POLITECNICO DI MILANO

Master of Science in Architectural Engineering

MINIMUM VERTICAL COMMUNITY IN SHANGHAI

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Thank you!

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Contents

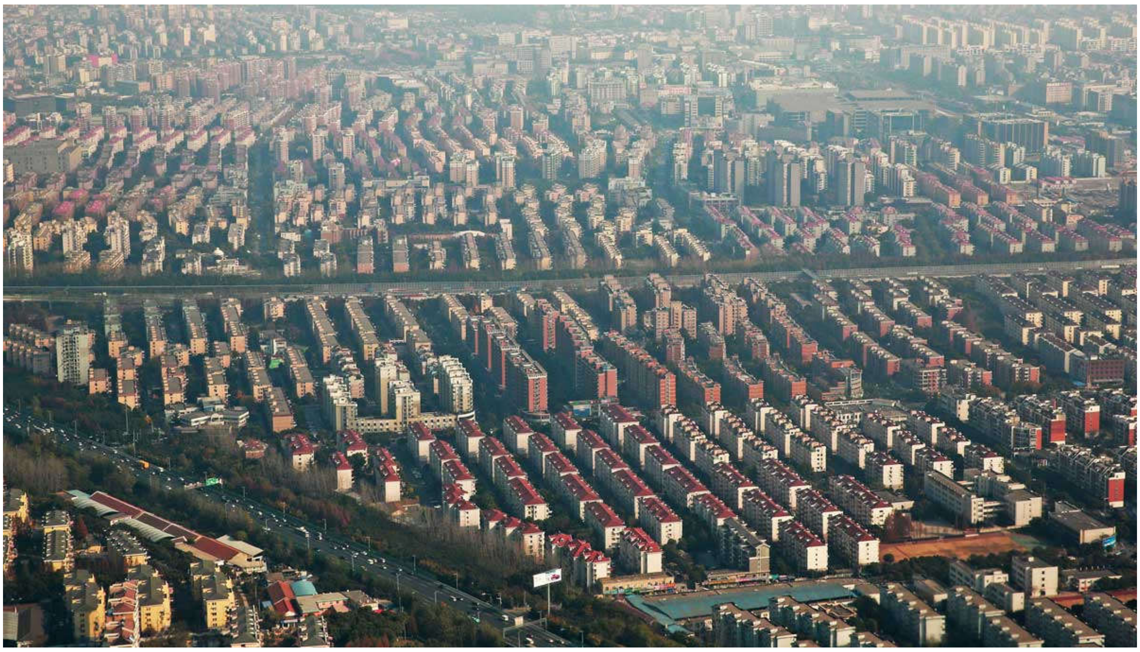
1. INTRODUCTION

1.1 High Density in Shanghai

High density housing in China is everywhere.

Since the mid 1990's unprecedented construction efforts took place to supply housing demands for a mass flux of population from rural areas to first tier cities. Huge apartment blocks and anonymous high-rise building bulldozing traditional housing communities are the characteristic features of today's urban and suburban landscapes in China.

The main problem now is how housing can absorb unavoidable outcomes of social, economic, material and human flows within Chinese cities. Shanghai is one of the epicenters of a growing economy and a laboratory for urban transformation. Shanghai has many rich but also diverse housing typologies, whose housing story is high population density and limited space and its several historic and cultural particularities. Shanghai has a long history of multistory housing, in the 1930's pioneered high-rise construction in Asia, the famous Lilong (literally system of alleys), the most common typology, can be considered precursors of mass housing in China.

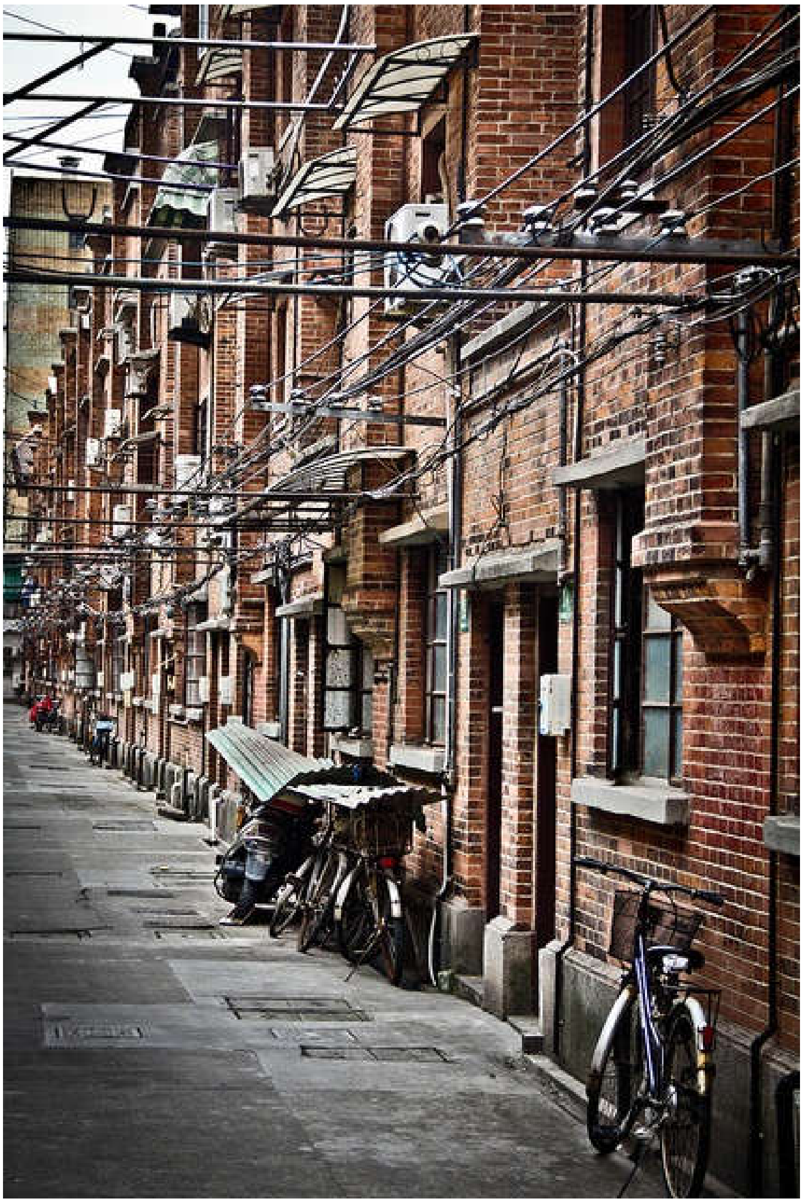


PICTURE 1.1 HIGH DENSITY IN SHANGHAI

1.2 Traditional building in Beijing

1.2.1 Lilong in Shanghai

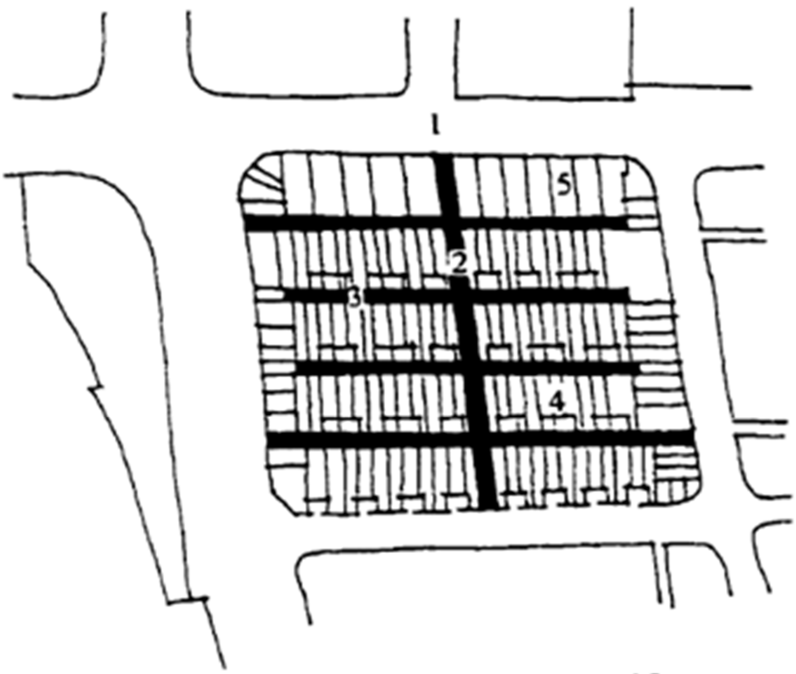
"If you enter a longtang, you will find urinals, snack stalls, flies flying in hordes, children fighting in groups, fierce turbulences and sharp curses. What a disorderly small world!" This was what in 1933 Lu Xun wrote in his essay, "Children in Shanghai" to depict a longtang of the lowest class.



PICTURE 1.2 LILONG IN SHANGHAI

Lilong is the Shanghai term for Longtang "lane houses" a group of houses that reflect the compositional layout of the Londoner's lane houses in the half of the nineteenth century seeing through the prism of the Chinese traditional housing.
"Li" means neighborhoods, "Long" means lanes. These two words are combined to describe an urban housing form which has characterized the city of Shanghai for 150 years. Being an integral part of the city growth from 1840 to 1949, Lilong settlements represented the majority of housing stock in the city center until the end of 20th century.

The Lilong settlement, as a low-rise, ground-related housing pattern, has many advantageous features: an hierarchical spatial organization network, the separation of public and private zones, a high degree of safety control, a strong sense of neighborly interaction and social cohesiveness, and so on.



Site plan of a Lilong Settlements
Source: *Sheng, Hua, Shanghai Lilong Housing, 1987*

PICTURE 1.3 LILONG'S LAYOUT

The whole settlement has a couple of main lanes, used as the major circulation passages, which are accessible from the commercial streets. The side laws, leading to each housing units, connect to the main lanes. The clear, rational structure of a Lilong settlement gives a high degree of security and quietness to its internal living environment, contrary to its noisy urban surrounding dominated by commercial developments. The front housing units along the perimeter of a Lilong settlement are generally converted to shops as well as some housing units inside the settlement, have also integrated small-scaled, home-based businesses to provide the daily amenities of the entire community.

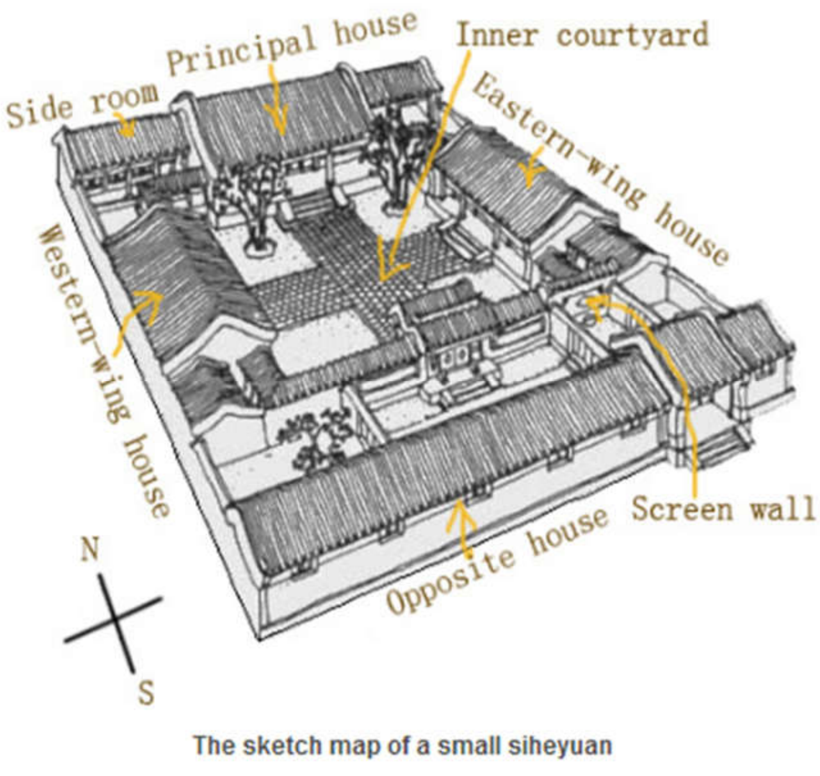
1.2.2 Siheyuan in Beijing

A Siheyuan is a historical type of residence that was commonly found throughout China, most famously in Beijing. Throughout Chinese history, the Siheyuan composition was the basic pattern used for residences, palaces, temples, family businesses, and government offices.

PICUTRE 1.4 SIHEYUAN IN BEIJING

"Si" means "Four", which here refers to the four sides: east, west, north and south. "He" refers to the surrounding, meaning the four sides circle into a square. Due to its special layout, Siheyuan is compared to a box with a garden in the center. There is only one gate leading to a hutong, so when the gate is closed, the courtyard loses touch with the outside world. The purposes of Siheyuan's design is to make family members fully enjoy tranquility and share the happiness of a peaceful family union.

Siheyuan means the term "quadrangel", and takes the courtyard as its nucleus, which is surrounded by four houses – a principal house (facing to south mostly), an opposite house, an eastern-wing house and a western0wing house. The construction of Siheyuan explains characteristic features of Chinese people and the strict hierarchical system of ancient times, and emphasize Fengshui (Chinese traditional theory of geomancy). The whole structure of Siheyuan is symmetrical and enclosed from four sides with privacy and confidentiality, keeping one gate towards outside which is highly suitable for a family.



PICTURE 1.5 SIHEYUAN'S LAYOUT

1.3 Vertical Community

Vertical communities are the products of global urbanization and economic development.

From a city's perspective, the vertical community should be rich in view. To preserve the original urban appearance of a city, the building should be given serious consideration. When determining the height of the vertical building, considerations shall be made to its relationships to the surrounding, to the city of Shanghai as a whole.

From a regional perspective, the vertical community should be able to improve functional programs of the whole area and enhance its potential for better regional development.

From a construction perspective, the vertical community simply must not make the building taller for the sake of it, but rater have a unique characteristic to its architecture and a distinct relationship to the city and surroundings.

PICUTRE 1.6 VERTICAL COMMUNITY IN SHANGHAI

1.4 Minimum Community

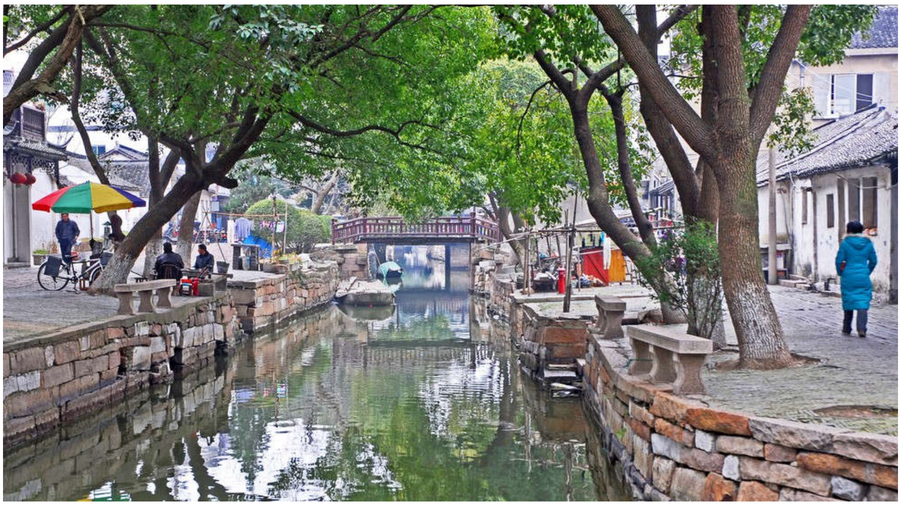
Minimal inhabitable space is typical suitable for Shanghai. The integration of minimal inhabitation needs coupled with specific design and prefabrication methodologies. The main focus is from "form" to "assembly" concentrating on "interior space optimization" and "building adaptability".

1.5 Green Community

Environmental protection and energy conservation are the general trends and therefore, the project's green concept shall be solidified.

The green building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on the climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.

The green building brings multiple benefits. The benefits of green buildings can be grouped within three aspects: environmental, economic and social. They provide some of the most effective means to achieving a range of global goals, such as addressing climate change, creating sustainable and thriving communities, and driving economic growth.



PICTURE 1.7 GREEN COMMUNITY IN SHANGHAI

2. Urban Design

2.1 Site Analysis

2.1.1 Site Location

PICUTRE 2.1 SITE LOCATION

The site is located at XIAONANMEN, SHANGHAI, CHINA.

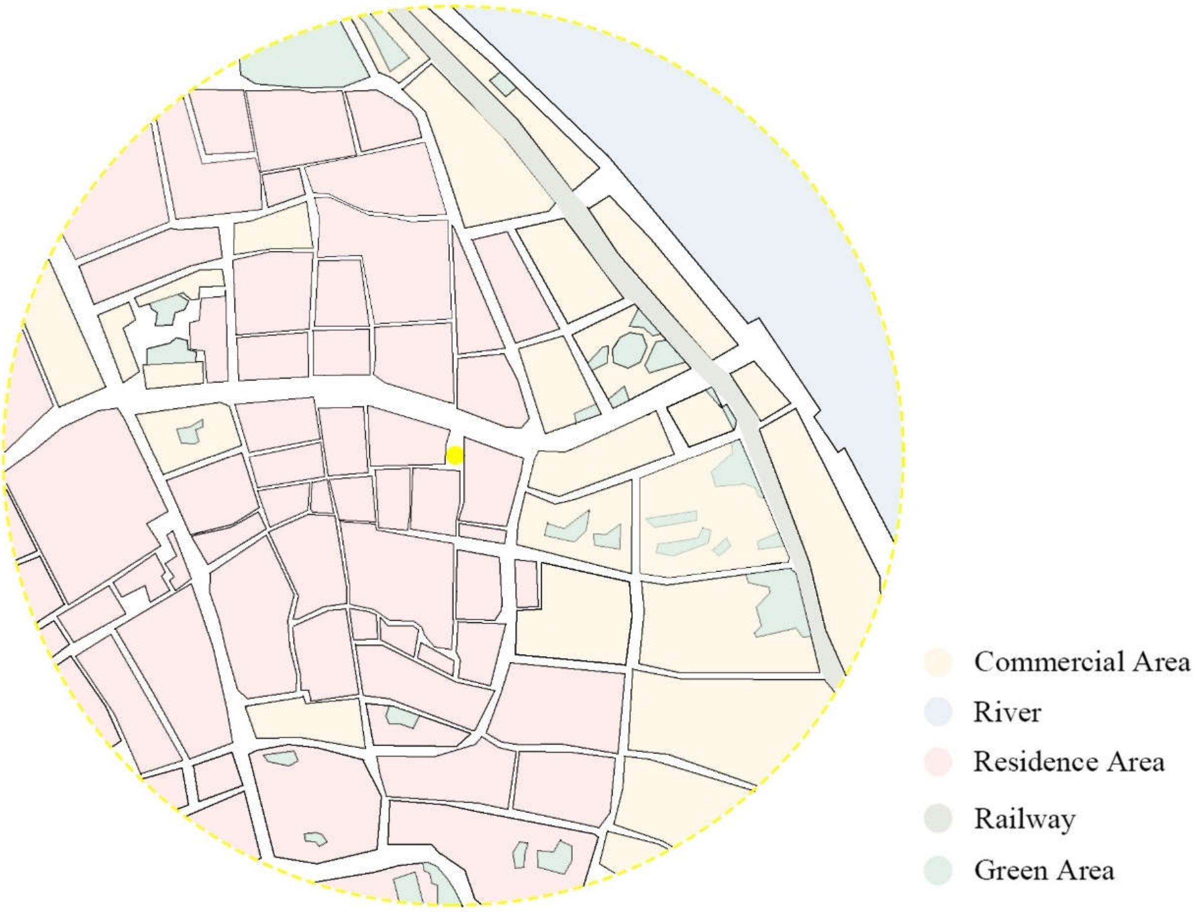
Shanghai is one of the four municipalities under the direct administration of the central government of China, the largest city in China by population, and the second most populous city proper in the world. It is a global financial center and transport hub.

Xiaonanmen is the typical old shanghai that goes largely overlooked and is shrinking by the day as the cranes and bulldozers move in. The residents in this area are normally living by family. This area is filled with Lilong which is one the traditional community in China.

2.1.1 Mobility Analysis

PICTURE 2.2 MOBILITY ANALYSIS MAP

2.1.2 Function Analysis



PICTURE 2.3 FUNCTION MAP – 1KM

As can be seen from the above analysis map, most of the area where the projected is located is residential area, and the distribution is relatively dense. At the same time, it also can be clearly observed that there are many commercial areas. In addition, the street side of the residential area is basically a shop. The overall green area of the whole area is small, and greening is less in large-scale residentiao areas.

PICTURE 2.4 FUNCTION MAP _ 200M

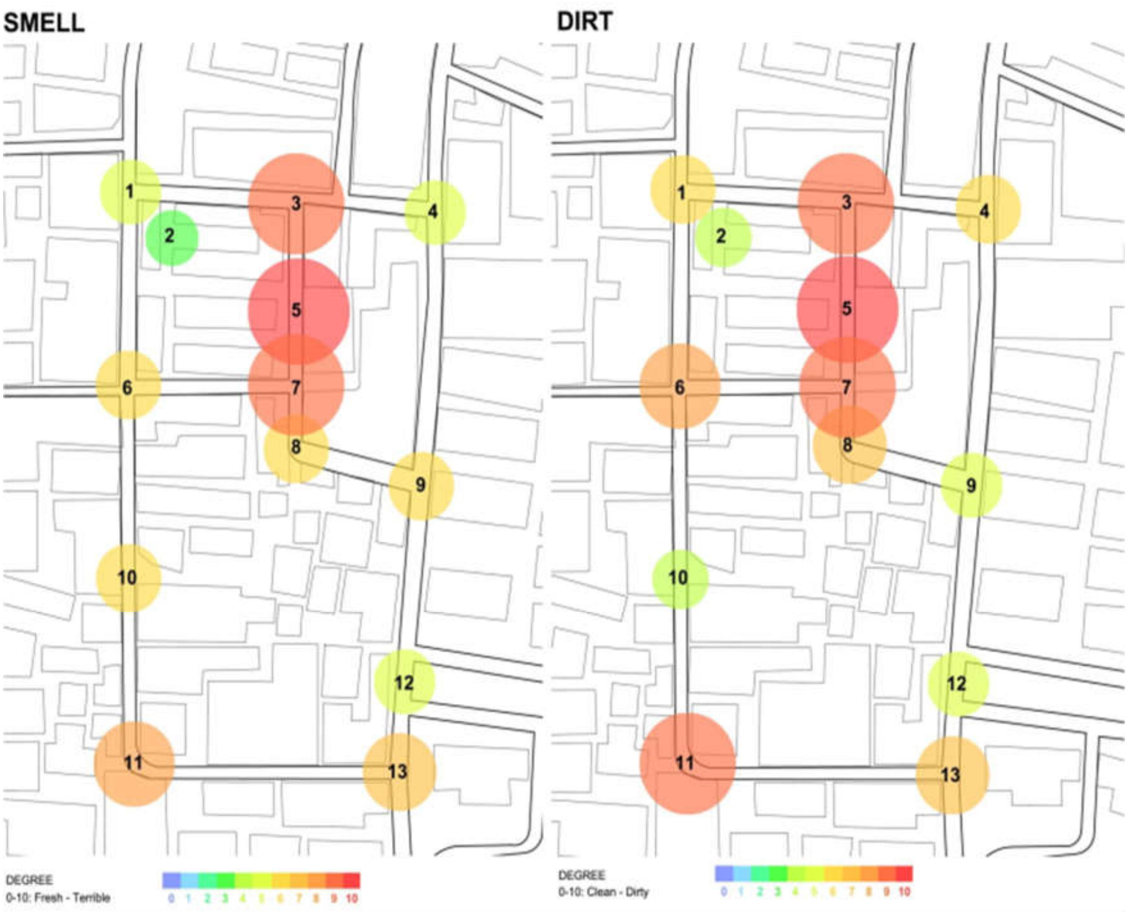
Zooming in the function analysis map to the radius of 200 meters makes it clearer that the surrounding areas are residential areas. The commercial area is on the right side of the residential area. But on the street side of the residential area, there are many shops along the street, which are more evenly distributed. The overall service in the region is relatively complete, which is able to meet the basic requirements of medical, education, catering and shopping.

2.1.3 Degree Analysis

10 aspects were analyzed to show the degree of 13 areas in the site.

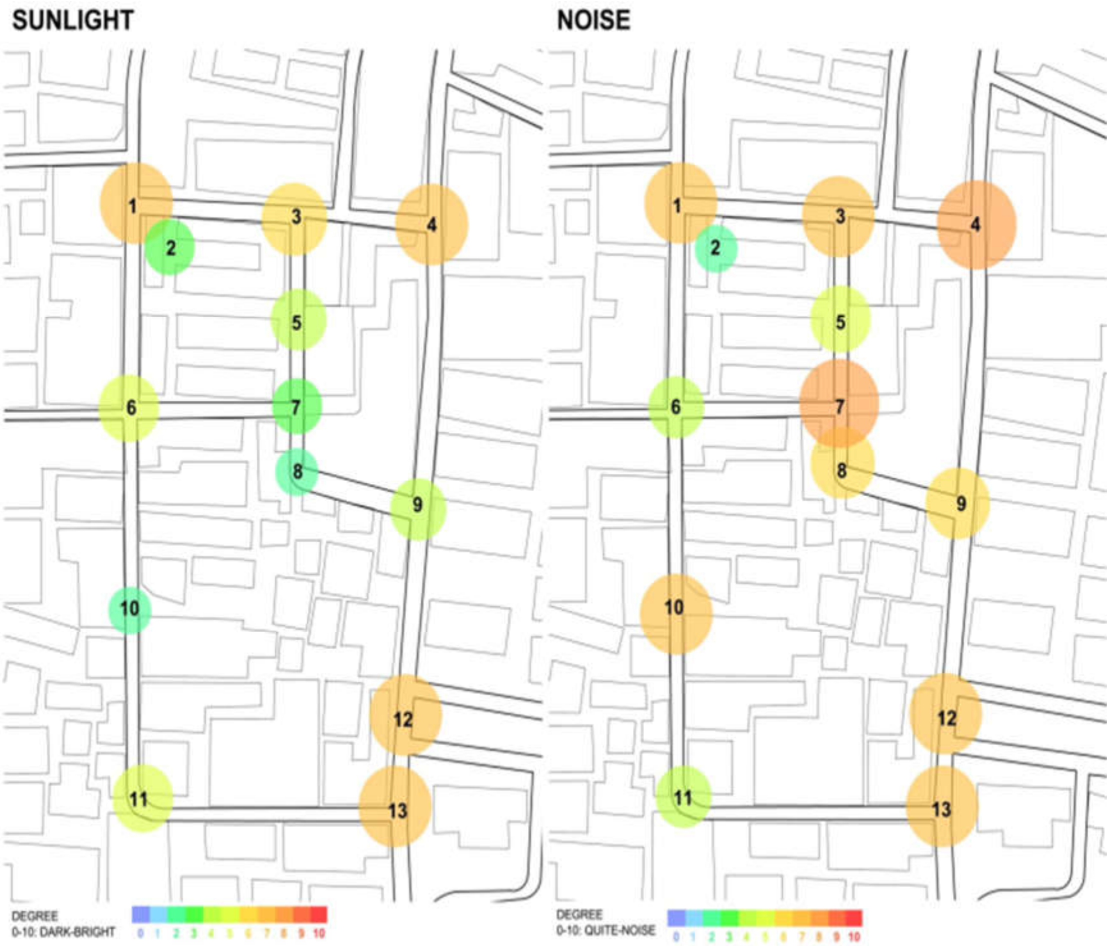
- Smell
- Dirt
- Sunlight
- Noise

- Green Space
- Drainage
- Number of People
- Number of Bikes
- Parking Spaces & Parking Access
- Temperature



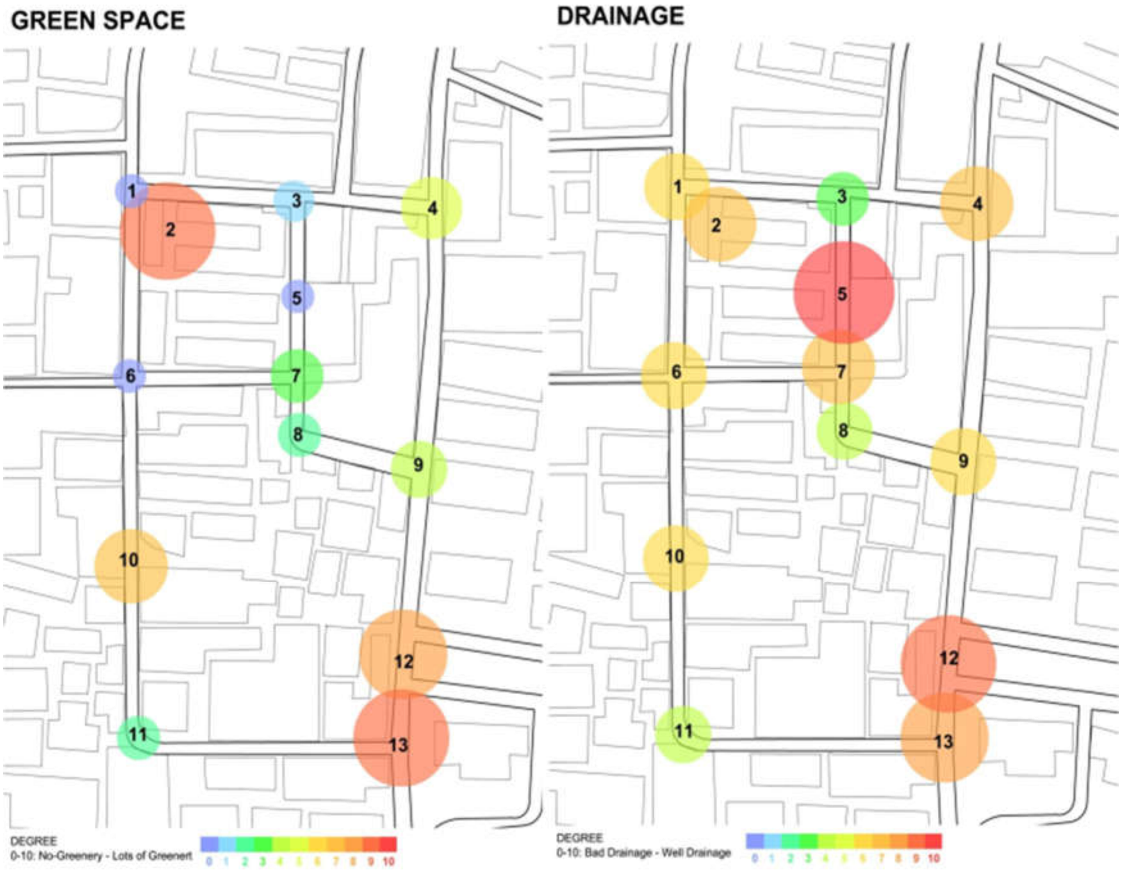
PICUTRE 2.5 SMELL & DIRT DEGREE MAPS

It can be clearly seen from the above picture that the sanitation environment in this area is not very good and urgently needs to be improved. The smell and the level of turbidity in this area are relatively high, especially in the main street, the sanitary environment is worse than other streets.



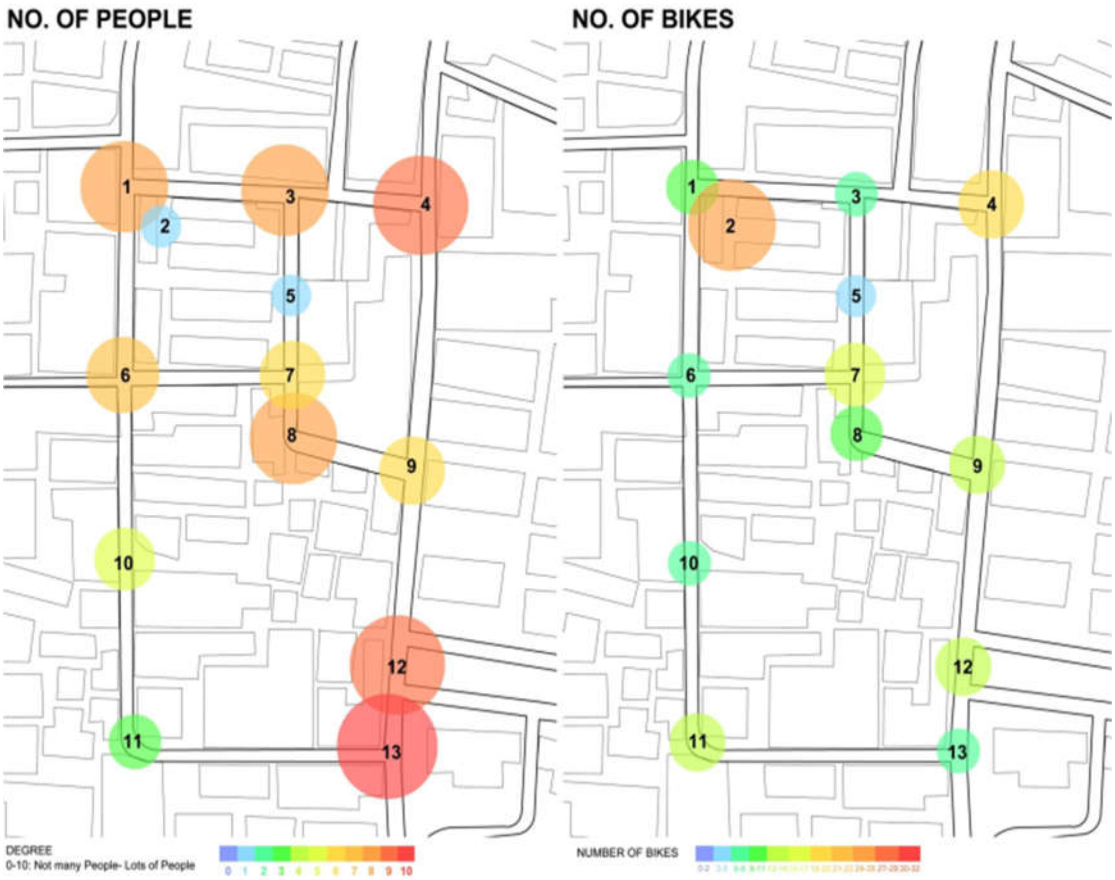
PICTURE 2.6 SUNLIGHT & NOISE DEGREE MAPS

It can be easily concluded from above analysis degree maps that the surrounding of the site in this area are densely populated, so that the daylight conditions are relatively poor. While on the main road, because the distance between the streets is wider than Lilong, the distance between the buildings is large, so the daylight conditions are obviously due to the central area.



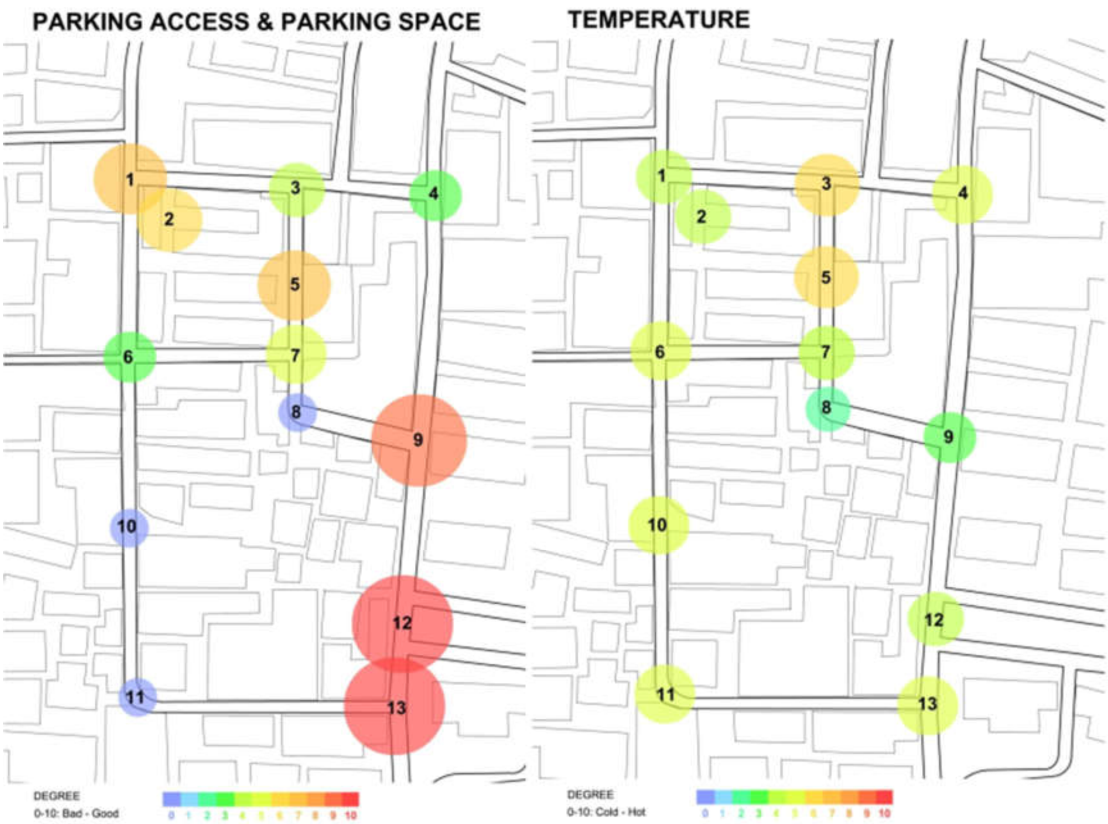
PICTURE 2.7 GREEN SPACE & DRAINAGE DEGREE MAPS

From the above analysis maps, it can be concluded that the green area is small around the project site, and the green area is relatively small in the entire residential area. This is mainly due to the layout of Lilong. But in the area closing to the main road, the green area is better than the project location. Therefore, greening is a very important consideration during the project design phase.



PICTURE 2.8 POPULATION & NUMBER OF BIKES DEGREE MAPS

The two maps shown above shows the number of bicycles in the area. It can be clearly seen that in the project area, the population is proportional to the number of bicycles. Due to the limited economic condition of the residents living in this area and the narrow streets, the main mode of transportation for the population in the area is public transportation or bicycles. Therefore, in the project design stage, the parking lots have not been considered, but the bicycle parking area have been considered.



PICTURE 2.9 PARKING ACCESS & PARKING SPACE & TEMPERATURE DEGREE MAPS

The picture on the left can clearly show that there are fewer parking lots around the project location, mainly because the streets are too narrow. On the main street, the parking area is much larger than Lilong area

The picture on the right can clearly show that the temperature is proportional to the population, the number of bicycle and vehicle distribution. The temperature in the main road is higher than the temperature in the Lilong area..

2.1.4 Interview

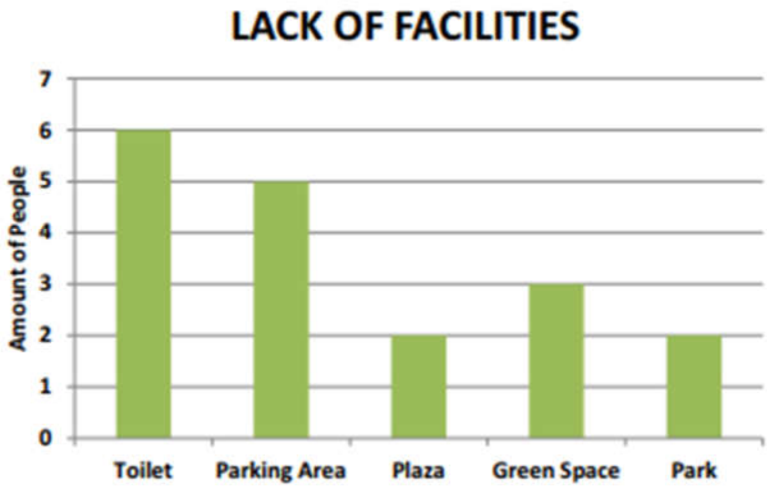


FIGURE 2.1 LAKE OF FACILITES

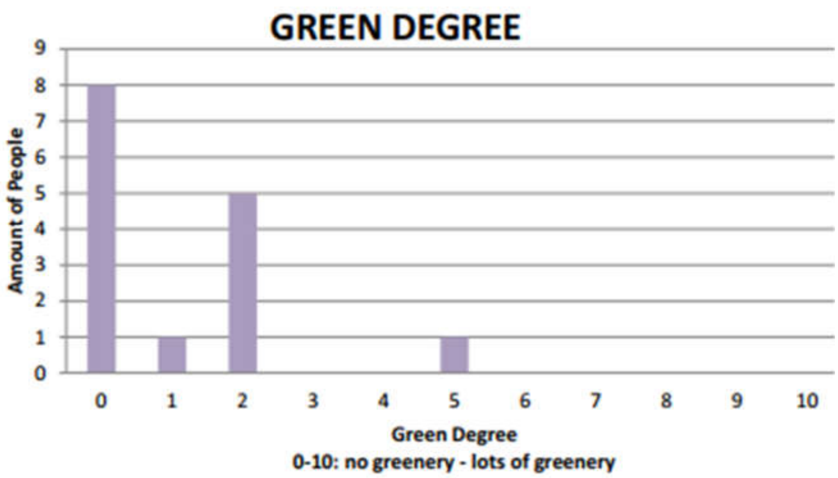


FIGURE 2.2 GREEN DEGREE

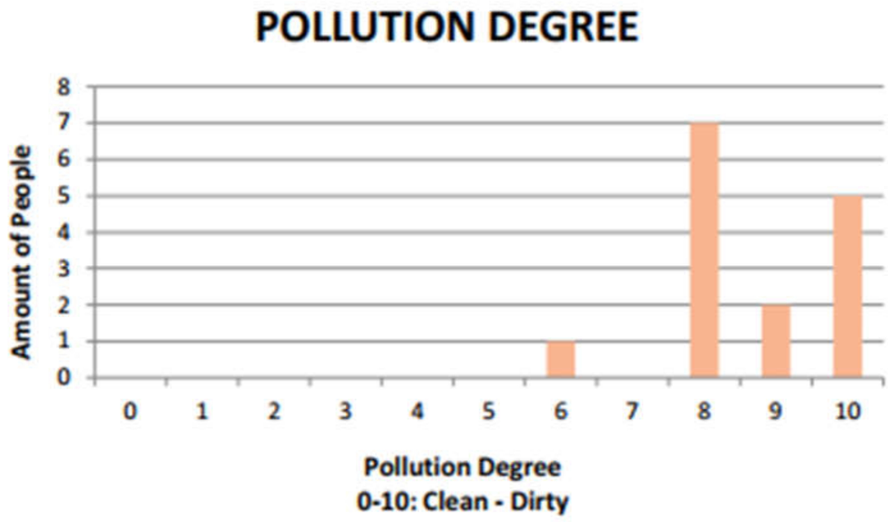


FIGURE 2.3 POLLUTION DEGREE

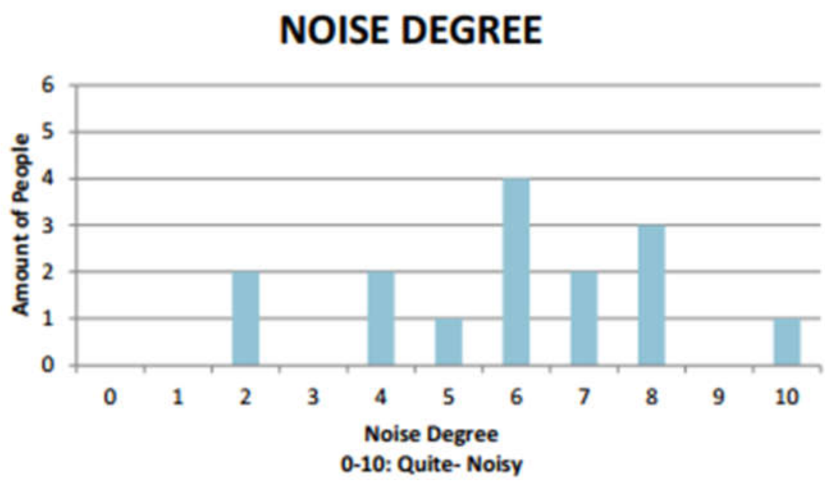


FIGURE 2.4 NOISE DEGREE

From the four charts shown above, it is easy to get the conclusion that the green area, leisure areas and bicycle parking areas in the area need to be redeveloped. At the same time, the sanitation environment in the area needs to be improved and the sound insulation of the building needs to be improved during the building design.

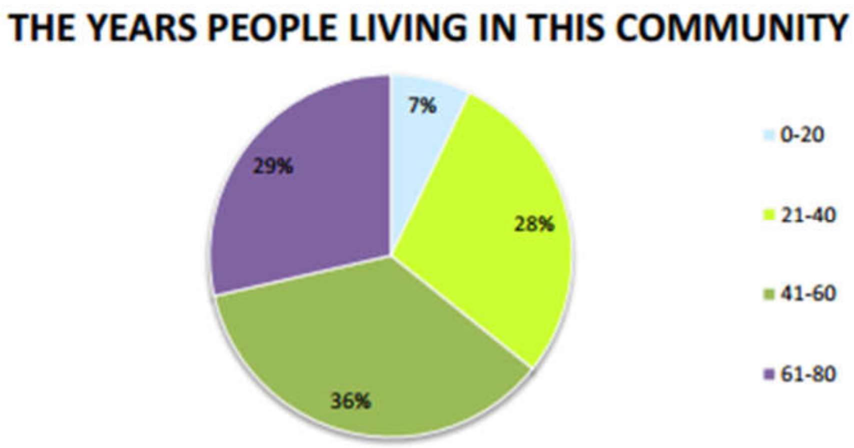


FIGURE 2.5 THE YEARS PEOPLE LIVING IN HERE

Through the investigation, it is easy to conclude that most of the people living in Lilong are the older. Among them, 93% people have lived here for more than 20 years, and some people have spent their lives here, which also shows that residents here are very familiar with each other and need a large space for common area.

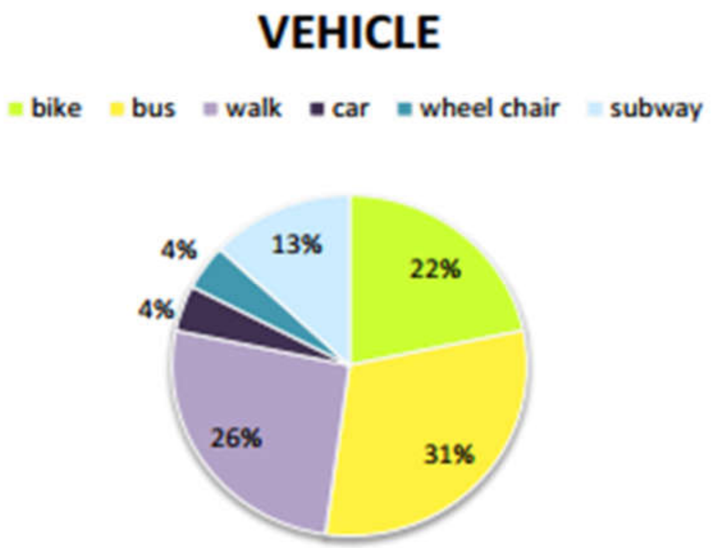


FIGURE 2.6 VEHICLE

This figure clearly shows that private cars are relatively small in the area, and most travel depends on public transportation and bicycles.

2.2 Climate Analysis

2.2.1 Temperature

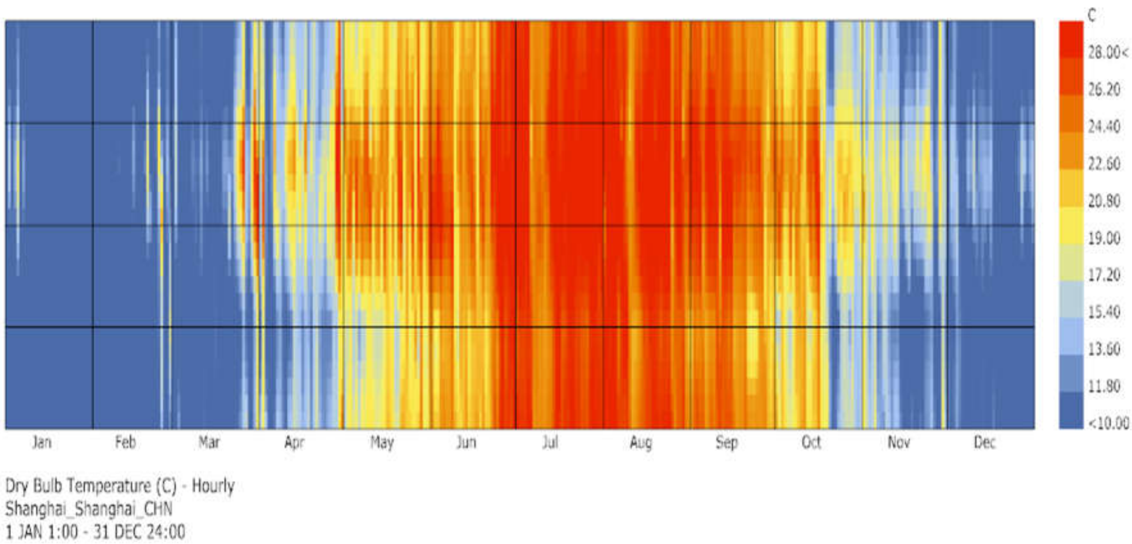


FIGURE 2.7 TEMPERATURE ANALYSIS

The weather condition in Shanghai is quite severe, with hot summers and cold winters. The hottest month in summer is August and most of the temperatures from July to September exceed 26 degrees. The winter in Shanghai is also quite long. From November to the next three months, the temperature is always below 10 degrees. So this is why in the energy consumption analysis, the energy required for heating is the highest which indicates the building in Shanghai is heating dominated, but at the same time, the energy consumption for cooling is not low.

2.2.2 Humidity

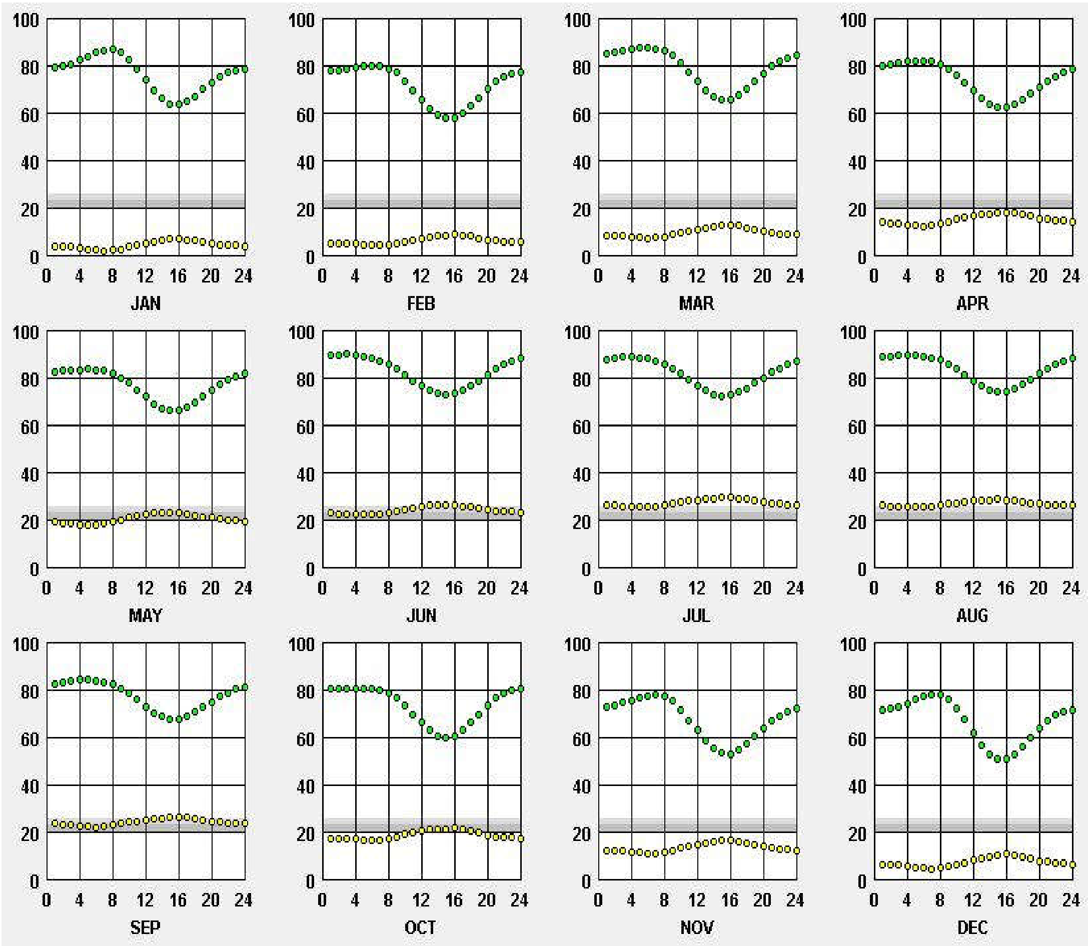


FIGURE 2.8 HUMIDITY ANALYSIS

Shanghai is a city with relatively high humidity, especially the location of the project is adjacent to the Huangpu River. During the summer, the temperature is relatively high, but the relative humidity is also maintained at around 80%. During the clod winter, when the temperature tends to zero degrees, the relative humidity is also maintained at around 80%, so the humidity in Shanghai is relatively high throughout the year.

2.2.3 Wind

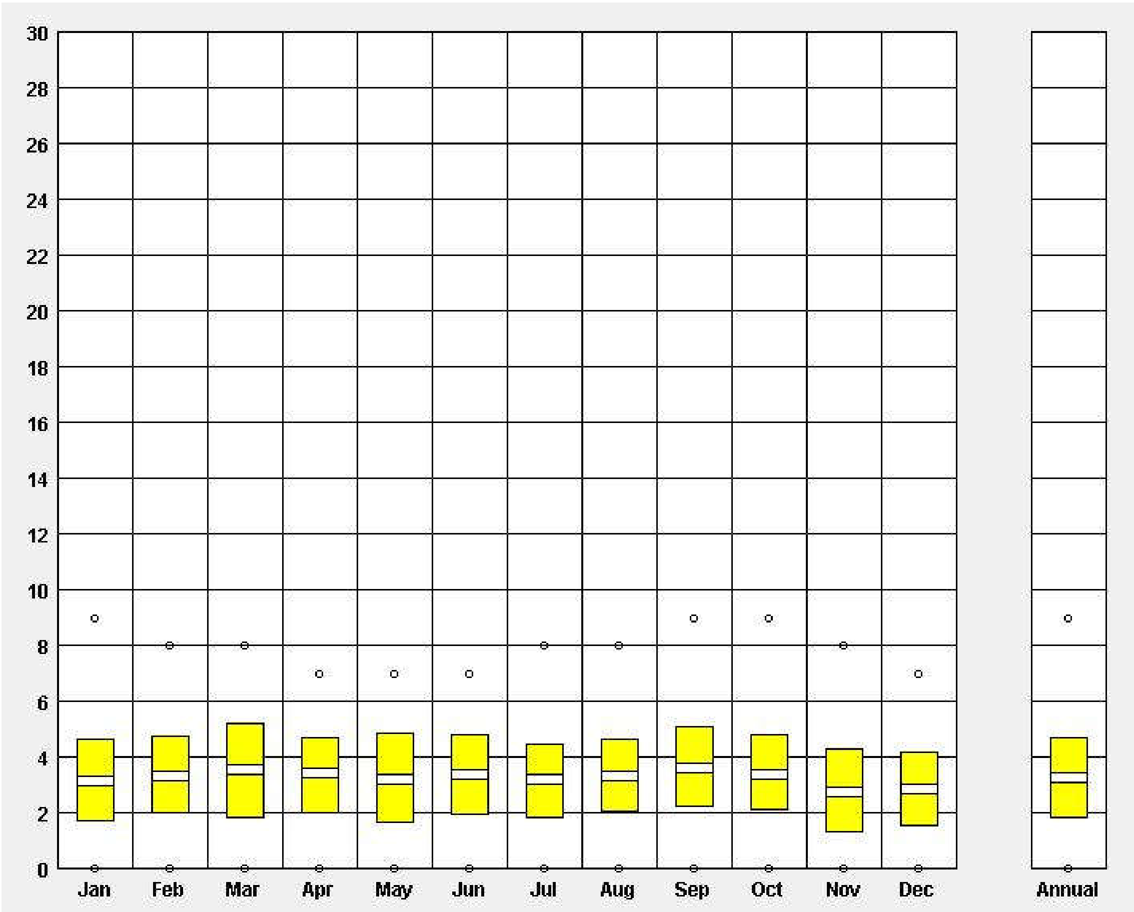
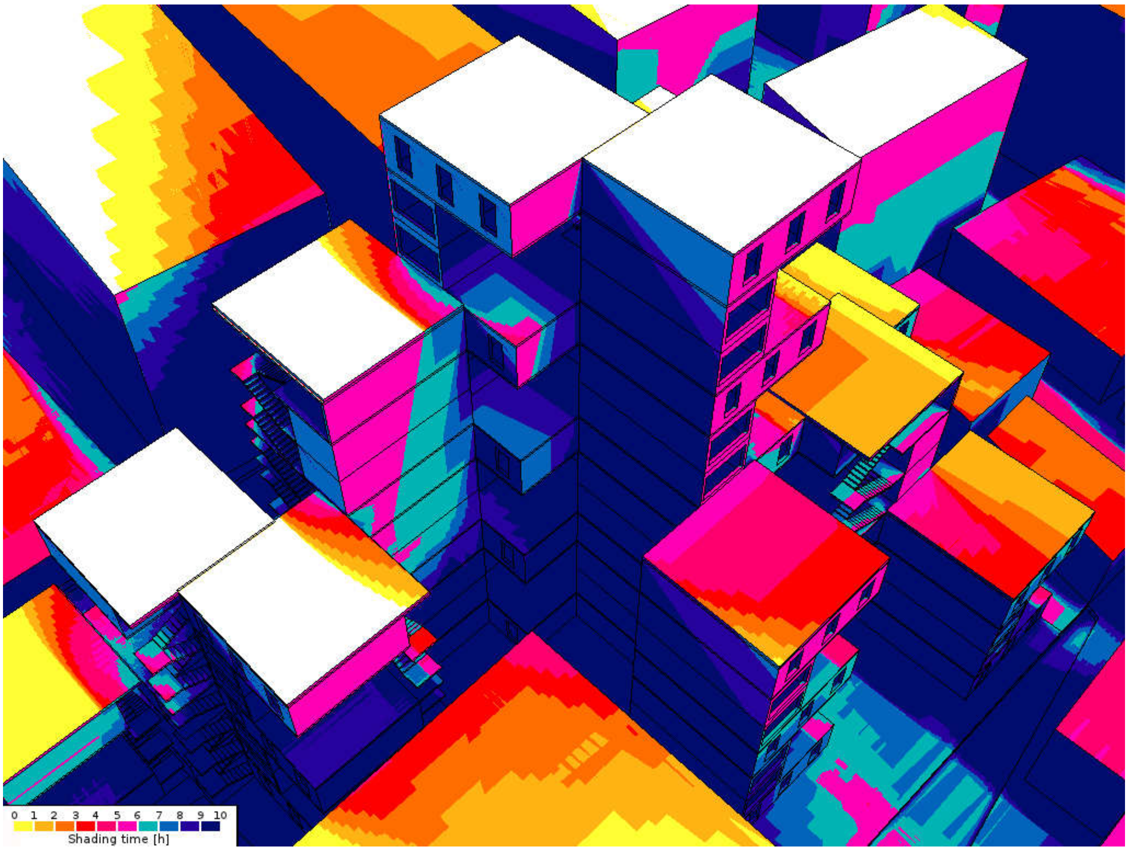


FIGURE 2.9 WIND SPEED ANALYSIS

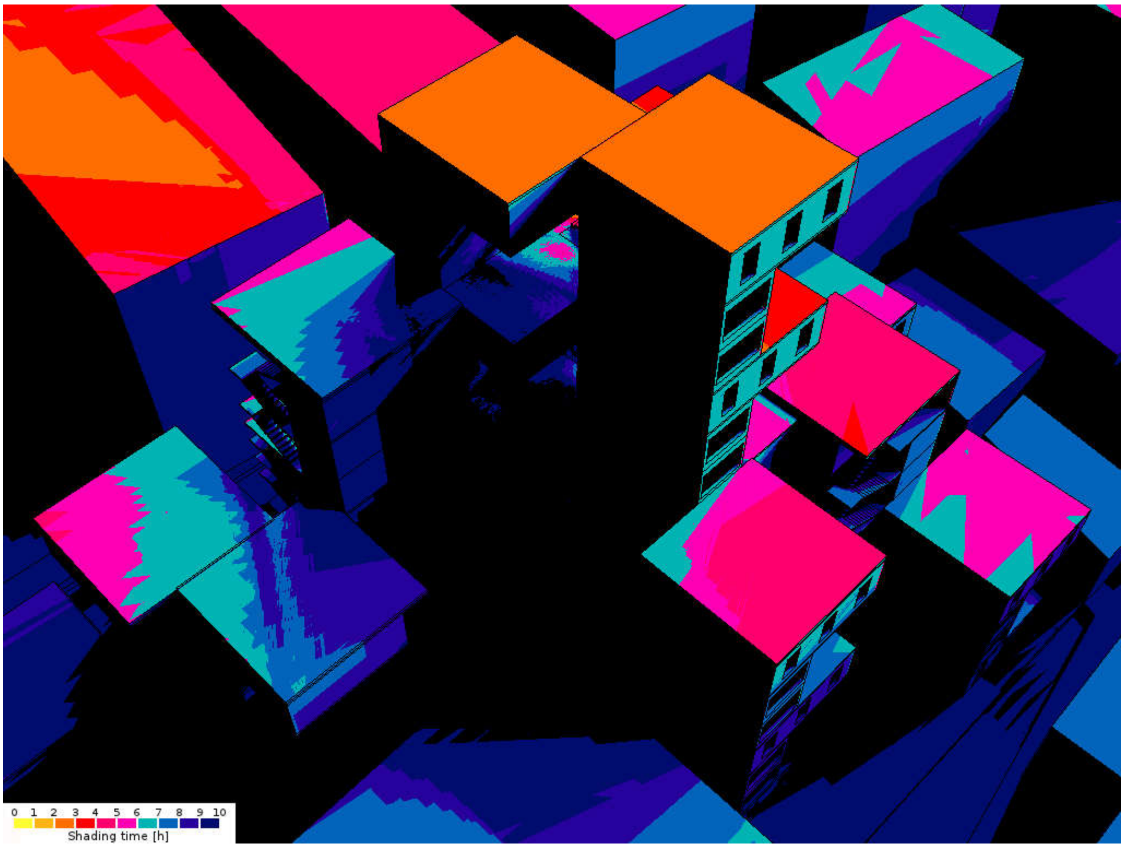
The wind speed in Shanghai is not high, and the average wind speed is about 8.5m/s. Since the surrounding buildings are all high-rise, the wind speed of the site will be relatively small. Therefore, some designs related to wind energy are not taken into accound.

2.2.4 Shadow Analysis



PICTURE 2.10 SHADOW ANALYSIS IN SUMMER

The date selected for the shadow analysis is the summer solstice day, which is the longest day of sunshine during the whole year. As can be seen from the figure, the roof area is exposed to sunlight for a long time, so the roof area can be considered to put PV panel to make the advantage of solar energy. However, in the building itself, especially in the ground floor area, the sunshine time is almost zero, this is also the reason why in the subsequent design, the adjustment of the size and quantity of the window has no major influence on the daylight visualization.



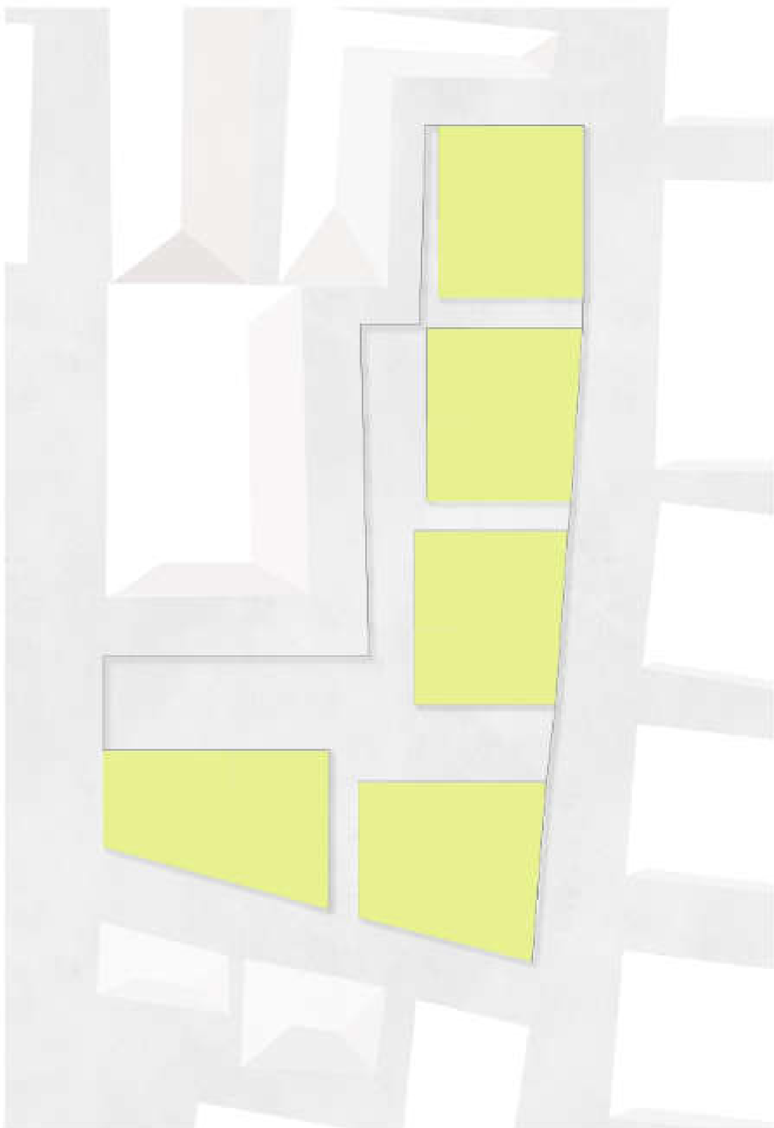
PICTURE 2.11 SHADOW ANALYSIS IN WINTER

The second shadow analysis selects the date of the winter solstice, which is the shortest ay of the year. From the figure, it can be clearly seen that in the winter, the roof still has a certain amount of daylighting, so it is possible to consider installation of PV panel on the roof. However, in the bottom area of the building, the daylight condition is terrible because the daylight hour is almost all zero. Again, it is shows that the size and number of windows will not have a significant impact on daylight visualization.

2.3 Urban Design Phase

2.3.1 Volumes

Through Preliminary calculations, approximately 5 “separate” buildings can be accommodated in the selected area. In keeping with the direction of the surrounding buildings and streets, the shape of the volumes is shown as follows.



PICTURE 2.12 VOLUMES

2.3.2 Function

As a community, in addition to the most basic residential, there should be also other basic facilities.

- Bicycle Parking Area: Because the street width of the area is limited, the vehicle cannot enter directly, so no parking lot is set. However, in order to meet the demand for entry and exit, a bicycle parking area was set up on one of the two building floors.

- Commercial Area: In order to meet the most basic shopping needs, a shopping area is set on the street-facing side which is typical in Shanghai. Mainly set to supermarket.

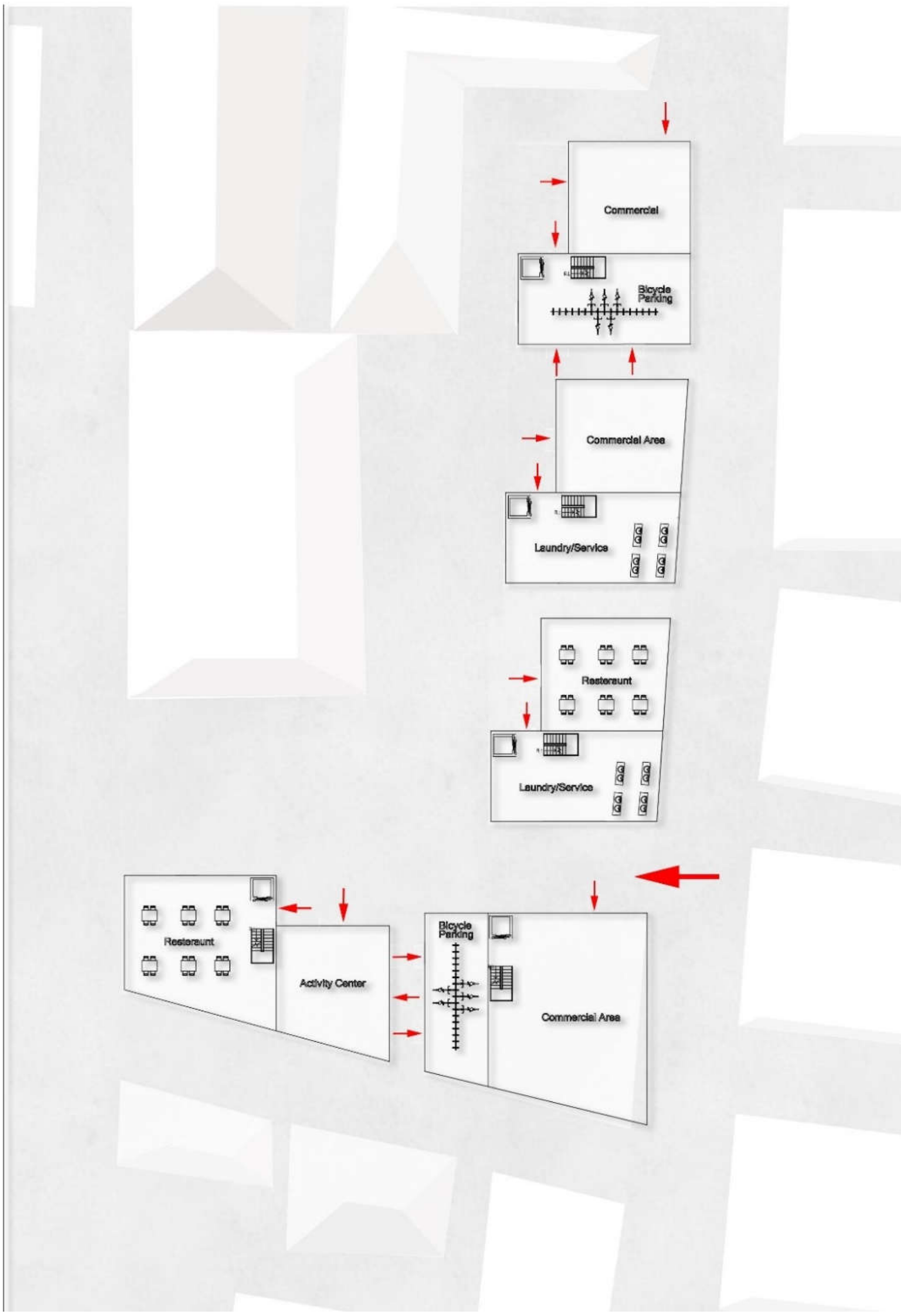
- Laundry room and service area: Due to the development of modern planning and the gradual improvement of community service, the laundry room and service area will be set to improve the convenience of life.

- Restaurant: Because the residents are mostly elderly or family, the number and size of the restaurant is not so big.

PICTURE 2.12 FUNCTION

2.3.3 Accessibility

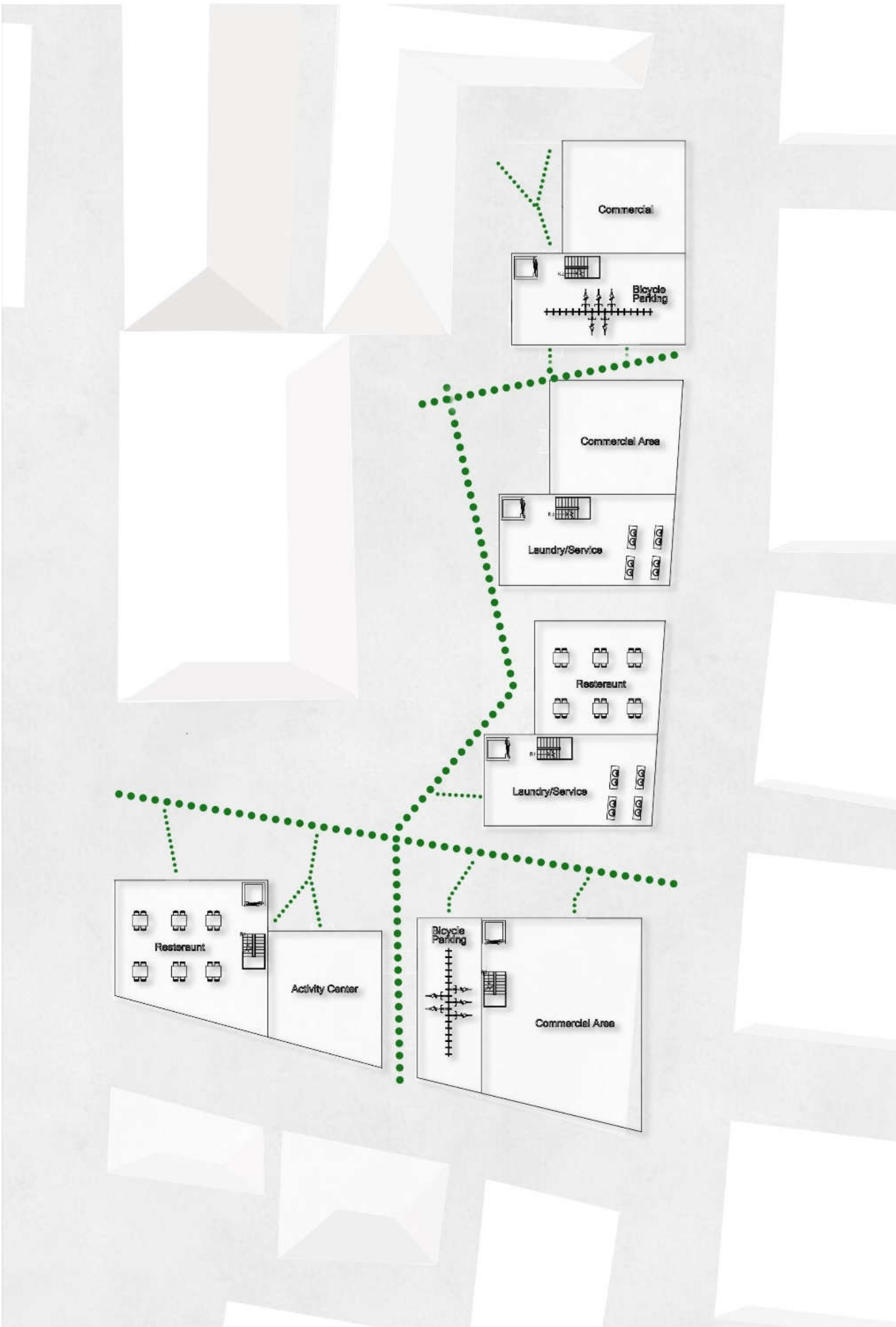
On the right side of the selected area is the main street, while on the left and above side are mainly small roads. Therefore, how to connect these lanes to the main road become the setting point of this design phase.



PICUTRE 2.13 ACCESSBILITY

2.3.4 Connection

Since there are five "independent" buildings on the plane, where is the main entrances set and how many entrances are designed to maximize the connectivity of each building to a design focus.



PICTURE 2.14 CONNECTION

2.3.5 Green Area

On the left side of the complex, which is the more private side, create a green area for the residents to enjoy the leisure.

PICTURE 2.15 GREEN AREA

2.3.6 Master Plan

Through all the above considerations and design, the final master plan is shown below.

PICTURE 2.16 MASTER PLAN

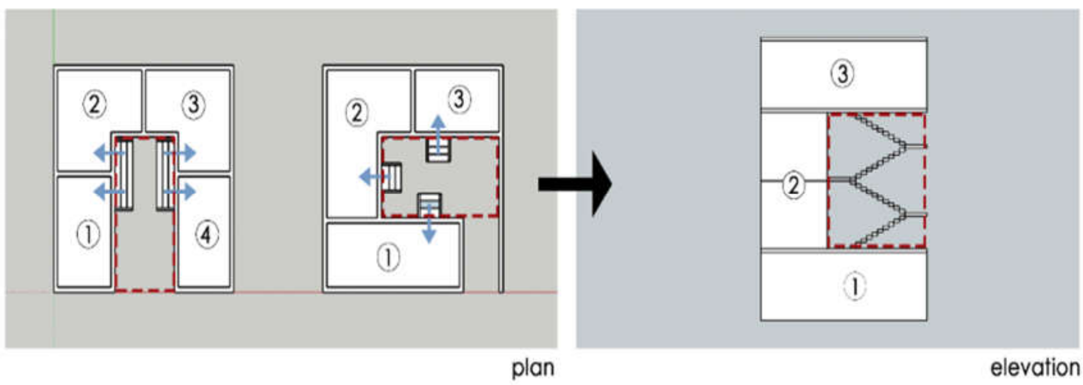
3. Architecture Design

3.1 Concept Design

With the development of economy and urbanization in China, more and more people are gathering in cities. Many skyscrapers have risen, and the courtyards and the Lanes have gradually disappeared. How to preserve these traditional buildings in the city while meeting people's living needs has become the starting point for the design of this project.

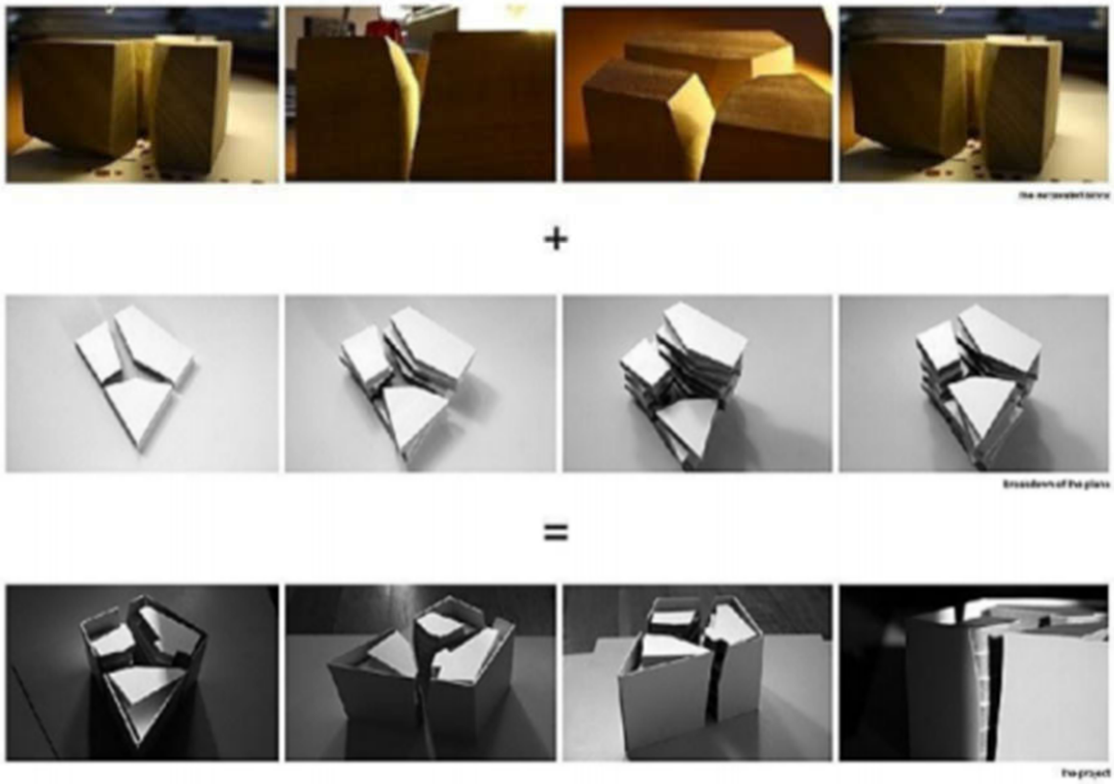
As it mentioned before, Lilong is characterized by four to five floors, but each household has a small living area and a small common area. The stairs are very narrow and people usually choose to enjoy the cold in the narrow streets. Most of the residents are elderly people who are alone or living alone, so this project has designed three different types of room suitable for different living types. Type A is single room. Type B is double room while Type C is designed for family. Each room has it own private bathroom and there is a sharing kitchen on each floor.

Siheyuan is characterized by the courtyard surrounding the center, but only one floor. Therefore, this project attempts combine Lilong and Siheyuan.



PICTURE 3.1 REDESIGN OF SIHEYUAN

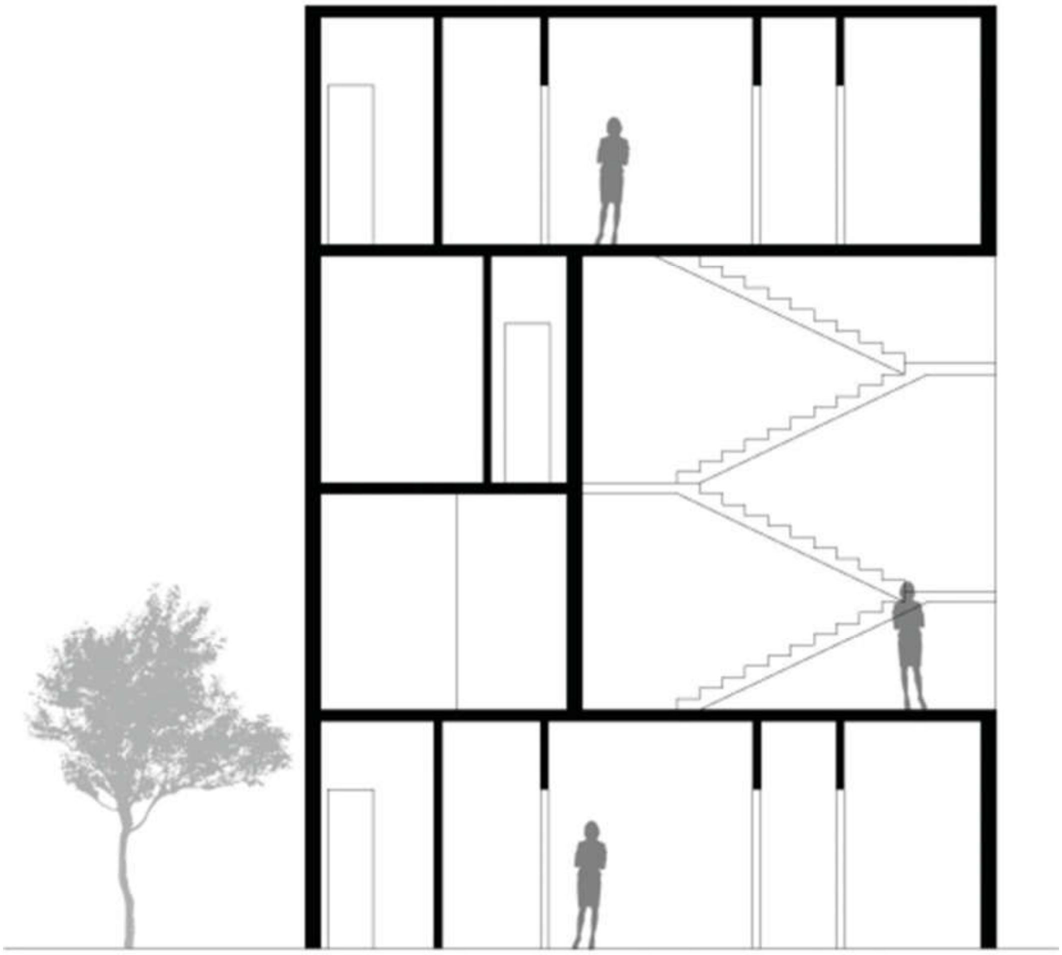
Firstly, the common area is created by playing the volumes. The planar features of the Siheyuan are preserved, and the middle courtyard is changed to a vertical connection surrounded by a corridor, so that everyone in each household an enjoy the public area and can move around each other.



PICTURE 3.2 PLAY VOLUMES AND COMBINATION

At the same time, different planes are superimposed to create some voids. A steel mesh is placed on the side facing the street, and plants are planted to be attached to the wire mesh.

One the plane, consider connecting the two main streets and extending the line language of the surrounding buildings to design a green garden and a sidewalk. Effective combination of private areas of the building and public areas outside the building.



PICTURE 3.3 BASIC UNIT-REDESIGN THE TRADITIONAL UNITS

3.2 Design Phase

3.2.1 Keywords

3.2.1.1 Minimum

Firstly, the minimum refers to the small living area. Since the project site is located at the central area of Shanghai and location value is truly high, the living area is limiter.

At the same time, the living population is mainly lonely elderly or family with only three people. Therefore, the requirements for living area are not high. Due to reasons mentioned above, three different types for room has been designed which are Type C for single (about $25m^2$), Type B for double (about $45m^2$) and Type A for family (about $65m^2$).

Secondly, the minimum also refers to the lowest energy consumption during the design process through different technical design and analysis.

3.2.1.2 Vertical

Due to the rising demand for living, traditional buildings are no longer able to meet the requirement of huge residences. Therefore, the high-rise buildings have gradually replaced traditional building. In order to protect those traditional buildings and ensure that traditional buildings do not completely disappear, this project combines traditional buildings with high-rise buildings. Retain the basic concept of traditional architecture, but increase the number of floors to increase the number of rooms to meet the residence demands.

3.2.1.3 Community

Because the essence of traditional architecture is that neighbors can share common space. The community culture is particularly important in traditional architecture. Therefore, the design phase of this project is not just one building, but several buildings composing to a community that allows people to share all the common area like the originally traditional building.

3.2.1 Function

As a community, in addition to the most basic residential requirements, there should be also other basic facilities.

- Bicycle Parking Area: Because the street width of the area is limited, the vehicle cannot enter directly, so no parking lot is set. However, in order to meet the demand for entry and exit, a bicycle parking area was set up on one of the two building floors.
- Commercial Area: In order to meet the most basic shopping needs, a shopping area is set on the street-facing side which is typical in Shanghai. Mainly set to supermarket.
- Laundry room and service area: Due to the development of modern planning and the gradual improvement of community service, the laundry room and service area will be set to improve the convenience of life.
- Restaurant: Because the residents are mostly elderly or family, the number and size of the restaurant is not so big.

3.2.2 Accessibility

On the right side of the selected area is the main street, while on the left and above side are mainly small roads. Therefore, how to connect these lanes to the main road become the setting point of this design phase.

Additionally, each building has the main entrance on the ground floor and each building has separate staircase and elevator. The elevator is opposite the stairs. When it comes out of the stairwell, there is a corridor. And the stairwell is wrapped in the middle. There are 4 rooms on each floor and each room faces to the corridor. Besides, each floor has a corridor leading to a balcony or public area. Every two buildings are connected by a balcony, which allows different buildings on the same floor to move around each other, which is also the embodiment of community culture.

3.2.3 Sustainability

In terms of architectural aspect, in order to achieve lower energy consumption, different building shape, surface to volume ratio and window to wall ratio has been analyzed. Eventually, the optimal results have been selected.

At the same time, in order to meet the requirements of sustainable building, the roof has been set as a green roof and PV panels has been placed to collect solar energy provided for the chiller and heater.

Additionally, in order to improve the air quality and increase the green area, nets have been placed around the balcony facing to the main street. Moreover, the plants are attached to the net. These are all due to the considerations from architectural aspect and there will be more sustainable design solution in terms of building services.

3.3 Architecture Plan

The entire community consists of five “independent” buildings. In the south parth, each of which is interconnected by two buildings. And three buildings in the east are connected to each other to achieve the purpose of sharing public areas.

The buildings has maximum of seven floors and is successively reduced to four floors. Each building has the green roof and is equipped with the PV panels. The first floor of the entire area is a public area, such as commercial supermarkets, restaurants and public services. The rooms that start from the second floor are divided into three types, which are suitable for single, double and family living.

Each floor has balconies and comer areas. Moreover, each building has staircase and elevator as vertical connection.

The floor area of each floor is as follows.

Ground Floor:	1012.66 m^2
1^{st} Floor:	1302.36 m^2
2^{nd} Floor:	1307.92 m^2
3^{rd} Floor:	1377.06 m^2
4^{th} Floor:	1251.64 m^2
5^{th} Floor:	853.40 m^2
6^{th} Floor:	260.56 m^2
Green Roof:	1225.95 m^2
Gross Area:	8682.63 m^2

3.3.1 Ground Floor Plan

PICTURE 3.4 GROUND FLOOR PLAN

3.3.2 First Floor Plan

PICTURE 3.5 FIRST FLOOR PLAN

3.3.3 Second Floor Plan

PICTURE 3.6 SECOND FLOOR PLAN

3.3.4 Third Floor Plan

PICTURE 3.7 THIRD FLOOR PLAN

3.3.5 Fourth Floor Plan

PICTURE 3.8 FOURTH FLOOR PLAN

3.3.6 Fifth Floor Plan

PICTURE 3.9 FIFTH FLOOR PLAN

3.3.7 Sixth Floor Plan

PICTURE 3.10 SIXTH FLOOR PLAN

3.3.8 Roof Plan

PICTURE 3.11 ROOF PLAN

3.4 Architecture Section

PICTURE 3.12 SECTION 1-1

3.5 Architecture Elevation

PICTURE 3.13 EAST ELEVATION

3.6 Architecture Rendering

4. Technology Design

4.1 Weather Information

As it mentioned above, the climate in Shanghai is serious during the whole year. In summer, the cooling and dehumidification system are needed, while in winter, the heating and humidification system are necessary.

The highest average monthly temperature is 27 degree in July while the lowest average monthly temperature is 4 degree in January. The relative humidity is high during the whole year whose highest value is 82%.
Because of the surroundings, the whole area is shaded and that is why the shading device are not included. Whatsmore, PV panel on the site will be useless unless it is put on the roof top.

According to the calculations by PMV model, the comfort temperature in winter ranges from 20.3 to 24.3 degree and in summer the highest value is 26.7.
Due to the huge difference in temperature, it is impossible to have passive cooling or passive heating. The mechanical system will be considered to reach 100% thermal comfort.

Wind speed is constant during the whole year which is 3m/s. According to the calculation, the wind speed above 8.5 m/s should be considered to have wind protection for outdoor space. So all the facilities relating to wind is not included.

4.2 General Strategies

In building sector, the best energy saving potential can be realized by proper energy efficient building design. The first step is to have preliminary design on building shape and widow size. After considering the building passive design, the mechanical system will be considered.

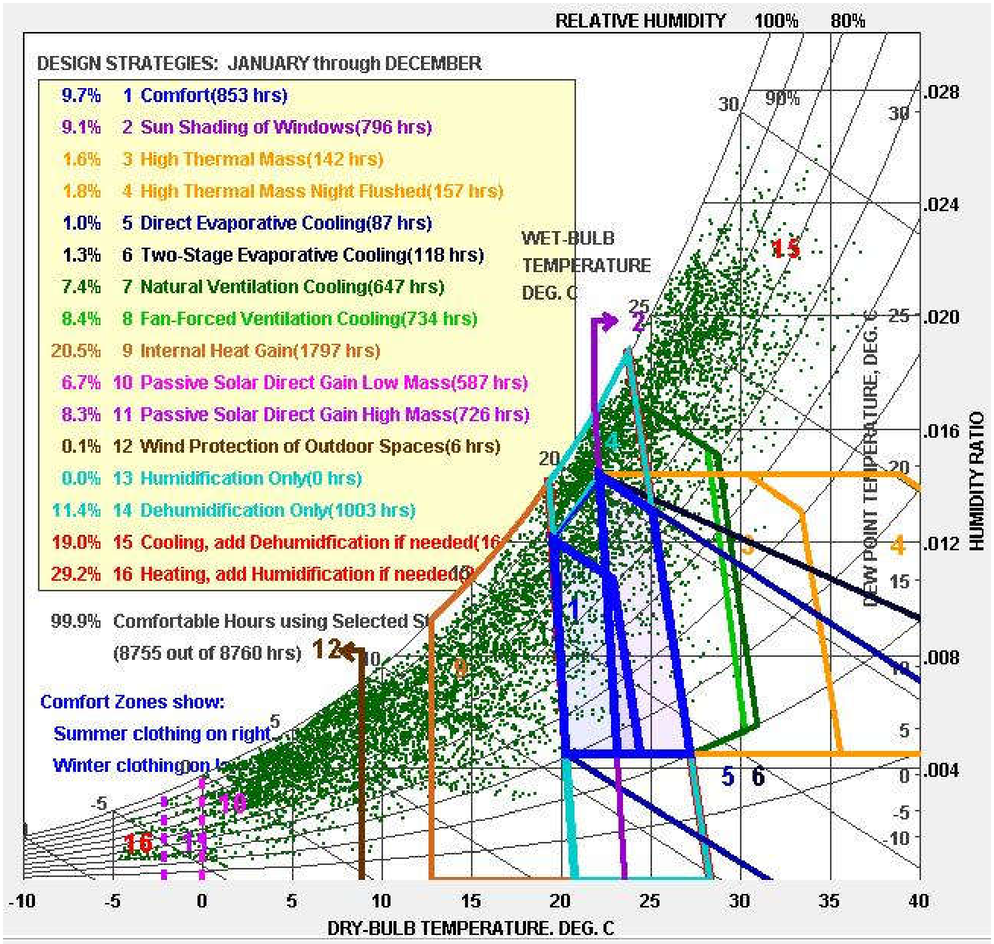


FIGURE 4.1 GENERAL STRATEGIES

In general there are following strategies for the passive design for energy efficient building:

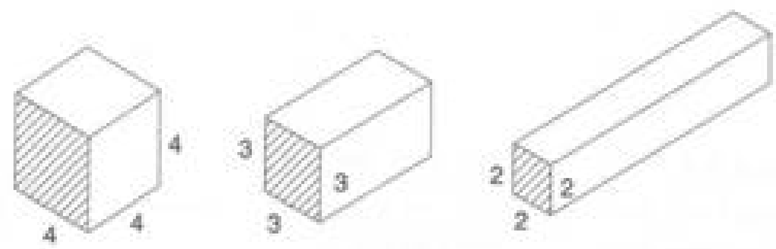
- Minimize the energy consumption
- Minimize the electricity demand especially for artificial lighting
- Maximize the solar gains in heating season
- Minimize the solar gains in cooling season

4.2.1 S/V Ratio

S/V ratio is surface area to volume ratio which is also called building shape factor is an important factor determining heat loss and gain. The greater the surface area the more the heat gain/loss through it. So small S/V ratio means minimum heat gain and minimum heat loss.

To minimize the losses and gains through the envelope of a building, the compact shape is desirable. In hot dry climate S/V ratio should be as low as possible as it could minimize heat gain. In cold dry climate also should have lower shape factor to minimize heat losses.

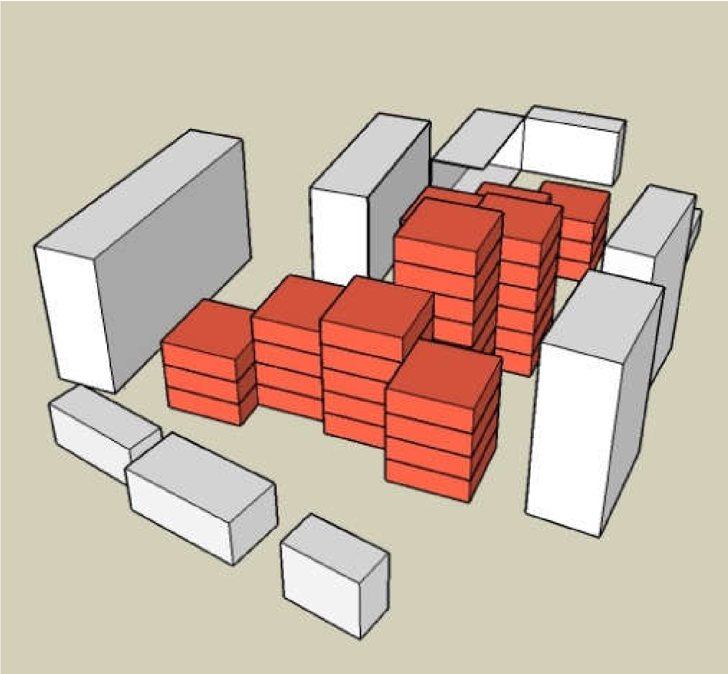
Meanwhile, the architectural aspects should be also considered. Therefore, there are 3 cases imply different S/V ratio and different building shape. The analysis results are as follows and all the data is derived from sefaira for sketch up. All the analysis baselines are the same for each case to have the comparison for a single variables.



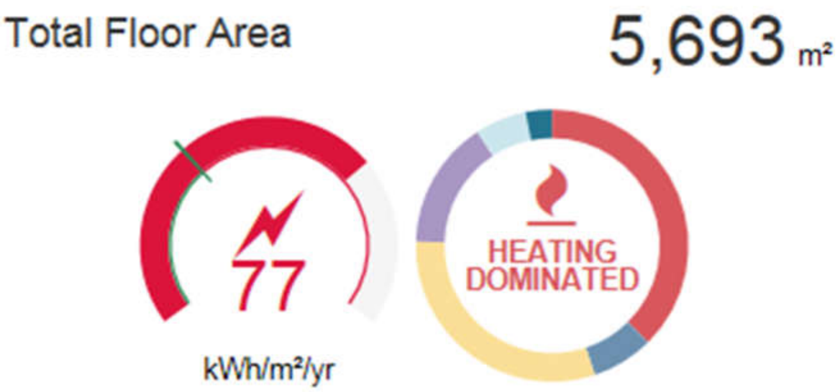
Solid shape type	Surface area (S)	Volume (V)	Ratio (S/V)
a	96	64	1.5
b	103.2	64	1.61
c	136	64	2.13

FIGURE 4.2 SURFACR AREA TO VOLUME RATIO

4.2.1.1 CASE 1



PICTURE 4.1 MODEL OF CASE 1



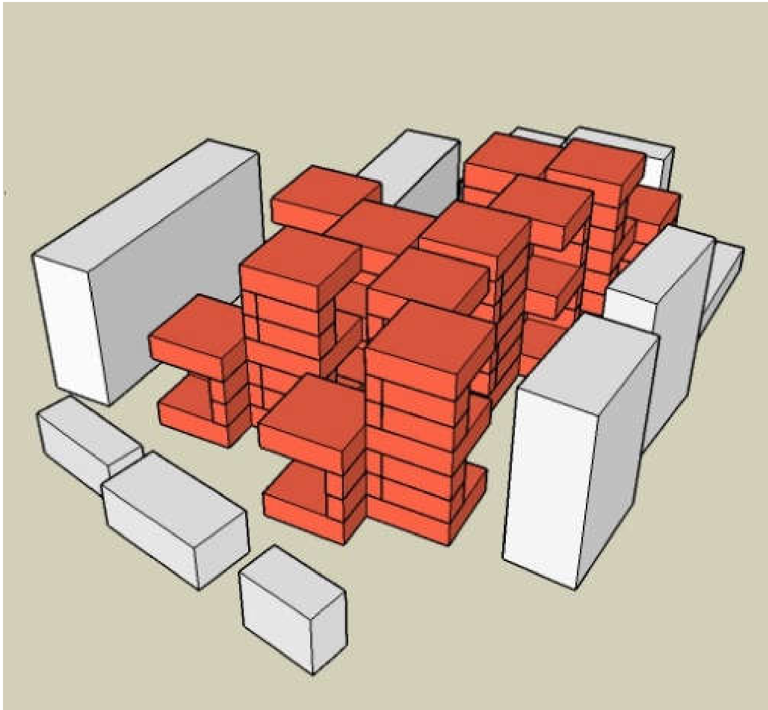
FIGGURE 4.3 ENERGY CONSUMPTION OF CASE 1

Energy Segments	Heating kWh/yr	Cooling	Lighting	Equipment	Fans	Pumps
Energy consumption	59788	37271	79105	197762	24432	12744

TABLE 4.1 ENERGY CONSUMPTION DETAIL OF CASE 1

In this case, the most compact shape is shown. Almost all the floors are cube. The surface area is 5782.63m^2 while the volume is 12013.82m^3. So the S/V ratio is 0.48 while the energy consumption is 77 Wh/m^2/yr.

4.2.1.2 CASE 2



PICTURE 4.2 MODEL OF CASE 2

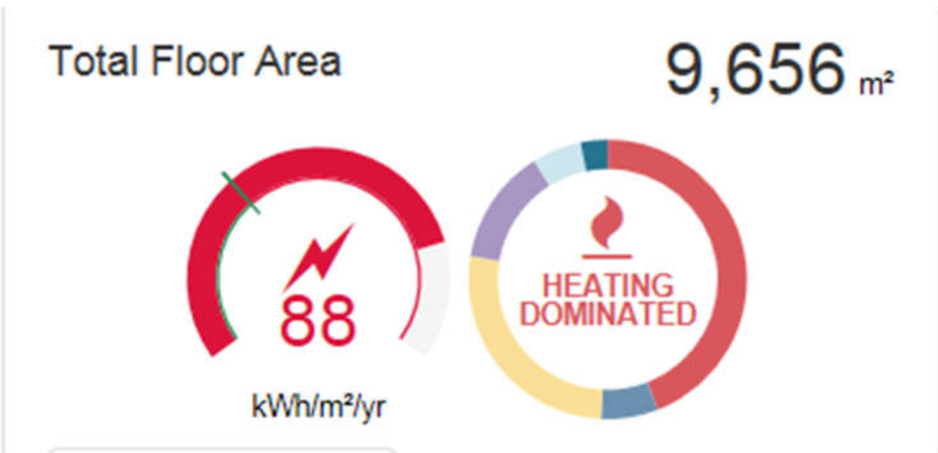


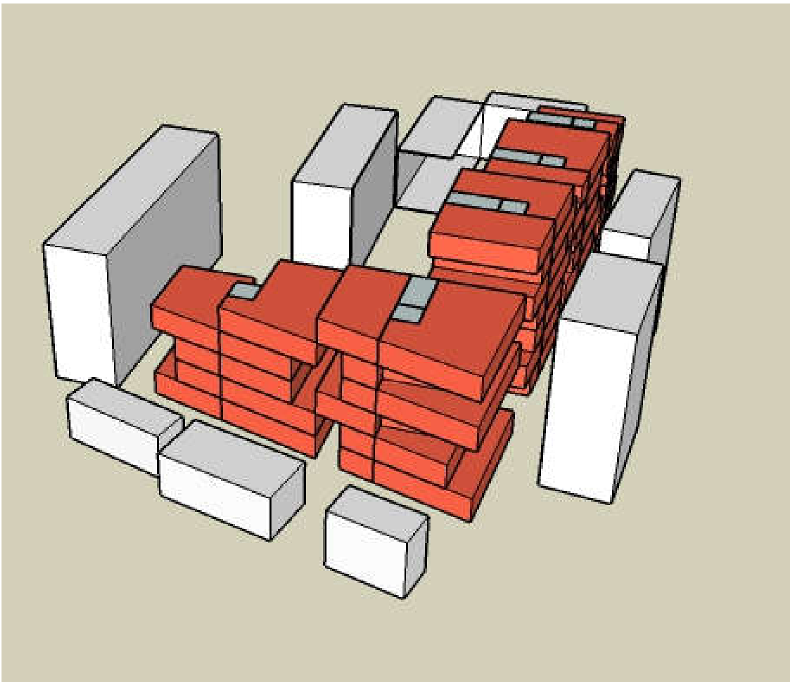
FIGURE 4.4 ENERGY CONSUMPTION OF CASE 2

Energy Segments	Heating kWh/yr	Cooling kWh/yr	Lighting kWh/yr	Equipment kWh/yr	Fans kWh/yr	Pumps kWh/yr
Energy consumption	77652	63069	154916	387290	49314	27142

TABLE 4.2 ENERGY CONSUMPTION DETAIL OF CASE 2

Case 2 incorporates architectural considerations, hollowing out a portion of the originally compact building and making changes in its exterior shape, which directly leads to an increase in surface area reaching to 12396.72m^2. Also the volume increases to 19932.48m^3. Finally, the building shape increases to 0.62 which corresponds to an increase in energy consumption reaching to 88 Wh/m^2/yr.

4.2.1.3 CASE 3



PICTURE 4.3 MODEL OF CASE 3

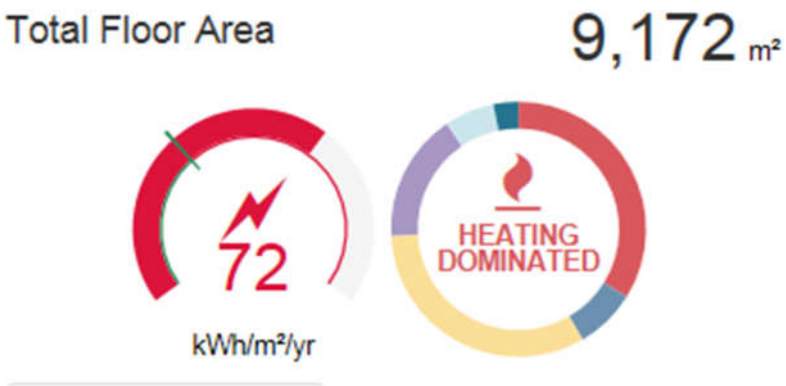


FIGURE 4.5 ENERGY CONSUMPTION OF CASE 3

Energy Segments	Heating kWh/yr	Cooling kWh/yr	Lighting kWh/yr	Equipment kWh/yr	Fans kWh/yr	Pumps kWh/yr
Energy consumption	83028	66138	139560	348900	42468	22647

TABLE 4.3 ENERGY CONSUMPTION DETAIL OF CASE 3

This is the final shape after the architectural changes. This solution combines architectural and sustainable aspect. So the final surface area is 6733.09m^2 and volume is 16062.92m^3, which reduces the S/V ratio from the second case to 0.42.So the energy consumption is also reduced to 72 Wh/m^2/yr.

Summary

Through the research and analysis of the above three cases, the approximate relationship between S/V ratio and energy consumption can be obtained. After comparing the three cases, finally the building shape in case 3 is chosen.

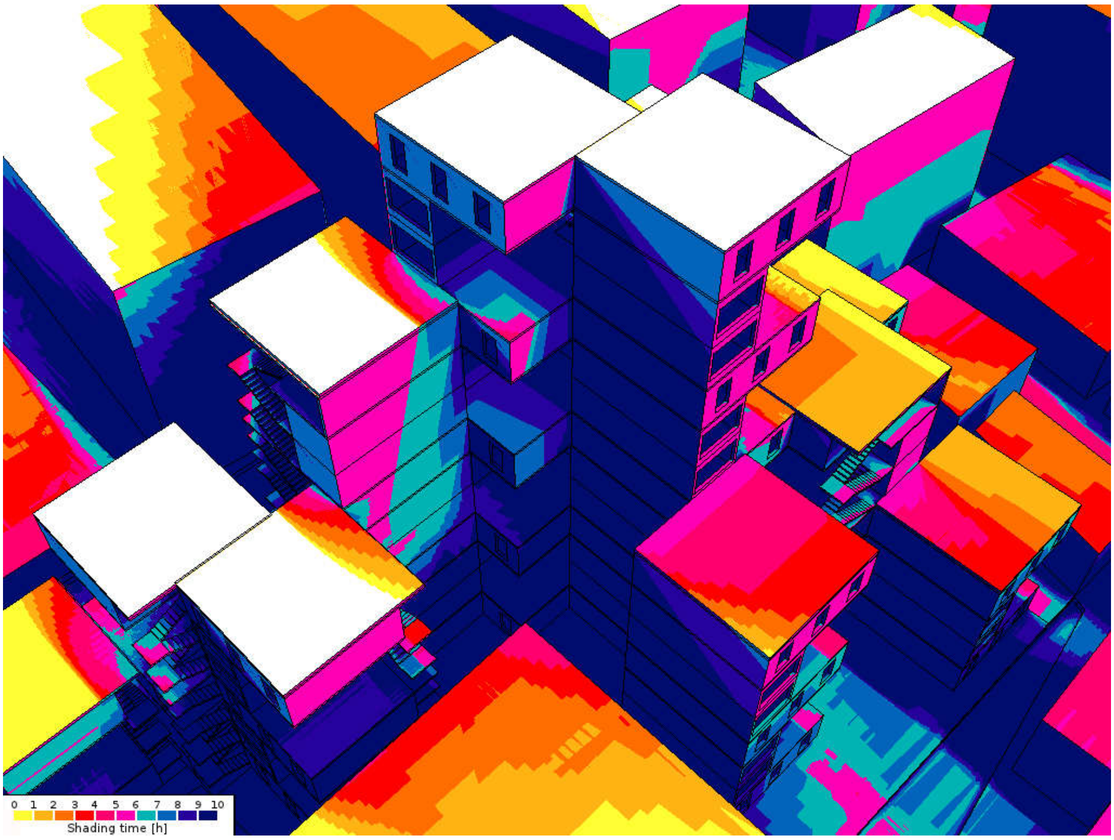
S/V Ratio Analysis						
CASE	Floor Area (㎡)	Surface (㎡)	Volumn (m³)	S/V Ratio	Energy Consumption (Wh/㎡/yr)	Property
1	5693	5782.63	12013.82	0.48	77	Heating Dominated
2	9656	12396.72	19932.48	0.62	88	Heating Dominated
3	9172	6733.09	16062.92	0.42	72	Heating Dominated

TABLE 4.4 S/V RATIO ANALYSIS RESULT

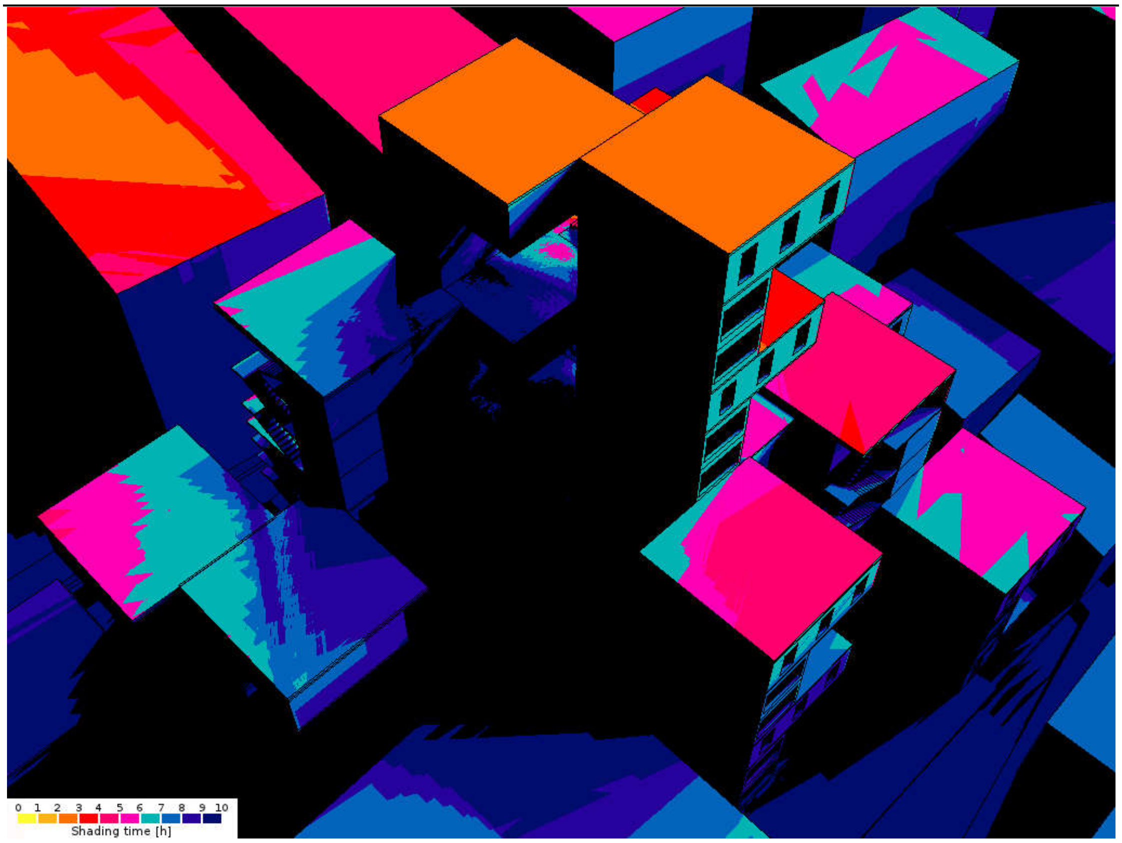
4.2.2 Shadow Analysis

A shadow analysis can help designer to determine the areas of the drawing that will receive less sunlight or remain in a shadow during a particular time of the year. By setting several directional light sources, each representing a different time of day, an overlapping range of shadow is generated which indicates the amount of time that each area is shaded over the course of the day.

Shadow analysis selects the summer solstice day and winter solstice day of the whole year since these two days are the most representative during one year, which are the day with the longest and shortest sunshine time. All the analysis use the same angel and same settings. All the data and graphs are derived from sketch up. The results are shown as follow.



PICTURE 4.4 SHADOW ANALYSIS IN SUMMER SOLITICE DAY



PICTURE 4.5 SHADOW ANALYSIS IN WINTER SOLITICE DAY

From the above two pictures, it can be concluded that almost the entire area is in the shadows throughout the whole year due to the occlusion of the surroundings and also the small distance between the buildings. Meanwhile. the enlarged area of the analysis shows that such a phenomenon does not only appear in the site, but also in larger area around it. Therefore, it can be concluded that the size and number of windows do not have much influence on the daylight visualization.

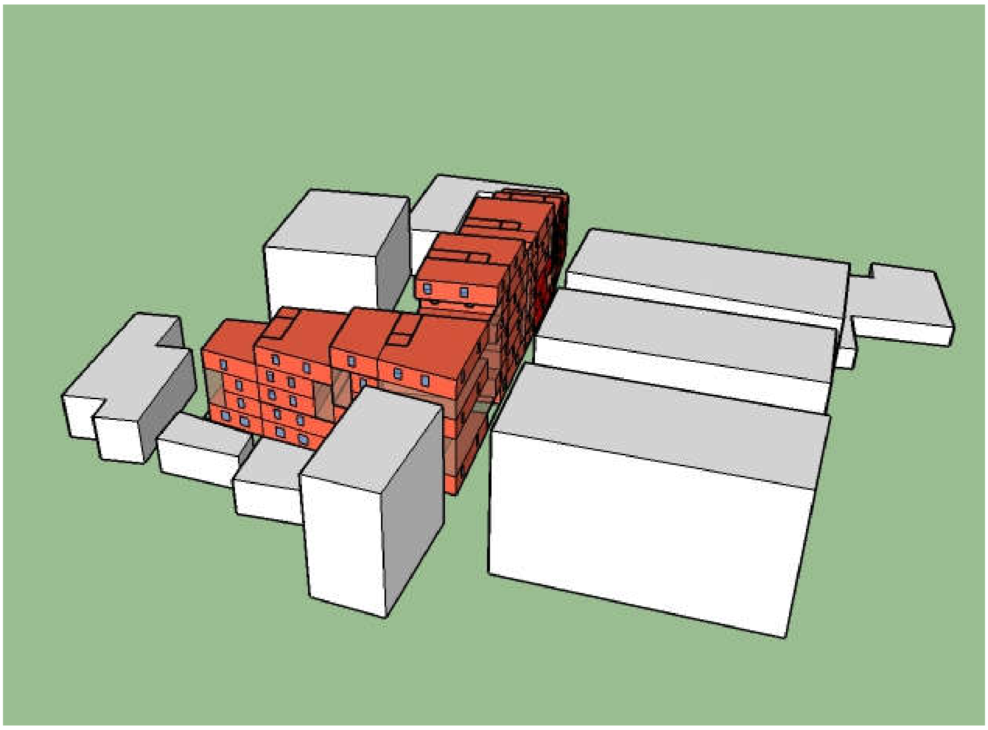
4.2.3 Window to Wall Ratio

Window to wall ratio is the measure of the percentage area determined by dividing the building's total glazing area by its external envelope wall area. It is an important variable affecting energy performance in the building. Window area has an large influence on building's heating, cooling and lighting, as well as relating it to natural environment in terms of access to daylight, ventilation and views.

From the analysis in the previous step, it is easily to conclude that the area of the window does not have a large impact on the daylight since almost all areas are shaded. However, window to wall ratio should still be analyzed because its impact on energy consumption cannot be ignored. At the same time, due to the needs from architectural aspects, it is necessary to increase the area of transparent area as much as possible to open the view to get a better visual experience.

Three different cases with different window to wall ratio are analyzed during this step. All the area of exterior wall keep the same value, so there is only single variable which is window area. All the data and graphs area derived from sefaira for sketch up.

4.2.3.1 CASE 1



PICUTRE 4.6 MODEL OF CASE 1

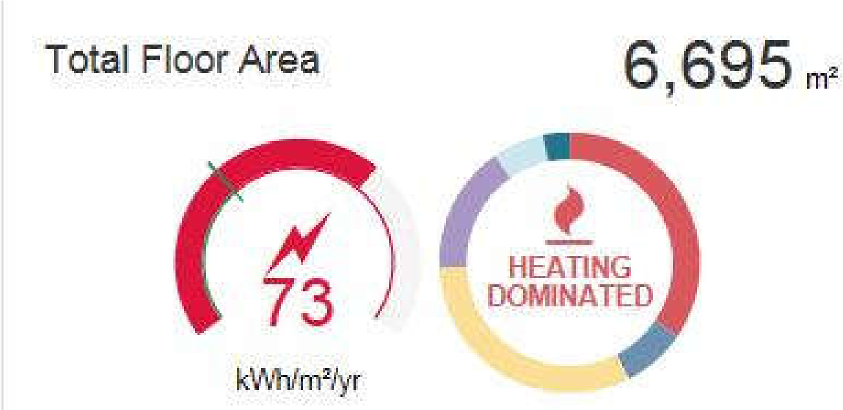


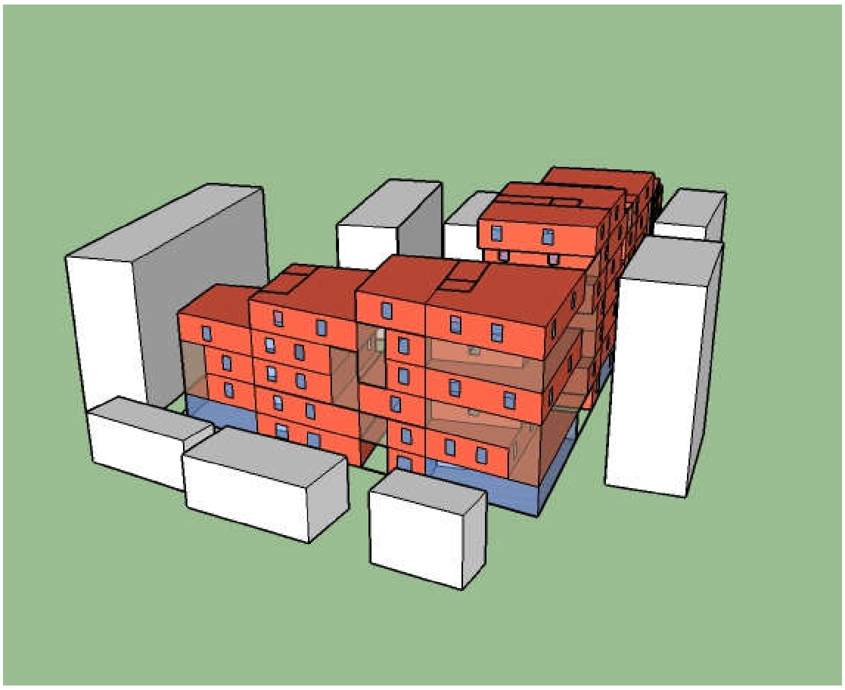
FIGURE 4.6 ENERGY CONSUMPTION OF CASE 1

Energy Segments	Heating kWh/yr	Cooling kWh/yr	Lighting kWh/yr	Equipment kWh/yr	Fans kWh/yr	Pumps kWh/yr
Energy consumption	85831	69781	141049	352622	43888	24272

TABLE 4.5 ENERGY CONSUMPTION DETAIL OF CASE 1

The first case is the most basic solution. The area of each widow is 1.5m*1.5m. And the position of the window is arranged according to the distribution and function of the indoor space. The window to wall ratio for the south and the north facades are both 0.11. The value for east façade is 0.06 while the value for west façade is 0.09. The energy consumption of this solution is 73 Wh/m^2/yr.

4.2.3.2 CASE 2



PICUTRE 4.7 MODEL OF CASE 2

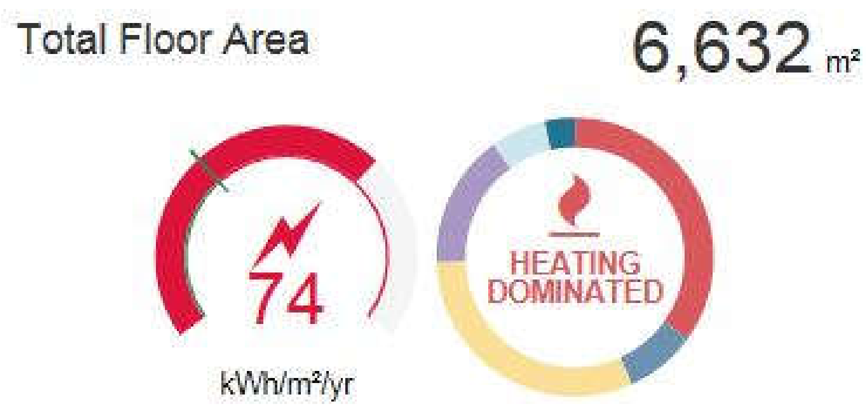


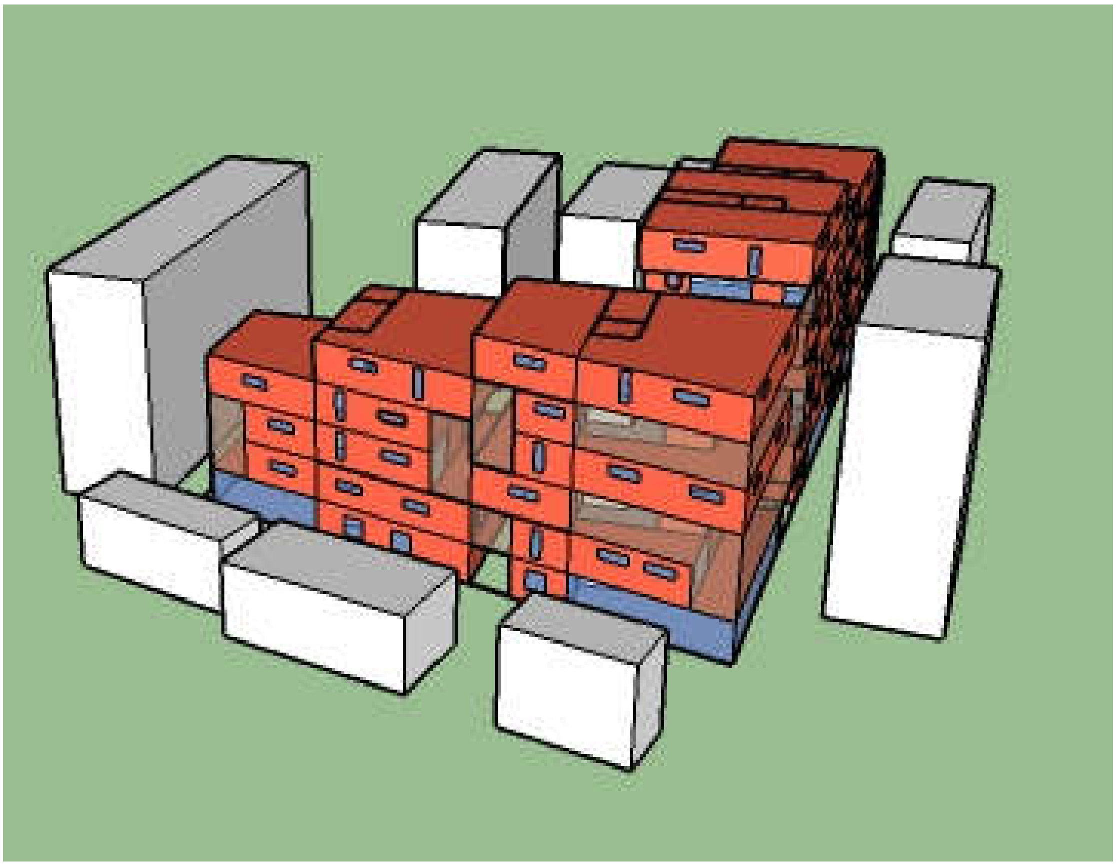
FIGURE 4.7 ENERGY CONSUMPTION OF CASE 2

Energy Segments	Heating kWh/yr	Cooling kWh/yr	Lighting kWh/yr	Equipment kWh/yr	Fans kWh/yr	Pumps kWh/yr
Energy consumption	93906	73546	142912	357279	45545	26663

TABLE 4.6 ENERGY CONSUMPTION DETAIL OF CASE 2

For architectural aspect considerations, the second case increases the window to wall ratio of all four facades. Mainly because the public area on the ground floor are almost all set as commercial areas, then the envelop on the side of the street is mostly changed to the transparent area which directly leads to a large increase in the ratio. Among them, the south façade has the largest growth rate reaching to 0.23. The northern façade follows, reaching to 0.16. And the western and eastern facades have the least increase, but there is also a small increase, reaching both to 0.13. While the energy consumption doesn't have much change which is 74 Wh/m^2/yr.

5.2.3.3 CASE 3



PICUTRE 4.8 MODEL OF CASE 3

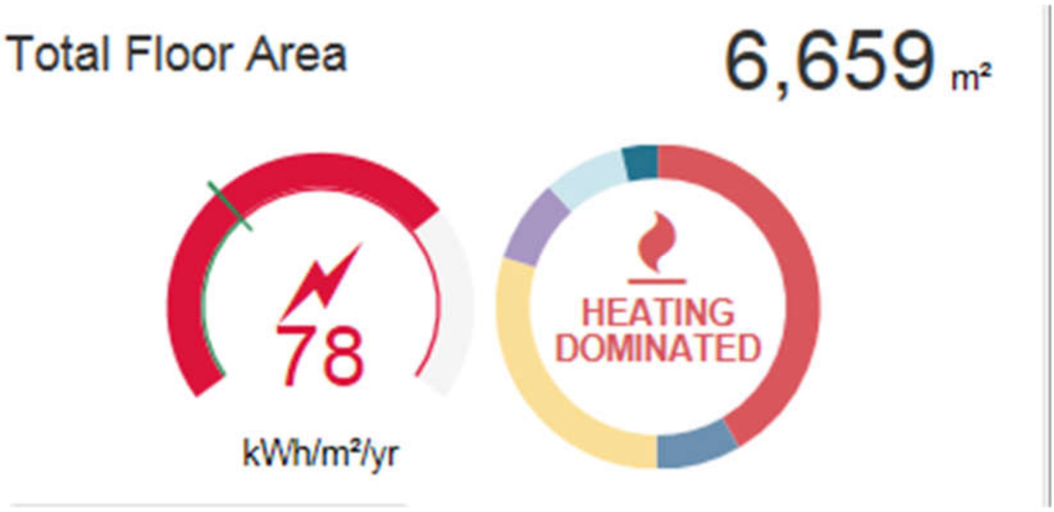


FIGURE 4.8 ENERGY CONSUMPTION OF CASE 3

Energy Segments	Heating kWh/yr	Cooling kWh/yr	Lighting kWh/yr	Equipment kWh/yr	Fans kWh/yr	Pumps kWh/yr
Energy consumption	92538	71265	140836	352090	44630	25853

TABLE 4.7 ENERGY CONSUMPTION DETAIL OF CASE 3

Case 3 is the finalization of the final architectural plan, mainly for the consideration on the architectural design aspect. The window shape is set to 2 types, horizontal and vertical. The size of 2 types are the same which is 1.2m*0.9m. While the vertical shape is rotated 90 degree from horizontal one. The transparent portion of the ground flor remains unchanged, and on the floor facing to the green roof, the transparent area is added to provide a better visual experience since it open the view to the nature. In the end, all the window to wall ratio has been improved a lot. The southern façade reaches to 0.27 while the northern façade has the highest value which reaches to 0.32. The ratio for eastern façade has also improved significantly, reaching to 0.24. But the value for western façade remains the original value which is 0.13. In the same time, the final energy consumption do not have significantly changing, and increased to a small extent 78 Wh/m^2/yr.

Summary

Window to Wall Ratio Analysis													
CASE	SOUTH			NORTH			EAST			WEST			Energy
	Window	Wall	WWR	Window	Wall	WWR	Window	Wall	WWR	Window	Wall	WWR	kWh/m²/yr
1	51.80	485.20	0.11	57.00	525.90	0.11	76.50	1196.30	0.06	74.30	805.50	0.09	73
2	113.80	485.20	0.23	85.80	525.90	0.16	156.30	1196.30	0.13	101.30	805.50	0.13	74
3	133.40	485.20	0.27	167.10	525.90	0.32	283.10	1196.30	0.24	101.30	805.50	0.13	78

TABLE 4.2 WINDOW TO WALL RATIO ANALYSIS RESULT

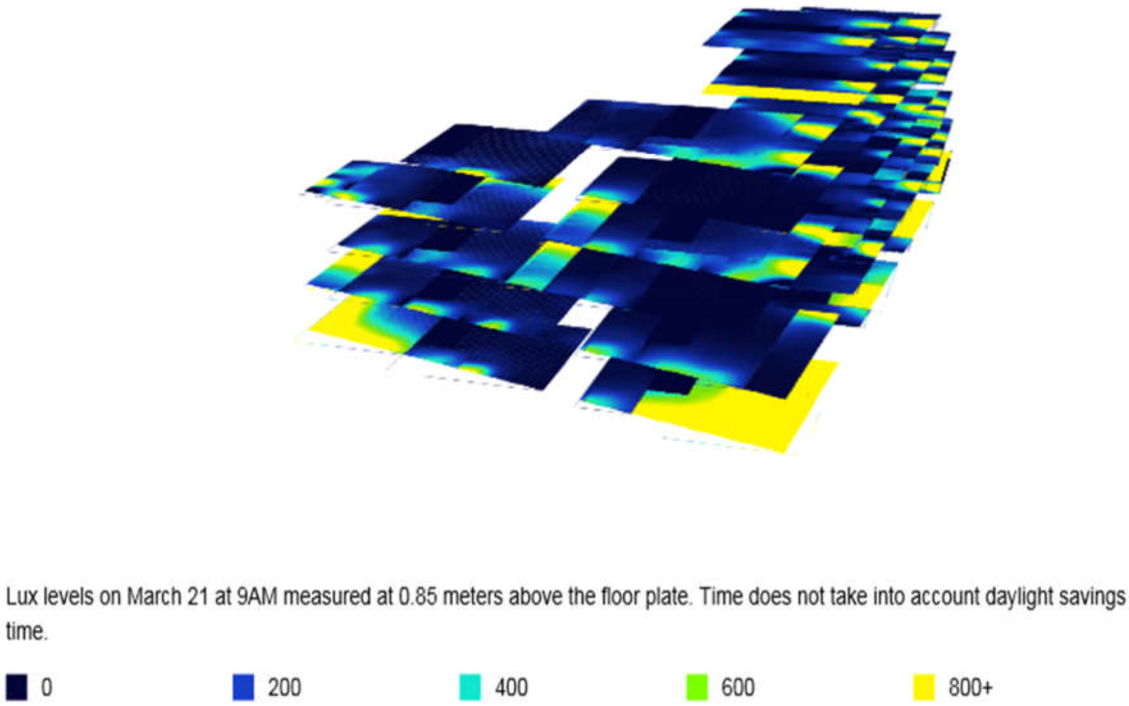
Through the analysis of three different cases with different window to wall ratio, it is not difficult to get the conclusion that the ratio does not have much influence on this project. Even if the ratio has a large increase, the value of energy consumption does not change significantly. But from architectural considerations, the window solution in case 3 has been chosen.

4.2.4 Daylight Visualization

Daylight is very important for the building not only because daylit environments increase occupant productivity and comfort, but also because it reduces electric lighting demand therefore reduces energy consumption.

However, from the shadow analysis shown above, it can be clearly observed that the overall area is covered by the shadow for a long period of time, even if in the summer solstice day, which is also the reason why an increase of the number and size of the transparent area has no positive impact on daylight. At the same time, the long shadow coverage time is also the direct reason of very high energy consumption in lighting equipment in the above analysis results. However, in order to show the indoor daylight condition, the daylight visualization is shown as follows.

5.2.4.1 Daylight Visualization Graph



PICUTRE 4.9 DAYLIGHT VISUALIZATION ON MARCH 21

4.2.5 Optimal Value

In the sefaira plugin, by setting 2 different outputs which one is annual electricity demand and the other is annual energy cost, the following graphs can be obtained through automatically calculations. From these graphs, the preliminary optimal U-value for different envelope can be obtained which can give a strong instruction for the envelop design.

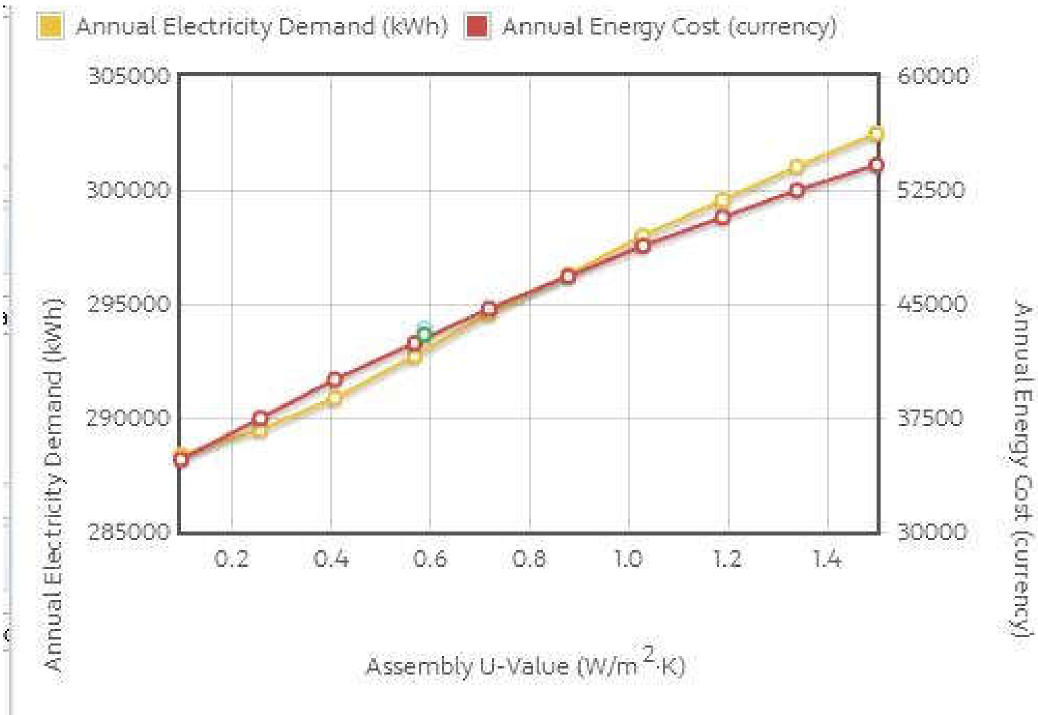


FIGURE 4.9 OPTIMAL VALUE FOR EXTERNAL WALL

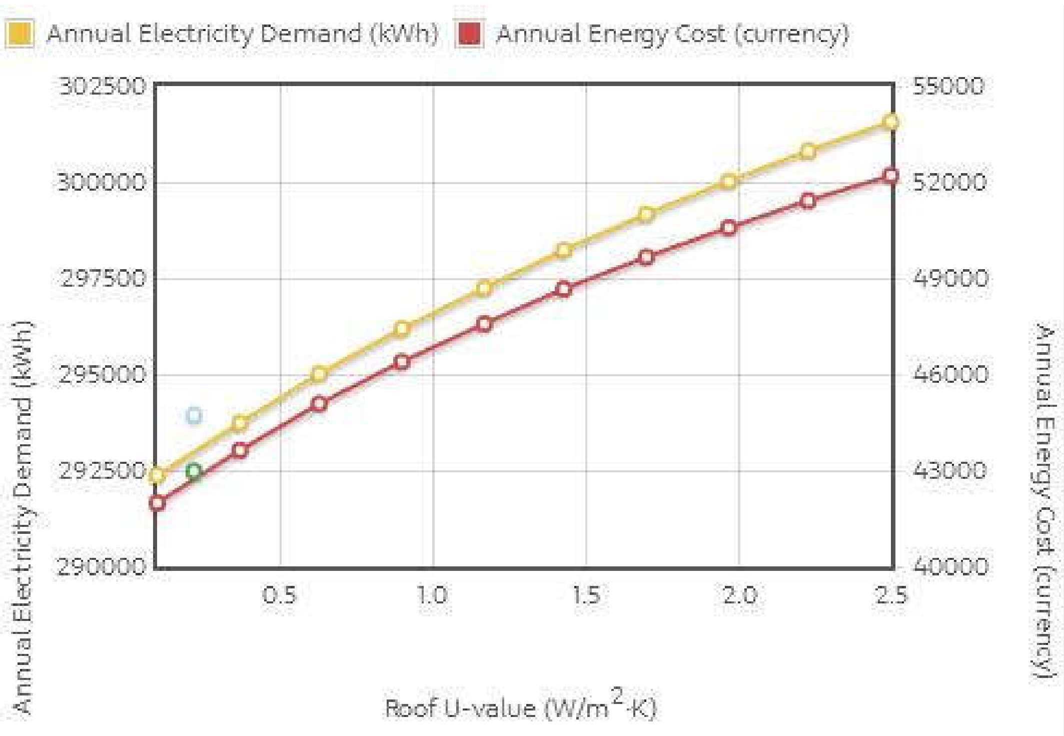


FIGURE 4.10 OPTIMAL VALUE FOR EXTERNAL ROOF

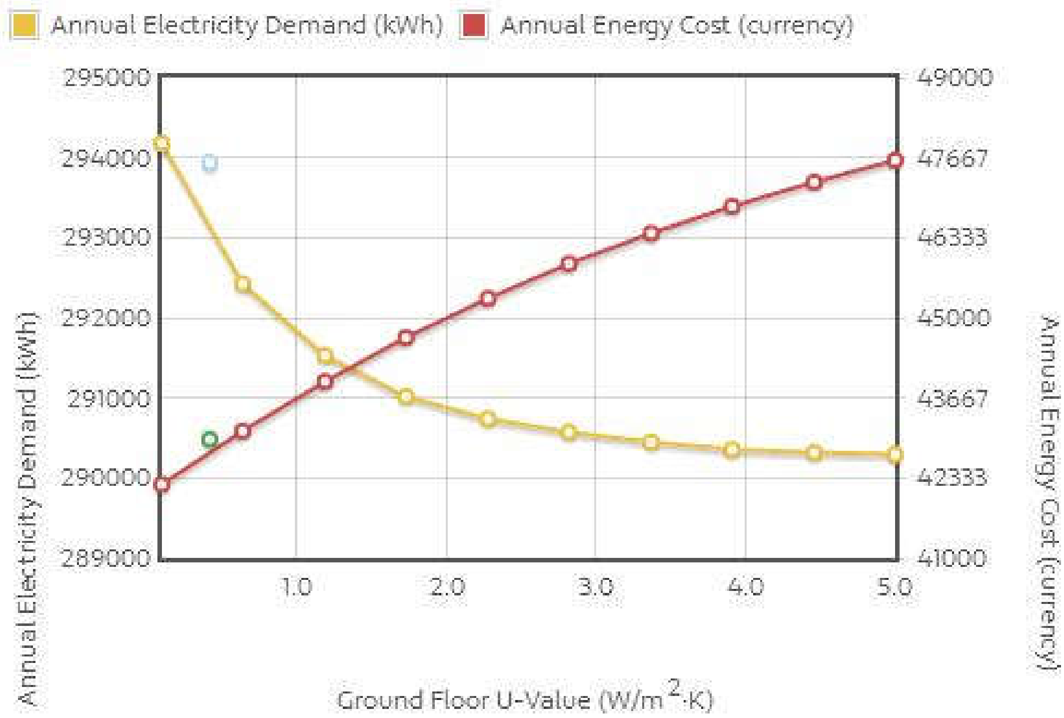


FIGURE 4.11 OPTIMAL VALUE FOR FLOOR

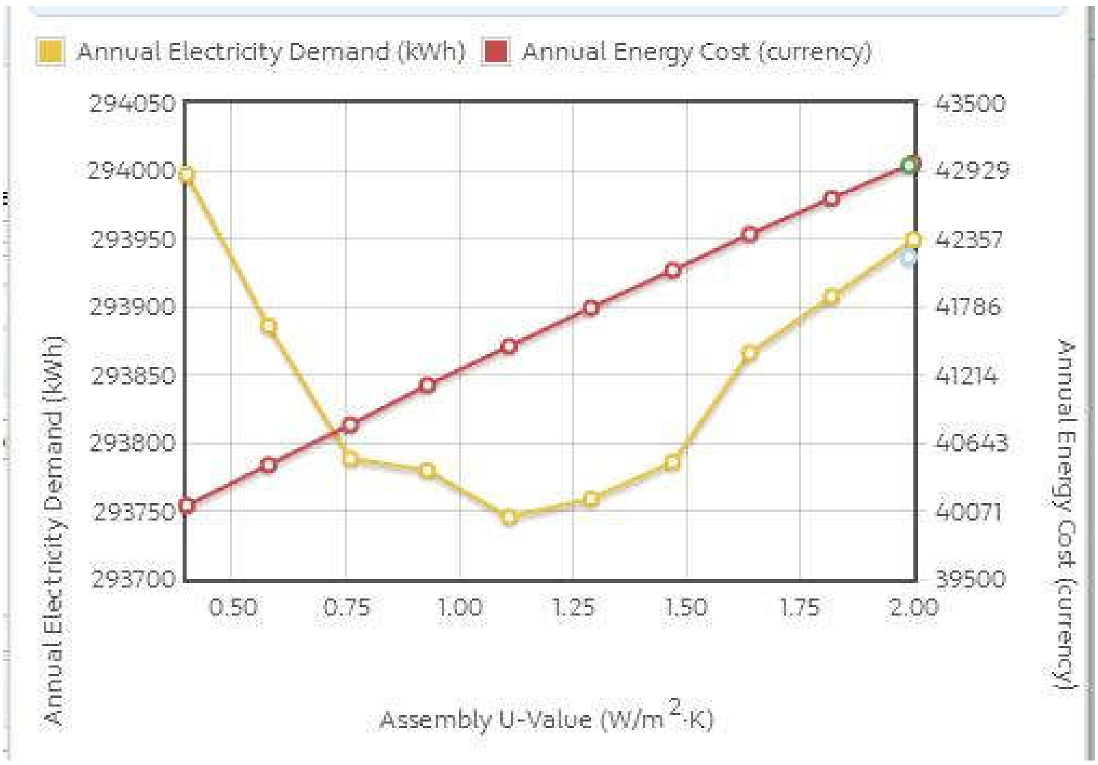


FIGURE 4.12 OPTIMAL VALUE FOR GLAZING AREA

From the graphs above, the optimal value for each construction type can be obtained. The value is shown as follow.

Envelope	Assembly Value
Opaque Wall	0.7
Glazing Area	0.75
Roof	As small as possible
Floor	1.2

TABLE 4.3 OPTIMAL VALUE FOR ENVELOPE

4.3 Building Envelop Design

A building envelope is the physical separator between the conditioned and unconditioned environment of a building including the resistance to air, water, heat, light and noise transfer. This step is significant not only because of its importance to be an outer shell for building, but also it is an architectural representation.

In this step, there are six construction part will be discussed which are ventilated ceramic façade, curtain wall, green roof, green net, waffle concrete slab and glass canopy.

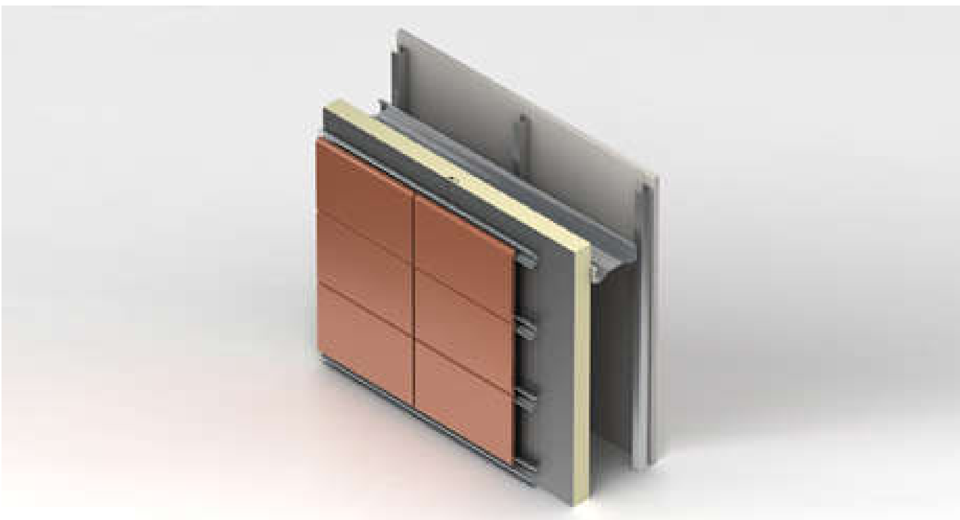
4.3.1 Ventilated Ceramic Façade

4.3.1.1 Why Double Ventilated Facade

Ventilated façade is one type of double façade which ensures high energy saving for buildings of up to 20% to 30%. In terms of thermal energy, ventilated walls can redue the amount of heat that buildings absorb from outside due to partial reflection of solar radiation by the covering and the ventilated air gap and to the application of insulation, therefore achieving considerable reduction in the costs of mechanical cooling. Vice versa, in winter, ventilated façade manages to restore heat, resulting in reducing heat loss.

In addition, their different layers improve on building's sound insulation, a factor of major importance in cities with high noise levels such as this project in the city center of Shanghai.

Besides, the installation system minimizes execution times which is suitable for the site in the city center. Moreover, ventilated facades only require minimal maintenance and broken tiles can be easily be replaced with no need for building work.



PICUTRE 4.9 DOUBLE FAÇADE SCHEME

4.3.1.2 Why Ceramic

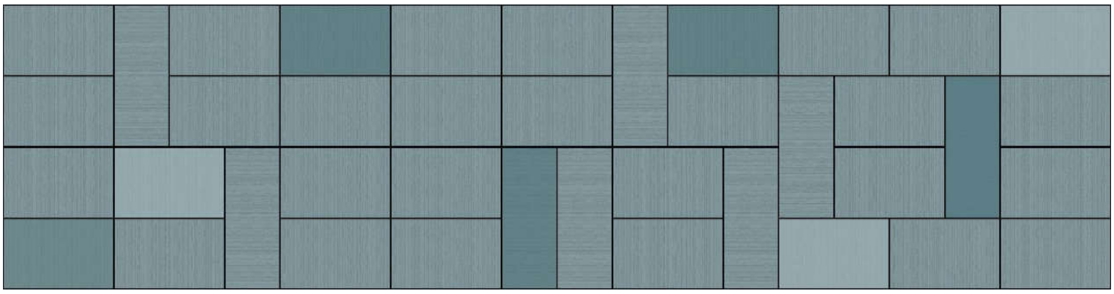
Ceramic tile is the most common types of cladding especially for residential building. The ceramic tiles are available in unlimited colors, flexible sizes and different textures which can provide good aesthetic appeal from architectural aspect.

In addition, ceramic tile has a good performance in thermal insulation and has heat saving properties which can reduce energy consumption by improving heat loss and heat gain. Besides, ceramic tile has relatively low weight and more economic. Moreover, the ceramic cladding is durable and easy to clean and maintenance.

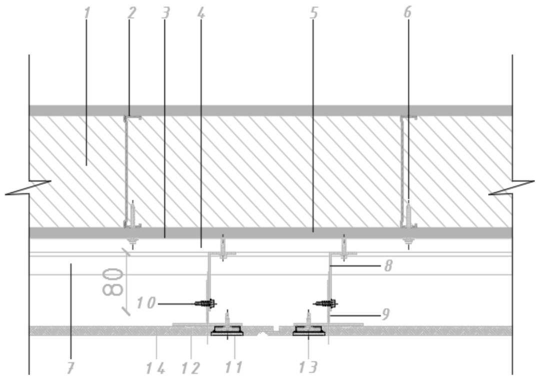
PICTURE 4.10 CERAMIC PANEL

4.3.1.3 Details

The ceramic tile used in this project is shown as follow. The size keeps constant as 150cm*75cm, but it has been put horizontally and vertically. At the same time , the main color is acqua blue but in 3 tones to make it randomly.



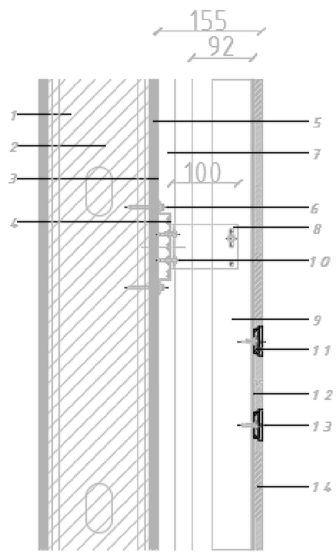
PICTURE 4.11 CERAMIC TILES IN PROJECT



1.Prefabricated Wall of Metal Substructure and Plasterboard
2.Steel Profile
3.Waterproofing Layer
4.Top & Hat Profile
5.Gypsum Board
6.Stainless Steel Self-Drilling Screw
7.Thermal Insulation
8.Single AlumInium Angle Bracket
9.Aluminium "T" Profile
10.Self-Drilling Screw
11.Sleeve
12.P404-Polyurethane
13.Self-Drilling Screw
14.Ceramic Panel

Ventilated Facade Details - Horizontal Section 1:10

DRAWING 4.1 VENTILATED FAÇADE DETAILS – HORIZONTAL SECTION



1.Prefabricated Wall of Metal Substructure and Plasterboard
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8.Single AlumInium Angle Bracket
9.Aluminium "T" Profile
10.Self-Drilling Screw
11.Sleeve
12.P404-Polyurethane
13.Self-Drilling Screw
14.Ceramic Panel

Ventilated Facade Details - Vertical Section 1:10

DRAWING 4.2 VENTILATED FAÇADE DETAILS – VERTICAL SECTION

4.3.2 Curtain Wall

4.3.2.1 Why Curtain Wall

Curtain wall system are non-structural cladding systems for external envelope of building which sperate the interior space from the exterior. Meanwhile, curtain wall is additionally able to slow the spread of fire between floors by acting as a barrier and preventing the fire from easily transferring across the surface of the building, which is very important in vertical building where the fire would otherwise quickly be able to spread upwards.

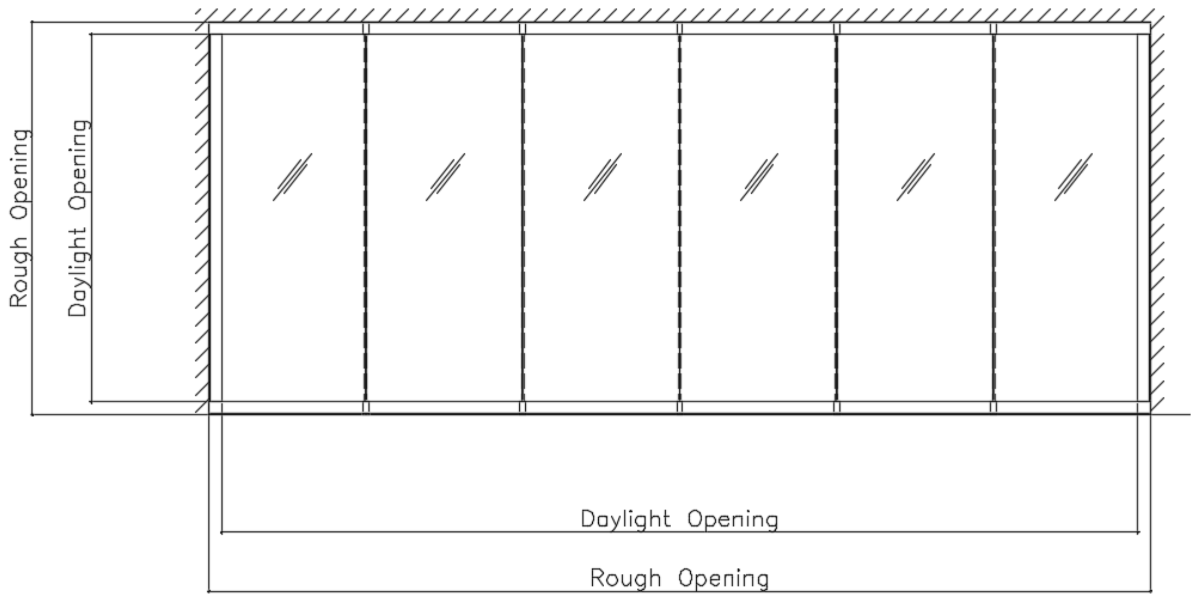
Moreover, curtain wall which properly treated and glazed also vastly improves the thermal efficiency of the building. Curtain wall is able to stabilize the temperature within and cut down on the operating costs of the building itself. Additionally, glazing can reduce UV light and keep building envelop from fading or degrading quickly.

The last but not least, there are many curtain wall designed for the fast and easy installation which can save installation time and procedure on site. Whatsmore, curtain wall can give a clean, sophisticated and unique appearance which improves a lot in architectural aspect.

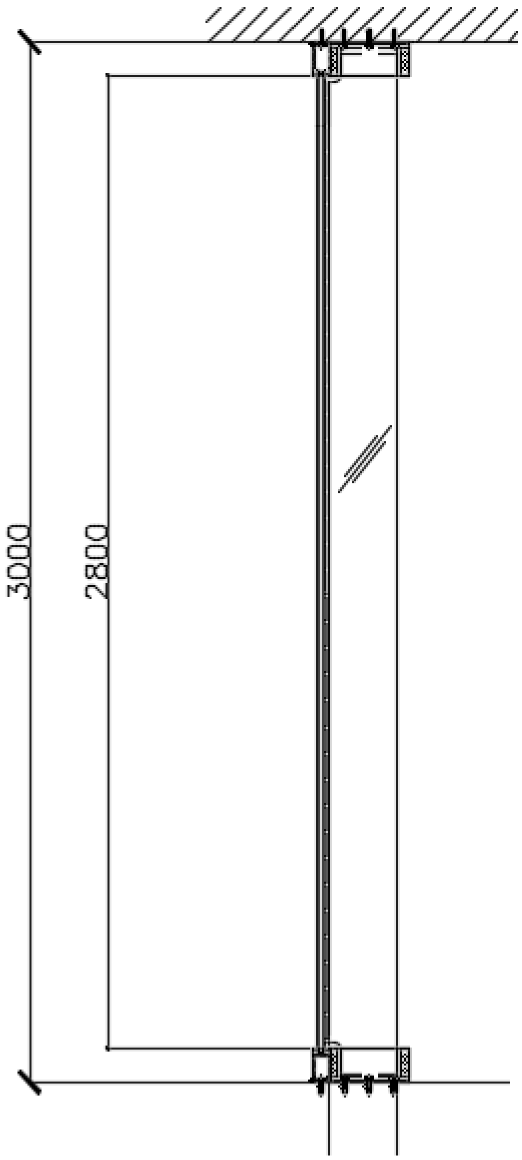
PICTURE 4.12 CURTAIN WALL

4.3.2.2 Details

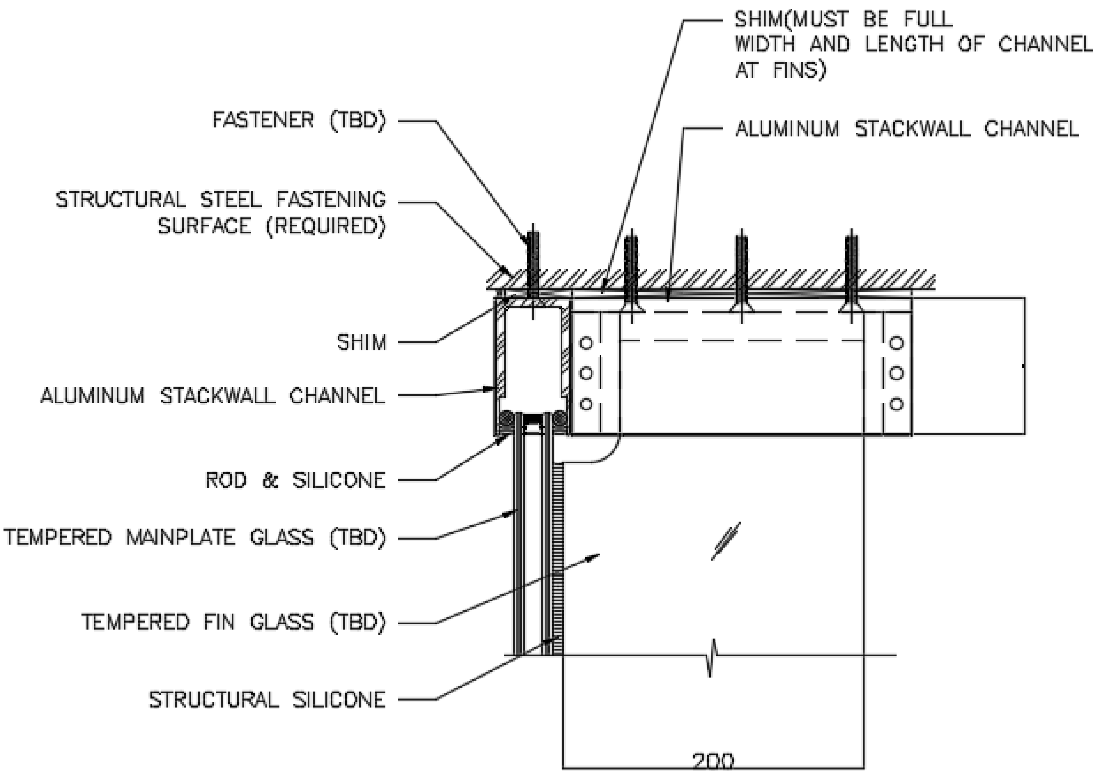
On the ground floor, all the curtain wall is designed as FINAWALL which provides aesthetic design characteristics of an exterior flush-glazed wall using interior glass mullions and fines instead of metal mullions. The glass fins provide support to the main glass plates. So FINEWALL is free from visual obstruction, limiting the need for metal framing to the perimeter, thus creating a seemingly floating glass façade.



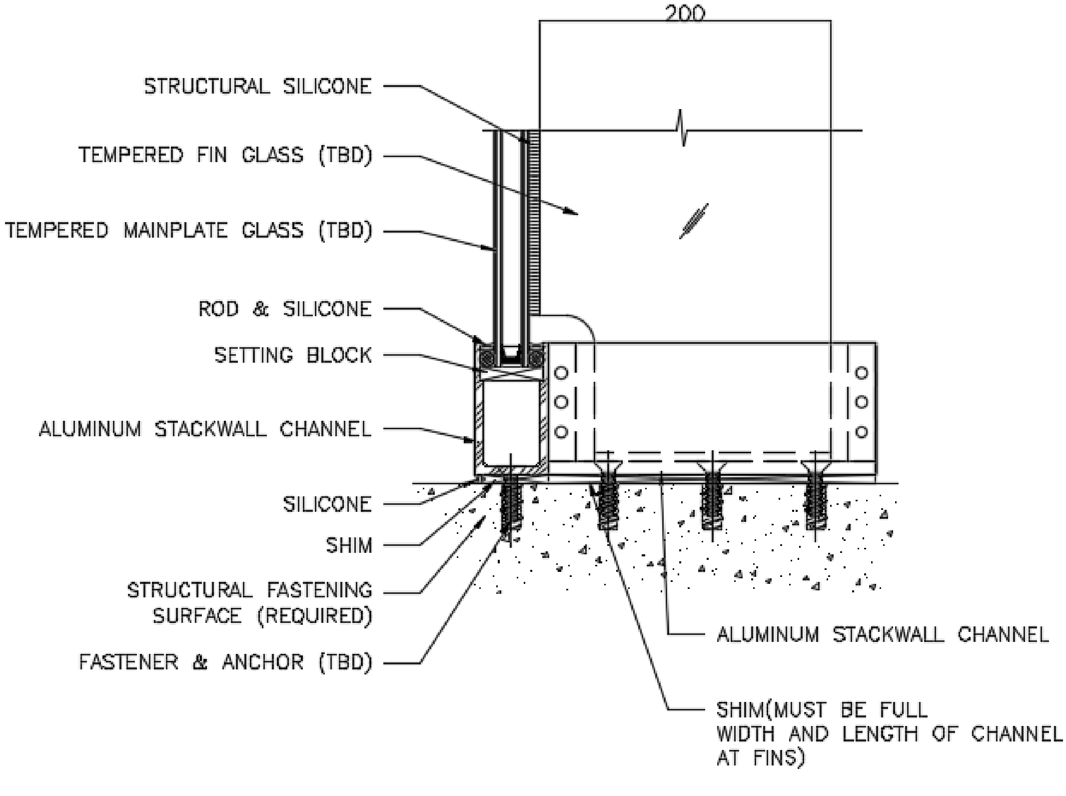
DRAWING 4.3 CURTAIN WALL DETAILS



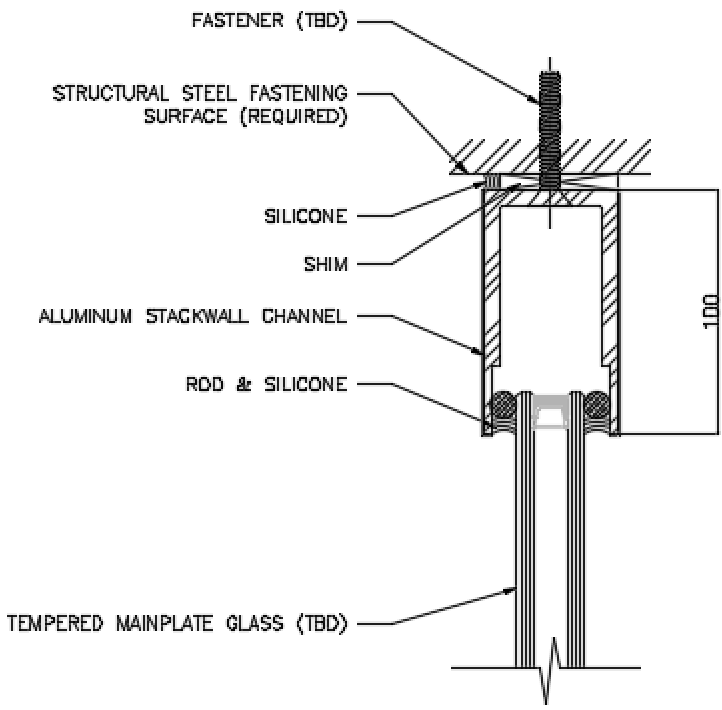
DRAWING 4.4 CURTAIN WALL SECTION DETAILS



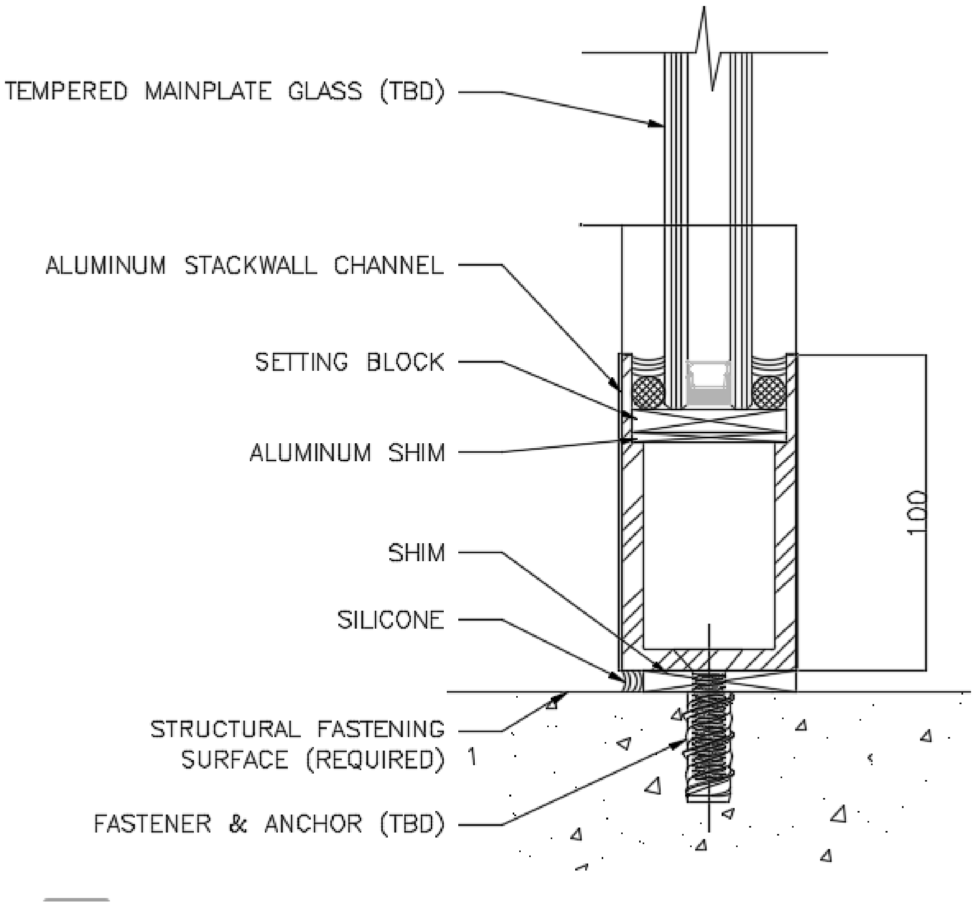
DRAWING 4.5 CURTAIN WALL DETAILS – FIN HEAD



DRAWING 4.6 CURTAIN WALL DETAILS – FIN HEAD



DRAWING 4.6 CURTAIN WALL DETAILS – MAINPLATE HEAD



DRAWING 4.7 CURTAIN WALL DETAILS – MAINPLATE HEAD

4.3.3 Green Roof

4.3.3.1 Why Green Roof

Green roof is a system of great environmental significance against the continued overbuilding of cities for the construction of roof gardens and green roofs to protect the waterproofing and with a guaranteed life of the garden. Green roof has many advantages as follow:

- Control of meteoric water: the green roof system has a higher capacity than the normal roof to retain and store water: up to 90% in this project
- Improvement of the macro- and micro-climate: green roof humidifies the air and contribute to decrease the global warming.
- Sound insulation: green roof mitigates the action of sound and electromagnetic waves, preventing them from entering the building.
- Improvement of air quality: atmospheric dust is retained and harmful substances are filtered and purified by the vegetation.
- Ecological balance: green roof habitats for animals and plants with formation of ecological corridors.
- Mitigation of environmental impact: nature is integrated into the buildings, helping to requalify and ennoble the urban settings, reducing their visual impact.
- Creation of new green area
- Increased durability of the cover: the waterproof coatings remain protected from temperature changes, UV rays, hail and frost.
- Increased thermal insulation: the temperature change is drastically reduced and the cushioning elements of the building remain shielded with green roof. The improvement of the microclimate inside the building ensures considerable saving on heating costs and energy consumption.

-

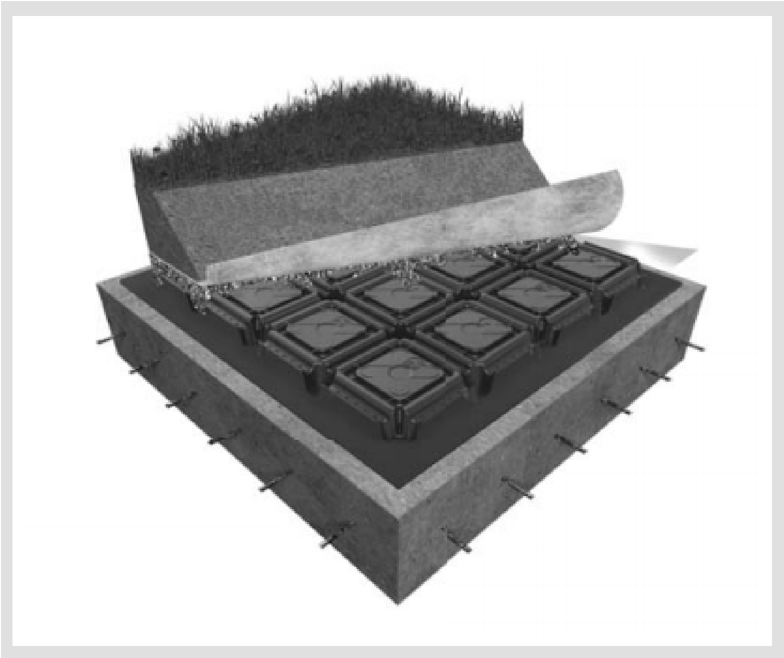
PICUTRE 4.13 GREEN ROOF

4.3.3.2 Details

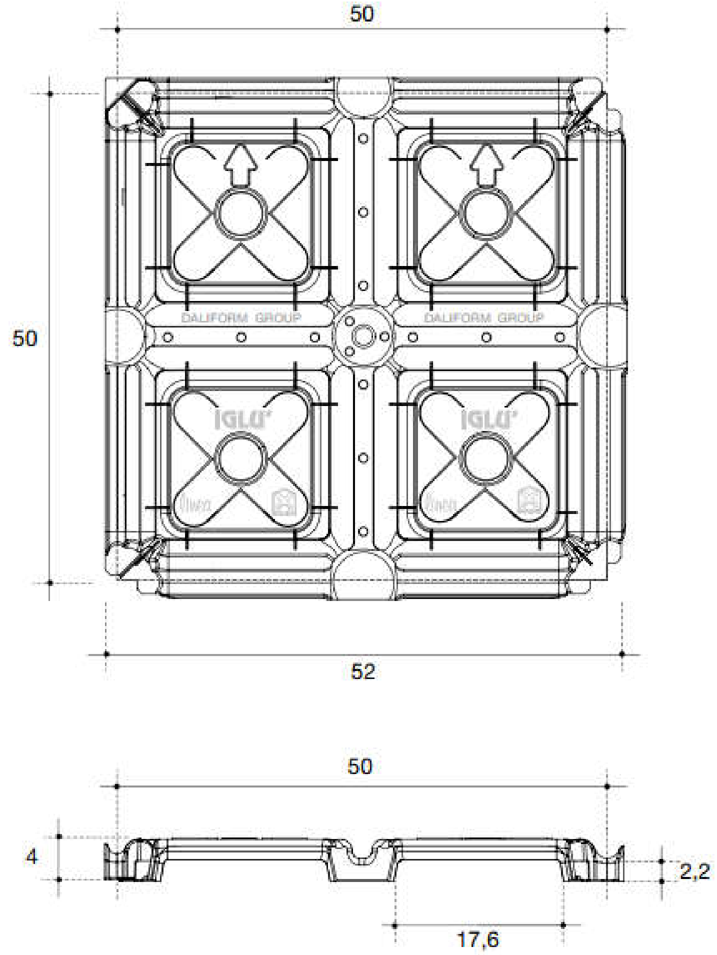
In this case, intensive Iglu green roof is applied. This solution allows the choice between a huge number of different species and has many advantages as follow:

- Stratigraphies with thickness up to over 60cm
- Heavy loads on the roof
- Use of bushy plants, medium height shrubs, and small trees similar to those planted in the soil
- Implementation of specific irrigation systems
- Full enjoyment of green area

The size for the roof system is 500mm*500mm for each piece and datasheet is shown below:



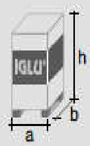
PICUTRE 4.14 GREEN ROOF IGLU SYSTEM



DRAWING 4.8 GREEN ROOF DETAILS – IGLU ROOF SYSTEM 50*50

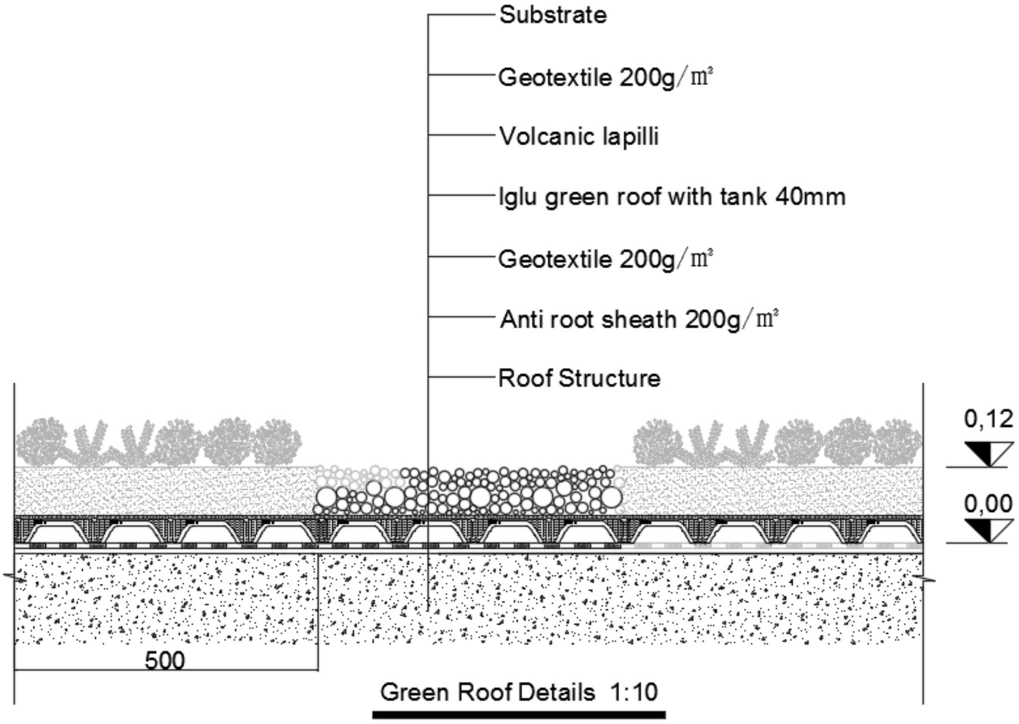
IGLU'® Green Roof H 4 cm - Formwork for water dispersion.

Working dimensions*	cm	50x50
Weight per piece	h cm	0,800
Compressive strength	Kg./m²	5.000
Draining surface	cm²/m²	~1.000
Total surface of feet of pillars	cm²/m²	210
Section for the water's passage	cm²/m² per lato	120
Pallet	a x b x h	110 x 110 x 252
	m²/PAL	500
	pz./PAL	600
	Kg./PAL	150

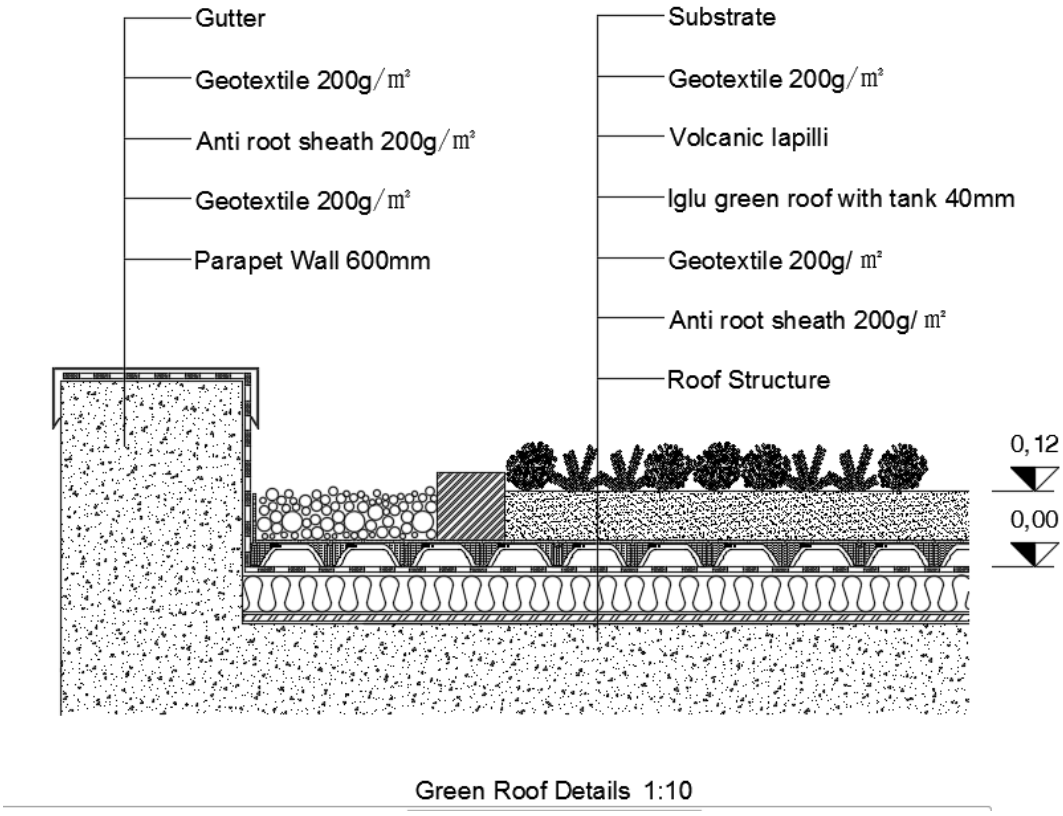


** In consideration of the recycled material, it is permitted a size tolerance of 2.5%.*

TABLE 4.1 IGLU ROOF SYSTEM – DATA SHEET



DRAWING 4.9 GREEN ROOF SECTION DETAILS

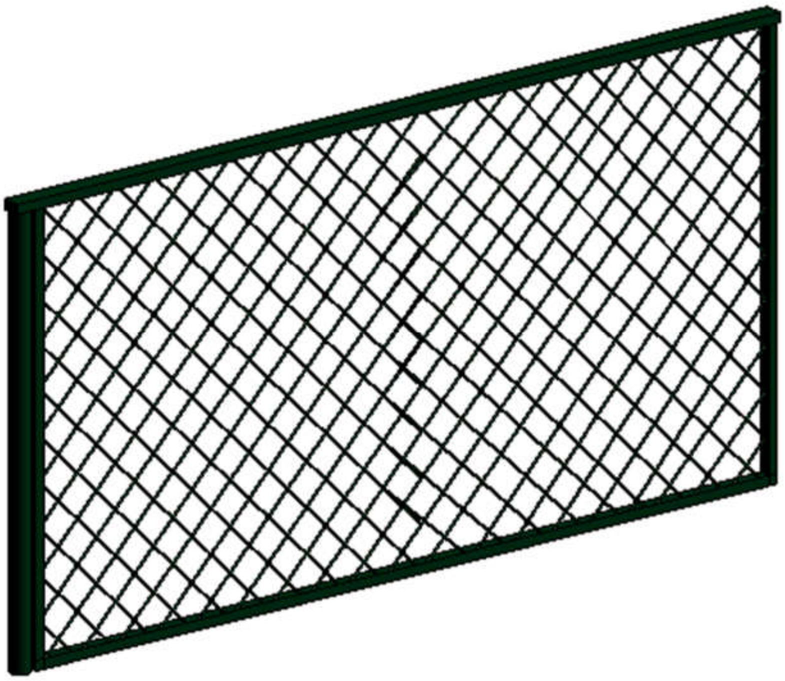


DRAWING 4.10 GREEN ROOF SECTION DETAILS

4.3.4 Green Net

4.3.4.1 Why Net

In the process of architectural design, due to the movement of volumes of each layer, the residents can share the common space, which at the same time directly exposes the balcony and common spaces without any obstructions. Since the four facades of the building are close to the street and the eastern façade is close to the main road, in order to keep privacy to give residents a better private space, the obstruction is needed. At the same time, in order to distinguish this obstruction from the outer wall, it is decided to use a mesh with a gap that can provide ventilation and only partially obscured.

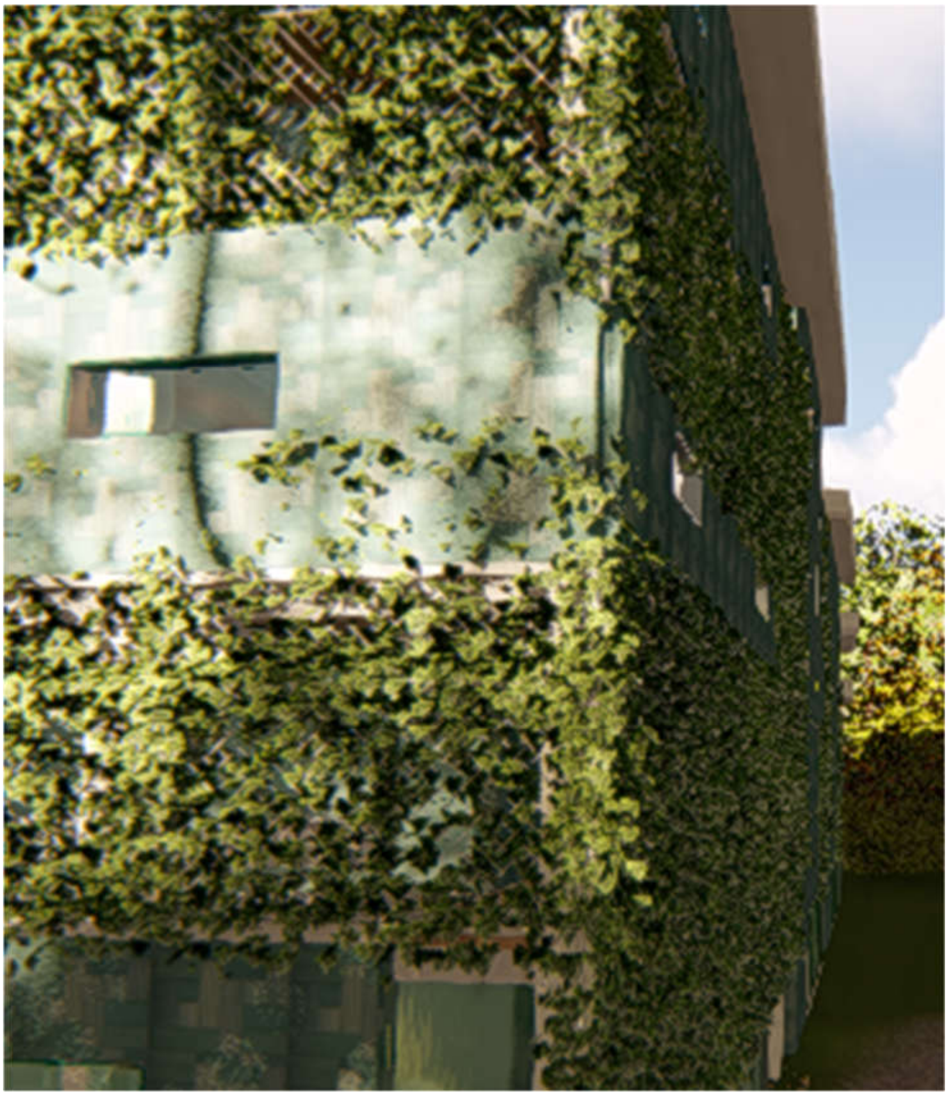


PICTURE 4.14 NET

PICTURE 4.15 MODEL OF NET IN THE PROJECT

4.3.4.2 Why Green Net

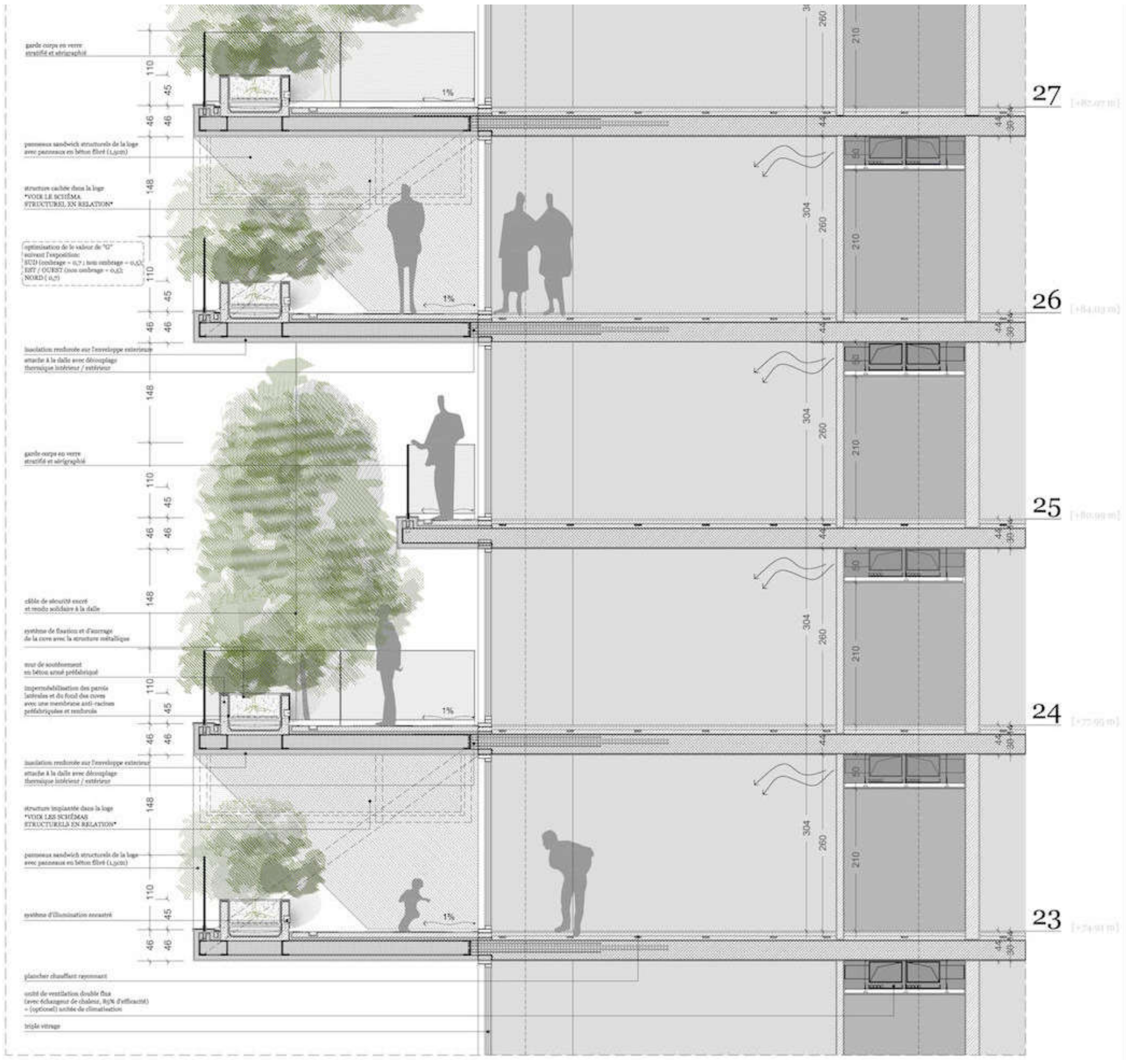
In order to give residents a better living condition, inspired by the BOSCO VERTICALE in Milan, it is decided to add plants to the net which therefore called “Green Net”. The green net provides a new green area, also improves air quality. At the same time, net provide a path for plants growing. From the surrounding, it also gives a better view to the nature.



PICTURE 4.16 GREEN NET IN THE PROJECT

4.3.4.3 Details

The green net is fixed to the floor while there is a box on the floor to provide soil for plants. Therefore the plants can grow along the net.



PICTURE 4.17 GREEN NET DETAIL

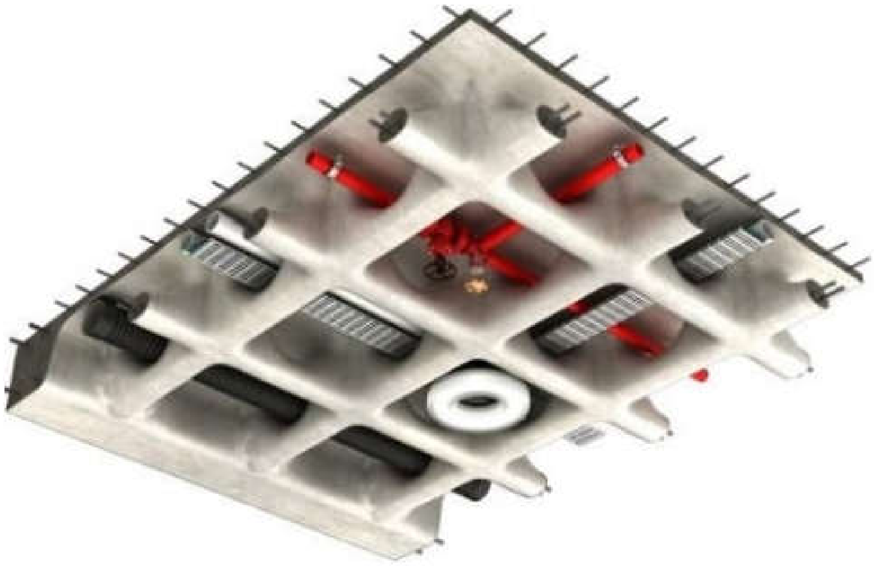
4.3.4 Waffle Concrete Slab

4.3.4.1 Why Waffle Concrete Slab

Waffle concrete slab is a structural component which is plain on its plan and contains grid like system on its bottom surface. Waffle slab has many advantages as follow:

- Volume of concrete used is very less compared to others.
- The load bearing capacity of waffle slab is greater than the other types of slabs.
- It provides good structural stability along with aesthetic appearance.
- It has good vibration control capacity because of two directional reinforcement.
- It has light weight.

- Construction of waffle slab is easy and quick with good supervision
- Several services like lighting, plumbing pipes, electrical wiring, air condition, insulation materials can be provided within the depth of waffle slab by providing holes in the waffle bottom surface.



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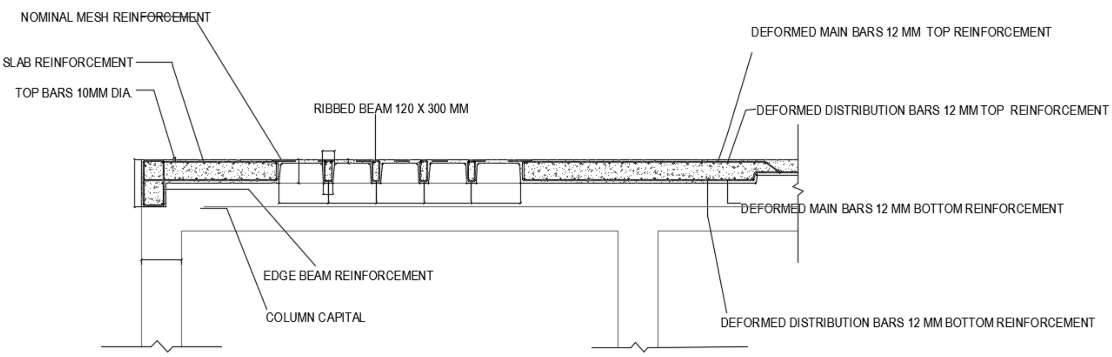
PICTURE 4.18 WALLF SLAB

4.3.4.2 Details

Waffle slab has two directional reinforcement. All the ribs are directed from column heads or beams. The depth of ribs maintained is as same as depth of column head or beam. Because of the ribs and double reinforcement, it is more stable.



DRAWING 4.11 WAFFL SLAB SECTION DETAILS

4.3.5 Glass Canopy

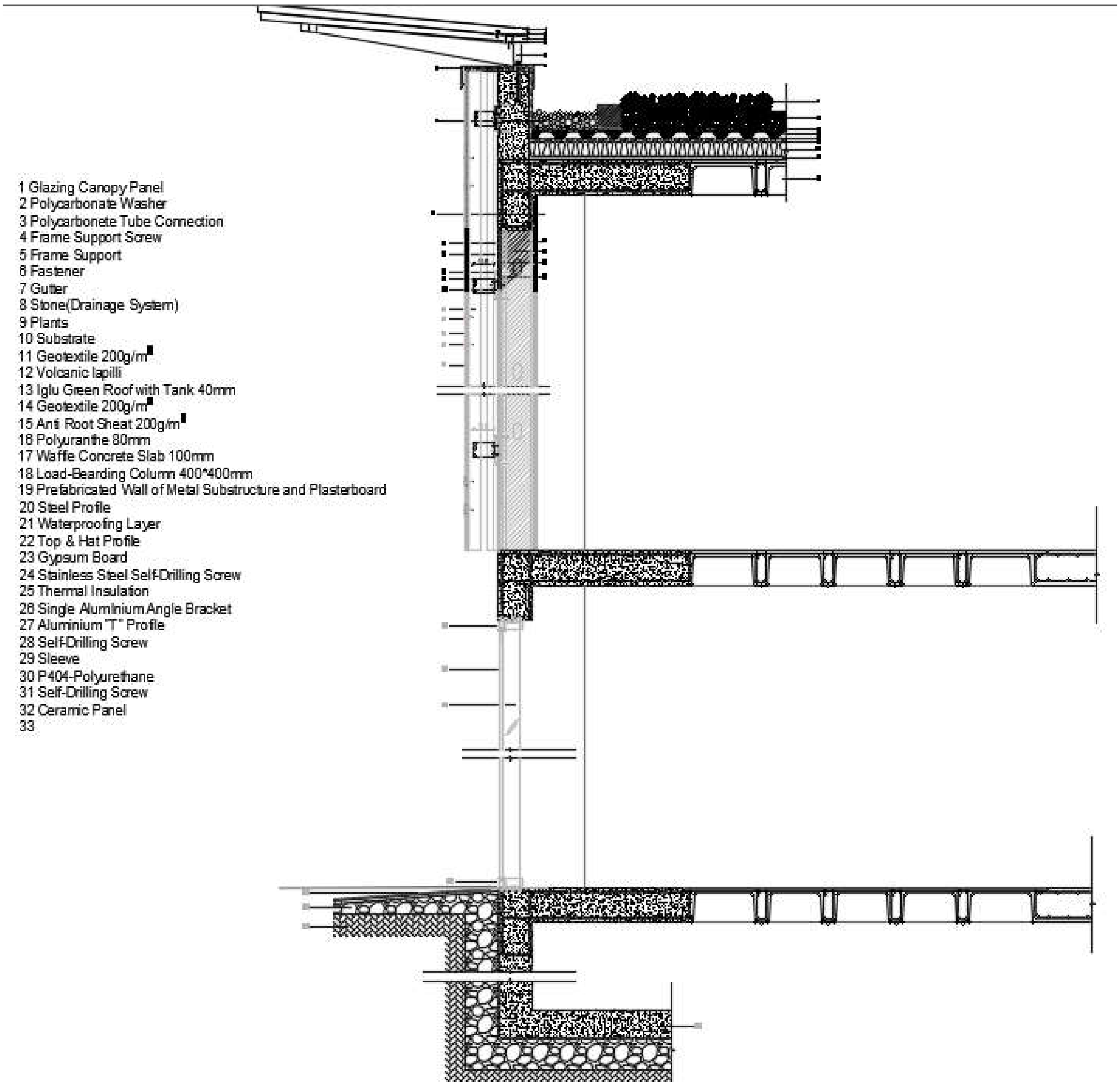
Canopy provides an attractive and practical feature to the building. The canopy can protect people entering the building, help to keep rain or other bad weather from also entering. While a glass canopy allow more natural light through into the entrance area compared to a solid canopy.

Glass canopy has many advantages as follow:

- Light the façade of the building and give more attractiveness to the building
- Identify the entry area and make it welcoming
- Provide protection from nasty weather
- Cover the walkway between buildings
- Create a signature for the façade

PICTURE 4.19 GLASS CANOPY

4.4 Technology Section



DRAWING 4.12 TECHNOLOGY SECTION

4.5 Building Service Design

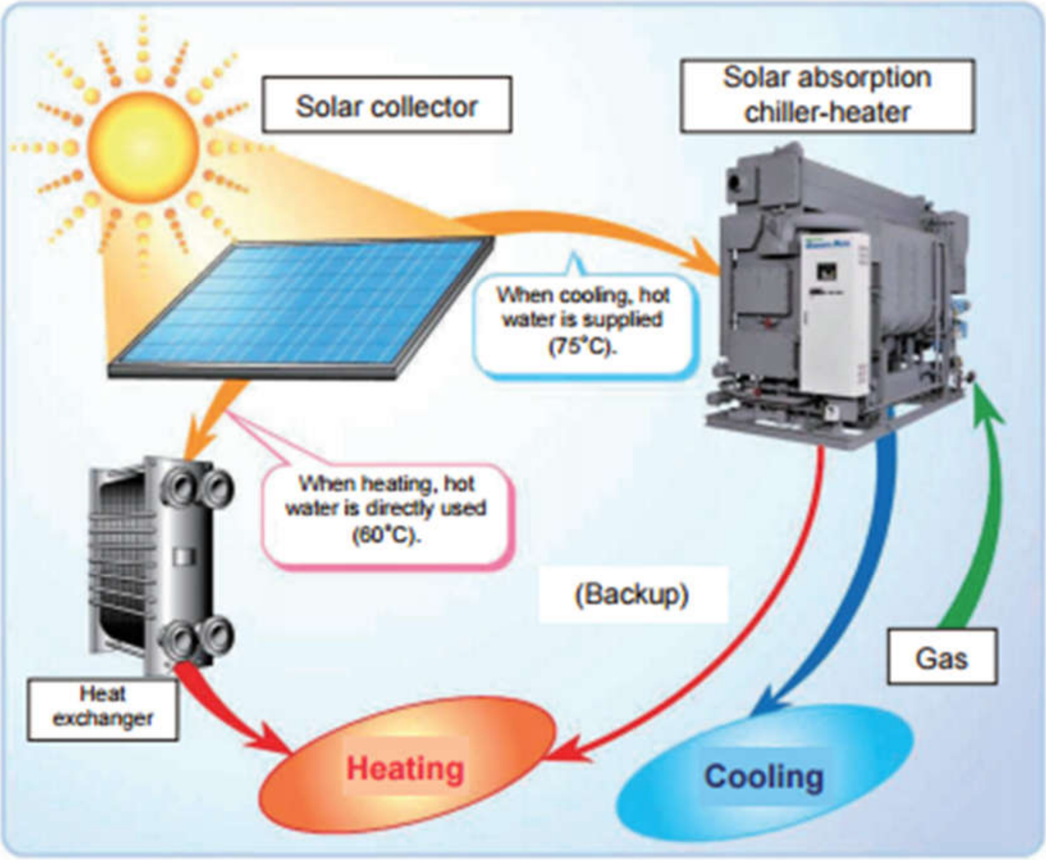
Building services are the systems installed inside buildings to make building more comfortable, functional, efficient and safe. Building services play a important role in contributing to the building design, not only in terms of overall strategies and standards to be achieved, but also in distribution of horizontal services, drainage, energy resources, sustainability and so on.

In this step, three service systems has been applied. There are ground source heat pump, rain water recovery system and PV panel.

4.5.1 Solar Absorption Chiller-Heater

Solar absorption chiller-heater is an air conditioner using solar thermal energy which is very suitable for the building in Shanghai due to its huge temperature difference between summer and winter.

The solar energy is absorbed by solar collector which is PV panel on the green roof in this case. Then the hot water heated by the solar thermal energy is supplied to the solar absorption chiller-heater. The solar absorption chiller-heater thermally recovers heat from hot water and exchanges it to lithium bromide solution in the machine, and then the natural gas consumption is reduced.



PICTURE 4.20 CONCEPTUAL DRAWING OF SOLAR ABSORPTION CHILLER-HEATER

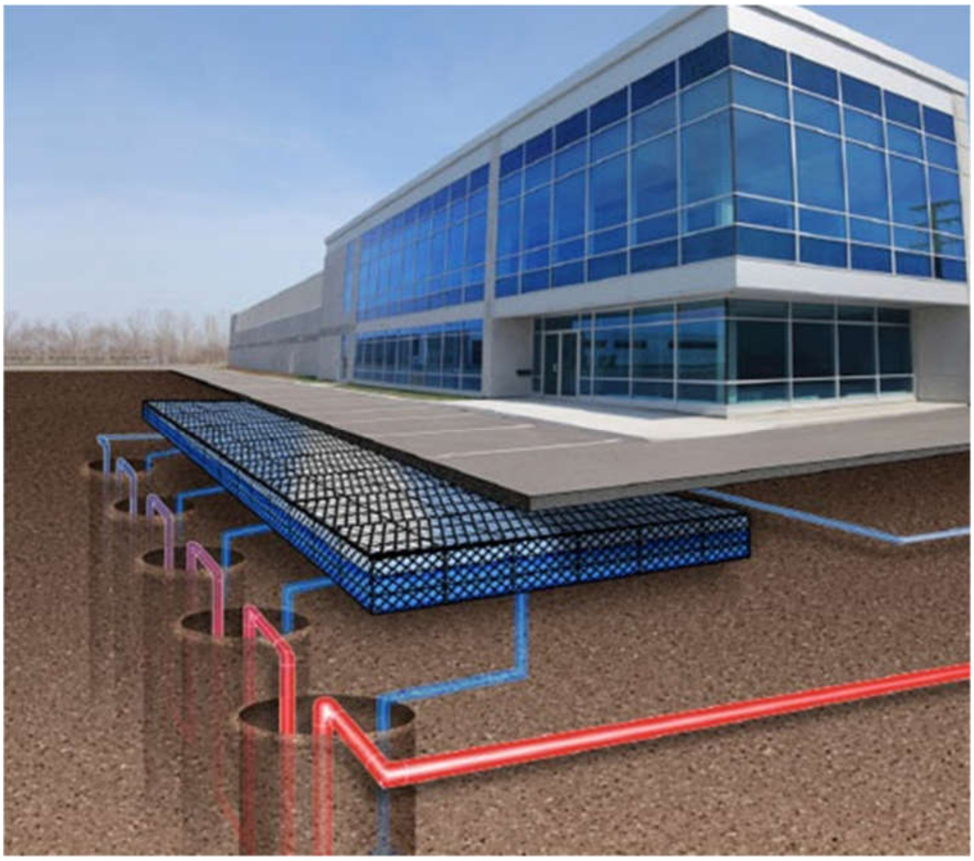
As the solar absorption chiller itself is equipped with a burner which provides combustion heat necessary in the machine, back-up system is not necessary even if the solar heat is insufficient. Furthermore, as hot water by the solar heat is preferentially used, the cooling operation is possible with the solar heat alone when cooling load is low.

4.5.2 Ground Source Heat Pump

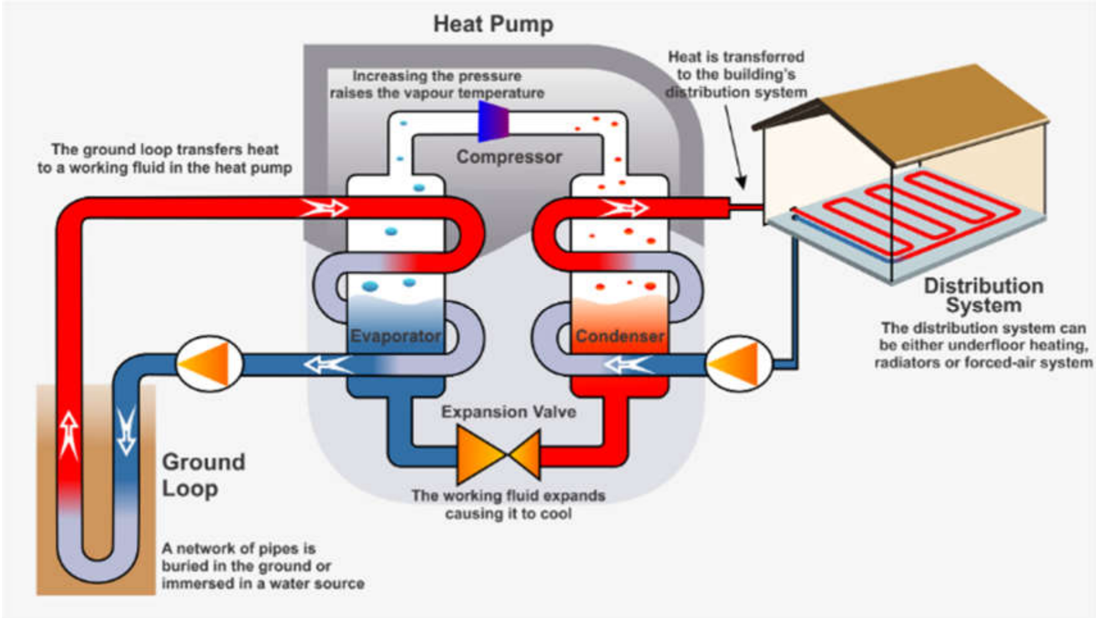
Ground source heat pump is also called geothermal heat pump which is a central heating/cooling system to transfer heat from the soil to the interior of the building. Meanwhile, the heat pump can also work the other way round, extracting heat from the building and releasing it to the ground.

The system is composed by 3 main parts which are heat pump itself, the ground loop and the distribution system. Each one of them is a separate closed circuit but it doesn't mean they work independently. Both the ground loop and the distribution system are connected to the heat pump, with which they exchange heat.

Ground source heat pump has unsurpassed thermal efficiencies and produce zero emissions locally. And it always produce fewer greenhouse gases than air conditioners, oil furnaces and electric heating. Moreover, the owner may save anywhere from 20% to 60% annually on utilities by switching from ordinary system to a ground source heat pump system.



PICTURE 4.21 CONCEPTUAL DRAWING OF GROUND SOURCE HEAT PUMP



PICTURE 4.22 GROUND SOURCE HEAT PUMP SCHEME

4.5.3 Rain Water Recovery System

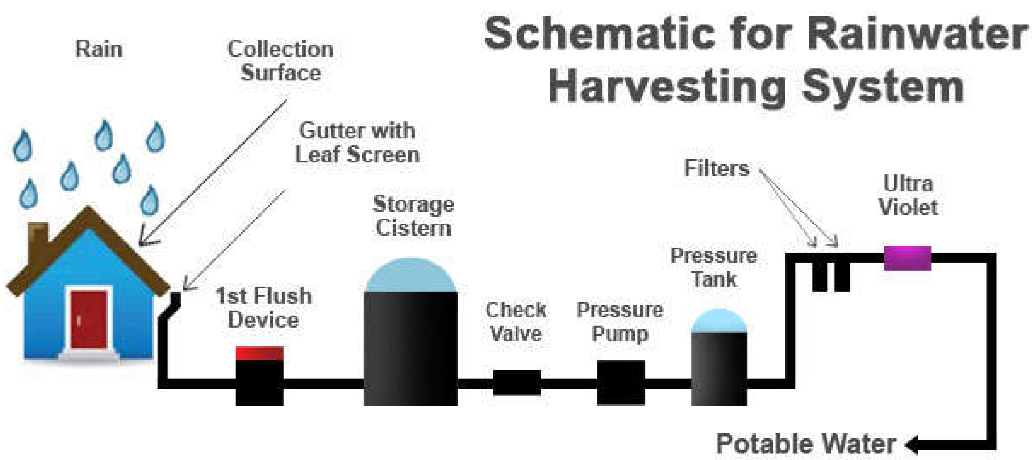
In the project, the rainwater can be absorbed by green roof. Besides, the rainwater recovery system is applied to collect the rest rainwater from roof and surface area. Rainwater recovery system is also called rainwater harvesting system.

The main element of a rainwater recovery system is the storage tank, which must be sized according to how much rainwater is to be recovered and must provide guaranteed reliability and strength. The system is composed by 4 parts which are storage tank for water storage, filter for pre-clean, submersible pump and controls to control the stored water delivered to the various points.

The main advantages for this application are as follows:

- Easy to maintain and the overall cost of installation and operation is much lower that that of water purifying or pumping systems.
- Reducing water bills: water collected in the system can be put to use for several functions as well, which leads to a large reduction in their utilities bill.

- Suitable for Irrigation: Rainwater is free from many chemicals found in ground water, making it suitable for irrigation and watering gardens. Besides, the roof garden is applied in this project, so it is beneficial to apply rainwater recovery system.
- Reduces demand on ground water: The huge demand of daily use had lead to depletion of ground water which has gone to significant low level in some areas where there is huge water scarcity .
- Reduces floods and soil erosion: It helps in reducing soil erosion and contamination of surface water with pesticides and fertilizers from rainwater run-off which results in cleaner water sources.
-



PICTURE 4.23 RAINWATER HARVESTING SYSTEM SCHEME

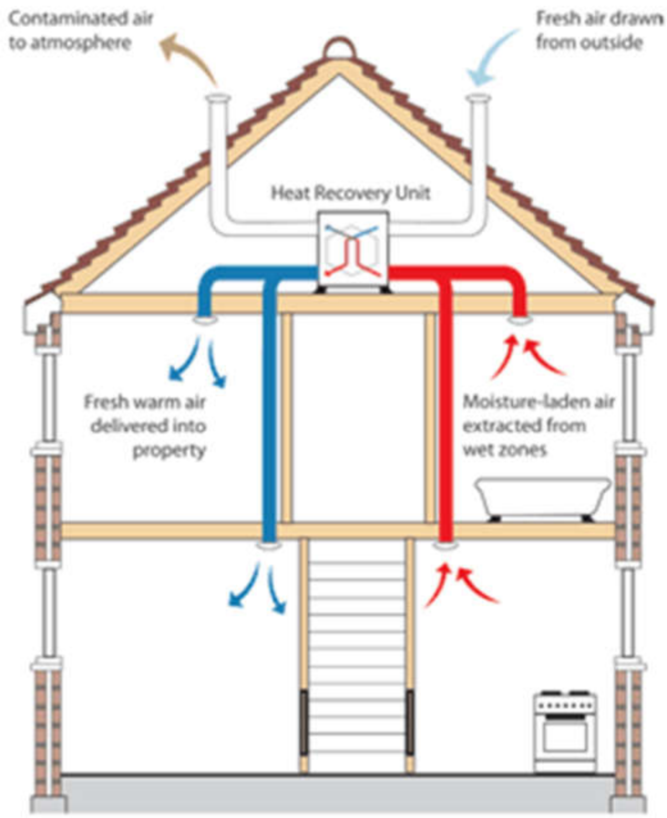
4.5.4 Heat Recovery Ventilation System

Heat recovery ventilation(HRV) is also called mechanical ventilation heat recovery, which is an energy recovery ventilation system using equipment known as a heat recovery ventilator, heat exchanger and air-to-air heat exchanger which employs a cross flow heat changer between input and output air flow. Meanwhile, the system also transfer the humidity level of the exhaust air to the intake air.

Fresh air is fed directly from outside into the ventilation system initially through a filter, then the heat taken from the extracted air is used to warm fresh filtered air in the heat exchanger and then enters the ducting system. By continuously supplying preheated air into living area and extracting contaminated air from inside room, the ventilation schedule is created in the whole area. Air is allowed to circulate from the supply air rooms to rooms.

Heat recovery ventilation system has many advantages as follow:

- With this system, the higher air quality is supplied at any time in the year, keeping them cool in the summer and warm in the winter.
- It significantly reduces the levels of carbon dioxide emitted and energy consumption.
- It significantly reduces heating and cooling bill and reduces the need for air conditioning.



PICTURE 4.23 HEAT RECOVERY VENTILATION SYSTEM SCHEME

5. Structure Design

5.1 Reinforcement Concrete Frame Structure

5.1.1Why Reinforcement Concrete

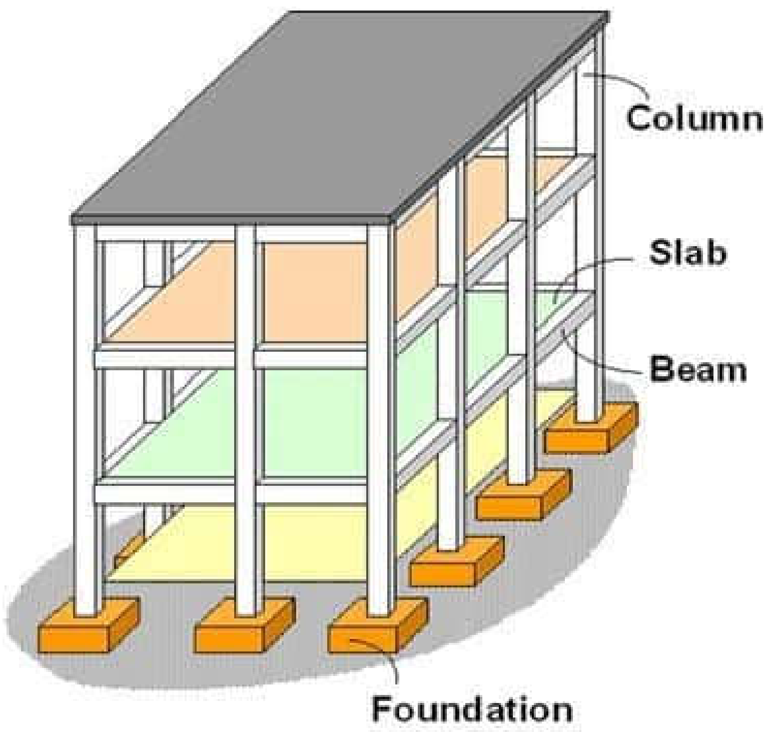
Nowadays reinforcement concrete is a popular material to help to ensure structure remaining strong and durable for many years. Reinforced concrete is made by casting wet concrete over a cage of steel reinforcing bars. The concrete then dries and hardens around the bars. Reinforcement concrete has many advantages as follows.

- High compressive and tensile strength. The concrete provides the compressive strength and the steel provides the tensile strength. This reinforcement allows the construction of tall buildings and other structures.
- Cost-effective. Reinforcement concrete is very cost-effective. It is cement mixed with aggregates and water, with a relatively small amount of steel added for reinforcement. This combination makes concrete much cheaper to use than steel and other building materials.
- Weather resistant. Water reducing additives that create air cells make concrete resistant to freeze-thaw cycles because the microscopic chambers of air relieve pressure when water expands as it freezes.
- Corrosion resistant. Water reducers can be used to create low permeability which helps keep out corrosive elements.
- Fire resistant. The low rate of heat transfer can also make the interior remains cooler than the surfaces.

5.1.2 Why Frame Structure

The frame structure utilizes a structural system formed by a frame of beams and columns in both vertical and horizontal direction which is subjected to both vertical and horizontal loads. The wall of frame structure does not bear any load, only for the separation and protection from exterior. Due to the lateral stiffness of the frame structure is relatively smaller than the other structures, the number of stories are limited if the frame structure is applied. The highest story in this project is 7. So the frame structure can be applied. The frame structure has many advantages as follows.

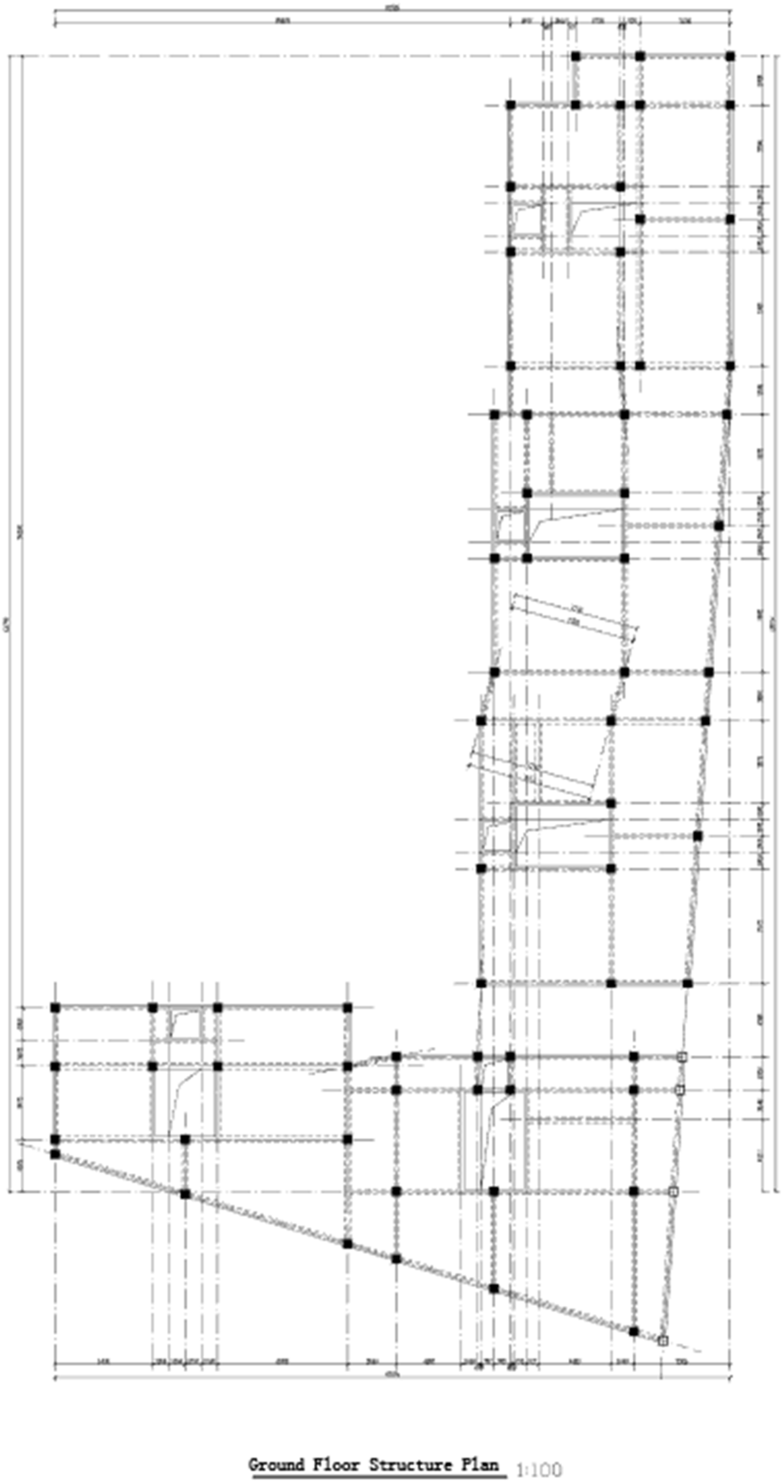
- Good resistance to compression and bending. Therefore, it is possible to increase the space and height of the building.
- Lower weight of the building.
- Good resistance to earthquake
- Good performance in integrity
- Good ductility



PICTURE 5.1 FRAME STRUCTURE SHCEME

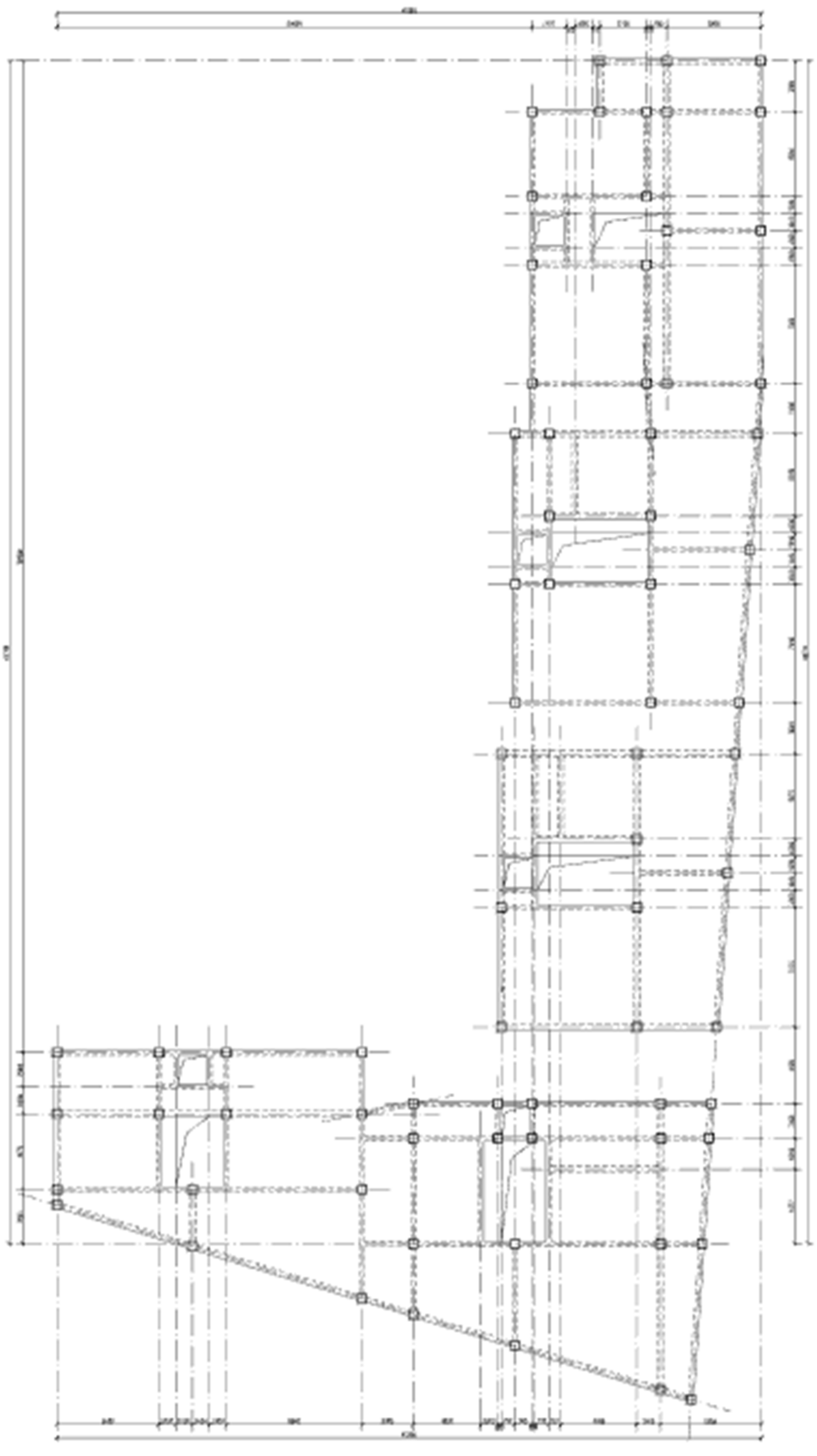
5.2 Structure Plan

5.2.1 Ground Floor Structure Plan



DRAWING 5.1 GROUND FLOOR STRUCTURE PLAN

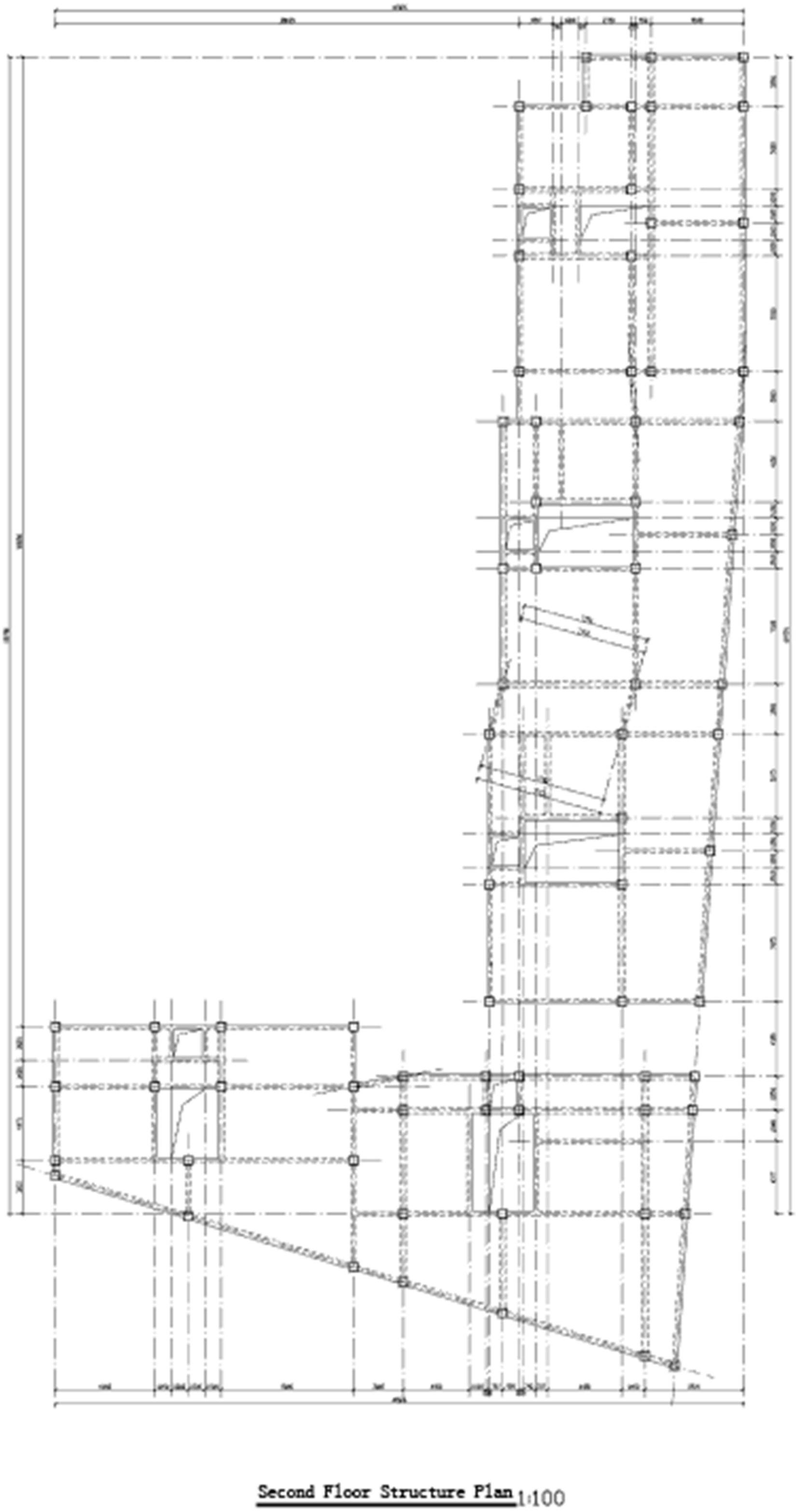
5.2.2 First Floor Structure Plan



First Floor Structure Plan 1:100

DRAWING 5.2 FIRST FLOOR STRUCTURE PLAN

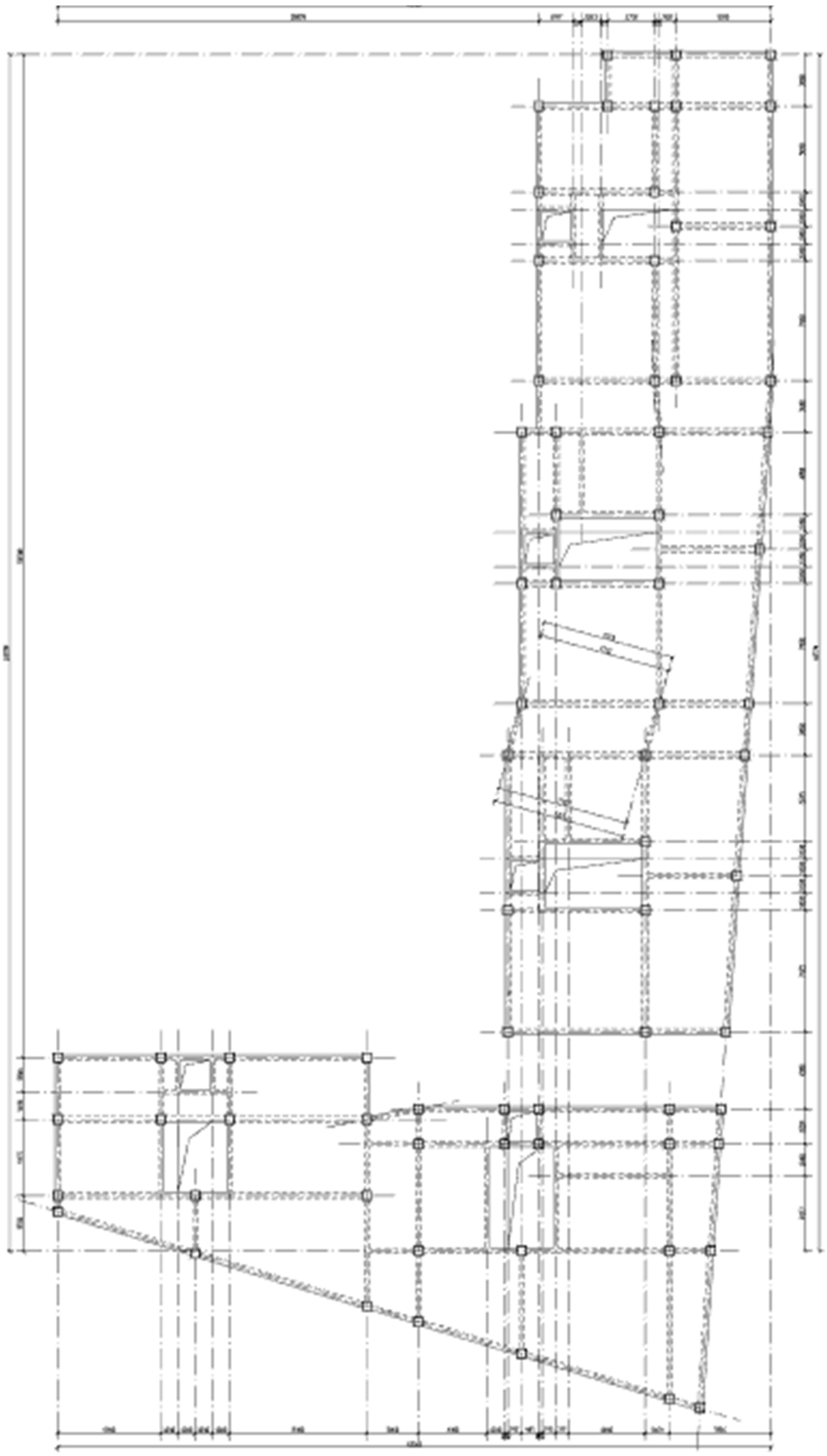
5.2.3 Second Floor Structure Plan



Second Floor Structure Plan 1:100

DRAWING 5.3 SECOND FLOOR STRUCTURE PLAN

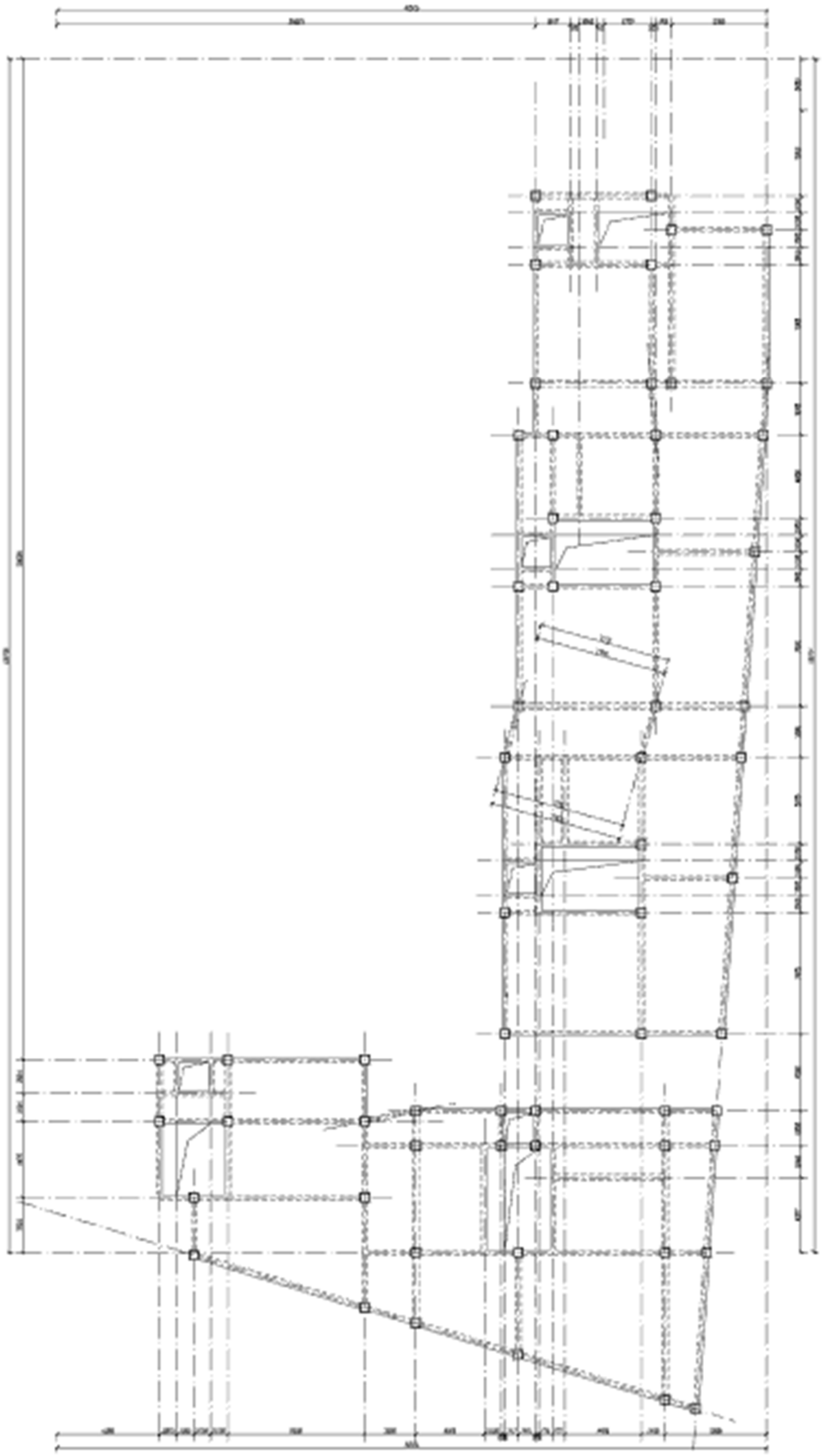
5.2.4 Third Floor Structure Plan



Third Floor Structure Plan 1:100

DRAWING 5.4 THIRD FLOOR STRUCTURE PLAN

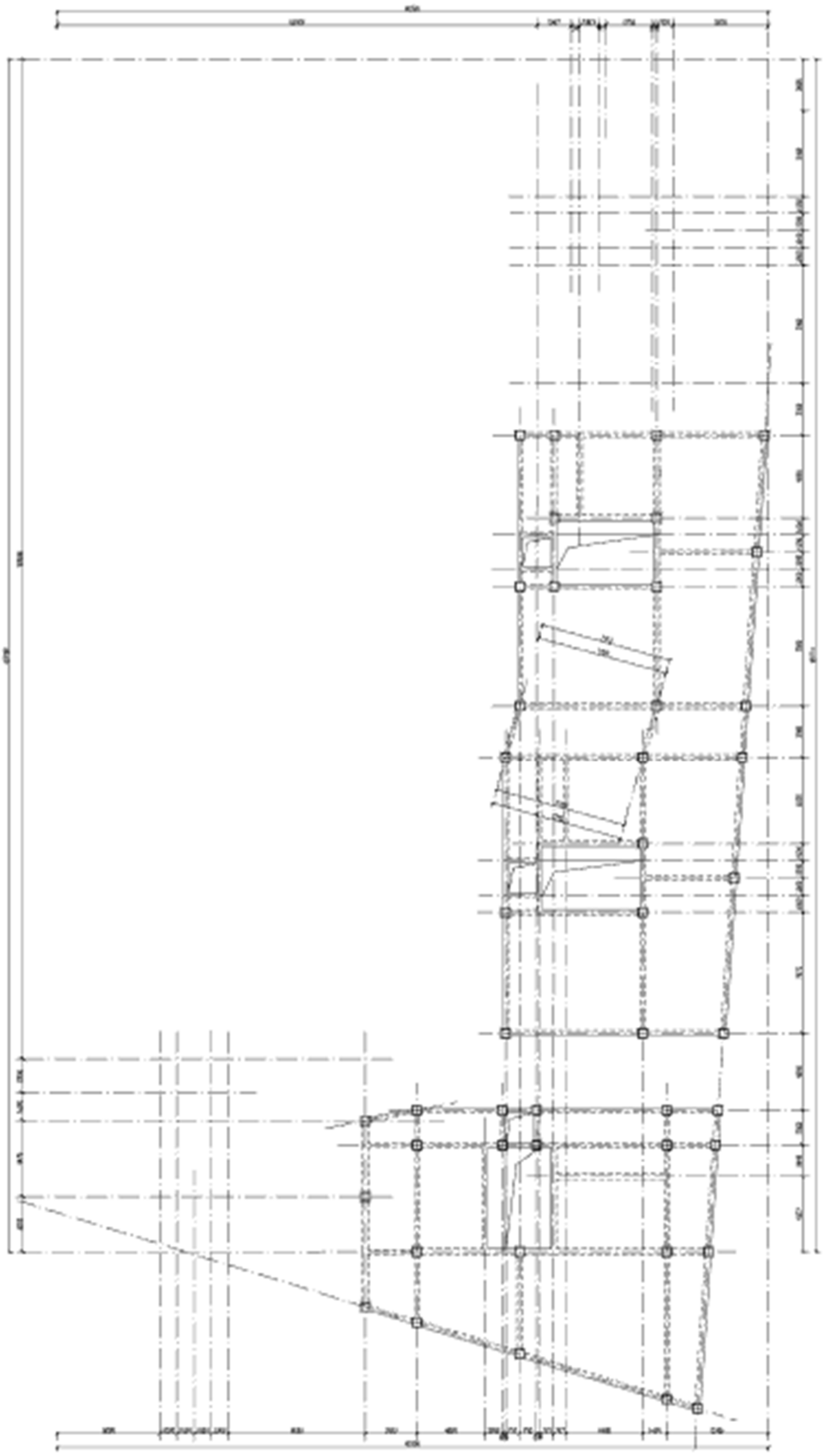
5.2.5 Fourth Floor Structure Plan



Fourth Floor Structure Plan 1:100

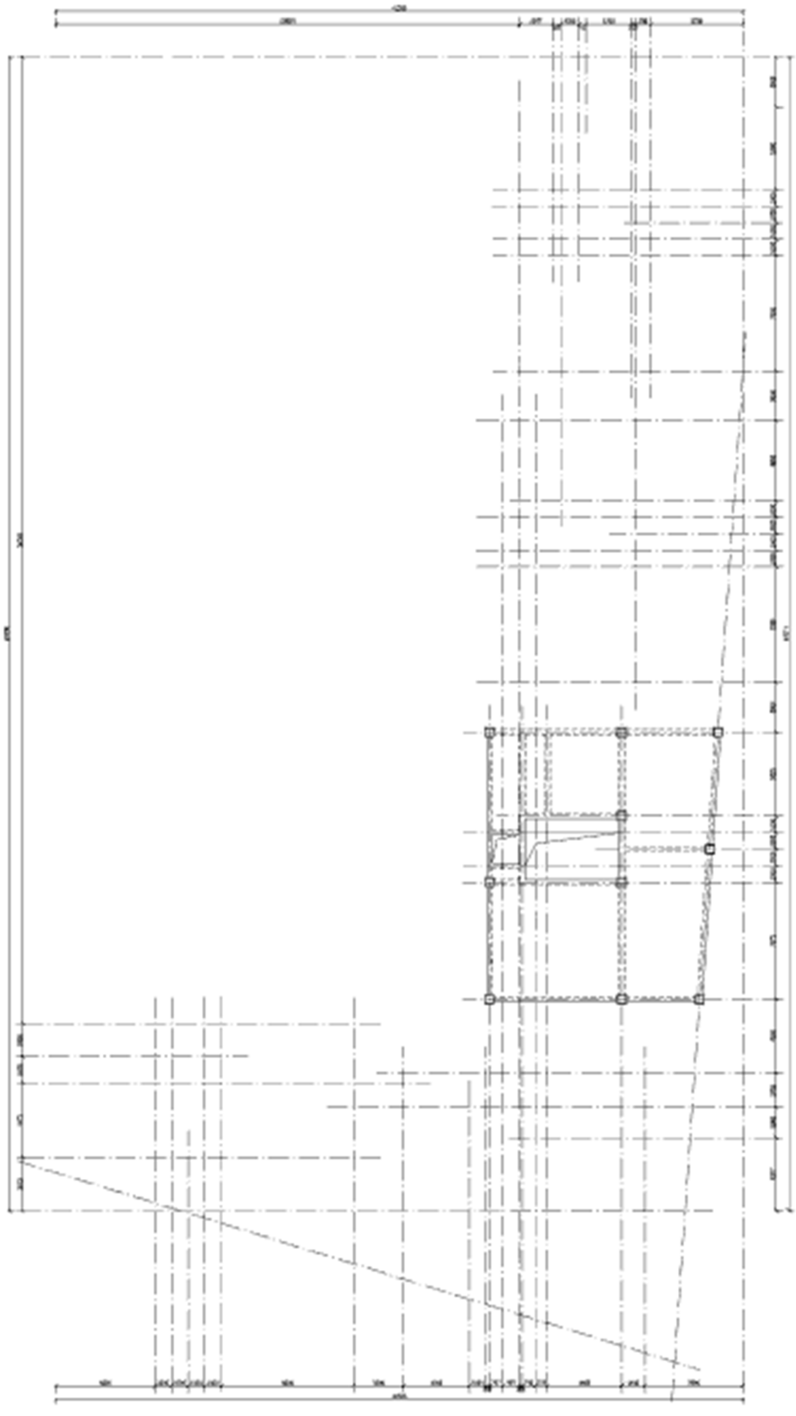
DRAWING 5.5 FOURTH FLOOR STRUCTURE PLAN

5.2.6 Fifth Floor Structure Plan



DRAWING 5.6 FIFTH FLOOR STRUCTURE PLAN

5.2.7 Sixth Floor Structure Plan



DRAWING 5.7 SIXTH FLOOR STRUCTURE PLAN

5.3 Load Calculation

5.3.1 Materials

Concrete strength class: C25/30

Characteristic cylinder compressive strength

$$fck = 25\ N/mm^2$$

Design compressive strength1 [EC2 – 3.1.6(1) and Table 2.1N for γ_c]

$$f_{cd} = \partial_{cc}\frac{f_{ck}}{\gamma_c} = 0.85*\frac{25}{1.5} = 14.2N/mm^2$$

Allowable compressive stress under characteristic combination of actions [EC2 – 7.2(2)]

$$\sigma c, adm = K1 * fck = 0{,}6 * 25 = 15\ N/mm^2$$

Medium tensile strength [EC2 – Table 3.1]

$$fctm = 0{,}3(fck)^{\frac{2}{3}} = 2{,}6\ N/mm^2$$

Characteristic tensile strength [EC2 – Table 3.1]

$$fctk; 0{,}05 = 0{,}7 * fctm = 0{,}7 * (2{,}6) = 1.8\ N/mm^2$$

Design tensile strength [EC2 – 3.1.6(2) and Table 2.1N for C]

$$fctd = \alpha ct\frac{fctk; 0{,}05}{\gamma c} = 1{,}2\ N/mm^2$$

Secant modulus of elasticity [EC2 – Table 3.1]

$$Ecm = 22 * \left(\frac{fcm}{10}\right)^{0{,}3} = 22 * \left(\frac{fck + 8}{10}\right)^{0{,}3} = 22 * \left(\frac{25 + 8}{10}\right)^{0{,}3} = 31000\ N/mm^2$$

High ductility steel type B450C

Characteristic yield strength

$$fyk \geq 450\ N/mm^2$$

Design yield strength [EC2 – 3.2.7 and Table 2.1N for S]

$$fsd = \frac{fyk}{\gamma s} = \frac{450}{1.15} = 391\ N/mm^2$$

Admissible stress under characteristic combination of actions [EC2 – 7.2(5)]

$$\sigma s, adm = K3 * fyk = 0{,}8 * 450 = 360\ N/mm^2$$

Modulus of elasticity [EC2 – 3.2.7(4)]

$$Ecm = 200000\ N/mm^2$$

5.3.2 Building Elements Loads

5.3.2.1 Self-weight of structural and non-structural elements

The following loads refer to a square meter of a typical floor.

TABLE 5.1 DEAD LOAD CALCULATION OF THE EXTERIOR WALL

No.	Layers	Thickness (m)	Specific weight (KN/m^3)	Weight (KN/m^2)
1	External Panel	0.003	20	0.06
2	Air Gap(Ventilation)	0.2	0	0
3	Plaster	0.02	20	0.4
4	Insulation	0.10	0.12	0.012
5	Internal Plaster	0.02	20	0.4
6	Fiber Cement	0.1	12.5	1.25
7	Internal Plaster	0.02	20	0.4
Total				2.522

TABLE5.2 DEAD LOAD CALCULATION OF THE EXTERIOR WALL

Weight	Floor Height	Opening	Total Liner Weight
KN/m2	m	%	KN/m
2.522	3	-20	6.53

The load of the external walls is directly applied on the beams along the perimeter and it is not shared out with slabs.

5.3.2.2 Internal Partition

TABLE 5.3 DEAD LOAD CALCULATION OF THE INTERNAL PARTITION

No.	Layers	Thickness (m)	Specific weight(KN/m^3)	Weight (KN/m^2)
1	Plaster board	0.02	15	0.3
2	Glass mineral wool	0.10	0.12	0.012
3	Plaster board	0.02	15	0.3
Total				0.612

TABLE 5.4 DEAD LOAD CALCULATION OF THE INTERNAL PARTITION

Weight	Floor Height	Opening	Weight
KN/m2	m	%	(KN/m^2)
0.612	3	0	1.84

EN 1991-1-1 [§ 6.3.1.2(8)] permits to consider an equivalent uniformly distributed load all over the floor, instead of the free action of movable partitions, if the slab can well redistribute the load transversally. The nominal value of this uniform load is given in function of the linear self-weight of the wall considered:

- for movable partitions with a self-weight 1.0 kN/m wall length: q_k = 0.5 kN/m2
- for movable partitions with a self-weight 2.0 kN/m wall length: q_k = 0.8 kN/m2
- for movable partitions with a self-weight 3.0 kN/m wall length: q_k = 1.2 kN/m2

So with the calculation of previous session it is concluded that q_k equals to 0.8 kN/m2.

This load is considered as a live load with a safe factor of γ_c=1.5 for Ultimate Limit State (ULS)
combinations and coefficients ψ_0=ψ_1=ψ_2=1.0 Serviceability Limit State (SLS) combinations.

5.3.2.3 Typical Floor

The slab is a tile-lintel floor made of concrete joists, 100 mm wide and 200 mm high every 500 mm, and a superior reinforced concrete slab 40 mm thick, formed up with lightened bricks (200 mm x 400 mm).

TABLE 5.5 DEAD LOAD CALCULATION FOR THE FLOOR FINISH

Layer	Dimension	Thickness	Specific Weight	Weight
	Cm2	m	kN/m³	kN/m²
Topping		0.04	25	1
Ribs	(2*10*20)/100	0.04	25	1
Bricks	(2*40*20)/100	0.16	11	1.76
Total	/	/	/	3.76

In order to estimate the incidence of concrete riddles the following procedure is applied.

The weight of a reinforced concrete slab with a height of 240 mm is

$0.24*25 = 6{,}00\ kN/\ m^2$

Detracting the weight of the tile-lintel floor previously calculated

$6.00\ kN/\ m^2 - 3.76\ kN/m^2 = 2.24\ kN/m^2$

The total width of riddles is estimated equal to 2.4 m (0.5 m each of the side beams, 1.2 m the central beam and 0.1 m each of the longitudinal joists) considering the entire width of the typical floor (11.1 m). In the end the following result can be achieved for the incidence of riddles.

$(2.24 \cdot 2.4)/11.1 = 0{,}48\ kN\ m^2$

TABLE 5.6 DEAD LOAD CALCULATION FOR THE TYPICAL FLOOR

Layer	Thickness	Specific Weight	Weight
	m	kN/m³	kN/m²

Tile-lintel Floor	0.24	/	3.76
Riddles	/	/	0.48
Sum			4.24
Tile Floor	0.02	20	0.4
Subfloor	0.06	20	1.2
Ceiling Plaster	0.02	20	0.4
Sum			2
Total			6.24

5.3.2.4 Roof

TABLE 5.7 DEAD LOAD CALCULATION FOR THE GREEN ROOF

No.	Layers	Thickness (m)	Specific weight(KN/m^3)	Weight (KN/m^2)
1	soil	0.12	9	1.08
2	Green roof system	/	/	3.08
3	Water proof membrane	0.006	9.5	0.057
4	Fiber glass insulation	0.15	11	1.65
5	Concrete slab	0.1	23	0.23
Total				6.10

5.3.3 Imposed Load

According to the EN 1991-1-1, section6.6, table 6.1 and 6.2 in accordance with the National Annex

Imposed load of the partition wall with less than 2 KN/m run q_k = 0.8 KN/m²

Imposed floor load for Office buildings (category B) = 2 to 3 KN/m²

Imposed floor load for Museum/ Exhibition halls (category C3) = 3 to 5 KN/m²

According to EN 1990:2002, table A.1.1 for office buildings, the partial safety factor and combination factor to be considered for ultimate limit state is

Partial safety factor, γ = 1.5

Combination factor, Ψ = 1.35

The imposed load is 2.00KN/m2

5.3.4 Snow Loads

s	1.2 KN/m2	$\mu_i . C_e . C_t . s_k$
S		Characteristic value of snow on the roof
μ_i	0.8	Snow load shape coefficient equal to 0.8 for an angle of the pitch of the roof less than 30°
C_e	1	Exposure coefficient function of the topography of the site. Ce=1.0 for normal topography that is “areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works, or trees”.
C_t	1	Thermal coefficient that should be used to account for the reduction snow loads on the roof without high thermal transmittance Ct=1
S_k	1.5 KN/m2	Characteristic value of the snow load on the ground. For provincial di Milano, for a design working life of the structure of 50 years in accordance with the initial design assumptions Sk=1.5KN/m2

5.4 Column Design

5.4.1 Pre-dimensioning

The influence area over the column is:

*5.55 m^2=16.65 m^2

Modified influence area (redundancy coefficient = 1.4);

1.4*16.65 m^2=23.31 m^2

For the calculation of columns only, a reduction factor defined by [EC1 – 16.3.2(10)] can be applied to variable loads:

$$\alpha A = \frac{5}{7}\psi 0 + \frac{A0}{A} \leq 1$$

Where

ψ_0=0.7

A_0=10 m2

A is the influence area of the column considered

For column P15: $\alpha A = 0.93$

Roof loads

- Roof slabs

6.1KN/m^2*16.65m^2=101.57KN

- Weight of the rib of the beam(redundancy coefficient = 1.2)

1.2*0.3m*0.4m*5m*25KN/m^3=18KN

- Snow

1.5KN/m^2*16.65m^2=24.98KN

Typical floor loads

- Slab self-weight

6.24 KN/m^2*16.65m^2=103.90KN

- Variable loads (inside partitions included)

0.612 KN/m^2*16.65m^2=10.19KN

Loads on every storey are:

TABLE 5.8 LOADS ON EVERY STOREY

	GF	1st	2nd	3rd	4th
Dead Load	330	354.04	354.04	354.04	354.04
Variable Load	18	234.87	234.87	234.87	234.87
Variable Load*αA		218.43	218.43	218.43	218.43

For the ULS combination of actions, a single multiplicative factor will be referred to, as a simplification: γ_{f^*} is obtained as weighted mean of the coefficients $\gamma_G = 1.35$ and $\gamma_Q = 1.5$, respectively concerning permanent actions and variable actions.

$$\gamma f = \frac{\gamma G * Gk + \gamma Q * Qk}{Gk + Qk} = \frac{1.35 * 263.02 + 1.5 * 139.59}{263.02 + 139.59} = 1.40$$

So the pre-dimensioning of the column is shown below.

TABLE 5.6 PRE-DIMENSIONING

	F_k	$N=\Sigma F_{kj}$	$N_{Ed} = \gamma f^* N$	Ac0=Ned/fcd	b	h	A_c
	(KN)	(KN)	(KN)	mm^2	mm	mm	mm^2
3RD Floor	550.8	550.8	771.12	4536.00	500	500	250000
2nd Floor	571.42	1122.22	1571.11	9241.81	500	500	250000
1st Floor	571.42	1693.64	2371.10	13947.62	500	500	250000
Ground Floor	571.42	2265.06	3171.08	18653.44	500	500	250000

Where

F_k is the axial load on each floor

N is the sum of the axial loads

Column self-weight

$0.4m*0.4m*3m*25KN/m^2=12KN$

The table below is updated to consider the column action

TABLE 5.7 SELF-WEIGHT INFLUENCE ON COLUMNS

Column	b	h	H	Weight concrete	Self weight
	mm	mm	mm	KN/m^3	KN
3^{RD} Floor	500	500	3000	25	18.75
2^{nd} Floor	500	500	3000	25	18.75
1^{st} Floor	500	500	3000	25	18.75
Ground Floor	500	500	3000	25	18.75

In the next Tab. the design axial load is modified in order to take into account the self-weight of the column at each floor.

TABLE 5.8 PRE-DIMENSIONING

	F_k	$N=\Sigma F_{kj}$	$N_{Ed} = \gamma f^* N$	Ac0=Ned/fcd	b	h	A_c
	(KN)	(KN)	(KN)	mm^2	mm	mm	mm^2
3^{RD} Floor	569.55	569.55	797.37	4690.41	500	500	250000
2^{nd} Floor	590.17	1159.72	1623.61	9550.64	500	500	250000
1^{st} Floor	590.17	1749.89	2449.85	14410.85	500	500	250000
Ground Floor	590.17	1764.30	2470.02	14529.54	500	500	250000

5.4.2 Longitudinal reinforcement pre-dimensioning

It is then necessary to dimension the longitudinal reinforcement.

According to EC2 the following limits is applied:

Technological limits: at least one bar needs to be placed at each corner of a polygonal column, whose diameter needs to be not less than 12mm [EC2 – 9.5.2(4) and 9.5.2(1) – National Annex]

Geometrical limit: As ≥0.003 Ac [EC2 – 9.5.2(2) – National Annex]

Static limit: As≥ 0.10 NEd/fyd [EC2 – 9.5.2(2)]

From the rules listed above, the proposed pre-dimensioning is shown below:

TABLE 5.8 PRE-DIMENSIONG OF LONGITUDINAL REINFORCEMENT

Column	A_c	$A_{s,min}$	$A_{s,min}$	4 ϕ12	n° x ϕ	A_s
	mm^2	ρ_s=0.3%	0.1 Nsd/fyd	mm^2	12ϕ20	mm^2
3RD Floor	250000	750	128.70	452	12ϕ20	2422
2nd Floor	250000	750	264.79	452	12ϕ20	2422
1st Floor	250000	750	400.88	452	12ϕ20	2422
Ground Floor	250000	750	537.97	452	12ϕ20	2422

5.4.3 ULS and SLS verification

Both Ultimate Limit States and Serviceability Limit States verifications can then be performed.

The translational equilibrium of the cross-section for SLS is:

N = σc Ac + σs As

Under the hypothesis of plane sections(Eulero-Bernoulli), same strain in steel and surrounding concrete (εc = εs) and elastic materials, it is σs = αe σc,where the ratio between the modulus of elasticity αe is assumed equal to 15 in order to take into account the timedependent behavior of concrete.

N = σc (Ac + αe As) = σc Aie

Obviously it needs to be

$$\sigma c = \frac{N}{Aie} \leq \sigma cadm = 0.6fck = 15\ N/mm2$$

TABLE 5.9 SLS VERIFICATION

Column	A_c	A_s	A_{ie}	N	σ_c	$<\sigma_{c,adm}$
	mm^2	mm^2	mm^2	KN	N/mm^2	
3RD Floor	250000	2422	286330	569.55	1.99	OK
2nd Floor	250000	2422	286330	1159.72	4.05	OK
1st Floor	250000	2422	286330	1749.89	6.11	OK
Ground Floor	250000	2422	286330	1764.30	6.16	OK

The translational equilibrium for ULS is

$N_{Rd} = A_c\, f_{cd} + A_s\, f_{yd}$

TABLE 5.10 ULS VERIFICATION

Column	A_c	A_s	N_{ed}	N_{rd}	N_{Rd}/N_{ed}
	mm^2	mm^2	KN	N/mm^2	
3RD Floor	250000	2422	797.37	4358.99	5.47
2nd Floor	250000	2422	1623.61	4358.99	2.68
1st Floor	250000	2422	2449.85	4358.99	1.78
Ground Floor	250000	2422	2470.02	4358.99	1.76

5.4.4 Transversal reinforcement

In Eurocode 2 some prescriptions on transversal reinforcement are outlined.The minimum diameter of transversal bars needs to be not less than 1/4 of the longitudinal diameter and however not less than 6mm.The spacing of the transverse reinforcement along the column needs not to exceed the following limits:

- 20 times the longitudinal bar size (20*12=240mm,20*14=280mm)
- the smaller dimension of the column (at most,300mm)
- 400mm

In those sections within a distance equal to the larger dimension of the column cross section above and below beams and slabs, the previous limits are reduced by a factor 0,6 (0.6*240=144mm)

Stirrups φ8/200 will be applied along all the columns, whereas at the bottom and the top of the columns for a distance equal to 500mm stirrups φ 8/125 will be applied.

5.5 Foundation Design

A simple calculation of the foundation under the column is shown as follow.

5.5.1 Bearing Capacity

The maximum axial load at the bottom of the column considered is:

N = 68031.1KN

Assuming a rectangular plinth, whose dimension is a*b*h=3.5*3.5*0.8m

The self-weight of the foundation is

G_{plinth}= (3.5*3.5*0.8)*25 = 245 KN

Assuming a gravel soil with internal friction angle equal to φ= 35° and density γ= 18 kN/m^3, the bearing capacity of the soil is given by the Terzaghi formula, where the pressure due to the lateral soil is not considered.

$$\sigma_{Rd,terreno} = s_\gamma\, N_\gamma\, \gamma\, b/2$$

where $s_\gamma = 1\text{-}0.4\ b/a$

$$N_\gamma = 2\,[e^{\pi tg\phi}\, tg^2\left(\frac{\pi}{4}+\frac{\phi}{2}\right)+1]\ tg\phi$$

The verification implies that σ_{Rd},> σ_{Ed}, where σ_{Ed} is the design pressure on the soil due to loads and foundation self-weight. According to Eurocode 7 [EC7 – 2.4.7.3.4] and Eurocode 0 [EC0 – A1.3(5), the following values for combination coefficients apply, where γ refers to actions, γ_m refers to geotechnical parameters and $_R$ refers to the soil resistance after the previous calculations.

γ_F = γ_G = 1.0 for permanent loads [EC7 – Table A.3]

γ_F = γ_G = 1.3 for variable loads [EC7 – Table A.3]

A single value can be used averaging the previous coefficients: γ_F = 1.3

γ_m = 1.25 for the internal friction angle [EC7-Table A4] and to be applied to the tangent of the angle φ

γ_m = 1.0 for the soil density [EC7-Table A4]

γ_m = 1.4 [EC7-Table A5]

N_{ED} = 1.13N +1.0 G_{plinth} = 1876.65 KN

σ_{Ed} = N_{Ed}/ab = 1876.65 /(3500·3500) = 0.153 N/mm

s_g = 0.6

tgφ = tg 35°/1.25 = 0.56

Ng = 20.06

σ_{Rd} = [0.6*20.06*18kN/m3*3500mm/2]/1.4 = 0.27 > σ_{Ed}

5.5.2 Plinth Verification

The reinforcement of the plinth is dimensioned and the coefficient to be applied to the combination of actions area taken in accordance with EC7 – 2.4.7.3.4 and EC0 – A1.3(5).

A direction:

da = 750 mm

ca = a'/4 = 100 mm

la = (a-a')/4 + ca = (3500-400)/4 + 100 = 875mm

λa = la/da = 8750/750 = 1.16

$P_{Ed,sa}$ = (a-a')/a , N_{Ed} = (3500-400)/3500*1.4*1501.47 kN = 1861.82kN

$Asa,min = P_{Ed,sa}*\lambda a/2f_{yd} = 2401\ mm^2$

Assuming 8φ20 (φ20/250) the reinforcement area is Asa = 2512 mm^2 and the resistance is

$P_{Rd,s} = 2A_{sa}\ f_{yd}\ \lambda_a = 2\cdot 2512\cdot 391\cdot 1 = 1964.38\ kN > P_{Ed,sa}$

B direction:

$d_b = 750\ mm$

$c_b = b'/4 = 100\ mm$

$l_b = (b-b')/4 + c_b = (3500-400)/4 + 100 = 875\ mm$

$\lambda_b = l_b/d_b = 875/750 = 1.16$

$P_{Ed,sa} = (b-b')/b*N_{Ed} = (3500-400)/3500*1.4*1501.47\ kN = 1861.22kN$

$A_{sb,min} = P_{Ed},s_b*\lambda_b/2f_{yd} = 2401\ mm^2$

Assuming 8φ20 (φ20/250) the reinforcement area is A_{sb} = 2512 mm^2 and the resistance is

$P_{Rd,s} = 2A_{sb}*f_{yd}*\lambda_b = 2*2512*391*1.16 = 2278.68\ kN > P_{Ed,sb}$

The compression struts verification can be performed as follows.

$$PEd,c = NEd\left(1-\frac{a'b'}{ab}\right) = 1.4*1501.47*\left(1-\frac{400*400}{3500*3500}\right) = 2074.60\ kN$$

$$PRd,c = 2*0.4\left(\frac{dab}{1+\lambda a^2}+\frac{db}{1+\lambda b^2}\right)fcd = 13.6\left(\frac{750*400}{1+1.16}+\frac{750*400}{1+1.16}\right) = 3777.77\ kN > PEd,c$$

5.6 Software Modeling

Due to the limitations of manual calculations, it is impossible to complete the structural calculation of all components, so the software is used for structural calculation. The calculation software used for this case is PKPM.

5.6.1 General Information

5.5.1.1 Materials Information

Concrete bulk density (KN/m^3)	G_c = 25.00
Steel weight	G_s = 78.00
Angle of horizontal force (degree)	ARF = 0
Wind load calculation information	Along X,Y direction
Seismic force calculation information	Along X,Y direction
"Prescribed horizontal force" calculation method	Normative method
Structure category	Frame Structure
Whether the elastic plate and the beam deformation are coordinated	Yes
Whether to impose rigid floor assumptions on the whole building	No
Structure Location	Shanghai

5.5.1.2 Wind Load Information

Corrected basic wind pressure (kN/m^2)	W_0 = 0.5
Verification wind pressure for comfort (kN/m^2)	W_{oc} = 0.5
Ground roughness class	Class A
Basic period along X direction(s)	T_x = 0.3
Basic period along Y direction(s)	T_y = 0.3
Whether to consider downwind to the wind	Yes
Damping ratio under wind load(%)	W_{damp} = 5.00

Damping ratio under wind load for comfort(%)	W_{dampc} = 3.00
Whether to calculate cross wind direction	No
Whether to calculate the torsional wind vibration	No
Wind load effect amplification factor for bearing capacity design	W_{enl} = 1
Shape coefficient(X)	$U_{si,x}$ = 1.3
Shape coefficient(Y)	$U_{si,y}$ = 1.3

5.6.1.3 Earthquake Load Information

seismic intensity	N_{af} = 6.00
Calculate number of modes	N_{mode} = 15
Location category	IV
Characteristic period	T_g = 0.65
Maximum earthquake impact coefficient	R_{max1} = 0.04
Maximum earthquake impact coefficient for checking the thickness of the weak layer of the rule structure below 12 layers	R_{max2} = 0.28
Frame seismic rating	N_F = 2
Live load combined value coefficient of gravity load representative value	R_{mc} = 0.5
Cycle reduction factor	T_c = 1.00
Damping ratio of structure (%)	DAMP = 5.00
Whether to consider accidental eccentricity	No
Whether to consider the two-way seismic torsion effect	No
Whether to consider the most unfavorable direction horizontal earthquake action	No

5.5.1.4 Live Load Information

Consider the number of layers where the live load is unfavorable	From 0 to 6^{th}
Whether the live load transmitted to the foundation is reduced	Yes
Live load adjustment factor considering the age of the structure	F_{ACLD} = 1.00

Column, wall, basic live load reduction factor

the number of layers above the cross section	Reduction factor
1	1.00
2-3	0.85
4-5	0.70
6-8	0.65
9-20	0.60
>20	0.55
Beam floor live load reduction setting	No reduction

5.6.1.5 Reinforcing Information

Main beam strength(N/mm^2)	IB = 360
Beam stirrup strength(N/mm^2)	JB = 360
Column main reinforcement strength(N/mm^2)	IC = 360
Column stirrup strength(N/mm^2)	JC = 360
Beam stirrup maximum spacing(mm)	SB = 100.00
Column stirrup maximum spacing(mm)	SC = 100.00

5.5.1.6 Design Information

Structural importance coefficient	1.00
Steel column calculation length calculation principle (X/Y)	Yes/Yes
Whether to consider the P-Delt effect	No
Column reinforcement calculation principle	Calculated by single bias
Net member area ratio of steel members	0.85
Minimum axial compression ratio calculated by beam bending	0.15
Beam cover thickness(mm)	20
Column cover thickness(mm)	20
Frame beam end reinforcement considering compressed steel bars	Yes

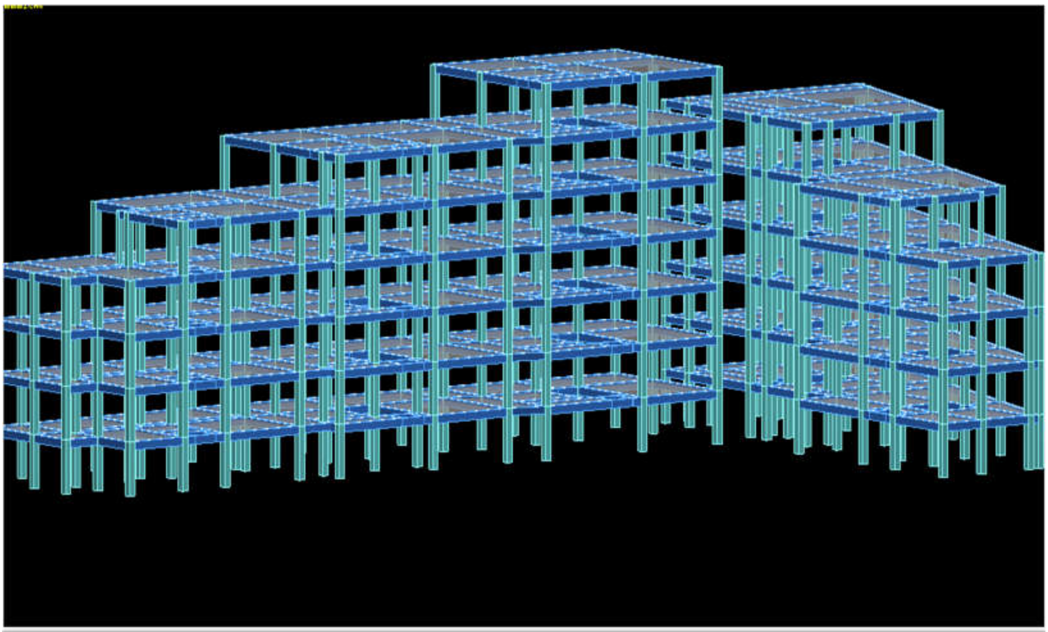
Whether to consider the second-order effect of the column according to concrete specification B.0.4	No
Column shear span calculation principle	Simplified

5.6.1.7 Load Combination Information

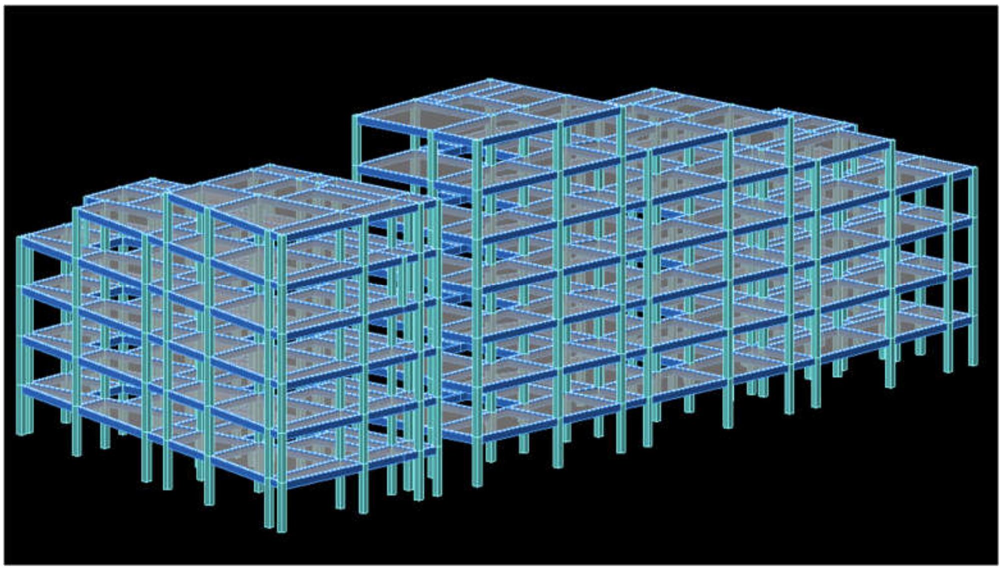
Dead load partial coefficient	C_{DEAD} = 1.20
Live load partial coefficient	C_{LIVE} = 1.40
Wind load partial coefficient	C_{WIND} = 1.40
Horizontal earthquake load partial coefficient	C_{EA-X} = 1.30
Vertical earthquake load partial coefficient	$C_{EA=Y}$ = 0.5
Thermal load partial coefficient	C_{TEMP} = 1.40
Live load combination load	C_{D-L} = 0.70
Wind load combination load	C_{D-W} = 0.60

5.6.2 Structure Model

The structure model is drawn according to the above structural layout plan. The structure is frame structure, the column extends to the roof, the reinforced concrete slab is placed on the beam, and the primary beam is placed on the column. The structural model is shown as follows.



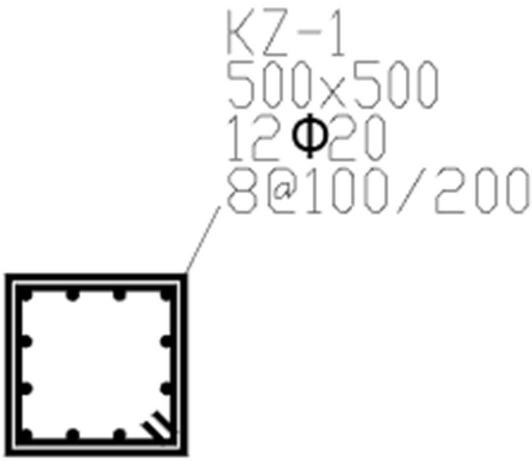
PICTURE 5.3 STRUCTURE MODEL



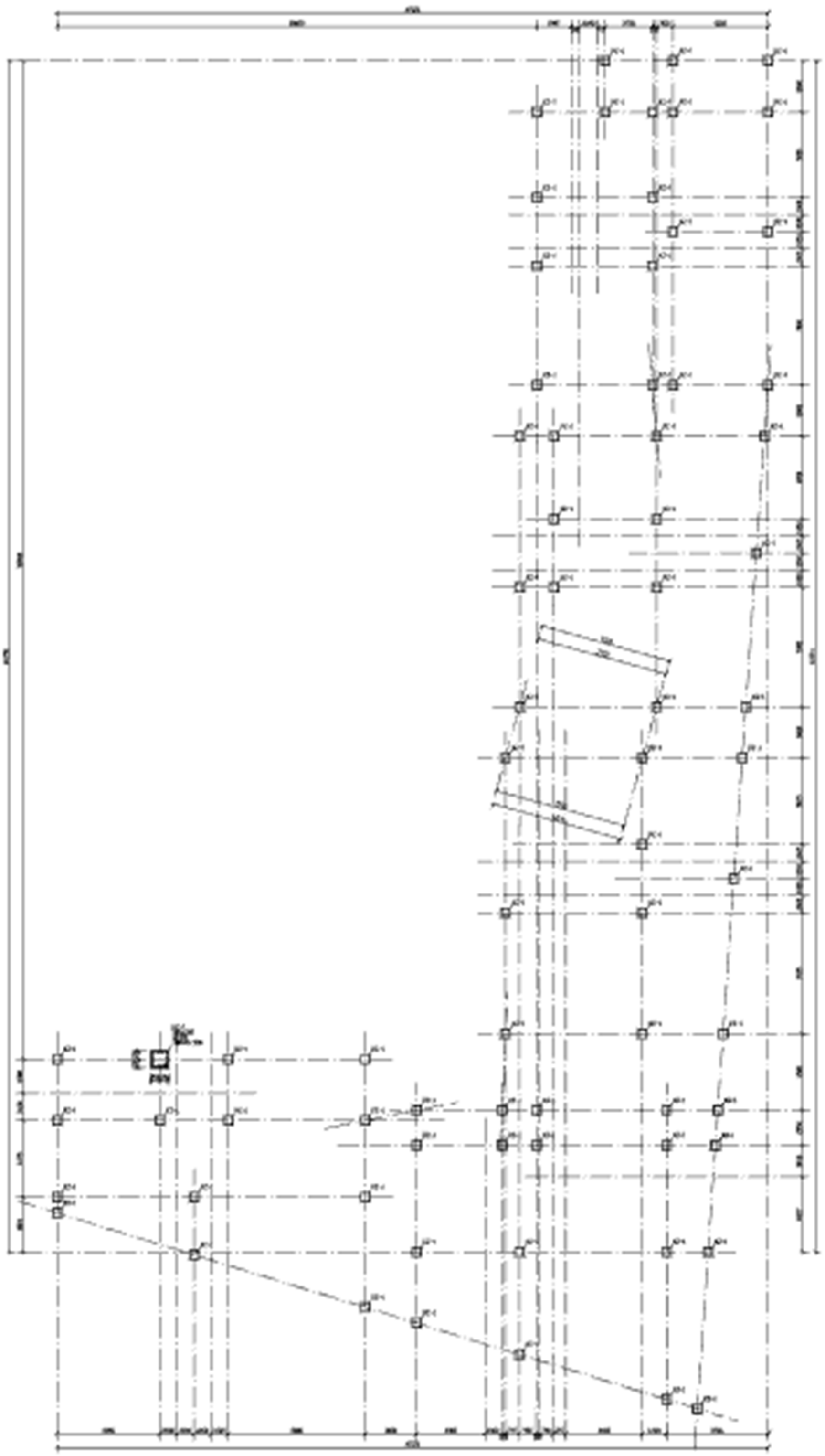
PICTURE 5.3 STRUCTURE MODEL

5.7 Structure Drawings

5.7.1 Column Drawings

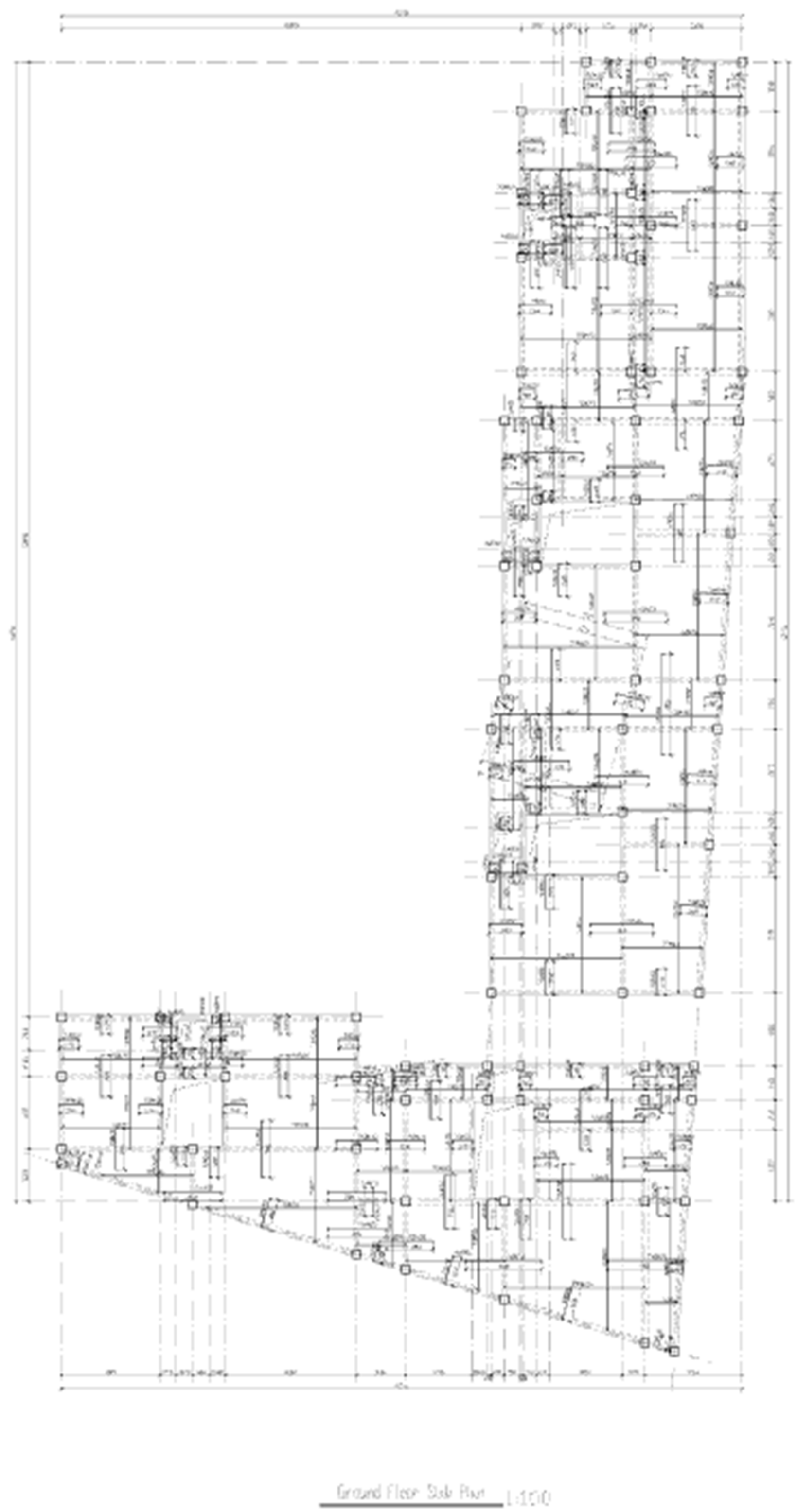


DRAWING 5.1 COLUMN SECTION



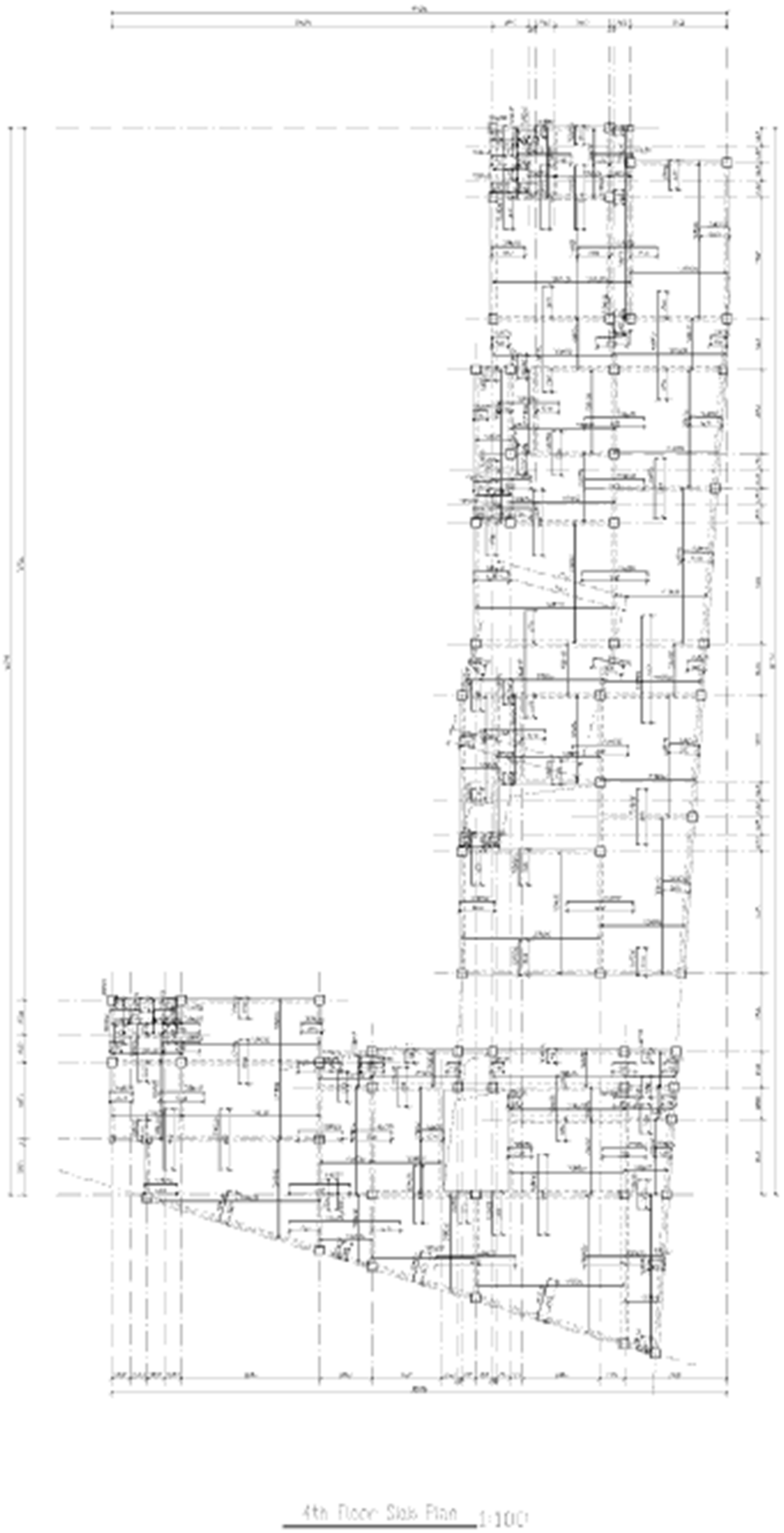
DRAWING 5.2 COLUMN PLAN

5.7.2 Ground Floor Slab Drawing



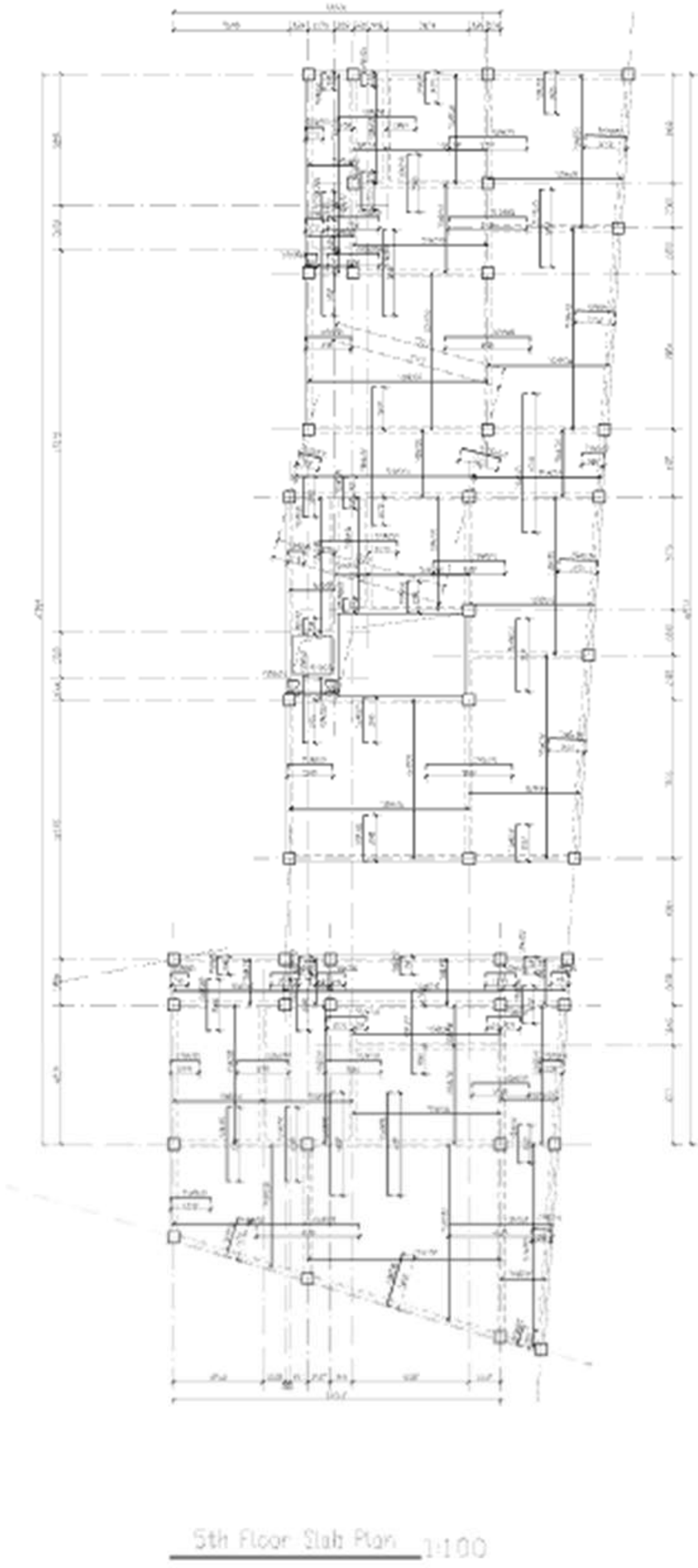
DRAWING 5.3 GROUND FLOOR SLAB PLAN

5.7.3 4th Floor Slab Drawing



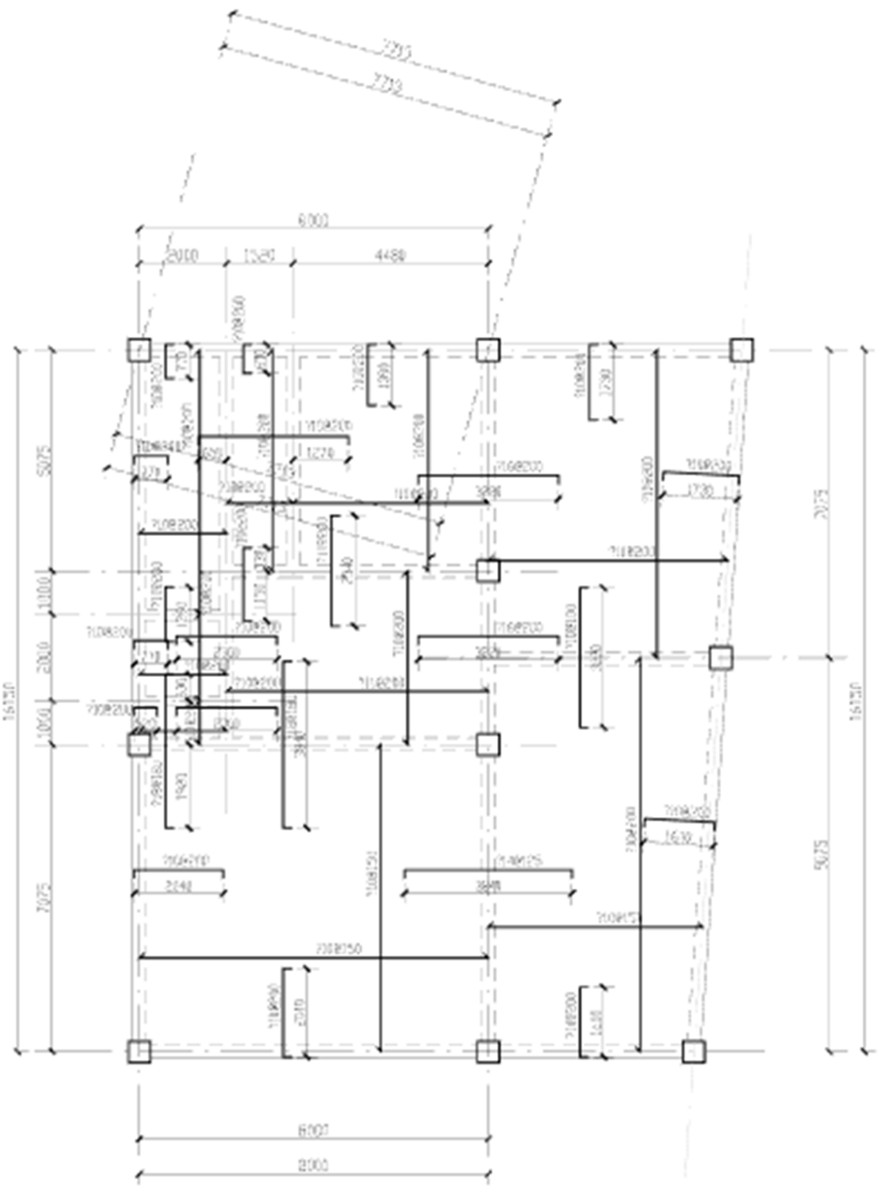
DRAWING 5.4 4TH FLOOR SLAB PLAN

5.7.4 5th Floor Slab Drawings



DRAWING 5.5 5TH FLOOR SLAB PLAN

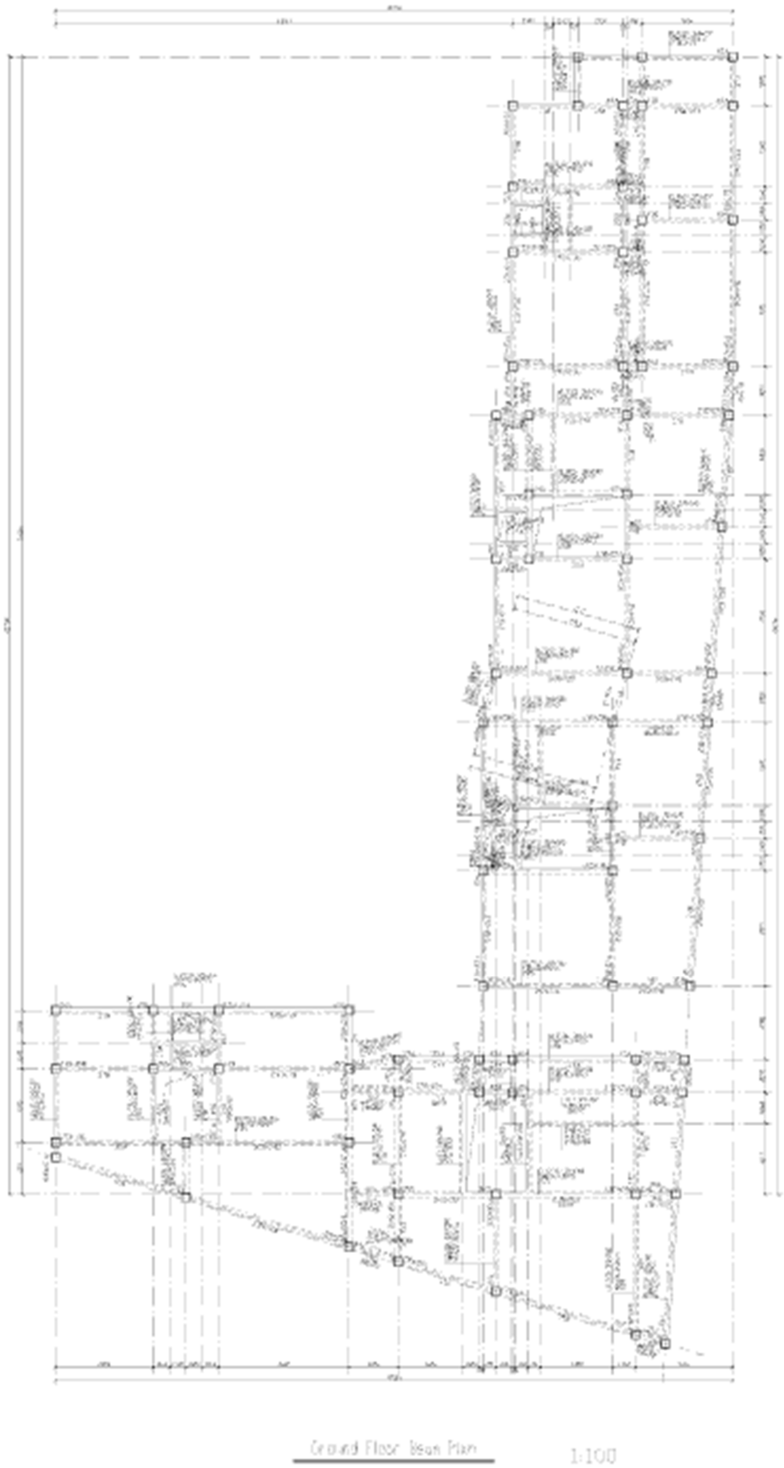
5.7.5 6th Floor Slab Drawings



6th Floor Slab Plan 1:100

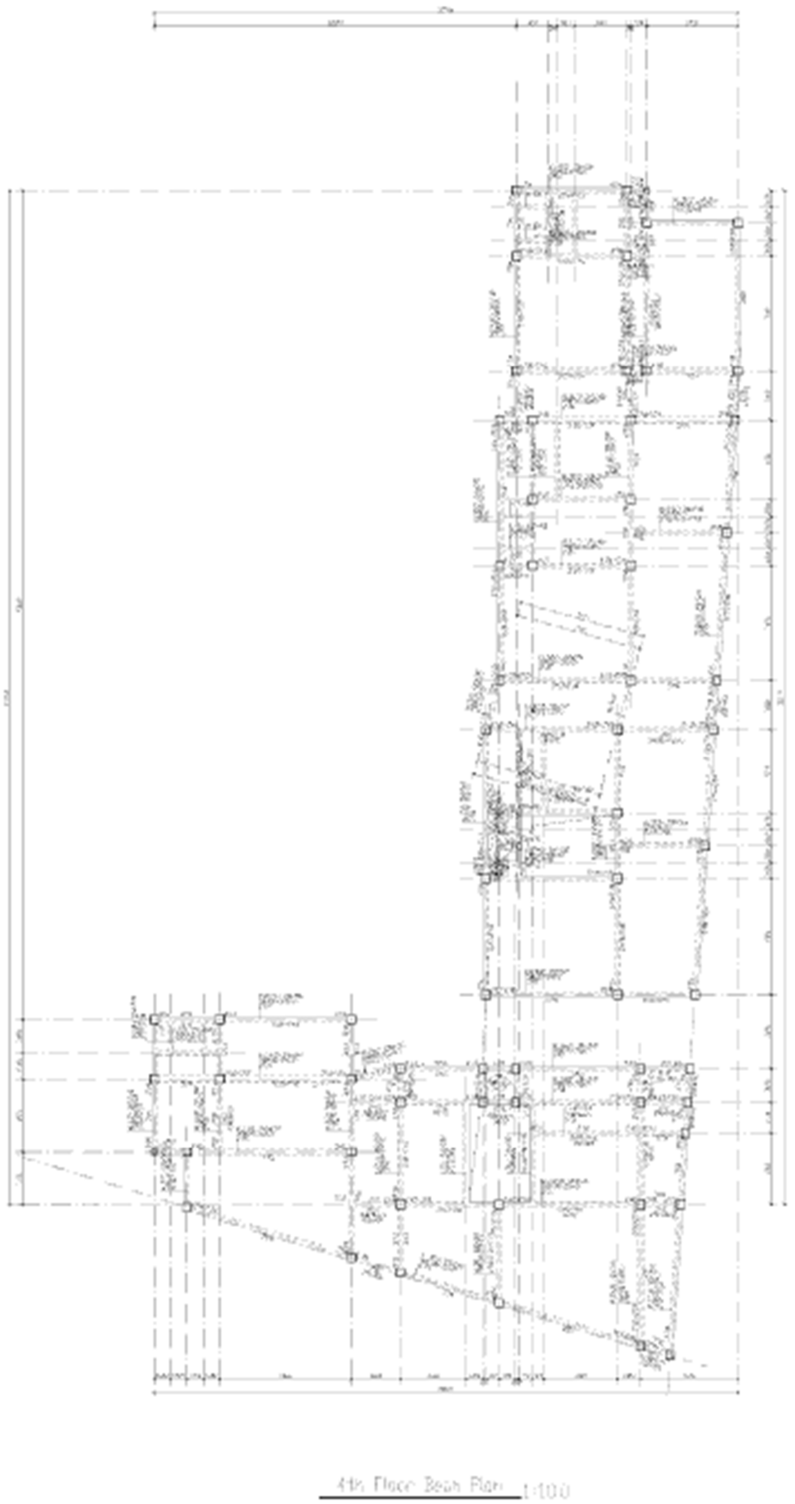
DRAWING 5.6 6TH FLOOR SLAB PLAN

5.7.6 Typical Floor Beam Drawing



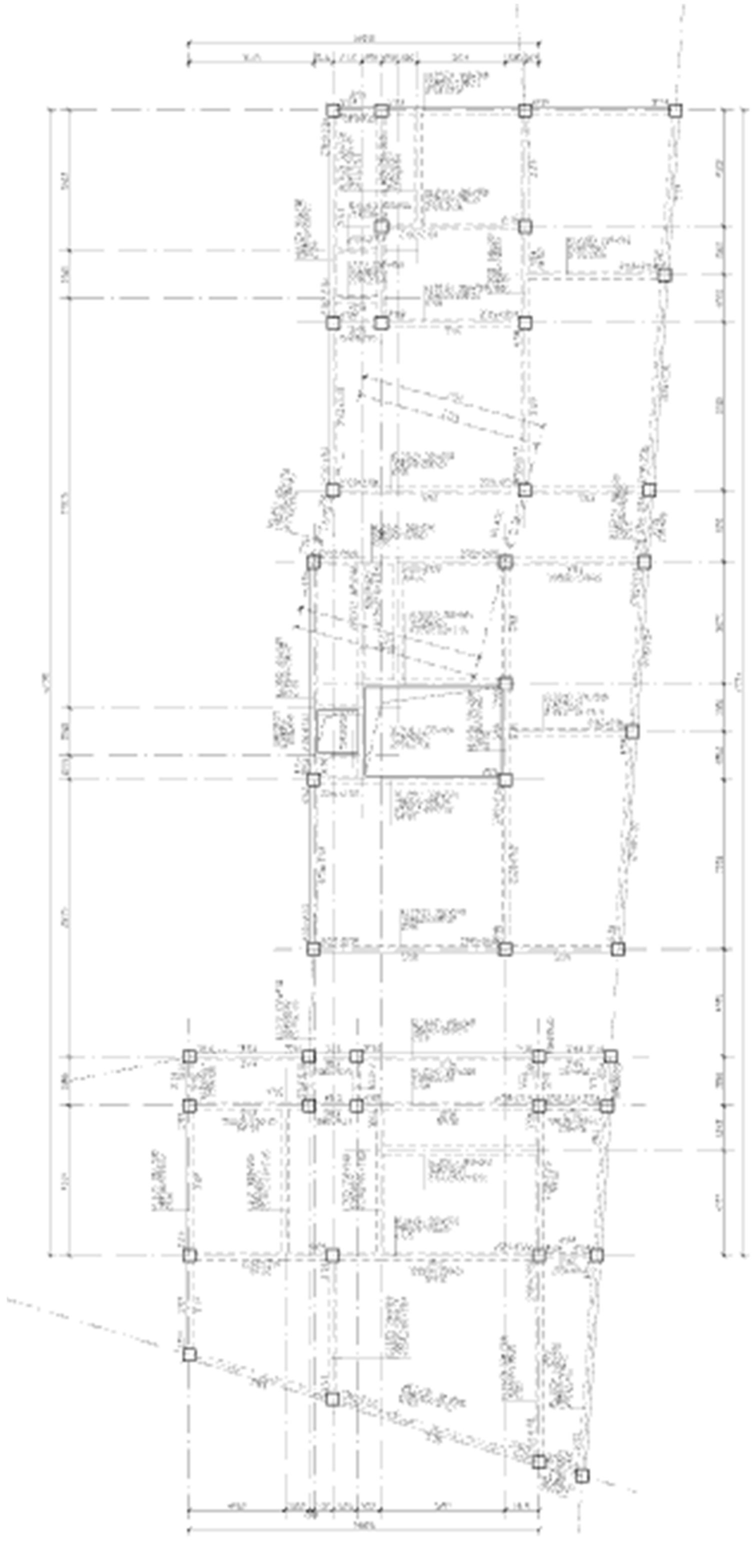
DRAWING 5.7 TYPICAL FLOOR BEAM PLAN

5.7.7 4th Floor Beam Drawing



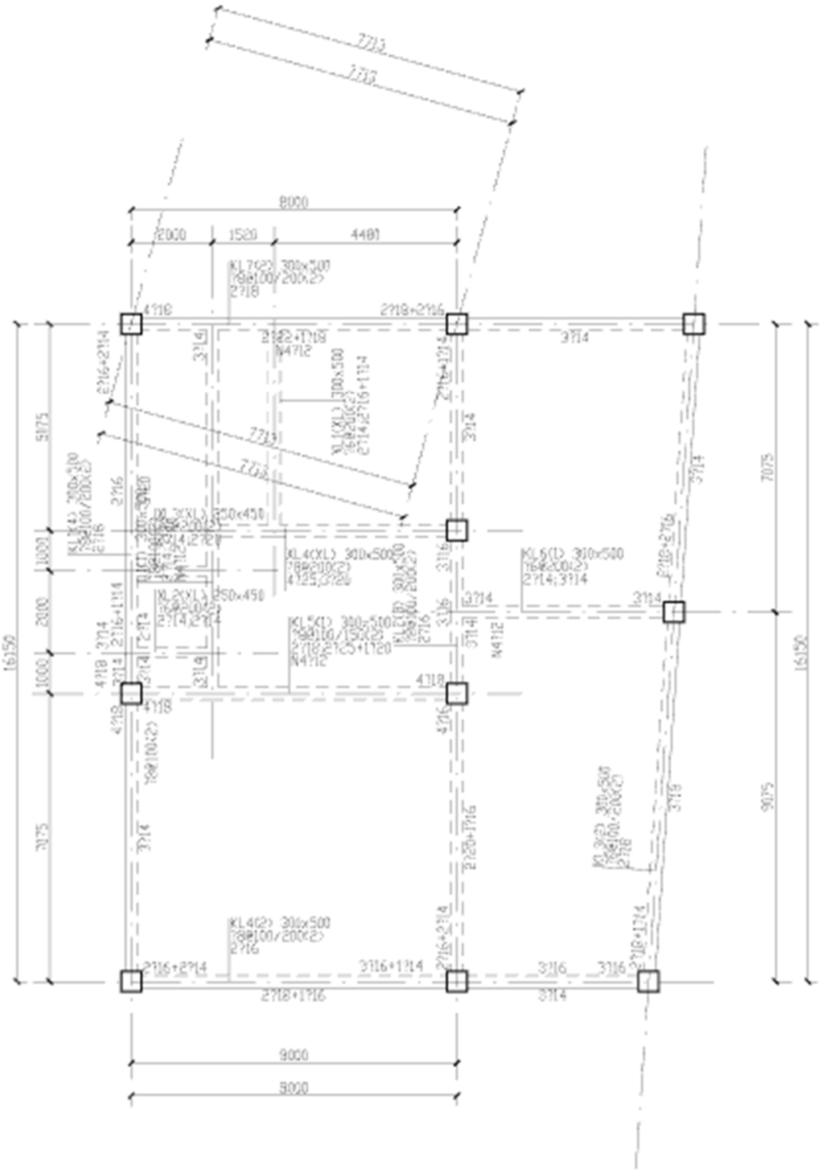
DRAWING 5.8 4TH FLOOR BEAM PLAN

5.7.8 5th Floor Beam Drawing



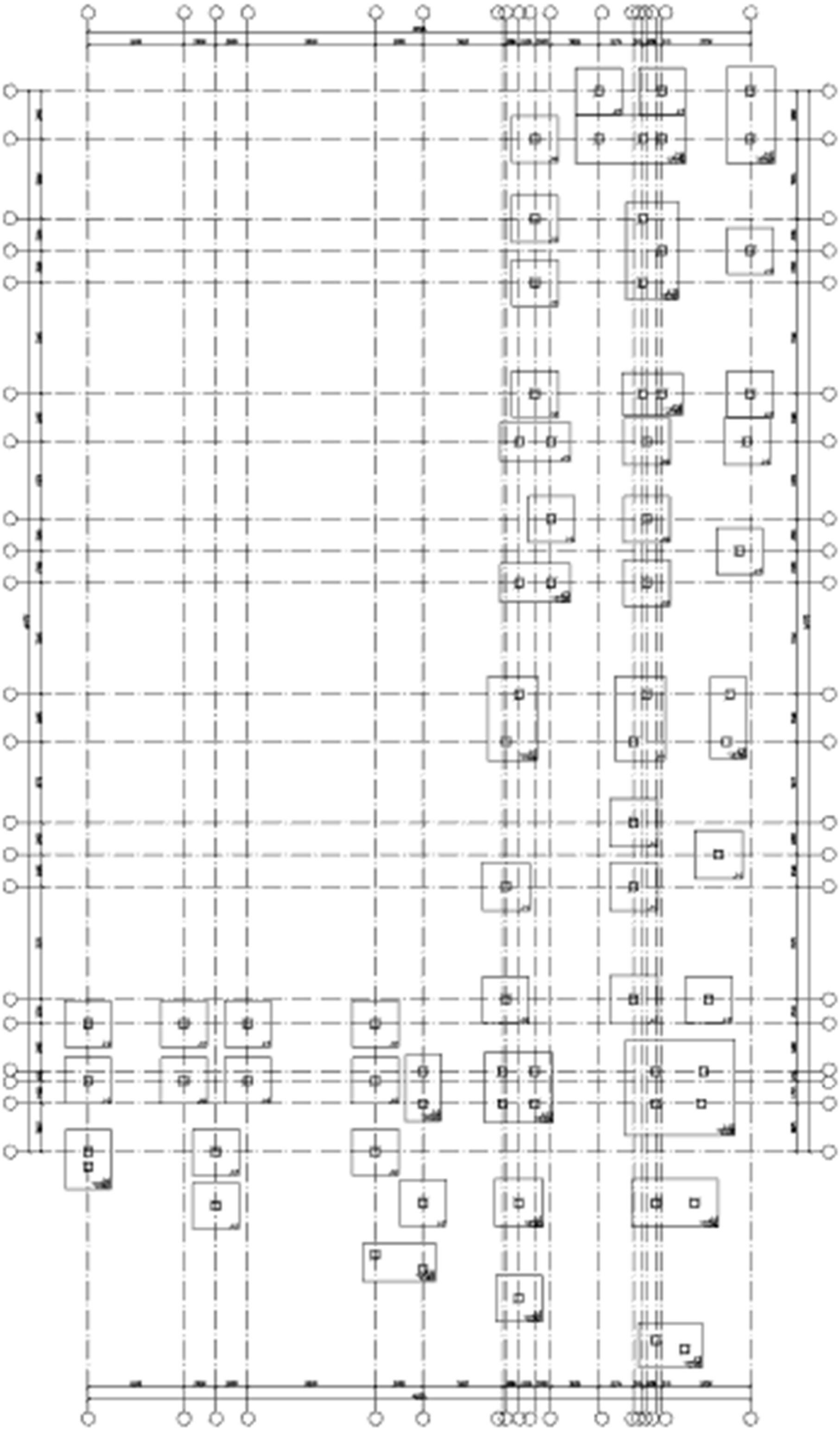
DRAWING 5.9 5TH FLOOR BEAM PLAN

5.7.9 6th Floor Beam Drawing

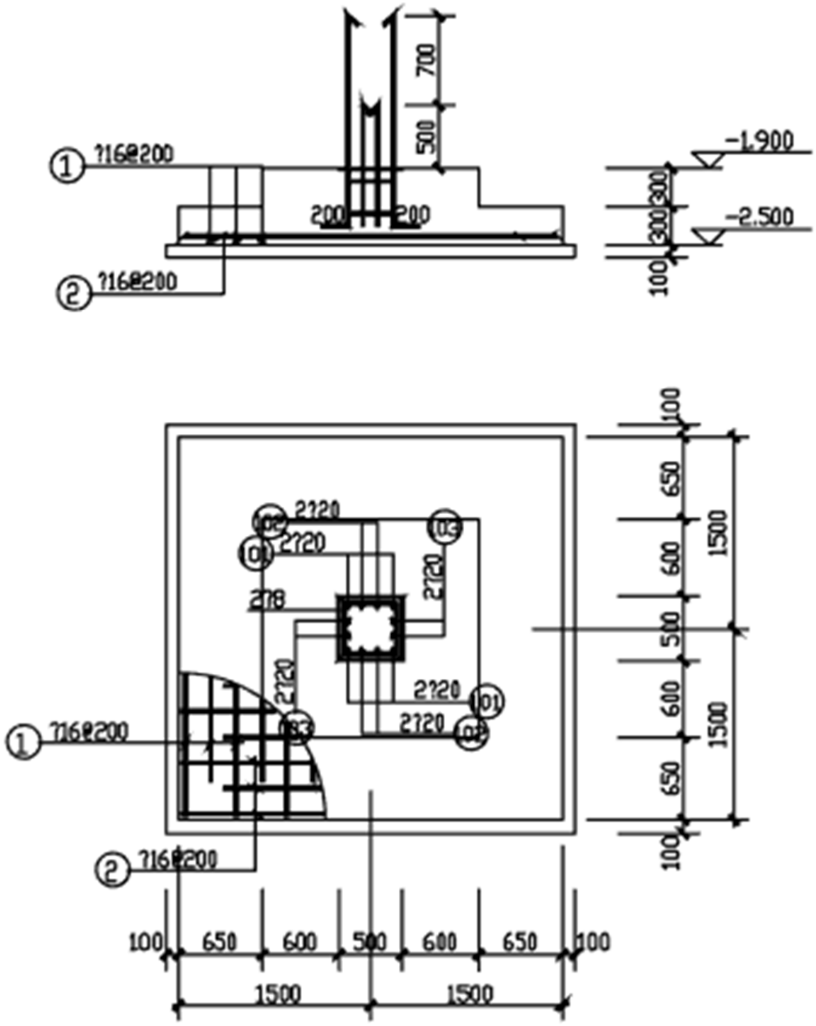


DRAWING 5.10 6TH FLOOR BEAM PLAN

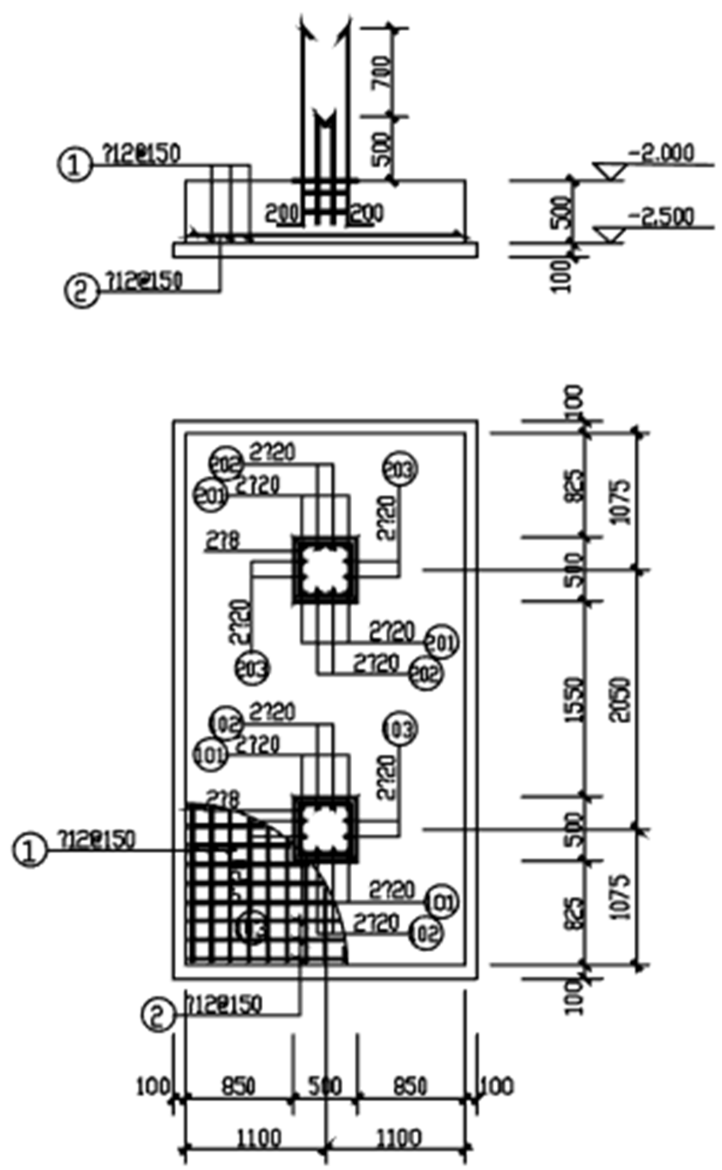
5.7.10 Foundation Drawings



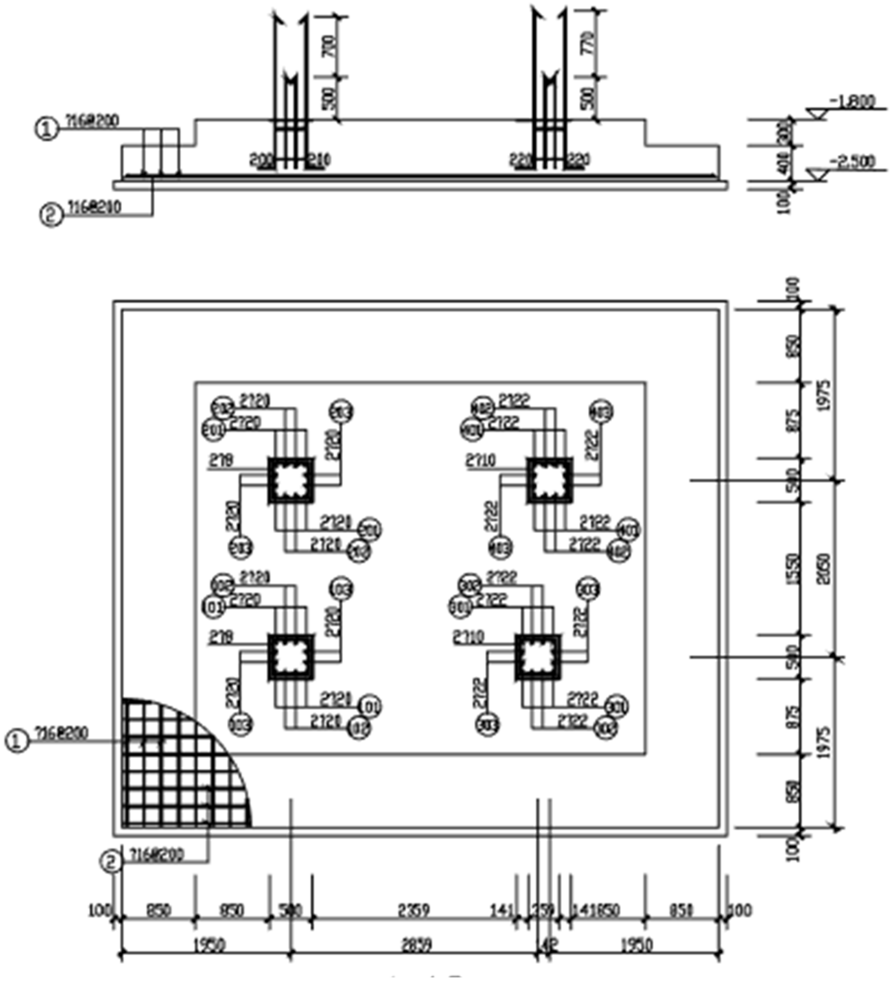
DRAWING 5.11 FOUNDATION PLAN



DRAWING 5.12 FOUNDATION – J-1 SECTION



DRAWING 5.13 FOUNDATION – J-3 SECTION



DRAWING 5.14 FOUNDATION – J-12 SECTION

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