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A New Skyscraper for Eindhoven
Design Approaches to Formal Definition

Supervisor: **Prof. Andrea ROLANDO,**
Politecnico di Milano

Assistant Supervisor: **Prof. Mario SASSONE,**
Politecnico di Torino

Masters Degree Thesis of:

Lucia D'AMATO ID 763331

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ABSTRACT

The thesis consists of the project for a high rise building located in the central part of the city of Eindhoven, The Netherlands, whose final features are reached through a design process based on different approaches, from the context analysis, to the structural, to the optimization of its aspects through parametrization.
The thesis work is composed by an introductive part with a brief history of the skyscraper and of the evolution of its features, to go deeper in the thesis topic analyzing the national and local context in which the project is inserted.
An extended description of the urban context in which the project is located offers a complete view of the urban fabric conformation, of the surrounding districts and of that in which the project site is located, of the building typologies and of the other high rises nearby, of the infrastructures and of the available services network.
To the contextualization of the designed building a wide description of the architectural features of the same follows, with the graphical representation of the project and a chapter on the structural design. In the latter the dimensioning of the bearing core structure, of the floors, of the vertical supports and of the foundations, besides verification calculations for horizontal acceleration and second order effects have been carried out.
The last chapter is dedicated to the description of a possible methodology for the application of the parametric modelling process through Grasshopper and Galapagos to the building design worth to the optimization of some aspects concerning the structure, such as the variation of the overhangs, or the form with the rotation of the floors according to wind direction or to passive shading necessities, the relation with the context, such as the variasion of the footprint or the height.
In order to reach a whole flexibility of the project in sight to fulfill different or changing needs, everything described in the abovementioned chapter leaves open the way to different possible methodologies to seek for the best solutions for improving some characteristics of the building or that would make it adaptable to new contexts.

ABSTRACT (ITA)

Questa tesi consiste nel progetto di un edificio di grande altezza collocato nel centro della città di Eindhoven, nei Paesi Bassi, le cui caratteristiche formali sono frutto di un processo progettuale basato su diversi approcci, dall'analisi contestuale, alla definizione tramite il dimensionamento strutturale, all'ottimizzazione dello stesso tramite un processo di parametrizzazione.
L'elaborato di tesi consta di una parte introduttiva con una breve storia del grattacielo e dell'evoluzione delle sue caratteristiche, per poi addentrarsi nell'argomento analizzando il contesto nazionale e locale in cui il progetto si colloca.
Un'estesa descrizione del contesto urbano in cui il progetto è localizzato fornisce un quadro completo della conformazione urbana, dei distretti che costituiscono la citta e di quello in cui il sito di progetto sorge, delle tipologie edilizie presenti e degli edifici di grande altezza già realizzati, delle infrastrutture e dei servizi fruibili.
Alla contestualizzazione dell'edificio progettato, segue un'ampia descrizione delle caratteristiche architettoniche dello stesso, corredata dagli elaborati grafici di progetto, e un capitolo sul design strutturale della costruzione. In quest'ultimo capitolo sono riportati il dimensionamento del nucleo portante, dei solai, delle strutture verticali e delle fondazioni, nonchè le verifiche addizionali per l'accelerazione orizzontale e gli effetti di second'ordine eseguiti.
L'ultimo capitolo della tesi è dedicato alla descrizione di una possibile metodologia per l'applicazione della modellazione parametrica tramite Grasshopper e Galapagos al progetto dell'edificio per raggiungere l'ottimizzazione di alcuni aspetti strutturali, come la variazione degli aggetti, di forma, con la rotazione dei piani in accordo con la direzione prevalente del vento o con le necessità di ombreggiamento passivo, o infine di relazione con il contesto, come la dimensione della base o dell'altezza dell'edificio.
In vista di una complessiva flessibilità del progetto per soddisfare diverse o nuove esigenze, quanto descritto nel suddetto capitolo lascia aperte numerose possibili metodologie per la ricerca di soluzioni che migliorino determinate caratteristiche dell'edificio o che lo rendano addattabile a nuovi contesti.

INTRODUCTION

fig. 0 - Shanghai Financial Center

The skyscraper is identified with a tall building in which the ratio between the plan area and the height is reversed in respect to traditional buildings: usually the footprint is much smaller than the facades area, which is developed with significantly greater height compared to the low-rise constructions.

The skyscraper evolved as a building typology since the necessities for optimizing land use due to increasing scarcity of this resource in parallel to world's population growth and to the consequent raising of land plots prices, enabling the realization of a significantly higher floor surface on a relatively small ground area.
Due to its peculiar characteristics, the high rise construction necessitates of specific solutions in order to work perfectly in their whole. The particular features of these building types, for instance, reverse the functioning of the structure, which is highly solicited at its base, working as a gigantic lever subject to stressful actions, in particular due to wind and, in exceptional cases, to earthquakes, that need for adequate structural expedients to work in safety.
Talking about services, the requirements for water transportation, which has to fight against gravity forces, for mechanical lifting of objects movement and people transportation, for fire protection, for electrical appliances, create a complex network of needs that could be satisfied with an as well articulated pattern of design solutions.

Relation between high-rise buildings and the context, meaning both the physical one (in terms of city-building relation, confrontation with the surrounding fabric, respect for the characteristics and the history of a place), the climatic and the geographic one, is much delicate than for other typologies. Besides the frequent absence of site-specific, at least aesthetic, characters of the skyscrapers makes this typology versatile and easily fitting to the most disparate conditions of location and weather factors, an accurate design process should, on the contrary, be aware of the differences in the features of each construction site in order to "customize" the product according to the particular challenges that the location imposes.
In order to reach this aim several aspects of the design should be accurately studied in order to give life to an high-quality result: the design of the building core and structure, with the related service spaces, should be tied to the specific use and influenced by the overall layout of the building, not less than to the structural necessities, the facades and the general form have to be enslaved to the resolution of the energetic and structural problems, following the requirements bonded to the orientation toward sun and wind forces, the building envelope has to answer to the necessities of functionality and environmental impact on the context, as well as the choice of materials, and finally the selection of energetic systems and green solutions should be improved to make the construction sensitive to environmental problems.
The use of high-tech technologies is worth **to search for a form of the building that has less impact as possible with the surrounding** landscape in order to be positively conformed to the neighbourhood and have less impact at sight. The challenge is, anyway, to establish if the skyscraper could really have, even if expressly designed for it, a small impact with its impressive presence.
For sure the necessity of the skyscraper is not anymore tied, or at least less than in the past, to the need for dwellings, but rather to the willingness to demonstrate technological capabilities, economical and social welfare of a nation, progress.

Besides some high rise structures, not for residential or commercial purposes, were realized long before the skyscrapers in Chicago or Manhattan able to compete in height (just refer as an example to the Tour Eiffel, realized in 1887 and 323 meters tall) the conditions for taking roots weren't still existing. There have been some fundamental reasons, besides the technical abilities to realize durable structures that were

obviously up to the necessities, that made the realization of the high rise buildings possible. These have been the invention of the lift and the patenting of a fire-retardant system of insulation of the iron structure.
Another parameter in the evolution of the skyscraper has to be taken into account: while in the "old continent" the building possibilities were widely allowing architecture styles to be expressed in the variety of the forms and of the styles, in the "new continent" the existence of strict urban grid with the regularity and standardization of the lots generated the necessity for applying compositional variation in height, in the care for aesthetical details and in the exploitation of the structure as a mean of architectural expression.

The high rise typology had a "window on the world" in the cases of the Universal Exhibitions, first of all in the Colombian Exhibition of Chicago in 1893, when the city had the occasion of implementing a part of it with new experimental buildings and to show to the public the innovations in the high rise field.
Of course, the acceptance of such an unusual typology was far to be reached and the architects, in order to see their buildings considered as a real architectural typology, were forced to hide all those elements that recalled the industrial past of the cities, such as steel structures, adopting however a more classical and historical style, with Romanesque, Gothic or Neoclassic elements.

With the increment of the height of the buildings, new legislations in the urban law were established in order to preserve the surrounding lots from being deprived of light and fresh air. This law defined some features of the buildings, in particular the form that was imposed to be tapered going higher with those setbacks that became a distinctive character of the American skyscraper, as in the famous Empire State Building.

A standstill point was reached in the 1930s when the economic crisis diverted the available capitals in other fields, such as the realization of dwellings at low prices and, in particular, in the war weapons and campaigns. However the diffusion of the myth of the American skyscraper through the exhibitions and International Architectural Congresses boosted the realization of similar architectural entities even in the other continents, such as in Europe and, in particular, in the Far East, such as in Shanghai. The continuous migrations were an incentive to the exportation of the high rise typology that brought the American architects all over the world.
However in Europe the instances to renovation never saw the realization but mainly remained in the utopian imaginary of pioneers such as Le Corbusier, with the projects of the city for 3 million inhabitants or the Ville Radieuse. (*High-rise manual: typology and design, Designing tall buildings: structure as architecture*)


fig. 0.1 - New York skyscrapers

chapter 1

BRIEF HISTORY OF THE SKYSCRAPER

fig. 1 - "Lunch Atop a Skyscraper"

The high rise typology was firstly born in the USA where the sudden growth of population evidenced the need for new lodgings to be developed in height in order to exploit better the available space.
While in the USA the typology was starting developing at the beginning of the 19th century, in Europe this typology flourished just after the First World War since the history of the cities of the old continent was sensitively different and less open to such a big change. Just some rare episodes were registered in the high rise building practice, such as the high rise district that was born in the 1960s in Frankfurt am Main.

No opportunity for building in height would have been provided without a revolutionary event that changed the way of moving people and materials: the elevator.
In 1853, in fact, the American inventor Elisha Graves Otis patented what was considered the first safe elevator for lifting people in high buildings. Even if different systems for materials transportation in the vertical direction were diffuse in the construction field before that date, this had a big impact on the public opinion since for the first time even men would have been able to be fastly transported in high buildings. In combination late in the years with the electric motor, the problem of building up to relevant height and living easily this spaces moving up and down with no risks and effort paved definitely the route to skyscrapers development. This innovation definitely pushed engineers and architects to think that the future of the construction sector would have been to bring materials and people at high eight and then that the building typology would have had its future in the high rise.
Not only the overall conception of the tall building was revolutionized, but also the hierarchy in force in the building: in fact while once the elegant and aristocratic apartments where located at the lower floors of the traditional building, with the introduction of the skyscraper the possibility of having more privacy, a better visual magnitude on the surrounding landscape and a better acoustic insulation from the trafficated roads made the spaces located in upper positions, toward the top of the towers, more desirable for people working and living in the new high rise constructions, and therefore the higher the rented space was, the more expensive it was as well.
A peculiar feature characterizing the skyscraper typology was, and still is, the combination of functions in the same building, characteristic that differentiated the American context from the European. This was mainly a speculation ploy since the realization of a wider range of functions in the same building not only diminished the construction costs, but was also useful to have a wider range of buyers for the same building.

The first step toward the construction of high rise structures was made in Chicago where, after the fire of 1871 an opportunity was created to revolutionize the building design process: the available land was no sufficient to cover the demand for lodgings, and then architects and builders were forced to devise to a new solution to meet the demand for housing.
The winning combination for the development of the skyscraper typology have been, however, the technological advancement in the use of cast iron and the prefabrication that enables fast assembling on-site of high-strength elements. This technology was firstly applied in 1885 in the Home Insurance Building, by William Lebaron Jenney, in Chicago that, with a height of 55 meters was, at the time, the higher building in the city, and not only, being rightly considered the forerunner of the modern skyscrapers.
In the following years Chicago has been the training ground for the growth of this typology with several buildings that experimented more and more audacious techniques, such as the Manhattan Building, the Monadnock Building, 1891, which was the first and unique unreinforced-masonry building, the Reliance Building, 1895, with a steel structure enclosed by a sort of first curtain glazed wall.

The first famous international competition for a high rise construction has certainly been that for the realization of the Chicaco Tribune Tower in 1922. This contest attracted several famous and emerging architects, such as Walter Gropius, Bruno Taut, Adolf Loos, evidencing as the new typology was imposing a new interesting challenge in architecture.
Authoritative personalities, in fact, acted in the field of high rise construction, such as Mies van der Rohe, with his 860 & 880 North Lake Shore Drive, 1951, 900 & 910 North Lake Shore Drive, 1956, with the experimentation of structural steel to realize minimalistic structures.

1.1 - Chrysler Building NYC

Chicago maintained its record till the 1920s when even outside the city, elsewhere in USA, the skyscraper typology started to diffuse. New York acquired the record in skyscrapers' construction with several higher and higher constructions that were erected at an impressive rhythm starting from 1900: the 500 Fifth Avenue, 212 meters, the Metropolitan Life Insurance Tower, 213 meters, the Chanin Building, 215 meters, the Woolworth Building, 241 meters, the General Electric Building, 270 meters, the Manhattan Bank, 282 meters, before the 1930s, the **Chrysler Building in 1930**, 320 meters high, the Empire State Building, 1931, 382 meters.

The Chrysler Building, commissioned by Walter Chrysler, famous automotive industry tycoon, is located in the East Side of Manhattan, in Lexington avenue, and have been the World's tallest building until 1931 thanks to its 40 meters-high stainless steel spire, designed by the architect William Van Allen. The style of the work echoes the more classic character of gothic cathedrals with an uncommon elegance in the details, such as the eagles hanging from 270 meters of height, and the elegant interior design.
Just two years later, John J. Raskob, chief of the brand Cadillac and stockholder of the General Motors, decided to occupy a whole building with its Corporation in order to impose its idealistic supremacy above the other brands. Since all the major buildings in Manhattan were already occupied by the most powerful corporations in every field, he planned the realization of a concurrent building in the 5th Avenue, where the old Waldorf Astoria Hotel had its base. The architects Shreve Lamb and Harmon designed the new **Empire State Building** that grew up at an impressive rhythm thanks to the best workers available in the construction field that concluded the work in just 16 months realizing the new World's tallest building with its 382 meters.

The techniques and the modalities of the construction improved with a fast rhythm allowing to reach unforeseen height with an incredible speed. The record reached in height by the Empire State Building remained unbeaten till the 1972 when the **World Trade Center** was constructed and reached the height of 417 meters. The architectural project of the WTC was realized thanks to the funds got from the fees for the goods movement and ships travelling through the New York and New Jersey harbour. The building was decided to be located, by the Port Authority, in the West Side of Manhattan in order to be near (1 kilometre of distance) to New Jersey. The architect Minoru Yamasaki, which worked in the architectural office that was in charge of the design of the Empire State Building, was destined to be the designer of the new skyscraper which was conceived as a couple of Twin Towers with completely new architectural features. A completely new system of ground disposal, construction techniques, vertical transportation had to be set up to built this giant work.

After this date the primacy went back to Chicago where the **Sears Tower** in 1973 reached 442 meters. This construction, also known as Willis Tower, was designed by Bruce Graham and Skidmore Owings & Merril. This is composed by 9 towers of different heights that are incorporated to constitute a unique giant block.
This has been the last milestone placed in the USA that, starting from 1998 lost its supremacy in the skyscrapers' field in favour of the emerging Asia, where in Kuala Lumpur, Malaysia, the **Petronas Towers** were built reaching a height of 452 meters. Commissioned by the famous petrol company Menara Petronas, these are two twin towers designed by the Argentinian architect Cesar Pelli connected by a so-called Skybridge, a hanging bridge at 171 meters above the ground that connects the two buildings allowing people to freely pass from one to the other.
Starting from this period, the vertical run toward the sky was no longer merely a matter of better exploitation of the available land for high density construction with lands saving, but the skyscraper became a symbol of power and health of a firm or a nation, or a demonstration of ability in engineering and architecture field to go beyond the limits.

1.2 - Petronas Towers, Kuala Lumpur

1.3 - Torre Hines, Milano

The last decade registered a relentless competition to reach the highest height. The "competitors" have been Taipei 101, 2004, realized in Taiwan and reaching 509 meters and **Burj Khalifa**, 2010, built in Dubai, United Arab Emirates, that became the highest building with its 828 meters and the world's fastest elevators.

The development in skyscrapers' architecture was made possible, however, thanks to the studies in the field of structural design, loads and wind actions calculation, geotechnical engineering, prefabrication systems, that where at the basis of the architectural possibilities of expression in the high rise buildings. Methods and materials have been continuously improved in order to make structures stronger, lighter, more functional and durable. The use of glass always went with the skyscraper construction, since the use of structural frames allowed to free the facade from massive bearing walls and to exploit at maximum natural light.
Deepen studies in the concrete techniques allowed to start using again this material as an economical and valid alternative to steel.

In Europe the development of high rise constructions has been hindered by the strong historical tradition of the old continent, with its medieval centers and the monuments scattered in the cities. Before the World War II, however, no high rise buildings arose from the projects that were widely designed by the architects. The choice of realizing skyscrapers was due to the reconstruction necessities emerged after the War, and mainly in the biggest centers such as Paris, London, Frankfurt and Moscow.

In Paris, for instance, a clustered high rise center was born at the periphery of the city and called La Défense starting from the 60s. Just in the same period in London some buildings overcame 100 meters, even if, differently from Paris, these

were more integrated in the existing urban fabric, both isolated and concentrated such as in the Bank Center with the 183 meters tall Nat West Bank Tower.
However, in London, in order to preserve the historical heritage a severe law regulates the buildings more than 150 meters tall: buildings of meaningful height are the Lloyds of London Tower by Richard Rogers built in 1986, the Swiss Re Tower, that reached 180 meters in 2001, those located in the Canary Wharf, the major business district of London, where some of the tallest buildings in Europe have been built, such as the One Canada Square was built in 1991 reaching 235 meters and the Heron Tower, built in 2010 and 230 meters tall.

In Italy, comparatively small buildings have however started to emerge. The urban regulations have always been more strict than in other parts of Europe, and in particular the strong historical past that characterized the Italian territory have always imposed a strong relation with the pre-existences, limiting therefore the possibilities of expression.

The first modern Italian "skyscraper" have been considered the Torre Piacentini in Genova, that overcame 100 meters in 1940 and kept the height record, at first even in Europe, till 1954, when the Torre Breda in Milano was realized.
The War blocked for a while the high rise boom that in the previous years brought to the realization of several constructions of relevant height. Just with the economical boom in Italy in the 1950s several constructions were again going vertical, such as the Pirelli Tower, realized by Gio Ponti in 1960, 127 meters tall, and the Torre Velasca, designed by the BBPR group in 1958, 106 meters tall.
The highest building in Italy is however being realized in Milan: the Torre Hines, or Unicredit in Milano, designed by Cesar Pelli, that just reached 231 meters.

chapter 2

HIGH RISE IN THE NETHERLANDS

fig. 2 - Erasmus Bridge, Rotterdam

In The Netherlands, more than in other countries in Europe, cities have strongly maintained in the years their original configuration, with the preservation of an architectural style typical and recognizable.
The famous houses on the canals, dated from the XVII and XXVIII centuries, still preserved their appearance and the major part of the modern houses and buildings realized in the surroundings in a certain way kept the fundamental characters of them, revisited in modern key.
Small lots, with semi-detached or terraced houses, with a thin bricks facade on the road, maximum 3 floors high, and a prevalent longitudinal trend in the interiors with the private backyard are still nowadays the imaginary that The Netherlands offer to the public.

Just few places had the occasion of developing a different kind of architecture, more oriented to the modernity and to the vertical development of the buildings. This untypical development involved mostly cities where the needs for office spaces or representative buildings came out, such as in Rotterdam, where the re-development of the entire area of the harbor allowed the major companies to establish there their business centers, or in The Hague, where the governmental bodies of The Netherlands and of Europe have their seats.

Even smaller centers, such as Eindhoven, as will be described after in the text, were involved in the construction of high rise buildings, in particular in the business districts of these cities. A common reason generated the occasion for this kind of development.
In The Netherlands, during the World War II relevant parts of the cities were bombed and completely destroyed: the need for reconstruction brought the architects that worked in these areas to intensify the construction of tall building, and in recent years names as Rem Koolhaas, Norman Foster, Mecanoo, Renzo Plano, to adopt the high rise typology as a symbol of economical power and health of the nation.

Huge investments of capital made the realization of numerous construction interventions, such as along the river Maas shore in Rotterdam. Here the modern buildings are in a way separated from the historical part, preserving its identity and creating a real island of the skyscrapers, connected to the other massive interventions on the other side of the river by the Erasmus Bridge.
Somwhere else the integration between new constructions and the historical urban fabric is stronger, such as in the Hague, and in other places, again, there was no more historical buildings to preserve, such as in Eindhoven, where the destructions of the war were so extended to eliminate the most of the old buildings and allowing the new construction to have no bonds on the territory.

However, high rise buildings in The Netherlands, compared with those in the rest of the world, are of limited height mainly because of strict regulation of the Dutch government about light penetration into the working and living spaces. According to the laws regulating this matter, in fact, due to the light deficiency during the year, the form of the building has to be exploited in order to grant the maximum possible entrance of natural light.
Given this, the buildings result to be endowed with a large height-to-width ratio and therefore they are usually with profound depth but quite narrow.
However, even if following the regulations several high rise building are emerging nowadays in The Netherlands, even if still not reaching record heights.

In this chapter a report of the highest buildings in The Netherland has been carried out in order to have a complete view of the state of the art in the Nation where the project is located.

MAASTOREN
ROTTERDAM

Location	**Wilhelminakade, Rotterdam**
Building use	**office, parking garage, restaurant**

Maastoren is the tallest in The Netherlands. Located in Rotterdam, its construction started in 2006 and ended in 2012. It consists of a 45 floors construction for a whole floors area of 36.500 m^2 hosting offices and a restaurant, besides a parking garage. The materials used are glass, steel and concrete. It has been designed by the architectural office Dam en Partners Architecten with a height of 165 meters.
This building is particularly advanced in the green aspects reducing sensitively the CO2 emissions.


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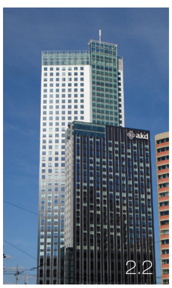
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NEW ORLEANS
ROTTERDAM

Location	**Otto Reuchlinweg, Rotterdam**
Building use	**residential, cinema**

New Orleans is located in Rotterdam, its construction started in 2007 and ended in 2010. It consists of a 43 floors construction for a whole of 238 living units hosting residential lodgings and a cinema. The materials used are steel and concrete. It has been designed by the architectural office Alvaro Siza Arquitecto with a height of 158 meters.


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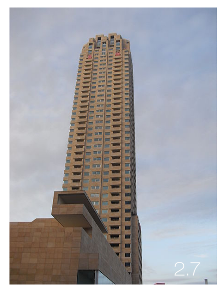
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GEBOUW DELFTSE POORT
ROTTERDAM

Location	**Weena 505, Rotterdam**
Building use	**office, parking garage, restaurant, retail**

Gebow Delftse Poort in Rotterdam is a complex with two twin skyscrapers next to the Rotterdam Centraal Station. The two towers are 151 and 93 meters tall and until 2009 they were the tallest office building in The Netherlands. Realized between 1989 and 1992 they are joined with a common basement and underground floor. They consist of a 41 floors construction with a surface of 106.000 m^2 hosting offices, a restaurant, retail services and a parking garage. The materials used are glass, aluminium, steel, reinforced concrete. It has been designed by the architect Abe Bonnema.


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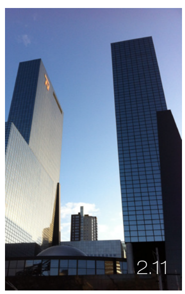
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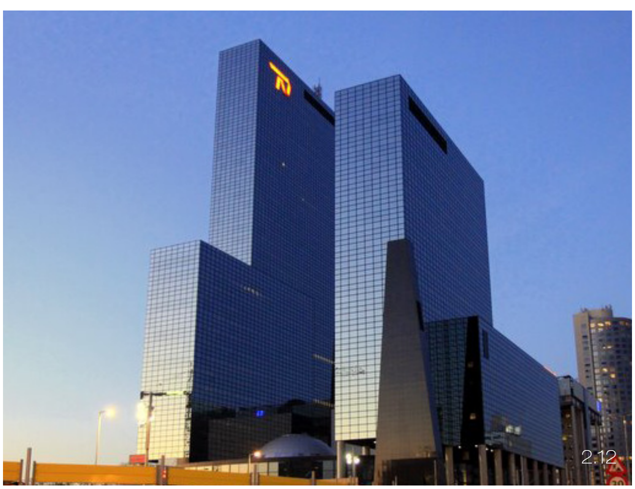
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DE ROTTERDAM
ROTTERDAM

Location	**Wilhelminakade, Rotterdam**
Building use	**mixed use**

De Rotterdam is located in Rotterdam, since 2009 it's still under construction and its conclusion is expected to be in 2012. It consists of a 41 floors construction for a whole of 136.000m^2 of floors area hosting residences, offices, a hotel, retail spaces, a fitness center and a parking garage. The materials used are steel and glass. It has been designed by the architectural Office for Metropolitan Architecture (OMA) and reaches a height of 149 meters.


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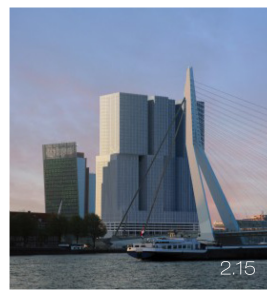
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NIEUW MINISTERIE VAN JUSTITIE
THE HAGUE

Location **Turfmarkt, The Hague**
Building use **office, government**

The Nieuw Ministerie van Justitie is located in The Hague. It is still under construction from 2008 and its conclusion is expected to be by the end of 2012.
It consists of a 39 floors construction 146 meters tall hosting offices and governmental functions. The materials used are glass, steel, bricks and concrete. It has been designed by the office Kollhoff und Timmermann Architekten.


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NIEUW MINISTERIE VAN BINNENLANDSE
THE HAGUE

Location **Turfmarkt, The Hague**
Building use **office, government**

The Nieuw Ministerie van Binnenlandse Zaken is located in The Hague. It is still under construction from 2008 and its conclusion is expected to be by the end of 2012.
It consists of a 39 floors construction 146 meters tall hosting offices and governmental functions. The materials used are glass, steel, marble and concrete. It has been designed by the office Kollhoff und Timmermann Architekten.


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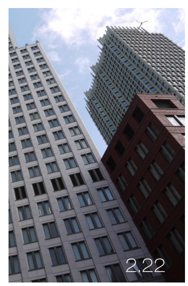
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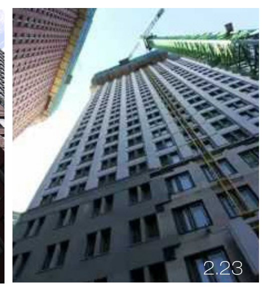
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HOFTOREN
THE HAGUE

Location	**Rijnstraat, The Hague**
Building use	**office, government**

The Hoftoren is located in The Hague. It has been built between 1999 and 2003 and it consists of a 30 floors construction 142 meters tall hosting offices and governmental functions in a 48.000 m^2 floor area. The materials used are glass, steel, aluminium and concrete. It has been designed by the office Kohn Pedersen Fox Associates.


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NEW BABYLON TOWER I
THE HAGUE

Location	**Bezuidenhoutseweg, The Hague**
Building use	**mixed use**

The New Babylon Tower I is located in The Hague. It has been built between 2007 and 2012 and it consists of a 45 floors construction 141 meters tall hosting residential functions, together with an hotel, a cinema, some offices and retail spaces and a parking garage. The materials used are glass and steel. It has been designed by the office Meyer en Van Shooten Architecten.


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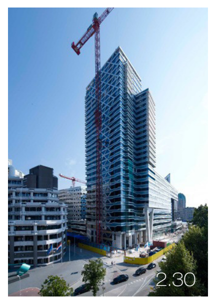
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WESTPOINT
RINGBAAN WEST TILBURG

Location	**Ringbaan West, Tilburg**
Building use	**residential**

The Westpoint is located in Tilburg and have been built between 2001 and 2004. It consists of a 47 floors construction 141 meters tall hosting residential lodgings on a surface of 33.022 m^2. The materials used are glass and concrete. It is currently the tallest residential building in The Netherlands and it has been designed by the office Van Aken Architectuur en Sedebouw.


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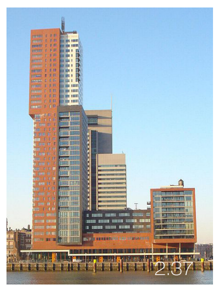
MONTEVIDEO
ROTTERDAM

Location	**Otto Reuchlinweg, Rotterdam**
Building use	**office, residential**

The Montevideo is located in Rotterdam. It has been built between 2003 and 2005 and consists of a 43 floors construction 140 meters tall hosting offices and residential functions distributed in 192 living units. The materials used are glass, steel, bricks and concrete. It has been designed by the office Mecanoo.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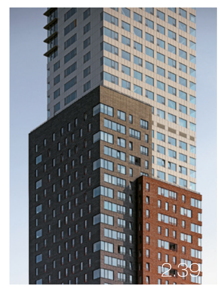
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chapter 2.1

HIGH RISE IN THE NETHERLANDS

HIGH RISE IN EINDHOVEN

fig. 2.1 - Vestedatoren, Eindhoven

HIGH RISE BUILDINGS IN EINDHOVEN

The realization of new constructions in Eindhoven started just after the World War II: the city was bombed and almost completely destroyed. Just few excerpts of the historical center survived and then the need for reconstruction was so urgent that a boom in constructions invested the city in the 1960s. The presence of important industries such as Philips and Bosch brought huge capitals that could have been invested in re-building the city. The new parts of the city were occupied mostly by production and office buildings, but the development toward the high rise happened just in the last decades with the realization of the business center in the surroundings of the central station.

Besides the biggest buildings were located in this area, some scattered episodes, in particular of residential constructions, emerged in the dense urban fabric of the center, such as the Vestedatoren or the Admiranttoren.

An important role was for sure played by the Technische Universiteit, that hosted some buildings of relevant height, but still far to be defined as skyscrapers.

The urban plan of the city is looking forward to the realization of other towers, besides the four massive buildings in the city, here described, in order to better exploit the small lots available for new constructions in the center.

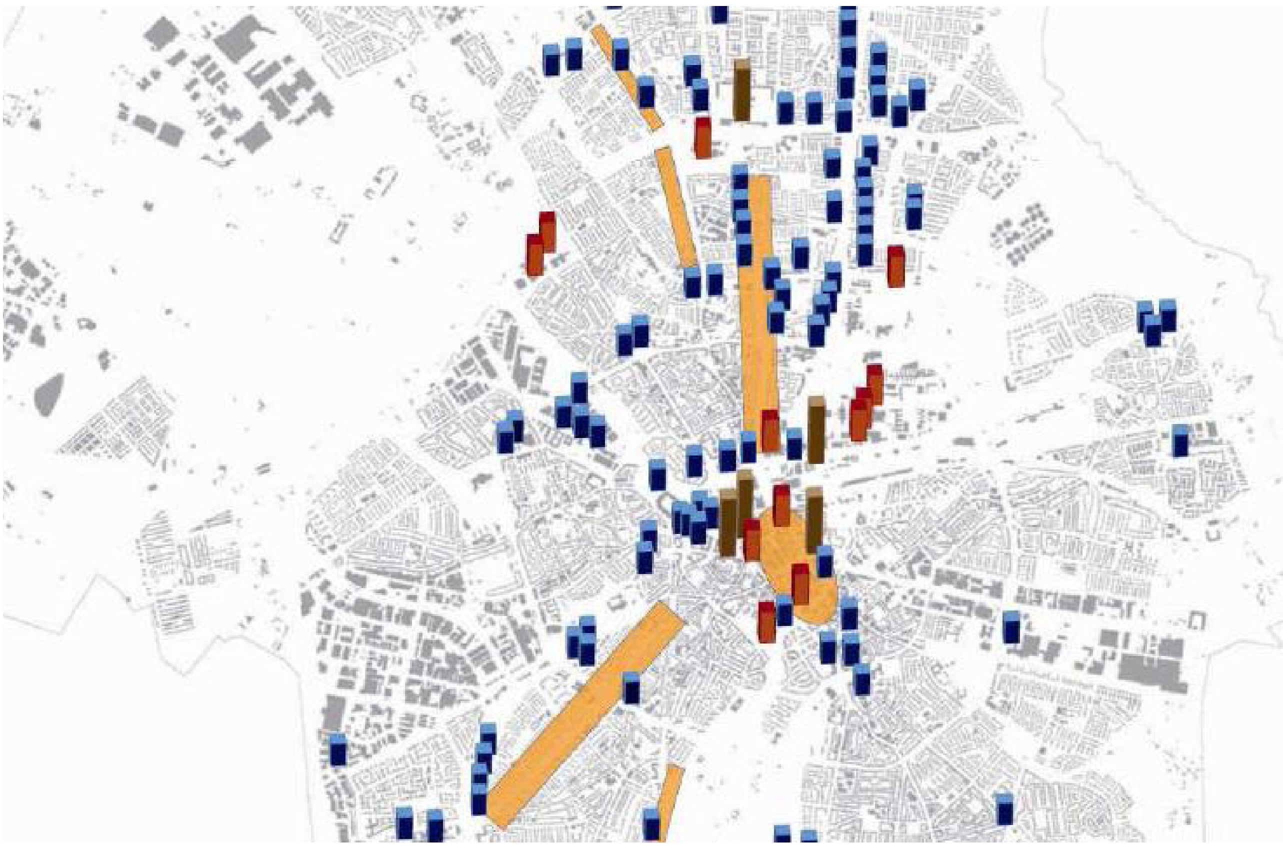

fig.2.1.1 - Eindhoven high-rises map


2.1.2

REGENTTOREN
VAN AKEN ARCHITECTEN

Location	**Eindhoven (1999)**
Building use	**commercial space, housing**

De Regent has been a pioneer building in the city because it has been the first tallest building of the city after the 35 years of record registered by the Philips Lichttoren. This introduced the high rise typology in Eindhoven and even during its construction several other buildings of relevant height appeared and overcame the Regent. Besides not in height, with 34 floors this is still the building with the highest number of floors used for housing purposes, above a basement dedicated to commercial spaces.


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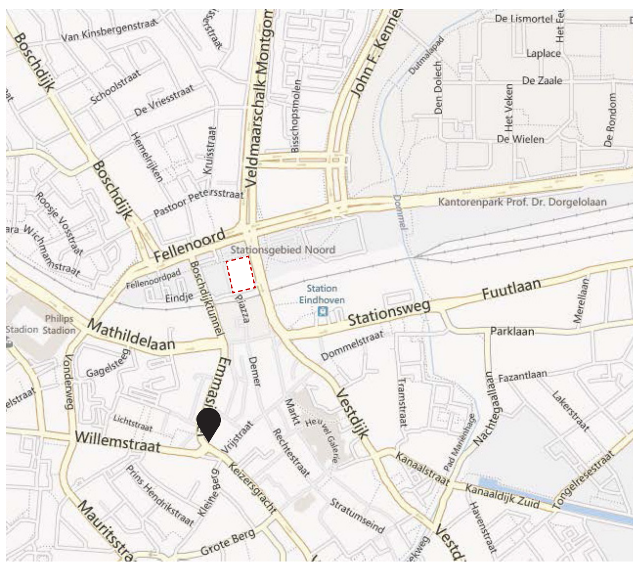


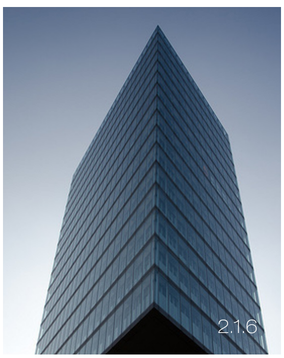
KENNEDYTOREN

VAN AKEN ARCHITECTEN

2.1.8

Location	**Eindhoven (2004)**
Building use	**offices**

This building is located at the head of the JF Kennedylaan and is an evident landmark for the city, just at the back of the station. The tower is completely faced by glass panels from floor to ceiling with a regular steel frame. The construction is impressive because the upper part is wider than the lower and a big cantilever is projecting outside from the basement. The facade is composed by a double skin with a ventilated space more than 1 meter wide and a double skin in the inner part of the same.



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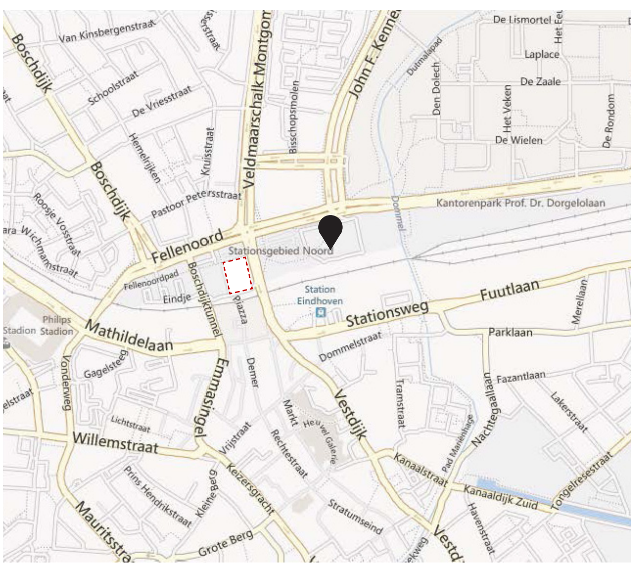

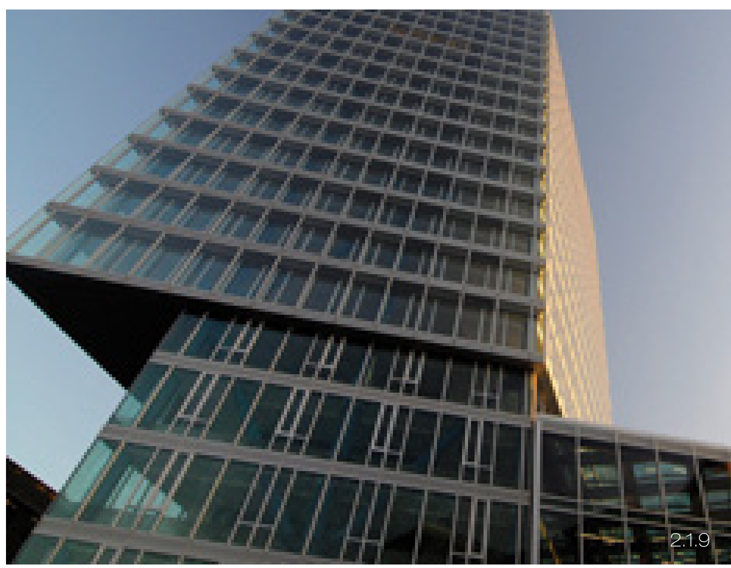

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ADMIRANTTOREN

DAM & PARTNERS ARCHITECTEN

Location	**Eindhoven (2006)**
Building use	**housing, offices**

The building is located in front of De Admirant, the former Philips tower, and is a real sculpture that emerges from the skyline of Eindhoven with its diamond profile.
The slenderness of the building is evidenced by the constructive details, such as the sloped roof, the irregular angles between the facades and the glazed corners, in contrast with the dense concrete facade with its rigid grid of windows.

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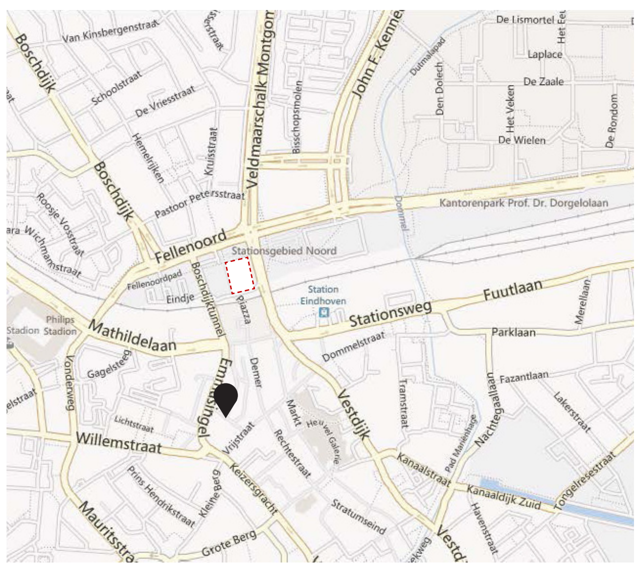

VESTEDATOREN
JO COENEN

Location **Eindhoven (2006)**
Building use **housing**

This building is evidenced by the rhomboidal form of the plan that is inspired by the former building that have been replaced on this lot in 2006, the Flatiron, built in 1902 with a diamond footprint. This is 90 meters tall and is, in the order, the fourth tallest building of the city with 27 floors occupied by big luxury apartments and a penthouse at the top.
The lower floors are occupied by commercial and office spaces.


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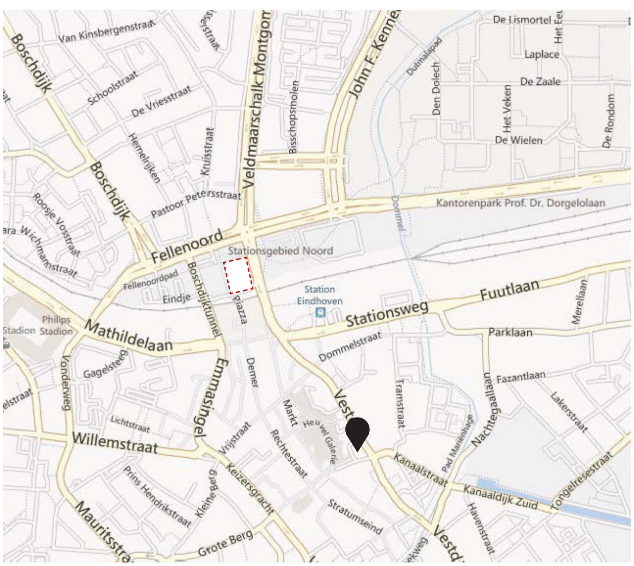

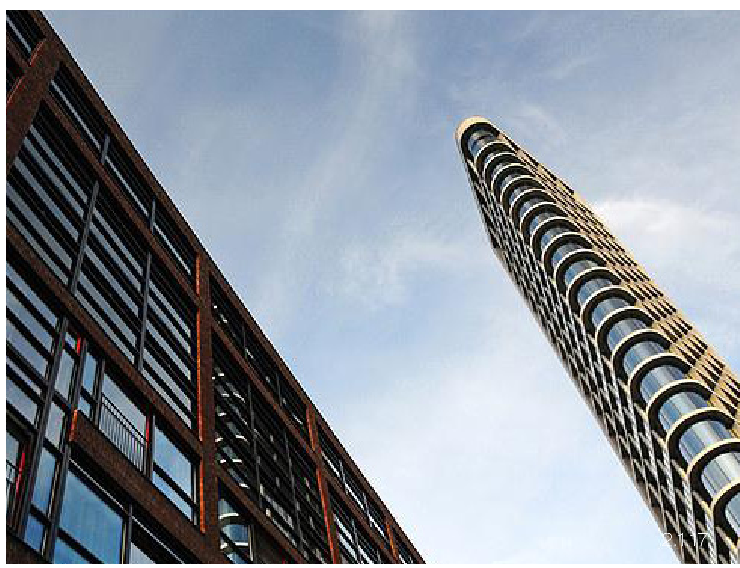
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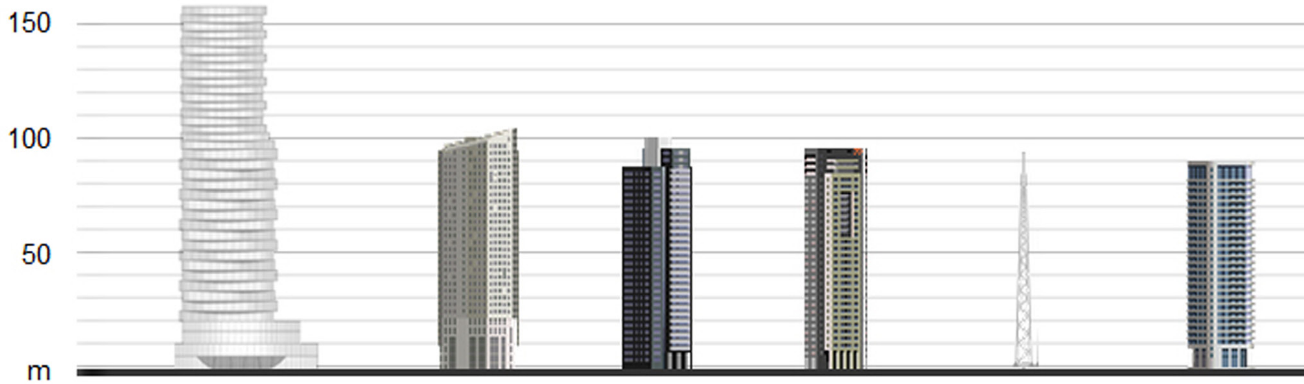
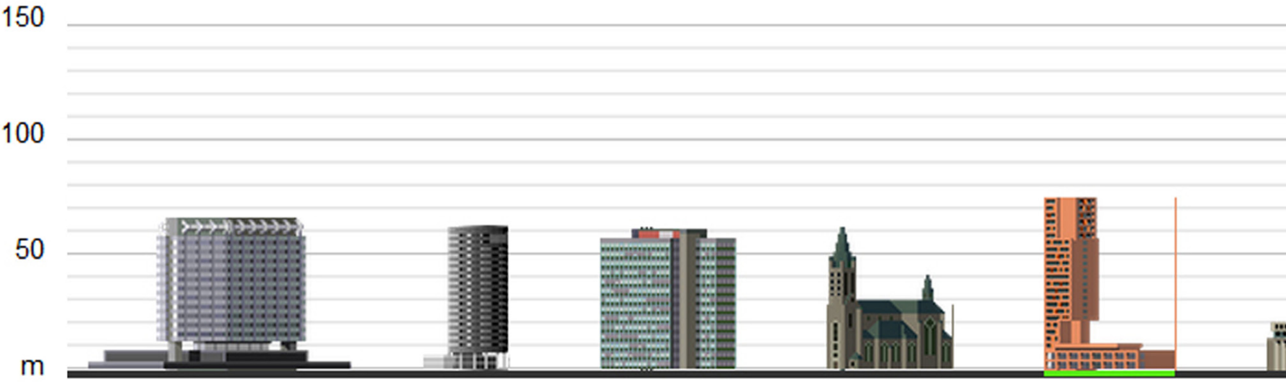


Name		De Admirant	Porthos	De Regent	DVB-T mast	Vestedatoren
City		Eindhoven	Eindhoven	Eindhoven	Eindhoven	Eindhoven
Country		Netherlands	Netherlands	Netherlands	Netherlands	Netherlands
Status		Built	Built	Built	Built	Built
Built		2006	2006	1999		2006
Floors		31	32	34		28
Use		Residential	Residential	Mixed use	Communication	Residential
Antenna					94 m	
Spire					84 m	
Roof		105 m	100.8 m	96 m		90 m



Name	Philips Nederland	De Parade	TU/e Potentiaal	Sint-Lambertuskerk	Roland Garros	
City	Eindhoven	Eindhoven	Eindhoven	Eindhoven	Eindhoven	
Country	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	
Status	Built	Built	Built	Built	Under construction	
Built	1964	2008	1963	1910	2013	
Floors	15	19	16		18	
Use	Office	Residential	Education	Religious	Residential	C
Antenna						
Spire						
Roof	66 m	63 m	62 m		60 m	

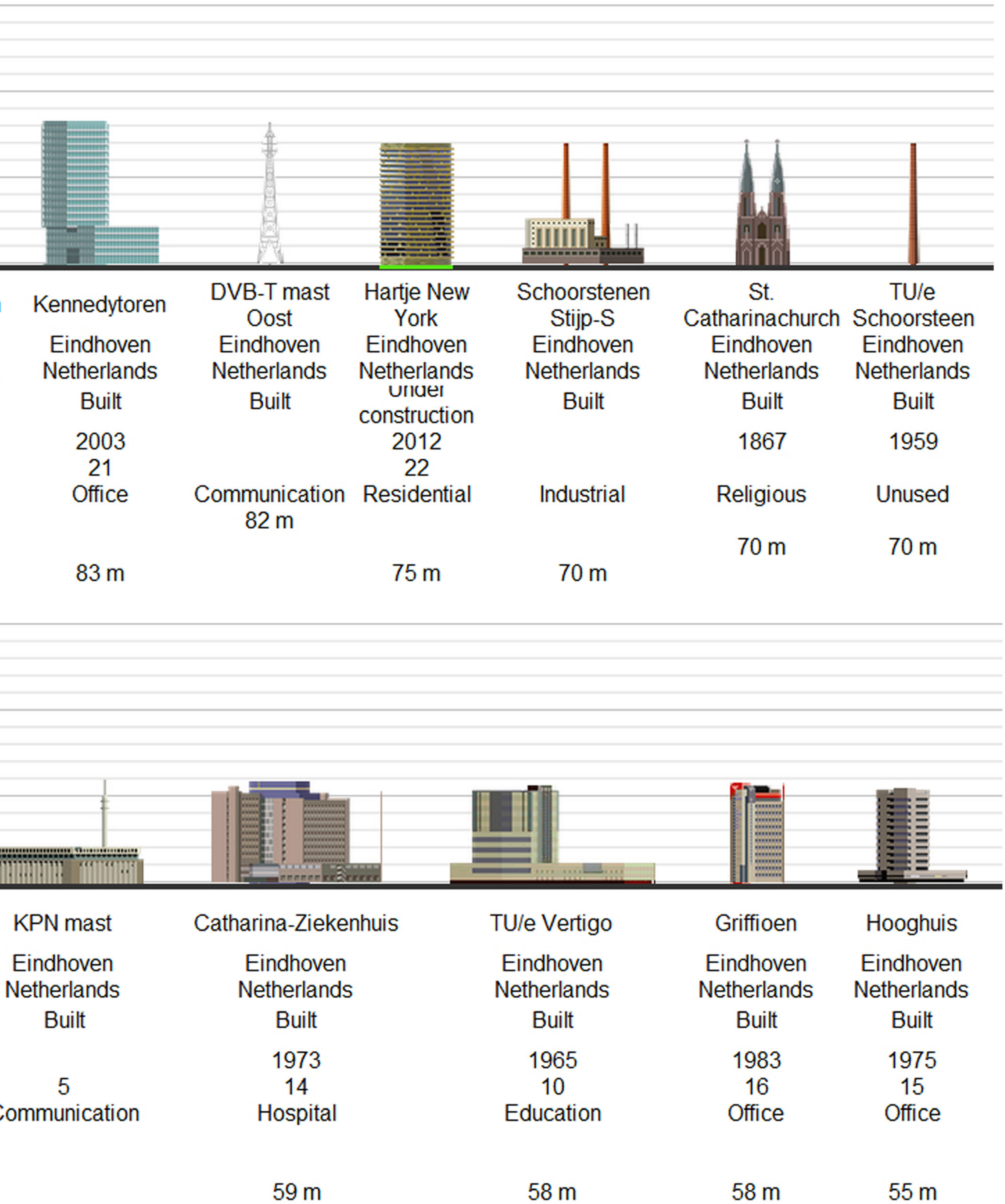
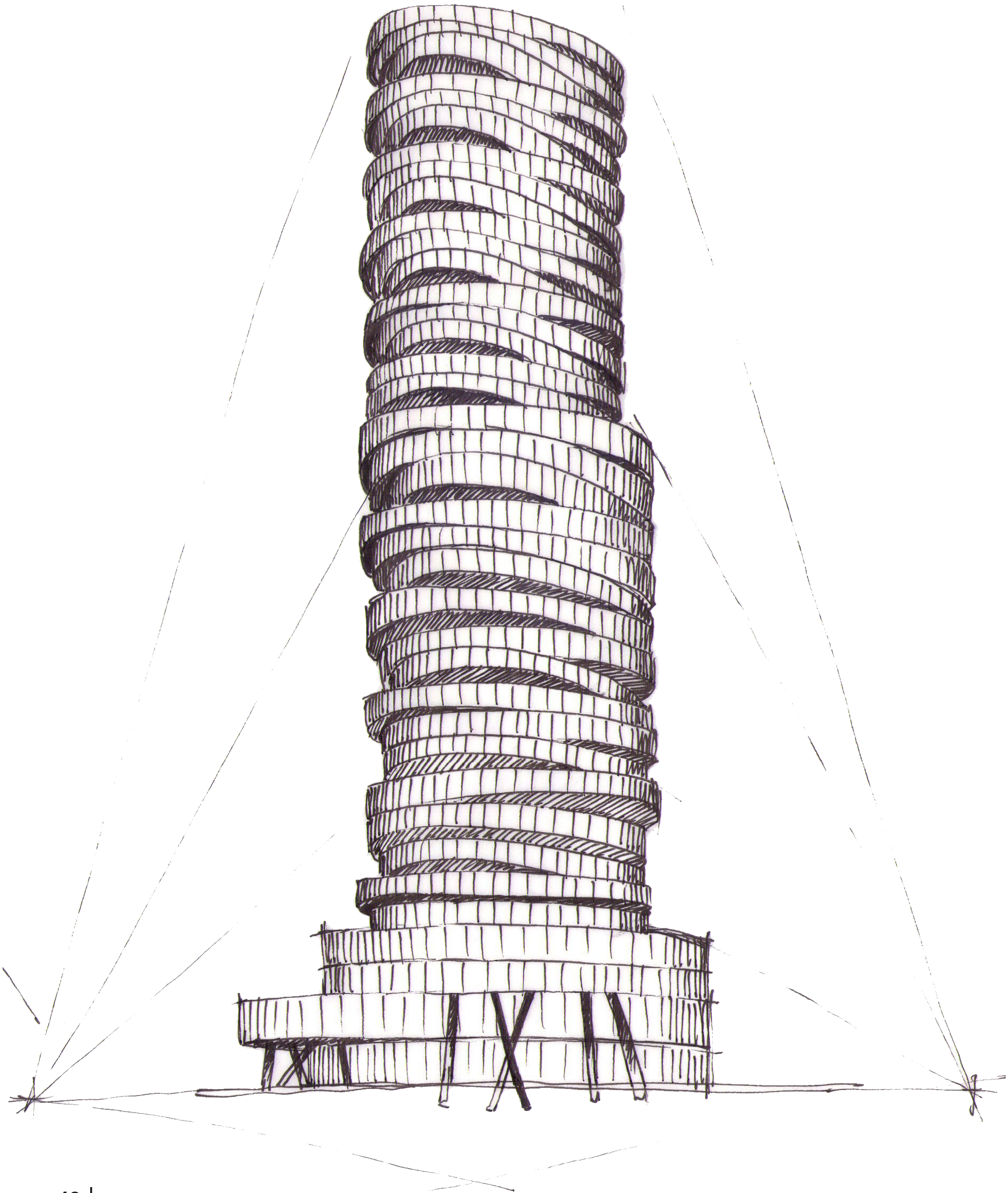


fig.2.1.18 - Eindhoven high-rises scheme

chapter 3

THE PROJECT
HIGH RISE BUILDING IN EINDHOVEN



PROJECT SPECIFICATIONS

The project requirements concern the design of a multi-functional high-rise building with a minimum height of 160 m in Eindhoven, in the Central Business District of the city, where other medium-height buildings host mainly office facilities and commercial activities.

The project site is characterized by the passing through of the railway that constitutes a strong division between two parts of the city: the rails wing crosses the city dividing it almost in the middle and separating what's surviving of the historical center which hosts nowadays the commercial part of the city, and the former industrial district, where Philips originally placed its productive center and where today several companies have set their business.
The two parts of the cities are connected, however, by a dense network of tunnels, both pedestrian and driveways, that in some cases host commercial activities.

The location of the project is in the northern part of the railway, in the 't Shimmelt district, where there is the present Beursgebow, a convention center and multi-purpose space that is actually located on the site where the project is meant to be developed. Nearby there is an existing pedestrian tunnel underneath the train tracks that connects the construction site with the Piazza and the Bijenkorf commercial center. Piazza is a commercial center located in the main city square, where the commercial and touristic roads of the city converge. Here the shops continues in the tunnel and therefore in the pedestrian street that run along the project site.

Because of its location in the business district near the city center and the present surrounding buildings, high-rise development is desired in the site. The project should consist therefore of a gross floor area of 35.000-45.000 m^2.

REQUIREMENTS FOR THE APARTMENTS

_middle to high income families and senior citizens
minimum of 30% luxury apartments 150-200 m^2
indoor balcony around 20 m^2

_home starters apartments
minimum of 20% studios, maximum 90 m^2
indoor balcony minimum 8 m^2

_two or three floors with penthouses 150-200 m^2
indoor balcony minimum 50 m^2

REQUIREMENTS FOR THE OFFICES

_flexible layout
_possibility for inter-storeys connection

REQUIREMENTS FOR THE SHOPPING SPACES

_minimum 600 m^2 each floor
_first story height 8 m, mezzanine included

REQUIREMENTS FOR THE PARKING FLOORS

_1,2 parking places per apartment
_4 parking places per 100 m^2 of office space

chapter 3.1

THE PROJECT

ANALYSIS OF THE URBAN CONTEXT

fig. 3.1 - Lichttoren, Eindhoven

The history of Eindhoven began in 1232 when it was officially recognized as a city: it had a strategic position, in a location where important trade routes were interchanging with each other, connecting the city with several important cities such as Antwerpen, Turnhout, Luik, in Belgium, Keulen, in Germany, Den Bosch, in The Netherland. For this reason a conspicuous network of infrastructure was realized and remained almost the same from the 13th till the 19th century, when important changes occurred such as the realization of the railway station.
Originally located at the level of the other road, the growing amount of traffic with the increasing of motorized vehicles generated the need for removing this obstacle and then in 1953, the elevated railway was launched.
The Second World War profoundly changed Eindhoven since a relevant part of the city was bombed and the districts of Demer and Fellenoord destroyed. A reconstruction of the city with a new urban plan was necessary, but this brought a sensitive change in the structure of the city itself since no attention was paid to the historical center of the city that was gutted to leave place to a new and overshadowing network of infrastructures for the new traffic plan. Some important shops-streets were realized, such as 18-Septemberplein, Demer was rebuilt and Fellenoord transformed into a big motorway to connect the two parts of the city separated by the railway.
An important transformation was made in 1969 when the Piazza shopping center was realized together with the opening of the Bijenkorf, and the tunnels that passing underneath the railway connected 18- Septemberplein with a big parking lot next to Fellenoord, on the back of the elevated railway, where in 1990 the Beursgebow convention center was realized, together with the Lardinoisstraat, the commercial pedestrian road that connects Deme and the Kruisstraat, and the three office buildings in the adjacent lot. Here, in the Fellenoord district, the project site is located. This quarter confine on the northern border with the districts of Limbeek, Hemelrijken, Gildebuurt, Woenselse Watermolen and the area of the Technische Universiteit, on the southern border with Binnenstad and Witte Dame. In each of these districts a different pattern of the built environment is recognizable.

ANALYSIS OF THE DISTRICTS

The different districts above listed are distinguishable by some peculiar features that characterize them.
The Limbeek quarter, on the North-West part of the city, having as a center the project area, is a residential one, with building blocks characterized by a long and thin body, with

fig. 3.1.1 - Eindhoven districts map

inner private gardens, that are dislocated along the street network.
In the Northern part, where the districts Hemelrijken, Gildebuurt and Woenselse Watermolen are based, there is an homogeneous structure of the building blocks, with a slightly different character in the Southern part, where some offices, schools and the student center “De Bunker” are located in bigger building complexes.
In the districts described above, just because the residential vocation of the area, low rise architecture, with typical Dutch-style single family dwellings, maximum three storey high, characterizes the surroundings. The only exception in this sense are the office buildings and some new residential along the Boschdijklaan.
A recognizable structure is that of the Technische Universiteit, in the North-West part of the city, dipped into a big park where the prismatic buildings are inserted in an irregular orthogonal structure. Some high buildings are here located and alternates with low rise lecture spaces.
These are the districts that overlook at the building site from the Northern part of the railway. On the Southern side of the railway the district Binnenstad is characterized by a different structure, with a dense building fabric and open spaces just corresponding to the street crossing the district itself.
This is the area where the major part of the former buildings survived to the bombing of the WWII and the density has been suitable for the shops location. Here, in fact, the highest density of shops, cafes, restaurants is detectable. These are located in small-facade and deep buildings with no separation between each other.
In the South-East part of the city, the district Witte Dame, a more open space area, hosts some offices and art spaces, together with former industries in disuse.
The Fellenoord, the district that hosts the project site, is the business district of the city. Big buildings, such as the Kennedy-tower, the Rabobank-tower or the Holiday-Inn Hotel, and large open spaces occupied by a complex network of infrastructures and facilities, e.g. the bus and railway station together with a wide bike parking, alternates here.
From this area some high rise buildings are erected, mostly in the Southern part of the city considering the railway: the most relevant-height buildings are the Regent and the Admirant, the residential complex of Willemstraat. However, even if lower than 20 meters of height, some buildings such as the Witte Dame or the Piazza Shopping Center overlook the city being higher than the average constructions.
The district in which the project site is located is peculiar because of the great number of infrastructures crossing the open space in the surroundings. This situation creates a duality in the area that is constituted by the contrast between


3.1.2 - Construction site and surroundings

the isolation of the site from the rest of the city since the ring road and the railway unavoidably constitute a barrier, and the strong connection of the site itself thanks to the wide network of public transport that interests the area.
The near train station, the bus stops and the bus terminal, the tunnels and the pedestrian area that surround the lot make, in reality, this place highly accessible for people travelling by public transport or moving by feet or by bike.
As well as for public transport, private means of transportation have no difficulties in reaching the area: the elevated roads have direct access through sloped street-connections to the site and there is a parking garage in the lot on the eastern side of the project location. The streets surrounding the project site are part of the inner ring of the city, a slow-route driveway that allows the crossing of the city and the connection, through radius, to the outer fast-route ring.
The whole area around the project building, at the ground level, is pedestrian/cycle only, with the connection to the other city sites through the tunnels that cross underneath the elevated routes. The cycle tracks are, of course, part of a complex network connecting every part of Eindhoven and the city with its surroundings.

3.1.3 - Eindhoven schematic map

1	bus terminal	4	TUE University	7	Regenttoren	10	City hall
2	train station	5	Piazza shopping center	8	St. Catharinachurch	11	Philip stadium
3	Kennedytoren	6	Admiranttoren	9	Vestedatoren	12	Clty park

chapter 3.2

THE PROJECT

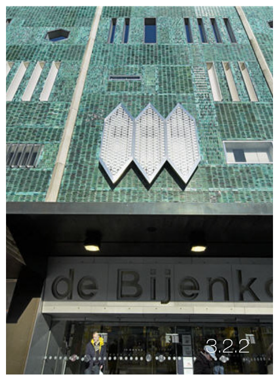
REMARKABLE SURROUNDING BUILDINGS


3.2

DE BIJENKORF
GIO PONTI, THEO BOOSTEN

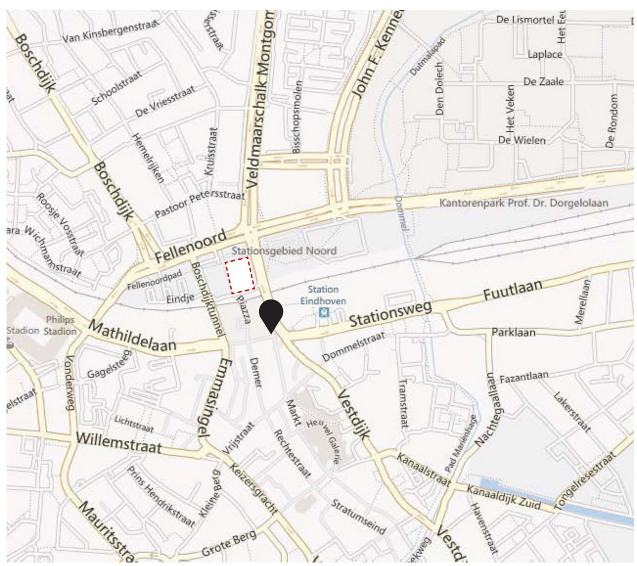
Location	**Eindhoven (1969)**
Building use	**shopping center**

The commercial center was designed by Gio Ponti with a characteristic facade covered with three-dimensional tile on the tones of green. Openings are realized in the form of hexagons, stretched and regular, as in the project of the Concattedrale di Taranto and for the San Carlo hospital chapel in Milan. The architect declared to have drawn his inspiration for this work looking at the green landscape alternated with water observed while flying on The Netherlands.


3.2.2

3.2.3


3.2.1



PIAZZA SHOPPING MALL

MASSIMILIANO & DORIANA FUKSAS

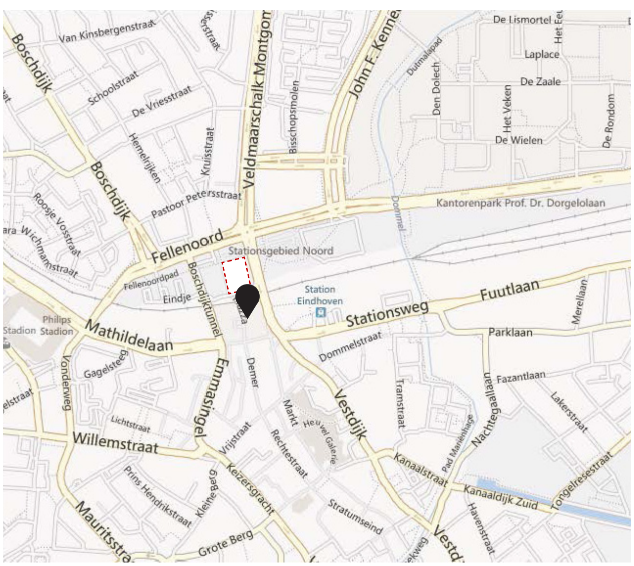
Location	**Eindhoven (2004)**
Building use	**square, shopping center**

The Piazza shopping mall is the redevelopment of a former building realized in the 1970s, with a restoration and enlargement. Next to the building designed by Gio Ponti, De Bijenkorf, the project consists of a public passage that connects the Beusegebow with the Southern part on the other side of the railway, on the back of the shopping center, with a modern glass roof that covers the passage and extends toward the square in front. The cover is supported by high stainless steel columns integrating the ventilation plants.


3.2.4


3.2.5

3.2.6



3.2.7

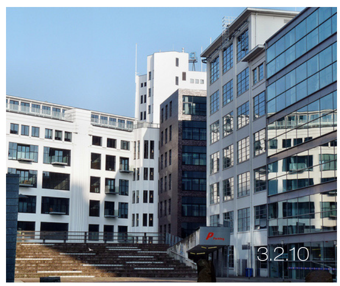
3.2.8

LICHTTOREN

AWG ARCHITECTEN, BURO LUBBERS

Location	**Eindhoven (2008)**
Building use	**mixed use development**

The Lichttoren (light tower) was realized in 1920 by the architects Roosenburg and Scheffer for the Philips firm and it originally was the site for the light bulbs production. It is in a way the symbol of the city and the 7-sided tower at the top was formerly used for testing the produced bulbs acting as a real lantern on the building. Philips moved its activity from Eindhoven starting from the 1970s exporting its production out of The Netherlands. The building remained abandoned from 1993 till 2006 when the same firm started the redevelopment and placing leisure activities, a public libraries and a design academy.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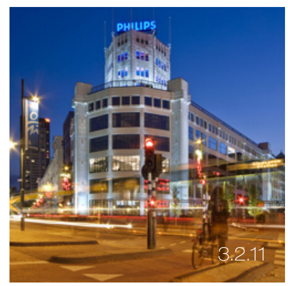

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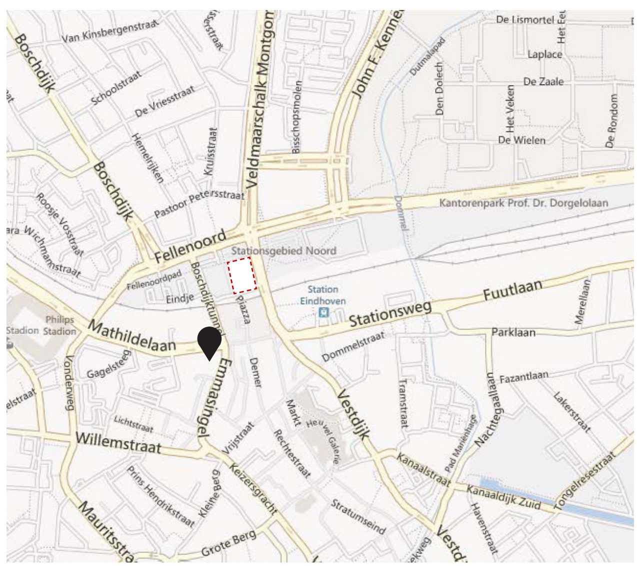
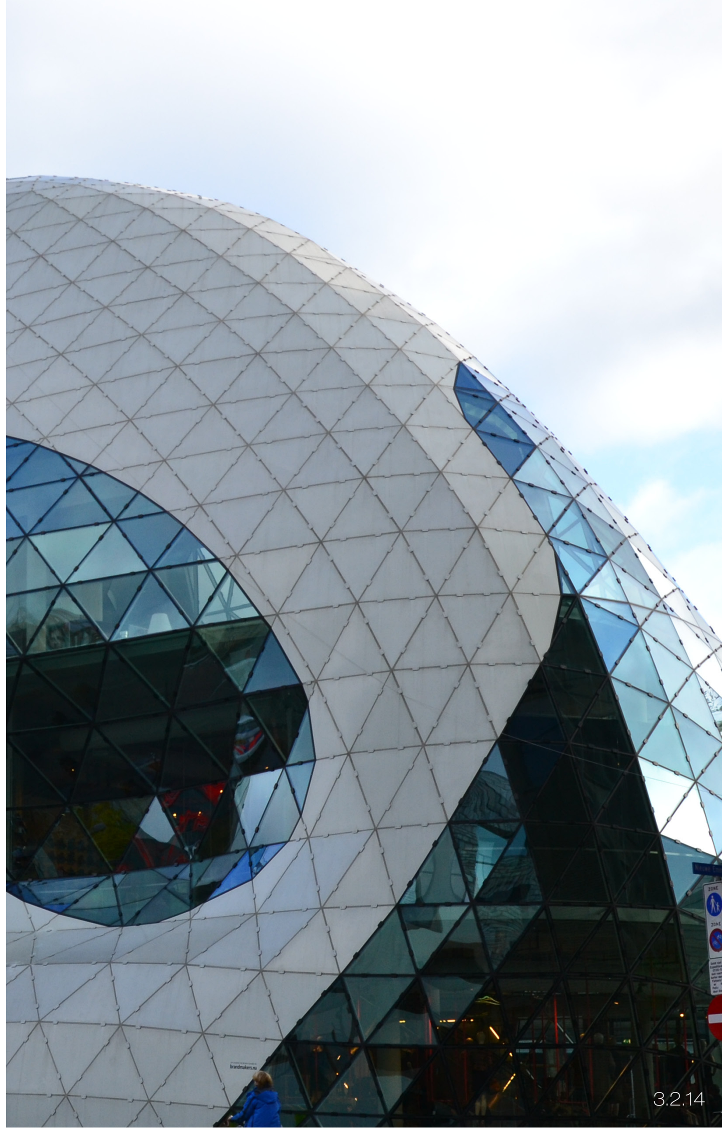


DE ADMIRANT ENTRANCE
MASSIMILIANO & DORIANA FUKSAS

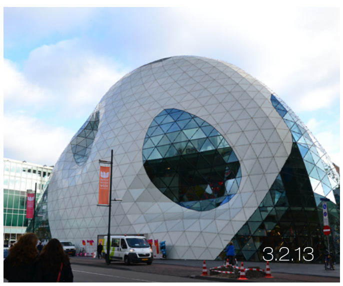


3.2.14

Location	**Eindhoven (2010)**
Building use	**shopping center, cafè, office**

This building has been realized by Studio Fuksas together with the 18-Septemberplein, a square with an underground parking for 1700 bicycles, the Piazza Shopping Mall, the Media Markt. These projects were scheduled by the master-plan of the city of 1998 and have been realized during the years. The Admirant entrance is a glazed element protruding from the square that hosts some commercial spaces accessible from the street and constitutes the entrance for underground levels where offices and other private functions are located.

3.2.12



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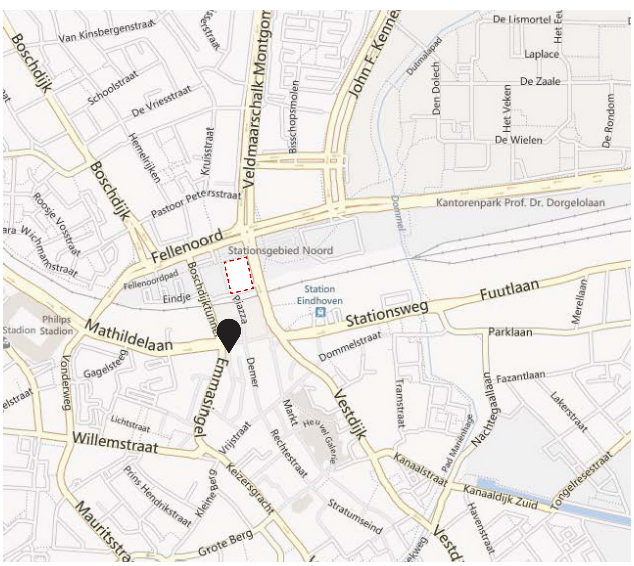


3.2.15

chapter 3.3

THE PROJECT

PHOTOGRAPHIC SITE SURVEY

A photographic survey of the project is here carried out in order to have an overview of the project site and to take a look at the surroundings of the location.
The location in respect to the rest of the city can be here clearly understood as well as to the other high rise structures.

The lot is adjacent to another building with office facilities distributed in three blocks joined at the basement by the parking garage.
The commercial pedestrian street separates the two and is connected to the network of roads surrounding the buildings. No open spaces are there that can be used by people going shopping. The railway, as evident in the geo-location photos, is really near to the lot and constitutes a visual and concrete barrier. Just crossing the adjacent tunnel, the bus terminal, the train station and the bicycles parking can be easily reached.

The pictures show the actual situation with the existing building of the Beusegebow, located on the lot destined to the project. The space occupied by this building will be completely freed in order to place the new high rise construction. The absence of a dense urban fabric near to the project site made easier to realize such a big building with less impact on the surrounding.

fig. 3.3 - Eindhoven, view of the city with the highlighted project area

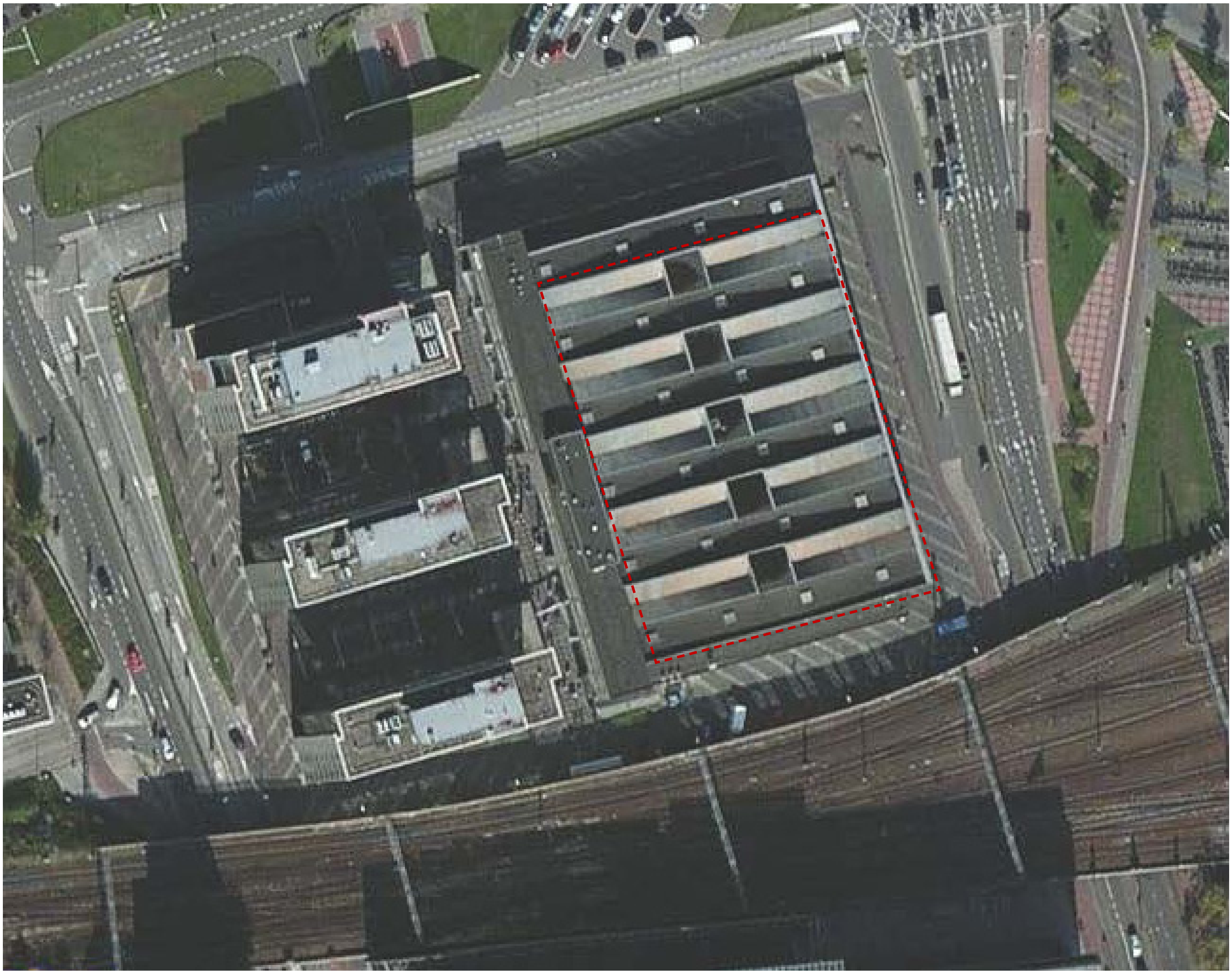
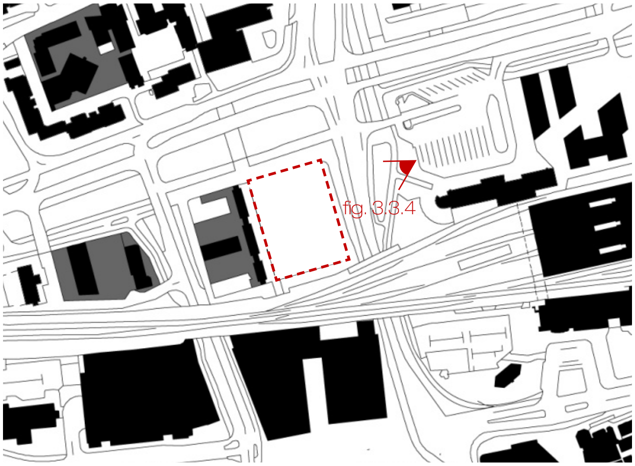


fig. 3.3.2

fig. 3.3.3 - site surveying
bus terminal and train station

The photo shows the adjacent buses terminal, on the back of the railway station. This is easily reachable through a tunnel directly connecting it, in few steps, with the project site. Behind the buildings of the station, is clearly visible the Kennedytoren, not far from the location of the new high rise building.

fig. 3.3.4 - site surveying
bikes parking nearby



The bike parking near the station. This area is a wide open space strategically located near the station with a free and a supervised bicycle parking that is useful to interchange with public means, i.e. bus or trains. On the background the Beusegebow, now located on the project site, is visible.

fig. 3.3.5 - site surveying
driveway tunnel underneath raylways

The project site is surrounded by a dense network of infrastructures that alternates between each other by elevated bridges. The roads that form a ring around the project area are elevated on the back, and go down again at ground level when crossing the elevated railway through a system of tunnels.

fig. 3.3.6 - site surveying
Piazza shopping tunnel

The shopping center Piazza is directly connected to the project site by a tunnel which is endowed with some shops continuing the commercial path of Demerstraat and De Bijenkorf and preceding the one of Lardinoisstraat, adjacent to the lot where the new high rise building will be realized.

fig. 3.3.7 - site surveying
pedestrian tunnel to bus terminal

The photo shows the pedestrian and bicycle tunnel that allows the direct connection between the designed building and the bus terminal and railway station. The tunnel Fellenoordpad passes underneath the road Fellenoord that connects the Northern and the Southern part of the city crossing the rails.

fig. 3.3.8 - site surbeying
view from the South side

On the side is shown the sight that people have coming from the tunnel that crosses the Plazza shopping center and that give access to the project area. The street is a shopping lane with several cafes and restaurants besides private offices. On the right the Beusegebow and on the left the three-blocks adjacent building.

fig. 3.3.9 - site surveying
view of the adjacent lot from the street

The conterminous building hosting offices and business activities is here shown. This is reachable again through a pedestrian tunnel that crosses, on the other side in respect to the Fellenoordpad, the road allowing access to the lot. The building hosts on the ground plate a huge car parking.

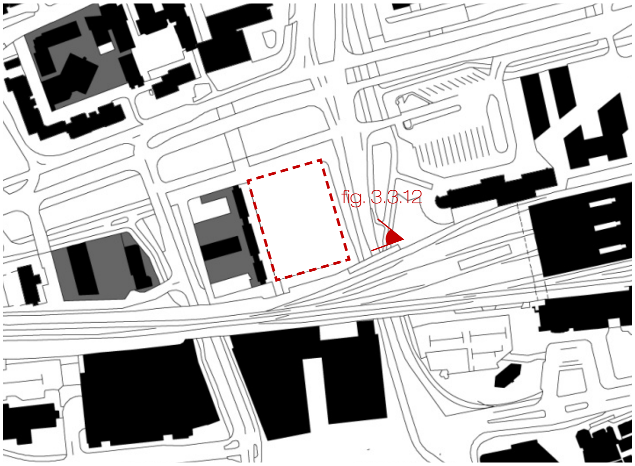
fig. 3.3.10 - site surveying
view from the North side

The shopping street dividing the lot in two part, seen from the opposite side in respect to the Piazza shopping center. The back of this building can be seen on the background with its tunnel. The Beusegebow is on the left, with the shopping side evident under the arcade. On the right the office building.

fig. 3.3.11 - site surveying
view of the South side

The area is now dedicated to commercial activities and the surrounding space is then intensively used as a loading and unloading zone for goods, directly accessible from the streets. The rest of the space, in particular behind the railway, is used as a parking for trucks and for people working in the current buildings.

fig. 3.3.12 - site surveying
the lot seen from the East driveway



The actual building present in the project area is here shown from the elevated road Fellenoord that constitutes a barrier, as well as the railway on the other side of the lot, separating this space from the northern part of the city. The traffic is intense here and causes unpleasant noise in the open space.

fig. 3.3.13 - site surveying
pedestrian street on the North side

The building area is surrounded by a wide pedestrian and cycle path displaced along the containment walls of the elevated street and constituting a buffer zone between the constructions and the road. These paths cross the roads through tunnels: the picture is taken from the elevated road above one of them.

chapter 3.4

THE PROJECT

PROJECT SPECIFICATIONS

PHOTOGRAPHIC SITE SURVEY

The project is developed, according to the requirements, with a 3-level parking under the ground level, able to host the vehicles of resident and working people. The building is meant to be a mixed-use building hosting both residential, office and commercial facilities.

The first four levels are dedicated to the shopping facilities: this is the public part of the project that preserves the commercial vocation of the former street-side and continues the commercial path that starts from Catharinaplein. Together with the shops other public functions are here based, such as a gym at the third level and a panoramic restaurant at the fourth. The first levels are freely accessible to the public since their space is separated from the access and the services of the offices and of the residential floors. The access to this area is connected and made a whole with the before square, developed together with the project in order to make easily accessible and recognizable the commercial public area of the building: this is left free from the building in order to create a “welcome zone” for the public coming from Piazza commercial center and this constitutes a gateway to the shopping center of the building. The access to the latter is fluid with the open space and can be closed or maintained open according to the season, creating in summer a pleasant covered open space.

The 18 levels above the first four are occupied by offices, which have an independent distribution system, as outlined before, as well as an independent entrance, in the North-West side of the building. The choice of placing in this wing of the tower the entrance of the office part, as well as of the residential, as will be later discussed, is tied mainly to working people needs: in fact most of the people that would use the building would use as well public transport to come to their job place. For those coming by car the underneath parking provide a direct access to the lifts and the stairs that connect all the floors, while for those using public transportation means, the recognition of the access is facilitated by the location of the entrance that faces the tunnel connecting the project site with the near bus and train station. Coming from this area, where also a big bike parking is provided, the access is immediately visible and accessible.
Near to the office entrance the apartments’ entrance is located, for the same reasons, to which that of the privacy from the commercial/public part of the site is added: the residential floors are located at the last 18 levels of the buildings and their distribution system is again separated from that of the office part of the building.

The underground is exploited for the realization of the parking spots with a three-levels parking space, also useful to reach the solid ground for foundations placing. The considerations about the parking are of fundamental importance because of the huge designed construction.
An important evaluation to be done, in fact, is tied to the number of occupants of the buildings: the entity of their presence makes necessary the evaluation of the traffic conditions modification that the building will carry with its localization. Managing the traffic intensity and the need for parking spots is a big challenge for designers and planners dealing with such a big project as a skyscraper construction. When so many people are involved as users of the building, the quantity of cars that need a halt space is significant, and it influences also the level of traffic in the surroundings. A careful sight to this problem could help in solving the issue by taking care to the position of the public transportation paths and ways of access from the main public means stops. However near to an existing covered parking, this was judged to not be sufficient to cover the needs that a new construction would have brought, even if, since the nearness and the attention paid to the presence of the public transportation terminal, people using the building have the possibility to comfortably use it without the need for an over-dimensioned parking.

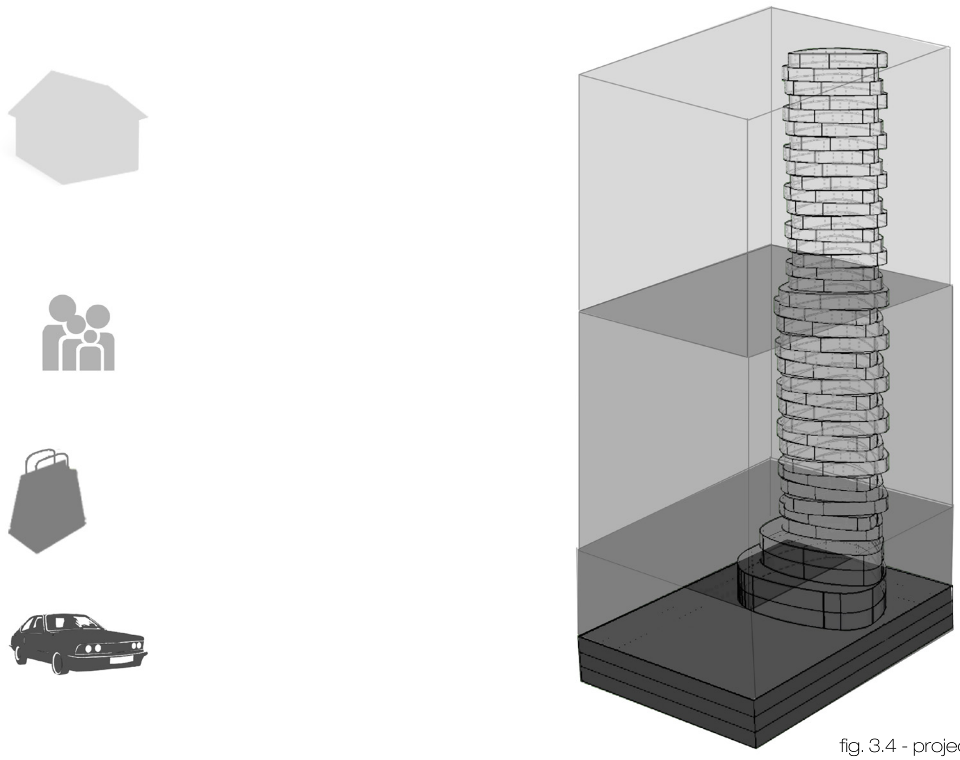


fig. 3.4 - project functions distribution

fig. 3.4.1 - scheme of the access to the project area

Limiting the traffic flow increasing by encouraging the use of alternative ways of moving, not only by the nearness to the public transportation stops, but also by organizing the lot accesses according to the main walking-people flows, is meant to significantly reduce the number of cars that need to be hosted for parking.
The designed parking as an area that cover the entire lot in order to bring the advantage, where geological limits does not exist preventing the exploitation of underground spaces (some considerations will be done in the foundation dimensioning paragraph), of being sufficiently large to bear the tension stresses caused by wind along the building's height. The foundations have been therefore exploited to create some underground parking levels to host conveniently almost all the cars belongings to permanent users of the building.

The choice about the distribution of the functions in the vertical direction, with the subdivision of the building in three parts, a public basement, a semi-private central body and a private crown, has been driven by the context: the presence of the railway and of the elevated roads creates, in fact, a barrier that imposes to rise over a certain level in order to be protected by the noise created by the train passage.

The analysis of the context evidenced the complexity of the circulation system in the location of the project. The lot is surrounded by large pedestrian and cycle routes, without the disturbance of the traffic letting people walk around the shopping areas. The car paths are, instead, realized on a higher level confronted with the pedestrian ones: all the roads are elevated of 4-5 meters above the ground level, and are passed through by the tunnels for bicycles and people. On a level even higher there is the railroad: where the rails run, the driveways go back to the ground and go through tunnels underneath the railway.
This net separation of the routes of the different transportation means introduces therefore the reflection concerning the location of the functions, in order to not clash with the traffic distribution.
The lower levels are, consequently, dedicated to all those activities open to the public (the shopping center, the gym, the restaurant) surrounded by the square that echoes the near Piazza and works as a buffer zone between the building and the railway. On the upper parts, the offices are located above the level of the car and the train traffic, in order to work again as a buffer body for the residential part, which is located at the highest levels in order to result protected by the noise and to have granted privacy and quiet, also assured by the relevant height of the building.
The entrance of the parking is located in the South-West part of the area, where the driveway drop to the ground level and is therefore connected to the lot, in order to leave free from the traffic the pedestrian and cycle paths that surround the site.

INTERNAL DISTRIBUTION

The shopping floors are distributed according to the necessity of integration with the square in front of the building and with the adjacent shopping places.
The solution adopted for the external columns, sloped and with a main decorative function, recalls the existent Piazza with its high columns and the glass roof on the square.
With a similar solution the project tries to protrude the building toward the front square welcoming into the commercial center people walking from Piazza through the shopping tunnel.
Similarly the North-West corner is emptied with the aim to give continuity to the southern and the northern part of the lot: on the western part the building faces the already existing shops line in the ground level of the adjacent building.
The ground floor is bounded by a long glass side enclosing an indoor square that is thought to be able to be opened during summer and to be joined with the outdoor square: shops overlooks this indoor space, some of which have also the entrance from the outside, and two curved stairs bring to the upper floors.
Integrated into the ground shopping floor there are the entrance halls for the residential and office part facing the tunnel that connects the project area with the station.
On the first level the shops follow more or less the same configuration of the ground floor.
The second level is occupied by the restaurant and the bar:

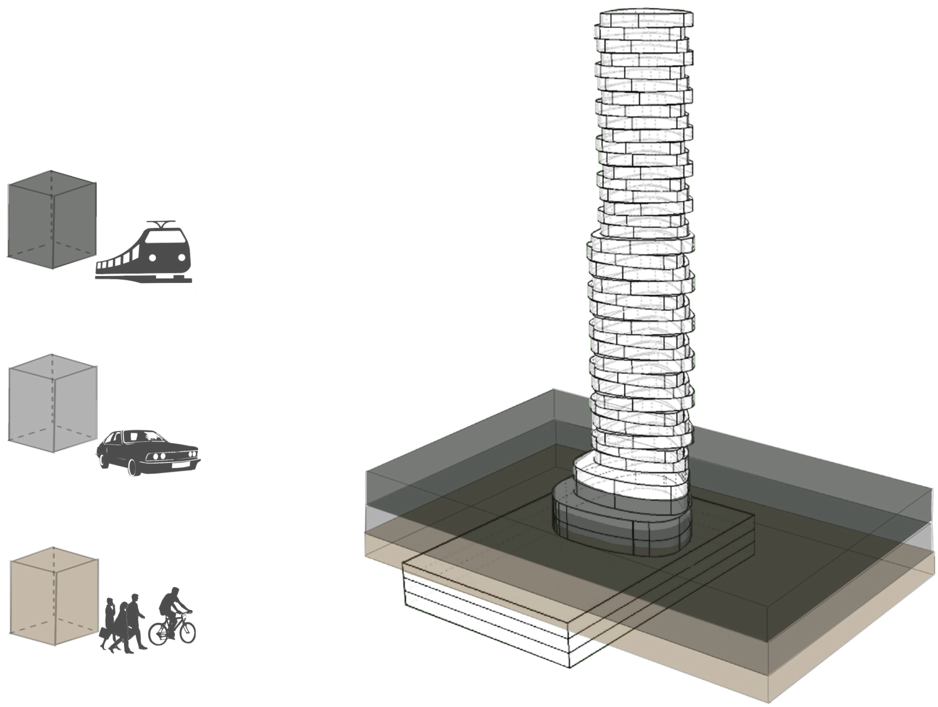


fig. 3.4.2 - traffic typology and level

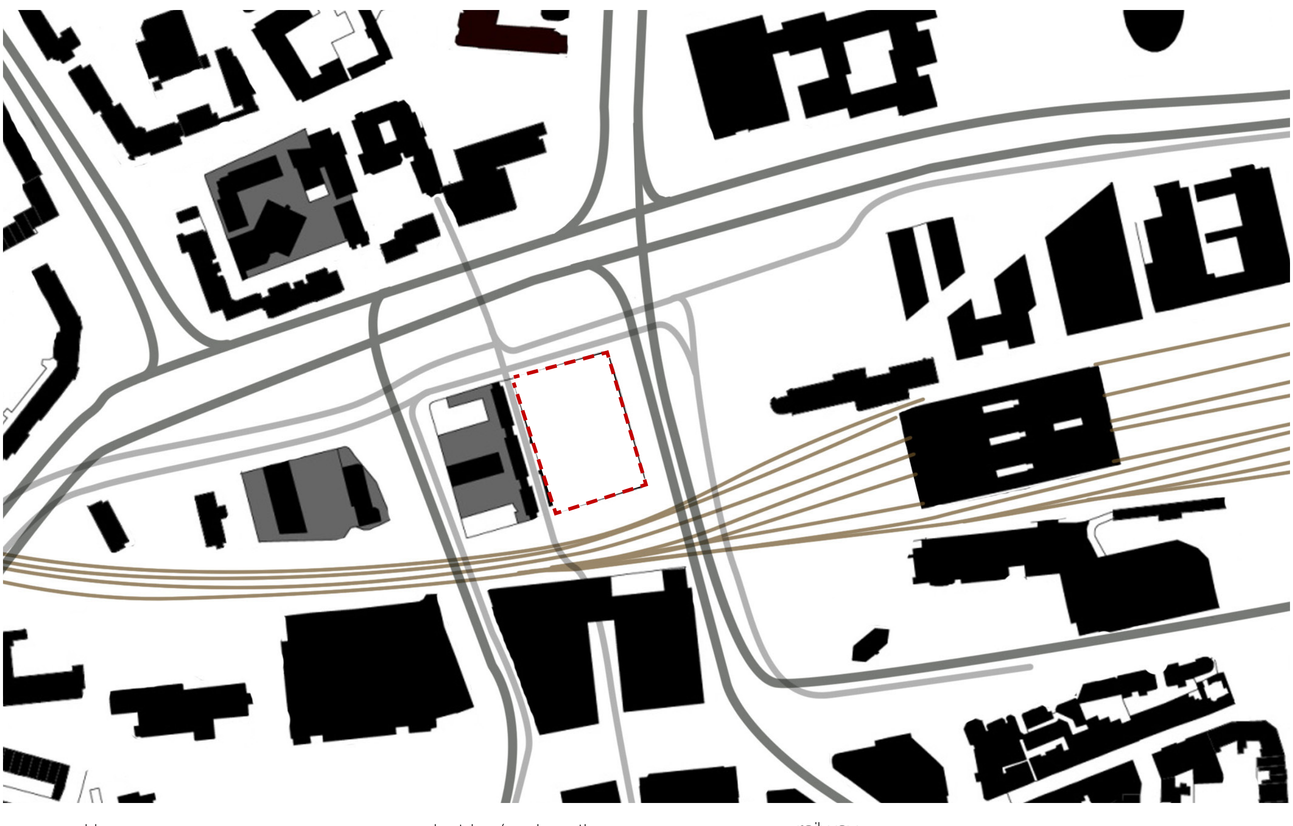
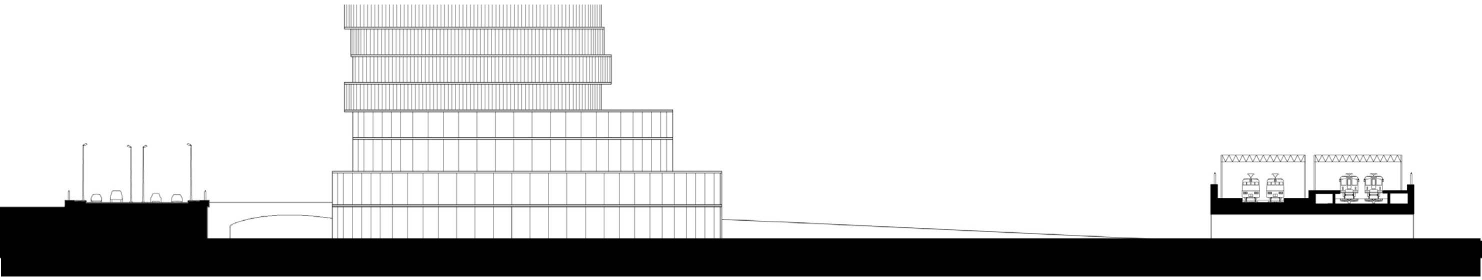
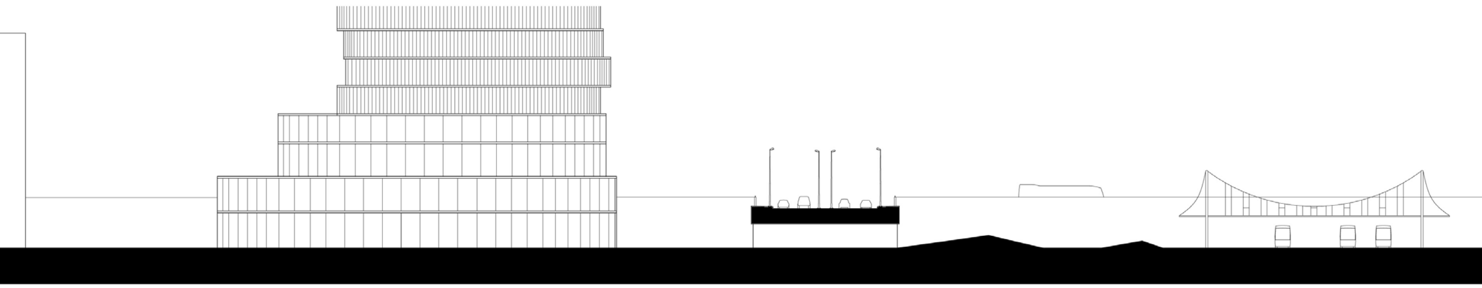


fig. 3.4.3 - scheme of the various transportation measns paths



B



A

fig. 3.4.4 - urban sections North/South (A) and West/East (B)

this is connected to the external terrace that can be exploited during the summer months. The restaurant can be used by the customers of the shops, external people as well as by the workers and people living in the same building.
The third level is occupied by a gym that is dedicated, as well as the restaurant, to external customers and residents of the same building.

The office floors are similar to each other and have a development of the working spaces on the perimeter of the building.
The distribution space is a corridor running around the core, exploiting the "blind" part of the building in order to use boundary windows for the natural lightning of the offices.
According to local law requirements, the offices cannot be deeper than 7,5 meters and then in the project the limit of the rooms is located at 6,5 meters from the boundary.
The offices are distributed radially along the perimeter: some of the offices are single or two-persons spaces, in particular located in the most regular spaces; the corners of the building are used for open space working areas.
In front of the lifts entrance a cafeteria is located with a relax space for the workers of each floor.
Some of the rooms are used as meeting rooms.
The configuration of the internal space of the building is highly flexible thanks to the structure constituted by the columns leaving the space free from obstacles to the eventual modification of the interior distribution.
In order to make the building adaptable to different needs, and to the realistic rapid interchange of companies into the designed spaces, the internal partitions can be modified in order to produced single-persons spaces or huge open working areas.
In order to better exploit this space, all the service areas are located in the central core.

The central-bearing core of the office part of the building follows the shape of the same: the corridor is just offset

around the core and distributes the office spaces, while the facade is offset from the corridor and then rotated around the core according to the explanation in the paragraph of shape concept.
The core consists of a rigid frame of walls inserted into a curved boundary that delimits some service spaces, deposits, bathrooms and the vertical distribution areas with elevators and stairs.
On the South side of the core, the distribution of the offices floors consists of 5 elevators, with a space for the waiting, and a stair.
In favour of safety, one elevator, overdimensioned for the use of the fire brigade, and one stair are placed in the middle of the core, isolated by compartment walls, and are used in case of fire emergency. This space is connected to the rest of the floor by a corridor that goes through the whole core from one side to another in order to guarantee to each office entrance to not have more than 20 meters of distance from the first useful emergency exit, as established by law.
This emergency vertical distribution system is common to the office and the residential part in order to not have discontinuities along the height.

The residential floors are smaller than the office ones, as well as the core. The corridor that distributes the apartments surrounds the core on three sides.
The apartments are of different sizes, for large or small families and studios for singles. The floor plan of each apartment is as much regular as possible, exploiting the rounded corners for placing the balconies: these are enclosed in the glass envelope in order to avoid undesired wind effects.
The last floors are dedicated to luxury penthouses and the area is occupied by three big apartments.
The vertical distribution system of the apartments consists of a part of the office core that runs through the whole building height.
This nucleus is smaller than the office one, but since the area of the apartments floors is smaller as well, the distance from the core to the perimeter remains approximately unchanged.
The emergency distribution system is in common with the offices core: while the rest of the core stops as the diameter of the floor changes and the residential part of the building starts, this part, and the distribution core of the apartments, goes till the top of the building.
The latter consists of 3 elevators and one stair that serve the

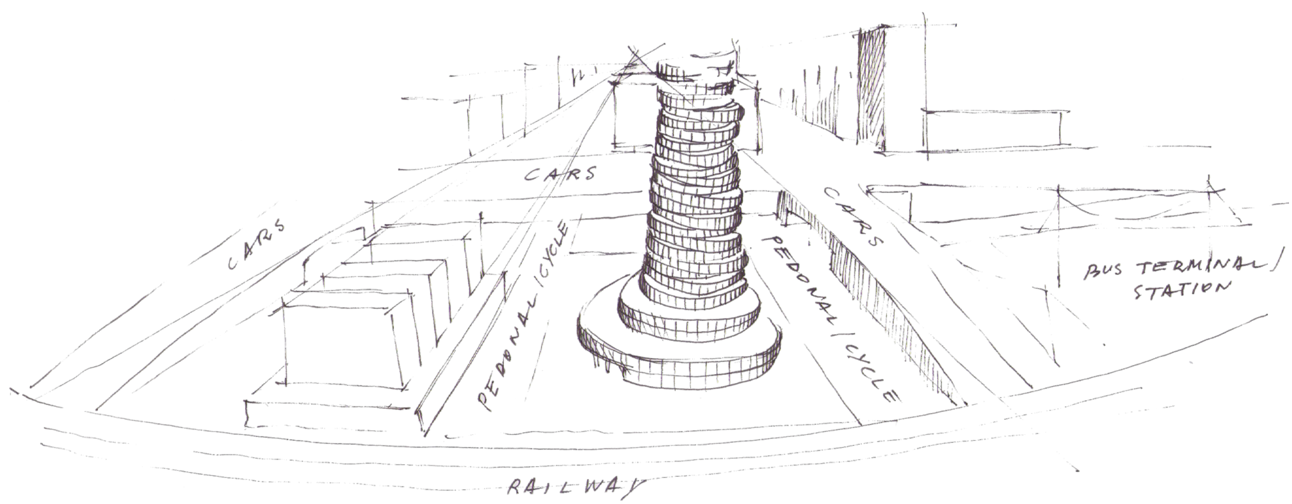
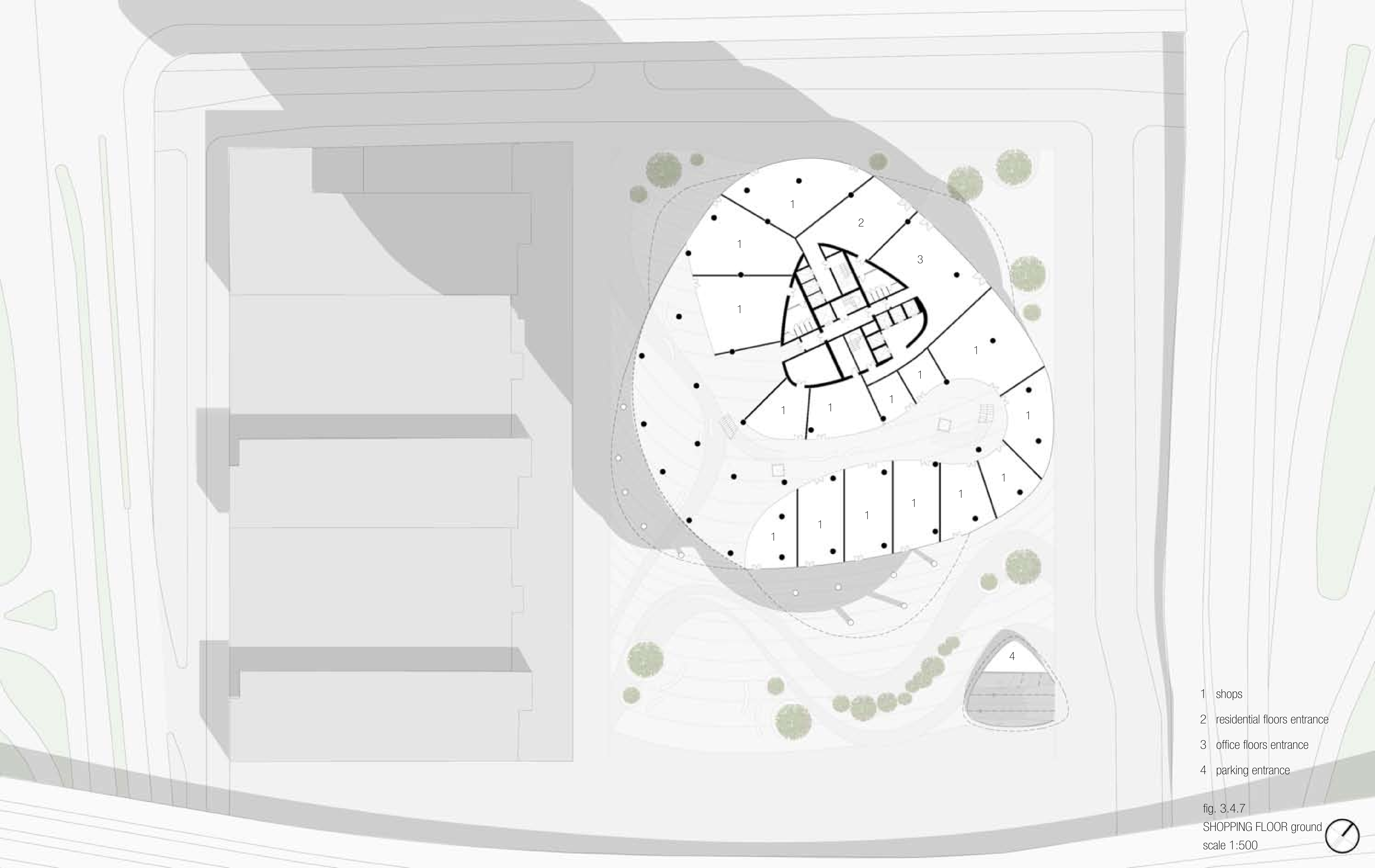


fig. 3.4.5 - urban sketch

residential floors.
Here, as in the office part, the core is offset and surrounded by a corridor which runs around three of the four sides of the core in order to distribute the apartments.
In this case as well as in the first, each door of the apartments has a maximum distance from the emergency stairs not higher than 20 meters. These are here doubled since above 120 meters of height, law imposes to have at least 2 emergency stairs.
Besides the slightly different shape of each floor, the apartments are similar on each level, with some little changes in the boundary and in the internal distribution of the furnitures consequent to these differences.
On average, 8 different apartments are located on each floor, with the exception of the last 3 levels on which luxury penthouses are placed, with big apartments that occupy the area of the entire floor.
On the typical living floor, the apartments are different in size and in the kind of users to which they are addressed: some of the apartments are regular houses for families, with one or two children and a complete set of rooms.
Some other apartments are dedicated to “studios”, open living spaces in which there is no subdivision between the different functions, with the exception of the bathroom, in which single users are supposed to live.
Some of the apartments have one or more balconies, which are usually realized exploiting the more irregular spaces of the floor area.


fig. 3.4.6 - render view from the South



1 shops

2 residential floors entrance

3 office floors entrance

4 parking entrance

fig. 3.4.7
SHOPPING FLOOR ground
scale 1:500

1 shops

fig. 3.4.8

SHOPPING FLOOR level 2

scale 1:500

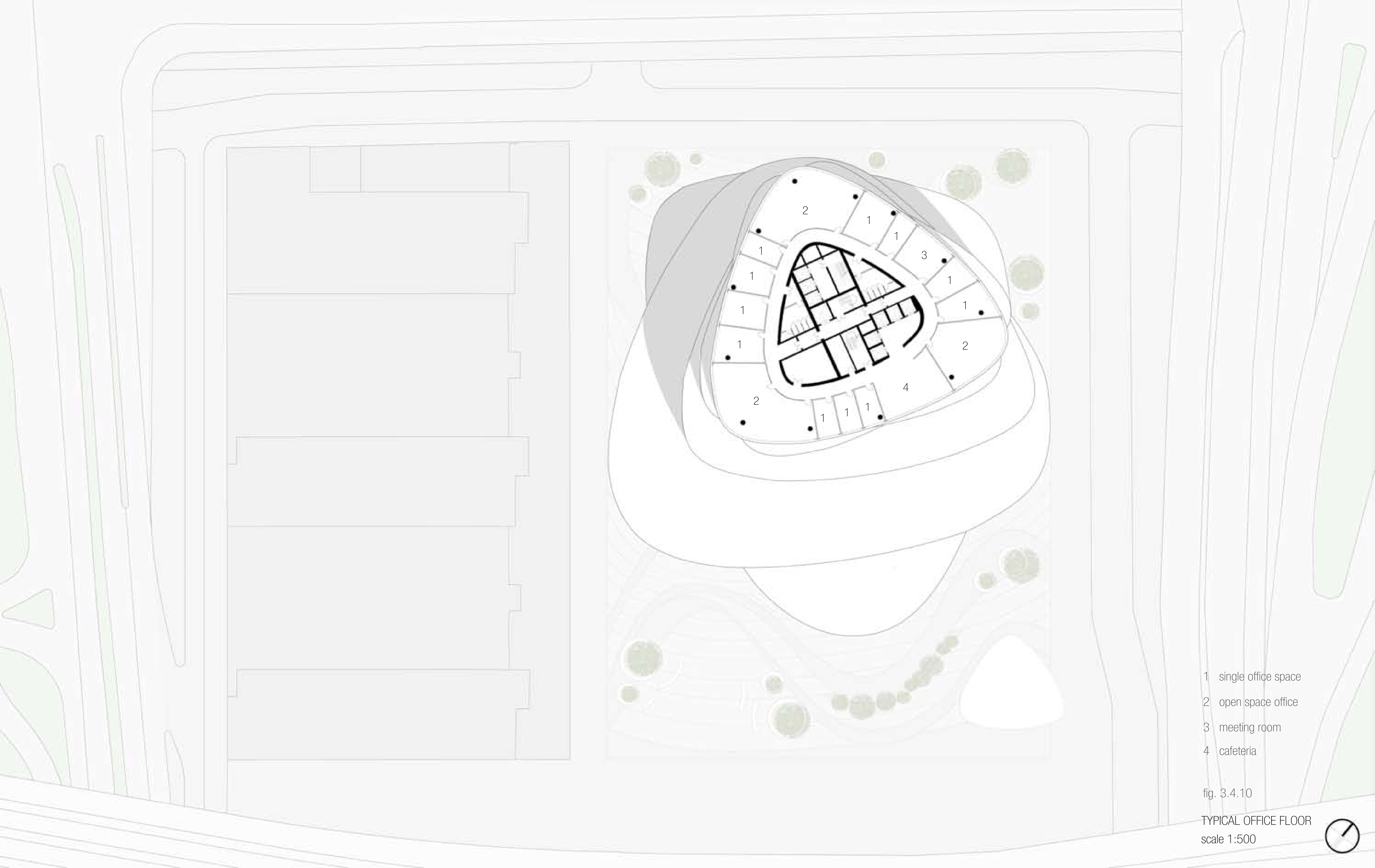
1 restaurant

2 bar

3 restaurant services

fig. 3.4.9

SHOPPING FLOOR level 3
scale 1:500



1 single office space

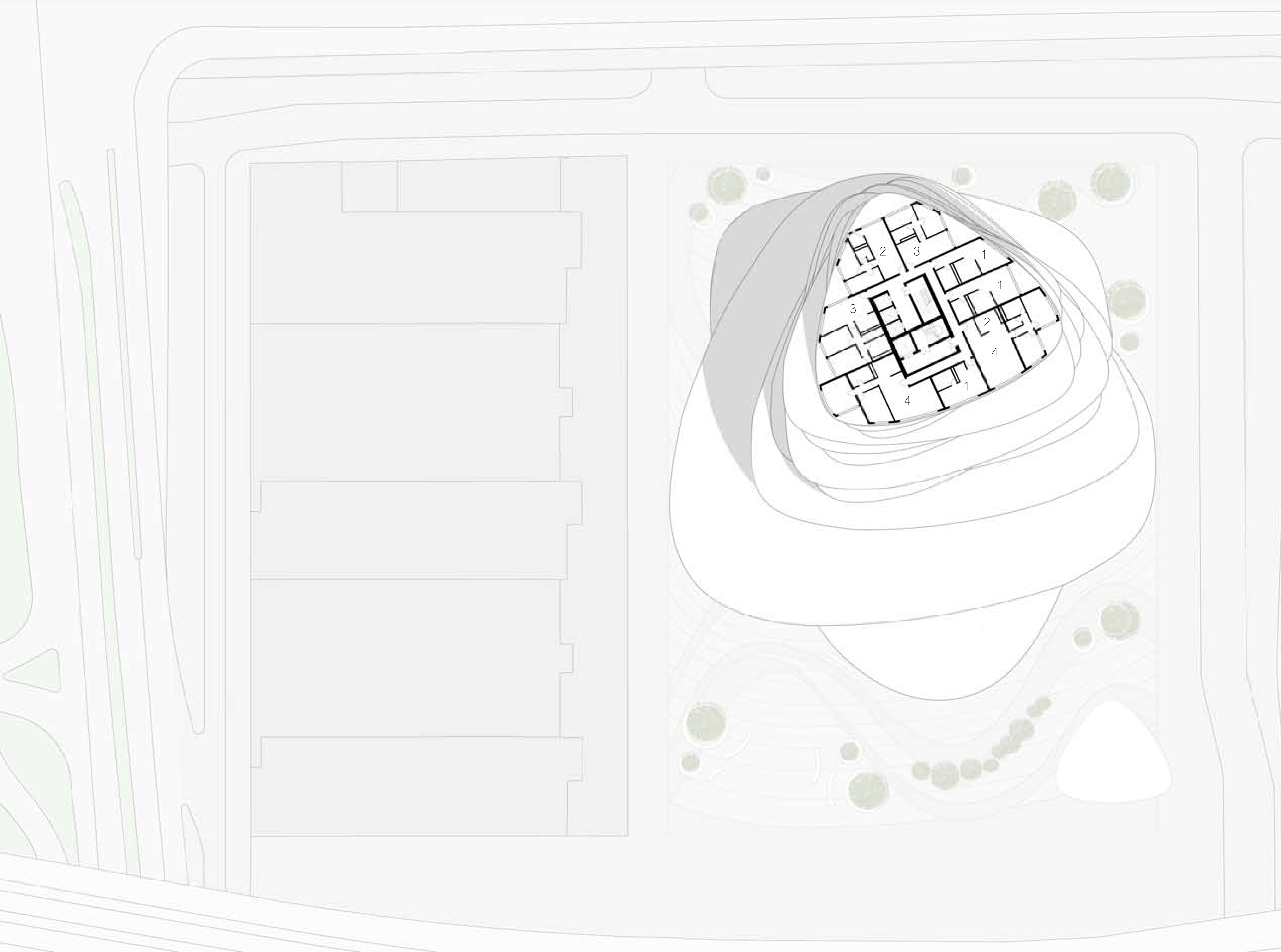
2 open space office

3 meeting room

4 cafeteria

fig. 3.4.10

TYPICAL OFFICE FLOOR
scale 1:500



1 single apartments

2 2-beds apartments

3 3-beds apartments

4 4-beds apartments

fig. 3.4.11

TYPICAL RESIDENTIALFLOOR
scale 1:500

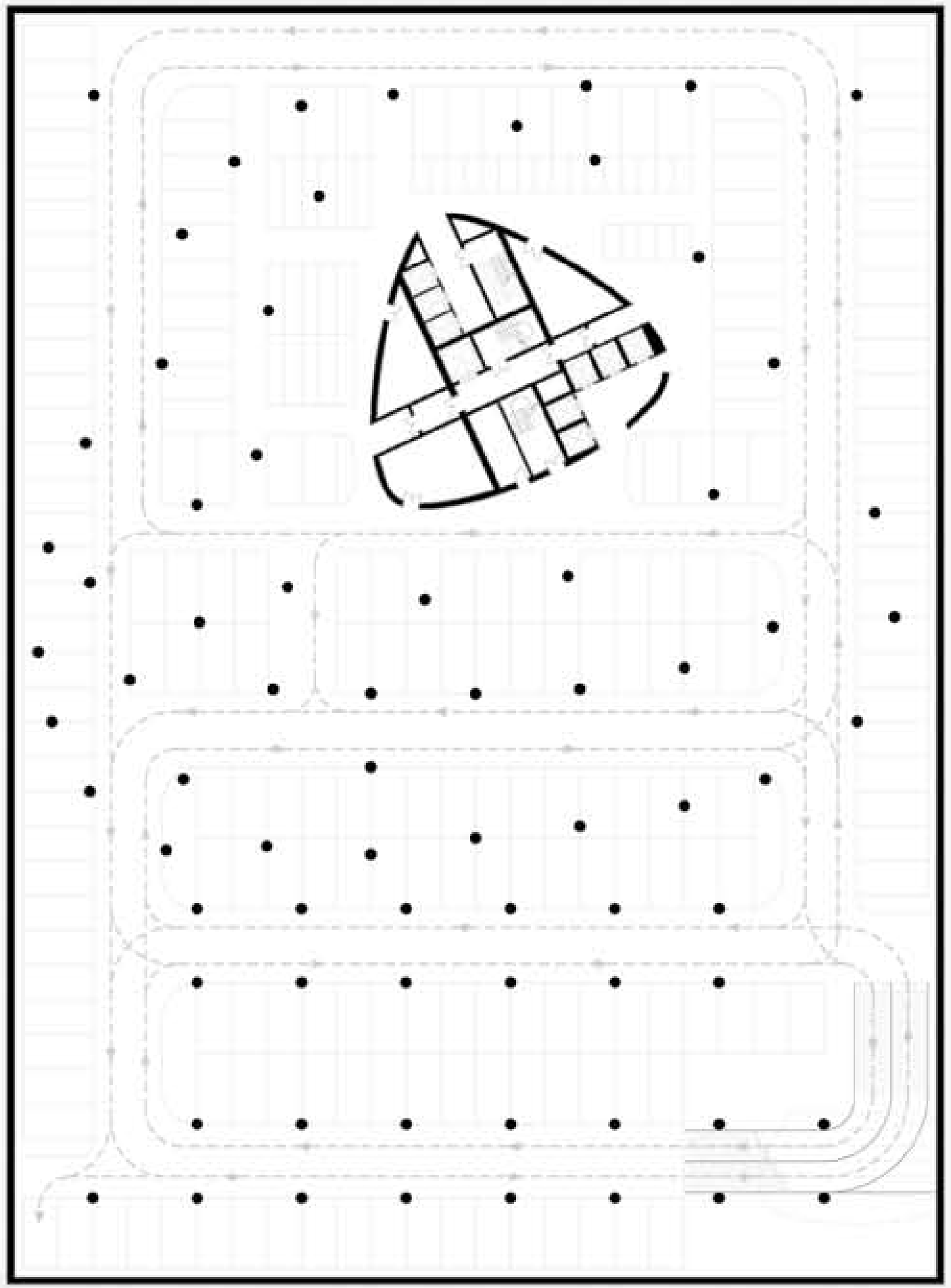


fig. 3.4.12
PARKING LEVEL underground
scale 1:500

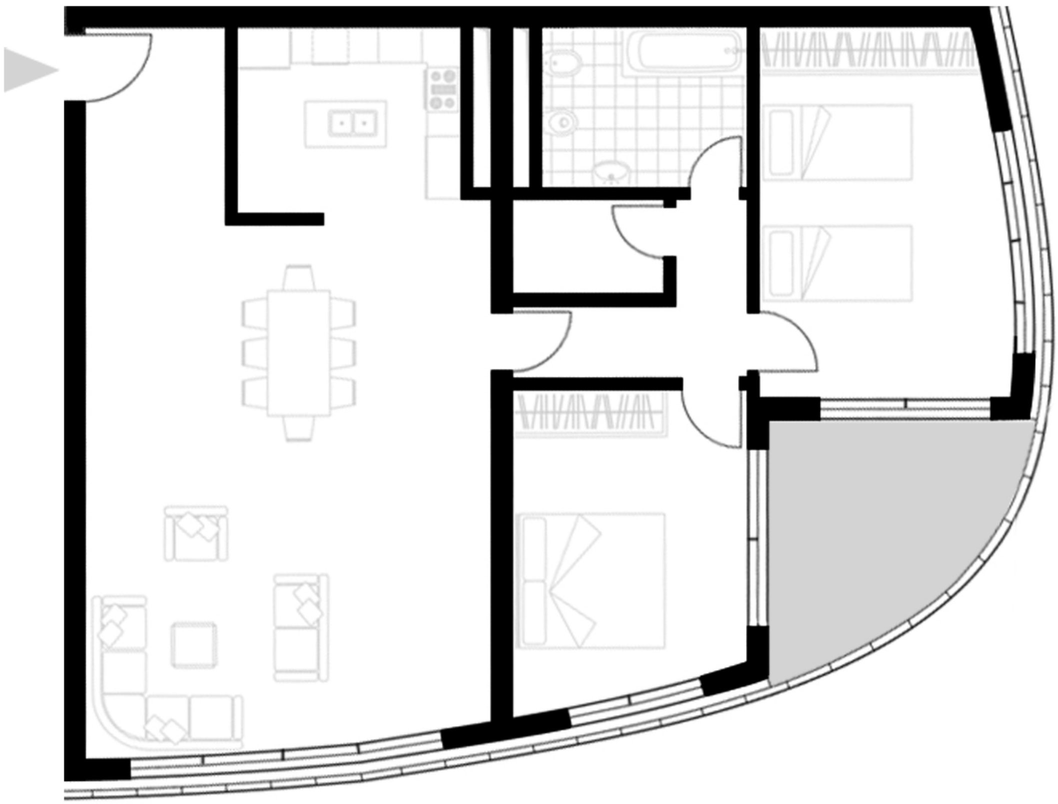
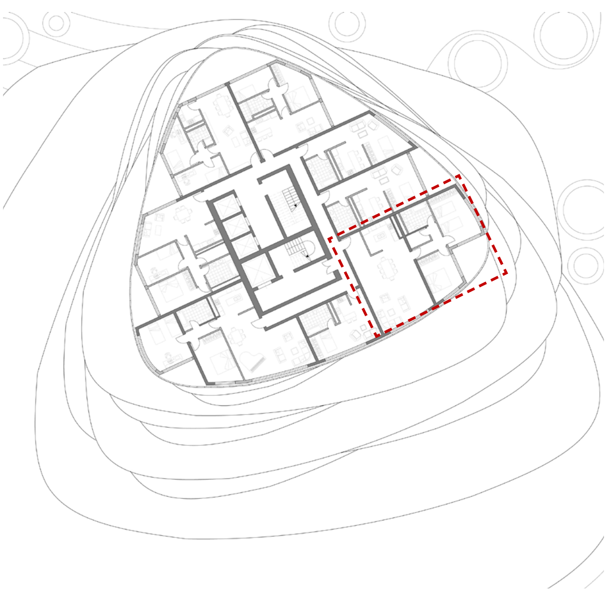


fig. 3.4.13 - apartment layout 1



APARTMENT TYPOLOGY 1

Indoor area	100 m^2
Outdoor area	9 m^2
Users	4

kitchen	1
living room	1
bedrooms	2
closet	1
bathroom	1

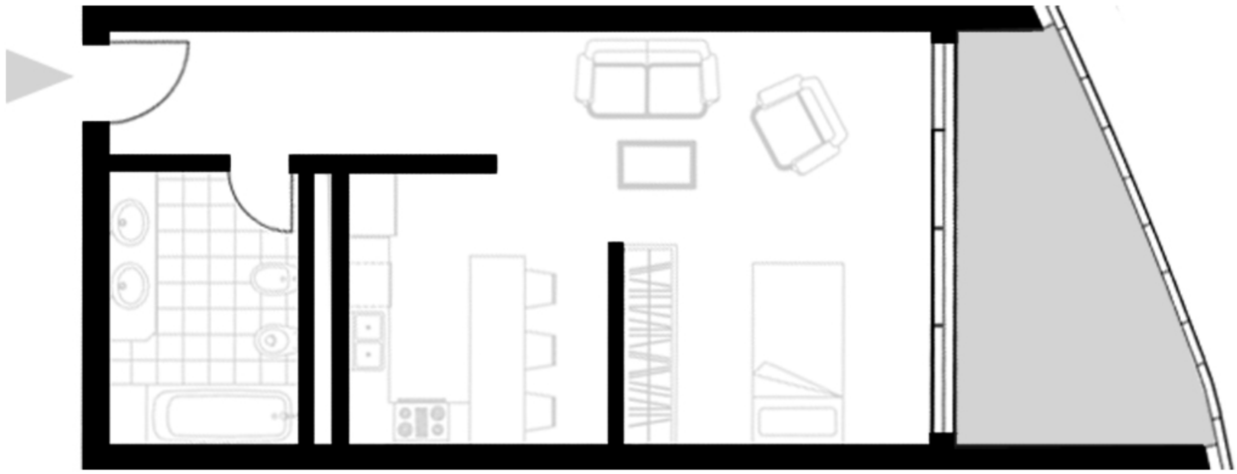


fig. 3.4.14 - apartment layout 2

APARTMENT TYPOLOGY 2

Indoor area	44 m^2
Outdoor area	10 m^2
Users	1

kitchen / living room / bedrooms	1
bathroom	1

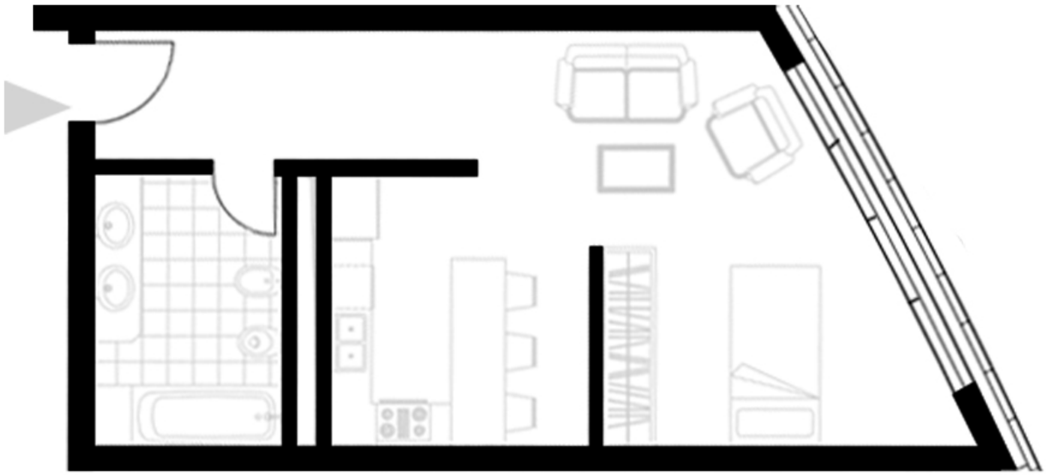


fig. 3.4.15 - apartment layout 3

APARTMENT TYPOLOGY 3

Indoor area 42 m^2

Outdoor area 0 m^2

Users 1

kitchen / living room / bedrooms 1
bathroom 1

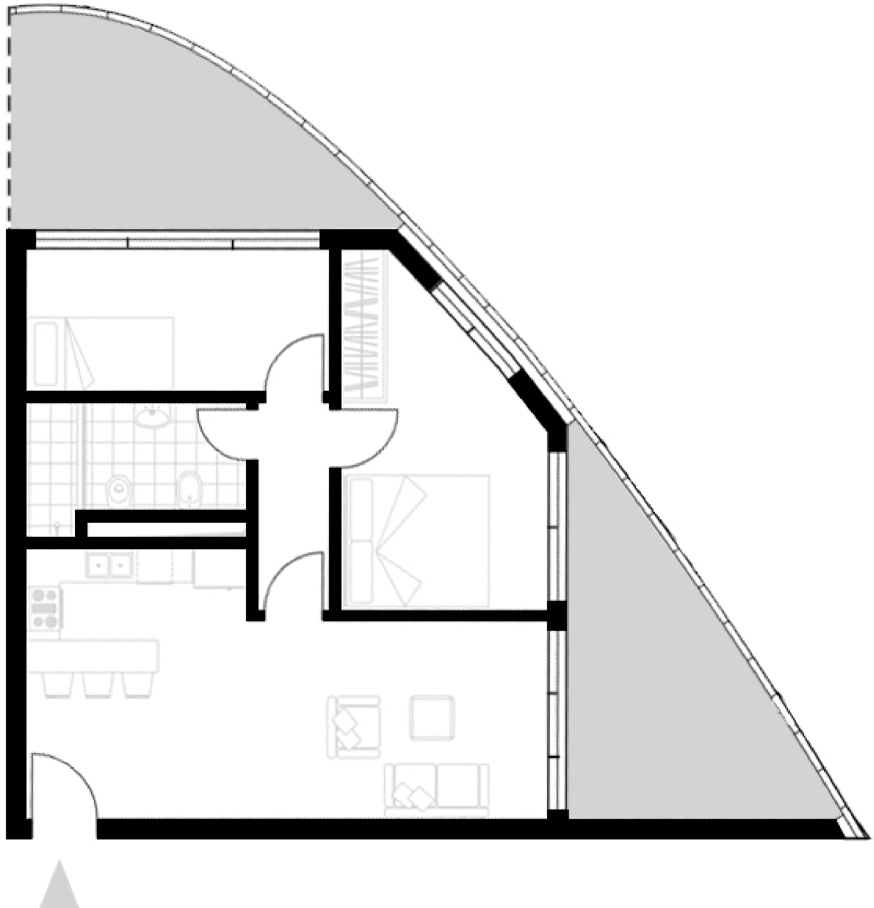
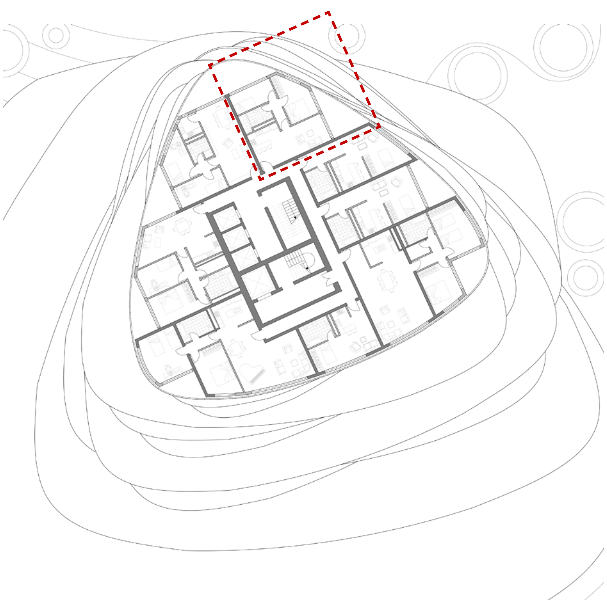


fig. 3.4.16 - apartment layout 4



APARTMENT TYPOLOGY 4

Indoor area	54 m^2
Outdoor area	23 m^2
Users	3

kitchen	1
living room	1
bedrooms	2
bathroom	1

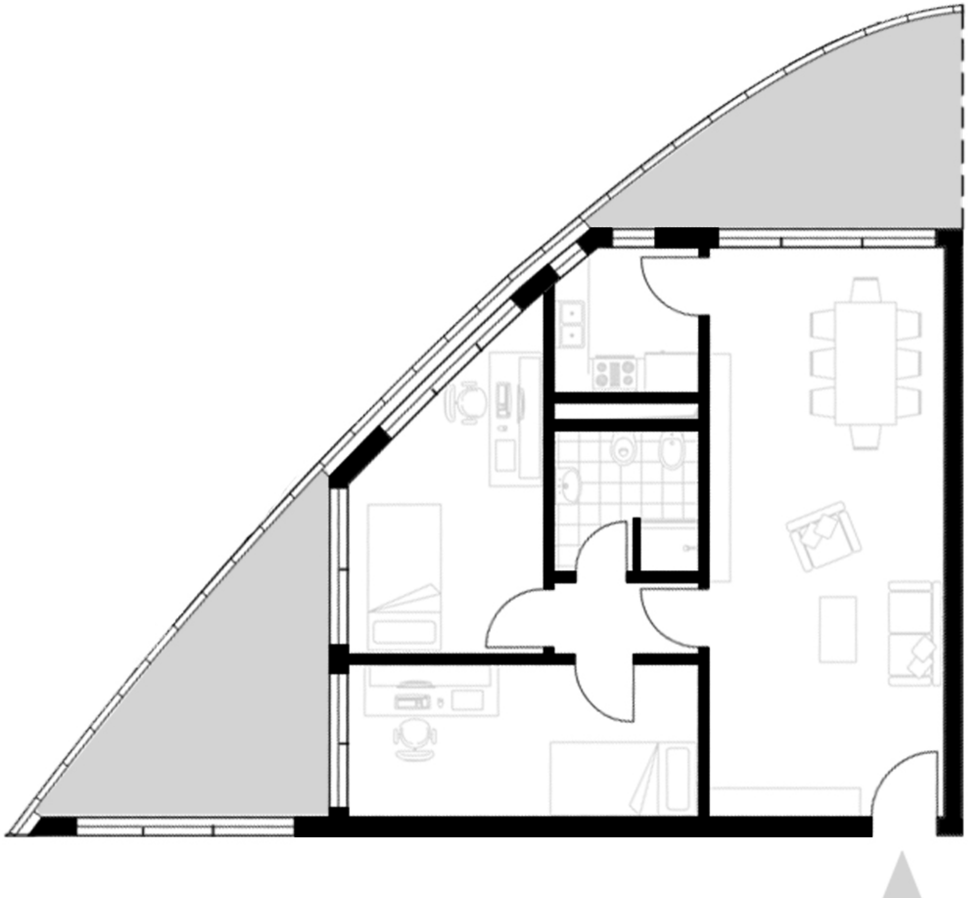
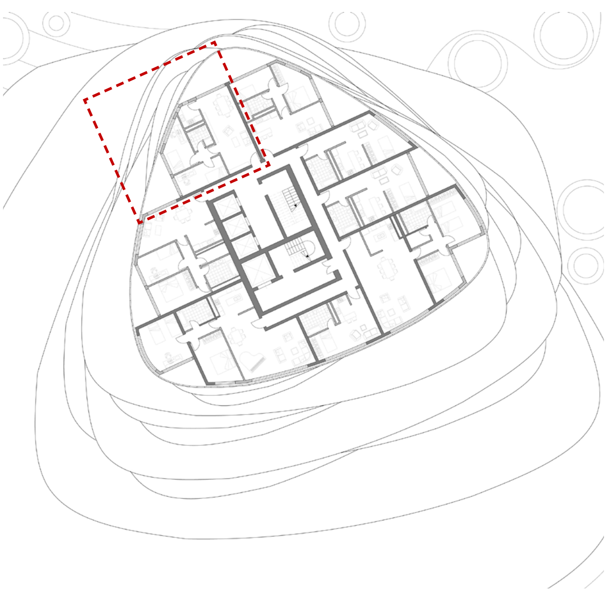


fig. 3.4.17 - apartment layout 5



APARTMENT TYPOLOGY 5

Indoor area	74 m^2
Outdoor area	19 m^2
Users	3

kitchen	1
living room	1
bedrooms	2
closet	1
bathroom	1

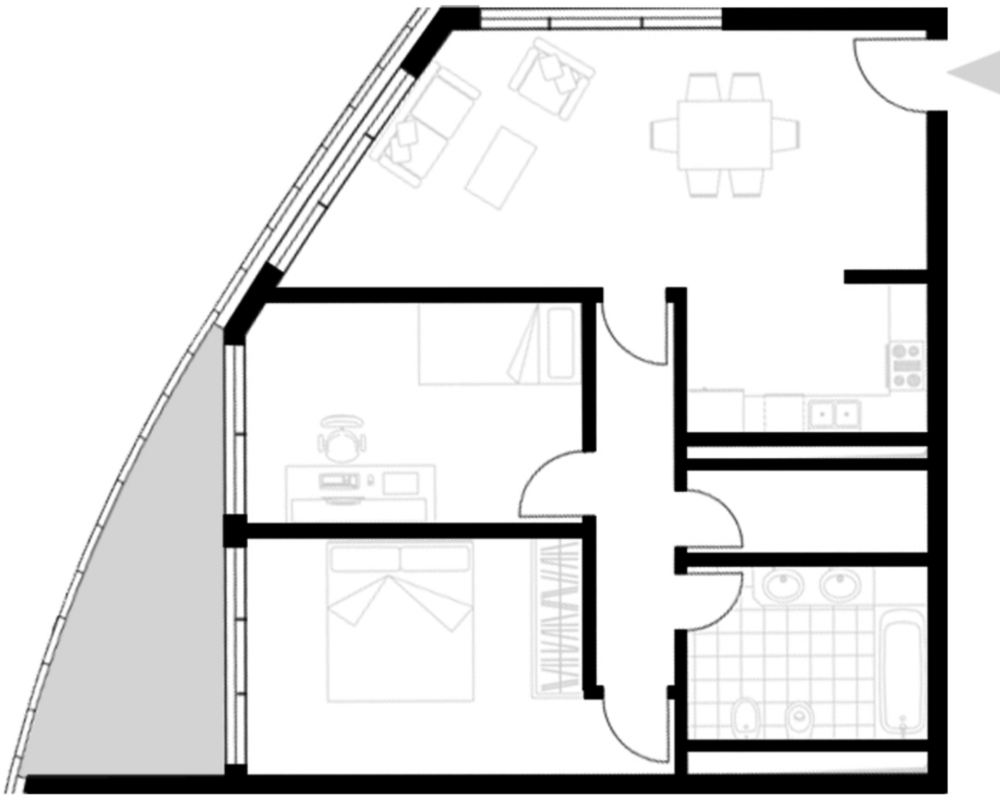
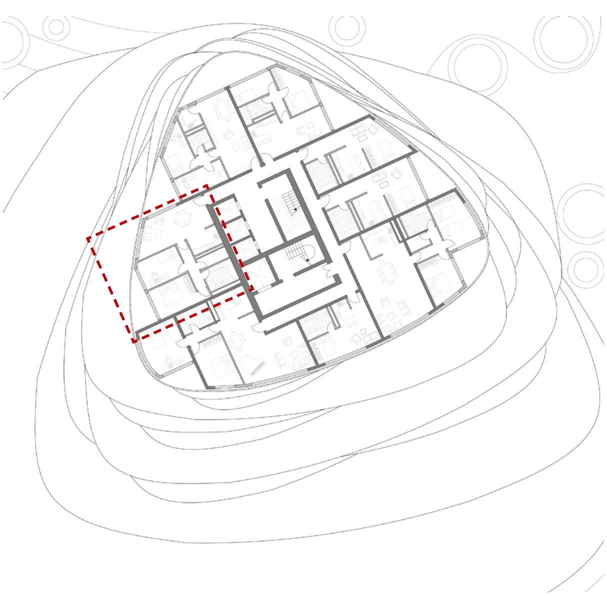


fig. 3.4.18 - apartment layout 6



APARTMENT TYPOLOGY 6

Indoor area	74 m^2
Outdoor area	9 m^2
Users	3

kitchen	1
living room	1
bedrooms	2
bathroom	1

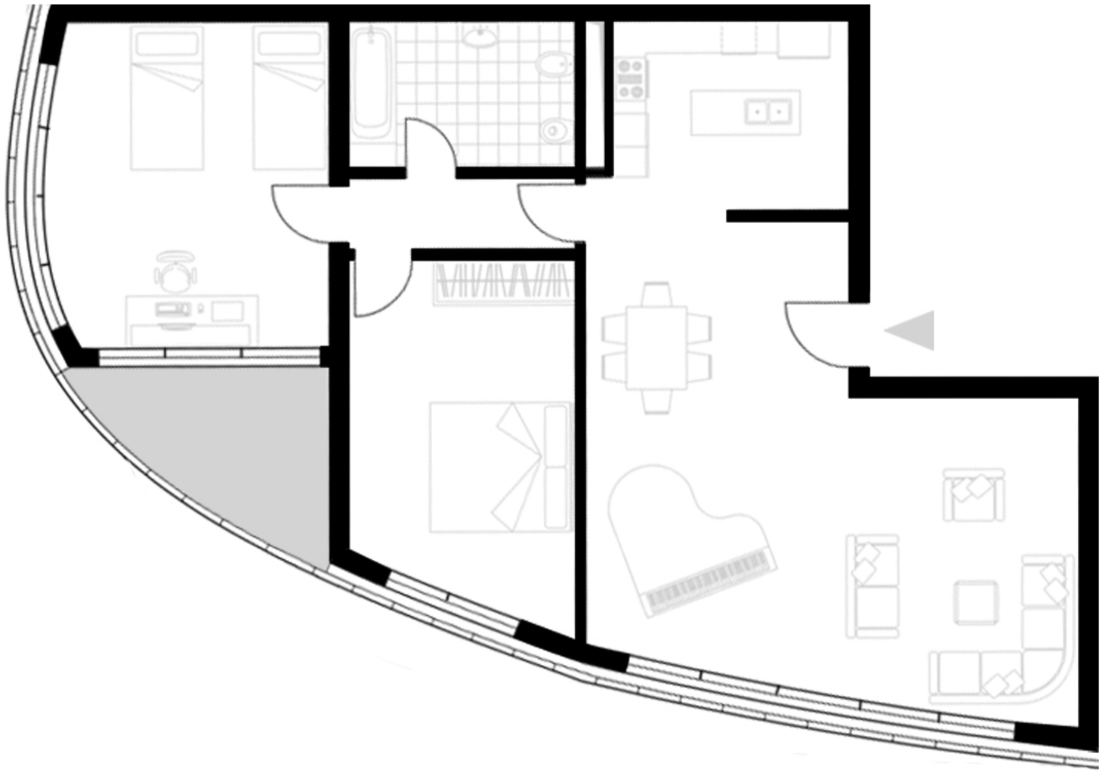


fig. 3.4.19 - apartment layout 7

APARTMENT TYPOLOGY 7

Indoor area	93 m^2
Outdoor area	7 m^2
Users	4

kitchen	1
living room	1
bedrooms	2
bathroom	1

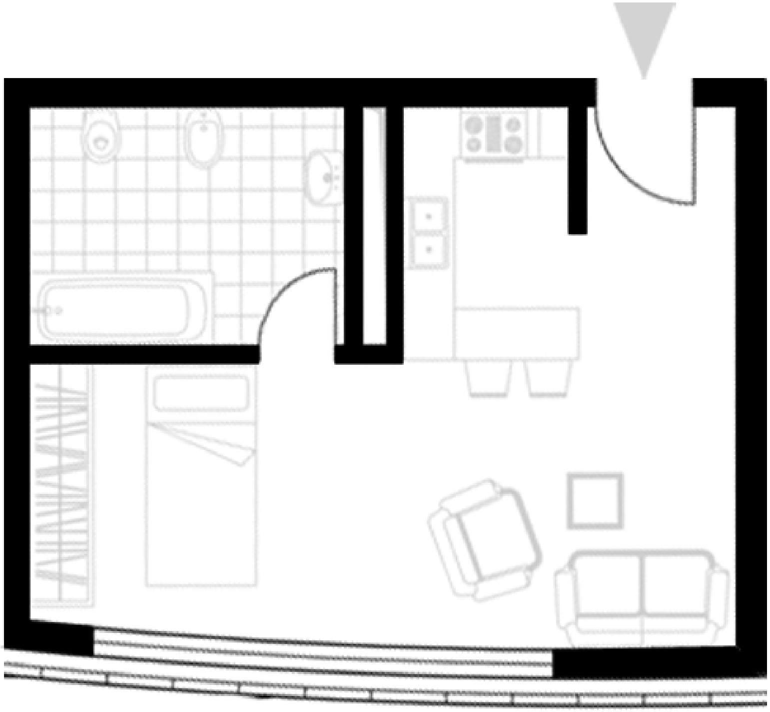


fig. 3.4.20 - apartment layout 8

APARTMENT TYPOLOGY 8

Indoor area	32 m^2
Outdoor area	0 m^2
Users	1

kitchen / living room / bedrooms	1
bathroom	1

fig. 3.4.14

WEST ELEVATION
scale 1:1000

fig. 3.4.15

SOUTH ELEVATION
scale 1:1000

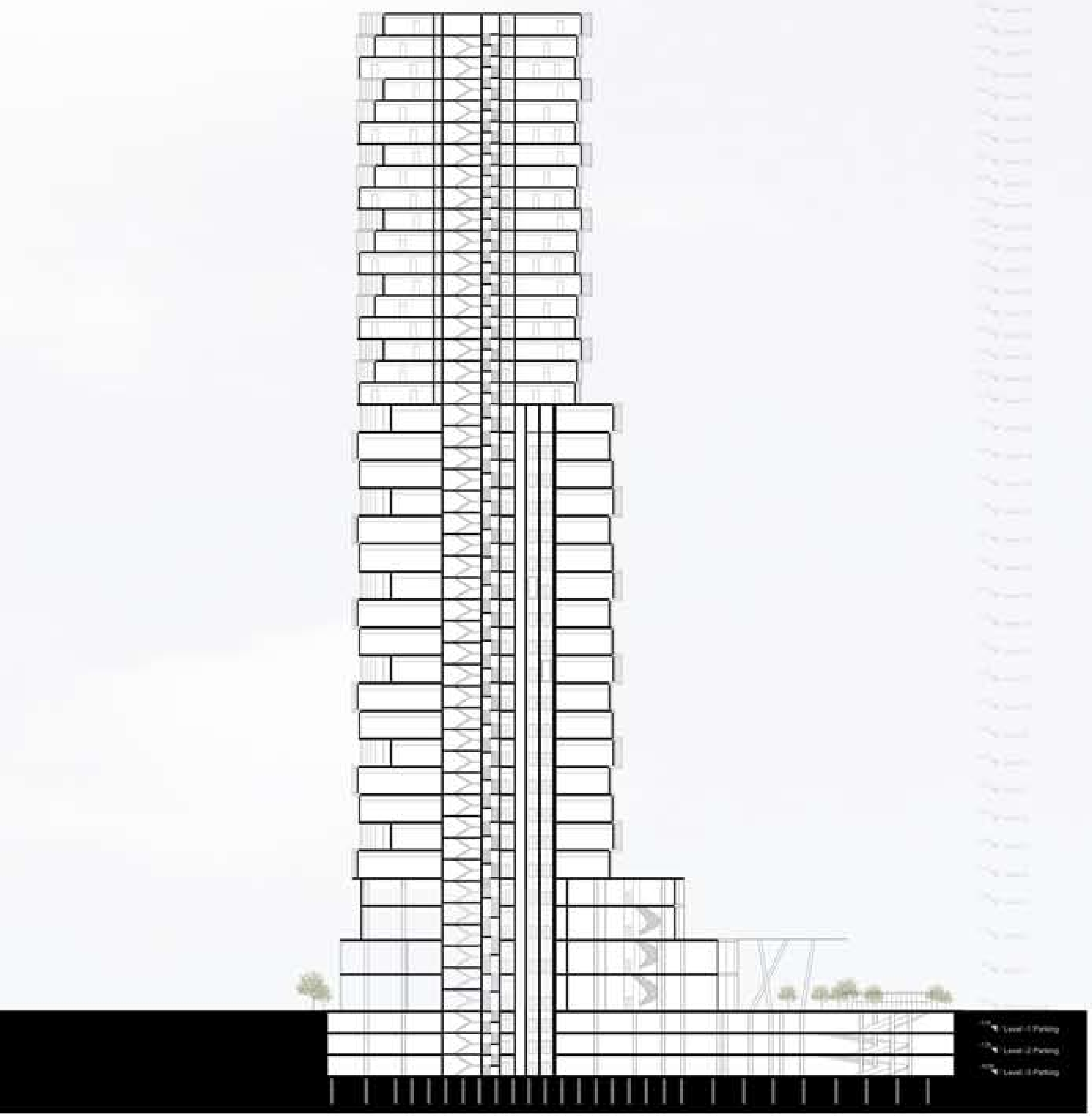


fig. 3.4.16

WEST SECTION
scale 1:1000

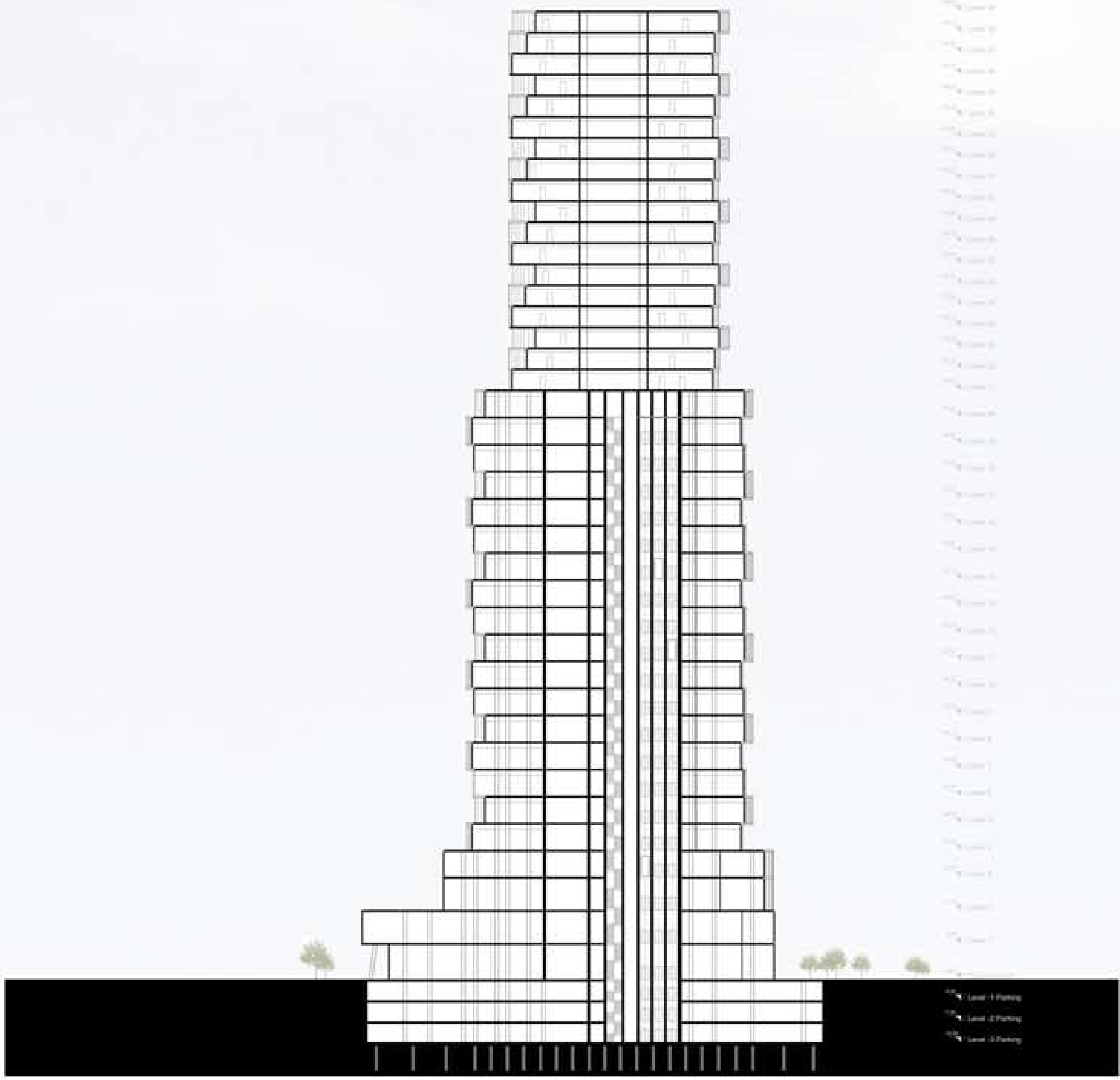


fig. 3.4.17

SOUTH SECTION
scale 1:1000

fig. 3.4.25 - render view from the XXI floor

fig. 3.4.26 - render view from the XVI floor

fig. 3.4.27 - render view from office indoor

fig. 3.4.28 - render view from the ground floor

fig. 3.4.29 - render view residential indoor 1

fig. 3.4.30 - render view residential indoor 2

chapter 3.5

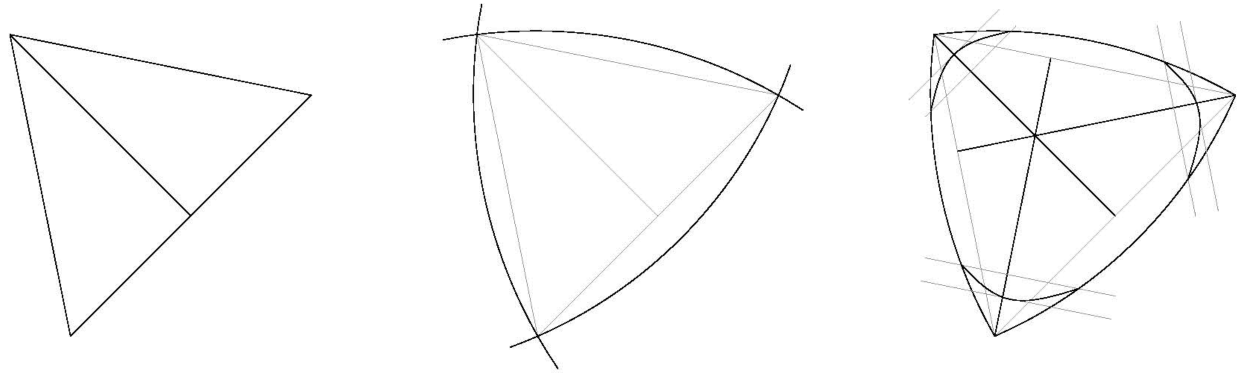
THE PROJECT

THE SHAPE OF THE BUILDING

THE SHAPE OF THE BUILDING

A primary consideration for high rise buildings design is the evaluation of the site conditions, in particular of the presence of the wind forces, of seismic effects and the examination of the geotechnical conditions. In the specific case of the project, the seismic effect doesn't have to be taken into account because there is no risk in The Netherlands of earthquake events and therefore there is no need for taking structural measures to protect the building.
On the contrary, the wind forces have to be taken into account here and are a delicate aspects for the structural dimensioning. For building of such a relevant height the wind forces, in fact, have a primary role even in those structures in reinforced concrete, with a sensitively greater mass in respect to structural steel.
The wind could, in fact, exert a certain degree of pressure on the windward facades and causes a small sway of the structures, according to its degree of flexibility. Of course a streamlined form could reduce the effect produced by the air mass moving toward the building.
The structure has to be, then, adequately designed for carrying the load generated by the wind blowing in order to reduce the tower displacement, in particular at the top where this effect could result particularly unpleasant for the occupants. Comfort is, in fact, an important aspect when considering the wind effects on a building. In fact the tolerance degree for displacement and vibrations caused by wind is different from building to building: the frequency and type of activity taking place in the building have to be carefully considered, also differentiating between day and night situations. Since human perception of the vibrations is proportional to the oscillation speed, the frequency of the oscillations to which building is subjected has to be analyzed in order to avoid unpleasant effects on the occupants. In the designed building, in particular, because of the position, at the top of the building, of the residential apartments which are the most exposed to wind effects on the building, the last have to be analyzed in order to preserve people from unpleasant feelings while they are at home.

The effect of the wind is different according to the facade on which it acts: in particular the windward facade comes under a dragging effect, while the leeward, the opposite one, suffer of a suction or negative pressure effect. The combination of these effects generates a whole net force on the building that for relevant heights, such as in this case, is amplified.
The effect of these wind forces is different even in sites with the same wind conditions: the characteristics of the construction site determine sensitively different effects of the



wind according to the presence or not of a built environment around the building that soften the consequence of wind blowing.
Considering the wind forces is useful in order to dimension the vertical structure of the construction that has to carry the wind load contrasting the sway effects and to exploit better the form of the building in order to reduce at maximum the wind effect on the same.

As visible from the graph, the project area is interested by windy phenomena with a prevalent direction: since wind blows mainly and with the greatest force from South-West, the choice about the orientation of the building, freely positioned according to the surrounding fabric, is mainly influenced by considerations about the possibility of having a "strong side" of the triangular shape toward the main wind direction.

Figure 3.5.2 shows the variance of the wind direction and strength during the year in Eindhoven: the red shape individuates percentage if the distribution of the area in which the wind forces acts more and vary during the period of time taken into consideration.

Considerations about the wind effect and its direction have been taken into account in order to conceive the form of the building. The shape of the floors derives from geometrical considerations upon the stiffness of the triangular form and the advantages that it brings according the wind direction.
Placing the triangular form with one of the angles toward the windward side of the building, the project is meant to expose less plain surface as possible to the direct wind blowing. This proposal has the aim of reducing the stress on the facade that would be cause by the wind blowing on a perpendicular surface. Placing the triangle vertex toward this direction, that, as evident from the graph, is the South-West direction, as the aim, then, to "break" the direct wind flow.
Moreover, the undeformability of the triangle should assure that the wind effect on the building wouldn't act negatively on the facades causing undesired stresses on the glazed envelope.

Some further considerations about the reaction of the building to the wind forces will be done in the chapter concerning the structural design to horizontal actions.

Concerning the form of the floors, the corners are rounded in order to better exploit the surface without having unusable corners, and exploiting them for services in the central core.
The choice concerning the shape of the building is based on the uniform principle of moving the floors respect to each others.
The floors have a similar shape, different in dimension according to the function, and becoming smaller as the building rises.
The form of the floors is the same for each floor, and is rotated, repeating the same rhythm, each 3 floors in order to maintain a common vertical structure and limiting floor spans. The projection of each floor functions as a shading for the lower floor's windows (figure 3.5).

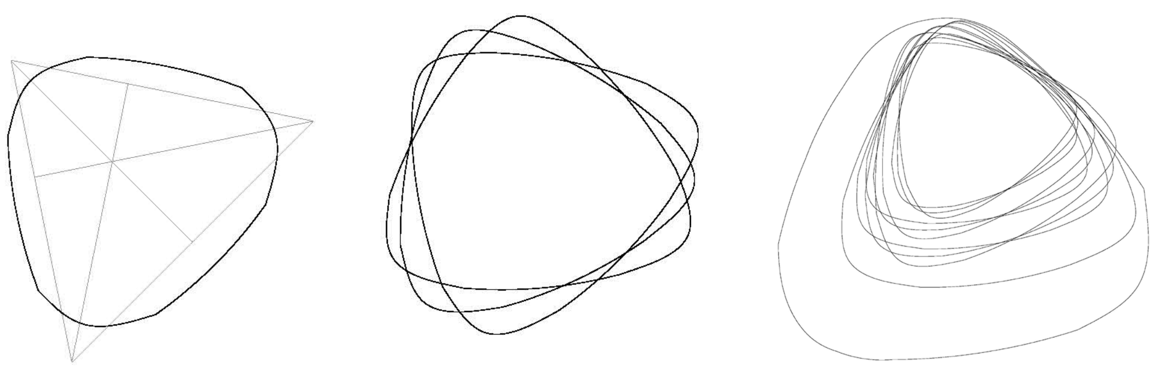


fig. 3.5 - evolution of the building form

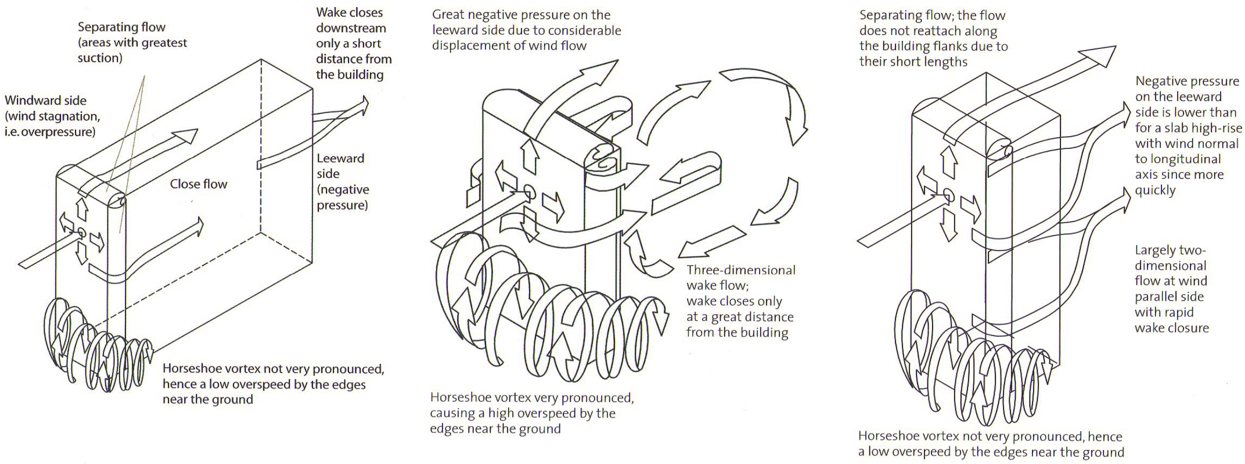


fig. 3.5.1 - wind forces distribution for different building configurations

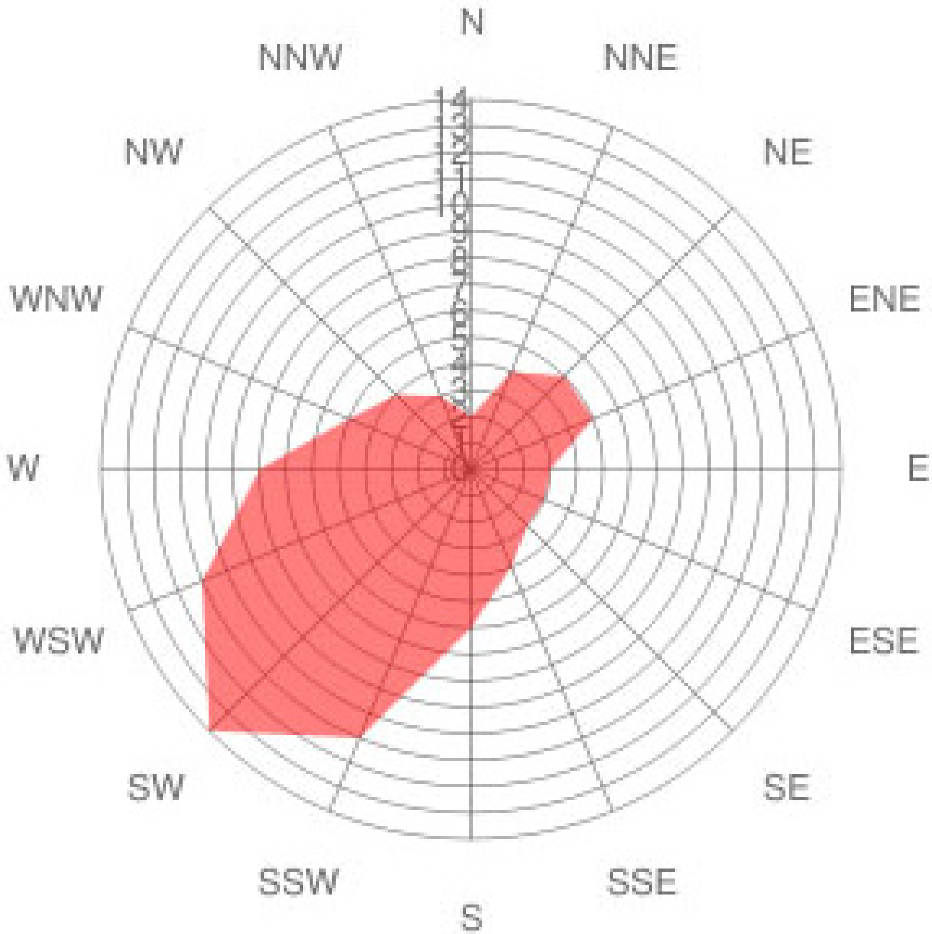


fig. 3.5.2 - prevalent wind direction in the project area

chapter 4

STRUCTURAL DESIGN

As well as a skyscraper can be so defined if the vertical dimension overcomes of a relevant measure the dimension of the base of the building, a similar definition can be assumed for defining high rise buildings in structural terms: a tall building can be so defined when in the structural elements the horizontal loads are larger than vertical loads.

Going higher the structure design becomes more and more delicate requiring innovative and economic structural systems. The possibility of having lighter structural elements or the repetition of the same formworks for such tall constructions is of fundamental importance in these kind of buildings. The building should result from the combination of integrated structures for lateral load resistance and vertical load bearing, as well as of architectural aspects and building services. The design of the structure plays an important role also determining, in some case, architectural features.

The factors that have been taken into consideration for the structural project of the building, however based on preliminary calculations for a pre-dimensioning of the whole structure, are strength, stability and stiffness.
Stiffness and stability are of dominant importance because for such a high rise structure the lateral load, in particular determined by wind actions as discussed in the dedicated paragraph, is the main actor.
Given this, because of the slenderness of the design structures, the major problem has been the realization of a lateral load-resisting structure as the first step in structural dimensioning, in order to diminish as much as possible the horizontal displacement of the top of the building, however maintaining a reasonable area for the interiors and a structure economically viable.

The structure of the designed building is constituted by a central bearing core, which carries almost the whole lateral load of the construction. The core is a reinforced concrete structure realized with bearing walls whose dimension is calculated according to the resistance to the stress caused by wind action.

This central element hosts the services of the buildings, such as emergency stairs and elevators that allow the access to all office and residential floors.
The bearing core for the two part of the building, which is subdivided, as described in the previous chapters, in height between the office part at the bottom, and the residential part at the top, is different: the residential core is smaller than the office's because the stairs and lift serving the first floors stop at the end of the lower block and the deposit spaces and common bathrooms that occupied the rest of the space in the core in the office floors are not necessary anymore here. This is functional to reduce the self weight of the structure as the building rises in height, even if a lower resistance of the core have been necessary to be taken into account for the reduced mass of the same.
However, the smaller core is included in the larger one since the first floors and is just reduced in size as the office part stops.
The central core is integrated by perimeter columns that however have no role in the resistance to lateral sway. These have just the aim of bearing the vertical loads determined by the self weight of the structure, i.e. the floors or facade weight, and live loads due to the presence of people using the building. Part of this complex load is anyway carried by the central core as well to which the floors are anchored.

All the calculations concerning the structural elements belong to a pre-dimensioning procedure based on the local regulations and on the Eurocode 1. In the cases in which precise measures weren't available calculations in favour of safety, considering the worst possible situation, have been done.

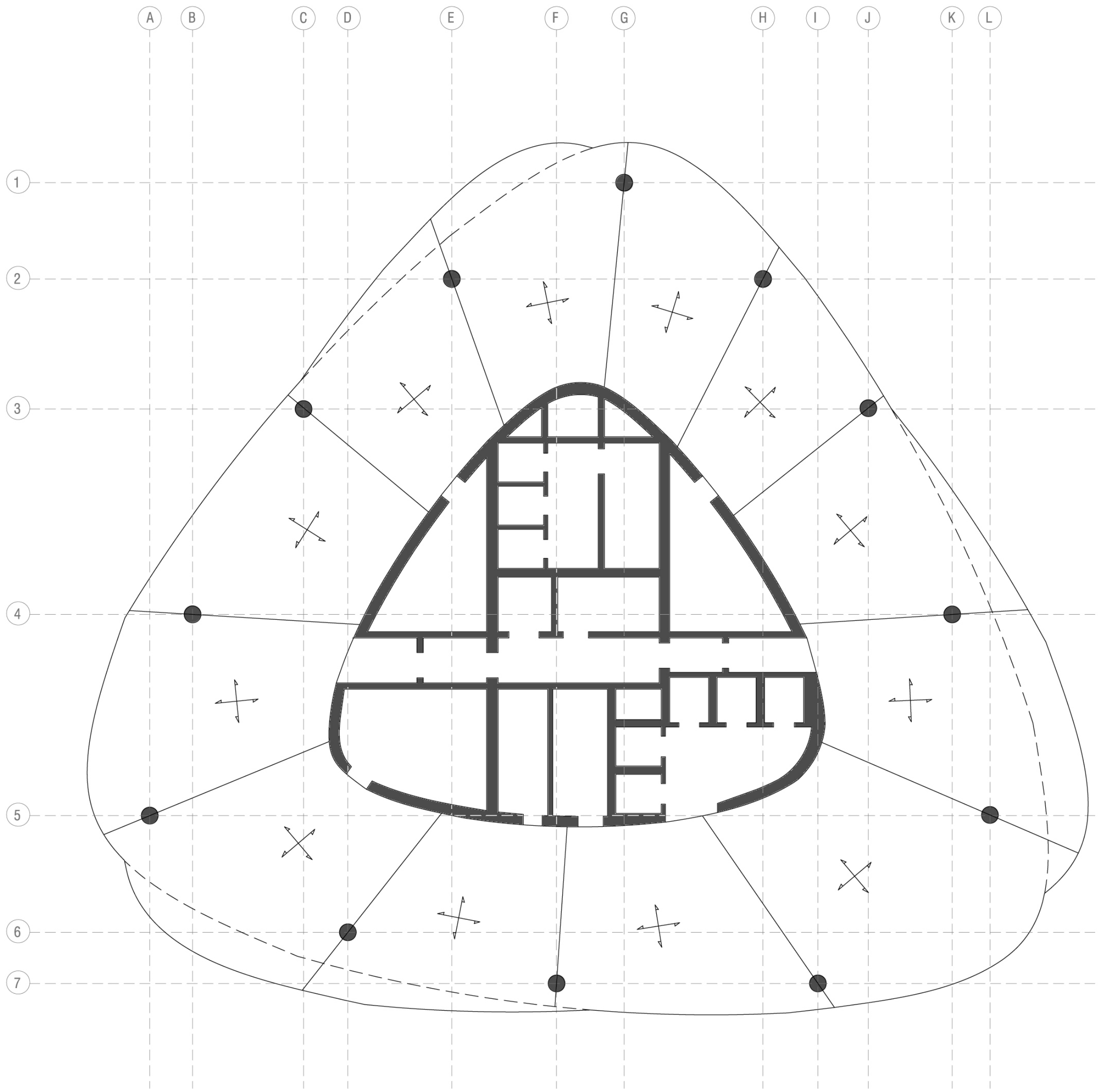


fig. 4.0 - scheme of the floor and vertical structure

chapter 4.1

STRUCTURAL DESIGN

CENTRAL BEARING CORE

The dimensioning of the bearing core is dependent from the influence of the lateral wind loads and on the shape of the structure.

Table 1 shows all the parameters that have been used.

The building is divided in two parts: one hosting mostly offices function and another dedicated to the residential function. The structure for horizontal loads, i.e. the core, is divided in the same two parts (figure 4.1 is the 2D schematization of this). The two parts of the core differ from each other because of the moment of inertia and of the wind load. Because the moment of inertia in the x-direction is the weakest, the largest deflection in this direction is expected.

The moments of inertia are determined using a specific function of the software AutoCAD: once drawn the perimeter of the core and identified it with a region, it is indeed possible to get a print out of the properties of the, including the moment of inertia. This operation is fundamental for the complex curved shape of the office core, which is assumed to be correct as identified by AutoCAD, while the output of the residential part can easily be checked by hand.

The residential core is divided in three areas (as shown in figure 4.1.1) and the moment of inertia of the core can easily be calculated as

$$I = I_1 - I_2 + I_3$$

The values obtained in the following calculations correspond to the values given by AutoCAD (table 1).
Assuming that the output values of the office part are corrected as well, the moment of inertia hasn't been calculated by hand.

table 1 - parameters for bearing core dimensioning

	office part	**residential part**
wind load on facade	2 kN/m²	2 kN/m²
width y-axis	42 m	35 m
width x-axis	46 m	32 m
line load on core y-axis (Q)	92 kN/m	70 kN/m
line load on core x-axis (Q)	84 kN/m	64 kN/m
length/height	100,5 m (parking incl.)	70 m
moment of inertia y-axis	2649 m^4	402 m^4
moment of inertia x-axis	2540 m^4	266 m^4
e-modulus	2 10^7 kN/m²	
total lenght	170,5 m	

RESIDENTIAL PART

The following calculation refers to the moment of Inertia of the residential part.

y - direction

$$I_y = \frac{b_1 \cdot h_1^3}{12} - \frac{b_2 \cdot h_2^3}{12} + \frac{b_2 \cdot h_3^3}{12} =$$
$$= \frac{8,81 \cdot 12^3}{12} - \frac{7,81 \cdot 11^3}{12} + \frac{7,81 \cdot 0,5^3}{12} = 402\,m^4$$

x - direction

$$I_y = \frac{h_1 \cdot b_1^3}{12} - \frac{h_2 \cdot b_2^3}{12} + \frac{h_3 \cdot b_2^3}{12} =$$
$$= \frac{12 \cdot 8,81^3}{12} - \frac{11 \cdot 7,81^3}{12} + \frac{0,5 \cdot 7,81^3}{12} = 266\,m^4$$

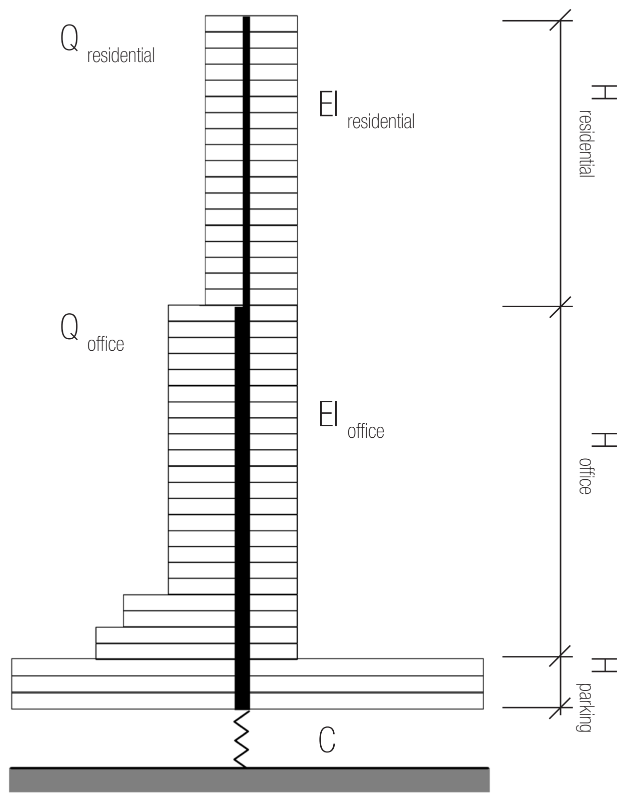


fig. 4.1 - bearing core schematization

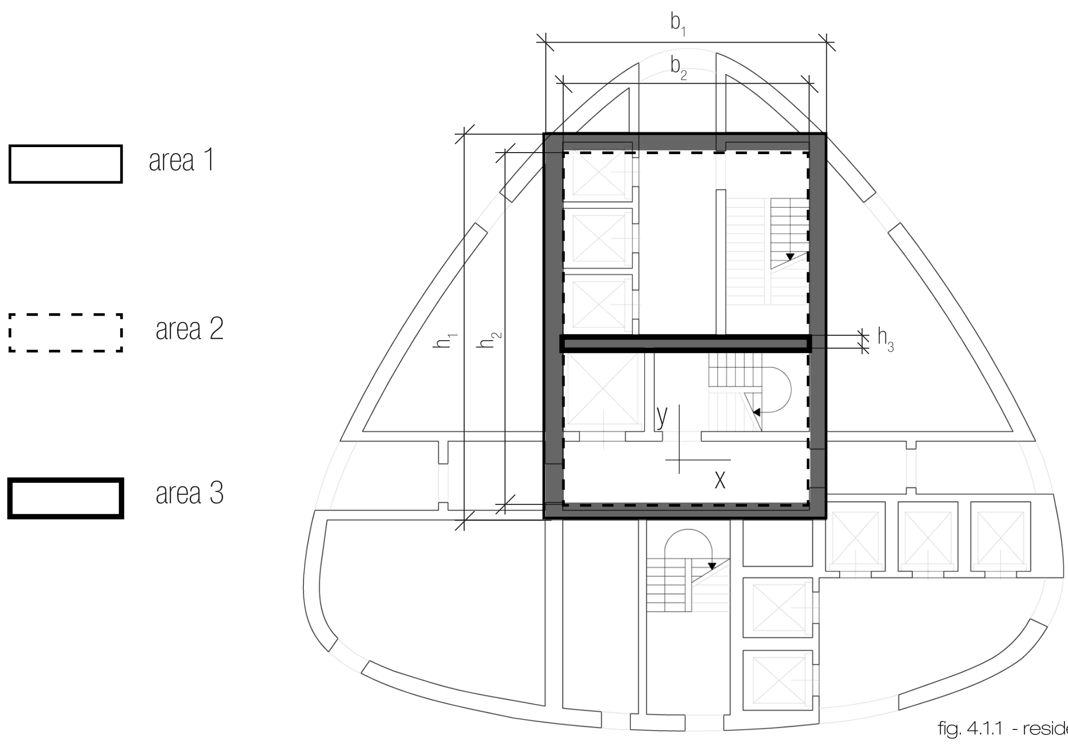


fig. 4.1.1 - residential core scheme

The following calculations are related to the deflection of the core.
A preliminary hand-calculation is done and then verified and compared with the output of a calculation program.

The dimensioning is referred to the wind loads: the wind load in x-direction would give the biggest deflections because the moment of inertia is the smallest. On the other hand the wind load in y-direction is smaller, because the width of the building is smaller. Both deflections will be calculated.

The deformations of the whole building can be calculated by adding the deflections of the two parts (figure 4.1.2).

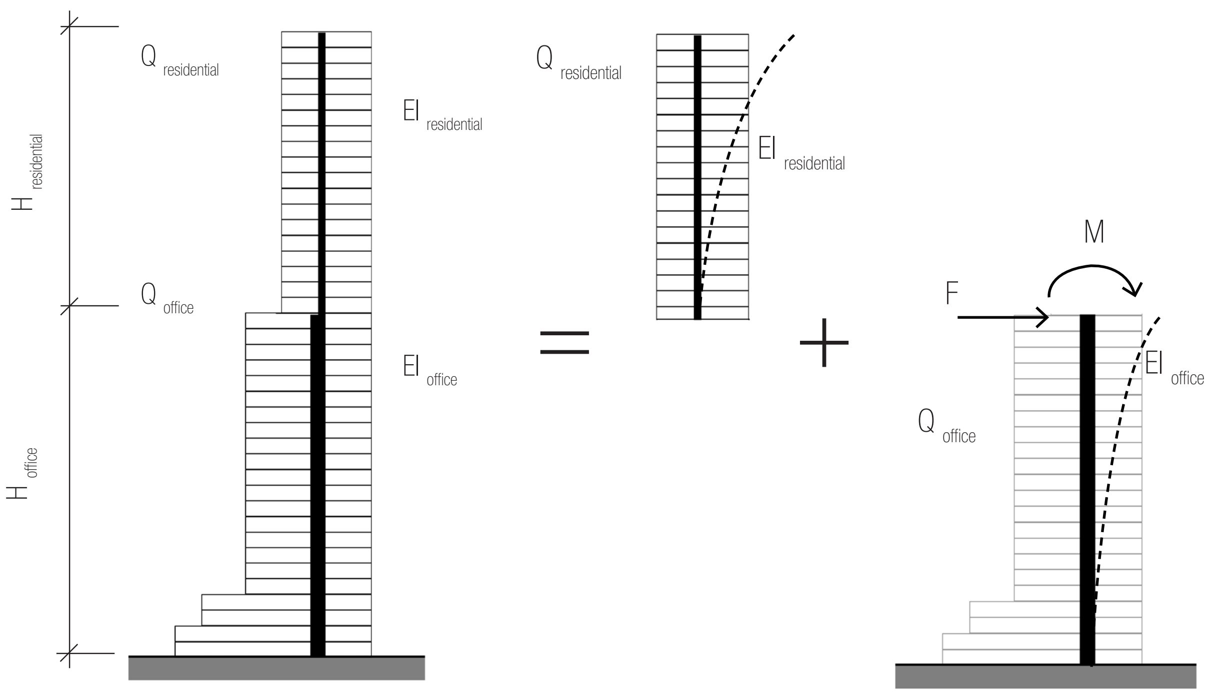


fig. 4.1.2 - bearing core composition

table 2 - forces acting on the core

point load F y-direction	$Q_{residential} \cdot L_{residential}$	$70 \cdot 70 = 4900\,kN$
point load F x-direction		$64 \cdot 70 = 4480\,kN$
moment M y-direction	$\frac{1}{2} Q_{residential} \cdot L^2_{residential}$	$(70 \cdot 70^2)/2 = 171.500\,kNm$
moment M x-direction		$(64 \cdot 70^2)/2 = 156.800\,kNm$

The total deflection of the office part is a sum of the deflection due to the line load Q_{office}, to the point load F and to the moment M in which L and I are the length and the moment of inertia of the office part.

The total deflection of the residential part is the deflection by the line load Q and the rotation of the office part (φ) in which L and I are the length and the moment of inertia of the residential part.

The total rotation of the office part is the sum of the rotation by the line load Q, the point load F and the moment M, in which L and I are the length and the moment of Inertia of the office part.

$$\delta_{office} = \delta_Q + \delta_F + \delta_M = \frac{Q_{office}L^4}{8EI} + \frac{FL^3}{3EI} + \frac{ML^2}{2EI}$$

$$\delta_{office} = \frac{92 \cdot 100,5^4}{8 \cdot 2_{10^7} \cdot 2649} + \frac{4.900 \cdot 100,5^3}{3 \cdot 2_{10^7} \cdot 2649} + \frac{171.500 \cdot 100,5^2}{2 \cdot 2_{10^7} \cdot 2649} = 22,1 + 31,3 + 16,3 = 69,8\,mm$$

$$\delta_{office} = \frac{84 \cdot 100,5^4}{8 \cdot 2_{10^7} \cdot 2540} + \frac{4.480 \cdot 100,5^3}{3 \cdot 2_{10^7} \cdot 2540} + \frac{156.800 \cdot 100,5^2}{2 \cdot 2_{10^7} \cdot 2540} = 21,1 + 29,8 + 15,6 = 66,5\,mm$$

$$\delta_{residential} = \delta_Q + \delta_\phi = \frac{Q_{residential}L^4}{8EI} + \phi L$$

$$\phi = \phi_Q + \phi_F + \phi_M = \frac{Q_{office}L^3}{6EI} + \frac{FL^2}{EI} + \frac{ML}{EI}$$

$$\phi_y = \frac{92 \cdot 100,5^3}{6 \cdot 2_{10^7} \cdot 2649} + \frac{4.900 \cdot 100,5^2}{2 \cdot 2_{10^7} \cdot 2649} + \frac{171.500 \cdot 100,5}{2 \cdot 2_{10^7} \cdot 2649} = 2,49_{10^{-4}} + 4,67_{10^{-4}} + 3,25_{10^{-4}} = 10,9_{10^{-4}}$$

$$\delta_y = \frac{70 \cdot 70^4}{8 \cdot 2_{10^7} \cdot 402} + 10,9_{10^{-4}} \cdot 70 = 26,1 + 76,0 = 102,2\,mm$$

$$\phi_x = \frac{84 \cdot 100,5^3}{6 \cdot 2_{10^7} \cdot 2540} + \frac{4.480 \cdot 100,5^2}{2 \cdot 2_{10^7} \cdot 2540} + \frac{156.800 \cdot 100,5}{2 \cdot 2_{10^7} \cdot 2540} = 2,80_{10^{-4}} + 4,45_{10^{-4}} + 3,10_{10^{-4}} = 10,4_{10^{-4}}$$

$$\delta_y = \frac{64 \cdot 70^4}{8 \cdot 2_{10^7} \cdot 266} + 10,4_{10^{-4}} \cdot 70 = 36,1 + 72,5 = 108,6\,mm$$

COMPARISON MATRIX CALCULATION

The scheme of the hand calculation is therefore used for the model in the software program MatrixFrame inserting a ‘user defined’ cross-section. Table 3 shows the properties of this cross-section.

The results from MatrixFrame are described in table 4: next to them, the results of the hand calculation are placed for comparison. The MatrixFrame results correspond almost totally to the results of the hand calculation, therefore the hand calculation is assumed to be correct.

Both calculations give as a result a total deflection of 172 mm in y-direction and 175 mm in x-direction.
The deflections of the office part show that not only the bending stiffness has an influence, like expected, but also the wind load. That’s why the deflection in y-direction is bigger than in x-direction despite a bigger moment of inertia.
For the residential part the difference between the moments of inertia in the two directions is larger, therefore the deflection due to the bending stiffness is larger in the x-direction.

All the deflections are within the limit, since the limit is

$$\frac{H}{500} = \frac{160}{500} = 0,32\,m = 320\,mm$$

SYMMETRIC LOADED COMPUTER MODEL

The core has been modelled in a three-dimensional analysis computer software in order to have a graphical output of the most stressed portions of the core.

The first model that has been made was a model of the acutal core but, especially modelling the asymmetric load, the curved shape lead to some problems. Therefore a new simplified model has been made, that is constructed of only straight walls (not curved) of one story high (figure 4.1.3). This gave the opportunity to model the loads in four different ways: surface loads on the walls of the core, horizontal line loads per floor, vertical line loads per element parallel to the wind load and point loads at the intersection between a floor and an element parallel to the wind load. The dimensions of these loads are clarified in table 5.

table 3 - core cross section properties

	office part		**residential part**	
	y-direction	x-direction	y-direction	x-direction
I_y (moment of inertia)				
I_z (moment of inertia)	$2649\ m^4$	$2540\ m^4$	$402\ m^4$	$266\ m^4$
I_t (polar moment of inertia)				
A (area)	$69\ m^2$		$24\ m^2$	
E (elasticity module)	$2\ 10^7$ kN/m			

table 4 - MatrixFrame calculations results

	height 100,5 m				**height 170,5 m**			
	y-direction		x-direction		y-direction		x-direction	
	Matrix	hand calc.	Matrix	hand calc.	Matrix	hand calc.	Matrix	hand calc.
deflection	69,8 mm	69,8 mm	66,5 mm	66,5 mm	172 mm	172 mm	175 mm	175 mm
rotation	$1,09\ 10^3$	$1,09\ 10^3$	$1,04\ 10^3$	$1,04\ 10^3$	$1,58\ 10^3$	-	$1,72\ 10^3$	-

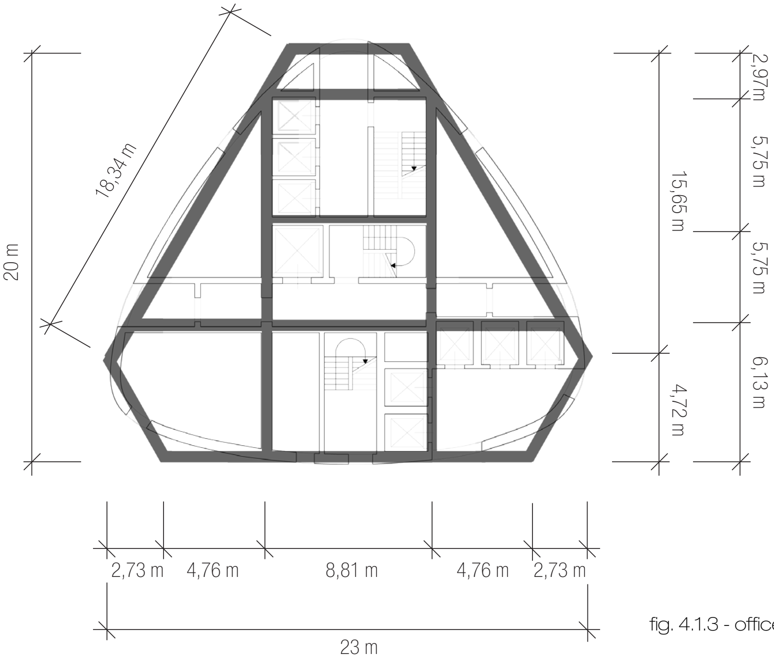


fig. 4.1.3 - office core schematization

table 5 - loads on the cores

		office part	
		y-direction	x-direction
surface load	*Q/width core**	$92/23=4\,kN/m^2$	$84/20=4,2\,kN/m^2$
horizontal line load	*Q/width core* by floor height*	$92/(23\cdot4)=16\,kN/m$	$84/(20\cdot4)=16,8\,kN/m$
vertical line load	*Q/n. of walls parallel to wind load*	$92/2=46\,kN/m$	$84/5=16,8\,kN/m$
point loads	*Q/n. of walls parallel to wind load by floor height*	$92/(2\cdot4)=184\,kN$	$84/(5\cdot4)=67,2\,kN$
		residential part	
		y-direction	x-direction
surface load	*Q/width core**	$70/8,31=8,42\,kN/m^2$	$64/11,5=5,57\,kN/m^2$
horizontal line load	*Q/width core* by floor height*	$70/(8,31\cdot3,5)=29,5\,kN/m$	$64/(11,5\cdot3,5)=19,5\,kN/m$
vertical line load	*Q/n. of walls parallel to wind load*	$70/2=35\,kN/m$	$64/3=21,3\,kN/m$
point loads	*Q/n. of walls parallel to wind load by floor height*	$70/(2\cdot3,5)=122,5\,kN$	$64/(3\cdot3,5)=74,7\,kN$

* *width core* is defined by the distance between the central lines of the elements

Every output is read out from corresponding elements: in x-direction elements parallel to the wind load and with the same size in both parts are used, because they bend the least out of plane (figure 4.1.4 A). In the y-direction the same criteria are used (figure 4.1.4 B).
The deflections due to the four load cases are compared with the results of the hand calculation (table 6).

The deflections of the model are higher than the deflections of the hand calculation, except for those of the office part due to the vertical line load in the x-direction. The 3D-diagrams of the rotation around z-axis make clear that the surface and horizontal line loads cause bending out of plane of the perpendicular wall they're applied on (figure 4.1.4-4.1.5 B) and all the loads in x-direction cause torsion (Figure 4.1.5 A-B).
The cause of the torsion is the uneven stiffness of the parallel walls.
In reality, the out of plane-bending of the walls is restricted by the floors.
Scia Engineer has a program function to create so-called 'master' nodes and 'slave' edges or nodes, through which the cross-section of the core can be maintained.
By this function, for each floor, the horizontal edges of the walls are made 'slave' edges of a node (figure 4.1.6). This expedient eliminates the greater part of the out of plane-bending, but it still occurs between the floors around the vertical edges of the elements. The forces in x-directions still elicit torsion of the building, but they are spread over the height instead of concentrated at the transition point of the two parts of the core. The torsion at the top is equal to the expected torsion in response to the symmetry of the core.
The loads in y-direction cause no torsion at the top and the loads in x-direction torsion of -0,1 milli-radians. This causes a deformation of

$$d = 0{,}1 \cdot 10^{-3} \cdot 17{,}5 \cdot 10^{3}\, mm = 1{,}75\, mm$$

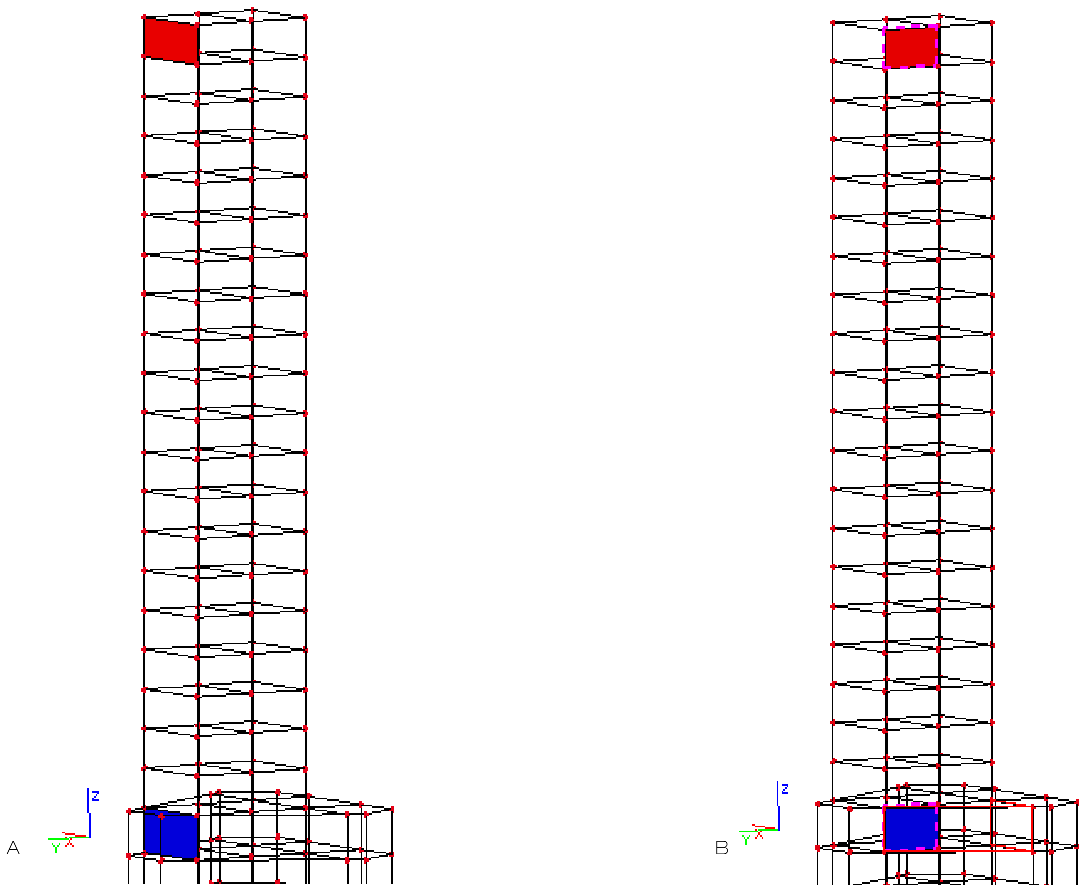


fig. 4.1.4 - schematization of walls behaviour on the core surface

table 6 - SciaEngineer analysis results

	office part		residential part		total	
	y-direction	x-direction	y-direction	x-direction	y-direction	x-direction
surface load	78,8 mm	74,7 mm	115,5 mm	125,1 mm	194,3 mm	199,8 mm
horizontal line load	74,1 mm	71,6 mm	111,5 mm	122,6 mm	185,6 mm	194,2 mm
vertical line load	73,3 mm	66,4 mm	110,8 mm	118,3 mm	184,1 mm	184,7 mm
point loads	73,6 mm	71,4 mm	111,1 mm	122,4 mm	184,7 mm	193,6 mm
hand calculation	69,8 mm	66,5 mm	102,2 mm	108,5 mm	172,0 mm	175,1 mm

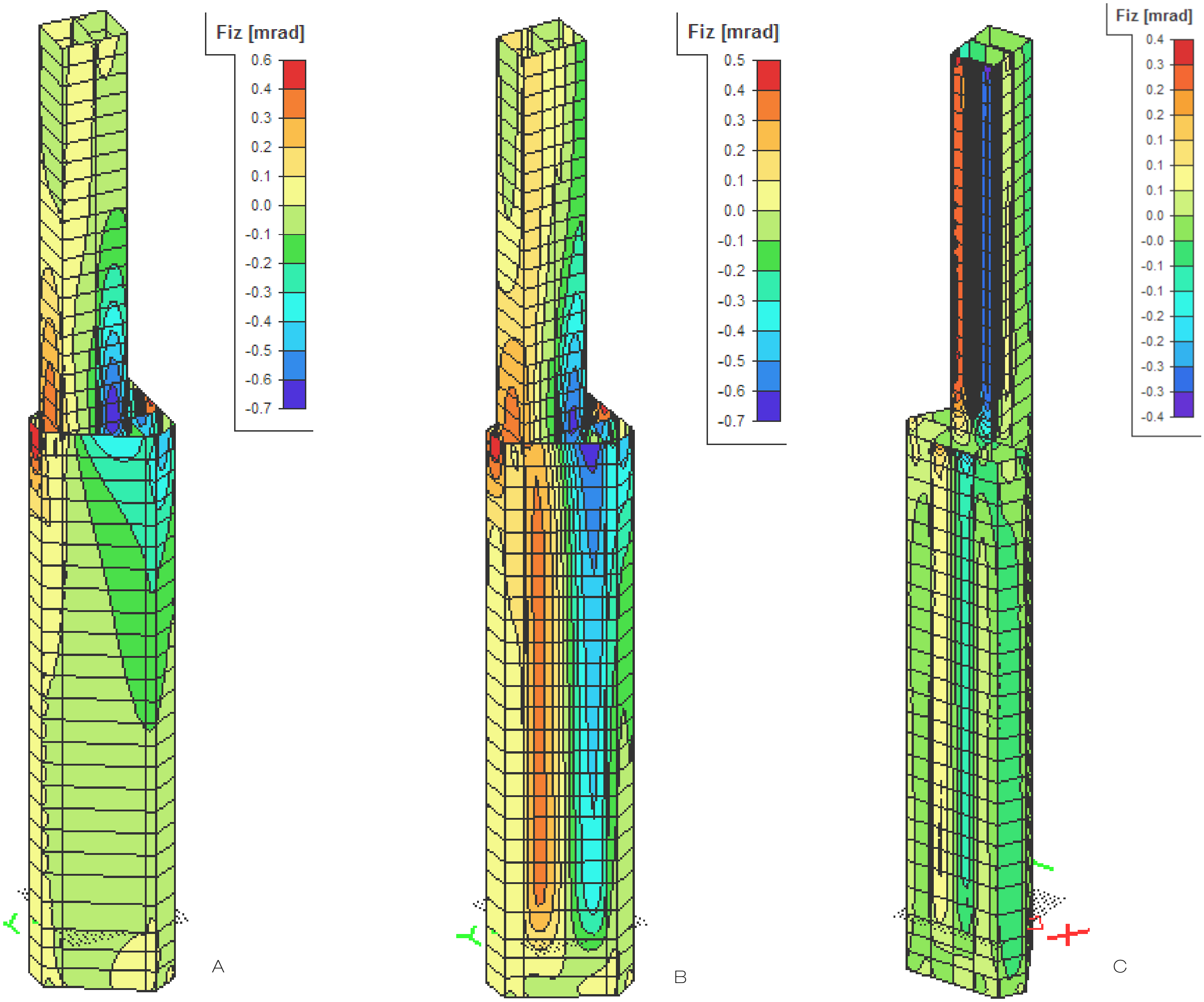


fig. 4.1.5 - three-dimensional deformation analysis SciaEngineer

Overall, the deflections of this model and the results of the hand calculation are similar (table 7).

In the y-direction the results of the surface line loads are higher: ±10mm at the top. The deflections by the vertical line loads in the x-direction are smaller: ±11mm at the top.

From now on only the horizontal load case will be analyzed, because it easily can be used for an asymmetric analysis.

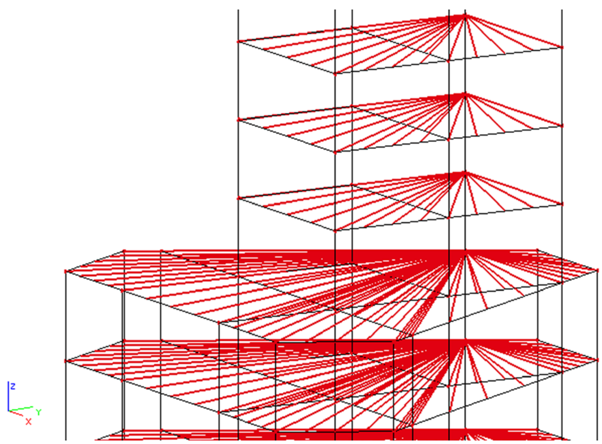


fig. 4.1.6 - floor constraints

OPENINGS IN THE WALLS

Deformation till now investigated are referred to a core with solid walls.
In reality there have to be openings for passing through, corresponding to the entrances of the elevators area, stairs, bathrooms or other service spaces.
According to the lay-outs of each floor, several openings are in the walls as shown in figure 4.1.7.

The part of the wall left between two sides of the opening, above the passage, has a height of one meter and a thickness of 500 millimeters, the same as other walls.
The areas between the openings are similar to beams and therefore will be subject to cracking-phenomena. Given that, the E-module of those parts is decreased. The increasing of the deflection due to those opening is in y-direction around 10 % and in x-direction 6-9%. The differences evidenced by the decreasing of the e-module are not so noticeable (table 8).
As a verification, a hand calculation of the core with those holes has been made.
Because of the openings in the cross section, the moment of inertia used in this calculation is smaller (table 9). The deformations increased by the openings correspond to the result of the hand calculation.

table 7 - hand calculations results

	office part		**residential part**		**total**	
	y-direction	x-direction	y-direction	x-direction	y-direction	x-direction
surface load	76,2 mm	69,8 mm	105,9 mm	108,1 mm	182,1 mm	177,9 mm
horizontal line load	71,5 mm	66,9 mm	101,9 mm	105,6 mm	173,4 mm	172,5 mm
vertical line load	70,9 mm	62,1 mm	101,2 mm	101,4 mm	172,1 mm	163,5 mm
point loads	71,1 mm	66,7 mm	101,5 mm	105,3 mm	172,6 mm	172,0 mm
hand calculation	69,8 mm	66,5 mm	102,2 mm	108,6 mm	172,0 mm	175,1 mm

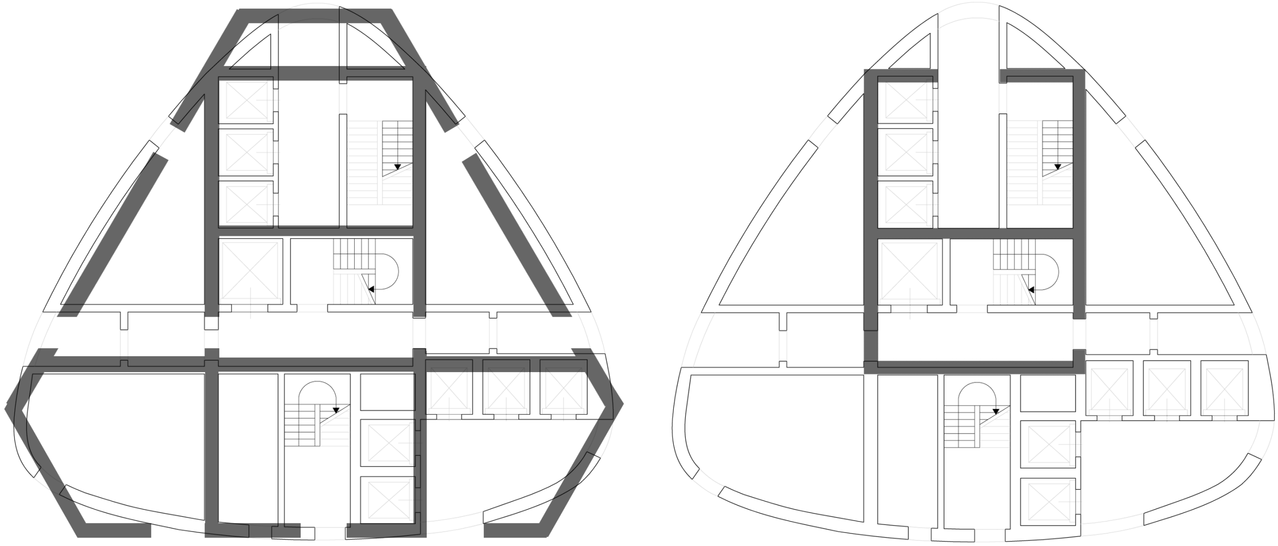


fig. 4.1.7 - office and residential cores with holes

table 8 - different hypothesis deflection comparison

horizontal linear load (no openings)	77,0 mm	70,4 mm	106,6 mm	108,7 mm	183,6 mm	179,1 mm
horizontal linear load (openings)	78,0 mm	71,8 mm	111,0 mm	112,1 mm	189,0 m	183,9 mm
horizontal linear load E 5000 (openings)	78,6 mm	72,3 mm	111,7 mm	112,9 mm	190,3 mm	185,2 mm
horizontal linear load E 100 (openings)	79,0 mm	72,7 mm	112,2 mm	113,4 mm	191,2 mm	186,1 mm
hand calculation (openings)	76,1 mm	71,7 mm	112,3 mm	115,5 mm	188,4 mm	187,2 mm

table 9 - different hypothesis Moment of Inertia comparison

	office part		**residential part**	
	y-direction	x-direction	y-direction	x-direction
I Moment of inertia (no openings)	2649 m^4	2540 m^4	402 m^4	266 m^4
I Moment of inertia (openings)	2429 m^4	2356 m^4	358 m^4	257 m^4

LOADS UNDER AN ANGLE OF 30 DEGREES

The shape of the building, as already discussed, is conceived as a triangular-like: as a consequence the wind also hits the building over the full width when it is rotated thirty degrees, with respect to the actual orientation of the building, in West direction as shown in figure 4.1.8.

The following paragraph investigates the entity of the influence of this rotation on the deflections.
Rotating the cross section of 30 degrees in West direction, in terms of wind load, loads and stiffness are modified. Has to be noticed that the width of the building in x and y-direction interchange (table 10).
Furthermore the change in stiffness doesn't evidence a reduction of the moment o inertia: they preserve more or less the same value (table 11).

The values of the stiffness are determined by AutoCAD and have been checked by hand, but evidencing slightly different results. This is the reason of the difference of the deflection in x-direction between the hand calculation and the model (table 12). The deflection of the rotated load case are similar to the non -rotated one, because the stiffness and loadings don't differ that much.

ASYMMETRIC LOADING

The building is sensitive to asymmetries because of its triangular shape. That's why asymmetric horizontal load case has been analyzed (figure 4.1.9). This analysis has been made for the regular and rotated cross-section.
At the leeward side of the building a tension force has been applied. The magnitude of this force corresponds to the wind load of the symmetric load case times a factor that depends on the height-depth ration of the building. At the windward side a triangular load has been applied. The minimum magnitude of this force is zero and the maximum magnitude is the wind load of the symmetric load case times 0,8.

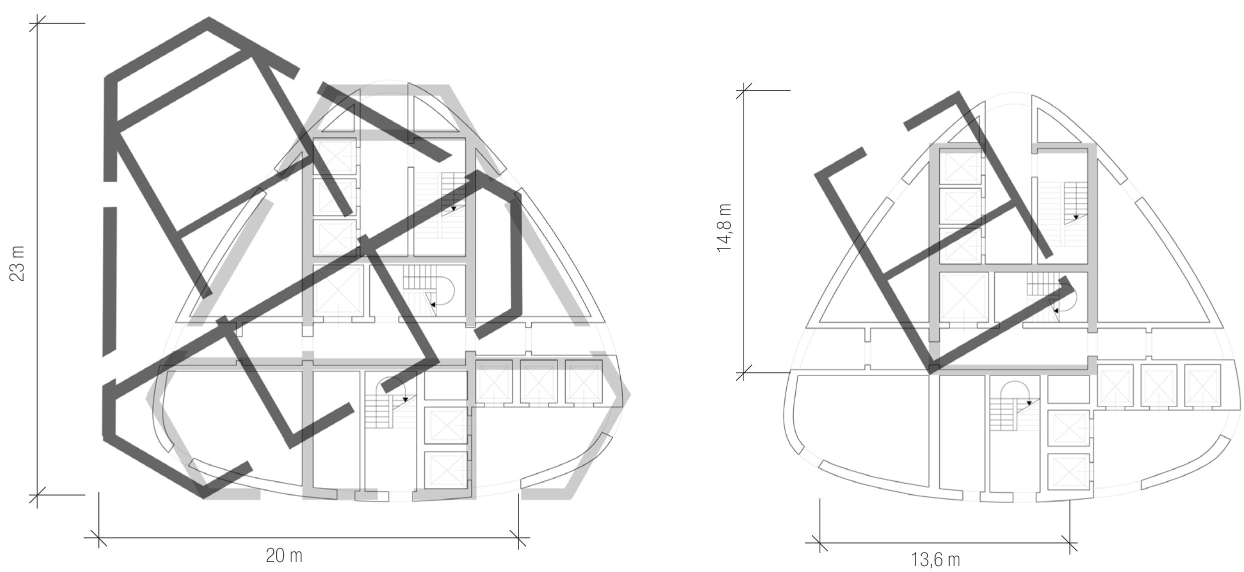


fig. 4.1.8 - 30 degrees angle rotated cores

$$\left.\begin{array}{l} q_s = c_{f,s}\, c_s\, c_d\, q_b \\ \left.\begin{array}{l} H/d = 5 \rightarrow c_{f,s} = 0,7 \\ H/d = 1 \rightarrow c_{f,s} = 0,5 \end{array}\right\} H/d = 4,4 \rightarrow c_{,s} = 0,67 \\ c_s\, c_d\, q_b = 2\,kN/m^2 \end{array}\right\} q_s = 0,67 \cdot 2 = 1,34\,kN/m^2$$

$$\left.\begin{array}{l} q_c = c_{f,s}\, c_s\, c_d\, q_b \\ c_{f,s} = 0,8 \\ c_s\, c_d\, q_b = 2\,kN/m^2 \end{array}\right\} q_s = 0,8 \cdot 2 = 1,6\,kN/m^2$$

table 10 - orthogonal and rotated core loads comparison

		office part	
		y-direction	x-direction
horizontal linear load (orthogonal)	*Q/width core * by floor height*	$92/(23 \cdot 4) = 16\,kN/m$	$84/(20 \cdot 4) = 16,8\,kN/m$
horizontal linear load (rotated)	*Q/width core * by floor height*	$84/(20 \cdot 4) = 16,8\,kN/m**$	$92/(23 \cdot 4) = 16\,kN/m**$
		residential part	
		y-direction	x-direction
horizontal linear load (orthogonal)	*Q/width core * by floor height*	$70/(8,31 \cdot 3,5) = 29,5\,kN/m$	$64/(11,5 \cdot 3,5) = 19,5\,kN/m$
horizontal linear load (rotated)	*Q/width core * by floor height*	$64/(13,6 \cdot 3,5) = 16,5\,kN/m**$	$70/(14,8 \cdot 3,5) = 16,6\,kN/m**$

* *width core* is defined by the distance between the central lines of the elements
** the parts which are unde an angle, considering the x and y-direction, have to be multiplied by the cosins of that angle

table 11 - Moments of Inertia with openings comparison

	office part		**residential part**	
	y-direction	x-direction	y-direction	x-direction
I Moment of inertia (openings)	2429 m4	2356 m	358 m	257 m
I Moment of inertia (openings/rotated)	2411 m	2374 m	341 m	275 m

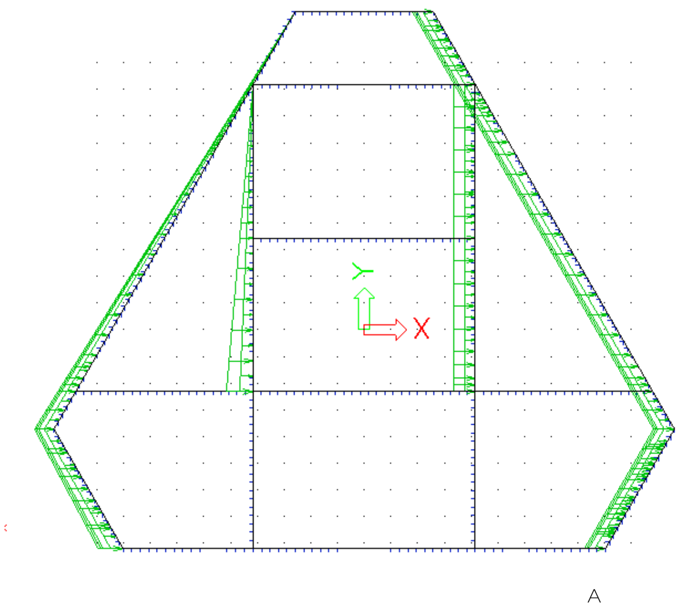
The regular cross-section is symmetric in y-direction, therefore just one asymmetric analysis has been conducted (figure 4.1.9 A). In the x-direction two analyses are needed, because of the asymmetry (figure 4.1.9 B-C).
The rotated cross-section is in both direction asymmetric, reason why two load cases in y and x-direction have been examined (figure 4.1.9 D to G).
The deformations slightly increase because of the asymmetric loading (table 13).

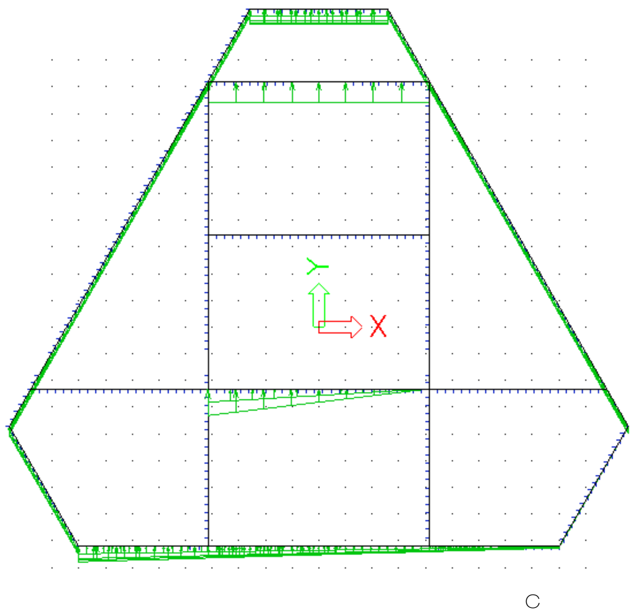
table 12 - hand calculation results

	office part		residential part		total	
	y-direction	x-direction	y-direction	x-direction	y-direction	x-direction
hand calculation (openings)	76,1 mm	71,7 mm	112,3 mm	115,5 mm	188,4 mm	187,2 mm
horizontal line load E 5000 (openings)	78,6 mm	72,3 mm	111,7 mm	112,9 mm	190,3 mm	185,2 mm
hand calculation (openings/rotated)	70,1 mm	77,9 mm	104,5 mm	123,0 mm	174,6 mm	200,9 mm
horizontal line load E 5000 (openings/rotated)	70,9 mm	75,9 mm	104,6 mm	114,8 mm	175,5 mm	190,7 mm

table 13 - deformations for different loads configurations

	office part		residential part		total	
	y-direction	x-direction	y-direction	x-direction	y-direction	x-direction
horizontal linear load E 5000 (openings)	78,6 mm	72,3 mm	111,7 mm	112,9 mm	190,3 mm	185,2 mm
horizontal linear load (asymmetric load 1)	83,3 mm	76,3 mm	118,7 mm	118,4 mm	202,0 mm	194,7 mm
horizontal linear load (asymmetric load 2)	-	75,7 mm	-	117,8 mm	-	193,5 mm
horizontal linear load (rotated)	70,9 mm	75,9 mm	104,6 mm	114,8 mm	175,5 mm	190,7 mm
horizontal linear load (asymmetric load 1/rotated)	78,0 mm	83,4 mm	113,2 mm	126,6 mm	191,2 mm	210,2 mm
horizontal linear load (asymmetric load 2/rotated)	77,5 mm	82,6 mm	112,7 mm	125,5 mm	190,2 mm	208,1 mm





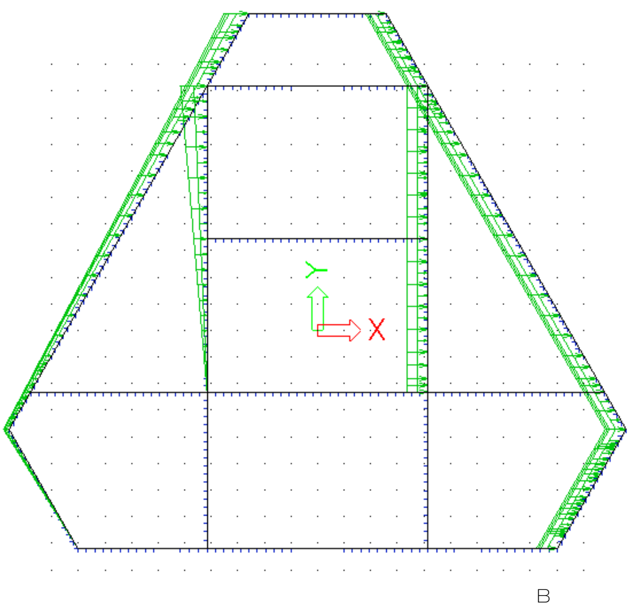
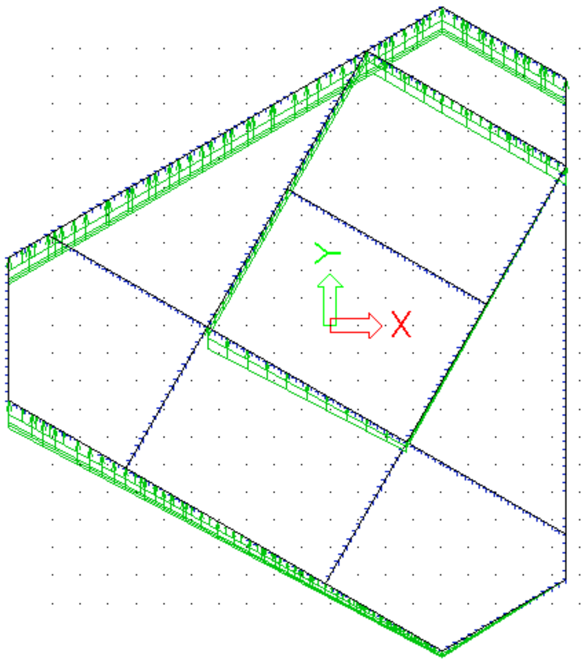
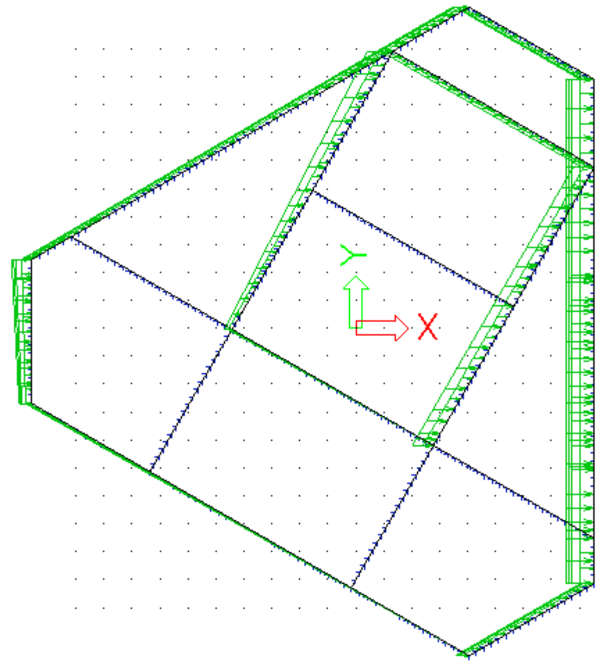


fig. 4.1.9 - loads distribution for the different configurations

The schemes above and in the next page show the different loads applied to the structure in order to take into consideration the different wind directions and load. The schematization is produced with Scia Engineer software. The figures from A to C exemplify the effects of the wind blowing in perpendicular direction to x-axis, while figures D to G shows the effects of the wind blowing in perpendicular direction to y-axis with the building rotated of an angle of 30 degrees in order to place the corner of the triangular shape on the windward side.



D



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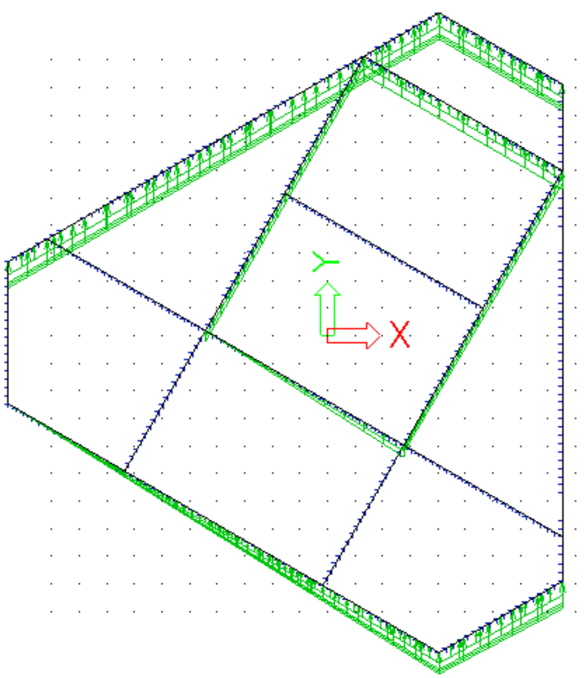
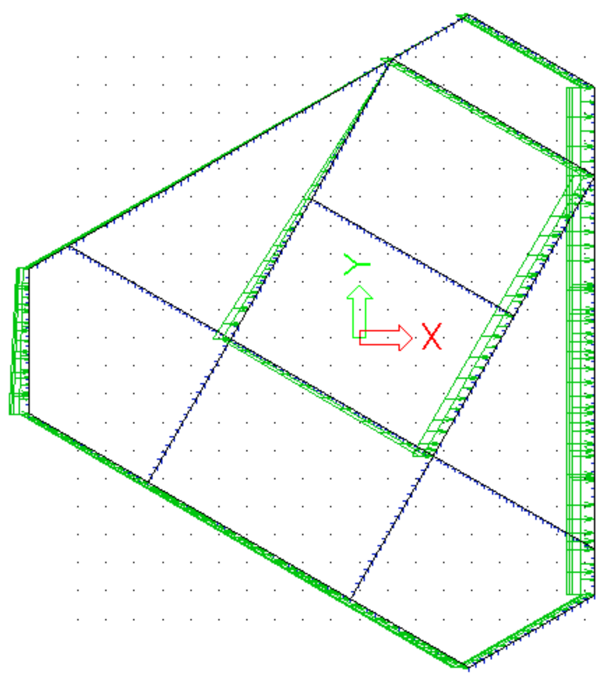


E



G

chapter 4.2

STRUCTURAL DESIGN

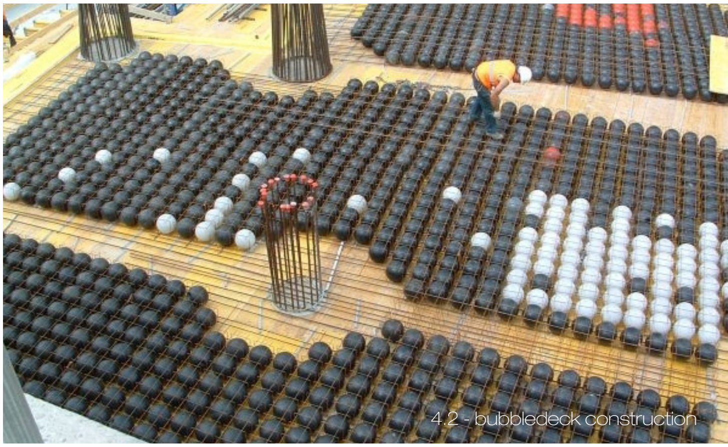
FLOOR SLABS

Bubbledeck is a technology for floors realization consisting of factory-made lattice balls integrated in a precast concrete deck already endowed with reinforcement-meshes.
Through these reinforcement cages containing the lightening elements in high density polyethylene, that have the purpose of eliminating the concrete that has no carrying effect, a modular construction system for the realization of reinforced concrete floors, both semi-prefabricated of completely cast in situ, is obtained.

Lightened floors structures are mostly required when large spans have to be realized without the use of protruding beams or when the big load of the structure has to be reduced because of its large dimensions. The necessity to have big spans with few columns is worth to the flexibility of the spaces, more and more required: in this sense the use of this kind of technology helps in reaching the goal. The main characteristic is the possibility to employ bi-directional decks that allow the bubbledeck floor to be used for large surfaces to be covered without, or at least minimizing, the use of beams of big dimensions and several columns.
Thanks to the use of the spheres, that reduce the self-weight of the structure between 2 and 5 kN/m^2 , the decks can reach spans up to 20 meters with a sensitive reduction of the thickness of the same.

This technology, as mentioned before, can be employed both using pre-cast element and casting on place the elements. In the second case, concrete is casted in two phases by fixing the reinforcement meshes to the formworks in order to avoid the bubbles, inserted into the cages, to float.
In the case of the semi-prefabricated modules, a thin concrete deck is already realized and has the aim to tangle the reinforcement elements and the plastic spheres. These elements are user as disposable shuttering to be integrated with casted in situ concrete, once integrated the reinforcement between the different panels.
The complete pre-fabricated version is rarely employed.

Through this technology a reduction of the self weight of the structure between 30 and 50% can be obtained confronted with the traditional solid slabs.
In fact, the HDPE bubbles replace the non-effective concrete in the center of the section, thus reducing the dead load of the same slab removing that part of the material that has no function in structural terms. A consequential advantage is the possibility of reduction of the quantity and dimension of the material used as reinforcement, besides a design of the foundations for smaller loads, with a complex advantage for the life-cycle of the building.


4.2 - bubbledeck construction


4.2.1 - spheres and reinforcement in bubbledecks

An indicative number for the dimensioning of these decks is that spans are usually 40 times the thickness in both directions and cantilevers can be approximately 10 times this thickness, with some exceptions.

Materials commonly used in bubbledecks constructions are steel, typically FeB 550/460, concrete made by standard portland cement C45/55 and HDPE (High Density Polyethylene/Propylene) spheres, also obtained from recycled materials.
Another important advantage using this kind of technology is the possibility of furthermore reducing the thickness of the floors by also integrating the plants into the same floor depth. The spheres in fact are distributed so as the ducts for air or water transportation can be dislocated in the left spaces before the completion of the concrete casting.

A flexible design is allowed by the application of this technology since this kind of floors can be easily adapted to every kind of form of the building, also to curved plan layouts, longer spans than traditional buildings and to the use of few supports, eliminating bearing walls and downstanding beams.
High resistance to earthquakes effects, even if not required in this specific project, is granted thanks to the light biaxial slab-column system.
The possibility of having semi or completely pre-cast elements allows fast erection of the construction.
The construction process requires some fundamental steps: the installation of temporary supports spaced of 1,8-2,5 meters allow the placement of the prefabricated elements which are lifted into position and juxtaposed. Once concluded this operation, the reinforcement elements are joint loosing the bottom splice bars and tying the top mesh across joints.
Shear reinforcement across columns is disposed and hairpins around perimeter slabs are useful to reinforce edges.

The perimeter shuttering is predisposed and the joint are sealed to prepare the precast concrete layer to receive the finishing with the casted concrete which is poured and vibrated.
Then the temporary works are removed, typically after 1 or 2 weeks, according to the specificity of the construction.

table 14 - lightweight biaxias slabs and solid decks comparison

lightweight biaxial slabs compared with solid decks (in % of a solid deck)			
	same strength	same bending stiffness	same concrete volume
strength	100	105	150
bending stiffness	90	100	300
volume concrete	66	69	100

table 15 - lightweight biaxial slabs characteristics

type	thickness	∅ balls	span	mass	concrete on site
	mm	∅ mm	m	kg/m²	m³/m²
BD 230	230	∅ 180	7-10	370	0,10
BD 280	280	∅ 225	8-12	460	0,14
BD 340	340	∅ 270	9-14	550	0,18
BD 390	390	∅ 315	10-16	640	0,20
BD 450	450	360	11-18	730	0,25

BUBBLEDECK FLOOR DECKS DIMENSIONING

The dimensioning of the structure off the core has been developed in two consecutive steps, i.e. the calculation for the sizing of floor slabs, and then the estimation of the necessary dimension of the vertical supports, in this case the perimeter columns.

Floor slabs' dimensions have been calculated taking into account the characteristics of the chosen bubbledecks floors and the live loads according to the location of the slab and so to the type of users, differentiating the office floors from the residential ones.

Bubbledeck is intended to be a flat two-ways spanning slab supported directly by columns. The design of this system is generally regulated by the allowed maximum deflection during service loading.
The live loads used for the dimensioning of the floors are

$$F_{L\,office} = 4,00 \cdot 1,5 = 6,00\,kN/m^2$$

$$F_{L\,living} = 1,75 \cdot 1,5 = 2,63\,kN/m^2$$

Since bubbledecks have been chosen as the suitable technology for the project, the sizing of the floor slabs has been done considering two-way slabs according to the capacity of these semi-precast elements of distributing loads on the four directions.
Being different in all its parts, in favor of safety, the dimensioning has been referred to the most stressed portion, in particular for the deck with the larger span to stand from one column to another. The slight curvature of the perimeter has been considered negligible. The schemes of the residential and office floor slabs are shown in figures 4.2.2 and 4.2.3.

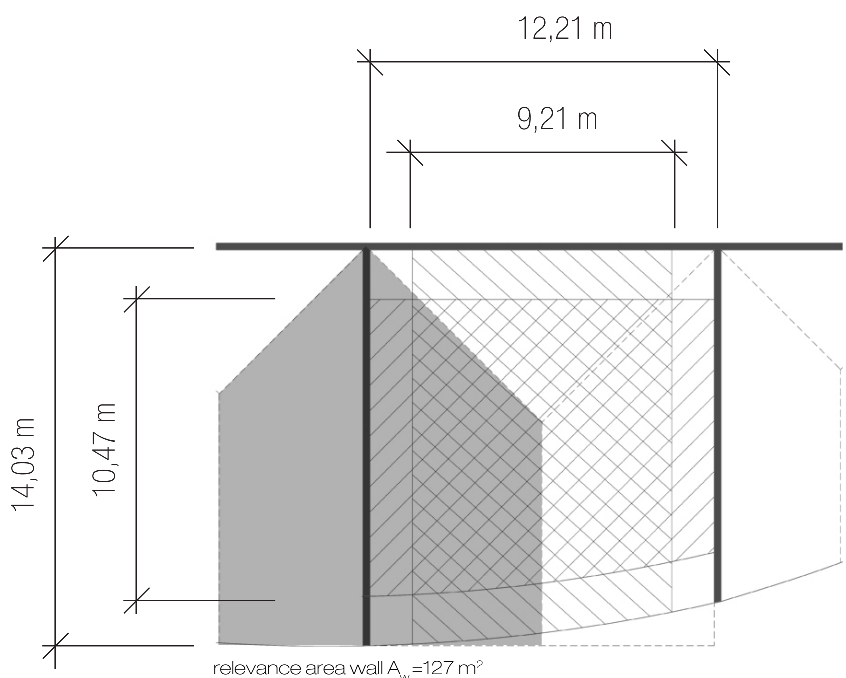


fig. 4.2.2 - residential floor structure scheme

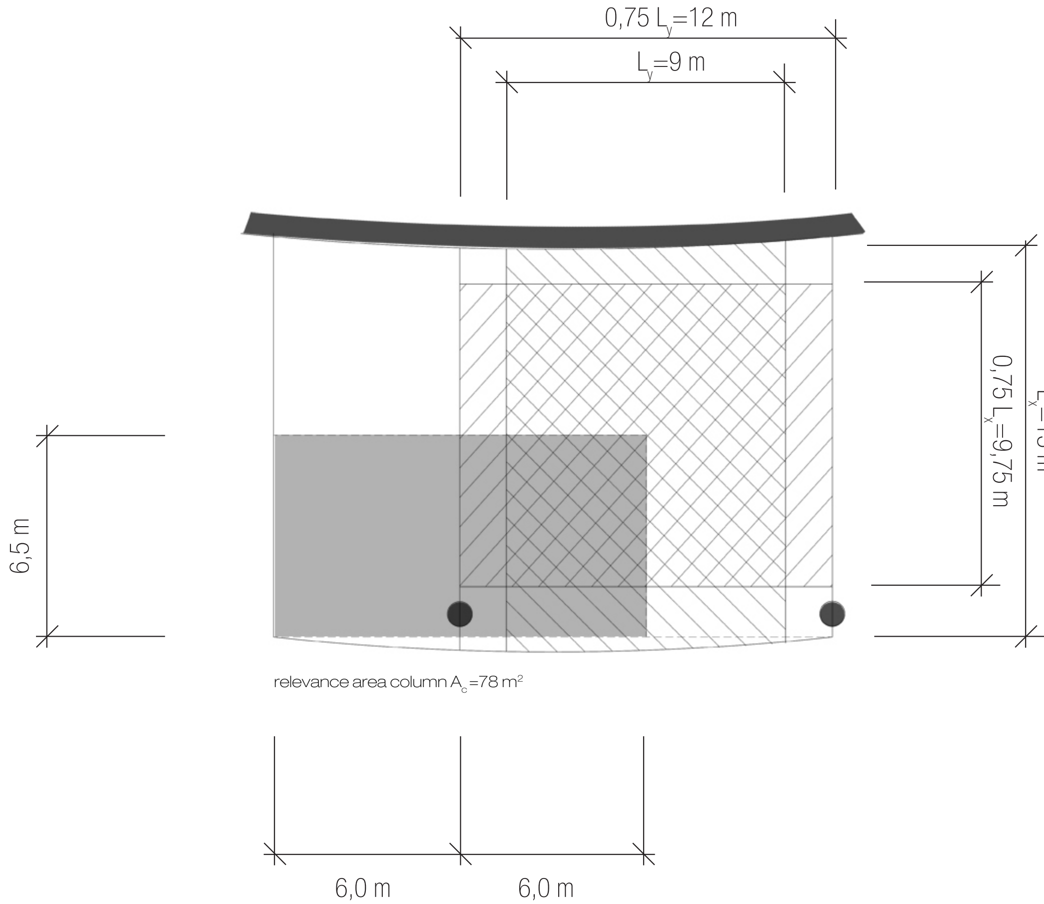


fig. 4.2.3 - office floor structure scheme

The dimensioning according the two-way distribution of loads has been done using some coefficients that differentiate the floor slabs according to their relation with the supports.
The table in figure 4.2.4 and the graph in figure 4.2.5 have been extracted from the "Design Handbook For Reinforced Concrete Elements", where the formula for the simplified calculation of the highest momentum for the two way slabs are indicated.

Using the factor β picked from the corresponding case of the label, the moments acting in the two directions of the slabs have been individuated and summed in order to obtain the total moment in the center of the element, which is the most stressed part, and on which value has been based the choice upon the bubbledeck element to use.
It should be noted that this calculation is just a pre-dimensioning of the plates, since this is based just on the live loads and doesn't take into account the self load of the same floor element (not yet known before choosing a product to use).

The following calculations refer to the pre-sizing of the floor slabs.

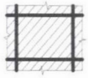
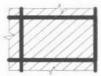
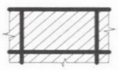
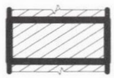
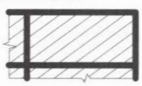
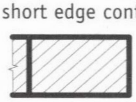
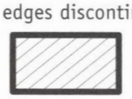
Edge Conditions	Short Span Coefficient βx Values L_y / L_x								Long-Span Coefficient β_y for All Values of L_y / L_x
	1.0	1.1	1.2	1.3	1.4	1.5	1.75	‡2.0	
1. Four edges continuous 	0.024	0.280	0.320	0.350	0.370	0.400	0.400	0.480	0.024
2. One short edge discontinuous 	0.028	0.032	0.036	0.038	0.041	0.043	0.047	0.050	0.028
3. One long edge discontinuous 	0.028	0.035	0.041	0.046	0.050	0.054	0.061	0.066	0.028
4. Two short edges discontinuous 	0.034	0.038	0.040	0.043	0.045	0.047	0.050	0.053	0.034
5. Two long edges discontinuous 	0.034	0.046	0.056	0.065	0.072	0.078	0.091	0.100	0.034
6. Two adjacent edges discontinuous 	0.035	0.041	0.046	0.051	0.055	0.058	0.065	0.070	0.035
7. Three edges discontinuous one long edge continuous 	0.043	0.049	0.053	0.057	0.061	0.064	0.069	0.074	0.043
8. Three edges discontinuous one short edge continuous 	0.043	0.054	0.064	0.072	0.078	0.084	0.096	0.105	0.043
9. Four edges discontinuous 	0.056	0.066	0.074	0.081	0.087	0.093	0.103	0.111	0.056

fig. 4.2.4 - biaxial slabs configurations and calculation indexes

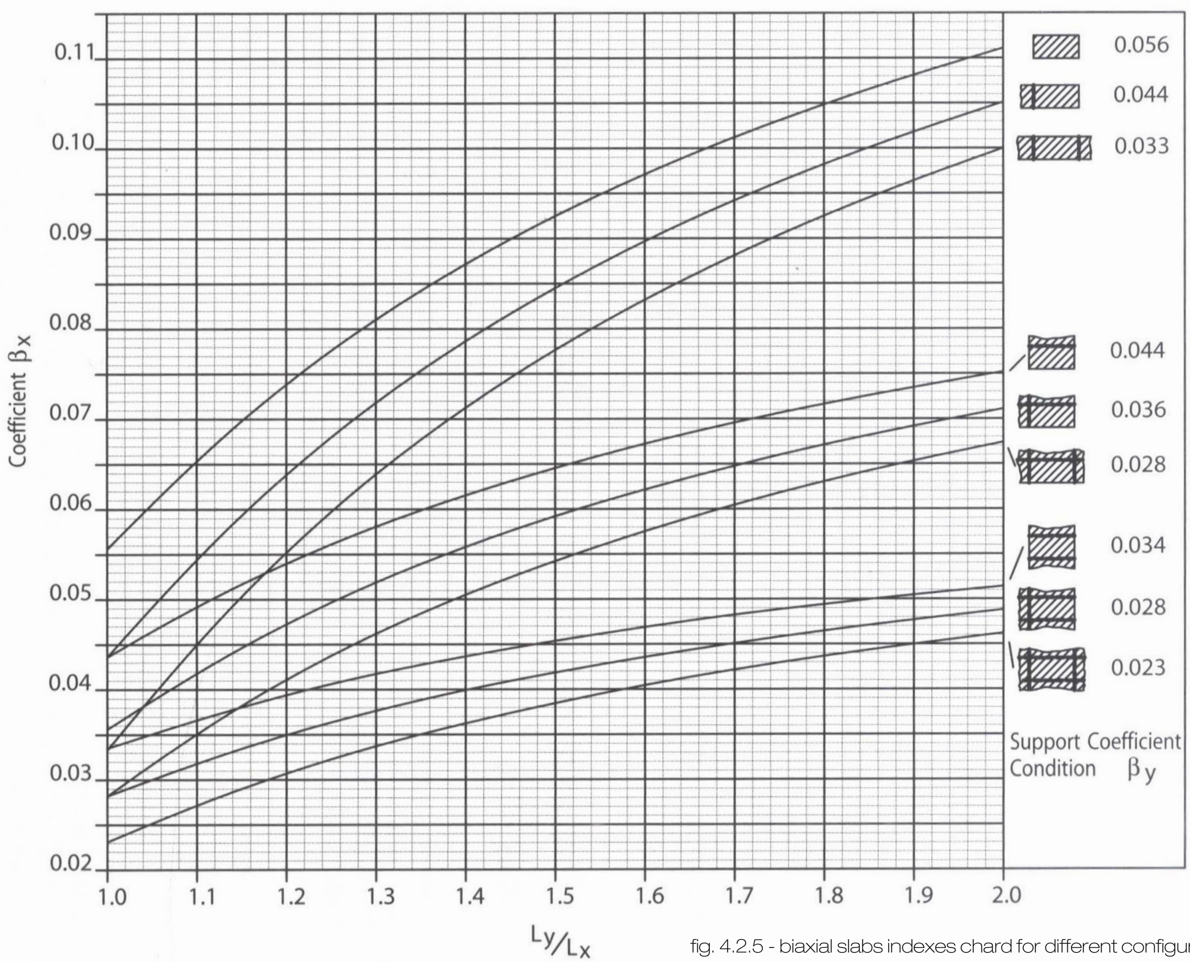


fig. 4.2.5 - biaxial slabs indexes chard for different configurations

Residential slabs

$$\beta_x = 0,046$$
$$\beta_y = 0.034$$

figure 4.2.4 case 5

$$L_x = 12\ m$$
$$L_y = 14\ m$$
$$L_y / L_x = 1,15$$

$$M_x = \beta_x \cdot F_{L\,living} \cdot L_x^2 = 18,03\ kNm$$
$$M_y = \beta_y \cdot F_{L\,living} \cdot L_x^2 = 13,33\ kNm$$
$$M_{tot} = M_x + M_y = 31,36\ kNm$$

Office slabs

$$\beta_x = 0,038$$
$$\beta_y = 0.034$$

figure 4.2.4 case 4

$$L_x = 12\ m$$
$$L_y = 13\ m$$
$$L_y / L_x = 1,08$$

$$M_x = \beta_x \cdot F_{L\,office} \cdot L_x^2 = 32,0\ kNm$$
$$M_y = \beta_y \cdot F_{L\,office} \cdot L_x^2 = 29,4\ kNm$$
$$M_{tot} = M_x + M_y = 61,4\ kNm$$

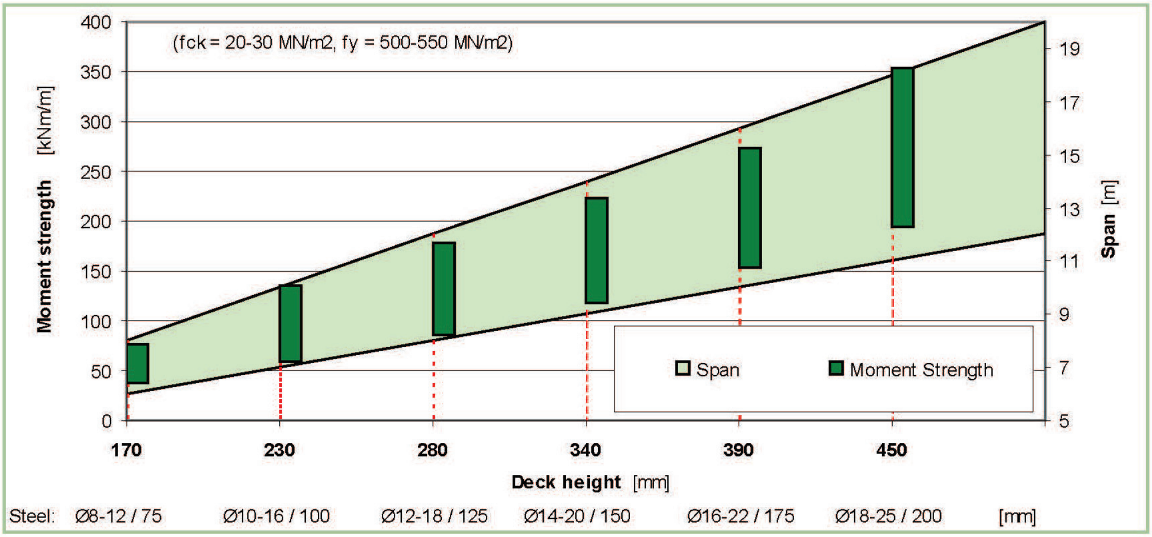


fig. 4.2.6 - bubbledeck dimensions according to moments

Bubbledeck provides a graph in which for different value of the maximum moment acting on the plates, there is suggested the right thickness of the same to use to have a sufficient strength of the floor.

The values obtained through the pre-dimensioning of the slabs, once inserted in the calculations with the self weight of the same, result of insufficient thickness. The verification for biaxial slabs of biggest height is here reported, judged sufficient to support the moment applied.

Once a pre-dimensioning of the floor have been done, according to the moments and to the applied live loads, and a product has been chosen according to the graph in figure 4.2.6, the verification of the probity of the chosen element is done taking this time into account also the dead load (now known from the relative product information) of the same decks.

In accordance to the graph above, both the office and residential floor slabs would necessitate a deck 230 mm thick. The dead loads for the chosen bubbledeck slabs are

Self load slabs 230	W_{bd230}	370	[kg/m²]
	F_{g230}	4,36	[kN/m²]

The total loads used for the verification of the chosen decks are the sum of the live loads and of the dead loads associated with the bubbledecks.

In the live and dead loads a factor of 1,5 and 1,2 is considered respectively in accordance to Appendix A of the Eurocode 0

Total load office	$F_{t\ office}$	10,36	[kN/m²]
Total load living	$F_{t\ living}$	6,98	[kN/m²]

The following calculations refer to the verification of the floor decks 230 mm thick

$$M_x = \beta_x \cdot F_{t\ office} \cdot L_x^2 = 123{,}17\ kNm$$

$$M_y = \beta_y \cdot F_{t\ office} \cdot L_x^2 = 110{,}20\ kNm$$

$$M_{tot} = M_x + M_y = 233{,}37\ kNm$$

$$M_x = \beta_x \cdot F_{t\ living} \cdot L_x^2 = 94{,}94\ kNm$$

$$M_y = \beta_y \cdot F_{t\ living} \cdot L_x^2 = 80{,}70\ kNm$$

$$M_{tot} = M_x + M_y = 175{,}63\ kNm$$

The verification of the pre-dimensioning of the bubbledecks evidences value of the moment in the middle part of the slabs higher than the maximum values born by the decks chosen according to the pre-dimensioning operations, that didn't include the self load of the same floor elements.
In this case the pre-dimensioning doesn't match with the verification that includes the self weight of the decks. The only slab dimension that satisfies the verification is the 450 mm thick for the office floors and the 340 mm thick for the residential floors.

Different thicknesses have been assumed according to the necessity of the office plates to stand higher live loads then residential. The following calculations refer to the verification of the floor decks 450 mm and 340 mm thick

$$M_x = \beta_x \cdot F_{t\,office} \cdot L_x^2 = 173,58\,kNm$$
$$M_y = \beta_y \cdot F_{t\,office} \cdot L_x^2 = 155,30\,kNm$$

$$M_{tot} = M_x + M_y = 328,88\,kNm$$

$$M_x = \beta_x \cdot F_{t\,living} \cdot L_x^2 = 123,75\,kNm$$
$$M_y = \beta_y \cdot F_{t\,living} \cdot L_x^2 = 105,19\,kNm$$

$$M_{tot} = M_x + M_y = 228,95\,kNm$$

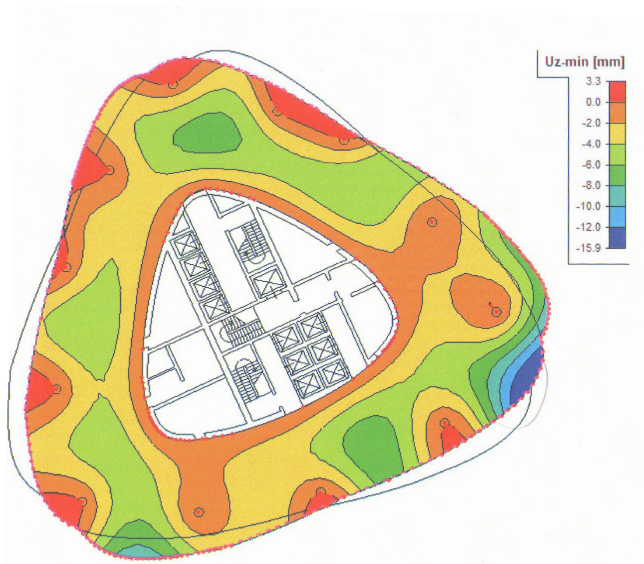
Once calculated the bubbledeck dimension to use for the office and residential floors, it is possible to have an idea of the weight of each floor and of the total horizontal structure, in order to be able to calculate the necessary minimum dimension of the vertical support (the perimeter columns are sized according to the vertical loads, while the core has been dimensioned according to the horizontal wind load).

Considering the total floor area of each level (office and residential) it is possible to calculate the weight that columns have to stand

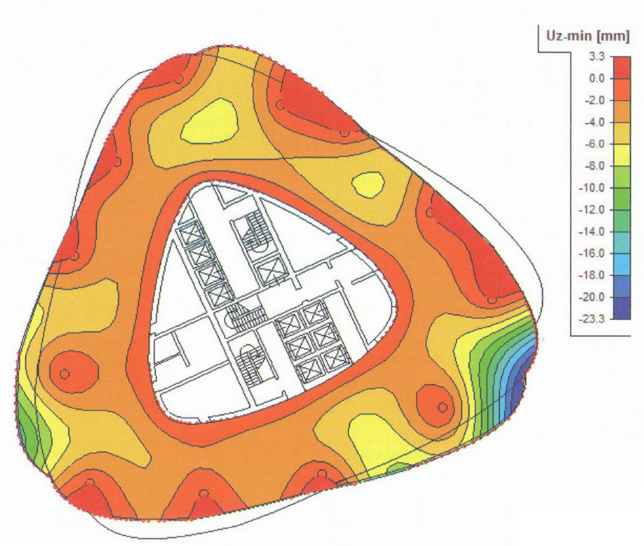
$A_{tot\ slab\ office}$	983,52	[m²]
$W_{floor\ office}$	36.3902,40	[kg]
	3.569,88	[kN]
$W_{tot\ floor\ office}$	71.397,65	[kN]

The floor slabs realized with the bubbledecks are anchored to the central bearing core, that supports part of the load, and have e continuous span supported at the boundary by the perimeter columns.
This technology doesn't require beams to support the floor slabs since they are in a way integrated in the precast panels in which bubbles are distributed leaving a void space for the realization of an integrated cast in situ beam in correspondence of the columns, connecting the latter with the central core.

The realization of the floors is simplified by the repetition of the same floor for the office levels and for the residential levels, with identical elements just rotated according to the floor direction described in the chapter concerning the building form. In this way the use of precast elements is optimized and the costs of construction are intended to be cut down, together with the complexity of the operations at such a tall height, where the decks, already composed at the ground have to be simply lifted by cranes.



A



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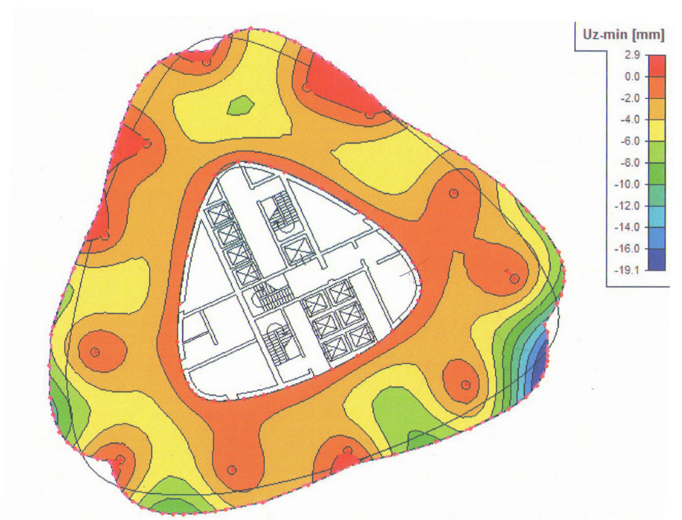
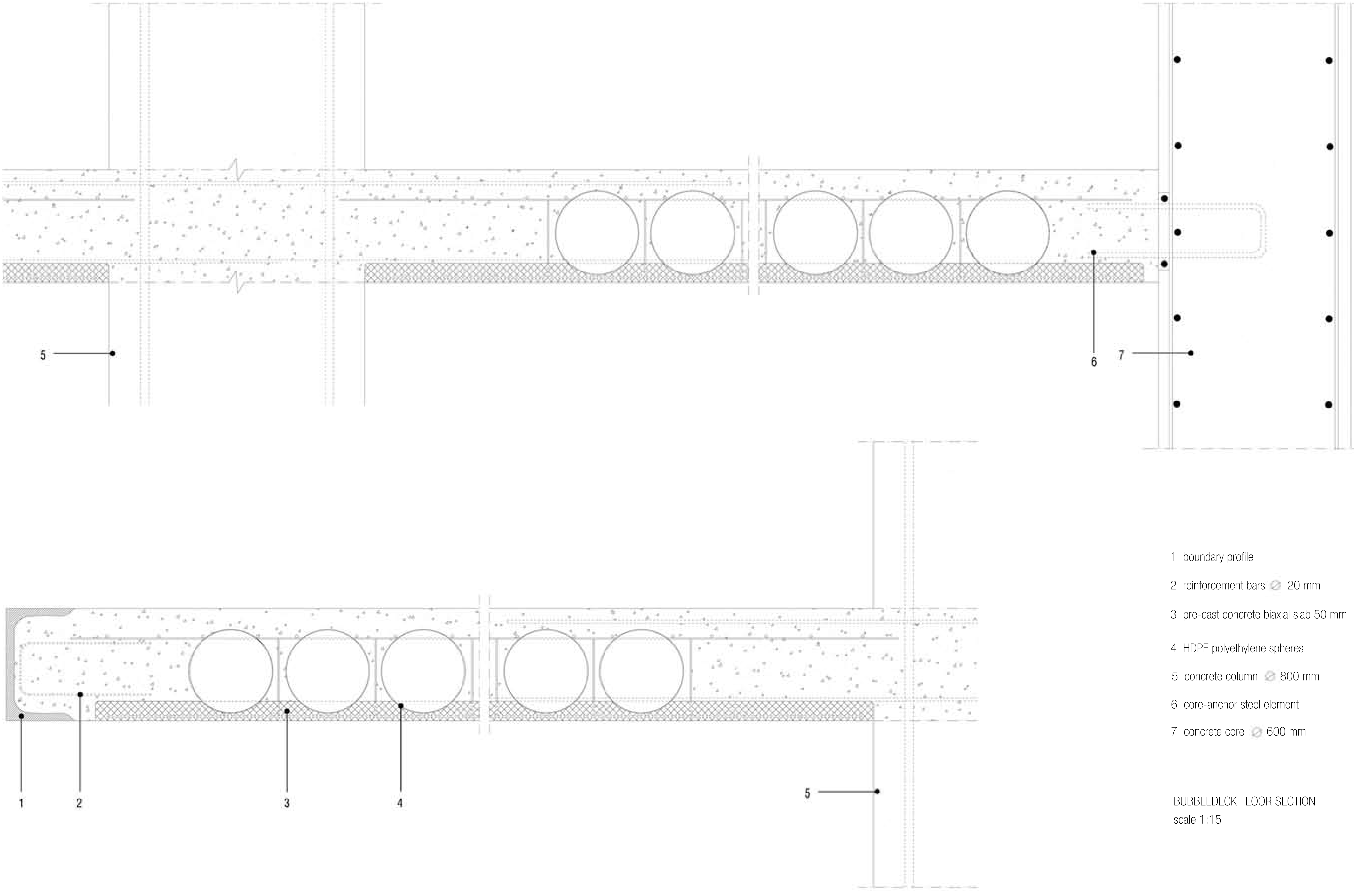


B

figure 4.2.7 - floors deflection analysis SciaEngineer

The images show the computer analysis of the vertical displacement caused in the floor slabs by gravity loads for the three different configurations. The critical points are evidenced by the blue traces, which are of course emerging in the overhangs and where the projecting spans are the largest.
The less solicited parts are, instead, those around the columns and the core.



1 boundary profile

2 reinforcement bars ⌀ 20 mm

3 pre-cast concrete biaxial slab 50 mm

4 HDPE polyethylene spheres

5 concrete column ⌀ 800 mm

6 core-anchor steel element

7 concrete core ⌀ 600 mm

BUBBLEDECK FLOOR SECTION
scale 1:15

chapter 4.3

STRUCTURAL DESIGN

VERTICAL SUPPORTS FOR GRAVITY LOADS

VERTICAL SUPPORTS DIMENSIONING

Gravity loads in the building, i.e. the self load of the construction with floor slabs and walls, the load of furnitures and of people living and working inside, are partially supported by the central bearing core and partially from the vertical supports, constituted by columns distributed on the perimeter for the office and shopping part, and by continuous walls in the residential part.

For the design for columns and walls in multi-story buildings it's necessary to apply a reduction factor to the vertical live loads that takes into account the fact that not all the floors of a so high construction have the whole live load at the same time on them.

These reduction factors are, respectively for residential and offices

$$\alpha_{office} = \frac{[2+(n-2)\cdot\psi_0]}{n} = \frac{[2+(39-2)\cdot 0,5]}{39} = 0,53$$

$$\alpha_{living} = \frac{[2+(n-2)\cdot\psi_0]}{n} = \frac{[2+(16-2)\cdot 0,4]}{16} = 0,48$$

In which n is the number of floors above the vertical member that is being dimensioned, and ψ_0 is a factor specific for the function (different for living and office spaces)

Therefore the loads applied for the calculation of the dimension of the vertical members are

$F_{L\ office}$	3,15	[kN/m²]
$F_{L\ living}$	1,25	[kN/m²]

Self load slabs 450	F_g	7,16	[kN/m²]
	W_{bd450}	730	[kg/m²]
Self load slabs 340	F_g	5,40	[kN/m²]
	W_{bd340}	550	[kg/m²]
Total load office	$F_{t\ office}$	10,32	[kN/m²]
Total load living	$F_{t\ living}$	6,64	[kN/m²]

FLOOR XXI WALLS DIMENSIONING

The dimensioning of the walls, useful to transfer the loads related to the residential part to the columns in the office floors, have been done in relation to the most stressed wall at the first of the living levels (floor XXI). The relevance area of the wall (the portion of the floor carried by the wall) is represented in grey in figure 4.2.2 and is 127 m², and considering a concrete class C20/25 (and therefore σ_{lim}=17 N/mm²) and a total weight of the whole relevance area of the floors above the wall of 16.028 kN, it's possible to individuate the minimum thickness of the wall necessary to stand the vertical loads. Once defined how thick the wall should be, it's possible to carry out the verification considering also the self weight of the same wall and of all the walls above it.

$$A_w = 127\,m^2$$

relevance area single floor

$$W_{t\,A_w} = (F_{t\,living}\cdot A_w \cdot n_{piani}) = (6,64\cdot 127\cdot 19) = 16,028\,kN$$

total weight relevance area

$$\sigma_{\lim} = 17\,N/mm^2 \quad cls\ C20/25$$

$$A_{\min} = \frac{W_{t\,A_w}}{\sigma_{\lim}} = 961,683\,mm^2 \rightarrow T_{\min} = \frac{A_{\min}}{L_w} = 68\,mm$$

minimum wall thickness with a wall length of $L_w = 14\,m$

It's necessary to note that the calculation of the thickness of the walls in the residential part gave as result a much lower number than the one considered at the end for the construction: being used as separation walls for the different apartments, in fact, these walls have to have a certain minimum thickness for acoustic insulation and maintenance of the privacy.

The thickness set for the walls as been established to be 250 mm.

The following verification is therefore operated considering the thickness of 250 mm and the correspondent weight.

The total weight of the residential floors (useful to calculate

$$H_w = 3,5\,m$$

wall height

$\gamma_{cls} = 25\ kN/m^3$

specific gravity

$V_w = A_w \cdot H_w = 10,5\, m^3$

wall volume

$W_{t\,V_w} = V_w \cdot \gamma_{cls} \cdot 19 = 4.987,5\, kN$

total weight walls

$W_{tot} = W_{t\,V_w} + W_{t\,A_w} = 21.016\ kN$

total weight supported by the wall

$$\sigma_{\lim} = \frac{W_{tot}}{L_w \cdot T_w} = 7 \quad verified$$

with $T_w = 250\, mm$

the weight above the office columns and for the foundations), including live and dead loads for walls and floor slabs, and the weight for single column at the ground floor are

total weight residential floors $W_{r\,tot} = 101.273\, kN$

total weight per columns $W_{r\,tot\,c} = 18.522\, kN$

GROUND FLOOR COLUMNS DIMENSIONING

The dimensioning of the columns has been done in relation to the most stressed one at the ground floor. The relevance area of the column is 78 m^2, and considering a concrete class, stronger than the one used for the residential par, C50/60 (and therefore $\sigma_{\lim}$=40 N/mm^2) and a total weight of the whole relevance area of the floors above the wall of 32500 kN, it's possible to individuate the minimum ray of the columns necessary to stand the vertical loads.

$A_c = 78\, m^2$

relevance area single column

$W_{t\,A_c} = (F_{t\,office} \cdot A_c \cdot n_{floors}) + W_{r\,tot\,c} = (10,32 \cdot 78 \cdot 19) + 18.522 = 33.809\ kN$

total weight relevance area

$\sigma_{\lim} = 40\, N/mm^2 \quad cls\ C90/105$

$$A_{\min} = \frac{W_{t\,A_c}}{\sigma_{\lim}} = 845.221\, mm^2 \rightarrow r_{\min} = \sqrt{\frac{A_{\min}}{\pi}} = 550\, mm$$

minimum column ray

$H_c = 4\, m$

column height

$\gamma_{cls} = 25\, kN/m^3$

specific gravity

$V_c = A_c \cdot H_c = 3,8\, m^3$

column volume

$W_{t\,V_c} = V_c \cdot \gamma_{cls} \cdot 19 = 1.806\, kN$

total column weight

$W_{tot} = W_{t\,V_c} + W_{t\,A_c} = 35.615\, kN$

total weight supported by the column

$$\sigma_{\lim} = \frac{W_{tot}}{L_w \cdot T_w} = 37 \quad verified$$

The total weight of the residential floors (useful to calculate the weight above the office columns and for the foundations), including live and dead loads for walls and floor slabs are

total weight office floors $W_{\sigma_{tot}} = 93.651\, kN$

total weight per column $W_{\sigma_{tot\,c}} = 35.615\, kN$

total weight per column $_{\text{foundations}}$ $W_{f\,c} = 54.136\, kN$

chapter 4.4

STRUCTURAL DESIGN

FOUNDATIONS

Foundation calculations are based upon documentation about the site characteristics compiled by the City Hall after drillings and investigations.
The report founded was redact by the 'consultative engineering agency Inpijn Blokpoel Son B.V.' and was concerning the foundation of the ground around "t Schimmelt' dated from 1990.
Several test borings have been done in this area and concluded the average ramming depth of the piles for the 'high rise' at the west part is 7m below Amsterdam Ordnance Datum (AOD) and for the 'low rise' at the east part 6m above AOD. Ground level is at 15 meter above AOD. Furthermore they measured the ground water level at 14m above AOD.
Because of the weight of the designed building is necessary to use the deepest and strongest bearing layer (7 m below AOD, 22 m below ground level in Eindhoven). The engineering agency calculated also the bearing loads of the piles using the method 'Koppejan' and the guide lines for foundations of buildings.
A pile of 500 x 500 mm has a bearing load of 1.820 kN.

For this calculation is used a compressive concrete strength of 31,5 N/mm^2, creep coefficient of 1,0, an elasticity module of 17.750 N/mm^2 and a ground resistance of 11 MN/m^2. For the rest they calculated a tension strength of the piles of 350 kN and a translation coefficient of 260 kN/mm (500 x 500 mm).
For the design of the foundation the bearing loads of the piles calculated by 'Inpijn Blokpoel Son B.V.' are used. To have as less piles as possible under the core and columns of high rise part the strongest piles (500 x 500 mm) are needed. For the other columns was also convenient to use these piles.

Because of the amount of piles under the core and columns of the high rise part, one thick slab will be used to transfer the loads in the core and these columns to the piles. Table 15 shows the vertical loads for the high rise part and from Table 16 can be seen how the piles are more or less divided. The other columns are split op into four types considering the levels they have to bear (table 18). For each type the

table 16 - loads on foundations

	live load	dead load	total load
slabs residential	23.484 kN	4.102 kN	27.586 kN
slabs office	62.037 kN	4.284 kN	66.321 kN
walls	-	12.064 kN	12.064 kN
columns	-	2.406 kN	2.406 kN
core	-	170.502 kN	170.502 kN
total	85.521 kN	254.196 kN	339.718 kN

table 17 - foundation piles distribution

total number of piles	187
number of piles core	134
number of piles columns	53
average number of piles per column	4,4

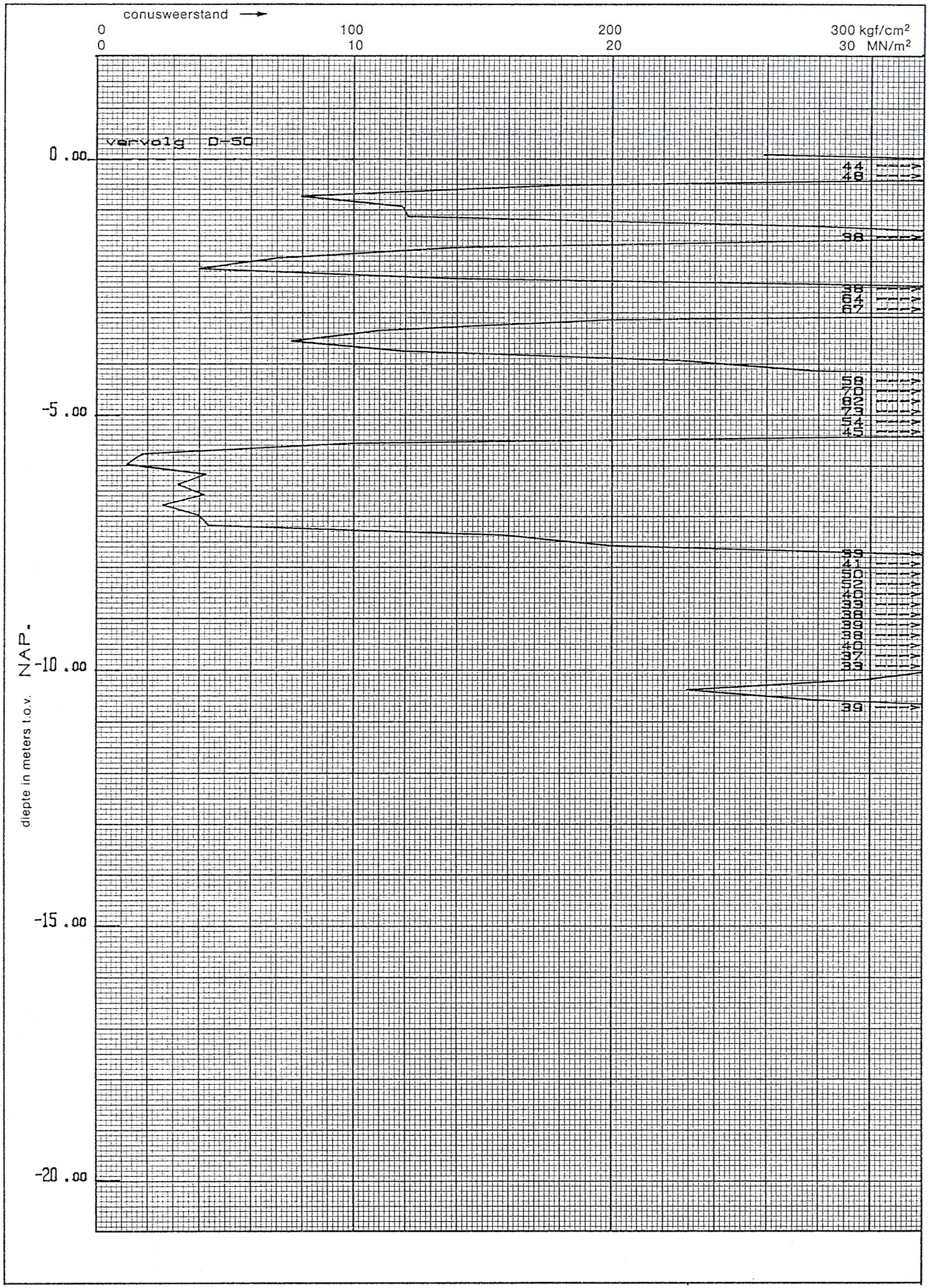


fig. 4.4 - soil characteristics

heaviest loaded column is used to calculate the number of needed piles.
Besides the vertical loading of the foundation also the lateral wind load have to be taken into account. The lateral wind load causes tension and compression in the foundation, figure 4.4.1 is a scheme of this effect.
For the schematization, a point load is used instead of numerous piles supporting a slab. 'x' is the distance from the central point of the whole slab to the central point of the half slab. Because of the low tension strength of the piles, the tension should be preferably lower than the vertical dead load. Therefore the distance from the tension force F to the central line (x) has to be large enough.

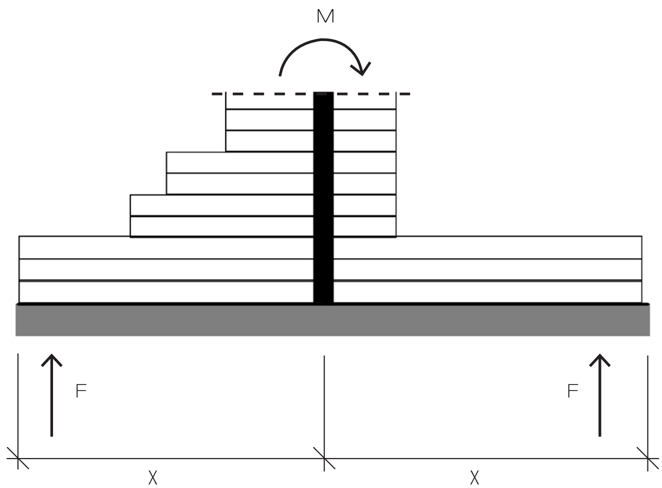


fig. 4.4.1 - foundation forces schematization

To have the most unfavorable combination for the tension, the factor for the dead load has to be 0,9 and for the life load 1,5. The largest moment is caused by the lateral wind load in y-direction

$$M = 1,5 \cdot (2\,kN/m^2 \cdot 46 \cdot 90\,m \cdot 45\,m + 2\,kN/m^2 \cdot 35\,m \cdot 70\,m \cdot 125m) = 1.477.650\,kNm$$

The vertical dead load is $0,9 \cdot (254.196/1,2) = 190.647\,kNm$

This results from the calculation below for the minimal distance between the central point of the whole slab and half of it. The designed slab is checked and verified.

$$x \cdot \frac{dead\,load}{2} < \frac{M}{2}$$

$$x \cdot \frac{190.647\,kN}{2} < \frac{1.477.650\,kNm}{2}$$

$$x < 7,75\,m$$

Of course there is also an influence of the lateral load on the compression.

The smallest distance x is used to calculate the largest force
The total compression force in the foundation will be
and this requests

$$2F = 1.477.650\,kNm / 7,75\,m = 190.665\,kN$$

$$F = 95.333\,kN$$

This amount is used for the foundation drawing.

$$339.718\,kN + 93.333\,kN = 435.051\,kN$$

$$435.051\,kN / 1.820\,kN = 239\ piles$$

table 18 - number of foundation piles per column

	life load	dead load	total load	number of piles
columns parking	900 kN	2.062 kN	2.962 kN	2
columns parking and shopping	1.620 kN	3.094 kN	4.714 kN	3
columns parking, shopping and gym/restaurant	2.580 kN	4.726 kN	7.306 kN	4
columns parking and cantilever	1.140 kN	2.406 kN	3.546 kN	2

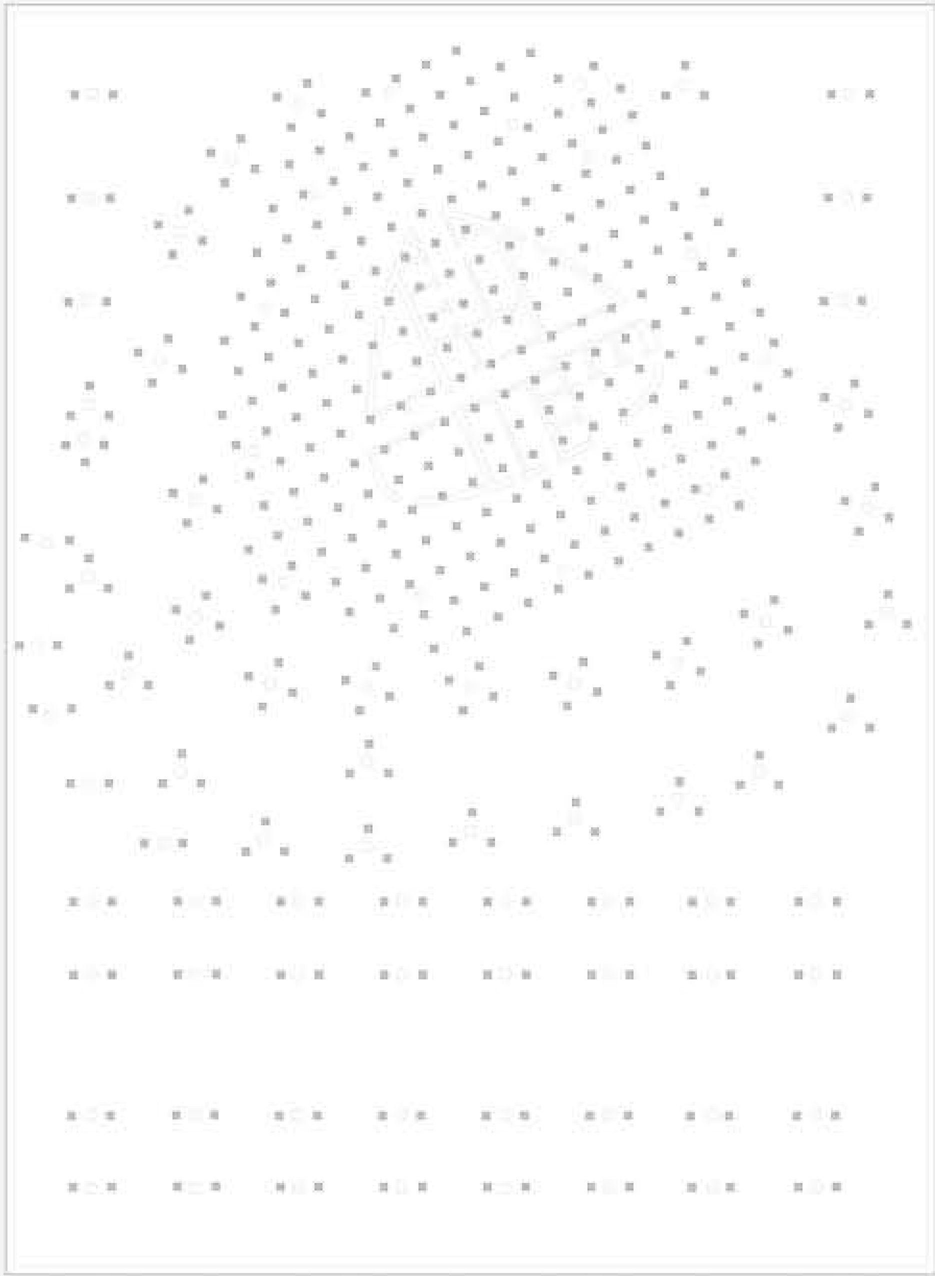


fig. 3.4.13

FOUNDATIONS
scale 1:500

chapter 4.5
STRUCTURAL DESIGN
ADDITIONAL VERIFICATIONS

HORIZONTAL ACCELERATION CALCULATION

The following calculation deals with the individuation of the entity of the horizontal accelerations that influence the design of lateral load resisting structures.
The horizontal accelerations have to be taken into account in order to create a comfortable indoor ambient for users: people standing into a high rise building do not have to notice sensitive movement of the structure. The verification for horizontal acceleration is useful to determine if the building is sufficiently static to not evidence movements of its components to the users.

$$H = 160\,m$$
$$d = 37,27\,m$$
$$b = 41,27\,m$$

$$H / d = 4,4$$
$$for\ H/d = 5 \quad c_f = 1,5$$
$$for\ H/d = 1 \quad c_f = 1,3$$

$$k_p = \sqrt{[2\ln(\nu \cdot T)]} + \frac{0,6}{\sqrt{[2\ln(\nu \cdot T)]}} \geq 3$$

$$\nu_{n_1} = 0,29\,Hz$$

fundamental frequency of building [Hz]

$$T = 600\,s$$
$$k_p = 3,4 \quad verified$$

peak factor

$$c_f = 1,47$$
$$\rho = 1,25\,kg/m^3$$
$$I_{v(x_s)} = \frac{1}{\ln\left(x_s / z_0\right)} = 0,17 \qquad x_s = 96\,m \qquad z_0 = 0,3$$

turbulence intensity

$$v_{m(x_s)} = v_b \cdot k_r \cdot \ln\left(\frac{x_s}{z_0}\right) = 30,44$$

average wind speed [m/s]

$$v_b = 24,5$$
$$k_r = 0,22$$

$$\mu_e = (\rho_b \cdot d) = 9.317,5$$

building mass per unit area [kg/m²]

$$\rho_b = 250\,kg/m^3$$

volumetric mass of building [kg/m³]

$$d = 37,27\,m$$
$$R = \sqrt{\frac{\pi^2}{2\delta} \cdot S_{L(x_s,n_1)} \cdot K_{n_1}} = 0,54$$

resonance response factor

$$\delta_s = 0,1$$
$$\delta_1 = 0,01$$
$$L_{x_s} = 191,75$$
$$f_L = 1,81$$

non-dimensional frequency

$$S_L = 0,09$$

non-dimensional spectral density function

$$\Phi_x = 17,38$$

non/dimensional parameter

$$\Phi_z = 4,48$$
$$K_s = 0,07$$
$$G_x = 0,41$$

mode shape coefficient, parabolic

The calculation is in accordance to Eurocode 1

$G_z = 0,50$

mode shape coefficient, uniform

$K_x = 1,27$

parameter parabolic

$K_z = 1$

parameter uniform

maximum horizontal acceleration

$$a_y = k_p \cdot c_f \cdot \rho \cdot I_{v(x_s)} \cdot V^2_{m(x_s)} \cdot R \cdot \frac{K_x \cdot K_z}{\mu_e} = 0,07\, m/\sec^2$$

The acceleration of the building has to be lower than the first frequency of the building.
The first frequency of the building is roughly

$$\frac{H}{42} = \frac{170,5}{42} = 4,06\, Hz$$

The first natural frequency can be calculated more accurate taking into account the bending stiffness and volumetric mass of the building and the rotational stiffness of the foundation. In figure 4.5 is however shown that a peak acceleration of 7 milli-g is always within the limit regardless the first natural frequency of the building. Therefore a more accurate natural frequency is not calculated.

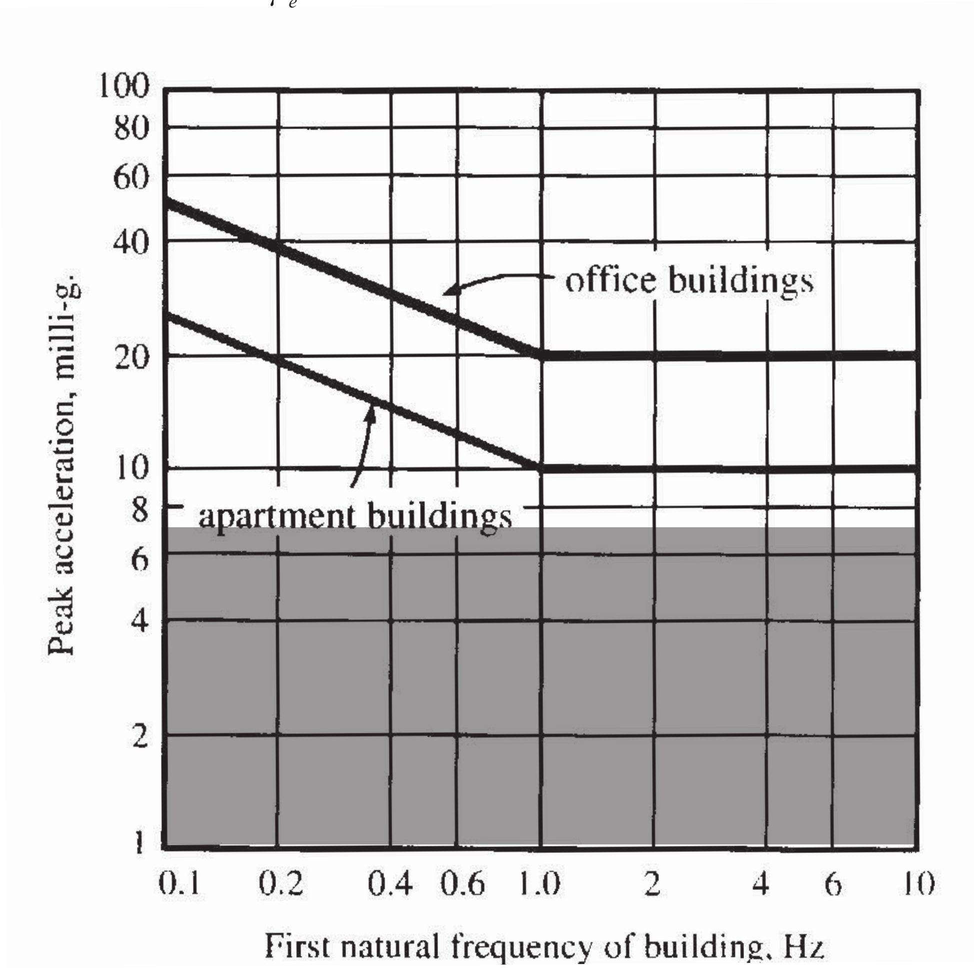


fig. 4.5 - horizontal acceleration limits

SECOND ORDER EFFECT

The eccentricity of the vertical loads introduces additional deflections of and forces in the building. If this effect is less than 10%, no extra calculations have to be done.

The second order effect $\frac{n}{n-1}$ depends on the critical load of the building and the actual load on the building

$$n = \frac{F_{cr}}{F}$$

In this case the critical load is defined by the critical load for bending of the building and the rotation of the foundation

$$n = \frac{F_{cr}}{F}$$

$$\frac{1}{F_{cr}} = \frac{1}{F_{cr,b}} + \frac{1}{F_{cr,f}}$$

$$F_{cr,b} = \frac{7{,}837 EI}{H^2} = \frac{7{,}837 \cdot 2\,10^7 \cdot 1076}{170{,}5^2} = 5.803.838\,kN$$

$$F_{cr,f} = \frac{2C}{H} = \frac{2 \cdot 7{,}60\,10^9}{170{,}5} = 23.460.791\,kN$$

$$\frac{1}{F_{cr}} = \frac{1}{5.803.838} + \frac{1}{23.460.411} \rightarrow F_{cr} = 4.652.791\,kN$$

An average moment of inertia is used for the critical bending

$$I = \frac{72{,}3}{185{,}2} \cdot 2356 + \frac{112{,}9}{185{,}2} \cdot 257 = 1076\,m^4$$

This critical load has gives a $n = \frac{4.652.791}{339.718} = 13{,}70$

and the second order augmentation factor

$$\frac{n}{n-1} = \frac{13{,}70}{13{,}70-1} = 1{,}079$$

The second order effect is thus 7,9%. This is within the limit of 10 percent, so additional calculations are necessary.

FINAL ELASTIC SWAY

As a result of the known second order effect the final elastic sway can be determined, but first it is necessary to calculate the initial sway of the building

Table xx shows how the elastic sway index is obtained. The limit for serviceability of the building was 1/500 or 2%, meaning the elastic sway is within the limit.

$$\psi = \psi_0 \alpha_H \alpha_m$$

$$\psi_0 = \frac{1}{200}$$

$$\left.\begin{aligned} \alpha_H &= \frac{2}{\sqrt{H}} \le \frac{2}{3} \\ \alpha_H &= \frac{2}{\sqrt{170{,}5}} = 0{,}15 \end{aligned}\right\} \alpha_H = \frac{2}{3}$$

$$\alpha_m = \sqrt{0{,}5\left(1+\frac{1}{m}\right)} = \sqrt{0{,}5\left(1+\frac{1}{12}\right)} = 0{,}736$$

$$\psi = \frac{1}{200} \cdot \frac{2}{3} \cdot 0{,}736 = 2{,}453\,10^{-3}$$

table 19 - second order effects indexes

sway index of the building due to wind	$210,2\,mm / 170.500\,mm$	1,235 %
initial sway index	-	2,453 %
total first order sway index	$1,235\% + 2,453\%$	3,688 %
second order effect	$0,079\% \cdot 3,688 \neq \%$	0,291 %
total sway index	$3,688\% + 0,291\%$	3,979 %
elastic sway index	$3,979\% + 2,453\%$	1,526 %

chapter 5
FACADE TECHNOLOGY

The solution adopted for the facade is derived by considerations upon the **aesthetical** necessities and the **functional** needs of both offices and residential functions.
The building should appear as much homogeneous as possible from the outside, without sensitive distinctions between shopping, office and residential parts of the same.
This distinction, in fact, is assigned to the dimension of the floors that decreases as the building reaches its top.
Moreover, the complexity of the external geometry of the construction requires a simple solution in terms of colours and materials.

The facade consists of a glass perimeter composed by panels 1 meter wide and with a height coincident with that of the floors: in this way the floor slabs remain visible defining the different levels according to the rotation of each, and each floor has no divisions along the height. The curtain wall facades have been designed to emphasize the trend of vertical building and consist, for all levels, in a double skin cavity and ventilated façade, made up of cells mounted profiles of aluminium tailor-made products.


5.1 - office glazed facade

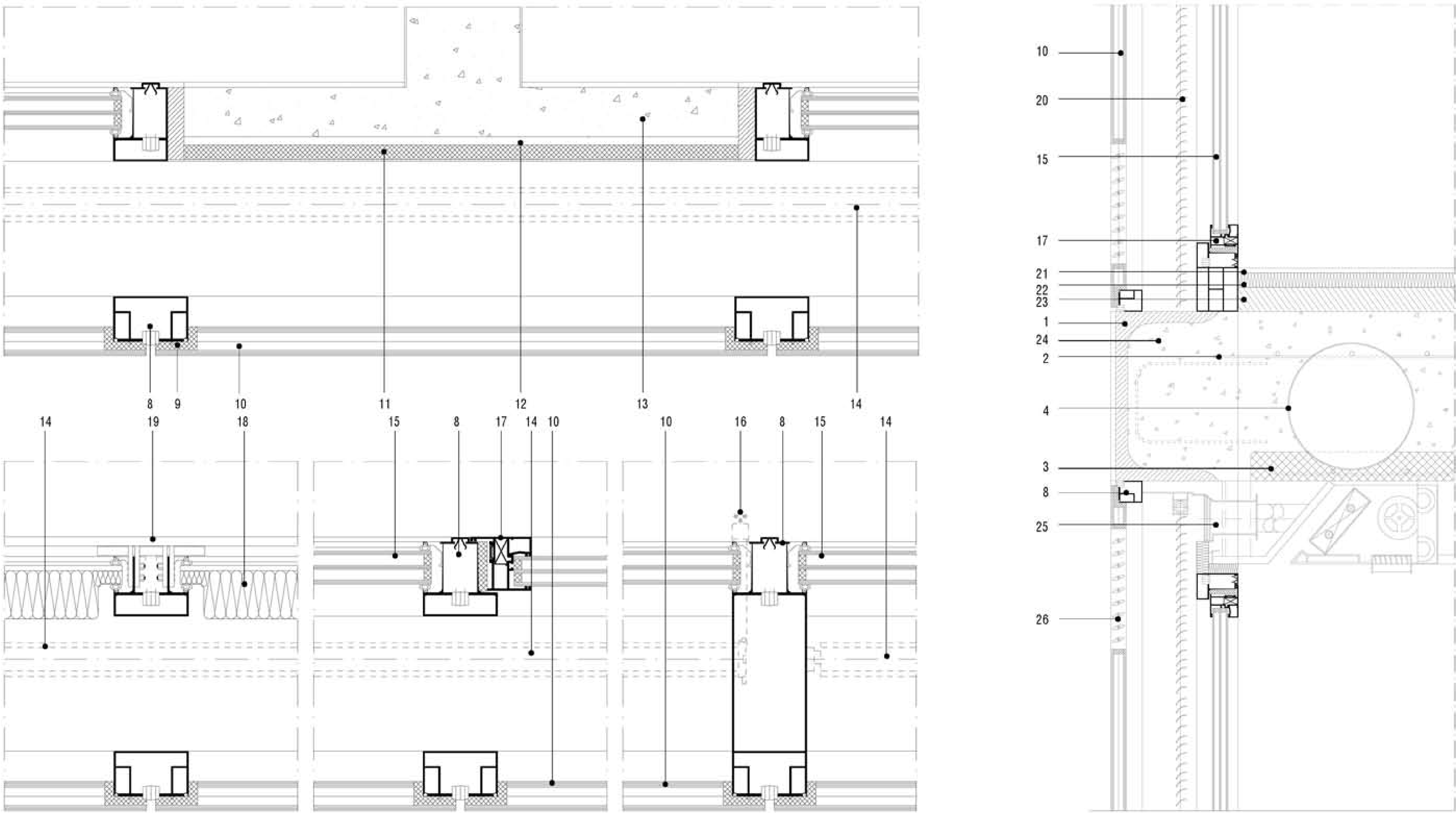

fig. 5 - glazed facade full-height panels

The glass have no reflective coating nor coloured pigments on it. The transparency of the glass is compensated by the double facade that maintain however the privacy of the interiors. The sandwich panels consist of two glasses with high-performance thermal and acoustic screen.
In the shopping portion of the building the showcases glasses are transparent and light in order to let people see inside, as well as for the restaurant and the gym, in order to let people from the inside to have a panoramic view of the outside.
The office floors are enclosed by a double skin facade with a hollow space in which is contained the shading device as well as an inter-space for ventilation: the latter is just mechanical, provided by a mechanism integrated with the false ceiling. There is no necessity for natural ventilation in the offices, and then a hermetic glazed facade is a suitable solution.
In the residential part, the facade solution is more complex due to the necessity of having natural ventilation, at least in the kitchens. Of course, with a so high building a traditional window is not suitable, in particular in the residential floors which are located at the top of the structure.
There is furthermore the necessity of having a solution simi-

lar to the office windows in order to maintain the homogeneity of the aesthetic result.
The solution adopted for the residential part is then a variation of the one installed in the office floors: while the external panels are the same of the lower floors, just integrated with a ventilation grid at the bottom and at the top, the internal part of the double skin facade is realized with different techniques. In particular, some of the windows are full height glasses also inside, in order to have more light in the interiors, such as in living rooms, some others are realized with a wall railing 1 meter high, in particular in those rooms, such as in the bedrooms, that need more privacy, in mostly during the night when lights evidence what's inside. When the internal walls intersect the facade, a solid wall is substituted to the internal glass panel.

The shading system is realized with a movable louver system located in the hollow space of the double-skin facade in order to reinforce the homogeneity of the external composition.
In order to maintain the external homogeneity of the facade, without the framing of little openings useful to ventilation necessities, in particular for the apartment floors in which at least the kitchen rooms are forced by law to have natural ventilation possibility because of the disposal of possible gas leaks, the facade is provided with openings, mechanically regulated by glazed louvers, at the top and at the bottom of the windows. These openings are useful to enhance both natural and mechanical ventilation: the ventilation mechanism located at the top and hidden in the false ceiling depth can exchange fresh and exhausted air through the windows gap exploiting the chimney effect, as well as opening one of the internal windows shutter in the apartments allow fresh air to circulate through the facade and inside the room.

fig. 5.2 - double glazed facade with internal shading



1 boundary profile
2 reinforcement bars 20 mm
3 pre-cast concrete biaxial slab 50 mm
4 HDPE polyethylene spheres
5 concrete column 800 mm
6 core-anchor steel element
7 concrete core 600 mm
8 windows aluminum profile
9 gasket
10 external double glazing 6-20-6
11 external wall coating 20 mm
12 wall air gap 10 mm
13 concrete partition wall 250 mm
14 shading mechanism
15 internal triple glazing 4-10-4-10-4
16 shading control mechanism
17 opening window shutter
18 sandwich panel 70 mm
19 plasterboard wall 15 mm
20 shading louvers
21 pavement 10 mm
22 floor insulation layer 30 mm
23 concrete floor screed 50 mm
24 poured concrete layer
25 ventilation mechanism
26 ventilation louvers

FACADE HORIZONTAL/VERTICAL SECTION
scale 1:10

chapter 6

PARAMETRIZATION OF THE PROJECT

Is the same skyscraper a suitable solution for different locations? Does it have the sufficient degree of flexibility to adapt the same project to different needs and for different site requirements?

The skyscraper typology evolved in the years with a more and more unspecific set of characteristics that made it completely untied to the context, in particular to the urban.
Of course this is, in a way, a characteristic of the high rise architecture that with its high tech solutions could be ideally set everywhere in the world, in every city or climate.
The image of a glazed tower shining above the urban surrounding with a peculiar and distinguishable aesthetic is in a way a symbol of contemporary architecture.

Most of the so-realized buildings, however, are site specific in the design since they have a certain dimension in relation to the construction site, a certain height in accordance to local laws and limits imposed by regulations, a certain envelope and shading system according to the sun path in the construction site, and so on. For instance, in the considered project site the main site-specific parameter is the height of the commercial floors, which are designed to be at least at the same level of the elevated railway, in order to leave more privacy to offices floors and apartments.
Traditional architecture is, then, unavoidably dependant from the constraints imposed by the use of a certain material, by the construction codes, by the culture and the landscape that surround the building that generate themselves the meaning of the building itself. The parameters of the context , and of the building itself, that influence the architectural product constitute a network that can be harnessed and controlled to manage the final result and make it dependant and adaptable to the same context.

By applying a parametric approach to architecture is therefore possible to realize a network of relations between several elements of the building and its contingencies, i.e. relations between the inside and the outside.

While traditional architectural design process imposes some limits to the applicability of a project in different contexts, or at least requires a complete adaptation of the same, by applying a parametric approach with the systematic design of the single elements of the building and of the relations occurring between them, the adaptation of a same project to different context results feasible and quite easy.
The project acquires, then, a certain degree of flexibility responding to changing situations in use, operation and location, interacting with the users and its framework.
In this way the design process could be innovative and up to date with the contemporary design issues associated with technological, economic and social change.

To "parametrize" the building components means to enslave the construction to certain parameters that can be modified in order to be adapted to the specific context in which the building is located. The parameters, which can be properties of the elements or relations between them, are associated to objects of different nature (colours, position, opacity, geometry, etc.) and these parameters can be associated in turn between themselves: parametricism is in fact based on the correlations which could be internal to the design or expressed between the design element and its context. Correlations internal to the design create an interdependency between the various subsystems and between the various components that constitute them. Correlation external to the design are substantially contextual adaptations.
In this way the project assumes some characteristics of specificity and universality at the same time.

Parametric architecture is of course more complex than traditional one, since it is not constituted just by the assembling of different and autonomous parts together with the others, but consists of the creation of a overall complex set of rules that regulates the final result through the creation of a series of chains between the different components of the building that determine the modification of the whole when even just one of these parameters is modified in order to maintain the same set of relations conceived by the designer.

In this way it is possible to regulate the transformation of the building by maintaining the coherence of the whole.
Establishing some parameters that have to be site specific, these can be inserted in the project design as algorithms regulating corresponding characteristics of the building and therefore changing them according to the necessities changing in different situations.

Using such an approach, it is therefore possible to realize a building which is coherent with the requirements of the specific project, but together easily adaptable to new situations and requests.
The main part of the design becomes, then, the determination of the parameters that have to be managed through algorithms.
These parameters can be related to the architecture of the building, to the urban context, to the climate and energy systems.

Here follows a description of the parameters that can be parametrized, that can be modified as required to make the final product suitable also for a different set of needs.
The kind of parameters selected establish different kinds of correlations, both internal to the design, meaning, as explained, the interdependencies between elements of the building itself and of its subsystems (e.g. the height of the floors and the dimension of the structure) and external to the design, putting in relation the project with its context (e.g. dimension of the footprint in relation to the site, or height of the building according to the surrounding).

METHODOLOGY

Dealing with parametrization the most important part of the work to be done as a premise and base for the correct development of the computer model, is the definition of the parameters.
Considering that computer programmes are so well-advanced to realize automatically the project itself, the fundamental step in automatizing the architectural design process become the a priori formulation of the set of rules and characteristics shaping and orienting the same computer model.

The parametrization of the project described in the previous chapters has been pursued through the Rhinoceros plug-in Grasshopper, a visual editor for scripting based on the algorithmic logic through which a sequence of instructions regulating different aspects of the model are traduced in three-dimensional visualization of the solution.
A furthermore improvement of the same has been done by making use of Galapagos, a platform for Grasshopper useful for the optimization of the parameters defined in the latter and for researching for the best solution given a defined aim.

The crucial point of this procedure is, therefore, the correct identification of the parameters that have to be analyzed and that have to deal to the final searched result.
The approach here described is, then, methodological rather that resolutory in order to establish the most convenient, or at least so considered, procedure and set of parameters to reach the intended goal.

The sequences of correlations established in Grasshopper can be improved, modified or integrated to be adapted to a different kind of aim rather than the one here described, or to make more precise the procedure to reach the latter.

In order to conveniently realize modifications to the project maintained as a base, some fundamental characteristics have been maintained fixed: in particular, the central bearing core and the vertical structure, i.e. the perimeter columns, have to be considered as a steady point.

OPTIMIZATION OF THE SHADING
Simplified method 1

The building is characterized by the rotation of the floors in respect to each others, which causes the overhanging of part of the same out of the boundary of each downstairs. This means that each floor acts, in part, as a horizontal shading system for the facade of the floor below.

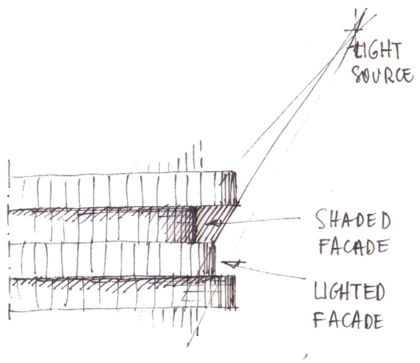


fig. 6 - shading on the facade due to floors moving

This characteristic, even if partially, can be exploited to provide passive shading for the building.

An extreme simplified situation has been analyzed: being each floor sticking out from the one below, considering a vertical source of heat/light, normal to the floor plane, it protects the floor below from this with a vertical projected shadow. When more than one floor is repeated in height, the total shadow projected by them can be assumed as a parameter to be modulated in order to reach the maximum possible degree of shading.
The parameter established to be evaluated is drawn out by projecting on the ground the shadow generated by the floors all together considered. This shadow evidences a shape whose area is then required to be maximized in order to obtain the maximum, as well, of shading.

Defining this parameter as the one to be evaluated for the optimization, it is inserted in Galapagos as the "fitness" parameter, which is the one to be maximized or minimized, as required, together with the angle of rotation of the single floors as "genome" or genetic input, which is the parameter to be modified to search for optimization. In this way the programme would search automatically the best combination of angles to reach the proposed aim.
The observation on the steps ranged by the engine evidences that the more the aimed result is near, the more the area to be maximized, as expected, tends to the circular form.

The exemplification here reported applies the above mentioned procedure to a limited number of floors: of course this can be implemented for a user-defined number of the same, as shown in the pre-set, but enabled, additional values for rotation of successive floors in Grasshopper graphical scheme of the algorithm in figure 6.2.

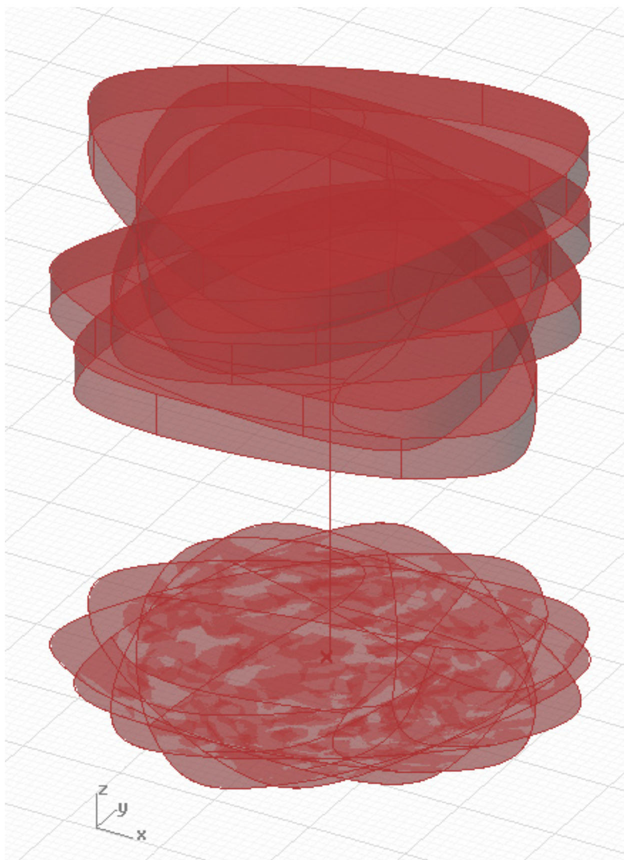


fig. 6.1 - floor shading vertically projected
(Grasshopper 3D model)

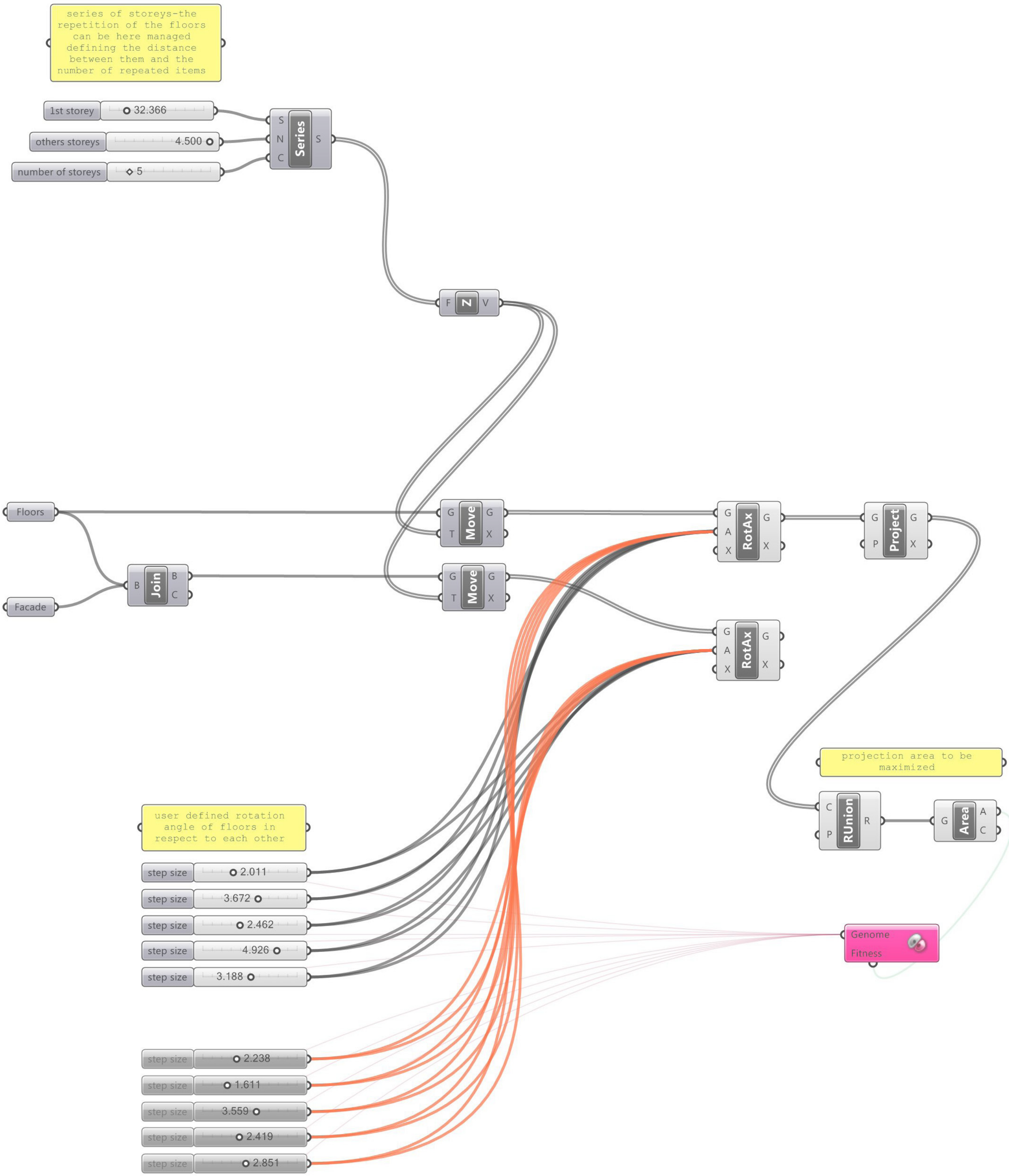
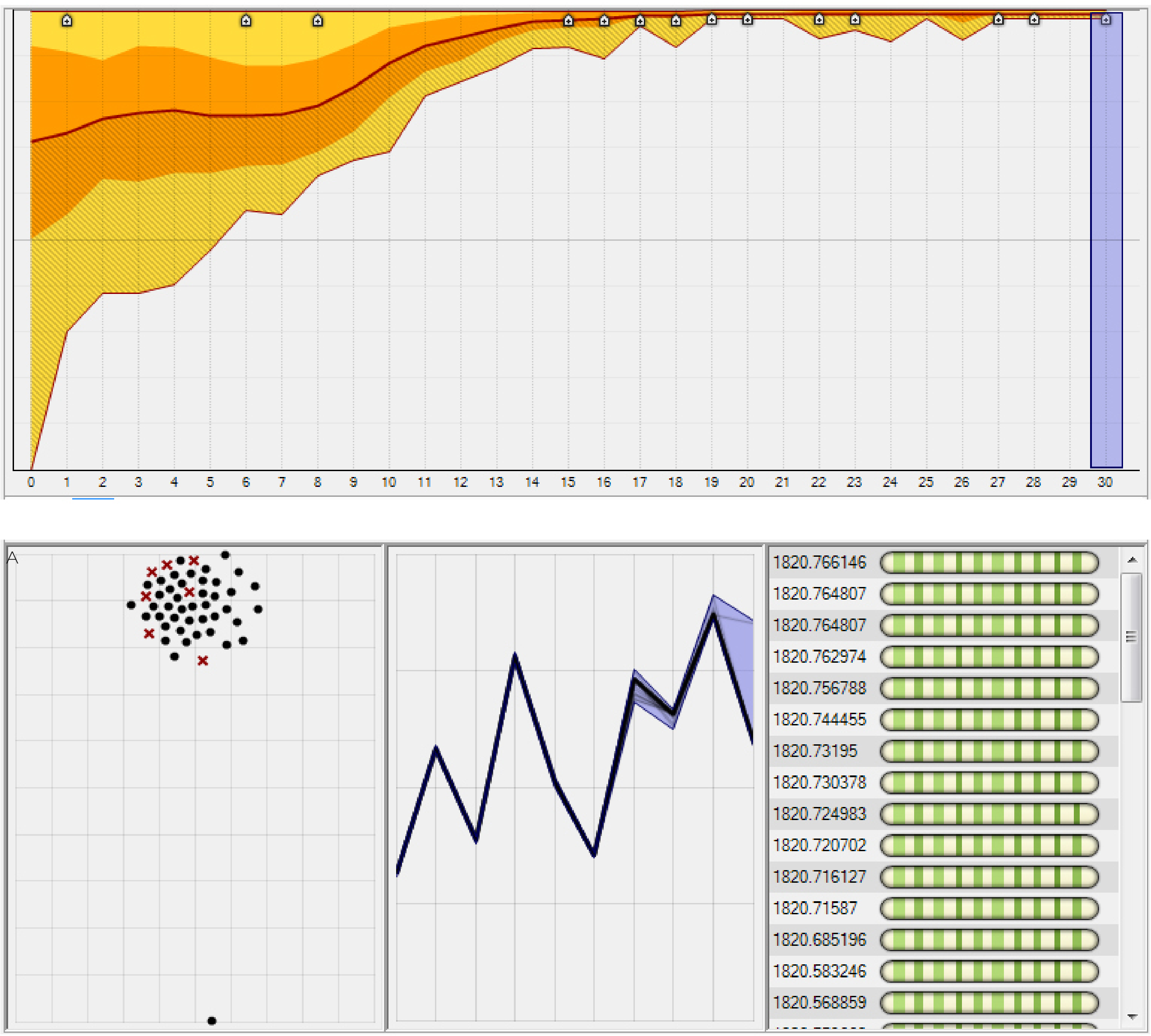


fig. 6.2 - vertical shading projection alhorithm visual schematization (Grasshopper)

The platform Galapagos provides a schematic graphical visualization of the optimization process with some charts showing the variations of the values inserted by the machine as angles and the degree of success of this combination in relation to the pursued objective.

In the graph in figure 6.3 A, for every generation, is displayed the fittest genome (upper boundary of yellow area), the worst genome (lower boundary of yellow area), average genome fitness (the thick red line) and the standard deviation of the fitness distribution in both directions (the orange area). Everything below the average is hatched.

In the chart in figure 6.3 B three different visualizations of the distribution of data and for every possible combination of these, there is a fitness value or a height on the two dimensional plane.



B

fig. 6.3 - vertical shading projection optimization process data graphs (Galapagos for Grasshopper)

Simplified method 2

Considering the relation between such a high rise building and its context, a methodology to be explored could be the analysis of shading caused by the building presence on its context.

The height of the building, in fact, could interfere with the surrounding fabric and then the analysis through the model could be useful to identify, for a given hour of a precise moment of the year, and then for a pre-set inclination of the sun rays, which is the portion in the shade. The aim could be to minimize this quantity in order to reduce the effect on the context.

The situation is therefore exemplified by projecting the shadow generated by the building subject to a light source with a pre-defined inclination.
The area of the projected shadow is, then, the parameter to be analyzed in Galapagos. In order to have the minimum quantity of shadows, the area has to be minimized by the engine.
The procedure follows the steps described in the previous method.

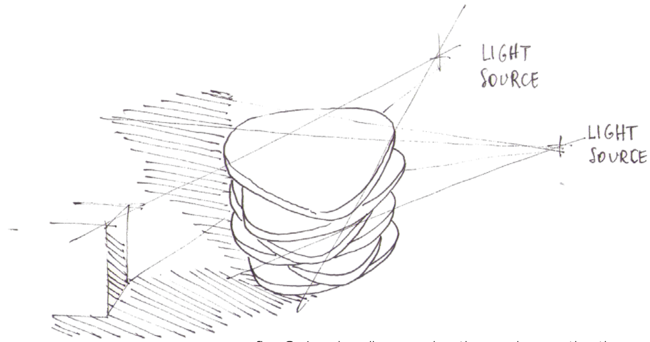


fig. 6.4 - shading projection schematization

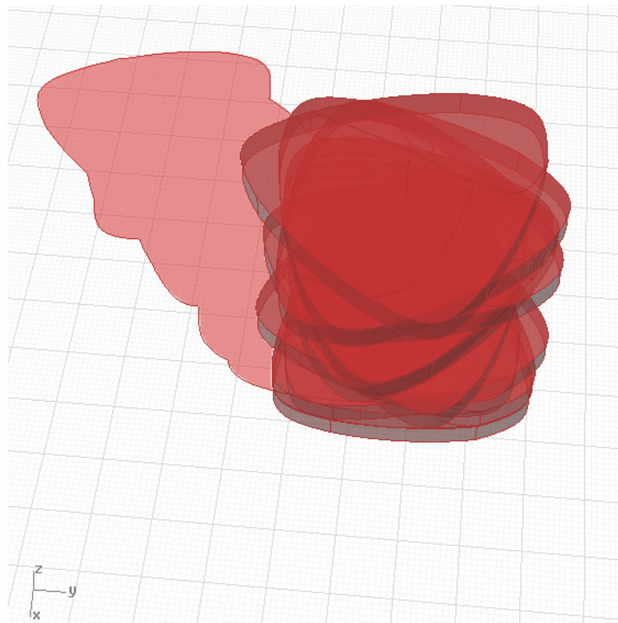


fig. 6.5 - shading projection on the surrounding (Grasshopper 3D model)

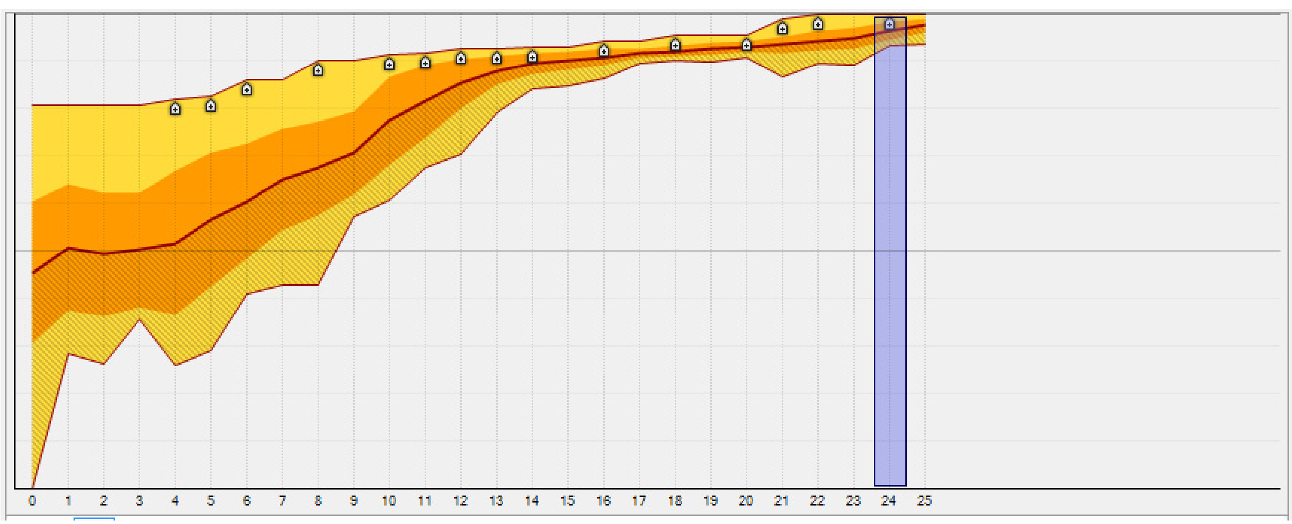


fig. 6.6 - shading projection optimization process data graphs (Galapagos for Grasshopper)

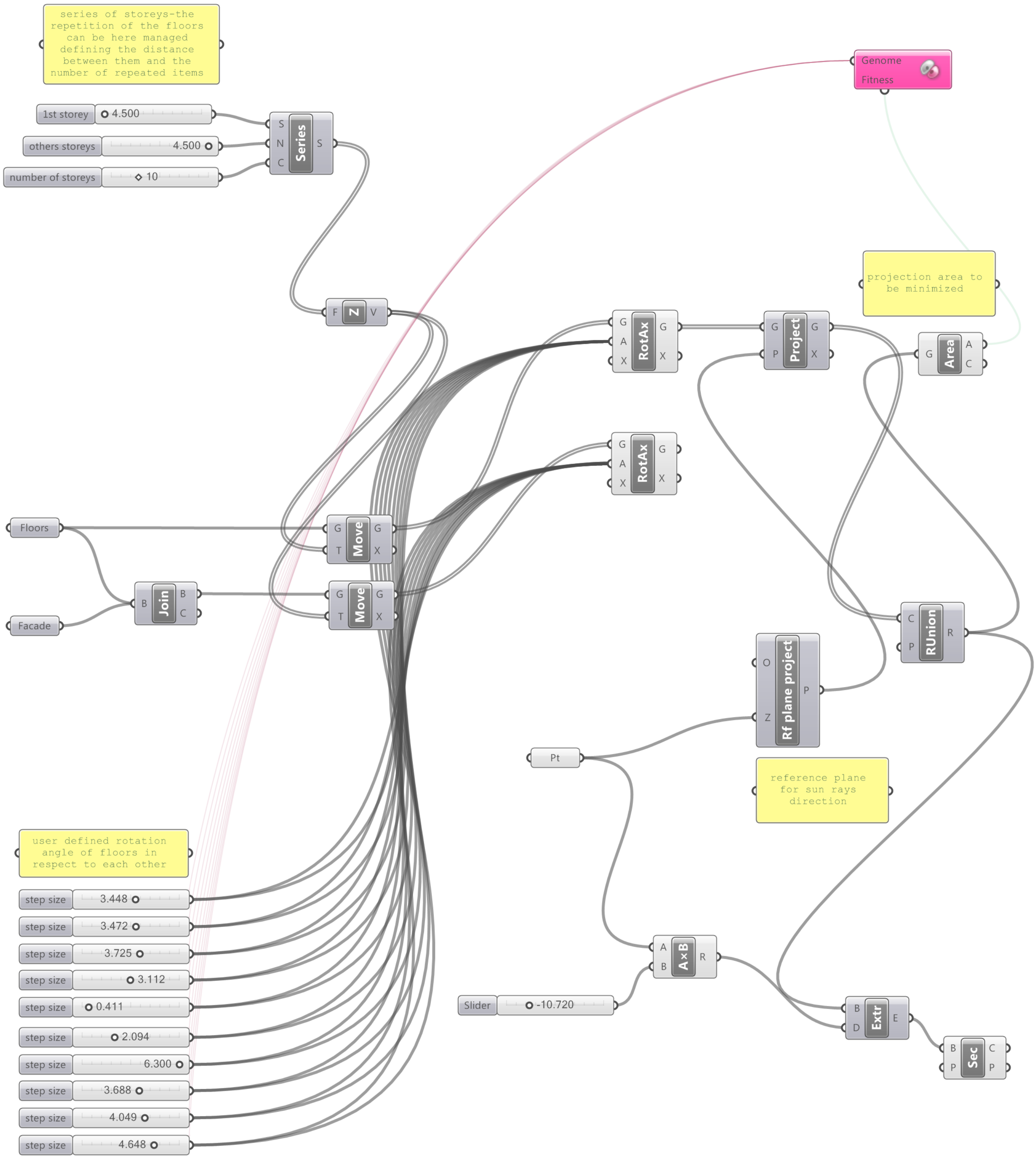


fig. 6.7 - projecting shaows alhorithm visual schematization (Grasshopper)

Simplified method 3

Another possibility for implementing an algorithm for the parametrization of the building features, is to act to the rotation of the floors in order to have a reciprocal position that allows to have on each overhangs, that could be used as a balcony, the less or the highest protection derived from the floors above.
This scenario evidences the possibility to create protected terraces, from the sun or from rain, whereas they have to be used by people, or to leave as much free as possible whereas these projecting elements have to be used for plantation that need the maximum possible quantity of rain and sun.

The described result could be obtained by parameterizing the rotation of the floors, as done in the previous chapters, and once evidenced the shape of the shadow produced by each of this floor due to a simplified vertical source (in this case rain is quite well represented, while sun should be adapted according to the inclination in the location and in the desired moment of the year) minimizing or maximizing the area of the shadows of all the above floors, according to the pre-determined goal.

Since going higher the protection of the floors' overhangs is relatively less useful, almost proportionally to the distance between the two floors considered, a reduction factor for the shadows of the successive floors has to be adopted in order to take into consideration this element.

Again acting a simplification of the problem, as it goes up in number of floors, the reduction factor assigned corresponds to the inverse of the identification number of the floor.

The summation of the areas of the shadows projected on the decided floor is the "fitness" parameter for Galapagos, while the rotation angle of the different floors remains the "genome" information.

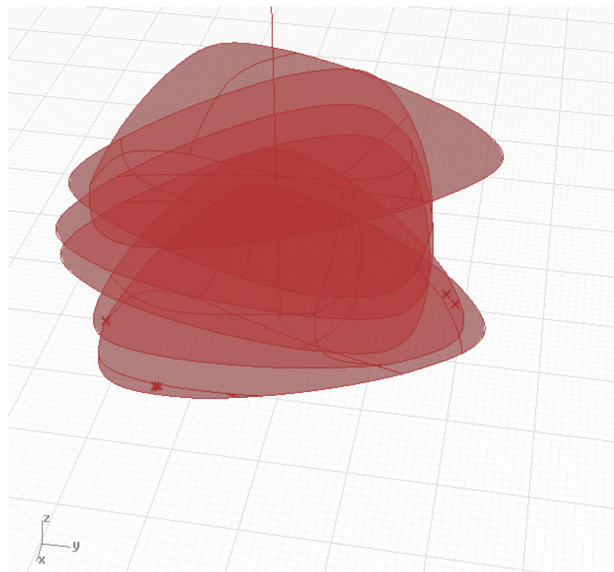


fig. 6.8 - balconies shading
(Grasshopper 3D model)

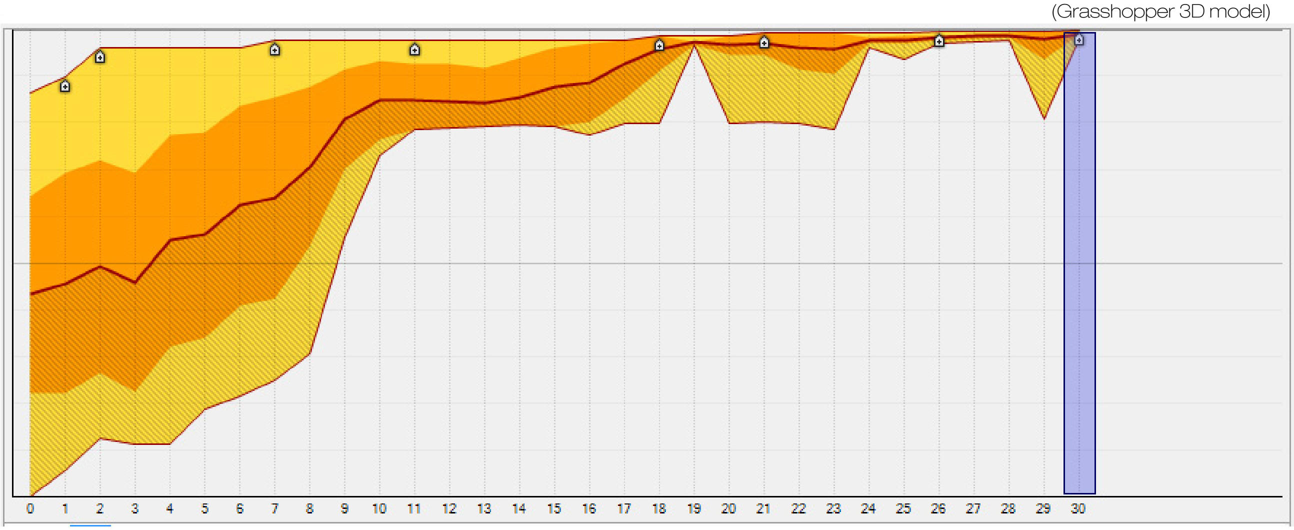
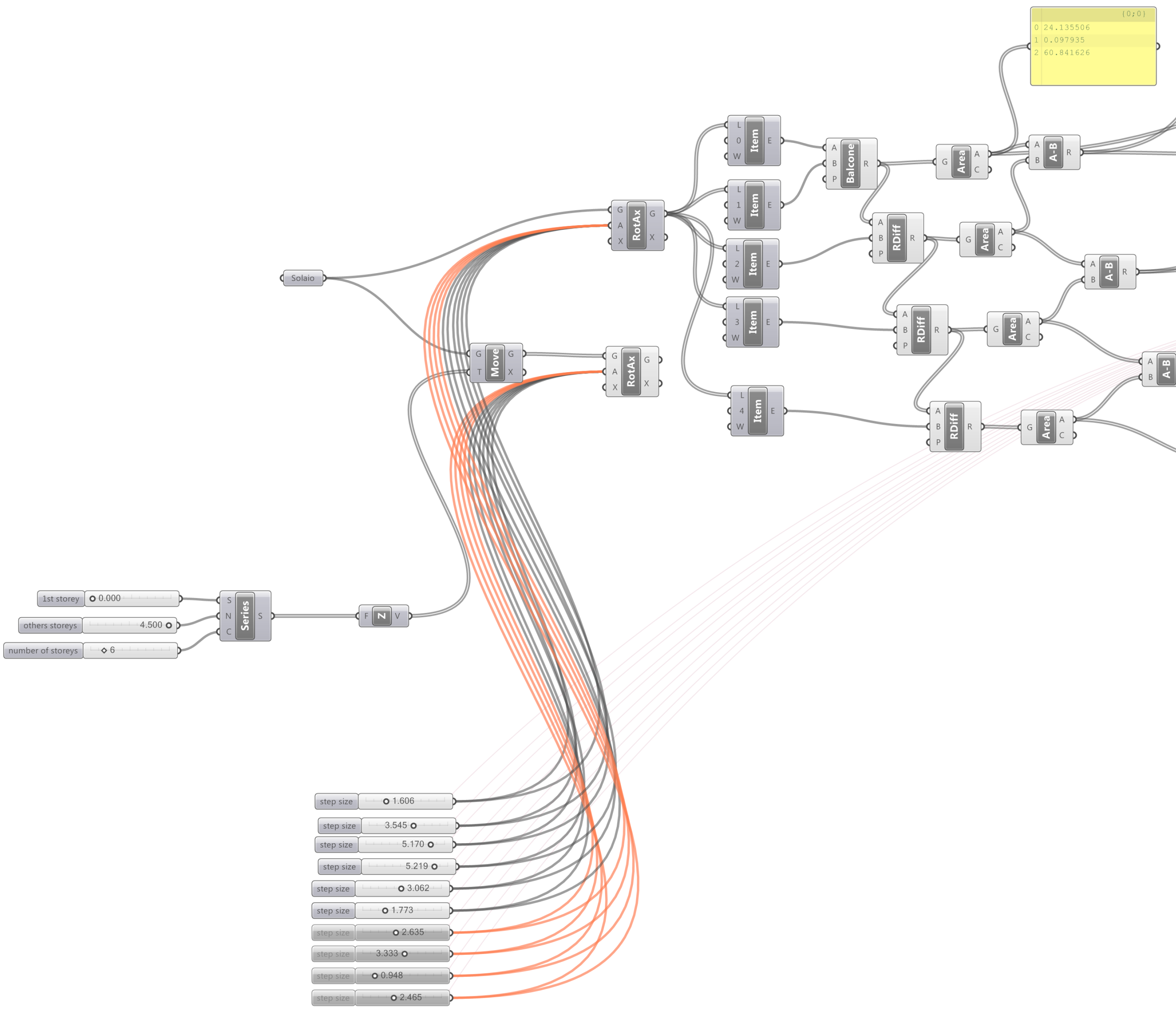


fig. 6.9 - balconies shading optimization process data graphs
(Galapagos for Grasshopper)


(0;0)
0 24.135506
1 0.097935
2 60.841626
Item
Balcone
Area
A-B
RDiff
RotAx
Solaio
Move
1st storey
0.000
others storeys
4.500
number of storeys
6
Series
Z
step size
1.606
3.545
5.170
5.219
3.062
1.773
2.635
3.333
0.948
2.465

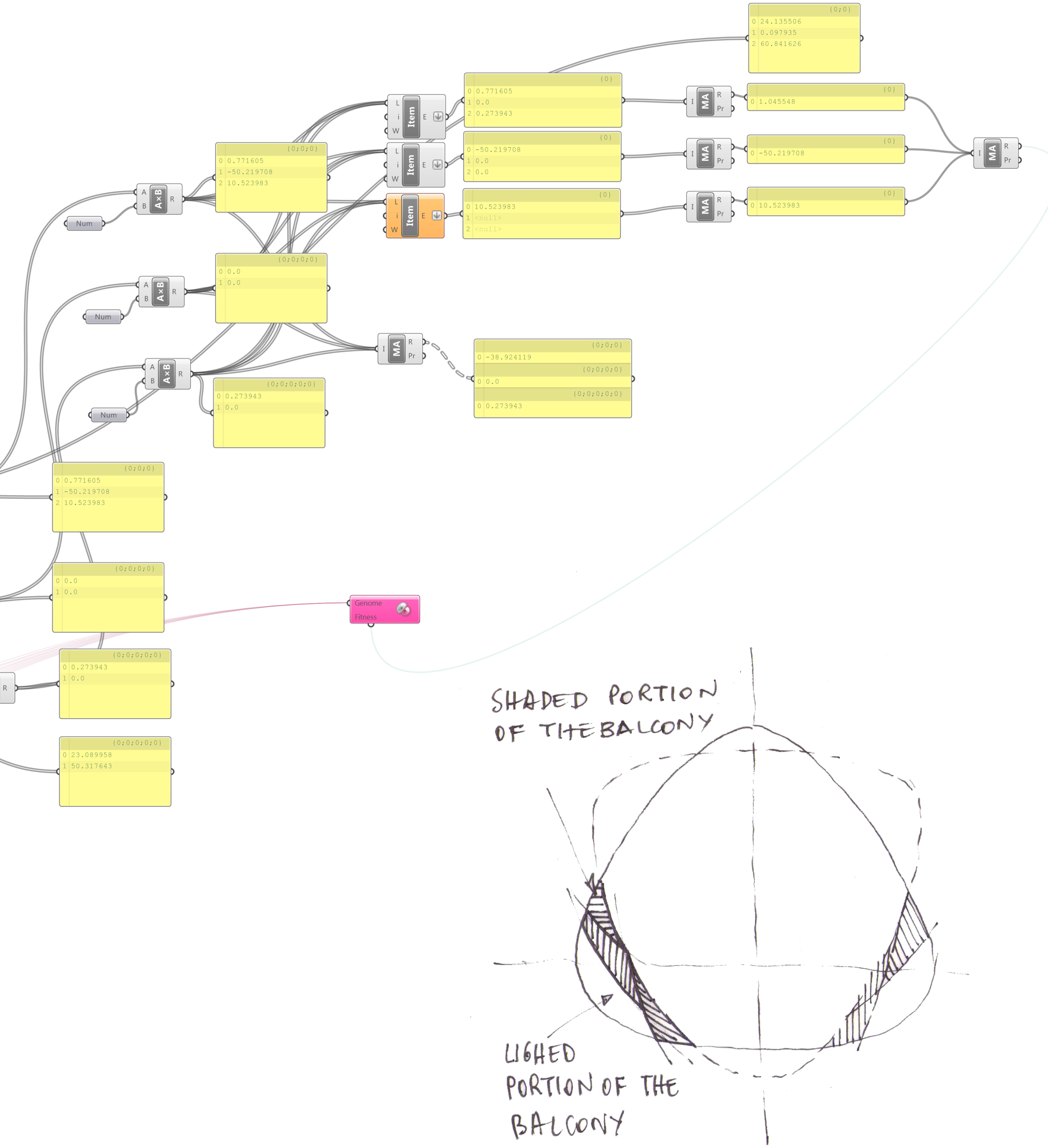


fig. 6.10 - balconies shading alhorithm visual schematization (Grasshopper)

OTHER PARAMETERS

Besides those described more in detail, there are other parameters that could be managed through the computer program in order to make the building suitable for different needs and situations.

Plan dimensions

The dimensions of the ground floor in the project have been determined according to the necessity of leaving a before open space between the elevated railway and the building itself. The necessities of having a square or a green area in front of the building could vary according to the project specifications. The dimension of the ground floor, in particular and extensively of the footprint of the whole building, can be varied according to the dimension of the site.

The footprint area is the parameter that can be varied according to the specificity of the construction area.

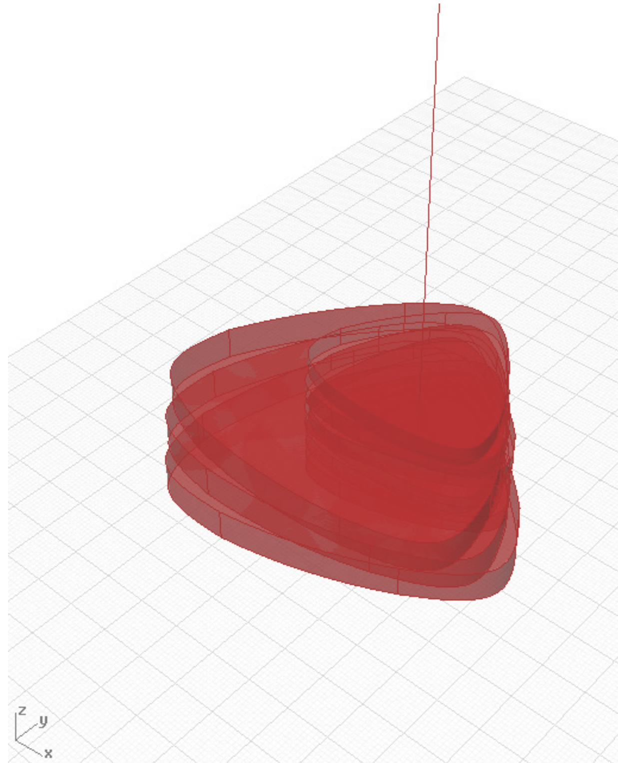


fig. 6.11 - footprint dimensions variation (Grasshopper 3D model)

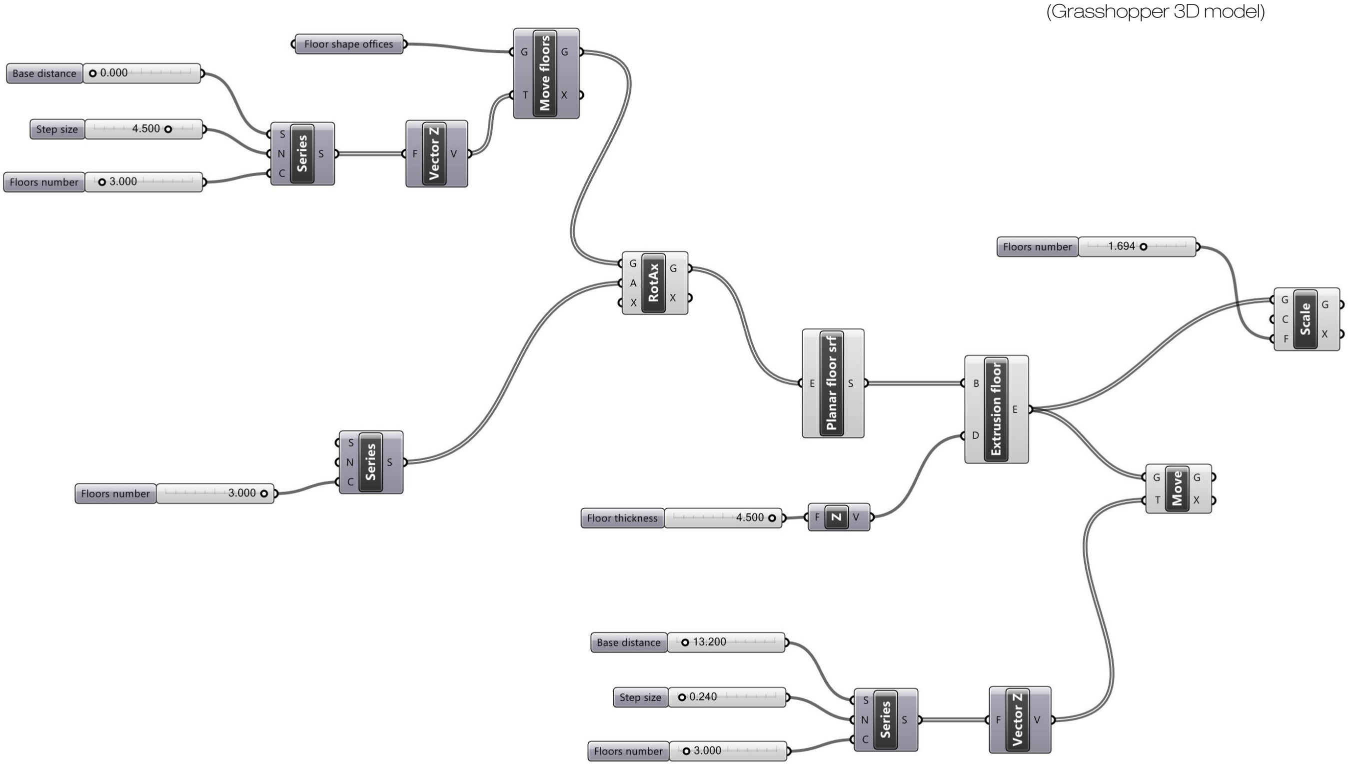


fig. 6.12 - footprint dimensions visual schematization (Grasshopper)

Number of floors

The required height could increase significantly, when dealing with a urban context where high rise constructions are set and no height limits are imposed, or when more space is required to be developed in height. On the other hand, the building could be placed in a context where such tall construction is not required or allowed. Therefore the height of the building could be modified by decreasing the number of floors.

The factor times which the floors number is repeated is the parameter to be varied when a lower or taller building has to be realized.
The factor could multiply the single floor or the blocks including the three floors rotated in respect to each other as conceived in the project.

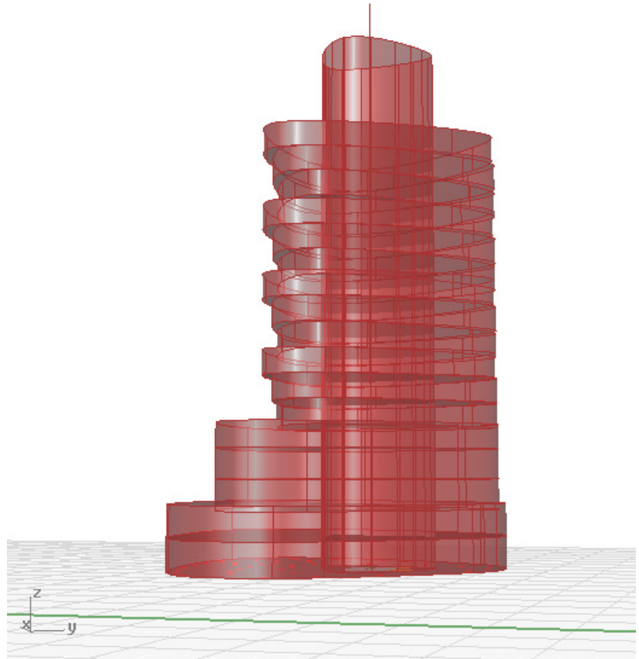


fig. 6.13 - number of floors variation (Grasshopper 3D model)

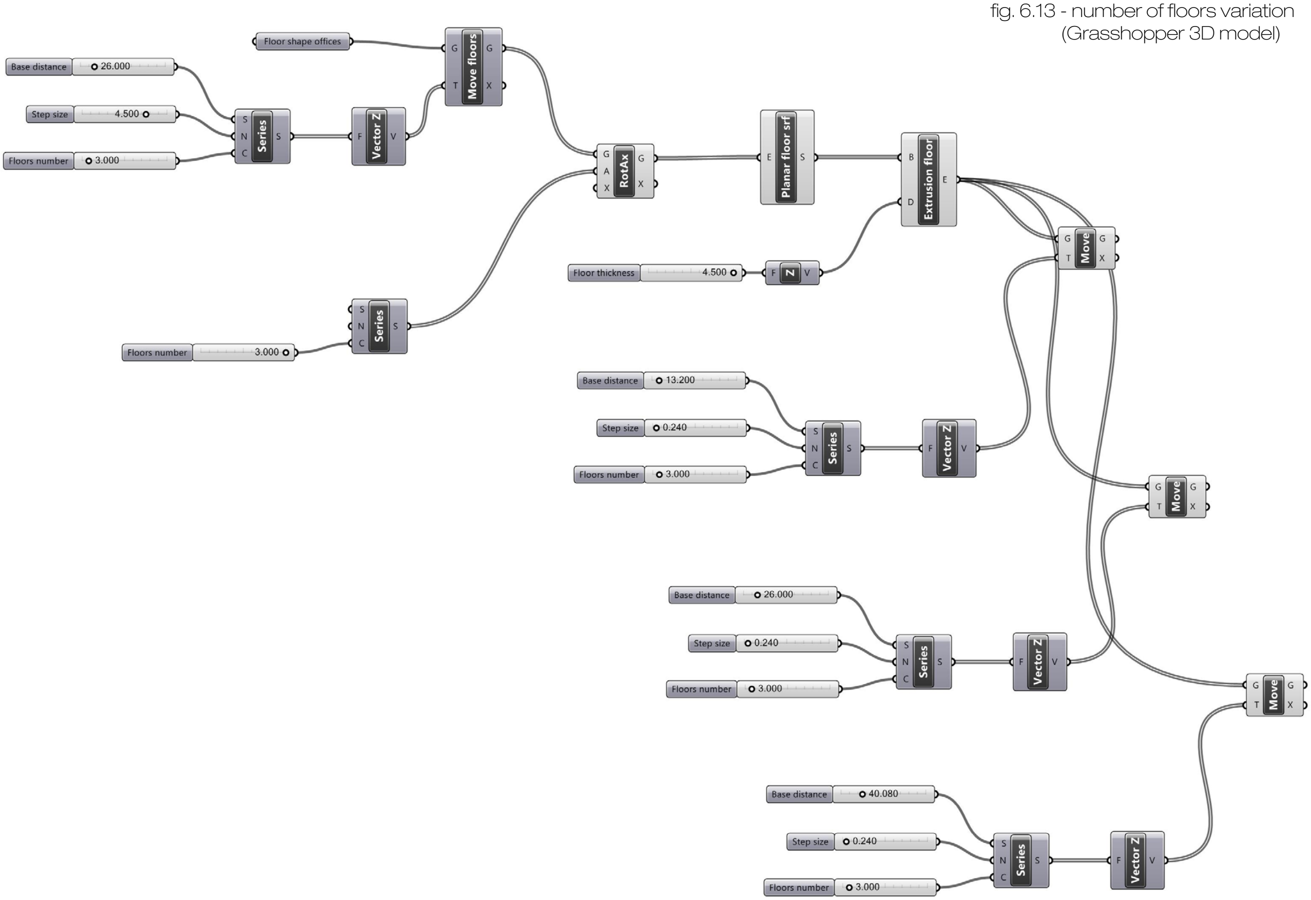


fig. 6.14 - number of floors variation visual schematization (Grasshopper)

Height of the floors

The height of each floor is determined by the function set in the same: office or shopping spaces requires much more space in height then residential apartments. Therefore according to the variation in the functionalization of each floor the height could be assumed as the parameter to be varied.

Rotation of the building

The building, as described in chapter 3, is located in the site with a particular direction of the floor plan according to the considerations around the prevalent wind direction toward the triangular-like form.
The wind study is specific for Eindhoven, but when changing location a different distribution of the wind blowing will certainly occur.
In this case the rotation of the building would conveniently be different in order to take advantage from the form of the building.

Varying the direction of the axes of the building shape in plan according to the specific wind direction graph of the location is the action to be parametrized.

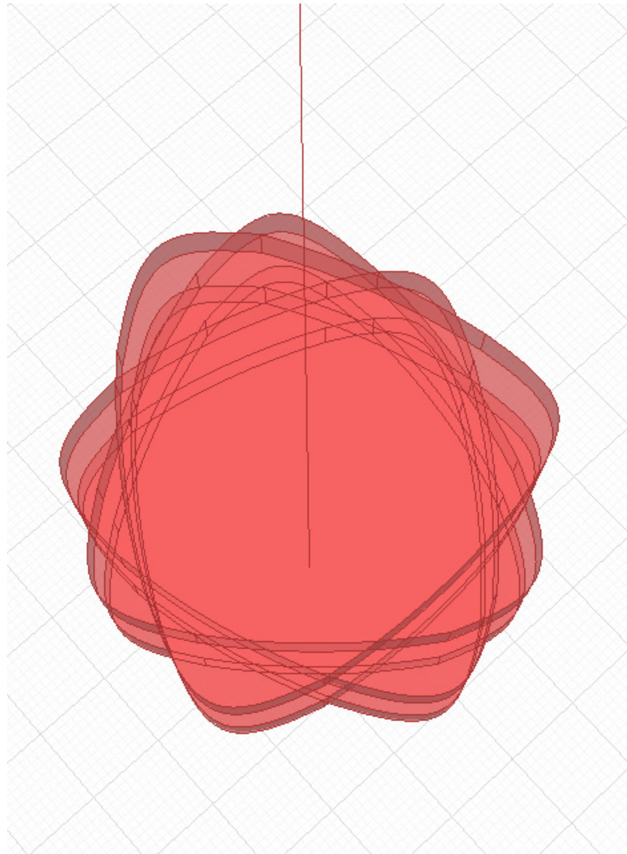


fig. 6.15 -modified shape rotation (Grasshopper 3D model)

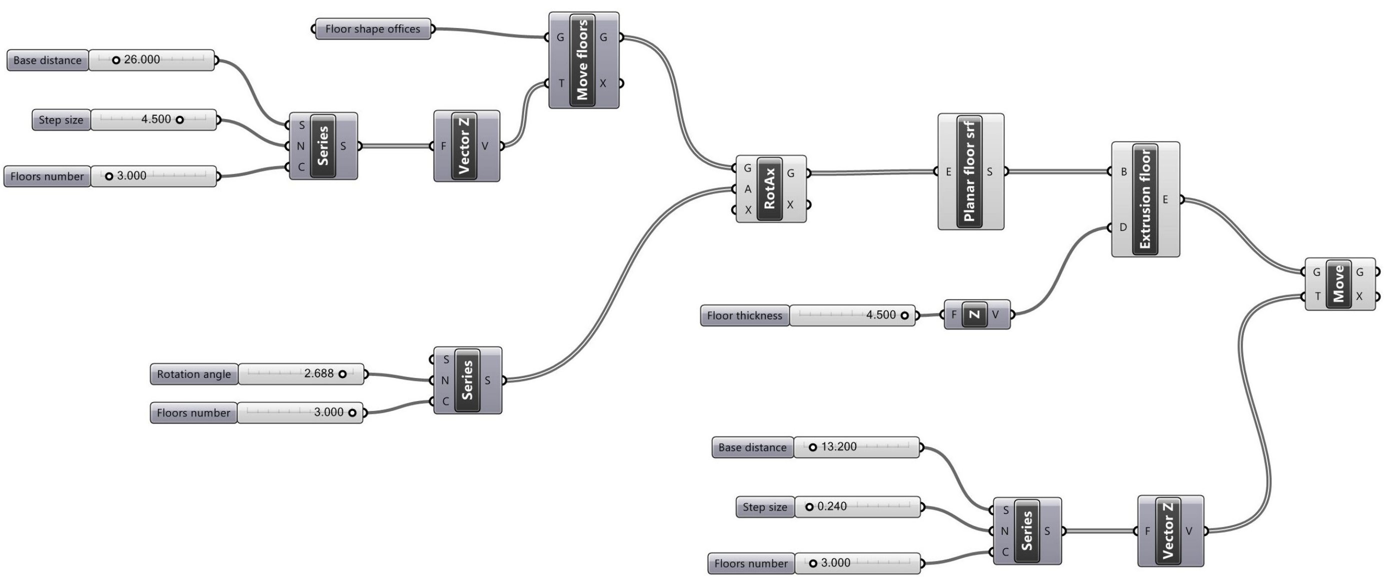


fig. 6.16 - modified shape rotation visual schematization (Grasshopper)

Variation of the overhangs

The rotation of the floors in respect to each other determines a certain entity of the projections of the floors. These are useful to shadow in part the below floors and could be varied in dimension according to the sun path in the location. In the specific site, the particular climatic conditions require to have as much as possible sun entrance in the indoor spaces, due to the lack of sun during the year.
Somewhere else, however, the need for protection from the sun is a fundamental aspect and then the parametrization of the hanging slabs dimension could improve the building performance

Structure dimension

The dimension of the structure depends for a big part from the self load of the same structural components of the building. Varying, as mentioned before, the number of floors, the height of the same, the dimension of the overhangs, means the need for a different structure, in particular, the dimension of the core walls and of the floor slabs thickness, or of the vertical supports should increase proportionally to the variation of the other parameters of the construction.

Roof inclination

The roof could be used for placing solar panels for energy production.
These could be of course placed with an own inclination in order to optimize the sun capture, but would be more conveniently placed on a sloped roof, with an inclination of the typical 30° according to the sun path. The inclination of the roof could be parametrized in order to be rightly directed toward the sun and with the optimum inclination according to the location characteristics. When no solar panels are needed, the roof could be simply made plane.
The roof inclination could be parametrized also accordig to the effect on the skyline that the varied roof could exert, even following the need of the designer.

The parametrization of the project could lead to interesting results in term of optimization of the form of the building in order to optimize several of its aspects, from the internal distribution and the use of the space, to the adaptation of the building to the changing urban context, to the energetic one, modifying the building in accordance to the shading necessities, to the need for natural lightning, to the use of sustainable methods for energy production (p.v. panels).

Of course, enslaving the set of "rules" that determine the aesthetical and composition result to the variation of the algorithm regulating the optimization of such aspects, besides improving the performance of the construction according to the elements abovementioned, causes a freedom in the overall transformation that could elude the designer control.

An aspect not to be underrated should be the final result of the project that, besides being improved, should always remain coherent with the primary intention of the designer.
The project, in fact, is the result of the creative process of conception through which the architect gives form to its ideas. Besides these latter have to face the reality and adhere to the structural or contextual necessities, the process of transformation and adaptation shouldn't turn upside down the design intentions and therefore the application of the parametric process should be somehow confined in order not to be completely revolutioning.

When carrying out a progess of parametrization, then, it is of the highest importance the definition of the constraints that have to be maintained fix in order to not let to the optimization intentions the ability to upset the essence of the design product.

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fig. 0.1 www.mesomo.com

fig. 1 Lunch atop a skyscraper, Charles C. Ebbets, 1932

fig. 1.1 www.dcaligari.blogspot.it/

fig. 1.2 www.photos4travel.com

fig. 1.3 www.flickr.com/

fig. 2 photo taken by the author

fig. 2.1 to 2.16 www.wikipedia.com/

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fig. 2.29 to 2.32 www.forum.skyscraperpage.com

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fig. 2.1.1 to 2.1.5 www.skyscrapercity.com

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fig. 3.5.1 *High-Rise manual : typology and design, construction and technology*

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