POLITECNICO DI MILANO

VI FACULTY OF ENGINEERING

POLO REGIONALE DI LECCO

Master of Science in Architectural Engineering

Course of Building Engineering

Master's Thesis

THE EARTH SHELTERED BODY FACTORY

Relatore

Prof.Massimo Tadi

Correlatore

Prof.Gabriele Masera

Prof.ssa.Angela Colucci

Master Thesis of

Ahmad Talkhan 781627

Mohamed Hassan El-Nashar 782860

Yasir Naseem 781473

July 2013

ACKNOWLEDGEMENTS

We acknowledge the guidance and effort by expressing our heartiest gratitude to the following personalities, in prompt completion of this thesis and achieving the milestone.

Professor Massimo Tadi;

Professor Gabriele Masera;

Professor Angela Colucci;

Professor Alfonso Senatore;

Professor Marco Imperadori;

Professor Martinelli Paolo;

Professor Liberato Ferrara;

Professor Oscar Pagani;

Professor Elisabetta Rosina;

Professor Ezio Riva;

Professor Bruno Daniotti;

Professor Fluvio Re cecconi;

Professor Giuseppe Rapisarda;

Professor Lorenzo Pagliano;

Professor Barbara Galli;

Professor Fabio Maria Bolzoni;

Professor Roberto Paolucci; and

all the teaching faculty of Politecnico di Milano.

We are also grateful to our family for their support and spiritual assistance throughout.

Ahmad Talkhan

Mohamed Hassan El-Nashar

Yasir Naseem

July 2013

ABSTRACT

Energy conservation has been the need of the hour since long, and mankind is constantly striving to achieve the goal of reducing the need of energy, since this is the only way to conserve it i.e., to utilize as low as possible. Apart from the resources, natural or artificial, in the world, we have so far expended most of these in a rather inefficient manner, resulting in belated realization of the same. Earth has been used as a building material through the history, natural caves, spaces carved out of rock or soil. With the growing awareness of energy needs and shortage in the early seventies, the increasing fears of the ozone layer depletion and the global warming phenomena as indicators of impending biological degradation, Earth Sheltering rapidly gained interest both as a conservation method and as an alternative life style.

From that, the growth of the earth sheltered facilities has been witnessed recently, as it gives the solution for the dilemma of providing long term humanity needs, along with responding to the recent shortage of capital energy resources. But, as a construction technique, it is dealing with unusual constrains including physiological, lighting and ventilation, undesired effects and impacts, which are completely different than the ones related to the traditional above ground structures. It also encompasses other severe technical aspects, with respect to the soil loads, humidity, dampness, toxic gases penetration, air/water tightness, etc,.

In view of above, it was required to come up with passive natural means and technological advancements in assisting the proposal to achieve sustainability. Not only limiting to theoretical framework, but an implantation to solve all of the issues related to design, detail and to ensued its constructability for urban, architecture, structure, technological and services i.e., practical comprehensive solutions.

In today's world, the ideas like preservation and adoptive reuse are being followed as a popular global trend, depicting nostalgia for the past and relevant historic significance also encompassing sustainability with no impact on new built environments. Thus, choosing a vintage city like Valmadrera with its iconic industrial character and the famous Gavazzi villa, providing the challenges to deal with transformation of the city and simultaneously focusing on the implementation of new technological advancements, fulfilling the development plan of PGT and PTCP from Lecco, especially having a better understanding after living in Italy for a couple of years.

Accordingly, our proposal focuses on creation of a sustainable-transformation scheme, based on the Therapeutic and Eco-tourism vision, including but are not limited to comprehensive techniques using earth sheltering, renewable energy, green envelope, effective lighting and ventilation tools starting from the urban planning integrating with the confined architectural and technological detailing.

The follow-on product of energy recipe, after testing and implementation of various techniques, was made absolute in quality and design for all necessary aspects of the project, resulting in a rather ideal amalgamation of urban, architectural, technological and structural aspects involved. Therefore, achieving a high-class energy efficient building, through a procedure which will definitely be beneficial for future implementation and adoption strategy.

ESTRATTO

La conservazione dell'energia è da sempre stata una necessità per l'uomo che, ancora oggi, continua a ricercare la maniera di ridurre il suo fabbisogno energetico. Ultimamente si è registrato un aumento del EARTH SHELTERED FACILITIES, fornendo una soluzione al dilemma dell'approvvigionamento a lungo termine relativo alle necessità umane, assieme col rispondere alla recente carenza di capitali di risorse energetiche.

Tuttavia ciò si relazione con vincoli inusuali che includono l'effetto e l'impatto di effetti indesiderati fisiologici, come l'illuminazione e la ventilazione.

Considerando quanto detto fin ora, era necessario ovviare alla questione con mezzi passivi naturali e innovazioni tecnologiche per raggiungere il proposito della sostenibilità. Tutto ciò non solo limitandosi ad uno schema teoretico bensì al progetto dei dettagli, ottenendo così la fattibilità del costruire servizi urbani, architettonici, strutturali e tecnologici. Dunque, scegliendo una città storica come Valmadrera, con il suo distinto carattere industriale e la famosa Villa Gavazzi, ci imbattiamo nella sfida del gestire la trasformazione della città concentrandoci, al tempo stesso, sull'implementazione di nuove soluzioni tecnologie, a completamento del PGT e PTCP Lecchese.

La nostra proposta si basa appunto sulla la creazione di uno schema di trasformazione sostenibile, caratterizzata dalla la visione terapeutica e dell'eco-turismo includendo, tra le altre cose, tecniche globali che usino EARTH SHELTERNIG, energie rinnovabili, cinte verdi, illuminazione efficiente e strumenti di ventilazione che partano da una pianificazione urbana integrata con i dettagli architettonici e tecnologici.

TABLE OF CONTENTS

CHAPTER I

Introduction

1. The competition

1.1 Why a competition in Valmadrera?

Being driven by the aim of providing practical comprehensive solutions for Earth sheltering as a design and construction technique, which can bring new richness to man's grasp and correspondence of the environmental condition around him, we had been looking for a challenging realistic opportunity to implement and test relevant strategy in all the phases of design process, starting from the analysis and investigation, implementation and design making, to end up with the simulation and constructability schemes.

Keeping in mind that applying and testing Earth Sheltering will require a complete detailed knowledge of the site and easy rapid access to relevant technical data base, the site should be almost fully accessible to give the advantage of being visited again and again, to check the adequacy of different alternatives and coming up with better ideas. That emphasizes selecting a site area within Lombardy region, considering how much it will facilitate the research phase and improve the quality of the final product.

Taking into account the human interaction factor, after spending two years in Italy observing the north European traditions, culture and way of life, gave us the opportunity to understand the social interaction of the citizens, their habits, outdoor activities and relevant social circle they want to be in. From that, it was convenient to choose a site area in the Northern region, close to our resident city, to implement relevant experiences, as eventually we are designing for people's comfort and their well being as architects.

In that manner, the competition of "Nuova vita per la ex-Filanda" or "a new life for the former spinning mill" was considered as our focal study case with respect to its feasibility and potentials. A call for ideas for 3 study prizes on the subject of the recovery and re-utilization of the former Gavazzi spinning mill, located in Valmadrera, was announced. The call was addressed to students enrolled to the 5th year courses offered by the School of Building Engineering and Architecture.

1.2 General Competition Goals

The competition aims to enhance the students' design skills, to stimulate their active participation and creativity, in order to develop both original and feasible ideas on the recovery of the former Gavazzi spinning mill in Valmadrera and the development of the park nearby.

In particular, the participants will develop their ideas in the form of a preliminary project in a multidisciplinary input (including urban design, architectural design and building design evaluations) that will demonstrate the feasibility of new features suggested. The projects will be evaluated by a jury according to the following criteria:

- Relevance to the theme and project feasibility
- Attention to environmental sustainability
- Respect for the historical aspects of the mill
- Enhancement of the park nearby
- Economical sustainability.

Each participant or group will prepare a preliminary draft including a master plan for the enhancement of the area and the park, and a renovation and conversion project for the former Gavazzi mill and the accessory bodies.

1.3 About the project Site

The building of the former silk mill of the Gavazzi family in Valmadrera is located 50 km from Milan and 3 km from Lecco. Valmadrera is a touristic and naturalistic site with significant routes that lead to the Lake Como area starting from city's Cultural area. It is also close to some famous grand tour places such as Menaggio and Bellagio. Various Sport activities can be found in the city thanks to the lake and the mountains – including surfing, sailing, skiing, hiking, tracking, etc. The city is a core for the Industrial heritage of the area – since the past two centuries there is a big concentration of factories (mostly iron) and other types of productions. Silk industry is a rooted one but no longer exists since the beginning of the 20th century.
Presence of historic places, industries, huge lake front and plentiful open green areas, undeveloped pre-industrial areas, etc., makes it valuable to the futuristic development with a potential to become a touristic and public focus.

Figure 1 General View of the site context

Figure 2 Project area in the Macro-scale

The monumental architectural complex of Villa Gavazzi encloses an area of 30,000 square meters. The large building of the mill is located at the uppermost side; also in the old complex we can find the vintage courtyard of the main villa, the chapel of San Gaetano, dormitory and the large famous romantic garden. The current villa complex is a result of more interfering events from the seventeenth to the nineteenth century, but still considered as a valuable iconic structure for the city of Valmadrera.

Figure 3 Site area and the Mill General views (Extracted from the competition brief)

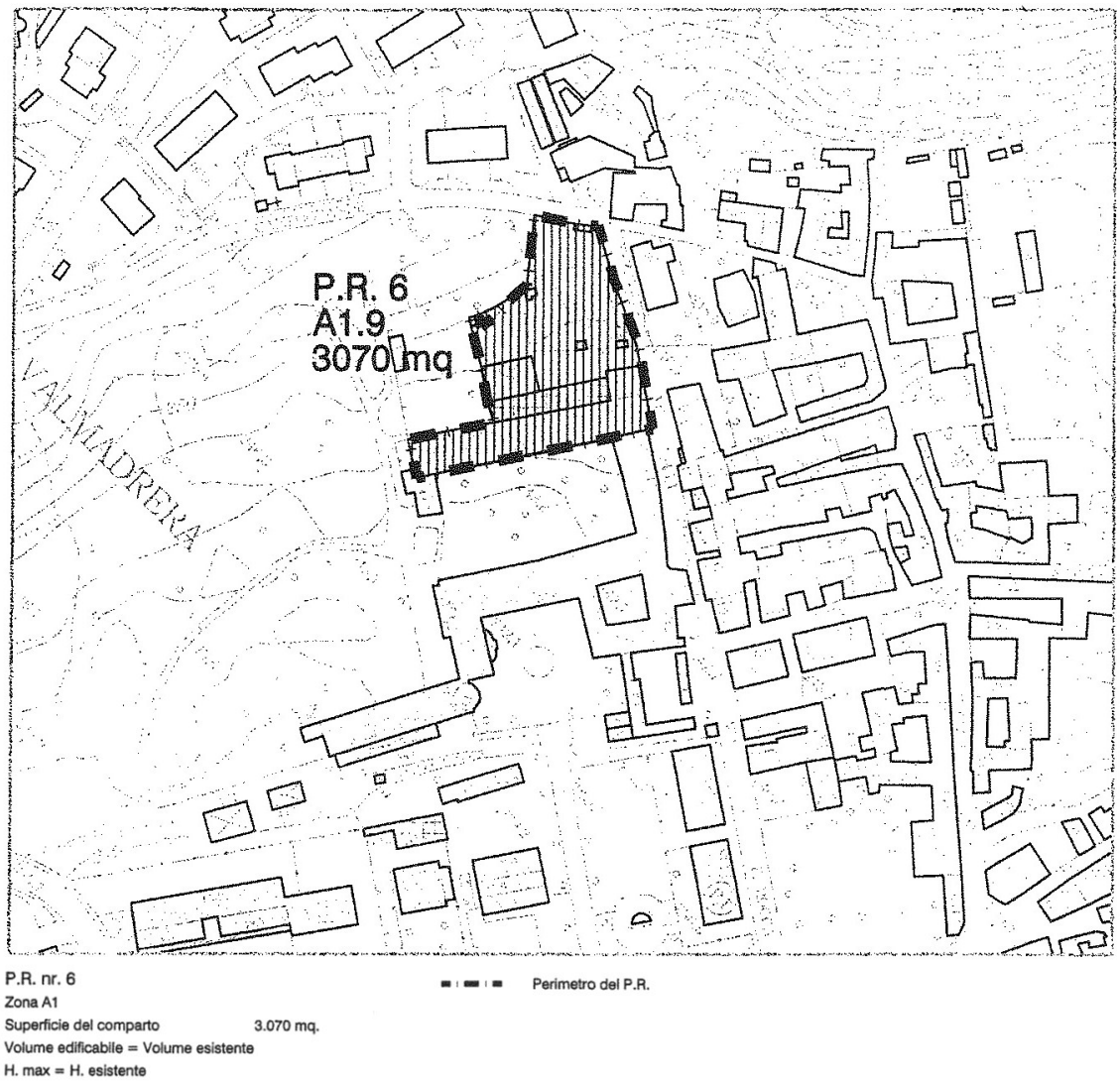


Figure 4 The complex and project area (Extracted from the competition base files)

1.4 Extended scope and objectives of the Thesis:

Apart from the aforementioned advantages and reasons behind selecting this project as a challengeable study case to implement and test the Earth sheltering, we are going to focus more on the new added subterranean mass which is located in the park area , specifically on the north western side of the Current Mill. Noting that developing and refurbishing the existing mill will be limited to a reasonable level only to guarantee its absolute integration in the final delivered study and the feasibility of the complete project.

On the larger urban scale, this thesis will take advantage of the opportunity to redesign and evolving the city, which is already under a process of transformation from a traditional industrial city to a new touristic modern destination. Relevant addition will add to the significance of the project, as it can be considered as a good chance to blend ideas and create a unique practical buildable scheme, which would not only serve the client's purpose of earning capital but also can

directly affect the quality of the environment, minimize the energy consumption as well as the improvement of the city resident's quality of life. Solutions for the enhancement of the Social fabric and Socio-economic aspects will be also addressed, as a part from the general scope.

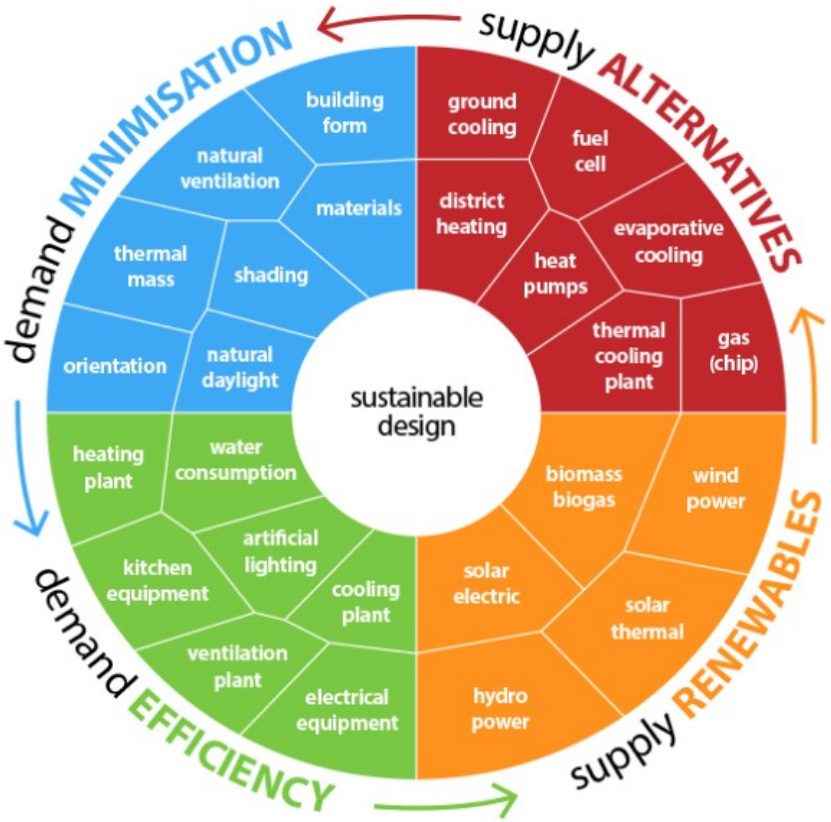


Figure 5 Sustainable design process by. Mario Cucinella[1]

From the environmental point of view, the figure 5 is an example for the followed methodology to approach the sustainable design problem, as the delivered solutions will be essentially driven by implementing energy conservative strategies and environmentally sustainable construction methods. In order to satisfy the global codes of green buildings and neighborhoods design, the LEED rating system will be mainly adopted, not to be used as a rigid frame work, but to expand our knowledge regarding the topics which need to be fulfilled as well as evaluating our accommodated strategies, with the aim of ensuring the adequacy of the developed product performance.

This rating system will be implemented while going through the design and detailing process, noting that the relevant rating system is further elaborated in Appendix B.

[1] http://www.mcarchitects.it/sostenibilita

2. Valmadrera

Valmadrera is an Italian town in the Province of Lecco, in the Region of Lombardy. The municipality covers 12.6 km² and has 11,668 inhabitants and they are called "Valmadreresi".

2.1 The city history

The old village has Roman origins; however it revealed its real appearance around the year 1000 A.D. Valmadrera went through difficult times when the area became a mandatory thoroughfare for migrating populations and shifting armies. In the middle ages, the area found itself involved in rivalries between the Torrianis, supported by Lecco, and the Viscontis, and with the ultimate victory of the latter the village was frequently used as a refuge by the people of Lecco.

Particularly, in the late XIII century there were already documents that report about settlements built around the already existing churches in the districts of St. Dionigi, Caserta, Al Ceppo and San Tomaso. Among the sights, the Sanctuary of the Madonna di San Martino, dating from the early middle Ages. The Church of Sant'Antonio Abate begun in 1791 and completed in 1823. The bell tower, erected in 1923, with its 90 meters is the highest in Lombardy.[2]

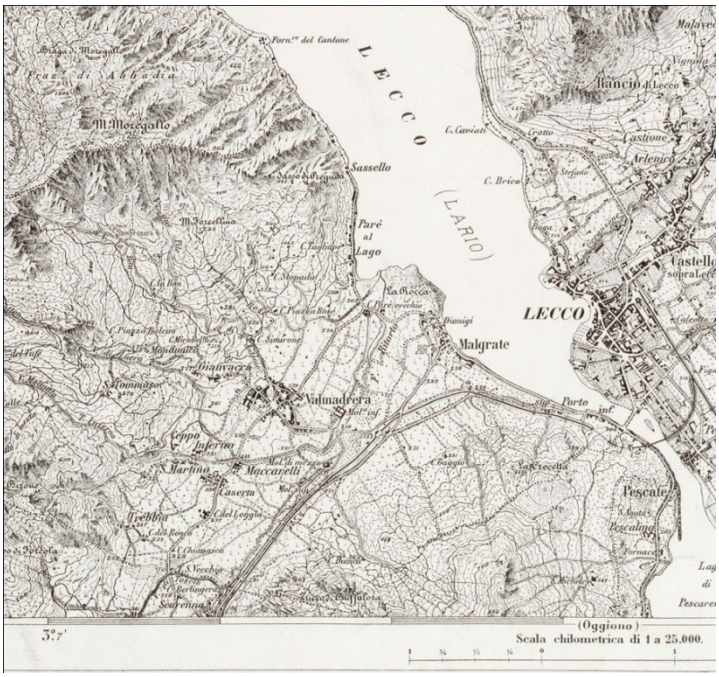


Figure 6 Valmadrera map dated 1888

2.2 City evolution and growth along the history

Valmadrera has remained an industrial nucleus, as the origin of the textile manufacturing in the area of Lecco dates back to the Renaissance age when mulberry and silk worm cultivation became widespread for the supply of raw materials to Milanese silk producers. The city used to behave as an important stock exchange thus establishing its importance in the region between Milan, Como,

Figure 7 Valmadrera, old town

[2] (Demographic evolution shown in Figure 2.Ref: ISTAT)

Bellagio and other cities, which emphasize the industrial and craftsmen's heritage of the area. Since the past 2 centuries there were a big concentration of factories (mostly iron) and other types of productions, silk was one of those and one of the most rooted but no longer existing since the beginning of the XX century.

Thanks to the Gavazzi silk factories, Valmadrera was literally transformed in the space of a few years, radically modifying its economic and social structure and evolving from a farming village into the model of a «people's town» inspired by the precepts of that industrial paternalism, in which it is a planned community within the larger community whose growth reflected the social and urbanistic structure of its innermost nucleus.

Figure 8 Valmadrera map dated 1931

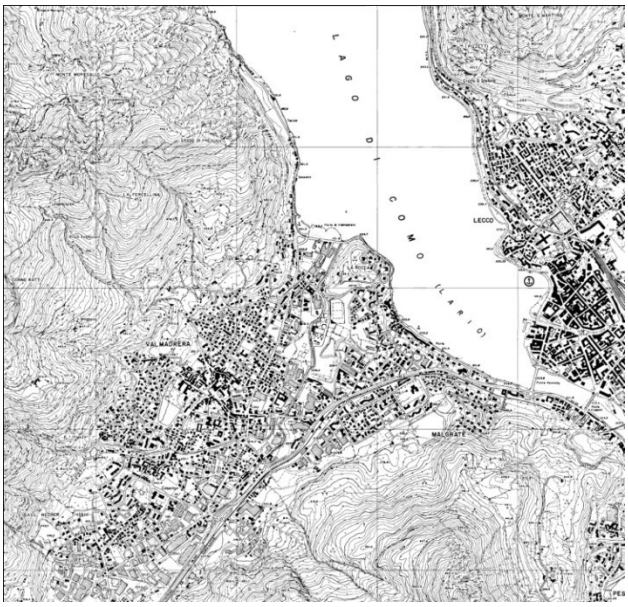


Figure 9 Valmadrera map dated 1994

2.3 Geography and Climate

Valmadrera is located 3 km to the southwest of Lecco the largest city nearby and the capital of the Province of Lecco in Lombardia, overlooking Lecco Lake (branch of the Como Lake) that is a charming tourist destination. Situated at 234 meters above sea level, the municipality of Valmadrera has the geographical coordinates of 45 ° 50 '53'' North, 9 ° 21' 30'' East, is surrounded by mountains from the north and south sides and has boundaries with Canzo (CO) , Civate , Galbally , Lecco , Malgrate , Mandello del Lario ,

RegioneLombardia

Figure 10 Lecco Province - Lombardy Region Italy

Valbrona (CO). It is a municipality in the Natural Park of Monte Barro, as many of the sites in Valmadrera are declared sacred and are under protection of bodies like Natura 2000 to preserve the native biodiversity.

Valmadrera has a warm humid temperate climate with hot summers and no dry season. The temperature typically varies from -1°C to 29°C and is rarely below -5°C or above 32°C. The median cloud cover ranges from 45% (partly cloudy) to 67% (partly cloudy). The probability of precipitation varies throughout the year mostly likely around end of May, least likely around end of January, with average wind speed of 2 m/s.

The relative humidity typically ranges from 45% (comfortable) to 93% (very humid) over the course of the year, rarely dropping below 29% and reaching as high as 100% (very humid).

Figure 11 Valmadrera City; Lecco Province

2.4 Population and Transportation

The data extracted from the national demographic data base3 describes the conditions in Valmadrera in terms of resident's population, annual growing and distribution by age4. As it can seen in the graphics the inhabitants number "Valmadreresi" is 11,668 with population density 929 inhabitants per km².

Figure 12 Age pie graph

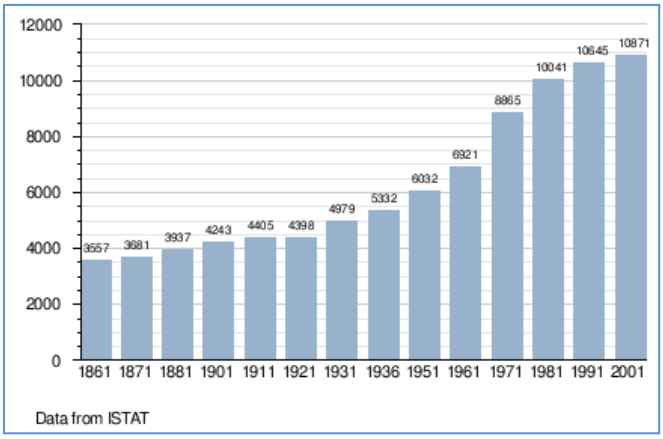


Figure 13 Population growth demography

[3] http://dati.istat.it
[4] http://www.comuni-italiani.it

VALMADREARA : POPULATION BY AGE						
Year	**0-14%**	**15-64%**	**% 65 +**	**People**	**Old Index**	**Age Media**
2,007	15.1%	66.1%	18.8%	11,200	124.6%	41.8
2,008	14.9%	66.2%	18.9%	11,362	126.7%	42.0
2,009	14.8%	66.2%	19.1%	11,445	129.0%	42.2
2,010	14.7%	66.1%	19.1%	11,542	130.0%	42.1
2,011	14.6%	65.9%	19.5%	11,668	133.2%	42.4

Table 1 Valmadrera population by age (wikipedia.org)

Viability of major communication and transit, the city has internal public transportation system through bus lines and it is connected to the surroundings by Train lines, Bus lines and provincial roads. The majority of trips with destination in the Province of Lecco originated within the Province itself (82%) and (9%) originates by the Province of Milan, minor shares of the provinces of Como and Bergamo, the rate of motorization private car is equal to 59.9 per 100 inhabitants and in recent years recorded a net increase, this increase expressed in the saturation of provincial road network.

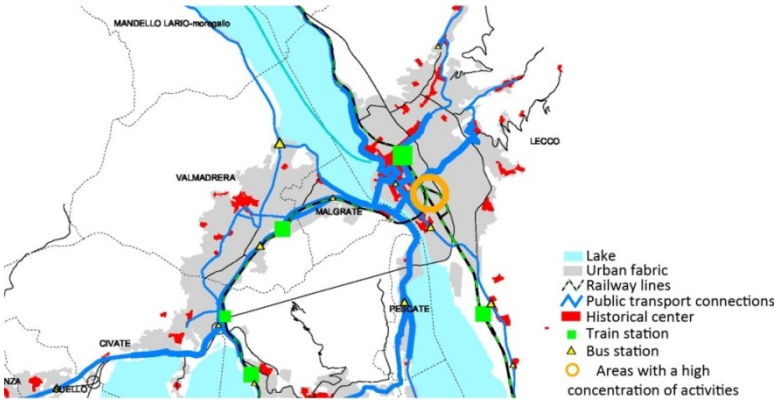


Figure 14 PTCP transportation map

2.5 Environmental analysis (Waste-Pollution)

Valmadrera is a site of the Alpine area that is characterized by limestone rock with deep fissures that give it a block, also of large marine fossils in addition of being very rich in wild life including birds as owls, bunting yellow, peregrine falcons, woodpeckers, goldfinches, ruler and several species of tit, beside The SPA of Monte Barro (protected area by Natura 2000 polices) that is an important crossroads for transit and the rest of migratory birds, there are species such as hawks, birds of prey, and thrush.

Figure 15 Diagram of protected areas in the context of the three municipalities in Lecco

In Valmadrera, the vegetation is endemic of the foothills of the Alps engaged in off-dry meadows. The institution Park is equipped with its own statute that governs the management. The PLIS grows in mountain areas, which is characterized by the presence of copses of oak, hornbeam, flowering ash and Rowan Mountain are traces of chestnut trees and plants conifers, in lowland are prevalent crops.

From the analysis conducted on drinking water in 2009, environmental restoration of rivers is needed as water pollution observed with excess aluminum episodes were recorded in the municipal area. The specific consumption of water resources is equal to 162 l / an. per day, most consumption is attributable to the use of the home (68%). The municipal area of Valmadrera has a sewage treatment plant in which the City is fully covered by the system.

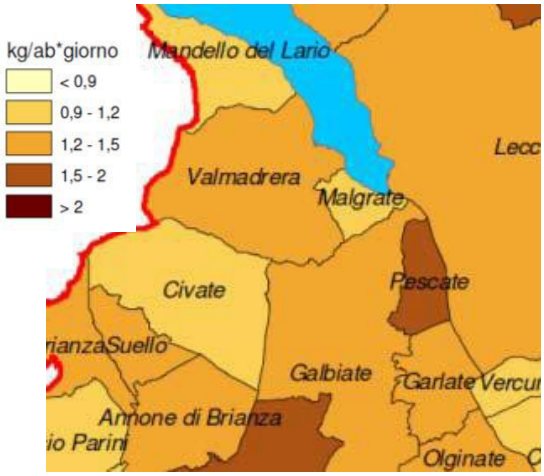


Figure 16 Production of municipal waste

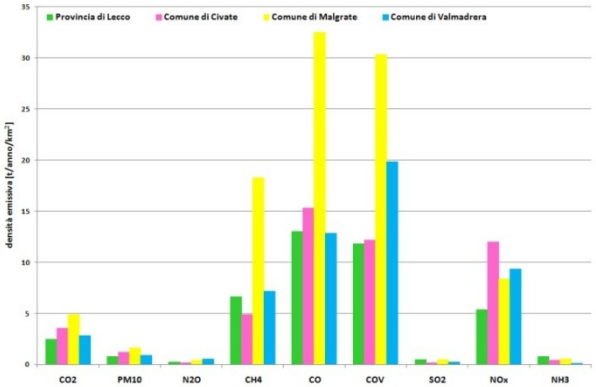


Figure 17 Comparison for communities pollution emission density for different

2.6 Culture and attractions

Valmadrera is considered Cultural district by the PTCP together with some neighboring cities due to its rich environment with cultural and significant heritage elements that had contributed in defining the role of the city in the past and still doing till today as; Palazzo Bovara Baracchetti garden, Villa Hermitage, Villa and park Gavazzi, Cultural Center Fatebenefratelli, Parish Church, Town Hall, Sanctuary of the Madonna di San Martino, and St. Isidore of Preguda according to real estate of artistic and historical interest Legislative Decree 42/2004 art. 10 and 11.

Figure 18 PTCP-Quadro Strategico territoriale-Natural and cultural district San Tomaso

The previously mentioned historical places in addition to the other natural monuments and attractions of as water front, the mountains with protected environmental zones as the Natural Park of Monte Barro, and Presence areas of artistic and religious interest as The local park supra

(plis) **Park San Pietro a Monte - San Tomaso** stretches for about 1,100 are between the towns of Civate, Suello and Valmadrera which have pooled in the management of the same. San Tomaso and the surroundings areas of Corni di Canzo Mountain as defined by the PTCP, all contributed in giving the city its potential.

Figure 19 San Tomaso church -Corni di Canzo Mountain

2.7 Architectural Style and Morphology

Valmadrera has the traditional architectural style of the mountains and villages regions of the surrounding in which typical hierarchy of elements and organization of space in the building exists as courtyards, parks, porches, roof shape, and entrances with construction elements used like wood and stones. The integration of industrial life with the private lives of the villagers differed Valmadrera from the others both in terms of the superior quality of the architecture and its advanced production and technology.

Figure 20 Centro CULTURALE FATEBENEFRATELLI

In addition to the historic center of original Valmadrera, there are several urban centers of ancient dates like: Caserta, Old Parè, Belvedere, Ca 'del Logia and Stump with very similar morphology. In particular, the core of Valmadrera has narrow streets crossing it, in which have been raised on the main historical buildings with the associated activity of the village, and it is still readable for the architectural morphological and typological qualities. The nuclei are now sewn up and incorporated in the building development recently.

Figure 21 The parish Church of Sant'Antonio Abate

Figure 22 PARE' district

3. The Gavazzi family and Filanda complex

3.1 History of the Family

The Gavazzi family had been a significant figure in Italy from sixteenth century to late twentieth century, covering fourteen generations involved in business and community works. They established some of the most modern silk mills in the region and bought a lot of property for the purpose. They had already running business successfully in other cities such as Milan, Bellano, etc., and by the addition of silk mill in Valmadrera, this was an immediate success and thus contributed to the recognition of Valmadrera as an industrial hub and gave it the definition of «people's town» as described previously.

Figure 23 Gavazzi family

Gavazzi silk was already being exported to France, Switzerland, Germany, Austria and even far-off England. Through agents in Vienna, the goods from the Valmadrera and Bellano factories reached markets as distant as Greece, Russia and the countries of Eastern Europe.

Figure 24 Aerial view of the Gavazzi complex in Valmadrera.

In Valmadrera, Giuseppe Antonio owned the mill complex and, on the road leading from the hamlet of Caserta to the Sanctuary of San Martino, spinning mills the three manufacturing units had been bought. In Valmadrera, the idea of extending the factory in the village to include dormitories, a nursery school and other social facilities was an expression of the theory of industrial paternalism.

In 1859, Cesare Cantù wrote in the book, *"After having seen the wealth of a gentleman of the lowlands in the houses of the Turina, Bisleri and Vertua families, there is no finer example of a merchant's estate than the Gavazzi property. We shall dispense with the description of the comforts and the charms of the villa and*

Figure 25 Driveway of the Gavazzi Villa in Valmadrera

mention only one hall, adjoining a vast windowed gallery, at the end of which is a hothouse for flowers. When in the evening one is met here by refined luxury, splendid hospitality and lively friendliness, one feels to what extent the independence acquired through trade, that is, through individual strength, is preferable to the adorned beggary of those who seek from governments a hard-earned loaf of bread and an imaginary superiority, which, in the end, is no more than servility".[5]

3.2 The Silk factory during the time

The "Villa Gavazzi" located in near the historic character, what Valmadrera used to enjoy in the past. The villa is based on the most ancient wing - built in the XV century then many additions and refurbishments had been done during the following centuries. In 1817 the family bought the villa, the surrounding fields and the waters of the river Luera to make the machineries work.

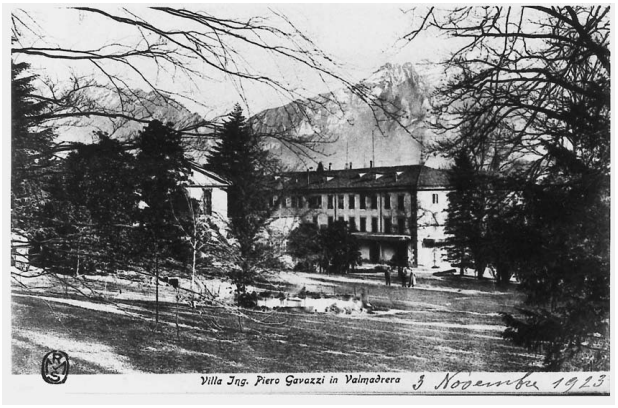


Figure 26 The villa view from the romantic garden dated 1923

The architectural monumental complex encloses an area of about 30,000 square meters. It comprises of the old court house Bonacina (nucleus of the San Gaetano, and the great romantic garden which was built in 1820-1840 and is one of the most remarkable examples of a romantic garden in Lecco. The park is accessed from the porch to the left of the court house, beyond which there is a large clearing on the lawn, surrounded by mature trees (chestnut, linden, tulip trees). In addition to large building of the mill factory that was built in neo-classical style with heating building and exterior pool for water supplying.

Figure 27 The chapel and the villa of the Gavazzi complex in Valmadrera

The complex had a vintage scheme in which it used to work as one comprehensive sustainable system, considering all activities for all ages and genders inside the complex, providing the city with other services like new fire station that was built in 1866, public gas lightening system in 1891 in addition to others with high sense of sharing and equity. The Mill used to be a stock and financial center and exchange market among the main surrounding cities in the region, not only on local scale.

Figure 28 Chimney and west side of silk mill

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

Between 1817 and 1820 the architect Giuseppe Bovara was charged with extensive work restructuring of the villa. Downstairs, modifying the original Baroque style. Bovara gave shape to the straight sides and opened an atrium to provide access on the west side, to the warehouses for silk, on the other side of the atrium were placed kitchens and service areas. Always at Bovara should be the opening of the driveway to the villa, which creates a strong perspective first missing.

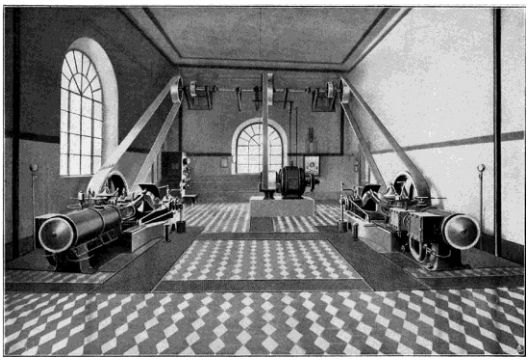


Figure 29 Interior of engine room of the Gavazzi complex in Valmadrera (from a brochure of the Pietro Gavazzi joint-stock company, early 1900s)

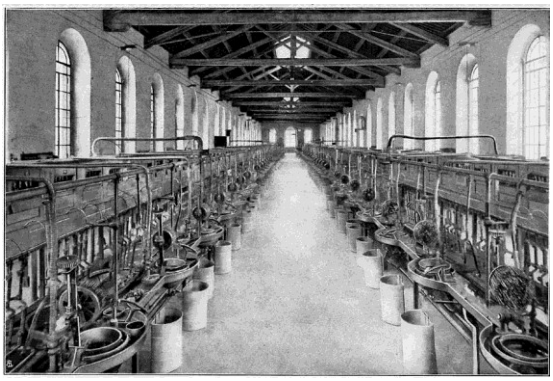


Figure 30 Interior of the Filandone, part of the Gavazzi complex in Valmadrera: the basin room (from a brochure of the Pietro Gavazzi joint-stock company, early 1900s)

3.3 The factory now

The spinning-mill has two floors and there had worked with the most modern steam machines of the time of its establishment that some of them still remaining. The access to the factory is only possible through the North-West through Campogrande Street way because is not allowed to pass and enter in Alessandro Volta Street. The ground floor has been deeply renovated during the years; the whole slab is actually an addition. The connecting wing in made with reinforced concrete pillars and beams. The first floor is more similar to the original structure, and an unusual but original roof structure with wood and steel beams in which some skylights have been newly opened. The Facades are degraded with some material loses. A relatively new building has been constructed in fifties of the twentieth century which is directly connected to the Mill from both floors with totally different architectural style.

Figure 31 West view from the garden, Heating building – Chimney

Figure 32 View from the romantic garden Silk mill behind winter garden

The heating building is also consisting of two floors with an existing boiler at the ground floor. Its state is similar to the mill from exterior in which the Facades are degraded in

addition to being modified by adding some elements like lateral stairs to connect directly the first floor, others are taken away, and some windows are closed. The exterior pool with its garden are totally abandoned with some ancient trees existing around.

Figure 33 North view from Campogrande Street

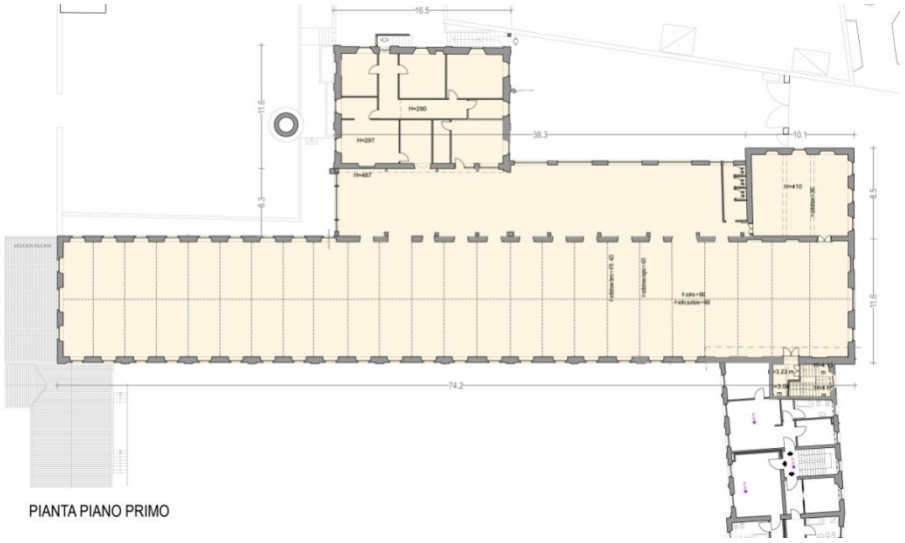


Figure 34 Groud floor plan

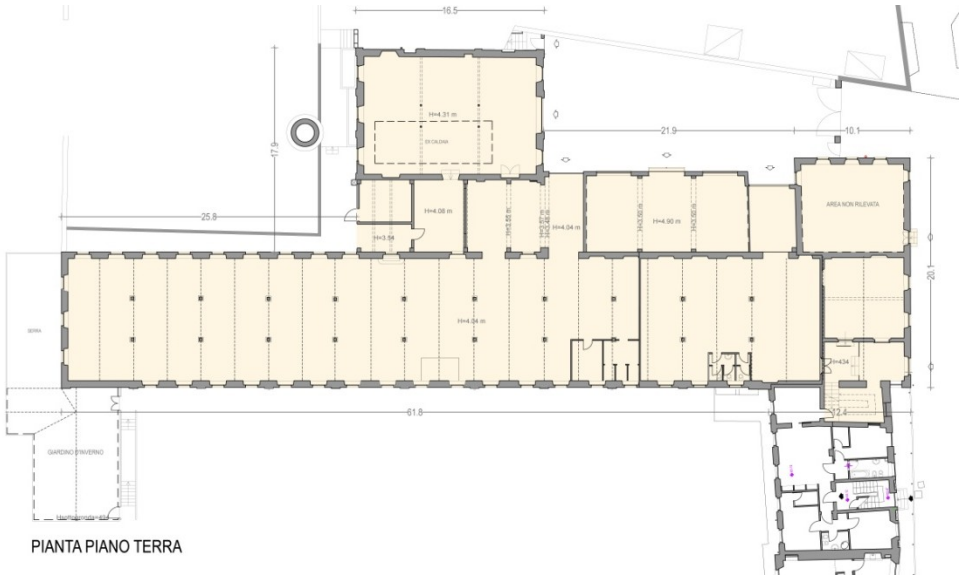


Figure 35 First floor plan

Figure 36 Transversal section of silk mill, 50s, Heating Building

4. Function suitability and feasibility

With respect to the Competition title (Nuova vita per la ex-filanda) and relevant brief, there was no specific function proposed for the former spinning mill or even a clear vision of how to recover and re-utilize it, but the competition goals gave the outer guidelines of the selection process, related to the feasibility of the project and the Mill's historical authenticity, as well as the relevant social, economical and environmental sustainability.

Keeping above in view, our main aim is to provide a Sustainable evolving scheme following a scientific decision making methodology. Relevant scheme is based on the righteous evaluation of the building potentials and constrains, compatibility of the chosen function with the building physical components and spiritual memory, as well as the economical profitability and Socio-Economics.

Considering a wider target of creating a sustainable transformation plan for Valmadrera, based on the Therapeutic and Eco-tourism vision, the idea is to innovate a building which is not only successfully provides its required functions, but also maximizes the usage of the rest of the city touristic attractions and potentials.

4.1 The existing Filanda evaluation and retrofitting

With respect to the definition of Culture heritage as "the entire corpus of material signs – either artistic or symbolic – handed on by the past to each culture and, therefore, to the whole of humankind[6], dealing with the Filanda as a part from the city cultural heritage guided us to introduce the concept of balanced intervention and adoptive reuse, by following a simple theoretical frame starting from the knowledge and evaluation, reaching to the function selection and retrofit action decision, which can be concluded as below:

- Building components' historic evaluation;
- Those parts which are unchangeable and strong features of the building;
- Features of the surrounding context and urban fabric (materials, shape, texture, morphology, functions, users ,etc);
- Damage and materials survey;
- Serviceability assessment analysis including structural functioning and the needed maintenance for MEP;
- Existing vertical connections assessment;
- Voids or no more existing parts;
- Building energy consumption audit (using Non Destructive Tests);
- Microclimate investigation of light (luminance level, UV and IR radiance), temperature (external and internal temperature, daily and seasonal gradient), relative humidity

[6] New architecture and existing buildings, Prof.ssa.E.Rosina, Lecture, Polimi.2012

(external and internal relative humidity, daily and seasonal gradient) and air (air change rate, indoor air movement, CO_2 concentration, and pollutants Dissemination)[7];

- Thermal, visual and acoustic comfort assessment ;
- Choice of the new use with relevant supporting studies;
- Definition of possible retrofitting actions with respect to the reversibility, compatibility and recognition;
- Feasibility and functionality analysis; and
- Critical points: solutions case by case (Standards requirements, energy efficiency, Accessibility and sustainability).

Considering the refurbishment of the ex-Filanda is not the main scope of this thesis, we will present a sample extracted from the studies and research we have accomplished regarding the existing building, to guaranty the comprehensiveness and coherence of the final achievement.

4.1.1 Building Survey:

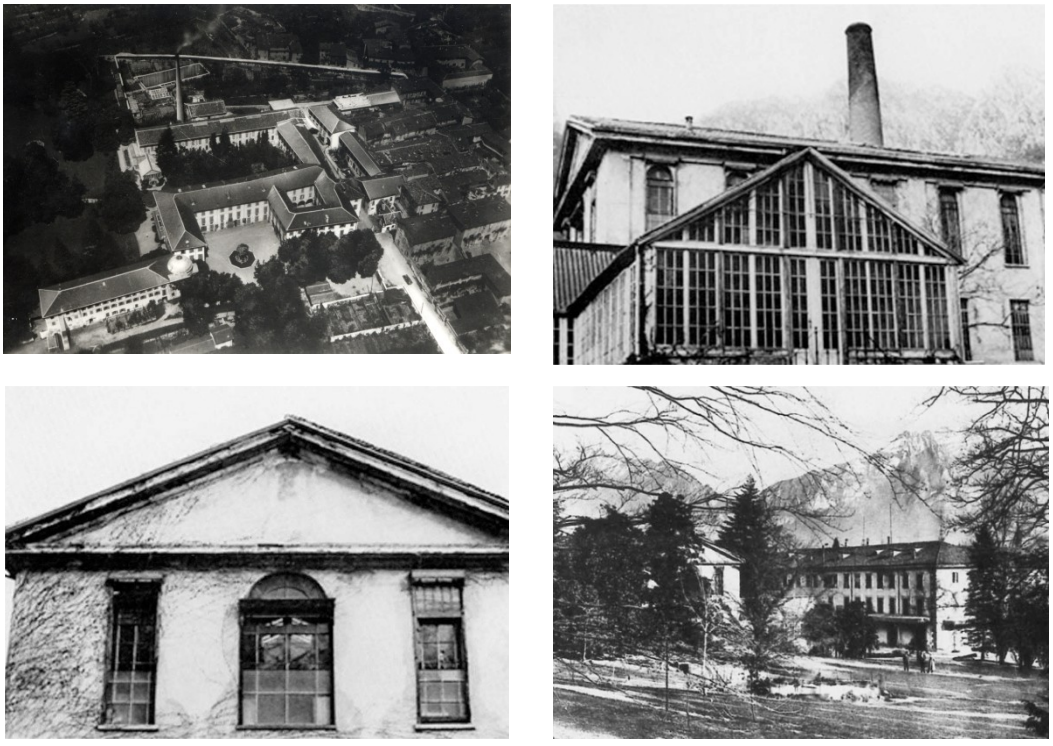


Figure 37 The Mill historical images (Extracted from the competition brief files)

[7] Energy Efficiency in Historic Buildings: a Tool for Analyzing the Compatibility, Integration and Reversibility of Renewable Energy Technologies, Elena Lucchi, Polimi.2011

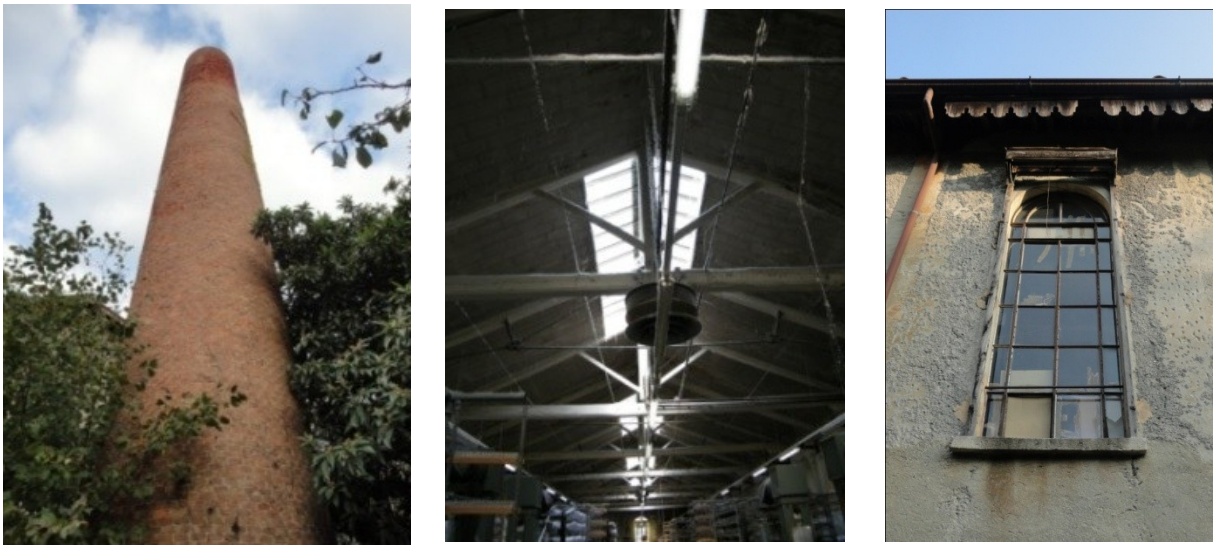


Figure 38 Building main features i.e., (Chimney, wooden truss and canopy)

Figure 39 Sample of the facade material survey

Sample of the drawing, as outcome from survey is presented above, noting that another set of drawings can be found in APPENDIX_C.

4.1.2 New Function, Reversibility and compatibility

After proceeding with an investigation phase to know what kind of spaces can be accommodated in different floors of the mill, with respect to adoptive reuse main key words (knowledge, Recognition, reversibility, and compatibility), the suitability of the subjected functions can be clarified as below:

- The 1st floor:
  We can find a longitudinal universal space with a pitched roof, sky lights and massive reinforced concrete flooring, which used to be the former production hall, in addition to an array of windows oriented towards the private Park. The new added function located inside that floor should maintain the visual and spiritual continuity of the space and maximize the usage of daylight and views, as well as taking advantage of the floor concrete slab which used to carry the heavy machinery. The accommodated functions should have the minimum MEP requirements, due to the lack of cavities and slops in this floor.
- The Ground floor:
  A grid of structural columns can be found with proper span intervals, relevant space can be furnished with a type of function which requires a modular partitioning division system, and should take advantage of the private view towards the park and the mountain. Also an existing drainage system with a proper slope can be found in the ground floor slab, which is quite suitable for wet and services spaces with a heavy MEP works.
  Direct access to "Via volta" with small inner stair case can be suitable for public, staff and after hours activities.

Note this point that further micro zoning analysis will be clarified in chapter II.

4.1.3 Proposed Interventions:

"Clearly, The Sub-disciplines of Heritage conservation and Green-Building Design fell under the Umbrella of Balanced Sustainable Design and had much to offer each other[8].

Interventions and retrofitting actions should follow sustainable conservation principles, as high energy and environmental performances may lead the preservation of a building, but each action on historic and listed heritage gives attention to the matter of vulnerability, physical alteration, and decreasing of immaterial and material value. The most important principles for sustainable conservation[9] are:

- **Compatibility**: modern materials tend to be harder, less flexible, and less moisture permeable than traditional ones. For these reasons when are used in direct conjunction with historic fabric can greatly accelerate decay in the original work;

[8] http://www.ncshpo.org/current/pdfinitiatives/APTGreenBulletin.pdf , John Lesak_2004
[9] Energy Efficiency in Historic Buildings: a Tool for Analyzing the Compatibility, Integration and Reversibility of Renewable Energy Technologies, by Elena Lucchi, Polimi.2011

- **Aesthetic** integration: history and authenticity of historic building should be respected as essential to its significance;
- **Reversibility**: the unavoidable changes of the building should wherever possible be made to be fully reversible. Adopting this principle, the valuable historic fabric can be returned to its original state without damaging the building; and
- **Emphasis on effective maintenance**: care, planned conservation, and management should include regular inspections so that defects can be discovered whilst still small and easily fixable. This permits to preserve historic fabric, minimize cost and disruption to the building's owners and users.

Measurements	Compatibility	Integration	Reversibility
Roofs			
Add rigid insulation on the top surface	■	■■	■
Apply sprayed foam insulation to the top	■	■■	-
Install underside insulation	■	■	■
Install insulated ceiling	■■	■	■
Walls			
Insulate with thermal plaster or wall	■	■	-
Basement			
Install underside insulation	■	■	■
Windows and doors			
Install high-efficiency doors and windows	■	■	-
Install low-e glasses on existing frames	■	■■	-
Transparent Insulating Materials	■	■	-
Install selective materials	■	■	-
Install weather-stripping on windows	■	■■	■■
Shading devices			
Install internal shading devices	■	■	■
Day lighting systems			
Install diffusers on existent glasses	■	■	-
Install interior curtain	■■	■■	■

Incompatible actions: replace with insulated or green roof; insert ETICS or double façades; install storm windows, films or supplemental glazing; add veranda or solar greenhouse; maintain fit, closure and sealing of windows; install external shading devices, skylights, light pipes or light shelves; painting for minimizing the sunlight absorption

Note: ■■ = Yes - = No ■ = Specific project is required

Figure 40 Examples of the envelope retrofit actions[10]

[10] Energy Efficiency in Historic Buildings: a Tool for Analysing the Compatibility, Integration and Reversibility of Renewable Energy Technologies, by Elena Lucchi, Polimi.2011

Measurements	Compatibility	Integration	Reversibility
Boiler plants			
Test boiler efficiency	■■	■■	■■
Optimize the air-fuel ratio	■■	■■	■■
Install air conditioning units and heat pumps	■■	■	-
Install an exhaust air heat recovery system	■■	■	■
Clean and repair radiators and convectors	■■	■■	■■
Replace exiting systems with radiant panel	■	■	-
Install single-zone systems	■■	■	■
Install thermostatic controls	■■	■■	■
Optimize the operating temperatures	■■	■■	■■
Electric systems and artificial lighting			
Install the most efficient lamps and ballast	■	■	■■
Install dimmers	■■	■	■
Maintenance of lamps	■■	■■	■■
Solar energy technologies			
Install photovoltaic panels	■	■	■
Install solar heating panels	■	■	■

Incompatible actions: install mechanical ventilation pant; insulate the distribution system; insert wind technology systems

Note: ■■ = Yes - = No ■ = Specific project is required

Figure 41 Examples of the Plants retrofit actions[11]

As emphasized above, the criteria for selection of retrofit action should consider the physical impact on the existing building components, in addition to its influence on the envelope's thermal performance. To take the Sustainable envelope preservation into account, different solutions were proposed based on the current U-Values, taking the walls for example[12]:

- Conservative Strategy:
  With a lower visual impact on the external facade, in order to preserve the historical value of the building.
- Ameliorative strategy:
  That includes thermal insulation on both the internal and external surface of walls.

Noting that both of the above approaches can be applied with Natural and Synthetic materials, and can improve the U-values as per the below schedule.

[11] Energy Efficiency in Historic Buildings: a Tool for Analysing the Compatibility, Integration and Reversibility of Renewable Energy Technologies. By Elena Lucchi, PolimI.2011

[12] Life Cycle Assessment of different refurbishment strategies for an historical building: the importance of the indicators for the comparison of synthetic and natural materials. By Gianluca Ruggieri, Giovanni Dotelli, Paco Melià and Sergio Sabbadini,Polimi

	Current walls Transmittance 2 w/m2 k	
	Conservative Strategy	**Ameliorative Strategy**
	.66 w/m2 k (67% Decrease)	**.31** w/m2 k (85% Decrease)
Ecological	External layer of painting (2 mm)	External levelling and finishing lime layer (3 mm)
	Existing wall	70 mm layer of lime and cork
	Internal 50 mm layer of insulating earth plaster	3 mm levelling lime layer
	Finishing earth plaster layer (3 mm)	Existing wall
		Internal 60 mm layer of insulating earth plaster
		Finishing earth plaster layer (3 mm)
Synthetic	External layer of painting (2 mm)	External levelling and finishing cement layer (3 mm),
	Existing wall	70 mm of insulating plaster (consisting of a mix of lime cement and expanded polystyrene, EPS)
	90 mm layer of insulating plaster (consisting of a mix of lime, cement and expanded polystyrene, EPS)	3 mm levelling lime layer
	levelling and finishing lime layer (4 mm)	Existing wall
		70 mm EPS board
		Finishing cement layer (3 mm)

Figure 42 The improved U-Values as per different intervention[13]

With respect to the environmental impact, Pay Back and Operational Phase of each solution, the GWP (Global Warming Potential _measured in kilograms of carbon dioxide equivalent) and the EF (Ecological footprint measures environmental direct and indirect impacts in terms of land occupation, land and/or sea consumed) , the figures below can be used to compare relevant alternatives.

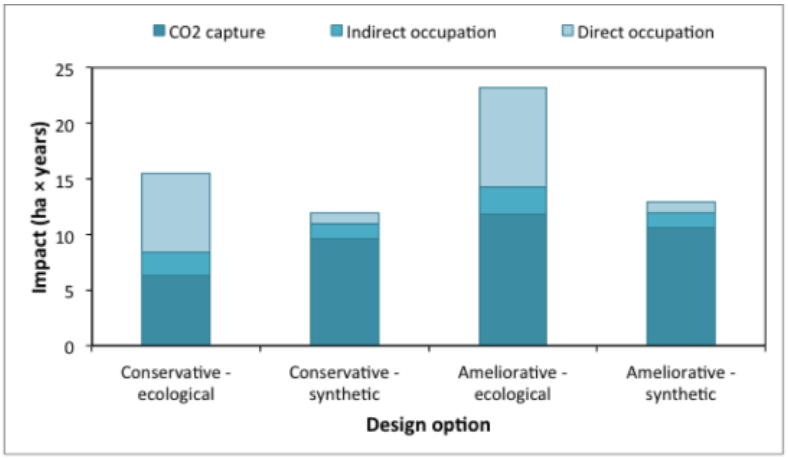


Figure 43 Ecological footprint of the different design options[9]

[13] Life Cycle Assessment of different refurbishment strategies for an historical building: the importance of the indicators for the comparison of synthetic and natural materials. By Gianluca Ruggieri, Giovanni Dotelli, Paco Melià and Sergio Sabbadini,Polimi

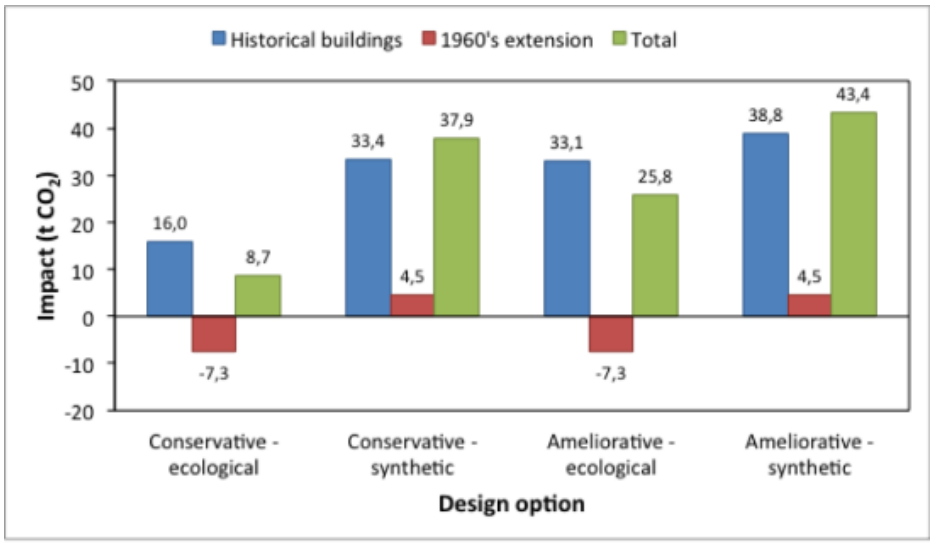


Figure 44 GWP impact of the retrofit for the different design options[14]

	Primary energy demand (kWh/m2 year)
Ex ante	279,2
Conservative strategy	210,4
Ameliorative strategy	196,0

Figure 45 Annual Primary energy demand of the buildings for heating[9]

Retrofit option	Emissions caused by retrofit (t $CO_{2,eq}$)	Avoided emissions (t $CO_{2,eq}$/year)	Payback time (months)
Conservative-ecological	8.7	46.4	2
Conservative-synthetic	37.9	46.4	10
Ameliorative-ecological	25.8	56.1	6
Ameliorative-synthetic	43.4	56.1	9

Figure 46 CO_2 emission payback[9]

Sample of the relevant techniques implementation is presented in the Set of drawings in APPENDIX_C

[14] Life Cycle Assessment of different refurbishment strategies for an historical building: the importance of the indicators for the comparison of synthetic and natural materials. By Gianluca Ruggieri, Giovanni Dotelli, Paco Melià and Sergio Sabbadini,Polimi

4.2 Economical and feasibility studies

Keeping in mind the goal of financial profitability and economical sustainability, the first step is accomplishing a project planning and feasibility study, to determine the most appropriate use for the property. Relevant investigation included a survey for the surrounding current functions, in addition to the supplementary missing activities.

Relevant study is based on a research prepared by (Politecnico di Milano) economical researchers15 as will be presented hereafter, including the feasibility of different uses to be accommodated, like shopping centers, libraries, supermarkets, goldsmiths, shops for animals, healthcare, social and health, banking and credit institutions, restaurant, and offices.

As per their initial analysis and conclusion, a Luxurious resort with wellness center and restaurant is the most efficient use for the property, some of those analyses are presented below.

4.2.1 The site characteristics and business idea

With respect to the presence of the romantic garden and being located only hundred meters away from Lake Como and the mountains, in addition to relevant centrality, proximity to Milan and Lecco that adds to the value of the place and maximizes its potentials. The business idea consists of upgrading of the former Gavazzi spinning mill through the opening to the public of a luxury wellness and spa resort, with possibility for short term accommodation to enjoy the natural scenery, the services offered and natural cuisine.

Figure 47 The context General view

4.2.2 Market Demand

In Italy, demand for services related to well-being and health is still growing rapidly, as the SPA is no longer dedicated only for middle and upper income groups. This favored the renewal and the expansion of the customer's categories, also very abundant in the lower age groups.

Young people under the age of 35 account for about half of the customers a health clubs according to 2007 data were 48%. The customers between 18 and 29 years attending the centers especially for beauty treatments, while that is more adult category is targeting massage and various relaxation techniques. Although women still make up the majority of users (approximately 70%), over the

[15] RIQUALIFICAZIONE DELL'EX FILANDA GAVAZZI, VALMADRERA (LC), Docente: Prof. Alberto Pavan,Polimi

years the rate of male customers has increased, not only for relaxation but also to take care of their physical appearance.

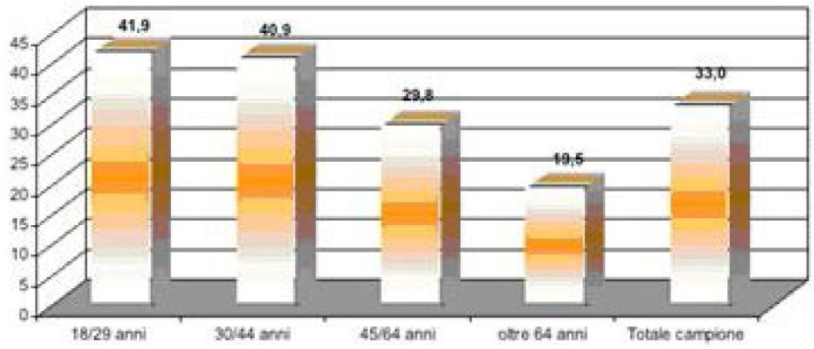


Figure 48 Demographic and age analysis[16]

By adding the short term accommodation and the presence of the restaurant, a large number of customers are expected to occupy the center, especially from the remote areas which are not easily accessible for a single day of relaxation at the spa.

4.2.3 Wellness Industry analysis

In Italy, firms that offer services related to welfare are about 30,000 and occupy 56,000 employees. also there are approximately 4,200 hotels and cottages with spa, 1400 gyms and swimming pools, spas and 2,500 bathing establishments[12].

The market of wellness, Spa, beauty farm and other similar centers, is growing 8 to 10% annually. This expansion did not stop even in 2008, with the decline of economic crisis. According to the latest available data from the Italian Association of Health Centers, the sector's income in 2008 was about 16 billion euro. It states that the sector is in the development phase, thanks to the increasing attention from the population to the issues of health, beauty and wellness.

4.2.4 Related market survey

The analysis had been carried out in relation to sport, fitness and wellness centers in the territory of Valmadrera, the results can be highlighted as per the figures below. Within the commune of Valmadrera there is already a center for fitness which is well equipped, it has fitness room, organizes courses of gymnastics, dance and spinning , in addition to swimming courses at all levels and for all ages (from 3 months to adult education). Other gyms and fitness centers are also present in the nearby town of Lecco.

[16] RIQUALIFICAZIONE DELL'EX FILANDA GAVAZZI, VALMADRERA (LC), Docente: Prof. Alberto Pavan,Polimi

Figure 49 Competition survey in the range of 30km

Figure 50 Competition survey in the range of 2.8 and 4.2 km

On the other hand, the lack of relaxation resorts can be stated, as the combination of (Wellness, Spa, green healing, restaurant, and short term accommodation) does not exist, as the closest are in the area of Bergamo, about 40 km away from the area of interest, or Sondrio which is about 80 km away, so the aspect of competition with other facilities is very limited.

From that, the activity would become in fact a point of interest not only for the inhabitants of the city of Valmadrera, but as a regional center for the "Therapeutic tourism ".

4.2.5 Pricing and financial plan

Based on a survey done for similar functions, the following expected rates can be assumed[17]:

- For Overnight + Dinner + Wellness center entry

High season: 70% of the rooms occupied during the weekend, 40% of the rooms occupied during the week at a price of 170 € per person. Low season: 50% of the rooms occupied during the weekend, 20% of the rooms occupied during the week at a price of 140 € per person.

- For Wellness center

High season: 50 people will use the wellness center (in addition to those who stay in the rooms). Low season: 20 people use the services of the wellness center (in addition to those that staying at the rooms).

Ingresso 3 ore (Lun-Ven)	25 euro (+3 euro ogni ora in più)
Ingresso 3 ore (Sab-Dom-Festivi)	30 euro (+3 euro ogni ora in più)
Ingresso Full Day (Sab-Dom-Festivi)	35 euro
Ingresso Full Day (Lun-Ven)	30 euro

Figure 51 Spa area access rates[13]

- For Restaurant

Price per person for a simple meal with drinks € 51

Price per person for a full meal with drinks € 100

Weekend: 75% of seats occupied.

Week days: 20% of seats occupied.

The final expected bills and evaluation of the economic return can be presented as below, as extracted from the previously mentioned study.

[17] RIQUALIFICAZIONE DELL'EX FILANDA GAVAZZI, VALMADRERA (LC), Docente: Prof. Alberto Pavan,Polimi

Figure 52 The payback period[18]

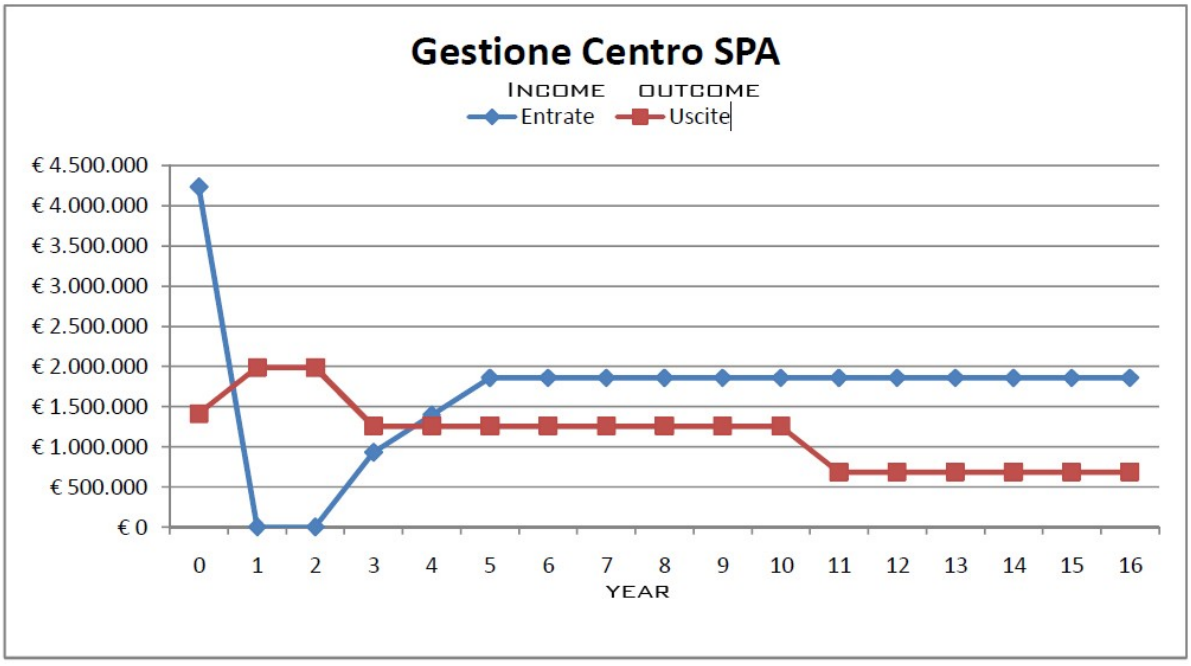


Figure 53 Income vs. outcome[18]

[18] RIQUALIFICAZIONE DELL'EX FILANDA GAVAZZI, VALMADRERA (LC), Docente: Prof. Alberto Pavan,Polimi

CHAPTER II

Urban Design

1. Scope definition and transformation Statement

"Making places people love to live in means making them safe, vibrant, active, appealing, and sustainable."[19]

Thus the vision is based on health, eco-tourism, humanization of mobility networks, and historic preservation and creating a new compact public spine following the sustainable transformation approach. Desired Transformation of the areas is for providing the city with a potential to become a touristic landmark concerning medical Therapy, health industry and general tourism exploiting the opportunities present therein.

Regarding those aspects, the development from historically industrial to a new touristic destination will have the following **Potentials and challenges**:

- Historical significance of the Valmadrera city and high social status of Gavazzi family itself.
- Former economic (industrial & stock market) hub of the Lombardy Region.
- Retransformation and birth of a new city with Status Resurrection and revival of the past glory by developing an iconic image.
- The financial and social layout of city residents.
- Sense of social equilibrium aspects under the public definition of the Site.
- Increasing quality of urban fabric and interconnection of the, cycling, hiking and walking routes.
- Preservation Flora and Fauna within the policies of "Natura 2000".
- Environmental Sustainability and Profitability "sustainable, eco-friendly and health oriented transformation".
- Considering PCTP and PGT visions for the transformation of the area.
- Integration and involvement of the public in defining their city development.

2. LEED ND as design guide line and polices

Since that the built environment has a profound impact on our natural environment, economy, health, and productivity, also with consideration to the Environmental global awareness and the green building movement which offers an unprecedented opportunity to respond to the most important challenges of our time, including global climate change, dependence on no sustainable and expensive sources of energy, and threats to human health, we addressed in our Thesis proposal to follow the LEED as a design guide line and development framework , during the project different

[19] Neighbourhood for people

phases, starting from the analysis and investigation , passing through the selected Strategies , and finally by relevant implementation into the Master plan.

Thus, the main LEED Prerequisites and Credits like (Smart Location , Wetland and Water Body Conservation , Agricultural Land Conservation , Walk able Streets , bicycle Network and Storage, locations with Reduced Automobile Dependency, reduced Parking Footprint, transit Facilities, Access to Civic and Public Spaces, on-Site Renewable Energy Sources, Solar Orientation , Compact Development , Connected and Open Community , Energy Efficiency , Water Efficiency , historic Resource Preservation and Adaptive Use etc,.) were been used to investigate/evaluate the site area and to select relevant improvement solutions

Figure 54 Adjacent and connected project site based on minimum 25% of perimeter adjacent to previously developed parcels and at least 90 eligible intersections per square mile with in 1/2 mile of boundary segment adjacent to previous development

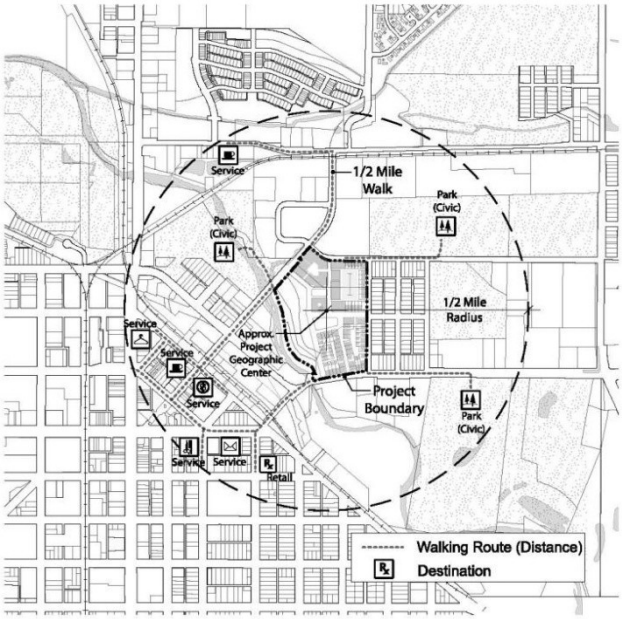


Figure 55 Walking routes on pedestrian network showing distances from dwellings and nonresidential uses to diverse use destinations

For example (but not limited to): the Existing Site context was analyzed by looking for the answers of some questions like:

- In a circle of 0.5 mile (800m) and 0.25 mile (400m),measured from the site boundaries[20] :
  - How many street intersections?
  - Are there any Local /Regional transportations station?
  - How many public spaces/recreation facilities can be found?

[20] LEED ND

- The mix of non-residential functions in the area, specially the Ground floors.
- Is it surrounded by a proper percentage of developed areas (the Infill site)?
- The neighborhood compactness and building footprint/pattern/ratio.

- Are there any ruined areas or Brownfield to be re-developed?
- Any available potential for Local food production and agricultural Landscape?
- Are the streets provided with suitable Tree-lined sidewalks, Bike path/racks, etc,
- Street network, Mobility, city accessibility, Transit facilities Parking lots, etc.,
- The situation of the water bodies/canals and wetlands, and their connection with the Lake.
- Any Historical abandoned buildings to be Refurbished and integrated into the cultural/ social urban fabric.
- Are there any remarkable Flora and Fauna to be preserved/restored, including the Green areas in general?
- Water /Air quality, land slopes and Natural Risks.
- Can we find any existing /potentials for waste treatment and renewable energy production units?

Relevant sub-credits will be implemented while going through the report, and evaluated.

3. Site Analysis

For the consideration of the area in which the urban analysis would occur, it was decided to do macro analysis for the whole city of Valmadrera including site investigation and considering previous studies and analysis from PTCP and PGT, from which a series of relationships between, historical center, public spaces, green, residential, industrial, degraded, and infrastructural areas can be extracted. We can elaborate the contextual importance of the site and the city, encompassing great potential to be converted into a touristic and social hub, thus playing a part in the futuristic economical and social up gradation

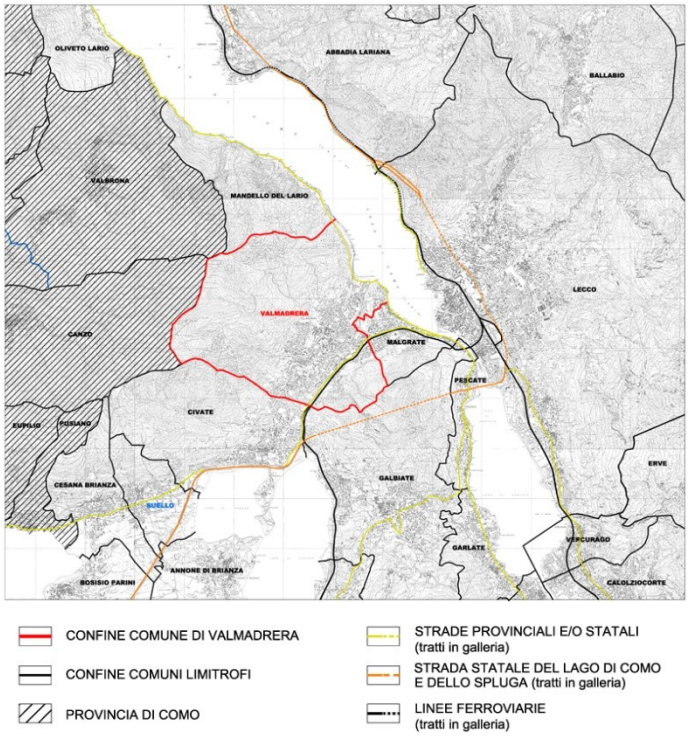


Figure 56 PGT definition of areas

of the city itself.

Then further analysis will focus on the spine connecting Valmadrera train station and the main entrance on Lecco-Como high way with the project site at Gavazzi complex with more emphasis on utilization of the areas along the spine to make available for the general public usage.

3.1 Solid to Void

With consideration to the sustainable advantages of the compact cities, we can notice the commune of Valmadrera has low density building and high un-efficient consume of territory (high dispersion). We can see many different urban fabrics, with problems of separation and fragmentation, with scattered residential areas all over the city which gives the impression of social segregation and lack of mixed integrated diverse communities.

Figure 57 Solid to void ratio

There are a lot of voids can be noticed in the form of open spaces and green areas, but most of them are neglected and scattered, such lack of connectivity creates abandon un-rehabilitated depressed areas, with no regular access form to the civic. Unrecognized city grid, with non-continuous, non-walkable, un-connected circulation network.

3.2 Land use Functions

As seen the land use functions can be observed as a collection of residential and industrial buildings in addition to the historical city center, service settlements and large areas of green wood's (some of them under protection). The presence of some former/ current yards and industrial areas which are abandoned, degraded and ready to be reused, renovated and integrated to the city transformation plan.

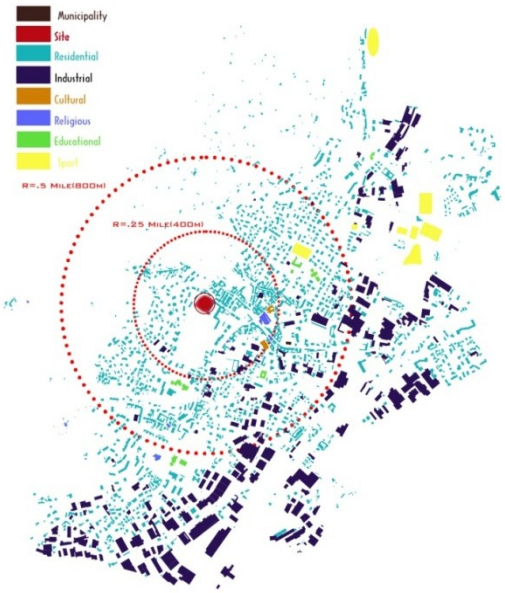


Figure 58 Land uses functions

The site surroundings have a problem of lack of mixed use and diversity of the functional contents, which directly affect the mobility, walk-ability, and socio economics. On the other hand, the city has a lot of touristic potentials in terms of the availability of related functions, like the presence of hotels beside historical center and attraction points.

3.3 Flora and Fauna

The presence of large amount of scattered green areas according to the local territorial plan in which some are protected within polices of Natura 2000 like Mount Barro Mountain with some surrounding forests, and others are subject to development like meadows, urban green areas and sparse vegetation. All of previous are some of the main characteristics of Valmardera that gives a lot of potentials to the relevant transformation and creation of an ecological network, enhancing the resident's quality of life and attracting people desiring health tourism.

Figure 59 Flora and Fauna

One of the main aims is to preserve relevant site habitat (bio-diversity), and Local food production should take place considering its positive effect on the resident's health, socio-economic and public participation.

3.4 Public and civic spaces

Public space provides a spatial framework that is enhanced by public life. Collecting data that describes public spaces and their surrounding buildings is a good way to measure the public dynamic and ephemeral sounds, climate, and the social interactions and human activities.

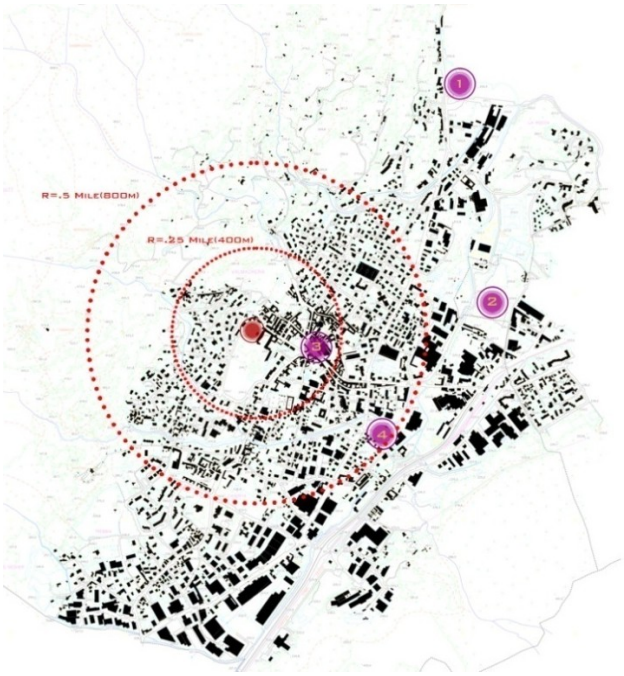


Figure 60 Public spaces

1. PARE' DISTRICT
2. CASETRA ZONE
3. PIAZZA MONS. CITTERIO
4. PIAZZA MERCATO

Thus it could be observed that there is small number of separated and unarranged public spaces that do not contribute in the connection and recognition of the city, and

increase social separation (do not invite and include city inhabitants). Creating abandoned unused areas affecting the liveliness and safety comfort.

3.5 Attraction points

Considering that it is small city, and by analyzing the gateways, thresholds and attraction points, it was observed unrecognized city entrance with a surrounding in general that is relatively rich with a lot of potentials (Historical sites, sport, Nature, touristic spots and recreation).

Important historical places in Valmadrera as highlighted by the Comune[21]: The areas under historical and artistic preference is exclusively highlighted by using the words “real estate of artistic and historical interest Legislative Decree 42/2004 and article 10 & 11”:

- Palazzo Bovara Baracchetti garden
- Villa Hermitage
- Parrocchia Di Sant'Antonio Abate
- Villa and park Gavazzi
- Building alley Giusti
- Cultural Center Fatebenefratelli
- Parish Church
- Town Hall
- Sanctuary of the Madonna di San Martino at Corni di Canzo mountain
- Property located in Piazza Bishop Bernardo Citterio (Ex Villa Ciceri)
- Sant 'Isidoro of Preguda at Corni di Canzo mountain

On the other hand those attractions are poorly connected with each other, not well promoted and badly integrated in the urban fabric affecting the outsider's engagement and interaction.

[21] http://www.comune.valmadrera.lc.it

Figure 61 Sant 'Isidoro of Preguda

Figure 62 The 'Madonna di San Martino'Sanctuary

Figure 63 San Tomaso natural terrace

Figure 64 Rione Caserta 1990

Figure 65 PARE' and behind Mount Barro mountain

3.6 Transportation

It was observed a good connectivity of the Valmadrera City with the region in general. Access to the city can be made by means of train, car and bus. The train is a good connector with southern part of the city which has the main entrance; however it is not used to the optimum due to poor transversal connection with the historical city center, in addition to limited access by pedestrians. This allows for more focus on the mobility of people and goods which is one of the main pressures from the point of view of environmental air quality and for the livability the urban environment.

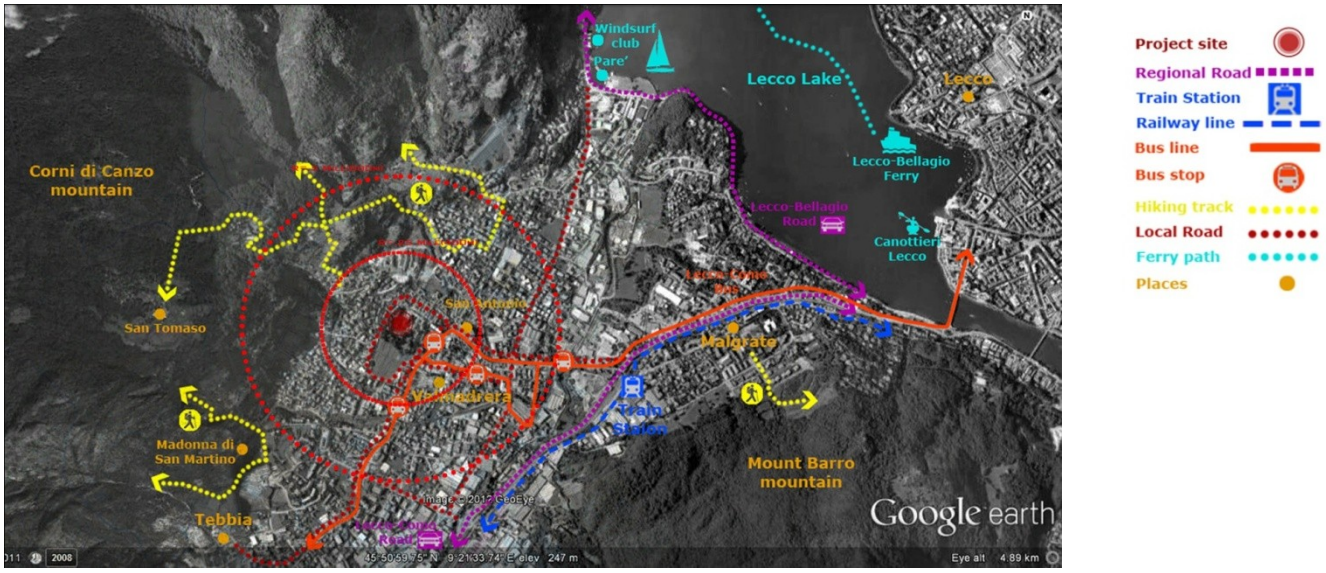


Figure 66 Connection with surroundings

3.7 Street network

The configuration of the city and the interfering of different urban fabrics model the street pattern which is important for the determination of the connectivity correlation in general and the quality of public spaces network which support public life through its scale, form, and use.

It could be observed that there is irregular network of regional streets connecting the city with its neighbors and local streets of the interconnections with a lot of dead-end and limited access streets to the residential zones and factories entrances. Thus, in general, affecting the accessibility to green areas, attraction points, historical center and the flow of public realm.

Figure 67 Street network

In terms of influence and hierarchy, it can be seen that the streets (Via Rome) which is connecting main entrance at the train station to the city center then to the project site and other (Viale Promessi Sposi) crossing the center of Valmadrera and connecting it with the lateral entrances the lake and Pare zone from one side passing through the Piazza Mercato and then to next city Civate from the other side are the dominating veins.

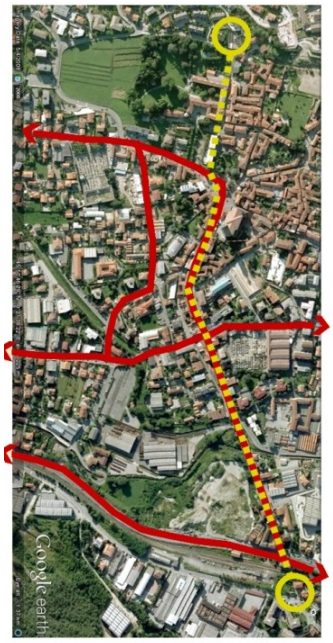


Figure 68 Dominating streets passing through main city axis from train station till Gavazzi complex

3.8 Pedestrians and walkability

Together arrangement of the physical easy accessibility to green spaces with unique pedestrian connections and the bicycle network contribute to the connectedness and recognition of a city.

In Valmadrera there is lack of sidewalks, shaded/ tree lined streets.

Pedestrians' corridors and Bike lanes even the existing are short, interrupted with other elements and not connected with each other in addition to scale being out of human scale.

3.9 Scale comparison

In order to understand and estimate the foreseeable intervention effects for the implementation of the transformation vision, a scale comparison was needed in which it was found that the distance between the train station at the entrance of the city till the Gavazzi complex was almost 1.1 kilometers which is a suitable distance to be made by walking (15 minutes) or even by bike (5 minutes).

For the comparison study we related this distance to the city center in Milan and it was almost the same distance from the starting of piazza Duomo till end of piazza Castello which is considerable for pedestrians specially if there are interesting activities through it.

Figure 69 Distance from Duomo to Castello- Milan

3.10 Topography

From the analysis and site investigation, a clear natural slope exists in which it contributed in good visual connectivity between the main focal points in the city including the bells' tower of church Saint Antonio (Parrocchia Di Sant'Antonio) and chimney in the site of the project, they are even recognized from the high way and the surroundings outside the city.

3.11 Spine Analysis

Focusing on the zone of the urban development, the main city spine which is considered as the area of intervention is connecting the train station and the entrance on Lecco-Como high way with the historical city center through (Via Roma) street then passing through (Via Manzoni) and ending with the project site at Gavazzi complex. This area has the required potential for the for the transformation vision due to its strategic location and historical value, in addition to existence of vital intersecting nodes and the proposed developments of some zones all along the chosen spine by the PTCP.

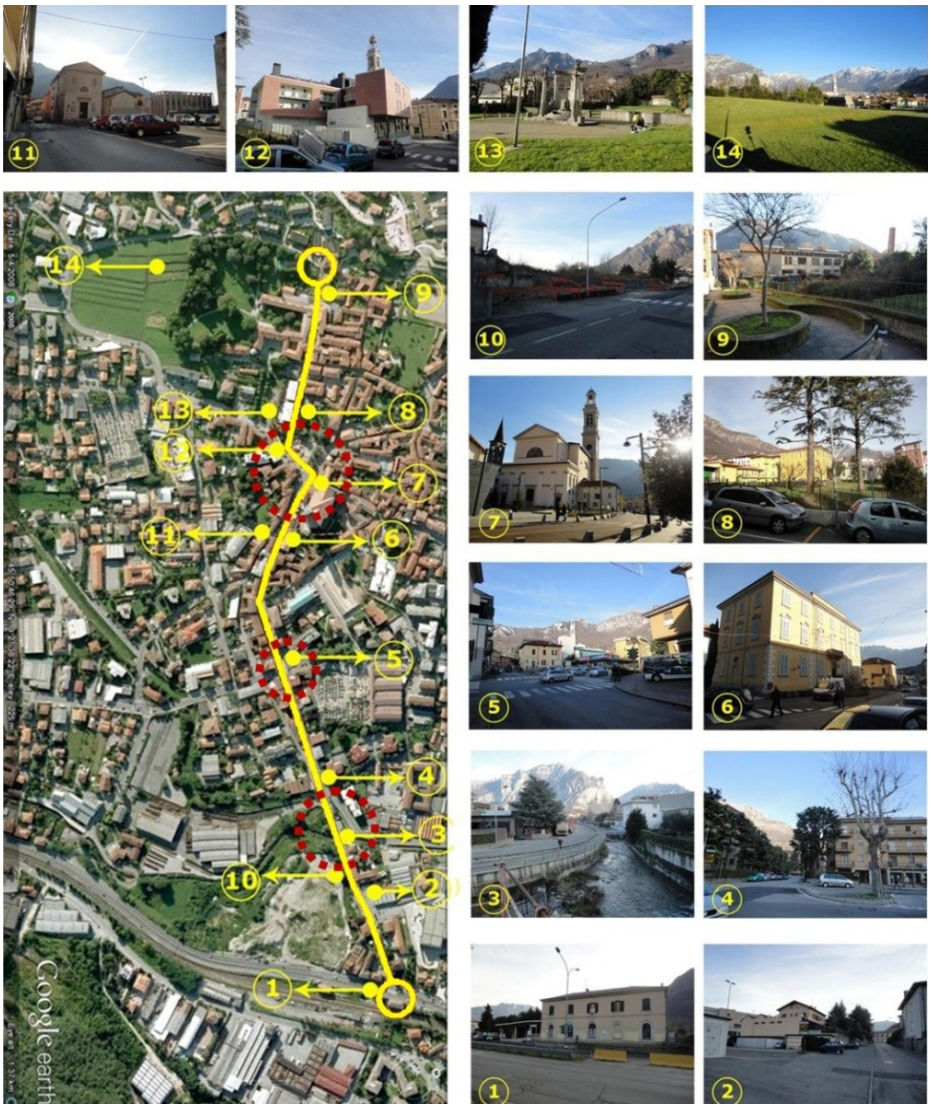


Figure 70 Spine typology and morphology

Moving to the typology and morphology of the previously mentioned spine, it was observed as seen from the illustration the existence of three crucial intersections with the transversal passages. Firstly; the river with the scenic interest, panoramic pathways, and uncompleted bike route towards

the Caserta public area and ending by the lake. Secondly; Promessi Sposi Street which connects Civate city to Pare zone and passing through Piazza Meracto. Thirdly; Monsignor Citterio Square which is at the nucleus of the historical center facing church Saint Antonio (Parrocchia Di Sant'Antonio) that is the starting point to the mountainous sport activities and touristic spots.

Besides that, the existence of abounded areas that needs development and ruined buildings that needs refurbishment, green meadow adjacent to the project site, in addition to public spaces that need to be created, connected, and enhanced with increasing its quality in some cases.

4. PTCP and PGT visions

PTCP vision that proposed the whole region as area of great development potential including Valmadrera as Eco-museum and cultural district of mountains (San Tomaso) in addition to other protected (Mount Barro) and lake in which corridors and pathways can be created and enhanced, rivers and canals streams defined as ecological corridors to be strengthen in order to connect Natural areas along with the environment that was affected by the urban growth and the infrastructure impact. Also proposed Landscape/environment in relation to heritage, be organized, infrastructure near the waterfront to be developed for tourists, and preservation of flora and fauna of native origin in addition to requalification of some spaces and zones.

Figure 71 PTCP Quadro strategic territoriale

4.1 PTCP approach

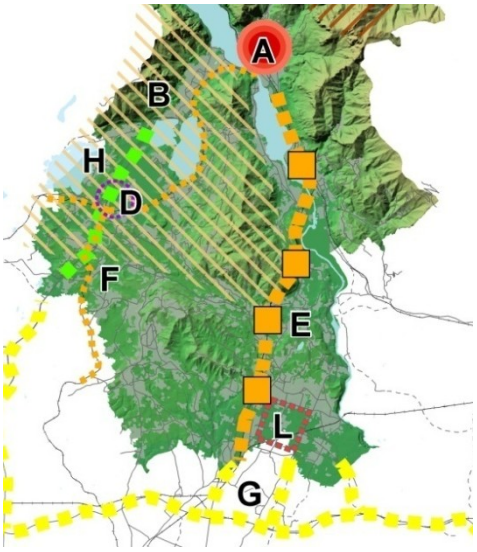


Figure 72 PTCP museum and cultural district area (B)

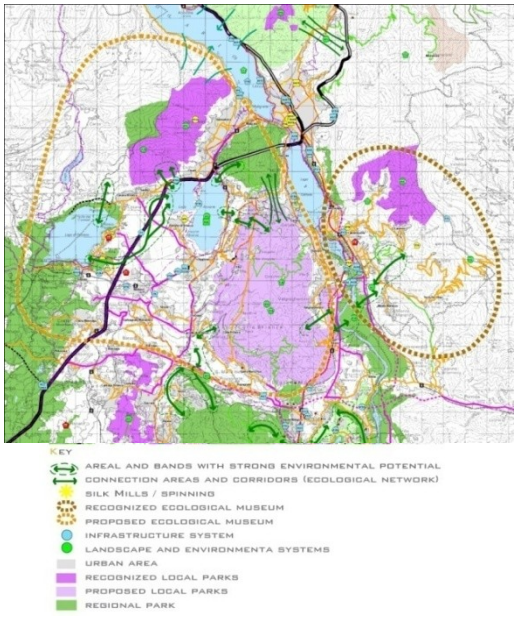


Figure 73 Proposed development plan by PTCP

- Valmadrera is an urbanized city which falls under the proposed development plan on a regional level.
- Valmadrera is one of the Museum and Cultural Districts of the Mountains and Lakes declared by PTCP.
- The roads in predominantly production facilities area and residential areas are highlighted along with the train station adjacent to the entrance point to the city.
- Viability of major communication and transit, just outside the city thus adding to its geographical importance.
- To exploit the recognized culture/touristic system involving the city and adjacent mountainous tracks (Corni di Canzo).
- Existence of landscape/environment system in the recognized area, falling under proposal for development of municipalities.
- Opportunity to develop infrastructure system near water front (lake), in reference to the framework agreement for territorial development.

FRAMEWORK FOR ENVIRONMENTAL QUALITY (Ref: PTCP)

Criteria for environmental sustainability were defined by PTCP including the following objectives:

- Minimization of land use.
- Protection of soil quality and restoration of degraded areas.
- Achieve a sustainable mobility
- Protection and enhancement of natural areas and ecological corridors.
- Increasing the area to urban green spaces and its connections.
- Protection of historical and architectural landscape of the areas of quality.
- Improving the quality of surface water containment and water consumption.
- Increasing eco-efficiency in the consumption and production of energy.
- Containment of air pollution and greenhouse gases.
- Reducing noise pollution.

Figure 74 Ecological Network defined by PTCP

- Limiting exposure to electromagnetic fields.
- Improving the process of waste management.
- Risk containment territorial.
- Improving the quality of the urban environment.

INDICATORS FOR MONITORING THE ENVIRONMENT (Ref: PTCP)

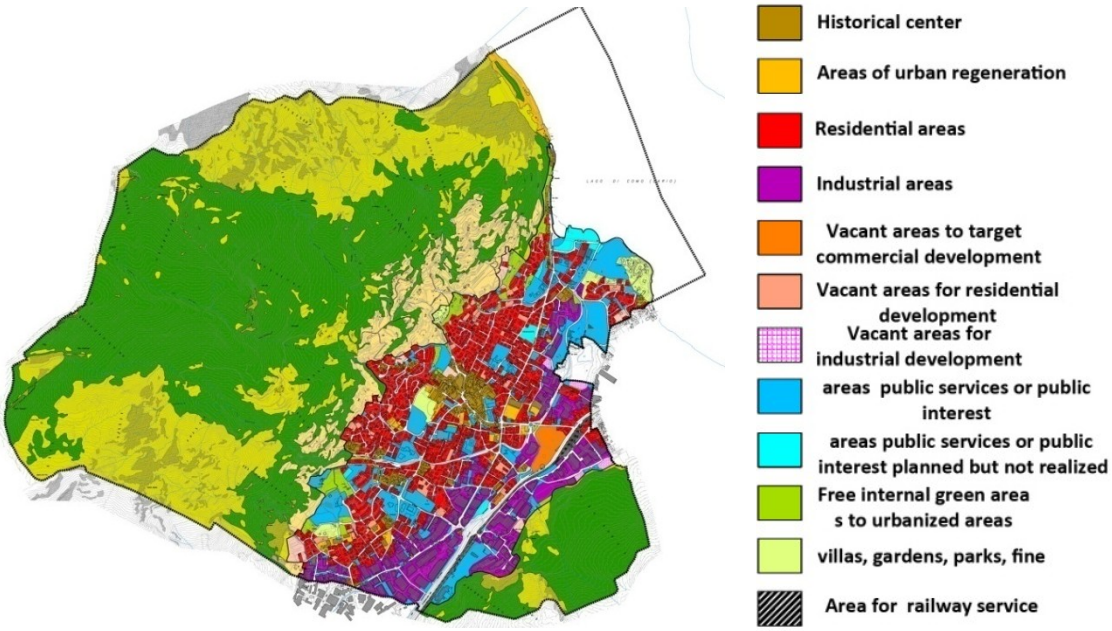
THEME	INDICATOR
Air	▪ Land area affected by risk or hydro geological danger
Noise	▪ Municipalities that have set Zoning Plan Acoustics (n.) ▪ Mitigation measures on infrastructure transport (km)
Water	▪ Quality of surface water and groundwater ▪ Lack of availability of water resources: frequency and duration of the crisis and affected population
Soil	▪ Land use and real rate of artificiality ▪ Total agricultural area and agricultural area used ▪ Surface of reuse of the land / surface urbanisable ▪ New built volumes ▪ Interventions aimed at overcoming the instability, the containment of hydro-geological risks (no.) ▪ Areas (quarries, former industrial, ...) degraded, abandoned, to be recovered and have been recovered and reclaimed ▪ Land area affected by risk or danger hydrogeological
Nature	▪ Implementation of mitigation and compensation (N.of interventions, extension, type) ▪ Realization of the ecological network (number of interventions / extension) ▪ Protected Areas (extension and implementation of new PLIS provided by TCP)

Mobility	▪ Differentiation and extension of the road network ▪ Municipalities that have set the PUT and PM ▪ Mobility managers (n.) ▪ Car sharing (No car) ▪ road accidents ▪ Public transport (buses, trains, navigation: passengers and network length) ▪ Implementation of the Provincial Plan of cycling (% Of implementing new network); cyclist (extension) ▪ Upgrade of the network and railway stations (no.,% of completion of Projects on Land)
Garbage	▪ Production of municipal and special waste ▪ separate collection
Energy and electromagnetism	▪ Contributions paid for energy saving and use of renewable energy ▪ Municipal building regulations and new adjustments PGT with directions to save energy and the use of renewable energy. Municipal plans light (n.) ▪ Installed power of photovoltaic and thermal on public buildings ▪ Electromagnetism (exposed population and the presence generating sources)
Production of quality	▪ Organic farming (extension surface and n. companies) ▪ Organizations with environmental certification
Tourism and activities Economic	▪ Tourist arrivals and overnight stays ▪ Use of eco-museums (number of visitors) ▪ Places to stay low impact (number of farms, B & B, etc.). ▪ Active enterprises by economic sector (no.) ▪ Companies at risk of accidents (no.) ▪ Production centers over municipal (no. those with total pre-requisites required by environmental regulations)
Coordination and integration of local territorial policies	▪ Coordinated projects and marketing actions (no.) ▪ Construction of Cultural Districts (n.)

Table 2 Indicators For Monitoring The Environment

4.2 PGT approach

On the other hand PGT vision represents the transformation potential of city from industrial to public/touristic nucleus and defines precisely the areas functions current state and its development potentials.



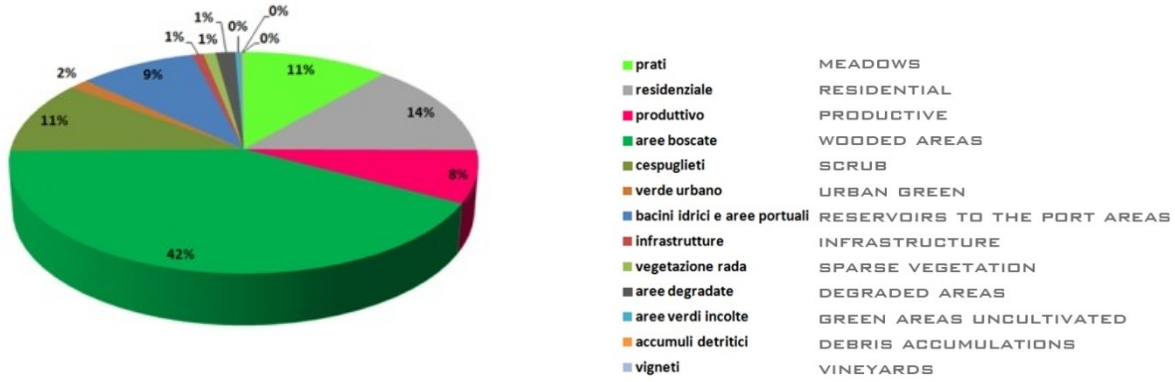


Figure 75 PGT synthesis

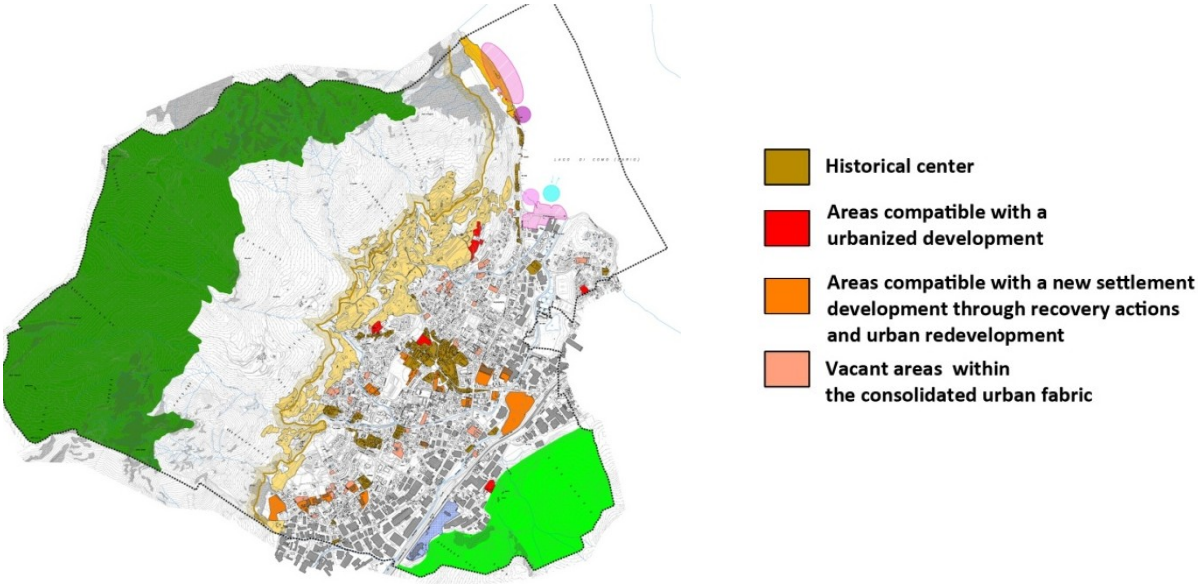


Figure 76 PGT potential areas

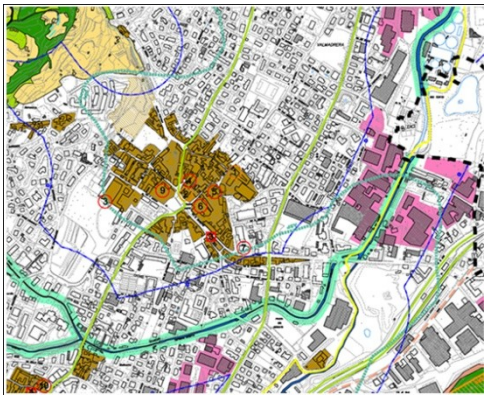


Figure 77 Protection of historical buildings in brown color and areas of respect of Rivers and Lake

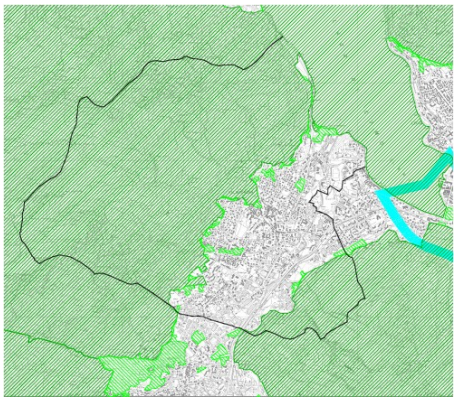


Figure 78 Ecological layout

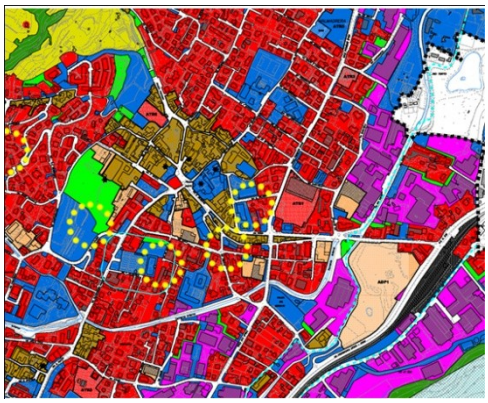


Figure 79 Ruined building to be refurbished

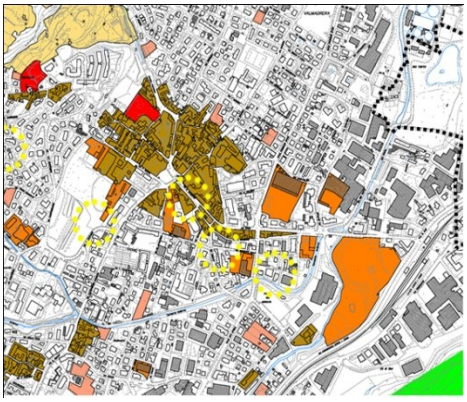


Figure 80 Abandoned areas to be recovered

PGT DEVELOPMENT REQUIREMENTS FOR VALMADRERA		
Theme	**Target**	**Strategies**
Land and Planning policies	Soil protection	▪ Use of areas already allocated to completion ▪ "Re-evaluate" the implementation plans removing critical aspects ▪ Completion of residential areas ▪ Retraining center and nuclei, with partial relief ▪ Protection of the non-urbanized soil ▪ Recovery of spaces for public use
Green System	Formation of large green areas	▪ Enhancement of green areas owned by the city pedestrian connections confirmation PLIS
Service	Social Construction of cultural and recreational facilities	▪ Polo for early childhood ▪ Apartments for elderly ▪ Multi-purpose facility for shows
Build Quality	Limiting energy consumption	▪ Incentives for renewable energy production plants ▪ Inventive for buildings with low consumption ▪ Reuse rainwater for non-potable purposes
Mobility	Qualification of the mobility	▪ Development of spaces for vehicle parking and increase supply parking ▪ Definition of road network routes "lean and safe" ▪ Definition of pedestrian paths and connection with routes supra ▪ Give priority to pedestrian access to the areas to use public (traffic calming, pedestrian zones)
Hydrogeological aspects	Mitigate the risk	▪ Ensure water course access for maintenance ▪ Rainwater through wells ▪ Maintenance scope mount

Productive activities	Business support	▪ Protection of the role of agriculture as a defense of the territory ▪ Encourage the establishment of new businesses in agriculture ▪ Confirmation of the production areas from PRG ▪ Check impacts on settlements and environmental regeneration (filter strips)
Businesses for Sale	Promotion of commercial	▪ Construction of protected pedestrian areas ▪ Urban and event space ▪ Facilitating change intended use in commercial ▪ Enhance the neighborhood businesses, limiting the average distribution
Sports	Creation of appropriate structures	▪ Develop infrastructure in Parè / Moregallo ▪ Realization multipurpose center ▪ Making trails ▪ Improve the Sports Center Rio Torto
Tourism development	Enhancement of economic armature	▪ Qualification of the lakeside area ▪ Links lake - mountain cycle paths ▪ Promote and safeguard the mountain area and its values landscape ▪ Finding parking areas for peak periods

Table 3 PGT development requirements for Valmadrera

The requirement of PTCP and PGT defines in detail the importance of the area in terms of future development and represents the transformation potential of the city as a whole:

- Reinforce the social role, cultural and economic development of the municipality.
- Applying the principles of compensation, equalization, translation and flexibility.
- Organize the network of inter-urban mobility.
- Maintaining and restoring the landscape and environmental character of habitat.
- Scope of protection of the scenic lake and the lake scenery.

- Immovable property of artistic and historical interest.
- Areas of respect from the rivers and lakes.
- Areas primarily for agricultural production.
- Areas compatible with a new settlement development through urban redevelopment and recovery actions.
- Protection and enhancement of historically protected buildings.
- Reallocation / functional recovery of degraded or abandoned areas especially in historical nucleus.
- Protection and enhancement of urban green areas of privately owned, productive and commercial buildings.

5. SWOT

Based on the analysis of all the previous information of the PTCP, PGT and site investigation it can be concluded the following;

5.1 Strengths

- The geographically significant Location along the Roads towards (Lecco, Milano, Bellagio, Como, etc,).
- The Cultural Heritage and Historical background of the city as economic attraction point on the larger scale of Lombardy, as a former industrial and financial/stock exchange center.
- The easiness of reachability and transportation facilities (Train, Highway, Bus line, etc.) mostly within a walkable range across.
- The existence of the Historic city center near the project Site.
- Existing Path along the spine linking the Train station, the Highway, city entrance and Mountain tracks, all within a walkable distance from the Site and from each other.
- The city Potentials and Attractions (Mountains, lake, Sports, Recreational spots, Water channels, etc,).
- Due to high natural topography and slope, the Site and the Historical center are visually recognized from the Highway and railway station including the city monumental skyline.
- The presence of large percentage of Green areas with diverse natural diversity/typology and unique Flora and Fauna.
- The presence of Waste water treatment plant sufficient to cater the needs of the city.

Figure 81 Strengths

5.2 Weaknesses

- Unrecognized city gate/entrance from the Highway.
- Defragmentation of urban fabric (public spaces, Nodes, Historical center, etc.
- A clear social segregation and lack of mixed land usage.
- Insufficient intercity public transportation facilities.
- Lack of connectivity/gathering nodes and undefined social network.
- Low building density and inefficient land/territory consumption.
- The existence of former industrial and abandoned buildings including degraded areas causing lack of safety, comfort and social activities.
- Presence of undefined city grid, street networks, dead-end streets and frequent traffic junctions.
- Lack of security and safety comfort feeling in the abandon areas adjacent to the Spine.
- Scattered and neglected Green areas.

- Poor pedestrian network because of the Lack of continuous sidewalks, bike lanes and shaded/tree lined streets, with out-of-scale, narrow and uninteresting pedestrians network.
- Exceeding level of vehicular traffic noise generation observed.
- High dependency on the SOV, considering 60% of the residents own cars (from studies).

Figure 82 Weakness

5.3 Opportunities

- The huge green meadow adjacent to the site in the middle of the city fabric, which is close to the historical center, and proposed to be enhanced for the public facility by PGT.
- The existence of the ruined and abounded areas along the spine, with a recovery plan provided by the PGT to convert it from un-rehabilitated depressed spaces into functional integrated ones.
- The intersection between the Vertical central spine and the horizontal longitudinal passages (1-the River, 2-scenic interest /panoramic pathways towards the lake, 3- bike path, etc…) in three main strategic points, to be turned into attractive public transition nodes.
- Scattered green areas and Public areas can be linked to make Ecological network and Touristic route.
- The approach proposed by the PGT of equalization and social equity of giving back to the city.

- The presence of the piazza Mercato area nearby the city exit, which is currently, used as parking area for San Tomaso tourists, with a route passing through the Historical center.
- The estimated 100 km bicycle path existing/incomplete proposed by PTCP, which is crossing the city Spine.
- The proposed plan by the PGT to enhance the public transportation (Ferry, Roads, etc...).
- Installation of renewable non-polluting techniques and low energy buildings as required by PTCP and PGT, to generate energy mainly for the public infrastructure and new buildings.

Figure 83 Opportunities

5.4 Threats

- Light and noise pollution expectations.
- Increasing Traffic rate and the impact of new users by affecting the comfort of local residents.
- Loss of Wildlife and Biodiversity as a result of the development and the new users/occupancy loads against Natura 2000 policies.
- Hydro geological risk of landslide, floods, avalanches etc…

- From municipal level study, almost all water bodies in Valmadrera presented minor water pollution (Rio Torto and Molgoretta being most polluted) except Adda, Pioverna and Varro streams. In addition to the detection of Macro-Wide emissions of Green house gases (Including CO_2, NO_2, SO_2, PM_{10}, etc,).

Figure 84 Threats

6. Goals and objectives

Regarding the competition requirements in addition to the previous analysis and the visions proposed by the PTCP and the PGT, the following Goals and Objectives to the project can be determined and specified;

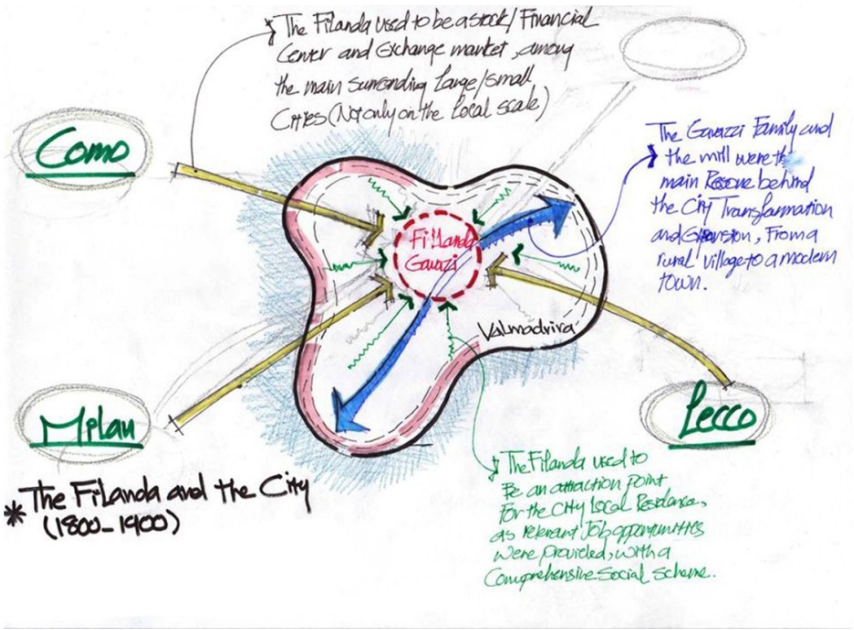


Figure 85 Capturing the historical spirit

- Creating a unique example of sustainable, eco-friendly, health oriented transformation from industrial to social nucleus.
- Developing an iconic image to the city using vision provided by PGT and PTCP.
- Improve quality of urban fabric and humanization of public mobility networks.
- Constructing protected pedestrian and cycle paths, interrelating surrounding cities creating central node of transit, facilitate access to the city historical center with Collective public parking.
- Improve Quality of life, health and well being of the citizens and Equity, to maintain all stakeholders‟ Engagement and Community outreach".
- Reusing the abandoned and ruined areas, to be integrated in a mixed use urban form with consideration to the adaptive reuse from the Historical preservation point of view.
- Minimizing the Ecological footprint and Built Environment impact, increasing eco-efficiency in consumption and production of energy to reduce input to environment.
- Preserving and strengthening the Bio-Diversity, vegetation, Flora and Fauna to maintain balance with Nature.
- Maintain cultural heritage and local regional Identity. Avoiding new interventions that alter visual perception interplay between town and the neighboring hills.
- Enhancing the potential of the site rendering it profitable in favor of the client.

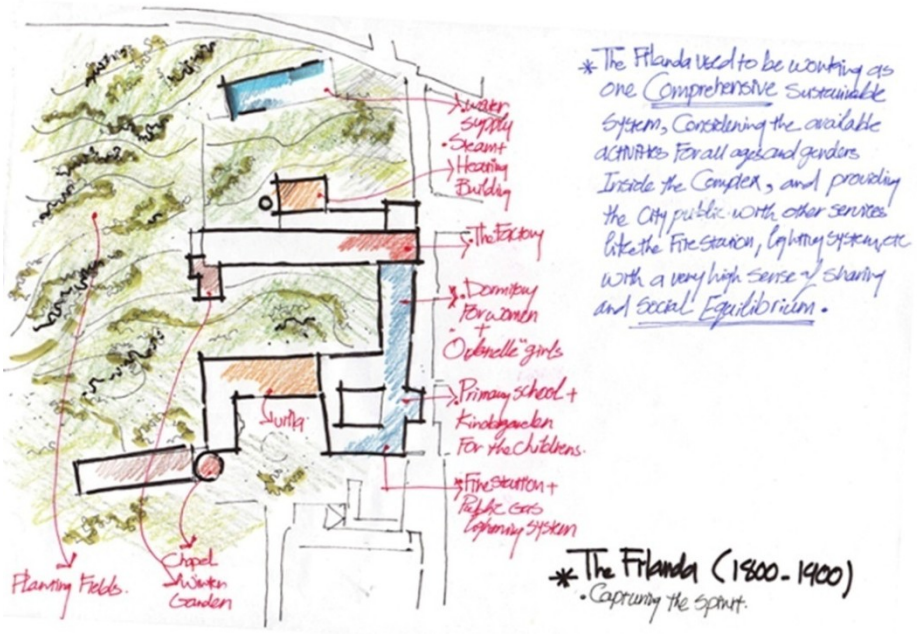


Figure 86 Considering the sustainable vintage scheme of Gavazzi complex that started the transformation in past

7. Actions and Strategies

7.1 Connectivity | Recognizability | Social Interaction

- Providing better connectivity along the city main Spine, linking the site, historical city center, train station and the highway, interconnecting the northern part spaces with southern one.
- Promote the connection between the lake and the mountain area with pedestrian and cycle paths interconnected with the central spine.
- Dynamic Livable/self secures city District , full of Public attraction spots, rich in the Mixed function facilities related to the city new image, to (work, live, play), which guarantees the social diversity , with 2 different themes (entertainment& historical).
- Relocating the starting point of Hiking path (San Tomaso) to the Piazza adjacent to the site.
- Enhancement of the 3 focal intersection points along the spine, to create an attractive coherent understandable link towards the city center, rich with mixed functions and free of charge activities which attract/interact with the Different Genders and Ages like a Large Urban Living Room (Family place, Children Play grounds, Open exhibition areas, Sports, Juggling, Entertainment, clamping, Exercise pads, Mini golf, skating, etc…).
- Introduction of the Biking and Walking along the interactive integrated passages , as an alternative for the typical SOV to limit the VMT , with consideration to the traveling distances and disables/elders , adjacently with the public transportation , with consideration to the scheme of 0.25 and 0.5 mile, proposed by LEED.
- Policies supporting change in the Function of the commercial Ground floor of some Existing buildings, to match the leisure, organic food production and tourism.

7.2 Mobility | Accessibility | Circulation Network

- Managing the transformation of the heavy traffic to a light one into the city, with a limited vehicular access in the center to prevent cutting the historical fabric.
- Converting the Historical city center main spine into a slow traffic street, with some specific areas to be closed during the weekends.
- Facilitate the access to the city, specially the train users, with a transportation entry Hub/piazza with a proper drop off areas, interactive land marks (Ex: London Eye), bike racks/showers, lockers, security points, cafes, etc…
- Maximizing the city gateways recognition/attractiveness for the Highway users, with a direct proper visual accessibility towards the city center.

- The Humanization and definition of the Traffic/mobility circulation (City entrance/exit, the street directions, bus station arrangement, roundabouts, bike lanes, shaded sidewalks, Interactive leisure Street furniture, etc…).
- Providing clean Zero Emission transportation facilities (Bus shuttles, Free Bike racks with Showers/Lockers) from the train transportation hub towards the city center, and vice versa.
- Minimize dependency on the automobile and Limitation of the SOV usage, by reducing the car parking lots in the city center (Only to meet the Local need), and providing an outer garage/parking spots, with free parking areas for car poolers.

7.3 Adaptive Reuse | Preserving History

- The recovery of the abandoned buildings by giving new attractive functions related to the proposed new city image (Silk museum, Open Theater, Visitor center, Play grounds, Conference center, Hotel, restaurants, etc.), in order to maximizing the Reuse of the old existing buildings/infrastructure and minimizing the demolishing , the built foot print and land use.
- Connecting/Linking of the abounded settlements, Infrastructure and ruined areas along/adjacent to the spine, to be renovated and integrated into the city urban routes.

7.4 Environment (Energy | Waste | Water | Climate)

- The new added/renovated spaces are to be designed to maintain their occupancy/usage during different climatic/seasonal changes, considering the accessibility, solar orientation, fresh air circulation and shading solutions.
- Proposing the creation of Biomass Plant in one of the degraded areas by the city boundaries , using that huge amount waste Clippings (coming out of the Massive surrounding green areas) in addition to the city collected waste , adjacently with a leisure Energy park for the public , to produce clean energy for the private and public infrastructure.
- Applying a high efficiency waste management and collecting system, like the big tube vacuum system.
- High efficiency rain water collection system to be used for irrigation and non-potable purposes.
- Improvement in quality of surface water and minimize the usage of the potable water.
- Maintaining the city natural slopes/terrain, with the approach of using specific types of planting to stop/manage the landslides and the soil protection from the phenomena of erosion, deterioration, contamination and pollution.

7.5 (Land & Biodiversity) Green areas | Flora & Fauna

- Creation of new Ecosystem and Ecological corridors increasing functional efficiency of the network by connecting the areas and zones according to PTCP and PGT requirements, passing through the Lake, Caserta Park, the city spine, etc...
- Definition, enhancement and Linkage of the scattered Green areas for the public use and planting the Local food, with a responsible irrigation system, in addition the usage of spiritual and acoustical separation.
- The usage of the engineered Wetland along the water canals banks, to maximize the migratory/native wildlife, Bio-Filtering the water, social activity (fishing, recreation, etc...).
- The Enhancement of the walkways/Bike passage adjacent to the water canals and maintaining their continuity/Linkage/Integration, leading form the lake up to the mountain and Madonna di San Martino church.
- The enhancement and the transformation of the Huge green Meadows adjacent to the site , to be acting like a green lung for the city in a botanical garden/farm and agricultural park/landscape, which improves the quality of life, wellness, social activities, Local food production, etc…
- Regenerate/restoration of degraded environments to maintain the original Bio diversity of Flora and Fauna, with the original native plant species /inhabitants (investigating the existing).

8. Definition of Intervention areas

By considering the transformation vision of the project, all the previous information and their analysis together with the PTCP and PGT visions of requalification, connecting and preserving, in addition to the site investigation and the potentials observed and perceived to achieve the foreseeable goals and objectives, the area of intervention and development will focus on:

- The main spine of Valmadrera connecting the city entrance and the train station with the historical center on which located the three strategic intersections that was mentioned previously (River with the scenic interest/Promessi sposi street/Monsignor Citterio square), and included all along it the abounded/scattered areas, ruined buildings, in addition it will be the transversal connection between two Major attractions; Mount Barro from East side as natural environmental protected zone and Corni di Canzo from west side with San Tomaso as historical cultural zone.
- Zones with required development by the PGT, mainly the huge degraded area on the spine entrance south side which was defined as area of high development potential to commercial and social aspects.

- The historical city center in addition to scattered public spaces and infrastructure settlements around it.
- The streets delivering to the project site, from one sides Francesco Rocca and Alessandro Volta), then the Gavazzi complex passing by Campogrande street reaching the huge green meadow southern the site.
- Passing by degraded side walk on a canal passing by the Mercato square then reaching the Spine again.

9. The Conceptual Design development

9.1 General description:

The specified intervention area of Valmadrera city is almost 1.1 Km long starting from the train station, moving through the spine, reaching the project site, and then turning back in a form of loop passing through the most significant spots in the city.

Valmadrera will be contemporary universal public space with diversity of public facilities that is blended into the urban texture with fusion of Architecture, Landscape, and Art in which includes rather than excludes the surroundings, local residents, and visitors encouraging them to explore its potentials and increase the feeling of belonging to the place.

9.2 Living Walkable Spine

The dynamic Spine as previously mentioned and specified precisely, will be divided into districts suitable for variant people activities from all ages with different attractive images, variety of functions with high excitement and diversity of urban experiences. It is divided according to the walkable travel distances, with a diverse of mobility/traffic hierarchy schemes, totally integrated into the daily social life of the residences.

The concept started by the division into main 4 districts:

i. Entry Hub | Mobility | Energy Park
ii. The Urban Living Room
iii. History | Culture
iv. Health | Recreation

Allowing visitors to feel and perceive the sense of urbanity of the street space that has the potential to take the role of a plaza that is to become a place where people stroll, sit, eat, and watch the activity going on around them.

9.2.1 Entry Hub | Mobility | Energy Park

- Providing a **lively public entrance** with soft boundaries that comes to create cohesion between two entities the **Spine** which connects Valmadrera and the **Train station** which has

a relation with the main city gate and Monte Barro zone that is natural protected area by Natura 2000 policies, and hitting to the first point of ecological corridor thread.

- Changing the road directions to have only the city entrance from the train station side in order to have better, transparent and sustainable humanized transportation network by providing decent Sidewalks, Bike lanes and electric public mobility linking the surrounding and bringing the visitors around.
- Moving the exit near the Piazza Mercato in order to limit re-access to the historical center in addition to smooth dynamic flow of traffic.
- Providing an **Energy Park** in which Nature and Technology will be merged together: Multi function spaces and collective piazza which is connected directly to the train station with maximum visual accessibility towards the city in addition to a drop off area beneath with mobility exchange hub connected to the previously mentioned transportation network that facilitate access to the city with non-motorized approach. It contains Green public areas, playgrounds, courts, soft hills/surfaces appeals to children and families, with leisure spaces, café shops and green porches beneath, that are accessible through corridors formed by slices moved away from the green upper pattern. It is considered city new core which draws people together for passive enjoyment, enabling the city residents and visitors to enjoy the afternoon sun with view towards the historical center and Corni di Canzo Mountain through the observation deck. Considering the orientation, a huge biomass plant can be provided with significant chimneys that can be adopted as a landmark with historical sprit. Using tree clippings from all the city green areas as a biomass fuel and by combining a geothermal system a large amount of clean sustainable energy can be generated that could allow Valmadrera to has self energy satisfaction in addition of providing the surrounding cities with energy if needed.

Figure 87 Chimneys at the energy park inspired by Chimneys at Gardens by the Bay- Singapore / Grant Associates and Wilkinson Eyre Architects

9.2.2 The Urban Living Room

This is the district in which Local residents along with visitors can meet and participate together in different social and sport activities.

- Aligning the activities along the street mean while maintaining the walkways, bike racks and transit stops in order to attract the visitors to the social network and move them gradually towards the city center while they are enjoying the street as plaza in addition to maintained visual connectivity with the tower of Saint Antonio's church.
- Providing street plazas which are a small portion of public open space immediately adjacent to the side walk and closely connected to the street in addition to street furniture like

permanent tables, benches, and facilities such as multifunctional rubber surfaces in addition to fountains with seating around, grills and out-door cafes that make the space serve as an urban living room for social interaction with physical activity, games like chess, backgammon and support weekends gathering and events.

- As sport is one of the few institutions in society, where people can still agree on the rules, no matter where they are from or believe in and which language they speak, so some sport facilities can be moved from the surrounding existing sport centers like Casetra and to be integrated along the urban living room district like some courts as basketball, volleyball, ping pong tables and badminton that will act as youth gathering spots for both residents and visitors, in addition to playgrounds for kids and others of old people like Bocce court, thus increasing the engagement and correlation consequently belonging feeling to the city.
- Extending the existing walkways and bike paths which connect the lake with Casetra then the cultural district into the city and along the degraded banks of the canals and rivers in order to strengthen the ecological corridors and the sustainable, transparent mobility network.
- Providing a Wetland area on the intersection of the river going to Casetra and the edge of the energy park in which it will be a host for biodiversity and for wildlife connection.

9.2.3 History | Culture

This is the district in which the public realm passing through the spine will start to have a different experience of the public space after sudden spatial exchange defined by the street configuration, typology and morphology of being the historical center of Valmadrera.

- Limiting the vehicular access through this district by creating transit mall which is a pedestrian mall that incorporates public transit, allowing for buses, shuttles or other electric public mobility, and limited for private automobiles that will be gathered for parking in one zone to permit the integration of the existing scattered parking facilities for different public functional use.
- The usage of the abandoned degraded areas and refurbishment of ruined buildings to preserve the heritage and maximise the reuse approach with proper linking by partially creating foyers connecting and containing the cultural district that can be defined as open galleries in which some Art works can be placed along which can describe the history of the city together with the existing heritage.
- Reintegration of some buildings in the public life by changing the its function to fit the cultural district vision as it may include museum, Art galleries, and cultural centers providing educational, leisure programmes that recall Valmadrera's historical role.

9.2.4 Health | Recreation

This is the last district of the dynamic spine and the entry of the project site in which it will serve by taking an image and character of health and recreation vision.Creating a mixed mall which is a pedestrian mall that allows limited use by automobiles, only during certain hours and typically on constricted roadbed, extending the bike pathway, and by creating a new parking complex for the residents of this area, this will give the opportunity to connect safely piazza Monsignor Citterio with public space at monument CAD then the project site passing through Francesco Rocca and Alessandro Volta streets.

- Changing the function of ground floor shops to be suitable for the new street vision by introducing new activities like markets for organic food that will be locally farmed in Valmadrera as it will be recommended.
- Providing an outdoor fitness area with some climbing playgrounds, swings, slides and benches that participate in the general fitness of the Valmadrera's residents in addition to fitness festivals for visitors can take place. And preparing people passing through for the head part of the spine at the Gavazzi complex containing the project site in which it will be the health and recreation spot for the surroundings.
- Reaching the project site at factory mill in which the project will exist, it will be defined a new Gavazzi piazza connected to the north of the park attached to the mill in which it will has multi-functional elegant entry plaza with decorative porch and impressive forecourt to attract people from a greater distances and in greater variety. This flexible enough to host different activities as, restaurant, outdoor herbal cafes, art shows, exhibits, some community services in addition to decent parking will be provided to the west side of the park reached from Campogrande street that will serve the residents and the wellness center visitors with high sense of equity and paying back to city some of what it deserves.

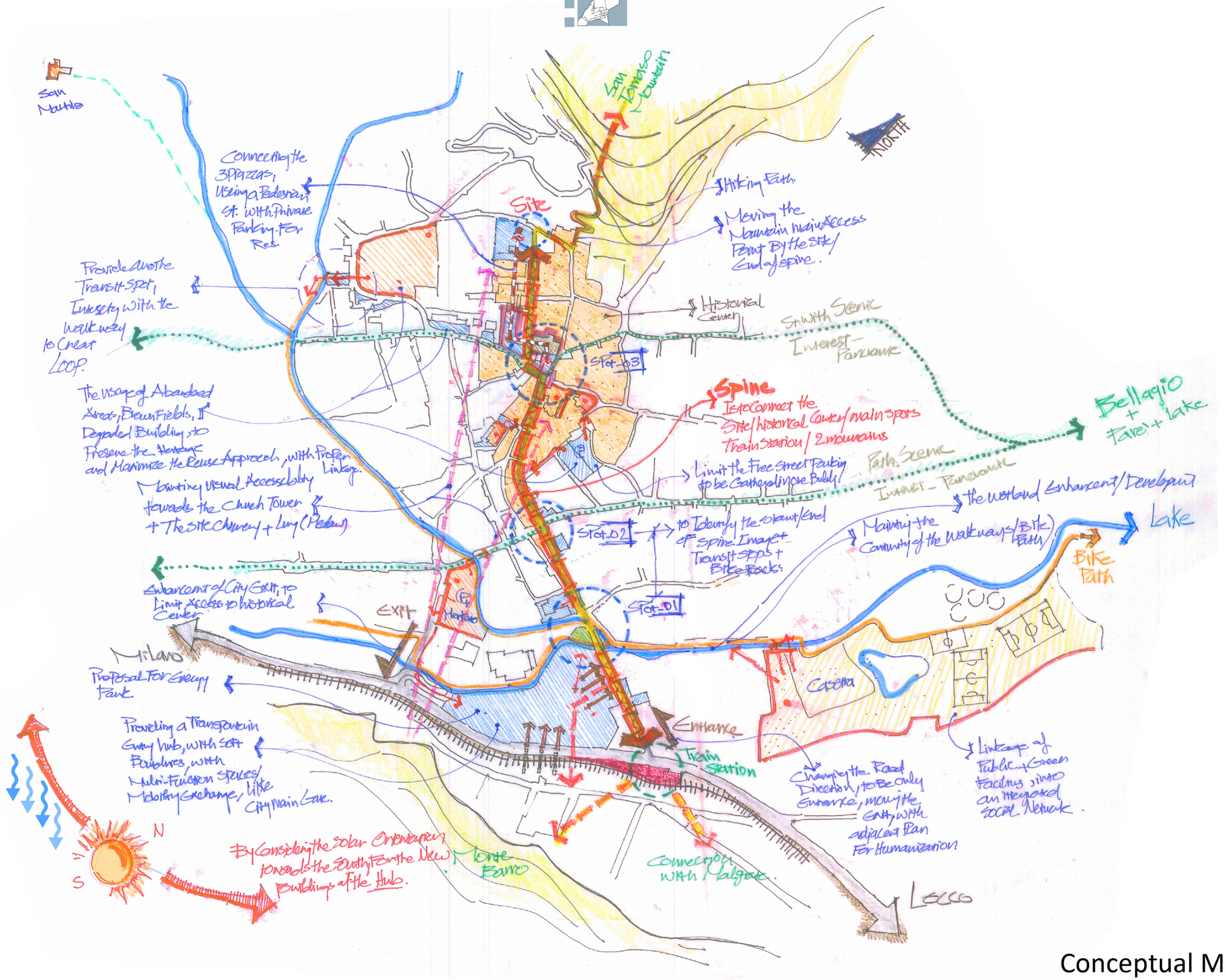
9.3 The Loop

After leaving the piazza Gavazzi which is the turning point was considered the head of the spine and the entrance of the project, the walkable street and the bike path will be extended adjacent to the green meadow attached to the south side of Villa Gavazzi which will be used for organic food production that will serve both the eco-health vision of transformation in addition to economic income of the city (financially).

By the end of the green meadow the way back will start in the form of a Loop using the walk way adjacent to the drainage canal coming from the mountains, passing through the piazza Mercato and reaching the first intersection of the spine at the cultural district. It will be an easy readable exciting way for visitors by giving them the feeling of getting lost and then find their way again by reaching the starting point of the cultural district and the energy park.

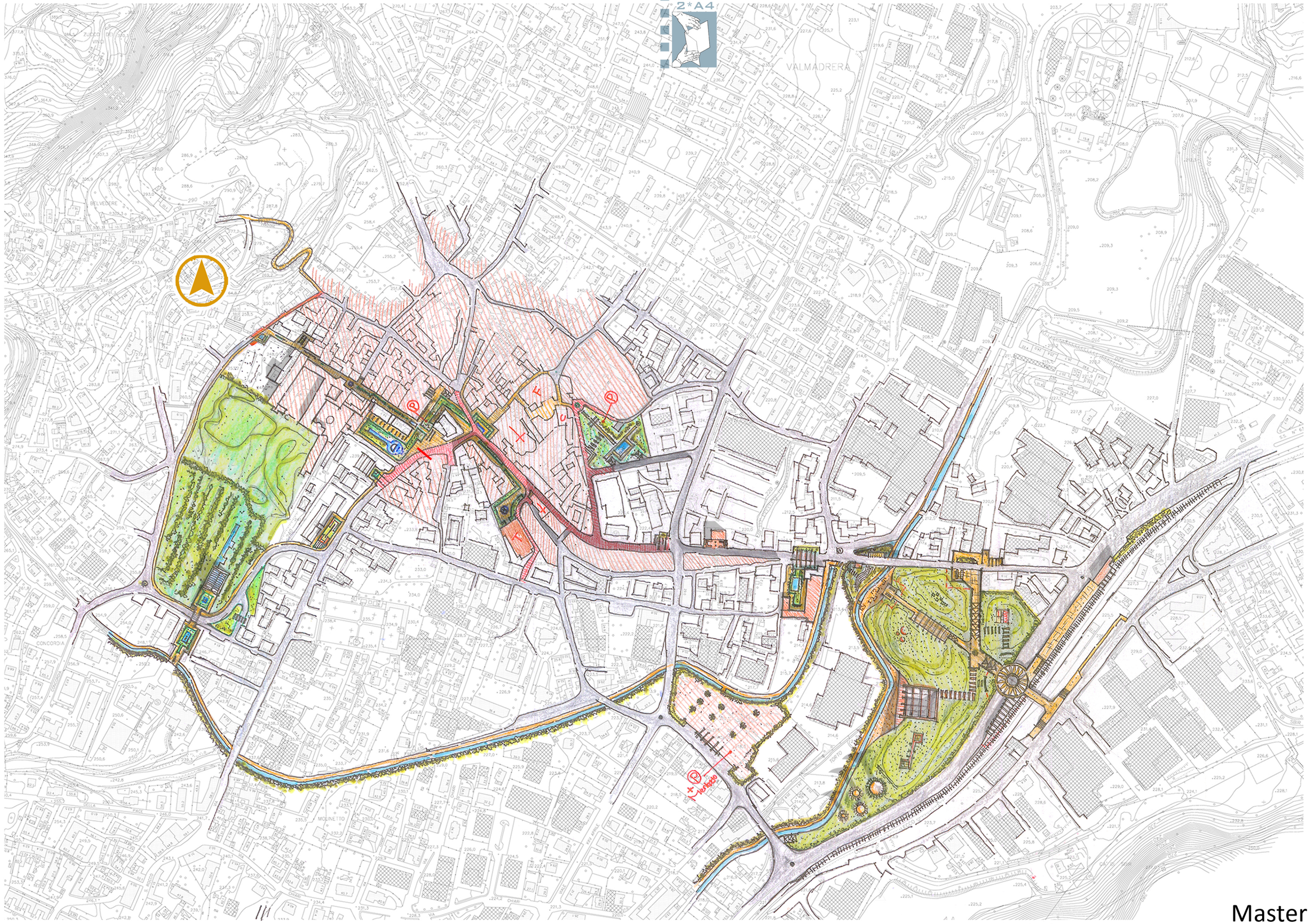
10. Master Plan Drawings and Schemes

2*A4



Conceptual Master Plan

2*A4



Master Plan

POLITECNICO DI MILANO VI FACOLTA' DI INGEGNERIA MASTER OF BUILDING ENGINEERING	The Earth sheltered Body Factory | VALMADRERA-LECCO	A.Y. 2012/2013	SCALE 1/6000	U 02

2*A4

1-Energy Park
2-Research|Admin|Service
3-Upper Collective Piazza
4-Lower Drop off area | Access to the lower parking
5-Outdoor Exercise area
6-Train Platform
7-Train Station
8-Skaiting Ring
9-Sculpture Garden
10-Below Grass Herbal Café and Green Shops
11-Lower water recreation Platform
12-Observation Deck + Restaurants
13-Steped Children Piazza
14-Underground Parking Access
16-Mercato
17-Refurbished (Cultural and Visitor Center)
18-Performance Piazza
19-Transite node
20-Historical District Access point with Art work
21-Theatre plaza
22-Park and underground Parking
23-Sport District access |the 3 collective Piazzas
24-The Lung Urban Farm
25-Glass Green House
26-Transite Node | Piazza
27-Urban Farm shop
P1-Parking For the Car free District residence
P2-Public Parking for the Historical District
P3-Mercato Parking | San tomaso users

Functional Master Plan

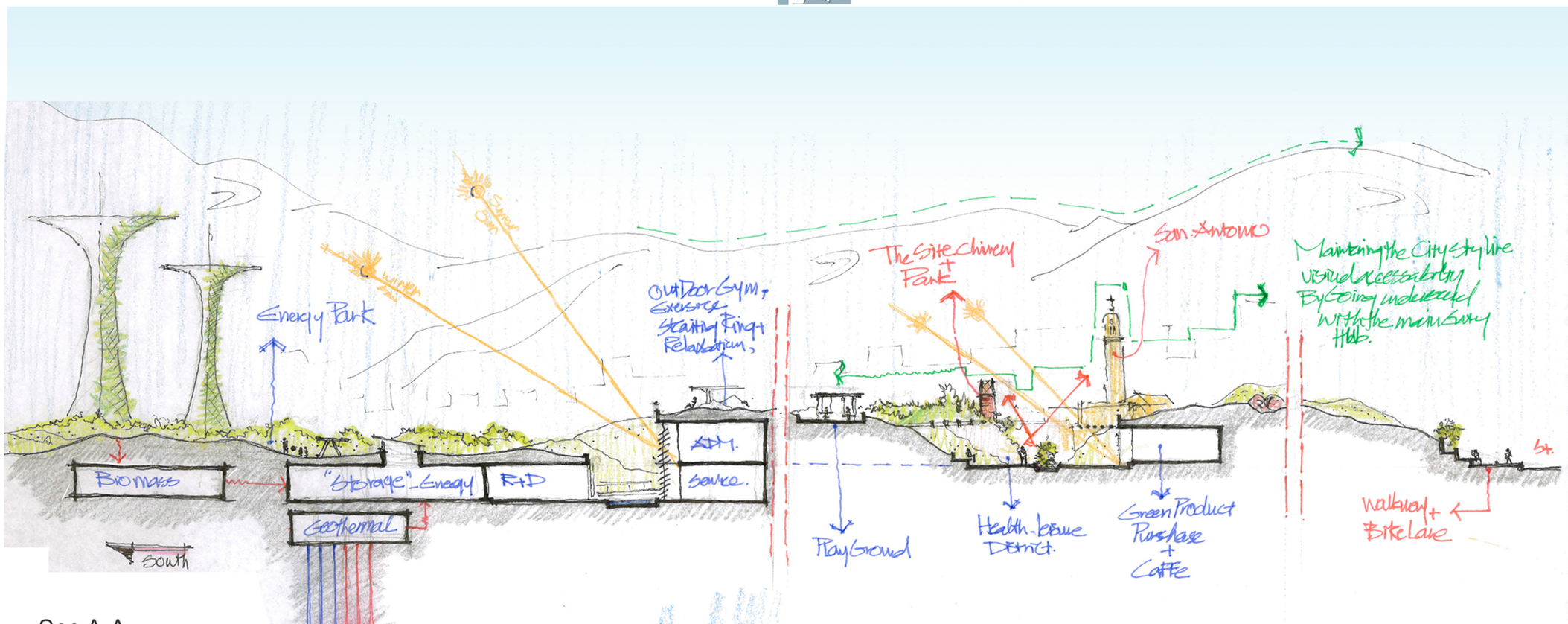
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1/6000

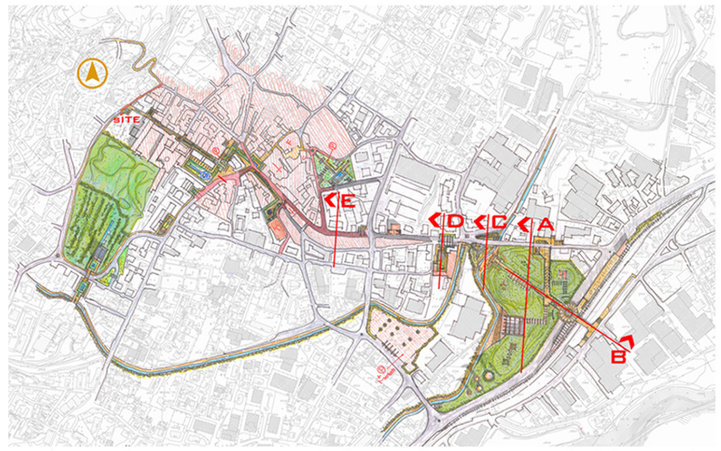
U 03



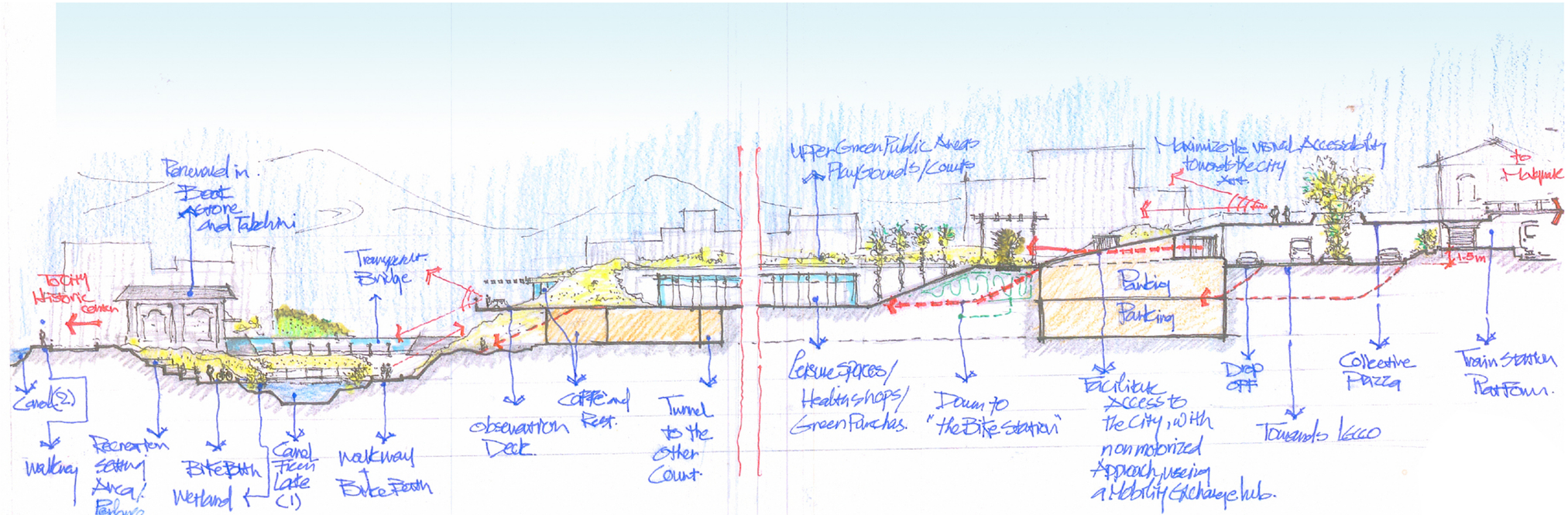
Sec A-A

BIOMASS PLANT USEING TREES CLIPPINGS

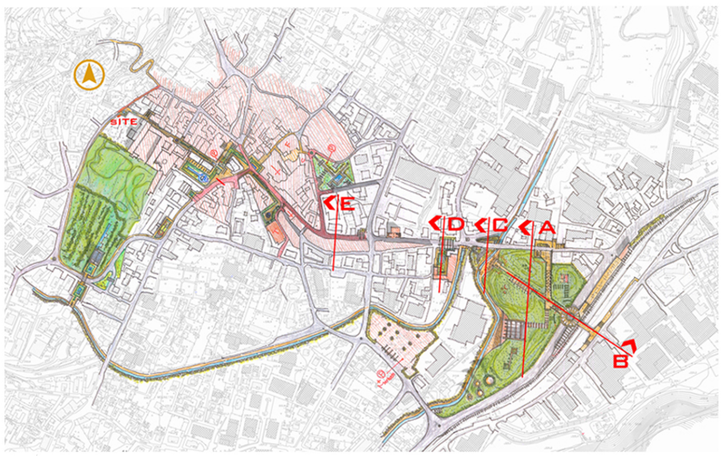
THE EXAMPLE IS SKETCHED OUT FROM SINGAPORE ENERGY PARK



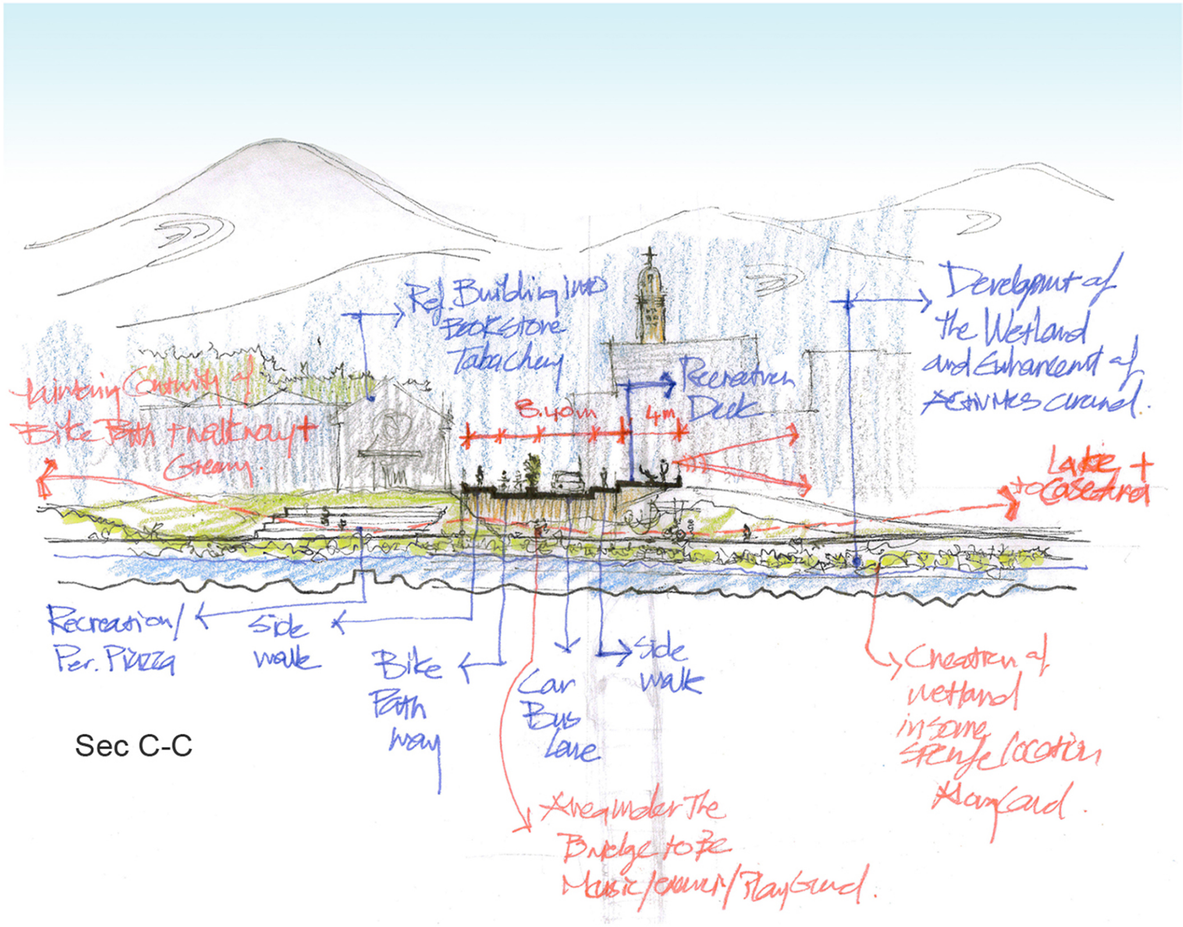
Conceptual Sections and Sketches



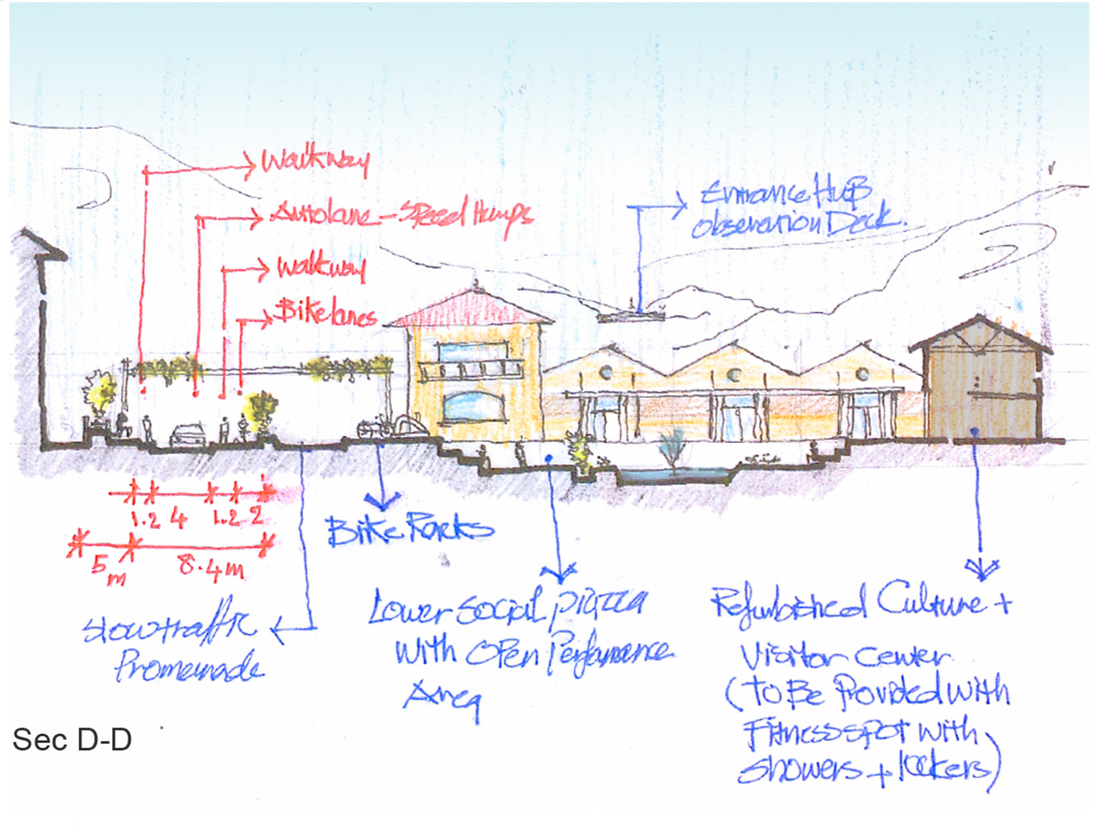
Sec B-B



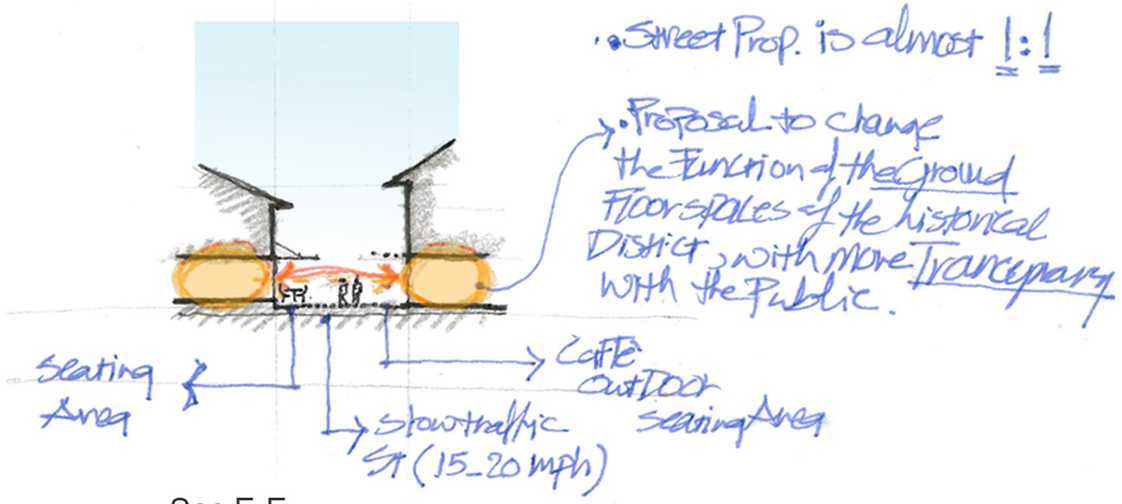
Conceptual Sections and Sketches



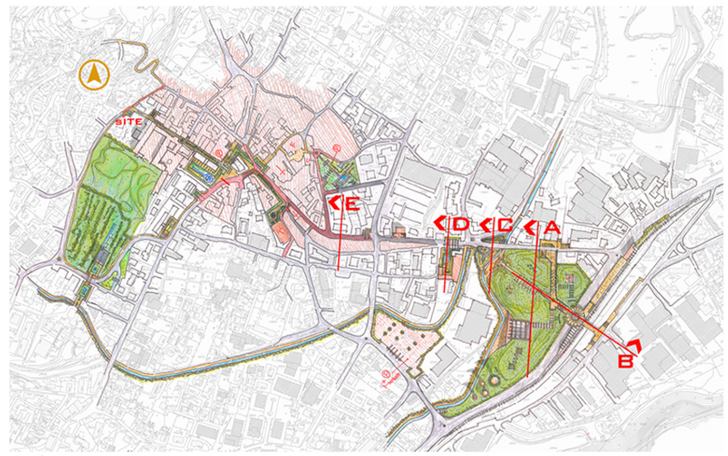
Sec C-C



Sec D-D



Sec E-E



Conceptual Sections and Sketches

2*A4

Health and Recreation
260 m_0 mph

History and Culture
3,1 0m_15mph

The Urban Living Room
360m _25mph

Mobility,Entry Hub and Energy Park

San Tomaso

Monte Barro

Site

The Spine Mood Board

CHAPTER III

Architectural Design

1. Scope and Vision statement

"*Smallness transforms Bigness*" [22]

In view of the fact that dealing with such complex context is quite delicate, we were driven by the approach of creating a structure which blends seamlessly and appears to grow from the surrounding landscape, with respect to the authenticity of the Former mill. We started from the conclusion of the urban design, to let the smallest details of the context forms the mass, shape the boundaries of our intervention and define the proper solutions, taking the area opportunities and constrains into account.

Subsequently, this chapter will focus on investigating and implementing the Earth sheltering as an architectural design approach. It will also introduce new solutions and strategies to solve the most common undesired effects and impacts of the subterranean technique, with respect to the energy demand and the building passive behavior.

Adjacently, the public area of the spine will be designed and integrated in the form of multi-level piazza, noting that the existing mill will be minimally developed only to guarantee the adequacy and the feasibility of the whole project, as one comprehensive product.

2. Leed NC polices as a design guide line

Nowadays, considering the impact of the built environment, the creation of a Eco-friendly building needs to cover many aspects, not only the ones related to the Energy consumption, Operational procedures and construction technologies, but a wider approach to cover the economical sustainability, social sustainability, health and wellbeing.

Since our aim is to create a New Paradigm in Environmentally Responsible Design and Construction, general design guide lines were needed, not to be used as a rigid frame work, but to expand our knowledge regarding the topics. This needs to be fulfilled to evaluate our accommodated strategies, in order to guarantee the adequacy of the developed product's performance.

Consequently, LEED for New Construction (NC) was adopted as will be explained in APPENDIX_B, but priority was given to the perquisites concluded as follows[23]:

- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Material and resources
- Indoor environmental quality
- Innovative design

[22] Shinobu Hashimoto, Thesis of Chip City, The Berlage Institute, Netherlands, 2001

[23] LEED GA, study guide, 2010

3. Function definition:

As a result of the previously mentioned economical and feasibility studies, in addition to the compatibility of the chosen function with the Ex-Filanda building and the surrounding context, we went deeper into investigating the Wellness center, Spa and health clubs to guarantee adherence to the adoptive reuse approach, in terms of components, activities, space requirements and needed facilities, before going into the concept phase.

3.1 Is it only a typical wellness center?

Going along with the wider target of creating a sustainable transformation scheme for Valmadrera, based on the Therapeutic and Eco-tourism vision, the idea is to innovate a building which not only successfully provides its required functions, but also emphasizes the usage of the rest of the city attractions and potentials. This leads to introducing the Idea of the "the Day use" or "come and spend the day" which was mandatory in designing our building. This was strongly reflected on the building spaces program and zoning, considering how the building internal activities can be linked to the city outdoor activities.

For the sake of the coherence of the thesis and the complete design process, relevant examples are presented in APPENDIX_D.

3.2 The Body factory Area Program

Floor	space	Area (m2)
Basement	Thermal treatments zone	317
	Showers & W.C	80
	Internal pools area & facilities	345
	Outdoor pool area& & facilities	371
	BMS & Mechanical rooms	129
	Lounges, receptions ,Storage& Corridors	310
Ground Floor	Meditation rooms	150
	Lounges, receptions ,Storage& Corridors	341
	Beauty area	76
	Shops and Cafe	90
	Vertical Circulation & services	188
	kitchen	70
	staff area	34
	Showers & W.C	288
	Restaurant	126
	Day use rooms	322
1st Floor	Showers & W.C	166
	laundry	86
	terrace	44
	Gym and Fitness area	435
	Admin. & Educational	272
	Lounges, receptions & circulation	234
Total area (new + existing)		4474

Figure 88 Spaces area program

4. The Conceptual Design development

4.1 Fundamental analysis:

With respect to the design inputs addressed from the Macro urbanistic level, we started to consider the outputs resulted from a precise micro site investigation process, in order to create a structure which works harmonically with the surrounding context, and grows out of the site according to well defined guidelines, by focusing on:

- Climatic and environmental analysis;
- Vegetation and green Identity;
- Accessibility and connectivity;
- Visibility and recognition;
- Local Identity and neighborhood morphology;
- Traffic and mobility;
- Public behavior around the area; and
- Skyline and Earth line.

Samples of those analysis are presented below, noting that further clarifications can be found in each related chapter, including the urbanistic analysis, environmental and climatic studies, etc,.

Figure 89 Site area panoramic view

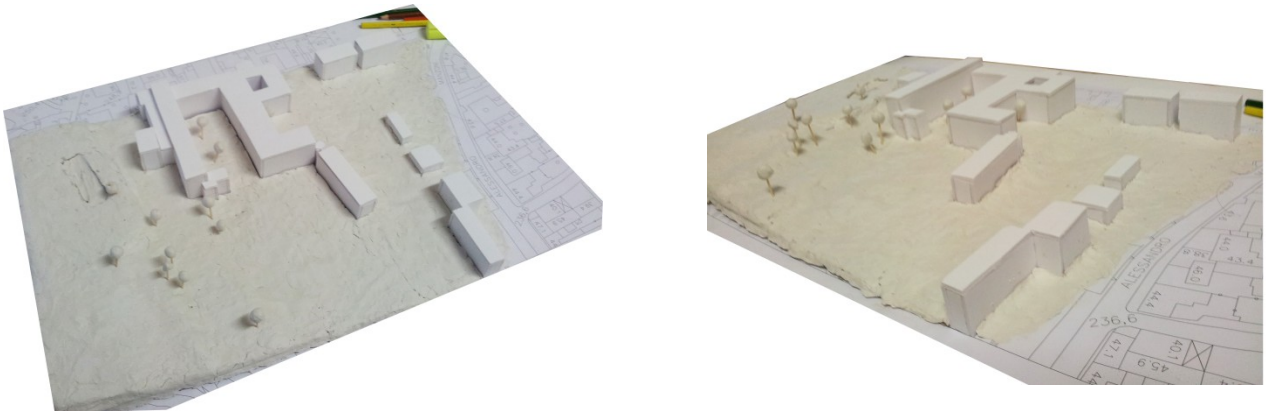


Figure 90 Existing site study model

Figure 91 Existing Site cross section

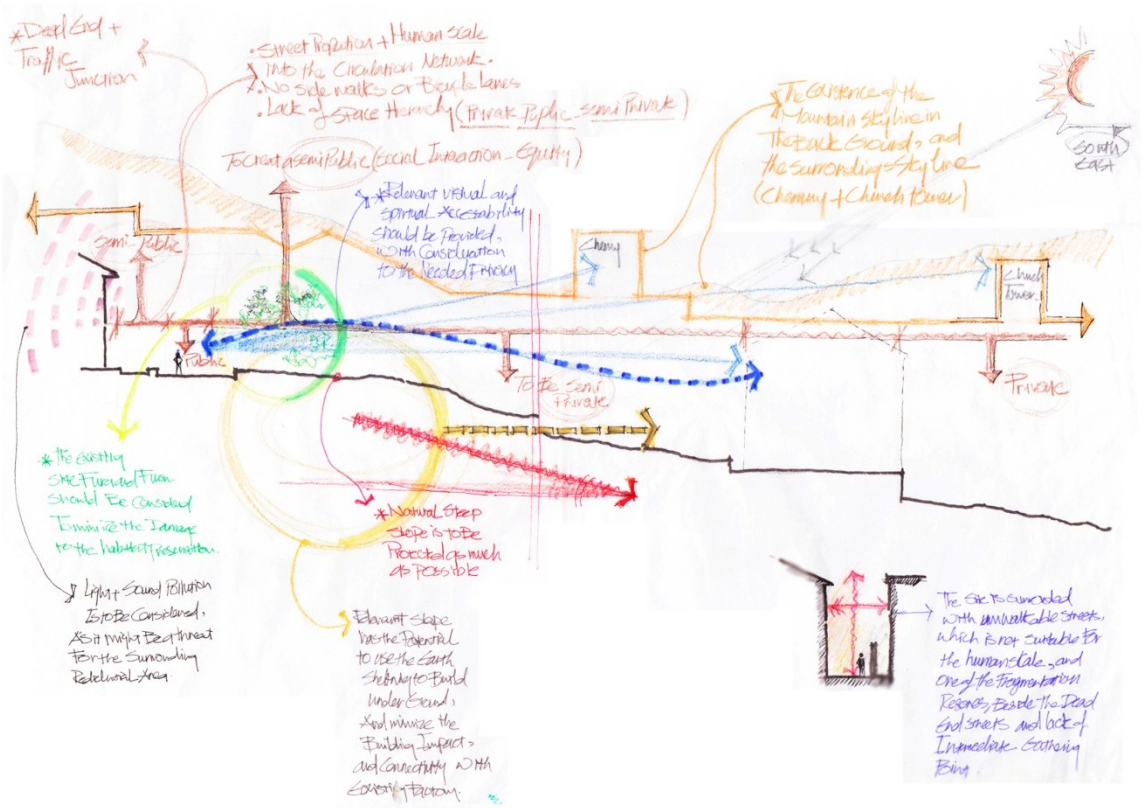
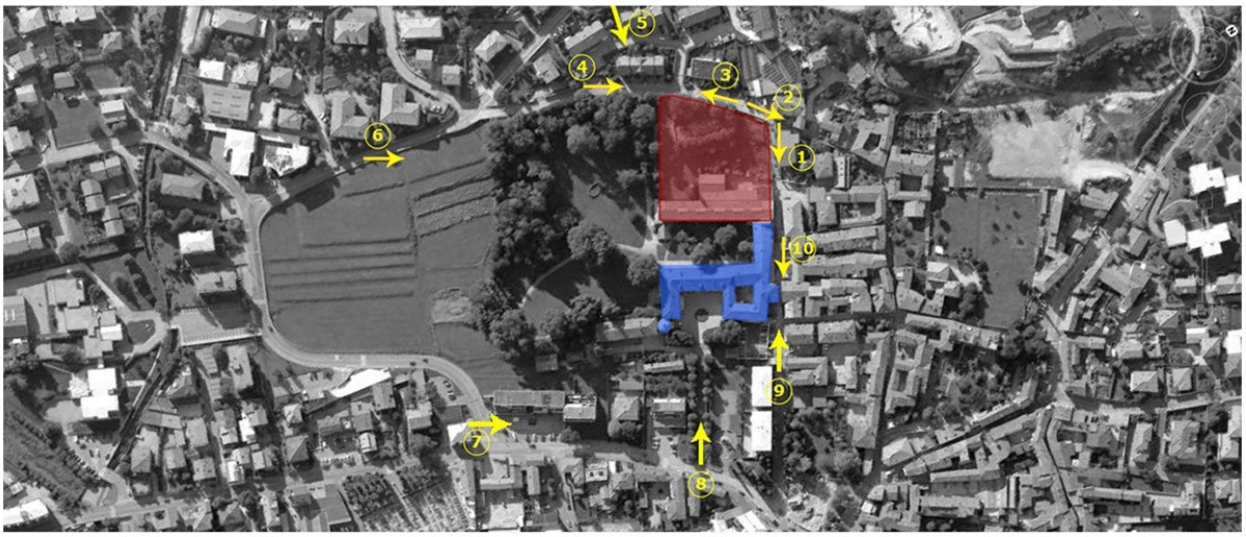


Figure 92 Existing site analysis



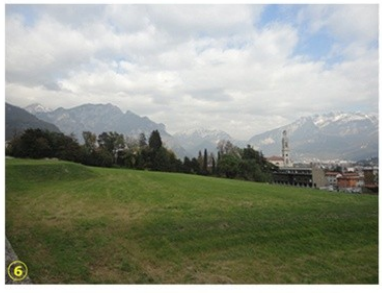


Figure 93 Surroundings typology/morphology

4.2 General Objectives:

a) Creation of a well connected **Ending point and gateway** (starting point) for the proposed spine, in front of the project site, with different entrance levels in terms of privacy.

b) Maximizing the **social interaction** and limiting firm-boundaries and rigid-separators, by providing a well defined (inside-outside) hierarchy schemes.

c) Maintaining the **visual connectivity** of the users towards the park and the mountains while guaranteeing full privacy, quietness and closeness.

d) The current **visual perception** and **Identity** of the site area is quite clear and strongly belongs to the context - in terms of the **Skyline, Green line, ground line, void to solid ratio**, etc.,- so priority should be given to minimize any visual and physical disturbance.

e) Taking advantage and maintaining the existing **natural green slope and plantation** located in the site.

f) The **full integration** of the existing Mill and chimney into the new design, taking into account the terms of compatibility, reversibility and adoptive reuse.

g) Maintaining the visual and physical **authenticity** of the Mill, the park and its surroundings.

h) Solving the **traffic junction** at the end of the spine, presented in the intersection between (Via Volta & Via Campogrande) and lack of parking lots.

i) Introducing new **sustainable techniques**, which can combine the daylight and natural ventilation with the internal spaces and resulting perceptions and feelings.

j) Newly added building's **Shape** and **Orientation** to follow a criteria suitable for the area seasonal wind direction, sun angles, existing built environment and shadows, etc.,

In order to be able to meet the above mentioned objectives, building design should be addressed through a combination of three main types of solutions, which can be categorized as follows**:**

- **Earth sheltering**
- **Sustainable Architectural approaches**
- **Subterranean Environmental strategies**

4.3 Earth Sheltering and Creation of a New Paradigm in Environmentally Responsible Design:

4.3.1 Decision making and strategy selection

To organize our design guidelines, an extensive research phase took place to define our possible alternatives, design development criteria and decision making methodology, to comply with the previously mentioned objectives and design patterns.

For the sake of Thesis' coherence and complete design process, relevant research results are presented in APPENDIX_A.

4.3.2 The solution of subterranean design

The relationship of architecture to the earth, the water, the sun and the wind had been a constant concern to architects. Today, there is a certain amount of hostility towards possibilities of using earth for sustaining better living conditions. Among these possibilities comes the use of earth sheltering.

Being a logical conservation method in valuable historical sites without destroying their cast or character, the below ground concept has gained further credits [24], with respect to the modern movement of the Romantic Nostalgia for the past which is becoming more popular nowadays.

With the growing awareness of energy needs and shortage in the early seventies, and the increasing fears of the ozone layer depletion and the global warming phenomenon, as indicators of impending biological degradation, earth sheltering rapidly gained interest both as a conservation method and as an alternative life style [25].

Taking into account that conventional homes lose from 35,000 to 70,000 BTU per hours through cracks, doors, windows and other openings, while earth covered structures on the east, west, north and on the roof lose only 2 to 4 BTU per hour[26].

Resultantly, Geo-tecture and cool green roofs are strongly coping with the green sustainable design roles to maintain the context ecosystem, some reasons behind that can be concluded as below:

- Its characteristic high value of SRI moderates the Urban Heat Island Effect[27]
- Reduction of temperature fluctuations and thermal stress over the envelope
- Reduction of the storm water runoff
- Free natural acoustical insulator
- Increasing the biodiversity, wild life attraction and urban agriculture
- Enhancement of the urban social life and users' well being
- Minimizes the light and sound pollution

[24] Andrew Blowers, planning for a sustainable environment ,London: Earthscan Publications, 1993
[25] Randall Thomas, Environmental design: An introduction for architects and engineers ,London :E& FN Spon,1996
[26] Barbara Bannon Harwood, "Earth shelters are here to stay" Concrete construction, 1980
[27] LEED GA, study guide, 2010

Subsequently, we achieved our preliminary concept of using earth integrated architecture, which can be visually transformed as below:

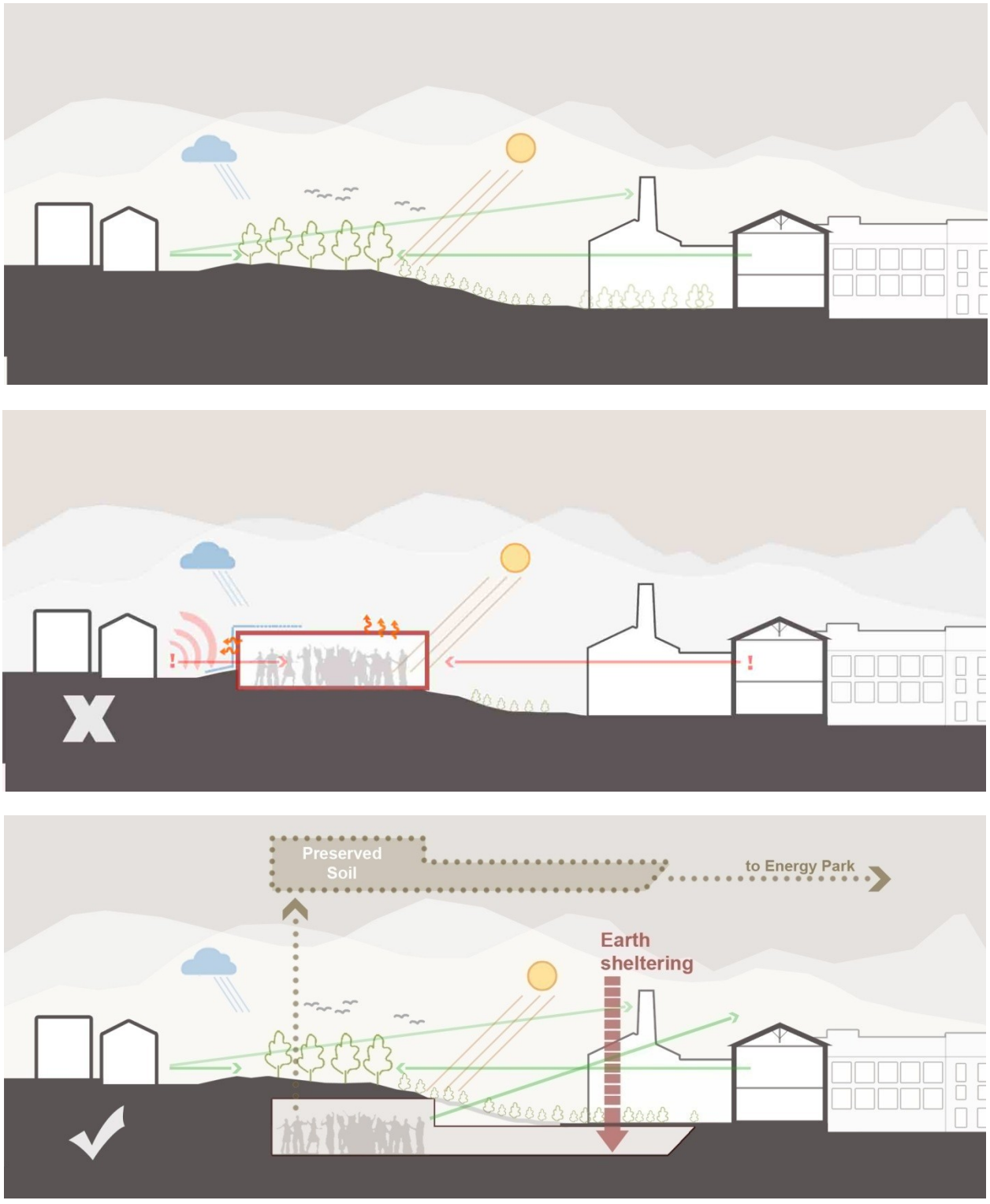


Figure 94 Earth sheltering conceptual development

4.4 Sustainable Architectural Approaches:

With respect to the previously mentioned objectives and the subjected subterranean architectural scheme, we started to translate relevant goals into solutions and strategies, using the keywords extracted from the LEED, in addition to the micro site-analysis results. This will be clarified in the next part with relevant preliminary sketches.

4.4.1 Macro zoning and Social equity

Since our site is located at the end of the proposed spine, which links the upper part of the city and the Project to the city center and train station, we realized that relevant termination point should be acting as a public Gateway for the spine. Its main function will be facilitating the entry and acting like a gathering node and social hub.

Also considering that the famous Gavazzi complex used to be the development core of Valmadrera, and believing in Social equity and the idea of giving back to the city, we proposed the creation of a shared space presented in the Gavazzi's Piazza. Relevant space will improve the quality of the social life and maximizes the controlled interaction with the project.

Taking into account the presence of the traffic junction located adjacent to the site, at the intersection of the dead end of Via Volta and Via Campogrande streets, this junction will severely affect the functionality of our project, so the solution will be addressed in the form of a roundabout and drop off point, as shown in the Figure 95 below.

All of the above helped to define our intervention boundaries, and clarified the general functions typology and zoning, with respect to hierarchy of privacy, to decide what belongs to the noisy city and what belongs to the cluster of quite nature.

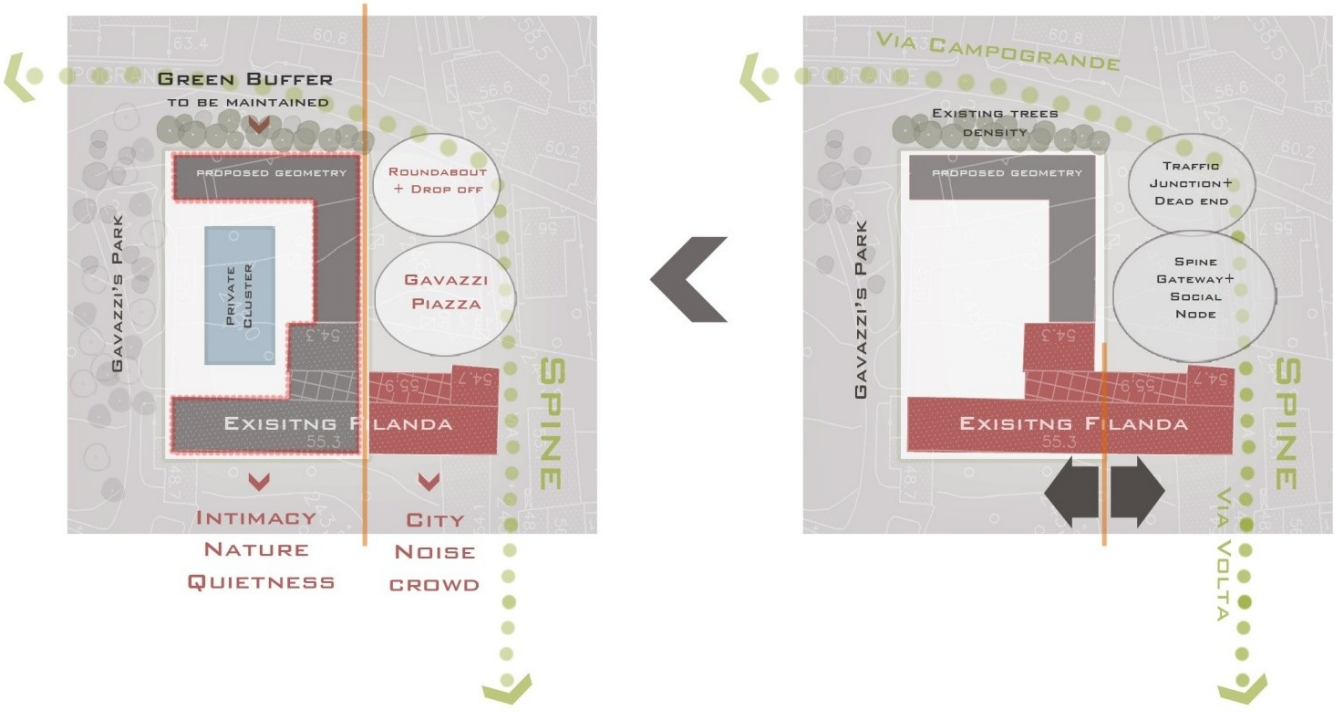


Figure 95 Macro zoning analysis and solution

4.4.2 Orientation and massing

As per the climatic analysis of north Europe, we maximized the façades area oriented towards south, to guarantee the highest amount of sun exposure, with a complete avoidance of the heat losses through the north. The direct speedy wind was completely avoided, but with a proper allowance for the fresh air to circulate the site using the well planted vegetation.

4.4.3 Urban fabric grid and geometrical alignment

By using the same language of lines, which belongs to existing Mill's industrial pattern and the context fabric grid, we achieved the creation of a structure which blends seamlessly in the context.

4.4.4 Maintaining the existing flora and green Identify

By applying the subterranean architectural scheme we not only maintained the biodiversity and minimized the impact of the new built environment, but also avoided cutting most of the existing native trees at the north western side, since it will be acting like a buffer between the residential neighborhood and the Body factory cluster.

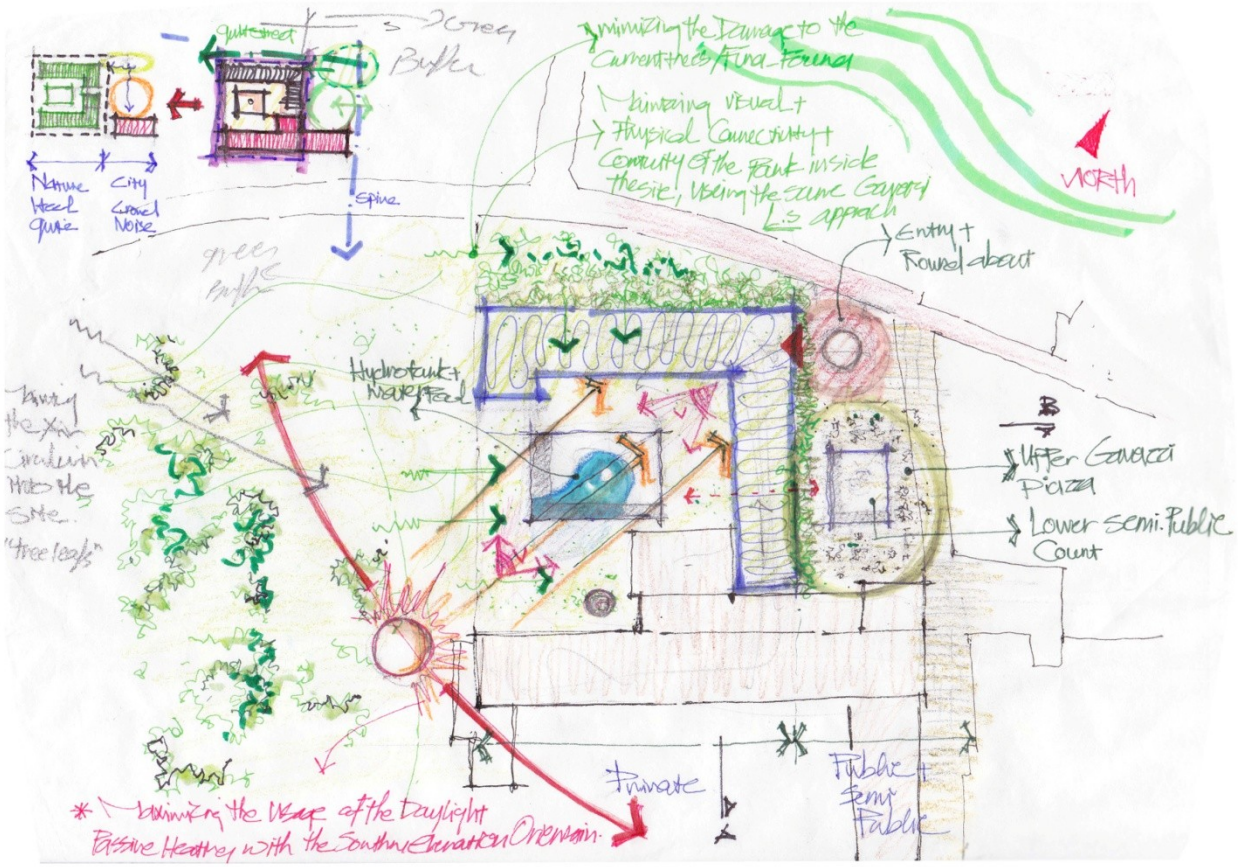


Figure 96 Preliminary conceptual sketch

4.4.5 Views and Green healing

Our aim was to provide the feeling of isolation and intimacy, in conjunction with introducing the Green healing as a new worldwide trend. By disconnecting any possible visual and acoustical connection with the external man-made environment as shown in the below figures, we achieved a well designed scheme which gives endless view towards the famous leveled Gavazzi Park and the surrounding mountains in the background.

4.4.6 Visual and physical connectivity

Due to historically arousing importance of the Filanda complex in Valmadrea and the context identity, we maintained the visual connectivity to the chimney and the St Antonio Church tower. This was in addition to maximizing the recognition by increasing the height of the chimney to its original height. So, basically, the only exposed mass is the solid contemporary canopy of the entry.

On the other hand, maintaining the absolute visual and acoustical privacy of the inner Lower Park and the concealed functional spaces was achieved, by using a combination of levels and vegetation solutions, as shown below.

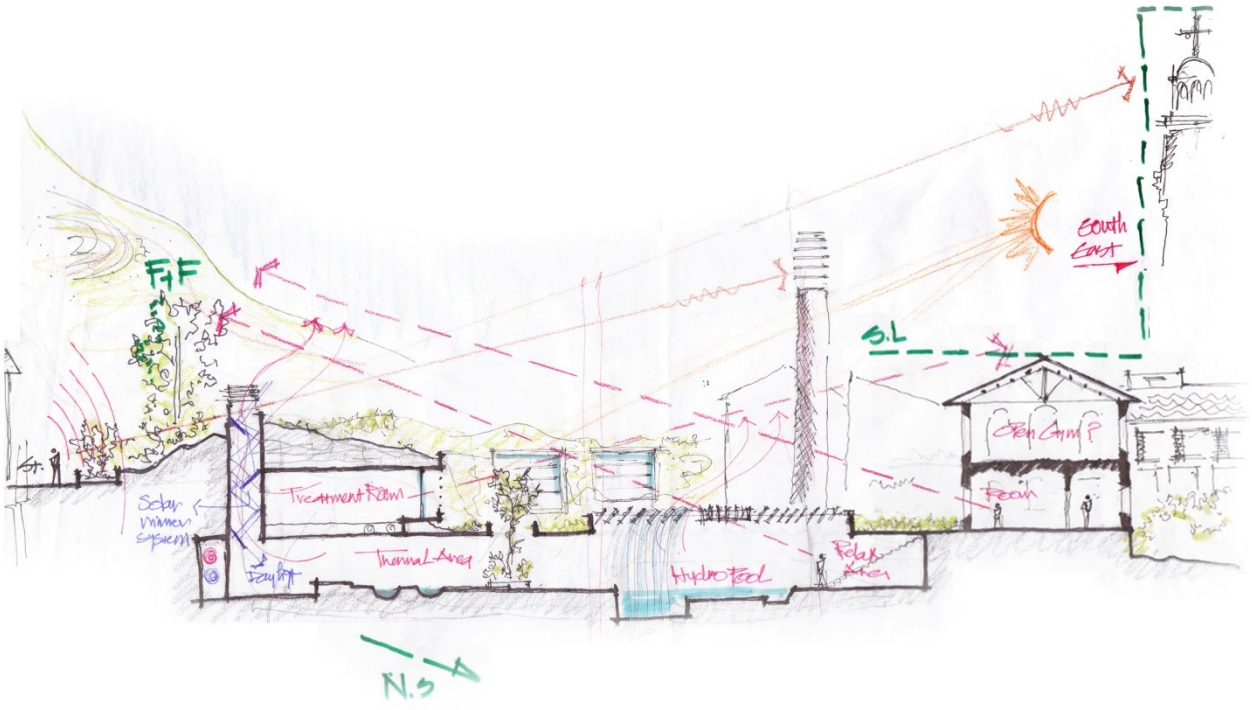


Figure 97 Conceptual cross section_01

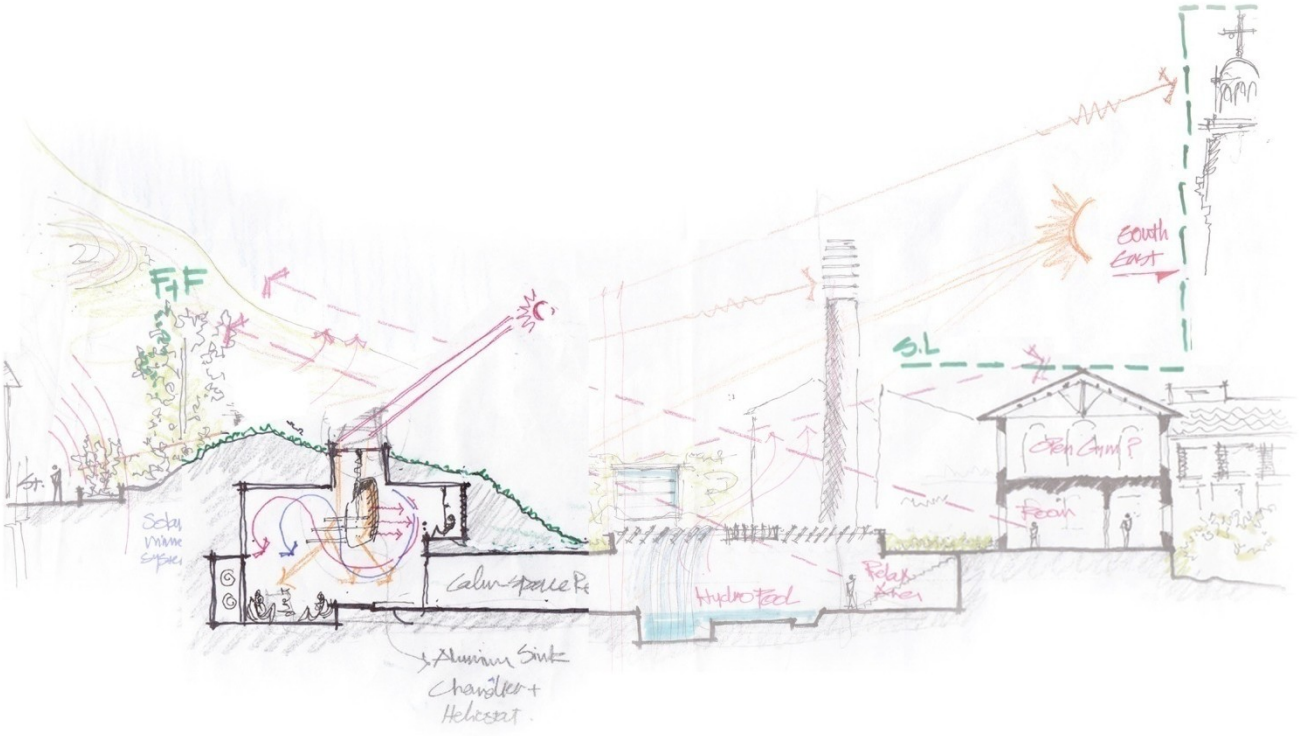


Figure 98 Conceptual cross section_02

4.4.7 Public to private hierarchy

Dealing with the aspect of privacy along with avoidance of the rigid boundaries was a dilemma, keeping in mind the additional constrains of maintaining the identity of the area, maximizing the social interaction at the gateway of spine and blurring the boundaries.

Therefore, introducing the Double level Gavazzi's piazza with its soft boundaries was the solution, as it will act like a buffer. The upper public level belongs to the residences' daily life and rapid pedestrians' circulation, where we can find related functions like Tabaccheria, newspaper kiosk, biglietteria, bus drop off and free bike racks .

The lower semi-Public level of the piazza belongs more to the Body factory users and the area residents', who will be attracted by the type of functions included in that level like Health shops, Herbal cafes and diet store.

Considering that the Body factory entrance will be located in the lower level, with a visual connection to the upper piazza.

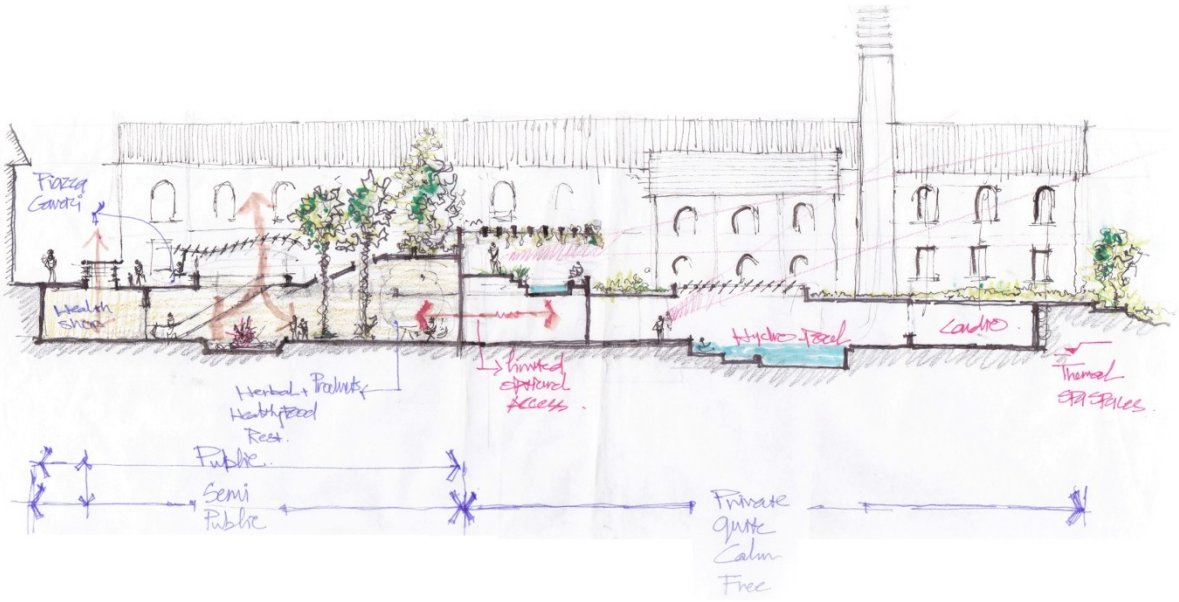


Figure 99 Conceptual longitudinal section

4.4.8 Restoration and adoptive zoning

"The adoptive reuse _preserving our past building our future"[28]

Preservation became a popular global trend, not only for the Romantic nostalgia of the past but mainly as one of the main approaches of sustainability. Thus, maintaining the authenticity and the complete integrity of the Mill is a must, along with maximizing the efficient usage of all of the available spaces of the Filanda. With respect to the previously introduced function selection and suitability analysis, an investigation process took place to know what kind of spaces can be accommodated in the Mill's different floors. This was with respect to adoptive reuse and the main key words which are Knowledge, Recognition, Reversibility, and Compatibility. As shown in the above schemes, the spaces distribution inside the Mill can be concluded as follows:

In the Ground floor: The presence of the existing drainage system and sloped flooring will be suitable for locating the showers, toilets and lockers. Also, by taking advantage of the direct access from (Via Volta), locating the restaurant and kitchen will be adequate, to guarantee full occupancy all day long, even after the wellness center daily working hours.

In the 1st floor: It used to be the factory main production hall , with huge universal space and a reinforced structural slab which was designed to sustain the loads of the heavy machinery, so locating the Gym and fitness machines hall in that floor will be sufficient.

Also, by taking advantage of the existing stairs with the direct access to (Via Volta), locating the Administration and staff areas will be adequate, to facilitate the staff entry and separate the circulation of the employees from the Users' private routes.

[28] http://www.environment.gov.au/heritage/publications/protecting

4.4.9 Thermal and Comfort zoning

Starting from the preliminary sketches, great attention was paid to the users' privacy and comfort, by maximizing the interaction with the outdoor green environment, which guarantees the proper receiving of daylight and well views along with the intimacy and privacy.

Also, the shown hierarchy of entry and spaces organization provides a clear circulation scheme, which separates the wet and dry circulations, according to the clothing level and hygiene codes.

But, since the heat production can be quite crucial for the Wellness centers and spas, we were mainly driven by a thermal zoning distribution scheme, to minimize the energy loss and to provide the maximum controllability over the building areas. In that manner, the related spaces have been gathered into enclosed zones, according to their thermal requirements and the above mentioned comfort and architectural criteria.

By taking advantage of the adjacent soil thermal mass, the Baths, Saunas and internal pool zones were located at the basement, considering how much the thermal and acoustical isolation is needed for those spaces and will not be affected by the moderate level of the received daylight.

On the other hand, zones located on the ground floor are suitable for the natural ventilation usage, full day lighting and controlled sun heat gain, as they are not thermally charged compared to the basement zones, and the user's sensitivity is much lower according to the normal clothing level needed in the ground floor.

Figure 100 Preliminary zoning_1st floor plan

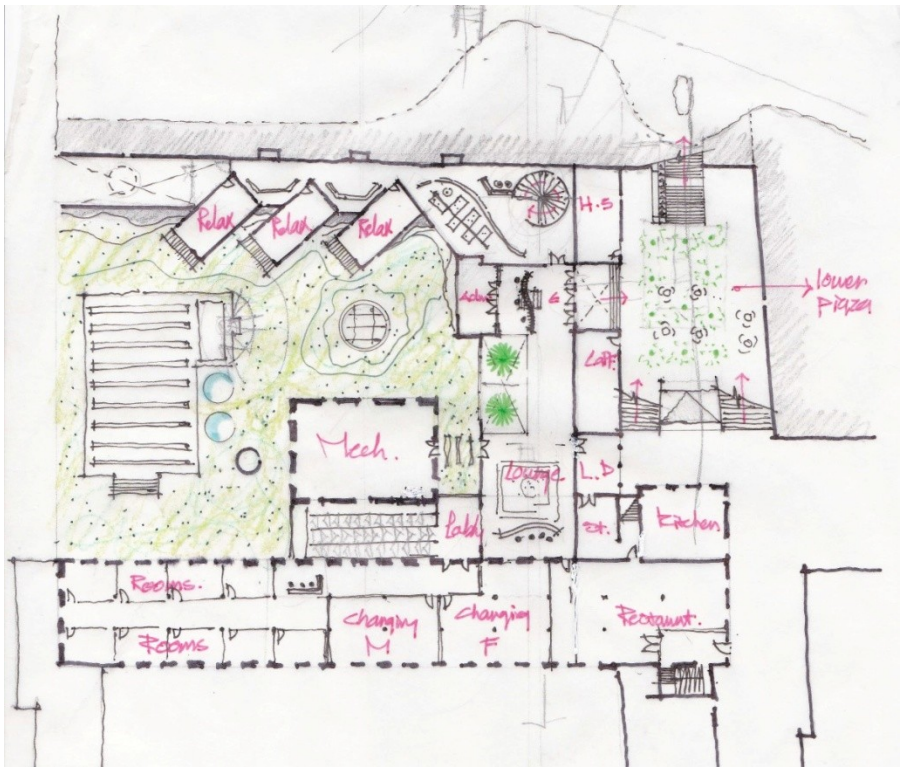


Figure 101 Preliminary zoning_ Ground floor plan

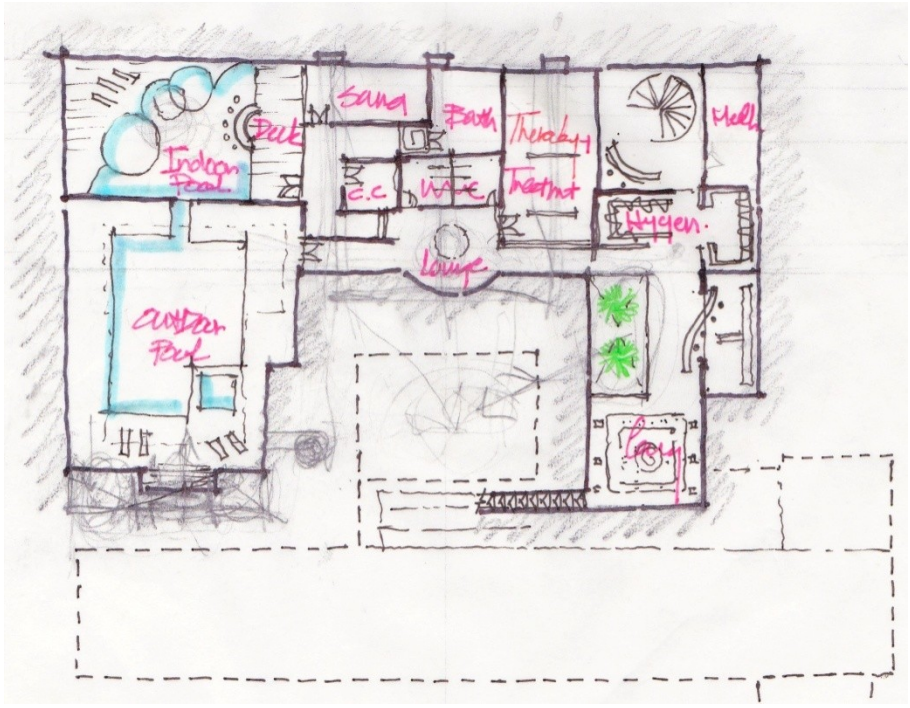


Figure 102 Preliminary zoning_ Basement floor plan

4.4.10 Transportation and Mobility

For a sustainable mobility scheme, spaces for the bike racks and the free (blue bike) project were dedicated in the Gavazzi piazza, with respect to its importance as a gateway for the spine.

Also the parking design followed the LEED guidelines, by limiting the available spaces for THE BODY FACTORY's workers and providing free parking for low-emitting vehicles and carpoolers. Managing the SRI (Solar reflective index) was unavailable, since we are using the Parking paving to collect the sun heat, to be delivered to the Earth thermal bank.

On the other hand, a small roundabout with a drop off area was created to solve the traffic junction at the intersection of Via Volta and Via Campogrande, which is expected to facilitate the access of public transportation vehicles to the site area, which will limit the usage of the SOV (single occupancy vehicle).

4.5 Subterranean Environmental strategies:

4.5.1 The combined integrated techniques:

By its very nature, an earth shelter provides quietness, peace, security, privacy, and uniqueness; some of which are the psychological bases of any successful architecture. Confirming these desired feelings, people prefer to be in a space that encloses them[29].

On the other hand, psychological barriers are crucial to earth sheltered design, which can be categorized as follows:

- **Light** as a very special type of energy, you can see it but you can't feel it. You can't weigh it or cut it down into manageable pieces, so it is not surprising that people have always been busy in uncovering and working with the secrets of light and light radiation, stating that how much it is important for daily healthy life[30].
- **Ventilation** and indoor air quality are an essential factor for the people's daily life, as air ventilation is necessary to dilute odours and limit the concentration of carbon dioxide and airborne pollutants such as dust, smoke and volatile organic compounds (VOCs), and can dramatically affect our feeling of comfort and wellbeing[31].

Considering the severity of those two psychological factors, which are also effecting the building energy consumption, the creation of innovative sustainable solutions combined with the interior design was obligatory, to avoid the risk of creating damp, unhealthy, unventilated and unsafe spaces, meanwhile still targeting the achievement of net zero energy requirements, by minimizing heating/cooling loads and the usage of the artificial lighting.

[29] S.Sheta, Earth sheltered housing design Mansoura University, Egypt ,1998
[30] http://www.coltgroup.com/news/heliostat-brochure.pdf
[31] http://en.wikipedia.org/wiki/Ventilation_(architecture)

4.5.1.1 The "Hammam" pool:

By capturing the spirit and the sensation of the old eastern Hammam, but in a modern energy conservative way, we will take advantage of its magnificent language of light and the natural release of excess heat and polluted air, meanwhile achieving a delight atmosphere for the Internal pool.

Figure 103 Oriental Hammam examples (Web source)

We tried to simulate the feeling of relevant Bath by introducing a combination of Heliostat system with sun tracking sensors, mirrors, chandelier of colored prisms and operable motorized vents connected to an indoor climate sensor and BMS.

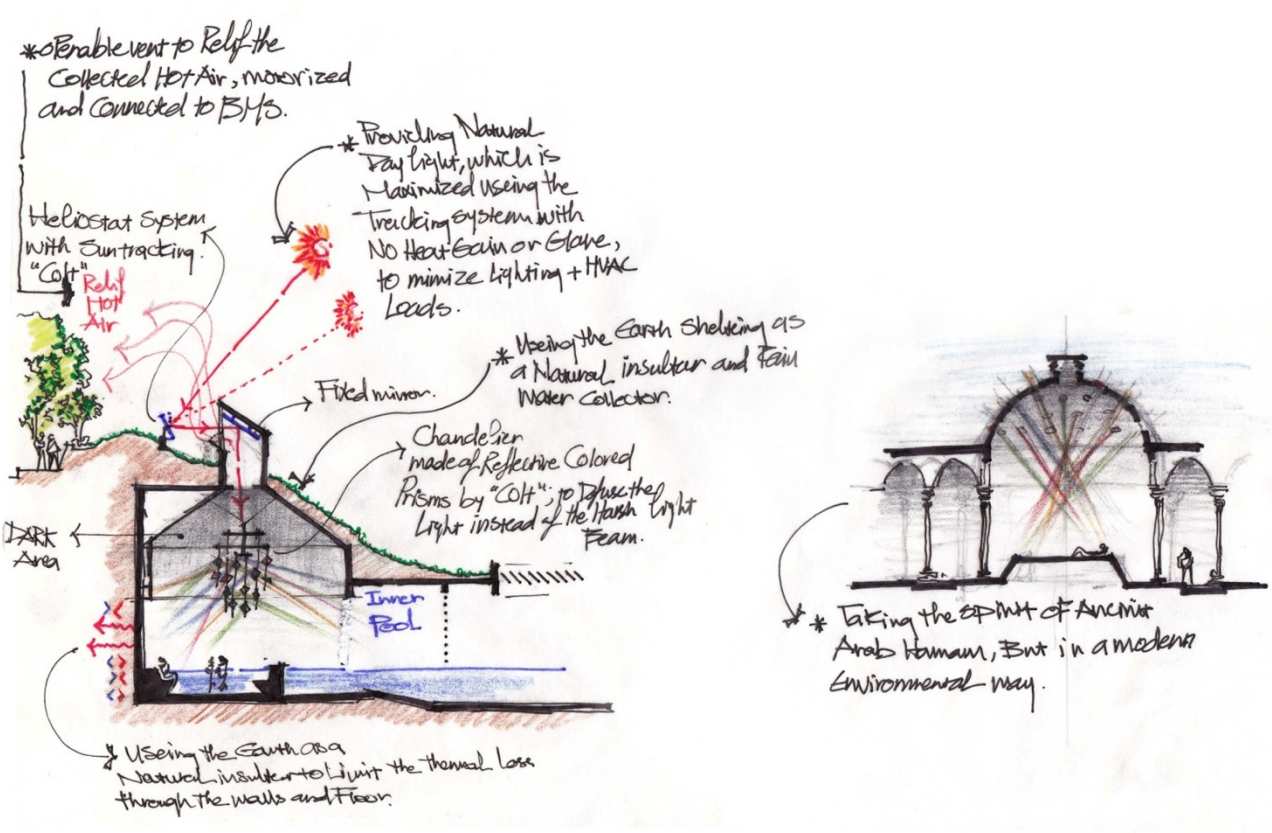


Figure 104 The Hammam conceptual sketch

By dealing with Light as a visual experience, Incident light is broken down into its component color spectrum providing dazzling display of lighting effects, and Creates the feeling of intimacy and closeness , with the total avoidance of heat gain, unwanted sun radiation and harsh light beam.

Figure 106 Colored chandeliers of mirrors (www.coltgroup.com)

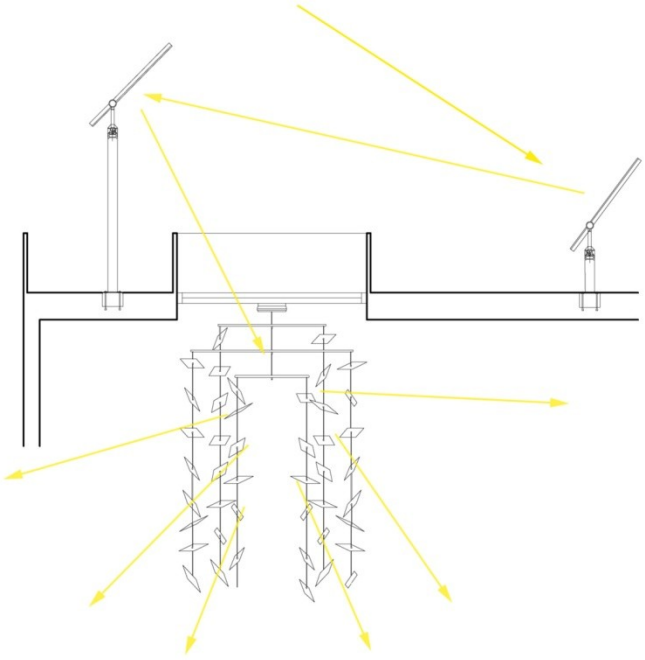


Figure 105 Heliostat with prism chandelier, Extracted from (elliscresswell.tumblr.com)

Keeping in mind that the internal pool area needs a special ventilation requirement, the maximum air quality is guaranteed by releasing the collected humid contaminated air with chloramines in a very low velocity to avoid any air drafts. This was achieved by connecting the upper motorized vent to a system of indoor air quality sensors, which is eventually connected to the BMS. Further explanation will be provided in the technological part.

4.5.1.2 The Oculus Lounge:

Aiming to introduce extraordinary self integrated techniques, combining solutions for daylight, ventilation and interior atmosphere design, the idea of the Oculus was used above the basement Lounge area, which serves as a transition zone for the entrance of the Spa and Pools area, and provides the interior of the lounge with a warm orange glow.

The motorized glazed oculus has an operable top which promotes air circulation and buoyancy effect, when hot air rises and goes out from the opened top that will create convection currents. To optimize this effect, especially during the warmer summer months, a perforated metal art of work “sun catcher” will be hung in the oculus to help create the temperature differential needed to favor the convection currents and the solar chimney effect.

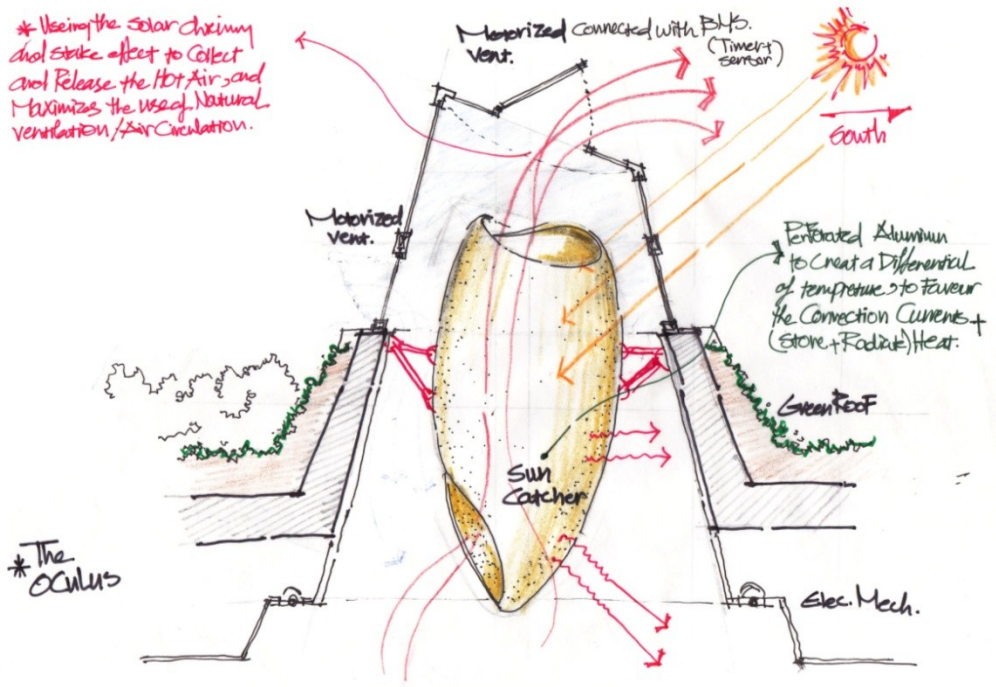


Figure 107 The Oculus cross section

In summer, the oculus and the created heat sink act as a natural air-conditioner triggered by the outside temperature and the sun heat, as the lounge area is connected to the rest of the building through system of corridors with high perforated ceilings, motorized grills and doors with operable vents. After exhausting and consuming the Pre-cooled air coming from the building 2 lungs (Green house and Outdoor pool), it will be slowly collected and extracted through the timed motorized oculus vent naturally by the buoyancy effect, after receiving a signal from the Air quality sensor.

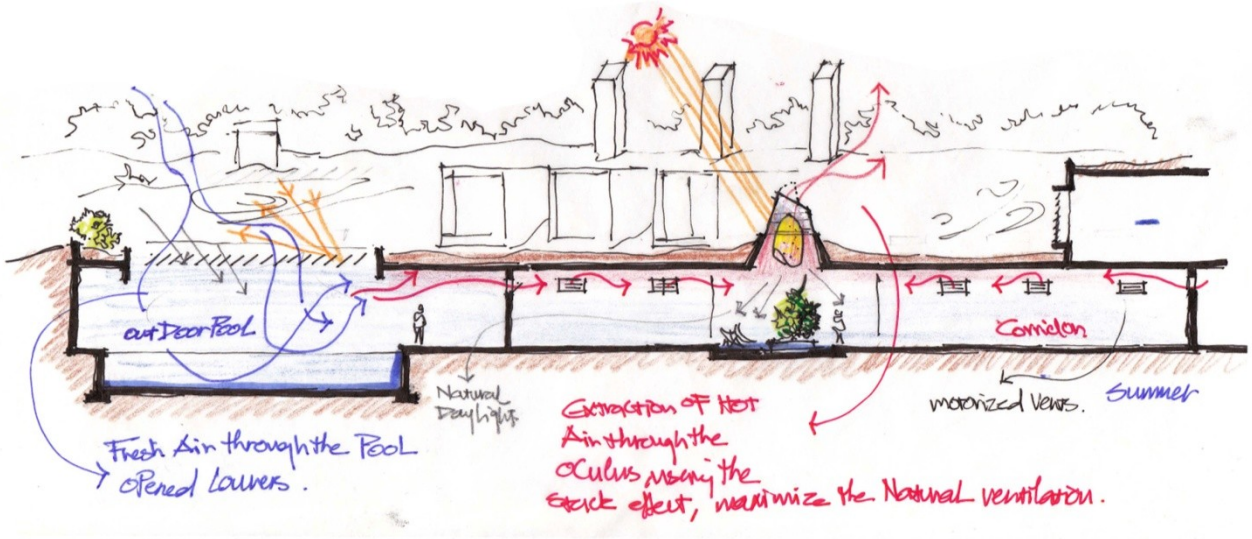


Figure 108 Building behavior with the oculus during summer

In winter, after disconnecting the lounge and corridors from the rest of the building, the Sun catcher will work as a free heat storage and radiator to warm up the area. The operable oculus will be opened only in case of the excess heat, measured by indoor sensors.

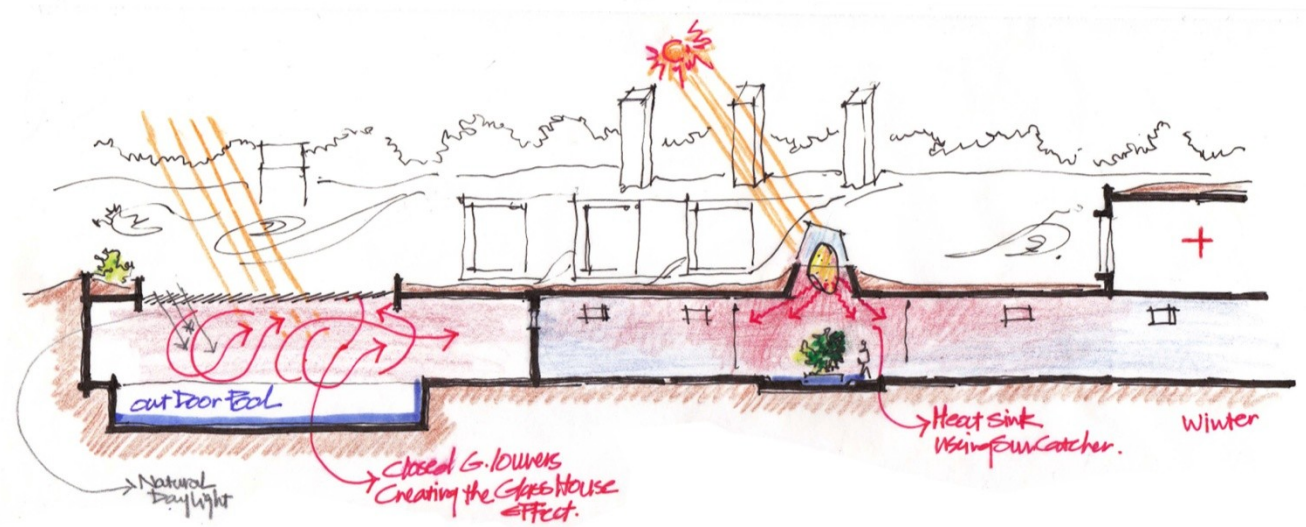


Figure 109 Building behavior with the oculus during winter

4.5.1.3 Towers of light and Earth labyrinths:

The historical scheme of oriental wind tower and earth tubing had been proving its efficiency, but, since we are dealing with a very sensitive indoor environment with a minimal clothing level, in addition to the previously mentioned target of providing the maximum energy savings, we developed this historical scheme using the modern technologies to guaranty the maximum efficiency and controllability.

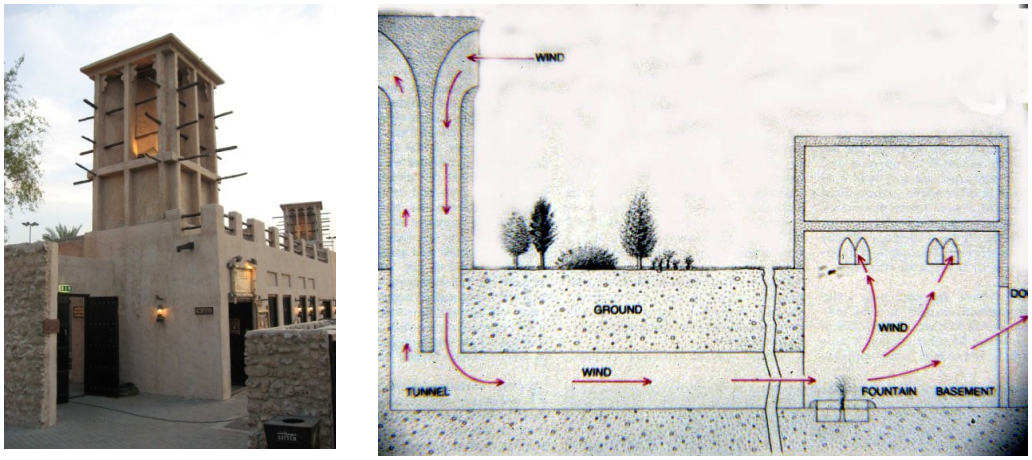


Figure 110 Oriental wind towers with earth tubing (www.krypton.mnsu.edu)

Keeping in mind the adoption of the combined solutions technique in our project, and by investigating our spaces requirements and zoning, we found that the spaces adjacent to the soil and retaining walls at the North western side (Spa Zone) needs the upper limit level of intimacy, privacy, quietness and indoor air control.

Subsequently, almost artificial ventilation and the minimum daylight with the maximum isolation will be needed.

Our proposal is to provide a simple comprehensive system, which can be consisting of a Reflective wind tower, system of Heliostat, Earth Thermal Bank and Thermal labyrinths.

The system provides fresh Pre-heated/pre-cooled air, in a temperature close to the indoor requirements, which extremely minimizes the heating/cooling loads.

This combination will provide an adequate constant level of day lighting all day long but in a quiet, heat-gain free and individually required way.

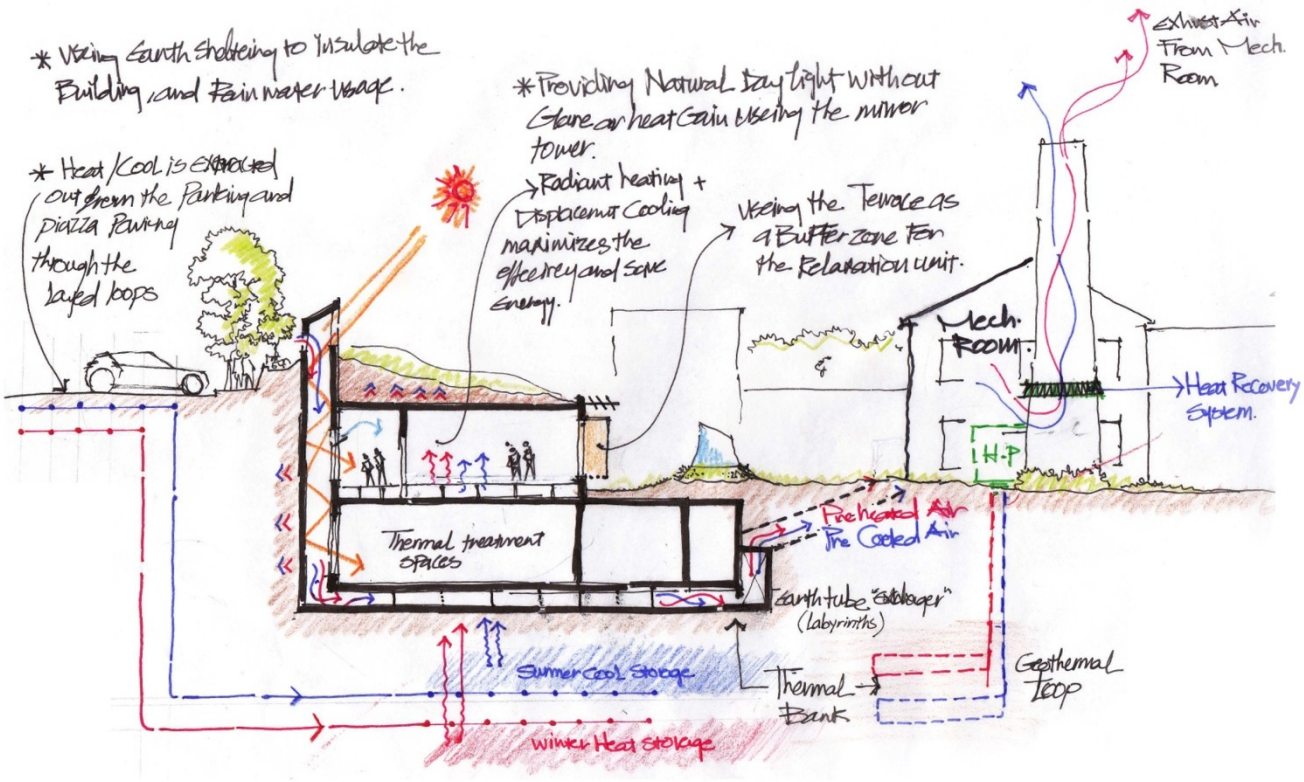


Figure 111 Wind tower, earth labyrinths, thermal bank and heat recovery system combined diagram

The tower of light:

It will be used to catch and supply the fresh air to the underground thermal labyrinths system, thanks to the motorized louvers which is oriented towards the site wind directions, and the green bushes which helps to drag the fresh air inside the tower, with a small low speed fan which can be used as required.

Figure 112 Heliostat with light tube, Extracted from (www.coltgroup.com)

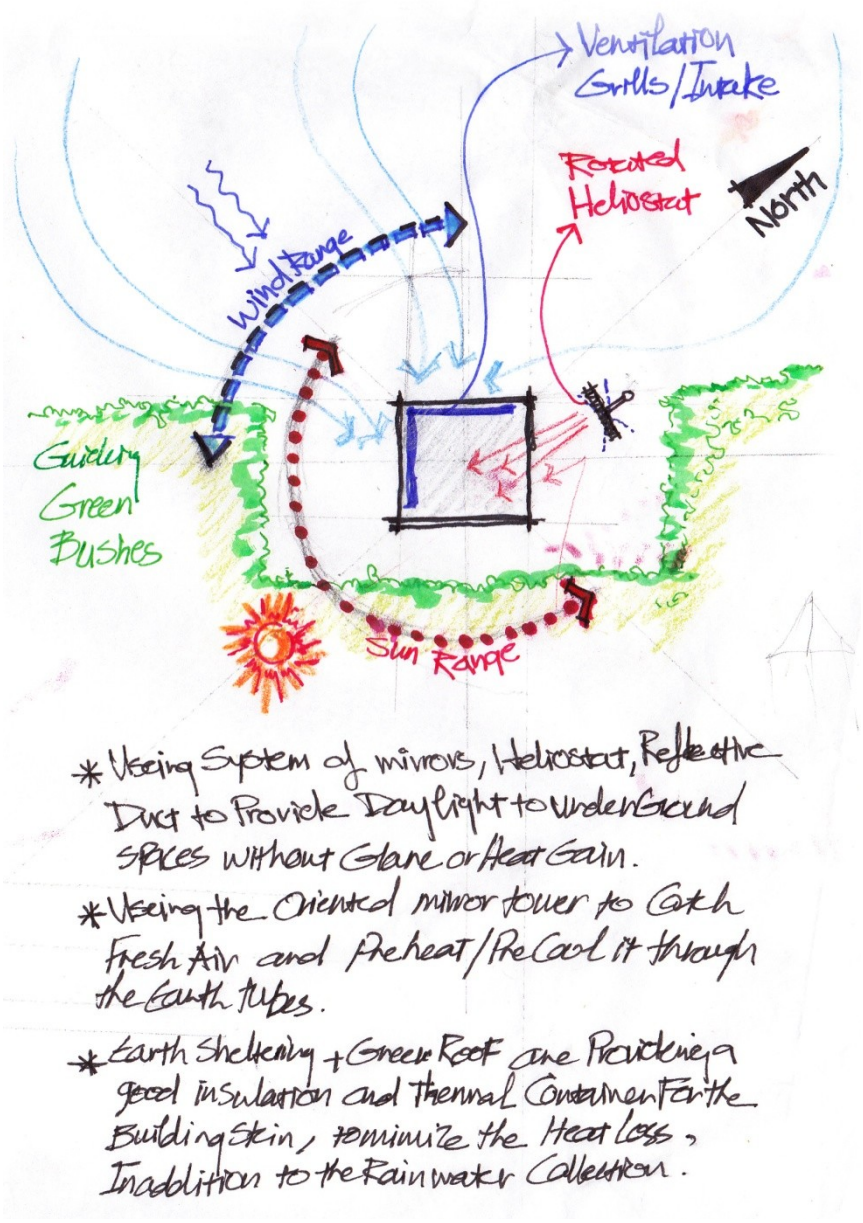


Figure 113 Tower of light and heliostat orientation

By integrating system of (Heliostat, sun tracking mirrors and inner reflective aluminum cladding), the tower will be able to capture the daylight all day long, and deliver it to the lower spaces like a permanent solar light tube.

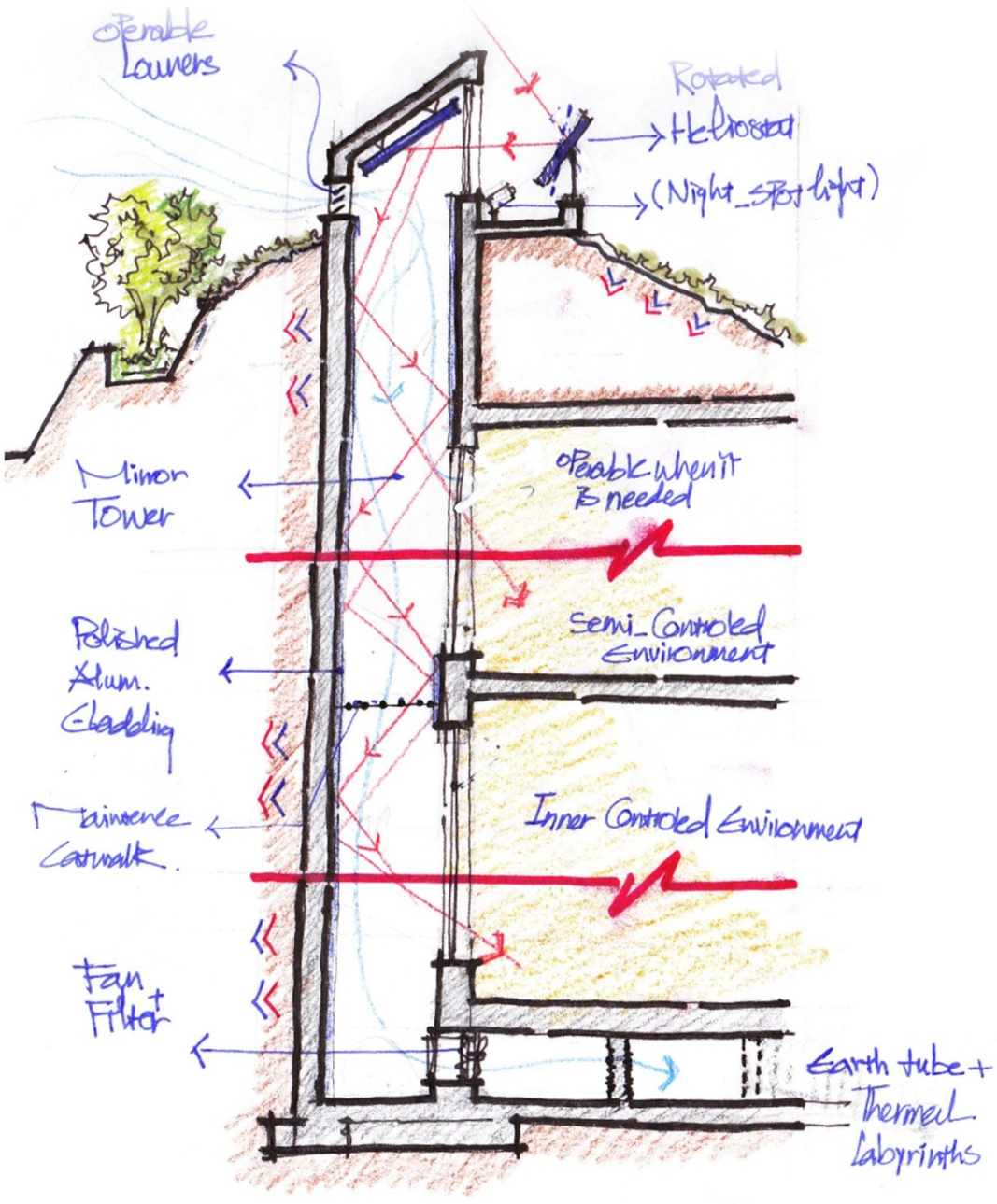


Figure 114 Tower of light section detail

Earth labyrinths:

Decoupled thermal mass storage and exchange system, which is often constructed directly beneath a building, it is simply a maze which uses a high thermal mass concrete undercroft with a large surface area, and due to the created air turbulence the roughness of the concrete surface and the bends of the maze, the fresh injected air will exchange heat, and been delivered to the HVAC system in the form of pre-heated/pre-cooled air. Meanwhile, the earth contact with the labyrinth gives the benefit of the charging the concrete panels with heat/cool from the earth thermal bank.

Earth thermal Bank:

It is on site renewable energy source that channels naturally occurring heat from the sun down to the ground in summer and back to buildings in winter to heat buildings without burning fossil fuels, on the contrary cold is captured on winter nights, stored in the ground in Thermal Banks to be released to cool the buildings in summer. Using a simple system of solar collection pipes imbedded in the soil, area below the building will be converted into a large thermal tank.

Further Technical clarifications regarding the previously mentioned integrated systems will be provided in the technological chapter.

4.5.2 The Living and smart skins:

Buildings communicate their function and status through a language of visual signs. A cross on the roof generally signifies a church, a grand arch commemorates a triumph, steel-and-glass curtain walls usually indicate there are offices inside, and a duck-shaped or hot-dog shaped building usually means that poultry or hotdogs are for sale[32].

A more dynamic system of communications arrived in the 20th Century with the first “zipper” sign in New York's Times Square in 1928, an illuminated bulletin board that transmitted the day's headlines: buildings henceforth began to communicate in data flows as well as via bricks and mortar, architects have begun working together to move beyond the facade and give buildings a living skin[11].

With respect to the final dynamic architectural image and visual coherence, in addition to the characteristic requirements of each internal space, priority was giving to provide a Smart controllable skin, which can react differently according to the external climatic conditions, to guarantee providing a permanent filtered interaction between inner/outer environments and to improve the passive behavior of the envelope.

[32] http://www.adobe.com/uk/designcenter/thinktank/livingskins/

4.5.2.1 The Meditation Room:

Now a-days, in the increasingly busy Western society, a lot of people are turning to the age-old Eastern practice of meditation. The reduced stress and increased focus that meditation gives us ultimately offers up a long list of physical and emotional benefits.

A meditation room should pretty much mirror your state of mind while you're meditating -- clear and uncluttered. This room is meant to be a sacred space to ground yourself and silence all of that inner chatter that bullies you throughout the day. Most of us are using an inner space, but if you have a place outside for your meditation room, is much better33.

For that reason, the creation of space which takes advantage of all of the inner space human comfort benefits and guaranties the full connectivity with the external nature was our target. To be able to give the impression that you are relaxing completely isolated in the middle of the outdoor park, but with full control over filtering the weather.

Introducing the terrace as an external translucent buffer zone was the solution, with a full controllable envelope, which maximizes the passive behavior of the unit and minimizes the thermal stress over the inner envelope.

Summer scheme:

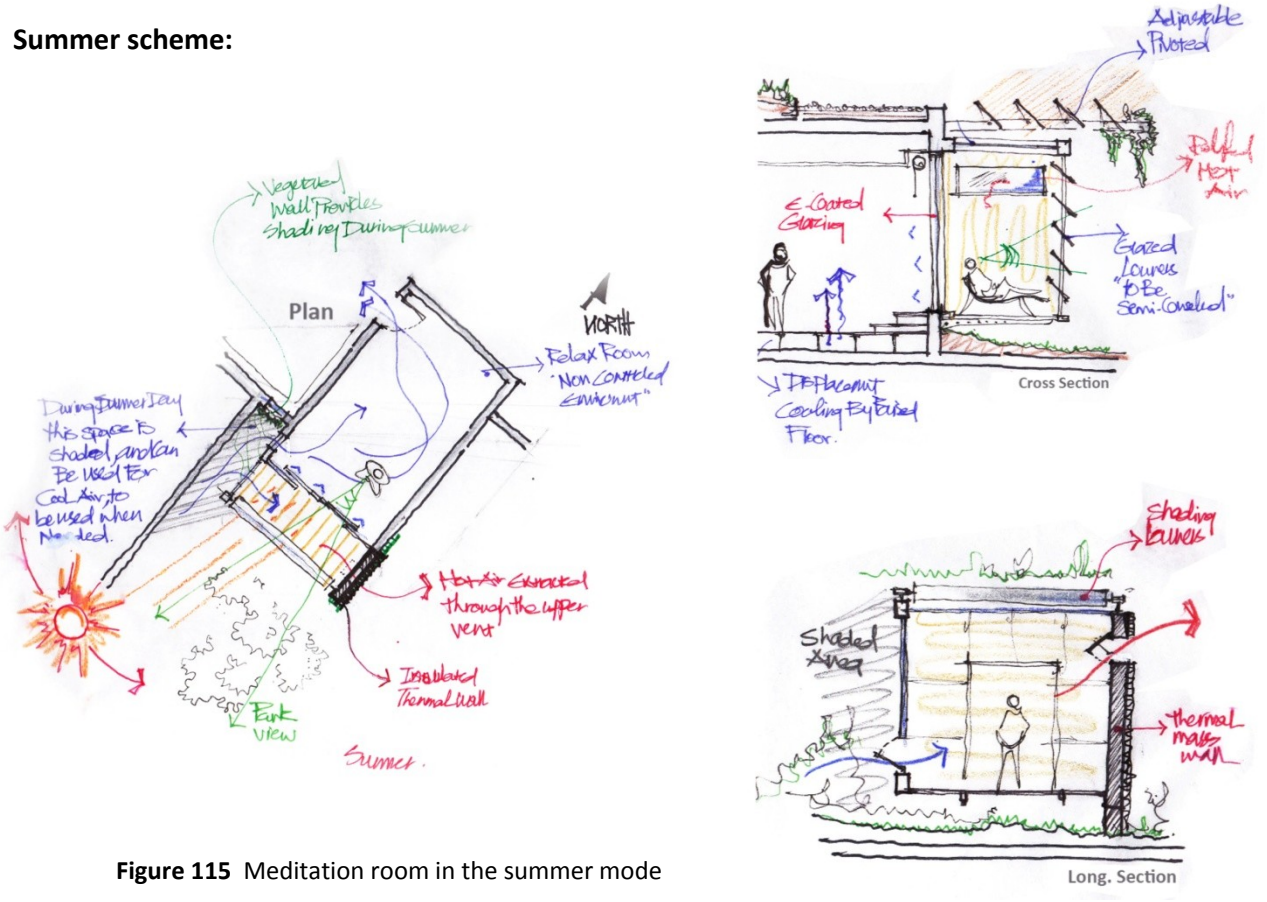


Figure 115 Meditation room in the summer mode

[33] http://tlc.howstuffworks.com/home/how-to-create-a-meditation-room.htm

With the summer 45° high sun angles, the 180° rotated automated roof blades will provide the complete shade to the buffer area and the thermal mass wall, in addition to the wall of operable motorized glazed louvers which deals with the morning low sun angles, and help cooling the buffer area.

Noting that the shaded small bit between the units works as a cool air tank, so by providing a lower motorized vent at one side of the terrace and another higher one in the non-shaded walled side, the air will be sucked into and extracted naturally. This will cool the terrace and minimizes the cooling loads of the inner space. The small side window, which is covered by the vegetated wall, can be used to allow the cool natural ventilation if needed.

Winter scheme:

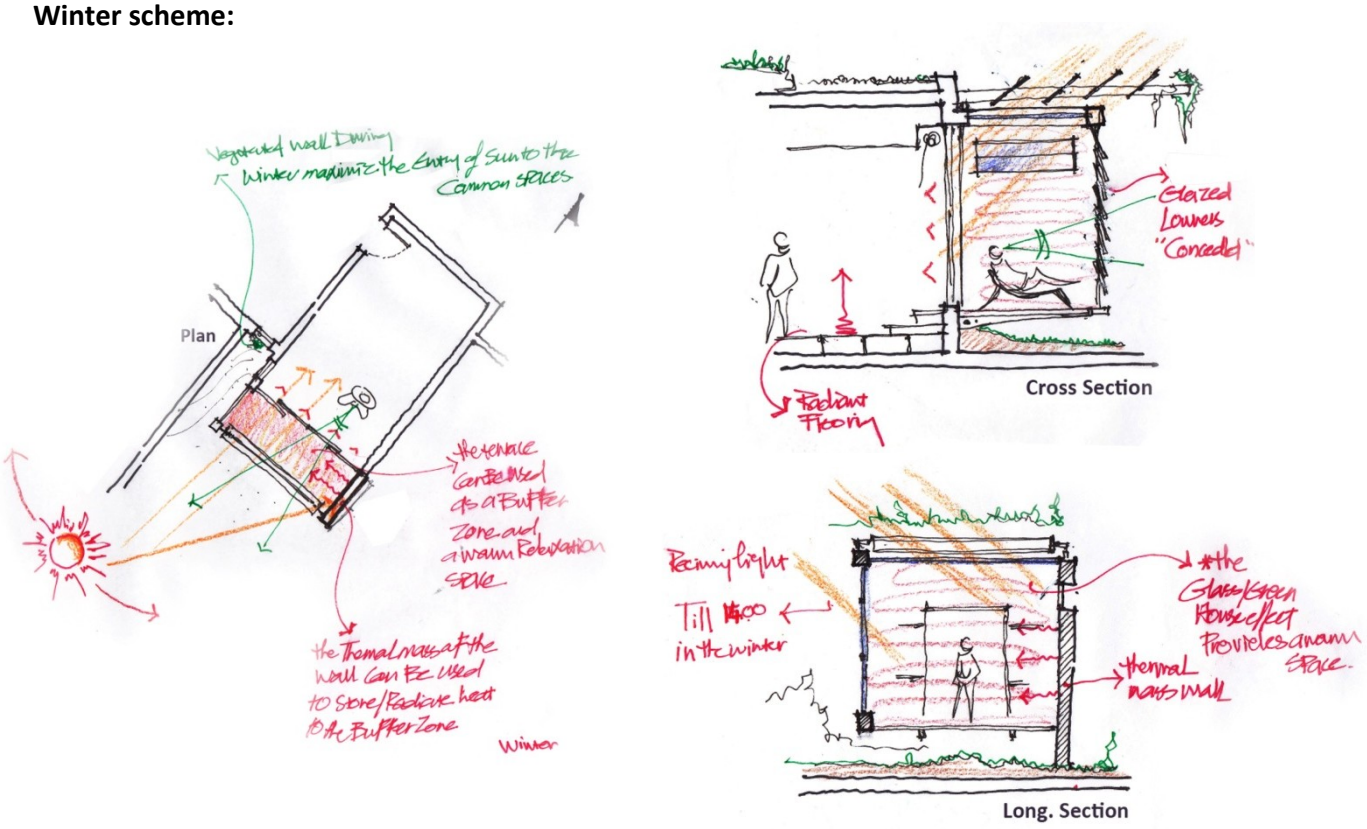


Figure 116 Meditation room in the winter mode

By adjusting the upper automated roof blades angle to let the maximum sun radiations come inside, the buffer zone and the thermal mass wall will receive and store heat all day long.

Considering that the closed motorized glazed louvers with weather strips will provide a complete sealed terrace. Relevant terrace will act like a warm glass house with respect to the thermal mass wall which will radiate heat even during the afternoons and the absence of the sun. Relevant warm buffer will provide a nice warm winter terrace and will also dramatically minimize the inner heating loads.

4.5.2.2 The two lungs of the building:

By developing two pre-heated and pre-cooled air tanks at the two sides of the building, we are creating a breathing and air wash scheme for the whole structure, using a system of PV solar shading.

The solar shading is a system of automated pivoted glazed louvers with integrated Photo voltaic cells connected to the BMS (Building management system) , which can provide a different seasonal passive behavior to the space behind it, in our case will be the Green house and the outdoor pool.

The filtered natural daylight will be maintained, in addition to minimizing the thermal stresses over the envelope, as will be clarified below:

Summer scheme:

Pre-cooled air will be stored in the Green house; by opening the solar shading to let the fresh air circulate the space, which is shaded by the louvers and the leafy trees.

A motorized vent will be provided for the inner green house glazed wall, to be opened simultaneously with the previously explained “Oculus”, to release the exhausted air out and drag the pre-cooled fresh air in for the building right wing ventilation.

Almost the same technique will be used for the left wing, but the air intake will be through the opened solar shading panels above the Outdoor pool, and exhausted in the same way.

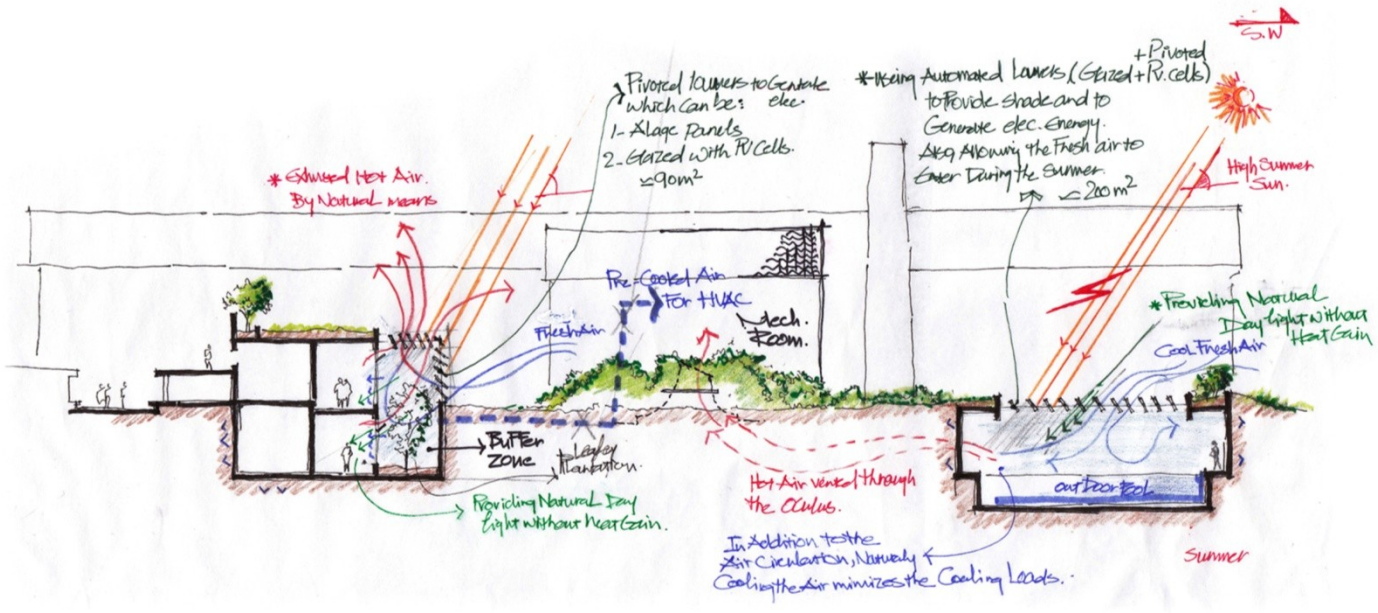


Figure 117 The Building 2 lungs in the summer mode

Winter scheme:

On the contrary, Pre-Heated air will be stored in the Green house, as per the usage of a seasonal leafing trees, the sun will access whole of the green house and heats the air trapped inside the green House by the closed louvers. That will create the glass house effect, which is needed during the cold seasons.

For the outdoor pool, the heated trapped air will have an extra benefit of maintaining the temperature of the heated water and minimizes the heat looses.

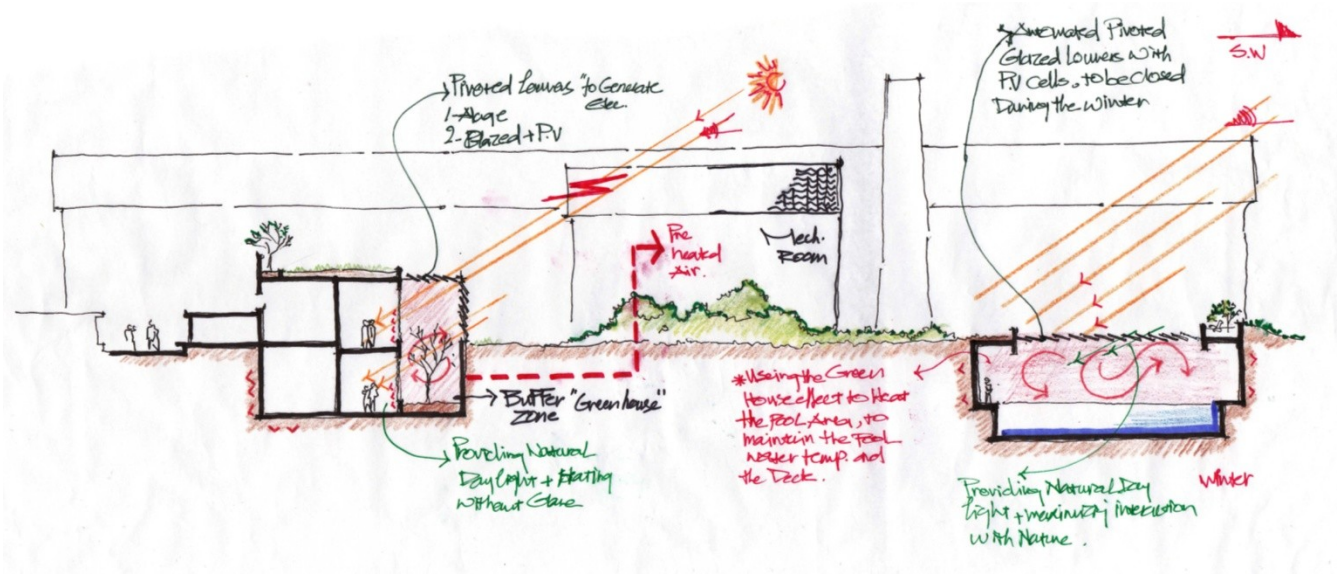


Figure 118 The Building's 2 lungs in the winter mode

4.5.2.3 Triangle windows:

The usage of the traditional window with a flat surface aligned to the wall for an office space oriented towards the south west can be crucial, as the façade will be exposed to the different south and west sun radiations with different summer and winter angles. Relevant situation brings the dilemma of Sun, Air and views, especially with a space with different needs during the seasons.

Thus, introducing an angled window with 2 surfaces oriented to the south and west separately can enhance the functionality of this opening and maximize the climatic controllability.

That will Improve the inner environment level of comfort, by letting the user to chose how much day light and with/without heat gain is needed -using the bent reflective integrated blinds from the southern side- and maintaining the continuous daylight, view and ventilation from the west oriented elevation, with respect to the mixed mode air conditioning approach we are using for non restricted areas, in terms of clothing code.

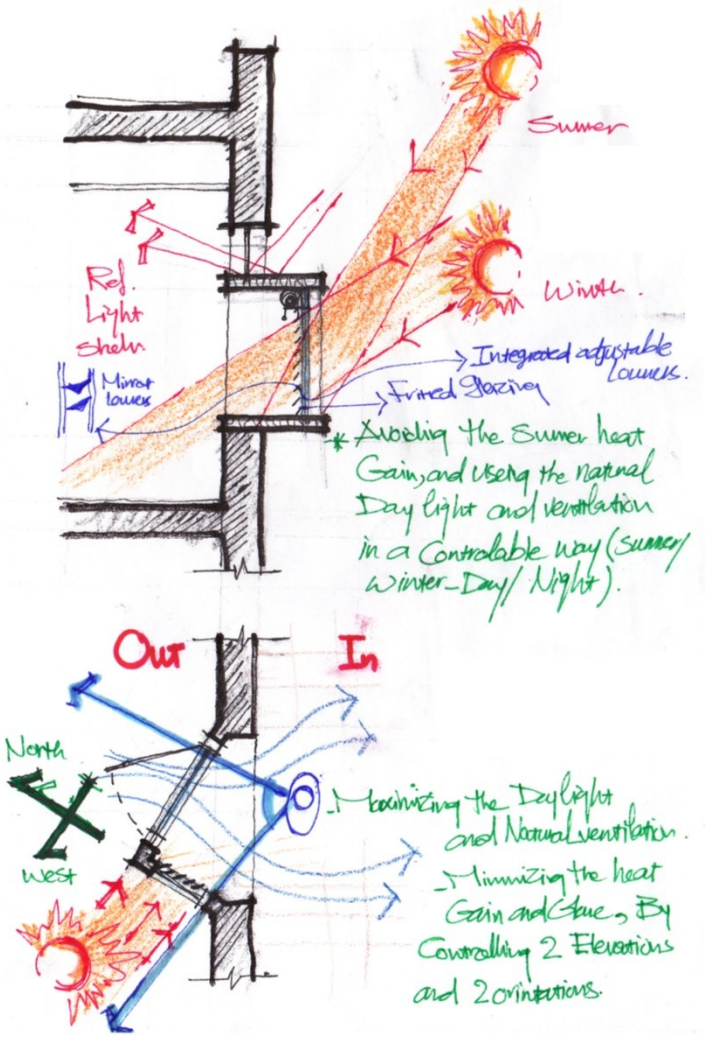


Figure 119 The triangle window details

4.5.2.4 Circulation Ramp:

Between the Existing factory building and the old boiler building (used for mechanical system), the recently added extension was located at the 1950's building, which does not belong to the era of the Mill and destroys the visual coherence of the complex.

New functions will be located inside this reconstructed extension, mainly the circulation ramp with a new south western façade. With respect to the ordinary clothing level in that area, connecting between the two existing mill floors, we can induce a passive ventilation scheme using a simple system of Solar inductors, which consists of a thermal mass wall with a dark color, single layer of glazing and operable motorized vents, as shown in the figures below.

During summer, by opening the lower and upper vents, the stack effect will be naturally activated to release the hot air form the top and extract the cool air from the shaded North eastern side.

During winter, the upper roof vent will be closed and the upper wall vent will be opened, to let the internal air be circulated and heated, after being exposed to solar radiations and thermal mass wall.

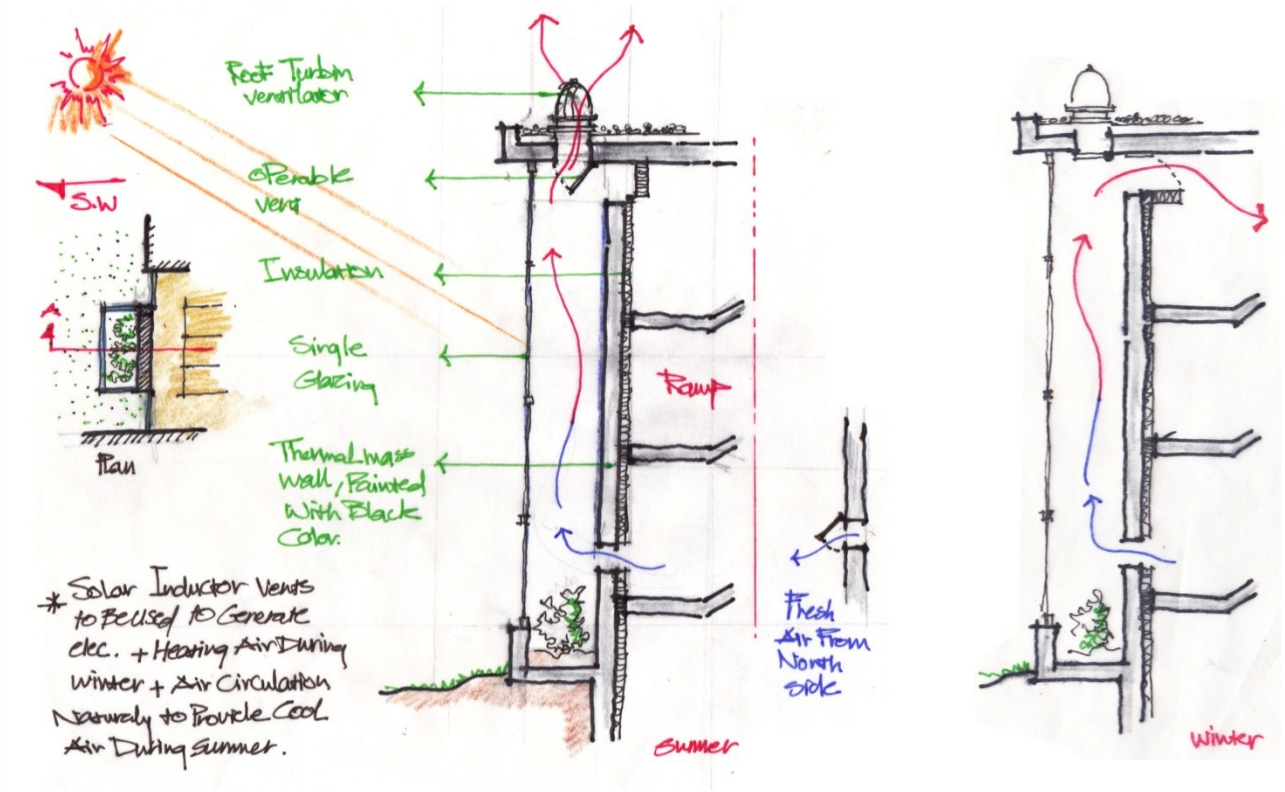


Figure 120 Solar wall inductor behavior in summer and winter

4.5.2.5 Vegetated vertical skins:

The earth sheltering technique and maintaining the visual harmony between the new added mass and the park are not the main reasons behind the usage of the vegetated wall, but mainly for its sustainable benefits mentioned below, as we were trying to avoid any kind of camouflage or fake Beautification.

Building Protection: Green wall works as Shield from harsh environmental conditions and reduce Temperature fluctuations of the building envelope, which extends the building's lifespan.

Air Quality: Green Walls improve the indoor and outdoor air quality,

and works as natural sponges for dust and toxins in the air. Considering that a 50 sq.ft of Green wall panel system consumes

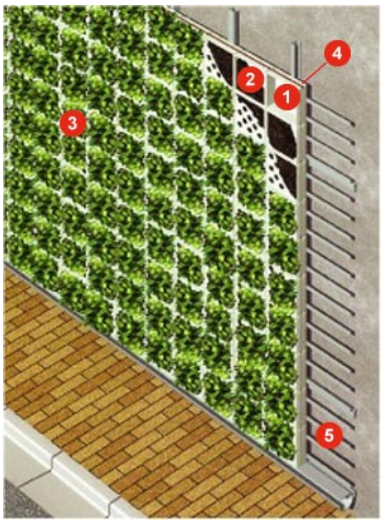


Figure 121 Soil modules, extracted from (www.gsky.com)

approximately the same amount of CO_2 as a 13 foot-high tree per year[34].

Energy Savings: Green Walls works as insulators that reduces energy bills, by minimizing heating and cooling loads, as they can reduce wall temperature as much as 15°F and reduce energy transfer into a building by ~0.24kWh/m^2 [13].

Temperature Regulation: Green Walls help to provide lower building temperatures and reduce the heat island effect, because of the cooling effect resulted from the evaporation process and shading surfaces that are conducive to heat absorption.

Urban Beautification and Branding: by softening the external finishes look and maximizing the sense of harmony with nature, we are creating a bold green iconic statement which attracts the public and emphasize the social interaction.

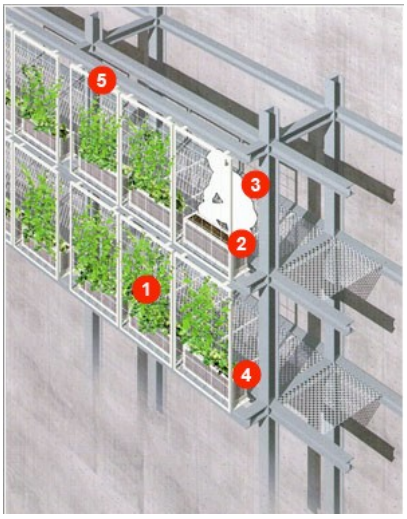


Figure 122 Containers and catwalk, extracted from (www.gsky.com)

Health, Wellness and green healing: generally greenery can improve a person's health and well-being. Also, Stress Reduction & Relaxation effect can be achieved due to the release of physiological and psychological pressures.

Urban Wildlife: along with the right choosing and planting attractive plant species, a Green Wall will attract birds and butterflies, which is quite effective to restore wildlife habitats.

Sound Insulation: Reducing the Noise by providing a noise buffer which significantly reduces outside noise and vibration (up to 40dB) inside spaces and sound reflection in a building[13].

Accreditation and certificates system: Considering that we are using the LEED NC to guide and evaluate our final project results, using the Green wall will improve our final rating, as will be concluded in the final chapter.

4.5.3 Compiled ventilation scheme

To guarantee the functionality of all of the above presented solutions, compiling them together was obligatory, to evaluate their adequacy and compliance with both of building envelope needs and spaces requirements, in order to ensure the final product efficiency as one comprehensive living machine.

Since we are dealing with a wellness and Spa center, where the inner comfort is quite crucial as a sensitive inner environment, the

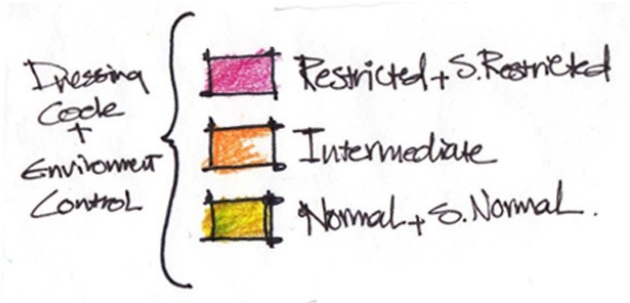


Figure 123 Spaces' classification diagram

[34] http://gsky.com/green-walls/benefits/

building was divided into different zones according to the clothing level, which can be translated into the degree of inner environment controllability and sensitivity to the air velocity, temperature and vapor content. The spaces can be divided into restricted, semi-restricted, Intermediate, Normal and Semi-normal spaces, relevant scheme can be explained according to the below presented draft sketches:

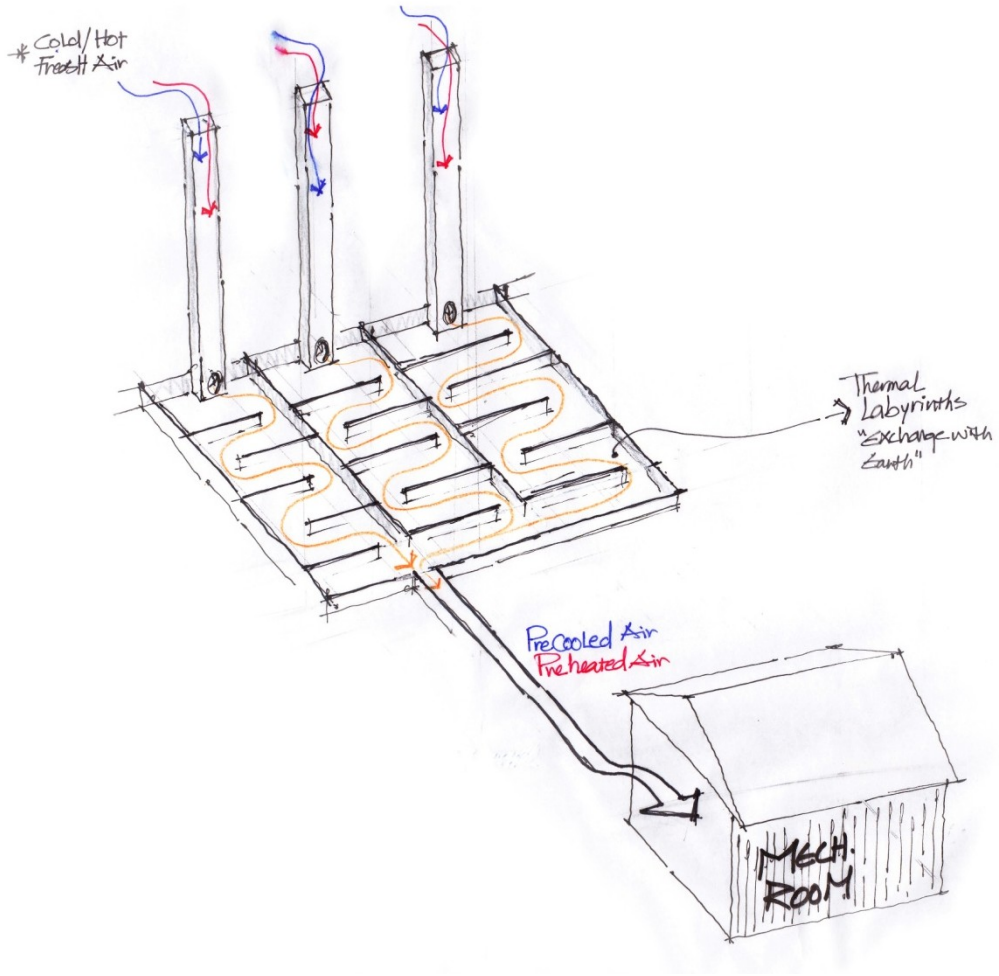


Figure 124 Supplying Pre heated/cooled air through the wind tower and the labyrinths

As highlighted earlier, the pre-heated/cooled air extracted by Earth labyrinths and tower of light will be used only to supply the AHU located in the mechanical room, to be filtered and supplied mechanically to the spaces, and will not interfere directly with any of the building internal spaces.

Summer scheme:

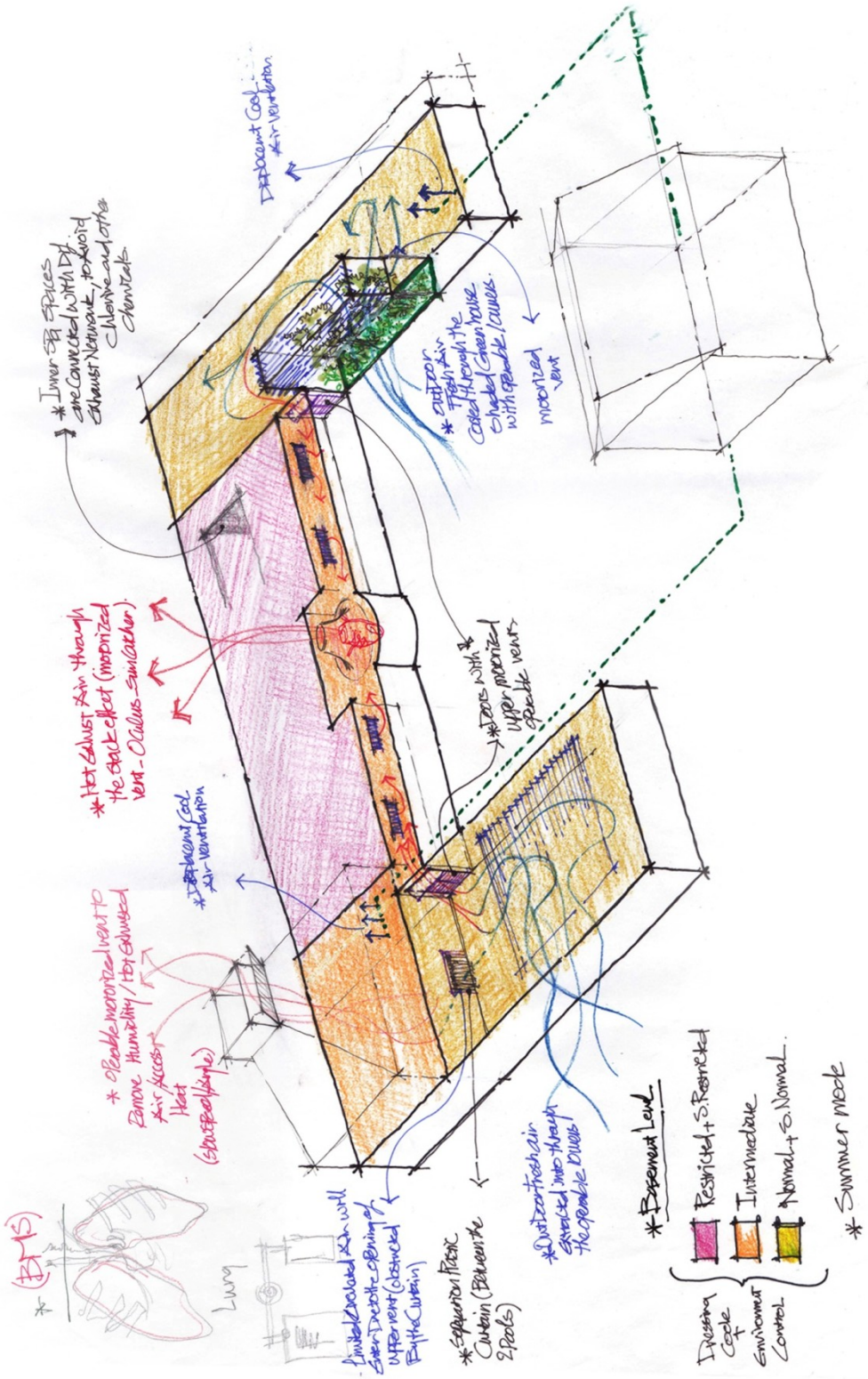


Figure 125 Summer ventilation and cooling scheme _ Basement level

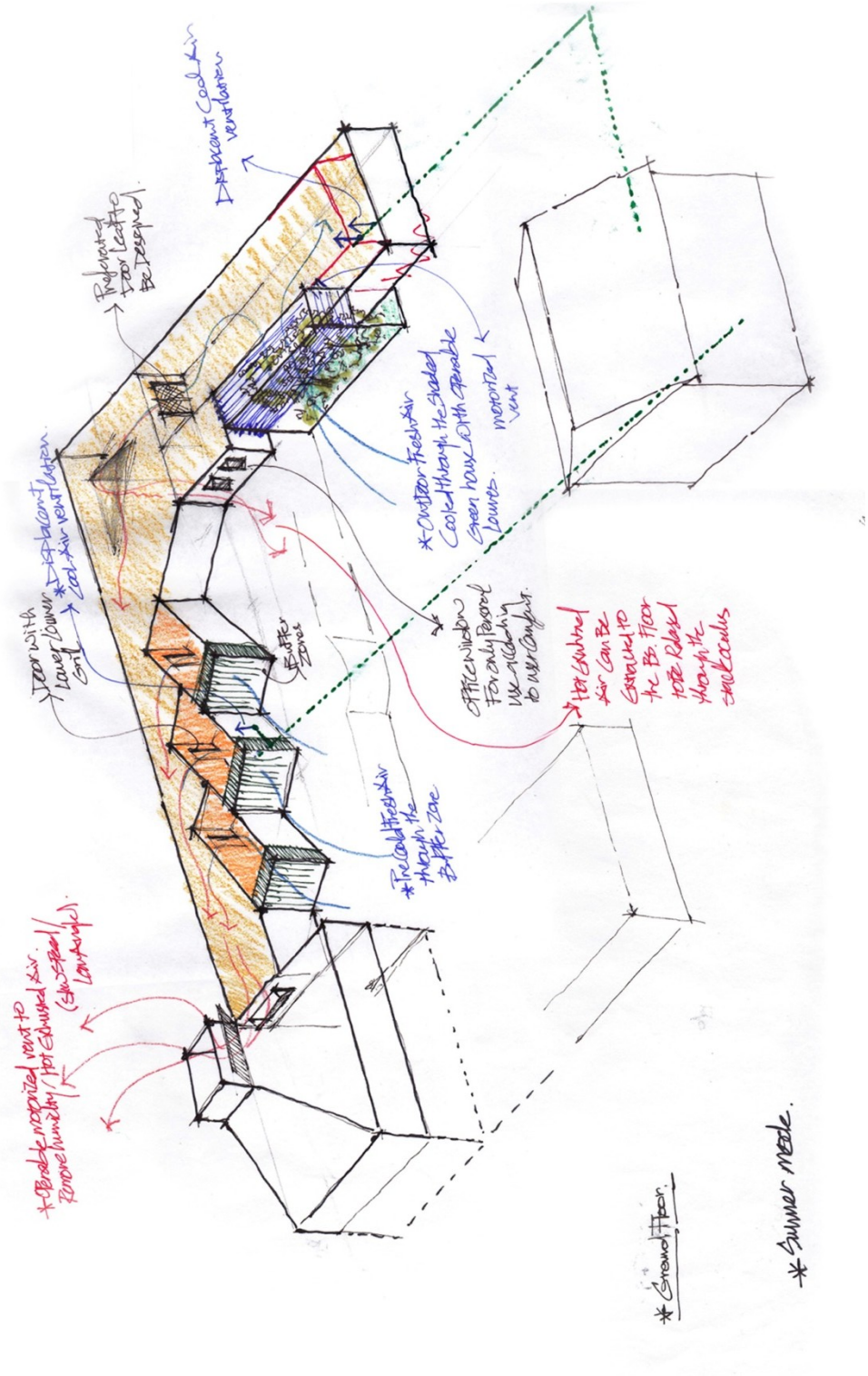


Figure 126 Summer ventilation and cooling scheme _ Ground Floor level

Winter scheme:

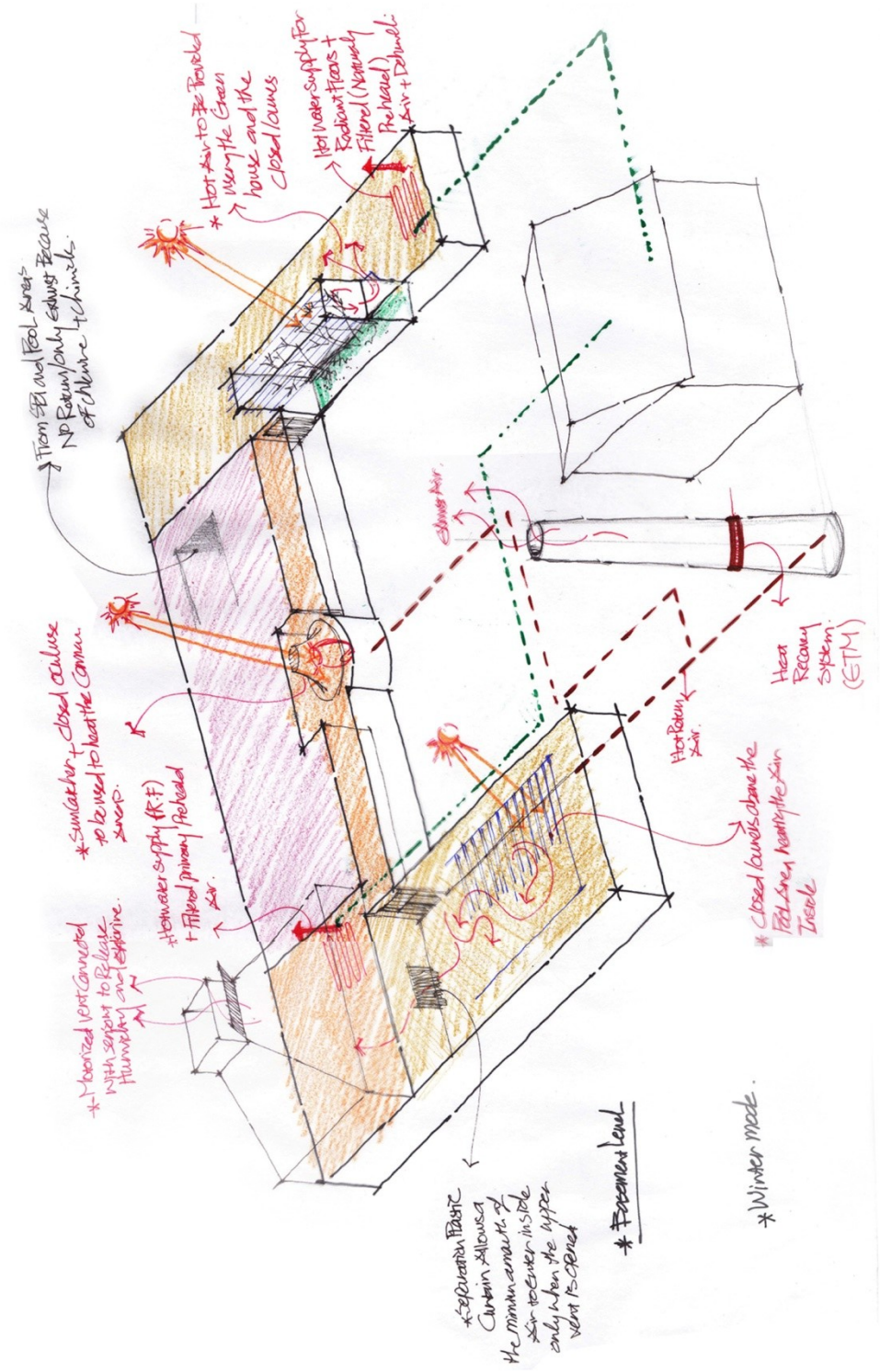


Figure 127 Winter ventilation and heating scheme _ Basement level

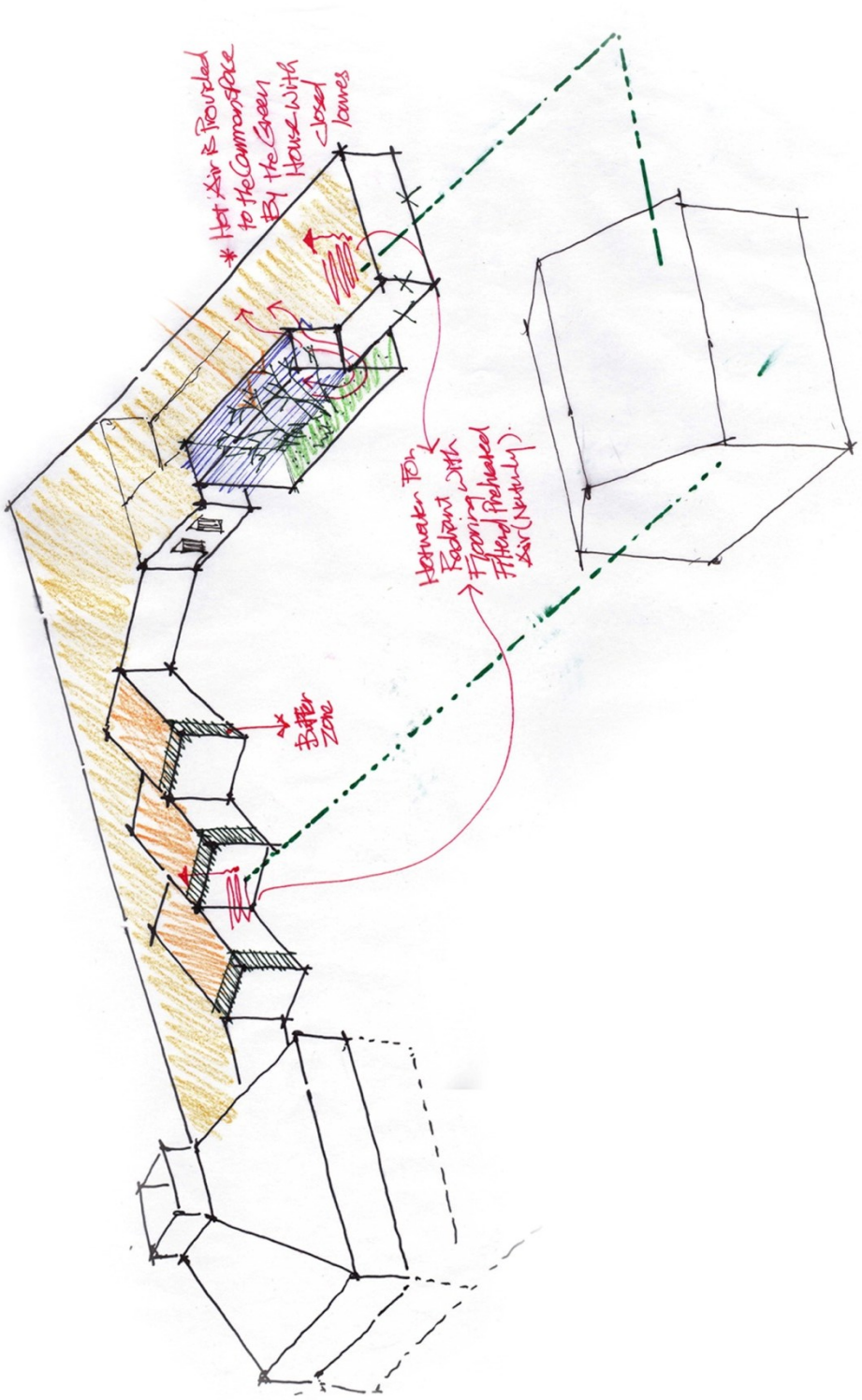


Figure 128 Winter ventilation and heating scheme _ Ground floor level

As clarified earlier, all of the building is controlled using a Building Management System unit, which is acting like the building brain, linking all of the motorized Vents, heliostat, Louvers, sky lights, solar shading, air out lets and artificial lighting with building sensors and meters network.

Further clarifications will be provided in the Chapter V - Technological and Services, linking all of the integrated systems to the Heating and cooling schemes.

5. The proposed solution drawings

By compiling all of the above mentioned techniques and strategies, the resultant design can be represented as shown in the following schemes, drawings and renders.

Site plan

Basement Floor plan

1-Arena Hydro massage
2-Areomassage Beds
3-Geysers
4-Outdoor relax area
5-Outdoor pool 34 ° C
6-Swan neck
7-Indoor pool 34 ° C
8-Cervical Whirlpool
9-Arena Areomassage
10-Cervical Geysers
11-Relaxation Deck
12-Sacks & Natural Herbal teas
13-Kneipp path (phlebological)
14-Kneipp path (phlebological)
15-Down to the Pool Mech. room
16-Stromwater and Grey water tanks
17-Turkish bath
18-The Oculus Lounge and bar
19-Alpine sauna
20-Cold Cloud
21-Hot reaction
22-Finnish sauna
23-Oils & Herbs Corne
24- Herbal sauna
25-Scottish bath
26-Roman Bath & Emotional showers
27-Personalized massage
28-massage
29-Personalized massage
30-massage
31-Physiotherapy
32-Treatmants
33-Feet shower
34-Info. & Program management
35-Electro.Mech. Room
36-BMS
37-Higiene shower
38-Clean Storage
39-Spa area reception
40-Used/dirty storage
41-Music Lounge and waiting area
42-Glass house
43-Fire exit

0 1 2 3 4 5 10 15 20 METRES
0 5 10 15 20 30 40 50 60 FEET

POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1:300

AR 02

Ground Floor plan

1-Meditation Room
2-opened to below
3-seating and waiting area
4-Beauty and facial care corner
5-Green Food market
6-Health shop
7-Reg. Office
8-Entry Vestibule
9-Herbal cafe
10-Bike racks
11-Lower piazza
12-Glass house
13-Corridor of memories
14-Fitness Reception Lounge
15-Mechnical room
16-Kitchen
17-Storage area
18-Snacks and beverages corner
19-Service elevator lobby
20-Loading dock
21-staff and security entry office
22-Restaurant and Admin. Entrance
23-Restuarant
24-Male Showers and lockers
25-Fermale showers and lockers
26-Electro-mechanical
27-The day use reception and lounge
28-Day use room

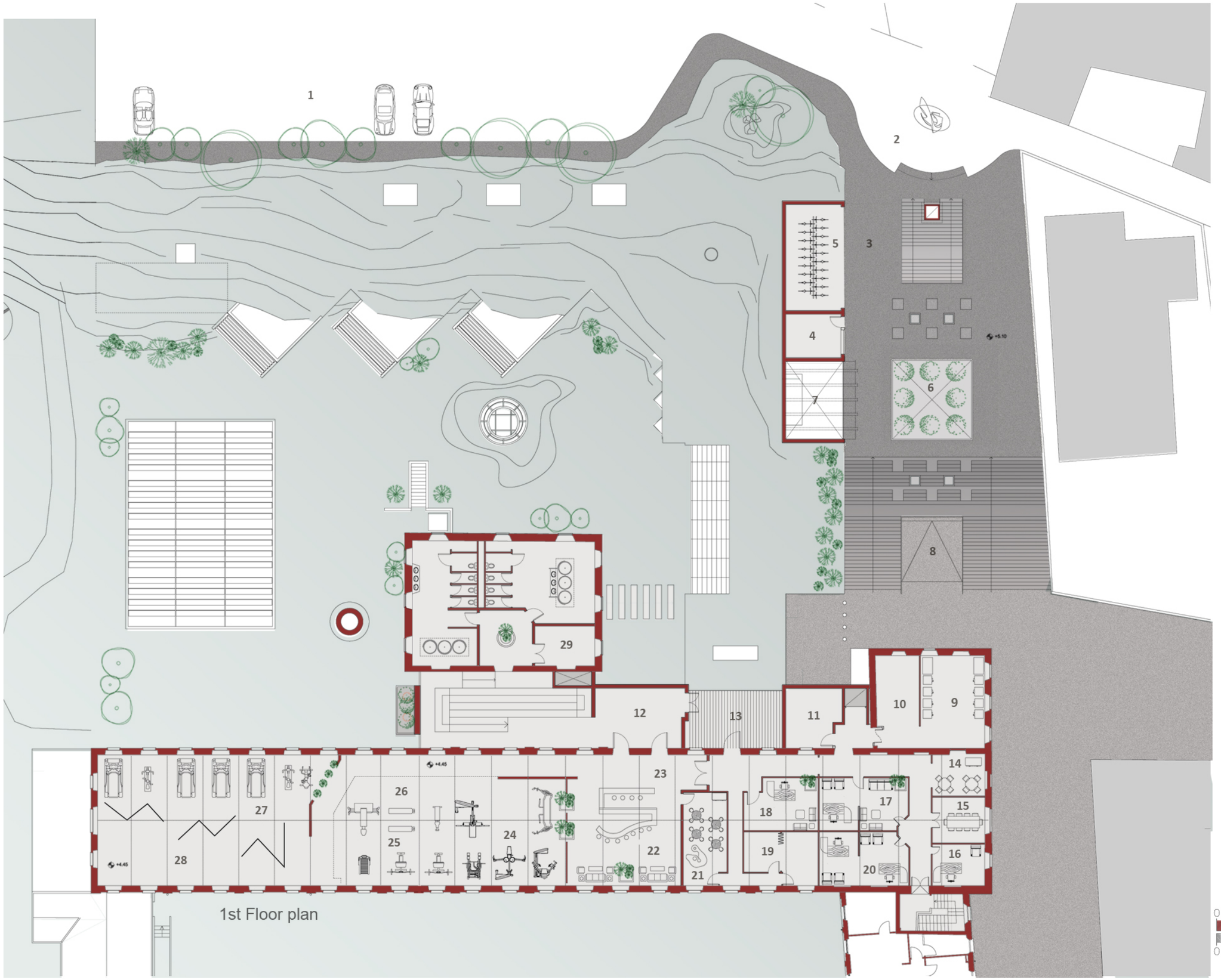
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1:300

AR 03



1-Parking
2-Drop off + round about
3-Upper piazza
4-N.P koisk +tabaccheria
5-Free BLUE bike
6-Opened to below
7-Opened to the below entry
8-to The lower piazza
9-Laundry
10-Towels and robs storage
11-Stroage
12-Lobby + Snack corner
13-Terrace
14-Staff Lounge
15-Meeting room
16-Admin.
17-Reservation office
18-Trip advisor and coordination
19-Clasroom
20-Promotion office
21-Childeren area
22-Lounge and bar
23-Reception desk
24- Strength equipment hall
25-Free weights area
26-Fitness hall
27-Group exercise hall
28-Cardio Theater
29-Electro.Mechanical

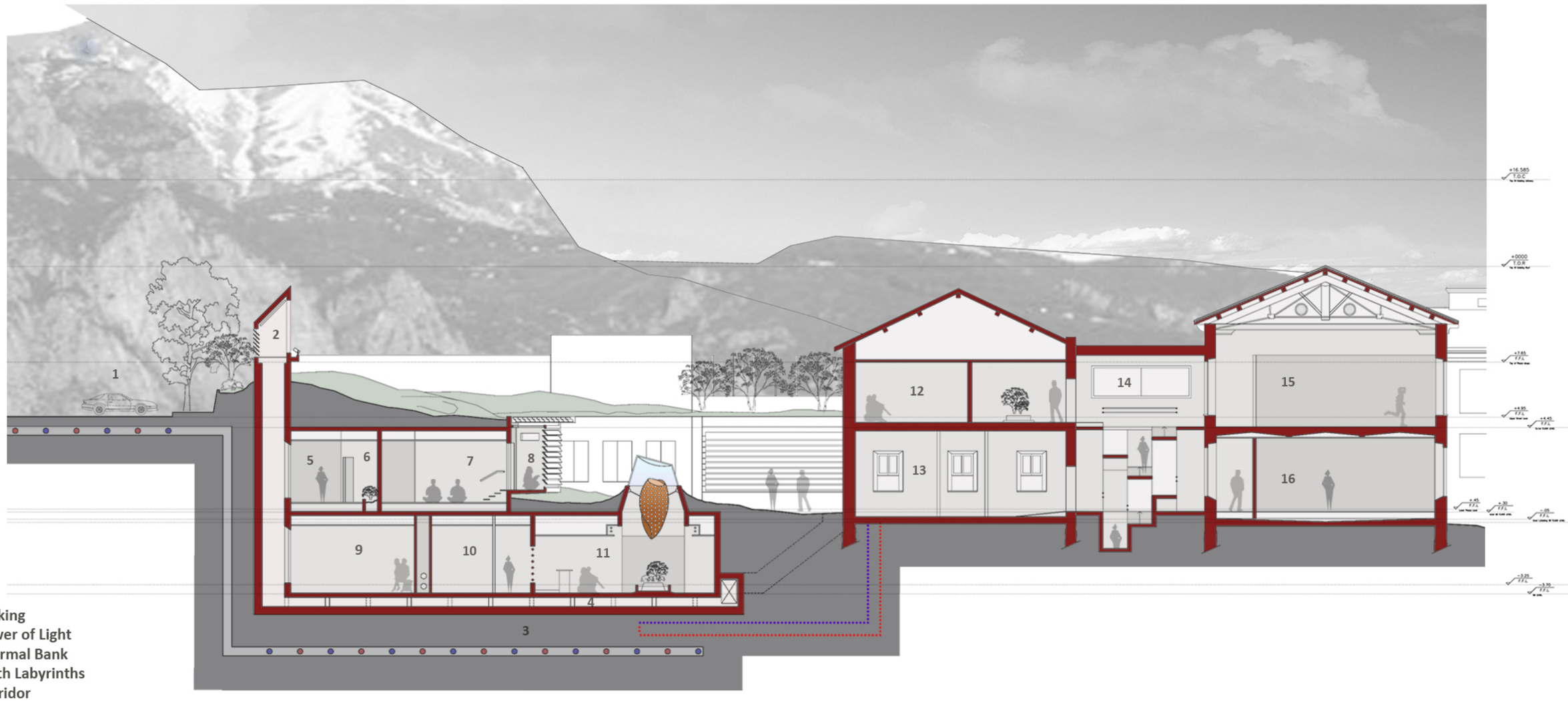
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

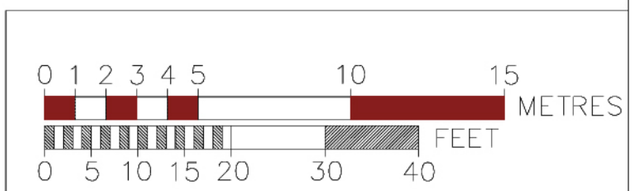
SCALE
1:300

AR 04



1-Parking
2-Tower of Light
3-Thermal Bank
4-Earth Labyrinths
5-Corridor
6-Setting Area
7-Mediation Room
8-Terrace
9-Roman bath
10-W.C
11-The oculus lounge
12-W.C
13-Mechanical Room
14-Circulation Ramp
15-Gym Hall
16-Showers and Lockers

Section 01



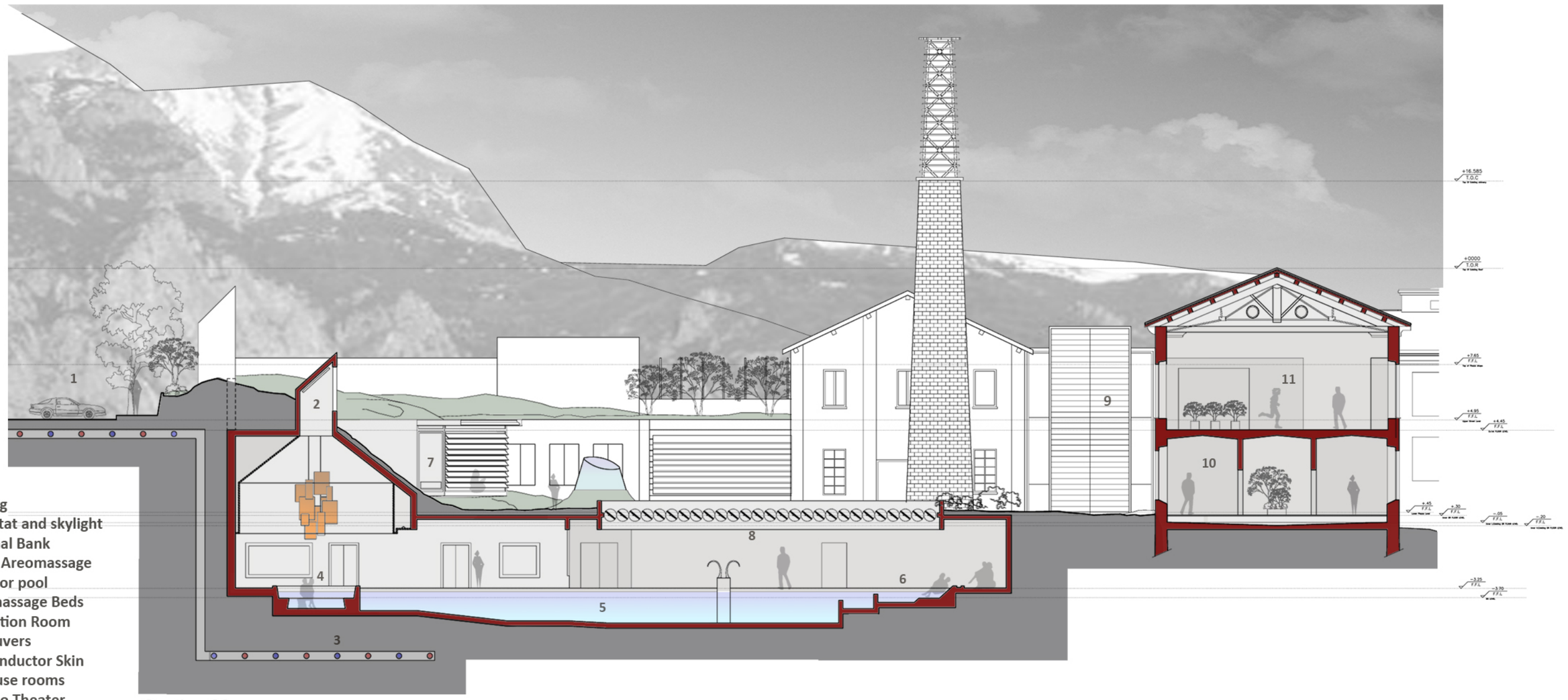
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1:200

AR 05



1-Parking
2-Heliostat and skylight
3-Thermal Bank
4-Arena Areomassage
5-Outdoor pool
6-Areomassage Beds
7-Mediation Room
8-PV Louvers
9-Solar Inductor Skin
10-Day use rooms
11-Cardio Theater

Section 02

0 1 2 3 4 5 10 15 METRES
0 5 10 15 20 30 40 FEET

POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1:200

AR 06

Section 03

1-To the lower Piazza
2-To the Upper Piazza
3-Towels and Robs storage +reception
4-Corridor
5-Passage of Memory
6-Herbal Cafe
7-Rain water and grey water storage
8-Pool mechanical
9-Glass House
10-Out door Pool
11-Down to the Lounge

0 1 2 3 4 5 10 15 METRES
0 5 10 15 20 30 40 FEET

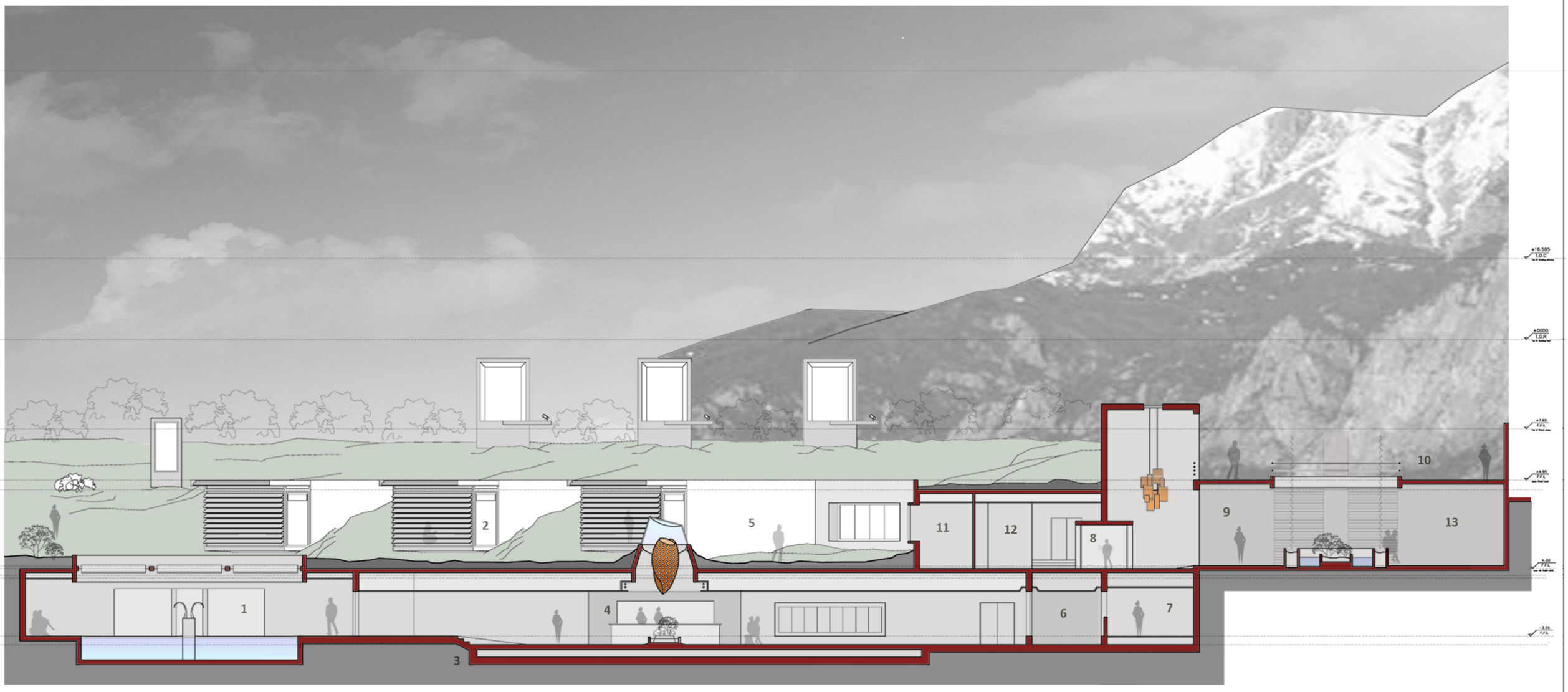
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

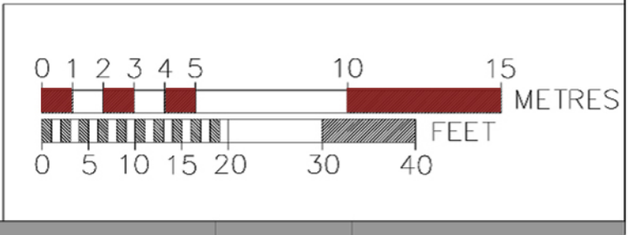
SCALE
1:200

AR 07



Section 04

1-Outdoor Pool
2-Terrace
3-Earth Labyrinths
4-The oculus lounge
5-Meditation Room
6-Corridor
7-Higiene Shower
8-Main Entrance
9-Lower Piazza
10-Upper Piazza
11-Rec. Office
12-Reception
13-Outdoor cafe



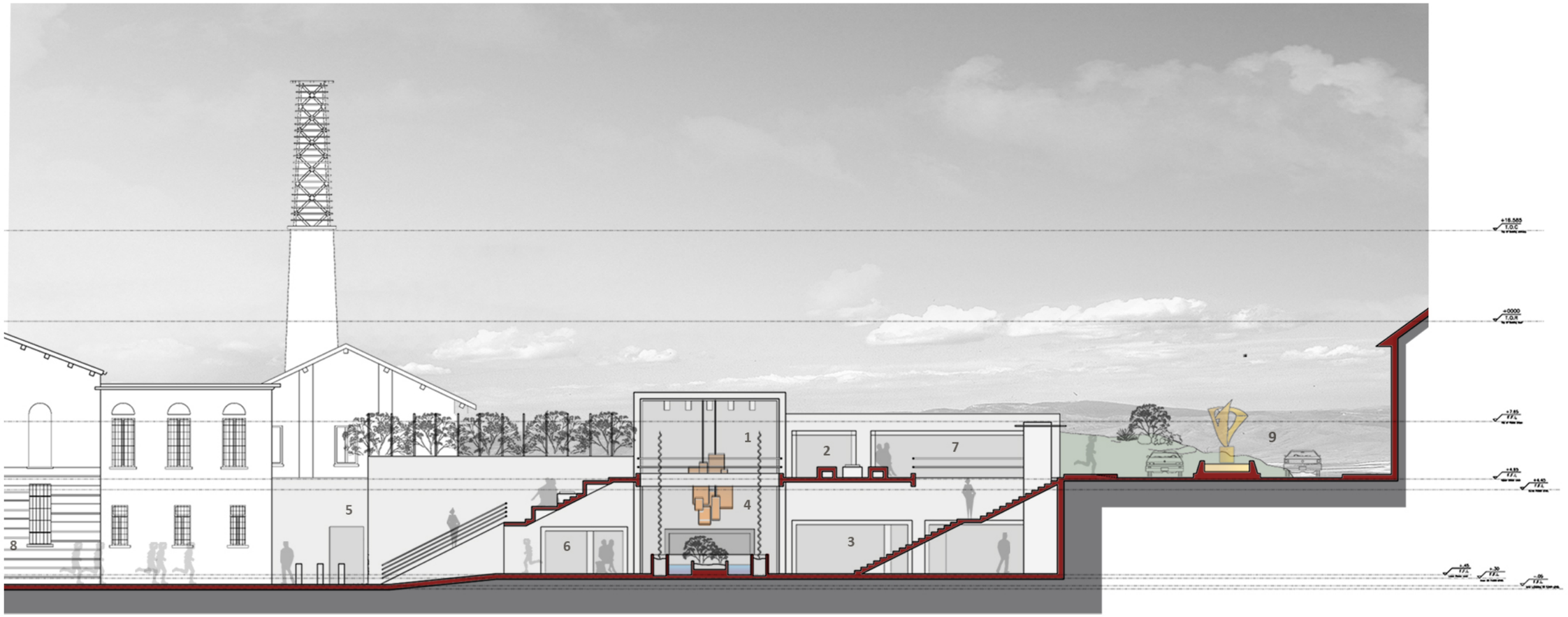
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

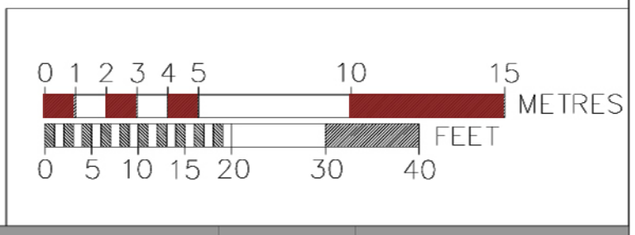
SCALE
1:200

AR 08



Section 05

1-Gavazzi Piazza
2-Tabacaria
3-Health shops
4-The Body factory Entrance
5-Service Entry
6-Herbal Cafe
7-Bike racks +Blue bike
8-Staff Entry
9-Roundabout + Drop off



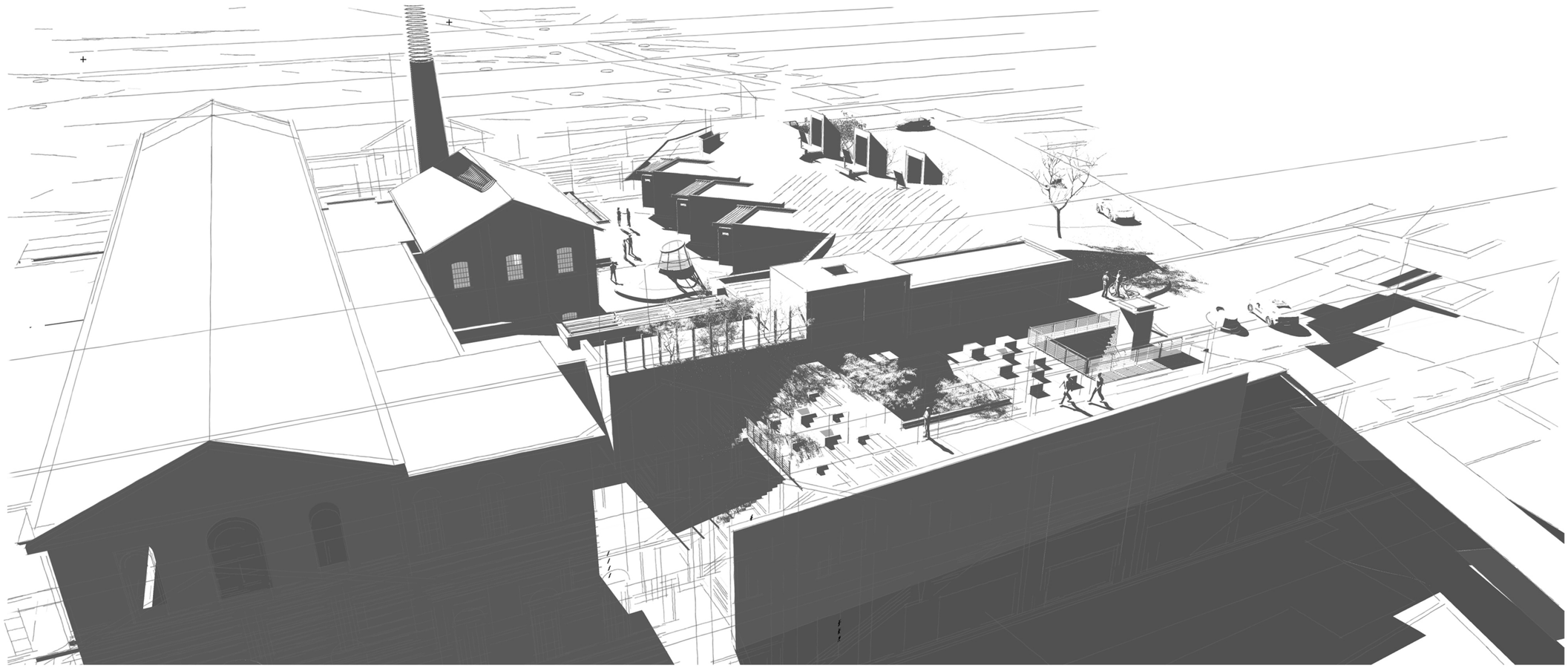
POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

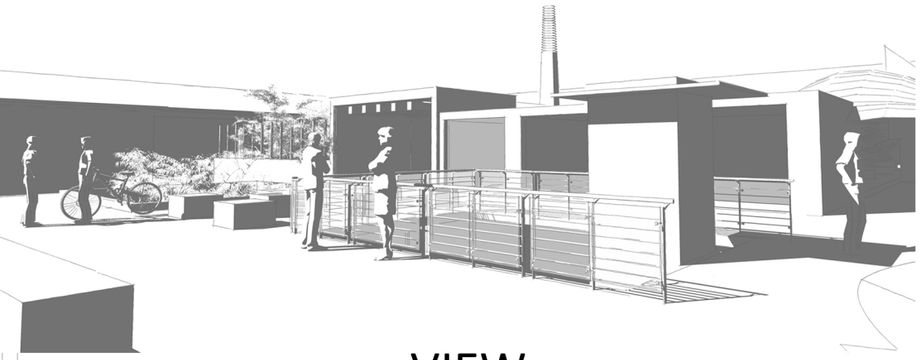
A.Y. 2012/2013

SCALE
1:200

AR 09



NORTH VIEW
VIA Volta Entrance

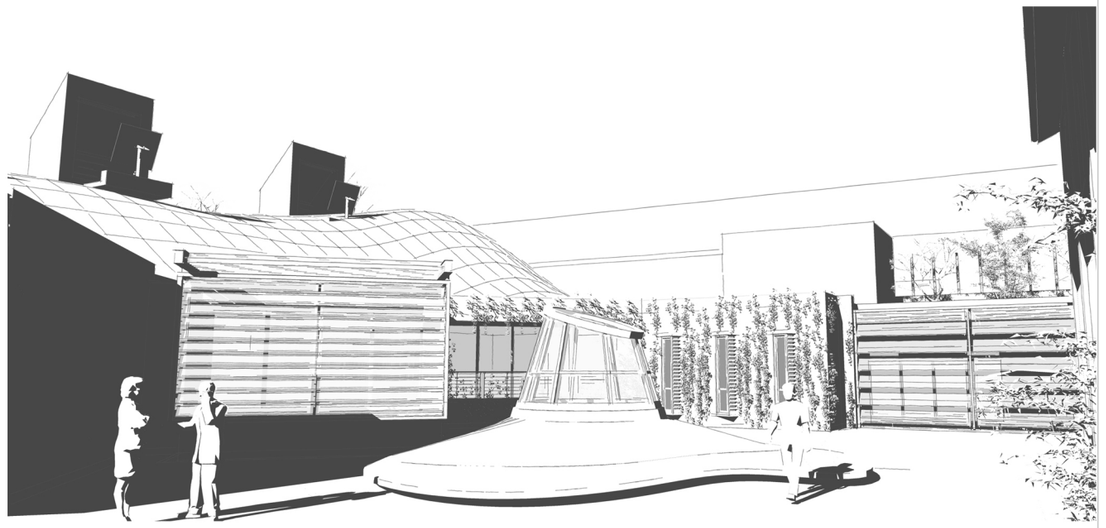


VIEW
Top Of Piazza

NORTH VIEW
VIA Campogrande Entrance

SOUTH VIEW
Corni di Canzo side

SOUTH VIEW
Romantic Garden side

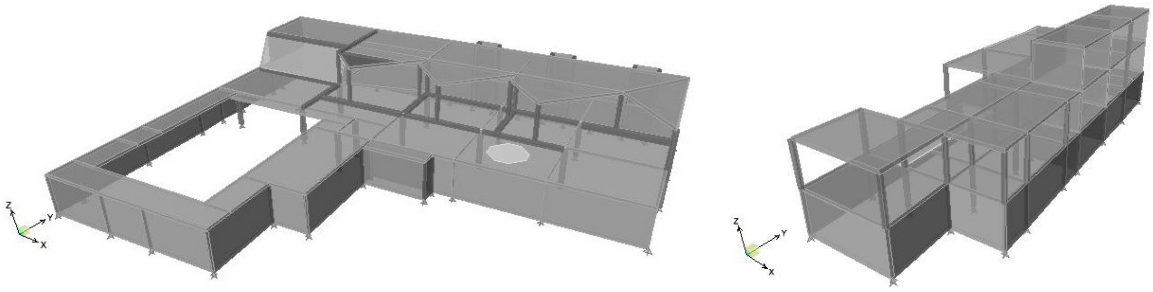


VIEW
Inner Court

CHAPTER IV

Structural Design

1. Introduction



Structural design is an integral part of the building design process. It plays a vital role not only in the stability of the structure but also for protecting the building against forces of nature and to avoid any pathology during the expected life of the building.

Our project site is located in Valmadrera, a small city, in the province of Lombardia, in Italy. The new structure is apart from the former silk factory building being there since long. The main body of the structure is underneath the ground level, exploiting the topography of the area and to have minimum foot print on the well conserved green landscape around the site.

The design of building is mainly in concrete, to achieve the desired results for the applications of structure design. The choice of concrete as a material is owing to the fact that most of the structure is below soil level and in order to retain the soil pressure and to bear other loads like snow, green roof etc, our ultimate choice came out to be concrete.

The analysis is made by both handmade calculations and computer based. For this very purpose we have used ETABS structure analysis software which gives sufficient descriptive and graphical representations of the stresses and forces, including bending moments, shear forces and axial forces etc. The applied load is used in different combinations in the software to cover exceptional and extreme load cases applied on different structural elements. The calculations are presented for different typical elements.

As a design code we followed the Eurocode approach for loading, actions, materials etc. The corresponding checks for different elements were verified as were mentioned in the corresponding documents of Eurocode standards.

1.1 Structural expansion joint

The complexity of the building concerning its linear dimensions resulted in the scale that it is better to design the structure into two parts, also following the reasons:

1- Preferably, every building should be separated after about 35 meters running length.
2- The irregular structural behavior of the building fulfilling seismic requirements.

3- For the matter of safety, if the building is of such a size, to prevent damage to only a part of it rather than the whole complex.

2. Sustainable Approach

2.1 Material selection

2.1.1 Fly-Ash Concrete

Fly-ash is a by-product of coal-fired electric generating plants. Although fly-ash offers environmental advantages, it also improves the performance and quality of concrete. Fly-ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. Fly-ash increases strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphate resistance, and reduces alkali-aggregate reaction[35].

Currently the Industry of cement and concrete makes use of 27% of the European production of fly ash residue; by increasing the use of this material a high contribution to the environment will be produced. *For every ton of fly ash/ton of Portland cement, 1 ton of CO_2 is reduced to be released into the atmosphere*[36].

2.2 System selection

2.2.1 Bubbledeck Slab

We have used the Bubbledeck technology for the slab structure in the project. As the name suggests, Bubble deck slab consist of plastic spheres which are made of recycled high density polyethylene HDPE. The basic effect of the bubbles is the weight reduction of the deck. The dead load of the Bubble Deck is 1/3 lesser than a solid deck with the same thickness and that without effecting the bending strength and the deflection behavior of the deck.

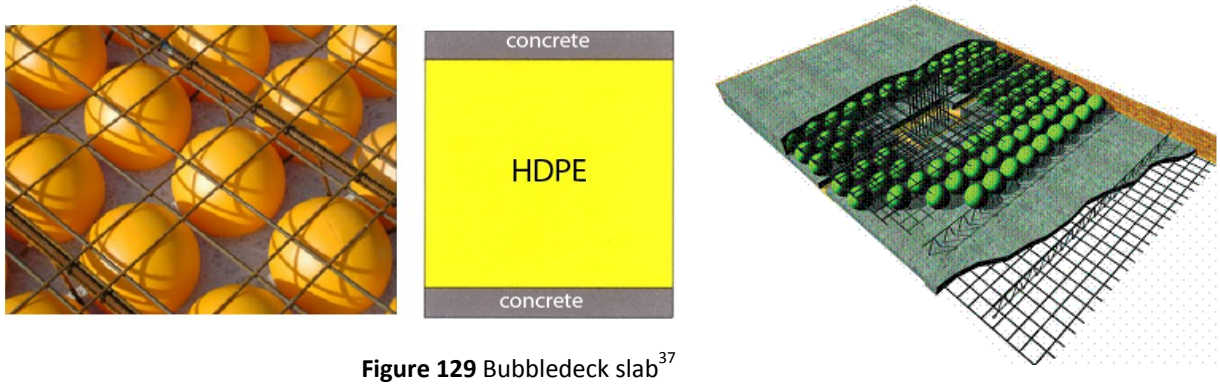


Figure 129 Bubbledeck slab[37]

[35] http://flyash.sustainablesources.com/
[36] http://www.nrmca.org/aboutconcrete/cips/33p.pdf.2011.

2.2.1.1 Comparison[37]:

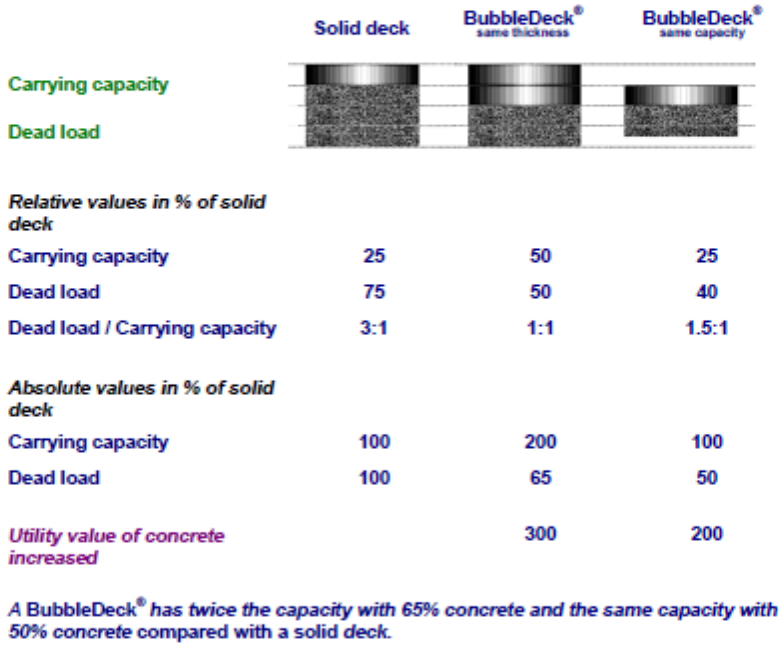


Figure 130 Comparison with solid deck

2.2.1.2 Advantages of Bubble Deck slab[38]:

1- Lesser amount of cement (apprx. 35% lesser than in conventional concrete)
2- Saving in CO_2 production, 40 kg/m^2
3- Lesser deflection for longer spans
4- Heat storage, thermo active slab i.e, radiating floor for heating
5- Green roof feasibility ; increased loads carrying capacity
6- Sustainability: Bubbles from recycled plastic material, 1 kg plastic replaces 1000 kg concrete

3. Earth sheltering analysis

Since, our design encompases major mass of the building below ground, so the emphasis on the earth sheltering is self explanatory. In order to cater the same for structural analysis, we describe here below how we have simplified the earth sheltering loads so that it may be easily analysed.

3.1 Load distribution sketches

The above sketches are self explanatory. As is clear from the relevant sketches and cross section, we have different types of green roof specifications, depending upon the requirement, position and slope of the roof areas. The green roof above the ground floor is different from the one on the

[37] http://bubbledeck-uk.com/download.html
[38] http://www.bubbledeck-uk.com/design.html

basement floor, and so forth. The green roofs are also of two types, which are selected owing to the need, ease of maintenance and aesthetic reasons involved therein.

a. Intensive green roof

These types are characterized by a much heavy load per square meter of roof area. They are labour-intensive requiring maintenance. This type is used, where there was sufficient depth of soil available wither on plain and sloping areas, and also to have a continuity of the green landscape from the garden and surrounding areas.

b. Extensive green roof

These, in contrast to above, are designed to be virtually self-sustaining and should require only a minimum of maintenance, perhaps a once-yearly. This type is used where the slope was steep enough and aesthetic would allow to plant extensive vegetation.

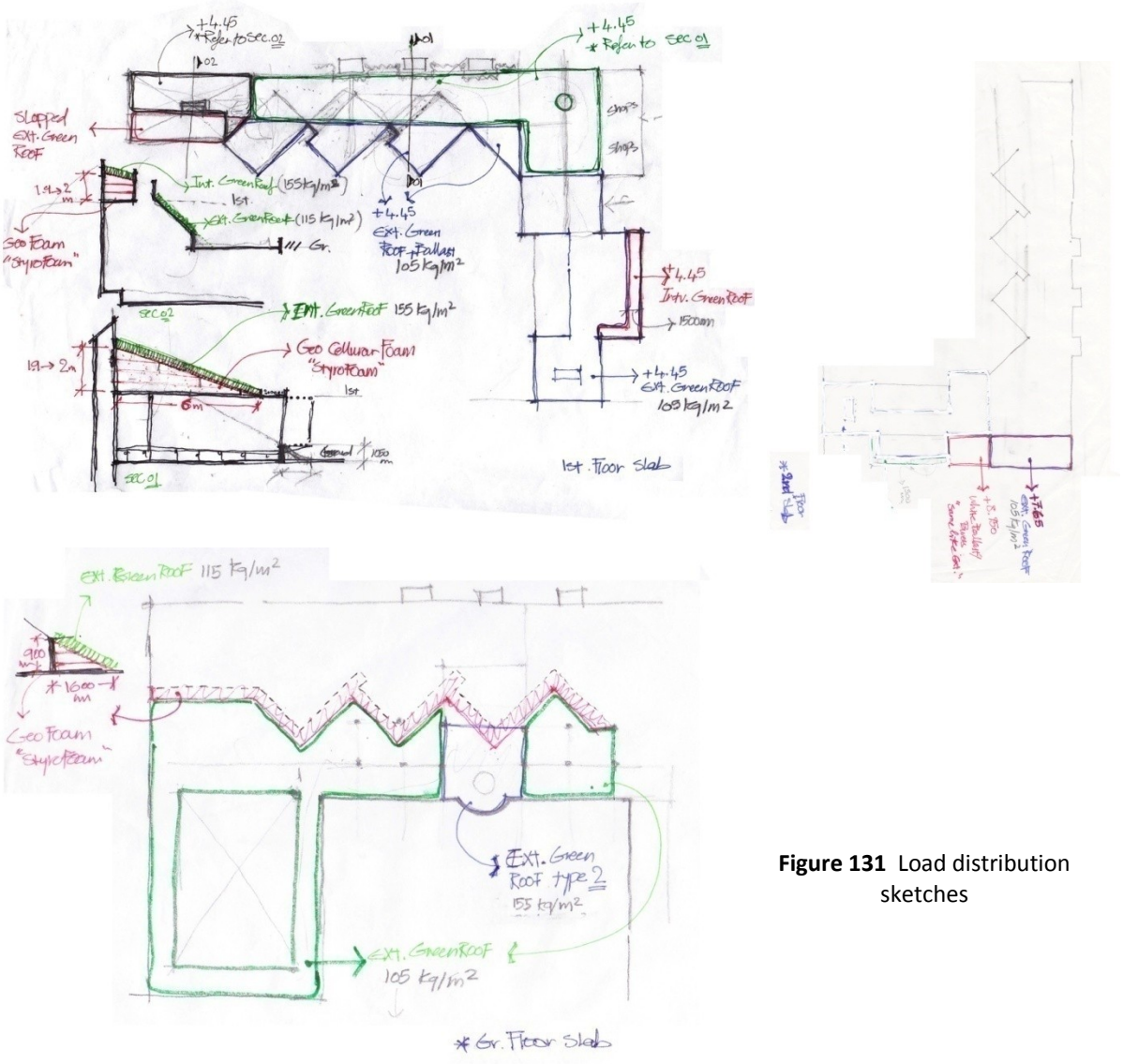


Figure 131 Load distribution sketches

3.2 Weight Distribution and Detailing

The weight distribution of different types of green roofs is also elaborated in the abovementioned sketches, and one can easily see that for different green roof sections, different mass per unit area are assigned. Here, the point of interest is to mention that we are using EPS rigid, cellular polystyrene geofoam, to raise the level of the roof to necessary height and then apply the green roofing above it, as necessary. This is to reduce the weight of the roof itself by avoiding a large mass of soil and replace it with a much lesser density material, as served by geofoam.

4. Load estimation and design

4.1 Assumptions / limitations

The analysis of the building structure is done in accordance with the Eurocodes applicable thereto and some basic assumptions regarding the design of elements are also mentioned hereunder:

Eurocode 0 (EN 1990): Basis of structural design

Eurocode 1 (EN 1991): General actions on structures

Eurocode 2 (EN 1992-1-1): Design of concrete structures

i. The Persistent & Transient design situation for materials (EC2 Table 2.1N) is considered.

ii. The load actions are based on Eurocode 1.

iii. The concrete strength is taken as specified in the design code (EC2 3.1.2(3)).

iv. The cover distances input will satisfy the minimum cover requirements (EC2 4.4.1.2).

v. The design value of the modulus of elasticity of steel reinforcement, Es, is assumed to be 200 GPa (EC2 3.2.7(4)).

4.2 Material Properties[39]

Concrete Properties			
For Columns and Beams			
Specific weight	2400 kg/m^3	Design value of compressive strength F_{cd}	33.3 N/mm^2
Elastic modulus E_{cm}	37000 N/mm^2	Characteristic compressive strength F_{ck}	50 N/mm^2
Poison's ratio	0.2		
For Slabs			
Specific weight	2400 kg/m^3	Design value of compressive strength F_{cd}	23.3 N/mm^2
Elastic modulus	33500 N/mm^2	Characteristic compressive strength F_{ck}	35 N/mm^2
Poison's ratio	0.2		

Steel Properties			
Specific weight	7850 kg/m^3	Yield strength of reinforcement F_{yd}	435 N/mm^2
Elastic modulus E_s	2. 10^5 N/mm^2	Yield strength of reinforcement F_{yk}	500 N/mm^2

Table 4 Material properties

4.3 Load estimation

4.3.1 Dead loads

Typical Floor dead load = 5.88 kN/m^2

Bubble deck Self weight = 5.17 kN/m^2

Exterior walls = 2.98 kN/m^2

Internal partitions = 1.47 kN/m^2

Green roof (avg) = 1 kN/m^2

[39] Design Aids for Eurocode 2: Design of concrete structures, Part 1, edited by The Concrete Societies of The UK, The Netherlands and Germany

4.3.2 Live loads

Live loads are a result of the occupancy of a structure. From EN 1991-1-1: 6.3; we inferred C2 category. As the building consists of multifunctional areas like spa, pool, offices etc, we used 4KN/m^2 as the live load, according to the EN 1991-1-1 Table 6.1.

4.3.3 Snow load calculation

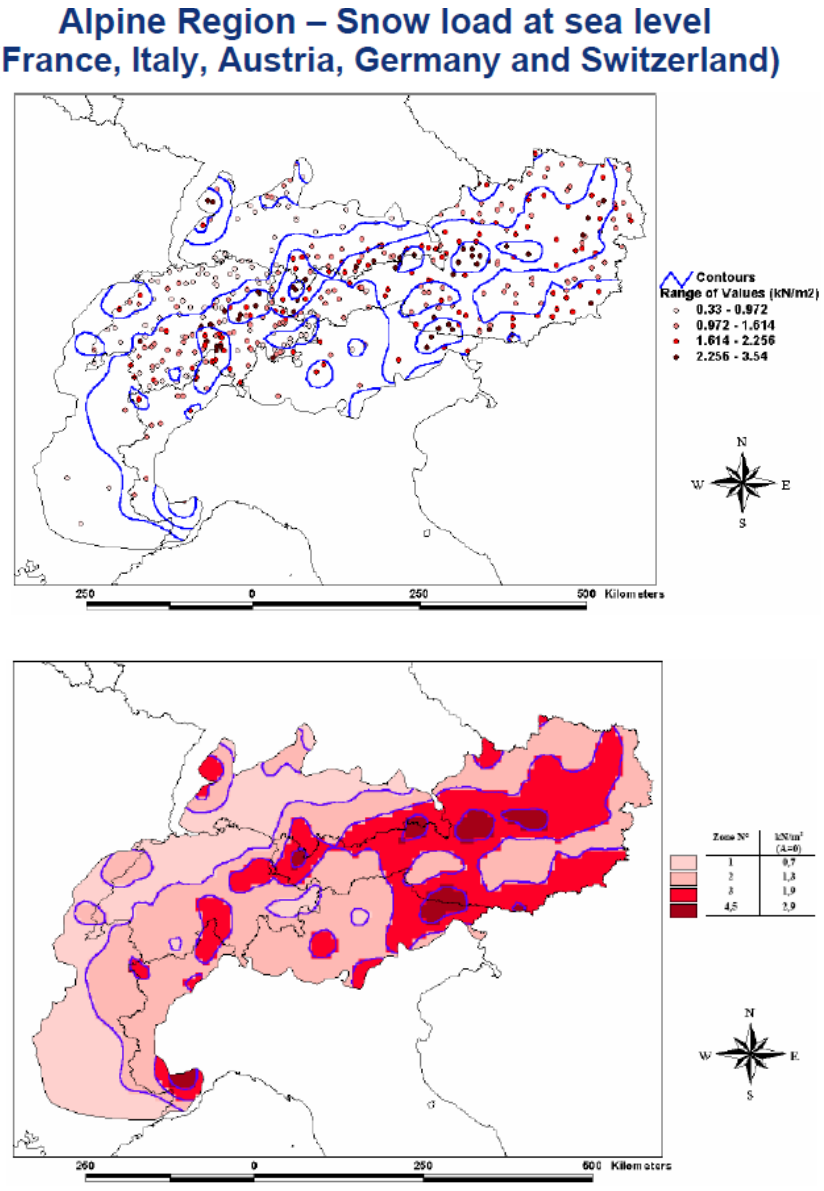


Figure 132 Snow load for Italy[40]

The snow load is calculated in accordance with Eurocode criteria using equation:

s = μi .Ce .Ct .sk

[40] Paolo Formichi, University of Pisa

where,

μ_i is the snow load shape coefficient

s_k is the characteristic value of snow load on the ground,

C_e is the exposure coefficient (taken as 1.0 unless otherwise specified for different topographies)

C_t is the thermal coefficient.

The altitude of the site is 234m and the zone number can be obtained from the Figure 131 above, which is 2. Therefore the characteristic value of snow load on the ground at the relevant site is taken as,

$S_k = 0.642z + 0.009 [1 + (A/728)^2]$

Where z = zone number on the map = 2

A = Altitude above sea level (m) = 234m for Valmadrera

$S_k = 1.3\ kN/m^2$

Therefore; the calculation is summarized as:

Snow load on the ground: $S_k = 1.3\ KN/m^2$

The snow load shape coefficient: $\mu_i = 0.8$ (alpha < 30degree)

Exposure coefficient: $C_e = 1$

Thermal coefficient: $C_t = 1$

$s = \mu_i . C_e . C_t . S_k$

$\boldsymbol{s = 0.8 \times 1 \times 1 \times 1.3 \approx 1.0\ KN/m^2}$

4.4 Load combinations

The combination of loads is to represent the maximum state of stresses that in term represent the most unfavorable conditions for the structure, taking the probability of occurrence of these loads simultaneously and in the specified combination. According to the methodology selected, partial factors Υ_f will be applied for safety reasons to the characteristic actions followed by the combination of the actions that will include a factor (Ψ) that takes into account the probability of happening of these mixed actions.

Table A1.1 - Recommended values of ψ factors for buildings

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0
NOTE The ψ values may be set by the National annex. * For countries not mentioned below, see relevant local conditions.			

Figure 133 Probability factor for mixed actions

Table A1.2(A) - Design values of actions (EQU) (Set A)

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The γ values may be set by the National annex. The recommended set of values for γ are :

$\gamma_{Gj,sup} = 1,10$

$\gamma_{Gj,inf} = 0,90$

$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

NOTE 2 In cases where the verification of static equilibrium also involves the resistance of structural members, as an alternative to two separate verifications based on Tables A1.2(A) and A1.2(B), a combined verification, based on Table A1.2(A), may be adopted, if allowed by the National annex, with the following set of recommended values. The recommended values may be altered by the National annex.

$\gamma_{Gj,sup} = 1,35$

$\gamma_{Gj,inf} = 1,15$

$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

provided that applying $\gamma_{Gj,inf} = 1,00$ both to the favourable part and to the unfavourable part of permanent actions does not give a more unfavourable effect.

Figure 134 Partial factor for load actions[41]

[41] EN 1990:2002 (E), Annex A1

Load combinations

Load combinations	
Comb C1	1.35 DEAD
Comb C2	1.35 DEAD + 1.5 LIVE
Comb C3	1 DEAD + 0.45 LIVE + 1 EQY
Comb C4	1 DEAD + 0.45 LIVE - 1 EQY
Comb C5	1 DEAD + 0.45 LIVE + 1 EQX
Comb C6	1 DEAD + 0.45 LIVE - 1 EQX
Comb C7	1 DEAD + 1 EQY
Comb C8	1 DEAD - 1 EQY
Comb C9	1 DEAD + 1 EQX
Comb C10	1 DEAD - 1 EQX

Table 5 Load combinations

5. Conceptual manual calculation for elements under load:

For better understanding of the structure, we went through the process of structure design in two stages. Firstly, the hand calculations were made for the desired structure and verified through different checks. Then, the results from the same were utilized as an input to the software to have computer based analysis.

For the purpose of this project, the flexibility method for manual calculations was chosen to analyse the elements and thus considering the bending moments and shear forces, obtained therefrom to complete the design. After calculation of the required forces and designing the elements the necessary checks were performed to have confirmation that the element will be able to sustain the loads applied upon and remain stable.

It was not possible to design all the elements of the structure, so typical horizontal and vertical elements were chosen to cover most of the structure and the rest of the elements would be designed on the same lines in accordance with the Eurocode requirements. These typical elements are sometime critical too, for instance a column resting on a beam or a beam resting on another beam etc., which will have different behavior under various loading combinations. The effect of earthquake was not covered under the manual calculations but only in the computer software ETABS.

5.1 Column Design

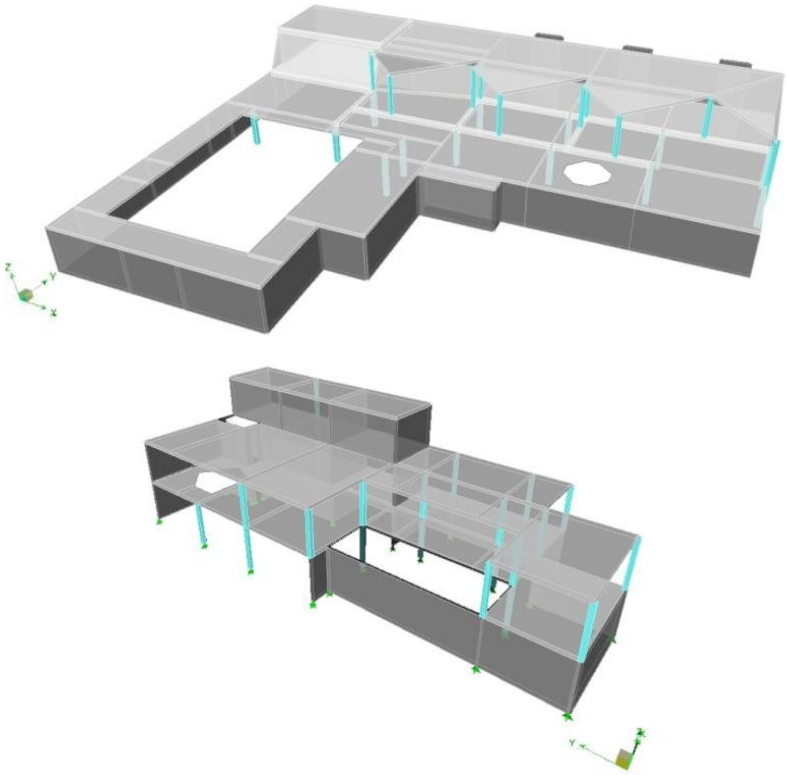


Figure 135 Column design 3D

5.1.1 Second Order Effect and Slenderness

According to EC2 – 5.8.3.3 the evaluation whether global second order effects may be ignored is performed. The total vertical load on the column needs to be calculated first. Here typical columns at grid point C'4, D'4 and E'4 (Figure 135) will be checked for the second order effect using the Eurocode 2 approach.

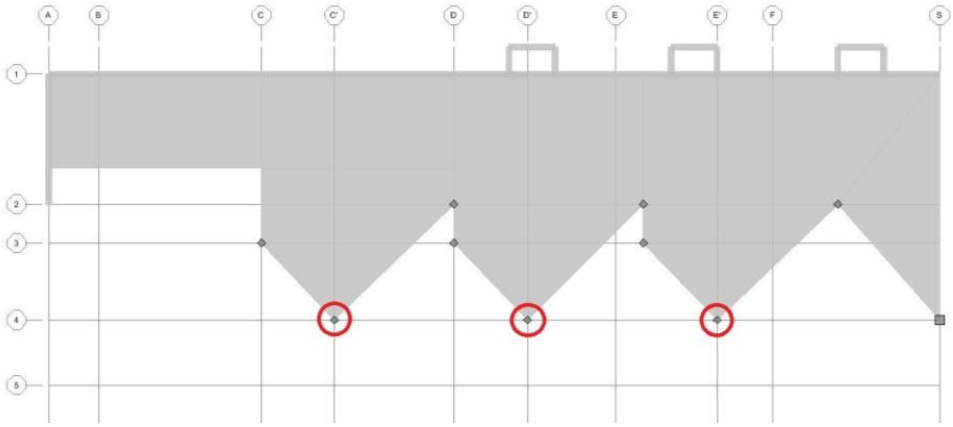


Figure 136 Typical columns for second order check (ground floor)

Global second order effects can then be ignored if the following expression[42] is satisfied

$$F_{V,Ed} \leq k_1 \frac{n_s}{n_s + 1,6} \frac{\sum E_{cd} I_c}{L^2}$$

where $k_1 = 0,31$ (recommended value)

$n_s = 2$ is the total number of storey

L = 8 is the total height of the building starting from the foundation

E_{cd} is the design value of the modulus of elasticity of concrete

I_c is the moment of inertia of the uncracked concrete section of the bracing structure

$F_{v,Ed} \leq 0.31 \times 2 \times 31000 \times 0.000675 / (2+1.6) \times 8^2$

$F_{v,Ed} \leq 326$ kN , is the condition to be satisfied.

For instance at column C2-1 in the structural plan:

Permanent Loads = 5.17 + 1.03 + 5.88 = 12.08 kN/m^2

Approximate influence area = 12 m^2

Applicable loads = 12 x 12.08 = G_k = 144 kN

Weight factor $\Upsilon_G = 1.35$

Permanent loads = $\Upsilon_G \times G_k = 1.35 \times 144$ kN = 194.4 kN

Variable Loads = 0.85 kN/m^2

Approximate influence area = 12 m^2

Applicable loads = 12 x 0.85 = Q_k = 10.2 kN

Weight factor $\Upsilon_Q = 1.5$

Variable loads = $\Upsilon_G \times Q_k = 1.5 \times 10.2$ kN = 15.3 kN

$F_{v,Ed} = (\Upsilon_G \times G_k) + (\Upsilon_G \times Q_k)$

$F_{v,Ed} = 194.4$ kN + 15.3 kN

$F_{v,Ed}$ = 209.7 kN

[42] EN 1992-1-1 – Expression 5.18

Hence,

209.7 kN < 326 kN

Therefore the Global Second Order effect can be ignored.

5.1.2 Slenderness check:

The classification of a column as a "short column" or a "slender column" is made on the basis of its "Slenderness Ratio," defined below.

The slenderness of a column or wall is given by[43]:

$\lambda = l_0 / l_i$

where:

l_i is the minimum radius of gyration

l_0 is the effective length of the member which can be assumed to be:

$l_0 = \beta \cdot l_w$

l_w clear height of the member

β coefficient which depends on the support conditions:

for columns $\beta = 1$ should in general be assumed;

For column under observation:

$l_0 = 1. 3.8 = 3.8$ m

$l_i = \sqrt{I} / A = 0.115$

$\lambda = 32.9 < 86$ (the slenderness should generally not exceed $\lambda = 86$)

Therefore the column is not a slender column.

5.1.3 Pre-dimensioning for the central axial loading:

A column at grid line E-4 represented in plan as C2-2 on the inside bay of the basement floor is analysed as a typical case. The "influence areas" method will be used in order to determine the axial load to be taken into account during the pre-dimensioning of reinforcement (Figure 137).

[43] EN 1992-1-1 – Part 1.1, 12.6.5.1

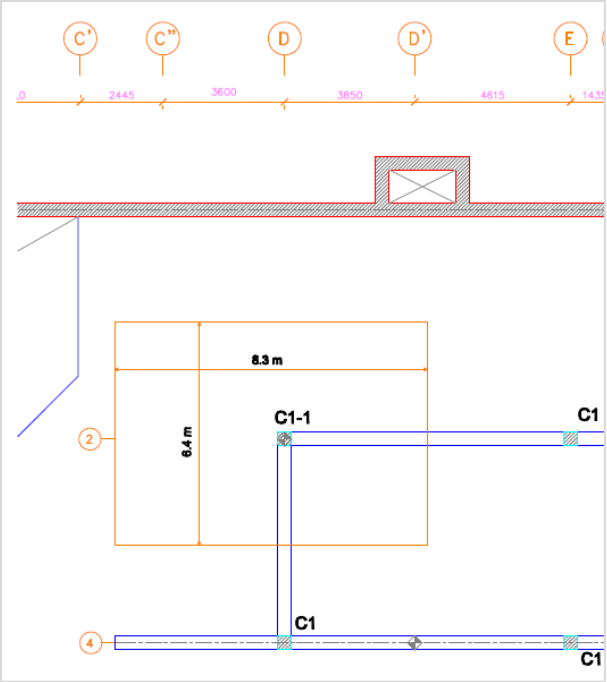


Figure 137 Column C1-1 (position @ basement floor)

From the figure representing the influence area we can calculate the desired load in the following way:

Influence area = 6.4 x 8.3 = 53.12m^2

Modified influence area taking redundancy into account = 53.12 x 1.4 = 74.36 m^2

Slab weight = 5.17 x 74.36 = 384.44 kN

Finishes = (5.88 + 4.2) x 74.36 = 751.77 kN

Variable loads = 0.85 x 74.36 = 63.2 kN

Loads	**Basement**	**Ground**
Permanent loads G_k (kN)	1043.26	1136.21
Variable loads Q_k (kN)	297.44	63.2
F_k	1340.7 kN	1199.41 kN

Table 6 Total load

5.1.3.1 For ULS combination of Actions:

A single multiplicative factor will be referred to, as a simplification: γ_F is obtained as weighted mean of the coefficients γ_G = 1.35 and γ_Q = 1.5, respectively concerning permanent actions and variable actions.

$$\gamma_f^* = \frac{\gamma_G\, G_k + \gamma_Q\, Q_k}{G_k + Q_k} = \frac{1.35 * 1043.26\,\text{kN} + 1.5 * 297.44\,\text{kN}}{1043.26\,\text{kN} + 297.44\,\text{kN}} \cong 1.38$$

In the Table 7 pre-dimensioning of the geometry of column is shown:

Column	**F_k (kN)**	**N (kN)** $N = \Sigma F_{kj}$	**$N_{Ed} = \gamma_F * N$ (kN)**	**$A_{c0} = \frac{N_{Ed}}{f_{cd}}$ (mm^2)**	**b x h (mm)**	**A_c (mm^2)**
Ground	1199.41	1199.41	1655.18	70433.43	300 x 300	90000
Basement	1340.7	2532.11	3494.31	148694.11	400 x 400	160000

Table 7 Column C1-1 pre-dimensioning for centred axial load

5.1.3.2 Column self weight influence:

Ground column = 0.3 x 0.3 x 3.8 x 25 = 8.5 kN

Basement column = 0.4 x 0.4 x 3.8 x 25 = 15.2 kN

Column	**F_k (kN)**	**N (kN)** $N = \Sigma F_{kj}$	**$N_{Ed} = \gamma_F * N$ (kN)**	**$A_{c0} = \frac{N_{Ed}}{f_{cd}}$ (mm^2)**	**b x h (mm)**	**A_c (mm^2)**
Ground	1207.91	1207.91	1666.91	70932.58	300 x 300	90000
Basement	1355.9	2563.81	3538.05	150555.65	400 x 400	160000

Table 8 Column C1-1 Self-weight influence

5.1.3.3 Longitudinal reinforcement[44]

Each bar at corner of the column should not be ≤ 12mm

Geometric limit $A_s \geq 0.003\ A_c$

Static limit As $\geq 0.10\ N_{Ed}/F_{yd}$

[44] EN 1992-1-1 – 9.5.2

Column	A_c (mm^2)	$A_{s\,min}$ (mm^2) $\rho_s = 0.3\%$	$A_{s\,min}$ (mm^2) $= 0.10\ N_{Ed}/f_{yd}$	4 ϕ 12 (mm^2)	n° x ϕ	A_s (mm^2)
Ground	90000	270	383.19	**452**	4 ϕ 12	452
Basement	160000	480	813.34	**452**	8 ϕ 12	904.8

Table 9 Column C1-1 Pre-dimensioning of longitudinal reinforcement

5.1.4 SLS verification:

The translational equilibrium of the cross-section for SLS is

$$N = \sigma_c A_c + \sigma_s A_s$$

Under the hypothesis of plane sections (Euler-Bernoulli), same strain in steel and surrounding concrete ($\varepsilon_c = \varepsilon_s$) and elastic materials, it is $\sigma_s = \alpha_e\ \sigma_c$, where the ratio between the modulus of elasticity α_e is assumed equal to 15 in order to take into account the time-dependent behaviour of concrete.

$$N = \sigma_c (A_c + \alpha_e A_s) = \sigma_c A_{ie}$$

$$\sigma_c = \frac{N}{A_{ie}} \leq \sigma_{c\,adm} = 0.6\ f_{ck} = 16.2\ N/mm^2$$

Column	A_c (mm^2)	A_s (mm^2)	A_{ie} (mm^2)	N (kN)	σ_c (N/mm^2)	$< \sigma_{c,adm}$?
Ground	90000	452	96780	1207.91	12.48	Yes
Basement	160000	924	173860	2563.81	14.74	Yes

Table 10 Column C1-1 SLS verification

5.1.5 ULS verification:

The translational equilibrium for ULS is

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

Column	A_c (mm^2)	A_s (mm^2)	N_{Ed} (kN)	N_{Rd} (kN)	N_{Rd} / N_{Ed}
Ground	90000	452	1666.91	2341	1.4
Basement	160000	924	3494.31	4222	1.2

Table 11 Column C1-1 ULS verification

5.1.6 Transversal reinforcement

In Eurocode 2, some prescriptions on transversal reinforcement are outlined.

The minimum **diameter** of transversal bars needs to be not less than ¼ of the longitudinal diameter and not less than 6 mm.

The **spacing** of the transverse reinforcement along the column needs not to exceed the following limits:

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

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

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

5.2 BEAM DESIGN:

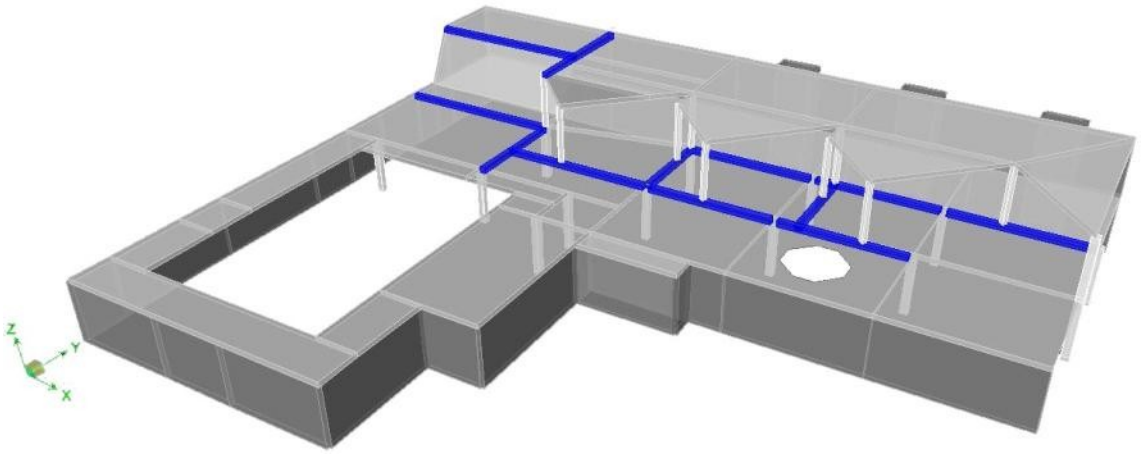


Figure 138 Beam design 3D

For the purpose of beam design firstly hand made calculations are performed considering here a typical internal beam DE at grid line 4, from the basement floor. There is a column resting above the beam at point P, as shown in Figure 138. For the sake of simplicity we are considering the beam as a simply beam. The beam will be initially designed by flexibility method to have sectional requirements, which will eventually be used as an input to the software analysis. The combination of loads used is 1.35 G_k + 1.5 Q_k .

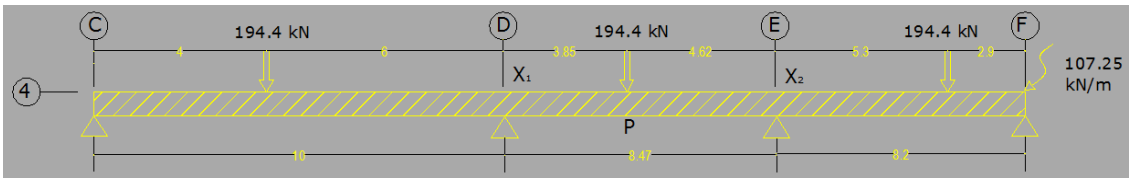


Figure 139 Beam design – Load distribution

5.2.1 Load calculations:

Pointed load from columns:

5.17 + 1.03 + 5.88 = 12.88 kN/m^2

Area of influence = 12 m^2

Point load at position X = G_k = 12.08 x 12 = 144 kN; and Υ_G = 1.35

Total point load = 194.4 kN

Distributed load from slab:

Floor Load = 11.05 kN/m^2 ; Distributed area = 6.4 m^2

Permanent load = G_k = 11.05 x 6.4 = 70.7 kN/m

Wall load = G_k = 1.5 kN/m^2 x 2.8 = 4.2 kN/m

Total permanent load = 1.35 x (70.7 + 4.2) = *101.25 kN/m*

Variable load = 4 kN/m^2; Υ_Q = 1.5

Total variable load = 4 x 1.5 = 6 kN/m^2

Total distributed load = 101.25 + 6 = 107.25 kN/m (Figure 139)

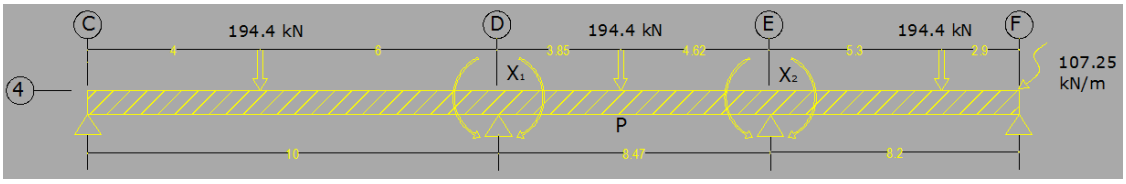


Figure 140 Beam flexibility method approach

Using the flexibility method; solving for moment and load cases manually and coming up with results as are explained hereunder.

Analysing grid point D4, for beam B-1 (*structural plan*) as in Figure 139 above:

$\Delta\emptyset = 0$

$\Delta\emptyset = [X_1 \times 10/3EI + 1088.6/EI + 4468.75/EI] + [X_1 \times 8.47/3EI + 890.6/EI + 2715.4/EI] = 0$

X_1 = -319.89 kNm

From here maximum bending moment was solved:

M_{max} = 1626.4 kNm

5.2.2 Longitudinal Reinforcement:

The pre-dimensioning of longitudinal reinforcement is carried out. The rotational equilibrium gives the position of the neutral axis, x.

$$0,8bx f_{cd}\left(d-0,4x\right)=M_{Ed}$$

Whereas, through the translational equilibrium the required reinforcement area can be evaluated.

$$A_s=\frac{0,8bx f_{cd}}{f_{yd}}$$

The following limit for the depth of the neutral axis applies.

$$\xi = \frac{x}{d} \le \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} = \frac{3,5}{3,5+1,96} = 0,641$$

The so determined reinforcement needs to be not less than the minimum recommended[45]

$$A_{s,\min} = 0,26 \frac{f_{ctm}}{f_{yk}} b_t \, d$$

The effective depth of the section, d, to be used in the previous formulas can be calculated after the evaluation of the concrete cover.

5.2.3 Concrete Cover:

According to the nominal concrete cover follows[46]

$c_{nom} = c_{min} + \Delta c_{dev}$

$c_{min} = \max (c_{min,b}; c_{min,dur} + \Delta c_{\gamma} - \Delta_{cdur,st} - \Delta c_{dur,add}; 10 \text{ mm})$

Transversal shear reinforcement (stirrups):

$c_{min,b} = \phi = 8$ mm

$c_{min,dur} = 10$ mm [47]

$\Delta_{c,\gamma} = 0$ (recommended value) [48]

$\Delta c_{dur,st} = \Delta c_{dur,add} = 0$ [49]

$c_{min} = \max (8\text{mm}, 10\text{mm}, 10\text{mm}) = 10$ mm

Assuming $\Delta c_{dev} = 10$ mm, as recommend[50]

$c_{nom\ transv} = 10+10 = 20$ mm

Longitudinal reinforcement:

$c_{min,b} = \phi = 20$ mm

[45] EN 1992-1-1 – 9.2.1.1, Expression 9.1N
[46] EN 1992-1-1 – 4.4.1
[47] EC2 – 4.4.1.2(5
[48] EC2 – 4.4.1.2(6)
[49] EC2 – 4.4.1.2(7) and (8)
[50] EN 1992-1-1 – 4.4.1.3

$c_{min,dur}$ = 10 mm[51]

$\Delta_{c,\gamma}$ = 0 (recommended value)[52]

$\Delta c_{dur,st} = \Delta c_{dur,add}$ = 0 [EC2 – 4.4.1.2(7) and (8)]

c_{min} = max (20mm, 10mm, 10mm) = 20 mm

Assuming Δc_{dev} = 10 mm, as recommend[53]

$c_{nom\ long}$ = 20+10 = *30 mm*

From the previous calculations, it appears that the concrete cover for longitudinal reinforcement is dominant. As a matter of fact, $c_{nom\ long}$ = 30 mm, the transversal reinforcement cover is c_{transv} = 30 – 8 = *22 mm* > $c_{nom\ transv}$).

The effective depth of the section in the end is

d = h – $c_{nom\ long}$ - $\phi_{s,long}$ /2 = 380 – 30 - 20/2 = *340 mm*

Using the expression to find the neutral axis position,

x/d ≥ 3.5/(3.5 + 1.96)

x = 217mm

$$A_s = \frac{0,8\,b\,x\,f_{cd}}{f_{yd}} = 0.8 \text{ x } .4 \text{ x } 0.217 \text{ x } 33300 / 435000 = 5315.75 \text{ mm}^2$$

$$A_{s,\min} = 0,26\frac{f_{ctm}}{f_{yk}} b_t\, d = 0.26 \text{ x } 4.1 \text{ x } 0.4 \text{ x } 0.34 / 500 = 289.95 \text{ mm}^2$$

Assuming a compression reinforcement area A'_s = 6 ø 20 = 1884 mm^2 the rotational equilibrium about the tension reinforcement is

$$0,8\,b\,x\,f_{cd}\left(d - 0,4\,x\right) + A'_s\,f_{yd}\left(d - d'\right) = M_{Ed}$$

M_{Ed} = 0.8 x 0.4 x 0.217 x 33300 (0.34-0.4(0.217) + 1884x10^{-6} x 435000 x (0.34 – 0.04)

M_{Ed} = 831.34 kNm

[51] EN 1992-1-1 – 4.4.1.2(5)
[52] EN 1992-1-1 – 4.4.1.2(6)
[53] EN 1992-1-1 – 4.4.1.3

And the new position of the neutral axis, x, can be found (*d' = h – d = 380 – 340 = 40 mm*). The hypothesis here made is that the compression steel is yielded. As a consequence, the neutral axis depth needs to be

$$\xi = \frac{x}{d'} \geq \frac{\varepsilon_{cu}}{\varepsilon_{cu} - \varepsilon_{yd}} = \frac{3,5}{3,5 - 1,96} = 2,273$$

Implies that, x = 90.92 mm

Superior steel is elastic, and equilibrium is $0,8\,b\,x\,f_{cd}\left(d - 0,4\,x\right) + A'_s\,\sigma'_s\left(d - d'\right) = M_{Ed}$

$\sigma'_s = \varepsilon_{cu}\,E_s\,\frac{x - d'}{x}$ = 570.96 N/mm^2

Therefore, the required tension reinforcement area in the end is given as

$A_{s,req} = \frac{0,8\,b\,x\,f_{cd} + A'_s\,\sigma'_s}{f_{yd}}$ = 4700.07 mm^2

M_{Ed} (kNm)	b (mm)	x (mm)	$A_{s,req}$ (mm^2)	b_t (mm)	A_{smin} (mm^2)	n° ϕ	A_s (mm^2)
1626.4	400	90.92	4700.07	400	289.95	15 ø 20	4710

Table 12 ULS – Pre-dimensioning of longitudinal reinforcement

5.2.4 Ultimate Limit States: Bending Verification

The translational equilibrium, under the hypothesis of yielded steel in tension and elastic steel in compression, is

$$0,8\,b\,x\,f_{cd} + \sigma'_s\,A'_s - f_{yd}\,A_s = 0$$

$$\sigma'_s = E_s\,\varepsilon_{cu}\,\frac{x - d'}{x} \leq f_{yd}$$ = 570.96 x 10^3 kN/m^2

The rotational equilibrium gives the value of the resisting moment

$$M_{Rd} = 0,8\,b\,x\,f_{cd}\left(d - 0,4\,x\right) + \sigma'_s\,A'_s\left(d - d'\right)$$

M_{Rd} = 0.8 x 0.4 x 0.217 x 33300 (0.217-0.4(0.217)) + 570.96 x 10^3 x 1884x10^{-6} x (0.34-0.04)

M_{Rd} = 908.18 kNm

Therefore *$M_{Rd} > M_{Ed}$* *check satisfied!*

5.2.5 Ultimate Limit State: Shear Verification

The shear reinforcement needs to comply with the following limit[54]

$$\rho_{sw} = \frac{A_{sw}}{b_w\, s} \geq 0.08\ \frac{\sqrt{f_{ck}}}{f_{yk}} = 0.08\ \frac{\sqrt{25}}{450} = 9\cdot10^{-4} = \rho_{sw,min}$$

The maximum longitudinal spacing between stirrups is[55]

$$s_{l,\max} = 0,75\,d\left(1+\cot\alpha\right) = 0,75\cdot 200 = 150\,mm$$

Whereas, the transverse spacing of the legs of stirrups needs not to exceed the value[56]

$$s_{t,\max} = 0,75\,d\left(= 0,75\cdot 200 = 150\,mm\right) \leq 600\,mm$$

Assuming ϕ8/150 mm with eight legs, it is

$$\rho_{sw} = \frac{8\cdot 50}{400\cdot 150} = 0{,}0066 > \rho_{sw,min}$$

The corresponding value of the shear resistance then is[57]

$$V_{Rd,s} = 0{,}9\ d\ b_w\ \rho_{sw}\ f_{ywd}\ ctg\ \theta = 0{,}9\cdot 340\cdot 400\cdot 0.0066\cdot 435\cdot 2 = 702.82\ kN$$

where ctgθ = 2 has been assumed.

The maximum value of the design shear, $V_{Ed,max}$, can be computed at a distance $\bar{x}$ from the ideal support equal to the semi-width of the column/stairwell wall. For combination 1 the maximum design shear at the continuity support is

$$V_{Ed,\ max} = |213.4 - 101.6\ \bar{x}| = |213.4 - 101.6\ (5 - 0.4)| = 253.96kN$$

Since *$V_{Rd,s} > V_{Ed,\ max}$* *check satisfied!*

[54] EN 1992-1-1 – Expression 9.5N
[55] EN 1992-1-1 – 9.2.2(6) and Expression 9.6N
[56] EN 1992-1-1 – 9.2.2(8) and Expression 9.8N
[57] EN 1992-1-1 – Expression 6.8

6. Structural Analysis using Software

Pursuing the handmade design process for structural elements, an estimate of the sizes and amount of reinforcement for the elements was obtained. Using the range and size of the cross sections for the elements and the corresponding loads upon them, the results were added as input to the software for computer based analysis. These achievements are beneficial in several ways like verifying the sections from software.

The software ETABS was used for modeling the complex buildings and all its analysis and design. The Eurocode 2 -1992-2004 was chosen as the criteria in the software. In line with the requirement of the structure to split into two separate units, it was necessary to make two separate models in ETABS for this purpose. The software's calculations are based on the force method. The gap provided between the buildings is usually taken as 2 percent of the height of the buildings. For the height of 9 meters in this project a gap of 20 centimeters is provided between two parts of the buildings.

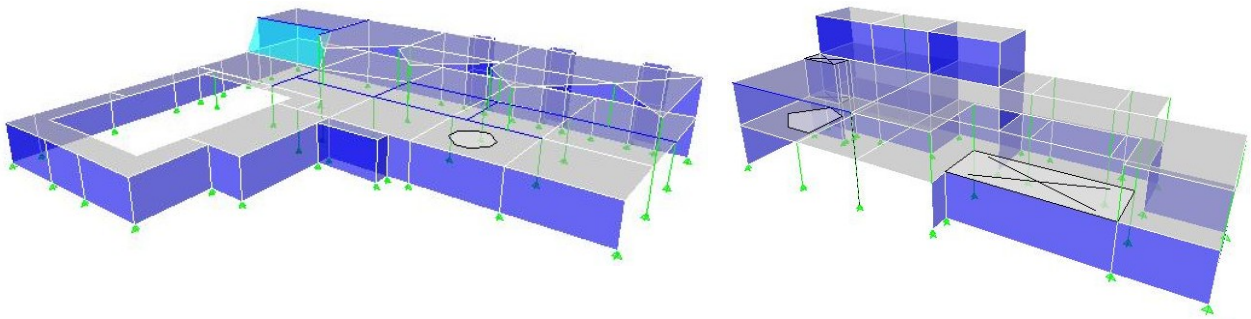
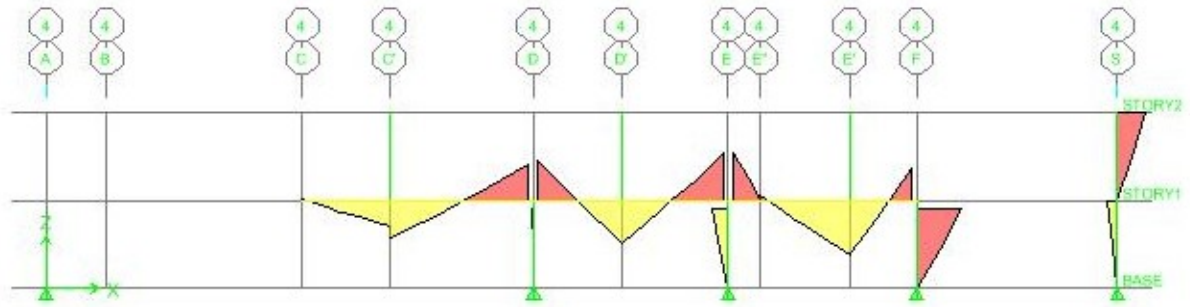


Figure 141 Left-side building and Right-side building

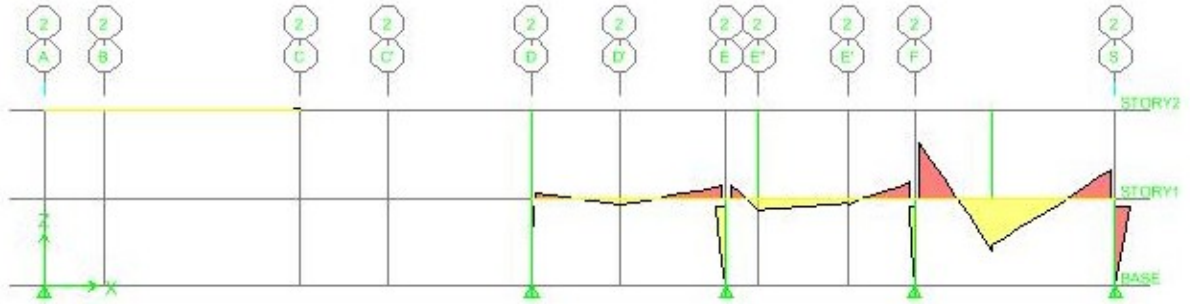
The designated left side building comprises of two floors, one below the ground and the other over it. This building also contains a bigger mass. It mostly comprises of functional areas. The right side building has three storeys, the third being only a coverage for the storage purposes. This side is smaller in size as compared to the left side building. It mostly comprises of administrative areas and the entrance to the building is also from the same.

We have proposed a flat slab structure, basically resting on concrete columns. For the stability and coverage of abnormalities in the structural geometry, at few places concrete beams have been introduced owing to the criticality of the situation. These have been analysed to make sure the structure remains stable under these crucial loads.

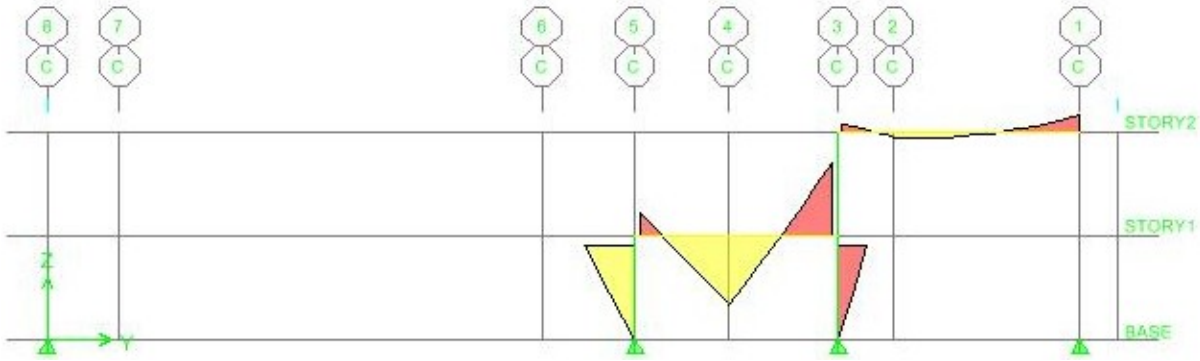
6.1 Bending moment diagram



At grid line 4



At grid line 2

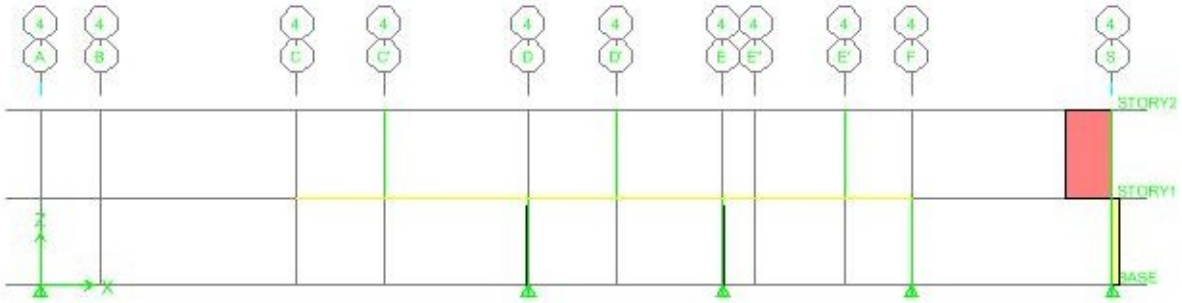


At grid line C

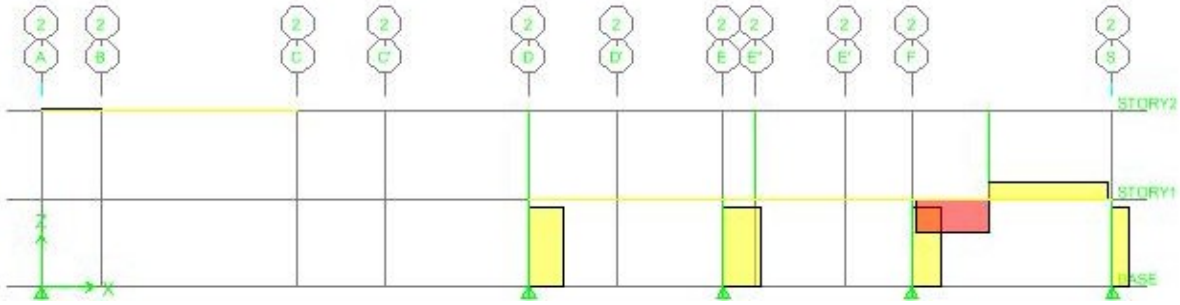
Figure 142 Bending moment diagrams

The above diagrams at specific gridlines represent the variability of bending moment in the design of structural elements. It's evident that the building's geometry is rather different producing bending moments at certain points but others. The values will be analysed afterwards to make sure that it falls within the criteria and too much bending is avoided for structural stability.

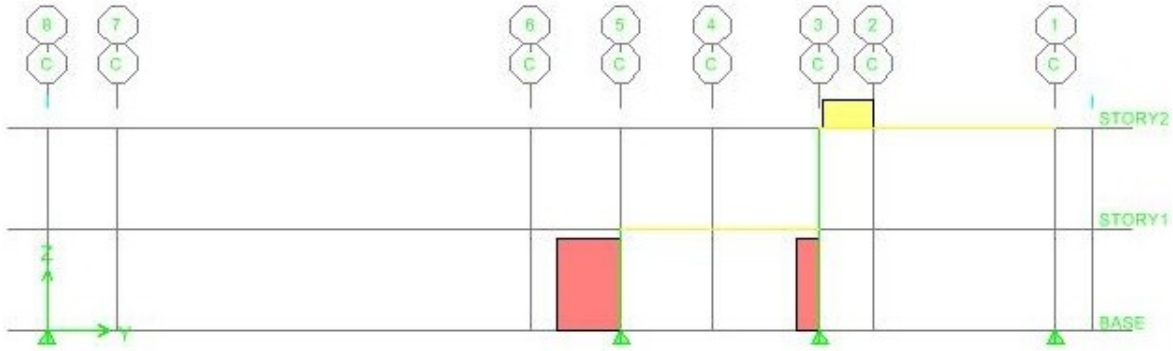
6.2 Shear force diagram



At grid line 4



At grid line 2

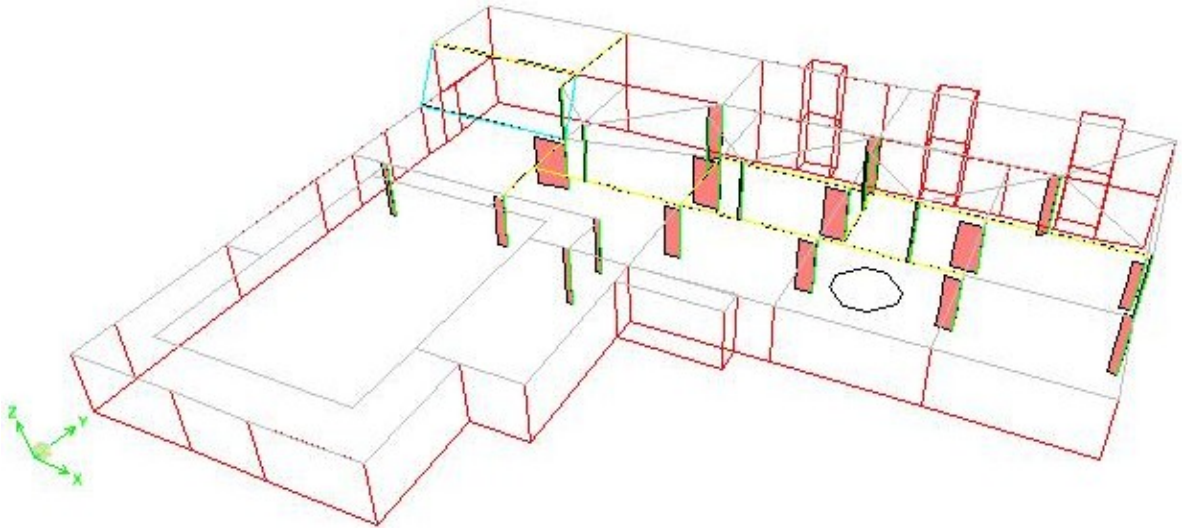


At grid line C

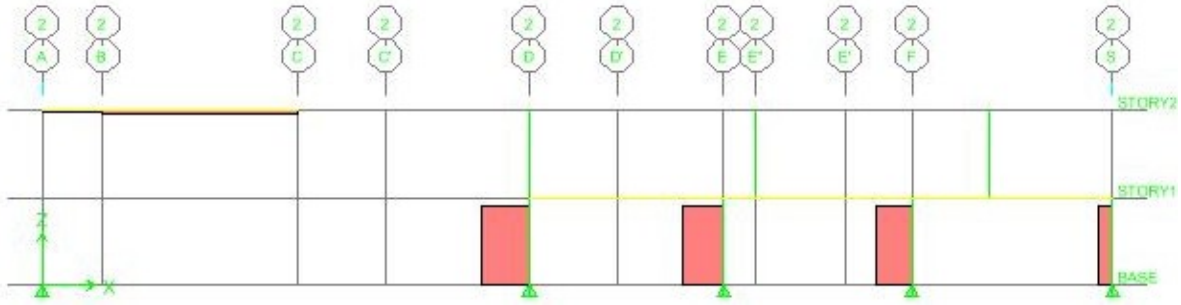
Figure 143 Shear force diagrams

The shear force diagrams above at specific gridlines represent the forces being applied on different elements, and the emphasis is on the columns which are the main load transferring elements to the foundations. The magnitude of force depends on the load from above and the position of the element in the structural grid. The

6.3 Axial force diagram



Axial force diagram



At grid line 2

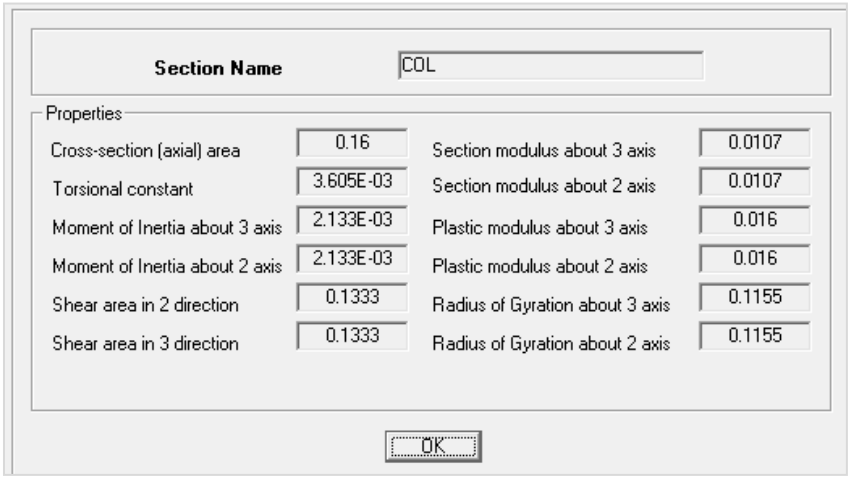
Figure 144 Axial force diagrams

The above axial load diagrams are a mere representation of the vertical axial load taken by the column elements, and transferring to the ground. The variety of load is owing to the fact that all the columns are not at the same load and thus are under different axial loads.

6.4 Designing of structural members

6.4.1 Column design

6.4.1.1 Sectional dimensions:



6.4.1.2 Sectional properties:

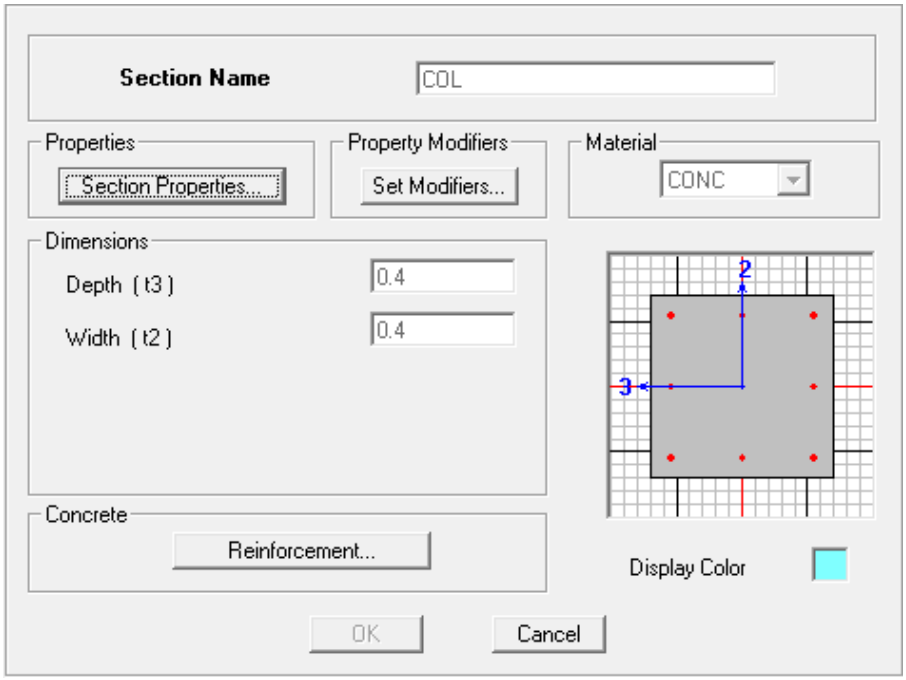


Figure 145 Column sectional properties

6.4.1.3 Design values from software:

Units KN-m

Eurocode 2-2004 COLUMN SECTION DESIGN Type: Sway Frame Units: KN-m (Summary)

Level	: STORY1	L=3.800		
Element	: C70	B=0.400	D=0.400	dc=0.046
Section ID	: COL	E=37000491.0	fck,cyl=50000.	Lt.Wt. Fac.=1.000
Combo ID	: C2	fyk=500000.000	fywk=500000.00	
Station Loc	: 3.420	RLLF=0.600	SOM: Nominal Stiffness	
Combo Eq.	: Eq. 6.10			
Gamma(Concrete)	: 1.500	AlphaCC=1.000	AlphaCT=1.000	
Gamma(Steel)	: 1.150	AlphaLCC=0.850	AlphaLCT=0.850	

AXIAL FORCE & BIAXIAL MOMENT DESIGN FOR NEd, MEd2, MEd3

Rebar Area	Design NEd	Design MEd2	Design MEd3	Minimum M2	Minimum M3
0.002	1730.685	-28.284	-284.525	34.614	34.614

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	M0e Moment	Madd Moment	Minimum Ecc	Beta Factor	L Length
Major Bending(M3)	-113.810	13.314	0.020	1.000	3.420
Minor Bending(M2)	-11.313	1.324	0.020	1.000	3.420

SHEAR DESIGN FOR V2,V3

	Rebar Asw/s	Shear VEd	Shear VRdc	Shear VRds
Major Shear(V2)	0.000	79.787	673.263	0.000
Minor Shear(V3)	0.000	8.182	673.263	0.000

Figure 146 Column Design sheet from software

6.4.1.4 Design Verification:

Longitudinal reinforcement:

$A_s \geq 0.10\ N_{Ed}/F_{yd}$

$0.002\ m^2 \geq 0.00039\ m^2$ satisfied!

Compression resistance:

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

1730.685 kN < 2341 kN satisfied!

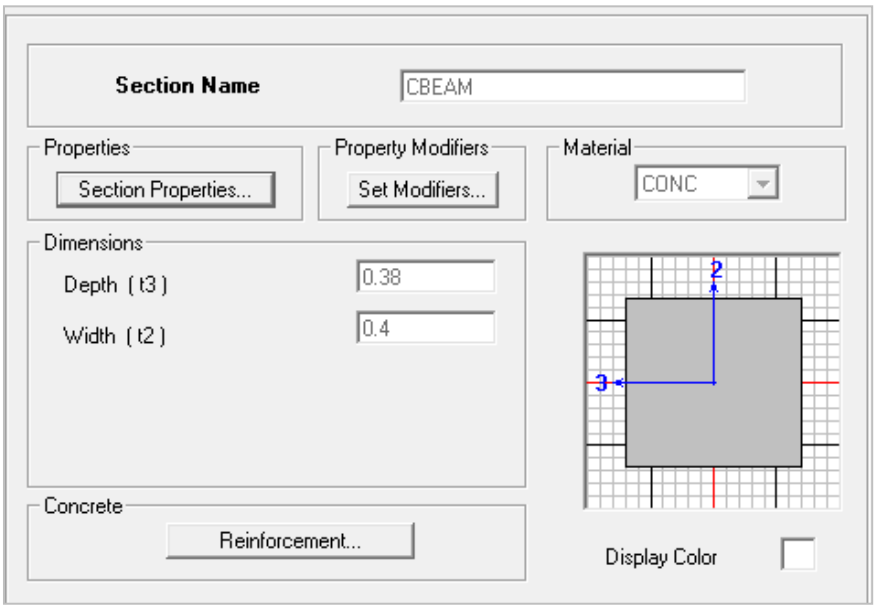
Transverse reinforcement:

$V_{Rd,c} = [0.035k^{3/2}(f_{ck})^{1/2} + 0.15\sigma_{cp}]\ bd > V_{Ed}$

673.26 kN > 79.78 kN satisfied!

6.4.2 Beam Design

6.4.2.1 Section dimensions:



6.4.2.2 Section properties:

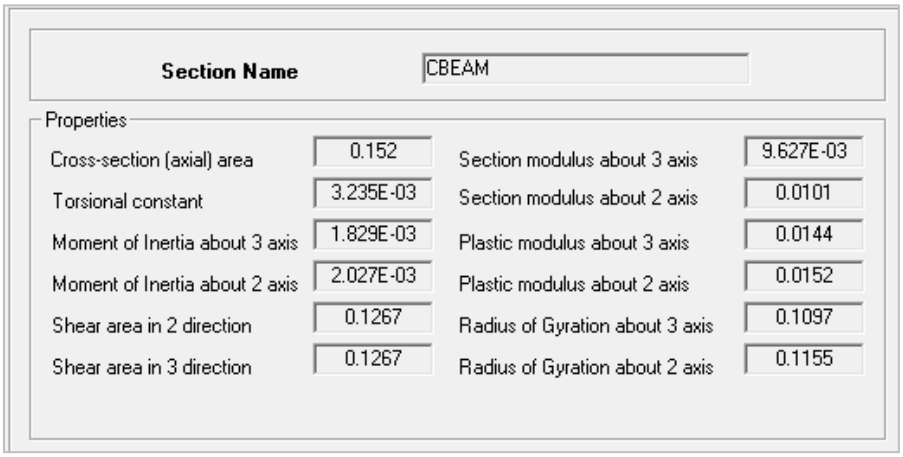


Figure 147 Beam sectional properties

6.4.2.3 Design values from software:

Units KN-m

Eurocode 2-2004 BEAM SECTION DESIGN Type: Sway Frame Units: KN-m (Summary)

Level	: STORY1	L=8.470			
Element	: B149	D=0.380	B=0.400	bf=0.400	
Section ID	: CBEAM	ds=0.000	dct=0.038	dcb=0.038	
Combo ID	: C2	E=37000491.0	fck=50000.000	Lt.Wt. Fac.=1.000	
Station Loc	: 3.850	fyk=500000.000	fywk=500000.00		

Gamma(Concrete): 1.500
Gamma(Steel) : 1.150

Design Moments, M3

Positive Moment	Negative Moment
302.894	0.000

Flexural Reinforcement for Moment, M3

	Required Rebar	+Moment Rebar	-Moment Rebar	Minimum Rebar
Top (+2 Axis)	2.693E-04	0.000	0.000	2.693E-04
Bottom (-2 Axis)	0.002	0.002	0.000	2.693E-04

Shear Reinforcement for Shear, V2

Rebar Asw/s	Shear VEd	Shear VRdc	Shear VRds
4.525E-04	140.826	649.927	60.563

Torsion Reinforcement for Torsion, T

Rebar At/s	Rebar Asl	Torsion TEd	Critical T	Area Ak	Perimeter uk
0.000	3.049E-04	19.370	19.597	0.085	1.170

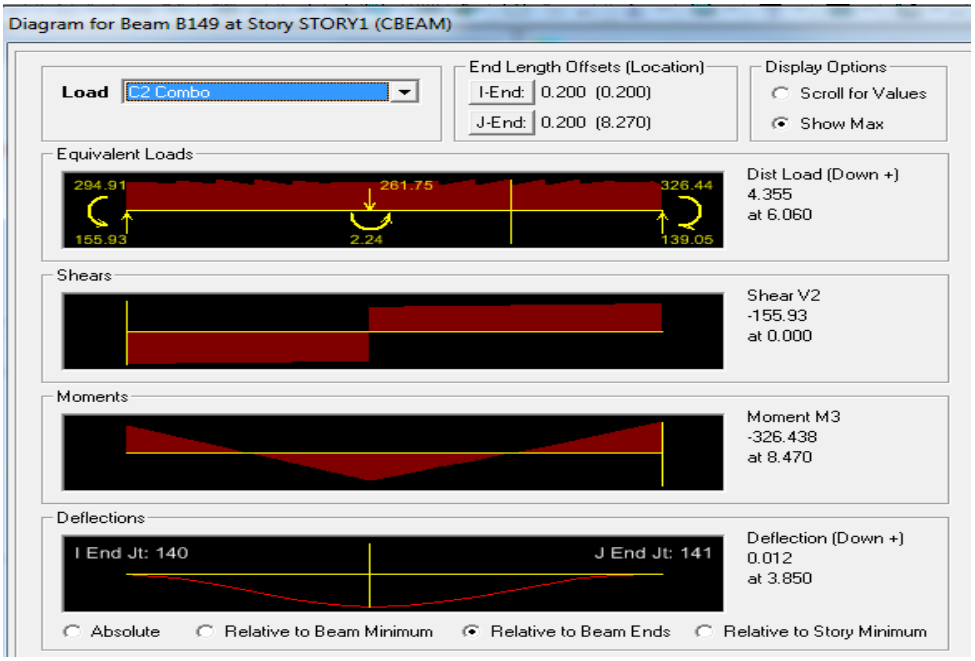


Figure 148 Beam Design sheet from software

6.4.2.4 Design Verification:

Longitudinal reinforcement:

$A_{s,\,min} > 0.0013\ b_t\ d$

$0.002\ m^2 > 0.00019\ m^2$ satisfied!

Shear reinforcement:

$$\rho_{sw} = \frac{A_{sw}}{b_w\ s} \geq 0.08\ \frac{\sqrt{f_{ck}}}{f_{yk}}$$

0.00119 > 0.00113 satisfied!

Deflection check:

Span / 250 = 8.47 / 250 = 0.033 m

Max deflection = 0.012 m

0.012 m < 0.033 m satisfied!

7. SLAB

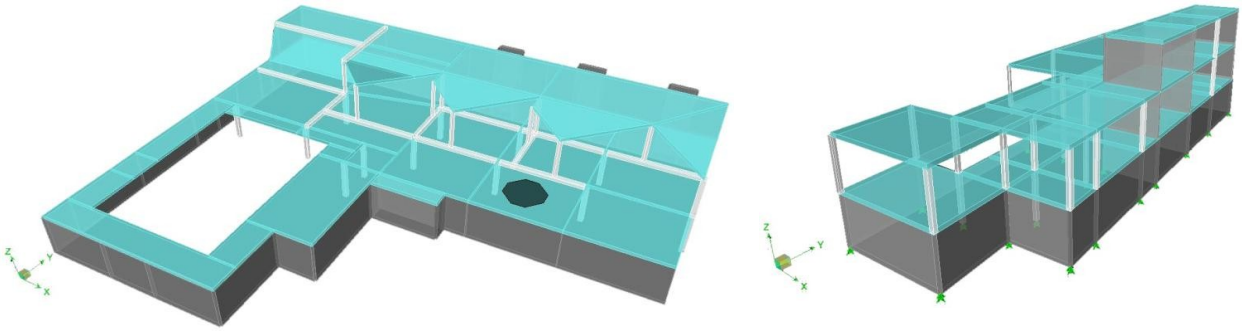


Figure 149 Slab Design 3D

7.1 Bubble Deck Slab:

7.1.1 Slab size:

The sizing of the slabs is given according to the estimated span width. The table of the manufacturer is utilized as a guide to get a preliminary design as follows[58]:

Version	Slab Thickness	Bubbles	Span (Multiple bays)	Cantilever Maximum Length	Span (Single bays)	Completed Slab Mass	Site Concrete Quantity
	mm	mm	metres	metres	metres	kN/m^2	m^3/m^2
BD230	230	Ø 180	5 – 8.3	≤ 2.8	5 – 6.5	4.34	0.109
BD280	280	Ø 225	7 – 10.1	≤ 3.3	6 – 7.8	5.17	0.142
BD340	340	Ø 270	9 – 12.5	≤ 4.0	7 – 9.5	6.25	0.186
BD390	390	Ø 315	11 – 14.4	≤ 4.7	9 – 10.9	6.93	0.213
BD450	450	Ø 360	13 – 16.4	≤ 5.4	10 – 12.5	7.94	0.245
BD510 *	510	Ø 410	15 – 18.8	≤ 6.1	11 – 13.9	9.06	0.291
BD600 *	600	Ø 500	16 – 21.0	≤ 7.2	12 – 15.0	10.22	0.338

Figure 150 Manufacturer proposed dimensions for slabs[57]

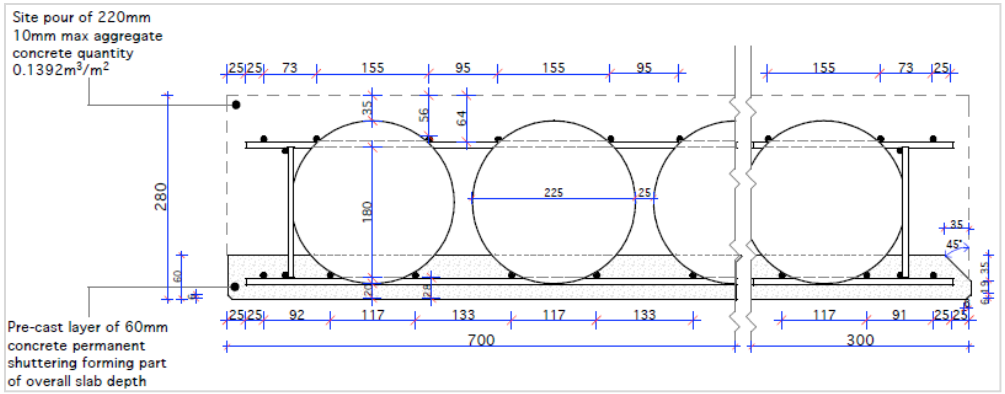


Figure 151 Typical slab dimensioning[57]

[58] http://www.bubbledeck-uk.com/download.html

7.1.2 Design requirements:

The hollow slab can be designed with conventional structural analysis of a full section, if the following limits are observed:

DIN 1045-1: $\mu_{sds} = m_{sd} \cdot D_{BD} \cdot 1.96 / (d_B^3 \cdot f_{ck}) \leq 0.2$

where:
- μ_{sds} = relative bending moment in the ball zone [-]
- m_{sd} = max. bending moment [MNm/m]
- D_{BD} = ball diameter [m]
- d_B = static height of the BubbleDeck® [m]
- f_{ck} = characteristic strength according to DIN 1045-1 [MN/m^2]

DIN 1045: $m_s = m \cdot D_{BD} \cdot 1.17 / (d_B^3 \cdot ß_R) \leq 0.2$

where:
- m_s = relative bending moment in the ball zone [-]
- m = max. bending moment under occupancy load [MNm/m]
- D_{BD} = ball diameter [m]
- d_B = static height of the BubbleDeck® [m]
- $ß_R$ = calculated strength according to DIN 1045 [MN/m^2]

Figure 152 Flexion requirements[59]

7.2 Handmade design calculations:

The design of the slab is made considering a 1 m wide strip.

Applied loads are:

- permanent actions:
  - self-weight + finishes: G_k = 5.17 + 5.8 = 11 kN/m
- variable actions
  - live load: Q_k = 4 kN/m

Slab thickness = 280 mm

Column size = 400 mm

[59] http://www.bubbledeck-uk.com/pdf/BDINTDesignGuide.pdf

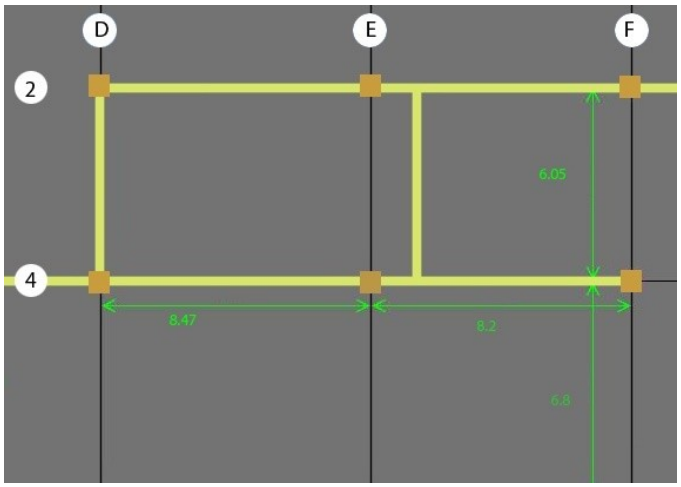


Figure 153 Slab section selected

7.2.1 Handmade Structural analysis

The structural analysis will be carried out using linear analysis based on the theory of elasticity, considering the combination of actions for Ultimate Limit States [EC2 – 5.1.3(1)P] that is[60]

$$\sum_{j\geq 1} \gamma_{Gj}\, G_{kj} + \gamma_{Q1}\, Q_{k1} + \sum_{i>1} \gamma_{Qi}\, \psi_{0i}\, Q_{ki}$$

The most unfavourable condition results in considering the live load Q_1 as the leading variable action and the load due to inside partitions with its combination value $\psi_{02}\ Q_2 = Q_2$ (ψ_{02} = 1,0 according to National Annex).

7.2.2 Load Combination

Permanent loads: $\gamma_G\ (G_k) = 1.35\ (G_k)$

Variable loads: $\gamma_Q\ (Q_k) = 1.5\ (Q_k)$

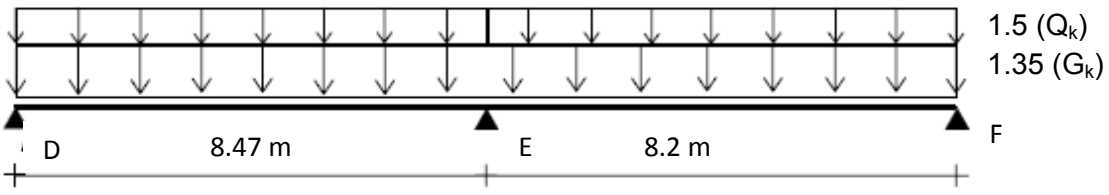


Figure 154 Panel centred on Grid line 4

[60] EN 1990-2002 (E) – Expression 6.10

The structure is solved using the Flexibility Method

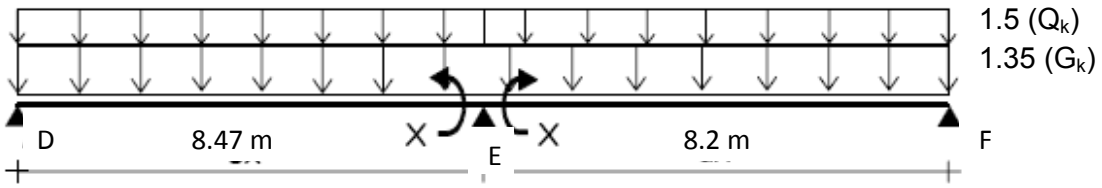


Figure 155 Flexibility method: load combination

The panel is center on Grid line 4.

The ultimate load is given by = 1.35 (G_k) + 1.5 (Q_k) = 20.92 kN/m

7.2.3 Cover

$C_{nom} = C_{min} + \Delta C_{dev}$
here C_{min} = max of [$C_{min,b}$; $C_{min,dur}$; 10 mm]
where;
$C_{min,b}$ = 20 mm, assuming 20 mm diameter reinforcement; and $C_{min,dur}$ = 10 mm [61]
ΔC_{dev} = 10 mm [62]
For Fire resistence:
For 1 hours fire resistance, a_{min} = 35 mm , so is not critical
$\Delta C_{nom} = 20 + 10 = 30$ mm

7.2.4 Analysis

Consider grid line 4.

Effective spans:

8.2 – 2(0.4/2) + 2 (0.28/2) = 8.08 m
8.47 – 2(0.4/2) + 2 (0.28/2) = 8.35 m

Check applicability of moment coefficients:

8.08 / 8.35 = 0.96 < 15%

As spans differ by less than 15% of larger span, coefficients are applicable, OK!

[61] EN 1992-1-1 table 4.4N
[62] EC2 – 4.4.1.3

Using the flexibility method to solve as shown in Figure 154. For two spans, using increased coefficients for central support moments and shear.

Design moments in bay:

M_{Ed} = *781.26 kNm*

At Support:

M_{Ed} = *894.63 kNm*

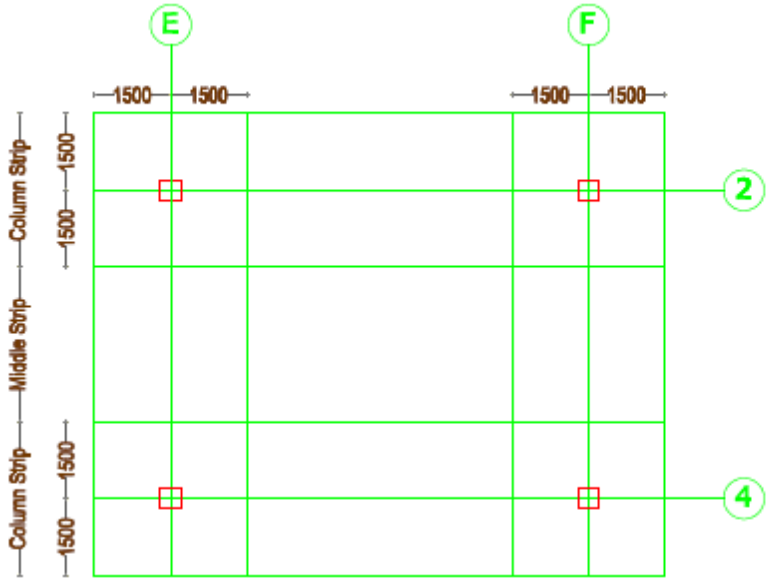


Figure 156 Column and middle strips allocation

From specifications[63]:

Apportionment of moments between column and middle strips

	Column strip portion (%)	Middle strip portion (%)
-ve (hogging)	Long span = 70% Short span = 30%	Long span = 30% Short span = 25%
+ve (sagging)	50%	50%

Parallel to Grid line 4, the column and middle strips are 3 m each.

[63] EC2 – Part 1.1, Annex I, Table I-1

Long span moments:

M_{Ed}	Column strip	Middle strip
-ve (hogging)	0.7 (874.63)/3 = 204.08 kNm/m	0.3 (874.63)/3 = 87.46 kNm/m
+ve (sagging)	0.5 (781.26)/3 = 130.21 kNm/m	0.5 (781.26)/3 = 130.21 kNm/m

Table 13 Long span moments

7.2.5 Punching Shear[64]:

$V_{Rd,c} = C_{Rd,}\, k\,(100\rho_1 f_{ck})^{1/3} + 0.10\,\rho_{cp} \geq (V_{min} + 0.10\,\rho_{cp})$

Where,

f_{ck} is in MPa

$k = 1 + \sqrt{200/d} \leq 2.0$ d in mm

$\rho_1 = \sqrt{\rho_{1y}.\,\rho_{1z}} \leq 0.02$

For column at grid line 3 F,

f_{ck} = 35 Mpa

k = 1.84 < 2.0 Ok!

ρ_1 = 0.02

$C_{Rdc} = 0.18/\gamma_c$

$V_{min} = 0.035\, k^{3/2}\, f_{ck}^{1/2}$

$V_{Rd,c}$ = **3817.9 kN** ; and

V_{Ed} = 20.92 x 6 x 8.47 x 0.63 x 2 = **917.59 kN**

Since $V_{Ed} < V_{Rd,c}$, therefore we conclude that shear reinforcement is not required.[65]

7.2.6 Designing the elements:

At Gridline B

Effective depth = 280 – 30 – 20/2 = 240mm

[64] EN 1992-1-1 eq 6.47
[65] EN 1992-1-1 – 6.4.3(2)b

7.2.6.1 Flexure: column and middle strip, sagging

The design moment is M_{Ed} = 130.21 kNm/m

$K = M_{Ed}/bd^2f_{ck} = 0.0167$

z/d = 0.94

z = 239.2 mm

$A_s = M_{Ed}/ f_{yd}z = 1251.39\ mm^2/m$

7.2.6.2 Deflection : column and middle strip

Checking span (l) to effective depth (d) ratio:

Allowable $l / d = N \times K \times F_1 \times F_2 \times F_3$

Where,

N = 23.68 (ρ = 0.51%, f_{ck} = 35 MPa)

K = 1.2 (for flat slab)

$F_1 = 1.0\ (b_{eff} / b_w)$

F_2 = 1 (because there are no brittle partitions)

$F_3 = 310/\sigma_s \leq 1.5$

Therefore, *L / d = 31.82*

Actual l / d is calculated as

L / d_a = 8200 / 260 = 31.53

$l / d_a < l / d$ Satisfied!

7.2.6.3 Flexure : column strip, hogging

M_{Ed} = 204.08 kNm/m

$K = M_{Ed}/bd^2f_{ck} = 0.086$

z/d = 0.89

z = 231 mm

$A_s = M_{Ed}/ f_{yd}z = 2030.94\ mm^2/m$

7.2.6.4 Flexure : middle strip, hogging

M_{Ed} = 87.46 kNm/m

$K = M_{Ed}/bd^2f_{ck} = 0.036$

z/d = 0.95

z = 247 mm

$A_s = M_{Ed}/ f_{yd}z = 813.9\ mm^2/m$

7.2.7 Requirements

7.2.7.1 In column strip, inside middle 1500mm

There is a requirement[66] to place 50 % of A_t within a width equal to 0.125 times the panel width on either side of the column.

Area required = (3 x 2030.94) + (3 x 813.9) / 2 = $8534.52mm^2$

Over width = 2 x 0.125 x 6 = 1500mm

i.e., required 8534.52/1.5 = $5689.68mm^2/m$ for 750mm on either side the column centerline.

7.2.7.2 In column strip, outside middle 1500mm

Area required = (3 x 2030.94) - (16.67 x 314) = $858.44\ mm^2$

Over width = 3000 – 2 x 750 = 1500 mm

i.e., $572.29\ mm^2/m$

7.2.7.3 Minimum area of reinforcement check

$A_{s,min} = 0.26\ (f_{ctm}/f_{yk})\ b_t d \geq 0.0013\ b_t\ d$

$0.26 \times 3.2/500\ b_t d \geq 0.0013\ b_t\ d$

$0.00166\ b_t\ d \geq 0.0013\ b_t\ d$ OK!

7.2.7.4 Deflection check

Span / 250 = 8.2 / 250 = 0.0328 m

Max deflection = 0.00761 m

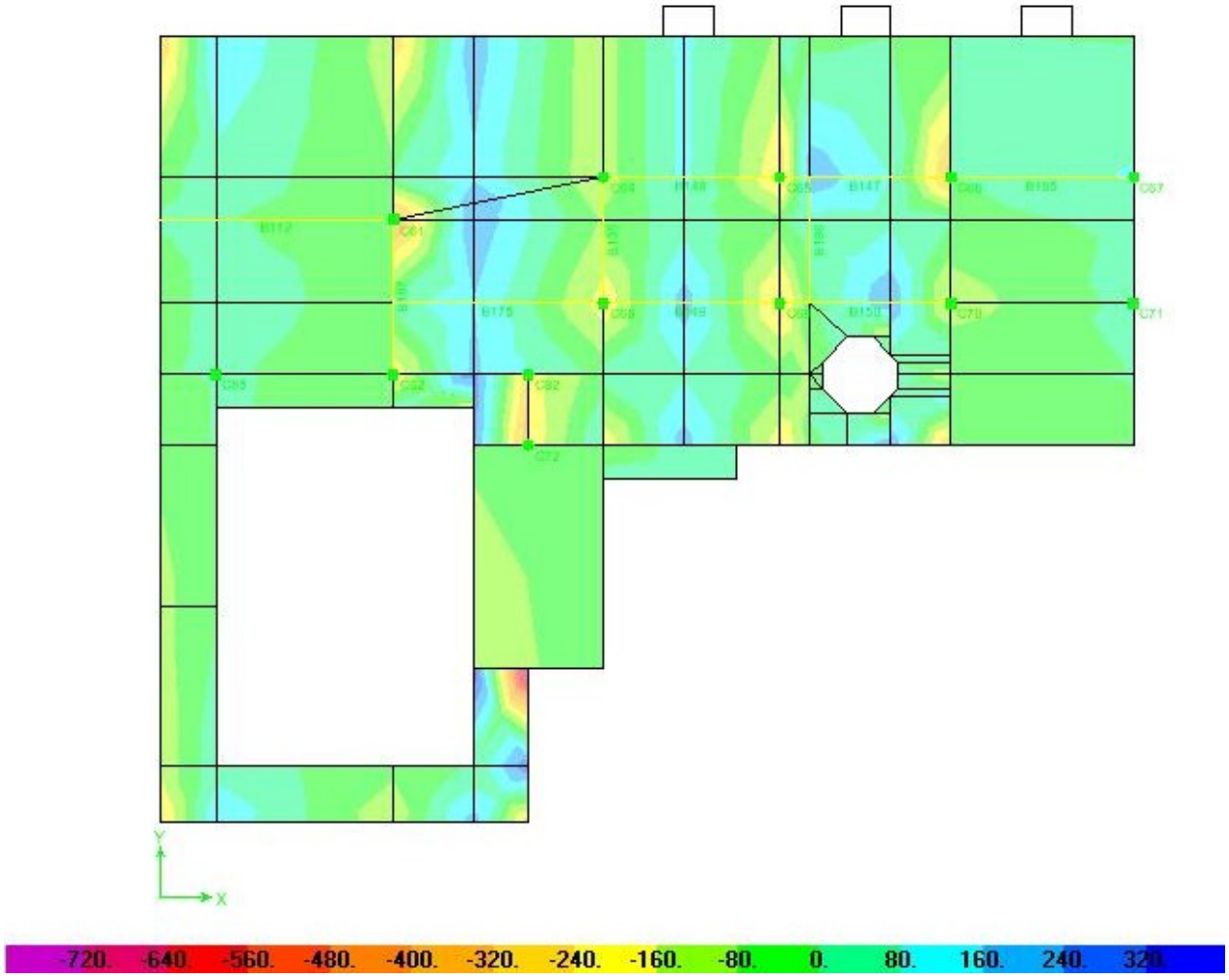
0.00761 m < 0.0328 m satisfied!

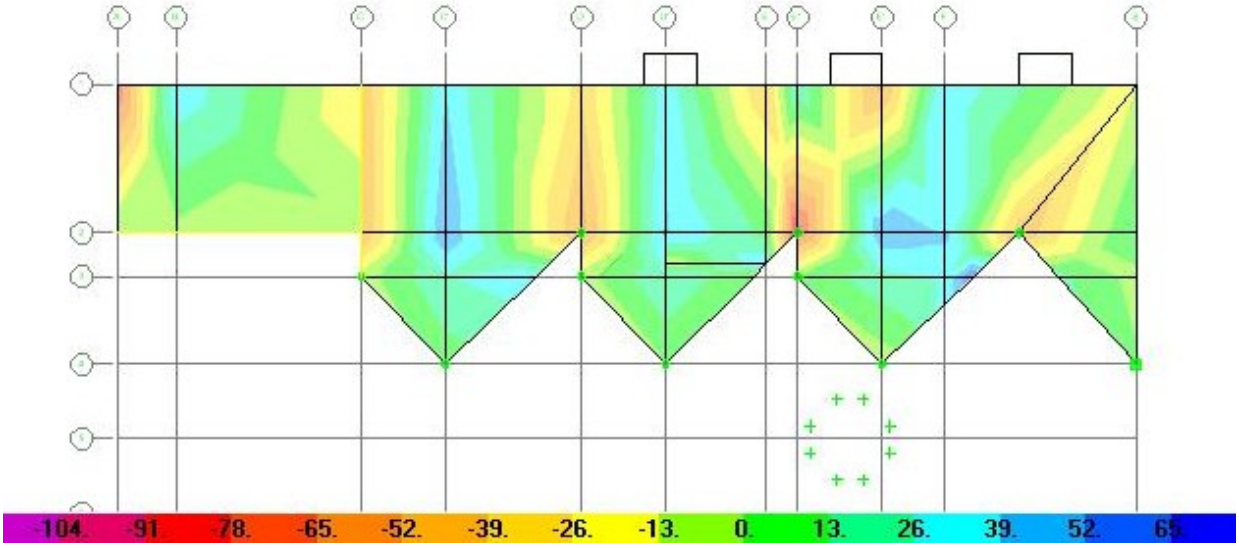
[66] EN 1992-1-1 – Part 1.1, (9.4.1)

7.3 Software Analysis

7.3.1 Internal Forces and Reactions:

Figure 157 Slab internal forces

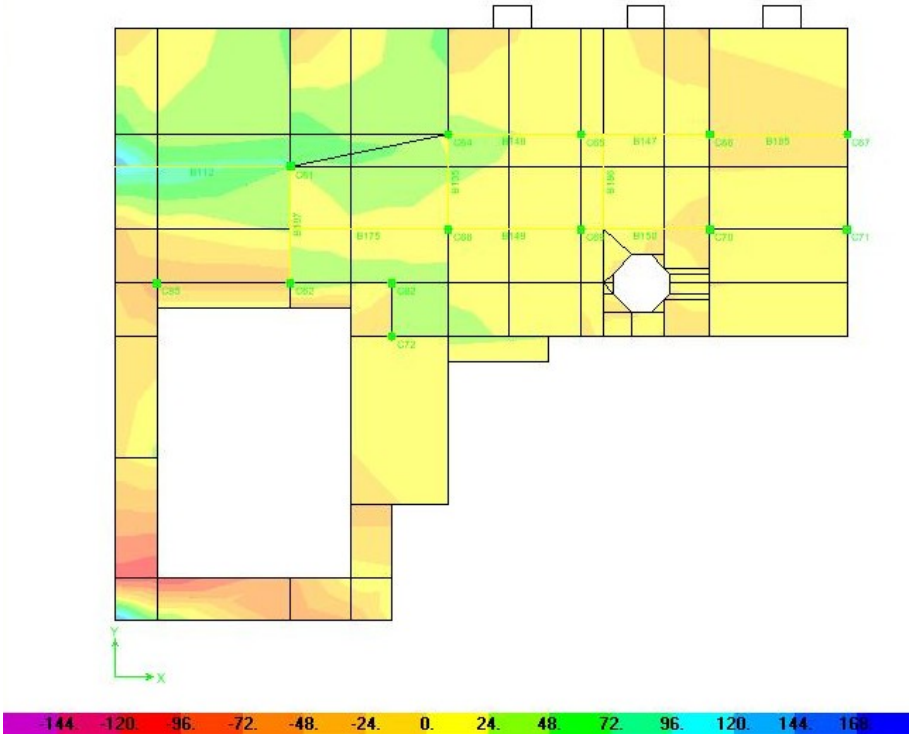




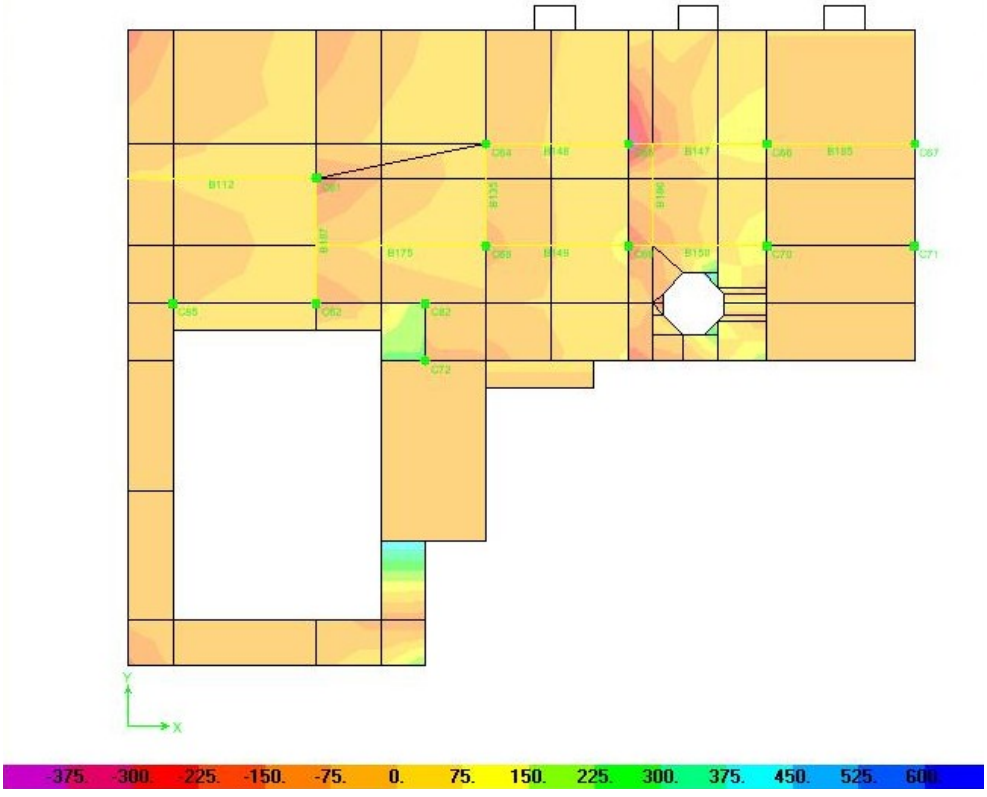
Slab Reactions M11

The above diagram reflects how the forces produced due to moment reaction are distributed over the slab area. It can be witnessed that the forces are greater in magnitude at and near the column supports (yellowish colour in Figure 156). Also, the blue colour on the right side of Figure 156 represents the column placed over the beam, so generating larger forces therein.

The following figures present further force diagrams for different forces of flexure and shear. The Colour variation depicts the change in forces at various points in the structure. Here, the magnitude of forces is more for larger span areas owing to the flexural and shear stresses therein.



Slab Reactions F11



Slab Reactions V13

7.3.2 Deflection check:

Span / 250 = 12.85 / 250 = 0.0514 m

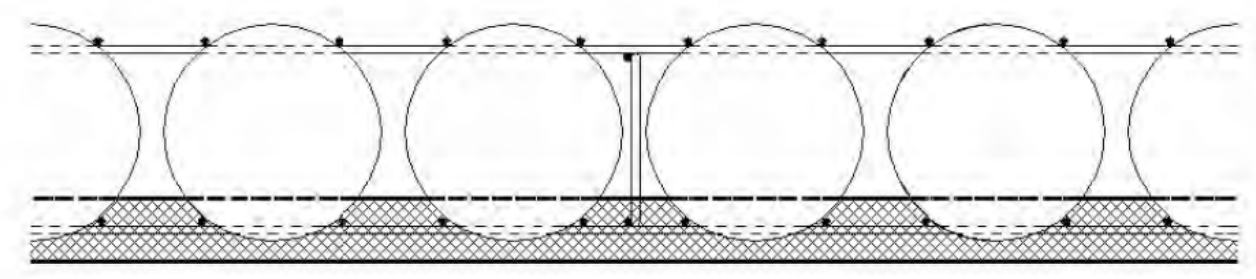
Deflection from software = 0.0080 m

0.00080 m < 0.0514 m satisfied!

7.3.3 Detailing:

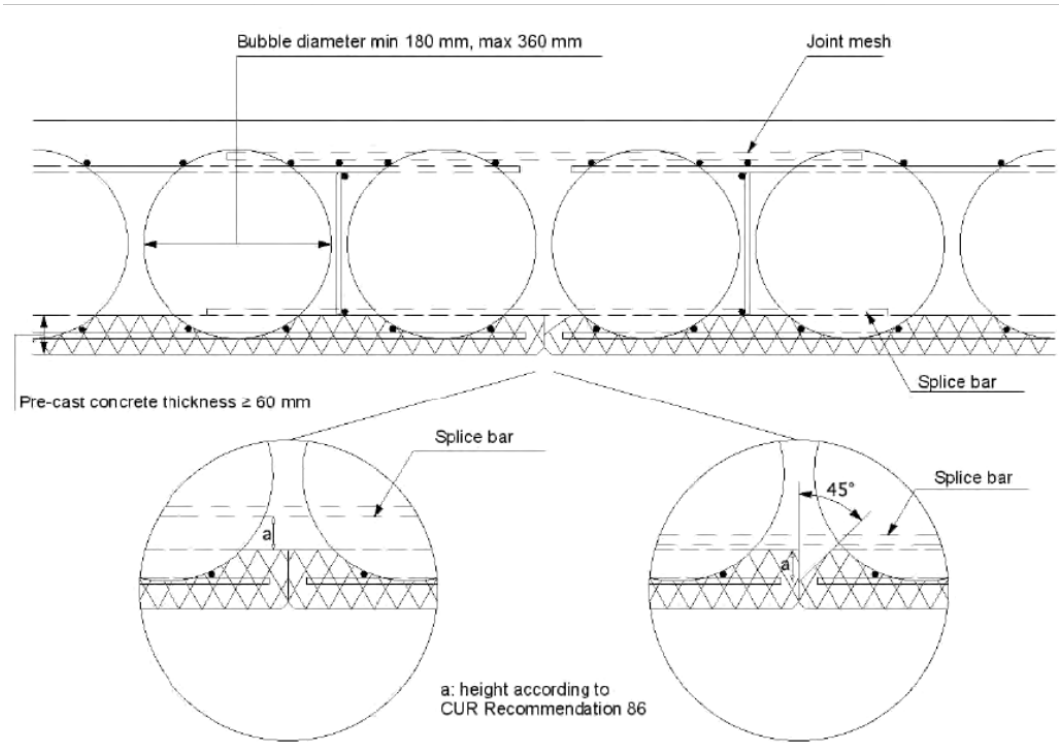
Since we are proposing to use the precast concrete permanent formwork type assembly, to be transported to the site and put to desired place and then concrete be poured to make it complete. In this regard, the following demonstrations are presented to have a better understanding of the process of casting and connection. These have been taken from the manufacturer's website as referred in the following page.

Figure 158 Slab Detailing demonstration[67]

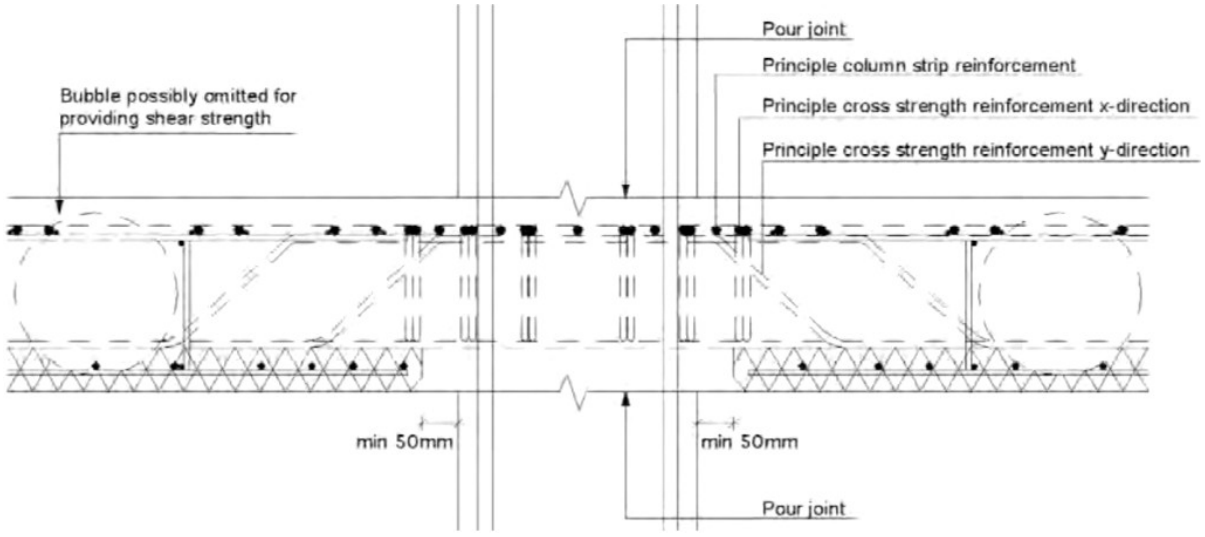


Elements where the bubbles are trapped between the upper and lower reinforcement supplied with pre-cast concrete permanent formwork.

[67] http://bubbledeck-uk.com/pdf/2-BDTechManualv1a.pdf



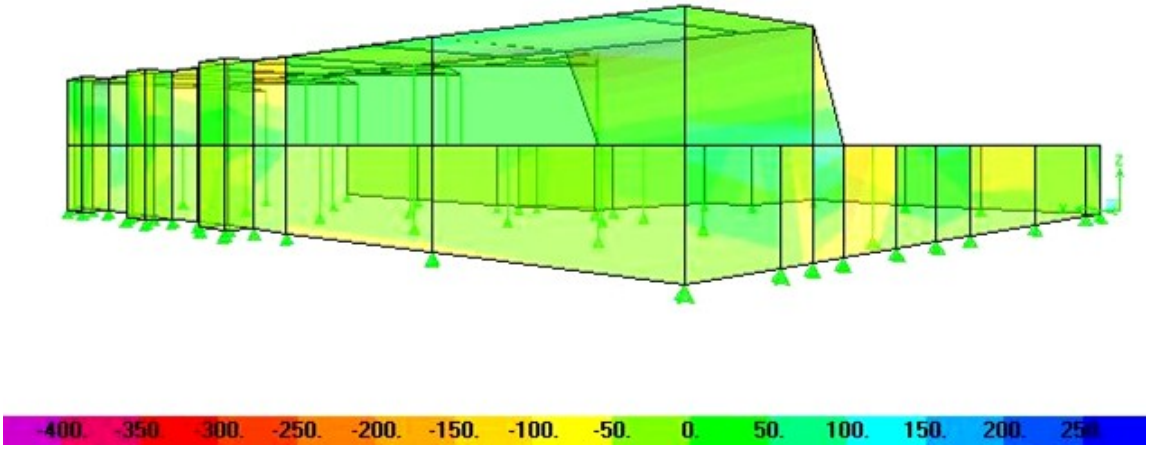
Detail of longitudinal joint between elements



Connection to in-situ concrete column

8. Shear Wall Design

The design of shear wall was developed using the software ETABS. The diagrams for the resultant force F11 for flexure are shown for the two parts of the building project, to have an overview of the forces therein. The design sheets for both the building parts of the project, as designed by the software are also attached here below. The steel reinforcement aareas are also mentioned in the sheets which will be utilized for the construction, and the boundary element check is also performed by the software.



Reactions F11 (left side building)

Story ID: STORY2 Pier ID: P1 X Loc: 23.39983 Y Loc: 41.18628 Units: KN-m

Flexural Design for P-M2-M3 (RLLF = 0.600)

Station Location	Required Reinf Ratio	Current Reinf Ratio	Flexural Combo	Pu	M2u	M3u	Pier Ag
Top	0.0025	0.0103	C10	3420.093	-1868.194	-2014.850	21.040
Bottom	0.0025	0.0103	C10	4948.801	205.481	-143.700	21.040

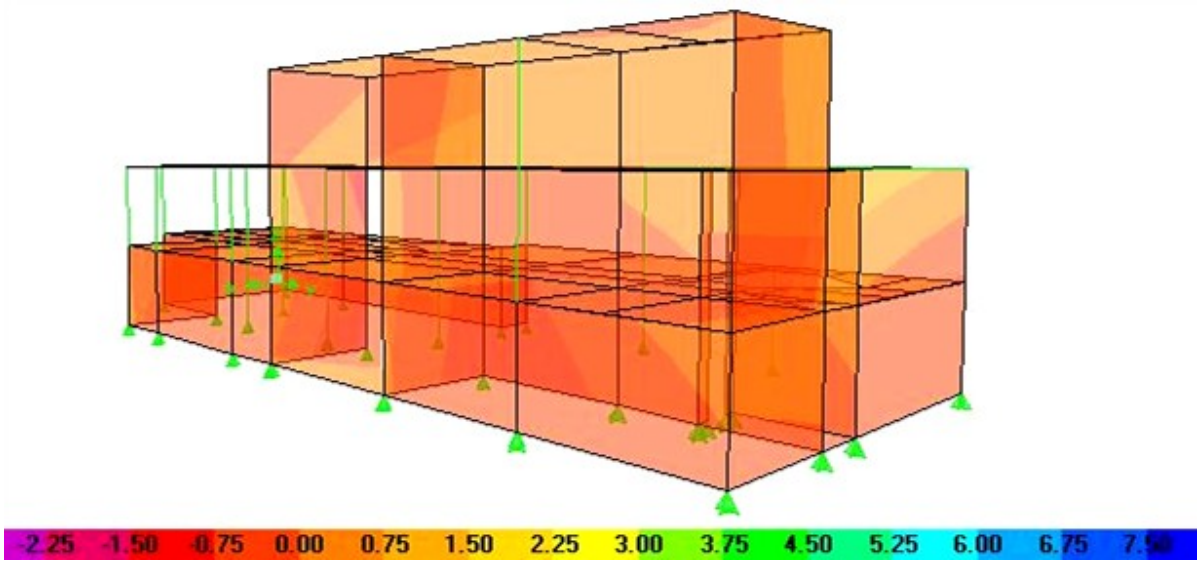
Shear Design - First Leg Requiring Most Rebar per Unit Length

Station Location	Rebar in^2/ft	Shear Combo	Pu	Mu	Vu	Capacity phi Vc	Capacity phi Vn
Top Leg 1	0.360	C3	294.830	-456.957	287.189	1460.325	3014.805
Bot Leg 1	0.360	C3	445.420	634.366	287.189	1460.325	3014.805

Boundary Element Check - First Inadequate Leg or Leg Requiring Longest Boundary Zone

Station Location	B-Zone Length	B-Zone Combo	Pu	Mu	Vu	Pu/Po
Top Leg 9	0.360	C7	1.417	-63.407	1.424	0.0000
Bot Leg 9	0.360	C7	54.567	-57.998	1.424	0.0014

Figure 159 General reinforcing pier section – Design for left side building



Reactions F11 (right side building)

Story ID: STORY1 Pier ID: P1 X Loc: 369.4556 Y Loc: 934.579 Units: Kip-in

Flexural Design for P-M2-M3 (RLLF = 0.400)

Station Location	Required Reinf Ratio	Current Reinf Ratio	Flexural Combo	Pu	M2u	M3u	Pier Ag
Top	0.0025	0.0088	C7	3199.194	-18635.955	550573.563	15943.748
Bottom	0.0025	0.0088	C7	3757.864	-19241.642	568101.331	15943.748

Shear Design - First Leg Requiring Most Rebar per Unit Length

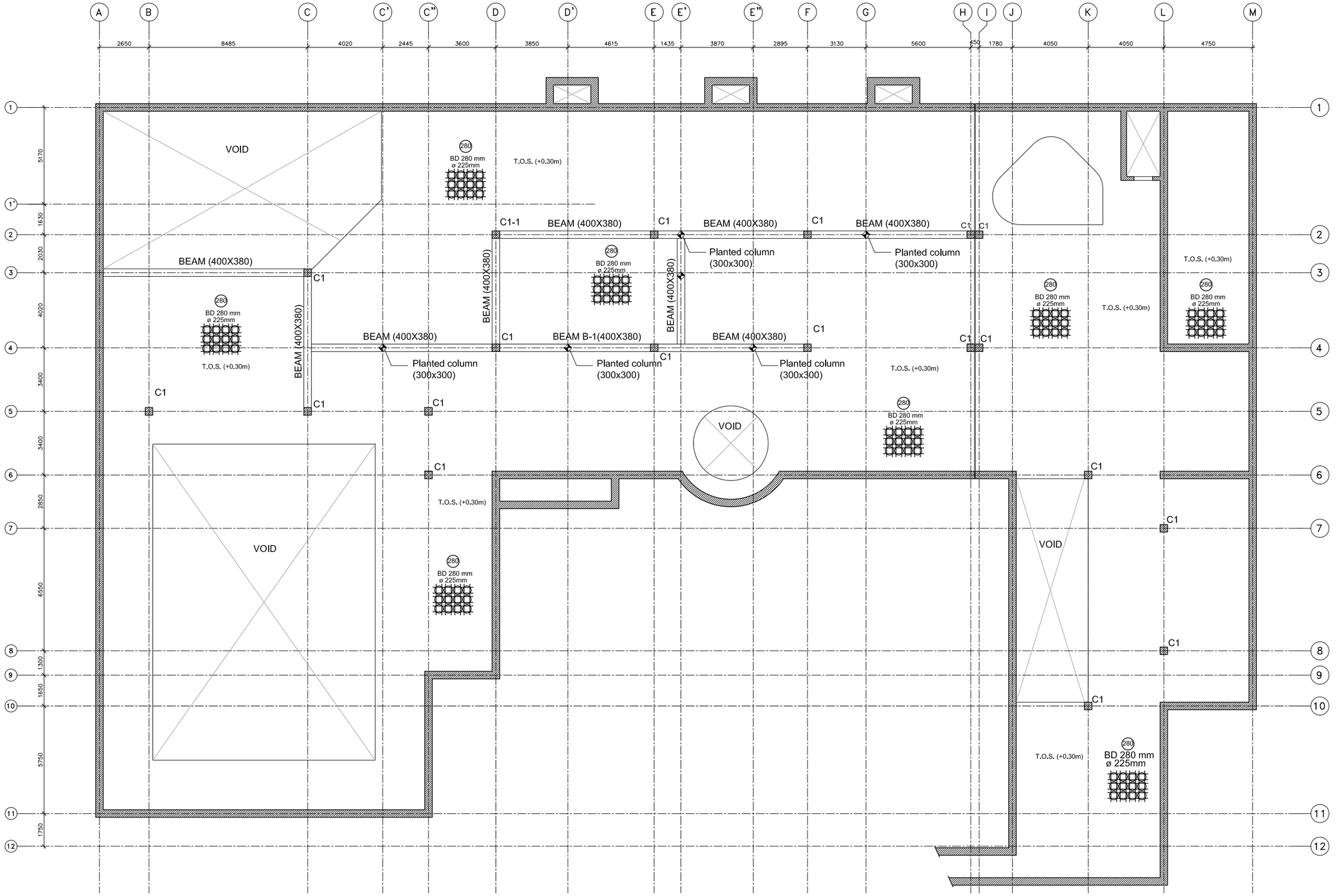
Station Location	Rebar in^2/ft	Shear Combo	Pu	Mu	Vu	Capacity phi Vc	Capacity phi Vn
Top Leg 5	0.370	C2	75.422	2130.556	-27.704	7.355	27.704
Bot Leg 7	0.363	C2	78.662	-2014.211	-27.704	7.714	27.704

Boundary Element Check - First Inadequate Leg or Leg Requiring Longest Boundary Zone

Station Location	B-Zone Length	B-Zone Combo	Pu	Mu	Vu	Pu/Po
Top Leg 13	188.740	C7	365.440	49379.282	-10.616	0.0032
Bot Leg 2	106.654	C7	167.646	-24310.977	-4.512	0.0026

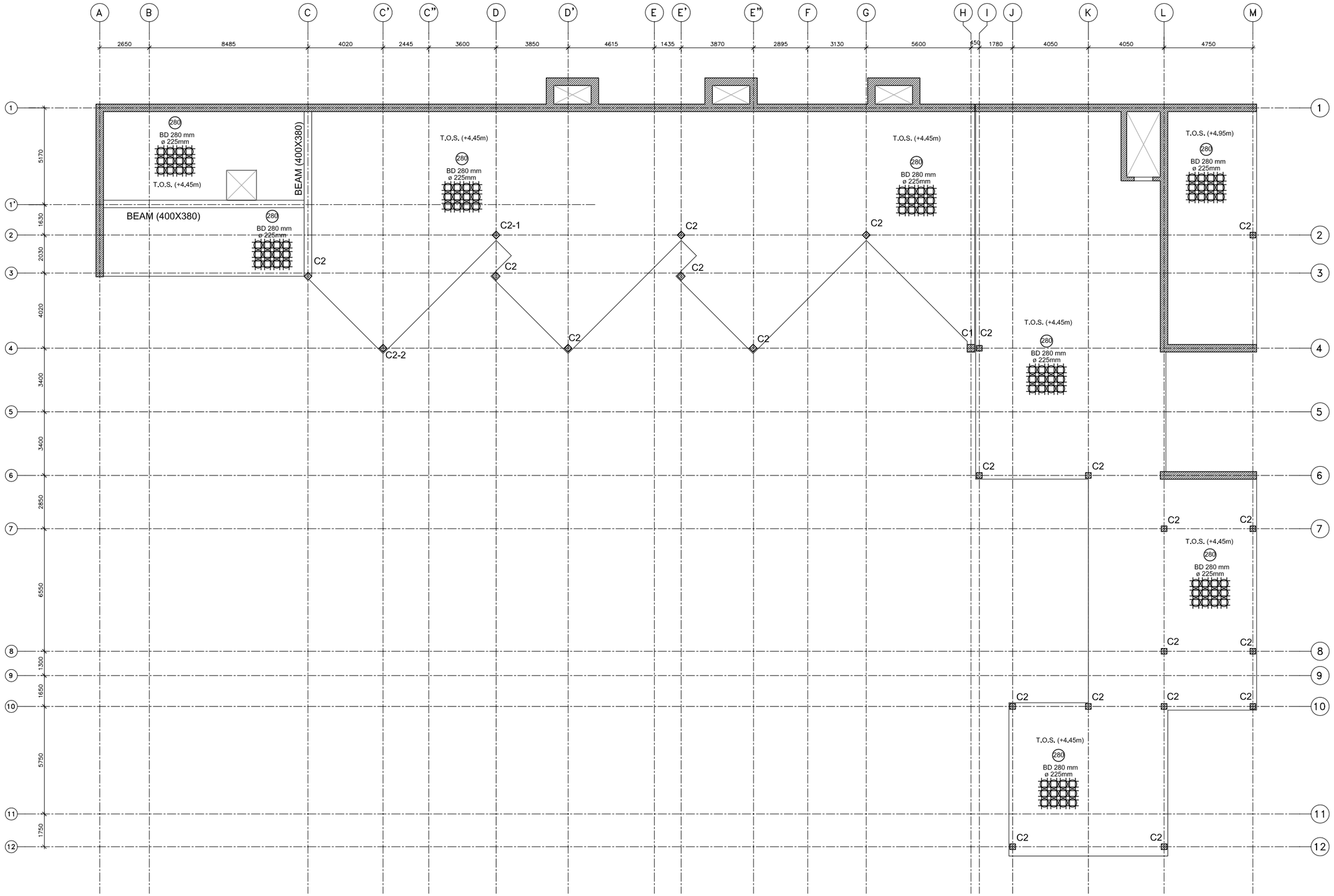
Figure 160 General reinforcing pier section – Design for right side building

9. Structural Drawings and Graphics



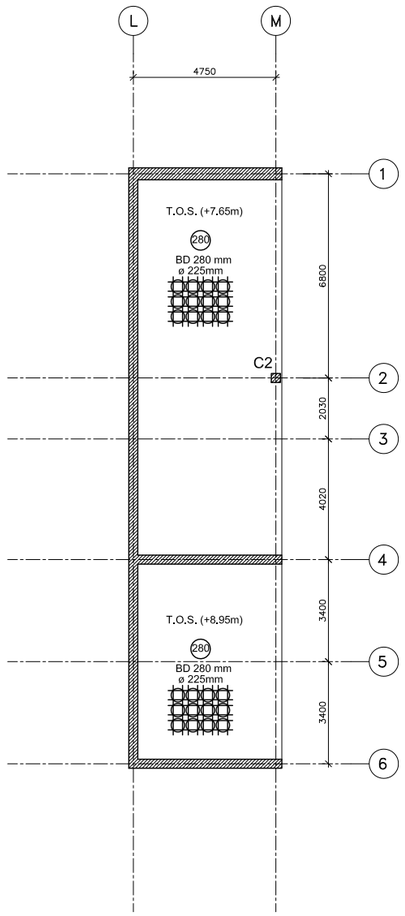
SLAB ABOVE BASEMENT FLOOR
1:200

POLITECNICO DI MILANO VI FACOLTA' DI INGEGNERIA MASTER OF BUILDING ENGINEERING	The Earth sheltered Body Factory | VALMADRERA-LECCO	A.Y. 2012/2013	SCALE 1:200	Str 01

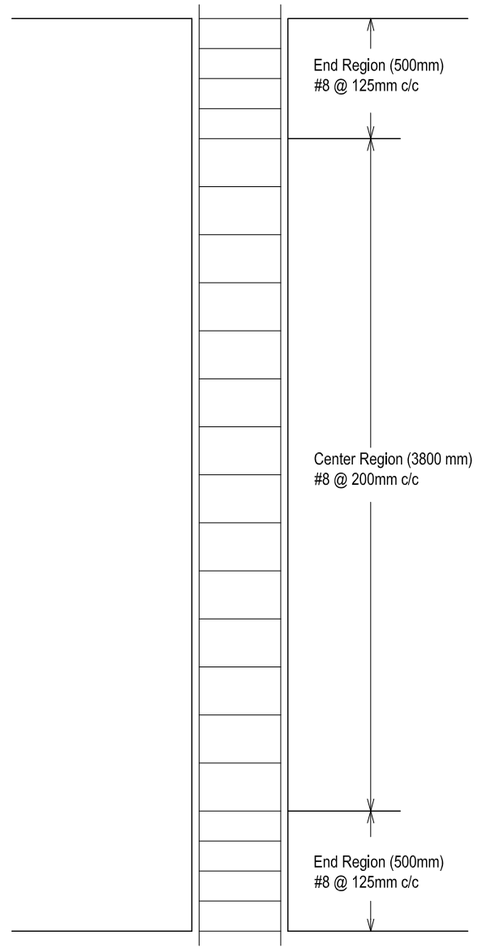


SLAB ABOVE GROUND FLOOR
1:200

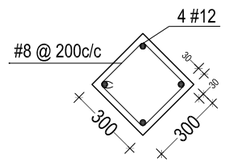
POLITECNICO DI MILANO VI FACOLTA' DI INGEGNERIA MASTER OF BUILDING ENGINEERING	The Earth sheltered Body Factory | VALMADRERA-LECCO	A.Y. 2012/2013	SCALE 1:200 / Str 02



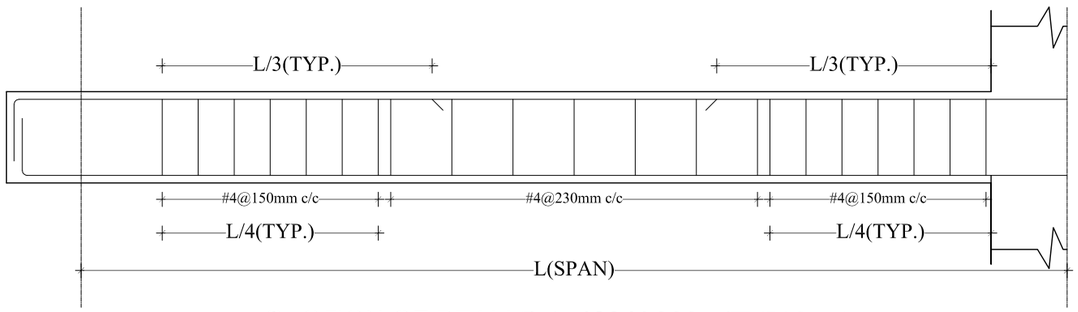
SLAB ABOVE FIRST FLOOR
1:200



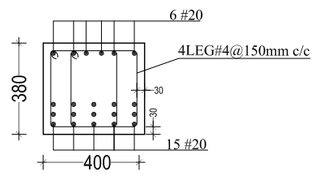
TYPICAL COLUMN DETAIL



Column C2-1 Detail

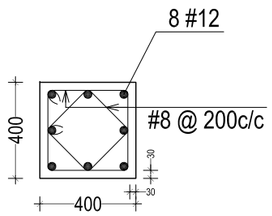


L-SECTION OF BEAM B-1 400 X 380 (TYPICAL)



BEAM B-1 (400 x 380)

1:25



Column C1-1 Detail

1:25

POLITECNICO DI MILANO VI FACOLTA' DI INGEGNERIA MASTER OF BUILDING ENGINEERING	The Earth sheltered Body Factory | VALMADRERA-LECCO	A.Y. 2012/2013	SCALE —	Str 03