POLITECNICO DI MILANO

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Msc. in ARCHITECTURAL ENGINEERING

GREENWICH TOWER

A new concept for a skyscraper in Manhattan, NYC

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Abstract

The title of our project is « GreenWich Tower » and it deals with the development of a multifunctional skyscraper and a new park in the area of Lower Manhattan, placed in NYC.
The subject of our thesis was proposed by a student competition in Turkey, promoted by Isover. In fact the destruction of the existent Battery Park Garage and the revitalization of the Battery Park Tunnel is a real issue, which might be realized soon and we wanted to present our proposal.
The choice of this subject was motivated by the will of accomplishing, as a final project of our Master Degree, a complex work about an original typology of building: the skyscraper.
The aims of this thesis are: the creation of a big park over the tunnel, the integration of a skyscraper in such a valuable area, the development of a sustainable project, the close examination of particular themes such as new technologies and the challenger study of the structure. We start detailing the urban analysis that lead us to reorganize the project area and develop a master plan of our district integrating the design of a contemporary multifunctional park over an existing tunnel. Then we explain our architectural concepts illustrating them through the drawing of plans for every use of the skyscraper, the cross sections, the elevations and three dimensional views. The architectural and structural project are developed together. Once the project is basically defined we deal with the constructive technology and quality of energetic performances of the tower. We tried to present some original technological solutions rather than create a summary of existent solutions.
This project has potential to cover well the four study areas of this Master of Science in Architectural Engineering, which are Urban Design, Architectural Design, Technological Design and Structural Design.

The Competition

The professors of Thesis Lab A and Thesis Lab B suggest the students to choose an architectural competition (either a current one or an expired one) to be the theme of their final thesis. This is because the competitions provide us all the information needed to start a project and also give us limits and conditions, that facilitate the design process. In the very beginning our group had three options to choose but we always knew which one we wanted: the "Skyscraper in New York" . So right after the teachers' approval we started our studies about New York and about Skyscrapers.

1. Introduction

fig. 01: Competition Announcement

The competition was issued in Turkey by Izocam that has been one of the biggest companies in Insulation Sector since its foundation in 1965. The company started glass wool production in 1967 as the pioneer in Turkey.

The competition was the "11th annual Izocam Insulation Competition" for University Students (bachelor and master students) for designing a sustainable structure. The first three finalists merit to represent Turkey in the 'multi comfort buildings' competition that is done by Isover, Saint-Gobain Insulation in Prague.

The topic of the competition is to create a high rise building in New York that will bring creative approaches to the concept of energy-efficient building. The idea is to design according to the definition of a multi-purpose tower with passive house components.

2. Location

The location is downtown Manhattan, in a neighborhood called Greenwich South. This tower is supposed to be a leading project in the business center of lower Manhattan, that achieves sustainability in different levels. The boundaries of the area are: on the south side, Battery Place, on the west side, West Street, on the north side, Liberty Street, and on the east side, Broadway Street. The project is located on the south of the World Trade Center. The Greenwich area has great potential that has not been the action yet relayed to be increasing concern, due to the new buildings of '11 September' which contribute the overall character of the urban fabric. It should be kept in mind that the building will define the downtown's skyline.

map 01: Competition Area

3. Conditions

The tower

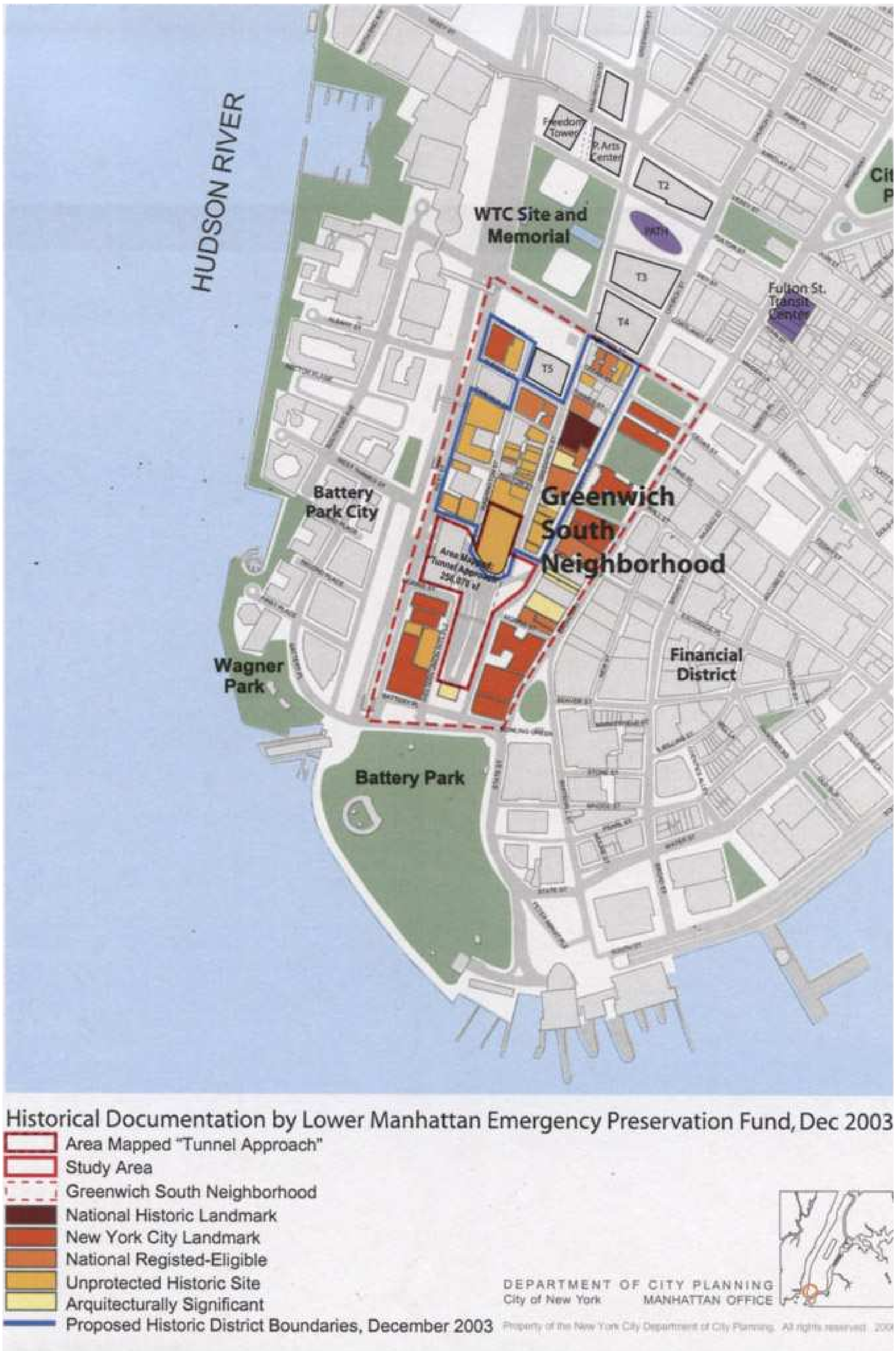
- It should be a 60 story building and the entrance is expected to be a 5-story building.
- The maximum horizontal dimension of each floor on the ground in New York City' pursuant to the rules of district, 175 feet (app. 53,34m) should not be exceeded.
- Distance from the adjacent skyscraper on the north must be ensured.
- It should be taken into consideration that the existing concrete parking building (pink line contour) will be demolished.
- The adjacent parking building (blue line contour) can also be demolished.
- The building and the entrance floors should have different identities according to usage.
  base: for the first floors maximum height can be 18m/ 60 feet. Usage should be more public than private.
  top: for the upper floors a new usage system should bring energy efficiency with a new architectural concept.

map 02: Competition Area

4. Provided Materials

map 03: Buildings Height

map 04: Land Use



map 05: Historical Buildings

fig.02: Battery Tunnel

fig.03: Battery Tunnel

fig.04: Battery Garage

5. Winners

Although the original plan of the group was to compete, we were not able to elaborate the project before the competition's deadline, which was on April 2011. The winner projects were announced on May 2011. Despite the interesting ideas, these projects were not used as references for this work.

1st place:

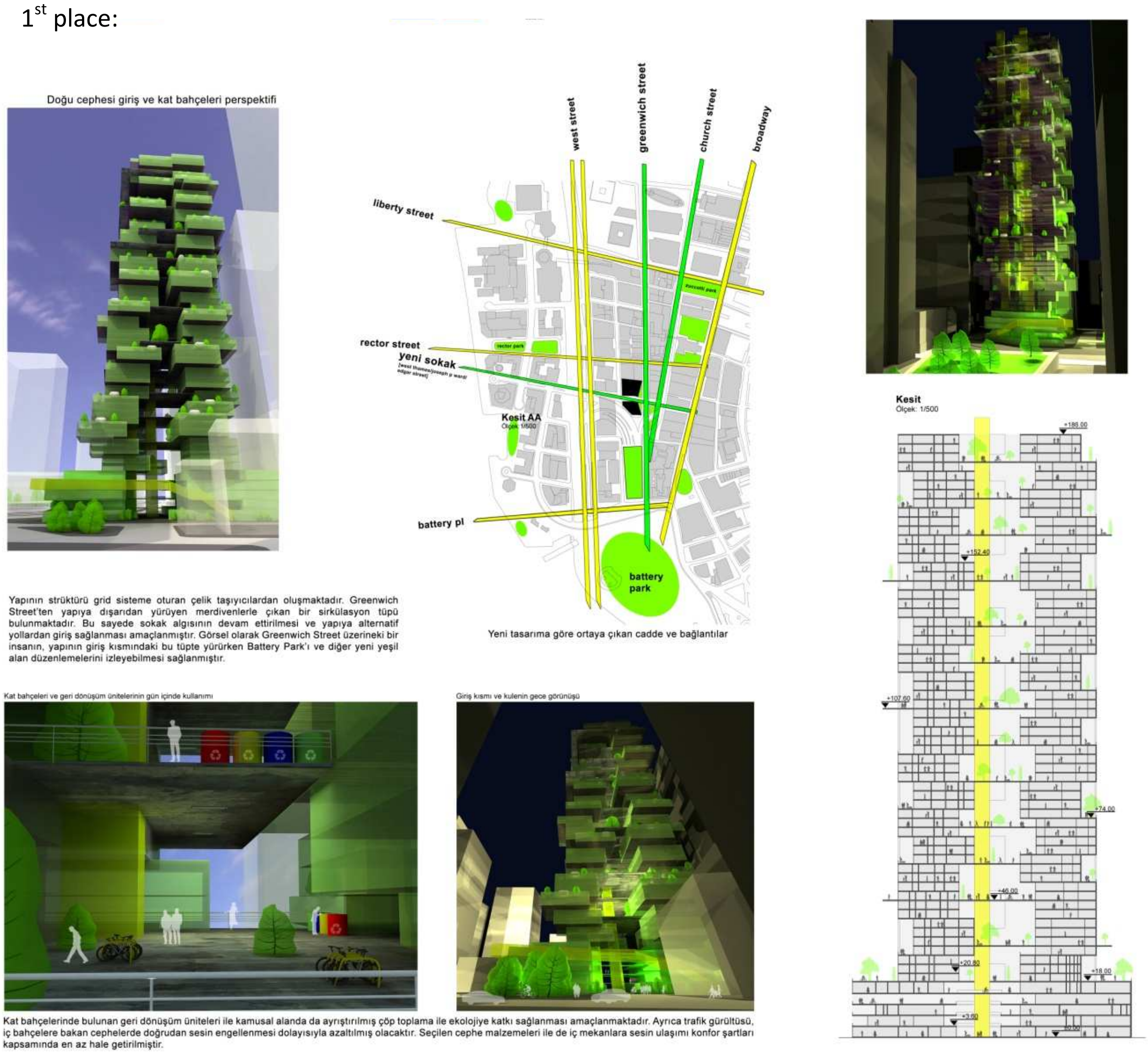


fig.05: Competition 1st place

2[nd] place:

fig.06: Competition 2nd place

3[rd] place:

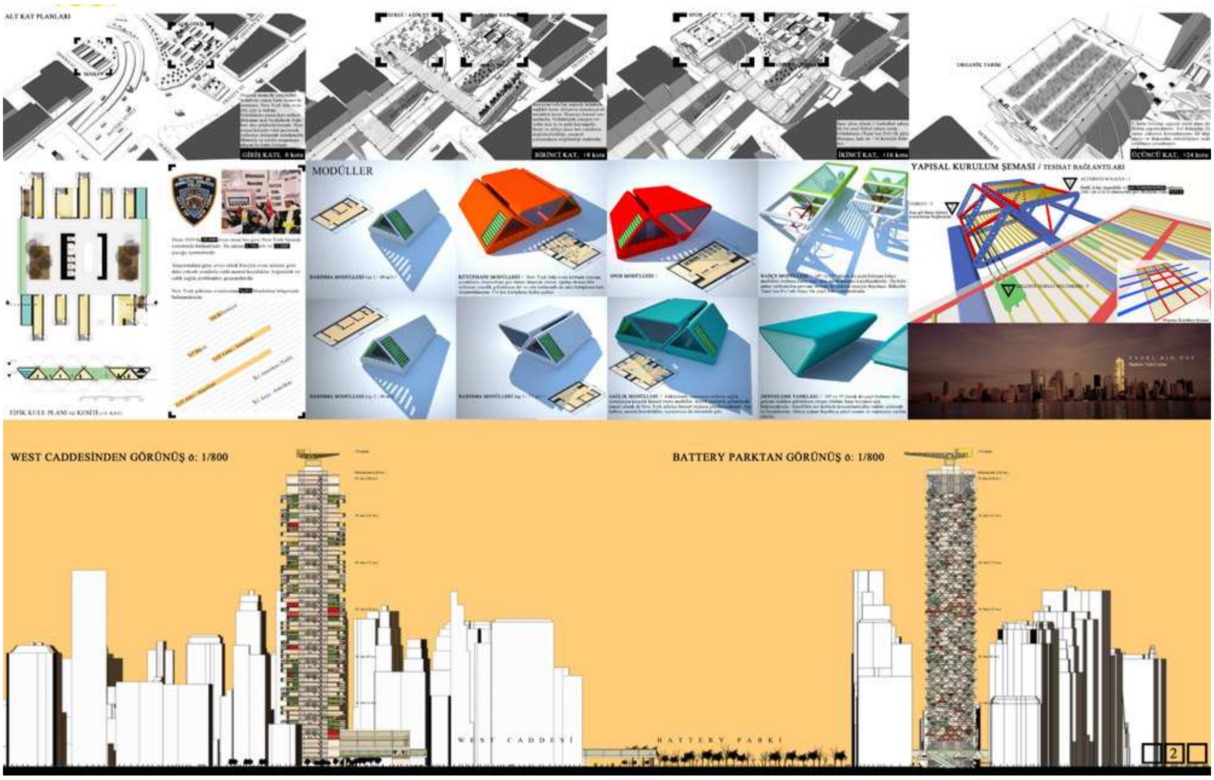


fig.07: Competition 3rd place

Urban Design

In this first part of the thesis we develop an analysis of the urban context considering mostly its social and economical aspects, in order to get an adequate master plan for the area. We start the reorganization of the district where the skyscraper is located with a new green park and redistribution of accessibility.

1. New York:

The urban part is started first with learning all about New York which is in the northeastern part of United States. It is the nation's third most populous state. New York is bordered by New Jersey and Pennsylvania to the south and by Connecticut, Massachusetts and Vermont to the east. The state has a maritime border with Rhode Island east of Long Island, as well as an international border with the Canadian provinces of Ontario to the north and west, and Quebec to the north. The state of New York is often referred to as New York State to distinguish it from the city of New York. (http://en.wikipedia.org/wiki/New_York)

fig.08: U.S. Map

fig.09: NY symbol

New York City is the most populous city in the United States, with a population of over 8.1 million. New York exerts a significant impact upon global commerce, finance, media, art, fashion, research, technology, education, and entertainment. According to the U.S. Department of Commerce, it is also a destination of choice for many foreign visitors. Both the state and city were named for the 17th century Duke of York, James Stuart, future James II and VII of England and Scotland As many as 800 languages are spoken in New York, making it the most linguistically diverse city in the world. New York is the most highly googled location in the world; registering 4.6 billion search results as of September 2011. (http://en.wikipedia.org /..i/New_York_City)

fig.10: NY skyline

Many districts and landmarks in New York City have become well known to its nearly 50 million annual visitors. Times Square (fig.04), iconified as "The Crossroads of the World", is the brightly illuminated hub of the Broadway Theater District (fig.05), one of the world's busiest pedestrian intersections, and a major center of the world's entertainment industry. The city hosts many world renowned bridges, skyscrapers and parks. Manhattan's real estate market is among the most prized and expensive in the world. Manhattan's Chinatown incorporates the highest concentration of Chinese people in the Western Hemisphere. Unlike most global rapid transit systems, the New York City Subway is designed to provide 24/7 service. Numerous colleges and universities are located in New York, including Columbia University, New York University, and Rockefeller University, which are ranked among the top 100 in the world. (http://www.trekearth.com /trip.php?tid=3778&display=full)

fig.11: Times Square

fig.12: Broadway Theater District

New York City consists of five boroughs (fig.13): The Bronx, Brooklyn, Manhattan, Queens, and Staten Island. This project design is located in an area of Lower Manhattan, called Greenwich South (fig.14).

fig.13: NY Boroughs

fig.14: Greenwich South

2. Greenwich South

2.1. Time Line

(Imdc_presentation_2005 GREENWICH STREET SOUTH URBAN DESIGN STUDY)

1609 - Founding of New Amsterdam.

1664 - British capture New Amsterdam and rename it New York (fig.15). The future Greenwich South is underwater.

fig.15

1725 - Outdoor securities trading in New York begins in the vicinity of Wall and Broad Streets.

1790 - Battery Park opens and becomes New Yorker's favored spot for an afternoon stroll (fig.16).

Fig.16

1797 - Lower Greenwich Street is known as "Millionaires' Row" (fig.17).

fig.17

1810 - Robert and Anne Dickey House built (one of five Federal Style townhomes remaining in Lower Manhattan).

1849 - "Curb Market" on Wall Street booms during the California Gold Rush (fig.18).

fig.18

1850’s - Castle Clinton, built in 1808, in anticipation of the War of 1812, is converted to an immigration station; Greenwich Street townhouses are transformed from residences into boardinghouses, saloons and shops.

1868 - Greenwich Street Elevated railway line opens, running from the Battery to 30th Street, along Ninth Avenue.

1869 - Trinity Place widened and extended to Morris Street.

1885 - Adams Express and American Express Stables built; Greenwich South provides support functions for the Financial District such as warehouses, stables and factories.

1921 - New York Club Market building built (fig.19); Greenwich South begins to attract office buildings; stables and other industrial buildings are converted into offices.

fig.19

1940 - Triborough Bridge Authority begins construction on Brooklyn-Battery Tunnel.

1950 - Brooklyn-Battery Tunnel (fig. 20) and Battery Parking Garage open.

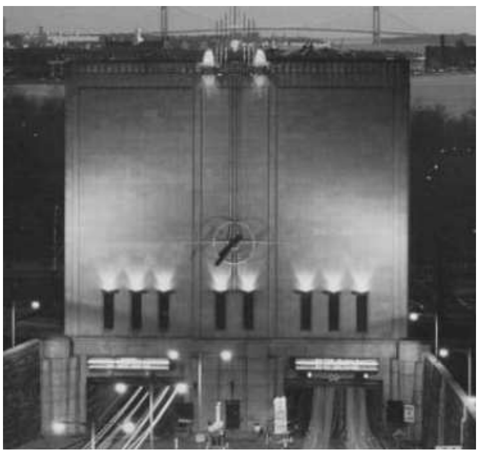


fig.20

1953 - New York Curb Market renamed American Stock Exchange.

1966 - The Lower Manhattan Plan, produced by the New York City Department of City Planning and the Downtown-Lower Manhattan Association, calls for the redevelopment of the waterfront, the World Trade Center and Battery Park City.

1966 - World Trade Center construction begins (fig.21), disconnecting Greenwich Street between Tribeca and the Battery. Low rise buildings including Radio Row are replaced with 13 million square feet of class-A office space.

fig.21

1933 - Plan for Lower Manhattan by New York City Department of City Planning calls for the conversation of class-B office to residential space and the creation of Downtown Alliance.

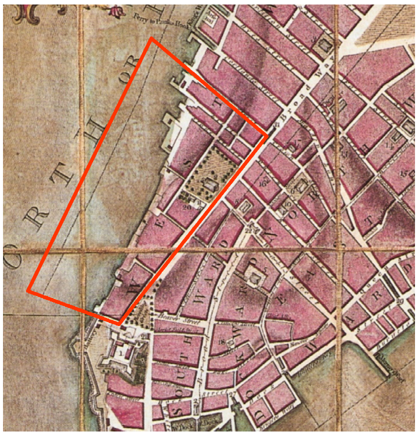
2001 - World Trade Center destroyed.

2002 - Mayor Bloomberg's vision for lower Manhattan proposes post-9/11 revitalization (fig.22), including the definition of a new neighborhood, "Greenwich Square," with thousands of residential units and a park on a deck over the Brooklyn- Battery Tunnel ramp.

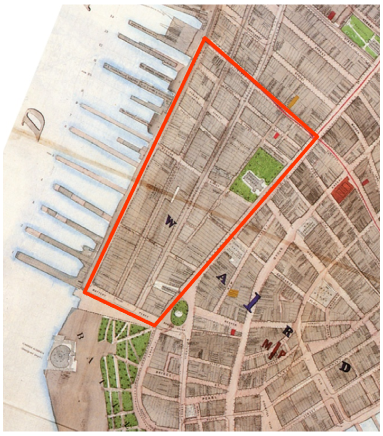
fig.22

2006 - Seven World Trade Center opens.

2.1.1 Transformation of the Neighborhood:



map 06: Greenwich South 1769



map 07: Greenwich South 1867

wich South 2001

Late in the 18th century, landfill was used to expand Lower Manhattan from the natural Hudson shoreline at Greenwich Street to West Street. When building the World Trade Center, 1.2 million cubic yards (917,000 m³) of material was excavated from the site. Rather than dumping the spoil at sea or in landfills, the fill material was used to expand the Manhattan shoreline across West Street, creating Battery Park City. The result was a 700-foot (210-m) extension into the river, running six blocks or 1,484 feet (450 m), covering 92 acres (37 ha), providing a 1.2-mile (1.9-km) riverfront esplanade and over 30 acres (12 ha) of parks.

2.2. Neighborhood

2.2.1. Financial District

The Financial District is an area at the southern tip of Manhattan which comprises the offices and headquarters of many of the city's major financial institutions, including the New York Stock Exchange and the Federal Reserve Bank of New York. Major sights include South Street Seaport (fig.23), Wall Street and the New York Stock Exchange, Battery Park, Trinity Church and the Woolworth Building (fig.24). The World Trade Center existed in the neighborhood until the September 11 attacks and is currently being rebuilt. The neighborhood roughly overlaps the boundaries of the New Amsterdam settlement in the late 17th century and has a residential population of about 56,000. During the day, the population swells to about 300,000.

fig.23: South Street Seaport
www.southstreetseaport.com

fig.24: Woolworth Building
http://www.whitworthfamily.org

fig.25 Financial District

http://tungstenproperty.com

As a district (fig.25), it encompasses roughly the area south of City Hall Park but excluding Battery Park and Battery Park City. The heart of the Financial District is often considered to be the corner of Wall Street and Broad Street, both of which are contained entirely within the district. The northeastern part of the financial district (along Fulton Street and John Street) was known in the early 20th century as the Insurance District, due to the large number of insurance companies who were either headquartered there, or maintained their New York offices there. The Greenwich south neighborhood is in the financial district and enclosed on the east Wall Street, on the south Battery Park, on the west Battery Park city and on the north World Trade Center.

2.2.2. The Wall Street

It is the main financial part of the district which gives the identity of the neighborhood. Anchored by Wall Street (fig.26) in Lower Manhattan, New York City is the financial capital of the world and is home to the New York Stock Exchange, the world's largest stock exchange by market capitalization of its listed companies.

fig.26: Wall Street
http://www.wreporter.com

2.2.3. Battery Park

Battery Park (fig. 27) is a 25-acre (10 hectare) public park located at the Battery, the southern tip of Manhattan Island in New York City, facing New York Harbor. The Battery is named for artillery batteries that were positioned there in the city's early years in order to protect the settlement behind them. At the north end of the park is Castle Clinton, the often re-purposed last remnant of the defensive works that inspired the name of the park; Pier A, formerly a fireboat station; and Hope Garden, a memorial to AIDS victims. At the other end is Battery Gardens restaurant, next to the United States Coast Guard Battery Building. Along the waterfront, ferries depart for the Statue of Liberty and Ellis Island, (fig.28), and there is also a New York Water Taxi stop. The park is also the site of the East Coast Memorial which commemorates U.S. servicemen who died in coastal waters of the western Atlantic Ocean during World War II, and several other memorials. (http://en.wikipedia.org/wiki/Battery_Park)

fig.27: Battery Park
www.mappingnyc.com

fig.28: Statue of Liberty and Ellis Island
www.essential-new-york-city-guide.com

2.2.4. Battery Park City

The neighborhood (fig. 29) built on the Southwest tip of Manhattan, is both quiet and convenient. The buildings that were built in the last twenty years are perfect examples of the sustainable buildings. It also offers a greenmarket that helps to increase an awareness into a sustainable future.

fig.29: Battery Park City
www.wikipedia.com

2.2.5. World Trade Center

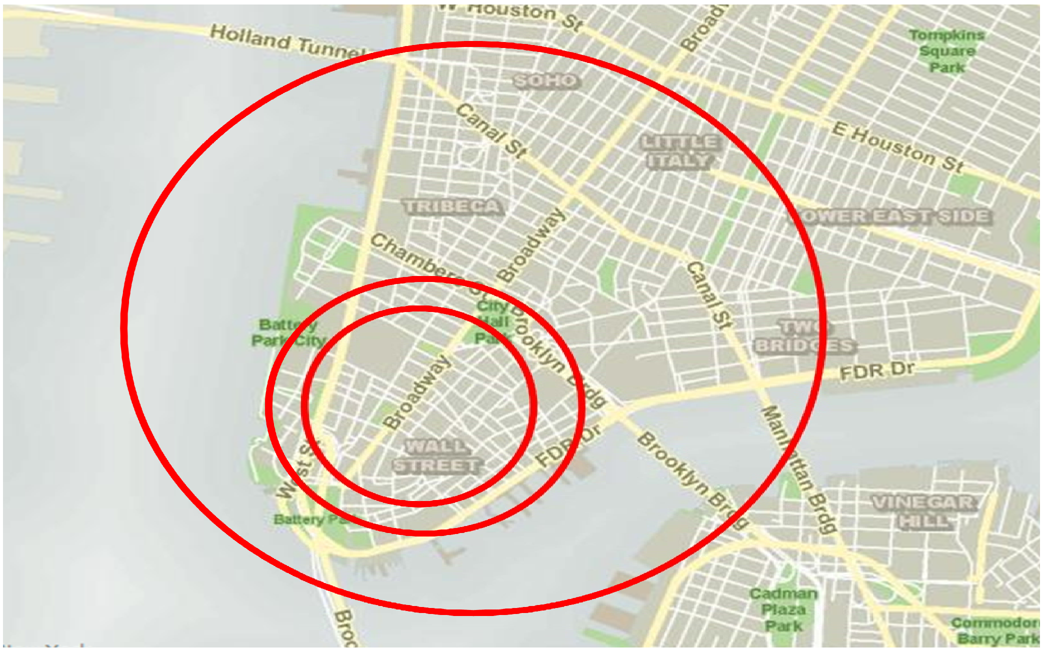
fig.30: World Trade Center
www.wikipedia.com

The original World Trade Center (fig.30) was a complex with seven buildings featuring landmark twin towers in Lower Manhattan, New York City, United States. The complex opened on April 4, 1973, and was destroyed in 2001 during the September 11 attacks. The site is currently being rebuilt with five new skyscrapers and a memorial to the casualties of the attacks. As of September 2011, only one skyscraper has been completed with four more expected to be completed before 2020. One World Trade Center will be the lead building for the new complex and is expected to be finished by 2013. A sixth tower is still awaiting confirmation to be built. At the time of their completion, the original 1 and 2 World Trade Center were the tallest buildings in the world, surpassing the Empire State Building, also in Manhattan.

2.3. Analysis

2.3.1. Walking Distances

By assuming that one person can walk in 10 minutes 800 meters, with starting from the center (auto park building) one can arrive to Battery Park, Battery Park City, The World Trade Center and Wall Street in five minutes. In 10 minutes one can finish all the downtown and in less than 20 minutes one can walk to Tribeca, Soho or Little Italy and even pass from the Brooklyn Bridge to Brooklyn.



map 09: Walking Distances

2.3.2. Green Areas

In the neighborhood there is no green space or park for public. The closest place which is Battery Park is less than five minutes walking distance and connected to Battery Park City Gardens. Also the new World Trade Center is providing open spaces which can be used by public.

map 10: Green Areas

2.3.3. Solid Void Relationship

The neighborhood is between two neighborhoods which are not like the rest of the Manhattan: Battery Park city which is not as dense as the rest and has more open areas because of the fact that it is a newly built neighborhood with the infill technique and financial district which does not have a proper grid like the rest of the Manhattan.

As it can be seen from the map the neighborhood is very dense but unlike the rest of Manhattan it doesn't have a perfect grid. The existence of the tunnel creates an open area which can be used so in a way it is the mixture of two neighborhood.

map 11: Solid-Void

2.3.4. Scale Approximation

The neighborhood is approximately 200000 m^2 which is as big as eleven Piazza del Duomo, in Milano. (the area of Piazza del Duomo is 17000 m^2)

map 12: Scale Approximation

2.3.5. Street Hierarchy

Map 13 shows the main streets in red and secondary streets in blue. The main streets are: West street, Broadway street and Church street that makes the neighborhood alive and gets the enough attention. Another lively street that is close to Church Street in the neighborhood is the Trinity Street which is full of shops, cafes, and restaurants.

map 13: Street Hierarchy

2.3.6. Transportation

Subway and bus: The main transportation is the subway and the exits are accumulated mainly on the trinity street because of the hierarchy.

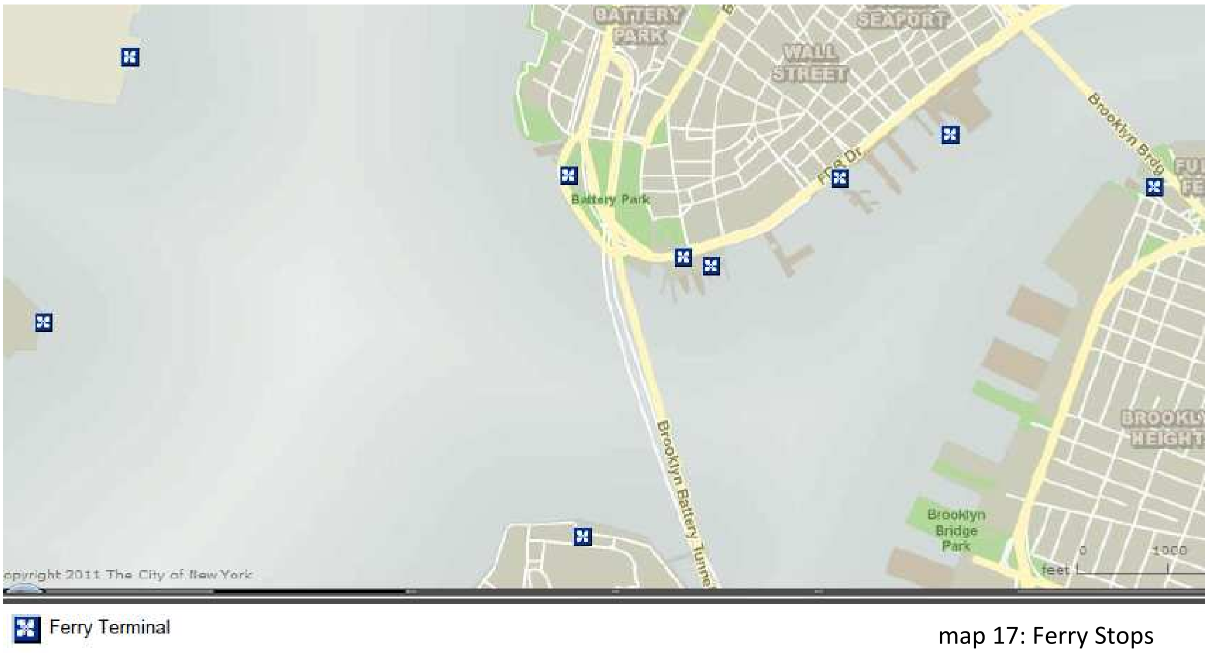
map 14: Metro Lines

Map 15 shows the lines and exits of metro lines which is accumulated in front of the suggested building place which makes it easier to arrive to the site without any problem.

map 15: Metro Lines and Exits

map 16: Bus Lane

Port: The Battery Park Ferry Port provides slips to ferries, water taxis, and sightseeing boats in the Port of New York and New Jersey. The Port is one of the main tourist attraction spot because of the ferries to Staten Island and Ellis Island.There are four bow-loading and two side loading slips at the terminal.



map 17: Ferry Stops

2.3.7. Landmarks

map 18: Landmarks

Examples of landmarks in the zone:

Whitehall building: The Whitehall Building (fig.31) is a 20-story skyscraper located at 17 Battery Place next to Battery Park which constructed from 1902-1904 as a speculative office building and then converted into apartments in 1999.

fig.31: Whitehall Building
www.wikipedia.com

fig.32: Downtown Athletic Club
www.wikipedia.com

Downtown Athletic Building: The Downtown Athletic Club was a private social club and athletic club in a 35-story building. The Club was founded in 1926. By 1927, it had purchased this site next to the Hudson River to construct its own building. It was completed in 1930 (fig. 32).

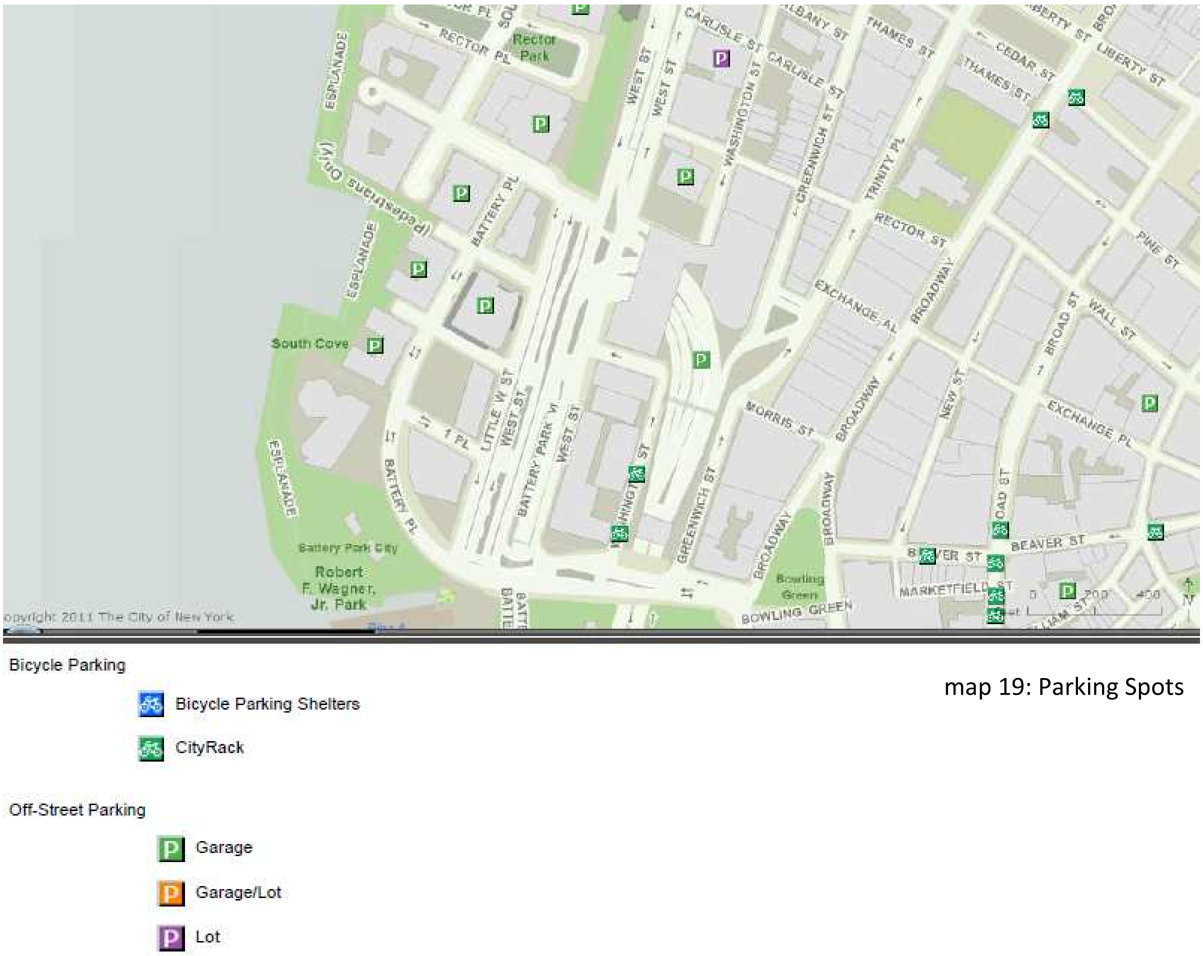
The high cost of land necessitated a tall building, and the relatively small lot size dictated that the different functions and facilities of the club, including swimming pool, gymnasium, miniature golf course, squash, and tennis courts, as well as dining rooms and living quarters, be accommodated on separate floors which now is a residential tower.

Lamp posts: The neighborhood has many lamp posts (fig.33) which has historical importance and counts as a landmark.

fig.33: Lamp Post 14
http://www.nyc.gov

2.3.8. Parking Spots

In the neighborhood there are two main parking garages and one parking lot. Also the Battery Park City building has parking garages underneath. Because of the bike route there are also two main city racks which also have a unique design (fig.34).



map 19: Parking Spots

fig.34: City Rack
http://nycityracks.wordpress.com

2.3.9. Skyline

Manhattan's skyline with its many skyscrapers is universally recognized, and the city has been home to several of the tallest buildings in the world. As of 2011, New York City had 5,937 high-rise buildings, of which 550 completed structures were at least 100 meters high, both second in the world after Hong Kong, with over 50 completed skyscrapers taller than 200 m. New York has architecturally noteworthy buildings in a wide range of styles and from distinct time periods.

fig. 35: Skyline

2.3.10. Cultural Institutions

New York City prominently excels in its spheres of art, cuisine, dance, music, opera, theater, independent film, fashion, museums, and literature. Manhattan has been the scene of many important American cultural movements, it is home to some of the most extensive art collections in the world and Broadway theatre is often considered the highest professional form of theatre in the United States. Manhattan is the borough most closely associated with New York City by non-residents; even some natives of New York City's boroughs outside Manhattan will describe a trip to Manhattan as "going to the city".

map 20: Cultural Institutions

Examples of museums in the zone:

The Skysraper Museum: The museum shows New Yorks's rich architectural heritage and examines the historical forces and individuals that have shaped its successive skylines. Through exhibitions, programs and publications, the Museum explores tall buildings as objects of design, products of technology, sites of construction, investments in real estate, and places of work and residence.

fig. 36: Skyscrapers

The Museum of Jewish Heritage: The museum is a living memorial to those who perished in the Holocaust. The architecture of building is unique which is topped by a pyramid structure called the Living Memorial to the Holocaust. Museum has welcomed more than 1.5 million visitors from all over the world.

fig. 37: Museum of Jewish Heritage

2.3.11. Bike Route

In the metropolitan cities where the transportation is so important and at the same time very pollutant, it is vital to look for other solutions. For New York walking and bicycling are easy to apply as a solution because of the plain terrain and countless view options. For these reasons the New York State Department of Transportation, the metropolitan planning organizations (MPO), local governments and other agencies and organizations are creating an extensive network of bicycle and pedestrian facilities. These range from sidewalks in cities and villages to shoulders for walking and cycling in rural areas to regional trail ways on their own rights-of-way.
These facilities will encourage people to bike and walk to go to work, school, shop and recreate. This can lead to more compact communities and a lessened dependence on the automobile. In turn, less use of the automobile will result in less air pollution and less energy use. Improvements in the transit system in the mid-Hudson Valley are complemented by better access to the transit system by pedestrians and bicyclists.

Bicycle Route

Bicycle Path Advisory

Bike Route

- Bicycle Path Link
- Bicycle Path, Class I
- Bicycle Path, Class II
- Bicycle Path, Class II and III
- Bicycle Path, Class II with Auto-Free Hours
- Bicycle Path, Class III

map 21: Bike Route

3.Urban Strategies

3.1.Mix Uses

In 21st century, the key to both economic vitality and environmental sustainability is to embrace a robust mix of uses- commercial, residential, retail and tourism. The neighborhood has a great opportunity to integrate these different uses and cultivate a growing and dynamic economy. The goal of the urban plan is to realize the potential synergies that can come from efficiently managing an intensely mixed-use environment.

fig.38: mixed use 1

fig.39: mixed use 2

fig.40: mixed use 3

3.1.1. Create a Neighborhood within a Business District

map 22: Districts

Since 1990s, the strategy for the new downtown is to transform it from a business-only district to a dynamic live-work community. In the recent years the population below Chambers Street has tripled, but the rate of residential growth outpaced the development of traditional amenities. This disparity is most prevalent in Greenwich South, where 5,000 residents live primarily in converted office buildings. Although the area has not struggled to attract residents, it has yet to define itself as a distinctive "neighborhood," one simultaneously independent from and completely integrated into the surrounding commercial district.

This means achieving a fully-functioning residential environment with services, amenities and open spaces that are the standard in other city neighborhoods. Our proposal in the field of Urban Design consists in covering the existing tunnel in order to create a big public green space and make the environment welcoming, personal and familiar.

The density, diversity of use and significant development potential in Greenwich South offer a rare opportunity to experiment with sustainability solutions on a district-wide scale. For example, the evolving residential / commercial mix in Greenwich South provides potential opportunities to exploit the varied schedules of home life and office work to better balance demands on the power grid. And streamlining service protocols might improve the integration of residential and commercial trash collection. As Greenwich South becomes increasingly dense and mixed-use, there will be ever more opportunities to develop creative solutions for achieving environmental sustainability in the existing built environment. Our proposal in the field of Architectural Design consists in a mixed use tower in the place of the old parking building, integrated with the new green platform.

map 23: Concept 01

Integration of Greenwich South with the residential area of the Battery Park City, the public area of the Battery Park and the commercial area of the Financial District.

map 24: Concept 02

New Tower + New Platform

3.1.2. Foster the Growth of a Diverse Economy

Lower Manhattan's economy is mainly based on the financial services industry. To remain competitive, however, the district must support a wide range of businesses. And this has benefits beyond protecting the real estate. Diversity of businesses within a dense commercial district allows for the unscripted collaboration that can spur innovation and economic growth. To achieve this, Greenwich needs to provide the basic amenities that support business, like ample lunch spots and access to taxi service. It also needs to offer such amenities as parking for bicycle commuters, co-working spaces and public WiFi, which appeal to a diverse and creative workforce. Just as a mix of business types can support a more dynamic economy, so too can a mix of users — residents, artists, tourists and workers — foster a more engaging and vibrant atmosphere. Future development in Greenwich should not be limited to a single use such as housing or big office towers, but should instead acknowledge all of the uses that contribute to the growing richness of the Downtown economy.
Our proposal is:

- to provide street shops along the new platform.

- to provide a shopping mall on the base of the tower and in this way solve the problem of the lack of basic amenities and lunch spots.

- to provide public wi-fi not only in the shopping mall but also for the green platform.

- to provide an easy bike access, as well as bike parking . Connection with the existing biking route.

- to open a new street between the tower and the platform, ideal for a taxi point.

3.2. Reconnect Greenwich Street

The restoration of Greenwich Street through the World Trade Center provides a tremendous opportunity to renew Greenwich South by rejoining it to the rest of the city and establishing it as the base of the emerging Lower West Side, made up of Tribeca, Hudson Square, the West Village, the Meatpacking District and Chelsea. A restored Greenwich Street can join Fulton Street and what will be an engaging promenade along the East River waterfront to create a loop of activity in Lower Manhattan.

map 25: Greenwich Street

3.2.1. Restore Greenwich Street from the Battery through the World Trade Center

Two hundred years ago, Greenwich Street was the main road linking the mansions and farms of Lower Manhattan to Greenwich Village. The development of the World Trade Center in the 1960s split Greenwich Street in two, which severed Greenwich South from the rest of Manhattan. The completion of the World Trade Center site redevelopment will reinstate Greenwich Street, connecting Greenwich South to Tribeca and creating a new pedestrian path from Battery Park to the 9/11 Memorial and on to the High Line. It is anticipated that millions of people will visit the World Trade Center each year. The priority should be building strong psychological and visual connections along Greenwich Street — including streetscape elements and way finding system that integrates Greenwich Street north and south of the World Trade Center site.

map 26: North-South

3.2.2. Create a Green Gateway to Manhattan at the Base of Greenwich South

Numerous visitor attractions, residential buildings and commuter transit nodes draw thousands of people to the Battery each day. This concentration of activity, combined with the redevelopment of Battery Park and the reconnections along Greenwich Street, creates an opportunity to make the base of Greenwich South a gateway to the city. New architectural, landscape, streetscape, retail and traffic designs can work together to make the base of Greenwich Street an iconic, welcoming point of entry into the district and to the rest of Downtown.

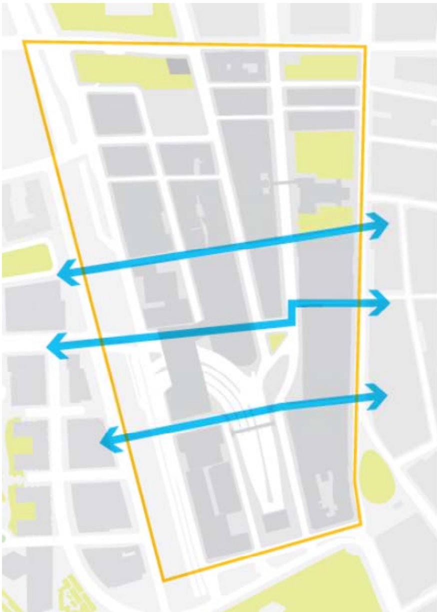
3.2.3. Make Greenwich Street Spine of the Greenwich South

Once reconnected through the World Trade Center, Greenwich Street will again be a main north south route through Lower Manhattan, creating a new hierarchy among Lower Manhattan's north south streets. Greenwich Street can even become a new kind of spine for Lower Manhattan, a more intimate alternative for people moving between Battery Park and the World Trade Center than the grand but often saturated Broadway.

Today, buildings shun the severed Greenwich Street. Restored connectivity will provide impetus for future buildings and redevelopment projects to acknowledge and engage with Greenwich Street. The whole of Greenwich South should be organized around this new connecting spine to capture the market demand of the thousands of workers and visitors at the World Trade Center. Greenwich Street is the obvious locus for programs and activities — restaurants, cultural programs, shopping and public spaces — to serve the area's many users. These new programs and spaces can strengthen Greenwich Street as the spine of the district — the central means of north south circulation and the primary destination for economic and pedestrian activity.

3.3. Connect East and West

Greenwich South should be the lynchpin for Lower Manhattan, yet it is defined by seemingly impenetrable borders that make passage difficult. Softening these hard edges and improving the east-west connection from Battery Park City to the Financial District will integrate Greenwich South into Lower Manhattan and begin to dissolve the barriers between these adjacent neighborhoods.



map 27: East-West 01

3.3.1. Strengthen East-West Connections and Commuter Corridors

West Street (fig.40), an eight-lane highway, is a prominent barrier that definitively divides Battery Park City from Greenwich South. It is the most significant obstacle to uniting Lower Manhattan. Crossing West Street is hazardous, difficult and unpleasant due to the width of the street and the speed of traffic. These conditions make it awkward for residents of Battery Park City to access Greenwich South, and impede New Yorkers and tourists hoping to enjoy the Hudson River Waterfront. The long-term goal must be to create many options for crossing West Street safely, pleasantly and conveniently.

map 28: limitations of traffic

A new bridge, like the one planned at West Thames Street (fig.42), is an important step towards improving connectivity from Battery Park City that's why a new bridge that connects Battery Park City with the proposed site is planned for pedestrians and bicycles. More steps, however, are needed to ameliorate fully the challenges of crossing West Street. Improvements to at-grade crossings can balance out the role of bridges decrease the importance of each individual intersection and encourage a more even distribution of pedestrian flow.

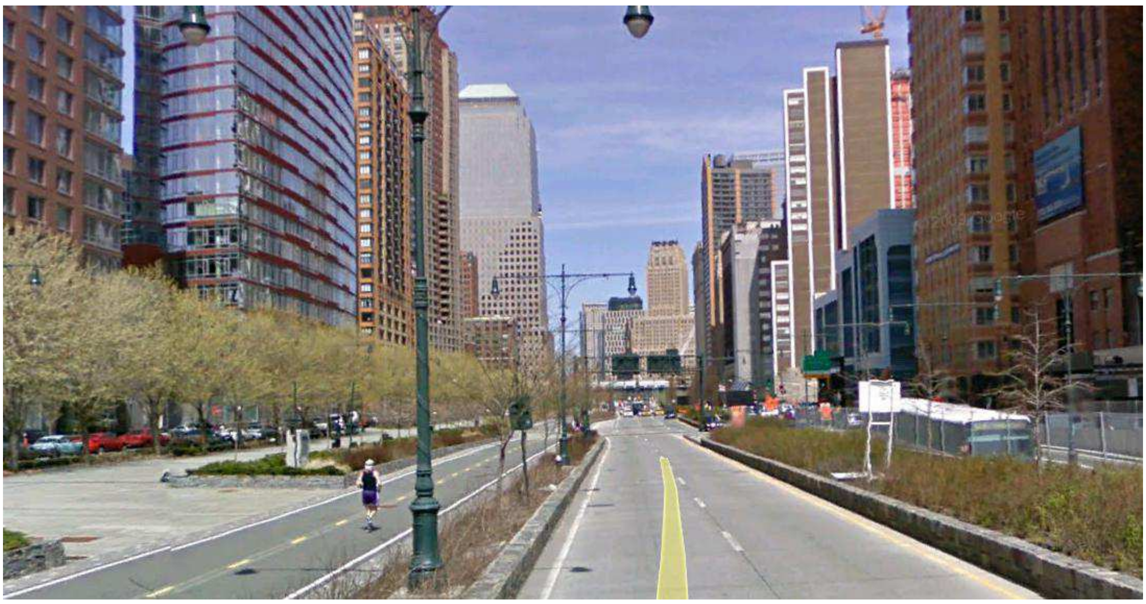


fig.41: West Street
Google Earth view

fig.42: Bridge at West Thames Street

In addition to addressing West Street's physical barriers, efforts should also be made to mitigate the image of the street as a psychological barrier to Greenwich South. The east side of West Street is visible from Battery Park City, yet, because the street wall is blank, the view is uninviting. The traffic, streetscape and retail environment along the eastern edge of West Street make it unappealing to pedestrians. Within Greenwich South, the difficulty in moving east to west is compounded by the lack of through streets and narrow sidewalks. The east-west route across Edgar Street and Exchange Alley, used by thousands of Battery Park City residents every morning, is especially deficient. Pedestrians cut through the parking garage, despite its being both unsafe and unpleasant. Furthermore, the route across the Brooklyn-Battery Tunnel approach is indirect and the existing bridge needs improvement. Rector Street is the only east-west through street for cars and pedestrians, but narrow sidewalks and unsafe intersections create hazardous conditions and impede auto and pedestrian traffic. Planning, building and landscape initiatives are required to redefine these corridors and strengthen the east-west experience through Greenwich South**.**

3.3.2. Reprogram Side Streets as Magnets of Activity

Many side streets in Greenwich South are blank, narrow and steep. This uninviting character discourages pedestrian flow into the site from Broadway. The desolate spaces do not offer engaging uses or activities. Redesigning and/ or reprogramming these side streets could turn a negative aspect of the district into a positive one by inviting transverse movement across the site. It could also create a diverse set of spaces and activities for residents, workers and visitors to explore. By capitalizing on the intimate scale, each of these streets could take on a particular character — and create places to be "discovered" in the neighborhood. One location might house a desirable lunchtime food court similar to Stone Street (fig.43) on the east side of Lower Manhattan, while another could be the site of a rotating public art installation and a third filled with inviting street furniture and a free WiFi zone. Creating spaces for artists to work, and for their work to be seen from those on the street, is another way to activate the public realm.

fig.43: Stone Street

fig.44: Proposal for a Side Street

After 9/11 with the destruction of World Trade Center, Lower Manhattan lost its "North Star." Though Greenwich South is close to notable towers, the location of Greenwich South was never well known to most New Yorkers. Upon completion, One WTC will be the most visible landmark in Lower Manhattan. It is important for Greenwich South to build off this renewed visibility and cultivate its own iconic skyline image. Strategically designed buildings and well-positioned artwork can provide eye-catching glimpses from outside Greenwich South — facilitating way-finding and drawing people into the neighborhood. These same design initiatives should also strengthen sightlines from inside Greenwich South, enhancing views to the water and to the World Trade Center. View corridors along narrow side streets can become ideal vantage points to attract pedestrians along a path of exploration and discovery. Public art, landscape, street furniture and building facades can all enhance the pedestrian environment and reinforce continuous connectivity through a previously undiscovered neighborhood.

fig.45: Sculpture in front of Seagram building

fig.46: Sculpture in the City Hall Park

3.4. Build for Density, Design for People

With the Brooklyn-Battery Tunnel approach and numerous under-built properties, Greenwich South offers millions of square feet of latent development potential that are key to Lower Manhattan's long-term growth and vibrancy. The challenge is finding a creative way to unlock that potential and to support Lower Manhattan's ongoing evolution as a globally competitive business district. Future development in Greenwich South also presents an opportunity to define a more welcoming, engaging pedestrian environment, with building design and programming that blurs the edges between public and private realm. A more densely-built Greenwich South will also require new infrastructure, the form and function of which must be compatible with an intensely used pedestrian environment.

3.4.1. Enable Dense, Large Scale Development

Millions of square feet of unused development capacity reside in Greenwich South, and there are multiple sites for future large-scale development. The redeveloped World Trade Center will reinforce a taller scale for the district, and, even before completion, will catalyze a broad transformation throughout Lower Manhattan. The market might not be ready yet for additional new development, but future market cycles will provide the impetus for building out Greenwich South. This future development should be contextually compatible with the areas that surround the World Trade Center, on a scale comparable to the World Financial Center and the Wall Street corridor. A coherent strategy is necessary to ensure that future development in Greenwich South furthers Lower Manhattan's primary function as a business district, creates a mix of uses, and enhances the Lower Manhattan skyline. New towers that mix commercial and hospitality uses in the northern part of Greenwich South for example, might complement towers with residential, retail, restaurants and cultural venues toward the south. Development in Greenwich South should follow massing criteria that allows for density and height but also creates an appealing pedestrian environment, avoiding forbidding canyons and maintaining views and light. Such high-density development, easily walkable and served by excellent transit access, is also inherently sustainable.

fig.47: Greenwich South

fig.48: Green Proposal for Greenwich South

3.4.2. Turn an Urban Void into a Positive Space

Leverage the Air Rights of the Brooklyn- Battery Tunnel Site: The single greatest challenge for Greenwich South is resolving the void and barrier created by the Brooklyn-Battery Tunnel approach. The redevelopment of the tunnel approach and parking garages also provides the greatest opportunity to transform Greenwich South. Given a favorable market environment, there are several strategies that could unlock the approximately three million square feet of development rights associated with the tunnel approach and the garages. One option would be to use one or both of the garages as the site of an office building or multiple mixed-use towers. Our project uses the site of one of the garages for a mixed-use tower, and redesigns the other garage, keeping its original function. Decking the tunnel approach generates additional air rights and creates a public use on the deck.

3.4.3. Integrate Infrastructure Planning and Design with Community Needs

History shows how the addition of new infrastructure in Greenwich South, though useful in supporting the needs of a growing city, had painful consequences on the local area. The dirt, noise and shadows that resulted from the construction of the elevated train in 1868 turned a thriving “Millionaire’s Row” along Greenwich Street into a district of brothels and boarding houses. The area recovered, and was a vibrant business district, until the building of the Brooklyn- Battery Tunnel in 1950 brought the noise and pollution of thousands of cars directly into the heart of Greenwich South. Finally, the creation of the super block for the original World Trade Center severed the connection along Greenwich Street, cutting off Greenwich South from the areas to the north and handicapping the district’s development for decades. The number of people who visit, live and work in the district will continue to grow, placing greater demands on the performance of each square foot of space. Infrastructure that is insensitive to the area’s connectivity or is inhospitable to intense pedestrian activity is simply incompatible with the needs of a vibrant and dynamic district. We must think more carefully about the role of infrastructure as Greenwich South evolves in the 21^{st} century — and recognize that form is just as important as function. Might there be opportunities to recapture some of the space taken up by infrastructure — such as creating a park over the Brooklyn Battery Tunnel — to better integrate it with a rapidly growing residential community. All future decisions about development of new infrastructure must be made in light of the needs of a dense, rapidly-growing neighborhood.

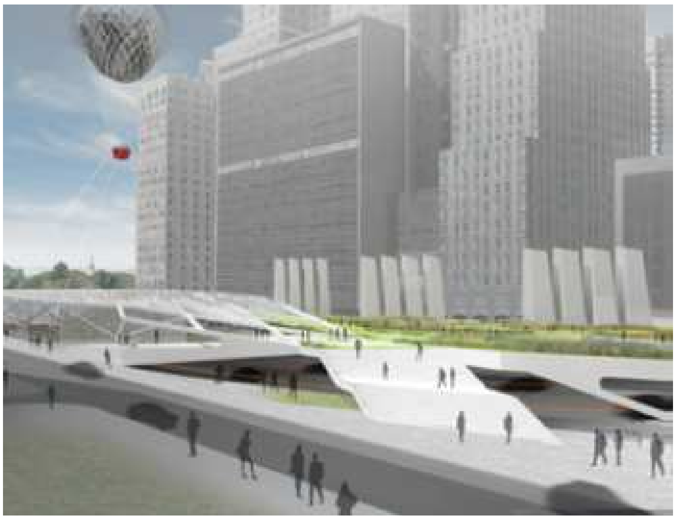
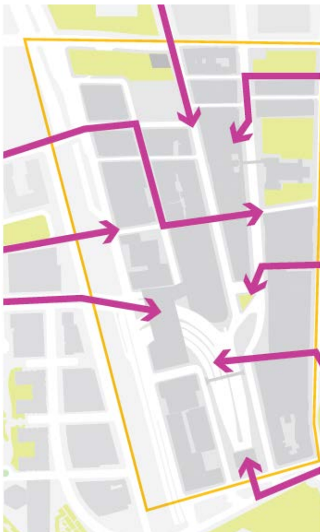


fig.49: Deck proposal for Brooklin Battery Tunnel

3.5. Create a Reason to Come and a Reason to Stay



map 29: Greenwich South

Though thousands of people live and work within the boundaries of Greenwich South, few if any of them relate to the area as a distinctive place because there is no "there" there. An important part of the evolution of Greenwich South requires establishing it as a place with unique qualities — and recognizable character that resonates in a powerful and positive way. Initiatives aimed at creating more open space, iconic and defining architecture and art, and engaging programming can help make Greenwich South more charismatic and welcoming to the people in the local area as well as those from across the city and around the globe.

3.5.1. Create Public Spaces to Support New Development and a Growing Population

Open spaces help to balance a densely-built environment with the growing population — they should be the centers of public life, places where workers, residents and visitors all interact. Multi-functional spaces should adapt to a range of uses — active and passive, programmed and unprogrammed, day, evening and weekend. Smaller pocket parks and plazas can animate Greenwich South and provide places for the area's diverse users, but we think Greenwich South also needs a signature open space — an immediately identifiable park or plaza that creates a local focal point for community gathering and daily life.

3.5.2. Establish Identities for North-South Streets

Changes to surrounding areas present an opportunity to organize uses along Greenwich South's three interior north-south streets. Greenwich Street, which reconnects the Battery and the World Trade Center, should become the organizing element for Greenwich South. Open spaces, retail, restaurants, cultural and entertainment venues along Greenwich Street should establish the street as a complement to Broadway: accessible from anywhere in the city by vehicle or on foot, and animated by a variety of uses. Trinity Place offers an extraordinary opportunity to extend a new retail promenade from Century 21 and the 500,000 square feet of retail at the World Trade Center to the street's terminus at a remade Edgar Park. Additionally, Trinity Place can become a hinge between the retail on Wall Street and the World Trade Center. Washington Street has a very different character from either Greenwich or Trinity. It primarily serves area residents and hotel guests. Dead ends at the north and south limit through traffic, making it an ideal laboratory to test a new street typology. It could be a shared street, open air lunchtime café with entertainment or something totally new that makes the street a neighborhood amenity. We want to propose an open market for Washington Street.

fig.50: Emphasize the Commercial Character of Greenwich Street

map 30: Greenwich South

3.5.3. Complement Cultural Destinations with Dynamic Programming to Draw Repeat Visitors

Signature arts and cultural offerings help define many cherished New York neighborhoods. Lower Manhattan has no lack of unique cultural destinations — its many historic sites and museums draw millions of visitors annually. Yet Lower Manhattan generally, and Greenwich South specifically, lack a compelling variety of venues to attract locals for repeat visits. A goal for Greenwich South's future should be to bring a variety of dynamic arts, cultural and entertainment programming to Greenwich South to create a more charismatic identity for the area. As the largest free concert series in the city, the Downtown Alliance's River to River Festival provides an excellent example of how thoughtful and dynamic arts programming can engage the public. Expanding the Festival, which pulls in a million people every summer, to include more programming in Greenwich South could be one way to start animating this underserved area with arts and culture. Our proposal for the platform is to have an open cinema. We are taking advantage of its inclination to accommodate the public in the grass and the screen is located in the back of the tunnel entrance building, which is used only for infrastructure.

fig.51: Open Air Cinema in La Quinta, CA
http://www.la-quinta.org

3.5.4. Create Icons that Establish a New Identity and Sense of Place for Greenwich South

fig.52: Red Cube
www.blueofthesky.com/redcube

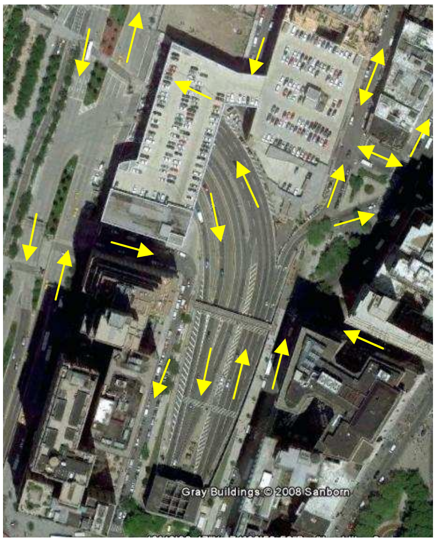
Urban touchstones, like the steps of the Metropolitan Museum, Isamu Noguchi's Red Cube (fig.52) at Liberty Street, or Union Square Park, define an image for an entire district. These icons create tangible incentives to visit the site. They can serve as a rendezvous destination, a location for public events or a lunch spot for workers, but they also become conceptual anchors that sustain neighborhood property values and enhance desirability. Creating large and small icons in Greenwich South would help provide both identity and gathering places within the district. New retail, cultural, dining and entertainment activities in the site can rely on these iconic destinations to attract activity, make way finding easier and support a 24-hour district. The new platform will have a "mirror sculpture" , inspired in the one from Millennium Park (fig.53) which will reflect the new skyscraper.

fig.53: Millenium Park Cloud Gate
culturalcapitol.com

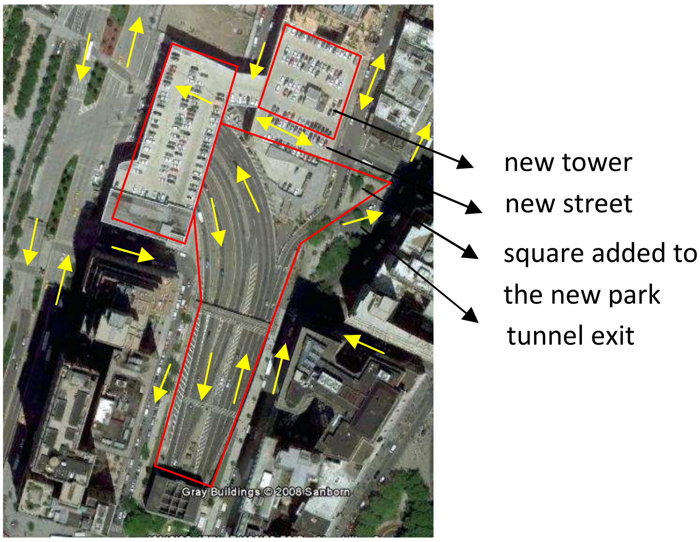
The creation of the World Trade Center Performing Arts Center and the possible renovation of Castle Clinton into a year-round entertainment venue might also present programming opportunities for Greenwich South to share in the cultural events taking place nearby. Cultivating Greenwich South's credentials within the art community should also incorporate venues for both the production and consumption of art and culture. Creating temporary and permanent rehearsal spaces studios and artists' residences within Greenwich South would bring working artists to the area, providing an interesting new dynamic to the mix of users in the area that would not only enrich the character of Greenwich South might also attract attention from locals and outsiders alike. We want to propose a space for temporary artistic exhibitions on the first floor of the garage building, which is connected to the platform.

4. Urban Design

4.1. Vehicles Accessibility



map 31: Accessibility



map 32: New Accessibility

The changes in the vehicles routes consist basically in creating a new street in front of the new tower, and aggregating the small square to the new park, in this way eliminating the piece of street between them.

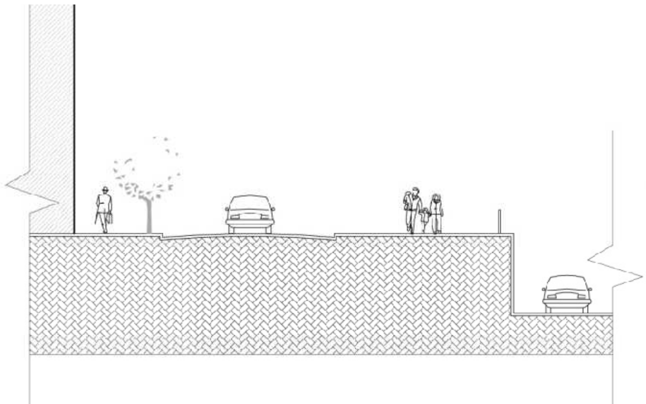
4.2. Side Streets

Washington Street and Greenwich street are facing the lateral sides of an inclined platform and this is one of the main issues of this project because these parts could never become simple walls facing the sidewalks. We took into account the different characters between the two streets to decide the different approaches for both sides of the platform.

4.2.1. Washington Street

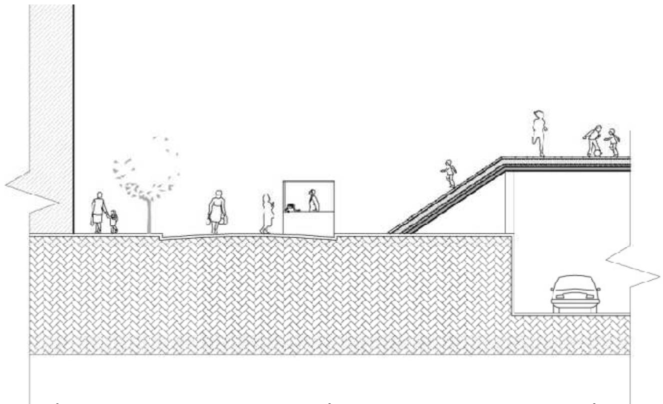
Washington Street is quite empty, it has been used mainly for accessibility of its residents. Our proposal is to have an open market during some days of the week. Instead of looking to a tunnel while walking by the street, there will be green zones and waterfalls, providing the access to the green platform in some points.

before



drawing 001: Section Washington Street - existent

after

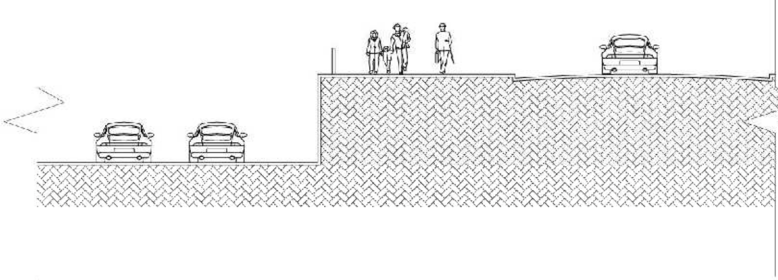


drawing 002: Section Washington Street - proposal

4.2.2. Greenwich Street

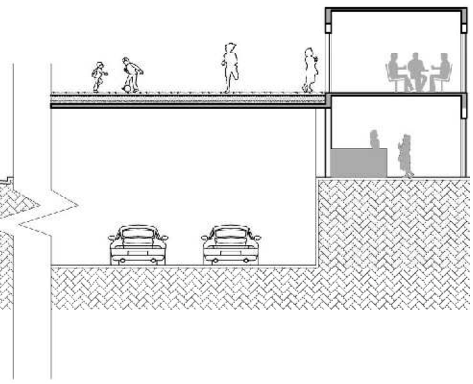
Greenwich Street is the main street of the neighborhood, it is the main connection in north-side direction and it is the street we are trying to turn into a complement for Broadway. The idea is to improve its commercial character and putting street shops in the transition zone between the platform and the sidewalk seemed to be appropriate.

before



drawing 003:
Section Greenwich Street - existent

after



drawing 004:
Section Greenwich Street - proposal

4.3. Master Plan

The new platform is composed by an inclined green park - which follows the inclination of the tunnel below - and a flat wood deck. There are three buildings interacting with the platform:

- a new tower - Greenwich Tower - in the site of one of the two existing garage buildings.

- a new garage building - in the site of the other existing garage building.

- an existing tunnel entrance building.

The two existing garage buildings should be demolished and the two new buildings should be designed from the beginning. The existing tunnel entrance building is used for the infrastructure of the tunnel and it requires a refurbishment project: a restaurant on the top, panoramic elevators for its access and a big screen in the back of the building will turn the inclined green park into an open cinema.

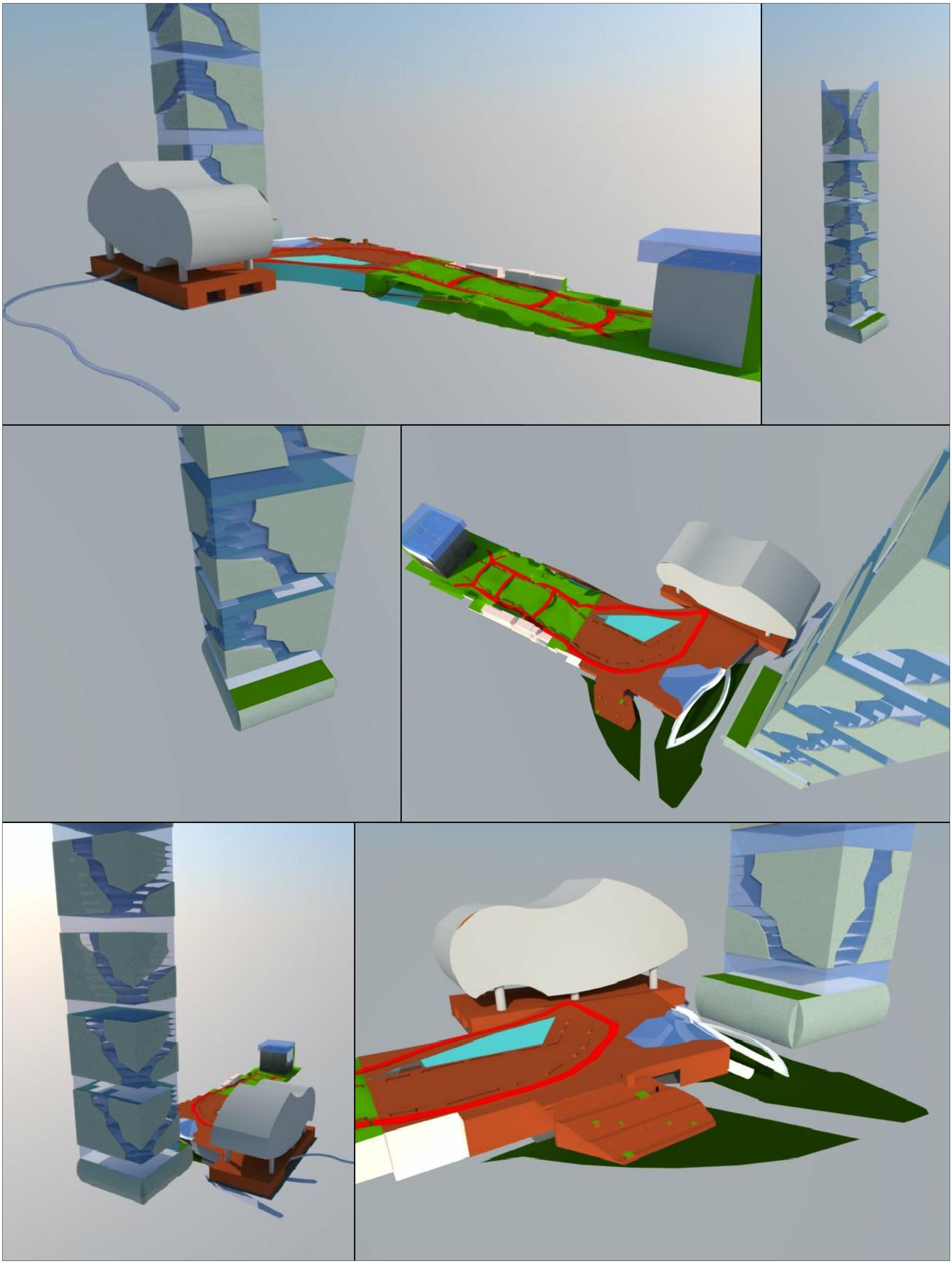
The first floor of the new garage building is completely integrated with the new platform and it is a transition between the platform and the new bridge over the avenue. This area will host temporary artistic exhibitions. The direct connection between the new tower and the platform is made by regular stairs and a "snake ramp" that arrive in the street level, where all the lobbies and access to the tower are located. There is also a direct bridge from the platform to a one of the commercial levels in the base of the tower.

Besides the possibility of reaching the flat deck through these two buildings, it is also accessible by large stairs located next to the tunnel exit in Greenwich Street. The stairs can be used as a sitting place as well. Under them there is a bike parking, as well as the access for an elevator.

The inclined green park is accessible through the zero level - close to the tunnel entrance building - through stairs and ramps on the side of Washington Street and through stairs, an elevator and a wood deck on the side of Greenwich Street. The wood deck is a path that connects all the new street shops and at the same time connect them with the platform level and with the street level. It allows some shops to be accessible by the street and some shops to be accessible by the platform. These shops are like movable boxes that vary in height, width and length. The primary colors chosen for these "boxes" can also give the idea of containers.

Although the main idea for the park is walking on the grass, there is path - connected with the existent bicycle route of the area - that is supposed to be used by everybody (runners, bikers, skaters...). The small hills spread around the grass not only are an entertainment for children but also helps the users of the open cinema to accommodate themselves.

The wood deck fits a water square and a transparent floor area, where is possible to see the new square of the street level. Cafeterias, tables and the snake ramp are located in the middle of the trees. The wood deck also has a mirror sculpture that reflects the skyscraper, which has a similar shape with the new parking building.



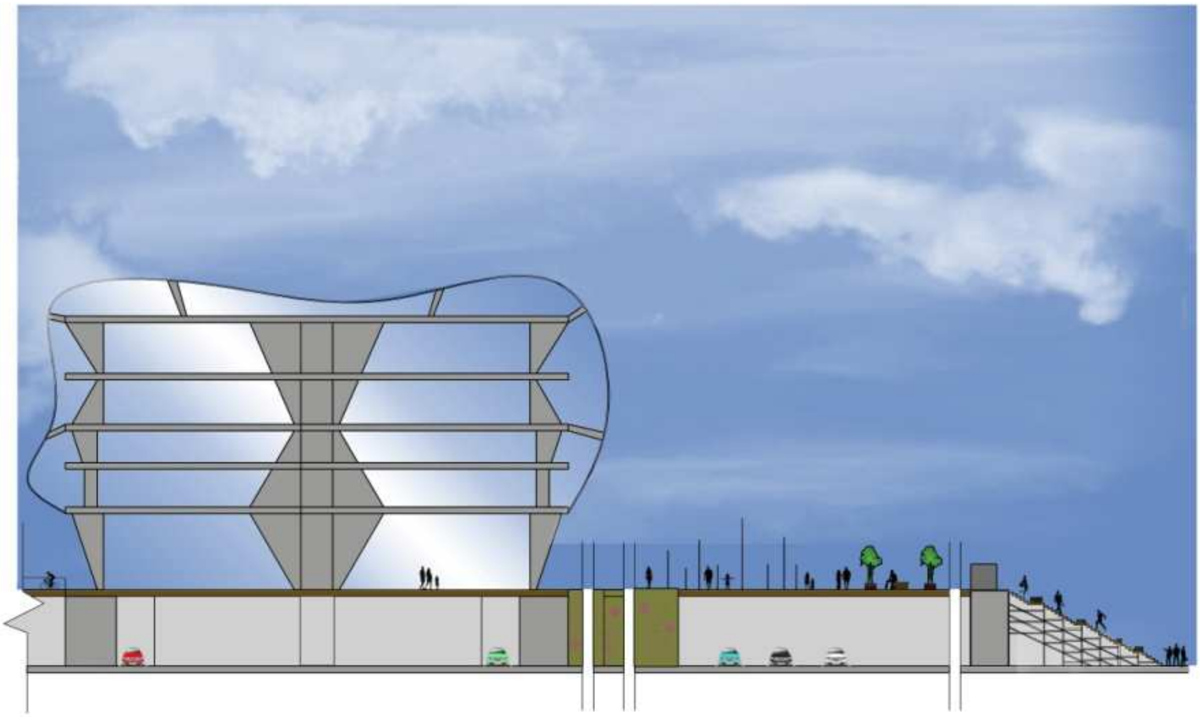
master plan
1/1000

GREENWICH TOWER

A005

4.4. Sections

Section A-A



drawing 006: Urban Section

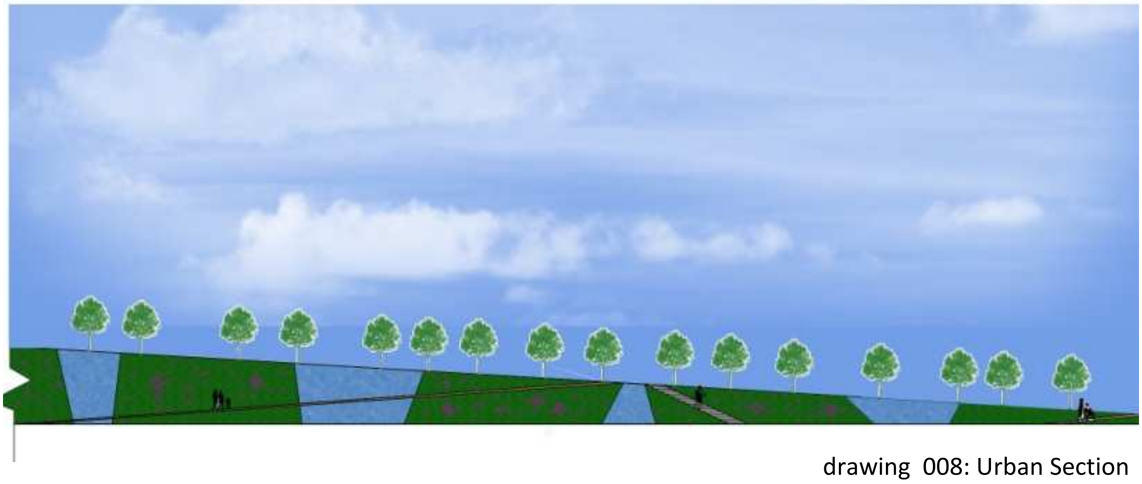
fig. 54: Existing Area

Section B-B

drawing 007: Urban Section

fig. 55: Existing Area

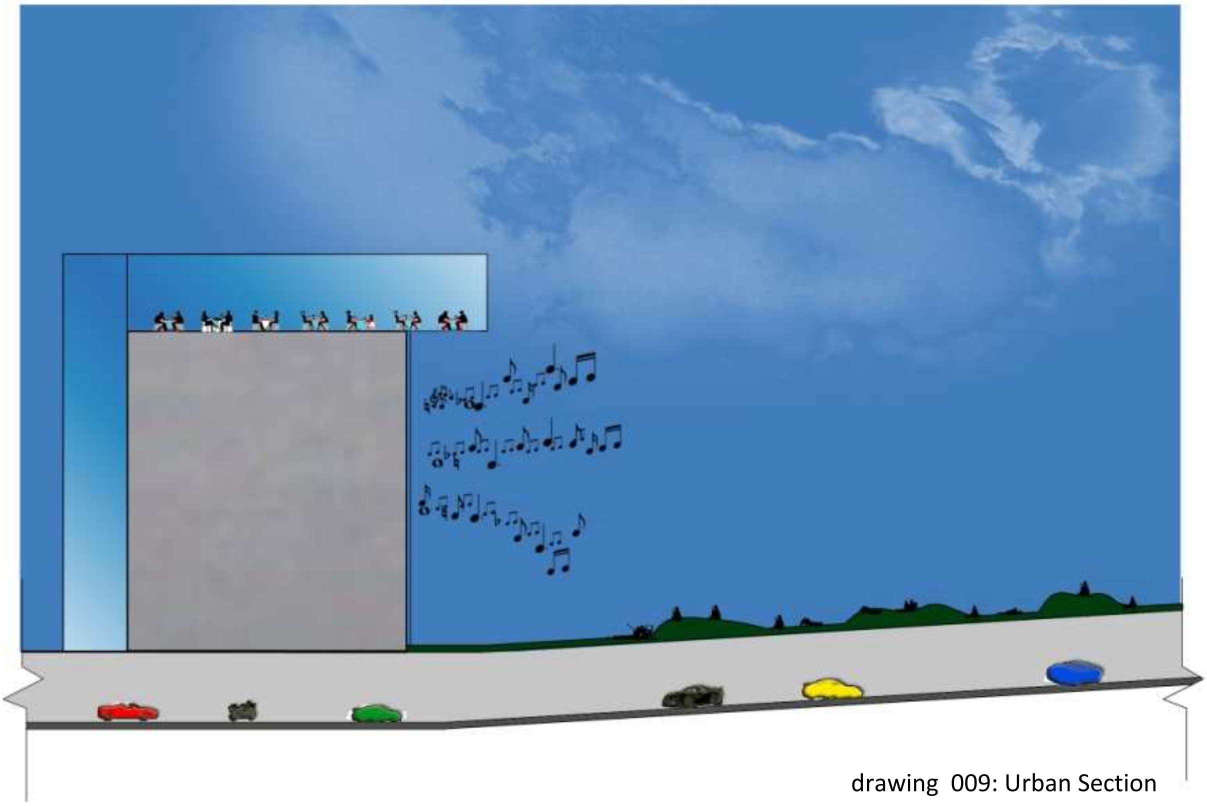
Section C-C



drawing 008: Urban Section

fig. 56: Existing Area

Section D-D



drawing 009: Urban Section

fig. 57: Existing Area

Section E-E

drawing 010: Urban Section

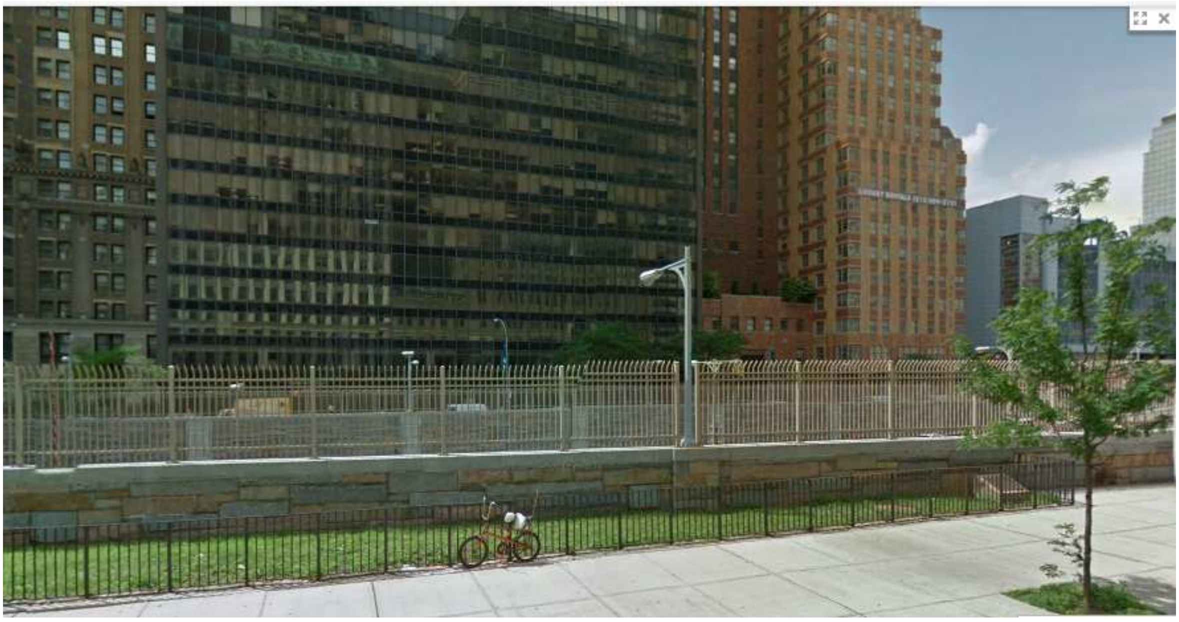
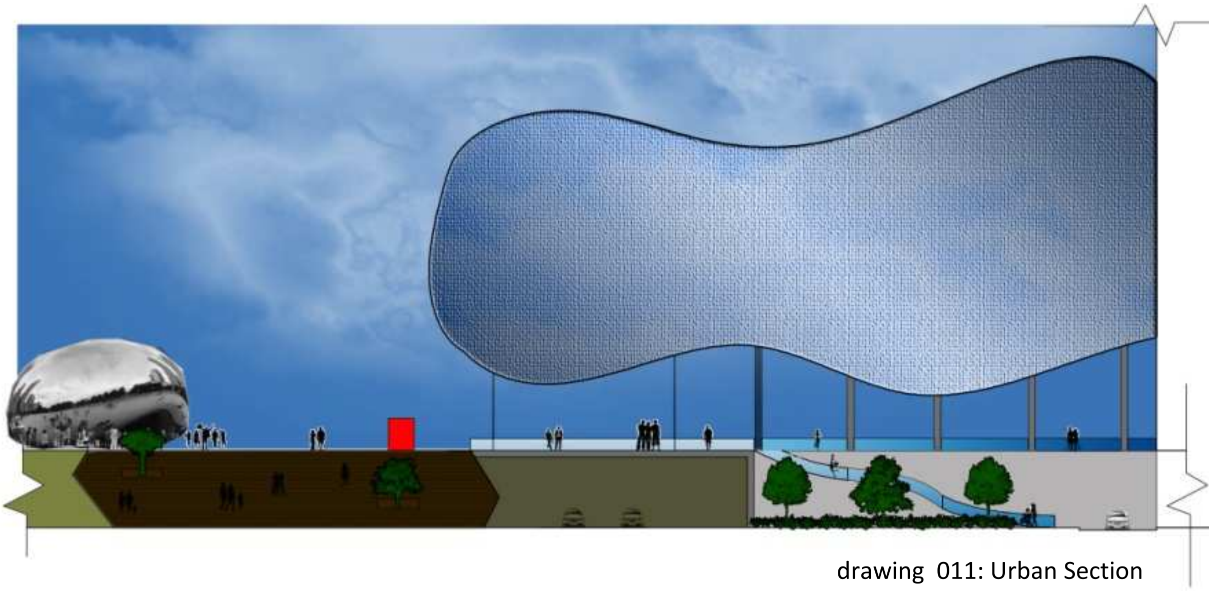


fig. 58: Existing Area

Section F-F



drawing 011: Urban Section

fig. 59: Existing Area

Architectural Design

As mentioned in the previous chapters, an important part of our work deals with the integration of a skyscraper - that we will refer to as Greenwich Tower - in an area of Lower Manhattan, in New York. Our main goal is to provide a sustainable mixed use tower with green areas. The tower should be a landmark in the city and at the same time interact with the new green platform, together they will develop one important entrance of the city, considering its strategic position.

1. Location

map 30: Building Location

New York City - Lower Manhattan: A dashed red line defines the neighborhood called Greenwich South. The red circle shows the area available for the construction of the new tower and the consequent demolition of the existent building dedicated to the Battery Park Garage. A continuous red line defines the area for the new park that will cover the Battery Park Tunnel. The yellow circle is the other garage building inside the area, which will be totally reconstructed but will keep the same function.

2. Mixed Use Concept

New York City - as many other big cities - is a natural generator of diversity and a modern tower integrated to the city should have a multifunctional program. Greenwich Tower should be a piece of vertical city, integrated with the urban fabric. We want to insure the presence of people in different schedules, who are in the building for different purposes, but who are able to use some facilities in common. The tower basically has a commercial public part on the base and on the top, between them there are residences, offices, hotel and green areas. It means that it is open to a wide range of users: the residents, the workers, the hotel guests, the visitors, the tourists, the owners of urban farms. (see next topic)

fig. 53: Tower as a Piece of a Vertical City

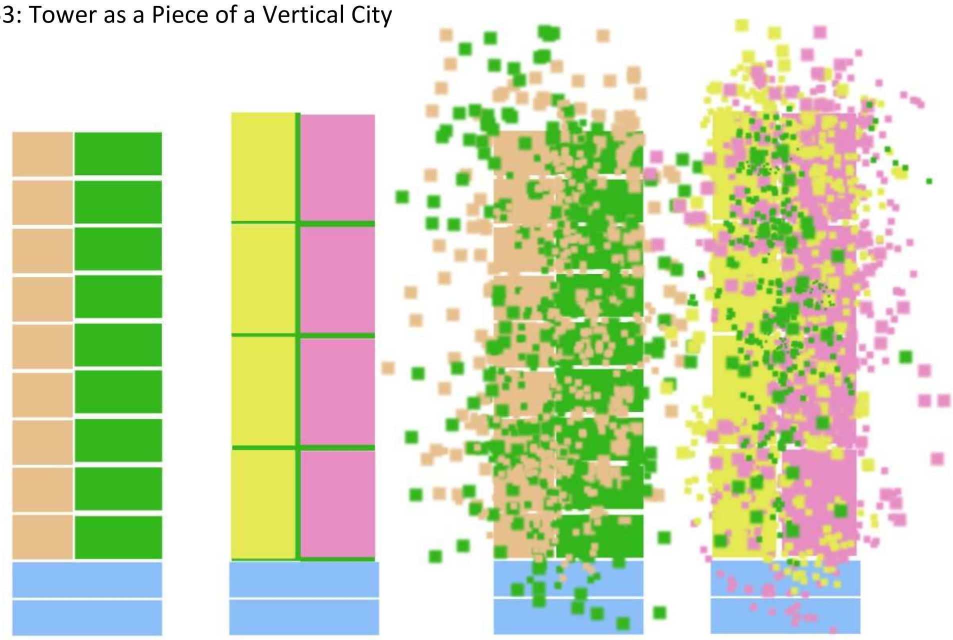


fig. 54: Mixing Functions

3. Green Areas Concept

Our concept of "green" for the Greenwich Tower has always been present and defined from the beginning. It is based in two main ideas:

- The first one is to have the "green as a function", with the same importance as the other functions (residential, hotel, offices) trying to mix all of them as much as possible.
- The second one is to connect the green areas in a vertical way, creating a walkable green path through the façade.

fig. 55: Green Tower

A good challenge was the distribution of these green areas between public and private.

- Main Public Green Areas: Six green floors that divide the tower in five main blocks (plus the base and the top). Each green floor can have a different character: for jogging, for leisure, for farming.
- Secondary Public Green Areas: Located on the south and west façade of every single floor of the tower. Not accessible by indoor spaces. These portions of green are all vertically connected, with each other and with the main green floors.
- Private Green Areas: Located on the east façade, they have a direct connection with the indoor spaces and depending on each case will be a garden that belongs either to offices or to the apartments.

The main concern was about the real use of the secondary public green areas, because if they turn out to be empty spaces, we would have a serious problem to deal with: the waste of valuable areas. The most appropriated solution, according to what we expect from this building, was to sell or rent these portions of land for hobby farming purposes. It would be a semi-public zone which is at the same time productive and useful, and will always have someone to take care of. Anyone who lives/works or in the building or in the neighborhood is a possible interested urban farmer. Urban farming is a trend that is popping up all over America and increasing in popularity each year. The fact that by the year 2050, nearly 80% of the earth's population will reside in urban centers confirms urban farming as an adequate alternative for the public green spaces of Greenwich Tower.

4. Volume

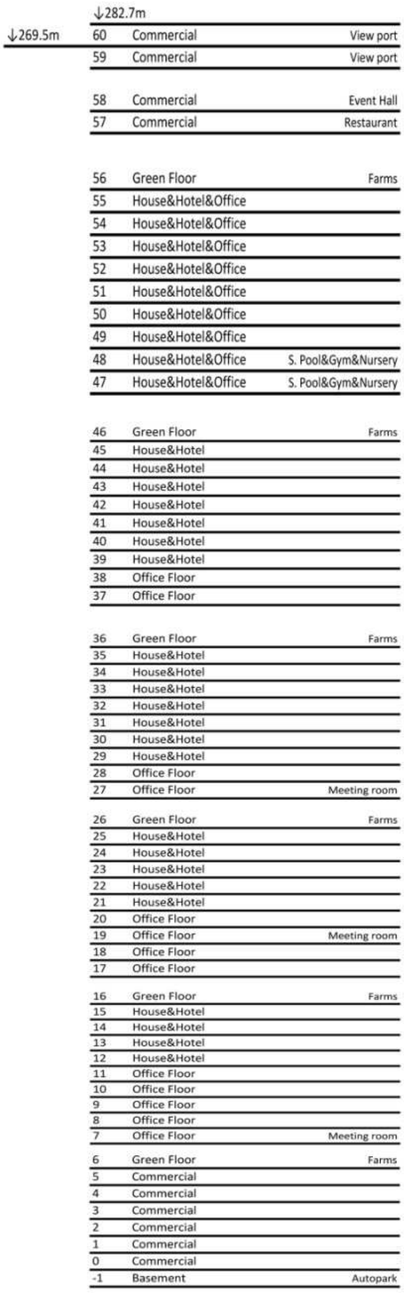
After several attempts the group decided for the simplest shape. A regular shape was adopted in order to optimize the usage of the internal spaces, to facilitate the structural issues and to give us more freedom to play with the "movement" of the four façades using technological elements and creating green paths. We are also sustaining an important principle for skyscrapers: this kind of building does not have a main façade, all the four sides are equally important, as they are visible by a lot of people from a lot of places.

fig. 56: Volume Studies

fig. 57: Volume Adopted

5. Sections

5.1. Distribution of Functions



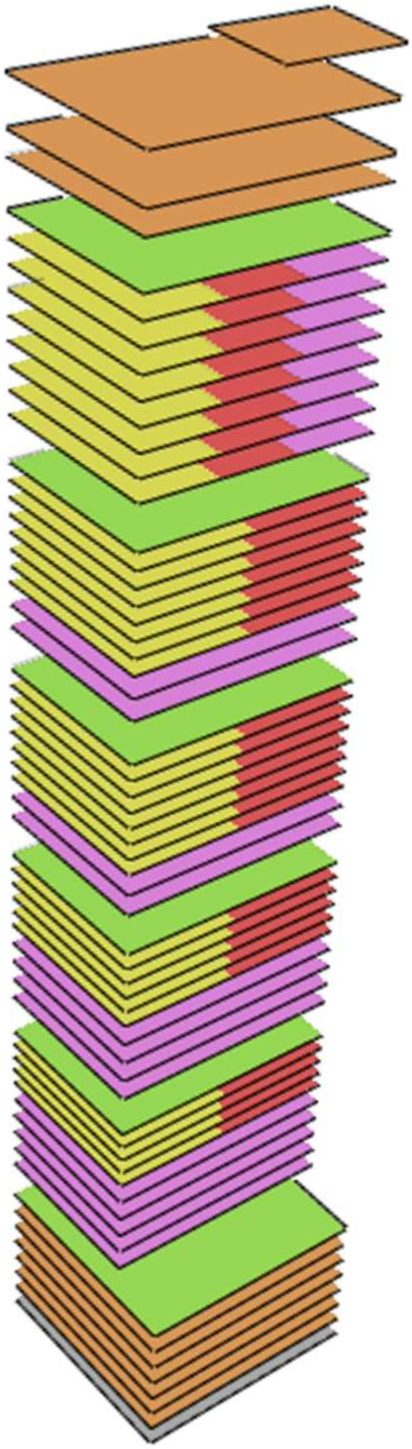


fig. 58: Functions Scheme

The skyscraper is 60 floors height and it is composed by:

Base
Commercial (public use):
6 floors, each one 48m x 48m.

Tower
Houses, Offices, Hotel:
45 floors, each one 48m x 36m.
Green Floors:
6 floors, each one 48m x 36m.

Top
Commercial (public use):
3 floors, each one 48m x 36m.

5.2. Accessibility - Vertical

5.2.1. Main Elevators - Core

Stops

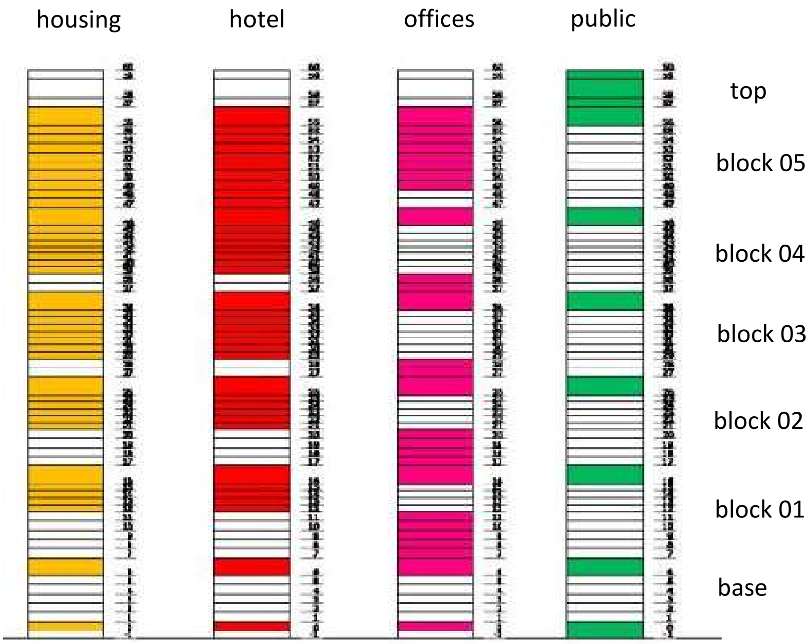


fig. 59: Stops of the Main Elevators

The elevators are separated by functions, one who takes an office elevator in the ground floor will not be able to access the zones destined to hotel or housing, even when they are all located in the same floor. Besides the lobbies of the ground floor, there are five groups of skylobbies along the tower, located in the public green floors (the first floors of each block). Giving the opportunity to switch to another group of elevators, these floors can be accessible by all the users of the building as well as outside users.

Public elevators (green): Accessible from the ground floor, from the underground, from the green floors and from the top floors destined to restaurants, coffee shops, event hall and panoramic deck.

Offices elevators (pink): Accessible from the ground floors, from the green floors, from the floors destined to offices only (the first 4 blocks) and from the floors that mix offices + houses + hotel (5th block)

Housing and Hotel elevators: Accessible from the ground floors, from the green floors, from the floors that mix houses + hotel (the first 4 blocks), from the floors that mix offices + houses + hotel (5th block) and from two facilities floors, that provide swimming pool, gym, spa, sauna, nursery. Housing and Hotel are always together in the floor plans but there is no communication between them, except for the facilities floors that they have in common.

The commercial base has an independent circulation and it is not accessible by the core of the tower.

5.2.2. Secondary Elevators - Green Areas

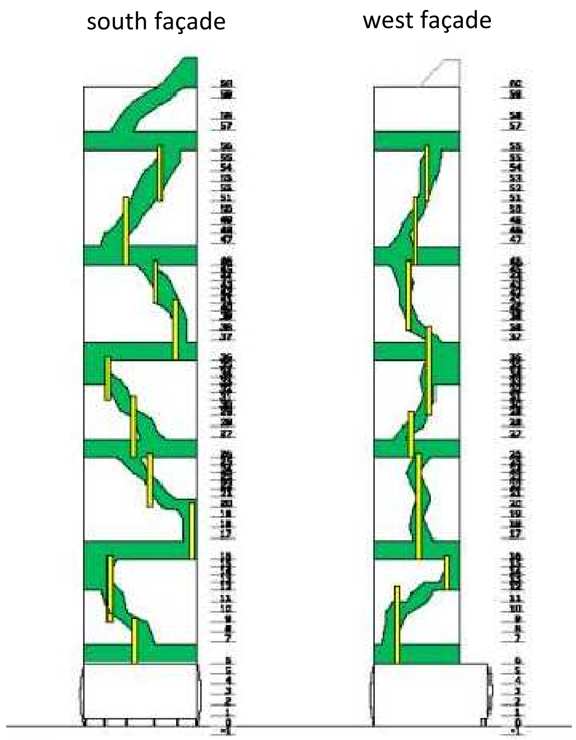
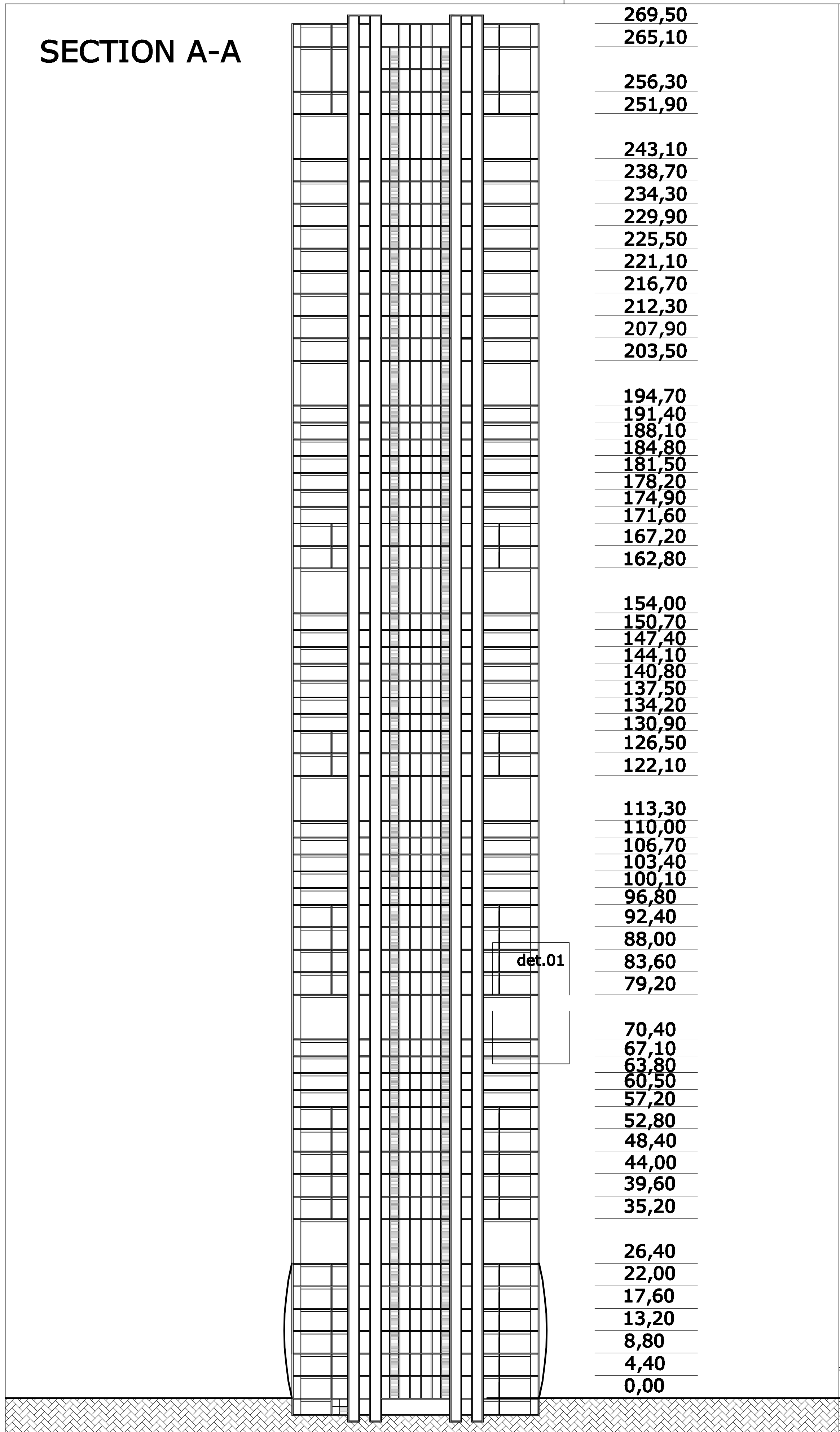


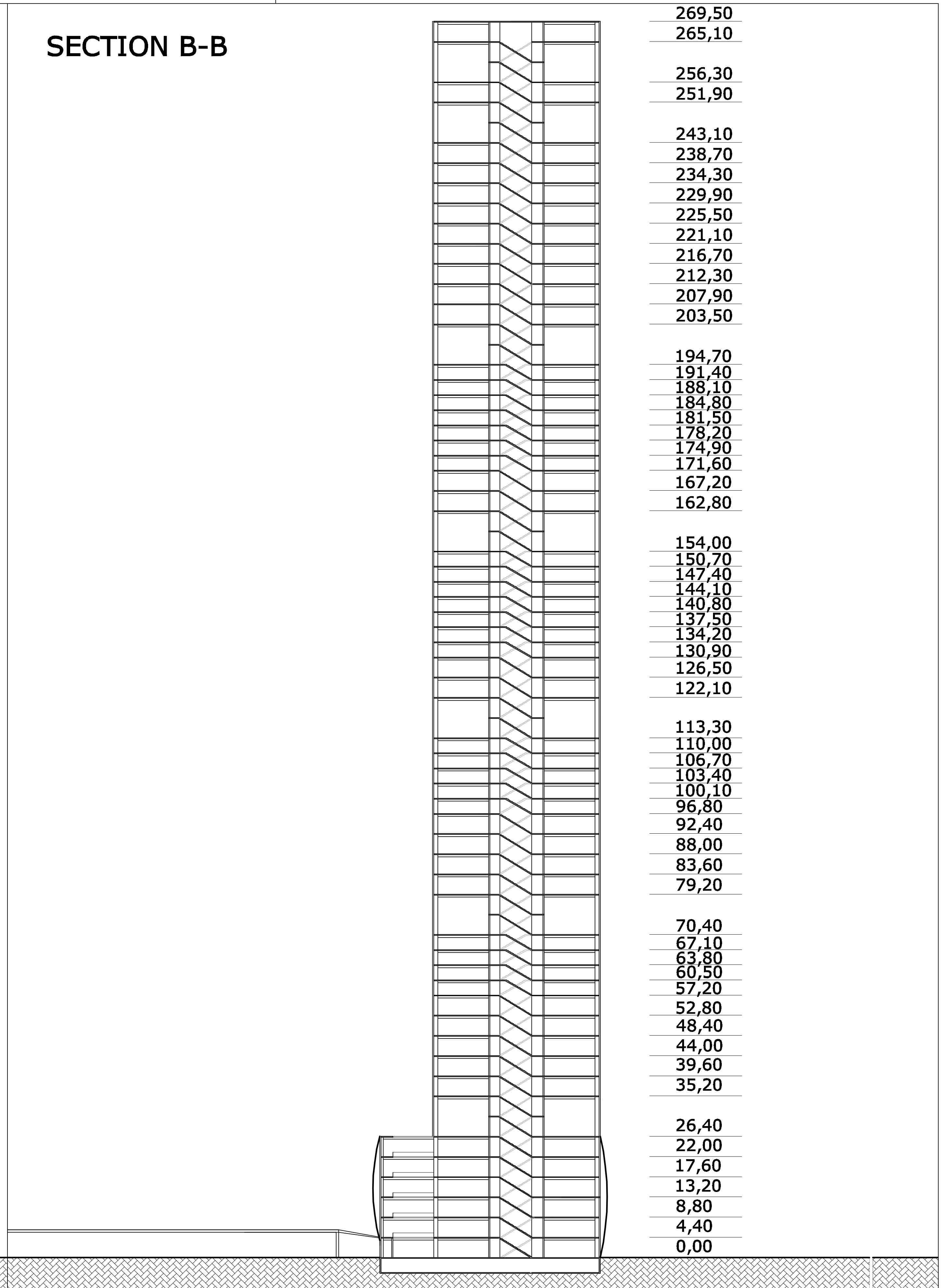
fig. 60: Stops of the Green Elevators

The smaller pieces of green areas in every floor of the south and west façades are all urban farms. These areas are all connected by secondary hydraulic elevators and helicoidal stairs, sustaining the initial concept of the "vertical walkable green path". Each green area in every single floor is easily accessible by first taking the express public elevator until one of the six main green floors, followed by taking one secondary elevator that goes up or down depending on each case. However, we would appreciate if the users use the open stairs for these areas.

It is important to remember that the north façade does not have green areas, our concept of "green" does not match with the lack of sunlight. Also, the green areas of the east façade are private, used by offices or apartments (depending on the floor) and obviously are not connected due to privacy and security reasons.

Green areas of the upper floors are disconnected because they belong to their respective functions of each floor (restaurant, event hall, observation deck).





A012

GREENWICH TOWER

sections

1/1000

POLITECNICO MILANO

6. Base

The public commercial base has to be differentiated from the tower. It is the only part of the skyscraper that can be seen at short distance by the human eye. The base has to "invite" the people on the streets to enter the building. The fig.61 shows the base of a Commercial Office Building in NY (Arch. Pierpaolo Ruttico) that is pretty similar to our case and was used as a reference: Glass modules different from the tower, four big transparent curved elements in front of all the sides of the base, the ground floor smaller than the others for shading and rain protection.

fig. 61: Reference for the Base

6.1. Module

A 3mx3m grid was chosen to organize the plans, according to the mullions of the façades that are spaced every 1,5m. The grid works as the width module for the hotel rooms and it is perfectly suitable for the other functions as well.

The core is composed by:

- 4 public elevators
- 4 elevators for housing
- 8 elevators for offices
- 8 elevators for hotel
- two pairs of scissors stairs
  (public x hotel and offices x housing)
- 4 elevators for services
- mechanical area
- restrooms (in commercial floors only)

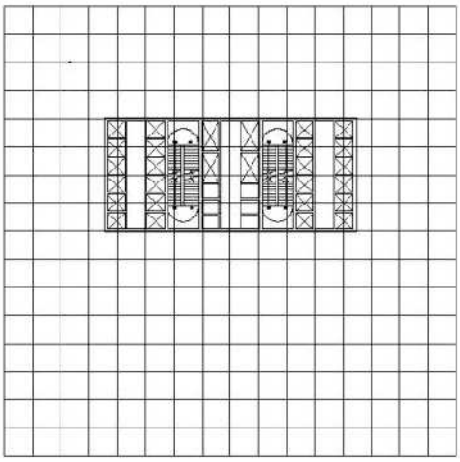


fig. 62: Grid

6.2. Ground Floor (see drw A013)

In the outer side, shops and services directly accessible from the streets. In the inner side, around the core, double height lobbies separated by usages.

Accessibility

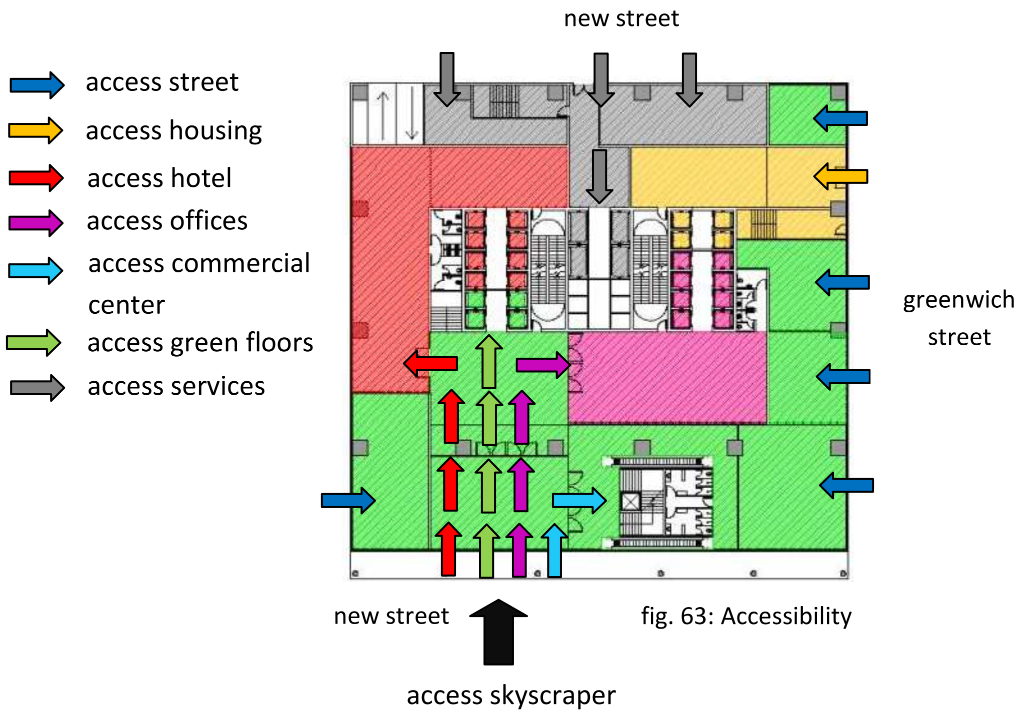


fig. 63: Accessibility

The base of the North Façade gives access for the parking entrance and the services areas, including the access for the service elevators, that can be also separated by usages. To reinforce the commercial character of Greenwich Street, there are street shops in the base of the east façade, each one with its independent entrance. Among the shops there is a private entrance for the housing users. The main entrance for the tower is in the south façade, in front of the new platform. All the different users of the building - except the apartment dwellers - enters through the same common hall, for a better security control. Close to the entrance appears the first possibility of access: the Commercial Center. If the user keep walking through the main hall he will find the lobby for the offices access on the right, and the lobby for the hotel access on the left. Besides entering the lobbies, the common hall itself gives an interesting option to access the tower: the public elevators. They are express elevators that lead the public for the Green Floors and the Upper Floors (Restaurant, Event Hall, Observation Deck).

A013

GREENWICH TOWER

ground floor
1/200

6.3. Underground (see drw A014)

Why there is only one parking floor:

- We do not want people to use cars (the site is well served by public transportation and it is designed to facilitate the use of the bicycle)
- We are proposing a parking building right next to the skyscraper.
- It is a mechanical parking, which increases a lot the capacity of the parking area. Aside from saving space the mechanical parking system also offers convenience and time saving methods. Instead of driving to an unknown spot in the parking lot hoping to find something people can simply leave their car at the entrance, push a button, and go about on their own business while the car parks itself. Retrieving the vehicle afterwards is just as simple, with a push of a button the car will be returned to the entrance, ready for the owner to drive away. (www.mechanicalparkingsystem.com)

The access from the outside to the underground is made through the "services street" on the north façade. The access from the underground to the other floors is made by the public elevators, which means that people have another option rather than going only from the underground to the ground floor: they can go directly to one of the public green floors in the tower, as they have skylobbies and security control. Considering that the fire-proof stairs should not arrive to the underground, there are two alternative stairs to connect the underground with the ground-floor: The ones located next to the public elevators arrive in front of the main entrance of the ground floor. The ones located in the right side arrive in front of Washington Street, next to the housing entrance, serving mainly parking users who live in the building.

Commercial Center

The commercial center has an independent circulation, served by escalators and an elevator. The service restrooms are also located in this part, while the public restrooms are located in the main core. There is an atrium passing through all the six commercial floors of the base, right in front of the entrance of the tower.

6.4. First Floor (see drw A015)

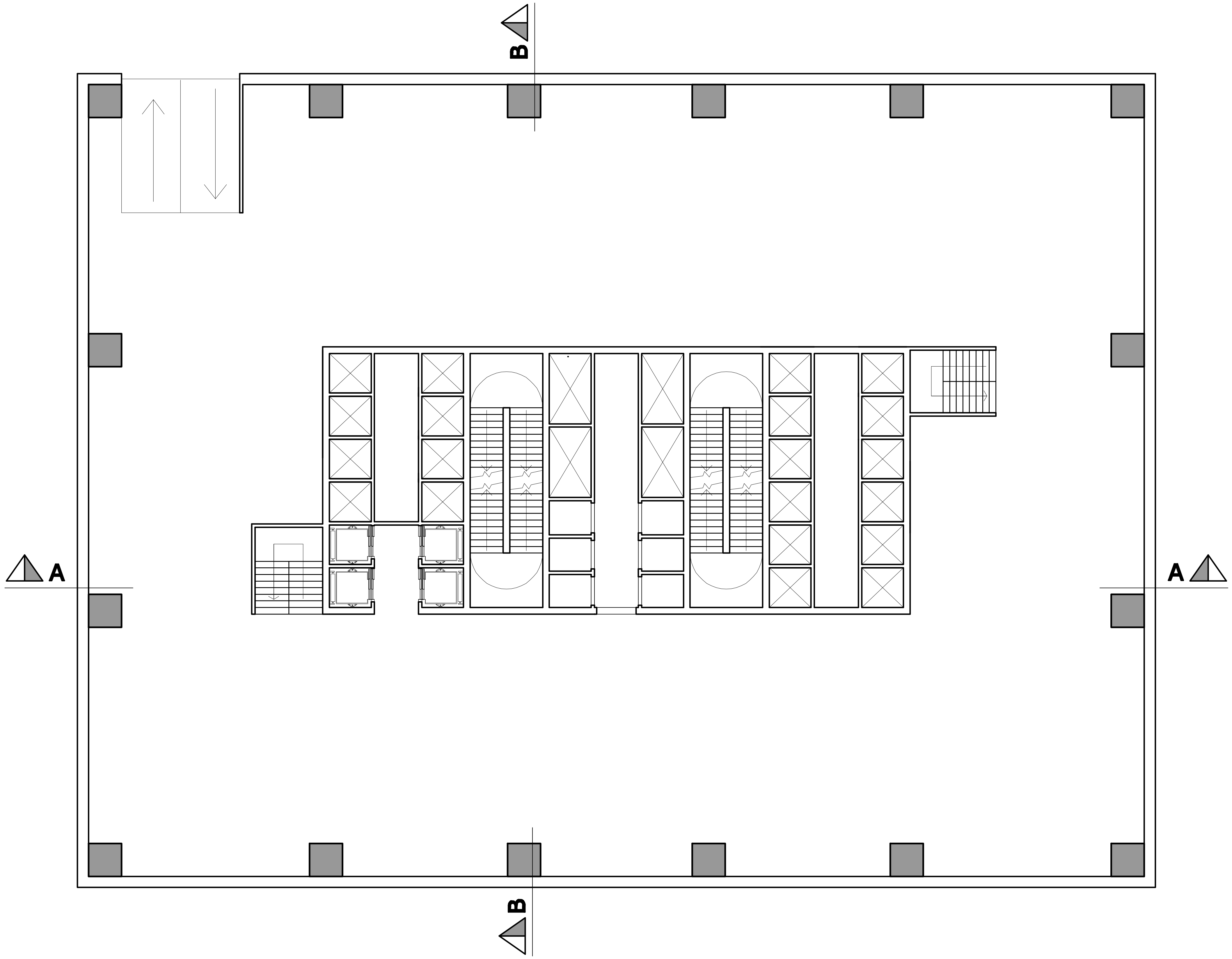
In the first floor of the commercial center we are supplying the need of places to eat, that are inexistent in the neighborhood. The food court floor is connected to the platform, through a bridge.

6.5. Second Floor (see drw A016)

The shops start in the second floor and continue until the fifth floor.

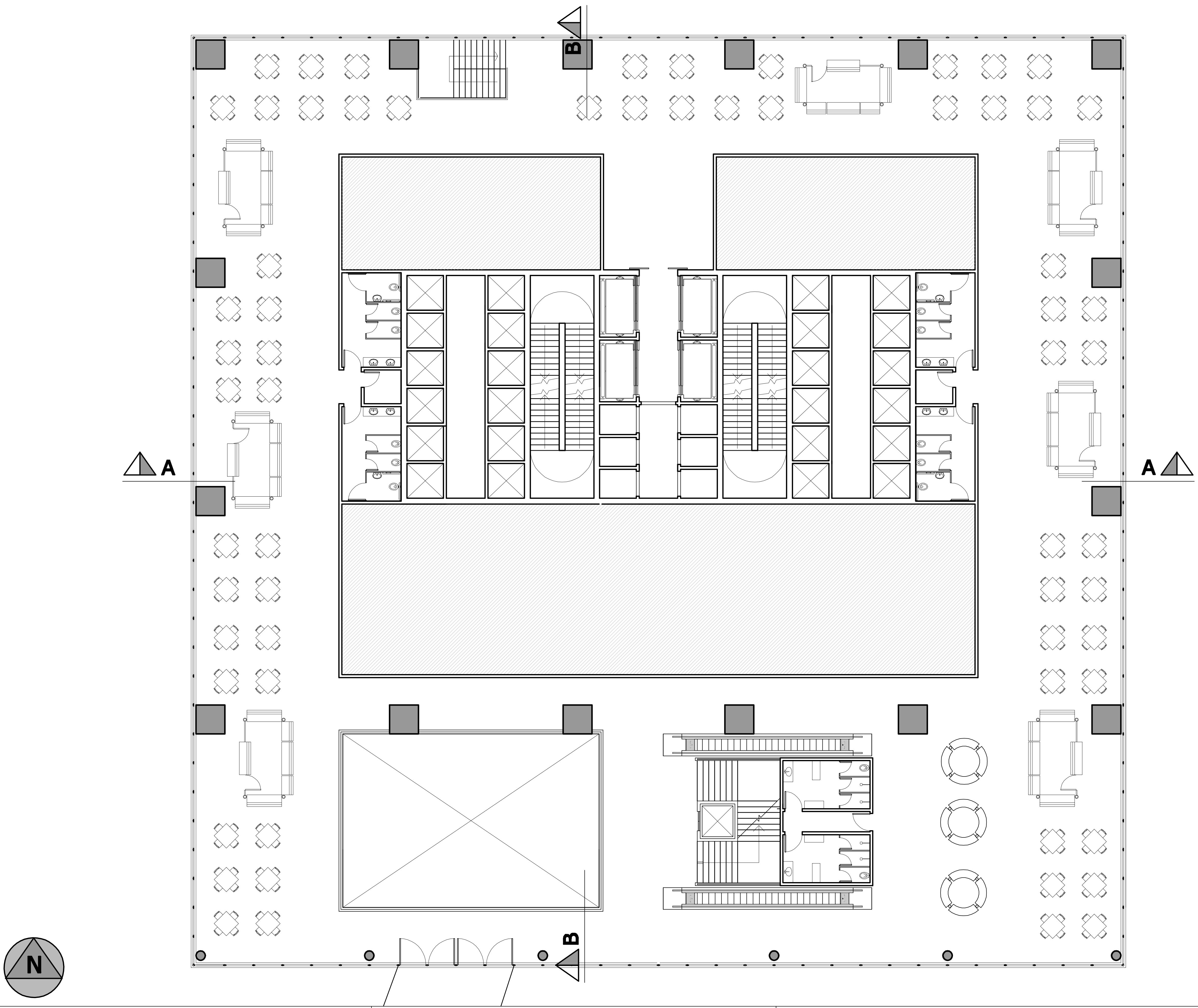
6.6. Green Floor (e.g. 6th) (see drw A017)

There are six green floors along the tower. We take the first one to show as an example. As mentioned before, these floors are supposed to be public and used by all the users of the tower and visitors.
The green floor has small skylobbies to control the access of the other usages, on this example the floor is working as a jogging area. It offers the "green secondary connections" in two points, allowing the access to the green areas of the adjacent floors. The 6th floor, as being the top of the base, has the differential of having a totally open area and a roof window on the top of the atrium.



A014

underground
1/200



A015

GREENWICH TOWER

1st floor
1/200

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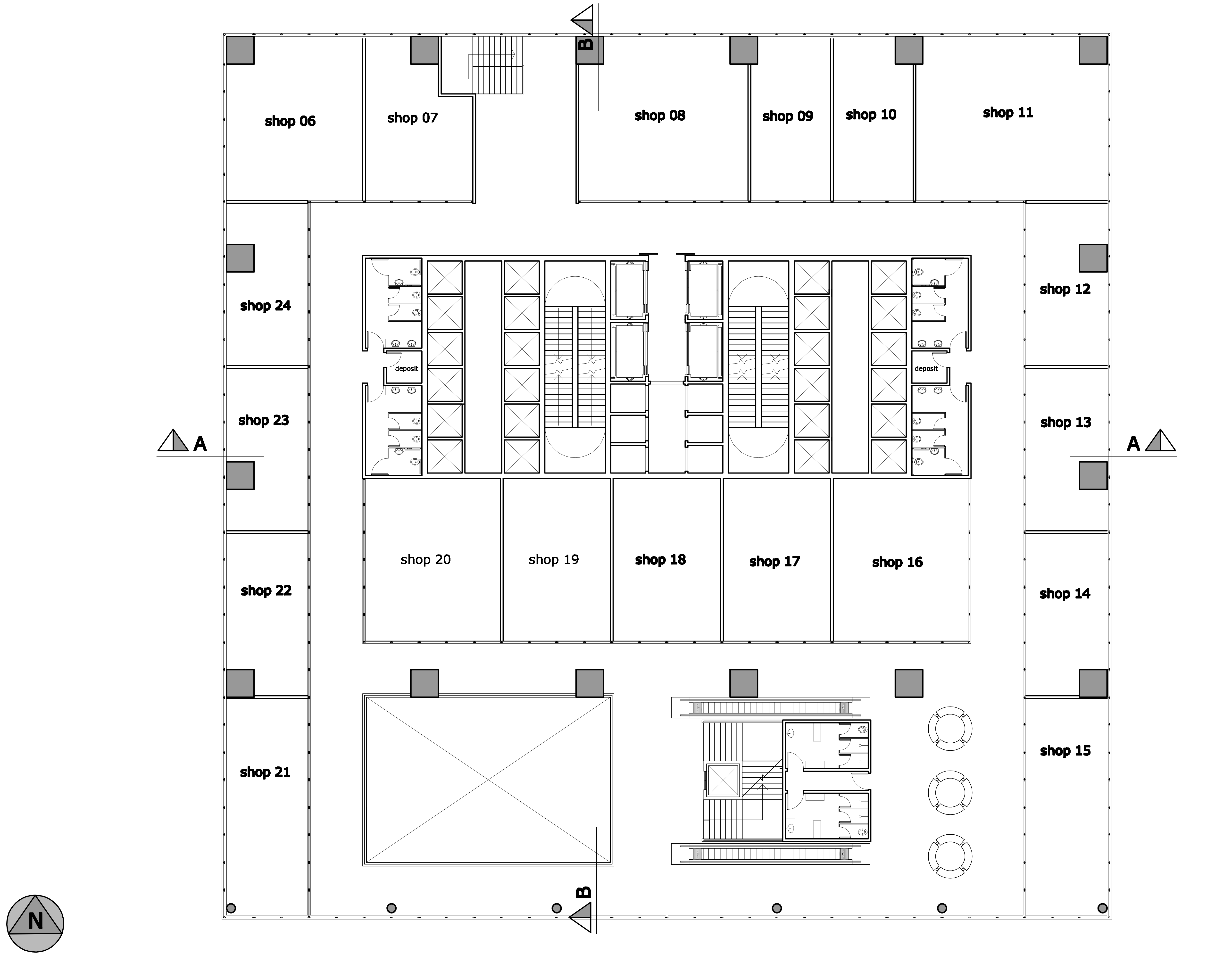
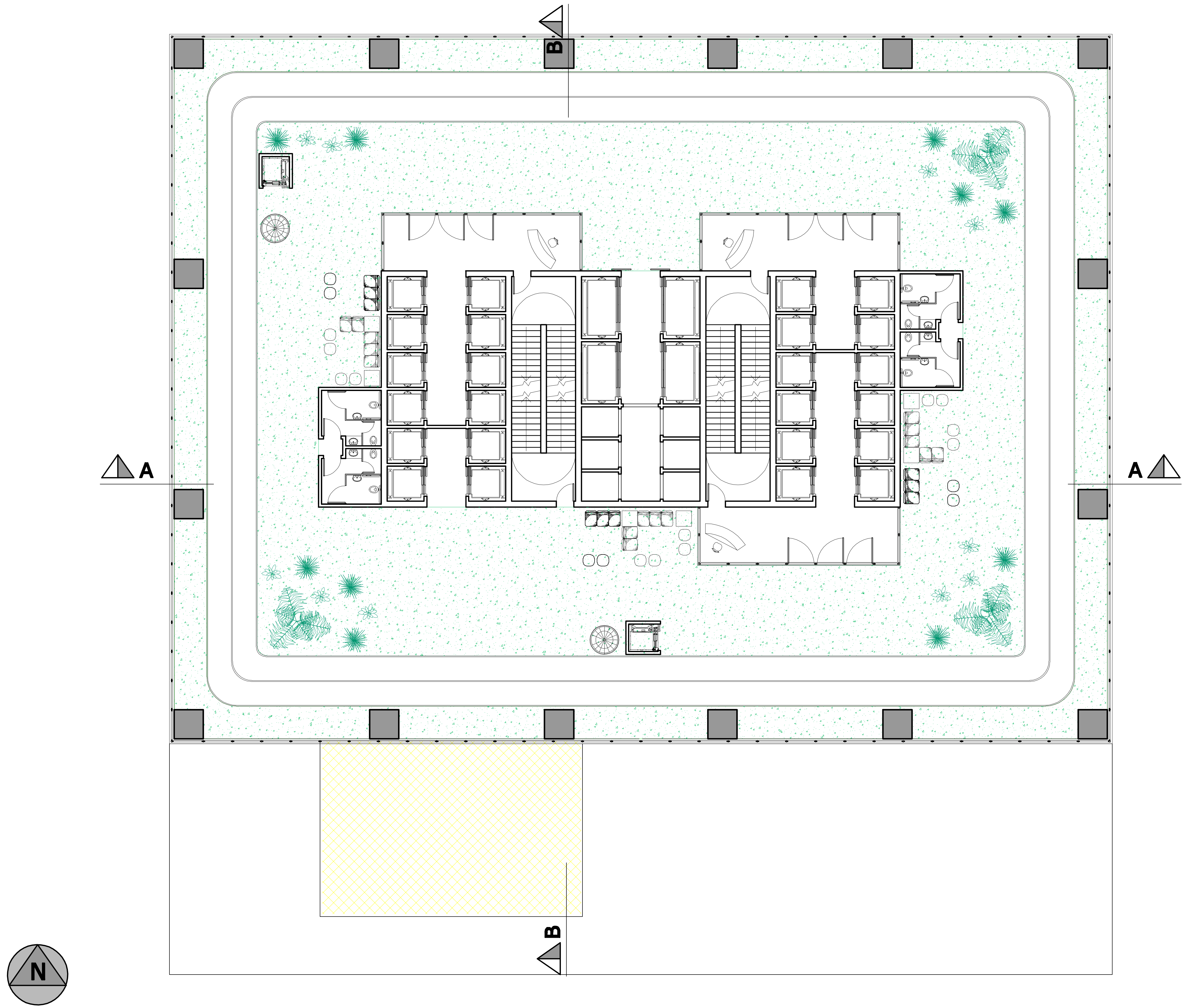


A016

GREENWICH TOWER

2nd floor
1/200

POLITECNICO MILANO



A017

GREENWICH TOWER

6th floor
1/200

POLITECNICO MILANO

7. Tower

Four functions: Offices, Residences, Hotel and Green Areas. In the beginning we wanted to mix all of them in the vertical way, but due to functionality reasons this concept had to be readapted. The companies usually prefer their office floors as an open plan layout, plus, the floor height required for offices is higher than the one required for a residence or an hotel room. So the final decision was that in every block the first floors are used for offices and the upper floors always mix residences and hotel rooms. Green spaces appear in both situations. This is the concept for the first 4 blocks of the tower. In the 5th and uppermost block we wanted to return to the original idea of mixing all the functions in every floor. It means that the offices part is smaller and composed by closed rooms, to be used by independent professionals, instead of big companies. The residences and hotel rooms will be luxurious to match with the higher floor height required for the offices.

7.1 Zoning

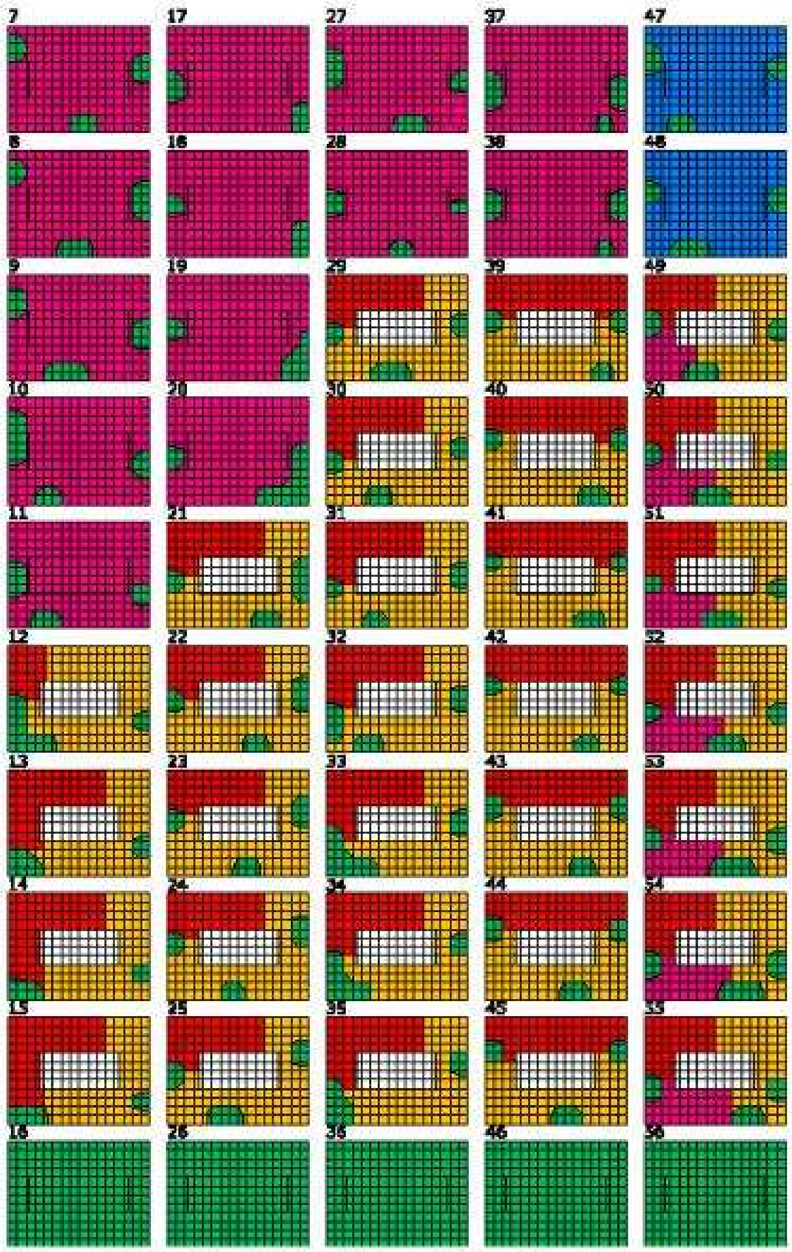


fig. 64: preliminary distribution of functions

7.2. Offices Floor (e.g. 8th floor)

The open plan layout helps employees to engage with one another on a more regular and informal basis, and fosters an environment of mutual support and cooperation. Creative industries such as advertising and design often feel that having an open plan layout increases the creativity of the staff without hindering their productivity. This layout is combined with some closed rooms, to be used by the directors, or to be used when privacy and more concentration are required.

7.3. Hotel and Residential Floor (e.g. 15th floor)

The needs of an apartment and a hotel room are pretty similar and the two functions are always together in the floors of Greenwich Tower.

7.4. Leisure (47th floor)

The 47th and 48th are the floors that hotel guests and apartment residents have in common. It is where they have the chance to meet and enjoy some facilities such as swimming pool, gym, sauna and nursery.

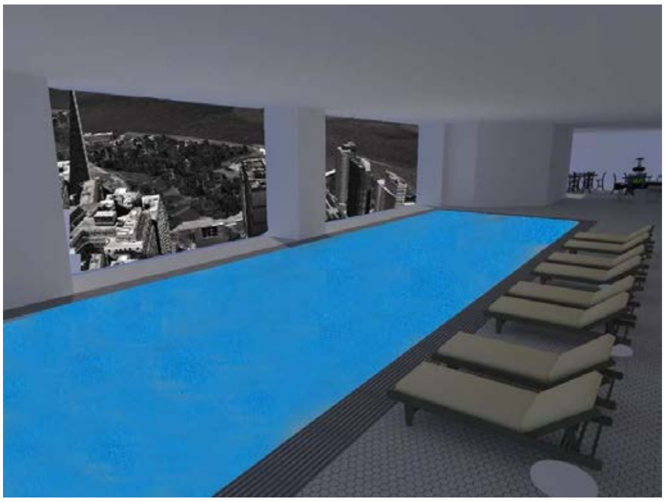
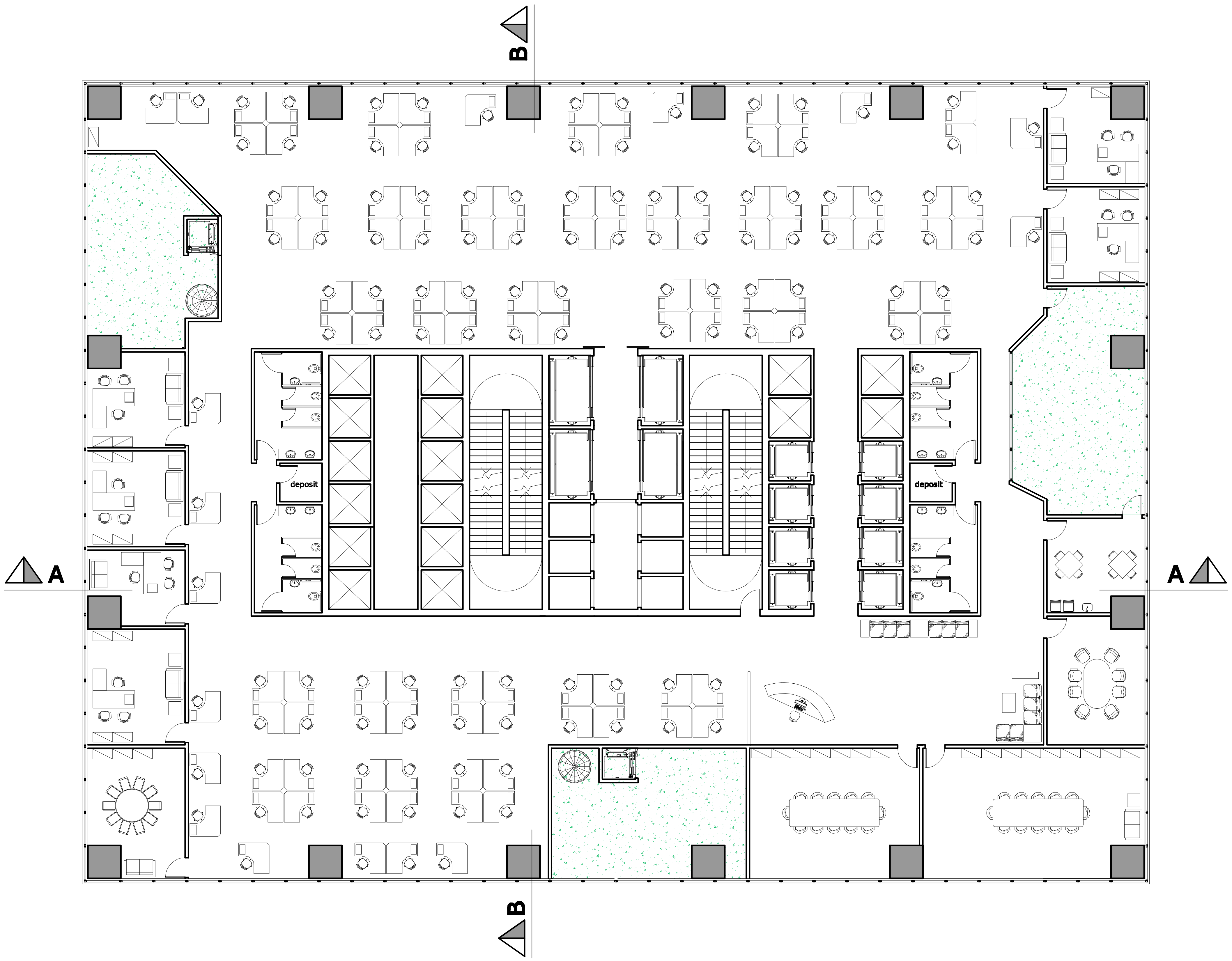


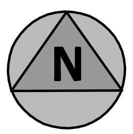
fig.65: Rendering of the Swimming Pool

7.5. Hotel, Residential and Offices floor (e.g. 50th floor)

In the last block all the four usages are finally mixed (green, hotel, offices and houses). Smaller office areas for a different concept of work. More expensive apartments/hotel rooms in the upper floors of the tower with higher floor height

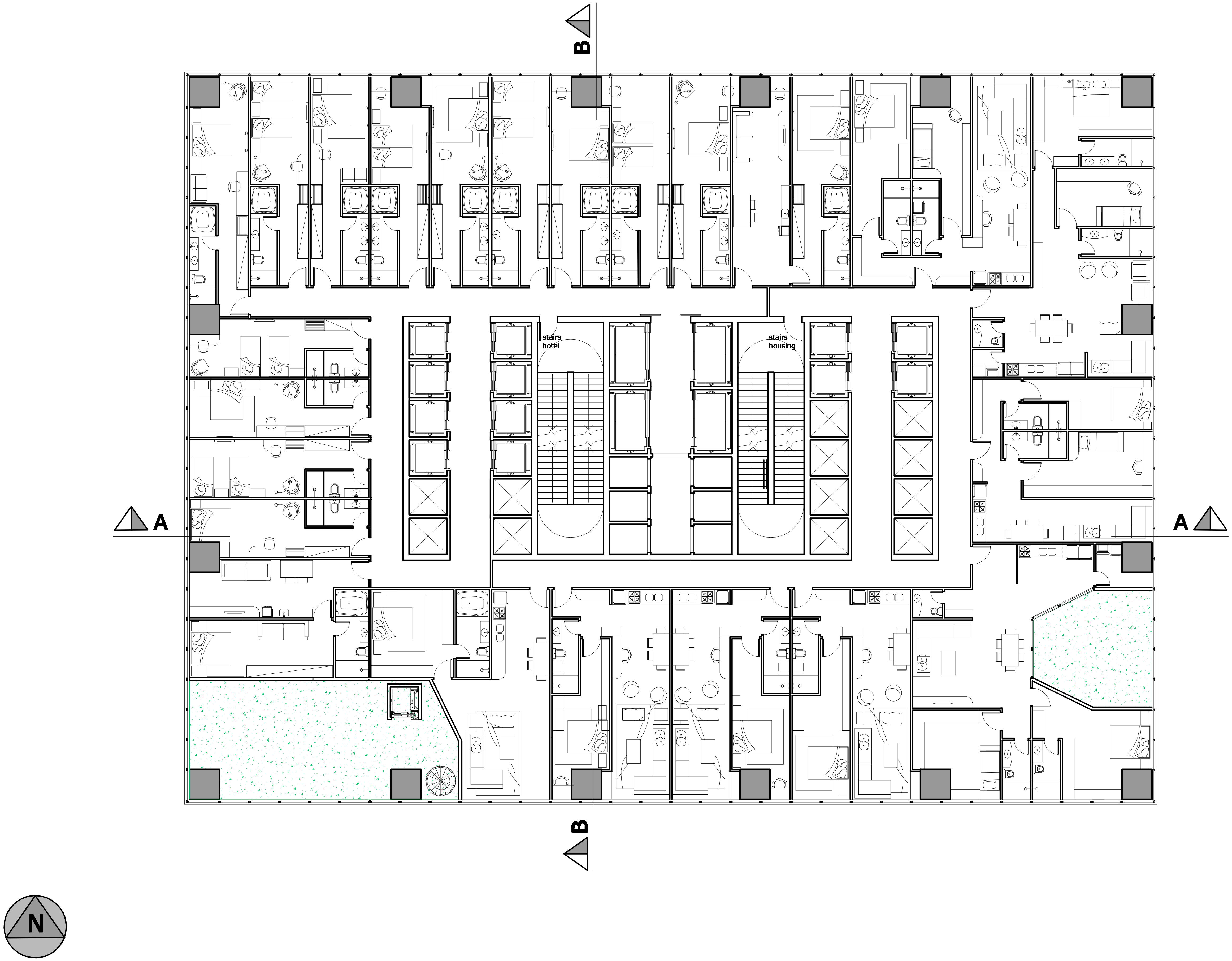
fig.66: Rendering of an Apartment with Garden





A018

8th floor
1/200

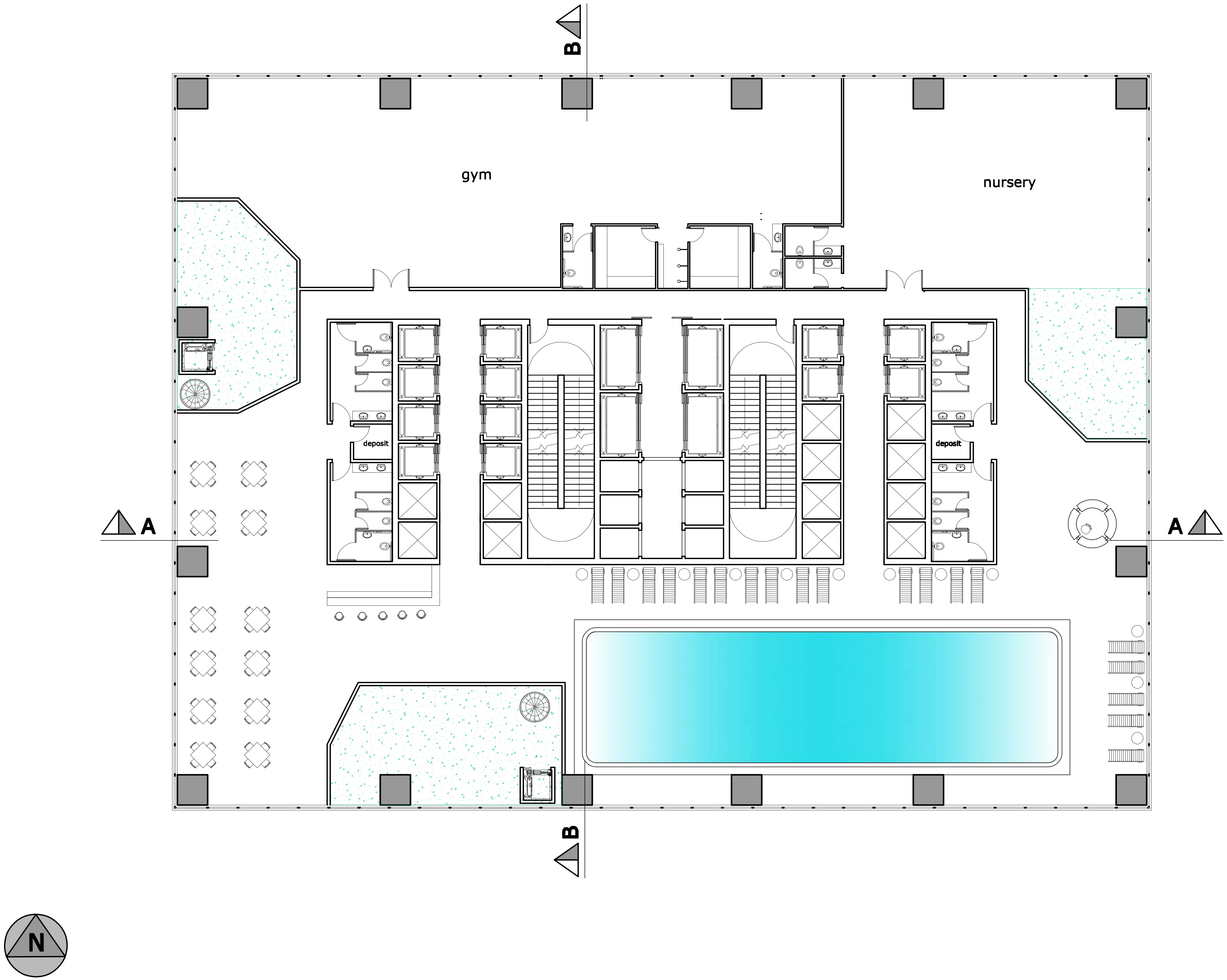


A019

GREENWICH TOWER

15th floor
1/200

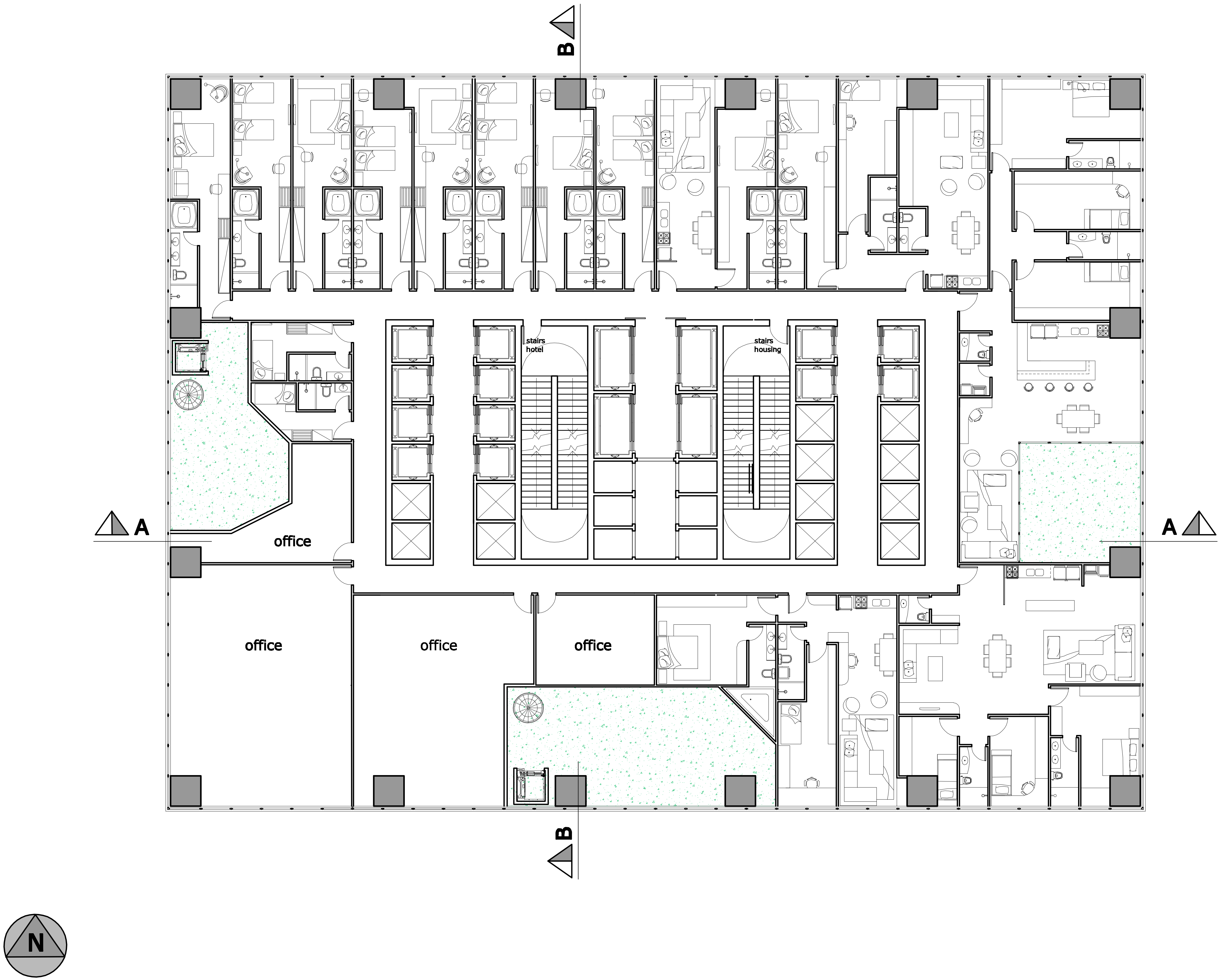
POLITECNICO MILANO



A020

47th floor
1/200

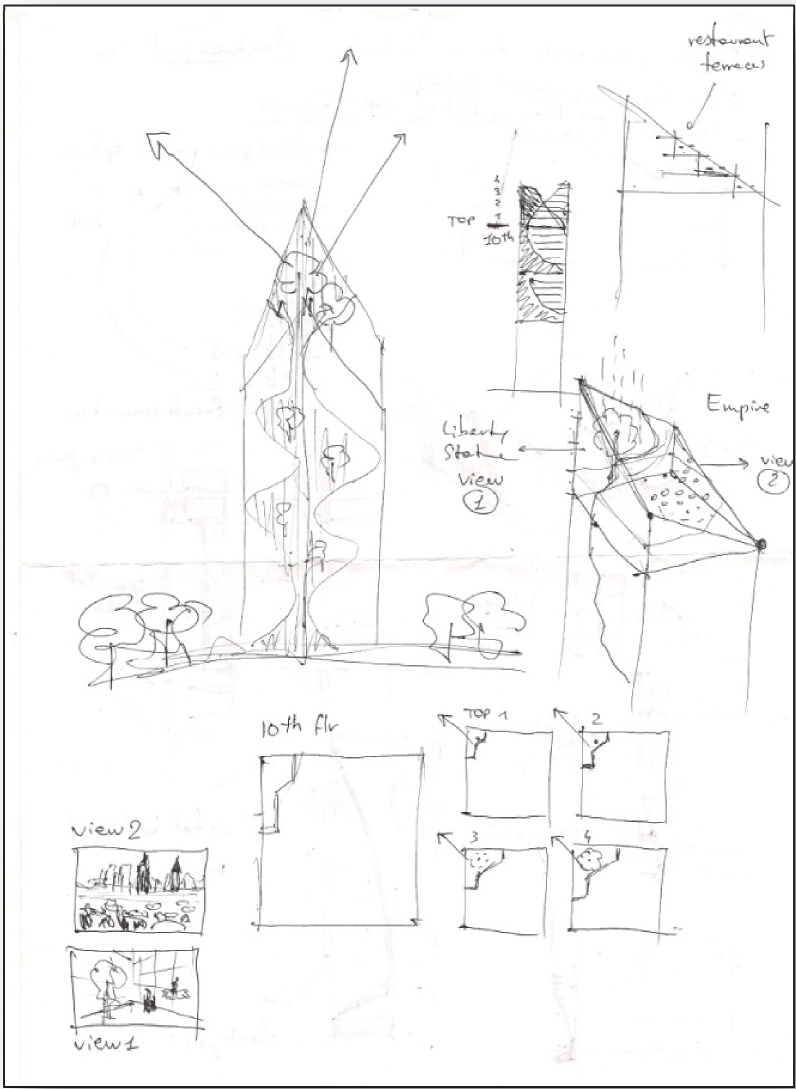
fig.67: Renderings of the Swimming Pool & Bar



A021

50th floor
1/200

8. Top Closing



The upper part of the tower, the one that begins on the 60th floor, is a triangular closing, a continuation of the green paths, in south and west façades. The idea is to create an independent circulation on the 59th floor (observation deck) that leads to this peculiar space, that in our opinion would perfectly work as a coffee shop, with different levels.

9. Façades

The building is all glazed, but in most of the areas the windows are not openable, the wind would be too strong. However, in the green areas, the concern about comfort can decrease a little, which allow us to put openable windows in all these areas.
Green areas need sun, so we do not locate them in the north façade. We take advantage of this façade putting most of the hotel rooms, which, in our conception, are used only at night.
Apartments deserve the best solar orientation and most of them are located in the south and east façades.

9.1. Orientation

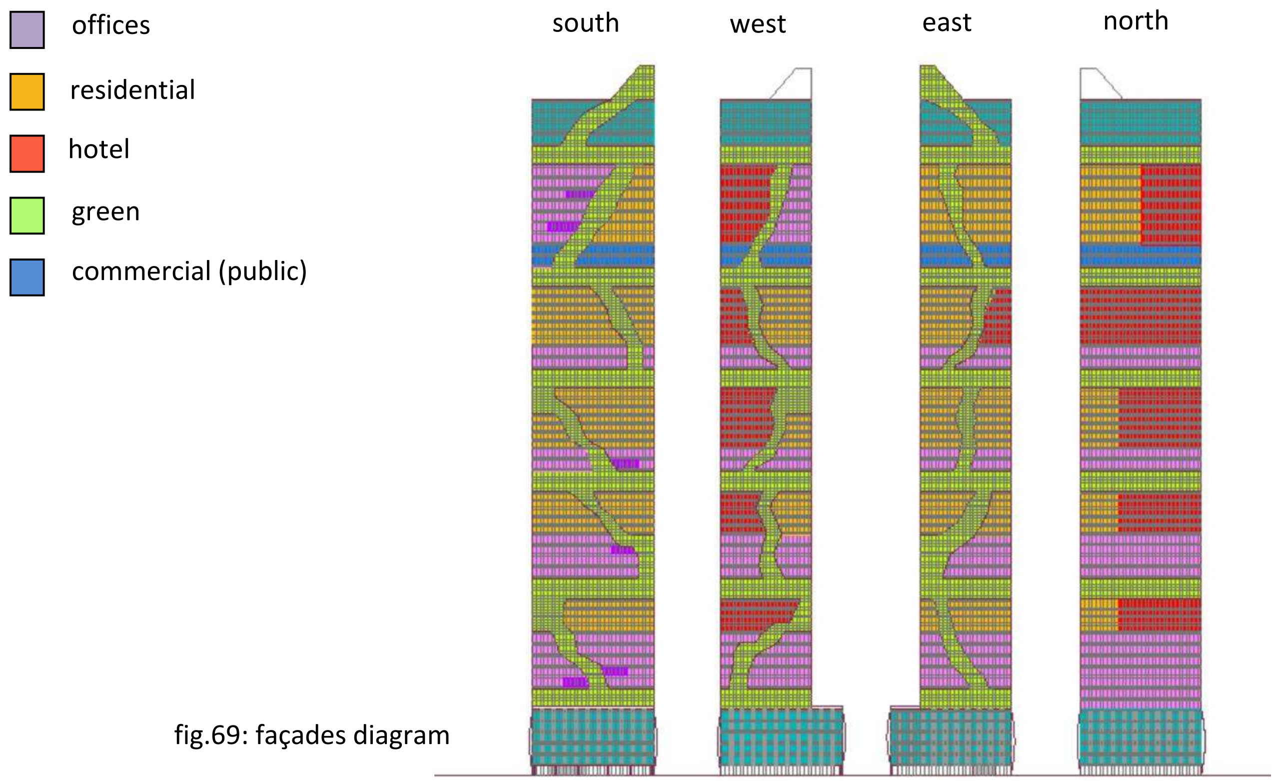
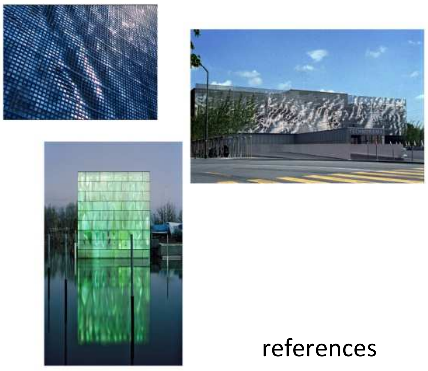


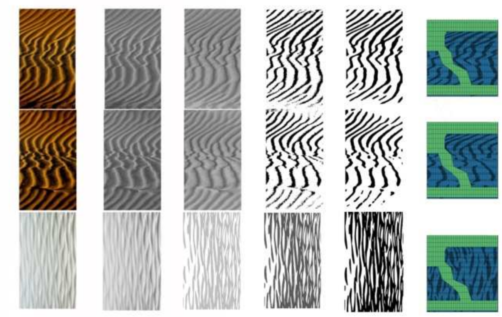
fig.69: façades diagram

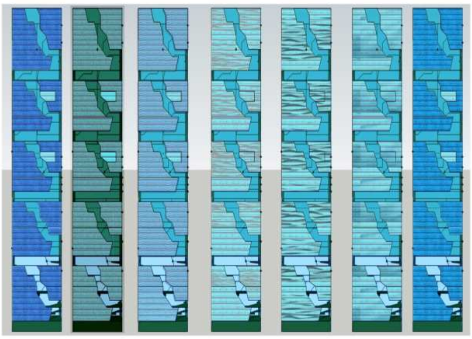
9.2. Materials :

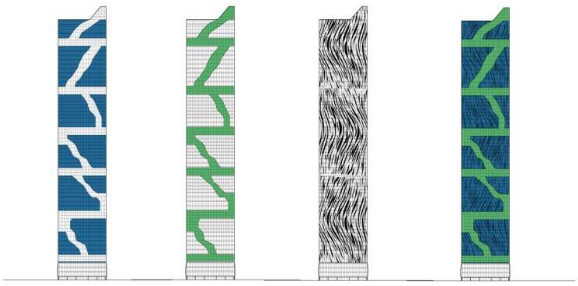
Curtain walls designed with fritted glass patterns and reflecting metallic elements.



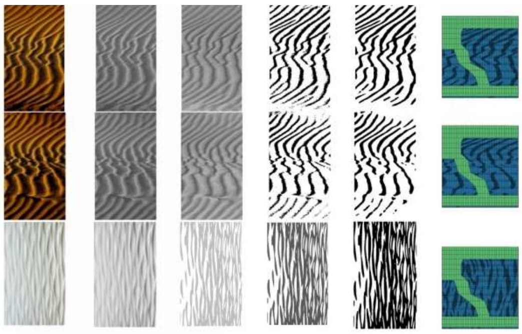
references







fritted glass - pattern studies



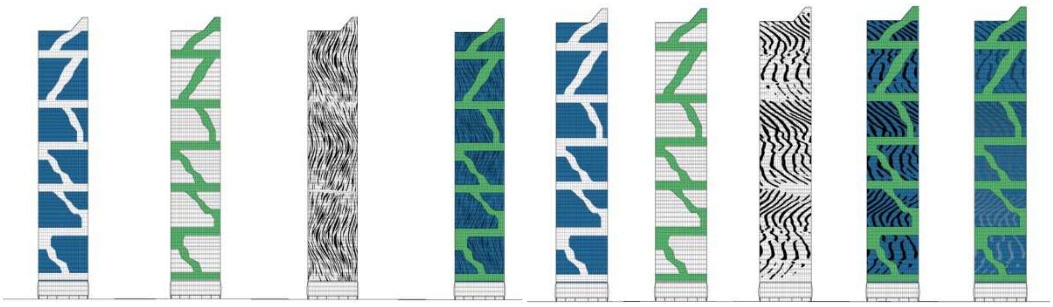
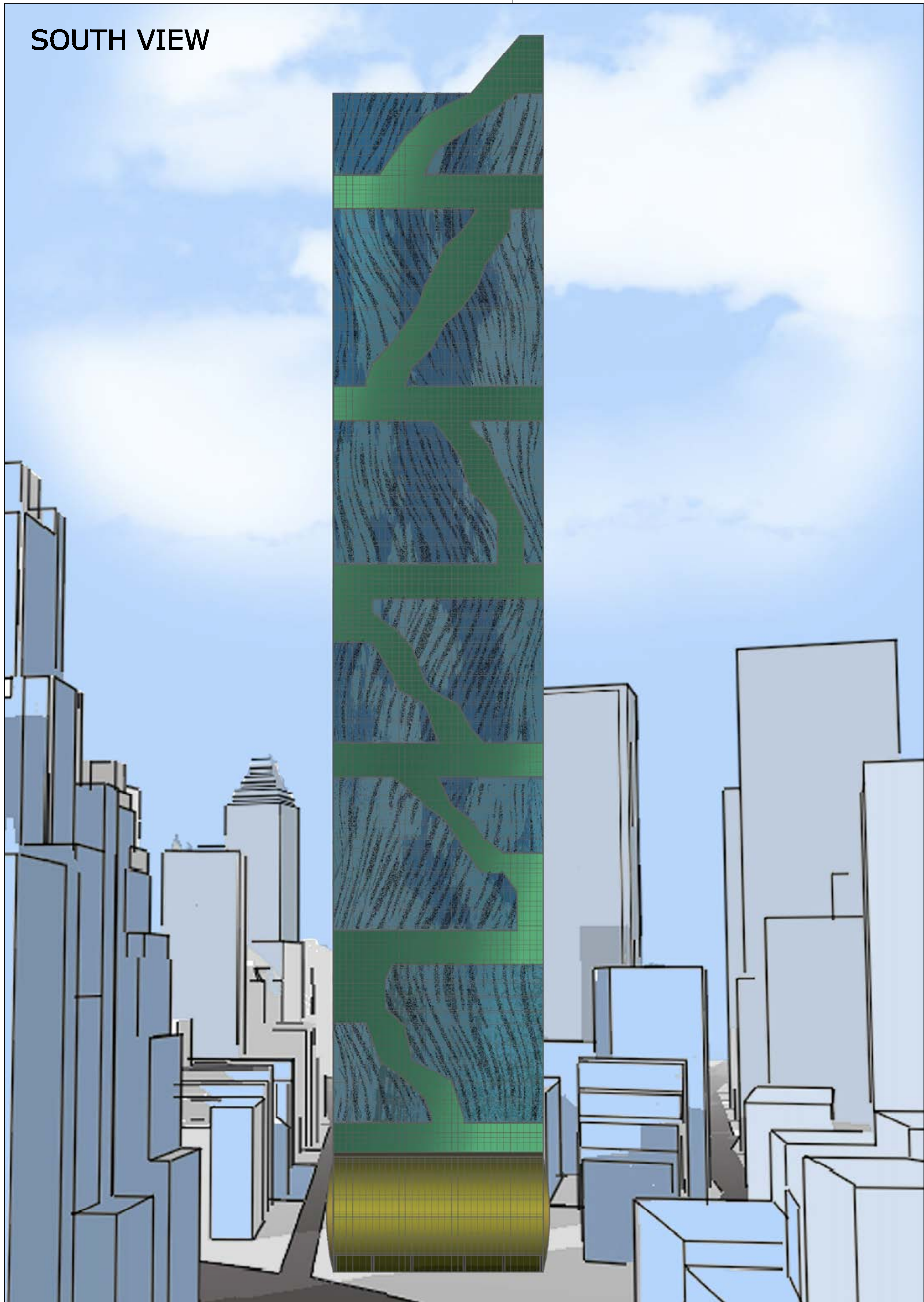
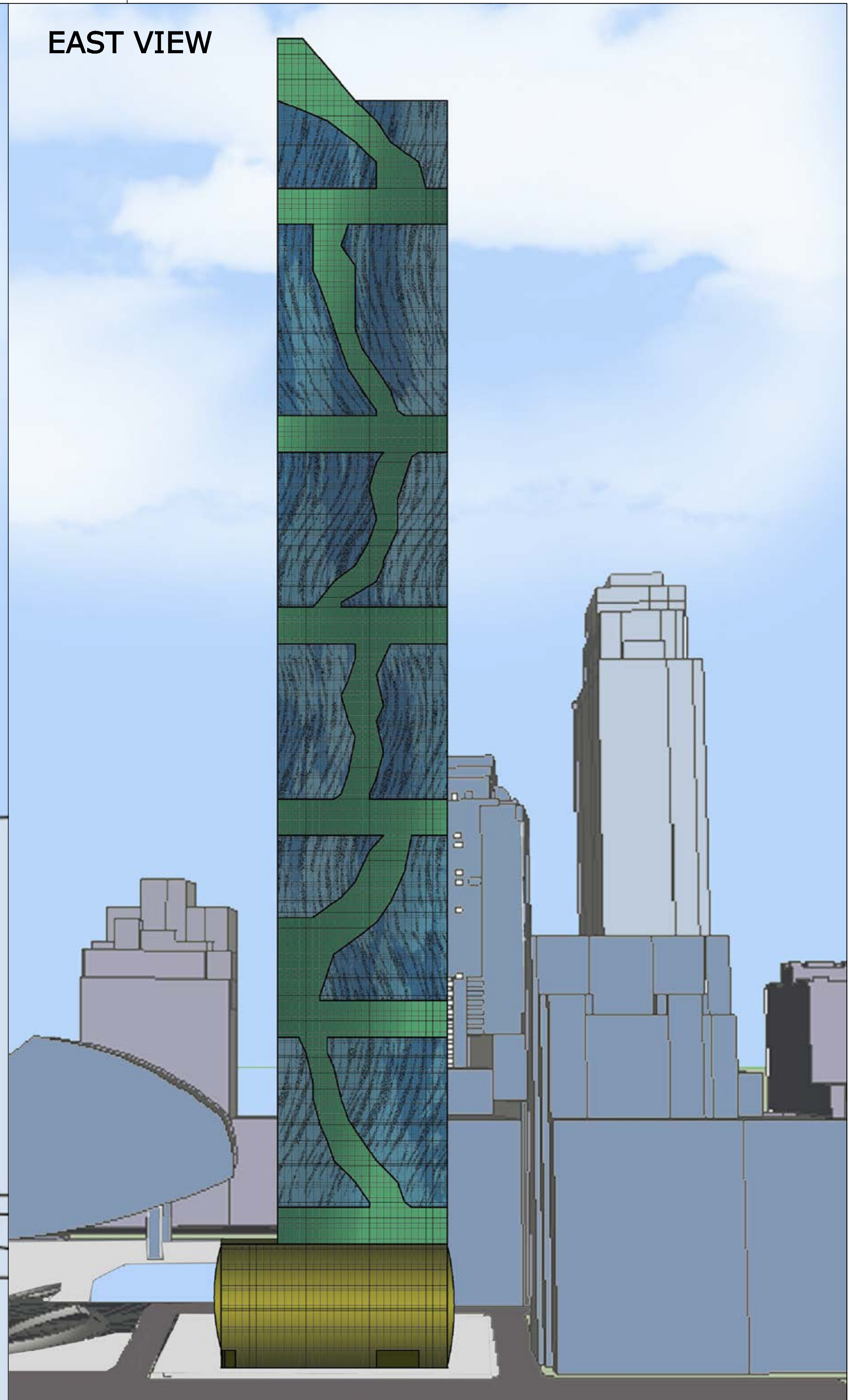


fig.70: façades studies

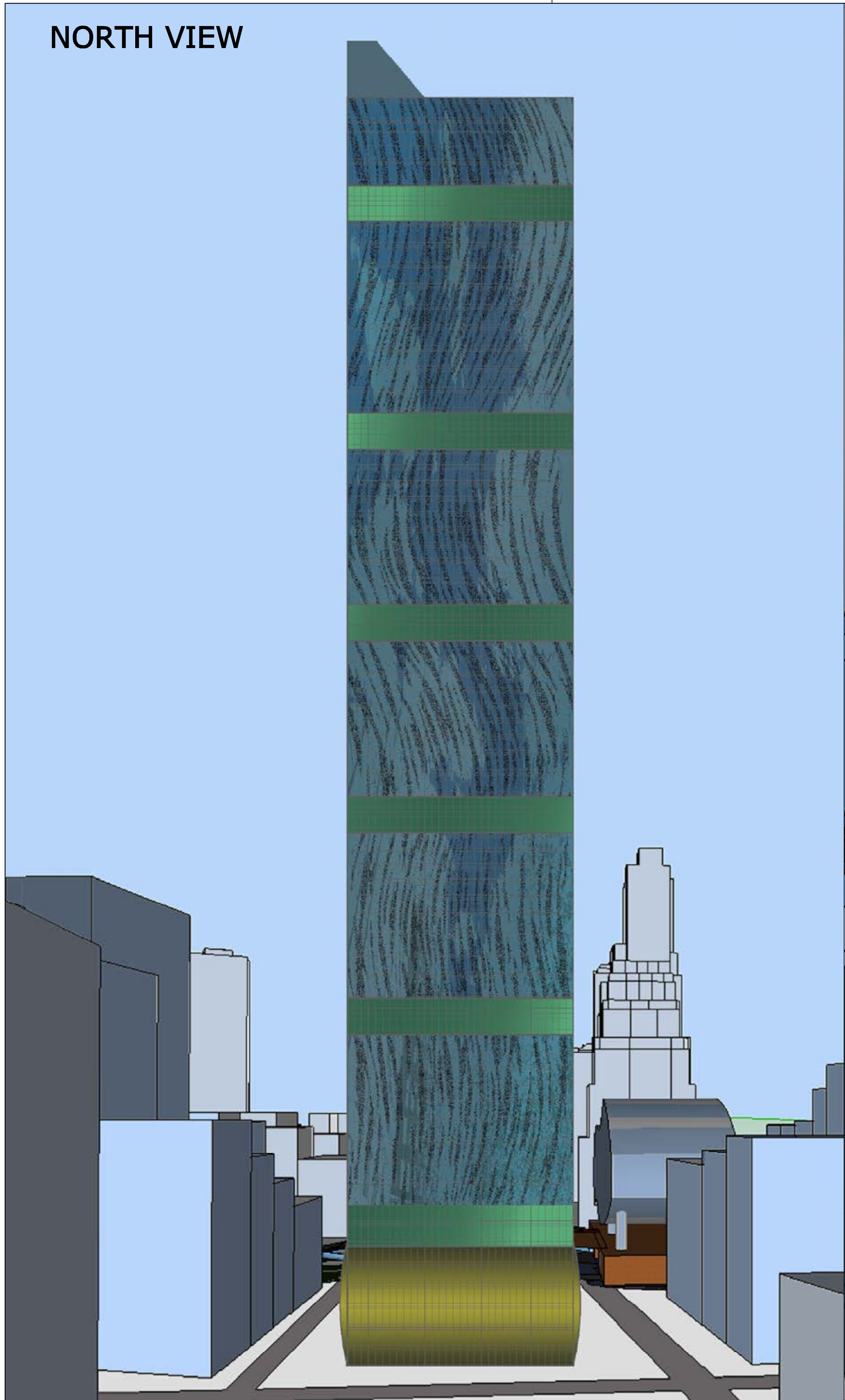




A022

GREENWICH TOWER

façades
1/1000



A023

GREENWICH TOWER

façades
1/1000

POLITECNICO MILANO

10. Appendix: Areas

Storey No:	Function	Height (m)	Total Height (m)	Total Storey Area (m^2)
60	Retail (View Deck)	4,4	273,9	
59	Retail (View Deck)	8,8	269,5	
58	Retail (Event Hall)	8,8	260,7	1403,6
57	Retail (Restaurant)	4,4	251,9	1403,6
56	Sky Lobby	8,8	247,5	1403,6
55	R+H+O	4,4	238,7	1403,6
54	R+H+O	4,4	234,3	1403,6
53	R+H+O	4,4	229,9	1403,6
52	R+H+O	4,4	225,5	1403,6
51	R+H+O	4,4	221,1	1403,6
50	R+H+O	4,4	216,7	1403,6
49	R+H+O	4,4	212,3	1403,6
48	Swimming Pool+ Gym + Spa +Nursery	8,8	207,9	1403,6
47	Sky Lobby	8,8	199,1	1403,6
46	R+H	3,3	190,3	1403,6
45	R+H	3,3	187	1403,6
44	R+H	3,3	183,7	1403,6
43	R+H	3,3	180,4	1403,6
42	R+H	3,3	177,1	1403,6
41	R+H	3,3	173,8	1403,6
40	R+H	3,3	170,5	1403,6
39	Office	4,4	167,2	1403,6
38	Office	4,4	162,8	1403,6
37	Sky Lobby	8,8	158,4	1403,6
36	R+H	3,3	149,6	1403,6
35	R+H	3,3	146,3	1403,6
34	R+H	3,3	143	1403,6
33	R+H	3,3	139,7	1403,6
32	R+H	3,3	136,4	1403,6
31	R+H	3,3	133,1	1403,6
30	R+H	3,3	129,8	1403,6
29	Office	4,4	126,5	1403,6
28	Office	4,4	122,1	1403,6
27	Sky Lobby	8,8	117,7	1403,6
26	R+H	3,3	108,9	1403,6
25	R+H	3,3	105,6	1403,6
24	R+H	3,3	102,3	1403,6
23	R+H	3,3	99	1403,6
22	R+H	3,3	95,7	1403,6
21	Office	4,4	92,4	1403,6

Public Green (m^2)	Private Green (m^2)	Office (m^2)	Hotel (m^2)	Housing (m^2)
		347,75	376,1	531,25
		323	376,5	519,5
		294	376,1	555,8
		298,5	376,1	585
		276,2	365	620,8
		202.4+81	337,4	634,3
		241,1	319,4	692,35
		-	538,45	723,4
		-	530,25	724,85
		-	538	730,6
		-	560,5	735,1
		-	574,5	709,85
		-	574,5	696,35
		-	611	677,85
		1259,6	-	-
		1230,35	-	-
		-	508,62	744,23
		-	484,5	721,1
		-	497,4	687,95
		-	483,4	740,2
		-	483,4	794,2
		-	476,67	800,93
		-	451,5	801,35
		1284,35	-	-
		1229,65	-	-
		-	445	796,6
		-	419,5	844,6
		-	419,5	840,1
		-	445,5	802,85
		-	451,5	776,6
		1171,85	-	-

20	Office	4,4	88	1403,6
19	Office	4,4	83,6	1403,6
18	Office	4,4	79,2	1403,6
17	Sky Lobby	8,8	74,8	1403,6
16	R+H	3,3	66	1403,6
15	R+H	3,3	62,7	1403,6
14	R+H	3,3	59,4	1403,6
13	R+H	3,3	56,1	1403,6
12	Office	4,4	52,8	1403,6
11	Office	4,4	48,4	1403,6
10	Office	4,4	44	1403,6
9	Office	4,4	39,6	1403,6
8	Office	4,4	35,2	1403,6
7	Lobby	8,8	30,8	1565,6
6	Retail	4,4	22	1565,6
5	Retail	4,4	17,6	1565,6
4	Retail	4,4	13,2	1565,6
3	Retail	4,4	8,8	1565,6
2	Retail	4,4	4,4	1565,6
1	Retail	4,4	4,4	1565,6
-1	Autopark	-4,4		1565,6
TOTAL				**84108,4**

		1261,83	-	-
		1297,85	-	-
		1286,6166	-	-
		-	594	699,35
		-	592	701,6
		-	558	717,35
		-	219	977,6
		1237,1	-	-
		1210,1	-	-
		1210,1	-	-
		1217,1	-	-
		1248,6	-	-
0	**0**	**17925,6466**	**13983,29**	**21583,61**

Technological Design

The starting point of the design is to create a high-performance tower that operates at maximum efficiency with minimum environmental impact. This is called a green building. For the design of a green tower in Manhattan, the first target to reach was to understand the conditions of LEED and accomplishing a building that is suitable for a future demand.

1. What is LEED?

For a Green Building design different rating systems are used by different countries. LEED is the system that is used by United States. The LEED– Leadership in Energy and Environmental Design, Green Building Rating System is a voluntary, consensus-based standard to support and certify successful Green Building design, construction and operations. As the design becomes better the number of the targets that are reached increase and as a result the design gets a better grade. (Silver, Gold, Platinum-fig.). The aim of creating a Green Building is to reduce or eliminate negative environmental impact and improve existing unsustainable design. Besides may benefits, green designs reduce operating costs, enhance building marketability, increase staff productivity and reduce potential liability resulting from indoor air quality problems.

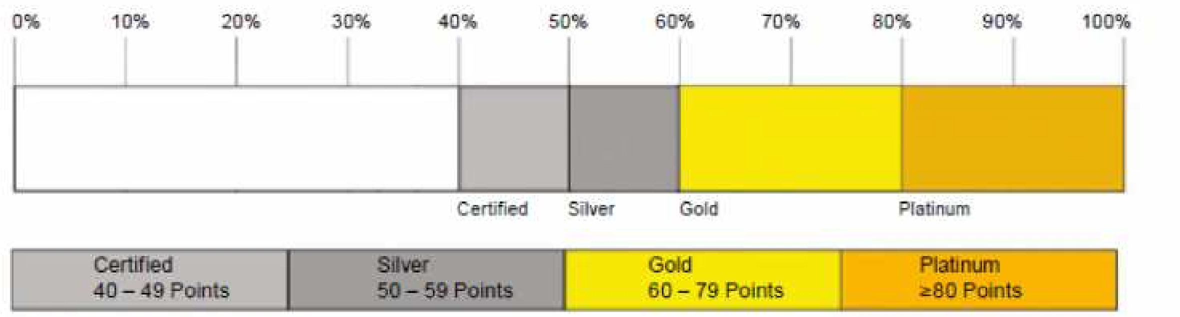


fig.71: Levels of LEED Certification

The rating systems were developed for the different uses of buildings: Rating is based on the same method, but the measures changes between the uses. Not only single and complete buildings but also neighborhoods, commercial interiors and core and shell are under assessment. The rating system is organized into five different environmental categories- fig: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources and Innovation.

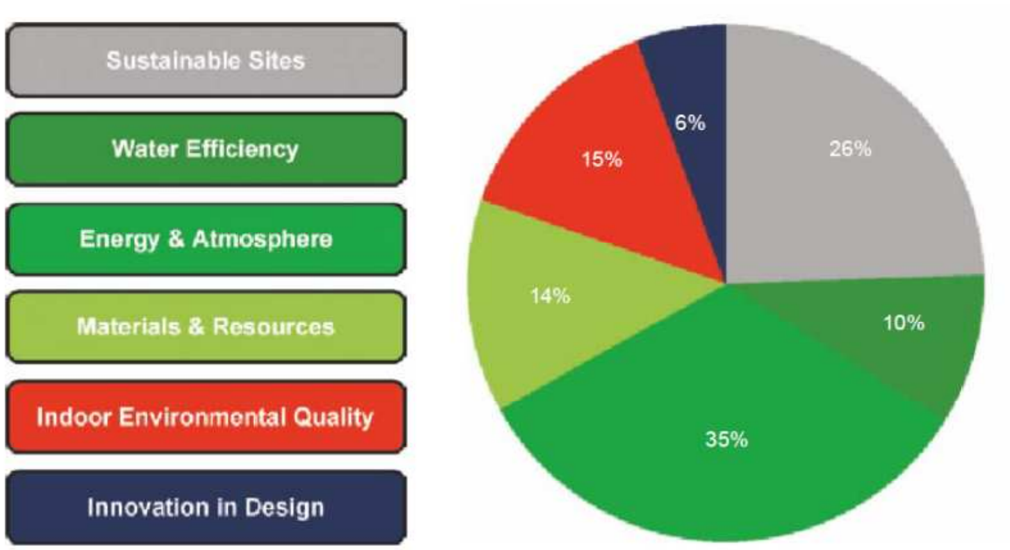


fig.72: Environmental Categories Certification

In order to design the energy efficient building, first of all it should be taken into consideration that the usage of the building. Usage demands are usually related to the desired comfort level and can be expressed in terms of minimum and maximum indoor temperatures, indoor humidity levels or luminance. Since the GreenWich Tower is a mixed use building, comfort level usually changes from almost floor to floor which makes the design more complicated. Further, there are time-related stipulations for adhering to the desired indoor conditions. For example decrease of room temperature at night has different effects for different usages. In office buildings, this requirement as a rule only exists for reasons of energy conservation, since no energy consumers are present at night. In residential buildings, however, this requirement can be for comfort reasons also. For instance, the kids' room, especially when it is also being used as a playroom, should be warm enough during the day while, at night, it is rather the cooler temperatures that are desirable for sleeping.

2.Energy Demand

The target of the GreenWich tower is to achieve a high indoor comfort level for various types of occupants and to use non health-hazardous materials with maximum care to minimize the energy and water need. At first glance, it seems to be a contradiction to expect elevated levels of indoor comfort while at the same time wishing to decrease energy requirements. However, through the concept of Green Buildings, this can actually be achieved with having targets that are both realistic and sophisticated at the same time. Those targets were:

2.1. Minimizing Building Energy Requirements through Constructional Measures

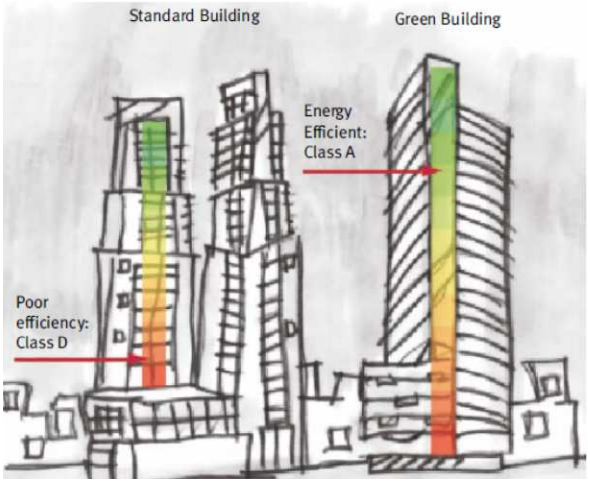


fig.73: Energy Efficiency Certification

Minimizing building energy requirements means, in essence, to adapt to utilization and climate both the building shape and the building envelope. In order to do that, first the geographical conditions of the site analyzed.

The latitude of New York City is 40,78N and the longitude is 73,97W with the elevation 57meters. The climate is humid subtropical. The area averages 234 days with at least some sunshine annually, and averages 58% of possible sunshine annually, accumulating 2,400 to 2,800 hours of sunshine per annum.

Winters are cold and damp, and prevailing wind patterns that blow offshore minimize the moderating effects of the Atlantic Ocean. The average temperature in January, the area's coldest month, is 0.1 °C. However temperatures in winter could for a few days be as low as −12 °C and as high as 10 °C. Spring and autumn are unpredictable, and can range from chilly to warm, although they are usually mild with low humidity. Summers are typically hot and humid with a July average of 24.7 °C. Nighttime conditions are often exacerbated by the urban heat island phenomenon, and temperatures exceed 32 °C on average of 18 days each summer and can exceed 38 °C every 4–6 years.

The city receives 1,260 mm of precipitation annually, which is fairly spread throughout the year. Average winter snowfall for 1971 to 2000 has been 57 cm, but this usually varies considerably from year to year. Hurricanes and tropical storms are rare in the New York area, but are not unheard of and always have the potential to strike the area.

Climate data for New York (Central Park) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	72 (22)	75 (24)	86 (30)	96 (36)	99 (37)	101 (38)	106 (41)	104 (40)	102 (39)	94 (34)	84 (29)	75 (24)	106 (41)
Average high °F (°C)	38.0 (3.3)	41.0 (5.0)	49.8 (9.9)	60.7 (15.9)	70.9 (21.6)	79.0 (26.1)	84.2 (29.0)	82.4 (28.0)	74.7 (23.7)	63.5 (17.5)	53.1 (11.7)	42.9 (6.1)	61.68 (16.49)
Average low °F (°C)	26.2 (−3.2)	28.1 (−2.2)	35.1 (1.7)	44.2 (6.8)	54.2 (12.3)	63.3 (17.4)	68.8 (20.4)	67.7 (19.8)	60.3 (15.7)	49.6 (9.8)	41.0 (5.0)	31.6 (−0.22)	47.51
Record low °F (°C)	−6 (−21.1)	−15 (−26.1)	3 (−16.1)	12 (−11.1)	28 (−2.2)	44 (7)	52 (11)	50 (10)	39 (4)	28 (−2.2)	7 (−13.9)	−13 (−25)	−15 (−26.1)
Precipitation inches (mm)	4.13 (104.9)	3.15 (80)	4.37 (111)	4.28 (108.7)	4.69 (119.1)	3.84 (97.5)	4.62 (117.3)	4.22 (107.2)	4.23 (107.4)	3.85 (97.8)	4.36 (110.7)	3.95 (100.3)	49.69 (1,262.1)
Snowfall inches (cm)	8.3 (21.1)	7.1 (18)	3.4 (8.6)	.4 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	.4 (1)	2.6 (6.6)	22.2 (56.4)
% humidity	63.8	63.0	62.3	60.9	69.4	71.7	70.7	73.2	74.7	71.6	68.3	66.6	68.02
Avg. precipitation days (≥ 0.01 in)	10.3	9.4	10.7	11.1	11.4	10.8	10.2	9.5	9.1	8.3	9.3	10.6	120.7
Avg. snowy days (≥ 0.1 in)	4.1	2.9	1.6	.2	0	0	0	0	0	0	.3	1.8	10.9
Sunshine hours	162.7	163.1	212.5	225.6	256.6	257.3	268.2	268.2	219.3	211.2	151.0	139.0	2,534.7

table 01: Climate Data for New York
http://en.wikipedia.org/wiki/NewYorkCity

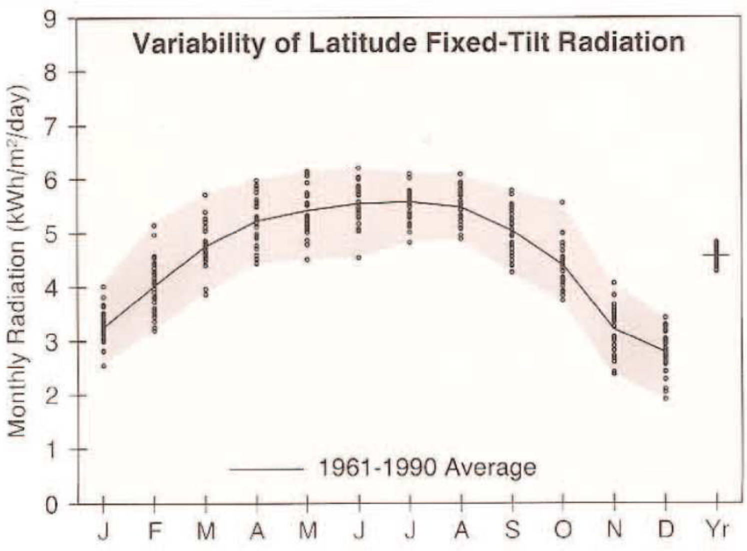


fig.74: Energy Efficiency Certification

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.9	2.7	3.8	4.9	5.7	6.1	6.0	5.4	4.3	3.2	2.0	1.6	4.0
	Min/Max	1.7/2.2	2.3/3.3	3.3/4.4	4.3/5.5	4.8/6.5	5.0/6.8	5.3/6.6	4.8/5.9	3.9/4.9	2.9/3.8	1.7/2.4	1.4/1.8	3.7/4.2
Latitude -15	Average	2.9	3.7	4.6	5.3	5.8	6.0	6.0	5.7	5.0	4.1	2.9	2.4	4.5
	Min/Max	2.3/3.5	3.0/4.6	3.8/5.5	4.6/6.1	4.8/6.5	4.9/6.7	5.2/6.6	5.1/6.3	4.3/5.7	3.6/5.1	2.2/3.6	1.8/3.0	4.3/4.8
Latitude	Average	3.2	4.0	4.8	5.2	5.4	5.5	5.6	5.5	5.0	4.4	3.2	2.8	4.6
	Min/Max	2.5/4.0	3.2/5.2	3.9/5.7	4.4/6.0	4.5/6.1	4.5/6.2	4.8/6.1	4.9/6.1	4.3/5.8	3.7/5.6	2.4/4.1	1.9/3.4	4.3/4.8
Latitude +15	Average	3.4	4.1	4.6	4.8	4.8	4.8	4.9	5.0	4.8	4.4	3.3	3.0	4.3
	Min/Max	2.7/4.3	3.3/5.4	3.7/5.6	4.1/5.6	4.0/5.4	4.0/5.3	4.2/5.3	4.4/5.5	4.0/5.5	3.7/5.6	2.4/4.3	2.0/3.7	4.0/4.6
90	Average	3.2	3.6	3.5	3.1	2.7	2.6	2.7	3.0	3.4	3.6	3.0	2.7	3.1
	Min/Max	2.4/4.2	2.8/4.9	2.8/4.3	2.7/3.7	2.4/3.1	2.3/2.8	2.4/2.9	2.8/3.3	2.8/3.9	3.0/4.6	2.1/3.8	1.7/3.5	2.9/3.4

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.7	3.7	5.1	6.3	7.1	7.5	7.5	6.8	5.7	4.3	2.7	2.2	5.1
	Min/Max	2.1/3.3	3.0/4.9	4.1/6.2	5.2/7.4	5.5/8.4	5.8/8.8	6.2/8.4	5.8/7.7	4.6/6.6	3.7/5.6	2.0/3.4	1.6/2.7	4.7/5.4
Latitude -15	Average	3.4	4.5	5.7	6.7	7.2	7.5	7.5	7.1	6.2	5.1	3.4	2.8	5.6
	Min/Max	2.6/4.3	3.5/5.9	4.5/7.1	5.4/7.9	5.5/8.6	5.8/8.8	6.2/8.5	6.0/8.0	5.0/7.2	4.2/6.6	2.4/4.4	1.9/3.6	5.1/5.9
Latitude	Average	3.7	4.7	5.8	6.6	6.9	7.2	7.2	6.9	6.2	5.3	3.7	3.1	5.6
	Min/Max	2.8/4.7	3.7/6.3	4.5/7.3	5.3/7.9	5.3/8.3	5.5/8.4	5.9/8.2	5.9/7.9	5.0/7.3	4.3/6.9	2.5/4.7	2.0/3.9	5.2/6.0
Latitude +15	Average	3.9	4.8	5.7	6.3	6.5	6.7	6.7	6.6	6.0	5.3	3.8	3.3	5.5
	Min/Max	2.9/5.0	3.8/6.4	4.4/7.2	5.1/7.6	5.0/7.8	5.1/7.8	5.5/7.6	5.6/7.5	4.8/7.1	4.3/7.0	2.6/4.9	2.1/4.2	5.0/5.9

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	3.9	4.8	5.8	6.7	7.3	7.7	7.6	7.1	6.2	5.3	3.8	3.3	5.8
	Min/Max	2.9/5.0	3.8/6.4	4.5/7.3	5.4/8.0	5.6/8.7	5.9/9.0	6.3/8.6	6.1/8.1	5.0/7.3	4.4/7.0	2.6/4.9	2.1/4.2	5.4/6.2

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W	Average	2.2	2.5	2.7	2.9	3.0	3.2	3.2	3.0	2.8	2.7	2.1	1.9	2.7
Horiz Axis	Min/Max	1.4/2.9	1.7/3.5	1.7/3.9	2.0/3.8	1.8/4.2	1.9/4.4	2.2/4.0	2.2/3.9	1.9/3.5	2.0/4.1	1.1/3.0	0.9/2.7	2.3/3.0
1-Axis, N-S	Average	1.5	2.2	3.0	3.7	3.9	4.1	4.1	3.8	3.3	2.6	1.5	1.2	2.9
Horiz Axis	Min/Max	0.9/2.1	1.4/3.1	1.8/4.3	2.4/4.9	2.2/5.4	2.4/5.6	2.7/5.2	2.8/4.9	2.2/4.2	1.9/4.0	0.8/2.3	0.6/1.8	2.4/3.3
1-Axis, N-S	Average	2.3	2.9	3.6	3.9	3.9	3.9	3.9	3.9	3.7	3.4	2.3	2.0	3.3
Tilt=Latitude	Min/Max	1.5/3.2	2.0/4.2	2.2/5.2	2.6/5.2	2.2/5.3	2.3/5.3	2.6/5.0	2.8/5.0	2.5/4.8	2.4/5.1	1.2/3.3	0.9/2.8	2.8/3.7
2-Axis	Average	2.5	3.0	3.6	4.0	4.1	4.2	4.2	4.1	3.8	3.4	2.4	2.1	3.5
	Min/Max	1.6/3.4	2.1/4.3	2.2/5.2	2.6/5.3	2.3/5.7	2.5/5.8	2.8/5.3	2.9/5.2	2.5/4.8	2.5/5.1	1.3/3.5	1.0/3.1	2.9/3.8

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-0.3	0.9	5.8	11.4	17.1	22.0	24.9	24.2	20.1	14.2	8.7	2.6	12.6
Daily Minimum Temp	-3.7	-2.8	1.6	6.6	12.1	17.2	20.2	19.6	15.6	9.8	5.1	-0.7	8.4
Daily Maximum Temp	3.1	4.6	10.0	16.2	22.1	26.7	29.6	28.7	24.6	18.5	12.2	5.8	16.8
Record Minimum Temp	-21.1	-26.1	-16.1	-11.1	0.0	6.7	11.1	10.0	3.9	-2.2	-15.0	-25.0	-26.1
Record Maximum Temp	22.2	23.9	30.0	35.6	37.2	38.3	41.1	40.0	38.9	34.4	28.9	22.2	41.1
HDD, Base 18.3°C	577	488	389	208	69	0	0	0	19	139	290	489	2669
CDD, Base 18.3°C	0	0	0	0	30	113	203	181	72	9	0	0	609
Relative Humidity (%)	61	60	60	59	64	65	65	67	67	65	64	63	63
Wind Speed (m/s)	6.1	6.1	6.1	5.8	5.2	4.9	4.7	4.7	5.0	5.1	5.8	6.0	5.5

table 02: Solar Radiation

2.2. Increasing Energy Efficiency for Technical Systems

Energy requirement, here, is determined by orientation and shape, by the quality of building materials and also by the amount and type of transparent building components and shading systems used. Energy efficiency not only encompasses the need to optimize every single system or installation inside the building but also the need to shape the overall system so the building becomes one efficient unit.

For GreenWich Tower the orientation is directly related to the grid of the street, however use of the building has a big impact on the distribution. The tower is a mixed used building and they are residential, office, hotel and green zones. At first the shape designed to be square, then for better use of light and to increase the south facade it became rectangular. Another important decision was which direction is going to be given for which use. South façade is given to residential and north façade is given to hotel because: For residential use the heating is more important than hotel which is mainly used at nights and comfort level is less important than residential use. And for green use the south façade was main façade and north direction was not used because the lighting is not enough.

2.2.1. Ecotect

At the design step, tower planned to have fully glass façade. And in order to check the internal heat gains and losses ecotect program used and different conditions were compared for the best solution.

The model that was used in ecotect is a single floor that has facades with totally glazed with an internal core (fig.76).

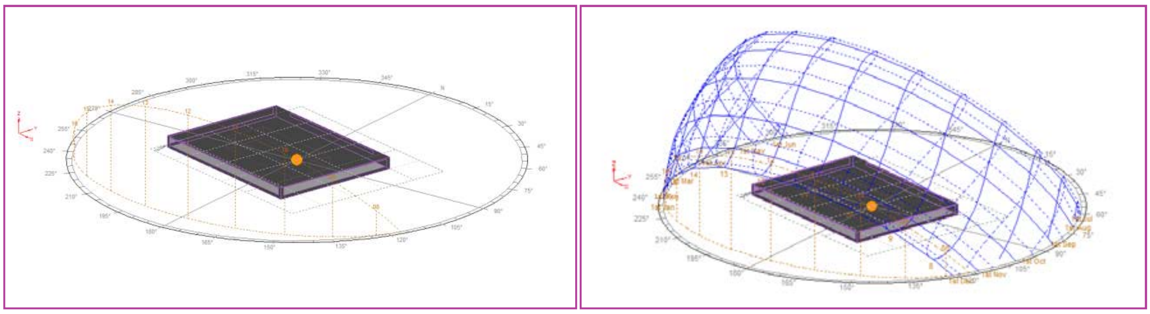


fig.75: Daily-Annually Sun Path

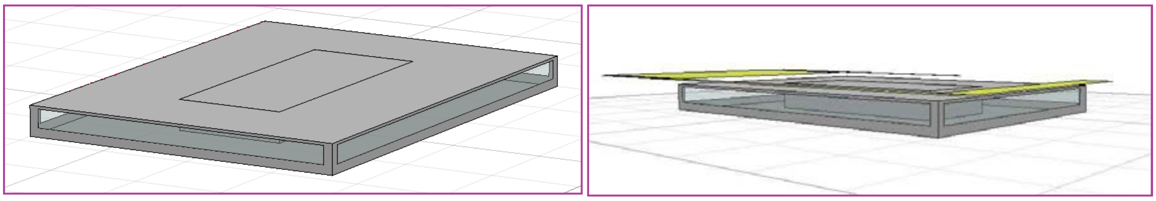


fig.76: Model with and withouth Shading

In order to compare results first the design is done for the same model but having single glazed windows with an aliminum frames:

1.Single glazed window with an aliminum frame:

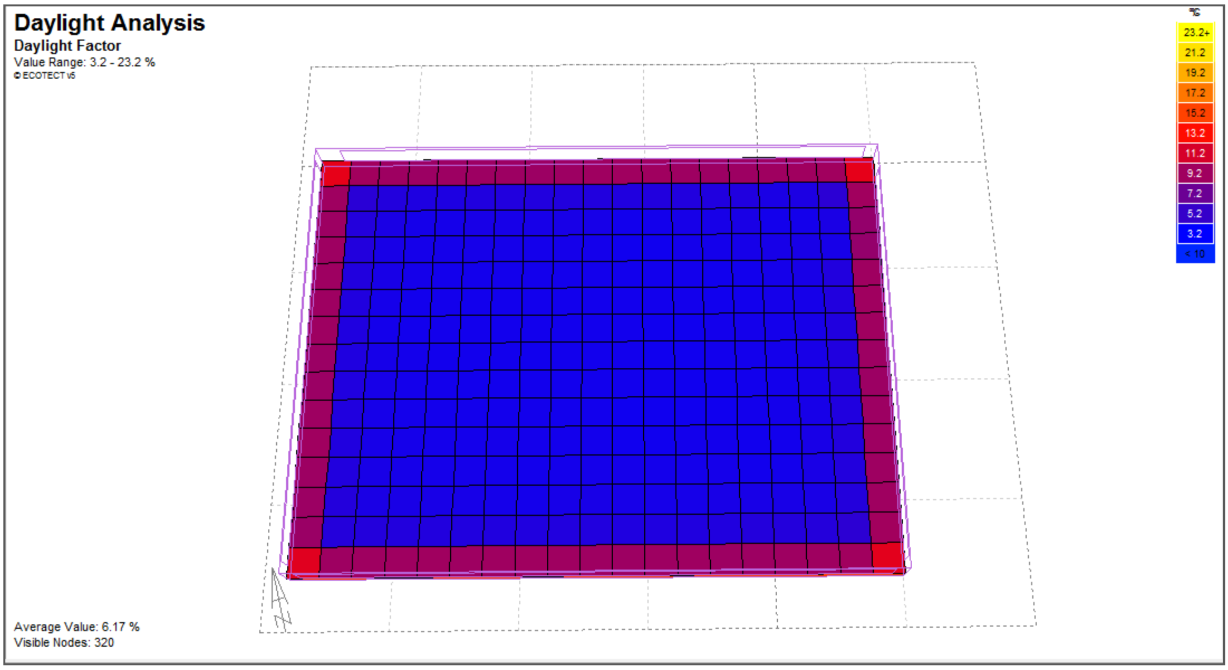


fig.77: Lighting Factor Results

According to the ecotect, the average daylighting factor is 6.17% and the maximum 15.16% at the corner of the tower.

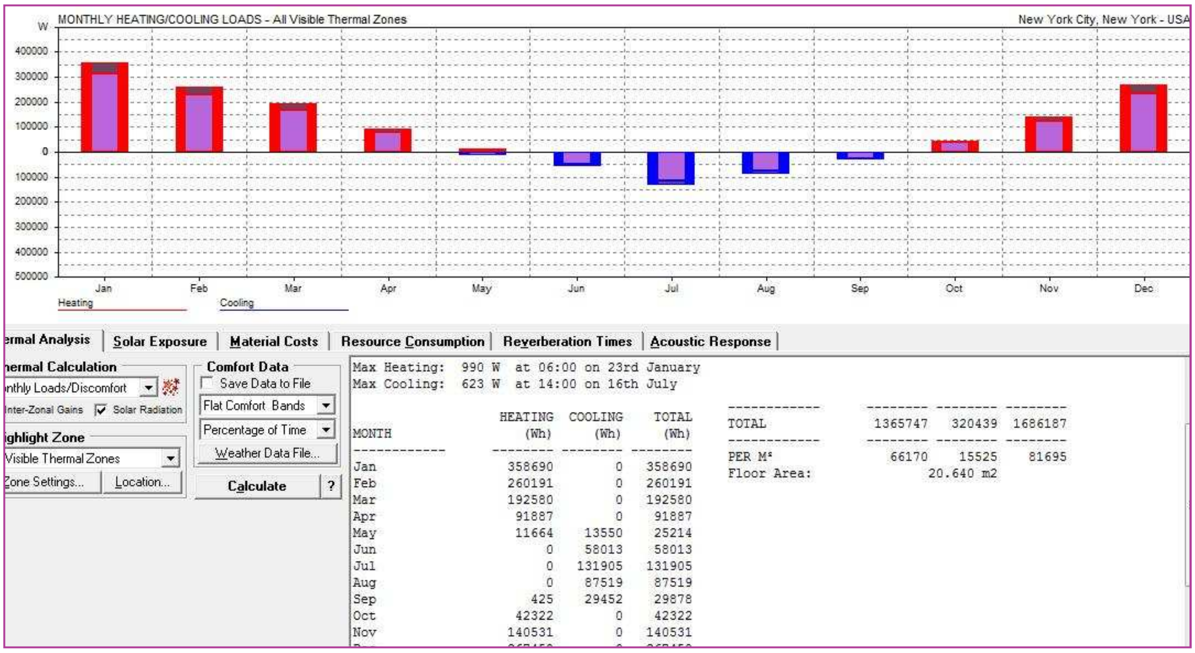
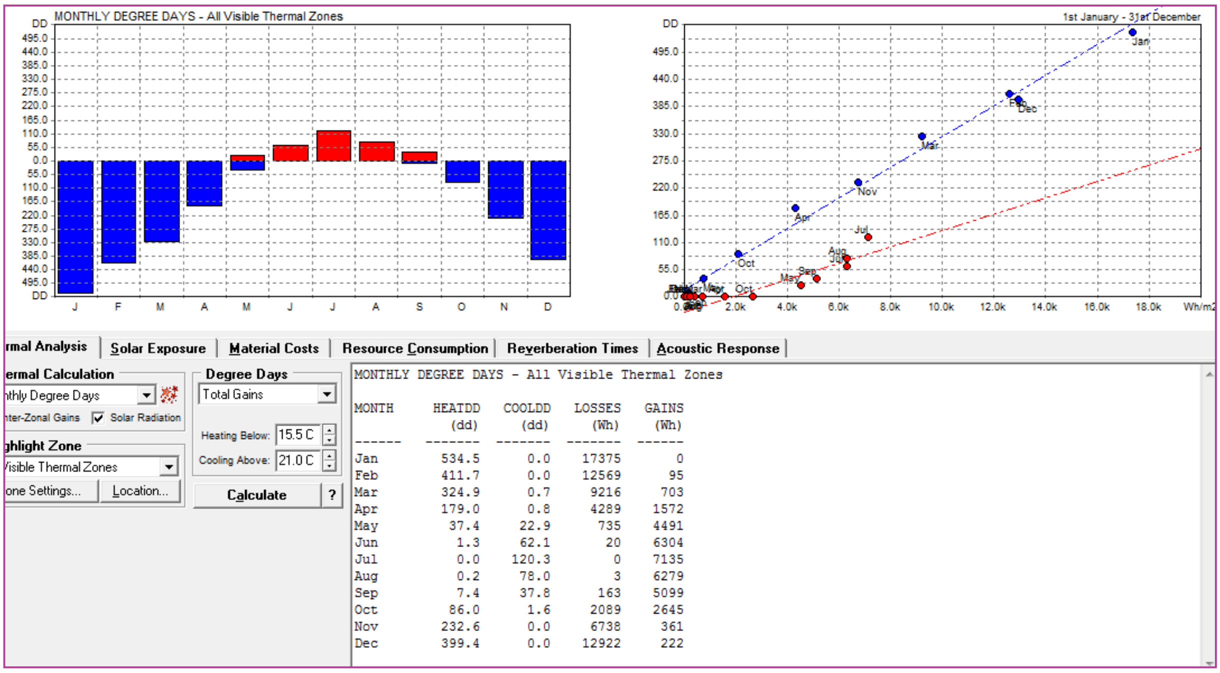


fig.78: Results from Ecotect

The total Heating load per m2 is 66.1kW and cooling load is 15.5kW and as a sum 81.5kW is the energy demand. Important information is the maximum heating is 990W on 23rd of January and maximum cooling load is 623W on 1st of July.



MONTH	HEATDD (dd)	COOLDD (dd)	LOSSES (Wh)	GAINS (Wh)
Jan	534.5	0.0	17375	0
Feb	411.7	0.0	12569	95
Mar	324.9	0.7	9216	703
Apr	179.0	0.8	4289	1572
May	37.4	22.9	735	4491
Jun	1.3	62.1	20	6304
Jul	0.0	120.3	0	7135
Aug	0.2	78.0	3	6279
Sep	7.4	37.8	163	5099
Oct	86.0	1.6	2089	2645
Nov	232.6	0.0	6738	361
Dec	399.4	0.0	12922	222

fig.79: Results from Ecotect

From this charts it can be seen the total losses and gains. The total loss is 66.2kWh and the total gain is 34.5kWh.

2. Double glazing low e windows with an aluminum framing:

The results for a model with double glazing low e windows with an aluminum framing are as follows.

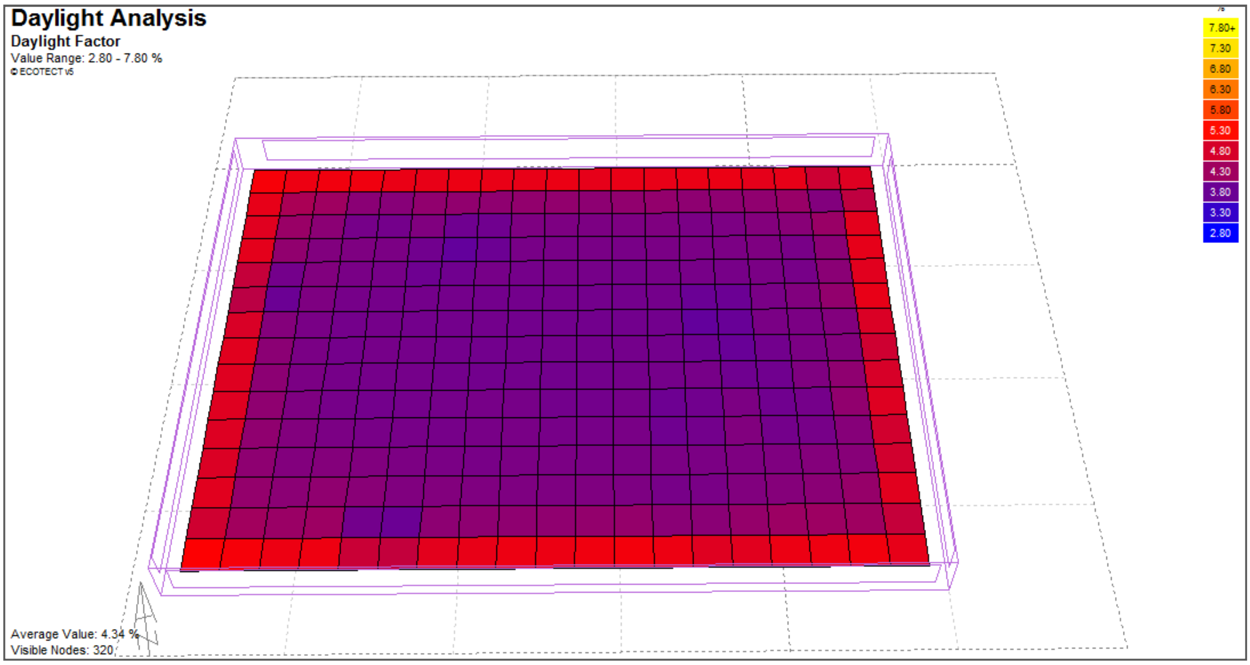


fig.80: Lighting Factor Results Certification

For design of shading device, the calculations are made for June 1st to august 31st from 9am to 5pm. Without shading the average value was 4.34% and after calculating with shading device this value becomes 3,82%: Especially the places that are close to windows can be prevented to be over heated after using shading devices.

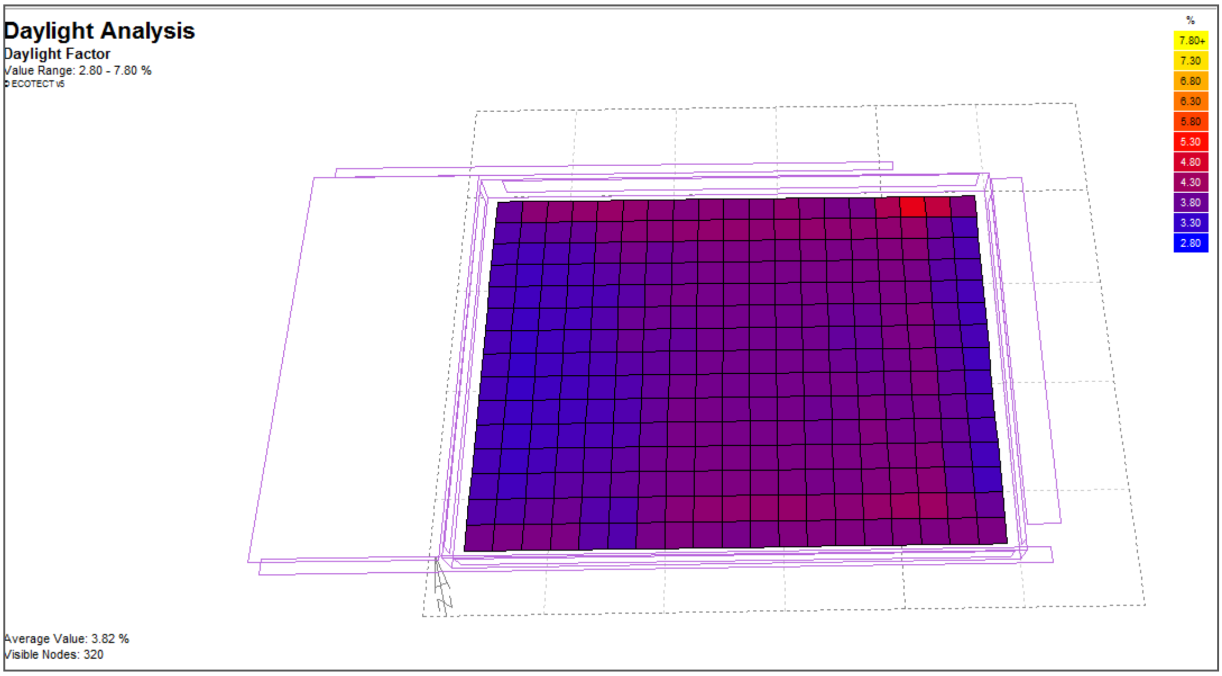


fig.81: Lighting Factor Results Certification

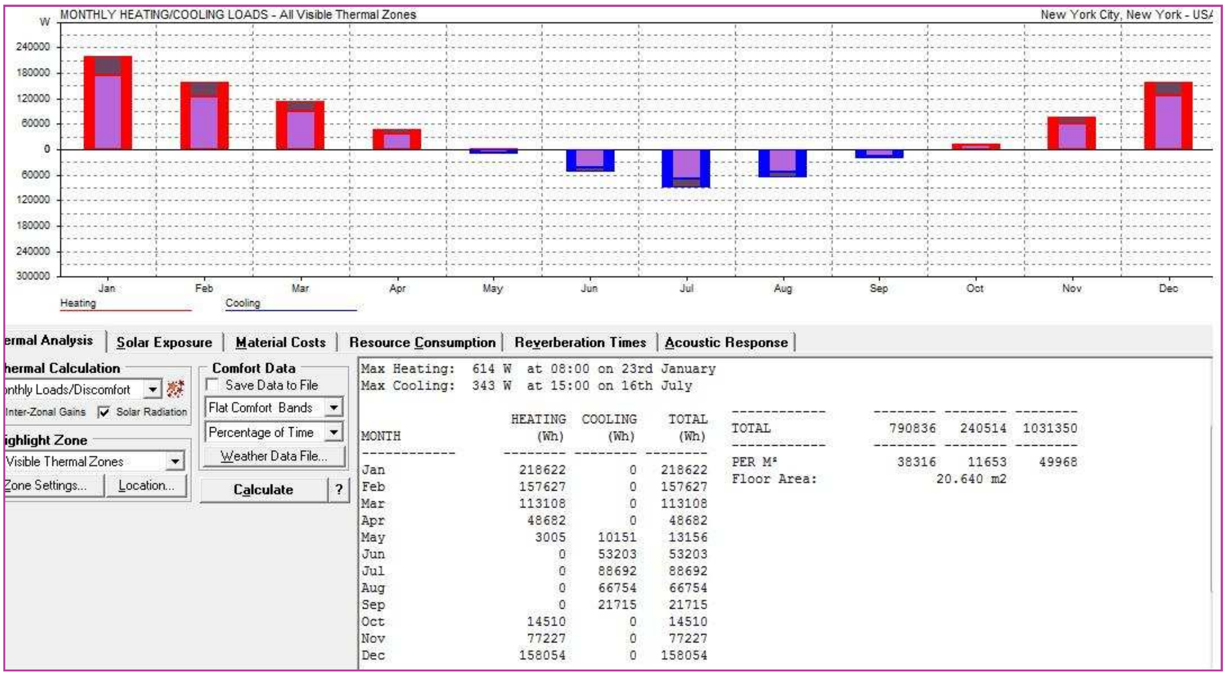


fig.82: Results from Ecotect

The results for shading and without shading are the same for low e glasses. The total heating load is 38.3kW; cooling load is 11.65kW and total load is 50kW per m2 which means with using low e glasses there is a reduction of 37%.

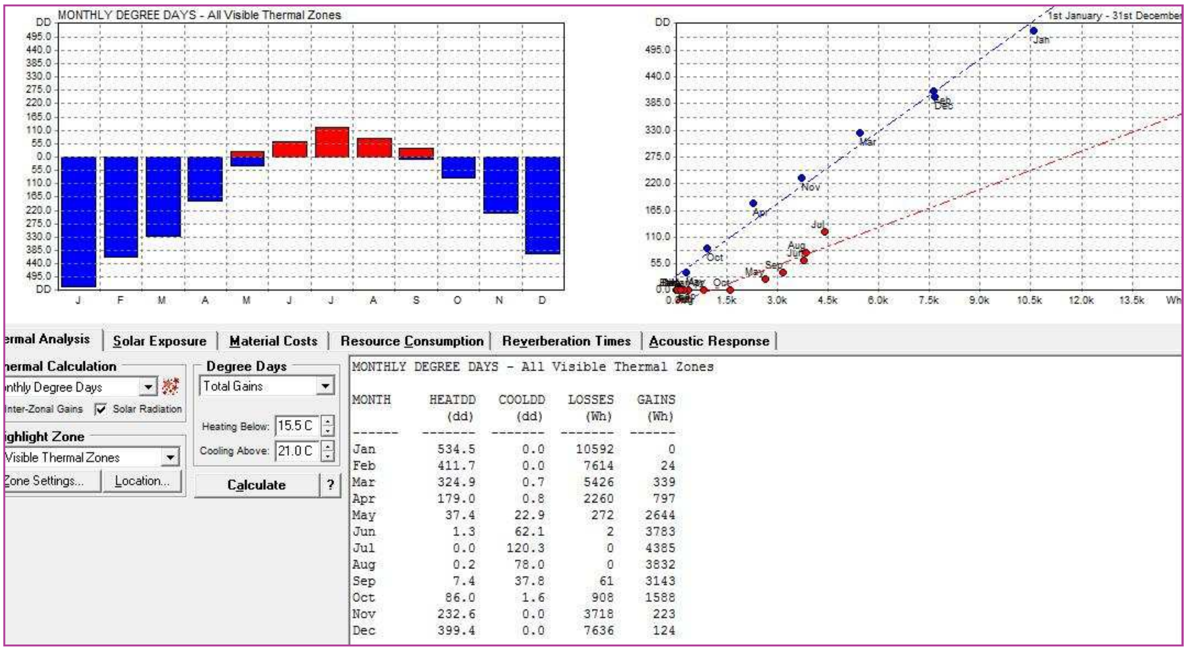


fig.83: Results from Ecotect

The charts show that the total loss is 38.5kWh and total gain is 20.8kWh which means usage of low e glasses reduces the loss 42% and it also reduces the gains 55% and the difference between the gain and loss also reduced.

According to the ecotect there is a need to use a shading system to protect from the sun. The use of fritted glass is limited because of the visual comfort so manually changeable louvers are used according to the usage and direction.

2.2.2. Solar Protection

The aim of solar protection is to keep both cooling energy requirements and expected cooling load as low as possible. The solar protection arrangement in the GreenWich tower is provided both by rigid and movable elements. Fritted glass is the main element for sun protection also the movable louvers (fig.84) are used as glazing. Since glazing and solar protection influence the amount of daylight in a given room, there is a direct proportional effect between energy requirements for room cooling and artificial lighting.

Also according to the ecotect there is a need to use a shading system to protect from the sun. The use of fritted glass is limited because of the visual comfort so automatic interior shading systems of louvered blinds are used to maximize the protection.

fig.84: Movable Louvres

2.2.3. Lighting

After using shading systems and fritted glass another problem that needs to be solved is the lighting. Because in green buildings daylighting is an important feature due to the many advantages, such as increasing user satisfaction and performance as well as the value and marketability of commercial property. Daylight also enables opportunities to boost energy savings by 35-60% using automatic daylighting controls.

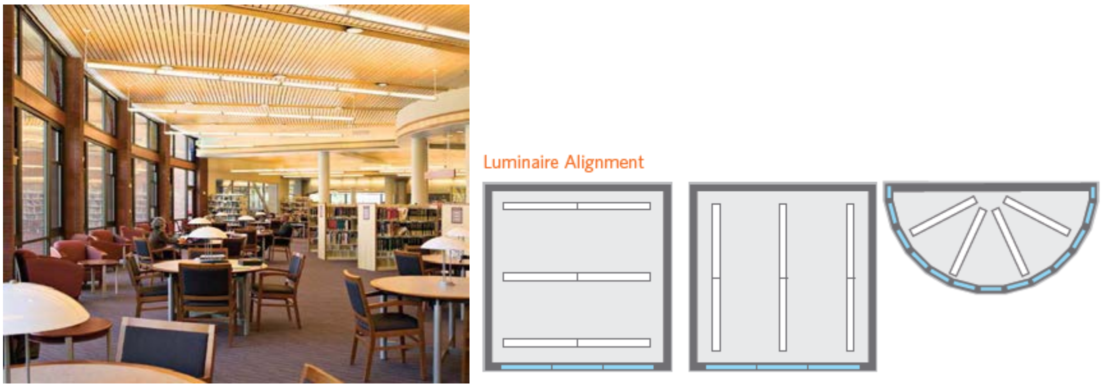


fig.85: Example of Lighting System and Arrangement

With daylighting controls, as daylight increases electric lighting decreases. Systems' potential energy savings and impact on sustainability are huge. The lighting system is composed by single luminaries with small and simple integrated dimming mechanisms. This system can easily be found from the market after a proper search.

2.3. Use of Regenerative Energy Sources for the Generation of Heat, Cooling and Electricity for the Buildings

2.3.1. Fossils and Regenerative Energy Resources

The primary energy sources are the most important resources-Coal, oil and gas-. For the GreenWich Tower New York steam system is another available source because of the location. The New York City steam system(fig.) is a district heating system which takes steam produced by steam generating stations and carries it under the streets of Manhattan to heat, cool, or supply power to high rise buildings and businesses. The system significantly increases the efficiency of fuel usage and thereby reduces the emission of pollutants and reduces the city's carbon footprint.
In GreenWich Tower heating will be provided via steam system that is supplied by shell and tube heat exchangers, which heats hot water and is then pumped through perimeter fin-tube radiation units.

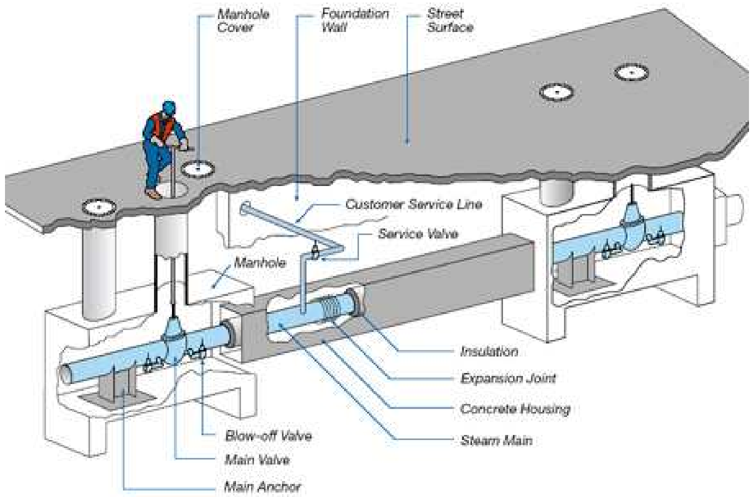


fig.86: Illustration of Connection of Geothermal Pipe

Regenerative, or renewable, energy sources are divided up into two sectors: natural energy sources and regenerative raw materials. Natural energy sources can be found anywhere and they differ in their performance capacity and available amounts, according to the region where they occur: sun, wind, earth heat, water, and outdoor air.

Regenerative raw materials, on the other hand, are from fauna and flora (biomass) and, during growth, draw the same amount of green- house-endangering carbon dioxide out of the atmosphere as they later emit during incineration and energy generation. The atmosphere is not loaded with further carbon dioxide during this form of energy generation and, therefore, no increase of greenhouse effect results. Only that energy which is used for manufacture and transport of the materials to the incineration facility is not yet considered to be regenerative primary energy.

Renewable resources are most often locally available materials like wood (pellets, wood shavings), energetic plants (grains and feed plants) and biogas. This means that energy intensive transportation routes are kept to a minimum and dependency on imported raw materials, like oil or gas, decreases.

The aim of using renewable energy resources is because they have no environmental stress and low energy costs.

In order still to be able to use renewable energy sources in an efficient and economical way, some targets were tried to be followed:

• Energy requirements must be minimized.

• Operating temperatures for heating and cooling must not differ too greatly from indoor temperatures in order to incorporate natural energy resources more efficiently. This means flow temperatures of 16 to 35°C for heating and cooling.

• The ratio of overall property size to building volume must be balanced in order to ascertain efficient use of both solar power and earth geothermal heat.

The GreenWich Tower under normal circumstances does not offer good conditions for natural ventilation, geothermal usage or solar energy usage through photovoltaic panels on the roof. That’s why the traditional solutions were changed.

First of all for natural ventilation the green spaces used as a buffer zone. As a start point the green areas designed to be totally open areas.

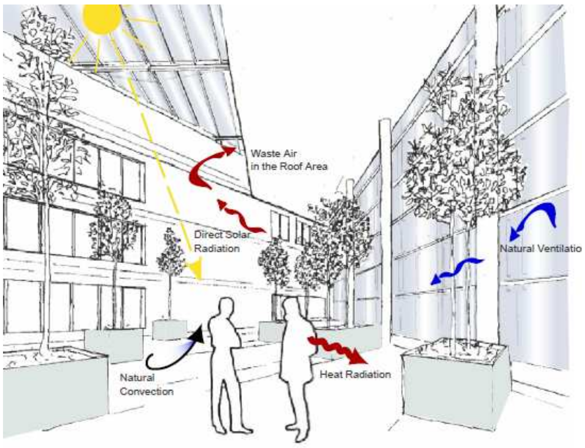


fig.87 : Sketch of the Natural Ventilation

Then taking into consideration of safety requirements and weather conditions the design was changes. The façade of the green space changed into open able windows for natural ventilation.

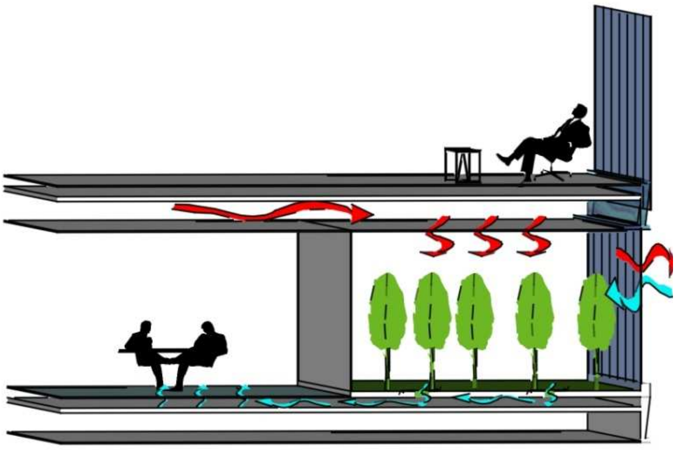


fig.88: Sketch of the Natural Ventilation in GreenWich Tower

The usage of geothermal energy is difficult for a skyscraper. Integration of near-surface geothermal facilities up to a depth of 200 m only makes sense when sufficient plot area is available for positioning different types of soil heat exchangers. Floor space index for residential construction should be somewhere between 3 to max 5 for this. For office buildings, values between 3 to max 6 are desirable. Since the GreenWich Tower is a mixed use building FSI set to be around 3 to 6. So not only the base of the tower used but also the parking garage surface was also used to increase the space for facilities. As a result the solution became a mixture of the building 1 and building 3 and it created 50% of potential. The idea of using geothermal energy is same as the steam energy. The energy that is gained from geothermal source is then used to heat or cool the water in the pipes which will be later used in the decentralized system of the tower.

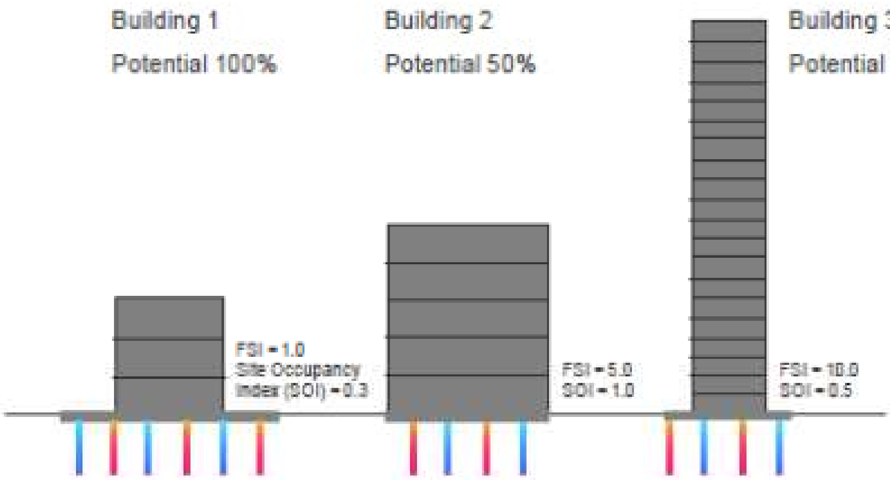


fig.89: Potentials for the Use of Geothermics for Different Ratios of Plot Area to Building Cubic Content

If solar power is to be used for heat generation, then there must be sufficient roof space available for positioning the collectors. The façade is only suitable in a limited manner for this since, for most rooms, daylight is required and yet the amount of sunshine on façade area only constitutes a maximum of 70 % of optimum yield. In order to cover a large proportion of drinking water heating requirements through solar energy, there should be no more than 10 to maximum 20 floors to the building.

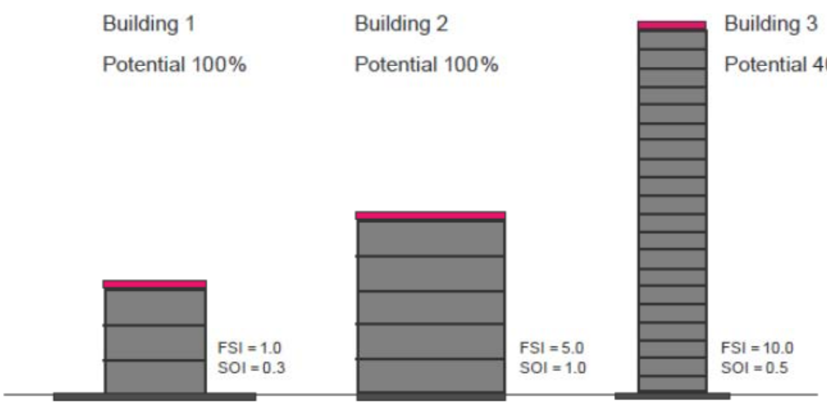


fig.90: Potentials for the Use of Thermal Solar Power for Different Ratios of Roof Area to Building Cubic Content

When using solar power for electricity generation there should be a maximum of 3 to 5 floors for residential, and 2 to 4 floors for office buildings. That is, if a large proportion of electricity requirements for room conditioning systems and for household and EDP appliances is to be met via photovoltaic systems. As it can be seen from the fig.91 the design had to be changed in order to increase the potential. So another solution was found:

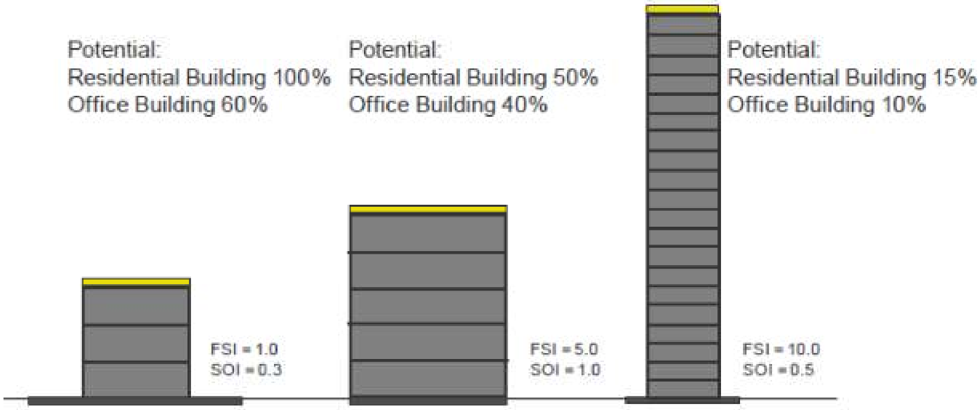


fig.91: Potentials for Photovoltaic Solar Energy Usage for Different Ratios of Roof Area to Building

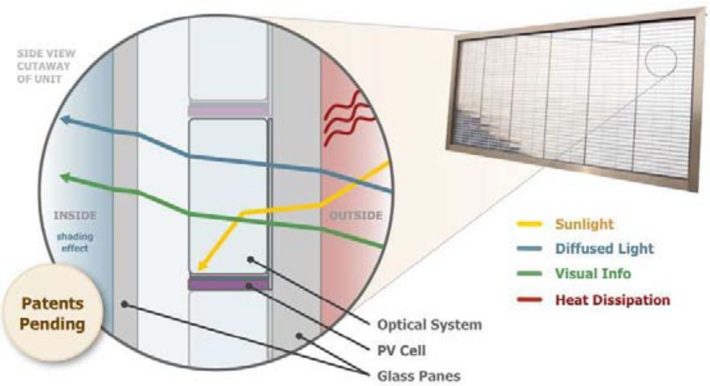


fig.92: Photovoltaic Fritted Glass

Design of the photovoltaic glass unit is an innovation for which the technology has not been applied widely yet. The idea is to create the only transparent and high-density photovoltaic glass unit, which combines solar PV power generation with the modularity in the form of fritted glass and insulating benefits of the standard insulating glass unit (IGU) while preventing direct solar radiation from entering the building.

Metric	Rating
Power density	13 W/ft^2 (140 W/m^2)
U-value	0.24
Solar Heat Gain Coefficient (SHGC)	0.15
Visible light transmission	50%

fig.93: View from a Photovoltaic Glass and Design Values

The PVGU provides an excellent thermal barrier and blocks all direct solar radiation, which reduce building heating and cooling costs. It also provides better daylighting, limiting lighting costs while creating an enhanced, comfortable work environment.

2.3.2. Heating Energy Demand

Aside from the original function of the heat-insulated envelope, which is to reduce heat emission to the outside, an elevated insulation level also leads to increased thermal comfort. Through low inlet heat movement in winter, and in summer the reverse, indoor surface area temperatures and indoor air temperatures draw increasingly closer together. This results in a comfortable, homogenous distribution of indoor temperature. With the original, passive house idea, the approach was taken so far as to completely forego the use of heaters and, instead, to apply mechanical ventilation systems to supply the rooms with the required amount of residual heat. This means that there is no heat radiation, although heat radiation is being perceived as very comfortable. A combination of optimum heat insulation, as can be found in a passive house, complemented by heat-radiation emitting components, All of this with overall comparable energy efficiency to a passive house.

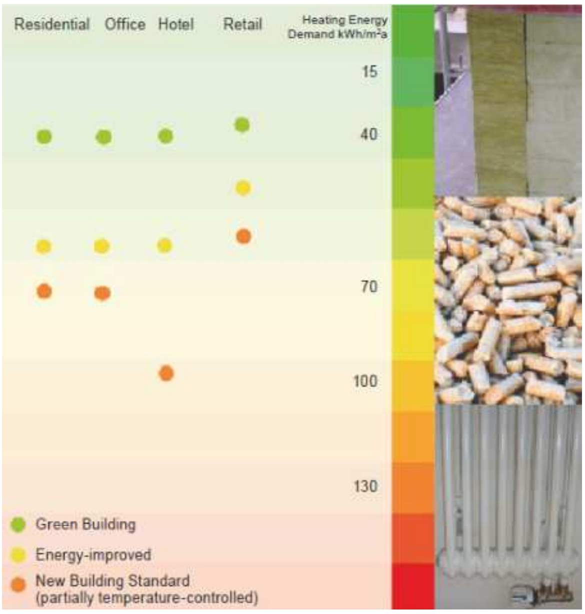


fig.94: Energy Demand for Heating for Different Type and Use of Buildings

From the ecotect solutions the heating demand is $38kW/m^2$ and after checking from the fig. 94 it is seen that the results are matching for the green building.

2.3.3. Cooling Energy Demand

Over the past 10 to 20 years, cooling energy demand has risen. There are primarily four reasons responsible for this development. Firstly, technical equipment, especially in office and administration buildings, tends to give off heat through the connected EDP devices and that heat needs to then be dissipated with the assistance of active or passive cooling measures. Secondly, there have been great improvements in glazing regarding heat protection and daylight influx, something which grants the architect greater scope for using glass in his design. There is, therefore, a trend toward glass architecture, which comes with numerous advantages regarding transparency and daylight utilization but at the same time, unfortunately, due to higher heat gain from solar radiation, also comes with a greater cooling load requirement. Thirdly, then, we have already advanced as a whole toward the construction of buildings that are much better insulated and increasingly more airtight. The building envelope, therefore, behaves like a thermos flask: inside, it stays warm, regardless of outdoor temperatures. This means that natural cooling processes during summer may be hampered but, in return, there is less energy demand for heating in winter. Fourth but not least, users' expectations regarding thermal comfort has risen considerably. In order to make it clearer we can use as an example when coming out of an air-conditioned car, train or airplane, one is then expected to enter a building for shopping, work or relaxation and stay there for a longer period of time if this building is not air-conditioned. Finally, it can be realized that performance output increases when comfortable climatic conditions prevail indoors.

So the envelope of the GreenWich Tower became more airtight and higher insulated which has a better chance for improved indoor comfort and also for less energy use. To make it more clear; The main aim of the design was to create a building performs like a thermos flask which is capable of keeping fluids cool, over long periods of time, during hot summer days. This means that a highly insulated building envelope causes heat to remain outdoors during hot summer periods, so long as the windows are closed. In the figure 95 that shows energy demand for cooling for different type and use of buildings , it is shown that demand coefficients for different utilizations. And from the ecotect we got the results that the cooling demand is 11kW/m^2 which is good enough for a green design.

fig.95: Energy Demand for Cooling for Different Type and Use of Buildings

2.3.4. Electricity Demand for Air Transport

Air Quality inside buildings is secured via ventilation. The simplest means of ventilation is through opening a window. But in skyscrapers the main ventilation is usually done by mechanically. The main reason for that are the natural forces, such as wind, pressure and temperature differences, cause different volume which creates pressure differences which are really critical for towers. In order to create more fresh environments natural ventilation is also created by open able windows at green parts. And mechanical ventilation is used that is capable of filtering and conditioning the outside air when it hits the building (air-conditioning). This results in a decrease of both heating and cooling energy requirements.

In order to allow for the desired amounts of air to enter the room in a conditioned manner, electric power is needed for the air transport. The amount is changes according to the usage, outside air exchange rate, outdoor climate etc.

3. Water Requirements

Drinking water is an important topic for the design of a green building since non-polluted drinking water is becoming scare as each day passes. The main consumers of drinking water are private households, small commercial operations and industry and the GreenWich Tower is a mixed use building that has a high potential to use the drinking water a lot. So some precautions were taken.

3.1. Water Requirement for Drinking Water

In residential use, an average household, 68% of drinking water is used for washing and toilet flushing. Laundry and dishwashing actions account for another 19%. The remaining water volume is used for drinking and cooking and also for garden watering and cleaning (fig.96).

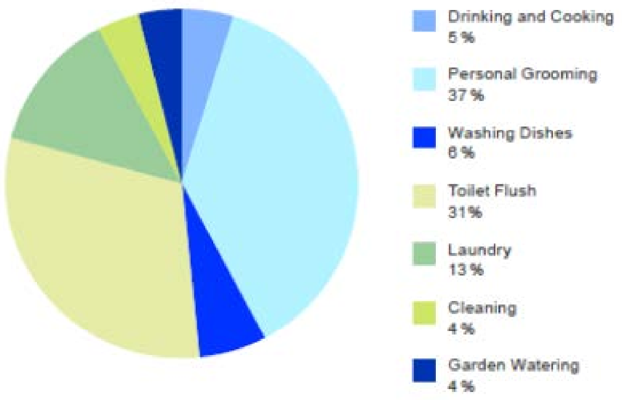


fig.96: Water Consumption Spread for the Average Household

For hotels, the usage of water is primarily, through washing and catering needs.

In office buildings, on the other hand, the requirements can be explained primarily by cleaning (façade and general cleaning).

High levels of drinking water consumption also lead to high levels of energy consumption for heating, while also placing additional load on wastewater systems and sewage facilities. However, water consumption can be reduced by up to 50% through the following measures: adjustment of habits, installation of water-conserving devices and use of natural and renewable resources (rainwater and grey water).

3.2. Water - Conserving Appliances and Technologies

In order to reduce the use of water some measures were taken:

• Lavatory flushes with economy switch
• Water-conserving taps (single lever handle faucet) and shower fittings
• Public sector: fittings with infrared sensors
• Waterless urinals

To explain it better we can use the waterless urinals and its effect on water consumption:

By using waterless urinals:

Approximately 2lts per flush*3flushes a day* 4000 males* 5 days * 50 weeks =6,000,000lts of water will be saved per year with just using waterless urinals.

3.2.1. Rain Water Use

In the design of GreenWich tower one of the main goal was to reduce the used amount of drinking water. More important than providing insulation, green roof of the tower collects rainwater and storage tanks collects around 180000lts of rain. This is filtered and used as gray water which can reduce drinking water consumption by about half. Another important use of rainwater in GreenWich tower is for flushing, washing and cleaning, as well as for watering the garden.

fig.97: Water Use in Green Roof

For our mixed use tower rainwater has many advantages one of which since rainwater is soft, less washing powder is needed for the laundry also for watering the garden, rainwater is especially useful due to its high mineral content, which means that the plants like it better than regular drinking water. Another advantage of rainwater use is that it takes load off the wastewater systems. In New York City, collecting rain is critical because, rainwater washes into the sewer system and ends up at a sewage treatment plant. When rainfall exceeds half centimeter, it overwhelms the plant's capacity to treat it. The overflow-a mixture of rainwater and sewage—is dumped, untreated, into the rivers and harbor. Green roof and rainwater storage tanks absorb the rain, slow the runoff, and help keep the harbor clean.

3.2.2. Grey Water Use

Grey water is waste water from households, stemming from shower, bathtub, bathroom sink and the washing machine and which, hence, is not contaminated with faeces or highly polluted kitchen waste water. It only contains a moderate amount of soap residue and skin oil. The average household produces about 60 liters of grey water per day, per person. . Grey water processing usually takes place through a biological and a mechanical process. Fine particles are filtered out. Afterward, the water is cleaned in the aerobe-biological stage and disinfected through UV radiation (fig.98).

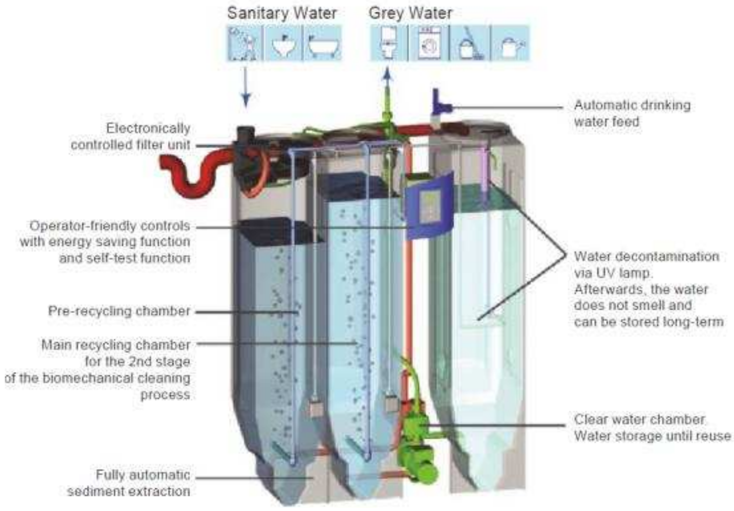


fig.98: Refinement of Black and Rain Water

In GreenWich tower this type of water is processed into usable water, which is totally safe from a hygienic point of view but does not have the same quality as drinking water. It is used for toilet flushing, watering the green areas and cleaning purposes. This means, in effect, that drinking water is then being used twice and the total amount of used drinking water is decreased.

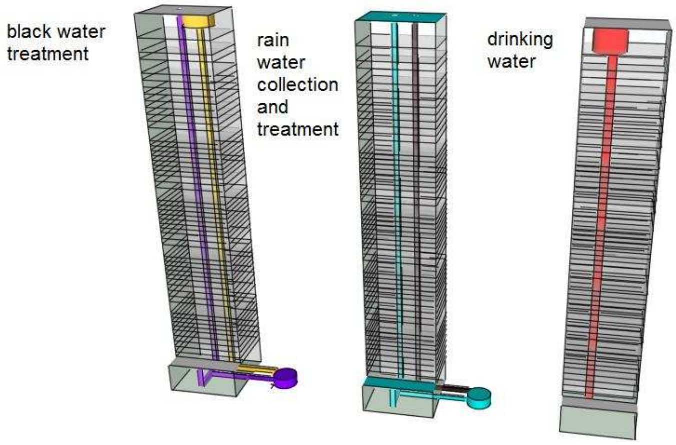


fig.99: Illustration of the Places of the Tanks

The figure illustrates the type of the pipes inside the tower: first one which collects the black water and after the treatment collects at the top grey water tank and reuses. Second one carries the collected rainwater from the rooftops and after treatment uses as grey water. And finally the last one which brinks the drinking water and because of the pressure problem first collected in the water tank on top of the building then used through the building.

4. Building Service Design

As it is known there are four broad categories of air-conditioning systems depending on the zoned cooling and heating. Those four systems are:

1. All-air systems: Which used in GreenWich tower and will be discussed further.

2. Air-and-water systems

3. All-water systems

4. Unitary, refrigeration-based systems.

4.1. All-air System

In the GreenWich tower All-air systems is used to provide air conditioning by using a tempered flow of air to the spaces. These all-air systems need substantial space for ducting the air to each zone. The heating or cooling effect of airflow, when it enters a zone, is dependent upon two factors:
-The flow rate, (measured in liters per second, L/s).
-The temperature difference between the supply air and the zone temperature, (measured in degrees Centigrade, °C).

When the unit is supplying one space, or zone, the temperature in the zone can be controlled by:
-Changing the air volume flow rate to the space.
-Changing the supply air temperature.
-Changing both air volume flow and supply air temperature.
In many buildings, the unit must serve several zones, and each zone has its own varying load. To maintain temperature control, each zone has an individual thermostat that controls the volume and/or temperature of the air coming into the zone.

All-air systems have a number of advantages:
• **Centrally located equipment**—operation and maintenance can be consolidated in unoccupied areas, which facilitates containment of noise.
• **Least infringement on conditioned floor space**—conditioned area is free of drains, electrical equipment, power wiring and filters (in most systems).
• **Greatest potential for the use of an economizer cycle**—this can reduce the mechanical refrigeration requirements by using outside air for cooling, and therefore reduce overall system operating costs.
• **Zoning flexibility and choice**—simultaneous availability of heating or cooling during seasonal fluctuations, like spring and fall. The system is adaptable to automatic seasonal changeover.
• **Full design freedom**—allows for optimum air distribution for air motion and draft control.
• **Generally good humidity control**—for both humidification and dehumidification.

There are two main zoned systems:
-Reheat system: The simplest, and least energy efficient system, is the constant volume reheat system.

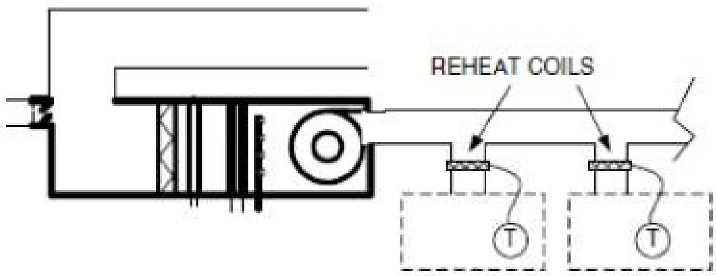


fig.100: Reheat System

-Variable Air Volume (VAV) System: Figure 100 illustrates another zoned system, called a Variable Air Volume system (VAV system), because it varies the volume of air supplied to each zone. This system is used in GreenWich Tower because of the different usages needs different air supplies. In the following section Variable air volume system will be explained better.

4.1.1. Variable Air Volume(VAV) System

Variable Air Volume systems are more energy efficient than the reheat systems. Again, assume that the basic system provides air that is cool enough to satisfy all possible cooling loads. In zones that require only cooling, the duct to each zone can be fitted with a control damper that can be throttled to reduce the airflow to maintain the desired temperature.

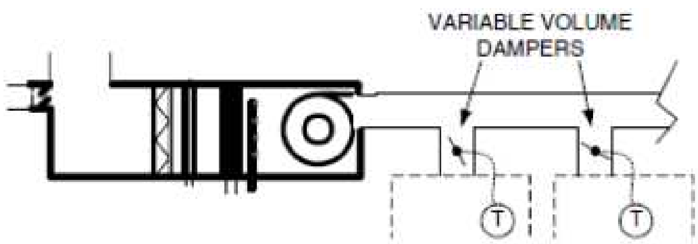


fig.101: Variable Air Volume System

Dual-Duct, Variable-Air-Volume Systems

This system is used for residential and hotel usage because of the change in demand depending on time. In a dual-duct system, cooling and heating coils are placed in separate ducts, and the hot and cold airflow streams are mixed, as needed, for temperature control within each zone. More complicated version; dual-duct, variable-air-volume (VAV) system provides the thermal efficiency of the VAV system while generally maintaining higher airflows, and thus better circulation of air in the room, when heating is required. The difference is that the air is not drawn into the building by a constant volume fan but it is split into two air streams that flow through two variable-volume fans. One air stream passes through a heating coil and one through a cooling coil. The two air streams are then ducted throughout the building.
The mixing of these two air streams is carried out in a mixing box serving each thermal zone. These mixing boxes can vary both the proportions of hot and cold air, and also the total flow rate of air to the zone. This is in contrast to the more conventional dual-duct system where the airflow delivered by the mixing box is constant.

The variation of flow in the dual-duct, variable-air-volume system is shown in figure 102 .This diagram indicates equal volume flows for both heating air and cooling air.

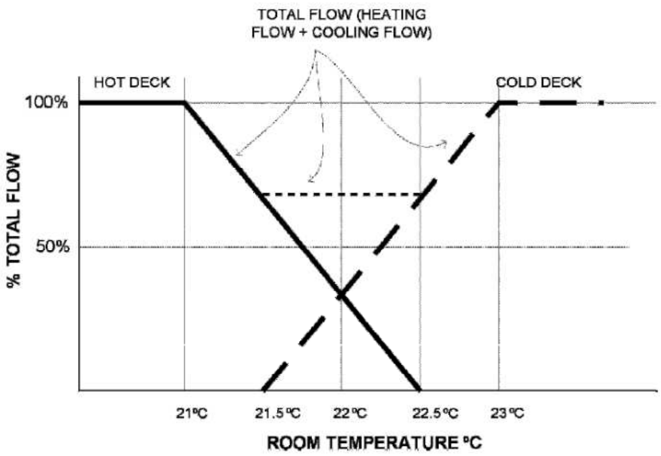


fig.102: Airflow for a Dual-Duct, Variable-Air-Volume System

Depending on the climate and resulting loads, the heating flow may be 50% less than the cooling airflow, but the control logic is the same. At maximum cooling load, the box provides sufficient cold air to meet the load. As the cooling load decreases, the volume of cold air is decreased, without addition of hot air to change the temperature. When the cooling load reaches the point where the cold airflow equals the minimum allowable flow, the cold flow continues to decrease, but the hot air is added to maintain sufficient total flow. As the heating load increases, the total flow remains constant while its temperature is increased above room temperature by increasing the proportion of air from the hot deck. When the cold deck flow reaches zero, the temperature of the delivered air will be the hot deck temperature. As the heating load increases further, the requirement for more heat is satisfied by increasing the volume flow rate of hot air.

4.1.2. Under Floor Air Distribution(UFAD)

In the design phase of GreenWich tower, offices designed to be heated or cooled with Underfloor Air Distribution (UFAD) system. In this system air is supplied from a raised floor through numerous small floor grilles. The only difference between all air system is that here there is no ducts to bring the air instead the underneath the floor is used like a duct. The floor consists of tiles that are supported by high supporting leg. Some of the tiles have outlet grilles installed in them. The tiles can be lifted and moved around, that makes grille re-location, addition, or removal, a simple task.

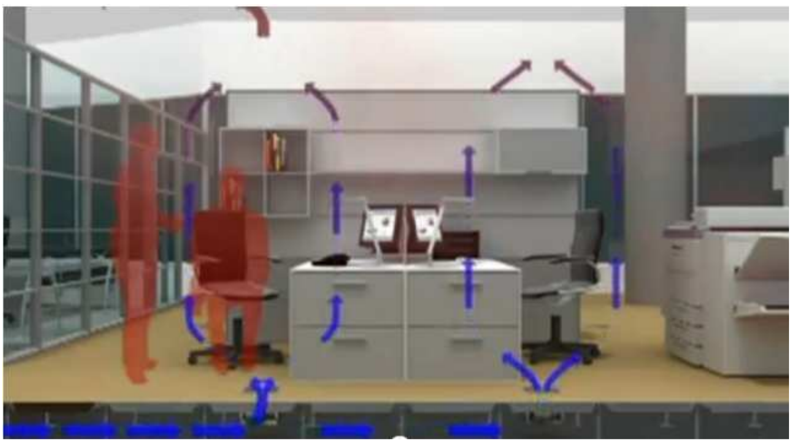


fig.103: Under Floor Air Distribution Scheme

Air, at 14.5–18 °C, is supplied to the cavity and discharges through the floor grilles. The floor grilles are designed to create mixing, so that the velocity is below 0.25 m/s within 1.2 meters of the floor. Return air is taken from the ceiling. The rising column of air takes contaminants with it up in displacement ventilation, so there is no restriction on cooling capacity. There is, however, a limit on how well the system will work with rapidly changing loads. For spaces with high solar loads, thermostatically controlled fans are used.

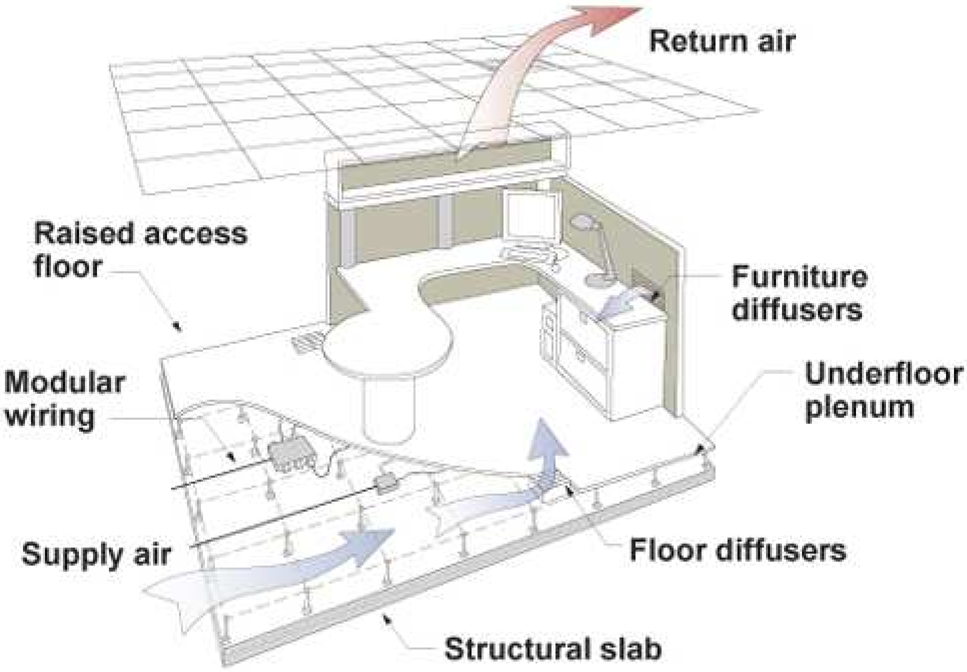


fig.104: Under floor Air Distribution Scheme in an Office

Since the air is rising toward the ceiling, the convection heat loads above the occupied zone do not influence the occupied zone temperature. Therefore, the return air temperature can be warmer than the occupied zone and a return air temperature sensor is a poor indicator of occupied zone temperature.
The cool air flows continuously over the structural floor that somewhat acts as a passive thermal storage unit. This storage can be used to reduce peak loads.
For perimeter heating, small fan-coil units are installed under the floor, using finned hot water pipes.

The underfloor air delivery system has the following advantages:

- Changing the layouts of partitions, electrical, and communications cables is easy. For buildings with high "churn" (frequent layout changes) this flexibility may, in itself, make the added cost of the floor economically justified.
- The flow of air across the concrete structural floor provides passive thermal storage.
- When the main supply duct and branches to the floor plenums are part of a well-integrated architectural design, the air supply pressure drop can be very low, resulting in fan-horsepower savings.
- Less ventilation outside air can potentially be used and out of the breathing zone. This sweep-away action is considered more effective rather than mix-and-dilute. As a result, the ventilation requirements of ASHRAE Standard 62.1 can be satisfied with 10% less outside air.

Multi-zoned, limited perimeter ductwork

It is another type of all air system which also uses underfloor partitioning to divide interior and perimeter zones. However, the amount of underfloor ductwork is reduced by relying on a single feeder duct to supply conditioned air to each of the four large perimeter zones, as shown. Standard methods of control at the central AHU are used to deliver a constant volume, variable temperature supply of air to the interior zone. Air flow from individual diffusers in the interior zone may be controlled by nearby occupants. Air flow to the perimeter zones is delivered through linear grills and controlled by VAV terminal units in response to zone thermostats. Perimeter finned tube heating coils, located directly under the linear grills in the underfloor plenum, and is used during the heating mode.

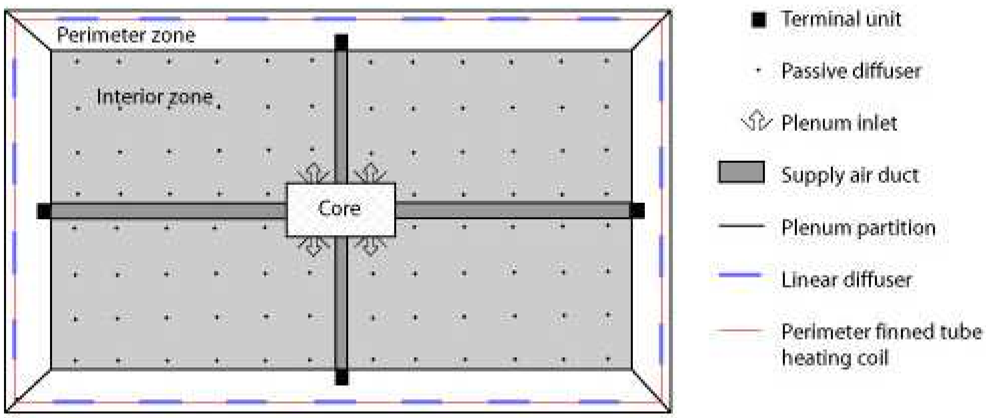


fig.105: Multizoned, Limited Perimeter Ductwork System's plan
http://www.cbe.berkeley.edu/underfloorair/exampleLayout.htm

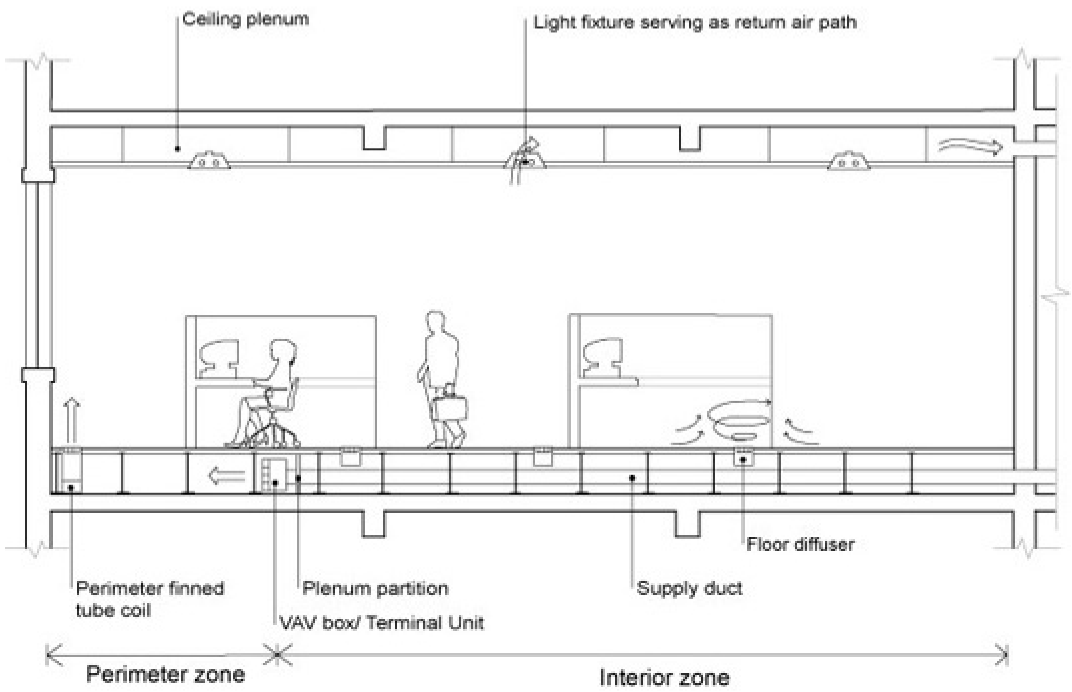


fig.106: Multizoned, Limited Perimeter Ductwork System's Section

5. Summary

The idea behind the design of the façade of the GreenWich Tower is so simple:

In theory with a design of a more compact structure is more energy can be saved. If one looks at heating energy requirement alone, then it is, of course, absolutely correct to minimize a building in respect to heat loss area while aiming to keep utilization area as is. However, this approach presents energetic disadvantages for highly insulated buildings, when taking into account cooling energy and electricity requirements for ventilation and lighting. By merely aiming to minimize heating energy requirements, no overall optimization can be achieved. That's why in the design of GreenWich tower the target was to create less compact tower, with more daylight and a higher potential for (at least part of the time) areas that are capable of being naturally ventilated. And for this purpose the floor to ceiling glass curtain walls are used. In order to meet the sustainable economical approach for the building envelope, double glazed low e windows are used, keeping in mind thermal comfort requirements. The U value of the windows is 0.36 W/m^2K

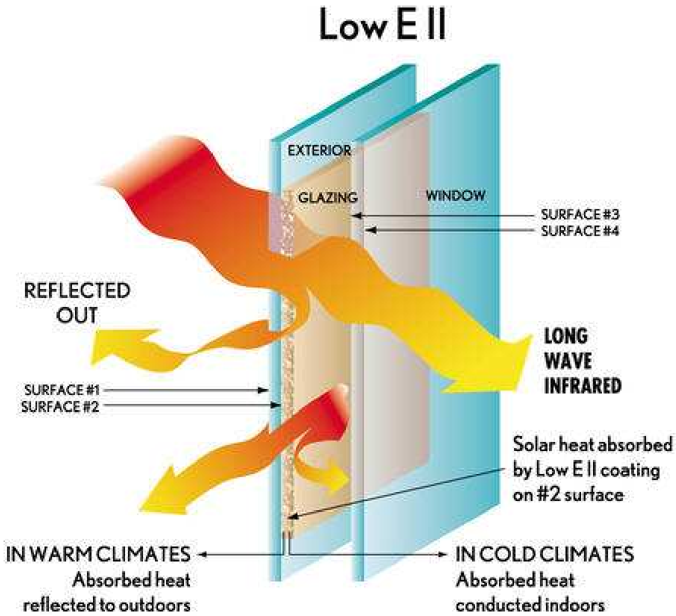


fig.107: Low E Glass

The main innovation that GreenWich Tower brings to the market is the farming activity inside a skyscraper. This is a new idea that is trying to be applied to the buildings, once the increasing population needs more area for farming, especially organic farming. Details at the end of this section show different soil types applied to the building.

fig.108: Production of Green Food

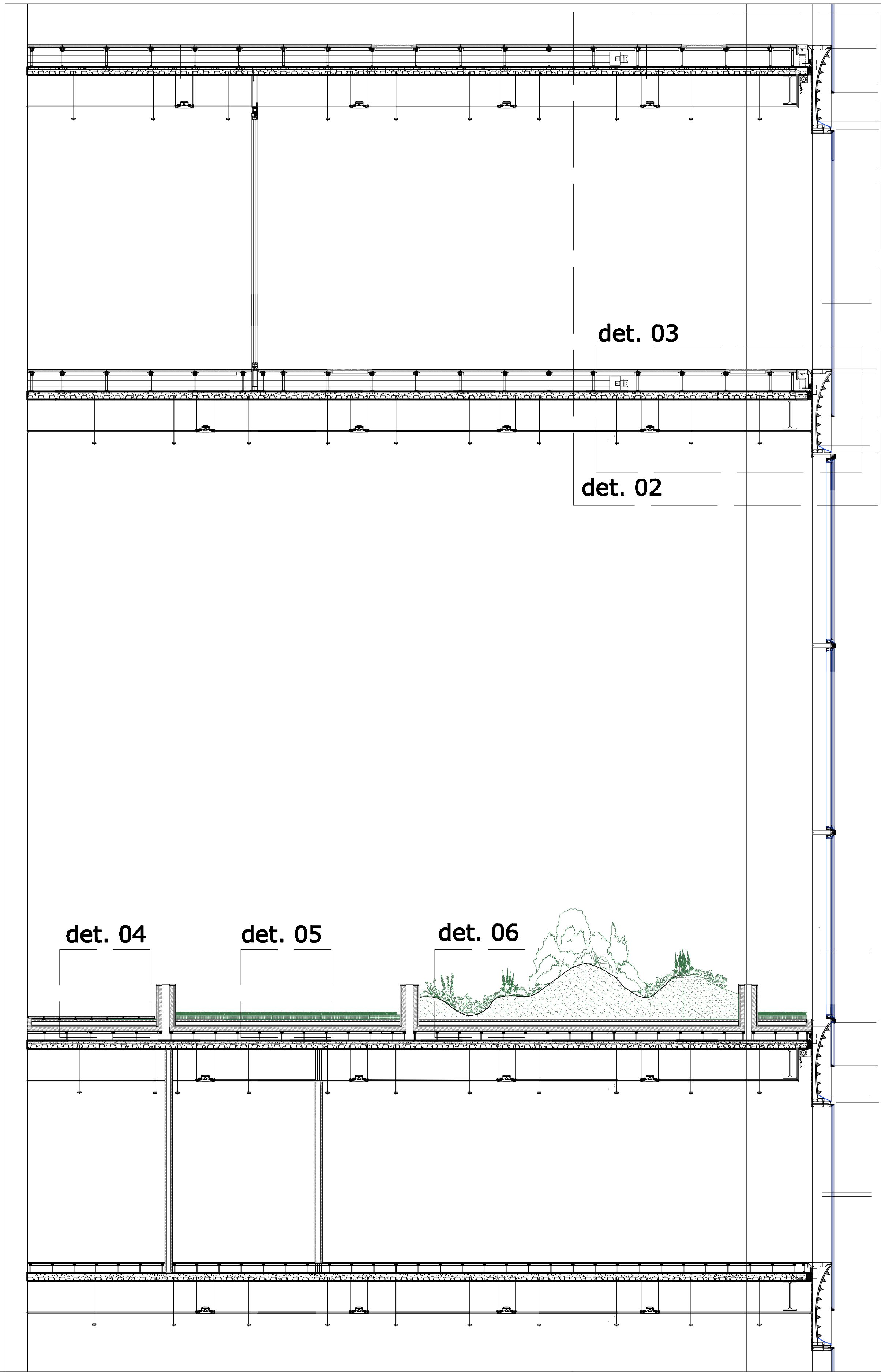
In the figure 109, different types of vegetables and fruits that can be produced inside a skyscraper.

fig.109: Proposal for Types of Food Production
http://www.verticalfarm.com/

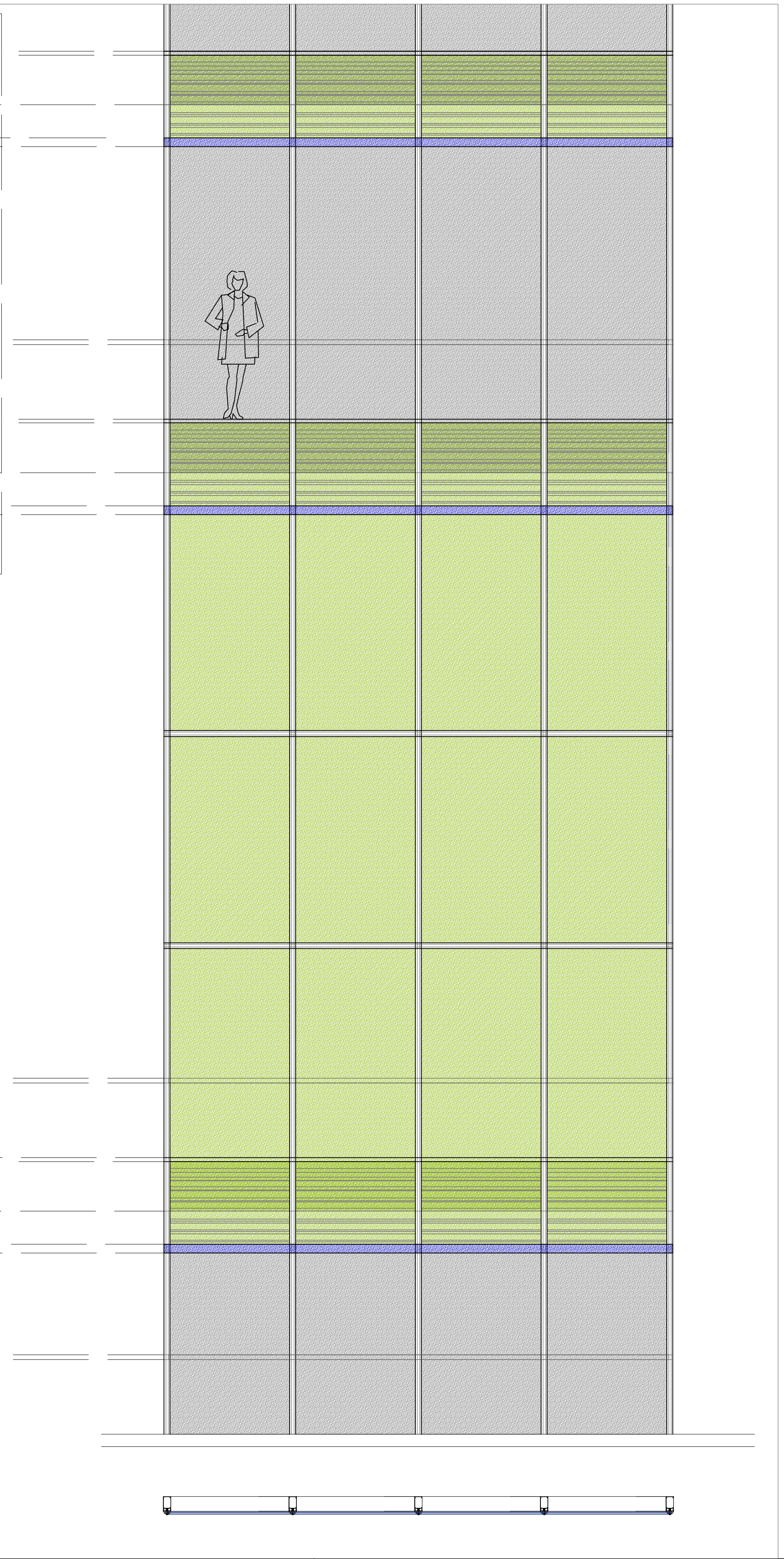
The GreenWich tower is a new conception that tries to bring a new perspective to suspended towers.

- One of a kind- Totally mixed use high rise that is a combination of office, hotel, residential and retail uses.
- Storm-water collection.
- Gray-water system captures and re-uses rainwater
- Waterless urinals and low-flow fixtures greatly decrease the use of water
- Natural ventilation through green farms
- As an energy source use of sun with photovoltaic fritted glass panels.
- Production of organic food inside the tower.

DETAIL 01 - section



DETAIL 01 - façade



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GREENWICH TOWER

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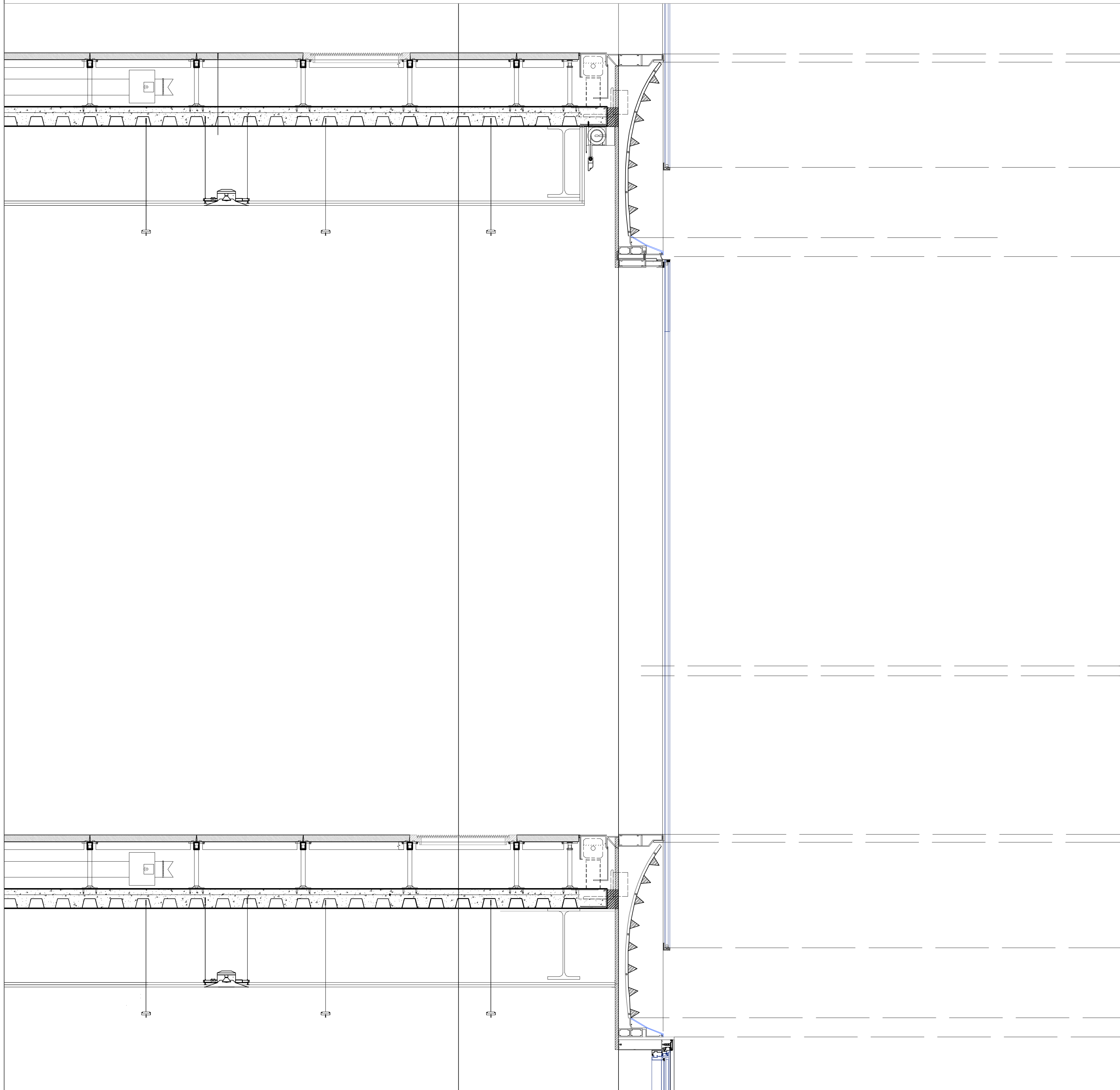
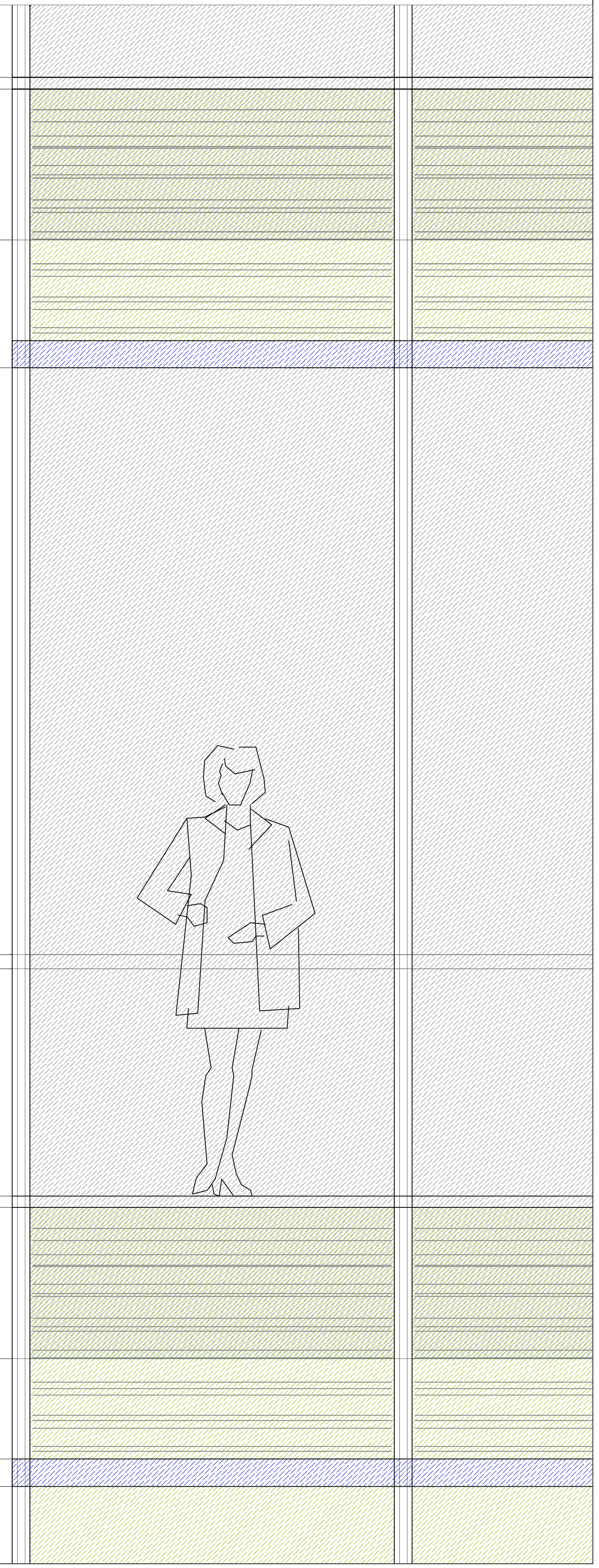
DETAIL 02 - section



DETAIL 02 - façade



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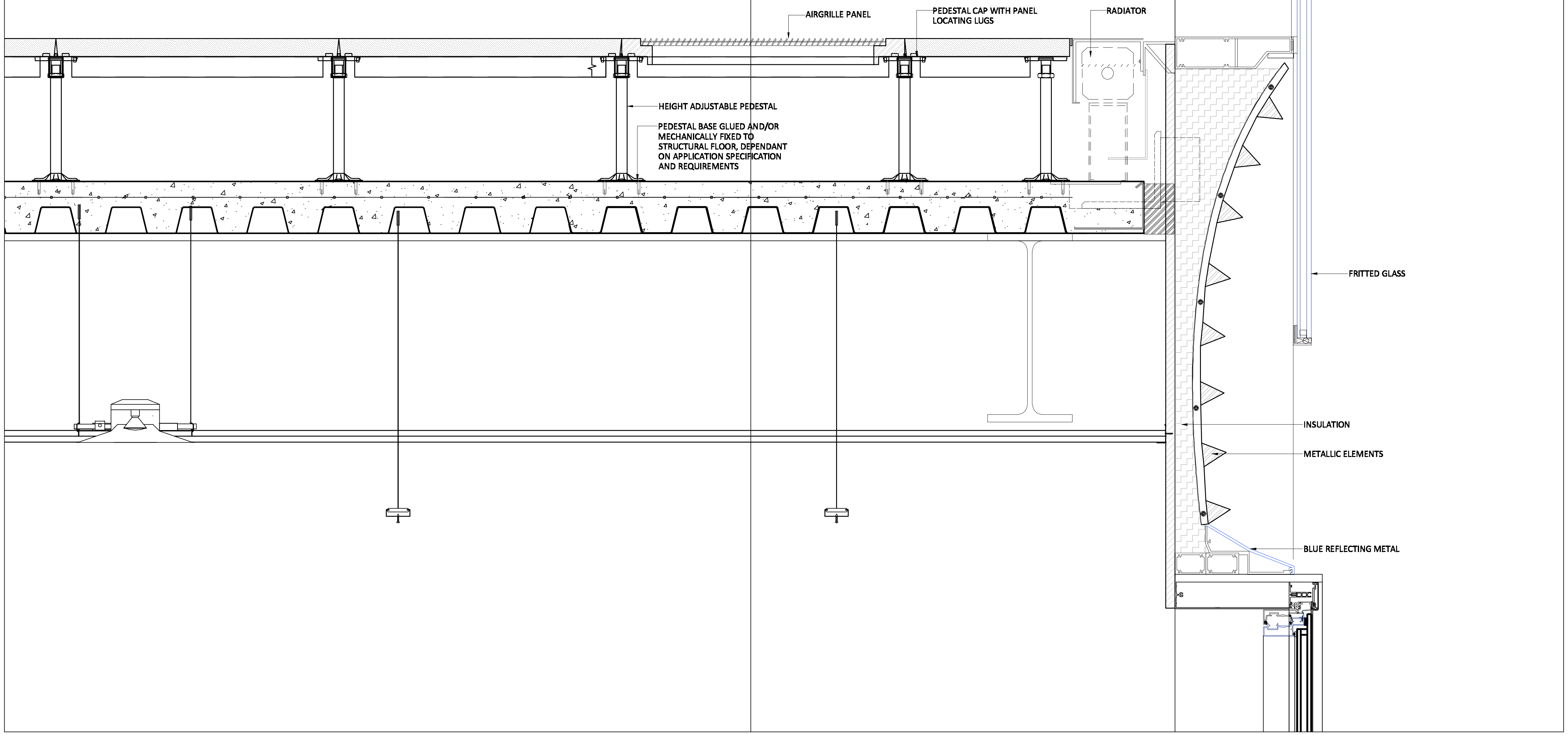
DETAIL 03



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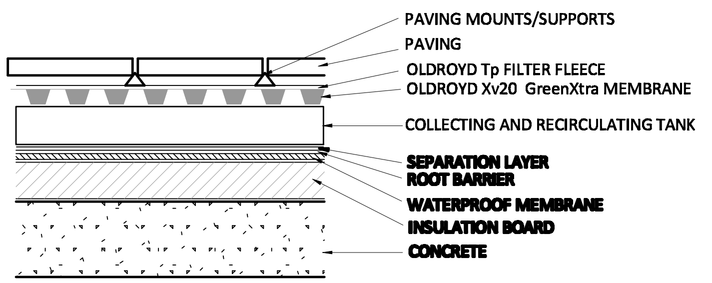

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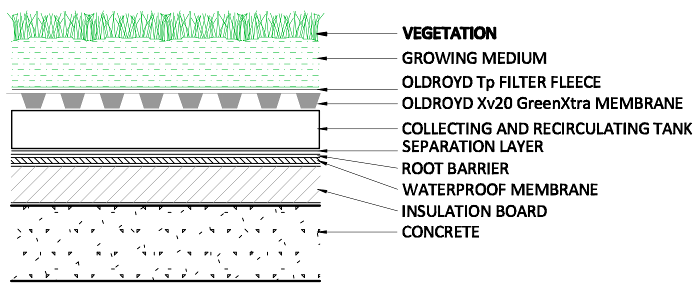

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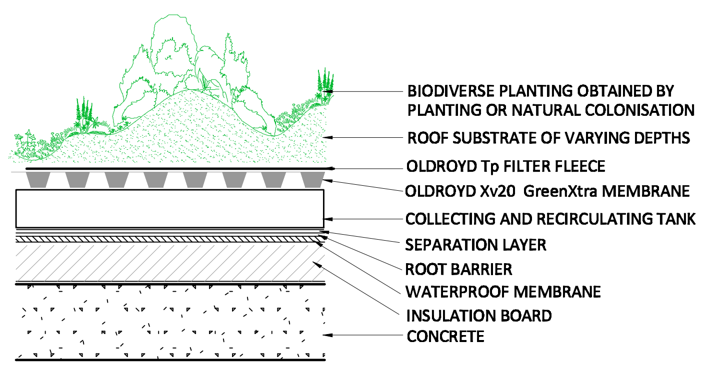

D003

GREENWICH TOWER

details
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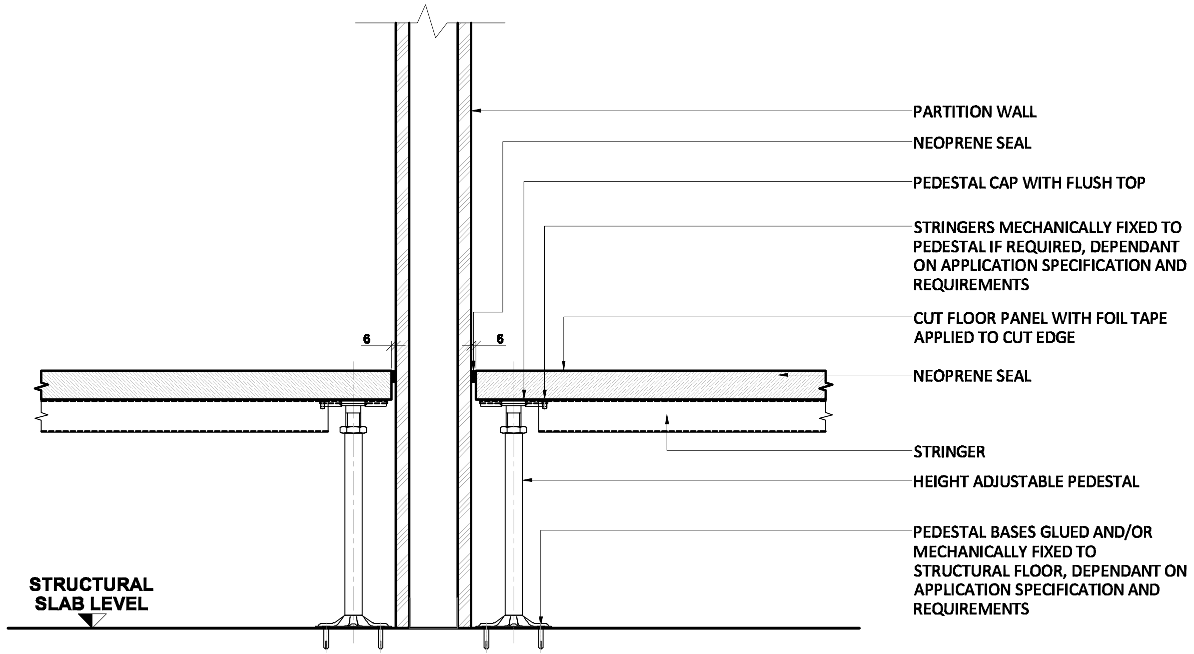
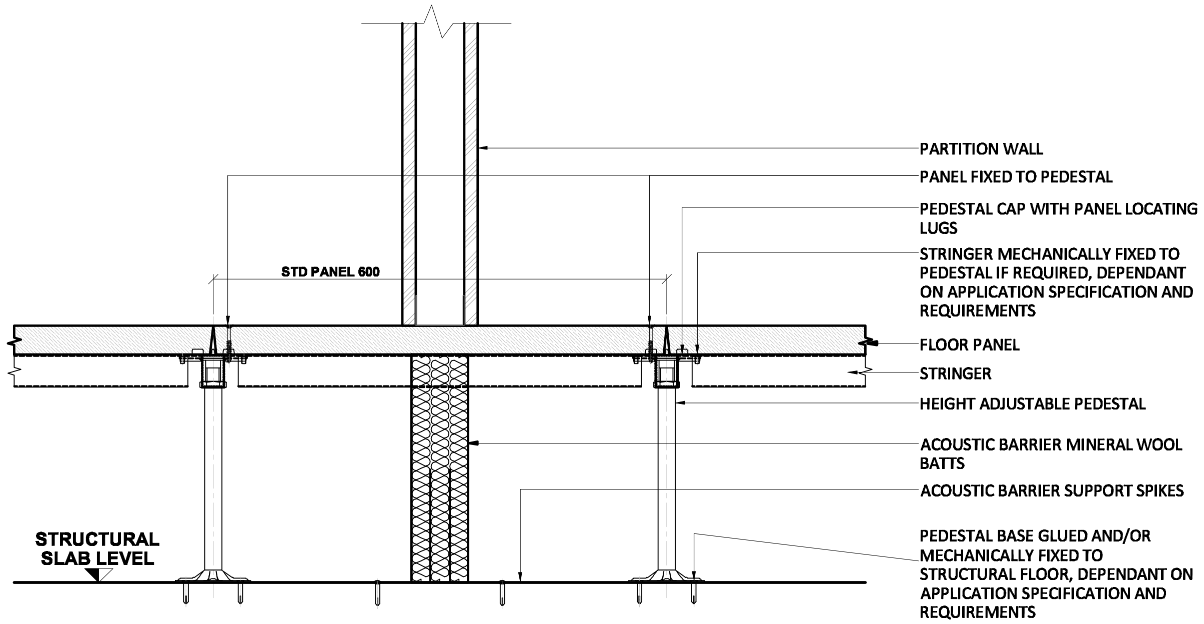
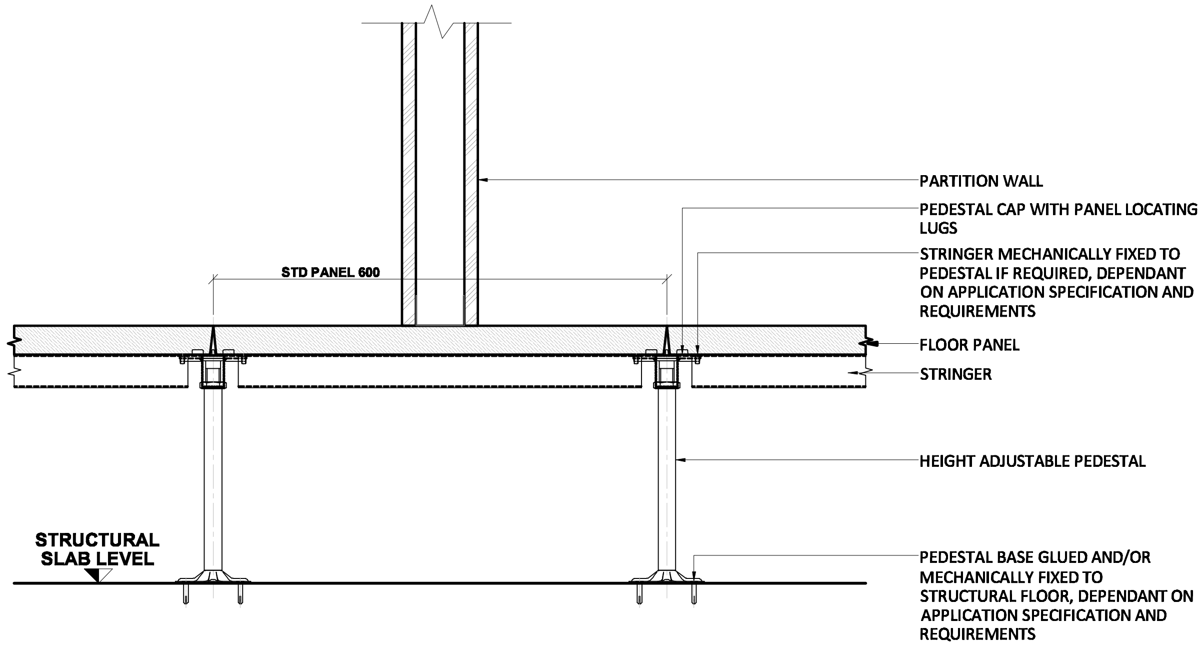
SLAB HOTEL x HOTEL



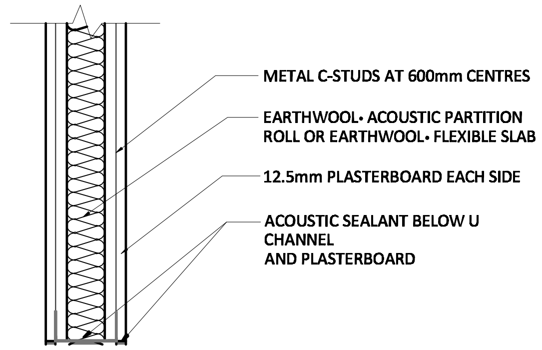
SLAB HOTEL x HOUSE



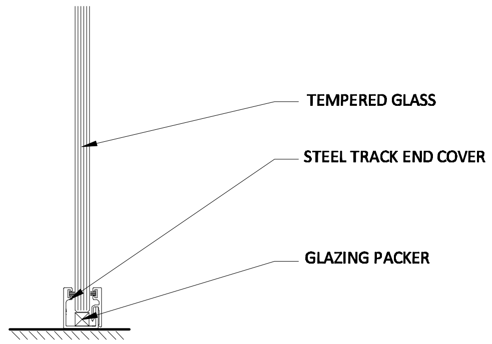
SLAB OFFICES x OFFICES



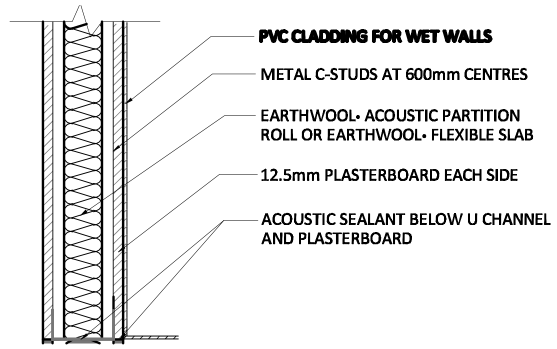
PARTITION WALL 01



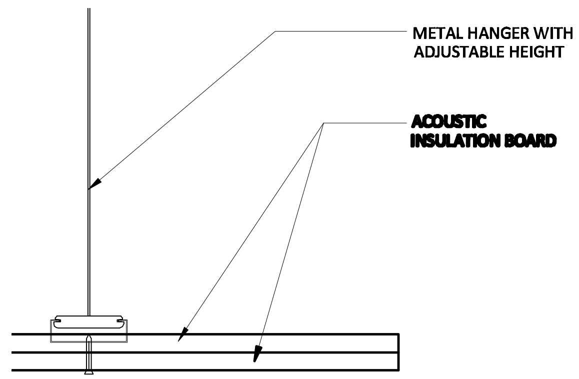
SINGLE GLAZED WALL
(scale 1/5)



PARTITION WALL 02 (wet)



SUSPENDED CEILING
(scale 1/5)



D004

GREENWICH TOWER

details
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POLITECNICO MILANO

Structural Design

1. Introduction

Tall buildings are an inevitable building form and part of the contemporary landscape. New design ideas are becoming common currency among progressive architects and developers. There are many ways to construct tall buildings and in practice it is the desired use of a buildings which predominantly determines its design. The exterior shape and the materials of the façade have the greatest impact on the outside public, whilst the arrangement of spaces inside determines the efficiency of a building's use by its occupants. The choice of materials for the structural frame is determined primarily to satisfy those requirements, with comparisons made of the most economical form that will do the job.

Efficiencies in the design and construction of the towers can make a significant difference both economically and environmentally. Engineers strive to find savings in materials through efficient design, making best use of concrete and steel in floors and structural frames. Hence, integrated design and the use of structural materials for optimum performance in controlling the internal environment of buildings can provide added benefits at no extra cost.

2. Design for Form, Structural System and Efficiency

The design of structural frames to resist lateral and vertical loads on buildings is a complex process which takes into account a multitude of requirements. As a result, there are a number of structural systems which make a tall building stand up.

Design methods for tall buildings have been developed to cope with earthquakes in places such as California and typhoons in cities such as Hong Kong. The main issue for stability in New York, however, is wind. The effects of lateral loading on the building frame are dramatically magnified for towers over about 60 floors, as their slenderness increases. The efficiency of the building frame has the greatest influence on the embodied energy of a tall building.

Figure 1 Comparison of Steel Systems

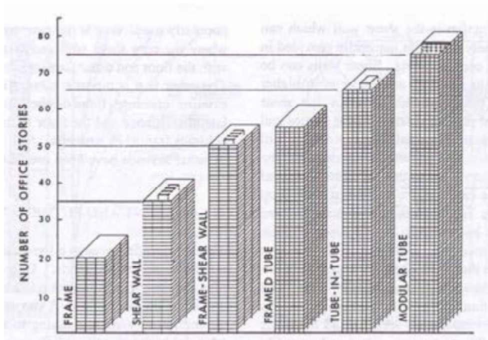


Figure 2 Comparison of Concrete Systems

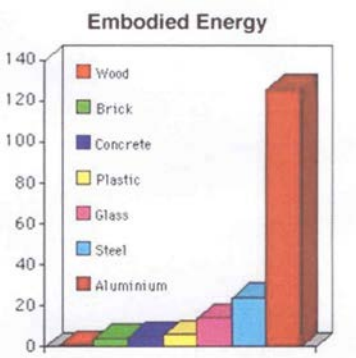


Fig. 110-111: Comparison of Steel – Concrete Structural Systems vs. Building Height
Fig. 112: Embodied Energy of Construction Materials in the USA

A combination of concrete and steel structures is often the most efficient form, utilizing the best characteristics of each material. Research into the performance of concrete-filled steel tubs has enabled their use at main supporting columns in some mega-structures. The most common form of structure in buildings up to 50 floors is a reinforced concrete shear core with composite mega columns used to stabilize the building against wind, with composite concrete floor slabs on a steel frame used to carry the building's gravity loads to the foundations.

Most tall buildings in the Downtown Manhattan are used for office accommodation. Open plan offices are more common now than in the 1960s and 1970s when many of New York's tall buildings were constructed. The change in demand and the requirement for flexibility has led to an increase in span of the floor beams of offices. Whereas column grids were previously laid out with 5-8m spacing, new buildings are constructed with clear floor spans of 10-15m. To improve the efficient use of materials to accommodate increasing spans, construction methods have been adapted and new techniques developed in the last decade. There has been a general move from the concrete framed structures of the 1960s towards longer span steel beam floor systems. Advantages of the composite action between a concrete floor slab and its supporting steel beams has reduced the depth of beams and hence the weight of steel by up to 30 per cent. For multi-storey buildings, the resulting reduction in material used and the associated energy and emissions savings on the manufacture and transportation of the steel becomes significant. One consequence of increased spans is a greater potential susceptibility to vibrations which must be limited at the design stage. The use of metal decking fixed to steel beams acting as permanent formwork for concrete floor slabs has increased the efficiency and speed of construction and is used in most new tall buildings. The dominance of this system is the result of constructability and economy. Progressive designers are also looking at embodied energy and environmental impacts in the selection of structural systems.

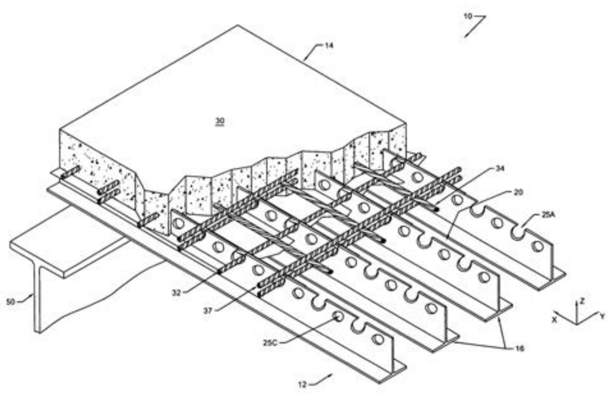


Fig. 113: Composite Slab Section

3. Design for Dimensioning of the System Components

3.1. Structural Report

Use AISC Specification for Structural Steel Buildings & AISC Specification for Concrete Structures.

Use AISC Seismic Provisions for Structural Steel Buildings, 2005.

Use ASCE Minimum Design Loads for Buildings and Other Structures.

Design All members using European rolled shapes.

Structural system selected:	Tube-in- tube system			
Steel type:	St52	A53GrB	355 Mpa	beams & composite column
Concrete Type:	C40	f'c=	27.6 Mpa	composite slabs
	C80	f'c=	55 Mpa	composite columns & shear wall (31-60 storey)
	C100 H.S.C	f'c=	70 Mpa	composite columns & shear wall (0-30 storey)

All beam to column connections are rigid connections.

The beams are designed to be steel sections, with composite slabs

The columns and shear walls (shafts) are designed to be reinforced concrete sections.

Design Type: Strength Design (LRSD)

Gravity Loads:				
Interior walls:		0.9	kN/m2	
Exterior walls:		1.4	kN/m2	(of wall area)
Floor Cover:		0.5	kN/m2	(of floor area)
Ceiling + HVAC:		0.5	kN/m2	(of floor area)

Table 03: Gravity Loads suggested by AISC.

Minimum Live Loads from ASCE 7-10:		
	uniform (kN/m^2)	concentrated (kN)
Lobbies	4.79	
Corridors (1st floor)	4.79	
Restaurants, recration, hall	4.79	
fire escapes	4.79	
corridors (above 1st fl off.)	3.83	
Retail (1st floor)	4.79	
garages	1.92	
offices	2.4	8.9
off. Access	2.4	2
residential	1.92	
roof garden	4.79	
retail(other)	3.59	4.45

Combinations to be investigated:
1.4D
1.2D+1.6L+0.5(L_r or S or R)
1.2D+1.6L_r+(L or 0.5W)
1.2D+1W+L+0.5(L_r or S or R)
1.2D+1E+l+0.2S
0.9D+1E
0.9D+1W

L_r= roof live load R=rain load

S= snow load W=wind load

Table 04-05: Minimum Live Loads & Load Combinations to be considered for design.

3.2. Preliminary Design, Slabs & Shear Studs

In steel framed structures, it is common practice to cast concrete floor slabs on stay-in-place steel deck. In all cases, the deck serves as the form and may, in some cases, serve an additional structural function. In its most basic application, the non-composite steel deck serves as a form, and the concrete slab is designed to carry all superimposed loads. Another type of steel deck commonly used develops composite action between the concrete and steel deck. In this type of construction, the steel deck serves as the positive moment reinforcement.

-Shored construction:

If composite flexural members are supported during construction so that, after removal of temporary supports, dead load is resisted by the full composite section, it shall be permitted to consider the composite member equivalent to a monolithically cast member for computation of deflection. For non-prestressed members, the portion of the member in compression shall determine whether values in table 9.5(a) for normal-weight or lightweight concrete shall apply.

d_{min}= 0.10714 m take d= 11 cm

TABLE 9.5(a) — MINIMUM THICKNESS OF NONPRESTRESSED BEAMS OR ONE-WAY SLABS UNLESS DEFLECTIONS ARE CALCULATED

	Minimum thickness, *h*			
	Simply supported	One end continuous	Both ends continuous	Cantilever
Member	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections			
Solid one-way slabs	$\ell/20$	$\ell/24$	$\ell/28$	$\ell/10$
Beams or ribbed one-way slabs	$\ell/16$	$\ell/18.5$	$\ell/21$	$\ell/8$

Notes:
Values given shall be used directly for members with normalweight concrete and Grade 420 reinforcement. For other conditions, the values shall be modified as follows:
a) For lightweight concrete having equilibrium density, w_c, in the range of 1440 to 1840 kg/m^3, the values shall be multiplied by $(1.65 - 0.0003w_c)$ but not less than 1.09.
b) For f_y other than 420 MPa, the values shall be multiplied by $(0.4 + f_y/700)$.

Table 06: Minimum Thickness of One-way Slabs

Assume PNA is at the intersection:

f_c'=27.6 Mpa, St52 steel, f_y= 355 Mpa

C= 0.85*27.6*2700*110=	6740415	}	C≠T
T= 30310*355 =	10760050		PNA is lower

Assume PNA is at the compression flange:

C= 2700*110*0.85*27.6 + 355*310*a

T= (21-a)*355*310+208*355*39+355*21*310 } C=T

6740415+110050a=7501860-110050a

a=	3.459541118	mm
C=T=	7121.1375	kN

∑M=0 wrt PNA

ϕM_n= 1187.957069 kNm>1120 kNm ok

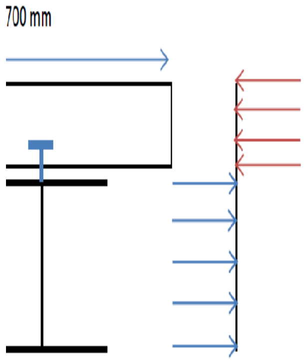
Use, 19 mm diameter, 75 m height studs:

F_u= 480 Mpa, f_c=27.6 Mpa E_c=4600√27.6 =24166 Mpa

ϕ_n=0.5*A_{sc}*√f_c'*E_c= 115.76572 kN

#ofstuds=7121/115.76 61.51335

use 62 _ 19 mm diameter studs per half length



M 300 & HEB 400

stress distribution through ection.

3.3. Beam Design

3.3.1. Preliminary Design

In the preliminary design step for the beams, moment estimation via hand calculation is used, which leads to a more conservative sections, to avoid further increase of the sections in the main design. Hence, the sections in the preliminary design are larger than the actual sections that would be needed, in the main design. Further reduction with respect to the analysis results have been accomplished in the main design. An example estimation is hereby evaluated, please see appendix for the further calculations.

interior+fl.cover+ceiling=	1.9	kN/m2
concrete=	26.4	kN/m2
Combinations:	1.2G+1.6L	

Floor Type 0	**CODE:**	**B01**
Beam Type 1		

Tributary area=	34.425	m2
Dead=	33.96	kN/m2
Live=	7.664	kN/m2
total,w=	41.624	kN/m2
l=	11.475	m
load per meter=	124.872	kN/m
moment=	1370.217	kNm
choose;	HeB500	
weight=	187	kg/m
ϕMp=	1543.32	kNm
(load+weight) per meter=	127.116	kN/m
Moment=	1394.84	kNm
HeB500 ok		

Table 07: Preliminary Beam Design

3.3.2. Secondary Design

The structural beams are designed to be "compact sections, in order to simplify the calculation processes, and to be more resistant for the possible unexpected loading of the massive skyscraper body. In addition to this, the necessary checks are computed for enduring the loading cases that are prescribed in the ASCE 7-10. An example estimation for the detailed design is hereby evaluated, please see the appendix, for the further estimation of the other beams.

Table 8.2.2.1
Limit States and Applicable Chapter F Sections
For Doubly Symmetric I-Shapes (W, M, S, HP and built-up Sections)
Bent About Their Major Axis

Flange	Web	Limit State				
		Y	CFY	LTB	FLB	TFY
Compact	Compact	F2.1	---	F2.2	---	---
Compact	Non-Compact	---	F4.1	F4.2	F4.3a	F4.4
Compact	Slender	---	F5.1	F5.2	F5.3a	F5.4
Non-Compact	Compact	---	---	F3.1	F3.2a	---
Non-Compact	Non-Compact	---	F4.1	F4.2	F4.3b	F4.4
Non-Compact	Slender	---	F5.1	F5.2	F5.3b	F5.4
Slender	Compact	---	---	F3.1	F3.2b	---
Slender	Non-Compact	---	F4.1	F4.2	F4.3c	F4.4
Slender	Slender	---	F5.1	F5.2	F5.3c	F5.4

Table 08: Limit States to be considered for Compact Steel Sections

B01	HeB 400	
M_{max}=	725.1154 kNm	
V_{max}=	265.052 kN	

	G	h	b	t_w	t_f	r	A	h_i	d	Ø	pmin	p_{max}	A_L	A_G
	kg/m	mm	mm	mm	mm	mm	cm^2	mm	mm		mm	mm	m^2/m	m^2/t
HE 400 B	155.0	400	300	13.5	24.0	27	197.80	352	298	M27	124	198	1.927	12.410
	I_y	$W_{el.y}$	$W_{pl.y}$	i_y	A_{vz}	I_z	$W_{el.z}$	$W_{pl.z}$	i_z	s_s	I_t	$I_w x10^{-3}$	I/L	
	cm^4	cm^3	cm^3	cm	cm^2	cm^4	cm^3	cm^3	cm	mm	cm^4	cm^6	cm^3	
	57680.0	2884	3232	17.08	69.98	10820	721.3	1104.0	7.40	93.13	355.70	3817	50.265795	

Flexural Design			
ϕ_b=	0.9		
h/t_w=	22.07	$<\lambda_p$=	89.246
$b_f/2t_f$=	6.25	$<\lambda_p$=	9.0195
design a compact section			
1)check yielding			
Z_x=	3232 cm3		
$M_n=M_p=F_y*Z_x$=	1147.36 kNm		
2)check Lateral Torsional Buckling			
L_b=	11.475 m		
L_p=	3.091328863 m		
r_{ts}=	0.083944013 m		
c=	1		
L_r=	11.69779488 m		
$L_p<L_b<L_r$	inelastic torsional buckling		
C_b=	2.38751711 ≤3		
M_n=	1737.690183 kNm		
$M_p\phi_b$=	**1032.624 $>M_{max}$ ok**		

Check for shear:			
h/t_w=	22.07 <	53.167818	
$\Phi V_n=0.6*A_w*F_y$=	1906.776 kN>	265.052 kN ok	
Weld design			
Q=	1526400 mm^3		
shear q= V*Q/I	701.4136144 N/mm		
$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$		t=	3.0620323 t_{min}=6 mm
use t=6mm			
Check for deflection	δ_{LL}=	0.0034172 m<	0.031875 m **ok**
Since the flange is compact the limit state of local buckling does not apply and			
since the section is symmetric the limit state of the tension flange yielding does not apply.			
Check for web behaviour under concentrated loads			
$k=t_f$=	24.0 mm		
i) check for the interior load		*ii) check for the exterior load*	
local web yield		*local web yield*	
ΦR_n=	1533.6 kN>283 kN ok	ΦR_n=	1246.05 kN>283 kN ok
web crippling		*web crippling*	0.5
ΦR_n=	11268.36563 kN>283 kN ok	ΦR_n=	1080.7248 kN>283 kN ok
check for sidesway web buckling		0.7746308 <1.7	
ΦR_n=	3406.874681 kN>283 kN ok		

Table 09- Beam Dimensioning and checks according to AISC- Steel Buildings Specifications.

3.4. Column and Shear Wall Design

3.4.1. Preliminary Design

Total tributary areas for columns:	781	m^2
Total tributary area for shear wall:	559	m^2

Total Load on columns=	588298.7	kN
Total load on shear wall=	316554.4	kN
Total area of columns=	36	m^2
Total area of shear wall=	37.3745	m^2

$\sigma_{columns}$=	16341.6309	kN/m^2
$\sigma_{shear\ wall}$=	8469.79632	kN/m^2
r=	1.929400694	OK

Single Column

Tributary area=	60.244	m^2
Load=	44598.43	kN
A_{column}=	2.25	m^2
σ_{c1}=	1982153	Mpa

f_c'= 70 Mpa>σ_{c1} ok

Assign 1.5*1.5 column

For the preliminary dimensioning of the vertical elements, a common check for axial stress distribution through vertical members is done. The main conflict about the area distributions between the composite columns and the shear walls would the creep effects; because the massive concrete shear walls would go under more creep deformation than the composite columns, and this unbalanced stress distribution may lead to non uniform deformations between the shear wall and column members, which is undesired. A detailed creep investigation is necessary for examining the non-linear creep effects, but it is beyond the scope of this thesis. Therefore, to minimize these effects, an increase to the column dimensions from 0.9*0.9 m^2 to 1.5*1.5 ^{2} is applied.

3.4.2. Design for Wind Loading

H= 260.7 m

Steps to Determine MWFRS Wind Loads for
Enclosed and Open Buildings of All Heights according to ASCE 7-10

Step 1: Determine risk category of building see Table 1.4-1

Risk Category	**III**

Step 2: Determine the basic wind speed, V, for the applicable risk category, see Figure 26.5-1B

V=	**58**	**m/s**

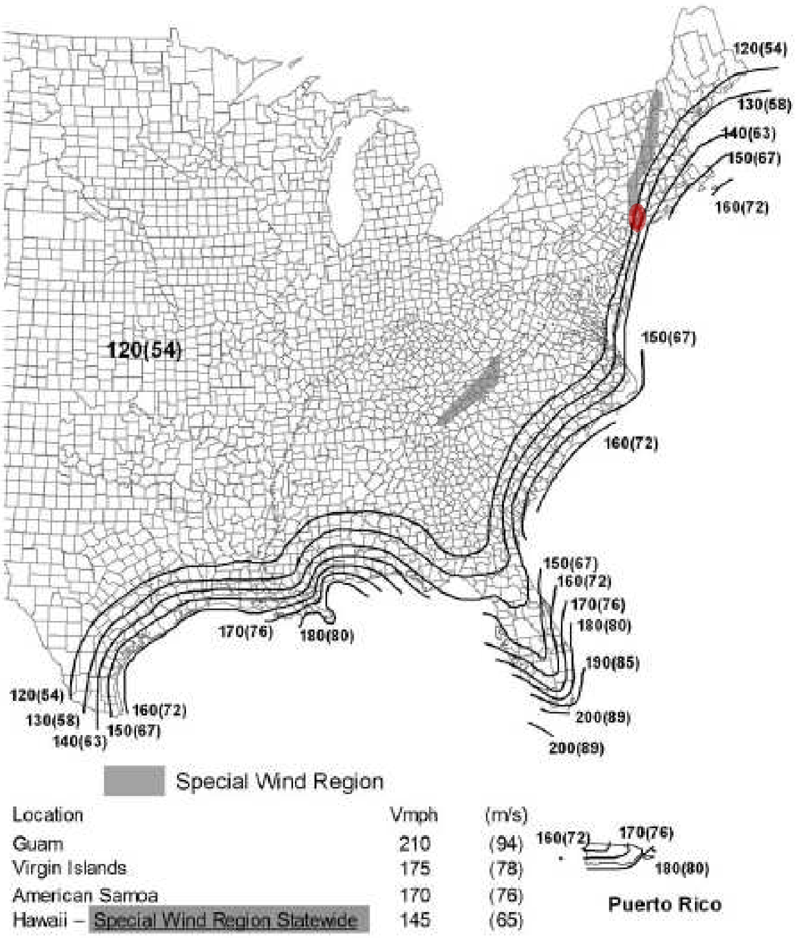


Figure 26.5-1B *(Continued)*

Figure 26.5-1B Basic Wind Speeds for Occupancy Category III and IV Buildings and Other Structures.
Notes:
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1700 Years).

Step 3: Determine wind load parameters:

➢ Wind directionality factor, K_d , see Section 26.6 and Table 26.6-1

K_d=	**0.85**

Structure Type	Directionality Factor K_d*
Buildings **Main Wind Force Resisting System** **Components and Cladding**	 0.85 0.85

➢ Exposure category, see Section 26.7 **B**

For buildings with a mean roof height greater than 30 ft (9.1 m), Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 2,600 ft (792 m) or 20 times the height of the building, whichever is greater.

Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

➢ Topographic factor, Kzt, see Section 26.8 and Table 26.8-1

K_{zt} =	**1**

➢ Gust Effect Factor, G, see Section 26.9 **0.85**

➢ Enclosure classification, see Section 26.10 **enclosed**

➢ Internal pressure coefficient, (GC_{pi}), see Section 26.11 and Table 26.11-1

0.18
-0.18

Step 4: Determine velocity pressure exposure coefficient, K_z or K_h, see Table 27.3-1

For 15 ft. $\leq z \leq z_g$

$$K_z = 2.01\,(z/z_g)^{2/\alpha}$$

For z < 15 ft.

$$K_z = 2.01\,(15/z_g)^{2/\alpha}$$

In metric

Exposure	α	z_g (m)	$\hat{a}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	ℓ (m)	$\bar{\epsilon}$	z_{min} (m)*
B	7.0	365.76	1/7	0.84	1/4.0	0.45	0.30	97.54	1/3.0	9.14

K_h=	**1.824653**

Step 5: Determine velocity pressure q_z or q_h Eq. 27.3-1

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

[In SI: $q_z = 0.613K_zK_{zt}K_dV^2$ (N/m2); V in m/s]

q_h=	**3198.274** N/m^2

K_d = wind directionality factor, see Section 26.6

K_z = velocity pressure exposure coefficient, see Section 27.3.1

K_{zt} = topographic factor defined, see Section 26.8.2

V = basic wind speed, see Section 26.5

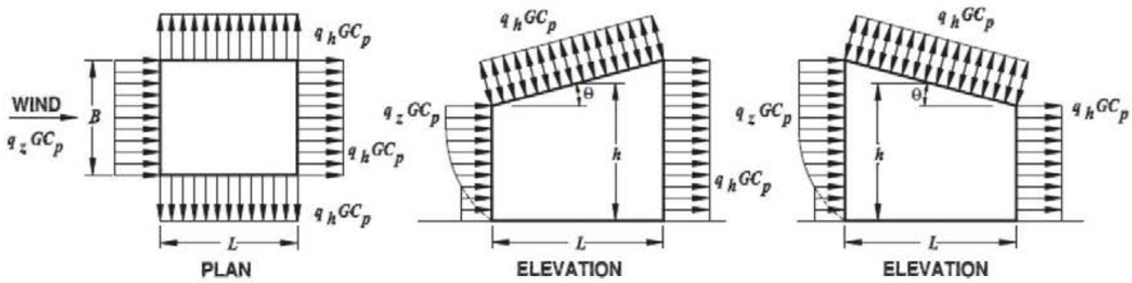
q_z = velocity pressure calculated using Eq. 27.3-1 at height z

q_h = velocity pressure calculated using Eq. 27.3-1 at mean roof height h.

Step 6: Determine external pressure coefficient, C_p or C_N

➢ Fig. 27.4-1 for walls and flat roofs

fig. 113: External Pressure Coefficient



MONOSLOPE ROOF (NOTE 4)

Wall Pressure Coefficients, C_p			
Surface	**L/B**	**C_p**	**Use With**
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥4	-0.2	
Side Wall	All values	-0.7	q_h

Roof Pressure Coefficients, C_p, for use with q_h

Wind Direction	Windward									Leeward		
	Angle, θ (degrees)									Angle, θ (degrees)		
	h/L	10	15	20	25	30	35	45	≥60#	10	15	≥20

Wind Direction	h/L	Horiz distance from windward edge	C_p		
Normal to ridge for θ < 10 and Parallel to ridge for all θ	≤ 0.5	0 to h/2	-0.9, -0.18	*Value is provided for interpolation purposes. **Value can be reduced linearly with area over which it is applicable as follows	
		h/2 to h	-0.9, -0.18		
		h to 2 h	-0.5, -0.18		
		> 2h	-0.3, -0.18		
	≥ 1.0	0 to h/2	-1.3**, -0.18	**Area (sq ft)**	**Reduction Factor**
				≤ 100 (9.3 sq m)	1.0
		> h/2	-0.7, -0.18	250 (23.2 sq m)	0.9
				≥ 1000 (92.9 sq m)	0.8

Notes:

1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.

2. Linear interpolation is permitted for values of L/B, h/L and θ other than shown. Interpolation shall only be carried out between values of the same sign. Where no value of the same sign is given, assume 0.0 for interpolation purposes.

3. Where two values of Cp are listed, this indicates that the windward roof slope is subjected to either positive or negative pressures and the roof structure shall be designed for both conditions. Interpolation for intermediate ratios of h/L in this case, shall only be carried out between Cp values of like sign.

4. For monoslope roofs, entire roof surface is either a windward or leeward surface.

5. For flexible buildings use appropriate Gf as determined by Section 26.9.4.

6. Notation:

B: Horizontal dimension of building, in feet (meter), measured normal to wind direction.

L: Horizontal dimension of building, in feet (meter), measured parallel to wind direction.

h: Mean roof height in feet (meters), except that eave height shall be used for θ ≤ 10 degrees.

z: Height above ground, in feet (meters).

G: Gust effect factor.

qz,qh: Velocity pressure, in pounds per square foot (N/m2), evaluated at respective height.

θ: Angle of plane of roof from horizontal, in degrees.

Step 7: Calculate wind pressure, p, on each building surface

➢ Eq. 27.4-2 for flexible buildings

$p = qG_fC_p - q_i(GC_{pi})$ (lb/ft2) (N/m^2)

$q = q_z$ for windward walls evaluated at height z above the ground

$q = q_h$ for leeward walls, side walls, and roofs, evaluated at height h

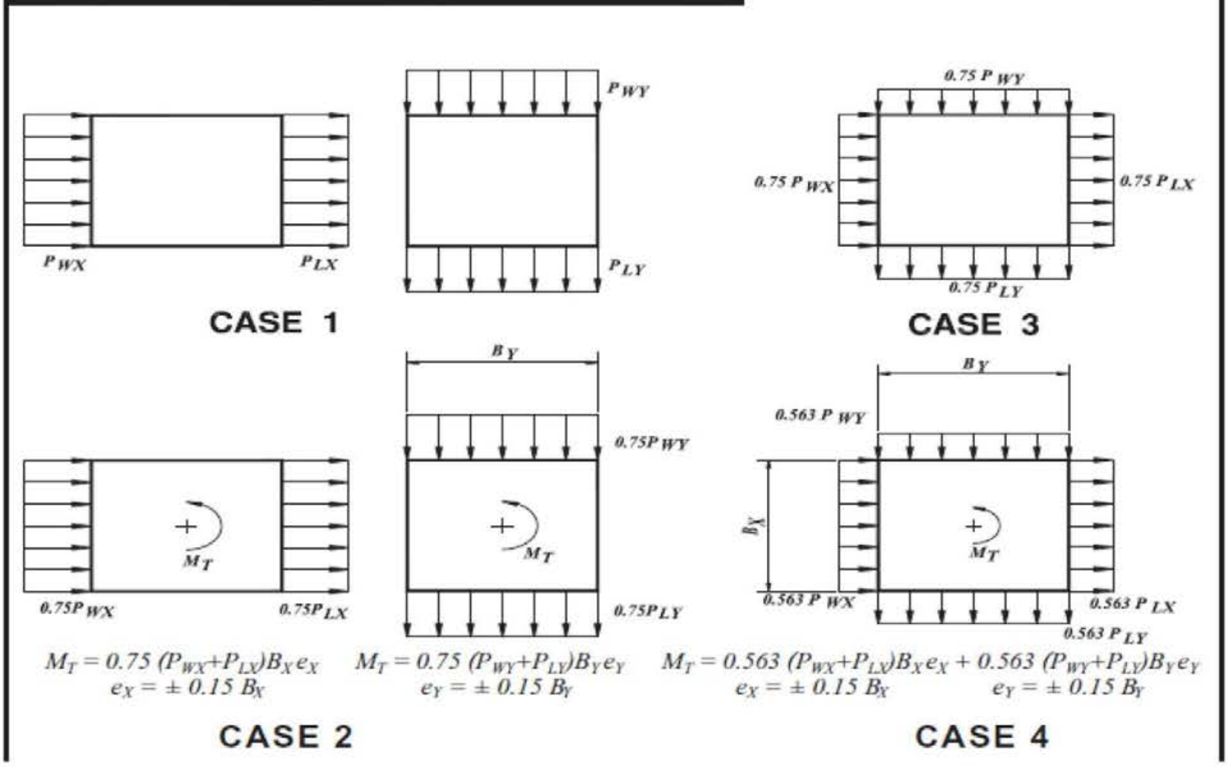
G = gust-effect factor, see Section 26.9

C_p = external pressure coefficient from Figs.27.4-1, 27.4-2 and 27.4-3

(GC_{pi}) = internal pressure coefficient from Table 26.11-1

q and q_i shall be evaluated using exposure defined in Section 26.7.3. Pressure shall be applied simultaneously on windward and leeward walls and on roof surfaces as defined in Figs. 27.4-1, 27.4-2 and 27.4-3.

Main Wind Force Resisting System – Part 1		All Heights
Figure 27.4-8	Design Wind Load Cases	



Case 1. Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.

Case 2. Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.

Case 3. Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.

Case 4. Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.

Notes:

1. Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of 27.4.1 and 27.4.2 as applicable for building of all heights.

2. Diagrams show plan views of building.

3. Notation:

PWX, PWY : Windward face design pressure acting in the x, y principal axis, respectively.

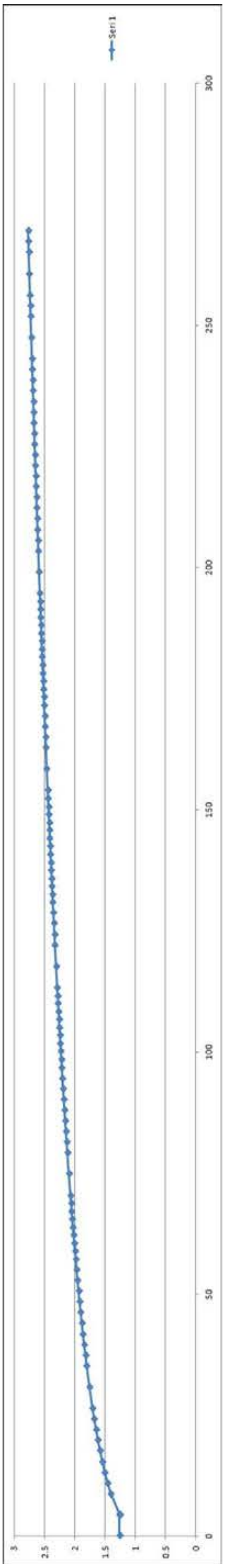
PLX, PLY : Leeward face design pressure acting in the x, y principal axis, respectively.

e (eX. eY) : Eccentricity for the x, y principal axis of the structure, respectively.

MT : Torsional moment per unit height acting about a vertical axis of the building.

i.e: In the structural model, the automatic loading case wrt. ASCE 7-05 is used.

Wind Pressure Distribution



Wind Loads to Horizontal Diaphrams

Z	FX
m	KN
269.5	304.429
265.1	910.651
256.3	905.281
251.9	902.547
243.1	896.975
238.7	596.089
234.3	594.171
229.9	592.226
225.5	590.255
221.1	588.256
216.7	586.228
212.3	584.170
207.9	582.082
203.5	869.944
194.7	791.481
191.4	430.469
188.1	429.206
184.8	427.927
181.5	426.632
178.2	425.319
174.9	423.989
171.6	493.081
167.2	561.086
162.8	837.907
154	761.055
150.7	413.643
147.4	412.142
144.1	410.617
140.8	409.067
137.5	407.491
134.2	405.887
130.9	471.631
126.5	536.043
122.1	799.508
113.3	724.194
110	393.170
106.7	391.285
103.4	389.358
100.1	387.386
96.8	449.596
92.4	510.131
88	506.311
83.6	502.352
79.2	747.362
70.4	673.066
67.1	364.518
63.8	361.816
60.5	359.012
57.2	415.447
52.8	469.356
48.4	463.581
44	457.418
39.6	450.798
35.2	1109.074
17.6	1014.996
13.2	392.440
8.8	937.820

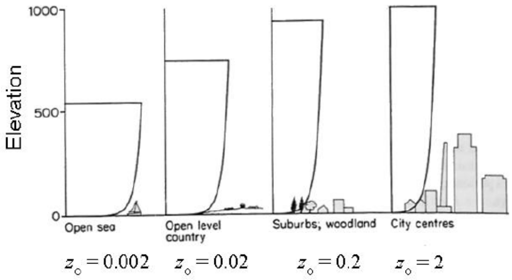


Fig. 115: Qualitative Wind Pressure Distribution according to different terrain.

In high rise structures, the effect of wind loading is a major conflict to be investigated. In most of the cases, the loading case is so severe that, the load effects go beyond the effects of an earthquake. For this purposes, a detailed investigation according to the ASCE 7-05, for the main structural elements, is provided in the general case.

For the other members, such as the façade elements, a detailed wind tunnel test should be accomplished for a more exact information about the wind loading. For the scope of this thesis, the members other than the main structural elements, are dimensioned with respect to existing structures in New York.

Table 10: Wind Pressure Distribution and Wind Loads calculated according to ASCE-7-10

3.4.3. Design for Seismic Loading

On the contrary to many other big cities in the world, New York is in a less critical situation against seismic loading, thanks to its rocky terrain and low seismic risk zone. Most of the time, the design loads are dominated by wind effects due to the cities high exposure to wind. Hence, usually the minimum requirements for the seismic design are evaluated. Nevertheless, an analysis for loading case should be evaluated, which is restricted by the building codes.

Soil Type:	B		h (m)	h^2	w_x=	$h*w_x$=	C_{VX}=	Fi (kN)	M (kNm)	h (m)	h^2	w_x=	$h*w_x$=	C_{VX}=	Fi (kN)	M (kNm)
S_s=	30% g		269.5	72630	6E+05	4E+10	0.059	1791	482655.7	134.2	18009.6	593575	1.1E+10	0.01472	444.09	59596.213
S_l=	7.3% g		265.1	70278	6E+05	4E+10	0.057	1733	459399.3	130.9	17134.8	593575	1E+10	0.01401	422.51	55306.994
S_{MS}=	0.3		256.3	65690	6E+05	4E+10	0.054	1620	415151.8	126.5	16002.3	593575	9.5E+09	0.01308	394.59	49915.186
S_{MI}=	0.0073		251.9	63454	6E+05	4E+10	0.052	1565	394135.6	122.1	14908.4	593575	8.8E+09	0.01219	367.61	44885.711
S_{DS}=	0.2		243.1	59098	6E+05	4E+10	0.048	1457	354255	113.3	12836.9	593575	7.6E+09	0.01049	316.53	35863.349
S_{DI}=	0.004866667		238.7	56978	6E+05	3E+10	0.047	1405	335365.5	110	12100	593575	7.2E+09	0.00989	298.36	32820.045
T_0=	0.004866667	s	234.3	54896	6E+05	3E+10	0.045	1354	317159.7	106.7	11384.9	593575	6.8E+09	0.00931	280.73	29953.969
T_S=	0.024333333	s	229.9	52854	6E+05	3E+10	0.043	1303	299625	103.4	10691.6	593575	6.3E+09	0.00874	263.63	27259.804
T_L=	6	s	225.5	50850	6E+05	3E+10	0.042	1254	282748.8	100.1	10020	593575	5.9E+09	0.00819	247.08	24732.234
T=	10.38		221.1	48885	6E+05	3E+10	0.04	1205	266518.5	96.8	9370.24	593575	5.6E+09	0.00766	231.05	22365.942
$T>T_L=>S_a$=	0.0292		216.7	46959	6E+05	3E+10	0.038	1158	250921.5	92.4	8537.76	593575	5.1E+09	0.00698	210.53	19452.572
I_S=	1.25		212.3	45071	6E+05	3E+10	0.037	1111	235945.2	88	7744	593575	4.6E+09	0.00633	190.95	16803.863
Seismic Design Category=		B	207.9	43222	6E+05	3E+10	0.035	1066	221577	83.6	6988.96	593575	4.1E+09	0.00571	172.34	14407.212
MCE_G PGA=	20% g		203.5	41412	6E+05	2E+10	0.034	1021	207804.2	79.2	6272.64	593575	3.7E+09	0.00513	154.67	12250.016
PGA=	1		194.7	37908	6E+05	2E+10	0.031	934.7	181994.8	70.4	4956.16	593575	2.9E+09	0.00405	122.21	8603.5779
C_{RS}=	0.87		191.4	36634	6E+05	2E+10	0.03	903.3	172896.8	67.1	4502.41	593575	2.7E+09	0.00368	111.02	7449.5266
C_{RI}=	0.9		188.1	35382	6E+05	2E+10	0.029	872.4	164107.1	63.8	4070.44	593575	2.4E+09	0.00333	100.37	6403.5846
For seismic design category B buildings Equivalent Lateral Force Analysis is permitted for all heights according to ASCE 7-10.			184.8	34151	6E+05	2E+10	0.028	842.1	155620.6	60.5	3660.25	593575	2.2E+09	0.00299	90.255	5460.435
			181.5	32942	6E+05	2E+10	0.027	812.3	147431.7	57.2	3271.84	593575	1.9E+09	0.00267	80.678	4614.7609
			178.2	31755	6E+05	2E+10	0.026	783	139535.3	52.8	2787.84	593575	1.7E+09	0.00228	68.743	3629.6344
R^a=	4.5		174.9	30590	6E+05	2E+10	0.025	754.3	131926	48.4	2342.56	593575	1.4E+09	0.00192	57.763	2795.7427
C_S=	0.055555556		171.6	29447	6E+05	2E+10	0.024	726.1	124598.5	44	1936	593575	1.1E+09	0.00158	47.738	2100.4829
C_S=	7.5281E-05		167.2	27956	6E+05	2E+10	0.023	689.3	115257.7	39.6	1568.16	593575	9.3E+08	0.00128	38.668	1531.252
C_S=	0.011	>0.01 ok	162.8	26504	6E+05	2E+10	0.022	653.5	106395.8	35.2	1239.04	593575	7.4E+08	0.00101	30.552	1075.4472
C_S=	0.010138889	OK	154	23716	6E+05	1E+10	0.019	584.8	90058.2	17.6	309.76	593575	1.8E+08	0.00025	7.6381	134.4309
C_U=	1.4		150.7	22710	6E+05	1E+10	0.019	560	84391.92	13.2	174.24	593575	1E+08	0.00014	4.2964	56.713038
C_t=	0.0488		147.4	21727	6E+05	1E+10	0.018	535.7	78968.44	8.8	77.44	593575	4.6E+07	6.3E-05	1.9095	16.803863
x=	0.75		144.1	20765	6E+05	1E+10	0.017	512	73782.45	Σ		2E+07	7.3E+11			6423158.3
k=	2		140.8	19825	6E+05	1E+10	0.016	488.8	68828.62							
V=	30161.7705	kN	137.5	18906	6E+05	1E+10	0.015	466.2	64101.65							

Table 11: Estimation for Design Earthquake Forces according to ASCE-7-10

As can be seen, neither the base shear force, nor the base moment values from earthquake loads do not exceed the amounts which can be seen from Table 21 Base reactions according to wind load cases. Hence, the design will be governed by wind load case.

3.4.4. Secondary Design

I) Columns

Before beginning to the design of the main lateral force resisting elements in the building, an investigation of the second order moments is necessary, since the effect of second order moments, due to story drifts in a skyscraper is unavoidable. Firstly, a second order analysis by Amplified First order Elastic Analysis is hereby provided, but later on a direct non-linear analysis including P-Delta effects is accomplished, and envelope values for the design of the members is applied.

Second - Order Analysis by Amplified First Order Elastic Analysis

	X-direction			Y-direction		
$M_r=B_1*M_{nt}+B_2*M_{lt}=$	$\Delta_H=$	0.0044	m	$\Delta_H=$	0.0104	m
	$L=$	8.8	m	$L=$	8.8	m
$P_r=P_{nt}+B_2*P_{lt}=$	$\sum H=$	32000	kN	$\sum H=$	43271	kN
	$\sum P_{e2}=$	54400000	kN	$\sum P_{e2}=$	31121835	kN
$B_1=C_m/(1-\alpha\sum P_r/P_{e1})\geq 1$	$P_{el}=$	584201.1	kN	$P_{el}=$	482369.9	kN
	$P_{nt}=$	48374.67	kN	$P_{nt}=$	48374.67	kN
$B_2=1/(1-\alpha\sum P_{nt}/P_{e2})\geq 1$	$\sum P_{nt}=$	1466683	kN	$\sum P_{nt}=$	1466683	kN
	$B_2=$	1.027708	>1 ok	$B_2=$	1.049458	>1 ok
$\alpha=1$ (LRFD)	$P_{lt}=$	12410.9	kN	$P_{lt}=$	12410.9	kN
$C_m=0.6-0.4*(M_1/M_2)$	$P_r=$	61129.46	kN	$P_r=$	61399.39	kN
or $C_m=1$ conservatively	$C_m=$	0.723413		$C_m=$	0.635761	
$P_{e1}=\pi^2*EI/(K_1*L)^2=$	$B_1=$	0.807955	<1 take 1	$B_1=$	0.728488	<1 take 1
$\sum P_{e2}=R_M*\sum HL/(\Delta_H)=$	$M_{nt}=$	57.1814	kNm	$M_{nt}=$	139.0189	kNm
$R_M=0.85$ for combined systems	$M_{lt}=$	3278.265	kNm	$M_{lt}=$	1511.144	kNm
$K_1=1$	$M_{rx}=$	3426.281	kNm	$M_{ry}=$	1724.901	kNm

Table 12: Second Order Analysis

The most critical design moments and forces, obtained according to a P-Δ Analysis by the Advanced Structural Analysis Program, evaluated according to the Code Requirements:

$P_r=$	-59608.478	kN	$M_{rx}=$	3570.392	kNm	$M_{ry}=$	1729.344	kNm

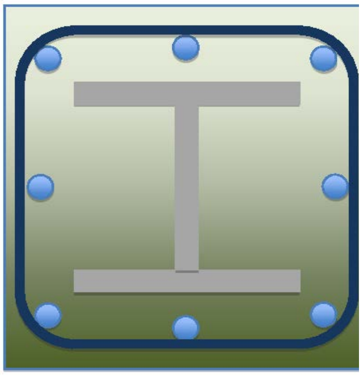
Table 13: Second Order Analysis Results on the most critical column from SAP Software.

The results are quite similar, hence design with respect to exact analysis results will be held.
Since the columns are identical, and the most critical cases are at the base level, a design for the most critical column will be made, and the same design will be valid for the other columns and along the rest of the building height, for simplicity purposes.

Design

P_r=	-59608.5	kN	M_{rx}=	3570.392	kNm	M_{ry}=	1729.344	kNm

A_{column}=	2250000	mm^2
$A_{min,steel\ core}$=	22500	mm^2
$\rho_{min,\ sr}$=	A_{sr}/A_g=	0.004
$A_{min,\ sr}$=	9000	mm^2
use 84 ϕ32,	A_{sr}=	39207.8 mm^2
$A_{min,\ sw}$=	6	mm^2 per mm



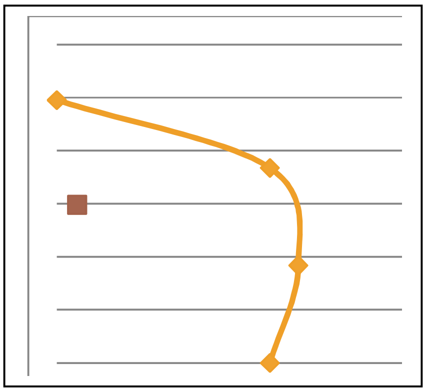


Fig. 116-117: Figurative composite Column section & Interaction Diagram according to plastic stress distribution.

1) Compressive Strength

ϕ_c=	0.75		
Steel section:		**HD 400*421**	
A_s=	53710	mm^2	
A_{sr}=	42223.01	mm^2	
A_c=	2154067	mm^2	
C_i=	0.15	<0.3 ok	
I_{sr}=	$A*h^2$=	7.98E+09	mm^4
I_c=	4.12E+11	mm^4	
$I_{s,x}$=	1.6E+09	mm^4	
$I_{s,y}$=	6.01E+08	mm^4	
E_c=	34323.94	MPa	
$EI_{eff,x}$=	3.22E+15	N/mm^2	
$EI_{eff,y}$=	3.02E+15	N/mm^2	
K=	1		
L=	8800	mm	
KL=	8800	mm	
P_e=	410506	kN	
P_o=	82323.37	kN	
36222.28	<	410506	
P_n=	360013.7	kN	
P_n=	75695.47	kN	

2) Flexural Strength

For the flexural strength evaluation of the columns, since the investigation of the composite columns require a detailed and complicated analysis, under the provisions of the code, the flexural capacity of only the steel profiles are designed to be sufficient for the necessary capacity needed. Furthermore, if necessary, the plastic capacity of the composite section can be investigated.

HD 400*421	KL (m)	M_{minor}	M_{major}	
f_y 235	9	7921	9917	kNm
f_y 355	9	9953	13978	kNm
M_r=	8.8	3570.392	1729.344	kNm **OK**

P_r/P_c=	0.787477434	> 0.2			
Check;	$P_r/P_c+8/9(M_{rx}/M_{cx}+M_{ry}/M_{cy})\leq 1$				
	1.22	>1			
→	check plastic section capacity of the whole composite section				
Pr=	59608.48	kN			
P_A=	99049.70	kN	M_A=	0.00	kNm
P_C=	73507.54	kN	M_C=	18236.20	kNm
P_D=	36753.77	kN	M_D=	20667.54	kNm
P_B=	0.00	kN	M_B=	18236.20	kNm

Table 14: Design for Composite Column Section for Axial Load & Bi-Axial Bending according to AISC.

Shear Strength

Where an entire composite member is assumed to resist vertical shear, design shall be in accordance with requirements of Chapter 11 'Shear strength' as for a monolithically cast member of the same cross-sectional shape according to ACI-318 reqirements.

Analysis Results (kN):		
V_x=	-319.63	309.682
V_y=	-235.14	144.52

Table 15: Second Order Analysis Results on the most critical column from SAP Program.

Shear contribution of the steel section:	Detailing Requirements:
h/t_w= 8.84< 53.16781829	16mm≥ϕ_{sw}≥10mm
$V_n=0.6*F_y*A_w*C_v$	s< 25.6 cm
ϕ_v=1	s< 38.4 cm
$V_{n,major}$= 2024.66 kN	s< 37.5 cm
$V_{n,minor}$= 4582.35 kN	$A_{v,min} = 0.062\sqrt{f_c'}\frac{b_w s}{f_{yt}}$ > $(0.35 b_w s)/f_{yt}$.
The shear capacity of the steel section alone is already sufficient for the required strength, hence, minimum amount of web reinforcement will be used in the design.	s= 0.183466268 m 0.000402124 > 0.000271 ok

Table 16: Design for Composite Column Section for Shear according to AISC.

Take ϕ16 mm every 7.5 cm in column-beam connection zones.
Take ϕ16 mm every 15 cm along the column height.

An example composite column cross section is provided, for the detailed composite column sections of The Greenwich tower, please refer to details.

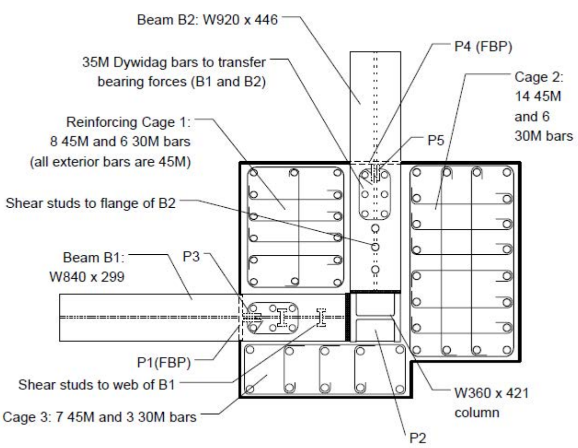


Fig. 116: Composite Column Section Example from Norwest Center in Minneapolis

II) Shear Walls

Direction	Name	#	t_w (m)	l_w (m)	H_w/l_w	Edge length(m) $h<h_{crit}$ ($0.2l_w$ or $2b_w$)	Edge length(m) $h>h_{crit}$ ($0.1l_w$ or b_w)
X- DIR.	SW1-2	2	0.3	6.4	40.734375	1.28	0.64
X- DIR.	SW3-4	2	0.3	3.6	72.41666667	0.72	0.36
X- DIR.	SW5	1	0.3	6.4	40.734375	1.28	0.64
Y- DIR.	SW6-12	6	0.3	11.85	22	2.37	1.185

		body ρ_{min} (25 cm spacing) (mm^2)		edge ρ_{min} (mm^2)		body # of $\phi 14$		edge # of $\phi 32$	
Direction	Name	$h<h_{crit}$	$h>h_{crit}$	$h<h_{crit}$	$h>h_{crit}$	$h<h_{crit}$	$h>h_{crit}$	$h<h_{crit}$	$h>h_{crit}$
X- DIR.	SW1-2	3840	4320	16384	8192	24.94510128	28.06323895	20.3718	10.186
X- DIR.	SW3-4	2160	2430	5184	2592	14.03161947	15.78557191	6.44578	3.2229
X- DIR.	SW5	3840	4320	16384	8192	24.94510128	28.06323895	20.3718	10.186
Y- DIR.	SW6-12	7110	7998.75	56169	28084.5	46.1874141	51.96084086	69.8404	34.92

$H_{critical}=H_w/6=$ 43.45 m

Design for Axial Load and Bending:

For the design, the minimum amount of longitudinal reinforcement specified in the AISC 318 is applied, and check with an interaction diagram, if the minimum requirements supply enough capacity for the most critical analysis Axial Load and Moment values.

Analysis Results for SW6-12:

$M_y=$	70772.6	kNm
P=	2351	kN

Reinforcement Applied:

Edges: 144ϕ32 with 5cm cover and 10 cm spacing

Body 138ϕ16 with 5cm cover and 15 cm spacing

Note: The amount of reinforcement may be decreased after $h_{critical}$ to 70ϕ32 and 52ϕ16 respectively for saving purposes.

Design for Shear:

$V_y=V_u=$	4034.5	kN
$\phi V_n \geq V_u$		
$\phi V_n=$	4482.777778	kN
$V_n=V_c+V_s$		
d=	9.48	m
$V_c=$	21.30429185	
$V_c=$	11361.57504	
$V_c<0.17\lambda\sqrt{f_c'}*h*d=$		118.66 OK
$V_s=$	4461.473486	kN>$0.5\phi V_c$
$V_s=A_v*f_{yd}/s$ --> ϕ16 tie bars		
s=	0.015998523	m

take s= 7.5 cm at connection zones.

take s= 15 cm at clear length.

Table 17-18: Design for Shear Wall Section according to ACI.

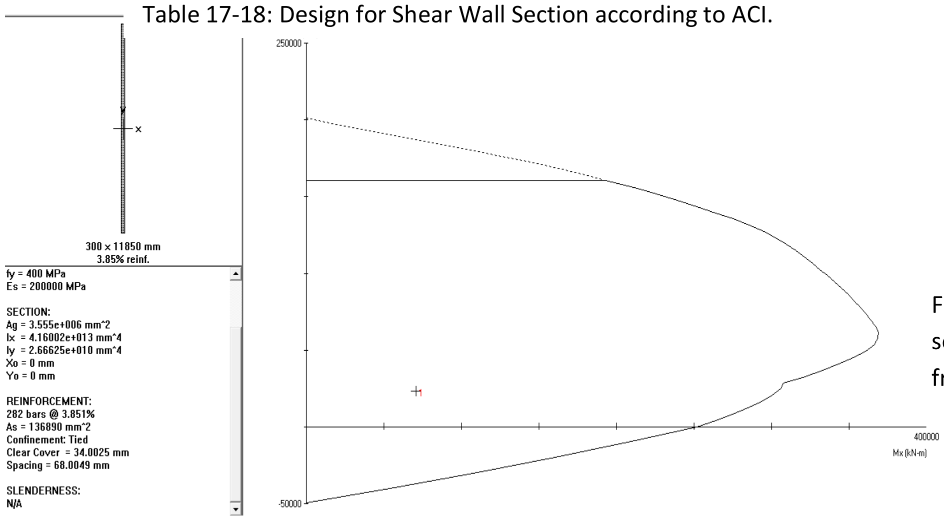


Fig. 117: Interaction Diagram of the shear wall section SW6 under Axial Load and bending from PCA-column Software.

III) Connections

The connection design between the structural elements, is the most critical design step in the structural design, for all kinds of buildings. The failure modes under extreme loading mostly are due to the missing or insufficient amount of detailing elements in the connections. This fact is due to the unpredictable nature of the connections under extreme cases and the amount of excessive load transfer that runs through a relatively small area.
In the case of the Greenwich Tower, which is a high-rise, the amount of the load transfer between the beams and vertical elements are evidentially, relatively high. The amounts of design loads for connections, are taken from the most severe case of P-Delta analysis of the lateral loading (Wind Loading). The connections of the beam elements other than B05, B15 and B25 to the composite column sections are designed to carry the moment and shear transfer between the elements between the steel profiles. The diagonal beams B05, B15 and B25 are designed to be cast in place anchored to the composite columns through bearing plates on the surface of the column. This approach is due to the lack of space on the steel profile of the column.
Example drawings for a moment shear transfer connection between steel profiles, and the nature of the connection of composite column - steel beam elements are provided hereby. An example estimation of the connection elements for the Greenwich Tower is also shown. For the final detailing, please refer to general details.

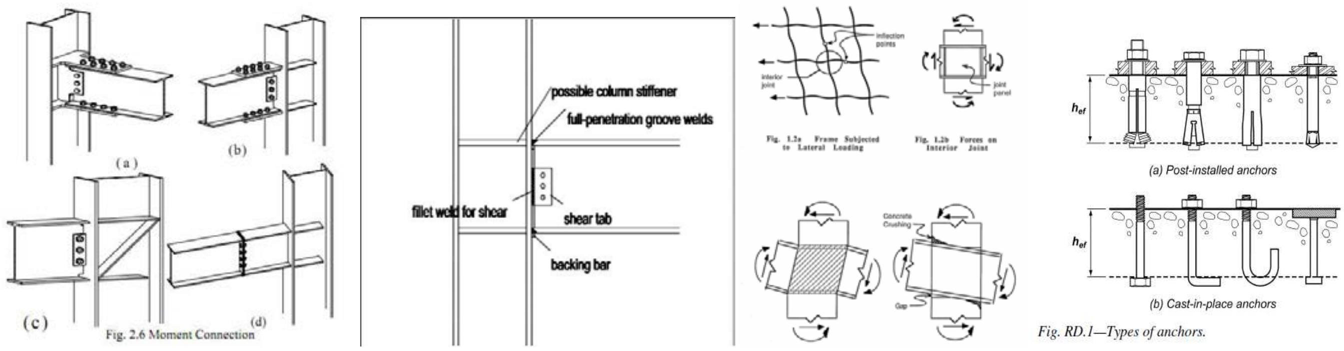


Fig. 118-121: Different Moment Transfer Connection Details& Composite Column connection zone nature & Anchorage elements

B01-C1					**B03-C1**				
t_w=	13.5		mm		t_w=	14		mm	
k=t_f=	24		mm		k=t_f=	26		mm	
N=	200		mm		N=	200		mm	
i)web crippling					*i)web crippling*				
N/d=	0.5				N/d=	0.444444			
ΦR_n=	1080.725		kN		ΦR_n=	1096.122		kN	
ii)local web yield					*ii)local web yield*				
ΦR_n=	1246.05		kN		ΦR_n=	1317.05		kN	
P=	5960.848		kN		P=	5960.848		kN	
stiffener required					***stiffener required***				
P=	4880.123		kN		P=	4864.726		kN	
$w+t_w/2>N/3$		w>	59.9167	mm	$w+t_w/2>N/3$		w>	59.66667	mm
$t_s>t_f/2$		t_s>	12	mm	$t_s>t_f/2$		t_s>	13	mm
$t_s>b_f/15$		t_s>	20	mm	$t_s>b_f/15$		t_s>	30	mm
use 140mm*50mm stiffeners					use 140mm*50mm stiffeners				
check:					check:				
13746.8253		<	14000	**OK**	13703.45257		<	14000	**OK**

B05-C1 anchored		
t_w=	21.0	mm
$k=t_f$=	40.0	mm
h	524	mm
b	306	mm
V_{max}=	498.143	kN
Required strength of bent plate A:		
ΦR_n=	245.492281	kN
Required strength of bent plate B:		
ΦR_n=	252.650719	kN
Assume that the welds across the top and bottom of the plates will be 12 cm. long, and that the load acts at the intersection of the beam centerline and the support face. While the welds do not coincide on opposite faces of the beam web and the weld groups are offset, the locations of the weld groups will be averaged and considered identical.		
Design welds		
Assume plate length of 30 cm		
assume 10 mm full penetration groove weld		
L=	136.918299	mm < 200 mm ok
Design bolts		
try 3*2 rows of M22 A490 bolt/ anchorage		
Check shear on bolts		
ΦR_n=	564.3	kN ok
Check bearing on support		
ΦR_n=	667.223	kN ok
Design bent plates		Use 20mm plate
Check bearing on plates		
BOLT 1-2	.@ 50mm	
L_c=	39	<44 mm
ΦR_n=	505.44	kN
BOLT 3-4	.@ 150mm	
L_c>44mm		
ΦR_n=	598.752	kN
BOLT 5-6	.@ 250mm	
ΦR_n=	598.752	kN
$\sum\Phi R_n$=	1702.944	kN ok
Check shear yielding of plates		
ΦR_n=	1296	kN ok
Check shear rupture of the plates		
ΦR_n=	738.72	kN ok
Check block shear rupture of the plate		
ΦR_n=	660.96	kN ok

B01-B03 & B01-C1 & B03-C1			
HEB 450			
t_w=	32.8	mm	
t_f=	52.6	mm	
V_{max}=	265.052	kN	
Assume M20 A490 bolt			
# of bolts required=		$V/\phi_b*m*A_b*F_u*0.4$	
=	3.410564		
use 2*2 = 4 M20 bolts			
Check plate bearing resistance at bolt holes			
Use 20mm plate			
Plate bearing =			
BOLT 1-2	.@ 60mm		
L_c=	49	>40 mm	
ΦR_n=	400.95	kN OK	
BOLT 3-4	.@ 140mm		
L_c>40mm			
ΦR_n=	349.92	kN OK	
Beam Web bearing =			
BOLT 5-6	.@ 140mm		
L_c=	49	>40 mm	
ΦR_n=	349.92	kN	
$\sum\Phi R_n$=	699.84	kN OK	
Welding Length			
t_{min}=8mm	L=	113.3246	mm
L_{min}=114+2*8mm	130	mm ok	
t=10 mm groove weld			
Column Stiffener:			
M_{max}=	725	kNm	
V_u=	1824.358	kN	
Assume panel zone remains in the elastic range:			
P_y=	19067.05	kN	
P_u=	5960.848	kN	
P_u/P_y=	0.312626	<0.4	
ΦR_v=	2672.298	kN ok	
For local flange bending:			
ΦR_n=	5003.326	kN ok	
For Local web yielding:			
ΦR_n=	2393.58	kN ok	
No stiffener needed.			
The detailing of the elements can be found in the plans and details section.			

Table 19: Design for Connection elements & sections according to AISC Design Guide 13.

3.5. Foundation Design

The foundation of a structure is one of the most critical and element in the design process. In fact, in reality, specialized geotechnical design firms accomplish the foundation design of the high rise buildings. Hence, this process is yet unavoidable and to be provided without doubt, a detailed analysis is beyond the scope of this thesis. We hereby have done a rough estimation for the dimensioning of the elements though, the geotechnical contribution is considered to be minimal.

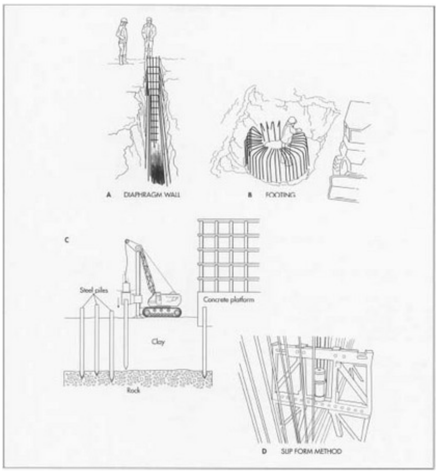


Fig.122 :Foundation Design Elements and construction steps.

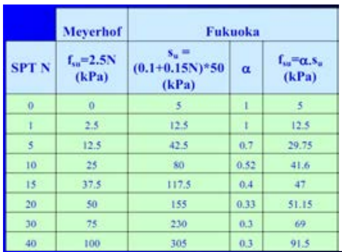
A. Diaphragm wall. B. Footing. C. One type of foundation for a skyscraper uses steel piles to secure the foundation to the ground. D. The slip form method of pouring concrete.

For the design purposes, pile foundation system is chosen. Although New York has a rocky-soil underground geo-system which makes possible to design even skyscraper foundations without pile systems, because of excessive overturning moments due to wind, closeness to the sea and for technological purposes (geo-thermical heat pumps) piles are preferred.

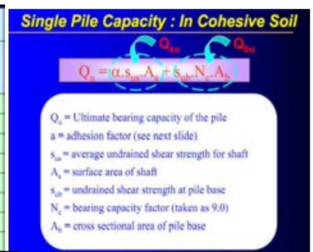
Table-20: General Information about pile foundations

Allowable Pile Capacity is the minimum of : 1) Allowable Structural Capacity 2) Allowable Geotechnical Capacity a. Negative Skin Friction b. Settlement Control
Structural Capacity: Concrete Pile $Q_{all}=0.25*f_{cu}*A_c$ R.C. Square Piles i)Size : 150mm to 400mm ii)Lengths : 3m, 6m, 9m and 12m iii)Structural Capacity : 25Ton to 185Ton iv)Material : Grade 40MPa Concrete v)Joints: Welded vi)Installation Method : –Drop Hammer –Jack-In
Geotechnical Capacity: Global Factor of Safety for Ultimate Capacity= -use 2 (typical) -Qall=(Qsu+Qbu)/2

Fig.123-124-125-126: Basic knowledge about soil estimations from www.gnpgeo.com.my



	Meyerhof	Fukuoka		
SPT N	f_{su}=2.5N (kPa)	s_u = (0.1+0.15N)*50 (kPa)	α	f_{su}=α.s_u (kPa)
0	0	5	1	5
1	2.5	12.5	1	12.5
5	12.5	42.5	0.7	29.75
10	25	80	0.52	41.6
15	37.5	117.5	0.4	47
20	50	155	0.33	51.15
30	75	230	0.3	69
40	100	305	0.3	91.5



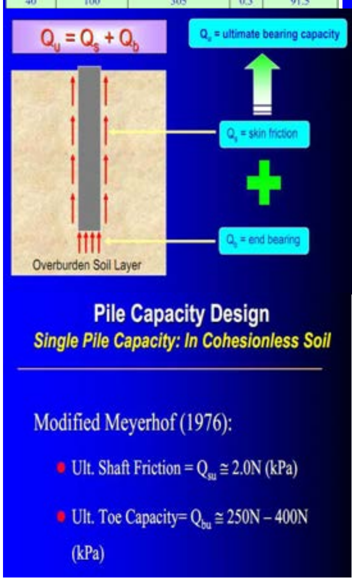


TABLE: Base Reactions								
OutputCase	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
pdelta envelope	Combination	Max	32263.267	33171.9	1337270	31836513	-3.1E+07	1206377
pdelta envelope	Combination	Min	-32263.267	-33172	1336697	17193528	-3.7E+07	-1041583

STRUCTURAL CAPACITY

Assume, 500 mm diameter, round concrete piles.

Assume L=20 m

# of piles $_{total}$=	24.6442399	take 30 piles.	
Area of Structure=	1653.21	m^2	
minimum footing depth=	30	mm	
minimum spacing=	1.25	m	
qs = U/Af,	5.631451926	Mpa	
$\rho_{s, min}$= 0.0025	A_s=	490.87	mm^2
use 5ϕ20 A=	1570.796327	OK	
$s_{sw, min}$= 15 mm	use ϕ14 mm s=15 mm		
$\phi_{sw, min}$= 9 mm			
min. reinforced length=	3m		
V_c=	83754.4071	kN ok	
M_r=	6185084.06	kNm ok	

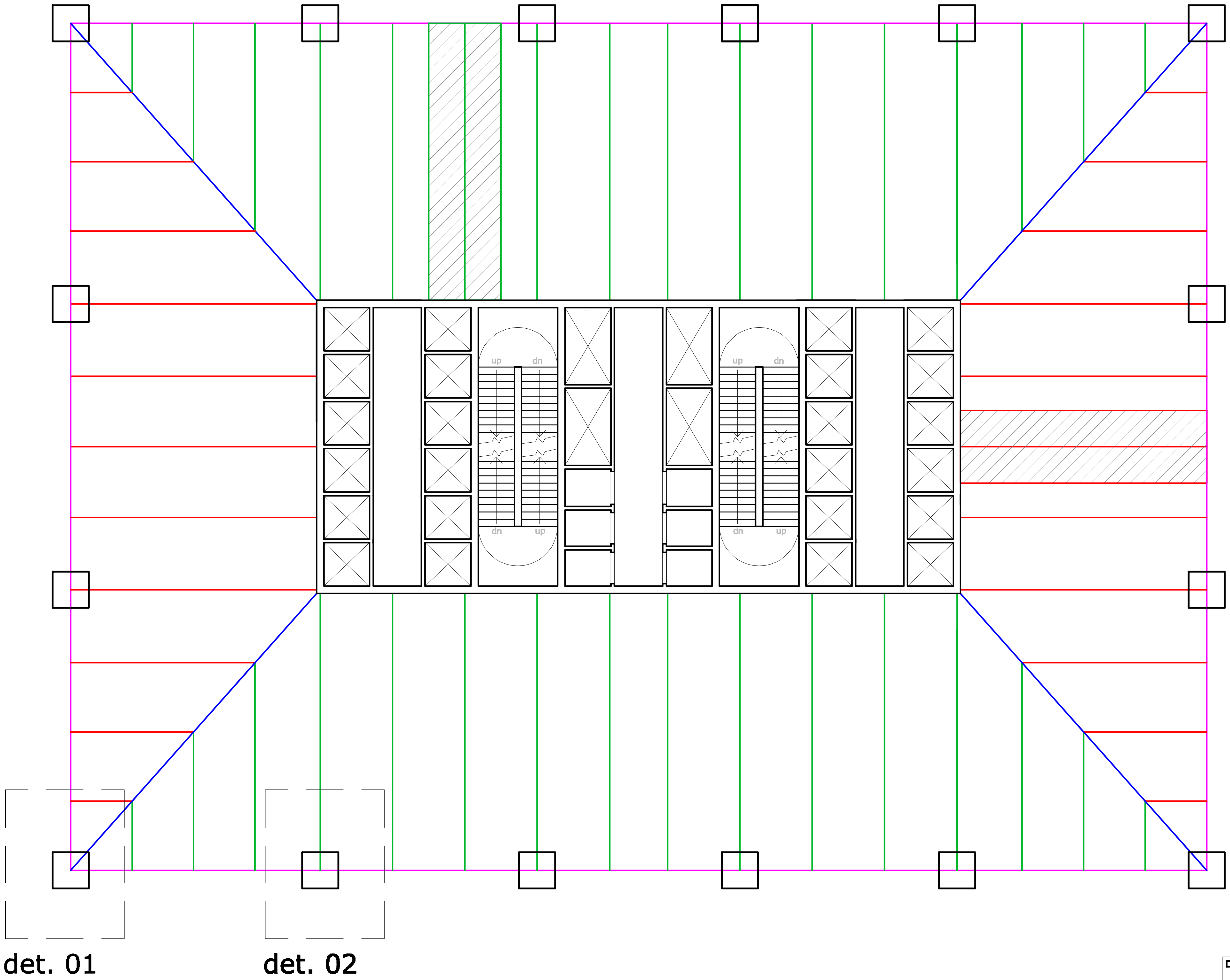
GEOTECHNICAL CAPACITY

Assume; N=20 for NYC.

Assume cohesionless soil

s_u=	170		
α=	0.3		
f_{su}=	51	kPa	
Q_{su}=	1602.212	KN	
Q_{bu}=	66758.84	KN	
Q_{all}=	47852.74	kN (single pile)	
$Q_{all, total}$=	1435582	kN	OK

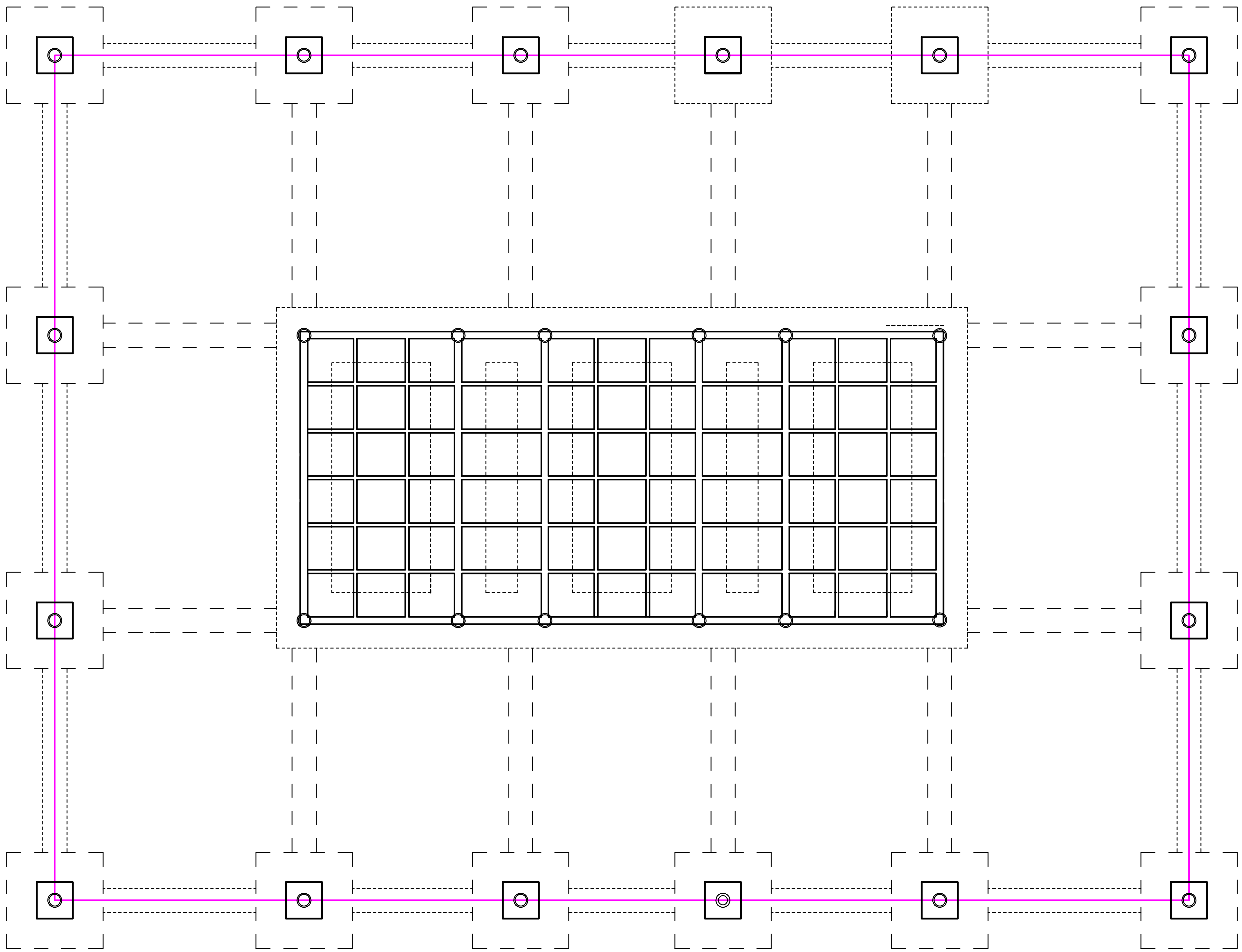
Table 21: A general estimation of pile foundation with minimum requirements from ACI-318.



Double Floor Slabs	Office Floor Slabs	Housing Floor Slabs
Section name	Section name	Section name
HEB 400	HEM 300	HEM 300
HEB 360	HEB 300	HEM 300
HEB 450	HEM 340	HEM 320
HEM 500	HEM 360	HEM 320

S001

structural plan
1/200

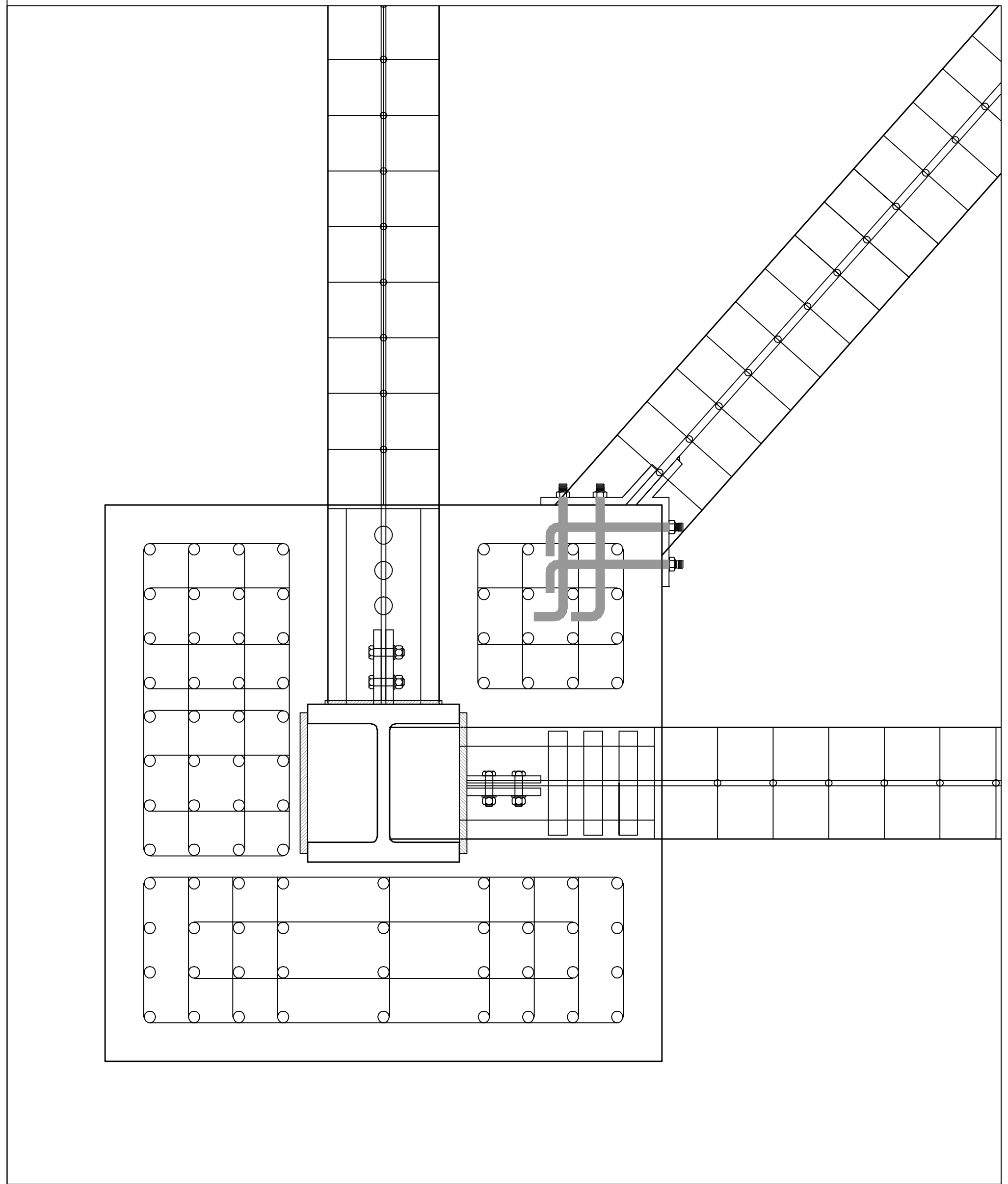


S002

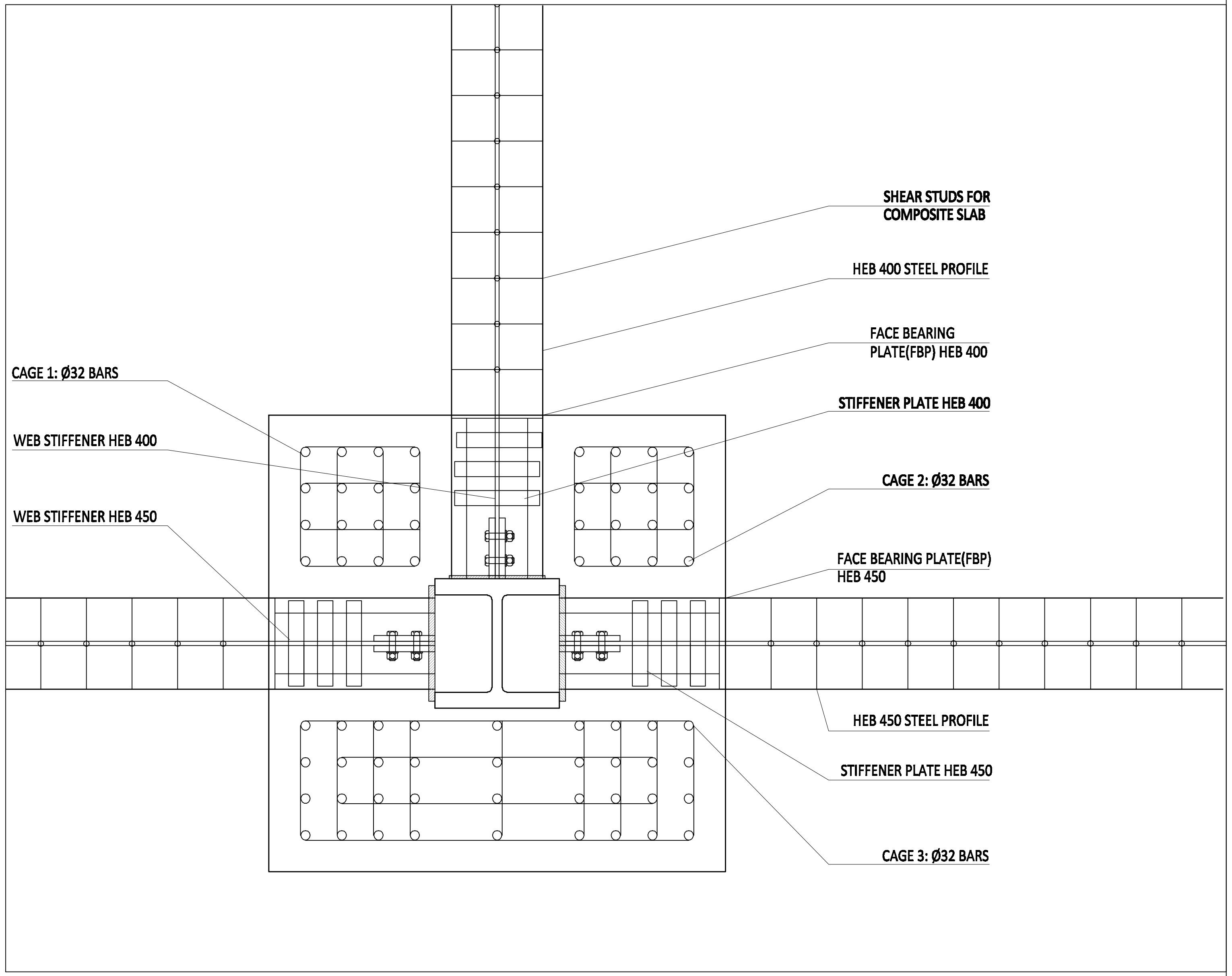
foundation plan

1/200

DETAIL 01



DETAIL 02



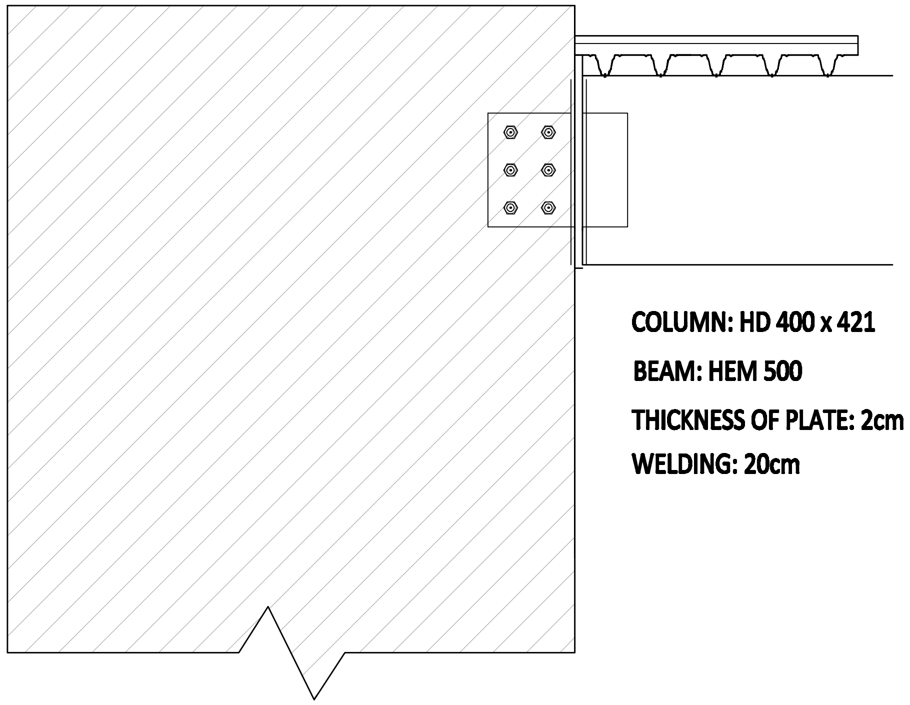
S003

GREENWICH TOWER

structural details
1/20

POLITECNICO MILANO

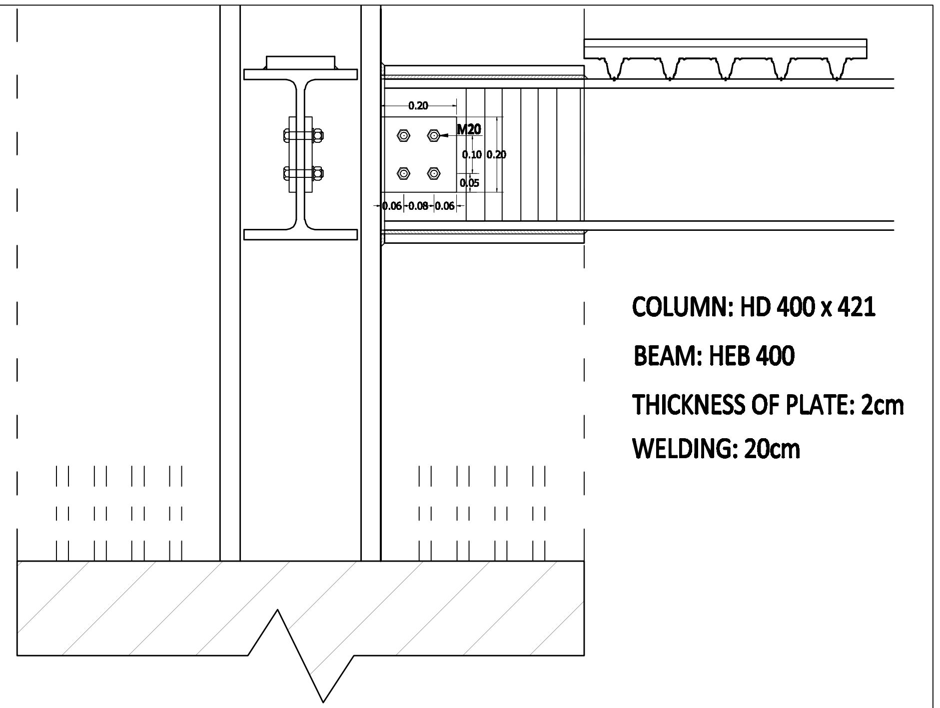
BEAM TO COMPOSITE COLUMN CONNECTION



MATERIALS:

CONCRETE : C40 for composite slabs
STRUCTURAL STEEL : ST 52 for beams and columns
: ST 52 for connections
BOLTS : A490 M22

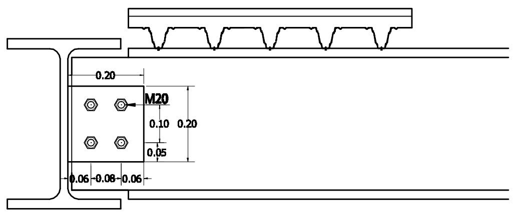
BEAM TO COMPOSITE COLUMN CONNECTION



MATERIALS:

CONCRETE : C40 for composite slabs
STRUCTURAL STEEL : ST 52 for beams and columns
: ST 52 for connections
BOLTS : A490 M20

BEAM TO BEAM CONNECTION

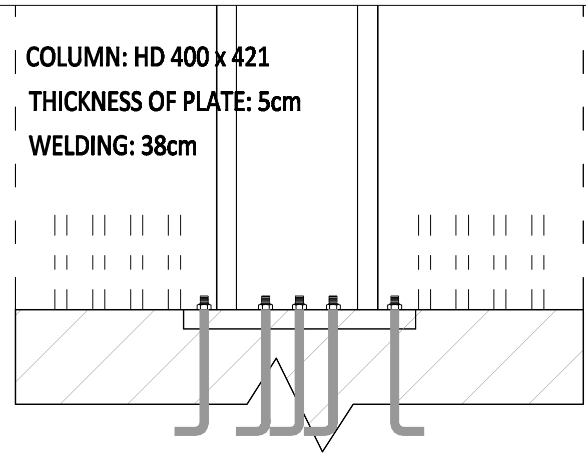


BEAMS: HEB 450 and HEB 400
THICKNESS OF PLATE: 2cm
WELDING: 20cm

MATERIALS:

CONCRETE : C40 for composite slabs
STRUCTURAL STEEL : ST 52 for beams and columns
: ST 52 for connections
BOLTS : A490 M20

COLUMN TO FOUNDATION CONNECTION



MATERIALS:

CONCRETE : C40 for composite slabs
STRUCTURAL STEEL : ST 52 for beams and columns
: ST 52 for connections
BOLTS : H 8.8 and galvanized

S004

GREENWICH TOWER

structural details
1/20

POLITECNICO MILANO

3.6. Structural Model

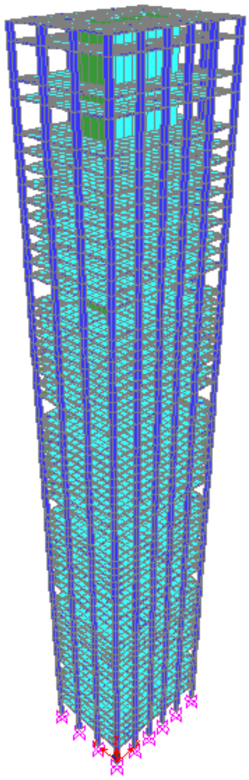


Fig. 127: Building Model

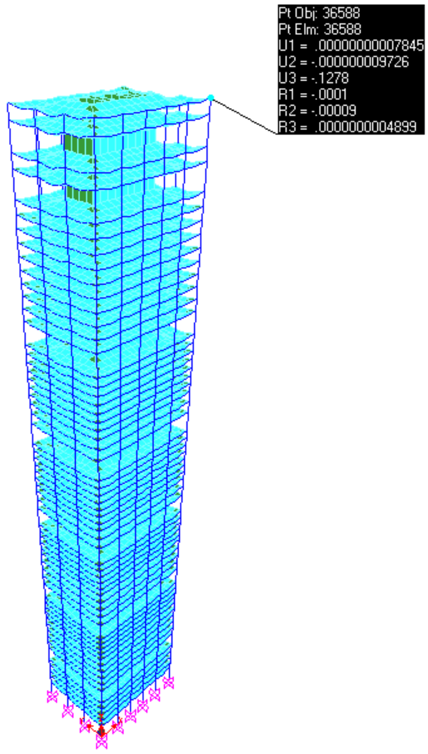


Fig. 128: Deformed Shape under Linear Analysis of Combination: 1.2D+1.6L

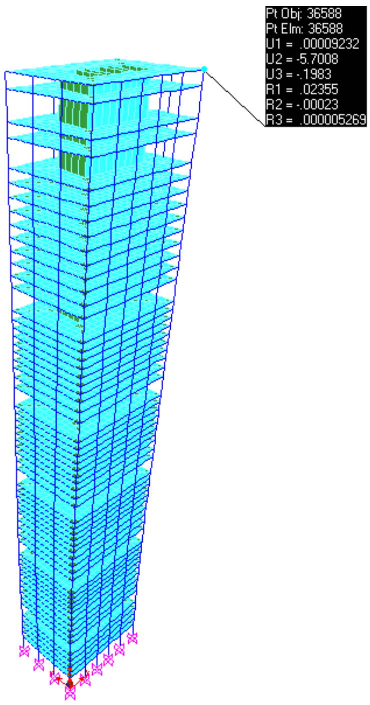


Fig. 129: Deformed Shape under Non-Linear Analysis of Combination: 1.2D+1L+1.6W_y

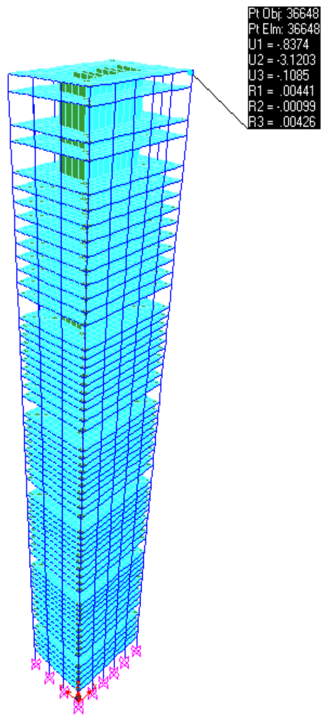


Fig. 130: Deformed Shape under Non-Linear Analysis of Combination: 0.9D-1.6(0.15e)W_y

3.7. Summary

The construction of a structural system composed of both steel and reinforced concrete elements, plus a skyscraper is with no doubt requires a well planned site management and quality workmanship. A simplified programming of the construction sequence for the structural members can be seen from the Fig. 131.

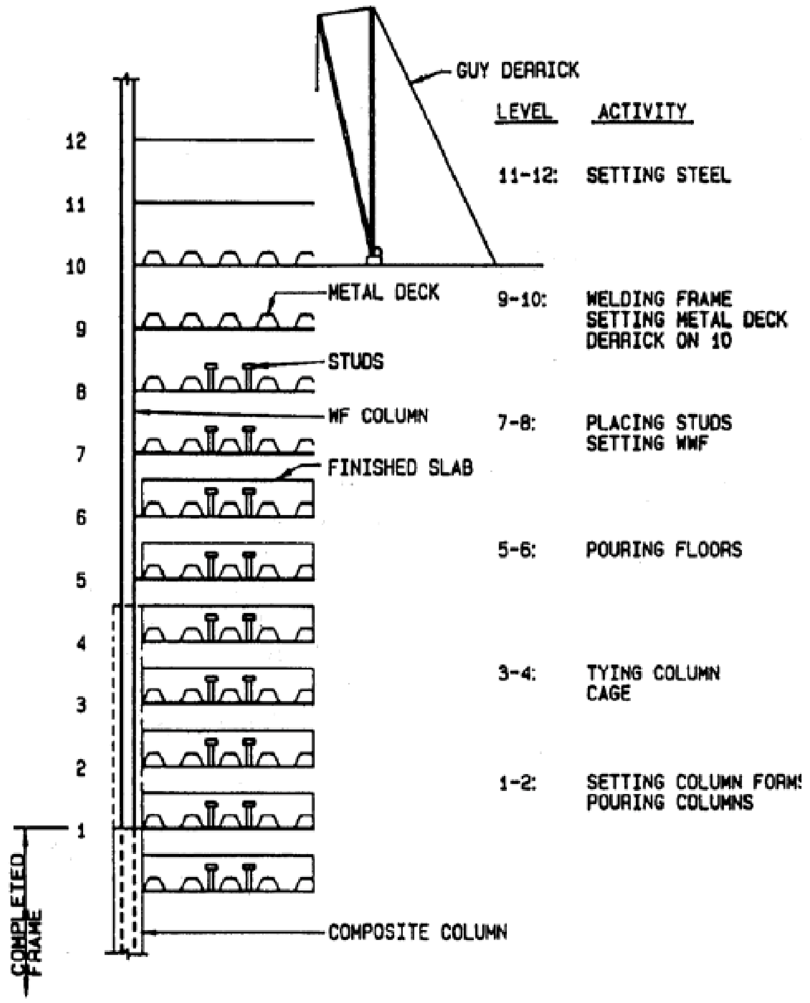


Fig. 131: Construction Sequence for a Structural System of Composite Members.

FINAL REPORT:

STRUCTURAL SYSTEM:	HYBRID TUBE IN TUBE SYSTEM
GRAVITY LOAD RESISTING SYSTEM:	
SLABS:	COMPOSITE CONCRETE CAST ON SITE ON METAL DECK (11cm)
MATERIAL:	C 40 CONCRETE (f_c= 40 Mpa) S420 LOW CARBON REINFORCING STEEL BARS (f_y=420 Mpa)
BEAMS:	EUROPEAN ROLLED STEEL SECTIONS: HEA-HEB-HEM
MATERIAL:	S 355 STEEL (f_y= 355 Mpa)
(The floor and roof systems are assumed to act as a rigid diaphram.)	
LATERAL LOAD RESISTING SYSTEM:	
REINFORCED CONCRETE COMPOSITE COLUMNS AND SHEAR WALL SYSTEM	
CRITICAL LATERAL LOADING CONDITION:	WIND
COLUMNS	(1.5 m* 1.5 m)
MATERIAL:	C 80 CONCRETE (f_c= 80 Mpa) (Story: 30-60) C 100 HSC. CONCRETE (f_c=100 Mpa) (Story: 0-30) EUROPEAN ROLLED STEEL SECTIONS: HD (f_y=355 Mpa)
SHEAR WALLS:	(L (m)* 0.3 m)
MATERIAL:	C 80 CONCRETE (f_c= 80 Mpa) (Story: 30-60) C 100 HSC. CONCRETE (f_c=100 Mpa) (Story: 0-30)
CONNECTION ELEMENTS	A 490 HIGH STRENGTH M20-M22 BOLTS &ANCHORAGES
FOUNDATION:	REINFORCED CONCRETE BEARING PILES
DIMENSIONS: *MATERIAL:*	30 * ϕ 30 cm L= 9m piles C 40 CONCRETE (fc= 40 Mpa) S420 LOW CARBON REINFORCING STEEL BARS (f_y=420 Mpa)
BUILDING CODES AND STANDARDS:	
ASCE 7-10 Minimum Design Loads for Buildings and Other Structures. AISC Specification for Structural Steel Buildings. ACI 318 Building Code Requirements for Structural Concrete. Use AISC Seismic Provisions for Structural Steel Buildings, 2005.	

4. Appendix

A- PRELIMINARY DIMENSIONING OF BEAM MEMBERS

interior+fl.cover+ceiling=	1.9	kN/m2
concrete=	26.4	kN/m2
Combinations:	1.2G+1.6L	

Engineers note: the outermost beams will be effected mostly on the lateral loading, hence larger sections than needed are assigned in the preliminary design stage.

Floor Type 0 Beam Type 1	CODE: B01		Floor Type 0 Beam Type 2	CODE: B02	
Tributary area=	34.425	m2	Tributary area=	30.6	m2
Dead=	33.96	kN/m2	Dead=	33.96	kN/m2
Live=	7.664	kN/m2	Live=	7.664	kN/m2
total,w=	41.624	kN/m2	total,w=	41.624	kN/m2
l=	11.475	m	l=	10.2	m
load per meter=	124.872	kN/m	load per meter=	124.872	kN/m
moment=	1370.217	kNm	moment=	1082.64024	kNm
choose;	HeB500		choose;	HeB450	
weight=	187	kg/m	weight=	171	kg/m
ϕMp=	1543.32	kNm	ϕMp=	1278.36	kNm
(load+weight) per meter=	127.116	kN/m	(load+weight) per meter=	126.924	kN/m
Moment=	1394.84	kNm	Moment=	1100.43108	kNm
HeB500 ok			**HeB450 ok**		

Floor Type 0 Beam Type 3	CODE: B03		Floor Type 0 Beam Type 4	CODE: B04	
Tributary area=	51.6375	m2	Tributary area=	61.175625	m2
Dead=	33.96	kN/m2	Dead=	33.96	kN/m2
Live=	7.664	kN/m2	Live=	7.664	kN/m2
total,w=	41.624	kN/m2	total,w=	41.624	kN/m2
l=	10.35	m	l=	11.85	m
load per meter=	222.4516	kN/m	load per meter=	229.6679	kN/m
moment=	1985.797	kNm	moment=	2687.54506	kNm
choose;	HeB600		choose;	HeM600	
weight=	212	kg/m	weight=	285	kg/m
ϕMp=	2052.36	kNm	ϕMp=	2757.6	kNm
(load+weight) per meter=	224.9956	kN/m	(load+weight) per meter=	233.0879	kN/m
Moment=	2008.507	kNm	Moment=	2727.56547	kNm
HeB600 ok			**HeM600 ok**		

Floor Type 0 Beam Type 5	CODE: B05		Floor Type 1 Beam Type 5	CODE: B15	
Tributary area=	60.96	m2	Tributary area=	60.96	m2
Dead=	33.96	kN/m2	Dead=	33.96	kN/m2
Live=	7.664	kN/m2	Live=	3.84	kN/m2
total,w=	41.624	kN/m2	total,w=	37.8	kN/m2
l=	15.353	m	l=	15.353	m
load per meter=	165.2706	kN/m	load per meter=	150.087149	kN/m
moment=	3246.391	kNm	moment=	2948.14447	kNm
choose;	HeM700		choose;	HeM600	
weight=	301	kg/m	weight=	285	kg/m
ϕMp=	3311.28	kNm	ϕMp=	2757.6	kNm
(load+weight) per meter=	168.8826	kN/m	(load+weight) per meter=	153.507149	kN/m
Moment=	3317.341	kNm	Moment=	3015.32314	kNm
HeM700 ok			**HeM600 try**		

Floor Type 1 Beam Type 1	CODE: B11		Floor Type 1 Beam Type 2	CODE: B12	
Tributary area=	34.425	m2	Tributary area=	30.6	m2
Dead=	33.96	kN/m2	Dead=	33.96	kN/m2
Live=	3.84	kN/m2	Live=	3.84	kN/m2
total,w=	37.8	kN/m2	total,w=	37.8	kN/m2
l=	11.475	m	l=	10.2	m
load per meter=	113.4	kN/m	load per meter=	113.4	kN/m
moment=	1244.335	kNm	moment=	983.178	kNm
choose;	HeM400		choose;	HeB400	
weight=	256	kg/m	weight=	155	kg/m
ϕMp=	1540.8	kNm	ϕMp=	1038.24	kNm
(load+weight) per meter=	116.472	kN/m	(load+weight) per meter=	115.26	kN/m
Moment=	1278.044	kNm	Moment=	999.3042	kNm
HeM400 ok			**HeB400 ok**		

Floor Type 1 Beam Type 3	CODE: B13		Floor Type 1 Beam Type 4	CODE: B14	
Tributary area=	51.6375	m2	Tributary area=	61.175625	m2
Dead=	33.96	kN/m2	Dead=	33.96	kN/m2
Live=	3.84	kN/m2	Live=	3.84	kN/m2
total,w=	37.8	kN/m2	total,w=	37.8	kN/m2
l=	10.35	m	l=	11.85	m
load per meter=	203.3731	kN/m	load per meter=	209.9265	kN/m
moment=	1815.487	kNm	moment=	2456.53366	kNm
choose;	HeM550		choose;	HeM550	
weight=	278	kg/m	weight=	278	kg/m
ϕMp=	2492.28	kNm	ϕMp=	2492.28	kNm
(load+weight) per meter=	206.7091	kN/m	(load+weight) per meter=	213.2625	kN/m
Moment=	1845.267	kNm	Moment=	2495.57112	kNm
HeM550 ok			**HeM550 ok**		

Floor Type 2 Beam Type 1	CODE: B21		Floor Type 2 Beam Type 2	CODE: B22	
Tributary area=	34.425	m2	Tributary area=	30.6	m2
Dead=	33.96	kN/m2	Dead=	33.96	kN/m2
Live=	3.072	kN/m2	Live=	3.072	kN/m2
total,w=	37.032	kN/m2	total,w=	37.032	kN/m2
l=	11.475	m	l=	10.2	m
load per meter=	111.096	kN/m	load per meter=	111.096	kN/m
moment=	1219.053	kNm	moment=	963.20232	kNm
choose;	HeM360		choose;	HeM340	
weight=	250	kg/m	weight=	248	kg/m
ϕMp=	1546.92	kNm	ϕMp=	1458.72	kNm
(load+weight) per meter=	114.096	kN/m	(load+weight) per meter=	114.072	kN/m
Moment=	1251.972	kNm	Moment=	989.00424	kNm
HeM360 ok			**HeM340 ok**		

Floor Type 2 **Beam Type 3**	**CODE:**	**B23**
Tributary area=	51.6375	m2
Dead=	33.96	kN/m2
Live=	3.072	kN/m2
total,w=	37.032	kN/m2
l=	10.35	m
load per meter=	199.5415	kN/m
moment=	1781.282	kNm
choose;	HeM500	
weight=	270	kg/m
ϕMp=	2224.8	kNm
(load+weight) per meter=	202.7815	kN/m
Moment=	1810.205	kNm
HeM500 ok		

Floor Type 2 **Beam Type 4**	**CODE:**	**B24**
Tributary area=	61.175625	m2
Dead=	33.96	kN/m2
Live=	3.072	kN/m2
total,w=	37.032	kN/m2
l=	11.85	m
load per meter=	205.9617	kN/m
moment=	2410.13807	kNm
choose;	HeM500	
weight=	270	kg/m
ϕMp=	2224.8	kNm
(load+weight) per meter=	209.2017	kN/m
Moment=	2448.05214	kNm
HeM500 try		

Floor Type 2 **Beam Type 5**	**CODE:**	**B25**
Tributary area=	60.96	m2
Dead=	33.96	kN/m2
Live=	3.072	kN/m2
total,w=	37.032	kN/m2
l=	15.353	m
load per meter=	147.0378	kN/m
moment=	2888.246	kNm
choose;	HeM600	
weight=	285	kg/m
ϕMp=	2757.6	kNm
(load+weight) per meter=	150.4578	kN/m
Moment=	2955.424	kNm
HeM600 try		

B- SECONDARY DESIGN FOR BEAM ELEMENTS

B01	**HeB 400**										
M_{max}=	725.1154	kNm									
V_{max}=	265.052	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	22.07	<	53.16781829				
h/t_w=	22.07	<λ_p=	89.25	$\Phi V_n=0.6*A_w*F_y$=		1906.776	kN>	265.052	kN ok		
$b_f/2t_f$=	6.25	<λ_p=	9.02	**Weld design**							
				Q=	2E+06	mm^3					
design a compact section				shear q=	V*Q/I	701.4136144	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	3.062032	t_{min}=6 mm	
Z_x=	3232	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1147.36	kNm		**Check for deflection**		δ_{LL}=	0.003417163	m<	0.031875	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	11.475	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.0913289	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.083944	m		$k=t_f$=	24.0	mm					
c=	1			*i)*	*check for the interior loa*		*ii)*	*check for the exterior load*			
L_r=	11.697795	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	1533.6	kN>283 kN ok	ΦR_n=	1246.05	kN>283 kN ok		
C_b=	2.3875171	≤3		*web crippling*			*web crippling*		0.5		
M_n=	1737.6902	kNm		ΦR_n=	11268	kN>283 kN ok	ΦR_n=	1080.725	kN>283 kN ok		
				check for sidesway web buckling			0.77463084	<1.7			
$M_p\phi_b$=	**1032.624**	**>M_{max} ok**		ΦR_n=	3406.9	kN>283 kN ok					

B02	**HeB 360**										
M_{max}=	670.9503	kNm									
V_{max}=	254.989	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	20.88	<	53.16781829				
h/t_w=	20.88	<λ_p=	89.25	$\Phi V_n=0.6*A_w*F_y$=		1595.9025	kN>	254.989	kN ok		
$b_f/2t_f$=	6.67	<λ_p=	9.02	**Weld design**							
				Q=	1E+06	mm^3					
design a compact section				shear q=	V*Q/I	762.1552725	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	3.327201	t_{min}=6 mm	
Z_x=	2683	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	952.465	kNm		**Check for deflection**		δ_{LL}=	0.003605809	m<	0.028333	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	10.2	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.1289261	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.0844044	m		$k=t_f$=	22.5	mm					
c=	1			*i)*	*check for the interior loa*		*ii)*	*check for the exterior load*			
L_r=	12.181324	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	1386.7	kN>235 kN ok	ΦR_n=	1137.109	kN>235 kN ok		
C_b=	2.4935896	≤3		*web crippling*			*web crippling*		0.555556		
M_n=	1681.5096	kNm		ΦR_n=	10125	kN>235 kN ok	ΦR_n=	973.6538	kN>235 kN ok		
				check for sidesway web buckling			0.847058824	<1.7			
$M_p\phi_b$=	**857.2185**	**>M_{max} ok**		ΦR_n=	4092.9	kN>235 kN ok					

B03&B04	**HeB 450**										
M_{max}=	464.4398	kNm									
V_{max}=	243.214	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	24.57	<	53.16781829				
h/t_w=	24.57	<λ_p=	89.25	$\Phi V_n=0.6*A_w*F_y$=		2342.574	kN>	243.214	kN ok		
$b_f/2t_f$=	5.77	<λ_p=	9.02	**Weld design**							
				Q=	2E+06	mm^3					
design a compact section				shear q=	V*Q/I	565.1551754	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	2.467194	t_{min}=6 mm	
Z_x=	3982	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1413.61	kNm		**Check for deflection**		δ_{LL}=	0.00382169	m<	0.032917	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	11.85	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.0620866	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.0836107	m		$k=t_f$=	26.0	mm					
c=	1			*i)*	*check for the interior loa*		*ii)*	*check for the exterior load*			
L_r=	11.199237	m		*local web yield*			*local web yield*				
$L_b>L_r$	elastic torsional buckling			ΦR_n=	1640.1	kN>260 kN ok	ΦR_n=	1317.05	kN>260 kN ok		
C_b=	1.9967046	≤3		*web crippling*			*web crippling*		0.444444		
F_{cr}=	463.66037			ΦR_n=	11838	kN>260 kN ok	ΦR_n=	1096.122	kN>260 kN ok		
M_n=	1646.458	kNm		*check for sidesway web buckling*			0.813743219	<1.7			
$M_p\phi_b$=	**1272.249**	**>M_{max}**	**ok**	ΦR_n=	3770.3	kN>260 kN ok					

B05	**HeM 500**										
M_{max}=	1838.8859	kNm									
V_{max}=	498.143	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	18.57	<	53.16781829				
h/t_w=	18.57	<λ_p=	89.25	$\Phi V_n=0.6*A_w*F_y$=		4234.44	kN>	498.143	kN ok		
$b_f/2t_f$=	3.83	<λ_p=	9.02	**Weld design**							
				Q=	3E+06	mm^3					
design a compact section				shear q=	V*Q/I	1062.032261	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	4.636319	t_{min}=6 mm	
Z_x=	7094	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	2518.37	kNm		**Check for deflection**		δ_{LL}=	0.002884401	m<	0.042647	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	15.353	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.1163937	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.0865477	m		$k=t_f$=	40.0	mm					
c=	1			*i)*	*check for the interior loa*		*ii)*	*check for the exterior load*			
L_r=	14.388011	m		*local web yield*			*local web yield*				
$L_b>L_r$	elastic torsional buckling			ΦR_n=	2982	kN>498 kN ok	ΦR_n=	2236.5	kN>498 kN ok		
C_b=	2.6684507	<3		*web crippling*			*web crippling*		0.381679		
F_{cr}=	694.72066			ΦR_n=	25685	kN>498 kN ok	ΦR_n=	2315.016	kN>498 kN ok		
M_n=	4293.3737	kNm		*check for sidesway web buckling*			0.49732486	<1.7			
$M_p\phi_b$=	**2266.533**	**>M_{max}**	**ok**	ΦR_n=	3295.8	kN>498 kN ok					

B11	**HeM 300**										
M_{max}=	638.9218	kNm									
V_{max}=	203.819	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	9.9	<	53.16781829				
h/t_w=	9.9	<λ_p=	89.24598	$\Phi V_n=0.6*A_w*F_y$=		2600.091	kN>	203.819	kN ok		
$b_f/2t_f$=	3.97	<λ_p=	9.019541	**Weld design**							
				Q=	2291055	mm^3					
design a compact section				shear q=	V*Q/I	788.7846943	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	3.443452	t_{min}=6 mm	
Z_x=	4078	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1447.69	kNm		**Check for deflection**		δ_{LL}=	0.003329425	m<	0.031875	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	11.475	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.341977	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.091528	m		$k=t_f$=	39.0	mm					
c=	1			*i)*	*check for the interior lo*		*ii)*	*check for the exterior load*			
L_r=	23.71283	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	2944.725	kN>203 kN ok	ΦR_n=	2217.863	kN>203 kN ok		
C_b=	2.979652	≤3		*web crippling*			*web crippling*		0.588235		
M_n=	3620.762	kNm		ΦR_n=	29608.46	kN>203 kN ok	ΦR_n=	2811.526	kN>203 kN ok		
				check for sidesway web buckling			0.437389771	<1.7			
$M_p\phi_b$=	**1302.921**	**>M_{max} ok**		ΦR_n=	5192.18	kN>203 kN ok					

B12	**HeB 300**										
M_{max}=	404.3214	kNm									
V_{max}=	135.762	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	18.91	<	53.16781829				
h/t_w=	18.91	<λ_p=	89.24598	$\Phi V_n=0.6*A_w*F_y$=		1104.831	kN>	135.762	kN ok		
$b_f/2t_f$=	7.89	<λ_p=	9.019541	**Weld design**							
				Q=	909150	mm^3					
design a compact section				shear q=	V*Q/I	490.3775221	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	2.140751	t_{min}=6 mm	
Z_x=	1869	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	663.495	kNm		**Check for deflection**		δ_{LL}=	0.006187321	m<	0.028333	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	10.2	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.166523	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.084645	m		$k=t_f$=	19.0	mm					
c=	1			*i)*	*check for the interior lo*		*ii)*	*check for the exterior load*			
L_r=	12.60676	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	1151.975	kN>135 kN ok	ΦR_n=	966.4875	kN>135 kN ok		
C_b=	2.514682	≤3		*web crippling*			*web crippling*		0.666667		
M_n=	1206.621	kNm		ΦR_n=	8373.763	kN>135 kN ok	ΦR_n=	838.7937	kN>135 kN ok		
				check for sidesway web buckling			0.802139037	<1.7			
$M_p\phi_b$=	**597.1455**	**>M_{max} ok**		ΦR_n=	2880.165	kN>135 kN ok					

B13&B14	**HeM 340**										
M_{max}=	340.1377	kNm									
V_{max}=	181.463	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	11.57	<	53.16781829				
h/t_w=	11.57	$<\lambda_p$=	89.24598	$\Phi V_n=0.6*A_w*F_y$=		2982	kN>	181.463	kN ok		
$b_f/2t_f$=	3.86	$<\lambda_p$=	9.019541	**Weld design**							
				Q=	2577060	mm^3					
design a compact section				shear q=	V*Q/I	612.3360466	N/mm				
1)check yielding				$\Phi R_n/L$=0.75*0.707*t*0.6*360=q/2				t=	2.673163	t_{min}=6 mm	
Z_x=	4718	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1674.89	kNm		**Check for deflection**	δ_{LL}=		0.003997837	m<	0.032917	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	11.85	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.300202	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.090484	m		$k=t_f$=	40.0	mm					
c=	1			*i)*	*check for the interior load*		*ii)*	*check for the exterior load*			
L_r=	21.31101	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	2982	kN>181 kN ok	ΦR_n=	2236.5	kN>181 kN ok		
C_b=	2.249178	≤3		*web crippling*			*web crippling*		0.530504		
M_n=	3053.941	kNm		ΦR_n=	28723.98	kN>181 kN ok	ΦR_n=	2663.42	kN>181 kN ok		
				check for sidesway web buckling			0.468125377	<1.7			
$M_p\phi_b$=	**1507.401**	**$>M_{max}$ ok**		ΦR_n=	5310.079	kN>181 kN ok					

B15	**HeM 360**										
M_{max}=	1317.62	kNm									
V_{max}=	361.764	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	12.43	<	53.16781829				
h/t_w=	12.43	$<\lambda_p$=	89.24598	$\Phi V_n=0.6*A_w*F_y$=		3135.36	kN>	361.764	kN ok		
$b_f/2t_f$=	3.85	$<\lambda_p$=	9.019541	**Weld design**							
				Q=	2679600	mm^3					
design a compact section				shear q=	V*Q/I	1142.19726	N/mm				
1)check yielding				$\Phi R_n/L$=0.75*0.707*t*0.6*360=q/2				t=	4.98628	t_{min}=6 mm	
Z_x=	4989	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1771.095	kNm		**Check for deflection**	δ_{LL}=		0.005502351	m<	0.042647	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	15.353	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.27096	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.089748	m		$k=t_f$=	40.0	mm					
c=	1			*i)*	*check for the interior load*		*ii)*	*check for the exterior load*			
L_r=	20.05508	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	2982	kN>362 kN ok	ΦR_n=	2236.5	kN>362 kN ok		
C_b=	2.665067	≤3		*web crippling*			*web crippling*		0.506329		
M_n=	3370.861	kNm		ΦR_n=	28230.37	kN>362 kN ok	ΦR_n=	2606.825	kN>362 kN ok		
				check for sidesway web buckling			0.377342105	<1.7			
				ΦR_n=	2533.429	kN>362 kN ok					
$M_p\phi_b$=	**1593.986**	**$>M_{max}$ ok**									

B21	**HeM 300**		
M_{max}=	638.9218	kNm	
V_{max}=	203.819	kN	
Flexural Design			
ϕ_b=	0.9		
h/t_w=	9.9	$<\lambda_p$=	89.24598
$b_f/2t_f$=	3.97	$<\lambda_p$=	9.019541
design a compact section			
1)check yielding			
Z_x=	4078	cm3	
$M_n=M_p=F_y*Z_x$=	1447.69	kNm	
2)check Lateral Torsional Buckling			
L_b=	11.475	m	
L_p=	3.341977	m	
r_{ts}=	0.091528	m	
c=	1		
L_r=	23.71283	m	
$L_p<L_b<L_r$	inelastic torsional buckling		
C_b=	2.979652	≤3	
M_n=	3620.762	kNm	
$M_p\phi_b$=	**1302.921**	**$>M_{max}$**	**ok**

Check for shear:							
h/t_w=	9.9	<	53.16781829				
$\Phi V_n=0.6*A_w*F_y$=		2600.091	kN>	203.819	kN ok		
Weld design							
Q=	2291055	mm^3					
shear q=	V*Q/I	788.7846943	N/mm				
$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	3.443452	t_{min}=6 mm	
use t=6mm							
Check for deflection	δ_{LL}=		0.003329425	m<	0.031875	m	**ok**
Since the flange is compact the limit state of local buckling does not apply and							
since the section is symmetric the limit state of the tension flange yielding does not apply.							
Check for web behaviour under concentrated loads							
$k=t_f$=	39.0	mm					
i)	*check for the interior load*		*ii)*	*check for the exterior load*			
local web yield			*local web yield*				
ΦR_n=	2944.725	kN>203 kN ok	ΦR_n=	2217.863	kN>203 kN ok		
web crippling			*web crippling*		0.588235		
ΦR_n=	29608.46	kN>203 kN ok	ΦR_n=	2811.526	kN>203 kN ok		
check for sidesway web buckling			0.437389771	<1.7			
ΦR_n=	5192.18	kN>203 kN ok					

B22	**HeM 300**		
M_{max}=	638.9218	kNm	
V_{max}=	203.819	kN	
Flexural Design			
ϕ_b=	0.9		
h/t_w=	26.1	$<\lambda_p$=	89.24598
$b_f/2t_f$=	8.57	$<\lambda_p$=	9.019541
design a compact section			
1)check yielding			
Z_x=	4078	cm3	
$M_n=M_p=F_y*Z_x$=	1447.69	kNm	
2)check Lateral Torsional Buckling			
L_b=	10.2	m	
L_p=	3.341977	m	
r_{ts}=	0.091528	m	
c=	1		
L_r=	23.71283	m	
$L_p<L_b<L_r$	inelastic torsional buckling		
C_b=	2.979652	≤3	
M_n=	3729.378	kNm	
$M_p\phi_b$=	**1302.921**	**$>M_{max}$**	**ok**

Check for shear:							
h/t_w=	26.1	<	53.16781829				
$\Phi V_n=0.6*A_w*F_y$=		2600.091	kN>	203.819	kN ok		
Weld design							
Q=	2291055	mm^3					
shear q=	V*Q/I	788.7846943	N/mm				
$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	3.443452	t_{min}=6 mm	
use t=6mm							
Check for deflection	δ_{LL}=		0.002630657	m<	0.028333	m	**ok**
Since the flange is compact the limit state of local buckling does not apply and							
since the section is symmetric the limit state of the tension flange yielding does not apply.							
Check for web behaviour under concentrated loads							
$k=t_f$=	39.0	mm					
i)	*check for the interior load*		*ii)*	*check for the exterior load*			
local web yield			*local web yield*				
ΦR_n=	2944.725	kN>203 kN ok	ΦR_n=	2217.863	kN>203 kN ok		
web crippling			*web crippling*		0.588235		
ΦR_n=	29608.46	kN>203 kN ok	ΦR_n=	2811.526	kN>203 kN ok		
check for sidesway web buckling			0.492063492	<1.7			
ΦR_n=	7392.772	kN>203 kN ok					

B23&B24	**HeM 320**										
M_{max}=	1121.84	kNm									
V_{max}=	325.65	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	32.5	<	53.16781829				
h/t_w=	32.5	$<\lambda_p$=	89.24598	$\Phi V_n=0.6*A_w*F_y$=		2828.64	kN>	325.65	kN ok		
$b_f/2t_f$=	6.52	$<\lambda_p$=	9.019541	**Weld design**							
				Q=	2465820	mm^3					
design a compact section				shear q=	V*Q/I	1178.6207	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	5.145287	t_{min}=6 mm	
Z_x=	4435	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1574.425	kNm		**Check for deflection**		δ_{LL}=	0.004481356	m<	0.032917	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	11.85	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.32109	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.090957	m		$k=t_f$=	40.0	mm					
c=	1			*i)*	*check for the interior load*		*ii)*	*check for the exterior load*			
L_r=	22.66312	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	2982	kN>325 kN ok	ΦR_n=	2236.5	kN>325 kN ok		
C_b=	2.569445	≤3		*web crippling*			*web crippling*		0.557103		
M_n=	3330.339	kNm		ΦR_n=	29267.08	kN>325 kN ok	ΦR_n=	2725.689	kN>325 kN ok		
				check for sidesway web buckling			0.445774563	<1.7			
$M_p\phi_b$=	**1416.983**	**$>M_{max}$ ok**		ΦR_n=	5056.547	kN>325 kN ok					

B25	**HeM 320**										
M_{max}=	1121.84	kNm									
V_{max}=	325.65	kN									
Flexural Design				**Check for shear:**							
ϕ_b=	0.9			h/t_w=	10.71	<	53.16781829				
h/t_w=	10.71	$<\lambda_p$=	89.24598	$\Phi V_n=0.6*A_w*F_y$=		2828.64	kN>	325.65	kN ok		
$b_f/2t_f$=	3.86	$<\lambda_p$=	9.019541	**Weld design**							
				Q=	2465820	mm^3					
design a compact section				shear q=	V*Q/I	1178.6207	N/mm				
1)check yielding				$\Phi R_n/L=0.75*0.707*t*0.6*360=q/2$				t=	5.145287	t_{min}=6 mm	
Z_x=	4435	cm3		**use t=6mm**							
$M_n=M_p=F_y*Z_x$=	1574.425	kNm		**Check for deflection**		δ_{LL}=	0.006854316	m<	0.042647	m	**ok**
2)check Lateral Torsional Buckling				*Since the flange is compact the limit state of local buckling does not apply and*							
L_b=	15.353	m		*since the section is symmetric the limit state of the tension flange yielding does not apply.*							
L_p=	3.32109	m		**Check for web behaviour under concentrated loads**							
r_{ts}=	0.090957	m		$k=t_f$=	40.0	mm					
c=	1			*i)*	*check for the interior load*		*ii)*	*check for the exterior load*			
L_r=	22.66312	m		*local web yield*			*local web yield*				
$L_p<L_b<L_r$	inelastic torsional buckling			ΦR_n=	2982	kN>325 kN ok	ΦR_n=	2236.5	kN>325 kN ok		
C_b=	2.569445	≤3		*web crippling*			*web crippling*		0.557103		
M_n=	3036.649	kNm		ΦR_n=	29267.08	kN>325 kN ok	ΦR_n=	2725.689	kN>325 kN ok		
				check for sidesway web buckling			0.344064911	<1.7			
				ΦR_n=	2325.034	kN>325 kN ok					
$M_p\phi_b$=	**1416.983**	**$>M_{max}$ ok**									

C- SNOW LOAD ESTIMATION FOR ROOF:

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads[a]

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.25	1.00	1.25
IV	1.20	1.25	1.00	1.50

[a]The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it is dependent on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

Table A-01 Building Importancy Factors According to ASCE 07-10.

Calculation for Design Snow Load

Risk Category III

Buildings and other structures, the failure of which could pose a substantial risk to human life.

Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.

Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where their quantity exceeds a threshold quantity established by the authority having jurisdiction and is suffi cient to pose a threat to the public if released.

Snow Loads

FLAT ROOF SNOW LOADS, p_f

The flat roof snow load, pf, shall be calculated in lb/ft2 (kN/m2) using the following formula:

$p_f = 0.7 C_e C_t I_s p_g$

Table A02- Exposure factor C_v for estimation on Snow loads according to ASCE 07-10.

Table 7-2 Exposure Factor, C_e

Terrain Category	Exposure of Roof[a]		
	Fully Exposed	Partially Exposed	Sheltered
B (see Section 26.7)	0.9	1.0	1.2
C (see Section 26.7)	0.9	1.0	1.1
D (see Section 26.7)	0.8	0.9	1.0
Above the treeline in windswept mountainous areas.	0.7	0.8	N/A
In Alaska, in areas where trees do not exist within a 2-mile (3-km) radius of the site.	0.7	0.8	N/A

The terrain category and roof exposure condition chosen shall be representative of the anticipated conditions during the life of the structure. An exposure factor shall be determined for each roof of a structure.

[a]Definitions: Partially Exposed: All roofs except as indicated in the following text. Fully Exposed: Roofs exposed on all sides with no shelter[b] afforded by terrain, higher structures, or trees. Roofs that contain several large pieces of mechanical equipment, parapets that extend above the height of the balanced snow load (h_b), or other obstructions are not in this category. Sheltered: Roofs located tight in among conifers that qualify as obstructions.

[b]Obstructions within a distance of $10h_o$ provide "shelter," where h_o is the height of the obstruction above the roof level. If the only obstructions are a few deciduous trees that are leafless in winter, the "fully exposed" category shall be used. Note that these are heights above the roof. Heights used to establish the Exposure Category in Section 26.7 are heights above the ground.

Table 7-3 Thermal Factor, C_t

Thermal Condition[a]	C_t
All structures except as indicated below	1.0
Structures kept just above freezing and others with cold, ventilated roofs in which the thermal resistance (R-value) between the ventilated space and the heated space exceeds 25 °F × h × ft²/Btu (4.4 K × m²/W).	1.1
Unheated and open air structures	1.2
Structures intentionally kept below freezing	1.3
Continuously heated greenhouses[b] with a roof having a thermal resistance (R-value) less than 2.0 °F × h × ft²/Btu (0.4 K × m²/W)	0.85

[a]These conditions shall be representative of the anticipated conditions during winters for the life of the structure.

[b]Greenhouses with a constantly maintained interior temperature of 50 °F (10 °C) or more at any point 3 ft above the floor level during winters and having either a maintenance attendant on duty at all times or a temperature alarm system to provide warning in the event of a heating failure.

C_t=	1	C_e=	0.9		
I_s=	1.1	p_g=	25	lb/ft^2=	1.1975 kN/m^2
p_f=	0.829868	kN/m^2			

Minimum Snow Load for Low-Slope Roofs, p_m

A minimum roof snow load, p_m, shall only apply to monoslope, hip and gable roofs with slopes less than15°. The minimum roof snow load for low-slope roofs shall be obtained using the following formula:

_Where p_g is 20 lb/ft2 (0.96 kN/m2) or less:

$p_m = I_s p_g$ (Importance Factor times p_g)

_Where p_g exceeds 20 lb/ft2 (0.96 kN/m2):

$p_m = 20 (I_s)$ (20 lb/ft2 times Importance Factor)

This minimum roof snow load is a separate uniform load case. It need not be used in determining or in combination with drift, sliding, unbalanced, or partial loads.

p_m=	1.056	kN/m^2	**<L_r=4.79 kN/m^2 use L_r**

D- WIND LOAD DISTRIBUTIONS TO STORY CENTROIDS

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
937.820	0.000	0.000	0.000	0.000	0.002	23.55	17.55	8.8
392.440	0.000	0.000	0.000	0.000	0.001	23.55	17.55	13.2
1014.996	0.000	0.000	0.000	0.000	0.002	23.55	17.55	17.6
1109.074	0.000	0.000	0.000	0.000	0.002	23.55	17.55	35.2
450.798	0.000	0.000	0.000	0.000	0.001	23.55	17.55	39.6
457.418	0.000	0.000	0.000	0.000	0.001	23.55	17.55	44
463.581	0.000	0.000	0.000	0.000	0.001	23.55	17.55	48.4
469.356	0.000	0.000	0.000	0.000	0.001	23.55	17.55	52.8
415.447	0.000	0.000	0.000	0.000	0.001	23.55	17.55	57.2
359.012	0.000	0.000	0.000	0.000	0.001	23.55	17.55	60.5
361.816	0.000	0.000	0.000	0.000	0.001	23.55	17.55	63.8
364.518	0.000	0.000	0.000	0.000	0.001	23.55	17.55	67.1
673.066	0.000	0.000	0.000	0.000	0.001	23.55	17.55	70.4
747.362	0.000	0.000	0.000	0.000	0.001	23.55	17.55	79.2
502.352	0.000	0.000	0.000	0.000	0.001	23.55	17.55	83.6
506.311	0.000	0.000	0.000	0.000	0.001	23.55	17.55	88
510.131	0.000	0.000	0.000	0.000	0.001	23.55	17.55	92.4
449.596	0.000	0.000	0.000	0.000	0.001	23.55	17.55	96.8
387.386	0.000	0.000	0.000	0.000	0.001	23.55	17.55	100.1
389.358	0.000	0.000	0.000	0.000	0.001	23.55	17.55	103.4
391.285	0.000	0.000	0.000	0.000	0.001	23.55	17.55	106.7
393.170	0.000	0.000	0.000	0.000	0.001	23.55	17.55	110
724.194	0.000	0.000	0.000	0.000	0.001	23.55	17.55	113.3
799.508	0.000	0.000	0.000	0.000	0.001	23.55	17.55	122.1
536.043	0.000	0.000	0.000	0.000	0.001	23.55	17.55	126.5
471.631	0.000	0.000	0.000	0.000	0.001	23.55	17.55	130.9
405.887	0.000	0.000	0.000	0.000	0.001	23.55	17.55	134.2
407.491	0.000	0.000	0.000	0.000	0.001	23.55	17.55	137.5
409.067	0.000	0.000	0.000	0.000	0.001	23.55	17.55	140.8
410.617	0.000	0.000	0.000	0.000	0.001	23.55	17.55	144.1
412.142	0.000	0.000	0.000	0.000	0.001	23.55	17.55	147.4
413.643	0.000	0.000	0.000	0.000	0.001	23.55	17.55	150.7
761.055	0.000	0.000	0.000	0.000	0.001	23.55	17.55	154
837.907	0.000	0.000	0.000	0.000	0.002	23.55	17.55	162.8
561.086	0.000	0.000	0.000	0.000	0.001	23.55	17.55	167.2
493.081	0.000	0.000	0.000	0.000	0.001	23.55	17.55	171.6
423.989	0.000	0.000	0.000	0.000	0.001	23.55	17.55	174.9
425.319	0.000	0.000	0.000	0.000	0.001	23.55	17.55	178.2
426.632	0.000	0.000	0.000	0.000	0.001	23.55	17.55	181.5
427.927	0.000	0.000	0.000	0.000	0.001	23.55	17.55	184.8
429.206	0.000	0.000	0.000	0.000	0.001	23.55	17.55	188.1
430.469	0.000	0.000	0.000	0.000	0.001	23.55	17.55	191.4
791.481	0.000	0.000	0.000	0.000	0.001	23.55	17.55	194.7
869.944	0.000	0.000	0.000	0.000	0.002	23.55	17.55	203.5
582.082	0.000	0.000	0.000	0.000	0.001	23.55	17.55	207.9
584.170	0.000	0.000	0.000	0.000	0.001	23.55	17.55	212.3
586.228	0.000	0.000	0.000	0.000	0.001	23.55	17.55	216.7
588.256	0.000	0.000	0.000	0.000	0.001	23.55	17.55	221.1
590.255	0.000	0.000	0.000	0.000	0.001	23.55	17.55	225.5
592.226	0.000	0.000	0.000	0.000	0.001	23.55	17.55	229.9
594.171	0.000	0.000	0.000	0.000	0.001	23.55	17.55	234.3
596.089	0.000	0.000	0.000	0.000	0.001	23.55	17.55	238.7
896.975	0.000	0.000	0.000	0.000	0.002	23.55	17.55	243.1
902.547	0.000	0.000	0.000	0.000	0.002	23.55	17.55	251.9
905.281	0.000	0.000	0.000	0.000	0.002	23.55	17.55	256.3
910.651	0.000	0.000	0.000	0.000	0.002	23.55	17.55	265.1
304.429	0.000	0.000	0.000	0.000	0.001	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
0.000	1258.442	0.000	0.000	0.000	0.000	23.55	17.55	8.8
0.000	526.608	0.000	0.000	0.000	0.000	23.55	17.55	13.2
0.000	1362.003	0.000	0.000	0.000	0.000	23.55	17.55	17.6
0.000	1488.245	0.000	0.000	0.000	0.000	23.55	17.55	35.2
0.000	604.917	0.000	0.000	0.000	0.000	23.55	17.55	39.6
0.000	613.801	0.000	0.000	0.000	0.000	23.55	17.55	44
0.000	622.070	0.000	0.000	0.000	0.000	23.55	17.55	48.4
0.000	629.819	0.000	0.000	0.000	0.000	23.55	17.55	52.8
0.000	557.479	0.000	0.000	0.000	0.000	23.55	17.55	57.2
0.000	481.752	0.000	0.000	0.000	0.000	23.55	17.55	60.5
0.000	485.514	0.000	0.000	0.000	0.000	23.55	17.55	63.8
0.000	489.140	0.000	0.000	0.000	0.000	23.55	17.55	67.1
0.000	903.175	0.000	0.000	0.000	0.000	23.55	17.55	70.4
0.000	1002.870	0.000	0.000	0.000	0.000	23.55	17.55	79.2
0.000	674.097	0.000	0.000	0.000	0.000	23.55	17.55	83.6
0.000	679.409	0.000	0.000	0.000	0.000	23.55	17.55	88
0.000	684.535	0.000	0.000	0.000	0.000	23.55	17.55	92.4
0.000	603.304	0.000	0.000	0.000	0.000	23.55	17.55	96.8
0.000	519.826	0.000	0.000	0.000	0.000	23.55	17.55	100.1
0.000	522.472	0.000	0.000	0.000	0.000	23.55	17.55	103.4
0.000	525.057	0.000	0.000	0.000	0.000	23.55	17.55	106.7
0.000	527.587	0.000	0.000	0.000	0.000	23.55	17.55	110
0.000	971.781	0.000	0.000	0.000	0.000	23.55	17.55	113.3
0.000	1072.844	0.000	0.000	0.000	0.000	23.55	17.55	122.1
0.000	719.306	0.000	0.000	0.000	0.000	23.55	17.55	126.5
0.000	632.872	0.000	0.000	0.000	0.000	23.55	17.55	130.9
0.000	544.652	0.000	0.000	0.000	0.000	23.55	17.55	134.2
0.000	546.804	0.000	0.000	0.000	0.000	23.55	17.55	137.5
0.000	548.919	0.000	0.000	0.000	0.000	23.55	17.55	140.8
0.000	550.999	0.000	0.000	0.000	0.000	23.55	17.55	144.1
0.000	553.046	0.000	0.000	0.000	0.000	23.55	17.55	147.4
0.000	555.060	0.000	0.000	0.000	0.000	23.55	17.55	150.7
0.000	1021.245	0.000	0.000	0.000	0.000	23.55	17.55	154
0.000	1124.372	0.000	0.000	0.000	0.000	23.55	17.55	162.8
0.000	752.911	0.000	0.000	0.000	0.000	23.55	17.55	167.2
0.000	661.656	0.000	0.000	0.000	0.000	23.55	17.55	171.6
0.000	568.943	0.000	0.000	0.000	0.000	23.55	17.55	174.9
0.000	570.727	0.000	0.000	0.000	0.000	23.55	17.55	178.2
0.000	572.488	0.000	0.000	0.000	0.000	23.55	17.55	181.5
0.000	574.227	0.000	0.000	0.000	0.000	23.55	17.55	184.8
0.000	575.943	0.000	0.000	0.000	0.000	23.55	17.55	188.1
0.000	577.638	0.000	0.000	0.000	0.000	23.55	17.55	191.4
0.000	1062.073	0.000	0.000	0.000	0.000	23.55	17.55	194.7
0.000	1167.361	0.000	0.000	0.000	0.000	23.55	17.55	203.5
0.000	781.085	0.000	0.000	0.000	0.000	23.55	17.55	207.9
0.000	783.887	0.000	0.000	0.000	0.000	23.55	17.55	212.3
0.000	786.648	0.000	0.000	0.000	0.000	23.55	17.55	216.7
0.000	789.369	0.000	0.000	0.000	0.000	23.55	17.55	221.1
0.000	792.051	0.000	0.000	0.000	0.000	23.55	17.55	225.5
0.000	794.696	0.000	0.000	0.000	0.000	23.55	17.55	229.9
0.000	797.306	0.000	0.000	0.000	0.000	23.55	17.55	234.3
0.000	799.881	0.000	0.000	0.000	0.000	23.55	17.55	238.7
0.000	1203.633	0.000	0.000	0.000	0.000	23.55	17.55	243.1
0.000	1211.110	0.000	0.000	0.000	0.000	23.55	17.55	251.9
0.000	1214.779	0.000	0.000	0.000	0.000	23.55	17.55	256.3
0.000	1221.985	0.000	0.000	0.000	0.000	23.55	17.55	265.1
0.000	408.508	0.000	0.000	0.000	0.000	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
703.365	0.000	0.000	0.000	0.000	3703.218	23.55	17.55	8.8
294.330	0.000	0.000	0.000	0.000	1549.649	23.55	17.55	13.2
761.247	0.000	0.000	0.000	0.000	4007.966	23.55	17.55	17.6
831.806	0.000	0.000	0.000	0.000	4379.458	23.55	17.55	35.2
338.099	0.000	0.000	0.000	0.000	1780.090	23.55	17.55	39.6
343.064	0.000	0.000	0.000	0.000	1806.231	23.55	17.55	44
347.686	0.000	0.000	0.000	0.000	1830.566	23.55	17.55	48.4
352.017	0.000	0.000	0.000	0.000	1853.369	23.55	17.55	52.8
311.585	0.000	0.000	0.000	0.000	1640.495	23.55	17.55	57.2
269.259	0.000	0.000	0.000	0.000	1417.651	23.55	17.55	60.5
271.362	0.000	0.000	0.000	0.000	1428.722	23.55	17.55	63.8
273.389	0.000	0.000	0.000	0.000	1439.392	23.55	17.55	67.1
504.800	0.000	0.000	0.000	0.000	2657.772	23.55	17.55	70.4
560.522	0.000	0.000	0.000	0.000	2951.147	23.55	17.55	79.2
376.764	0.000	0.000	0.000	0.000	1983.664	23.55	17.55	83.6
379.734	0.000	0.000	0.000	0.000	1999.298	23.55	17.55	88
382.599	0.000	0.000	0.000	0.000	2014.382	23.55	17.55	92.4
337.197	0.000	0.000	0.000	0.000	1775.342	23.55	17.55	96.8
290.540	0.000	0.000	0.000	0.000	1529.692	23.55	17.55	100.1
292.018	0.000	0.000	0.000	0.000	1537.477	23.55	17.55	103.4
293.464	0.000	0.000	0.000	0.000	1545.087	23.55	17.55	106.7
294.877	0.000	0.000	0.000	0.000	1552.530	23.55	17.55	110
543.145	0.000	0.000	0.000	0.000	2859.661	23.55	17.55	113.3
599.631	0.000	0.000	0.000	0.000	3157.057	23.55	17.55	122.1
402.032	0.000	0.000	0.000	0.000	2116.701	23.55	17.55	126.5
353.723	0.000	0.000	0.000	0.000	1862.352	23.55	17.55	130.9
304.415	0.000	0.000	0.000	0.000	1602.747	23.55	17.55	134.2
305.618	0.000	0.000	0.000	0.000	1609.079	23.55	17.55	137.5
306.800	0.000	0.000	0.000	0.000	1615.304	23.55	17.55	140.8
307.963	0.000	0.000	0.000	0.000	1621.426	23.55	17.55	144.1
309.107	0.000	0.000	0.000	0.000	1627.448	23.55	17.55	147.4
310.233	0.000	0.000	0.000	0.000	1633.375	23.55	17.55	150.7
570.791	0.000	0.000	0.000	0.000	3005.218	23.55	17.55	154
628.431	0.000	0.000	0.000	0.000	3308.688	23.55	17.55	162.8
420.815	0.000	0.000	0.000	0.000	2215.591	23.55	17.55	167.2
369.811	0.000	0.000	0.000	0.000	1947.056	23.55	17.55	171.6
317.992	0.000	0.000	0.000	0.000	1674.228	23.55	17.55	174.9
318.989	0.000	0.000	0.000	0.000	1679.479	23.55	17.55	178.2
319.974	0.000	0.000	0.000	0.000	1684.662	23.55	17.55	181.5
320.945	0.000	0.000	0.000	0.000	1689.778	23.55	17.55	184.8
321.905	0.000	0.000	0.000	0.000	1694.828	23.55	17.55	188.1
322.852	0.000	0.000	0.000	0.000	1699.816	23.55	17.55	191.4
593.611	0.000	0.000	0.000	0.000	3125.362	23.55	17.55	194.7
652.458	0.000	0.000	0.000	0.000	3435.192	23.55	17.55	203.5
436.562	0.000	0.000	0.000	0.000	2298.499	23.55	17.55	207.9
438.128	0.000	0.000	0.000	0.000	2306.744	23.55	17.55	212.3
439.671	0.000	0.000	0.000	0.000	2314.868	23.55	17.55	216.7
441.192	0.000	0.000	0.000	0.000	2322.875	23.55	17.55	221.1
442.691	0.000	0.000	0.000	0.000	2330.769	23.55	17.55	225.5
444.170	0.000	0.000	0.000	0.000	2338.553	23.55	17.55	229.9
445.628	0.000	0.000	0.000	0.000	2346.232	23.55	17.55	234.3
447.067	0.000	0.000	0.000	0.000	2353.809	23.55	17.55	238.7
672.731	0.000	0.000	0.000	0.000	3541.930	23.55	17.55	243.1
676.910	0.000	0.000	0.000	0.000	3563.935	23.55	17.55	251.9
678.961	0.000	0.000	0.000	0.000	3574.731	23.55	17.55	256.3
682.988	0.000	0.000	0.000	0.000	3595.934	23.55	17.55	265.1
228.322	0.000	0.000	0.000	0.000	1202.116	23.55	17.55	269.5
703.365	0.000	0.000	0.000	0.000	-3703.216	23.55	17.55	8.8
294.330	0.000	0.000	0.000	0.000	-1549.648	23.55	17.55	13.2
761.247	0.000	0.000	0.000	0.000	-4007.964	23.55	17.55	17.6
831.806	0.000	0.000	0.000	0.000	-4379.455	23.55	17.55	35.2
338.099	0.000	0.000	0.000	0.000	-1780.089	23.55	17.55	39.6
343.064	0.000	0.000	0.000	0.000	-1806.230	23.55	17.55	44
347.686	0.000	0.000	0.000	0.000	-1830.565	23.55	17.55	48.4
352.017	0.000	0.000	0.000	0.000	-1853.367	23.55	17.55	52.8
311.585	0.000	0.000	0.000	0.000	-1640.494	23.55	17.55	57.2
269.259	0.000	0.000	0.000	0.000	-1417.650	23.55	17.55	60.5
271.362	0.000	0.000	0.000	0.000	-1428.721	23.55	17.55	63.8
273.389	0.000	0.000	0.000	0.000	-1439.391	23.55	17.55	67.1
504.800	0.000	0.000	0.000	0.000	-2657.770	23.55	17.55	70.4
560.522	0.000	0.000	0.000	0.000	-2951.145	23.55	17.55	79.2
376.764	0.000	0.000	0.000	0.000	-1983.663	23.55	17.55	83.6
379.734	0.000	0.000	0.000	0.000	-1999.296	23.55	17.55	88
382.599	0.000	0.000	0.000	0.000	-2014.381	23.55	17.55	92.4
337.197	0.000	0.000	0.000	0.000	-1775.341	23.55	17.55	96.8
290.540	0.000	0.000	0.000	0.000	-1529.691	23.55	17.55	100.1
292.018	0.000	0.000	0.000	0.000	-1537.476	23.55	17.55	103.4
293.464	0.000	0.000	0.000	0.000	-1545.086	23.55	17.55	106.7
294.877	0.000	0.000	0.000	0.000	-1552.529	23.55	17.55	110
543.145	0.000	0.000	0.000	0.000	-2859.659	23.55	17.55	113.3
599.631	0.000	0.000	0.000	0.000	-3157.055	23.55	17.55	122.1
402.032	0.000	0.000	0.000	0.000	-2116.699	23.55	17.55	126.5
353.723	0.000	0.000	0.000	0.000	-1862.351	23.55	17.55	130.9
304.415	0.000	0.000	0.000	0.000	-1602.746	23.55	17.55	134.2
305.618	0.000	0.000	0.000	0.000	-1609.078	23.55	17.55	137.5
306.800	0.000	0.000	0.000	0.000	-1615.303	23.55	17.55	140.8
307.963	0.000	0.000	0.000	0.000	-1621.425	23.55	17.55	144.1
309.107	0.000	0.000	0.000	0.000	-1627.447	23.55	17.55	147.4
310.233	0.000	0.000	0.000	0.000	-1633.374	23.55	17.55	150.7
570.791	0.000	0.000	0.000	0.000	-3005.216	23.55	17.55	154
628.431	0.000	0.000	0.000	0.000	-3308.686	23.55	17.55	162.8
420.815	0.000	0.000	0.000	0.000	-2215.589	23.55	17.55	167.2
369.811	0.000	0.000	0.000	0.000	-1947.055	23.55	17.55	171.6
317.992	0.000	0.000	0.000	0.000	-1674.227	23.55	17.55	174.9
318.989	0.000	0.000	0.000	0.000	-1679.478	23.55	17.55	178.2
319.974	0.000	0.000	0.000	0.000	-1684.661	23.55	17.55	181.5
320.945	0.000	0.000	0.000	0.000	-1689.776	23.55	17.55	184.8
321.905	0.000	0.000	0.000	0.000	-1694.827	23.55	17.55	188.1
322.852	0.000	0.000	0.000	0.000	-1699.815	23.55	17.55	191.4
593.611	0.000	0.000	0.000	0.000	-3125.360	23.55	17.55	194.7
652.458	0.000	0.000	0.000	0.000	-3435.190	23.55	17.55	203.5
436.562	0.000	0.000	0.000	0.000	-2298.497	23.55	17.55	207.9
438.128	0.000	0.000	0.000	0.000	-2306.742	23.55	17.55	212.3
439.671	0.000	0.000	0.000	0.000	-2314.866	23.55	17.55	216.7
441.192	0.000	0.000	0.000	0.000	-2322.873	23.55	17.55	221.1
442.691	0.000	0.000	0.000	0.000	-2330.767	23.55	17.55	225.5
444.170	0.000	0.000	0.000	0.000	-2338.552	23.55	17.55	229.9
445.628	0.000	0.000	0.000	0.000	-2346.231	23.55	17.55	234.3
447.067	0.000	0.000	0.000	0.000	-2353.807	23.55	17.55	238.7
672.731	0.000	0.000	0.000	0.000	-3541.927	23.55	17.55	243.1
676.910	0.000	0.000	0.000	0.000	-3563.932	23.55	17.55	251.9
678.961	0.000	0.000	0.000	0.000	-3574.729	23.55	17.55	256.3
682.988	0.000	0.000	0.000	0.000	-3595.932	23.55	17.55	265.1
228.322	0.000	0.000	0.000	0.000	-1202.115	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
0.000	943.832	0.000	0.000	0.000	6668.171	23.55	17.55	8.8
0.000	394.956	0.000	0.000	0.000	2790.364	23.55	17.55	13.2
0.000	1021.502	0.000	0.000	0.000	7216.913	23.55	17.55	17.6
0.000	1116.184	0.000	0.000	0.000	7885.838	23.55	17.55	35.2
0.000	453.688	0.000	0.000	0.000	3205.305	23.55	17.55	39.6
0.000	460.350	0.000	0.000	0.000	3252.376	23.55	17.55	44
0.000	466.553	0.000	0.000	0.000	3296.195	23.55	17.55	48.4
0.000	472.364	0.000	0.000	0.000	3337.254	23.55	17.55	52.8
0.000	418.110	0.000	0.000	0.000	2953.945	23.55	17.55	57.2
0.000	361.314	0.000	0.000	0.000	2552.681	23.55	17.55	60.5
0.000	364.136	0.000	0.000	0.000	2572.618	23.55	17.55	63.8
0.000	366.855	0.000	0.000	0.000	2591.831	23.55	17.55	67.1
0.000	677.381	0.000	0.000	0.000	4785.696	23.55	17.55	70.4
0.000	752.153	0.000	0.000	0.000	5313.960	23.55	17.55	79.2
0.000	505.572	0.000	0.000	0.000	3571.869	23.55	17.55	83.6
0.000	509.557	0.000	0.000	0.000	3600.020	23.55	17.55	88
0.000	513.402	0.000	0.000	0.000	3627.182	23.55	17.55	92.4
0.000	452.478	0.000	0.000	0.000	3196.756	23.55	17.55	96.8
0.000	389.870	0.000	0.000	0.000	2754.429	23.55	17.55	100.1
0.000	391.854	0.000	0.000	0.000	2768.447	23.55	17.55	103.4
0.000	393.793	0.000	0.000	0.000	2782.148	23.55	17.55	106.7
0.000	395.690	0.000	0.000	0.000	2795.551	23.55	17.55	110
0.000	728.836	0.000	0.000	0.000	5149.227	23.55	17.55	113.3
0.000	804.633	0.000	0.000	0.000	5684.730	23.55	17.55	122.1
0.000	539.479	0.000	0.000	0.000	3811.421	23.55	17.55	126.5
0.000	474.654	0.000	0.000	0.000	3353.430	23.55	17.55	130.9
0.000	408.489	0.000	0.000	0.000	2885.973	23.55	17.55	134.2
0.000	410.103	0.000	0.000	0.000	2897.376	23.55	17.55	137.5
0.000	411.689	0.000	0.000	0.000	2908.585	23.55	17.55	140.8
0.000	413.250	0.000	0.000	0.000	2919.608	23.55	17.55	144.1
0.000	414.784	0.000	0.000	0.000	2930.452	23.55	17.55	147.4
0.000	416.295	0.000	0.000	0.000	2941.124	23.55	17.55	150.7
0.000	765.934	0.000	0.000	0.000	5411.322	23.55	17.55	154
0.000	843.279	0.000	0.000	0.000	5957.764	23.55	17.55	162.8
0.000	564.683	0.000	0.000	0.000	3989.486	23.55	17.55	167.2
0.000	496.242	0.000	0.000	0.000	3505.951	23.55	17.55	171.6
0.000	426.707	0.000	0.000	0.000	3014.685	23.55	17.55	174.9
0.000	428.046	0.000	0.000	0.000	3024.142	23.55	17.55	178.2
0.000	429.366	0.000	0.000	0.000	3033.473	23.55	17.55	181.5
0.000	430.670	0.000	0.000	0.000	3042.685	23.55	17.55	184.8
0.000	431.957	0.000	0.000	0.000	3051.780	23.55	17.55	188.1
0.000	433.229	0.000	0.000	0.000	3060.761	23.55	17.55	191.4
0.000	796.555	0.000	0.000	0.000	5627.660	23.55	17.55	194.7
0.000	875.520	0.000	0.000	0.000	6185.552	23.55	17.55	203.5
0.000	585.814	0.000	0.000	0.000	4138.774	23.55	17.55	207.9
0.000	587.915	0.000	0.000	0.000	4153.621	23.55	17.55	212.3
0.000	589.986	0.000	0.000	0.000	4168.249	23.55	17.55	216.7
0.000	592.026	0.000	0.000	0.000	4182.667	23.55	17.55	221.1
0.000	594.038	0.000	0.000	0.000	4196.881	23.55	17.55	225.5
0.000	596.022	0.000	0.000	0.000	4210.898	23.55	17.55	229.9
0.000	597.979	0.000	0.000	0.000	4224.725	23.55	17.55	234.3
0.000	599.911	0.000	0.000	0.000	4238.368	23.55	17.55	238.7
0.000	902.724	0.000	0.000	0.000	6377.748	23.55	17.55	243.1
0.000	908.333	0.000	0.000	0.000	6417.371	23.55	17.55	251.9
0.000	911.085	0.000	0.000	0.000	6436.812	23.55	17.55	256.3
0.000	916.488	0.000	0.000	0.000	6474.991	23.55	17.55	265.1
0.000	306.381	0.000	0.000	0.000	2164.581	23.55	17.55	269.5
0.000	943.832	0.000	0.000	0.000	-6668.171	23.55	17.55	8.8
0.000	394.956	0.000	0.000	0.000	-2790.364	23.55	17.55	13.2
0.000	1021.502	0.000	0.000	0.000	-7216.913	23.55	17.55	17.6
0.000	1116.184	0.000	0.000	0.000	-7885.838	23.55	17.55	35.2
0.000	453.688	0.000	0.000	0.000	-3205.305	23.55	17.55	39.6
0.000	460.350	0.000	0.000	0.000	-3252.376	23.55	17.55	44
0.000	466.553	0.000	0.000	0.000	-3296.195	23.55	17.55	48.4
0.000	472.364	0.000	0.000	0.000	-3337.254	23.55	17.55	52.8
0.000	418.110	0.000	0.000	0.000	-2953.945	23.55	17.55	57.2
0.000	361.314	0.000	0.000	0.000	-2552.681	23.55	17.55	60.5
0.000	364.136	0.000	0.000	0.000	-2572.618	23.55	17.55	63.8
0.000	366.855	0.000	0.000	0.000	-2591.831	23.55	17.55	67.1
0.000	677.381	0.000	0.000	0.000	-4785.696	23.55	17.55	70.4
0.000	752.153	0.000	0.000	0.000	-5313.960	23.55	17.55	79.2
0.000	505.572	0.000	0.000	0.000	-3571.869	23.55	17.55	83.6
0.000	509.557	0.000	0.000	0.000	-3600.020	23.55	17.55	88
0.000	513.402	0.000	0.000	0.000	-3627.182	23.55	17.55	92.4
0.000	452.478	0.000	0.000	0.000	-3196.756	23.55	17.55	96.8
0.000	389.870	0.000	0.000	0.000	-2754.429	23.55	17.55	100.1
0.000	391.854	0.000	0.000	0.000	-2768.447	23.55	17.55	103.4
0.000	393.793	0.000	0.000	0.000	-2782.148	23.55	17.55	106.7
0.000	395.690	0.000	0.000	0.000	-2795.551	23.55	17.55	110
0.000	728.836	0.000	0.000	0.000	-5149.227	23.55	17.55	113.3
0.000	804.633	0.000	0.000	0.000	-5684.730	23.55	17.55	122.1
0.000	539.479	0.000	0.000	0.000	-3811.421	23.55	17.55	126.5
0.000	474.654	0.000	0.000	0.000	-3353.430	23.55	17.55	130.9
0.000	408.489	0.000	0.000	0.000	-2885.973	23.55	17.55	134.2
0.000	410.103	0.000	0.000	0.000	-2897.376	23.55	17.55	137.5
0.000	411.689	0.000	0.000	0.000	-2908.585	23.55	17.55	140.8
0.000	413.250	0.000	0.000	0.000	-2919.608	23.55	17.55	144.1
0.000	414.784	0.000	0.000	0.000	-2930.452	23.55	17.55	147.4
0.000	416.295	0.000	0.000	0.000	-2941.124	23.55	17.55	150.7
0.000	765.934	0.000	0.000	0.000	-5411.322	23.55	17.55	154
0.000	843.279	0.000	0.000	0.000	-5957.764	23.55	17.55	162.8
0.000	564.683	0.000	0.000	0.000	-3989.486	23.55	17.55	167.2
0.000	496.242	0.000	0.000	0.000	-3505.951	23.55	17.55	171.6
0.000	426.707	0.000	0.000	0.000	-3014.685	23.55	17.55	174.9
0.000	428.046	0.000	0.000	0.000	-3024.142	23.55	17.55	178.2
0.000	429.366	0.000	0.000	0.000	-3033.473	23.55	17.55	181.5
0.000	430.670	0.000	0.000	0.000	-3042.685	23.55	17.55	184.8
0.000	431.957	0.000	0.000	0.000	-3051.780	23.55	17.55	188.1
0.000	433.229	0.000	0.000	0.000	-3060.761	23.55	17.55	191.4
0.000	796.555	0.000	0.000	0.000	-5627.660	23.55	17.55	194.7
0.000	875.520	0.000	0.000	0.000	-6185.552	23.55	17.55	203.5
0.000	585.814	0.000	0.000	0.000	-4138.774	23.55	17.55	207.9
0.000	587.915	0.000	0.000	0.000	-4153.621	23.55	17.55	212.3
0.000	589.986	0.000	0.000	0.000	-4168.249	23.55	17.55	216.7
0.000	592.026	0.000	0.000	0.000	-4182.667	23.55	17.55	221.1
0.000	594.038	0.000	0.000	0.000	-4196.881	23.55	17.55	225.5
0.000	596.022	0.000	0.000	0.000	-4210.898	23.55	17.55	229.9
0.000	597.979	0.000	0.000	0.000	-4224.725	23.55	17.55	234.3
0.000	599.911	0.000	0.000	0.000	-4238.368	23.55	17.55	238.7
0.000	902.724	0.000	0.000	0.000	-6377.748	23.55	17.55	243.1
0.000	908.333	0.000	0.000	0.000	-6417.371	23.55	17.55	251.9
0.000	911.085	0.000	0.000	0.000	-6436.812	23.55	17.55	256.3
0.000	916.488	0.000	0.000	0.000	-6474.991	23.55	17.55	265.1
0.000	306.381	0.000	0.000	0.000	-2164.581	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
703.365	-943.832	0.000	0.000	0.000	0.001	23.55	17.55	8.8
294.330	-394.956	0.000	0.000	0.000	0.001	23.55	17.55	13.2
761.247	-1021.502	0.000	0.000	0.000	0.001	23.55	17.55	17.6
831.806	-1116.184	0.000	0.000	0.000	0.002	23.55	17.55	35.2
338.099	-453.688	0.000	0.000	0.000	0.001	23.55	17.55	39.6
343.064	-460.350	0.000	0.000	0.000	0.001	23.55	17.55	44
347.686	-466.553	0.000	0.000	0.000	0.001	23.55	17.55	48.4
352.017	-472.364	0.000	0.000	0.000	0.001	23.55	17.55	52.8
311.585	-418.110	0.000	0.000	0.000	0.001	23.55	17.55	57.2
269.259	-361.314	0.000	0.000	0.000	0.000	23.55	17.55	60.5
271.362	-364.136	0.000	0.000	0.000	0.000	23.55	17.55	63.8
273.389	-366.855	0.000	0.000	0.000	0.000	23.55	17.55	67.1
504.800	-677.381	0.000	0.000	0.000	0.001	23.55	17.55	70.4
560.522	-752.153	0.000	0.000	0.000	0.001	23.55	17.55	79.2
376.764	-505.572	0.000	0.000	0.000	0.001	23.55	17.55	83.6
379.734	-509.557	0.000	0.000	0.000	0.001	23.55	17.55	88
382.599	-513.402	0.000	0.000	0.000	0.001	23.55	17.55	92.4
337.197	-452.478	0.000	0.000	0.000	0.001	23.55	17.55	96.8
290.540	-389.870	0.000	0.000	0.000	0.001	23.55	17.55	100.1
292.018	-391.854	0.000	0.000	0.000	0.001	23.55	17.55	103.4
293.464	-393.793	0.000	0.000	0.000	0.001	23.55	17.55	106.7
294.877	-395.690	0.000	0.000	0.000	0.001	23.55	17.55	110
543.145	-728.836	0.000	0.000	0.000	0.001	23.55	17.55	113.3
599.631	-804.633	0.000	0.000	0.000	0.001	23.55	17.55	122.1
402.032	-539.479	0.000	0.000	0.000	0.001	23.55	17.55	126.5
353.723	-474.654	0.000	0.000	0.000	0.001	23.55	17.55	130.9
304.415	-408.489	0.000	0.000	0.000	0.001	23.55	17.55	134.2
305.618	-410.103	0.000	0.000	0.000	0.001	23.55	17.55	137.5
306.800	-411.689	0.000	0.000	0.000	0.001	23.55	17.55	140.8
307.963	-413.250	0.000	0.000	0.000	0.001	23.55	17.55	144.1
309.107	-414.784	0.000	0.000	0.000	0.001	23.55	17.55	147.4
310.233	-416.295	0.000	0.000	0.000	0.001	23.55	17.55	150.7
570.791	-765.934	0.000	0.000	0.000	0.001	23.55	17.55	154
628.431	-843.279	0.000	0.000	0.000	0.001	23.55	17.55	162.8
420.815	-564.683	0.000	0.000	0.000	0.001	23.55	17.55	167.2
369.811	-496.242	0.000	0.000	0.000	0.001	23.55	17.55	171.6
317.992	-426.707	0.000	0.000	0.000	0.001	23.55	17.55	174.9
318.989	-428.046	0.000	0.000	0.000	0.001	23.55	17.55	178.2
319.974	-429.366	0.000	0.000	0.000	0.001	23.55	17.55	181.5
320.945	-430.670	0.000	0.000	0.000	0.001	23.55	17.55	184.8
321.905	-431.957	0.000	0.000	0.000	0.001	23.55	17.55	188.1
322.852	-433.229	0.000	0.000	0.000	0.001	23.55	17.55	191.4
593.611	-796.555	0.000	0.000	0.000	0.001	23.55	17.55	194.7
652.458	-875.520	0.000	0.000	0.000	0.001	23.55	17.55	203.5
436.562	-585.814	0.000	0.000	0.000	0.001	23.55	17.55	207.9
438.128	-587.915	0.000	0.000	0.000	0.001	23.55	17.55	212.3
439.671	-589.986	0.000	0.000	0.000	0.001	23.55	17.55	216.7
441.192	-592.026	0.000	0.000	0.000	0.001	23.55	17.55	221.1
442.691	-594.038	0.000	0.000	0.000	0.001	23.55	17.55	225.5
444.170	-596.022	0.000	0.000	0.000	0.001	23.55	17.55	229.9
445.628	-597.979	0.000	0.000	0.000	0.001	23.55	17.55	234.3
447.067	-599.911	0.000	0.000	0.000	0.001	23.55	17.55	238.7
672.731	-902.724	0.000	0.000	0.000	0.001	23.55	17.55	243.1
676.910	-908.333	0.000	0.000	0.000	0.001	23.55	17.55	251.9
678.961	-911.085	0.000	0.000	0.000	0.001	23.55	17.55	256.3
682.988	-916.488	0.000	0.000	0.000	0.001	23.55	17.55	265.1
228.322	-306.381	0.000	0.000	0.000	0.000	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
703.365	943.832	0.000	0.000	0.000	0.001	23.55	17.55	8.8
294.330	394.956	0.000	0.000	0.000	0.001	23.55	17.55	13.2
761.247	1021.502	0.000	0.000	0.000	0.001	23.55	17.55	17.6
831.806	1116.184	0.000	0.000	0.000	0.002	23.55	17.55	35.2
338.099	453.688	0.000	0.000	0.000	0.001	23.55	17.55	39.6
343.064	460.350	0.000	0.000	0.000	0.001	23.55	17.55	44
347.686	466.553	0.000	0.000	0.000	0.001	23.55	17.55	48.4
352.017	472.364	0.000	0.000	0.000	0.001	23.55	17.55	52.8
311.585	418.110	0.000	0.000	0.000	0.001	23.55	17.55	57.2
269.259	361.314	0.000	0.000	0.000	0.000	23.55	17.55	60.5
271.362	364.136	0.000	0.000	0.000	0.000	23.55	17.55	63.8
273.389	366.855	0.000	0.000	0.000	0.000	23.55	17.55	67.1
504.800	677.381	0.000	0.000	0.000	0.001	23.55	17.55	70.4
560.522	752.153	0.000	0.000	0.000	0.001	23.55	17.55	79.2
376.764	505.572	0.000	0.000	0.000	0.001	23.55	17.55	83.6
379.734	509.557	0.000	0.000	0.000	0.001	23.55	17.55	88
382.599	513.402	0.000	0.000	0.000	0.001	23.55	17.55	92.4
337.197	452.478	0.000	0.000	0.000	0.001	23.55	17.55	96.8
290.540	389.870	0.000	0.000	0.000	0.001	23.55	17.55	100.1
292.018	391.854	0.000	0.000	0.000	0.001	23.55	17.55	103.4
293.464	393.793	0.000	0.000	0.000	0.001	23.55	17.55	106.7
294.877	395.690	0.000	0.000	0.000	0.001	23.55	17.55	110
543.145	728.836	0.000	0.000	0.000	0.001	23.55	17.55	113.3
599.631	804.633	0.000	0.000	0.000	0.001	23.55	17.55	122.1
402.032	539.479	0.000	0.000	0.000	0.001	23.55	17.55	126.5
353.723	474.654	0.000	0.000	0.000	0.001	23.55	17.55	130.9
304.415	408.489	0.000	0.000	0.000	0.001	23.55	17.55	134.2
305.618	410.103	0.000	0.000	0.000	0.001	23.55	17.55	137.5
306.800	411.689	0.000	0.000	0.000	0.001	23.55	17.55	140.8
307.963	413.250	0.000	0.000	0.000	0.001	23.55	17.55	144.1
309.107	414.784	0.000	0.000	0.000	0.001	23.55	17.55	147.4
310.233	416.295	0.000	0.000	0.000	0.001	23.55	17.55	150.7
570.791	765.934	0.000	0.000	0.000	0.001	23.55	17.55	154
628.431	843.279	0.000	0.000	0.000	0.001	23.55	17.55	162.8
420.815	564.683	0.000	0.000	0.000	0.001	23.55	17.55	167.2
369.811	496.242	0.000	0.000	0.000	0.001	23.55	17.55	171.6
317.992	426.707	0.000	0.000	0.000	0.001	23.55	17.55	174.9
318.989	428.046	0.000	0.000	0.000	0.001	23.55	17.55	178.2
319.974	429.366	0.000	0.000	0.000	0.001	23.55	17.55	181.5
320.945	430.670	0.000	0.000	0.000	0.001	23.55	17.55	184.8
321.905	431.957	0.000	0.000	0.000	0.001	23.55	17.55	188.1
322.852	433.229	0.000	0.000	0.000	0.001	23.55	17.55	191.4
593.611	796.555	0.000	0.000	0.000	0.001	23.55	17.55	194.7
652.458	875.520	0.000	0.000	0.000	0.001	23.55	17.55	203.5
436.562	585.814	0.000	0.000	0.000	0.001	23.55	17.55	207.9
438.128	587.915	0.000	0.000	0.000	0.001	23.55	17.55	212.3
439.671	589.986	0.000	0.000	0.000	0.001	23.55	17.55	216.7
441.192	592.026	0.000	0.000	0.000	0.001	23.55	17.55	221.1
442.691	594.038	0.000	0.000	0.000	0.001	23.55	17.55	225.5
444.170	596.022	0.000	0.000	0.000	0.001	23.55	17.55	229.9
445.628	597.979	0.000	0.000	0.000	0.001	23.55	17.55	234.3
447.067	599.911	0.000	0.000	0.000	0.001	23.55	17.55	238.7
672.731	902.724	0.000	0.000	0.000	0.001	23.55	17.55	243.1
676.910	908.333	0.000	0.000	0.000	0.001	23.55	17.55	251.9
678.961	911.085	0.000	0.000	0.000	0.001	23.55	17.55	256.3
682.988	916.488	0.000	0.000	0.000	0.001	23.55	17.55	265.1
228.322	306.381	0.000	0.000	0.000	0.000	23.55	17.55	269.5
527.993	-708.503	0.000	0.000	0.000	7785.456	23.55	17.55	8.8

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
527.993	-708.503	0.000	0.000	0.000	7785.456	23.55	17.55	8.8
220.944	-296.480	0.000	0.000	0.000	3257.903	23.55	17.55	13.2
571.443	-766.808	0.000	0.000	0.000	8426.143	23.55	17.55	17.6
624.409	-837.882	0.000	0.000	0.000	9207.149	23.55	17.55	35.2
253.799	-340.568	0.000	0.000	0.000	3742.370	23.55	17.55	39.6
257.527	-345.570	0.000	0.000	0.000	3797.328	23.55	17.55	44
260.996	-350.226	0.000	0.000	0.000	3848.489	23.55	17.55	48.4
264.247	-354.588	0.000	0.000	0.000	3896.427	23.55	17.55	52.8
233.896	-313.861	0.000	0.000	0.000	3448.893	23.55	17.55	57.2
202.124	-271.226	0.000	0.000	0.000	2980.396	23.55	17.55	60.5
203.703	-273.344	0.000	0.000	0.000	3003.673	23.55	17.55	63.8
205.224	-275.386	0.000	0.000	0.000	3026.105	23.55	17.55	67.1
378.936	-508.487	0.000	0.000	0.000	5587.563	23.55	17.55	70.4
420.765	-564.616	0.000	0.000	0.000	6204.340	23.55	17.55	79.2
282.824	-379.516	0.000	0.000	0.000	4170.354	23.55	17.55	83.6
285.053	-382.507	0.000	0.000	0.000	4203.221	23.55	17.55	88
287.204	-385.393	0.000	0.000	0.000	4234.934	23.55	17.55	92.4
253.122	-339.660	0.000	0.000	0.000	3732.388	23.55	17.55	96.8
218.099	-292.662	0.000	0.000	0.000	3215.947	23.55	17.55	100.1
219.208	-294.152	0.000	0.000	0.000	3232.313	23.55	17.55	103.4
220.293	-295.607	0.000	0.000	0.000	3248.311	23.55	17.55	106.7
221.355	-297.031	0.000	0.000	0.000	3263.959	23.55	17.55	110
407.721	-547.113	0.000	0.000	0.000	6012.005	23.55	17.55	113.3
450.123	-604.011	0.000	0.000	0.000	6637.235	23.55	17.55	122.1
301.792	-404.969	0.000	0.000	0.000	4450.043	23.55	17.55	126.5
265.528	-356.307	0.000	0.000	0.000	3915.314	23.55	17.55	130.9
228.514	-306.639	0.000	0.000	0.000	3369.532	23.55	17.55	134.2
229.417	-307.850	0.000	0.000	0.000	3382.846	23.55	17.55	137.5
230.305	-309.041	0.000	0.000	0.000	3395.933	23.55	17.55	140.8
231.178	-310.213	0.000	0.000	0.000	3408.803	23.55	17.55	144.1
232.036	-311.365	0.000	0.000	0.000	3421.464	23.55	17.55	147.4
232.881	-312.499	0.000	0.000	0.000	3433.924	23.55	17.55	150.7
428.474	-574.961	0.000	0.000	0.000	6318.016	23.55	17.55	154
471.742	-633.021	0.000	0.000	0.000	6956.017	23.55	17.55	162.8
315.892	-423.889	0.000	0.000	0.000	4657.944	23.55	17.55	167.2
277.605	-372.512	0.000	0.000	0.000	4093.391	23.55	17.55	171.6
238.706	-320.315	0.000	0.000	0.000	3519.811	23.55	17.55	174.9
239.455	-321.319	0.000	0.000	0.000	3530.851	23.55	17.55	178.2
240.194	-322.311	0.000	0.000	0.000	3541.747	23.55	17.55	181.5
240.923	-323.290	0.000	0.000	0.000	3552.502	23.55	17.55	184.8
241.643	-324.256	0.000	0.000	0.000	3563.120	23.55	17.55	188.1
242.354	-325.210	0.000	0.000	0.000	3573.607	23.55	17.55	191.4
445.604	-597.947	0.000	0.000	0.000	6570.602	23.55	17.55	194.7
489.778	-657.224	0.000	0.000	0.000	7221.972	23.55	17.55	203.5
327.712	-439.751	0.000	0.000	0.000	4832.246	23.55	17.55	207.9
328.888	-441.328	0.000	0.000	0.000	4849.580	23.55	17.55	212.3
330.046	-442.883	0.000	0.000	0.000	4866.660	23.55	17.55	216.7
331.188	-444.414	0.000	0.000	0.000	4883.493	23.55	17.55	221.1
332.313	-445.925	0.000	0.000	0.000	4900.089	23.55	17.55	225.5
333.423	-447.414	0.000	0.000	0.000	4916.455	23.55	17.55	229.9
334.518	-448.883	0.000	0.000	0.000	4932.599	23.55	17.55	234.3
335.598	-450.333	0.000	0.000	0.000	4948.528	23.55	17.55	238.7
504.997	-677.645	0.000	0.000	0.000	7446.372	23.55	17.55	243.1
508.134	-681.855	0.000	0.000	0.000	7492.633	23.55	17.55	251.9
509.673	-683.921	0.000	0.000	0.000	7515.332	23.55	17.55	256.3
512.696	-687.977	0.000	0.000	0.000	7559.908	23.55	17.55	265.1
171.394	-229.990	0.000	0.000	0.000	2527.267	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
527.993	-708.503	0.000	0.000	0.000	-7785.454	23.55	17.55	8.8
220.944	-296.480	0.000	0.000	0.000	-3257.902	23.55	17.55	13.2
571.443	-766.808	0.000	0.000	0.000	-8426.141	23.55	17.55	17.6
624.409	-837.882	0.000	0.000	0.000	-9207.147	23.55	17.55	35.2
253.799	-340.568	0.000	0.000	0.000	-3742.369	23.55	17.55	39.6
257.527	-345.570	0.000	0.000	0.000	-3797.327	23.55	17.55	44
260.996	-350.226	0.000	0.000	0.000	-3848.488	23.55	17.55	48.4
264.247	-354.588	0.000	0.000	0.000	-3896.426	23.55	17.55	52.8
233.896	-313.861	0.000	0.000	0.000	-3448.892	23.55	17.55	57.2
202.124	-271.226	0.000	0.000	0.000	-2980.395	23.55	17.55	60.5
203.703	-273.344	0.000	0.000	0.000	-3003.672	23.55	17.55	63.8
205.224	-275.386	0.000	0.000	0.000	-3026.104	23.55	17.55	67.1
378.936	-508.487	0.000	0.000	0.000	-5587.562	23.55	17.55	70.4
420.765	-564.616	0.000	0.000	0.000	-6204.338	23.55	17.55	79.2
282.824	-379.516	0.000	0.000	0.000	-4170.353	23.55	17.55	83.6
285.053	-382.507	0.000	0.000	0.000	-4203.220	23.55	17.55	88
287.204	-385.393	0.000	0.000	0.000	-4234.933	23.55	17.55	92.4
253.122	-339.660	0.000	0.000	0.000	-3732.388	23.55	17.55	96.8
218.099	-292.662	0.000	0.000	0.000	-3215.946	23.55	17.55	100.1
219.208	-294.152	0.000	0.000	0.000	-3232.313	23.55	17.55	103.4
220.293	-295.607	0.000	0.000	0.000	-3248.310	23.55	17.55	106.7
221.355	-297.031	0.000	0.000	0.000	-3263.958	23.55	17.55	110
407.721	-547.113	0.000	0.000	0.000	-6012.004	23.55	17.55	113.3
450.123	-604.011	0.000	0.000	0.000	-6637.233	23.55	17.55	122.1
301.792	-404.969	0.000	0.000	0.000	-4450.042	23.55	17.55	126.5
265.528	-356.307	0.000	0.000	0.000	-3915.313	23.55	17.55	130.9
228.514	-306.639	0.000	0.000	0.000	-3369.532	23.55	17.55	134.2
229.417	-307.850	0.000	0.000	0.000	-3382.845	23.55	17.55	137.5
230.305	-309.041	0.000	0.000	0.000	-3395.932	23.55	17.55	140.8
231.178	-310.213	0.000	0.000	0.000	-3408.802	23.55	17.55	144.1
232.036	-311.365	0.000	0.000	0.000	-3421.463	23.55	17.55	147.4
232.881	-312.499	0.000	0.000	0.000	-3433.923	23.55	17.55	150.7
428.474	-574.961	0.000	0.000	0.000	-6318.014	23.55	17.55	154
471.742	-633.021	0.000	0.000	0.000	-6956.015	23.55	17.55	162.8
315.892	-423.889	0.000	0.000	0.000	-4657.943	23.55	17.55	167.2
277.605	-372.512	0.000	0.000	0.000	-4093.390	23.55	17.55	171.6
238.706	-320.315	0.000	0.000	0.000	-3519.810	23.55	17.55	174.9
239.455	-321.319	0.000	0.000	0.000	-3530.851	23.55	17.55	178.2
240.194	-322.311	0.000	0.000	0.000	-3541.746	23.55	17.55	181.5
240.923	-323.290	0.000	0.000	0.000	-3552.501	23.55	17.55	184.8
241.643	-324.256	0.000	0.000	0.000	-3563.120	23.55	17.55	188.1
242.354	-325.210	0.000	0.000	0.000	-3573.606	23.55	17.55	191.4
445.604	-597.947	0.000	0.000	0.000	-6570.600	23.55	17.55	194.7
489.778	-657.224	0.000	0.000	0.000	-7221.970	23.55	17.55	203.5
327.712	-439.751	0.000	0.000	0.000	-4832.245	23.55	17.55	207.9
328.888	-441.328	0.000	0.000	0.000	-4849.579	23.55	17.55	212.3
330.046	-442.883	0.000	0.000	0.000	-4866.658	23.55	17.55	216.7
331.188	-444.414	0.000	0.000	0.000	-4883.492	23.55	17.55	221.1
332.313	-445.925	0.000	0.000	0.000	-4900.088	23.55	17.55	225.5
333.423	-447.414	0.000	0.000	0.000	-4916.454	23.55	17.55	229.9
334.518	-448.883	0.000	0.000	0.000	-4932.598	23.55	17.55	234.3
335.598	-450.333	0.000	0.000	0.000	-4948.526	23.55	17.55	238.7
504.997	-677.645	0.000	0.000	0.000	-7446.370	23.55	17.55	243.1
508.134	-681.855	0.000	0.000	0.000	-7492.631	23.55	17.55	251.9
509.673	-683.921	0.000	0.000	0.000	-7515.330	23.55	17.55	256.3
512.696	-687.977	0.000	0.000	0.000	-7559.906	23.55	17.55	265.1
171.394	-229.990	0.000	0.000	0.000	-2527.266	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
527.993	708.503	0.000	0.000	0.000	7785.456	23.55	17.55	8.8
220.944	296.480	0.000	0.000	0.000	3257.903	23.55	17.55	13.2
571.443	766.808	0.000	0.000	0.000	8426.143	23.55	17.55	17.6
624.409	837.882	0.000	0.000	0.000	9207.149	23.55	17.55	35.2
253.799	340.568	0.000	0.000	0.000	3742.370	23.55	17.55	39.6
257.527	345.570	0.000	0.000	0.000	3797.328	23.55	17.55	44
260.996	350.226	0.000	0.000	0.000	3848.489	23.55	17.55	48.4
264.247	354.588	0.000	0.000	0.000	3896.427	23.55	17.55	52.8
233.896	313.861	0.000	0.000	0.000	3448.893	23.55	17.55	57.2
202.124	271.226	0.000	0.000	0.000	2980.396	23.55	17.55	60.5
203.703	273.344	0.000	0.000	0.000	3003.673	23.55	17.55	63.8
205.224	275.386	0.000	0.000	0.000	3026.105	23.55	17.55	67.1
378.936	508.487	0.000	0.000	0.000	5587.563	23.55	17.55	70.4
420.765	564.616	0.000	0.000	0.000	6204.340	23.55	17.55	79.2
282.824	379.516	0.000	0.000	0.000	4170.354	23.55	17.55	83.6
285.053	382.507	0.000	0.000	0.000	4203.221	23.55	17.55	88
287.204	385.393	0.000	0.000	0.000	4234.934	23.55	17.55	92.4
253.122	339.660	0.000	0.000	0.000	3732.388	23.55	17.55	96.8
218.099	292.662	0.000	0.000	0.000	3215.947	23.55	17.55	100.1
219.208	294.152	0.000	0.000	0.000	3232.313	23.55	17.55	103.4
220.293	295.607	0.000	0.000	0.000	3248.311	23.55	17.55	106.7
221.355	297.031	0.000	0.000	0.000	3263.959	23.55	17.55	110
407.721	547.113	0.000	0.000	0.000	6012.005	23.55	17.55	113.3
450.123	604.011	0.000	0.000	0.000	6637.235	23.55	17.55	122.1
301.792	404.969	0.000	0.000	0.000	4450.043	23.55	17.55	126.5
265.528	356.307	0.000	0.000	0.000	3915.314	23.55	17.55	130.9
228.514	306.639	0.000	0.000	0.000	3369.532	23.55	17.55	134.2
229.417	307.850	0.000	0.000	0.000	3382.846	23.55	17.55	137.5
230.305	309.041	0.000	0.000	0.000	3395.933	23.55	17.55	140.8
231.178	310.213	0.000	0.000	0.000	3408.803	23.55	17.55	144.1
232.036	311.365	0.000	0.000	0.000	3421.464	23.55	17.55	147.4
232.881	312.499	0.000	0.000	0.000	3433.924	23.55	17.55	150.7
428.474	574.961	0.000	0.000	0.000	6318.016	23.55	17.55	154
471.742	633.021	0.000	0.000	0.000	6956.017	23.55	17.55	162.8
315.892	423.889	0.000	0.000	0.000	4657.944	23.55	17.55	167.2
277.605	372.512	0.000	0.000	0.000	4093.391	23.55	17.55	171.6
238.706	320.315	0.000	0.000	0.000	3519.811	23.55	17.55	174.9
239.455	321.319	0.000	0.000	0.000	3530.851	23.55	17.55	178.2
240.194	322.311	0.000	0.000	0.000	3541.747	23.55	17.55	181.5
240.923	323.290	0.000	0.000	0.000	3552.502	23.55	17.55	184.8
241.643	324.256	0.000	0.000	0.000	3563.120	23.55	17.55	188.1
242.354	325.210	0.000	0.000	0.000	3573.607	23.55	17.55	191.4
445.604	597.947	0.000	0.000	0.000	6570.602	23.55	17.55	194.7
489.778	657.224	0.000	0.000	0.000	7221.972	23.55	17.55	203.5
327.712	439.751	0.000	0.000	0.000	4832.246	23.55	17.55	207.9
328.888	441.328	0.000	0.000	0.000	4849.580	23.55	17.55	212.3
330.046	442.883	0.000	0.000	0.000	4866.660	23.55	17.55	216.7
331.188	444.414	0.000	0.000	0.000	4883.493	23.55	17.55	221.1
332.313	445.925	0.000	0.000	0.000	4900.089	23.55	17.55	225.5
333.423	447.414	0.000	0.000	0.000	4916.455	23.55	17.55	229.9
334.518	448.883	0.000	0.000	0.000	4932.599	23.55	17.55	234.3
335.598	450.333	0.000	0.000	0.000	4948.528	23.55	17.55	238.7
504.997	677.645	0.000	0.000	0.000	7446.372	23.55	17.55	243.1
508.134	681.855	0.000	0.000	0.000	7492.633	23.55	17.55	251.9
509.673	683.921	0.000	0.000	0.000	7515.332	23.55	17.55	256.3
512.696	687.977	0.000	0.000	0.000	7559.908	23.55	17.55	265.1
171.394	229.990	0.000	0.000	0.000	2527.267	23.55	17.55	269.5

FX	FY	FZ	MX	MY	MZ	X	Y	Z
KN	KN	KN	KN-m	KN-m	KN-m	m	m	m
527.993	708.503	0.000	0.000	0.000	-7785.454	23.55	17.55	8.8
220.944	296.480	0.000	0.000	0.000	-3257.902	23.55	17.55	13.2
571.443	766.808	0.000	0.000	0.000	-8426.141	23.55	17.55	17.6
624.409	837.882	0.000	0.000	0.000	-9207.147	23.55	17.55	35.2
253.799	340.568	0.000	0.000	0.000	-3742.369	23.55	17.55	39.6
257.527	345.570	0.000	0.000	0.000	-3797.327	23.55	17.55	44
260.996	350.226	0.000	0.000	0.000	-3848.488	23.55	17.55	48.4
264.247	354.588	0.000	0.000	0.000	-3896.426	23.55	17.55	52.8
233.896	313.861	0.000	0.000	0.000	-3448.892	23.55	17.55	57.2
202.124	271.226	0.000	0.000	0.000	-2980.395	23.55	17.55	60.5
203.703	273.344	0.000	0.000	0.000	-3003.672	23.55	17.55	63.8
205.224	275.386	0.000	0.000	0.000	-3026.104	23.55	17.55	67.1
378.936	508.487	0.000	0.000	0.000	-5587.562	23.55	17.55	70.4
420.765	564.616	0.000	0.000	0.000	-6204.338	23.55	17.55	79.2
282.824	379.516	0.000	0.000	0.000	-4170.353	23.55	17.55	83.6
285.053	382.507	0.000	0.000	0.000	-4203.220	23.55	17.55	88
287.204	385.393	0.000	0.000	0.000	-4234.933	23.55	17.55	92.4
253.122	339.660	0.000	0.000	0.000	-3732.388	23.55	17.55	96.8
218.099	292.662	0.000	0.000	0.000	-3215.946	23.55	17.55	100.1
219.208	294.152	0.000	0.000	0.000	-3232.313	23.55	17.55	103.4
220.293	295.607	0.000	0.000	0.000	-3248.310	23.55	17.55	106.7
221.355	297.031	0.000	0.000	0.000	-3263.958	23.55	17.55	110
407.721	547.113	0.000	0.000	0.000	-6012.004	23.55	17.55	113.3
450.123	604.011	0.000	0.000	0.000	-6637.233	23.55	17.55	122.1
301.792	404.969	0.000	0.000	0.000	-4450.042	23.55	17.55	126.5
265.528	356.307	0.000	0.000	0.000	-3915.313	23.55	17.55	130.9
228.514	306.639	0.000	0.000	0.000	-3369.532	23.55	17.55	134.2
229.417	307.850	0.000	0.000	0.000	-3382.845	23.55	17.55	137.5
230.305	309.041	0.000	0.000	0.000	-3395.932	23.55	17.55	140.8
231.178	310.213	0.000	0.000	0.000	-3408.802	23.55	17.55	144.1
232.036	311.365	0.000	0.000	0.000	-3421.463	23.55	17.55	147.4
232.881	312.499	0.000	0.000	0.000	-3433.923	23.55	17.55	150.7
428.474	574.961	0.000	0.000	0.000	-6318.014	23.55	17.55	154
471.742	633.021	0.000	0.000	0.000	-6956.015	23.55	17.55	162.8
315.892	423.889	0.000	0.000	0.000	-4657.943	23.55	17.55	167.2
277.605	372.512	0.000	0.000	0.000	-4093.390	23.55	17.55	171.6
238.706	320.315	0.000	0.000	0.000	-3519.810	23.55	17.55	174.9
239.455	321.319	0.000	0.000	0.000	-3530.851	23.55	17.55	178.2
240.194	322.311	0.000	0.000	0.000	-3541.746	23.55	17.55	181.5
240.923	323.290	0.000	0.000	0.000	-3552.501	23.55	17.55	184.8
241.643	324.256	0.000	0.000	0.000	-3563.120	23.55	17.55	188.1
242.354	325.210	0.000	0.000	0.000	-3573.606	23.55	17.55	191.4
445.604	597.947	0.000	0.000	0.000	-6570.600	23.55	17.55	194.7
489.778	657.224	0.000	0.000	0.000	-7221.970	23.55	17.55	203.5
327.712	439.751	0.000	0.000	0.000	-4832.245	23.55	17.55	207.9
328.888	441.328	0.000	0.000	0.000	-4849.579	23.55	17.55	212.3
330.046	442.883	0.000	0.000	0.000	-4866.658	23.55	17.55	216.7
331.188	444.414	0.000	0.000	0.000	-4883.492	23.55	17.55	221.1
332.313	445.925	0.000	0.000	0.000	-4900.088	23.55	17.55	225.5
333.423	447.414	0.000	0.000	0.000	-4916.454	23.55	17.55	229.9
334.518	448.883	0.000	0.000	0.000	-4932.598	23.55	17.55	234.3
335.598	450.333	0.000	0.000	0.000	-4948.526	23.55	17.55	238.7
504.997	677.645	0.000	0.000	0.000	-7446.370	23.55	17.55	243.1
508.134	681.855	0.000	0.000	0.000	-7492.631	23.55	17.55	251.9
509.673	683.921	0.000	0.000	0.000	-7515.330	23.55	17.55	256.3
512.696	687.977	0.000	0.000	0.000	-7559.906	23.55	17.55	265.1
171.394	229.990	0.000	0.000	0.000	-2527.266	23.55	17.55	269.5

E- SECOND ORDER ANALYSIS RESULTS FOR GROUND LEVEL COLUMNS

p-delta values(design values)										
TABLE: Element Forces - Frames										
Frame	**Station**	**OutputCase**	**CaseType**	**StepType**	**P**	**V2**	**V3**	**T**	**M2**	**M3**
Text	m	Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
5348	0.225	pdelta envelope	Combination	Max	-23898.7	127.771	214.563	79.9625	761.7798	520.859
5348	4.5125	pdelta envelope	Combination	Max	-24171.5	127.771	214.563	79.9625	1786.55	859.7466
5348	8.8	pdelta envelope	Combination	Max	-24444.2	127.771	214.563	79.9625	3081.085	1493.046
5348	0.225	pdelta envelope	Combination	Min	-47329.4	-152.783	-294.939	-80.1814	-1624.4	-27.408
5348	4.5125	pdelta envelope	Combination	Min	-47602.2	-152.783	-294.939	-80.1814	-2543.27	-189.211
5348	8.8	pdelta envelope	Combination	Min	-47875	-152.783	-294.939	-80.1814	-3299.21	-764.024
5362	0.225	pdelta envelope	Combination	Max	-24332.9	62.477	214.551	79.9625	812.9992	101.9873
5362	4.5125	pdelta envelope	Combination	Max	-24605.6	62.477	214.551	79.9625	1777.116	735.9627
5362	8.8	pdelta envelope	Combination	Max	-24878.4	62.477	214.551	79.9625	2702.994	1726.976
5362	0.225	pdelta envelope	Combination	Min	-56007.7	-234.821	-319.625	-80.1814	-1624.42	-471.538
5362	4.5125	pdelta envelope	Combination	Min	-56280.4	-234.821	-319.625	-80.1814	-2543.2	-287.738
5362	8.8	pdelta envelope	Combination	Min	-56553.2	-234.821	-319.625	-80.1814	-3299.08	-577.873
5376	0.225	pdelta envelope	Combination	Max	-23932.5	94.432	140.248	79.9625	914.8435	298.9083
5376	4.5125	pdelta envelope	Combination	Max	-24205.3	94.432	140.248	79.9625	1828.987	793.4744
5376	8.8	pdelta envelope	Combination	Max	-24478.1	94.432	140.248	79.9625	2578.102	1606.851
5376	0.225	pdelta envelope	Combination	Min	-53545.2	-192.16	-148.959	-80.1814	-1554.84	-240.829
5376	4.5125	pdelta envelope	Combination	Min	-53818	-192.16	-148.959	-80.1814	-2527.05	-239.143
5376	8.8	pdelta envelope	Combination	Min	-54090.8	-192.16	-148.959	-80.1814	-3271.25	-669.578
5390	0.225	pdelta envelope	Combination	Max	-23932.6	99.304	140.246	79.9625	911.2526	327.3833
5390	4.5125	pdelta envelope	Combination	Max	-24205.3	99.304	140.246	79.9625	1828.333	801.3877
5390	8.8	pdelta envelope	Combination	Max	-24478.1	99.304	140.246	79.9625	2580.443	1591.846
5390	0.225	pdelta envelope	Combination	Min	-55798	-186.915	-168.41	-80.1814	-1554.84	-212.88
5390	4.5125	pdelta envelope	Combination	Min	-56070.8	-186.915	-168.41	-80.1814	-2527.04	-231.785
5390	8.8	pdelta envelope	Combination	Min	-56343.5	-186.915	-168.41	-80.1814	-3271.23	-683.475
5404	0.225	pdelta envelope	Combination	Max	-25903.7	98.476	169.622	79.9625	908.497	325.2341
5404	4.5125	pdelta envelope	Combination	Max	-26176.5	98.476	169.622	79.9625	1828.526	801.7415
5404	8.8	pdelta envelope	Combination	Max	-26449.3	98.476	169.622	79.9625	2581.143	1590.957
5404	0.225	pdelta envelope	Combination	Min	-57324	-186.379	-224.856	-80.1814	-1552.25	-213.897
5404	4.5125	pdelta envelope	Combination	Min	-57596.7	-186.379	-224.856	-80.1814	-2527.19	-232.883
5404	8.8	pdelta envelope	Combination	Min	-57869.5	-186.379	-224.856	-80.1814	-3270.76	-681.358
5418	0.225	pdelta envelope	Combination	Max	-25903.6	94.463	169.627	79.9625	926.3343	302.3317
5418	4.5125	pdelta envelope	Combination	Max	-26176.3	94.463	169.627	79.9625	1832.308	795.8079
5418	8.8	pdelta envelope	Combination	Max	-26449.1	94.463	169.627	79.9625	2570.525	1602.104
5418	0.225	pdelta envelope	Combination	Min	-51230.6	-190.3	-198.761	-80.1814	-1552.25	-236.924
5418	4.5125	pdelta envelope	Combination	Min	-51503.3	-190.3	-198.761	-80.1814	-2527.23	-238.946
5418	8.8	pdelta envelope	Combination	Min	-51776.1	-190.3	-198.761	-80.1814	-3270.83	-669.906
5432	0.225	pdelta envelope	Combination	Max	-23898.9	144.52	309.682	79.9625	1266.63	571.9936
5432	4.5125	pdelta envelope	Combination	Max	-24171.7	144.52	309.682	79.9625	1919.319	861.1234
5432	8.8	pdelta envelope	Combination	Max	-24444.5	144.52	309.682	79.9625	2825.166	1459.646
5432	0.225	pdelta envelope	Combination	Min	-55573.7	-161.105	-205.174	-80.1814	-1078.61	14.4113
5432	4.5125	pdelta envelope	Combination	Min	-55846.5	-161.105	-205.174	-80.1814	-2399.73	-164.044
5432	8.8	pdelta envelope	Combination	Min	-56119.3	-161.105	-205.174	-80.1814	-3570.39	-811.888
5446	0.225	pdelta envelope	Combination	Max	-32576.9	45.748	309.673	79.9625	1389.485	101.2955
5446	4.5125	pdelta envelope	Combination	Max	-32849.6	45.748	309.673	79.9625	1931.412	737.3361
5446	8.8	pdelta envelope	Combination	Max	-33122.4	45.748	309.673	79.9625	2422.053	1729.344
5446	0.225	pdelta envelope	Combination	Min	-56007.4	-235.137	-219.667	-80.1814	-1078.6	-498.064
5446	4.5125	pdelta envelope	Combination	Min	-56280.2	-235.137	-219.667	-80.1814	-2399.66	-313.091
5446	8.8	pdelta envelope	Combination	Min	-56552.9	-235.137	-219.667	-80.1814	-3570.27	-530.29
5460	0.225	pdelta envelope	Combination	Max	-27197.5	94.075	190.671	79.9625	1200.673	298.1826
5460	4.5125	pdelta envelope	Combination	Max	-27470.3	94.075	190.671	79.9625	1904.232	794.8326
5460	8.8	pdelta envelope	Combination	Max	-27743.1	94.075	190.671	79.9625	2435.978	1609.233
5460	0.225	pdelta envelope	Combination	Min	-59062.9	-202.183	-99.136	-80.1814	-1265.57	-242.894
5460	4.5125	pdelta envelope	Combination	Min	-59335.7	-202.183	-99.136	-80.1814	-2450.9	-239.791
5460	8.8	pdelta envelope	Combination	Min	-59608.5	-202.183	-99.136	-80.1814	-3415.09	-668.67

TABLE: Element Forces - Frames										
Frame	Station	OutputCase	CaseType	StepType	P	V2	V3	T	M2	M3
Text	m	Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
5474	0.225	pdelta envelope	Combination	Max	-29450.1	99.682	190.669	79.9625	1203.856	328.2439
5474	4.5125	pdelta envelope	Combination	Max	-29722.9	99.682	190.669	79.9625	1905.361	802.7457
5474	8.8	pdelta envelope	Combination	Max	-29995.7	99.682	190.669	79.9625	2434.951	1593.499
5474	0.225	pdelta envelope	Combination	Min	-59062.9	-197.199	-117.546	-80.1814	-1265.57	-210.725
5474	4.5125	pdelta envelope	Combination	Min	-59335.6	-197.199	-117.546	-80.1814	-2450.89	-231.323
5474	8.8	pdelta envelope	Combination	Min	-59608.4	-197.199	-117.546	-80.1814	-3415.07	-684.665
5488	0.225	pdelta envelope	Combination	Max	-26910.5	94.559	218.794	79.9625	1191.141	301.9876
5488	4.5125	pdelta envelope	Combination	Max	-27183.3	94.559	218.794	79.9625	1902.048	797.169
5488	8.8	pdelta envelope	Combination	Max	-27456.1	94.559	218.794	79.9625	2438.816	1604.355
5488	0.225	pdelta envelope	Combination	Min	-58330.7	-201.015	-151.849	-80.1814	-1270.2	-236.38
5488	4.5125	pdelta envelope	Combination	Min	-58603.5	-201.015	-151.849	-80.1814	-2452.95	-238.908
5488	8.8	pdelta envelope	Combination	Min	-58876.3	-201.015	-151.849	-80.1814	-3411.12	-670.295
5502	0.225	pdelta envelope	Combination	Max	-33003.5	98.399	218.79	79.9625	1207.699	324.5113
5502	4.5125	pdelta envelope	Combination	Max	-33276.3	98.399	218.79	79.9625	1907.323	803.1016
5502	8.8	pdelta envelope	Combination	Max	-33549.1	98.399	218.79	79.9625	2432.326	1593.337
5502	0.225	pdelta envelope	Combination	Min	-58330.6	-197.051	-173.625	-80.1814	-1270.19	-214.353
5502	4.5125	pdelta envelope	Combination	Min	-58603.3	-197.051	-173.625	-80.1814	-2452.91	-233.108
5502	8.8	pdelta envelope	Combination	Min	-58876.1	-197.051	-173.625	-80.1814	-3411.05	-681.249
5516	0.225	pdelta envelope	Combination	Max	-34374.8	53.027	263.136	79.9625	1068.649	261.9281
5516	4.5125	pdelta envelope	Combination	Max	-34647.5	53.027	263.136	79.9625	1870.696	832.7429
5516	8.8	pdelta envelope	Combination	Max	-34920.3	53.027	263.136	79.9625	2924.042	1374.485
5516	0.225	pdelta envelope	Combination	Min	-48531.6	-112.449	-237.591	-80.1814	-1323.68	49.1219
5516	4.5125	pdelta envelope	Combination	Min	-48804.4	-112.449	-237.591	-80.1814	-2468.72	-48.7025
5516	8.8	pdelta envelope	Combination	Min	-49077.2	-112.449	-237.591	-80.1814	-3445.36	-286.753
5530	0.225	pdelta envelope	Combination	Max	-44316.2	10.649	263.126	79.9625	1163.275	48.3837
5530	4.5125	pdelta envelope	Combination	Max	-44588.9	10.649	263.126	79.9625	1873.06	776.4584
5530	8.8	pdelta envelope	Combination	Max	-44861.7	10.649	263.126	79.9625	2539.133	1480.76
5530	0.225	pdelta envelope	Combination	Min	-52375.6	-149.68	-261.324	-80.1814	-1323.68	-193.94
5530	4.5125	pdelta envelope	Combination	Min	-52648.4	-149.68	-261.324	-80.1814	-2468.64	-112.768
5530	8.8	pdelta envelope	Combination	Min	-52921.2	-149.68	-261.324	-80.1814	-3445.23	-165.787
5544	0.225	pdelta envelope	Combination	Max	-34374.8	47.866	247.738	79.9625	984.2898	240.0288
5544	4.5125	pdelta envelope	Combination	Max	-34647.6	47.866	247.738	79.9625	1848.461	832.2774
5544	8.8	pdelta envelope	Combination	Max	-34920.4	47.866	247.738	79.9625	2966.517	1373.216
5544	0.225	pdelta envelope	Combination	Min	-42417.5	-112.274	-252.471	-80.1814	-1412	19.5607
5544	4.5125	pdelta envelope	Combination	Min	-42690.2	-112.274	-252.471	-80.1814	-2491.99	-56.3644
5544	8.8	pdelta envelope	Combination	Min	-42963	-112.274	-252.471	-80.1814	-3401.4	-271.874
5558	0.225	pdelta envelope	Combination	Max	-38218.7	15.781	247.729	79.9625	1071.992	48.6459
5558	4.5125	pdelta envelope	Combination	Max	-38491.5	15.781	247.729	79.9625	1848.74	775.9933
5558	8.8	pdelta envelope	Combination	Max	-38764.3	15.781	247.729	79.9625	2583.747	1479.49
5558	0.225	pdelta envelope	Combination	Min	-52375.6	-149.505	-277.197	-80.1814	-1411.99	-164.463
5558	4.5125	pdelta envelope	Combination	Min	-52648.4	-149.505	-277.197	-80.1814	-2491.92	-104.869
5558	8.8	pdelta envelope	Combination	Min	-52921.1	-149.505	-277.197	-80.1814	-3401.28	-180.289

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