

MASTER

Caves and skyscrapers

a research on the use of a CAVE system as a design medium for a high-rise building project

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Award date:
2012

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Caves and Skyscrapers

A research on the use of a CAVE system as a design medium for a high-rise building project

P.J.P. van Montfort (0634532)

31-8-2012

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ir. Maarten Willems
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Foreword

Thank you for reading this thesis. This thesis has been written for my graduation on the Eindhoven University of Technology, department of the built environment. For the research I wanted to bring two of my interests together in one projects. These interests are skyscrapers and computer graphics. The university owns a desk-CAVE and this gave me the idea to use its capabilities in a design project for a high-rise building. This also appeared to have never been done before and thus it was a valid research topic, and so I began creating the tools necessary for the job. Due to my interest in skyscrapers, I was already familiar with many buildings in Hong Kong, the project location. I've been modeling these buildings with 3ds Max for many years now. This taught me to look into buildings in the smallest detail which in turn gave a good impression on how buildings work in Hong Kong. This, with the knowledge I picked up on 3ds Max through many years of use gave me an advantage in design and modeling speed in this project. However, this didn't mean that there were setbacks as well. Working on one project for a whole year proved to be a strain. 3ds Max didn't help on this part, the program became slow and the viewports cluttered as the project advanced. Luckily everything worked out well in the end. The project is finished and I'm proud of it.

I want to thank my supervisors, Bauke de Vries, Maarten Willems and Christian Rapp for their critical approach and their confidence. They helped me stay on track and pointed out important details which I otherwise would have missed. They also showed me that I still have a lot to learn in the field of architecture, but mainly they thought me to stay critical of my own creations. I also want to thank Joran Jessurun for his help with the scripts for Vizard. Without him, I would not have been able to pick up the scripting language and the workings of Vizard as fast as I did now. This knowledge, combined with the knowledge of 3ds Max will surely be helpful in my oncoming career.

I hope you enjoy reading this thesis.

Paul van Montfort

August 2012

Summary

Introduction

From the beginning of the skyscraper era, the main reason to build them is to gain money and prestige. Through the years, skyscrapers became bigger due to advances in technology. The size of skyscrapers often gives birth to a number of issues. People get overwhelmed by them and feelings of isolation occur on higher floors. This happens mainly because it is impossible to see what happens on street level. These problems are enhanced by the lack of interaction inside the building and the streets dominated by cars and closed lifeless plinths the buildings have.

Hong Kong is the most densely populated city in the world. According to the Hong Kong Census and Statistics department approximately 7.108.100 people live in an area of 1.104 km². Due to the scarcity of land and the high number of people living in the city, Hong Kong is constantly being developed with large real estate projects. These huge residential projects show characteristics defining the problems with which many high-rise buildings cope.

This scenario forms the basis for testing a CAVE system as a design tool. This gives the possibility to walk through and around a project before it is built giving new insights 2d sketches and CAD-drawings do not give. Next to this, ideas are developed to address the issues of the skyscraper typology

Methodology

The CAVE works with the program Vizard. It is not possible to model with this program. Therefore 3ds Max was used as the modeling program. To be able to view the models from 3ds Max in Vizard, an exporting and importing plug-in were programmed. This reduced the conversion sequence to a simple push of a button.

To record the results, A backup of the model was made every half an hour. To document the progress, a datasheet was created from these backups. With this data sheet it is possible to see which kind of design decisions were made in different phases as well as where the CAVE clearly showed an impact on the design.

Results and Conclusion

The design process resulted in a multi-use skyscraper in the Tai Kok Tsui neighborhood in Hong Kong. The design reacts to the problems mentioned above by introducing a smaller scale into the building, achieved by assembling the building out of smaller building blocks. This way social plazas are created between the building blocks. Users of the building use these plazas along their way through the building creating opportunities for interaction. Each of the 5 blocks is specified for a unique target group from small children, to elderly and from starters to childless business families. Because of this, each block has different apartment typologies as well as a unique appearance of the collective sky lobbies. The base of the building contains shops and amenities creating a lively street view around the building.

Working in a 3d environment proved to have both positive and negative effects. First of all it helped track down errors in the design which would have been hard to notice working with 2d drawings.

The CAVE also gave a much better insight in the working of spaces in the building. Here the CAVE caused several changes and additions in the design because it was possible to see the space as it would be in real life. Therefore it was much easier to see when a design idea would or would not work. The CAVE gave the insight to come up with solutions otherwise not or later thought of.

Although the CAVE made decision making easier and quicker, the more objects the model contained the harder it was to work with and make changes. This caused the process to slow down again. In the end of the design process however, it could still be concluded that this new design method was faster based on the size of the project and the length of the design process.

It can be concluded that with the help of the CAVE it was possible to design a high-rise structure that is more fitting to a scale better comprehensible by its users. Although most ideas that cause this were developed on paper rather than in the CAVE. The CAVE did help in giving these ideas their final form, enhancing the initial ideas and being able to tweak small and big details into a harmonious whole. Working with the CAVE proved to be more efficient.

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1. Introduction

The main goal of this research is to test whether a CAVE can be used as a design tool in an architectural design assignment. A CAVE is a computer with multiple screens to simulate real time virtual environments. By using multiple screens, the user has a sense of being inside the virtual environment as it is projected all around him or her. This gives the possibility to walk through and around a project before it is built giving new insights 2d sketches and CAD-drawings do not give.

In order to fully exploit the benefits of the CAVE, an exceptionally big project is used. In a big project, it is easier to lose the sense of scale due to the large size. This is especially true for skyscrapers. Therefore the assignment used to test the CAVE as a design tool is that of a skyscraper.

Skyscrapers are a relatively new building typology only existing 150 years. In its lifespan, the typology has much evolved due to advances in technology and business plans. Although these advances meant that skyscrapers could become increasingly bigger, it also brought with it a number of problems making skyscrapers less attractive as a type.

High-rise buildings, especially the office type, are largely dominated by financial criteria or the will of businesses who build them to create an expression of their wealth and power. This is partly visible in the race for the tallest building in the world which is going on for over a 100 years. This causes many high-rise buildings to be designed as autonomous objects and thus, the relation to their context is often lost. This is especially evident in tall buildings in a low-rise context such as the Tour Montparnasse in Paris. This is also the main reason for protests against high-rise buildings in low-rise cities such as Paris and London. The other type of office tower exists for financial purposes rather than prestige. This office tower is often built as efficient as possible and this results in the American box-office type. Both types are rather autonomous objects. The plinth is often bare with only an entrance making the street rather lifeless and unpleasant.

This autonomy is also found inside the building as offices or apartments are located on higher levels, it is impossible to see what is happening in the street and the surroundings giving a feeling of isolation to the users of the building. Residents go out to work in the morning and return in the evening. The only time they see their neighbors is in the elevator which limits social interaction. Inhabitants also often complain about the lack of greenery in or near the building.

Tall buildings are also notorious as energy consumers. Because of the deep floor plans of office buildings, lighting has become a necessity. Although these problems are recognized and advances in technology reduce the energy consumption. Tall buildings remain to consume a lot of energy.

Although the skyscraper can be considered an American invention, in the last few years most of the new skyscrapers being built are located outside of America. Most of them in are built Arabic and Asian countries. However, apparently, most skyscrapers are still designed by Americans. This causes a globalization of the skyscraper. Although some attempts to put local ideas and culture into the design, most of them are taken too literal according to Wood.

Research on tourism also concludes that high-rise development has a negative effect on tourism. This is especially the case within a cluster of tall buildings: people can feel overwhelmed and insignificant which can lead to stress which is the opposite of leisure and the main goal for tourists. Residents are less prone to these effects because they have grown accustomed with the situation and deal with it more easily than tourists do. This effect is of course more prominent within the cluster of high-rises than it is when viewing the skyline from a distance like for instance on the Peak in Hong Kong.

Not everything about high-rise buildings is bad. They are very capable of doing what they are designed for, having a lot of floor space on a limited area of land. This is cost effective, especially when land values are high. There is a turn over point though, when the building costs per floor become so high that it isn't profitable anymore. Going up has another more sustainable advantage. It takes up less space and thus lowers urban sprawl, leaving more space for nature or parks. Locating more people in a smaller area also means people don't have to travel far and good transportation facilities can be more compact. Locating more people in a smaller area however also means the area is busier and more prone to congestion and so requires better transportation facilities than a larger low rise area with the same average floor space.

These problems can also be found in the city of Hong Kong. Hong Kong is the most densely populated city in the world. According to the Hong Kong Census and Statistics department approximately 7.108.100 people live in an area of 1.104 km². The geography of the area prevents large areas to be developed meaning only a small portion of the total area of Hong Kong is actually built upon. Due to this scarcity of land and the high number of people living in the city, it is constantly being developed with large real estate projects with up to 10 towers on a common base. These huge residential projects show characteristics defining the problems with which many high-rise buildings cope. This scenario forms the basis of a skyscraper design assignment in Hong Kong which addresses the mentioned problems.

If done properly, the CAVE will lend itself perfectly to address the problems of modern high-rise buildings mentioned above. In the CAVE it is possible to see a high-rise design from a human viewpoint. That way the building can be experienced as a user during the design phase. Looking through the user's eyes should give better sense of scale and insight in the cause of the problems and how to resolve them. This way, it should be possible to design a higher quality building in less time. Therefore the goal of the research is to develop a tool with which one can model directly into a cave and after that, design a high rise building with the new tool and addressing its problems. It is important to note that the focus of this research will be on the design

method with the cave modeling tool. The focus will be on the following main question:

Does the possibility to design, work and experience a high-rise in a real size, 3dimensional environment using CAVE-technology give a better insight in the scale and space in the project over 2D techniques, resulting in a design humans can more easily relate to, is better thought off and is made faster?

The following sub questions can be asked:

- Does working in 3d prevent common mistakes in a design rather than having to resolve them?
- Does working in 3d give solutions otherwise not or later thought of?
- Does the 3d environment serve as a better medium of communication with the tutors?
- Does working in 3d save time?

A full literature study on CAVEs, skyscrapers and Hong Kong can be found in appendix 9.2

1.1 Relevance of the research

Although CAVEs already have a widely established positive reputation in the building world, they are mostly used as presentation media or to validate the design at certain moments during the design process. There are some researches in which the CAVE is used as a design medium but only in limited stages in the design process, mainly because of the inaccuracy of the developed tools. No records have been found on a project in which the CAVE was used during all of the design stages. It requires a modeling tool that is able to model accurately. The research therefore is based on a new design method which is potentially faster and more accurate than more traditional methods.

Besides the introduction of a new design method, the research addresses current problems with skyscrapers, providing new insights and recommendations for possible solutions and improvements, rethinking the skyscraper.

1.2 Structure of the report

The report starts with an explanation of the design assignment and the design method with the CAVE that is used. This is followed by a thorough explanation of the final design, explaining how, and for what reasons the design decisions are made. This way, the reader already knows the final product before hand and he or she sees the design evolve gradually towards this final product in the explanation of the design process. After this explanation, the process of the research is described from beginning to end, starting with the workings of the developed scripts used during the design process followed by a step by step explanation on the design process itself. Important decisions which are relevant for the research are highlighted to back up the conclusions at the end of the research and to be able to answer the research question.

2. Research Method



2.1 Requirements

2.1.1 Location

For the design assignment, a location was sought that shows signs of the problems mentioned earlier. Therefore a number of cities were investigated. As a result of this investigation, Hong Kong was chosen as the building location.

Hong Kong is the most densely populated city in the world. According to the Hong Kong Census and Statistics department approximately 7.108.100 people live in an area of 1.104 km². The geography of the area prevents large areas to be developed meaning only a small portion of the total area of Hong Kong is actually built upon. Due to this scarcity of land and the high number of people living in the city, it is constantly being developed with large real estate projects with up to 10 towers on a common base. These huge residential projects show characteristics defining the problems with which many high-rise buildings cope and therefore this is an ideal project location.

Within Hong Kong, a project site was found. The criteria for this site were that it had to be surrounded by residential mega complexes common in Hong Kong. Most of these residential complexes can be found in the newer parts of Hong Kong, namely Lantau Island, Upper Kowloon and the New Territories. Here there is available land still and therefore, more of these complexes can be built. A very suitable vacant lot was found in west Kowloon, in the district of Tai Kok Tsui. This location is also surrounded by several mega complexes and a shopping mall. Also, there are a primary and secondary school nearby as well as Nam Cheong Park. Public transport in the neighborhood is also good. There are bus stops across the street and a train station can be reached within 600 meters. The area is built on land reclaimed from Victoria Harbor and is located west of the old Kowloon inner city area. It is separated from the inner city of Kowloon and Nam Cheong Park by the West Kowloon Highway.



2.1.2 Set of Requirements

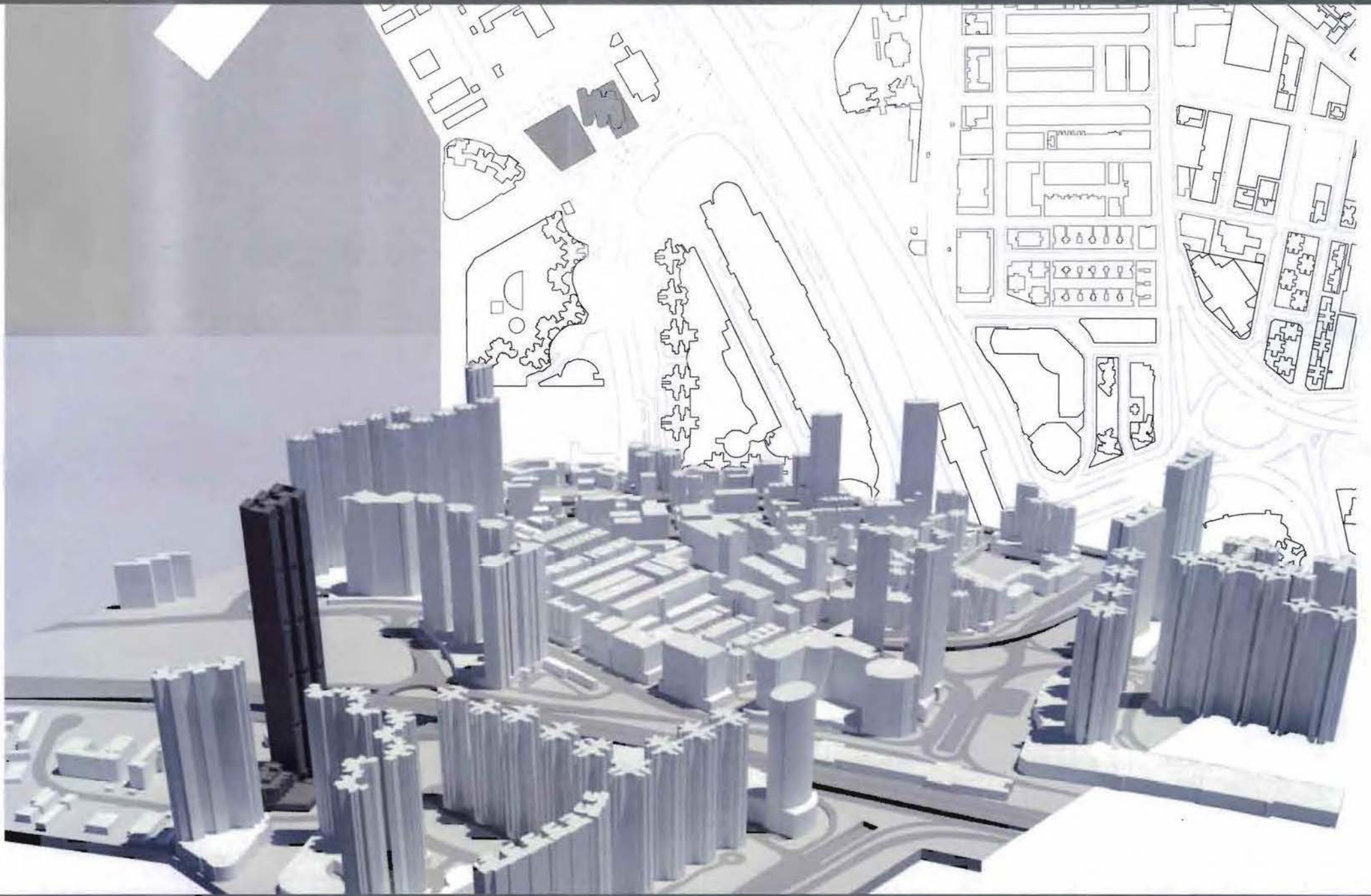
To be able to address certain problems of high-rise buildings, a mixed-use program was preferred. To come up with a realistic set of requirements, several mixed-use buildings were analyzed on office space, number of apartments and when there were shops, retail space. Next to this, the building also has amenities common to residences in Hong Kong including a clubhouse, a swimming pool and a gym. This resulted in the following requirements:

- Apartments: 290 units
 - o 100 triple bedroom
 - o 140 double bedroom
 - o 44 single bedroom
 - o 6 penthouses
- Offices: 20000 m2
- Retail: 2000 m2

The number of parking spaces has been calculated according to the Hong Kong parking standards. For offices, this means 1 car space per 150-200 m2. This means there should be between 100 and 134 office parking spaces. Residential parking spaces can be calculated with the formula: Parking Requirements = GPS x R1 x R2.

GPS is 1 car space per 6-9 flats, R1 is 2,5 for apartment sizes between 70 and 99,9 m2 and R2 is 0,85 because there is a rail station within a 500 m radius. This results in a minimum of 69 parking spaces and a maximum of 103 parking spaces. For retail spaces there should be 1 parking space per 200-300 m2. There should be between 7 and 10 parking spaces for retail.

In total, there should be a minimum of 174 and a maximum of 247 parking spaces.



2.2 Research Method

The research requires the use of the CAVE as the design tool. The desk CAVE at the University of Technology in Eindhoven, a smaller version of a CAVE, works with the program Vizard. Vizard is a 3d viewing environment which is customizable with the help of the Python scripting language. It however is not set up for modeling tasks. Basic modeling tasks could be programmed with the Python script but this would not be enough for this project. Therefore a package was sought in which it was possible to model and view the model. However no package was found that supported the CAVE. Therefore it was decided to keep the modeling and viewing packages separate. This means that the viewing is done with Vizard in the CAVE and a separate computer with 3ds Max was used for modeling.

To be able to quickly switch between Vizard and 3ds Max, the modeling was done on a laptop placed inside the CAVE as can be seen on the picture. Because 2 packages were used, it was necessary to export the model from 3ds Max into a file format that Vizard could read. A special exporter plug in was downloaded from the Worldviz website which exports 3d models from 3ds Max to the .JVE file format which is readable by Vizard. To speed up this exporting and importing process, it had to be automated. This was possible because both programs have a scripting language. By using these scripting languages, it was possible to reduce the exporting and importing sequence to a simple push of a button. How these scripts work exactly, can be read in chapter.....

To be able to test this method with the CAVE, a backup was created every 30 minutes during the time 3ds Max was active. With the help of these backups, a log sheet was created in which it was stated what had been done during these 30 minutes including whether a decision was made with the help of the CAVE. With this log it was possible to see when the CAVE came in handy. It was also possible to see what kinds of modifications were done during the process. By putting them in a graph, it can be seen what kind of modifications take place during certain moments during the process.

Before work could start on the design, a 3d model of the environment was created. This was done to see how the building would fit in its environment. To be able to do this, first a map was created. This map was based on a base map found on the website of the government of Hong Kong. This map was in .jpg format and therefore it was not possible to convert it to a vector based format like .pdf or .dwg. Therefore the map was loaded in illustrator and traced with vector lines. The vector based map could then be loaded into Autocad and 3ds Max to make models out of it. The model includes streets, elevated streets and building shapes that represent the building's height and shape. After this, work on the design was started.



3. The final design



3.1 Design challenges

The goal of the design project was to rethink the way a high-rise building works. This meant various design challenges which are typically found in high-rise buildings had to be addressed in a new and innovative way. Aspects like environmental impact, city integration and social impact are becoming more and more important. This design project responds to these changes and integrates them with the specific design challenges offered by its location in Hong Kong.

As opposed to other major cities, Hong Kong does not have much room for expansion. This is caused mainly by terrain issues and borders. Because available land is scarce in Hong Kong, the city is the most densely populated city on earth. This means that the majority of Hong Kong residents live in tall apartment buildings. This causes a different composition of households that live in apartment buildings as opposed to western cities resulting in a different variation of apartment typologies in the building.

Another important design challenge is created by the B(P)R. The Hong Kong Building (Planning) Regulations state that every room meant for living, preparing food, bathrooms and lavatories required natural ventilation and/or daylight entry. It is due to these regulations that apartment buildings in Hong Kong have a distinct shape. Although, these standards are not obligatory anymore nowadays, they are still widely applied as a standard for better quality homes. Thus these regulations could not just be ignored. The impact these regulations have on apartment buildings is an enlarged façade area to floor area ratio.

3.2 Ideas on skyscrapers

3.2.1 Looking back

Ever since the first skyscraper was built, the main reason for erecting them was making money. This made them as efficient as possible for their time. However as technology advanced in lighting and ventilation, skyscrapers increased in size which was good at the time. Nowadays personal conditions of employees and residents are getting more important. View and natural lighting are more and more demanded. The earliest generations of skyscrapers couldn't rely on technology as much as the current skyscraper can, they had to rely on primitive yet effective methods to optimize conditions. Daylight had to enter as far as possible into the building and also natural ventilation had to be applied. This meant, the depth of the skyscrapers could not be too large or light courts would have to be integrated. Keeping these simple yet effective solutions in mind, together with the currently available technology, increased working and living conditions can be created while keeping environmental impact minimal.

3.2.2 Social issues

A normal daily routine in a high rise building usually consists of people entering the building, taking the elevator and going to the workspace in the morning. In case of residential buildings, this works the other way around. During the evening this process is reversed. This causes people to meet only in the elevators for a brief amount of time. There's a lack of social interactivity and often a cause for complaints. However, some people may prefer it this way, in a place like Hong Kong where everyone is forced to live in apartment buildings, this problem is more profound and a reason for Hong Kongers to spend most of their time outside their homes to 'socialize'. On the other hand, social isolation also occurs on higher floors of tall buildings where there is no view on the streets below, only in the distance. On these levels it is hard to see any activity going on in the city.

to address these issues, there should be a possibility for people to interact

within a building. By introducing collective spaces inside the building people will have a chance to meet each other. If this concept is combined with a balanced mix of functions within the tower, the tower will be busy during every part of the day and the different functions benefit from each other's presence.

3.2.3 Context

Most skyscrapers are autonomous buildings, designed to express the wealth of the company that built them or to make as much money as possible. This often results in a lack of relation to the context. This is effectively most notable in the lower floors of most buildings as these relate directly to the streets around it. The plinth is often left bare and uninviting with only an entrance to the building. The tower rising above the plinth could create an overwhelming feeling especially with people not used to high-rise buildings. In order to better fit skyscrapers into their context, more awareness and interaction to surrounding buildings has to be created. The plinth should be inviting and open to the public making the streets more attractive and lively.

3.3 The Concept

3.3.1 Concept of Partitioning

In the project, social attractiveness plays an important role. The goal was to keep the building simple and understandable and not overwhelming, autonomous and standard. To achieve these goals, the building would logically have to be kept small. However, it still has to fit a program for a tall skyscraper and therefore, keeping the building small is not an option. To fit the program into the building and still manage to keep the building readable, several small buildings would have to be created to form a complex. This idea of partitioning is the basic concept of the building. By merging small buildings into one tower complex by means of stacking them on top of one another, it is possible to create a tall tower and still keep a notion of a smaller scale.

3.3.2 Building Blocks

As a result of the chosen concept of partitioning of the building, it consists of several individual buildings or building blocks. The tower itself is built up out of 5 of these blocks. These blocks can be seen as separate functioning buildings with their own transport system. As a result a sky lobby is created at the base of each building block. It functions as the lobby for the building block and thus all users of the building block pass through it. This way, the lobby functions as a social meeting place on the way to the final destination within the tower.

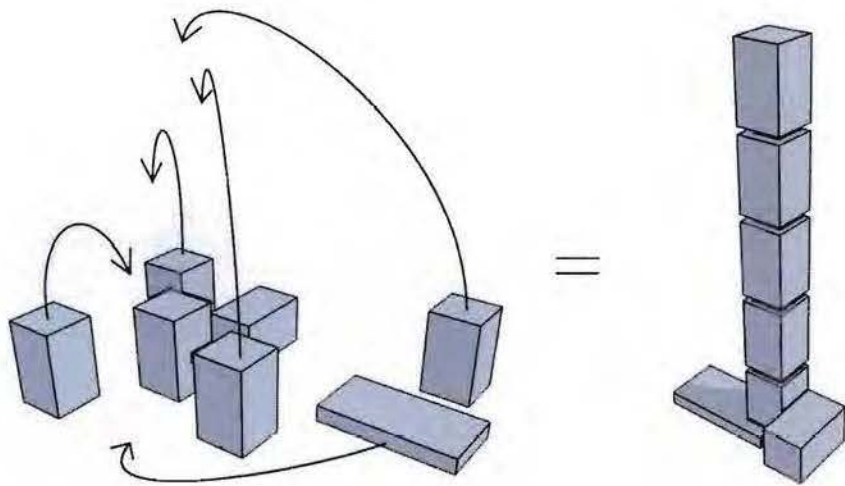
By keeping a mix of apartments and offices within the building block, these functions have a positive effect on each other. By designing the sky lobbies as multistory atria, both the offices and apartments have a view on this interior collective space. This way the lobby functions as a plaza in a city. Due to the combination of functions with a different daily rhythm, the plaza is always in use. It thus works as a virtual exterior space. It keeps the distance between the floors and virtual ground level minimal reducing the social isolation created by living or working on higher floors in a skyscraper. Instead, it creates an attractive, lively view for office workers and inhabitants on their way out

and this way, enhances working condition and sparks creativity. 14 floors high atria however would be too high and wouldn't solve the problems for people living on the upper floors of a building block. For this reason, the 14 floor tall building block is divided into 3 sections. The bottom and the top one always being an atrium and the middle one either being additional office space or mechanical space combined with refuge floors.

3.3.3 Three slabs design

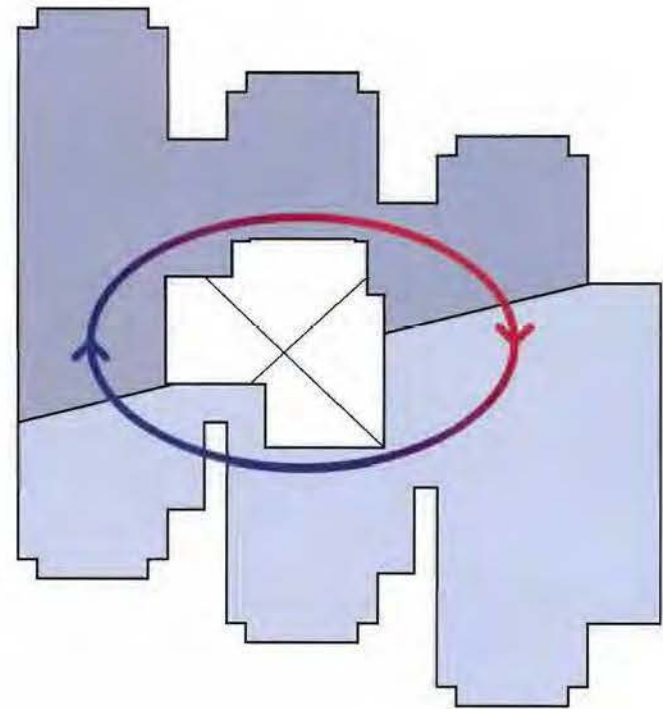
The individual building blocks of the tower are divided into 3 slabs. This is the result of the large façade to floor surface ratio required for apartment buildings in Hong Kong. Due to the combination with offices it was unpractical to suggest a typical Hong Kong residential floor plan for the tower. It would require a hybrid tower with different floor plans for the office and residential parts. The design however had to be kept simple for reasons of understanding the concept behind it, thus more unity was preferred. By dividing the floor plan into slabs and leaving space between the slabs, the necessary façade surface would also be created and the floor plan typology would work for both offices and apartments, increasing the functionality of the building. This way offices could easily be turned into apartments and vice versa based on demand. It also increases the number of much wanted 'corner offices' in Hong Kong.

As a result of the slabs design, light trenches are created along the height of the building. These light trenches provide the needed daylight entry and natural ventilation of the building and help lighten up even the inner parts of the building where the atria are located reducing the need for lighting systems.



Small scale becomes large scale

Buildings with different functions and targets group are stacked together to form the tower. This way, small buildings are combined in one large building creating a social pleasant and vibrant climate on the inside.



Functions

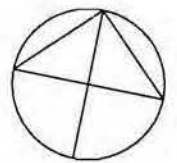
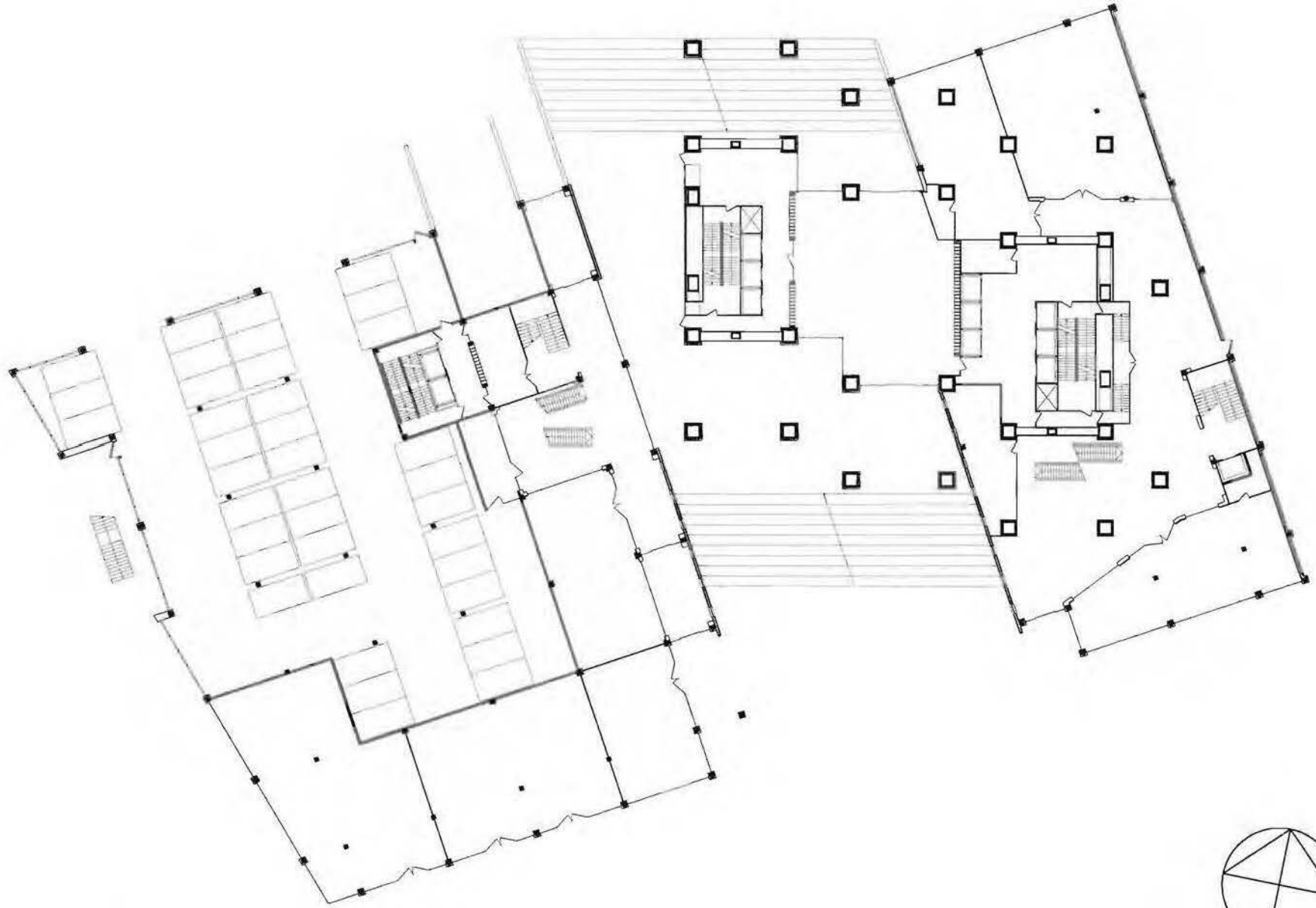
Offices and apartments are located on the same floor improving exchange efficiency of heat and cold as well as creating social interaction between these functions.

3.4 The Building

3.4.1 The concept of the base

The base of the building functions as the transition between tower and city, the connection to the context. For this reason and to be able to house all its functions it is significantly larger in size than the tower itself. It follows the lines created by the surrounding buildings in order to make it fit in its environment. By positioning the tower to the back of the base, the base can smoothen the transition from street to tower. This way, people are not confronted with a sheer wall 300 meters into the sky directly at street level, thus reducing the overwhelming feeling. They are first confronted with a low 3 and 4 story tall base. By filling this base with public retail space and keeping it transparent, it helps to create a pleasant and inviting staying area in contrast to the closed concrete bases of the surrounding buildings.

The base also houses amenities for the inhabitants of the building as well as a small number of apartments. These form a separate building block on top of the actual base smoothening the transition to the tower even further. To be able to reach the tower, a passage is cut out of the base dividing it into two separate blocks. This passage forms the entrance to all parts of the building. The base gradually rises away from this passage in a stepwise manner in order to present the tower at the back. The tower stands rotated on the base. This way, the base follows the lines of the context and lot and the tower faces directly into Hoi Fai Road.



3.4.2 Appearance of the building

Hong Kong's vision is to become Asia's cosmopolitan city. Much like New York is for America and London for Europe. Key points in achieving this vision include strengthening its role as a global and regional financial and business centre and developing as a innovation and technology centre for southern Asia. Therefore they also want to provide good living qualities and enhance the townscape.

Examples of buildings in Hong Kong that carry this vision include the Hong Kong and Shanghai Bank Headquarters, the Bank of China tower, International Finance centre, International Commerce centre, and Summit and Highcliff. These towers formed the inspiration and basis of design for the project. In order to carry Hong Kong's vision a High Tech appearance similar to the buildings mentioned was a suitable choice.

In tall buildings, the building structure plays a dominant role and it has to be considered from the start of the design process. Because of the building concept with sky lobbies and requirements of lighting and ventilation, an open structure was preferred. This together with the High Tech appearance resulted in a steel structure with diagonal braces. This way, it is unnecessary to create closed structural walls or a concrete core structure.

The steel frame structure also helps segmenting the building into smaller pieces. By making the structure visible in the façade, an easy to understand rhythm is created. The structure is divided into 5 parts by façade riggers. These separate the building blocks. Each block is then separated into 3 parts representing the division within a building block. The core of each block is namely divided by a 2 storey lobby with a 4 storey atrium, then 4 stories of extra office space or utility rooms and then again a 4 storey atrium. Each of the 3 parts is then further divided into two parts where the offices and apartments are located. Because of the exposure of the structure, a high tech appearance is achieved. It also helps in understanding how the building works as none of the structure is hidden away in walls. This makes the building appear light and airy even though the structural members are large in size.



Hong Kong and Shanghai Bank Headquarters
<http://picasaweb.google.com/lh/photo/MIE2Czy8ncwUo7icZquXg>



Bank of China Tower
<http://openbuildings.com/buildings/bank-of-china-tower-hong-kong-profile-2547>



International Finance Centre
http://en.wikipedia.org/wiki/File:HK_International_Finance_Centre_200809.jpg



International Commerce Centre
<http://www.travelsfy.com/2011/11/ritz-carlton-hotel-hong-kong/>



the Summit and Highcliff
<http://shafir.livejournal.com/72888.html>



North side of the building



3.4.3 Building Structure

Because the structure is so important in high rise buildings, it had to be taken into account from the beginning of the project. The idea behind the structure is to use the 3 slabs of the design as structural elements. To keep views in the apartments and offices unobstructed, it was not preferred to have diagonals in these parts. This resulted in 6 structural braces in the north-south direction and several smaller braces in the east west direction. Outriggers could be applied on the lobby floors to connect all the structural elements and to make sure all the columns participate in the load bearing structure. This method didn't leave much room inside the building and members would stick through the atria. After calculating a 2D structure with the use of the program Scia Engineer, it was found that the building was very stiff in the north-south direction, but not stiff enough in the east-west direction. This meant that some of the internal members could be removed leaving more space inside the building and extra braces would have to be added in the other direction. This resulted in the construction principle shown on the right. The structure on the left is represented by the green lines, the structure on the right is represented by the red lines.

Because of the asymmetrical shape of the tower, a full 3d analyses was required to accurately calculate translations. This 3d analyses was also performed with Scia Engineer. The total load due to wind that had to be taken into account was 4.0 kN/m^{-2} . The maximum amount of deflection at the top of the structure is $1/500$ of the height. This results in a maximum deflection of 532 millimeters. The maximum deflection in the north-south direction is 371,1 millimeters and the total deflection in the east-west direction is 561,9 millimeters which is still slightly too large. However these calculations were done with hollow columns. If the columns were to be filled with concrete, the stiffness would be higher and the deflection would be less.

The dimensions of the used profiles are as follows:

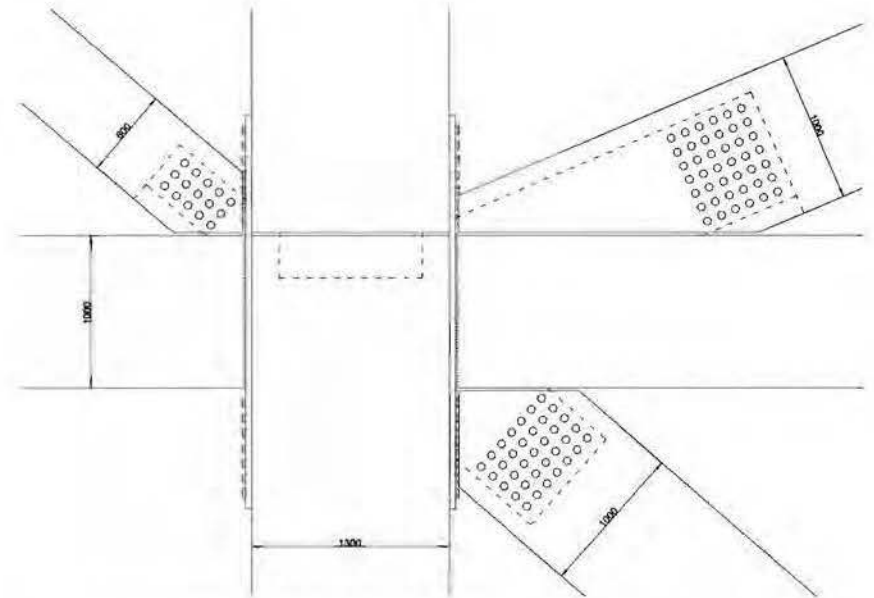
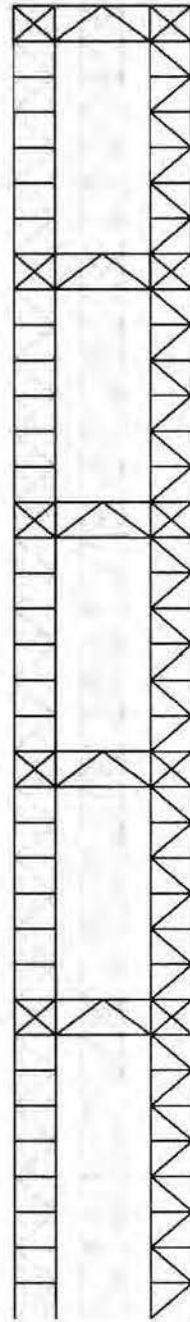
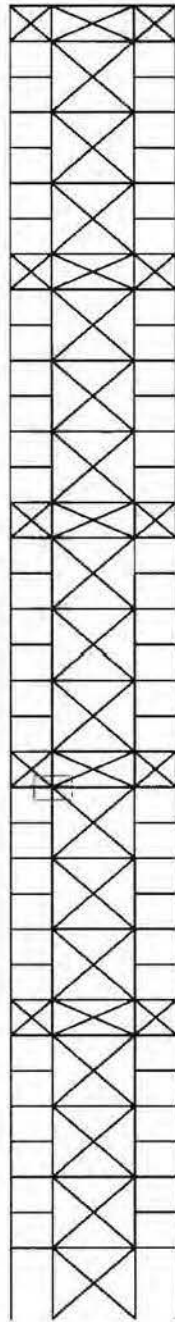
Columns: 1300 x 1300 x 180 mm

Beams: 1000 x 1000 x 120 mm

Large diagonals: 1000 x 1000 x 120 mm

small diagonals: 600 x 600 x 120 mm

All elements are made out of S275 steel.



Scale 1:50 Detail of beam connections

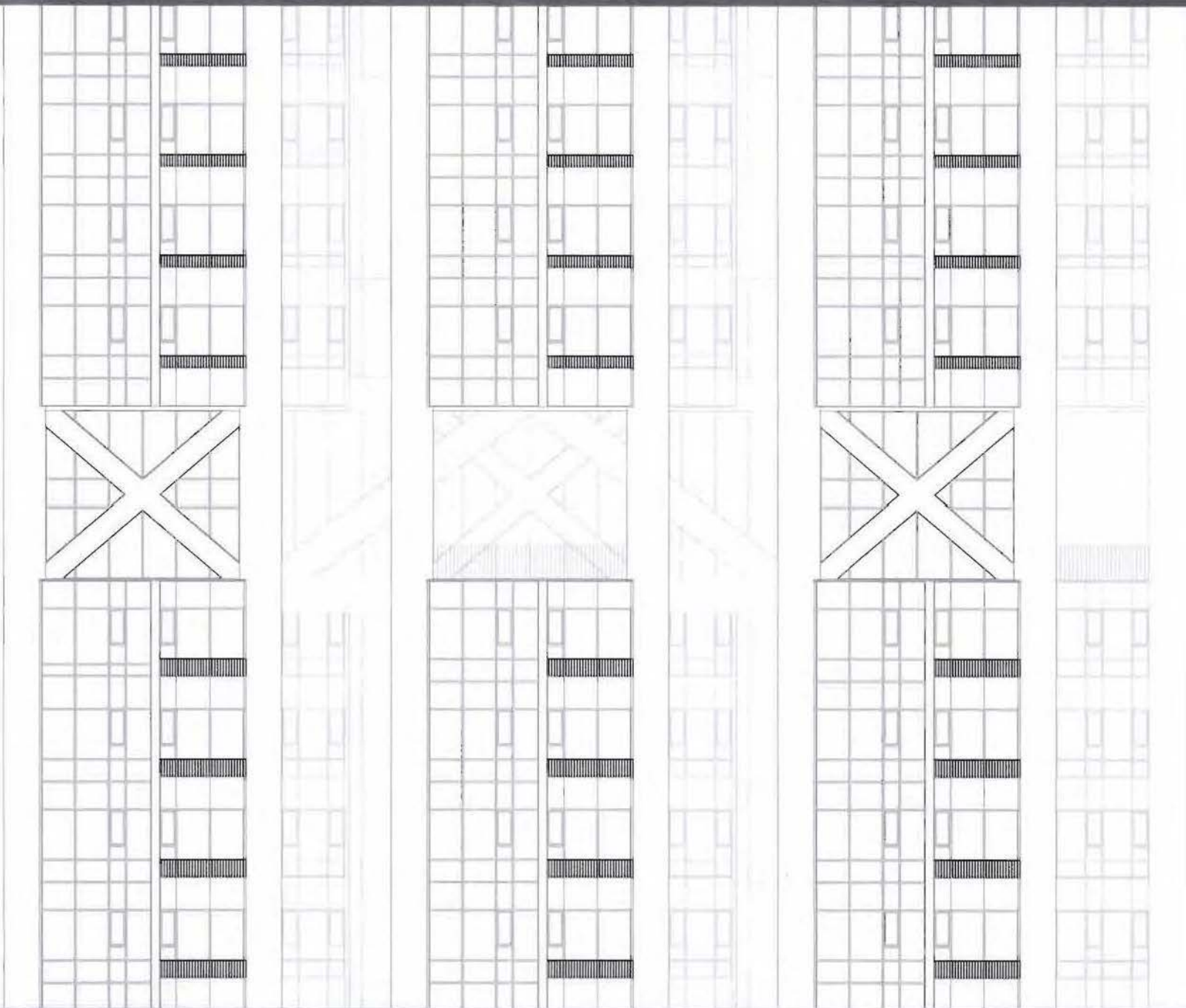
3.4.4 The Façade

Because of the daylight entry in the building, a transparent façade was preferred. However, making a façade completely out of glass with visible structural elements causes a building to look like an office building, which is only partially true for this building. A different kind of façade would have to be designed for the residential part. Creating 2 different façades on a building which forms one unity in all its other elements however seems like an out of place decision. Therefore a façade type was developed that could both act as an office and as a residential façade. A residential façade is often recognized due to its composition of smaller elements such as windows, balconies etc. An office façade is often much more generic with bigger elements. To be able to design a uniform façade over the whole building, common elements of office and residential façades were sought and found in parapets. By adding parapets on the façade pieces that stick out in front of the construction on the north and south sides, these façades look similar in design, yet by applying different materials, one gets a more office look and the other a residential look. This is achieved by adding a warm beige colored stone on the residential side and grey stones on the office side. In addition, the residential façade has a smaller less uniform division. This is achieved by the addition of narrow openable windows, a feature common and necessary in Hong Kong's residential buildings, the division of the façade in two halves and the addition of railings. The division in two halves represents the functions behind the façade. Behind the part with the parapet and the railing, the living room is located. The other is a bedroom.

The same façade on the north side of the building is much more strait forward with no division other than the grey granite parapets.

The east and west façades form the transition. This is represented by vertical strips of stone on the residential parts and a clear glass façade on the office part. The vertical strips represent inner walls meeting the façade. Due to these strips, the residential look is maintained. Because the strips' locations are determined by the connection to inner walls, their positions change up the height of the tower because of the different apartments typologies in different building blocks.

The façades in the light trenches are designed to let as much light as possible into the atria and offices in the building and thus are kept as transparent as possible.



3.4.5 Apartment typologies

The building's location, Hong Kong demanded different apartment typologies in the building. The building therefore contains 108 triple bedroom apartments, 132 double bedroom apartments, 45 single bedroom apartments and 6 penthouse suites. The single bedroom apartments are located in the base of the building. The rest is located inside the tower divided over the building blocks. There are 4 apartments per floor in the tower. They are located on the south and east sides of the building. These sides face the other apartment buildings in the area. The different typologies are divided over the building blocks. The first 3 building blocks contain 3 triple bedroom apartments and 1 double bedroom apartment per floor, the other 2 building blocks contain 4 double bedroom apartments per floor. Furthermore, the triple bedrooms are divided into 2 types, 72 with 2 master bedrooms and 36 with 1 master bedrooms. This has been done to accommodate vertically extended nuclear families which are quite common in Hong Kong. These are families where parents, children and grandparents live in the same home. Due to the division of apartments over the different building blocks, each building block gets a different kind of target group. Namely, parents with children and grandparents, parents with children and childless families.

All of the apartments are laid out in a way which is typical in Hong Kong. This means one enters the apartment through the living / dining room. From this room, all other rooms are accessible. The kitchen is often combined with a storage and lavatory and the master bedroom often has its own bathroom. The apartments on the south side in this building are also laid out to the same principles. The one on the east side is different as the other 3. This one always is a double bedroom apartment.

Triple bedroom type 1

The first type of triple bedrooms are located in the lower two building blocks. These types are designed for families with grandparents and thus contain 2 bigger bedrooms and 1 smaller bedroom. The master bedroom, kitchen and storage are reachable from the living room. The other 2 bedrooms and

the bathroom are reachable from a hallway leading from the living room. Because of the 2 bigger bedrooms in this type of apartment, there's only one bathroom.

Triple bedroom type 2

This apartment type is very similar to the first triple bedroom type. The difference lies in the size of the rooms. Because there is only one big bedroom and 2 smaller bedrooms, the kitchen is transferred to the other side of the apartment. This leaves room for an extra bathroom for the master bedroom. This type is mainly meant for bigger families with children of all ages.

Double bedroom type 1

The first type of double bedrooms is the type located on the east side of every building block floor. It differs from the other apartments because it is much more stretched out. Besides the kitchen with its storage, the other rooms, 2 bedrooms and a bathroom, are reachable from a long hallway leading from the living room. The reason for having this apartment is so that smaller families can live on the lower floors as well without having to pay for an extra room. This way, the program requirements for the buildings are met as well.

Double bedroom type 2

The second double bedroom type is similar to the second triple bedroom type. By removing the extruded part of the building on the south side, the smaller bedrooms are merged into one slightly bigger bedroom. This type of apartment is located in the highest 2 building blocks and is meant for either childless families or small families with children.

Single bedroom type

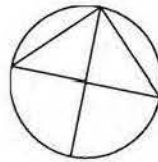
The single bedroom type is located on top of the base. There are a total of 4 rooms in this type, a living room, a bedroom, bathroom and storage room. This type is meant for younger people without children or elderly people.



Triple bedroom type 1a



Triple bedroom type 1b



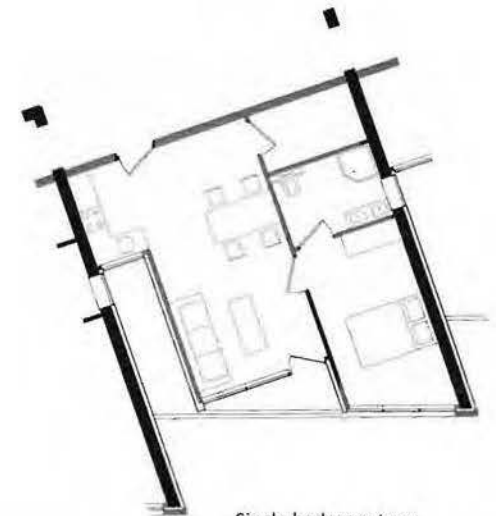
Double bedroom type 1



Triple bedroom type 2



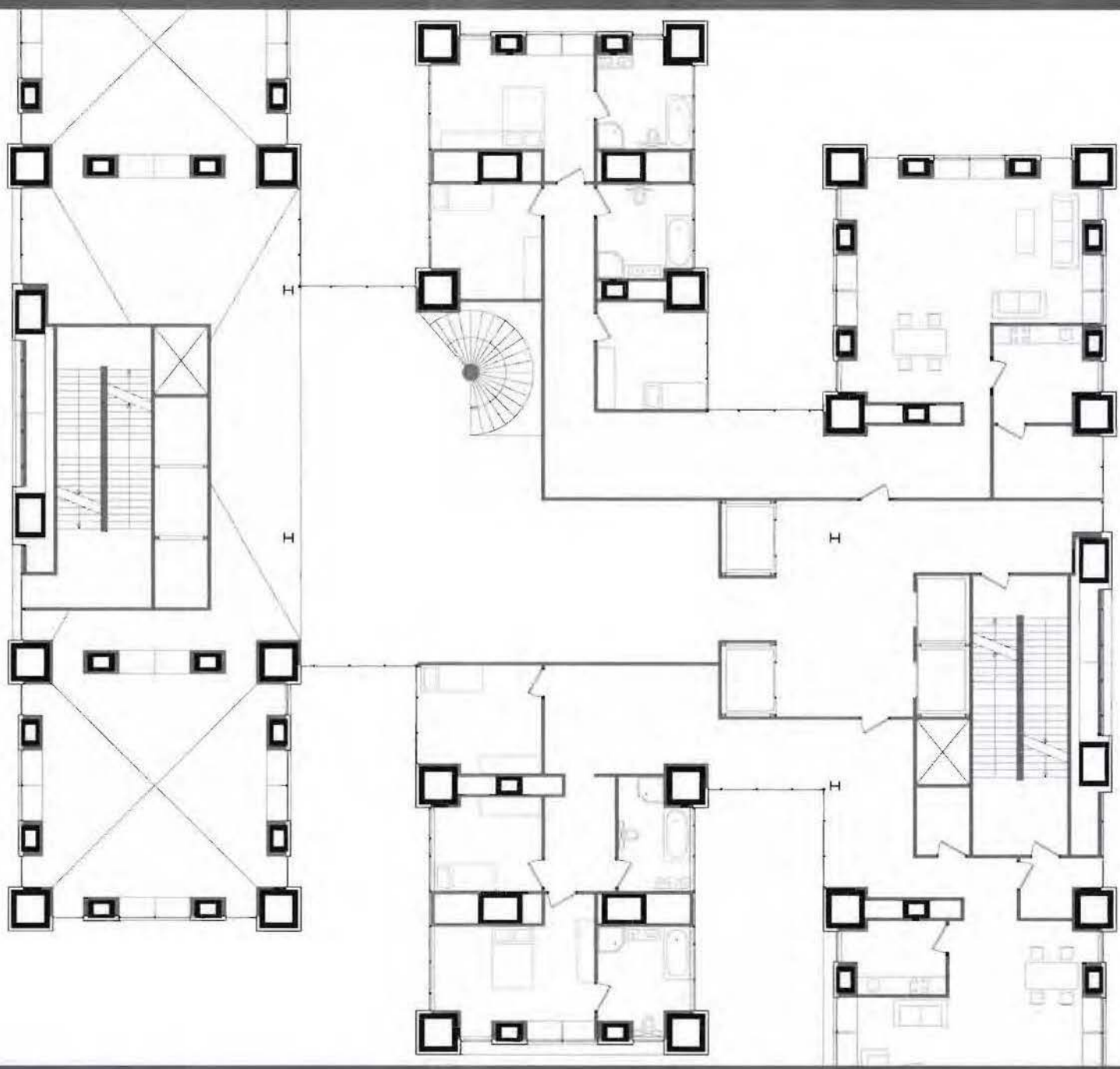
Double bedroom type 2



Single bedroom type

The penthouse type

The penthouses, although all slightly different in plan due to structural elements, all have the same basic principles. Each of the apartments has 3 bedrooms, 2 bathrooms a large living room and kitchen with storage. In total there are 6 of these penthouses, all located in the top floors of the tower. The 2 highest apartments are located underneath the angled roof of the top and thus have an angled ceiling as well.



Floor plans scale 1:200, showing one of the penthouse floors

3.4.6 Apartment design

As said before, every room meant for living had to be located on the outside of the building. This resulted in light trenches. This also poses another design challenge as it shouldn't be possible for neighbors to look into each other's apartment. For this reason, bedrooms are located to the front and bathrooms and kitchens to the back of the light trench. These rooms are used less frequent and have higher window sills preventing looking straight into the opposing room. On the other hand, looking into a light trench gives a totally different experience as opposed to looking outside. This is best illustrated in the picture below. This picture shows a typical living room of one of the apartments. The window to the left looks into a light trench. The window to the right looks to the exterior. As a result, the view from window to the left gives the idea of a narrow street thus giving the illusion that the apartment isn't high from the ground. This helps preventing the feelings of social isolation on higher floors. The front facing window in the living room, however does look out over the city. Because of this, the view from this window, changes along the height of the building. On the lower levels, the streetscape is still visible and you can see things happening on the street below. On higher floors it's only possible to watch into the distance. Because it is impossible to see the ground on higher floors, people may get uncomfortable standing close to a window. For this reason, on lower floors the windows go all the way to the floor and there's a railing placed in front of them. This way, the view is maximized and people can see as much of the streetscape as possible. With every building block up the height. The window sills rise 20 centimeters. This created a solid border and provides a safer feeling. The more profound the feeling can get, the higher the sills. This also causes the views from the living rooms to become increasingly more panoramic which fits the actual view on those heights. The changing heights of the window sills is reflected to the exterior of the building by the increasing height of the stone parapets. The ratio between glass and stone surface changes up the height causing the façade to look more beige on the south or grey on the north side higher up the tower.

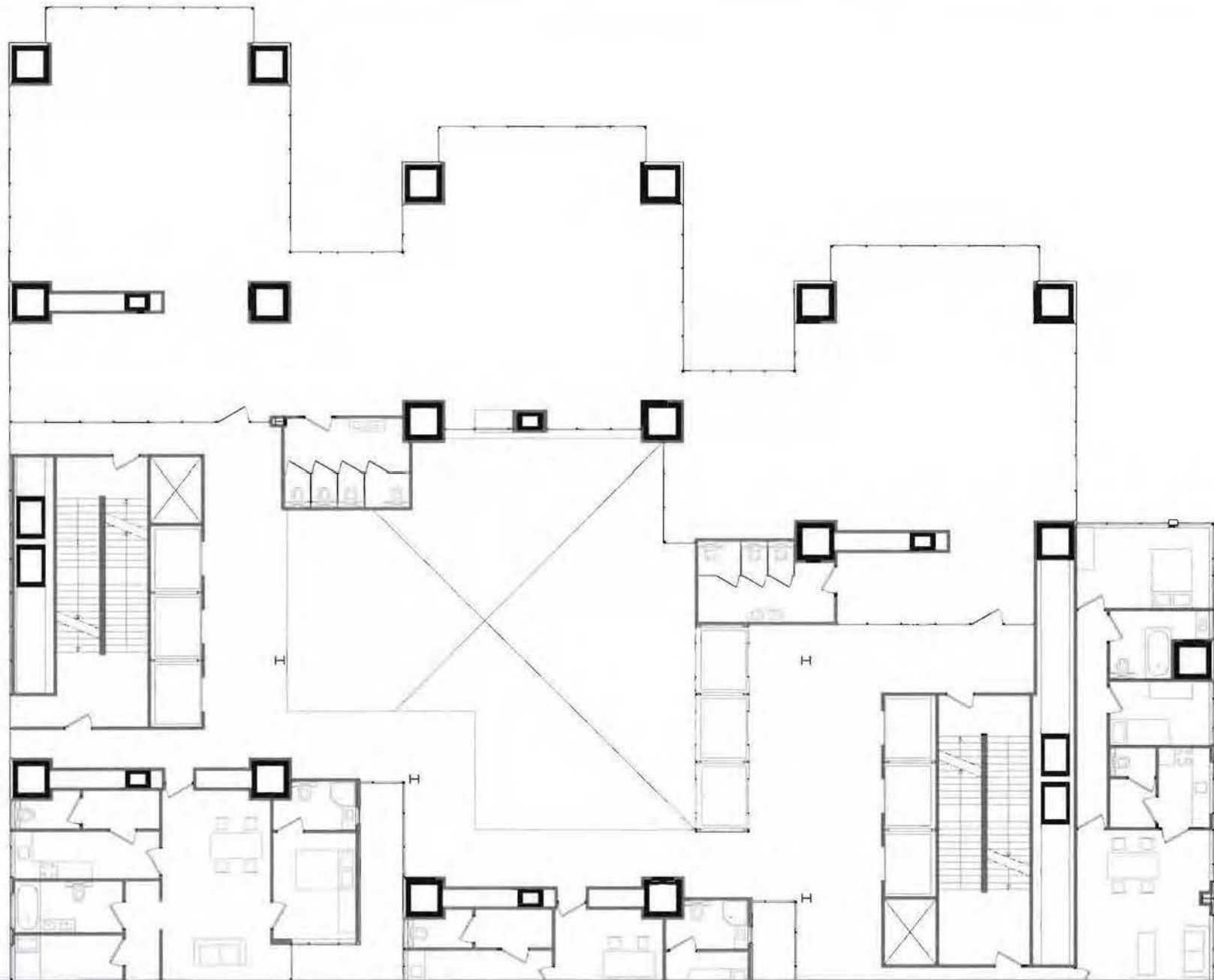


3.4.7 Offices

All offices in the building are located on the north side of the tower. This way, no direct sunlight enters the offices and unwanted effects such as glare and low visibility on computer screens are prevented. By keeping the depth of the offices low and with the addition of the light trenches also present on the south side, the total daylight entry is still high. Due to the light trenches, the amount of façade is increased and thus, more offices are located on the outside of the building. This also increases the desirable corner offices. Offices located on a corner of a building that have an increased viewing angle. The offices look out over the northern part of the city. There's a harbor located directly north of the tower. Behind this, the view consists of more typical Hong Kong high-rise apartment buildings and the mountains of the New Territories. A typical floor in the tower boasts 372 square meters of office space. In addition there are 6 floors that boast an extra 152 square meters of office space located in the centre of the tower. This gives a total of 23232 square meters of office space in the building. Because of the need of refuge floors in a tower of this size, on 3 floors, the offices are replaced by refuge rooms leaving a total of 22116 square meters of office space.

To prevent inhabitants of the building to enter the offices unattended, the offices are closed off from the elevator lobbies by means of a glass wall. The offices can be entered from either the west or the east side although the main entrance is always the one on the east side. This is done because the elevators on this side of the building are the ones used to travel to individual floors in a building block. Near both of the entrances there's a toilet block and room for a pantry or secretary.

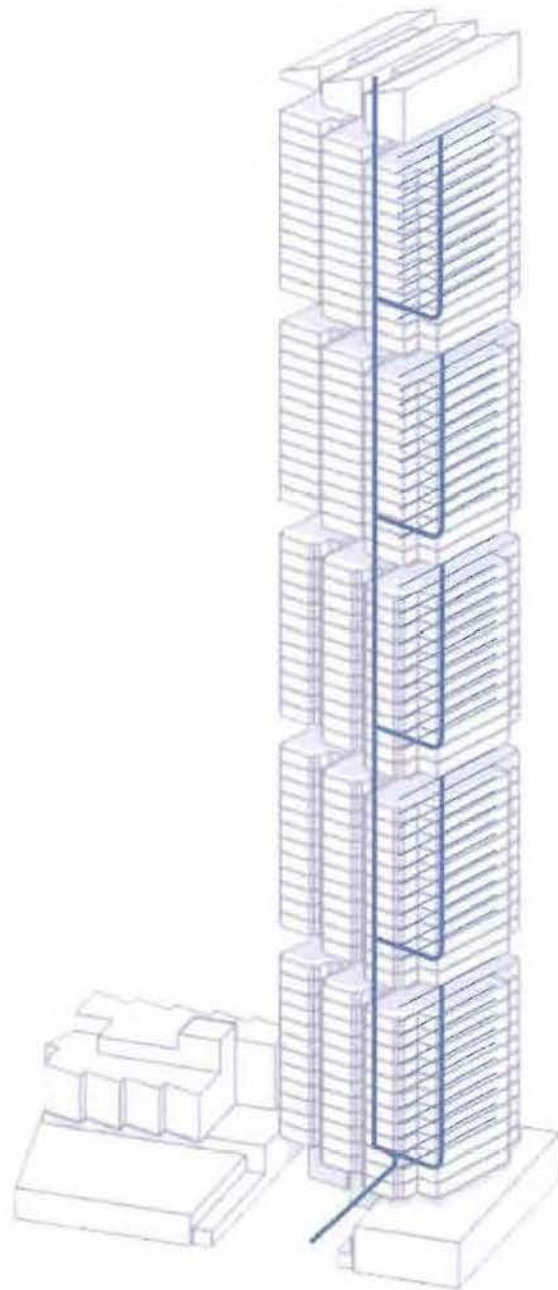
Just like on the south side, the stone parapets on the northern side of the building increase in height per building block. The same reason applies here as for the southern façade. To increase comfortableness and to get a more panoramic view on the higher levels of the building. This way, the façade on the exterior is also more uniform.



Floor plan scale 1:200, showing the typical office floor

3.4.8 Routing

The routing in the tower is kept as simple as possible. People first enter the building thru the entrance in the base of the tower. The tower contains a total of 9 elevators of which 6 are for normal use, 2 are for supplies and there is one fire elevator. The elevators on the west side of the building which can be reached from the lobby by a door on the left, are high speed elevators and normally only stop in the sky lobbies. The elevators closest to the middle are low speed elevators. These stop on every floor within a building block. There is a set of low speed elevators for each building block. On a typical floor in a building block, when exiting the elevator, the apartments can be reached on the right and the offices on the left. Furthermore there are 2 double staircases for safety purposes, these are located behind the left most and right most elevators.



3.4.9 Sky lobbies and atria

Because there are 5 building block, there are 5 sky lobbies as well. All of them have a collective function and thus are not accessible for the general public. All of these sky lobbies have the same floor plan except for the first which is missing the 6 extensions on the north and south sides. This lobby is the hub between all of the amenities in the building and therefore doesn't need extra collective recreational areas. These have thus been left out to create a bigger entrance area for the tower.

All of the lobbies and atria have a different theme based on the target group living in the accompanying building block. With 5 building blocks come 5 different themes. These themes are expressed in a material found best fit with the target group but they are also in some way all used somewhere in the building other than the atria. The 5 themes are: glass, brown stone, plastic, metal and grey stone. All chosen for their expression and atmosphere they create. The glass creates a generic atmosphere being the most used material in the building, thus mimicking the theme of the entire building. This is done because of the hub function of the lowest atrium. It also has the broadest target group being families with children and grandparents.

The second atrium has the brown stone themes. This material creates a nostalgic feeling, resembling the main material used in most colonial buildings in Hong Kong. It creates a rustic atmosphere which fits well with its target group, elderly people.

The third atrium is designed for children. It thus has a much more playful character which is expressed by creating rounded and colorful shapes. It gives a juvenile character to the atrium. The chosen material here is plastic because of its plastic properties.

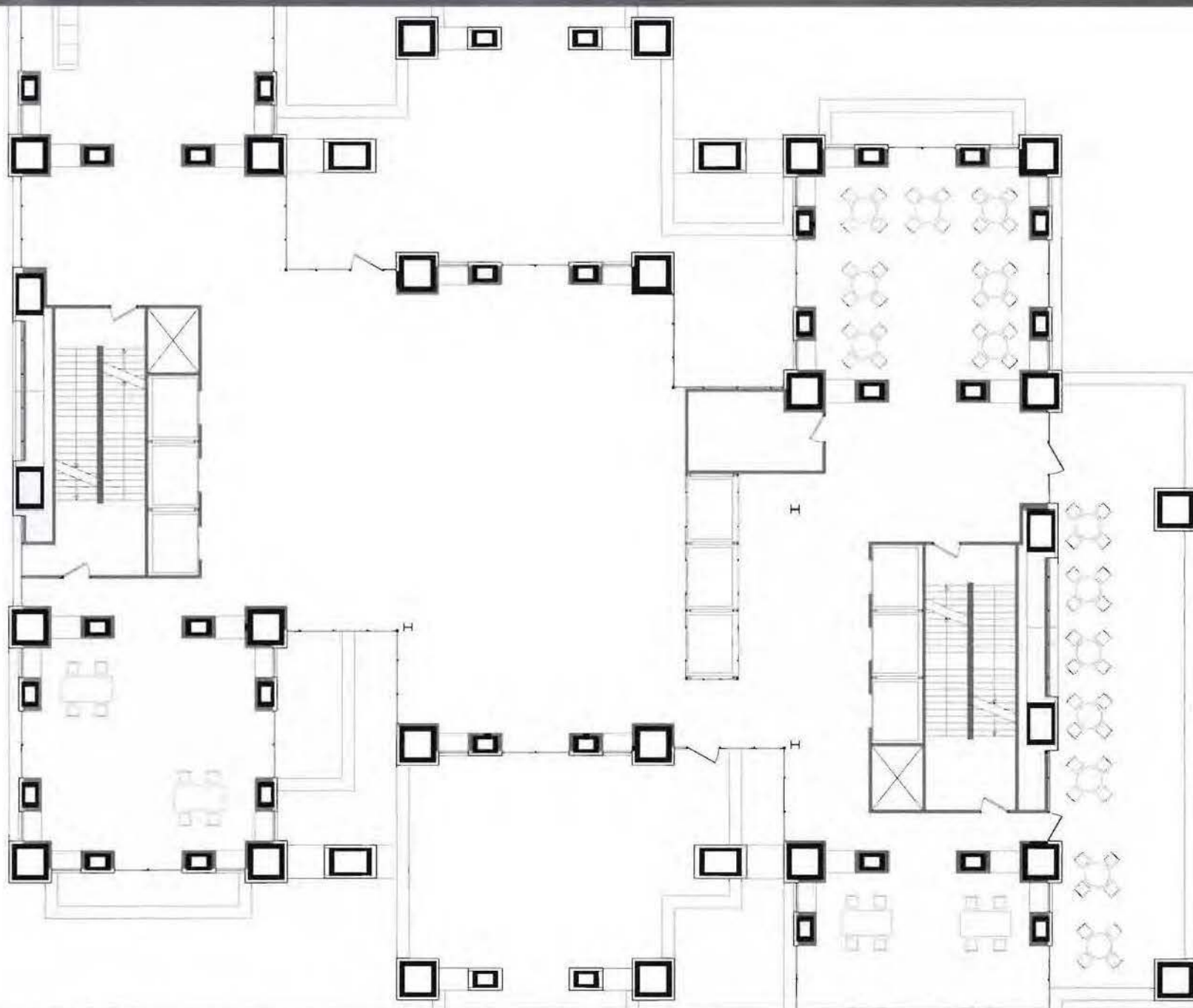
The fourth atrium is designed more towards older children, teens and young adolescents. Therefore this atrium's theme expresses a technological, touch and adventurous character. This fits well with teenagers as they start exploring. To express this theme, metal as the main material is chosen.

The highest building block contains the most expensive apartments and due to this, it is home to wealthy people. The accompanying theme for this is thus

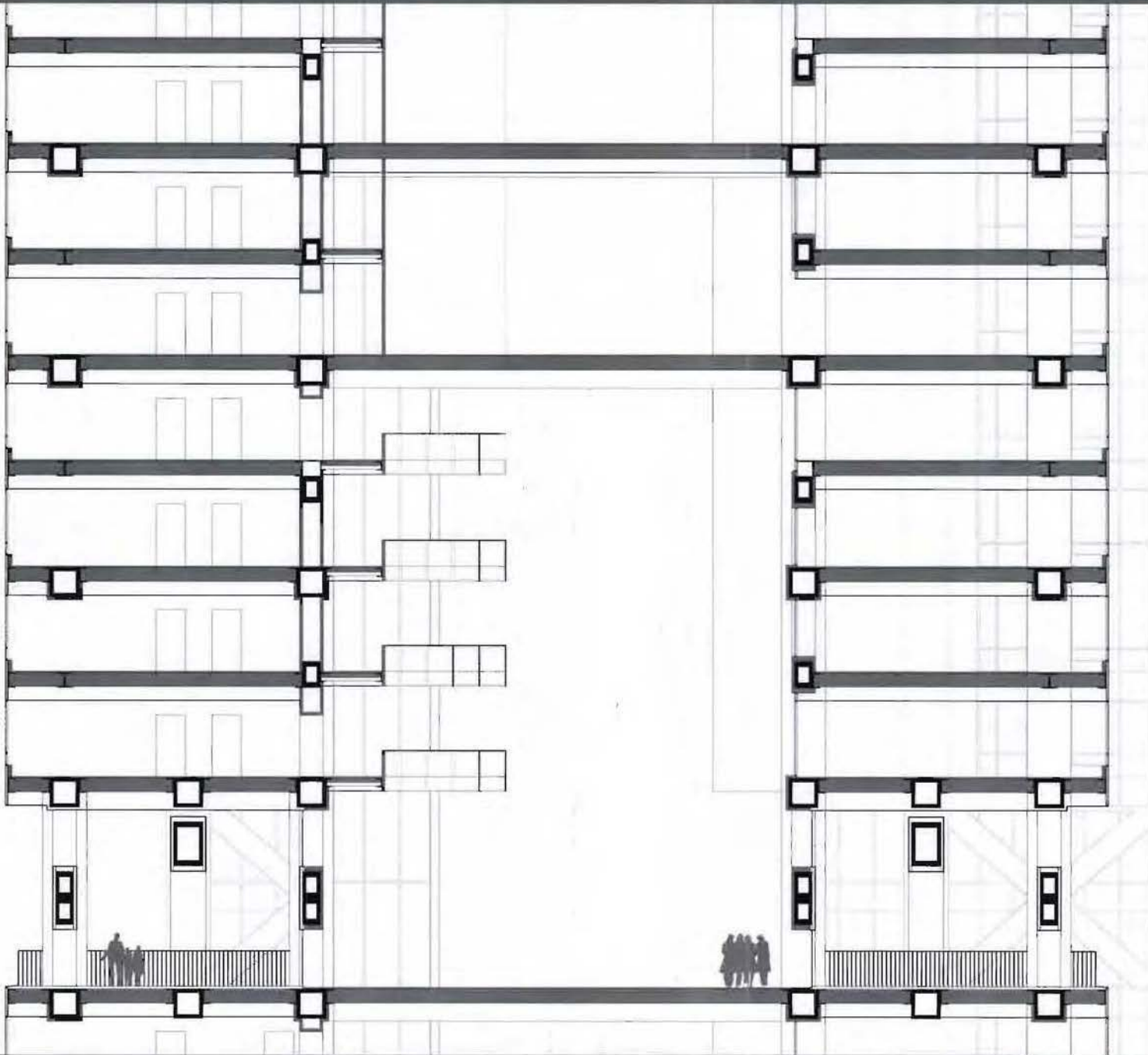
wealthy and business like. To express business and wealth, grey stone was found best. It gives a static and office like atmosphere.

Although all the atria have a different theme, the design rules that apply in them are all the same. These rules apply to the four inner façades of the atrium. The north and east side are the same in all the atria. Behind these façades, the offices and elevators are located. The other 2 façades give the atria their theme. These 2 façades are different in treatment due to their nature. The south side contains walkways and the west side contains fixed floors. This difference in nature is expressed in the applied direction of the elements. For the walkways, the direction is horizontal. The south facing façade is thus treated with parapets and railings. The west side is treated with vertical elements resulting in a wall with holes. This wall always reaches all the way to the ground floor of the atrium while the parapets on the south side do not.

Each building block is divided into 3 interior areas. This is done to limit the height of the atria and to create extra space for office space or mechanical rooms and safety rooms. This makes that each building block contains 1 sky lobby and 2 atria. The 2 atria of a building block are the same in theme. The bottom one is combined with the sky lobby creating a bigger space while the top one only contains the interior atrium without the extended collective areas on the north and south sides.



Floor plan scale 1:200, showing a sky lobby



Glass atrium

The glass atrium is the first of the atrium. It gives direct access to the sports club, roof gardens and the bridge leading to the west side of the base and the rest of the amenities. For it to be able to give access to the roof gardens, a stairs is located in the atrium as well.

The glass theme is expressed in the railing, which is similar to the railing in the shopping mall and a glass curtain wall, also similar to the wall separating the shopping mall with the amenities. This is combined with brown marble flooring also found in the shopping mall and accents of granite in the walls. As a whole, this atrium thus only consists of elements borrowed from other parts of the building expressing the generic character of it.



Brown stone atrium

The elements in the brown stone atrium are arranged in a way to form a typical colonial façade with extruded vertical columns and parapets in between them. The walkways have the same system although they don't feature the vertical columns leaving only the parapets. Due to the brown color of the stone, the atrium gets a warm feeling. This is further enhanced by the colonial garden theme of the sky lobby with its patches of grass laid down in a geometrical shape. Here elder people can sit down on one of the park benches to chat or read a newspaper. The four outer extensions of the sky lobby contain areas for playing games or watching television. The 2 extensions in the middle are open terraces where people can sit and enjoy the view.



Plastic atrium

The concept in this atrium was to create a wall with rounded holes in it creating a playful look. Behind these holes, sitting areas are located where children can sit and play individually or in a group. To prevent children from climbing in these holes and falling, the holes are partially filled with railing with glass infill. Like the brown stone atrium, the south side of this atrium also has parapets to keep the vertical nature of the walkways.

The ground floor of this atrium is a combination of a winding path and grass patches for children to play on. The four outer extensions are also all meant for playing purposes containing sitting out areas designed in a similar fashion as the sitting areas behind the holes, a small football field and a multistory playground.



Metal atrium

To create the industrial feeling in this atrium, the wall is covered in metal panels. To create a dynamic effect, the panels are all extruded in 10 cm increments. The rule is that no panel is in line with its neighbors. The parapets apply to the same rule, consisting of segments equal in width with the panels on the west side. The panels and parapet segments are all perforated and filled with noise dampening materials to prevent strong echo effects caused by the use of metal.

The four outer extensions of the sky lobby contain different functions including a bar, a sitting out area and gaming room.



Grey stone atrium

The west side wall in this atrium is built up out of narrow 600 millimeter wide granite panels to resemble a static office façade. To tone down the office feel of the wall, a brown marble floor together with a wooden platform and planters is added to create a warmer feeling. This together with the granite wall causes the overall atmosphere to be high end and classy.

In this atrium, the four outer extensions and the central court are lounge areas where people can sit, relax and enjoy the view. There is also a bar with views over the city.



3.4.10 Appearance of the base

The base contains several different functions including parking, shops and restaurants, amenities for the inhabitants and housing. The same principle applies here as in the tower. This means the functions have a shared entrance improving social interaction here as well. This shared entrance is formed by the lowest part of the base. This however is only true for the left part of the base because the right part solely contains retail space. This lowest part of the base forms a passage leading into the base. Ultimately it splits in a route further into the shopping mall part and a route towards the elevator lobby for the inhabitants of the base.

Because one of the challenges of the design assignment was to create an inviting plinth for the building it is kept as transparent as possible. This way, people can see what happens inside the building. Due to the shops and restaurants in the base, the sight into the building is vibrant and thus attractive.

The need for transparency in the façade asked for a façade made of glass. This was also a logical choice to make it fit with the tower because it also consists for the most part of glass. However most of the façades of base structures in the neighborhood are closed concrete shells. Thus connection to the context was sought in other aspects including direction, height and composition of form. Bases containing shops is also uncommon in the area, however in the older parts of Kowloon on the other side of the West Kowloon Highway, shops are very common. Although these buildings are also made out of concrete, their typology is very different. These buildings don't have a base and are built very compact against each other. The ground floor most of the time contains shops and it is laid back from the middle part of the building. The top floors are often laid back as well creating an extruded middle part. To make a reference to this part of Kowloon, the design also has an extruded middle part.



The shopping malls

The shops and restaurants are divided over the 2 parts of the base but their design is the same. Hong Kongers are fond of luxury and shopping. To attract people, the design should be luxurious but also warm and intimate. To create a pleasant shopping atmosphere and to keep in line with the high tech design of the building, a combination of warm colors is used as well as references to the rest of the building. In all this resulted in large storefront windows framed in the same grey stone as used in the offices, a combination of neutral white and warm red plastered walls and multistory voids not only housing the escalators but also creating a visual link between the shopping mall and the amenities. In total, the shopping malls contain 2904,5 square meters of retail space.

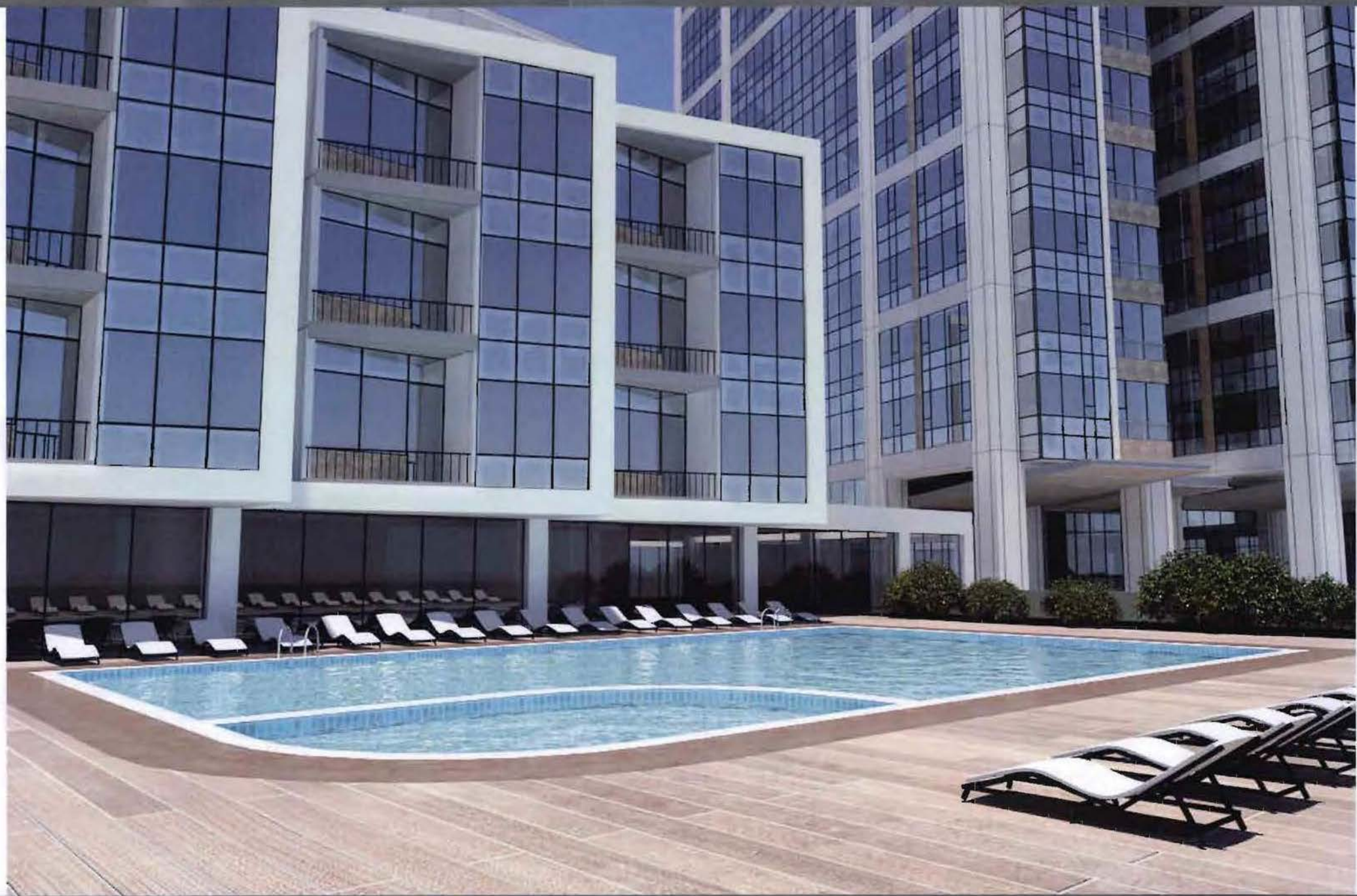


The base apartments

The apartments in the base of the building are located on top of the left part of the shopping malls. There are a total of 45 single bedroom apartments here. The design forms a hybrid between the tower and the rest of the base. Although, like the rest of the base, the apartments are rotated relative to the base, Their front facing façade is rotated into the same direction as the tower. This together with the required light trenches also present, mimic the 3 slabs design concept and thus creating a horizontal extension of the tower. For the same reason as has been done in the tower, the apartments are framed. This creates clusters of either 3 or 6 stories keeping the whole clear and easily understandable by accentuating the edges of each stack of apartments. Like the apartments in the tower, these apartments are located around an atrium which forms a small collective space.

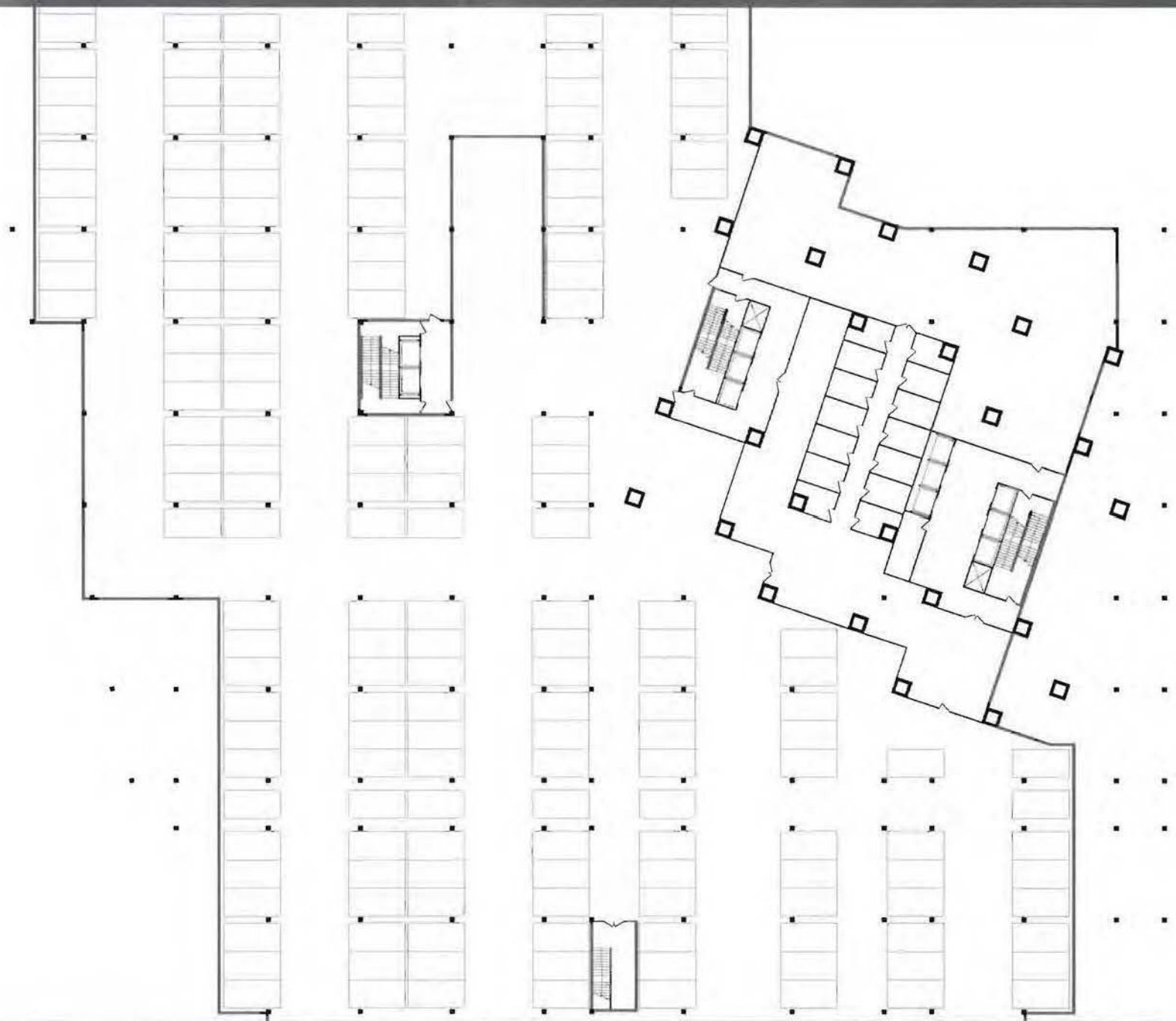
Amenities

Between the shops and the apartments there's a floor of amenities. This includes a fitness club, a clubhouse and a swimming pool on top of the roof of the shopping mall. These amenities are available for the inhabitants only and thus can only be reached from the tower or the apartments on the base. Therefore, the lowest of the sky lobbies in the tower forms a gathering place from which the amenities can be reached. The fitness club can be reached directly from the lobby, the other amenities can be reached via a bridge to the left part of the base.



3.4.11 Parking

Most of the parking places are located underground underneath the plaza in front of the building and underneath the base. There are a few parking spaces above ground as well. In total there are 177 parking spaces below ground and 38 parking spaces on ground floor level. The total number of 215 parking spaces lies between the minimum of 174 and a maximum of 247 parking spaces.



4. The Scripts

The basis of the design method with the CAVE consists of 2 programs, 3ds Max for 3d modeling the building and Vizard for viewing the building in the CAVE. To view a 3d model with Vizard however, it is needed to export the 3d model to the .IVE or .OSG file format. An exporter for 3ds Max can be downloaded on the Vizard website. It however takes a lot of time to export a file from 3ds Max and restart Vizard whenever a change is made. Luckily, both 3ds Max and Vizard have the ability to be customized using scripts. Thus a script was written for both programs. Together, these scripts reduce the export and import sequence to a single push of a button, leaving more uninterrupted time for designing and modeling. In addition, a backup system had to be made to generate backups every half an hour. These are necessary for the research as well as providing a backup in case of a crash and data got lost. This way, the maximum amount of data lost is reduced to half an hour. This backup system is implemented in the 3ds Max script. A step by step explanation for both the 3ds Max export script and Vizard import script is given below.

4.1 3ds Max exporter script.

The task of the 3ds Max exporter script is to export the scene with just the click of a button. This greatly reduces the time and effort needed to export a file. In addition to this, a backup system is also integrated into the script. This backup system saves a new copy of the scene every half an hour. The script automatically arranges the files by date and time to keep the data clear. It does this by creating a new folder for every scene based on the name of the Max file. After this, a system of folders is created to keep the files separated by date. The actual backup files are named according to the saving time. The whole script is written in the Maxscript language, an easy to understand scripting language for 3ds Max. To be able to comprehend the inner workings of the script, here follows a step by step explanation.

The script consists of two separate parts, the export part and the backup part. The export part consists of 3 functions and requires a small text file named 'pvmexported.ini' to work. This file is retrieved in the first line of the

code. The file is used to store the export path of every file. Without it, the path would have to be specified each time an export is done. Or else all files would have to be exported to the same directory because the script loses its memory as soon as it is closed. The actual script is triggered by pressing a button. The pvmexport rollout is created at line 41. It contains two buttons each triggering a different function. The export button triggers the exportIVE function at line 23. This function first triggers the enterpath function at line 3 in order to check whether the filename of the scene is in the 'pvmexporter.ini' text file. If it is, it prompts you to enter a new file path. If it is, it retrieves the file path which is stored with the filename which can then be used to export the file to. This is again done back in the exportIVE function. At line 26, the exportIVE functions then checks for a layer called 'hidden' in the scene and hide it if it exists. This layer is used for objects which are needed in the scene but should not be exported. The scene can now be exported. This is done in line 31.

For Vizard to be able to notice a file has been updated, a small text file is saved. The 'last modified date' of this 'exportdone.ini' has then been updated which is noticed by Vizard. Last, the 'hidden' layer is unhidden and work can be resumed.

The other button, the 'Project Folder' button of the pvmexport rollout lets you change the file export path. What it does is basically delete the file name from the pvmexporter.ini file and runs the enterpath function explained above. The file name is deleted with the 'newpath' function on line 17.

```

1 global gINIFile = (getDir #maxroot) + "scripts\startup\pvmexporter\pvmexporter.ini"
2
3 fn enterpath =
4 (
5   if (hasINISetting gINIFile "Configuration" maxfilename == false) then
6     (
7       messagebox "please specify the project path"
8       global filepath = getSavePath caption:"Select Project Folder" initialDir:"C:\\"
9       setINISetting gINIFile "Configuration" maxfilename (filepath + "\\")
10    )
11   if (hasINISetting gINIFile "Configuration" maxfilename == true) then
12     (
13       global filepath = getINISetting gINIFile "Configuration" maxfilename
14     )
15  )
16
17 fn newpath =
18 (
19   delINISetting gINIFile "Configuration" maxfilename
20   enterpath()
21 )
22
23 fn exportIVE =
24 (
25   enterpath()
26   layer = LayerManager.getLayerFromName "hidden"
27   if (layer != undefined) then
28     (
29       layer.ishidden = true
30     )
31   exportFile (filepath + getfilenamefile (maxfilename) + ".ive") #noPrompt
32   INIstuff = openFile (filepath + "exportdone.ini") mode:"w"
33   close INIstuff
34   messagebox "scene is exported" title: "Export"
35   if (layer != undefined) then
36     (
37       layer.ishidden = false
38     )
39  )
40
41 rollout pvmexport "PvM OSG Exporter"
42 (
43   button export "Export OSG" width:140
44   button filepath "Project Folder" width: 140
45

```

The second part of the script is the backup part. It starts with a timer rollout. This rollout contains a timer created at line 70 which triggers a function every 1800000 milliseconds, or once half an hour. The timer rollout displays a number indicating the number of backups made. The timer triggers the 'createbackup' function. This function gets the current time from the computer system. This returns an array from current year to current second. Next the function creates a directory with the date and filename as a name. It does this in the already existing backup folder in the 'my documents/3dsmax' directory. In line 65, the filename for the backup is created. This is basically: hour.minute.second.max. It is then saved in the previously created directory. With the backups it is possible to trace back which work was done when and it forms the basis of measurement for this research.

```

46     on export pressed do exportIVE()
47     on filepath pressed do newpath()
48 )
49
50 fn createbackup =
51 (
52   if (maxfilename != undefined) then
53     (
54       s = getLocalTime()
55       day = s[4] as string
56       month = s[2] as string
57       year = s[1] as string
58       hour = s[5] as string
59       minute = s[6] as string
60       second = s[7] as string
61       c = hour + "." + minute + "." + second
62       date = day + "-" + month + "-" + year
63       filename = " " + maxfilename as string
64       makeDir ("C:\Documents and Settings\Paul van Montfort\Mijn documenten\3dsMaxDesign\autoback\afstudeerproject\\" + date + filename )
65       backup = ("C:\Documents and Settings\Paul van Montfort\Mijn documenten\3dsMaxDesign\autoback\afstudeerproject\\" + date + filename + "\\\" + c + ".max") as string
66       savemaxfile (backup) usenewfile: false
67     )
68 )
69
70 rollout test "Test Timer"
71 (
72   timer clock "testClock" interval:1800000
73   label test "1"
74   on clock tick do
75     (
76       createbackup()
77       valUp = (test.text as integer)+1
78       test.text = valUp as string
79     )
80 )
81
82 createDialog test
83 cui.RegisterDialogBar test
84
85 createDialog pvmexport
86 cui.RegisterDialogBar pvmexport
87
88 addRollout pvmexport rolledup: false

```


4.2 Vizard importer Script

The Vizard importer script is the counterpart of the 3ds Max exporter script. Its task is to automatically notice a new file has been exported by 3ds Max and then load the new model. Because Vizard is based on the python scripting language, it is very easily customizable and it was possible to implement a lot of extra features that helped designing the building. Due to this, the final script became a lot longer than needed for the import function. The actual import script is just a fraction of the total script. It is displayed on the right.

The script works by checking if the 'exporthdone.ini' file is updated every second. The exporthdone.ini file was refreshed by the max scrip each time a file was exported and thus the modified time changes whenever an export sequence was performed.

First a scene, a model and test1 need to be defined before the script is executed. The scene is the name of the file that has to be imported. The other 2 are defined by the script later on so they are set to 'None' for now. The definition that controls the import is called every second. This is done in the last line of code. The first thing the definition does is check the modified date of the .ini file and saves that time in 'test'. 'Test' is then compared to 'test1'. On startup, test1 was set to 'None' which means that in the beginning test is not the same as test1. The definition then sets test1 to be the same as test and it checks if the model is already loaded. This way, the next time the definition runs and the exporthdone.ini file isn't updated, 'test' will still be the same as 'test1' causing nothing to happen. If the model isn't loaded yet, the script simply loads the model. If it already is loaded, the model is removed first and reloaded.

The 3ds Max export script and the Vizard import script together form the basis of the design method of this project. They automate the process of exporting and importing and this way, significantly reduce the time needed compared to doing the same procedure manually. They are simple yet effective.

```
scene = 'gebouw.IVE'  
model = None  
test1 = None  
  
def checkmodel():  
    global model  
    global test1  
  
    test = os.path.getmtime('exportdone.ini')  
    if test == test1:  
        pass  
    else:  
        test1 = test  
        if model == None:  
            model = viz.add(scene)  
        else:  
            model.remove()  
            model = viz.add(scene)  
  
vizact.ontimer(1, checkmodel)
```

4.3 Additional functions in the Vizard script

The script in Vizard was extended with much more functionality besides the import function. This was done to make the model more lifelike. Additional functions that were implemented include animated people, the ability to open doors, the ability to operate elevators and moving escalators. All these functions make the model much more realistic. In order for these functions to work, it was however necessary to take them into account while modeling in 3ds Max. Therefore a small library of models including doors, elevator systems and escalators was made on which the script would work. These models were then used in the building model. To understand the working of the script, here follows a step by step explanation:

In the first few lines of code, a lot of assets are defined that are used in the rest of the script. Line 1 to 7 import a few additional functions preprogrammed in Vizard. They are used throughout the rest of the code and they are necessary for some of the functions to work. Line 9 sets the antialiasing or the softness of the edges of the model being displayed. Next a skybox is added in line 11 to 18. This is the horizon being displayed. This actually is a separate model of a box with textures applied. By linking it to the Main View, the view the user has, it always appears in the same place relative to the main view.

After this, some variables and lists are defined used later on in the code. The environment which is added is actually the surrounding city model and usquare is a building located in the distance but which was important to add to the model.

In line 35, the first definition is presented. This is the same definition as the one already explained earlier, however the actual definition is much more comprehensive. In it, the 3 lists defined in lines 22 to 24 are filled with data. For all 3 lists, the script checks every object in the model and compares all the names of the objects with some defined conditions. If the conditions are met, the object is put in the list. For `modelnodenames`, these are all door objects (`ispivotdoor(name)` is actually a separate function defined on line 159). This is later used for the ability to open doors. In `modelnodenames2`,

`escalator` objects are added for working escalators and in `modelnodenames3`, elevators are added.

In line 73, billboards are defined. These are objects that always face the view. This is used for simulating trees or people without the need of having complex geometry. This way, a simple picture of a tree or person can be used which then always faces the user.

```

1  import viz
2  import dswalker
3  import vizinfo
4  import vizact
5  import os.path, time
6  import vizdlg
7  import viztask
8
9  viz.setOption('viz.antialias', 4)
10
11  skybox = viz.add('skybox.IVE')
12  skybox.disable(viz.DEPTH_WRITE)
13  skybox.disable(viz.LIGHTING)
14  skybox.disable(viz.PICKING)
15  skybox.appearance(viz.TEXMIPMAP)
16  viz.MainView.setPosition((35.62, 1.82, -135.4))
17  skybox.setPosition(viz.MainView.getPosition())
18  viz.link(viz.MainView, skybox, mask = viz.LINK_POS)
19
20  scene = 'gebouw.IVE'
21  model = None
22  modelnodenames = {}
23  modelnodenames2 = {}
24  modelnodenames3 = {}
25  test1 = None
26  input = None
27  environment = viz.add('hongkong.IVE')
28  usquare = viz.add('unionsquare.IVE')
29  environment.disable(viz.PICKING)
30  usquare.disable(viz.PICKING)
31
32  environment.drawOrder(1)
33  usquare.drawOrder(2)
34
35  def checkmodel():
36      global model
37      global modelnodenames
38      global modelnodenames2
39      global modelnodenames3
40      global test1
41
42      test = os.path.getmtime('exportdone.ini')
43      if test == test1:
44          pass
45      else:
46          test1 = test
47          if model == None:
48              model = viz.add(scene)
49          else:
50              model.remove()
51              model = viz.add(scene)
52
53      modelnodenames = {}
54      for name in model.getNodeNames():
55          if ispivotdoor(name):
56              node = model.getChild(name)

```

From line 82 to line 95, a lighting rig is defined. By standard, the scene is illuminated by a headlight. This is a light always facing the direction of the view. This means, light always comes directly from the user. In this case, fixed light is preferred so the headlight is disabled. Instead, 3 new lights are added, each with a different intensity and rotation. This is done to illuminate all parts of the scene. By giving them different intensities, shadow effects on surfaces in different orientations are simulated. One of the lights acts as a sun, being the brightest and facing downwards at an angle. The other 2 are used for simulating indirect lighting.

After all this, the main window and dswalker are loaded. Dswalker is a script provided by the TU Eindhoven which provides a walking and collision system. The clipping planes and eye height are adjusted as well. In line 103, the script creates a variable when the CAVE is used. This is necessary because some functions work different in the CAVE as opposed to a normal screen. The first example of this comes directly afterwards in line 105. Because of the setup in the CAVE with the extra laptop, part of the screen projected on the table isn't needed and projection on this part would be considered annoying. Therefore a black rectangle is laid over this part of the screen. This only happens when the CAVE is used. To draw the rectangle, first the size of the screen has to be known. This is done in line 107. Next the rectangle is added with the correct color and scale. Next a crosshair is added. This is done to ease clicking on doors to open them. It marks the point where the click works. The crosshair is a simple image that is added to the center of the screen. Because the screen is variable in size, an extra function is added in line 115. This function recalculates the centre of the screen whenever it is resized. The function is called as soon as the window size changes. This is done in line 119. Next the onMouseDown function is defined. This function contains everything that has to be done when a mouse button is clicked. For this script, only the middle mouse button is defined and the only actions performed are opening and closing doors. Different kinds of doors exist in the model however, including pivot doors, sliding doors and elevator doors. These all have their own piece of code, but first the script has to check which object is clicked and whether it is a door or not. The definition starts with 2 sequences. These

```

57         modelnodenames[node] = name
58
59     modelnodenames2 = {}
60     for name in model.getNodeNames():
61         if name.startswith('escalator') or name.startswith('slidesssembly') or name.startswith('elevatorassembly'):
62             node = model.getChild(name)
63             modelnodenames2[node] = name
64
65     modelnodenames3 = {}
66     for name in model.getNodeNames():
67         if name.startswith('elevatorpart') and name.endswith('-GEODE'):
68             node = model.getChild(name)
69             modelnodenames3[node] = name
70
71     model.setPosition(0,0.1,0)
72
73     for i in model.getNodeNames():
74         if i.startswith('person') and i.endswith("-GEODE"):
75             person = model.getChild(i)
76             person.billboard(viz.BILLBOARD_YAXIS)
77
78
79     vizact.ontimer(1,checkmodel)
80
81
82     headLight = viz.MainView.getHeadLight()
83     headLight.disable()
84
85     myLight1 = viz.addLight()
86     myLight1.setEuler( 20, 45, 0 )
87     myLight1.intensity(0.8)
88
89     myLight2 = viz.addLight()
90     myLight2.setEuler( 90, 0, 0 )
91     myLight2.intensity(0.5)
92
93     myLight3 = viz.addLight()
94     myLight3.setEuler( -90, -45, 0 )
95     myLight3.intensity(0.3)
96
97     viz.go()
98     dswalker.go()
99
100    viz.clip(0.2, 6000)
101    viz.eyeheight(1.62)
102
103    indeskcave = 'deskcave_viz' in sys.modules
104
105    if indeskcave:
106        window2 = viz.VizWindow(1)
107        w,h = viz.MainWindow.getSize( viz.WINDOW_PIXELS )
108        blackrectangle = viz.addTexQuad(viz.ORTHO, window2)
109        blackrectangle.color(0,0,0)
110        blackrectangle.scale(2 * w, h, 0)
111
112    crosshair = viz.addTexQuad(viz.ORTHO, texture=viz.add('cross.png'))

```

are sequences of actions that have to be performed when clicking on sliding doors and will be explained later. The `onMouseDown` definition is triggered whenever a mouse button is clicked. However, only the middle mouse button actually triggers events. In line 124 it is checked whether the mouse button is the middle one. Next, the object which is clicked on is retrieved. `Pick()` refers to another definition which handles the picking. This is split into another definition because picking objects works differently in the CAVE and normal screens. The `pick` definition is defined on line 165 and what it does is return the object that is in the middle of the screen, the same position as the crosshair. The `onMouseDown` definition then checks if a valid object is clicked and in line 128, it checks if the picked object is in the `modelnodenames` list. This was the list which contains every door in the model. If this is the case, all conditions are met and the different events depending on the type of door can be triggered.

For pivot doors, this means rotating the door around its pivot point. When the name of the clicked object starts with 'PivotDoor', it is checked whether the door is opened or closed i.e. whether the door's angle is 0 or 90 degrees. When the door is in a 0 degree angle, it rotates to 90 degrees and vice versa. The rotation is done in 1 second.

Next are the sliding doors. The elevator door and the normal sliding door work the same. The difference is that for the elevator door, an elevator is brought to the door's floor. Sliding doors consist of 2 components that slide in opposite direction. These are 2 separate objects which means that on a click, only one half of a sliding door is recognized by the script. To recognize the other half as well, the two halves are grouped together in 3ds Max. This means that in Vizard, the first parent object of one sliding door element actually is this group. Thus, the children of this parent are the objects in the group, the 2 halves of the sliding door. The script works by getting the parent of the clicked sliding door half and then getting all the children of this parent and apply an action sequence to them. This action sequence is one of the 2 defined at the beginning of the definition. For the elevator door, this is `seq2`. The sequence first opens the door in 1 second, then waits 3 seconds and automatically closes the door again. The sequence of the normal sliding door is the same but it opens the doors further than the elevator doors.

For the elevator doors, the elevator cart has to move to the correct floor. Therefore, all the doors and the cart of one elevator shaft are grouped together as well. This means that the second parent of the elevator door is the group of all the doors and the cart. This parent is retrieved in line 140. To be able to move the elevator cart to the right floor, the position along the z axis of the door has to be known. This position is retrieved in line 141 and rounded off to a 1 decimal number. From line 145 onwards, the elevator cart is found and positioned to the same height as the door that was clicked on.

In line 159, the previously used `ispivotdoor` definition is defined. All it does is return a name of an object if its name starts with "Pivotdoor", "slidingdoor" or "elevatorslidingdoor" and ends with "-GEODE". These are all the door objects used in the `onMouseDown` definition.

```

113 crosshair.scale(50,50,1)
114
115 def onWindowSize(e):
116     w,h = viz.MainWindow.getSize( viz.WINDOW_PIXELS )
117     crosshair.setPosition((0.5 * w, 0.5 * h,0))
118
119 viz.callback(viz.WINDOW_SIZE_EVENT,onWindowSize)
120
121 def onMouseDown(button):
122     seq = vizact.sequence((vizact.moveTo(pos=[0,0,0], time = 1) }, vizact.waittime(1)), (vizact.moveTo(pos=[0,0,0], time = 1)))
123     seq2 = vizact.sequence((vizact.moveTo(pos=[0,0,0], time = 1) }, vizact.waittime(2)), (vizact.moveTo(pos=[0,0,0], time = 1)))
124     if button == viz.MOUSEBUTTON_MIDDLE:
125         pickedobject = pick()
126         if pickedobject.valid:
127             door = pickedobject.object
128             if not door in modelnodenames or not ispivotdoor(modelnodenames[door]):
129                 return
130
131             if modelnodenames[door].startswith('PivotDoor'):
132                 if door.getEuler()[2] == -90:
133                     door.runAction( vizact.spinTo(euler=[0,0,0], time = 1) )
134                 else:
135                     door.runAction( vizact.spinTo(euler=[0,0,-90], time = 1) )
136
137             if modelnodenames[door].startswith('elevatorslidingdoor'):
138                 child = model.getChild(modelnodenames[door])
139                 assembly = child.getParents()
140                 elevatorassembly = assembly[0].getParents()
141                 pos = child.getPosition(viz.ABS_GLOBAL)[1] - 0.1
142                 pos = round(pos, 1)
143                 for d in assembly[0].getChildren():
144                     d.addAction(seq2)
145                 for name in elevatorassembly[0].getNodeNames():
146                     if name.startswith('elevatorcart') and name.endswith('-GEODE'):
147                         e = model.getChild(name)
148                         e.setPosition(0, pos, 0)
149
150             if modelnodenames[door].startswith('slidingdoor'):
151                 child = model.getChild(modelnodenames[door])
152                 assembly = child.getParents()
153                 assembly = assembly[0].getParents()
154                 for d in assembly[0].getChildren():
155                     for f in d.getChildren():
156                         f.addAction(seq)
157
158
159 def ispivotdoor(name):
160     return name.startswith("PivotDoor") or name.startswith("slidingdoor") or name.startswith("elevatorslidingdoor") and name.endswith("-GEODE")
161
162 viz.callback(viz.MOUSEDOWN_EVENT,onMouseDown)
163
164 def pick():
165     if indeskcave:
166         return viz.MainWindow.pick(1, viz.WORLD, (0.125, 0.5))
167     else:
168         return viz.MainWindow.pick(1, viz.WORLD, (0.5, 0.5))

```


From line 171, the definitions for moving the elevators are defined. To be able to explain these definitions, the next definition has to be explained first because some elements used here, are defined in this next definition.

The pickesc definition is used to check the surface the user is currently standing on. This is important for the escalators and elevators. This definition works by shooting a line from the user downwards. The first object the line intersects with is returned. To do this, the definition first checks the current position of the user in line 230. Next the coordinate 2 meters below the user is acquired (pos[0] is the x-coordinate, pos[1] is the z-coordinate and pos[2] is the y-coordinate). Then an intersection line can be shot from the user's coordinates to the coordinates 2 meters below the user. If the line intersects an object it is returned as 'i'. Now it can be checked if the object is a step of an escalator or an elevator cart. If the object is a step of an escalator (the name starts with 'esc01step' and ends with '-GEODE'), the user is automatically moved along the escalator. To do this, escalator the step belongs to, rotation of the escalator in the form of a quaternion rotation and the position of the user has to be known. These values are respectively retrieved in lines 236, 237 and 238. The escalator the step belongs to has to be known to know whether the escalator goes up or down. Here again, all the escalator steps are grouped in 3ds Max. When the escalator goes up, the group is called 'escalatorup'. Otherwise it's called 'escalatordown'. Depending on the direction of the escalator, then a vector is created along which the user moves as long as he or she stands on one of the steps. This is done by multiplying speed (0,4 m per elapsed frame) with the quaternion rotation of the steps to get the right direction. A new position for the user can then be calculated and the user is set in this new position, first in the horizontal direction in lines 243 and 249 and then in the vertical direction in lines 244 and 250. The pickesc definition is called every update which means the function works as long as the user either stands on a step or in an elevator cart.

The next part of the definition is for the elevators. Here a dialog is created in which the user can fill in the floor to which he or she wants to go. This dialog must only show when the user is in the elevator so it is first checked if the

intersected object isn't an elevator cart. If this is true and there is a dialog, it is removed. If there is no dialog, nothing happens.

If the user is in the elevator, the user's position is set to be 1,62 meters above the elevator cart on every update. This is done to make sure the user always moves at the same speed as the cart. Next the dialog is created in which the user has to fill in the floor number. The floor number is checked with the checkfloor definition on line 171. The checkfloor definition makes sure a valid number is entered. The number has to be a number between 0 and 73. If the number is not in between these values, an error text is displayed. The same happens when text is entered in the dialog. This is checked on line 179. The dialog is not visible yet at this point, therefore the showdialog definition is called on line 183. This definition is called as soon as the user enters an elevator. First, the input dialog appears in which the user can enter a number. The number is checked with the previously mentioned checkfloor definition and when it is a valid number, the input is accepted and the showdialog definition can continue on line 188. The elevator type can now be checked. There are 2 types of elevators, slow and fast ones. For both types, the same sequence of actions is required. The only difference is the speed of the elevator. For slow elevators the speed is 1,5 m/s and for fast elevators it is 5 m/s. Because the ground floor is higher than the other floors, it doesn't fit in the sequence that every floor is 3,6 meters above the floor below it. Therefore a separate code was written for the ground floor. If the entered floor is 0, the elevator moves to its location 1,6 meters above ground. This is the height of the ground floor. For all other floors the position of the elevator can be calculated with the formula $3,6(\text{floor} + 1)$. Floor is the number entered in the dialog. The + 1 is added to the function because the first floor is at 7,2 meters above ground and not 3,6 meters due to the higher ground floor.

Every time the elevator moves position, the time it takes to move from the current position to the desired position is calculated. This is done by extracting the z coordinate of the current position with the z coordinate of the desired position and dividing it by the elevator speed. Because this would yield a negative number when the elevator goes up, the resulting time is multiplied by -1 if the number is smaller than 0. This is done in line 211.

```

189
190 def checkfloor(data):
191     try:
192         floor = int(data.value)
193         if floor < 0 or floor > 73:
194             data.error = 'Choose between 0 and 73'
195             return False
196         else:
197             return True
198     except ValueError:
199         data.error = 'You have to fill in a number'
200         return False
201
202 def showdialog(elevator, type):
203     global input
204     while True:
205         yield input.show()
206
207         if input.accepted:
208             pos = elevator.getPosition()
209             floor = int(input.value)
210             if type.startswith('elevatorcartalow'):
211                 if floor == 0:
212                     time = (pos[1] - 1.6)/1.5
213                     elevator.addAction(vizact.moveTo(pos=[0, 1.6, 0], speed = 1.5))
214
215                 else:
216                     time = (pos[1] - (3.6 + (floor + 1))) / 1.5
217                     elevator.addAction(vizact.moveTo(pos=[0, (3.6 + (floor + 1)), 0], speed = 1.5))
218
219             else:
220                 if floor == 0:
221                     time = (pos[1] - 1.6)/5
222                     elevator.addAction(vizact.moveTo(pos=[0, 1.6, 0], speed = 5))
223
224                 else:
225                     time = (pos[1] - (3.6 * (floor + 1))) / 5
226                     elevator.addAction(vizact.moveTo(pos=[0, (3.6 * (floor + 1)), 0], speed = 5))
227
228             if time < 0:
229                 time = time * -1
230             yield viztask.waitTime(time + 1)
231             p = elevator.getParents()
232             for name in p[0].getNodeNames():
233                 if name.startswith('elevatorslidingdoor') and name.endswith('-GEODE'):
234                     d = model.getChild(name)
235                     pos2 = d.getPosition(viz.ABS_GLOBAL)
236                     pos2 = round(pos2[1], 1) - 0.1
237                     if pos2 == round(elevator.getPosition()[1], 1):
238                         seq = vizact.sequence((vizact.moveTo(pos=[0.8, 0, 0], time = 2), vizact.waittime(3),
239 (vizact.moveTo(pos=[0, 0, 0], time = 2)))
240                         d.addAction(seq)
241
242
243
244 def pickesc():

```

The reason why the time is calculated is to be able to open the elevator doors as soon as the elevator arrives at its destination. This is done from line 212 onwards. Line 212 tells the script to wait one second longer than it takes for the elevator to move to its new location. After this, it searches for the door on the floor the elevator stopped at. Because all the doors and the elevator cart belonging to a specific shaft are grouped together it is possible to search the doors in the parent object of the elevator cart. This results in a list of all the doors belonging to one shaft. To get the right door to open, its position is compared to the position of the elevator cart. Both positions are rounded off to one decimal number to avoid errors. If the 2 positions are the same, the action sequence of the sliding door is applied to the right door. The elevator sequence is now complete.

The last parts of the code from line 270 down are for convenience. The scrollup and scrolldown definitions set the position to 3,6 meters higher or lower when in flying mode. This way, it is easy to scroll through floors and quickly go to the desired floor. To prevent scrolling underground, the scrolldown function only works when the resulting z coordinate position is above 0.

```

225 global floor
226 global elevinfo
227 global input
228 global modelnodenames3
229 pos = viz.MainView.getPosition()
230 pos2 = [pos[0], pos[1]-2, pos[2]]
231 i = viz.intersect(pos, pos2)
232 if i.valid:
233     if i.name.startswith('esc01step') and i.name.endswith('-GEODE'):
234         step = model.getChild(i.name)
235         escalator = step.getParents()
236         trans = viz.Transform.quat(step.getQuat(mode=viz.ABS_GLOBAL))
237         posstep = step.getPosition(viz.ABS_GLOBAL)[1]*1.62
238         for escname in escalator[0].getNodeNames():
239             if escname.startswith('escalatorup'):
240                 dir = viz.Vector(-0.4, 0, 0) * trans * viz.getFrameElapsed()
241                 pos = viz.Vector(pos) + dir
242                 viz.MainView.setPosition(pos)
243                 viz.MainView.setPosition(0, posstep, 0)
244
245             if escname.startswith('escalatordown'):
246                 dir = viz.Vector(0.4, 0, 0) * trans * viz.getFrameElapsed()
247                 pos = viz.Vector(pos) + dir
248                 viz.MainView.setPosition(pos)
249                 viz.MainView.setPosition(0, posstep, 0)
250
251 e = i.object
252 if not e in modelnodenames3 or not (modelnodenames3[e].startswith('elevatorcart') and modelnodenames3[e].endswith('-GEODE')):
253     if input != None:
254         input.remove()
255         input = None
256
257     return
258
259 if modelnodenames3[e].startswith('elevatorcart'):
260     type = modelnodenames3[e]
261     elevator = model.getChild(modelnodenames3[e])
262     pos = elevator.getPosition()[1]*1.62
263     viz.MainView.setPosition(0, pos, 0)
264     if input == None:
265         input = vizdlg.InputDialog(prompt='Which floor do you want to go?', length=1.0, validate=checkfloor)
266         viz.link(viz.CenterCenter, input)
267         viztask.schedule(showdialog(elevator, type))
268         viz.MainView.setPosition(0, pos, 0)
269
270 vizact.onupdate(1, pickesc)
271
272 def scrollup():
273     pos = viz.MainView.getPosition()
274     viz.MainView.setPosition(pos[0], pos[1]+3.6, pos[2])
275
276 def scrolldown():
277     pos = viz.MainView.getPosition()
278     if pos[1] - 3.6 > 0:
279         viz.MainView.setPosition(pos[0], pos[1]-3.6, pos[2])
280
281 vizact.onwheelup(scrollup)
282 vizact.onwheeldown(scrolldown)
283

```

From line 285 onwards, a list with floor heights is created that is used to display the current floor the user is located on. For every floor except the ground floor, the floor number and the floor's height above ground is stored. In the heightchecker definition which is called on every update, the correct floor number to display in a little dialog is calculated. First the z coordinate of the position of the user must be known. Then it is checked whether the position is somewhere between ground floor and floor 80, which is 291,6 meters above ground. If the position is below 0, the counter displays 0, if it is above 80, the counter displays "Flying high". For every value in between, the list created with the floorcounter definition is used. The z coordinate of the position of the user is compared to the stored floor heights in the list. This is done until a floor height value is found that is larger than the value of the z coordinate of the position of the user. The floor number to which the floor height belongs is then displayed in the dialog. Due to the nature of the list, every floor has the floor height of the floor above it stored. This makes it possible to display the correct floor number while the script searches for the first documented floor height above the user.

```

281 floorlevels = []
282 floorheight = 3.5
283
284 def floorcounter():
285     for i in range(81):
286         floorlevels.append(7.2 + i * floorheight)
287
288 floorcounter()
289
290 counter = vizinfo.add("Counting")
291
292 def heightchecker():
293     pos = viz.MainView.getPosition()
294
295     floor = int((pos[1] - 3.5) / floorheight)
296     if floor < 0:
297         floor = 0
298     elif floor > 80:
299         pass
300
301     for floor in range(len(floorlevels)):
302         if pos[1] < floorlevels[floor]:
303             counter.message(str(floor))
304             return
305
306     counter.message("Flying high!")
307
308 vizact.onupdate(1, heightchecker)

```

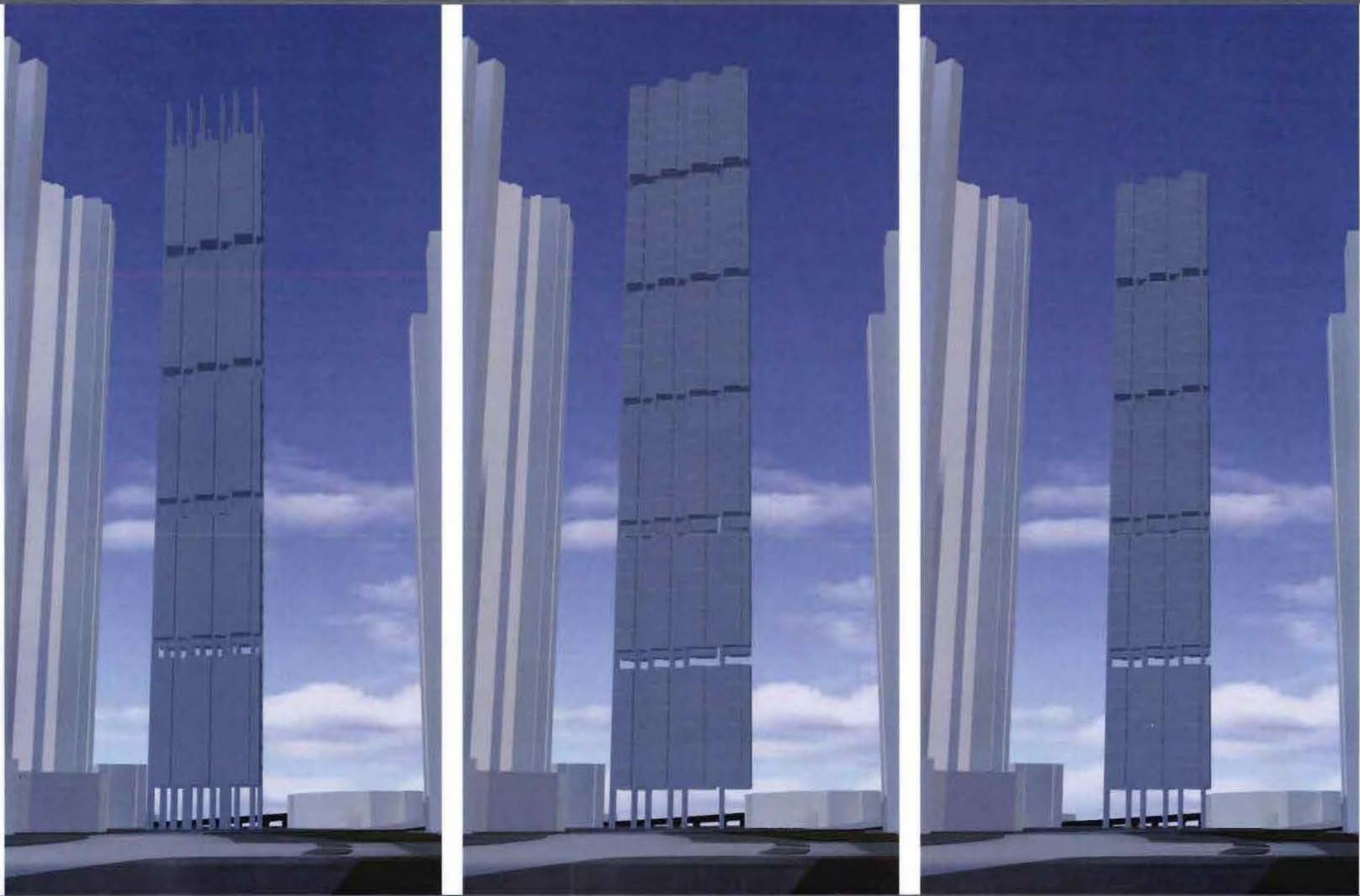
5. Design Process

5.1 Stage 1, building shape

5.1.1 The tower

Unlike a smaller scale design assignment, a tower is often designed from the inside out starting with a basic floor plan for a room, copying it and designing a shell around it. This is done because it is much more difficult to design a shell and later on fit everything in the building. (Form Follows Finance) This way, the building is optimized.

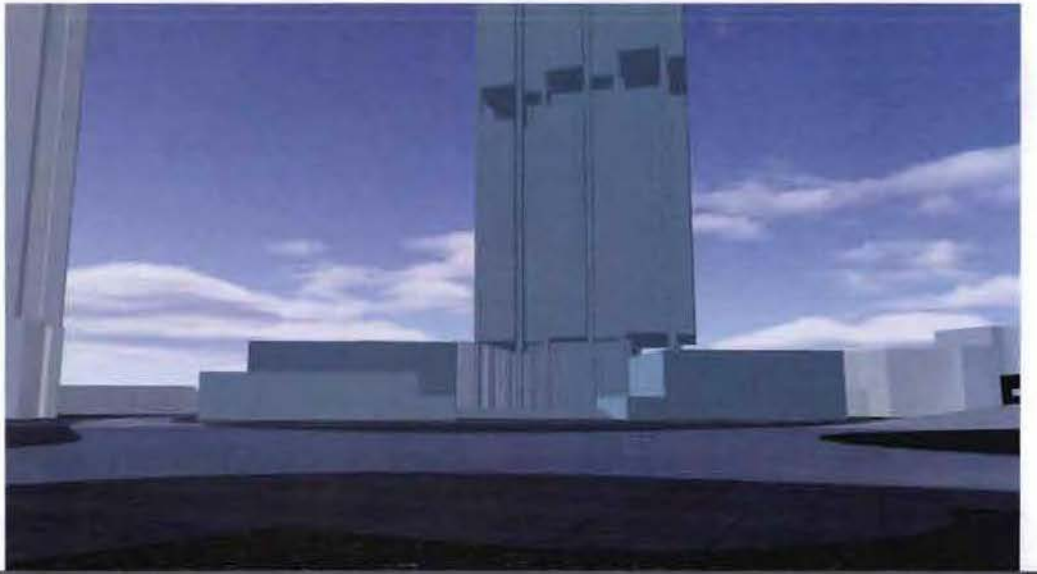
During the literature study phase, some design ideas were already developed including the idea of segmenting the building. Therefore this idea is present in all the preliminary sketches with which this design phase started. By means of sketching, a few ideas were worked out which were then put into 3ds Max. Like stated before, the transferring into 3ds Max first started with designing a floor plan for the apartments. The first design to be transferred to 3ds Max was the 'slabs' design. An apartment layout was designed according to the 'slabs' concept, stacked together to form a basic building shape. This is shown in the first picture to the right. After having designed and modeled the first concept, it was viewed in the CAVE and inspected from all angles. Looking how it stood within the city from different angles and how its height compared to other buildings. The building was found to stand in an awkward position as can be seen in the first picture. It stands too far to the left and creates an unbalanced composition with the built environment. To compensate for this, an extra slab was added as seen in the second picture. After viewing this model in the CAVE however, the width to depth ratio was found to be unpleasant and the building looked a bit too wide. One slab was removed again and the tower was moved to different positions to find an optimal location. The final location at this point can be seen in the third picture. Later it was moved again a few times for other design purposes, but never too far from the location in the third picture.



5.1.2 The base

After being satisfied with the tower's location, a base form had to be designed. This was mainly a trial and error procedure as no satisfying result was produced by sketching. By trying different compositions and reviewing them with the CAVE, it was still possible to come up with a shape quite quickly. A known fact that had to be integrated was that the base had to be significantly larger than the tower footprint to be able to create enough mass in front of the tower to ease the transition to the tower. Therefore experiments were done with different lower and wide shapes until a good basic shape was found. Due to the use of the CAVE, heights, directional lines and views from different angles could be reviewed immediately. 4 steps that led to the final shape can be seen to the right. By starting off with a very crude shape and tweaking it bit by bit, the final design was gradually realized.

By starting off with a basic L-shape, the basis was laid out. This however would not be enough mass to accommodate all functions and thus a new rectangular mass which was larger in surface area was created. This way, a passage was formed towards the tower. At this stage it was closed to the back connecting all parts of the base together. It was a logical decision to open up the passage to the back. Behind the building is a primary school. By creating a passage here, it is possible to directly reach the school behind the building. This can be seen in the second picture. At this point, the height of the left part was too low in comparison to the rest. To compensate this, a taller volume was created to partially bring back the L-shape. By placing it to the back of the lower volume, the building gets a distinct front side and back side with the front facing the rest of the neighborhood and the back facing the school and industrial area. The lower volume was still found to be too low and thus it was raised. This resulted in the final picture.



5.1.3 Different designs

After working on the 'slabs' design for a while, another idea previously sketched had to be taken into account as well so it was transferred to 3ds Max and the CAVE as well. This was a rounded tower. However after designing a floor plan system for it that would work within the regulations of Hong Kong and putting it in the CAVE, the tower got too bulky just like the design with the 4 slabs shown earlier. The same problem occurred with another idea later developed as shown in the second to last picture.

The second picture shows a variation to the 3 slabs design in the first picture. It included 2 building blocks with smaller apartments causing the façade to lay back. However this principle returned in the final design. At this point, due to the visible construction elements, this design was found to be too messy. In the end it was decided to continue with the first design idea and work it out further. It was still the one which fitted the best in the context.



5.2 Stage 2: Building design

5.2.1 Structure

After the generic shape of the building was done, the process continued by turning the shape into a building. The first thing to do at this point was designing a building structure. This had to be done to prevent surprises later on in the design process. The idea was to turn the slabs into constructive elements. The slabs would be connected through the floor and extra riggers would be added in the gaps where the sky lobbies will be added later on. After this basic structure was added, floors were added as well.

5.2.2 Atria

At his point, the idea of creating multistory atria was developed. At first by means of sketches of how this space would look and after that, it was implemented into the 3D model. The first problem that arose which could be seen directly due to the CAVE was that the structure previously designed for the building penetrated the atria obstructing much of the view. These were removed for this reason. The second problem which was found and was not visible in the 2D sketch was the height of the atria. By going up 14 floors they were very tall and rather unpleasant. The idea for which they were designed would be lost this way. At this point it was decided to divide the atrium into 3 sections with floors in between. This way, the atria would be much lower and less massive and overwhelming. This decision was a direct result from working with the CAVE. By experiencing the space as it would be in real life, it was directly noticeable that it was too massive and had to be made more intimate to reach its goal.

After this point the vertical transportation services were added. This included elevators and staircases. Here, being able to walk through the building helped with positioning the elevators. By trying different positions and orientations including in the atria on the north and south sides and on the east and west sides, what would work and what not could directly be seen. The number of

elevators and their position at this point was still not final, but it was decided to keep them on the east and west sides of the atria. Later, the structure was put through some preliminary calculations and it was found that the building had to be wider. Due to this, there was more room in the elevator areas and extra elevators were added.

Toilet blocks also had to be created for the offices. The same procedure applied here as for the elevators. 2 boxes were created that represented the toilet blocks. These were then moved to different potential locations and with the CAVE it was checked whether the position was good or not.



5.2.3 Façade design

At the point where the interior of the building was completed to some extent, the design of the façade started. The most important part in this was to design a façade that both worked on the office and on the residential side. The first ideas for this came from references in Hong Kong. Different façade types typical for Hong Kong were tried on the building as can be seen on the image to the right. The façade types tried included all glass, grey parapets and a yellowish stone façade mimicking the typical residential buildings of Hong Kong. By using the CAVE and flying around the building, the façade could be examined immediately and the different types could be compared. At this point, an all glass façade looked the best on the building. The other types were found to look out of place. The all glass façade looked too much like an office though but for now, it was left as it was because no better solution could be found. Much later in the process, parapets on the northern and southern façade were added and the problem of the residential building that looks like an office building was solved.

5.2.4 Apartments on the base

After the global design of the tower was done, 44 single bedroom apartments still had to be allocated. There was no room for these apartments in the tower or it would become too tall. The other option was to locate them in the base. This was a plausible idea as these were single bedroom apartments which are the cheapest apartments in the building meant for younger people. By placing them on the base they are cheaper than when they would have gotten a spot in the tower. This way, the base is made taller and this improves the function of transition because it becomes more gradual. For the design of these apartments, a concept was first sketched out on paper and then translated to 3ds Max in the form of a mass study. After approving the shape with the help of the CAVE, apartment layouts were designed to fit in the mass and the whole was further refined. Frames were added to the individual 'columns' of apartments to accentuate the edges and to more clearly define them. After this, different kinds of frame infill were tested as seen in the final image. Here again by using the CAVE, the different design ideas could be compared and a decision was made.



5.2.5 Façade part 2

The façade of the base was one of the more difficult to design. Making it the same as the tower and the building would become too monotonous and making it different and it doesn't fit in with the building. This was the case for the first design that was made. It had a different color and a different composition and therefore it looked as if it wasn't actually part of the building. It needed more study on this part which was again done first by means of sketching. Unfortunately a satisfying result wasn't reached at this point so it had to be addressed again later. It was due to the CAVE that this became obvious immediately.

After sketching ideas on the façade of the tower, good results were achieved on this part. After taking a closer look on the appearance of the apartments on the base, the idea was found to bring the façade of the tower closer to them. This was first tried by adding balconies on the tower with a frame around it just like the apartments on the base. This however didn't look good in the CAVE and a simpler solution had to be found. This was done by adding yellow parapets like the ones already present in the base. These immediately gave a more residential feeling to the façade and it still fitted in with the rest of the building.

A satisfactory result also still had to be found in the façade pieces on the side of the apartments. By again looking to the typical Hong Kong façade types, a new idea was found in making bay windows. These are typical on residential building and they still consist mostly of glass. They thus make sure the building looks residential and that it transitions gradually into the office side.



5.2.6 Entrance of the base and shopping mall interior

Up until now, the entrance of the left side of the base was located on the east side. Due to this, stairs had to be cramped into a small space to connect the raised plaza underneath the tower to the ground floor and first floor of the base. It was difficult to make the entrance area inviting this way. A new concept had to be created. This was found in the lowered part of the base which was already there. It could function as a combined entrance for shoppers and inhabitants. This meant the raised plaza no longer functions as entrance but the plaza in front of the stairs to the tower now has this function. This idea could then later on also be applied to the east part of the base. This however meant that more room had to be reserved for the entrance leaving less room for parking spots. It did mean that there now is room to add escalators. This again gave an opportunity to exploit the CAVE. The escalators are for vertical transport and thus create a hole in the floor making the area more spacious. With the CAVE it was possible to look at this space from different angles and it was found that it still felt cramped and it had to be loftier still to function as a good entrance. This led to the decision to make a perforation through the ceiling directly above the escalator. This creates a direct visual connection between the shopping mall and the amenities above it, contributing to the concept of social interaction.

At this point, work on the interior of the shopping mall was started as well as can be seen in the pictures. Only the first concept was worked out for now. Although the CAVE was used to view the progress, nothing was changed because of it. At a later stage, when work on the interior continued it was noticed that the interior lacked a pleasant intimate atmosphere. Due to all the grey tones it had an industrial feel to it. To make the atmosphere more intimate, warmer tones were introduced. This in combination with the existing grey tones created an interior that had both a business look and is intimate. To see what addition worked best, different materials of wood and painted colors were tried ultimately resulting in the addition of red colored stucco walls.





5.2.7 Exterior of the lower part of the base

Due to the new concept of the combined entrance in the base, the lowest part of the base would logically have a different appearance than the base itself. This together with the fact that the façade wasn't satisfactory at this point resulted in another study with the CAVE. For this, examples were sought to serve as references. These references were found in the older parts of Kowloon. This resulted in the concept of having an extruded middle part which could serve as an overhang. It was tried to copy elements of the façade as well. To keep more in line with the style of the building, this resulted in the first concept. It however, looked too industrial and still didn't fit very well with the rest of the building. Second, the design was brought closer to the old Kowloon typology by adding broad strips below and above the window. It still didn't fit in with the building very well. As a result, the façade of the tower was studied again and an all glass variation to the first concept was applied. This fitted the building best and so this design was chosen as final.

Other parts of the façade of the base had to be looked at as well. The first part was at the parking garage. Applying the same façade as the shops wasn't logical. People would look into the parking garage from the outside and it also has to be ventilated. Elements that look closed but allow ventilation were required. This resulted in the idea was to apply fins. Different types of fins were tried including horizontal and vertical configurations, different spacing and thicknesses and different colors and materials. Metal fins were rejected because of their industrial look and finally they were replaced by wooden fins in a horizontal configuration placed in an aluminum framing that looks the same as the framing of the shops.

The other part that had to be redesigned was the entrance to the base. It had to be different from the rest of the base yet similar enough to form a harmonious composition. This is achieved by creating an extension of the back of the base along the front in the form of a white stucco wall. To give extra direction towards the tower and to improve lighting conditions, small square windows are added into the wall. A large overhang on the front part of this extension indicated the entrance to the shopping mall. This wall is mirrored on the other side of the plaza.

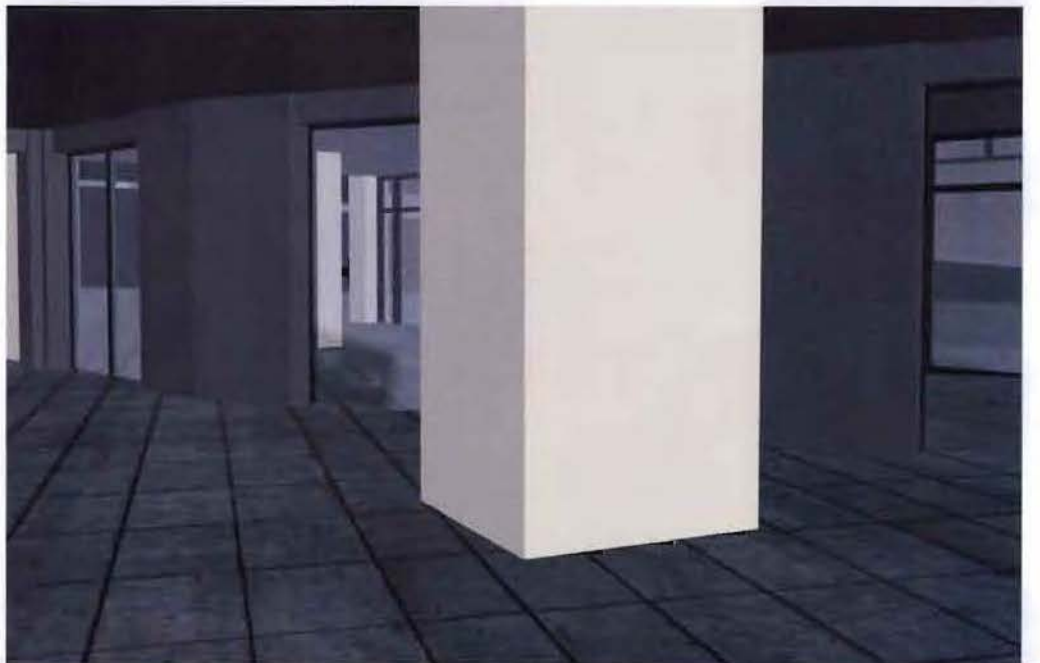
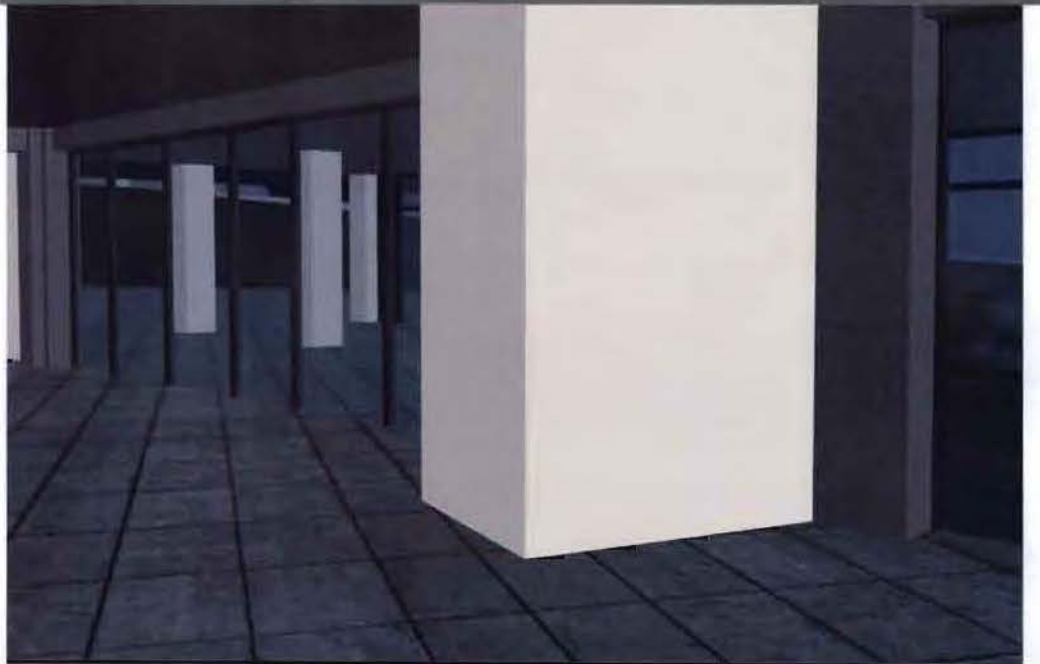


5.2.8 Other half of the base

The eastern part of the base would be the same in appearance as the western part. Thus no designing on the exterior was necessary. The interior would also comply with the same design rules as the already finished west part. The difference was to be found in the internal division. Here, the large columns of the tower penetrated the space and provided extra challenges. At this point, the CAVE again proved to be a helpful tool. A good example of this is the placement of the escalators. At first, the escalators were placed the same way as the escalators in the eastern base part. On the 2D view, this seemed to be possible. Enough space would be left between the escalators and the columns of the tower for people to walk by them. After analyzing in the CAVE it was noticed that there was enough space to walk but it was very narrow due to the height to width ratio. It didn't look comfortable to walk there. It was then decided to place the escalators in a different way to provide more room as shown in the second picture.

For the same reason, the storefronts were also relocated after viewing in the CAVE. The entrance area was really small which doesn't suit a shopping mall. To make it bigger, the storefront was rotated at the same angle as the angle between the tower and the base, but in the opposite direction. The difference can be seen in the third and fourth picture. By doing this, the path along the shops gets narrower to the back creating a more natural flow to the back.

The rest of the shopping mall designing included adding a staircase and elevator and more shops in the back and copying everything to all 3 floors. All this work was a matter of course and involved little input from the CAVE. It was only used to check whether everything lined up the way it should as this was sometimes hard to see in 3ds Max.



5.2.9 Adding the details to the tower

In the tower, still a lot of small modeling tasks had to be done including filling up all the gaps left in the façade, replacing the boxes that represented elevator shafts by actual shafts and modeling the bridge between the tower and the base. There were still some last design tasks here as well.

Big towers like these create a strong downdraft causing strong winds near the entrance. Therefore overhangs or extrusions are often used to prevent people from being blown off their feet. This tower also needed some kind of wind deflectors. By first sketching some ideas on paper, a satisfying result was reached by hanging canopies underneath the tower. To determine how these canopies would look, the CAVE was used. A global design with a metallic look was already conceived with the sketches, but to see how it worked out the CAVE was needed. This resulted in a minor but significant design change as can be seen in the pictures. It was found to look better if the canopies follow the lines of the tower.

Next up was the entrance lobby. Here extra walls had to be added to form a barrier between the public space and the collective space. Not everyone should be able to reach the elevators. To do this, large closed walls were added with post boxes in them. The glass entrance to the elevators was positioned so that the structural braces would not be in the way. To prevent people from hitting their head, glass walls were also added in front of these braces on other floors. Openings were added in places where there were no obstructions. This however, caused quite narrow hallways where people have to wait for the elevator. At this point, no good solution was found for this problem. Later on, it was found that the braces were unnecessary and they were removed together with the glass walls.



5.2.10 The top of the tower

The top of the tower was the last part of the building that had to be designed at this stage. The top houses 6 penthouse suites, thus as a start, 3 floors were added to house 2 suites per floor. A glass façade was then added to see how the top looked at this point. It was not very convincing. The top functions as the physical ending of the tower and thus should look like one. To find a fitting shape, mass elements were added and examined in the CAVE to see what would look right. At first, some variations were tried using setbacks. These setbacks were all located within the top floors making them not visible from the ground and you could only see them from some distance from the building. They were also out of proportion with the rest of the building. Setbacks thus were not an option for this building or they had to be implemented in a much earlier stage. Next to this other design elements were tried including cornices and angled roofs. This last one proved to be a good solution to the tower. Unlike a straight cut off of the tower, an angled cut off automatically looks like more natural ending to the tower. Its impossible imagining something can be build on top of an angled roof. In the end, this idea was chosen as final and it was further worked out.

The angled roof top in turn also provided a number of challenges. The most notable at this point was the design of the façade. The tower consists of two distinct parts when it comes to the façade treatment. The all glass façades in between the diagonal braces in the sky lobby areas and the façades of the building blocks themselves. The top of the tower actually is a third type due to its angled roof, but because it houses apartments, its functional typology is the same as those of the building blocks. It was thus chosen to use the façade type of the building blocks on the top of the tower adding the yellow parapets here as well. The ending of the building is formed by wrapping the large structural columns around the top of the building. The interior of the top was left open for now. It will be designed later on near the end of the detailing stage.



5.3 Stage 3: Detailing

Before actual designing in this stage could commence, the building had to be completely remodeled in a more accurate and detailed manner. Working on a more detailed level in 3d proved to be an excellent way to get better understanding in the inner workings of the building because it forced you to think of how everything would work on how it should connect together. It also gave better insight in the 3 dimensional connections of different elements normally barely thought of in 2D drawings.

The remodeling first started with the construction and the attachment of floors. At this point it forced to think about these connections. For instance how to connect a floor slab to a square hollow beam measuring 1 x 1 meter. The idea was to add a secondary structure to connect the floors to. This secondary structure consists of u beams attached to the square beams of the primary structure. From these U beams it is possible to span profiled steel plates as a lost formwork for in situ concrete floors. At this moment it was found that some of the u beams would have to span a distance of 16,8 meters which is a very large distance. To minimize this distance, extra columns were added to bring the span down to 8,4 meters which is more reasonable.

Next a system had to be conceived for the façade. For tall buildings, several systems are commonly used. The system for this building would have to be as slender as possible to get maximum transparency and daylight entry. Therefore it was chosen to use the most common system: façade panels. These are prefabricated panels that consist of an aluminum framing with glass or another material in it. These panels are hung from the floors. The panels slightly overlap to make them wind- and watertight. Different sizes and types of these panels would have to be used, but in the building was designed to use as few variations as possible.

A system to cover the building structure for protection and isolation was also needed. For this, a system of white anodized aluminum panels is used. This together with the façade paneling system caused a slight alteration of

the overall façade. Instead of letting all the structural members stick out of the façade, they now lay in line with the glass panels creating a smoother surface. This was mainly done to keep the isolation material in one line. For the same reason, the façade pieces on the west side of each apartment were changed as well. Instead of having indents in the façade, these are replaced by flat stone panels. This can be seen in the last two pictures. The gray granite elements are now replaced by flat travertine panels. This is mainly the result of a struggle to get the detailing right. Due to this change, the façade on these parts also fit better with the south facing façade pieces. Due to this decision it was also decided to make the north and south façades more similar. These are the same in shape but the south side has the travertine parapets. Therefore, the north side also got parapets. To keep the office look on this side it was chosen to make these parapets out of granite instead of travertine.

Next, interior work could commence. This started with adding walls in the different kind of apartments which was a straight forward modeling job. The apartments were fitted with ceilings and flooring to make them look more finished at this point. An advantage of working in 3D and with the cave came in placing the staircases and elevators. A previously added floor beam ran straight through the staircase and elevator shafts making it impossible to add elevators and stairs. Therefore the one central floor beam was replaced by 2 floor beams to the side. These beams now run in between the elevator shafts and they can be used as supports for the stairs.

The rest of the interior work mainly consisted of covering all the bare structural elements. For this, the CAVE was a good tool to find spots that still had to be done as this was becoming increasingly difficult in 3ds Max. After adding the two lavatory blocks and filling in the openings dividing the offices from the rest, the generic building block was done.

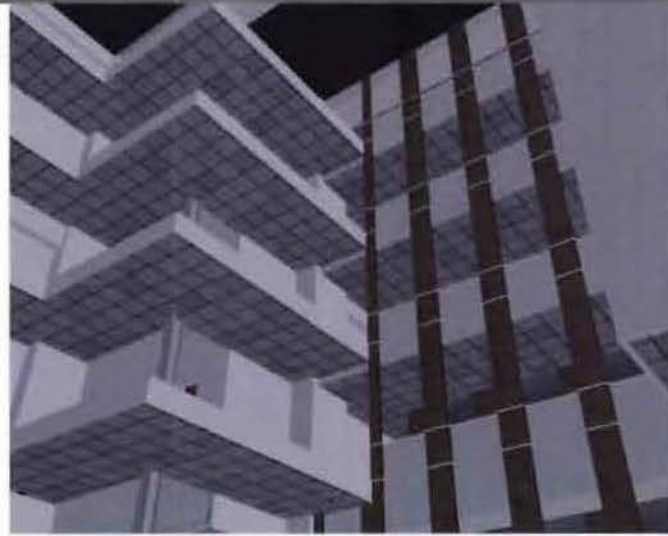


5.3.1 The second atrium

After finishing the global building block it was possible to start on the interior design of the atria. The first atrium to be designed was actually the second one up the height of the tower. At this point, the first one could not yet be designed because it is slightly different in shape. The base and the tower entrance would have to be modeled first.

The idea of this atrium was to design it in a colonial style. Therefore the basic concept was to add vertical strips of stone with horizontal bands between them. The floor of the lobby would then be themed as a colonial garden.

The CAVE proved to be a great tool for designing these spaces. And many ideas could be examined in a quick manner. The CAVE especially helped in getting a better idea of the spatial qualities of the interior. This resulted in design decisions like the color of the parapets and the rejection of the arches above the top floor. With the CAVE it could directly be seen if something was going to work or not. The pictures on the right show the design process of this atrium, starting with adding the vertical strips of stone and the addition of parapets. At this point, the result still looked a bit bare, thus metal strips were added for detail. To add more color to the atrium, the material of the parapets was changed from white to brown stucco. To add to the colonial style, arches were added. These were then removed again because they didn't fit in with the rest of the design very well. In the end, the result of the final picture was achieved. The atrium at this point wasn't finished but it was decided to continue on another part of the building first.



5.3.2 Base of the tower

A copy of the model of the second atrium was converted to the model for the base of the tower. This meant first, obsolete objects had to be removed, stripping down the atrium again. Other elements like floors could be reused but they required some adjustments. The conversion could be done quickly because most of the required elements were already modeled. The process of conversion is illustrated with the 4 pictures to the right. First objects were deleted and converted. This mainly consisted of obsolete façade panels and parts of floors not present in this part of the building. Next, the model was raised to incorporate the ground floor lobby and walls were added on the left and right side of the south facing side of the ground floor. Then the ground floor was added. Because this floor is higher than the other floors, the stairs had to be adjusted as well. Next the lobby could be made. This included adding the postboxes and a reception desk. At this point, the only new design decisions to be made were the materials of the flooring. In the lobby which is shared by both inhabitants and office personnel, the flooring was chosen to be a dark marble. On the floor of the first atrium, there was a light marble added to give a warm feeling to it.



5.3.3 The east side of the base

The next task was to remodel the east side of the lower base which contains the shopping mall. At first the columns and floors were added and after this the wall on the west side with the small windows. At first, this wall was made out of the same aluminum panels that cover the building structure but this made these walls very sterile and formal. To make them fit better with the shopping mall, the material was changed to white stucco which has a more friendly feeling to it. To prevent damage to the stucco by trolleys, bikes or shopping carts, the bottom part of the wall is made out of concrete.

After this was done, the rest of the façade could be added starting with the parts of the upper floors. Here due to the detailing there has been done a slight redesigning. This is done to match the horizontal mullions of to the ones of the tower. This was not the case in the old model. After this the façade panels could be added to the ground floor including the connection of the ground floor façade and the extruded upper floor façade. Design decisions at this point all relate to the detailing and the connections between different materials.

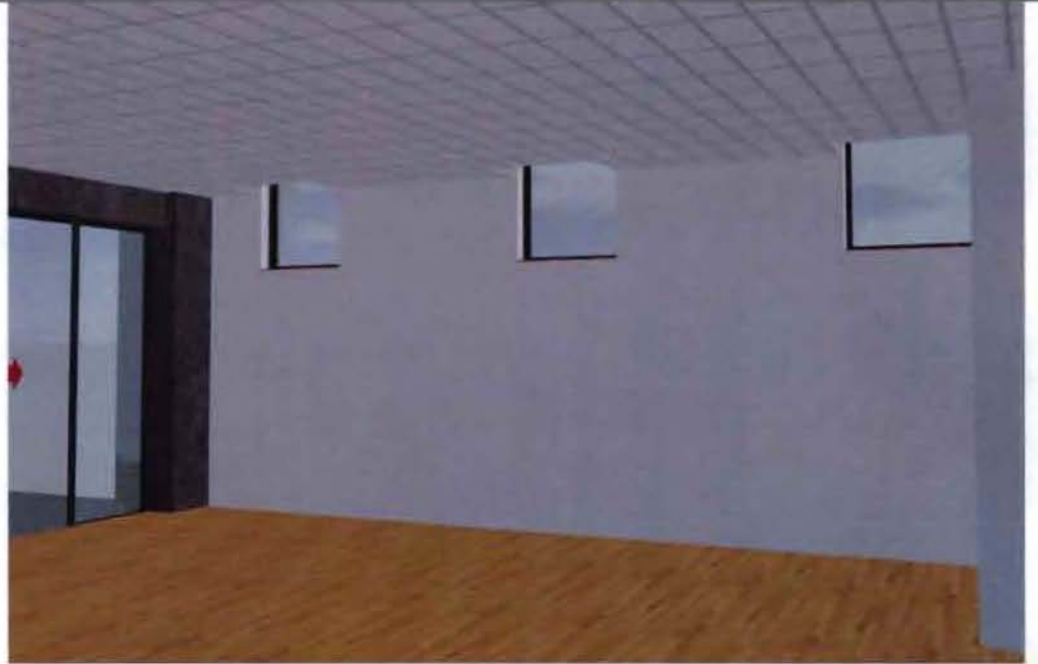
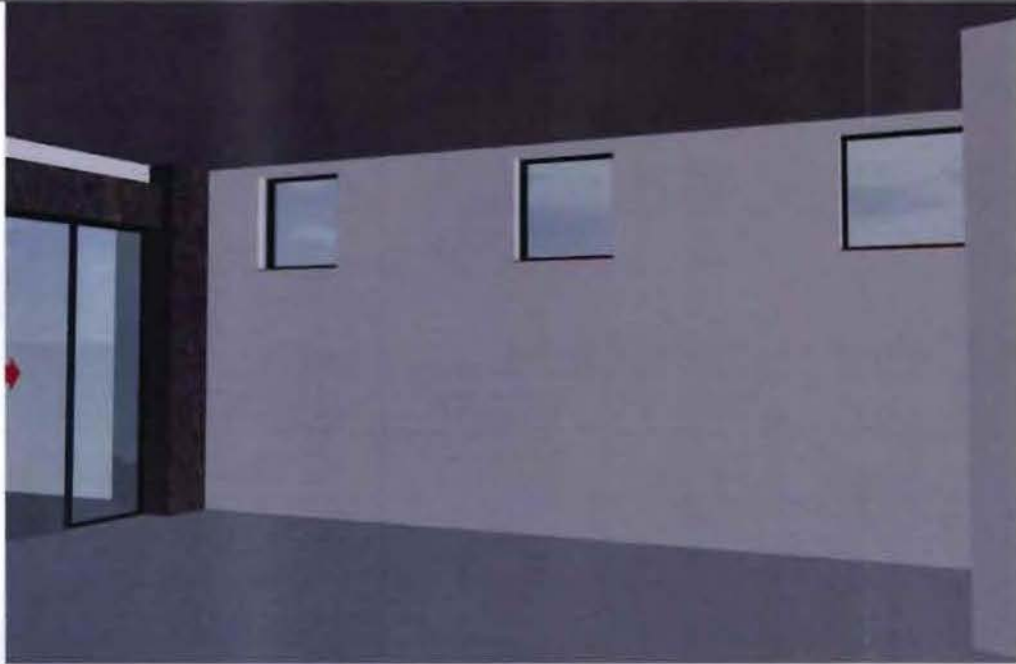


5.3.4 Interior of the east side of the base

After the completion of the exterior, the new interior could be made. Also this part consisted mainly of remodeling already worked out ideas. Due to the detailing, some previously unseen problems had arisen. One of these problems was with the small square windows in the stucco wall near the entrance. These were higher than the ceiling. This was noticed when looking in the CAVE. Lowering of these windows was not an option. This would cause problems on the exterior because the windows would reach under the concrete band. The windows would also preferably be kept square. Therefore, indents were made in the ceiling.

Other problems that existed had to do with connections of interior walls to the façade. The rule for these cases was to close the façade at that point with a wall and connect the interior wall to it.

One thing left to design was a more detailed version of the railing system. It was already decided that it would be a black metal framing with glass panels in between, but the exact shape and connection of the glass to the frame still had to be done. For this, working in 3d again helped. A global concept was worked out and with the help of the CAVE, dimensions could be checked. This way, the railing system could be designed fast and efficiently. After checking in the CAVE it was decided to chamfer the top and bottom of the vertical frames. This was done to make them less robust.



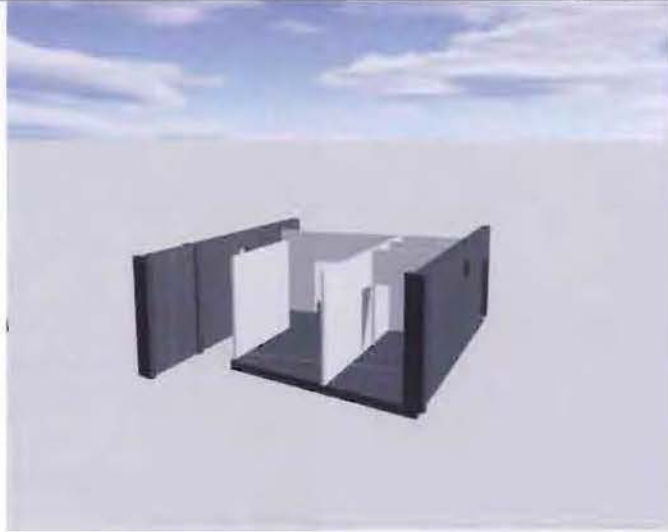
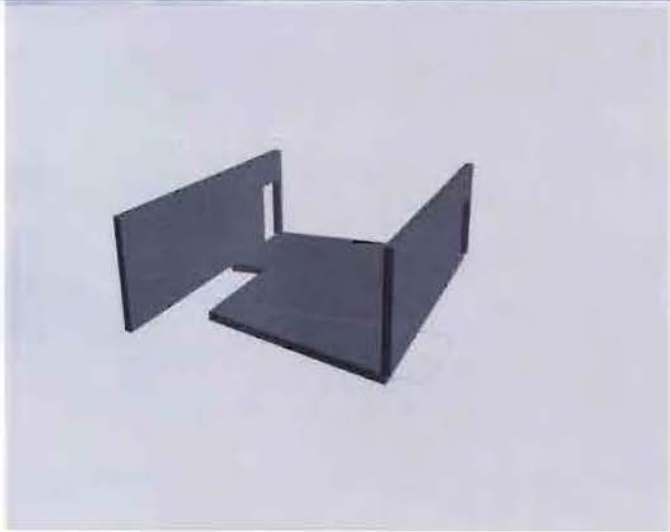
5.3.5 Western part of the base

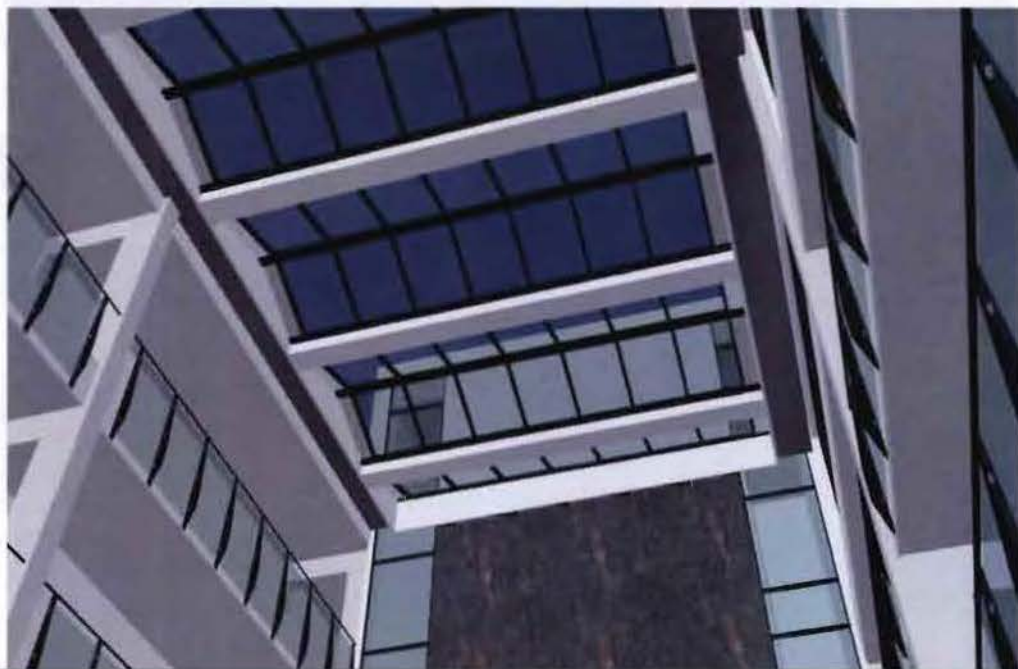
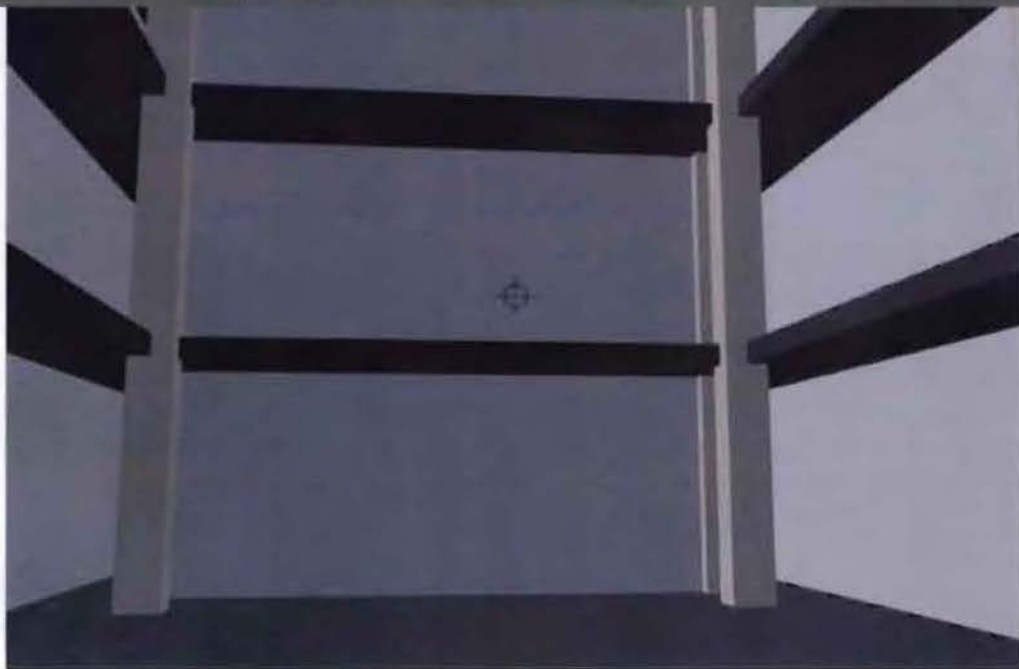
The western part of the base was modeled in the same way as the eastern part, starting with the columns and floors and the stucco wall on the east side. After this, work on the interior began adding walls and the grey granite walls in the shopping mall part.

A different approach had to be used for the apartments in this part of the building. Previously, the structure of the apartments consisted of the same columns as used in the rest of the base. It would be more logical to use the apartment dividing walls as structural elements. Therefore, structural walls were created with openings on one end for the galleries as seen in the first picture to the right. These walls span the distance of 8,1 meter and rest on both ends on the columns of the ground floor. Next, the non-load bearing walls were added followed by the façade elements. This way, the apartment was modeled as a module that could be copied multiple times as seen in the last picture. The new structural system caused a slightly different look of the atrium in the middle of the apartment cluster and the hallways along the backside of the lower apartments. This change is that there are now portals visible in the atrium and hallways instead of just columns.

After viewing the atrium in the CAVE, it was also decided to create a visual connection between the atrium and the amenities below by adding 2 glass domes in the atrium. This was done to enhance the concept of social interactivity. At this point, except for the shopping mall in the eastern base, all functions have a connection with at least one other function.

The last part that had to be modeled was the roof of the atrium. This roof was not designed yet in the previous model. It was decided to make a glass roof to let as much light as possible into the atrium. What wasn't decided was whether the roof should be aligned with the roof of the apartments in the back or the ones in the front. To prevent the creation of another hallway along the apartments at the back, it was decided eventually to align the roof to them. This resulted in the atrium as shown in the pictures on the next page.





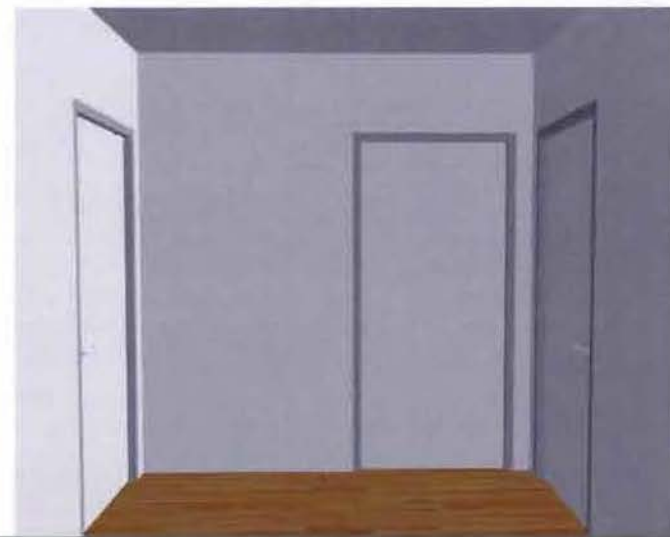
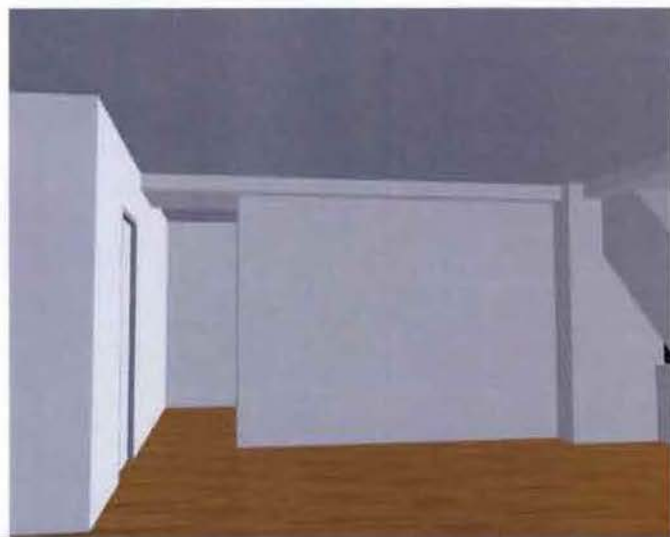


5.3.6 The top

The last part of the building that had to be modeled was the top. To do so, another part of the building was used as a base model. By removing and adjusting geometry it was converted to the top. This included removing floors and shortening the elevator shafts and staircases. The interior of the top was not yet designed before. Thus after finishing the exterior, the interior was made. The top had to contain 6 apartments. To design these, first, sketches on paper were made of possible floor plans. This resulted in 2 apartments per floor, one on the south side and one on the north side. The apartments would then be spread over two of the 3 slabs, leaving room for a small collective recreational area in the west slab. This posed a problem at this point because the collective space would be unreachable. To create a passage, one of the elevator shafts was removed. It is not necessary to let all elevators go all the way to the top because as floors pass by, the traffic declines. Therefore, the capacity of the system can be lower on higher floors.

The previously sketched floor plans for the apartments could now be implemented in the model. A problem occurred due to the diagonal braces running through some of the floors of the apartments. It was almost impossible to take them into account while drawing the floor plans. Instead, the CAVE was used to find any conflicts and resolve them. 2 examples of these conflicts and their solution can be seen in the pictures to the right.

The 2 highest apartments are located directly underneath one of the angled roofs. This creates an extra spacious living room as seen in the last picture. The glass façade seen on the left in this image would actually have to be designed like all façades on the sides of the apartments: per floor and with stone strips along them. This type would be inappropriate and out of place for such a room. Therefore it was decided to make an all glass façade. The façade faces the other half of the same apartment containing the bedrooms and bathrooms and a utility room on the top most floor of the building.



5.3.7 The atria

The building contains 5 atria, all with a different style. One of them, the second, was already designed earlier but the other four still had to be done. It was found that the CAVE for this job was an especially helpful tool. The design process of the four remaining atria is described below.

First atrium

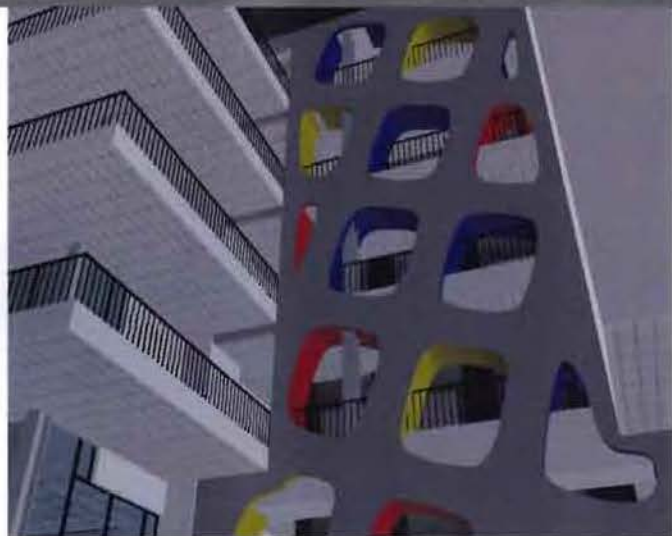
The first of the atria, unlike the other ones, functions as a hub between all the amenities and therefore is used by most people in the building. For this reason, this atrium is designed in the style of the rest of the building instead of having its own identity. This means it has marble flooring with the same glass railings along the galleries as found in the shopping mall. This atrium also has a stairs in it. This stairs is used for reaching the roof of the base where a roof garden is located. Because the railing was already designed in a previous phase, the modeling of this atrium was done quickly. The only new element was the stairs. For placing this stairs, the CAVE was used to find the best location. In this case, this meant moving the stairs only a few decimeters to find a harmonious position within the atrium. The modeling process can be seen in the pictures to the right.



The third atrium

For this atrium, the idea was to create an environment for younger children. This would be done by creating a plastic looking environment with rounded forms. For this, first sketches were made on paper. Later, the idea was converted to the 3D model resulting in the first image to the right. The design rule was to create a wall with holes in which children could sit and play. These holes were tilted at an angle. The same angle as to which the tower is rotated with respect to the base. When this design was viewed in the CAVE, it was noticed that due to the rotation, some strange holes were created. These were then removed. The design however had another flaw. Some of the holes were unpractical while others were dangerous because children can easily climb over the railing. Therefore it was decided to remove the rotation of the holes and add extra tall railing with glass to keep it transparent and to prevent children sticking their heads in between the bars of the railing. It was also decided to make the wall less thick as can be seen in the third picture as opposed to the first 2. This is done to make the wall less massive and to further prevent the ability to climb on them.

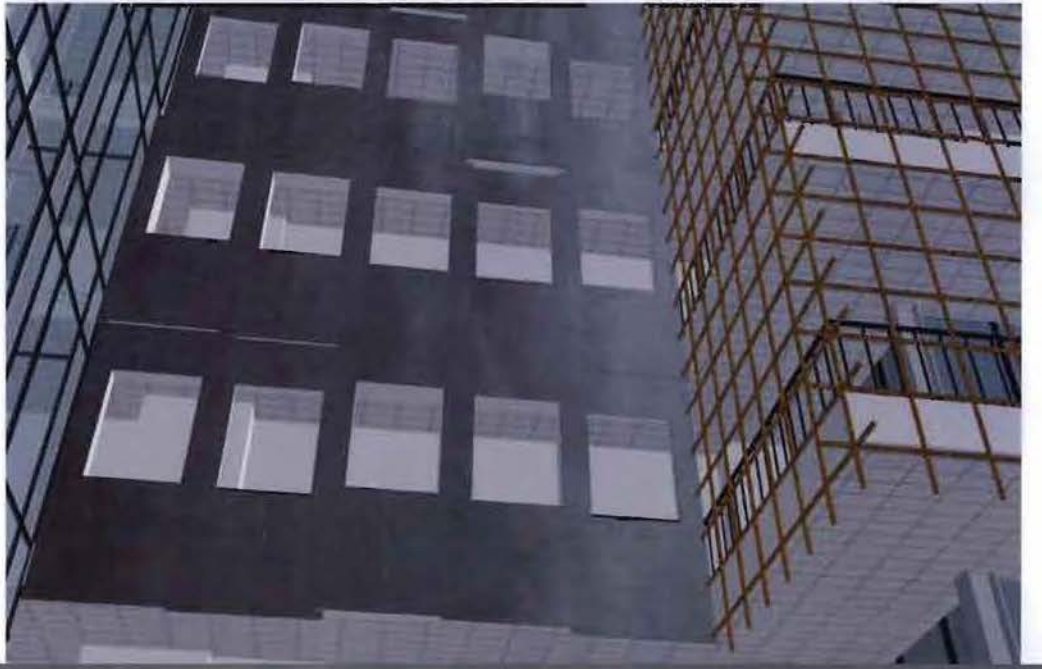
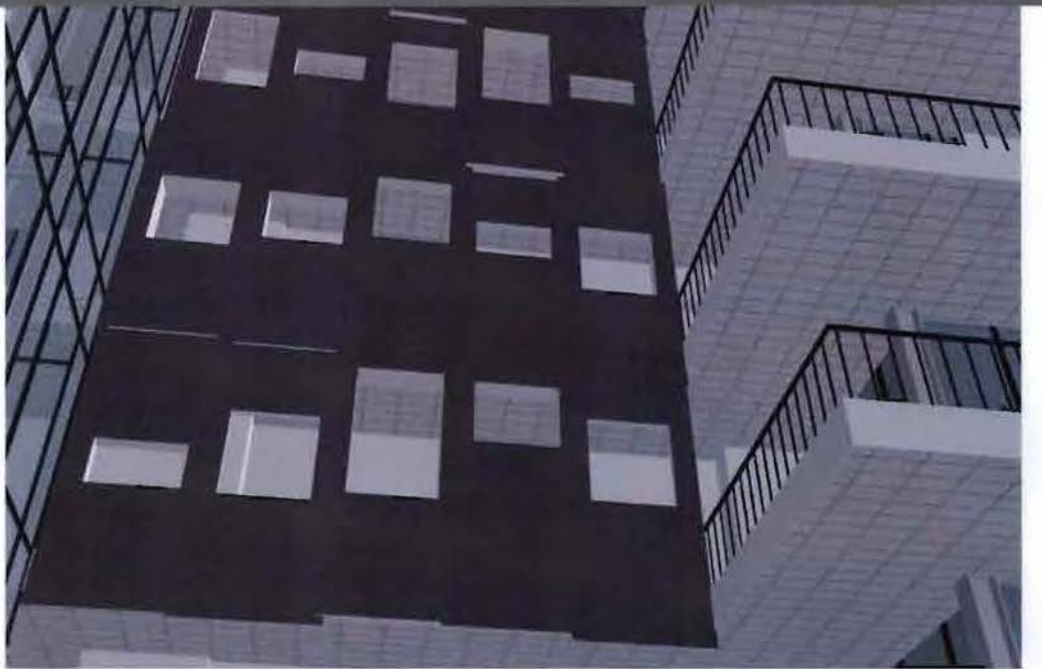
Another part of the atrium where the cave was helpful was in the 4 spaces in every corner of the lobby. Here hangout areas are created, one as a playing field, one as a playground and 2 as hangouts for older children. For the 2 hangouts, sitting areas were designed. The idea was to create intimate more private shelters. This is seen in the 4th picture by creating sitting holes. After trying different designs for these, no satisfying result was found. The big volumes created for these shelters didn't fit in the space very well and it was difficult to incorporate them with the x bracing in these spaces. Ultimately the shelter idea was abandoned and replaced with simple benches which fitted in much better.



The fourth atrium

This atrium is designed towards older youth. Therefore the concept was to create a more industrial look. The concept was to create a wall with extruded facing of different widths. The rule is that no panel is in line with its adjacent panels. The other rule is that the hole in every panel is of a different height. Next, different materials were tried for these panels which led to the choice of metal panels. A problem that was found with the help of the CAVE was that the concept made the wall look too busy. Therefore the holes in the panels were all made equal in size. This still had a more playful effect but it looked much calmer.

Next the idea was to add to the industrial look by adding bamboo scaffolding common in Hong Kong as a railing system. This can be seen in the last picture. Later, diagonals were added to the scaffolding and the metal fencing was removed completely.



The fifth atrium

The fifth atrium is designed with rich business people in mind. Therefore a more business look together with a bit of romance was the concept. By sketching, the idea of creating triangular balconies was created. The hardest part in designing this atrium was choosing the materials of out of which the balconies would be made. Different colors and materials were tried in the CAVE including red stucco, travertine, river stone and granite. Even a whole new concept was tried to see whether that would work or not. In the end it was chosen to use only grey materials in the balconies to keep the business look.

The design process started with adding the frames for the balconies, a reference to the frames of the apartments on the base. The frames were filled in with parapets. First a red color was tried but it did not give the desired business effect. After this, different materials were tried and analyzed with the CAVE but nothing seemed to create the desired effect. Therefore another concept was tried, similar in shape as the colonial atrium but with different colors. This way it was researched whether simpler shapes with the same materials as already tried gave the required effect. It worked better but it also gave the idea to try granite on the previous design with the triangular balconies. This created more of a business look. To keep the aspects of romance in the design, planters were added which gave the whole atrium which at this point would become the final design.

The floor of the atrium was then further designed as an abstract garden with planters and a fountain. The fountain was later removed again because it did not fit in with the rest of the design.



5.3.8 Revision of the atria

Up to this point, all of the atria lacked thoroughly worked out design ideas. This resulted in design decisions that did not fit in with the building. All the elements in the atria are just decoration without having any function. This was also visible in their design. An example of this is the fact that elements expected to be load bearing, like walls or columns, are now hanging in the air and do not touch the ground.

To solve these problems with the atria, a common set of rules was made to apply to all the atria. This means that every atrium will have a theme, chosen with regards to the target group of the building block the atrium is located in. The target groups ordered from bottom to top are:

1. Extended families: Parents with children and grandparents
2. Elderly people
3. Families with younger children
4. Families with teenage children
5. Business families without children

For the theme of the atria, a material was chosen that fits with the target group. The lowest atrium has a broad target group and it is a hub between the different amenities in the base. Therefore this atrium has the most diverse users. This resulted in a generic theme for this atrium. It is themed in the style of the building itself. This means the main material used here is glass.

The second atrium is designed with regards to elderly people. For this target group, a warm and calm atmosphere was preferred. Warm colors were used together with elements referring to Hong Kong's colonial history. The material best fit for this theme is brown colored stone like travertine.

The main material in the third atrium is plastic. Due to its properties, plastic can be formed into any shape creating a playful atmosphere fit for children in this atrium. By creating rounded shapes instead of sharp edges, the

atmosphere is also friendly and inviting for youngsters.

The fourth atrium is designed in metal creating a tough and industrial look. This look fits well with teenagers because of its tough and adventurous character.

The fifth atrium, designed for wealthy business people has a more business look. This is achieved by using granite as the main material. Due to its grey color it has an office look. To make it friendlier and fit for a living environment, it is combined with planters and a wooden platform. This combination in turn creates a high wealth environment.

After defining the materials for each atrium, a set of design rules was created. After thoroughly analyzing the south and west side of the atrium space it was found it could be divided into two distinct parts, a part with fixed floors and a part with galleries. The other two sides of the atrium were already given and do not need additional designing. Because the south west part can be divided into two sections, two design rules apply. It isn't a logical decision to hang walls on the part with the galleries. These are horizontal elements; the vertical wall elements previously hung here were out of place. Therefore these vertical elements are replaced by horizontal parapets. For the other part, with fixed floors, vertical elements can be applied. Thus the west side of every atrium is fitted with a wall element with openings similar to the ones previously designed. The difference is that these wall elements now reach all the way to the ground floor of the atrium making these elements standing rather than floating elements.



5.4 Findings during the design process

During the design process, not only the CAVE was used to view the model. Because the desk CAVE of the University of Technology of Eindhoven uses beamers, temperatures inside the room rise. To get a clear image on the screens the room also had to be dark or else it was hard to distinguish between slight color-variations. For these reasons, a normal computer was used to view the model as well. This in turn gave the opportunity to invest the differences between a normal computer screen and the 3D view the CAVE offers.

The main difference between the 2 is that the normal computer screen shows much less of the model. It only shows the things you're looking at directly while the CAVE gives a much broader viewing angle also letting you see the model from the corner of your eyes. This gives much more depth and a sense of scale to the image. By looking on both types of screens, it was found that the CAVE is especially useful in interior spaces. For exterior viewing, the normal screen often provided sufficient information. This can be related to the relative scale of the part being worked on. The relative scale is the ratio between the parts being worked on as compared to the bigger picture. The smaller this relative scale is, the less depth the part has and the less the CAVE is really needed. This concept appears to work on every scale level.

A good example to illustrate this is appeared in the beginning of the design process. The scale of the tower compared to the neighborhood is big. While doing the massing study for the shape of the tower and base, the CAVE had more advantages over the normal computer screen. The building shape could be viewed from different angles and due to the CAVE; it was possible to really see the bigger picture as a human being actually walking around in the neighborhood.

Later, when work started on the façade, especially on the 2 floors high façade elements on the west sides of the apartments, the scale of the elements is very small compared to the neighborhood, even to the whole tower. For this task, the flat computer screen proved to give sufficient information.

Working on the interior of the building, most of the elements are relative big

in scale compared to the whole interior space. Therefore, the flat computer screen was not sufficient in most cases, only when working on small details like the exact height of railing and the shape of the seats in the 'plastic' atrium. Last the flat screen also proved to be sufficient in the first stage of stage 3 of the design process, the detailing. This is the stage in which the details for the floor system and façade system were designed. These details again are small compared to the whole structure. In addition most of these details aren't visible in the final design and thus, their exact design doesn't have a direct influence on the visible part of the design.

When a computer screen was sufficient, the perspective viewport in 3ds Max could also be used to view the model. This was done in a few occasions giving the same results. However, 3ds Max is very slow compared to Vizard, especially on large complex scenes. Therefore Vizard was still the preferred viewing software in these cases.

Another completely different finding had to do with the design method itself. As the 3d model became more and more complex, it also became harder to work with. Not only due to insufficient computer power, a problem that can be avoided by working efficiently, but mainly due to visibility. This was also caused by the asymmetric design and the rotation of the base. The orthographic wireframe viewports of 3ds Max (top, left and front views) became scattered with lines making it hard to distinguish between different objects. This slowed down the design process. Sometimes it different elements could be hidden to clear up the viewports but this was not always possible because those objects were needed for the alignment of other objects. This problem to some extends prevented working on small details in the later stages of the design. If this problem didn't occur, it would have been possible to spend more time working on these smaller details and refine the design further.

This problem also meant that the design process became increasingly slower towards the end and that it was less likely to try different ideas.

5.5 Graphical representation of the data

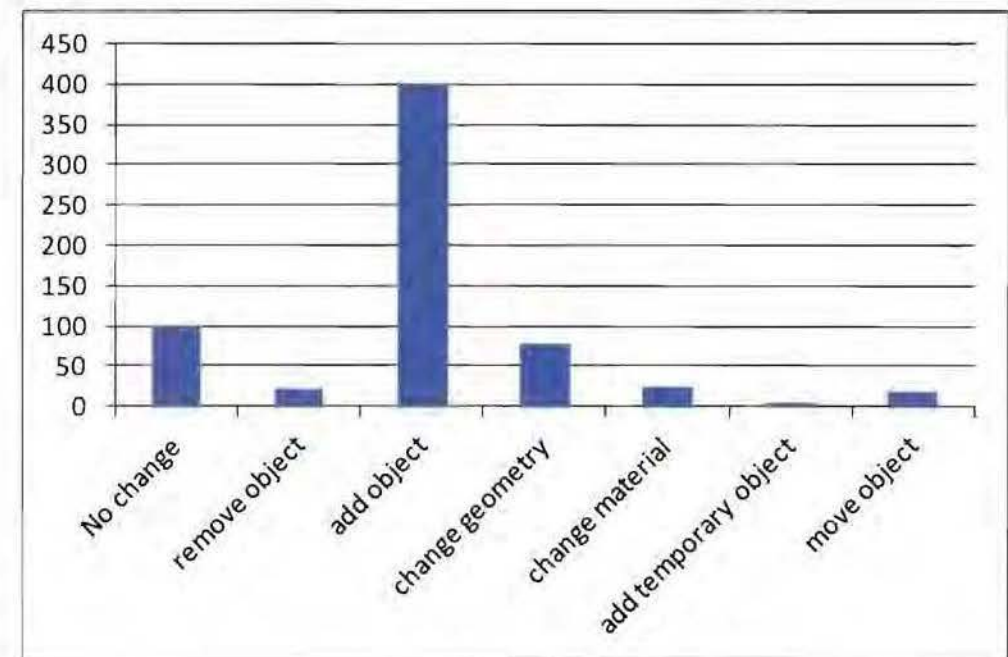
The adjustments that have been done each half an hour, which can be found in appendix 1, have been categorized in 7 categories. No change, remove object, add object, change geometry, change material, add temporary object and move object. This helped with getting a graphical representation of the data. 2 graphs are displayed to the right. The first one shows all the adjustments and their frequency in time. The bottom graph also shows the frequency, but here it is done in percentages. Here the surface of each color represents the percentage with which the adjustment appears as opposed to the others.

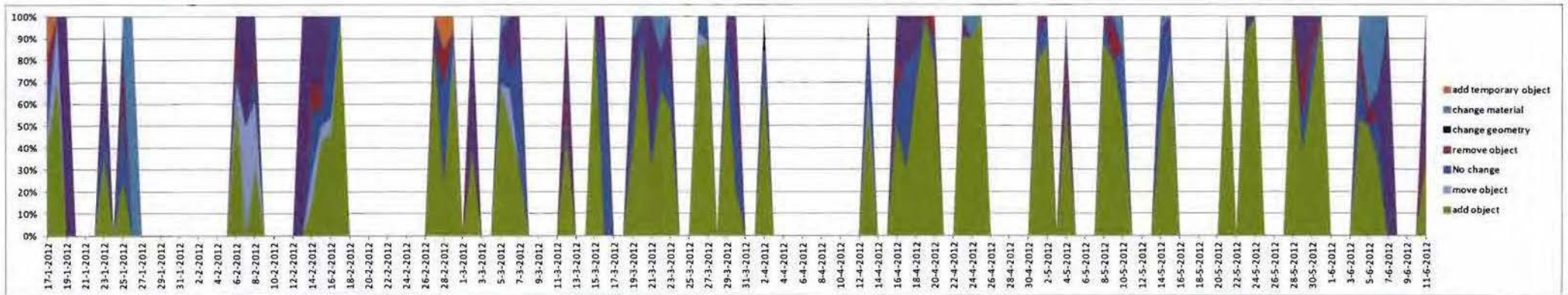
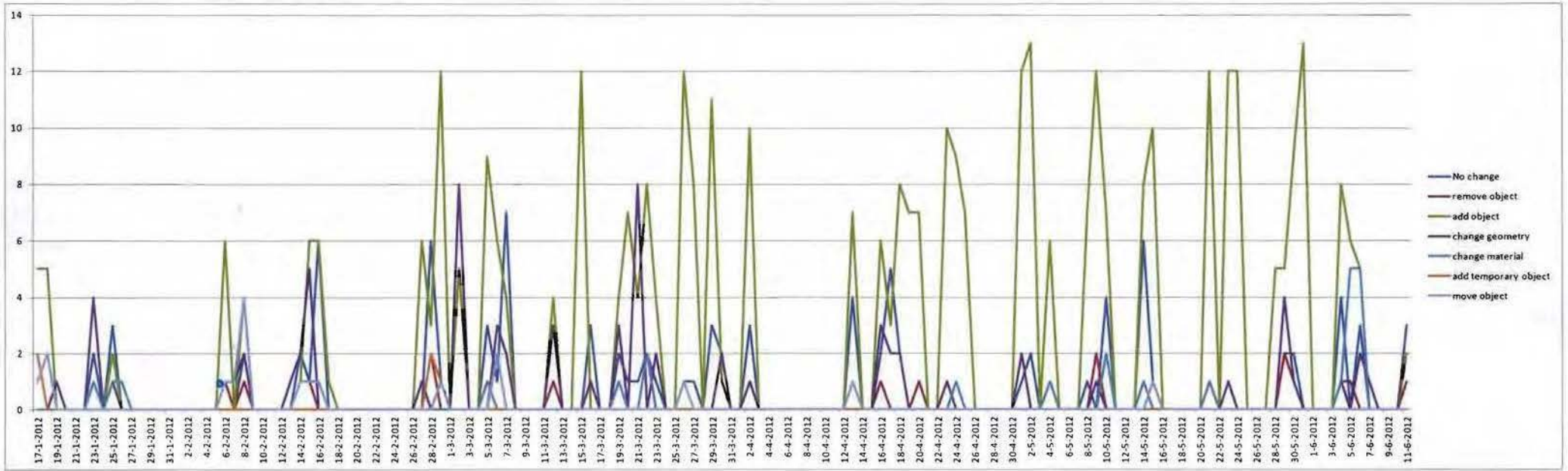
It can easily be seen that the most frequent type of adjustment is adding objects. Throughout the whole design process, objects have mainly been added to the scenes. This is also the most time consuming of the adjustments. The second most frequent adjustment is no change. This has happened because the computer was left running while doing other tasks like working out ideas in the sketchbook. Next to this it can be seen that some adjustments are stage specific. The adjustment adding temporary objects, mainly concentrates in the beginning of the design process. After a while, all the shapes are known and no replacement geometry is needed anymore. In the beginning it was easy to test different shapes with basic replacement geometry. The other adjustment, changing materials, tends to be more frequent towards the end. This can easily be explained because no materials were added yet in the first stage and the first part of the second stage. Materials became especially important in the final stage, the detailing. Changing objects is mainly focused in the first and second design stage. In these stages, the tower was designed globally. In the last stage, most of the building was thus already designed and geometry could just be added without changing it because the shape was already known.

It is also clearly visible that in the beginning and towards the end, the frequency of adjustments is lower, less dense than in the middle. In the beginning, adjustments could be done quickly, because there was not that

much geometry yet and during the shape design, a lot of testing in the CAVE was done, viewing the building from different angles in the city. This consumed more time. Towards the end, adjustments became less frequent because the model became hard to work with due to computer power and the number of objects.

The graph below shows the total frequency with which each adjustment appears.





6. Conclusions

The question asked at the beginning of this research was:

Does the possibility to design, work and experience a high-rise in a real size, 3dimensional environment using CAVE-technology give a better insight in the scale and space in the project over 2D techniques, resulting in a design humans can more easily relate to, is better thought off and is made faster?

The following sub questions were asked:

- Does working in 3d prevent common mistakes in a design rather than having to resolve them?
- Does working in 3d give solutions otherwise not or later thought of?
- Does the 3d environment serve as a better medium of communication with the tutors?
- Does working in 3d save time?

The main question can be divided into several parts with a different answer. Therefore, the question will be broken up in parts and answered separately starting with the sub questions.

On different occasions, design mistakes were found while walking through the model. These mistakes mostly consisted of misalignments or structural elements sticking through passages. Thus it can be concluded that working in a 3D environment doesn't prevent mistakes. It even creates mistakes instead, although these mistakes are on the modeling level rather than on the design level. By walking through the model however, mistakes were easily spotted and they could be addressed immediately. These mistakes would have been much more difficult to spot in traditional design methods. Especially the mistakes where diagonal braces ran through door openings and passages. The exact course of these diagonals would not have been drawn in normal 2D drawings and the mistakes would not have been seen. Instead, for every occasion where a passage crosses a wall with a diagonal brace in it, a special

drawing would have to be created in order to determine its location. This would take more time. It can be concluded that although the CAVE didn't prevent mistakes, it did have a positive impact on the speed with which mistakes are found and resolved.

For the next question there were instances where the CAVE directly caused the final design decision, but also caused the rejection of design ideas. This can be read in the previous chapter on the design process. A good example for this is the final shape of the base structure. Because no form could be conceived on paper, different shapes were tried and evaluated in the CAVE leading to the final design. This design looks quite odd on paper due to the angle at which the west most façade is oriented, but it appears to work well in the CAVE and thus in the real life situation as well.

Probably the most adjusted parts due to the CAVE are the atria. This started with the height. At first, being 14 floors high, with the CAVE it was noticed immediately that these were too high. This caused the reduction to 6 floors. This would normally go unnoticed until a section or a 3d model of the atrium is made, both tasks done later in the design process. The sketch of the atrium that was made didn't provide enough depth to notice the problem either. Next came the positioning of the elevators and the lavatory blocks. With the help of the CAVE, views on the construction in the atrium were found to look pleasing. These views were wanted to be preserved and thus, a position for the elevators and lavatories was sought that preserved these views. Without the CAVE, these views wouldn't have been noticed and the elevators could have blocked them in the final design. Later on in the design phase, when the atria were themed, the CAVE again caused design decisions on this part. Due to the CAVE, the 'pasted on' nature of the added elements was discovered. This caused a complete rethinking of the concept for the interior of the atria.

Another design decision that was made with the help of the CAVE was the addition of much needed colors in the shopping mall. The design of the shopping mall with granite frames with glass or white stucco walls in between them looked to business like, although it did fit the shopping mall. To make it more intimate and boast the shopping mall character, it was found that

warm colors were needed here. With the help of the CAVE different colors and materials were tested quick and easy.

It is hard to say whether these examples of design decisions were made completely due to the CAVE. What can be said about them is that they would have required extra resources to be made in a traditional design process. It could be done by means of sections, sketches and models. All of these things would have been made eventually but then the changes would come much later in the design process and it would be harder to make them. If all these design decisions were evaluated with models and drawings during their design phase, it would have taken much more time to make these decisions.

The fact that the design could be seen as it is in 3D helped greatly during consults with the tutors. Due to the exactness of the model as opposed to drawings, it contained much more information which made the design easier to explain and understand. Due to this exactness, the model also can't be interpreted in different ways preventing misunderstandings and unwelcome surprises later on in the process. It also helped the tutors in noticing points for improvement more easily making the consults more efficient. The CAVE system thus did have a positive effect on the consultations and it is a better medium of communication.

For the last of the sub questions, it was already found out that working with the CAVE speeds up complex decision making. However it is also seen that as progress advanced, modeling slowed down leaving more time between decisions. The decisions that were made however were much better grounded than what would have been possible in the same amount of time in a more traditional way. In the end of the design process, it had taken even longer than a normal design project but also a lot more was designed than normally possible. Despite of the slowing down caused by the modeling it is thus still faster than traditional methods. Also due to the quality of the decisions, not much redesigning had to be done.

Concluding from these questions together with the analyses of the design process, the main question can be answered with yes. With the help of the CAVE it was possible to design a high-rise structure that is more fitting to a scale better comprehensible by its users. This is especially true on the inside. Although most ideas that cause this were developed on paper rather than in the CAVE. The CAVE did help in giving these ideas their final form, enhancing the initial ideas and being able to tweak small and big details into a harmonious whole. Although it took more time than a normal project to do it, the size of this project required more designing than average. This means, more design decisions were made in slightly more time and these decisions were better grounded. Working with the CAVE thus proved to be more efficient.

In all, the CAVE had a positive effect on the design process, not only for the process itself but for communication with tutors or clients as well. It is much easier to understand when everything can be seen as it is going to be in real life. Besides this, the CAVE allows to work much faster than normal, speeding up the design process without loss of quality and giving better insights in the design.

6.1 Conclusions on the design

The goal of the design was to address the problems of the skyscraper typology. This meant the feeling of social isolation should be diminished. The building should be less intimidating for tourists and be more open especially on ground level to make the streets around it more attractive for pedestrians. It should be more aware of its context.

The building was designed with these problems in mind and concepts were devised to give solutions. The building has been made more socially attractive with the introduction of the building blocks and thus the sky lobbies and atria. By introducing these building blocks, the overall size of the building is divided into smaller parts creating smaller groups and communities, as if one was to live in a medium sized building block. By keeping this size minimal, less families and office workers live and work inside the block, making the block less massive and more intimate. The inner sky lobby provides users with a small plaza where they can meet each other. This is one of the 2 ways social isolation is addressed. The other way lies in the shape of the apartments. Because of the light trenches that were required by Hong Kong law; the apartments have 2 sides, the front side which looks out over the city, providing a common skyscraper view and the sides, which look out on other parts of the building. This second side gives the illusion of living in a street which isn't high off the ground due to the proximity of the neighboring apartment also diminishing the feeling of social isolation.

By creating an open plinth with shops that are publically accessible, together with an open plaza in front of the tower should make it an attractive area. By placing the tower itself further to the back, attention is drawn away from it and focuses more on the base. Due to the division of the tower itself into building blocks, the tower becomes more comprehensible. This is further enhanced by the visible structural elements that divide the façades within the building blocks. This also makes it less intimidating for tourists and the shopping audience making the plaza more attractive.

The base of the building is aligned with the neighboring Hampton Place complex and the tower itself is rotated towards the Hoi Fai Road. This way, the building is embedded into its context and creates a natural flow towards the park between Hampton Place and the Long Beach. Also the base has features referring to the older part of Kowloon. This, together with the transparent and public nature of the base makes the building fits well into the context.

It can be concluded that all the problems mentioned are addressed in the building. This was partially achieved with the help of the CAVE but also with concepts worked out on paper. It can thus be said that the building achieved its goal.

7. Recommendations

For this research, the design method was tested on an exceptionally large project, this made it difficult to compare to other projects. For a next experiment, it could be possible to apply the design method on a smaller project which involves a smaller amount of design decisions to be made. This way, it should be easier to compare it to similar projects by means of time and quality of the final design. To optimize the results it could also be possible to have the same design assignment done by different parties, with the help of the CAVE and without. This way, the designs can be compared one on one. By doing a smaller assignment it would also be possible to go into much more detail in designing, leaving the final results conceived better.

Due to the software package chosen for this project, the design process became increasingly slower towards the end. This was caused by computer power, but mainly also due to the readability of the viewports in 3ds Max. The lines in the viewports became so dense that it was hard to distinguish the different objects. To prevent this from happening again, a smaller project could help, but a better solution would be to consider different software packages. Recommendations on this matter go to software packages especially designed for building modeling, like Revit or ArchiCad. Unfortunately, an exporting plug in for Vizard doesn't exist for these packages, only for 3ds Max. Thus another viewer has to be used that supports files that can be exported from these packages or a new exporter has to be written. This however gives the opportunity to eliminate the exporting process and use a package that supports multiple 3d viewports to use in the CAVE or use a direct viewing plug in for the package.

8. References

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9. Appendixes

9.1 Data sheets

The datasheets show the adjustments that have been done every half an hour in which work on the model has been done. If there was a clear influence of the CAVE present in the adjustment, the adjustment is flagged with 'cave came in handy'. The last column shows the type of adjustment the adjustment has been added to. These were used for the graphs in paragraph 5.5. It is possible more than one type of adjustment appears in 1 half an hour. In this case, there are 2 numbers present. The adjustments are:

1. No change
2. Delete objects
3. Add objects
4. Change objects
5. Change materials
6. Add temporary objects
7. Move objects

line	date	time	description	comments	adjustment type
1	17-1-2012	11:48	first design sketch transferred to MAX	3 slabs design	3
2		12:38	experimented with different floor plans and added 4th slab		5
3		12:48	added a global less detailed representation	for easy adjustments in height and experiments in width	6
4		13:18	added a detailed fourth slab	design is bulky and width dept ratio is skewed	3
5		13:48	removed 4th slab and adjusted the tower location to south		2, 7
6		14:18	designed a new floor plan type		5
7		14:48	reverted to old floor plan		2
8		15:18	no changes		1
9		15:48	no changes		1
10		16:18	added a global model and a fourth apartment	apartment on the east side of the building created after a study in AutoCAD	3, 6
11	18-1-2012	15:00	designed a new floor plan type	created deep light wells to provide light and air to all spaces	3
12		15:30	connected the apartments to see the building outline		3
13		16:00	designed 2 bedroom floor plan and skewed the north and south side	new design doesn't look as clear	3, 7
14		16:30	added a fourth apartment and extruded a mass model	apartment on the east side to reflect previous design idea	3
15		17:00	added a base structure and moved tower to north-east	L shaped mass creating a square towards the road crossing	3, 7
16	19-1-2012	14:47	experimented with floor plans for 2 bedroom apartments	distributed on 2 levels takes up the same space as 3 bedroom	4
17	23-1-2012	10:45	added columns		3
18		11:15	added a core structure and a different base design	rotated the tower slightly to fit on the new base	3, 4
19		11:45	further refined the base and added an entrance stairs		3
20		12:15	further refined the base	added setbacks to the lower structure to ease transition towards the tower	4
21		12:45	further refined base		4
22		13:15	further refined base	added lower section behind stairs	4
23		13:45	made the columns white	structure is now better visible up the height of the tower	5
24		15:16	worked out a new alternative	alternative is very wide and bulky	5
25		15:46	no changes		1
26		16:16	no changes		1
27	25-1-2012	10:55	added a mass model of a new alternative	shell shaped floor plan	3
28		11:25	hide the new alternative		2
29		11:55	no changes		1
30		12:25	no changes		1
31		12:55	no changes		1
32		13:25	made the tower red		5
33		14:25	refined the shell shaped alternative and added a base	made renders of all the alternatives up until now today	3, 4
34	26-1-2012	10:29	texture baked the 3 slabs alternative	to view lighting conditions in Vizard	5
35	6-2-2012	10:03	started refining collective interior, enlarged apartments by extruding them outward 1.8m	adding brace frames and floors, changed floor to floor height from 3,2 to 3,6m	4
36		10:33	adding outriggers and the core shape		5
37		11:03	no changes		1
38		11:33	copied the 12 floor structure and placed it on top		3
39		12:03	removed interior braces of middle slab and divided hollow core in 3 parts	braces floated in the hollow core and space was too tall	2
40		12:33	started redesigning east part of tower	apartment didn't have all rooms on exterior	3
41		13:03	found satisfying result by making a 2 bedroom apartment	instead of 3	5
42		13:33	added more braces in the collective area		3
43		14:03	added interior walkways to reach the apartments	noticed brace frames blocked a clean passage, solved by making a go around	3
44		16:03	positioned worked out design on top of the base		7
45	7-2-2012	15:47	after an elevator study started positioning vertical transport	number of elevators is hard to calculate, definitive number not yet found	7
46		16:17	made the stairs shorter and calculated office space		4
47	8-2-2012	10:31	positioned elevators in hollow core	added 2 elevators to a total number of 8	7
48		11:01	no changes	noticed 4 elevators don't fit on the south side due to the passage	1
49		11:31	removed 2 elevators and positioned them on the east and west side	braces aren't visible anymore	7
50		12:01	added u type stairs instead of strait. Takes up less space		4
51		12:31	tried different ways of positioning u type stairs in hollow core	added 2 service elevators (fire and service)	7
52		13:01	removed u-type stairs and positioned west elevators behind braces	they didn't satisfy safety demands (max distance to stairs < 25 m)	2, 7
53		13:31	created holes in floor for stairs and added glass in the light wells		3
54		14:01	no changes		1
55		14:31	cutting sections off the base to integrate the entrance of the tower	also added additional floor in the entrance	4
56		15:01	covered entrance in glass	noticed west part isn't part of entrance, made this part closed	3
57		15:31	added structural ending on the roof, this will incorporate penthouses		3
58		16:01	added spiral stairs in the entrance	result isn't satisfying so I removed it again	3
59	13-2-2012	12:15	rebuilt the structure in separate layers	the building is now more adjustable and manageable	4
60	14-2-2012	12:50	worked on the east staircase area	removed an elevator shaft	2
61		13:20	worked on the east staircase area	added the elevator shaft again	3
62		13:50	made the building 4 meters deeper	from 30 to 34 meters to make the building more stiff	4
63		14:20	started rearranging the interior elements to comply to the new depth		7
64		14:50	nothing changed		1
65		15:20	changed the column's thickness	from 1,2 meters to 1,5 meters	4

line	date	time	adjustments	comments	estimated type
66		15:50	nothing changed		3
67	15-2-2012	10:46	adjusted the base to the new width and added a new elevator in the central collective space.	made the walkways wider resulting from the cave view	talked with professor Hoenderkamp and as a result tested the structure in Scla engineer
68		11:16	working on the base	added a stairs on the northern side of the building	4, 3
69		11:46	rebuilt the structure to be more adjustable.		3
70		12:16	added diagonals in the interior walls between the columns.		4
71		12:46	removed some of the glass parts in the base	they were outdated and didn't fit anymore	3
72		13:16	started adding updated glass parts in the base		2
73		13:46	adding updated glass parts in the base		4
74		14:16	working on the western staircase.		4
75		14:46	nothing changed		3
76		15:16	repositioned staircase	to incorporate fire safety doors	1
77		15:46	detailing the staircase area to incorporate the fleeing route		7
78		16:16	added a lavatory space for the offices		3
79		16:46	repositioned east staircase and added 2 elevators and redesigned east apartment	tested different locations for lavatories. Apartment wasn't possible; diagonals	3
80	16-2-2012	10:03	positioned lavatories in the final location.	next to the elevators	cave came in handy
81		10:33	started adding doors to the staircases	first on the western stairs	7
82		11:03	nothing changed		3
83		11:33	nothing changed		1
84		12:03	nothing changed		1
85		12:33	nothing changed		1
86		13:03	nothing changed		1
87		13:33	nothing changed		1
88		14:03	finished the bottom part of the stairwell	there's a different floor height here	3
89		14:33	added the doors on the other side of the west staircase		3
90		15:03	adding glass infill panels in the diagonals area on the west façade		3
91		15:33	started with façade in the smaller squares in the west façade	try traditional Hong Kong façade	3
92		16:34	also added grey natural stone panels	slightly based on the Maastoren in Rotterdam	both façade types weren't satisfactory after checking in the cave
93	17-2-2012	11:52	added another total glass panel	more satisfactory but not really looking residential	3
94	27-2-2012	11:09	started adding grey natural stone façade elements in the office part		3
95		12:09	the same for the glass panels	slightly different to look more office-like	1
96		12:39	copied the glass panels over a bigger area, also tested simpler office glass panel	to see how it looks	3
97		13:09	added interior walls in an apartment	slightly different to the initial design	to see how an apartment looks
98		13:39	added a glass façade system on the southern wall		3
99		14:09	copied the glass system over an entire 12 floor sub-flat.		3
100		14:39	slightly changed the design and applied in on the northern office façade		4
101	28-2-2012	9:26	nothing changed		1
102		9:56	added mass on top of the building to house the penthouses		6
103		11:00	cleaned up the file by removing old parts and added façade elements on the east side	between the 12 floor flats	2
104		11:30	nothing changed		1
105		12:00	did a study on the parking space sizes and added some to derive the grid from them	for the lower base sections	3
106		12:30	continued adding parking and adjusting the base size accordingly		3
107		13:00	nothing changed	noticed the number of parking spaces required would never fit	1
108		13:30	nothing changed	found a document on the Hong Kong government site on parking spaces	1
109		14:00	nothing changed	recalculated the number of parking spaces	1
110		14:30	nothing changed	went back from 1000 parking spaces to 202	1
111		15:00	added mass on the base to conform to the adjacent road	doesn't look good	cave came in handy
112		15:30	removed the part again and cut off the base at an angle	looks better	6
113		16:00	started working on the single bedroom apartments on top of the base	drawn floor plan outlines	cave came in handy
114	29-2-2012	8:50	added some people in the building to get a better understanding of scale and size		3
115		9:24	designed some furniture to place inside the apartments to see how it fits	apartment's living room is rather narrow	3
116		10:35	started adding columns in the base between parking spaces to determine the grid size		3
117		11:05	determined final position of the columns and added conceptual mass for the apartments	according to hand-drawn design (ideal grid size is 8,1m x 8,1m)	cave came in handy
118		11:35	designed a new floor plan to conform with the columns and conceptual mass.		7, 6
119		12:05	added frames to the south side of the mass	to better divide the apartments	3
120		12:35	started with the infill of the façade in the frame		3
121		13:30	tried different façades in each frame, also added more apartments on the northern side	with and without balconies and to reach the required number of apartments	cave came in handy
122		14:00	nothing changed		1
123		14:56	further designing the most desired of the façade types.		3
124		15:26	further designing the most desired of the façade types and added floors	also copied it to see how it looks on a bigger whole	3
125		15:56	finalized the design of the façade element	made the floor on the east side of each apartment parallel to the grid	cave came in handy
126		16:26	added a core for vertical transport		3
127		16:56	completed the vertical transport system		3
128	2-3-2012	10:08	made each apartment bay in the tower 0,6m wider	each apartment is now square	4
129		10:38	start adjusting all the elements to conform to the new width		4
130		11:08	start adjusting all the elements to conform to the new width		4

line	date	time	description	comments	adjustment view
131		11:36	start adjusting all the elements to conform to the new width		4
132		12:08	with the new width, the apartments are slightly redesigned	mostly dimensions are changed. Also front doors added through the diagonals	4
133		12:38	front doors slightly repositioned due to the diagonals		4
134		13:08	adding façade elements on the office side in the collective space	checked them in the cave	3
135		13:38	adding façade elements on the office side in the collective space		3
136		14:08	copying the apartments on the front of the base to the back	they were still the old design	3
137		14:38	adjusting them slightly to fit 6 apartments in 1 frame	instead of 3	4
138		15:08	adding windows in the kitchen area	made the walls above them yellow to conform to the part on the balcony	3
139		15:38	copied the apartment floor plan to all 3 bays in the tower	to check the view from each room	3
140		16:08	changed the height of the front of the base slightly	looked worse after viewing in the cave	4
141	5-3-2012	9:58	added interior walls in the lower base part	dividing the shops	4
142		10:28	added a first design idea on the façade of the lower base part	different from the rest of the building	3
143		10:58	started finishing the upper apartment parts of the base	just started	3
144		11:59	adding windows in the hallway areas		3
145		12:29	nothing changed		1
146		12:59	added swimming pool		3
147		13:29	nothing changed		1
148		13:59	started adding windows underneath the apartments at pool level		3
149		14:29	finished adding the windows		3
150		14:59	detailing the entrance area of the base on the tower side		3
151		15:29	detailing the entrance area of the base on the tower side		5
152		16:29	nothing changed		1
153		16:59	tried different colors for the front side of the base		5
154	6-3-2012	9:55	started designing the upper floor of the front of the base	not very happy with the result so far	3
155		10:25	continued the façade around the south west corner		3
156		10:55	tried another façade design on the upper part	continuing the ground floor façade	4
157		11:25	still working on finishing the façade design		4
158		11:55	finished the façade		4
159		12:25	started filling in the east façade		3
160		12:55	finished façade and created interior walls for the east apartment		3
161		13:25	finished with the apartment		3
162		14:25	filling the top floor of the base with glass		3
163		14:59	nothing changed		1
164		15:29	analyzing how parking spaces would fit underneath the tower		7
165		15:59	analyzing how parking spaces would fit underneath the tower		7
166	7-3-2012	9:26	added a stairs to enter the shopping mall on the west façade	it looks a bit small and clumsy	3
167		9:56	worked on the entrance area on the east side of the shopping mall		3
168		10:26	unhide all the geometry to check the whole picture		1
169		10:56	nothing changed		1
170		11:26	tried a different kind of stairs in the east entrance area		4
171		11:55	nothing changed		1
172		12:25	nothing changed		1
173		12:55	nothing changed		1
174		13:25	nothing changed		1
175		13:55	nothing changed		1
176		14:25	started working on new façade elements for the sides of the apartments	based on typical Hong Kong façade elements	3
177		14:55	trying slightly different variations		4
178		15:25	chosen one variant to be the best	also tried balconies on the south façade	3
179	12-3-2012	12:03	finished with the façade elements and reworking the lower shopping mall part	it didn't fit with the rest of the building	2
180		12:37	continued reworking the shopping mall		4
181		13:07	nothing changed		1
182		13:37	façades looked too office like	tried something different on the south façade: yellow parapets	4
183		14:07	came up with a satisfying result		4
184		14:37	refining the design of the façade		3
185		15:07	refining the design of the façade		3
186		15:56	started on the façades on the east side of the apartments		3
187		16:26	continued on the façades		3
188	15-3-2012	9:57	continued on the façades		3
189		10:27	finished the design of the façades		3
190		10:57	started on the façade of the south east apartment	this is slightly different than the rest	3
191		11:27	done with all the south façades		3
192		11:57	started on the façades of the east apartment		3
193		12:27	continued on the façades		3
194		12:57	continued on the façades	yellow parapets around the corner	3
195		13:27	continued on the façades	yellow parapets stop around the corner	3

line	date	time	adjustments	comments	adjustment type
196		13:57	finished the corner of the façade of the east apartment		3
197		14:27	started on the big infill east façade	change it to match the typical Hong Kong façades on the west sides	3
198		14:57	continued on the façade		3
199		15:27	copied the façades up the height of the building		3
200	16-3-2012	11:56	changing the entrance area of the shopping mall	not satisfied with previous result	4
201		12:26	nothing changed		1
202		12:56	nothing changed		1
203		13:26	nothing changed		1
204	19-3-2012	11:41	adding escalators in the entrance area		3
205		12:11	nothing changed		1
206		12:41	designing the entrance area with the escalators		4
207		13:11	continued designing the entrance area		4
208		13:41	flipped the transportation shaft in the low rise part	to locate the elevators in front of the stairs with regards to the entrance	4
209		14:11	defining the elevator lobby area		3
210		14:41	nothing changed		1
211		15:11	changed color of entrance area and added façade on the back side	also added a staircase for the shopping mall	3
212		15:41	working on the façade of the lower part		3
213		16:11	started on the inside of the shopping mall		3
214	20-3-2012	13:02	continued on the inside		3
215		13:32	continued on the inside		3
216		14:02	west entrance area and inside of shopping mall		3
217		14:32	west entrance area and inside of shopping mall		3
218		15:02	continued on the inside	escalator area, adding railings	3
219		15:32	continued on the inside	escalator area	3
220		16:02	nothing changed		1
221		16:32	added an entrance road for the parking		3
222	21-3-2012	10:27	working on the façade of the parking garage	tried horizontal metal fins	3
223		10:57	continued of the façade	copied elements	3
224		11:27	started on completely reworking the shopping mall façade	the existing design didn't fit with the rest of the building	4
225		11:57	continued of the façade	added an overhang like the shops in Kowloon	4
226		12:27	trying different designs		4
227		12:57	trying different designs		4
228		13:27	trying different designs		4
229		13:57	trying different designs		4
230		14:27	trying different designs		4
231		14:57	nothing changed		1
232		15:27	trying different designs	finally came up with a good result	4
233		15:57	modeling the final design		3
234		16:27	modeling the final design		3
235	22-3-2012	9:39	modeling the final design		3
236		10:09	nothing changed		1
237		10:39	modeling the final design		3
238		11:09	modeling the final design		3
239		11:39	modeling the final design		3
240		13:27	refining the inside of the shopping mall	adding colors and materials	5
241		13:57	refining the inside of the shopping mall	trying wood	5
242		14:27	modeling the inside of the shopping mall		3
243		14:57	nothing changed		1
244		15:27	modeling the inside of the shopping mall		3
245		15:57	modeling the inside of the shopping mall		3
246		16:27	modeling the inside of the shopping mall		3
247	23-3-2012	11:04	finished the entrance doors		3
248		11:34	nothing changed		1
249		12:04	working on connections of walls		3
250		12:34	working on inner walls		3
251		13:04	working on west entrance	adding doors etc	3
252		13:34	drawing working lines to start designing the east base part		6
253		14:04	drawing working lines to start designing the east base part		6
254	26-3-2012	9:34	adding columns east base part		3
255		10:17	adding safety route from lower staircase through the base	also added floors in the base	3
256		10:47	working on safety routing		3
257		11:17	working on safety routing		3
258		11:47	working on entrance area and connection to the tower of the east base part		3
259		12:54	adding escalators in the entrance area		3
260		13:24	adding doors and stairs		3

date	time	description	comments	adjustment type
261	13:54	adding interior walls/façades	same as in the already designed part of the base	cave came in handy
262	14:24	nothing changed		1
263	14:54	started adding exterior façade of ground floor	same design as other base part	3
264	15:24	adding exterior façade	ground floor	3
265	15:54	working out connection between base and tower	north part	3
266	16:24	changed the escalators orientation	they were using too much room	7
267	16:54	adding walls and railings on upper floors of the base		cave came in handy cave came in handy
268	27-3-2012	10:51 adding façade on upper levels of the base		3
269	11:21	adding façade on upper levels of the base and trying different walls setup in base	to create a bigger entrance hall	3
270	11:51	continue on interior walls	upper floors	3
271	12:21	adding the yellow parapets on the upper part of the south façade	didn't do this before	3
272	12:51	start adding façade on the north part of the building	in the gaps	3
273	18:21	start working on the glass façade connection between base and tower	on the north part	3
274	18:51	finished connection		3
275	14:21	start working on a working elevator system for Vizard		3
276	14:51	nothing changed	working in Vizard	1
277	29-3-2012	10:07 adding elevator systems		3
278	10:37	adding elevator systems		3
279	11:07	nothing changed		1
280	11:37	adding elevator systems		3
281	12:07	started on final interior walls of the base		3
282	12:37	working on final interior walls		3
283	13:07	nothing changed		1
284	13:37	adding façade on northern part of the base		3
285	14:07	adding façade on northern part of the base		3
286	14:37	adding façade on northern part of the base	finished	3
287	15:07	start on bridge between tower and base		3
288	15:37	finished bridge		3
289	16:07	added a stairs in the first collective space in the tower	to be able to reach the roof gardens 1 floor higher	cave came in handy
290	16:37	nothing changed		1
291	30-3-2012	9:30 started adding wind deflectors		3
292	10:00	trying different designs		4
293	10:30	trying different designs	came up with a satisfactory solution	cave came in handy
294	11:00	nothing changed		1
295	11:30	nothing changed		1
296	2-4-2012	10:15 adding glass elevators in collective space		3
297	10:45	adding glass elevators in collective space		3
298	11:15	modeling glass shafts for the elevators		3
299	11:45	finished the shafts		3
300	12:15	nothing changed		1
301	13:04	added a door to the main lobby		3
302	13:34	started adding glass façade elements on the collective floors		3
303	14:04	adding glass façade elements on the collective floors		3
304	14:34	nothing changed		1
305	15:04	designing the lobby	adding walls and postboxes	cave came in handy
306	15:34	designing the lobby	adding walls and postboxes	3
307	16:04	changing the walls of the parking garage	changing metal fins to wooden ones and adding elements behind stairs	4
308	16:34	adding details in the parking garage		3
309	17:04	nothing changed		1
310	13-4-2012	10:30 adding glass walls in the base of the tower near the elevators		3
311	11:00	changed the orientation of the x bracing on the second floor	to create a clearer passage towards the bridge	cave came in handy
312	11:30	nothing changed		1
313	12:00	adding balustrades in the collective space	similar to the ones in the shopping mall	3
314	12:30	nothing changed		1
315	13:00	nothing changed		1
316	13:30	started filling up the gaps in the collective space façades		3
317	14:00	filling up the gaps		3
318	14:30	adding balustrades on the south façades at collective space level		3
319	15:00	nothing changed		1
320	15:30	started working out the top floors and roof	adding floors	3
321	16:00	working out the top floors and roof		3
322	16-4-2012	9:52 working out the top floors and roof	start adding façade	3
323	10:52	deleted obsolete objects	made renders	2
324	11:22	started working on the parapets of the south façade	after consulting with Christian Rapp	3
325	11:52	trying new design	grey and yellow color and diagonal over the height of the façade	cave came in handy 4

Row	Date	Time	Adjustments	Description	Adjustment Type
326		13:27	continued adding glass to the top floors		3
327		13:57	focusing on the roof top trying different variations	crowd flat roof	4
328		14:27	focusing on the roof top trying different variations		4
329		14:57	filling in the last remaining sections of façade on the tower		3
330		15:27	nothing changed		1
331		15:57	nothing changed		1
332		16:27	continued on the top of the building		3
333		16:57	continued on the top of the building		3
334	17-4-2012	10:17	nothing changed		1
335		10:47	nothing changed		1
336		11:17	nothing changed		1
337		11:47	nothing changed		1
338		12:17	adding internal spaces, office and tech floors in the core of the building		3
339		14:08	completing the façade of the top of the tower		3
340		14:38	completing the façade of the top of the tower		3
341		15:08	nothing changed		1
342		15:38	trying other shapes for the roof	not satisfied with previous result	4
343		16:08	trying other shapes for the roof and tower		4
344	18-4-2012	10:39	trying other shapes for the roof	angled roof looks good	4
345		11:09	working out the angled roof variant		3
346		11:39	nothing changed		1
347		12:38	redrawing the parapets changing up the height		4
348		13:08	working out the angled roof variant		3
349		13:38	working out the angled roof variant		3
350		14:19	working out the angled roof variant		3
351		14:49	working out the angled roof variant		3
352		15:19	nothing changed		1
353		15:49	adding parapets to the top floors	to integrate better with the rest of the tower	3
354		16:19	continued with the façade		3
355		16:49	continued with the façade		3
356	19-4-2012	10:11	continued with the façade		3
357		10:41	global design of the building is finished	continued with detailing after this	3
358					
359			Start detailed part		
360	19-4-2012	13:59	made the load bearing structural elements		3
361		14:29	added secondary structure for connections of floors	made me think of how to connect the floors to columns etc	3
362		14:59	added the floors		3
363		15:29	added textures and protruding floor elements	made me think about how to connect these to the main structure	3
364		15:59	added secondary floor and aluminum panels	panels cover the structure and are visible in the façade	3
365	20-4-2012	12:16	continue adding panels	also started on a façade hanging structure	3
366		12:46	nothing changed		1
367		13:16	designed façade panels to hang on the structure		1
368		13:46	continued adding panels	removed the hanging structure, panels are now hung directly to the floors	2
369		14:16	continued adding panels	now with stone and finishing the front façade	3
370		14:46	adding panels on the west side		3
371		15:16	adding walls behind the panels		3
372		15:46	adding walls on the inside and designing a structure for the interior galleries		3
373		16:16	adding floors to galleries		3
374	23-4-2012	10:12	adding façade elements in the light trenches		3
375		10:42	adding façade elements in the light trenches	aluminum panels on the side of the master bedroom of the apartments	3
376		11:12	adding façade elements in the light trenches	copied the trench	3
377		11:42	adding walls inside the apartment	2 variations of a 3 bedroom apartment	3
378		13:22	start adding the staircases		3
379		13:52	continued on staircases	adding holes in the floor	4
380		14:22	adding elevator shafts and walls	also added ceilings	3
381		14:52	modeled a toilet		1
382		15:31	modeled a toilet		1
383		16:01	adding façade elements on the west side of the apartments		3
384		16:31	adding façade elements on the west side of the apartments	also added floors and ceilings to the apartment	3
385	24-4-2012	9:39	adding parapets behind the façade		3
386		10:09	making a window for the bathroom		3
387		10:39	defining a stone material for the west façade	tried different shades of grey	5
388		11:09	adding aluminum panels to the diagonal braces in the lobby area		3
389		11:39	making a façade piece to fit in the area where the diagonals are		3
390		13:25	also making a façade piece for the wider diagonal part		3

Time	Date	Time	Adjustment	Comments	Attachment Page
391		13:55	Start adding a secondary construction of the east side		3
392		14:29	continued adding structure		3
393		14:59	started adding façade elements in the east side		3
394		15:29	continued adding façade elements		3
395	25-4-2012	10:32	continued adding façade elements	also added floors	3
396		11:02	continued adding façade elements	on the north east corner	3
397		11:32	started finishing the façade on the office side	this is the northern part	3
398		12:02	finished façade on the office side		3
399		12:32	started adding aluminum panels on the most eastern diagonals		3
400		13:02	continued with the aluminum panels		3
401		13:32	adding façade panels to the same part		3
402	1-5-2012	9:36	adding railing on the south apartment façade	to give a more comforting feeling on higher altitudes	3
403		10:06	adding aluminum panels on the bigger diagonals on the south side		3
404		10:36	start reworking the façade on the sides of the apartments	not happy with the indents made in stone	4
405		11:06	added flat stone panels in travertine instead	looks better	4
406		11:36	adding stone elements on the north façade	similar to south façade but colored in grey	3
407		12:06	start working on the finishes of the exterior balconies		3
408		12:36	continued working on the finishes	adding aluminum corner profiles	3
409		13:06	nothing changed		1
410		13:36	started adding ceilings and floors		3
411		14:06	ceilings and floors done		3
412		14:36	start adding the glass elevator system	making holes in floors and added a supporting structure	3
413		15:06	elevator part done, toilet block done and started on interior façade offices		3
414		15:36	added second toilet block		3
415		16:06	adding finishing on the galleries	ceilings and planks on the side	3
416		16:36	done with finishes		3
417	2-5-2012	9:47	added ceilings on northern balconies		3
418		10:17	adding finishing on the columns on the interior		3
419		10:47	continued adding finishes		3
420		11:17	continued adding finishes		3
421		11:47	continued adding finishes		3
422		12:17	continued adding finishes		3
423		12:47	adding glass on the interior office façade with diagonals		3
424		13:17	nothing changed		1
425		13:47	adding flooring		3
426		14:31	nothing changed		1
427		15:01	adding finishes	previously not seen	3
428		15:31	adding elevator doors and finishes		3
429		16:01	making door openings in the east most apartment		3
430		16:31	changing finishes to fit everything together		3
431		17:01	changing finishes to fit everything together		3
432					3
433			global detailed model is now finished.		
434					
435	4-5-2012	11:53	start implementing a concept of colonial style	added travertine columns and wall covering	3
436		12:23	adding detailing	metal strips and parapets	3
437		12:53	nothing changed		1
438		13:23	changing parapets to stone colored		5
439		13:53	adding balustrades on the galleries	not to block the daylight entry	3
440		14:23	adding arches on the upper floors	between the travertine columns, but it didn't work very well	3
441		14:53	removed the arches and trying different colors for the parapets	white	2
442		15:23	changing the planters in the parapets		4
443		15:53	start working on the floor	adding stone circle	3
444		16:23	adding flooring		3
445	8-5-2012	11:56	further detailing	adding grass, a bench and textures floors	3
446		12:48	nothing changed		1
447		13:17	detailing the bench/planter		3
448		13:47	adding parapets to the sides of the first floor	also added walls to separate the offices and the apartments	3
449		14:17	adding railing on the balconies	on the exterior	3
450		14:47	adding railing on the balconies		3
451		15:17	adding railing on the balconies		3
452		15:47	added lowered ceilings		3
453	9-5-2012	10:03	started converting the model to the model of the base	deleting unnecessary objects	2
454		10:33	deleting unnecessary objects		2
455		11:03	modifying existing objects		4

line	date	time	adjustments	comments	adjustment type
456		11:33	start adding new walls	stone bricks on the base of the tower	3
457		12:03	laying down ground floor		3
458		12:33	adding new facade panels on the west side		3
459		13:03	adding facade elements in the entrance part		3
460		13:33	adding concrete of ground floor		3
461		14:03	making the stairs to the ground floor	stairs is longer than other stairs so it had to be made separately	3
462		14:33	copying the stairs to the other side	and added walls of the elevator shafts and elevator doors	3
463		15:03	adding finishes	ceiling in entrance lobby and column/beam coverings	3
464		15:33	adding columns of the lower base part	also added more facade panels near the entrance	3
465		16:03	adding post boxes in entrance lobby	also added walls between lobby and elevators	3
466		16:33	continued detailing the lobby		3
467		17:03	continued detailing the lobby		3
468	10-5-2012	10:32	nothing changed		1
469		10:53	adding doors to the entrance	finishing the facade around the lobby	3
470		11:23	adding different flooring	dark grey granite	5
471		11:53	added a reception desk in the lobby	looks ugly	3
472		12:23	started on the lower base	adding floors	3
473		12:53	fitting the floors with the tower	cutting out the tower part	3
474		13:23	adding stairs to the entrance and walls to the side of this stairs	walls in aluminum panels	3
475		13:53	nothing changed		1
476		14:23	nothing changed		1
477		14:53	nothing changed		1
478		15:23	changed the aluminum walls to stucco	they looked to sterile	5
479		15:53	adding the windows to the stucco wall		3
480		16:23	adding lattice of the facade of the upper floors of the base		5
481	14-5-2012	10:10	adding walls around the columns in the base	also added walls in the facade	3
482		10:40	nothing changed		1
483		11:10	nothing changed		1
484		11:40	nothing changed		1
485		12:10	nothing changed		1
486		12:40	nothing changed		1
487		13:10	nothing changed		1
488		13:40	textures the stucco wall		5
489		14:10	started detailing the ground floor and entrance	added aluminum covering on exterior columns and added ceiling on overhang	3
490		14:40	added plants on the entrance roof and added escalators	making holes in the floors as well	3
491		15:10	working on escalator area	adding details	3
492		15:40	adding stairs and walls near the escalators		3
493		16:10	working on connection between facade of the base and tower	in the northern part they meet each other	3
494		16:40	working on the exit area of the east staircase	leads to the shopping mall	3
495		17:10	added door in the area where the base and tower facade meet	fleeing route is done	3
496	15-5-2012	9:45	start working on interior of the mall	adding granite wall elements on ground floor	3
497		10:15	adding windows, doors and walls	to the previously added granite wall elements	3
498		10:45	adding floors and ceilings in the shops		3
499		11:15	adding granite with glass walls to the northern part as well		3
500		11:45	adding interior shop dividing walls and start on exterior wall next to stairs	on the northern side	3
501		12:15	working on the wall		3
502		12:45	nothing changed		1
503		13:15	working on the wall		3
504		13:45	finished wall and added floors and ceilings in the mall		3
505		14:15	made indents in ceiling where the windows of the stucco wall are		4
506		14:45	start working on the first floor	copied interior walls and start making adjustments	3
507		15:15	repositioned walls that had to change		7
508		15:45	designed a railing system for the holes in the floors	with glass in between posts	3
509	21-5-2012	10:32	finished with the 2nd floor as well	also adjusted the floor material to marble	3
510		11:02	finished the interior of the base		3
511		11:32	adding the newly design railing to the atrium in the tower	the lowest of the atria	3
512		12:02	changed floor material to marble and added stairs in the atrium		5
513		12:32	add extra floor piece and railing to the stairs		3
514		13:02	finishing the last pieces before finishing this part	adding pieces of forgotten facade	3
515		13:32	finishing the last pieces before finishing this part		3
516					
517		14:02	start on the other part of the base		3
518		15:03	added columns, floors and parts of the ground floor facade		3
519		15:33	add stucco wall next to the stairs	including windows	3
520		16:03	adding staircase core and start on interior walls		3

line	date	time	activity/comments	comments	commitment type
521		16:33	adding more interior walls and adding parking spaces		3
522		17:03	started on first part on interior granite walls with glass		3
523	23-5-2012	10:37	finished with ground floor walls and added the escalators		3
524		11:07	added hole for escalators and added railing		3
525		11:37	start on granite walls of the 1st floor		3
526		12:07	continue on walls		3
527		12:37	continue on walls		3
528		13:07	started on the 1st floor façade	adding walls fist	3
529		13:37	adding horizontal lattices		3
530		14:07	added vertical lattices	also did the different detailing around the west entrance	3
531		14:37	adding walls around the west entrance		3
532		15:07	doing the connection between interior granite wall and façade	south west side	3
533		15:37	doing the parking garage façade	wooden mullions	3
534		16:07	working on cutting out the swimming pool from the deck floor		4
535		16:37	finished the pool		3
536	24-5-2012	10:57	adding the stairs to the west entrance	also started on the railing	3
537		11:27	finished stairs and railing and started on an apartment unit		3
538		11:57	started with constructive elements of apartment	floor and bearing walls in concrete	3
539		12:27	added interior walls and started on façade		3
540		12:57	adding façade on the balcony part		3
541		13:27	adding aluminium panels finish		3
542		13:57	adding flooring and ceiling and kitchen window		3
543		14:27	finished the apartment and copied it onto the base		3
544		14:57	working on the amenities area	adding façade facing the pool	3
545		15:27	working on the south east corner	removing excess floor and add aluminium covering on columns	3
546		15:57	working on the south east corner	adding glass on corner and east side	3
547		16:27	finish north east corner		3
548	28-5-2012	14:23	adding aluminium panels where they're still missing	west part	3
549		14:53	adding glass in the core in the atrium		3
550		15:23	added railings to the galleries in the atrium and added glass domes in floor		3
551		15:53	adding hole above escalators		3
552		16:23	added flooring in amenities part		3
553	29-5-2012	10:56	start on the building top	adjusting a previously made model, adding the top of the structure	3
554		11:26	adjusting façade elements and deleting obsolete objects	also added aluminium panels to the top of the structural elements	3
555		11:56	adjusting floors		2
556		12:26	deleting unnecessary objects		4
557		12:56	nothing changed		2
558		13:26	adjusting floors		1
559		13:56	shortening elevator shafts to fit within the building part		4
560		14:26	adjusting the top balcony		4
561		14:56	start adding new façade elements on the roof		4
562		15:26	continue adding façade elements		3
563		15:56	adding concrete infill under the angled roof parts		3
564		16:26	nothing changed		1
565		16:56	adding new wall around the columns on the interior		3
566	30-5-2012	10:29	adding finishes on the inside of the angled roof	walls around columns	3
567		10:59	nothing changed		1
568		11:29	working on apartments	removing one elevator	3
569		11:59	adding walls to the lowest south apartment		3
570		12:29	making door openings		3
571		12:59	nothing changed		1
572		13:29	adding doors		3
573		13:59	flooring and ceiling added		3
574		14:29	start adding walls for the north apartment		3
575		14:59	finished walls and added doors, flooring and ceilings	also copied the south apartment up one floor	3
576		15:29	repositioning some of the openings	due to diagonal's which were in the way	4
577		15:59	removing one of the glass elevators to form a passage	to be able to reach collective space on west side	3
578		16:29	working on the apartments of the second floor	copied apartments and reposition walls etc.	2
579	31-5-2012	10:33	working on south second floor apartment	part under the angled roof	3
580		11:03	done the floors		3
581		11:33	adding roofs on the angled parts		3
582		12:03	finishing all the angled roof parts		3
583		12:33	working on finishes of the collective areas		3
584		13:03	working on finishes of the collective areas	adding ceiling and flooring textures	3
585		13:33	adding railing in collective space		3

date	date	time	adjustments	comment	adjustment type
586		14:03	adding spiral stairs in collective space		3
587					
588			continued working on second base part		
589					
590		14:33	adding glass to the upper part of the east side		3
591		15:03	continue adding glass on the top of the atrium		3
592		15:33	working on glass roof for the atrium		3
593		16:03	finished all the upper parts		3
594		16:33	finished the lower parts of the base	entrance and pool areas	3
595					
596	1-6-2012		spent day removing floors from lower block model	put these floors in separate files to keep individual file sizes minimal	
597					
598	4-6-2012	9:32	started with the next atrium design in the lower		1
599		10:02	nothing changed	sketched concept on paper first	1
600		10:32	start working on concept	creating wall with rounded holes	3
601		11:02	finished one of the walls with rounded holes		3
602		11:32	nothing changed	examining model in cave	1
603		12:02	added a floor in the south west corner space	meant to house a playing area	3
604		12:23	nothing changed		3
605		13:02	removed some of the holes in the wall and removed the old wall on the south side		2
606		13:46	added a new wall on the south side and added a stairs		3
607		14:17	finished stairs and added planters		3
608		14:47	trying different floor and planter materials		5
609		15:16	added a path to the floor and grass patches	changed floor material again	3
610		15:46	adding stairs to the play area	to be able to reach the previously added floor	3
611		16:17	adding sitting out areas in south east corner		3
612		16:46	came up with a different design	for sitting areas	4
613					
614	5-6-2012	10:55	removed the previously added walls	to start the next atrium	2
615		11:49	changed the south façade and start working on new concept	south façade lays back at this height to incorporate 2 bedroom apartments	3
616		12:19	working on wall of the new concept	south side wall	3
617		12:49	working on wall of the new concept		3
618		13:19	placed wall inside atrium and trying different materials on it		5
619		13:49	working on west wall		3
620		14:19	changed material of walls and toilet blocks		5
621		14:49	working on materials of the walls	made all the holes in de wall the same size (it was too busy looking)	5
622		15:19	finalized materials	metal finish	5
623		15:49	changed toilet block wall	start adding bamboo decoration	3
624		16:19	finished with bamboo		3
625		16:49	changed flooring material to wood		5
626					
627	6-6-2012	10:13	start on final atrium	trying different floor materials	5
628		10:43	added another floor material	also changed planters and toilet block walls	5
629		11:13	start modeling wall system for this concept		3
630		11:43	trying different colors for the parapets of the new walls		5
631		12:13	further detailing the walls		3
632		12:43	nothing changed		1
633		13:13	further detailing the walls	added vills	3
634		13:43	added the wall on the south side		3
635		14:13	trying different colors for the parapets of the new walls	adding travertine material	5
636		14:43	nothing changed		1
637		15:13	nothing changed		1
638		15:43	trying a completely different concept	similar to the colonial of the second atrium	4
639		16:13	changed it back and changed the parapet material to granite	added a fountain but it looks out of place	4, 5
640		16:43	added planters and mullions	mullions in front of the part with the window	3
641					
642	7-6-2012		spent the day putting the right apartments in every building part	this affects the façade appearance	4
643					
644	11-6-2012	10:03	starting revising the atrium with the round hole walls	after getting comments from the tutors	4
645		10:33	implementing a new concept	changing the shape of the holes	4
646		11:03	changing the shape of the holes		4
647		11:33	adding new balustrades in the holes		3
648		12:02	added seats in the holes		3
649		12:32	deleting old objects		2
650		13:02	nothing changed		1

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9.2.1 Introduction

This paper is meant to summarize the literature study done for a combined master's project combining the studies of Design Systems and Architecture. Therefore there are two subjects addressed in this paper. These subjects are CAVE Automatic Virtual Environment for the Design Systems part and High-rise Buildings for the Architecture part. Both parts are addressed separately in the oncoming chapters. A chapter on Hong Kong is also added as this is the project location.

9.2.2 CAVE

The goal of the research following this paper is to make extensive use of computer technology in the design process of a building, in particular, the use of CAVE technology. CAVE technology however, is an advanced form of virtual reality graphics display on normal computers. This type of 'flat screen' VR already has a wide application in architectural design studies. Thus information about its application was also gathered to include in this paper. This part for the most part summarizes the applications and tools already invented for integrating VR technology in architectural design including both positive and negative aspects of these programs. The most important requirement for these applications is that they enable editing in the CAVE.



This is the desk CAVE system at the University of Technology in Eindhoven. It is smaller than a normal CAVE system and because you are sitting behind a desk, it is called desk cave.

9.2.2.1 CAVE Applications

Numerous CAVE applications have already been developed. This part describes these applications in detail.

The first one is CaveMax (Ribeiro et al). This application is designed for use with the 3ds Max package, a powerful 3d modelling tool. CaveMax works by enabling data exchange between two separate 3ds Max instances on different computers: one on a personal computer or laptop and one in the CAVE. With the push of a button, the scene is saved on a server and opened in the CAVE. For navigation in the scene, a camera is activated on the computer and then panned and rotated to the desired position. The CaveMax application captures the camera information and sends it to the CAVE updating the CAVE's camera in real time.

Although it is a handy tool and enables modelling with the CAVE there are also some drawbacks. The current configuration only enables one viewport of 3ds Max in the CAVE so it won't use all screens available. Also navigation has to be done on the separate computer and may be difficult if your actions do not directly correspond to what you see.

The same paper also describes other similar applications namely:

- The CaveUT System needs file conversion to work so can only be used to view models.
- VR4Max also needs file conversion.
- Walkinside also needs file conversion.
- Conduit transfers OpenGL calls to a 3ds Max instance on another computer thus is real time updated, however in the optimization process, important data is lost distorting the CAVE views.

At the Brown University in Providence, USA a digital massing study tool was developed for use in a CAVE system (Chen). This system relies on direct 3d manipulation and uses a pen for fine styling and a glove for less accurate manipulations like grabbing and moving. The system is therefore gesture based. The system allows for rough shape creation and manipulation in various ways. A physical transparent table is placed in the CAVE and is tracked. That way, objects can be displayed and manipulated on this table.

This table thus works similar to a drawing tablet and pen. By using the pen and glove, all basic manipulations on an object can be performed in the CAVE also including Boolean operations.

The tool is intended for use during the massing study design phase and therefore doesn't need to be very accurate so it isn't. Direct 3d manipulation proves to be an inaccurate modelling method in general, especially when it is gesture based. Although other advances improve the accuracy like Google Sketchup, the methods are still intended for use during the earlier design phases and not very handy when used for more detailed modelling.

Deisinger et al. describe several CAVE modelling tools similar to the one described before like 'Lotus' and 'Naegeli RT' these tools also rely on drawing and manipulation of shapes and forms in different ways.

Cavernsoft (Leigh et al) collaborative system with which, participants are able to collaborate using network of computers. The system evolved from two previous programs by the same authors. The first one is Calvin. With this tool, participants are able to manipulate a space by moving, rotating and scaling objects such as walls and furniture. The participants who can work remotely in one scene are represented by avatars to let the other participants know where they are and what they are doing. The other tool is called NICE and is based on the same idea. Here the participants are children and their task is to maintain a flower garden in a collaborative manner.

Cavernsoft itself is not specific for use in the CAVE anymore. Instead it has a much broader functionality to further enhance the collaborative design process. Cavernsoft works with Information Request Brokers (IRB's). An IRB is a database which is accessible from different networking computers for sharing information. Different IRB's are linked together to create a goal specific client. This way, programs such as Calvin and NICE can also be created.

9.2.2.2 Other CAVE uses

Although, many CAVE modelling tools exist. The most used application for the CAVE in architecture still remains viewing and reviewing. Experiments (Fröst et. al.) show the effect reviewing models in a CAVE has. The technology

provides designers a better way of formulating, analyzing, testing and realizing their ideas. In other words, it helps the designers in a positive way.

The experiment let students participate in a real design exercise on their own campus. The students had to come up with ideas for a new laboratory by means of traditional designing. Afterwards they were able to view their results in the CAVE twice. In between they could alter their designs based on the experiences in the CAVE. The experiment was a positive experience for both the participating students and the people involved in the actual laboratory assignment.

For the designing of a new office building for VTT, a company based in Finland specializing in virtual and augmented reality, they used a number of visualisation techniques to view the architectural plans (Woodward et al). At first, a 3d Studio Max model was created and transferred to VTT's CAVE for walkthrough visualisations.

Next to this, a system for PDA was developed. The PDA's camera captured images which could be tracked by a laptop which then created a video. This video was then displayed on the PDA projecting the 3d model over the real life construction site.

After construction commenced, a web camera was placed on a neighbouring building. A 3d model of the building was projected over the camera's view. Users could then choose to view the 3d model or not and use clipping planes to view only portions of the model.

Nearing completion of the actual building, an augmented scale model was created for projection on a conference table using data glasses. Other implementations included models of the building and its surroundings and decision making on the final furniture of the building.

The virtual and augmented reality techniques were found useful especially in the planning and design phases of the building. It was found that the techniques provided useful information for the architect as well as owners of the building.

9.2.2.3 Conclusions

Virtual and augmented reality are relatively new techniques. Despite of this, they are already to a great extent recognised and used in the building world. Although many tools have already been developed and also many experiments have been conducted, a CAVE design tool with great accuracy hasn't been created or documented yet to my knowledge. As a result, the CAVE system also has not yet been used as a design tool throughout the process. Most times it is used as a design tool for form study or to evaluate the design after it was conceived. Therefore apart from the form studies, design decisions have not yet been done within the cave system.

9.2.3. High-rise Buildings

High-rise buildings come in many shapes and sizes although they have one thing in common, their height. This part of the research focuses on typologies and the impact of tall buildings on their environment and what the pros and cons of these buildings really are.

9.2.3.1 History of the Skyscraper

The first modern high-rise buildings date back to New York and Chicago of the late nineteenth century. The evolution of the skyscraper can be attributed to the technological advances during the time but also to a great extent to prestige and grandeur of their owners. The skyscraper era started around 1850 as a result of important inventions such as the drop-safe elevator and the commercialisation of electric lighting which allowed for deeper floor plans. Skyscrapers became first economically feasible in New York and Chicago. Due to foreign trade, New York had already established itself as the economic capital of the United States during the first half of the 19th century, causing a lot of immigrants to arrive in the city. With the increase in economy and the rapid growth of the city, new manufacturing and trade businesses were also established and existing ones expanded. With this, the need for office buildings grew. This also made tall buildings more desirable.

The height of these first skyscrapers was still limited though. Although wrought iron was already being used in small scale buildings, most of the earlier buildings in New York were mainly constructed out of stone. This meant that for building taller, foundations, walls and columns had to be very thick. This prevented large window openings and floor space. After the Civil War in 1865, land values, building costs and rental costs became higher making the iron frame a necessity. Introducing iron meant that constructions could be thinner leaving more useable space. More technological advances including wind bracing, secure anchoring, fire protection, power operated construction equipment, heating, ventilation, plumbing, elevator service and lighting made tall buildings even more practical. Technological advances in these inventions continued buildings to become taller up to 10 floors in the 1870s. The 1880s saw the introduction of U type floor plans for increased natural lighting and ventilation and steel box construction. However, certain

iron frame types allowed for a non bearing exterior wall, this type became more available with metal cage construction giving rise to the curtain wall type.



One of the first buildings to use a cage construction which allowed for non bearing outer walls was the Produce Exchange building in New York (1884). Photo: http://www.bc.edu/bc_org/avp/cas/fnart/fa267/19_sky.html

During the second half of the 1880s, the first steel structures came into existence. Steel was first only used in low-rise constructions but soon also became known in the skyscraper world. Steel however was found to be very prone to corrosion and so was not yet widely used in construction. Right before the turn of the century, the combination of wrought iron and steel were developed in the skeleton frame construction. This construction type which is still known today is a combination of columns and beams forming a load bearing grid. This method pushed skyscrapers past the 20 floor mark.



The Empire building in New York (1898). An example of a steel framed building passing the 20 floor mark. Photo: [http://en.wikipedia.org/wiki/Empire_Building_\(New_York_City\)](http://en.wikipedia.org/wiki/Empire_Building_(New_York_City))

Although technological advances made it possible to build ever taller structures during the second half of the 19th century and the start of the 20th century, the main reason these buildings came to be is because of 'the confidence, power and wealth of businesses. This was expressed by building taller and grander than the predecessors. One of the best examples for this is the Woolworth Building completed in 1913 in New York. Its commissioner F. W. Woolworth wanted the building to be taller and more prestigious than any building ever built before. As a result, the tower is 241 metres high and counts 57 floors, overtaking its predecessor by 28 metres. At its grand opening it was nicknamed the cathedral of commerce not only because of its shape, but also for its rich ornamentation. It remained the tallest building in the world for 27 years when it was overtaken by the Bank of Manhattan Trust Building and the Chrysler Building in 1930.



The Woolworth Building (1913) marked the end of the first skyscraper era in New York. Photo: <http://www.nyc-architecture.com/SCC/SCC019.htm>

The first decade in the new century also saw the rise of concrete. Although concrete existed since Roman times and was also used in some factories it was not yet used in high-rise construction before this time but became feasible with the invention of reinforced concrete. It took a while for concrete to gain recognition though. The first concrete structures had to be very massive taking up valuable floor space. Because of this, steel construction remained in favour at first. Major projects like the Empire State Building in New York (1931) were still built in steel. It was not until the 1940s with the introduction of shear wall construction that concrete gained momentum as a construction material in high-rise buildings. Nowadays concrete has become the building material of choice in many skyscrapers.

All the innovations in construction and installations are also reflected in the architecture of the skyscraper. The bearing walls of the first skyscrapers limited window size. This together with businesses wanting to mimic the grandeur of classical Greek and Roman structures caused a classical architecture. The invention of the steel frame meant the facade wasn't limited anymore and windows grew bigger. To let in even more light, the H and U floor plans were invented. The classic style gradually changed to a more gothic style in the Woolworth building. As the ideas of style modernised, art deco became the widely expected style during the 1920s and 1930s. As the thoughts on modernity changed and advances were taken in the heat resisting properties of glass, the glass skyscraper became more common.

9.2.3.2 Cons of high-rise buildings

High-rise buildings, especially the office type, are still largely dominated by financial criteria or the will of businesses who build them to create an expression of their wealth and power. This is partly visible in the race for the tallest building in the world which is going on for over a 100 years. This causes many high-rise buildings to be designed as autonomous objects and thus, the relation to their context is often lost. This is especially evident in tall buildings in a low-rise context such as the Tour Montparnasse in Paris. This is also the main reason for protests against high-rise buildings in low-rise cities such as Paris and London. The other type of office tower exists for financial purposes rather than prestige. This office tower is often built as efficient as possible and this results in the American box-office type. Both types are rather autonomous objects. The plinth is often bare with only an entrance making the street rather lifeless and unpleasant.

This autonomy is also found inside the building as offices or apartments are located on higher levels, it is impossible to see what is happening in the street and the surroundings giving a feeling of isolation to the users of the building. Residents go out to work in the morning and return in the evening. The only time they see their neighbours is in the elevator which limits social interaction. Inhabitants also often complain about the lack of greenery in or near the building.

Tall buildings are also notorious as energy consumers. Because of the

deep floor plans of office buildings, lighting has become a necessity. Although these problems are recognised and advances in technology reduce the energy consumption. Tall buildings remain to consume a lot of energy.

Although the skyscraper can be considered an American invention, in the last few years most of the new skyscrapers being built are located outside of America. Most of them in are built Arabic and Asian countries. However, apparently, most skyscrapers are still designed by Americans. This causes a globalisation of the skyscraper. Although some attempts to put local ideas and culture into the design, most of them are taken too literal according to Wood.

Research on tourism (Leiper & Park) also concludes that high-rise development has a negative effect on tourism. This is especially the case within a cluster of tall buildings: people can feel overwhelmed and insignificant which can lead to stress which is the opposite of leisure and the main goal for tourists. Residents are less prone to these effects because they have grown accustomed with the situation and deal with it more easily than tourists do. This effect is of course more prominent within the cluster of high-rises than it is when viewing the skyline from a distance like for instance on the Peak in Hong Kong.



View from the Peak in Hong Kong. Photo:
<http://www.luxuo.com/luxury-locations/hong-kong-record-land-plot.html>



The view of skyscrapers can be overwhelming when walking between them. This is a picture of Queensway in Hong Kong, one of the main arterial roads on the island. Photo: http://en.wikipedia.org/wiki/Queensway,_Hong_Kong

9.2.3.3 Pros of High-rise Buildings

Not everything about high-rise buildings is bad. They are very capable of doing what they are designed for, having a lot of floor space on a limited area of land. This is cost effective, especially when land values are high. There is a turn over point though, when the building costs per floor become so high that it isn't profitable anymore. Going up has another more sustainable advantage. It takes up less space and thus lowers urban sprawl, leaving more space for nature or parks. Locating more people in a smaller area also means people don't have to travel far and good transportation facilities can be more compact. Locating more people in a smaller area however also means the area is busier and more prone to congestion and so requires better transportation facilities than a larger low rise area with the same average floor space.

9.2.3.4 Sustainability

Sustainability has become an important topic in the last few years and is also especially important in high-rise design. According to Ali and Armstrong, a sustainable building is more than an energy saving structure. It is also a pleasant place for its users. To do so, a building should be incorporated and work together with its environment. By creating a sustainable cluster, it becomes a pleasant working and living environment. By mixing different

functions like living, shops and working, people have to travel less so they don't take the car that often anymore. This saves on carbon emissions. By creating a mixed environment, the social interaction between people is also improved. For creating a sustainable environment, a mixed use building is thus preferred.

Sustainability can however also be improved in the buildings shape. The human scale is also an important aspect in this. Compact design where people are within walking distance of important resources without congestion can improve the sense of community. To achieve this compactness it is also important to keep the building compact and understandable for the users. It should not be overwhelming to them.

Of course, technical solutions are also important for a sustainable design. This mainly includes energy saving and producing installations but also the orientation of the building to maximize the use of natural daylight.

Well known examples of already existing sustainable high-rise buildings are, the Commerzbank in Frankfurt am Main by Norman Foster and the Elephant and Castle tower by Ken Yeang in London.

3.5 Mixed-use high-rise buildings

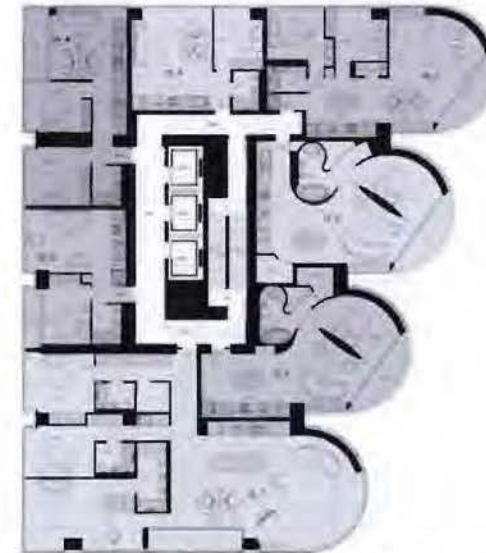
Because of the sustainable properties of mixed-use buildings, they became very popular in recent years. Because of their beneficial properties, the project in this research will also have a mixed-use program. Therefore a number of mixed-use skyscrapers have been analysed.

Mixed-use high-rise buildings often need a more complex core because residential and office users have their own transportation services. More elevators are needed for this purpose and all functions have their own entrance. Because of this complexity, these buildings are almost always arranged in the specific vertical order of retail on the first floors, office space above and residential or hotel functions on the upper levels. This is also the most practical and least expensive division because all functions have a different floor plan type. Retail space is often divided in medium sized blocks for stores with sometimes a bigger space for a super market. Office space requires spacious open plans for maximum flexibility. Residential and hotel floor plans have, in contrary to office floors, smaller cellular spaces.

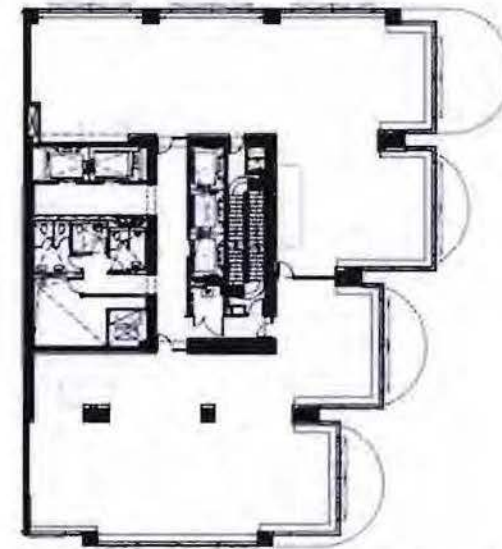
To further improve the mixing of functions in a tower, dividing them horizontally may be an option. There are no known existing buildings of this type although some case studies exist. The main problem with these kinds of buildings is that the mixing of functions on the same floor means that less space is available per function. This is no problem for apartments but it also means office space is smaller and thus less likely to be attractive for larger businesses. For interaction between these functions, this however is a plausible idea. Also, if the functions are placed carefully, they can benefit from each other in a physical way by acting as buffers for heat and light.

9.2.3.6 Conclusions

Skyscrapers are a relatively new type of building only being around for 150 years or so. The typology, although the necessity of them can be well argued in most cases, is still often being built as a symbol of prestige or to earn as much money as possible out of them. As a result, most skyscrapers are autonomous structures that cope with several problems which can however be overcome. In more recent years, architects are addressing these problems more often however this is still not always the case. In order to address the problems a more pleasant environment will have to be created in which mixing functions and human scale play an important role.



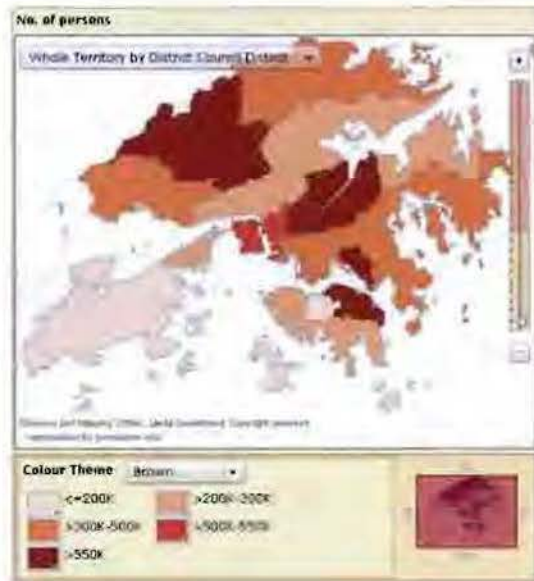
Typical residential floor plan of the Jameson House in Vancouver, Canada. It clearly shows the cellular division of space common in a residential tower. Source: <http://www.vancouver-canadarealestate.com/images/jameson-house-vancouver.pdf>



Typical office floor plan of the Jameson House in Vancouver, Canada. It clearly shows the open space which can be divided into spaces as needed. Source: http://matrix.cwcanada.com/filecabinet/Property/486113/Jameson_House_individual.pdf

9.2.4. Hong Kong

Hong Kong is the most densely populated city in the world. According to the Hong Kong Census and Statistics department approximately 7.108.100 people live in an area of 1.104 km². The geography of the area however prevents large areas to be developed meaning only a small portion of the total area of Hong Kong is actually developed. Because of this Hong Kong also has the most high-rise buildings of any city in the world. The map below shows the population distribution of the Hong Kong SAR.



Source:

http://www.censtatd.gov.hk/hong_kong_statistics/dashboard/index_en_GHS.html

In 1898 Hong Kong was leased for 99 years by the United Kingdom resulting in a fast economic growth during the 20th century but also in a westernized culture mixed with eastern traditions. Although 95% of the population is Chinese, culture here is different from the mainland of China. Here, the Chinese have also adopted western habits and with the transition back to China, the capitalism stayed in favour of the communism in China making

Hong Kong one of two Special Administrative Regions (SAR's) in China. The other one is Macau on the other side of the Pearl River Delta.

9.2.4.1 Demographics

Because of the scarcity of developable land, most of the residents in Hong Kong live in tall apartment buildings. Because of this, in contrary to European habits where apartment buildings are mainly occupied by childless families, here all different groups live in tall buildings. This also makes the typologies of tall residential buildings different from European and American ones. In appendix 9.2.6.2, graphs are shown, showing the different household compositions and their frequency. Apparently most families in Hong Kong consist of 2 to 4 individuals. Most households are unextended nuclear families, meaning parents with their children followed by single person households and vertically extended nuclear families meaning families with more than 2 generations. This usually means grandparents living with the family. The area where the project for this research will be located is a little different however. Here 2 person households are the most common followed by single and 3 person households. Because the rate of single person households is higher in this area, there are relatively less unextended nuclear families. The area is populated by all age groups but most people are between 25 and 54 years old. What can be concluded by this is that the area is very diverse and requires facilities for all age groups.

9.2.4.2 Leisure activities

Most apartments in Hong Kong are small and thus are unattractive to invite family and friends. This is one of the main reasons why Hong Kongers spent most of their free time outside their homes. Because of the mix of eastern and western culture, leisure facilities for both cultures are common and can be found in the same street.

The most popular activities are swimming, hiking and betting on horse races. 40% of Hong Kong's landmass is taken up by country parks and numerous beaches and swimming facilities can also be found. In general sporting activities are popular in Hong Kong.

Next to this, Hong Kong is also well known for its shopping culture. There are many malls and markets to provide the shopping needs. Younger people have a preference for internet and computer games and thus spend more time at home or in arcade halls while elderly people still play traditional games like Mah-jong and Chess.

9.2.4.3 Housing

Many typologies of housing exist in Hong Kong ranging from single room to apartments with 3 or 4 bedrooms and penthouses. Many of these apartments are either private apartments or public apartments. The apartment buildings in Hong Kong however are very characteristic. The cause of this is the B(P)R (building (planning) regulations). Although they have been adjusted in recent years, they demanded lighting and/or ventilation of different rooms for living, preparing food, bathrooms and lavatories. This means that all these rooms had to face the exterior of the building creating the typical floor plan of a central core with lobed extensions



Typical lobed Hong Kong residential floor plan. Source: <http://community.gohome.com.hk/Pokfulam/The-Belcher-s/floorplan/en/>

This kind of floor plan is usually found in huge multi tower complexes in Kowloon and the New Territories.

Another well known typology is the result of the scarcity of space on Hong Kong Island. This type is also known as a 'pencil tower' and is basically a very narrow tower on a very small lot. They often have only single or sometimes 2 apartments per floor in contrary to the 4 or 8 in an estate tower. These towers can mainly be found uphill on Hong Kong Island and in parts of Kowloon.



View of a high density pencil tower district just west of Hong Kong Central district. Source: <http://www.corbisimages.com/stock-photo/rights-managed/AACR001135/aerial-view-of-sheung-wan-and-the>

Although the B(P)R has been less strict, still many apartment buildings are built traditionally according to the old rules. However exceptions are also appearing.

9.2.4.4 Construction Methods

Although there are some well known exceptions like the Hong Kong and Shanghai bank headquarters and the Bank of China Tower, the majority of the buildings in Hong Kong are constructed using in situ concrete structures and because of their height are constructed on a pile foundation. The local contractors developed a well established expertise on this method and they're among the fastest builders using in situ concrete in the world. Because of the lack of space in Hong Kong, all building materials have to be imported making

in situ concrete casting one of the cheapest methods available. Almost all housing projects are constructed out of in situ concrete. More variation is present in office towers where steel structures are also common.

The project location is located on a reclaimed piece of land and thus consists of a clay and sand underground. Also because of the height of the building, a pile foundation is necessary.

9.2.4.5 Weather

Hong Kong is located in a sub-tropical climate meaning that it is generally warm during the whole year. Minimum temperatures hardly ever drop below 10°C and maximum temperatures stay around 30 to 35°C. Because of Hong Kong's location, tropical cyclones are common during the summer months. These tropical storms sometimes reach typhoon strength.

Most important for this research is wind speed in the area because of window openings and balconies on higher levels. Although, wind speed can reach up to 118 km/h during a typhoon, on average wind speed at the project location is around 4 m/s (14,4 km/h) at a height of 60m. For wind speeds per month, see appendix 9.2.6.3

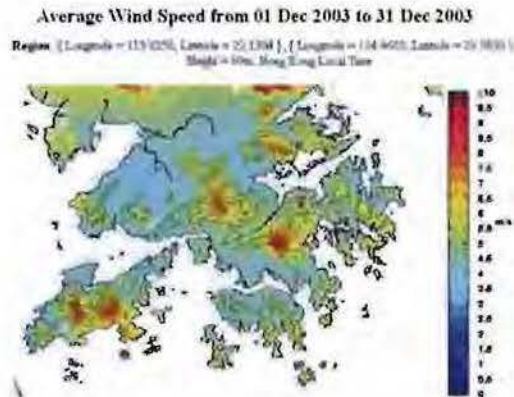


Chart showing the average wind velocity during the year on a height of 60m above ground. Source: <http://envf.ust.hk/werhk/windpotential.html>

9.2.4.6 Conclusions

Because of its high density, Hong Kong was chosen as the location for the research. Because Hong Kong was under British lease for 99 years, western culture became an important part of society and this society is therefore similar to western culture in many aspects. The majority of residents in Hong Kong is Chinese so eastern culture is mixed with the western one creating an interesting hybrid of western habits with eastern tradition. This means that living needs are also similar to western culture. However because of the scarcity of land, most people live in tall apartment buildings with their whole family meaning that apartments with more than one room are more common than in Europe and America.

Although there were strict building regulations in the past, these have now been relaxed. This together with the fact that most building materials are imported means that there are almost no limits in designing compared to designing in western cultures.

9.2.5. References

The references are the same as the ones of this thesis.

9.2.6. Appendixes



9.2.6.1 Collection of mixed-use high-rise buildings

CitySpire Center, New York City, United States

Completed in 1989, it is the tallest mixed-use building in New York.

Floor count: 73

The bottom 23 floors are for commercial use. The upper floors contain luxury apartments.

Jameson House, Vancouver, Canada

Completed in 2010 and designed by Foster + Partners. The division of functions is clearly visible in its design.

Floor count: 37

The bottom floors are for retail and office purposes, the upper floor contain various types of apartment units.

The Index, Dubai, United Arab Emirates

Also completed in 2010 and design by Foster + Partners, it shows some resemblance to the Jameson House as also the division of functions is visible in the façade.

Floor count: 80

The lower 25 floors are for offices and the upper 47 are for residential purposes. In between there are facilities for the residents.

Raffles City, Hangzhou, China

Construction of this complex by UN Studio has just recently begun.

Floor count: 60

The complex of 2 towers incorporates retail, office, hotel and residential functions in one building.

Aqua Tower, Chicago, United States

Completed in 2009 and designed by Jeanne Gang.

Floor count: 86

The building sits on a podium with commercial and retail functions. Above this, floor 1 to 18 contain hotel functions and floor 19 to 80 contain residential functions divided between apartments and condominiums.

Jin Mao Tower, Shanghai, China

Completed in 1999 and designed by Adrian Smith at SOM. It is one of the tallest buildings in the world.

Floor count: 88

The base contains a shopping mall and other public functions. Floor 53 to 87 contain a hotel, the rest is reserved for offices.

John Hancock Center, Chicago, United States

One of the earliest examples of multi-use high-rise buildings. It was completed in 1970 and designed by Skidmore Owings and Merrill.

Floor Count 100

Floor 44 to 92 contain apartments. Other functions include parking, retail, offices, and a restaurant on the 95th floor.

Beetham Tower, Manchester, United Kingdom

Completed in 2006 and designed by Ian Simpson Architects.

Floor count: 48

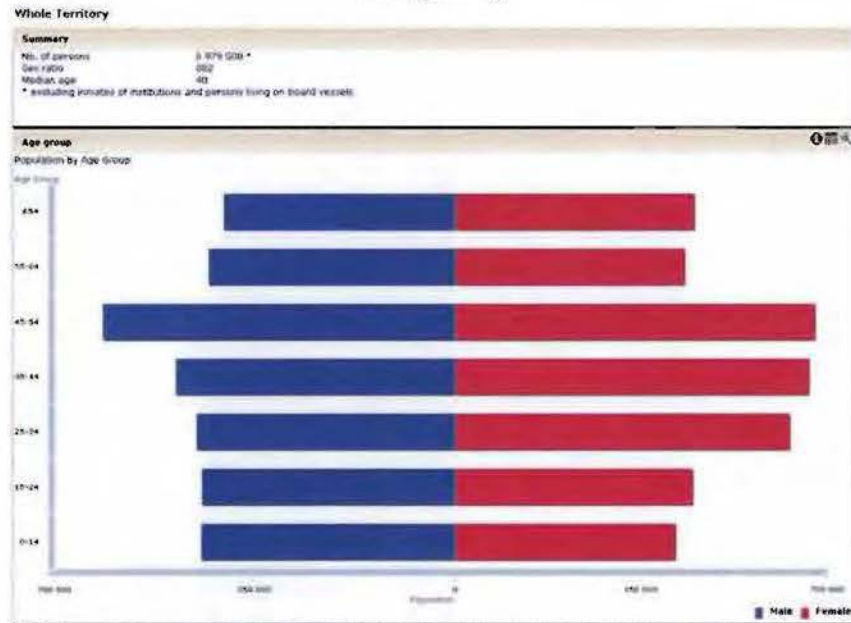
Floor 25 to 47 contain apartments and up to floor 23 there is a hotel. The project also includes offices and retail, they are located in different buildings.



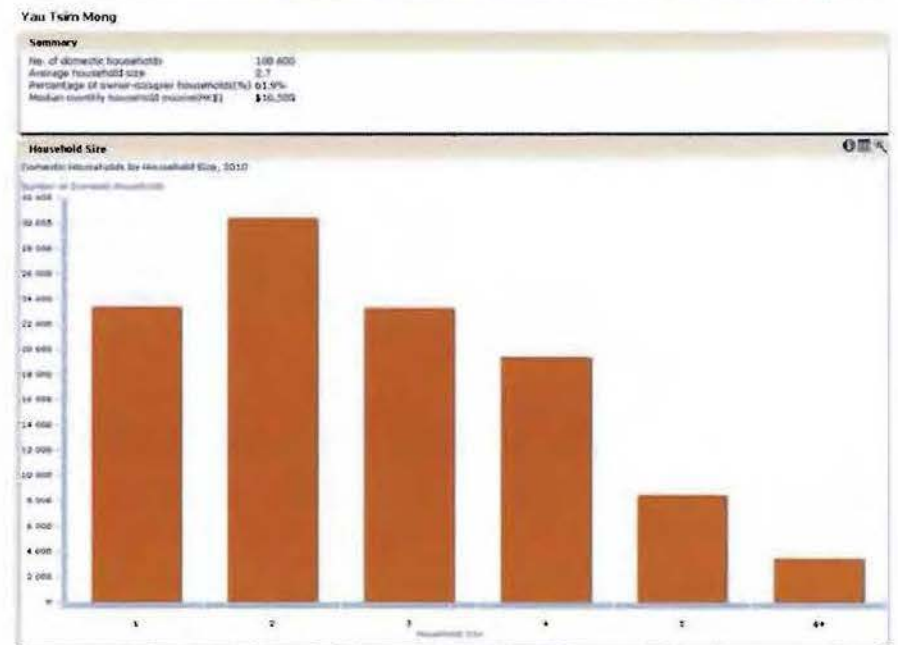
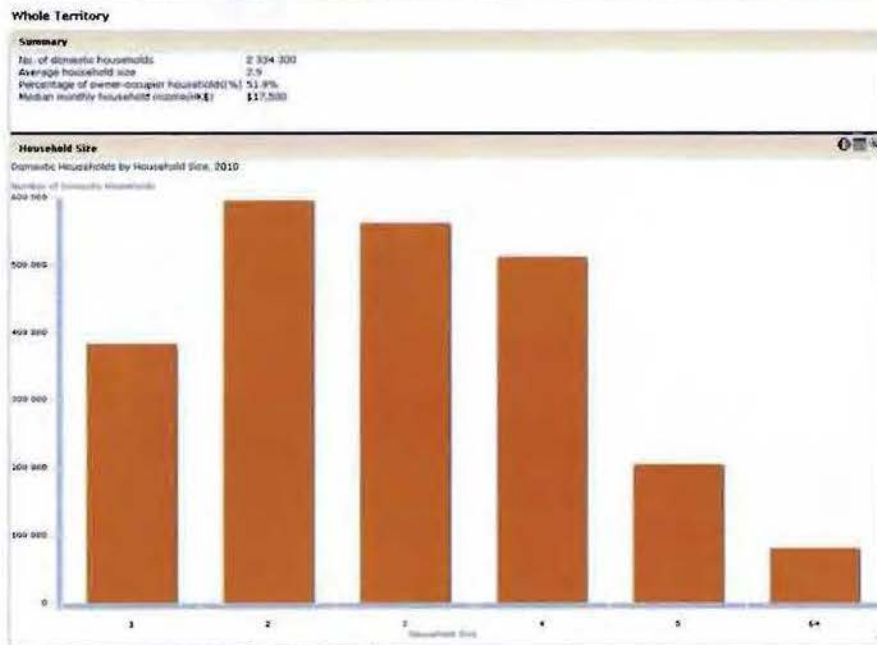
9.2.6.2 Demographic charts of Hong Kong

These are official charts of the Hong Kong government. Most of them date from 2006. The charts are divided in Hong Kong as a whole and the district of Yau Tsim Mong where the project location is.

Hong Kong



District of Yau Tsim Mong



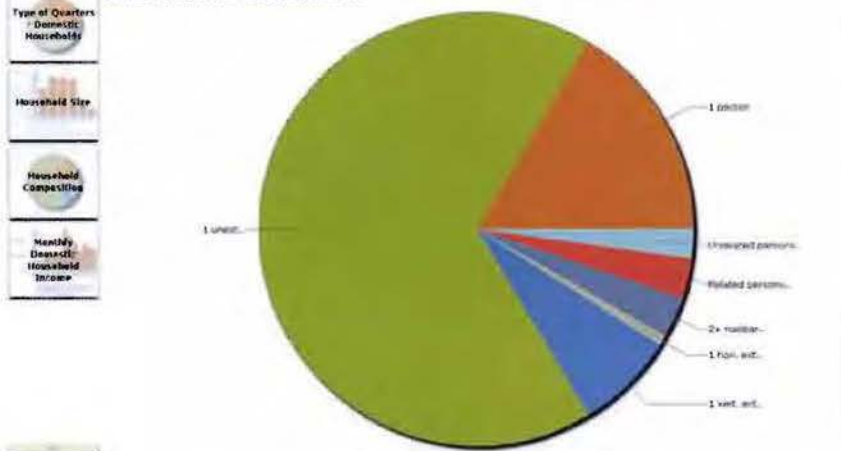
Hong Kong

Whole Territory

Summary
 Number of domestic households: 2,026,946
 Average domestic household size: 3.0
 Median monthly domestic household income (HK\$): \$17,259

Household Composition

Domestic Households by Household Composition, 2006

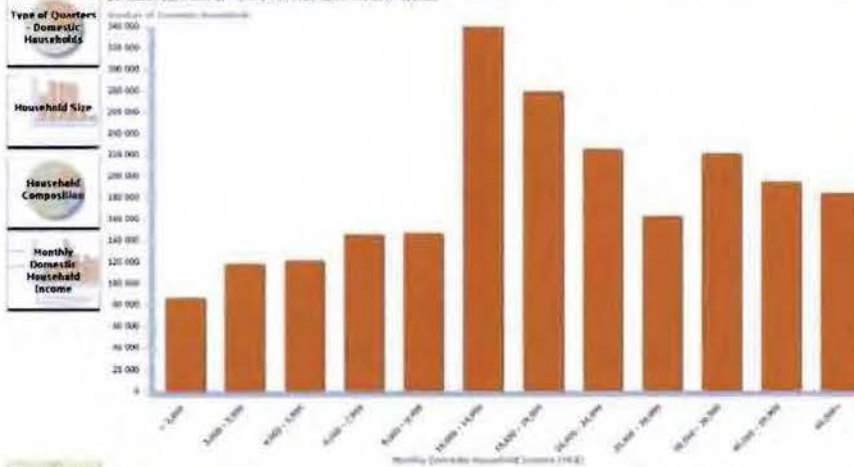


Whole Territory

Summary
 Number of domestic households: 3,226,545
 Average domestic household size: 3.0
 Median monthly domestic household income (HK\$): \$17,259

Monthly Domestic Household Income

Domestic Households by Monthly Domestic Household Income, 2006



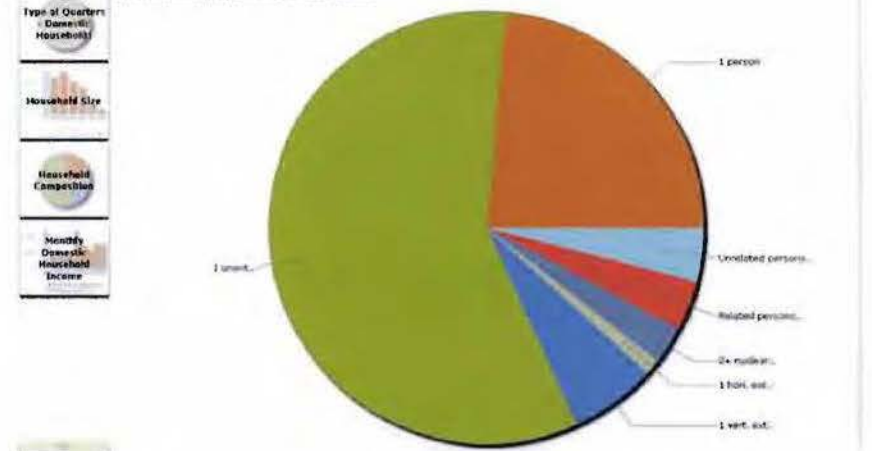
District of Yau Tsim Mong

Yau Tsim Mong

Summary
 Number of domestic households: 100,589
 Average domestic household size: 2.7
 Median monthly domestic household income (HK\$): \$17,500

Household Composition

Domestic Households by Household Composition, 2006

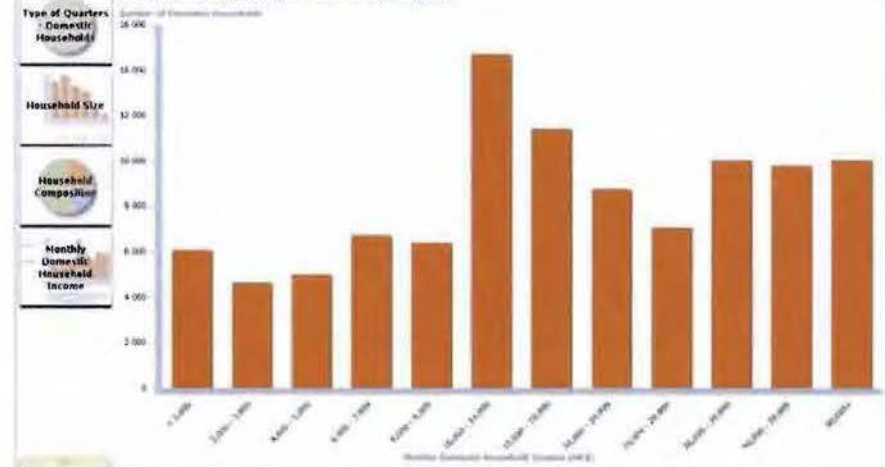


Yau Tsim Mong

Summary
 Number of domestic households: 100,589
 Average domestic household size: 2.7
 Median monthly domestic household income (HK\$): \$17,500

Monthly Domestic Household Income

Domestic Households by Monthly Domestic Household Income, 2006



District of Yau Tsim Mong

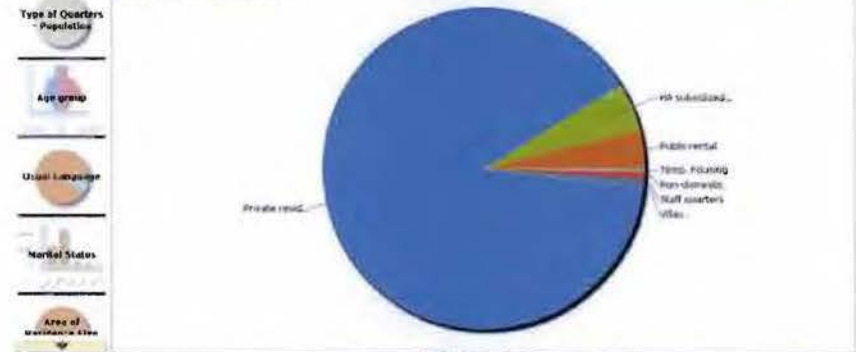
Yau Tsim Mong

Summary

Population	240 546
Proportion of population (%)	
- Aged under 15	12.0%
- Aged 15 - 64	74.7%
- Aged 65 and over	13.3%
Median age	39
Proportion of population aged 15 and over being never married (%)	
- Male	33.0%
- Female	20.5%

Type of Quarters - Population

Population by Type of Quarters, 2016



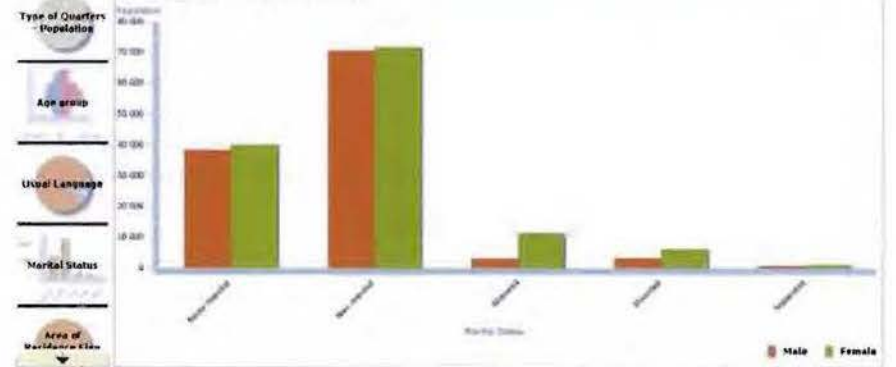
Yau Tsim Mong

Summary

Population	240 546
Proportion of population (%)	
- Aged under 15	12.0%
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- Aged 65 and over	13.3%
Median age	39
Proportion of population aged 15 and over being never married (%)	
- Male	33.0%
- Female	20.5%

Marital Status

Population Aged 15 and Over by Marital Status, 2016

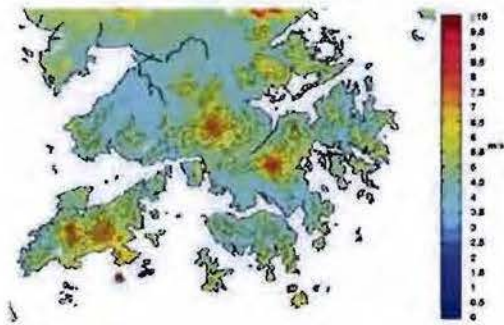


9.2.6.3 Average wind speed in Hong Kong

These charts show the average wind speed per month on a height of 60 meters. The charts were found at <http://envf.ust.hk/werhk/windpotential.html>.

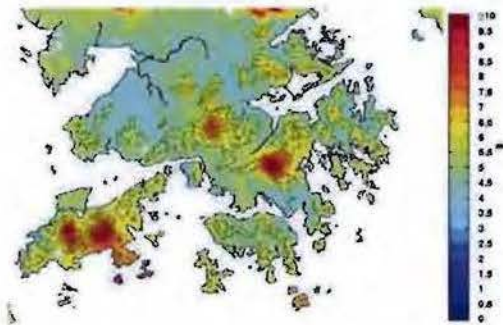
Average Wind Speed from 01 Oct 2003 to 31 Oct 2003

Region: [Longitude = 113.8250, Latitude = 22.1304], [Longitude = 114.4699, Latitude = 22.5850]
Height = 60m, Hong Kong Local Time



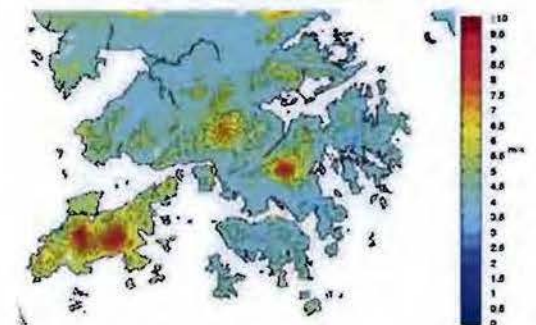
Average Wind Speed from 01 Jan 2004 to 31 Jan 2004

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Height = 60m, Hong Kong Local Time



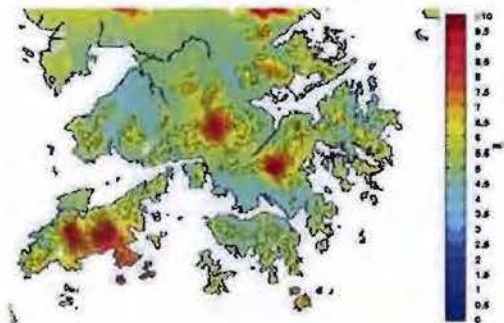
Average Wind Speed from 01 Apr 2004 to 30 Apr 2004

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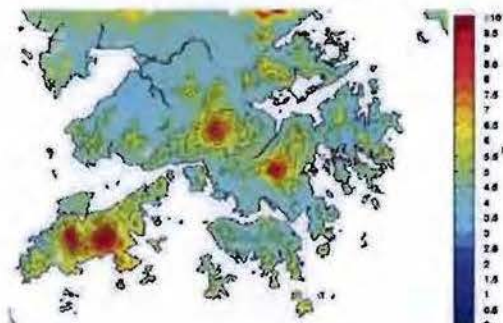
Average Wind Speed from 01 Nov 2003 to 30 Nov 2003

Region: [Longitude = 113.8250, Latitude = 22.1304], [Longitude = 114.4699, Latitude = 22.5850]
Height = 60m, Hong Kong Local Time



Average Wind Speed from 01 Feb 2004 to 29 Feb 2004

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Height = 60m, Hong Kong Local Time



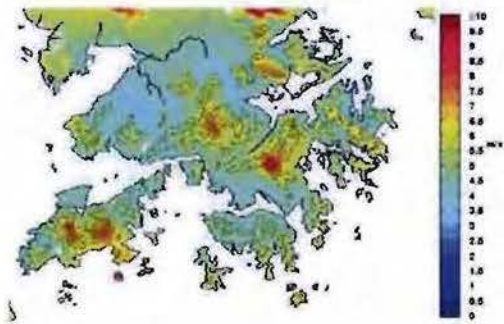
Average Wind Speed from 01 May 2004 to 31 May 2004

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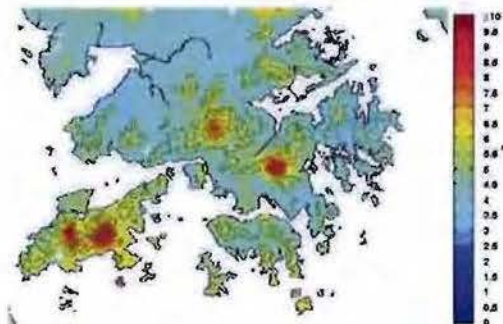
Average Wind Speed from 01 Dec 2003 to 31 Dec 2003

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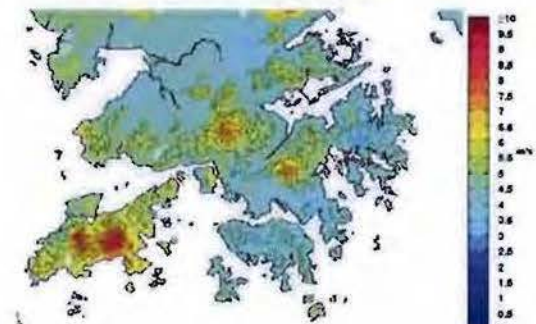
Average Wind Speed from 01 Mar 2004 to 31 Mar 2004

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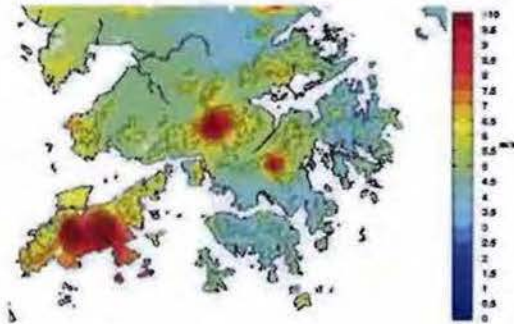
Average Wind Speed from 01 Jun 2004 to 30 Jun 2004

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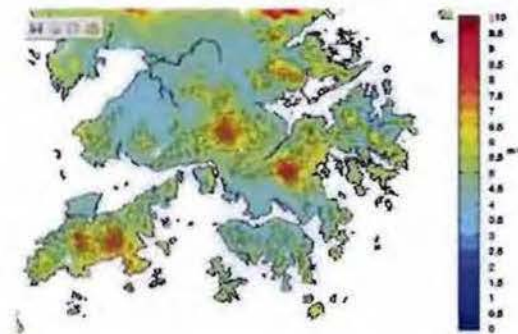
Average Wind Speed from 01 Jul 2004 to 31 Jul 2004

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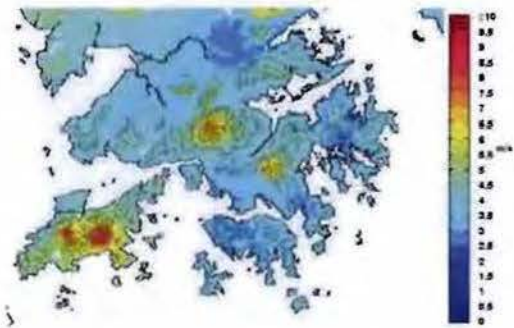
Average Wind Speed from 01 Oct 2004 to 31 Oct 2004

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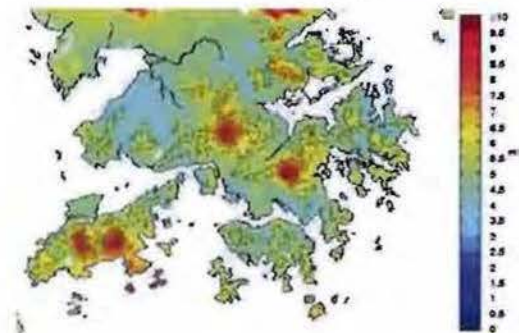
Average Wind Speed from 01 Aug 2004 to 31 Aug 2004

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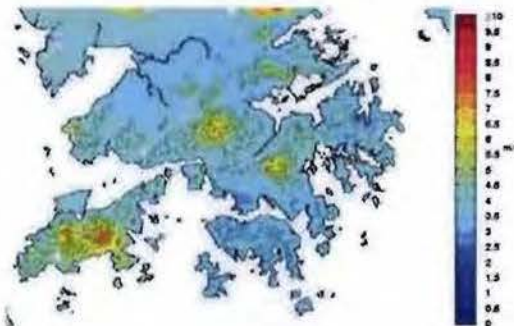
Average Wind Speed from 01 Nov 2004 to 30 Nov 2004

Region: [Longitude = 113.8250, Latitude = 22.1304], [Longitude = 114.4546, Latitude = 22.5850],
Height = 60m, Hong Kong Local Time



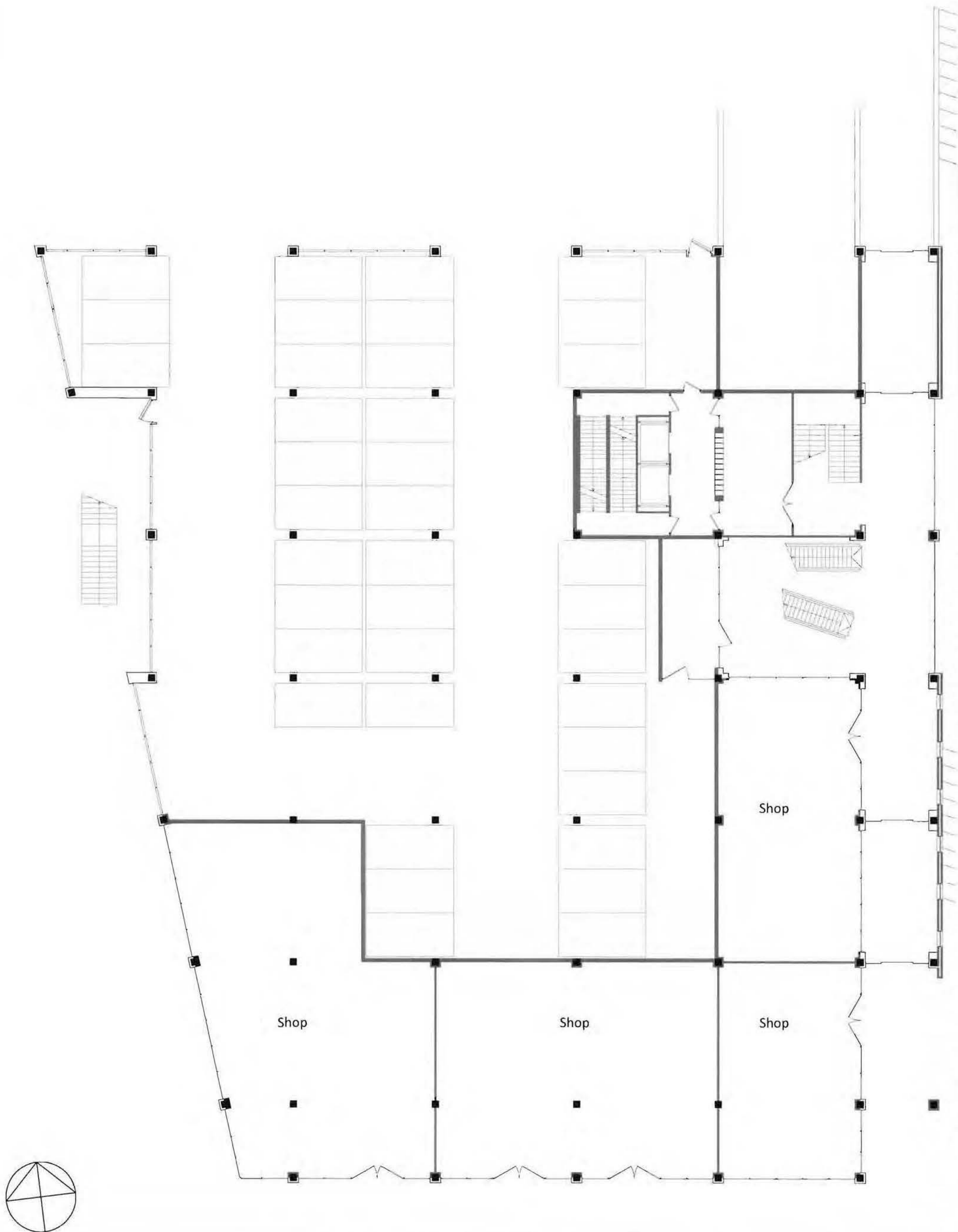
Average Wind Speed from 01 Sept 2004 to 30 Sept 2004

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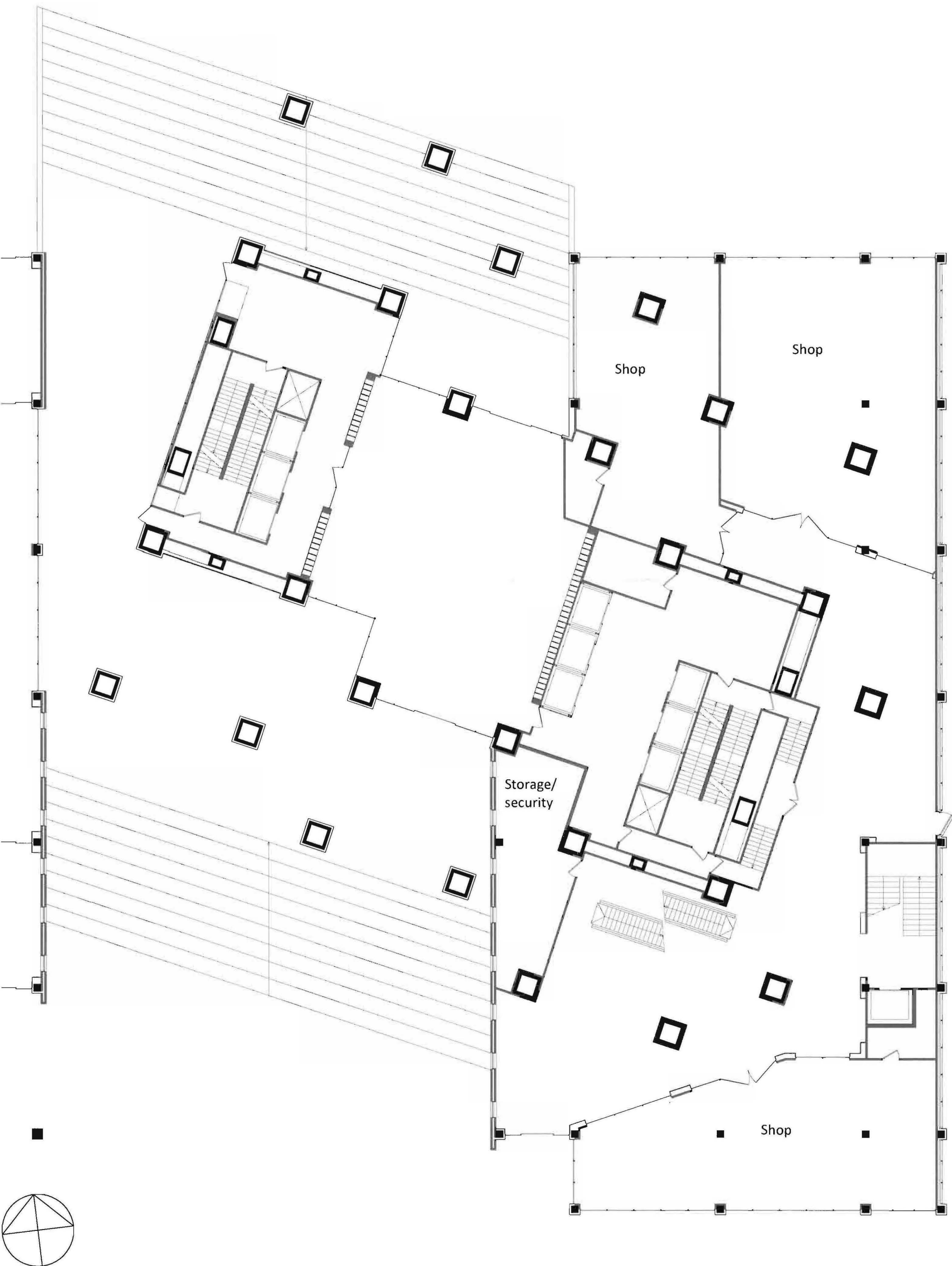


9.3 Plans, sections and elevations

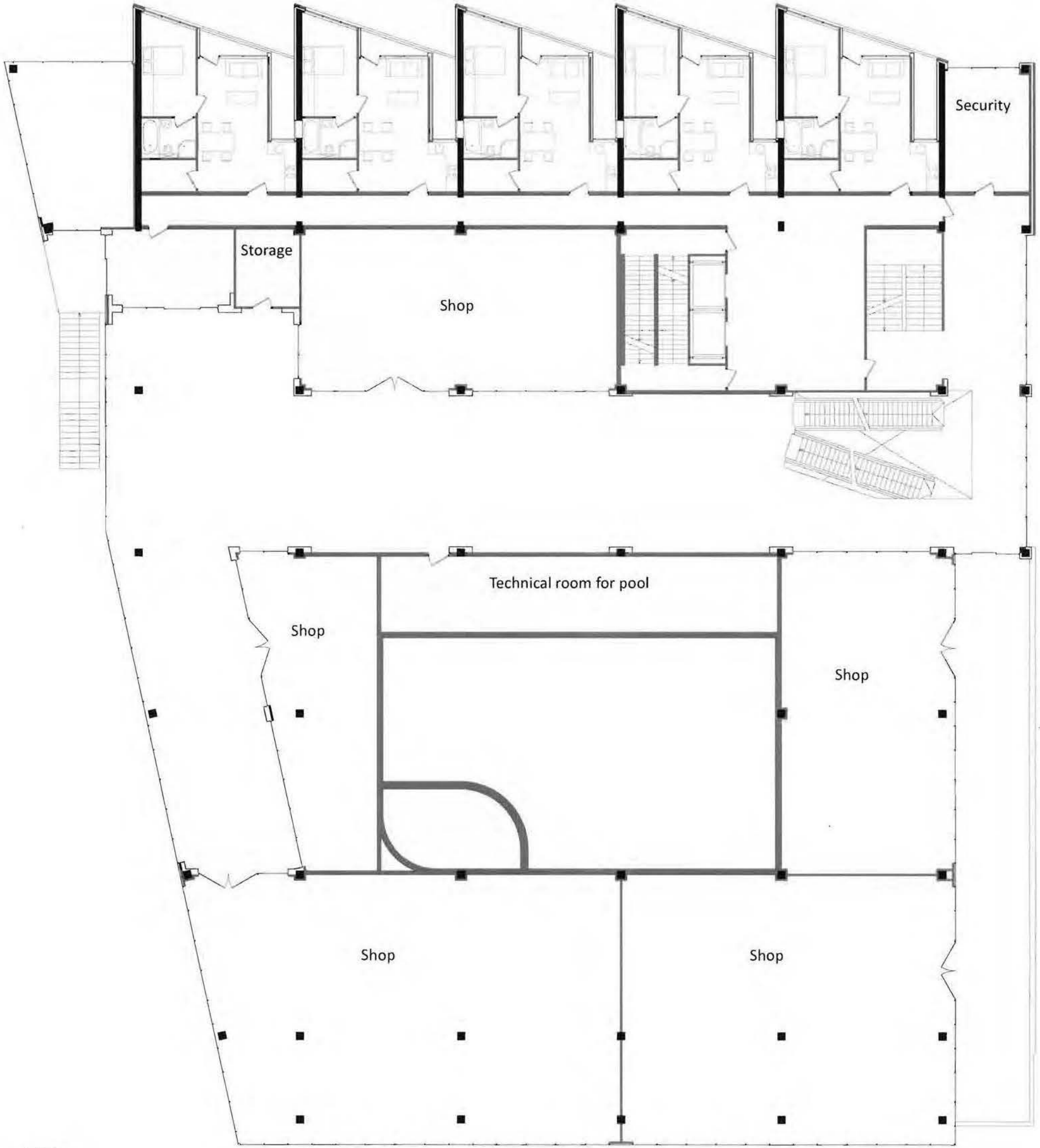
Floor plan ground floor (left side). Scale 1:200



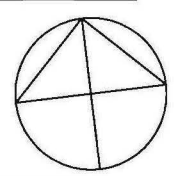
Floor plan ground floor (right side). Scale 1:200



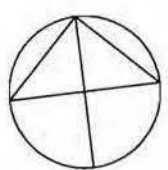
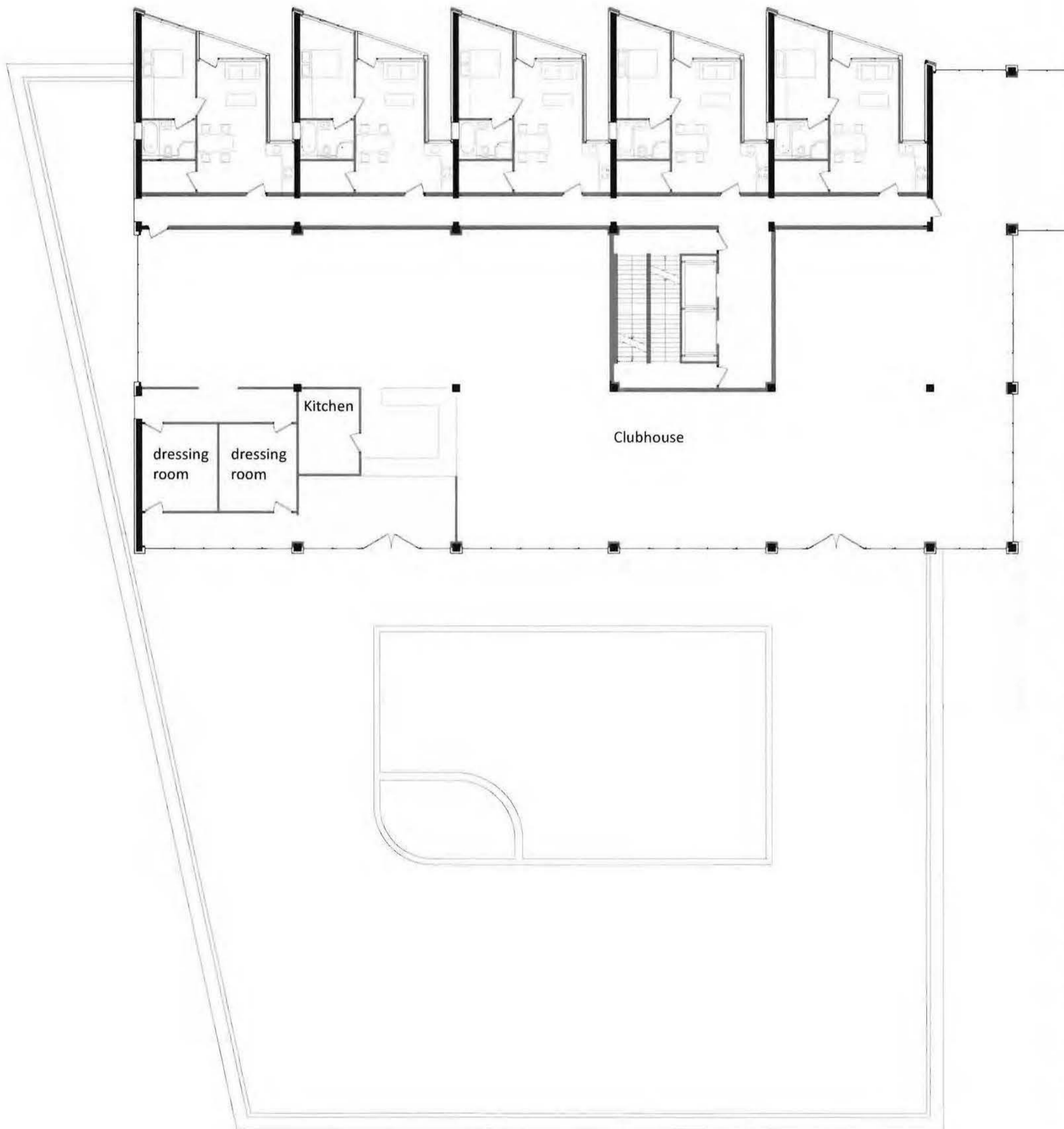
Floor plan floor 2 (left side). Scale 1:200



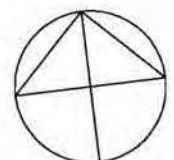
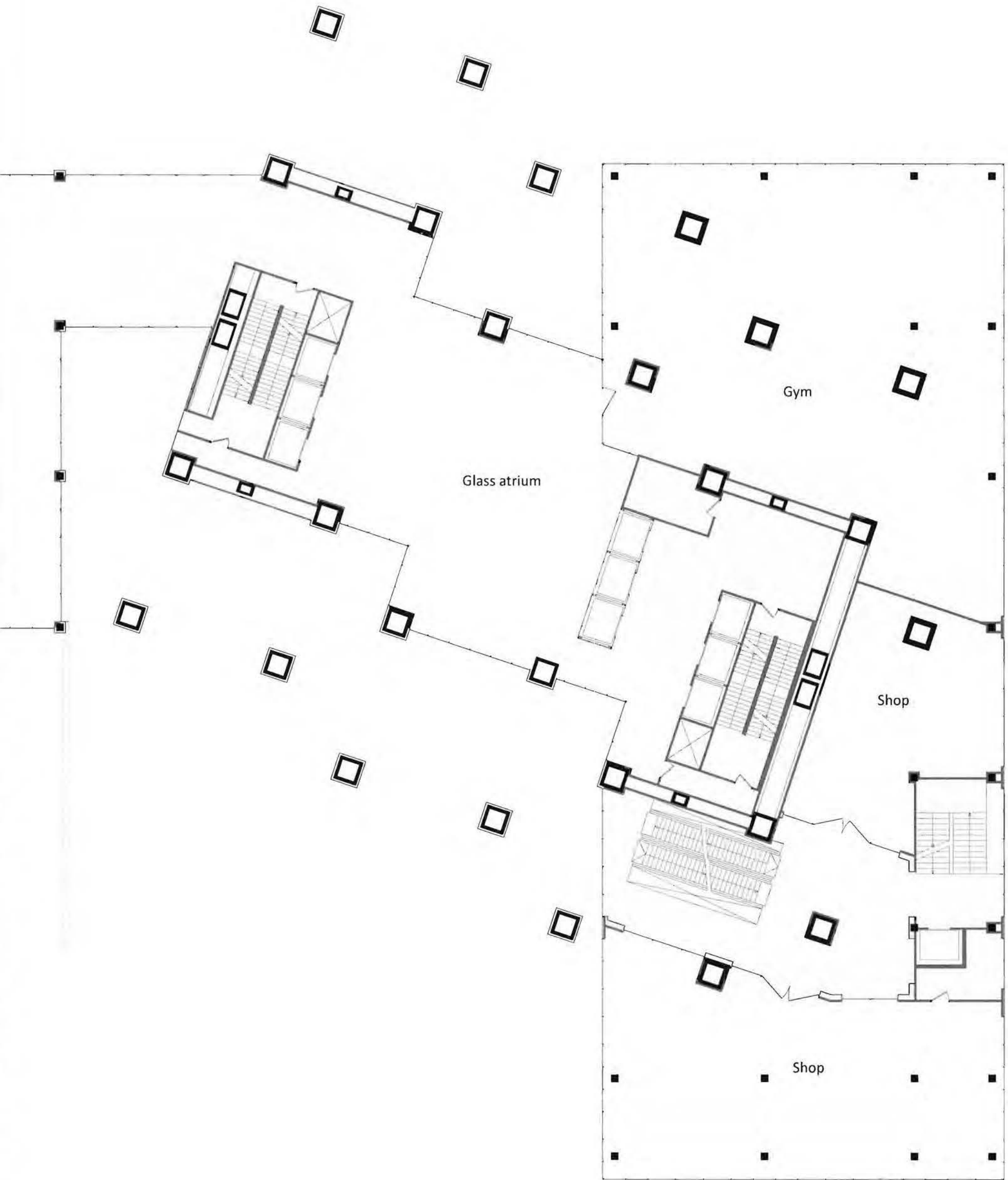
Floor plan floor 2 (right side). Scale 1:200



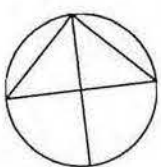
Floor plan floor 3 (left side). Scale 1:200



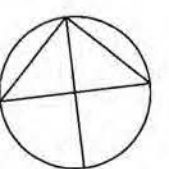
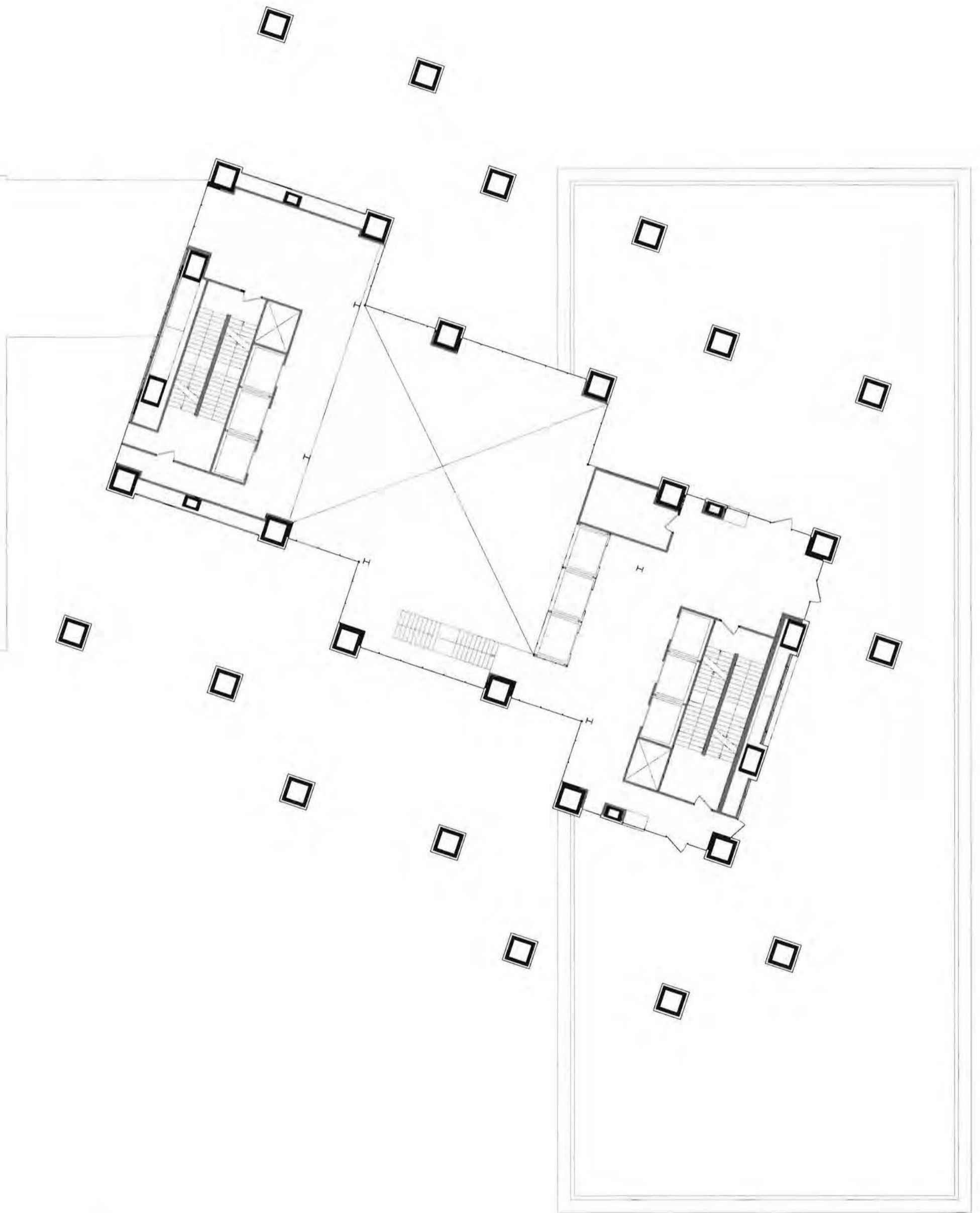
Floor plan floor 3 (right side). Scale 1:200



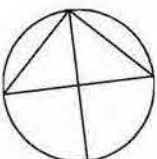
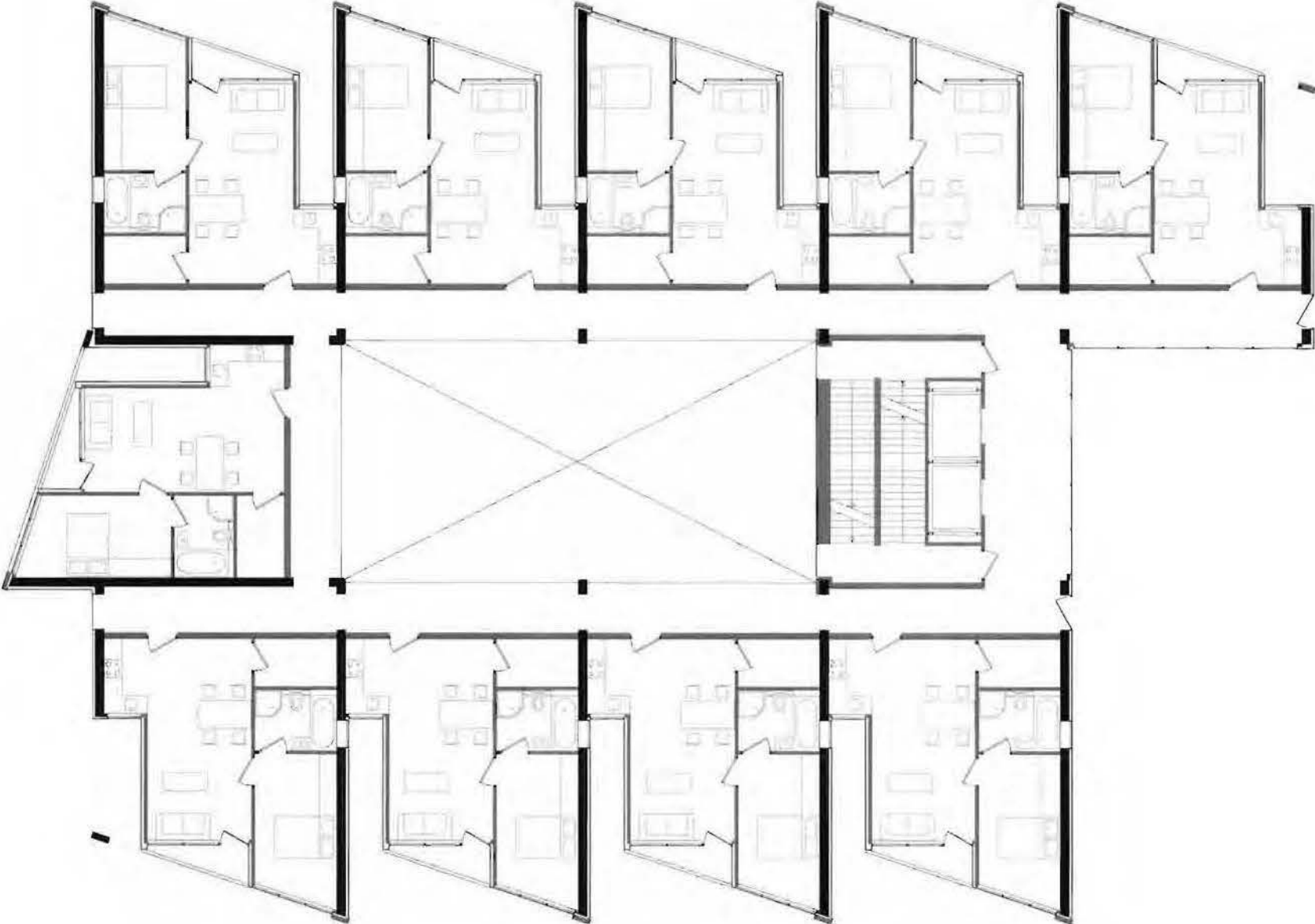
Floor plan floor 4 (left side). Scale 1:200



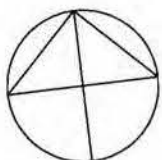
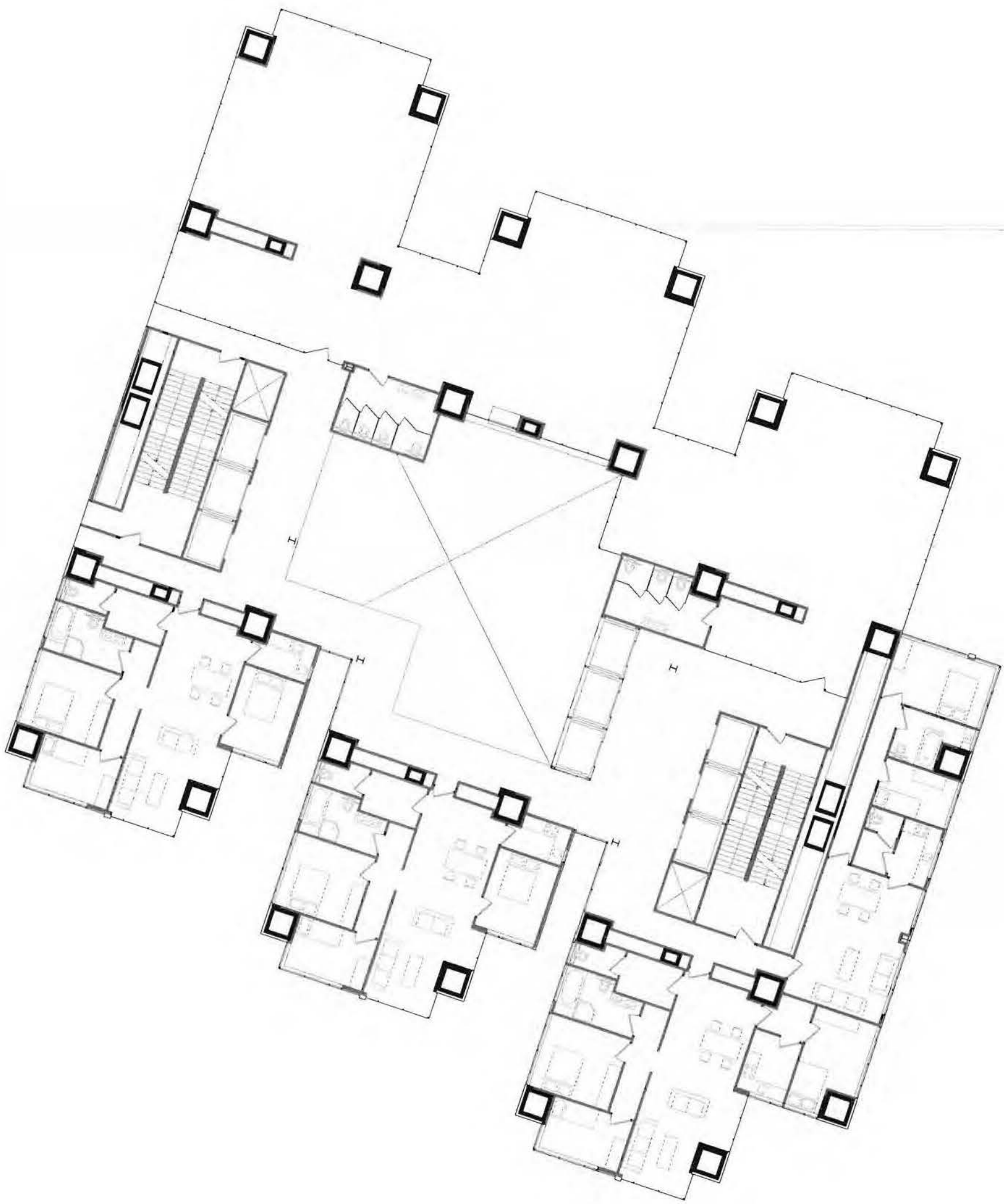
Floor plan floor 4 (right side). Scale 1:200



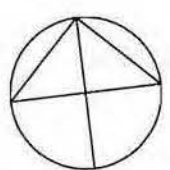
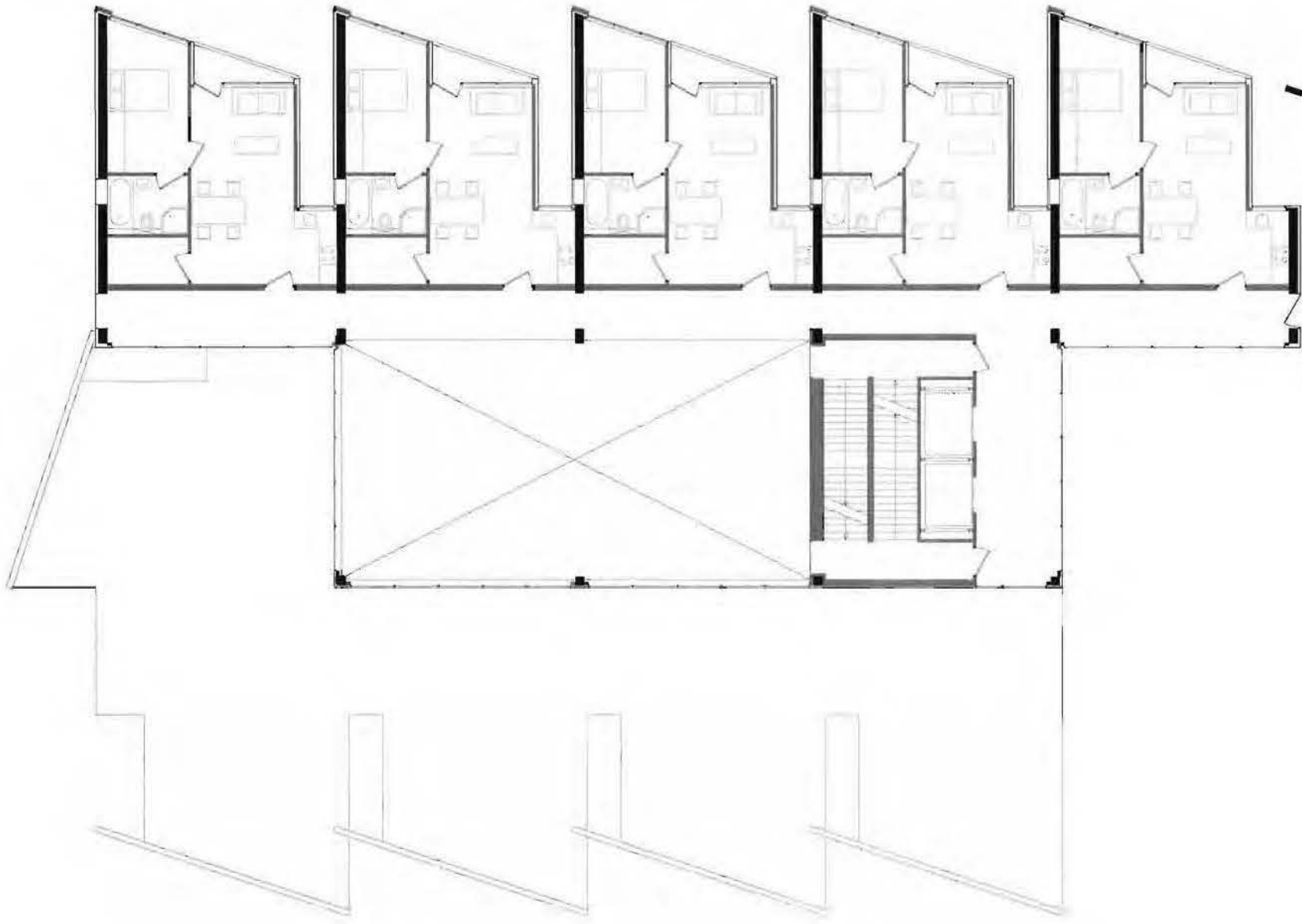
Floor plan floor 5 and 6 (left side). Scale 1:200



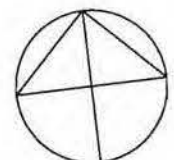
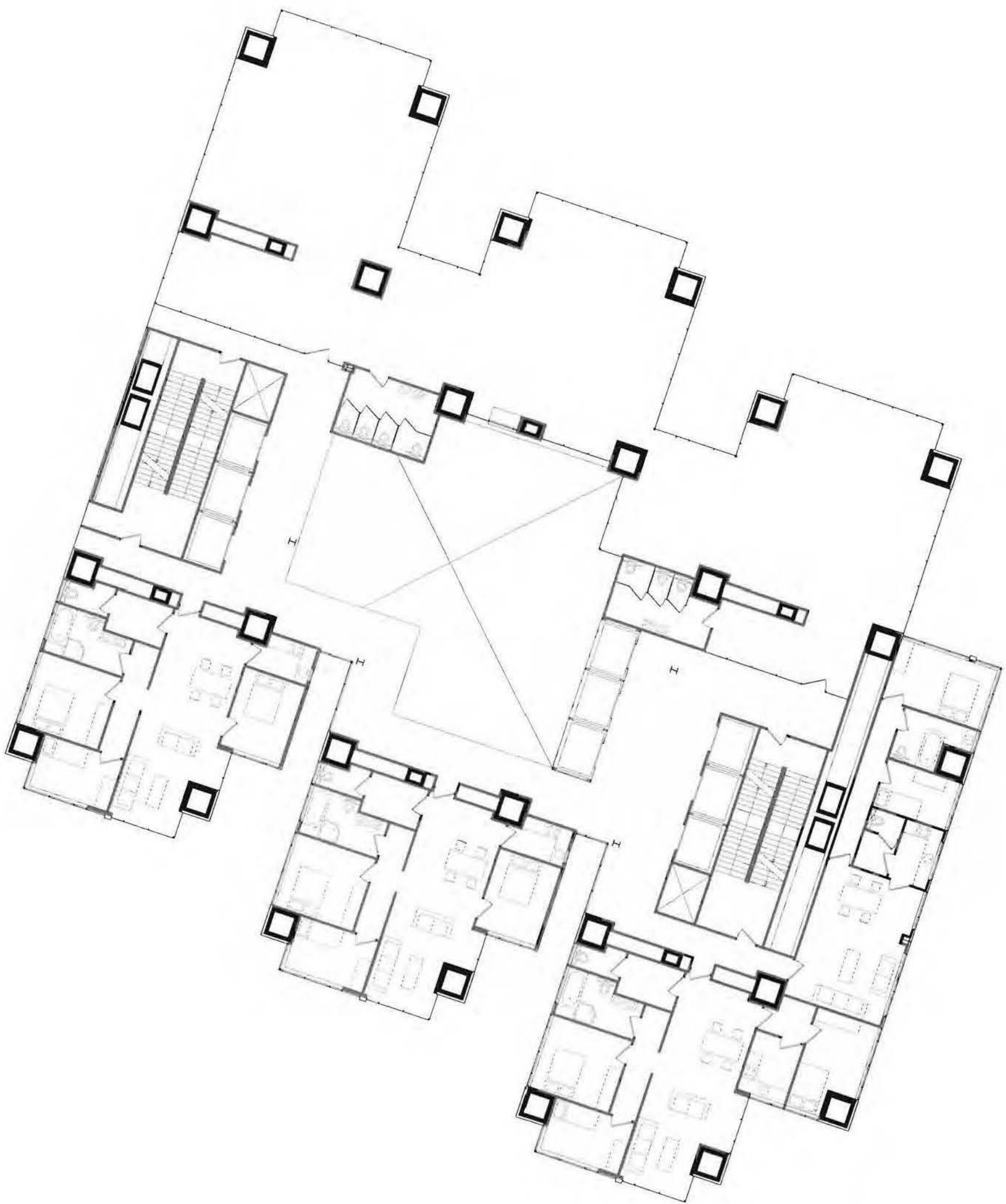
Floor plan floor 5 and 6 (right side). Scale 1:200



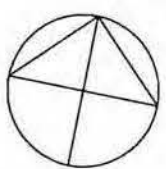
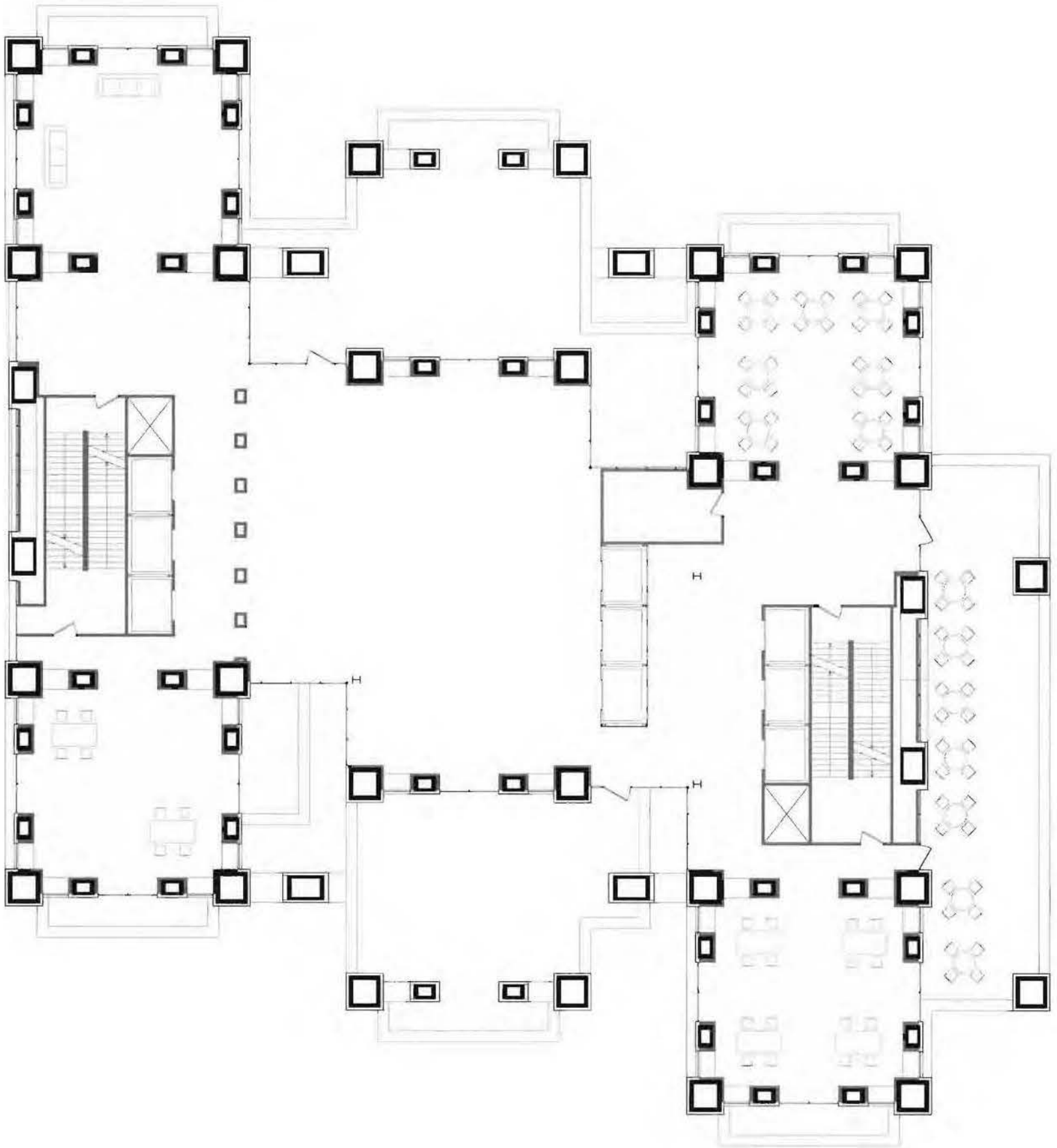
Floor plan floor 7 (left side). Scale 1:200



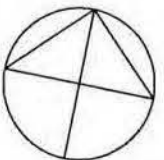
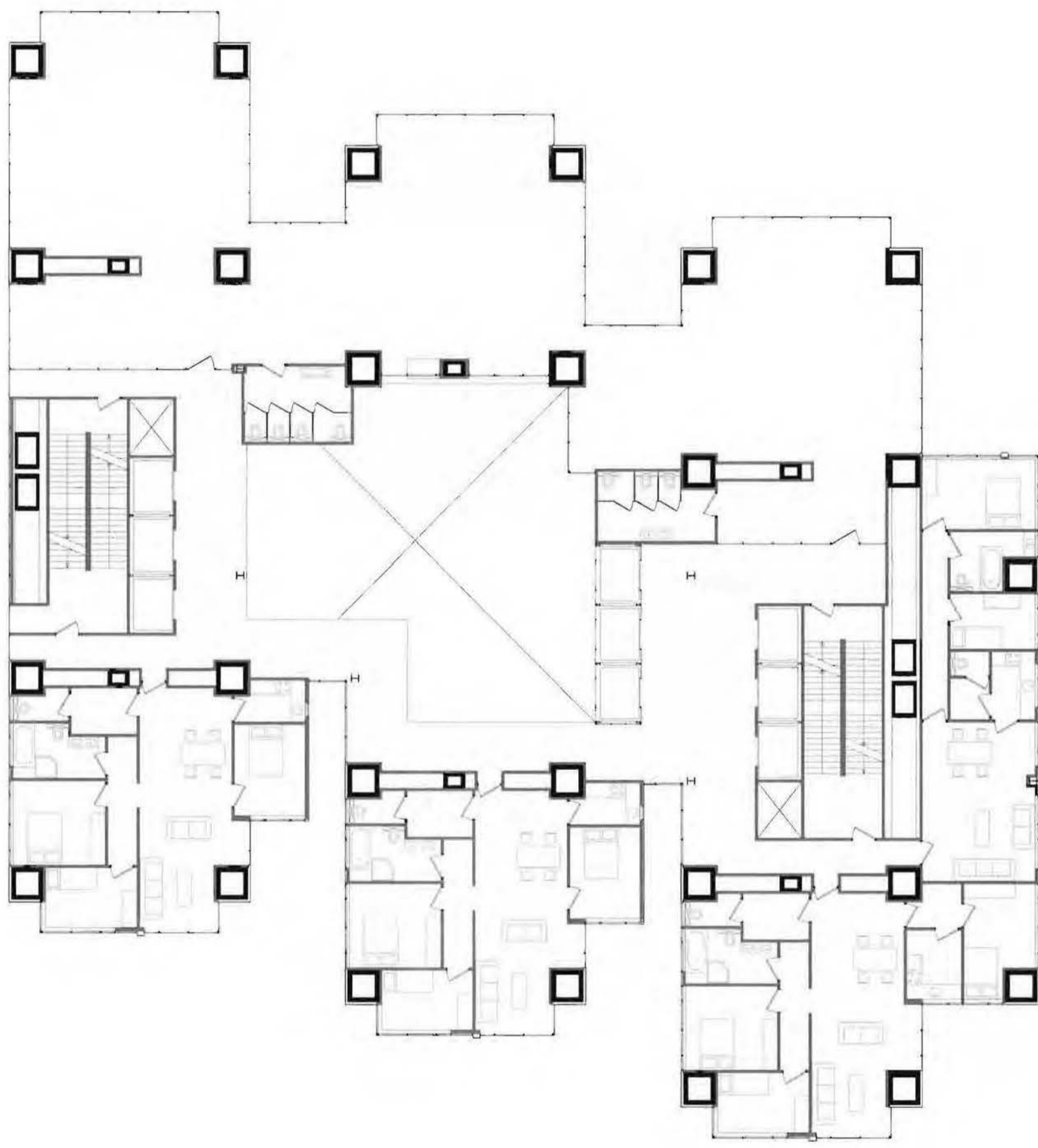
Floor plan floor 7 (right side). Scale 1:200



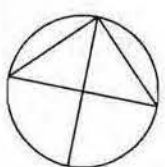
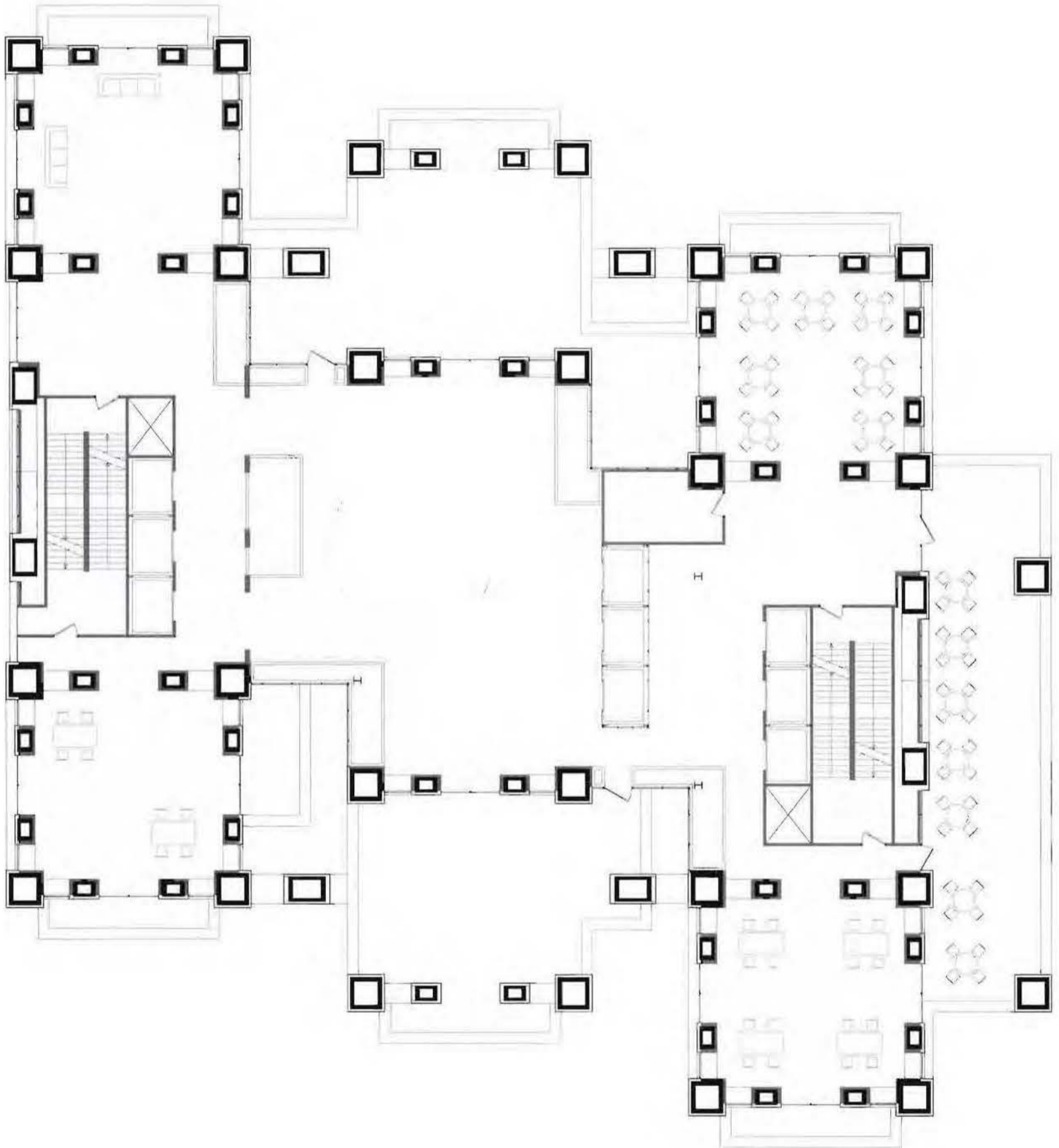
Floor plan floor 16 (Brown stone atrium). Scale 1:200



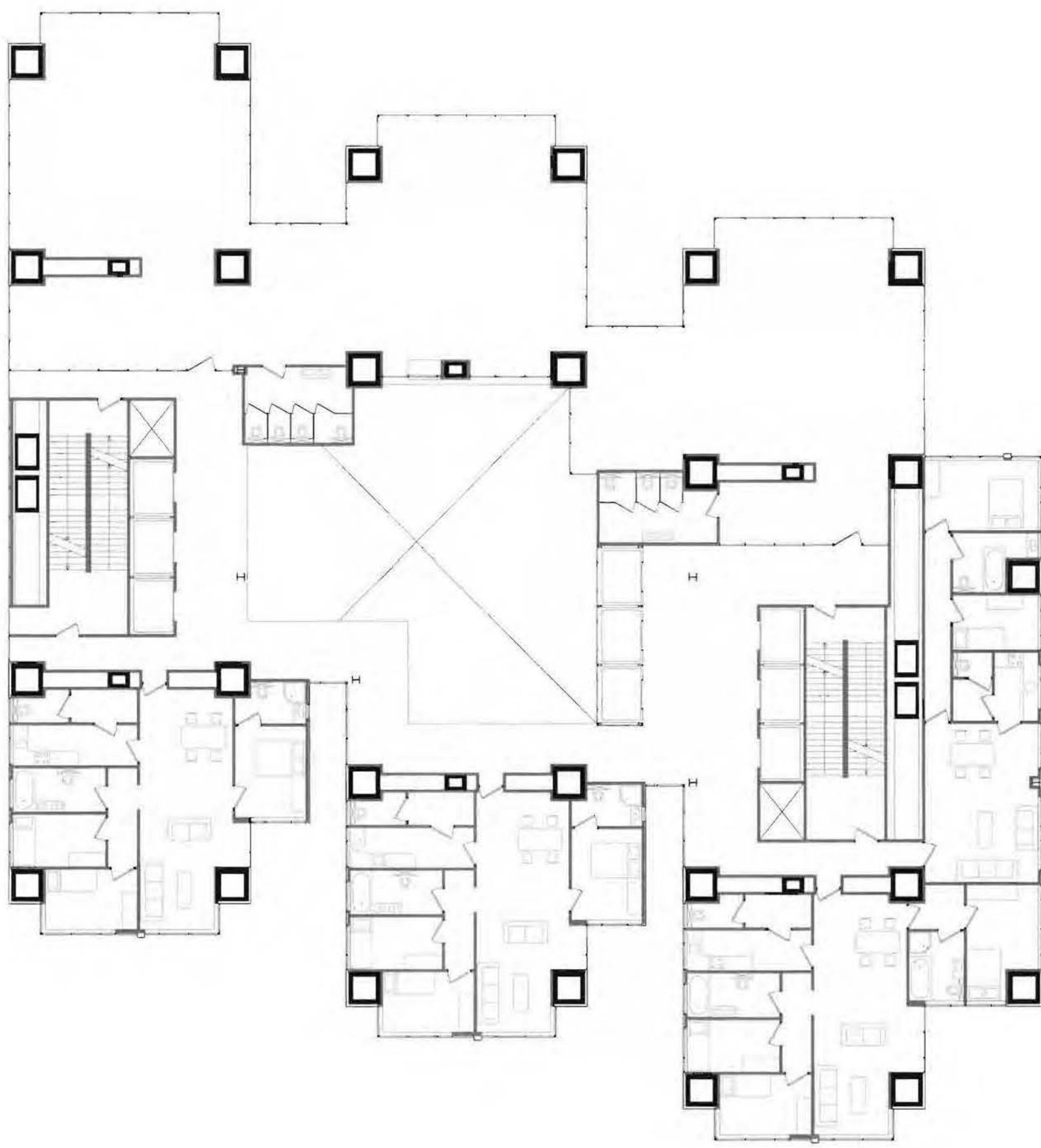
Floor plan typical floor 18 - 29. Scale 1:200



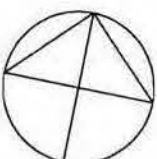
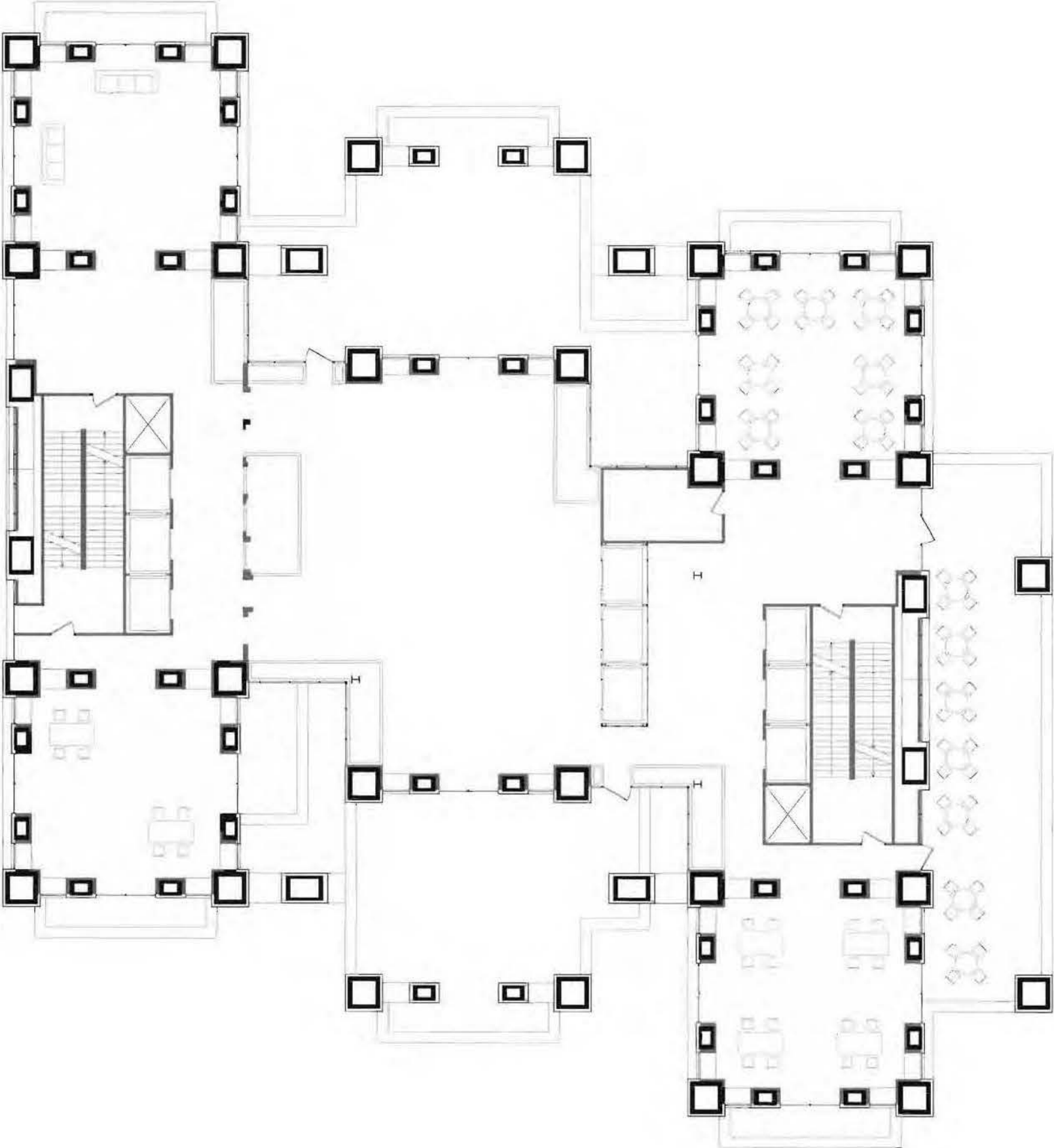
Floor plan floor 30 (Plastic atrium). Scale 1:200



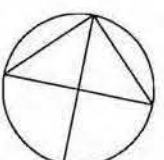
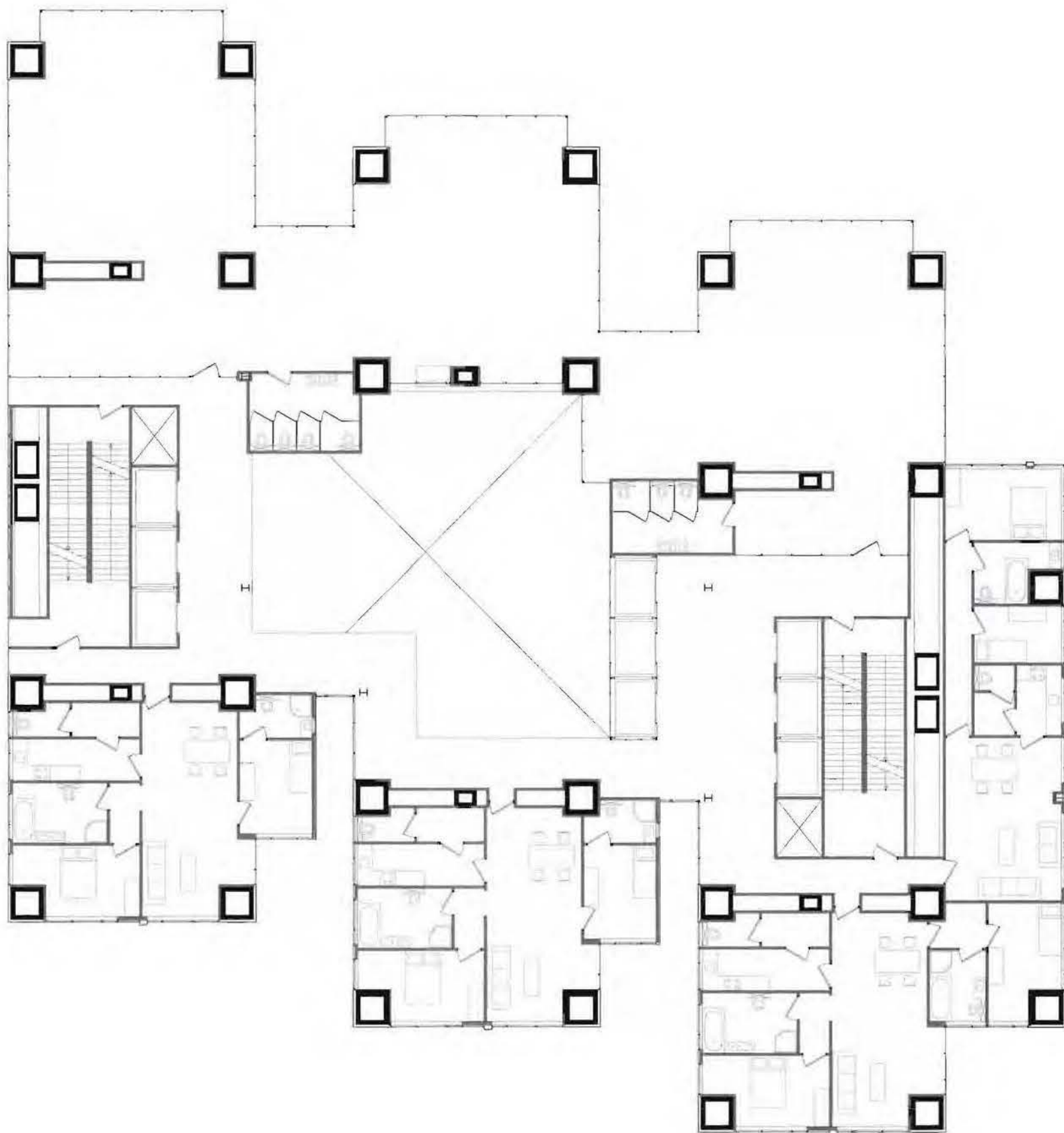
Floor plan typical floor 32 - 43. Scale 1:200



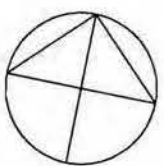
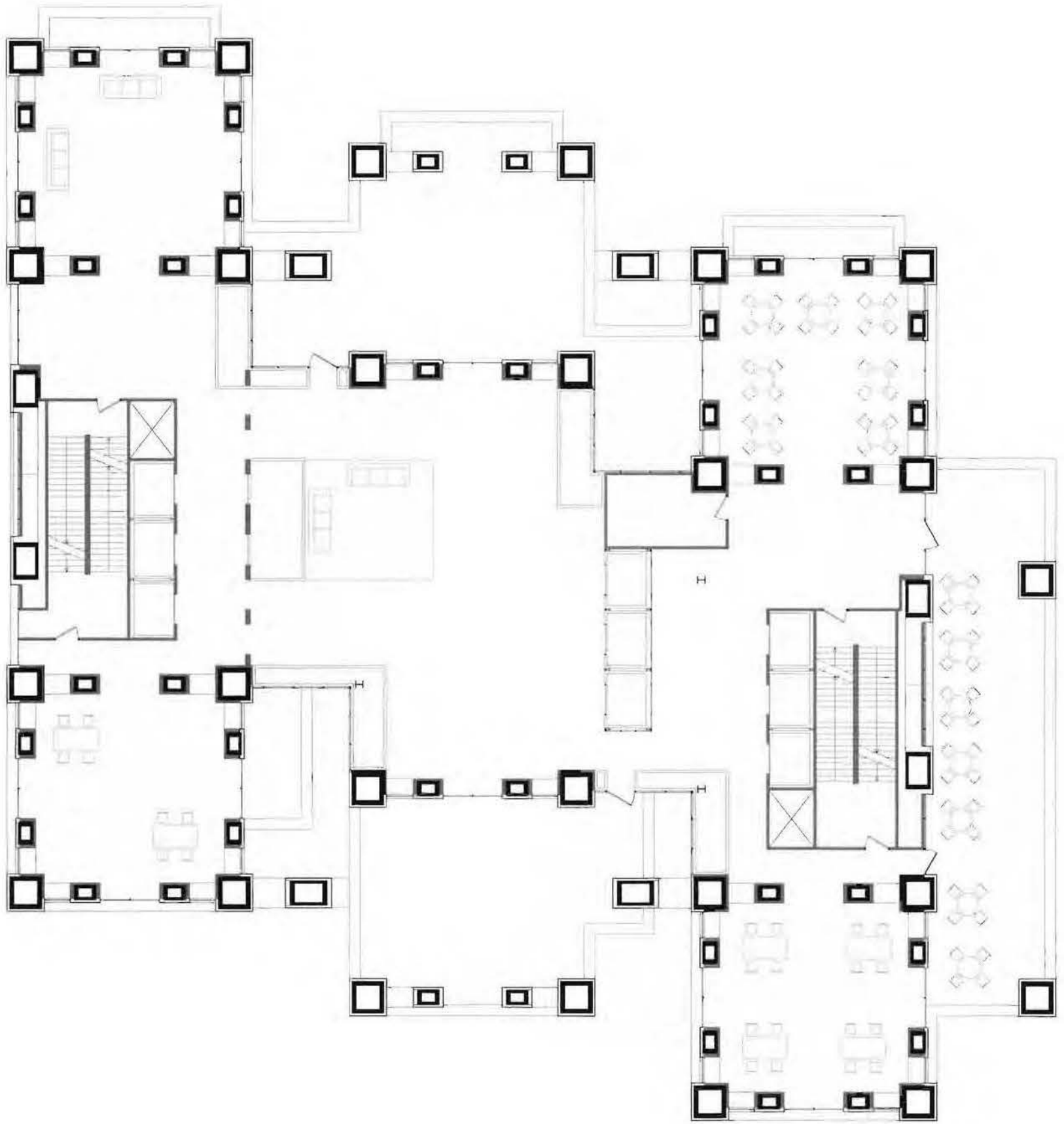
Floor plan floor 44 (Metal atrium). Scale 1:200



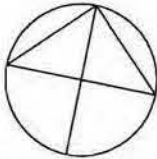
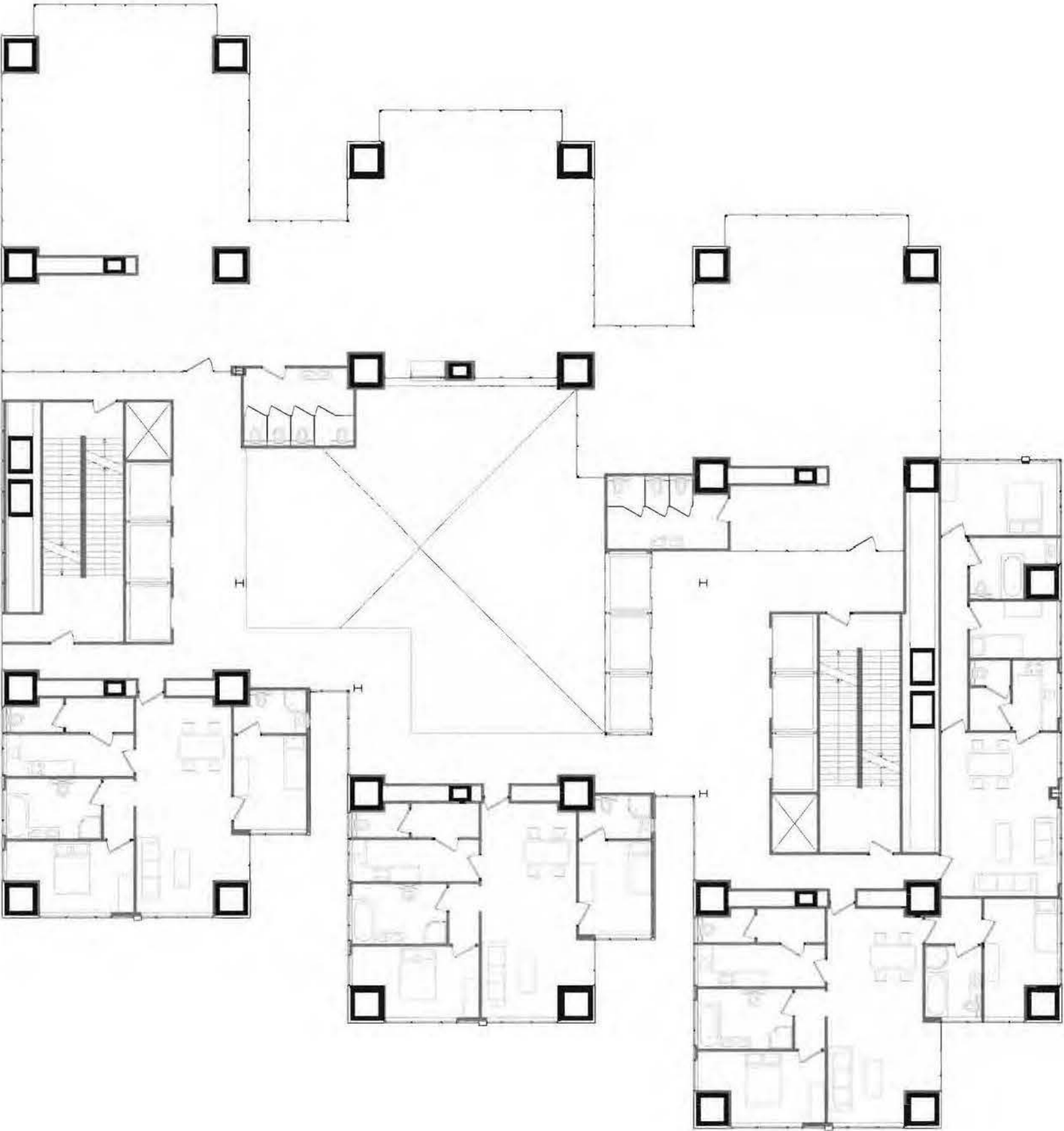
Floor plan typical floor 46 - 57. Scale 1:200

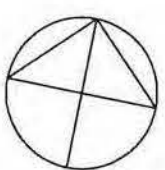
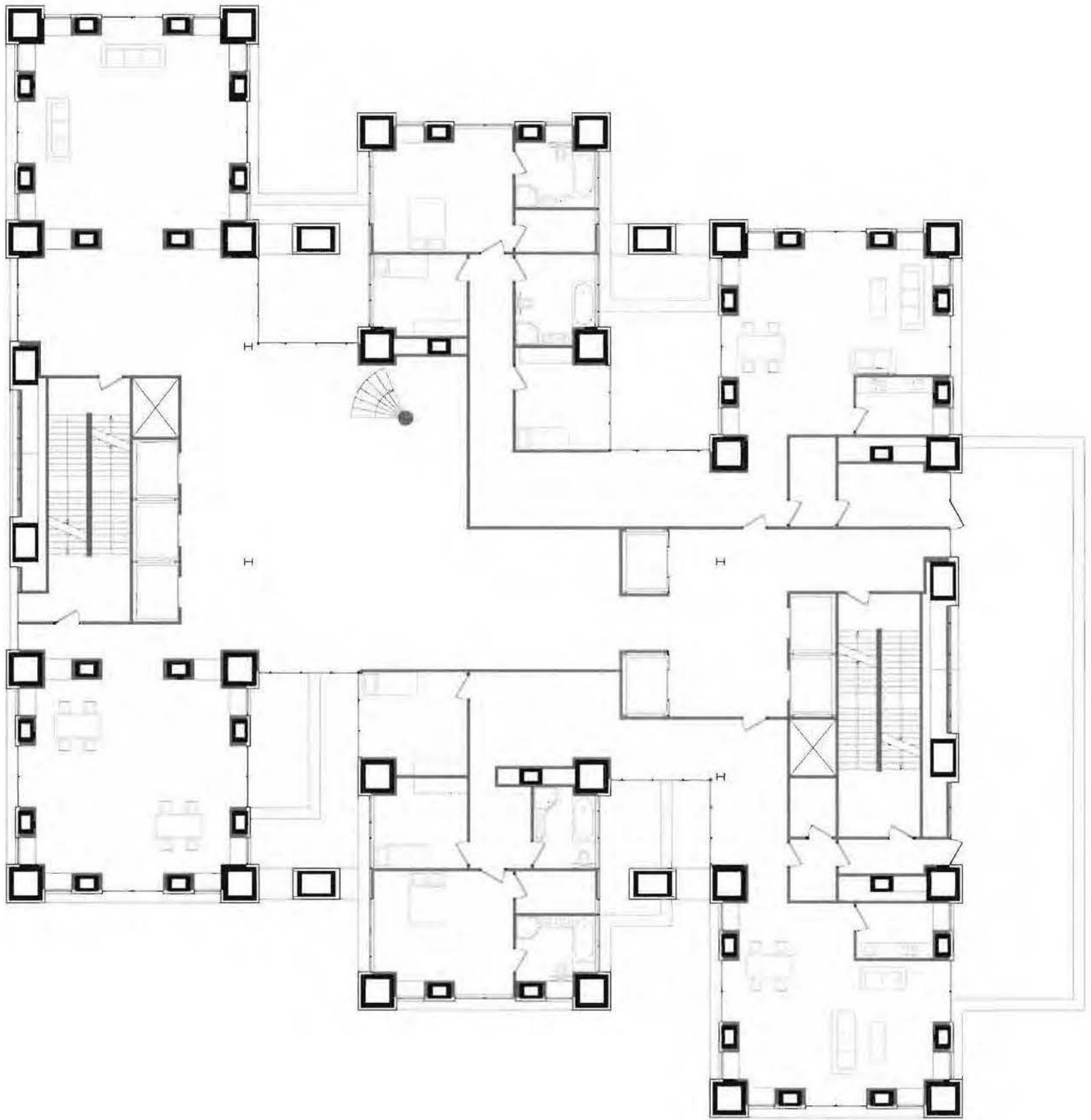


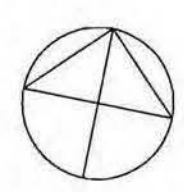
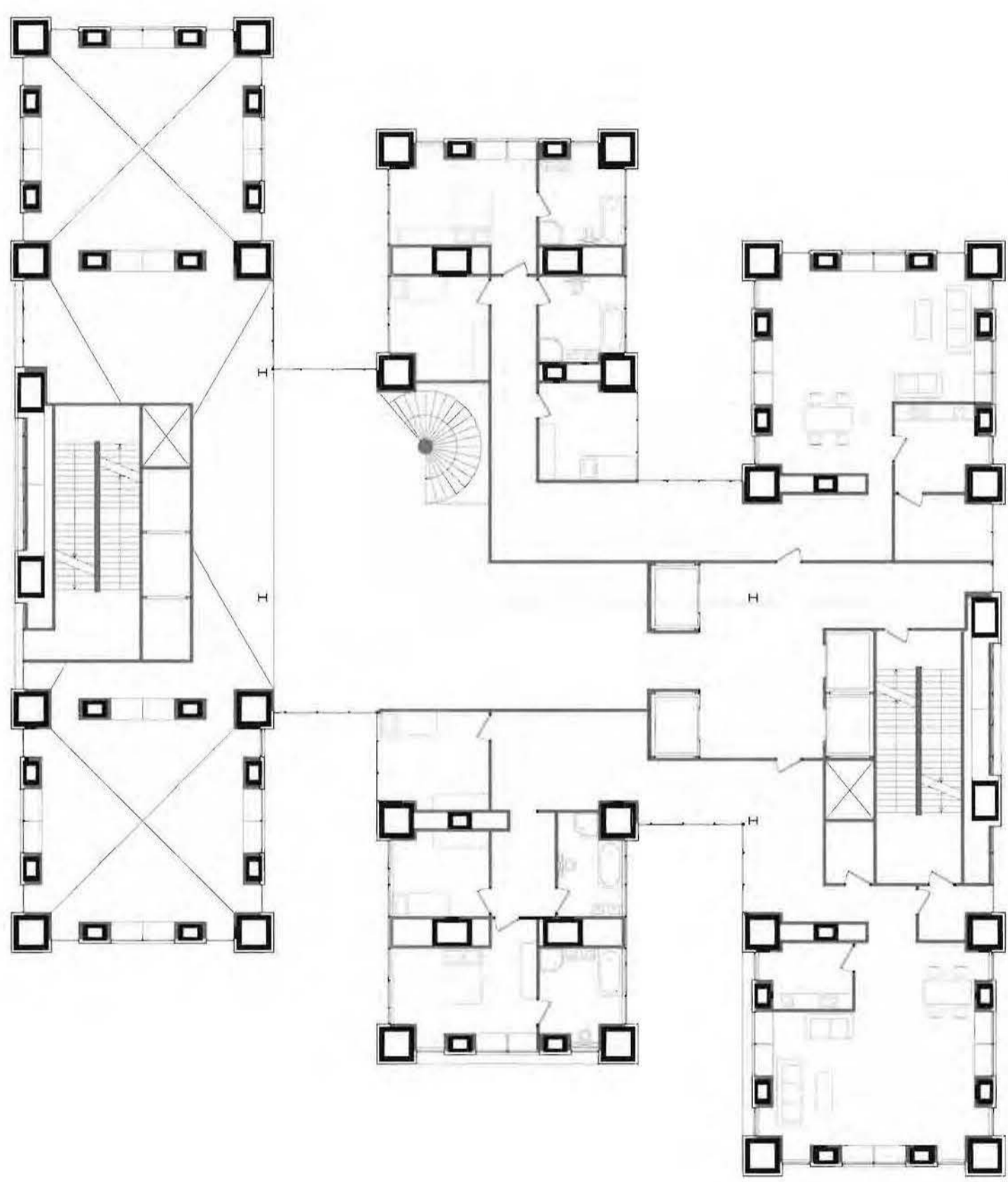
Floor plan floor 58 (Grey stone atrium). Scale 1:200

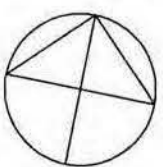
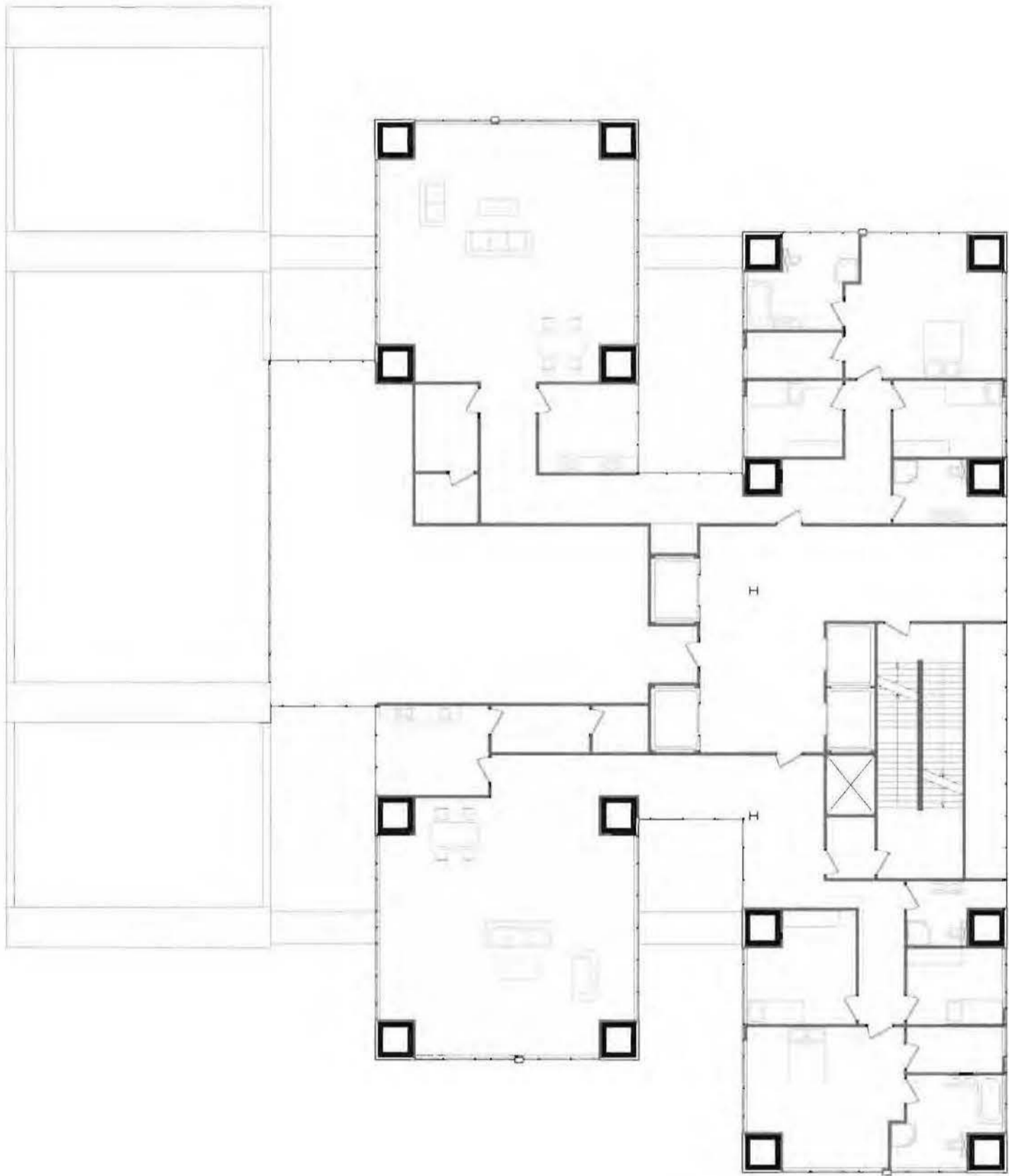


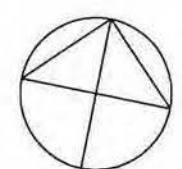
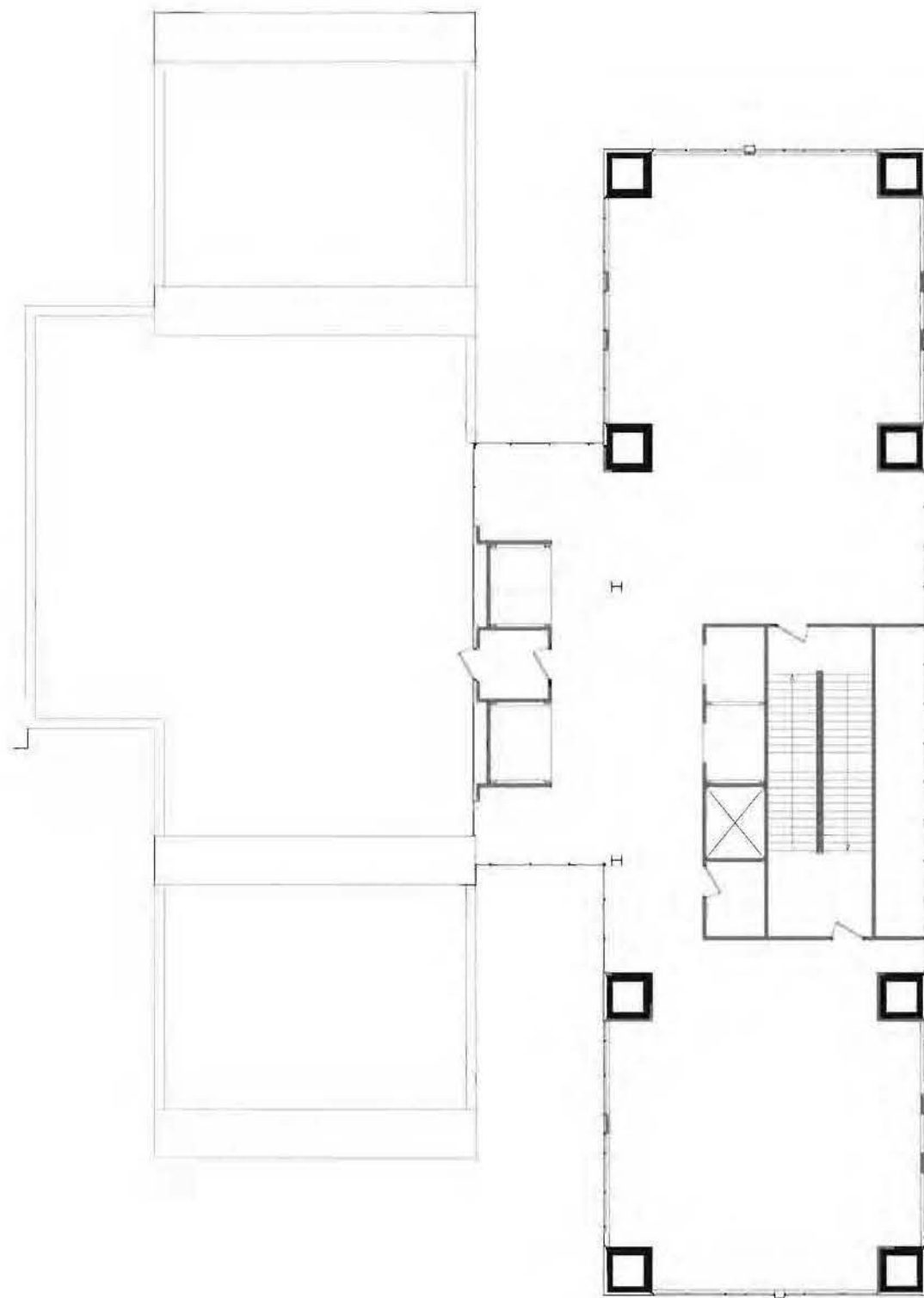
Floor plan typical floor 60 - 71. Scale 1:200

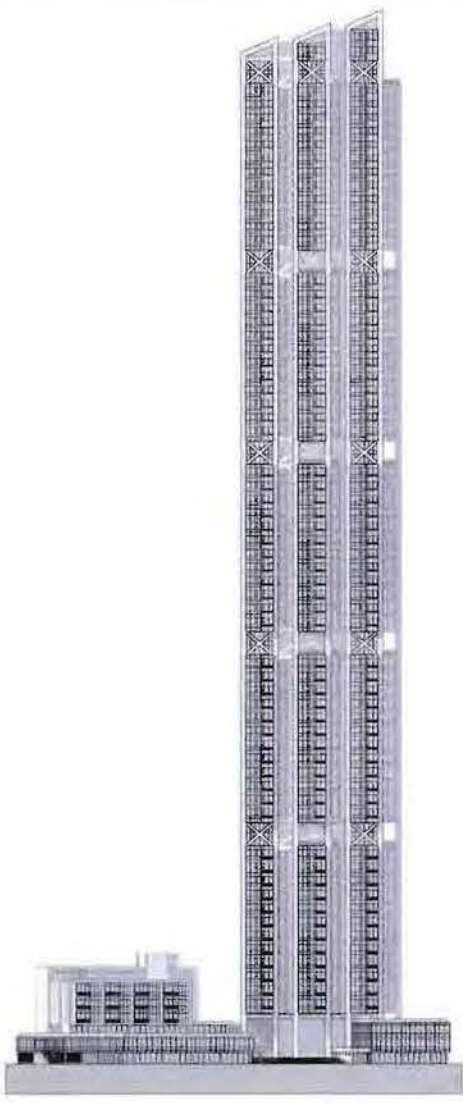




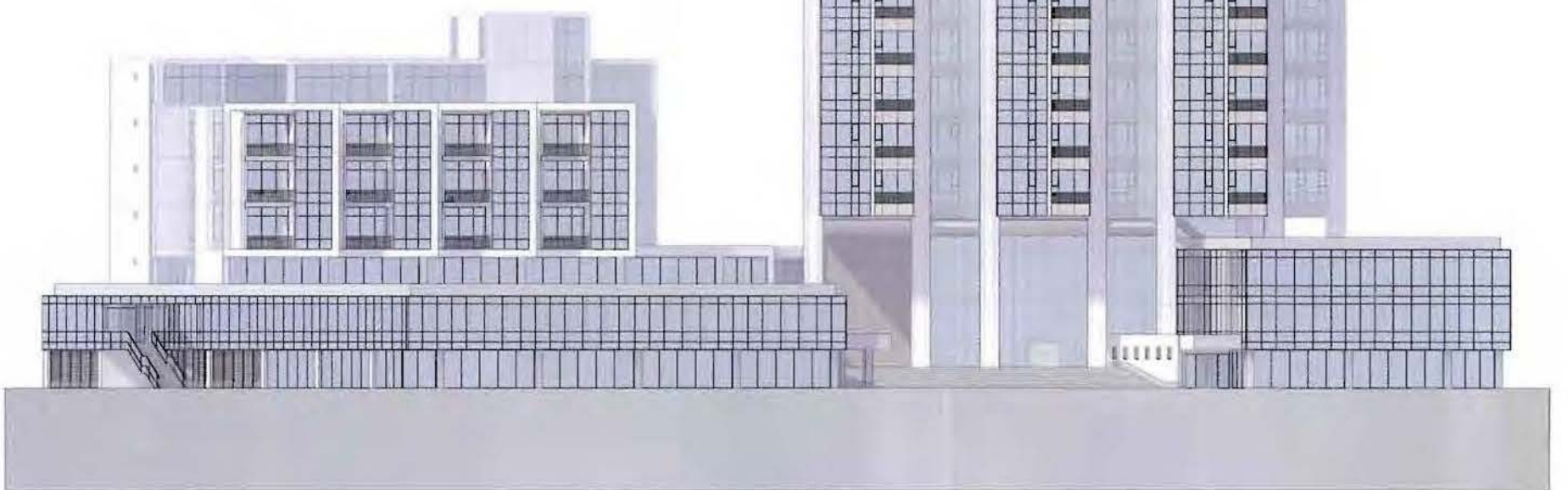




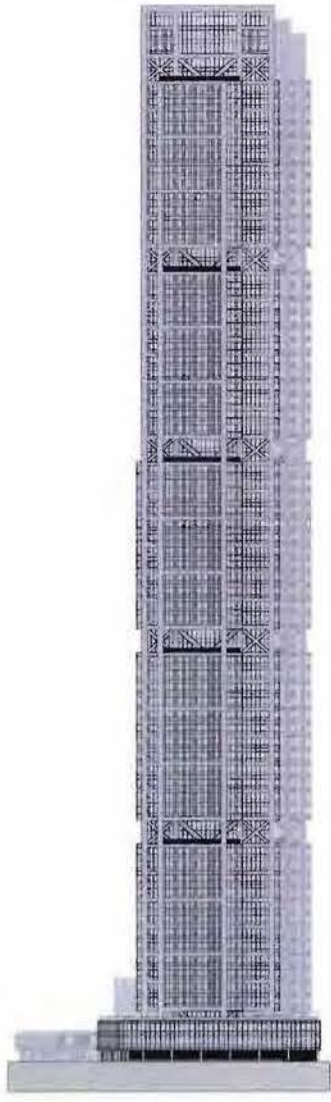




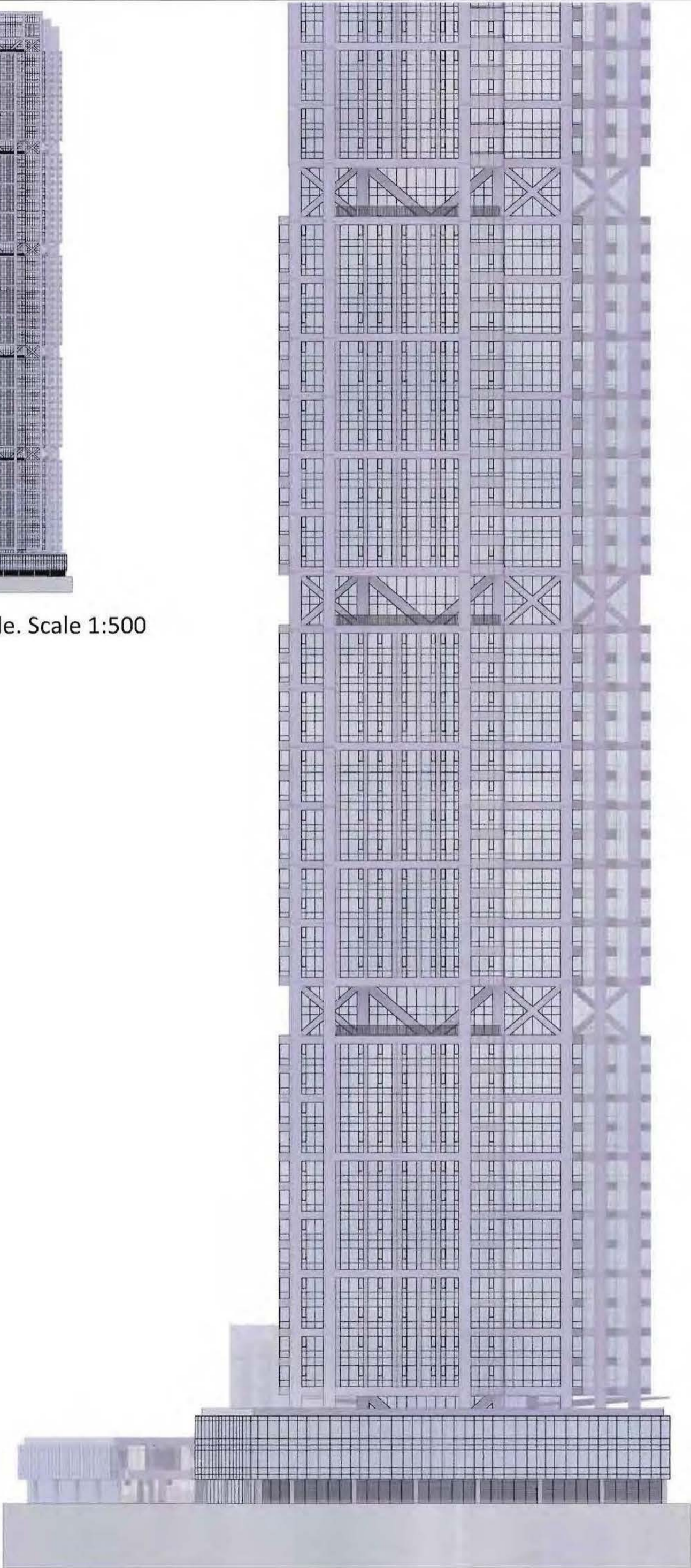
Elevation south side. Scale 1:500

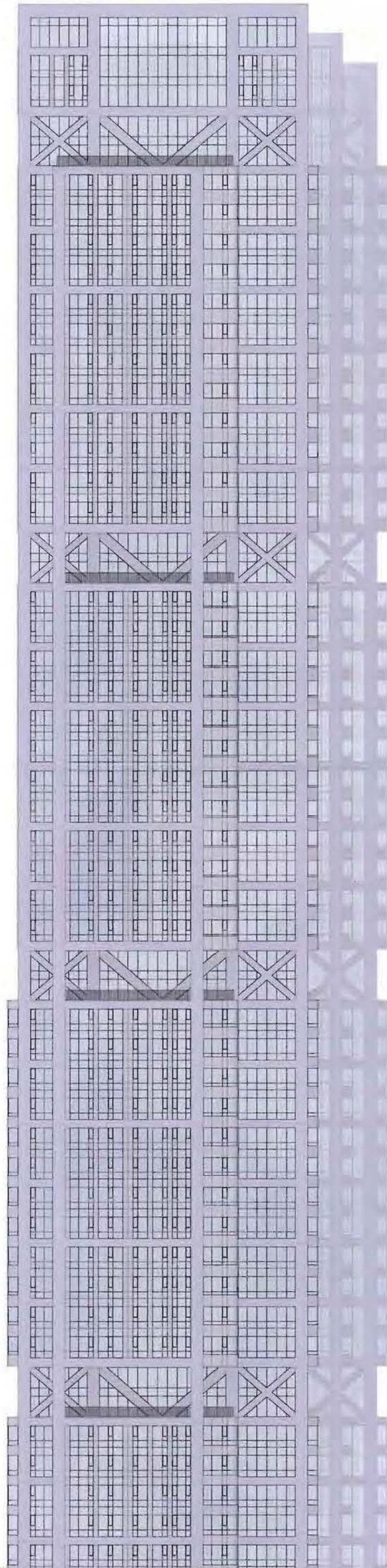


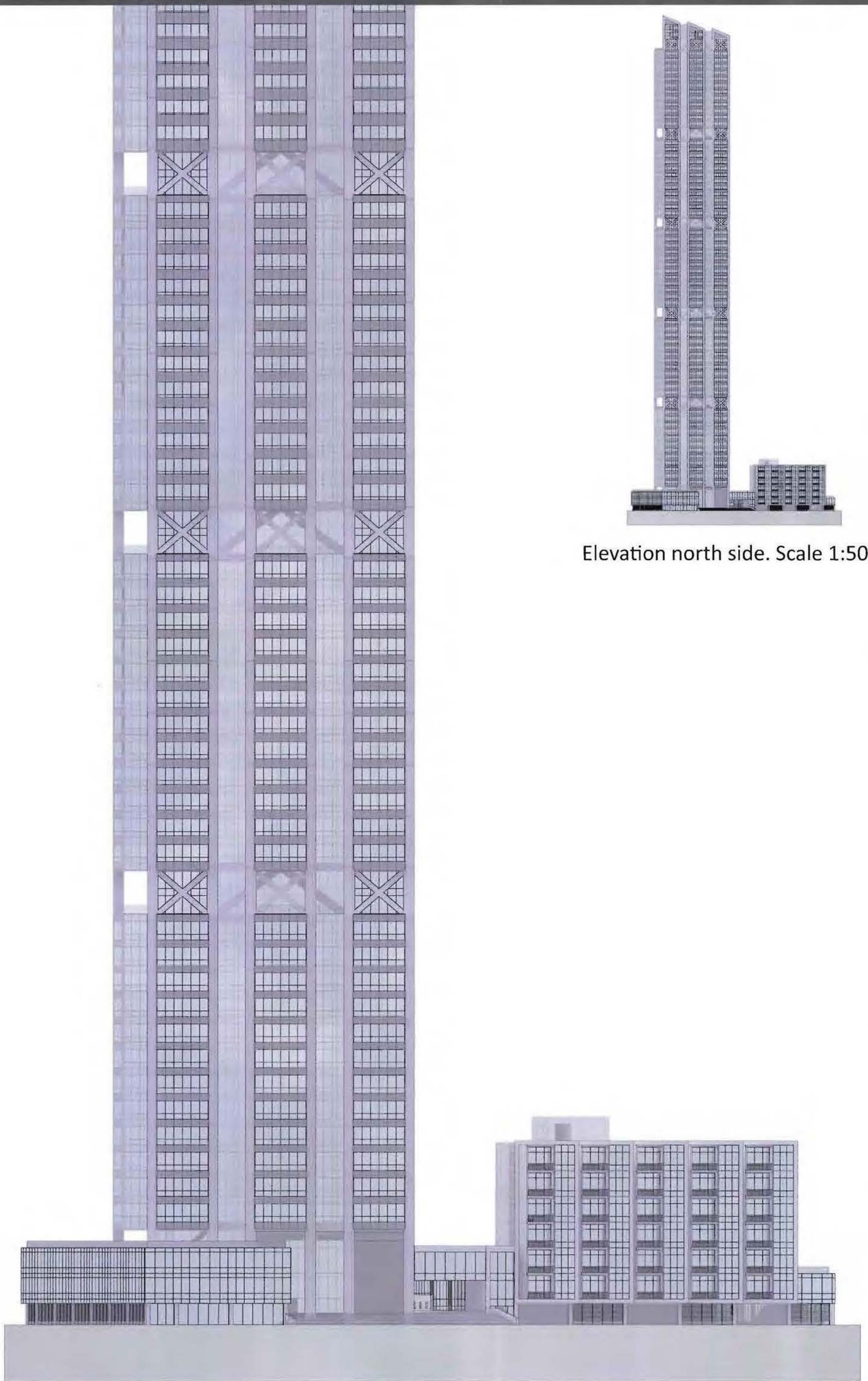




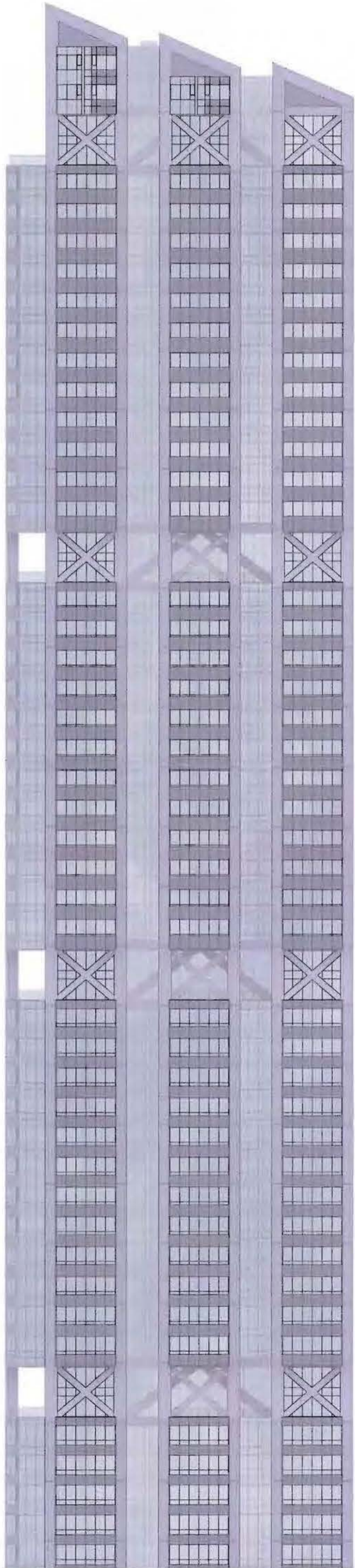
Elevation east side. Scale 1:500

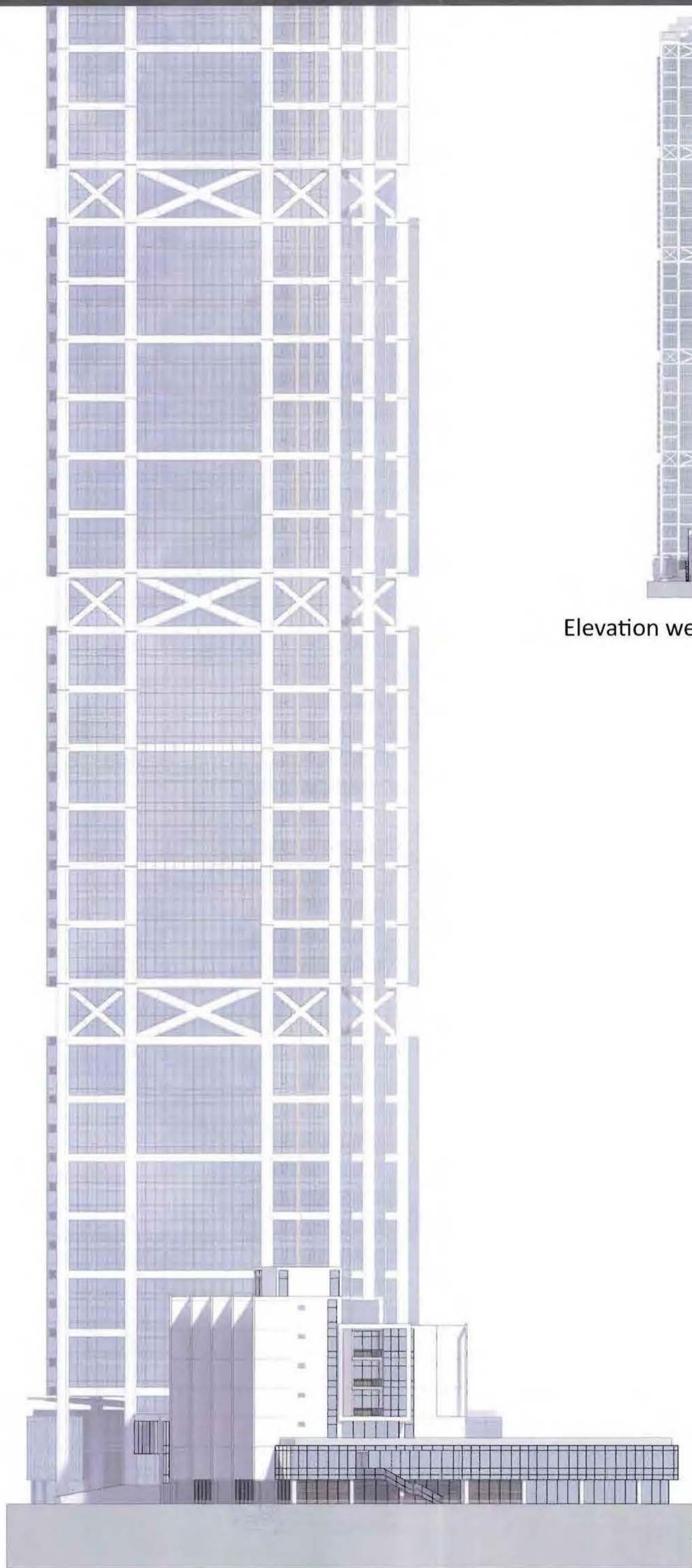




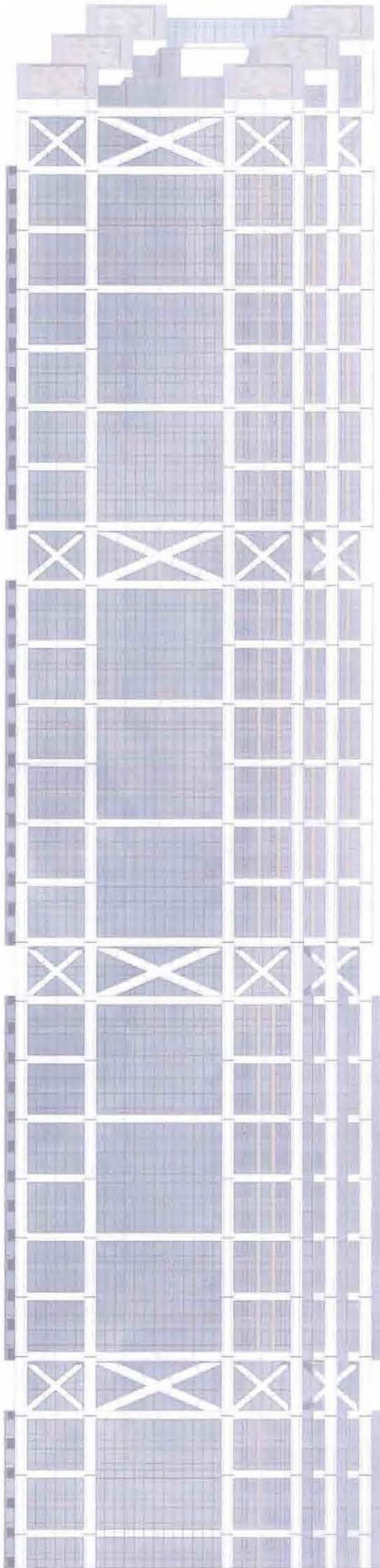


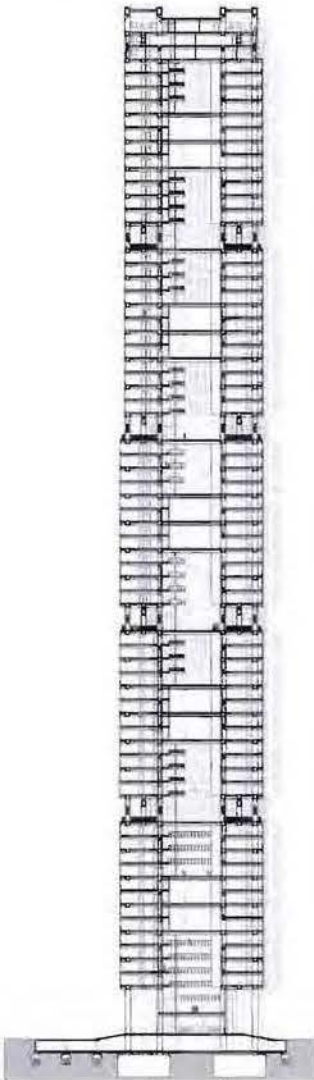
Elevation north side. Scale 1:500





Elevation west side. Scale 1:500





Section north-south looking west.
Scale 1:500

