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Filtering Corso Porta Ticinese

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Abstract

After spending two years studying Architectural Engineering at Politecnico di Milano, it was of a great interest to focus on a project with great potentials. In fact, there was not a better project than the new addition to Diocesan museum since it gives the opportunity to implement new technologies within one of the most historical and important centers of Milan. It enables us to really absorb and understand the Milanese culture.

As a Thesis theme for the Master of Science in Architectural Engineering, a project which has the potential for designing and developing in Architectural and Technological as well as structural aspects was more preferred. Therefore, the project of new addition to Diocesan Museum was selected for the same reasons. Furthermore, the availability of the site to visit, well-defined brief of the competition and familiarity of the project supervisors with the competition and the site of the project were the strong points which helped the final project through its realization and removal of the constraints.

The project has been approached, on the urban scale, by acquiring the necessary knowledge about the history and the urban evolution of Milan in general and Corso Porta Ticinese in particular , leading us to a fair understanding of the particularity and historical significance of the area subject to study. However, since Milan is a living city, a conscious grasp of the contemporary strategic planning had to be done. Consequently, deep studies were carried out in order to investigate the ongoing plans and strategies for the metropolitan region of Milan as well as the neighborhood area around the site in the content of the PGT of Milan. From those ongoing plans, we can mainly mention “La Passeggiata Urbana dei Bastioni”, “Raggi Verdi” that had direct impact on the vision concerning the future aspect of the historical center of Milan.

The architecture concept started with the contrast between the highly dense identity of Corso Porta Ticinesse and the urban void of Parco delle Basiliche. The guidelines of the project were directly obtained from the brief of the competition of “Concorso Internazionale di Progettazione Museo Diocesano” in terms of functional requirements and areas of the spaces.

Since flexibility of the spaces in the exhibition buildings are out of an extraordinary importance, therefore the structural system which is chosen should be free of structural constraints and obstacles. Steel structures are always a good solution since it provides rather large spans in a covered space. Also a system of dry construction was preferred which reinforced our choice of structural system. Furthermore, despite the previous approaches concerning the seismic design severity in Milan, the latest unfortunate events proved that more conservative attitude should be taken into account.

After studying the climate situation of Milan, it was obvious that a well-insulated envelope is the sine qua non of a thermal efficient building. Moreover, the typologies of the spaces required the application of both transparent and opaque walls. Since the brief was concerned about both energy efficiency and light control, a compromising solution between indirect natural lighting and artificial lighting had to be opted. Being constrained by providing sophisticated air conditioning systems in terms of specific controlled temperature, relative humidity and air quality conditions, an all-air system was obviously chosen.

Introduction

Monumental complex of Sant'Eustorgio

On 10 August 1220 the church of Sant'Eustorgio was ceded to the Dominicans, who built the monastery. In 1798, with the establishment of the Cisalpine Republic, the Dominican order was stripped of its property and the troops of the republic quartered in the monastery's cloisters. The monumental complex of Sant'Eustorgio became the property of the municipality in 1905, with the deed of transfer of the Headquarters of the Civil Engineers registered in Milan on 14 March 1906. The different and improper uses to which it was put over time, culminating in the heavy damage of the Second World War, made necessary a restoration, aimed at the unified and coordinated upgrading of the entire complex. Immediately after the war negotiations were begun with the Milanese Curia, and these seemed to have reached a conclusion in 1960, when the municipality of Milan decided to cede the undivided property of the cloisters to the parish church of Sant'Eustorgio and the Diocesan Board for the Preservation and Diffusion of the Faith. However, the ministry refused to give its authorization for the transfer, declaring the property inalienable. An agreement was drawn up in which the parties stated their mutual interest in carrying out the restoration of the cloisters in accordance with the aims and conditions listed in the deed under private seal of 1 December 1960: the agreement "confirms the objectives of urbanistic and structural reorganization of the cloisters and of their public utilization for parish activities, as a Diocesan Museum, for artistic, cultural and archival activities with related service areas and as accommodation for the staff in charge of the foresaid activities, consistent with the original use of the cloisters connected with the basilica". With the agreement of 5 September 1997 "for the urban and structural renovation of the cloisters and annexes in implementation of the General Update of the Town-Planning Scheme" a building lease of ninety-nine years was granted to the parish of Sant'Eustorgio and the Diocesan Board of Trustees. The agreement provided for the parish of Sant'Eustorgio and the Diocesan Board of Trustees to carry out the restoration of the cloisters, at their own responsibility and expense, returning the complex to its original character, with the following uses:

- Parish activities in the cloister adjoining the basilica, under the supervision of the parish.

- Diocesan Museum and cultural activities (library, restoration workshops, diocesan archives, exhibition rooms, lecture rooms and annexed services) in the cloister facing onto the Parco delle Basiliche, under the supervision of the Diocesan Board of Trustees.

While this differentiated granting of a building lease with the attribution of a variety of purposes was the premise for the commencement, in 1998, of work on the adaptation of the cloisters, including the preparation of the seat of the Diocesan Museum, it has at the same time hampered the utilization and appreciation of the complex as a unified whole. The church and museum of Sant'Eustorgio, the underground archaeological remains of the Roman and early

Christian cemetery and the Portinari Chapel are in fact now separate, both in their management and their use, from the Diocesan Museum. Currently it is not even possible to walk through the cloisters, interrupting an architectural and monumental promenade of great significance that would lead from Piazza Sant'Eustorgio to the Parco delle Basiliche[1].

Diocesan Museum

The Diocesan Museum was opened by Cardinal Carlo Maria Martini on 5 November 2001 after a long period of gestation that had commenced at the beginning of the thirties, when the archbishop of Milan, IIdelfonso Schuster, came up with a plan to promote Christian art and at the same time bring together and conserve the artistic heritage of the diocese.

In the sixties, at the urging of Cardinal Montini, the complex of the basilica of Sant'Eustorgio was selected as the seat of the Diocesan Museum, and in the eighties work commenced, according to principles of conservation and historical accuracy, on the restoration and reconstruction of the cloisters of the ancient Dominican monastery, gravely damaged during the Second World War. The Diocesan Museum fulfills its aim of promotion of Christian art and preservation of the diocese's artistic heritage in two ways, with a permanent display of works of art like paintings, sculptures and liturgical objects and by staging exhibitions of art and organizing conferences, lectures and study and research activities.

The cultural activity now conducted by the Diocesan Museum "goes beyond its role of active conservation of the works to hold a dialogue with the city, with the territory of the diocese and with the individual parishes through initiatives and events that are intended to stimulate the public, by introducing it to the beauty, and the spirituality, of art".

The permanent collection has now found a home in the spaces of the cloister facing onto the Parco delle Basiliche. The temporary exhibitions and the spaces used for reception of the public, meetings and educational activities, as well as the facilities for collection, cataloguing and study of the works will be located in the new part, subject of this DPP.

Arrangement of the works in the Diocesan Museum

The Diocesan Museum, with a total area of around 3600 sm, is laid out on both floors of the three arms of the cloister opening onto the Parco delle Basiliche. The present entrance is located at the blind end of the east arm. The long vaulted entrance corridor now houses the ticket offices and information spaces and provides access to rooms at the sides used for meetings and as rest and service areas. These reception facilities will have to be transferred to the new part, subject of the competition, and suitably upgraded.

[1] Competition brief

On the first floor, directly connected with the exhibition area, are located the offices of the museum director, the curators and the administrative staff. At present eleven main sections house over six hundred works of sacred art dating from between the 4th and the 20th century. A vast and varied patrimony, built up through a series of bequests, donations and episcopal collection ever since the time of St Ambrose, it reflects disparate cultural tendencies and offers a cross-section of different historical and artistic periods. To the nucleus of works from the abolished museum of the Basilica of Sant'Ambrogio, have been added the Monti, Visconti, Pozzobenelli and Erba Odescalchi Collections. These have been supplemented by the collection of Tuscan 14th- and 15th-century paintings on a gold ground assembled by Alberto Crespi, the Mercenaro Collection, the series of canvases from the archconfraternity of the Santissimo Sacramento and Gaetano Previati's Via Crucis from the cemetery of Castano Primo. Works from the 20th century, by artists like Aldo Carpi and Lucio Fontana, already acquired by the Diocesan Museum, will be given a suitable location with the reorganization of the existing spaces, following the construction of the new part, subject of this DPP. On the ground floor, after the long entrance corridor, the tour of the museum begins with the room devoted to St Ambrose. The display hinges on the large clypeus representing the saint giving his blessing, a polychrome stucco dated to the 10th century. The room contains other works of significance, such as the 4th- to 6th-century wooden springers of the main portal of the basilica of Sant'Ambrogio and a silver capsule from the 4th century. The following room houses section I of the Works from the Diocese. One of the most important parts of the museum, its contents are arranged chronologically from the 14th century onwards and consist of paintings on wood and canvas, detached frescoes and sculptures in wood and marble from parish churches in the diocesan territory. In the crossing are located the multimedia stations for examination, study and in-depth analysis of the works present in the museum. Next comes Previati's Via Crucis. Fourteen large frescoes from the cemetery of Castano Primo, detached and transferred onto canvas, are on permanent display here, in a room conceived for the purpose. The Room of the Arch confraternity of the Santissimo Sacramento is arranged as if it were a picture gallery. The fifteen large canvases representing devotional subjects, executed sometime in the 18th century, are the only ones to have survived from the longer series of paintings, commissioned by the arch confraternity to be put on display in the nave of Milan Cathedral during the celebration of the Corpus Domini. The present arrangement reflects the order in which the paintings are presumed to have been hung in the cathedral. On the floor below, beneath the Room of the Archconfraternity, is an underground room dating from the 13th century that has been renovated and devoted to Church Ornaments and Vestments, dating from between the 4th and the 20th century. The numerous pieces that make up this section are displayed in showcases in rotation, something that is made necessary by the large number of objects and the continual acquisition of new ones. The first floor houses the collections that have come to the museum through bequests and donations and sections II and III of the Works from the

Diocese, again ranged along the three arms of the cloister. The first room on this floor is the one containing sculptures from the Marcenaro Collection. The works, which come from different areas (Northern Europe, Liguria, Central Italy), cover a span of time from the 13th to the 17th century. Like the group of paintings from the same collection and in the Diocesan Museum on deposit, they are still the object of study and attribution. The Crespi Collection, presented as a long gallery, is made up of paintings on a gold ground. Forty-one panels, executed in the 14th and 15th centuries and mostly of Tuscan and Umbrian origin, “reflect the fundamental stages in the development of Italian painting, with specific reference to sacred subjects”. Section II of the Works from the Diocese covers the period from the middle of the 15th century to the end of the 16th, bearing witness to the important changes that took place in the Lombard art of the time, with the influence of Leonardo represented here by paintings by Marco d’Oggiono. With its 172 works, the collection assembled by Cardinal Cesare Monti (1593-1650), the successor of Federico Borromeo, formed the original nucleus of the Milanese archiepiscopal collections. On display in the Archbishop’s Palace of Milan until 1811, some of the works were then transferred to the Pinacoteca di Brera, where they remain to this day. The part of the Monti Collection now in the Diocesan Museumcomprises paintings from the Veneto school of the 16th century and the Lombard school of the early 17th, along with drawings by artists from the time of St Charles Borromeo. Section III of the Works from the Diocese contains works from between the middle of the 16th centuryand the 19th century. It opens with the large canvas of the Annunciation by Pederzano, executed in line with the directions of the Council of Trent, and continues with Lombard paintings from the 17th century, in which works by Procaccini and Nuvolone stand out. The section closes with a comparison between two Crucifixions of the 19th century, one by Mosè Bianchi and one by Francesco Hayez. The collection of Archbishop Giuseppe Pozzobenelli of Milan (1696-1783) is devoted entirely to “[...] Arcadian subjects, landscapes and views with figures”: works dating from between the end of the 17th century and the 1770s painted mostly by artists from Rome, the Veneto and, to a lesser extent, Lombardy and Flanders. The room of the Collection of Cardinal Federico Visconti (1617-1693) houses three works from the larger collection, which forms part of the Raccolte Vescovili, made up almost entirely of paintings by 17th century artists[2].

At the end of the long side of the east arm is set the Altarpiece of the Passion, a large polyptych in carved and painted wood made in the second half of the 16th century by a workshop in Antwerp for a chapel of the church of San Giorgio at Annone di Brianza near Lecco, and on deposit at the Diocesan Museum since 2000. The permanent exhibition concludes with the collection of Erba Odescalchi, archbishop of Milan from 1712 to 1734: forty-one portraits of the bishop saints of Milan, from St Barnabas the Apostle to St Charles Borromeo, hung here in the manner of a private collection of the time on the south wall of the monumental staircase.

[2] Competition brief

Scope of the project

As a sustainable oriented project, the thesis theme is architectural and technological design of the new addition to Diocesan museum (3800 Sqm of gross surface area), while, the project as a suitably-organized whole, deals with a number of problems in urban design and townscape: the relationship with Corso Porta Ticinese, the rehabilitation of the blind elevations of the buildings adjoining the empty space left by the wartime demolitions, the provision of proper access to the Parco delle Basiliche, and the relationships with the open cloister and the Santo Eustorgio monument complex as a whole. Also structural design and analysis were carried out for the buildings of the new addition.

Use and function of the new addition:

-Entrance and common spaces
-Exhibition
-Meetings and educational activities
-Delivery of works, storerooms and workshop studios
-New typologies and materials, their appropriate installation, the correct orientation to exploit the solar input, the form of building and the modes of insulation are investigated in the design phase. These ideas are considered along with fact that they have to permit optimal utilization of the resources, in the construction phase as well as in that of running and maintenance.

URBAN STUDIES

Urban transformation of Milan

Historical transformation

Urban development , as we see today, was carried out more significantly between the eighteenth and twentieth centuries and also, perhaps with the most recent transition from manufacturing to the post industrial city, with the extensive remodeling of the sites originally occupied by forms of production now rendered obsolete through processes of modernization common to many European cities. The deep urban structure of the city which resisted the continuous growth of urbanization and alternative models of territorial development is referred to as the main sign of history today. From the network of the Navigli canals, built between the twelfth and the fifteenth centuries, after the covering of the inner circle, the most significant part is now the Darsena of Porta Ticinese, where the Naviglio Grande brings in water from the Ticino and the Naviglio Pavese carries it away to the south. This area of Milan is studded with historical remains connected with the old waterways. More recently it has seen the growth of cafes and restaurants and other amenities of the catering and leisure facilities[3].

It could be stated that Milan, situated at the crossroads of two important commercial passages, is ideally located to produce work. Before industrialization of 19th century Milan was rather a city of handcrafts, artisans and commerce. Milan acted as a supporter for all the upper Milanese areas that were well known for their silk factories. Their owners lived in the center of Milan and Banks related to their activities located there too. Magazine publication and generally publishing industry flourished thanks to the interest of the inhabitants for reading. Soon Milan moved rather toward tertiary industry which was design related like fashion, furniture, banks and shops. The expression design by Milan could be defined well if we consider the design history of Milan as a city of innovation and knowledge owes its identity to numerous sectors perhaps not as visible as fashion or furniture, like universities, IT technology and research areas. Therefore, Milan formed a knowledge district where each sector profits from the benefits of fruitful relationship, research, experimentation and industrialization.

Milan history was always related to the needs and the use of the people living at each different time. The city evolved through different phases over its history achieving always the need of the people living there and also trying to adapt to the increase of people through the time. Through a general overview of the history of Milan we could understand that it had passed through different phases until it achieved a point of always growing and developing city. At that time it was a very attractive city for people from all near cities and towns to come and live in Milan. This was obvious through simple analysis of number of population growth in a very small period of time as will be explained and clarified later.

[3] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007.

Nowadays, where Milan urban form appears as a pattern of interlocking circles and radials, it has totally evolved as a number of concentric belts. One of the very famous quotes about Milan's actual appearance and its transformation through history is the one stated by Cesare Bureto: "the plan of our city, represented on a small scale, is very like a cross-section of a tree. You can clearly see the outgrowth and the concentric layers. It is a highly rational scheme that is explicate in nature. All this plan has done is to give the requisite greater extension." Obviously belts were of different historical dates and different functions inside the urban fabric of the beginning of Milan as a city.

The oldest belt of Milan was the wall enclosing the system of Cardo. The next one was the mediaeval walls studded with the different city gates along the circumference which also was intersecting with the Naviglio canal. This canal also along the history of Milan's urban has changed a lot after the realization of the artificial canal, it was again removed to allow the expansion of the urban fabric of the city. This was in the 1930s when there was a need for a new master plan and was converted to a ring road. This is one of the very important points affecting the relation with Porta Ticinese due to its adjacency to the canal[4].

Just after the previous belt and also close to it, was the presence of the Spanish wall, where you could find traces of it until nowadays in different scattered parts. It was also enabling it to absorb the belt of suburbs of the expected growing's outside the urban fabric of Milan. The relationship between the radials and circles was very visible at the time, since at the intersection, there were present the Gates of Milan, where each of them had its own historical importance.

Another very important point that played an important role also in realizing the urban fabric of Milan was the railway station around the fabric of the city. By the realization of the old Milano central station it was a very attractive point to the city and eased a lot the interaction with other cities. It also developed the area around the central station.

Process of transformation

The relationship between the dwelling areas and the primary elements of a city is responsible for configuring that city in a given way. If this can be demonstrated in cities in which historical events have always acted to unify disparate elements, it is even more apparent in the case of cities that have never manage to integrate in an overall from the urban artifacts that constitute them. In this way, formerly peripheral parts of large cities in transformation often appear beautiful: London, Berlin, Milan, and Moscow, reveal entirely unexpected prospective, aspects and images. The transformation of particular parts of the city over time is very closely linked to the objective phenomenon of the decay of certain zones. This phenomenon, generally referred

[4] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007. P11

to in the English and American literature as “obsolescence”, is increasingly evident in large cities[5].

In distinguishing between the two principal artifacts found in the city, the dwelling area and the primary elements, we have strongly denied that housing is something amorphous and transitory. Thus, instead of focusing on the single house, in which material decay and a necessary accommodation to different social classes and modes of life are empirically observable over time, the concept of the characteristic area is submitted. Entire parts of the city manifest concrete signs of their way of life. Their own form, and their memory, may be distinguished from one another for the purpose of investigating.

The project of Enlightenment of the City

Along the urban transformation of Milan, there occurred very important and significant projects that were related to the development of the city. Also, after the French arrived, Napoleon adopted Milan as the capital. This decision was one of the very important decisions concerning the urban transformation of Milan and the urban development as well. Being the capital totally changed the personality of Milan as a city and the personality of the people living there at the time as well. The city started to have greater expectations in developing itself in all aspects which was of course with a great impact on the fabric of the city itself. Although the projects development was not following a certain plan but it was just a spontaneous growth along the main streets axes to achieve and fulfill the requirements of the people’s amenities and residence demands.

The projects at the time were more related to the French but this didn't deny its importance and positive effect on the city itself. For example, one of the very first projects was the "Foro Bonaparte" which was to celebrate the victory of Napoleon on the Austro-Russian army. This point by itself was very new to the city at the time, and the idea of revolutionary spirit and enlightenment was brand new. The project was to create a big circular Piazza (530 m), surrounded by a Doric colonnade. The demolition of some parts of the castle was needed while the main part of it, which was built by the Sforza dynasty, was kept. Connections were made to the piazza through emphasizing the canals and improving them. The piazza mainly contained different functions and uses such as a public theatre, a national museum baths and a custom house[6].

On the other hand, there were other projects that were demanded by the public at the time, but unfortunately they were not realized. Lack of funds and the rigidity and complexity of these projects could be referred as the main reason that they were abandoned. Also, their guidelines and main core ideas could be easily noticed and observed in later projects.

[5] Di Aldo Rossi, The Architecture of the City. P.95

[6] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007.p.18

Napoleonic period also had a very important contribution in the development and the transformation of the urban fabric of Milan. In 1807, the drafting of the actual existing general plan of the city (Piano Regolatore della commissione d'Ornato or piano dei rettifili) was presented to Napoleon himself. It was drawn by hand by the photographer Pinchetti. The presence of such a plan facilitated the starting of new projects such as improving the buildings' front across important streets, and also divided the city to five areas each assigned to a commissioner to provide a deeper and clearer drafting for them. The project also influenced the new buildings because it made it possible to examine the aesthetic of the buildings. By the end of Napoleonic rule, the "Commissione d'Ornato" plan also was eventually abandoned. It is also to mention that some of the basic ideas of the project were realized such as the arch of Porta Nuova also the restoration of the Porta Marengo which was called later the Porta Ticinese[7].

Another important project during the same period was the development of Corso Vittorio Emanuele, as a result of the redevelopment of the Cathedral Square and construction of the cathedral's façade. The Corso was the main reason of forming the commercial center in Milan as a sign of dominance of the financial and business classes.

Fig.1.1. Milan development 1722[8]

[7] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007. P.20
[8] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Major Projects in the inner city and the first real estate developments

The role of Milan as a functional capital in unifying Italy was great, which was a strong motivation for the realization of new projects in Milan. Inhabitants of the city were 196,000 within the walls of the city and 47,000 outside the walls in the Corpi Santi; this was in the year 1861.

Being affected by Napoleotanic and Astrian rules which added numerous aristocratic palaces, monumental edifices and large establishments main streets and squares centuries were redecorated and restored.

Early in 1860's, two main alterations to the city's face were taking place. The first was the work on the layout of Piazza Duomo and the construction of the galleria Vittorio Emanuele, and secondly, the new axis linking the cathedral square (Piazza Duomo) with the Castello Sforzesco. Connecting the religious and civil power in the city, reorganization of Piazza Duomo could be mentioned as the main reason of such controversial projects[9].

Between 1856 and 1878, Giuseppe Mengoni solved the problem of the layout connection around the Duomo. This involved the demolition of some of the buildings around it to improve the whole urban space of the square. After redeveloping the projects, the areas around the castle were subjected to be built as a residential district; However, Parco Sempione, the second greatest park of Milan, after the public park of Porta Venezia, was realized at the end, and residential districts were built partially in the area[10].

In the same period of time the realization of the Porta Genova station was of great importance. The effect of the project was significant on the urban aspect, since it was the second after the central station to be built outside the ramparts after unification. In 1865-71 the new street axis of Corso Genova , which was founded due to the presence of the station, flanked by a grid of streets running parallel and at right angles to it. In 1873, part of the wall was demolished to create Porta Genova, flanked by customs booths. The road extension beyond the city wall caused a dense new district of working class housing and industry along the canal called the Naviglio Grande and the dock at Porta Ticinese. Today, the region still keeps its both characters of urban fabric, with manufacturing activities located in the courtyards; however, in a continuous process of urban transformation, manufacturing sector is being replaced with design and fashion related buildings. This is referred to as the most spontaneous urban regeneration in Milan. Later in this chapter this concept of spontaneity is going to be explained in detail[11].

[9] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007.p.25
[10] *Ibid*
[11] *Ibid.* p.30

Fig.1.2. Milan development 1822[12]

Planning the urban design in the creation of the nineteenth century

From the last two decades of the nineteenth century a new methodology for the urban transformation started to take place, since before that time the development of the city was always spontaneous and not on a long term plan. Maybe there was an attempt that wasn't finished and realized during the time of Napoleon, but it was abandoned after his leaving from Milan.

In 1881, the first master plan was starting to be produced, where at that time 322,000 inhabitants and unsurprisingly after just ten years that number was increased to 424,000. The master plan was named after Cesare Beruto. This master plan discussed two very important issues; the steady spread of built up areas and construction of new housing and factories, and the other point was the transfer of the capital from land to finance. The master plan was still growing and wasn't yet in its final version since it was then showed to authorities and re-modified according to the guidelines and the requirements. The master plan was still following the same radial growing urban trend of Milan. Again, obstacles to the plan appeared, but this time there weren't the canals as the case before for the spreading of Milan which resulted in removing the canals in 1930. This time was the railway problem which was forming a boundary around the city. This resulted in changing the place of the central station also this expansion was the perfect way of converting farms to industrial lands and functions, also coherent with

[12] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

the new financial muscle and identity of the city which was necessary the time. Despite the importance of this master plan, due to the very fast growing requirements of the city another master plan was demanded that could more focus on the relation between the projects and the outer belt of the city and the inner belt, also to take into account the area around the Castello Sforzesco.

The new master plan was presented on two phases at which the first phase was with a grid of large blocks each of 200 m2 capable of containing housing, industry and public facilities. The second version, just one year after, was presented which considered the modifications regarding the consideration of the projects submitted by the big landowners[13].

Urban area expansion of 1920s and 1930s

Thanks to years of prospective economic situation, following the Beruto plan, city experienced a considerable expansion. The regularity in the networks of some of the regions built at the end of the century showed that they were designed based on a purposeful plan. On the east of the city, at Porta Vittoria, one of the largest expansions happened while the city exceeded the northern boundaries through Corpi Santi toward the Sesto San Giovanni where later a linear town consisting both housing and factories was realized. Working class blocks of flats and gardens suburbs grew up along the road. Later in 1912 Pavia-Masera plan was delivered in which a new urban plan was suggested for the potential expansions and finally the Albertini plan was approved in 1934 as the Piano Regolatore.

In this period, major public facilities were constructed such as the Citta Annonaria (wholesale food market) at Porta Vittoria, the city's main public hospital (Ospedale Maggiore di Niguarda, Giulio Ulisse Arata), the law courts (Palazzo di Giustizia, Corso di Porta Vittoria, Marcello Piacentini, Ernesto Rapisardi) and the university quarter[14].

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[13] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007. P.34
[14] *Ibid*. p.42

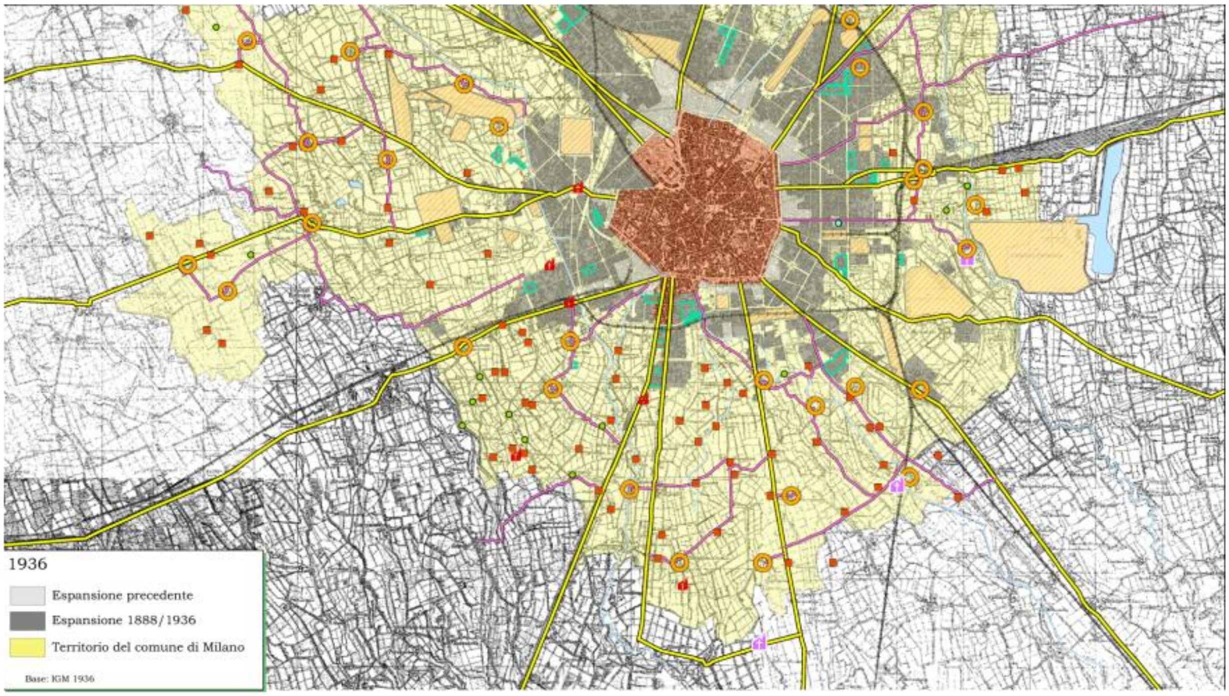

Fig.1.3. Milan development 1936[15]

After war reconstruction and population growth

The air bombardments of 1943 influenced the trend of reconstruction of the city since many buildings in the central part of the city were destroyed. It was during these days that a coherent master plan was drafted. It consisted of detailed plans relating to the central part of Milan in areas of Corso Vittorio Emanuele, Piazza San Babila, the zone lying between Piazza Duomo, Piazza Missori and Piazza degli Affari, as well as archeological zone around the basilica of San Lorenzo, the zone around the basilica of San Simpliciano, Piazza Cavour, and the area providing access to the new Stazione Centrale with the “Palazzate” of Via Vittor Pisani. In late 1944 “Secchi” as the first version of master plan was delivered in which the main directions of development were set to be in north-west and north-east. Studying the first versions of master plan together with the growth tendency in the years of war would help to understand the most intense urban growth of the years between 1948-1960s[16].

Due to the change in the railway lines positions, extensive land became available for possible constructions. The start of a series of plans and projects to transform these pieces of land was marked by the new business center that is located between Stazione Garibaldi and the Stazione Centrale. According to AR plan of 1944-45 the new business center was suggested to be in the

[15] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

[16] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007. P.51

north-west of the city. Also old heart of Milan was supposed to be gradually free from business and commercial uses and to be used for residential and cultural functions. But overall result of these transformations, twenty years after the war, was the increase in the density of the buildings in the inner city, which is due to the reconstruction of the damage buildings and adding stories to the existing buildings or building inside the gardens. The intermediate zone near the site of Diocesan museum which largely was developed under Beruti plan quickly became saturated with new buildings.

For the first time it can be seen in the AR plan that the regional vision of development is applied which is a conception of the city as an organism in continuous development as a result of economic and social processes. These regional developments mainly concerned the residential complexes to cope with the ever-rising demand of the population of the city which from 1939 to 1971rose from 1.22 to 1.73 million.

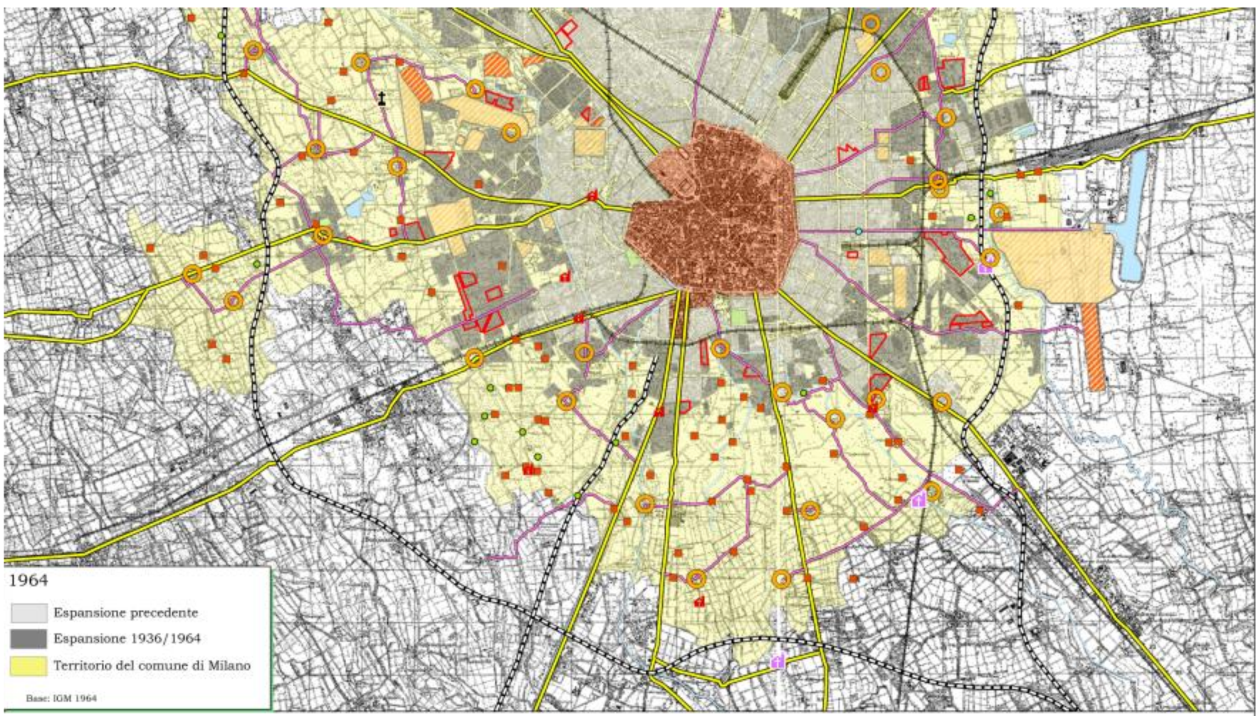

Fig.1.4. Milan development 1964[17]

The first "self-sufficient" housing estate to be built was the Comasina, on the extreme northern outskirts of Milan, an area still characterized in the early fifties by rural villages, assisted housing estates built by the City between 1938 and the early years of Reconstruction, and major health facilities like the Ospedale Maggiore at Niguarda, the hospital-sanatorium at Vialba, and the Paolo Pini psychiatric hospital at Affori.

[17] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

On the east side of the city, there is public housing estate of Quartiere autosufficiente Feltre. It has a strong layout around large courtyards that houses, services and the estate's gardens with a mixed fabric of housing and production zones hemmed in between the railway, Lambrate Station and the Tangenziale (bypass), itself the object of recent programs of urban transformation[18].

QT8 public housing estate is worthwhile to mention on the west side of the city. Architecturally the housing estate is in accordance with the AR plan approach and a Rationalist approach and concern for urban design led to the creation of an organism composed of various "neighborhood" units with different building types. Later, QT8 housing estate continued toward the north-west.

The city planning typologies of the typical public housing estates have following characteristics:

-Rationalist scheme

-Lamellar blocks of same shape and size

-Parallel and same orientation

In the new outer city a number of parks were planned and gradually laid out from which are on the west side the Parco di Trenno and on the east Parco Forlanini where the Idroscalo (a lake for flying boats) had been installed in the thirties and the , and the extension to Parco Lambro. In the contrary to the outer city parks, in the inner city and in the intermediate belt there the few new public gardens such as the Parco delle Basiliche between Sant'Eustorgio and San Lorenzo were not enough influential to mitigate the urban fabric compactness impression.

Metropolitan expansion

The consolidation of the metropolitan area between 60s and 70s could be mainly because of physical and social reasons like the creation of the conurbation and transfers between Milan and its hinterland for access to housing and jobs. Anew distribution of population happened by reduction of inhabitants in the circle of the Navigli (canals) and the intermediate belt as far as the outer circonvallazione (ring-road), while the new periphery and the towns of its hinterland gained population. Planning process in the fifties had the decentralization of the industry and the relocation of factories in regional poles as appendages of residential districts, but a rather not well organized process of relocation in the city's extreme periphery and hinterland, along the radial roads of the Strada Paullese to the south east and Vigevanese and Via Novara to the west were the real transformation that happened[19].

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[18] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007.p.59

[19] *Ibid* . p.64

In order to establish an inter-municipal approach to deal with the models of housing development, improvements of transport networks and the location of large public facilities, a Centro Studi was set up to conduct research of this kind. (Piano Intercomunale Milanese PIM). The idea of treating the metropolitan area as well as central city center as parts of a single system initiated with the studies of the PIM with a model of territorial reorganization with the emphasis on the system of mobility and spread of services so as to make location in any given point of the metropolitan area the "same". The contribution of the PIM helped the Territorial plan of Provincial Coordination to develop a hypothesis of Polycentric reorganization of the metropolitan area, based on certain outstanding poles of the territory lined with nodes in the upgraded infrastructural system and with urban transformation areas brownfield sites. Namely, it means to see the city of Milan as the central pole in a network of smaller towns. Nowadays the metropolitan of Milan is a territory of 1.5 Million people and 800,000 cars[20].

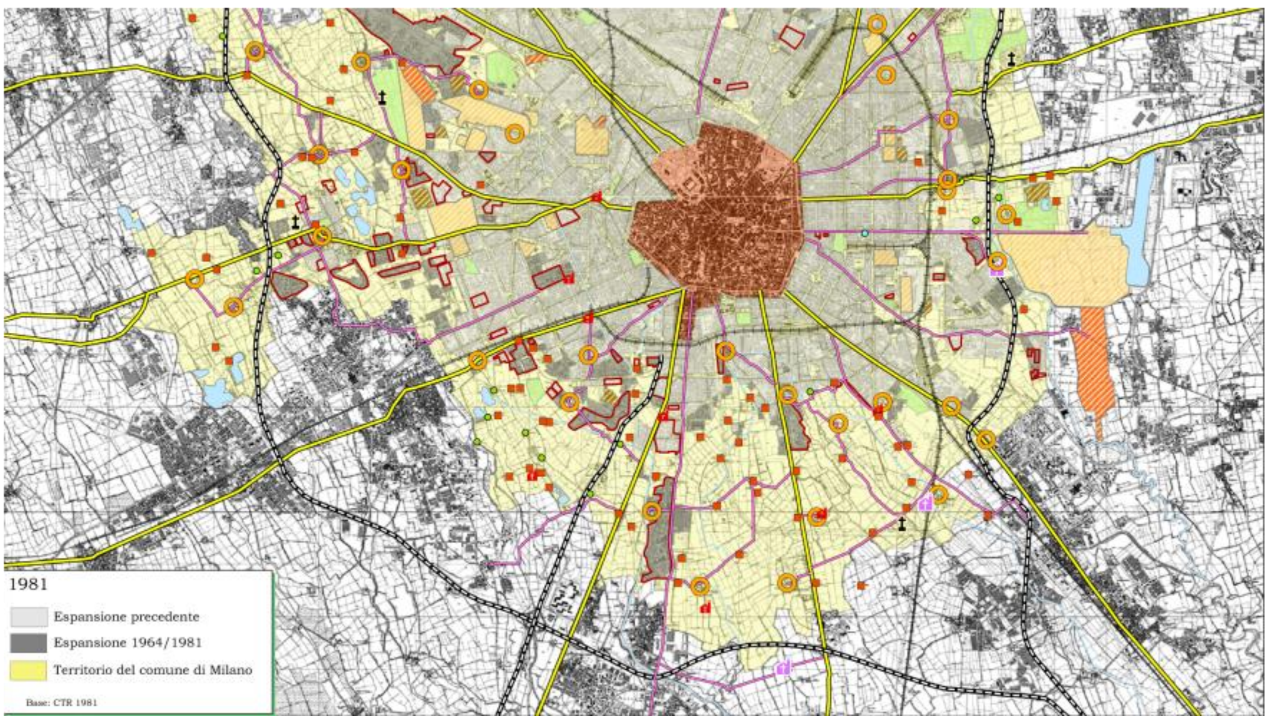

Fig.1.5. Milan development 1981[21]

[20] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007. P.66-69
[21] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Case studies

Zona Tortona

Zona tortoan in south of Milan used to be an industrial zone and now it has changed completely to a fashion and design zone. Now it contains streets of show rooms and boutiques and photographic studios, and advertising agencies in former factory buildings. Until 19th century the area around via Savona, via Tortona, was under control of Corpi Santi. Naviglio Grande and Olona waterways caused area to be characterized by agricultural looting, with irrigation canals, Path and fenced fields. There was also a rural residential settlement, around the intersection between Darsena and Naviglio. Then through a complex process of subsequent overlapping, this area entered into the urban system of Milan.

In the meantime, railway tracks, streets, plazas, residential buildings industries, commercial spaces and public structures were added to the agricultural fabric of the territory that there were fields, rural houses, trees, paths. Transformation of the area from countryside to a city started in 1865 thanks to the construction of the railway to Vigevano and the Porta Genova railway station. Like many other marginal areas in Milan of that time the expansion is brought by new infrastructure and industries. Along with factories workers houses also were built. But till the end of 1960s due to changes in production system and energy crisis, industrial factories became vacated leaving huge pavilions and courtyards behind. The yea of 1983 was the start of new transformation of the area which led to the new identity for Zona tortona. Transformation was done by artists and workshops, small and big projects by companies, institutes.

Factors such as fashion related artists influenced so much the transformation of the Tortona. At its peak Fashion design like Armani, Versace, Krizia and others together with other design fields like furniture, lighting accessories strengthened the design identity of Milan. A lot of different industries understood the potential of the area to provide them necessary space for business and art. Beside super studios usage of the buildings by photographers other sectors like publishing management, model agencies, marketing agencies, graphic studios, and schools were attracted to the region.

The identity of Zona Tortona was defined and developed by a spontaneous initiative and now is working as a united character and is returning its contribution back to the area of Zona Tortona. Since transformation of Zona Tortona as a design district was done spontaneously the territory as a result developed a kind of consensus which works as a guide and as a criterion of any social architectural and urban interventions that are going to be applied in the area. Therefore, as Zona Tortona's existing architectural and urban fabrics were almost maintained and converted to another type of original space adapted to new uses, Zona Tortona could be mentioned as a good territory transformation[22].

Bovisa

The necessity to study project interventions in true order is important in the Bovisa area from the founding of the Politecnico di Milano till present. Politecnico di Milano Project, the first meaningful intervention in Bovisa, is assumed therefore an important role for subsequent transformations. But one problem was that the project remained within a settlement of existing buildings without interaction with its context and created two facts: one existing and the other with students coming and going which left Bovisa unvivid. The Politecnico di Milano, having occupied all the areas around Piazza Leonardo da Vinci, was looking for a new space to satisfy its strong growth and to guarantee adequate services to its 50000 students. After having evaluated various locations, Bovisa was chosen in 1987, in particular are of the old gasworks. The expansion phase of Politecnico di Milano is currently very intense thanks to interventions that will involve re-converting two industrial areas for new departments of Energetica, Meccanica and Ingegnereia Gestionale. There could be a similarity between transformation of Zona Tortona and Bovisa and that is both have been transformed building a distinct vocation of the area. Both zones caused a powerful identity to be given to the areas. Zona Tortona gave design and fashion treats and Bovisa gave educational identity along with young and creativity.

For Bovisa, after the first arrival of Politecnico di Milano in 1987, it had quite a long period of undergoing territory transformation and as a large scale intervention in the region the project could not well be integrated to the surrounding context to let students to mix with them and not to just pass them. However small private interventions together with large scale ones were enough o give a new identity to the Bovisa[23].

[22] So IK Jung, *Enzyme, for progressive actuation of Urban Planning Milan thru Design, to switch urban background to social playground.* 2009

[23] *Ibid*

2000 and onward urban transformation

Immigrations to the city caused the population to grow slightly in the first decade of twenty-first century. Urban transformation projects experienced acceleration in this period by upgrading areas that are "peripheral" from the city's point of view but all belong to the core of the urban region. From now on, a new period of urban transformation depends on the urban and architectural qualities of the projects now under construction and the city's ability to fulfill the demands of a complex society[24].

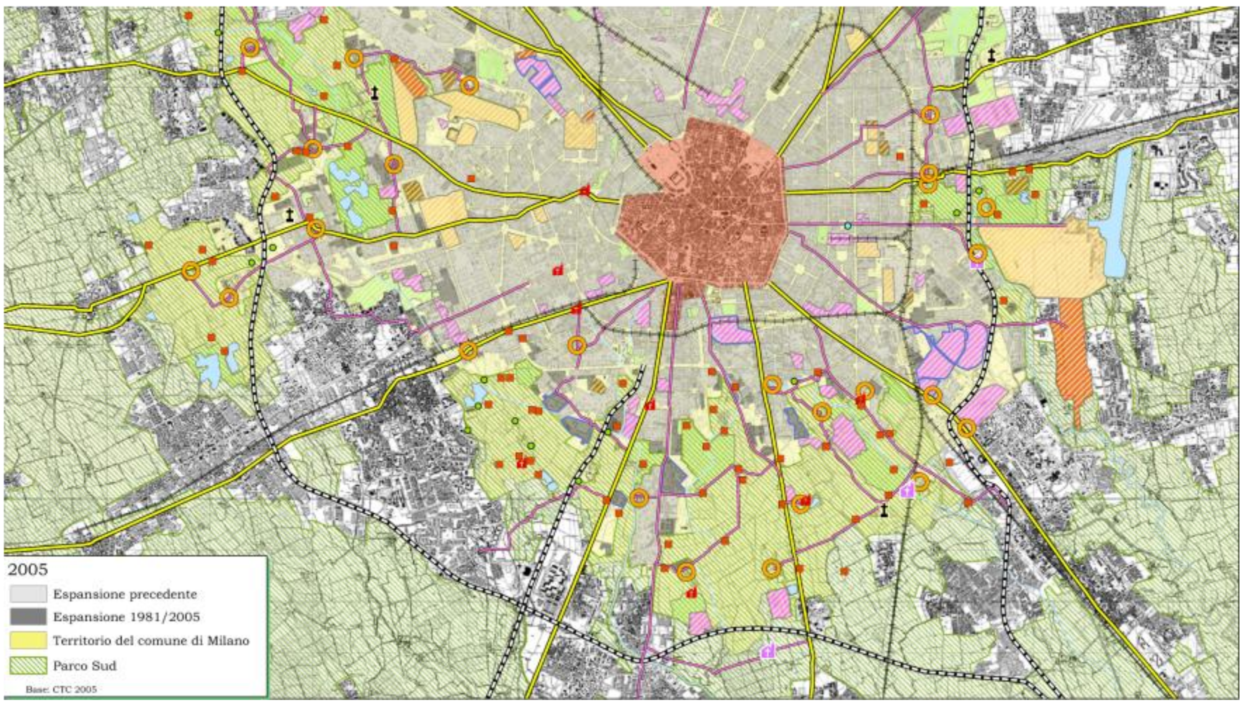

Fig.1.6. Milan development 2005[25]

[24] Corinna Morandi, *Milan the great urban transformation*, Vicenza 2007. P.70

[25] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

General Demographic and Economic facts

Residents Vs Users

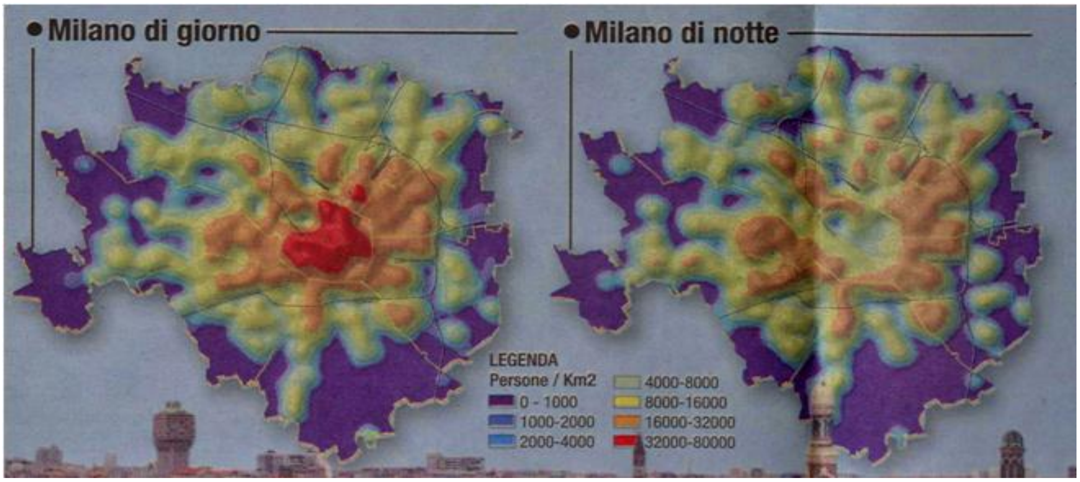

Fig.1.7. Day and night comparison of population[26]

The tension between the city of residents and the city of the so-called "city users" is becoming increasingly greater. Each day between 700,000 and 900,00 vehicles enter the city for different reasons and the central railway station of Milan alone is used by 320,00 people. There 642 million users of the ATM public transport network in 2008 and 52 million used the Ferrovie Nord railway network. There were almost 176,00 students enrolled in Milanese universities for the academic year 2003-2004 according to a survey by MeglioMilano and only 34,800 of these were Milanese; 43,250 were temporarily residents and 97,800 were commuters. There were 350,00 patients in Milanese hospitals in 2000. These few indicators are sufficient to understand the volume and at the same time the intensity of the flows that affect a large urban region like Milan. "Strategic Planning for Contemporary Urban Regions: City of Cities: a project for Milan" Alessandro Balducci, Valeria Fedeli, Gabriele Pasqui .

[26] Danilo Palazzo, *Milan's Data and Figures*, Universidade Federal do Rio di Janeiro 2011.

Demography Evolution

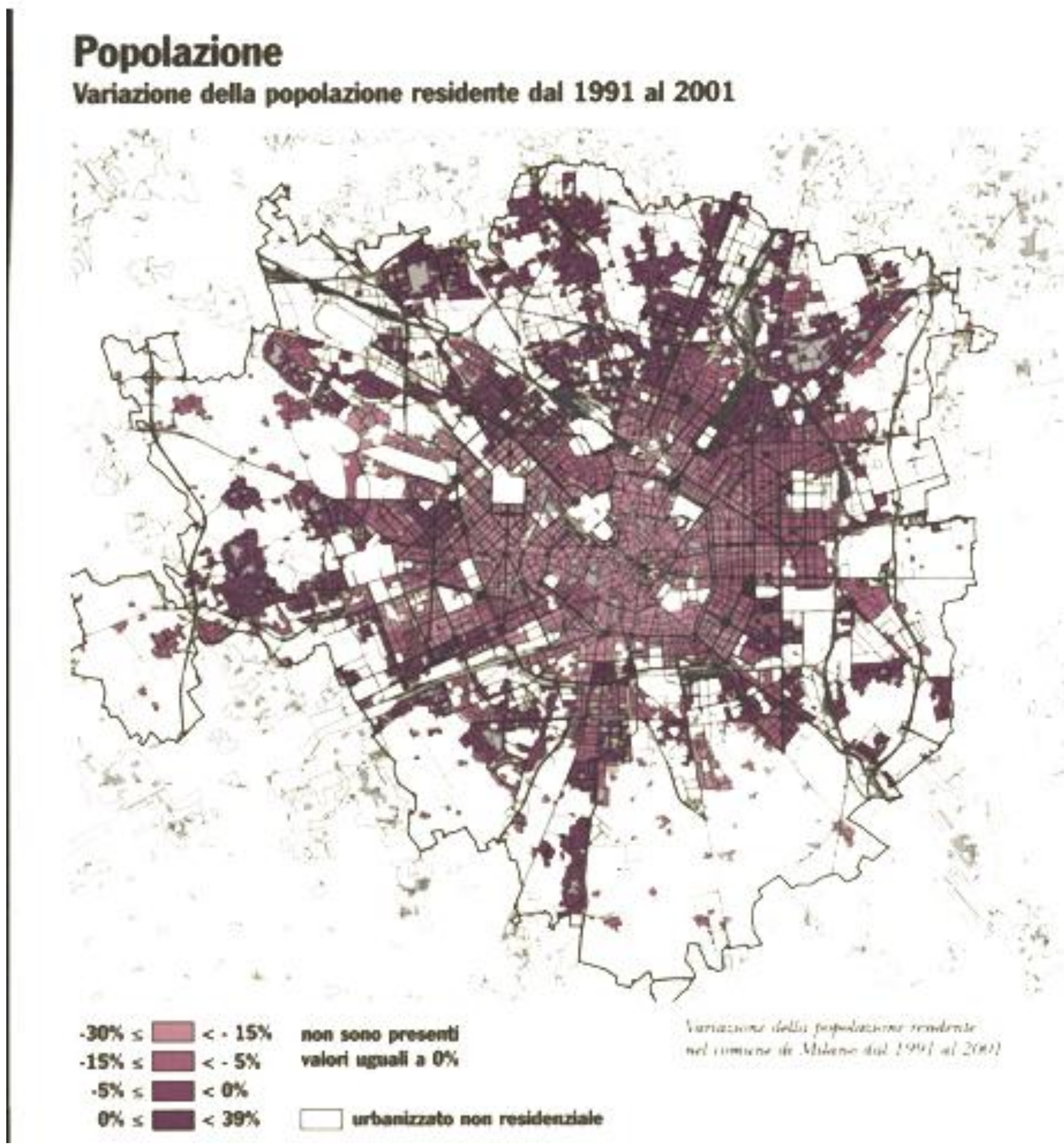

Fig.1.8. Population variation from 1991 -2001[27]

In the nineties, the Milanese population has consistently recorded negative growth figures, with an overall decrease in absolute value of 40 thousand units. At this stage the province of Milan has lost an annual average, of 0.11 percent of its residents.

[27] Danilo Palazzo, *Milan's Data and Figures*, Universidade Federal do Rio di Janeiro 2011.

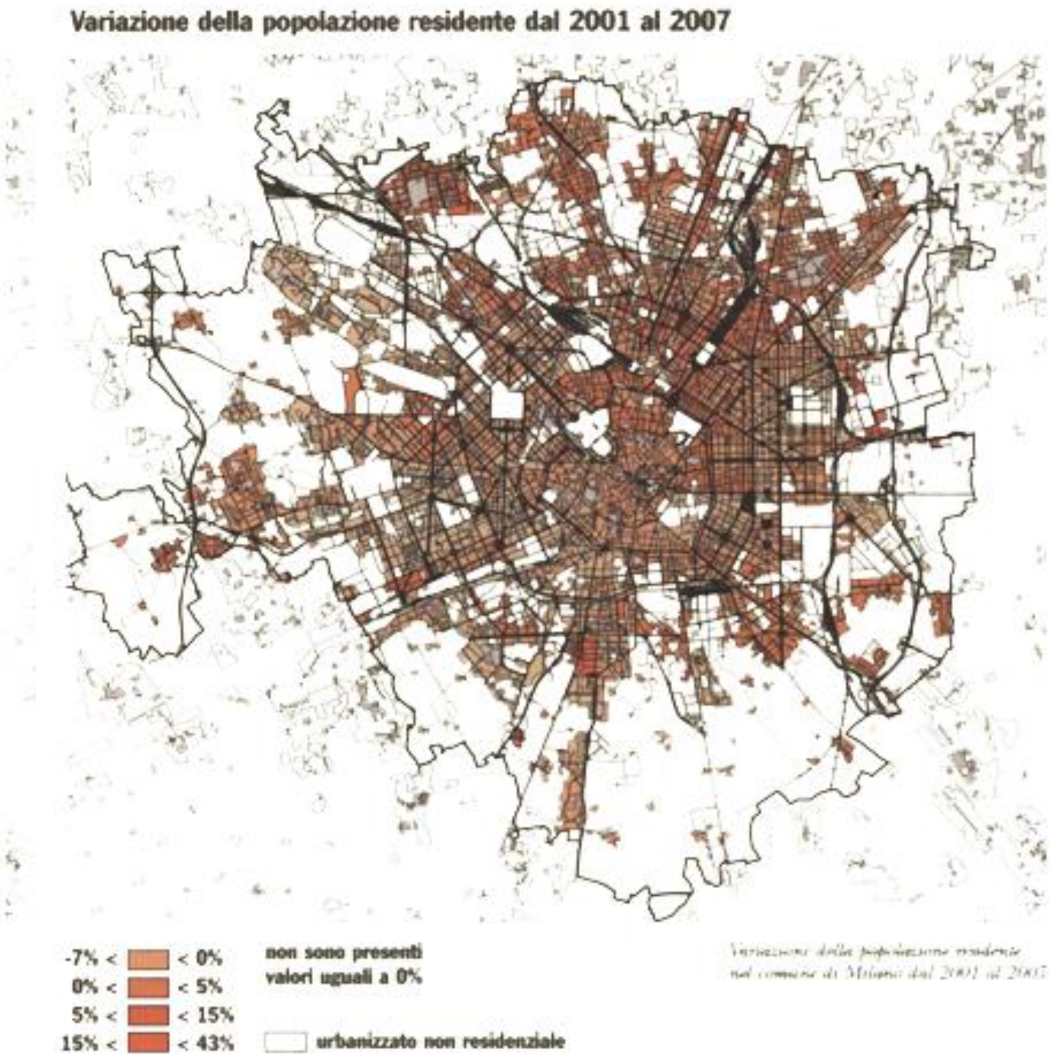

Fig.1.9. Population variation from 2001-2007[28]

The second phase, from 2001 to 2007, has been particularly significant from a demographic point of view with the resident population increases significantly higher than those recorded in previous years. In particular, the population growth recorded in 2003 was 1,44 %, and in 2004, it was 1,65%. Analyzing the demographic data records of 2003 and 2004, with the aim to explain the resurgence of growth, there are two elements: first, concerning the development of the number of births and deaths. After holding negative values in the Nineties, natural balance begins to record positive values at the beginning of new millennium, touching the highest peak in 2004 (+ 5,000 units). The second, relative to the weight of the foreign component: the current Italian quota of 6 per cent of foreigners was reached in Milan in 2004, rising to 10% today

[28] Danilo Palazzo, *Milan's Data and Figures*, Universidade Federal do Rio di Janeiro 2011.

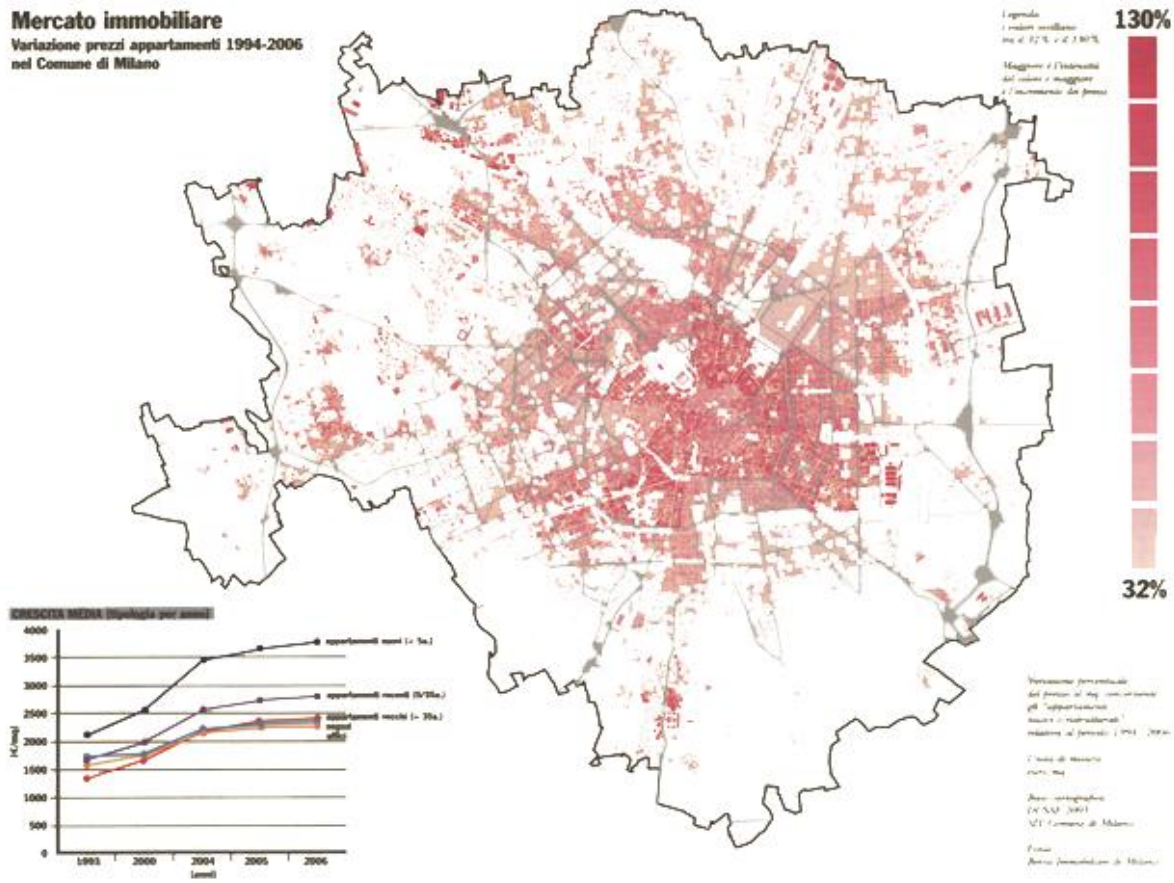

Fig.1.10. Mercato immobiliare[29]

Real-Estate Market

From 1991 to 1998, we record a steady decline in prices, but also in the number of transactions: the boom years of 88-91 were totally decreased and we went back at the prices of the years 1985-86, without taking into account any inflation adjustment. Since 1998, the trend has reversed: in Milan, now trades increased by nearly 30%; prices, for new buildings, have risen on average by 60%.

The "peak" of the increases happened in 2002; then, in the residential, there were still increases, but in a more controlled way. In the second half of 2005, in the new buildings, there was a further rise in prices, very controlled, and exclusively due to increases in monitored areas where the city is significantly being transformed (ie the periphery); in the historical center and the adjacent areas, no variations appear, but, for the first time in the last 7 years, variations of negative sign also appeared, even if very small.

[29] Danilo Palazzo, *Milan's Data and Figures*, Universidade Federal do Rio di Janeiro 2011.

Piano del Governo del Territorio PGT

PGT vs PRG of Milan

Urban design deals with proposed projects which are built or are affected badly or even failed. While social happiness means an improvement both mentally and physically of people's standard of living related to and affected by urban transformations. There is always a gap between planning on desk and applying the plan in real situation and that is the reason why some highly invested projects often fails to create a pleasant urban transformation and remain in isolation while a simple urban feature is more successful to make connection with its surrounding environment. In Italy, the time factor was affected to this detachment of urban planning from society for structural, cultural reasons. Urban planning laws Piano Regolatore Generale (PRG) increase the gap between urban planning and society since they are more quantitative rather than qualitative. There have been different attempts to surpass PRG structural problems, for example through strategic planning.

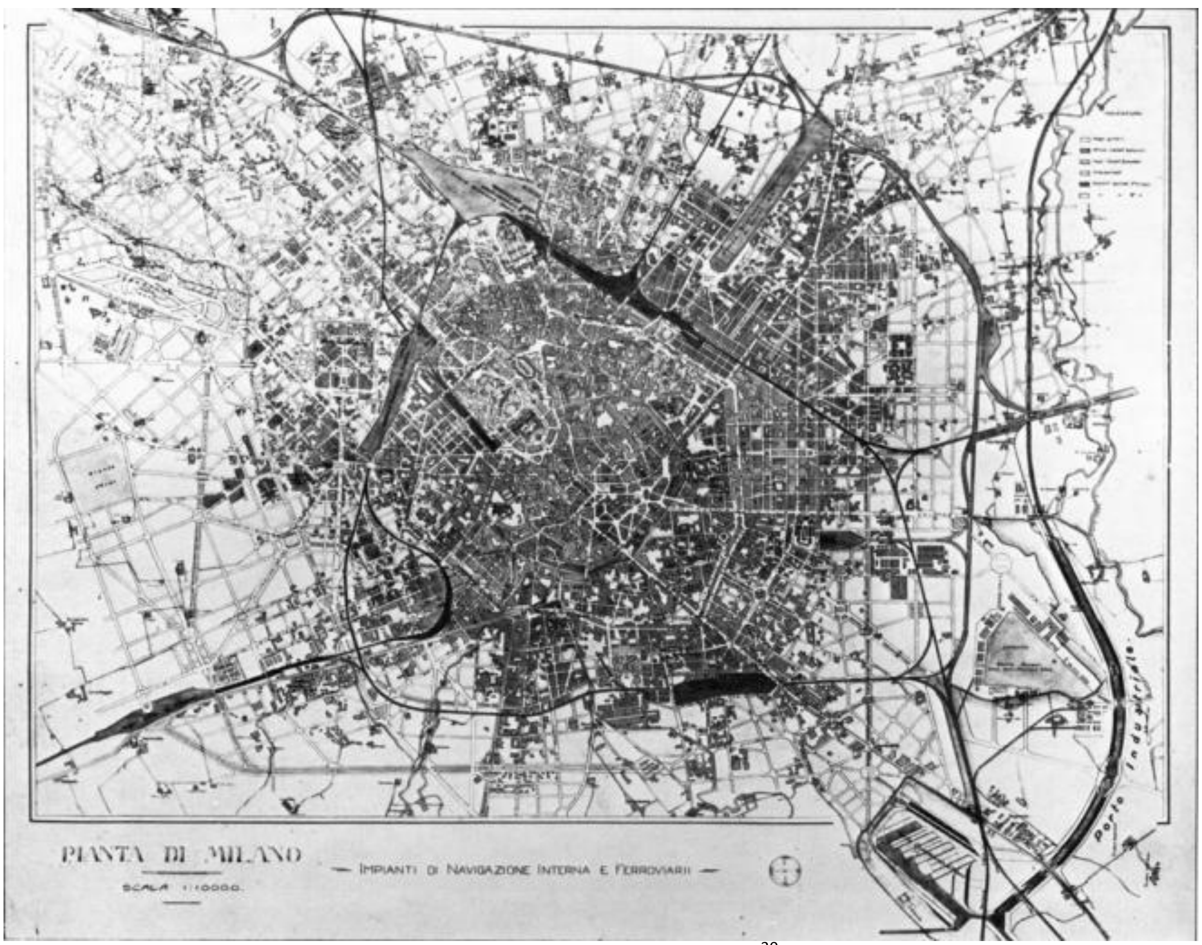

Fig.1.11. Old map of Milan 1930[30]

[30] http://www.skyscrapercity.com

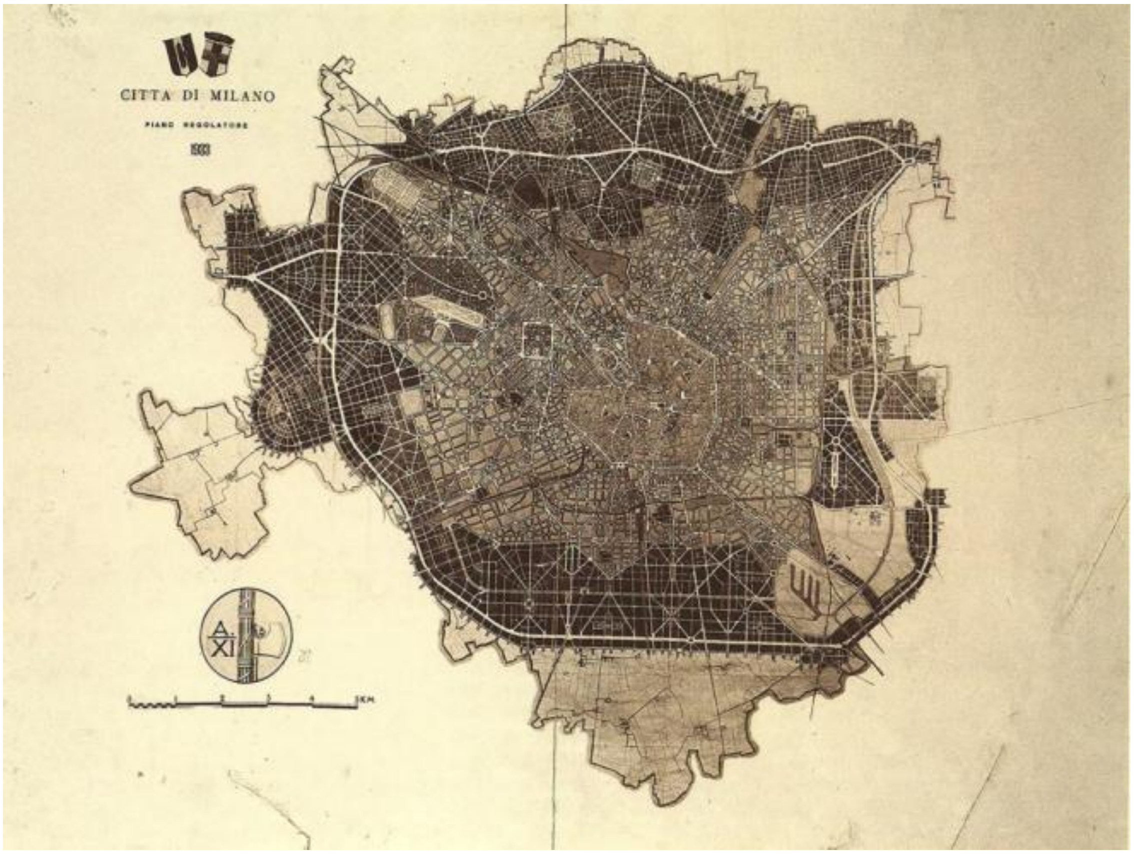

Fig.1.12. PRG 1934[31]

First PRG was introduced in 1942 to orientate or coordinate urban activities. It is very clear that one of the main goals of urban planning is to guarantee proper placing of public services by organizing and governing the territory to finally having better standard of living and development of territory.

One prime consideration when dealing with urban planning perimeters is question of integration and communication with the context of a project. PRG plan imposes a static way to perceive territory, forcing it to be mono functional and flat and this made it difficult to manage mutating necessities in a dynamic way. Even subsequent strategic planning is not exactly changing the way to perceive a territory, but focuses more on smoothing and accelerating the "processes" of a project. PGT the new Lombardy urban planning norm, Piano di Governo del Territorio is trying to move toward dynamic attitudes rather than previous static ones of PRG.

Each zone in the urban area has its own personality and behavior which cause it to have its own relationships with its own features. In other word one can say territory should be perceived as a living organ and not as a static entity.

[31] http://www.skyscrapercity.com

Planning can be considered as a catalyst to activate a specific transformation process of insertion of a project within existing contexts, not only physically but also socially. Also activates the integration of a project with consequent chains of territory transformations. It means a positive contribution to the territory development through an ethical approach of any urban planner.

PGT Vision:

PGT construction is based on the use of land, density and policy on services. The PGT mentions the city as full and empty; full from construction and volumetric point of view and empty from ecological and environmental sustainability. Addition of pure growth of the city has not produced the necessary quality and functionality. Milan should become a multicenter city through new PGT. The transformation of the city must be oriented towards an organizational structure mainly of "mesh networking" which provides new network of mobility and new infrastructural network for environmental system and the system of services. Some of the main goals of the PGT could be summarized here:

-Creation of central services of accessible on foot, in a few minutes from residential houses.

-Public structure of the city: Summation of open spaces plus green areas and infrastructure of network and services cause the structure of the city as a public, while soil consumption should reduce from 73% to 65%.

-New shape of city consisting of public open spaces, such as green areas, parks, avenues, squares, boulevards, gardens, hard paved areas.

-Epicenters

-Raggi Verdi: Green rays are linear paths mostly along radial lines passing Spanish walls to connect the ancient city Milan to the epicenters and the Parks and the Belt around the city. Eight rays with average length of 7 and 12 kilometers connect the center to epicenters and further to Belt.

-Design of a system of connections between the green areas has defined network capillary green corridors that form Rays. 16 million square meter of green space means 12.7 square meters for every citizen. It shows good statistical figure in number while the same perception does not exist among the citizens due to discontinuity and inaccessibility of the green spaces.

Urban Policies introduced in PGT are characterized as follow:

Attractive city: Modernizing the network of public and private mobility, while protecting monuments and scenic areas.

Livable: connect existing agricultural parts to new environmental urban parks accessible. Restore environmental function of waterways and canals redevelopment of contaminated land

Effective: Increasing the system of Green at the local scale and slow mobility base on public spaces and pedestrian and cycle paths, ensure quality and maintenance of public spaces and facilities.

Also there are some complains about the policies of the PGT such as the fact that no care and consideration was taken for children like the consideration of kindergarten and dedicated services or the attempt to dislocate the industry would cause problems for workers who lived like that till at least 15 years.

PGT intention: redefine new vision of city from parks, agricultural areas, streets squares, sidewalks, piazzas, gardens with close relationship with the existing built. Reading of urbanized territory could be done in ways of slow city or quick city. Slow city means quality of housing, services at the local scale, mobility capillaries while Rapid City means whose vocation far more to the dynamics of work, services on a territorial scale, move quickly through the metropolitan area. The future of the Milan could be ideally the coexisting of fast and slow city. The goal is twofold: one is to support livability and quality of housing in some neighborhoods and urban areas and second is concretely promote the development and improve accessibility of the rare areas where growth is expected in the density and services. It is always possible to describe every city and /or urban system through three points of view:

1-Consumption of soil

2-Density

3-Scope of services

Densify action of PGT: It means strengthen and reinforcing of nodes of the network and does not mean the increase is volumetric of the city in any event within limits carefully defined. Equipment services: PGT considers it essential to identify a system of public parks with their equipment on which to find the new social relations of the community engaged that is able to relate all current episodes of green-equipped and not currently existing on the territory municipality.

"*The city is a complex structure, a single organism, a living body subject to continuous developments and transformations that constitute its living, in constant relationship with human actions, individuals and collectivities that take place into it.* " (Giuseppe De Finetti)

The lack of land is a structural condition of the city-region of Milan. The spread of settlements in the territory of the province has over the years gradually consumed the land and the gap between built spaces has always been considered as the result of administrative constraint that has prevented its construction (South Park) but was not able to turn it into a public space of environmental quality. Nowadays, the void between the built environments can be read as a valuable asset from the environment and landscape point of view within the metropolitan area, and as an extraordinary resource to provide new project opportunities in terms of urban quality.

Milan is a city that cannot afford to consume more land, and therefore adopts the principle of zero-footprint, which should start a serious policy of sustainability in a way to shape a more attractive city, with a real environmental strategy on the urban and regional scale, and above all, able to improve significantly the efficiency of its services on the base of a forecast on the likely number of residents that it could accommodate and their real needs from now till the next few years. (Forecast to be checked each 5 years).

Density

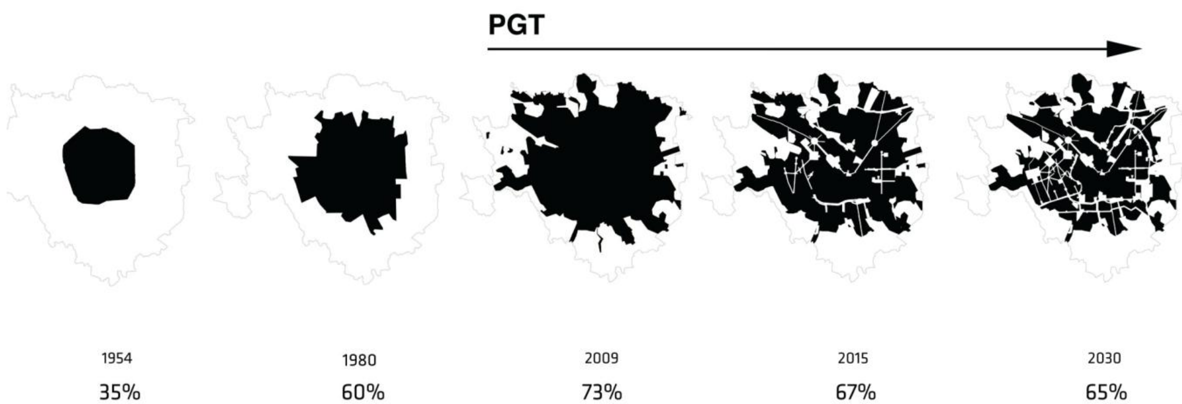

Fig.1.13. Density[32]

A plan that bases its ambitions on sustainability and the quality of "urban voids" as the perspective of future warranty for its citizens, in return, implies a "policy of solid". After all, it is precisely the solid-void relationship that best describes the meaning and the significance of a city.

The PGT takes the strategy of densification precisely to respond to the policy of urban voids and to activate the different pathways of requalification and transformation coordinated on all the parts of the city, from the implementation and redevelopment of pieces of crumbling cities, to the redevelopment of underutilized areas (railway areas, military zones, industrial areas, etc.),

[32] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

with incremental transformations connected to construction substitution processes , and small expansions linked to objects of reorganization (edge of town).

To densify doesn't mean to generically increase and without distinction, the volumetric over the city, within carefully defined limits, but to consolidate and strengthen the "nodes" of the city network or, more generally, some "solid islands" on the basis of a conscious planning that doesn't ignore the real settlement capacity of the city and its metropolitan area.

Pieces of crumbling cities, to the redevelopment of underutilized areas (railway areas, military zones, industrial areas, etc.), with incremental transformations connected to construction substitution processes, and small expansions linked to objects of reorganization (edge of town).

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Cores of ancient formation

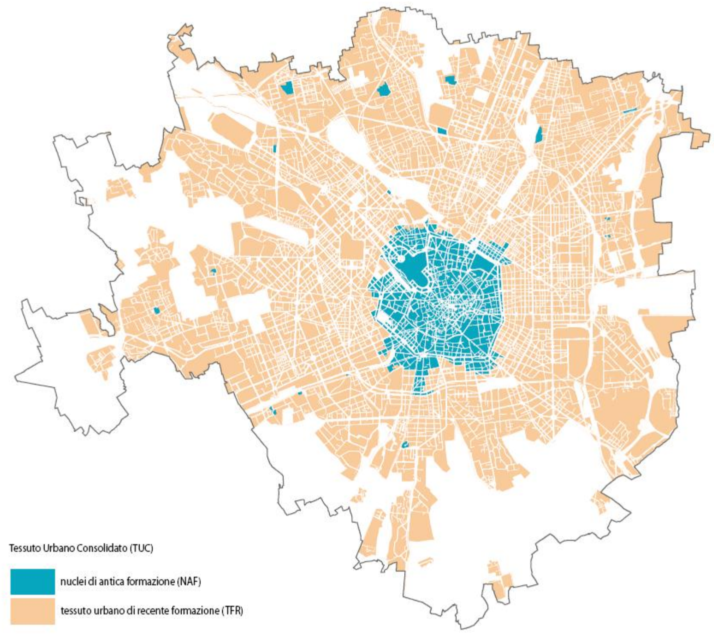


Fig.1.14. Cores of ancient formation[33]

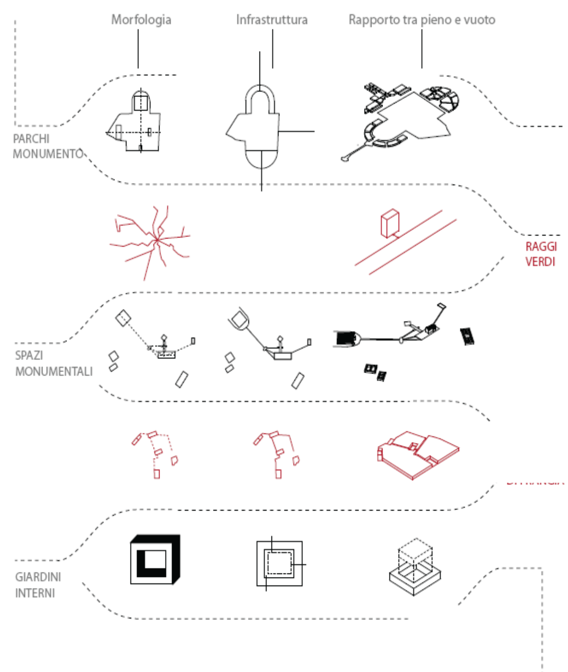


Fig.1.15. Analysis of the central core organism[34]

[33] PGT, Piano di Governo del Territorio, Commune di Milano 2009.
[34] *Ibid*

The work on the cores of ancient formation requires an adaptation of knowledge about the historical, architectural and environmental heritage of the city and is done to identify buildings worthy of preservation, in accordance with the current normative. The goal is to simplify the procedures for implementing the PGT, or to allow more freedom in urban and construction interventions in these areas without sacrificing the necessary protection of the historical and environmental heritage. The new regulatory framework dictates that every building, yard, patio, etc.. is given a historical, artistic, documentation value and therefore is assigned a typology of maximum intervention. It should be noted that the classification of properties is based on information received from the competent administrations responsible about the management of the cultural constraints. This work has concerned the historical center corresponding to the Roman-medieval core inside the ring of canals, the band immediately outside it corresponding to the urban expansion up to the 800, identifiable till the Spanish Bastions and the extra-walls villages. To these areas were integrated parts of the city, also of historical formation, forming the outer suburbs and out-of-town villas.

Raggi Verdi

Unlike the epicenters, Raggi Verdi is a unique redevelopment project of existing public spaces. Raggi Verdi is linear paths, mostly planted with trees. Radial paths going from the "Spanish walls" along radial lines bring into connection the ancient core of Milan with the network structure of the epicenter and with the Belt Parks around the city. Within these tracks characterized by a slow or local mobility, you can walk, laze around, run, cycle… Those are the precondition for the construction, inside the urban fabric, of a protected continuous cycling network. Along the Rays, it will be possible to design new greeneries throughout the neighborhoods and increase the accessibility of the existing ones. Raggi Verdi redefine a permeable structure able to connect the existing urban materials in all the city branches, like a garden, a neighborhood park, a large urban park, with the new central neighborhoods and the old city center. If Milan is not a green city in the collective imagination, the new project of Raggi Verdi becomes a crucial opportunity for the construction of a new image of the city, reconsidered in the physical dimension of public space[35].

[35] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

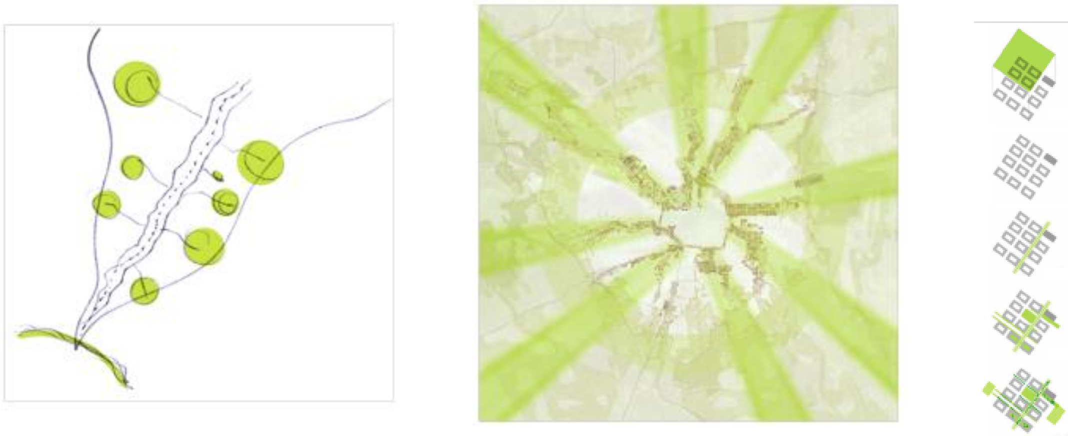


Fig.1.16. Raggi Verdi[36]

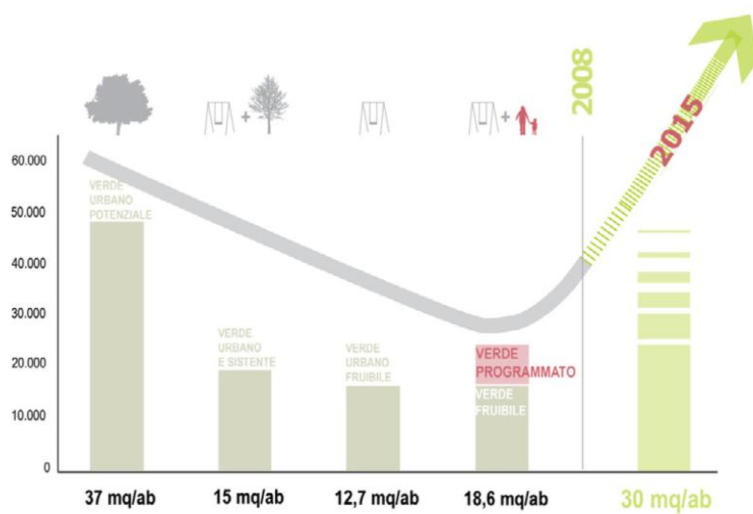


Fig.1.17. Construction of a green ray: the backbone, the radius of action, the interception of existing excellence Greeneries ratio over time[37]

[36] PGT, Piano di Governo del Territorio, Commune di Milano 2009.
[37] *Ibid*

La Passeggiata Urbana dei Bastioni

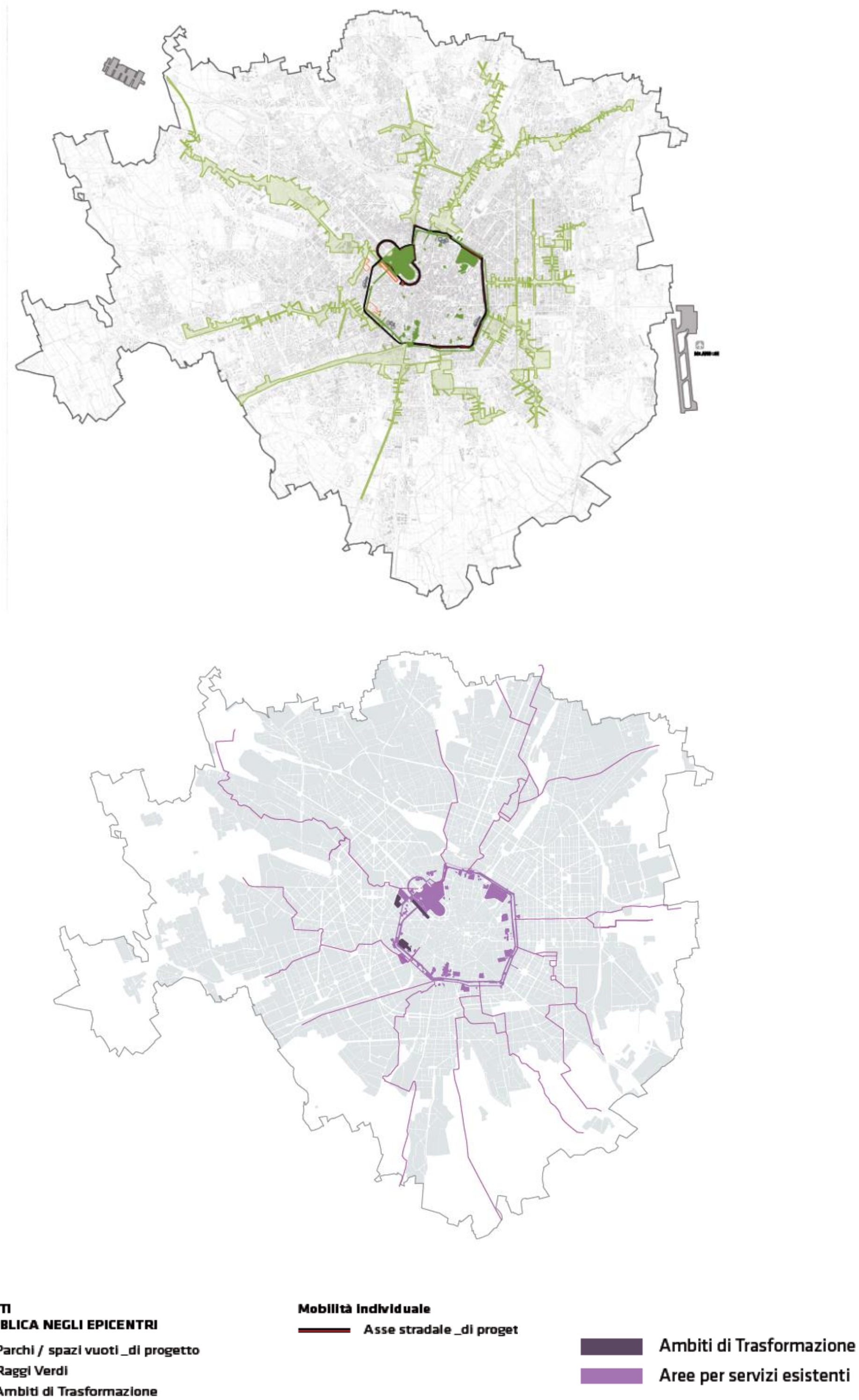


Fig.1.18. La Passegiata Urbana[38]

[38] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Fig.1.19. A view showing the relation between passegiata Urbana and Porta Ticinese[39]

[39] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

The dual system of Cerchia dei Bastioni (Viale Majno, Caldara, Beatrice d'Este, Papiniano, etc..) and the ring of the Viali just outside it (Viale Monte Nero, Bligny, Zugna cones, etc..), in addition to being the mostly invisible perimeter of the ancient Spanish walls, is today a single urban area characterized by an extraordinary potential for transformation. The Plan suggests, in fact, a redevelopment project of a "Passeggiata Urbana" with about 12km of length. The goal is to give the city a high quality efficient cyclo-pedestrian system.

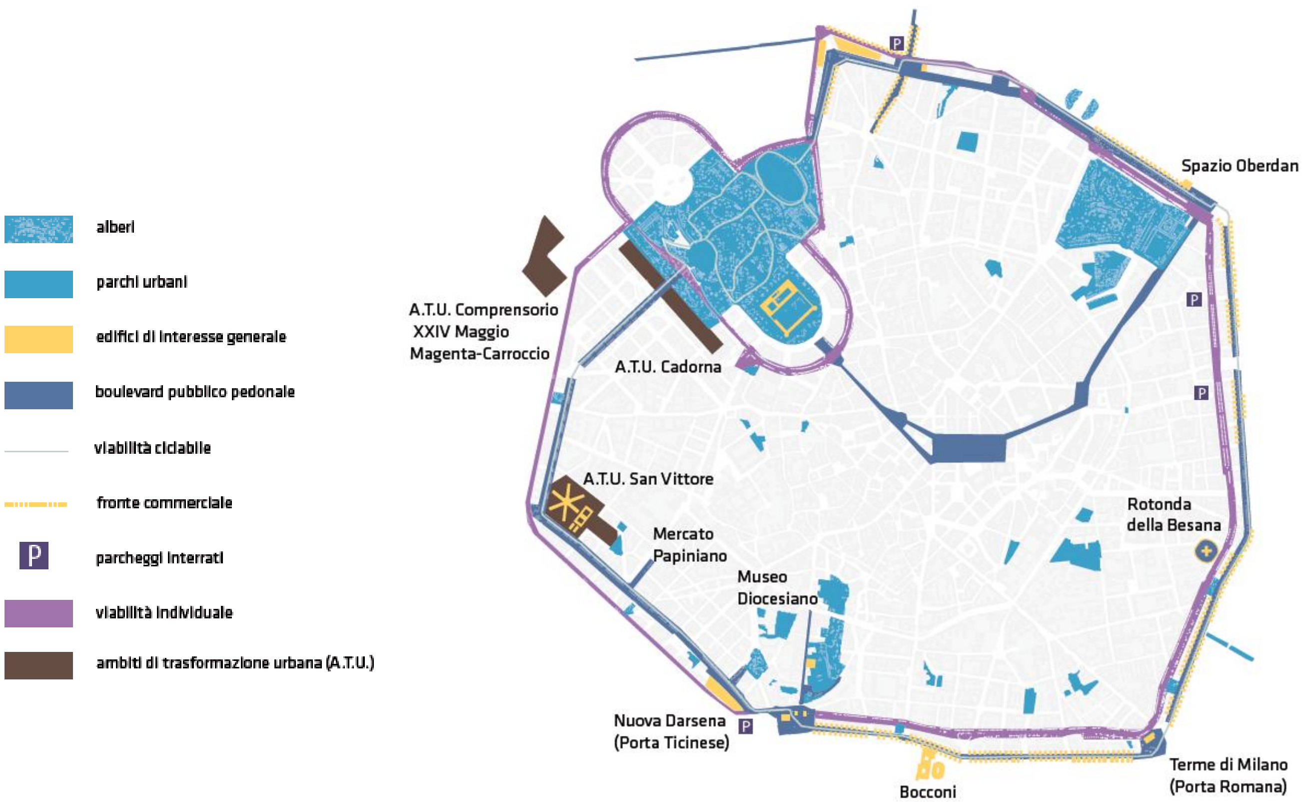


Fig.1.20. La Passeggiata Urbana[40]

On this project, are based elements of new development and centrality, which should help in terms of resources to this transformation; in particular, the Fields of Transformation of San Vittore, Cadorna, Comprensorio XXIV Maggio-Magenta-Carroccio. The realization of this project involves the introduction of new solutions for mobility and for parking (alternatives to surface parking). The bastions took shape in the Spanish Milan, forming a large ring outside of the canals circle and converging on the Sforzesco Castle, moving to the outside the control points, incorporating permanently in the urban core, what used to be the citadel and other villages. This laid the base of what would be the future opportunities of development of the city. At the end of the '700, the transformation of the bastions into large tree-lined streets, together with the formation of Public Gardens, introduced in the and relatively low and flat city of Milan, the

[40] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

ability to walk at a higher altitude with striking views of the countryside and the major monuments. Today, from this remains only a small episode, the bastions of Porta Venezia. For tourists and the citizens of Milan, it is an invisible system, nowadays occupied mostly by traffic and car parks. The double track which is referred to, represents a valuable opportunity for the city to qualify an important branch of the public city, also because it is not, in spite of appearances, a linear system; it actually reacts with some of the emergencies in the city, linking between narrow and wider areas, symbolic places such as Parco Sempione, the public gardens of Porta Venezia, Parco delle Basiliche and Parco Solari.

The Cerchia dei Bastioni is nowadays being a "hinge point" between the historical center of the ecopass area and the free individual traffic city. It is, therefore, certainly interesting to address the issue, not only in relation to open public spaces, but also from the point of view of mobility, parking and the public transportation network. The project will transform the Cerchia dei Bastioni in a real green ring, where the traffic flows next to the genuine area dedicated for the promenade (passeggiata). The Circle becomes the structure from which radiate the Green Rays, to underline how the historical gates of the city are still significant for its future. Depending on the context and the type of functions that open directly on the street, it is proposed to transform to a limited traffic zone, or even just pedestrian, sometimes the outer boulevard, sometimes the inner one, while maintaining a “controviale” for residents and scheduled passages for the cars.

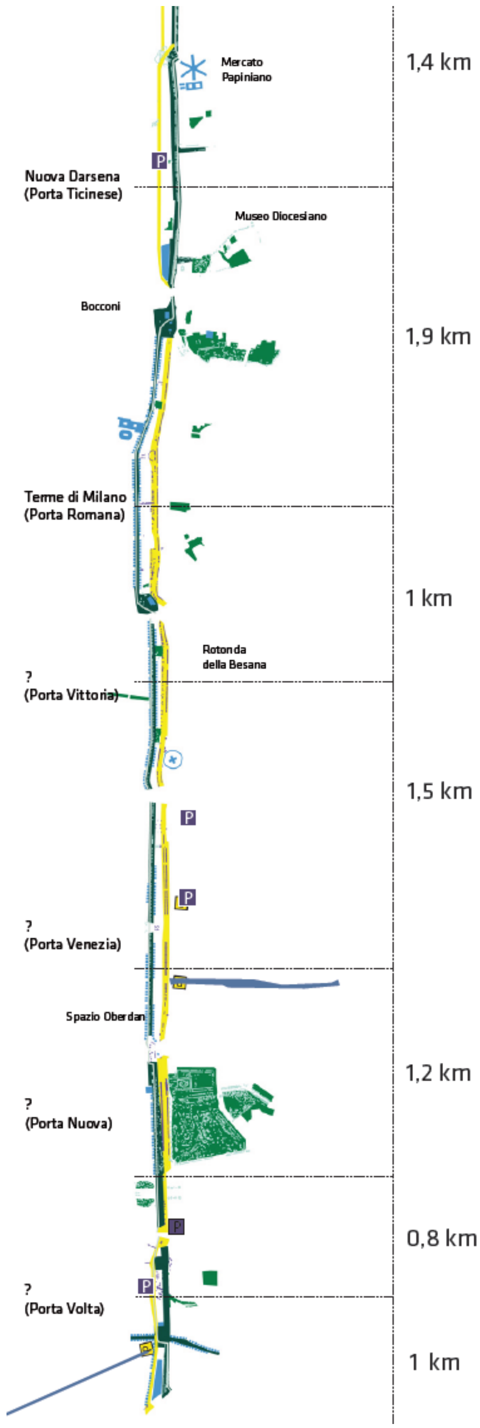


Fig.1.21. Linearization of the Passeggiata Urbana around Porta Ticinese[41]

[41] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

A path will host a wide paved sidewalk, where the passage of public transport and cycling path will be provided. It is envisaged, moreover, to redevelop the rows system enhancing the monumentality of the Circle; the other track will remain a city street that will allow a faster flow to a direction of travel. The project must include a system of underground parking lots (ie Darsena Project) and parking buildings; only in this way, we can free and return the land to the city as an urban promenade.

Fig.1.22. Darsena Project[42]

Neighborhood Centrality

The design of the PGT on the Local Scale of Milan is based on the historical memory and the contemporary identity of the places. The Plan will not be limited to the redevelopment of the traditional characters of the neighborhoods, but also rethinking the identity by the mean of design, increasing the spatial qualities. Strengthening the centrality of existing neighborhoods, introduce new ones, develop connections, are the primary goals in designing on the local scale. In addition to the existing more traditional centralities (squares, shopping streets, churches, common services, etc..), other elements provide the comfort of the neighborhood: local and metropolitan public transportation systems and urban green spaces, like parks and gardens, which are connected to each other and to major regional environmental networks. The design of the system of open spaces in the city overlaps, therefore, with a work of programming and promotion of services, functions and different cultural systems, trying to avoid the possible phenomena of spatial segregation and enclaves. The projects, neighborhood by neighborhood,

[42] http://ordinearchitetti.mi.it/index.php/page,Notizie.Dettaglio/id,1389/type,oa

however, should not be confused neither with an "ordinary maintenance" of the minute portions of the city, nor with a simple reduction of scale of the general project. In particular, the attention must be given to today's most degraded neighborhoods, which are, unfortunately, more often, the popular buildings neighborhoods. The districts are designed as a different city within a city, which are valued in their identity and are connected to each other, so as to overcome phenomena of isolation and ghettoization, aiming to give a voice and equal quality to the different ways of living and promoting every single specificity, connecting it to the largest subway system.

Fig.1.23. Neighborhood Centrality: concentrations of local commercial activities, gardens and social aggregation places.[43]

Nuclei of Local Identity: Porta Ticinese in the NIL concept

The identification and design of the so-called "services of large land consumption", i.e. parks, infrastructure and in general all those categories of outdoor public spaces is faced from all the scales without giving priority to any of these, but trying to maintain a constant and fruitful balance between the general size and particular one. The goal of the project is therefore to ensure an increased distribution of services, both qualitative and quantitative, in every area of the city by promoting and planning an isotropic and reticular system of the public spaces in contrast with the traditional centripetal and radial arrangement of the city.

This new planning horizon is not intended as a will to waiver the identifying characteristics of a city that is historically radio centric, but as the attempt to exploit the cultural history of the rays as a starting condition to design a new city that builds its wealth and its development on the creation of transversal relations and the promotion and design of its internal differences.

[43] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

The basis of this project is, in fact, the idea of identity as a synthesis of different and numerous specific capacities, ie as an expression of a society of relations, able to accept and work out the differences that compose it. In the city of Milan, different districts can be recognized, and they define a unitary and internally complex when read in continuity with the different urban centers of the metropolitan area. From the attention to individual districts and the attempt for their contemporary reinterpretation, especially in terms of their identity's development, the idea of the Nuclei of Local Identity was born. NIL corresponds to a vision of "slow city", based on proximity relations, on livability of residential and daily living places. The "fast city" of epicenters is related to design reflection on districts aimed to ensure greater quality and quantity of spaces and local services and to connect these easily with the great infrastructure system and the environmental metropolitan systems. The design of the city neighborhoods does not only allow a balance between the urban dimension of Milan and its territory, but corresponds to a project reflection within the city willing to build a system of public spaces in balanced among them and widely scattered throughout the urban area. These areas were identified from the centrality of the public space and for that the design of the configuration is not defined clearly. The space design and services programming represent on a scale lower than that of the epicenters, the same design response to the asphyxia structure of the city. As in the large scale, even in the local one, the project focuses on the definition and the requalification of the system of urban voids that become the support of a requalification strategy of a diffused system of centrality on the city.

Porta Ticinese area in the NIL

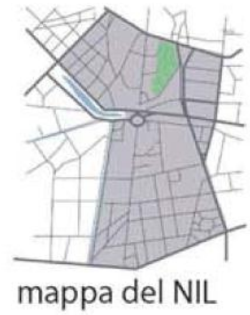


Fig.1.24. Porta Ticinese area in the NIL

Numerical and Statistical Data[44].

Analisi della struttura della popolazione

Residenti
20.394 ab
Stranieri: 11,1 % pari a 2.272 unità
Nazionalità prevalente: filippina
Bambini da 0 a 5 anni
5,4 % / 1.099 unità
Anziani oltre 75 anni
9,7 % / 1.971 unità

Densità abitativa
16.249 ab/km²

Città diurna
23.404 ab
Città notturna
21.183 ab

Popolazione che si sposta giornalmente
Popolazione in entrata
12.075 ab
Popolazione in uscita
9.065 ab

Proiezioni demografiche (2027)
19.973 ab
Bambini da 0 a 5 anni
4,4 % / 882 unità
Anziani oltre 75 anni
11,4 % / 2.271 unità

Analisi mobilità

Mezzi pubblici
Numero fermate metro (FNM, Passante)
0
Numero fermate mezzi di superficie
37 pari a 0,29 unità/ha

Mobilità Ambiente
Piste ciclabili
m/ab
Superficie sosta veicoli

Destinazione d'uso prevalente degli edifici

categoria
NIL / media milano

abitazione
90 % / 83,1%
ufficio
1,9% / 3,7 %
commercio industria
2,5 % / 6,9 %
servizi pubblici
4,1 % / 3,4 %
altro
1,5 % / 2,9 %
abitazioni in affitto
36,9 % / 35,6 %

Attività produttive
4.058 unità locali

Servizi NIL

totale abitanti
20.394 ab

dotazione servizi
totale - per abitante
280.823 mq - 14 mq/ab

dotazione minima servizi
totale - per abitante
192.770 mq - 9 mq/ab

Analisi esercizi di vicinato

Numero di esercizi di vicinato
701 pari a 5,59 unità/ha

Numero di esercizi commerciali media struttura di vendita
16 pari a 0,13 unità/ha

Numero di esercizi commerciali grande struttura di vendita
1 unità

Numero di pubblici esercizi
219 pari a 1,74 unità/ha

Superficie di vendita di esercizi di vicinato per unità di superficie territoriale
314 mq/ha pari a 1,93 mq/ab

Superficie di vendita per esercizi di media distribuzione per unità di superficie
55 mq/ha pari a 0,34 mq/ab

Numero imprese (2007)
253 unità

Analisi delle superfici

Superficie Totale
(estensione areale totale, al lordo delle strade)
125,51 ha

Aree in trasformazione da PGT
% / ha

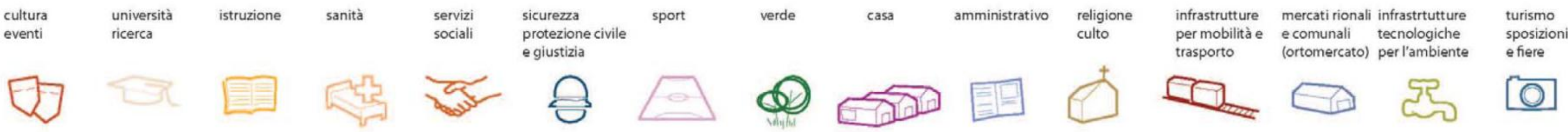
Superficie coperta / ha
37,31% / 46,8 ha

Superficie coperta ERP/ ha
% / ha

Aree a verde / ha
% / ha

[44] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Opportunities



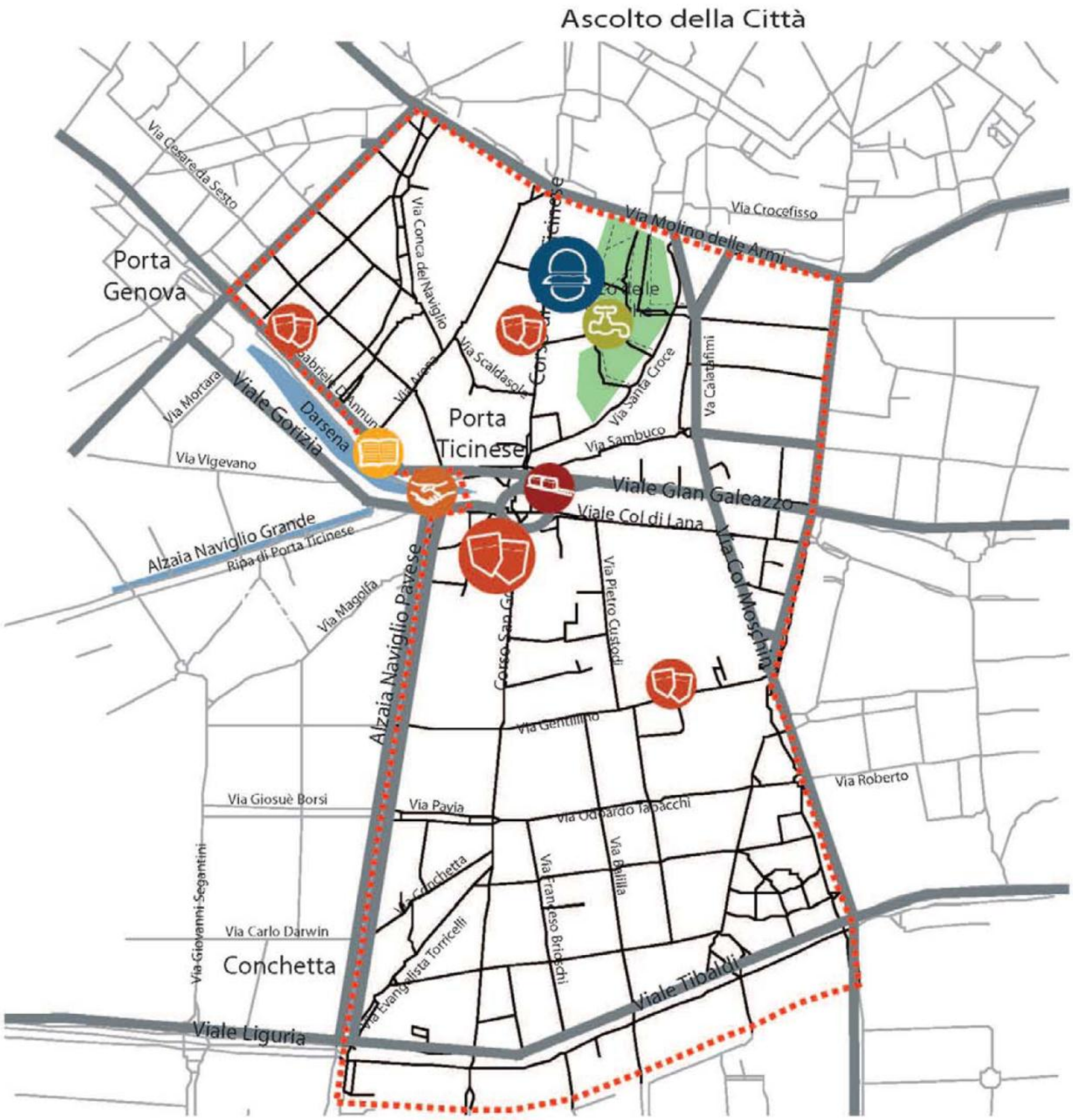


Fig.1.25. Porta Ticinese area in the NIL[45]

[45] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Threats

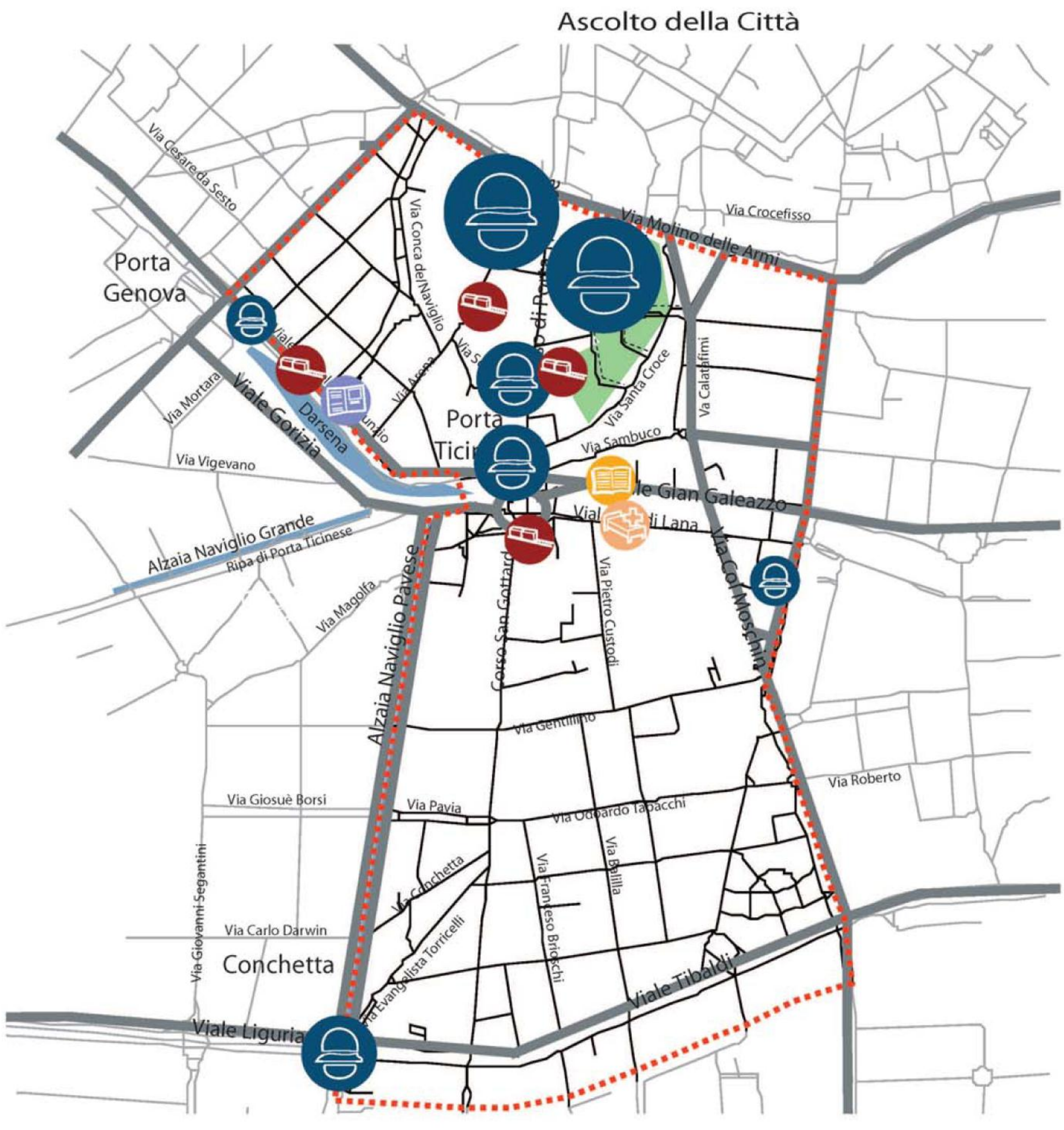
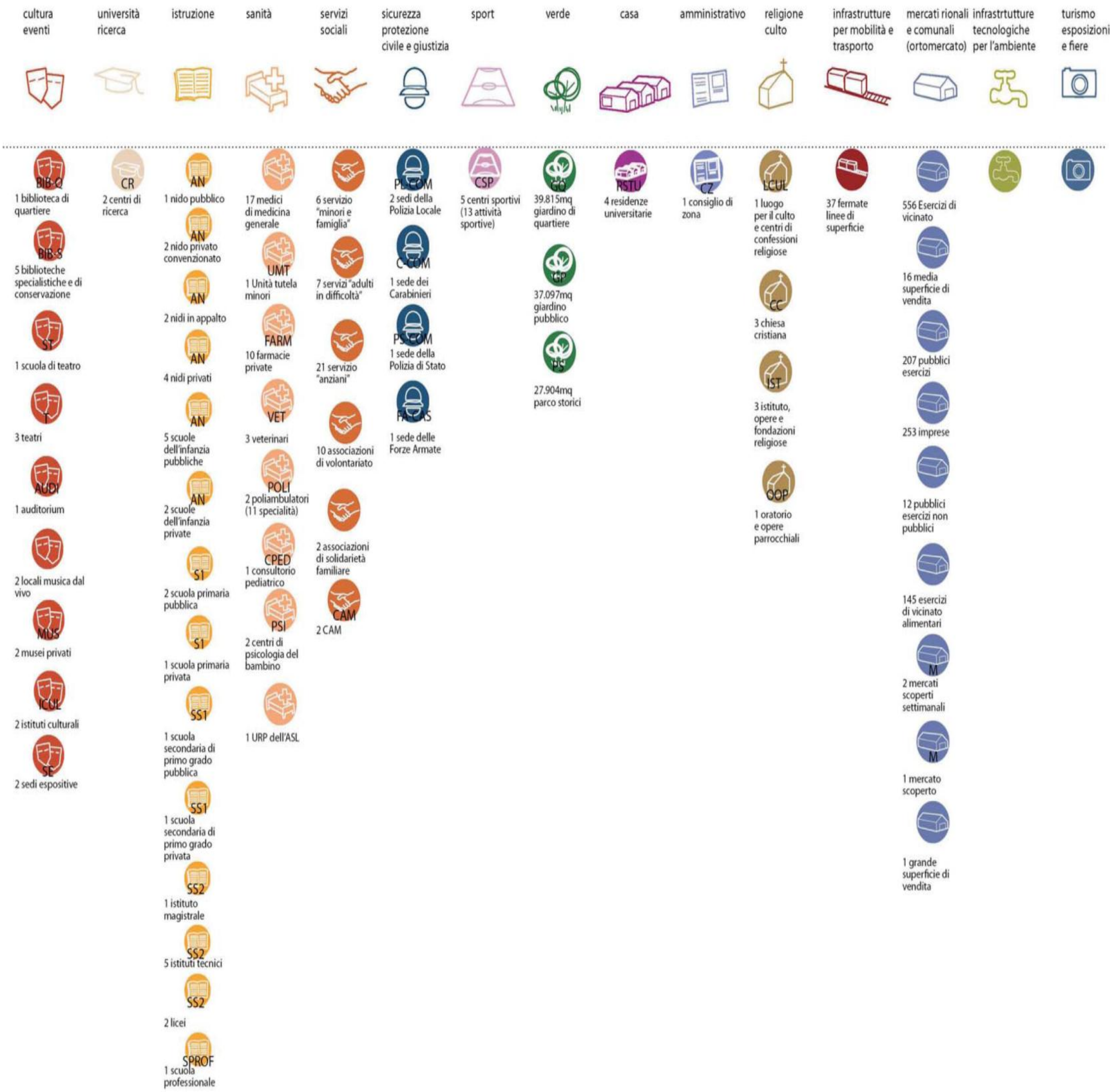


Fig.1.26. Threats[46]

[46] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

List of Services[47]



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[47] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Planned Interventions[48]

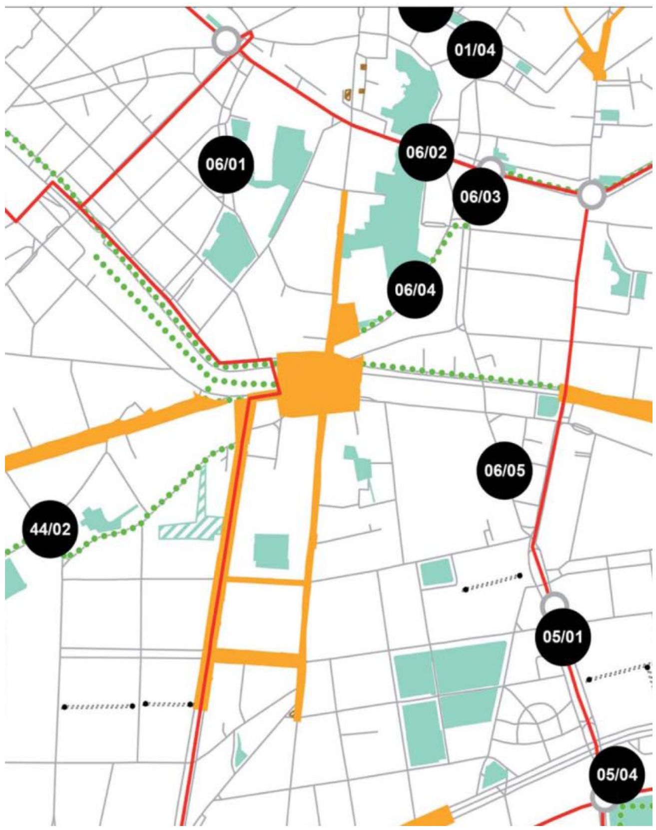
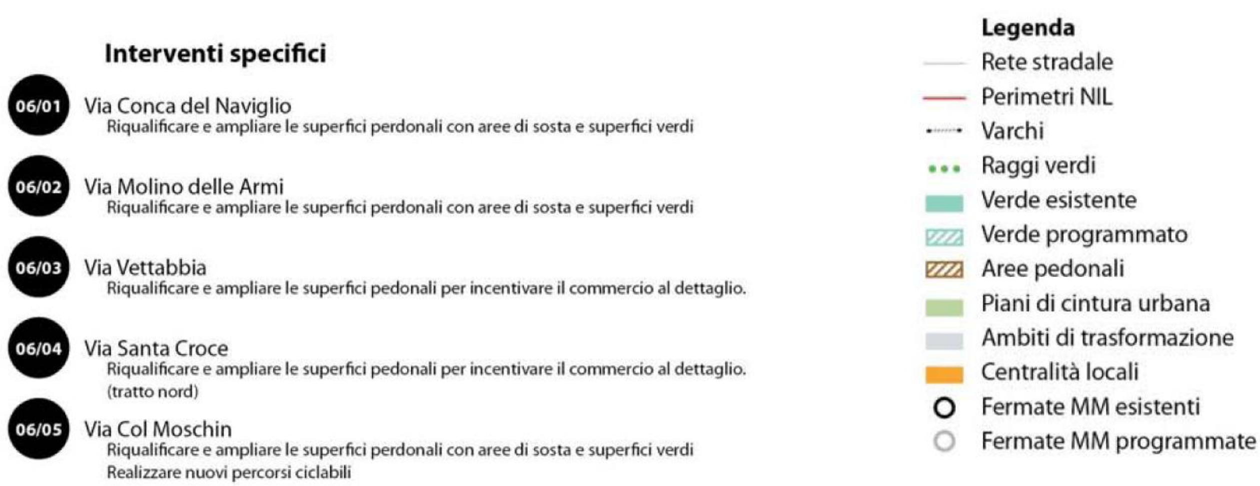


Fig.1.27. Planned Intervention[49]



General development and increasing of saturated spaces of aggregation in the district: redevelopment of Via Conca del Naviglio, with a green path between the Darsena and Via

[48] PGT, Piano di Governo del Territorio, Commune di Milano 2009.
[49] *Ibid*

Cesare Correnti and widening of sidewalks on open spaces to encourage the development of commercial activities. Redevelopment of Via Santa Croce, Via Vettabbia and the widening of Via Molino delle Armi.

Ranking in the NIL[50]

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[50] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Porta Ticinese area in the NIL[51]

Zona Porta Ticinese-Sant'Eustorgio

Descriptive indicators of the ranking among the NIL
The best situation is represented where the indicator is on the top positions (green).

Historical Overview

1603

Francesco Maria Richini, Pianta della città di Milano ("Plan of the City of Milan"), 1603. Civica Raccolta Bertarelli, Milan.
Richini's map shows the oblong form of the "borgo di Cittadella", bounded to the north by the circle of canals called the Navigli, to the east by the channel of the Vettabia, to the south by the Bastions and to the west by the branch of the canal – the Conca – that connected the circle with the basin known as the Darsena. A built-up area represented without subdivisions is traversed by what is now Via Arena an by the bisecting line of what is now Corso di Porta Ticinese, a strategic axis that links the central part of Milan with the area of infrastructure to the south. The complex of Sant'Eustorgio with the basilica and its two cloisters is clearly identified and seems to costituite the main nucleus of a dense system of buildings of a religious character.

1699

Giovanni Battista Bonacina, La Gran città di Milano ("The Great City of Milan"), 1699. Civica Raccolta Bertarelli, Milan.
In this map the isometric view underlines the pre-eminence of the complex of the Dominican monastery with respect to the existing fabric and the other religious buildings. Also evident is the strategic location of the Piazza di Sant'Eustorgio as a widening of Borgo di Porta Ticinese.
The column with a cross was erected at the behest of Carlo Borromeo and was one of many located at various points of the city to mark the route of a procession.

1734

Marc'Antonio dal Re, Città di Milano ("City of Milan"), 1734. Civica Raccolta Bertarelli, Milan.
Marc'Antonio dal Re introduces a greater differentiation in the representation of urban fabric, monuments, gardens, infrastructure and watercourses into his map.
The two cloisters of the complex of Sant'Eustorgio mark the transition between the spaces of the city and the great open area of the cultivated gardens, hemmed in between the buildings constructed along the axis of Porta Ticinese and
the previous walled boundary of the "citadel".

[51] Competition brief

1801

Giacomo Pinchetti, Città di Milano ("City of Milan"), 1801. Civica Raccolta Bertarelli, Milan.
From this map the differentiation of the constructions in Borgo di Porta Ticinese emerges clearly, with the west side beginning to be characterized by buildings set on deep lots for mixed residential, commercial and craft use. The nucleus of infrastructure providing access to the city at the mouth of Borgo di Porta Ticinese, close to the Bastions, also appears to have been consolidated, with the Marketplace around the Darsena and the ends of the towpaths along the Naviglio Pavese and the postal roads from Vigevano and Pavia.

1807

Corps of Astronomers of Brera, Milano Capitale del Regno of Italia ("Milan Capital of the Kingdom of Italy"), 1807-10. Civica Raccolta Bertarelli, Milan.
This map represents the city's "empty spaces" in detail: the gardens set between the constructions and the large spaces of the religious buildings. The basilica of Sant'Eustorgio is represented in detail, with the side chapels to the south and the Portinari Chapel; the central space of San Lorenzo Maggiore with its four exedras and cluster of chapels is also shown in detail. Towards the Darsena it is apparent that a section of the Bastions has been demolished to reorganize the entrance to the city functionally and symbolically with the erection of the neoclassical Porta Marengo, now Porta Ticinese, by Cagnola in 1801.

1855

Mappa del Comune Censuario della città di Milano, Distretto I di Milano, 1855 ("Map of the Taxable Borough of the City of Milan, District I of Milan, 1855"). Archivio di Stato, Milan.
This first cadastral map shows the increase in building density that has occurred principally in the garden areas facing onto the watercourses. But the biggest changes concern the uses to which buildings are put, with many more of them serving craft and commercial purposes, in both the Borgo di Porta Ticinese and the Borgo di Santa Croce. The function of the complex of Sant'Eustorgio has also changed: with the establishment of the Cisalpine Republic in 1796, the Dominican monastery was turned into a military barracks.

1881

Mappa del Comune Censuario della città di Milano che comprende i Mandamenti dal I al VI, 1881 ("Map of the Taxable Borough of the City of Milan Comprising Districts I to VI, 1881"). Archivio di Stato, Milan.
A significant change in the urban structure of this part of the city is evident: Via Vetere, a street of open apportionment for the construction of rented buildings, splits the large internal space of the gardens into two parts.

1906

Pianta di Milano coll'indicazione dei piani di ampliamento e regolatori esecutivi compilata dall'Ufficio Tecnico municipale ("Plan of Milan Indicating the Working Schemes of Expansion and Development Compiled by the Municipal Technical Office"), 1906. Civica Raccolta Bertarelli, Milan.
The covering of the channel of the Vettabia, the extension of Via Vetere and the configuration of Via Calatafimi, inexplicably wide in comparison with the existing streets, are what stand out most clearly in this map.

1910

Pianta di Milano coll'indicazione del Piano Generale Regolatore ("Plan of Milan Showing the General Town-Planning Scheme"), 1910. Civica Raccolta Bertarelli, Milan.
The plan of development represented here, demolishing a cloister of the Sant'Eustorgio complex to open up a new street with building lots parallel to Via Vetere, would fortunately never be implemented.

1942

Giuseppe de Finetti, Mappa delle demolizioni belliche tra il '42 e il '45 ("Map of the Wartime Demolitions between 1942 and 1945"). 1969. (Gambi)
The destruction of buildings in the Second World War is well documented by this map drawn up by de Finetti on the basis of a survey carried out by the municipal offices. Destroyed buildings are marked in black and seriously damaged buildings are indicated by hatching. In the zone of the Ticinese "citadel" note the total demolition of the buildings on the east side of Corso di Porta Ticinese, along Via Santa Croce and Via Vetere; the complex of Sant'Eustorgio is indicated as heavily damaged.

1972

Photogrammetric Map Updated to July 1972, Municipality of Milan 1972
The photogrammetric map of 1972 shows the interventions made since the war.
The covering of the Conca del Naviglio with the construction of the street on top that has kept its name; the reorganization of the area of Porta Ticinese with Piazzale XXIV Maggio; the demolition, following the damage inflicted in the war, of one side of the cloister of Sant'Eustorgio and the adjoining buildings on Corso di Porta Ticinese; the building along Via Calatafimi, Via Santa Croce and Via della Chiusa that took place in the fifties and sixties; the configuration of the Parco delle Basiliche, preserved, after the wartime demolitions, by the building ban imposed by the Town-Planning Scheme of 1953.

2000

Photoplan of 2000
The Parco delle Basiliche, although overlooked by two of the most prestigious and celebrated monuments in the history of Western architecture – the complexes of San Lorenzo Maggiore and Sant'Eustorgio – has never succeeded in developing into a park with a significant landscape and freeing itself from the limitations of a mere zoning decision. The weak formal definition, the not very well-thought-out disposition of the plants and trees, the short-sighted layout of the paths and the makeshift enclosures conceived solely in terms of security and public order prevent this 'interspace', among the largest and most important in the heart of Milan, from rising to the level of an urban garden of significance, comparable to other famous examples in Italy and Europe.

Morphology and Classification of the Surrounding Context

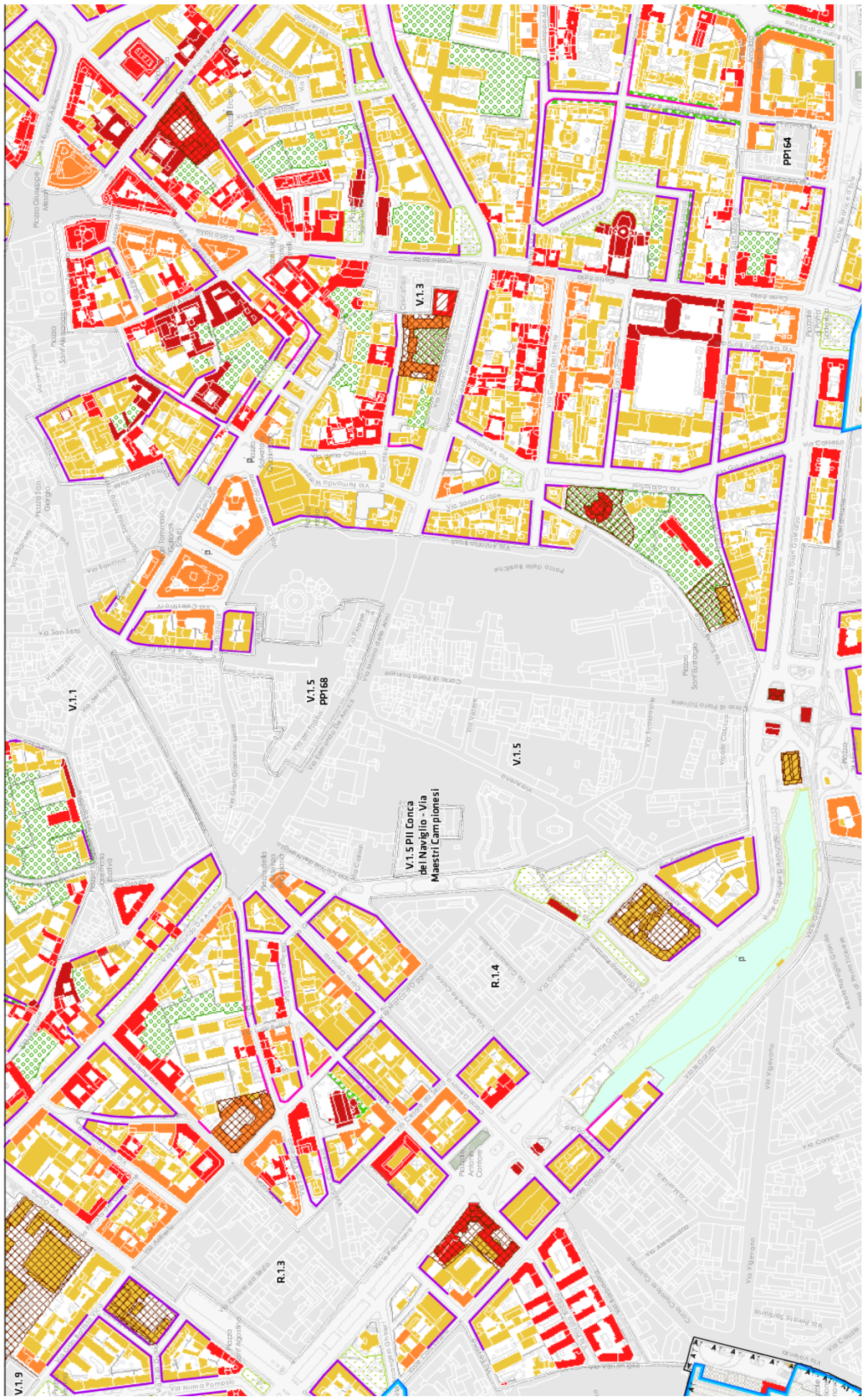

Fig.1.28. Morphology[52]

[52] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

TUC - Tessuto urbano consolidato (Art. 2.1.a)

TUC - Tessuto urbano consolidato (Art. 2.1.a)

NAF - Nuclei di antica formazione (Art. 2.1.a.i)

TRF - Tessuto urbano di recente formazione (Art. 2.1.a.ii)

NAF - Nuclei di antica formazione: Tipologie di intervento (Titolo II - Capo I)

Interventi di manutenzione ordinaria, straordinaria e restauro (Art. 13.2.a)

Interventi di manutenzione ordinaria, straordinaria e restauro (Art. 13.2.a)

Interventi di manutenzione ordinaria, straordinaria, restauro e risanamento conservativo (Art. 13.2.b)

Interventi di manutenzione ordinaria, straordinaria, restauro, risanamento conservativo e ristruttura-zione edilizia con mantenimento della sagoma e del sedime (Art. 13.2.c)

Interventi di manutenzione ordinaria, straordinaria, restauro, risanamento conservativo e ristruttura-zione edilizia anche con demolizione e ricostru-zione, completamento e nuova costruzione (Art. 13.2.d)

Mantenimento o ripristino delle cortine edilizie (Art. 13.3.a)

Completamento del fronte continuo (Art. 13.3.a)

Recupero e realizzazione di corti, cortili e giardini (Art. 13.3.b)

ADR - Ambiti contraddistinti da un disegno urbanistico riconoscibile (Titolo II - Capo II)

Tessuti urbani compatti a cortina (Art. 15.2)

Tessuti urbani a impianto aperto (Art. 15.3)

Tessuti urbani della città giardino (Art. 15.4)

Tipologia rurale (Art. 15.5)

Insiemi urbani unitari (Art. 15.6)

ARU - Ambiti di rinnovamento urbano (Titolo II - Capo III)

Ambiti di rinnovamento urbano (Art. 17)

Orientamento da privilegiare nella realizzazione di passaggi privati aperti all'uso pubblico (Art. 17.2.c)

Allineamento di almeno il 50% della linea di altezza dell'edificio sul confine di proprietà verso lo spazio pubblico (Art. 17.2.a)

Arretramento di almeno 3 m. della linea di altezza dell'edificio dal confine di proprietà verso lo spazio pubblico (Art. 17.2.b)

Aree sottoposte alla normativa dei Parchi Regionali (Titolo III - Capo II)

Perimetro del Parco Nord Milano (Art. 19)

Aree sottoposte alla disciplina del Parco Nord Milano

Perimetro del Parco Agricolo Sud Milano (Art. 19)

Aree sottoposte alla disciplina del Parco Agricolo Sud Milano

Piani di Cintura Urbana

Norme transitorie e finali (Titolo V)

Ambiti interessati da provvedimenti in itinere approvati e adottati (Art. 31)

Aree soggette a trasformazione urbanistica dal Documento di Piano (Art. 33)

"Zone A di Recupero" e "Zone B di Recupero" (cd. "B2") (Art. 34)

Piani attuativi obbligatori (PA) (Art. 35)

Ambiti disciplinati dal Piano dei Servizi

Verde urbano e mobilità stradale di nuova previsione (pertinenze indirette)

Aree per il verde urbano di nuova previsione su proprietà privata (pertinenza indiretta)

Aree per la mobilità stradale di nuova previsione su proprietà privata (pertinenza indiretta)

Aree per i nuovi depositi dei trasporti metropolitani (pertinenze indirette)

Verde urbano esistente

Zona di recupero V 1.5 ex A/B2 1.7 (variante 4 gruppo III)

The recovery (recupero) zone V 1.5 A/B2 ex zone 1.7 "San Lorenzo-S.Eustorgio", affects the portion of the historic city, growing along the historic corso Porta Ticinese, extending from Carrobbio to Cerchia dei Navigli and from there up to the cerchio dei Bastioni. In particular, the variant affects the urban fabric between Via Cesare Correnti, Piazza Resistenza Partigiana, Via Conca del Naviglio, Via Arena, Via Panzeri, Piazza XXIV Maggio, Via Sambuco, Via Santa Croce, Parco delle Basiliche, Via Pio IV and Corso di Porta Ticinese[53].

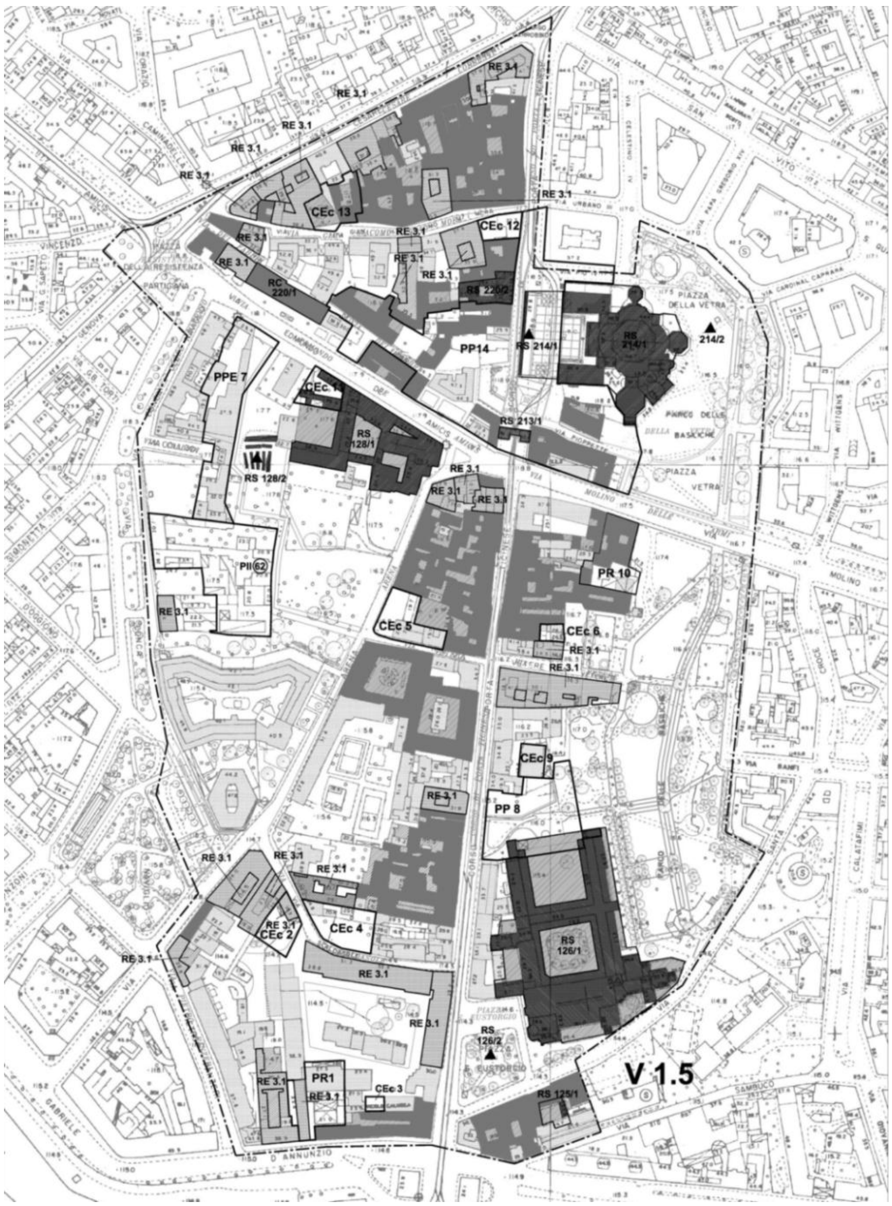

Fig.1.29. Zona di recupero[54]

[53] PRG of Milan
[54] *Ibid*

LEGENDA MODALITA' D'INTERVENTO

V 1.5 — Perimetro zona A di recupero - V 1.5
art.18-bis N.T.A.

PP — Ambiti a pianificazione esecutiva / Program
Integrati d' Intervento: perimetro e tipo di st
Indici e prescrizioni: allegato E delle N.T.A.

⑤ ⑥ — Unità di intervento degli ambiti a pianificazione esecutiva: perimetro e relativa numerazione

CEc — Ambiti a concessione edilizia convenzionata. ●
Indicazione perimetro.
Indici e prescrizioni: allegato E delle N.T.A.

CE — Ambiti a concessione edilizia con prescrizioni specifiche.Indicazione perimetro. ●
Indici e prescrizioni: allegato E delle N.T.A.

1 — Numerazione ambiti con prescrizioni specifiche.
Prescrizioni: allegato E delle N.T.A.

RS — Complessi edilizi con valore storico-architettonico intrinseco.
Interventi ammessi: fino al restauro
art.18-bis 5.2, lett. a) N.T.A.

RS — Giardini storici.
Interventi ammessi: fino al restauro
art.18-bis 5.2, lett. b) N.T.A.

RC — Complessi edilizi con valore architettonico intrinseco.Interventi ammessi:
fino al risanamento conservativo.
art.18-bis 5.2, lett. c) N.T.A.

344/3 — Riferimento elenco beni di interesse storico-architettonico ai sensi dell'art. 17 Legge Regionale 51/75

Complessi edilizi con valore storico-testimo
Interventi ammessi: fino al risanamento conservativo.
art.18-bis 5.2, lett. c) N.T.A.

RE 3.1 — Immobili con elementi di valore ambientale.
Interventi ammessi:fino alla ristrutturazione comma 3.1 art.66 Regolamento edilizio
art.18-bis 5.2, lett. d) N.T.A.

Altri immobili.
Interventi ammessi:tutti
art.18-bis 5.2, lett. e) N.T.A.

29 29 — Aree a verde privato:
perimetro e relativa numerazione.
Interventi ammessi:
art.18-bis 5.3 e art 29 N.T.A.

▲ — Manufatti / monumenti.
Interventi ammmessi:
restauro del manufatto / monumento

● — CE e CEc ora Permesso di Costruire e Permesso di Costruire convenzionato, ai sensi della 12/2005
(anche in Allegato E alle NTA)

Nota: Nelle zone omogenee di cui alla presente tavola, non sono ammessi interventi di ristrutturazione urbanistica ai sensi dell'art. 27 comma 1, lettera F) della L.R. 12/2005

Cultural and Landscape Heritage (Beni Culturali e Paesaggistici)

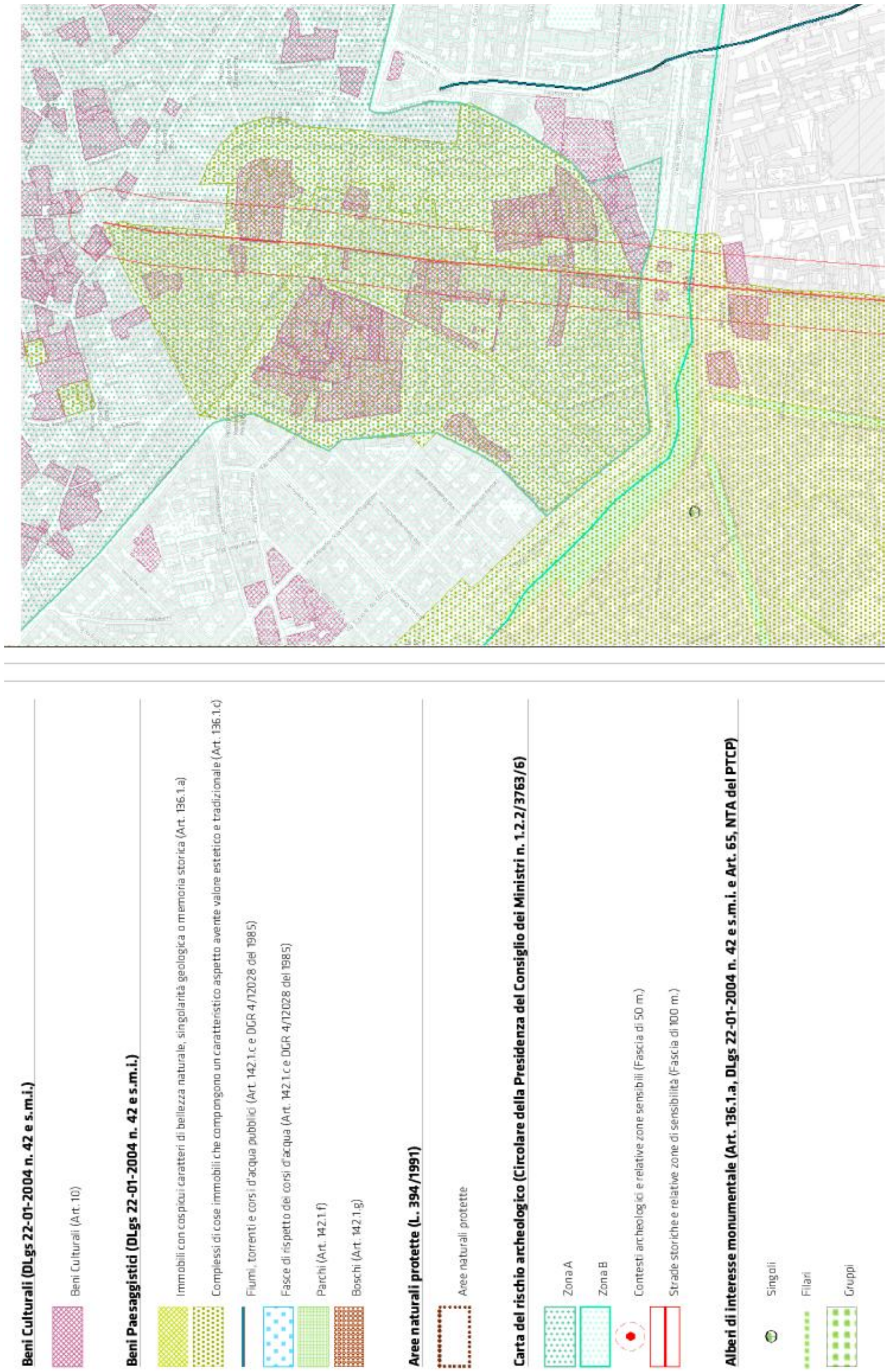

Fig.1.30. Beni culturali e Paesaggistici[55]

[55] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Accessibility to Corso Porta Ticinese

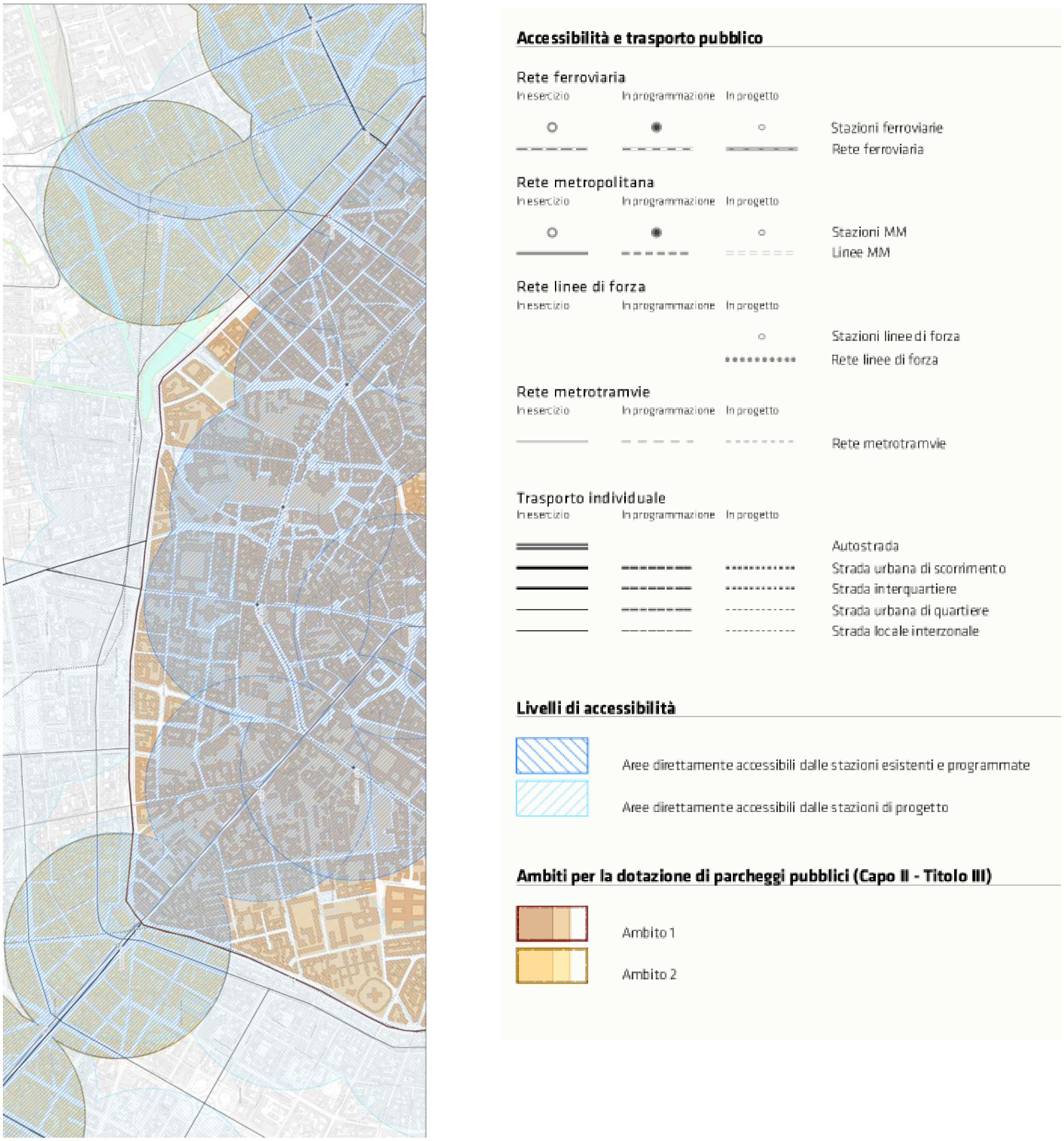

Fig.1.31. Accessibility to Corso Porta Ticinese[56]

[56] PGT, Piano di Governo del Territorio, Commune di Milano 2009.

Fig.1.32. Pedestrian Shortest path from Sant'Agostino Metro Station (0.94km; estim. 16min.)

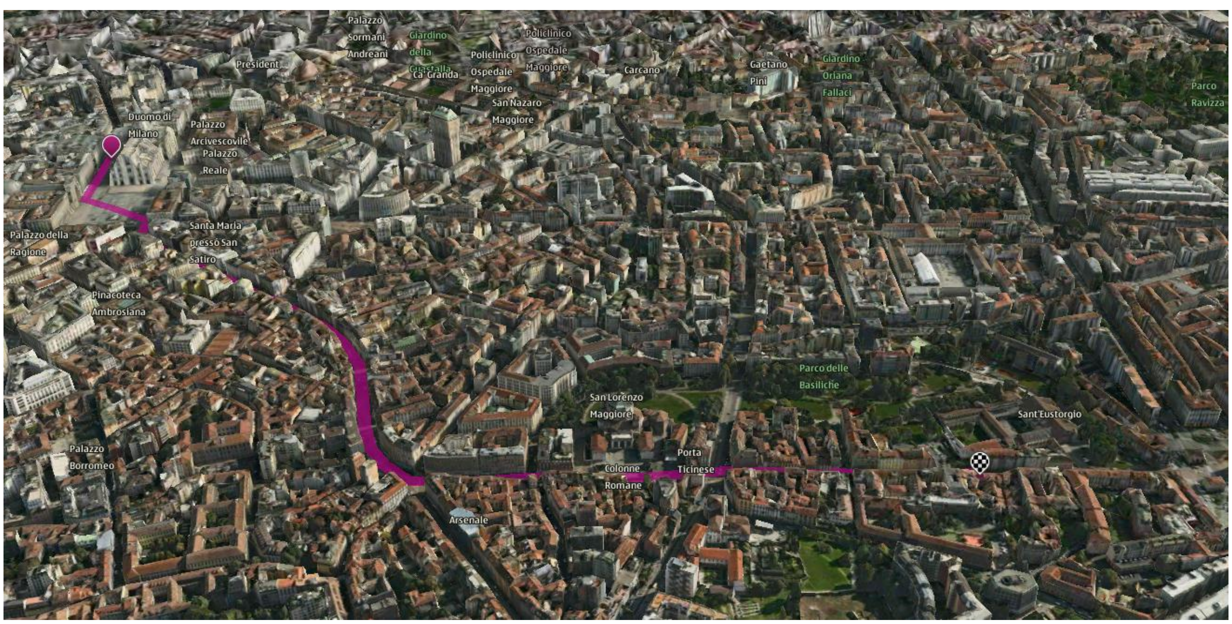

Fig.1.33. Pedestrian path from Piazza Duomo (1.6km; estim. 27min.)

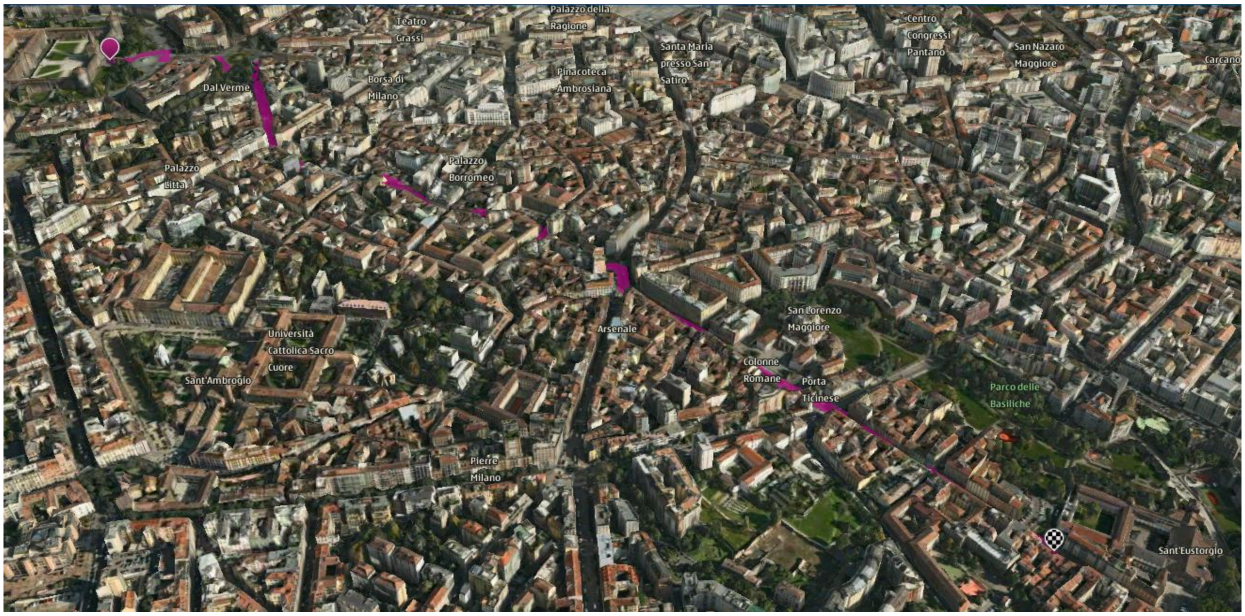

Fig.1.34. Pedestrian path from Castello Sforzesco (1.8km; estim. 31min.)

Fig.1.35. Pedestrian path from Crocetta Metro Station (1.1km; estim. 19min.)

Conclusion: Value of Design, a different planning attitude:

City is a complex structure, single organism, living body-transformations that make up life. The life of a city is not only consists of tangible assets such as land and buildings, services and goods. Its evolution depends on the social components and conditions.

The value of design should find common basis not only in related professionals but also in all citizens. Milan Communicated and discussed with the same shared language, that is design, could build a consensus between institutions, people and its territory, and that consensus coming from a shared core value-Design, would suggest the direction where urban politics should go towards creativity, innovation and knowledge.

Architectural Design

Introduction

The goal of this section is to show the process of design of the new addition of the Diocesano museum in Milano. The design process is passing through different scales starting from a wide scale, which is the zone scale. In this scale we analyzed the functions and the potentials of the existing area. Going through the architectonic scale by which we applied our design principles on the specific site of the project.

The project of the new addition of the Diocesano museum was an international competition. The brief of the project is very precise showing all the required objectives and goals that are expected in the new addition.

This section is starting by showing the location of the project and the important buildings surrounding it. The part following it is expressing the competition brief and the design requirements. The brief also contains very interesting historical information about the surroundings of the site. The final design intervention is showed at the end after passing through different analysis and studies of the site and the concept.

Before we started to approach our design analysis were done on a larger scale in order to understand the existing zone with all its potentials and constraints. This analysis was the motive for us to approach out final design.

Location

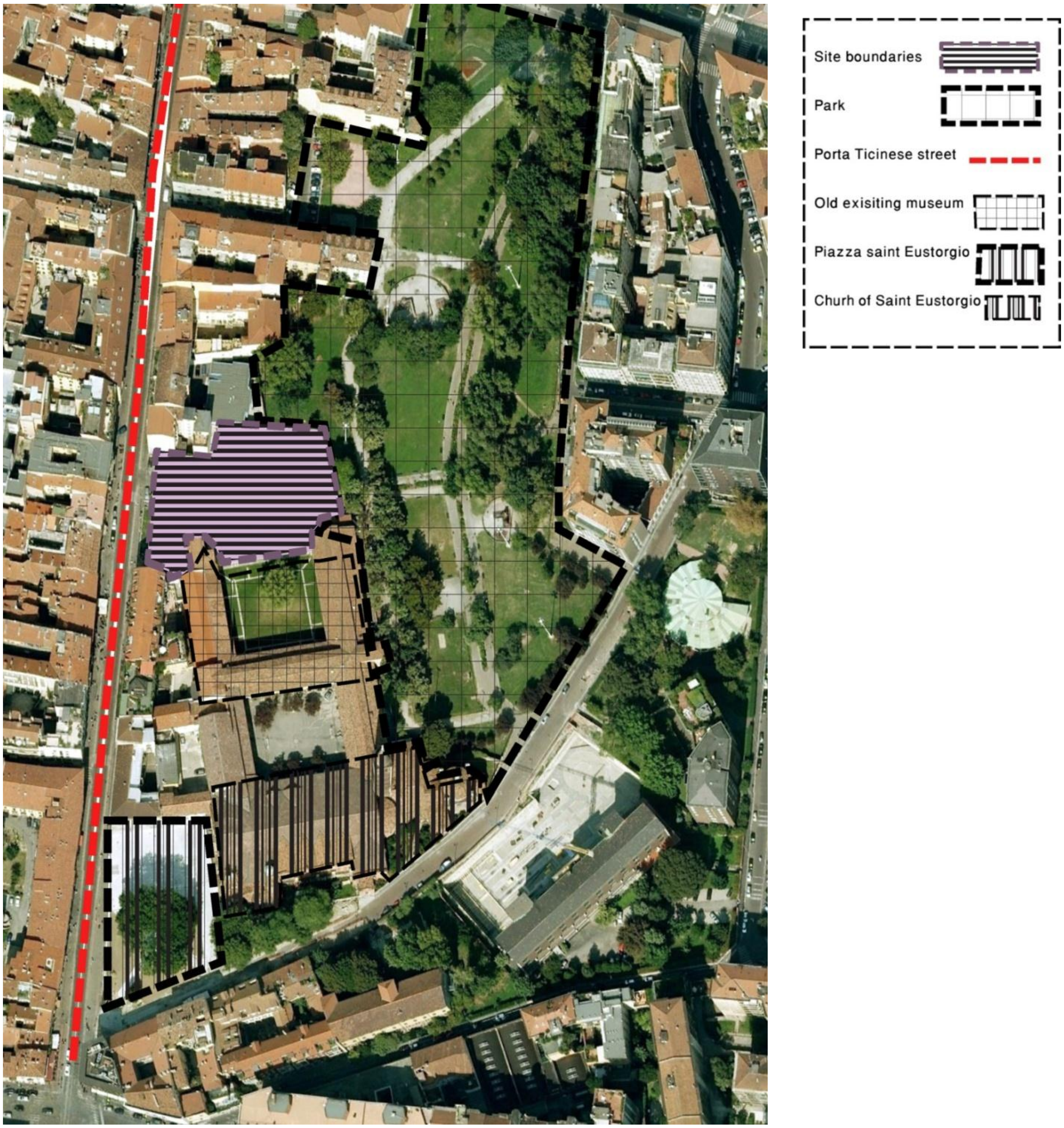

Fig.2.1. Top view of the site.

These figure shows the site boundaries, the Porta ticinese , Parco delle Basiliche and the oldexisiting museum.

Summary of the Brief

As have been well understood, through the urban research about Milan, that the site of the project is located in the historical center of the city, which is rich with its historical heritage and implications

The project case to study is the addition of the Diocesano Museum. It was announced as an open international competition with defined brief and explicit objectives.

The main aim is the addition to the open cloister arrangement in the Sant'Eustorgio complex occupying the area between the Parco delle Basiliche and the Corso Di Porta Ticinese.

The main objectives were to design a project which is well defined and suitably organized tackling critical problems which are:

- The relationship with the Corso Di Porta Ticinese
- The rehabilitation of the blind elevations of the buildings adjoining the empty space left by the wartime demolitions.
- The provision of proper access to the Parco delle Basiliche
- the relationships with the open cloister and the Santo Eustorgio monument complex as a whole

The new addition of the museum should contain, beside the exhibition zones that need to be visible and easily accessed from the Porta Ticinese, a complex of cultural activities.

The complex is expected to include extra educational classes, meetings and conferences zones. It is also required to facilitate the urban connectedness and exploitation of activities belonging to the museum complex.

The two parts of the museums should be connected together physically, the old part of the existing and the new part with the new temporary exhibitions and cultural complex.

No particular instructions are given on the delicate question of the closure of the frontage on the Corso di Porta Ticinese, or conversely the maintenance of the Corso's opening onto the Parco delle Basiliche: this is a strategic decision to be taken by the designer.

Historical overview for the surroundings

Sant'Eustorgio

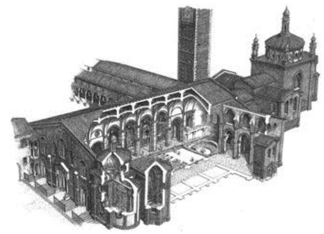

Fig.2.3

Fig.2.2 The basilica of Sant'Eustorgio www.santeustorgio.it

Fig.2.4

The analysis of the history of the Basilica was of a great importance for us in order to understand well the near surroundings of our project[57].

From early Christianity to the twelfth century

The foundation of the church, located on a cemetery dating to the III-IV century AD, traditionally coincides with the place where it was believed that the Apostle Barnabas had baptized the first Christians, has long been attributed to Eustorgio I, Bishop of Milan (344-350 AD). The remains of a church, the early Christian period (sixth century), are visible under the apse, whose walls, dating from the first half of the eleventh century, testifies to the successive transformations Romanesque. The basilica had longitudinal layout, perhaps covered by a barrel vault, entered by three semicircular apses.

From Thirteenth century the arrival of the Dominicians

In 1220 the archbishop's vicar Ugolino gave the order to the Dominican basilica and its outbuildings. Seven years later, ownership was confirmed by Archbishop Henry Settle. The series of measures undertaken during the thirteenth century led to radical transformations of existing space. The church took up an "in room", which suits the needs of preaching order, under which was erected a pulpit, originally wooden, outside the church, replaced in 1597 by a masonry construction. All ' coupling of the apse, on the right was placed an arm of the transept

[57] Storia delle Basiliche, from the website www.santeustorgio.it ,Translated from Italian.

with two chapels and proceeded to remake the entire roof with ribbed cross vaults. Since the last quarter of the two hundred, the room looks to be enriched in the southern flank, four chapels which, two centuries later, it joined other foundations, according to a custom widespread in the churches of the Order of Preachers. In 1234 he was assigned to St. Eustorgio the Office of the Inquisition of Lombardy. In 1251 he was appointed papal inquisitor of Milan and Como Friar Peter of Verona, who was assassinated April 6, 1252 in an ambush by some heretics tesogli at the forest of Barlow. The monk was canonized less than a year, and his remains, buried in St. Eustorgio, became objects of veneration. In the last decades of the thirteenth century began the construction of the tower, which lasted until 1309.

Decoration of the chapels of the Basilica

The protection of the Visconti family, and the support given to the policy taken by them by order of preachers, are attested by the numerous committees for the church and convent documented in the fourteenth or fifteenth century. The chapel was founded in 1297 by Matthew I, whose bust appears outside the Company, during the fourteenth century was equipped with frescoes. Gian Galeazzo gave large sums to build the new library and commissioned the marble altarpiece with scenes from the Passion of Christ for the high altar (1395-1402). The Duke Filippo Maria promoted the building of the refectory and cloister of the lost (1420). During the fourteenth and fifteenth most influential families discounted the patronage of the chapels of the basilica, commissioned funerary monuments that often over the centuries, were broken and reassembled in an arbitrary manner. In the seventh decade of the fifteenth century Florentine nobleman Pigello Portinari, who built a chapel , with burial feature, designed to contain the relic of the head of St. Peter Martyr. Between 1483 and 1489 was the year of Brivio chapel, in which were placed on polyptych of the Madonna and Child with Saint James and Saint Henry Ambrose from Fossano called Bergognone and the tomb of James Stefano Brivio, by Tommaso Cazzaniga and Benedict Briosco[58].

From the sixteenth century to the present

In the second half of the fifteenth century, the monastery began to enter into a phase of crisis and slow decline. In 1559 the Inquisition Tribunal was transferred to the Dominican community of reformed S. Maria delle Grazie. However, the complex eustorgiano took on new importance due to the revaluation of the basilica, promoted by Carlo Borromeo, who established the first Christian settlement and burial place of martyrs. In 1526 clashes between French and Spanish soldiers who were fighting the city of Milan provoked serious damage to buildings. The convent was restored in 1600, under the direction of Jerome sitone. Between the sixteenth and the

[58] Storia delle Basiliche, from the website www.santeustorgio.it ,Translated from Italian.

eighteenth century a number of interventions and Reconstruction of the redecorating affected the church, involving important Lombard artists among whom were, in second half of the sixteenth century, Giulio Campi, Urbino Carlo, Andrea Pellegrini, for the seventeenth century Daniele Crespi, Mauro Giovanni della Rovere, said Fiammenghino, and Frederick Bianchi, the architect Francesco Croce and Antonio Lucini for the eighteenth century. The pictorial heritage of the monastery was enriched by the legacy of large works on canvas by Giovanni Battista Marone (1666). In 1798 the Cisalpine Republic decreed the suppression of the convent. With the Restoration, the convent building remained in use for military purposes. In the seventh to eighth decade of the nineteenth century the basilica was the object of a major renovation. The major works were concentrated on the facade, where a design by John Pitcher and Enrico Terzaghi, the central rose window and side openings were replaced by three double and two single windows. The entrance was completed with a portico, supported by columns resting on lions stilofori, and paintings, also extended to the side gables, Augustine Caironi.

The painter widely even within the church with the decorative style of Romanesque Revival. The work continued until 1874, including the reshaping of some chapels and the rediscovery of frescoes in the Portinari. A second, large, restoration campaign began in 1950 in order to recover the appearance of two-fourteenth-century basilica, the resurfacing of the floor led to important archaeological discoveries. In 1911 the monastery complex was acquired by the City of Milan and used, mostly in productive activities. The bombings in August 1943 led to the destruction of the monastery. In 1960 the Municipality of Milan decided to make a radical static consolidation. At the same time, it came to an agreement for the sale of property ownership to the Curia, with the burden of carrying out all repairs and reordering of the cloisters to recover to new destinations. In 1999 the second cloister is the Diocesan Museum is open. In 2000 the parish has taken charge of a conservative restoration of the facade of the basilica and the first three chapels of the south side, and a redevelopment project functional in order to establish a new museum , the rooms of the south side of the first cloister and chapter house, where there are no new decorative and structural elements[59].

[59] Storia delle Basiliche, from the website www.santeustorgio.it ,Translated from Italian.

The Diocesano museum

Fig.2.5. view from the cloister of the existing museum www.dietrolanotizia.eu

Fig.2.6. interior view of the museum

The Diocesano Museum was opened by Cardinal Carlo Maria Martini on 5 November 2001 after a long period of gestation that had commenced at the beginning of the thirties, when the archbishop of Milan, Idealfonso Schuster, came up with a plan to promote Christian art and at the same time bring together and conserve the artistic heritage of the diocese[60].

In the sixties, at the urging of Cardinal Montini, the complex of the basilica of Sant'Eustorgio was selected as the seat of the Diocesan Museum, and in the eighties work commenced, according to principles of conservation and historical accuracy, on the restoration and reconstruction of the cloisters of the ancient Dominican monastery, gravely damaged during the Second World War.

The Diocesan Museum fulfills its aim of promotion of Christian art and preservation of the diocese's artistic heritage in two ways, with a permanent display of works of art like paintings, sculptures and liturgical objects and by staging exhibitions of art and organizing conferences, lectures and study and research activities.

[60] Historical evolution, *Brief of the competition*.

The cultural activity now conducted by the Diocesan Museum “goes beyond its role of active conservation of the works to hold a dialogue with the city, with the territory of the diocese and with the individual parishes through initiatives and events that are intended to stimulate the public, by introducing it to the beauty, and the spirituality, of art”.

The permanent collection has now found a home in the spaces of the cloister facing onto the Parco delle Basiliche. The temporary exhibitions and the spaces used for reception of the public, meetings and educational activities, as well as the facilities for collection, cataloguing and study of the works will be located in the new part, subject of this Project[61].

Monuments of the museum

The Diocesan Museum collection has over 600 works of art, of which almost 400 are on display, divided into various sections62.

The Quadreria Arcivescovile picture gallery has contributed many of the artworks in the Museum, from the collections created by Milan's archbishops, providing an overview of the cultural preferences of those who succeeded Ambrose on the archbishop's throne. For instance, the Museum has part of theVisconti and Pozzobonelli collections, and the entire Erba Odescalchi collection.

The Diocesan Museum also contains numerous works from the Diocese, dated sixth to nineteenth century. Following a meticulous study of the Diocese's Artistic Heritage Archive, moved to the Museum in 1998, prior to its inauguration investigation and visits to the various parishes enabled the identification of some real hidden treasures. This was the start of the recovery and valorization of the Diocese's artistic heritage, which is one of the Museum's chief aims. This nucleus of works was enlarged by the addition of a section dedicated to St Ambrose, the Fondi Oro (artworks made on a gold background, produced mainly in Tuscany during the fourteenth and fifteenth centuries, collected by Prof. Alberto Crespi, and donated to the Museum in 2000), sculptures and paintings from the Marcenaro collection (loaned by the Fondazione Cariplo in 2004), the cycle of canvases from the Arciconfraternita del Santissimo Sacramento and, lastly, a significant section dedicated to religious furnishings. In the near future there are plans to dedicate an entire section to the 1900s.

Design Guidelines

The design guidelines, as mentioned in the brief, are mainly addressing the issue of the integration of the new addition of the museum with the old existing museum. This integration should take into account the historical and architectural aspects of site.

From the urban point of view the competition brief is also mentioning the importance of the connectivity between the site of the project and the surroundings.

[61] Historical evolution, *Brief of the competition*.

[62] Monuments of the museum*, retrieved from www.museodiocesano.it*

The new design of the addition will also define the geometry and the relation between the open spaces and the existing Park.
The Brief left a very interesting and crucial point open with no restrictions of design requirements which is the relation between the frontage of the cloister and the Porto Ticinese.

Focusing more on the new addition itself and the requirements stated in the brief which were categorized into four main parts:
1. Reception and internal and external extra-institutional spaces
2. Display
3. Meetings and educational activities
4. Documentation and research

These four main parts are then explained in details, related to the function of each part and the objectives needed to be achieved by it from the functional and the architectural point of view[63].

1. Reception and internal and external extra-institutional spaces

-*Entrances*

Different users of the museum should have different entrances. Separation should also be in the level of the pedestrian entrances which defines different circulations and entrances for visitors and for researchers and staff.

-*Foyer*

To be conceived as an addition to the existing building. The two parts of the institution that of the existing monumental complex, housing the fixed collections, and the new one, intended for temporary exhibitions will have to function in synergy.
However, it is necessary for the foyer to permit differentiated accessibility to the two parts, allowing visitors independent access to the fixed collections, the temporary exhibitions and the Meetings and Educational Activities area.

-*Bookstore*

This space can assume a complex character, in reference to the design of the foyer and the Meetings and Educational Activities area.
It should be made up of several separate and interacting sections, for books, posters and museum gifts. It should be in direct contact with the spaces of the city and have independent services for the staff. It could also be conceived in synergy with the cafeteria, with the aim of creating an attractive space that can be used outside the opening hours of the museum.

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-Cafeteria

A facility not linked exclusively to the museum, it will be open for use by a broader section of the public. For this reason it will have to be in direct contact with the open spaces of the park or the city and have its own service spaces, for the staff and for the preparation of food, allowing it to operate even when the museum is closed.

Also to be provided, possibly underground but with easy connections with the areas of the cafeteria open to the public, are several spaces for the preparation and heating of food, for use by catering services on the occasion of events and dinners attended by large numbers of people.

-Areas for relaxation and reflection

Areas made up of small spaces for reading, meditation and rest, to be located in the reception zone, along the routes through the museum and in places connected with the exhibition areas or close to the areas of the bookstore and the cafeteria.

Strategically located, they can also provide an interesting mediation between indoors and outdoors, between the interior of the institution and the open spaces of the park, the cloister and the city[64].

-The garden and the cloister

The parts of the garden adjoining the museum (the outdoor areas located within the boundary marked in red on the enclosed Plate 1) can also be laid out in such a way as to permit them to be used for temporary exhibitions in the open air and for meetings, possibly with a provision for the installation of temporary structures.

-Services

The toilets, with facilities for women, men and the disabled, will be located in discreet units at easily accessible points.

2-Exhibition

The exhibition area should be designed to permit considerable versatility and flexibility of configuration, by means of movable walls or structures, as it will have to be able to adapt to a wide range of display conditions. It must be conceived for use as a whole, in a major exhibition or for general display purposes, as well as in separate parts, to permit the mounting of more than one exhibition at a time.

[64] Competition Brief

Thus it will have to be possible for the different parts to be linked together so that visitors will find it easy to move around, as well as to permit the movement of materials, the mounting of display systems and the location of works65.

-Gallery

The Gallery will be flexible and divisible to permit the staging of more than one exhibition at a time. It will have to be designed so that it is able to house exhibitions of various kinds with the minimum amount of preparation possible.

The artificial and natural lighting and screening systems must be able to adapt to the requirements of exhibitions of works of ancient and modern art as well as such contemporary forms as light, multimedia and video installations.

The required height is 4/5 m.

-Loft

The specific architectural characteristics of the Loft must permit a high degree of flexibility, allowing it to house large works, installations and display systems specifically designed for exhibitions or events. It will also be used to stage performances and exhibitions. The floor slabs will have to be designed to support the load of large works and of display structures, platforms or partitions. A flexible system of plant must be adapted to a wide variety of uses and configurations without the operation of the equipment being affected. It will be provided with both artificial and natural illumination and systems for the screening of light.

The required height is 6/7 m.

3. Meetings and educational activities

Spaces for meetings and educational activities supplement the traditional image of the museum, founded exclusively on seeing and enjoying the works on display. The inclusion of such spaces is linked to broader strategies that are intended to open up the institution to a variety of cultural activities, including the promotion of cultural initiatives and programs

Thus the museum structure, conceived in terms of a broader vision of its function, will become a venue for a wide range of cultural activities, interacting with urban spaces and with various initiatives carried out in the city.

Multipurpose modular hall

A space to be located in relation to the areas used for temporary exhibitions, in view of the growing tendency to combine such events with debates, conferences and public meetings with curators and artists. It should also be designed to serve as a multipurpose space for experimental events, performances and the screening of videos and films. It will have to be extremely flexible and allow the arrangement of the seating to be changed to adapt to multiple

[65] Competition Brief

forms of use. It should also be possible to use the space for Educational activities involving large groups of schoolchildren as well as meetings, seminars and conferences.
From the outset it must be designed so that it can be divided into several independent units in order to permit the simultaneous staging of performances and events and opened up to other adjoining spaces so that its capacity can be increased when necessary.

-Rooms for seminars and courses

These are facilities for joint work programs and meetings and for lectures to organized groups and school parties. The spaces will need to be able to hold between 20 and 40 people and to be fitted with the equipment needed for them to be used as lecture rooms, with seats and a table at the front for the speaker.
The classroom for children can be organized in a more informal manner and subdivided for small study and creative play groups.
It should be possible to darken the rooms so that they can be used for screenings, and they should be soundproofed and equipped with sound systems. Criteria of flexibility and adaptability are essential so that such rooms can also be used for small meetings,
book presentations, press conferences or initiatives that are collateral to or synergic with the activity of the institution66.

4. Documentation and research

-Delivery of Works

The zone for delivery of works must be accessible by van from a secure, protected and covered outdoor space for loading and unloading operations. The area should be connected with a reception and control office, a zone for unpacking and packing and a temporary storeroom.
These spaces will be used to house works that are not immediately put on display in the galleries but require sorting and cataloguing.
They should be closely connected with the workshops and study rooms and permit easy access to the storerooms for the works and the exhibition spaces.
Workshops and study rooms These are the work and research facilities of the members of the museum staff responsible for study, cataloguing and conservation, as well as for the care, maintenance and if necessary restoration of works of art entering the museum, as a result of acquisitions or loans for temporary exhibitions, or leaving it on loan to other institutions.
These spaces may occasionally be used to house students and researchers from outside, and for this reason it will be advisable to provide for temporary work stations for use in rotation.

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[66] Competition Brief

-Storerooms

In the contemporary conception of the museum, viewed as a place not just for the display of works of art but also for their study, research and conservation, the storeroom is no longer a simple storage area but has acquired a more complex function. The centre of the Documentation and Research sector, it is also a place open to scholars or to guided tours by groups, as part of the educational programmes organized by the institution. For this reason it will need to have a synergic relationship with the facilities for Meetings and Educational Activities67.

[67] Competition Brief

Dimensional requirements[68]

Meetings and Educational Activities

	Number of spaces	Area of Occupation sm	Common Areas 30% sm	Technical Areas 10% sm	GFA sm	Total GFA sm	Minimum Heights m
Multifunctional Room	1	400.0	120.0	40.0	560.0	560.0	5.00
Seminar Rooms	2	70.0	21.0	7.0	98.0	224.0	3.50
Classroom for children	1	70.0	21.0	7.0	98.0	112.0	3.50
Total						896.0	

Underground service spaces

	Area of Occupation sm	Common Areas 20% sm	Technical Areas 10% sm	Total GFA sm	Minimum Heights m
Catering support spaces				100.0	3.50
Temporary materials store				300.0	3.50
Plant				300.0	3.50
Total				700.0	3.50

Documentation and Research

	Number of spaces	Area of Occupation sm	Common Areas 20% sm	Technical Areas 10% sm	GFA sm	Total GFA sm	Minimum Heights m
Delivery of works office	1	40.0	8.0	4.0	52.0	52.00	3.50
Temporary store	1	40.0	8.0	4.0	52.0	52.00	3.50
Workshops and study rooms	3	30.0	6.0	3.0	49.0	147.00	3.50
Storerooms	2	150.0	30.0	15.0	195.0	390.00	3.50
Total						641.00	

Summary

	Area of Occupation sm	Common Areas 20% sm	Technical Areas 10% sm	Total GFA sm
Reception				866.5
Exhibition spaces				1430.0
Meetings and Educational Activities				896.0
Documentation and Research				641.0
Service spaces				700.0
Total				4533.5

[68] Competition Brief

Case Studies

In order to approach the design of the project in a historical city like Milan, it was of a great importance to start analyzing two case studies in the city.

The two case studies are different from each other since one of them is resembling the historical and architectural heritage of the city. This is analyzed through the Sant'Ambrogio Basilica.

The other example is the University of Bocconi. This example is a modern example but it is very near to the project's site.

The Basilica of Sant'Ambrogio

The Basilica of Sant'Ambrogio is one of the vital and historical monuments of Milan.

The Diocesano museum is located in the historical center of Milan and is surrounded by buildings which have very high historical and architectural characteristics. For understanding how important buildings were approached in the Milanese culture we chose to focus on the Basilica of sant'Ambrogio.

In this case study there is a very interesting linkage between urban and architectural aspects.

Fig.2.8 view for the open space
www.cooltourworld.com

Fig.2.7 Aerial view for the basilica
www.cooltourworld.com

Fig.2.9 Interior of the Basilica
marisamoles.wordpress.com

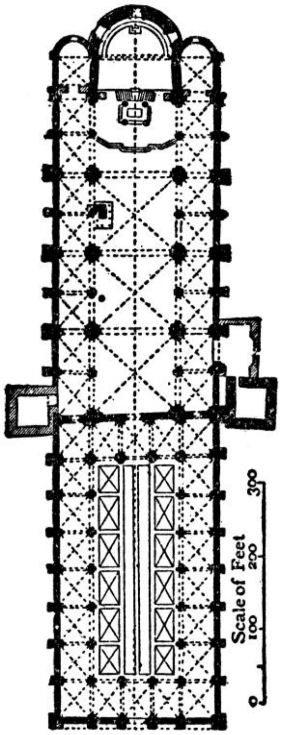

Fig.2.10 Plan of the Basilica
www.etc.usf.edu

Architectural analysis

The Basilica consists of a simple plan in shape. The entrance of the Basilica is then directed to three aisles where they are different in dimensions. The center or the middle one is different from the other two. These three aisles are then ended in another covered space. This is twice as wide and is divided to four main bays, which are vaulted in the first three squares, whereas the fourth in covered with a dome. The aisles are defined by number of smaller spans at which these spans called (campatelle).The façade of the building consists of three windows which resemble on the exterior a lodge with five arches superimposed on the arms of the Portico. The materials used for the construction were mostly brick and plaster which were a typical Milanese and a traditional Lombard for the time.

Urban-architectural analysis

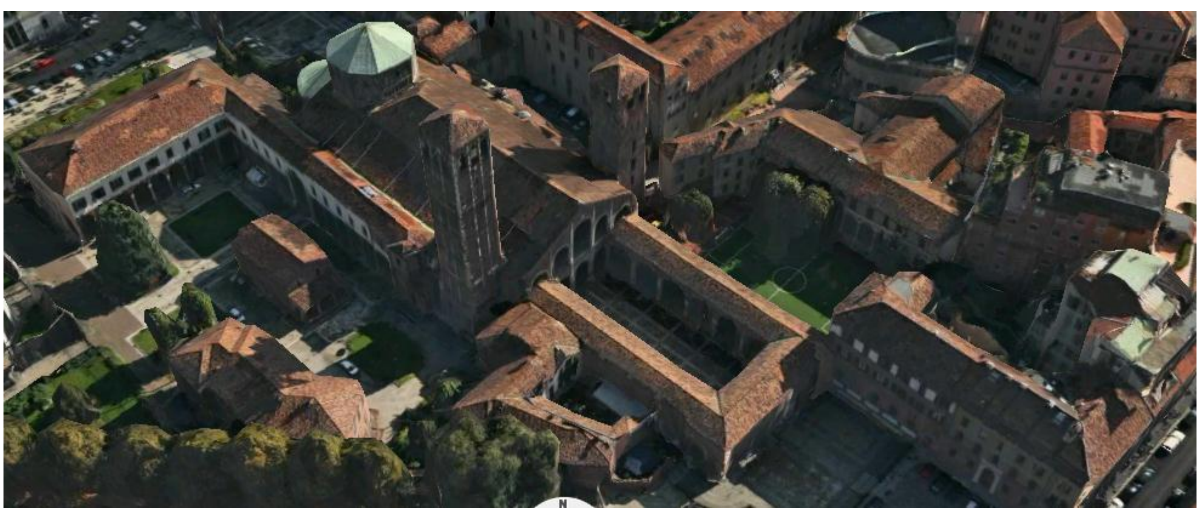

Fig.2.11 Aerial view for the basilica
Maps.Nokia.com

As in Fig.2.10 this aerial view for the Sant'Ambrogio, where it could be seen that the main building of the Basilica and the two towers in the middle before the entrance to the nave and the Dome. The interesting aspect here, which is significant for the Milanese architecture, is the transition of spaces from the entrance until the arrival to the core of the building. This transition gives the opportunity for the visitors to have different experiences and interpretations through their short journey.

Fig.2.12 Aerial view for the basilica
Maps.Nokia.com

The short journey starts from point number 1 where a general view of the façade of the building could be taken, exciting people more to come and explore what's beneath the gates.

From point number 2 an important short transition where a different feeling is addressed. This feeling is perceived because it is the transition between the exterior and the interior of the building.

Fig.2.13. Aerial view for the basilica
www.cooltourworld.com

Fig.2.14. Aerial view for the basilica
www.cooltourworld.com

Three different aisles surrounded by colonnades as in point 3. In this space the perception of different kind of big open interior space with another view of the façade of the Basilica, with the two towers in the background.

Point 4 is the last transition barrier before arriving below the dome of the basilica. In this space which is divided to four main bays. The bays are vaulted in the first three squares, whereas the fourth in covered with a dome.

These transition points are abstract points that were used in order to show in a simple way the idea of different spaces inside the basilica.

Conclusion

A major monument such as the Sant'Ambrogio church has a lot of architectural and historical characteristics. We focused on a very substantial point more related to the linkage between architecture and urban the basilica. This feature is the transition between spaces from the entrance until reaching the nave. The transition of spaces also underlines that the greatness of a building could be felt through passing by its spaces from one space to another.

This concept is very interesting since the design of the building is strongly affected by the design and the setting of the open space. The different pereception by visitors, when they keep changing from open space to indoors and then to semi open enclosed space, articulates a lot this methodology. Visitors are integrated with the spaces of the building as well as the volume itself.

This trait is inspiring for the design of the new project of the addition of the Diocesan museum, since applying it from the urban scale until reaching the building and itself where also the building is divided with the same scale.

This concept favors more the idea of the interaction between the users and the building and denies the idea that the building could only be perceived from the exterior geometry.

The University of Bocconi:

Fig.2.15. university of Bocconi
www.dezeen.com

This example is chosen for study because of two main reasons. The first is that it is located very close to our project's site. The second is that it is also a project of extension to an old existing building.

The design of the university is very inspiring for us. The building was chosen to be the World Building in the inaugural world architecture festival for 2008.

The main feature of the design in this building is the mixture between architecture and light. This merging was done through hiding all main lighting sources form the view of the users of the building. The largest amount of light was from the exterior lighting source and lighting inside the building was the minimum required level.

Fig.2.16. www.dezeen.com

Architectural aspects:

The new building occupies a rectangular lot, 70mx160m, between Viale Bligny and Via Roentgen, located within the university complex of the University Luigi Bocconi, Which boasts previous collaboration of architects such as Mario Pagano, designer of the first building in 1941, Giovanni Muzio, who designed the extension of 1966, and Ignazio Gardella, designer of the building inaugurated in 2001.

In this context, the new extension interjects itself like a filtering mechanism with the city. Complex and fragmented, it is composed of several buildings that are developed in five or six floors above ground and are united by a common base of three underground floors. The result is an articulated complex defined by compact volumes suspended on courts and semi-public spaces, and opened both internally and externally. The large foyer of the Great Hall, courtyards, and the different levels of terraces are all defined by areas with grand spaces, projections, large cuts, and openings that allow natural light to enter and illuminate[69].

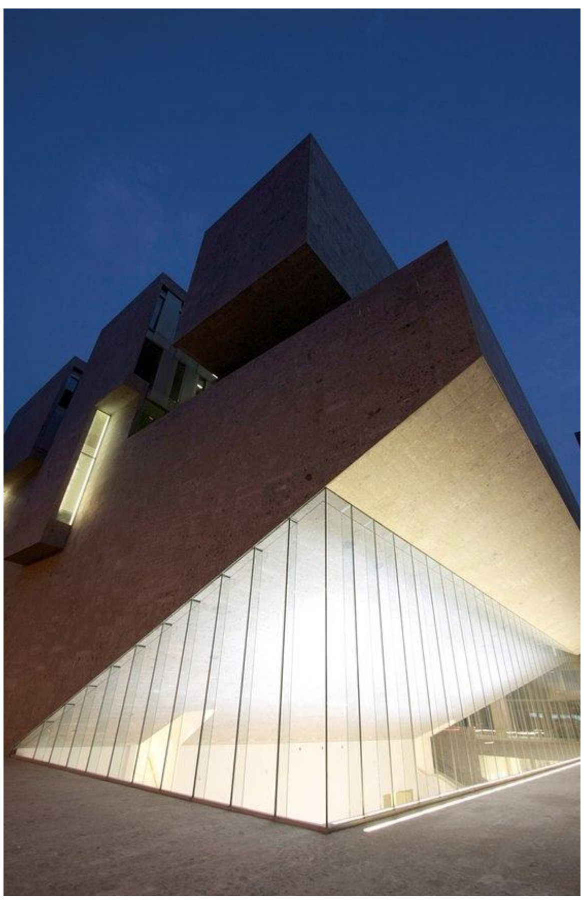

Fig.2.17. www.dezeen.com

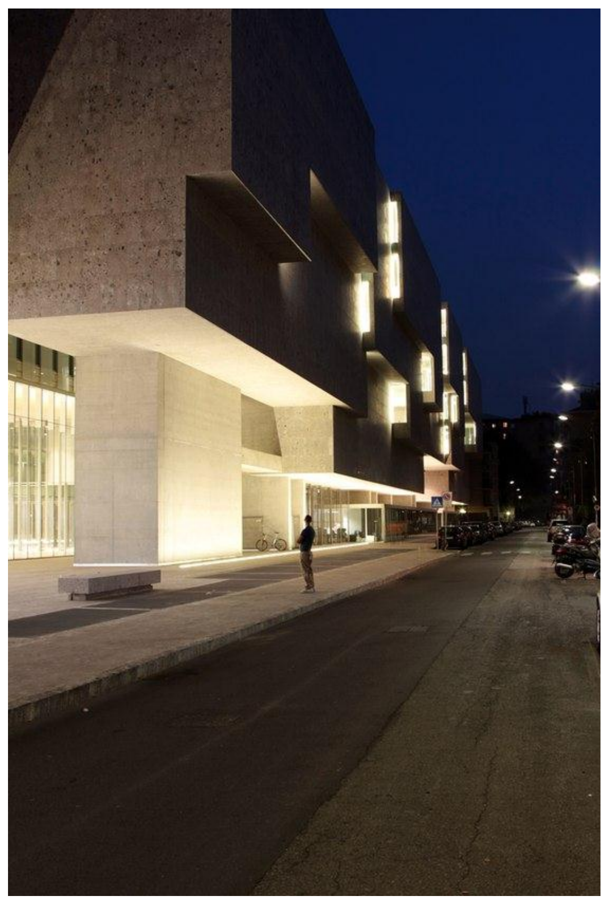

Fig.2.18. www.dezeen.com

[69] Zanchi Flores, Materia magazine 59

Conclusion:

The University of Bocconi is an example for merging light and architecture. This building proves that a very interesting architecture could be easily obtained by the control of lights. The diversity of light integration concepts inside the building helped a lot to underline that approach. Light is intended to be hidden from the users and at the same time kept at the minimum required level.

The materials used for the building were also very simple and contributed strongly to express that the building really belongs to the context of the site, despite being a new building. The manipulation of solid and void of the building is used to control the use and the amount of light inside the building.

The extension to an old existing building should not be perceived as an alien to the site of the project but at the same time not also just a copy of the existing one. The possibility of having this contrast should be maintained in the new design.

Architectural Vision

The main vision of the project was not only to create a project belongs to the context of the site. But rather a project that is fully integrated with the surrounding and inspired by simple and available materials. The project is intended to fulfill the brief requirements and to offer an outstanding experience for the users of the building.

Being located in the historical center of Milan where it is a great challenge, the project is aiming to assimilate the architectural and the urban features of the area. Satisfying the linkage between the two aspects in a building where beauty of the building is contented through the open and outdoor spaces.

Using light in defining the architecture of the building by manipulating the relations between the solid and the void.

A complex used building is intended to be projected to integrate with the historical surroundings especially with the existing museum, Parco delle basiliche and the Piazza of the Sant'Eustorgio.

Site Analysis

As a preliminary step to start to understand well the site and the surroundings in order to approach the concept, it was mandatory to analyze the zone around the site.

The analysis is done in different layers to give a clear figure about the characteristics of the site in a clear and a presentable way.

In these analysis road networks, greens, solids and voids, open spaces and important buildings surrounding the site were studied.

Fig.2.19. street patterns diagram.

The analysis of the street networks and patterns in the zone is useful to understand the accessibility of the site and the possible entrances.

This study helped us to understand the use of the Corso Porta Ticinese. The street is used only for trams and private transportation like taxis and limited car access. This limited use defines the density of the street and addresses for us how to use the actual state of the street to integrate with our project.

The figure shows the hierarchy of streets from the main streets and the secondary streets.

Greens

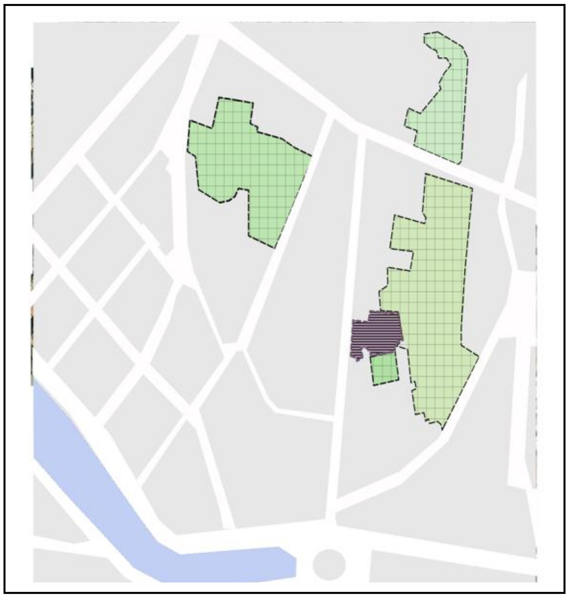

Fig.2.21. street patterns diagram.

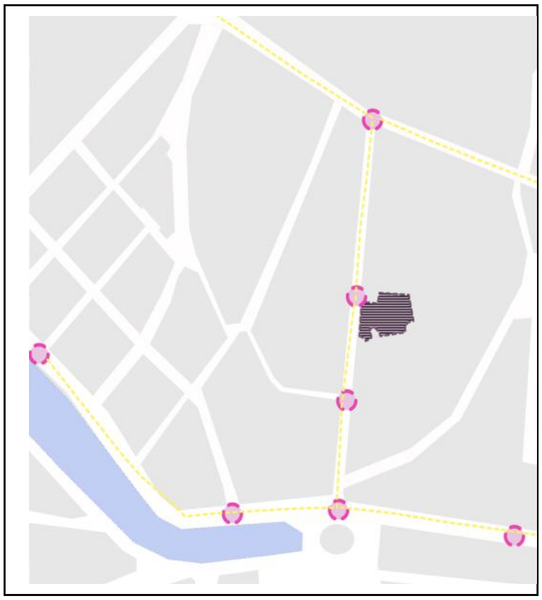

Fig.2.22. Tram stops diagram.

Figure 2.21 is showing the green areas around the site. These areas are divided in different zones. The first one is the Parco delle basiliche. The park is very close to the site of the project. The main aspect for us is to understand how the connection could be done from the Porta Ticinese and the park passing through our site.

The second important open space is the open cloister of the existing Diocesan museum. This cloister defines the architecture of the museum since it creates a magnificent view from inside to outside. The connectivity between the addition of the project to that open cloister is also of a great interest for our design.

The existence of very close green zones has a great potential in defining and articulating our new design.

In figure 2.21 public transportation represented by the tram lines show the possible means of connectivity around the site. Highlighting the tram stops shows the actual accessibility to the site using Tram.

The analysis of the tram lines we understood the connectivity and how it is possible to approach the site.

Overlaying of different elements

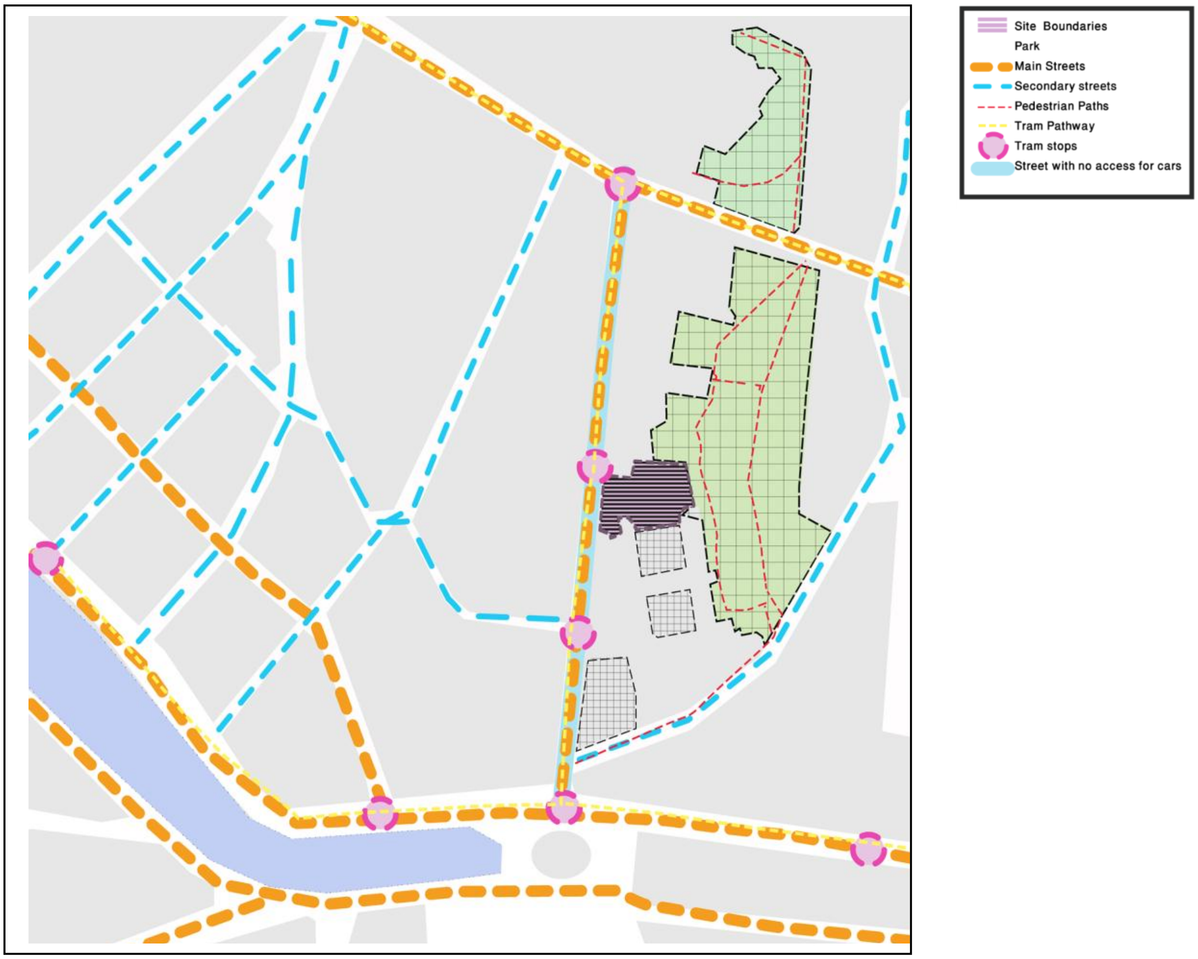

Fig.2.22. site analysis diagram.

Overlaying all the layers through the existing situation assisted us a lot in understanding the use and the effect of each layer with the coloration to the other layers. We also comprehended the important relation between the site zone and the nearby open spaces like the piazza sant'Eustorgio and the cloister of the existing Diocesano museum.
The use of the Corso Porta Ticinese since it is a street with limited car paths with the presence of a public transportation axis represented by the tram and the existence of the park beside our site.
The challenge which we chose to fulfill in our design is to connect these aspects with our new design, such that the new addition is perceived as a part of that very rich and complex urban and architectural context of the zone.

Conceptual approach

The expansion of The Diocesano Museum of Art fuses architecture with landscape and urban design to generate an observed architecture that unfolds for users as it is perceived through each individual's movement through space and time. The new addition of the Diocesan engages the existing garden, transforming the entire Museum site into the precinct of the visitor's experience. The new addition extends along the innovative merging of landscape, architecture and art was executed through close collaboration with museum curators and artists, to achieve a dynamic and supportive relationship between art and architecture.
As visitors move through the new addition, they will experience a flow between light, art, architecture and landscape, with views from one level to another, from inside to outside.

The use of simple architectural element such as the vertical connections in an abstract way in order to realize and achieve the design required.
This methodology files the link between architecture, landscape and urban design in order that users perceive the project as a whole experience from approaching it and not just the building geometry or interior.

The project design is inspired from the complexity of the site. The main aim was to provide a new project in terms of energy efficiency and architectural hierarchy but at the same time to be integrated within the urban and historical fabric of the site.
Being surrounded by the Parco delle basiliche from one side and from the other side the well-defined, highly diverse and complex corso Prota Ticinese was of a great challenge for us in order to provide a suitable and a vital connection between them through the design of our project.

The ongoing discussion of keeping the frontal of the site to the Porta Ticinese open or just closing it was a very rich conversation in order to help us approach the design.

The project by itself as an addition, of mixed uses, to the old existing Diocesan museum was a critical aspect as well. The ability and the possibility of connecting the new addition with the old museum and also to the cloister of the new museum had to be achieved.
Visual connectivity was also used since it gives a wide perspective to the project and helps easily to integrate the new addition to the old existing cloister.

After focusing and understanding some important features from the culture of Milan as has been done in the case study of Sant'Ambrogio which helped to achieve some sorts of urban integrity in our project with respect to the surrounding potentials.
Our concept was to design the project by the design of open spaces. This was fulfilled by providing different experiences of the users from one space to the other.
In other words the smooth transition of spaces starting from the urban and the landscape, meaning, the entrance passing through different spaces provided until reaching the main open space then the buildings itself.

Moreover, the analysis of the University of Bocconi was useful for us in order to grasp how an addition to an old existing building with respect to a complex existing surrounding could be done. The use also of materials addressed the same concept, since the materials used fully integrate with the context of the University.

Taking advantage of the complexity of the site and its surroundings it was also intended that the different entrances to the site of the project always address different perspective to the project with different views.

Architectural approach

Starting from the site analysis done on the existing site plan, major aspects are clearly visible. By merging these aspects and guidelines we started to approach our design decision.

We were driven by the will of manipulating architecture, urban, landscape and light all together in order to produce a design which is in a full harmony with itself and then with the surroundings.

The use of materials was also of a great importance for us, since we chose materials which exist in the context of the city such as concrete finishes and other more energy and technological efficient materials such as the Corten.
The management of these materials in the solids together with the openings represented by glass transparent facades has strongly defined the shape of the exterior of the building itself.

Representing the potentials we have from the site analysis and the aims we want to achieve in our new design on the site map helps us to arrive to our final design.

Street connectivity

The first point that we took into consideratoin was the presence of the Corso Porta Ticinese beside the site of the museum, this street as has been understood from before has special use since it is of a great historical significance. The street is opened only for public transportation represented by the tram so cars are not allowed to pass there in this street.

Fig.2.23. Porta Ticinese street

Fig.2.22. Porta Ticinese street

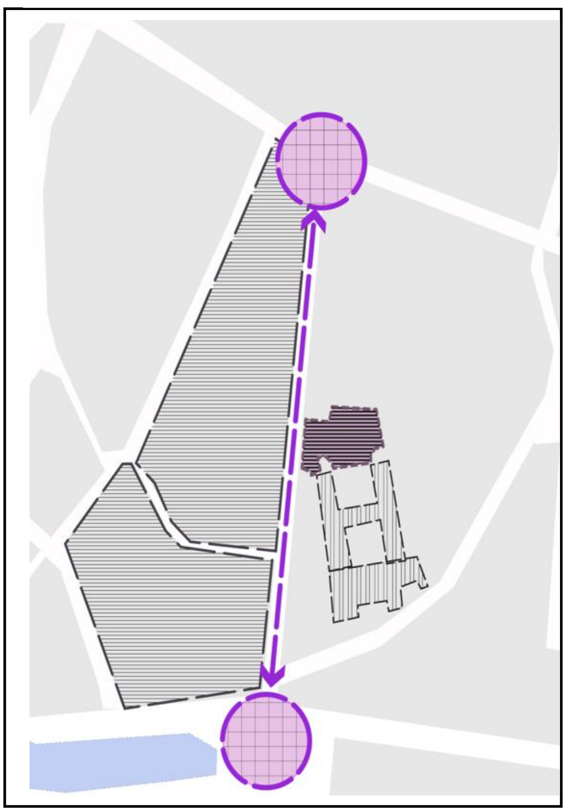

Fig.2.24. Porta Ticinese street
between the site and the Parco delle Basiliche

From these photos it is obvious that the street despite its significance is not a wide street.

The connection between the two important nodes along the Porta Ticinese Street which are from the north represented by the Porta Ticinese and the Piazza 24 Maggio from the south.

Keeping this axis as it is, which resembles the heritage and historical significance, and making use of it as an axis to the project is a very important point for our design in order to integrate successfully with the existing context.

From Figure 2.24 we can see the two important nodes that are being connected through the Porta Ticinese. Despite the use of the street but it is of a great importance to have a direct accessibility to our site through the existing street.

Fig.2.25. Basilica sant'Eustorgio with the view of the Parco delle basiliche

Fig.2.26. Connectivity, greens zones and site boundaries map

The existence of the park beside the site, which is a wide open green space with a very high potential, in some times of the day, to attract people and is considered as an open public space.

On the other hand west to the site is the Porta Ticinese Street with the frontal to the buildings part with no public or open spaces.

In Figure2.26 the orange arrow shows the direct connection between these two contradicting urban phenomena. This was a point also that directed us in approaching our design, by which we realized the importance of the relation between the park the street and our site.

Fig.2.27. concept plan base map

Fig.2.28. Concept plan accessibility base map

The relation between public and open spaces was also a matter of attention in the design of the project since the project is an addition of the existing Diocesano museum.

The museum contains an open space which is the cloister. At the beginning of the Corsa Porta Ticinese as well there is the interesting Piazza Sant'Eustorgio.

The existence of the site near these public and open spaces was taken into consideration in our design.

We planned to provide an open space inside the site of the project which could integrate in terms of the urban contextually with the surrounding public spaces.

The connection to the cloister was also of a great importance but we intended to provide a visual connection from the open space to the cloister. In Fig2.27 the blue colored hatched spaces resembles the open spaces around the site

The accessibility to the site from different places is also taken into account. The main access is from the Porta Ticinese Street. There are other axes which is connecting the site to the eastern direction.

The south pathway from near the Piazza Sant' Eustorgio is integrating the civil and the pedestrian entrances to the site.

This analysis has underlined for us the importance of redesigning the existing park. The main aim is to integrate the site with all the possible and available axes.

From these conceptual approaches and the site analysis done design decisions were taken. These decisions addressed for us architectural and urban objectives that we need to fulfill in order to provide a project that could be integrated with the urban and architectural context of the site.

New design objectives

1-Providing an open enclosed space that could act as a link between the two contradicting use of the surrounding of the site, represented by the park and the Porta Ticinese Street.

2-The design of the project should have different architectural perspective from different views. This is in order to provide different experience for users approaching the site through different axes.

3- Maintaining the visual connectivity form inside the open space to the cloister of the Diocesan museum.

4- Connecting to the open spaces of urban context surrounding the site through integrating with the open space provided.

5- Defining the relation between the new addition and the old existing museum.

6-Articulating the relation between the skyline of the new addition and the existing building

7-Integrating the landscape materials of the new addition open space with the old historical pavement of the surrounding.

8- Defining the relation between the frontages of the site with the Corso Porta Ticinese.

Design process

Based on the analysis that we have done it was time to go deeper in exploring the design of the new addition of the museum.
Keeping in mind the concept that has been evolved through the analysis and studies, we started to draft some sketches.

The sketched helped us to understand the scale of the site, the requirements of the brief and the actual relation between the site and the surrounding buildings and spaces.

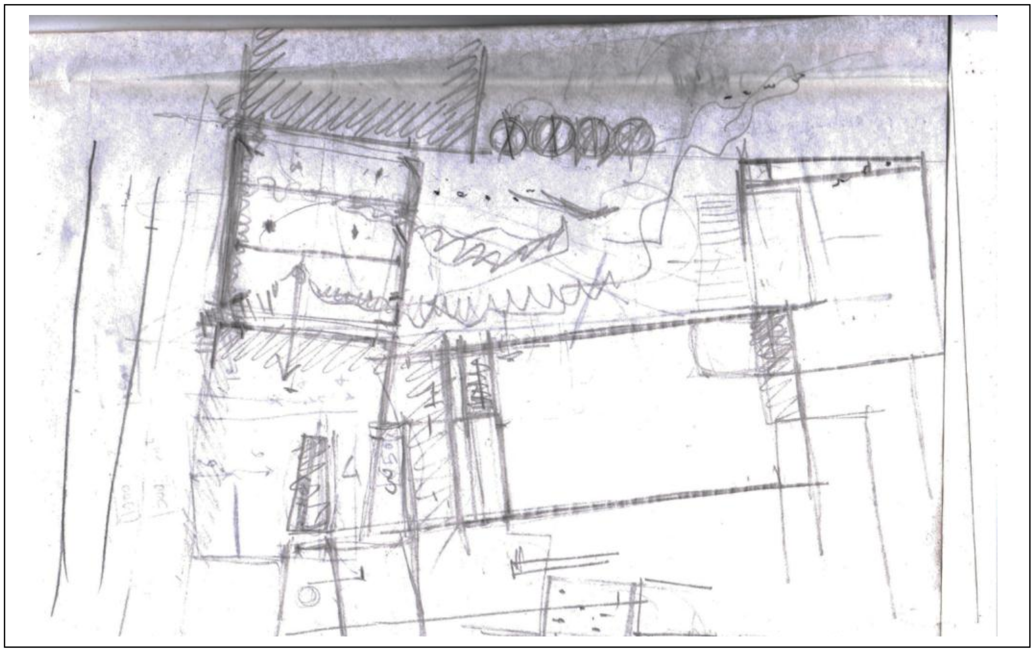

Fig.2.29. layout sketch

From the very first sketches that we had was a sketch of the layout of the project. In this sketch we realized the need of having a buffer space that is opened to the Porta Ticinese Street. The open enclosed space inside has also been preliminary defined. This open space was used as well to define set of volumes for the new addition.

The main feature of the sketch is the relation between the site and the Porta Ticinese and the Parco delle Basiliche. The site is intended to offer a connection between them; this connection is physical and visible.

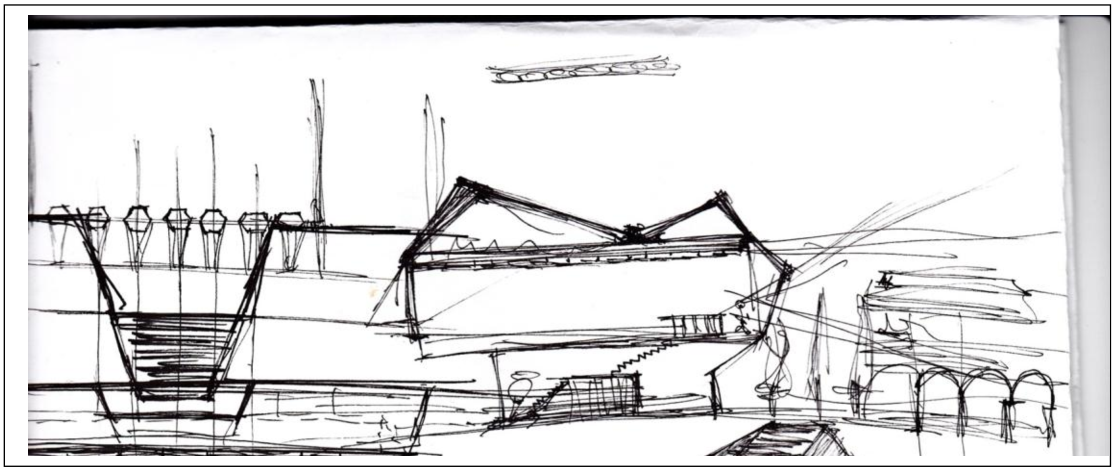

Fig.2.30. primary volume sketches

Fig.2.31. Layout draft showing the primary zoning

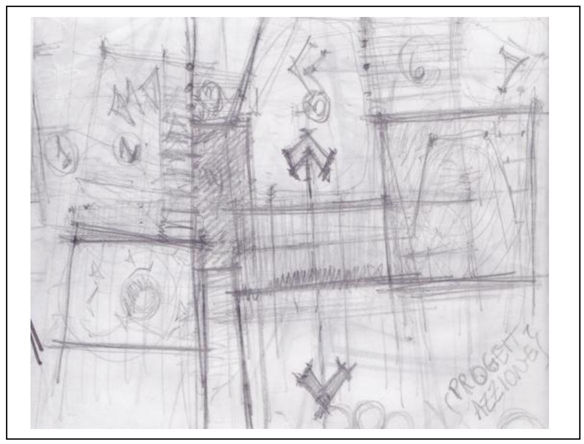

Fig.2.32. connectivity diagram between the park and the site

The volume sketches shown in Figure 2.30 articulates the relation between the new added volumes and the existing Diocesano museum.

The inclination of the new added volume was inspired by the actual existing museum. The existing museum colonnade zone is on two levels with the same angle of inclination.

From the architectural aspect in order to keep an equilibrated view from the cloister this inclination had to be added.
There is also another technological use of this inclination in the volume, since it is south oriented by which we can maximize the heat gains in winter and decrease the effect of direct sun rays in summer. This technological relevance will be discussed in details in the technological section.

Figure 2.32 is showing the visual connectivity between the open space and the cloister. From these sketches we realized the importance to provide this connection.

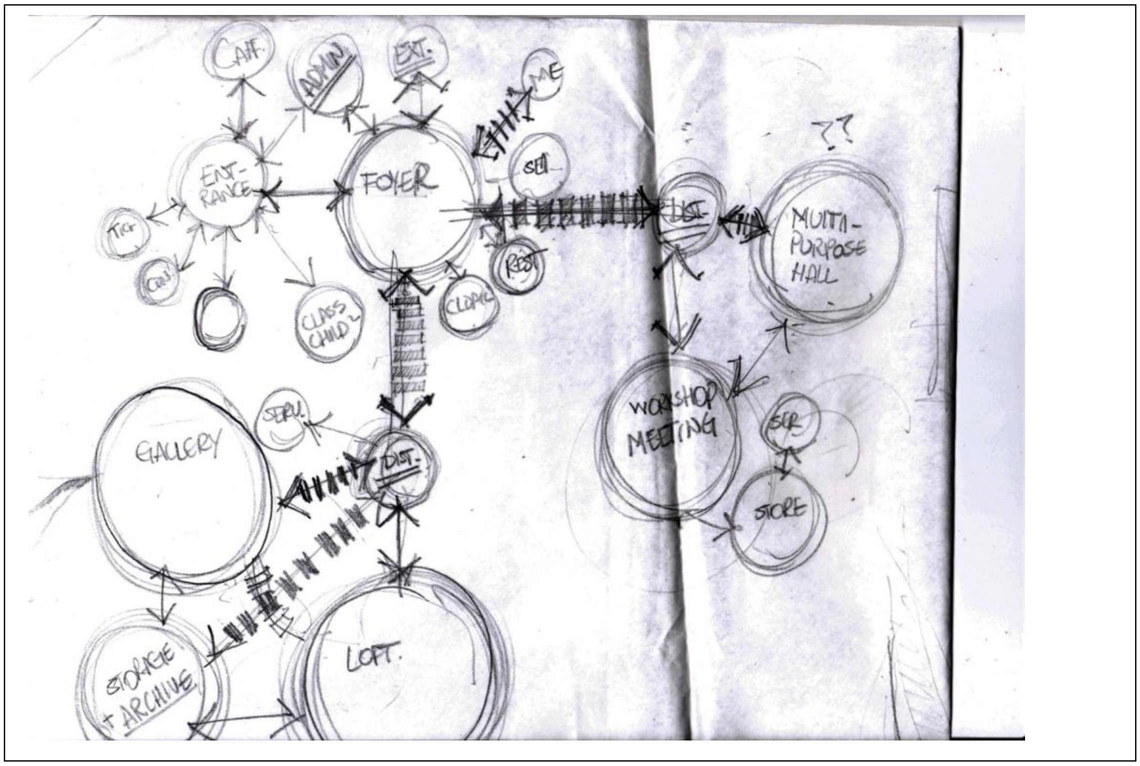

Fig.2.33. Conceptual bubble diagram

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The bubble diagram shown in figure 2.33 was the first application of the competition brief requirements. Different elements have been drawn together in a proportional scale in order to understand the hierarchy of spaces inside the building.

The transition from one space to another was expressed from that sketch. It is obvious that the entrance is connected to the Foyer. The foyer, as mentioned in the brief, should be perceived as an addition, is a distribution zone where users could reach almost every part of the museum through the foyer.

The bubble diagram defines the primary zoning of the new design. It is clear that there is a separation in uses between different functions. Despite being separated in uses, they are still connected by means of vertical connections and also by the foyer.

The scale proportionality of different functions is based on the precise design requirements of the brief. These variations helped us to create the final shape of the volumes of our new design.

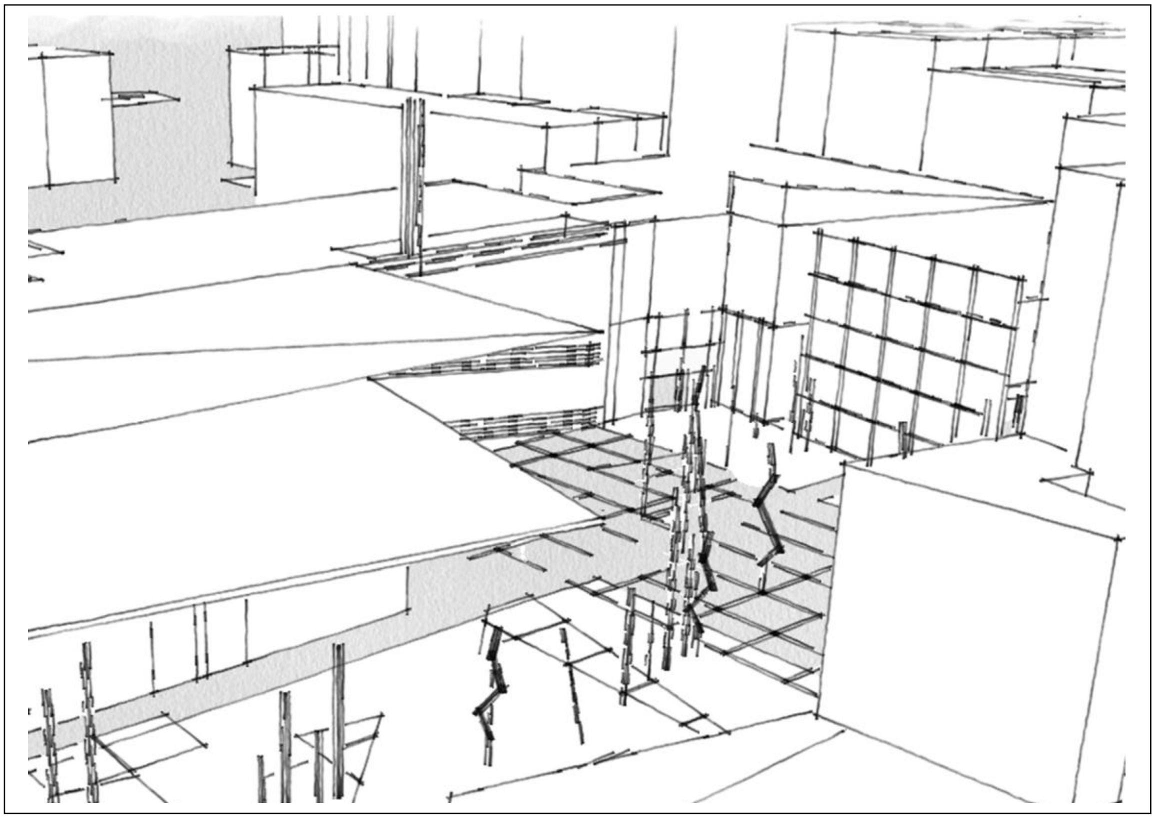


Fig.2.34. abstract design of volumes and open space

Passing from the interior bubble diagram of the project and starting to understand the relation between volumes based on actual areas and design requirements. Figure 1.34 is showing the abstract design of the enclosed space and its relation with the buffer zone. The abstract design of the volumes was the base for us in order to go further in details and start developing the plans that correspond with these primary design decisions.

We also understood the relation between the new volume in terms of heights and skyline with the old existing buildings around the site. The realization of our design in the same height as the surrounding and especially the old museum enhances the idea that the building is a part of the context of the site.

Conclusion

In our design process we have passed through different phases. These phases were essential for us to start realizing the design of our project.
Starting from the site analysis, historical significance and the careful considerations of the projects brief we started to develop our project.

This level was a broad and wide level. The analysis of the site zone and the surroundings history was a tool that helped to approach the required design. Then moving to another deeper scale at which the specific aspects of the site are taken into consideration. At this scale the application of the design requirements of the brief takes place.

The compiling and merging of all the analysis that we have done was the base guideline of our conceptual approach. We have been also inspired by the case studies that we have studied. In these case studies we discovered different and more complex aspects of the Milanese culture. This helped us to pass with our conceptual approach to a well-defined concept.

Design proposal for the new addition of the museum.

Layout

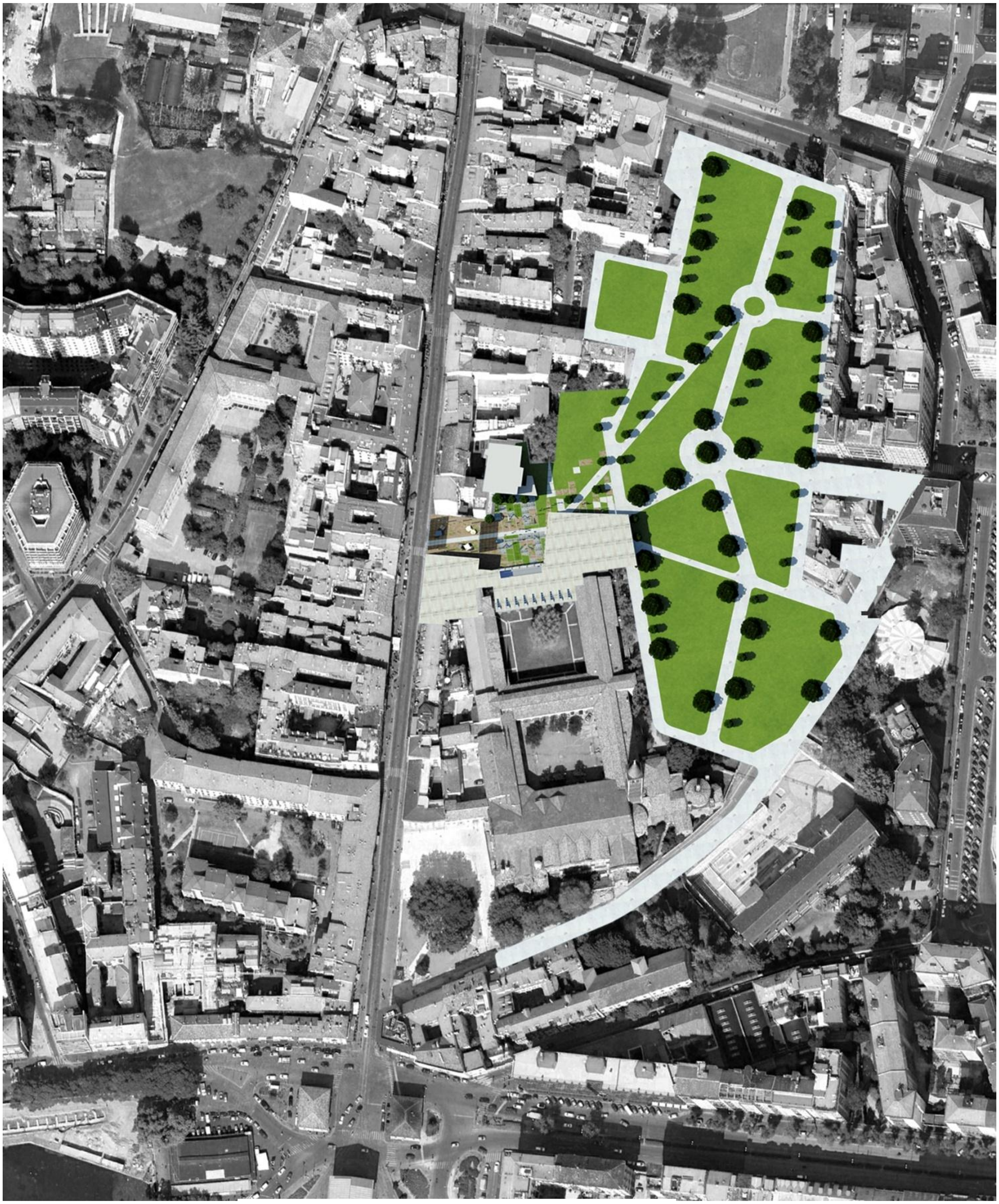


Fig.2.35. merging of the new layout design in the site of the project in black and white

Fig.2.36. merging of the new layout design in the actual site

Plans

Ground floor master Plan

Fig.2.37. Master Plan of the new addition of the

The plan is showing the interaction between the park and the highly diverse Porta Ticinese Street. The decision was made to leave the frontage of the site of the project open to the Porta Ticinese but with providing a buffer zone at the entrance which is an open exterior exhibition. This was done in order to have complete axis through the site of the project even at times were the Museum is closed. The second point was to provide a transition which enhances the strong effect between urban and architecture of the new addition of the museum.

The plan is divided in different zones where there is a significant separation between the use of the building as a museum and the other educational activities inside the building.

The separation in uses is maintained through simple vertical connections in the form of ramps. Through these ramps users could experience a nice perspective through the glass façade opened to the exterior.

In The educational zone of the addition workshops and educational classes are free to users where they can easily access without passing through or crossing the exhibition zones.

A one way circulation is provided for the visitors of the exhibition. They follow a direct well-defined path starting from the entrance and then taking the ramps to the Loft in the first floor. Taking the other ramp again to the galleries zone by which it is the end of the path and the interior exhibition zone.

The integration with the old existing museum is taken into consideration. The old museum is easily accessible from the ground floor of the new addition.

First floor plan

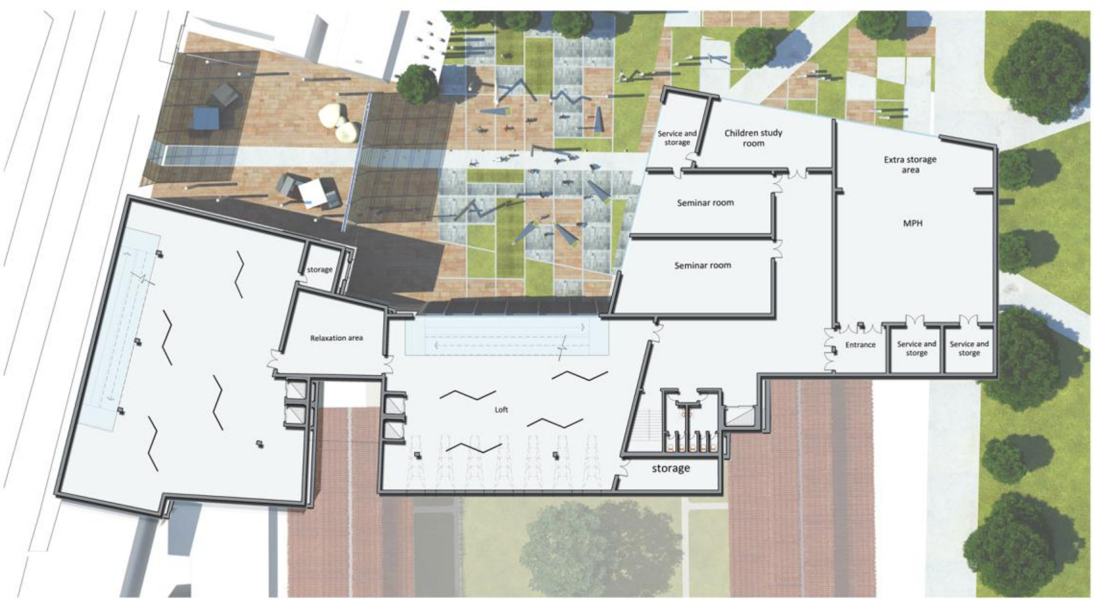


Fig.2.38. First floor plan

In the first floor plan there is a separation in uses between the zone of exhibitions and the zone of educational and cultural activities.

The access to the first floor is through ramps for the part of the loft and the gallery with the presence of elevators for handicaps.

The educational zone is accessed through stairs directly to the zone of seminar rooms and multipurpose hall.

A skylight is added above the part of the ramps in order to use daylight in lighting the exhibition zone. The skylight is also used to give a different experience inside the ramps.

The façade of the ramp is all transparent by which there is a visual interactivity between people inside the building and the people in the outdoor open space.
This transparency addresses the open space as a part of the building when visitors are using the ramps.

Basement floor plan

Fig.2.39. Basement floor plan

As have been stated in the brief that the basement floor plan should have services requirements. The basement contains the catering zone which is just below the part of the cafeteria and is connected to the upper level through internal service elevator.

Areas of storage are provided in that floor as well that are connected to the exhibitions zone through a big service elevator. The storages are for the expositions in the loft and the gallery.

A vehicular entrance is as well provided to the building through the basement from the eastern side. The plan is divided in a way that all the storages are very near to the parking of the service truck. This was intended to keep the expositions as much safe as possible by decreasing the distance from the truck to the storages zone. The vertical connection element from the basement floor directly to the first floor is also very close to the entrance of the truck, so expositions could arrive and easily and quickly lifted to the exhibition zone.

A space for plant and service area is also provided in the basement. This is fully matching with the requirements by the competition brief.

Functional layouts

Ground floor plan

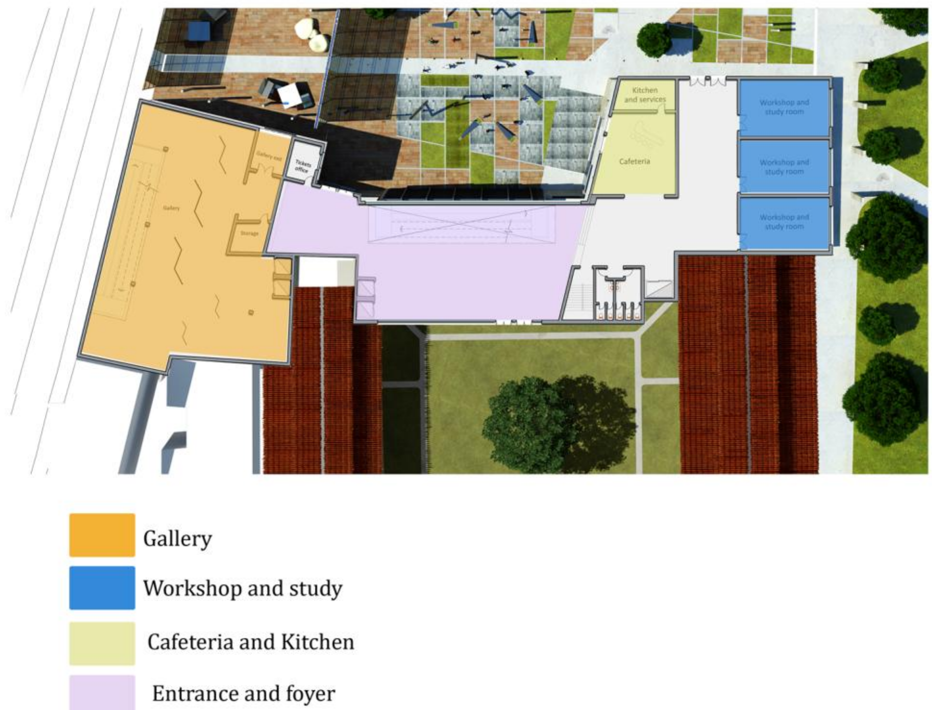


Fig.2.40. Functional layout for the ground floor plan

Figure1.40 shows the functional layout. As have been stated that the plan is divided in different well defined zones. The entrance of the ground floor plan is directed to the Foyer. In the foyer there is a different experience inside the building, since it is visually connected to the two open spaces near the building. First which is the cloister green space and the other is the new designed open space. This connectivity gives the users of the building a very wide feeling of the interior of space since nothing is blocking the vision on both sides. The use of bright interior materials in the interior of the space forces the same concept.

The presence of the cloister with the classical colonnades on one side is a very special experience and totally different from the new designed space where modern landscape features is used.

This diversity of uses strengthens the special feeling of the space. Following the competition brief the foyer is providing a distribution zone to the other spaces inside the building.

Since through the foyer visitors take the exhibition circulation path, or get directed to the cultural and educational zone and even the zone of cafeteria.
The cafeteria is opened to the new open space where visitors have a special experience being part of the open space.
The educational zone contains three workshops rooms at which they could be used meetings or trainings.

The ground floor plan also contains the main gallery of the new addition, but this gallery is not accessed from the entrance and it has to be accessed from the first floor plan in order to maintain a direct separated one way circulation for visitors of the exhibition. This conceptual section is showing exactly the one way circulation. The white arrow is starting from the

Fig.2.41. conceptual 3D section to show the one way circulation path

entrance where visitors use the ramps to get to the first floor and then to the loft. The loft is on the first floor where there is a separation between the two lofts by a relaxation area. From the second loft zone visitors take another ramp to reach the ground floor again to visit the gallery and then they are automatically directed outside the building where they find the part of the exterior cotemporary exhibition.

First floor functional layout

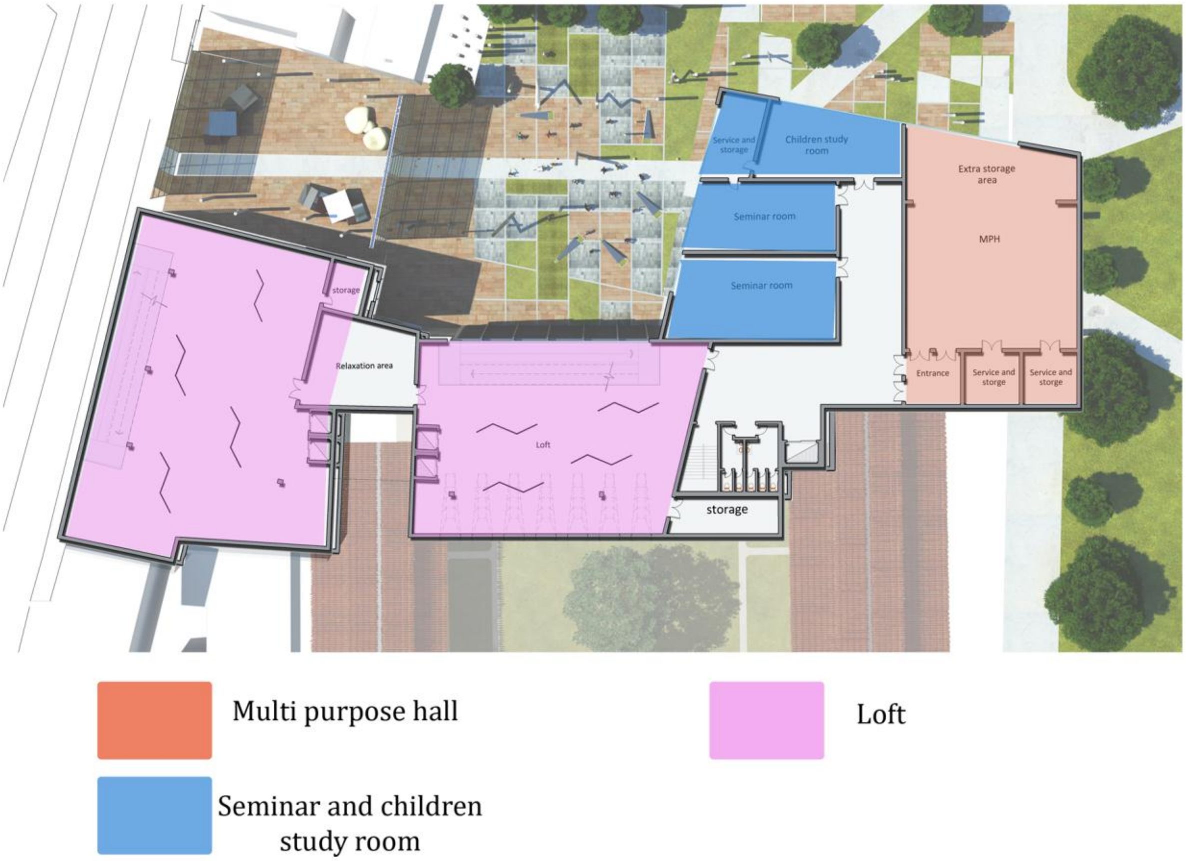


Fig.2.42. functional layout for first floor plan

The functions of the first floor are divided between the exhibition zones. This zone contains two lofts that are separated by a relaxation area in between.

The other zone is the educational and cultural zone where it consists of the multipurpose hall. The hall is huge open wide space that could host up till 250 people.

The zone also contains seminar rooms and a children study room. These spaces are used for educational or seminar purposes when meetings or conferences are held in the museum.

There is a separation between the two zones except for a service door between them. The need of the door is to facilitate importing the expositions form the basement floor to the loft and also for escape issues.

Volume Dismantle

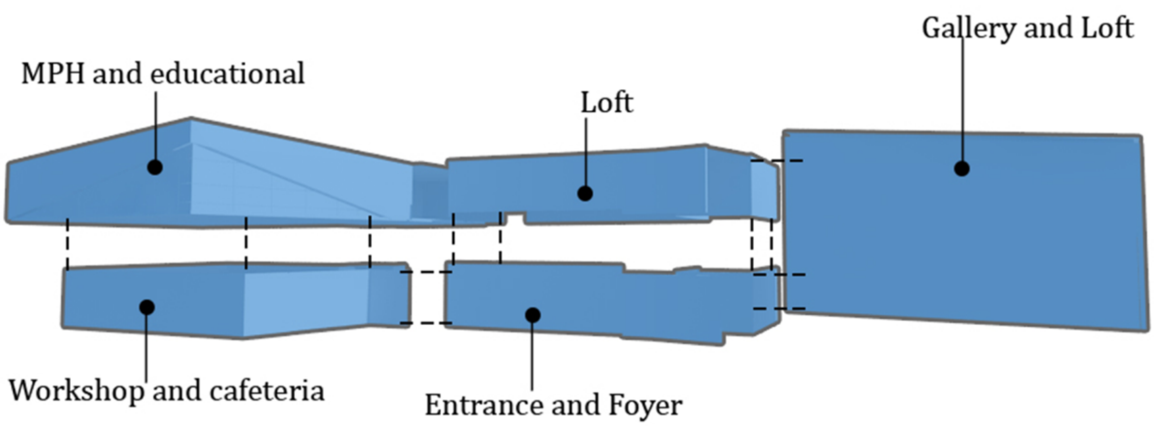


Fig.2.43. volume dismantling diagram

It is obvious that the building consists of different volumes. The entrance volume where there is also the foyer is a single volume in the ground floor. This volume is connected to a similar volume in the first floor which is the volume of the loft.
The gallery volume is a consistent volume on the two floors. The volume is connected to the loft volume in the first floor.

The other part of the building is two separated volumes that are connected vertically. The lower one is for the cafeteria and workshop classes. The other volume is for the multipurpose hall and the seminar rooms.
These volumes were inspired by the design guidelines and the objectives of the new addition of the Diocesano museum.

Layout and transition spaces analysis (Project views)

Fig.2.44 layout

The figure is showing a zoom in for the layout of the new addition of the Diocesano museum. From this layout it is clear the design of the new open space and the use of different floor patterns in order to define the space.

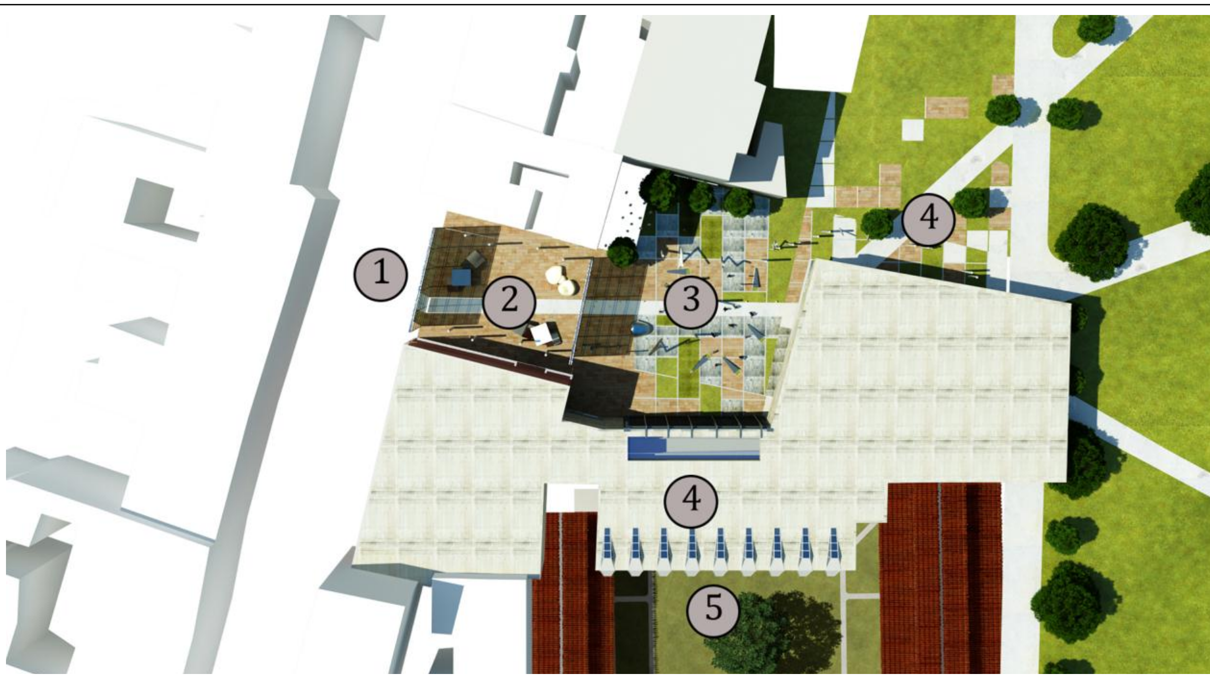


Fig.2.45. Layout with transition points

Figure 2.45 is showing different spaces with different experiences in the new addition of the museum.

In point 1 which is the entrance to the project from the Porta Ticinese street, where the small width of the street is not enough for users to read the elevation of the building as a whole. It well be perceived as a solid mass with perforated material as a corten.

Fig.2.46. Shot of the outdoor open gallery

As shown in Figure 2.46 it is the transition space number 2 as in figure2.45. This space is an outdoor exterior contemporary exhibition. This outdoor gallery is partially connected to the Porta Ticinese Street since the façade is a glass transparent façade, creating a very strong visual connection with the street.

From the other side the open enclosed space is also visible. The experience of being surrounded by the volume of the building from one side with the contemporary exterior expositions is very interesting.

The space is also defined by different floor patterns where it is obvious that there is a main pattern for visitors to just cross to the open enclosed space. The other pattern is for visitors who wish to enjoy more that midway space and to enjoy the exterior expositions.

The space is also defined by some sticks. These sticks are used here in this space to articulate the proportions of the space.

The experience of the huge bulk perforated building of the gallery is a particular characteristic of this outdoor gallery or we could name it as well a buffer zone.

Fig.2.47. view from the new designed open enclosed space

Fig.2.48. view from new designed open enclosed space

Figure2.47 and figure 2.48 corresponds to the transition space number 3 in figure 2.45
This space is the new designed open enclosed space. After arriving at this space a total different view and perspective of the project is perceived. Going from the buffer zone directly to such an open space where visitors are surrounded by diverse elements.

The open space is surrounded from one side by the new addition of the museum, where concrete finishes are used as the render for the façade. The building in this particular part is defined by solids and glass where there is a massive transparent glass façade. Visual connectivity between the open space and the interior of the building and the cloister is achieved thanks to the transparent façade.

The space is surrounded also by the existing buildings from one side and from the other side by a wide open view for the Parco delle basiliche. This view widens so much the space since there is nothing blocking the view to the park especially when arriving from a high diverse narrow street, as the Porta Ticinese Street.

The space is defined by different floor patterns at which there is the continuity of a main pattern from the buffer zone. Around this specific floor pattern there is the manipulation of two different patterns. Greens are also integrated with these floor stone patterns. Stone patterns are used to integrate with the Porta Ticinese street since the pavement of the existing Porta Ticinese is of stone.
The manipulation of these patterns resembles the urban diversity around the site.
Stone patterns represent the high density of the Porta Ticinese and the greens represent the Parco delle basiliche.

Another element is also the sticks. These sticks define another organic path which intersects with the rigid paths by the stones and the greens. These sticks also act as contemporary exterior features.

In this space visitors could go to two totally different zones. In figure 1.45 there are two points with the same number 4, this is because they are both accessed from the open enclosed space (point 3).

Fig.2.49. view from the cloister to the new addition

From point 3 to point 4 inside the building where by this point visitors are inside the space of the new addition of the museum. Users are connected visually to the open enclosed space from one side and the old existing cloister from the other side.
Arriving to point 5 a total different view of the building is perceived. The space is surrounded by the colonnade of the old museum in three sides. The fourth side is the façade of the new addition.

The colonnade and the inclined roof of the Diocesno museum was the main motive for us to design the façade of the building in such an inclined angle. Users of the building inside the cloister could feel no change in proportions between the old museum and the new addition.

The greens of the cloister of the old museum were kept as it was from before and the human pathways inside were left the same.

From the cloister the ramp inside the building is visible and the enclosed open space of the other side is as well seen. This kind of connection widens the cloister and enhances its proportions.

Fig.2.50. volume dismantling diagram

Going back again to the point number 3 in Figure 2.45 where another view with a total different experience could be perceived inside the space. In figure 2.50 the view of the overhanging volume enclosing the cafeteria in the ground floor and the educational zone in the first floor. The view of the park from that space is interesting and the overhanging of the new added volume addresses a total different view of the park that could not be perceived except at this place.

The use of the sticks in the space from this view guides in an abstract way the users to a fake pathway that is smoother and less rigid.

From this space and going forward towards the park is another experience. The view from the park to the building is different than the view from any other location.
According to Figure 2.51 point 5 is the point where users arrive to the park from the enclosed open space.

Fig.2.51. view from the Parco delle Basiliche

The view is form the park where the overhanging volume of the new addition is very dominant in this shot. From this angle it is difficult to realize the presence of the volume of the galleries with the special corten material. Users need to go to the space or at least a little bit closer to the building in order to explore.

Through this journey from a point to another or better say from one space to the other the language of the design is always perceived in a different way. The word design here is mentioned since, thanks to that special transition, there is not a huge difference between open spaces and volumes of the building. The threshold of each space is strongly defined by the end of the one before, if we consider them as a series pathway.

This concept as well addresses that open spaces are not just left or just designed by the addition of greeneries. In fact open spaces act as an important feature in the total design of the project. It could also be stated that open spaces design volumes.

This new addition could be an example of such a concept. The new designed enclosed space and the cloister played an important role in the design of the volumes of the new addition.
This special concept lies at the very thin border between urban design and architectural design. The complete mixing of buildings with spaces as have been shown is a very strong tool to design a project that is fully integrated with the context of the existing site.

Fig.2.52. view from the Parco delle Basiliche

Sections

Section AA

Fig.2.53. ground floor plan with section line AA

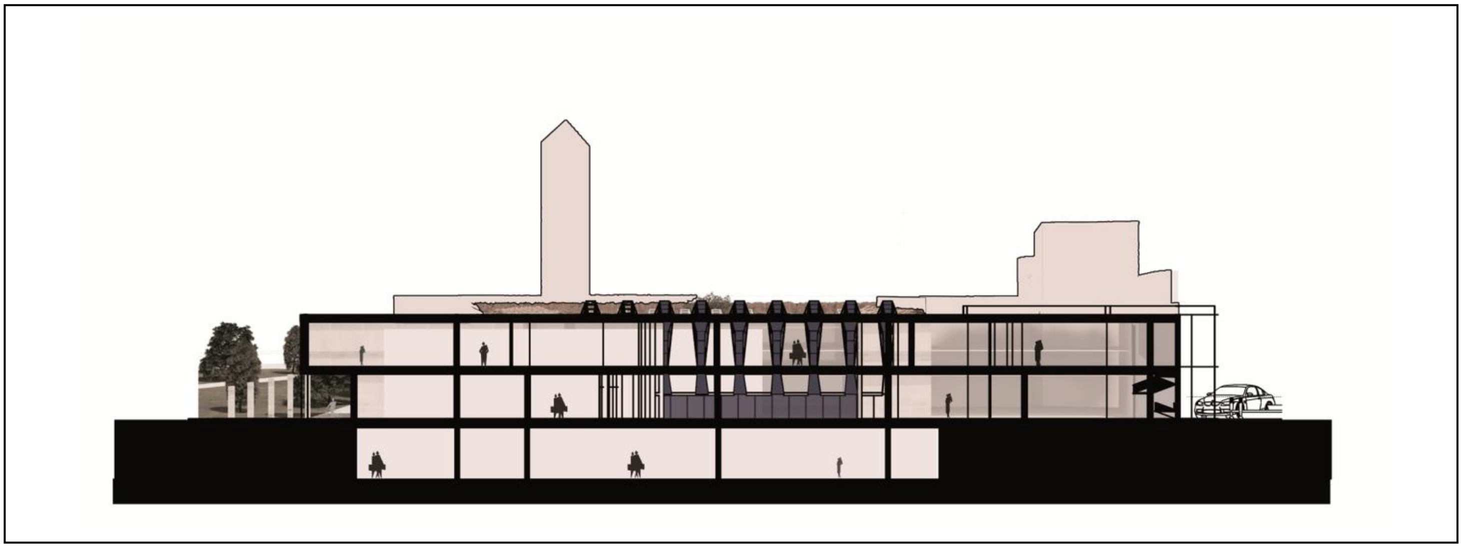


Fig.2.54. section AA through the new addition of the museum

Section BB

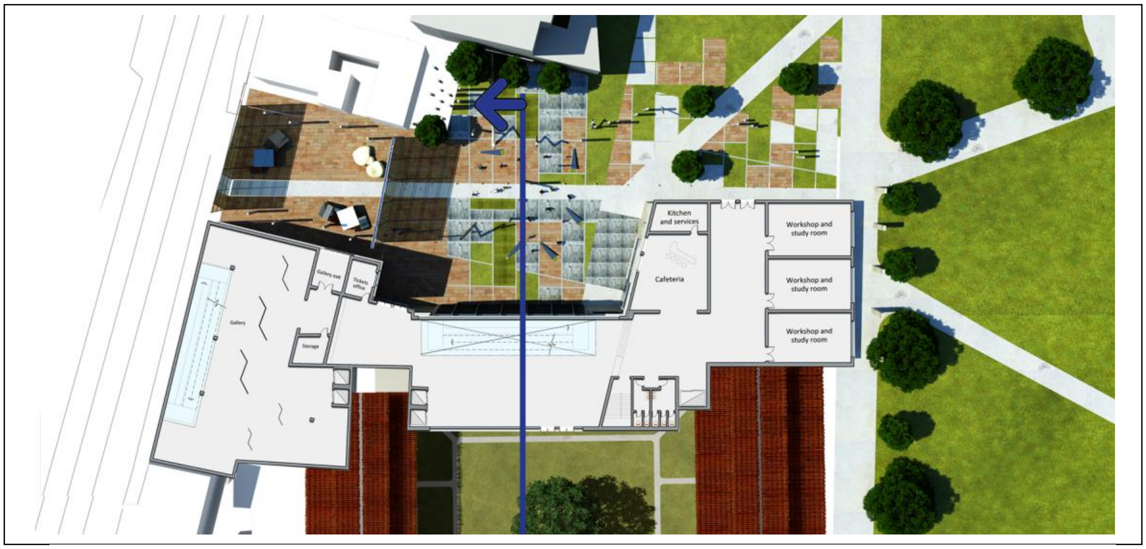


Fig.2.55. layout with section line BB

Fig.2.56. section BB

3D section

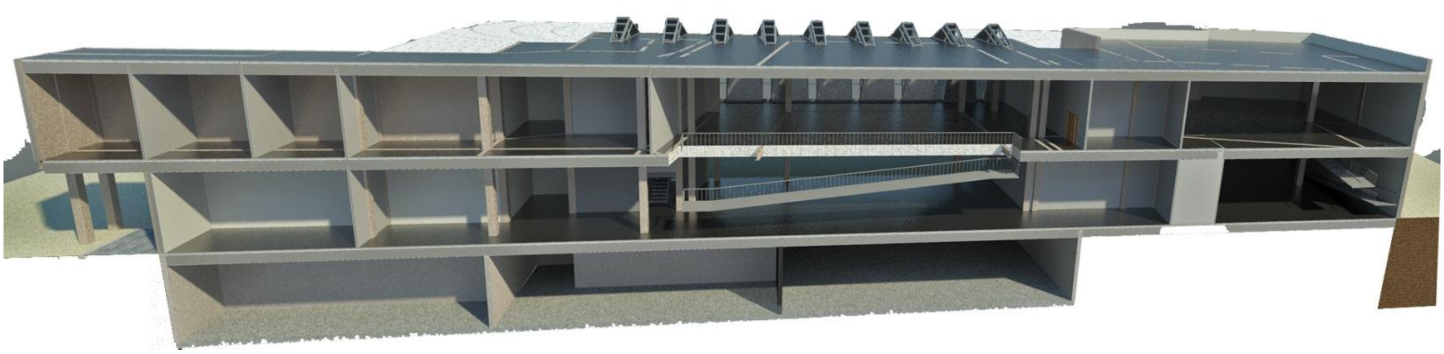


Fig.2.57. 3D section

Elevations

Fig.2.58. North elevation

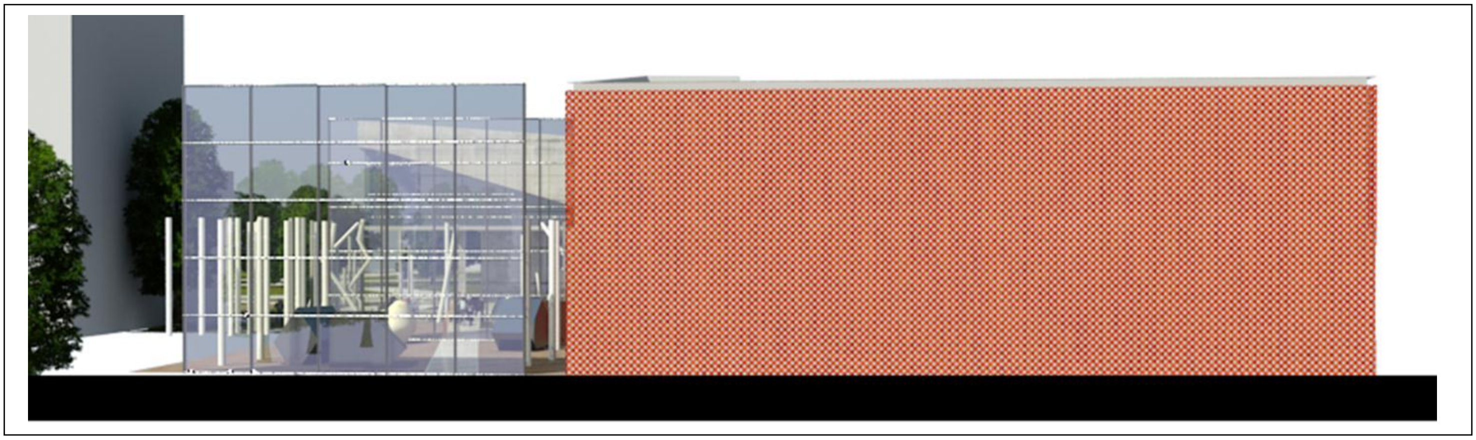


Fig.2.59. West elevation

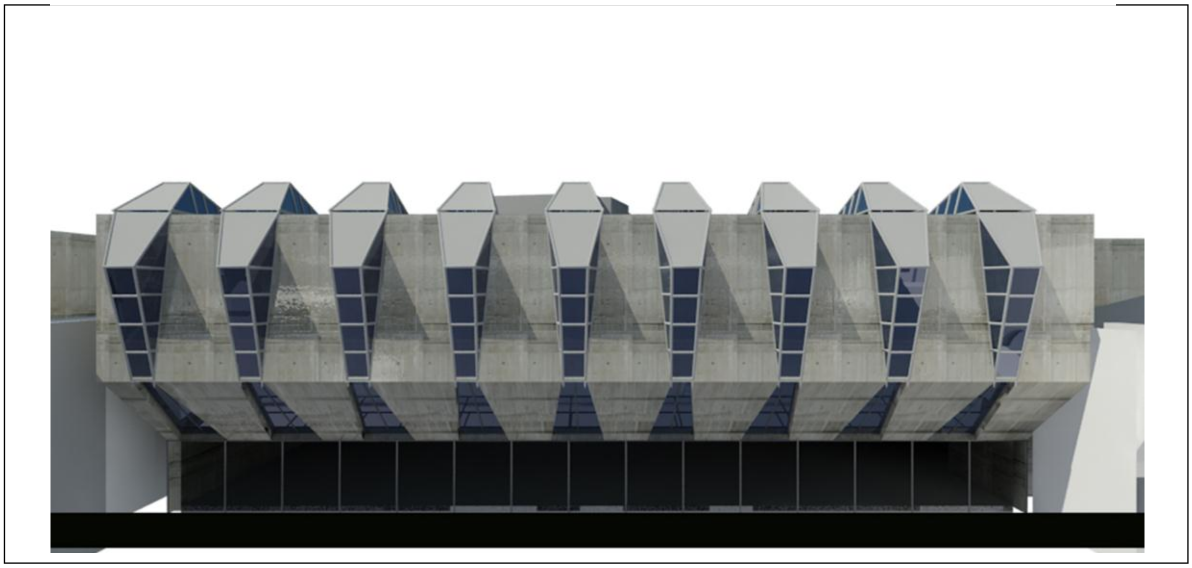


Fig.2.60. south elevation

Structural Design

Introduction

This chapter presents the necessary design and analysis which fulfill the structural integrity of the building and/or series of buildings of the project of the new addition to Diocesan museum belonging to the municipality of Milan. For structural simplicity, the building complex is divided in three buildings separated by a given distance as a gap.

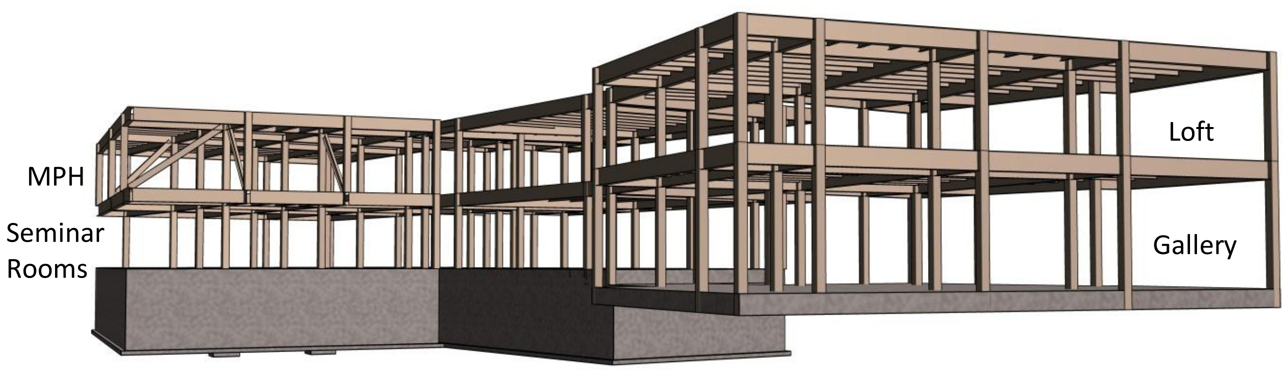


Fig.3.1. Building structural distribution and functions

Since the buildings have functions in which people may congregate, therefore type C3 is used for the categories of use in the standard[70]. The building on the right side of the graphic is dedicated to the exhibition areas in its two levels and the building which is located at the left part of the graphic has the multifunctional uses, while the one in between, holds the foyer in the first level which also works as a connector between two other buildings and on its second level, is providing the space for the loft. In figure one, for identifying buildings, they are named from right to left as building number one, two and three starting from Porta Ticinese toward the Parco delle Basiliche. Axis X is toward north and Y axis is toward Parco delle Basiliche and till the end of the chapter they would be referred to with their numbers. In the next three pages the architectural plans together with the position of the columns and structural gridlines are presented.

[70] EUROCODE 1. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. Table 6.1 categories of use. prEN: 1991-1-1-2001.

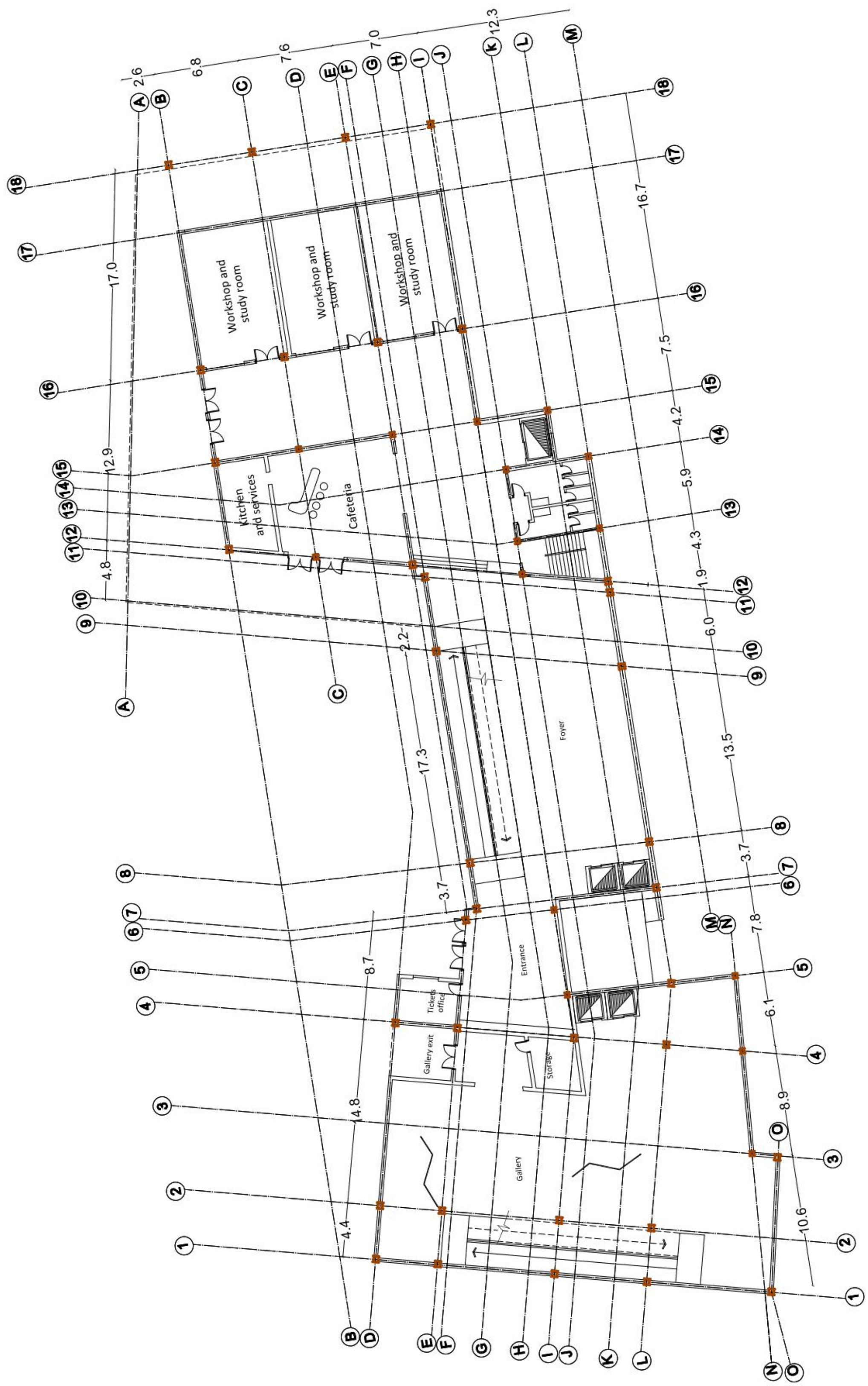


Fig.3.2. Ground floor plan and position of the columns

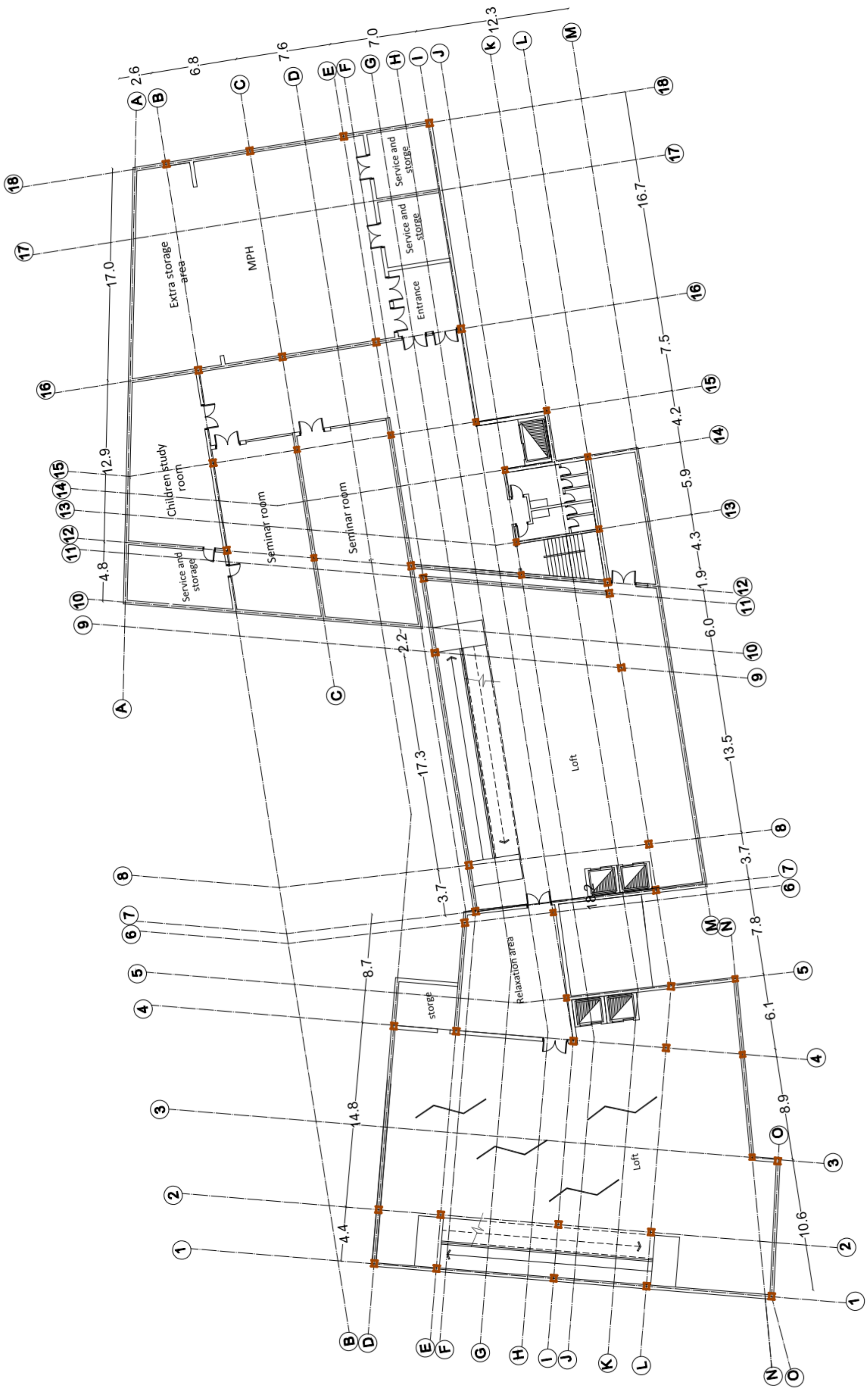


Fig.3.3. First floor plan and position of the columns

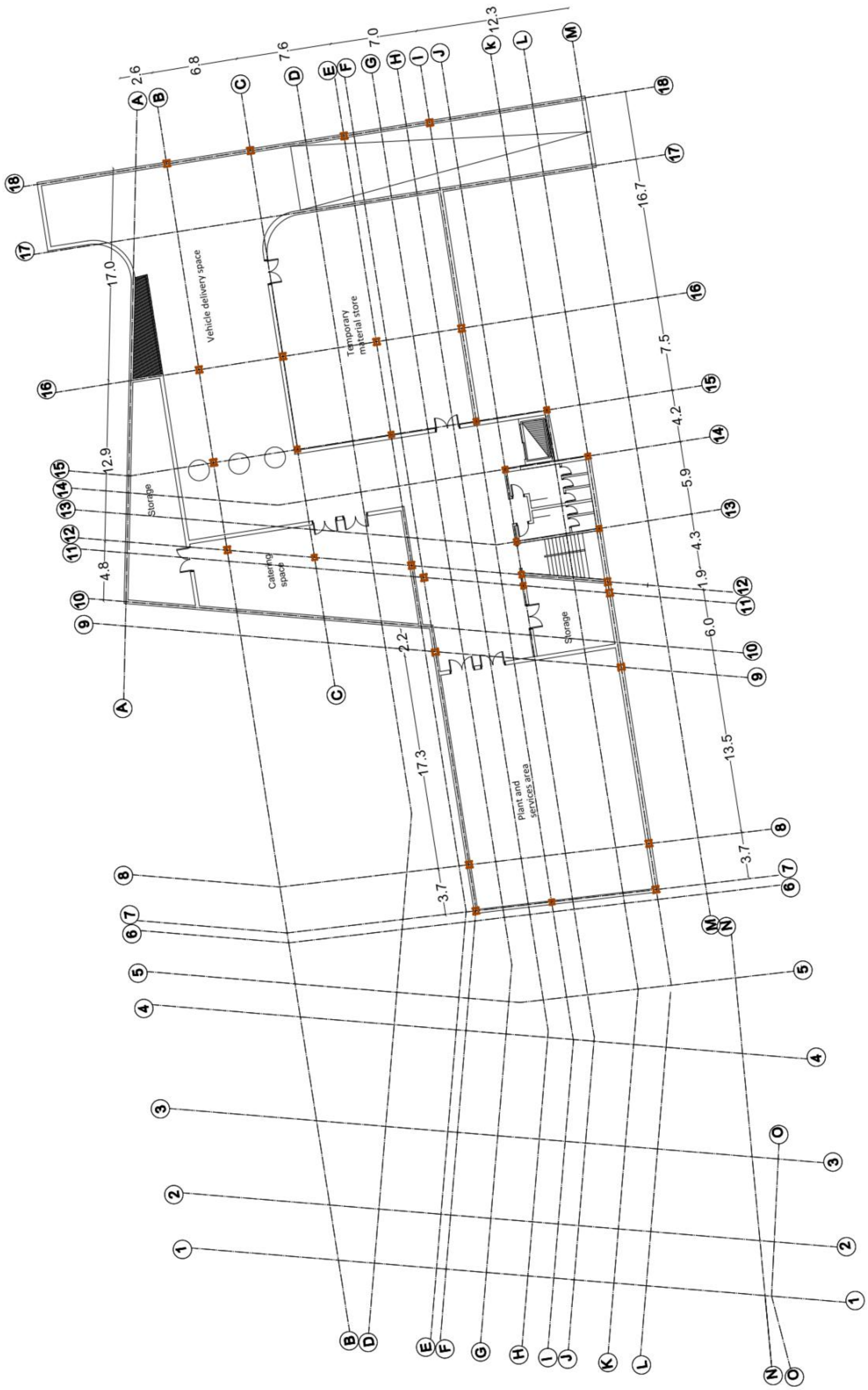


Fig.3.4. Basement plan and position of the columns

Loading Actions

In this project, for standards, generally, the Eurocodes are used for load calculation, structural design and design of the building against earthquake loading.

Gravitational loads

Gravitational loads by transitions from the slab to the beams and columns create axial and flexural loads for the columns and shear and flexural loads for the beams. They are mainly:

1- Dead Load of floors (stories-rooftop-stairs)
2- Dead Load of walls (internal partitions, external walls with façade or without)
3- Snow load in the rooftop
4- Live Load (stories-rooftop-stairs)
5- Elevators' live and dead loads

Dead loads of floors

Floors consist of a rather thick layer of concrete slab which lies over the main and secondary beams. Secondary beams are placed with the distance of 2.5 meters in respect to each other and their load is approximated and presented in the table.

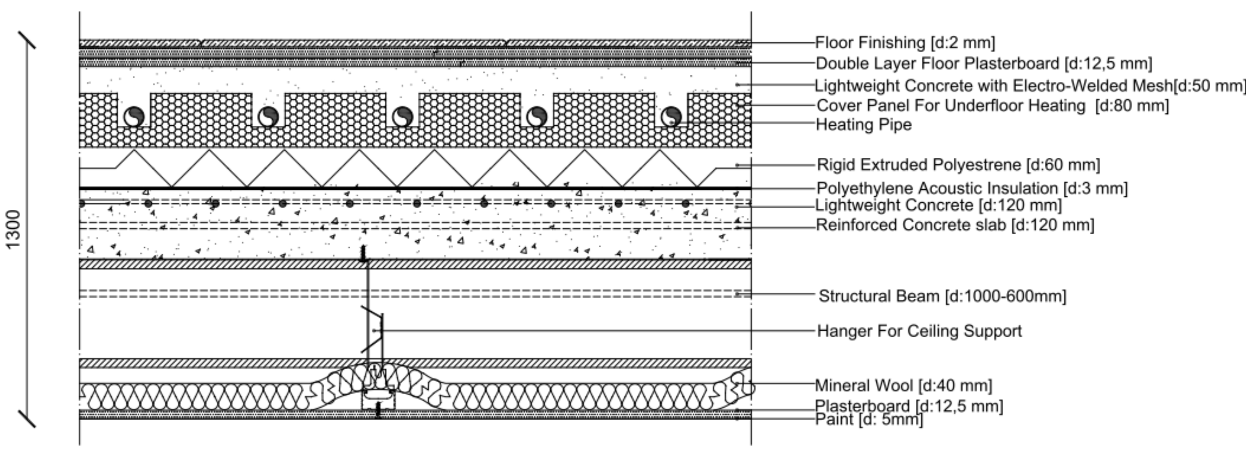


Fig.3.5. Technological solution for the intermediate floors

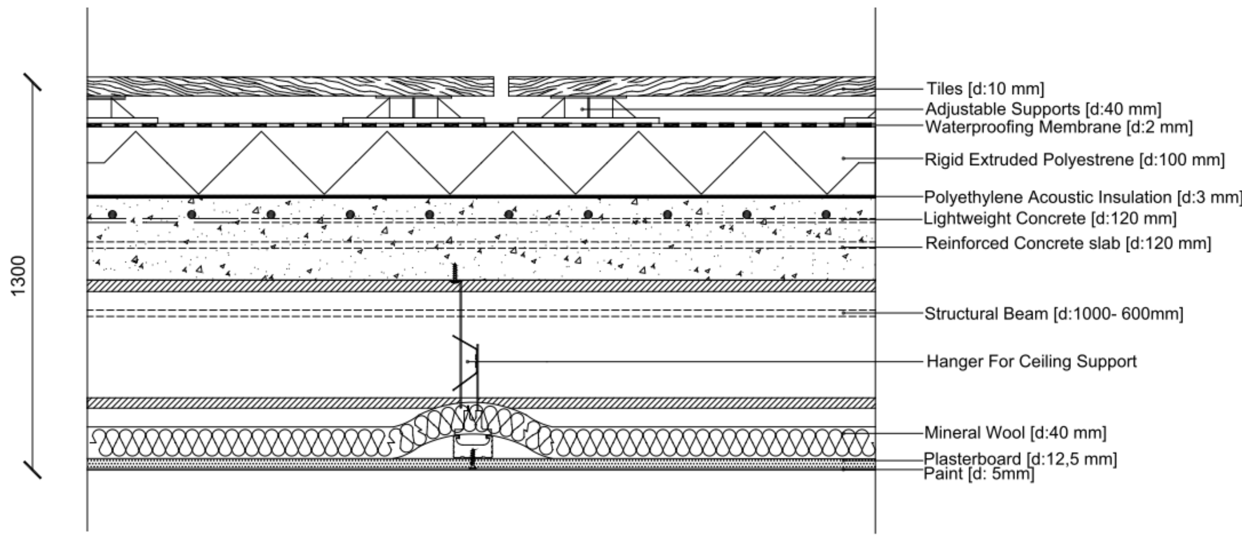


Fig.3.6. Technological solution for the roof

Dead Loads of the Ground and Intermediate floors			
Materials	Specific weight (Kg/m^3)	Thickness (cm)	Total weight of layer Kg/m^2
Finishing Tiles	2200.00	2.00	44.00
Mortar support	2100.00	3.00	63.00
water insulation-Bituminous	-	-	15.00
Lightweight concrete	600.00	12.00	72.00
Reinforced Concrete	2500.00	12.00	300.00
Secondary Beams each 2.5 m	-	-	50.00
Suspended ceiling with gypsum boards	60.00	-	60.00
Total weight in kg per square meter	-	-	604.00

Table.3.1. Dead loads of the Ground, intermediate and roof floors

Dead loads of walls

In this project, walls are built based on the combination of studs and Plasterboards installed on both sides or on one side. The space which is provided between the studs is used for placement of thermal insulations. Vertical partitions could be regarded as lightweight systems since there is no usage of heavy weight traditional materials like mortar and bricks in their configuration. Figure and Table below show the properties and specification of walls.

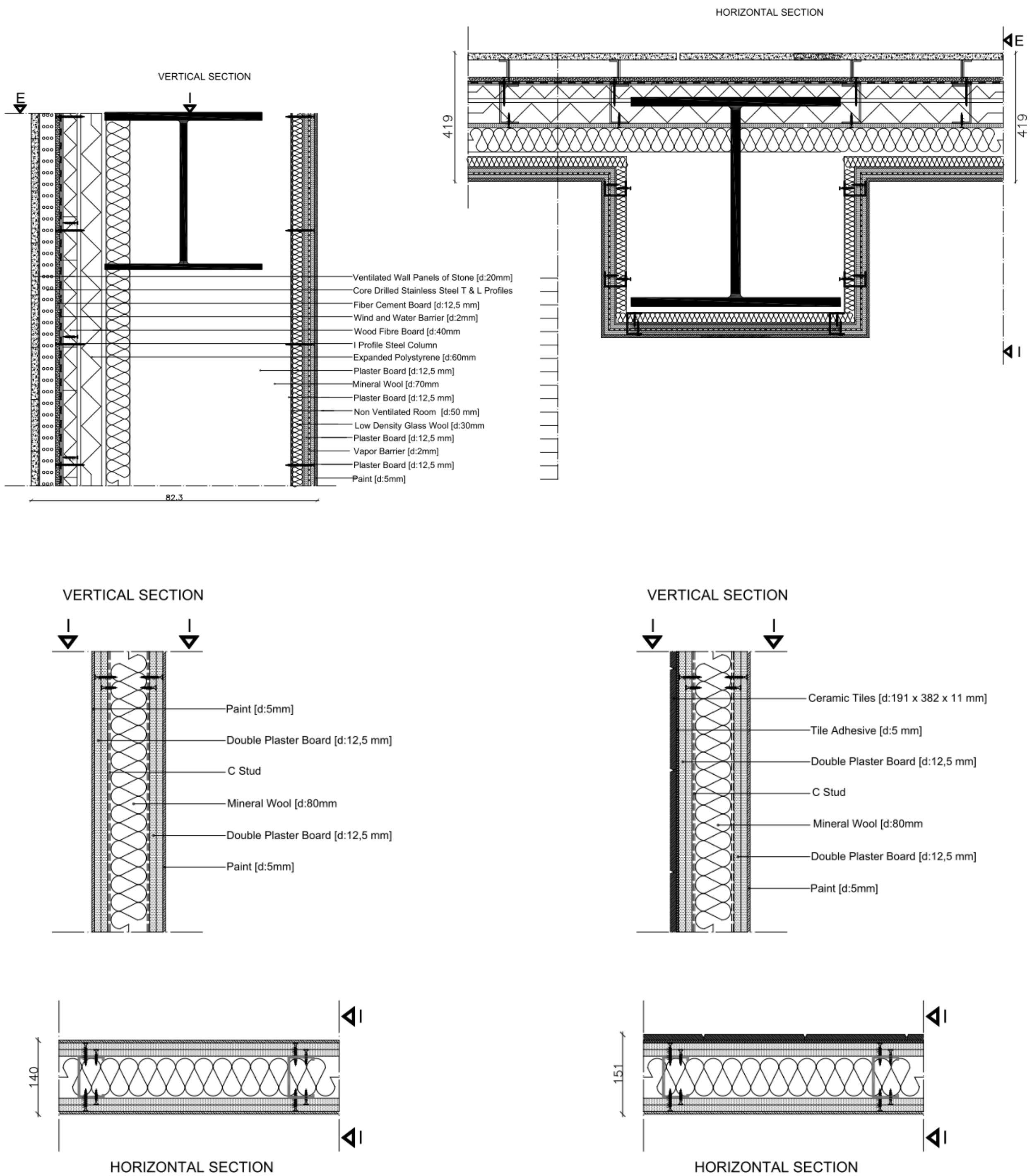


Fig.3.7. Technological solution for the walls and partitions

Weight of the walls				
Materials	Floor-to-Floor distance He (m)	Free Distance (m)	Weight of wall in unit surface area (Kg/m^2)	Weight of the wall in unit length (Kg/m)
Exterior and main interior walls	7.30	6.00	300.00	1800.00
Bathroom separation partition	7.30	6.00	150.00	900.00
Roof top edge wall	1.00	-	300.00	300.00

Table.3.2. weight of the walls

Snow load action

Properties of a roof or other factors mentioned below could cause the snow load to vary.

- The shape of the roof;
- Its thermal properties and the amount of heat generated under the roof;
- The roughness of its surface;
- The proximity of nearby buildings;
- The surrounding terrain;
- The local meteorological climate;

For the persistent / transient design situations: $S = \mu_i * Ce * Ct * S_k$

μ_i	is the snow load shape coefficient
$C\,e$	is the exposure coefficient
$C\,t$	is the thermal coefficient
S_k	is the characteristic value of snow load on the ground

The site has normal topography which means there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees. Therefore, C_e is chosen as 1. *Ct* is also assumed as 1 since the roof is very well insulated. Since the roof is flat, $\alpha = 0$ and $\mu_i = 0.8$.

$S = \mu_i * Ce * Ct * S_k = 0.8*1*1*190 = 152$ Kg/m^2

By considering the live load equal to 200 Kg/m^2 for the roof the total live load of the roof top is assumed as 200 (Kg/m^2)[71].

[71] Eurocode 1 - Actions on structures - Part 1-3: General actions -Snow loads

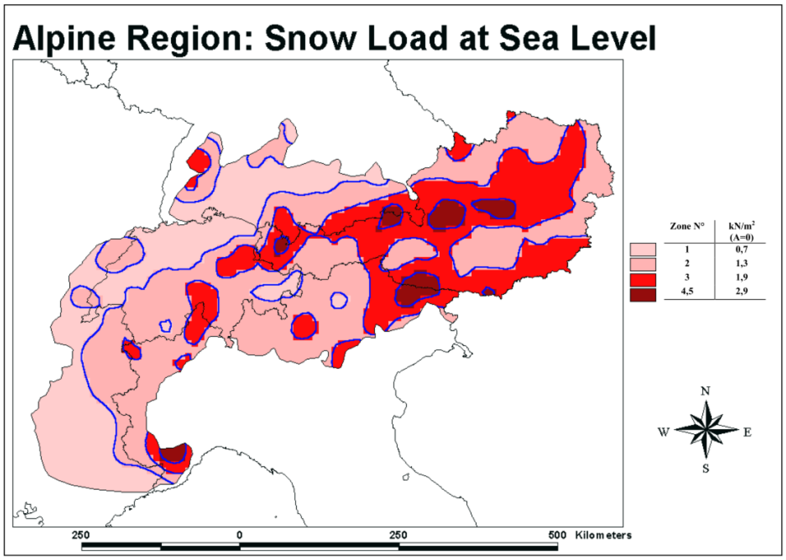


Fig.3.3. Snow load intensity on the ground level

Live load action of floors and rooftop

According to the Eurocode category of occupancy, the value of live load of 500 kg/m^2 is suitable to be considered for the public places like multipurpose halls and exhibition buildings. By applying this value for the whole buildings the live load considerations for children classrooms, corridors, lobbies and seminar rooms are fulfilled as well. Live load of the roof is considered as 200 kg/m2 and because the snow load is lower than this value the live load of the roof is assumed to remain as 200 (Kg/m2)[72].

Total Dead and Live Loads		
	Dead Load Kg/m^2	Live Load Kg/m^2
Floors	600.00	500.00
Rooftop	600.00	200.00

Table.3.3. Dead and live loads

Earthquake load action

Seismic and wind loads are main contributor to the lateral forces applied in a building. Since the probability of occurrence of both loading situations is rather rare and also the buildings are only around 15 meters tall, therefore hereby, only analysis relating to the lateral forces created by earthquake is presented.

[72] EUROCODE 1. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. Table 6.1 categories of use. prEN: 1991-1-1-2001.

To determine seismic force applied to the building there are two methods of equivalent static force and Dynamic method. Dynamic analysis of structure is utilized for buildings with the height higher than 50 meters which itself consists of two methods of Time History and Spectrum method. In Spectrum method, by using earthquake spectrum and earth properties, vibration frequencies during the earthquake will be determined and from that, the acceleration is found and with the Matrix analysis it is possible to find the displacements and forces in each level of bulling. In this project, in both directions of X and Y the buildings are resisting to the lateral forces by moment resisting frames. Therefore:

$T_x = 0.085H^{3/4}$ Parameters to be determined from the standard:

$S_e(T)$	is the elastic response spectrum;
T	is the vibration period of a linear single-degree-of-freedom system;
a_g	is the design ground acceleration on type A ground;
T_B	is the lower limit of the period of the constant spectral acceleration branch;
T_C	is the upper limit of the period of the constant spectral acceleration branch;
T_D	is the value defining the beginning of the constant displacement response range of the spectrum;
S	is the soil factor;
η	is the damping correction factor. K = 1 for 5% viscous damping;

By using the method of equivalent static load and calculating the period of vibration for steel structures with moment resisting flexural frames in both direction of X and Y, the response of the structure is determined. Considering the soil type, importance factor of the structure, the type of the system and by having the weight of each story it is possible to determine the lateral forces for each level.

$T = 0.085 * (15\ m)^{3/4} = 0.65$ sec

For type B of the soil: S = 1.35 T_B (s) = 0.05 T_C = 0.25 T_D = 1.2

$$T_C \le T \le T_D : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5\left[\frac{T_C}{T}\right]$$

$S_e(T) = 0.2 * 1.35 * 1 * 2.5 * [1.2/0.65] = 1.3\ m/s^2$

Since buildings are being favored by the same lateral resisting system in both directions, the distribution of seismic forces is equal for both directions[73].

Structural gap

Since the project, as one building, would be so huge from structural point of view, for the following reasons it is decided to divide the building in three separate structures:

1- It is preferred to separate the buildings every 40-50 meters in length of each side.

[73] Eurocode 8 - Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

2- Due to the irregularity of the building as a whole and seismic considerations.
3- In order to increase the safety of the complex; in the case of damage to a building other buildings are still safe.

Base Shear calculation

The following formula would provide the base shear for the desired building: $V = S_e(T)/g * W$

Building number 1	Floor area (m2)	D+0.2 L (Kg)	Weight of floor (Kg)	length of walls (m)	length of partitions (m)	height of wall (m) half to half level	height of partitions (m) half to half level	weight of walls (Kg)	Total weight of level (Kg)
Level zero	750.00	700.00	525000.00	120.00	20.00	2.50	2.50	97500.00	97500.00
level one	750.00	700.00	525000.00	120.00	20.00	5.00	5.00	195000.00	720000.00
level two	750.00	640.00	480000.00	120.00	0.00	3.50	2.50	126000.00	606000.00
							Total weight		1326000.00

Table.3.4. Building number one (Gallery) weight

Building number 2	Floor area (m2)	D+0.2L (Kg)	Weight of floor (Kg)	length of walls (m)	length of partitions (m)	height of wall (m) half to half level	height of partitions (m) half to half level	weight of walls (Kg)	Total weight of level (Kg)
Level zero	380.00	700.00	266000.00	15.00	20.00	2.50	2.50	18750.00	18750.00
level one	465.00	700.00	325500.00	20.00	20.00	5.00	5.00	45000.00	370500.00
level two	465.00	640.00	297600.00	100.00	0.00	3.50	2.50	105000.00	402600.00
							Total weight		773100.00

Table.3.5. Building number two (Loft) weight

Building number 3	Floor area (m2)	D+0.2L (Kg)	Weight of floor (Kg)	length of walls (m)	length of partitions (m)	height of wall (m) half to half level	height of partitions (m) half to half level	weight of walls (Kg)	Total weight of level (Kg)
Level zero	715.00	700.00	500500.00	100.00	80.00	2.50	2.50	105000.00	105000.00
level one	1140.00	700.00	798000.00	140.00	100.00	5.00	5.00	285000.00	1083000.00
level two	1140.00	640.00	729600.00	140.00	0.00	3.50	2.50	147000.00	876600.00
							Total weight		1959600.00

Table.3.6. Building number three (MPH) weight

Distribution of the Earthquake force in the levels: $F_i = (V_i - F_t)\, W_i h_i / \sum W_i h_i$ $T<0.7 \rightarrow F_t=0$

Building one	hi (m)	wi (Kg)	wihi	wihi/sum(wihi)	V (Ton)	Fi (Ton)	Fihi (Ton.m)
level one	6.50	1083000.00	7039500.00	0.38	172.38	65.82	427.85
level two	13.00	876600.00	11395800.00	0.62	172.38	106.56	1385.24
Total			18435300.00			172.38	1813.09

Table.3.7. Building number one (Gallery) story forces

Building two	hi (m)	wi (Kg)	wihi	wihi/sum(wihi)	V (Ton)	Fi (Ton)	Fihi (Ton.m)
level one	6.50	370500.00	2408250.00	0.32	100.50	31.67	205.86
level two	13.00	402600.00	5233800.00	0.68	100.50	68.83	894.78
Total			7642050.00			100.50	1100.64

Table.3.8. Building number two (Loft) story forces

Building three	hi (m)	wi (Kg)	wihi	wihi/sum(wihi)	V (Ton)	Fi (Ton)	Fihi (Ton.m)
level one	6.50	1083000.00	7039500.00	0.38	254.75	97.28	632.29
level two	13.00	876600.00	11395800.00	0.62	254.75	157.47	2047.16
Total			18435300.00			254.75	2679.46

Table.3.9. Building number three (MPH) story forces

Load combinations

For each design situation, the design values of the effects of the action(s) should be determined from the combination of the actions that may occur simultaneously. Since all of the assumed loads would happen simultaneously in a very rare situation, therefore, it is necessary to have load combinations in which only part of the loads are acting at an instance based on their probability of occurrence.

Serviceability limit state: $LC = \Sigma i\ Gk,i + Qk,1 + \Sigma j\ \gamma Qj\ \psi 0j\ Qkj$ where:

$G_{k,i}$ are the characteristic values of permanent actions
Q_{k1} is the characteristic value of the dominant variable action
$\psi_{0j}\ Q_{kj}$ are the combination (ψ_{0j} = 0.7) values of all other variable actions.

Ultimate limit state: $LC = \Sigma_I\ \gamma_{Gi}\ G_{ik} + \gamma_{Q1}\ Q_{1k} + \Sigma_j\ \psi_{0j}\ \gamma_{Qj}\ Q_{jk}$ where:

G_{ik} are the characteristic values of permanent actions and γ_{Gi} = 1.35 if against safety and γ_{Gi} = 1.0 if in favor of safety are the related load factors;

Q_{1k} is the characteristic value of the dominant variable action and γ_{Q1} = 1.5 if against safety and γ_{Q1} = 0 if in favor of safety is its load factor.

Q_{jk} are the characteristic values of the other variable actions and γ_{Qj} = 1.5 if against safety and γ_{Qj} = 0 if in favor of safety are the related load factors; ψ_{0j} = 0.7 are non- combination factors accounting for non-contemporaneous presence of all variable actions.

Ultimate Limit State	Permanent Actions $\gamma_{G,j}$		Leading or Main Variable Action $\gamma_{Q,1}$	Accompanying Variable Action $\gamma_{Q,i}$
	Unfavourable	Favourable		
EQU	1.1	0.9	1.5	1.5
STR	1.35	1.0	1.5	1.5

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A: domestic, residential areas	0.7	0.5	0.3
Category B: office areas	0.7	0.5	0.3
Category C: congregation areas	0.7	0.7	0.6
Category D: shopping areas	0.7	0.7	0.6
Category E: storage areas	1.0	0.9	0.8
Category H: roofs[a]	0.7	0	0
Snow loads on buildings (see EN 1991-3)			
– for sites located at altitude H > 1 000 m a.s.l.	0.70	0.50	0.20
– for sites located at altitude H ≤ 1 000 m a.s.l.	0.50	0.20	0
Wind loads on buildings (see (EN 1991-1-4)	0.5	0.2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0.6	0.5	0

Fig.3.9. Load Combination coefficients and Partial factor for actions (λ)[74]

Load Combinations in the project	
DSTLS1	1.350*DEAD
DSTLS2	1.350*DEAD + 1.500*LIVE
DSTLS3	1.000*DEAD + 0.450*LIVE + 1.000*EX
DSTLS4	1.000*DEAD + 0.450*LIVE – 1.000*EX
DSTLS5	1.000*DEAD + 0.450*LIVE + 1.000*EY
DSTLS6	1.000*DEAD + 0.450*LIVE – 1.000*EY
DSTLS7	1.000*DEAD + 1.000*EX
DSTLS8	1.000*DEAD – 1.000*EX
DSTLS9	1.000*DEAD + 1.000*EY
DSTLS10	1.000*DEAD – 1.000*EY
DSTLS11	1.000*DEAD + 1.000*EX
DSTLS12	1.000*DEAD – 1.000*EX
DSTLS13	1.000*DEAD + 1.000*EY
DSTLS14	1.000*DEAD – 1.000*EY

[74] M E Brettle, D G Brown , “*Steel Building Design: Concise Eurocodes In accordance with Eurocodes and the UK National Annexes*” table 2.2

Preliminary design for columns

Hereby, a preliminary design for a typical column is presented. The other columns have the same calculation process and the purpose is to have an initial stage grasp of the elements cross-section size to start modeling the building in the Software. Material properties are presented in the underneath tables and the formula are takes from Eurocode Standard for Steel Structures.

Steel Properties			
Analyzing Properties		Designing Properties	
Specific weight	7850 kg/cm^3	Yielding strength F_y	2400kg/cm^2
Elastic modulus E	2.04*10^{10} kg/cm^2	Ultimate strength F_u	4000kg/cm^2
Poison ratio	0.30		

Table.3.10. Steel Properties

Concrete Properties			
Analyzing Properties		Designing Properties	
Specific weight	2400 kg/cm^3	Compressive strength Fc	2400kg/cm^2
Elastic modulus E	2.20*10^9 kg/cm^2	Reinforcement yielding strength F_y	3000 kg/cm^2
Poison ratio	0.20	Transverse reinforcement yielding strength F_{ys}	3001 kg/cm^2

Table.3.11. Concrete Properties

Conceptual hand calculation for frame E Under vertical load

By approximate method of analysis of the frames, an engineer would grasp a good understanding of the loading situation in order to have a preliminary design of the sections. For the purpose of approximate analysis the inflexion point or point of zero moment is assumed to occur at 0.1L from the supports. In reality the point of zero moment varies depending on the actual rigidity provided by the columns. However, for the purpose of conceptual design of sections, this method is giving sufficiently accurate results. The load combination of (D+0.2L) is considered for this purpose and was applied in the form of a linear distributed force on the beams. The calculations are presented for all of the beams shown in the frame, however, only the column in the axe number E-4 is chosen for designing.

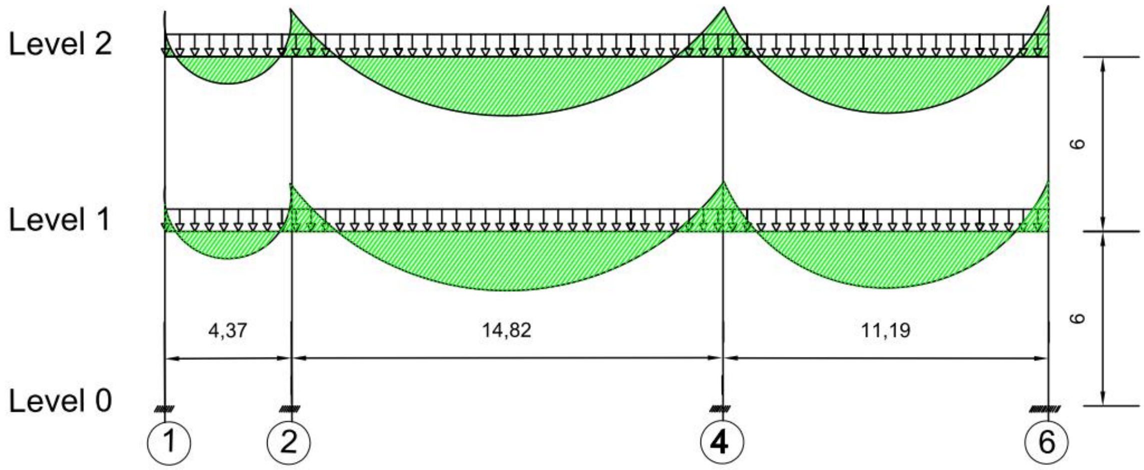


Fig.3.10. Conceptual moment diagram under the vertical loading condition

Level two

Shear forces at the supports of the beams

$V_{12} = 0.5qL = 0.5*4.64*4.37 = 10.13$ Ton

$V_{24} = 0.5qL = 0.5*4.64*14.83 = 34.4$ Ton

$V_{46} = 0.5qL = 0.5*4.64*11.2 = 25.984$ Ton

Moment at the edges and in the middle of the beams

$M_{12-} = 0.045qL^2 = 0.045*4.64*4.37^2 = 3.987$ Ton.m

$M_{12+} = q(0.8L)^2/8 = 4.64*(0.8*4.37)^2/8 = 7.08$ Ton.m

$M_{24-} = 0.045qL^2 = 0.045*4.64*14.83^2 = 45.92$ Ton.m

$M_{24+} = q(0.8L)^2/8 = 4.64*(0.8*14.83)^2/8 = 81.63$ Ton.m

$M_{46-} = 0.045qL^2 = 0.045*4.64*11.2^2 = 26.19$ Ton.m

$M_{46+} = q(0.8L)^2/8 = 4.64*(0.8*11.2)^2/8 = 46.56$ Ton.m

Level one

Shear forces at the supports of the beams

$V_{12} = 0.5qL = 0.5*5*4.37 = 10.92$ Ton

$V_{24} = 0.5qL = 0.5*5*14.83 = 37.07$ Ton

$V_{46} = 0.5qL = 0.5*5*11.2 = 28$ Ton

Moment at the edges and in the middle of the beams

$M_{12-} = 0.045qL^2 = 0.045*5*4.37^2 = 4.29$ Ton.m

$M_{12+} = q(0.8L)^2/8 = 5*(0.8*4.37)^2/8 = 7.63$ Ton.m

$M_{24-} = 0.045qL^2 = 0.045*5*14.83^2 = 49.48$ Ton.m

$M_{24+} = q(0.8L)^2/8 = 5*(0.8*14.83)^2/8 = 87.97$ Ton.m

$M_{46-} = 0.045qL^2 = 0.045*5*11.2^2 = 28.22$ Ton.m

$M_{46+} = q(0.8L)^2/8 = 5*(0.8*11.2)^2/8 = 50.17$ Ton.m

Conceptual hand calculation for lateral force

There are two approximate methods for analysis the frames against lateral forces: 1- Cantilever method and 2- Method of Portal. Cantilever method is useful for the frames with more than 5 stories. For the purpose of this project, the method of portal is chosen. The horizontal forces shown in the figure below were obtained by dividing the total value of static equivalent force of earthquake in the directions of X by the number of frames in that direction for each story. In this method the lateral force applied to each level is distributed to the columns of that level based on a ratio relating to the span of which a column is collecting the vertical loads. Therefore, it is a good approximation if we assign the lateral force to the middle columns twice as big as the corner columns. The lateral force is assigned directly to the center of the column in each level and it represents the shear force in that columns. By multiplying that shear to the half distance of the level it is possible to obtain the moment at the end of the column and consequently at the beginning of the beam. The moment of the beam, again, would give the shear force of the beam which represents the axial loads in the columns. This method, since it is very quick in terms of calculation time, would present valuable results in the initial stages of the designing in which usually time consuming accurate methods are not preferred. For the selected column E-4, since the slab is one dimensional, therefore, the moment created due to gravitational loading is only in 2D plane of the frame, but, the earthquake loading action is active on both X and Y directions.

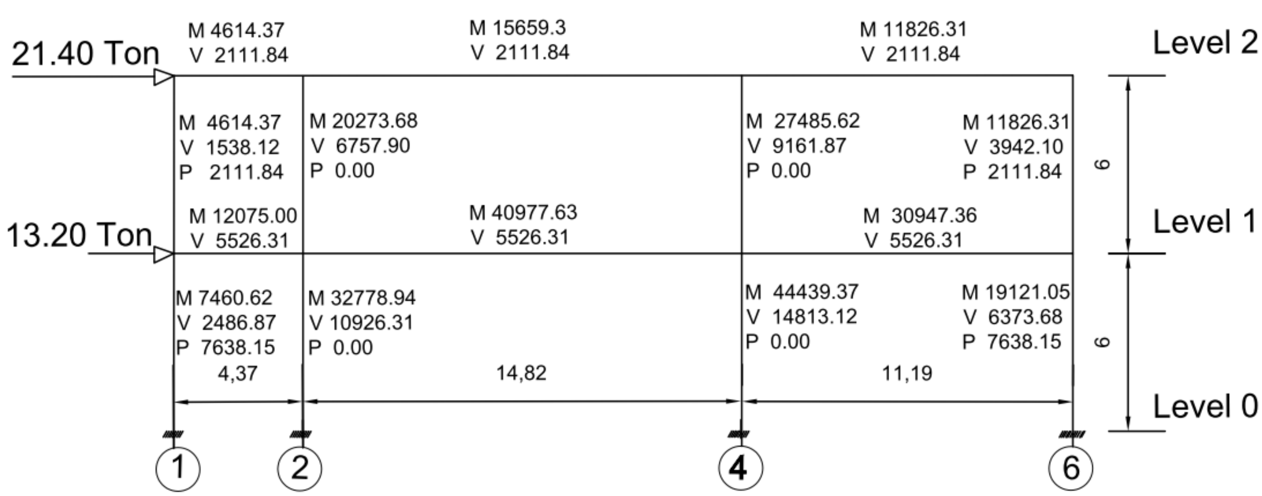


Fig.3.11. Members' forces obtained by portal method Axe E (Kg-m)

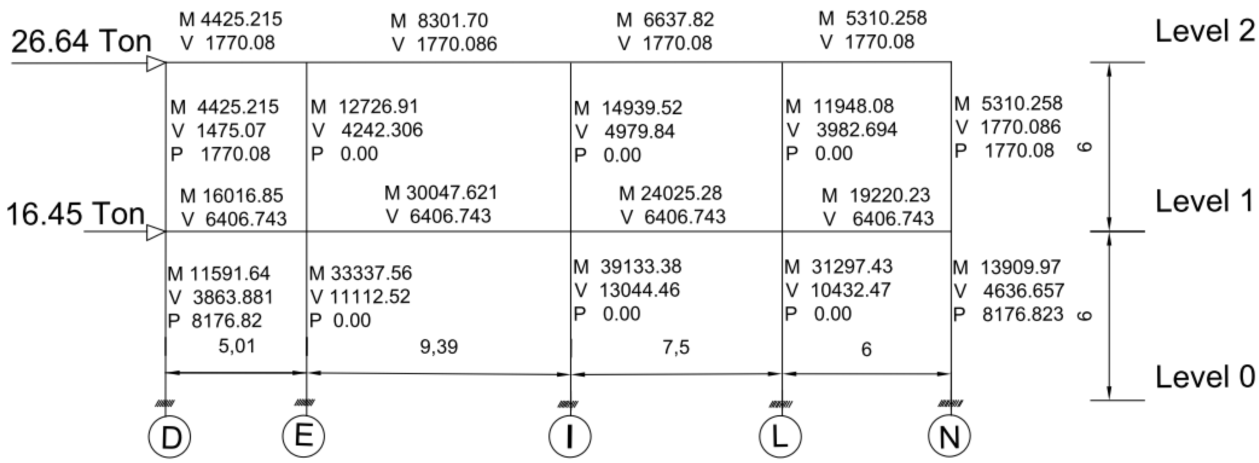


Fig.3.12. Members' forces obtained by portal method Axe 4 (Kg-m)

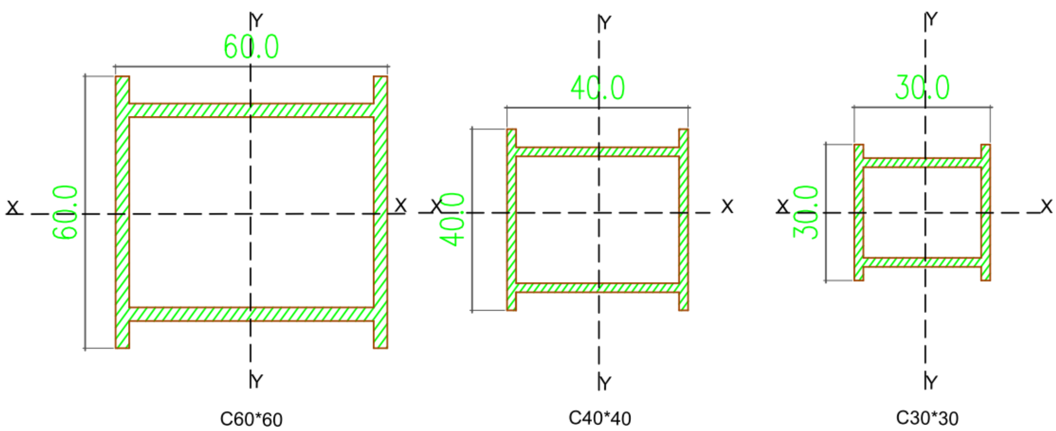


Fig.3.13. Types of columns (plate thickness is t=2.5cm for all types)

Properties of typical columns

A typical column, the column in the axe E-4, is chosen for the designing process. The forces which were calculated for the chosen frames under the gravitational loading and earthquake action are considered in this section. The difference between the moment at the right and left side of the column represents the amount of the moment applied to the column at the connection due to unbalance distribution of the loads in the gravitational loading condition. From analyzed frame it is found that:

Moment at level 1 applied on the column due to gravitational forces:

M_c = (49.48 (Ton.m) - 28.22 (Ton.m)) = 21.26 Ton.m

Also the summation of the beams' shear forces at their supports (axial loads for columns) would give the following axial force at level 1:

P_c= V23+V34+V23+V34 = 34.4+25.98+37.07+28 = 125 Ton

Three types of the columns were chosen here for preliminary stage of designing. (C60*60, C40*40 and C30*30 with the thickness of steel plates of 2.5 centimeters). Plates are welded to each other and the column creates a square shape meaning the moment of inertia in both direction of X and Y is almost the same.

Section	Area cm^2	Moment of Inertia over neutral axes cm^4 $I_x = I_y = bh^3/12+Ad^2$
C60*60	600	$I_x = I_y = (60*2.5^3/12+60*2.5*31.125^2)*2+2*2.5*60^3/12 = 290788.73\ cm^4$
C40*40	400	$I_x = I_y = (40*2.5^3/12+40*2.5*21.125^2)*2+2*2.5*40^3/12 = 116023.95\ cm^4$
C30*30	300	$I_x = I_y = (30*2.5^3/12+30*2.5*16.125^2)*2+2*2.5*30^3/12 = 44705.46\ cm^4$

Table.12. column types' moment of inertia and area of cross section

Eurocode approach for column designing

Design Process[75]:

1- Determine the $N_{b,y,Rd}$ and $N_{b,z,Rd}$ maximum axial loads to prevent buckling
2- Determine $M_{b,R}$ Maximum moment to prevent torsional buckling
3- Determine $M_{cb,z,Rd}$
4- Determine C_{my}, C_{mz} and C_{mLT} based on the shape of the bending moment diagram
5- Determine the K factors
6- Verify the biaxial bending combined with flexural buckling about the major axis using: $$\frac{N_{Ed}}{N_{b,y,Rd}} + k_{yy}\frac{M_{y,Ed}}{M_{b,Rd}} + k_{yz}\frac{M_{z,Ed}}{M_{cb,z,Rd}} \leq 1$$
7- Verify for biaxial bending combined with flexural buckling about the minor axis using: $$\frac{N_{Ed}}{N_{b,z,Rd}} + k_{zy}\frac{M_{y,Ed}}{M_{b,Rd}} + k_{zz}\frac{M_{z,Ed}}{M_{cb,z,Rd}} \leq 1$$

Class of cross section

In order to define the class of cross section, we should obtain the maximum value of *C/t* from the table 5.2 of the Eurocode 3. There are 4 classifications that start with the class number one which is working in Plastic range and class number 4 which is prone to local buckling before reaching the maximum resistance of the cross section.

[75] M E Brettle, D G Brown , "*Steel Building Design: Concise Eurocodes In accordance with Eurocodes and the UK National Annexes*" – Design Procedures

$$\alpha = \frac{1}{2}\left(1 + \frac{N_{Ed}}{f_y c\, t_w}\right)$$

$$\psi = \frac{2N_{Ed}}{Af_y} - 1$$

α = 0.5 * (1+ 125000 kg/ (2400 kg/cm^2*40 cm *2.5 cm) = 0.76

Ψ = 2*125000 kg/ (400 cm^2*2400 kg/cm^2) -1 = - 0.739

For the steel type S275 the maximum value of *C/t* for having class number one is obtained by 365/ (13α -1) when the alpha value is more than 0.5. Therefore:

Max C/t = 365/ (13*0.76-1) = 41.10

For the selected column: C/t = 40 cm /2.5 cm=16 < 41 → class type one for cross section[76].

Partial factors for resistance

The partial factors y_m should be applied to the various characteristic values of resistance in this section is given as:

Resistance of cross-section whatever the class is: y_{M0} = 1.00
Resistance of members to instability: y_{M1} = 1.00
Resistance of cross-sections in tension to fracture: y_{M2} = 1.10

Plastic modulus of the cross section (W_{pl})

The plastic section modulus is the sum of the areas of the cross section on each side of the PNA (which may or may not be equal) multiplied by the distance from the local centroids of the two areas to the PNA (Plastic Neutral Axes).

For the column C40 as class one → W_{pl} = 2(45*2.5*21.25) + 2*2.5*402/4 = 6781.25 cm^3

Column buckling resistance

A compression member should be verified against buckling as follows:

$$\frac{N_{Ed}}{N_{b,Rd}} \le 1.0$$

Where:

N_{Ed} is the design value of the compression force

$N_{b,Rd}$ is the design buckling resistance of the compression member

The design buckling resistance of a compression member should be taken as:

$$N_{b,Rd} = \chi \frac{Af_y}{\gamma_{M1}}$$

[76] Eurocode 3: Design of steel structures — Part 1.1: General rules and rules for buildings , Table 5.3.1

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \overline{\lambda}^2}} \text{ but } \chi \leq 1$$

$$\phi = 0.5\left[1 + \alpha\left(\overline{\lambda} - 0.2\right) + \overline{\lambda}^2\right]$$

α is the imperfection factor and could be found from table. For the cross section of C40 α=a=0.21

Buckling curve	a	b	c	d
Imperfection factor α	0.21	0.34	0.49	0.76

Fig.3.14. Imperfection Factor[77]

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \overline{\lambda}^2}} \text{ but } \chi \leq 1$$

The non-dimensional slenderness ƛ is given by:

$$\overline{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}}$$

N_{cr} is the elastic critical force for the relevant buckling mode For flexural, or strut buckling, N_{cr} is the Euler load, i.e.

$$N_{cr} = \frac{\pi^2 EI}{L^2}$$

N_{cr}= Π^2*E*I/L^2=3.14^2 * 2.04*10^4*116023.95/600^2 = 6355276.319 kg = 6355.27 Ton

λ = √(400*2400/6355276.319)=0.388

Φ = 0.5* [1+0.21(0.388-0.2) +0.388^2]=0.5950

X = 1/ (0.5950 + √(0.5950^2 – 0.388^2)= 0.9559

$N_{b,Rd}$ = 0.9559 * 400 cm^2 *2400 kg/cm^2 = 917664kg

Bending resistance

The design buckling resistance of a laterally unrestrained element should be taken as:

$$M_{b,Rd} = \chi_{LT} W_y \frac{f_y}{\gamma_{M1}}$$

X_{LT} is the reduction factor for lateral-torsional buckling.

[77] M E Brettle, D G Brown , "*Steel Building Design: Concise Eurocodes In accordance with Eurocodes and the UK National Annexes" Table 6.5*

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \beta \bar{\lambda}_{LT}^2}} \quad \text{but } \chi_{LT} \leq 1$$

$$\phi_{LT} = 0.5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - \bar{\lambda}_{LT,0}\right) + \beta \bar{\lambda}_{LT}^2\right]$$

$$\bar{\lambda}_{LT,0} = 0.4 \text{ for rolled sections} \qquad \beta = 0.75 \text{ for rolled sections}$$

In its conservative form:

$$\bar{\lambda}_{LT} = \frac{L/i_z}{96}$$

$\bar{\lambda}$ = 600 cm/(17.03cm*96) = 0.37

Φ_{LT} = 0.5* [1+0.21*(.37-.04)+0.75*.037^2] = 0.548

χ = 1/ [0.548+ √(0.548^2-0.75*0.37^2)] = 1.007 <1 → χ=1

→ $M_{b,Rd}$ = 1*6781.25*2400/1 = 16275000 kg.cm

Shear control

Where *VEd < 0.5Vpl,Rd* the effect of the shear force on the bending resistance may be neglected, except where shear buckling reduces the section resistance. Therefore, since the existing shear forces are much less than V_{pl}, the effect of shear is neglected in the calculation of the column.

$$V_{pl,Rd} = \frac{A_v\left(f_y / \sqrt{3}\right)}{\gamma_{M0}}$$

A_v is the shear area $V_{Pl,Rd}$= 400*2400/√3/1= 554256.25 Kg

Maximum moment resistance of cross section

The design resistance for bending about one principal axis of a cross-section is determined as follows:

$$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$$

$N_{c,Rd}$= Af_y/y_{M0}= 400*2400=960000 kg N_{Ed}= 125000 kg

$M_{c,Rd}$=$M_{pl,Rd}$= W_{pl}*f_y/y_{M0}= 6781.25*2400/1=16275000 kg.cm M_{Ed}= 65699.37 kg.m

Verification of the column under both bending and axial forces

Major axes:

125000 kg/960000*(0.9559)kg +0.72*6569937kg.cm/16275000kg.cm + 0.576*3333756 Kg.cm/16275000 Kg.cm= 0.4373 < 1 → Ok

Minor axes:

125000 kg/960000*(0.9559)kg +1*6569937kg.cm/16275000kg.cm + 0.96*3333756 Kg.cm/16275000 Kg.cm= 0.7365 < 1 → Ok

Allowable stress design Method

Gyration Radios $r_x=r_y=\sqrt{(116023.95/400)} = 17.03$ $\lambda = K*L/r$

K: is the effective length factor and for the column of both ends fixed would be 0.5

L: is the length of the column

$\lambda_x= 0.5*600/17.03 = 17.61$

$C_c=\sqrt{(2\pi^2*E/2400)} = 6440/\sqrt{2400}=131.5$ 17.61<131.5

$ß= \lambda/C_c = 17.61/131.5 = 0.1339$ $\lambda<C_c$ → $F_a= (1-.5ß^2)/F.s*Fy$

$Fs = 5/3+3\lambda/8C_c-1/8*(\lambda/C_c)^3 = 5/3+3/8*17.61/131.5-1/8*(17.61/131.5)^3 = 1.71$

$F_a = (1-.5*0.1^2)/Fs = 0.585*2400 = 1404.7$ Kg/cm^2

$F_{bx} = 0.6*2400 = 1440$ Kg in the case without buckling consideration

Existing stresses:

$F_a=P/A=125000/400=312$ Kg/cm^2 < 1400 Kg/cm^2

S=I/y= 116023.95/20=5801.1958

$f_{bx}=M/S=21.26*10^5/5801.19 = 366.47$ Kg/cm^2

Consideration of Earthquake

The chosen column under lateral forces of earthquake does not have any axial load generated according to the approximate method but it carries considerable amount of Moment generated due to the lateral force.

$M_{EX+Vertical} = 44439.37+21260.00 = 65699.37$ Kg.m

$f_{bx} = M/S = 65699.37*10^5/5801.19 = 1132.51$ Kg/cm^2 <1440 Kg/cm^2

Total stress: $f_{bx}+ f_a$ = 1132.51 Kg/cm^2 +312 Kg/cm^2 = 1444.51 Kg/cm^2 since the extra stress is only 0.3 percent higher than the allowable stress design; therefore, the cross section is accepted.

Software analysis

Following the conceptual design of the selected frame in the complex, the overall range and size of the cross sections for the beams and columns, a good perception of the amount of loads and a good approximation of the building weight were obtained. These achievements are beneficial in several ways like introducing the correct sections as input for software and checking the final result of the software. The analysis and design software of Etabs is used for modeling the complex buildings in which the Eurocode 3-1993 is used for the software analysis and design. Since the whole project consists of three separate buildings, therefore, the whole project needs to be modeled separately in three buildings, but, the initial assumptions and input data and even the typical beam and columns sections are the same for three buildings. The gap provided between the buildings is 2 percent of the height of the buildings. For the height of 15 meters in this project a gap of 30 centimeters is provided between the two separated buildings.

Building of Gallery (number one)

This building is built in two levels from ground floor and total height of the building is 15 meters consisting of two levels of 6 meters and about 1.3 meter thickness of the floors. For the floor system, the one-way slab is used.

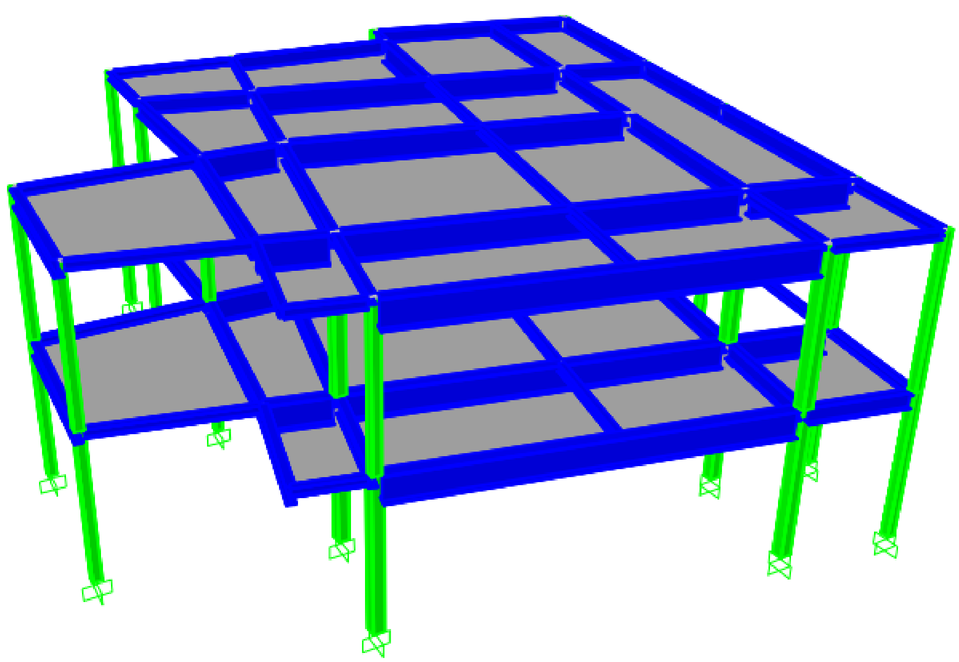


Fig.3.15. 3D introduction of the Building

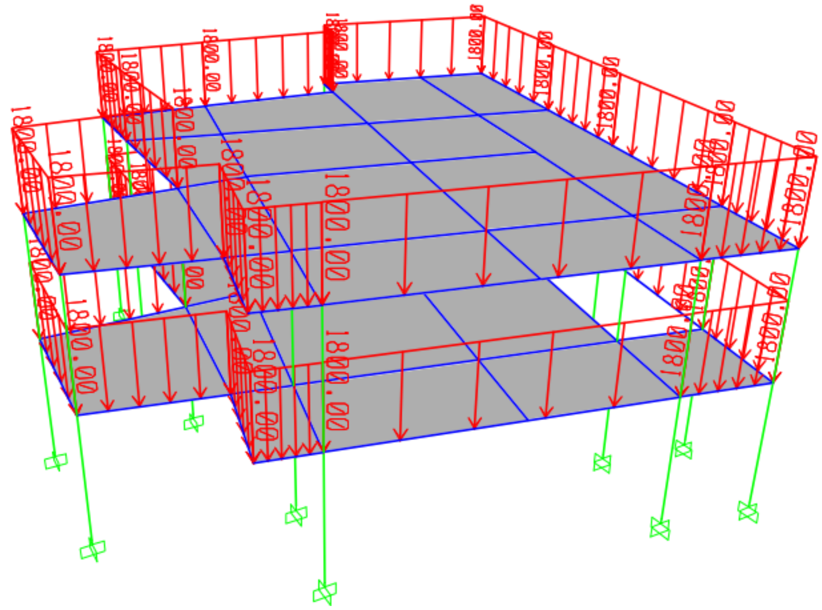


Fig.3.16. Exterior wall applied Loads (Kg)

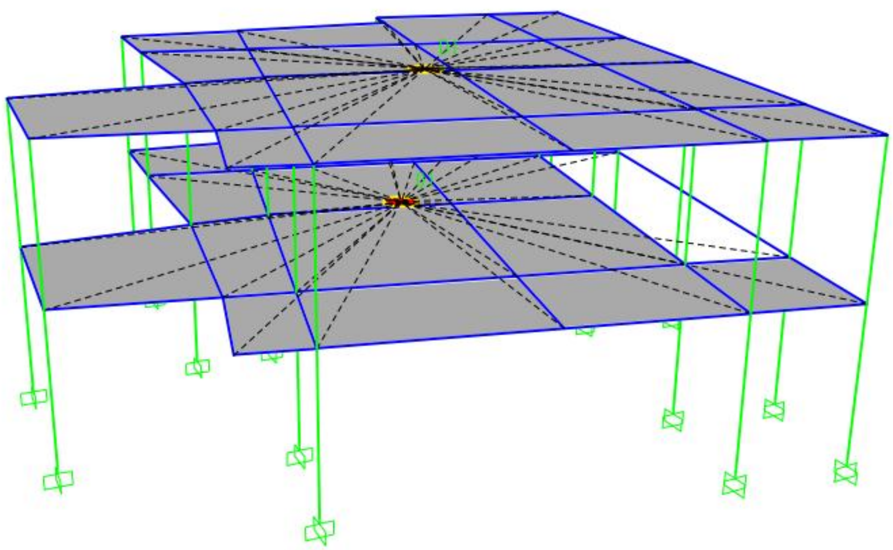


Fig.3.17. 3D of the structure showing the Extent of the floor Diaphragm

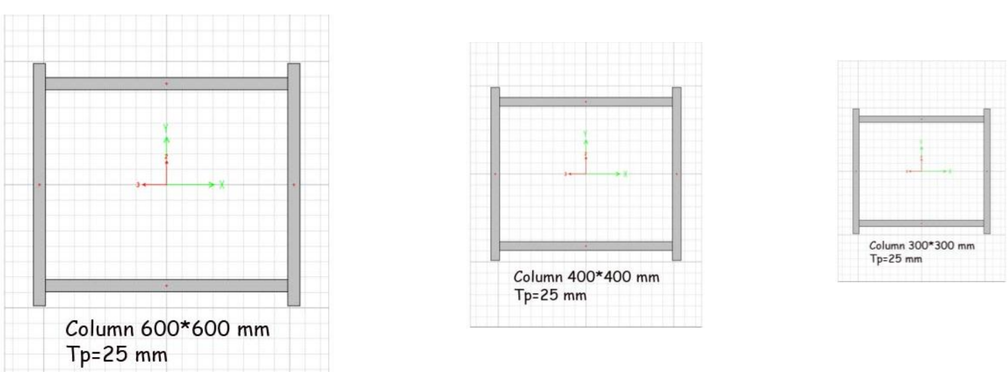


Fig.3.18. Columns' types (60*60-40*40-30*30)

Structural Plans

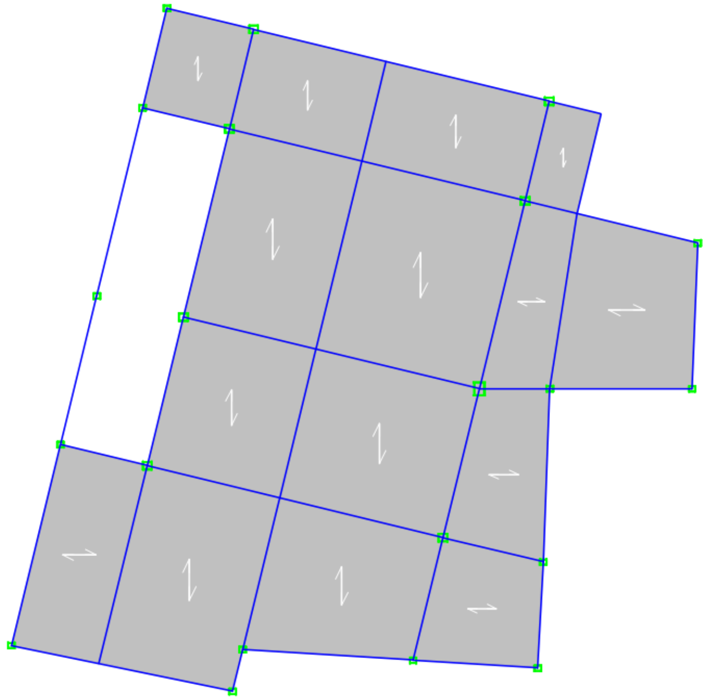


Fig.3.19. First level beams' plan and direction of the slab

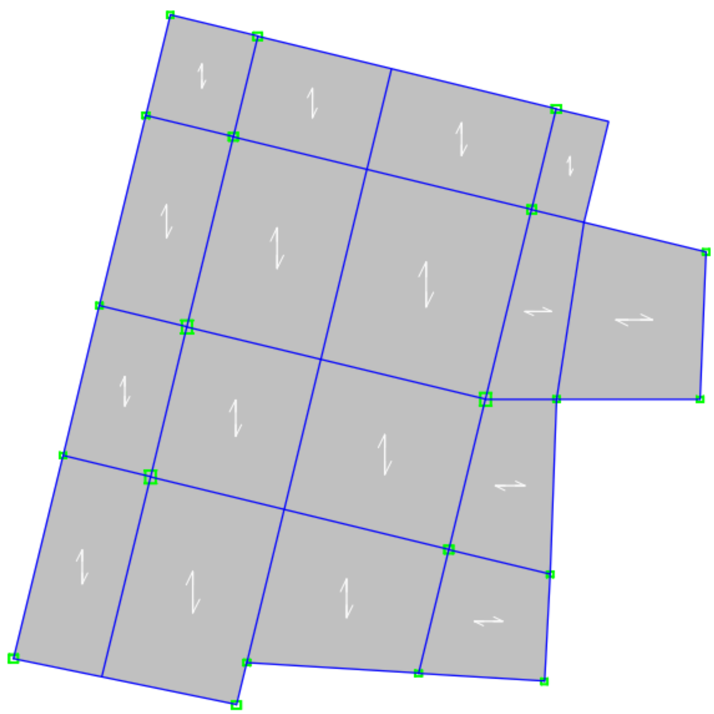


Fig.3.20. Second level beams' plan and direction of the slab

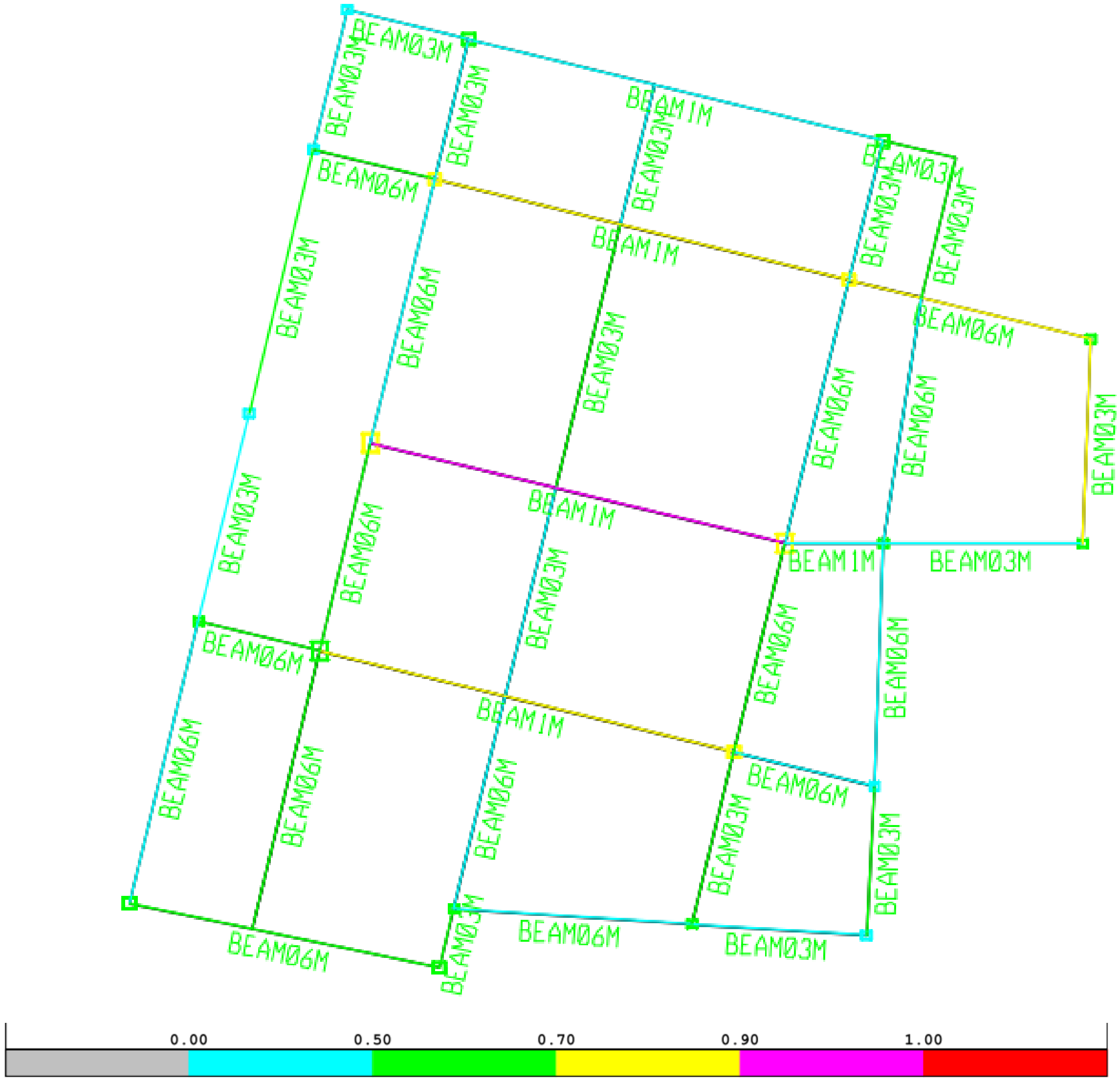


Fig.3.21. Designed beams' plan and associated stress ratio of the members- First level

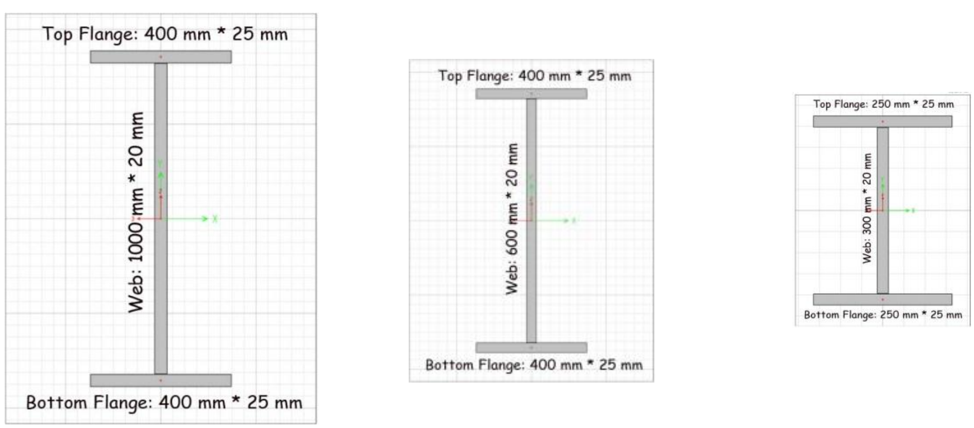


Fig.3.22. Beams' types (1m, 0.6m and 0.3m)

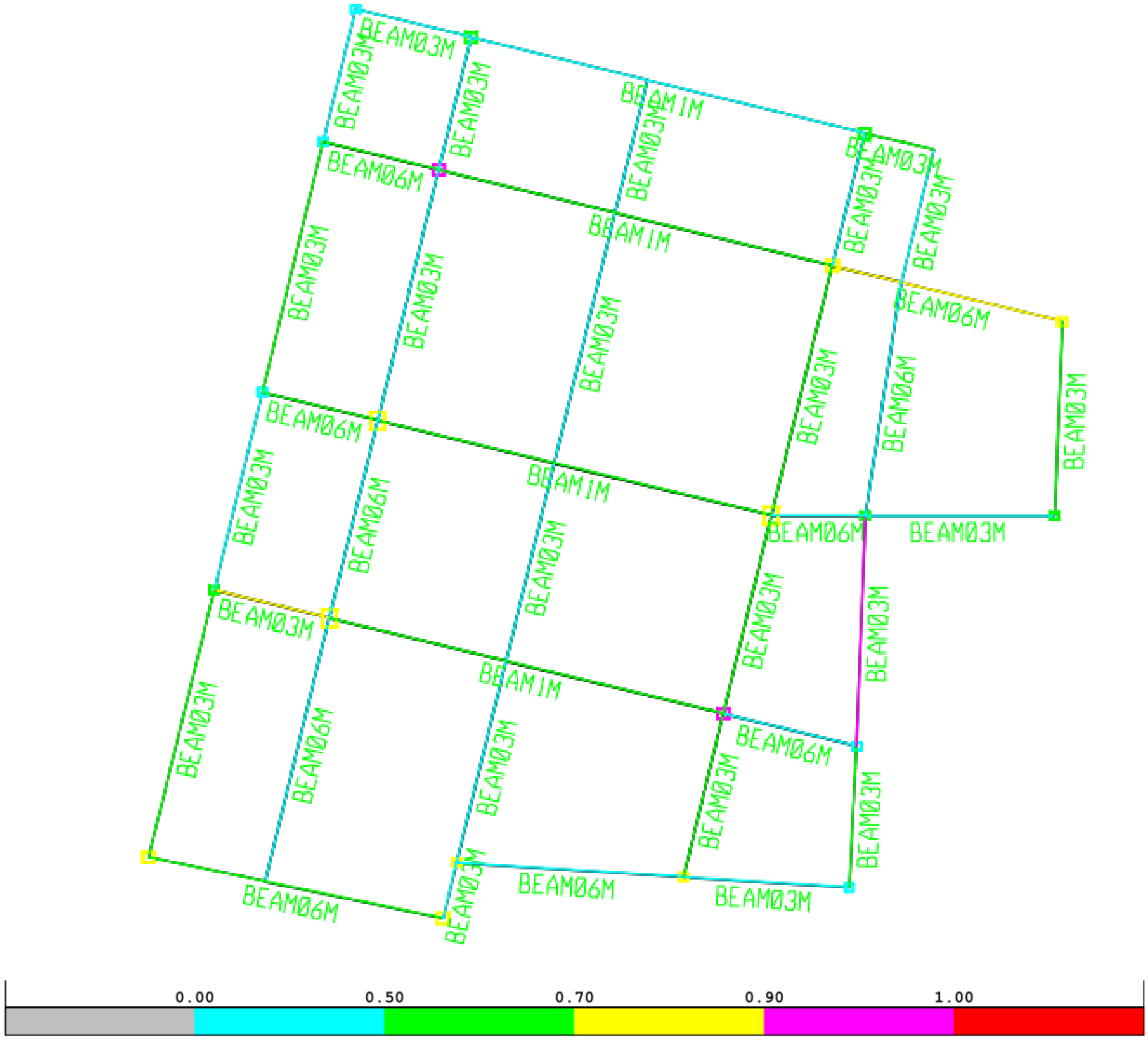


Fig.3.23. Designed beams' plan and associated stress ratio of the members – second level

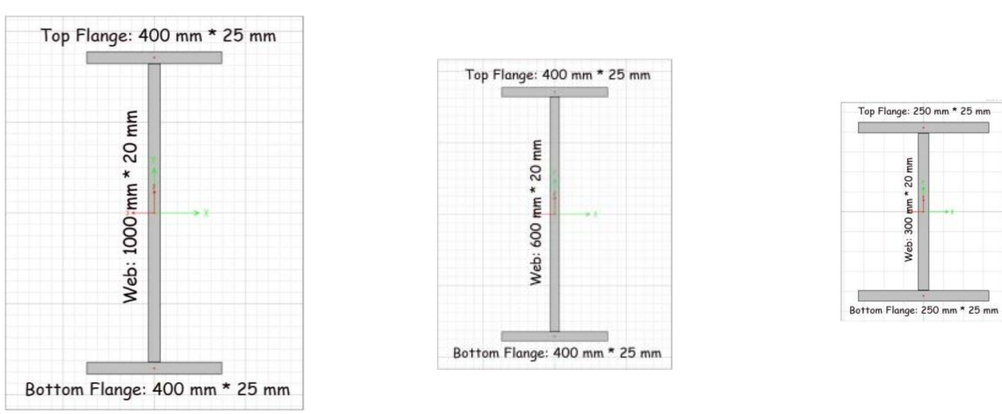


Fig.3.24. Beams' types (1m, 0.6m and 0.3m)

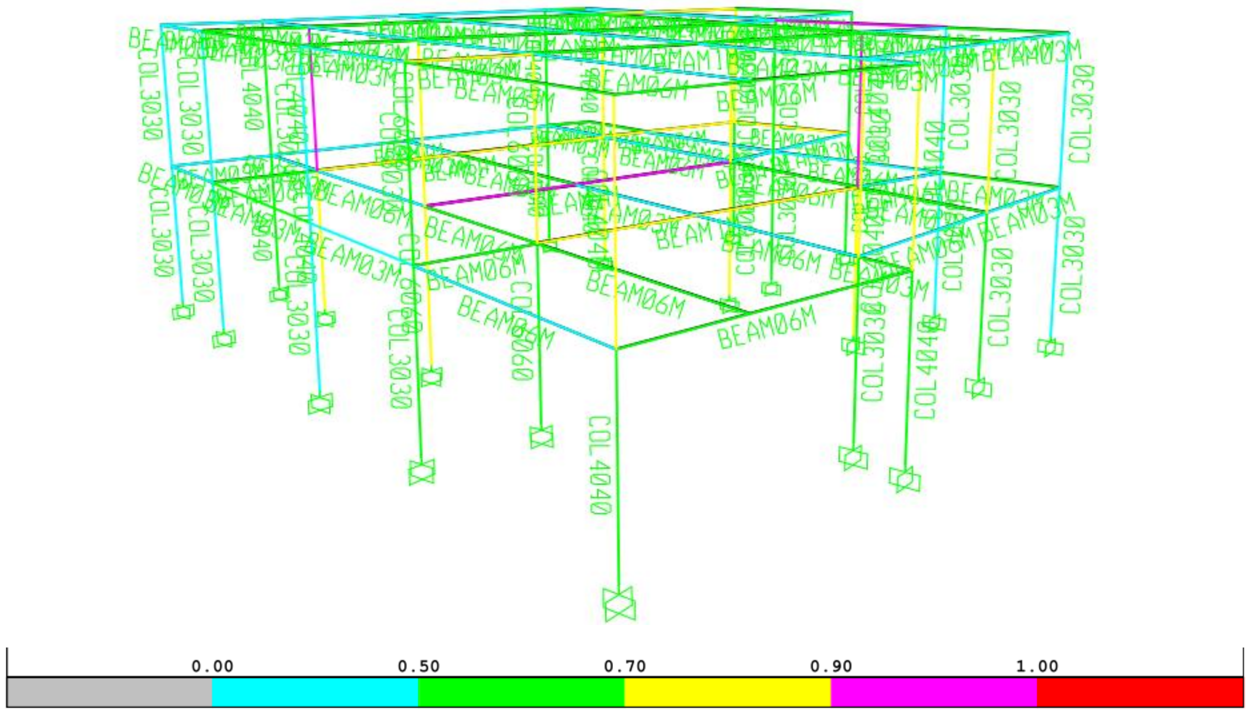


Fig.3.25. Designed members and their associated stress ratio – Stress check of all elements

Selected frame-E

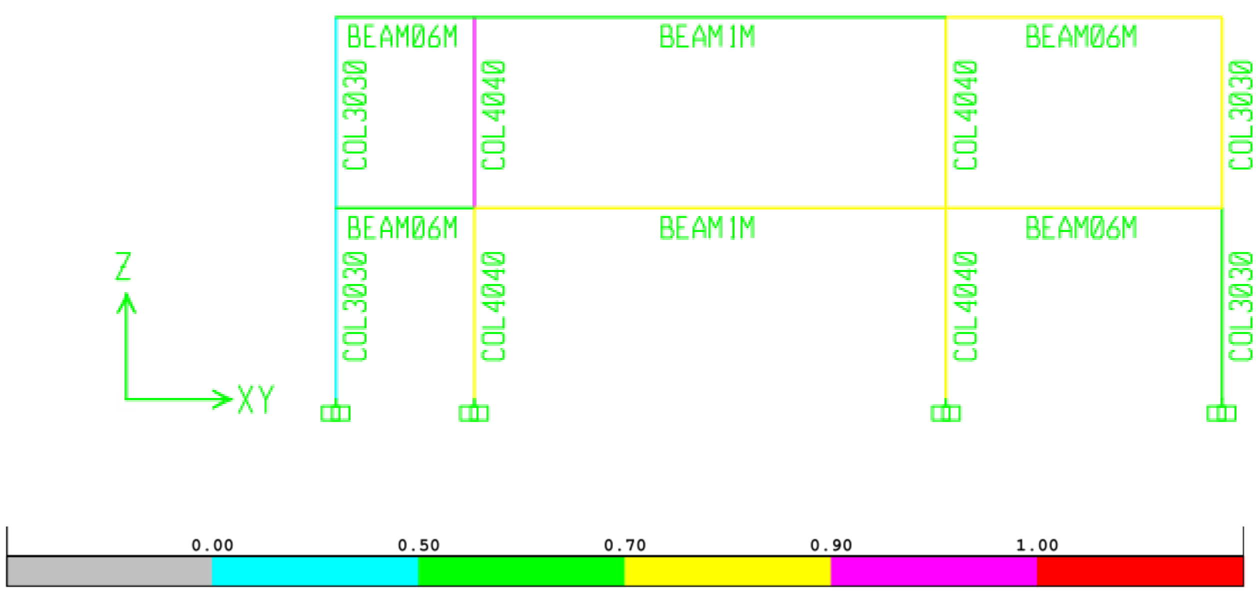


Fig.3.26. Designed members for the selected elevation of E

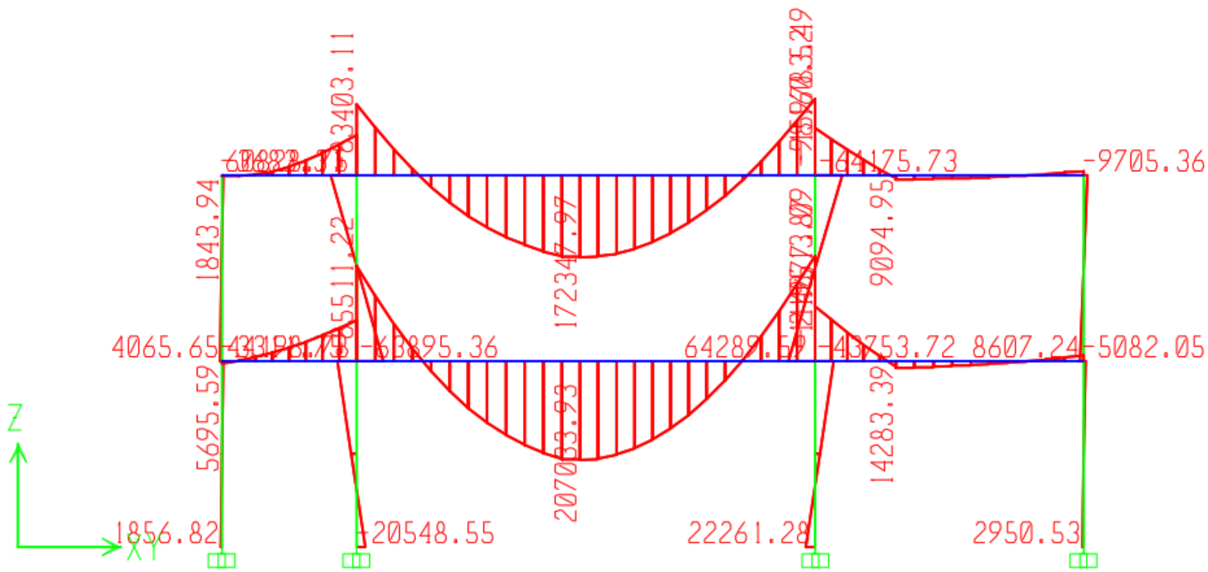


Fig.3.27. Moment diagram under Load DSTLs2 (DEAD + LIVE)

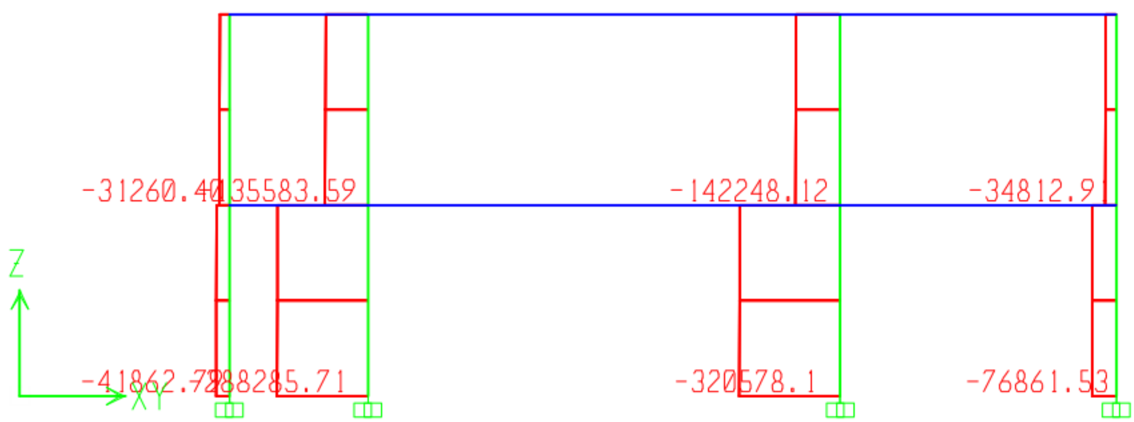


Fig.3.28. Axial Load under load DSTLs2 (DEAD + LIVE)

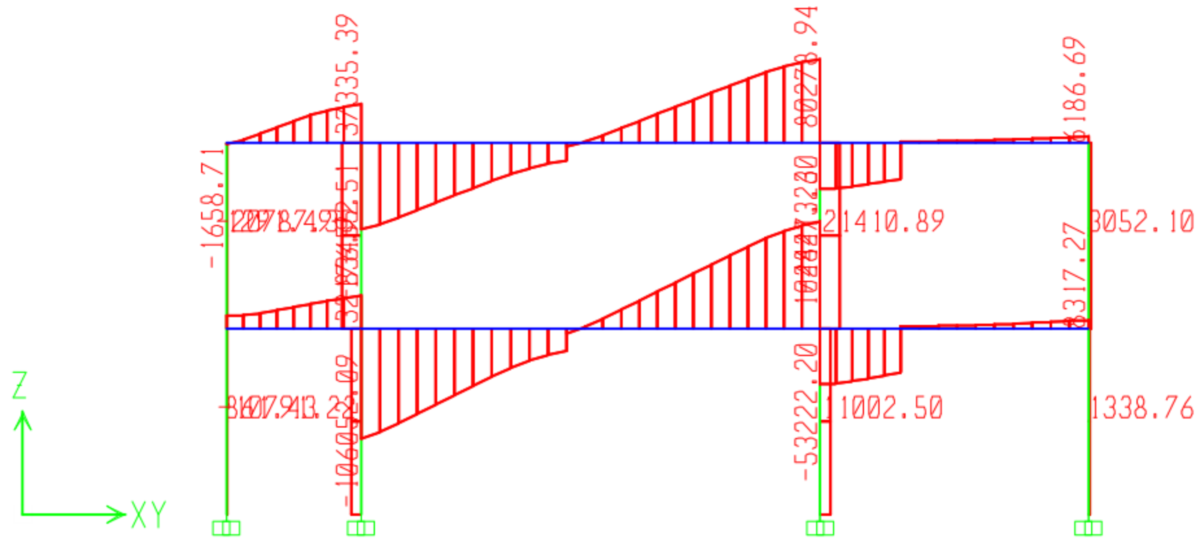


Fig.3.29. Shear diagram under load combination of DSTLs2

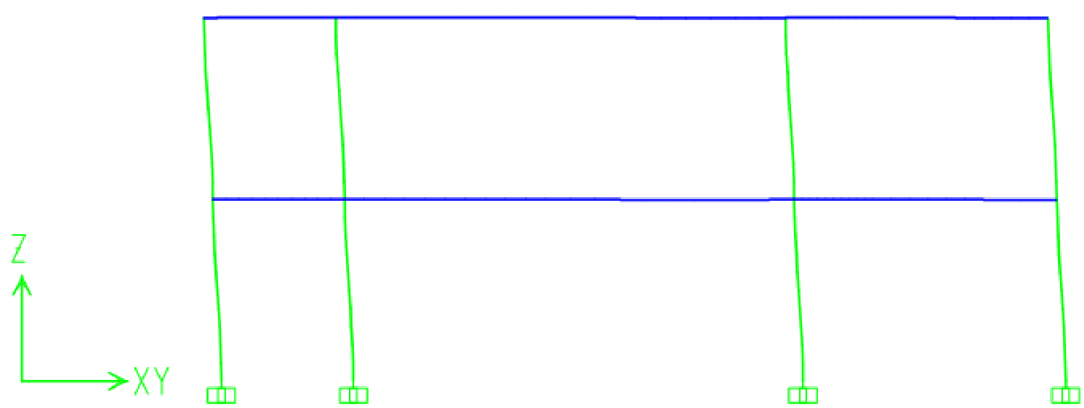


Fig.3.30. Earthquake mode shape one

DESIGN SHEET - Middle Column of Gallery E-4

Maximum internal forces

Ped KN	Med33-yy KN.m	Med 22-xx KN.m	Ved 33-yy KN	Ved 22-xx KN
-198826.904	15034.582	-41750.759	-12514.387	7267.16

Material Property Data - General

Name	Type	Dir/Plane	Modulus of Elasticity	Poisson's Ratio	Thermal Coefficient	Shear Modulus
STEEL	Iso	All	20390000000	0.3	0.0000065	7842307692

Material Property Data - Mass & Weight

Name	Mass per Unit Volume	Weight per Unit Volume
STEEL	798.14	7833.4

Material Property Data - Steel Design

Name	Steel Fy	Steel Fu
STEEL	24000000	37000000

Frame Section Property Data - Dimensions

Frame Section	Section Depth	plate width	Plate thickness
COL4040	0.4502	0.4	0.025

Frame Section Property Data - Properties

Frame Section	Section Area	Torsional Constant	Moment of Inertia I33	Moment of Inertia I22	Shear Area A2	Shear Area A3
COL4040	0.04	0.0016	0.0012	0.0009	0.0218	0.019

Frame Section Property Data - Properties

Frame Section	Section Area	Section Modulus s22	Plastic Modulus Z33	Plastic Modulus Z22	Radius of Gyration r33	Radius of Gyration r22
COL4040	0.04	0.0016	0.0012	0.0009	0.0218	0.019

Steel Column Design - Element Information

Story level	column line	Section Name	Frame Type	RLLF Factor	L-Ratio Major	L-Ratio Minor
STORY1	C47	COL4040	MOMENT	0.4	0.839	0.839

Steel Column Design - Capacity Check Output

Story	Column	Section	Moment Interaction Check Ratio = AXL + B33 + B22	Shear22 Ratio	Shear33 Ratio
STORY1	C47	COL4040	0.785 = 0.266 + 0.132 + 0.388	0.068	0.051

AXIAL FORCE & BIAXIAL MOMENT DESIGN

	Nc.Sd or Nt.Sd	Nc.Rd	Nt.Rd	Nb33.Rd	Nb22.Rd
Axial	198826.904	748369.26	872727.273	781971.387	748369.26
	M.Sd	Mc.Rd	Mv.Rd	Mb.Rd	
Major Bending	15034.582	113567.323	113567.323	113567.323	
Minor Bending	41750.759	103877.273	103877.273		
	K	L	k	klt	C1
Major Bending	1.253	0.839	0.949	0.997	2.7
Minor Bending	1.33	0.839	0.964		

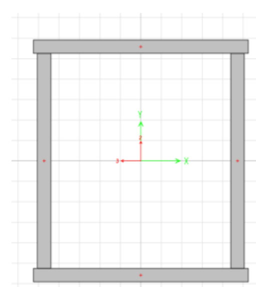
SHEAR DESIGN

	V.Sd	V.Rd	Ratio
Major Shear	7267.16	274518.34	0.026
Minor Shear	12514.387	243991.106	0.051

Stress ratio	0.839 < 1
Final check	Confirmed

FINAL DESIGN TABLE

PLATE SIZE (mm)	PLATE THICKNESS (mm)	Area of cross section (cm2)
400	25	400



Rigid Welded-connections

Design resistance of fillet welds

The design resistance of a fillet weld may be assumed to be adequate if, at every point along its length, the resultant of all the forces per unit length transmitted by the weld satisfy the following criterion:

$F_{w,Ed} < F_{w,Rd}$ Where:

$F_{w,Ed}$ is the design value of the weld force per unit length.

$F_{w,Rd}$ is the design weld resistance per unit length.

Independent of the orientation of the weld throat plane to the applied force, the design resistance per unit length $F_{w,Rd}$ should be determined from:

$F_{w,Rd} = f_{vw,d}\, a$

$f_{vw,d}$ is the design shear strength of the weld.

The design shear strength $f_{vw,d}$ of the weld should be determined from:

$$f_{\mathrm{vw,d}} = \frac{f_{\mathrm{u}}/\sqrt{3}}{\beta_{\mathrm{w}}\gamma_{\mathrm{M2}}}$$

f_u is the nominal ultimate tensile strength of the weaker part joined;

β_w = 0.85 for Grade S275

β_w = 0.9 for Grade S355

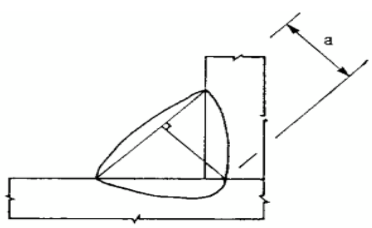


Fig.3.31. Throat thickness of a deep penetration fillet weld[78]

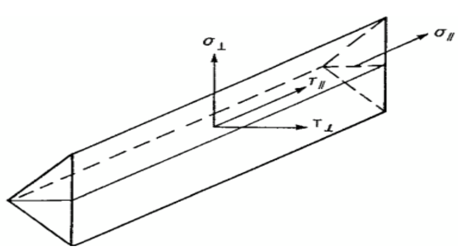


Fig.3.32. Stresses on the throat section of a fillet weld[79]

[78] Eurocode 3: Design of steel structures – Part 1-8: Design of joints Figure 4.4
[79] Eurocode 3: Design of steel structures – Part 1-8: Design of joints Figure 4.5

Modeling of beam-to-column joints

For moment resisting frames, it is important to design rigid connections to carry the moments generated due to the lateral forces and gravitational loads. For beam-to-column joints and splices the applied moment should satisfy:

$$\frac{M_{j,Ed}}{M_{j,Rd}} + \frac{N_{j,Ed}}{N_{j,Rd}} \leq 1,0$$

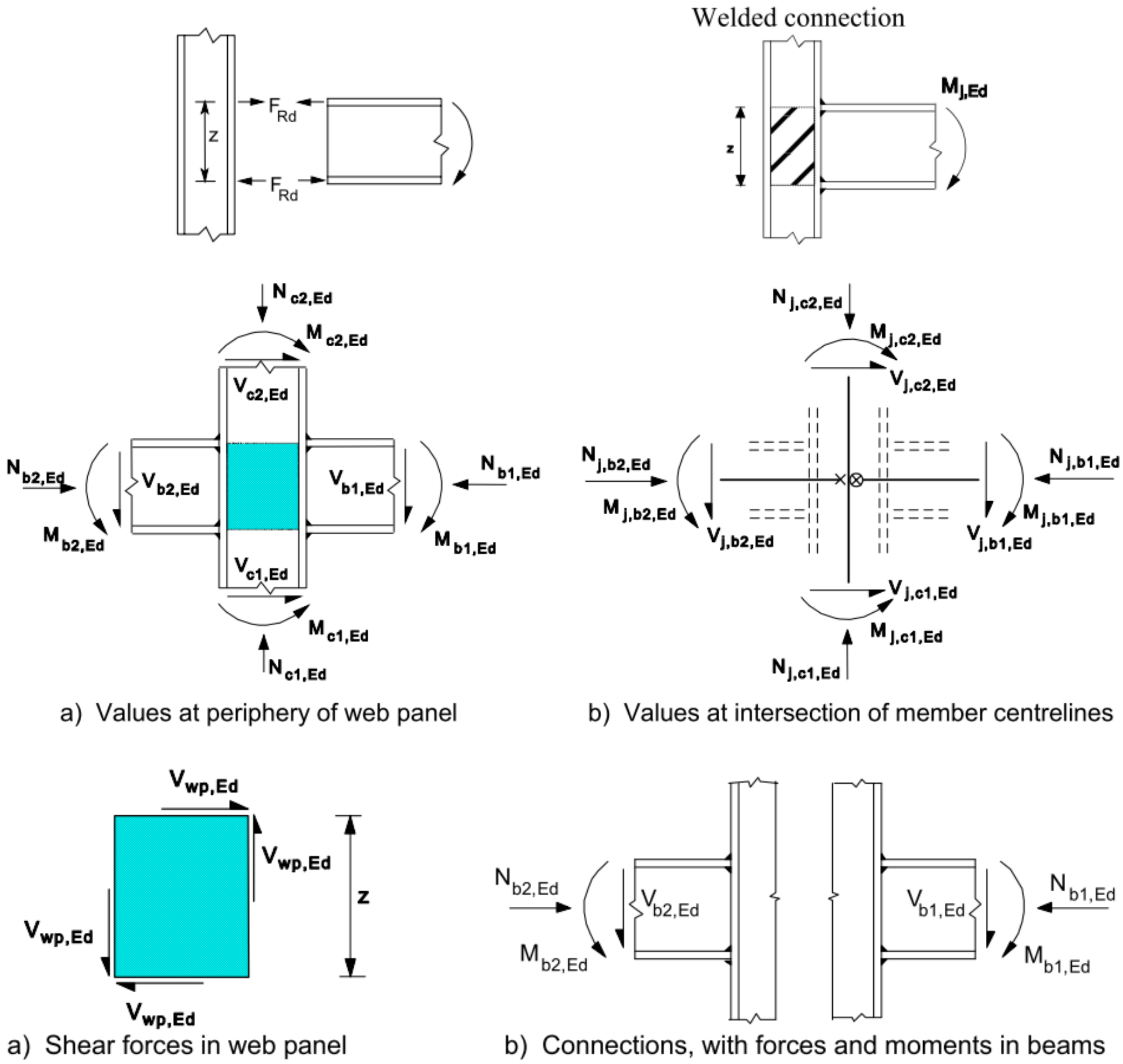
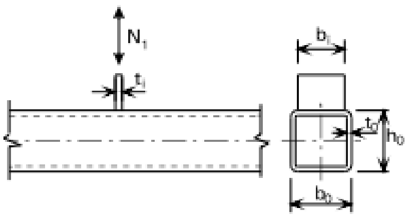


Fig.3.33. Forces and moments acting on the joint[80]

[80] Eurocode 3: Design of steel structures – Part 1-8: Design of joints - Figure 5.7

Transverse plate	Brace failure $[i = 1]$
	$N_{1,Rd} = f_{y1} t_1 b_{eff} / \gamma_{M5}$ *)
	Chord side wall crushing when $b_1 \ge b_0 - 2t_0$
	$N_{1,Rd} = f_{y0} t_0 \left(2t_1 + 10t_0\right) / \gamma_{M5}$
	Punching shear when $b_1 \le b_0 - 2t_0$
	$N_{1,Rd} = \frac{f_{y0} t_0}{\sqrt{3}} \left(2t_1 + 2b_{e,p}\right) / \gamma_{M5}$

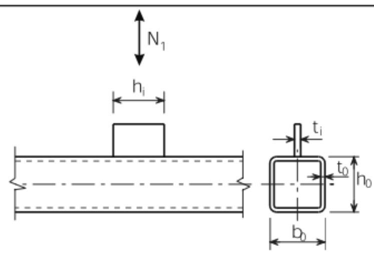
Longitudinal plate	Chord face failure
 $t_1/b_0 \le 0,2$	$N_{1,Rd} = \frac{k_m f_{y0} t_0^2}{1 - t_1/b_0} \left(2h_1/b_0 + 4\sqrt{1 - t_1/b_0}\right) / \gamma_{M5}$

Fig.3.34. Box shape column connection to beam[81]

Existing forces

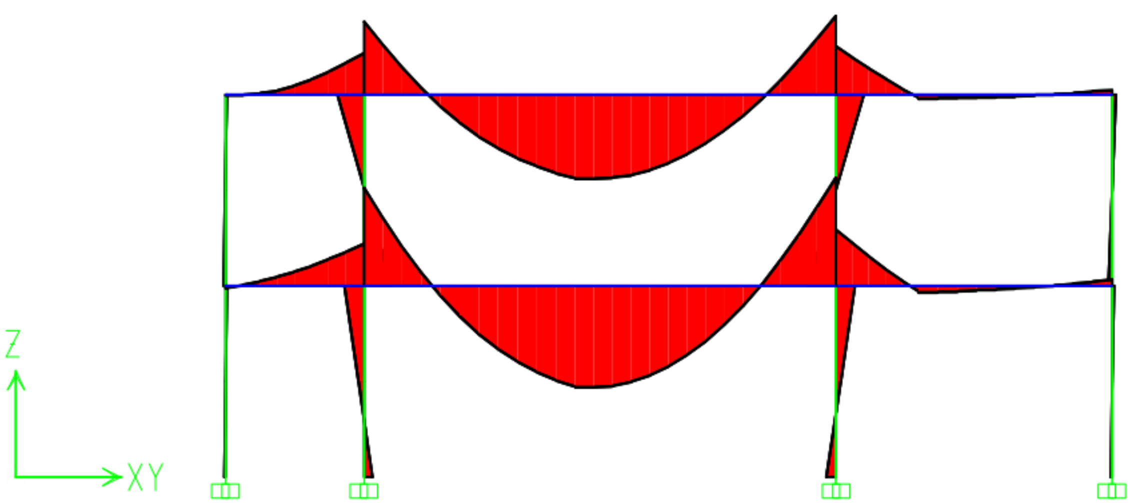


Fig.3.35. Moment diagram under Load DSTLs2 (DEAD + LIVE)

[81] Eurocode 3: Design of steel structures – Part 1-8: Design of joints – Table 7.13.

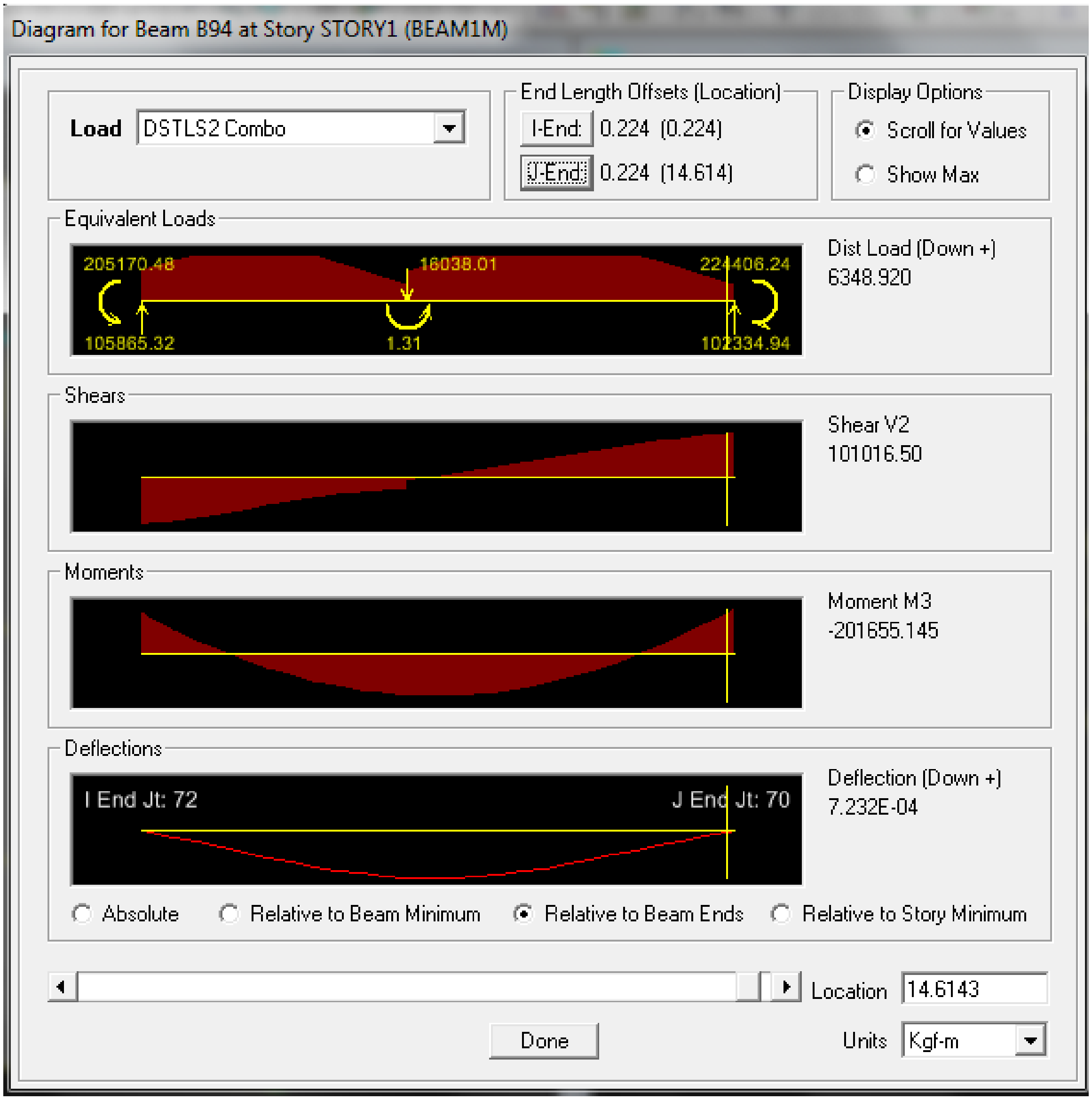


Fig.3.36. Selected beam forces from Etabs

Design moment resistance of beam-to-column rigid joint

Horizontal Plates

The following relation should be satisfied in order to design a rigid support of beam to column in terms of Moment resistance. Existing moment is due to the load combination DSTL 2 (Dead + Live) which creates the most critical force on the joint.

$$\frac{M_{j,Ed}}{M_{j,Rd}} + \frac{N_{j,Ed}}{N_{j,Rd}} \leq 1,0$$

$N_{l,Rd} = f_y * t_1 * b_{eff} / \gamma_{M5}$ → $b_{eff} = 2*t_w + 5*t_f$ = 2*2.5+5*2.5 = 17.5 cm

Also $b_{eff} <= 2*t_w + 5*k*t_f$ = 2*2.5+5*1*2.5=17.5 cm (K=1 since the thickness of the plate and the chord of column is the same)

Brace failure:

$N_{1,Rd}$ = 2400 kg/cm^2*2.5 cm*17.5 cm/1 = 105000 Kg for γ_{M5}=1 (Resistance of Joints in hollow section lattice girder: γ_{M5}=1)

Chord side wall crushing:

$N_{l,Rd} = f_{y0}*t_0 (2*t_1 + 10 t_0) / \gamma_{M5}$ = 2400 kg/cm^2 *2.5 cm *(2*2.5 cm +10*2.5 cm) /1=180000 Kg

Punching Shear:

$N_{l,Rd} = (f_{y0}*t_0/ \sqrt{3}) (2*t_1 + 10 t_0) / \gamma_{M5}$ = 2400 kg/cm^2 *2.5 cm* (2*2.5 cm+2*40 cm)/1*√3= 294448.6373 Kg

Vertical plates

$N_{1,}Rd$ = 1*2400*2.5^2/(1-2.5/40) *(2*45/40 + 4*√(1-2.5/40)/1 = 97967.73 Kg

For two parallel plates → 2*97967.73 Kg = 195935.4 Kg

Changing this axial force to the Moment by taking into account linear distributions of the stress in the cross section:

M = 195935.4*(30 cm*2) = 11756128.2 Kg.cm for two parallel vertical plates of 80 cm welded between beam web and columns chord.

Taking the most critical N from above:

$M_{j,Ed} / M_{j,d} < 1$ → 202000 Kg.m/ (105000 +117561.282) kg.m = 0.90 <1

The resultant of all the forces per unit length transmitted by the weld satisfy the following criterion[82]:

$F_{w,Ed} < F_{w,Rd}$

$f_{vw,d} = f_u / \beta\gamma\sqrt{3} * a$ = 4100/√3/0.85/1.25 = 2227.89 Kg/cm

$F_{w,Rd} = f_{vw,d} * a$ = 2227.89 Kg/cm * 1.2 cm = 2673.468 kg/cm

Max moment (cross section remains planar):

M_{max} = 1300 Kg/cm *90 cm + 2673 Kg/cm *40 cm = 223920 Kg.m > 202000 Kg.m

$F_{w,Ed}$ = 202000 kg /130 cm = 1553.84 Kg/cm < 2673.468 kg/cm → Ok

Connection Drawings

Based on the calculations, the joint consists of two plates with the thickness of 2.5 centimeters and the width of 40 centimeters on the top and bottom of the beam flanges and two plates

[82] Eurocode 3: Design of steel structures – Part 1-8: Design of joints

with thickness of 2.5 cm parallel to each other welded to the web of the beam. They are welded with the weld of 1.2 cm size and the bottom and top plates are supported by stiffeners welded underneath and on the top of them. This type of joint is applicable to the smaller or bigger columns by adjusting the width of the plates.

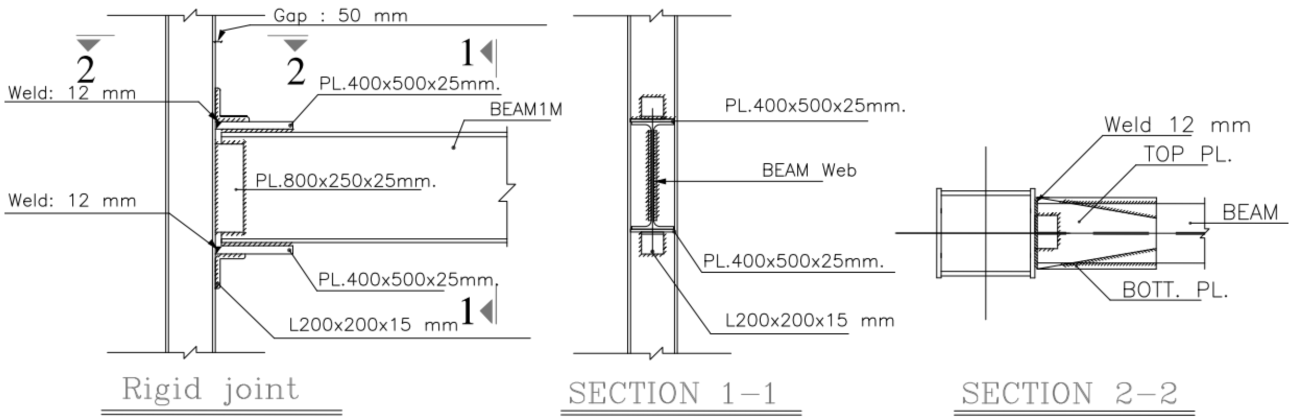


Fig.3.37. Rigid connection of Beam-Columns

Buildings of Loft and MPH (number 2 and 3)

Buildings number two and three are modeled separately in the software. The gap between the buildings is between axes 11 and 12 in the structural gridline. It is worthwhile to mention that however in the 3D visualization of the project, building number two and three are shown adjacent to each other, but there is no structural connection between them in the software.

Building number two has the function of the receptions, entrance and foyer for the whole complex on the ground level and it is providing a big portion of the required loft space for the complex in its second floor. Both the first and second floors have some functions which require the consideration of the flexibility of the space. It means the building should be free of the structural constraint like columns. Therefore, columns are positioned either in the edges or in the corners of the building. These considerations caused to have rather large spans in this building and consequently to have beams with the height of up to 1 meter in the design. This building, on the façade toward the cloister has an extension in the form of a cantilever on its second level which is supported by bracing elements in specific distances.

Building number three is a rather huge building in three levels above basement. Mainly, the existence of the multipurpose hall in the second floor affected the columns position in the plan for the whole building. In an attempt to provide at the same time a rather big courtyard on the ground level in the site of the project and necessary requirements mentioned in the brief for the new addition project, it is decided to have extension to the building number three at its second level. This extension without any columns on the ground level helps to fulfill the requirements of the brief and keep the area of the ground level free for the courtyard.

Therefore, the rather huge cantilevers were the subject of careful structural design both in the software and by hand calculations. The amount of the extension of the building in the second level made the usage of bracing elements in specific distances for supporting the cantilever almost inevitable. Both the extensions are visible in the 3D visualization of the structure in the figure.

The following parameters are important to the structural design of the building number two and three:

1- Rather large distances between columns
2- Existence of a huge balcony (cantilever) turning around the front façade of the building starting from the façade of the building number two toward the park.
3- Variation of the height of the stories in different elevations of the building.

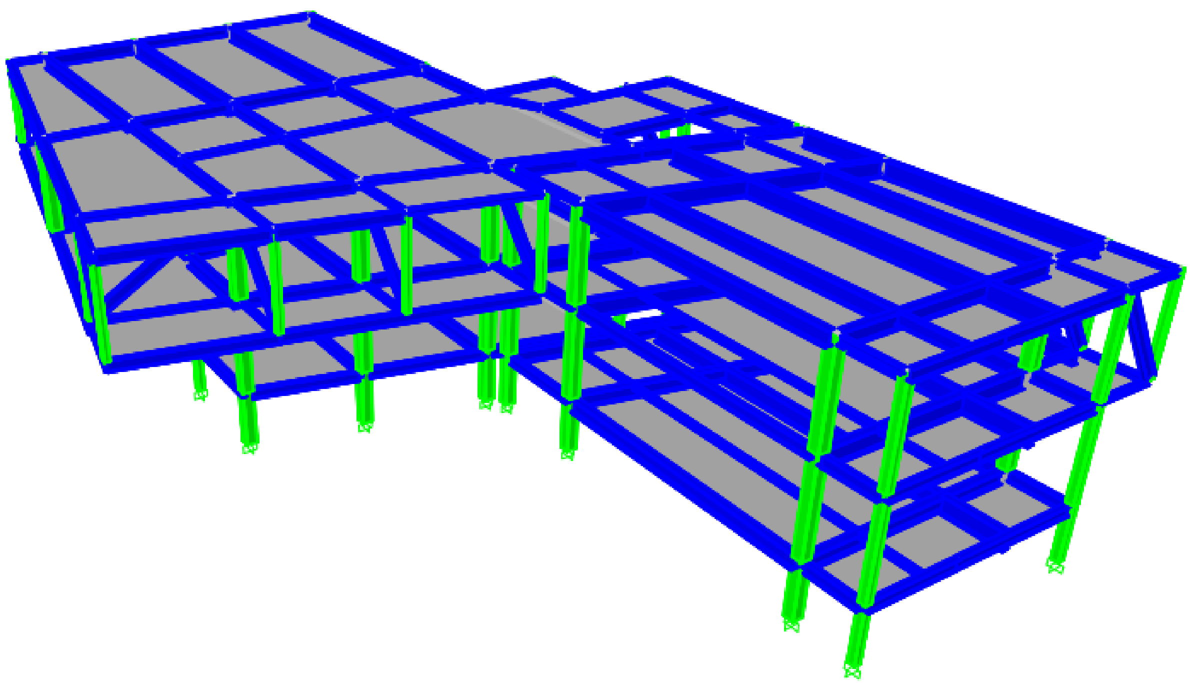


Fig.3.38. 3D introduction of the Building

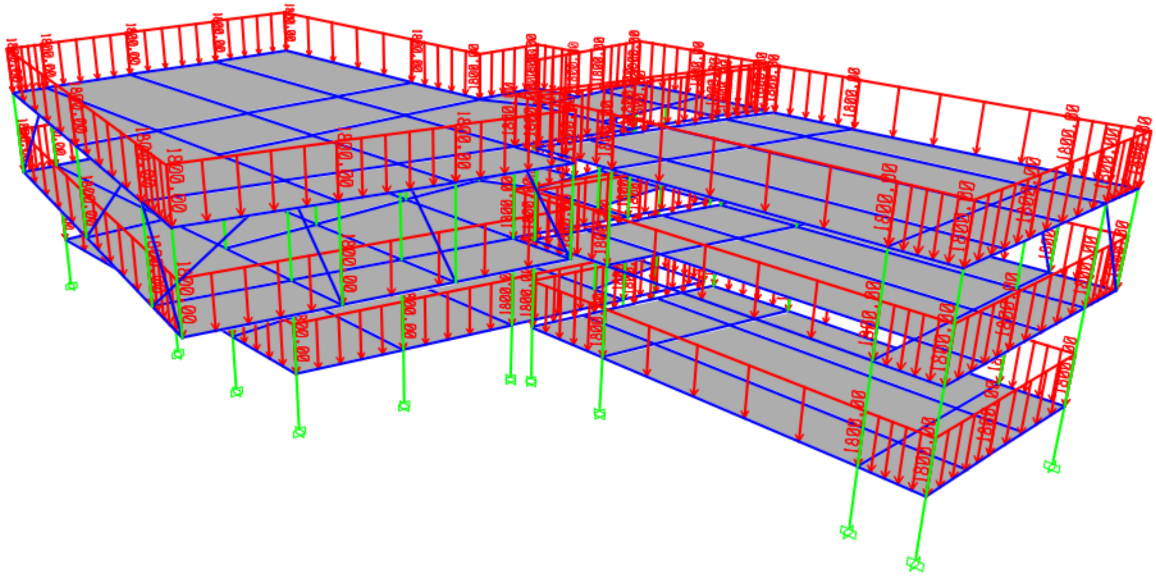


Fig.3.39. External walls load application (Kg)

Structural Plans

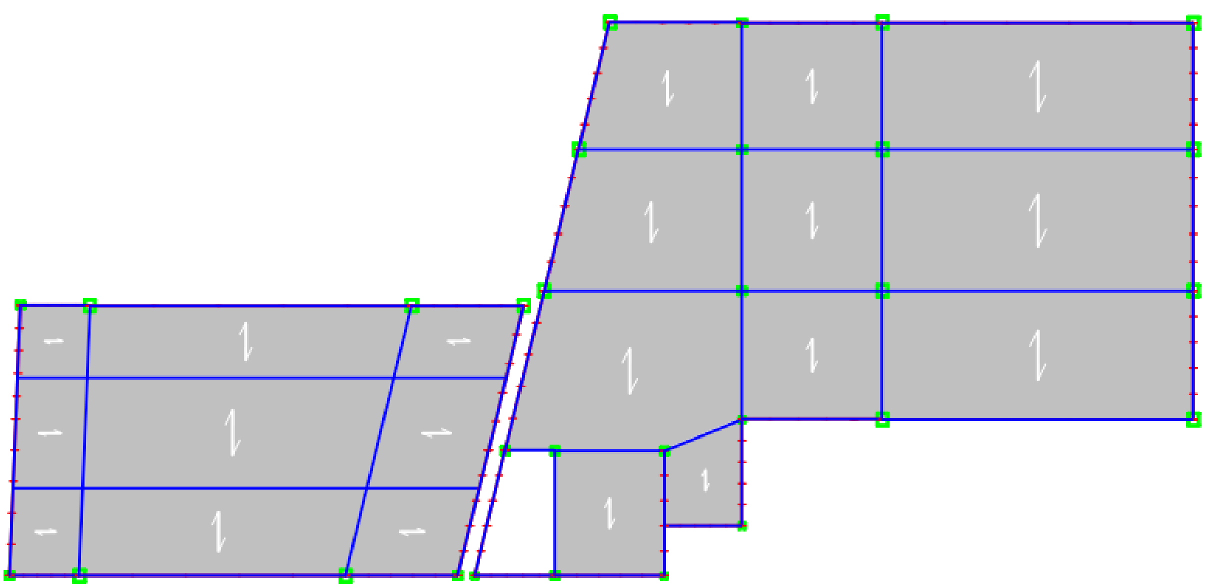


Fig.3.40. First level beam plans and direction of the slab

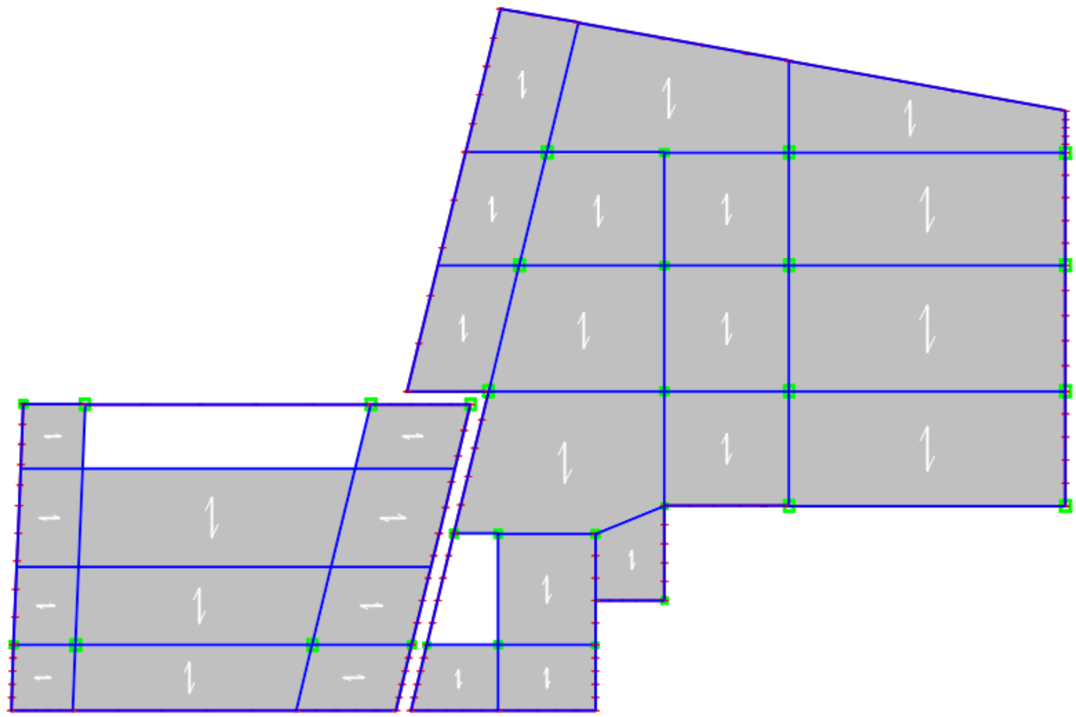


Fig.3.41. Second level beam plan and direction of the slab

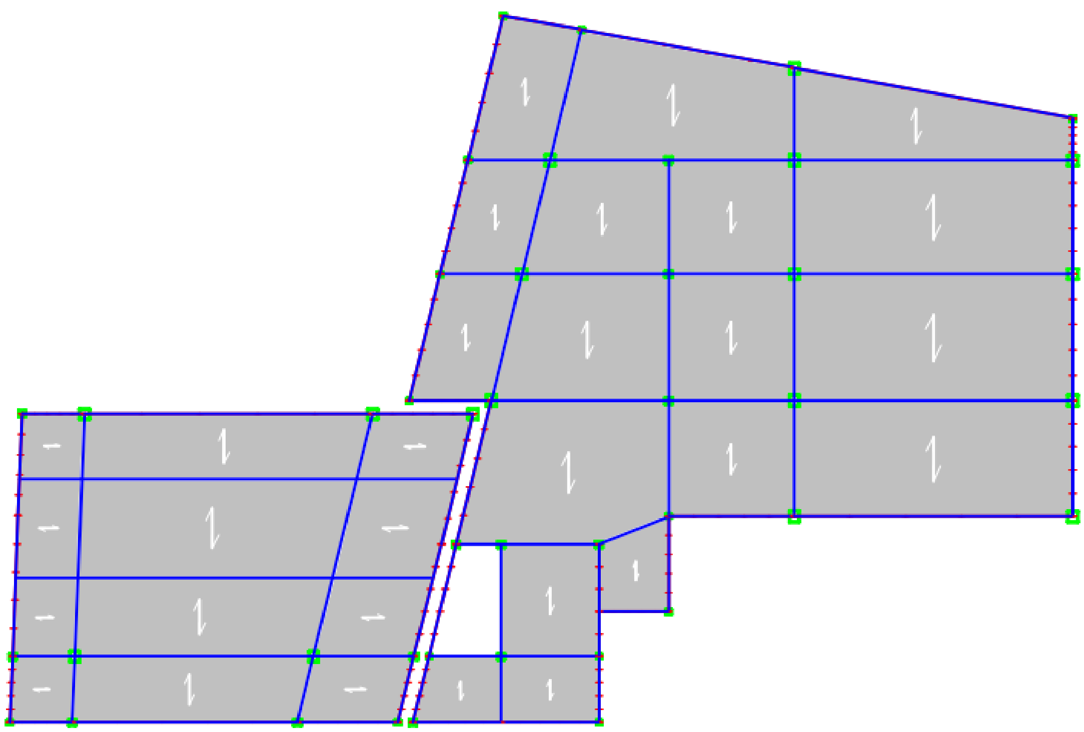


Fig.3.42. Roof beam plan and direction of the slab

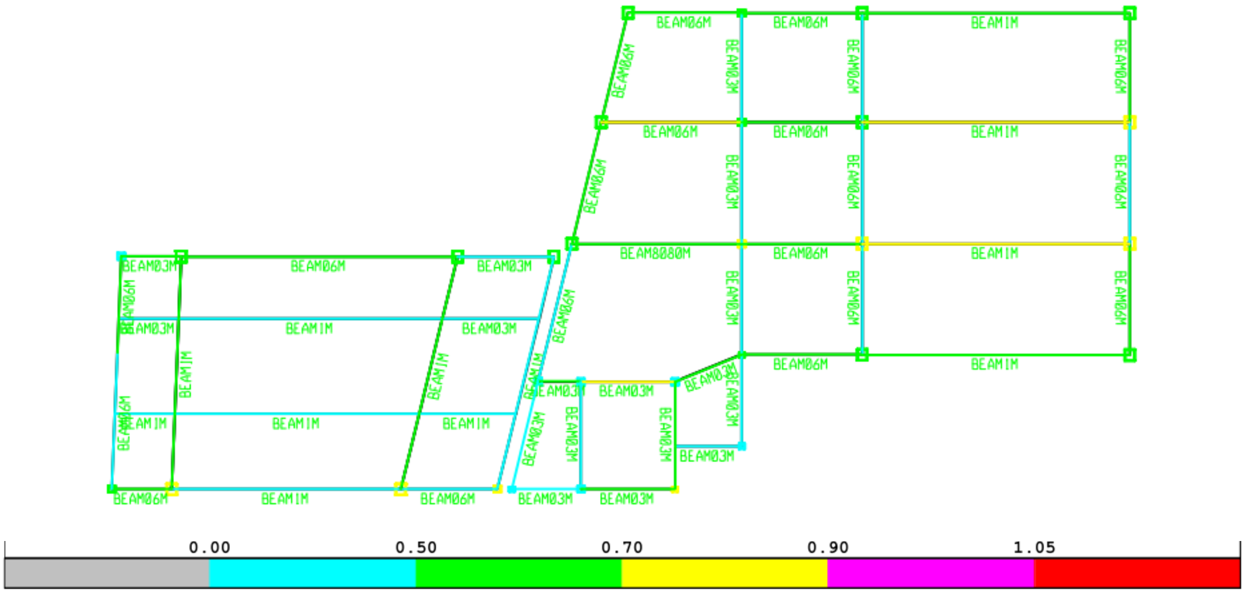


Fig.3.43. First level beam plan and associated stress ratio

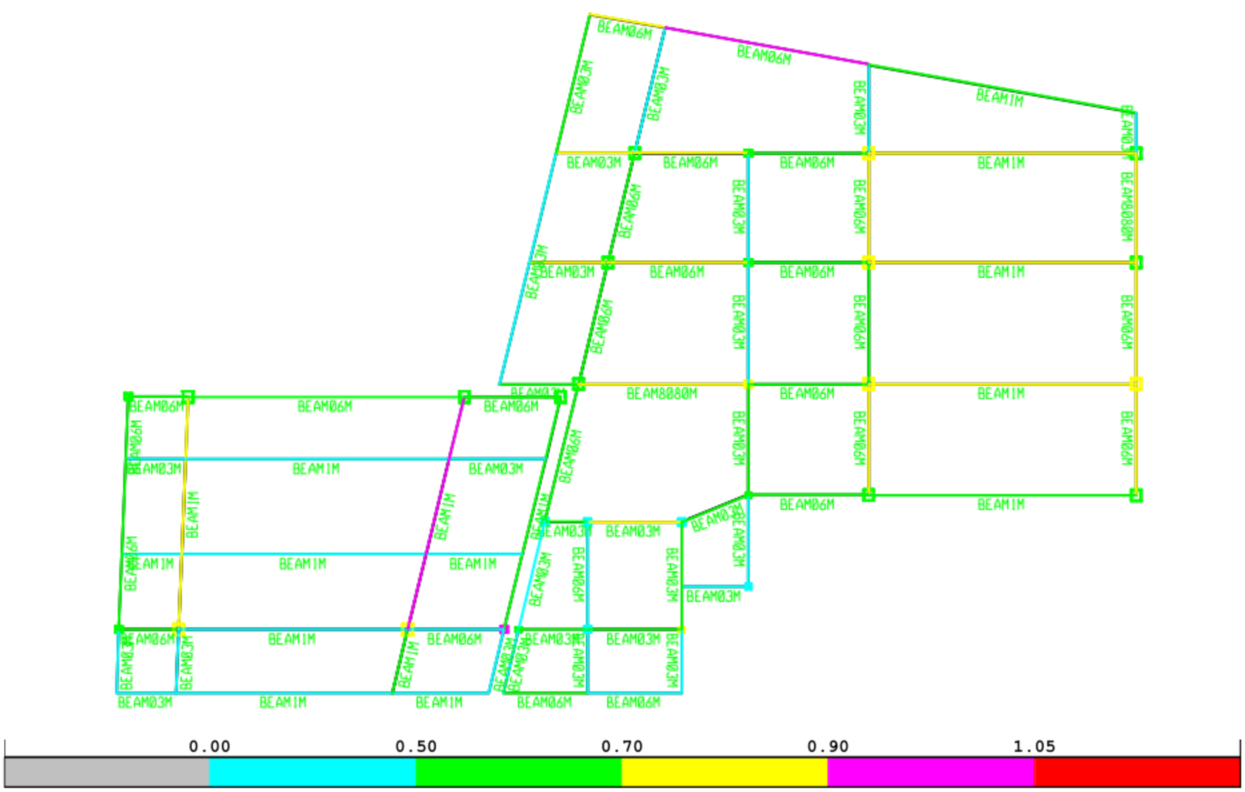


Fig.3.44. Second level beam plan and associated stress ratio

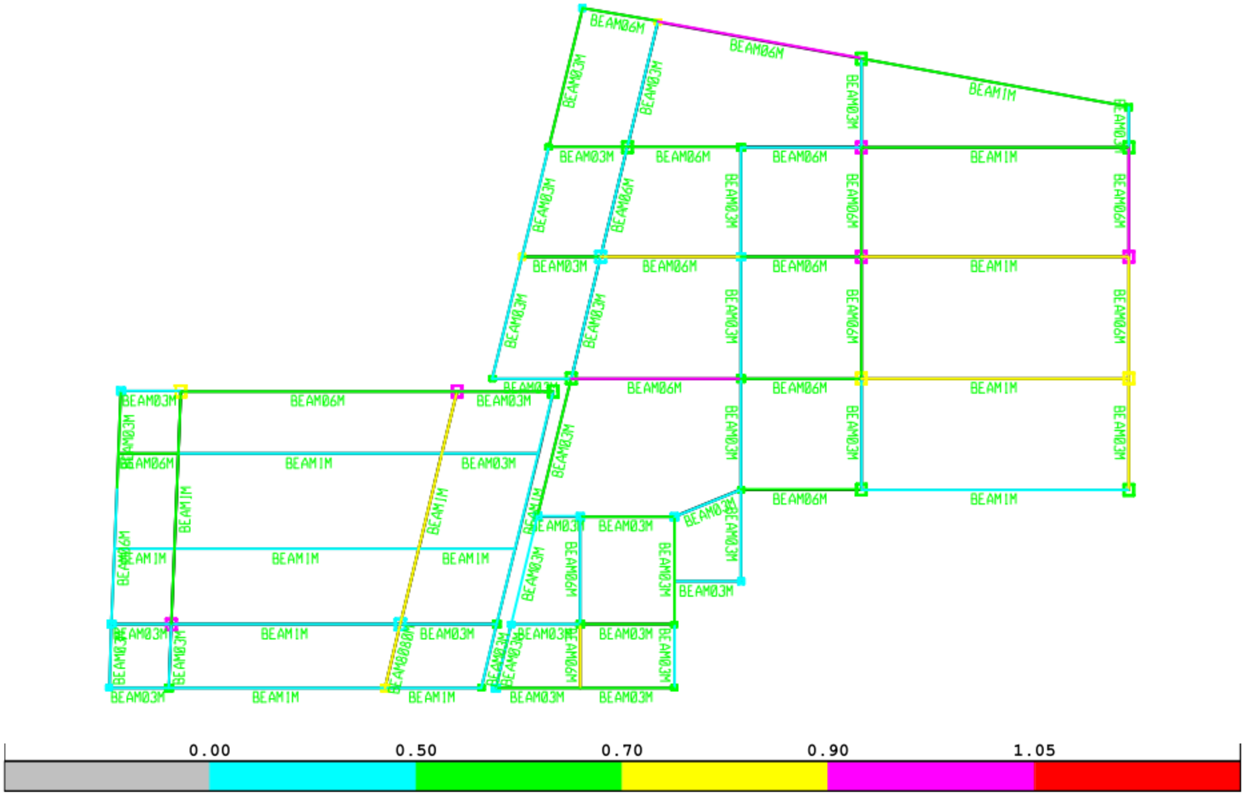


Fig.3.45. Third level beam plan and associated stress ratio

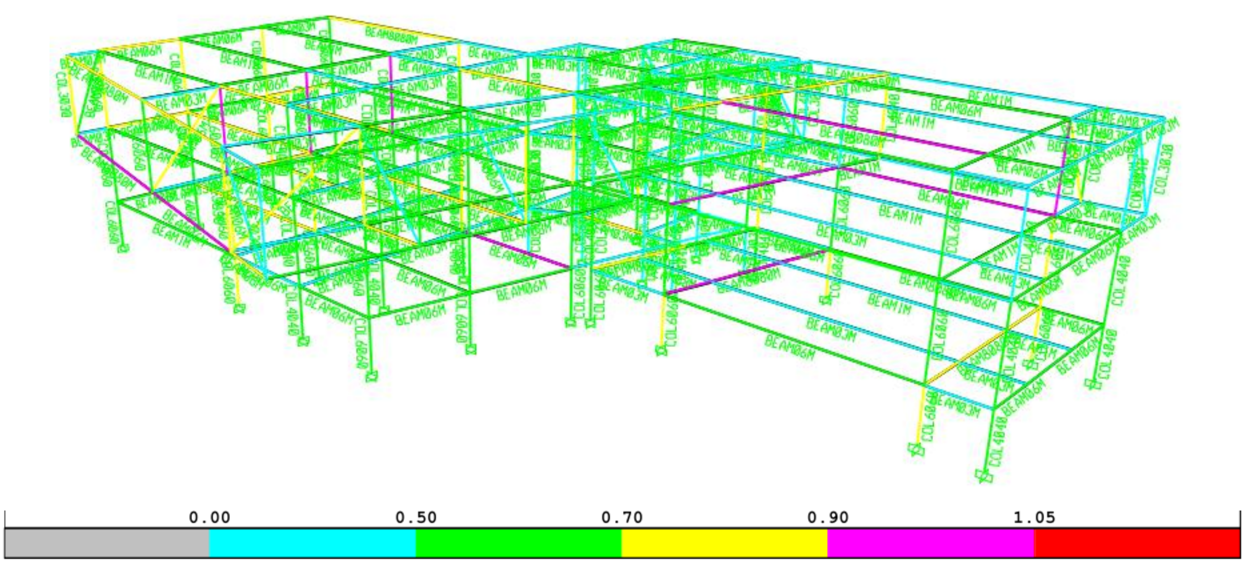


Fig.3.46. Designed members and their associated stress ratio – 3D view- Stress check of all elements

Selected frame in axe 12

Hereby, the focus of the report is on the important frame in the elevation shown below. This frame consists of columns beams and bracing elements. Frame has all the three types of the columns used in this project in different positions.

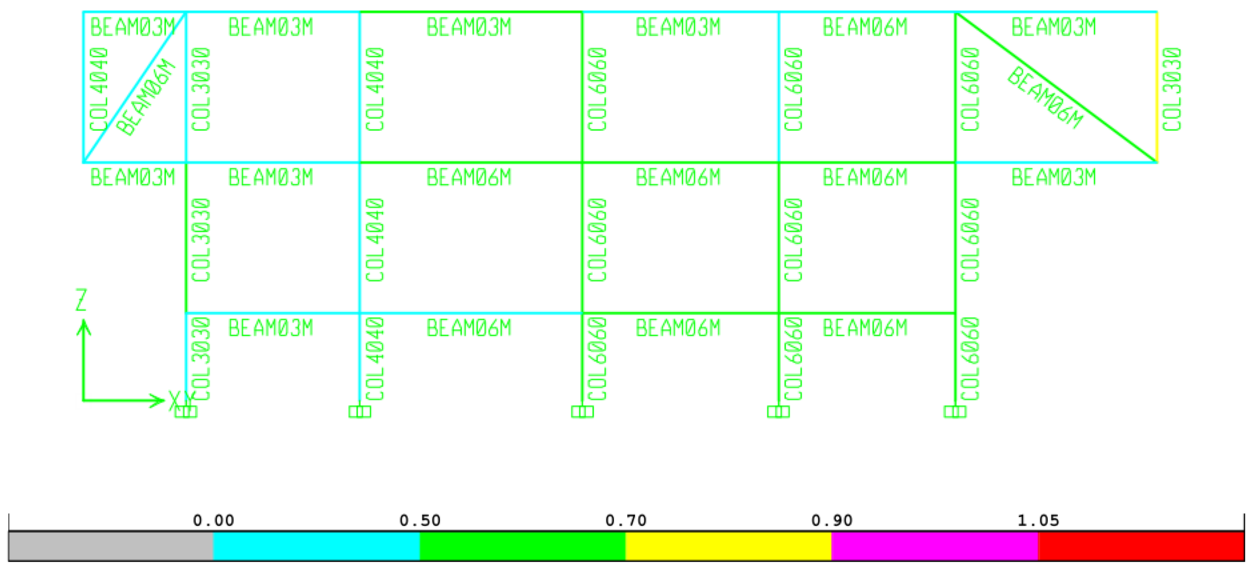


Fig.3.47. Elevation 12 members and associated stress ratio

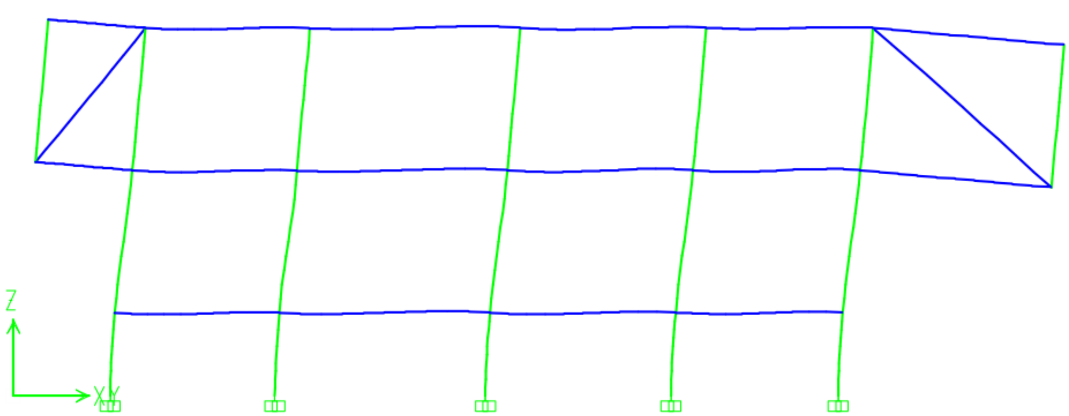


Fig.3.48. Earthquake first mode of the elevation 12

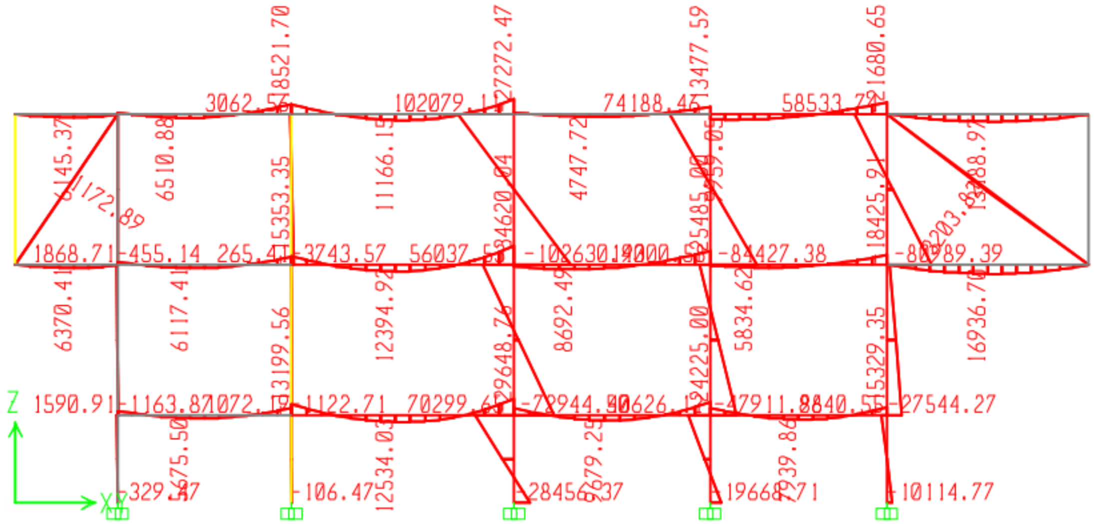


Fig.3.49. Moment under load combination of DSTLs2 (DEAD + LIVE)

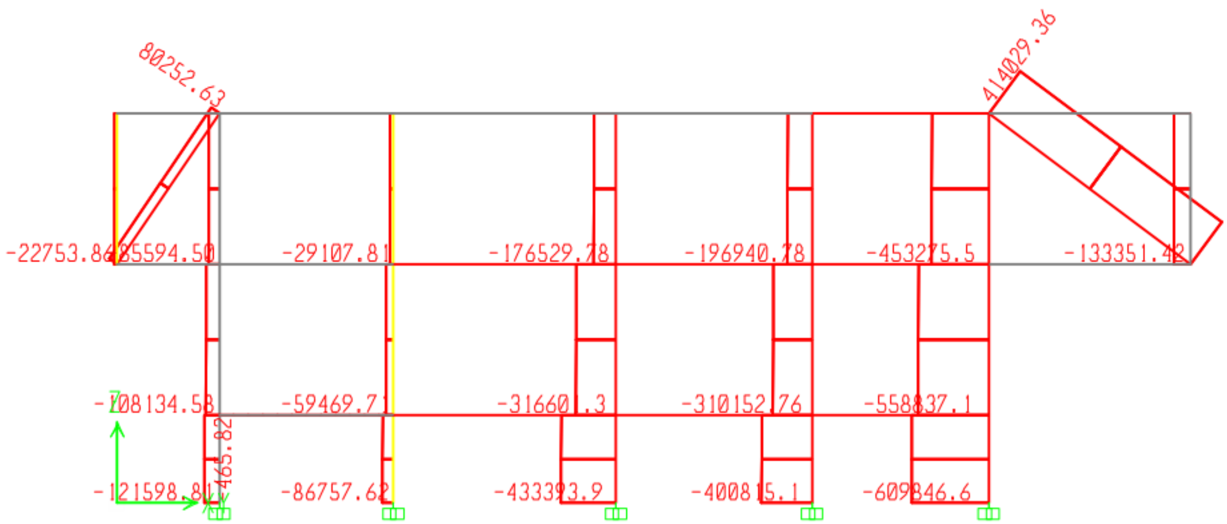


Fig.3.50. Axial loads under load combination of DSTLs2 (DEAD + LIVE)

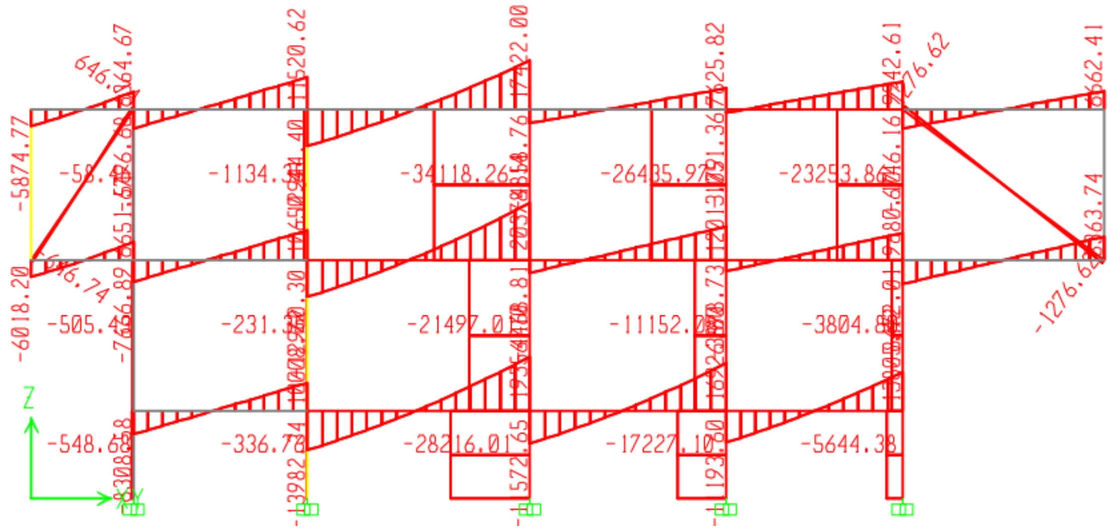


Fig.3.51. Shear force under Load combination of DSTLs2 (DEAD + LIVE)

Relative Virtual Work/Unit Volume

ETABS determines the energy per unit volume associated with each element in the structure. For any plane selected by the user, the values are normalized with the largest one which has a value of 100. In this way, the designer is able to see which elements are "working" the hardest and is able to make calculated choices on which elements to strengthen to meet a certain criterion.

To control lateral displacements in your structure, the energy diagrams are helpful as an aid to determine which elements should be stiffened.

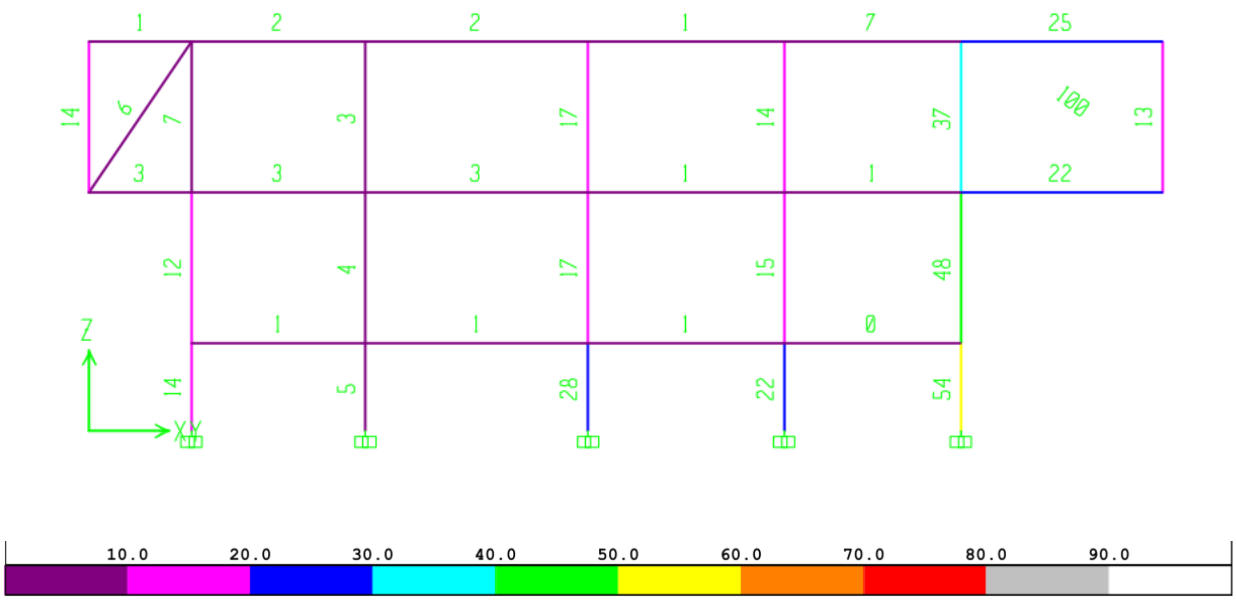


Fig.3.52. Relative virtual work

Conclusion of the design

The results of the analysis and design by software showed a good correspondence with the preliminary design and calculations in a way that not many changes were necessary in respect to the beam and columns cross-sections. In this project the architectural considerations prevented the usage of bracing systems to carry the lateral forces, therefore, the structural system is moment resisting system in both directions of X and Y. This design approach requires the careful design and construction of the connections in order to ensure the stability of the structure under loading conditions. The finalized sizes of element sections are assigned by taking into account both the software design output and the constructions and economical considerations. Finalized map of the structure showing the position of the beams and columns are presented in the structural plans specific for every story.

Structural details and drawing

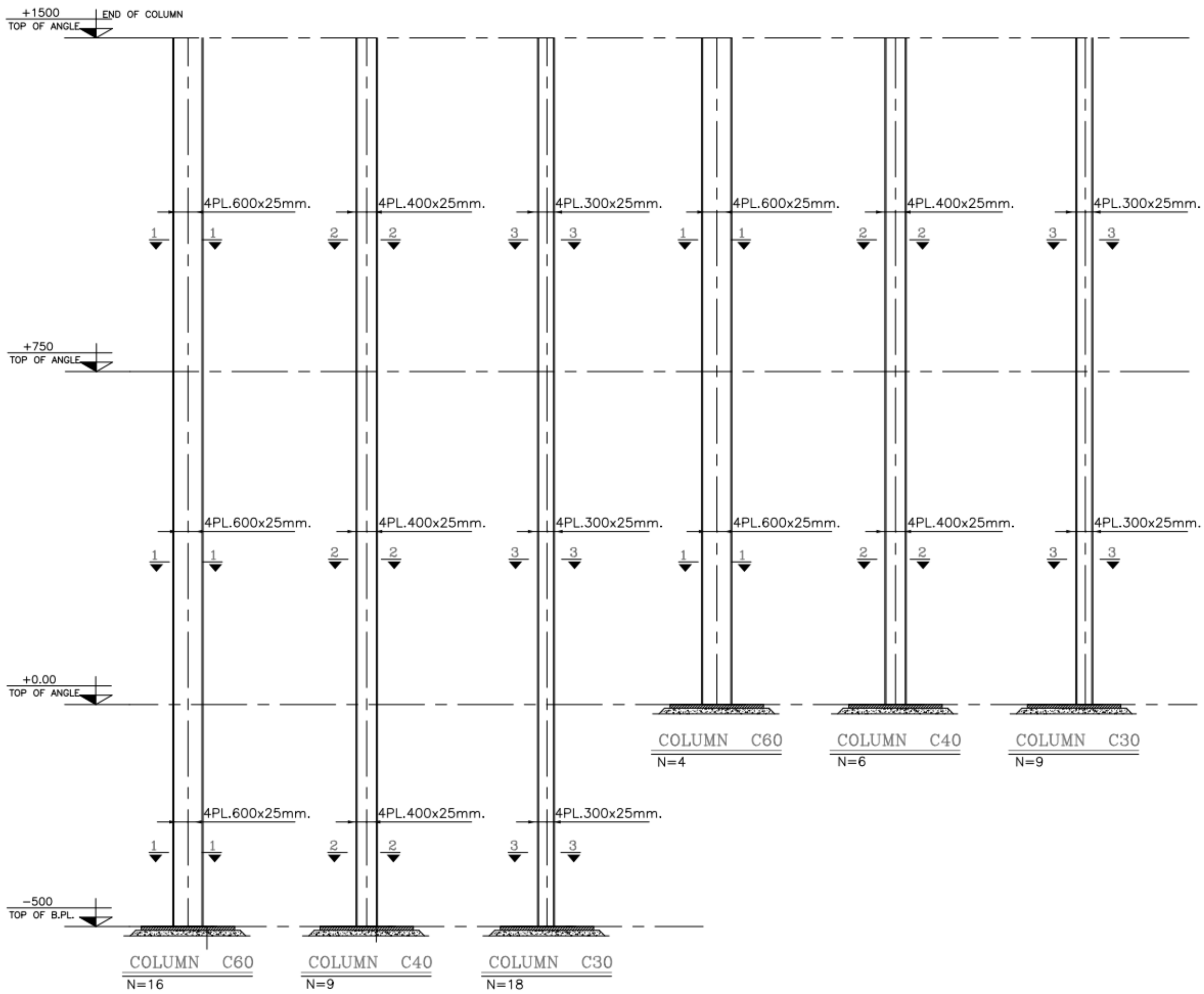


Fig.3.53. Typical Columns of the Project

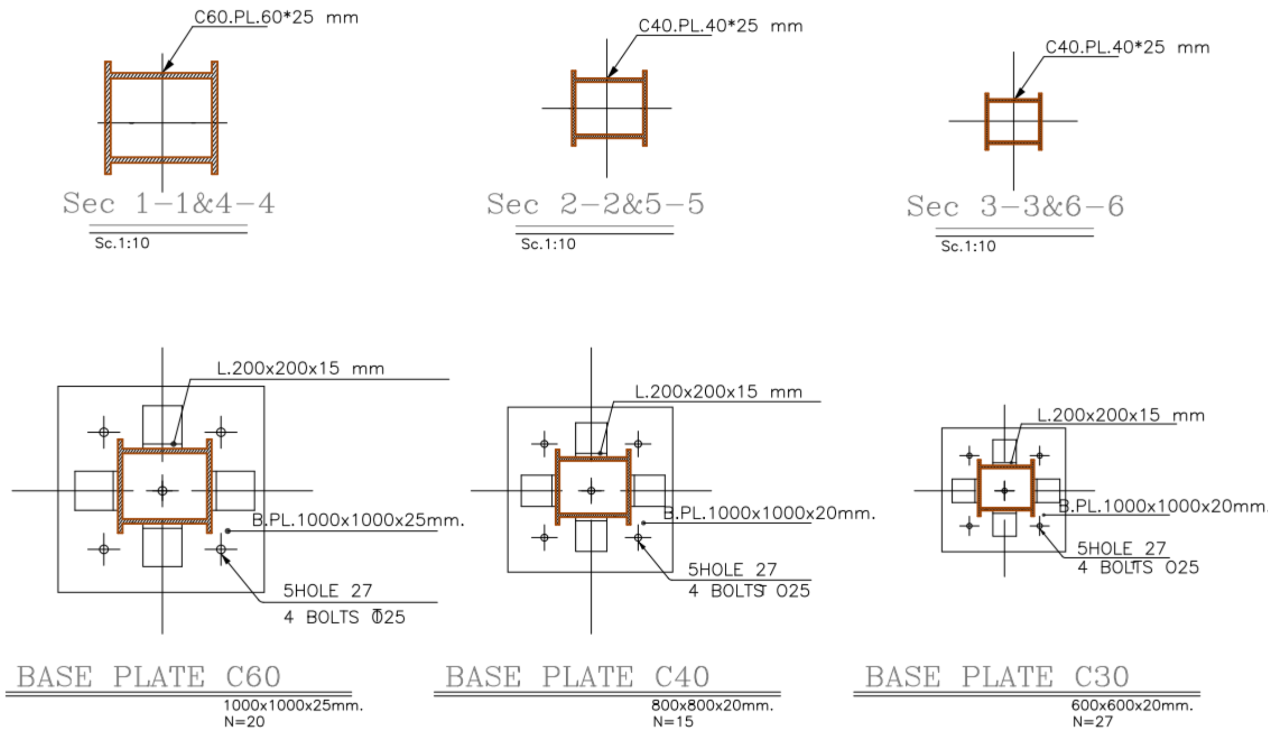


Fig.3.54. Columns and Base Plates

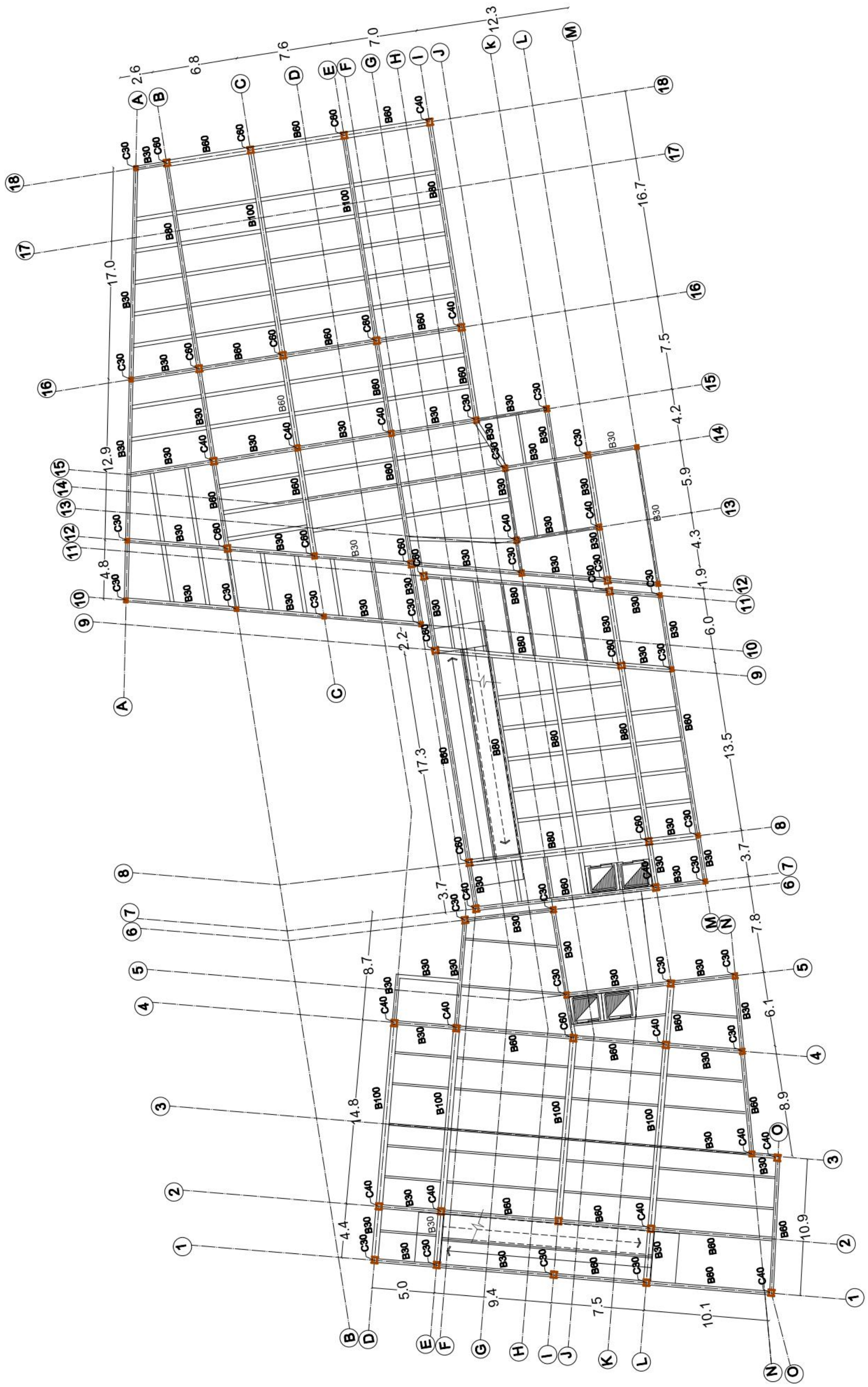


Fig.3.55. Structural plan of First level

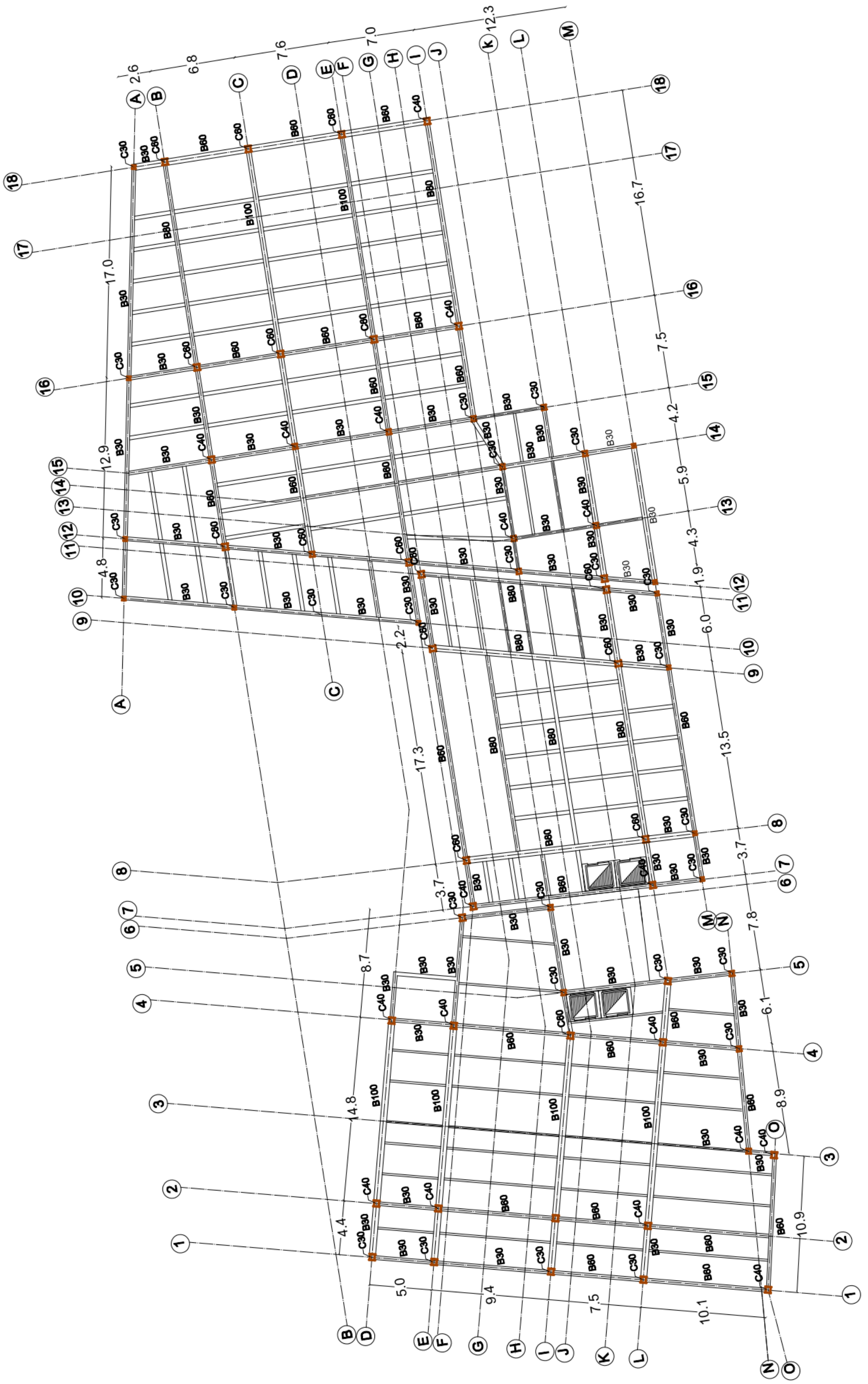


Fig.3.56. Structural plan of second level

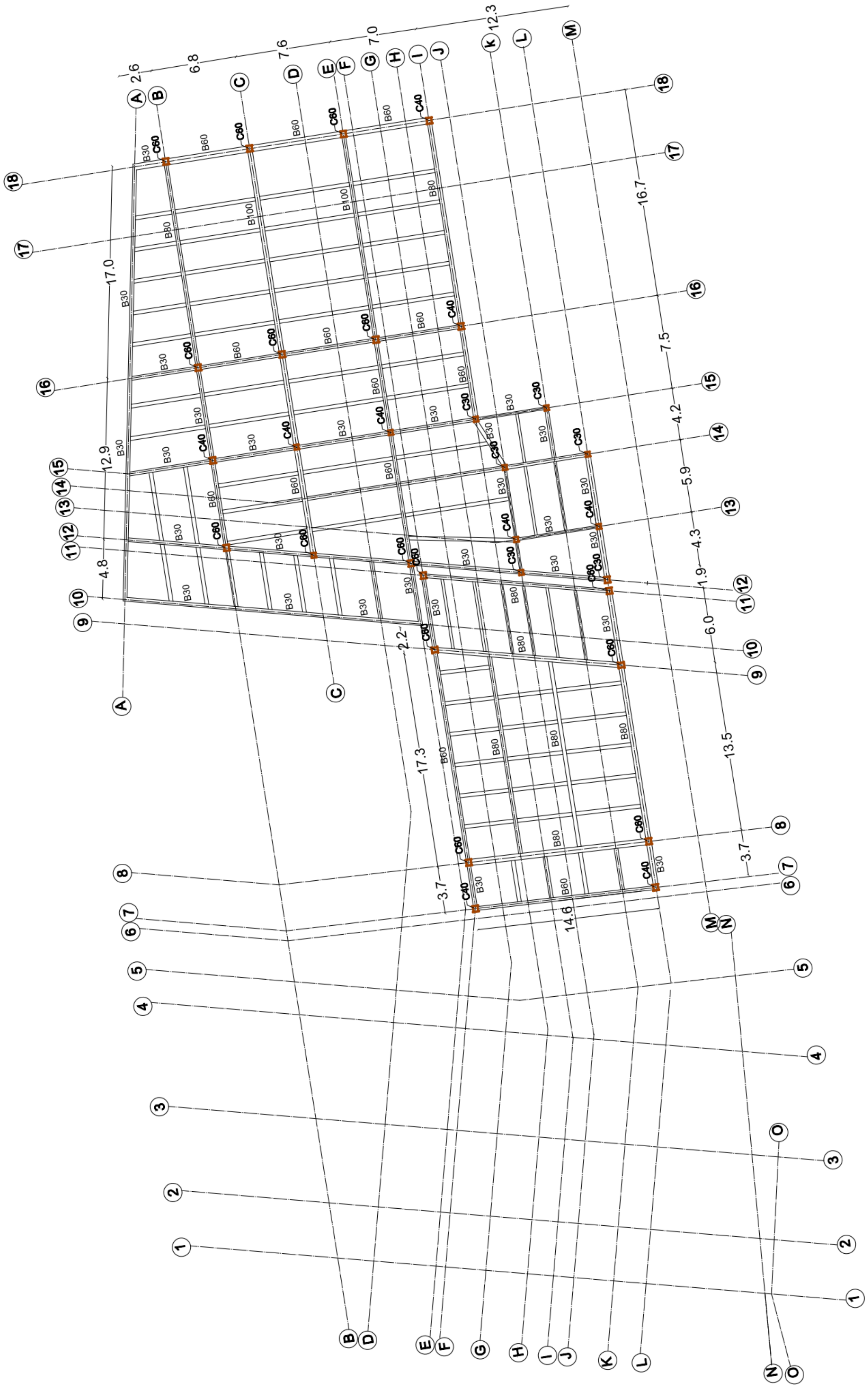
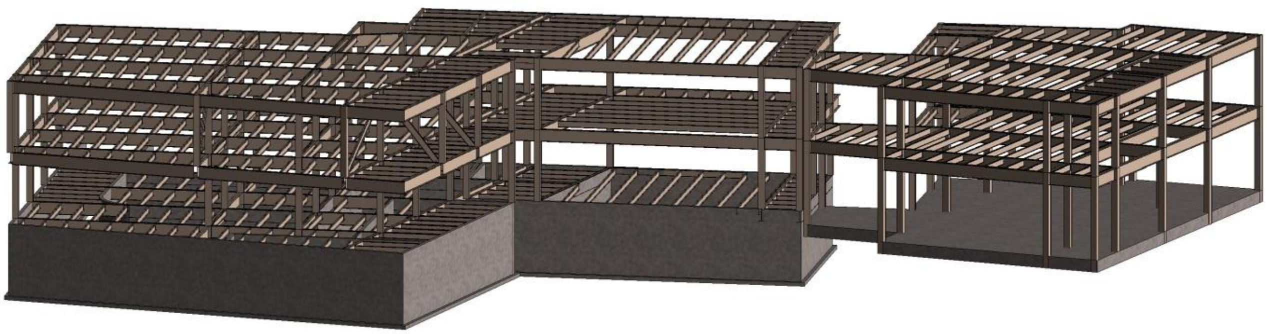
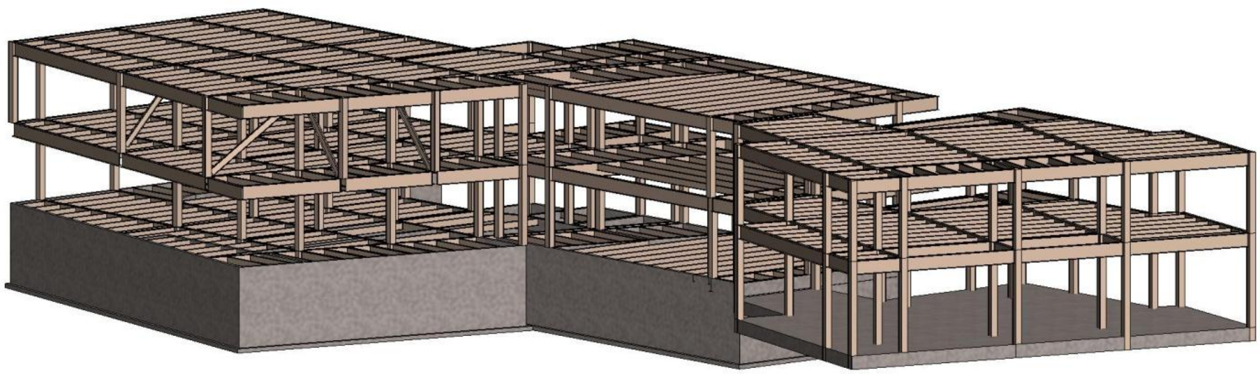
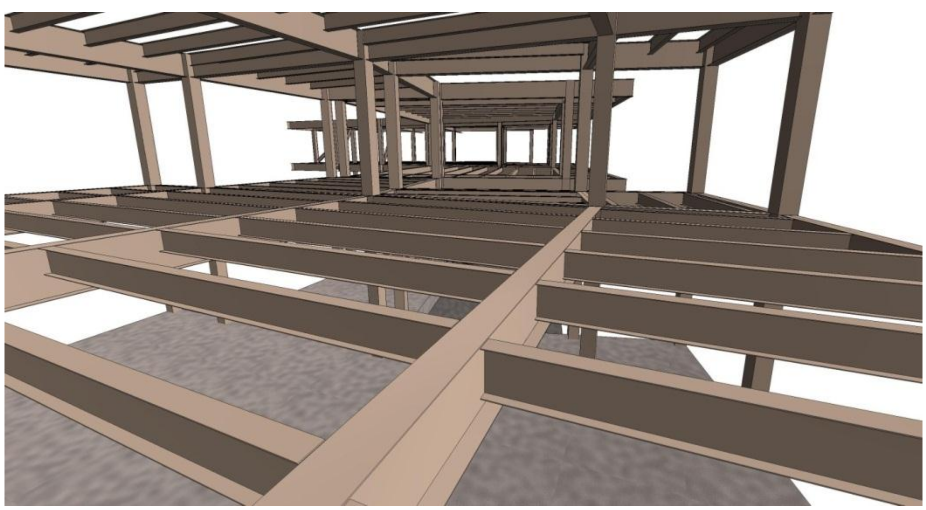
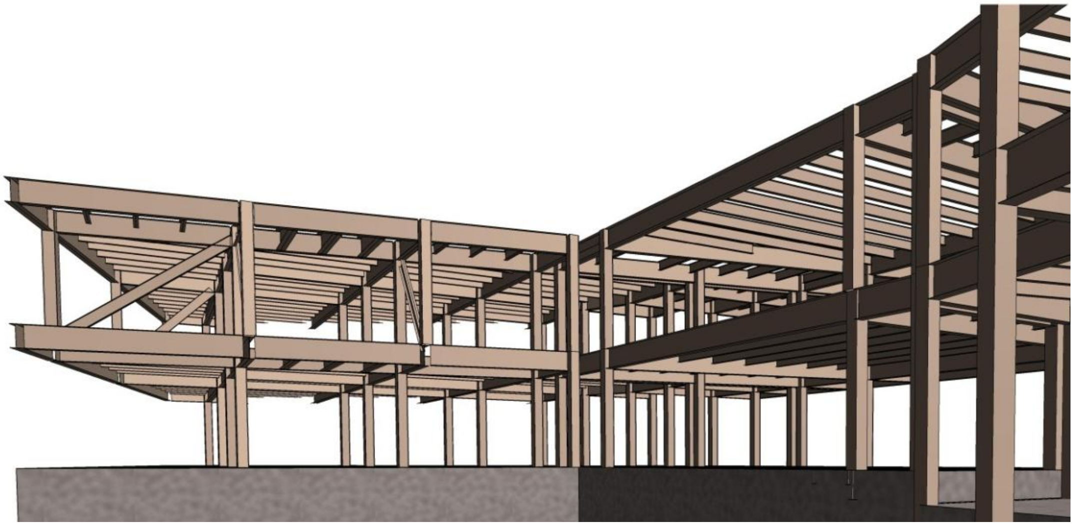


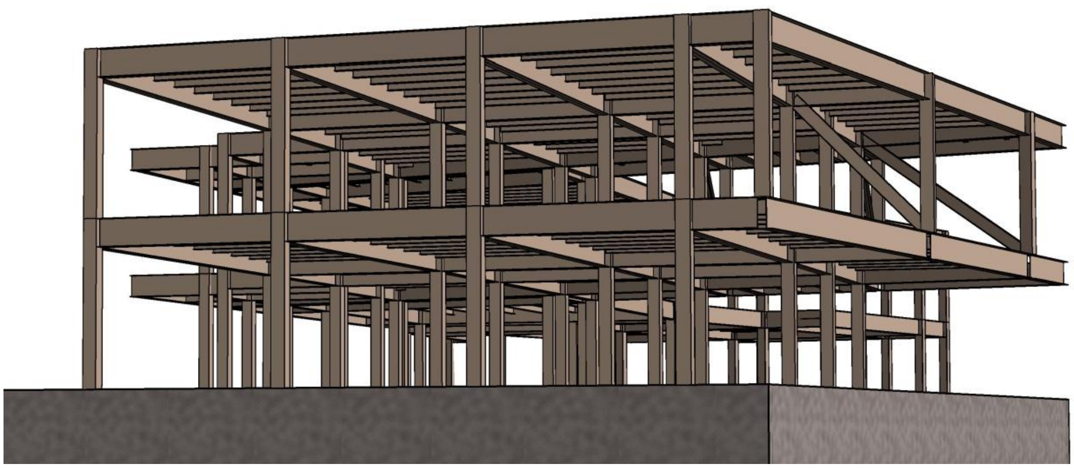
Fig.3.57. Structural plan of zero level

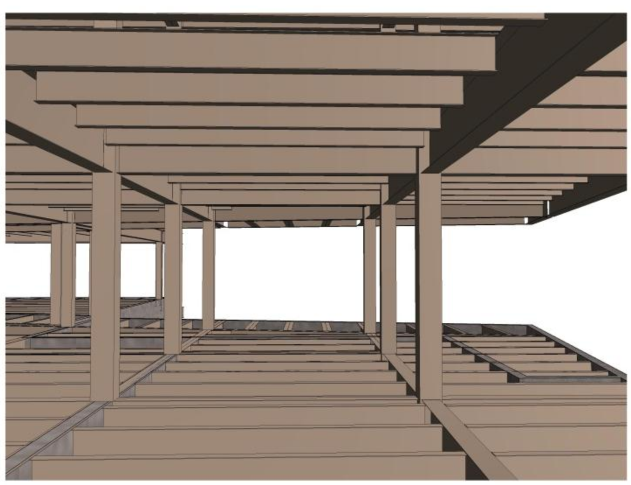












Technological Design

Introduction

The high dependence on energy supplied from countries outside the EU and the increase in greenhouse gas emissions led EU Member States to draw up a common energy policy, with the former being regarded as an extremely critical factor by the European Commission. Indeed, 50% of energy demand in the EU is currently provided by imported supplies and it is estimated that this could reach 70% in the next 20–30 years.

As regards the environment, research undertaken by the Intergovernmental Panel on Climate Change (IPCC) has shown that if appropriate measures are not taken, then there is a risk that the earth's temperature will rise by between 1.4 and 5.8 °C by the end of this century as a result of global warming caused by greenhouse gas emissions[1].

European approach versus the impact of buildings on energy consumption:

The building sector is responsible for more than 40 percent of the European energy consumption. At the same time, the potential to save energy by appropriate building operation management, i.e. by taking measures involving very low or no investment costs, ranges from 5 – 30%. This applies particularly to the nonresidential building stock.

At present, however, technical systems in buildings are not usually monitored to guarantee their performance or to check the energy efficiency of their operation.

Maintenance is limited to ensuring that the primary functional aim is fulfilled e.g. warm or cool rooms. Even in new buildings, an energy optimized operation is often not achieved. Often technical systems in buildings operate far below their energetic/economic optimum. At the same time, the system owner or operator lacks the technical know-how and/or capital necessary to make any improvements.

The Energy Performance of Buildings Directive (Directive 2002/91/EC) which prescribes energy certificates for new and existing buildings might offer some opportunities in this field. With the increasing dissemination of energy certificates the awareness of building owners concerning energy efficiency will rise. Furthermore the EPBD is considering the building envelope and the HVAC systems as parts of the same entity and could thereby establish a basis for global optimization of building performance[2].

Implementation of the EPBD in Italy[3]:

The implementation of the EPBD in Italy is a shared task between the State and the 21 Regions and Autonomous Provinces.

The Energy Performance (EP) requirements are modulated in three steps, corresponding to buildings, whose permit requests are presented respectively after 1st January 2006, 1st January 2008 and 1st January 2010.

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[1] Science Direct Energy Policy, Volume 38, Issue 10, October 2010, Pages 5840–5866

[2] ASHRAE Building EQ - Guidelines for the Evaluation of Building Performance, 2008

[3] EPBD, Stato del recepimento della direttiva 2002/91/CE

The type and level of EP requirements for heating differ according to the function of the building: the residential (except community buildings), which express the EP in kWh/m2, and the non-residential, which express the EP in kWh/m3. All EP values are expressed as a function of the climatic zone and of the shape factor, represented by the ratio (envelope surface)/(building volume).

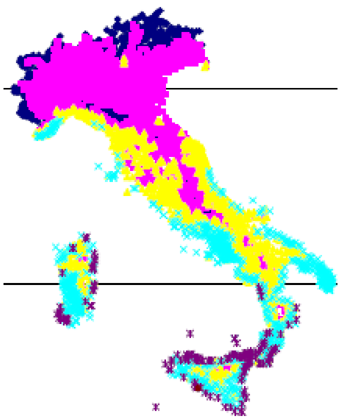


Fig.4.1. Distribution of climatic Zones across the Italian territory

Building form factor S/V	Climatic Zones									
	A	B		C		D		E		F
	Up to 600 DD	*from 601 DD*	*to 900 DD*	*from 901 DD*	*to 1400 DD*	*from 1401 DD*	*to 2100 DD*	*from 2101 DD*	*to 3000 DD*	*beyond 3000 DD*
<0,2	2,5	2,5	4,5	4,5	7,5	7,5	12	12	16	16
>0,9	11	11	17	17	23	23	30	30	41	41

Table.4.1. Energy performance limits for non-residential buildings expressed in kWh/m3 in force starting 1st

Building form factor S/V	Climatic Zones									
	A	B		C		D		E		F
	Up to 600 DD	*from 601 DD*	*to 900 DD*	*from 901 DD*	*to 1400 DD*	*from 1401 DD*	*to 2100 DD*	*from 2101 DD*	*to 3000 DD*	*beyond 3000 DD*
<0,2	2,0	2,0	3,6	3,6	6	6	9,6	9,6	12,7	12,7
>0,9	8,2	8,2	12,8	12,8	17,3	17,3	22,5	22,5	31	31

Table.4.2. Energy performance limits for non-residential buildings expressed in kWh/m3 in force starting 1st

The designers have also to consider additional minimum parameters:
Maximum U-value of vertical or inclined opaque walls, horizontal surfaces (roofs and floors) and transparent glazing, all of them subdivided in three levels, corresponding to the above mentioned three dates of implementation.

Climatic Zones	from 1st January 2006 U (W/m^2K)	from 1st January 2008 U (W/m^2K)	from 1st January 2010 U (W/m^2K)
A	0,85	0,72	0,62
B	0,64	0,54	0,48
C	0.57	0.46	0.40
D	0,50	0,40	0,36
E	0,46	0,37	0,34
F	0,44	0,35	0,33

Table.4.3. Limit values of the thermal transmittance of opaque vertical

Climatic Zones	from 1st January 2006 U (W/m^2K)	from 1st January 2008 U (W/m^2K)	from 1st January 2010 U (W/m^2K)
A	0,80	0,42	0,38
B	0,60	0,42	0,38
C	0,55	0.42	0.38
D	0,46	0,35	0,32
E	0,43	0,32	0,30
F	0,41	0,31	0,29

Table.4.4. Limit values of the thermal transmittance of roofs.

Climatic Zones	from 1st January 2006 U (W/m^2K)	from 1st January 2008 U (W/m^2K)	from 1st January 2010 U (W/m^2K)
A	0,80	0,74	0,65
B	0,60	0,55	0,49
C	0.55	0.49	0.42
D	0,46	0,41	0,36
E	0,43	0,38	0,33
F	0,41	0,36	0,32

Table.4.5. Limit values of the thermal transmittance of basement.

Climatic Zones	from 1st January 2006 U (W/m^2K)	from 1st January 2008 U (W/m^2K)	from 1st January 2010 U (W/m^2K)
A	5,5	5,0	4,6
B	4,0	3,6	3,0
C	3,3	3,0	2.6
D	3,1	2,8	2,4
E	2,8	2,4	2,2
F	2,4	2,2	2.0

Table.4.6. Limit values of the thermal transmittance of vertical windows (frame and *panes).*

The Energy Performance Certificate

The Energy Performance Certificate (EPC) is the most visible aspect of the ECB (Energy Conservation of Buildings). This document assigns an energy performance label to residential and non-residential buildings or building units, and it lists measures for improving their energy performance, sorted by cost-effectiveness. The energy label classifies the energy performance (EP) of buildings in kWh/m2 (residential buildings) or kWh/m3 (nonresidential buildings) of primary energy, on an efficiency scale ranging from A+ (high energy efficiency) to G (poor efficiency). Performance is expressed for the whole energy used in the building, and separately for the single end uses: heating, hot water, cooling. For cooling, performance concerns the building summer load (system performance is not yet considered). Lighting will be considered, for nonresidential buildings only, in a later phase.

The global EPgl is the sum of the partial EPs:

EPgl= EPi + EPacs + EPe + EPill

where:

EPi: is the EP for heating;

EPacs: is the EP for domestic hot water;

Epe: is the Ep for summer cooling;

EPill: is the EP for artificial lighting.

In Italy, the definition of a public building includes:

Buildings owned by the State, regional, or local administrations, or other public organizations, irrespective of the activity performed therein, or any building not publicly owned, but used by a public body. Every public building larger than 1,000 m2 is required to display the energy certificate in a place easily visible to the public. However, no deadline or fine has been specified for non-compliance with this requirement. All public buildings must have an EPC, when an operation and maintenance contract is signed for their management. Since December 2006, about 8 M€ has been budgeted for energy diagnosis and certification of public buildings, throughout the Regions. Evolution of Minimum quality requirements in building regulations:

The evaluation of minimum quality requirements is difficult, due to the differentiation of climates and shape factors. Taking climatic zone E and a shape factor of 0.5 as an example, the first EP legal requirements on building energy performance stated in 1993, which can be assumed as approximately 120 kWh/m2.year (final energy needs), have been reduced to 87.5 in 2006, to 80.5 in 2008 and to 71.2 in 2010.

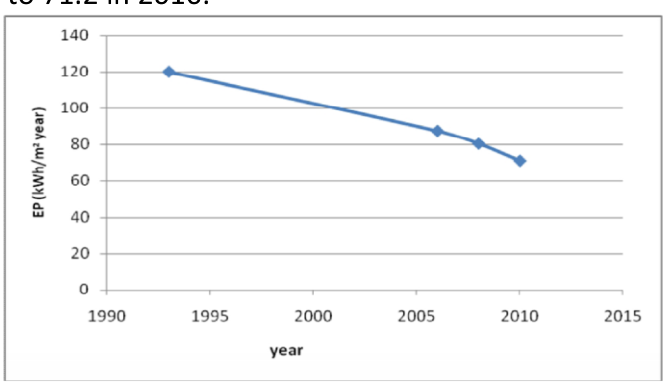


Fig.4.2. Evolution of Minimum requirements in building regulations

Fig.4.3 Decrease of the maximum legal EP with time

Weather Analysis of Milano

Qualitative approach: One year in Milano[4].

The climate of the city is irrevocably affected by the substantial influence caused by human activities.

The considerable expansion of residential areas with a consequent loss of many green areas, the wild and unchallenged invasion of motor vehicles, the use of more effective heating systems, not to mention what is happening in the rest of the world, are bringing the climate of the city to a gradual warming that could produce devastating effects in the long run.

The zonal subdivision shows significant differences in terms of heat, humidity and precipitation.

If thunderstorms are more frequent and violent on the North-East metropolitan side, leaving sometimes the western and southern sides in a dry state, the record of moisture belongs to the southern side, the heat one is around the city center, and the precipitation one is generally more significant in the northern areas.

Early fog patches in the 60s and 70s for example, already occurred at the Western outskirts of the city from the early days of September.

Currently the first foggy phenomena occur in this area starting only in half of October.

Conversely, The first frosts were known by the second week of November and were still quite frequent until the middle of March, and currently the major frosts are concentrated from the first days of December, and finish, with certain exceptions, at the end of February.

It is worth to add that the snow became less frequent and it is almost exclusively caused and preceded by cold Easter inflows.

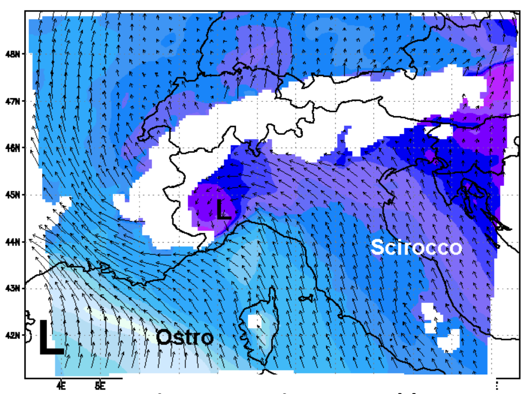


Fig.4.3. Cuscinetto Freddo- Centro Meteo Lombardo

Fig.4.4. Snow day in Milano- meteolive.it

The Po basin is nearly no longer able to independently produce the "cuscinetto freddo" to host the snowfall: the heat island formed in the city center is also accentuating this trend.

The wind speed affects the thermal gap with the rural area.

A unique situation of Favonico winds is also occurring in neighborhoods where the Katabatic wind is unable to infiltrate, the cool night moist air is trapped between the meanders, causing

4 Alessio Grosso, Il clima di Milano: Illustriamo le principali caratteristiche del clima milanese, 2002. Translated from Italian.

frosts in sheltered places, while a few kilometers to North, the air is dry and the temperature is well above the freezing level due to the Favonico effect.
The phenomenon was already known a time ago but has increased with the accumulation of pollutants, principally the notorious greenhouse gases: carbon dioxide, CFCs, methane, ozone, nitrous oxide. In particular, ground-level ozone is the main component of summer smog.
The particularly intense solar radiations and the pollutants produced by traffic and industry, are transformed into ozone, harmful to health.
Consider for example a summer morning: the sky is clear with haze and calm winds since the previous night, the buildings have freed all the heat accumulated in the previous day, bringing the minimum of the city to differentiate from the 3 ° C one in the rural area. The transparency of the air is reduced, but the accentuated thermal gap anticipates the formation of breezes, which increase the transparency of the air and the intensity of sunshine: the gap still rises and the ozone proliferates, but the breeze presses and exceeds 5 knots; at this point, the heat island is almost destroyed with the reduction or the elimination of the thermal gaps, such like during heavy rain or a marked “Cumulogenesi” on the city.

Fig.4.5. Milano Parco Nord- CML

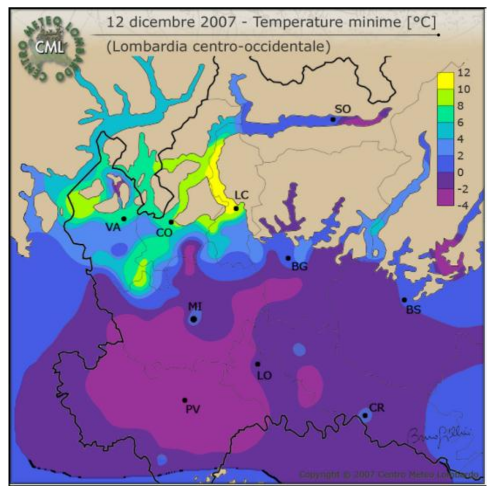


Fig.4.6. Min. temperature distribution

In winter, due to the low incidence of the sun, the cool and moist air accumulates in the peripheral parts of the town, protected by the shade of the buildings, maintaining the temperature, despite the heat produced by domestic heating, at values close or sometimes even lower than the rural one.
Moreover, people, burning fuel, emit huge amounts of sulfur dioxide in the atmosphere, which turns into aerosol: countless particles that contrast the heating phenomena, by reflecting solar radiation and dispersing it into the space. With overcast skies but light winds during winter, the night temperature in the city does not decrease for almost nothing, since heat loss is strongly inhibited by the cloud layer and also during the summer, although without heating radiators, the decreasing of the temperature is still negligible. It's barely necessary to remember that the curious "district snowfalls" have been reduced dramatically.
Going from Piazza Duomo under the rain, when the public transport reached the height of Porta Genova station, south-east from the original departure, the precipitation tended to become snowy, coinciding with a decrease in the visibility and the temperature.
These pockets of cold air were still able to spread to the rest of the city, especially in the early morning hours, favored by the still limited urban development and so by limited road traffic, and then further circumscribed by the arrival of more mild air. The formation of cold mists,

associated to very low temperatures, supported mainly these phenomena. These fogs today in the city center have very low frequency, sometimes reduced to one time a year.
The construction of new residential neighborhoods in the suburbs, with the birth of tower blocks, up to 10 floors and a lot of paved roads connecting them to the main roads, has resulted a further accumulation of local heat, first absorbed and then released slowly during the night with consequent extension of artificial heat islands.

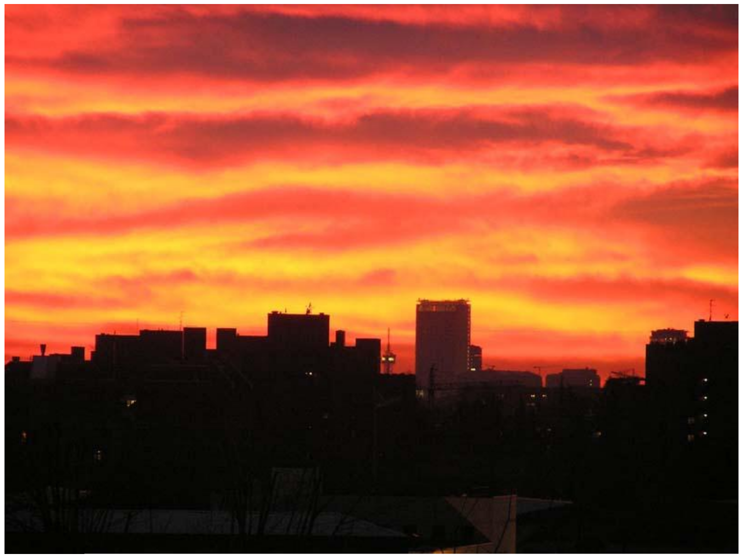


Fig.4.7. Favonico symptoms on a Milanese sun set- CML

Sometimes the NW suburbs are the ones of more interest, others the south of the city.
In recent years however winter precipitations tends to be between mid-December and early January and then reduce clearly until getting prolonged periods of drought.
The month of March is always warmer, characterized by precocious flowering of the vegetation.
April marks the return to episodically winter conditions with some singular cases (famous snowing of 17/04/1991). In any case, this month marks significant changes in temperature, but the mercury column starts to rise then more constantly in May, marked by increased storm activity, with showy symptoms sometimes.
With the end of May, the first heat waves alternates with moderate eruptions of cold air with frequent thunderstorms sometimes hail. The storm from the SW is generally accompanied by heavy but rare hail showers. The storms from the NW are short but turbulent with local hail and wind gusts, more frequently on the eastern part of the city. The sky becomes again clear quickly by the Favonico effect influence. The storms from NE are hardly prognostic and generally related to highly variable series. Heat storms originated in the city center seem to have almost disappeared: this would weaken the argument that the concentration of heat in city centers, favoring the rise, would activate thunderstorm outbreaks, while the presence of meadows, football fields, ponds, would favor the fall.
July marks a decrease in storm episodes, although some occasional intense tornadoes are still present, more frequently in the NE of the city, in the direction of Brianza.
The heat is stifling, especially in the late morning and evening hours, with maximum values frequently exceeding 30 ° C.

August, who until a few years ago marked a gradual but steady decline in temperature, especially in the second decade (10th till 20th of august), has become almost as hot as July even if the thunderstorm tendency increases, sometimes intense, with temporary relief.
Also in September, the summer conditions tends to prolong but with lower peaks.
Then, major rains that mark the passage of the autumn season will take over.
Generally on time, and with water supplies within the norm, the autumn disturbances come, alternated with anticyclonic coinciding periods, with modest foggy phases.
The Favonico effect (foehn) accompanies the passage of the first winter fronts of the NW with large sunny spells and warm northerly wind. These Favonico episodes were repeated with increasing frequency and persistence in recent years, reaching even considerable top speeds.
At the end of the phase, the currents can orient themselves from E, with a considerable cooling and the presence of low cloud or fog.

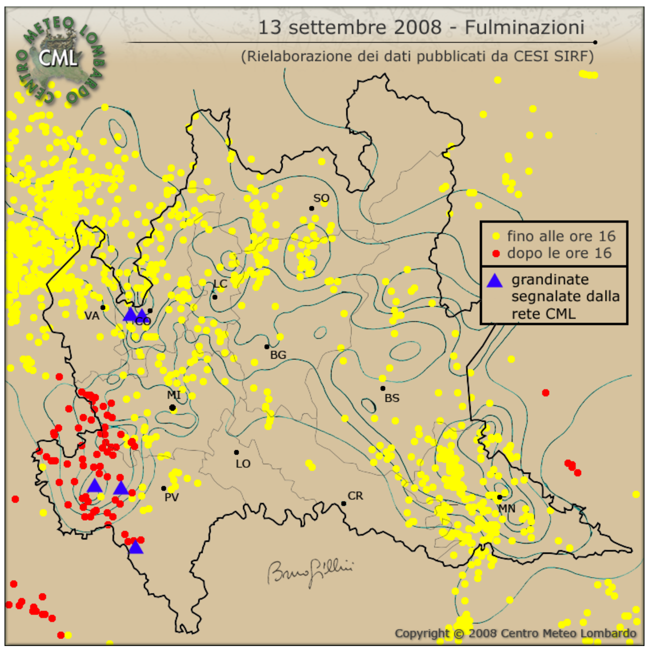


Fig.4.8. Lightening phenomena-CML

The arrangement of the currents from SW, after a Favonico phase however, tends to worse and even snowy situation, if the previously flowed air had polar or arctic origins.
This is the second case of "external intervention" in the western Po basin, besides the already mentioned cold Eastern irruption, able to bring snow to the city, even if for only a few hours.
It's a quite rare but possible event, due the capacity of cold and dry air to absorb, cool and evaporate partly, at least initially, the mild and moist air put in contact.
The temperature then decreases more abruptly before increasing gradually due to saturation, the intensity of rainfall and the mild flow.
The precipitation starts then in the form of “nevischio”, then changes in snow, and finally ends with the rain. If the front is actually coming from the NW with cool features, but with SE winds, the dynamic is the same but the precipitations assume a reversed snowy character, have short-term and are locally granular.
The formation of the “cuscino freddo” however is also activated after days of the Favonico effect, followed by weak inflows of southern moist air, which tends to stagnate for days with

consequent formation of fog which, if not disturbed by low cloudiness, can persist for days, getting cooler.
In conclusion, the weather in Milan can be described as increasingly "irregularly regular" with worrying extremes…

Quantitative approach[5]

Quick Definitions:

Global Horizontal Radiation is defined as the amount of direct and diffuse solar radiation received on a horizontal surface during the 60 minutes preceding the hour indicated. The units are in Wh/sq.m or Btu/sq.ft.

Direct Normal Radiation (also called Beam Radiation) is defined as the amount of solar radiation received within a 5.7º field of view centered on the sun during the 60 minutes preceding the hour indicated. The units are in Wh/sq.m or Btu/sq.ft.

Diffuse Radiation is defined as the incoming solar radiation onto a horizontal surface from the entire sky vault during the 60 minutes preceding the hour indicated except for the Direct Beam Radiation that is incoming from the sun. The units are in Btu/sq.ft or Wh/sq.m.

Global Horizontal Illumination is defined as the total visible light that falls on a horizontal surface from the entire sky vault plus Direct Normal Illumination from the sun. The units are in footcandles (also called lumens per square foot) or in lux (also called lumens per square meter).

Direct Normal Illumination is defined as the visible light from the sun that is measured by a narrow angle meter pointed directly at the sun and that excludes the surrounding sky. The units are in footcandles (also called lumens per square foot) or in lux (also called lumens per square meter).

Dry Bulb Temperature is the sensible temperature typically measured by a thermometer with a dry bulb. The units are either in degrees C or F.

Dew Point Temperature is typically defined as the temperature of a surface on which dew or precipitation will form under the current dry bulb temperature or humidity conditions. On the psychrometric chart this represents the intersection of the saturation curve (100% relative humidity) with a line drawn horizontally from the current dry bulb and relative humidity point. The units are in degrees C or F.

Relative Humidity is the ratio of the amount of moisture in the air compared to the total amount it could hold at the same dry bulb temperature. Relative Humidity is measured as a percent.

[5] Climate Consultant 5.3 Beta [For Windows]

Wind Direction, from which the wind blows, is defined as the number of degrees from North, measured clockwise. For calm winds, wind direction equals zero.

Ground Temperature is defined as the dry bulb temperature of the earth measured at the given depth. Because of the thermal mass of earth this temperature changes very little from day to day, and the deeper the measurement the less will be the annual temperature difference. The units are in degrees F or degrees C.

Temperature Range

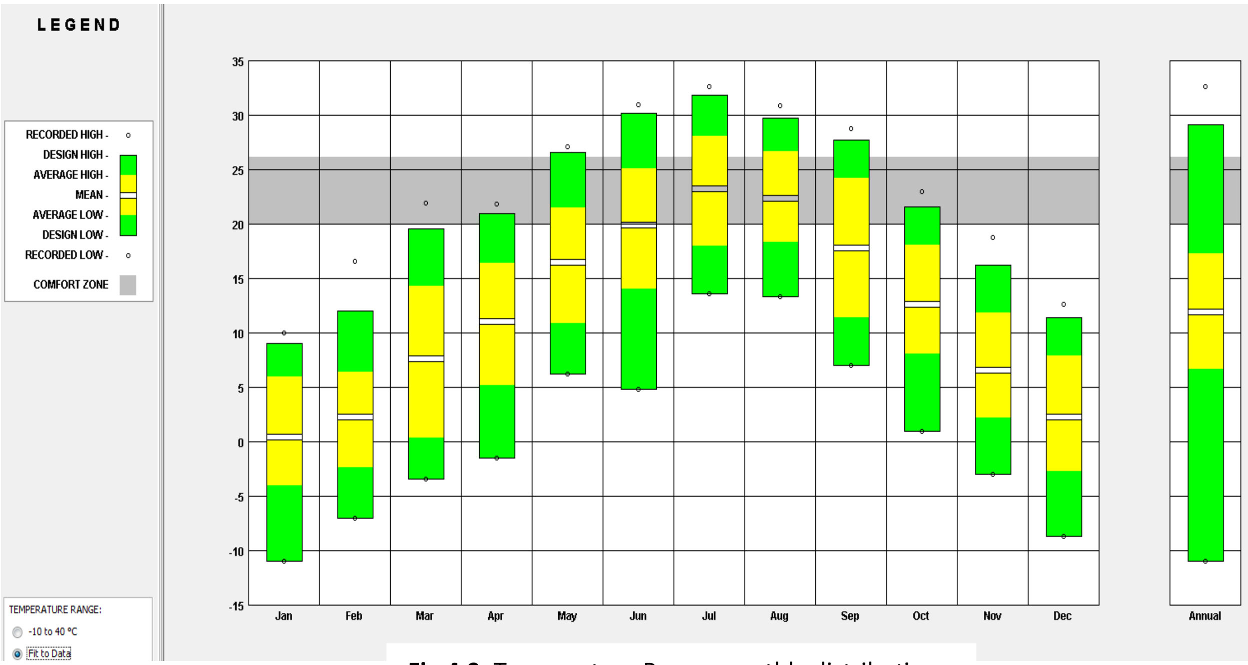


Fig.4.9. Temperature Range monthly distribution

This is the simplest of all charts and shows the dry bulb temperature ranges enclosing the Recorded High and Low Temperature (round dots), the Design High and Low Temperatures (top and bottom of green bars), Average High and Low Temperatures (top and bottom of yellow bars), and Mean or Average Temperature (open slot). These values are calculated for each month and for the full year by Climate Consultant. We notice that the overlapping with the comfort zone is happening mainly in the months of June, July and August.

Monthly Diurnal Averages

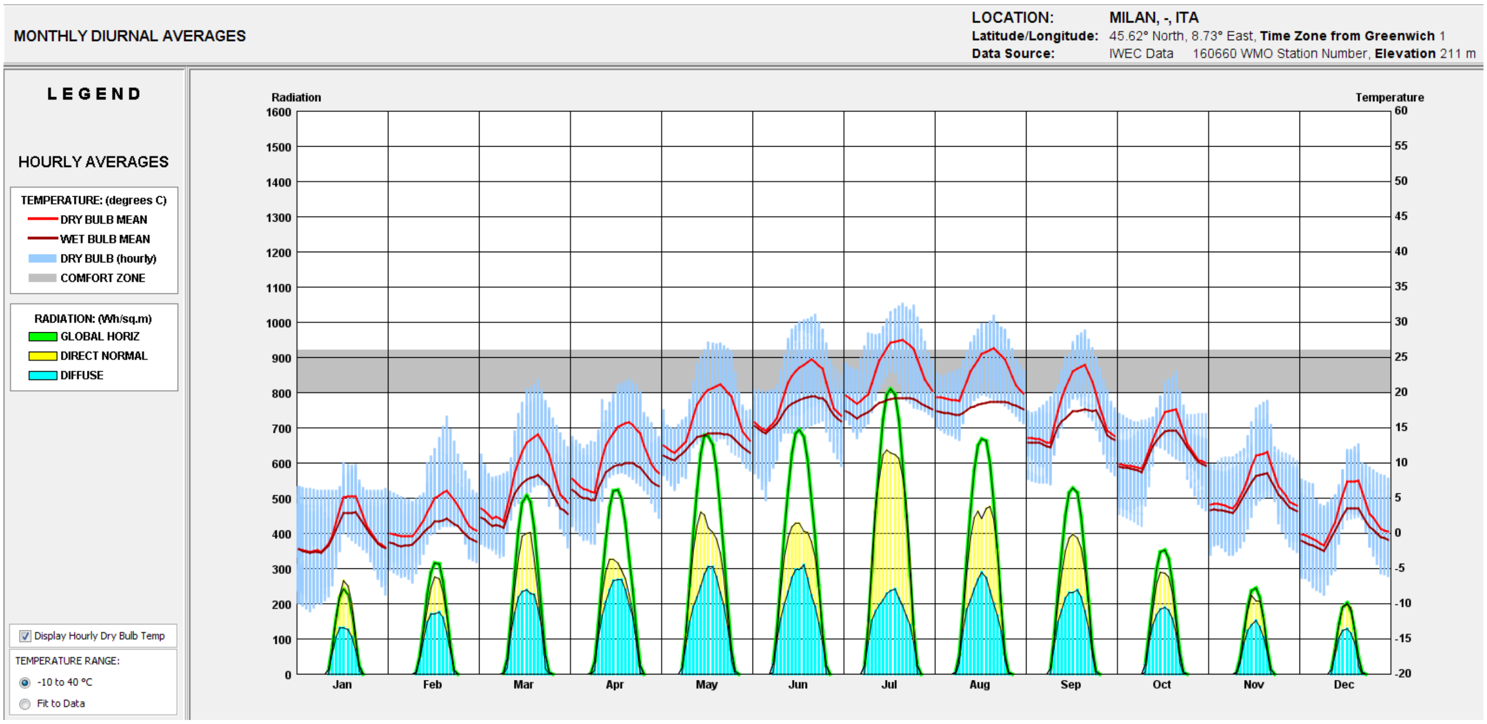


Fig.4.10. Monthly Diurnal Averages

For each month of the year this chart shows the diurnal (24 hour) average data for each hour of each month. It shows the average Dry Bulb Temperature (upper red curve) and average Wet Bulb Temperature (lower red curve) against a grey bar that represents the comfort range as defined on the Criteria Screen, all in degrees F (degrees C). If you click on the box that says Display Hourly Dry Bulb Temperatures then the temperature for every hour of the day throughout the year will be shown in light blue underlain behind the average dry bulb temperature curves. The Average Hourly Radiation for each month is indicated on the left hand scale in Btu/sq.ft (Wh/sq.m) and is shown in green for Global Horizontal, in yellow for Direct Normal, and in blue for Diffuse Radiation. When Diffuse Radiation is higher, it usually means that the sky is more overcast and so Direct Normal Beam Radiation will probably be cut down, thus Total or Global Horizontal Radiation will be reduced. Global Horizontal Radiation is the sum of Diffuse Radiation from the entire sky vault plus Direct Normal Radiation from the sun times the cosine of its angle of incidence to the ground.

Radiation Range

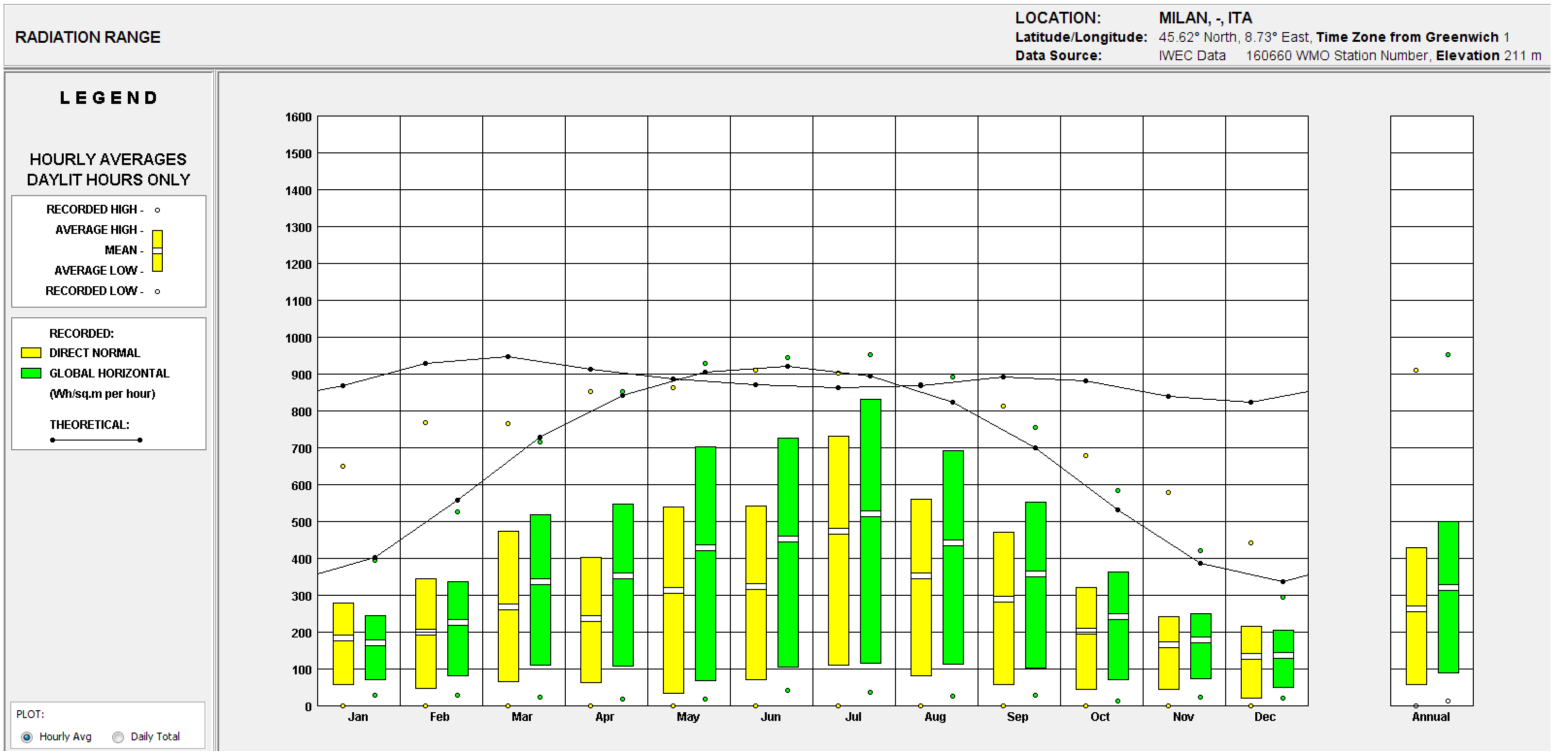


Fig.4.11. Radiation Range monthly distribution

The Hourly Averages Chart shows for each month and for the full year, the Direct Normal Solar Radiation (yellow) and Global (Total) Horizontal Solar Radiation (green) for all daylight hours. Using ASHRAE formulas Climate Consultant calculates the Theoretical maximum hour during each month for both Direct Normal and Global Radiation and displays it as the solid black line. The Recorded (or Peak) highest hour of radiation is shown as a small colored circle. The Average High is the average of the highest value from each day of the month or annually and is shown as the top of the colored bar. The Mean or average of all the daylight hours is shown as the break in the colored bar. The Average Low value is the average of all the lowest values of the month during daylight hours.

The Daily Total Radiation is the total Radiation for each day of the month showing the highest day of the month, the lowest day, and the mean or average day of the month.

Illumination Range

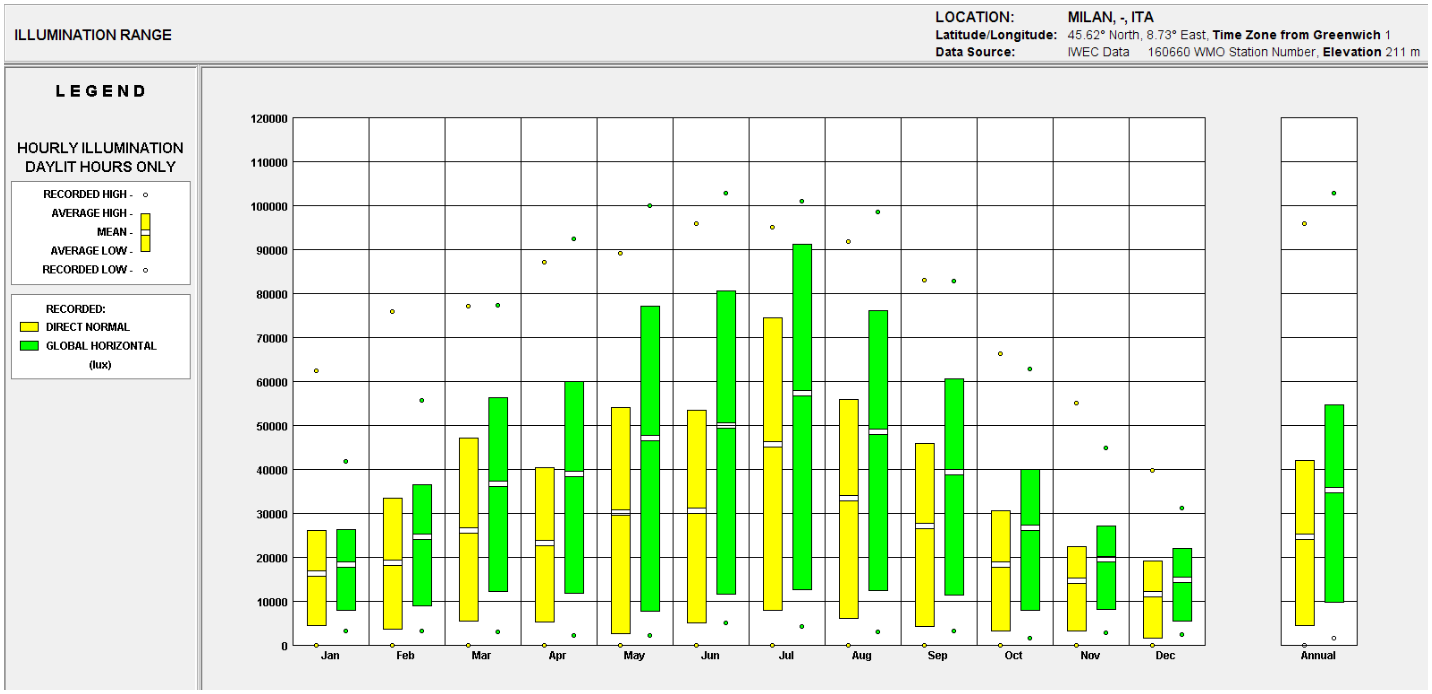


Fig.4.12. Illumination Range monthly distribution

The Visible Direct Normal Illumination shows for each month the Recorded High and Low Daily value (green dot), the Average High and Low value (top and bottom of the yellow bar), and the Daily Mean Illumination (center of the yellow bar). These same variables are shown in green bars for Global Horizontal Illumination. The units are in footcandles (also called lumens per square foot) or in lux (also called lumens per square meter). Note that the Recorded Low Illumination for each month might be greater than zero because of sky glow that appears before the sun rises or after it sets.

Sky Cover Range

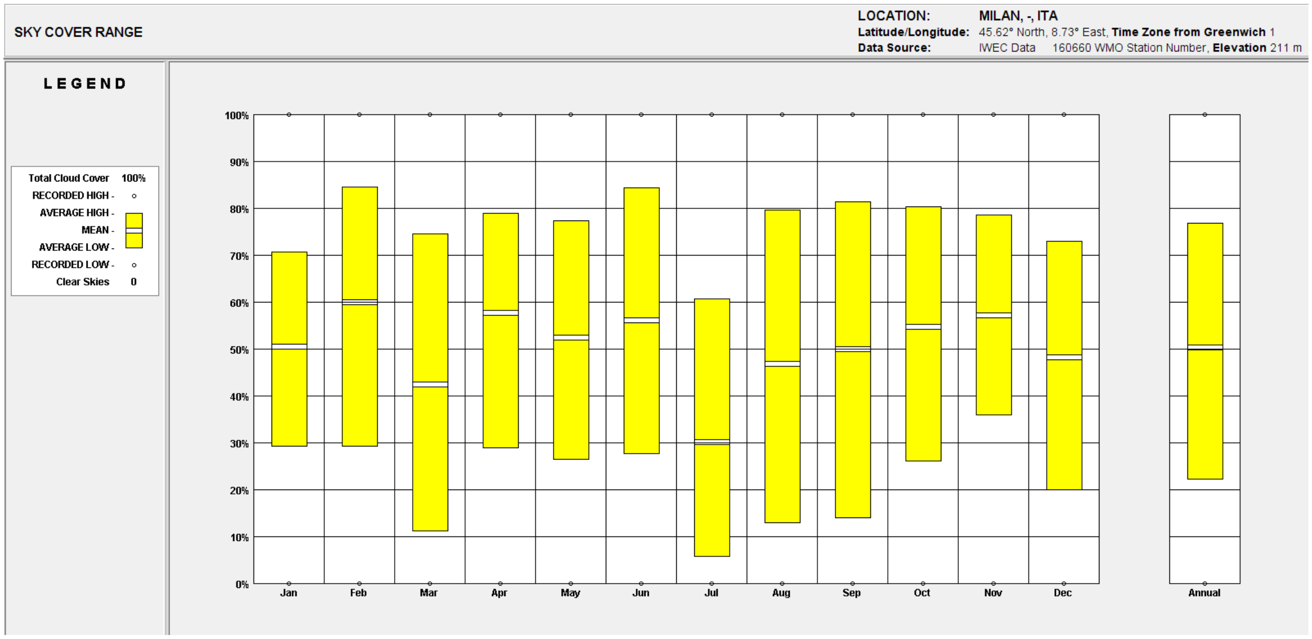


Fig.4.13. Sky Cover Range Distribution

This chart shows Sky Cover for each month and for the full year. A clear sky has 0% Sky Cover and a completely obscured sky has 100% Sky Cover. This corresponds to the amount of the sky dome in tenths covered by clouds or obscuring phenomena at the hour indicated. This data is given in the EPW file as tenths, but is shown in Climate Consultant as a percentage. The Recorded highest amount in the EPW data file is shown as a small colored circle. The Average High is the average of the highest value from each day of the month or annually and is shown as the top of the colored bar. The Mean or average is shown as the break in the colored bar. The Average Low is the average of the lowest values from each day of the month or annually and is shown as the bottom of the colored bar. The Recorded Low value is shows as the small colored circle.

Dry Bulb vs. Relative Humidity

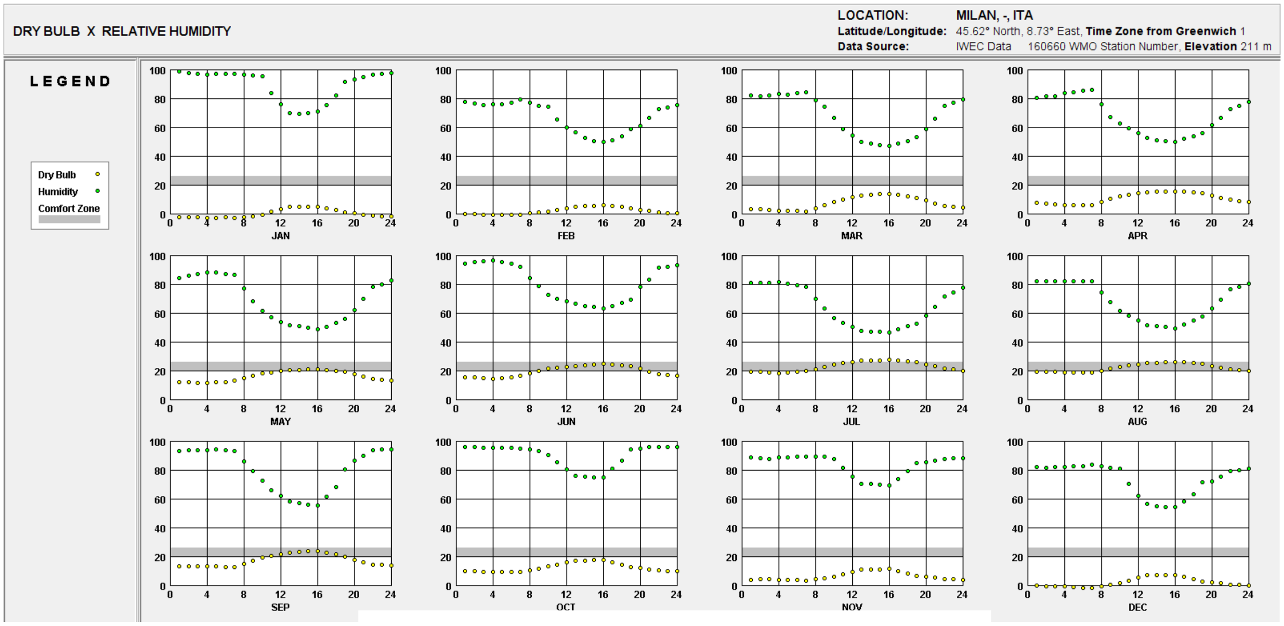


Fig.4.14. Monthly Dry Bulb vs. RH

These 12 charts are the average for each hour of each month of the Dry Bulb Temperature (yellow dot) and the concurrent Relative Humidity (green dot). Also shown on each monthly chart is a gray bar for the Comfort Zone as defined on the Criteria screen. Notice that dry bulb temperature is almost exactly the inverse of relative humidity.

Dry Bulb vs. Dew Point

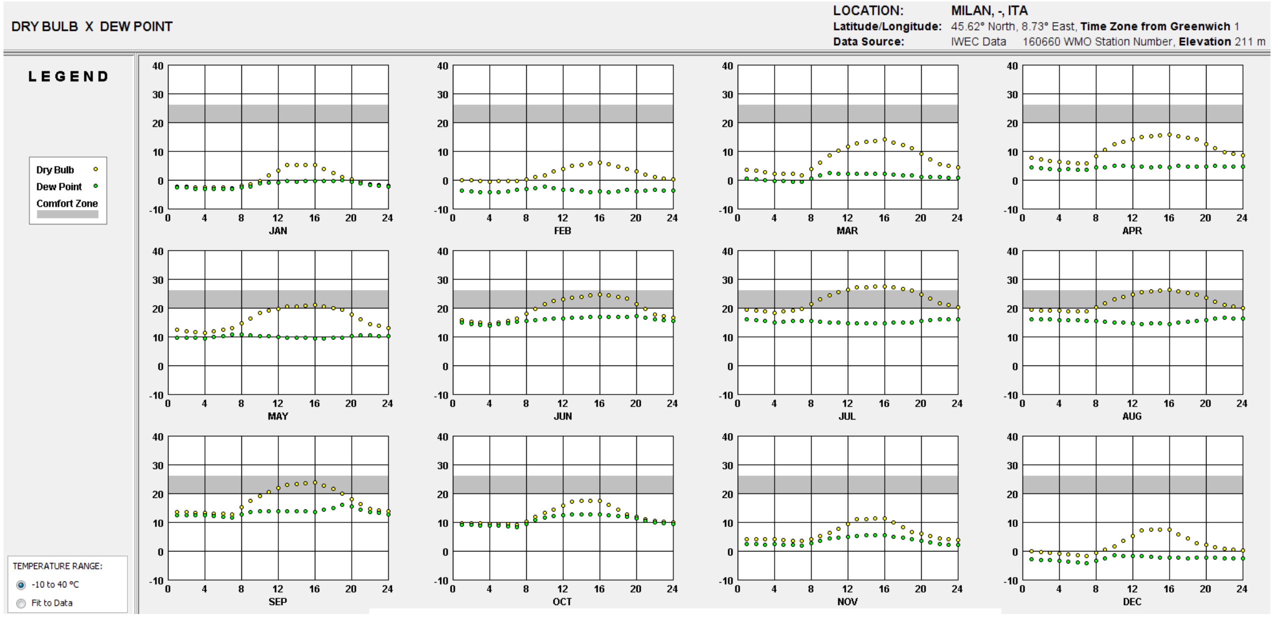


Fig.4.15. Monthly Dry Bulb vs. Dew Point

These 12 charts are the average for each hour of each month of the Dry Bulb Temperature (yellow dot) and the concurrent Dew Point (green dot). Also shown on each monthly chart is a gray bar for the Comfort Zone as defined on the Criteria screen. Notice Dry Bulb temperature increases sharply at sunrise and peaks around 2 or 3 in the afternoon, but that Dew Point temperature is relatively stable throughout the day.

Now after having studied the climate in both qualitative and quantitative points of view, emerge the necessity to benefit from them in our Design Strategies.

Design Strategies

ASHRAE Handbook of Fundamentals Comfort Model, 2005 (select Help for definitions)

1. COMFORT: (using ASHRAE Handbook 2005 Model)

20.0	Comfort Low - Min. Comfort Effective Temp @ 50% RH (ET* C)
23.3	Comfort High - Max. Comfort Effective Temp @ 50% RH (ET* C)
17.8	Max. Wet Bulb Temperature (°C)
2.2	Min. Dew Point Temperature (°C)
2.8	Summer Comfort Zone shifted by this Temperature (ET* C)
1.0	Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1	Activity Level Daytime (1.1 Met=sitting,reading)

2. SUN SHADING ZONE: (Defaults to Comfort Low)

20.0	Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:

8.3	Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8	Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:

16.7	Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8	Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)

20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
11.0	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:

50.0	% Efficiency of Indirect Stage

7. NATURAL VENTILATION COOLING ZONE:

2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)
3.7	Max. Perceived Temperature Reduction (°C)
90.0	Max. Relative Humidity (%)
22.8	Max. Wet Bulb Temperature (°C)

8. FAN-FORCED VENTILATION COOLING ZONE:

0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (°C)
	(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE:

12.8	Balance Point Temperature Above Which Building Runs Free (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)

12. WIND PROTECTION ZONE:

8.5	Min.Velocity above which Wind Protection is Desirable (m/s)
11.1	Min. Dry Bulb Temperature Difference Below Comfort Low (°C)

13. HUMIDIFICATION ZONE: (directly below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (directly above Comfort Zone)

Fig.4.16. Design Strategies Conditions

In the following, we are going to simulate different building strategies on a Psychometric Chart containing the dots taken each 1 hour along one year and analyzing the evolution of their comfort according to the Design Strategy used in order to understand which Strategy could be the most appropriate for this climate. For a full explanation of the logic behind these Design Strategies and how they can be used (see Govoni-Milne, Milne, Givoni, or Stein-Reynold for more details).

Comfort Model

This comfort model is defined in the 2005 ASHRAE Handbook of Fundamentals. It shows how the comfort zone changes as a function of clothing (CLO), with the warmer zone correlating with people wearing lighter summer clothes. The temperatures are defined by slightly sloped lines that account for the effect of humidity on comfort (as it gets dryer people will be comfortable at slightly higher temperatures).
The starting point is the representation of the comfort percentages without any Design Strategy.

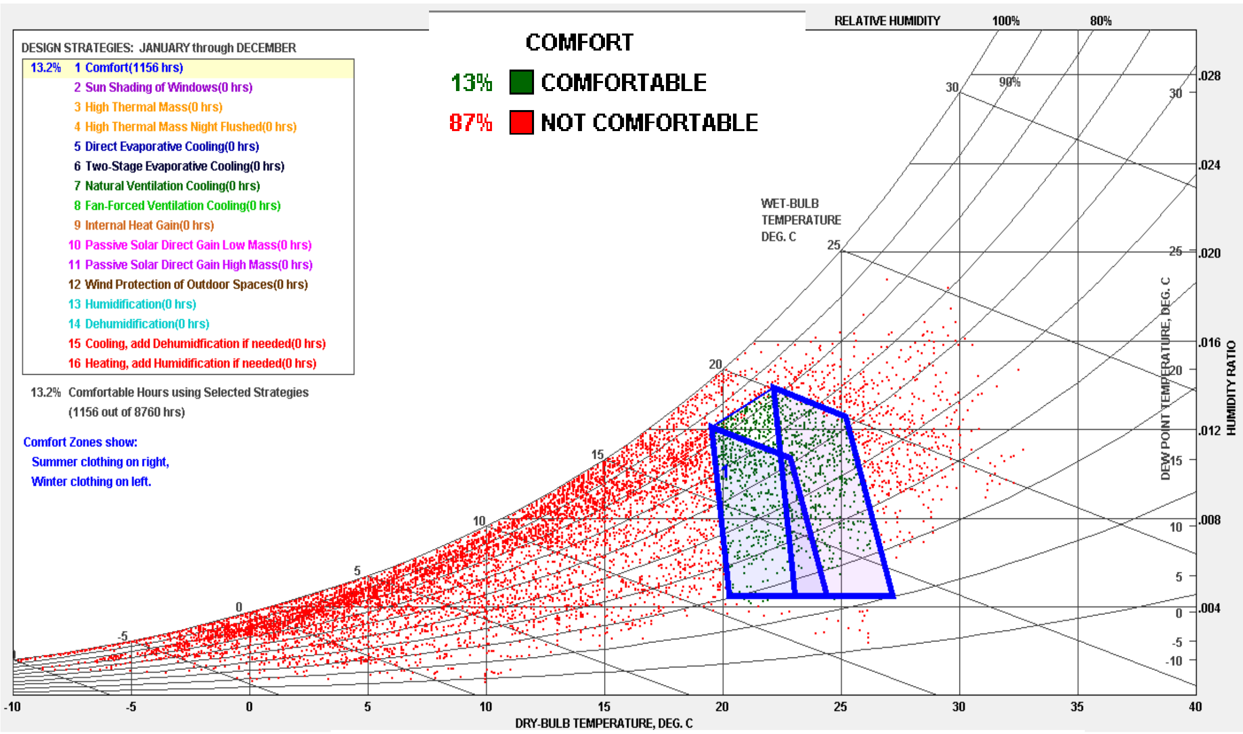


Fig.4.17. Comfort Zone location on the Psychrometric

The starting point of the comfort is 13,2%.

Sun Shading Zone

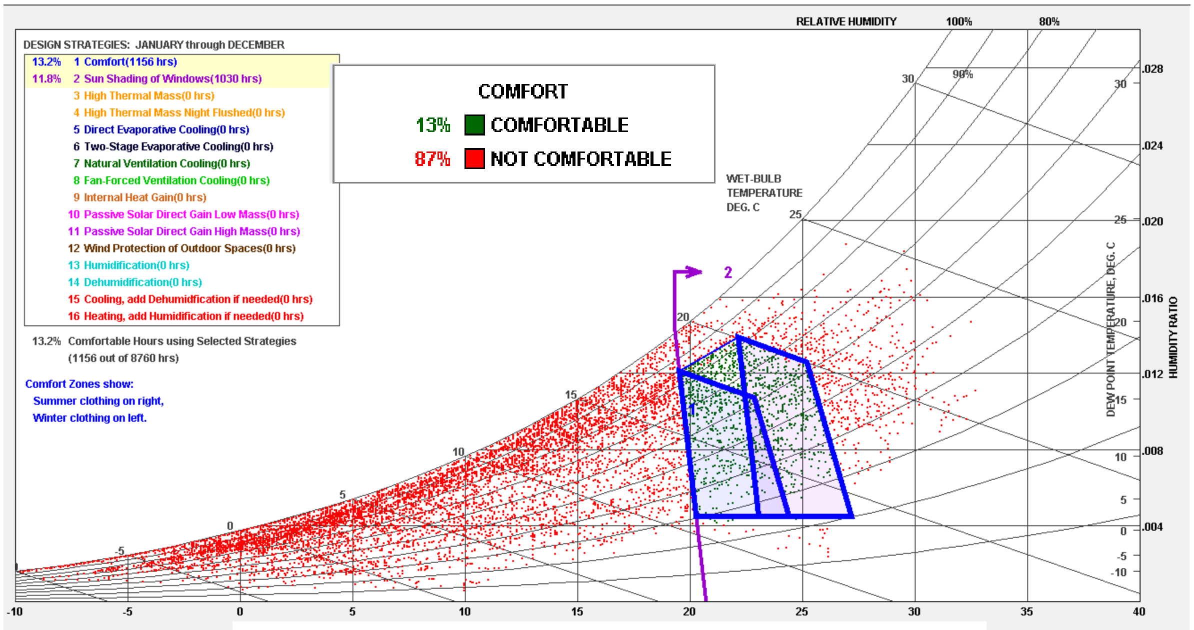


Fig.4.18. Sun Shading Zone on the Psychrometric Chart

It is defined by an outdoor Dry Bulb Temperature and a Minimum Total Horizontal Radiation above which all windows should be shaded. A good rule of thumb is to use the lowest temperature that defines the comfort zone, because above this temperature any solar radiation that enters the building will not contribute to comfort and probably will contribute to overheating the space. Note that the Psychrometric Chart shows the number of hours when it is assumed that Sun Shading is provided, but these hours are not added to the total number of comfortable hours because shading by itself cannot guarantee comfort.

High Thermal Mass Zone

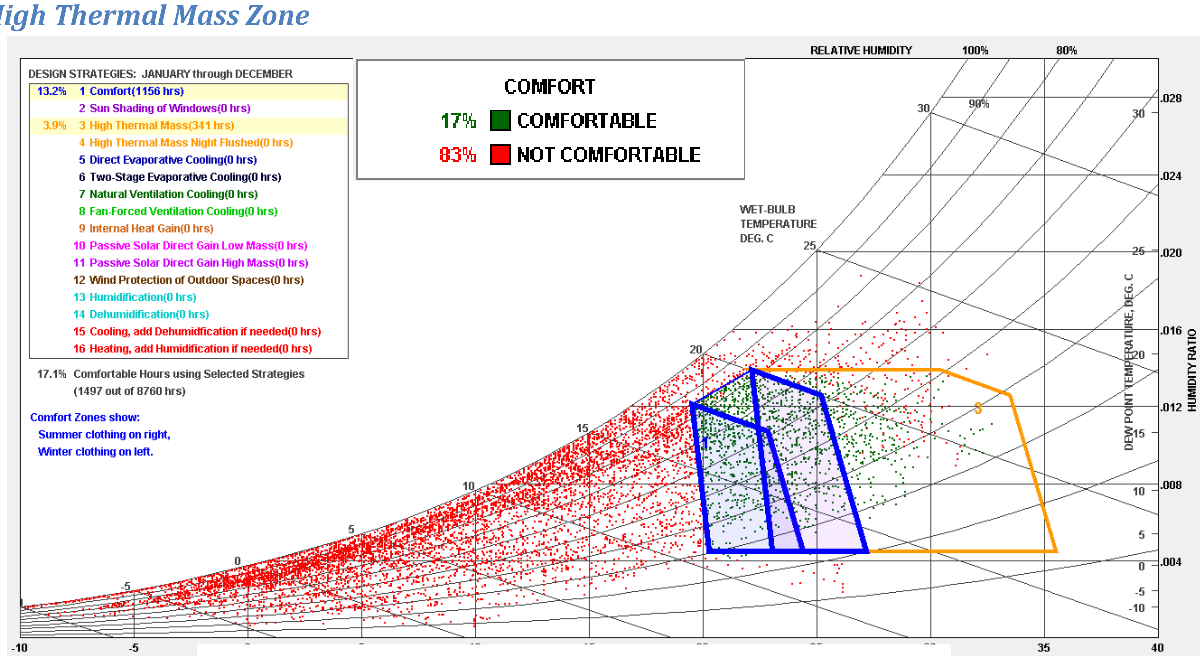


Fig.4.19. High Thermal Mass Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart horizontally and to the right of the Comfort Zone. It defines conditions when using high thermal mass on the interior is a good cooling design strategy. This counts on the thermal storage, time lag and damping effects of the mass. Thus high daily outdoor temperature swings will become low indoor temperature swings. This is why high mass construction is a good natural cooling strategy in hot dry climates. This zone is defined by a Maximum Dry Bulb temperature difference above the Comfort High, and by a Minimum Nighttime Dry Bulb temperature which must be below the Comfort High during the preceding evening. In those conditions, the % of comfort is raised to 17%.

High Thermal Mass with Night Flushing Zone

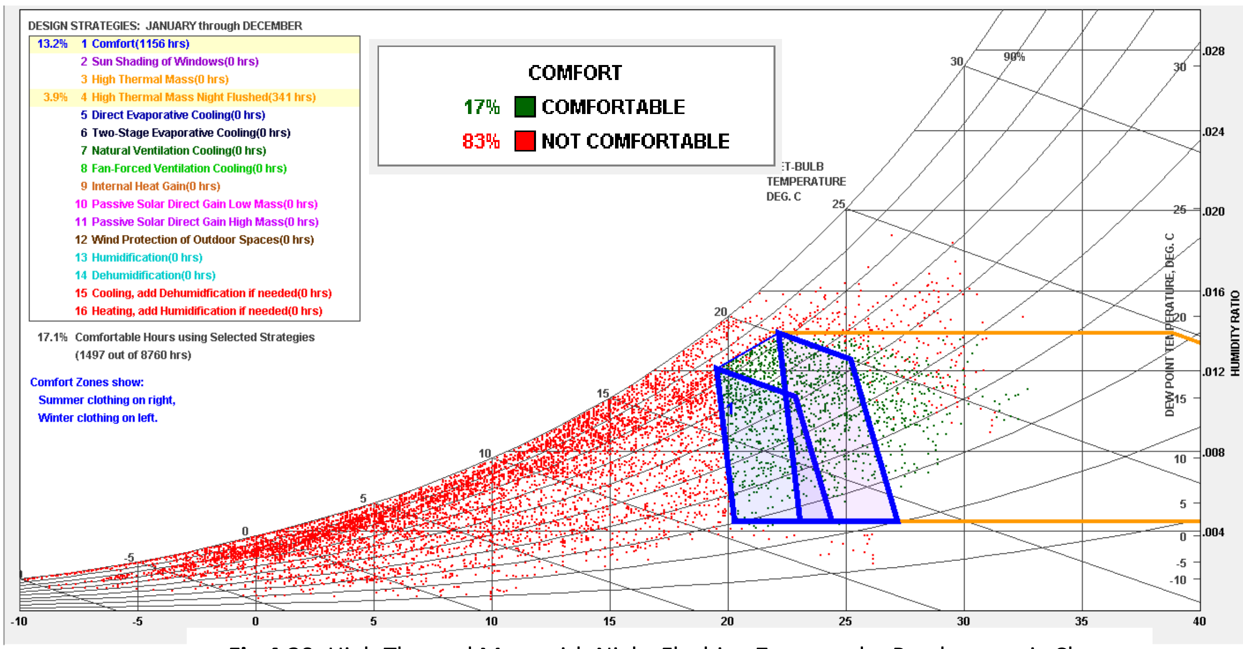


Fig.4.20. High Thermal Mass with Night Flushing Zone on the Psychrometric Chart

This zone defines when using high thermal mass on the interior is a good cooling design strategy when either natural ventilation or a whole house fan is used to bring in a lot of cool night time air, and then the building is closed up during the heat of the day. Thus the building will be able to 'coast' through these higher daytime temperatures then if there was no night flushing. Using this strategy even though there are very high daily outdoor temperature swings, there will be relatively low indoor temperature swings. In those conditions, the % of comfort is also raised to 17%.

Direct Evaporative Cooling Zone

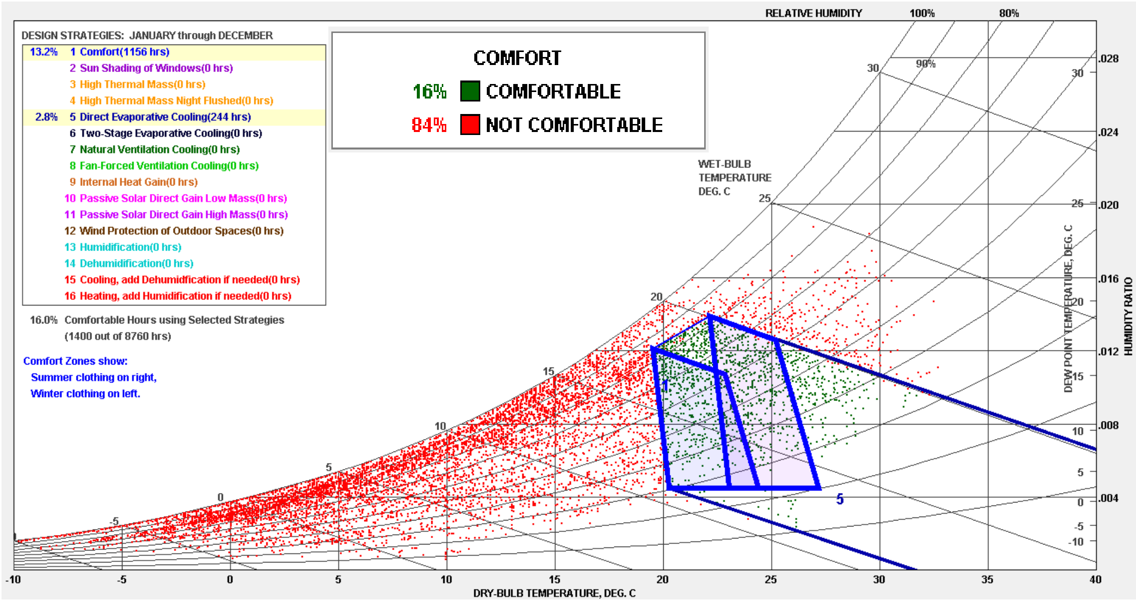


Fig.4.21. Direct Evaporative Cooling Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart down and to the right of the Comfort Zone. Evaporative cooling takes place when water is changed from liquid water to gas (taking on the latent heat of fusion), thus the air becomes cooler but more humid. Evaporation follows the Wet Bulb Temperature line on the Psychrometric Chart. This makes an evaporative cooler a good cooling strategy for hot dry climates, but for a more humid climate like Milano: the comfort using this system reaches 16%.

Natural Ventilation Cooling Zone

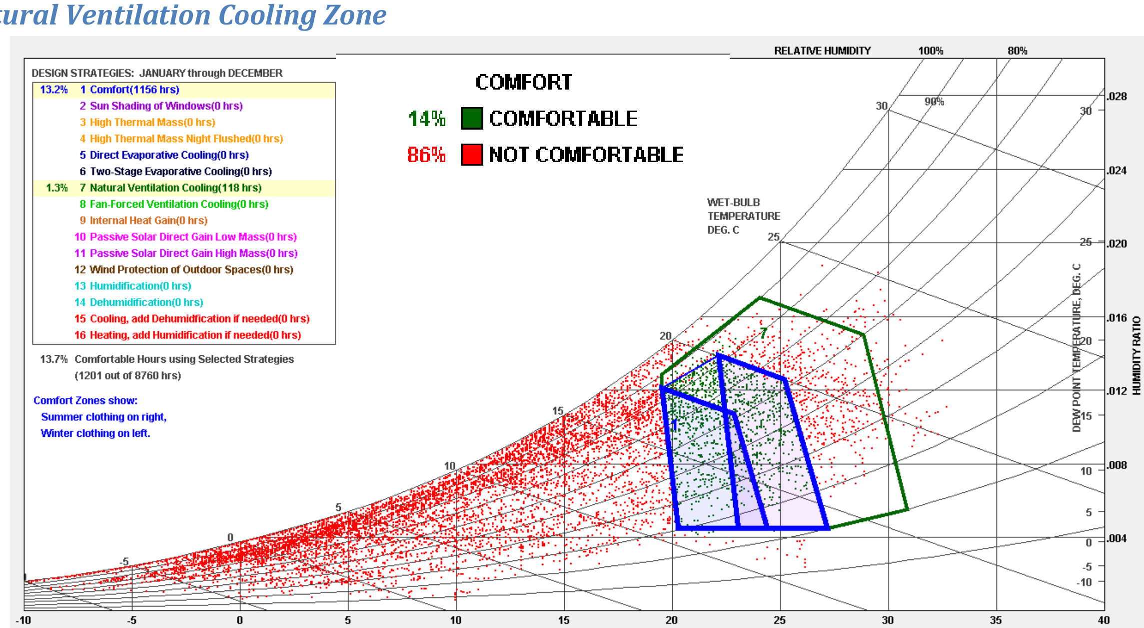


Fig.4.22. Natural Ventilation Cooling Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart above and to the right of the Comfort Zone. In hot humid climates air motion is one of the few ways to produce a cooling effect on the human body. It does this by increasing the rate of sweat evaporation and giving the psychological sense of cooling (note that ventilation does not actually reduce the dry bulb temperature). In this case, the comfort can just reach 14%.

Fan Forced Ventilation Cooling Zone

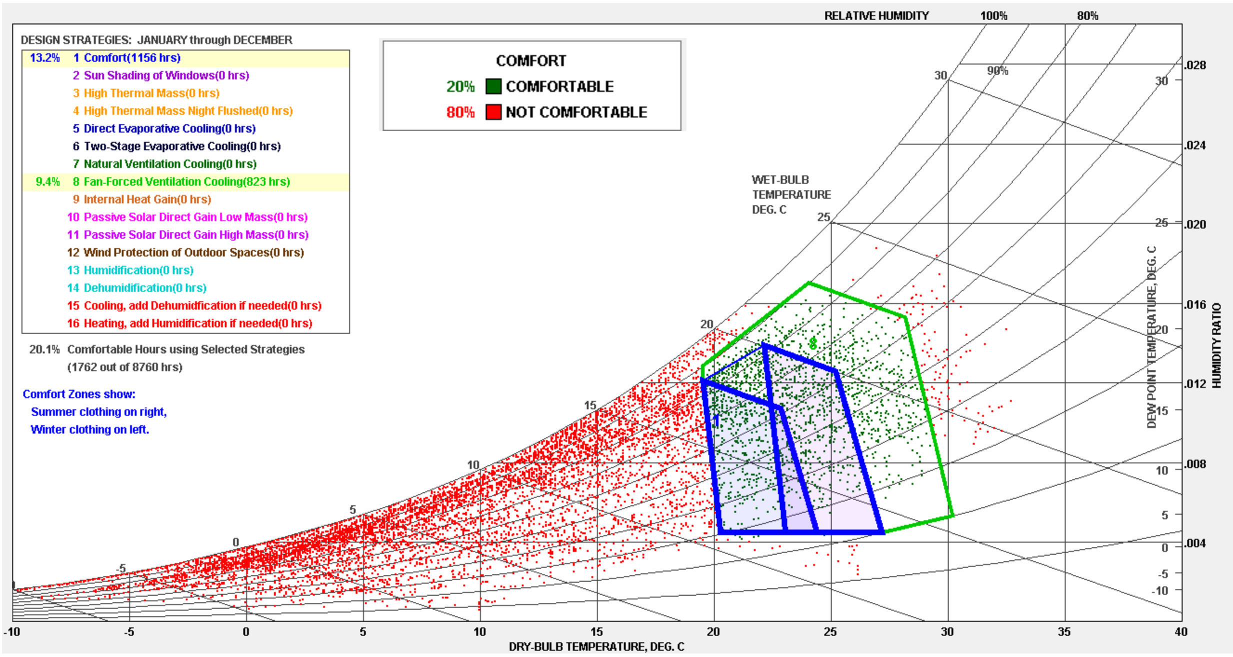


Fig.4.23. Fan Forced Ventilation Cooling Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart above and to the right of the Comfort Zone. It is assumed that when ventilation cooling is needed, fan forced air motion can be created by centralized mechanical fans or ceiling fans or even small local fans on a desk or table. In this case, the comfort is raised to 20%.

Internal Heat Gain Zone

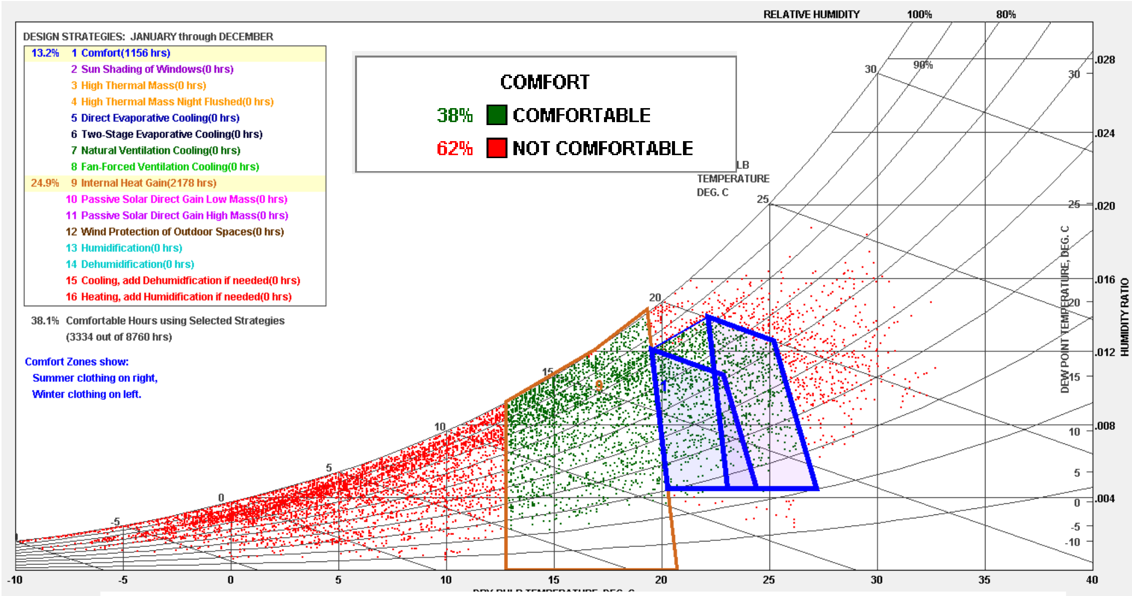


Fig.4.24. Internal Heat Gain Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart to the left of the comfort Zone. It represents a rough estimate of the amount of heat that is added to a building by internal loads such as lights, people, and equipment. It is very dependent on the building type and design. This Balance Point Temperature is the outdoor air temperature at which internal loads alone will keep the building in the comfort zone. Well designed, well insulated buildings have much lower balance point temperatures, thus use much less heating energy. Some building types (like our case for museums for example which has low occupancy) have relatively low internal loads and need more supplemental heating. The comfort is increased to 38%.

Passive Solar Direct Gain High Mass Zone

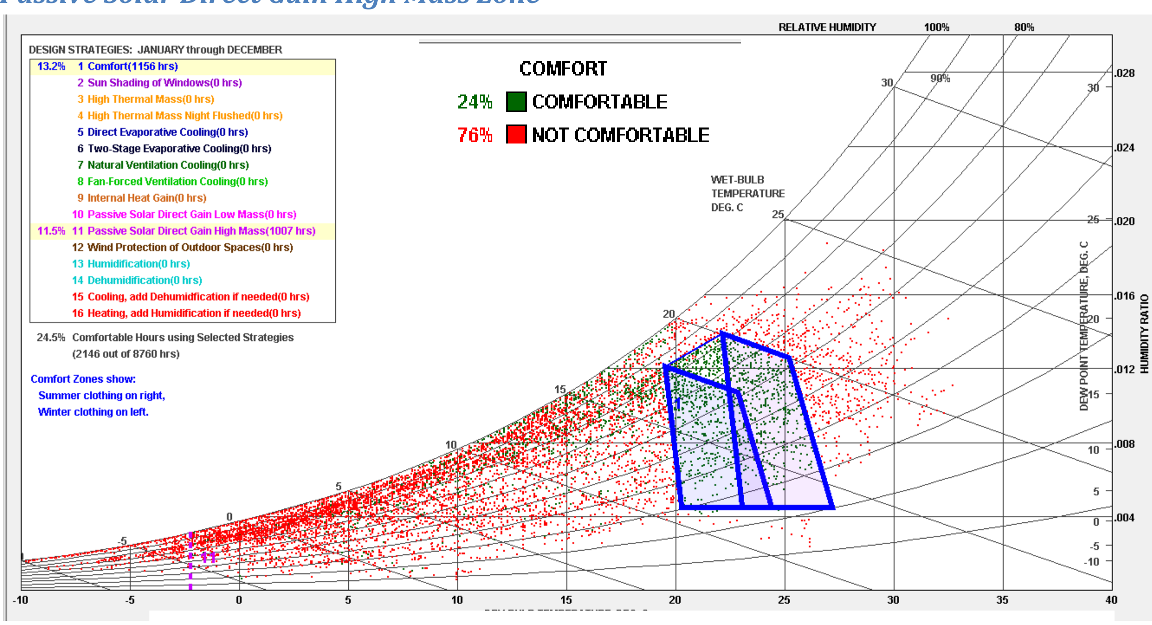


Fig.4.25. Passive Solar Direct Gain Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart to the left of the Comfort Zone. This can only be a rough estimate because it is very much a function of building design. If the building has the right amount of sun-facing glass, then passive solar heating can raise internal temperatures. In high mass building, the amount of glass can be much greater without the danger that solar gain might over heat the space. The internal mass in contact with the internal air will store up this solar heat gain and then give it back later when it is needed. In this case, the comfort is raised to 24%.

Dehumidification Zone

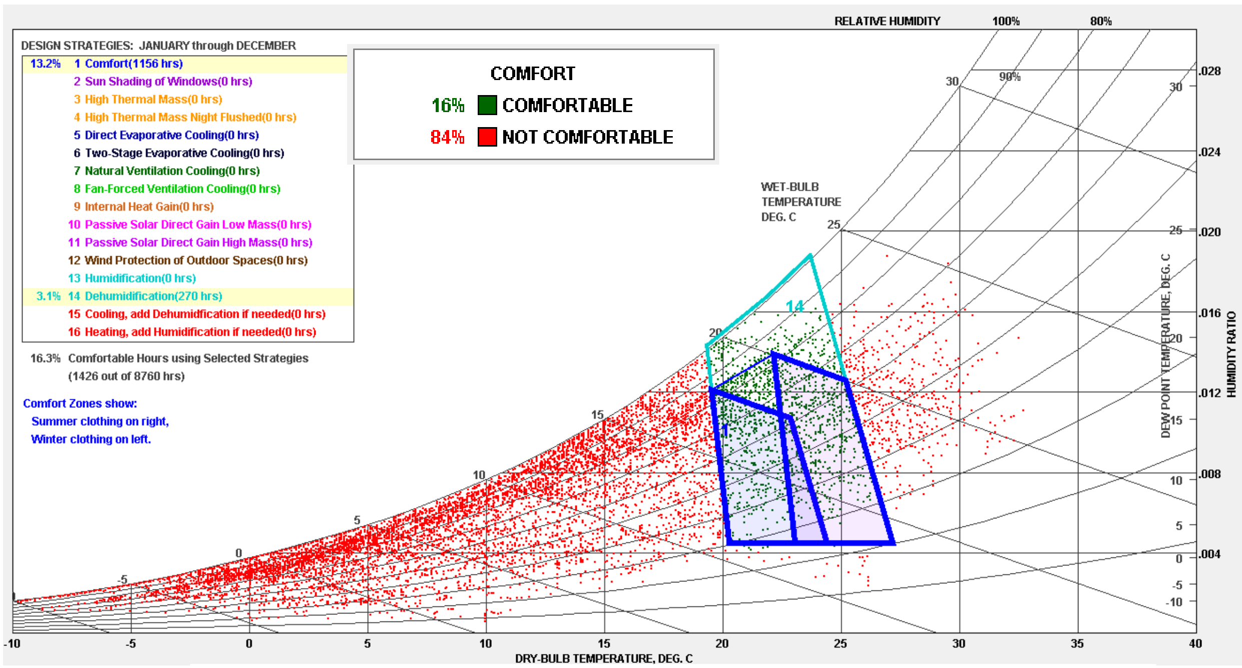


Fig.4.26. Dehumidification Zone on the Psychrometric Chart

This zone is defined on the Criteria screen and is displayed on the Psychrometric Chart directly above the top of the Comfort Zone. It represents the case where the indoor air is within the dry bulb comfort range but is too humid and so would need to have moisture removed. Often some amount of dehumidification happens when an air conditioner is used in humid conditions. The comfort is raised   to 16%.

Cooling, add Dehumidification if needed

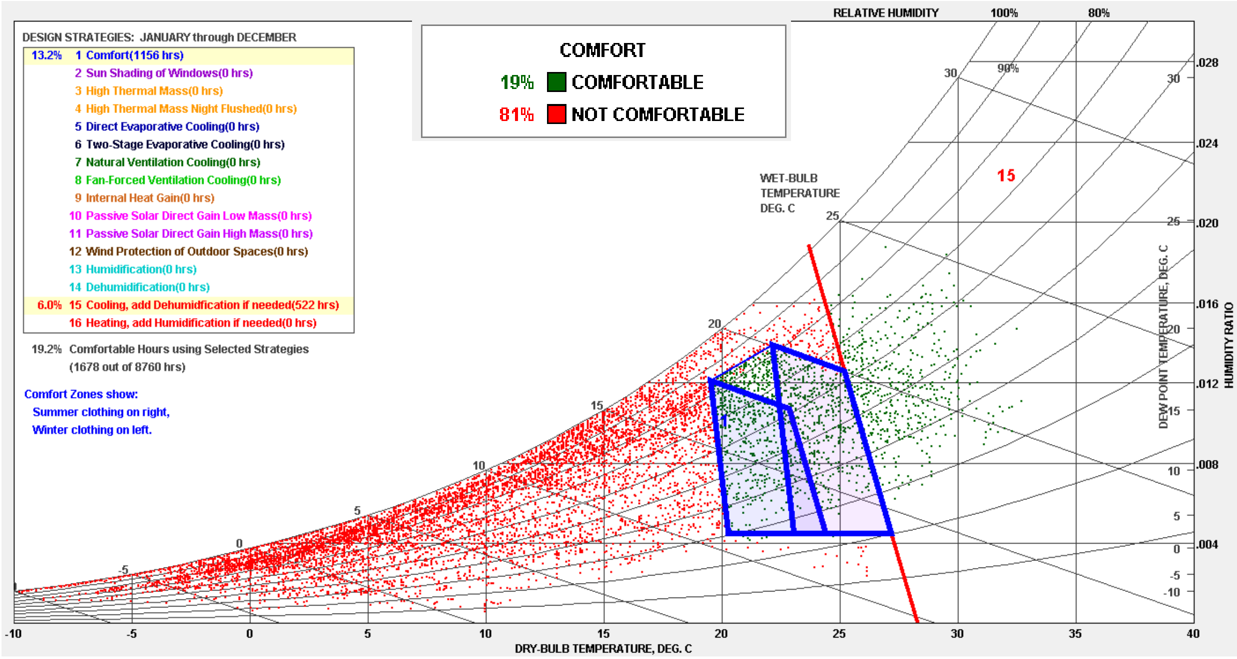


Fig.4.27. Cooling/Dehumidification Zone on the Psychrometric Chart

This zone is displayed on the Psychrometric Chart in the upper right. It represents the number of hours when none of the other selected strategies can provide comfort conditions and so some form of cooling is required, for example, as provided by an air conditioner. The comfort is raised to 19%.

Heating

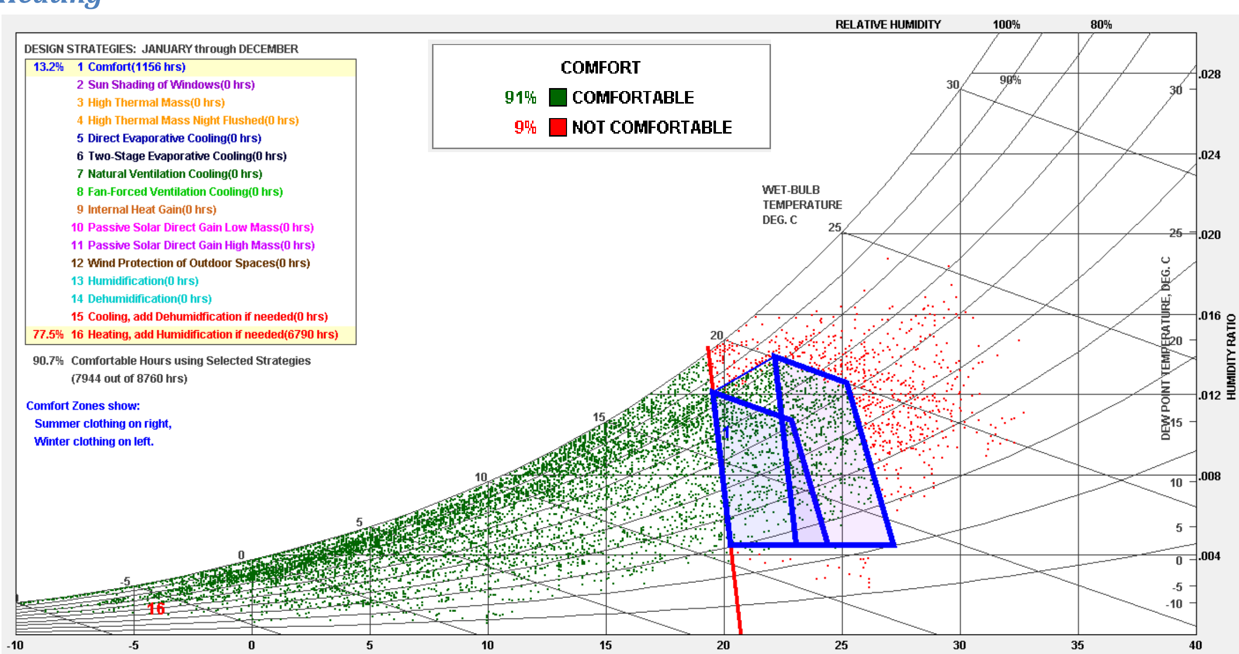


Fig.4.28. Heating Zone on the Psychrometric Chart

This zone is displayed on the Psychrometric Chart to the far left of all the other Zones. It represents the number of hours when none of the other strategies can provide comfort conditions and so some form of heating is required, for example as provided by a furnace, boiler, heat pump, or resistance heaters. Notice that the actual number of hours requiring conventional heating might be greater than those that appear to fall in this zone. This is because some hours apparently within other zones may in fact require conventional heating, for example when hours within the Passive Solar Direct Gain zone did not collect enough solar radiation gain the day before. The comfort is greatly raised to 91%.

***Conclusion*:**

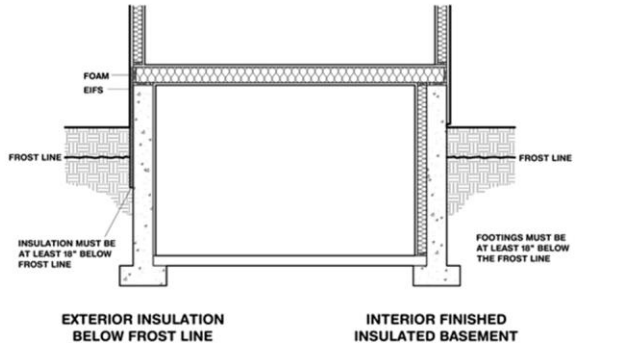
Despite that this preliminary study is independent from the shape and the envelop of the building, it still gives us a fine suggestion to what could be the system used in the building. In fact, since a combination of heating in winter conditions and forced ventilation cooling in summer conditions can give us satisfying comfort conditions of 98%, we had to take this fact into consideration in our next and further design of the building.

Design Guidelines

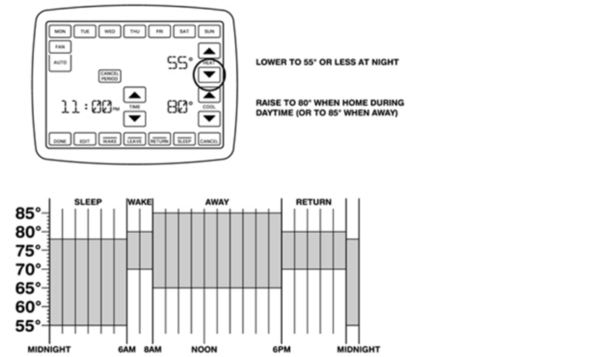
After having aimed our design strategy to Heating and Forced Ventilation cooling, we moved to the next phase, the design guidelines.

The Design Guidelines is a list of suggestions, specific to this particular climate and selected set of Design Strategies, to guide the design of envelope dominated buildings like ours, because they do not have large internal thermal loads and thus the design of the building's envelope will have a great deal of impact on the thermal comfort of the occupants. Those guidelines, selected by an algorithm working software, according to the climate of Milano, and applying Heating (Winter) and Forced Ventilation strategies (Summer). We also had to make a further selection according to the function of the building (Museum) and its operational schedule.

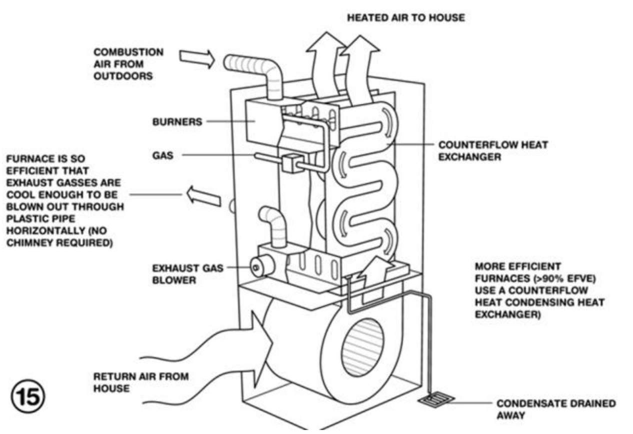
Winter Design Guidelines:



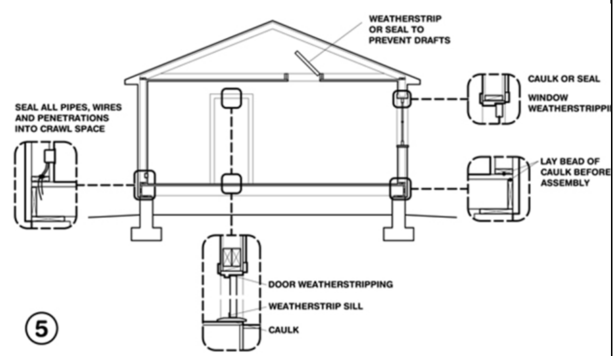
If a basement is used it must be at least 45cm below frost line and insulated on the exterior (foam) or on the interior (fiberglass in furred wall)



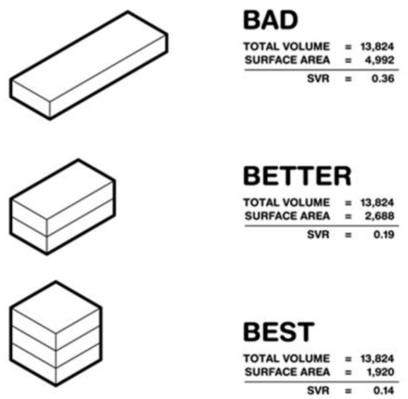
Lower the indoor comfort temperature at night to reduce heating energy consumption (lower thermostat heating setback)



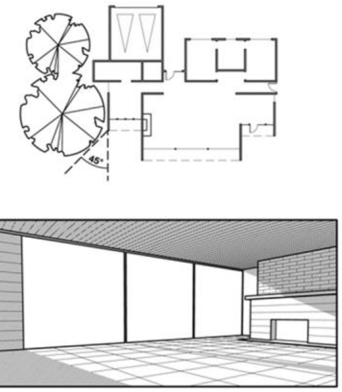
High Efficiency furnace (at least Energy Star) should prove cost effective.



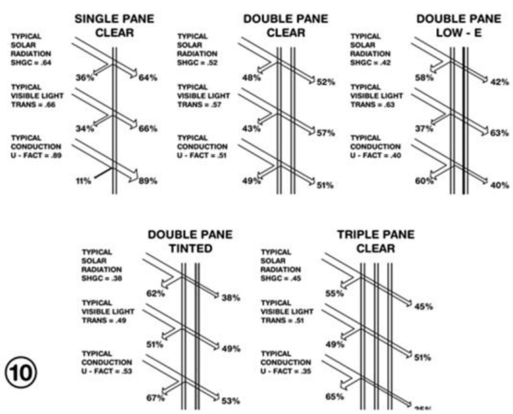
Carefully seal building to minimize infiltration and eliminate drafts, especially in windy sites (housewrap, weather stripping, tight windows)



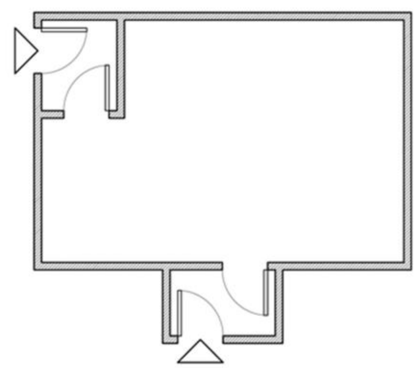
Use compact building form and multiple stories to minimize heat loss from building envelope (minimize surface to volume ratio)



Organize floor plan so winter sun penetrates into daytime use spaces with specific functions that coincide with solar orientation.

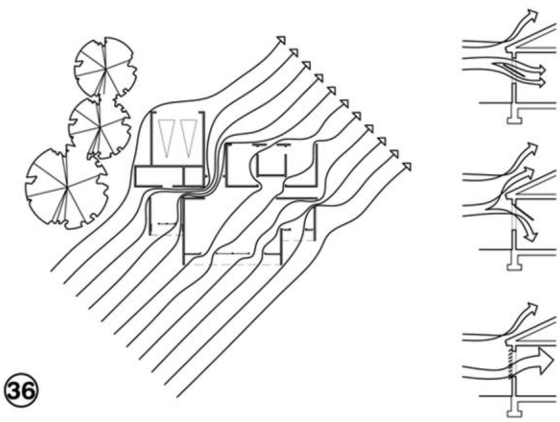


Glazing should minimize conductive loss and gain (minimize U-value) because undesired radiation gain or loss has less impact in this climate

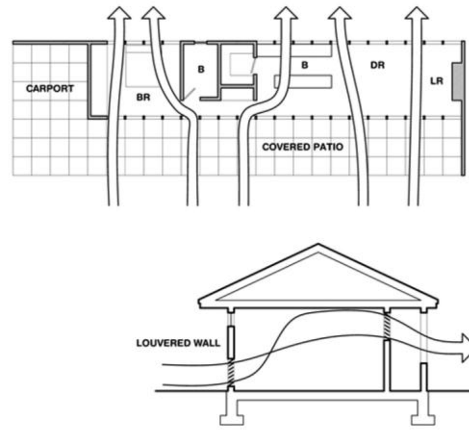


Use vestibule entries (air locks) to minimize infiltration and eliminate drafts, in cold windy sites

Summary Design Guidelines:

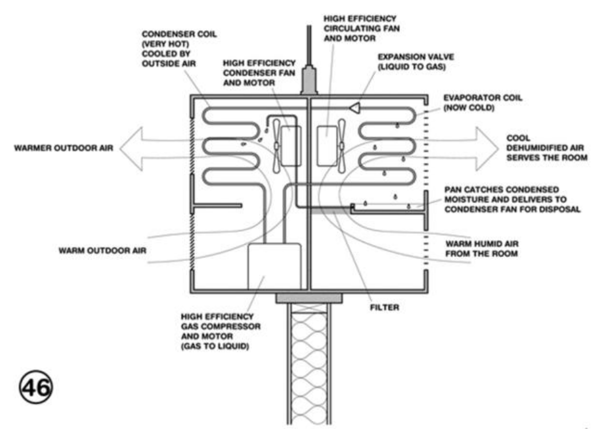


Locate door and window openings on opposite sides of building to facilitate cross ventilation, with larger areas facing up-wind if possible



Use open plan interiors to promote natural cross ventilation, or use louvered doors, or instead use jump ducts if privacy is required

Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain



High Efficiency air conditioner (at least Energy Star) should prove cost effective.

From winter and summer design guidelines, we extracted keywords such as: sealing, efficient system, compact, minimize U-value, cross ventilation, minimize W façade… But since our project is about designing a museum in a very particular context, a further look on the realistic potentialities of urban context and indoor environment of our project was more than necessary, and was a sine qua none for the accomplishment of an design integrated project.

Case Studies:

Influence of Conservation requirements and urban constraints on the Technological Design Decisions

Conflicting needs of the thermal indoor environment of museums: In search of a practical compromise [6]

The growing demand for culture, along with improvements in indoor conditions of exhibition spaces, encourages people to spend an increasing amount of time in museums where, together with exhibitions of terracotta objects, sculptures and historical documents, dinners, musical concerts and plays often take place.

The different ways in which museums can be enjoyed call for greater attention to be paid to the quality of the indoor environment with the aim of ensuring people's comfort. But the requirements for the optimal preservation of cultural artifacts do not necessarily coincide with those of thermal comfort.

This suggests particular care must be taken when assessing the thermal indoor requirements of such buildings in order to identify a set of parameters capable of satisfying both demands.

Such problems are generally addressed by means of the appropriate design and management of heating, ventilating and air conditioning (HVAC) systems (thermal and hygrometry requisites) and by correctly selecting and positioning lighting fixtures (visual requisites).

Particularly in countries with a noticeable cultural heritage recognized on an international level, however, very old buildings often function as exhibition spaces devoid of air climatization systems. Indeed, such buildings, which must be considered in many cases as works of art by themselves, do not easily lend themselves to the installation of conventional equipment to avoid the worst excesses of indoor climatic failure. These considerations, therefore, open up the way for a new approach in the design and management of the indoor environment of museums. Italy is one of the first countries in Europe which has formulated specific regulations for the conservation of cultural artifacts. For example, various technical standards have been recently specified which refer to the definition and control of microclimates with the specific aim of preserving cultural items in indoor environments. Some of these documents introduce interesting elements that go far beyond their strict application to the Italian context.

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[6] Science Direct, Journal of Cultural Heritage Volume 9, Issue 2, April–June 2008, Pages 125–134

Work of art materials	θ_0 (°C)	$\Delta\theta_{max}$ (°C)	u_0 (%)	Δu_{max} (%)
Organic materials/objects				
Paper, papier mâché, paper artwork, tissue-paper, wallpaper, stamp collections, manuscripts, papyri, printings, cellulose materials	18–22 15–24	1.5	40–55 50–60	6
Fabric, veils, drapery, carpets, fabric tapestry, arras, silk, costumes, dresses, religious vestments, natural fibre materials, sisal, jute	19–24	1.5	30–50 40–60	6
Wax, anatomical waxes	<18	N.S.	N.S.	N.S.
Herbaria and botanical collections	21–23	1.5	45–55 40–60	2
Entomological collections	19–24	1.5	40–60	6
Animals and anatomical organs preserved in formalin	15–25	–	N.S.	N.S.
Animals, dried anatomical organs, mummies	21–23 19–24	1.5	20–35 40–60	–
Furs, feathers, stuffed animals and birds	4–10 15–21	1.5	30–50 45–60	5
Water-colours, drawings, pastels	19–24	1.5	45–60 50–60	2
Ethnographic collections, masks, leather, leather clothes	19–24	1.5	45–60 50–60	6
Painting on canvas, oil painting on cloth and canvas, tempera, gouaches	19–24	1.5	40–55 35–50	6
Documents, file material	13–18	–	50–60	–
Books of great value, leather-bound books, leather bindings, parchment, miniatures	19–24	1.5	45–55 50–60	6
Lacquer, inlaid, decorated or lacquer furniture	19–24	1.5	50–60	2
Polychromatic wood carvings, painted wood, paintings on wood, icons, wood pendulum-clocks, wood musical instruments	19–24	1.5	50–60 45–65	2
Unpainted wood carvings, wickerwork, wood or bark panels	19–24	1.5	45–60 40–65	2
Inorganic materials/objects				
Porcelain, ceramics, stoneware, terracotta, tiles and demineralised tiles from excavation	N.S.	–	N.S. 20–60	10
Stones, rocks, ore and stable (porous) meteorites	19–24	–	40–60	6
Stone mosaics, stones, rocks, ore, meteorites (non porous), fossils and stone collections	15–25	–	20–60 45–60	10
Metals, smoothed metals, metal alloys, silver, armour, weapons, bronze, coins, copper objects, tin, iron, steel, lead, pewter	N.S.	–	<50 <55	–
Metals with active corrosion sites	N.S.	–	<40	–
Gold	N.S.	–	N.S. <45	–
Gypsum and plaster	21–23	1.5	45–55	2
Unstable, iridescent and sensitive glass, sensitive glass mosaics	20–24	1.5	40–45	–
Various objects				
Murals, frescoes, sinopite (detached)	10–24 6–25	–	55–65 45–60	–
Dry murals (detached)	10–24 6–25	–	50–45 45–60	–
Ivories, horns, malacological collections, eggs, nests, corals	19–24	1.5	40–60 45–65	6
Phonographic records	10–21	–	40–55 40–60	2
Man-made fibres	19–24	–	40–60	–
Film, colour photograph	0–15 −15 to −5	–	30–45 30–50	–
Film, black and white photograph	5–15 2–20	–	40–60 20–30	–
Organic material objects coming from damp excavation areas (before treatment)	19–24	–	Saturated air 50–65	–
Plastics	19–24	–	30–50	–

Table.4.6. Suggested values for the optimal conservation of works of art for steady-state indoor climate conditions*).*

Comparing indoor thermal requisites relating to people's comfort and preserving works of art starting from the reasonable assumption that air temperature and operative temperature are sufficiently similar in value, indoor thermal conditions for preserving works of art can be represented on the same graph. This enables the singling out of possible common zones where both requirements (people's comfort and taking care of works of art) are achieved. The next figures show the optimal zones for both requirements for selected works of art under typical winter and summer conditions, respectively.

It is possible to observe from the figures that increasing air velocity increased the operative temperature of people's comfort. Moreover, a greater common control zone can be obtained for selected works of art by increasing indoor air velocity in winter and decreasing it in summer. The common area of values relating to air temperature and relative air humidity for people's well-being and safely preserving works of art represents the zone where the indoor environment of a museum can be controlled.
This suggests the introduction of a suitable index for quantitatively assessing the level at which the needs for people's comfort and preserving works of art are contemporaneously satisfied. For this purpose, a ''simultaneousness index'', IS, is defined here as the ratio between the (possible) common area for people's comfort and preserving works of art, and the whole area representing the conditions of comfort. In other words, the IS index represents (in percentages) the level at which the requirements of people's comfort coincide with the need to safeguard works of art.

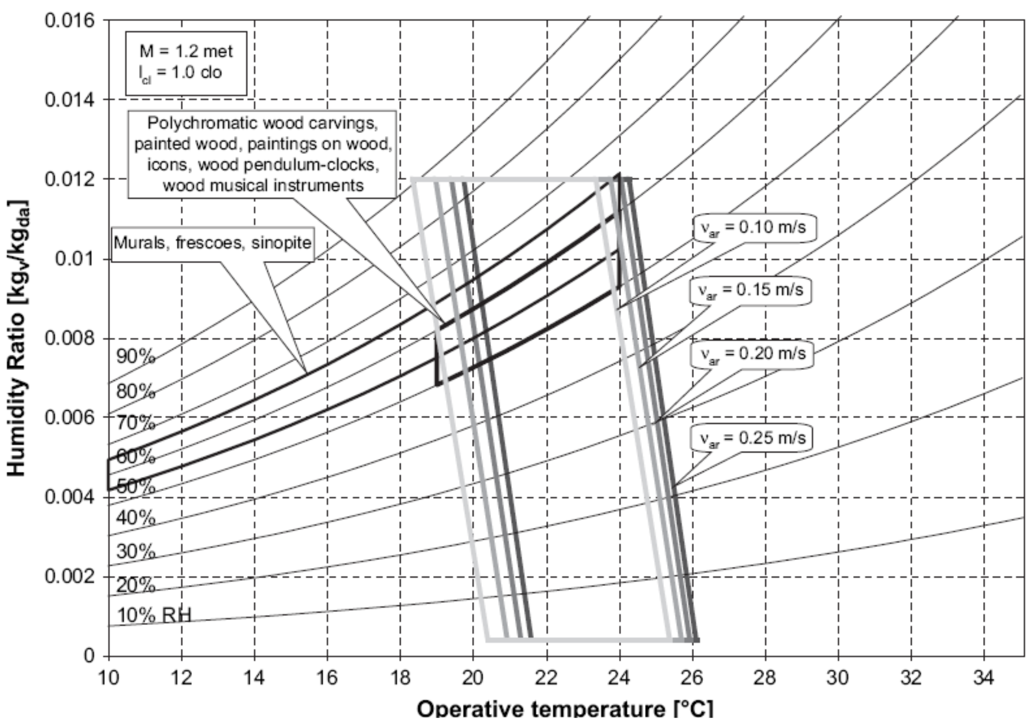


Fig.4.29. Overlapping zones between people's comfort and taking care of works of art requisites in typical winter conditions, for selected works of art.

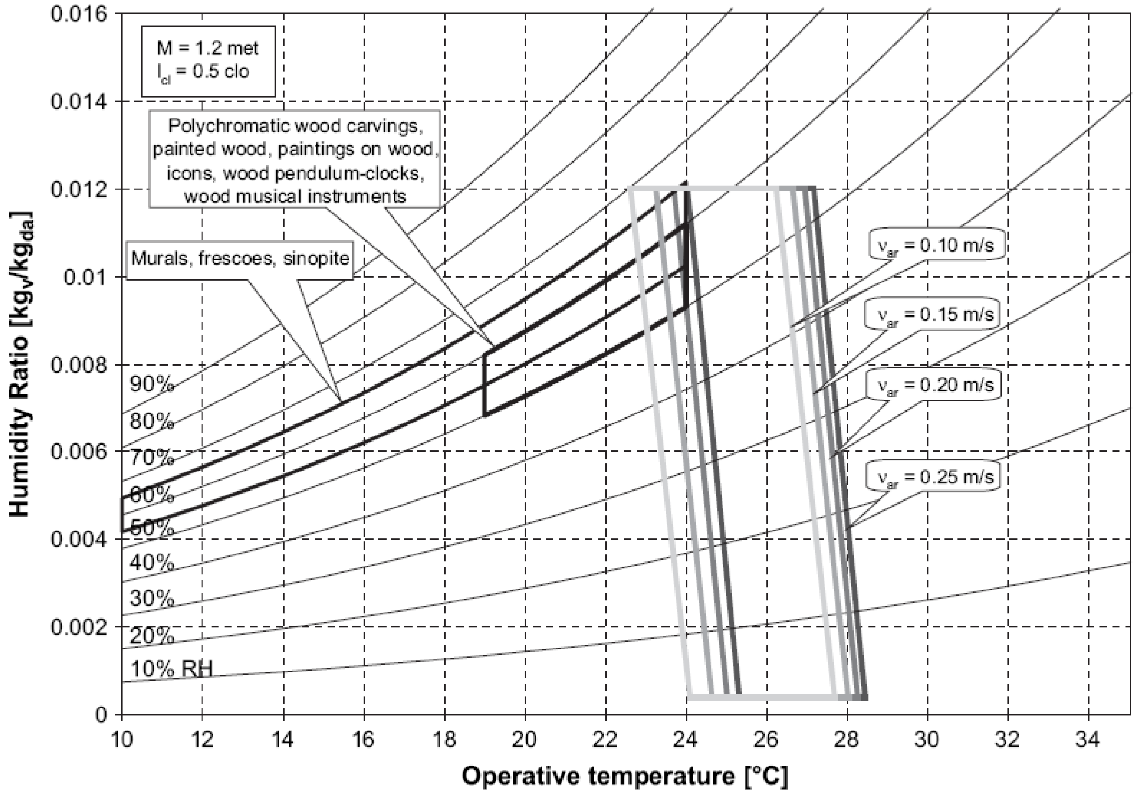


Fig.4.30. Overlapping zones between people's comfort and taking care of works of art requisites in typical summer conditions, for selected works of art.

Since the same museum room could host various works of art, belonging to different homogeneous classes, the shape of the common areas in this case has also been reported.

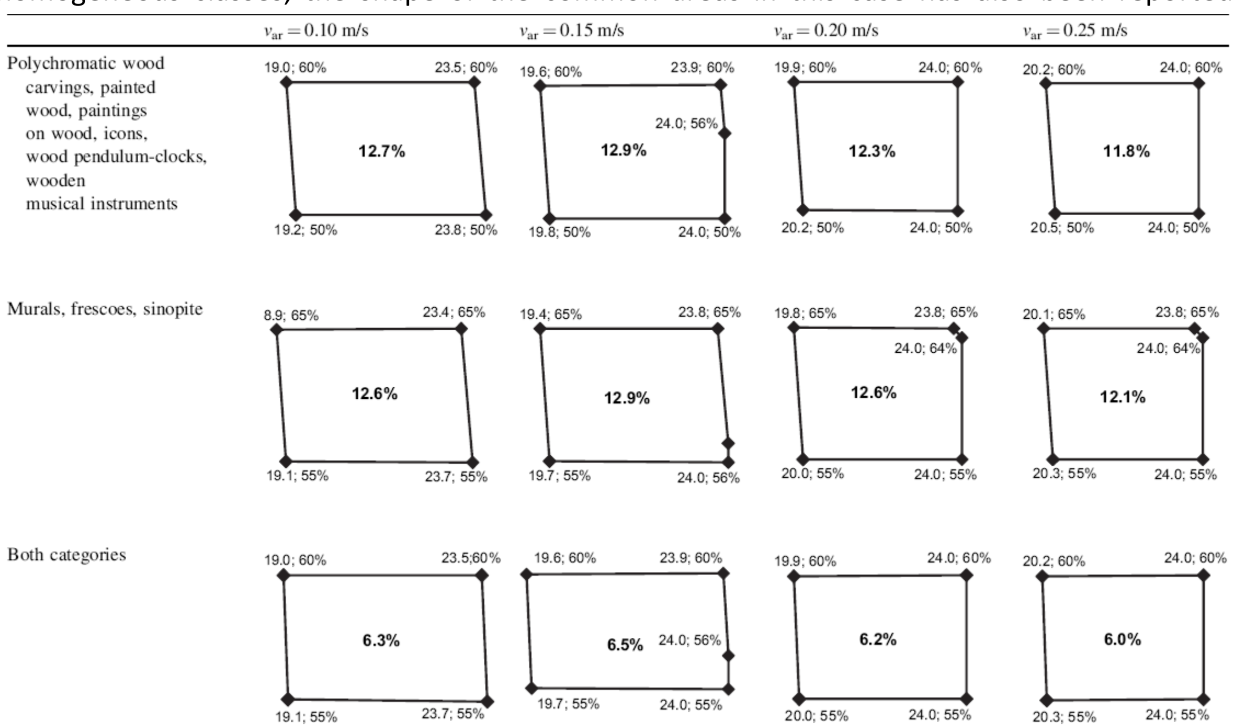


Fig.4.31. Simultaneousness index I_S in winter conditions

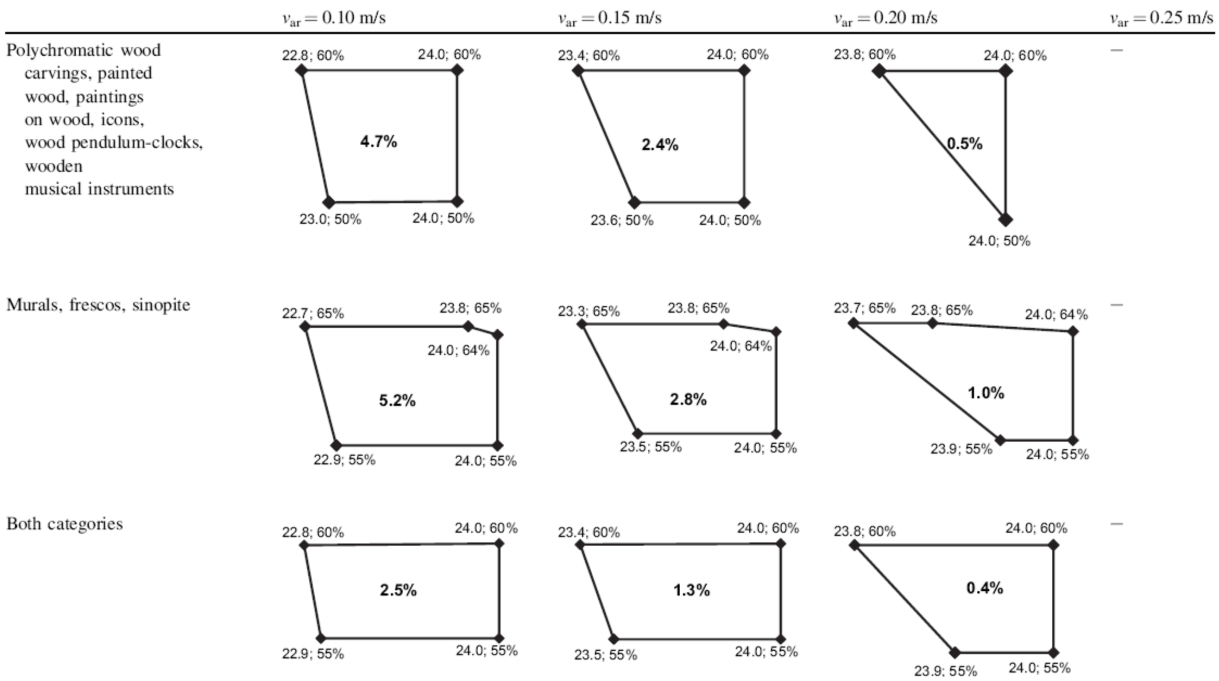


Fig.4.32. Simultaneousness index I_S in winter conditions

These data can be directly used by designers and museum curators for optimizing the distribution of works of art in various rooms.

Clearly, the higher this index, the easier it is to suitably control the indoor climate of an exhibition space containing works of art. The difficulties involved in balancing the requirements for preserving works of art on display in exhibition spaces and the thermal comfort of visitors to these spaces are here outlined, especially in the summer periods, where the overlapping conditions can barely reach 0.4% for some materials and air velocity.

Influence of the study on the Design Guidelines:

After having promoted the "Forced Ventilation" as a solution of cooling in the summer season in weathers similar to Milano, we conversely find ourselves in a situation where this solution seems to be not that much adapted since the level of control is not enough for the use of our building where sophisticated, controlled and monitored indoor environments are required.

The Street Canyon of Corso Porta Ticinese: Natural Ventilation Potential

After having studied Corso Porta Ticinese in its historical, urban, and cultural aspects, we are now interested in its significance from the technological point of view. In the following, we are going to present a study about the effect of lack of wind, noise, and pollution on limiting the natural ventilation potentials in the urban contexts known as “Street Canyons”; and then we are going to show some simulations concerning Porta Ticinese itself.

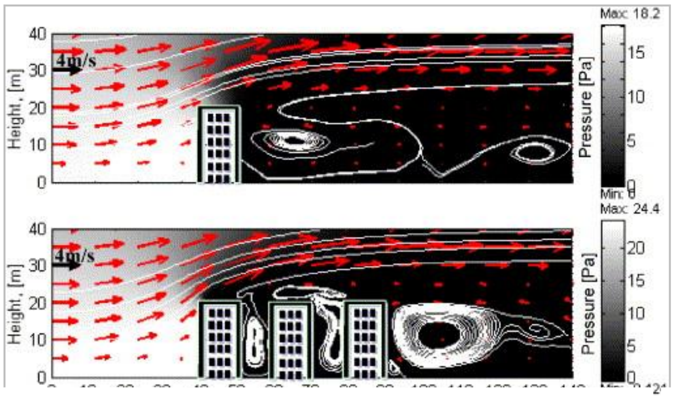


Fig.4.33. Stack effect in street canyons

Fig.4.34. Shot from Corso di Porta Ticinese

When it is used for free-cooling, natural ventilation can replace air-conditioning systems for large periods of time during a year. Consequently, natural ventilation has the potential to save energy for cooling. However, urban environment has drawbacks for the application of natural ventilation: lower wind speed, higher temperatures due to the effect of urban heat island, noise and pollution.

The airflow in street canyons has much lower values as compared with the undisturbed wind. Lower wind velocity means reduced wind pressure on the building façade and less effective cross ventilation. Temperature in urban areas is larger than in rural surroundings affecting thus the potential for stack effect.

Noise and pollution protection requires tightening the building, reducing further the natural driven airflow rate. While noise reverberation is augmented in street canyons, the balconies could have a dumping effect (not high presence of balconies in Corso Porta Ticinese).

Consequently to this study, we started to avoid the option of using natural ventilation in our project, since we were far from being in convenient conditions[7].

[7] Science Direct, Building and Environment Volume 41, Issue 4, April 2006, Pages 395–406

South Façade Technology

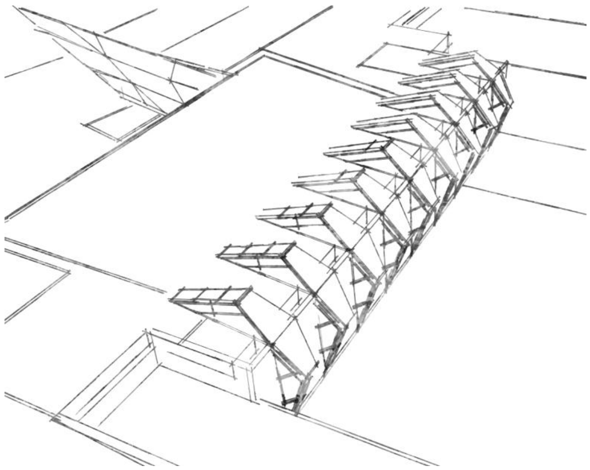


Fig.4.35. Sketchy Perspective of the southern façade

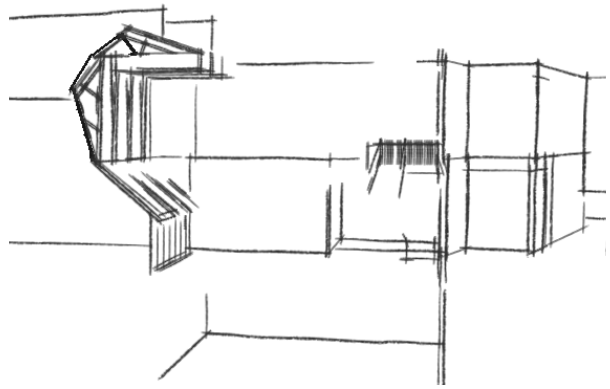


Fig.4.36. Interior space sketch

In order to solve the problem of Solar overheating in summer and to benefit as much as possible from the solar gains in winter, we had to think about an integrated solution that can satisfy both conditions. The idea of inserting extra shading devices on the Southern Façade was not a very encouraging solution in terms of architecture especially that the Southern Façade is in direct contact with the historical existing complex.

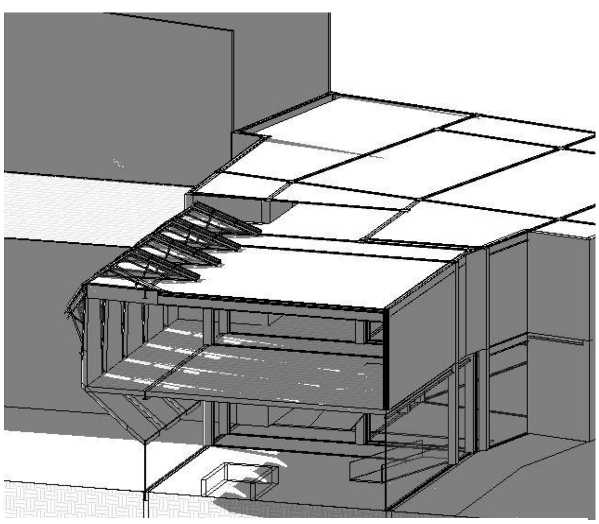


Fig.4.37. Winter Sun Exposure

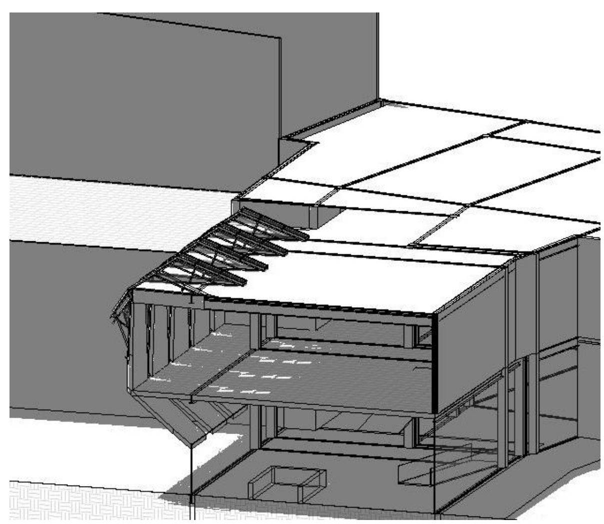


Fig.4.38. Summer Sun Exposure

Furthermore, we wanted to create a solution from the building itself rather than importing a solution that fits everything. The idea was to study the position of the sun in both winter and summer conditions, and to design the façade accordingly; in other terms, to have a certain dynamism that follows the sun all over the year, without moving the building physically.

We combined a kind of a glass “shell” with the angles of the building. That combination was interesting in terms of shading but also in terms of lighting.

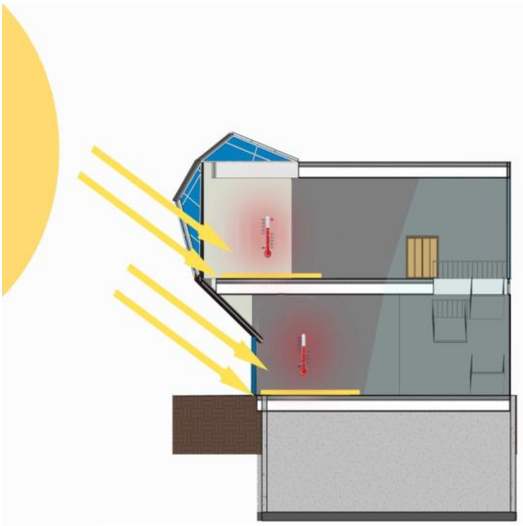


Fig.4.39. Winter Behavior in section

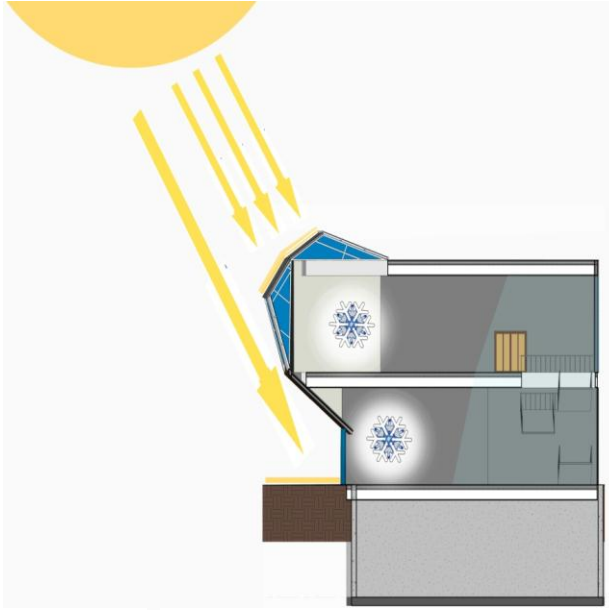


Fig.4.40. Summer Behavior in section

The geometry of the façade is designed in a way that allows the low solar rays in the winter to penetrate the building and to irradiate inside the building. On the other hand, when the sun is high, the glazing elements are not facing the sun anymore which makes the building cooler since the solar gains are negligible.

From the lighting point of view, this element has also some interesting figures. Since the function of the space is for exhibition, the indirect light provided by both horizontal and vertical glazing of the element, gives it particular features and effects.

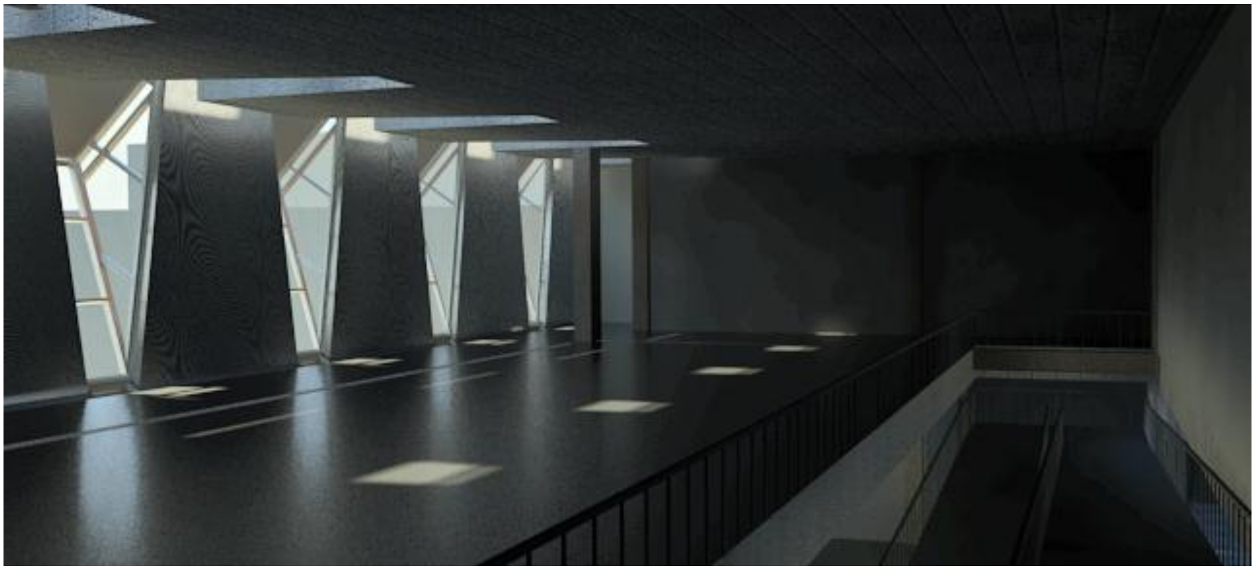


Fig.4.41. Shot from the second floor showing the direct-indirect lighting effects

Fig.4.42. Shot from the entrance to the foyer showing how the Sun is entering the building on winter days

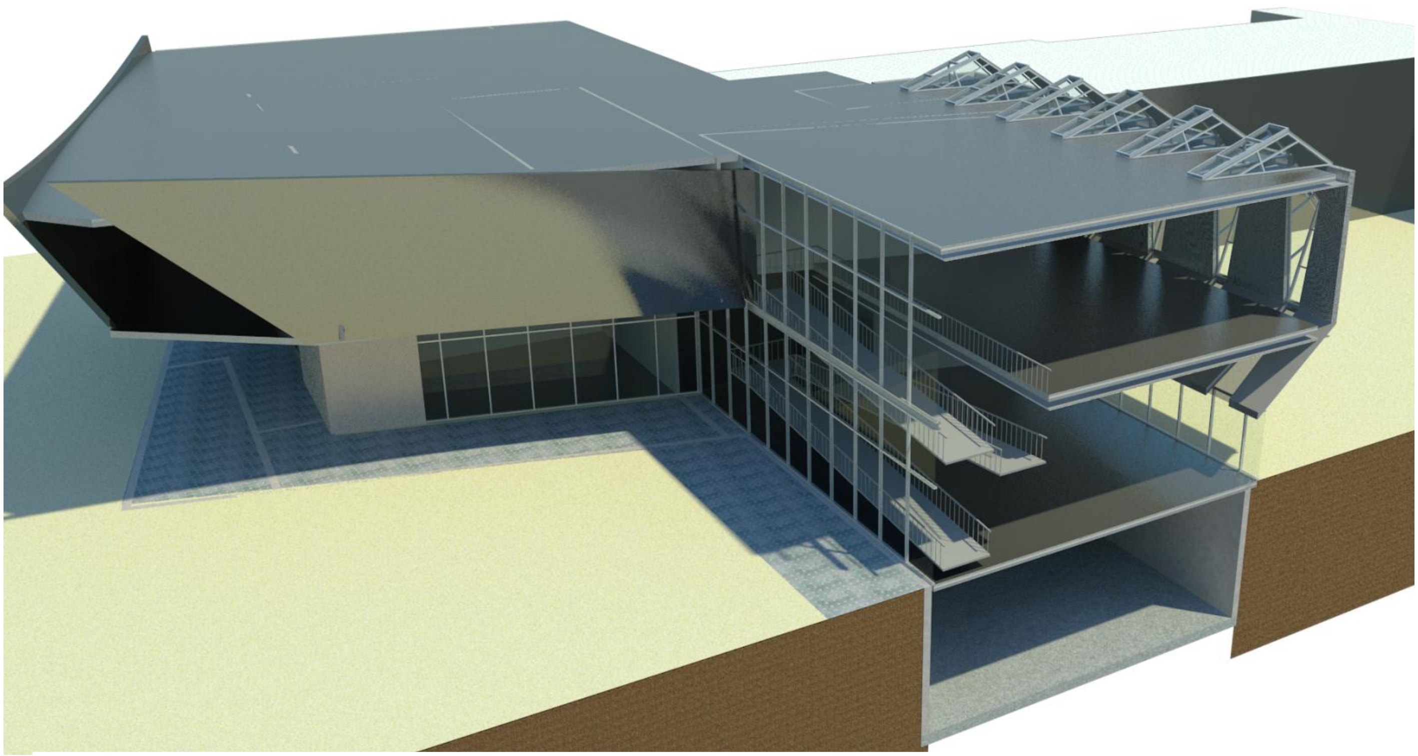


Fig.4.43. 3D section showing the lighting and the accessibility between the Foyer and the Loft

Proposed Technological Solutions for the Envelope

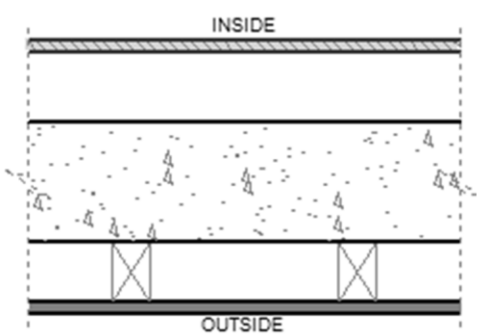
As we mentioned above, our building is considered as an envelope dominated building. Consequently, it is impossible to start our thermal analysis approximation without having a clear idea about the structure of the envelope and its characteristics.

Properties and behavior comparison with traditional solutions

As a primary study, we wanted to analyze the thermal behavior of the building considering traditional brick-plaster exterior walls and concrete suspended ceiling for horizontal partitions and slabs. The goal was not to see if the results are satisfying enough in order to apply it as our final solution but to understand the performance of our final solution in comparison with the traditional systems. Then, we did more or less the same studies, but this time with the new solution (the one that will be adopted later on). For significance reason and to emphasize the comparison, the results of the 2 simulations will be shown simultaneously, according to the study itself and not according to the chronological order in the Design Process. Later on, we will magnify on the chosen solutions in blow-ups showing technological details. The color "light orange" will be used for the Traditional Solution. The color "dark green" will be used for the new Proposed Solution.

Slabs:

Concrete Suspended (traditional)

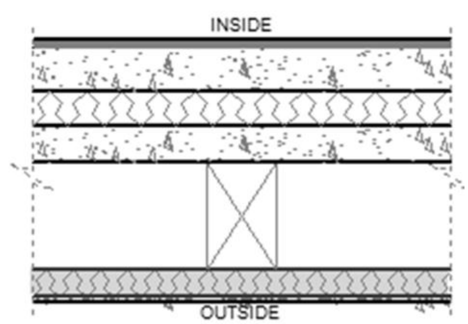


	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Plaster Board	10.0	1250.0	1088.000	0.431
2.	Air Gap	50.0	1.3	1004.000	5.560
3.	Concrete	100.0	3800.0	656.900	0.753
4.	Air Gap	60.0	1.3	1004.000	5.560
5.	Copper	10.0	8600.0	390.000	384.000

U-Value (W/m2.K):	1.440
Admittance (W/m2.K):	2.300
Solar Absorption (0-1):	0.475208

Fig.4.44. Traditional Slab Properties

Proposed Solution



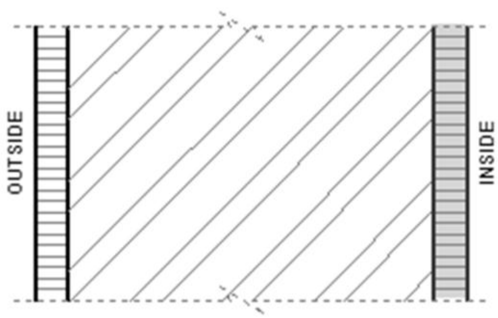
	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Plaster Board	25.0	1250.0	1088.000	0.431
2.	Concrete Lightweight	100.0	950.0	656.900	0.209
3.	Polystyrene Prefoamed F	100.0	100.0	1130.000	0.042
4.	Concrete Lightweight	120.0	950.0	656.900	0.209
5.	Air Gap	500.0	1.3	1004.000	5.560
6.	Wool	75.0	140.0	840.000	0.038
7.	Plasterboard	12.0	950.0	840.000	0.160

U-Value (W/m2.K):	0.260
Admittance (W/m2.K):	3.460
Solar Absorption (0-1):	0.597

Fig.4.45. Proposed Slab Properties

External Walls

Brick-Plaster (traditional)

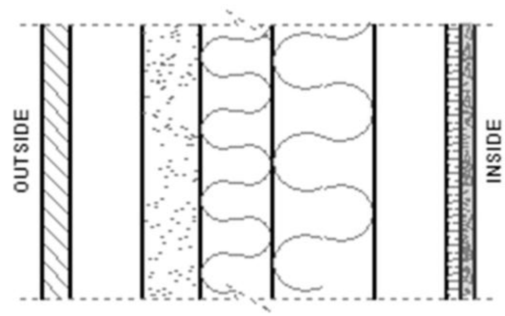


	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Plaster Building (Molded Dry	10.0	1250.0	1088.000	0.431
2.	Brick Masonry Medium	110.0	2000.0	836.800	0.711
3.	Plaster Building (Molded Dry	10.0	1250.0	1088.000	0.431

U-Value (W/m2.K):	2.620
Admittance (W/m2.K):	4.380
Solar Absorption (0-1):	0.418
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.7

Fig.4.46. Traditional Wall Properties

Proposed Solution



	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Steel Alloy Cast	20.0	7830.0	460.200	46.024
2.	Air Gap	50.0	1.3	1004.000	5.560
3.	Wood Fibres, Compresse	40.0	320.0	100.000	0.055
4.	Polystyrene Prefoamed F	50.0	40.0	1130.000	0.042
5.	Wool	70.0	140.0	840.000	0.038
6.	Air Gap	50.0	1.3	1004.000	5.560
7.	Wool, Fibrous	10.0	96.0	840.000	0.043
8.	Plasterboard	10.0	950.0	840.000	0.160

U-Value (W/m2.K):	1.830
Admittance (W/m2.K):	3.340
Solar Absorption (0-1):	0.6
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.79
Thermal Lag (hrs):	15

Fig.4.47. Proposed Wall Properties

After having presented the suggested technological solution and the traditional solution to which we are going to compare in our study, we are going to show the behavior of each one, independently of the building itself, respecting to the climate of Milano. The study, executed on the Celenit simulation will include:

-Temperature Profile.
-Condensation Risks.
-Thermal Lags.

To note that the same solution is used as a slab and as a roof since the goal of this study is to show the behavior of the layers and not the technical drawings of the solution.

Temperature Profile-Condensation Risks

	T. esterna (°C)	Press. est. (Pa)	T. interna (°C)	Var. (Pa)	P. Interna (Pa)	Press. Sat. (Pa)	T. Sup. min (°C)	Fatt. Temp.
Ottobre	14,00	1412,00	20,00	203,51	1635,87	2044,83	17,86	0,6434
Novembre	7,90	958,00	20,00	616,24	1635,87	2044,83	17,86	0,8232
Dicembre	3,10	671,00	20,00	877,15	1635,87	2044,83	17,86	0,8734
Gennaio	1,70	590,00	20,00	950,79	1635,87	2044,83	17,86	0,8831
Febbraio	4,20	645,00	20,00	900,79	1635,87	2044,83	17,86	0,8646
Marzo	9,20	943,00	20,00	629,88	1635,87	2044,83	17,86	0,8019
Aprile	14,00	1163,00	20,00	429,88	1635,87	2044,83	17,86	0,6434

Table.4.7. Condensation Conditions

Critical Month: January, with a temperature factor of 0.8831

Slabs

Concrete Suspended

Mese	Interf. 1 Flusso di	Condensa	Data fine	Interf. 2 Flusso di	Condensa	Data fine	Interf. 3 Flusso di	Condensa	Data fine
Ottobre	0	0	0	0	0	0	0	0	0
Novembre	26,45	26,45	0	0	0	0	235,5	235,5	0
Dicembre	30,31	56,76	0	0	0	0	1175,03	1410,53	0
Gennaio	30,96	87,71	0	0	0	0	1424,88	2835,41	0
Febbraio	29,66	117,38	0	0	0	0	971,3	3806,71	0
Marzo	24,88	142,26	0	0	0	0	-42,45	3764,26	0
Aprile	16,75	159,01	0	0	0	0	-1163,48	2600,78	0
Maggio	6,83	165,84	0	0	0	0	-2193,22	407,56	0
Giugno	-717,13	0	24	-5,7	0	0	-3601,51	0	27
Luglio	0	0	0	0	0	0	0	0	0
Agosto	0	0	0	0	0	0	0	0	0
Settembre	0	0	0	0	0	0	0	0	0

(yellow)	Condensazione
(cyan)	Evaporazione
(red)	Condensa residua o superiore al limite

Table.4.8. Traditional Slab Condensation Risks

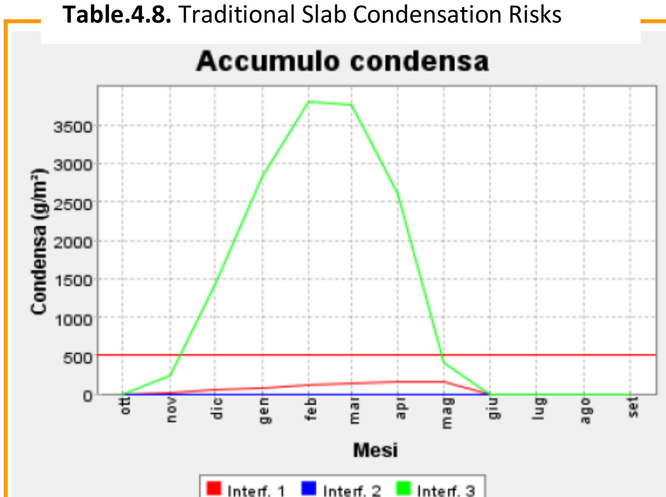


Fig.4.48. Traditional Slab Accumulated Condensation

We notice that the layer of concrete is the most risky in terms of condensation, and reaches values much higher than the limit (500 g/m2) in several months, but there is no residual accumulated moisture from the condensation on the year cycle: it is all evaporated during the summer high temperature period.

Proposed Solution

Mese	Interf. 3 Flusso di	Condensa	Data fine	Interf. 4 Flusso di	Condensa	Data fine	Interf. 5 Flusso di	Condensa	Data fine
Ottobre	0	0	0	0	0	0	0	0	0
Novembre	15,01	15,01	0	41,92	41,92	0	0,94	0,94	0
Dicembre	16,92	31,94	0	48,5	90,41	0	57,8	58,73	0
Gennaio	17,19	49,12	0	49,66	140,07	0	73,21	131,94	0
Febbraio	16,62	65,74	0	47,36	187,43	0	45,32	177,27	0
Marzo	14,18	79,92	0	39,33	226,77	0	-15,56	161,71	0
Aprile	9,66	89,58	0	26,21	252,98	0	-80,63	81,07	0
Maggio	3,93	93,51	0	10,59	263,57	0	-138,41	0	13
Giugno	-6,07	87,44	0	-202,97	60,61	0	0	0	0
Luglio	-13,1	74,34	0	-258,23	0	23	0	0	0
Agosto	-10,11	64,23	0	0	0	0	0	0	0
Settembre	-74,13	0	5	0	0	0	0	0	0

Table.4.9. Proposed Slab Condensation Risks

Condensazione
Evaporazione
Condensa residua o superiore al limite

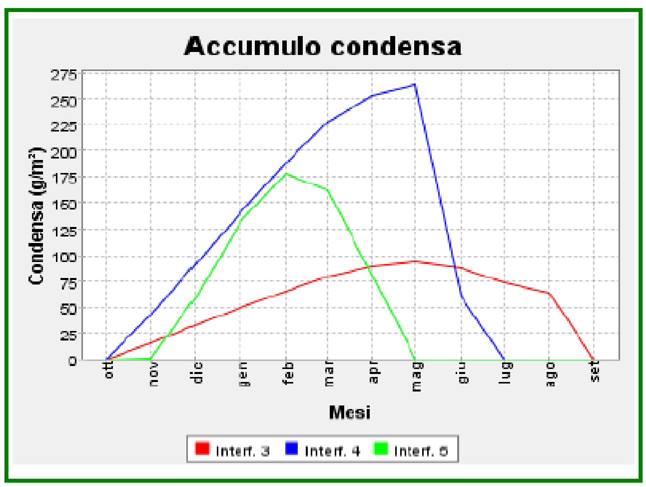


Fig.4.49. Proposed Slab Accumulated Condensation

In this proposed solution, the condensation that happens never crosses the limit, and there is no residual condensation. The solution is then working properly in terms of preventing considerable condensations.

Exterior Walls

Brick-Plaster

Mese	Interf. 2 –> Flusso di vapore (g/m²)	Condensa accumulata (g/m²)	Data fine evaporazione
Ottobre	0	0	0
Novembre	0	0	0
Dicembre	189,11	189,11	0
Gennaio	204,83	393,94	0
Febbraio	138,92	532,86	0
Marzo	-965,59	0	14
Aprile	0	0	0
Maggio	0	0	0
Giugno	0	0	0
Luglio	0	0	0
Agosto	0	0	0
Settembre	0	0	0

Table.4.10. Traditional Wall Condensation Risks

	Condensazione
	Evaporazione
	Condensa residua o superiore al limite

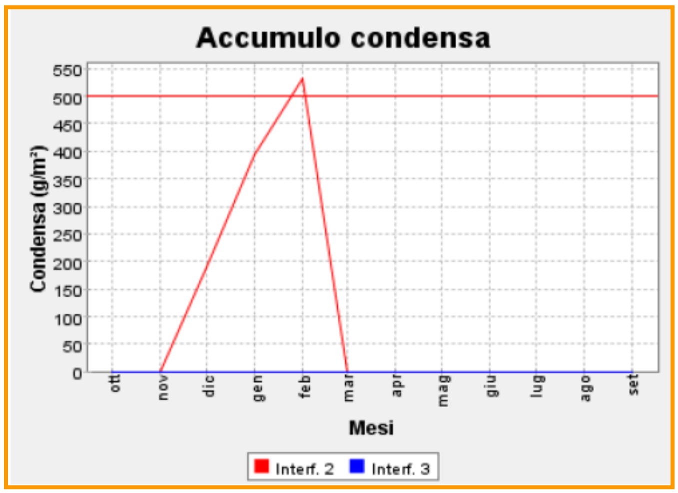


Fig.4.50. Traditional Wall Accumulated Condensation

In this solution, the condensation crosses eventually the limit but is not as critical as the traditional solution used for the slab/roof. No accumulation.

Proposed Solution

Mese	Interf. Fluss	Cond	Data	Interf. Fluss	Cond	Data	Interf. Fluss	Cond	Data	Interf. Fluss	Cond	Data	Interf. Fluss	Cond	Data
Ottobre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Novembre	0,01	0,01	0	0	0	0	0	0	0	0	0	0	28,6	28,6	0
Dicembre	0,02	0,03	0	0	0	0	0	0	0	0	0	0	50,61	79,21	0
Gennaio	0,02	0,05	0	0	0	0	0	0	0	0	0	0	56,15	135,36	0
Febbraio	0,01	0,06	0	0	0	0	0	0	0	0	0	0	46	181,36	0
Marzo	0,01	0,07	0	0	0	0	0	0	0	0	0	0	21,73	203,09	0
Aprile	0,01	0,08	0	0	0	0	0	0	0	0	0	0	-7,45	195,64	0
Maggio	-0	0,08	0	0	0	0	0	0	0	0	0	0	-36,22	159,43	0
Giugno	-118,8	0	30	-33,61	0	0	-0,35	0	0	-0,01	0	0	-78,01	81,41	0
Luglio	0	0	0	0	0	0	0	0	0	0	0	0	-103,8	0	7
Agosto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Settembre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table.4.11. Proposed Wall Condensation Risks

(yellow)	Condensazione
(cyan)	Evaporazione
(red)	Condensa residua o superiore al limite

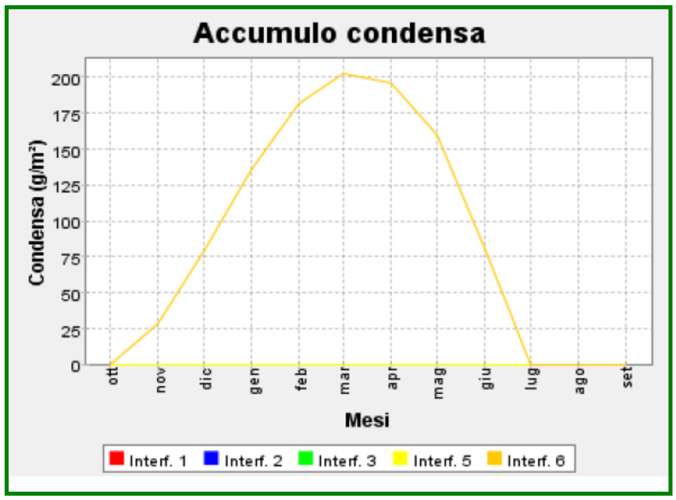


Fig.4.51. Proposed Wall Accumulated Condensation

This solution is very safe in terms of condensation: only one layer is having condensation but the level never crosses the limit.

Conclusion

Since Milano climate is considered as cold and humid, the condensation is a very serious problem that participates as a primary agent in the degradation of building constituents. We clearly notice that the solutions we proposed present in different level of importance, a better behavior in terms of condensation prevention.

Thermal Lags

The time delay due to the thermal mass is known as a time lag. The thicker and more resistive the material, the longer it will take for heat waves to pass through. The reduction in cyclical temperature on the inside surface compared to the outside surface is knows and the decrement. Thus, a material with a decrement value of 0.5 which experiences a 20 degree diurnal variation in external surface temperature would experience only a 10 degree variation in internal surface temperature.

Slabs

Concrete Suspended

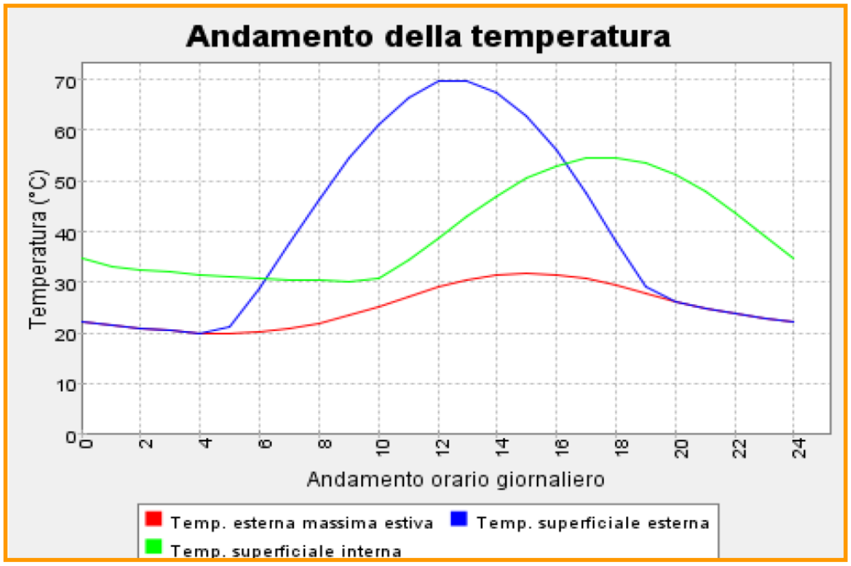


Fig.4.52. Traditional Slab Temperature Daily Variation

Thermal Decrement: 0,49
Thermal Lag : 5h6'
The exterior temperature maximum effect is delayed by 5 hours in the interior but is still in the "hot" period of the day.

Proposed Solution

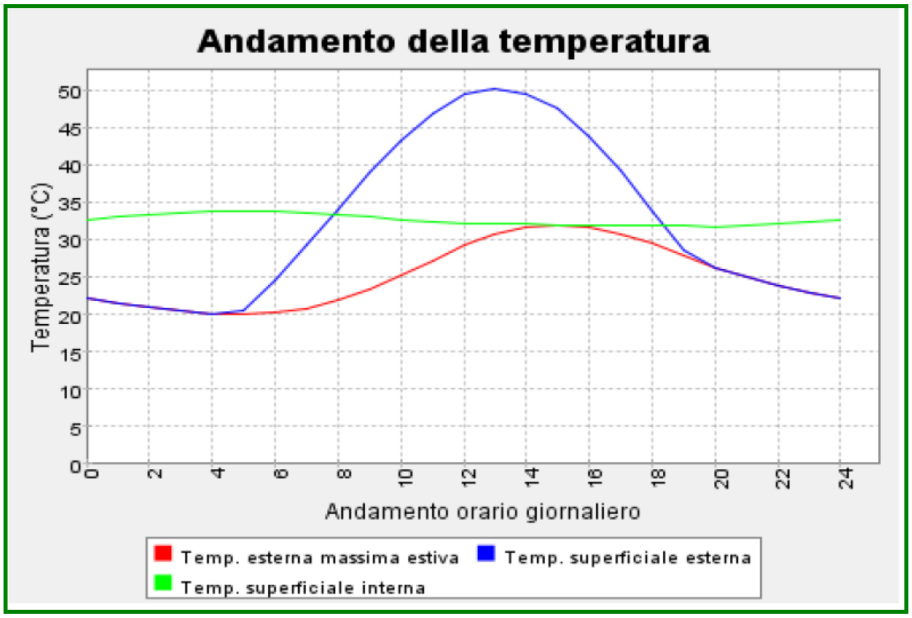


Fig.4.53. Proposed Slab Temperature Daily Variation

Thermal Decrement: 0,066

Thermal Lag : 15h39'

The thermal lag is so high that the building is "almost" not depending from the variation of the exterior temperature, the interior temperature is high, but in a constant rate.

Walls

Brick-Plaster

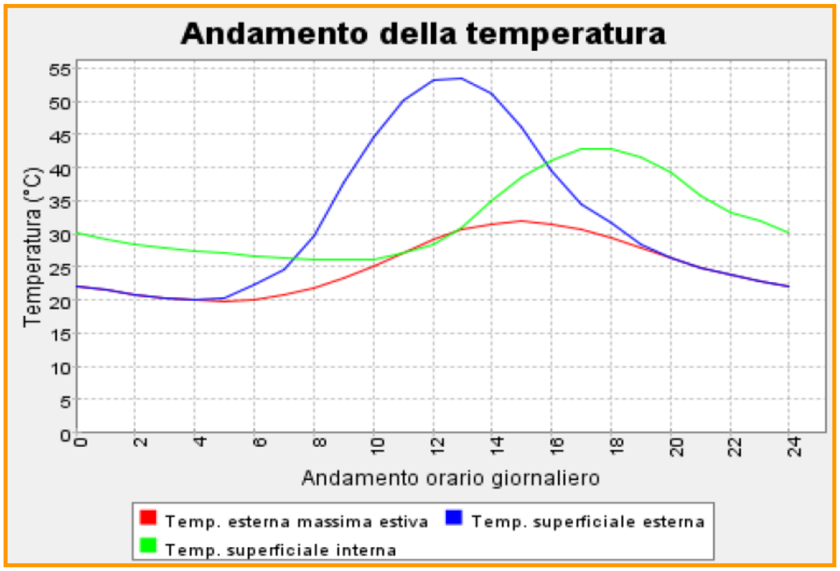


Fig.4.54. Traditional Wall Temperature Daily Variation

Thermal Decrement: 0,5
Thermal Lag : 4h33'
The exterior temperature maximum effect is delayed by 4,5 hours in the interior but is still in the "hot" period of the day.

Proposed Solution

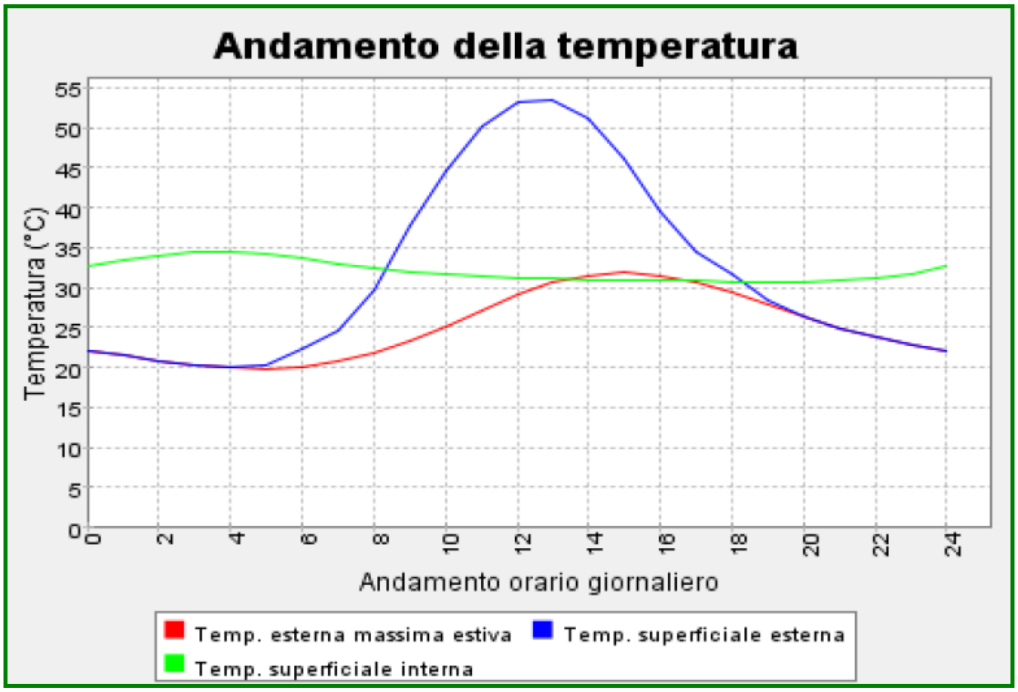


Fig.4.55. Proposed Wall Temperature Daily Variation

Thermal Decrement: 0,11
Thermal Lag : 15h6'
The exterior temperature The thermal lag is so high that the building is "almost" not depending from the variation of the exterior temperature, the interior temperature is high, but in a constant rate.

Conclusion

Finally, since our proposed solution seemed to be working efficiently preventing condensation and delaying the temperature phase, a yearly representation of the thermal profiles inside the solutions (slab and wall) was considered as relevant and interesting:

Temperature Profiles

Proposed Slab:

	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Plaster Board	25.0	1250.0	1088.000	0.431
2.	Concrete Lightweight	100.0	950.0	656.900	0.209
3.	Polystyrene Prefoamed F	100.0	100.0	1130.000	0.042
4.	Concrete Lightweight	120.0	950.0	656.900	0.209
5.	Air Gap	500.0	1.3	1004.000	5.560
6.	Wool	75.0	140.0	840.000	0.038
7.	Plasterboard	12.0	950.0	840.000	0.160

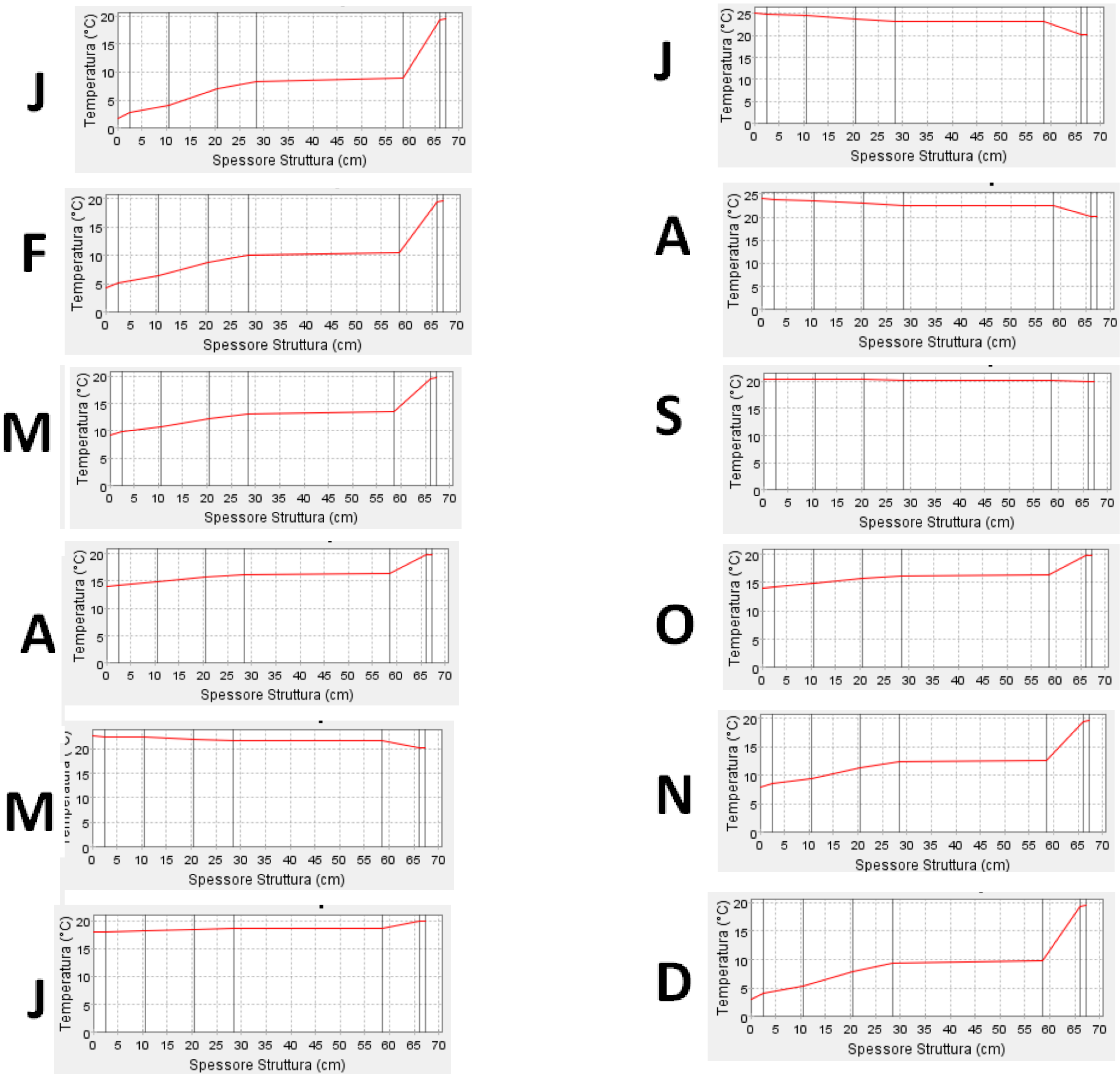


Fig.4.56. Proposed Slab Monthly Temperature Profile

Proposed Wall

	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Steel Alloy Cast	20.0	7830.0	460.200	46.024
2.	Air Gap	50.0	1.3	1004.000	5.560
3.	Wood Fibres, Compresse	40.0	320.0	100.000	0.055
4.	Polystyrene Prefoamed F	50.0	40.0	1130.000	0.042
5.	Wool	70.0	140.0	840.000	0.038
6.	Air Gap	50.0	1.3	1004.000	5.560
7.	Wool, Fibrous	10.0	96.0	840.000	0.043
8.	Plasterboard	10.0	950.0	840.000	0.160

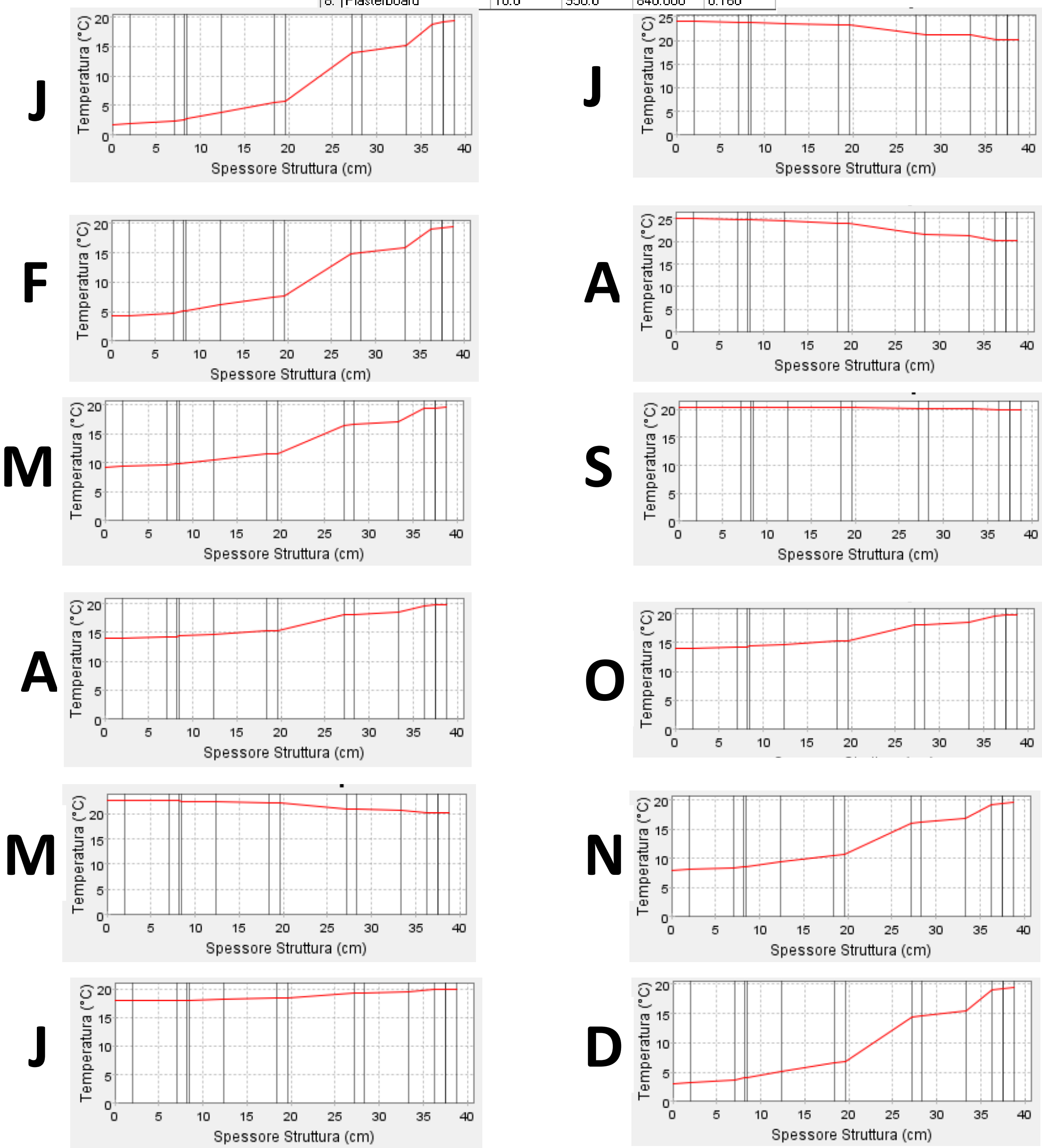


Fig.4.57. Proposed Wall Monthly Temperature Profile

Blow-Ups

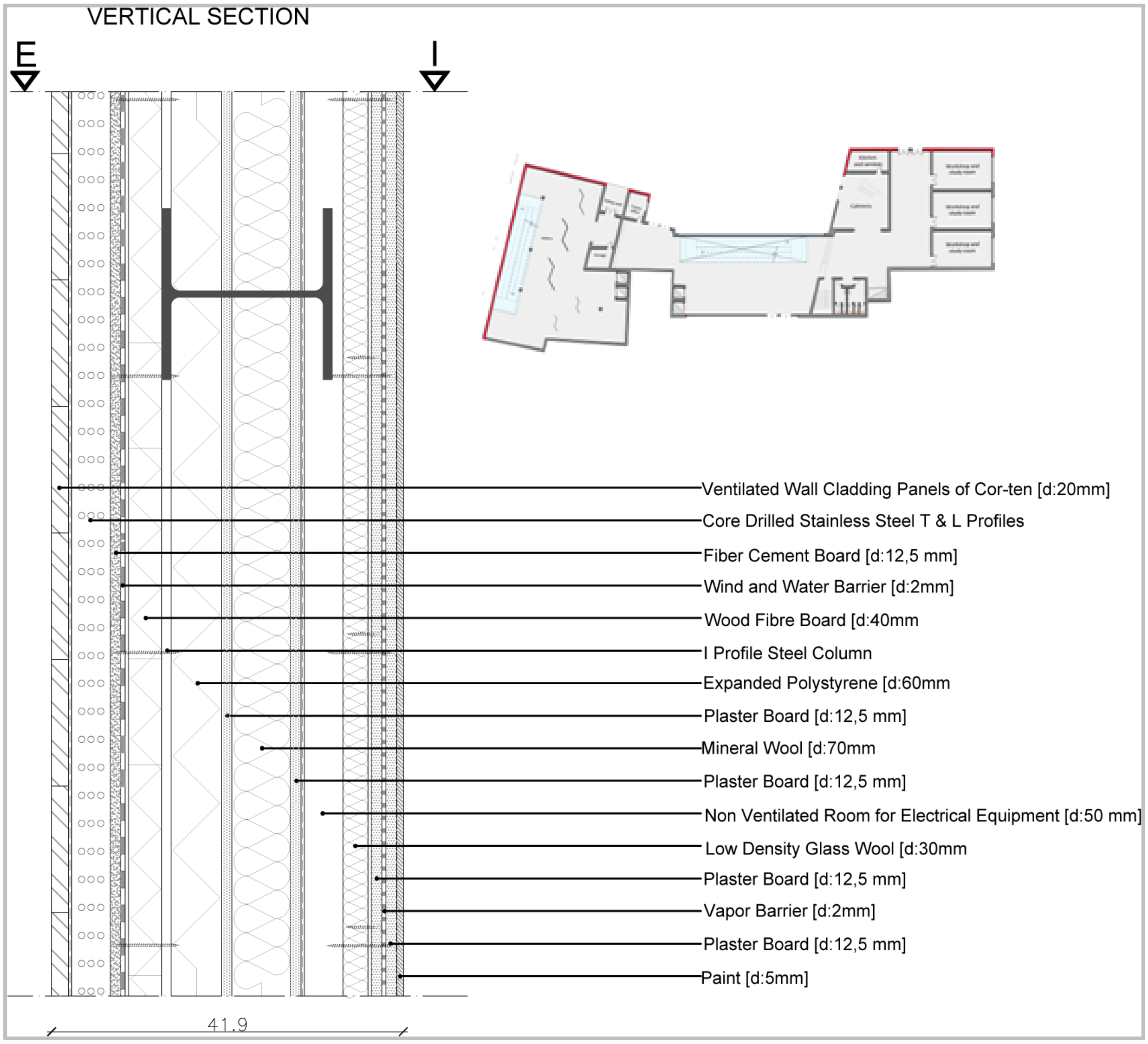


Fig.4.58. Detailed Section of the External Walls (VS)

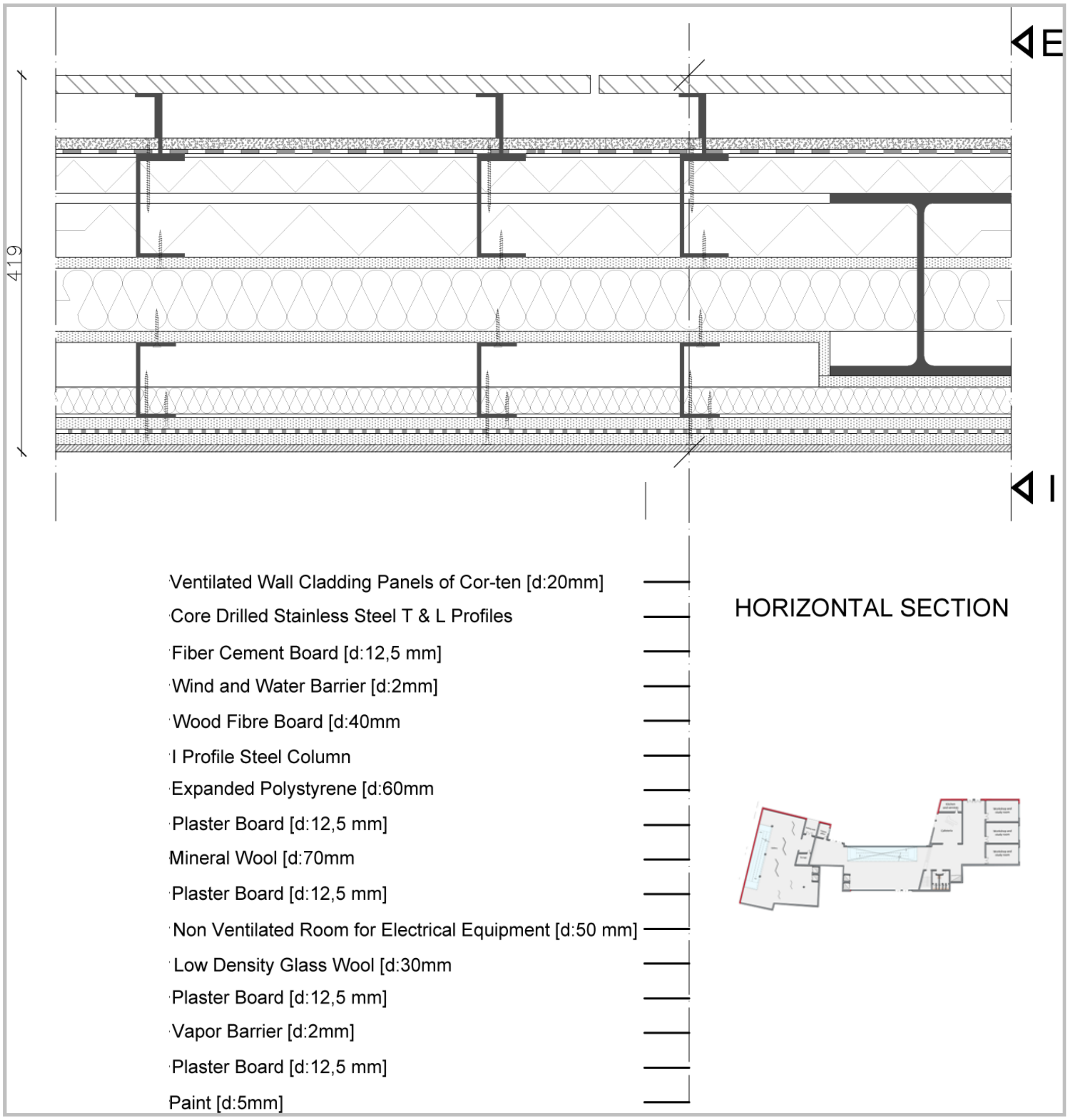


Fig.4.59. Detailed Section of the External Walls (HS)

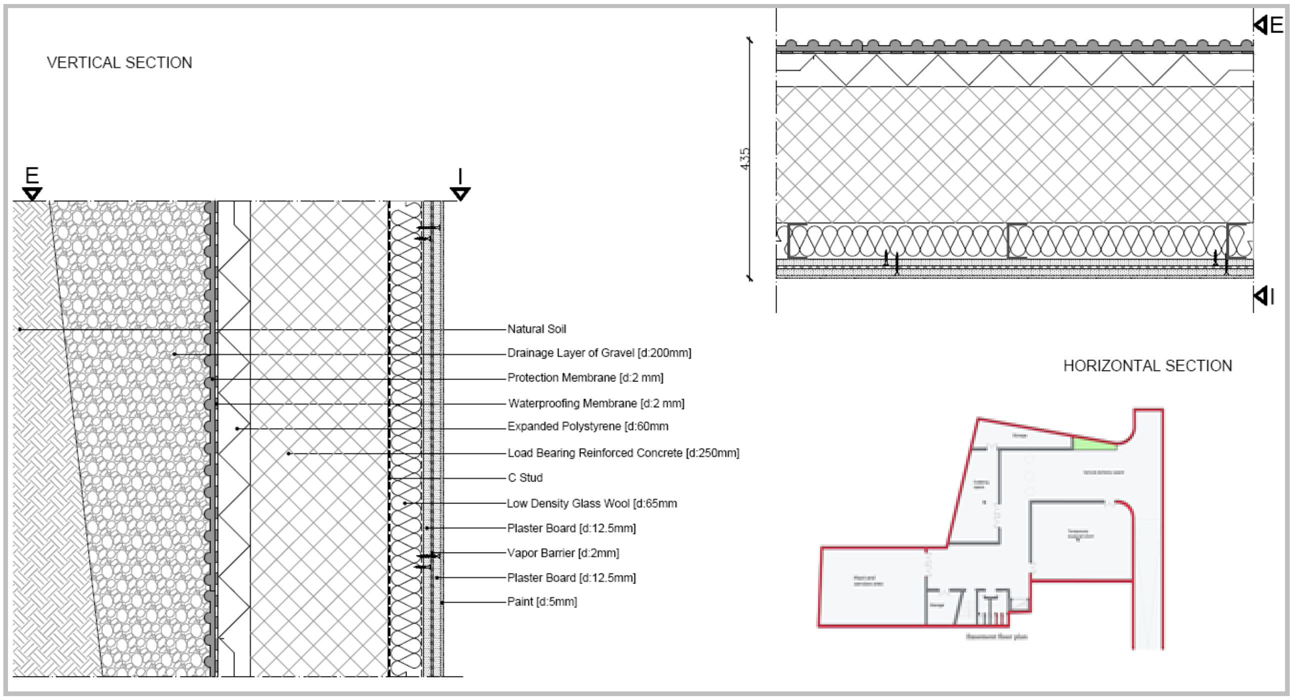


Fig.4.60. Detailed Section of the Basement Walls

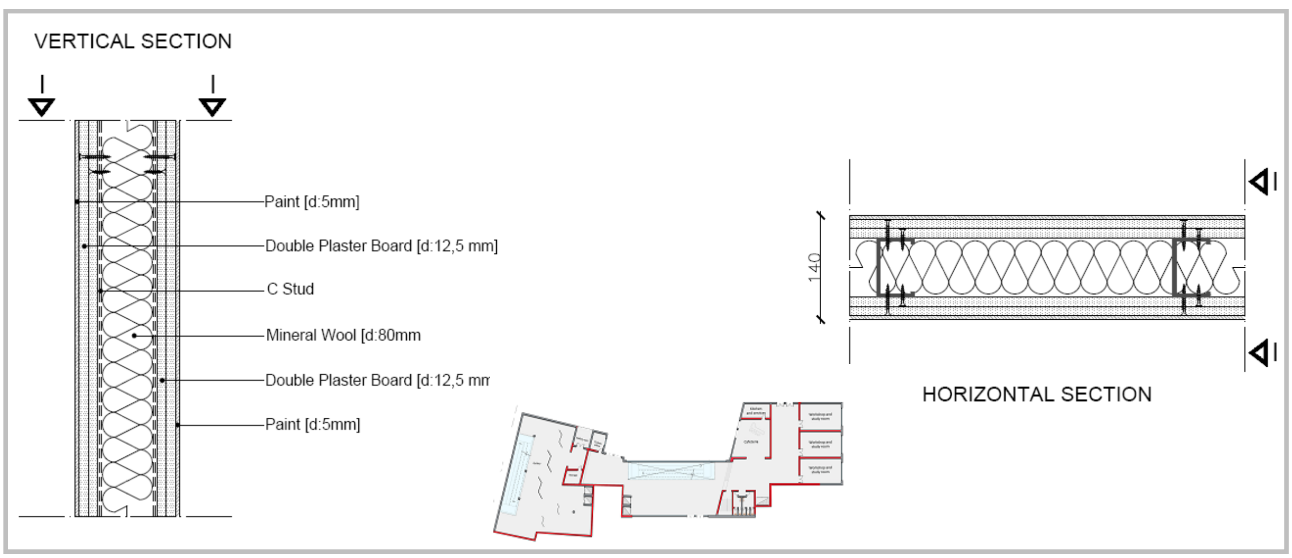


Fig.4.61. Detailed Section of the Interior Partitions

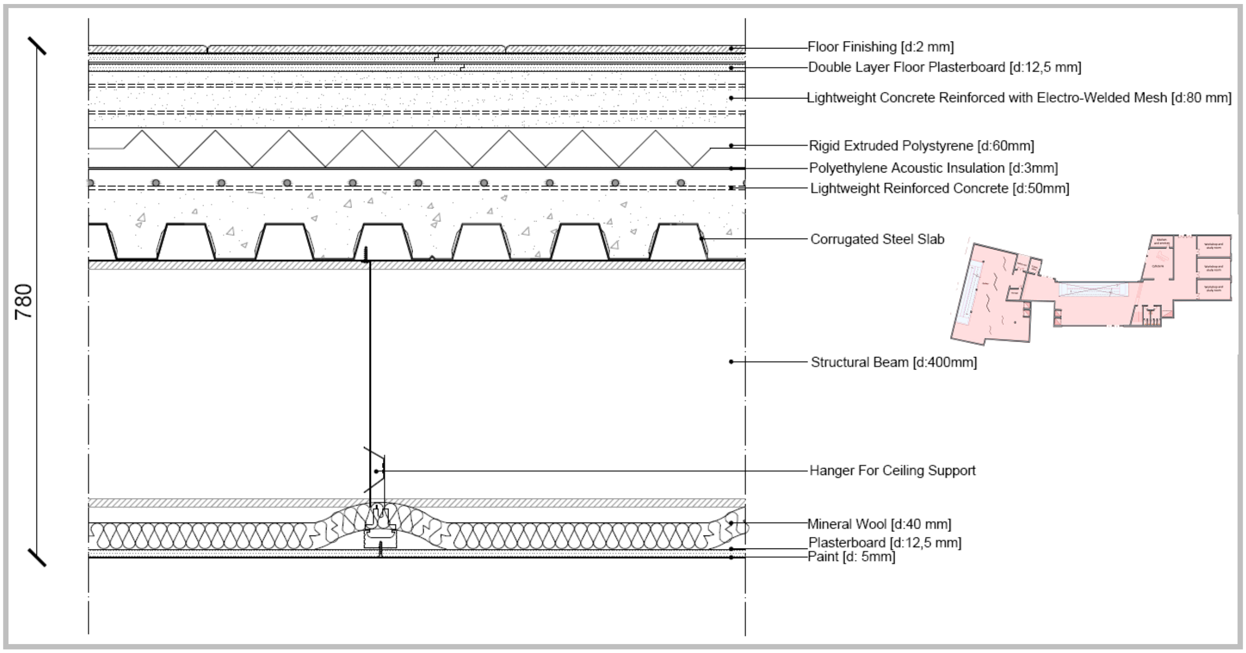


Fig.4.62. Detailed Section of the Interior Slab

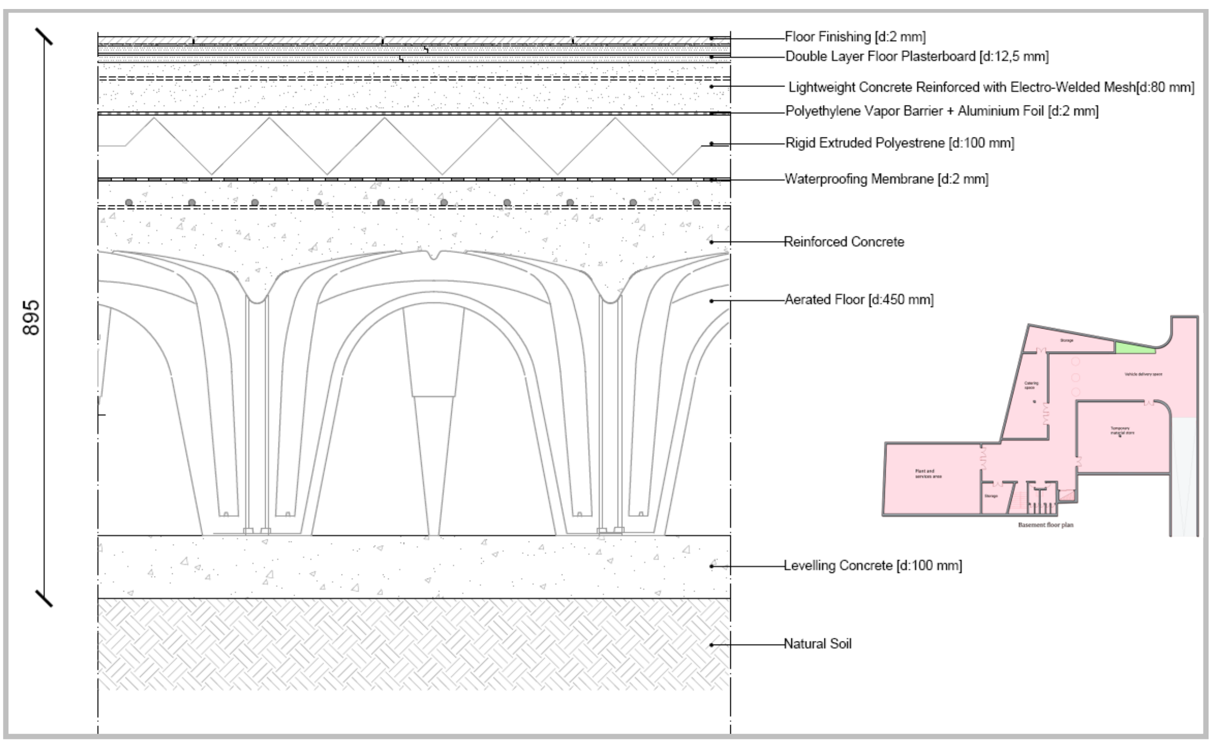


Fig.4.63. Detailed Section of the Basement Slab

Thermal Analysis

Introduction

It is of crucial importance to clarify the objectives and the purpose of the thermal analysis and simulation that we did, and to accurately locate it in the Design process. We wanted as much as possible to avoid marketing our project through what is called "green washing" by speaking about a passive/zero footprint building independently from the building potential and use. The issue of compromising between Architecture and Energy Efficiency was not one of the obstacles in our design; it was instead used as a guideline in main elements of the building from the architectural point of view. The real "issue" or better the strongest and most rigid parameter was nothing but comfort. We saw in the previous cases that the indoor spaces of the building had to provide very specific conditions, and so the margin of comfort has not only shrink but also lost from its flexibility.

The aim has therefore became to reduce the yearly but also the lifecycle energy consumption, costs, and the carbon emission of the building, for specific and well defined indoor conditions. The comparison that we have done between the traditional solutions and the proposed ones for the slab and the external walls will also appear in this section. The aim was to understand where and how much are the proposed solutions contributing in reducing the thermal loads and consequently the HVAC costs.

The comparison will include parameters such as: Hourly/Annual Temperature Distribution, Comfort, Losses/Gains through the envelope, HVAC loads etc… (Ecotect); but also Energy Costs, Consumption and rough sizing of the systems.

The Simplified Volume

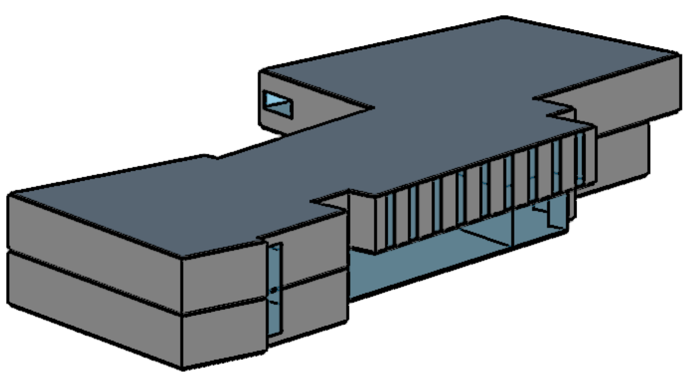


Fig.4.64. Simplified 3D volume to be exported and studied

A simple reproduction of the building model has been done in order to estimate its thermal behavior.

We got:

- Building pad: 1932 m^2
-Perimeter: 261m
-Height: 12m
-Volume: 26895m^3

SVR ≈ 0.26

The SVR should have been more optimal if we were targeting a Passive House for example where the SVR is usually around 0,15. But in the case of a Museum where exhibition spaces are preferably horizontal, the volume of our building is considered as rather compact.

Since the addition and the existing museum should have a certain independency in terms of functionality, and for simplicity reasons, we decided to isolate our model and not consider the adjacent spaces as heated spaces.

Thermal Zones

The building was later divided into thermal zones according to the function and the geometry. The occupancy was one of the most critical parameter in our simulation for two reasons;

First, because the building occupancy was not homogeneous: we have spaces that will always have relatively low occupancy (Loft space) and we have other spaces that could have rather high occupancy (Multipurpose hall).

Second, because the building occupancy was also randomly depending on time, and random situations could never be taken into consideration in the design stage, i.e. if the internal gains coming from the full occupancy of the multipurpose hall could be enough to compensate the heat losses, we could not design the MPH as always fully occupied, because designing a system means designing for all the situations, especially the worst.

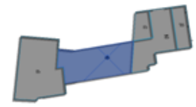
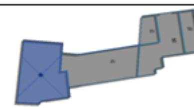
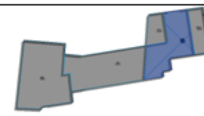
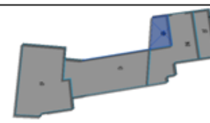
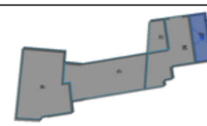
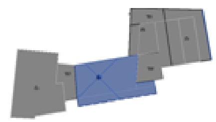
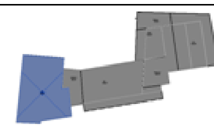
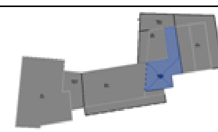
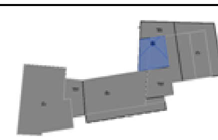
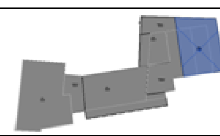
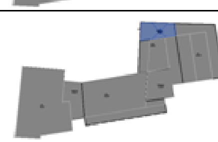
Zone and color	Floor Area (m^2)	Volume (m^3)	Occupancy (persons)	Activity	Position
Foyer	588	3347	40	Walking-80W	
Gallery	656	3736	40	Walking-80W	
Secondary Entrance	409	2327	15	Walking-80W	
Cafeteria	117	665	15	Sedentary-70W	
Classroom	152	863	40	Sedentary-70W	
Loft 1	713	4279	40	Walking-80W	
Loft 2	656	3938	40	Walking-80W	
Transition Loft	154	925	6	Walking-80W	
2nd Floor Foyer	285	1707	10	Walking-80W	
Seminar	139	836	30	Sedentary-70W	
MPH	467	2800	120	Sedentary-70W	
Children Area	108	651	15	Sedentary-70W	

Table.4.12. Thermal Zones Properties

After dividing the building into thermal zones, we had to assign the technological system to the external surfaces of the thermal simplified model, which is known by Ecotect as "Materials".

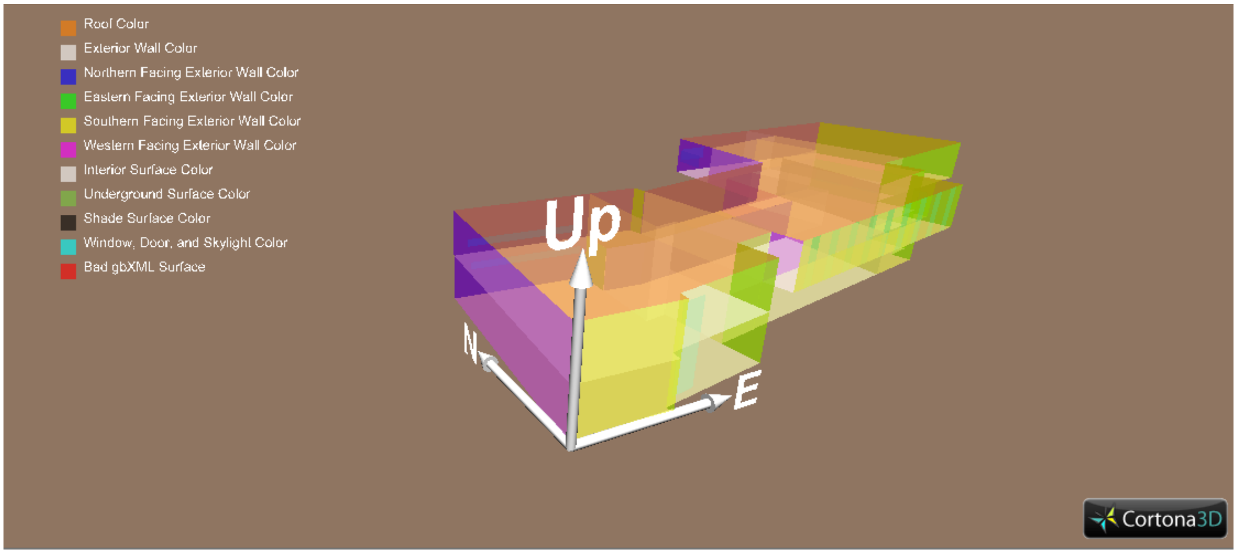


Fig.4.65. gbxml model with faces attributions

The operational profile considered was a 12h/7d profile: supposing that the Museum will be functioning everyday from 8am till 8pm. The holidays were not taken into consideration for simplicity reasons.

Some studies such as hourly temperature profiles and hourly gain/loss were just magnified on the hottest day (August 6th) and the coldest day (January 17th) of 2010.

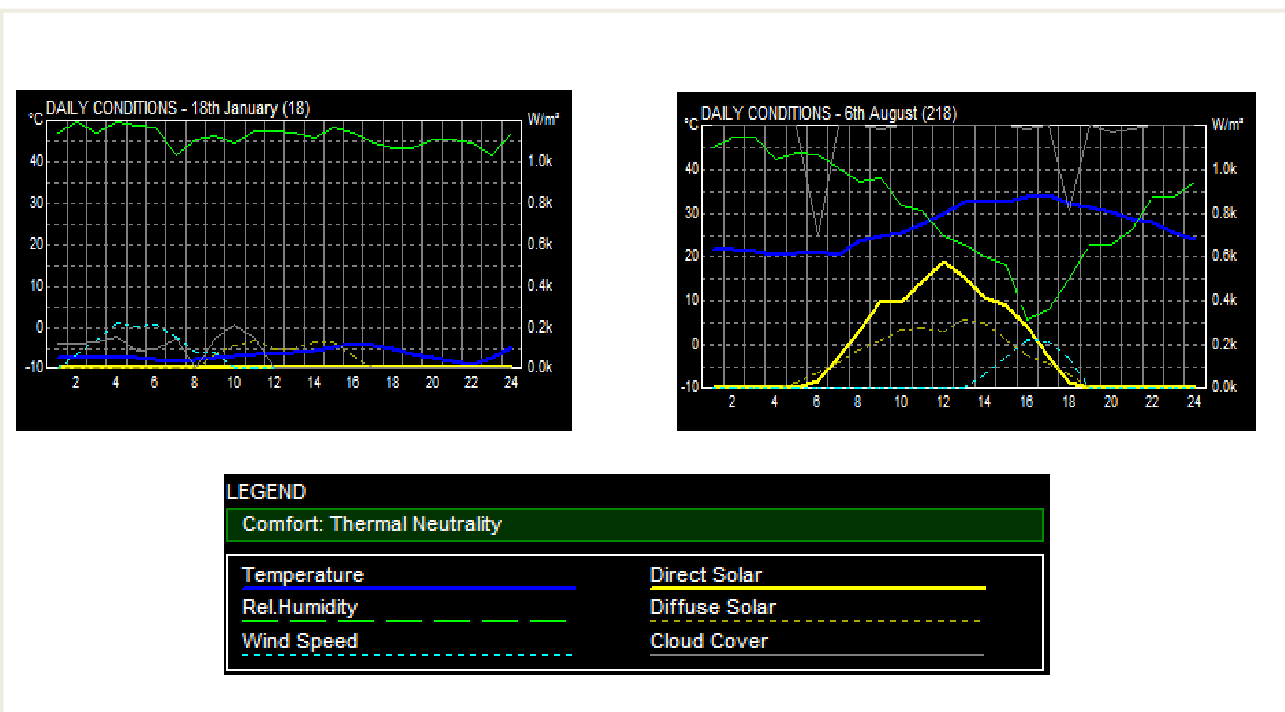


Fig.4.66. Coldest and Hottest days Climatic Conditions

Temperature Hourly Profile

Coldest day:

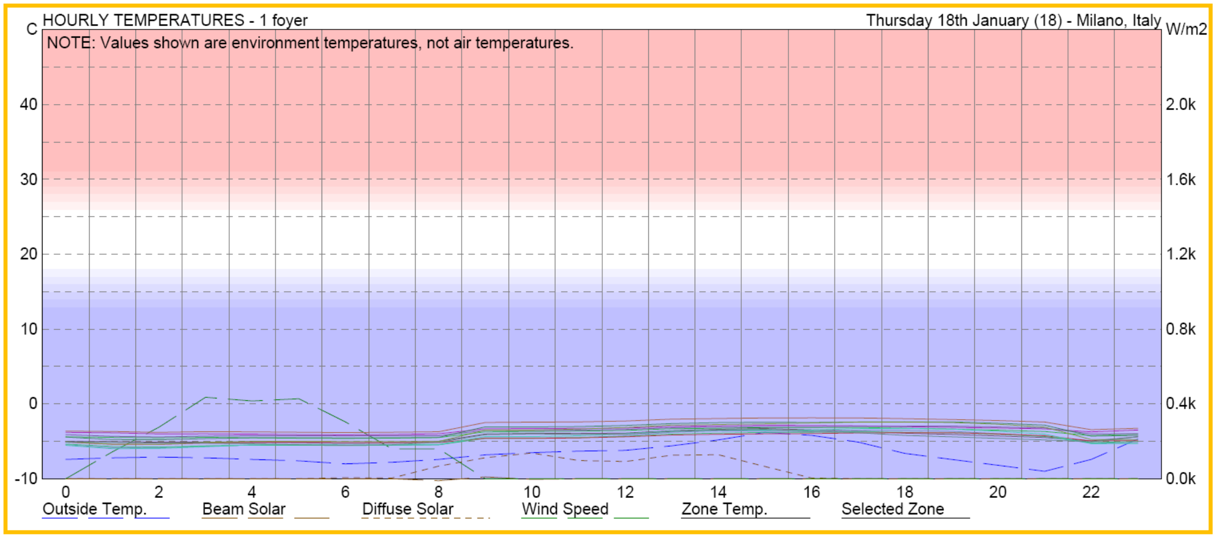


Fig.4.67. Coldest Temperature Profile in the Traditional Case

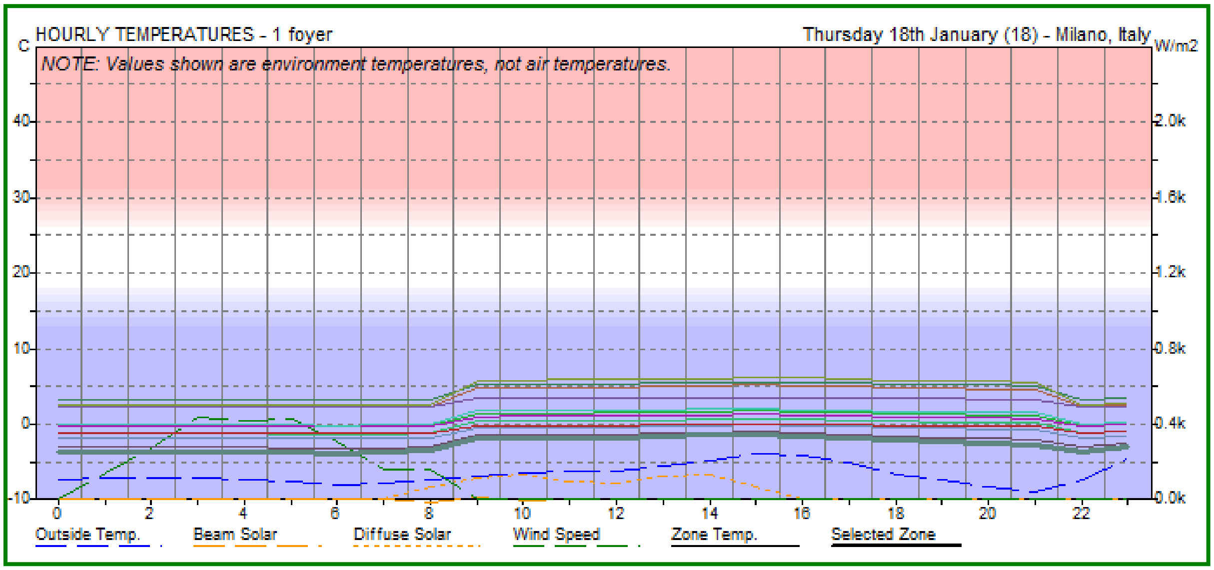


Fig.4.68. Coldest temperature Hourly Profile in the Proposed Case

We notice that the temperature in the case of the proposed technology is about 5 degrees higher. There is not much difference since the high thermal resistance of the the proposed solution can save the heat inside the building, but in this case, the internal gains are very low because of the low occupancy of the building compared to it's volume. Supporting this argument, we notice that the MPH (refer to zone table for the colors) which is the most occupied is the one with the highest temperature, while the lowest one goes for the Foyer which is the zone with the most glazed surfaces.

Hottest Day

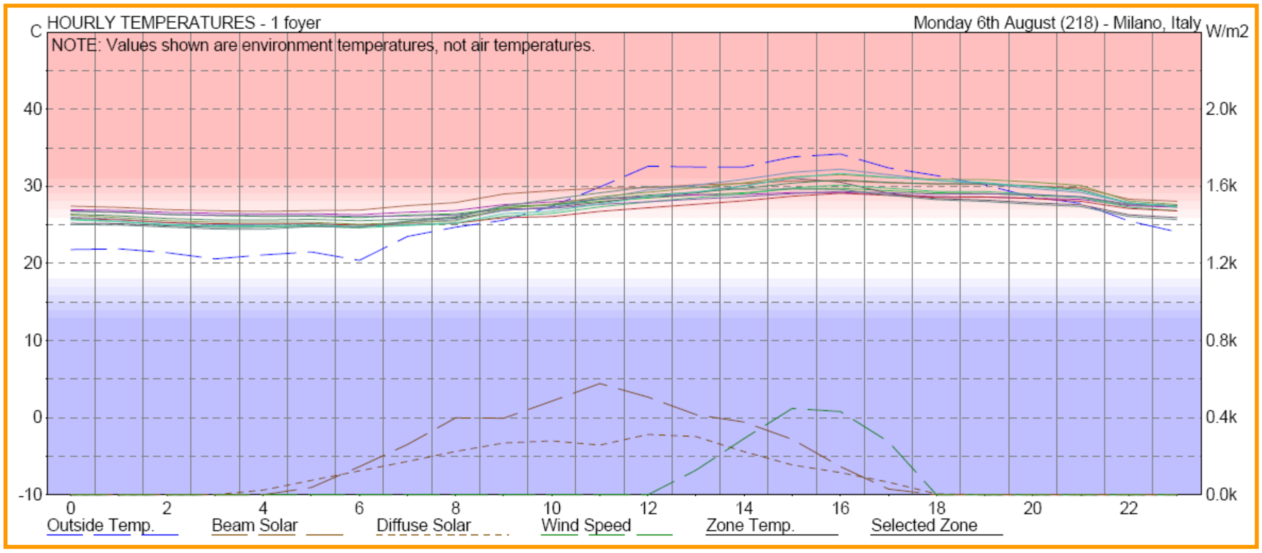


Fig.4.69. Hottest temperature Hourly Profile in the Traditional Case

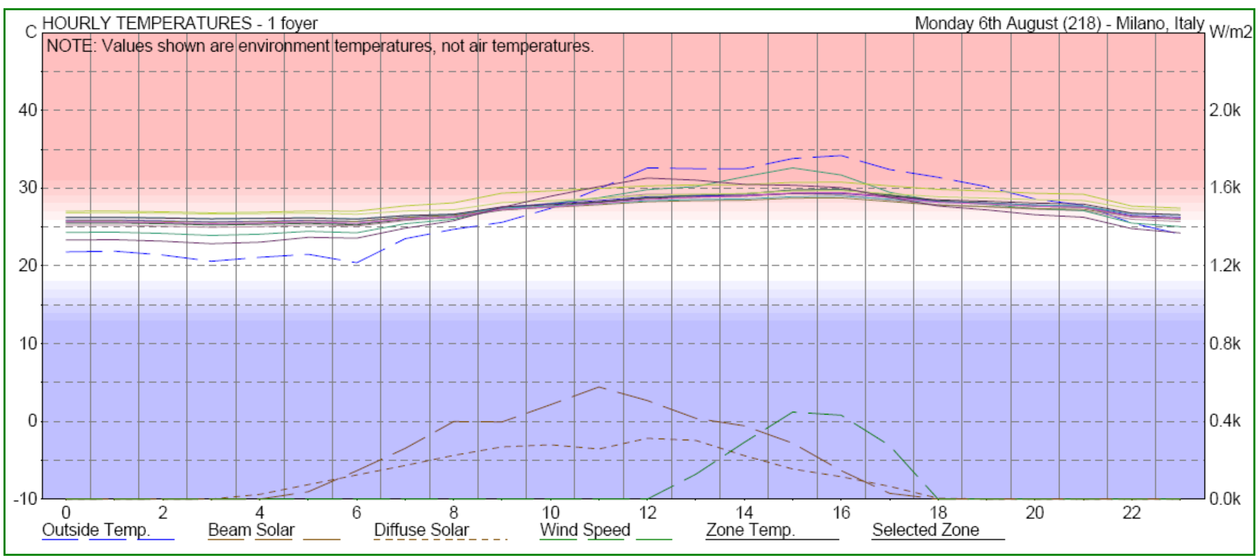


Fig.4.70. Hottest temperature Hourly Profile in the Proposed Case

The values during the hottest day are very close, this will be clearer when we go to the gains/losses comparison to see that the internal and the ventilation gains are more dominant that the gains by conduction. We can say that the behavior of the system and the benefits of insulation are not as relevant as in the cold situation

Natural Ventilation Opportunities (Proposed tech. solution)

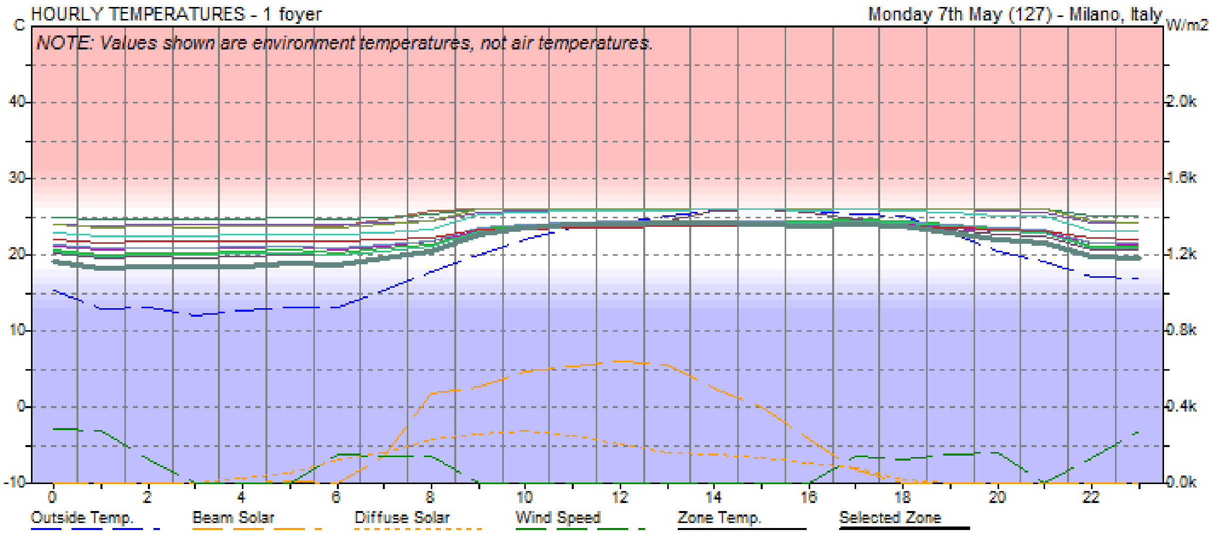


Fig.4.71. First Period of Natural Ventilation Potential

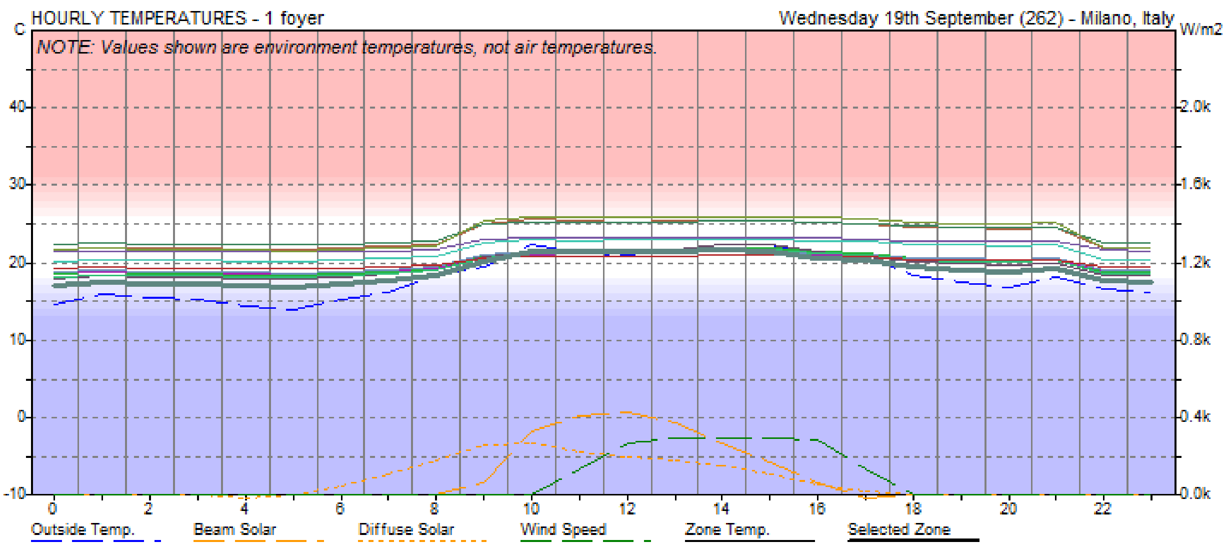


Fig.4.72. Second Period of Natural Ventilation Potential

In the period of May 1st-July 5th and August 18th-September 29th, the temperature in all the zones is between the comfort limits (18ºC-26ºC). It is in this period that we can theoretically benefit from natural or forced ventilation to provide comfort. There is almost no need to heat or to cool the outside air. Nonetheless, filtering and eventual dehumidification are always needed.

Profiles using HVAC systems (Proposed tech. solution)

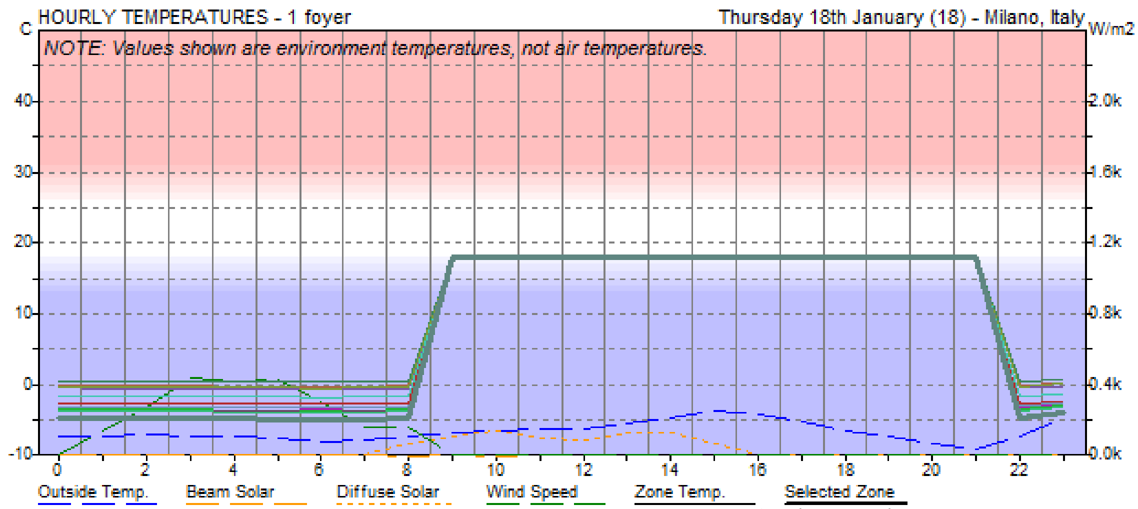


Fig.4.73. HVAC controlled temperature Profile (Heating)

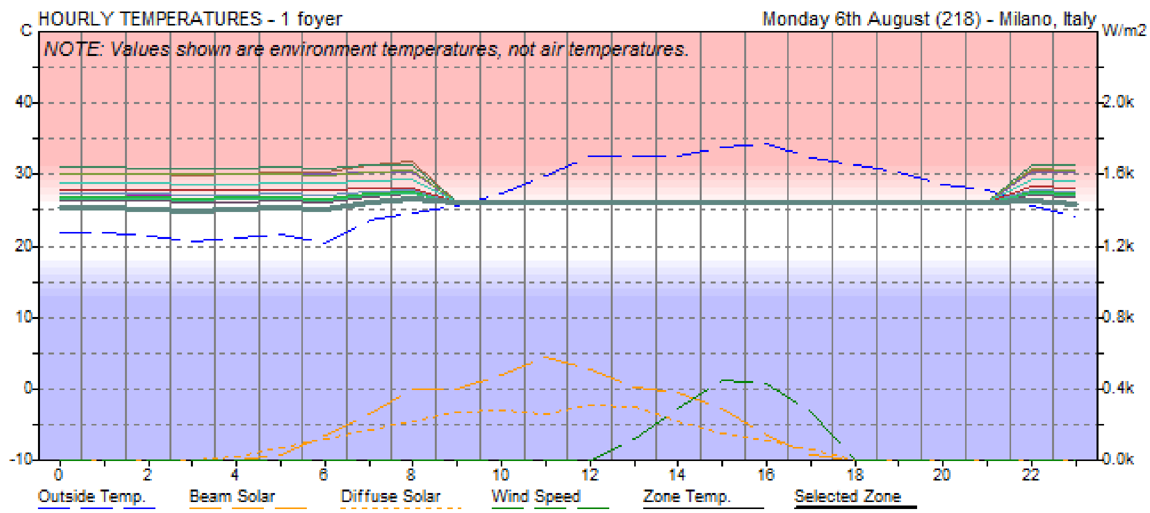


Fig.4.74. HVAC controlled temperature Profile (Cooling)

After all what we have seen until now, it is clear and obvious to notice that the heating system is doing much more work than the cooling system; consequently, taking the temperature from ~ -5ºC to 18ºC is consuming a huge energy, incomparable to the energy spent to cool by few degrees in the hot period. To note that the interior temperature would not be allowed to reach such critical values; moreover, to conserve the works of art and history, the temperature will remain over a certain minimum limit. The heating system is following the operative schedule of the building (internal gains). Another note is about the increase of the temperature after the cooling system is shut off. It is because as we saw previously, the solution we chose has a high thermal lag ~15h. The internal temperature is then made more or less independent from the variation of the external temperature, and even if the external temperature is going down, the phase of the solution used is delayed and still carrying heat from previous heating hours.

Hourly Gains/Losses

Coldest Day

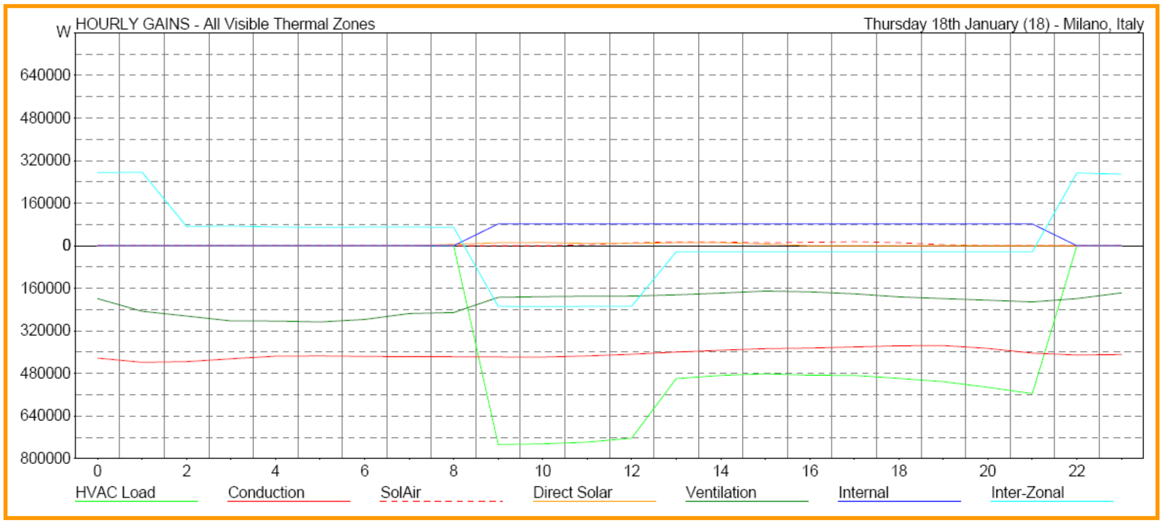


Fig.4.75. Coldest Day Gains/Losses (Traditional)

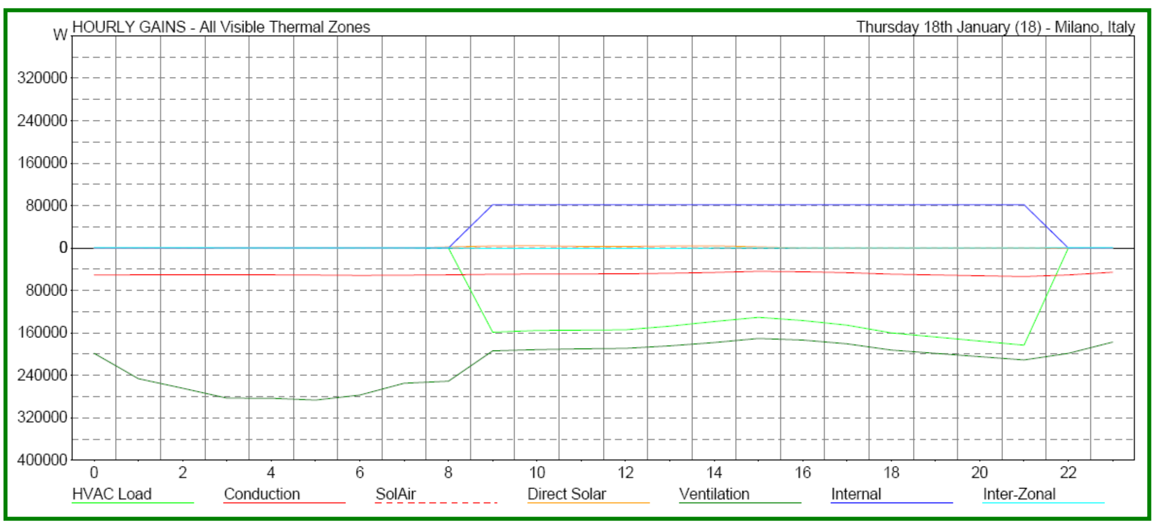


Fig.4.76. Coldest Day Gains/Losses (Proposed)

This is the point where the difference between the traditional solution that we took as a comparison reference, and the solution that we proposed starts to become highly relevant. In fact, as we said previously, the comfort conditions are fixed, and our goal is to reduce the costs to provide them. We notice here that for the same day, using the traditional solution, the conduction losses are about 400kwh, when it could be decreased to 50kwh by using the proposed solution. The conduction losses has their effect on the HVAC loads and then on the costs. To note that the inter-zonal losses were created in the traditional solution and not in the proposed one, just because in the simulation using the proposed solution, the same highly insulated solution was used for the roof and for the slab and then the zones were not able to exchange heat.

Hottest Day

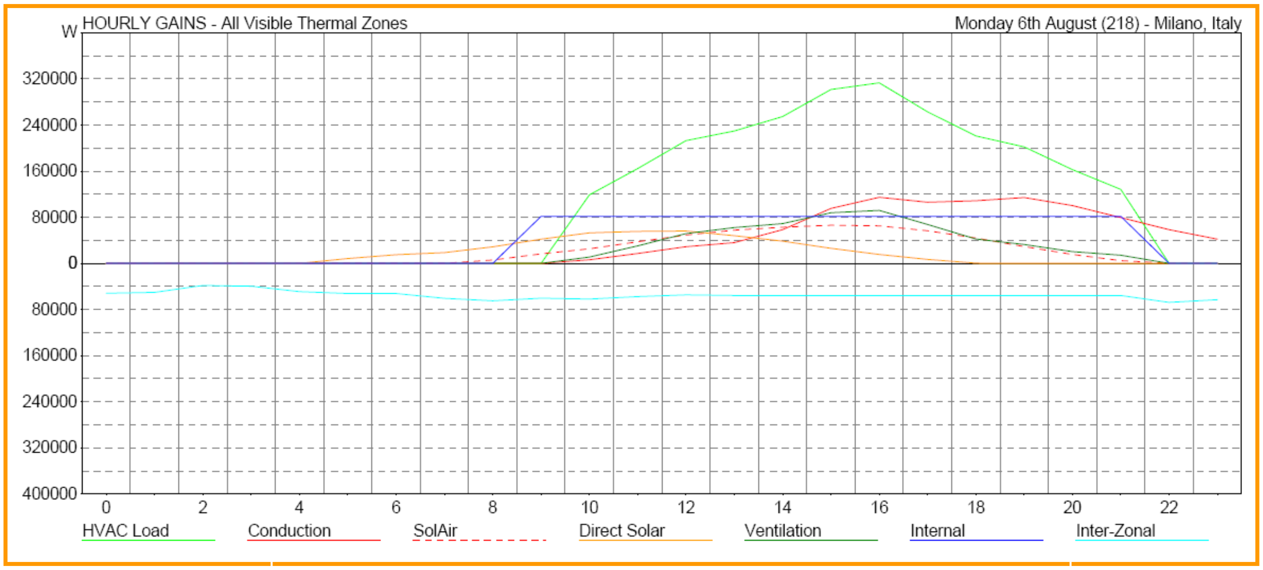


Fig.4.77. Hottest Day Gains/Losses (Traditional)

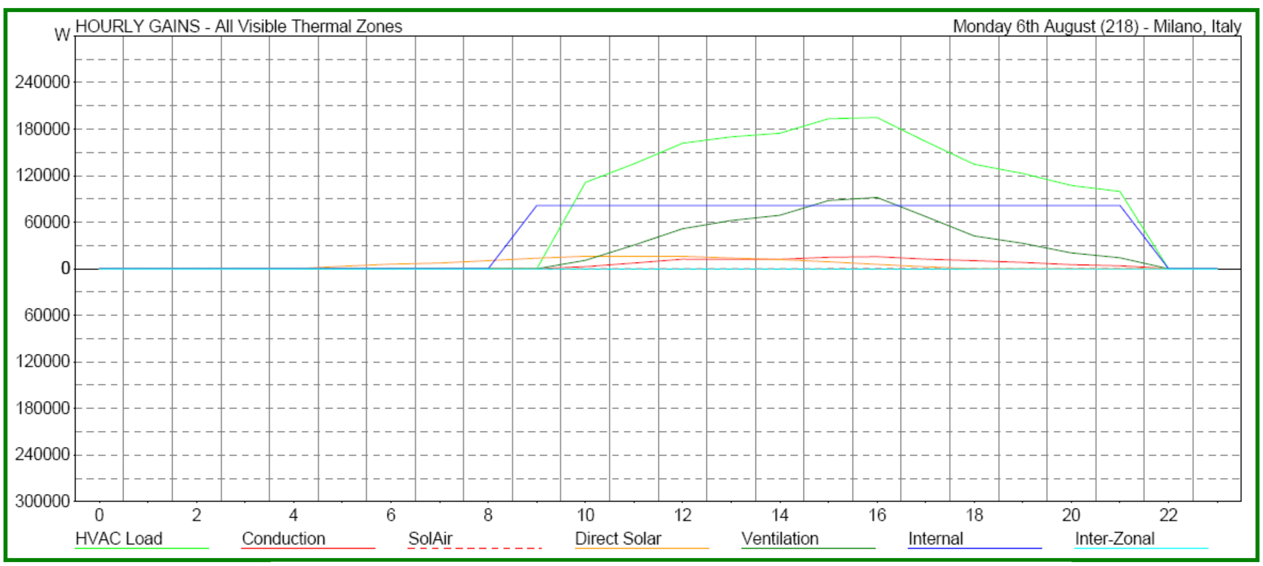


Fig.4.78. Hottest Day Gains/Losses (Proposed)

In the case of cooling, the difference is still clearly visible (~100Kwh vs. 10Kwh), and conduction gains which are very negligible in the case of the proposed technology, are instead a serious issue in the case of the traditional solution since they are participating as much as ventilation and internal gains in the total HVAC loads.

Fabric Gains/Losses

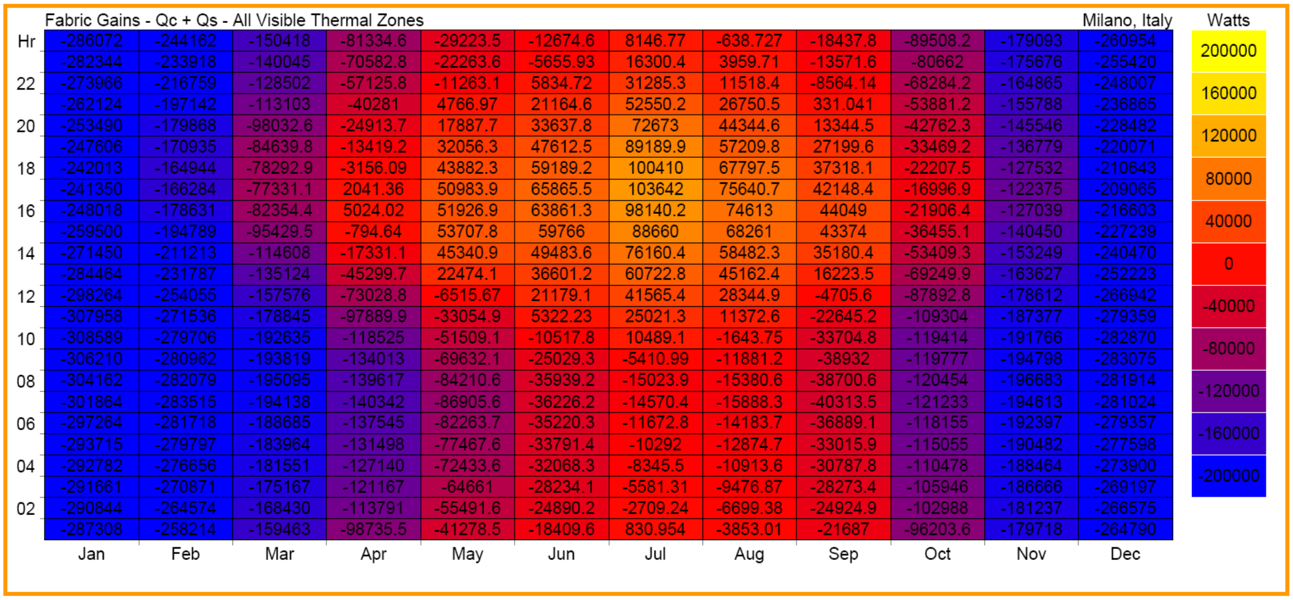


Fig.4.79. Annual Fabric Gains/Losses (Traditional)

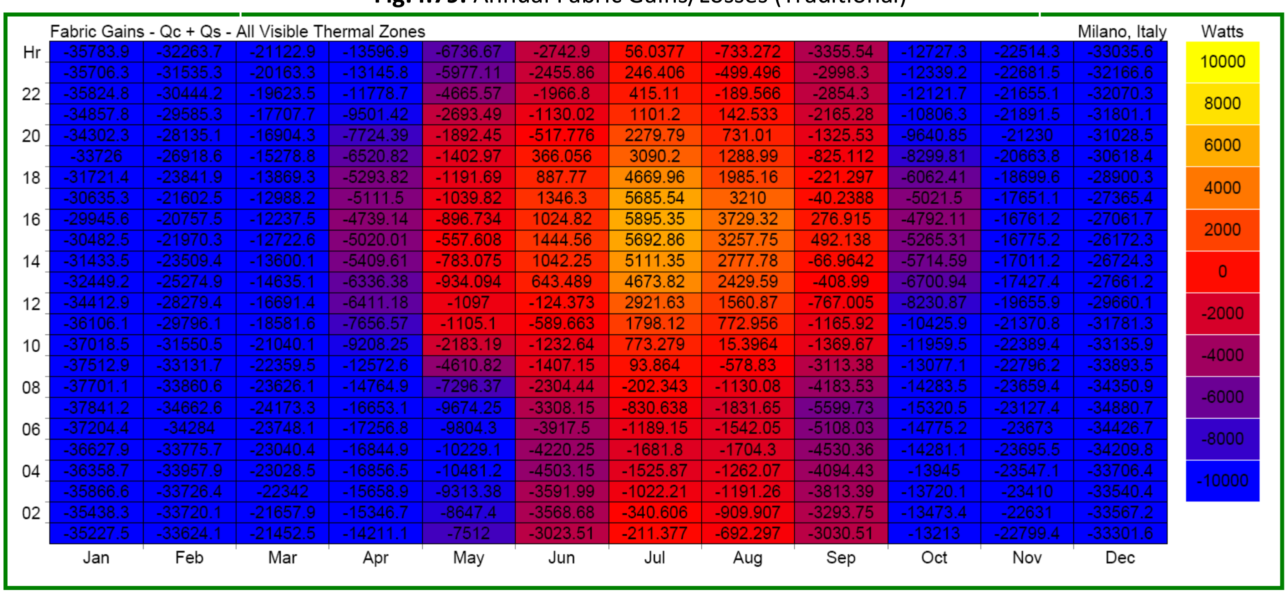


Fig.4.80. Annual Fabric Gains/Losses (Proposed)

This is the graph that has the straightest relation with the original choice of the solutions. The gains are in fact directly governed by the transmittance of the envelope. Since there is a huge difference between the U values of the considered solutions, we can say that the result of this graph was a priori expected.

Passive Gains Breakdown

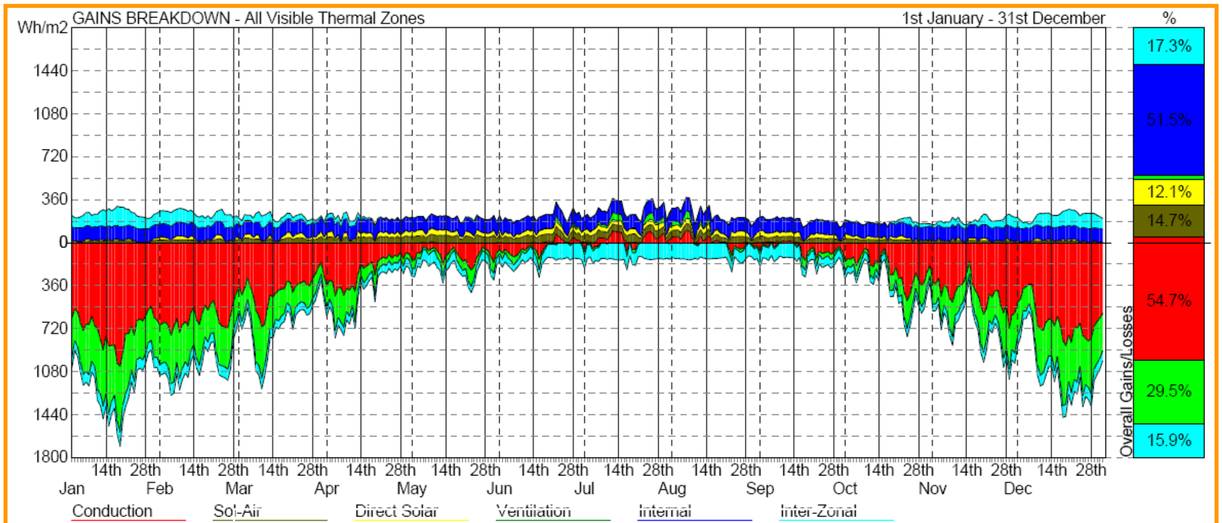


Fig.4.81. Passive Gains Breakdown (Traditional)

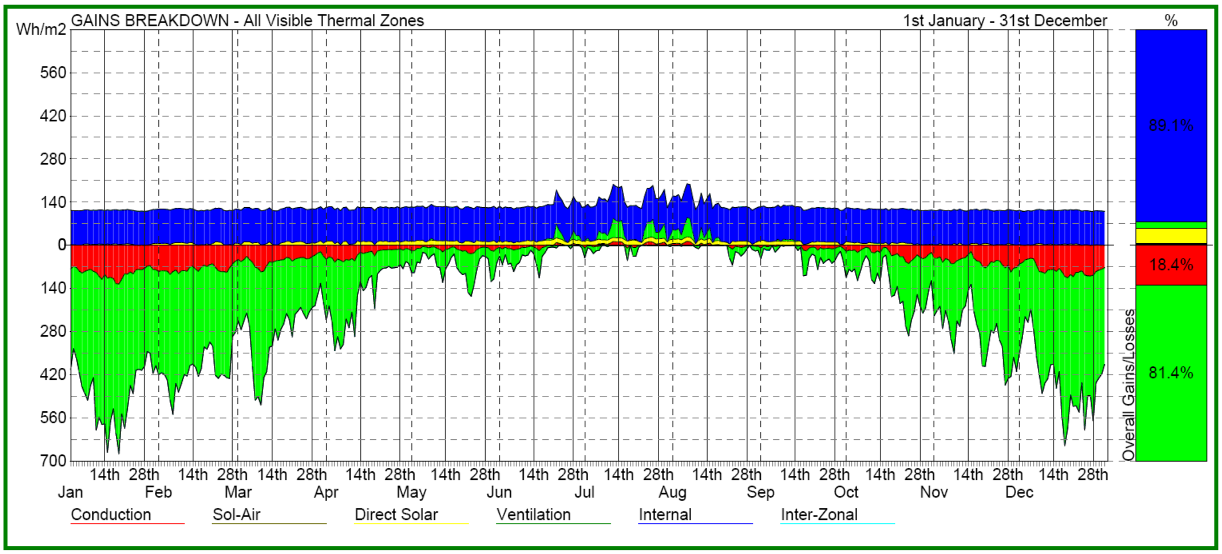


Fig.4.82. Passive Gains Breakdown (Proposed)

Those graphs are interesting to show in which period the building is closer to its passive state. Comparing the two graphs, we notice another time the major influence of conduction in the case of the traditional solution, and the minor one in the case of the proposed high insulated one. In any case, the building is closer to be in it's passive state (gains = losses) in the months of June and October. Having chosen the second solution, we see that the ventilation issue is the major one, and this will be very critical in the choice of the HVAC system. To note that this graph shows the losses of the building due to ventilation, in the case where all the internal air is exhausted; in an efficient system, a heat recovery system can greatly reduce the costs of ventilation and then the effective losses are reduced.

Heating/Cooling Loads

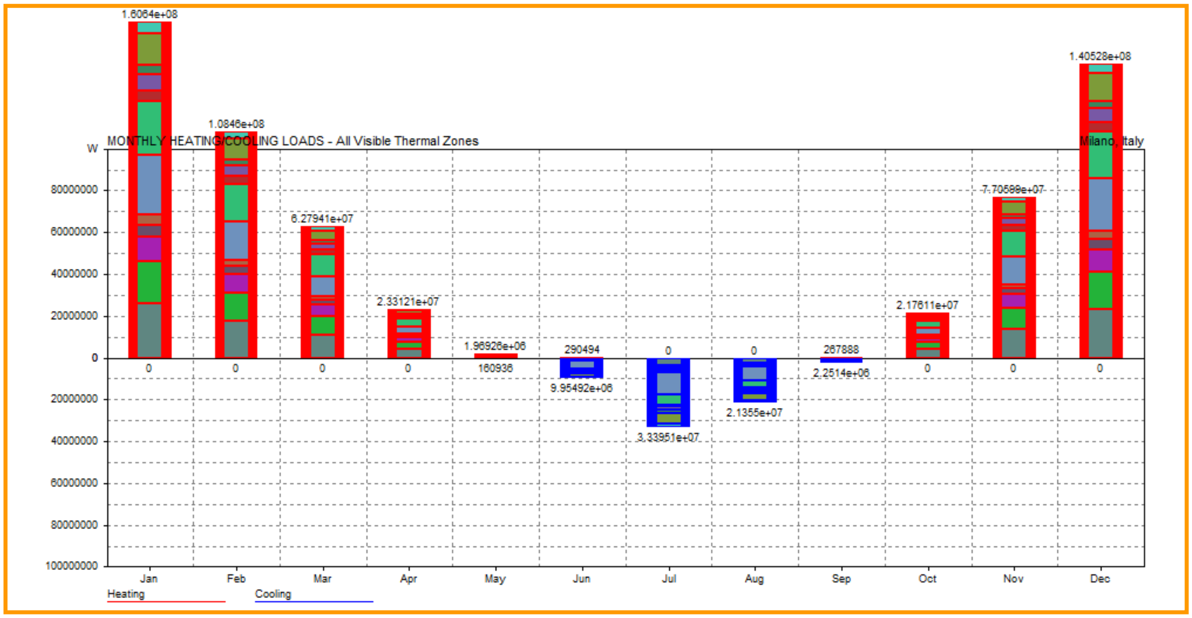


Fig.4.83. Heating/Cooling Loads (Traditional)

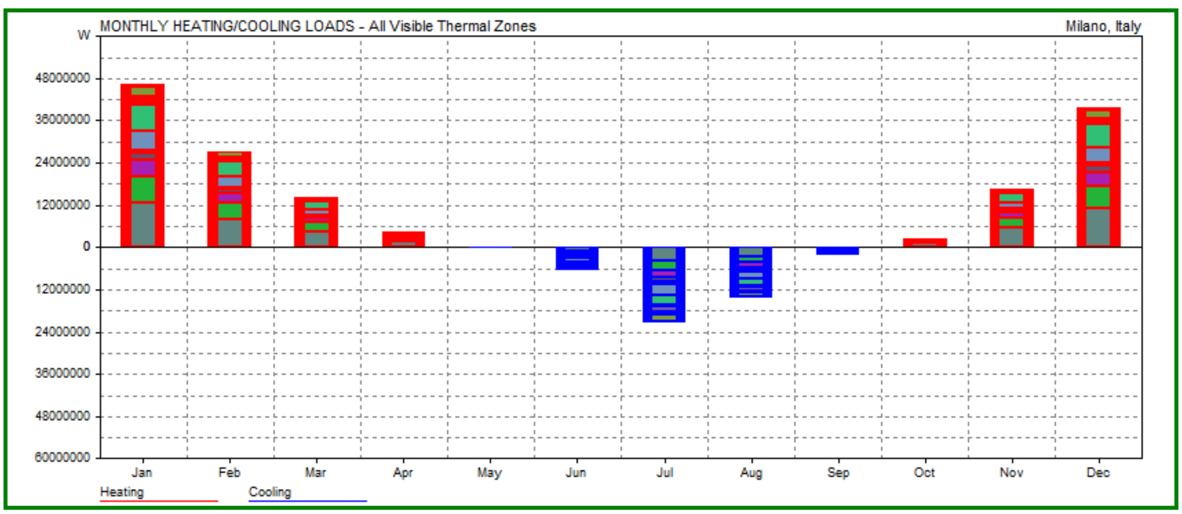


Fig.4.84. Heating/Cooling Loads (Proposed)

In those graphs, we are seeing the participation of each zone, in the total monthly heating/cooling load. As expected, the largest zones (Foyer, Gallery, Loft 1, Loft 2) are the most prevailing ones. The results obtained in the case of using the traditional solution (larger by one order of magnitude than second solution) are crossing the maximum value accepted by the software inside the graph since the calculation is for the total area and not a specific one. The numbers themselves are not as relevant as the comparison between: the two solutions, the needs of each month, and the needs of each zone.

Average monthly Mean Radiant Temperature without HVAC

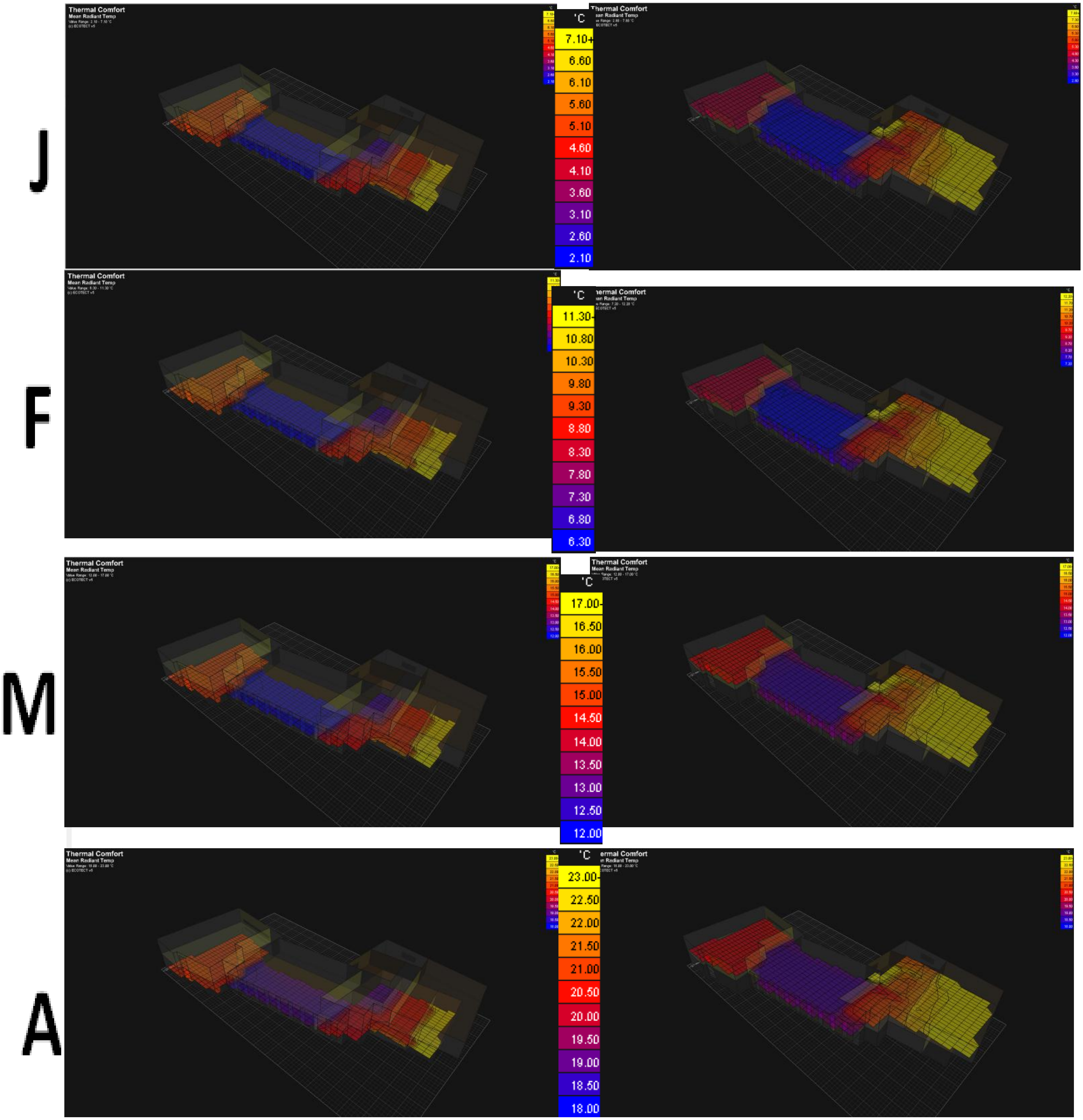


Fig.4.85. Ground Floor Comfort Distribution (January-April)

Fig.4.86. First Floor Comfort Distribution (January-April)

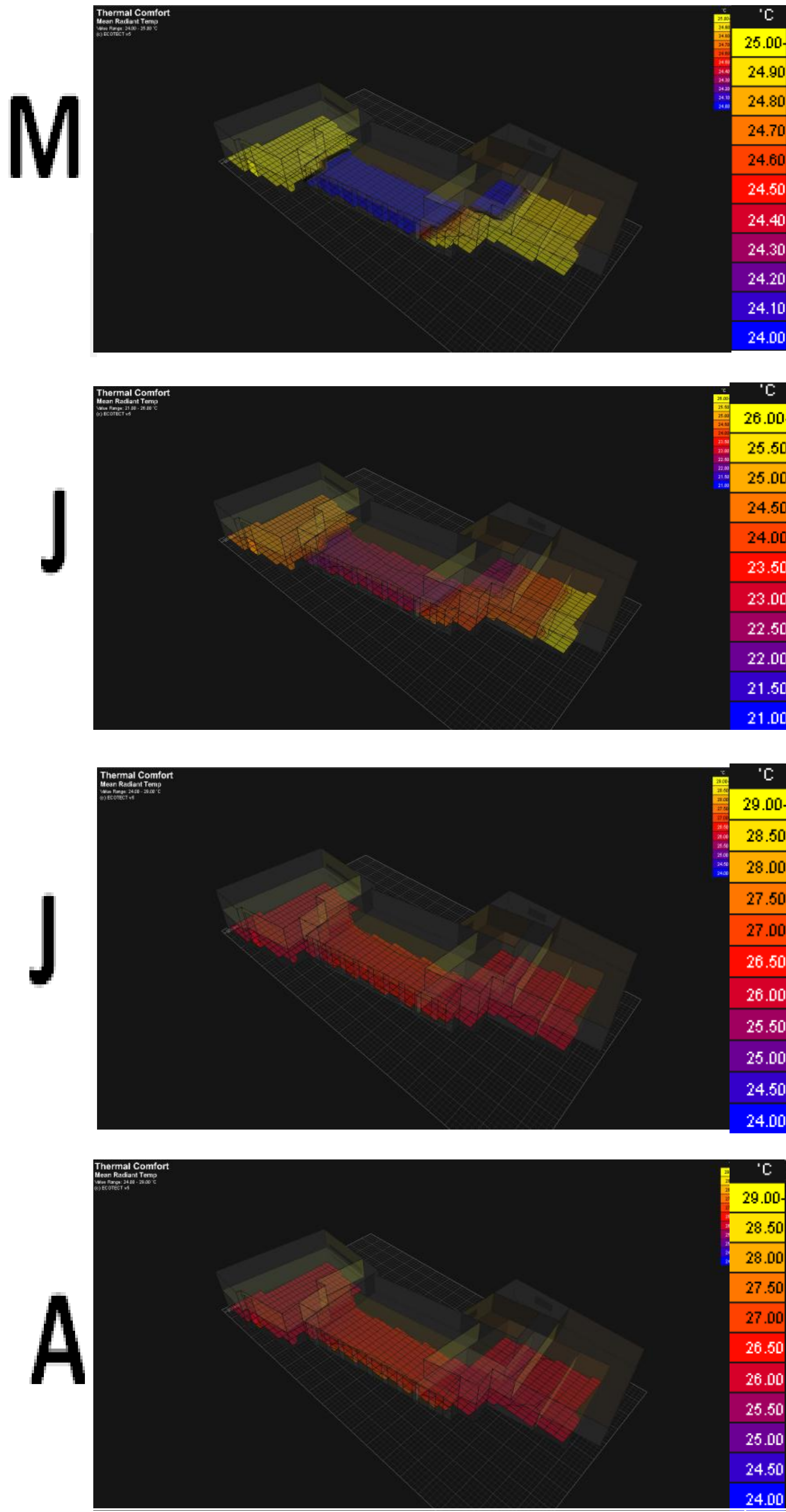


Fig.4.87. Ground Floor Comfort Distribution (May-August)

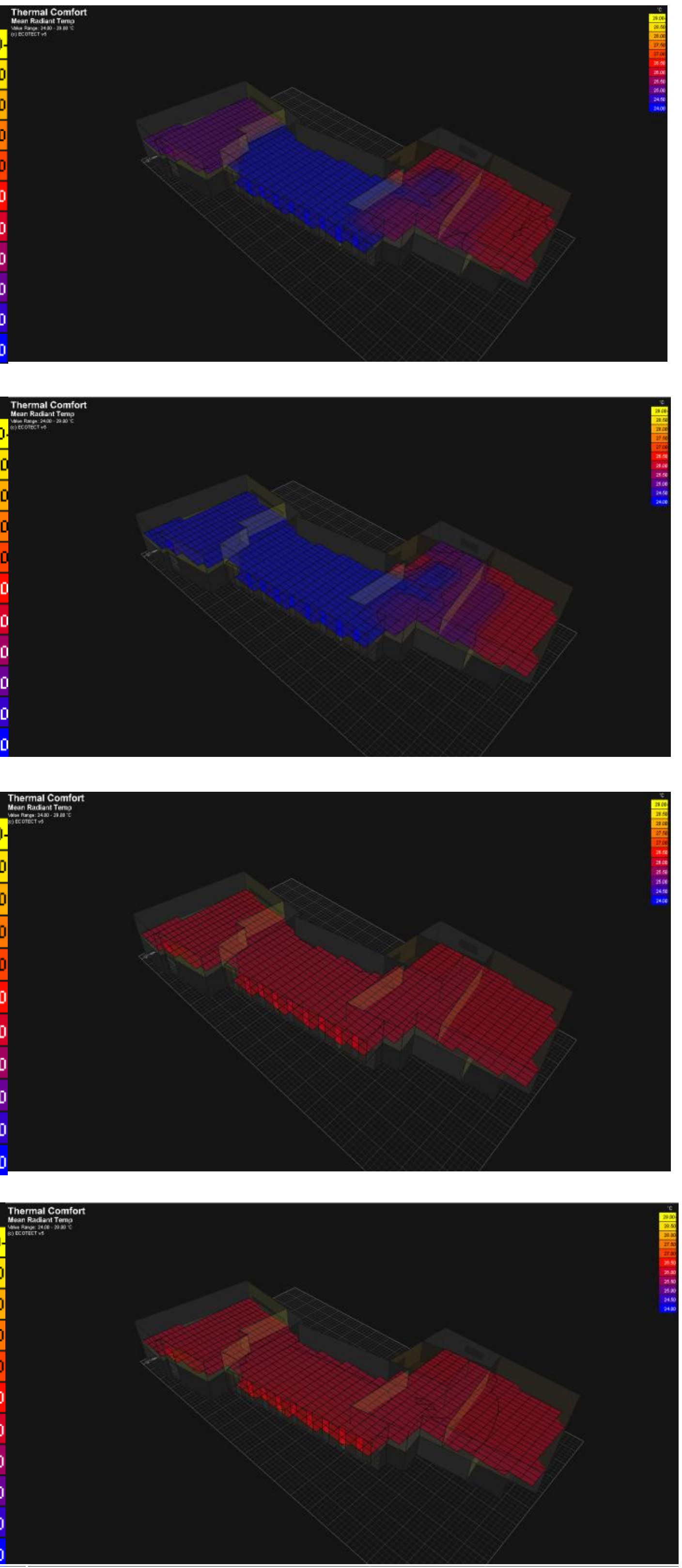


Fig.4.88. First Floor Comfort Distribution (May-August)

S

O

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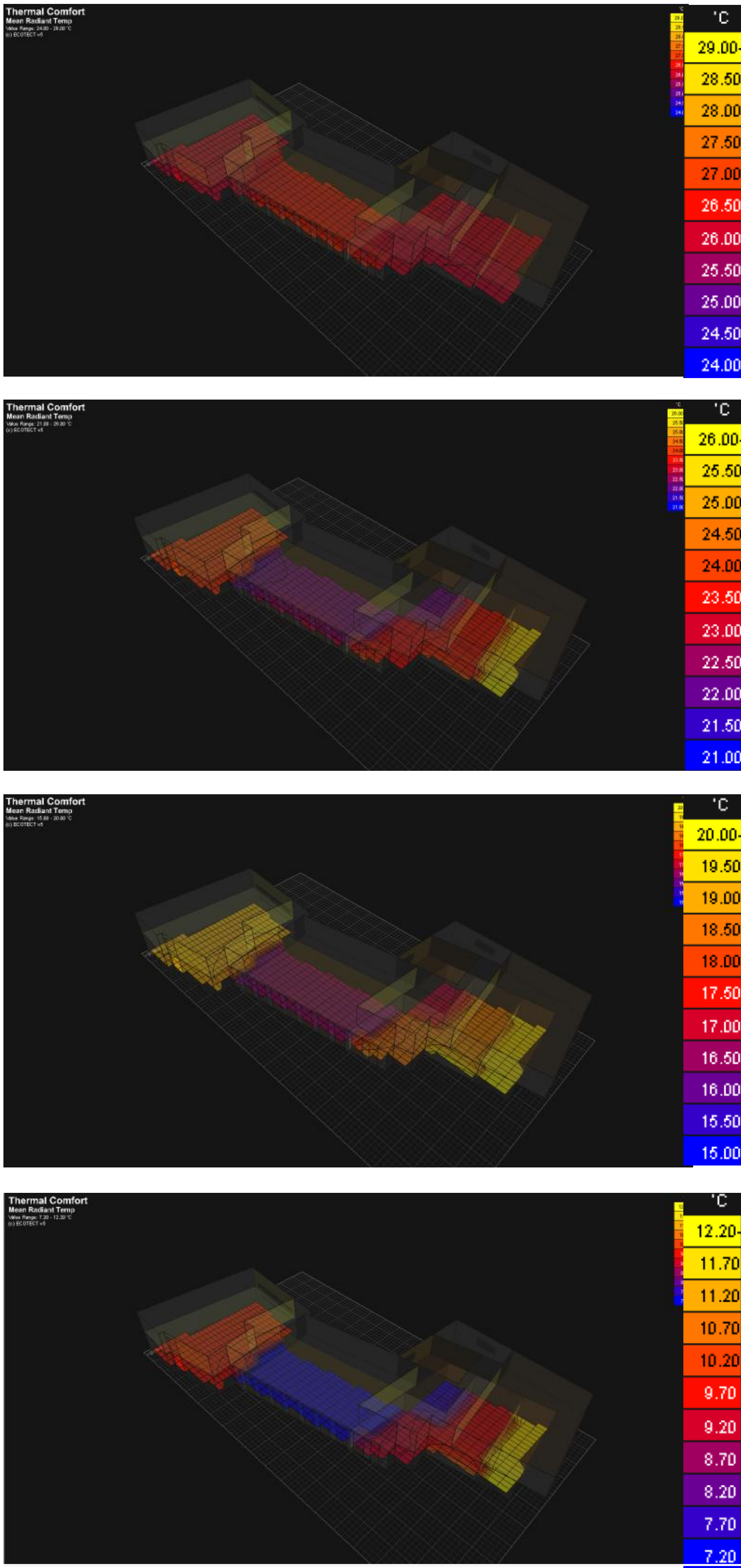

Fig.4.89. Ground Floor Comfort Distribution (September-December)

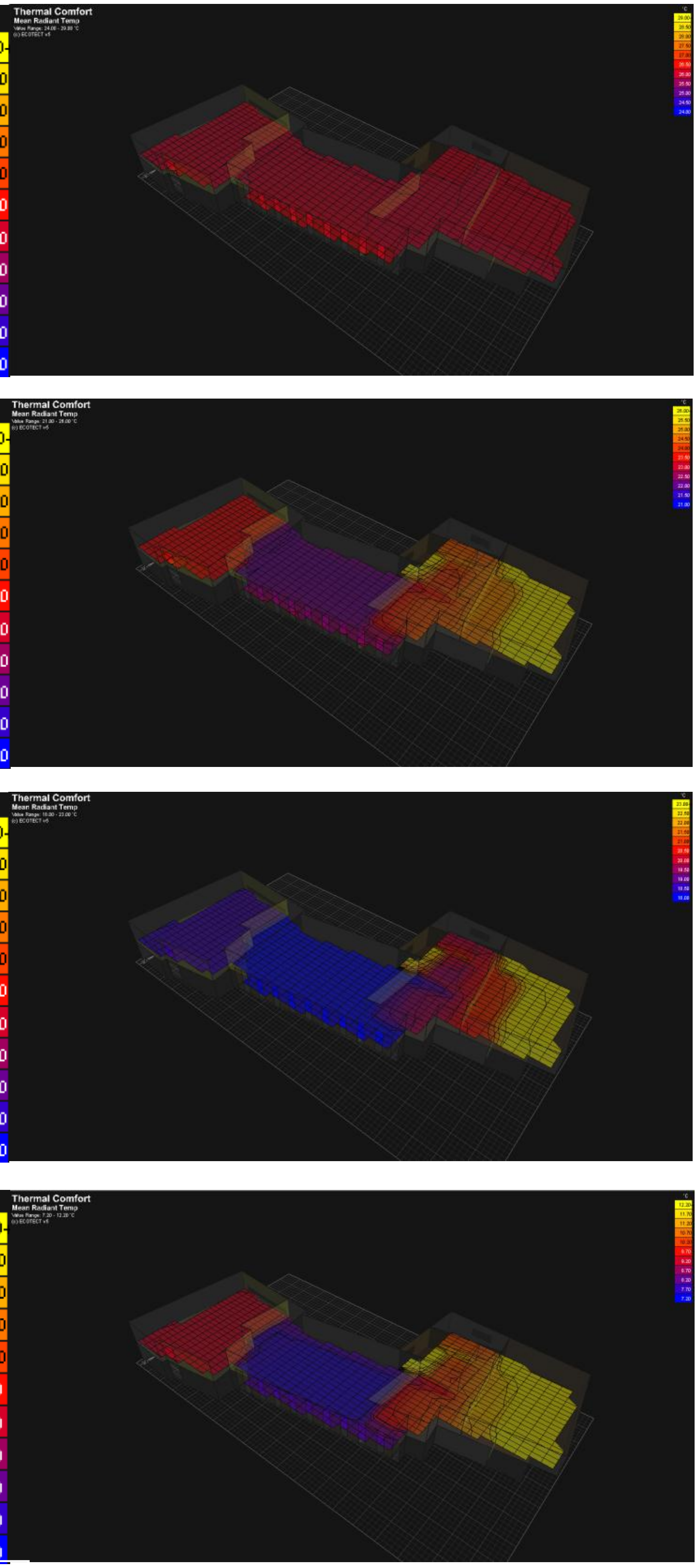

Fig.4.90. First Floor Comfort Distribution (September-December)

The distribution of the mean radiant temperature is generally irregular across the building zones; some parts like the foyer and the loft 1 are colder than the rest of the building because of two reasons:

- More glazing surfaces.
- Lower occupancy.

The conclusion that we can make is that despite that the building can provide comfort for almost all the zones in the months of May, June, September and October, the design is supposing that the HVAC systems are working all around the year because we cannot compromise the comfort, and we have to design for the most critical situation, where the building is highly occupied.

Conclusion

The Previous analysis underlined two crucial considerations:

- The proposed technological solution participates in saving of more than 50% of the total HVAC loads compared to the traditional solution.
- Comfort is still far away from being provided without an adequate Mechanical System to promote and sustain the indoor conditions.

From here emerges the necessity of choosing cautiously the HVAC system.

Building Systems

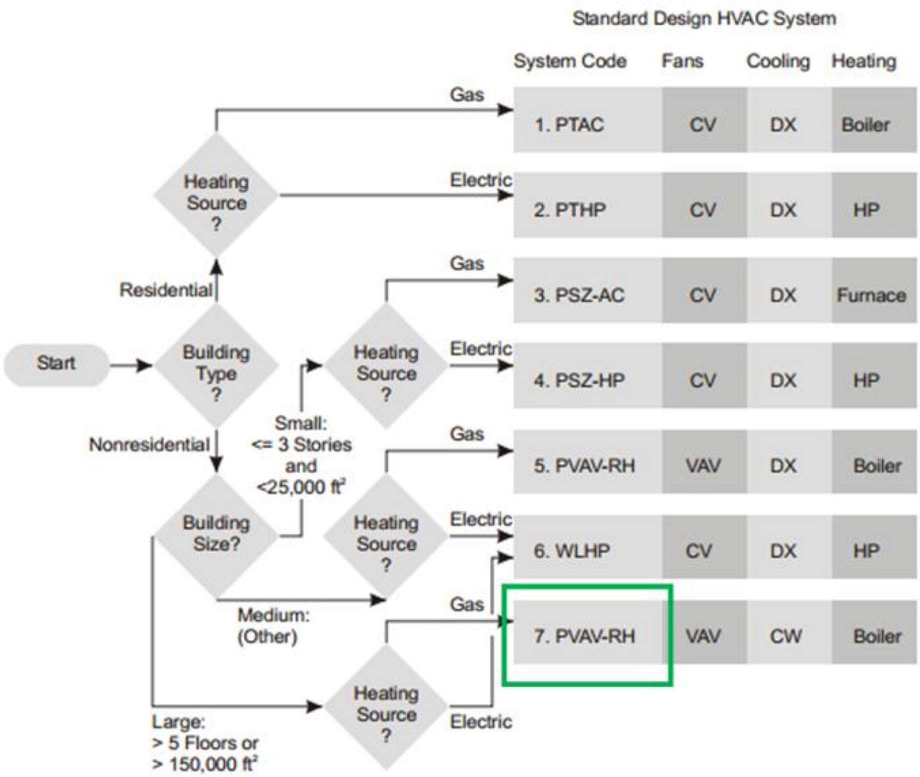

Fig.4.91. Organigram for HVAC systems selection

In order to select an appropriate HVAC system between a multitude of available options, we referred to the following organigram[1] .

The optimal choice went for the Packaged Variable Air Volume Chilled-Water Cooling and Boilers Heating, which is favorable in cases like ours where we have to control zones with different thermal requirements and occupancy.

All-Air System[2]:

The basic all-air system concept is to supply air to the room at conditions such that the sensible and latent heat gains in the space, when absorbed by supply air flowing through the space, bring the air
to the desired room conditions. Because heat gains in the space vary with time, a mechanism to vary the energy removed from the space by the supply air is necessary. There are two such basic mechanisms:
(1) vary the amount of supply air delivered to the space by varying the flow rate or supplying air intermittently; or (2) vary the temperature of air delivered to the space, either by modulating the temperature or conditioning the air intermittently.

[1] COMNET draft manual, September 2009
[2] ASHRAE 2008 HVAC Systems and Equipment (SI Edition)

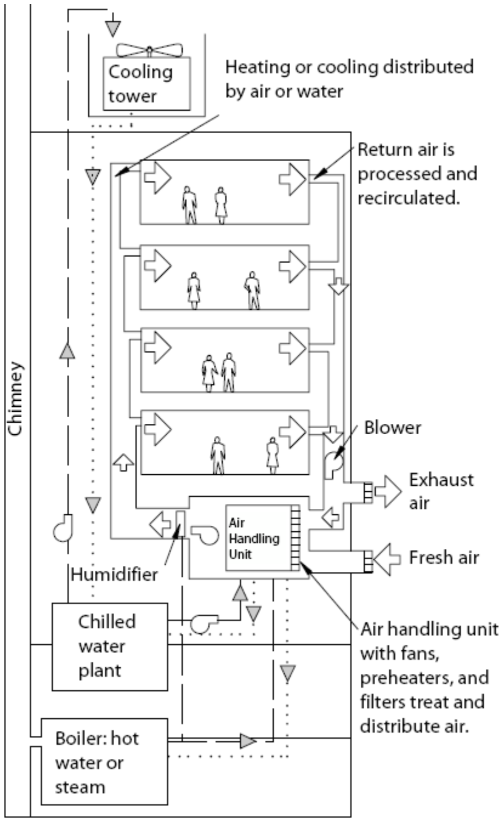

Fig.4.92. All-air System functional section

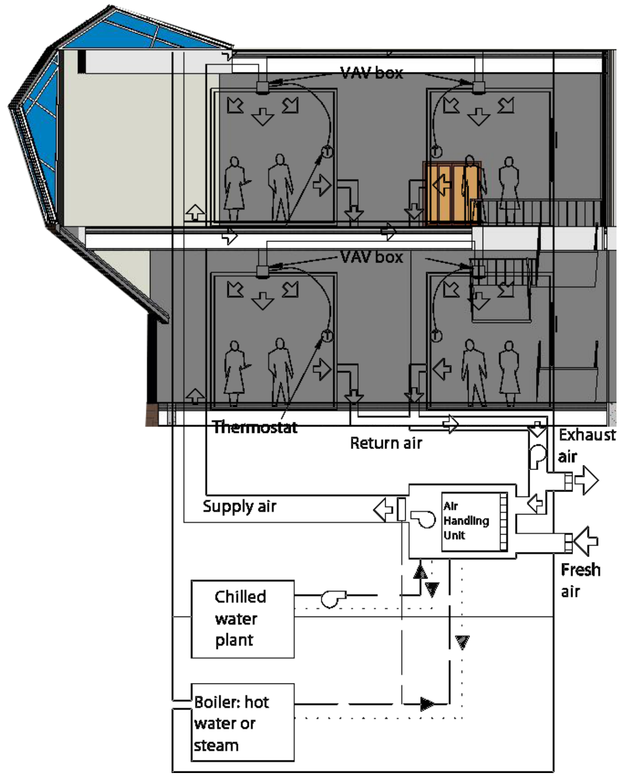

Fig.4.93. Schematic application in the project

Advantages:

•Operation and maintenance of major equipment can be performed in an unoccupied area (e.g., a central mechanical room in the basement). It also maximizes choices of filtration equipment, vibration and noise control, humidification options, and the selection of high-quality and durable equipment.

• Piping, electrical equipment, wiring, filters, and vibration- and noise-producing equipment are away from the conditioned area, minimizing (1) disruption for service needs and (2) potential harm to occupants, furnishings, and processes.

• These systems offer the greatest potential for using outside air for economizer cooling instead of mechanical refrigeration.

• Seasonal changeover is simple and adapts readily to automatic control.

• A wide choice of zoning, flexibility, and humidity control under all operating conditions is possible. Simultaneous heating of one zone and cooling of another zone during off-season periods is available.

• Air-to-air and other heat recovery may be readily incorporated.

• Designs are flexible for optimum air distribution, draft control, and adaptability to varying local requirements.

• All-air systems take advantage of load diversity. In other words, a central air-handling unit serving multiple zones needs to be sized only for the peak coincident load, not the sum of the peak loads of each individual zone. In buildings with significant fenestration loads, diversity can be significant, because the sun cannot shine on all sides of a building simultaneously.

Variable Air Volume VAV[3]

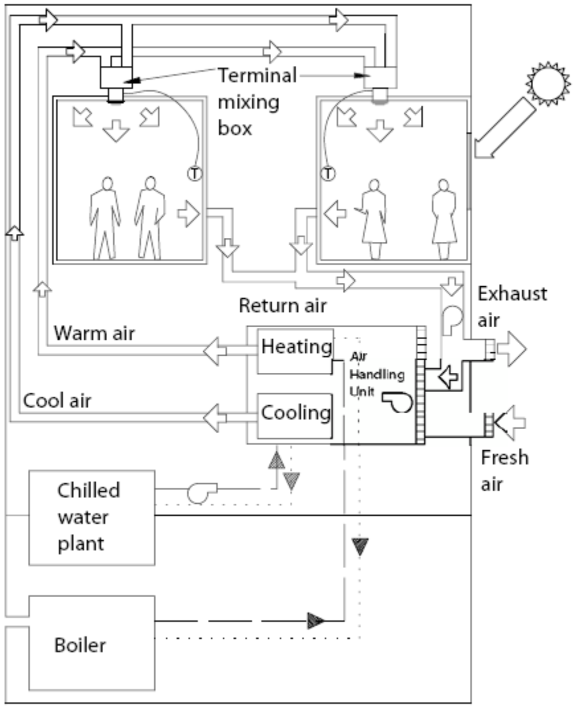

Fig.4.94. Double Duct VAV function

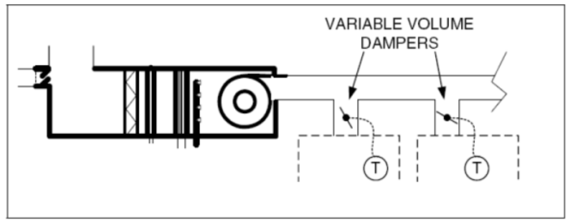

Fig.4.95. Conceptual Mixing and Distribution

A VAV system controls temperature in a space by varying the quantity of supply air rather than varying the supply air temperature. A VAV terminal unit at the zone varies the quantity of supply air to the space. The supply air temperature is held relatively constant. Although supply air temperature can be moderately reset depending on the season, it must always be low enough to meet the cooling load in the most demanding zone and to maintain appropriate humidity.
A VAV terminal unit at the zone varies the quantity of supply air to the space. The supply air temperature is held relatively constant.
VAV systems can be applied to interior or perimeter zones, with common or separate fans, with common or separate air temperature control, and with or without auxiliary heating devices.

[3] ASHRAE 2008 HVAC Systems and Equipment (SI Edition)

Air Handling Unit with Economizer[4]

Economizer Cycle

In many climates (like Milano summer climate), there are substantial periods of time when cooling is required and the return air from the space is warmer and moister than the outside air.

During these periods, you can reduce the cooling load on the cooling coil by bringing in more outside air than that required for ventilation. This can be accomplished by expanding the design of the basic air-conditioning system to include an economizer.

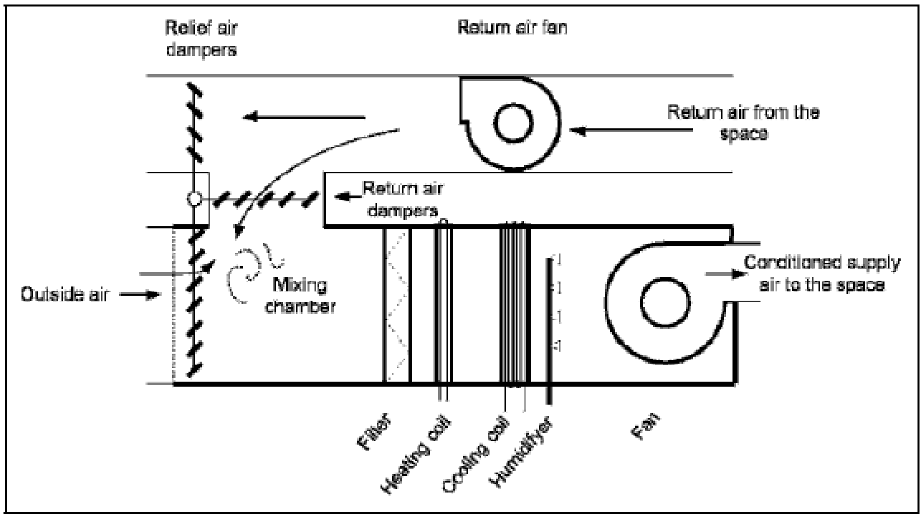

Fig.4.95. Air Handling Unit Components

Main Components

- Extended air intake and damper: sized for 100% system flow.
- Relief air outlet with automatic damper, to exhaust excess air to outside.
- return air damper, to adjust the flow of return air into the mixing chamber.
-Return fan in the return air duct. The return fan is often added on economizer systems, particularly on larger systems.
- Mixing chamber, where return air from the space is mixed with the outside ventilation air.
- Filter, which cleans the air by removing solid airborne contaminants (dirt).
- Heating coil, which raises the air temperature to the required supply temperature.
- Cooling coil, which provides cooling and dehumidification. A thermostat mounted in the space will normally control this coil. A single thermostat and controller are often used to control both the heating and the cooling coil.
-Humidifier, which adds moisture, and which is usually controlled by a humidistat in the space.
-Fan, to draw the air through the resistance of the system and blow it into the space.

[4] G. Rapisarda, Politecnico di Milano, Dipartimento di Energia

Conclusion: Energy, Carbon and Cost Summary

As a conclusion, we wanted to assign a certain quantitative value to the building's overall behavior in terms of yearly but also annual Energy Consumption, Carbon Emission, and Costs. The same "gbxml" model was imported in the Autodesk Green Building Studio Simulation where we once again computed the values for the traditional solution and this time with a traditional VAV system with a low efficiency, and then we computed for the same model, the results we can get with some Design Alternatives (proposed highly insulated technological solution, low emissivity double glazing, more efficient HVAC system …) in order to understand how we can save money, energy and carbon emission with just few steps, and to show that the Green Building design is not just a trend, but is rather an investment. The analysis will include also a realistic approach towards the photovoltaic potential of the Building showing the surfaces we can exploit for this purpose and their corresponding payback time.

Independent Parameters

The parameters depending on the geometry and the function of the building, but not on the systems used in the envelop neither from the system.

Building Summary - Quick Stats	
Number of People:	143 people ⬇
Average Lighting Power Density:	16.15 W / m² ⬇
Average Equipment Power Density:	10.95 W / m²
Specific Fan Flow:	6.5 LPerSec / m²
Specific Fan Power:	1.907 W / LPerSec
Specific Cooling:	6 m² / kW
Specific Heating:	6 m² / kW
Total Fan Flow:	27,851 LPerSec
Total Cooling Capacity:	672 kW
Total Heating Capacity:	747 kW

⬆ higher than typical value
⬇ lower than typical value

Fig.4.96. Building Functional Summary

The values of this chart are practically the inputs of the software; some of them are generated automatically by the software depending on the geometry, function and occupancy of the building.

Photovoltaic Potential

Panel Type	Installed Panel Cost		Applied Electric Cost	Max Payback Period
Single Crystalline - 13.8% efficient	€8.00	€1,104.62	€0.28	50
	(per Watt)	(per m²)	(per kWh)	(per surface, in years)

Surface Variables					Shading Variables		Summary			
								Potential Cost Savings		
ID	Type	Direction	Tilt (degrees)	Panel Area (m²)	Solar Exposure	Obstruction Shading	Annual Energy (kWh)	per year/m²	per year	Payback per Surface (years)
su-63	Roof	FLAT	0	621	62.5 %	0.0 %	111,746	€50.39	€31,289	**18.2**
su-79	Roof	FLAT	0	667	62.6 %	0.0 %	119,954	€50.39	€33,587	**18.2**
su-96	Roof	FLAT	0	257	62.5 %	0.0 %	46,336	€50.39	€12,974	**18.2**
su-102	Roof	FLAT	0	184	62.6 %	0.0 %	33,044	€50.39	€9,252	**18.2**
su-108	Roof	FLAT	0	475	62.6 %	0.0 %	85,453	€50.39	€23,927	**18.2**
su-113	Roof	FLAT	0	111	62.6 %	0.0 %	19,910	€50.39	€5,575	**18.2**
su-59	ExteriorWall	S	90	141	53.0 %	11.4 %	22,454	€44.47	€6,287	**20.2**

Fig.4.97. Photovoltaic Investment Potentials

The surfaces that could be worth the installation of photovoltaic panels are the Roof surfaces but also the main wall facing south (the existing court). The payback time of those panels is around 20 years and their investment income is approximately 50 euros/year/m^2; since the design lifecycle of the building is 50 years, we consider the photovoltaic investment on those surfaces as a worthy investment.

Traditional Solution and System inputs

Envelop Solution:

Roofs	R0 over Roof Deck U-Value: 2.52	2,438 m²
Exterior Walls	R11.4 8in Concrete U-Value: 0.50	3,279 m²
Interior Walls	R0 Metal Frame Wall U-Value: 2.35	1,314 m²
Interior Floors	Interior 4in Slab Floor U-Value: 4.18	4,379 m²
Air Walls	Air Surface U-Value: 15.32	5 m²
Fixed Windows	North Facing Windows: Single Clear-L Tint (2 windows) U-Value: 4.99 W / (m²-K), SHGC: 0.25 , Vlt: 0.13	323 m²
	Non-North Facing Windows: Single Clear-L Tint (2 windows) U-Value: 4.99 W / (m²-K), SHGC: 0.25 , Vlt: 0.13	222 m²
Operable Windows	North Facing Windows: Single Clear-L Tint (4 windows) U-Value: 4.99 W / (m²-K), SHGC: 0.25 , Vlt: 0.13	72 m²
	Non-North Facing Windows: Single Clear-L Tint (15 windows) U-Value: 4.99 W / (m²-K), SHGC: 0.25 , Vlt: 0.13	151 m²
Operable Skylight	North Facing Windows: Single Clear-L Tint (9 skylights) U-Value: 4.99 W / (m²-K), SHGC: 0.25 , Vlt: 0.13	102 m²

Fig.4.98. Traditional Envelope Simulation inputs

HVAC system: 1999 ASHRAE 90.1. VAV reheat 0.639 kW/ton Chlr/80% Boiler

Proposed Solution and System inputs

Envelop Solution

Roofs	R50 over Roof Deck-cool roof U-Value: 0.11 (i)	2,438 m²
Exterior Walls	Structurally Ins. Panel (SIP) Wall 12.25 in (311mm U-Value: 0.15 (i)	3,279 m²
Interior Walls	R0 Metal Frame Wall U-Value: 2.35 (i)	1,314 m²
Interior Floors	Interior 4in Slab Floor U-Value: 4.18 (i)	4,379 m²
Air Walls	Air Surface U-Value: 15.32	5 m²
Fixed Windows	North Facing Windows: Double Low-E Clear U-SI 1.96, U-IP 0.35, SHGC 0.67, VLT 0.72 (2 windows) U-Value: 1.96 W / (m²-K), SHGC: 0.67 , Vlt: 0.72	323 m²
	Non-North Facing Windows: Double Low-E Clear U-SI 1.96, U-IP 0.35, SHGC 0.67, VLT 0.72 (2 windows) U-Value: 1.96 W / (m²-K), SHGC: 0.67 , Vlt: 0.72	222 m²
Operable Windows	North Facing Windows: Double Low-E Clear U-SI 1.96, U-IP 0.35, SHGC 0.67, VLT 0.72 (4 windows) U-Value: 1.96 W / (m²-K), SHGC: 0.67 , Vlt: 0.72	72 m²
	Non-North Facing Windows: Double Low-E Clear U-SI 1.96, U-IP 0.35, SHGC 0.67, VLT 0.72 (15 windows) U-Value: 1.96 W / (m²-K), SHGC: 0.67 , Vlt: 0.72	151 m²
Operable Skylight	North Facing Windows: Double Low-E Clear U-SI 1.96, U-IP 0.35, SHGC 0.67, VLT 0.72 (9 skylights) U-Value: 1.96 W / (m²-K), SHGC: 0.67 , Vlt: 0.72	102 m²

Fig.4.99. Proposed Envelope Simulation inputs

HVAC system: Central VAV, HW Heat, Chiller 5.96 COP, Boilers 84.5 eff

Lighting: LPD 40% less than traditional

Lighting control: occupancy/daylight sensors & controls

Final Bills

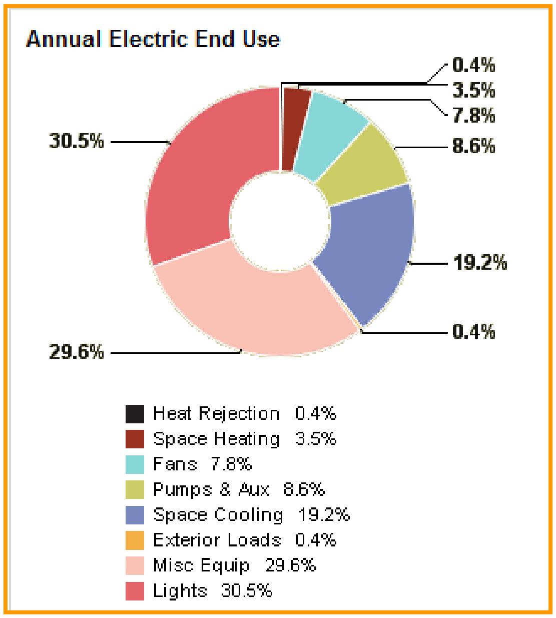

Fig.4.100. Traditional Simulation Electricity End Use

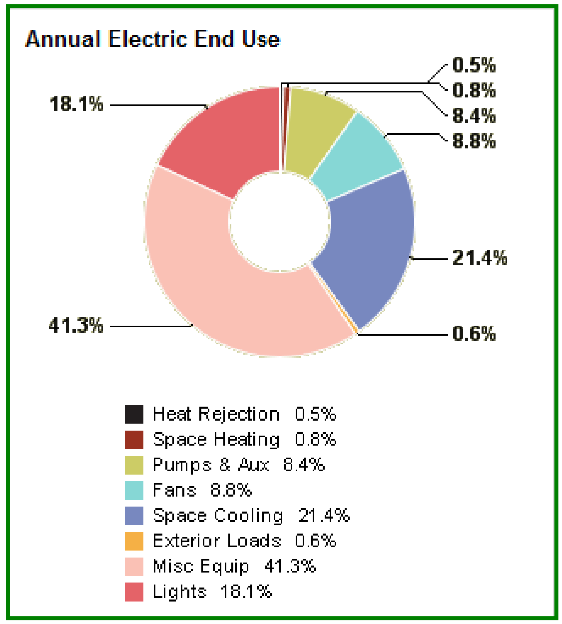

Fig.4.101. Proposed Simulation Electricity End Use

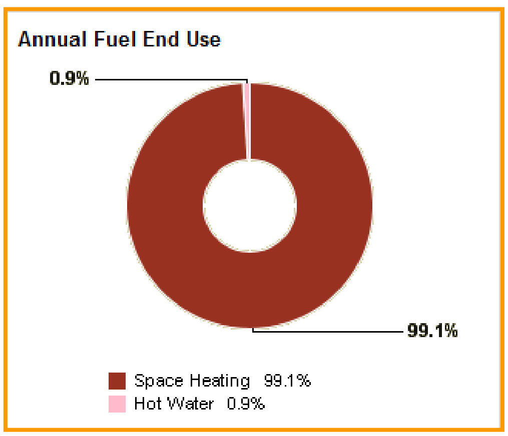

Fig.4.102. Traditional Simulation Fuel End Use

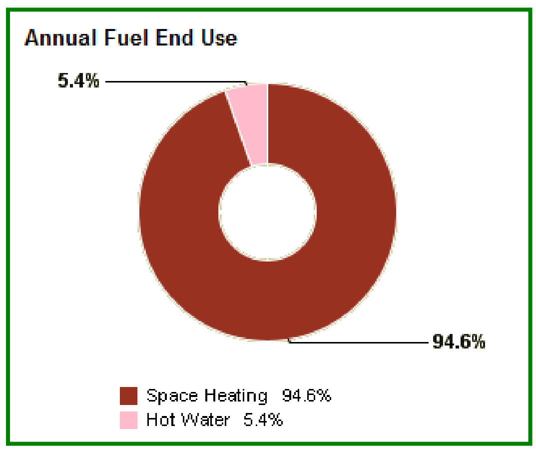

Fig.4.103. Proposed Simulation Fuel End Use

The Results are close to what we were expecting, since the proposed solution had more efficiency in terms of Building Envelope, HVAC system, and Lighting Fixtures, the needs of Electricity that are related to heating and lighting were greatly shrink and this is manifested with the decreasing of their participation in the total end use.

Same but not as provocative in the case of Fuel since the part going for Heating cannot be compared to the part compared for Hot Water in the case of a Museum Building.

Energy, Carbon and Cost Summary	
Annual Energy Cost	€299,168
Lifecycle Cost	€4,074,675
Annual CO_2 Emissions	
Electric	375.4 Mg
Onsite Fuel	153.0 Mg
Large SUV Equivalent	53.0 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	681 MJ / m² / year
Electric	935,493 kWh
Fuel	3,068,391 MJ
Annual Peak Demand	294.5 kW
Lifecycle Energy	
Electric	28,064,787 kW
Fuel	92,051,730 MJ

Fig.4.104. Consumption/ Emission Bill (Traditional)

Estimated Energy & Cost Summary	
Annual Energy Cost	€192,022
Lifecycle Cost	€2,615,334
Annual CO_2 Emissions	
Electric	253.2 Mg
Onsite Fuel	25.9 Mg
Large SUV Equivalent	28.0 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	681 MJ / m² / year
Electric	670,403 kWh
Fuel	519,677 MJ
Annual Peak Demand	193.9 kW
Lifecycle Energy	
Electric	20,112,078 kW
Fuel	15,590,310 MJ

Fig.4.105. Consumption/ Emission Bill (Proposed)

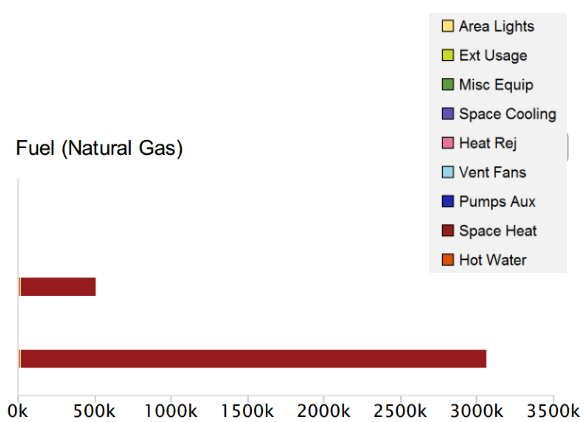

Fig.4.106. Consumption of Energy by Natural Gas Comparison (MJ)

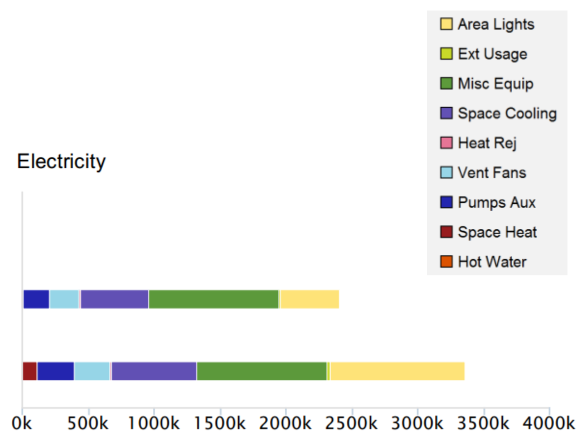

Fig.4.107. Consumption of Energy by Electricity Comparison (MJ)

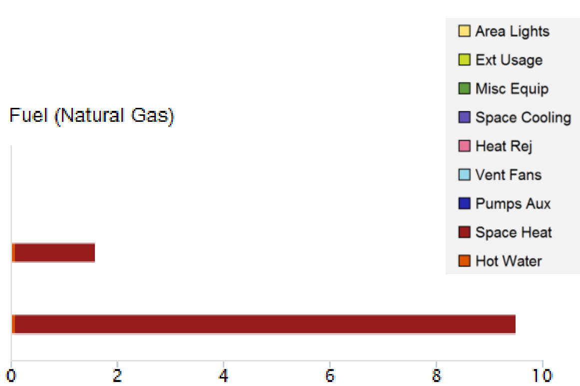

Fig.4.108. Cost of Energy by Natural Gas Comparison (Euro/m^2)

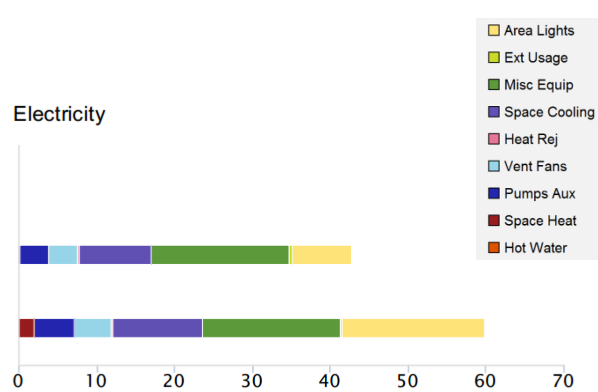

Fig.4.109. Cost of Energy by Electricity Comparison (Euro/m^2)

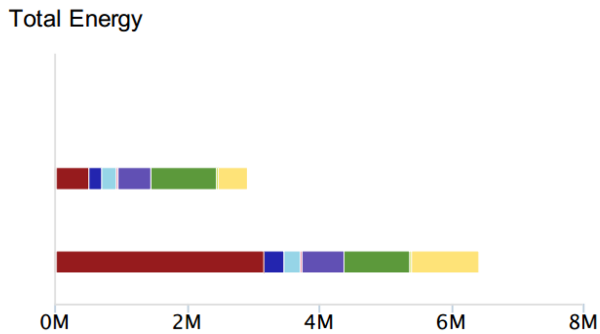

Fig.4.111. Total Consumption of Energy Comparison (MJ)

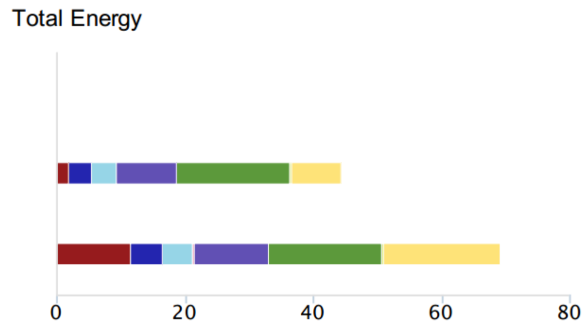

Fig.4.112. Total Energy Costs (Euro/m^2)

We would like to reemphasize that the goal of this study was not to demonstrate that the decisions we took are better than the traditional ones; it was instead to have a sensitivity vis-à-vis the scale of the improvements in terms of efficiency, just by following a multidisciplinary integrated design process. We wanted to add to the usual environmental and ecological arguments, a realistic financial touch, in order to present the sustainable approach, not as a constraint or a requirement, but rather as a challenge to the designer, an economical investment to the client, and a comfortable environment to the user.

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