POLITECNICO DI MILANO

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POLO REGIONALE DI LECCO

Master of Science in Architectural Engineering

Master Thesis

THE V CUBE
Modular Residential Complex
Lecco, Italy

Supervisor: Professor Gabriele Masera
Assistant supervisors: Professor Massimo Tadi
Professor Danilo Palazzo

Authors:

Luka Stefanović	764539
Seyedehsana Seifi	764762
Somayeh Khoshdelmishamandani	770338

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Sana Seifi
Somayeh Khoshdel
Luka Stefanović

Abstract

Have you ever passed some places in a city where you suddenly felt a pause in the stream of life and activities? These gaps are scattered without any order or relation all over the town. When facing a considerable number of them, they can be a serious threat to the integration and discipline of the urban fabric. They can easily convert to the most favorable places for gathering homeless people, rabbles and criminals, which potentially form source of different social problems.

Unfortunately, this emptiness is not always conceived as an opportunity. In the following research, we aim to address a corresponding treatment to the negative aspects of these voids, making them habitable, safe and productive. So, they can bring a new spirit in their neighborhood, promoting its qualities by the mutual interaction between the user and the place.

To regard the scope of thesis, we chose the void beside the church of San Nicolo in Lecco to be a residential complex for students. However, it is a considerable area inside the boundary of the historical center; it is abandoned under management as a parking lot. This project addresses not only the immediate void, but also the adjacent spaces which cooperate in order to renovate a new zone for the city.

Starting from the wider urban and architectural scales and coming to the precise details of construction; thinking sustainable has been the main approach of this project. The theme of the design is to leave as few impacts on the site as possible, keeping in mind that the promotion of the area might be only a short-term policy of the municipality-until the budget arrives for the further permanent visions of the city.

To achieve the aim of the project, the very first step is recycling an undefined space itself, giving it a function which interact more with its rich surroundings. Next, in order not to interfere the current contributing action of the void in the city, an intermediate platform covers the existing parking and provides the base for placing the new housing modules.

In favor of speeding up the construction time, the issues regarding prefabrication has been studied and analyzed to find the most appropriate concept which suits our project. Moreover, the different attitude in application of the Quadror structural system, ease the process of assembling/dismantling the units. Last but not the least, is the concern towards energy and performance of the modules. Strategies are discussed for promoting the efficiency, energy saving considerations and renewable energy sources. Executive construction details for the specific project are designed and technological trends are applied in order to optimize the building performance level and increase inhabitants' comfort.

In conclusion, however the outcome modules are designed to answer specifically the conditional constraints in their site, the main approach and attitude can be a guideline to in order to revive voids located in other locations.

Contents

1. Introduction

1.1. Urban Voids

Urban Voids as a term in urban studying are referred to spaces which disrupt the urban tissue, leaving it incomplete and throw into question the use of those spaces. Sometimes called urban ruins, they are at the limit between private and public space, without belonging either to the one or to the other. Urban voids are containers of memory, fragments of the built city and the natural environment; memories of the city which constitute a random, unplanned garden.[1]

Also, in our daily lives we have all passed some places in a city where we suddenly experienced a gap in our surrounding, a pause in the stream of life and activities. It can probably be recognized by everyone at the first glance. Unfortunately, this emptiness is often perceived as a forgotten and insecure place, a vague terrain in the urban tissue.

But what is the special characteristic of these spaces, which figures differentiate them from other vacant spaces. In the following parts, we aim to define better these places to get more familiar with their nature, reasons of creation, influences and damages on the city. In the end, we conclude this topic with a new approach in dealing with these spaces. We will see later how this change in our point of view, towards this issue will set the first milestone to define the subject for our thesis.

Fig 1.1: Different samples of urban voids

1.1.1. Urban Voids versus Solid-Void Theory

In architecture, considering the voids and positive spaces is as important as designing the figures and masses. As Louis Kahn has declared, "Architecture is the thoughtful making of space". Solid-void theory holds that the volumetric spaces shaped or implied by the placement of solid objects are as important as, or more important than, the objects themselves.[2] *Obviously, this emptiness is something desirable which have been considered to enrich the architecture and works as a complementary in the success of its function. In some cases they are so integrated that is difficult to distinguish which one exists first; the building which forms the emptiness or the void that makes the mass more legible. As an example, we can mention the courtyard in Islamic mosques or the cloisters of monasteries which are in doubtfully inseparable from the main building.*

[1] http://aporee.org

[2] 101 things I learned in Architecture School, Matthew Frederick , The MIT Press, London, England, 2007page 20

Fig 1.2: Jameh Mosque, Isfahan, Iran

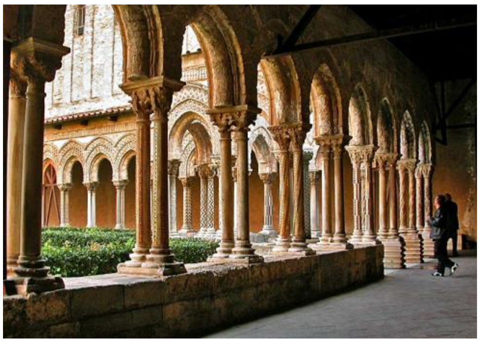

Fig 1.3: Monreale Cathedral, Palermo, Italy

But can any space be named a positive one?!

A three dimensional space is considered a positive space if it has a defined shape and a sense of boundary or threshold between in and out. Positive spaces can be defined in an infinite number of ways by points, lines, planes, solid volumes, trees, building edges, columns, walls, sloped earth and innumerable other elements.[3] *The shape and the quality of architectural spaces greatly influence human experience and behavior. Generally we tend to move through negative spaces and dwell in positive spaces and this is another evidence for their importance.*

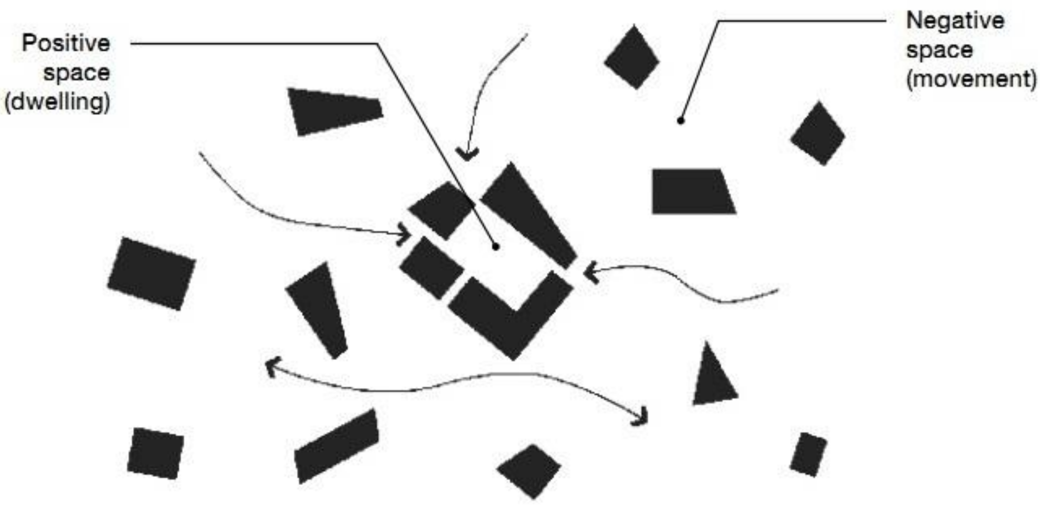

Fig 1.4: illustrating positive and negative spaces (From the book, 101 thing I learned from architecture school)

Now that we have studied the differences between the positive and negative spaces, in which category can we place the urban voids!? Are they simply referred to any normal vacant space!?

Urban voids are considered as incomplete areas and the use of those spaces is put under question; they are the limit between private and public spaces without belonging to the one or to the other.

[3] Ibid, page 20

Going by meaning of the term 'void' is something which is 'being without'; hence an urban void can be interpreted as an urban area being without permeability and social realm. Urban voids are undesirable urban areas that are in need of redesign, anti-space, making no positive contribution to the surroundings or users. They are ill-defined, without measurable boundaries and fail to connect elements in a coherent way.[4]

Ignasi Solà-Morales had described them as interior islands without activity, forgetfulness areas, converted in unhabituated, unsecure and unproductive. At least, these are strange places in the urban structure. They are mental exteriors in the physical interior of the city, where they appear like another image of the same place, as in the sense of its critic, as in the sense of its possibility.[5]

In the sprawled settlement pattern typically to the post war era in which the cities and the territories have become immense collection of objects tactically placed next to one another, mute. The missing links are inept definition in these areas are the reflection of a decomposed contemporary society in which 'the spaces in between things', between objects and subjects, between my house and my neighbor's, between their office and mine, is traversed by many strangers, and is not a meeting place, it has become 'empty' because it plays no recognizable role.[6]

1.1.2. Creation of Urban Void

An urban void is created mainly due to three factors. These factors that create an urban void can also become the basis for classification of these urban voids.

1. *Phenomenological Voids*

   The phenomenological void could be defined as a place that has been characterized by context and history that are now outside the realm of urban functionality, growth and transformation (i.e. natural disasters, wars, etc.) The phenomenological void is an individual event within the city: it builds itself by its own phenomena. The attack on the twin towers of New York on September 11th, 2001 was a terrorist event that destroyed an important place of the city. In Chaitén, a south Chilean city, the eruption of the Llaima volcano in June 2008, destroyed the whole city. The events were different, but the resulting voids are similar.

2. *Functional Voids*

   Functional voids are voids created due to leftover space or a built mass that has become defunct. A functional void have a great legal aspect associated with it: in general defunct areas/buildings are either under litigation or are government property where reallocations of functions have to go through a mammoth bureaucratic process.

3. *Geographical Voids*

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[4] (*Trancik, 1986).*
[5] *Solá Morales, Ignasi. Territorios, Editorial GG. Barcelona, 2000*
[6] *(Secchi, 1993).*

*Fig 1.5: Respectively examples of **Phenomenological, Functional and Geographical voids***

Geographical voids are voids that are created due to existence of geographical features such as hills, rivers and valleys which have generated voids in urban space. Such voids are resultant of planning process.

In spite of considering the cause of its creation, urban void is a cavity which can form in the structure of any city. They are scattered without any order or relation all over the town. When facing a considerable number of them, they are serious threats to the integration and the order of arrangements in the urban fabric. However, they are temporary vacant spaces, as a result of not having a specific responsible owner or organization, the necessity of solution for them will be often postponed to an indefinite time. These nodes will usually convert to the trashes of the city, a place where in addition to collecting the physical dirt and rubbish, weaken the aesthetical aspects of the town. They are the most favorable places for gathering homeless people, rabbles and criminals, which potentially forms source of different social problems.

Our approach is analyzing the negative aspects of these problems and responding them. In fact, by studying the features of these areas carefully, we aim to address a direct treatment to each issue according to the supplementary properties of the corresponding obstacle. We are thinking of a new definition for these places, substituting each weakness with an appropriate answer. A way to make these areas habitable, converting them to a safe and productive place. It can be a new function, which fulfill the necessities of a part of society, a new configuration which attracts the attention of the passengers and sticks in their minds, a place, where belong to both, the public and the private; so users find themselves a part of it and therefore feel responsible for it. The aim is to use the potentials of a free land and convert it to a functional space which can serve for the city and its habitants.

Fig 1.6: Illustration of possible threats which can occur in the voids.

1.1.3. The Proposal: Recycling the Space

Our proposal is a new function which brings life and productivity to the area, a function which assures the security of the place. We suggest a new accommodation style for students and researchers who enter cities for a period of time. They can be students for an exchange program, Erasmus students or research ers working on a project. They can all bring a new spirit to these areas and at the same time they can take benefit from the space. Moreover, the neighborhood is promoted by their mutual interaction.

These are innovative units which not only accomplish their own duty but even will help to promote the level of their surroundings in variable ways. These units are utilizing the latest achievement in the technology to improve their performance in different criteria. They can produce their own energy, using renewable sources. Orienting consideration will helps them to take the most profit from the natural light and ventilation. The design of the envelope and the joints minimize the unwanted infiltrations and helps to maintain the internal heat. The materials have low embodied energy and they are recyclable to respect the environmental concerns. Due to the uncertain border of the emptiness, the design requires flexible approaches to be able to fit into the specific site. It will help the designing process to be unique for each case by respecting the context. In the result of their uncertain location, which can be changed in the very near future and need to be applied in another place, it is also vital to consider the ease of assembling and dismantling them. They all together make a unified complex which gives a new characteristic to once neglected areas in the city.

Moreover, they can be a model for attracting the attention of people towards the subject of energy and environment. Each of these units can influence its own surrounding. When there are a considerable amount of them, spreading all over the city, these modules with their

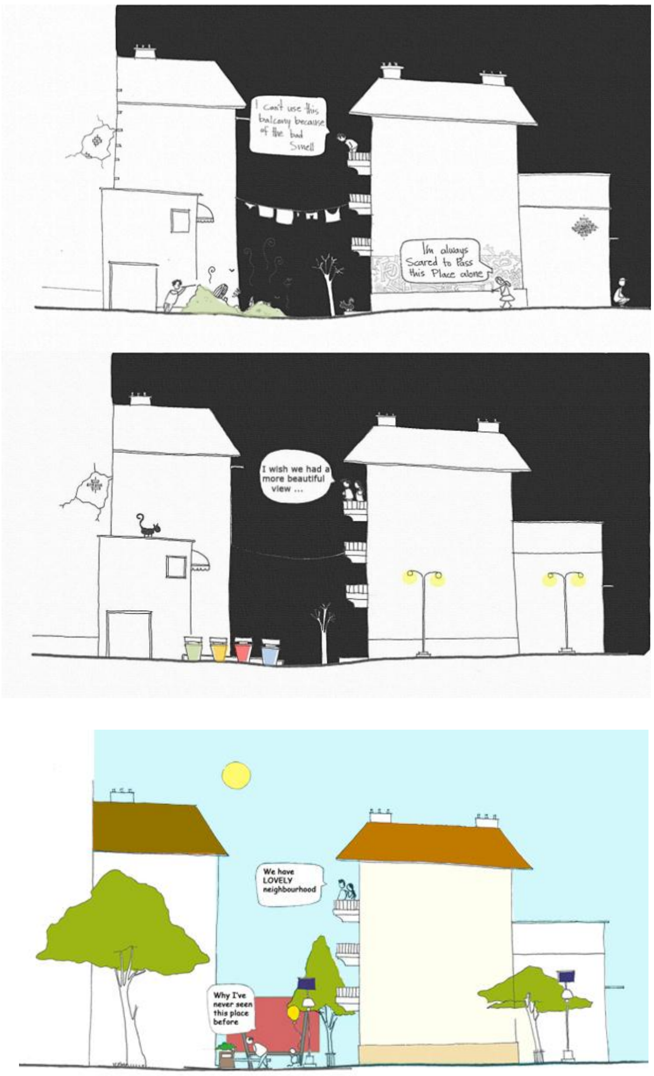

Fig 1.7: Three sequences of converting a void, illustrating the change in neighborhood and the reaction of people.

performance can increase the knowledge and awareness of citizens. Specially, they can perform an initiating role in the developing countries where the necessity of concerning to these issues has not been felt yet by the majority of people.

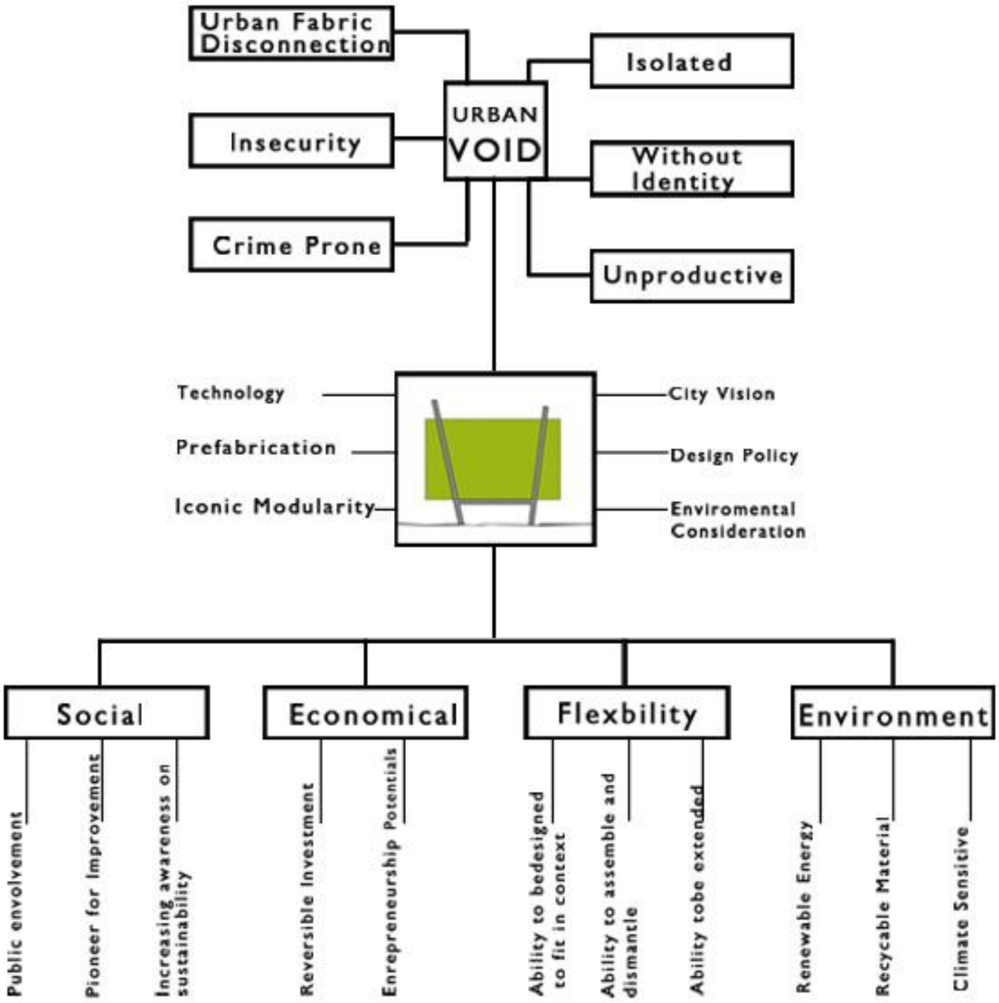

Fig 1.8: concluding the working process: identifying the problem, explaining the solution, clarifying the goals in different aspects

1.2. Project Location

1.2.1. Lecco

We chose Lecco for the site of the thesis project as a familiar territory, a place where we lived for 2 years, and a place we know and is accessible. Also, we felt to pay our contribution to the city which is our home for this time spent in Italy and we were happy to try to improve it.

In the very center of Lecco we identified an urban void, property of the church, belonging to a now unused factory. We chose it for its position, importance and potential.

Fig 1.9: Lecco coat of arms

1.2.2. Location, Urban Area and Historical Development

Lecco is the capital of the Province of Lecco in the Lombardy Region in the north of Italy. It's located on the south of the eastern branch of Lake Como and on the left bank of river Adda, among the Alps Mountains under the shared name Grigna.

Urban agglomeration area of Lecco includes surrounding towns of Vercurago, Calolziocorte, Malgrate, Pescate, Garlate, Civate, Olginate, Valmadrera and Ballabio, doubling its population[7].

Fig1.10: Lecco territory and its surrounding towns

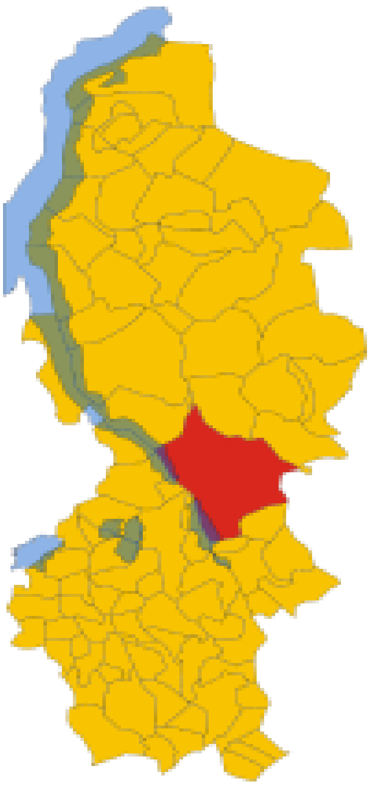

Fig1.11: Comune di Lecco in Provincia di Lecco

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[7] http://www.scoprilecco.it/

The city is set in a natural plane surrounded by the Alps to the east, south-east and north, dominated by mount Resegone and mountains arising from Brianza towards Lecco culminating in Monte Barro. Lecco territory varies significantly in altitude within the city – from 198m to 1875m, making the distinct difference in climate between lakeside and mountainous city outskirts to the north-east, east and south-east.

Distances to main cities in surrounding:

30 km from Como
30 km from Bergamo
35 km from Monza
50 km from Milano,
70 km from Sondrio

Airports:
Orio al Serio (Bergamo) – 35 km
Linate Airport – 55 km
Malpensa Airport – 90 km

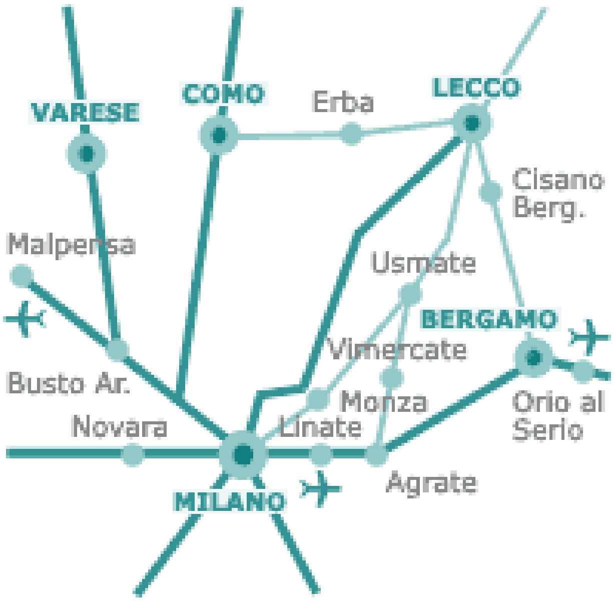

Fig 1.12: Distances to airports and surrounding towns and cities

Fig 1.13: Panorama of Lecco from Malgrate

1.2.3. Historical evolution

From these figures we can see the urban development of the city in the last 125 years. Analyzing these maps, and comparing them with demographic data allows us an insight into the development towards the city as it is today, showing us valuable feedback of urban history of Lecco through components of area, inhabitants and time.

Fig 1.14: Lecco in 1888

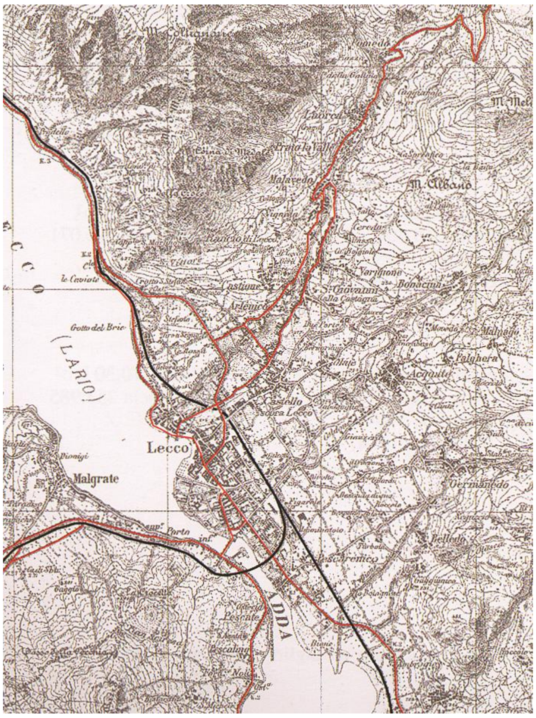

Fig1.15: Lecco in 1931

From these figures we can see the urban development of the city in the last 125 years. Analyzing these maps, and comparing them with demographic data allows us an insight into the development towards the city as it is today, showing us valuable feedback of urban history of Lecco through components of area, inhabitants and time.

In the map that demonstrating the year 1888 it is clear that the city spreading just in a small area around the historical center where used to be a renaissance castle, and a little in the direction of the roads built until then. The population of the city in those years was around 20000 people. In this period Lecco has been divided into smaller towns and lost the status of city due to political struggles the city was involved in.
By 1931, the small towns were united and Lecco regained the status of city, and we can see the road and railway network spreading out to connect them. Since 1888, Lecco has almost doubled its population now counting 33500 inhabitants, and started to sprawl further into the surrounding area, along the lakeside and towards the mountains on both sides of the lake.

Biggest change followed in the next 40 years when the city entered the post-war industrial era, which resulted in the expansion in the infrastructure as well as in population increase, now reaching its historical maximum of around 53000 people living in the city itself. The city has now increased immensely in area size, now occupying most of its today's territory. In that time the major outlines of the city was shaped as they are in present time.

It can be seen from the 1994 map that the area of the city is the same like in the 70s, but we can see a significant densification in urban tissue, but there was a population drop to around 46000 inhabitants. The reason lies in the moving of heavy industry outside of the city's boundaries, a more recent trend leading to people leaving to work in bigger cities.

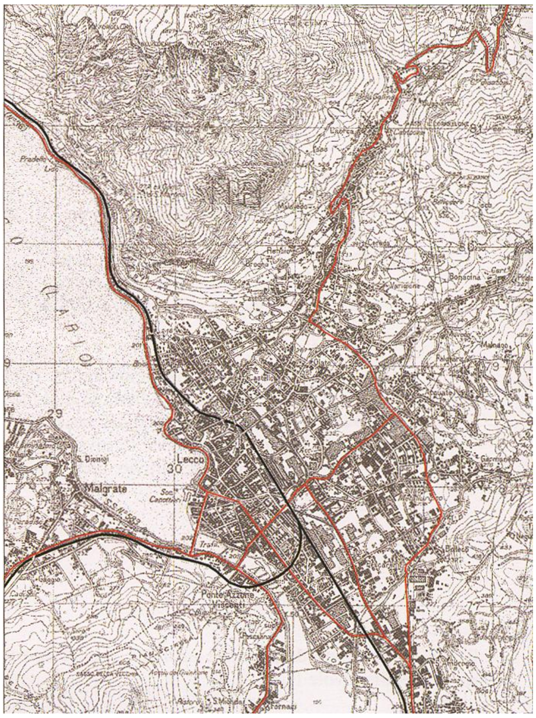

Fig 1.16: Lecco in 1971

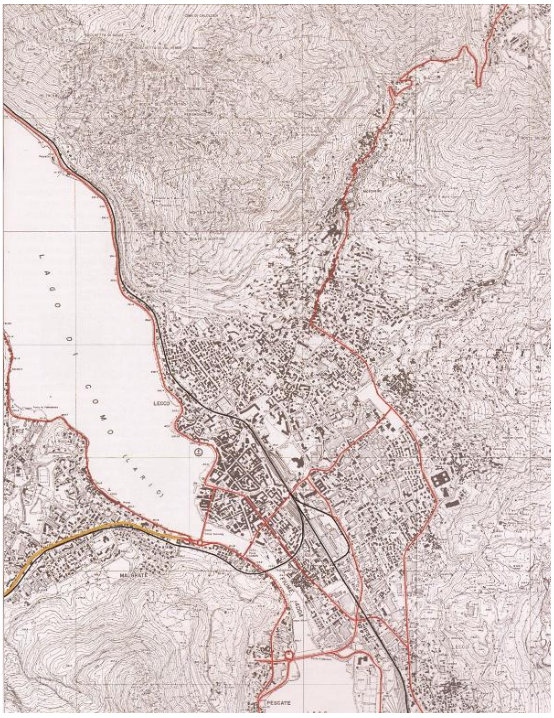

Fig 1.17: Lecco in 1994

1.2.4. Demography

According to the last demographic survey done by ISTAT (Italian Statistics Institute) in 2011, the total population of Lecco is 48114 inhabitants, while the urban agglomeration area reaches around 107000 inhabitants.8

ISTAT data for year 2010	*Male*	*Female*	*Total*
Population on 1st January	*22791*	*25000*	*47791*
Population on 31st December	*22925*	*25189*	*48114*
Number of families	*20738*		
Mean number of family members	*2.29*		

As we can see from figure, Lecco has witnessed a peak in the population in 1970s, at the height of the post-war revival period, and since then it has been declining slowly, although the last surveys show the trend of growth once more since the 2000s. The foreign population in Lecco according to ISTAT data for year 2011 is 4388 inhabitants, which is 9,12% and also shows the increase compared to recent years (i.e. 2009 was 7,65%).9

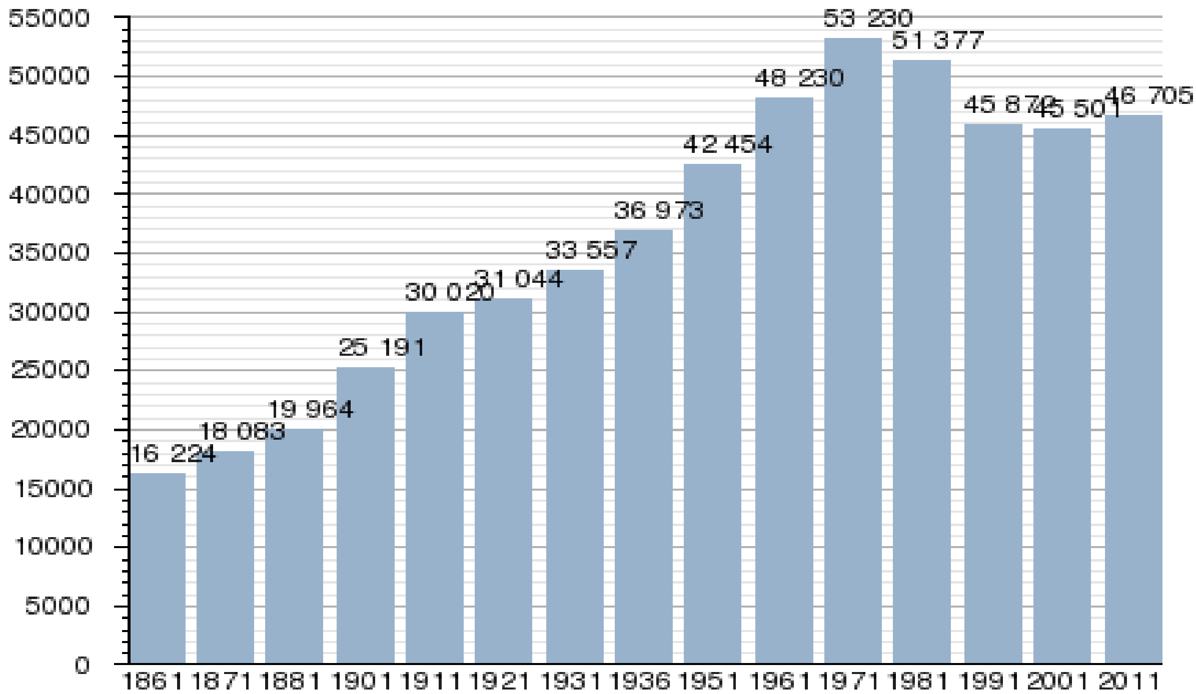

Fig 1.18: Demographic growth trend over time for Lecco

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[8] *http://demo.istat.it/pop2011/index.html*
Table: ISTAT
[9] *http://demo.istat.it/bil2010/index.html*
Image : http://it.wikipedia.org/wiki/Lecco#Evoluzione_demografica

1.2.5. Student Population in Lecco

The Lecco campus of Politecnico di Milano is attracting student population to Lecco since 1993, and according to University data, each year around 700 students are enrolled to the courses held there. Politecnico is further expanding its facilities in Lecco by inaugurating a new campus building and attracting more people in the future.

International students: 260
Italian students: 450

Fig 1.19: Politecnico di Milano new campus in Lecco

Fig 1.20: Politecnico di Milano, International student s

1.2.6. History

Lecco history dates back to ancient times, to the Celtic and Roman settlements in these areas as early as 9th century BC. The name Lecco itself probably comes from Celtic word Lech or Loch which means lake. Traces of metallurgy production were found and evidence that in areas surrounding Lecco were border settlements protecting Mediolanum (Milano).

In medieval times areas of Lecco had some military importance as several routes connecting Lombardy to regions north of Alps intersected there, so it was a scene to many clashes and battles. The fortified city of Lecco (Castrum Leuci) became a seat with Carolingian dynasty in rule but by the end of the first millennium were deprived of this power and came under influence of the Archbishop of Milano and stayed under his dominion for several centuries.

Relations with Milano were always tense is the next centuries, in the periods of unrest and conflicts Lecco was sometimes sided with, other times against Milano. At the end of one of these conflicts in late 13th century Lecco was completely destroyed, their allies having lost the battle for dominion over Milano. However, few decades after, Azzone Visconti, the lord of Milano and founder of the state which became a duchy later, took over the rule of Lecco and in 1336 built a fortification – walls surrounding the village and incorporating a castle at the lakeside. This fortified city of Lecco was supposed to serve as a protection from Venetian intentions of expanding their territory which led to often conflicts between the two states.

In mid-15th century, a peace treaty defined the borderline along the Adda river, thus

Fig1.23: old map of Lecco

giving Lecco even more importance to its strategic position. In the second half of the 15th century the Sforza family of Milano further developed and improved the fortification, building a fortified gate towards the lake and another one on the other side. It was in this period when the castle assumed its final shape and size. In the mid-16th century the final large intervention was undertaken to further strengthen the defensive abilities of the castle, glacis (artificial sloped earth to prevent the enemy getting closer) was built to surround the castle and trenches between glacis and the walls were added. This intervention was motivated by new techniques of warfare which arose in those times – the use of artillery.[10]
This period is known as the Comunità Generale (General Community) and was highly prosperous for Lecco. During those times Lecco became the most important city in Lombardy in iron manufacturing due to presence of waterways used to move hammers for forging iron. In addition to iron industry, silk manufacturing was also highly developed.[11]

These territories passed to the Spanish rule after the fall of Duchy of Milano in second half of 16th century, although officially Lecco remained under dominion of Milanese Duke. Situation remained like this until early 18th century when powerful Austrian dynasty Habsburg takes over Milano and its belonging towns. Austrian Emperor had the walls of Lecco finally abolished. Milano and Lecco fought as part of Russian-Austrian alliance against Napoleon, and fell under French for a short period until Austrian rule was reinstated and they cancelled all French institutions which were made during their reign, among them Lecco which was divided into smaller towns and lost its importance and status. It was not until 1923. that they were united again in the Fascist period, while the status of city was regained in 1859.[12]

Lecco became an important cultural center in 19th century as it made home to the Scapigliati (Bohemians), famous group of Milanese writers who used to gather in Lecco. The city played its part in the battle for unification of Italy in the mid-19th century and later developed hand in hand with all of the country. As an industrial city, it faced labor struggles for better work conditions at the beginning of 20th century. It suffered during the World Wars with many lost lives, which are remembered by monuments throughout the city.

[10] "*Il castello in riva al lago di Lecco*", Biblioteca civica di Lecco, October 2009
[11] http://www.scoprilecco.it/industrie/prime_industrie.htm
[12] http://it.wikipedia.org/wiki/Storia_di_Lecco

2. Urban Analysis and Design

2.1. Site Analysis

2.1.1. Site Boundaries

Project site is located in the vicinity of the main church of Lecco, San Nicolò. The site from the northern part is limited by the intersection of Via Giuseppe Parini and Via Giuseppe Ongania, and from southern part, the boundary is defined by intersection of Via San Nicolò and via Pietro Nava. The project is located inside historic boundary of the city.

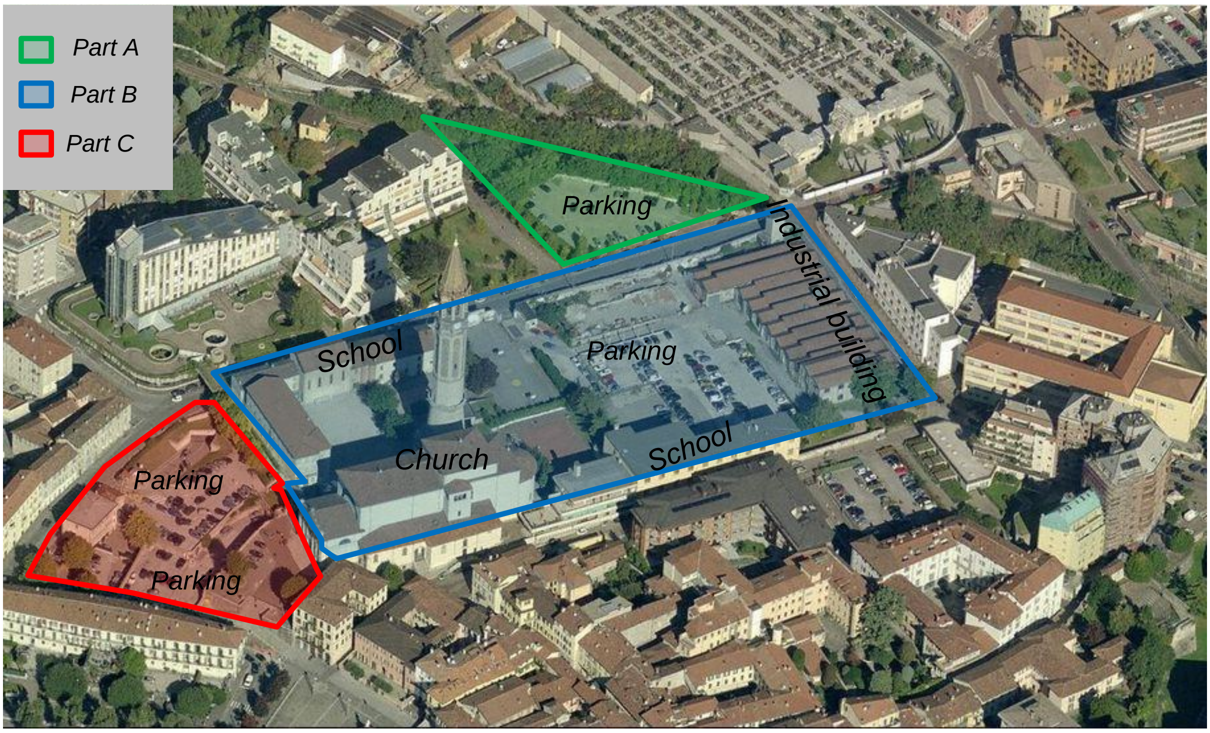
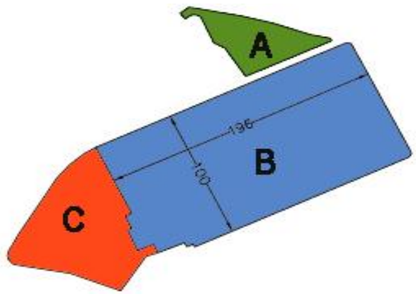
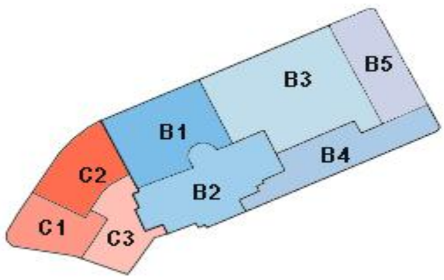


Fig 2.1: site boundary is comprised of the three main parts

The site consists of three parts; part A, part B and part C. Total area of the site is 28255 m^2. The main part of the site is part B which has the landmark of the city inside its boundary. The northern part of boundary B is blocked by remains of the old factory, and the southern part is occupied by the church San Nicolò. Total area of the part B is 19740 m^2.
Parts A and C both are working as public parking. Part A is located on the northern part of the site and it has the direct connection with part A. The total area of the part A is 2400 m^2.
The part C is divided into two independent parking areas and an access area for the church San Nicolò. The total area of part C is 6115 m^2.



Area
A: 2400 m^2
B: 19740 m^2
C: 6115 m^2
Total: 28255 m^2



Area
C1: 18880 m^2
C2: 2300 m^2
C3: 1935 m^2

Area
B1: 3665 m^2
B2: 4045 m^2
B3: 6345 m^2
B4: 3100 m^2
B5: 2575 m^2

Fig 2.2: site dimensions

Fig 2.3: different views to the site and its boundary

2.1.2. Existing Urban Section

Due to existing complex topography, design team decided to provide several urban sections to study the existing connections and relationship of the different parts in a more deep way.

All three parts of the site are located in the flat level but the connection among them is not flat. As it is clear in the section, all the access ways are located in on the inclined path.

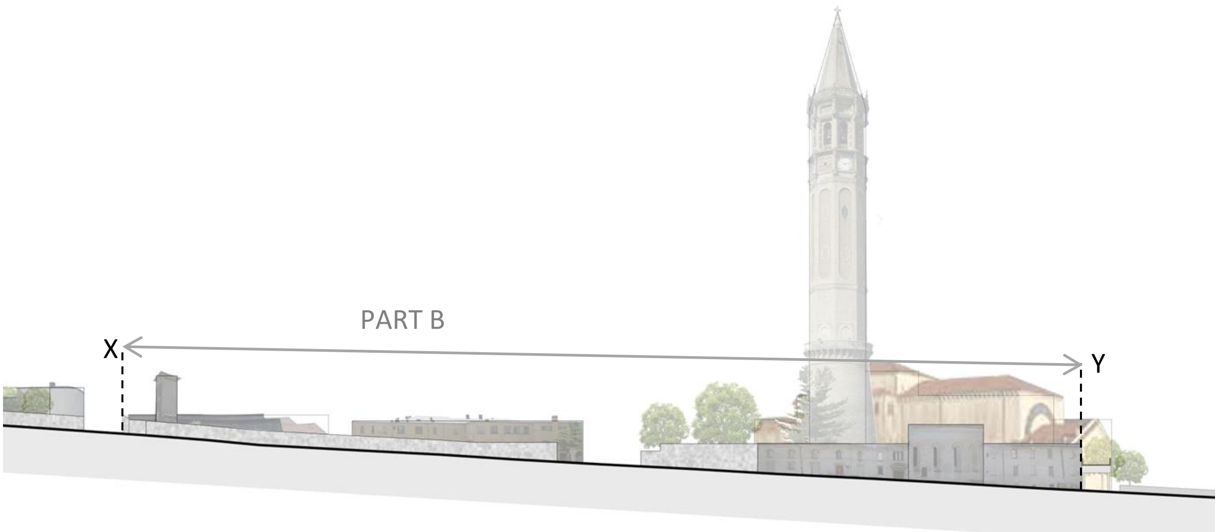


Fig 2.4: section aa .The difference in height between point X and Y is about 14 m

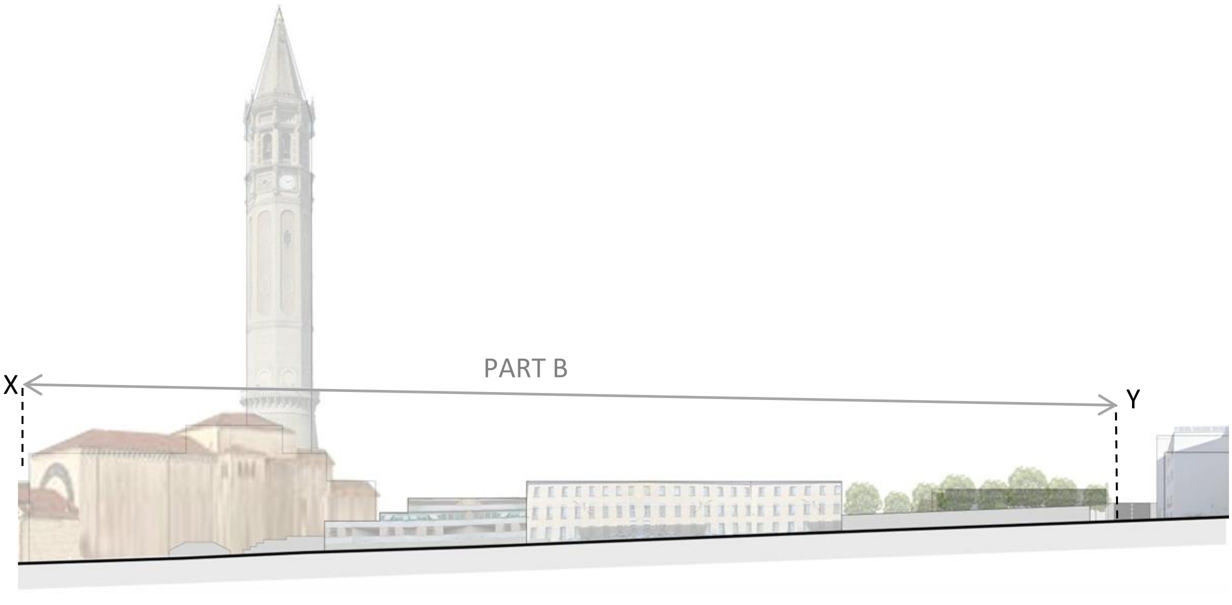


Fig 2.5: section bb. The difference in height between point X and Y is about 7.5 m. This part of the façade is almost entirely blocked by the school and church.

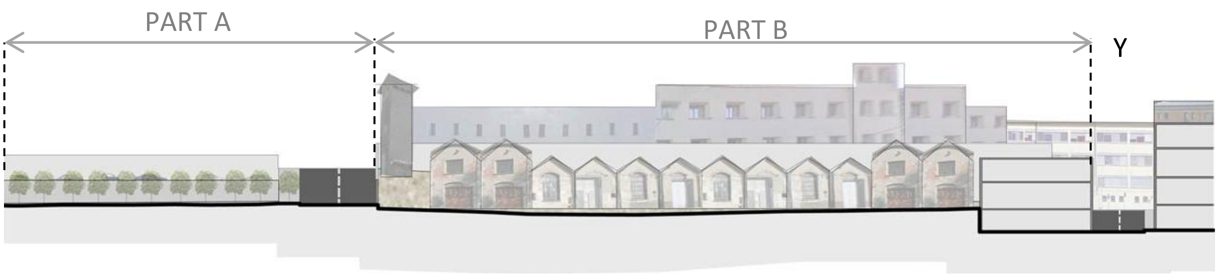


Fig 2.6: section cc. as it is seen in the section, each part has flat topography

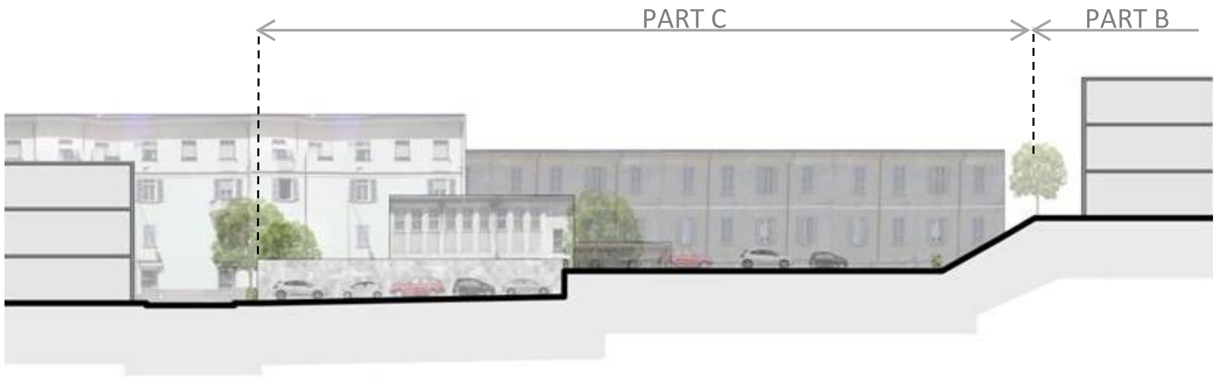


Fig 2.7: section dd. This section mostly focuses on the part C that works as parking. As it is clear from the section that parking is in two different levels, the parking is in the direct connection with via Pietro Nava. The access from parking to part B is from the stairs

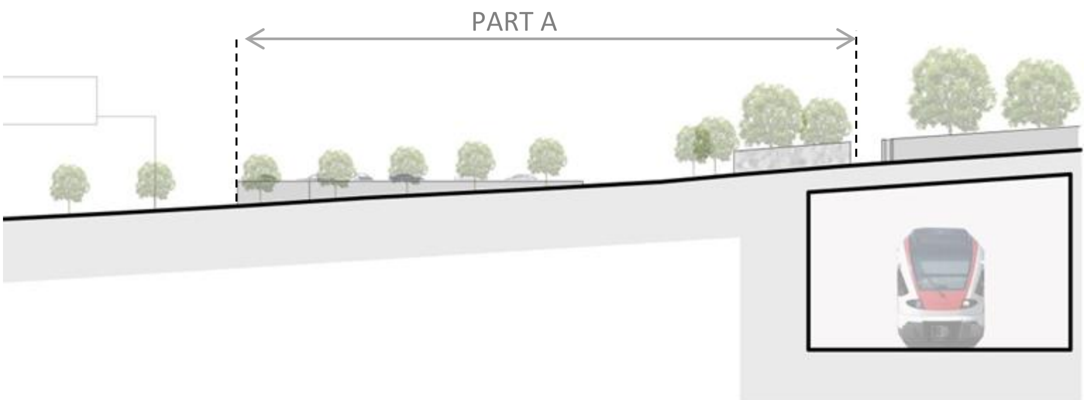


Fig 2.8: section ee. This section mostly focuses on the part A that works as parking. As it is clear from the section, there is railway passing by its boundary, the train is passing in the underground level with respect to the parking level. Along the parking boundary, railway is uncovered, so there is sound pollution around

2.1.3. Solid and Void Analysis

The Nolli map provides an immediate and intuitive understanding of the city's urban form through the simple yet effective graphic method of rendering solids as dark gray and rendering voids as white. The city, thus conceived as an enormous mass that has been "carved" away to create "outdoor" rooms is rendered intelligible and vivid through this simple graphic convention.[1] *As it is clear from the map, the area is mostly comprised of voids, and the main solids are on the perimeter of the site boundary.*

Fig2.9: mass and void map of the area

[1] http://nolli.uoregon.edu

2.1.4. Mobility and Transportation

The mobility is studied in three different layers, public car access, private car access and pedestrian access.

Private car access: the site is located on the boundary of the historical area, and it has possibility of accepting private car inside.

The pedestrian access: the quality of the pedestrian path is really low around site boundary. Also the study of the accessibility inside the site boundary shows the demand for redesigning.

Fig 2.10: the low quality of the pedestrian pathway. Via Parini

Fig 2.11: the intersection of Via Giuseppe Parini and Via Giuseppe Ongania

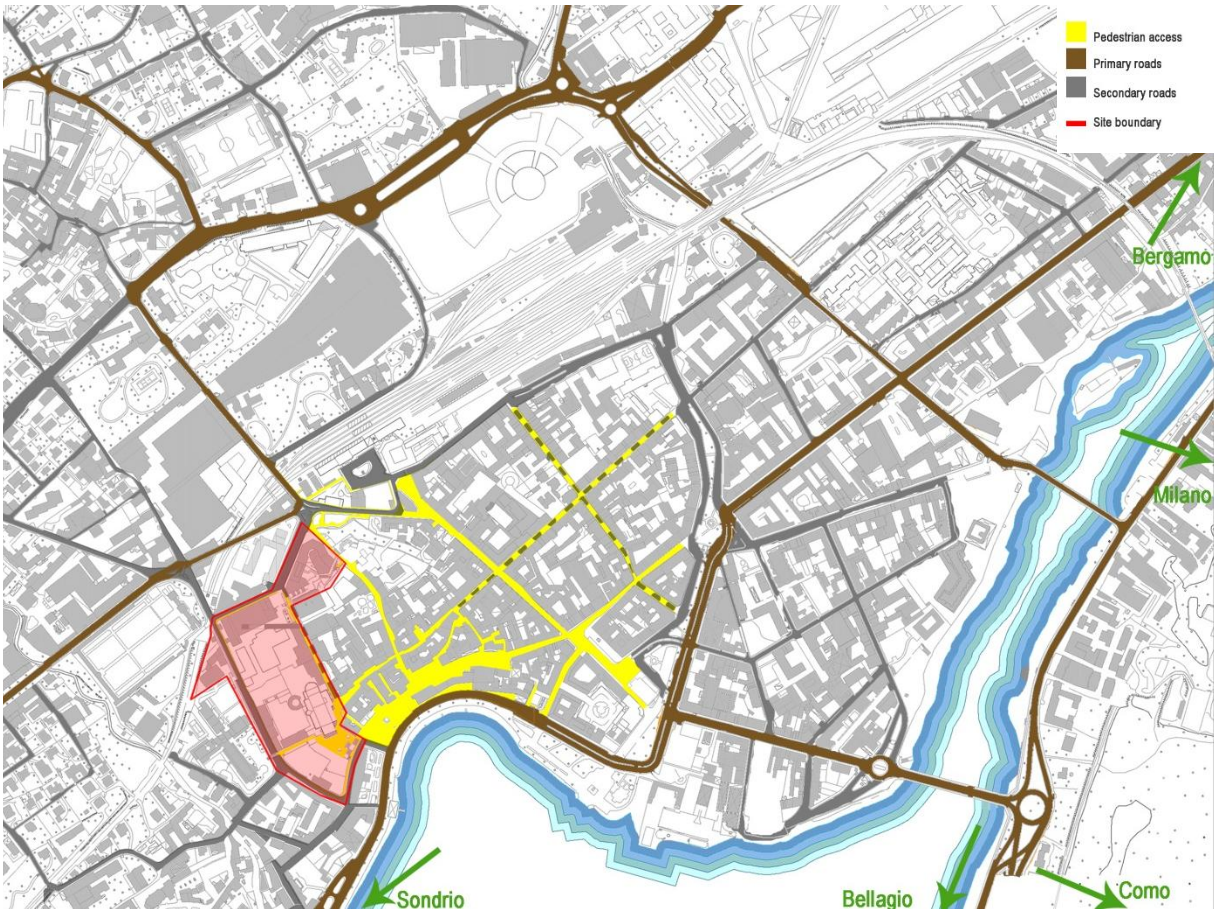


Fig 2.12: mobility map of the area

2.1.5. Function

The main public functions are available in less than 500 meter from the center of the site. It is worth mentioning that new campus of Politecnico di Milano is located in 1 km distance from the site.

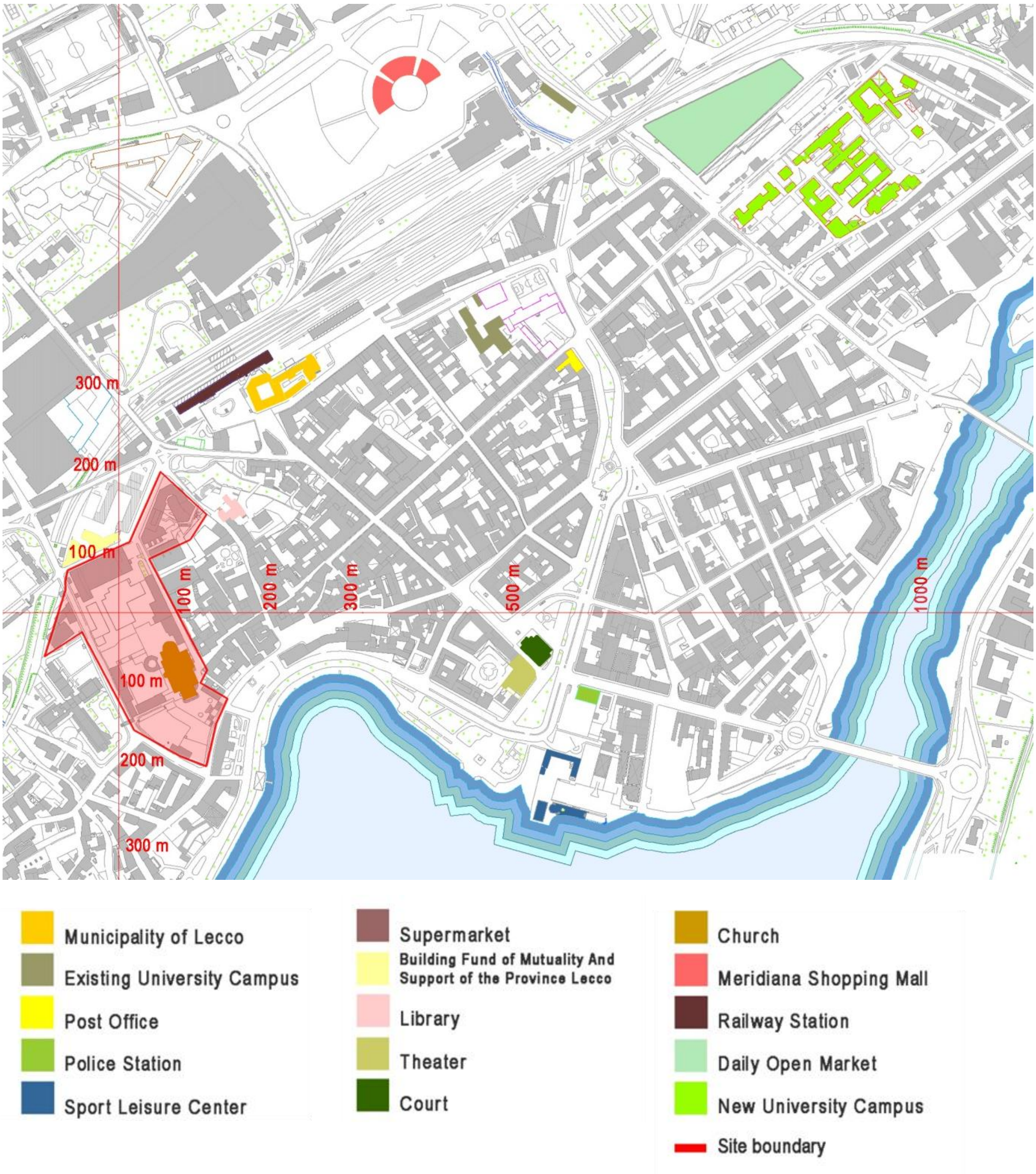


Fig 2.13: functional map of the area

Fig 2.14: the main functions around site boundaries

2.1.6. Piazza

According to PGT of the Lecco, Piazza Cermenati and its extension Via Pietro Nava, as well as the presence of water, allow for an open public space as an enhancement of the system of piazzas in the city center, to be developed in the car-transit protected area. Restructuring of certain parts should be foreseen, also demolition with reconstruction for having desired functions in order to define the boundary of the new piazza between the part of the city inside the historical walls and the part outside of them.

The intervention should foresee:

1. Refurbishment and reuse for the existing building (accommodation and recreational use)
2. Realization of:
a) Public parking on two levels, using the existing natural slope, with green roof
b) Public open space piazza, as a part of the system and continuation of Piazza XX Settembre and Piazza Cermenati, with materials and finishing related to the existing ones
c) Plants, trees and green areas
d) Regard to conservation, safeguarding and development of historical heritage present on site. (Respect area to the church, adequate lighting, etc.)[2]
As it is clear from the map, the southern part of our site boundary is allocated for the project of the expansion of the piazzas and also there is upgrading proposal for the northern part of our area.

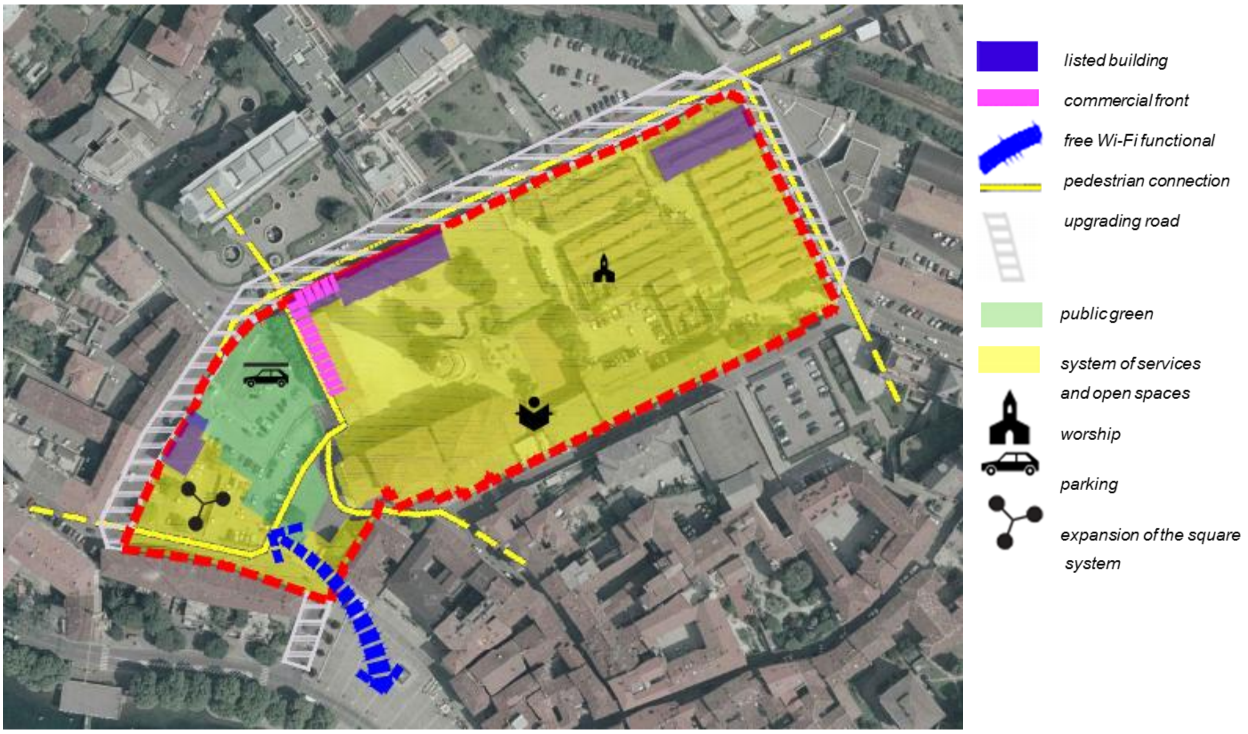


Fig 2.15: development plan of the area, PGT Lecco

[2] PGT of Lecco

The main piazzas of the city are studied in order to find an appropriate visual and functional connection among them.

As it clear from the map, the connections between piazzas are outside the site boundary, so there is a missing connection between the project site and city center.

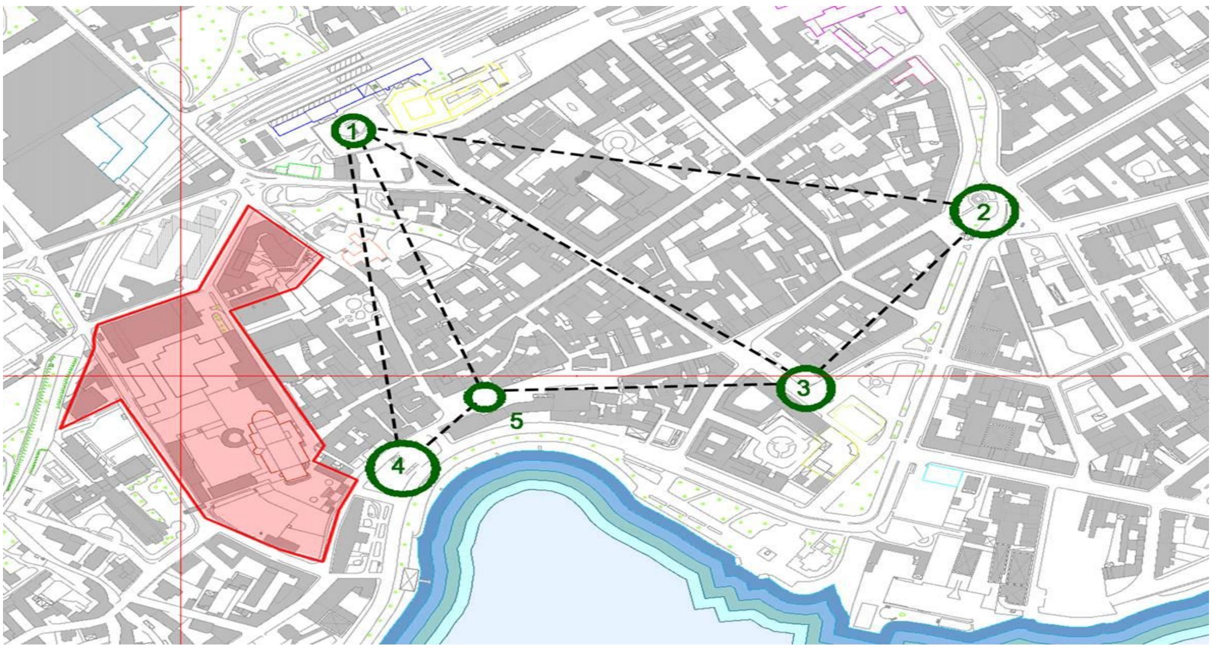


Fig 2.16: connection among different piazzas, their respecting piazza's pictures

2.1.7. Environment and Greenery

The green system of the area is studied in three different layers private greenery, public greenery and non-accessible public greenery.
The central part of the site area does not have adequate greenery. The main greenery is in the North part of the site.
The lake Como is an important feature in Lecco.

Fig 2.17: Lake Como

Fig 2.18 The non-accessible public green area

Fig 2.19: the public green space along the Lake Como

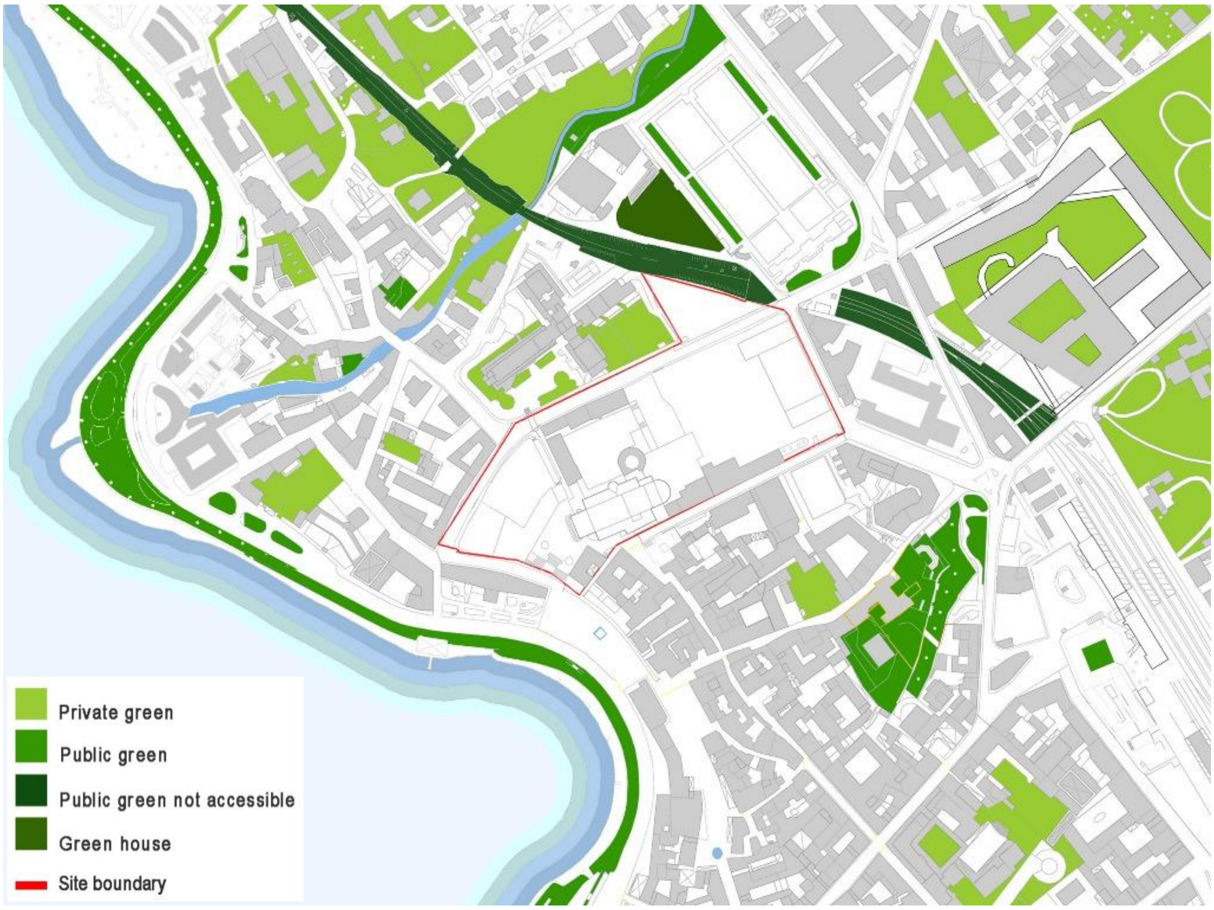


Fig 2.20: green system of the area

2.1.8. Parking

The site is comprised of six parking lots, four of which are inside site boundary and the other two have entrance from the site boundary.

All four parking lots that are located inside the site boundary are open parking lots on the ground level, so they have really bad visual effect on the neighborhood.

Parking A is a public parking with one access from Via Parini.

Parking B is located inside architectural boundary. It is a private parking under authority of the church San Nicolò. This parking has two entrances from northern part of the site. The main one is from Via Parini, and the secondary entrance is from via G.Ongania.

Parking C is a public parking with one access from southern part of Via Parini.

Parking D is a public parking with one access from Via P. Nava.

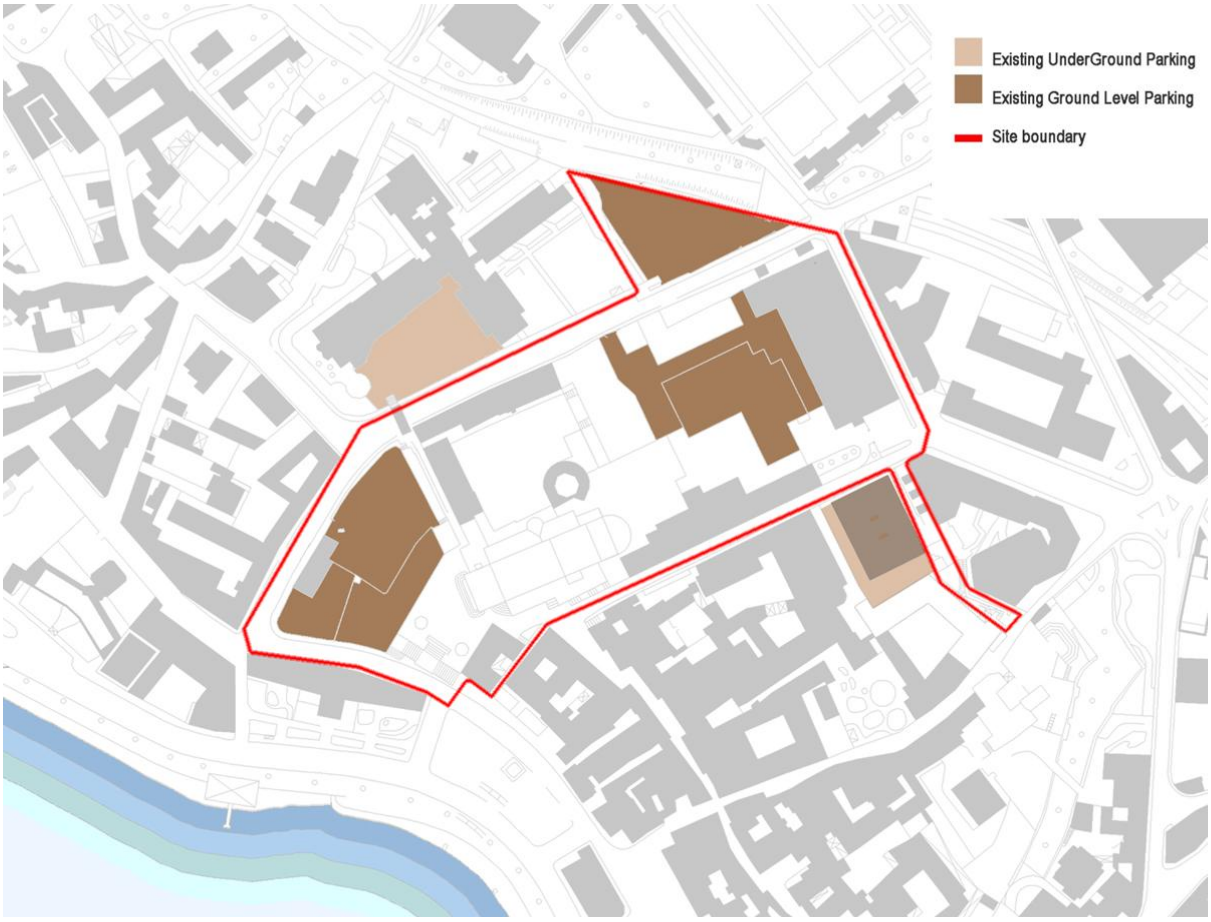


Fig 2.21: existing parking map

2.1.9. Scale Comparison

The scale comparison is done to understand the dimensions of in the area more realistic way.

Fig 2.22: site boundary

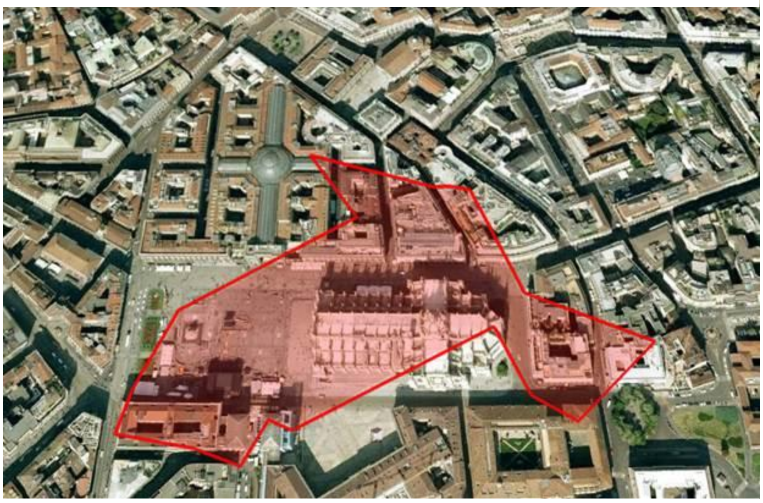


Fig 2.23: Scale comparison with Duomo

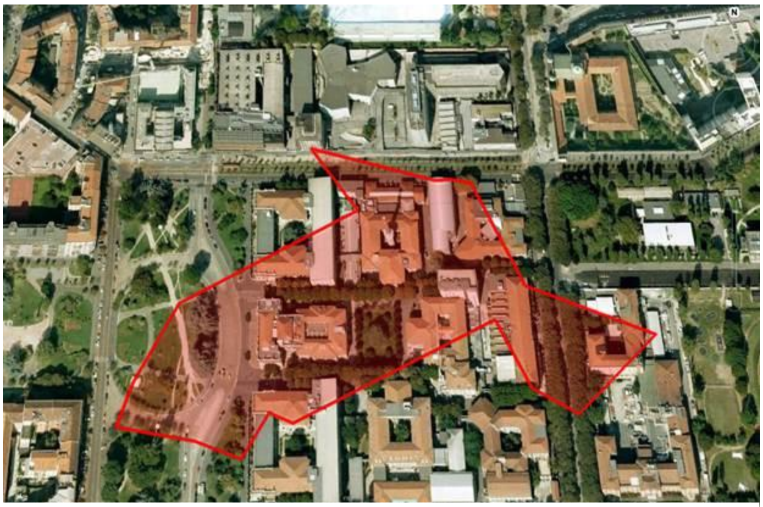


Fig 2.24: Scale comparison with Leonardo Campus in Milano

2.2. Summary

2.2.1. SWOT Analysis

Strength

1. *Environmental and Visual aspect*
    a. *visual connection with mountain area*
    b. *presence of the an open space inside site boundary*
2. *Mobility and accessibility network*
    a. *Easy and direct access to the site from main street (Via Giovan Battista Grassi, Viale Filippo Turati and Piazza Stazione)*
    b. *Existing parking spaces inside the site*
3. *Identity*
    a. *Presence of building with historical value (Church San Nicolò)*
    b. *Presence of mixed function inside site boundary*
4. *Land use*
    a. *Located near the main church (San Nicolò) of Lecco*
    b. *Presence of two schools inside the site boundary*
    c. *Presence of the remain of the industrial building inside site boundary*

Weakness

1. *Environmental and Visual aspect*
    a. *Lack of green area*
    b. *No visual connection between site and surroundings due to presence of solid perimeter wall*
    c. *Presence of noise and air pollution due to existing parking*
    d. *Absence of the visual connection between site and via Giovan Battista Grassi*
    e. *Presence of several open parking lot inside site*
2. *Mobility and accessibility network*
    a. *Separated and undefined pedestrian path*
    b. *Absence of connection between site and surroundings*
3. *Identity*
    a. *No safety during the night time*
    b. *Known as urban void (unsafe area)*
4. *Land use*
    a. *No function during night*
    b. *The new construction constraint due to the adjacent cemetery*
    c. *The new construction constraint due to the adjacent railway*
    d. *Presence of an abandoned industrial building inside the site boundary*

Opportunity

1. *Environmental and Visual aspect*
    a. *Close to lake Como*
    b. *Location of the site close to main public space of the city*
    c. *Close to mountain area from the northern side of the site*

2. *Mobility and accessibility network*
    a. *Presence of several parking space around the site*
    b. *Presence of the railway station*
3. *Identity*
    a. *location of the area near the historic zone of the Lecco*
    b. *location of the area near cultural zone*
    c. *connections between different piazzas according to Lecco PGT*

4. *Land use*
    a. *Presence of residential, commercial and mixed use area in surrounding area*
    b. *New campus of Politecnico di Milano in Lecco*
    c. *Presence of the open space in front of the site*

Threats

1. *Environmental and Visual aspect*
    a. *Presence of noise and air pollution, especially from railway*

2. *Mobility and accessibility network*
    a. *Presence of one way street (via Giovan Battista Grassi)*

3. *Identity*
    a. *Residents are not interested in presence of the cemetery beside site*

4. *Land use*
    a. *Presence of the cemetery and railway near site*

2.2.2. Opportunity and Constrains Map

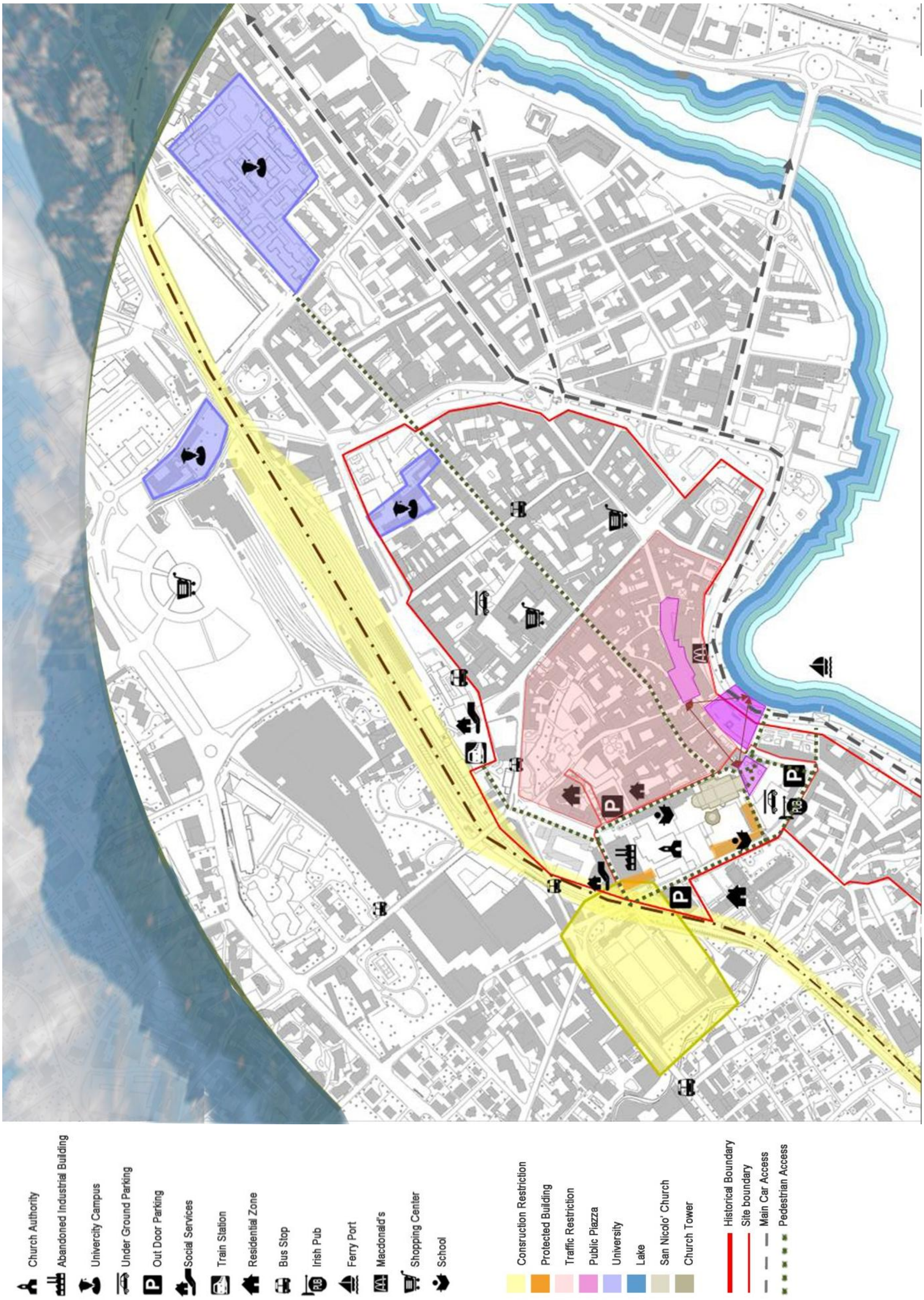


Fig 2.25: Opportunity and constrains map

2.2.3. Vision

Purpose of this project is to show the way in which the abandoned area of the site with its surroundings is transformed into one of the live and active zones of the Lecco. Strong desire to increase public activity of the area to work among other zone in historic part of Lecco is the most important guide for proposing the transformations.

2.2.4. Goals and Strategies

In order to accomplish this task, following goals are defined: mobility and accessibility, sustainability, vitality and variety of activities, integration, identity, comfort, universal design and safety.

GOAL 1: to achieve ease of MOBILITY AND ACCESSIBILITY on local scale, engaging many different means of transportation with special attention paid to pedestrian transportation.
Strategy 1.1: Ensure proper vehicular, cycle and pedestrian access to the site, as well as adequate parking spaces near them.
Strategy 1.2: Provide good pedestrian connectivity with surrounding pathways
Strategy 1.3: Reorganize the parking area inside the site and in surrounding

GOAL 2: ENVIRONMENTAL goal will be achieved through careful management of land and other resources. Proposing different renewable energy solution; solar energy, geothermal, surface water collection…
Strategy 2.1: Minimize the sound and air pollution
Strategy 2.1: Increase the visual connection between site and surroundings
Strategy 2.3: Increase the greenery
Strategy 2.4: Use local materials

GOAL 3: VITALITY AND VARIETY OF ACTIVITIES will be ensured by introducing different functions both for buildings and open spaces.
Strategy 3.1: define different piazzas inside site boundary which work with the existing piazzas
Strategy 3.2: reorganizing the open parking spaces, locating them mostly in underground level and transforming the ground level to urban public spaces.

GOAL 4: Physical and social INTEGRATION between different parts should be accomplished through all the stages of the design process. Spatial and social segregation must be overcome by strong connections that are about to be introduced.
Strategy 4.1: connection between new piazzas and the existing.
Strategy 4.2: Internal connection between new functions.

GOAL 5: IDENTITY of the place is related to ability of the users to understand and define its boundaries and meanings.
Strategy 5.1: Ensure continuity and enclosure to create clear spatial units that stimulate movement through which they can be completely perceived.
Strategy 5.2: Respect historical values to retain strong sense of identity.
GOAL 6: COMFORT means more than just placing urban furniture around the site. It means a logical and suggestive design enabling usage of the space with ease.
Strategy 6.1: Design effective urban furniture inside piazzas and along connection lines.

2.3. Concept Plan

Understanding the relationship between people (society) and their environment (space) is an essential component of urban design. Consideration of the relationship between people and their environment starts with architectural or environmental determinism where the physical environment has a determining influence on human behavior.[3]

After studying the urban analysis, the application of the goals and strategies is presented as concept plan.

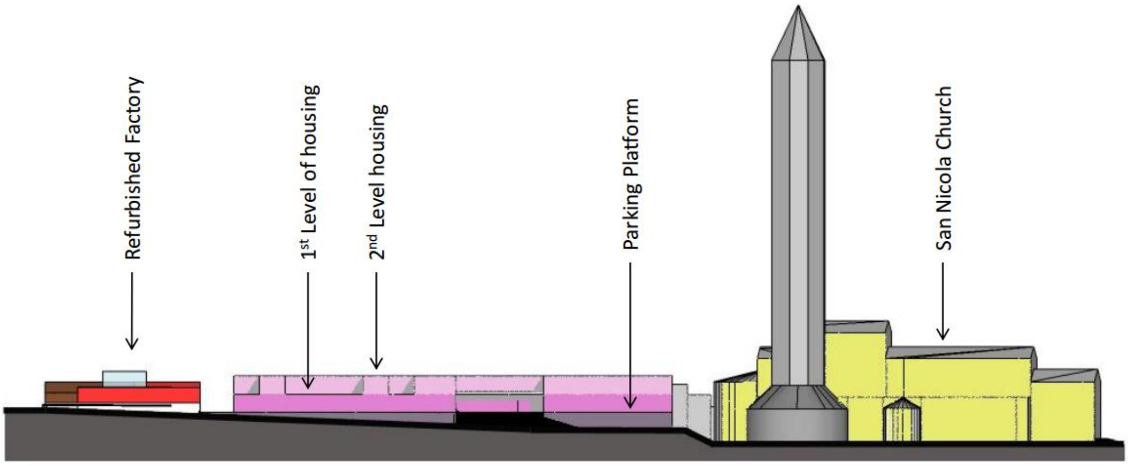


Fig 2.26: concept plan and section

[3] Matthew Carmona, Steve Tiesdell, Tim Head & Taner OC, Public places urban spaces the dimension of urban design ,2010

The main concept of the design can be summarized in three parts:

1. *Transformation and vitality of the spaces:*

As it mentioned the site is located on the boundary of the historic part of city, which does not have adequate parking lot and car access inside, so there are several parking lots inside site boundary which provide facilities to people that need to go to city center. Therefore removing an existing function which is necessary for the heart of the city is not an appropriate strategy. But on the other hand, the visual impact of these places is not negligible. So it is decided to keep the existing function inside site boundary but rethinking about their visual impact. To do this; different strategies are defined for each parking area:

Parking A: the area is redesigned for the same existing function. After rearrangement of the site, the number of proposal parking places is almost doubled, and the area is covered by a foundationless platform structure.

Parking B: the function is relocated from the ground level to underground level, and the ground level is allocated to public spaces.

Parking C: the area is redesigned with the same existing function.

Parking D: the function is removed from the area and the main public space is designed instead of the parking.

Fig2.27: parking proposal

2. *Ease of connection*

The main part of site is located at back part of church San Nicolo, and the accessibility to center of the city is blocked by church San Nicolo and school beside. In order to integrate the functions inside the area an internal access is defined to ease the accessibility to the main part of the city.

3. *Public functions*

A public space is an integral part of the public realm, and is receiving increased attention across the range of social science and humanities disciplines.

Lecco is an old city with the timeworn public spaces, in recent decade a new campus of Politecnico di Milano is transferred to Lecco and one of the main rules of this transformation is upgrading the city. Young people are moving to Lecco for studying in university. They belong to the new generation; they need to have more alive and active public spaces. The PGT of Lecco mentioned several strategies for Lecco new transformation. One of them is piazzas connection, which goal is to define new nodes in city and provide visual or functional connection among them.

To do this three piazzas are defined:

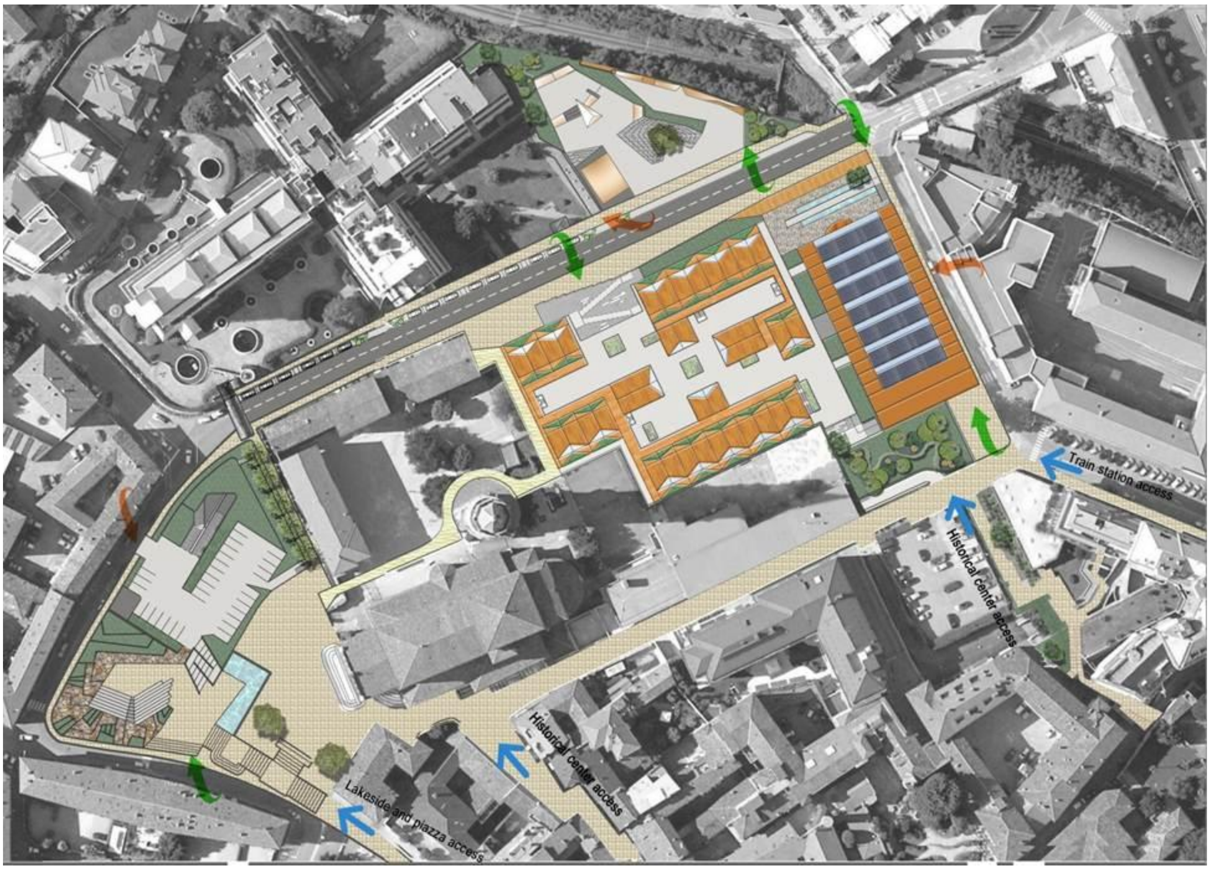
Piazza A
Piazza B
Piazza C

Fig 2.28: proposed piazzas

2.4. Master Plan

The area is divided into three different spatial segments:

Different functions are introduced after urban analyses inside the site boundary; also in some part by rearranging the existing functions, new proposals are defined.



Proposed access to the site

Car

Pedestrian

Direction

Fig 2.29: master plan

2.4.1. Part One:

Piazza Teatro

The first part is located in front of the church San Nicolò, in the southern part of the site boundary. Parking D is removed from the area and parking C is redesigned with the same function.

Due to proximity to Piazza M. Cermenati which is one of the main public spaces in the city and also considering PGT goals, the mentioned area is defined to work as public space and the extension part of Piazza Cermenati. The design team considered an outdoor theatre for this area. The area is also designed for multiuse functions.

The area is located on the lower level with respect to the northern and western boundary of the site. So design team has used these features of the site in order to create a sloped sitting area around the screen.

The area has both the potential to be used for live performances and also as urban screen with sitting area in front.

In order to avoid the distraction caused by the urban screen for the drivers, the screen is located in the lower level with respect to street level.

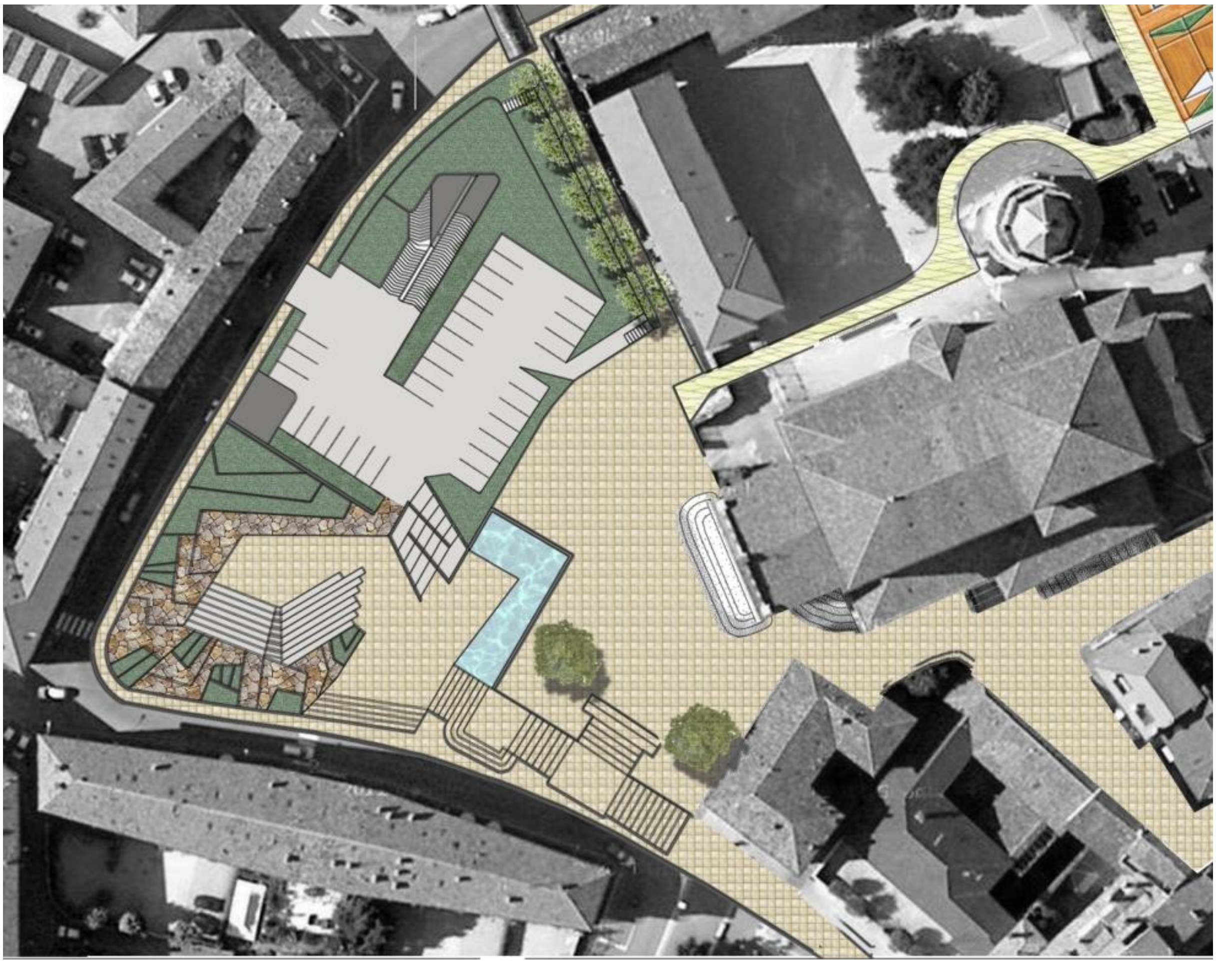


Fig 2.30: outdoor theatre piazza, plan

The pavement of area is the same texture that has been used in the Piazza Cermenti.

Fig 2.31: view of piazza teatro

Fig 2.32: view of piazza teatro, there is a perforated wall covering the perimeter of piazza under the green stairs

The boundaries of the area are green stairs which connect the piazzas level to the upper parking. In order to provide an access from the piazza to the parking a stairway is considered. Also in the northern corner a water curtain is defined to show continuity of the lake inside this area (the lake view of the area is blocked by an apartment block).

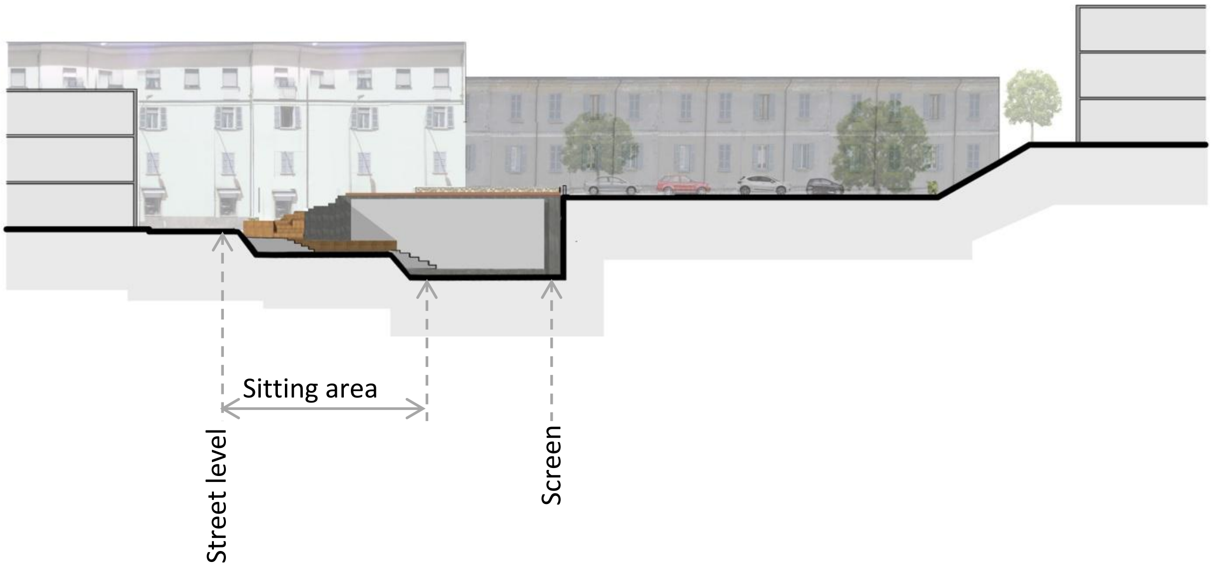


Fig 2.33: section through piazza teatro

2.4.2. Part Two

Piazza dello Sport

The function of this area is transferred from the ground level to the underground level. The street on its boundary has sharp slope towards south, so there is almost 2.5 m difference in height with regard to the existing parking level. Design team has decided to use this inclination in order to transfer the parking to the underground level. The existing access to the parking area is from the northern part, but in the transformation process, the access is provided from the southern part of the area, so the parking is located on the ground level with respect to the entrance and the roof is used as ground level from the upper part of the area.

An outdoor sports zone is defined for the area.

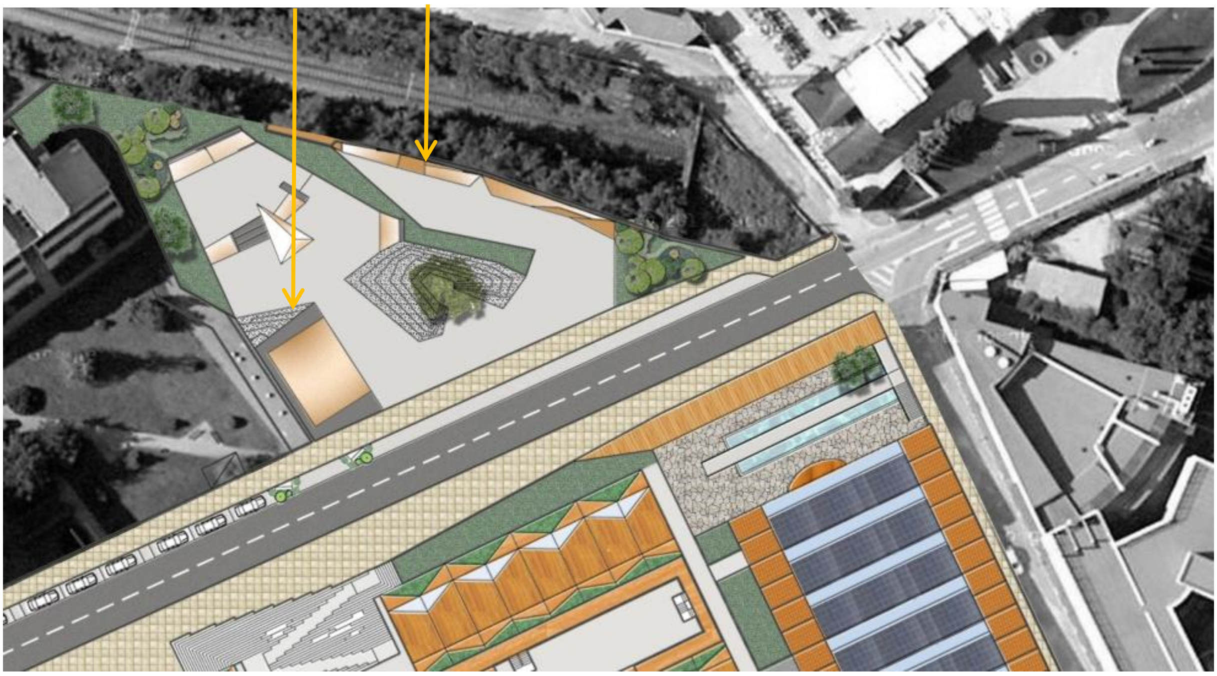


Fig 2.34: piazza dello sport, plan

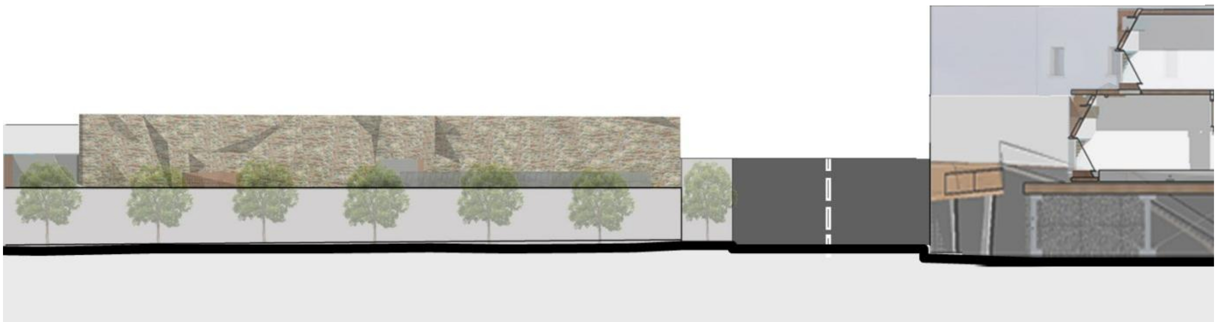


Fig 2.35: the section looking to the rock climbing wall

Northern part of the area is defined by railway, and the trains passing are making pollution for the area. A rock climbing wall is designed for the area to work as an outdoor sports facility which is very popular in Lecco, and it can work also as sound barrier for the public space.

Fig 2.36: rock climbing

Fig 2.37: natural rock climbing wall

Fig 2.38: piazza dello sport

2.4.3. Part Three

There is lack of internal connection from the northern part of the area to the southern part.

All the area B is under authority of the church San Nicolò, so there is possibility to propose an internal connection from North to South.

A covered pathway passing along the church is proposed to this goal.

Fig 2.39: the wooden covered path way

The pathway is made of light wooden structure and is covered with greenery. Also the minimum distance to the church boundary is considered in the proposal.

Fig 2.40: the internal pedestrian pathway

2.4.4. Part Four

This area is the main part of the project. The function on the ground level is kept and it is covered by a platform. The residential function is proposed for the upper level. The old industrial building in the northern part of the area is transformed to the mixed use functional building which works for citizens.

Fig2.41: section

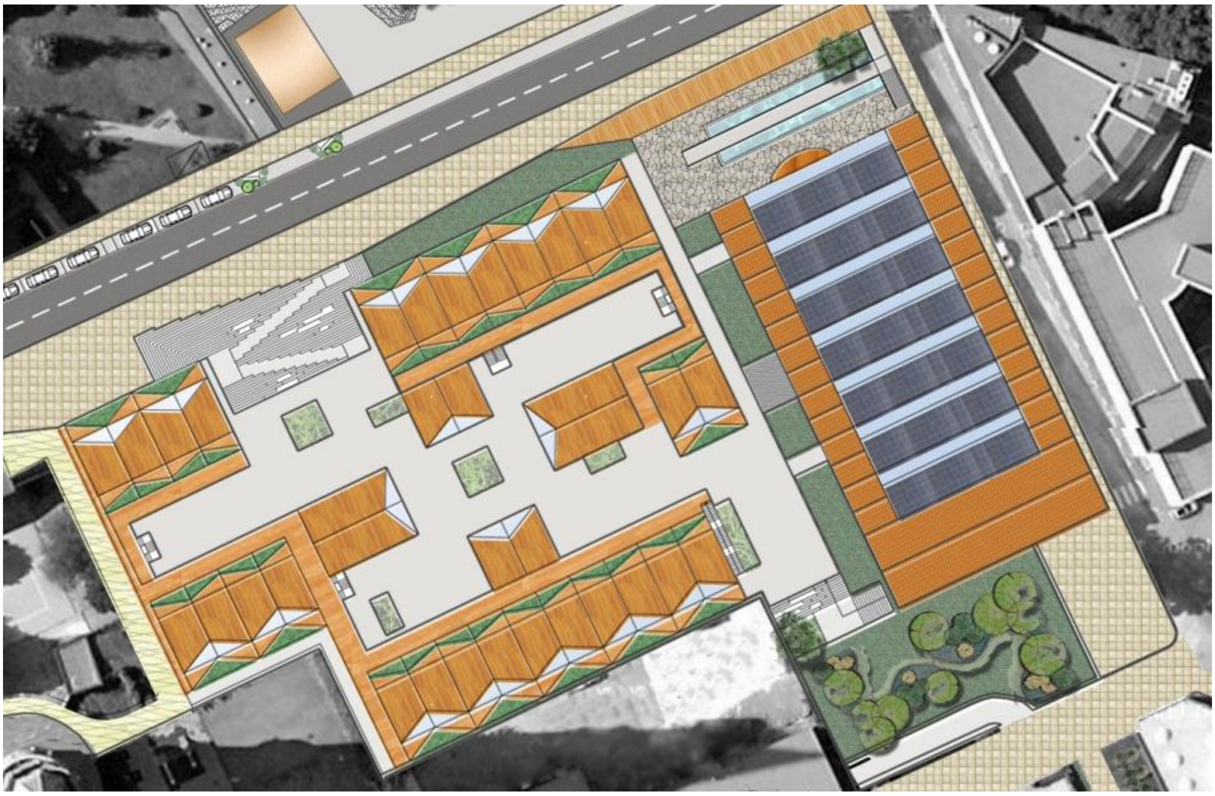


Fig 2.42: the central part of the masterplan comprises of a public mixed function building, parking and residential part

In order to use local material and resembling the rocky mountains of Lecco the material for the parking perimeter wall is gabion. Several car and pedestrian accesses are defined for the area.

Fig2.43: the gabion wall is proposed for the parking perimeter wall

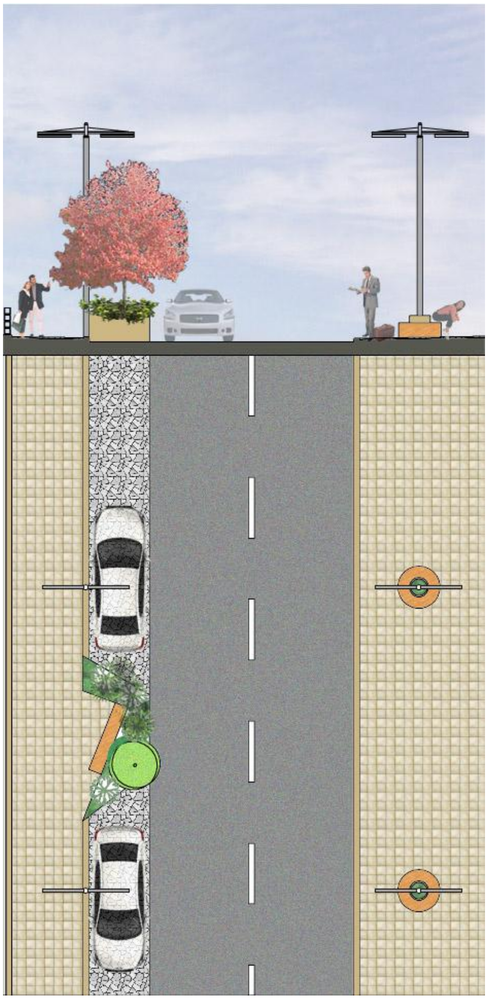


Fig 2.44: section 1-1

Fig 2.45: view from Via Ongania

Proposal for the improvement of the Via Parini pedestrian and parking site

3. Architectural Design
3.1. Introduction

As it was discussed before in the previous chapter, the void selected for the project is the area near the church of San Nicolò in Lecco. The whole site boundary is one property, under the authority of the church. So the master plan for upgrading the existing situation should cover all the areas considering all the actual elements. In the urban session, general decisions such as access for cars and pedestrians, parking, connection between piazzas, had been made for the improvement of the site with its surrounding. In this chapter issues are studied more in architectural details. To achieve his goal, the whole work is divided to three parts which are going to be discussed shortly after:*

- ***The refurbishment of industrial building,*** *it is the row of modular pitched roof units along via G.Ongania.*
- ***The parking,*** *the current use of the lot is a parking which is not going to be removed in the new plan.*
- ***The proposal of the modular residential complex,*** *these are the new housing for the non-local students in Lecco.*

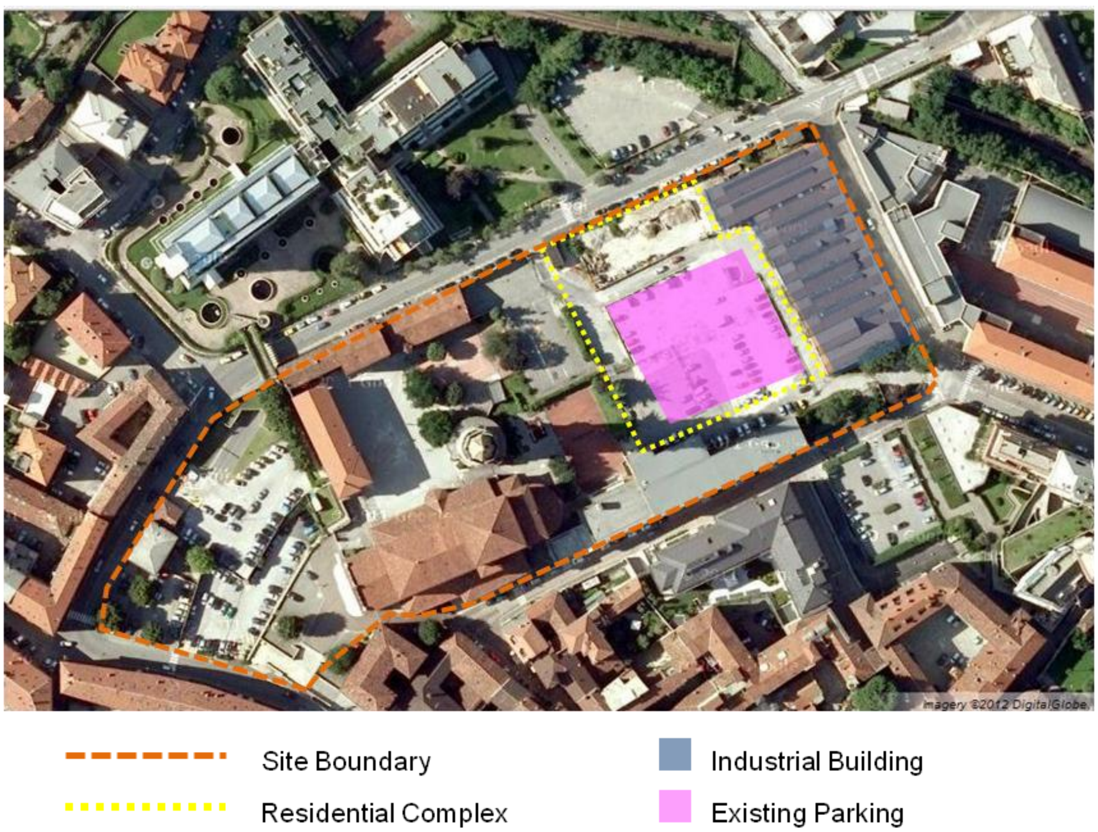


Fig. 3.1: site boundary

3.1.1. Strategies

The aim of the project is to recycle a forgotten space of the city and give it a new function and identity. To give a function which is practically needed and will serve for the habitants of the city, and identity that will bring life and attract citizens' attention to this zone of the city.

Being aware that the city has further development plans for this zone, the design should have the possibility to adapt the changes. Also, the area, as one of the pioneer points of the development of the city, should respect the environment and consider the issues regarding energy saving and carbon emission to leave as few impacts as possible on the site.

To accomplish these goals, following strategies have been considered during the design process:

- *Considering the user interaction with the neighborhood.*
- *Considering renewable energy system*
- *Respecting sustainability approaches in different design procedure*
- *Respecting city morphology*
- *Choosing a function which is needed for city*
- *Interaction between the residential area, mixed functional part (refurbishment project) and the city*
- *Providing the same or more parking capacity*
- *Arranging accesses towards various surrounding zones, with the respect to the privacy of the church, schools and the residences*
- *Providing enough natural light and ventilation for all the residences*
- *Respecting the hierarchy from public spaces to semi-public and private spaces*

3.2. Abandoned Building Refurbishment

Along the Via G.Ongania, on the North-East side of the site, there are remains of an old industrial building. Today, it is abandoned and exposed to aging and weathering degradations. It is composed from eleven simple two sided pitched roof modules. As it is illustrated on the picture 3.2, the first two from the left, are in the restricted area of cemetery and railway zone, where construction is forbidden by Italian law. According to PGT of Lecco these two cannot be renovated, they can just be conserved from damage and degradation, but it is possible to demolish them. Just like all the other buildings this one is also under the authority of the church and it should have a social function which serves for the city and its inhabitants.

Fig. 3.2: Site boundary and refurbishment boundary

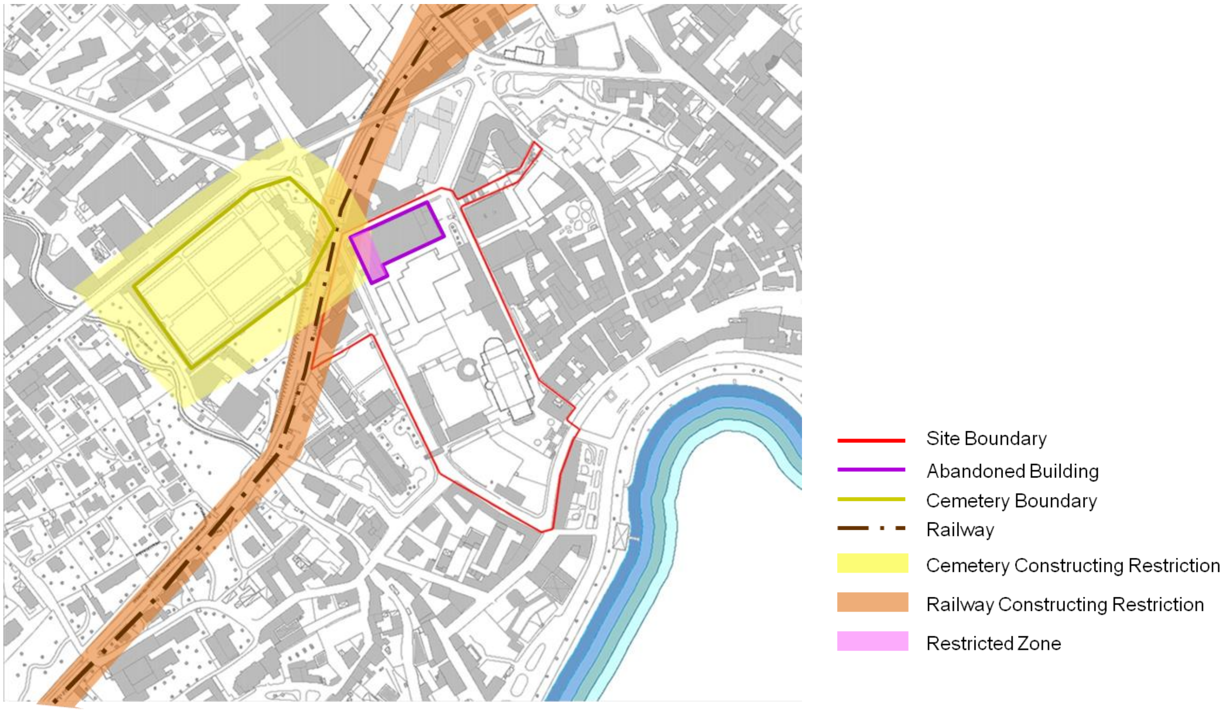


Fig. 3.3: constraints around site boundary

3.2.1. General Concepts

3.2.1.1. Demolition Idea

Since the two discussed modules are in the restricted zones the intervening limitation is very serious to them. This fact will cause problem in designing a homogeneous concept for the entire building. On the other hand, this building does not have a very rich historical background, so we decided to totally demolish them. Also, the last module on the other side is going to be removed, with the reason to provide a better entrance for the complex.

Fig. 3.4: the demolished parts are painted by yellow

3.2.1.2. Functional Distribution

The goal is to address the intermediate modules functions which make the site to interact more with the people and also the student residence. The building plays these two roles through a vertical arrangement of services. Mainly, the ground floor level is considered to work for the city, while the first level is supposed to be connected with the platform and serve the students. Also, the church management office is placed on the upper level to impose its power and importance but a separate access is considered for it.

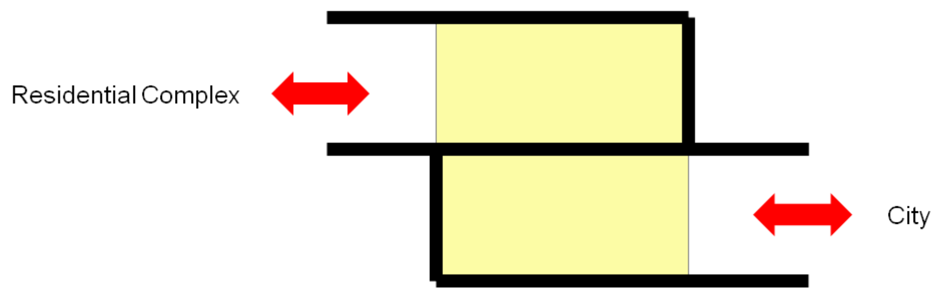


Fig. 3.5: the horizontal relationship

The functions for this building are chosen according to the necessities of the zone. They have the role to bring more vitality to the area, serve for the local area and due to the presence of the church as an iconic figure of the city, represent some services in the larger scale of the city. In the diagram below, the chosen activities and the accessibility to them are illustrated.

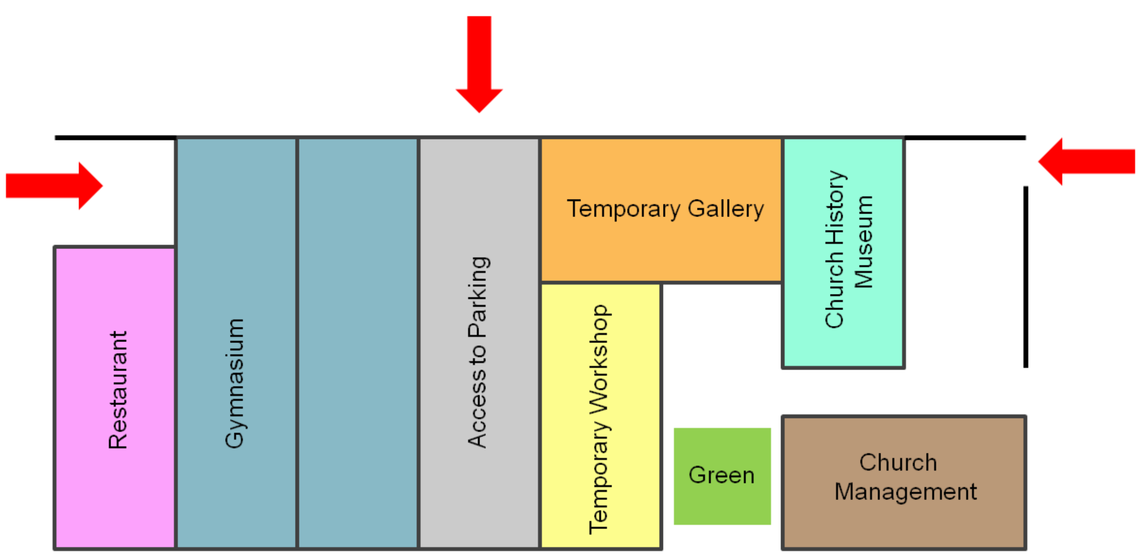


Fig. 3.6: the function distribution on plan

3.2.1.3. Building Accesses

The important point which should be noticed is that the building is lower from the surrounding streets and due to the natural slope of the ground the heights vary in different zones.

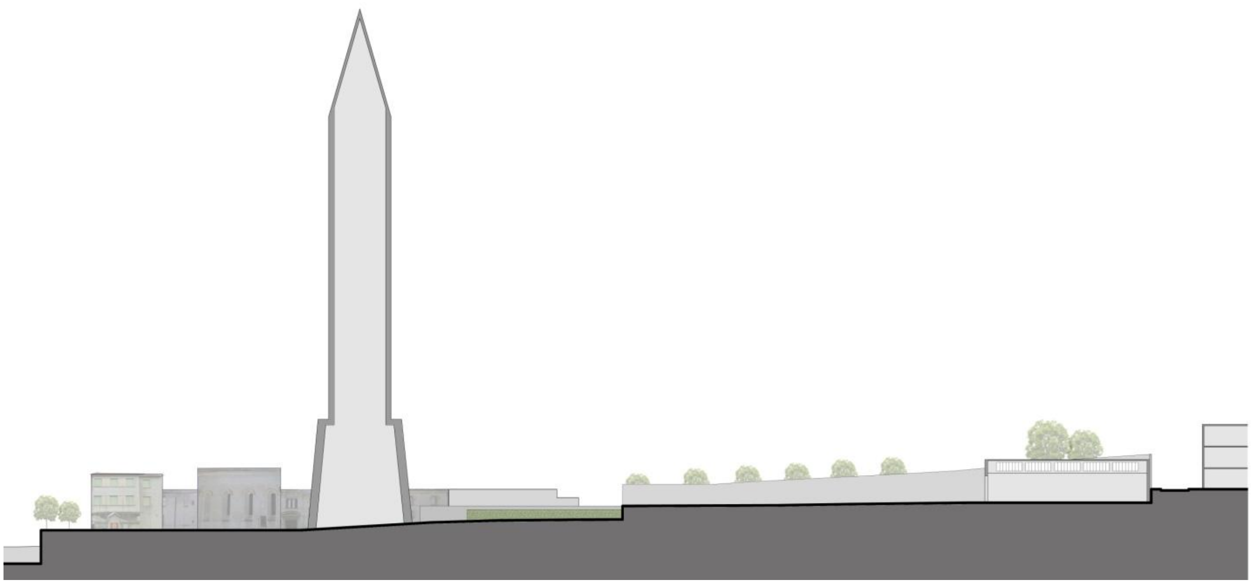


Fig. 3.7: urban section demonstrating site's different levels.

The Via G.Ongania, which goes along the building is about 4 meters higher than the ground floor level when it starts at from the intersection with Via G.Parini and at the end of the its length when it arrives to Via G.Resinelli the street is at the same level of the ground floor where we enter the site. The street is 6 meters wide and the pedestrian way along it is for the passage of limited number of people. So it was decided not to insert any access from this side, keeping the continuity of its elevation.

Fig. 3.8: the height difference between two streets besides the building

Knowing these relations, after omitting the first two modules, the third one is placed inside a big whole, where a good potential is provided for a public space which can work with inside and outside. We take advantage of this opportunity to consider entrances of the restaurant and the gymnasium. Another module is used to work as the entrance of the parking. It connects the one-way Via G.Ongania to the parking below the platform. A temporary gallery and workshop are also considered to serve for the city. Their access is through the other side of the building which arrives from the direction of the station. There is also a museum which exhibits the history of the town and the antiquity of church and its tower.

3.2.1.4. Symbolic Features

A ramp is designed to make access from the street level to the entrance of the gymnasium and the restaurant. Also to remark the once existing two modules in this place, the ramp is placed in the middle of the area and parallel to the building. Its length exceeds the shallow pool around it to emphasize the larger dimension of the former building. However, a stairway is also considered to work with the ramp for the quicker access to the site.

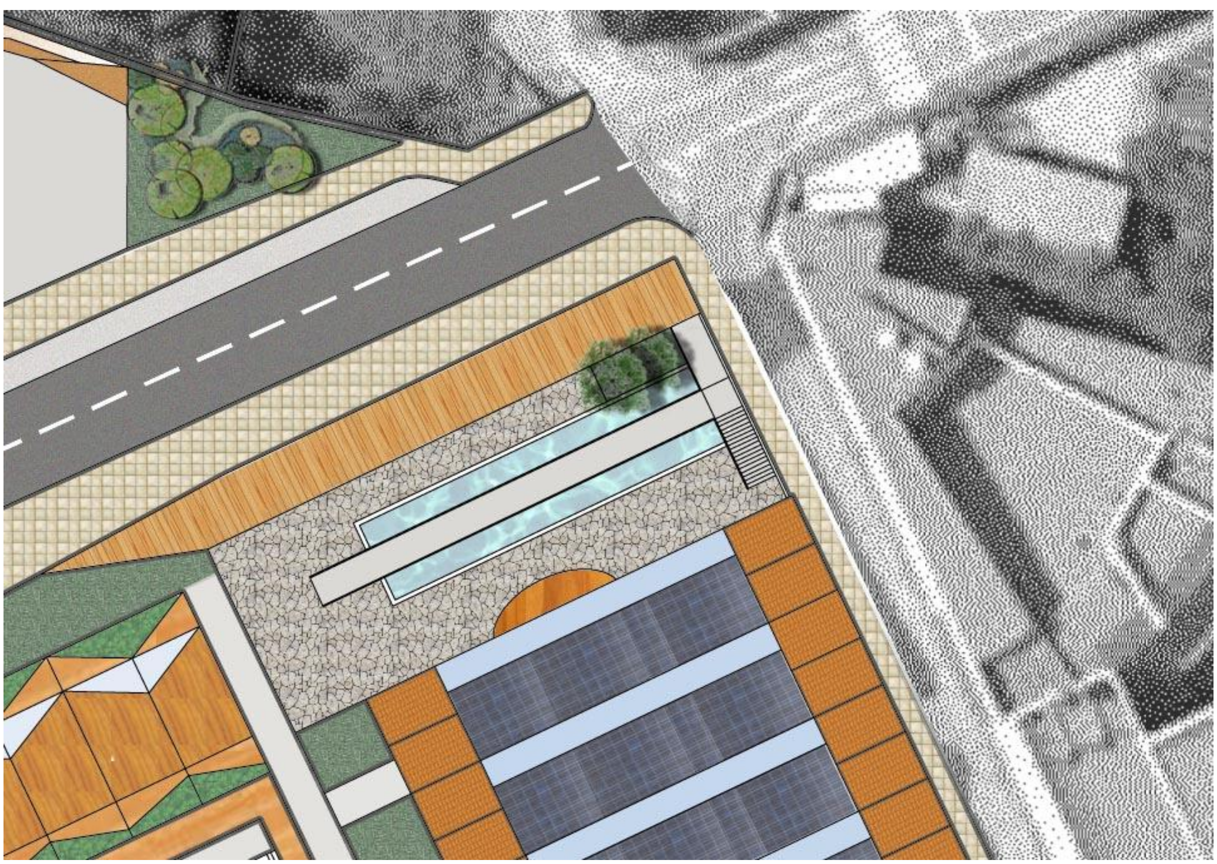


Fig. 3.9: the memorial ramp and its accesses

Although the general form of the building has been conserved during the refurbishment, significant changes can be seen in some limited parts. In these places according to the needs of the new function, especially the relation with the houses and parking, new forms have attracted the building as a "punch". They are so evident which can be recognized in the first look, on the other hand enough strong to impose their independent characteristic to the building. An arch-shaped volume is reduced from the Northern part, where it provides better sight for the drivers at the entrance ramp of the parking. While a similar positive volume is attached on the left side to create a buffer zone for the restaurant entrance. The fitness rooms in the middle are not receiving any natural light, so a transparent cube was ejected from the roof to provide more light. It also plays as a chimney to conduct the hot air outside through the natural ventilation. Accesses between the platform and the second level are solved with narrow bridges which enter the building like a duct.

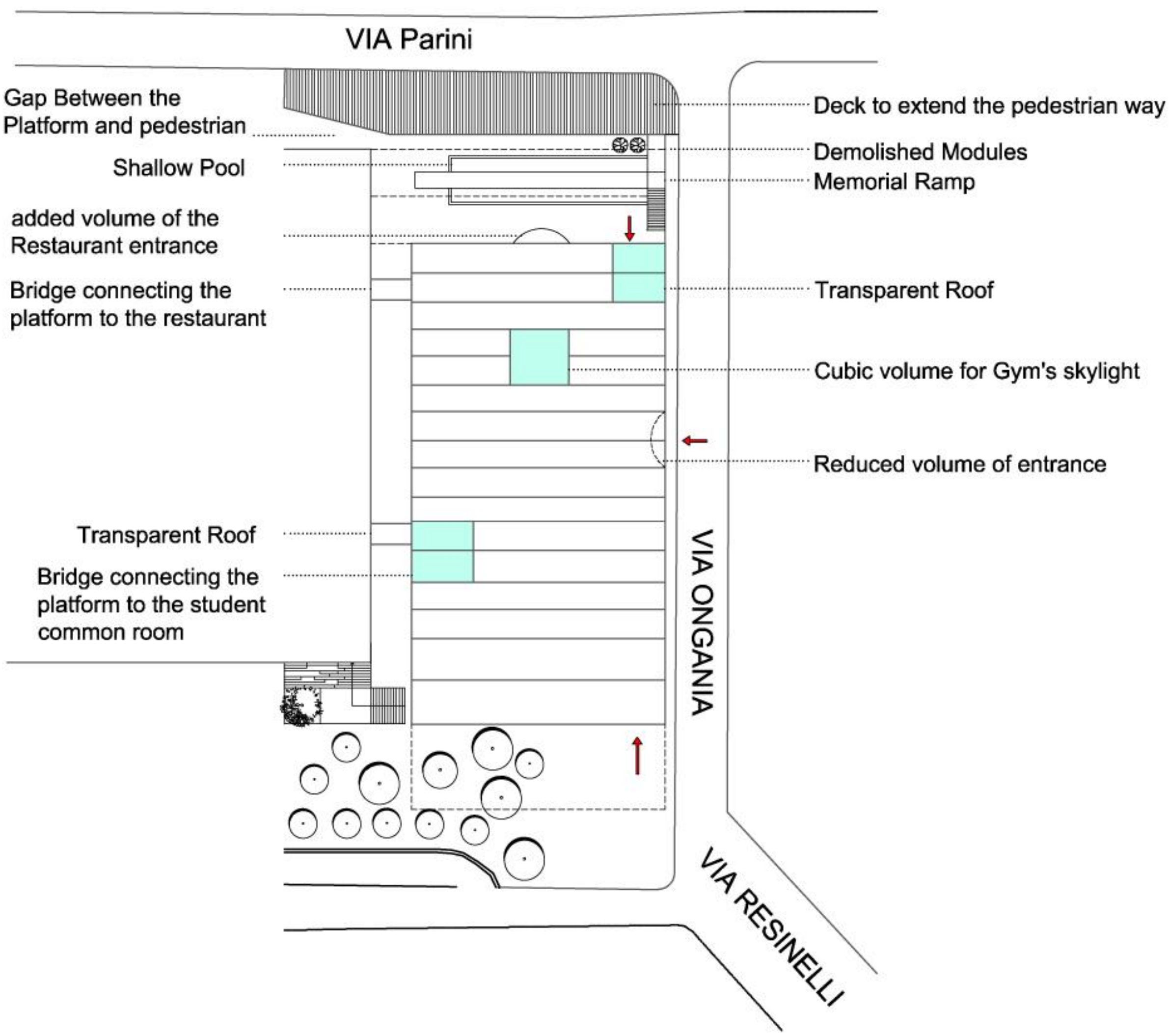


Fig. 3.10: refurbishment interventions

3.2.2. Demolition and Construction Plans

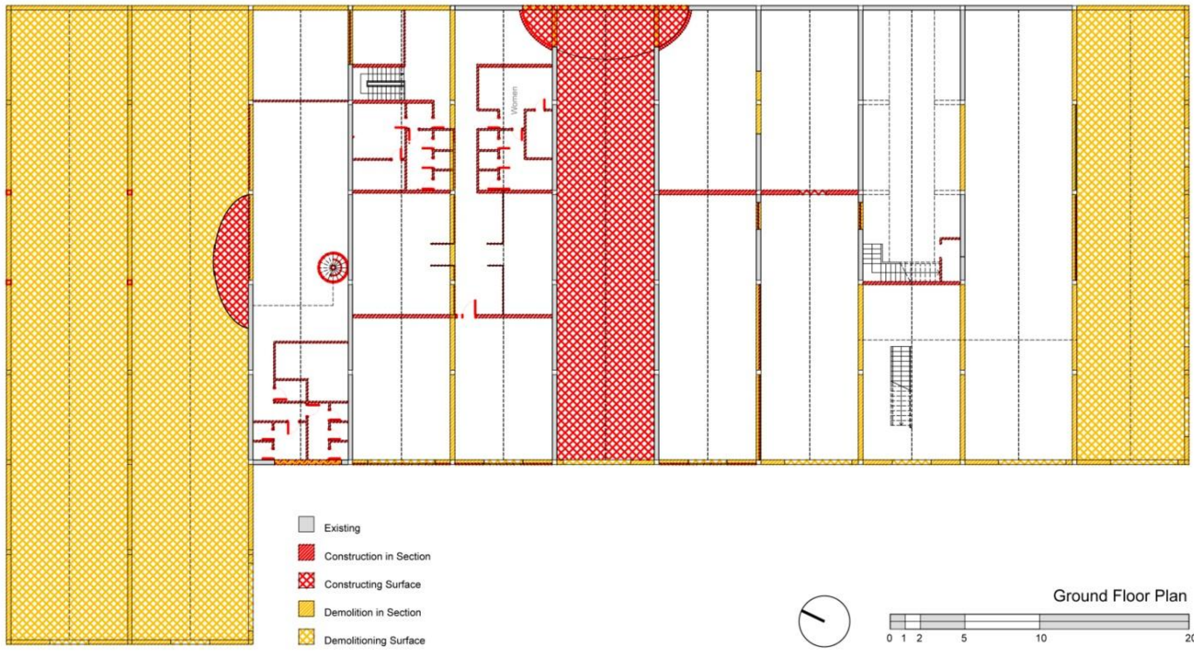


Fig. 3.11: ground floor demolition and construction Plans

Fig. 3.12: first floor demolition and construction plan

3.2.3. Refurbishment Drawings

3.2.3.1. Plans

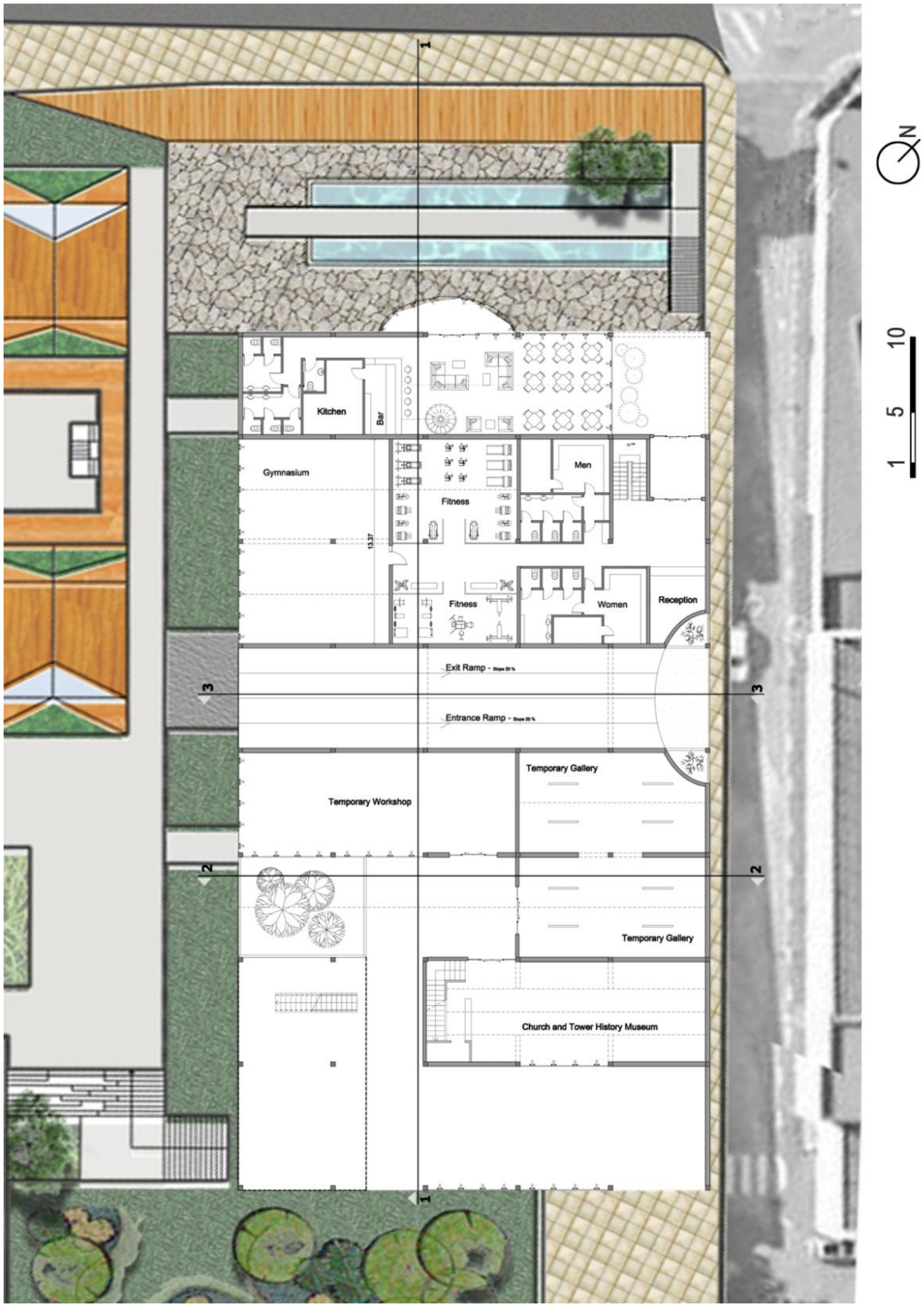


Fig. 3.13: the ground floor refurbishment plan

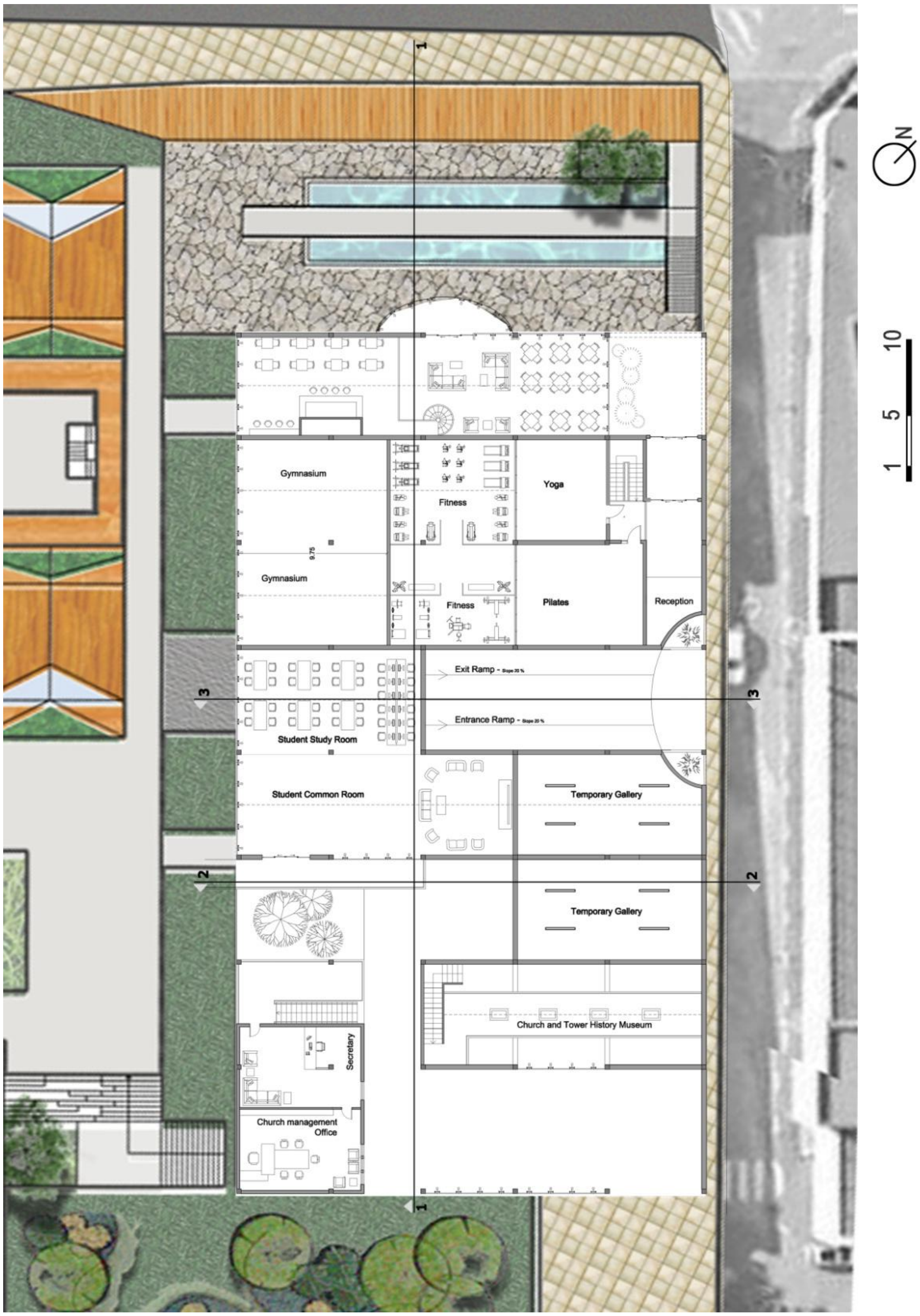


Fig. 3.14: the first floor refurbishment plan

3.2.3.2. Sections

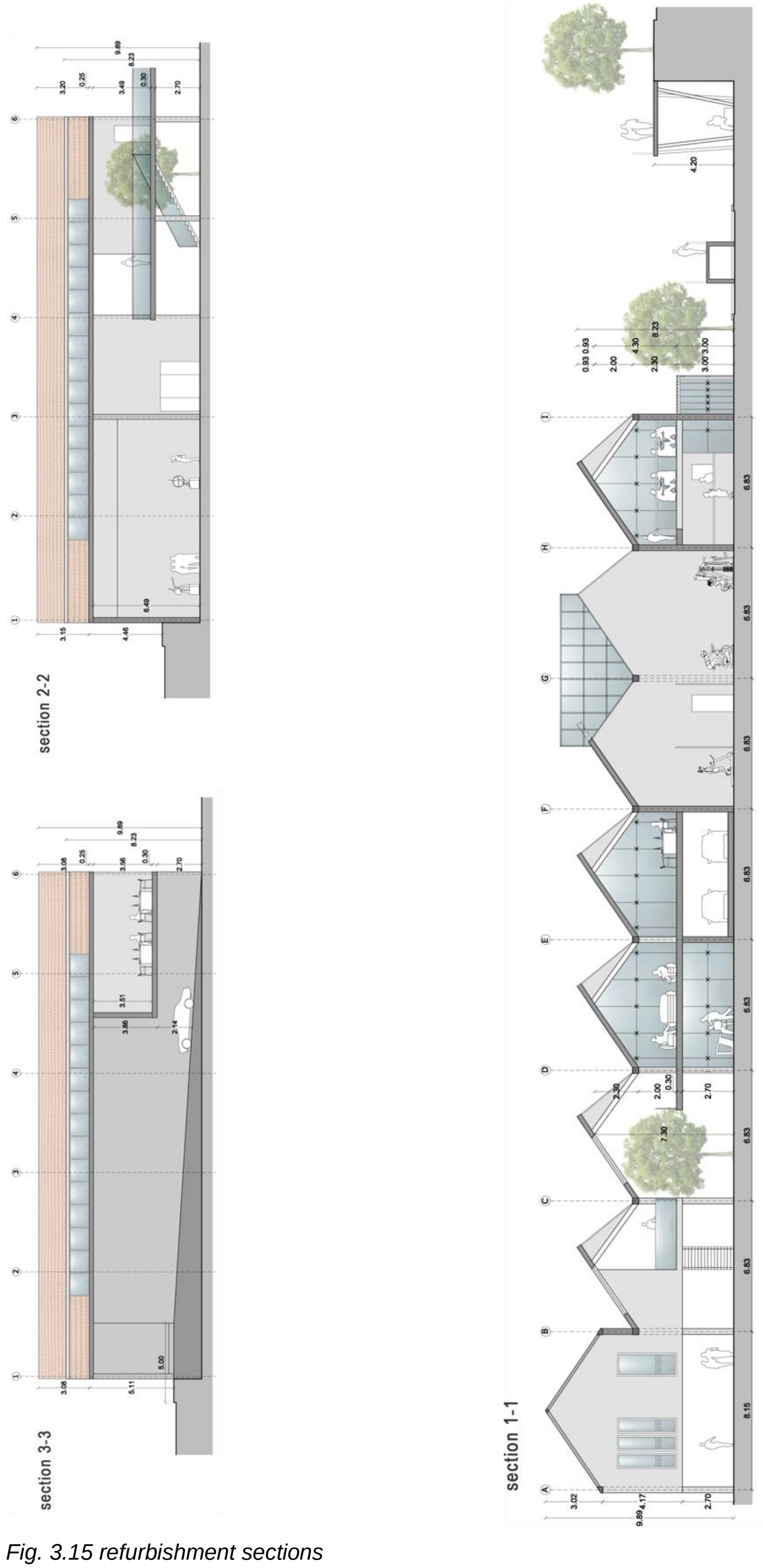


Fig. 3.15 refurbishment sections

3.2.3.3. Renders

Fig. 3.16: 3D view from the platform to the connecting bridge

Fig. 3.17: 3D view to the parking entrance

Fig. 3.18: 3D view to the public space in front of restaurant

3.3. Parking

The current usage of the site is a controlled parking which is under the management of the church. As central part of Lecco has a strict traffic regulation, this parking is bearing a considerable load, especially for the local neighborhood. This capacity should be observed also in the new program for the area. Due to the dense urban fabric in this zone, the best place is the same existing one. Then the modules will be placed on a platform which covers the parking area.

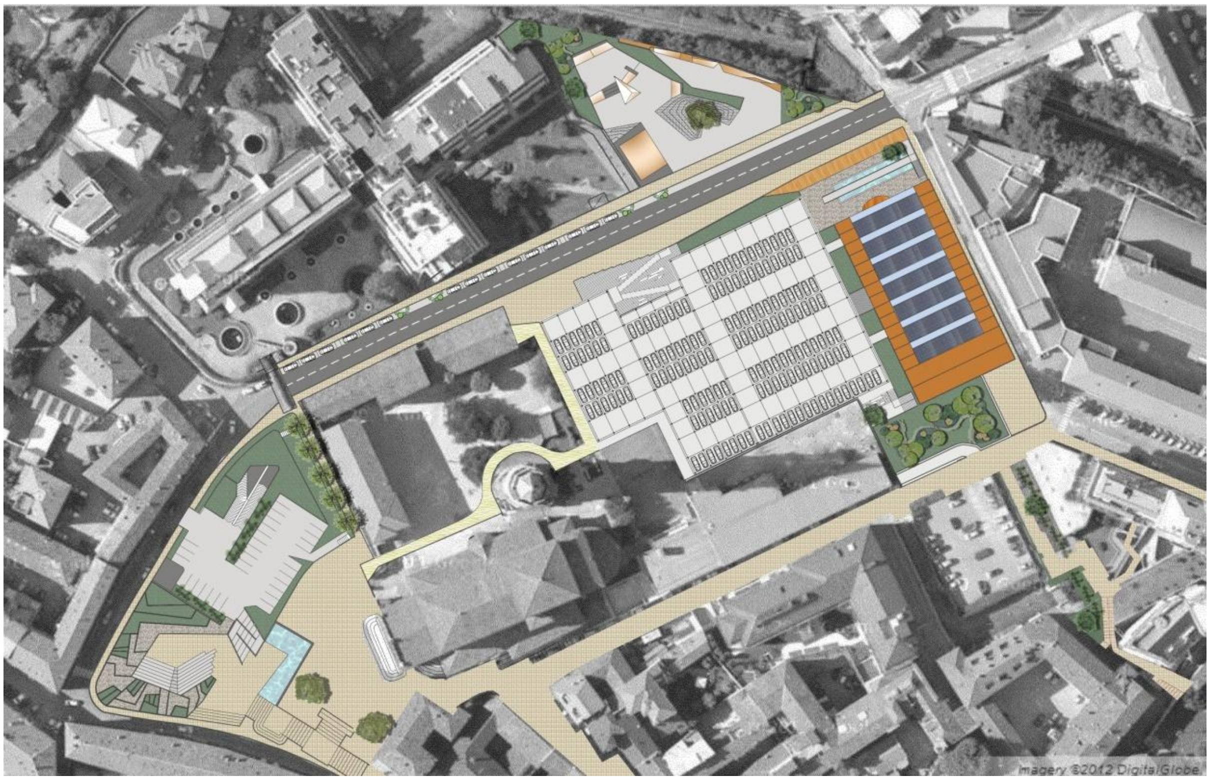


Fig. 3.19: parking in the master plan

3.3.1. General Concepts

3.3.1.1. Foundation

As it is spoken before, the municipality of Lecco might have a general plan for development of area which due to insufficient budget is postponed to an undefined time. Reconstruction will impose not only more costs but also more environmental pollution, waste of material and energy. In order to avoid that, from the very early step, the possibility to get dismantled easily and be used again was one of the main concerns of the project. For this reason, the system is chosen to be foundationless. It is anchored to the prepared ground. This is the typical solution for the single story parking. The resistance of the upper level story is enough to bear the load of a low traffic of cars.

Fig. 3.20: a foundationless single story parking

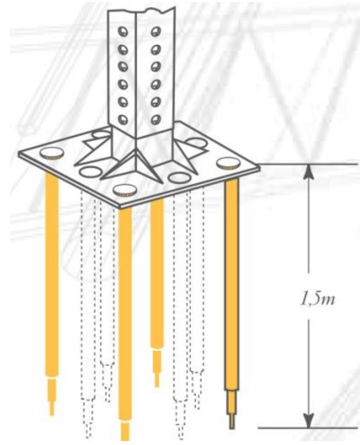


Fig. 3.21: demonstration of foundation system

3.3.1.2. Gabion

One of the most important characteristics of Lecco is the rocky mountains which surround it. This is for sure one of the iconic images which will stick in mind of anyone who has ever visited this city. To remind this image and emphasize on the rigidity of the base which will later host the modules, the material chosen for some parts of its envelope is chosen to be gabion full of the local stones.

Fig. 3.22: city of lecco

Fig. 3.23: typical gabion wall

Fig. 3.24: 3d view to gabion wall around parking

3.3.2. Access and Circulation

The car circulation has been designed in a way not to have longer direct pathway more than 30 meters. In this way, unnecessary traffic inside the parking will be avoided. The main entrance and exit access for the cars is through one of the modules of the refurbished building. This length provides the desired ramp to connect the street level to the lower level of the parking. Several exits have been considered for the pedestrians, each of them arrives towards a different destination:

1. *Exit towards the residential neighborhood*
2. *Exit arriving to the main stairs of the student residents*
3. *Exit to the public space in front of the new restaurant and GYM*
4. *Exit for the church museum and towards the station direction*
5. *Exit going to the lake side through the pathway along the church*

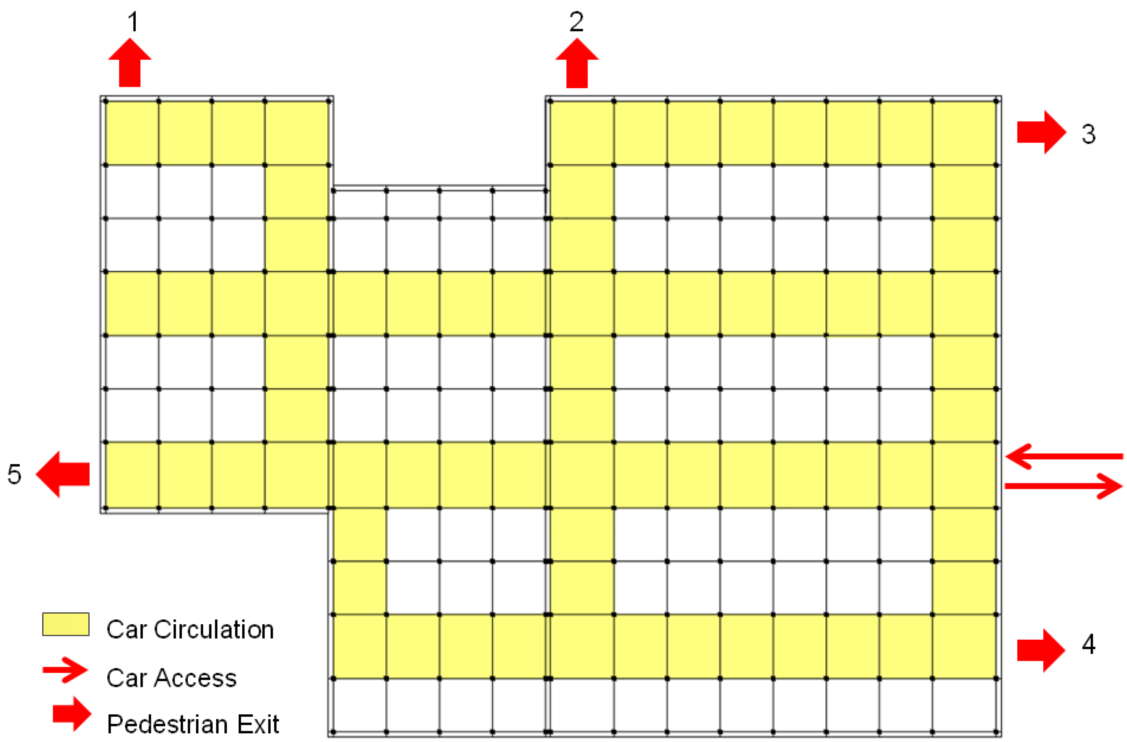


Fig. 3.25: circulation and accesses

3.3.3. Capacity

The new arrangement provides enough space for 156 cars. This number is more than the existing capacity of the site which is not defined in any specific order.

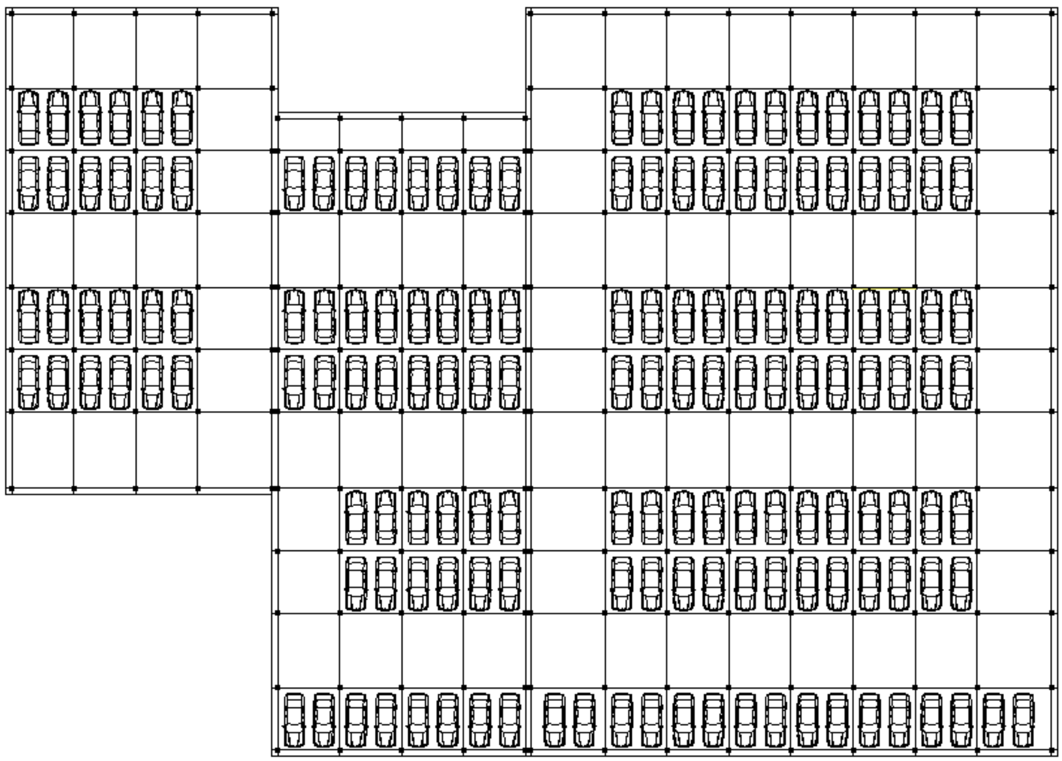


Fig. 3.26: parking arrangement inside the parking

3.4. Modular Residential Complex

Due to the presence of the Politecnico di Milano campus in Lecco, many non-local students live in this city. Besides, opening the new campus will attract more people who need to be accommodated. This was the main reason for choosing the function. Moreover, the community of highly educated people can make a good co-operation with the church site, in order to improve the cultural quality of the neighborhood. Their combination can bring a new spirit of life and activity for this zone. As a result, young students are inhabited in a well located area of the city center, a forgotten land will be upgraded and more safety will be provided by their presence and interaction with the city.

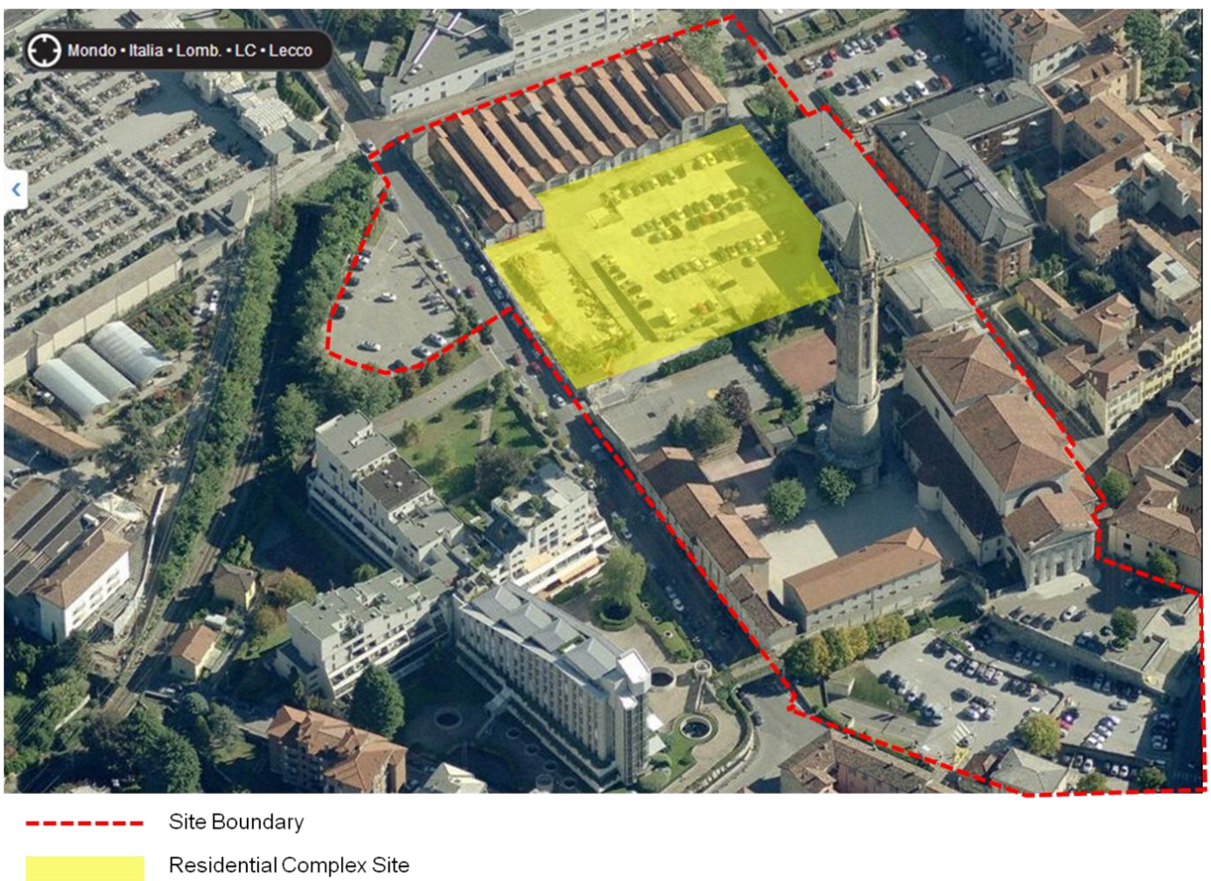


Fig. 3.27: location of the proposed site

3.4.1. General Concepts

3.4.1.1. Separated Structures

The scope of this thesis, is studying alternatives to recycle the empty spaces inside the city. In this project to find an answer to this concern, the focus is mainly on the residential complex to reach a modular system for student housing. The parking is an additional necessity for this particular site, so it is not logical to involve it in the design theme of the project. That is the reason that the structure of the modules is seen something different from the parking. The parking provides only a base to place the units.

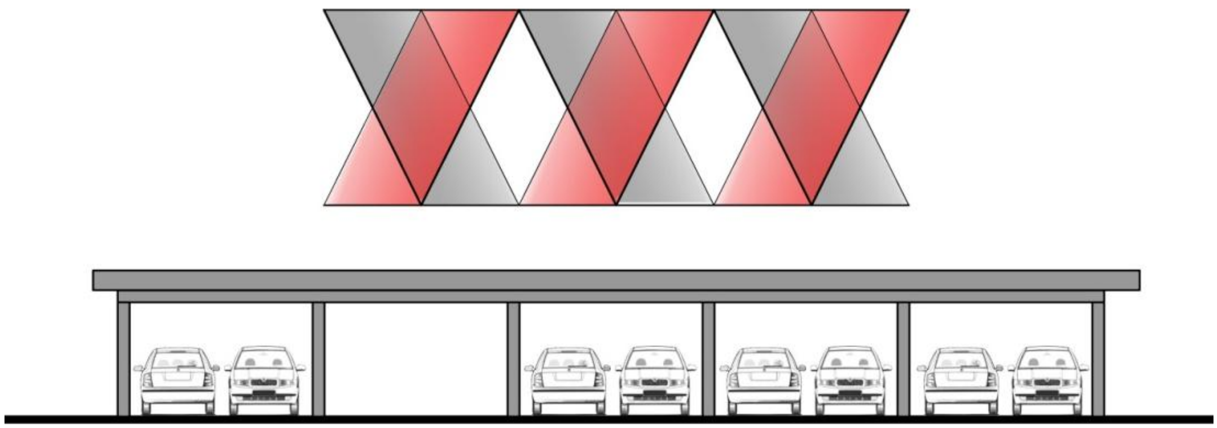


Fig. 3.28: illustrating the separation concept

3.4.1.2. Assembling and Dismantling

The voids inside the city might be located in any place and any shape. This fact requires the system to respond issues of mobility and buildability. The modules should be designed lightweight to faceplate the transportation and on-site work. On the other side, the municipality and the owners not always have a clear plan for these empty lands. These modules might be used for a long or short period but they should be able to satisfy the possibility to serve for a long time or get dismantled after a period and be reassembled in a new location. The methods applied for this dual feature are discussed in detail in the part of Buildability.

3.4.1.3. Cloisters

It was discussed before that the entire site boundary belongs to the church of San Nicolò. This includes all the properties inside the land, the schools, the abandoned building and also the parking zone which is decided to be the location for the modules. This knowledge, in addition to the strong spiritual effect of church on the site reminded us of the idea of "cloisters".

In definition, cloisters are quadrilateral enclosures surrounded by walkways which are usually attached to a monastery or a church, sometimes to a college. It afforded a mean of communication between the buildings and was the center of activity for its inhabitants.

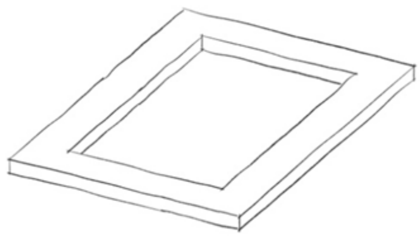
All these concepts suit this project conditions and requiries. The students also live in a community and a small scale society will form among them which requires its own features. It is a semi public-private space that belongs only to the complex and its inhabitants while being separated from the surrounding neighborhood. This internal public space in the heart of the complex, not only facilitate the physical connection among the units but it also can strengthen the relation between the students.

Fig. 3.29: Cluny Abbey, France [1]

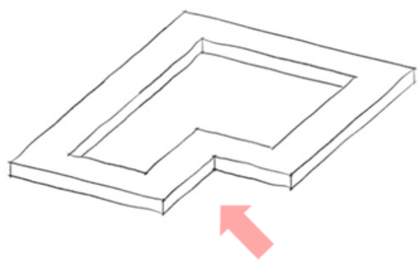
Fig. 3.30: Cloisters, South Transept of Cluny Abbey[2]

[1] *http://www.familyholiday.net*
[2] *http://www.travelblog.org*

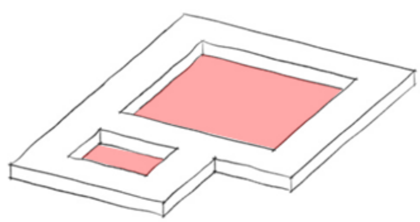
The pictures below illustrate the conceptual sequence of transforming a simple cloister to a desirable configuration according to the needs of the project and the restrictions of the site.



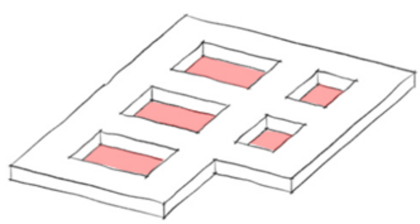
1. The initial site boundary is a perfect rectangle.



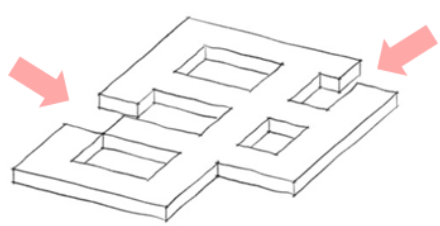
2. The corner adjacent to the church sets back towards inside to regard the church importance.



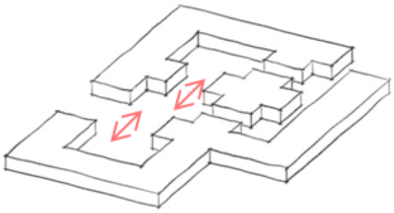
3. The internal cloister is divided to two parts in order to achieve perfect rectangular shapes.



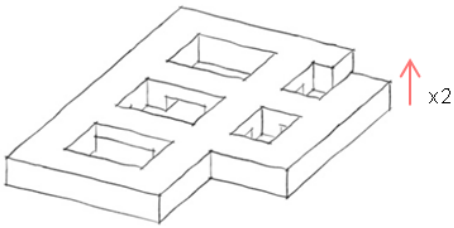
4. Additional divisions has been applied to harmonize the proportion of small cloisters.



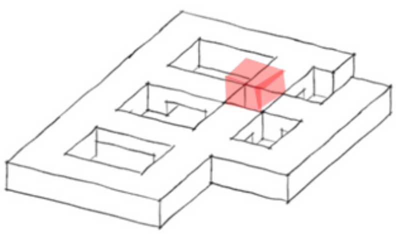
5. The accesses to the site has been opened.



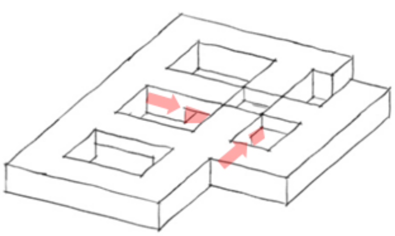
6. The internal access to connect the cloisters to each other has been opened.



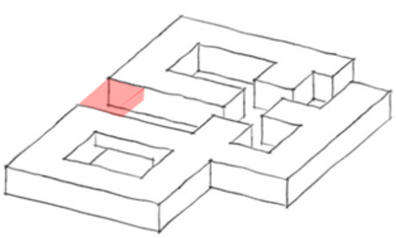
7. The whole complex is elevated to double story height.



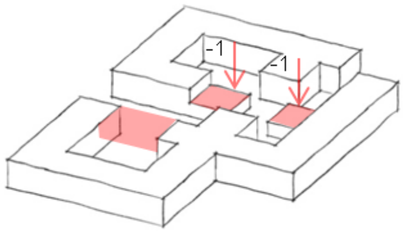
8. The central intersection gets empty to emphasize on the zone.



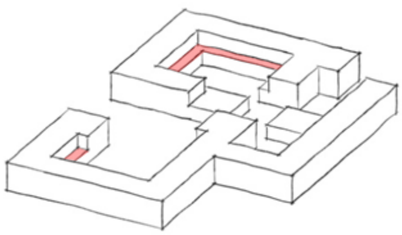
9. The entrances of internal cloisters are moved towards the central zone.



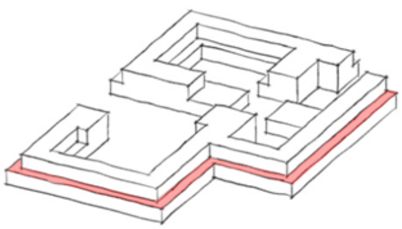
10. The volume over the main entrance has been removed and those around the central zone set a bit backward.



11. The height of two sides of the central zone is reduced to one story. The volume on the corner cloister is removed.



12. The conceptual pathway for the second level is considered.



13. The possibility for balconies is seen on the second floor.

3.4.1.4. Voids inside Void

The former feature of the site was a void inside the city but a void should not always be perceived as a negative place. If designed properly, it can improve the perception of space.

However he parking and the residential complex are separated from each other in terms of structure, they can indirectly be connected by the means of some green holes inside the platform. These internal voids have a dual advantage which works for the parking and for the modules. The green space will transform the spiritless atmosphere of the parking, granting a new spirit of life to it. While the above cloisters and units can also take advantage of the beauty and micro climatic benefits of the gardens.

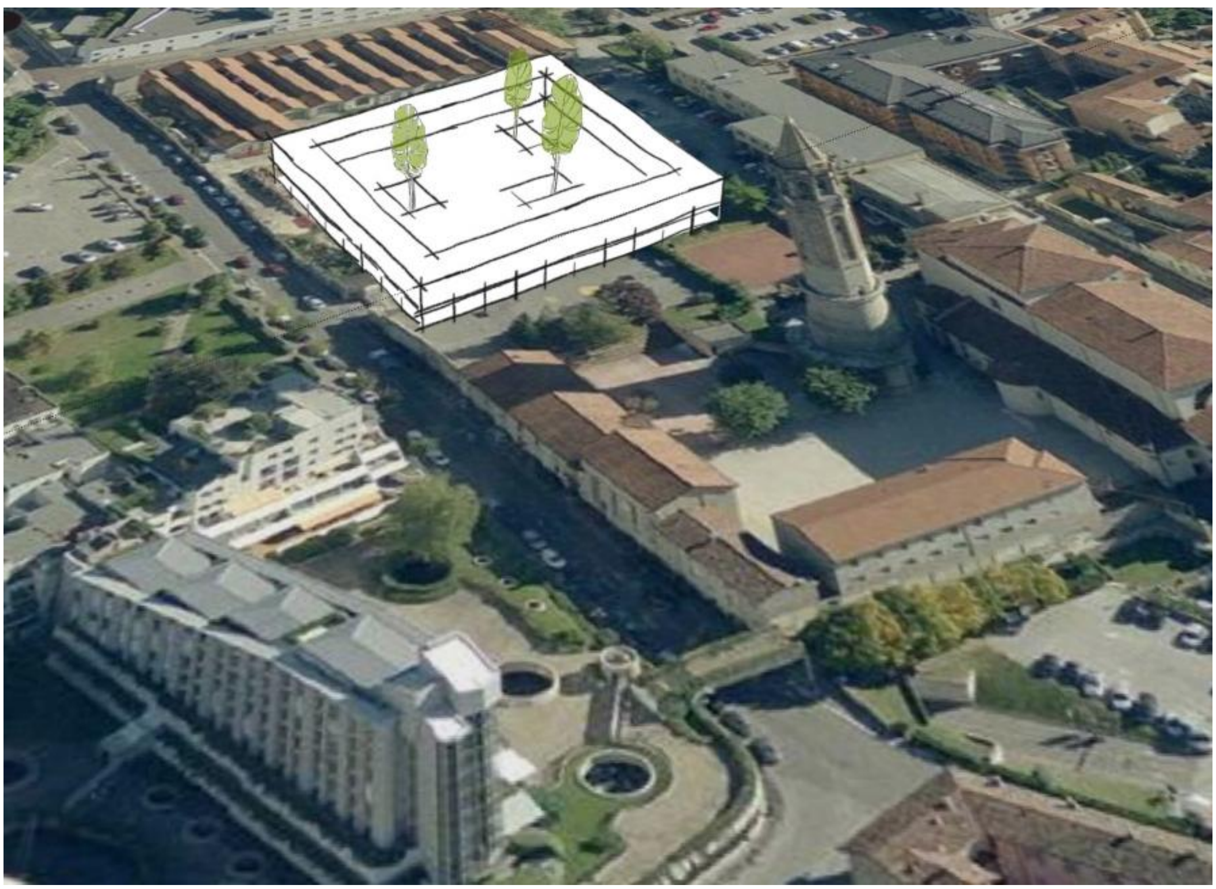


Fig. 3.31: illustration of the proposal void inside the city and the concept.

3.4.2. Residential

3.4.2.1. Accesses

3.4.2.1.1. Platform Accesses

The main access to the complex is considered from Via Parini where a significant ramp-stair is designed to emphasize on it. It is consisted of stairs and a ramp which connects the street level to the height of the platforms. The stairs continue downward to the parking surface. This continuity provides a vertical connection among the three levels of parking, street and platform. In between the stairs, some random openings have been considered in order to change its role from a pure passage mean to a place where people also can sit.

The other entrance is provided to welcome the people arriving from the station direction. The access is possible from the side corner of the refurbished building which is indicated by an arrow in the figure 3.31. The same possibility as the main entrance is seen also for these stairs, but the passing and staying zones are separated from each other not to interfere in each other criteria.

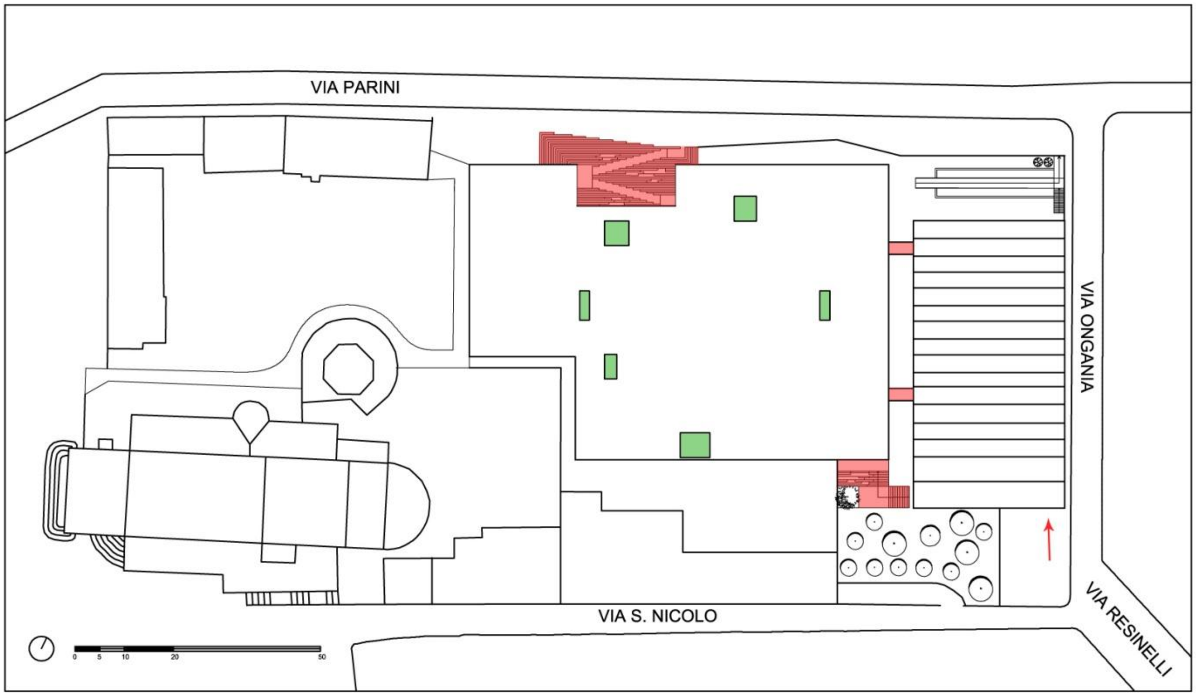


Fig.3.32: illustration of accesses to the platform

Fig.3.33: access through the refurbished building

Fig.3.34: main entrance

There are two narrow bridges which connect the platform to the second level of the refurbished building. The first one directly arrives in the restaurant while the second one provides a passage to the internal courtyard of the building where there is a common gathering place for the students.

Fig. 3.35: bridge connection the platform to thestudent common room

3.4.2.1.2. Modules Layout and Connection

The final arrangement of the modules on the platform, based on the previously discussed concepts of cloisters and also the restrictions due to the land size and surrounding buildings are illustrated in the figures 3.36 and 3.37. The modules are mainly placed in the direction of South-North and their entrance is provided from the internal courtyards.

The staircases which enable the vertical connection between the two levels are also shown in the picture. They are designed in different locations in order to cover all the second floor level. So, the residents do not pass more the 20 meters to reach their houses.

All types of the modules have been applied in the first level to take the most out of their features. The variety of types also enables the possibility to make a good mass and void relation for the complex.

Fig. 3.36: first level layout

On the second level, there are only modules of type B. They are connected to each other through the walkways which go around them and are drawn in the figure below. As the first level, all the entrances are seen around the internal courtyards of each part.

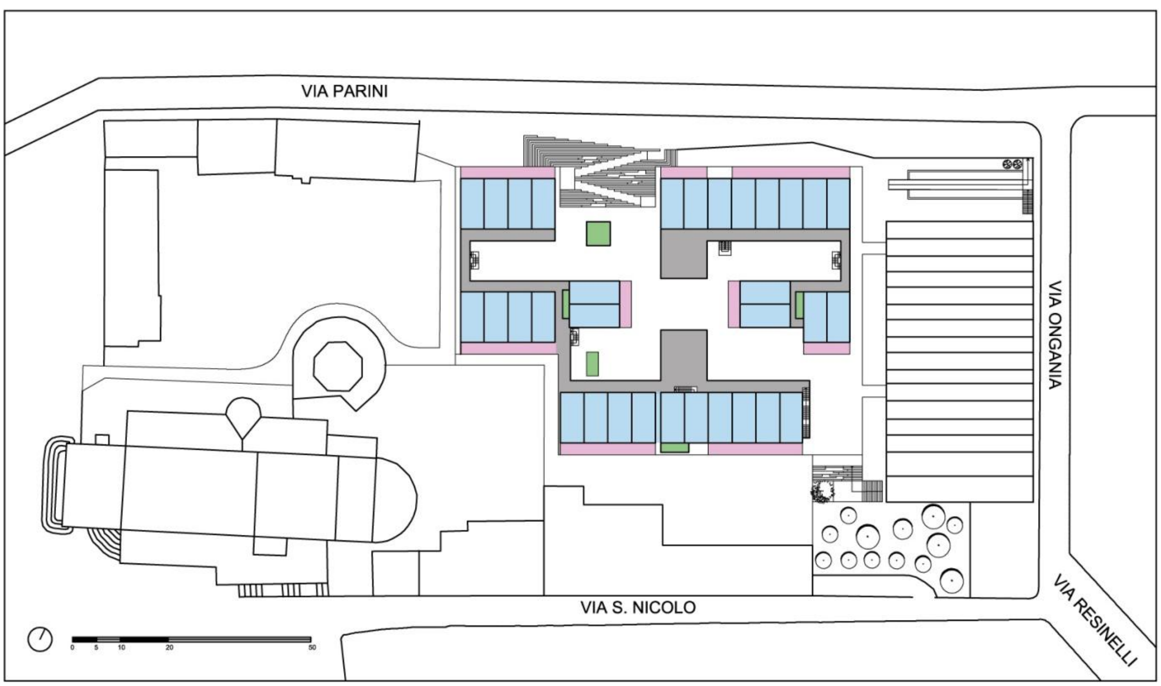


Fig. 3.37 second level layout

3.4.2.1.3.   *Modules Layout Typology*

Fig.3.38:first level typology

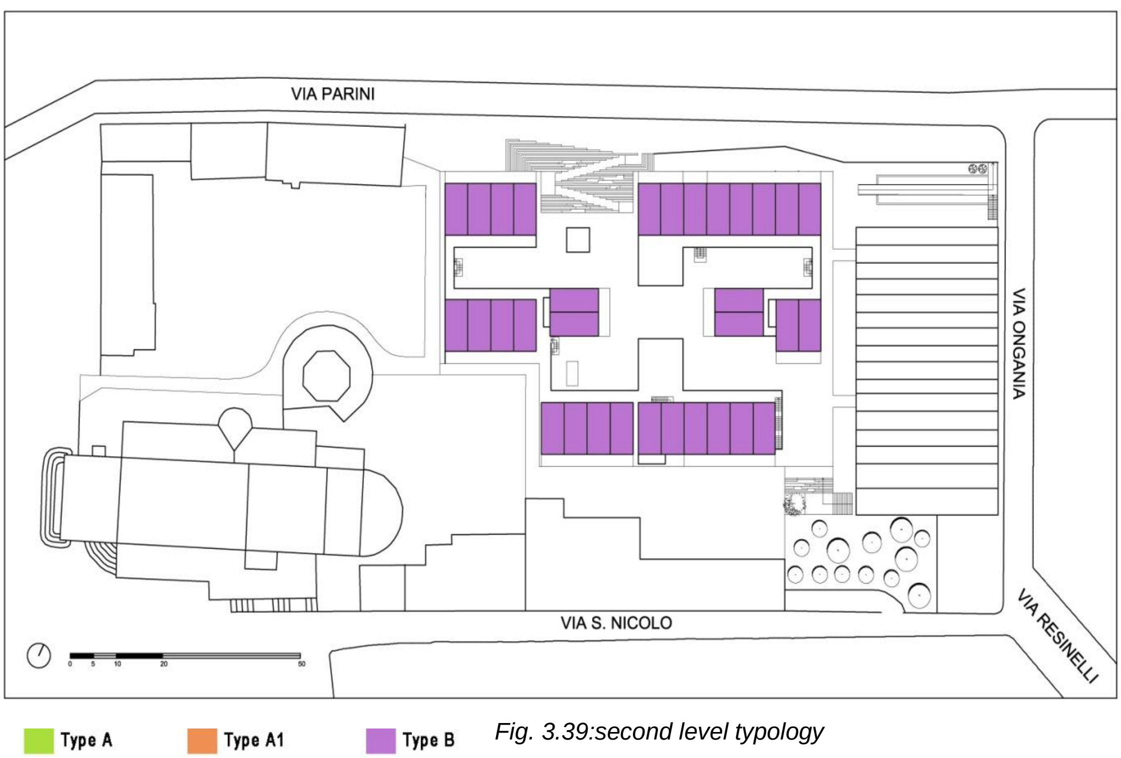


Fig. 3.39:second level typology

The table below is demonstrating the quantity of modules applied in the proposal site layout.

Typology	Quantity	Inhabitance
A	21	42
A1*	6	12
B	38	38
Total	65	92

*

The type A1 is a subtype of building Type A which is half module (2.5 m) smaller in length.

3.4.2.2. QuaDror

3.4.2.2.1. QuaDror Joint System

QuaDror is a new space truss geometry that is made from the assembly of four identical L-shaped pieces, either thin resulting in a trestle structure, or thick resulting in a solid panel. [3]
To reach the interlocked planar joint, both plates need an adequate thickness in Z direction to provide the proper support for the other plate.
Configuration process:

1. *Division of two planar square elements to four by four parts.*

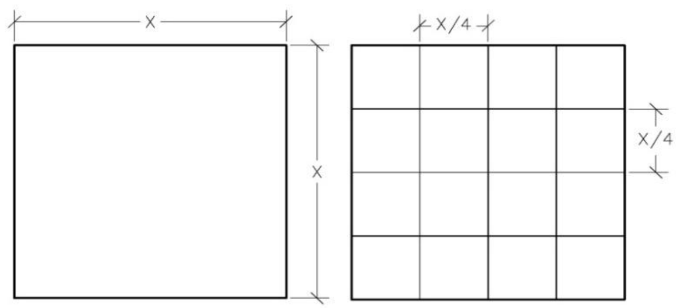


Fig. 3.40: initial planar division

2. *Splitting each square to two L shape*

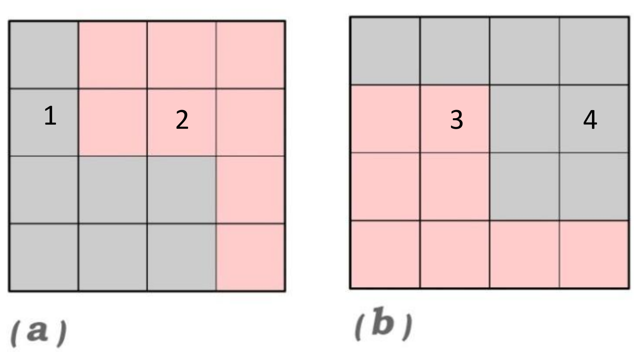


Fig. 3.41

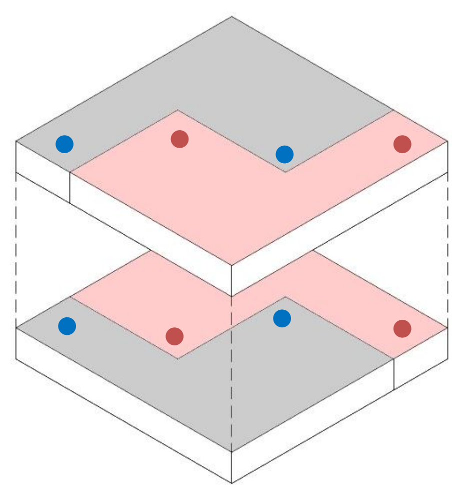


Fig. 3.42: The connection geometry

3. *fasten the L shape blocks together in pairs before we can unfold it in following order:*

Element number one to number four are connected face to face on two module faces as shown and similarly with elements number two and three. The two pairs of blocks have to be fastened while they are interlocked.
There is an axis of symmetry, perpendicular to the shear direction. This is the hinge axis, and is the axis that the blocks rotate around to unfold the QuaDror.

---

[33] http://www.quadror.com

The QuaDror angle is the angle that each half must be rotated in order to fully open the QuaDror. The inside (stopped) cuts angle in different directions. The concept of the QuaDror hinge can be extended to large numbers of modules.

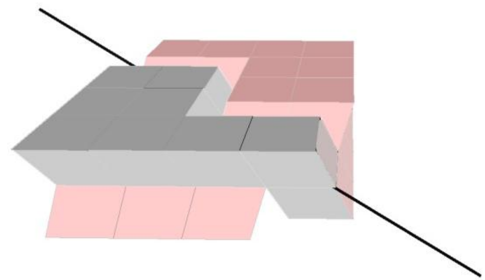
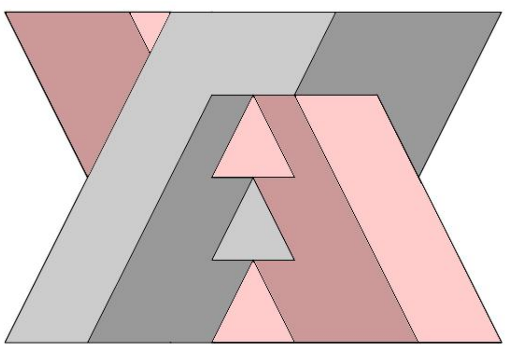
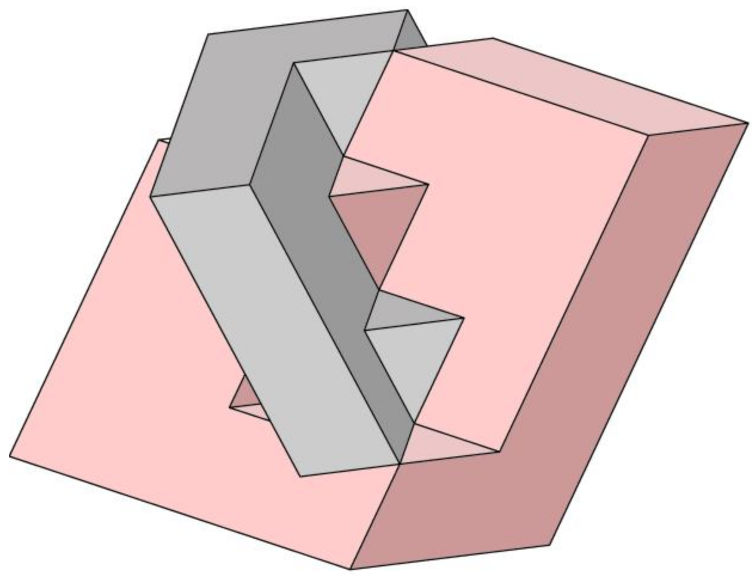


Fig. 3.43: axis of the symmetry is perpendicular to shear direction

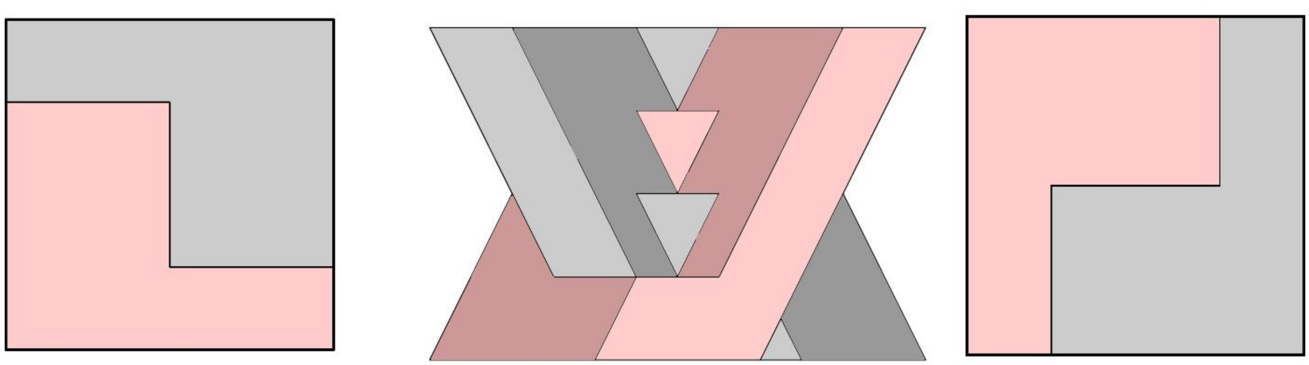
As it mentioned the joint is made of two planar pieces, which are first cut to L shape pieces and screwed and then are tilted and expanded to provide the final shape.to reach this, the interfaces between L shaped pieces need to have specific angle, so the front screwed elements can interlock and form the final shape. To reach the specific angles, first one needs to know the final angle which the joint is needed to provide for horizontal (beam) and vertical (column) elements.
So, by a reverse process it is possible to reach the required angle.



Plan



3D view



Left side view

Front view

Right side view

Fig. 3.44: QuaDror joint

Main advantages of the joint

- *Self-standing joint*
- *load-bearing capacity of a cube with only 1/5 of its volume*
- *The panels can be pre-manufactured and shipped flat, reducing both construction time and use of heavy machinery on-site.*
- *Adaptable to a variety of conditions and configurations.*

Frame system

also this joint system is developed by the same designer to use as frame configuration.

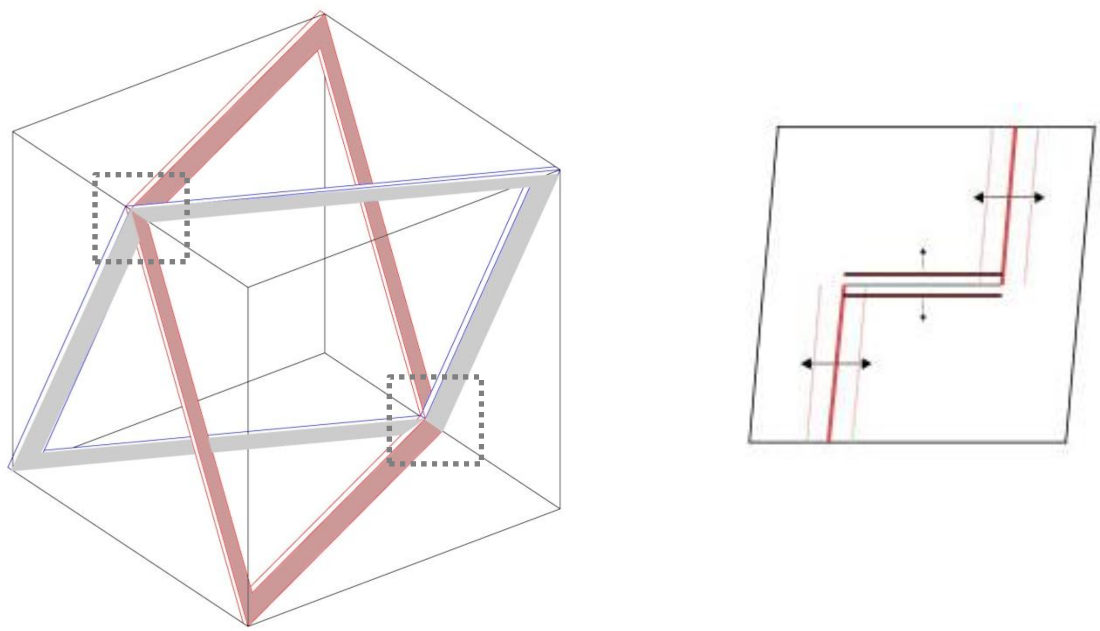


Fig. 3.45: application of the QuaDror in frame system

Main advantages

· Comparable to an internal diagrid, the diagonalized QuaDror elements provide vertical and lateral support for efficient member design

· QuaDror elements are made from axially loaded, dual-purpose members

· The bearing of the structure is spread to many points consistent with spread footings or plates on grade

· No uplift exists in the structure, which means no anchoring or modification of temporary grounds

· The QuaDror elements are perfectly suited for gravity loads

· The use of typical I-beams for beams and columns

· The performance of the structural support systems lies partially in its collapsibility (self-opening from flat to 3d space truss) and its structural efficiency (which allows for less material)

· Pyramid-, dome- and other polyhedral-solutions for shelters often don't maximize an urban density grid, whereas QuaDror can co-exist with cuboids and rectangular frames.

Dwelling

The housing units employ the QuaDror interlocking frame technology as comprised of eight laminated wood beams. This structural unit works with the same geometric concept. The houses take advantage of the collapsibility of the frames, and are designed as pre-fabricated modular housing units. These structural units are able to ship to site flat, and can then be erected with the corners secured to form four triangular trusses. The trusses are responsible for the downward and lateral forces acting on the house.

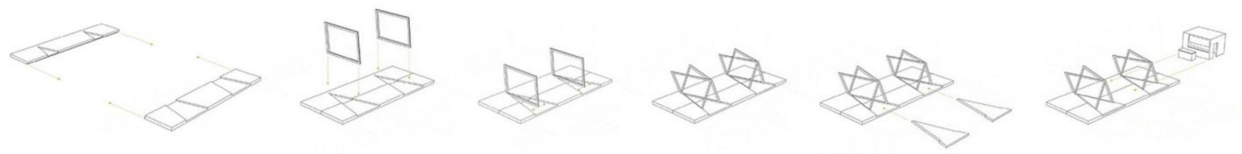
Due to the separation of skin and structure, different options are available for the type and location of solid and glazed walls, allowing for a variety of configurations and appearances.

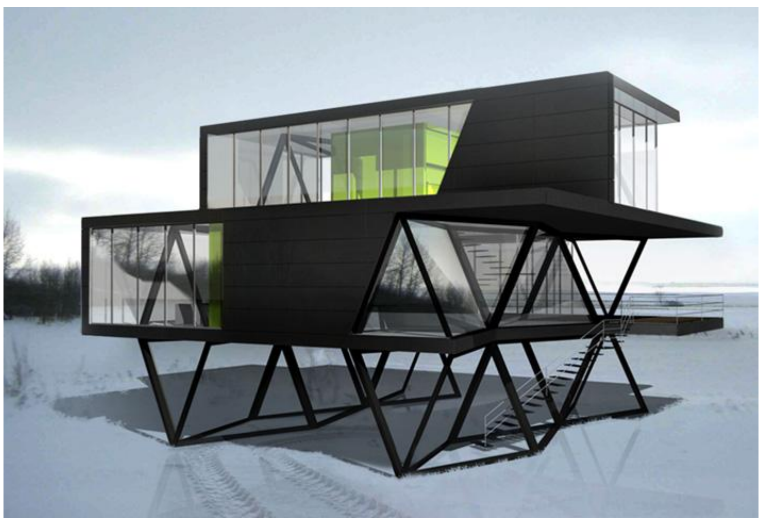
Main Advantages

- *All QuaDror Houses are pre-fabricated, allowing for shorter construction timelines, less labor and less financing fees, minimal material waste, and a reduction of on-site problems, all of which provide for an overall lower cost of construction.*
- *The QuaDror structural system allows for a separation of the skin and the structure, permitting moving enclosure and separation walls.*
- *This separation allows for the house to transition from open to solid for protection during harsh climatic conditions, or when unused.*
- *Adaptability and changeability for unseen future demand is possible when all structure is concentrated to solely QuaDror structural system.*
- *The QuaDror system is able to reduce the amount of foundation; reducing cost, allowing it to be elevated, and permitting it to be placed in difficult sites.* [4]

Fig 3.46: the application of QuaDror frame system in dwelling [2]

[4] http://www.quadror.com





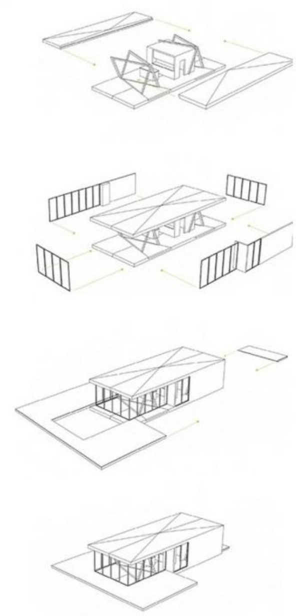


Fig3.47: QuaDror system in dwelling, the process of installation [3]

Art Center

the QuaDror structure has been proposed to Love and Art Children Foundation for the construction of an exhibition space attached to Love & Art Center for the Arts – Casa da Crancia - in Jatai, Brazil. Located in a neighborhood of approximately 1500 children, Casa da Criança Amor e Arte will offer daily enrichment programs. The presence and accessibility of Casa da Criança Amor e Arte aims to empower and have a meaningful cultural impact on the local community.[5]

Project ***The Art Gallery At La Casa Da Crancia***
Location ***JATAI, BRAZIL***
Function ***EXHIBITION SPACE***
Program ***1120*** m^2
Materials ***White Painted Steel, White Polycarbonate Roof, Black Polycarbonate Wall Panels, Corrugated Steel Roof Structure , And Diminution Lumber***

Fig 3.48: art center [3]

[5] http://www.quadror.com

3.4.2.2.2. *Application*

Previously, the QuaDror frame is use as column in buildings. The initial module is comprised of the two QuaDror modular units which are connected with the roof system. In this technique the structure is wrapped by the building envelope.

In this master project, the QuaDror frame system is used as whole structural system of the building, so the modules are replicated in vertical and horizontal direction.

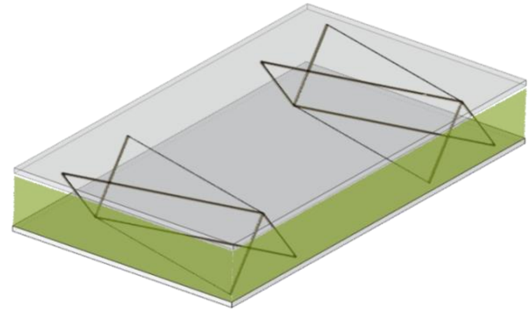


Fig3.49: the QuaDror frame application at DROR studio

The horizontal extension: there are two axes of X and Y in horizontal plane.

> *In Y direction the module is mirrored in XZ plane to be attached in the first module.*
>
> *In X direction the module is placed beside each other in its original shape.*

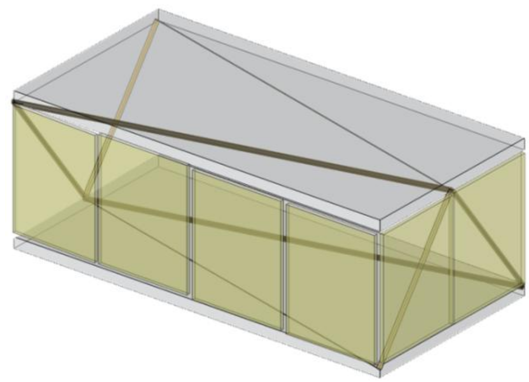


Fig 3.50: the new application of the QuaDror frame

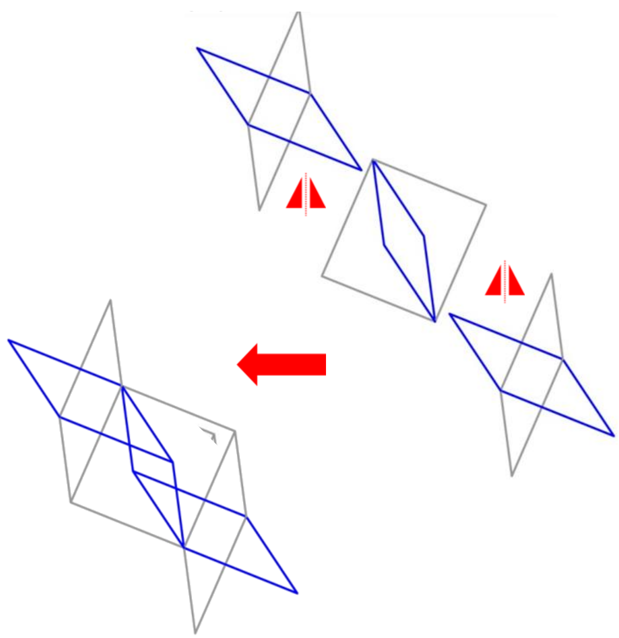


Fig. 3.51: horizontal extension y direction

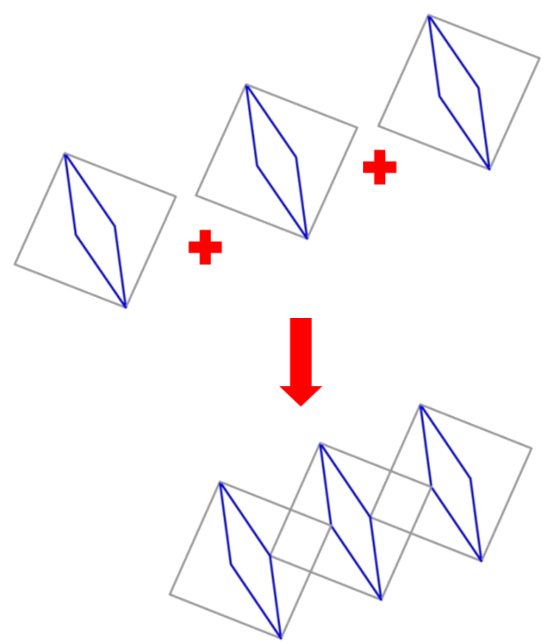


Fig. 3.52: horizontal extension in X

The Vertical extension: the module is mirrored in XY plane to be attached on the up of the first module.

The figures below show the 3D internal spaces that are created by QuaDror frame system.
There are two direction of X and Y. along the Y direction there is pitched space made by the frame and along the X direction there is the rectangular space which is used in this project as main direction of the residential building.

In the next part the process to reach the final dimension and size will be discussed

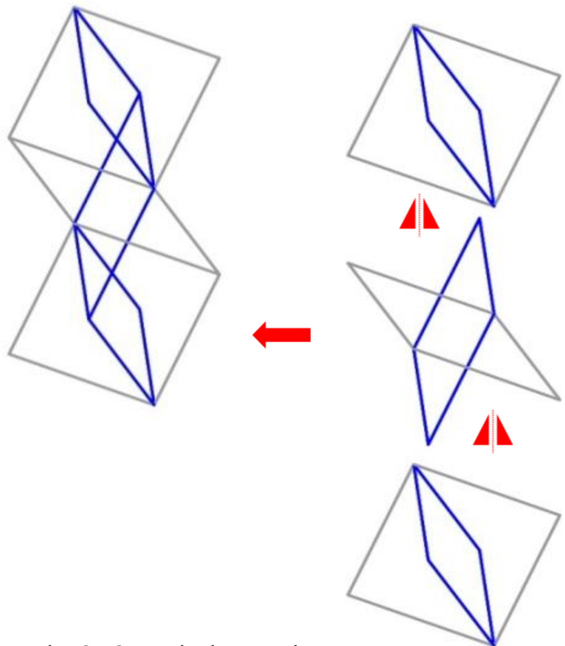


Fig. 3.53: vertical extension

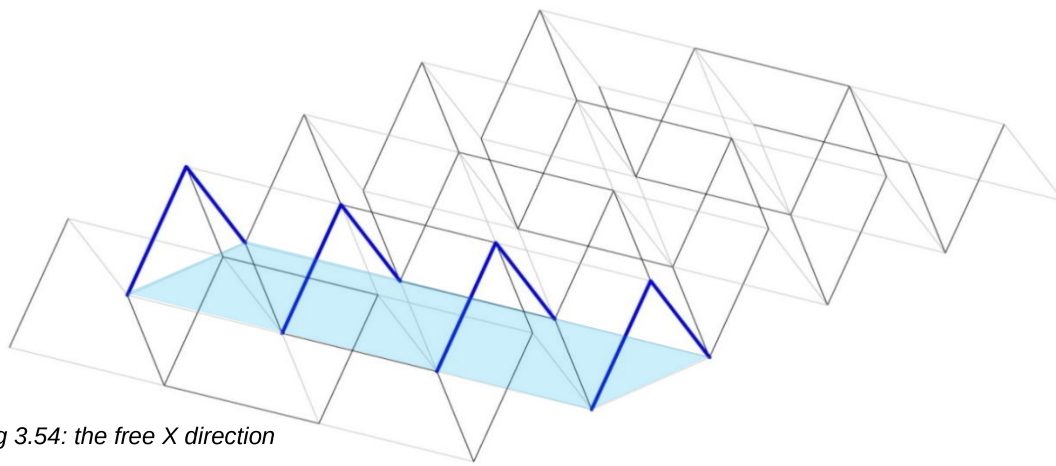


Fig 3.54: the free X direction

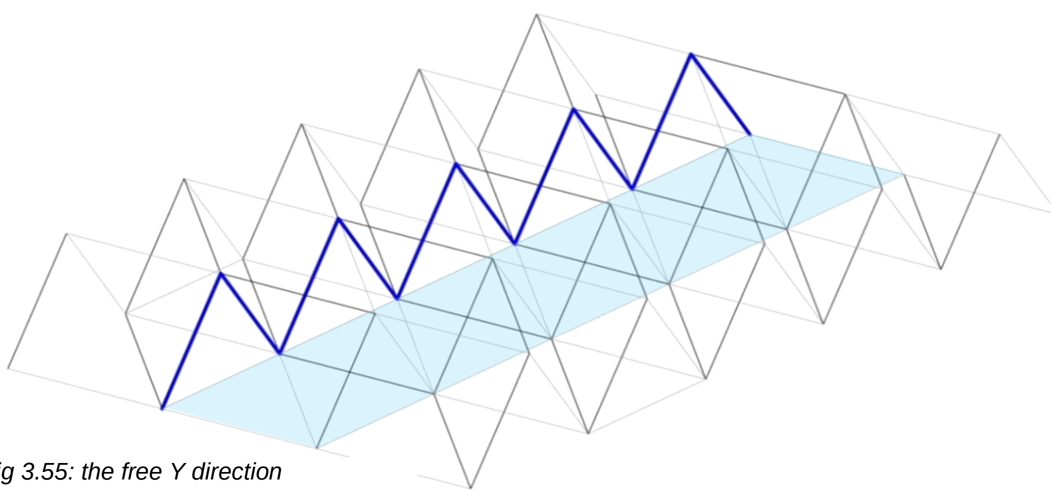


Fig 3.55: the free Y direction

3.4.2.2.3. Scaling the modules

The size of our modules is an important thing. They are meant for living, enjoying, working and providing quality to lifestyle inside them. They shouldn't be narrow or have low ceiling, or dark and confined, but also not empty and with meaningless space without use. Dimensions should be thought at the beginning of the process of designing interior functions as well as they define the final outer shape. This was our process of determining dimensions of our modules.

We had several things to keep in mind and to take care of while sizing the modules:

1. *Structural demands of QuaDror system: The joint where two triangular shapes meet is designed as to have the same angle (**α**) between the two bars coming into the joint from each of the two planes. This is only possible if the height (**c** side) would be equal to the length (**a** side) of the module. The width (**b** side) can vary from these two according to design.*

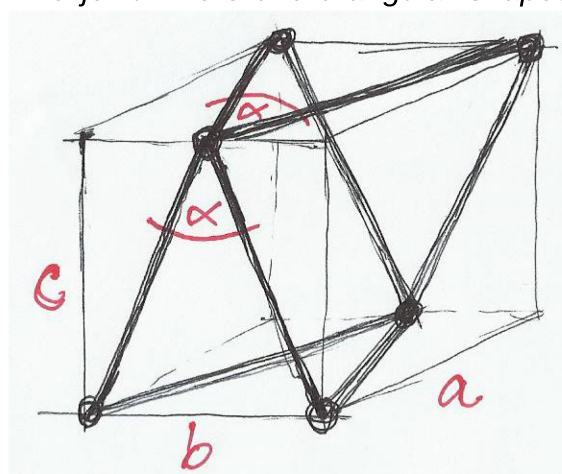


Fig 3.56: angle proportion

2. *Adaptation to human scale: We analyzed the space needed for kitchen, bathroom, dining area and passing space between them and came to conclusion that around 4m would be the minimum dimension of interior width considering these needs and our preferred orientation.*

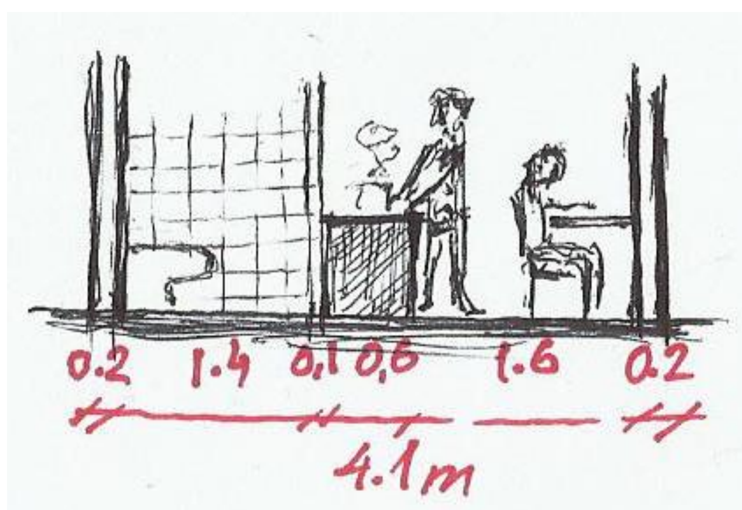


Fig 3.57: human scale adaption

3. *Height: We considered having mezzanine level which needs minimum 2.1m above and beneath the mezzanine slab. Another thing which needed to be kept in mind is the height of the factory and the relation between it and the modules arrangement. Since the modules are placed on top of the platform and thus already raised, and we considered multiplying the modules in height as well, the total height of one module should be kept to a reasonable number.*

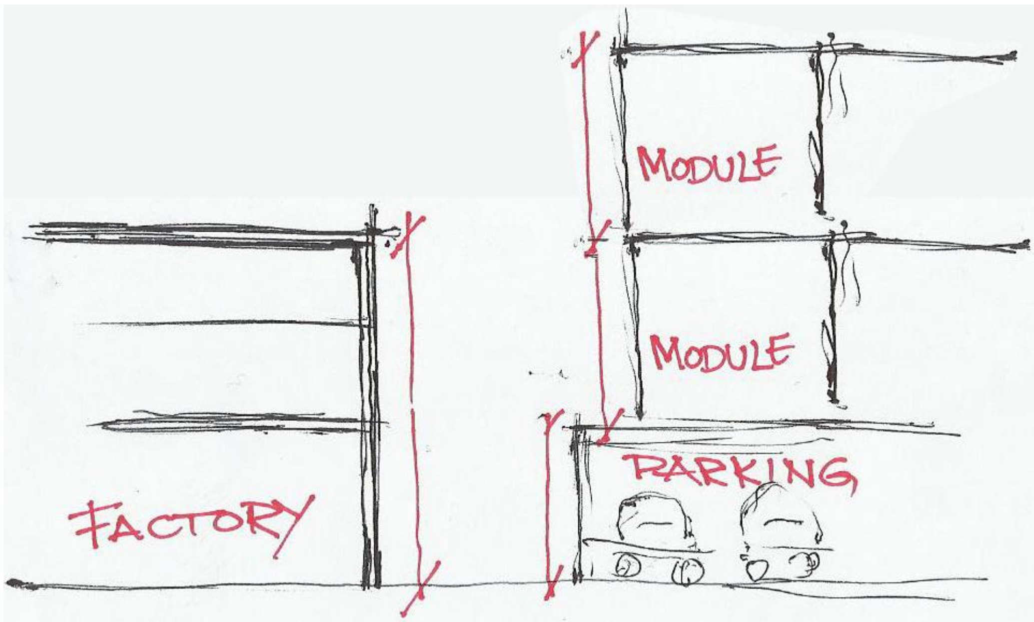


Fig3.58: height consideration

4. *Multiplication of modules: B side is the dimension where the structural members are located, and the modules are multiplied with **a** side adjacent to one another. This is important because the movement is confined through the **b** side while the direction perpendicular to the **a** side remains completely open and column-free.*

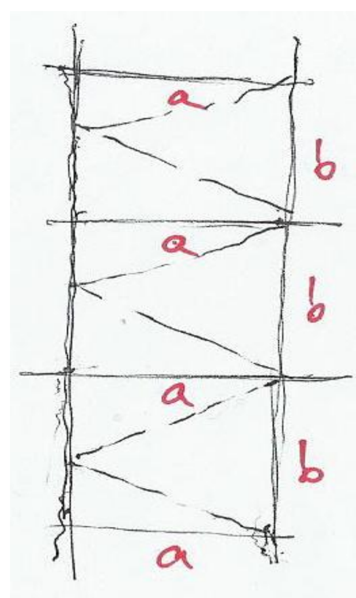


Fig3.59 module multiplication

Having analyzed the requirements we decided the best shape for our module is the cube. By design limits of Quadror system the height should be equal to length, having the width same as well and having a cube allowed us to arrange them in a better way. We realized that the interaction between the modules would be better if they are cubicles because it would allow us to rotate them avoiding bends and parts sticking out; just simply the architecture would be smoother. Also in order to create more dynamic spaces by interacting solids and voids, we would have a good shape to add or remove one cube from the arrangement in order to change the perception of the combination of the modules.

Options: *Knowing this, we had 3 options that came as result of these analyses. All of them were essentially related to height of the module, how we deal with organizing a double or single story apartment in terms of height.*

1. *Single story: One level apartment in various dimensions and internal arrangements, and for different number of people. Benefits would be that the single module would be one apartment, and possibilities of arranging them in the site would be good. However, problem with this solution was that according to Quadror system height should be same as length. For the modules to be multiplied adjacent side is the **a** side to provide a column-free space, which in our design means that in that arrangement **a** side becomes width of the apartment, and we already decided we would need around 4m to be comfortable and have enough space. That gives us the height of each module at 4m, which is problematic in the relationship with the factory height if the modules are to be multiplied in height as well.*

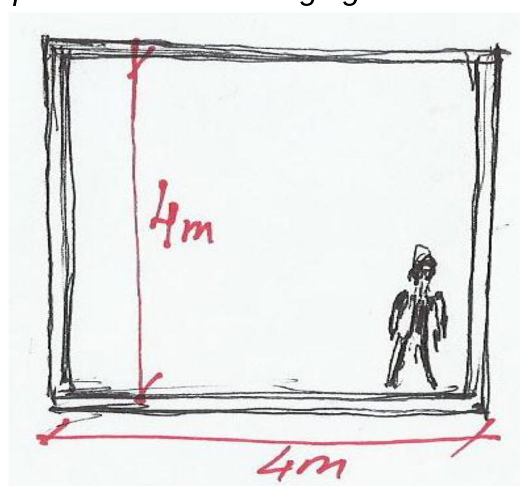
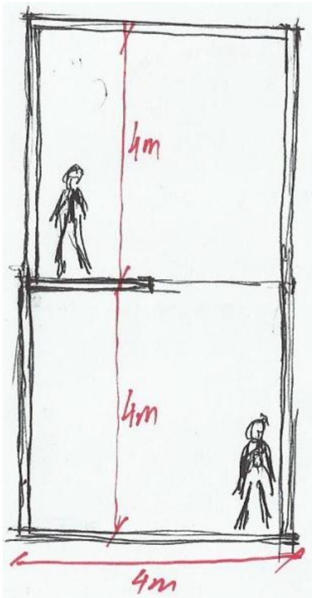


Fig 3.60: single story height

2. *Double story: Similar to the first solution, but with the difference that the modules would be connected creating double story apartments. This gives opportunities to combine the modules in all directions, but again has same problems with relationship to factory as the previous one, and in addition has problems of accessing the second floor, due to structural members going through the floor rather than around it.*



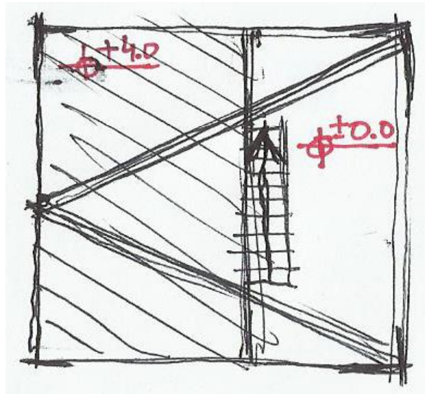


Fig 3.61: double story height

3. Mezzanine: This solution actually increases the height of each module, but within a single module there are 2 levels. This solves the problem of access because the mezzanine level would have different type of structure, also uses the space and volume better and more efficient. Mezzanine levels would be used for bedroom and working space, while the services, living and dining room would remain downstairs, the two latter ones with double height.

Fig3.62: final dimension

Finally, we opted to have mezzanine for the reasons mentioned above, and final dimensions of one module came out as a cube of 5x5x5m, giving us enough height to fit mezzanine level, and enough width to be comfortable in the interior.

3.4.2.3. Residential Complex Drawings

3.4.2.3.1. Plan

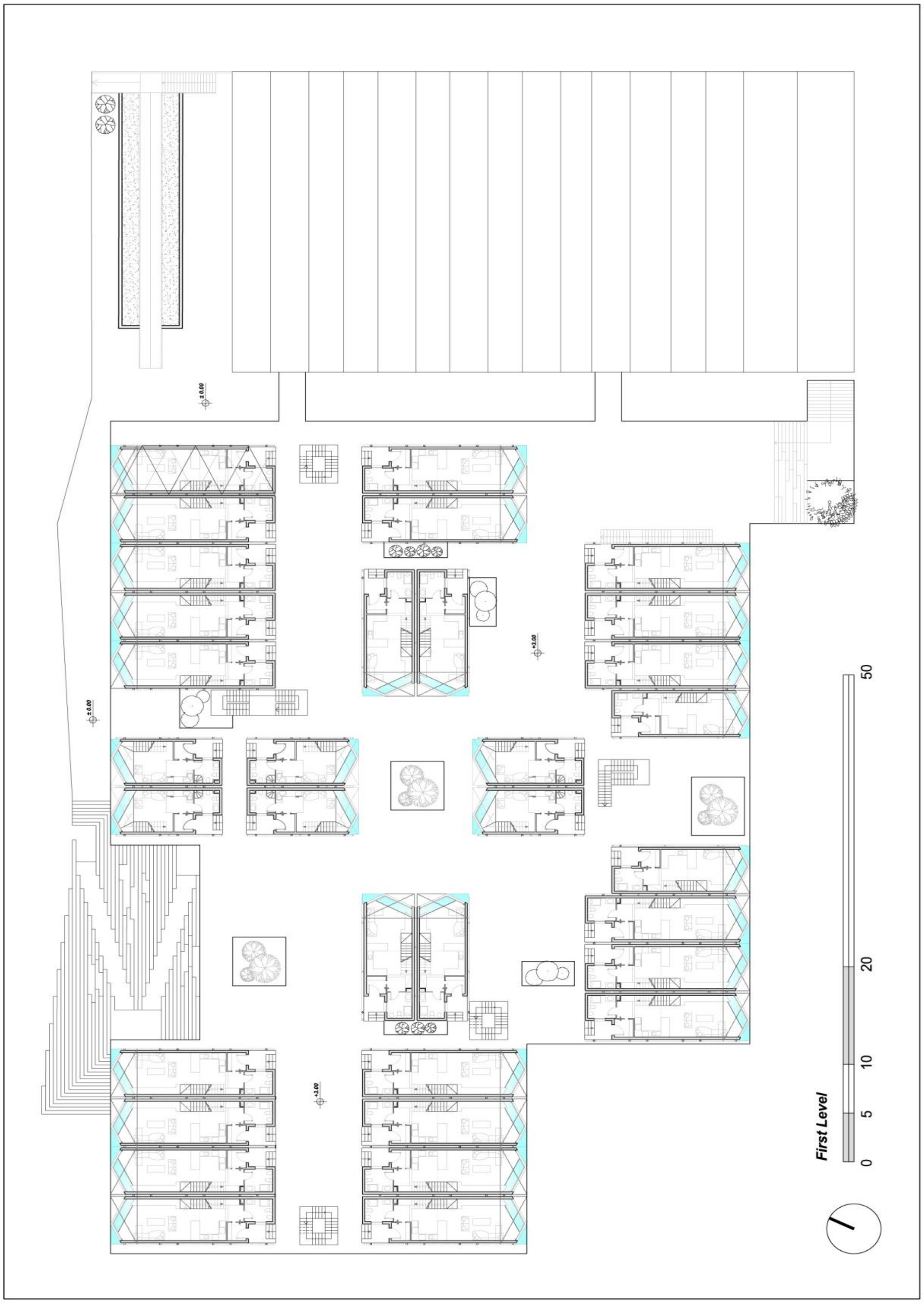


Fig. 3.63: complex first level

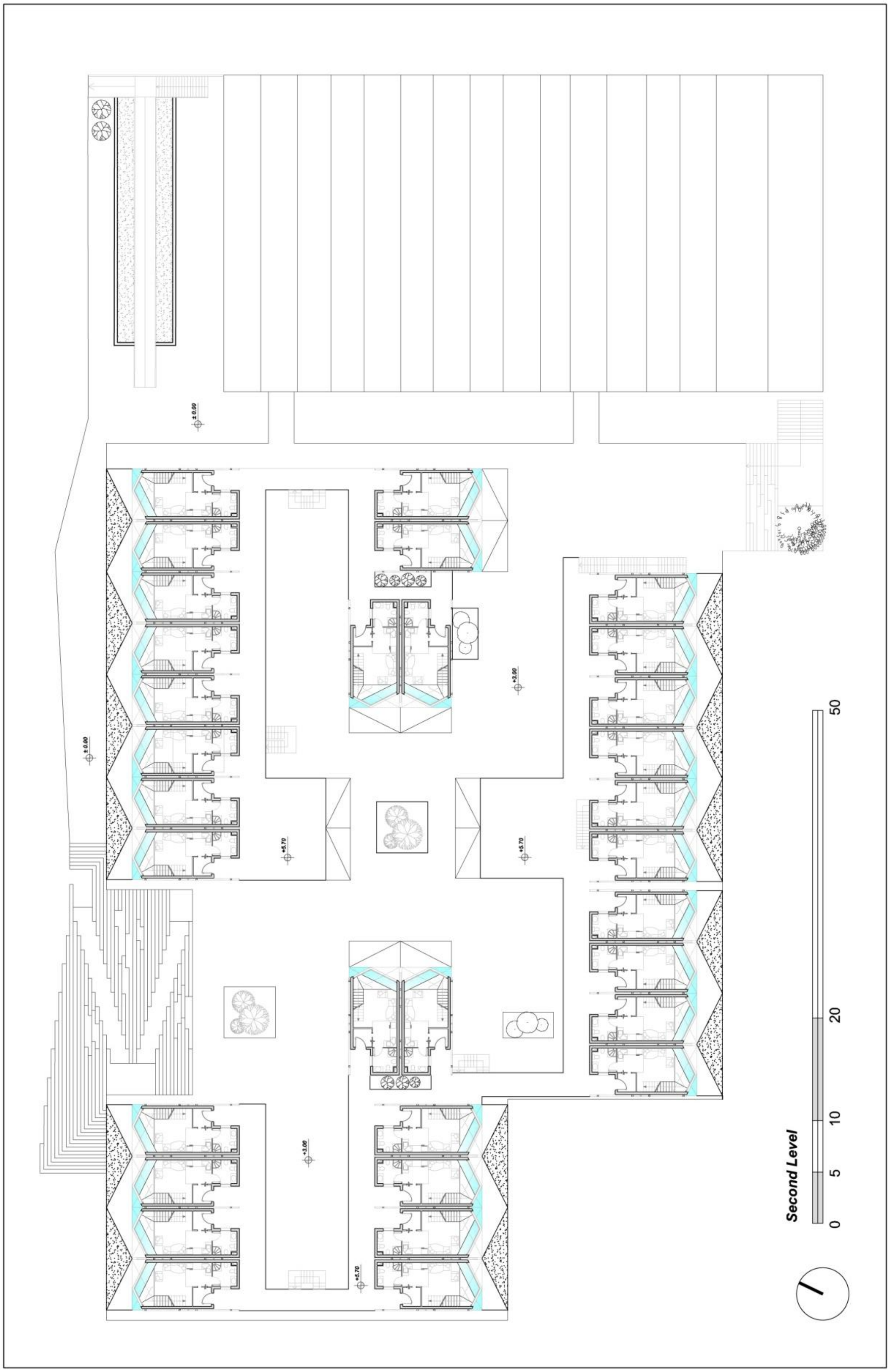


Fig.3.64: complex second level

3.4.2.3.2. Section And Elevation

Fig. 3.65: Section A-A

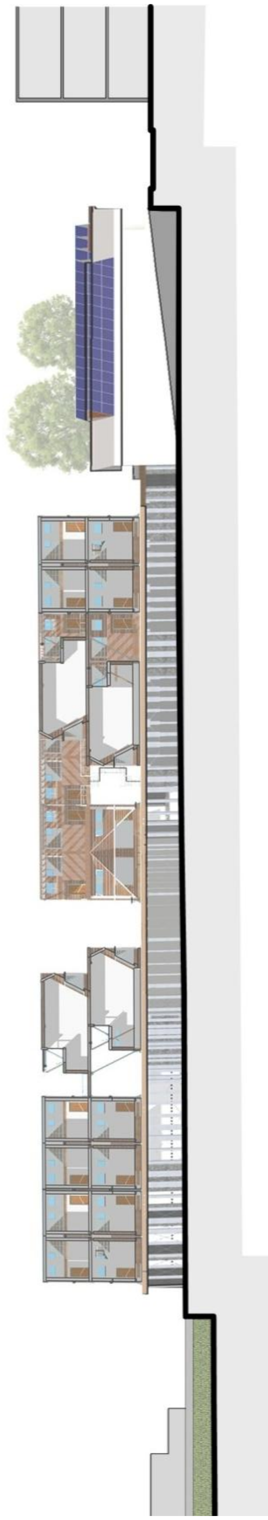


Fig. 3.66: Section B-B

Fig. 3.67: Section C-C

3.4.2.3.3. Exterior Renders

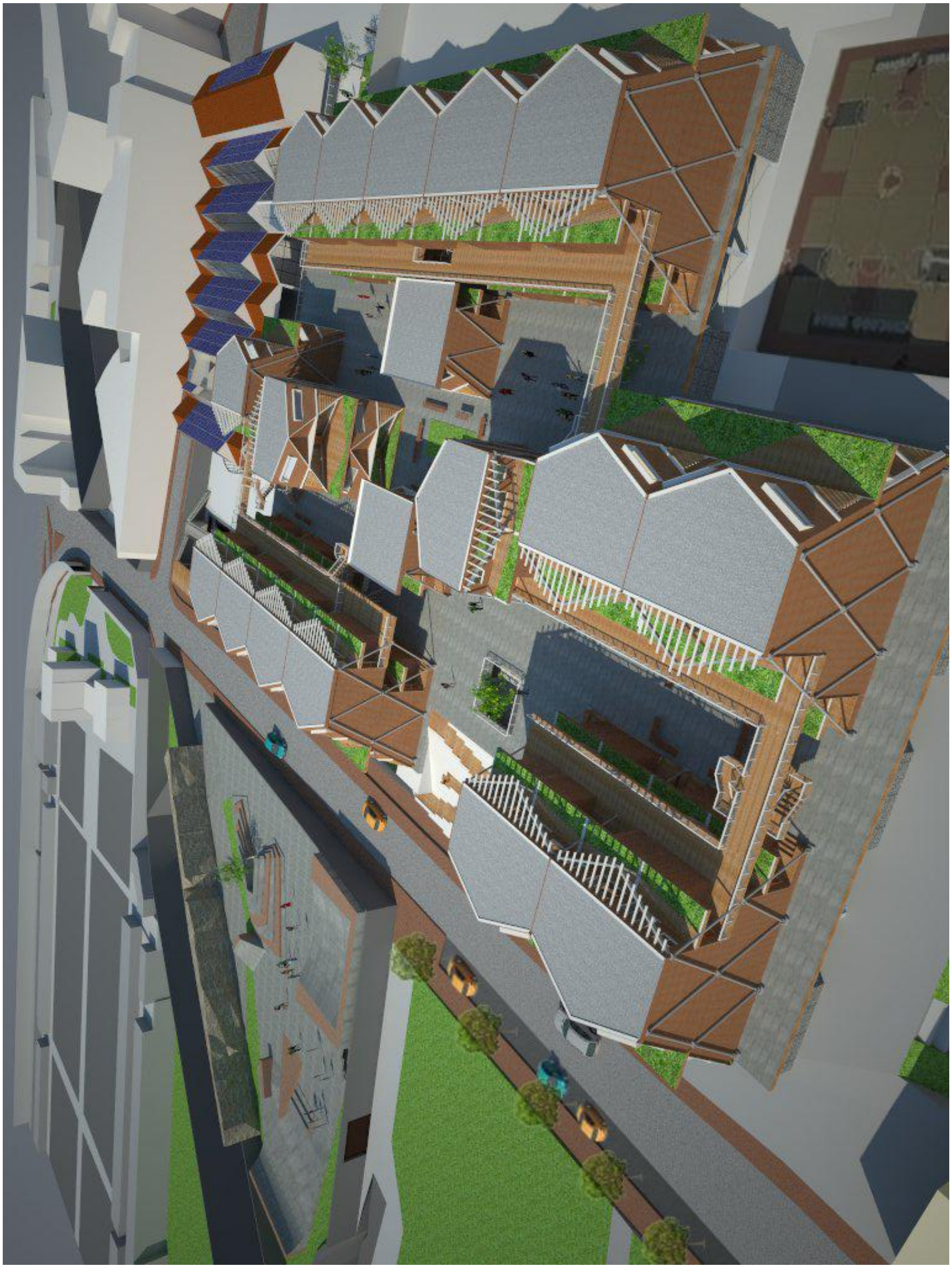


Fig. 3.68: aerial view to the residential complex

Fig. 3.69: view to the residential complex from hole along Via Parini

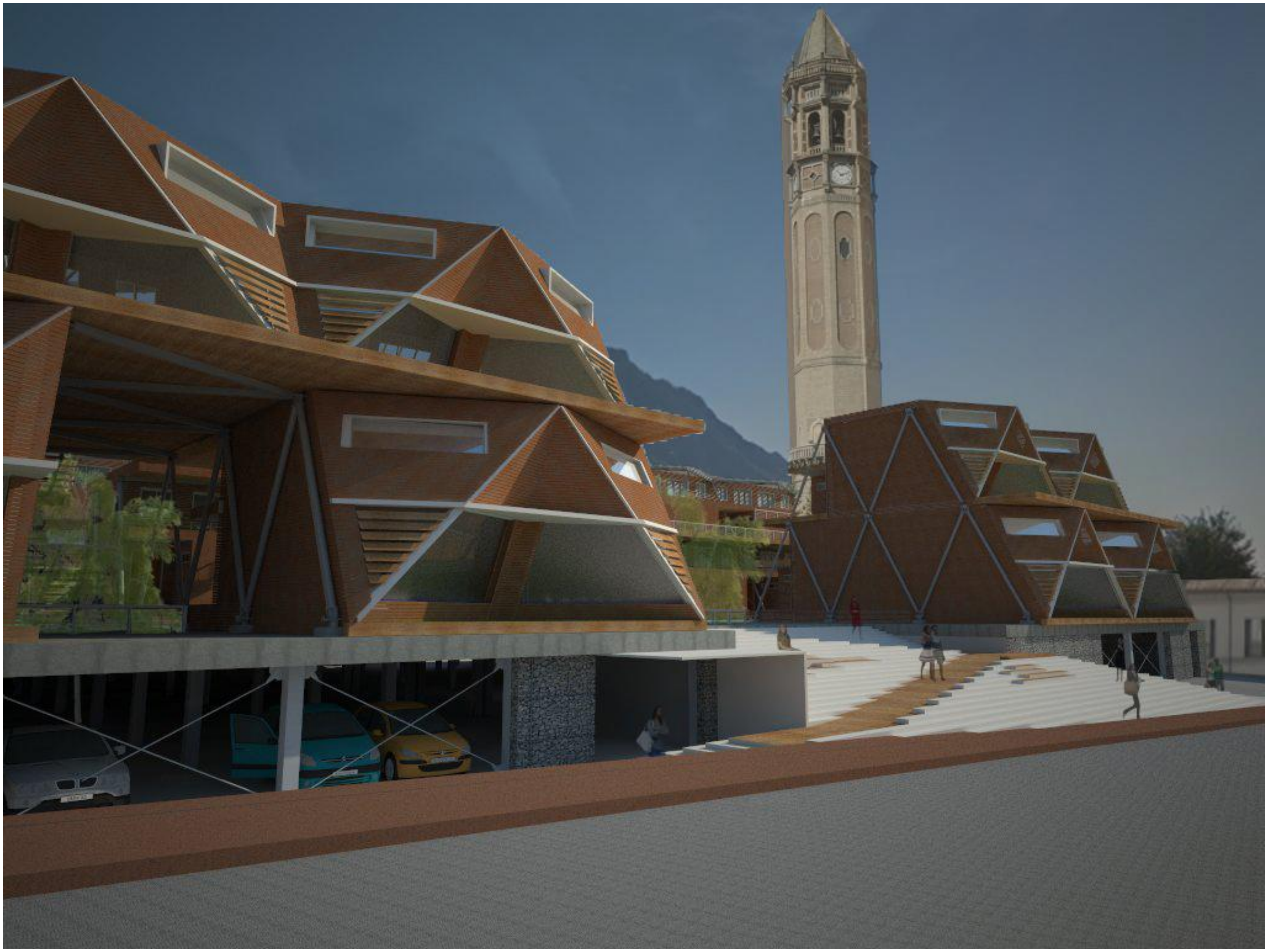


Fig. 3.70: view to the residential complex from Via Parini

Fig.3.71: view to the residential complex from internal courtyard

Fig.3.72: view to the residential complex form stairs to internal courtyard

Fig.3.73: view to the green wall and courtyard

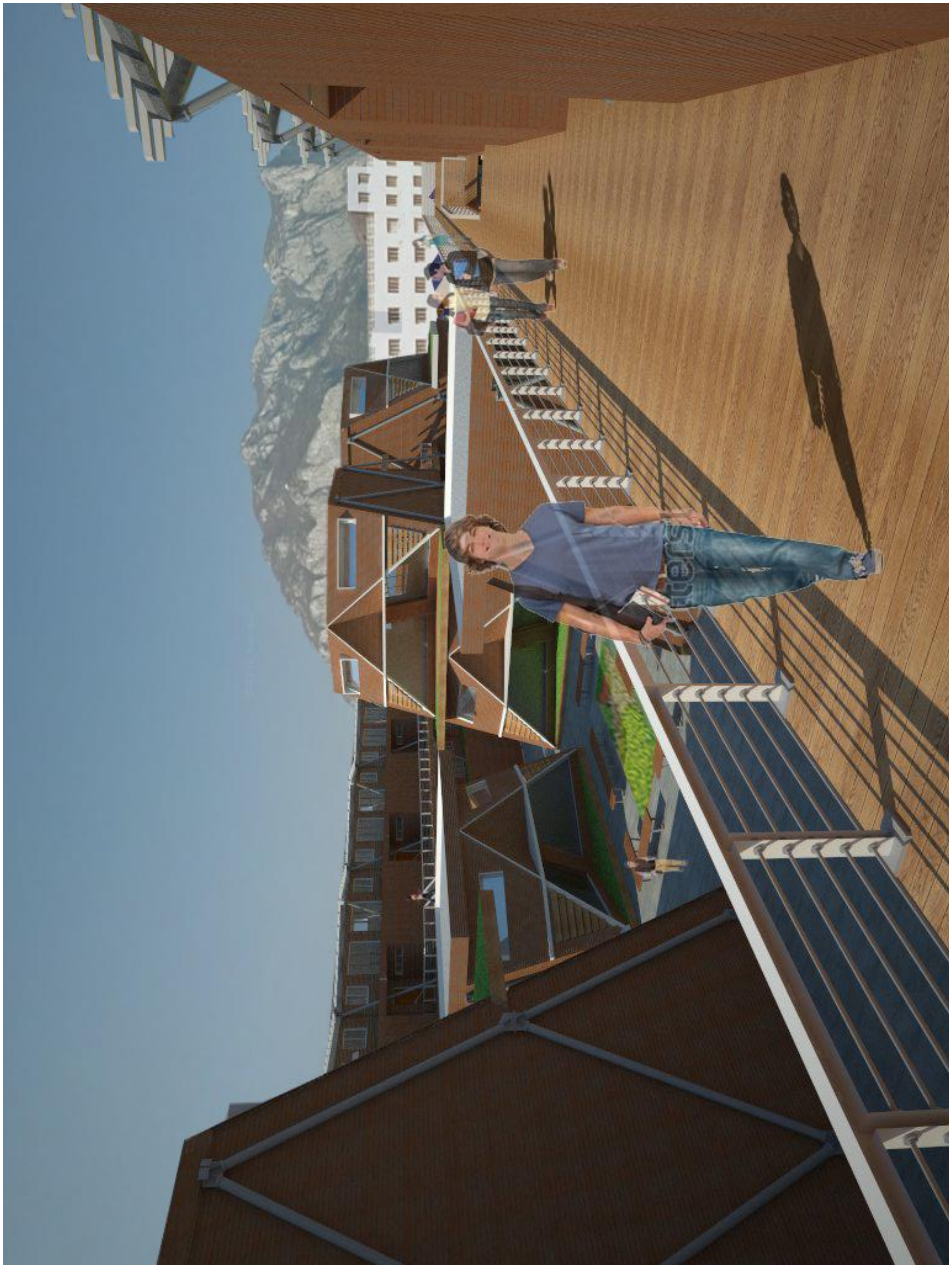
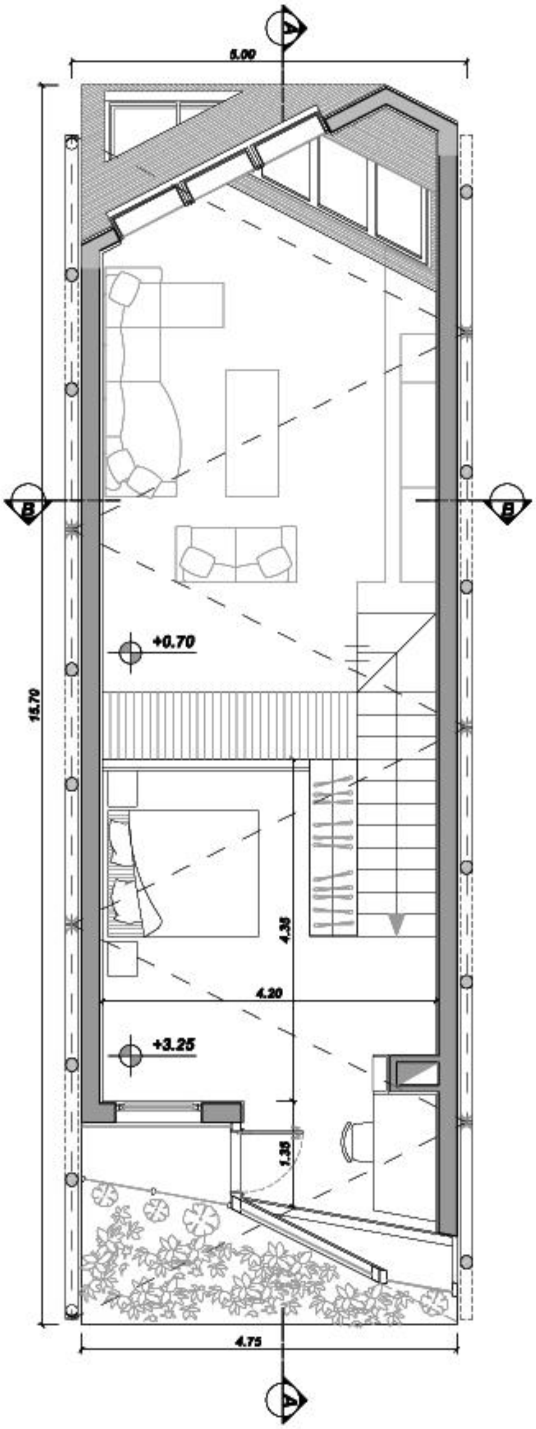


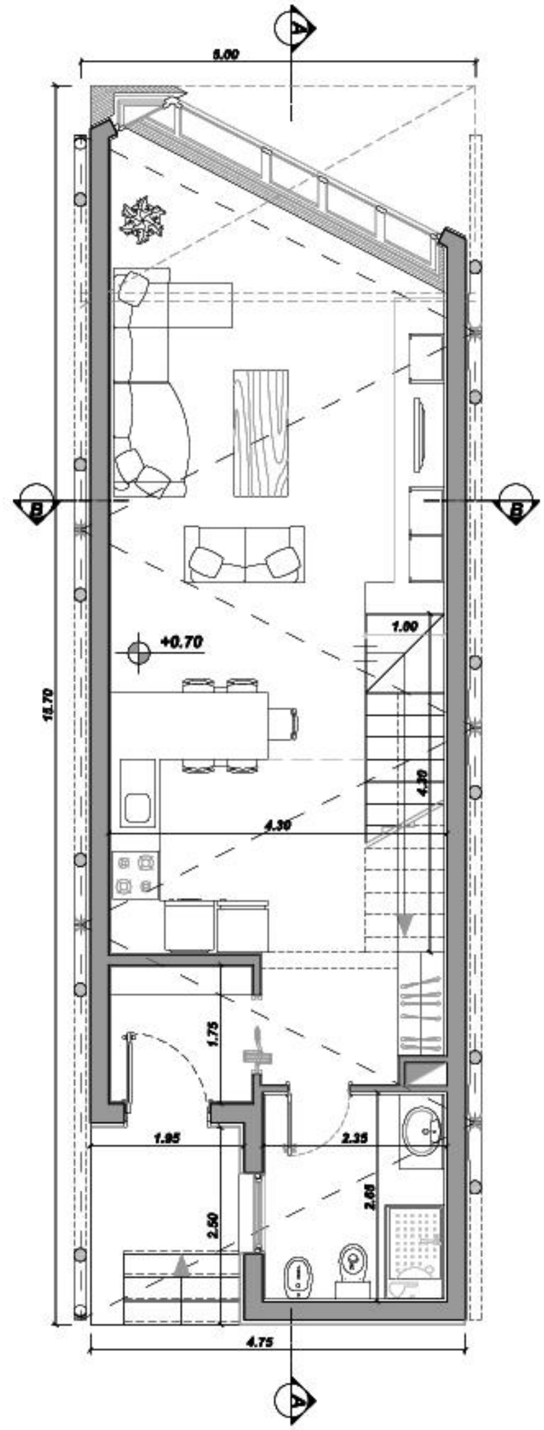
Fig.3.74: view to first floor corridor

3.4.2.4. Apartment Typology

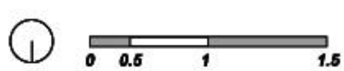
3.4.2.4.1. Type A Plan



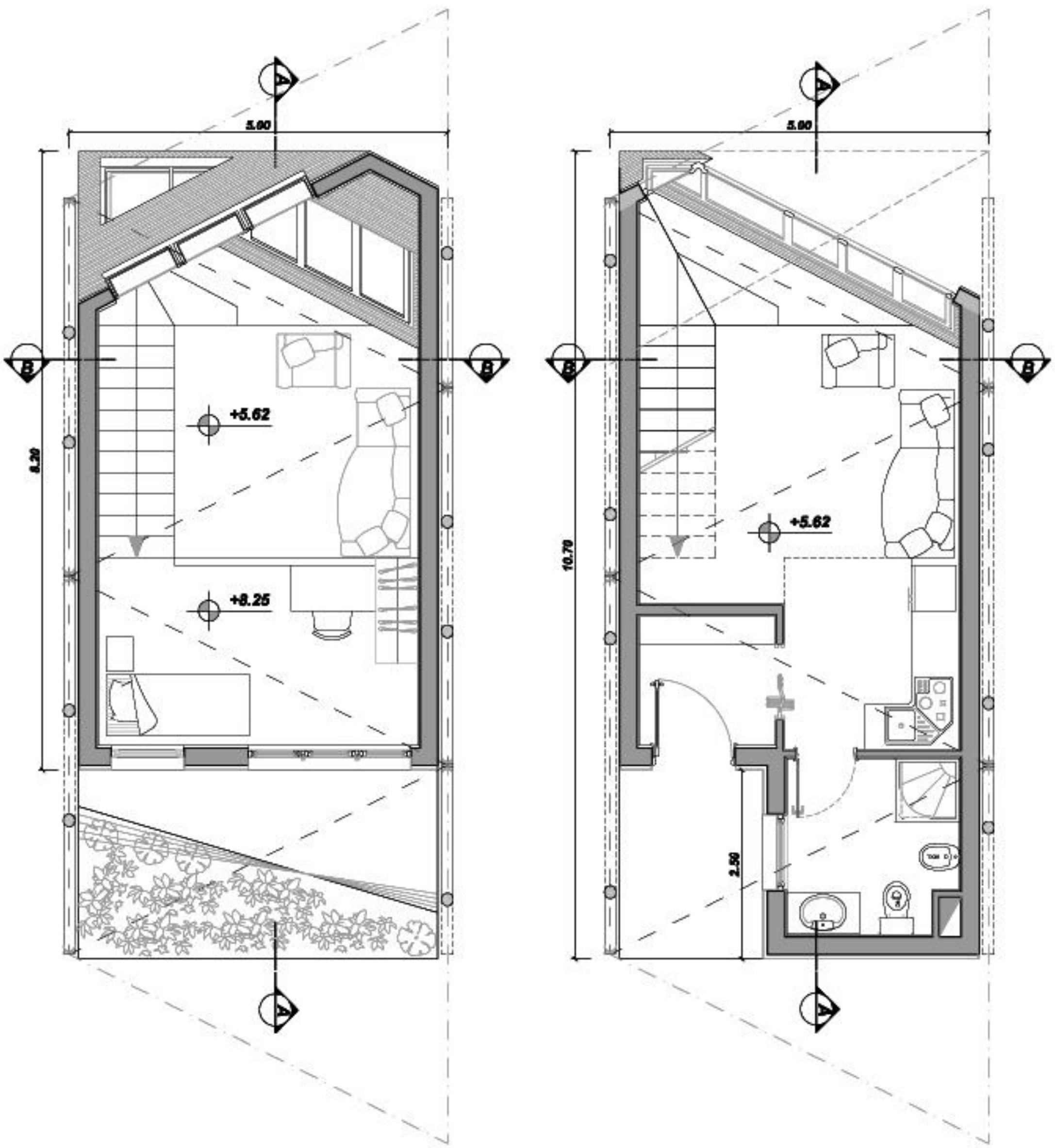
Module A - Mezzanine Level



Module A - First Level



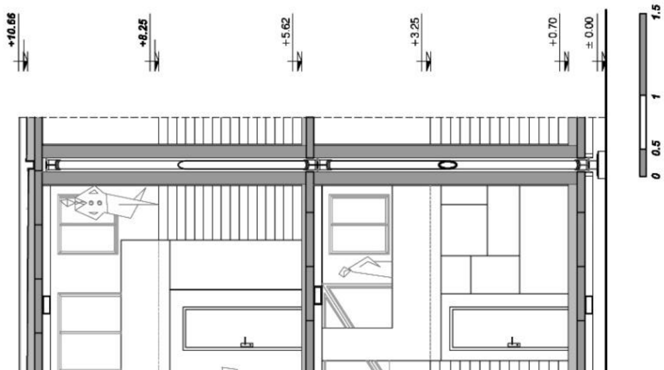
3.4.2.4.2. Type B Plan



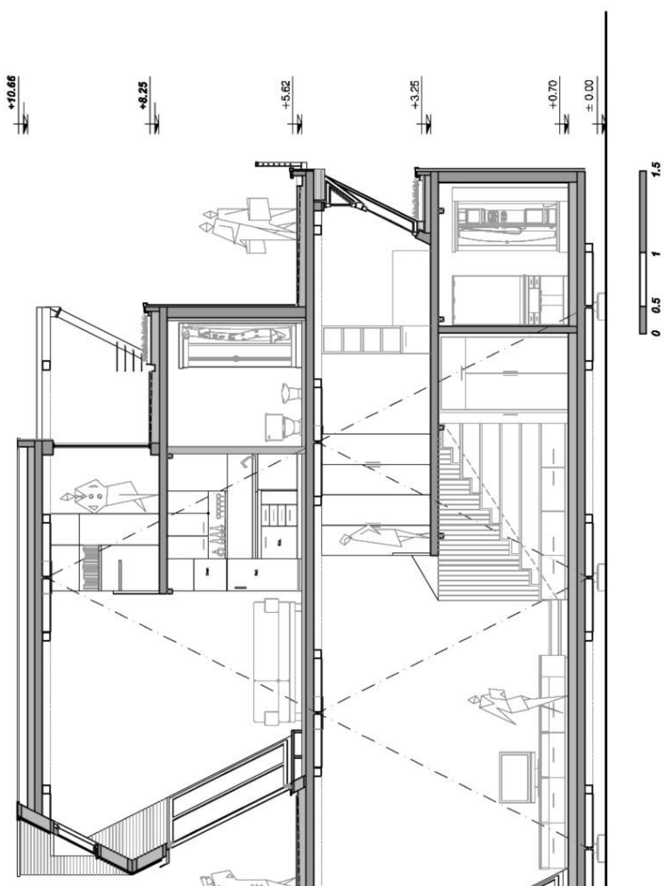
Module B - Mezzanine Level

Module B - First Level

3.4.2.4.3. Sections

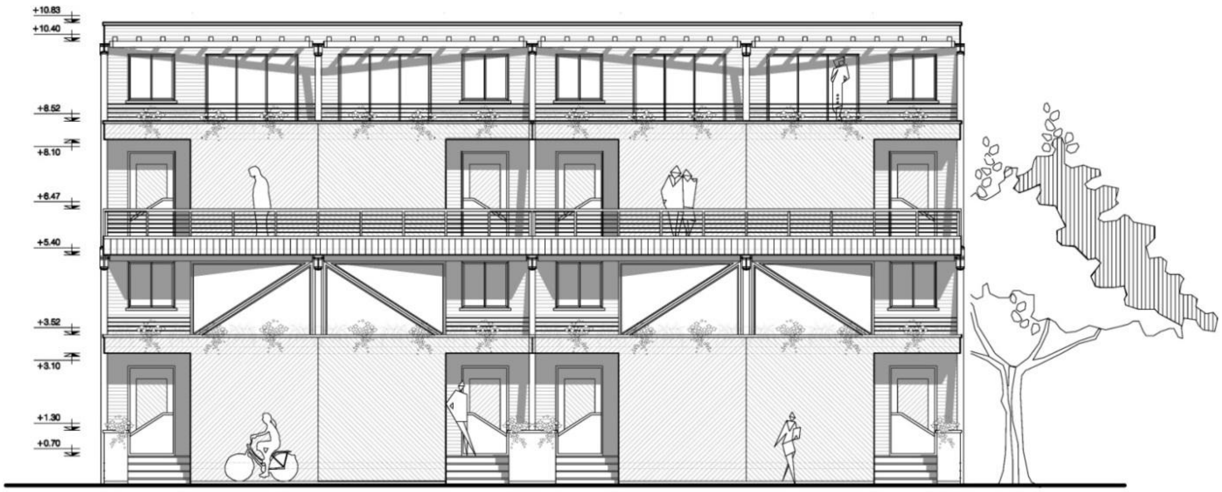


Section B-B



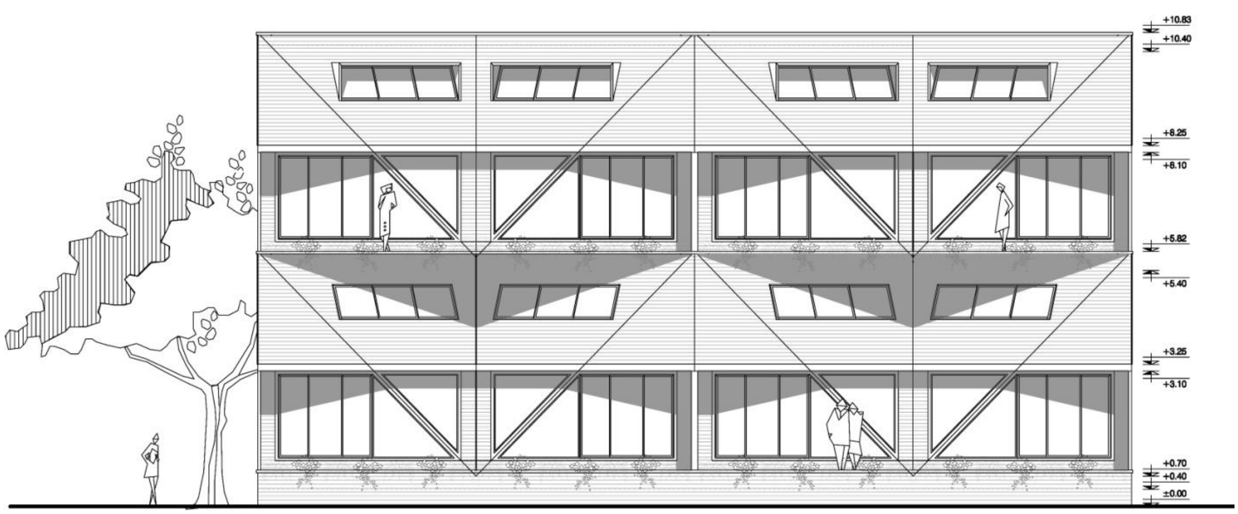
Section A-A

3.4.2.4.4. Elevation



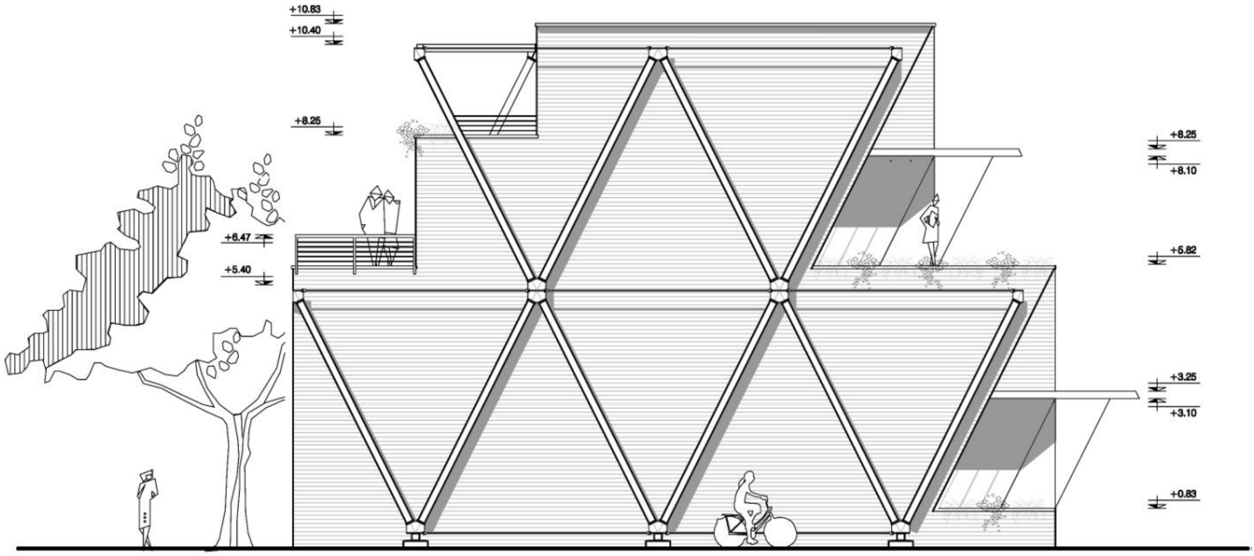
0 1 2 5

North Elevation

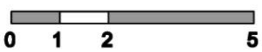


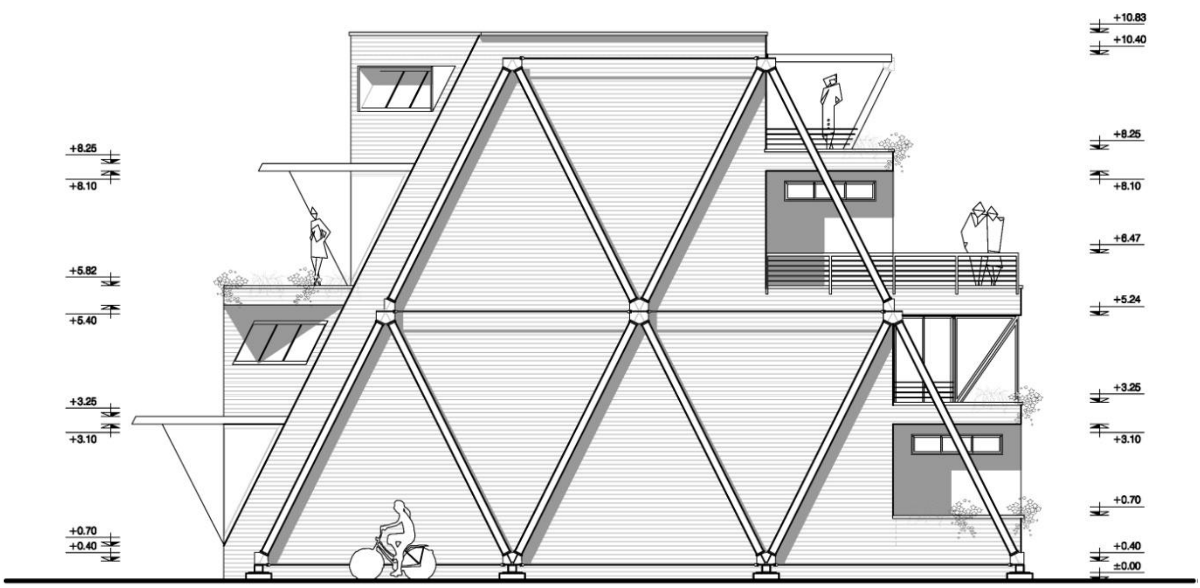
South Elevation

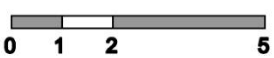
0 1 2 5



East Elevation







West Elevation

3.4.2.4.5. Renders

Fig.3.75: interior view 1

Fig.3.76: interior view 2

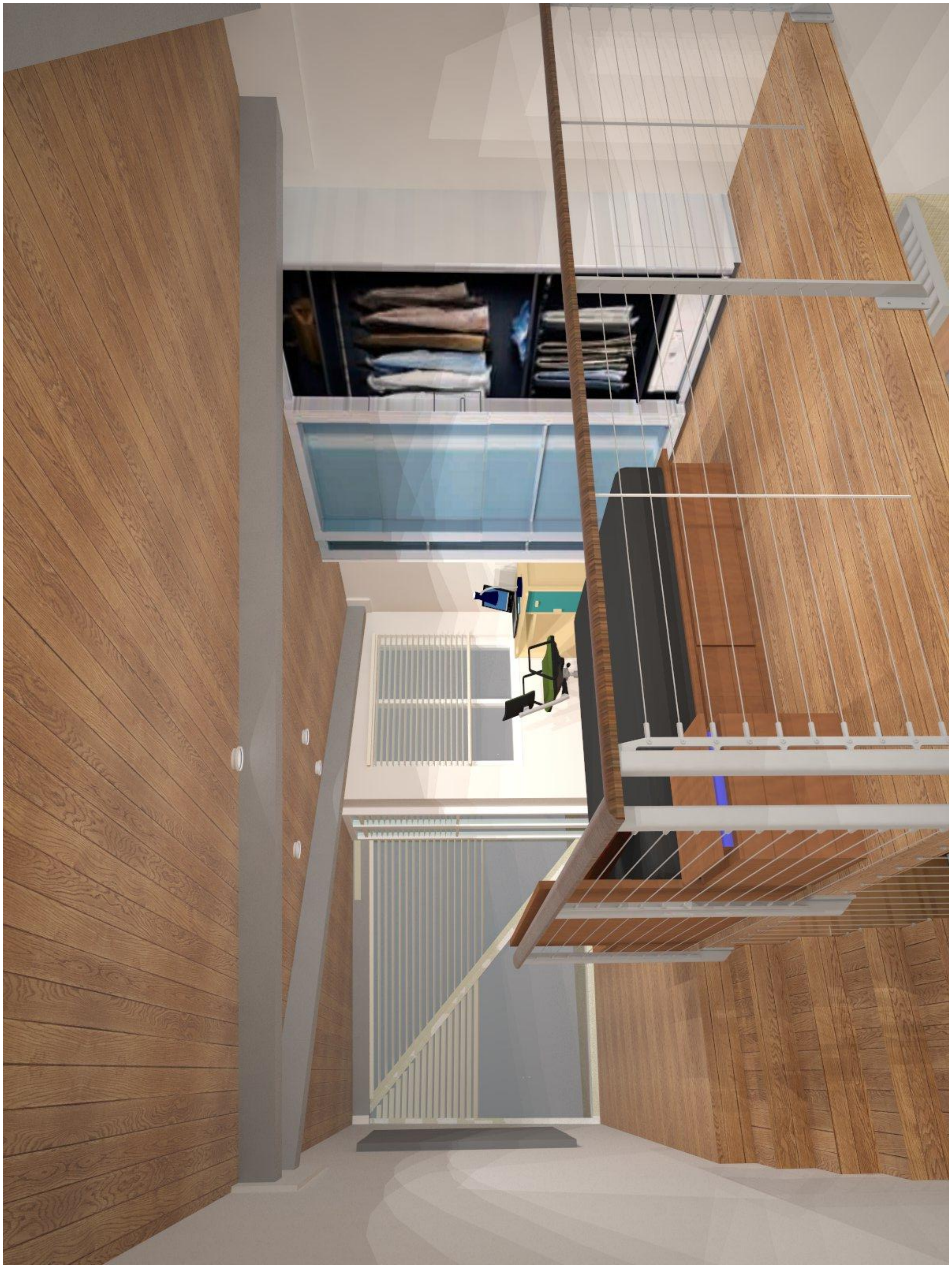


Fig.3.77: interior view 3

Fig.3.78: interior view 4

4. Structure Assessment

4.1. Introduction

This chapter presents the conceptual design and analysis which fulfill the structural integrity of the project. For structural simplicity and separate design concept, the whole complex is divided in two main separated systems each one of which has the internal subdivision according to structural and architectural needs.

Since the buildings have functions for domestic and residential activities, therefore type A is used for the categories of use in the standard.[1]

The building on the bottom is dedicated to the parking level that is provided the platform for the upper level and the building on the top is the residential level which is realized in two stories.

This chapter is composed of two main parts:

1. *Modules analysis*
2. *Platform analysis*

In first part of this chapter, structural analysis of one single module will be demonstrated.

In the second part of this chapter, structural analysis of the platform, by considering the dead load and live load that is imposed by the upper level (residential parts) will be demonstrated.

4.2. Module Structure

4.2.1. Modules Analysis:

According to design decision, a single type of structural module is considered for two types of houses in the residential level.

Three identical structural modules are assembled to create one flat type A.

Two identical structural modules are assembled to create one flat type B.

In order to do a conceptual analysis of residential part, one module as prototype is analyzed.

---

[1] *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*

4.2.2. Loading Actions

In this project, for standards, generally, the Eurocodes are used for load calculation, structural design.

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:

- *Dead Load of floor and ceiling*
- *Dead Load of perimeter walls*
- *Snow load and Wind load*
- *Live Load*

Load calculation for one module:

Module dimension:

- *length : 5 m*
- *Width : 4.8 m*
- *Height:5 m*

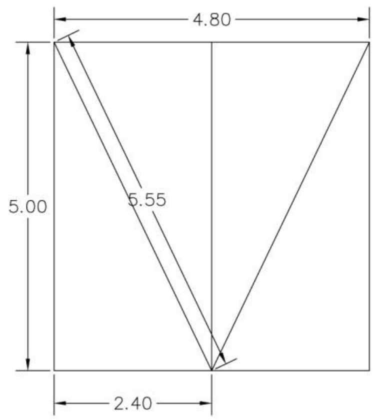


Fig 4.1: plan dimension

*Floor area= length *width*

$A_{Floor}=4.8*5=23.5\ m^2$

Perimeter wall area = 2(height *width) +2(height * length)*

$A_{wall}=2*(5*4.85)+2(4.7*5)=97\ m^2$

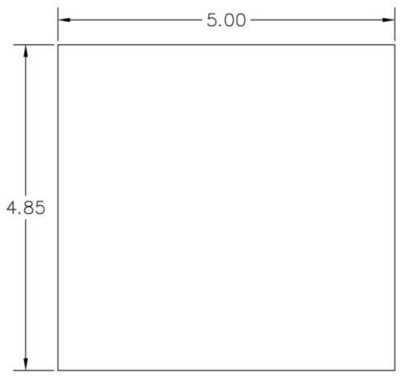


Fig4.2: elevation dimension

Wooden sub structure

*Length for each façade (6*4.65)+(2*5)=37.9 m*

*Total façade length =4*39.1=151.6 m*

*Cross section area=0.07*0.18=0.0126 m^2*

*Total volume = area cross section *total façade length=0.0126*151.6=**1.91 m^3***

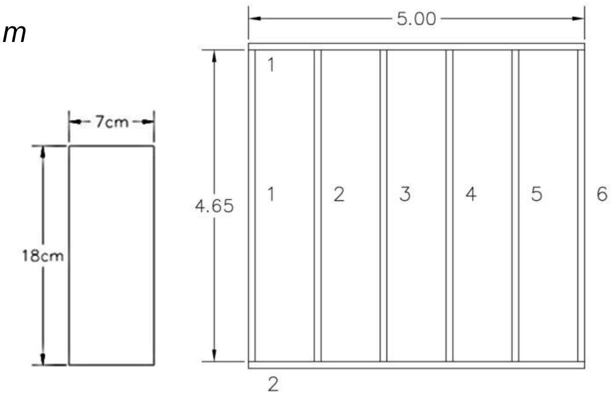
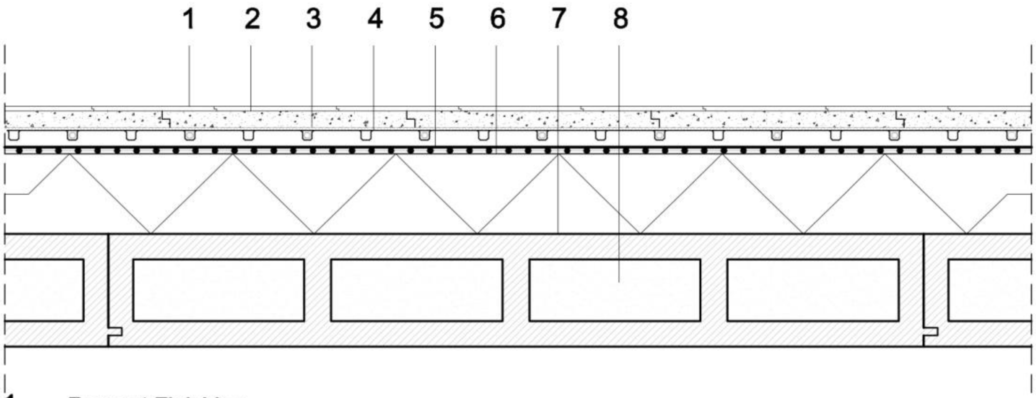


Fig 4.3: the wooden sub structure of the walls

4.2.3. Dead Loads Of Floors

Floors consist of a rather thick layer of hollow timber slab (Lignatur) which lies over the beams and their load is approximated and presented in the table.



1 Parquet Finishing

2 Dry Screed Board

3 Velta PE Slip Membrane

4 Velta Siccus Panel

5 Synthetic Vapor barrier

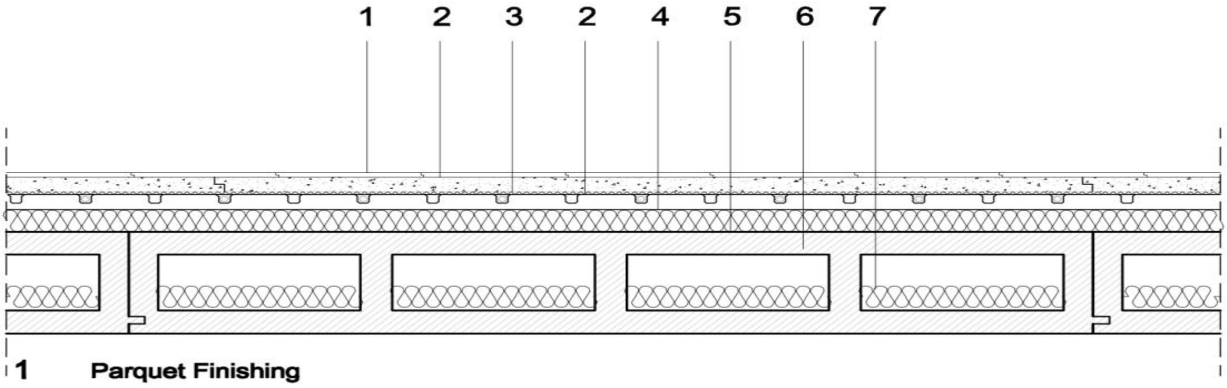
6 Extruded Polystyrene

7 Lignatur Flooring System (LFE)

8 Fibrewood

Fig 4.4: Ground floor section

Layer	*Material*	*Specific weight*	*Thickness*	*Total weight of layer*
		Kg/m3	*s (m)*	*Kg/m2*
1	*ballast*	*2241*	*0.05*	*112.05*
2	*Rockwool(high density)*	*180*	*0.12*	*21.6*
3	*Lignatur with insulation*	*525*	*0.14*	*73.5*
4	*Beams*		*0.15*	*19.8*
	Total weight in kg per square meter			***207.15***



1 **Parquet Finishing**

2 **Dry Screed Board**

3 **Velta PE Slip Membrane**

4 **Velta Siccus Panel**

5 **Acoustic Blanket**

6 **Lignatur Flooring System (LFE)**

7 **Additional Acoustic Insulation**

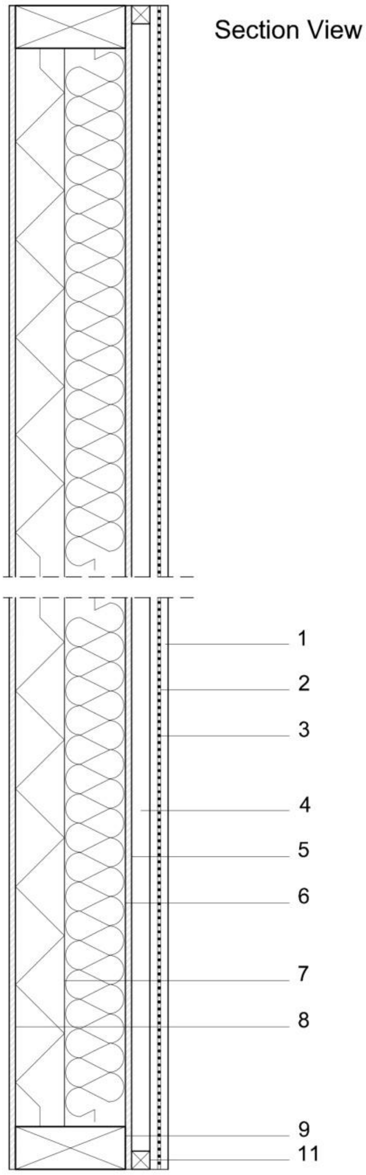
Fig 4.5: Intermediate floor slab section

Layer	*Material*	*Specific weight*	*Thickness*	*Total weight of layer*
		Kg/m3	*s (m)*	*Kg/m2*
1	*parquet*	*700*	*0.005*	*3.5*
2	*Dry screed board*	*1100*	*0.02*	*22*
3	*Extruded polystyrene*	*50*	*0.1*	*5*
4	*Lignatur with insulation*	*525*	*0.14*	*73.5*
5	*Beams*	*-*	*0.15*	*19.8*
	Total weight in kg per square meter			***123.8***

4.2.4. Dead Loads Of Walls

In this project, perimeter walls are prefabricated elements based on the combination of studs covered in both sides by OSB boards and Plasterboards installed on one side. The space which is provided between the studs is used for placement of thermal insulations. Perimeter walls are regarded as lightweight systems since there is no usage of heavy in their configuration.

Figure and Table below show the properties and specification of walls.



External Wall System

1 Plaster Board
2 Vapor Barrior
3 Plaster Board
4 Service Gap
5 OSB
6 Mineral Wool
7 Polystyrene Board
8 OSB
9 Wooden Runner
10 Wooden Stud
11 Service Gap Substructure

Fig4.6: External wall plan and section

Layer	*Material*	*Specific weight*	*Thickness*	*Height*	*Total weight of layer*
		Kg/m3	*s (m)*	*m*	*Kg/m*
1	*Knauf Plaster board*	*723*	*0.0125*	*4.85*	*43.83*
3	*Knauf plaster board*	*723*	*0.0125*	*4.85*	*43.83*
4	*OSB Board*	*615*	*0.01*	*4.85*	*29.83*
5	*Mineral wool*	*35*	*0.1*	*4.85*	*16.98*
6	*Polystyrene Board 45Kg/m3*	*45*	*0.08*	*4.85*	*17.46*
7	*OSB Board*	*615*	*0.01*	*4.85*	*29.83*
9	*wooden sub structure*	*750*	*-*	*-*	*73.875*
	Total weight of the wall in unit length				***255.63***

4.2.5. Snow Load Action

The snow load on the roof is determined by multiplying the characteristic value of the snow load on the ground by a snow load shape coefficient μ. The snow load on the roof is affected by the topography of the site and the amount of heat loss through the roof and EN 1991-1-3 makes provision for adjustment of the roof snow load using an exposure and thermal coefficient factors.

Thus Snow loads on roofs for the persistent / transient design:

$S = \mu_i * C_e * C_t * S_k$

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. The recommended value for exposure coefficient, C_e *is chosen as 1. And the value for thermal coefficient,* C_t *is also assumed as 1 since the roof is very well insulated. Furthermore, the roof is flat,* $\alpha = 0$ *and* $\mu_i = 0.8$*.*

$S = \mu_i * C_e * C_t * S_k = .8*1*1*190 = 152\ kg/m^2$

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)*.* [2]

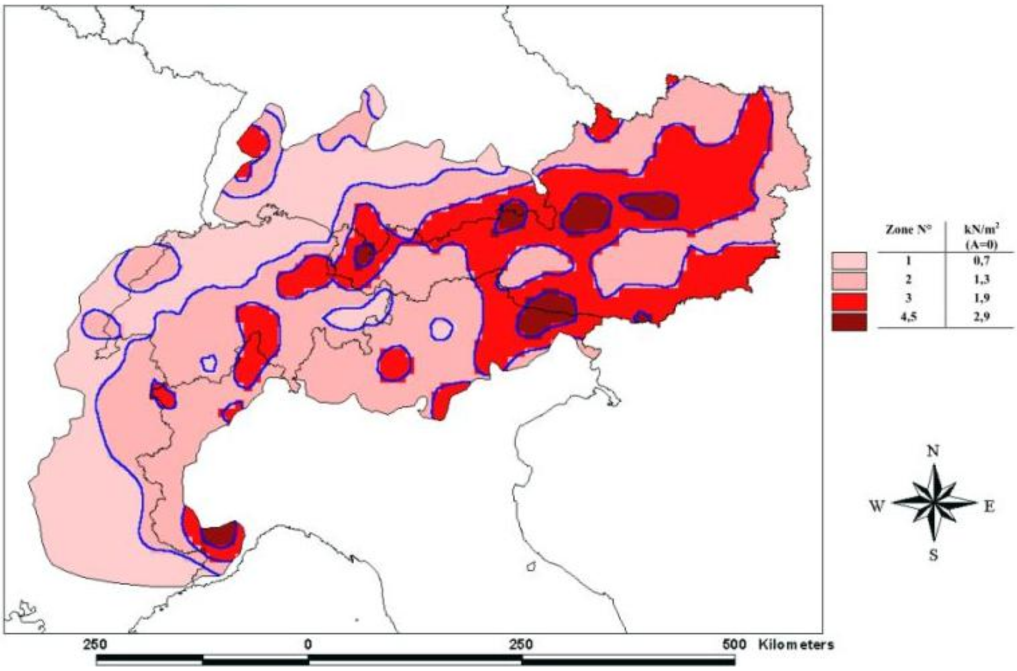


Fig4.7: Snow load intensity on the ground level

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

4.2.6. Live Load Action Of Floors and Rooftop:

According to the Eurocode category of occupancy, the value of live load of 200 kg/m^2 is suitable to be considered for the area of domestic and residential activities. And finally the overall live load of 200 (Kg/m^2) is assumed for the first level and 152(Kg/m^2) as live load on the ceiling level.

4.2.7. Structural Gap

Since the structure of the platform, as one building, would be so huge from structural point of view, by compromising structural and architectural factors, it is divided to three parts. List below explains the consideration to specify the separation line in plan.

- *It is preferred to separate the buildings less than 50 meters in length of each side.*
- *Architectural design consideration of upper level (residential part): due to different structural system in upper level it is preferred first to have the overall configuration of upper level then try to define structural gap of the platform level, so in this case there will be completely separated structure in height.*

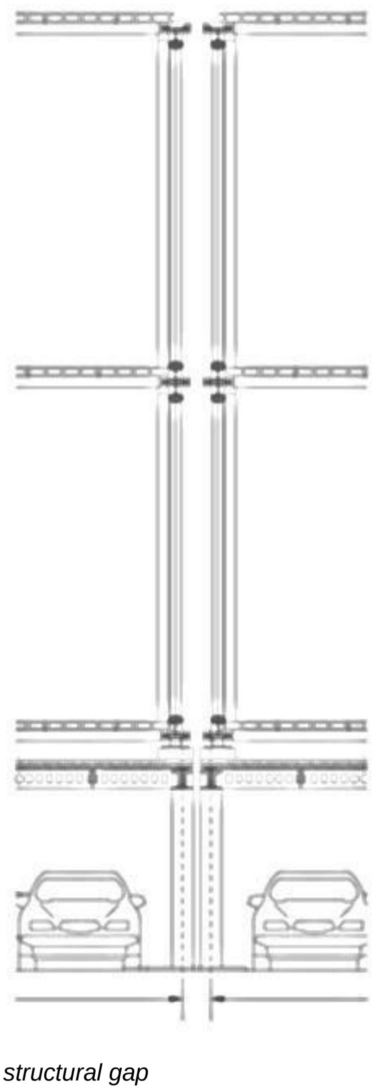


Fig 4.8: structural gap

4.2.8. Structural Plan

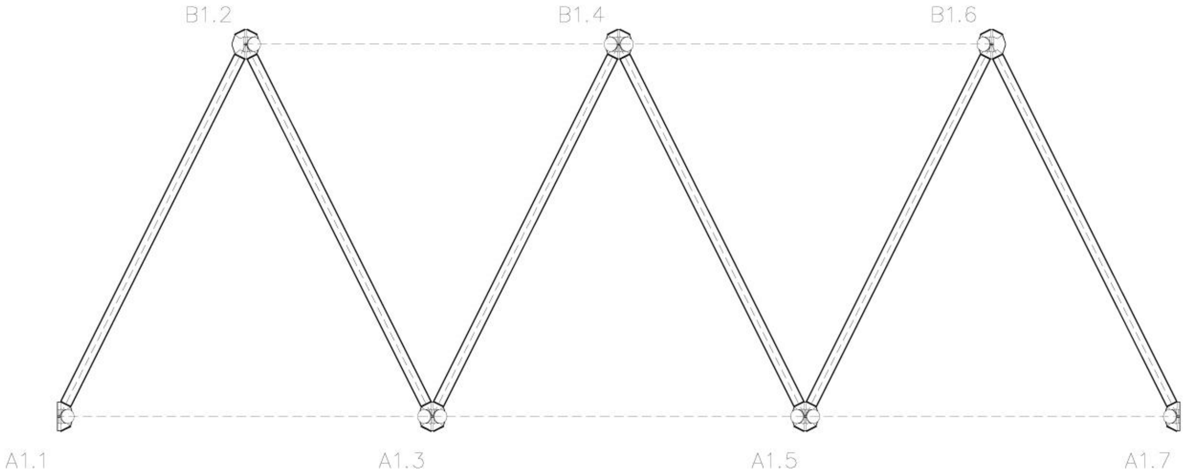


Fig 4.9: structural plan, Ground level

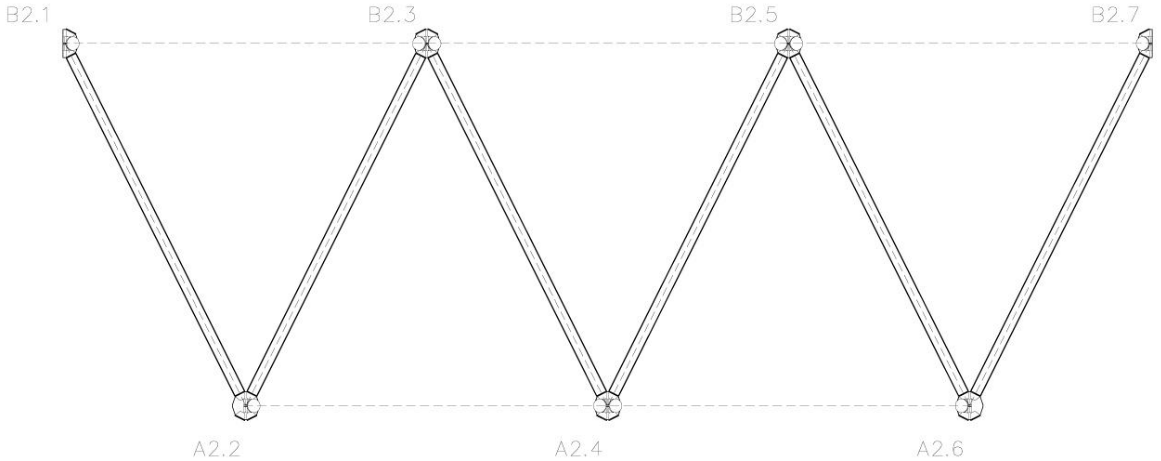


Fig 4.10: structural plan, first level

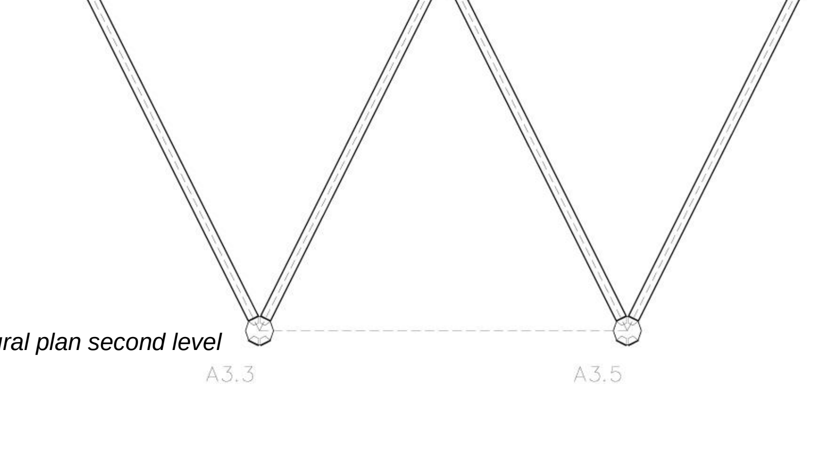


Fig 4.11: structural plan second level

4.2.9. Modular Structure ,Distribution On Site Plan

The structural gap is considered also in upper

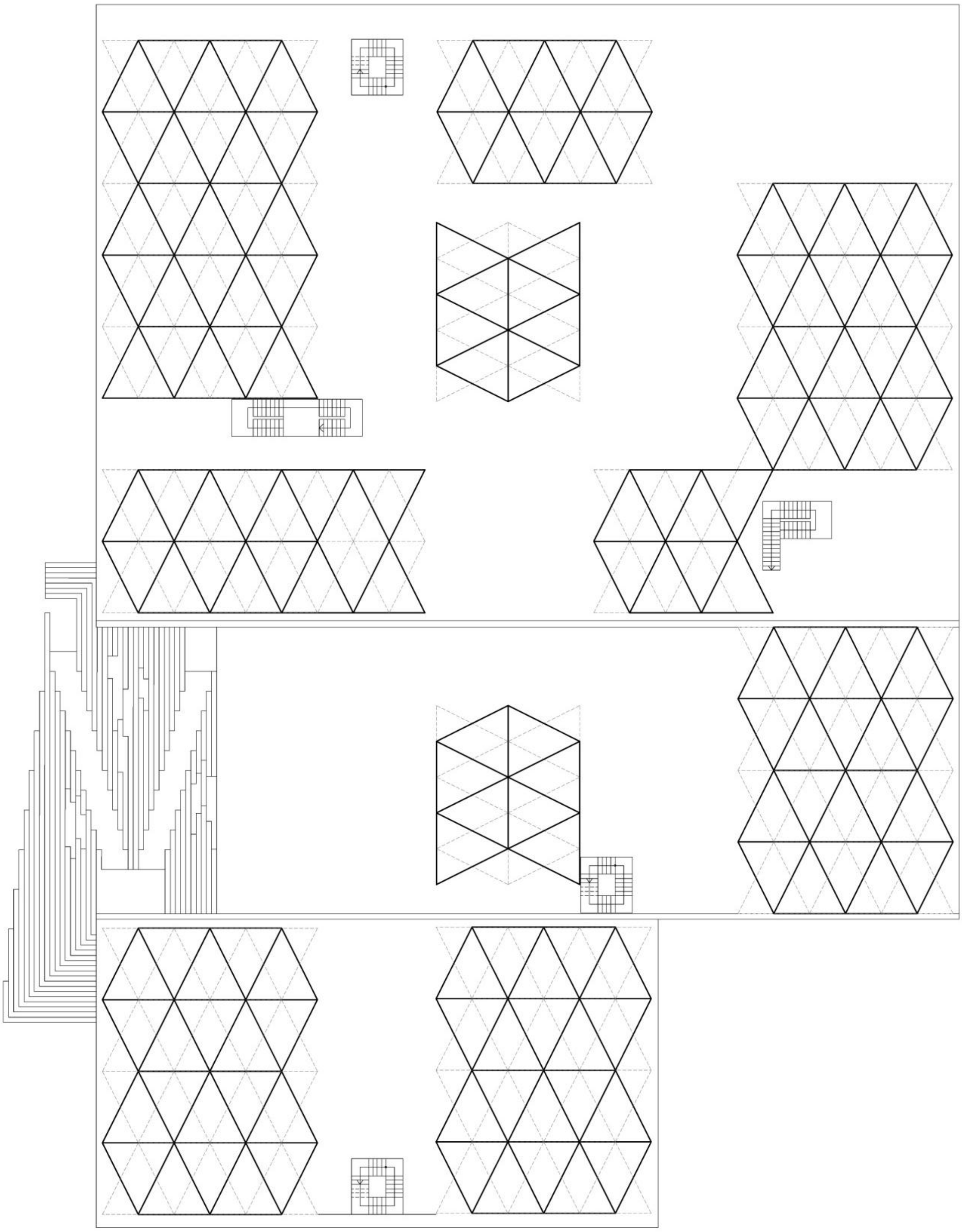


Fig 4.12: first level structural distribution

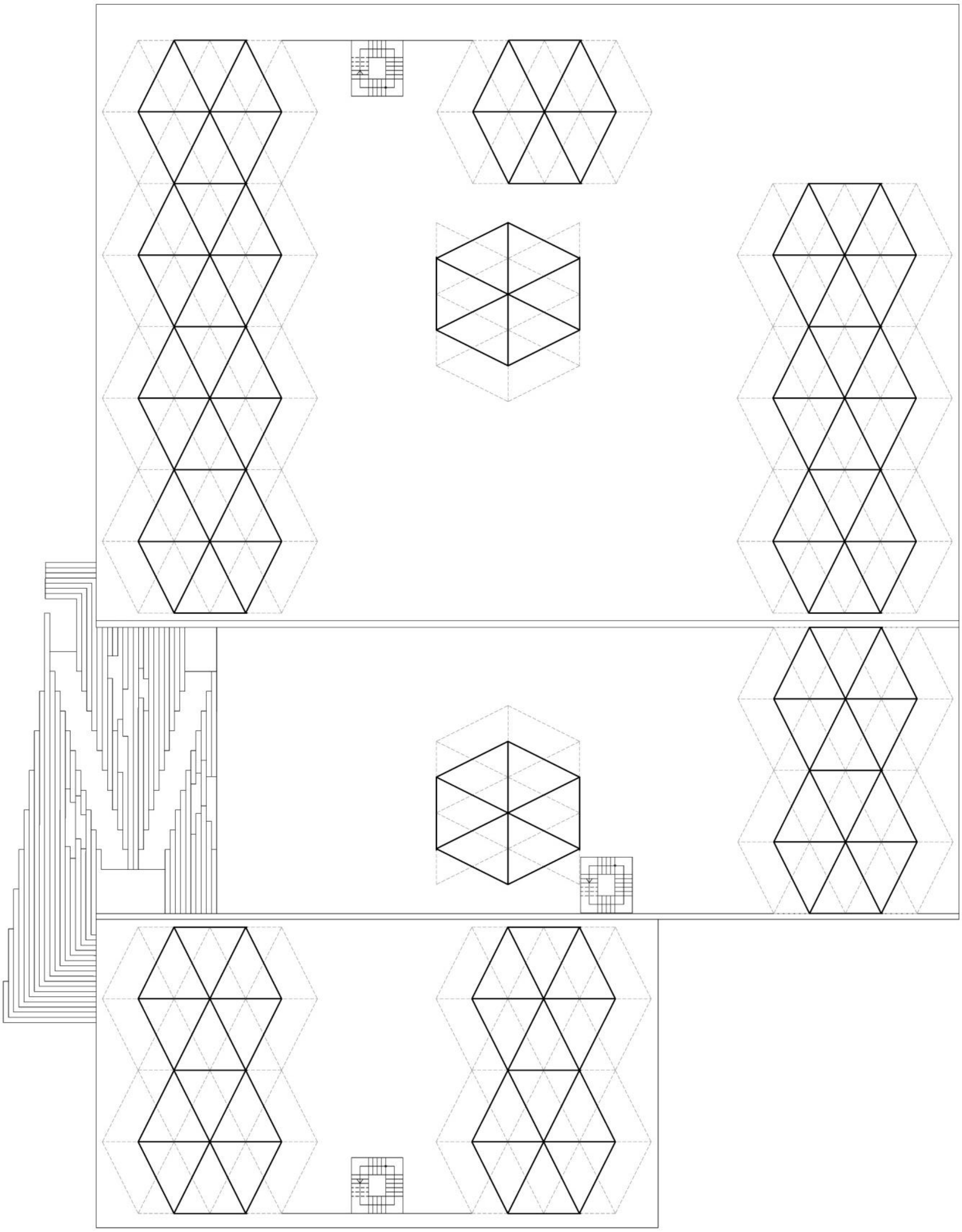


Fig4.13: second level structural distribution

4.2.10. Structural Analysis in SAP

One module is selected to be studied under hypothetical live and dead load.

The joints are defined as hinge in all connections. The presumptive structural elements are steel.

The advantage and disadvantages are as following:

Advantages:

1. Good property of earthquake resistance: the ductility of steel is higher; this good property can reduce the effect of the earthquake and also make the steel structure have higher ability of deformability in the case of intense earthquake happens.

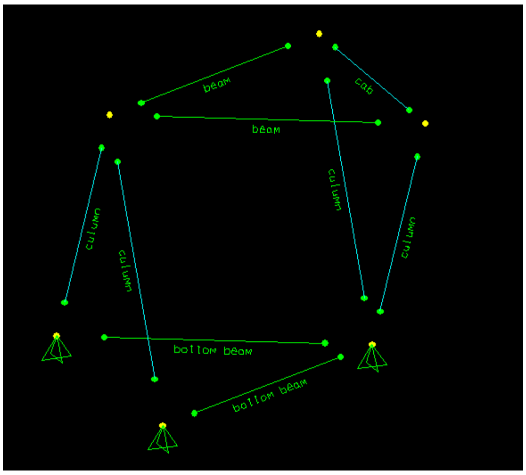


Fig4.14: the conceptual model in SAP

2. Self-weight is lower: this can reduce the vertical load and earthquake effect which are transferred from the structure to the foundation.

3. Make the most of the architecture space: steel structure can increase 2~4% effective area because of its smaller cross section of the column.

4. High speed and short time of construction.

Disadvantages:

1. Lower resistance of fire: the beam, column, bracing and the trapezoidal metal sheeting should be covered by fire resisting dope.

2. The damages of structure such as crack of the connection and buckling of the bracing maybe happen because the random of the earthquake and the complexity of the construction.

Three structural elements are defined:

Beam

the green elements are defined as beam. The cross section is rectangular tube

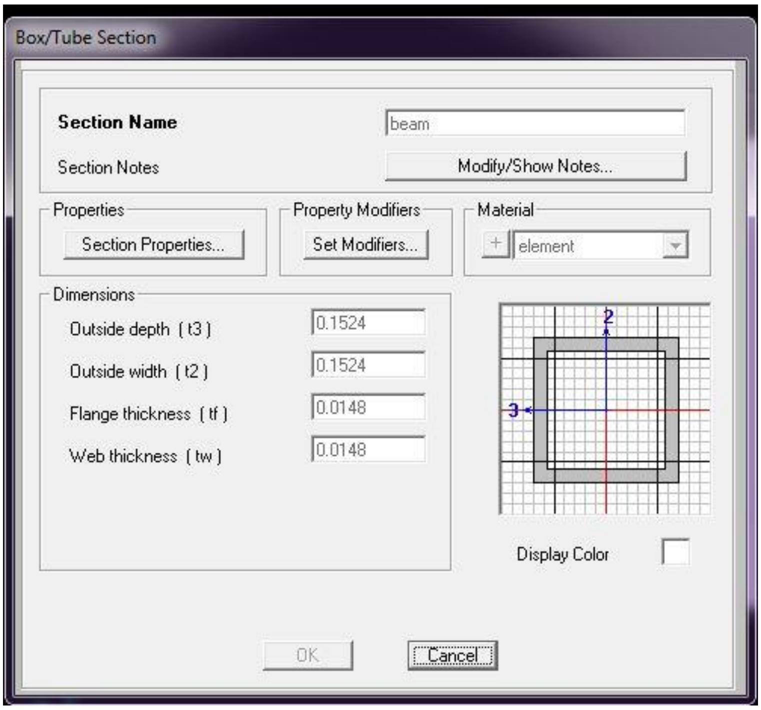


Fig4.15: beam cross section information

Column

The vertical elements in module are introduced as column. The cross section is circular tube.

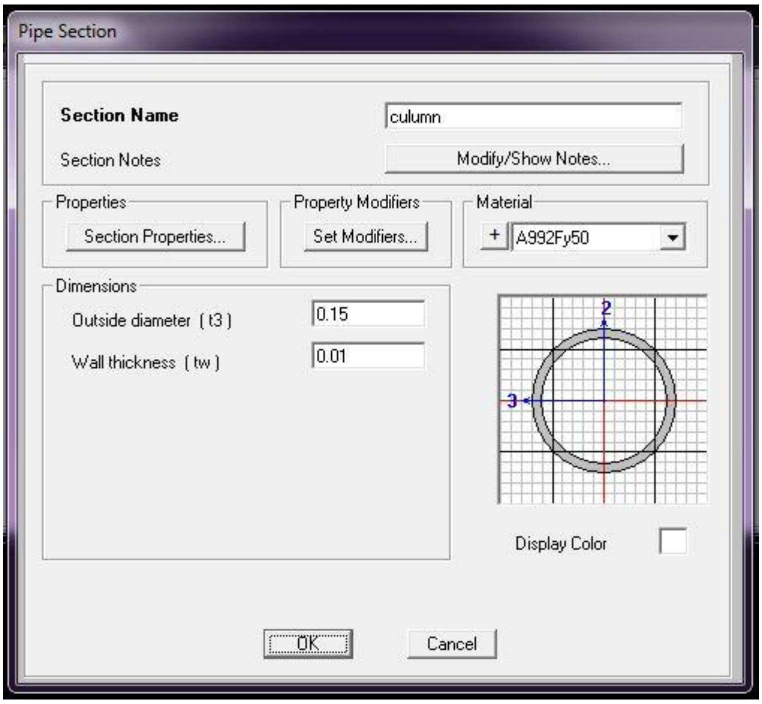


Fig 4.16: column cross section information

Tendon

In order to stabilize the structure the tendon are introduced. the cable is considered for working in tension with diameter of 20 mm.

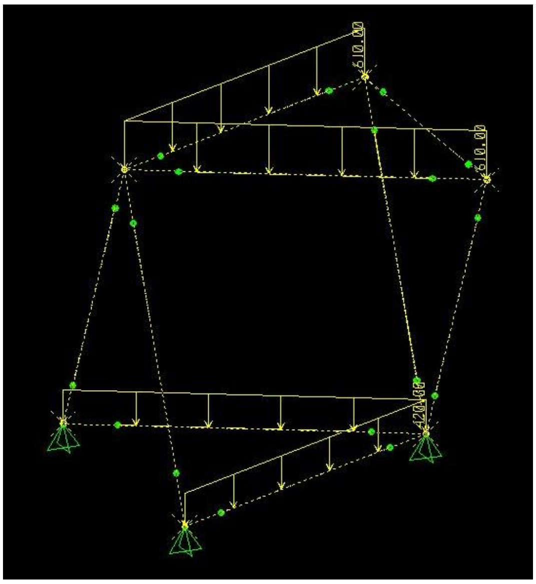


Fig 4.17: Dead load over beam

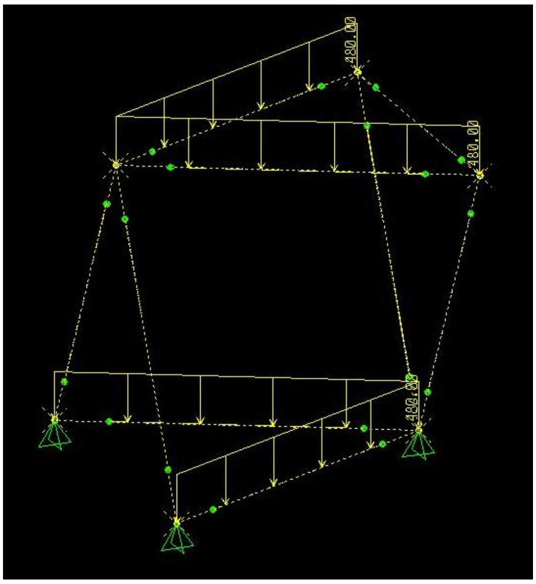


Fig 4.18: live load over beam

The basic analysis is done in SAP in order to prove that the structure is stable, then the proposed cross section are checked to be sure that they can bear the initial hypothesis .

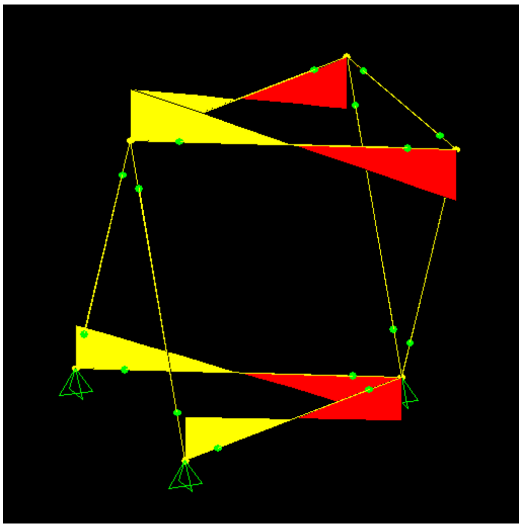


Fig4.19: shear force diagram under combined load

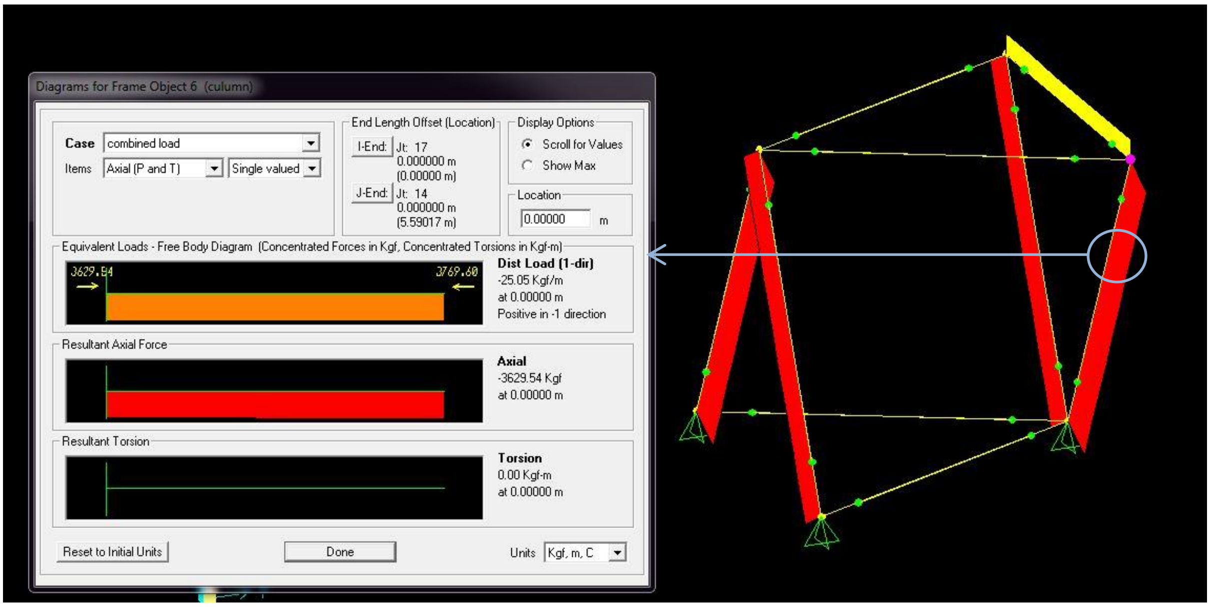


Fig 4.20: axial force under combined load

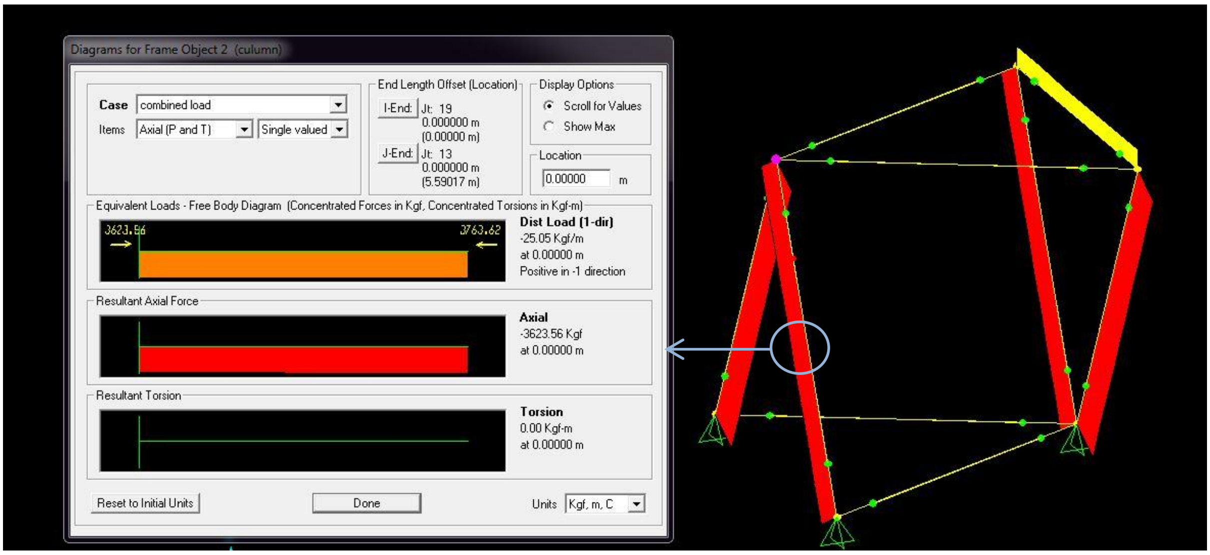


Fig4.21: axial force under combined load

4.2.11. Joint type

Joint A1.5

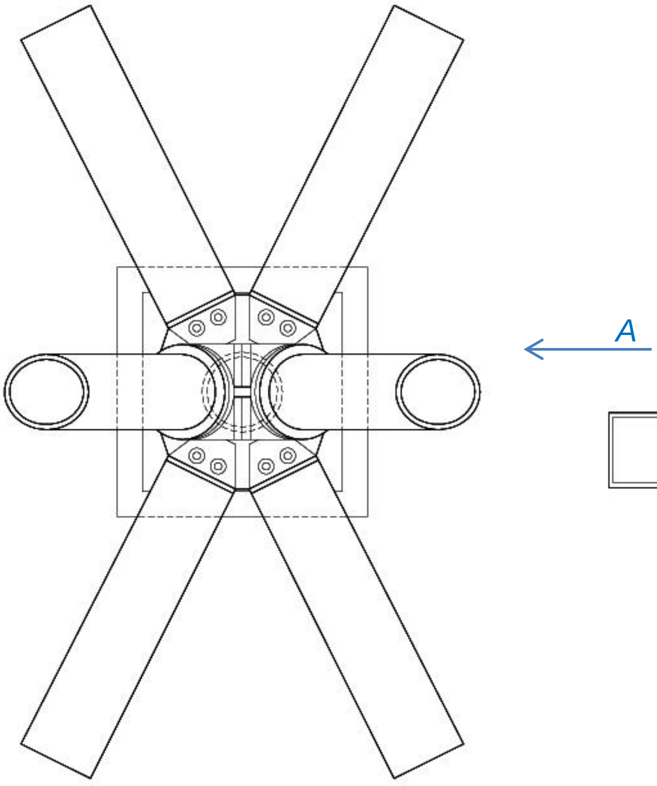


Fig4.22a joint A1.5: Plan

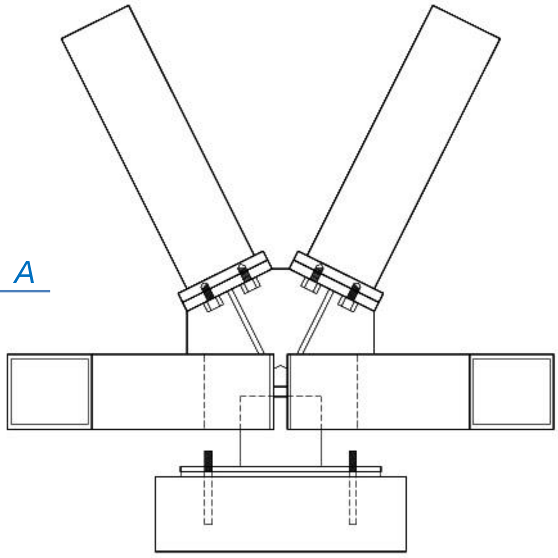


Fig4.22 b: joint A1.5 View B

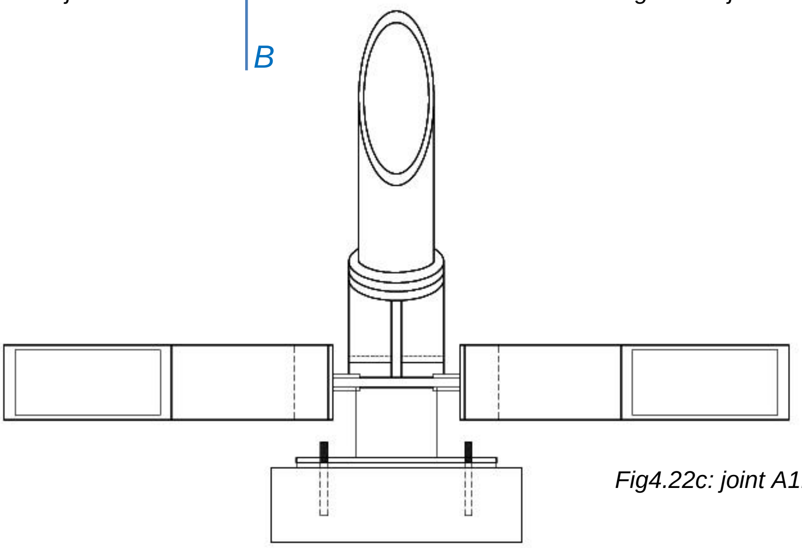


Fig4.22c: joint A1.5 View A

Joint B1.6:

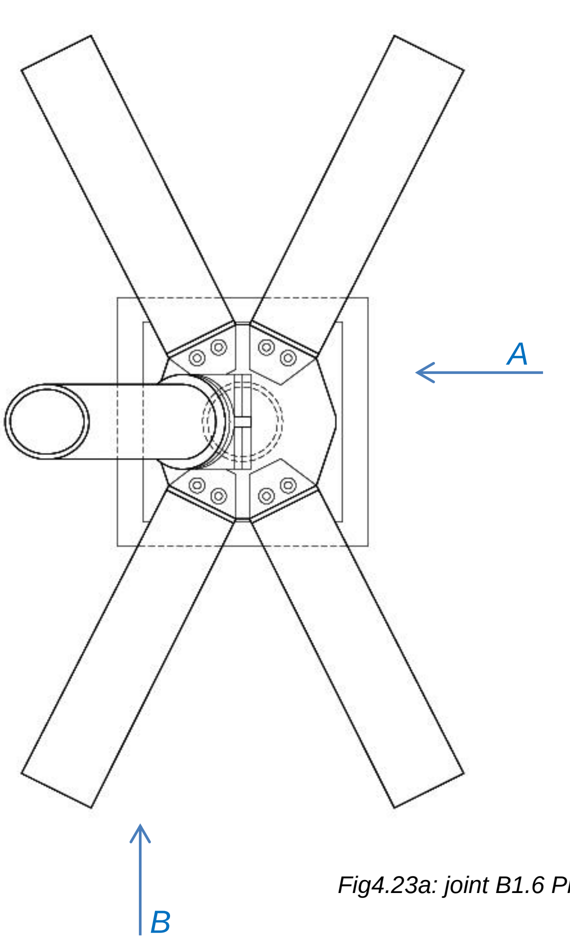


Fig4.23a: joint B1.6 Plan

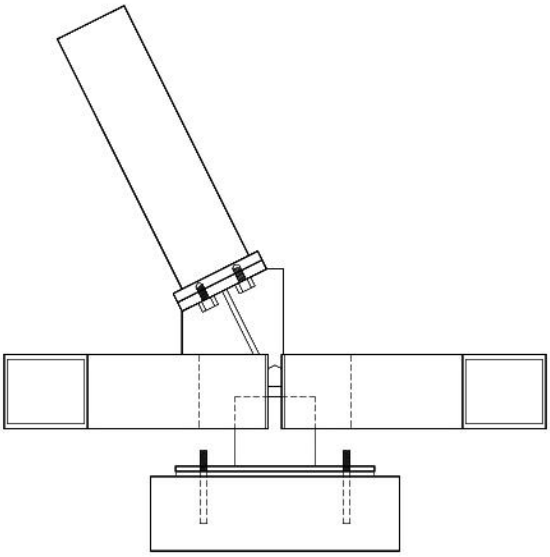


Fig4.23b: joint B1.6 View B

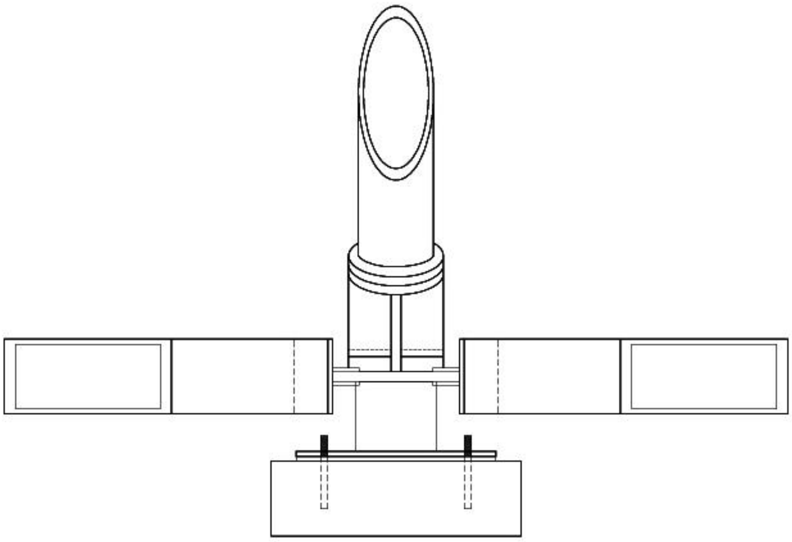


Fig4.23c: joint B1.6 View A

Joint A1.7

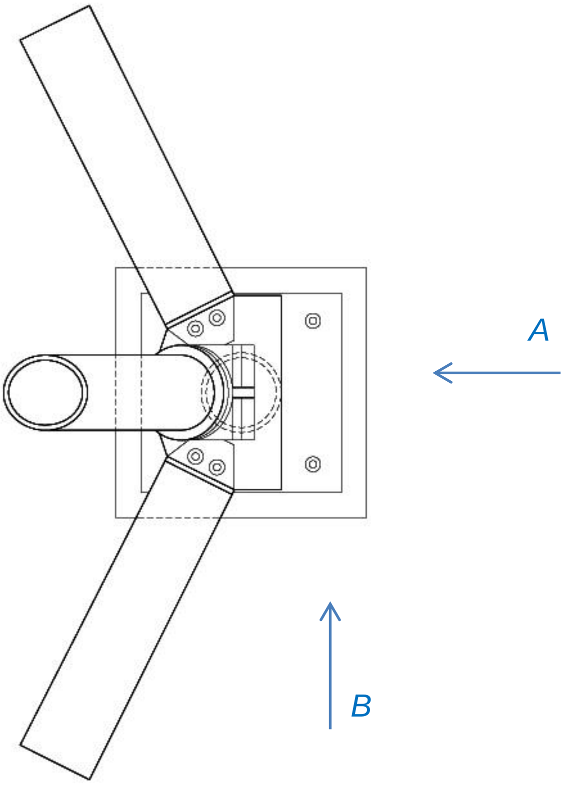


Fig4.24 a: joint A1.7 plan

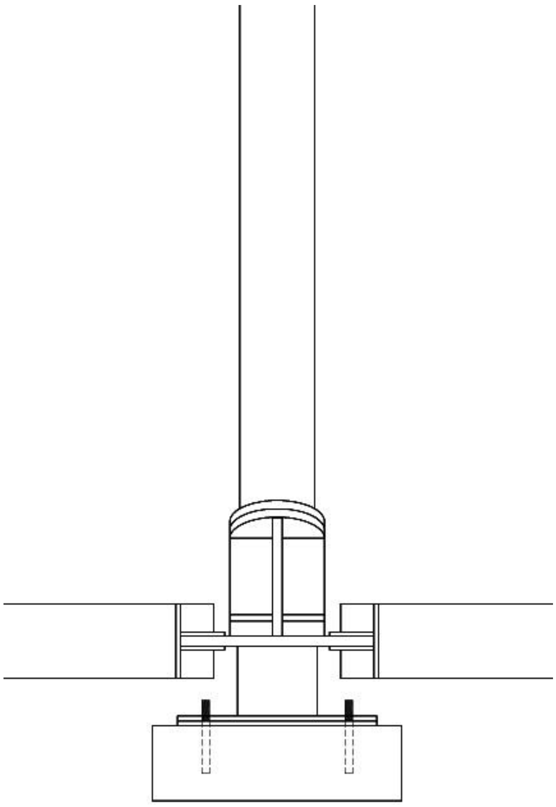


Fig 4.24 b: joint A1.7 view A

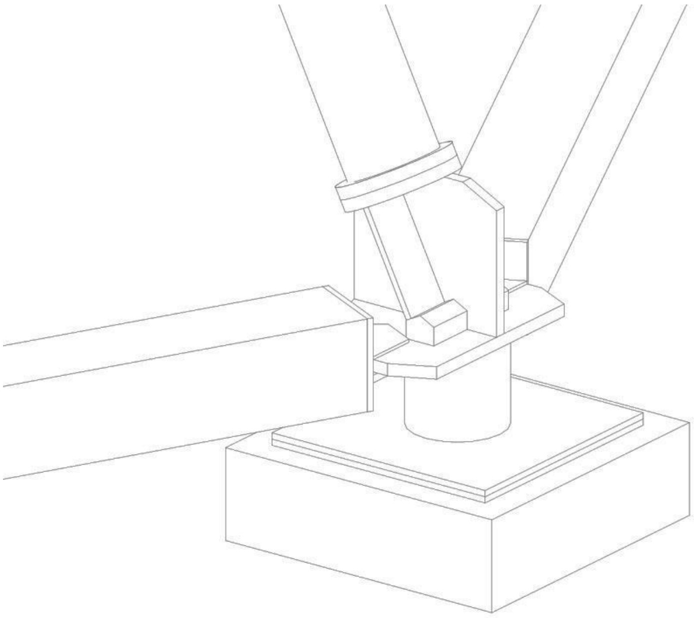


Fig 4.24 c: joint A1.7 3D view

Joint A2.4

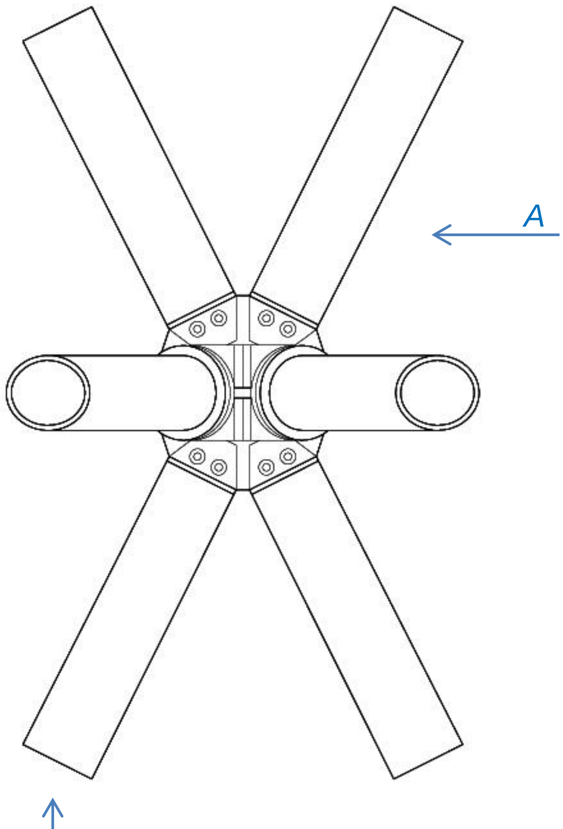


Fig4.25 a: joint A2.4 plan

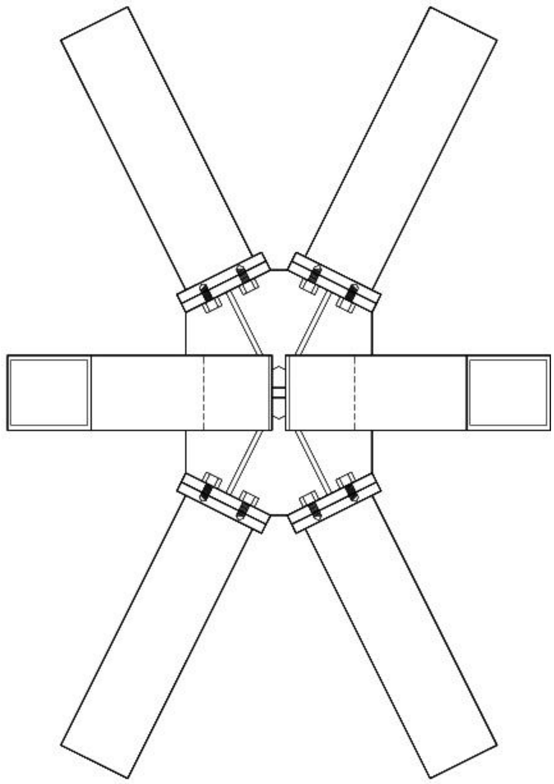


Fig4.25 b: joint A2.4 View B

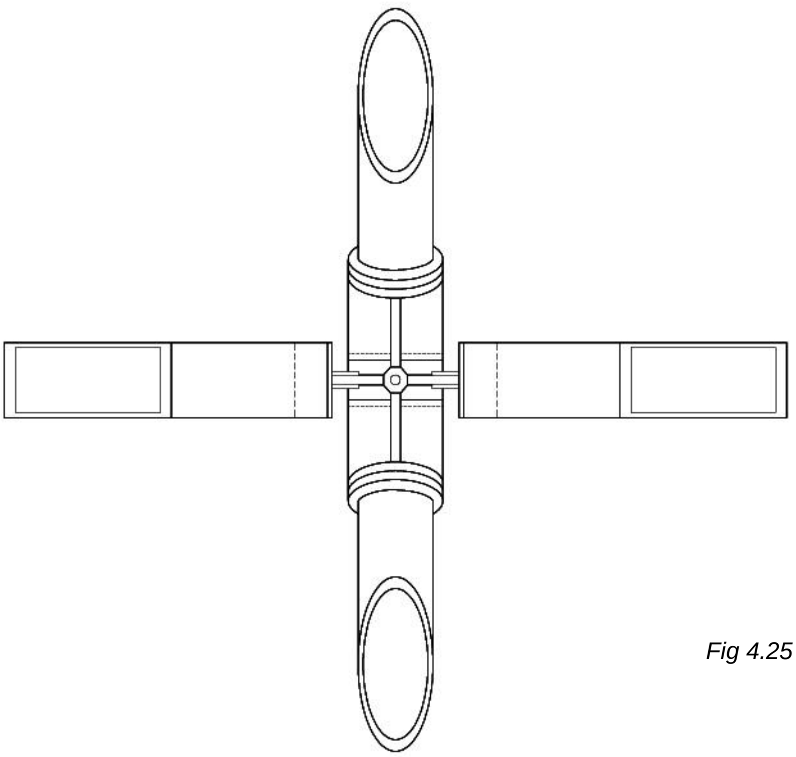


Fig 4.25 c: joint A2.4 View A

Joint A2.6

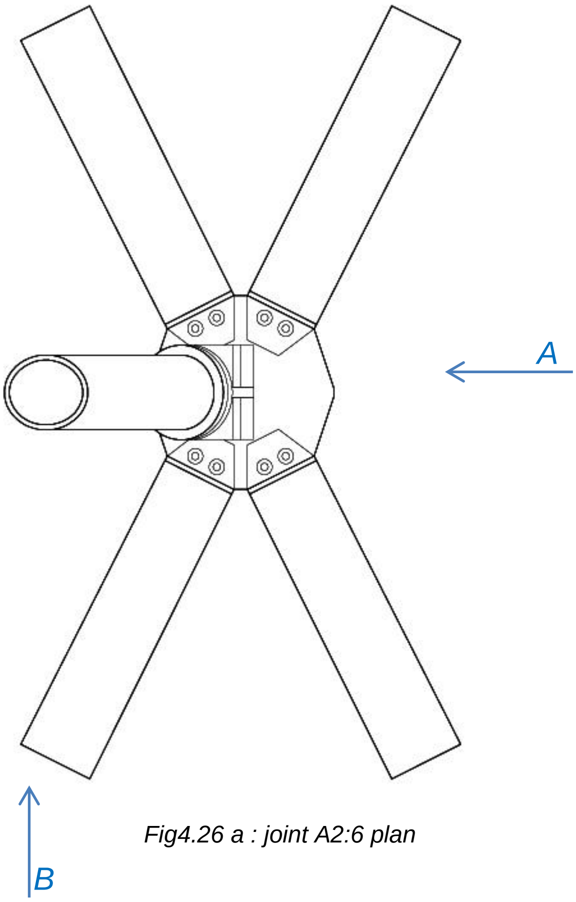


Fig4.26 a : joint A2:6 plan

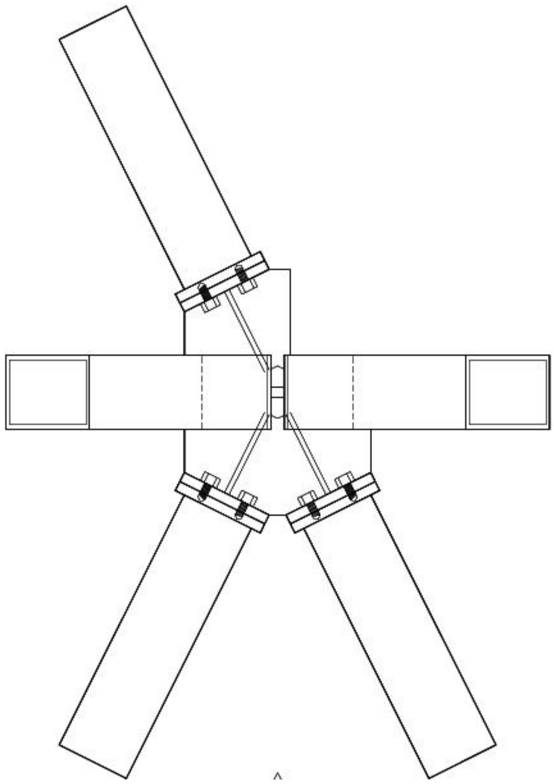


Fig 4.26 b: joint A2:6 View B

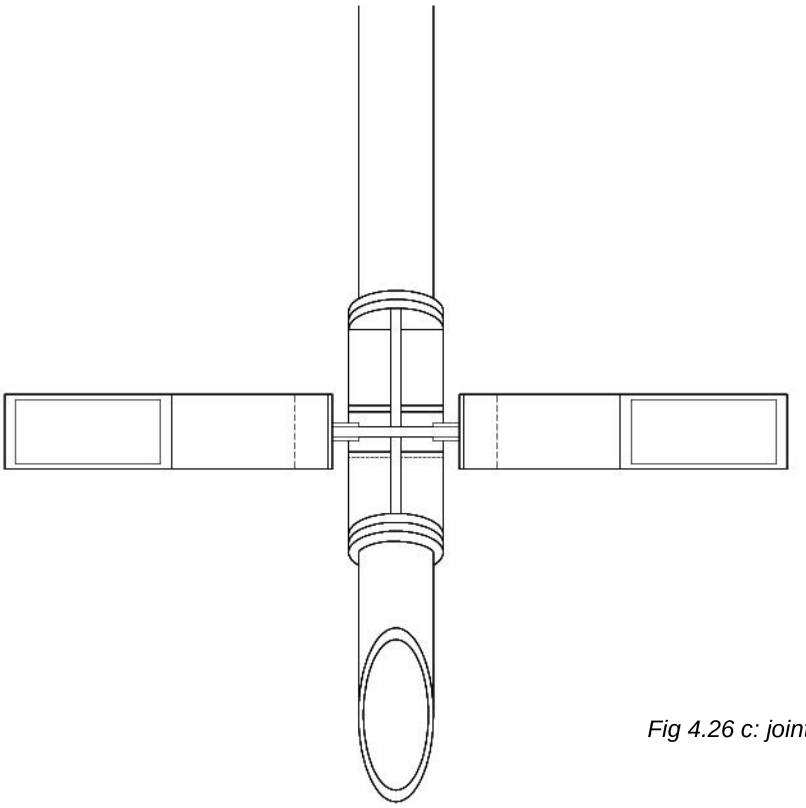


Fig 4.26 c: joint A2:6 View A

Joint B2.7

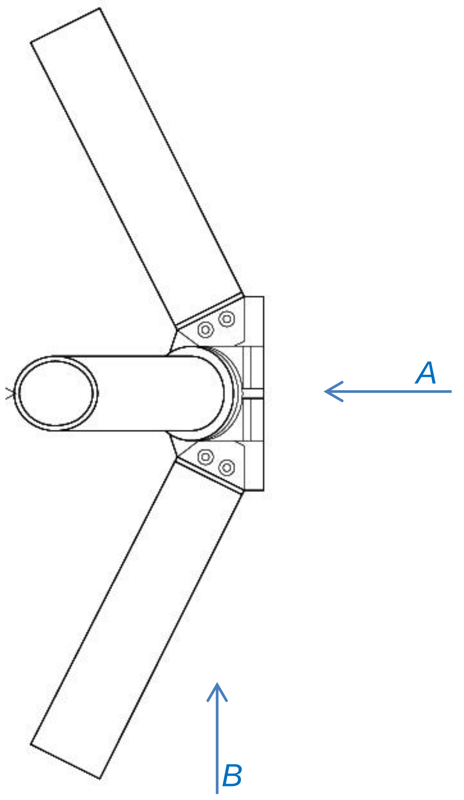


Fig4.27 a: joint B2:7 plan

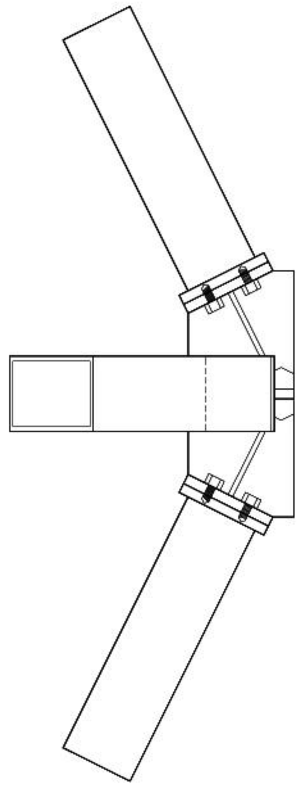


Fig 4.27 b: joint B2:7 View B

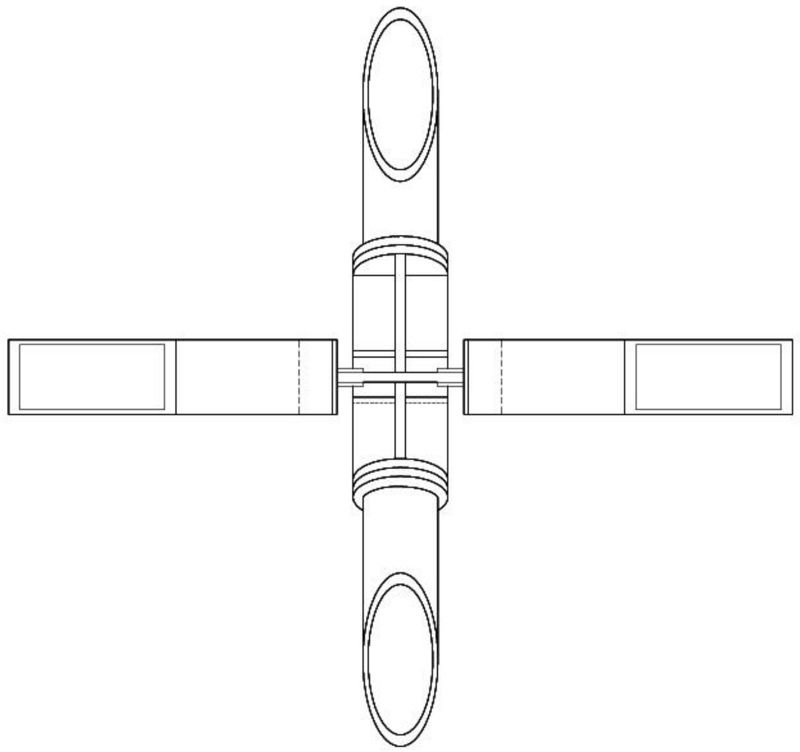


Fig 4.27 c: joint B2:7 View A

Joint B3.4

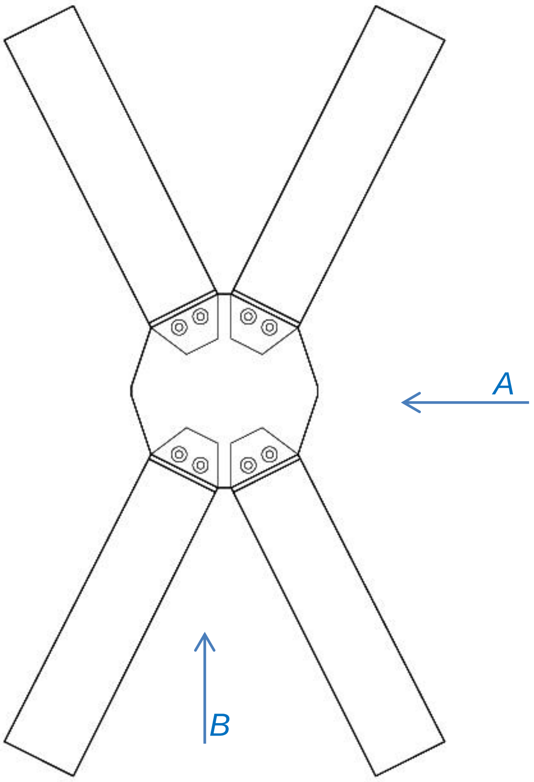


Fig 4.28 a: Joint B3.4 plan

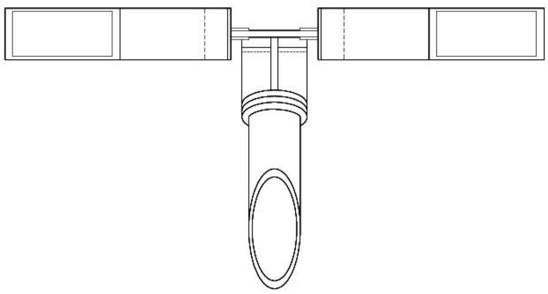
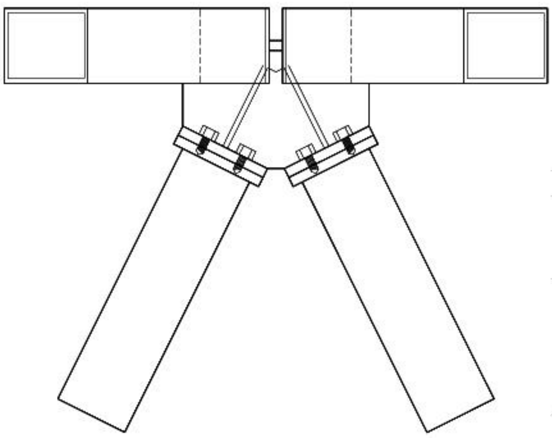


Fig 4.28 b: Joint B3.4view A



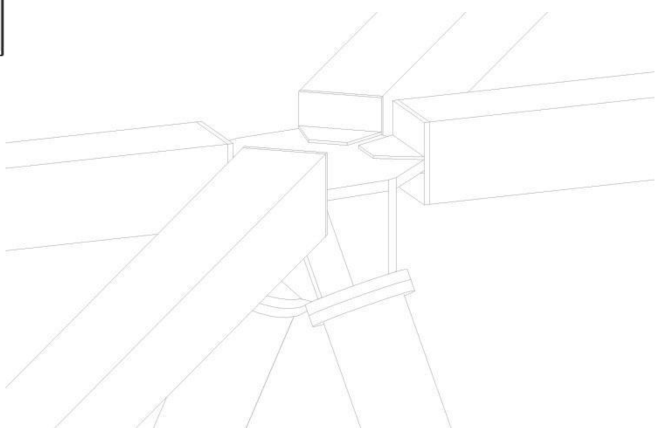


Fig 4.28 c: Joint B3.4view B

Joint B3.6

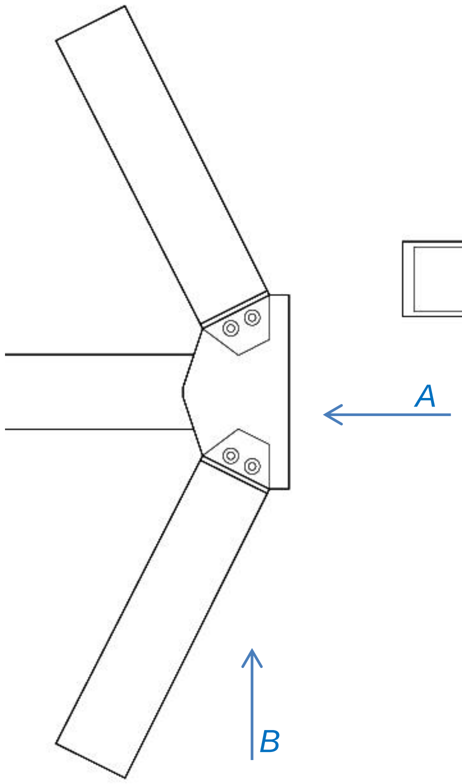


Fig 4.29 a: Joint B3.6 plan

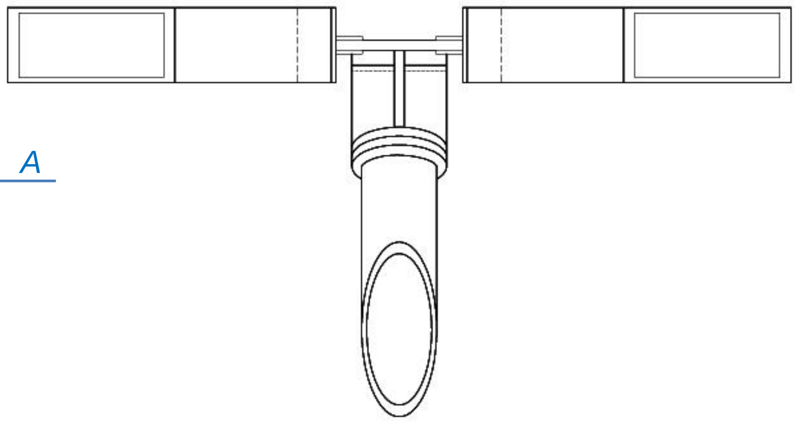


Fig 4.29 b: Joint B3.6 view A

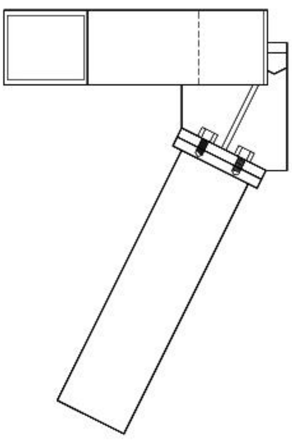
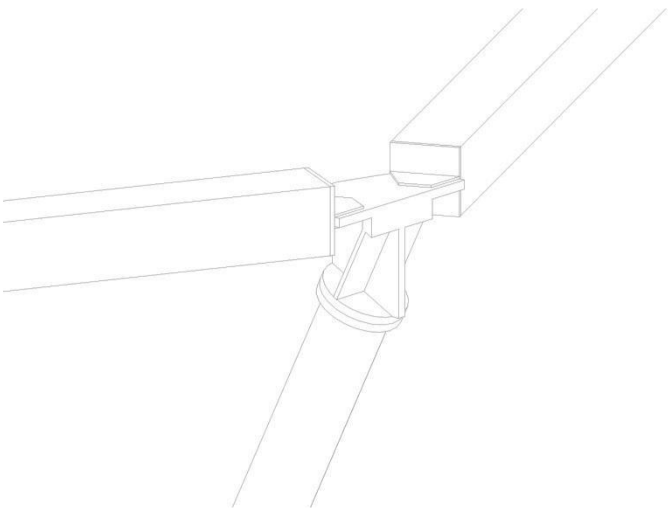


Fig 4.29 c: Joint B3.6 view B



4.2.12. Buildability

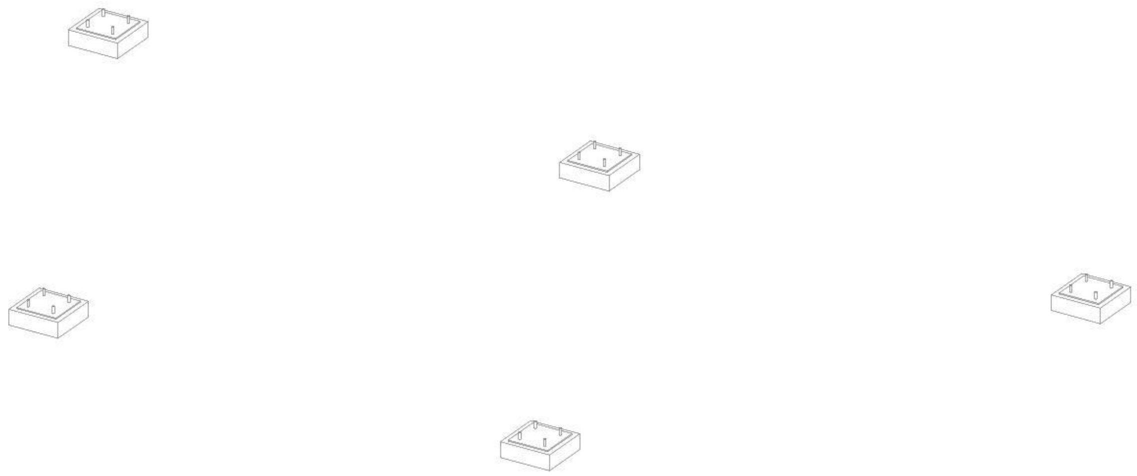


Fig 4.30: step one, the heavy concrete blocks with base plate and waiting bars are located on the flat platform

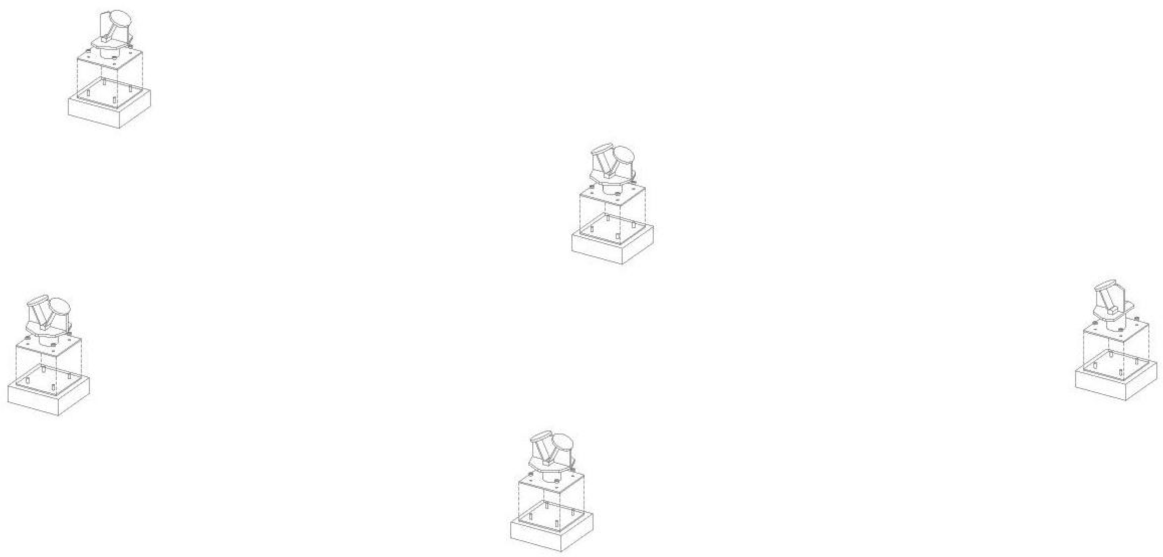


Fig4.31: step two, the ground level joint is installed

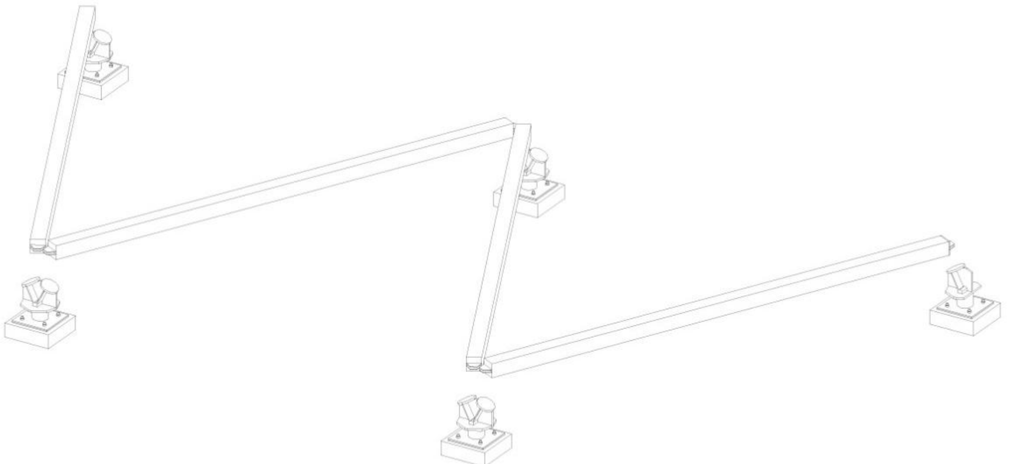


Fig 4.32: step three, the rectangular tube section beams are installed in this stage

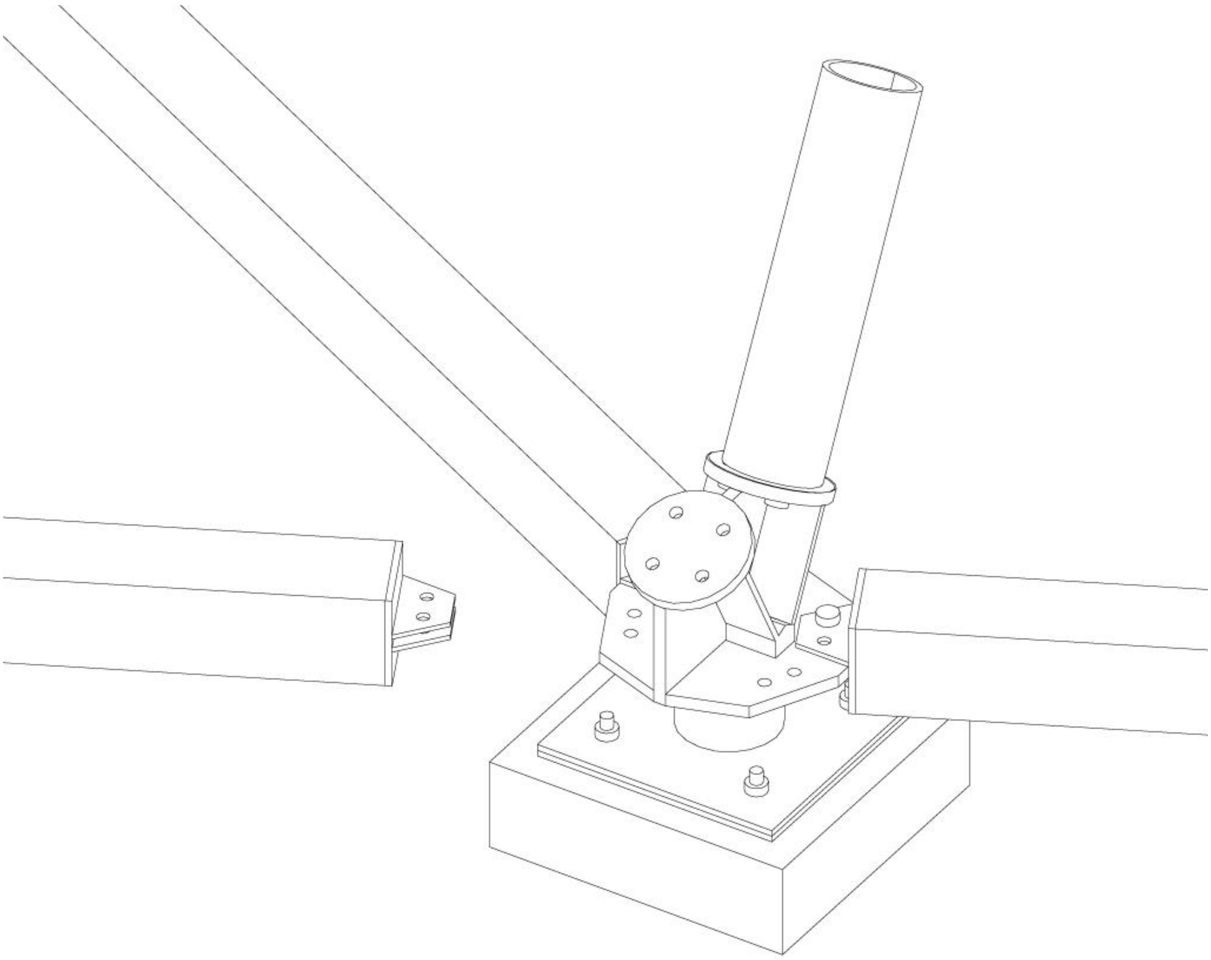


Fig 4.33: detail of installation of the beam to the joint

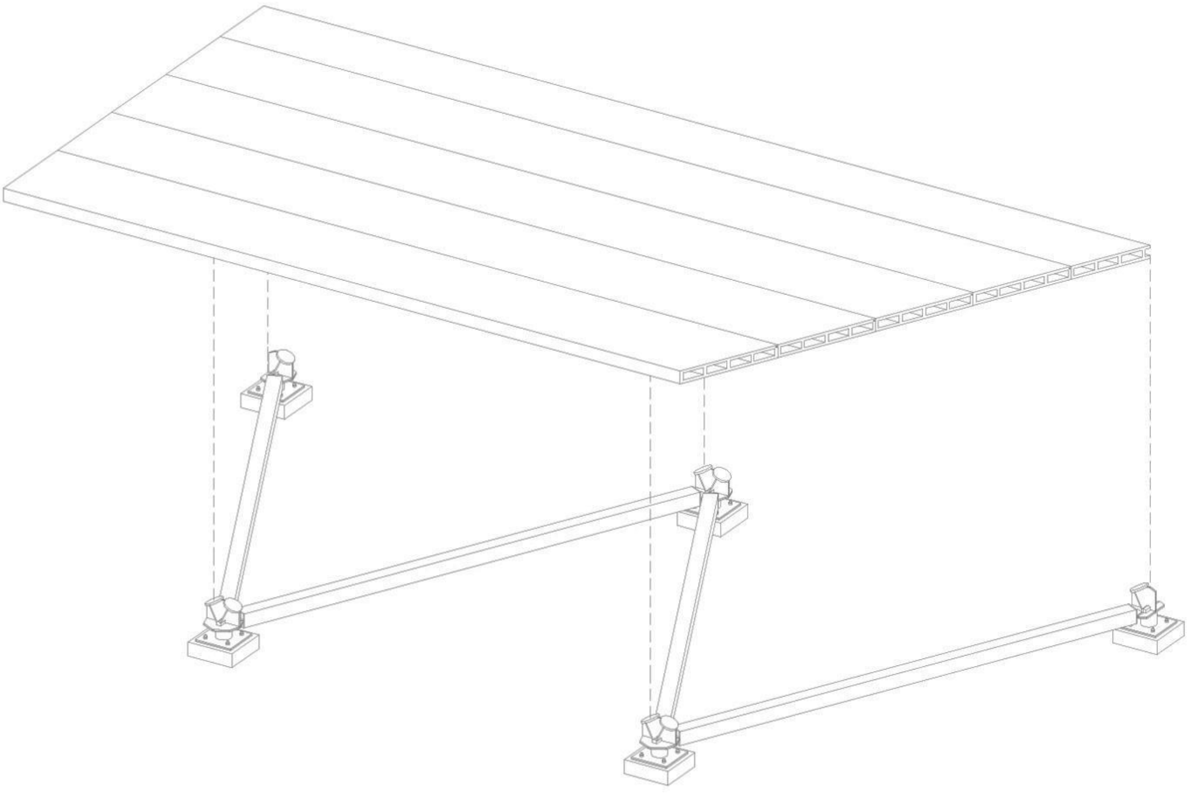


Fig4.34: step four, the flooring system (Lignatur) will be placed on the beam

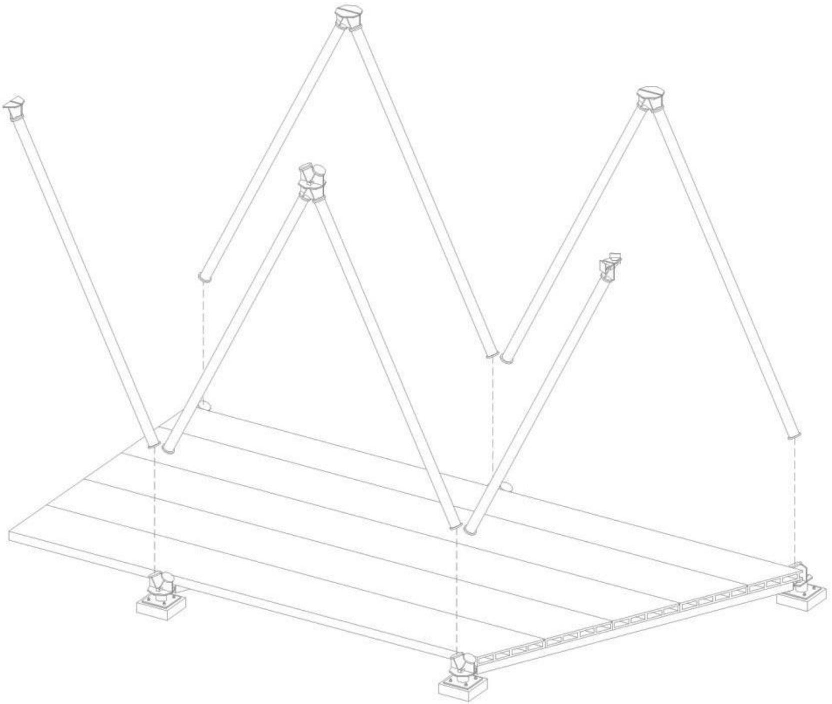


Fig4.35: step five; the columns with installed joint on the top are tilt up

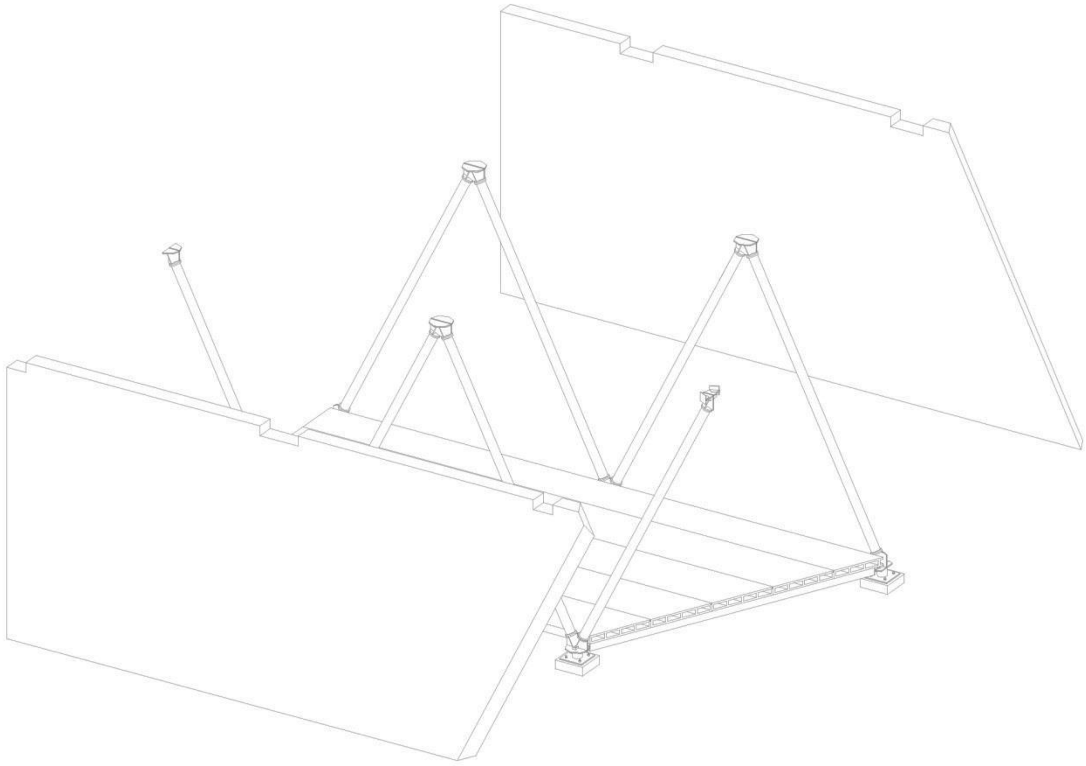


Fig 4.36: step six, the wall system will be located inside columns boundary

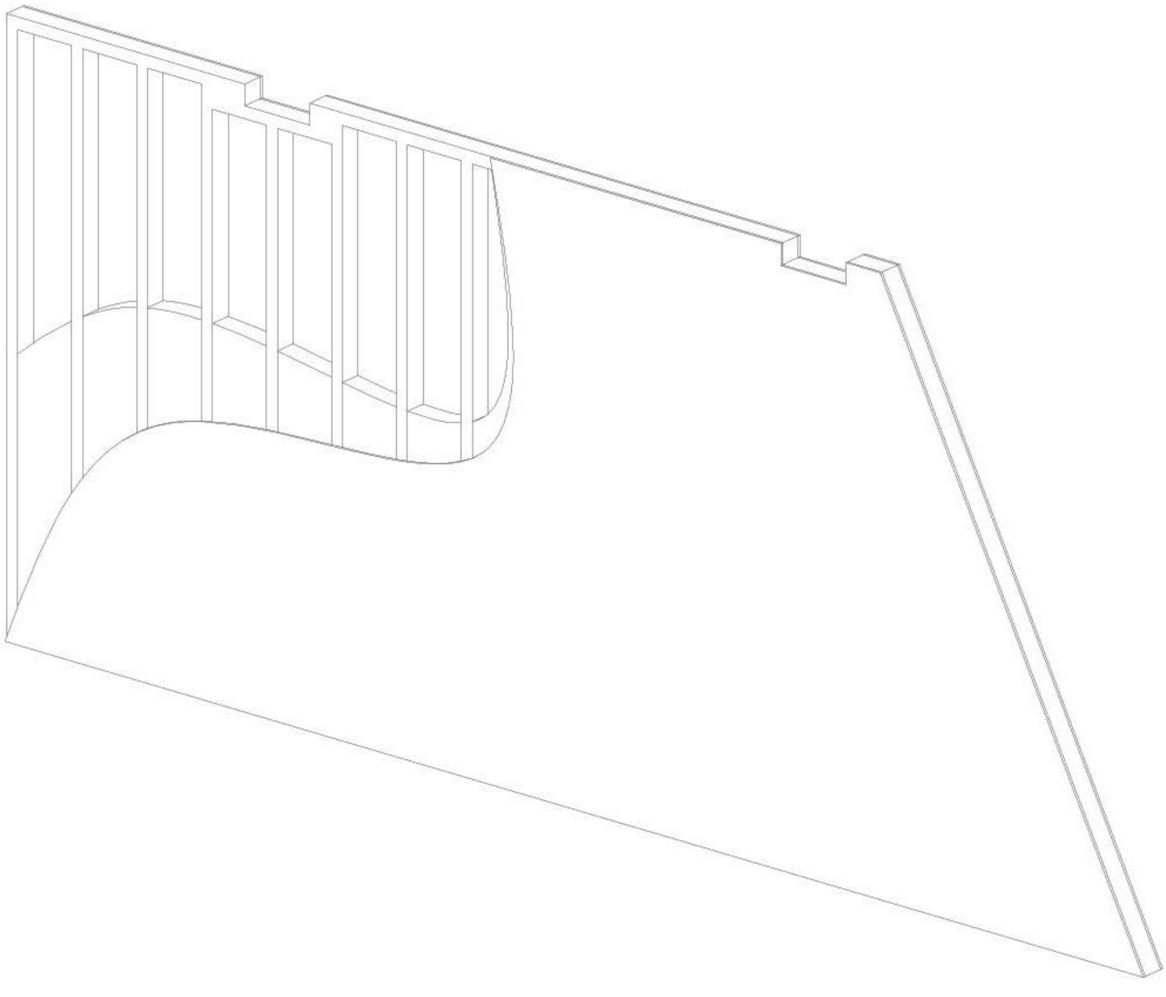


Fig 4.37 the wall system is comprised of the wooden structure with vertical elements each 60 cm. the facades are covered by OSB boards. The spaces between vertical elements and OSB boards are filled with insulation material

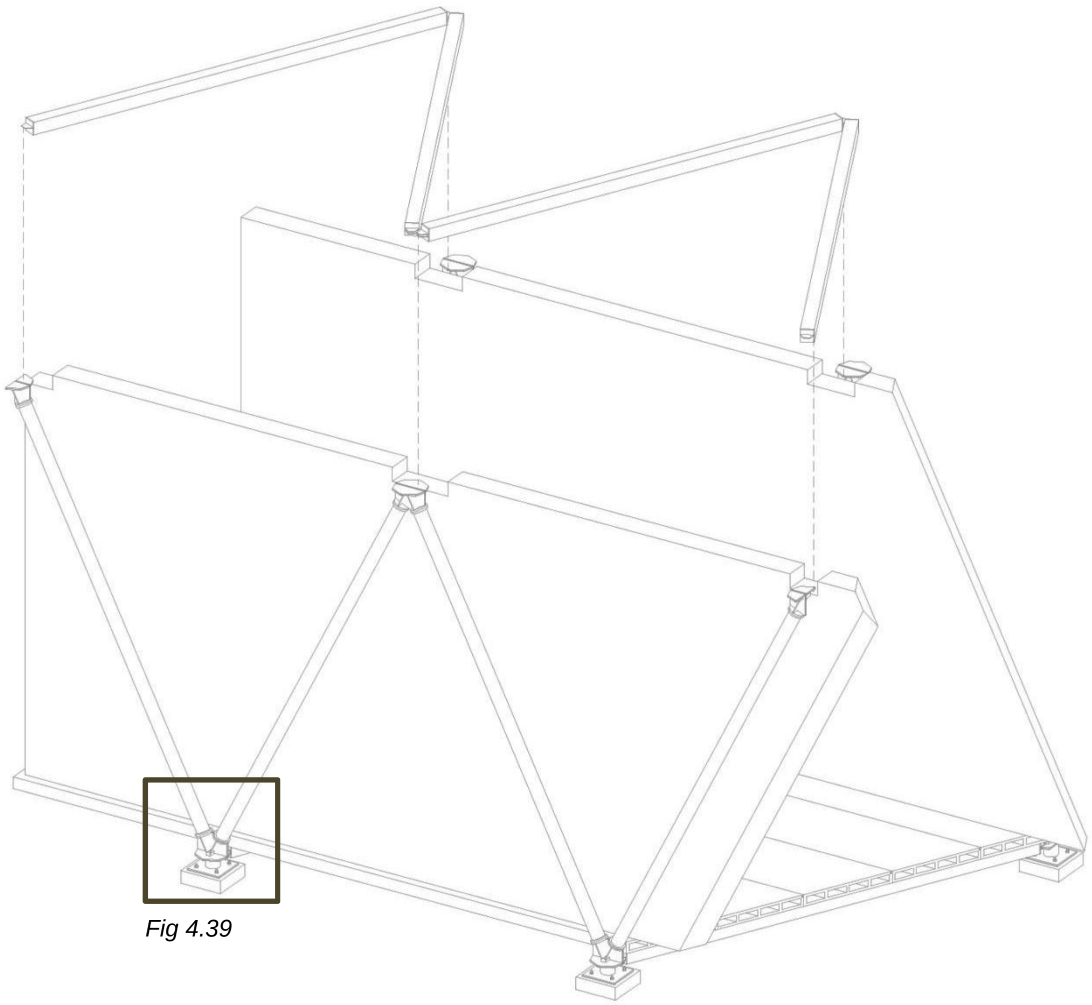


Fig 4.38: step seven, the top beam are installed to the top part of the columns

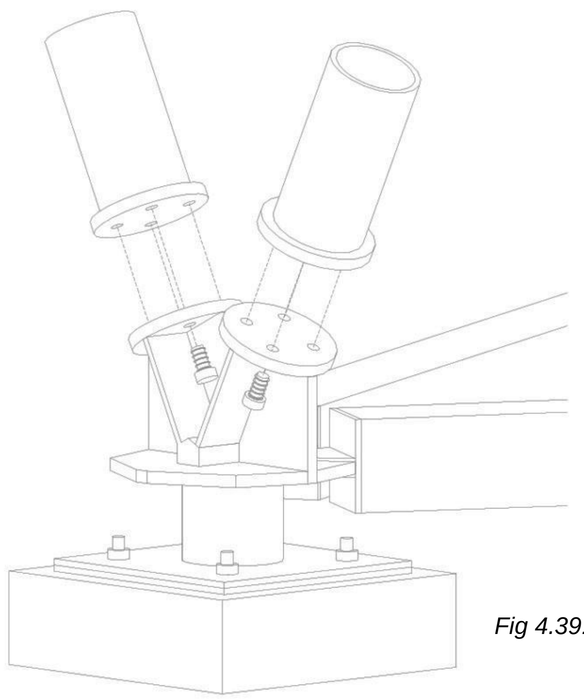


Fig 4.39: the installation detail of the column to the joint

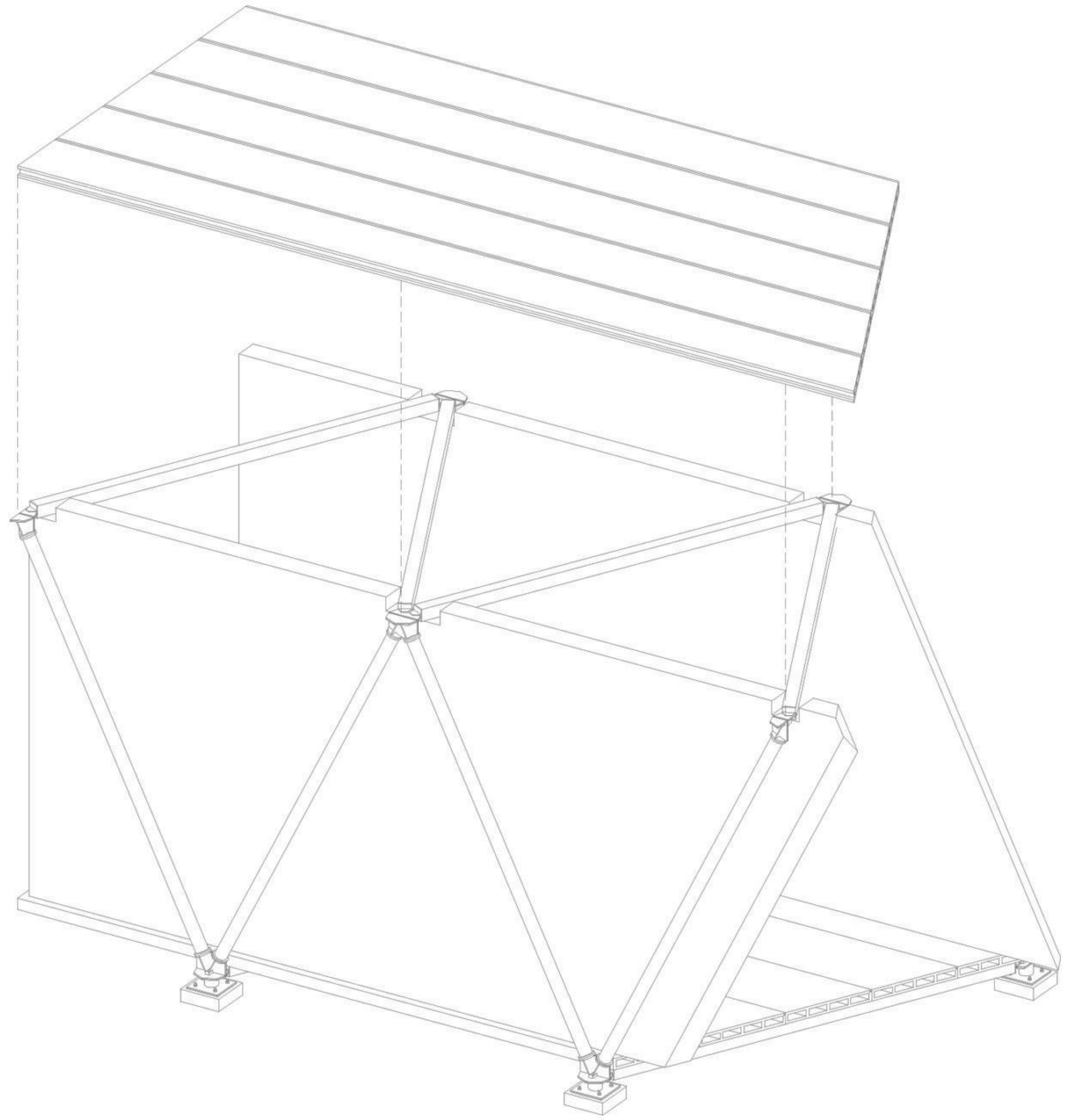


Fig4.40: step eight the ceiling system will be located above the upper beam

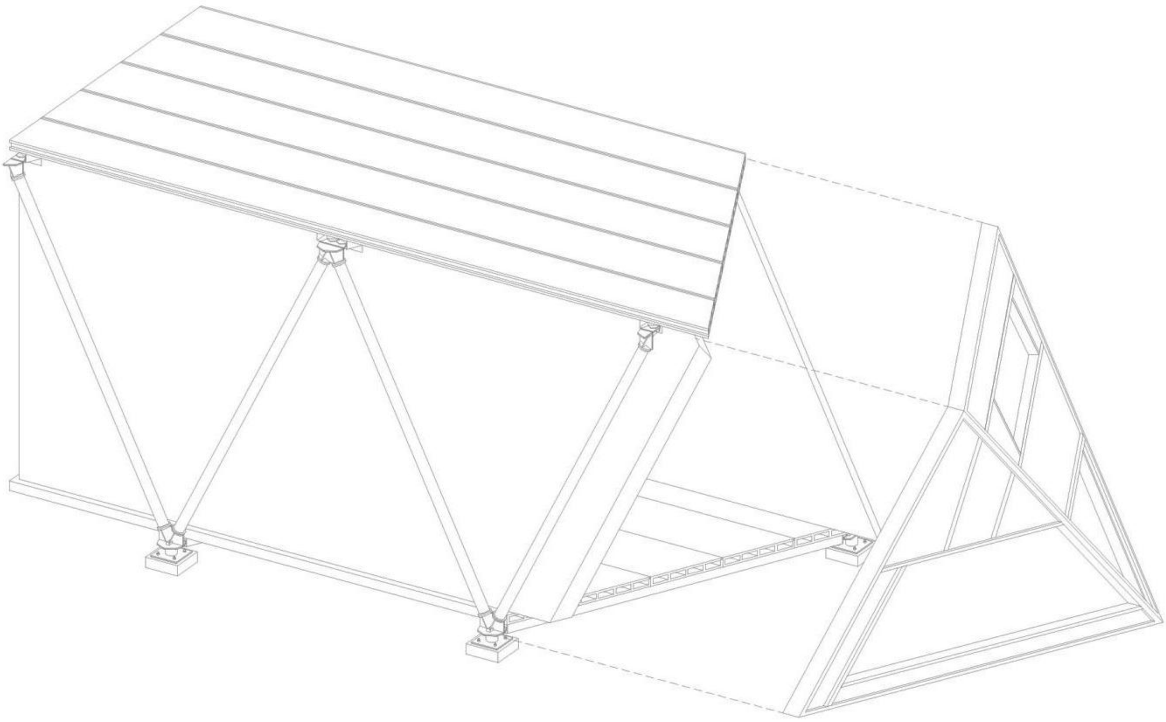


Fig 4.41: step nine, the structure of the inclined façade is installed in this step

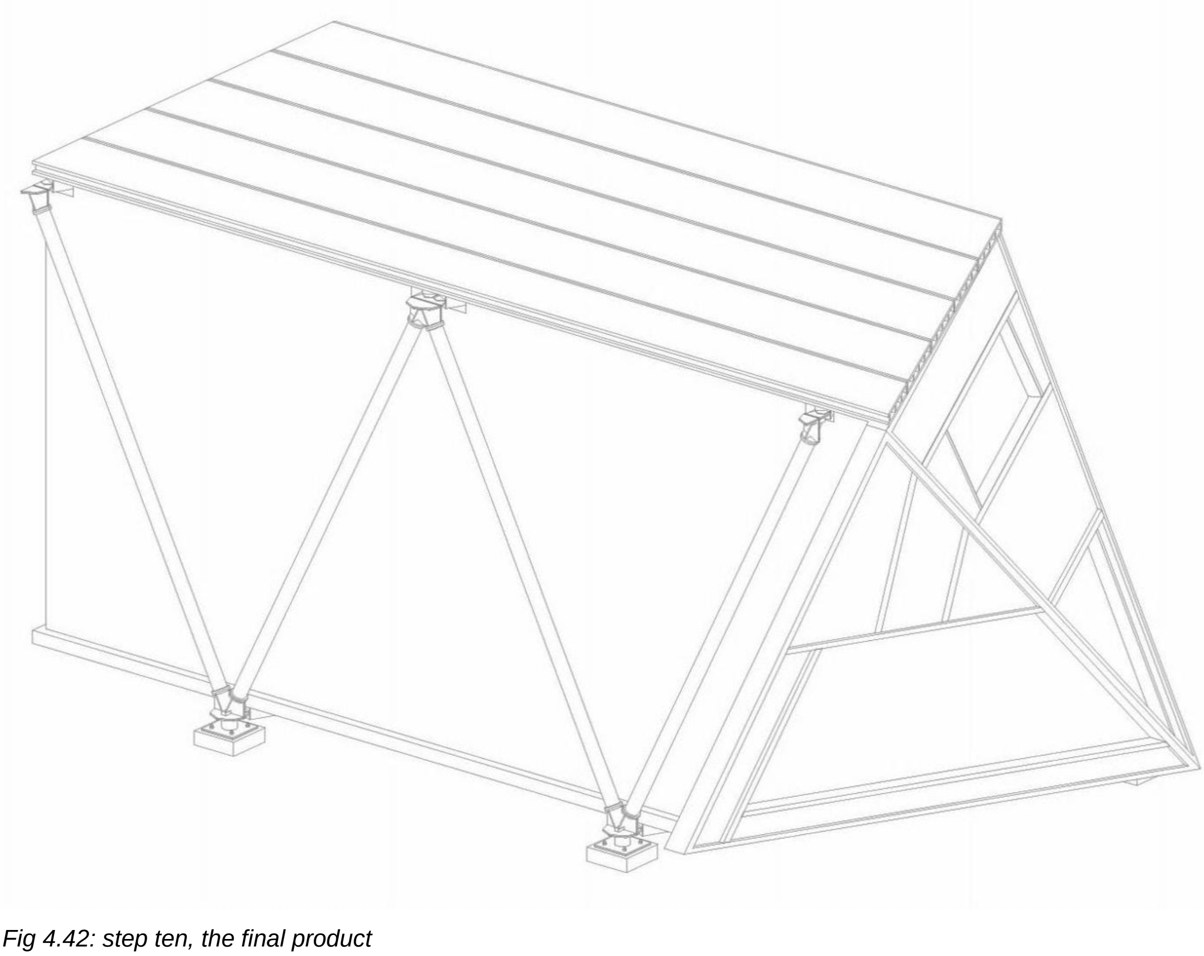


Fig 4.42: step ten, the final product

4.3. Parking Structure

Since one of the very first concepts of the project was to tackle the problem of urban voids and to create a solution which would not be imposing and permanent to the site, that is to say complete structure could at some point be removed so that the site could be restored to its previous condition with minimum possible changes. The location is now an urban void and it is being used as a public parking under the authority of Church, which the whole site belongs to. Knowing this, and seeing that the parking is active and used by a lot of people, we decided not to remove it, instead we would expand it, cover it and use it as a base to build on. Instead of going underground with it, it would keep its current place and the ground level of our modular habitat would be elevated as per above mentioned idea of minimum impact to site.

4.3.1. Organization

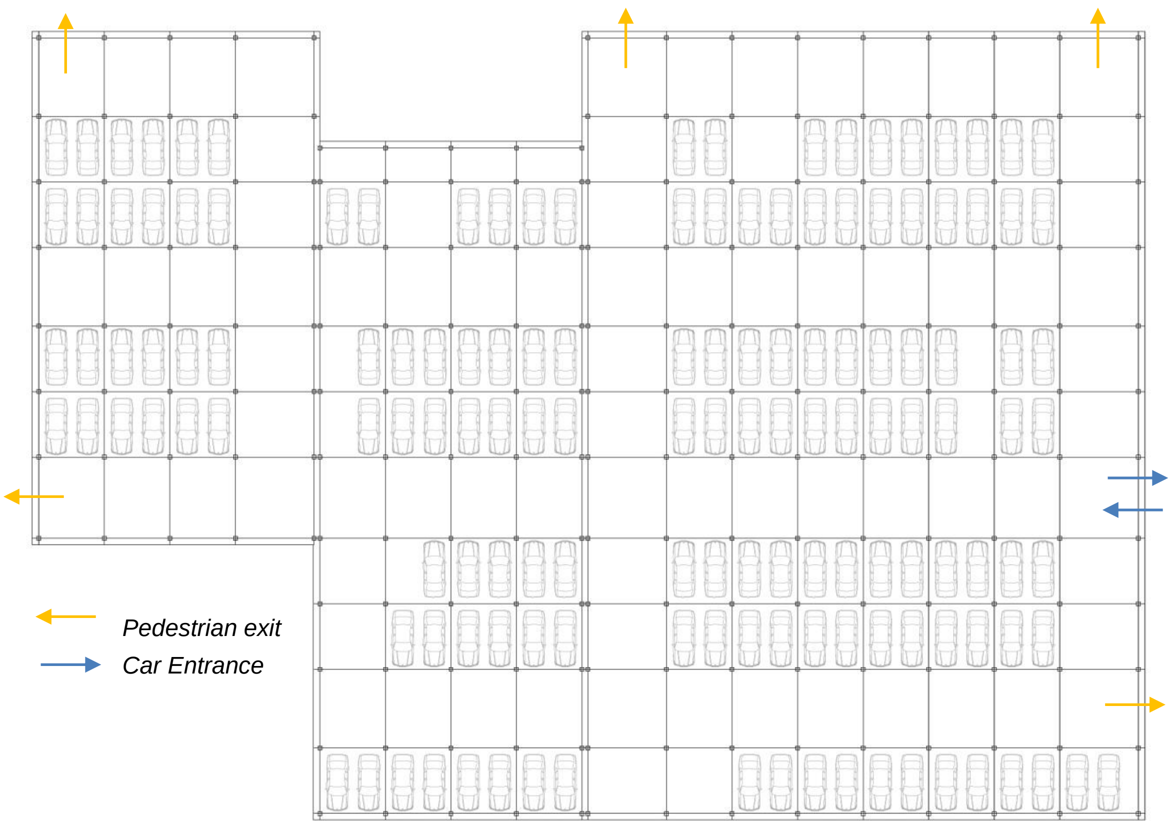


Fig4.43: Parking organization and layout

Instead of current non-regulated parking, we organized it in such a way to maximize the capacity of vehicles and their movement inside. Now there are 132 parking places, one 2-way access ramp for the cars, and 5 pedestrian exit points. Parking is covered, more than 50% open on sides, on ground level with residential functions above it.

4.3.2. Structural System

Span of the structure is 5 m in the direction of parking spaces and 6 m for the bay, with the exception of the entrance ramp bay, where due to the dimensions of the factory units through which the ramp is passing width of the bay is 6.2 m. The elements are easily assembled on site, and the whole system is foundationless.

4.3.2.1. Foundation and Columns

System is chosen as per Intrapark system by Intrakat group.[3] The solution offers a foundationless structure with a base plate to which columns are attached. Base plate is then anchored to the ground by several high strength steel anchors (number of anchors depends on the seismicity of the area, varying from 0 to 8) up to 1.5 meters deep into the ground. This provides quick on site work and assembly, as well as possibility to be completely removed with no permanent change to the site. Columns are a 30 cm hollow steel square cross section, made from two parts which slide into each other telescopically allowing a 50 cm gap to balance possible ground irregularities or smaller slopes.[4]

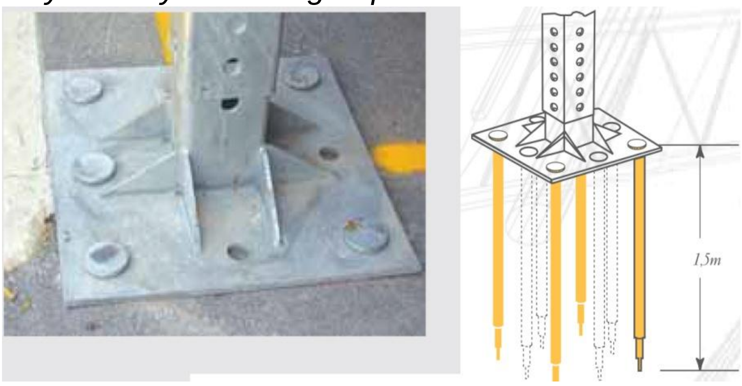


Fig 4.44: Column base plate and anchors by Intrakat system

4.3.2.2. Beams and Slab System

System is chosen to be precast solution to provide a slimmer slab as it contains the beam within the slab, while keeping the supporting strength. This is a precast slab system with elements assembled and tied together, again providing ease and speed to on site construction.

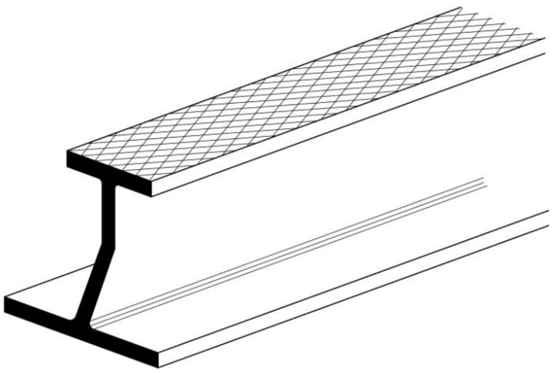


Fig 4.45: typical ASB section, lower flange wider

[3] *http://www.intrakat.gr/en/activities/the-intrapark-system/*
[4] *Intrapark parking system presentation – www.intrakat.gr*
Design of Asymmetric Slimflor Beams with Precast Concrete Slabs; J W Rackham, S J Hicks, G M Newman, SCI (Steel Construction Institute) Publication P342

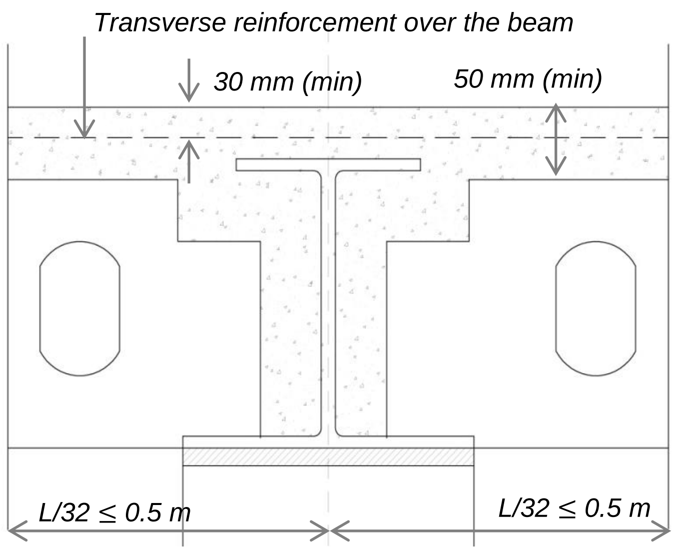


Fig 4.46: Limited composite action between ASB and precast hollow core slab

Beams are a fire engineered hot rolled steel Asymmetric Slim floor Beam ASB 280(FE). The lower flange is wider and the precast concrete decking rests on it, while the top flange is embedded in concrete, giving the limited composite action, and protecting the beam from fire. The bottom flange is only part exposed, and is covered with a fire resistant board, applied to the column as well.[5] The slab is a precast prestressed concrete hollow core unit with thickness of 25 cm and 120 cm width. The slab elements are placed on the bottom flange of the ASB beams and concrete is cast over it to make the composite action and tie the elements together.[6] [7]

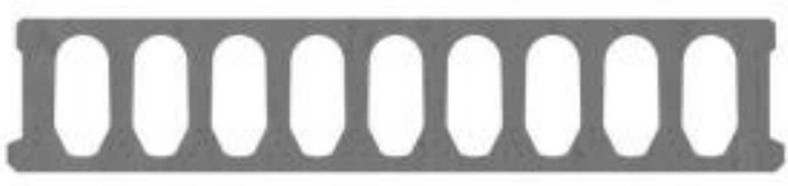


Fig 4.47: Hollow core precast slab unit 250 mm, by Bison

4.3.2.3. Bracing

Since this is essentially an open deck platform, bracing is required in order to restrict sway. Bracing provides a pathway to transfer the horizontal loads like wind loads or second order effects to the ground and provides stiff resistance to structure. Vertical bracing, in the form of diagonal steel members, is applied along the perimeter (with exception of entry and exit points) of the geometry in plan of structure, to provide stability. Floor slab is assumed to act as a diaphragm to provide horizontal bracing.[8]

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[5] Slimdek manual; Chapter 1: Components: 1.3 ASB and ASB(FE) - Asymmetric Slimflor® Beams
[6] http://www.bison.co.uk/products/hollow-core-floors
[7] Design of Asymmetric Slimflor Beams with Precast Concrete Slabs; J W Rackham, S J Hicks, G M Newman, SCI (Steel Construction Institute) Publication P342
[8] http://www.steelconstruction.info/Braced_frames
Figure 2.4: Design of Asymmetric Slimflor Beams with Precast Concrete Slabs; J W Rackham, S J Hicks, G M Newman, SCI (Steel Construction Institute) Publication P342

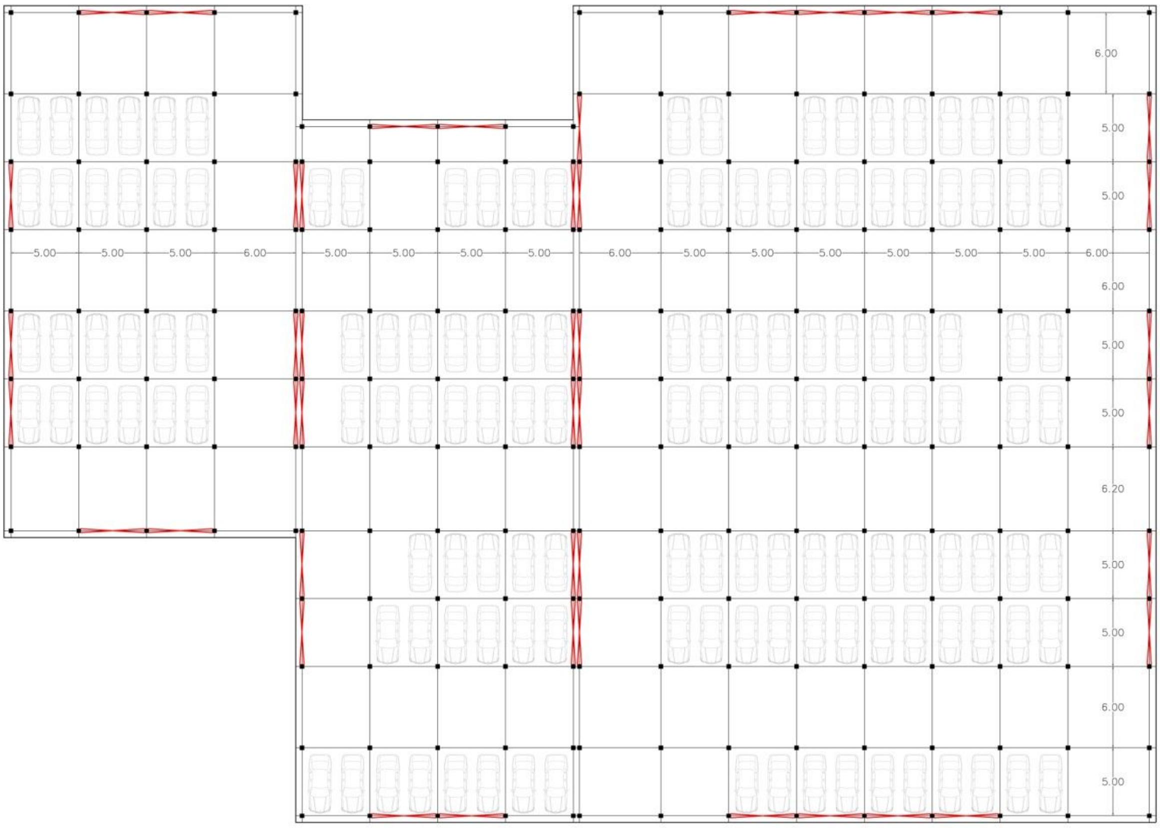

Fig 4.48: Bracing (thick line around perimeter) and expansion joints (shaded line) locations

4.3.2.4. Structural Gap

Because of irregular shape of the platform and the dimensions, also to withstand the thermal expansion and contraction due to annual temperature difference, as well as ground settlement and seismic activity, separating the structure was necessary. It was done in such a way to create three simple geometrical shapes in such a way that the distance would be no more than 50m in each direction. Since there would be modules on the top, we took care to design in such a way that no module would be built crossing the expansion joint line. We placed a double row of columns to create the gap. Since the column height is 3m, and 5% of the column height is the allowed movement so the distance between gaps is 15 cm. [9]

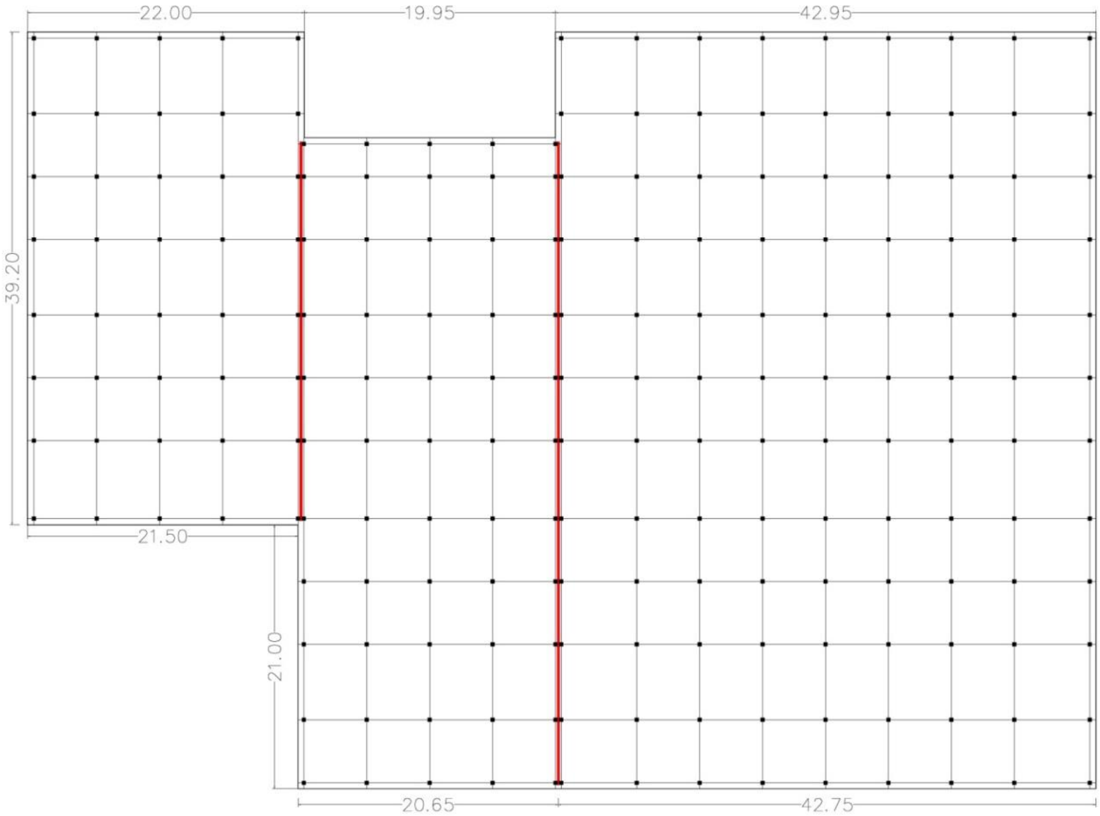

Fig 4.49: the structural gap in parking

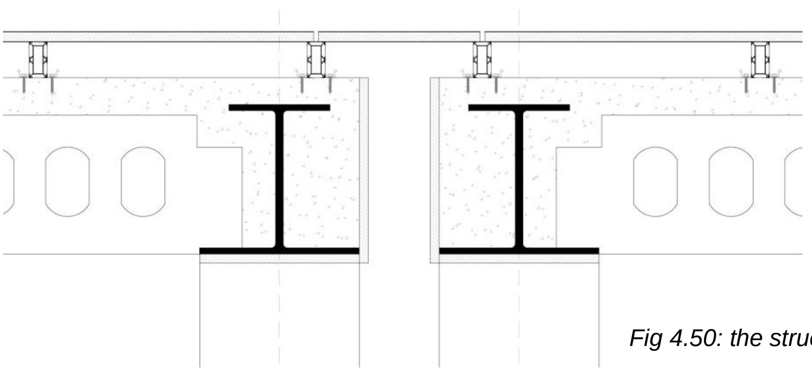

Fig 4.50: the structural gap between columns

[9] *James M. Fisher, "Expansion Joints: Where, When and How", Modern Steel Construction, 2005*

4.3.2.5. Gabion Wall

Fig 4.51: Gabion wall

Along the parking perimeter would be placed a gabion wall, with openings to facilitate natural ventilation so mechanical one is not necessary as this would be an open deck covered parking. Stones and rocks are an important geological reference to Lecco, everywhere one looks around one can see mountains, cliffs and rocks. Visually and metaphorically gabion wall encloses the perimeter as the mountains surround Lecco. Gabion wall is self-supporting, has no need for foundation and has no load bearing function, just aesthetic and enveloping parts of the perimeter.

4.3.3. Fire Regulations

Referring to the Italian fire codes, categorization of the parking space is:

- *Mixed (miste)*
- *Open (aperta)*
- *Over ground (fuori terra)*
- *With open space (a spazio aperto)*

Total surface of the parking is rounded off to 4500 m^2 it has only ground level.
According to the categorization and total surface area of the parking, it might be necessary to divide the parking into more compartments. From table we can see that maximum area for mixed, open, over ground, ground level parking spaces is 7500 m^2 which means that one compartment is sufficient. Furthermore, this tells us that the number of car access ramps per each compartment needs to be either two ramps of minimum 3 m for one way direction, or one ramp of minimum 4.5m for two way direction for car parks with more than 15 vehicles.

Piano	Fuori terra				Sotterranee			
	Miste		Isolate		Miste		Isolate	
	Aperte	Chiuse	Aperte	Chiuse	Aperte	Chiuse	Aperte	Chiuse
Terra	7500	5000	10000	7500				
1^0	5500	3500	7500	5500	5000	2500	7000	3000
2^0	5500	3500	7500	5500	3500	2000	5500	2500
3^0	3500	2500	5500	3500	2000	1500	3500	2000
4^0	3500	2500	5500	3500	1500		2500	1500
5^0	2500		5000	2500	1500		2000	1500
6^0	2500		5000		1500		2000	1500
7^0	2000		4000					

Fig4.52: Maximum area for one parking compartment due to classification

In order to find the exit space needed, first we need to calculate the crowding density (densitá di affolamento), which is by the code one person per each 10 m^2 of parking area – so crowding density is 4500/10=450
Next we need to take the value for the outflow capacity (capacitá di deflusso) to be 50 for the ground level parking, and take the module (modulo) of the exit point per person to be 0.6m. Then the total length of exits is calculated as 450/50 · 0.6 = 5.4m
We have the total length of exit ways as 5.4m, but they need to be distributed in such a way that there is at least 2 exit doors, and that from each point inside parking there is no more than 40m away from exit.[10]
The beams and slab have been designed to resist fire, since the whole beam is embedded in concrete, only the bottom side of the lower flange is exposed, but it can be additionally protected by using boards.

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[10] *Decreto ministeriale 1° febbraio 1986 (G.U. n. 38 del 15 febbraio 1986) NORME DI SICUREZZA ANTINCENDI PER LA COSTRUZIONE E L'ESERCIZIO DI AUTORIMESSE E SIMILI, Leonardo Corbo, "Manuale di prevenzione incendi nell'edilizia e nell'industria", 10ª edizione*

5. Technological Solutions

5.1. Introduction

How the building performs and whether it does well or badly, depends on the design of its form, its plan, its section arrangements and heights, the size and layout of internal and external openings and connections, the thermal inertia and transparency of its construction, the orientation of its spaces and finally, in physical terms, on the design of building's immediate external environment. [1] *The precise choice at every stage is needed to achieve the desired result. These items should be observed all through the design process, in the selection of the materials, building technologies and construction details and last but not least, careful and consecutive supervision must be executed in every sector to reduce the chance of labor defects. However, in order to design respecting the environmental concerns, the architect should always stay in contact with the surrounding. Solar architecture involves designing with climate: for wind, shelter, outdoor space; light and day light; heat and warmth; cooling and ventilation.*

For the better life quality of the inhabitants and also consuming less energy which laterally ends in less environmental pollution, natural lighting and ventilation are almost expected in every room in the dwellings. However, houses are generally characterized by fairly continuous occupation; there have been changes in the pattern of use of the dwellings. Intermittent occupation during the day is now commonplace. This has implications for heating and ventilation. For much of the day, an unoccupied dwelling needs almost no heat, but in the evening it must quickly warm its returned occupants.

Nowadays, cooking and washing concentrate and increase the production of water vapor inside the dwelling. This is coupled with tighter sealing of the building envelope. Consequently, there is now more likelihood of condensation occurring than in the past. For this reason, controlled ventilation in dwelling design is important, in order to avoid condensation while minimizing heat loss. In further examination, a layer of vapor barrier might also be needed, to prevent moist air to penetrate into the layers of the wall. In case of this event, apart from the degradation of the material, the efficiency of the insulation will also be dramatically reduced.

[1] *The Climatic Dwelling, E. O. Cofaigh; J. A. Olley; O. Lewis, James & James Ltd, 1998, page:9*

5.1.1. Environmental Conditions

"Sunshine is delicious, rain is refreshing, wind braces us up, and snow is exhilarating; there is really no such thing as bad weather, only different kinds of good weather."

John Ruskin

5.1.1.1. Project Site Localization

The project site is in Lecco, at an average altitude of 214 m.a.s.l. and at coordinates 45˚51'26'' N and 9˚23'24'' E. The data presented is extracted from the analysis of the meteorological station located close to Lecco of the data available for the last 5 years.[2]

The weather is considered humid subtropical climate zone. It is marked by hot and wet summers, while winters are moderately cold. The precipitation is higher and there is no dry season. The territory of Lecco is well sheltered by mountain ranges and its climate enjoys the beneficial influences of the lake water and local winds present.

	High:	Low:	Average:
Temperature:	**36.7** °C	**-9.8** °C	**13.8** °C
Dew Point:	**23.4** °C	**-17.8** °C	**5.1** °C
Humidity:	100.0%	18.0%	61.0%
Wind Speed:	**52.9**km/h from the North	-	**1.8**km/h
Wind Gust:	**371.5**km/h from the North	-	-
Wind:	-	-	South
Pressure:	**1084.9**hPa	**634.9**hPa	-
Precipitation:	**7151.4**mm		

Fig. 5 1: Climatic data for Lecco on yearly basis

[2] *http://www.wunderground.com/weatherstation*

5.1.1.2. Temperature

The city of Lecco has a yearly average temperature of about 14°C and an average relative humidity close to 60%. Winters are rainy with occasional snowfall, with temperatures staying around 0°C, but rarely less than -5°C. Mid-seasons are mild in temperature and wet. During summer days are warm, with temperatures averaging 25°C, not exceeding 33°C very often. Nights however are fresh, dropping temperatures even to 10°C.

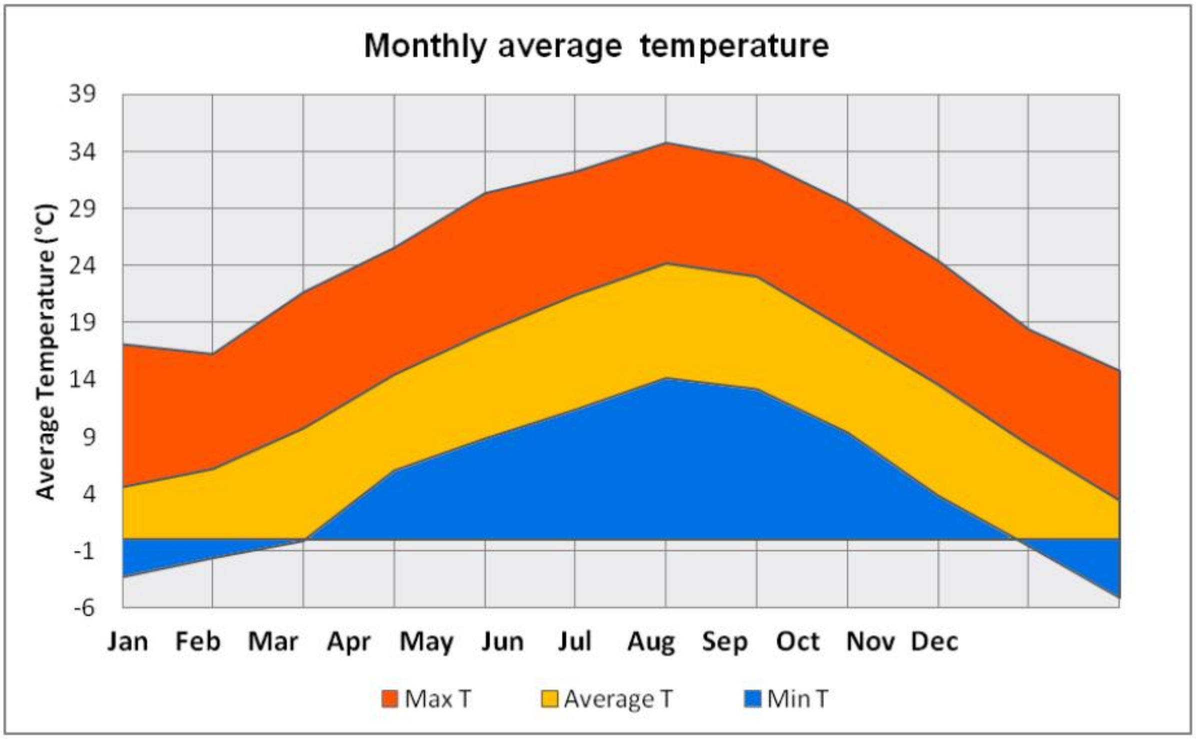

Fig. 5.2: Maximum, minimum and average temperature per month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max T °C	21.2	17.1	24.3	27.8	37.8	33.4	35.8	36.4	31.4	25.3	20.6	16
Min T °C	-5.1	-4.5	-3.4	2.6	7	10.9	13	10.5	8.1	2	-2.5	-9.8
Average T °C	4.4	4.8	9.5	13.8	18.0	21.3	31.2	23.1	18.4	13.5	8.3	3.2
Average humidity %	75.2	70.4	55.3	55.3	52.6	55.6	46.3	53.0	58.3	65.9	77.3	71.8

Fig. 5.3: Temperature and humidity data per month

5.1.1.3. Precipitation Rates

As mentioned before, the area is humid subtropical climate zone, with higher precipitation in all seasons. The local climate is marked by the characteristic of hot and particularly wet summers, adding up to 30% of the total annual precipitation. The mid seasons are mild in temperature and also wet, with precipitation rates around 50% of the total yearly sum. Winter is moderately cold, with snowfall and rain.

These data and the proximity of the lake make the city area conditions suitable for extraction and facilitation of subterranean water, much to the benefit of the agricultural purposes and the territory's environmental development. Furthermore, the high precipitation rates in all seasons guarantee the presence of rainwater which can be harvested as a renewable source.

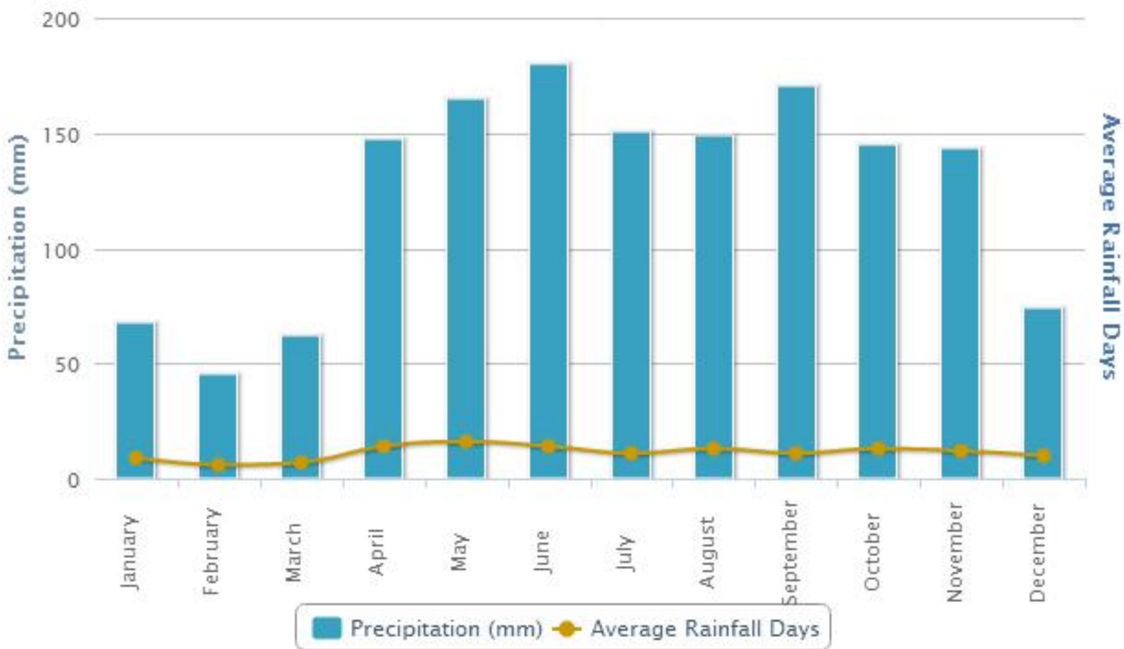

Fig. 5.4: Monthly precipitation and average rainfall days for Lecco[3]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	67	45	61.8	146.8	164.8	179.3	149.9	148.7	170.1	144.8	143.1	73.8
Av. rainfall days	9	6	7	14	16	14	11	13	11	13	12	10

Fig. 5.5: Monthly precipitation and average rainfall days for Lecco

[3] *http://www.worldweatheronline.com/Lecco-weather-averages/Lombardia/IT.aspx*

5.1.1.4. Wind Conditions

The area is characterized by light winds and calm breezes, 0-3 in Beaufort scale – calm, light air, light breeze and gentle breeze. Probability for winds over 4 exists but it's not very high, so we can say that the air movements in the region are in general pleasant. Average annual wind speed is around 1.5 m/s, and the principal wind direction is west-south-west and south-west.[4]

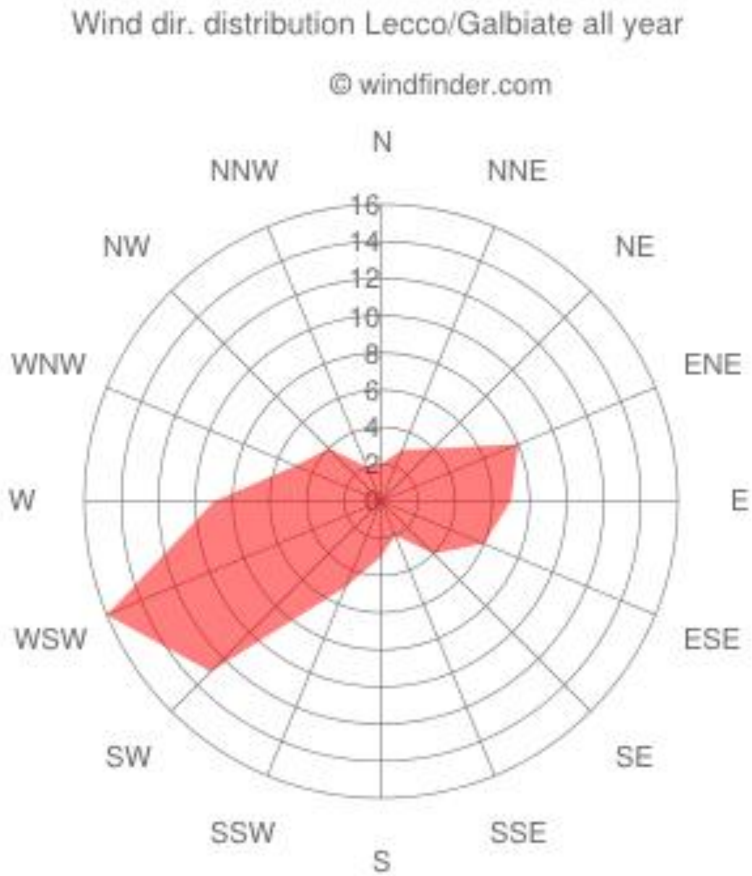

Fig. 5.6: Annual average wind speed and direction

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dominant wind direction	*wsw*	*wsw*	*wsw*	*ese*	*wsw*	*sw*	*sw*	*sw*	*sw*	*wsw*	*wsw*	*wsw*
Wind probability >=4 Beaufort (%)	*1*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*2*	*0*	*1*
Av. wind speed m/s	*1*	*1*	*2*	*2*	*2*	*1*	*2*	*2*	*2*	*1*	*1*	*1*

Fig. 5.7: Monthly wind direction, probability and average wind speed

[4] *http://www.windfinder.com/windstats/windstatistic_lecco_galbiate.htm*
http://en.wikipedia.org/wiki/Beaufort_scale

5.1.1.5. Solar Exposure Data

Analyzing solar data like sun path diagrams, altitude, azimuth angles is useful for the knowledge about the and hourly, daily and seasonal changes in the relative position of the sun as the Earth orbits around it. It is a major factor in solar heat gains of buildings and performance of solar energy systems.

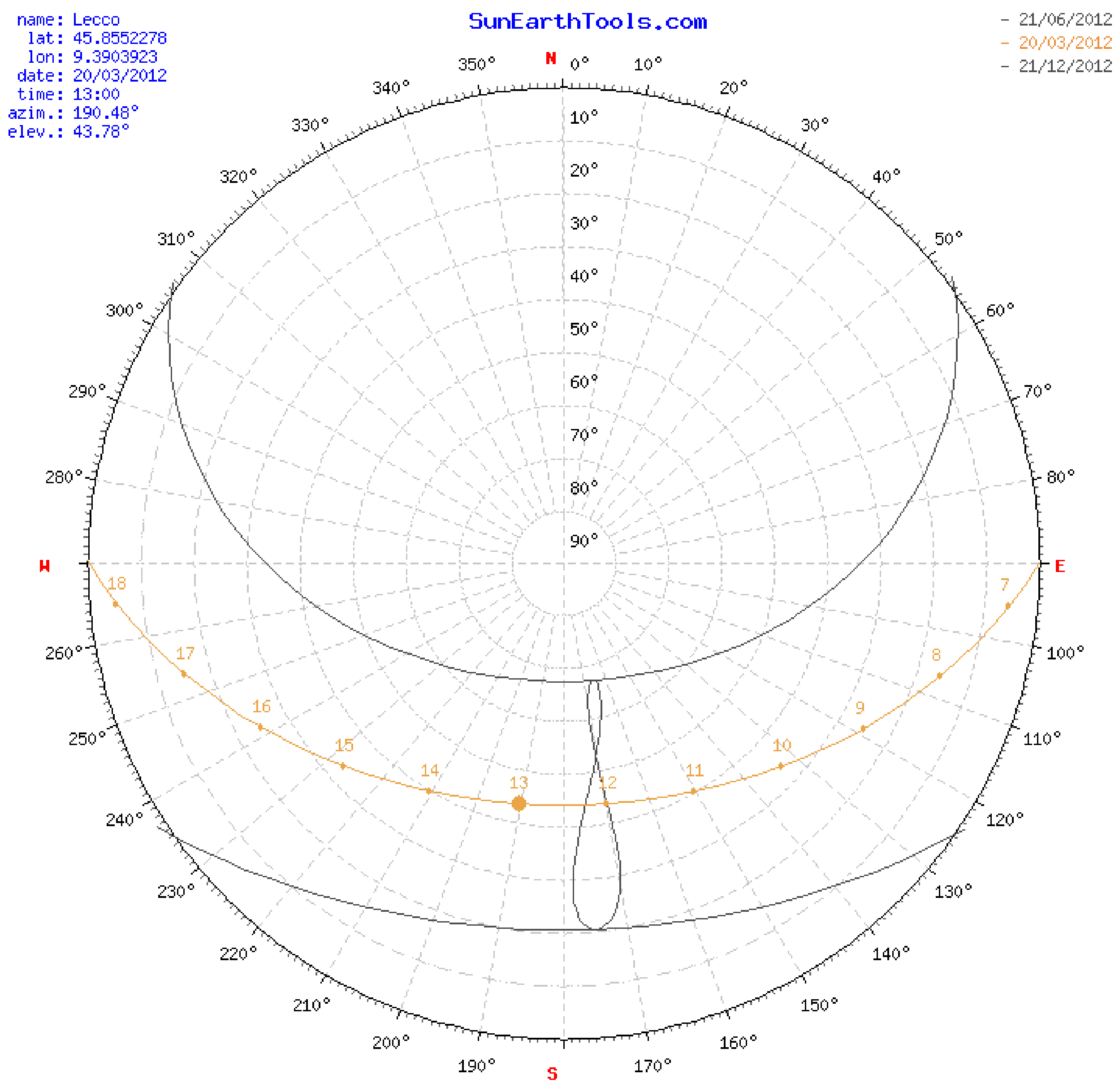

Fig. 5.8: Sun path diagram for Lecco on March 20th, polar representation

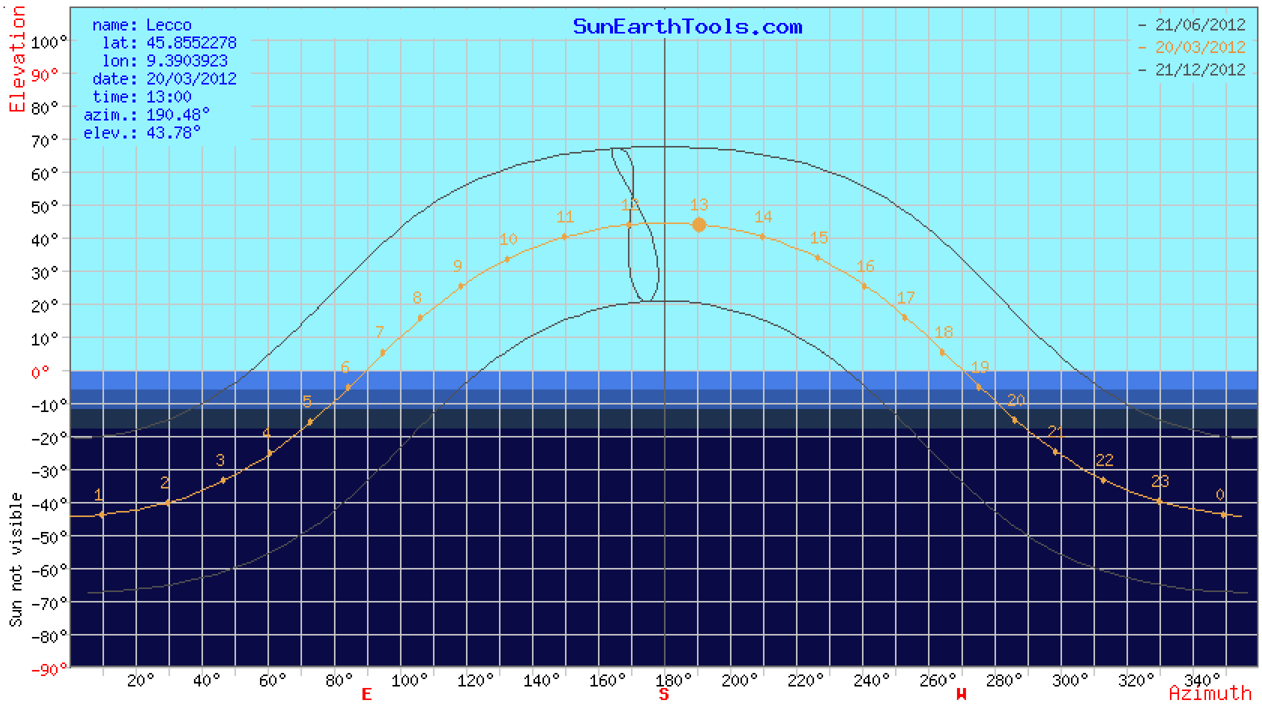

Fig. 5.9: Sun path diagram for Lecco on March 20th, Cartesian representation

sun position	Elevation	Azimuth	latitude	longitude
20/03/2012 13:00	43.78°	190.48°	45.8552278° N	9.3903923° E
twilight	**Sunrise**	**Sunset**	**Azimuth Sunrise**	**Azimuth Sunset**
twilight -0.833°	06:25:04	18:35:23	89.13°	271.16°
Civil twilight -6°	05:55:21	19:05:07	83.78°	276.52°
Nautical twilight -12°	05:20:27	19:40:08	77.36°	282.98°
Astronomical twilight -18°	04:44:37	20:16:07	70.47°	289.93°
daylight	**hh:mm:ss**	**diff. dd+1**	**diff. dd-1**	**Noon**
20/03/2012	12:10:19	00:03:14	-00:03:15	12:30:13

Fig. 5.10: Relevant solar exposure data for Lecco, March 20th

From these data we can extract all the necessary information to understand the sun path and its relation with the building we design, in order to optimize its performance in terms of shading, exposure, heat gains, orientation and lighting levels. [5]

[5] http://www.sunearthtools.com/dp/tools/pos_sun.php

5.1.1.6. Comfort Conditions

From the psychrometric chart we can observe the comfort band that we will aim to achieve in the design. The charts illustrated show us the comfort zone for medium and low activities for Lecco during summer and winter respectively.

During summer we can notice that the temperature and relative humidity stay mostly within the comfort band. The average temperature range is in the 20-25˚C and outside humidity around 50- to 60%. For the summer days where the temperature and humidity stray outside of this zone cooling with slight dehumidification should be provided.

As the winter period is concerned, the temperatures fall below the comfort band at around 0-5˚C in average, and the relative humidity reaches higher values at 80-90%, so the outside air needs to be heated and dehumidified to reach the desired levels.

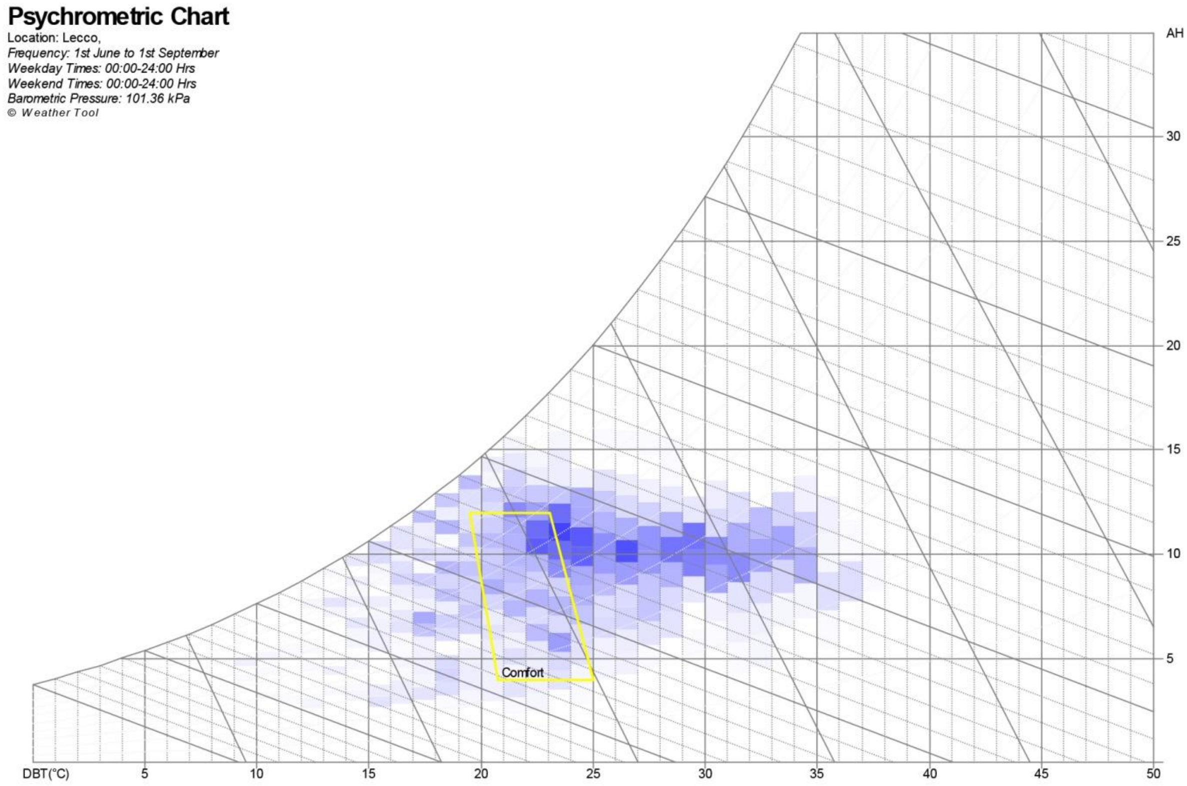

Fig. 5.11: Psychrometric chart for Lecco in the summer period

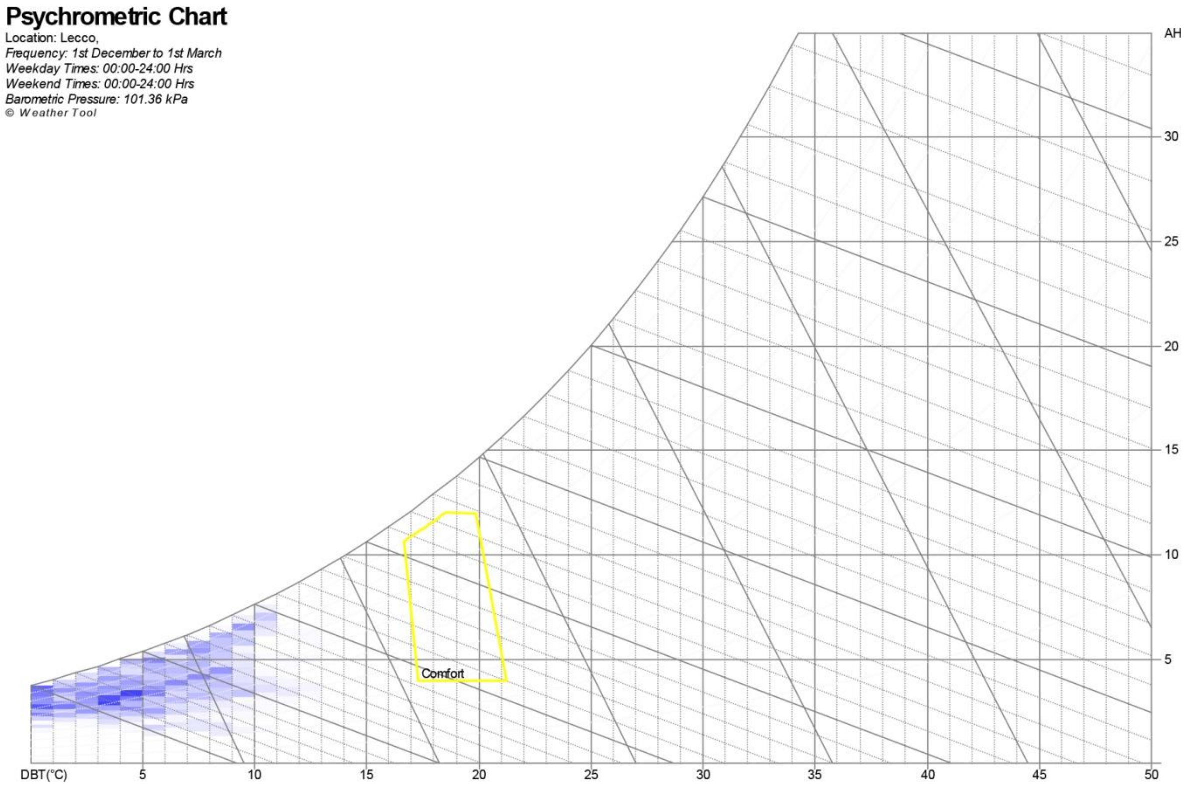

Fig. 5.12: Psychrometric chart for Lecco in the winter period

5.1.2. Strategies

In general we use dwelling for a variety of purposes. The usage is generally more continuous than intermittent and year-round. In houses we require privacy, daylight and natural ventilation. In the following pages, the strategies which should be applied regarding a dwelling design are discussed.

5.1.2.1. Energy

The climate-related needs of residential buildings can be categorized in the following list:

-Heating

-Cooling

-Day light

-Ventilation

Depending on the regional climate and the predominant need for heating or cooling, two major strategies are possible:

- ***In cold weather:*** *Maximize solar and other free heat gains, provide good heat distribution and storage, reduce heat losses and allow for suitable ventilation.*

- ***In warm weather:*** *minimize heat gains, avoid overheating, and optimize cool air ventilation and other forms of natural cooling.*

5.1.2.2. Building Arrangement and Siting

The building should be located to benefit from the best available microclimate. In cold seasons when heating is necessary, shelter and insulation are both required. That is because cold winds increase heat loss by cooling the external envelope and also increase air infiltration through openings. On the other hand, in the warmer seasons, it may be useful to direct the prevailing wind flow to funnel cooler breezes through the dwelling in order to reduce the cooling load. Furthermore, vegetation can be applied to improve natural ventilation or to reduce insolation in the cooling season.

Solar obstruction might be resulted from the natural topography, existing or proposed buildings and vegetation. This item should be analyzed by using scale or computer modeling.

In this project, the gap produced between the modules due to the presence of the courtyards, prevents the buildings to lay shadow on each other.

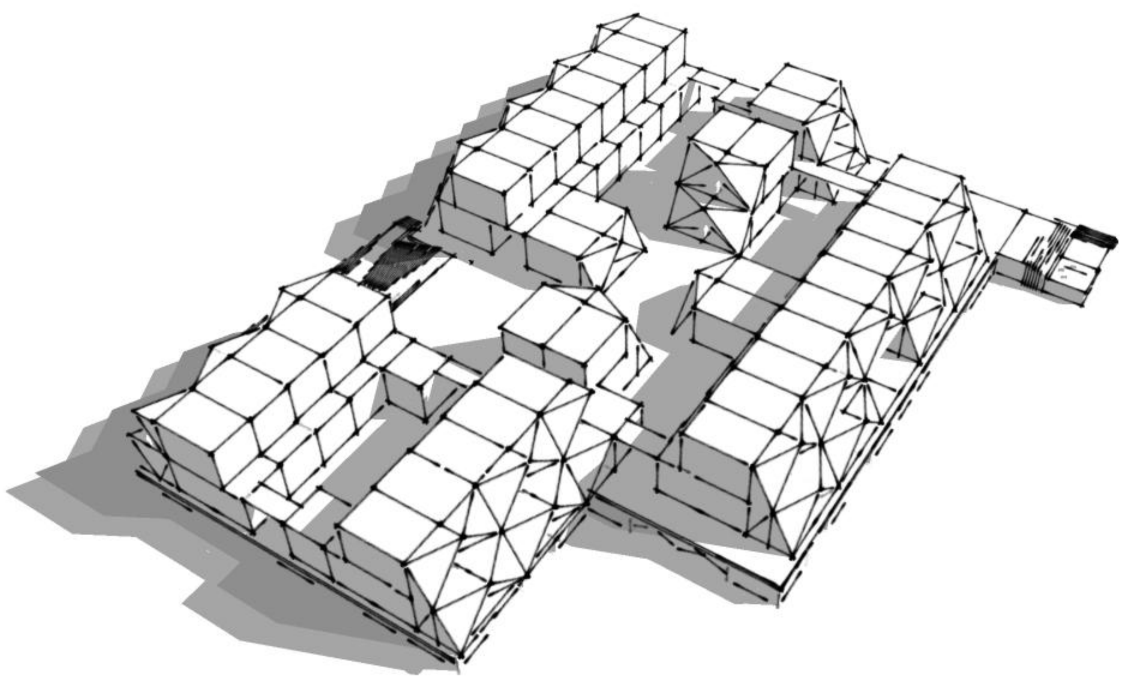

Fig. 5.13: sketch of site layout, showing the basic shadow effect of buildings.

5.1.2.3. Thermal Zoning

The concept is to use buffer spaces to shield heated spaces from the outside. Tight fitting doors or windows separate these areas from adjacent heated spaces. In the design of the modules, this space is considered at the main entrances, this strategy will reduce the infiltration of the cold air from outside, or in the opposite case, the exfiltration of the heated air from inside.

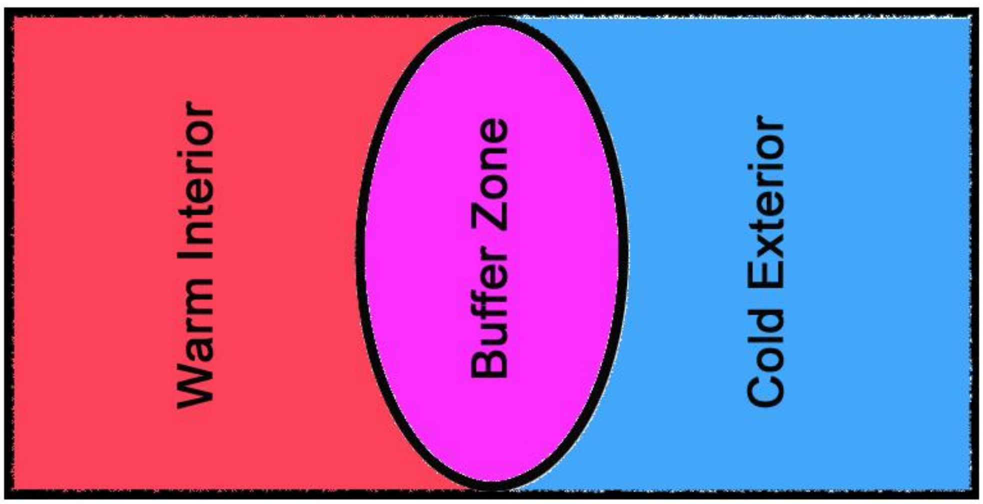

Fig. 5.14: The concept of intermediate Buffer zone

5.1.2.4. Cooling

The need to cool dwellings is not as great as the need to cool other building types. Houses usually do not have much equipment to give off and are generally easily ventilated by opening windows and other openings.

For cooling the considerations are:

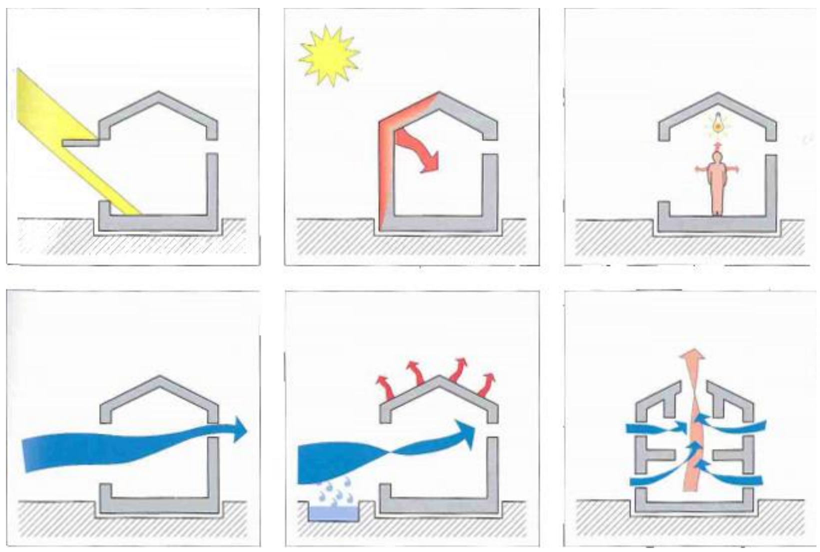

Fig. 5.15: Illustration of different means of cooling[6]

- ***Solar control:*** *solar gain through glazing which is welcomed in wintertime, a few months later can result in uncomfortably warm interiors. External screens, movable shutters, canopies, blinds or screens of vegetation can all be solutions to partially solve the problem. This item will be completely discussed shortly after in the part related to the shadings.*

- ***External gains:*** *in sunny weather, external surfaces can become very hot, facilitating the transfer of heat to the building interior. However, this is mostly the issue in hotter climates and buildings with more thermal mass.*

[6] Picture taken from: The Climatic Dwelling, E. O. Cofaigh; J. A. Olley; O. Lewis, James & James Ltd, 1998

- ***Internal gains:*** *Electrical equipment (lighting, refrigerators, cookers and so on) gives off heat as a by-product of use. Such internal gains can be excessive in deep-plan buildings. But this is generally not a great problem in dwellings, because it is usually possible to open windows. Moreover, the development and installation of more energy-efficient appliances and lighting equipment tends to reduce these gains.*

Fig. 5.16: Different means of heat gain in a living space.[7]

- ***Ventilation:*** *As long as the outside temperature is lower than the inside, the simplest way of cooling the dwelling is by natural ventilation; simply by opening the window. When air heats, it tends to rise. High volumes permit the warmer air to rise and the cooler air to stay around floor level near the people. This works specially in spaces high in section. In addition, if the warm air is vented at the top of a high space, it will create a convection force sufficient to drive the ventilation of the whole building. In our design, the high ceiling of the modules created by the mezzanine and the possibility for the cross air ventilation contributes to the mentioned concepts.*

[7] *http://www.your-solar-energy-home.com/Passive-solar-cooling.html*

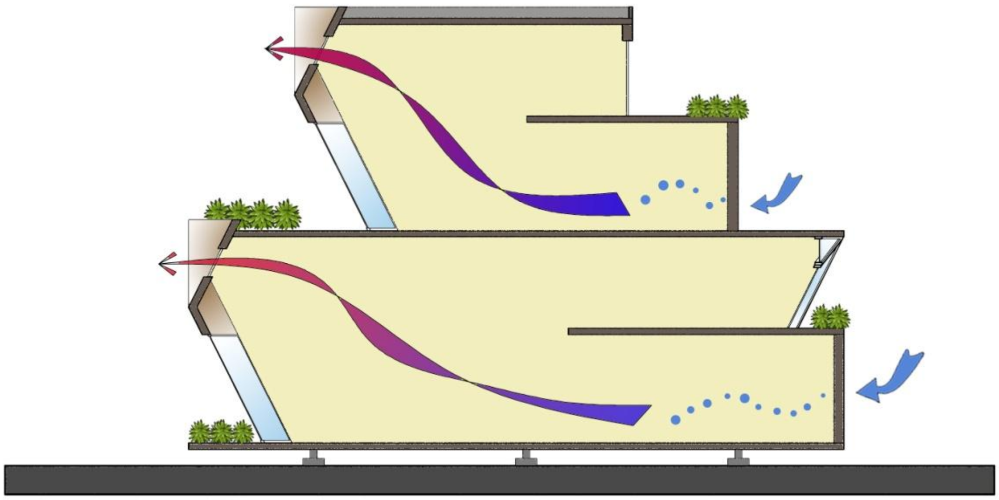

Fig. 5.17: A scheme illustrating the air movement inside the dwellings.

- ***Natural cooling:*** *Positive natural cooling can be achieved by using the benefits of night-time air. Evaporative cooling due to plant transpiration can significantly reduce temperature. In the cooling season, grass-covered ground surfaces are cooler than hard surfaces for this reason. Heavily planted outdoor spaces, are cooler than less vegetated areas for the same reason. The green roofs on both sides of the units, also the gardens which are considered in every small courtyard, will partially improve the microclimate.*

5.1.2.5. Day lighting

In dwellings designers have never forgotten that sun and daylight are fundamental of the quality of the building and delight of the inhabitants. Besides achieving the central attributes of daylight and contrast in architecture, the provision of daylight and the avoidance of the need for artificial light during daytime means less energy is consumed.

However, good daylight does not necessarily equate with large areas of glazing. Too much glass can lead to overheating and inappropriate juxtapositions of dark surfaces with windows can lead to glare. Light reflected off window jambs or walls, or modulated by shutters can gently lead the eye from outside to inside. Internal window shutters can conserve heat when closed, minimizing heat gains. By reflecting or obscuring, they can direct and module the quality and quantity of day lighting in the interior. In addition their angle can be varied to protect occupants or sensitive objects from the direct glare of the sun's ray as their penetration changes with the time of the day. Obscuring the source of light from the field of vision with in the room can avoid glare and produce a softer quality to the perceived internal luminous environment.

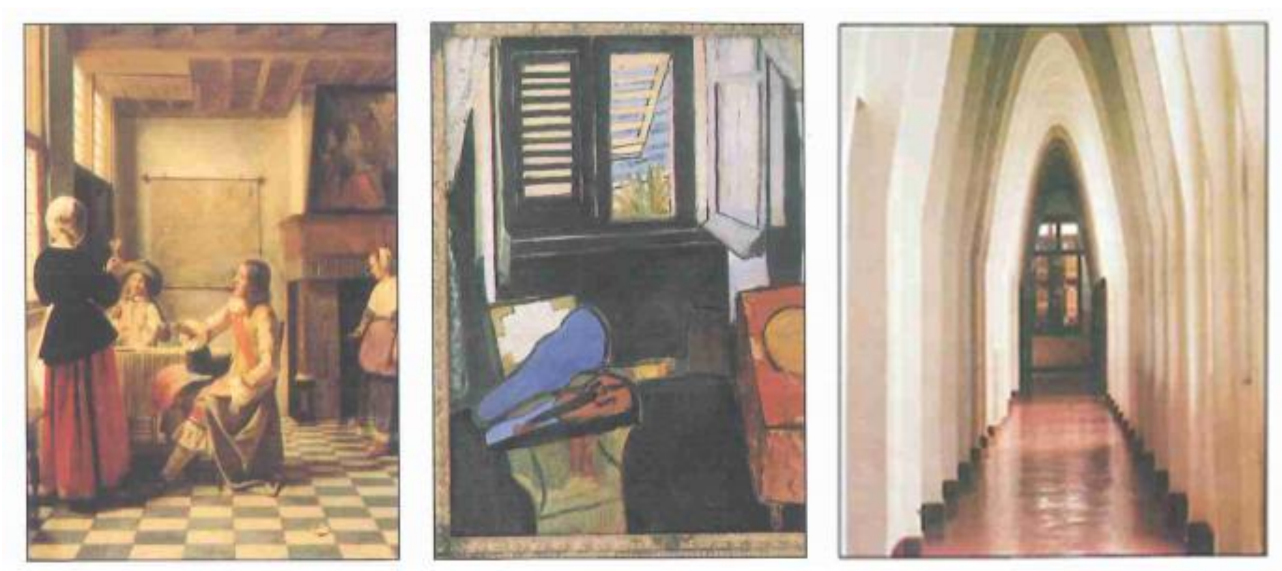

Fig. 5.18: The effect of natural light.[8]

[8] Ibid

5.1.3. Applied Elements

To achieve the goals which have been in the previous section, some elements have been used in the design process. In this section, they are introduced and their application in the project is explained.

5.1.3.1. Courtyard

The courtyard is a ubiquitous European form. It creates enclosure for security and privacy, and can establish its own interior thermal environment. It exists at the urban scale: The square or piazza; and at individual scale, whether embedded in the city fabric or standing out in the landscape. It has been used from distant antiquity to the present. The plan and the section proportions and dimensions distinguish its potential for climatic modulation or microclimatic creation.

The deep courtyard creates a space shaded from sun yet admitting daylight. The shallow courtyards create shelter from the chilling wind, while allowing the sun to contribute to a created microclimate. In the enclosed space of the deep shaded space of some courtyards, the external environment is excluded and a new microclimate is constructed. Trees secure extra summer shading and cool the air by transpiration.

Fig. 5.19: A scheme of the courtyards with the internal voids.

5.1.3.2. The Balcony

Balconies in Lecco, especially in the center, are characterizing elements of the housing architecture. But they are much more than aesthetical elements. A balcony can be a shaded place in summer and a sun space in winter, protecting the interior from summer overheating, yet allowing the lower sun of winter to penetrate for solar advantage. A north facing balcony is a cool summer space. The early morning sun's extended summer path allows it to take away the chill of the night from the north facing portico before this becomes an airy space turned away from the fierce midday rays. Finally, in the evening, the balcony welcomes in the glory of the last dying rays of the sunset.

Fig. 5.20: Center of Lecco

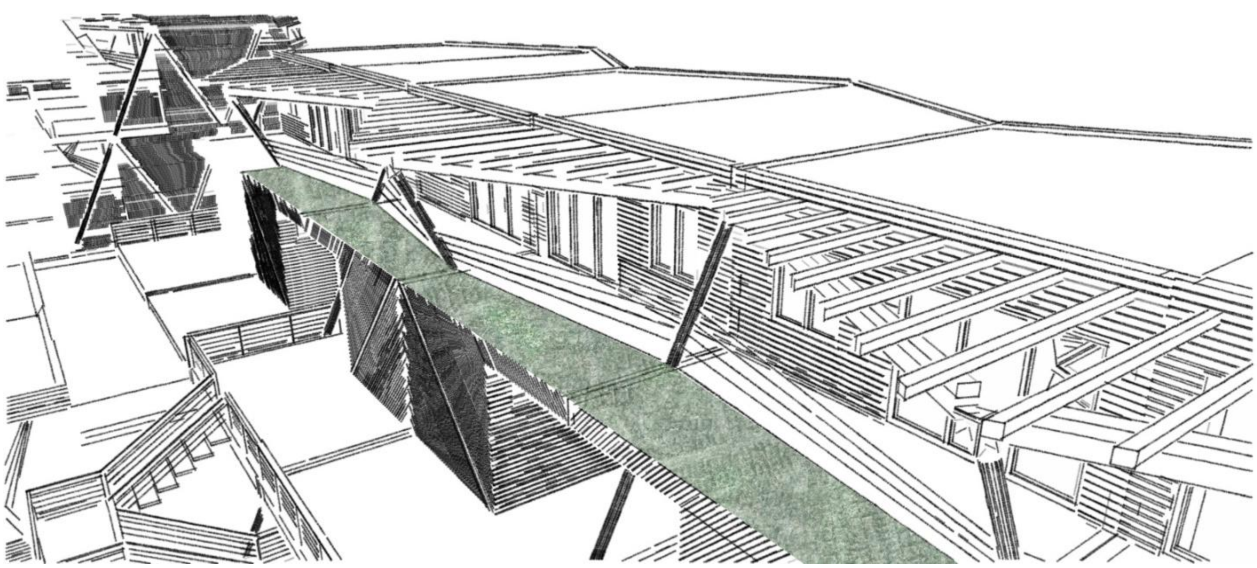

Fig. 5.21: A scheme of the balconies in the project.

5.1.3.3. Shelter

In certain climates and generally throughout Europe, a breeze is welcome in summer. However, during the cold seasons, it can be unpleasant and chilling in its effects upon people, and the buildings they inhabit.

In most parts of Europe there is a prevailing wind. It is useful to plant a shelter belt against these winds. Also Buildings can shelter each other against the prevailing wind. In this case, considerations for wind funnel effect should be considered in the design.

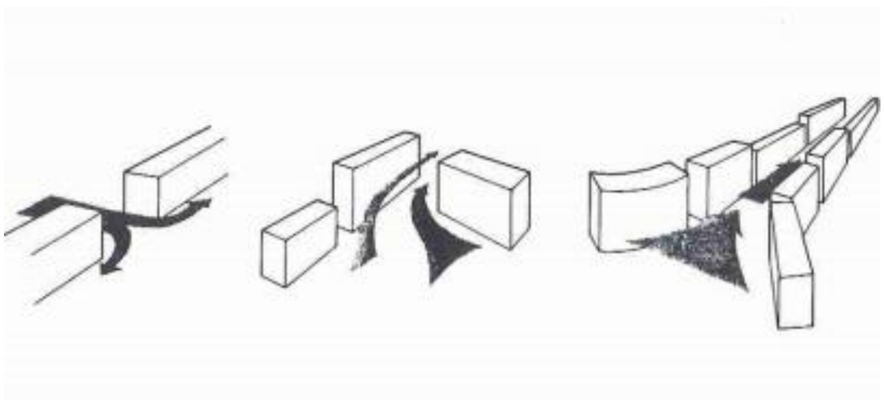

Fig. 5.22: Wind Funnel effect.

For a good climatic design, the architect should know the wind climate at the site. He can then decide on the location and nature of shelter elements: planting, building, screen walls. Proper shelter design should provide insolation in the heating season, and shade in the cooling season with good outdoor spaces.

In our site the direction of the prevailing wind is from West-South West. In the design of the modules no opening is seen on the sides. So, a solid wall is resisting the wind which is illustrated with continuous red line on the fig 5.22. The dotted lines indicate the opening to the western courtyards which are protected by semi perforated shelters as wind screens.

Semi perforated shelter are large scale shelters, partially porous to the wind that have the effect of reducing wind speed behind it and also of they avoid unpleasant side-effects of wind turbulence. This kind of shelter can be artificial or natural like shelter belts of trees and shrubs. Screens can vary in permeability from 0 % (solid wall) to almost 100% (chain link fence). For most effective performance, screens should be 40-50%

permeable, with slightly greater permeability at the bottom to reduce the risk of frost pockets behind and less at the top.[9]

Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Dominant Wind dir.													

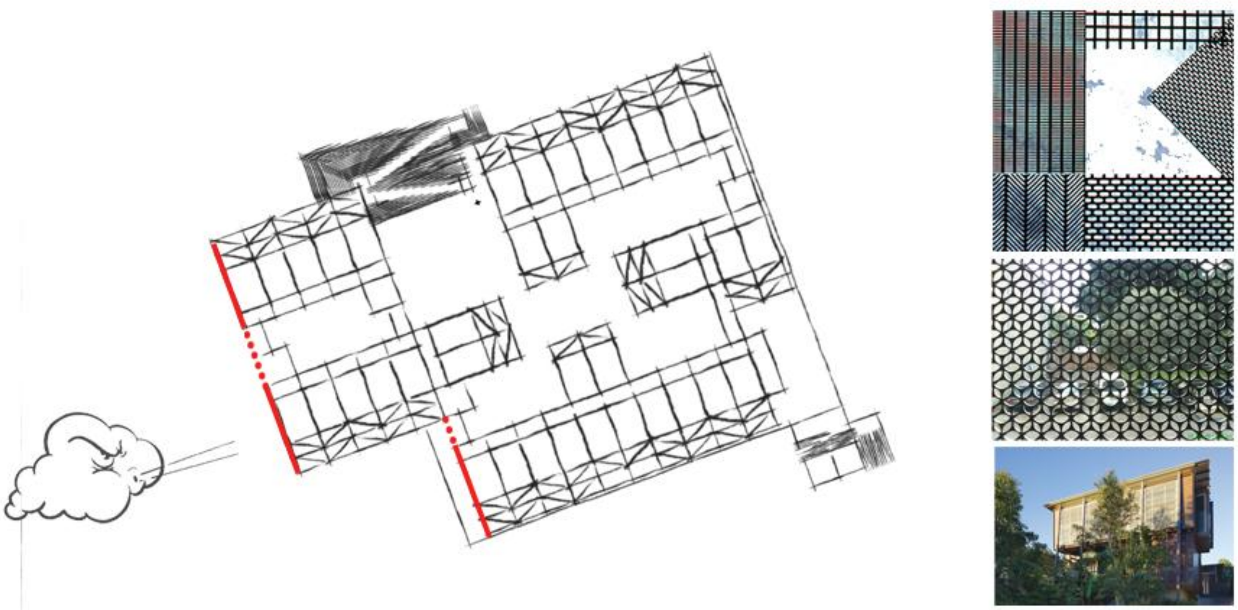

Fig. 5.23: A scheme showing the sheltered area from the prevailing wind.[10]

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[9] *IBID*

[10] *Data taken from http://www.windfinder.com/windstats/windstatistic_lecco_galbiate.htm*

5.1.3.4. Envelope

However, the influence of climate on the design of elements like walls, roofs and floors is less than other transparent elements, but still they are of paramount importance. Thermal inertia and insulation, contact with ground and air and external colors and surfaces all affect the performance.

- ***External colors and surfaces** influence heat absorption and reflection, which in turn affects the quantity of heat transferred to inside. Light colors reduce heat uptake. Dark colors absorb heat.*

- ***Thermal inertial** or mass of walls, floors and roof influence the rate of temperature change inside the building and hence the comfort conditions. In our case which is a light weight structure, the benefit of this item is negligible comparing to others.*

- ***Insulation** of the external envelope and the reduction of the casual infiltration can significantly reduce heat loss to the outside and heat gain to the interior. The layer of insulation applied in the units' envelope (which is going to be shown shortly after) provides the following amounts for the U values of different parts:*

Exterior walls: 0.17 w/m^2k
Roof: 0.15 w/m^2k
Balcony: 0.15 w/m^2k
Ground floor level: 0.14 w/m^2k

- ***Contact with external air*** *can be useful in cooling. Cross ventilation with cool night-time air can help to reduce the temperature to achieve better comfort during the day. This can be achieved by the ventilation of basements.*

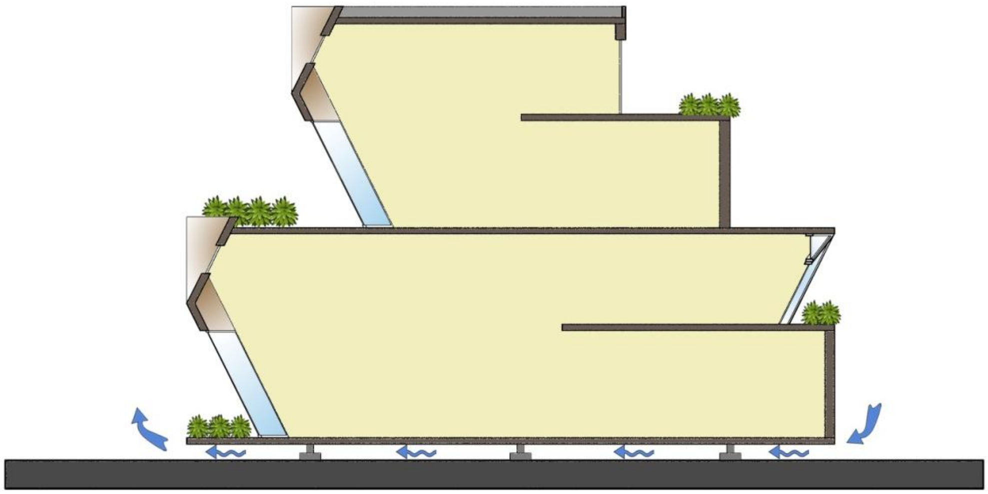

Fig. 5.24: The ventilation through underneath of the units

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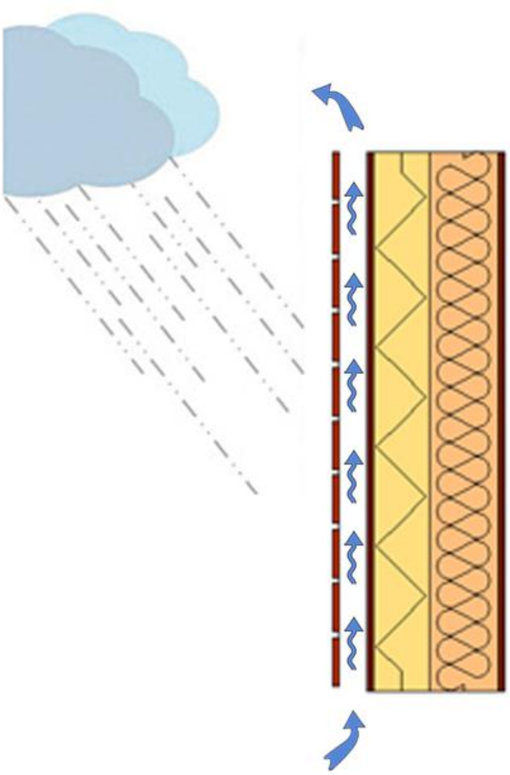


Rainscreen façade system allows air to circulate behind the external facade to provide pressure equalization, preventing water from being drawn into the building. Additionally, a vapor barrier on the outside face of the back-up wall acts as a final air and water barrier.

Fig. 5.25: scheme of External wall

5.1.3.5. Materials

The selection of materials is not only made on visual criteria. The use of materials which compose the site and the building can change, enhance or negate climatic advantage. Materials have varying thermal properties. A masonry building will heat or cool slowly, while a lightweight building heats or cools quickly. Floor tiles will conduct heat to a slab underneath, while carpeting will insulate space from the structure below. These varying performances implicate careful choice and careful design.

Furthermore, our sensual perception of an interior space is largely determined by the materials. As light is transmitted and refracted through materials, or reflected by the texture and color of the internal surfaces, its quality, delight and utility are established. The absorption or reflection of sound from the surfaces within a room determines its reverberant character, a kind of acoustic signature to the room which contributes to our sense of enclosure or spaciousness. Finally, thermal sensation is influenced by the interaction of the material with heat. An individual's perception of the thermal environment involves the exchange of heat with the surroundings, by radiation for which the surface temperature are important, by convection which is affected by air temperature and movement and by the evaporation governed by relative humidity and again air speed.

In the current project, the materials are chosen respecting the above facts. External cladding has a very particular influence on the architectural aspects. Besides, it protects the building against moisture - especially driving rain, temperature effects, incident solar radiation and the wind. Western red cedar wood slat is chosen for the external façade. It has a high resistance to fungal and insects attack.

The exposed structure is made out of steel and it is treated by epoxy zinc primers against weathering agents and corrosion.

For the enclosure of the parking area, gabion walls have been chosen due to the characteristic of Lecco and their local availability.

Fig. 5.26: Sample materials.

5.1.3.6. Windows

Windows provide choices for controlling and adjusting solar gain, ventilation, noise penetration, privacy and the quality of light within the room. The penetration, quantity and quality of light within the room can vary at will by the use of shutters that hinge from reveals or window heads by those which cover the upper or lower parts separately and by those which can reflect the light first to the ceiling.

Windows design and orientation should seek to maximize useful solar gains and minimize heat losses for the heating season. However, it should not cause overheating in the cooling season. Adequate ventilation and daylight should be ensured.

Depending on the geographic location, window area and orientation, some care may be needed to prevent overheating. Solar gain can be controlled by the use of fixed or movable shading, including screens of vegetation and by the sensible sizing and positioning of glazing. The larger the unprotected windows are the greater is the solar gain and the larger the likelihood of overheating. Fixed shading can permit low sun and block high sun. Internal blinds or shutters do not function as effectively in reducing solar gain as external screens, as the energy is admitted into the dwelling and tends to remain. Glazing type also affects heat loss and gain and light transmission.

For the presented project, windows have been decided to be double glazed filled with gas.However for north facing windows the efficincy is increased by applying with low emmisivity coating. This feature, is very permeable to solar radiation but reflects most of the heat.

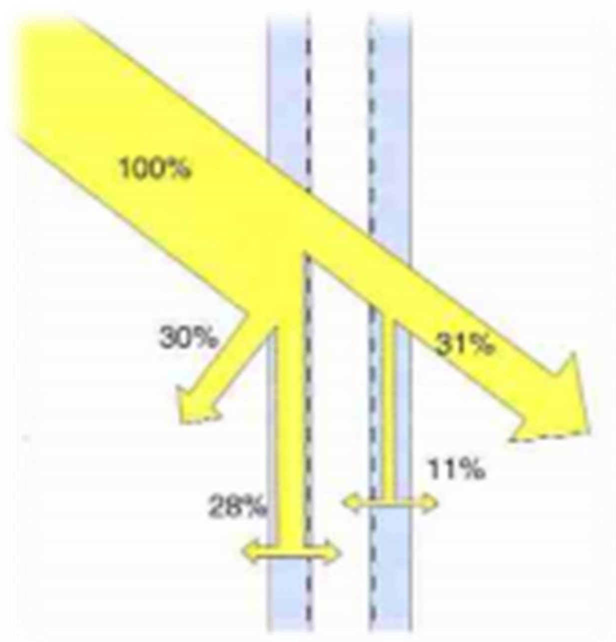


Fig.5.27: double glazed reflecting window

5.1.3.7. Shading

Well-designed shading effectively prevents solar energy reaching the building interior during the cooling season. Shading elements may be external, internal, seasonal, fixed or movable.

External shading is the most effective in preventing overheating, because comparing to the internal ones they do not allow the sun to reach the building interior at all, while in the other alternative the incident energy once being admitted, is absorbed and heat is then difficult to expel. Deciduous planting, whether of shrubs, trees and climbers can all be very effective in shading. Planting provides elegant shading and can be effective in admitting or screening light as required.

Different types of external shading suit different orientations. For south vertical glazing, horizontal or slightly angled screening is best to block high angle summer sun but admit low-angled winter sun. Roof overhangs can help shade facades and combine with roof-top structures to provide shaded spaces exposed to breezes. They can also be of advantage in shading the roof itself to minimize indirect gains to the interiors. For west facing glazing however the need is to screen out low level summer evening sun and here vertical screens are more effective.

On the face showing in the figure 5.28, no shading is considered because its inclined direction towards inside cause shadow on itself

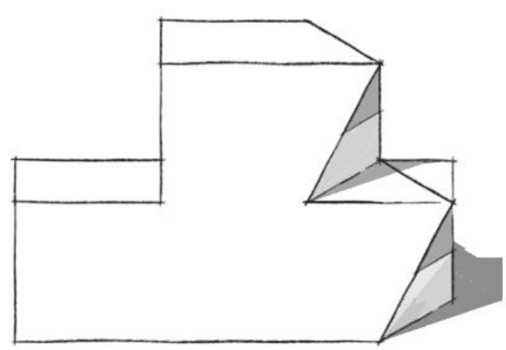


Fig.5.28

For the face illustrated in the figure 5.29, which has the most solar gaining, additional shading has been seen. The green roof lays shadow on the window below while the similar opening of the upper module is protected by fixed shading.

For the south facing modules, movable shading is considered which can control the incident radiation according to the time and season.

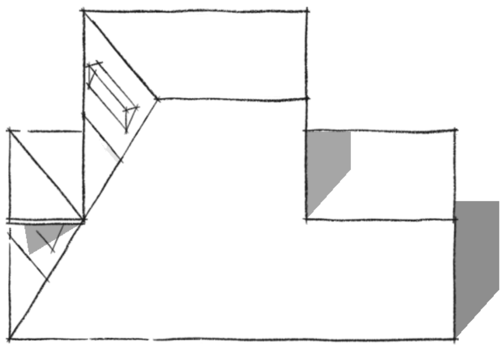


Fig. 5.29

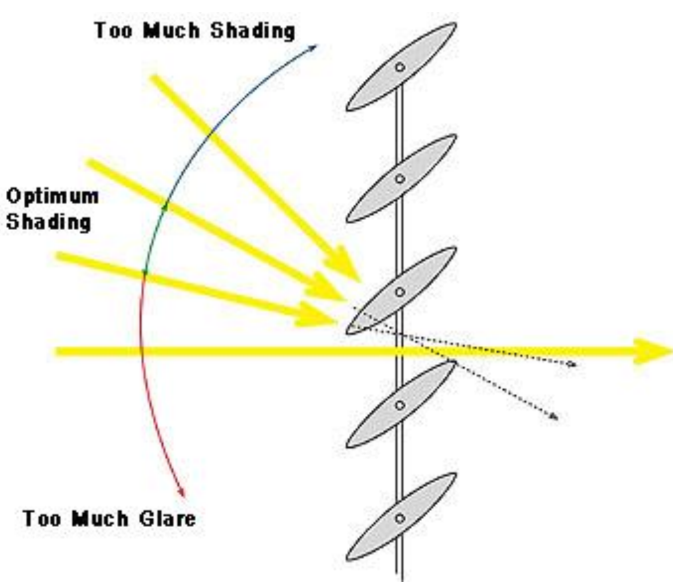


Fig. 5.30: Movable shading mechanism.

5.2. Building Envelope Design and Assessment

Building envelope separates outdoor space, thus practically creating the indoor environment and providing area which we design to have certain characteristics. It should provide aesthetics both to exterior and interior, resist and transfer mechanical loads and control flow of rain, air, heat and vapour in both directions. Here is presented the project design envelope describing the layers and assessing their performances.

5.2.1. Layers Description

5.2.1.1. Flooring System

Lignatur AG is a Swiss company set in Waldstatt, producing industrial wooden floor and roof elements. LFE is a flooring system by type of surface elements, where boards of coniferous wood are arranged in such a way to create cells, which can be filled with insulation or left hollow.

We chose this system because it doesn't need finishing and we wanted to have a visible wood surface, further, this is a ready-made panel with insulation included, just to be installed on-site, spans up to 12 m, provides with fire protection, sound proofing and heat insulation.

We applied this system with cells filled with wood fiber insulation where this is a part of slab construction which separates non-heated zones from heated ones and filled with acoustic insulation where it separates two heated spaces.

Fig. 5.31: Lignatur surface element

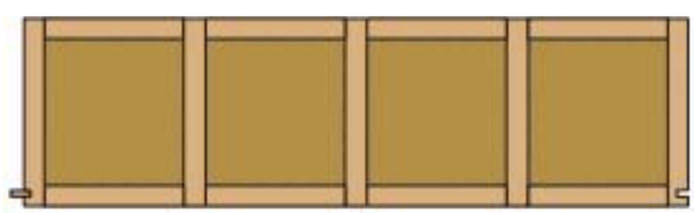


Fig. 5.32: LFE filled with wood fiber – cross section

5.2.1.2. Wall System

The external wall is a composite panel which is prefabricated, just to be dry-assembled on site. Dimensions are specific to the construction system, with the width and height of our modules.

The panel is wood frame structure, with mineral wool fill and polystyrene board insulation between the studs, and closed with OSB boards on both sides. Interior side of the panel is then clad with double plasterboard finishing, set on a wooden stud substructure, which also leaves the service gap for wiring.

The gaps are left in order for the square horizontal beams to pass through. These holes would be filled with foam to prevent thermal bridges and air and water infiltration. The beam would also be filled with foam in this part.

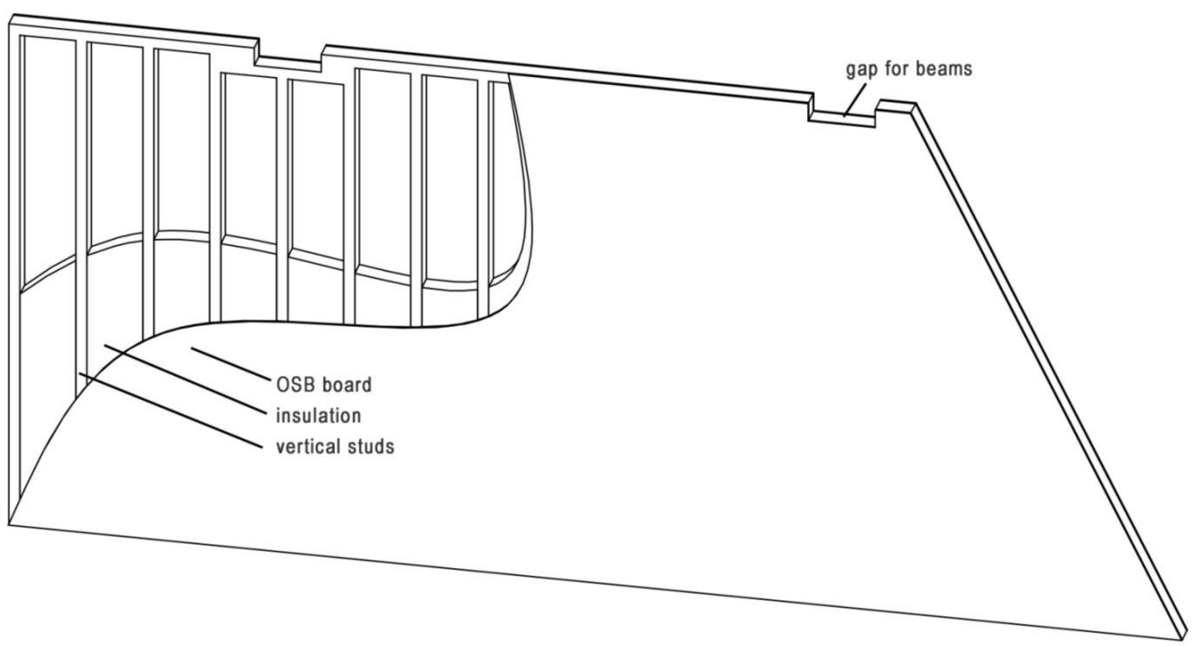


Fig. 5.33: External wall panel system

5.2.1.3. Green Roof

Green roof solution for our project is per ZinCo system by Alumasc. The green roof is installed for aesthetical reasons, and for enhancement of storm water management, heat transfer reduction, noise protection and reduced carbon emissions.

All the components are as provided by the manufacturer – filter membrane to keep the efficiency of drainage layer by preventing soil particles to leave substrate; drainage elements to ensure the elimination of excess water, with perforations to provide aeration; moisture mat for keeping nutrients and moist; root membrane to prevent damage to waterproofing membrane from growing roots.

The project green roof is flat, so on top of Lignatur system we placed the green roof components as described below:

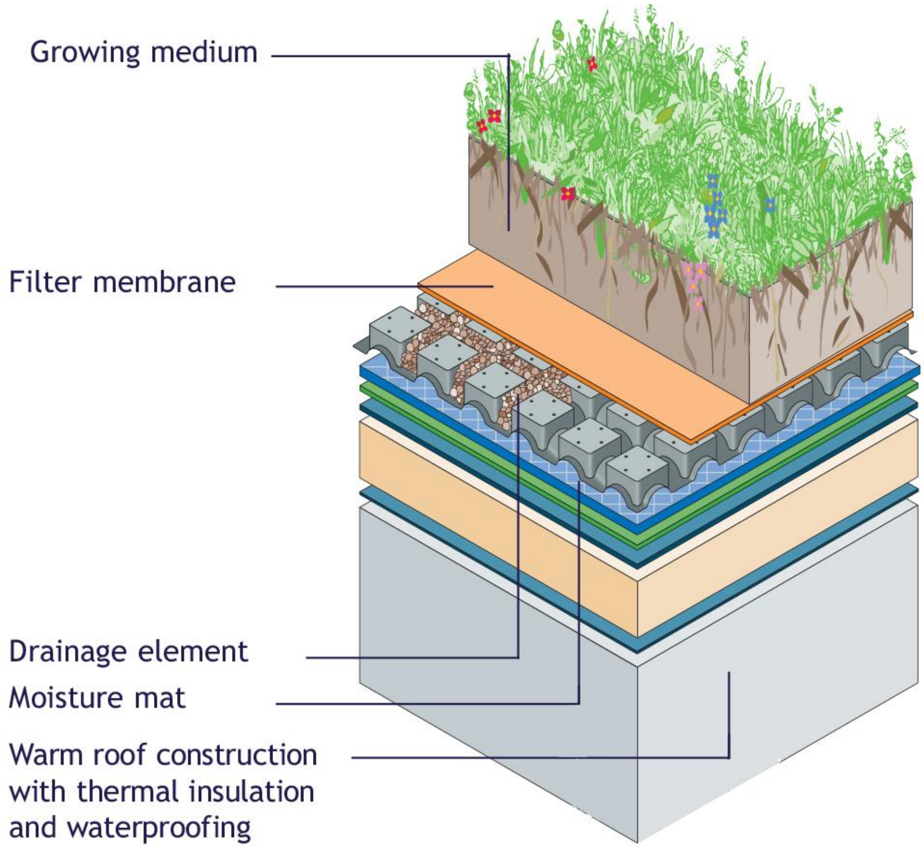


Fig. 5.34: Green roof composition

5.2.2. U-values Calculation

U-value, U-factor or more correctly the overall heat transfer coefficient is a measure of how well is a building or its component conducting heat. The smaller the U value, the more efficient insulator the layer or component is. It is the inverse value of heat resistance.

Calculation

1. *Determining U-value from the properties of the material*

It is calculated as:

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_e} + \frac{\Sigma s}{\lambda}}$$

Where:

h_i *– internal convective coefficient in* m^2K/W
h_e *– external convective coefficient in* m^2K/W
s *– total thickness of the component in m*
λ *– thermal conductivity in W/mK*

With the convective coefficients given as:

	Vertical	*Horizontal (upward flux)*	*Horizontal (downward flux)*
Internal – h_i	*0.13*	*0.10*	*0.17*
External – h_e	*0.04*	*0.04*	*0.04*

5.2.3. Glaser Diagram Calculation

In parts of the envelope separating two environments with different vapour pressure and concentration, condensation might occur within the layers if the pressure exceeds the saturation level. By condensation risk analysis the probability of interstitial condensation occurring in a multilayered system is numerically measured. It is important to prevent this phenomenon from happening in order to ensure the reliability of the components throughout their service life. Condensation can lead to biological growth, efflorescence and general deterioration of material, or in case of insulating layers, makes them ineffective. In general, condensation does not happen in single layer walls, while in the multilayered walls it is probable to occur if the inner layers are insulating and with small resistance to passage of vapour. If the analysis show the condensation is likely to occur, there are two ways to prevent it:

- *Increasing the saturation value by raising inner surface temperature by better insulation*
- *Decreasing the partial pressure by providing a vapour barrier on the warm side of the layer where condensation is likely to occur*

In order to assess the risk of condensation and the need for a vapour barrier, we control the temperature and pressure distribution throughout the layers of the envelope by tracing a Glaser diagram: at each point p_v curve should remain below p_s curve.

***Calculation**:*

1. *Temperature at the each interface can be calculated by using the following formula:*

$$T_i = T_{i-1} - \frac{\Delta T}{k_i} * U$$

Where:

T_i = Temperature of the i-th interface in ˚C
T_{i-1} = Temperature of the previous interface in flux direction in ˚C
ΔT = Temperature difference ($T_{in} - T_{out}$) in ˚C
k_i = Thermal conductivity of the i-th layer (s_i/λ_i)
U = Thermal conductivity of the whole section in W/ m^{2}K

Calculating the internal surface temperature by:

$$\Phi = US\Delta T$$

Where:

Φ = Heat flux in W
S = Total thickness of the section in m

And:

$$T_{pi} = T_i - \frac{\Phi}{S} * \frac{1}{h_i}$$

Where:

T_{pi} = Internal surface temperature in ˚C
T_i = Internal ambient temperature in ˚C
$1/h_i$ = Internal convective coefficient

2. *Vapour pressure at each interface can be calculated by using the following formula:*

$$P_i = P_{i-1} - \frac{\Delta \mathrm{P}}{\rho_{\mathrm{tot}}} * \rho_{\mathrm{i}}$$

Where:

ΔP = Difference in vapour pressure between two sides of the section ($P_{in} – P_{out}$)
P_{in} = Internal pressure at 20˚C and 50% relative humidity
P_{out} = External pressure at -5˚C and 80% relative humidity
ρ_i = resistance to vapour diffusion of the i-th layer (s_i/δ_i) $\rho_{tot} = \Sigma\rho_i$
δ_i = vapour permeability of the i-th layer. Values extracted from UNI 10351

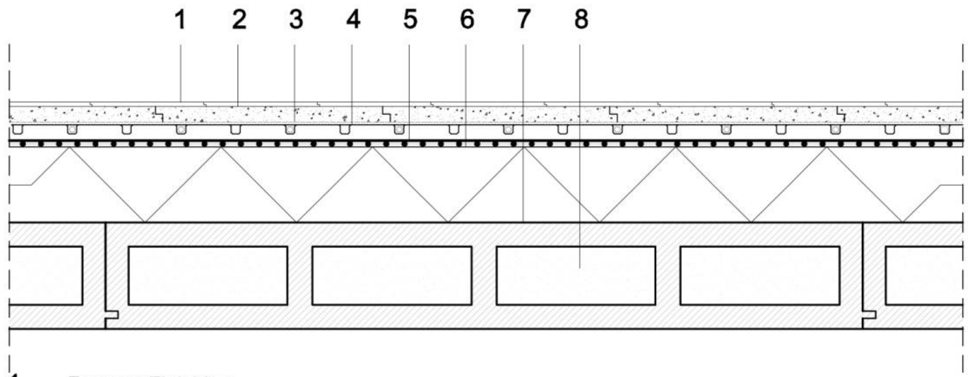
The saturation pressure for different temperatures at interfaces can be obtained from psychrometric chart or approximated by:

$$P_{si} = e^{26.23 - \frac{5416}{T_i + 273}}$$

Input conditions are:

- *Inside temperature 20˚C*
- *Outside temperature -5˚C*
- *Inside relative humidity 50%*
- *Outside relative humidity 80%*

5.2.4. Ground Floor



1 Parquet Finishing

2 Dry Screed Board

3 Velta PE Slip Membrane

4 Velta Siccus Panel

5 Synthetic Vapor barrier

6 Extruded Polystyrene

7 Lignatur Flooring System (LFE)

8 Fibrewood

Fig. 5.35: Ground floor section

Ground Floor					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Downward flux hi=0,17 ; he=0,04
	Inside				
	Internal surface			0,17	
1	Parquet	0,005	0,078	0,06	
2	Dry screed board	0,02	0,2	0,10	
3	Velta siccus panel(EPS)	0,025	0,035	0,71	
4	Extruded polstyrene	0,1	0,03	3,33	
5	Wood (Lignatur system)	0,03	0,1	0,30	
6	Fibre wood (Lignatur system)	0,08	0,04	2,00	
7	Wood (Lignatur system)	0,03	0,1	0,30	
	External surface			0,04	
	Total	0,29	0,583	7,0217	
			U-value (w/m²k)	0,14	

Fig. 5.36: U-value for ground floor slab

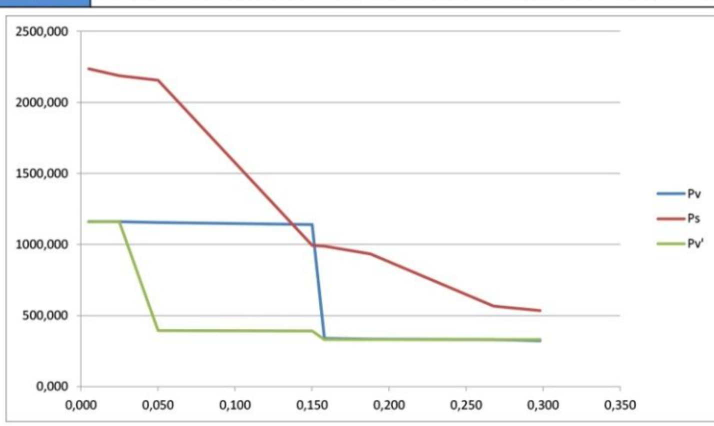
	Glasier Diagram For Floor Slab						

Relative Humidity Inside	**0,5**	**Relative Humidity outside**	**0,8**	**U value (W/m2K) =**	**0,14**		
Pint(Pa) at: 20 c & 50 % Rh=	**1161,079**	**Pext(Pa)at: -5 C & 80% Rh =**	**330,863**	**ΔP (Pa) =**	**830,216**		
Inside Temp (Ti)	**20**	**Outside Temp (Te)**	**-5**	**ΔT**	**25**		
Downward flux 1/hi =	**0,17**	**Φ=USΔT**	**1,043**	**Tpi=Ti - Φ/(hi*S)**	**19,405**		

No	Material	λ thermal Conductivity (w/mK)	Thickness (m)	Ki = λ/s	Temperature	Thickness for Graph	
1	Parquet finishing 5 mm	0,078	0,005	15,6	19,4050	0,005	
2	Dry screed board 20 mm	0,20	0,020	10	19,0550	0,025	
3	Velta EPS siccus panel	0,400	0,025	16	18,8363	0,050	
4	Extruded polystyrene 100 mm	0,030	0,100	0,3	7,1696	0,150	
5	Synthetic Waterproofing membrane 8 mm	0,27	0,008	33,75	7,0659	0,158	
6	Coniferous Wood (Lignatur system)	0,13	0,03	4,3333	6,2582	0,188	
7	Wood Fiber (Lignatur system)	0,04	0,08	0,5	-0,7418	0,268	
8	Coniferous Wood (Lignatur system)	0,13	0,03	4,3333	-1,5495	0,298	
			0,298				

No	Material	δ(Vapour Permiability) 10^12 (Kg/m s pa)	ρ = s/δ(m2 s pa/Kg)	Temperature	Pv (Pa)	Ps(Pa)	Vapour Pressure with Vapour Barrier Pv' (Pa)
1	Parquet finishing 5 mm	4,5	0,0011	19,4050	1159,970	2236,38	1160,9942
2	Dry screed board 20 mm	23	0,0009	19,0550	1159,102	2187,26	1160,9275
3	Velta EPS siccus panel	6,3	0,0040	18,8363	1155,141	2157,05	394,1539
4	Extruded polystyrene 100 mm	6,3	0,0159	7,1696	1139,296	995,47	392,9373
5	Synthetic Waterproofing membrane 8 mm	0,01	0,8000	7,0659	340,713	988,36	331,6197
6	Coniferous Wood (Lignatur system)	4,5	0,0067	6,2582	334,058	934,56	331,1087
7	Wood Fiber (Lignatur system)	25	0,0032	-0,7418	330,863	567,43	330,8635
8	Coniferous Wood (Lignatur system)	4,5	0,0067	-1,5495	324,209	534,80	330,3525
			0,831688613				

Conclusion: To avoid the condensation risk , Vapour barrier should be provided below Velta EPS siccus panel layer

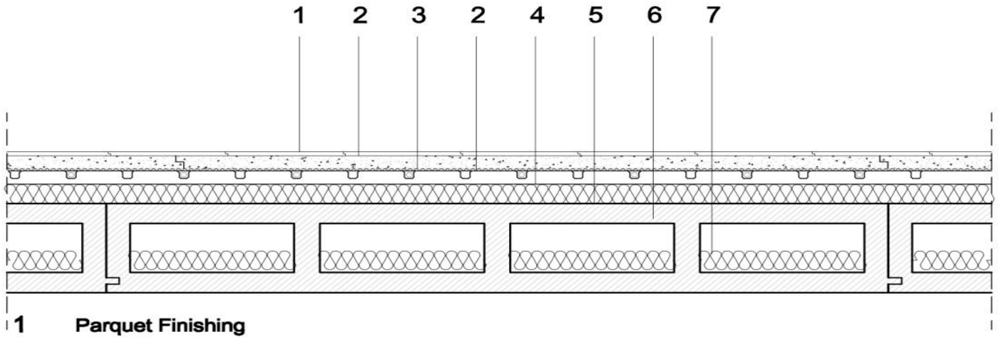


Thickness of Vapour Barrier(S)	0,001	m
δ	0,0001	$Kg/(m^2sPa)$
Rbv	10,0000	$(m^2sPa)/Kg$

Fig.5.37: Glaser diagram for floor slab

Condensation risk analysis showed that a vapour barrier should be provided on the warm side of the extruded polystyrene insulating layer to prevent the risk.

5.2.5. Intermediate Floor



1 Parquet Finishing
2 Dry Screed Board
3 Velta PE Slip Membrane
4 Velta Siccus Panel
5 Acoustic Blanket
6 Lignatur Flooring System (LFE)
7 Additional Acoustic Insulation

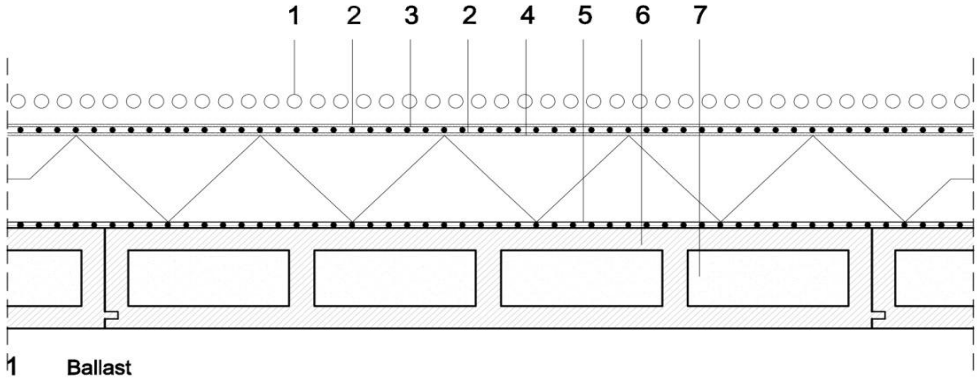
Fig. 5.38: Intermediate floor slab section

Intermediate Floor					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Upward flux hi=0,1 ; he=0,04
	Inside				
	Internal surface			0,135	
1	Parquet	0,005	0,078	0,06	
2	Dry screed board	0,02	0,2	0,10	
3	Velta siccus panel(EPS)	0,025	0,035	0,71	
4	Sound insulation blanket(mineral wool)	0,03	0,04	0,75	
5	Wood (Lignatur system)	0,03	0,1	0,30	
6	Wood (Lignatur system)	0,03	0,1	0,30	
	Internal surface			0,135	
	Total	0,14	0,553	2,4984	
			U-value (w/m²k)	0,40	

Fig. 5.39: U-value for intermediate floor slab

The U-value of the intermediate level is increased intentionally because even in case of non occupancy the space around it is not assumed as outdoor.

5.2.6. Roof



1 Ballast

2 Filter Fleece

3 Synthetic Waterproofing Layer

4 Rigid Rockwool Thermal Insulation (slope of 1.5%)

5 Synthetic Vapor Barrier

6 Lignatur Flooring System (LFE)

7 Fibrewood Insulation

Fig. 5.40: Roof slab section

Flat Roof					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Upward flux hi=0,1 ; he=0,04
	Outside				
	External surface			0,4	
1	Ballast	0,05	0,5	0,10	
2	Rockwool (high density)	0,12	0,035	3,43	
3	Wood (Lignatur system)	0,03	0,1	0,30	
4	Fibre wood (Lignatur system)	0,08	0,04	2,00	
5	Wood (Lignatur system)	0,03	0,1	0,30	
	Internal surface			0,1	
	Total	0,31	0,775	6,6286	
		U-value (w/m²k)		0,15	

Fig. 5.41: U-value for flat roof slab

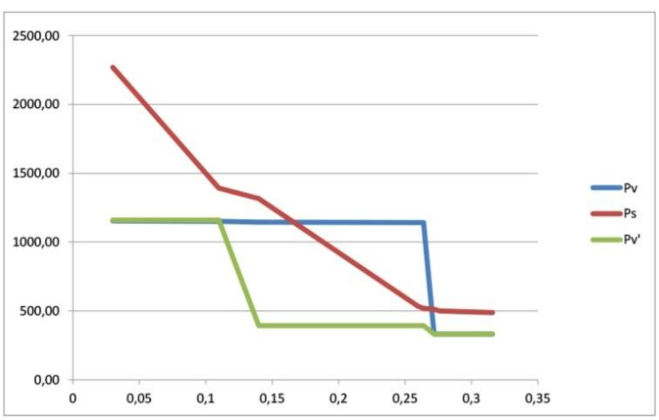
	Glasier Diagram For Roof						

Relative Humidity Inside	0,5	Relative Humidity outside	0,8	U value (W/m2K) =	0,15		
Pint(Pa) at: 20 c & 50 % Rh=	1161,079	Pext(Pa)at: -5 C & 80% Rh =	330,863	ΔP (Pa) =	830,216		
Inside Temp (Ti)	20	Outside Temp (Te)	-5	ΔT	25		
Upward flux 1/hi =	0,1	Φ=USΔT	1,185	Tpi=Ti - Φ/(hi*S)	19,625		

No	Material	λ thermal Conductivity (w/mK)	Thickness (m)	Ki = λ/s	Temperature	Thickness for Graph	
1	Coniferous Wood (Lignatur system)	0,13	0,03	4,33	19,63	0,03	
2	Wood Fiber (Lignatur system)	0,04	0,08	0,50	12,13	0,11	
3	Coniferous Wood (Lignatur system)	0,13	0,03	4,33	11,26	0,14	
5	Rigid Rock Wool Thermal Insulation 120 mm	0,035	0,12	0,29	-1,60	0,26	
6	Filter fleece 4 mm	0,039	0,004	9,75	-1,98	0,264	
7	Synthetic Waterproofing membrane 8 mm	0,27	0,008	33,75	-2,09	0,272	
8	Filter fleece 4 mm	0,039	0,004	9,75	-2,48	0,276	
9	Gravel ballast layer 40 mm	0,5	0,04	12,50	-2,78	0,316	
		Total:	0,316				

No	Material	δ(Vapour Permiability) 10^12 (Kg/m s pa)	ρ = s/δ(m2 s pa/Kg)	Temperature	Pv (Pa)	Ps(Pa)	Vapour Pressure with Vapour Barrier Pv' (Pa)
1	Wood plate (Lignatur system)	4,5	0,00667	19,63	1154,32	2267,76	1160,57
2	Wood Fiber (Lignatur system)	25	0,00320	12,13	1151,08	1393,25	1160,32
3	Wood plate (Lignatur system)	4,5	0,00667	11,26	1144,32	1314,92	392,43
4	Rigid Rock Wool Thermal Insulation 120 mm	63	0,00190	-1,60	1142,39	532,91	392,29
5	Filter fleece 4 mm	40	0,00010	-1,98	1142,28	518,03	392,28
6	Synthetic Waterproofing membrane 8 mm	0,01	0,80000	-2,09	331,19	513,79	330,89
7	Filter fleece 4 mm	40	0,00010	-2,48	331,09	499,39	330,88
8	Gravel ballast layer 40 mm	180	0,00022	-2,78	330,86	488,40	330,86
			0,81886				

Conclusion:	To avoid the condensation risk , Vapour barrier should be provided below Rigid Rock Wool Thermal Insulation layer

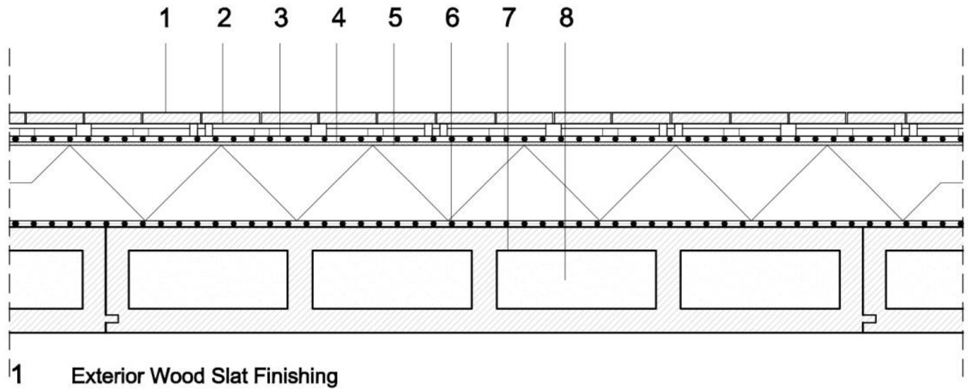


Thickness of Vapour Barrier(S)	0,001	m
δ	0,0001	$Kg/(m^2*s*Pa)$
ρbv	10,000	$(m^2*s*Pa)/Kg$

Fig. 5.42: Glaser diagram for roof section

Condensation risk analysis showed that a vapour barrier should be provided on the warm side of the rigid rock wool insulating layer to prevent the risk.

5.2.7. Balcony Slab



1 Exterior Wood Slat Finishing
2 Interlocking Flooring Base
3 Synthetic Waterproofing Membrane
4 Filter Fleece
5 Rigid Rockwool Thermal Insulation
6 Synthetic Vapor Barrier
7 Lignatur Flooring System (LFE)
8 Fibrewood

Fig. 5.43: Balcony slab section

Balcony roof					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Upward flux hi=0,1 ; he=0,04
	Outside				
	External surface			0,17	
1	Finishing wood	0,016	0,078	0,21	
2	Interlocking base	0,015			
3	Rockwool	0,13	0,035	3,71	
4	Wood (Lignatur system)	0,03	0,1	0,30	
5	Fibre wood (Lignatur system)	0,08	0,04	2,00	
6	Wood (Lignatur system)	0,03	0,1	0,30	
	Internal surface			0,04	
	Total	0,301	0,353	6,7294	
			U-value (w/m²k)	0,15	

Fig. 5.44: U-value for balcony roof slab

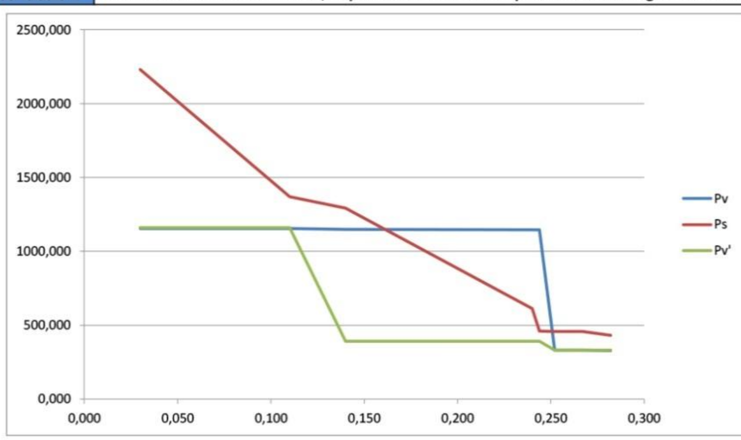
Glasier Diagram For Balcony Slab

Relative Humidity Inside	0,5	Relative Humidity outside	0,8	U value (W/m2K) =	0,15		
Pint(Pa) at: 20 c & 50 % Rh=	1161,079	Pext(Pa)at: -5 C & 80% Rh =	330,863	ΔP (Pa) =	830,216		
Inside Temp (Ti)	20	Outside Temp (Te)	-5	ΔT	25		
Downward flux 1/hi =	0,17	Φ=USΔT	1,058	Tpi=Ti - Φ/(hi*S)	19,363		

No	Material	λ thermal Conductivity (w/mK)	Thickness (m)	Ki = λ/s	Temperature	Thickness for Graph	
1	Coniferous Wood (Lignatur system)	0,130	0,030	4,3333	19,3625	0,030	
2	Wood Fiber (Lignatur system)	0,040	0,080	0,5	11,8625	0,110	
3	Coniferous Wood (Lignatur system)	0,13	0,03	4,3333	10,9971	0,140	
4	Rigid Rock Wool Thermal Insulation 100 mm	0,035	0,1	0,35	0,2828	0,240	
5	Filter fleece 4 mm	0,0039	0,004	0,975	-3,5633	0,244	
6	Synthetic Waterproofing membrane 8 mm	0,27	0,008	33,75	-3,6744	0,252	
7	Interlocking base gap		0,015		-3,6744	0,267	
8	Exterior wood finishing	0,078	0,015	5,2	-4,3956	0,282	
			0,282				

No	Material	δ(Vapour Permiability) 10^12 (Kg/m s pa)	ρ = s/δ(m2 s pa/Kg)	Temperature	Pv (Pa)	Ps(Pa)	Vapour Pressure with Vapour Barrier Pv' (Pa)
1	Coniferous Wood (Lignatur system)	4,5	0,0067	19,3625	1154,302	2230,3662	1160,5677
2	Wood Fiber (Lignatur system)	50	0,0016	11,8625	1154,302	1369,0590	1160,4448
3	Coniferous Wood (Lignatur system)	4,5	0,0067	10,9971	1147,524	1291,9496	392,3960
4	Rigid Rock Wool Thermal Insulation 100 mm	63	0,0016	0,2828	1145,910	611,4025	392,2741
5	Filter fleece 4 mm	40	0,0001	-3,5633	1145,809	460,6666	392,2664
6	Synthetic Waterproofing membrane 8 mm	0,01	0,8000	-3,6744	332,490	456,8598	330,8635
7	Interlocking base gap			-3,6744	332,490	456,8598	330,8635
8	Exterior wood finishing	4,5	0,0033	-4,3956	329,101	432,8330	330,6076
			0,816620635				

Conclusion: To avoid the condensation risk , Vapour barrier should be provided below Rigid Rock Wool Thermal Insulation layer

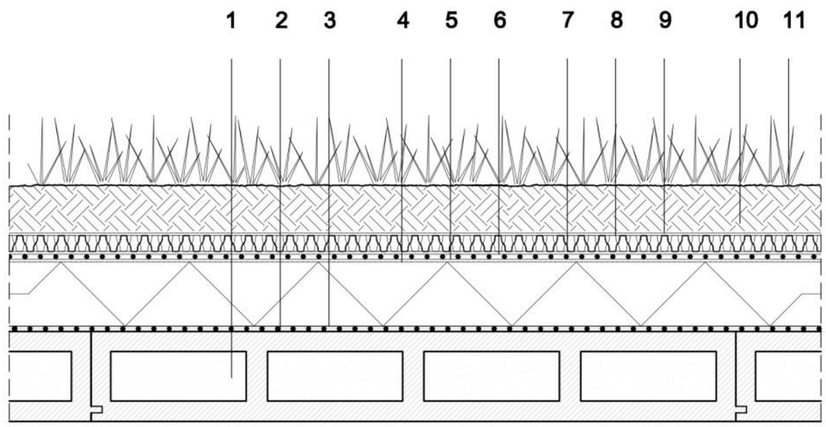


Thickness of Vapour Barrier(S)	0,001	m
δ	0,0001	$Kg/(m^2sPa)$
Rbv	10,0000	$(m^2sPa)/Kg$

Fig. 5.45: Glaser diagram for balcony slab

Condensation risk analysis showed that a vapour barrier should be provided on the warm side of the rigid rock wool insulating layer to prevent the risk.

5.2.8. Green Roof Slab



1 **Lignatur Flooring System (LFE)**
2 **Fibrewood Insulation**
3 **Synthetic Vapor Barrier**
4 **Rigid Rockwool Thermal Insulation**
5 **Filter Fleece**
6 **Synthetic Waterproofing Layer**
7 **Polyethylene Protective Sheet**
8 **Floradrain FD25 2000 x 1000 x 25mm drainage sheets**
9 **Filter Fleece**
10 **Soil**
11 **Sedum Species Extensive Planting**

Fig. 5.46: Green roof slab section

Green roof					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m^2.k/W)	Upward flux hi=0,1 ; he=0,04
	Outside				
	External surface			0,17	
	Roof Vegetation				
1	Soil	0,07	0,6	0,12	
2	Floradrain drainage sheets	0,025	0,2	0,13	
3	Rockwool	0,13	0,035	3,71	
4	Wood (Lignatur system)	0,03	0,1	0,30	
5	Fibre wood (Lignatur system)	0,08	0,04	2,00	
6	Wood (Lignatur system)	0,03	0,1	0,30	
	Internal surface			0,04	
	Total	0,365	1,075	6,7660	
			U-value (w/m^2k)	0,15	

Fig. 5.47: U-value for green roof slab

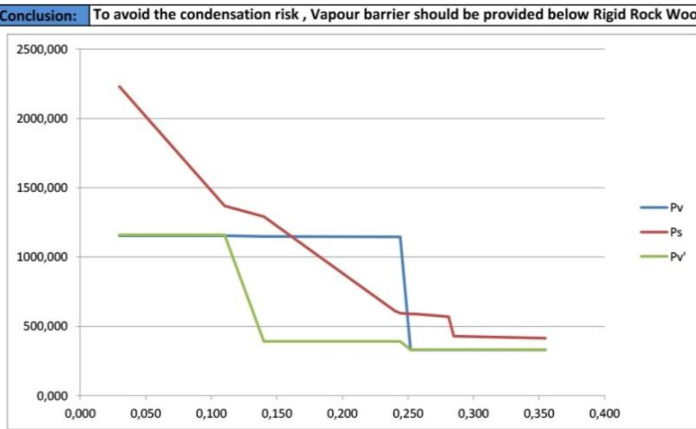
	Glasier Diagram For Green Roof Slab						

Relative Humidity Inside	0,5	Relative Humidity outside	0,8	U value (W/m2K) =	0,15		
Pint(Pa) at: 20 c & 50 % Rh=	1161,079	Pext(Pa)at: -5 C & 80% Rh =	330,863	ΔP (Pa) =	830,216		
Inside Temp (Ti)	20	Outside Temp (Te)	-5	ΔT	25		
Downward flux 1/hi =	0,17	Φ=USΔT	1,331	Tpi=Ti - Φ/(hi*S)	19,363		

No	Material	λ thermal Conductivity (w/mK)	Thickness (m)	Ki = λ/s	Temperature	Thickness for Graph	
1	Coniferous Wood (Lignatur system)	0,130	0,030	4,3333	19,3625	0,030	
2	Wood Fiber (Lignatur system)	0,040	0,080	0,5	11,8625	0,110	
3	Coniferous Wood (Lignatur system)	0,13	0,03	4,3333	10,9971	0,140	
4	Rigid Rock Wool Thermal Insulation 100 mm	0,035	0,1	0,35	0,2828	0,240	
5	Filter fleece 4 mm	0,039	0,004	9,75	-0,1018	0,244	
6	Synthetic Waterproofing membrane 8 mm	0,27	0,008	33,75	-0,2129	0,252	
7	Polyethylene protective sheet	0,5	0,004	125	-0,2429	0,256	
8	Floradrain drainage sheets 25mm	0,2	0,025	8	-0,7116	0,281	
9	Filter fleece 4 mm	0,0039	0,004	0,975	-4,5578	0,285	
10	Soil 70mm	0,6	0,07	8,5714	-4,9953	0,355	
12	Roof Vegetation						
			0,355				

No	Material	δ(Vapour Permiability) 10^12 (Kg/m s pa)	ρ = s/δ(m2 s pa/Kg)	Temperature	Pv (Pa)	Ps(Pa)	Vapour Pressure with Vapour Barrier Pv' (Pa)
1	Coniferous Wood (Lignatur system)	4,5	0,0067	19,3625	1154,302	2230,3662	1160,5677
2	Wood Fiber (Lignatur system)	50	0,0016	11,8625	1154,302	1369,0590	1160,4448
3	Coniferous Wood (Lignatur system)	4,5	0,0067	10,9971	1147,524	1291,9496	392,3960
4	Rigid Rock Wool Thermal Insulation 100 mm	63	0,0016	0,2828	1145,910	611,4025	392,2741
5	Filter fleece 4 mm	40	0,0001	-0,1018	1145,809	594,5510	392,2664
6	Synthetic Waterproofing membrane 8 mm	0,01	0,8000	-0,2129	332,490	589,7611	330,8635
7	Polyethylene protective sheet	40	0,0001	-0,2429	332,388	588,4739	330,8558
8	Floradrain drainage sheets 25 mm	300	0,0001	-0,7116	332,304	568,6855	330,8494
9	Filter fleece 4 mm	40	0,0001	-4,5578	332,202	427,5880	330,8417
10	Soil 70mm	250	0,0003	-4,9953	331,917	413,7260	330,8202
12	Roof Vegetation						
			0,816903968				

Conclusion:	To avoid the condensation risk , Vapour barrier should be provided below Rigid Rock Wool Thermal Insulation layer



Thickness of Vapour Barrier(S)	0,001	m
δ	0,0001	$Kg/(m^2sPa)$
Rbv	10,0000	$(m^2sPa)/Kg$

Fig. 5.48: Glaser diagram for green roof slab

Condensation risk analysis showed that a vapor barrier should be provided on the warm side of the rigid rock wool insulating layer to prevent the risk.

5.2.9. External Wall

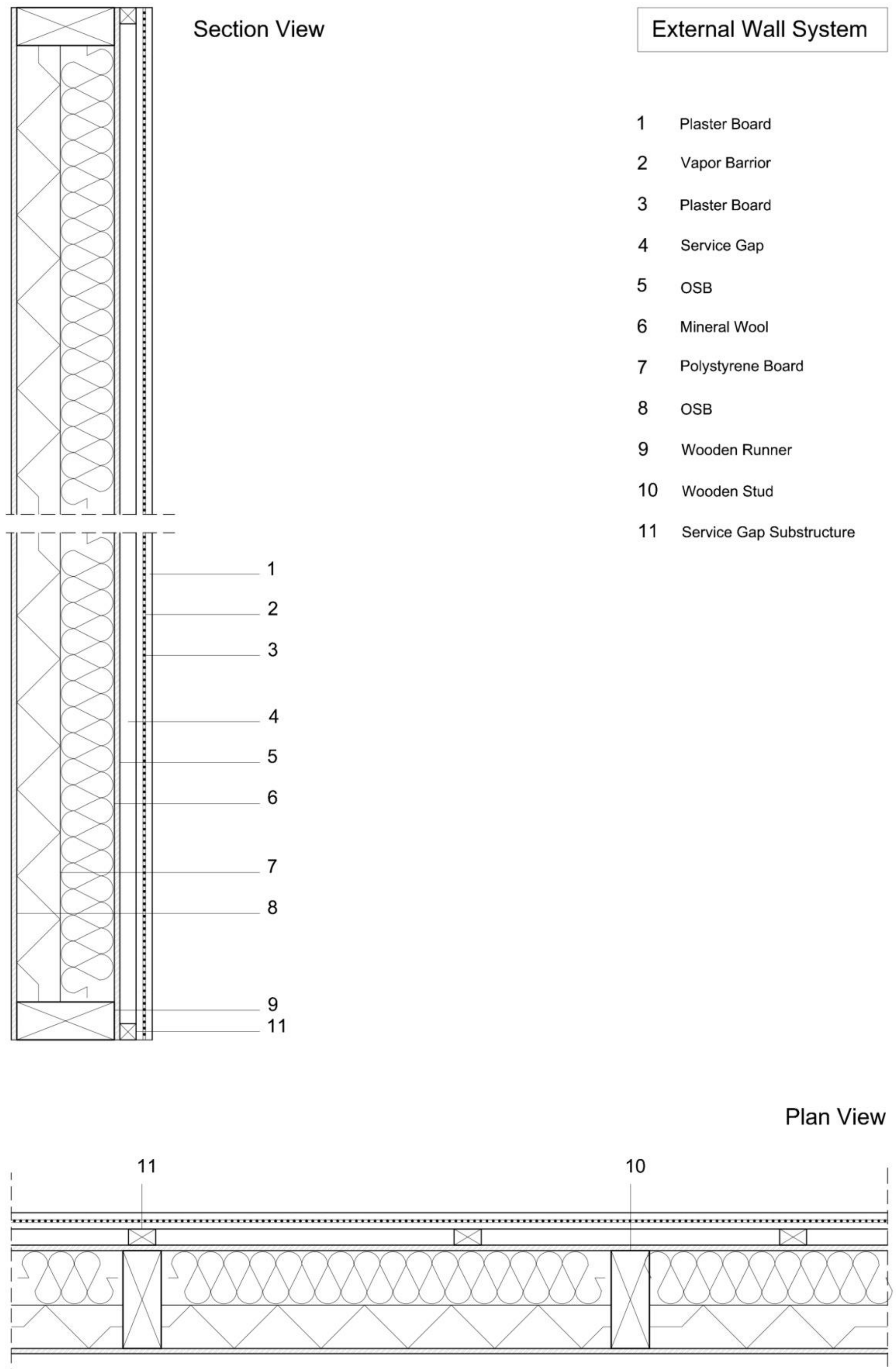


Fig. 5.49: External wall plan and section

Wall					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Ressistance R (m².k/W)	Vertical flux hi=0,13 ; he=0,04
	Internal surface			0,13	
1	Knauf Plaster board	0,0125	0,16	0,08	
2	Knauf plaster board	0,0125	0,16	0,08	
	Service gap				
3	OSB Board	0,01	0,13	0,08	
4	Mineral wool	0,1	0,035	2,86	
5	Polystryene Board 45Kg/m3	0,08	0,03	2,67	
6	OSB Board	0,01	0,13	0,08	
	External surface			0,04	
	Outside				
	Total	0,225	0,645	6,0039	
	Total without the rainscreen façade	0,225		5,9639	
			U-value (w/m²k)	0,17	
			U-value (w/m²k) without the rainscreen facade	0,17	

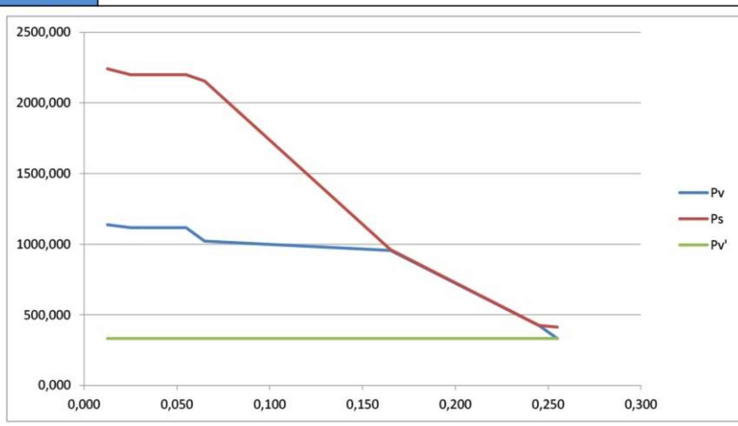
Fig. 5.50: U-value for wall

	Glasier Diagram For Wall						
Relative Humidity Inside	0,5	Relative Humidity outside	0,8	U value (W/m2K) =	0,17		
Pint(Pa) at: 20 c & 50 % Rh=	1161,079	Pext(Pa)at: -5 C & 80% Rh =	330,863	ΔP (Pa) =	830,216		
Inside Temp (Ti)	20	Outside Temp (Te)	-5	ΔT	25		
Vertical flux 1/hi =	0,13	Φ=USΔT	1,296	Tpi=Ti - Φ/(hi*S)	19,448		

No	Material	λ thermal Conductivity (w/mK)	Thickness (m)	Ki = λ/s	Temperature	Thickness for Graph	
1	Plasterboard 12.5 mm	0,17	0,0125	13,6	19,448	0,013	
2	Plasterboard 12.5 mm	0,17	0,0125	13,6	19,135	0,025	
3	Service gap		0,0300		19,135	0,055	
4	OSB board 10 mm	0,130	0,010	13	18,808	0,065	
5	Mineral wool thermal insulation 100 mm	0,035	0,100	0,35	6,665	0,165	
6	Polystyrene board 80 mm	0,03	0,080	0,375	-4,668	0,245	
7	OSB board 10 mm	0,13	0,010	13	-4,995	0,255	
8	Gap for façade substructure		0,030			0,285	
9	Rainscreen façade		0,020			0,305	
			0,305				

No	Material	δ(Vapour Permiability) 10^12 (Kg/m s pa)	ρ = s/δ(m2 s pa/Kg)	Temperature	Pv (Pa)	Ps(Pa)	Vapour Pressure with Vapour Barrier Pv' (Pa)
1	Plasterboard 12.5 mm	23	0,0005	19,448	1138,311	2242,42	332,46
2	Plasterboard 12.5 mm	23	0,0005	19,135	1115,543	2198,40	332,42
3	Service gap			19,135	1115,543	2198,40	332,42
4	OSB board 10 mm	4,5	0,0022	18,808	1022,445	2153,18	332,23
5	Mineral wool thermal insulation 100 mm	63	0,0016	6,665	955,947	961,34	332,10
6	Polystyrene board 80 mm	6,3	0,0127	-4,668	423,961	424,05	331,05
7	OSB board 10 mm	4,5	0,0022	-4,995	330,863	413,73	330,86
8	Gap for façade substructure						
9	Rainscreen façade						
			0,020				

Conclusion:	There is no need to provide Vapour Barrier as (Ps) is higher than (Pv), but as the values are close, for safety it is added between plasterboards



Thickness of Vapour Barrier(S)	0,001	m
δ	0,0001	Kg/(m²*s*Pa)
ρbv	10,000	(m²*s*Pa)/Kg

Fig. 5.51: Glaser diagram for wall section

Condensation risk analysis showed that a vapour barrier is not necessary in the wall section as Ps is higher than Pv thus the probability of condensation within the layers is low, but as the values are very close, it is provided between the plasterboards to remain on the safety side.

5.3. Technological Drawings

5.3.1. Plan

Plan type A

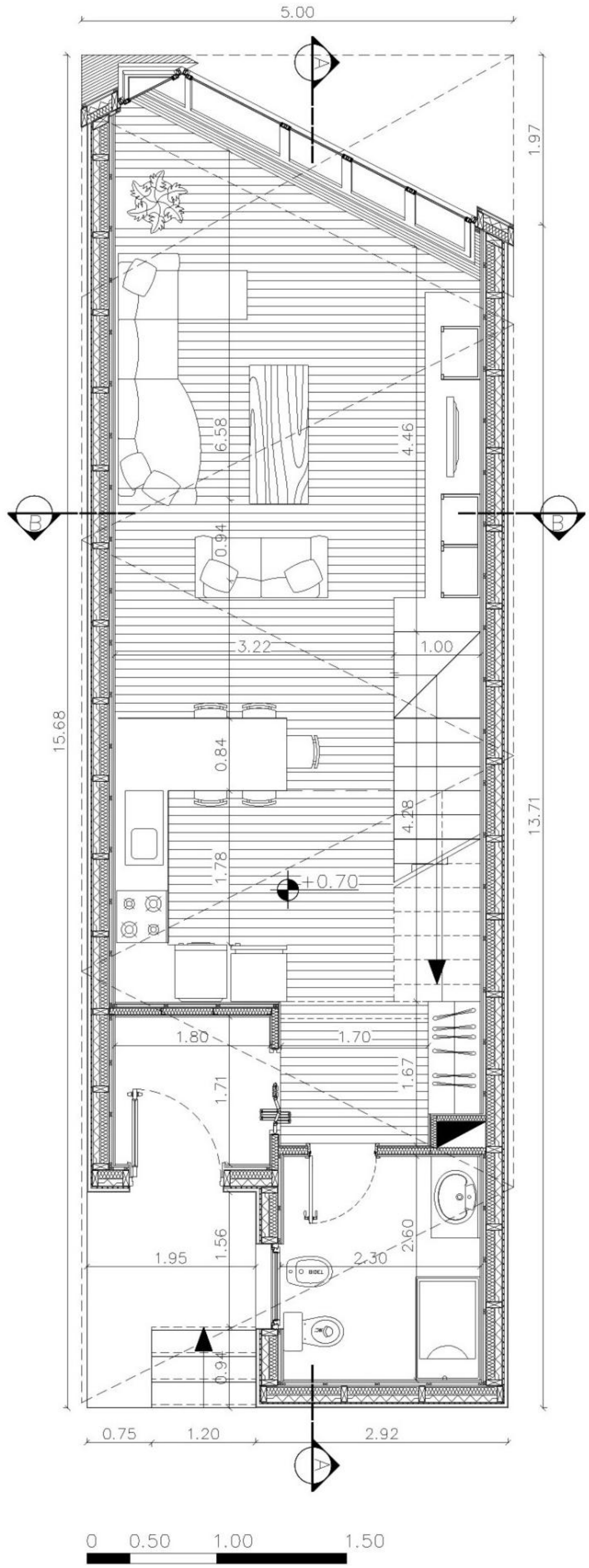


Fig. 5.52: Plan module A, First Level

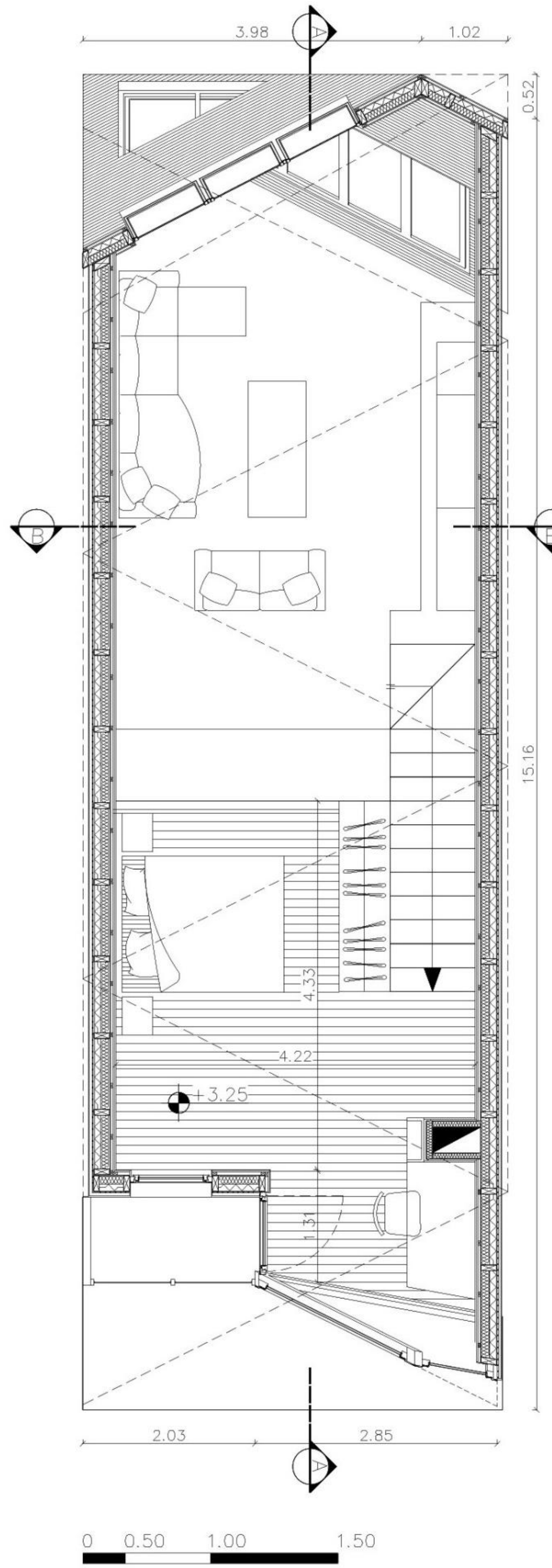


Fig. 5.53: Plan module A, mezzanine Level

Plan type B

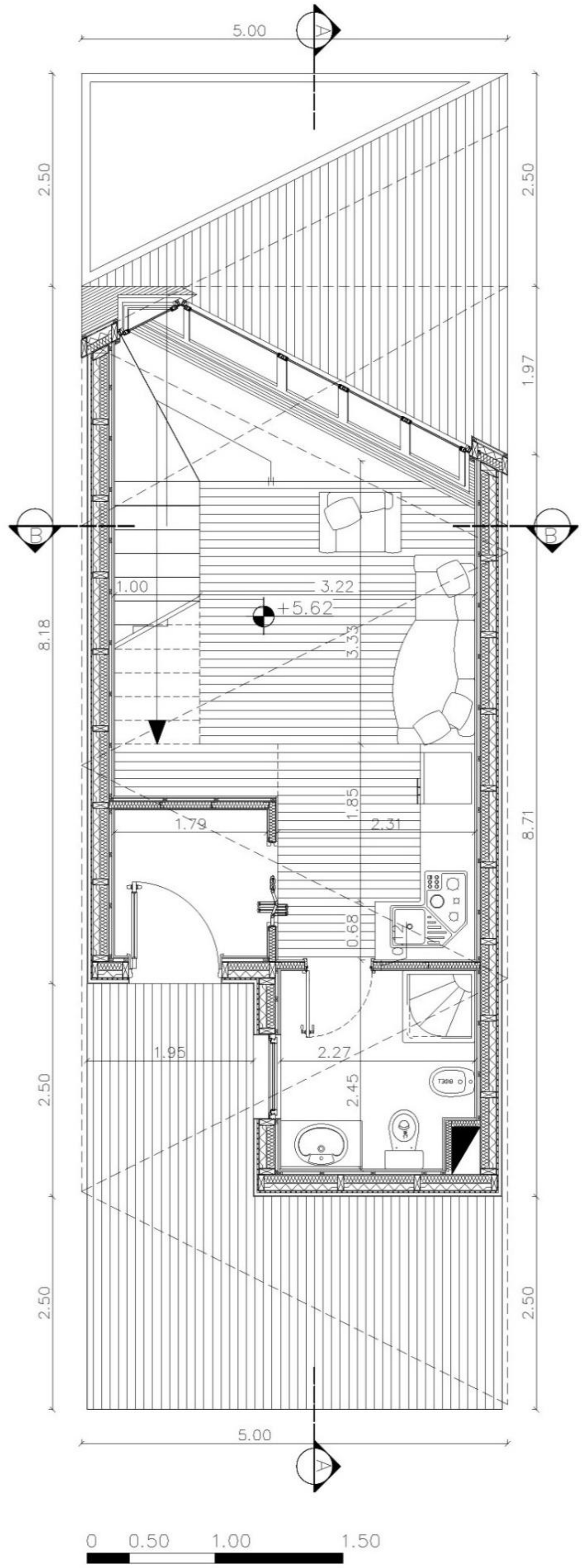


Fig. 5.54: Plan module B, first level

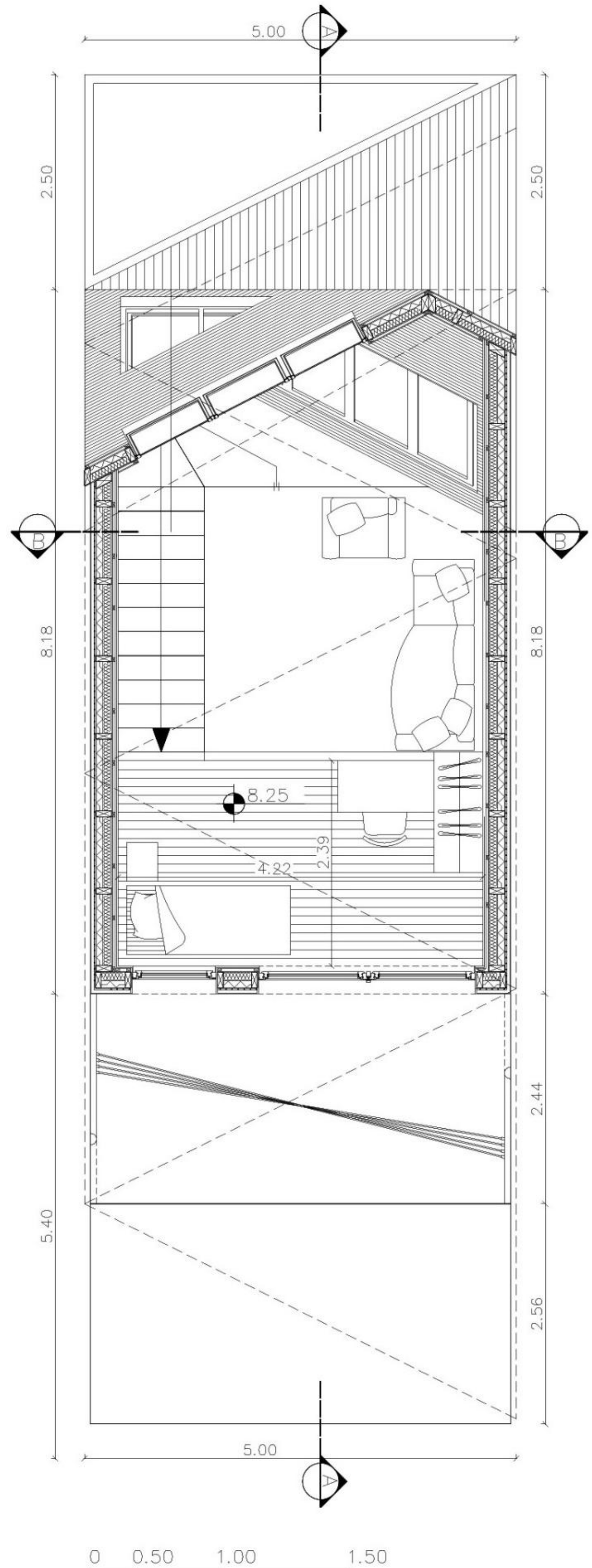


Fig. 5.55: Plan module B, mezzanine level

5.3.2. Section

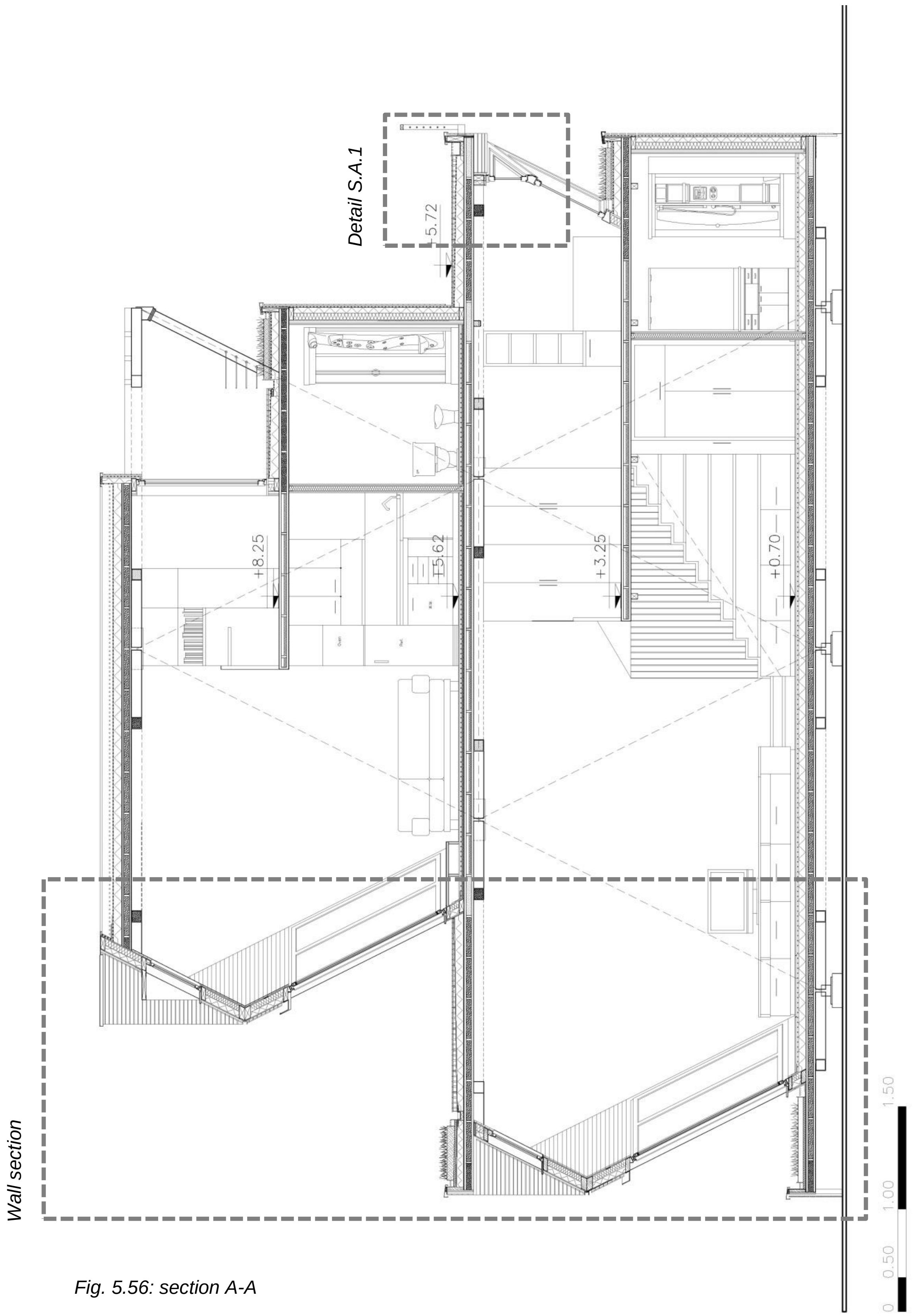


Fig. 5.56: section A-A

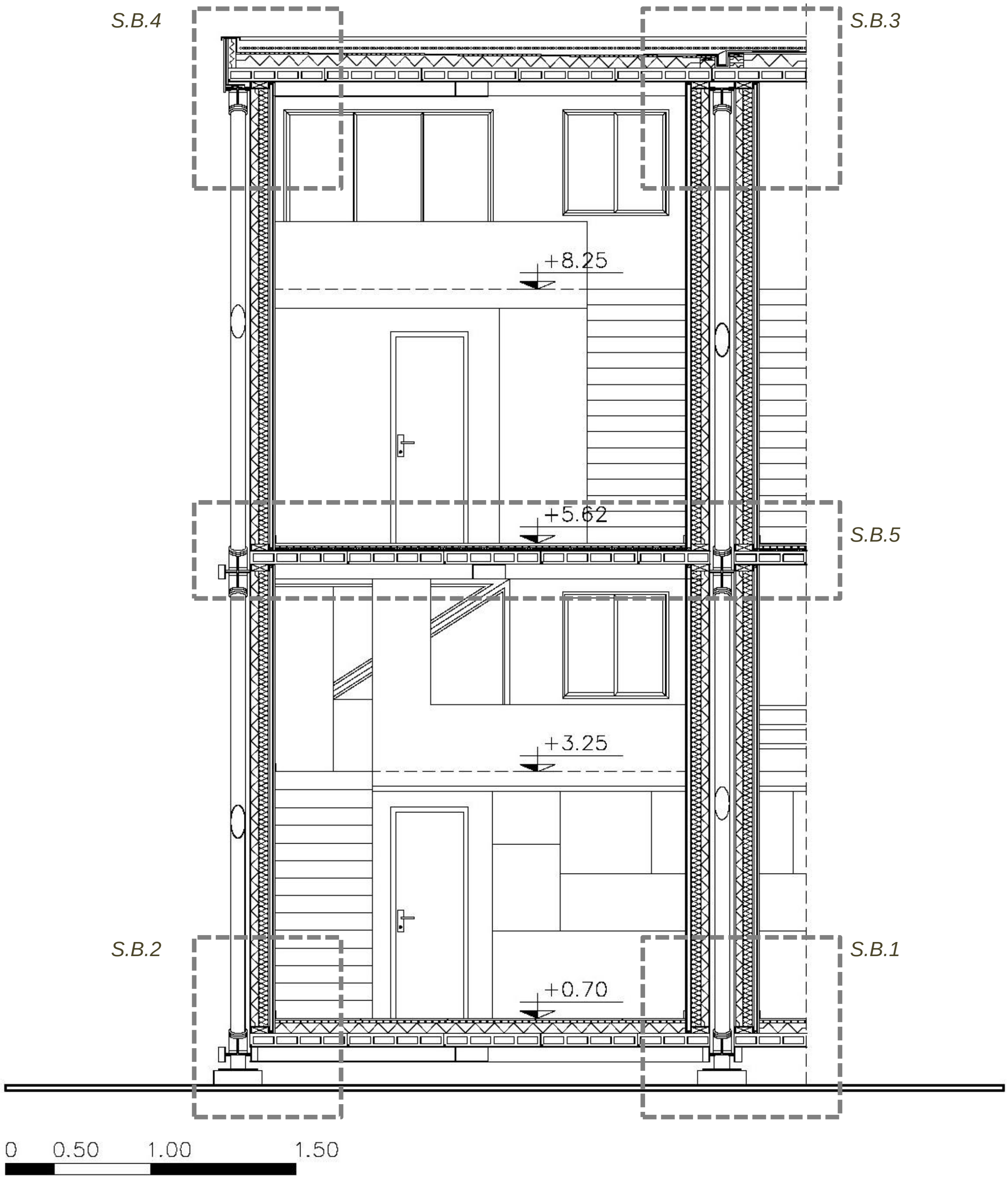
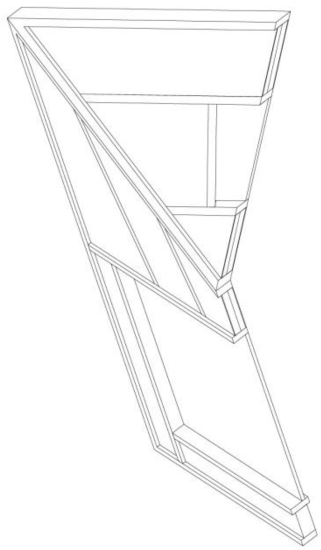


Fig. 5.57: section B-B

5.3.3. Wall Section



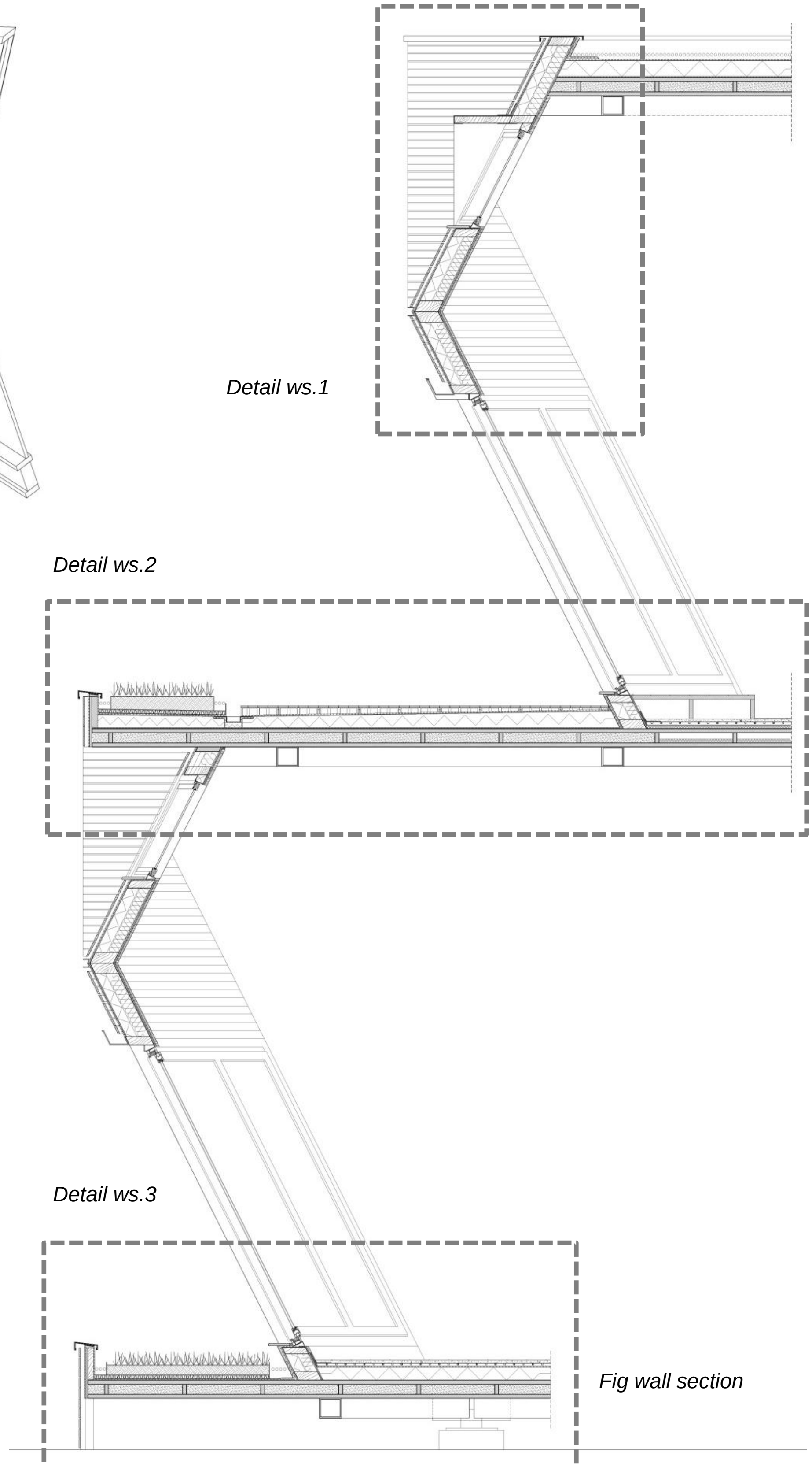
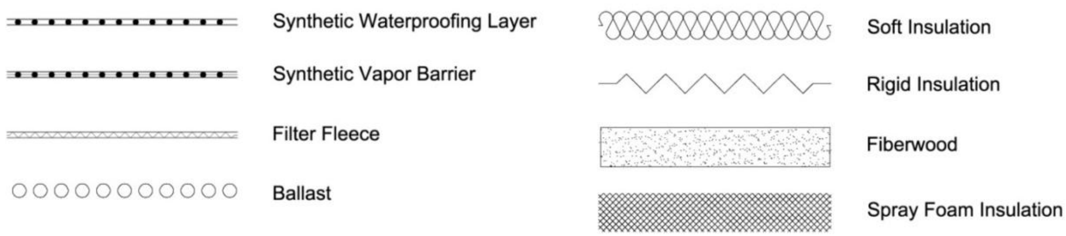


Fig. 5.58: wall section with the vertical 3D section of the inclined face

Fig wall section

5.3.4. Details

In the followings details, the symbols below have been used in order to differentiate between the individual layers of construction.



Note1: Synthetic waterproofing membrane might be incompatible with thermal insulation, so a protective membrane always is laid in between them. Also as they have a tendency to shrink they are fixed to the structure with means of mechanical fastener in form of vertical clamping bar or horizontal linear fixings.

Note 2:By placing the external wall on the inner side of the constructional joints, the general chance of cold bridge effect is minimized. The only critical place is when the structure penetrates inside the envelope and enters the module.

As a solution which improve the problem to an acceptable extend, the hollow cubic tubes are injected with insulation foam. Also in the last steps of construction, when the walls are fixed and the upper floor or roof is placed, the voids inside the wall where the structure goes inside will be filled with spray foam insulation. This will guarantee the air tightness and waterproofing of the area.

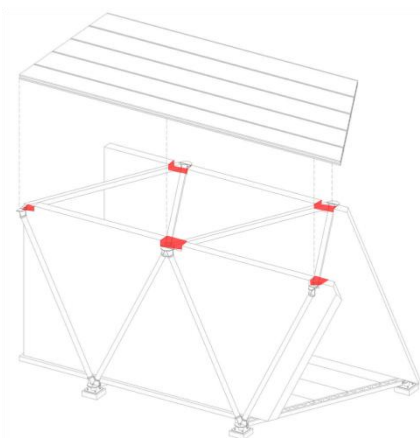


Fig. application of the insulation foam.

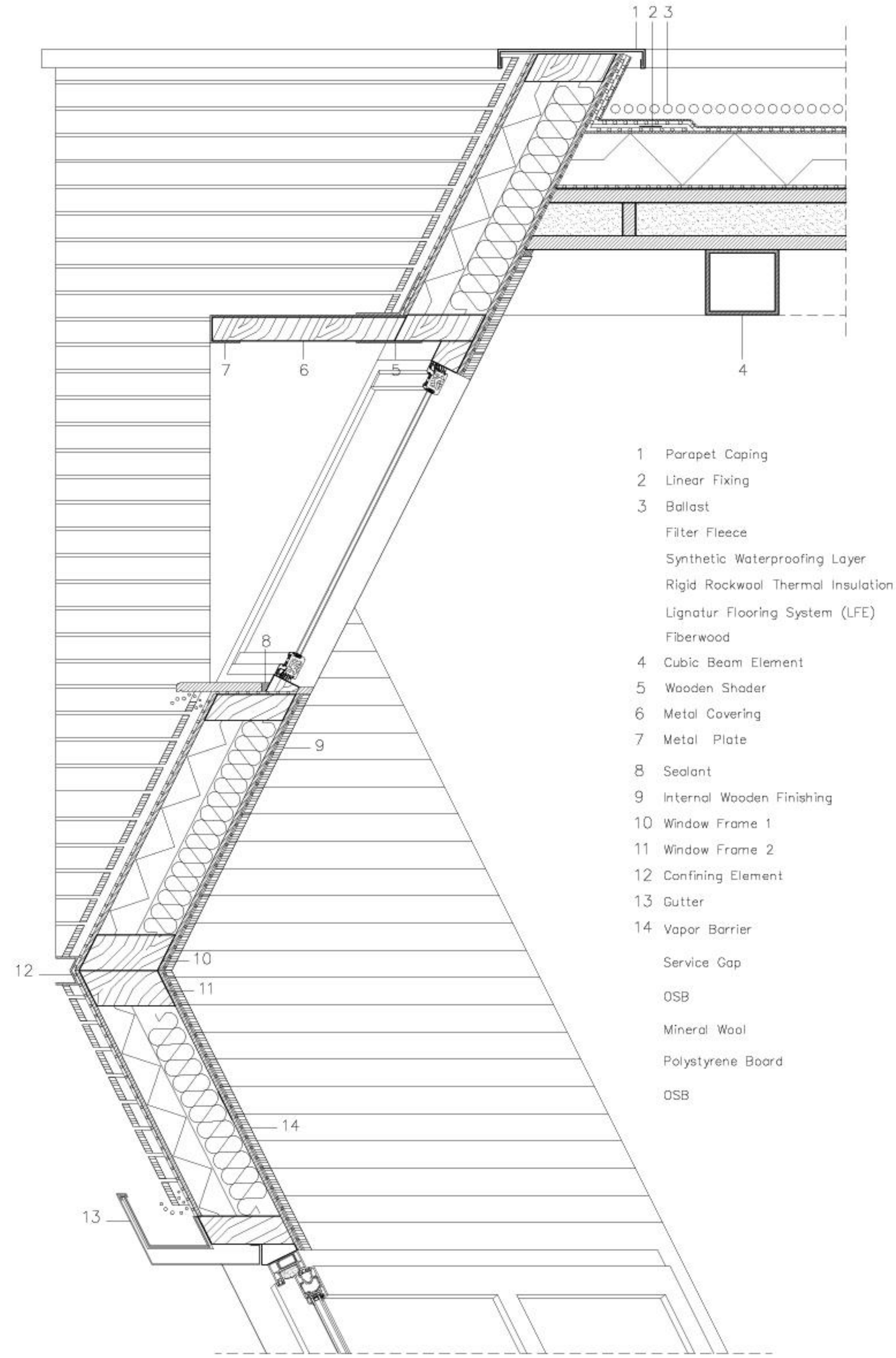
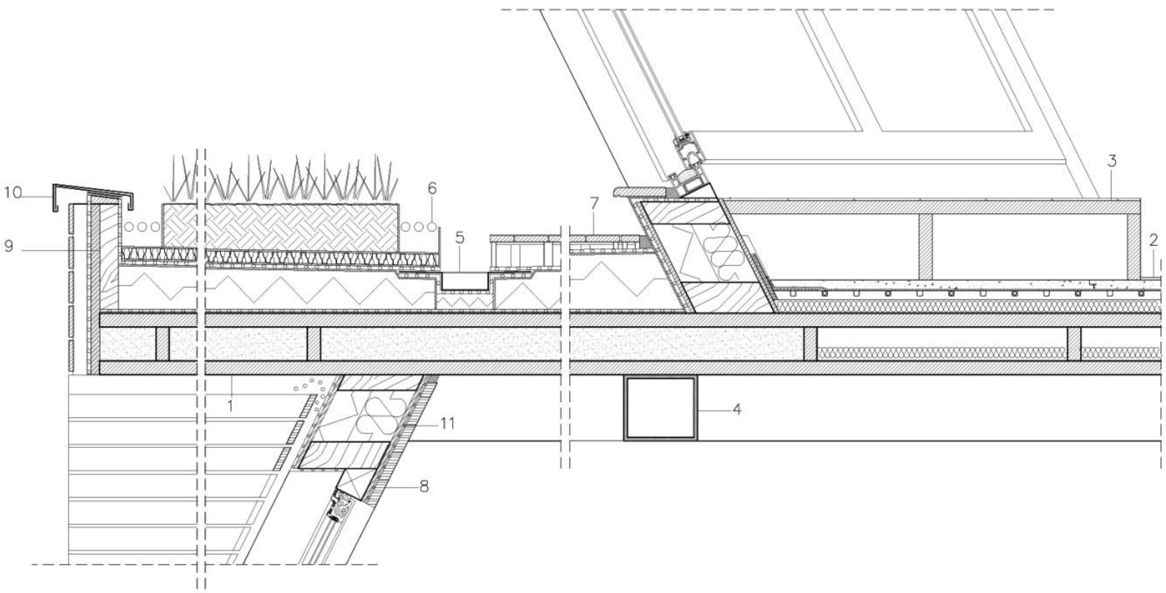


Fig. 5.59: detail ws.1



1 Lignatur Flooring System (LFE)
Fibrewood Insulation
Synthetic Vapor Barrier
Rigid Rockwool Thermal Insulation
Filter Fleece
Synthetic Waterproofing Layer
Polyethylene Protective Sheet
Floradrain FD25 2000 x 1000 x 25mm drainage sheets
Filter Fleece
Soil
Sedum Species Extensive Planting

2 Parquet Finishing
Dry Screed Board
Velta PE Slip Membrane
Velta Siccus Panel
Acoustic Blanket
Lignatur Flooring System (LFE)
Additional Acoustic Insulation

3 Stair Substructure

4 Cubic Beam Element

5 Gutter

6 Ballast

7 Exterior Wood Slat Finishing
Interlocking Flooring Base
Synthetic Waterproofing Membrane
Filter Fleece
Rigid Rockwool Thermal Insulation
Synthetic Vapor Barrier
Lignatur Flooring System (LFE)
Fibrewood

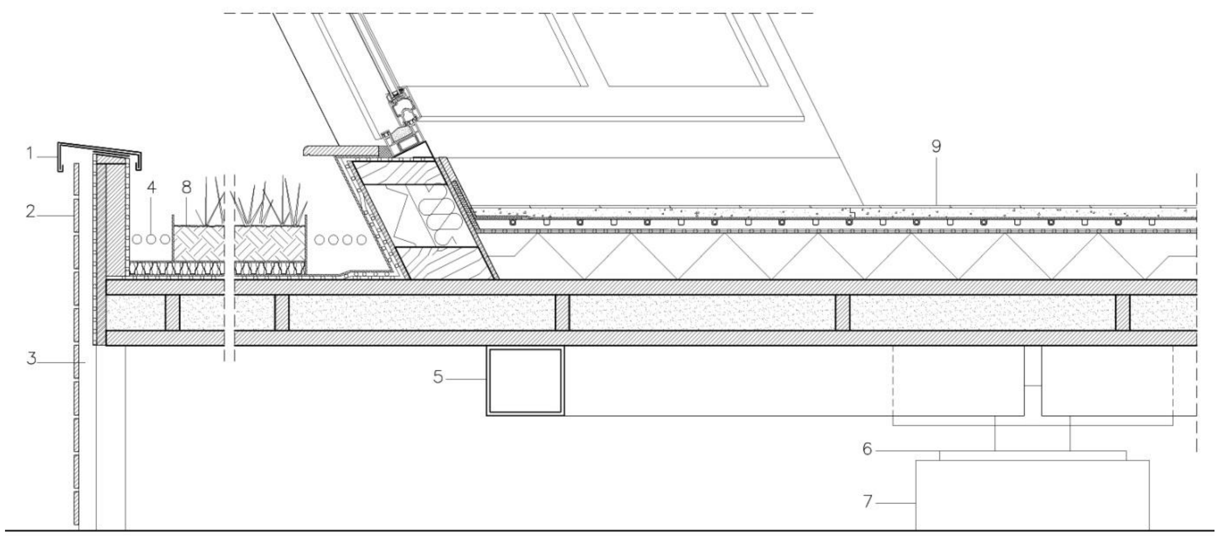
8 Internal Wooden Finishing

9 Wooden Support

10 Parapet Caping

11 Vapor Barrier
Service Gap
OSB
Mineral Wool
Polystyrene Board
OSB

Fig. 5.60: detail ws.2

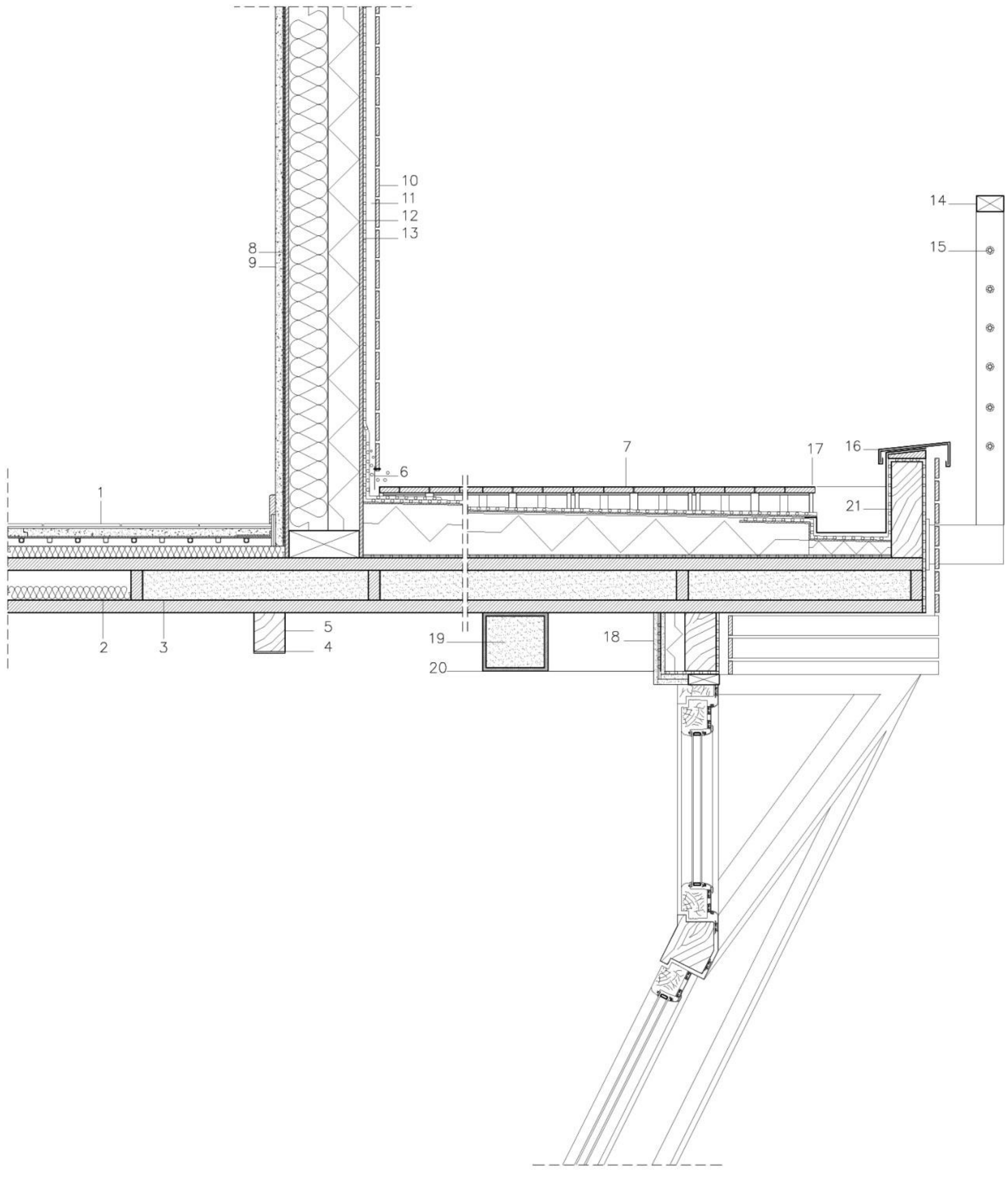


1 Parapet Caping
2 Red Cedar External Finishing
3 RainScreen Facade Substructure
4 Ballast
5 Cubic Beam Element
6 Base Plate
7 Prefabricated Foundation

8 Lignatur Flooring System (LFE)
Fibrewood Insulation
Synthetic Vapor Barrier
Rigid Rockwool Thermal Insulation
Filter Fleece
Synthetic Waterproofing Layer
Polyethylene Protective Sheet
Floradrain FD25 2000 x 1000 x 25mm drainage sheets
Filter Fleece
Soil
Sedum Species Extensive Planting

9 Parquet Finishing
Dry Screed Board
Velta PE Slip Membrane
Velta Siccus Panel
Acoustic Blanket
Lignatur Flooring System (LFE)
Fiberwood

Fig. 5.61: detail ws.3



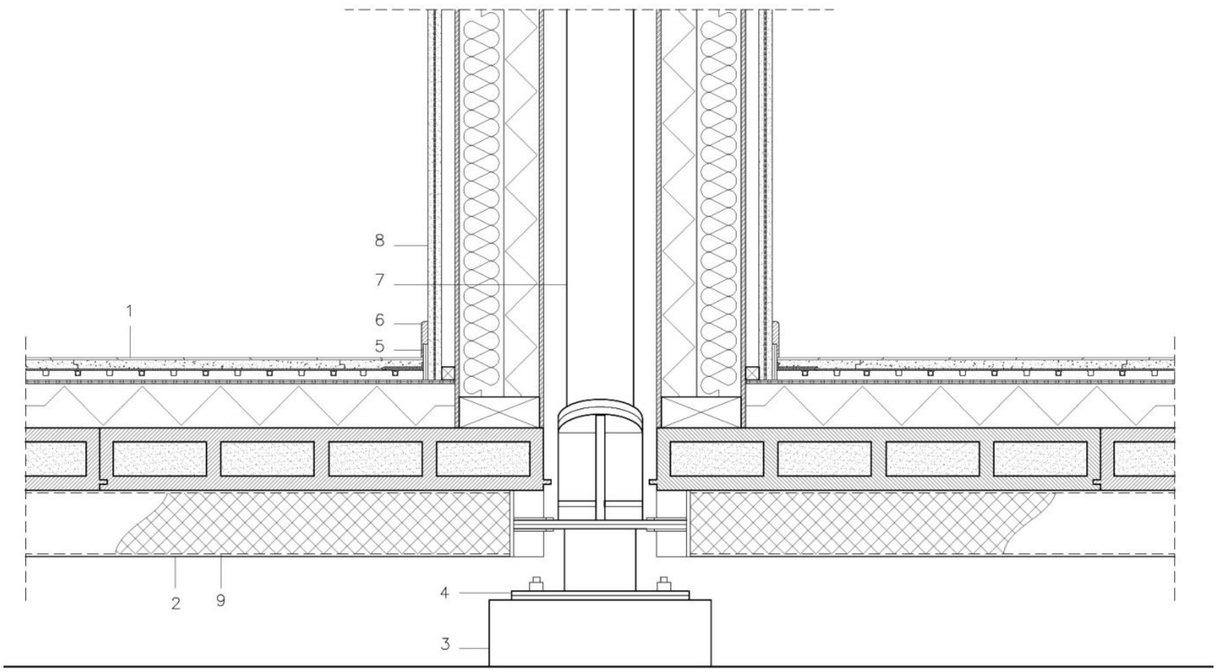
1 Ceramic Tiles
Ceramic Glue
Dry Screed Board
Velta PE Slip Membrane
Velta Siccus Panel
Synthetic Vapor barrier
Extruded Polystyrene
Lignatur Flooring System (LFE)
2 Acoustic Insulation
3 Fibrewood

4 Metal Angel
5 Wooden Beam
6 Perforated Metal Sheet
7 Exterior Wood Slat Finishing
Interlocking Flooring Base
Synthetic Waterproofing Membrane
Filter Fleece
Rigid Rockwool Thermal Insulation
Synthetic Vapor Barrier
8 Synthetic Vapor Barrier

9 Aqua Panel Board
10 Western Red Cedar Boarding
11 Rain Screen Facade Substructure
12 Synthetic Waterproofing layer
13 OSB
Mineral Wool
Polystyrene Board
OSB

14 Wooden Parapet Frame
15 Steel Rod
16 Parapet Caping
17 Gutter
18 Plaster Board
19 Injected Foam Insolation
20 Cubic Beam Element
21 Wooden Support

Fig. 5.62: detail S.A.1

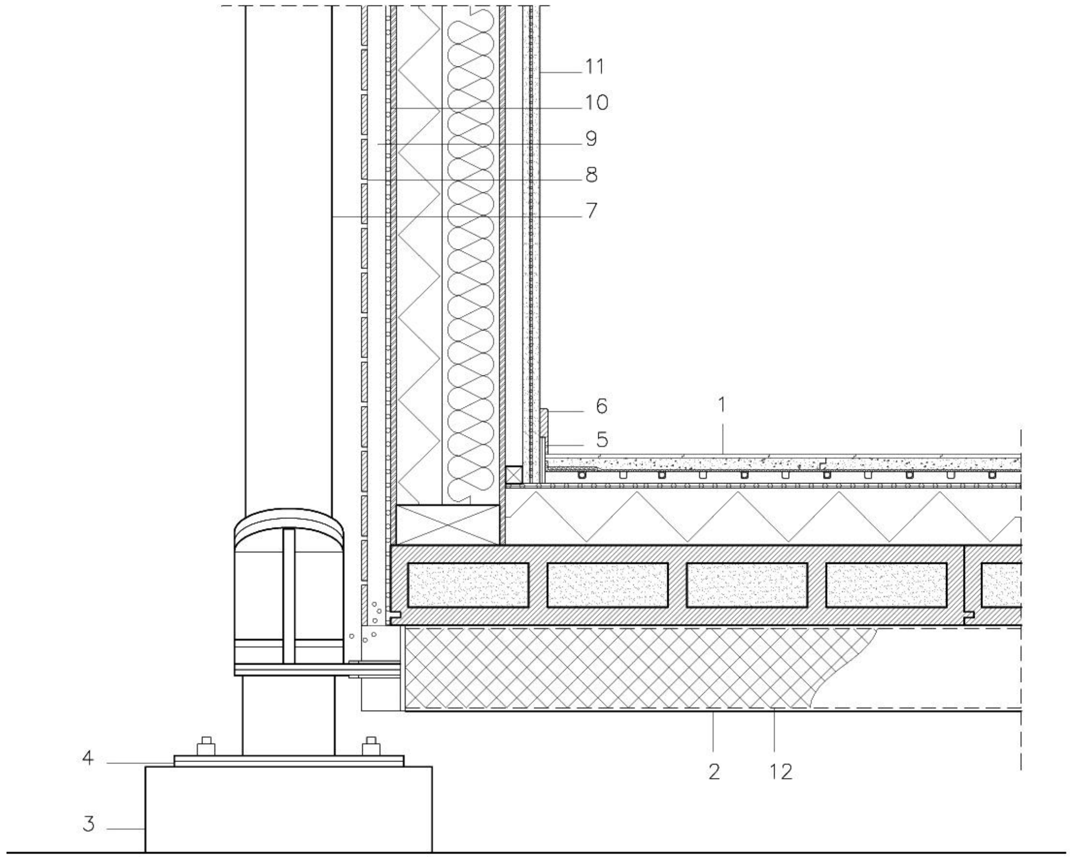


1 Parquet Finishing
Dry Screed Board
Velta PE Slip Membrane
Velta Siccus Panel
Synthetic Vapor barrier
Extruded Polystyrene
Lignatur Flooring System (LFE)
Fibrewood

2 Cubic Beam Element
3 Prefabricated Concrete
4 Base Plate
5 Edge Sound Insulation
6 Wooden Skirting
7 Circular Column Element
9 Injected Foam Insolation

8 Two Layers of Plaster Board
Vapor Barrior
Service Gap
OSB
Mineral Wool
Polystyrene Board
OSB

Fig. 5.63: detail S.B.1



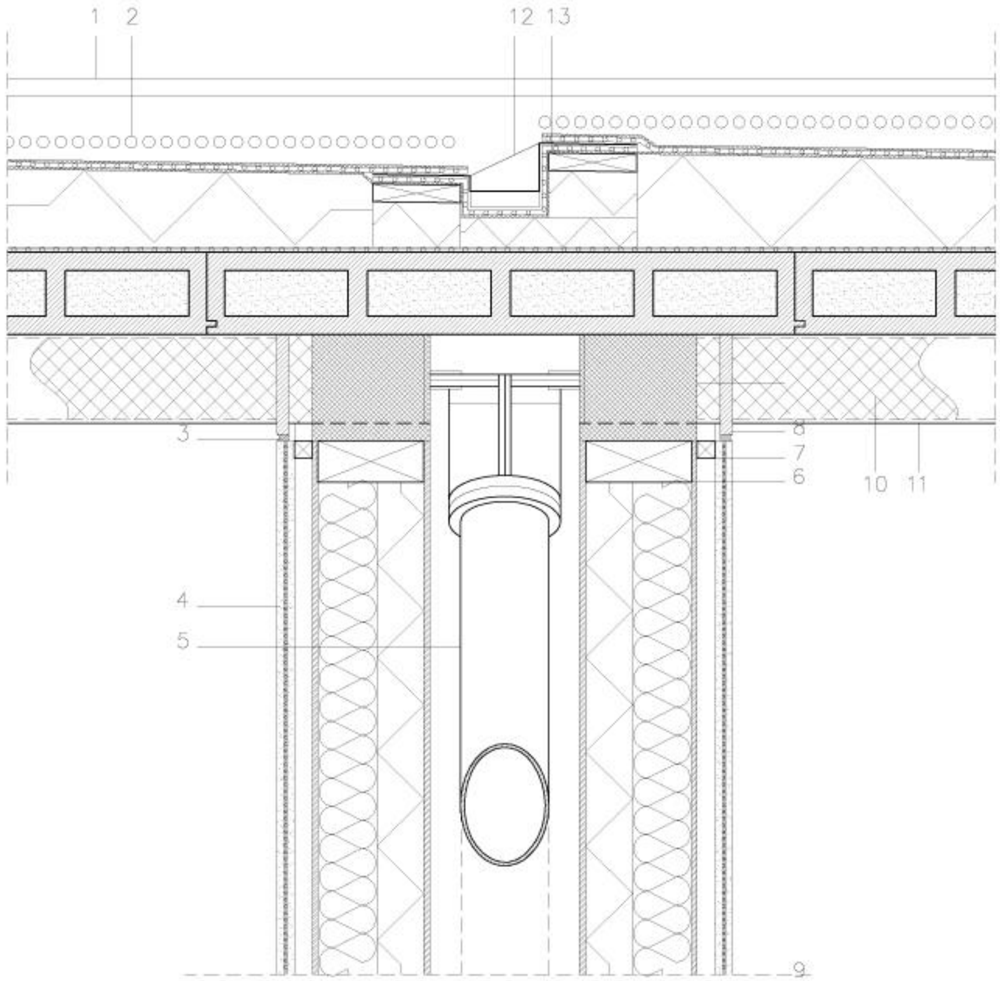
1 Parquet Finishing
Dry Screed Board
Velta PE Slip Membrane
Velta Siccus Panel
Synthetic Vapor barrier
Extruded Polystyrene
Lignatur Flooring System (LFE)
Fibrewood

2 Cubic Beam Element
3 Prefabricated Concrete
4 Base Plate
5 Edge Sound Insulation
6 Wooden Skirting
7 Circular Column Element
8 Western Red Cedar Boarding
9 Rain Screen Facade Substructure
10 Synthetic Waterproofing layer

11 Two Layers of Plaster Board
Vapor Barrior
Service Gap
OSB
Mineral Wool
Polystyrene Board
OSB

12 Injected Foam Insolation

Fig. 5.64: detail S.B.2

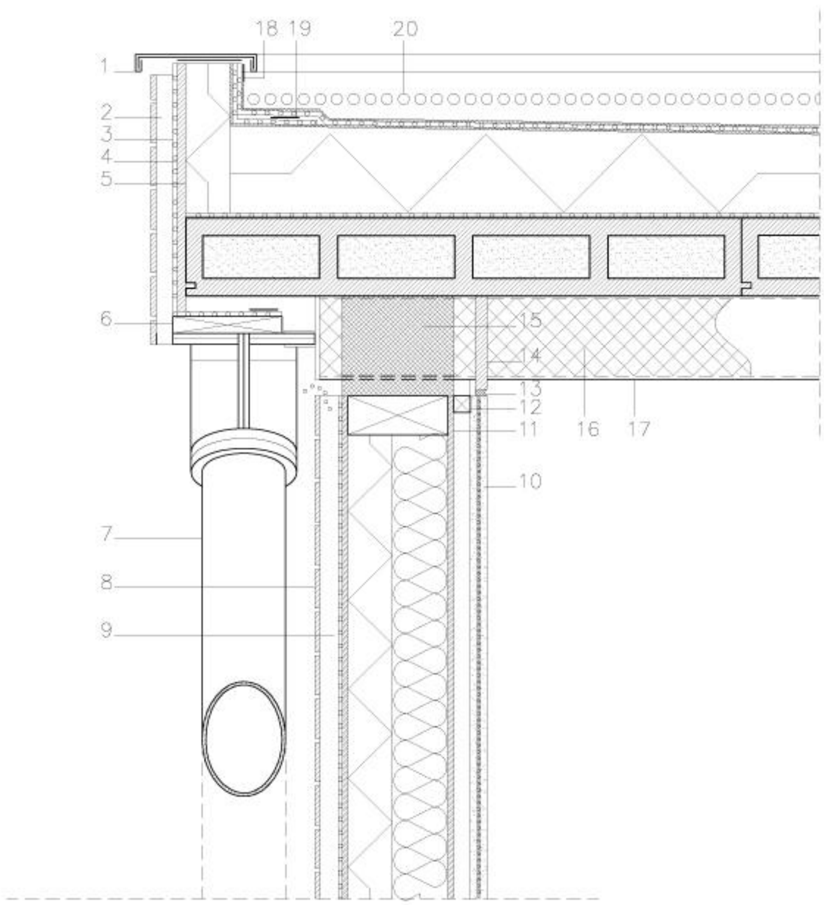


1 Parapet Caping
2 Ballast
Filter Fleece
Synthetic Waterproofing Layer
Rigid Rockwool Thermal Insulation
Lignatur Flooring System (LFE)
Fibrewood Insulation
3 Sealant

4 Two Layers of Plaster Board
Vapor Barrier
Service Gap
OSB
Mineral Wool
Polystyrene Board
OSB
5 Circular Column Element

6 Wooden Runner
7 Service Gap SubStructure
8 Intermediate Element
9 Spray Foam Insulation
10 Injected Foam Insolation
11 Cubic Beam Element
12 Gutter
13 Glulam Board

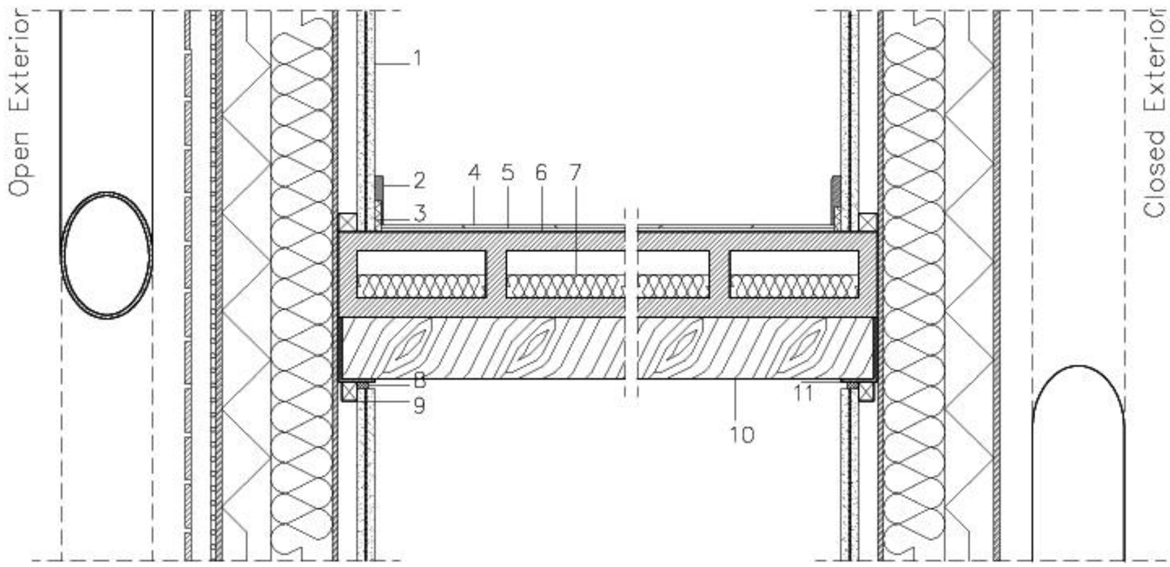
Fig. 5.65: detail S.B.3



1 Parapet Coping
2 Facade Element
3 Synthetic Waterproofing layer
4 OSB
5 Rockwool
6 Glulam Board
7 Circular Column Element
8 Western Red Cedar Boarding
9 Rain Screen Facade Substructure
10 Two Layers of Plaster Board
Vapor Barrier
Service Gap
OSB
Mineral Wool
Polystyrene Board
OSB

11 Wooden Runner
12 Service Gap SubStructure
13 Sealant
14 Intermediate Element
15 Spray Foam Insulation
16 Injected Foam Insolation
17 Cubic Beam Element
18 Clamping Bar
19 Linear Fixing
20 Ballast
Filter Fleece
Synthetic Waterproofing Layer
Rigid Rockwool Thermal Insulation
Lignatur Flooring System (LFE)

Fig. 5.66: detail S.B.4



1 Two Layers of Plaster Board
Vapor Barrior
Service Gap
OSB
Mineral Wool
Polystyrene Board
OSB
Synthetic Waterproofing layer
Service Gap SubStructure
Wooden Runner

2 Wood Skirting
3 Edge Sound Insulation
4 Parquet Finishing
5 Parquet Glue
6 Lignatur Flooring System (LFE)
7 Sound Insulation (Mineral Wool)
8 Sealant
9 Service Gap Substructure
10 Glulam Beam
11 Metal Angel

Fig. 5.67: detail S.B.5

5.4. Building Performance Assessment

5.4.1. Scope Of Analysis

Considering that the project consists of modular housing typology in different arrangements, with two types of apartments – type A and type B, analysis will be done on both types of apartments in the most common occurring typology, module in the middle with other modules on both sides, meaning that only front facades are exposed to outside environment. The other case is that one of the lateral sides is open to outside, but this case is much less occurring in the typology, and is not considered in the analysis, however, envelope composition is the same for all the modules, so the results wouldn't differ so much. Geometry is simplified for the sake of accuracy of results.

Case A and Case B are considered: the same middle module with opposite orientation, as they are rotated in the site, with two considered orientations being the most often ones.

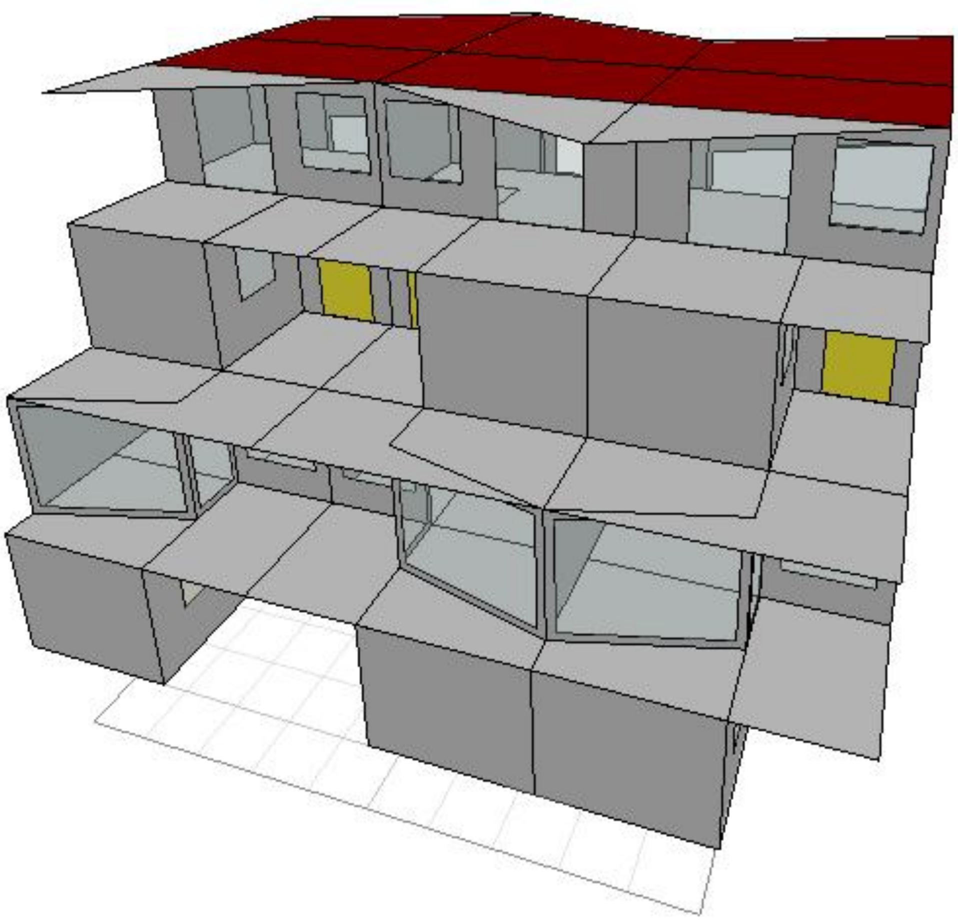


Fig. 5.68: Model of the structure in Ecotect software. Analysis is done on the middle module

5.4.2. Shadow Analysis

Sun path diagrams are projection of suns path on the sky on a surface, and are used to determine the position of the sun at any given time during the day and year, and they also depend on the location's coordinates. They are useful to analyze solar heat gains, orientation, solar energy, and to assess and design shading devices.

By using environmental and geo-reference data, Ecotect software can generate sun paths for the specified time of day and year, and characteristic data are seasonal solar paths for spring, summer, autumn and winter:

Case A:

Winter solstice, 22nd December: ***Summer solstice, 22nd August:***

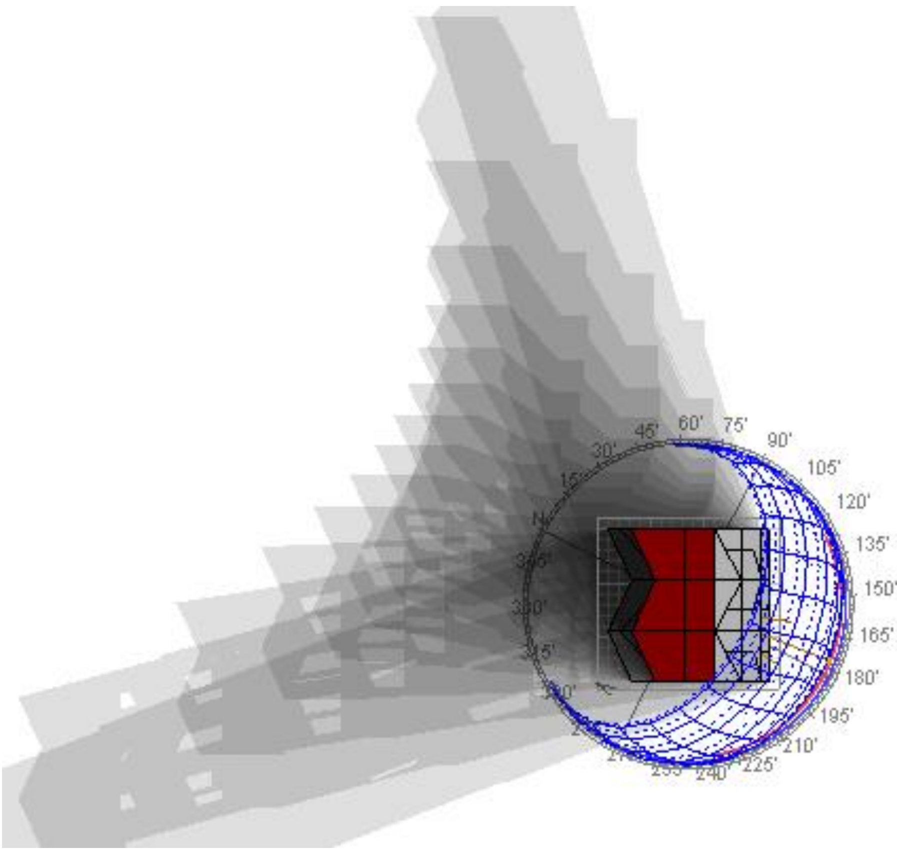


Fig. 5.69: Sun path diagram for winter

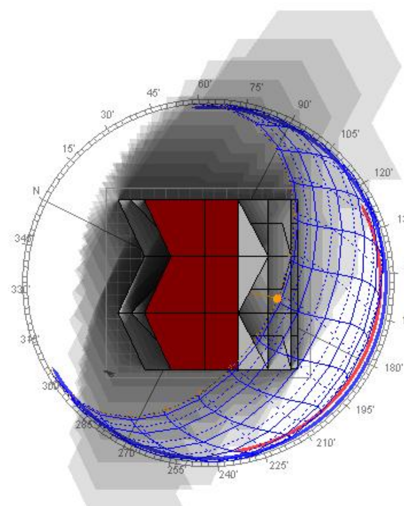


Fig. 5.70: Sun path diagram for summer

During winter solstice, occurring on the shortest day and longest night of the year, the sun is in its lowest point in the sky, which is why the shadow range is elongated as can be seen from the diagrams. Long shadows mean maximum solar radiation entering the building, which is a good point for solar gains during winter on the south-oriented glazing.

On the contrary, summer solstice occurs on the longest day and shortest night of the year, with sun in its highest point in the sky, giving shorter shadow range in the diagrams. As it is the longest day of the year, it has maximum solar exposure, but also the penetration angle is steep, so shading devices are provided on the south glazing to prevent overheating and undesired solar gains in the summer period.

Vernal equinox, 20th March: ***Autumnal equinox, 20th September:***

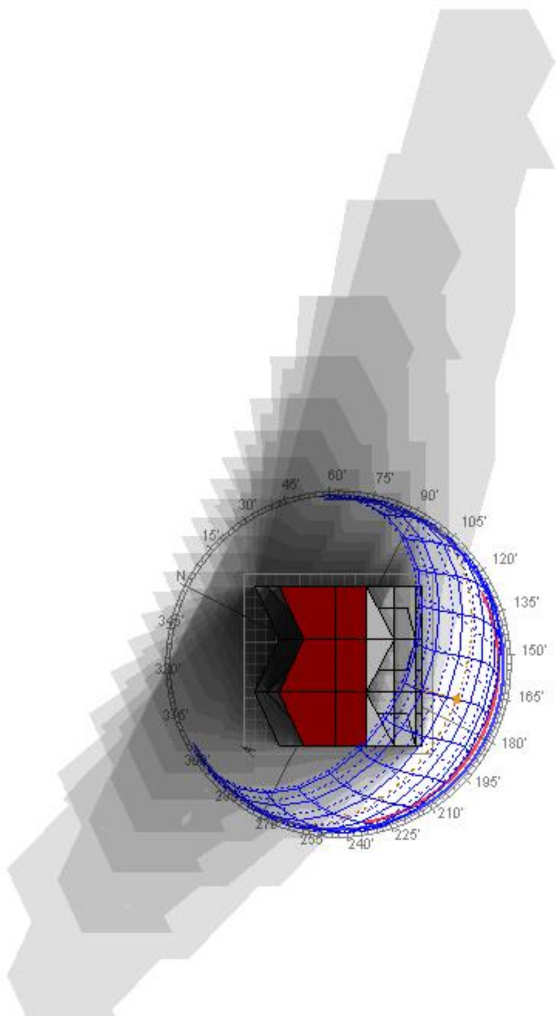


Fig. 5.71: Sun path diagram for spring

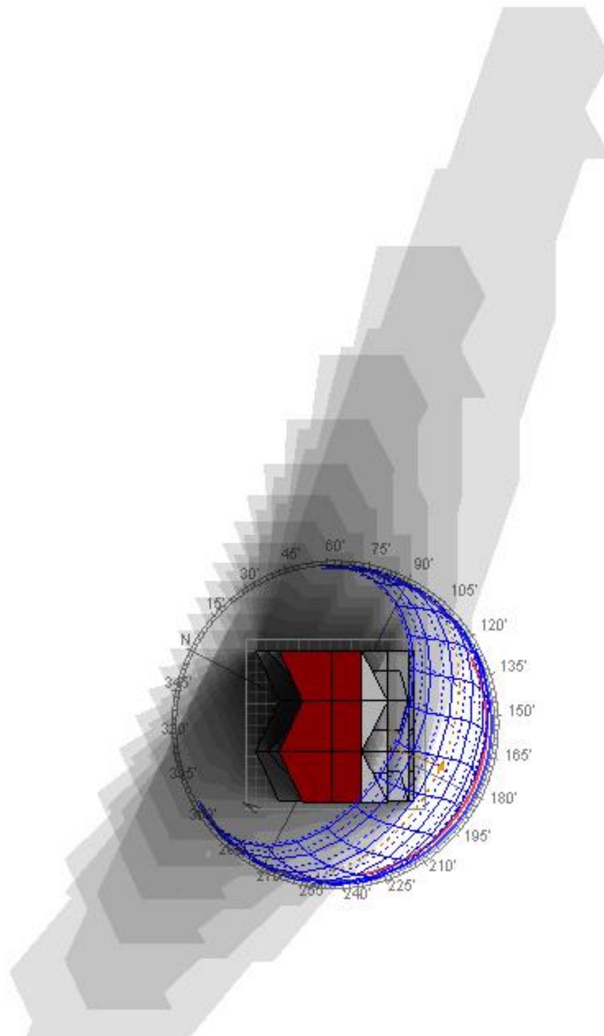


Fig. 5.72: Sun path diagram for autumn

Vernal and autumnal equinox, more precisely should be called March (Southward) and September (Northward) equinox, as to avoid confusion because on southern hemisphere spring and summer are vice-versa with respect to the northern hemisphere. The shadow ranges are similar because on this day the sun rises directly in the east and *sets directly in the west, making the day time and night time equal, thus the name equinox (Latin for equal night). As solar exposure and radiance penetration, east and west façade don't have glazing, and the south windows have from 30-90% shading, and are provided with louvers.*

Case B:

Winter solstice, 22nd December: ***Summer solstice, 22nd August:***

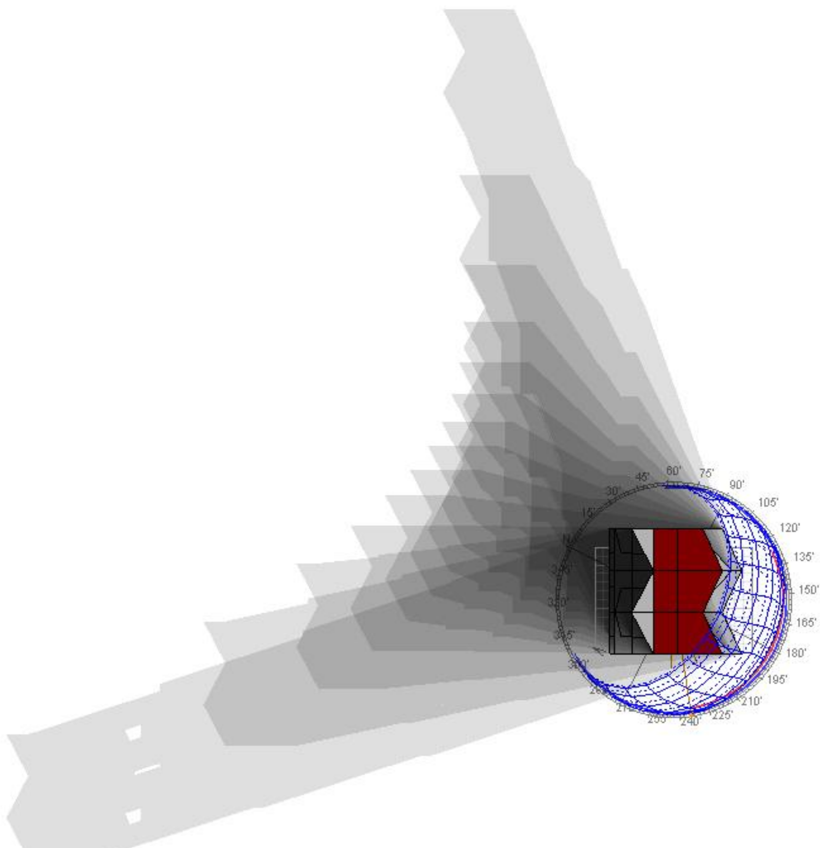


Fig. 5.73: Sun path diagram for winter

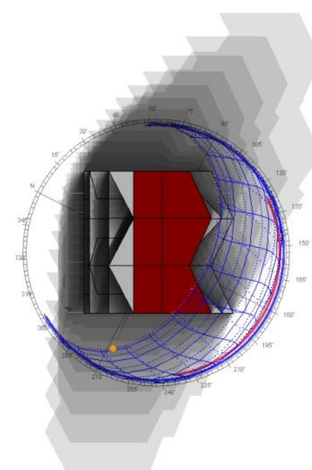


Fig. 5.74: Sun path diagram for summer

Vernal equinox, 20th March:

Autumnal equinox, 20th September:

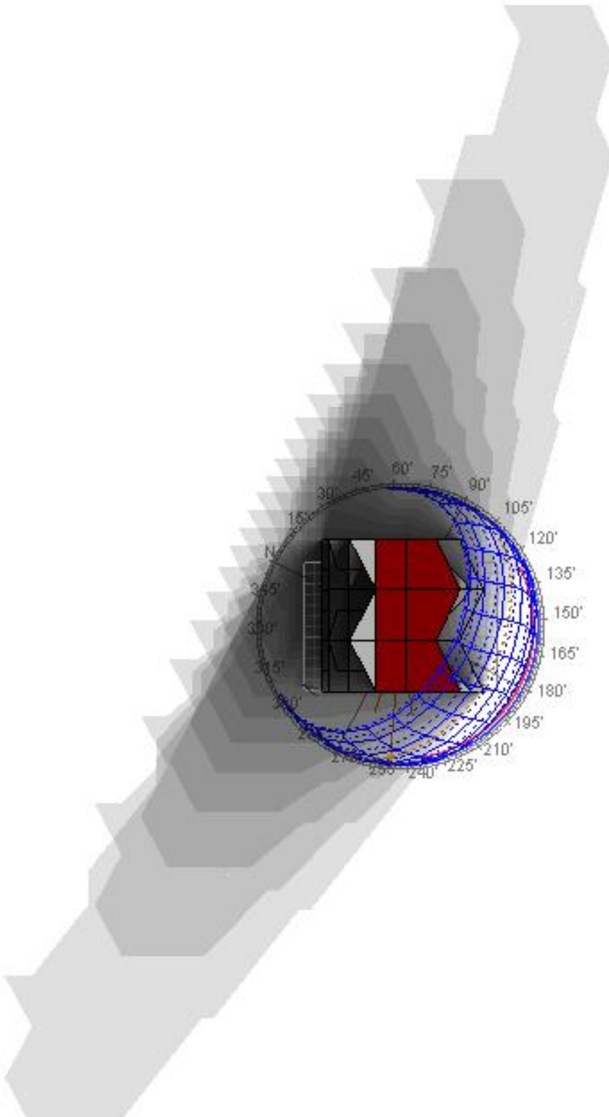


Fig. 5.75: Sun path diagram for spring

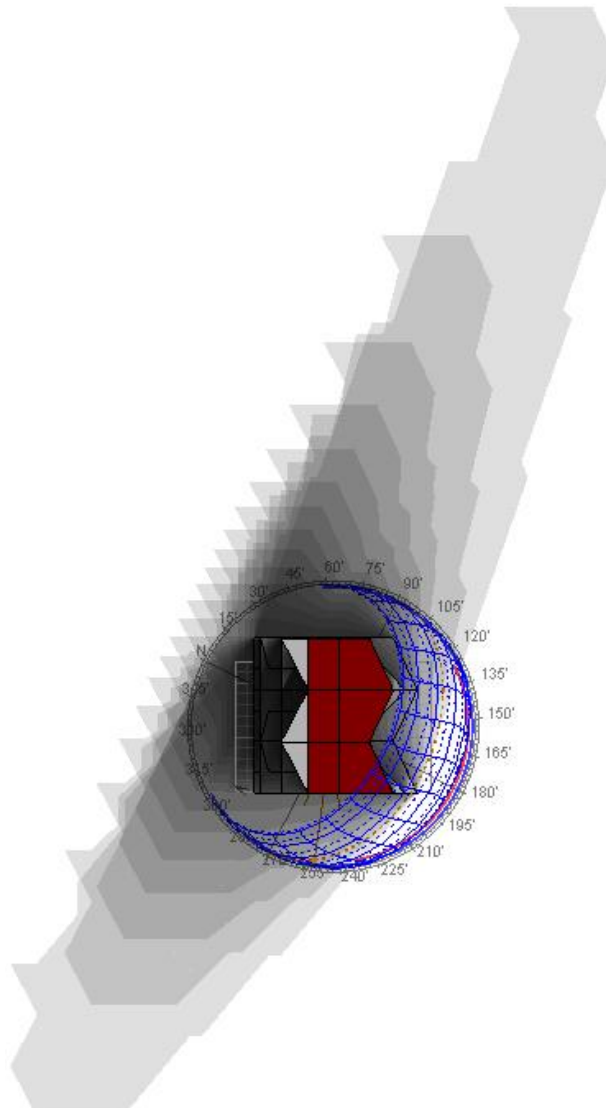


Fig. 5.76: Sun path diagram for autumn

5.4.3. Window Shading Percentage

In order to determine shading and solar exposure of glazing surfaces, we apply the Sun-Path Diagram calculation in Ecotect software. It gives us percentage of shading for the selected window during different periods of the year and different times of day. For the example below the most exposed window on the south side has been taken to determine the quality of shading devices. Due to simplified model in Ecotect, the inclination of windows has not been taken into account, so the actual situation would be better than these results, as the windows inclination would provide for itself some extra shading.

Case A:

<u>South windows:</u>

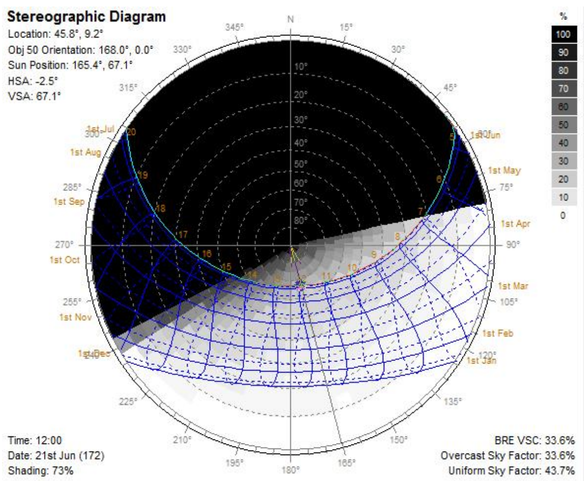


Fig. 5.77: South window shading percentage - June

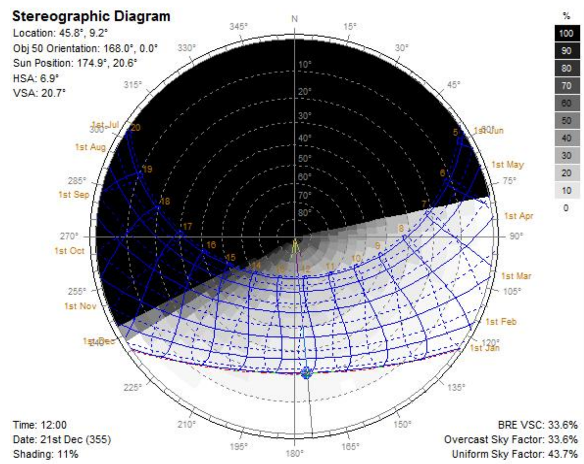


Fig. 5.78: South window shading percentage - December

As it can be noticed from diagram and the results in percents, shading on 21st June is 73% and 11% on 21st December. Moreover, the percentage during summer months does not drop below 65% and does not exceed 35% in the winter months, while transient values are found in spring and autumn period. This shows a good balance in room lighting, and also benefits from solar gains in winter and limits them in summer.
Other south-oriented windows have similar diagrams, good exposure during winter and shaded in the summer, but with more shading and less exposure in general, because the window considered in the example is the most exposed one. The windows are provided with louvers.

North windows: *In these figures we examine the north windows, as it can be noticed for most of the year they don't have direct sunlight, except in period of April through September and only after 5 pm. The windows are provided with louvers.*

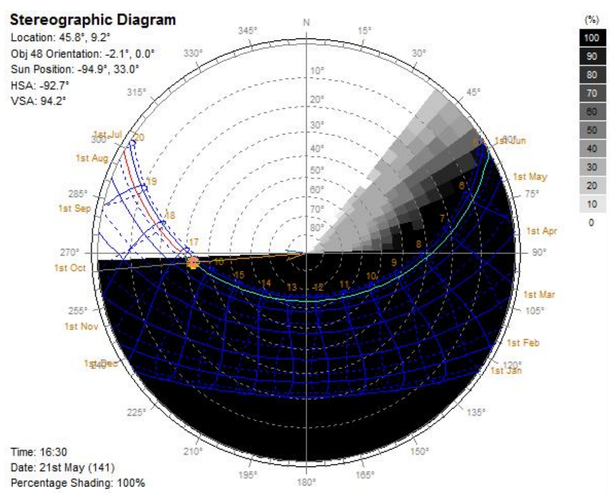


Fig. 5.79: north window shading percentage - June

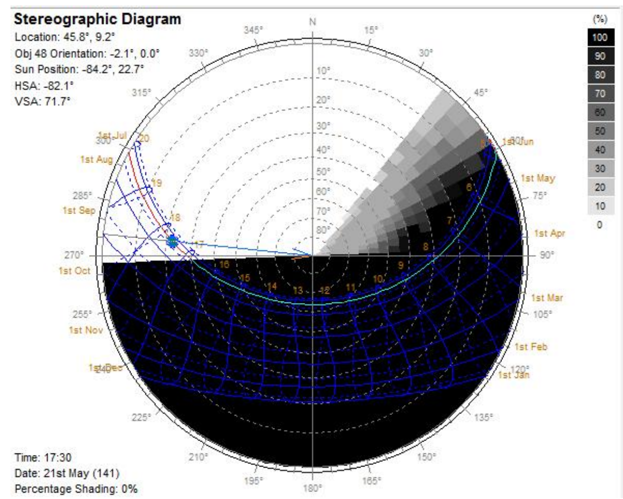


Fig. 5.80: north window shading percentage - December

Case B:

South windows:

In comparison to case A situation, the window shading percentage is slightly less, overall around 5-10%, which is better for winter period, but can cause more solar gains during summer. Windows are provided with louvers.

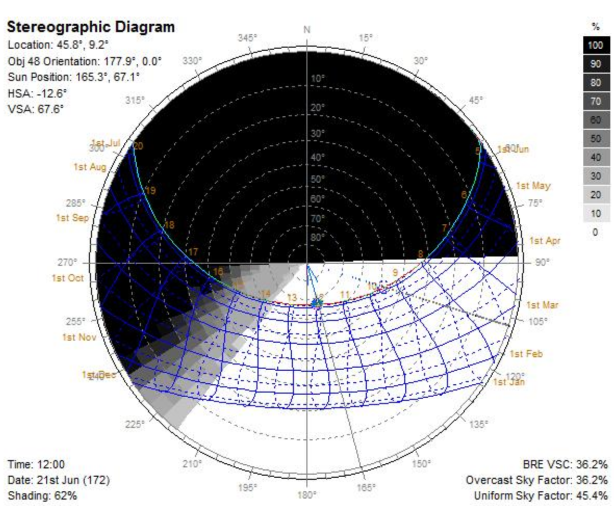


Fig. 5.81: South window shading percentage - June

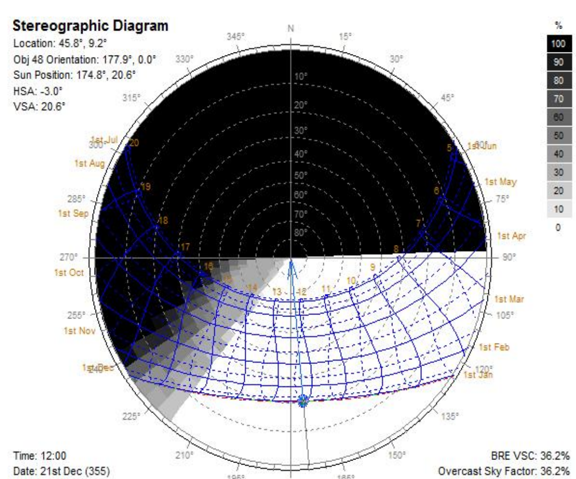


Fig. 5.82: South window shading percentage - December

North windows:

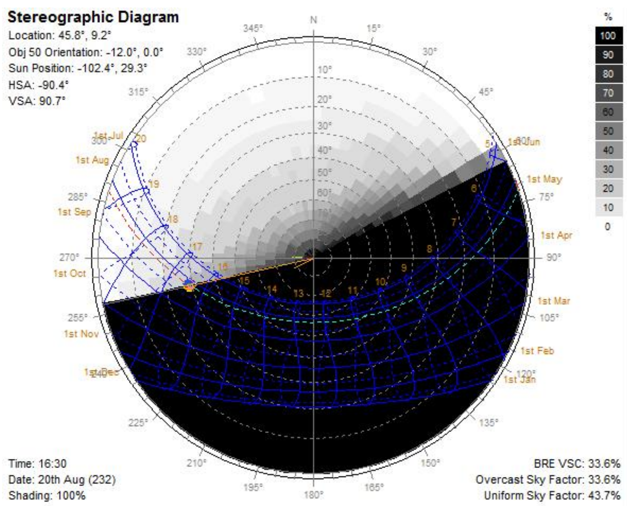


Fig. 5.83: North window shading percentage – 16:30

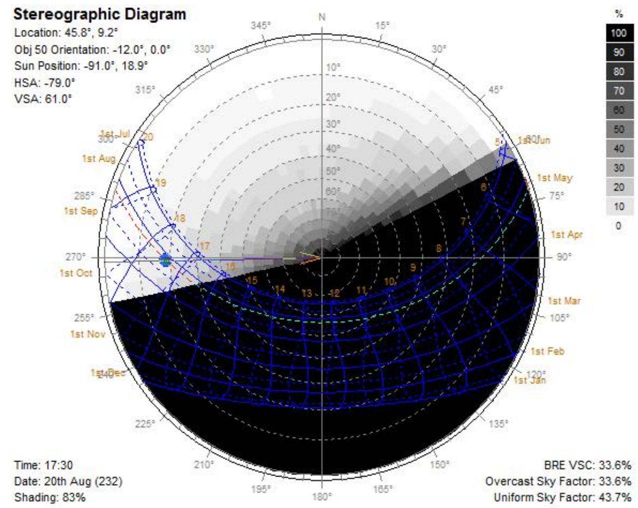


Fig. 5.84: North window shading percentage – 17:30

As in the previous case A, north oriented windows are completely shaded except of April through September and after 5 pm. The windows are provided with louvers.

5.4.4. Natural Lighting

The use of natural light has always been treated with care in building design, as to provide better quality lighting and living conditions inside an environment, and to reduce the need for the artificial light in terms of quantity and time, cutting the electric power consumption as a direct consequence.

As the function is residential we will calculate the lighting levels for living space, dining room (kitchen) and bedroom (work space). Since the geometry of the modules is dominantly longitudinal and there is no glazing in the sides, just the front, it is important to check whether or not the necessary amount of daylight is provided.

The daylight factor is used to calculate illuminance levels at each point on the analyzed surface at any time of day for any day of the year. Then we need to determine the occurrence of these levels by calculating the daylight autonomy, which is given as a percentage of time during the year that the given point on the surface will maintain the selected level without artificial lighting.

The average values for daylight factor for residential use are:

- *<2% – Not adequately lit – artificial lighting will be required.*
- *2% to 5% – Adequately lit but artificial lighting may be in use for part of the time.*
- *>6% – Well lit – artificial lighting generally not required except at dawn and dusk – but glare and solar gain may cause problems*[11]

Input conditions for daylight factor:

- *Average window cleanliness – 0.9 transmittance reduction factor*
- *CIE overcast sky distribution model at 8500 lux illuminance*
- *Analyzed surface height 60 cm for working and dining area and 40 cm for living*

Input conditions for daylight autonomy:

- *300 lux illuminance for the residential living, dining, sleeping and working areas*[12]

Note: Case B results are almost the same in value and distribution both for daylight factor and autonomy and they are not presented here.

[11] http://home.wlv.ac.uk/~in6840/Daylightfactor.htm
[12] http://www.arca53.dsl.pipex.com/index_files/lightlevel.htm

Living room at ground level module type A:

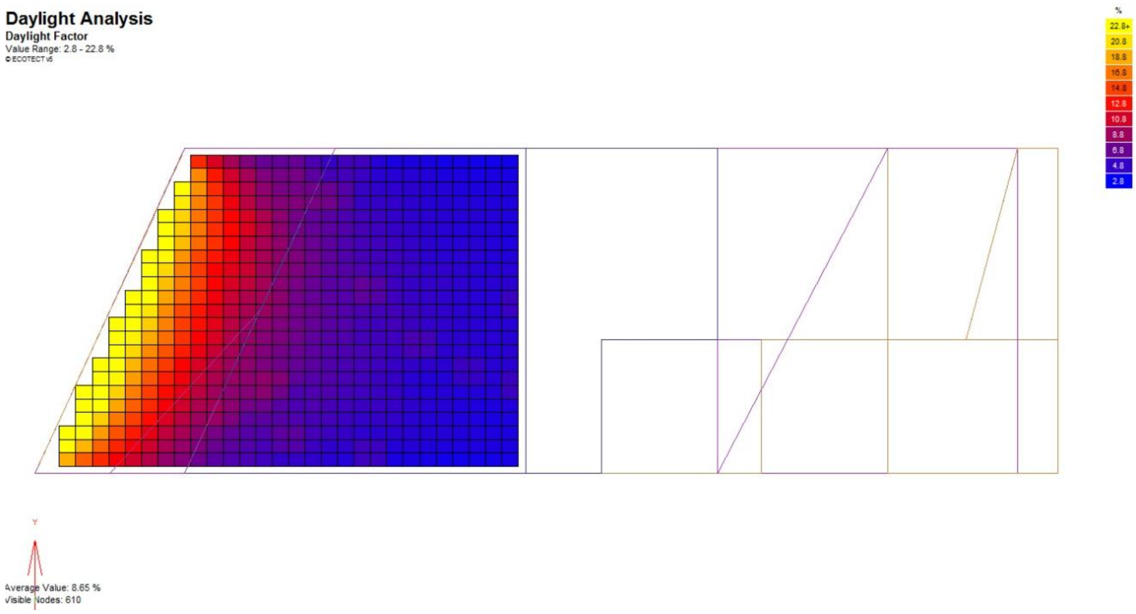


Fig. 5.85: Daylight factor for living room at ground level module – 8.65%

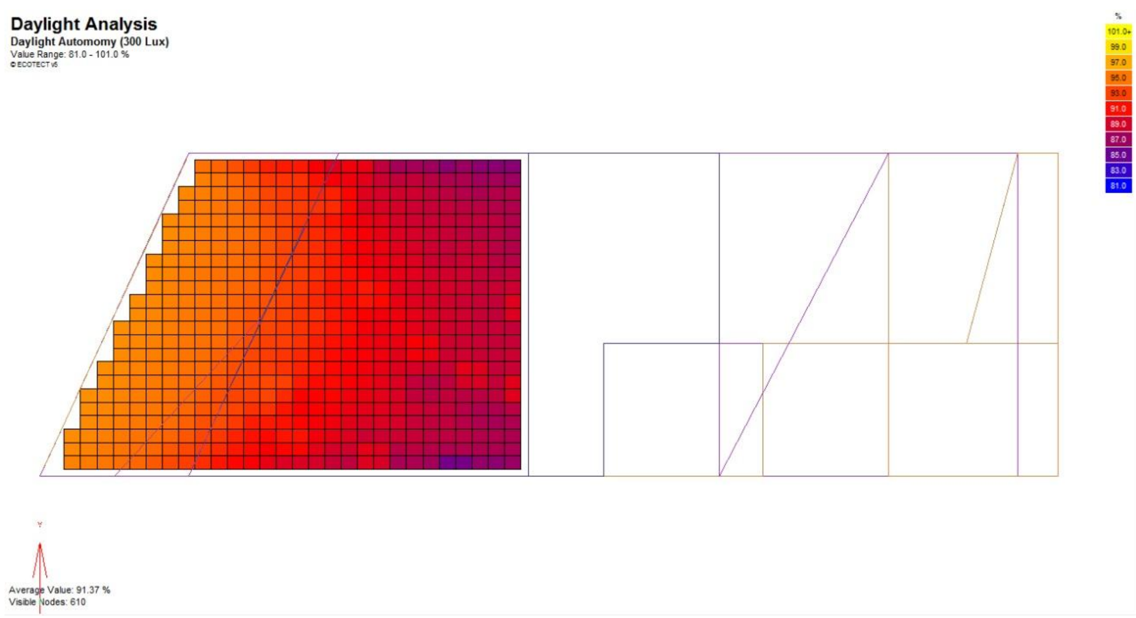


Fig. 5.86: Daylight autonomy for living room at ground level module – 91.37%

<u>Comments:</u> Minimum daylight factor values are sufficient, but the average value is higher which could cause some glare problems, so the windows are provided with louvers to control the sunlight coming in. The autonomy values are very high, showing a good balance of the natural light distribution throughout the year, with sufficient surface coverage so the need for artificial light is minimal.

Kitchen at ground level module type A:

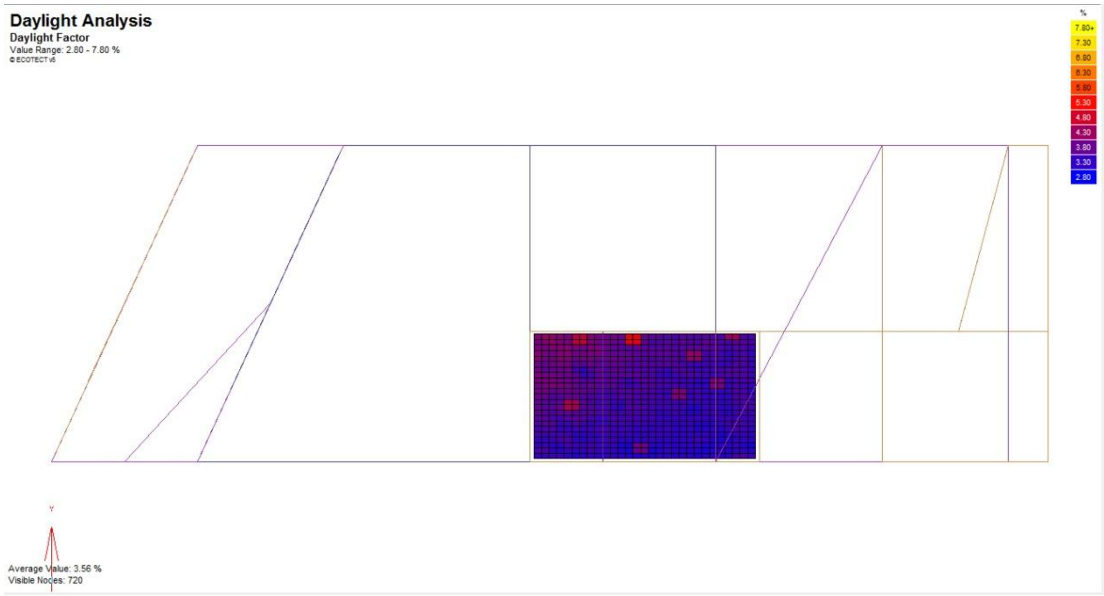


Fig. 5.87: Daylight factor for kitchen at ground level module – 3.56%

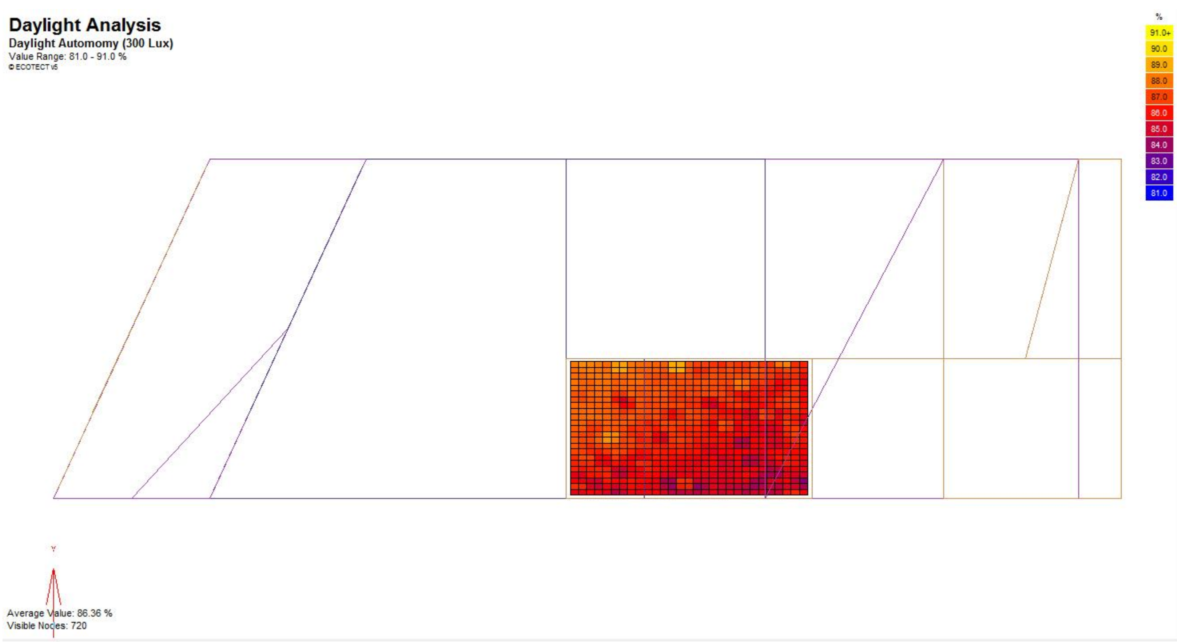


Fig. 5.88: Daylight autonomy for kitchen at ground level module – 86.36%

<u>Comments:</u> Kitchen and dining space is quite far from the windows due to geometry of the modules, but the natural light levels is enough because of the size of the windows on the double height living room next to it. Autonomy shows very good percentage to keep those levels during day and year, providing a quality lit space. However, artificial lighting might be necessary due to presence of louvers on the windows in the living room.

Bedroom at ground level module type A:

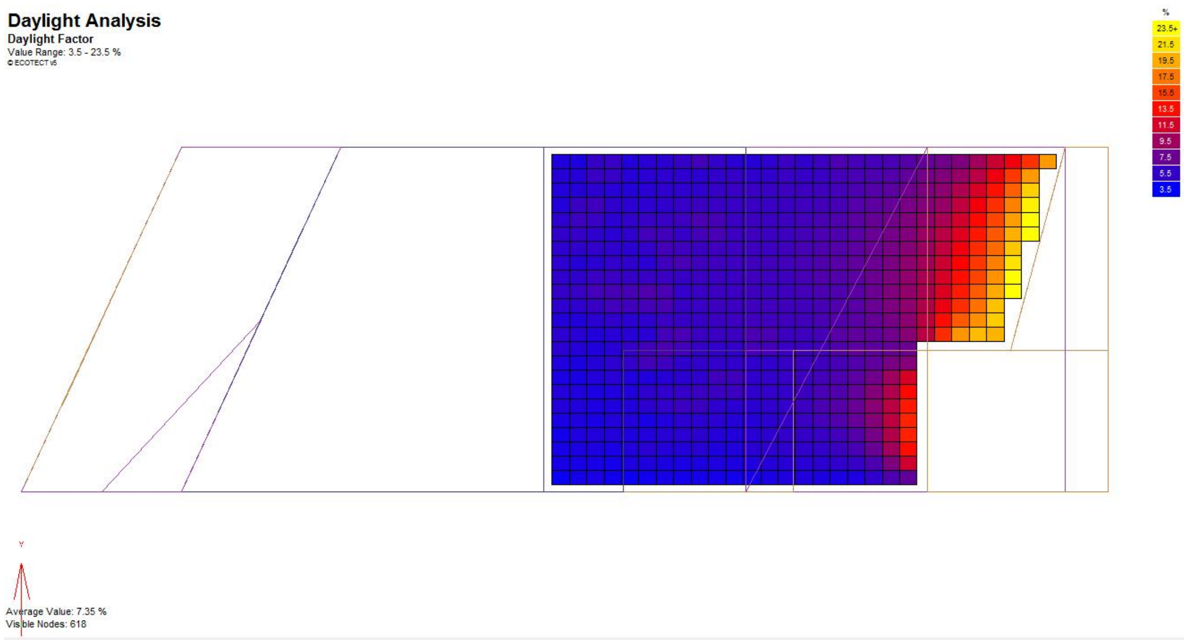


Fig. 5.89: Daylight factor for bedroom at ground level module – 7.35

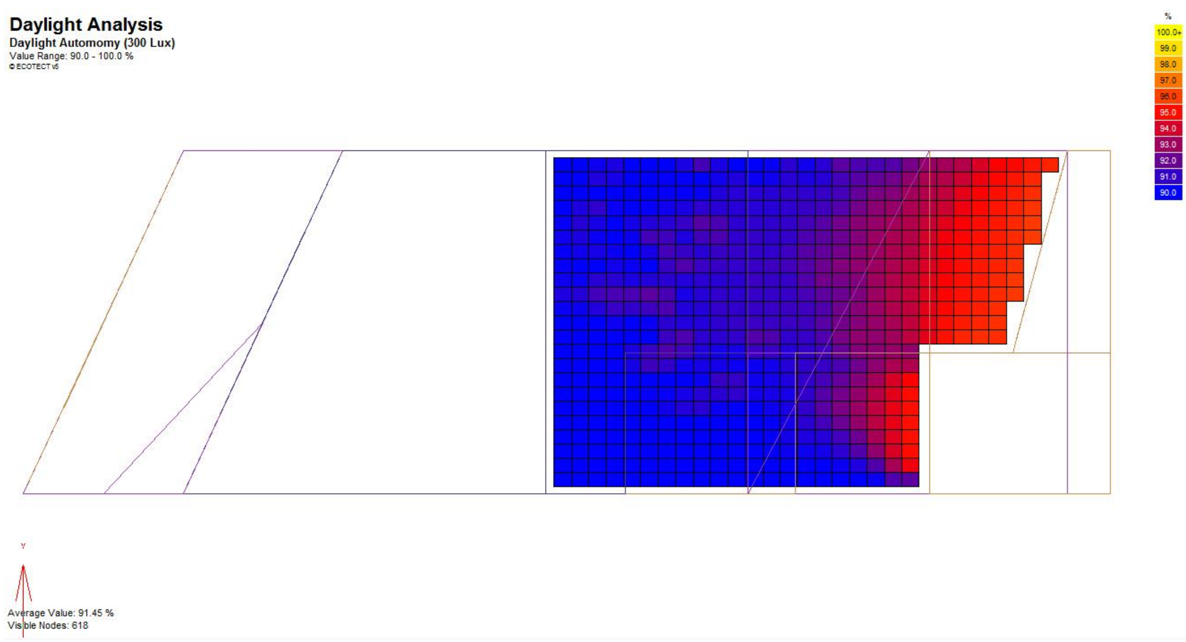


Fig. 5.90: Daylight autonomy for bedroom at ground level module 91.45%

<u>Comments:</u> The light distribution shows that working areas next to glazing are more lit, while sleeping area has lower daylight factors, which is good, but average value is higher so in order to control the glare problems, louvers are provided on these windows. Daylight autonomy shows high values which is a good indicator.

Living room at first floor level module type B:

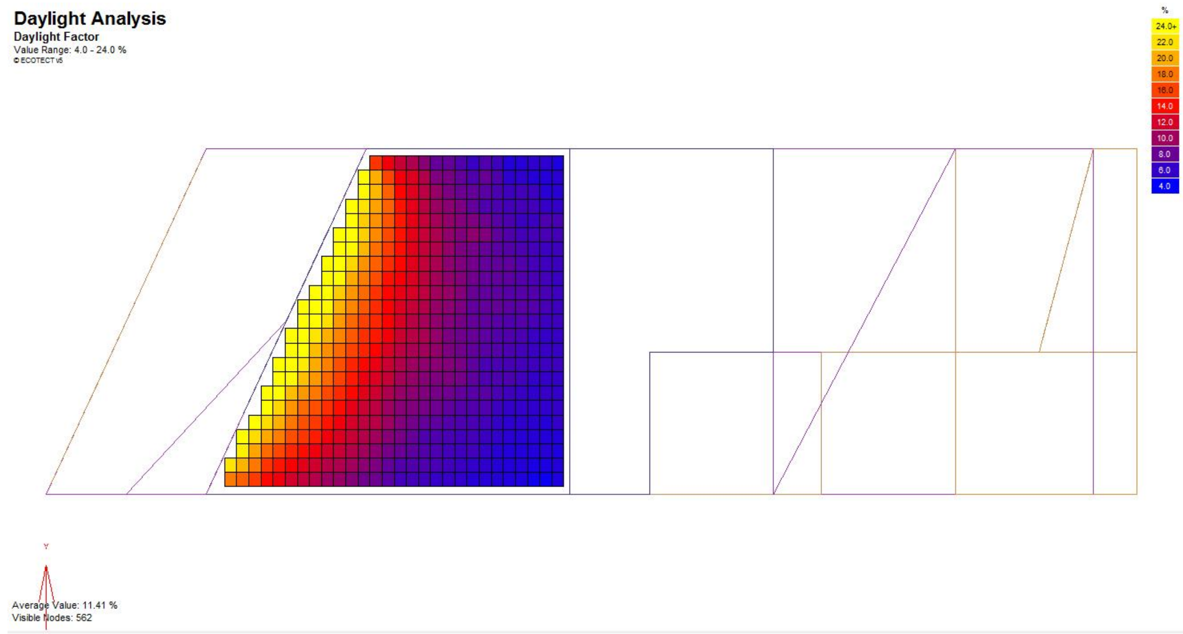


Fig. 5.91: Daylight factor for living room at ground level module - 11.41%

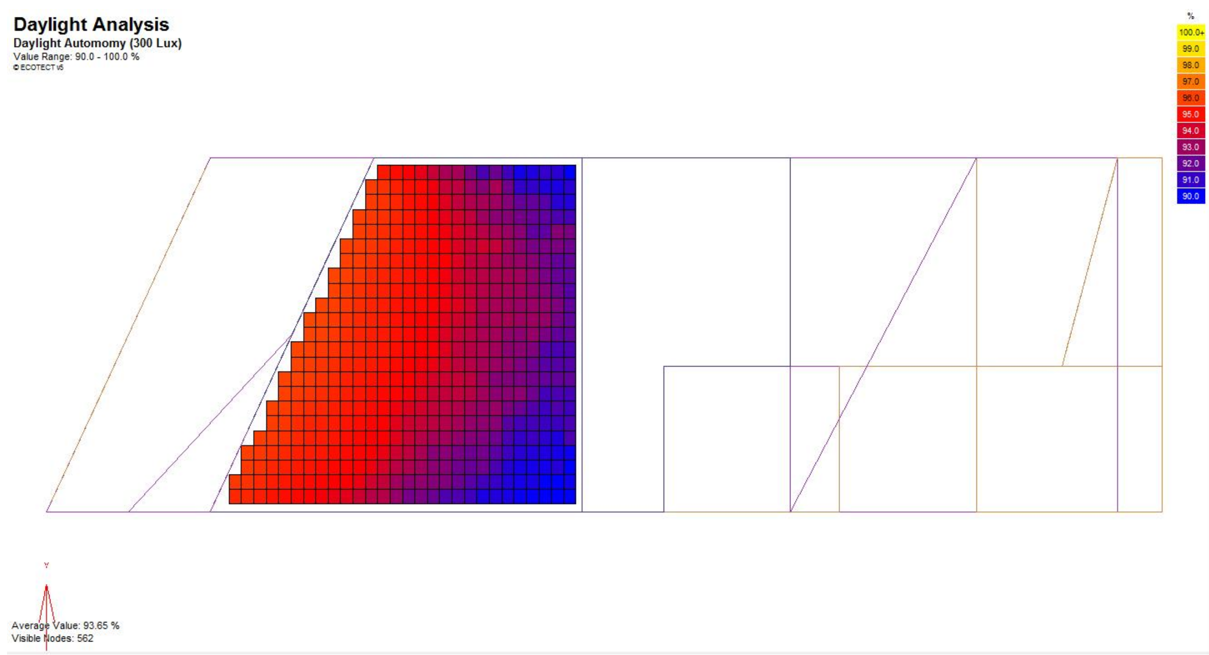


Fig. 5.92: Daylight factor for living room at ground level module – 93.65%

Comments: This is the room with the highest average values for the daylight factor and autonomy, which shows that the room is well lit, but the windows should be provided with louvers in order to control the glare problems.

Kitchen at first floor level module type B:

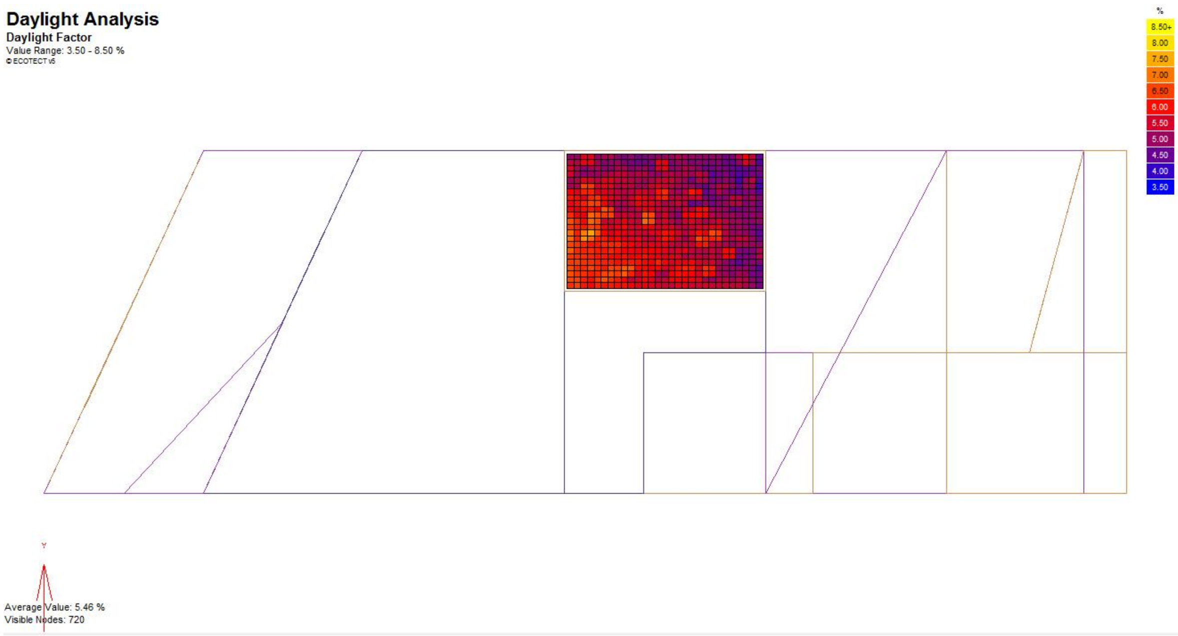


Fig. 5.93: Daylight factor for kitchen at first floor level module – 5.46%

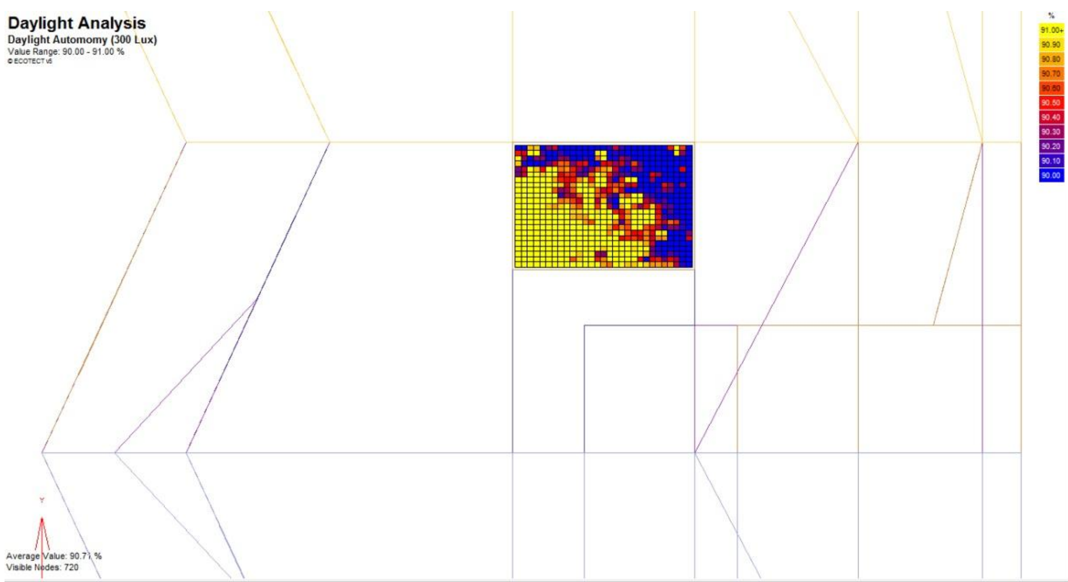


Fig. 5.94: Daylight autonomy for kitchen at first floor level module – 90.71%

<u>Comments:</u> Kitchen in module type B shows very good values in both daylight factor and autonomy, providing a well-lit space with very low percentage of necessary artificial lighting, which might be needed because of the louvers on the living room windows.

Bedroom at first floor level module type B:

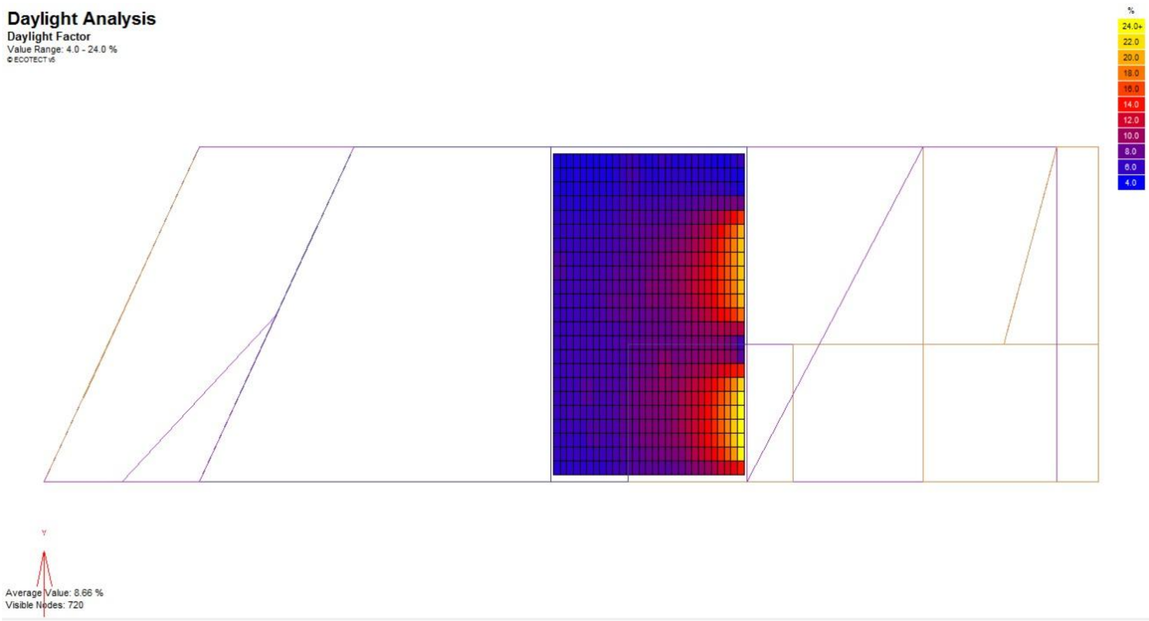


Fig. 5.95: Daylight factor for bedroom at first floor level module – 8.66%

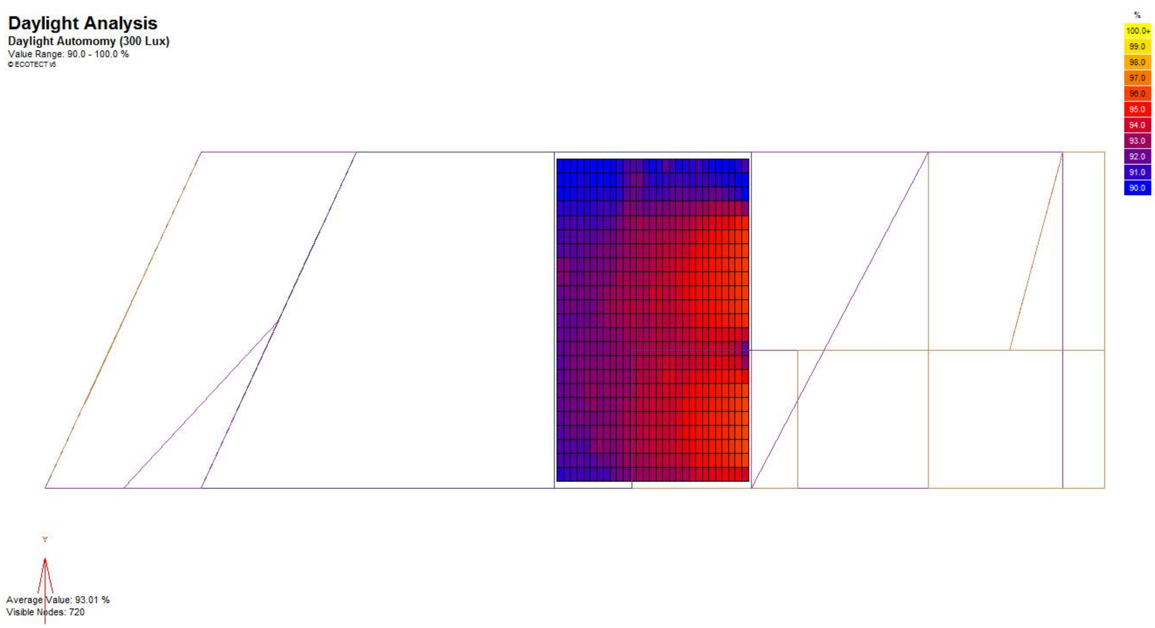


Fig. 5.96: Daylight autonomy for bedroom at first floor level module – 93.01%

<u>Comments:</u> The average value of daylight factor is higher and these windows also need to be provided with louvers in addition to shading devices. The light distribution is favourable because the working space is more lit than the sleeping one. Autonmy shows very high level with little need for artificial lighting.

5.4.5. Thermal Analysis

Building is a man made shelter to provide for quality space to spend certain amount of time in pleasant surroundings. Thermal comfort of the occupied space is an important factor and special care is dedicated to achieving thermal performance and comfort whilst keeping the energy consumption low. The building envelope is the interaction place between the outdoor and indoor environment, and its components and their arrangement is the most influential factor in the thermal performance of the whole system and its energy consumption.

Objective

The objective of a building design is to provide a quality environment to the users. The approach is to obtain knowledge about the behavior of all factors influencing thermal performance, and having also analyzed the comfort conditions for the given environment, we can optimize the parameters to achieve the desired goal. Depending on priorities, building and operating costs, or thermal loads or thermal discomfort, or energy consumption can be minimized.

Output

Heating and cooling loads are the amount of energy which a space needs to be added in or removed from in order to achieve the desired levels of thermal comfort and air quality, either by mechanical or natural systems, or both. Once the loads are known, understood and analyzed, one can begin to design and size these systems according to the results. The values obtained from the thermal analysis will be a guideline to choosing the equipment, sizing ducts to provide conditioned air to spaces and size the HVAC system.

Simulation

Ecotect software has been used to evaluate the thermal properties such as annual heating and cooling loads of the project building. The Mixed mode system is used to apply the heating and cooling loads to the environment, since it is the system which combines the air-conditioning with the natural ventilation, while the HVAC shuts the supply down whenever the outside conditions meet the design conditions.

Material Input

In Ecotect software we can assign the properties of the layers and components to our model by adding previously calculated values for U-value and layers. This is a sample of the material editing interface from Ecotect:

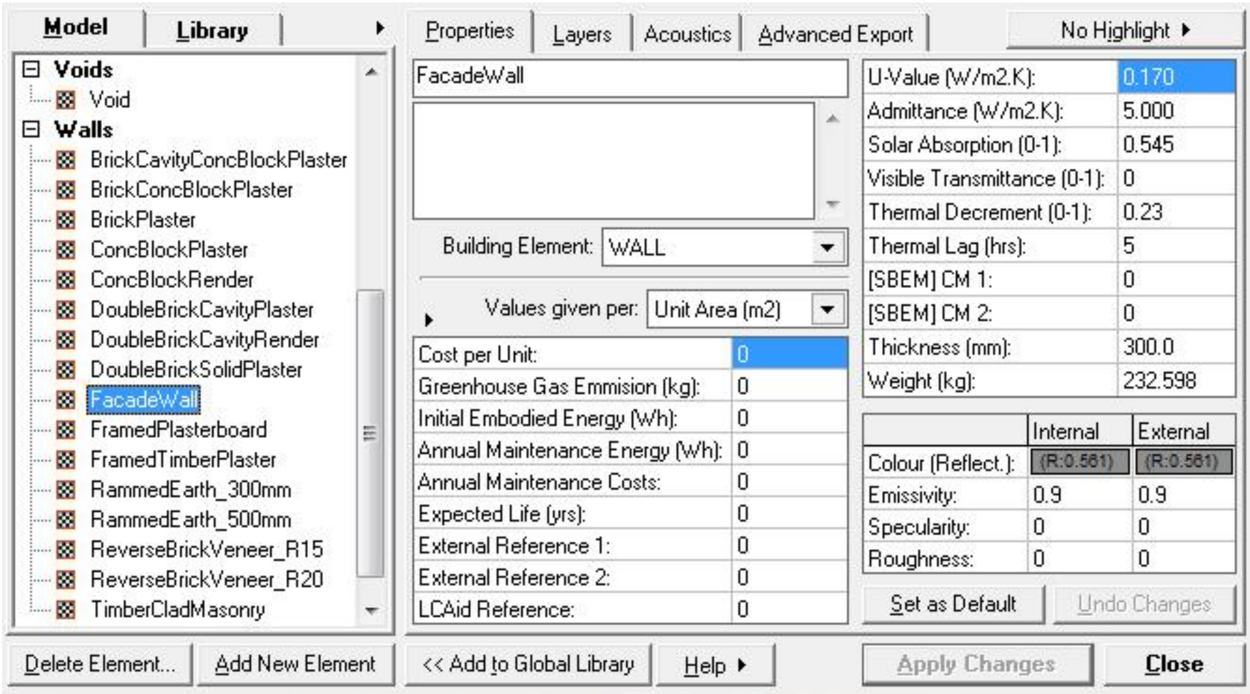


Fig. 5.97: Ecotect material editor sample for wall

The U-values and layers for all the envelope components are as previously analyzed.

Energy Class

Once the loads are assessed, we can assign an energy class to the building to evaluate its performance with respect to the annual energy consumption. The energy classes according to Italian standards are:

Fig. 5.98: Italian energy classes

All visible thermal zones

Case A

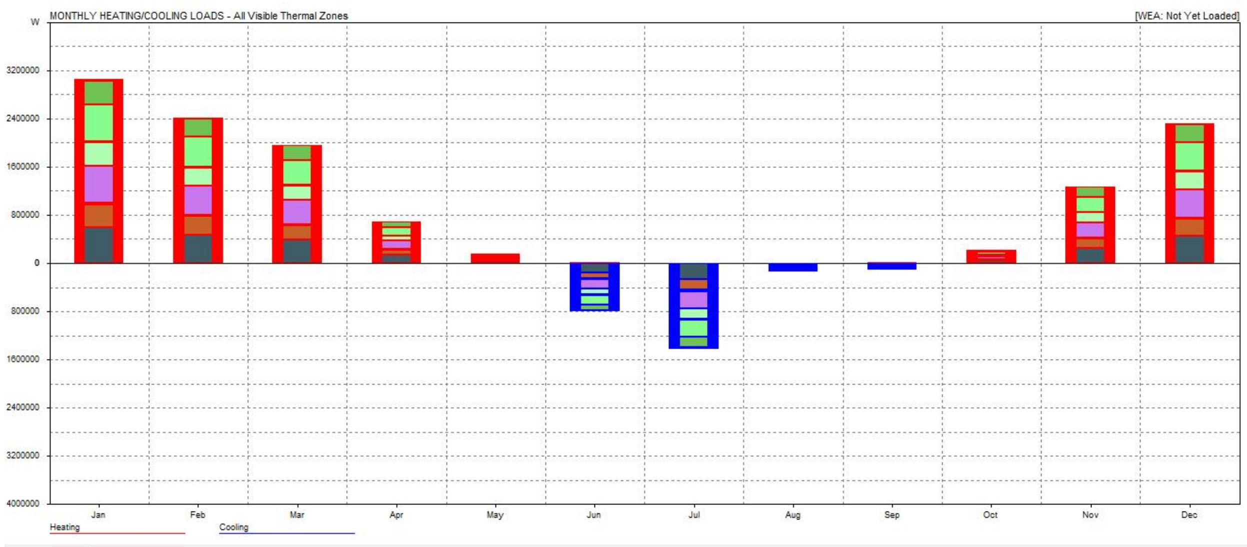


Fig. 5.99: Monthly thermal loads for all visible thermal zones

Case B

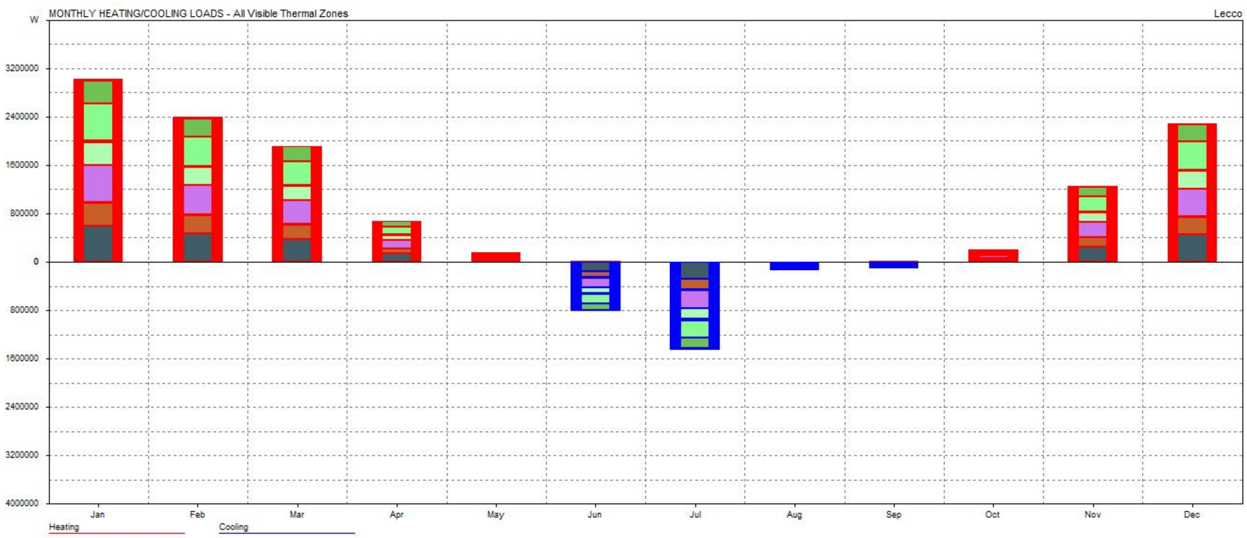


Fig. 5.100: Monthly thermal loads for all visible thermal zones

Having considered three module arrangements in row as explained above, the total load calculation for all visible thermal zones is giving the results 3 times larger than we are interested in analyzing. This result will however not be for an apartment, but for the typical arrangement of one apartment (type B) on top of another apartment (type A), which is then repeated throughout the site with different orientation.

Case A

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones

Comfort: Zonal Bands

Max Heating: 11625 W at 08:00 on 12th March

Max Cooling: 7981 W at 15:00 on 22nd July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	3048771	0	3048771
Feb	2417990	0	2417990
Mar	1962397	0	1962397
Apr	693658	0	693658
May	155580	0	155580
Jun	14946	798202	813148
Jul	0	1419884	1419884
Aug	1458	135726	137184
Sep	13755	102423	116178
Oct	218194	0	218194
Nov	1272681	0	1272681
Dec	2313732	0	2313732
TOTAL	12113161	2456234	14569396
PER M2	31918	6472	38390
Floor Area:	379.5 m2		

Fig. 5.101: Monthly heating/cooling loads for all visible thermal zones

<u>*Notices:*</u>

For this orientation the total energy demand is 38.4 kWh/m^{2}year, which corresponds to the B energy class building according to the Italian energy certification. As we can notice the heating demand is high, which is due in great length to double height apartments, increasing immensely the heated volume. The result is given for three typical arrangements of two apartments.

Case B

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones

Comfort: Zonal Bands

Max Heating: 11415 W at 08:00 on 12th March

Max Cooling: 7897 W at 15:00 on 22nd July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	3019752	0	3019752
Feb	2389134	0	2389134
Mar	1914870	0	1914870
Apr	669969	0	669969
May	149493	0	149493
Jun	13545	808159	821705
Jul	0	1450985	1450985
Aug	1211	142156	143367
Sep	13314	106119	119433
Oct	204892	0	204892
Nov	1246466	0	1246466
Dec	2291731	0	2291731
TOTAL	11914375	2507420	14421795
PER M2	31394	6607	38001
Floor Area:	379.5 m2		

Fig. 5.102: Monthly heating/cooling loads for all visible thermal zones

<u>Notices:</u>

We can see in this orientation that the results are practically the same, again heating is over 80% of total energy demand which is now 38 kWh/m^{2}year, again due to the fact that we have double height in both apartments. The result is given for three typical arrangements of two apartments.

Apartment type A

Case A

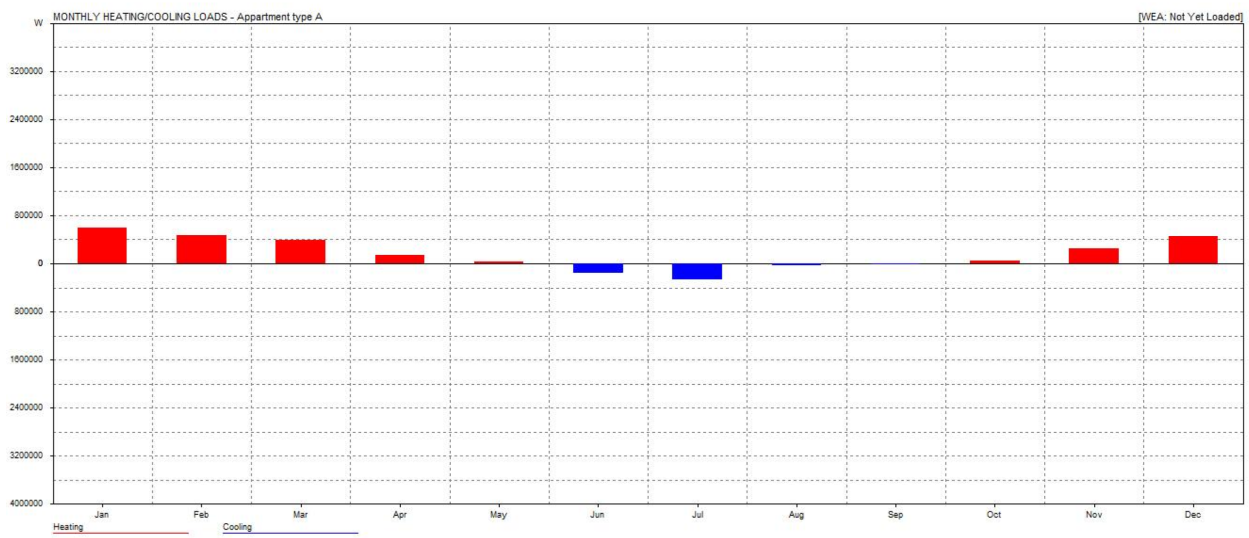


Fig. 5.103: Apartment type A monthly thermal loads

Case B

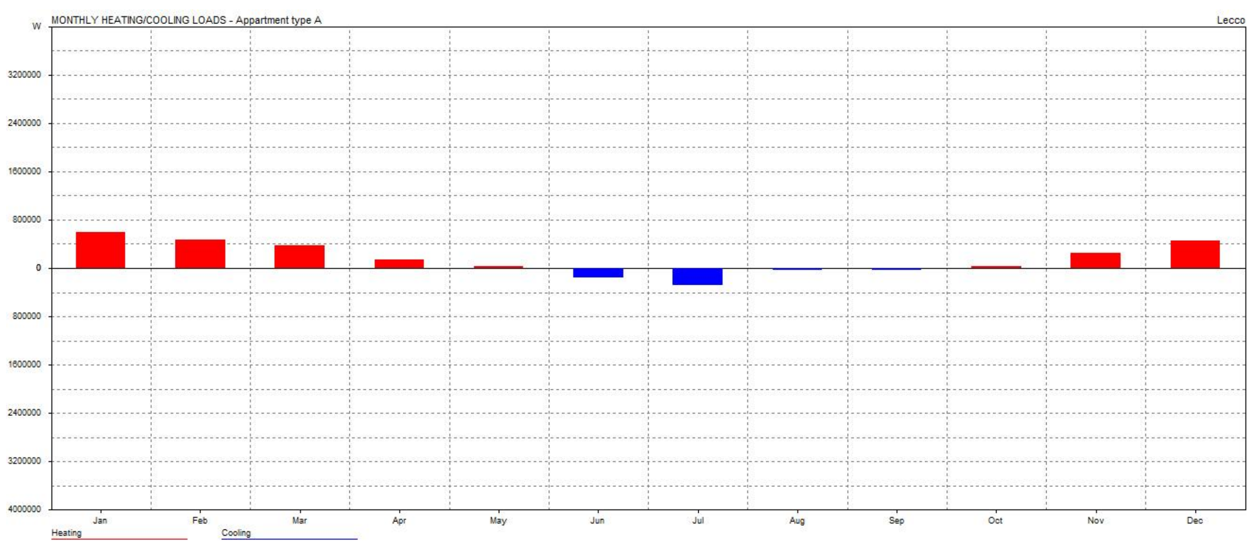


Fig. 5.104: Apartment type A monthly thermal loads

This is the larger apartment of the two types, and the one in the ground floor level below the second one. The total area is 80 m^2, with 57 in the ground floor and 23 in mezzanine.

Case A

MONTHLY HEATING/COOLING LOADS

Zone: Apartment type A

Operation: Weekdays 07-22, Weekends 07-22.

Thermostat Settings: 20.0 - 25.0 C

Max Heating: 2398 W at 08:00 on 12th March

Max Cooling: 1548 W at 15:00 on 22nd July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	599679	0	599679
Feb	476990	0	476990
Mar	392605	0	392605
Apr	139268	0	139268
May	30448	0	30448
Jun	2816	152800	155616
Jul	0	272452	272452
Aug	246	26756	27002
Sep	2600	22209	24809
Oct	40621	0	40621
Nov	251567	0	251567
Dec	455576	0	455576
TOTAL	2392416	474217	2866634
PER M2	29905	5927	35832
Floor Area:	80 m2		

Fig. 5.105: Monthly heating/cooling loads for apartment type A

Notices:

For this orientation the total energy demand is 35.8 kWh/m^{2}year, which corresponds to the B energy class building according to the Italian energy certification. The heating demand is quite high, again due to double height of the apartment being one thermal zone with increased heated volume.

Case B

MONTHLY HEATING/COOLING LOADS

Zone: Appartment type A

Operation: Weekdays 07-22, Weekends 07-22.

Thermostat Settings: 20.0 - 25.0 C

Max Heating: 2362 W at 08:00 on 12th March

Max Cooling: 1570 W at 14:00 on 22nd July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	591163	0	591163
Feb	468603	0	468603
Mar	379039	0	379039
Apr	133592	0	133592
May	29254	0	29254
Jun	2628	156589	159217
Jul	0	281657	281657
Aug	220	28420	28639
Sep	2507	23731	26237
Oct	37553	0	37553
Nov	243908	0	243908
Dec	449092	0	449092
TOTAL	2337558	490396	2827954
PER M2	29219	6130	35349
Floor Area:	80 m2		

Fig. 5.106: Monthly heating/cooling loads for apartment type A

Notices:

This orientation gives almost the same results as the previous one, because the walls on all sides are the same, and since the windows with the approximately same dimensions in total are only on the north and south façade, analyzed cases are rotated 180˚and we get similar results, which is good because we will not get temperature differences between apartments and thermal comfort should remain the same.

Apartment type B

Case A

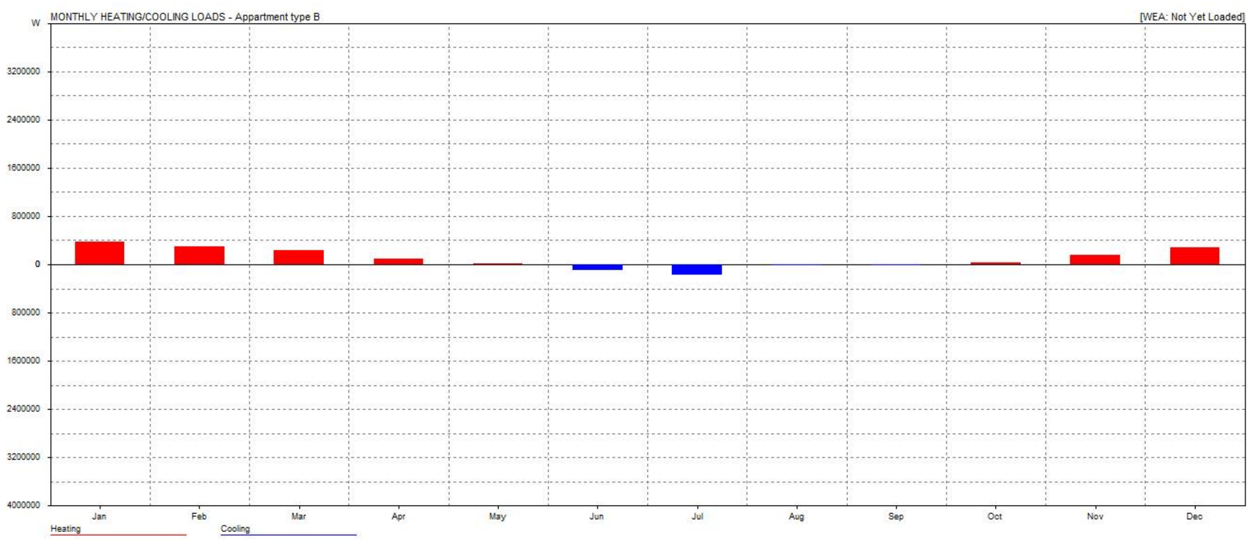


Fig. 5.107: Apartment type B monthly thermal loads

Case B

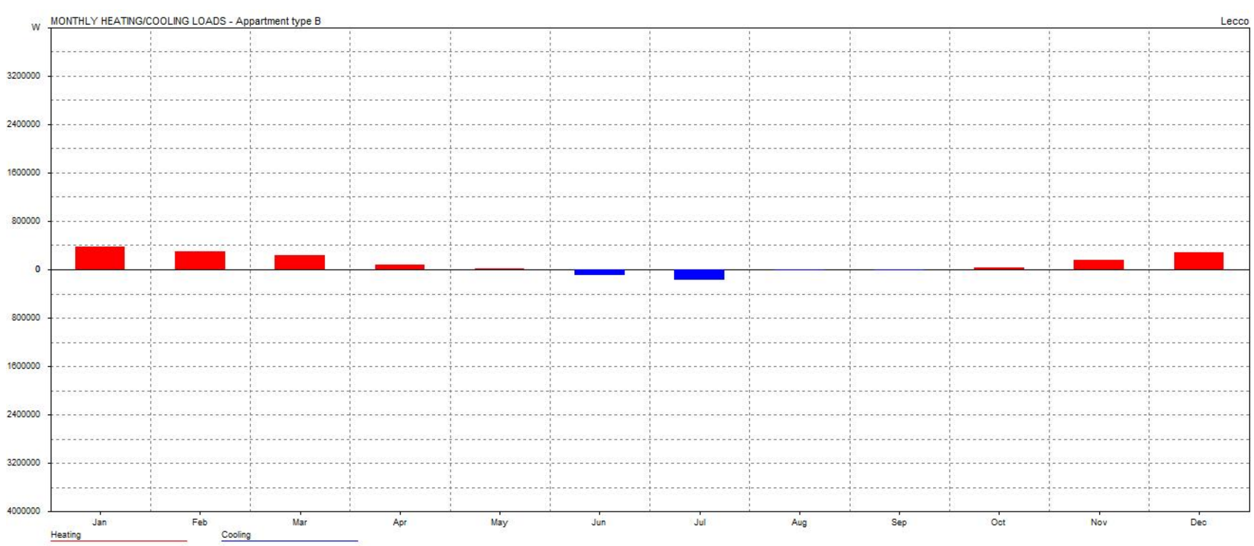


Fig. 5.108: Apartment type B monthly thermal loads

This apartment is on the second floor, located above the previous type A. It is smaller in dimension, as it has setback to provide the corridors and balconies on the upper level. The total floor area is 46.5 of which 36 is on the first floor level, and 10 in the upper story mezzanine.

Case A

MONTHLY HEATING/COOLING LOADS

Zone: Apartment type B

Operation: Weekdays 07-22, Weekends 07-22.

Thermostat Settings: 20.0 - 25.0 C

Max Heating: 1388 W at 08:00 on 12th March

Max Cooling: 945 W at 15:00 on 22nd July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	377693	0	377693
Feb	299408	0	299408
Mar	241170	0	241170
Apr	87244	0	87244
May	20669	0	20669
Jun	2155	94424	96579
Jul	0	169445	169445
Aug	220	14610	14830
Sep	1807	9160	10967
Oct	29715	0	29715
Nov	159771	0	159771
Dec	287913	0	287913
TOTAL	1582944	287638	1795404
PER M2	34042	7165	41207
Floor Area:	46.5 m2		

Fig. 5.109: Monthly heating/cooling loads for apartment type B

Notices:

This apartment has higher energy demands compared to the type A, because it is more exposed to exterior environment because it is the last story. The total energy demand is 41.2 kWh/m^{2}year, which is again class B by Italian standard.

Case A

MONTHLY HEATING/COOLING LOADS
Zone: Appartment type B
Operation: Weekdays 07-22, Weekends 07-22.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 1387 W at 08:00 on 12th March
Max Cooling: 974 W at 14:00 on 22nd July

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	374488	0	374488
Feb	296233	0	296233
Mar	235881	0	235881
Apr	85498	0	85498
May	20397	0	20397
Jun	2198	96350	98548
Jul	0	172894	172894
Aug	236	15242	15478
Sep	1782	9670	11453
Oct	28621	0	28621
Nov	156815	0	156815
Dec	285463	0	285463
TOTAL	1487611	294156	1781767
PER M2	33991	6326	40317
Floor Area:	46.5 m2		

Fig. 5.110: Monthly heating/cooling loads for apartment type B

Notices:

This orientation gives almost the same results as the previous one, which is good because we won't get temperature differences between apartments and thermal comfort should remain the same. The total load is higher because we have again double height and this apartment is more exposed to outdoor environment.

Conclusion

The building can be assigned energy class B (<50 kWh/m^{2}year)

5.5. Building Services

5.5.1. HVAC System

5.5.1.1. Under Floor Heating System

Underfloor heating is a form of central heating which achieves indoor climate conditions of thermal comfort using conduction, radiation and convection. It is common to use also the terms radiant heating because radiation accounts for significant portion of total heating, although it is technically correct to use it only when more than 50% of total heat exchanged between floor and indoor ambient comes from radiation. There are two types of systems for underfloor heating, with respect to the heat transporting medium: electrical or hydronic. They can be installed as cast into slab – wet system, or placed under the floor finishing layer – dry fixed. Underfloor heating is thought to be a more efficient way of heating a room - where that room's walls, doors and windows are well insulated - because of the way the heat is distributed.

The electric heating sheets or cables are fitted beneath the flooring, and usually on top of a layer of screed (to ensure the surface is completely flat) and a layer of floor insulation (to keep the heating source travelling upwards rather than down). The system is connected to electric mains supply, and a sensor is fit that connects to the thermostat. This allows control of the temperature and pre-setting the system to turn on or off. Because electric systems are generally quite thin, they're easier and less hassle to install in an existing room than a wet heating system, which requires space for pipework and could involve the floor being raised.

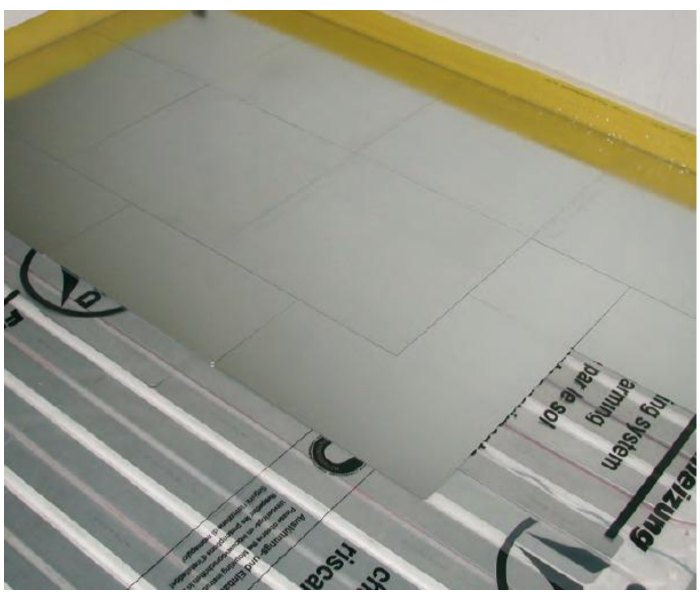


Fig. 5.111: Underfloor heating system

We opted for the electrical, dry fit system as per solution of Siccus panels by Velta. The reason behind this is its excellent compatibility with suspended timber floors, because it is completely dry fixed, and due to its total thickness of 25 mm.

Aluminium heat conducting plates and 14 mm cross-linked polyethylene pipes are set into 25 mm thick expanded polystyrene insulation boards and distributed under the parquet finishing layer.[13]

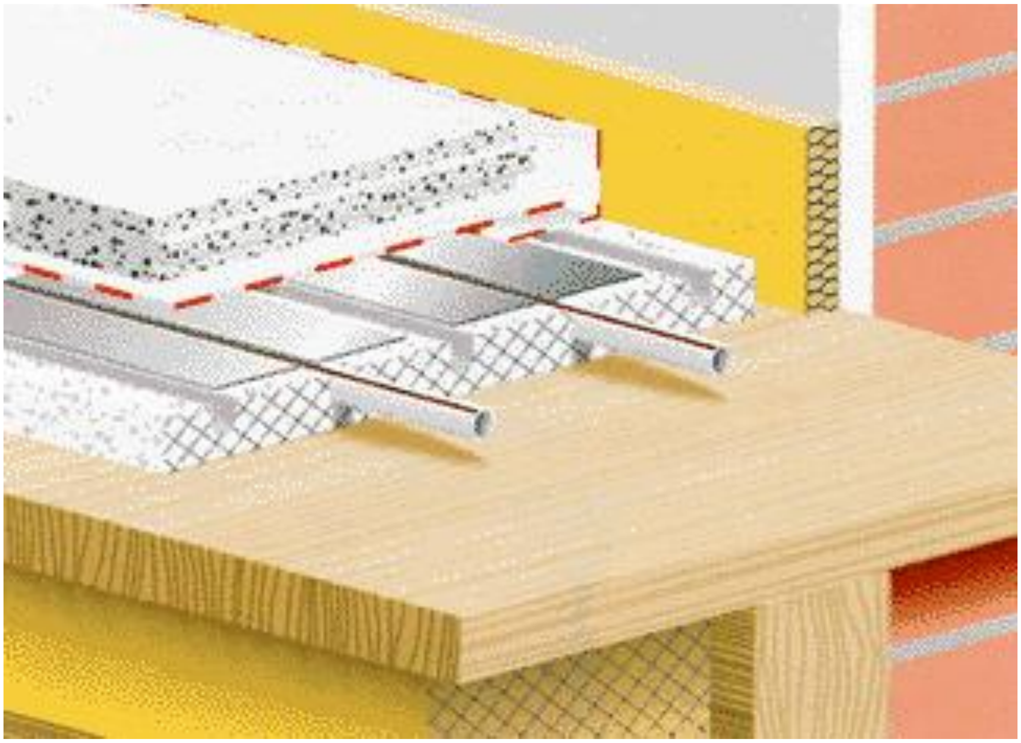


Fig. 5.112: Velta siccus panel system section

[13] http://www.velta-uk.com/solutions.asp?solid=15&parent=8#
http://en.wikipedia.org/wiki/Underfloor_heating
http://www.which.co.uk/home-and-garden/heating-water-and-electricity/guides/underfloor-heating-systems/electric-underfloor-heating/

5.5.1.2. Air Conditioning

Air conditioning and refrigeration are provided through the removal of heat. Heat can be removed through radiation, convection, and by heat pump systems through a process called the refrigeration cycle using refrigerants such as water, air, ice, and chemicals. An air conditioning system provides cooling, ventilation, and humidity control for all or part of the house.

Dehumidification in an air conditioning system is provided by the evaporator. Since the evaporator operates at a temperature below dew point, moisture in the air condenses on the evaporator coil tubes. This moisture is collected at the bottom of the evaporator in a pan and removed by piping to a central drain.

Air conditioning is achieved by using air cooled water chillers, which are vapour compression refrigeration systems. They absorb heat from process water, and the heat is then transferred to the air around the chiller unit. The main components of a vapour compression refrigeration system are the compressor, condenser, expansion valve and evaporator.

The system is central, "all-air" and space necessary for ducting is provided in the project. Thermostats and zone-control can provide more flexibility and energy saving, since in our project we have apartments that need different times for cooling depending on use and season.[14]

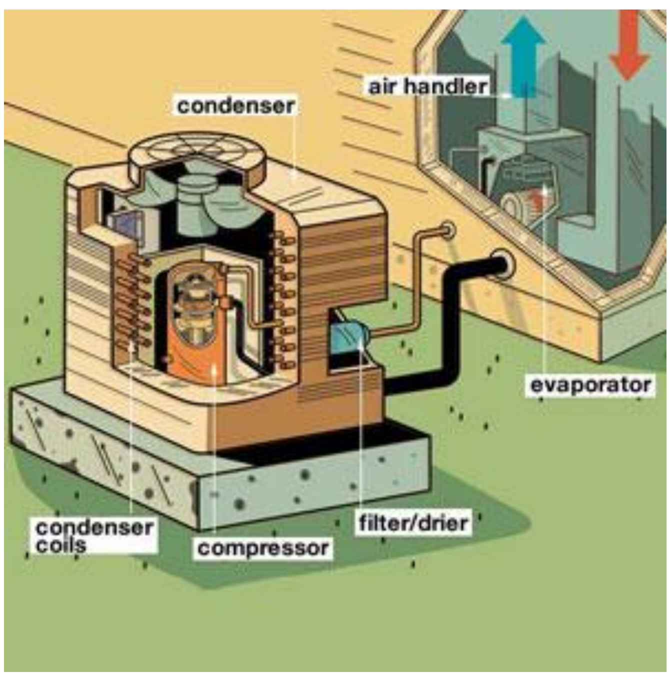


Fig. 5.113: Central air-conditioning system

[14] http://en.wikipedia.org/wiki/HVAC#Air_conditioning

5.5.1.3. Heat Recovery

Ventilation systems bring cool fresh air into a building using fans in Air Handling Units (AHUs). The AHUs also contain heating coils to allow the fresh air to be raised to the required temperature by the buildings boiler. The air continues to be heated by the occupants and equipment in the room and all this heat energy is lost when the air is extracted and dumped into the environment.

The addition of heat recovery means that some of the heat contained within the extract air can be recovered. The heat energy is passed into the incoming fresh air effectively pre-heating it and meaning the boiler needs to add less heat. The two air streams need not mix directly to allow the transfer of heat.

Heat recovery ventilation (HRV) is an energy recovery ventilation system which provides fresh air and improved climate control, while also saving energy by reducing heating and cooling requirements. As building efficiency is improved with insulation and air tightness, there is less need for them to be frequently ventilated. Since all buildings require a source of fresh air, the need for HRVs has become obvious. While opening a window does provide ventilation, the building's heat and humidity will then be lost in the winter and gained in the summer, both of which are undesirable for the indoor climate and for energy efficiency, since the building's HVAC systems must compensate. HRV introduces fresh air to a building and improves climate control, whilst promoting efficient energy use.

Batteries of multiple-row finned heat pipe tubes are located within supply and exhaust air stream of air handling unit. Within the exhaust air side of the heat pipe, the refrigerant evaporates, taking its heat from the extract air. The refrigerant vapor moves towards the cooler end of the tube, within the supply air side of the device, where it condenses and gives up its heat. Thus heat is transferred from the exhaust air stream through the tube wall to the refrigerant, and then from the refrigerant through the tube wall to the supply air stream.

Because of the characteristics of the device, better efficiencies are obtained when the unit is positioned upright with the supply air side mounted over the exhaust air side, this allows the liquid refrigerant to flow quickly under gravity back to the evaporator. Generally, gross heat transfer efficiencies of up to 75% are claimed by manufacturers. Using heat recovery ventilation system approximately 20% savings can be achieved in annual energy consumption, and about 30% of air-conditioning consumption.[15]

[15] http://www.carbontrust.com/resources/guides/energy-efficiency/heat-recovery

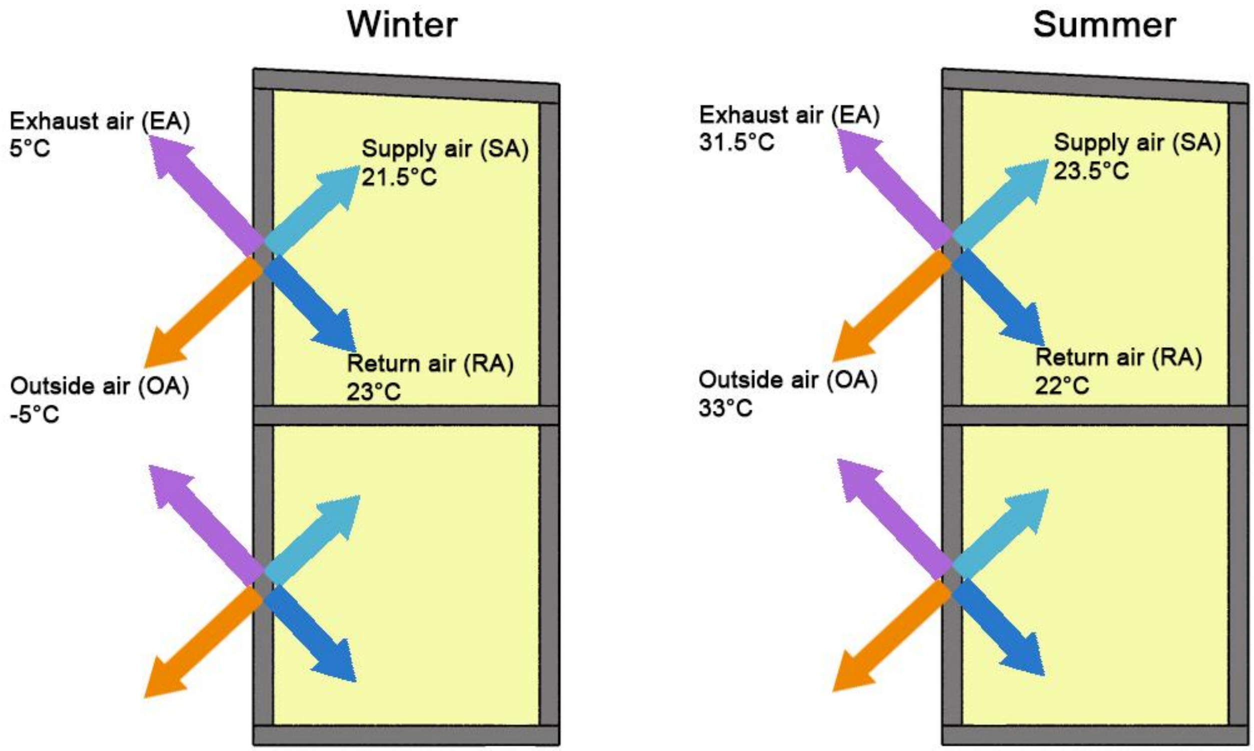


Fig. 5.114: Heat recovery ventilation scheme

5.5.2. Geothermal Energy System

Geothermal energy is simply the heat derived from the Earth, where it's previously been generated and stored. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems, and may be combined with solar heating to form a geosolar system with even greater efficiency. Almost everywhere, the shallow ground or upper 6 m of the Earth's surface maintains a nearly constant temperature between 10° and 16°C. Geothermal heat pumps can tap into this resource to heat and cool buildings. A geothermal heat pump system consists of a heat pump, an air delivery system (ductwork), and a heat exchanger-a system of pipes which are buried in the shallow ground near the building. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer can also be used to provide a free source of hot water.

All geothermal (geo exchange) systems have three main components:

- *a means of transferring heat to and from the subsurface,*
- *a heating and cooling device (heat pump),*
- *a heating and cooling distribution system.*

Figure shows a typical configuration for what is known as a "closed loop" geothermal system. Heat is extracted from, or transferred to, the subsurface via a series of high density polyethylene (HDPE) loops through which a fluid is circulated. This fluid may be water or an aqueous solution of a pre-approved heat transfer material such as propylene glycol or denatured ethanol. Loop systems are classified as either open or closed, and those loops can be configured in one of three ways: vertically, horizontally, or in a pond/lake. The type chosen depends on the available land area, and the soil and rock type at the installation site. In an open loop geothermal system, water is pumped directly from an aquifer via one or more wells into the building where it passes through a heat pump before being returned to the aquifer by a separate (discharge) well or released into a nearby lake or stream. However, despite their relative simplicity, open-loop geothermal systems are not as popular as the closed-loop variety. This is largely due to the fact that they require an abundant and constant supply of clean groundwater, and they are subject to many regulations.[16]

[16] https://www.dmr.nd.gov/ndgs/newsletter/nl0107/geothermal.pdf

In our project we implemented the closed loop system, due to the regulations regarding the temperature difference between intake and discharge. Even with the lake so close to our site, it would be somewhat difficult to reach with pipes because of historical area which is between the site and the lake. However, exactly because of the proximity of the lake, we can rightly assume that the presence of the groundwater at certain depth would be sufficient for the optimal functioning of the closed loop system.

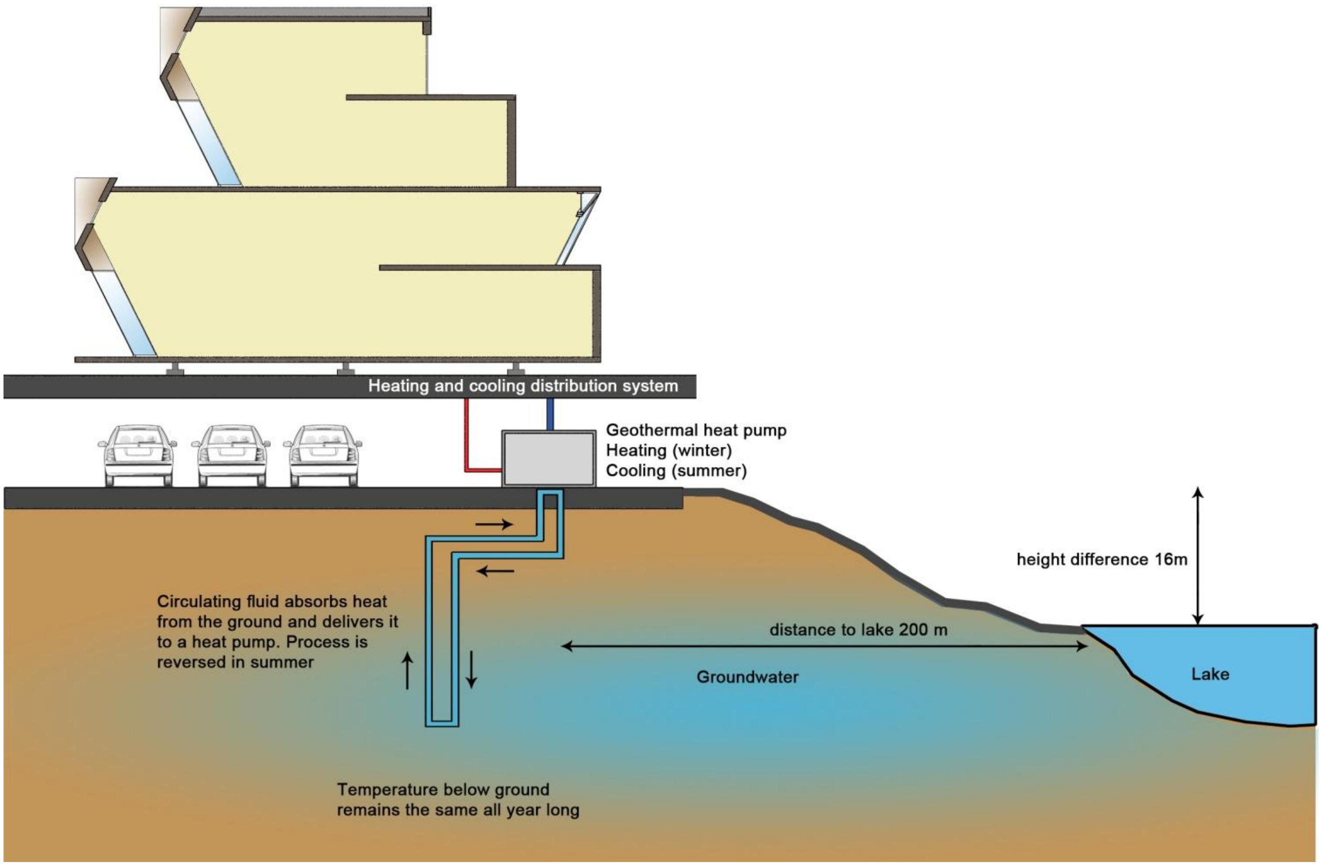


Fig. 5.115: Closed loop geothermal system, vertical configuration

5.5.3. Solar Energy Production

5.5.3.1. Solar Photovoltaic Energy

Photovoltaic panels collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for electrical loads. These cells do not need direct sunlight to work – they can still generate some electricity on a cloudy day. PV cells are made from layers of semi-conducting material, usually silicon. When exposed to sunlight, these layers release electrons. The stronger the sunshine, the more electricity is produced. This flow of electrons produces direct current (DC) which is converted to alternating current (AC) by an inverter. So it can be used by appliances in the home. The power of a PV cell is measured in kilowatts peak (kWp). That is the rate at which it generates energy at peak performance in full direct sunlight during the summer.

The main advantage of this system is using the sun as a free and clean source of energy. In addition, this system limits considerably the released amount of CO2 in the atmosphere comparing to the other means of producing electricity from non renewable sources.

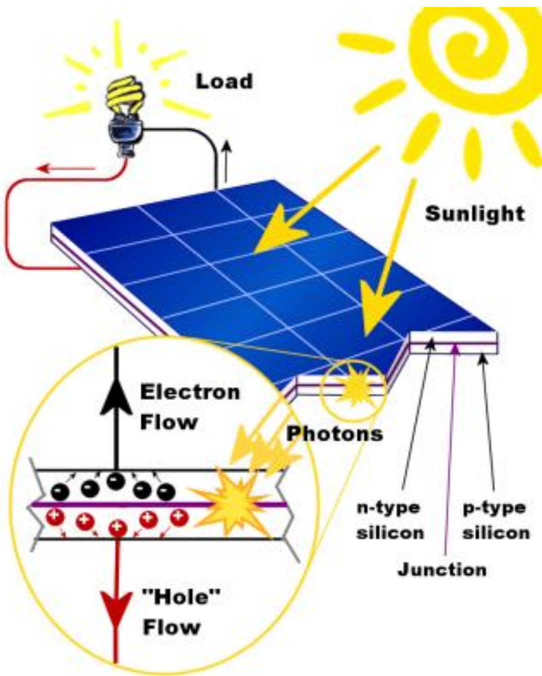


Fig. 5.116: The PhotoVoltaic Mechanism Diagram[18]

In our project, we consider the panels on the roof of the upper modules. One of the best mounting systems which suit well with our flat roofs is the ConSole assembly system. The ConSole is weighed down with ballast in order to resist the wind loads. The necessary weight of the ballast depends on the height of the building, its location and the condition of the ground and the wind and snow loads. The ConSole is made from 100% recycled chlorine-free polyethylene (HDPE).[17]

[17] *ConSole Installation Instructions, http://www.centrosolar.de/fileadmin/user_upload/downloads/product_info/ConSole_IM_A03_EN.pdf*
[18] *Picture taken from: http://www.mrsolar.com*

Fig. 5.117: the process of installation.[19]

[19] *Pictures taken from : http://www.centrosolar.de*

5.5.3.2. Solar Exposure Analysis

Analysis of solar exposure gives us the data for incident solar radiation, or else insolation, which is the radiant energy upon a surface of a building. It is the amount of energy actually falling on the surface, not related to the surface properties of materials which can affect only the amount which would then be reflected, absorbed or transmitted. Incident solar radiation is made of two components – direct, which is the sunshine from the sun itself, and a diffuse on, which is the skylight from the visible sky.

This can give us the total solar energy that falls upon the surface; we want to transform this energy to electric energy by using PV panels in order to decrease the annual energy demand of the building by supplying produced electricity.

Typical PV panels are considered to have around 15% efficiency rate when converting solar energy into electricity. Most common commercial PV panels use crystalline silicon technology and we implemented these types in our project. The panels are fixed due to less maintenance required as opposed to solar tracking systems, with an optimum tilt angle of 38˚ and are oriented towards the south.

The results represent the total potential electric energy which the system could produce daily or annually. But on certain periods of the year or on certain days, depending on the energy demand, insolation and hours of sun available, one can have a system completely independent of the electric grid, sometimes even be able to feed the exceeding energy back to it, while sometimes the production wouldn't be sufficient to the demand so electric supply from the grid would be necessary.

We used Ecotect to analyze the incident solar radiation upon the tilted surface of the solar panels, and then multiply the obtained data with efficiency factor of 0.15 to get the potential energy which can be produced annually. We checked the data against the ones obtained from the Photovoltaic Geographical Information System by Joint Research Centre of European Commission.

Results from Ecotect

TOTAL MONTHLY SOLAR EXPOSURE

Lecco

Exposed Area: 18.869 m2

Month	Available	Avg. shade	Incident total	Incident
	Wh/m2		Wh	Wh/m2
Jan	40392	37%	387470	18897
Feb	40342	33%	406817	19825
Mar	91030	24%	1008790	49089
Apr	107335	16%	1357126	65869
May	125402	12%	1763979	85433
Jun	165720	20%	2340151	113407
Jul	162435	16%	2361186	114657
Aug	137821	12%	1883328	91466
Sep	101550	21%	1247938	60782
Oct	58155	30%	622292	30368
Nov	36322	37%	359348	17536
Dec	25795	41%	224968	10969
TOTAL	1092299		13963393	740025

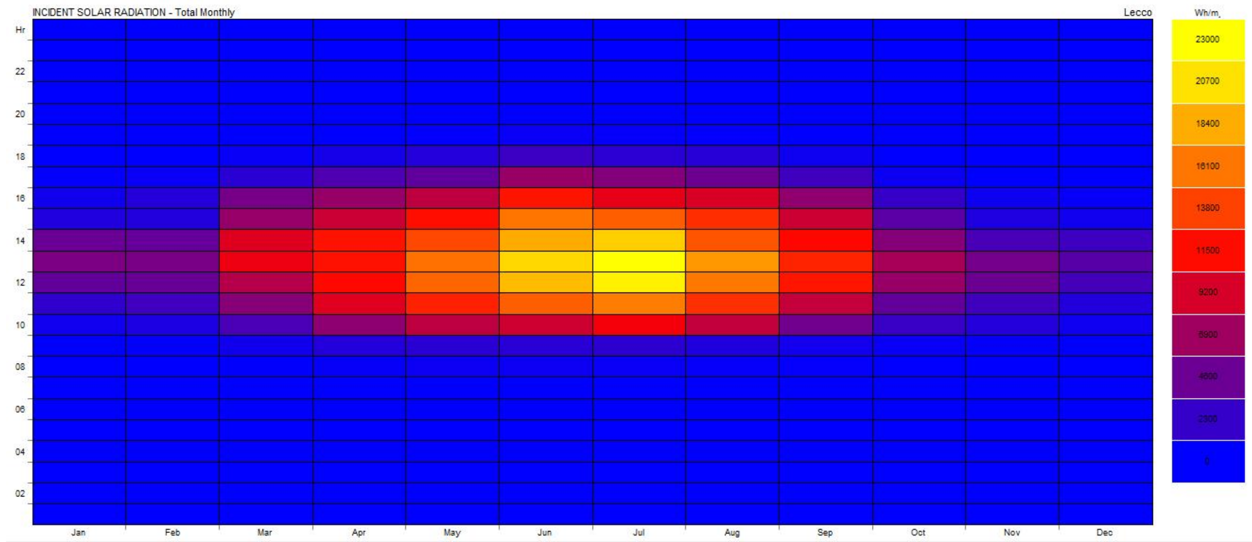


Fig. 5.118: Incident solar radiation per month

The values which we obtained from this analysis need to be reduced with the factor of 0.15, which finally gives us 111.03 kWh/m^2 as the potential of the electric energy to be produced. This is higher than the total energy demand calculated previously in the thermal analysis, so we can draw a conclusion that we can have system which can occasionally be independent and occasionally depending on the grid.

Photovoltaic Geographical Information System Results

Fixed system: inclination=38°, orientation=0°				
Month	**E_d**	**E_m**	**H_d**	**H_m**
Jan	2.26	70.0	2.69	83.4
Feb	3.22	90.2	3.92	110
Mar	3.74	116	4.76	148
Apr	3.86	116	5.03	151
May	4.18	130	5.58	173
Jun	4.41	132	5.99	180
Jul	4.68	145	6.42	199
Aug	4.28	133	5.86	182
Sep	3.78	113	5.05	151
Oct	2.69	83.5	3.47	107
Nov	2.05	61.4	2.53	75.8
Dec	2.12	65.9	2.56	79.4
Yearly average	**3.44**	**105**	**4.49**	**137**

E_d: Average daily electricity production from the given system (kWh)

E_m: Average monthly electricity production from the given system (kWh)

H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Fig. 5.119: Estimates of solar electricity generation

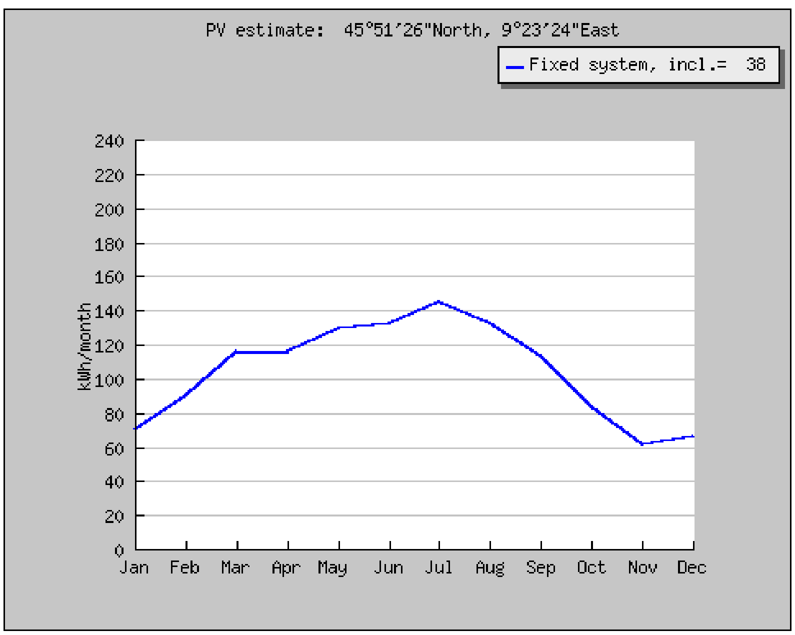


Fig. 5.120: PV estimate

The results obtained from this tool are also consistent with the results from Ecotect, so we can verify the conclusions made previously.[20]

[20] http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

5.5.3.3. Load Match Analysis

In order to assess the balance between the energy demands and energy produced from PV panels as previously calculated, we compare the results in a load match analysis. We perform analysis on a single roof, which covers two apartments, type A and type B, with total floor area of 126.5 m^2. The demand by m^2 of floor area is 38 kWh/m^2 annually which makes 4807 kWh in total per year.

Energy produced by PV panels reaches to 111 kWh per m^2 of panel, with the total area of panels being 19 m^2 thus the total annual production with 15% efficiency of panels considered is 2109.57 kWh, which is 44% of the total yearly demand.

We can also analyze results by month, and see that in winter months, production is much lower than demand, which is expected because of high heating loads and short time of day and solar exposure. During summer the production is at the peak due to high insolation, but cooling load is still higher. Best results are noticed in the transition seasons of spring and autumn, because the solar exposure time and number of sunny days are enough, whereas the temperatures are still optimal, so not much heating and cooling is required, therefore the total loads are not high.

kWh	Demand	Production
Jan	3019,8	58,1
Feb	2389,1	61,2
Mar	1914,9	151,3
Apr	287,2	203,6
May	149,5	264,6
Jun	821,7	351,1
Jul	1451	354,2
Aug	143,4	282,5
Sep	119,4	187,2
Oct	205	93,4
Nov	1246,5	53,9
Dec	2291,7	33,8

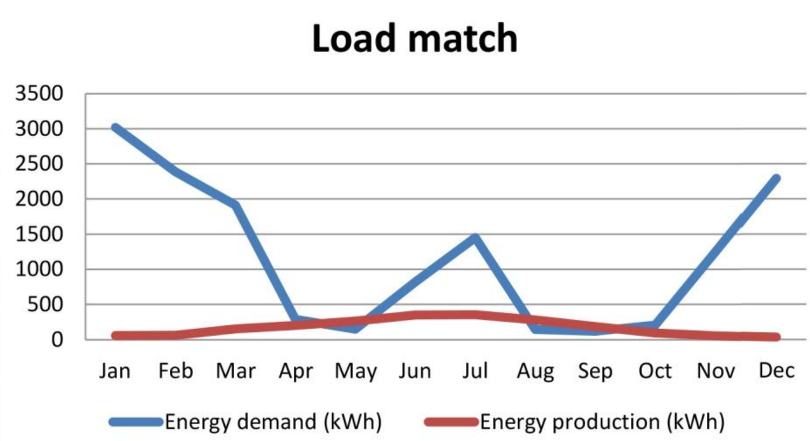


Fig. 5.121: Comparison of energy production and energy demand

5.5.4. Rainwater Harvesting

Water has become a valuable commodity, while climate change has altered the pattern of rainfall – leading to shorter heavier bursts of rain. There is a lot of pressure to ensure that every drop of water is accounted for.

Rainwater harvesting is the process of intercepting rainwater runoff from a surface (e.g. roof, parking area, land surface), and putting it to beneficial use. Rainwater harvesting reduces the need for mains water. In most buildings naturally clean rainwater is left to wash away while expensive purified water is used for flushing toilets and washing - only a fraction is used for potable-use. In recent years it has become harder to ignore this illogical way of using our natural resources. Environmental issues are becoming increasingly important – so is the awareness of the contribution that good building design can make to reducing pollution and improving the environment.

The water collected depending on the materials and the treatment chosen can be used for different purposes. In our project it is applied only for the irrigation of the existing gardens in the parking area, toilets and flushing water.

The harvested water can serve the fixtures in two main ways:

- *A passive way, which by locating the storage tank in a higher level from the fixtures take advantage of gravity and head pressure.*
- *An active way, which require a pump to return the collected water stored in a ground tank back into the fixtures.*

In our project, according to the site arrangement constraints of the modules we chose the active method. To compensate a part of energy needed for the electricity used in the pumps, photovoltaic panels are placed on the roof as we will see in the next part.

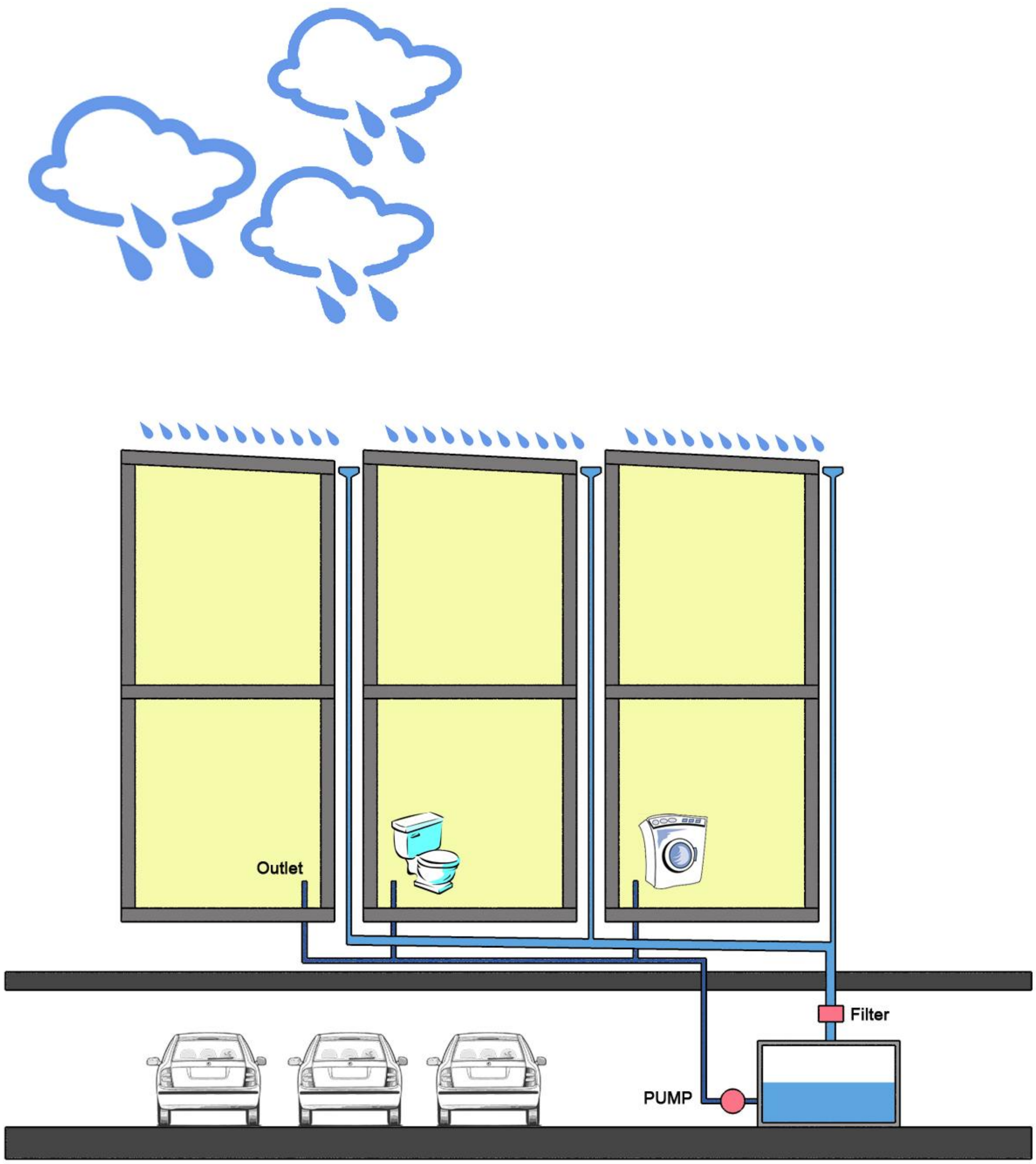


Fig. 5.122: Rainwater harvesting scheme

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