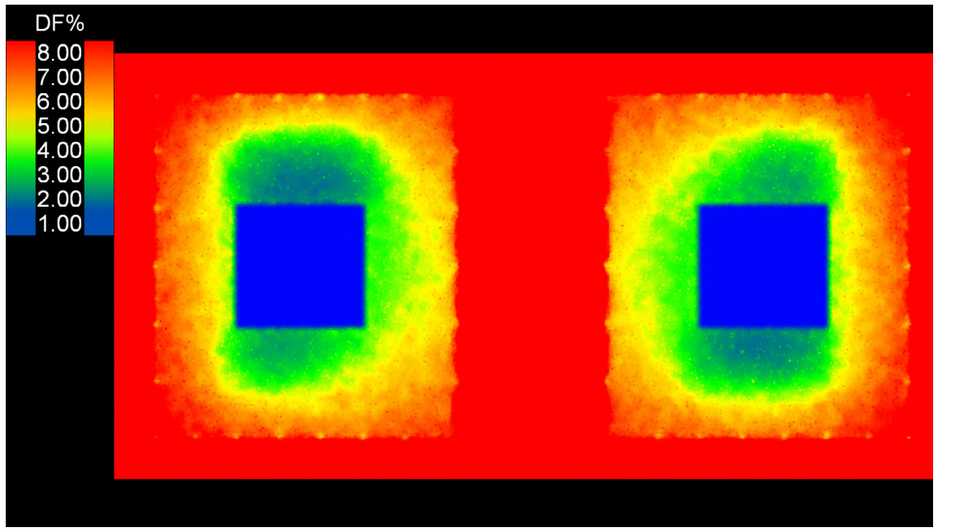


Primary section - illumination

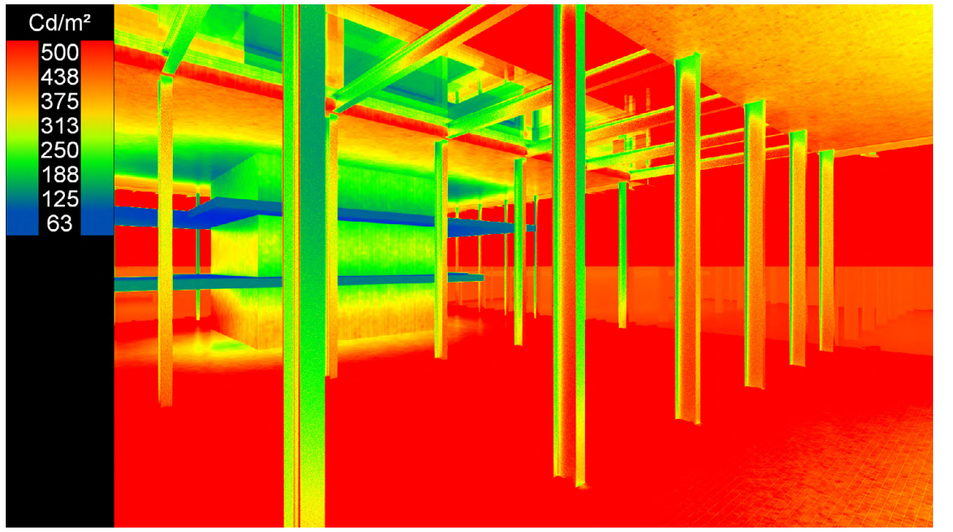


Perpendicular section - illumination

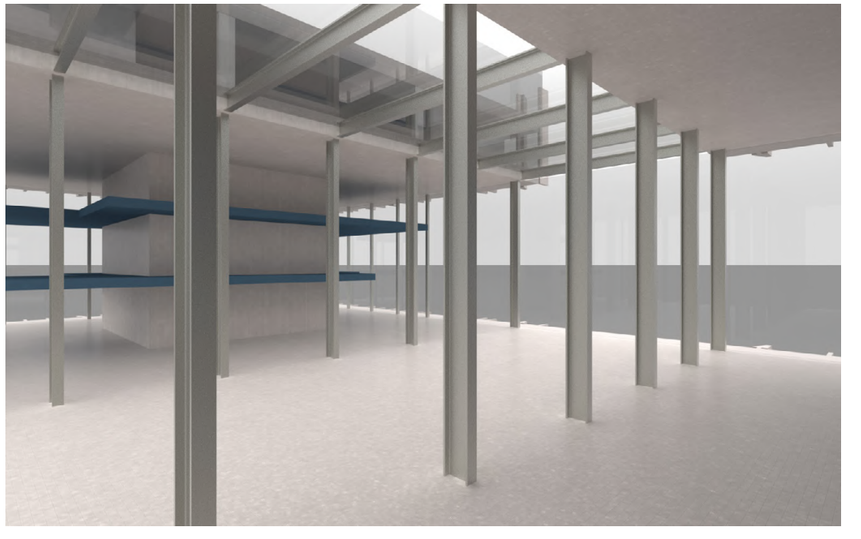
Top view of garden - illlumination



Perspective view - illumination

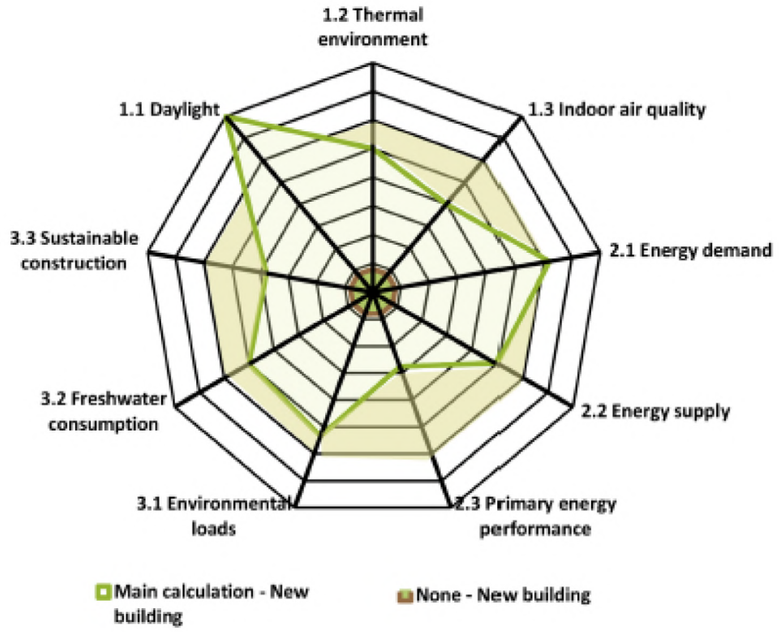


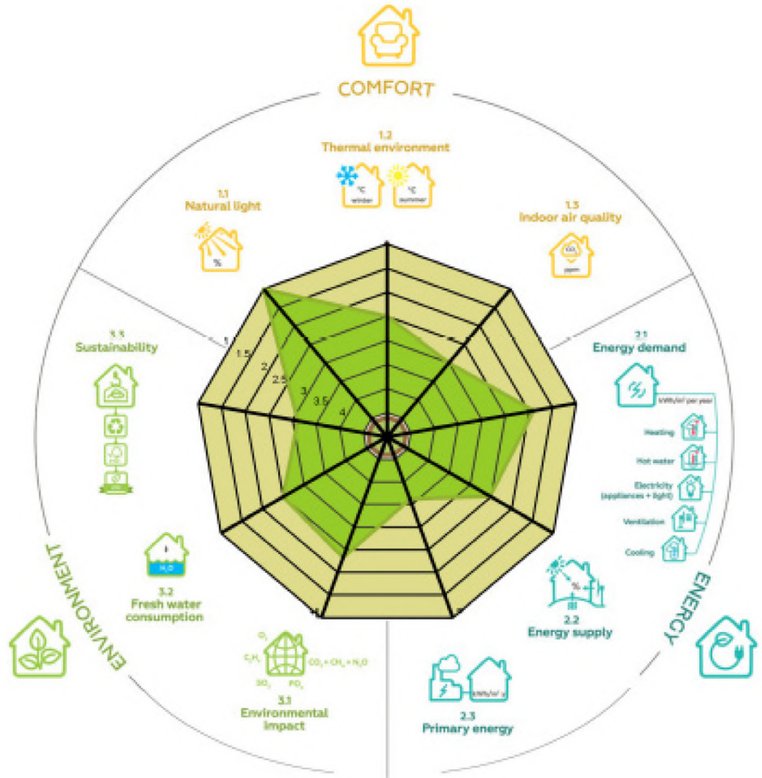
Perspective view basic



ACTIVE HOUSE

Garden floor illumination check





COMFORT

Parts in yellow show that this parameter of the building needs improvement. The daylight in the garden floor is good, reaching above 6.5%, as can be seen in the radar. The tested area of the building has decent thermal balance thanks to the applied ventilation strategies and shading systems. The air quality is reaching less than 1000 ppm, which can be considered a good result; that is attained by applying mechanical ventilation based on the needs of users; also, the choice of materials had been done as t osupport good air quality.

ENERGY

Energy-efficient technologies allowed the building to reach good levels of energy demand. Renewable energy is able to cover 35% of the needs of the building. The light supply of the internal gardens is mostly covered by the use of natural light - the shading system is designed to maximise light in spaces that need it and diffuse it where it is a problem.

Main calculation - New building		
Comfort	**Value**	**Category**
1.1 Daylight:	6.5 %	1.0
1.2 Thermal environment:	Good level	2.5
1.3 Indoor air quality:	≤ 1000 ppm	3.0
Classification		
Energy	**Value**	**Category**
2.1 Energy demand:	58.0 kWh/m²	1.9
2.2 Energy supply:	35.8 kWh/m²	2.5
2.3 Primary energy:	24.3 kWh/m²	3.6
Classification		
Environment	**Value**	**Category**
3.1 Environmental loads:	Good level	2.3
3.2 Freshwater:	25 % savings	2.5
3.3 Sustainable construction:	Good level	3.1
Classification		

None - New building		
Comfort	**Value**	**Category**
1.1 Daylight:	0.0 %	-
1.2 Thermal environment:	Out of AH category	-
1.3 Indoor air quality:	> 1200 ppm	-
Classification		
Energy	**Value**	**Category**
2.1 Energy demand:	0.0 kWh/m²	-
2.2 Energy supply:	0.0 kWh/m²	-
2.3 Primary energy:	0.0 kWh/m²	-
Classification		
Environment	**Value**	**Category**
3.1 Environmental loads:	Lowest level	-
3.2 Freshwater:	0 % savings	-
3.3 Sustainable construction:	Lowest level	-
Classification		

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