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EVOLVING CALCO

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ABSTRACT

Today, we are driven by a new sustainability ethic, necessarily systemic in scope. Carbon-neutrality is the rage, location efficiency, clean energy and the return for the neighborhood are the watchwords of change. Formulas and metrics, and new regulatory systems attempt results, and show the quest to measure how close we are to achieving ideal forms of location and development.

The goal of this research is to envision the recreation of the setting of the city of Calco, starting from an Urban and Architectural scales, and reaching to the design of the building details and services design, in order to achieve the goal of reaching zero footprint.

The project, with its series of proposals of intervention (from regional to local level), aims to promote and to make the most out of the current governmental policies in matter of sustainable design, renewable sources exploitation, green areas development, public transport and connectivity. By analyzing these facts it was possible to present a complete conception in a detailed level of Urban, Architectural, Structural, Technological and Building services sustainable alternatives.

The research starts with a thorough analysis of the PTCP plan provided by the Province of Lecco; strongly taking into consideration the constrains, guidelines and future projects within the documents. Following this step is the process of intervention on three scales, the urban city scale, the zone of intervention scale and the architectonic project scale; this intervention is based on a theoretical knowledge base which focuses on the concepts of the evolution of place and sustainability in the context of Urban and public space design as essential topics in approaching the design proposal. The theory is then followed by a set of intervention patterns, and finally the application of these patterns in each part of the project. The project was then renamed as “Evolving Calco” following its relation to the intervention concept, trying to achieve the incentives of the municipality of Calco as well as the researchers involved in the design process.

The subsequent part of the research focuses on the technical approach in achieving sustainability and zero footprint building. It is considered to be the tools for testing and evaluating the efficiency of the proposed design. By considering the inclusion of the concept of Zero Foot print building (towards a Zero CO_2 emissions production emitted from fossil fuels consumption), the project sets a compound of strategies and ideas that take advantage of the state-of-art’s technologies and processes, in order to create an overall solution able to satisfy low energy consumption levels, and a total on-site energy autonomy from renewable energy sources only.

The outcome of the research gives a complete understanding of the practical processes which can be employed to get a zero foot print building by taking into consideration energy saving strategies, renewable energy sources, and optimization of the building envelope; Therefore, this thesis work can be

considered a guideline for architects and engineers for projecting a zero foot print building starting from an urban scale until a detailed technical level.

ITALIAN SUMMARY

Oggi siamo guidati da una nuova etica della sostenibilità. Carbon-neutralità e l'efficienza sono le parole chiave del cambiamento. Formule e parametri, e nuovi sistemi di ordinamento risultano, e mostrano il tentativo di misurare quanto siamo vicini al raggiungimento di forme ideali di posizione e di sviluppo sostenibile energetico.

L'obiettivo di questa ricerca è di immaginare la ricreazione della regolazione della città di Calco, partendo da una scala urbana e architettonica, e raggiungendo la progettazione dei particolari dell'edificio e del design dei servizi, alla fine d'ottenere l'obiettivo zero foot print .

Il progetto, con la sua serie di proposte di intervento (da livello regionale a livello locale), mira a promuovere e rendere al meglio le attuali politiche governative in materia di progettazione sostenibile, sfruttamento di fonti rinnovabili, sviluppo aree verdi, trasporti pubblici e connettività . Analizzando questi dati è stato possibile presentare una concezione completa in un livello dettagliato di una progettazione sostenibile urbanistica, architettonica e tecnologica.

La ricerca inizia con un'analisi approfondita del piano fornito dal PTCP della Provincia di Lecco; fortemente prendendo in considerazione le vincoli, direttive e progetti futuri all'interno dei documenti. A seguito di questa fase è il processo di intervento su tre scale, la scala urbana della città, la scala della zona di intervento e la scala del progetto architettonico, questo intervento si basa su una base di conoscenze teoriche che si concentra sui concetti dell'evoluzione del luogo e della sostenibilità in contesto della progettazione dello spazio urbano e pubblico, come argomenti essenziali per avvicinarsi alla proposta progettuale. La teoria è poi seguita da una serie di modelli d'intervento e infine, all'applicazione di questi modelli in ogni parte del progetto. Il progetto è stato poi rinominato come "Evolving Calco" dopo la sua relazione al concetto d'intervento, cercando di ottenere gli incentivi del comune di Calco, nonché i ricercatori coinvolti nel processo di progettazione.

La parte successiva della ricerca si concentra su un approccio tecnico a raggiungere la sostenibilità edilizia e Zero footprint, il quale 'considerato il tool per testare e valutare l'efficienza del progetto proposto. Considerando l'inserimento del concetto di edificio Zero footprint (verso una produzione a zero emissioni di CO_2 emessa da consumo di combustibili fossili), il progetto definisce un complesso di strategie e d'idee che si avvalgono di tecnologie allo stato dell'arte e dei processi, al fine di creare una soluzione globale in grado di soddisfare bassi livelli di consumo energetico, e una totale on-site autonomia energetica da fonti energetiche rinnovabili. L'esito della ricerca fornisce una

completa comprensione dei processi di pratiche che possono essere impiegati per ottenere un edificio Zero Foot print prendendo in considerazione strategie energetiche di risparmio, fonti di energia rinnovabili e l'ottimizzazione dell'involucro edilizio; Pertanto, questo lavoro tesi può essere considerato una linea guida per architetti e ingegneri per la proiezione di un edificio Zero foot print partendo da una scala urbana fino ad un livello tecnico dettagliato.

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LA GARA

ZERO FOOT-PRINT

"DESIGNING A NEW MULTIFUNCTIONAL SPACE AND REDEFINING THE SAN VIGILIO AREA IN THE CITY OF CALCO"

CHAPTER I: *LA GARA, ZERO FOOT-PRINT COMPETITION*

1. COMPETITION BRIEF

1.1. INTRODUCTION

For the academic year 2010/20011, a competition of ideas is announced, where 3 prizes & 2 mentions will be awarded for the architectural design of a "New Multifunctional Public Space with Zero Emissions, High Sustainability and Redefinition of The San Vigilio area in the City of Calco, Lecco Province".

1.1.1. Location

The project is located in the city of Calco- province of Lecco in the north part of the Brianza Lechesse of the region of Lombardia. The area distinguished as San Vigilio to the one which extents form the front of the church San Vigilio up to Via Trieste, and from via San Vigilio to the border of the residential and educational area bordering via rimembranze.

1.1.2. Functional areas

The San Vigilio area located in the city of Calco comprises 4 main functional areas that should be developed as it is described in the main plan and aim of this competition.

Illustration 1 Area of the project and surroundings

1.2. OBJECTIVES

1.2.1. General Objective

The objective of the initiative is to increase the level of knowledge and investigation of all integrated components that composes the architectural & urban design of the area. The competition aims to define a New City Center that can have the same function also within a wide geographical area. The proposal comprises the architectural and urban design of a central area through the recovery and redesign of new functions, spaces and services of public interest raised in the zone.

1.2.2. Specific Objectives

The challenge of the project is to achieve a balanced summary of the reports and problems between the new complex and rigid structure of the country, where the new intervention is able to act as a new landmark in the City of Calco and surrounding areas. In particular, projects should be developed in a draft form according to a preliminary multidisciplinary input including choices of architectural and urban design and the definition of constructive choices which demonstrate the feasibility. Particular emphasis will be given to aspects related to construction methods, technology-oriented energy conservation and sustainability moderation of the atmospheric emissions. The project will be strongly characterized with the definition of strategies and environmentally sustainable construction methods aimed to satisfy energy saving standards and reduction of CO_2 emissions. In particular the project area will include:

1. The Reorganization of the children playing area.

2. The Expansion of existing facilities and bars.

3. The Construction of a multipurpose modular building to replace the existing "Theater Pergula/Tent" which can host events of different nature from the parties of the country & concerts, dances, performances to public meetings with a capacity of not less than 300 seats, and the possibility to alternately accommodate about 1,000 people standing. The intervention should have the outdoor areas directly related to the facility to host activities during specific periods of the year, especially during the summer.

4. The Redesigning of public open spaces, their relationship with the country, with the existing public buildings and the surrounding historical presence.

5. The Connection with the pedestrian walkways network and the purpose of linking the area to the system of sustainable mobility at the urban scale and regional / provincial level.

6. The Redesigning of parking spaces in line with the system of public spaces and the structure of urban mobility.

1.3. ADMINISTRATIVE RULES

1.3.1. Eligibility

Students enrolled in the 1st year of International MSc Degree in Architectural Engineering at the Politecnico di Milano - Faculty of Architectural Engineering course "Architectural Design" and "the Laboratory of Architectural Design Studio" under the supervision of Prof. Massimo Tadi and Prof. Franck Nolesini respectively; as well as all students or groups of students enrolled in other courses that would show interest in the subject.

1.3.2. Professional advisor(S)

Prof. Massimo Tadi massimo.tadi@polimi.it
Prof. Franck Nolesini franck.nolesini@polimi.it

1.3.3. Jury

Gilberto Fumagalli, the Mayor Pro/tempore of the City of Calco.
Brambilla Alberto, the Deputy Mayor Pro/tempore of Urbanism, Territory and Environment of the City of Calco;
Dean of the faculty of Architectural Engineering, Politecnico di Milano;
The Chairman of the board of studies in the faculty of Architectural Engineering, Politecnico di Milano;
Prof. Gabriele Masera, Professor in Politecnico di Milano, Polo regionale di Lecco;
Eng. Giancarlo Alderighi, representative of the Order of Engineers of the Province of Lecco with responsibility for relations with the University;
Prof. Arch. Giuseppe Turchini, Editor of the Arketipo editions "il sole24ore".

1.3.4. Applications

Students enrolled in the 1st year of International MSc Degree in Architectural Engineering at the Politecnico di Milano - Faculty of Architectural Engineering, "Architectural Design" and "the Laboratory of Architectural Design Studio" Course under the supervision of Prof. Massimo Tadi and Prof. Franck Nolesini respectively are automatically admitted to the competition. As for the other students or groups of students enrolled in other courses that would show interest in the subject & would like to apply; should apply through contacting with Prof. Massimo Tadi.

1.4. AWARDS

The 5 awards established by the Municipality of Calco that will be assigned are as follows:

1st Group Prize: €1500.
2nd Group Prize: € 1000.
3rd Group Prize: € 500.

The 4th & 5th Groups with mentions; will be given a certificate of participation in the competition over some volumes on topics related to architecture.

1.5. SUBMISSION REQUIREMENTS

To consent the constitutional participation to the contest, the delivery of the projects planned by the countersigned will be within the hours of 12:00 P.M of the 16th of February 2011 at the Class C.2.7 of the Politecnico di Milano - Polo Regionale di Lecco, Via Marco d'Oggiono, 18 / a - 23900 LECCO.

The graphical materials requested for the competition consists of No.4 Boards A1, one or more physical models of the project, including:

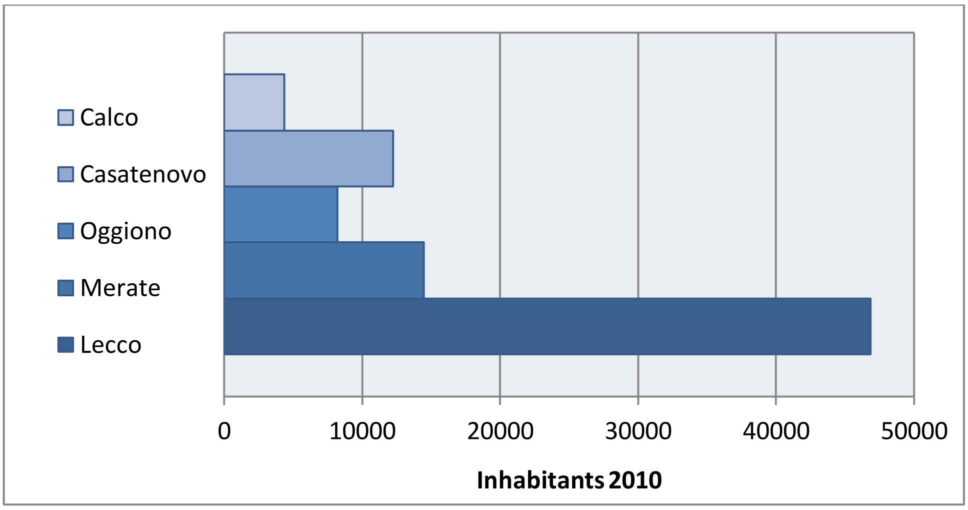
Board No. 1. Table A1 (59.4x84.1) containing the project master plan, scales 1:1000. The table may contain graphic diagrams explanatory concepts and sketches.
Board No. 2. Table A1 (59.4x84.1) containing the building plans of the project, scale 1:100.
Board No. 3. Table A1 (59.4x84.1) containing the sections and elevations of the project buildings, scale 1:100.
Board No. 4. Table A1 (59.4x84.1) containing the views and renderings of the project as a whole and building design.
Draft No. 5. An A4 Report (21x29.5) consisting of not more than 5 pages, including the eventual cover.
Physical model of the building design, scale 1:100 / 1:200

All tables must be equipped with a Title Block that will be provided from the course and be available online within the official website of the Politecnico di Milano in "Corsi On-line." Attached to the tables, has to be delivered, the form of participation in the competition which will be available online on the course website.

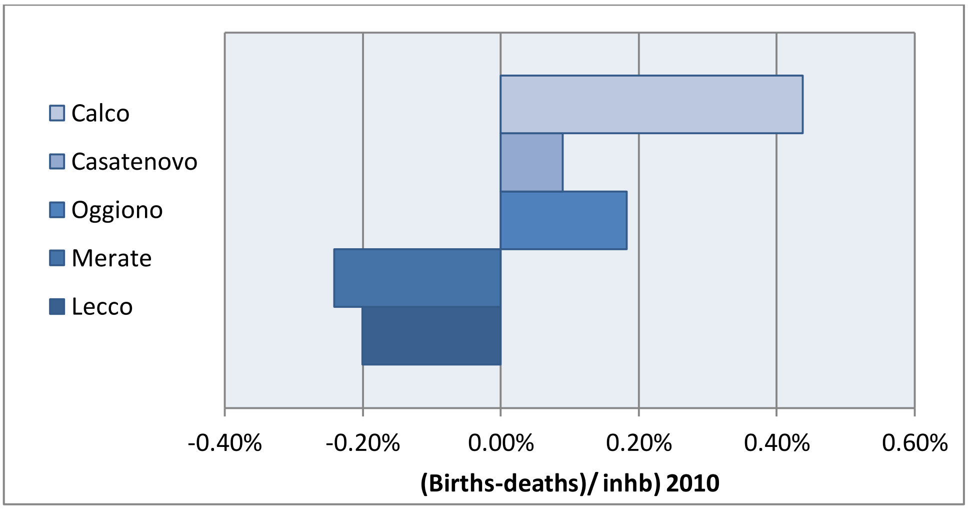
2. CALCO AND ITS HISTORY

2.1. DEMOGRAPHICS

The data extracted from the national demographic data base describes the conditions in which Calco is located in terms of resident population in comparison to the main cities in the region Brianza Lechesse. As it can be seen in the next compound of graphics Calco is reaching the 5000 inhb limit according to its expected annual growing; however its development conditions in terms of growing rates in relation to other important cities is higher (I.e Lecco and Merate presents a negative rate for 2010) than main cities in the region.



Graphic 1 Population compared to the main cities of the Brianza Lechesse region and Lecco (Istat 2010)1



Graphic 2 growing rate compared to the main cities of the Brianza Lechesse region and Lecco (Istat 2010)2

1 ISTAT. Demo – tool – Demographic data base per region of the country. 2010 . [Online Content]. http://www.demo.i stat .it/bi l2006/index.html.

2.2. GEOGRAPHICAL LOCATION

Calco is located in the province of Lecco in Lombardia in part of the territory identified as Brianza Lechesse which constitutes the 50% of the population of the entire province, Lecchese region 40%, and the Valsassina & Lario 10%, out of 327.510 inhb. 3

Scattered in various localities like Arlate which is the most important and populous, it borders the municipalities of Brivio, Olgiate Molgora, Merate and Imbersago. It is crossed by two main highly important roads linking Milano to the Valtellina, and it is close to the railway station Olgiate Molgora, which connects Milano, Lecco & Sondrio line.

Illustration 2 Lombardy region (Regione lombardia)4

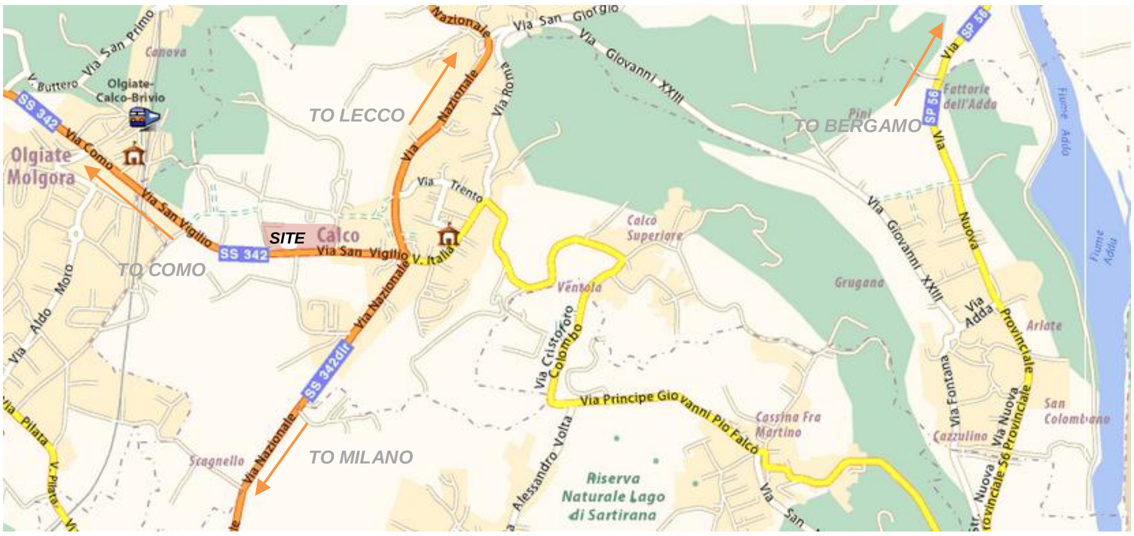


Illustration 3 Site and Calco location (Michelin maps)

The City spreads out in a hilly area located on the right bank of the river Adda, the border with the province of Bergamo. It is about 15 kilometers from the capital Lecco, about 35 km from Milano & 25 km from Bergamo.

2 ISTAT. Demo – tool – Demographic data base per region of the country. 2010 . [Online Content]. http://www.demo.i stat .it/bi l2006/index.html.
3 Ibid. Piano Territoriale di Coordinamento Provinciale (PTCP): Monografia D- Politiche insediativi. 2008. p.15 .
4 UFFICIO DEL SINDACO CALCO. Progetto San Vigilio Presentation. [power point slides]. 2010. Sl 9.

2.3. COMMUNITY GOALS

1. To create a new "aggregation center" in town keeping the area alive, and improving the citizen's quality of life.

2. To Issue a clear message for an active support of bio-construction, renewable energy sources and energy saving as a way toward a new style of life.

3. To promote and reassess the existing infrastructures through an effective public expense too.

4. To stimulate some new business opportunities to achieve a better and quicker economic payoff (ROI).

2.4. HISTORY

The origins of the city's name, has had an evolution which origin can be attributed to the Celtic voice CALK (Lime or from Calcareus origin) regarding the wide availability of calcareous rock in the territory.The origin of the two communities of Calco & Arlate are lost in the mist of time, and the first existence of the country, or rather the existence of a human on the Calco hills, are in a parchment of 936 or 937 which has been known as the Longobardi domination in accordance to the signature of one of the inhabitants at the time: "Signum + minibus Umberti filli quondam Gumperti de **Calego**.

Along the feudalism period, several vassals and representatives of the cities around the region of Brianza present before the Milan Duke its loyalty the 10th of July of 1412, including the lands in which the fractions of Arlate and Calco were located into the Duke reign of Fillippo Maria Visconti. During this reign, the river of Adda becomes the border of the whole Brianza-Milan duke with the Reign of Venice; situation that incurred into the constant submission of the zone by sudden invasions, robberies and more hungry and poverty problems

Several dominations of the territory occurred across the years; including incursions of the Spanish crown from, German and French crown from 1530 to 1713 when the Austrian domination took place, lasting during more than 70 years, bringing calm and prosperity to the zone. Maria Teresa Queen of Austria promoted the agriculture production and communication of this zone to the rest of the Austrian territory. During the period Calco is joined to the city of Arlate (1753).

Future invasions and conquest of the territory by part of the Italico Reign (1805-1814) did not affect too much the poor condition of the city mainly inhabited by farmers, and slaves of noble families.

From 1815-1866, after the falling of Napoleon Buona parte, the Austrian reign retake control over the zone up to when the control of the zone is lost under the activity and invasion of the Italian reign (1864-1946), which joins the cities of Olgiate and Brivio to Calco In the 1930’s. Finally Calco is divided to its original and current territory composition in 1953 after the proclamation of the also current Italian republic.

OBJECTIVES DEFINITION

"OBJECTIVES OF THE PROJECT TOWARDS A ZERO FOOT PRINT INTERVENTION "

CHAPTER II: *OBJECTIVES DEFINITION*

1. INTRODUCTION

1.1. ZERO FOOT PRINT CONCEPT

In order to talk about a zero foot print building, it is imperative to introduce the concept of carbon neutrality. The carbon neutrality or zero carbon footprint relies in the idea of obtaining a total balance between the amount of carbon dioxide emitted,and a equivalent amount of it that is avoided to be released. In practice it can be considered as the balance that an anisotropic intervention (in our case a building) in terms of carbon dioxide, releases to the atmosphere from fossil fuels consumption compared to renewable energy sources, which can be used in order to compensate carbon emissions, or alternatively, mitigate them at all. However, the use of renewable sources is not the only aspect that is considered inside this concept. It has to be stated that the production of CO2 due to the increasing need of energy and use of fossil fuels for this aim in the planet, can be abolished by a simple reduction in the energy consumed.

According to the statement above presented, a ZERO FOOT PRINT Building can be considered as the kind of intervention to the natural context of the planet that uses tools such as reduction in energy consumption and more than all, renewable energies, in order to avoid or compensate the energy needs for the normal operation of the facility.

1.2. NET-ZERO ENERGY BUILDING CLASSIFICATION

The widely used classification standard for zero foot print buildings has been developed by the USA department of Energy and it is called NET-Zero energy building (NZEB) which is defined as follows:

> *…"A net-zero energy building (NZEB) is a residential or commercial building with greatly reduced energy needs. In such a building, efficiency gains have been made such that the balance of energy needs can be supplied with renewable energy technologies. …"*[5]

The main scope of this type of classification is to encourage the building contractors, owners and designers to use the highest possible amount of renewable sources and technologies that are located on the building and at the site.

1.2.1. Renewable energy supply Options:

5 Torcellini, Paul. Pless, Shanti. – U.S Department of Energy. Net Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Option. Pag 2. 2010.

The standard purposes and classifies a series of renewable supply options that can work as guide for the designer and contractor to join the system. The next graphic show these strategies.

Option Number	NZEB Supply-Side Options	Examples
0	Reduce site energy use through energy efficiency and demand-side renewable building technologies.	Daylighting; insulation; passive solar heating; high-efficiency heating, ventilation, and air-conditioning equipment; natural ventilation, evaporative cooling; ground-source heat pumps; ocean water cooling
On-Site Supply Options		
1	Use RE sources available within the building footprint and connected to its electricity or hot/chilled water distribution system.	PV, solar hot water, and wind located on the building
2	Use RE sources available at the building site and connected to its electricity or hot/chilled water distribution system.	PV, solar hot water, low-impact hydro, and wind located on parking lots or adjacent open space, but not physically mounted on the building
Off-Site Supply Options		
3	Use RE sources available off site to generate energy on site and connected to the building's electricity or hot/chilled water distribution system.	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or collected from waste streams from on-site processes that can be used on site to generate electricity and heat
4	Purchase recently added off-site RE sources, as certified from Green-E (2009) or other equivalent REC programs. Continue to purchase the generation from this new resource to maintain NZEB status.	Utility-based wind, PV, emissions credits, or other "green" purchasing options. All off-site purchases must be certified as recently added RE. A building could also negotiate with its power provider to install dedicated wind turbines or PV panels at a site with good solar or wind resources off site. In this approach, the building might own the hardware and receive credits for the power. The power company or a contractor would maintain the hardware.

Illustration 4 NZEB Renewable energy supply options. (Extracted from U.S Energy department) 6

1.2.2. Energy performances:

Within the scope of the classification system, the energy performance of the building is accounted in 4 main methods:

> ***Net-Zero Site Energy:*** *A site NZEB produces at least as much renewable as it uses in a year, when accounted for at the site.*
> ***Net-Zero Source Energy:*** *A source NZEB produces (or purchases) at least as much renewable energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to extract, process, generate, and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the*

6 Torcellini, Paul. Pless, Shanti. – U.S Department of Energy. Net Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Option. Pag 4. 2010.

appropriate site-to-source conversion multipliers based on the utility's source energy type.
Net-Zero Energy Costs: *In a cost NZEB, the amount of money the utility pays the building owner for the renewable energy, the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.*
Net-Zero Emissions*: A net-zero emissions building produces (or purchases) enough emissions-free RE to offset emissions from all energy used in the building annually. Carbon, nitrogen oxides, and sulfur oxides are common emissions that NZEBs offset. To calculate a building's total emissions, imported and exported energy is multiplied by the appropriate emission multipliers based on the utility's emissions and on-site generation emissions (if there are any)…"* 7

1.2.3. Classification Scale

Basically the standard covers a classification system based on the use of renewable sources and building uses. The classification states 4 main levels at which the building can be considered as a ZERO FOOR PRINT BUILDING. The first level NSEB A at the top of the scale requires a building that can auto satisfy totally all its internal energy uses from renewable sources. On the other hand the last level of the scale NZEB D requires a building that can satisfy its internal needs by a mix use of onsite renewable energy + offsite renewable energy purchases. In this way a building that uses any amount of non renewable sources of energy, is not considered a net-zero foot print building.

NZEB:A Buildings generate and use energy through a combination of energy efficiency and renewable energy collected on-site or within the boundaries of the building area.

NZEB:B Buildings generate and use energy through a combination of energy efficiency, and part of renewable energy collected on-site or within the boundaries of the building area, other part of the energy is acquired outside the building footprint but not off-grid purchased

NZEB:C buildings uses the directions stated for a NZEB:A and/or NZEB:B building but part of the energy is purchased in off-sites sources with direct production of energy within the boundaries of the building. (I.e. wood chip burner).
NZEB:D buildings uses the directions stated for a NZEB:A, NZEB:B and/or NZEB:C building but part of the renewable energy is purchased from off-sites sources with direct production of energy out of the boundaries of the building.

7 Torcellini, Paul. Pless, Shanti. – U.S Department of Energy. Net Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Option. Pag 7-8. 2010.

1.2.4. Guide for Classification attaining.

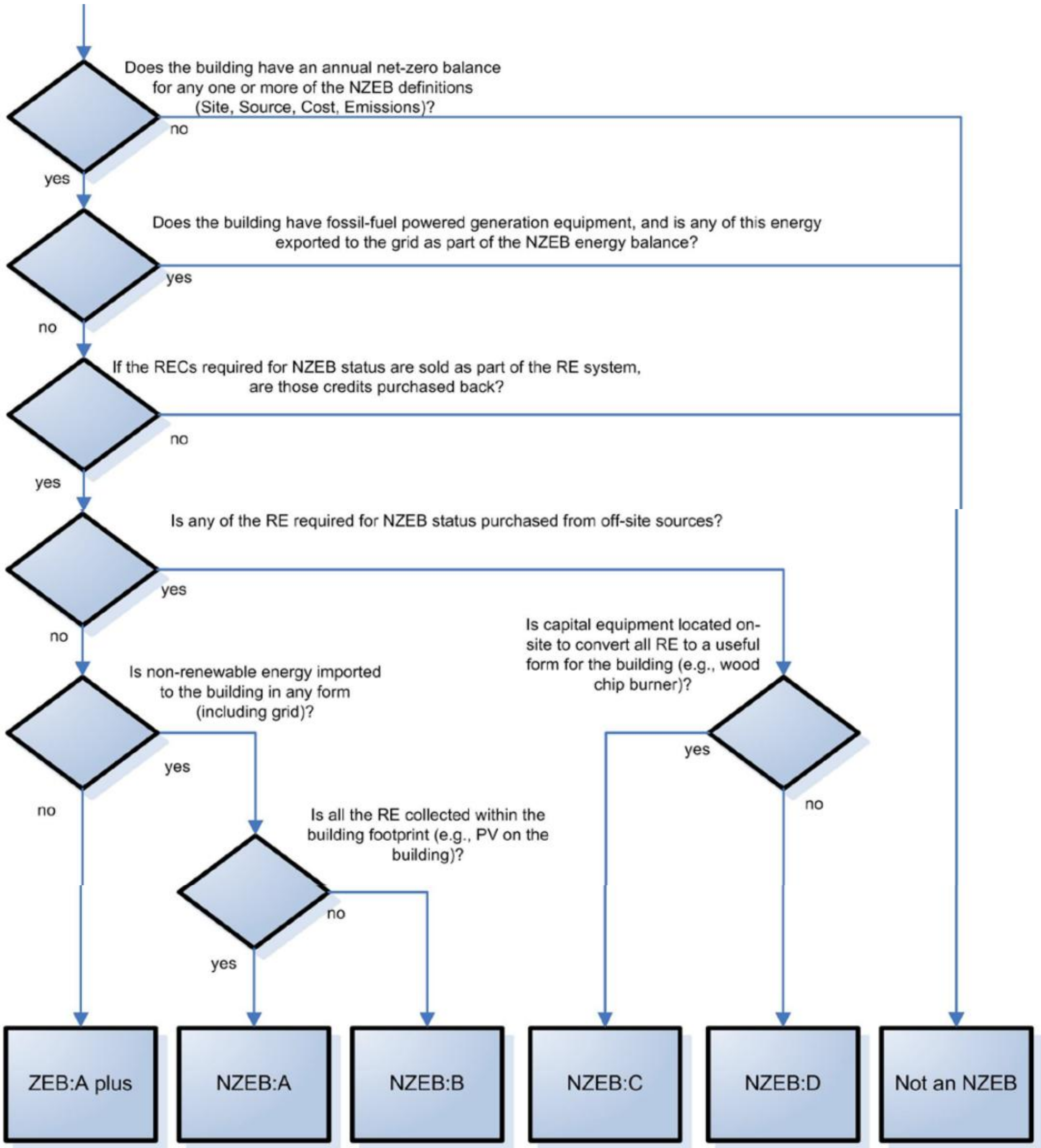


Illustration 5 NZEB Classification guide (Extracted from U.S Energy department) 8

8 Torcellini, Paul. Pless, Shanti. – U.S Department of Energy. Net Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Option. Pag 13. 2010.

2. PROBLEM STATEMENT

Which are the Urban, Architectural, technological, structural and energy conditions that the project in the area of San Vigilio - Calco should satisfy in order to develop a ZERO FOOT PRINT BUILDING?

3. OBJECTIVES

3.1. GENERAL

To provide the Urban, Architectural, structural, technological and energy solutions that can satisfy the requirements established by the competition and a NET ZERO FOORPRINT BUILDING, by taking into consideration the state of art in matter of technologies, techniques and strategies aiming to save energy and indirectly to exclude the use of fossil based fuels.

3.2. SPECIFIC

Urban Project:

Ecological corridor

- To propose and underline in detail the main ecological network of the city, as a buffer zone that should be protected from the environmental and sustainability point of view, and which will give a balance between the open green spaces and the urban areas to be developed.
- To provide protection to the identity of existing landscapes.
- Ecological path (Eco-path):
- To take advantage of the Eco-Museum plan stated by the PTCP, including Calco–Arlate zone as a source of both, ecological sites and interesting heritage buildings.
- To take advantage of the vast agricultural zones as a possible future development of agro-tourism.
- To enhance the pedestrian activity of the intervention zone by means of rescaling the uses of roads to a human scale.
- To overlap and redefine pedestrian connections in very limited spaces and those concerning the Eco-path.
- To provide transversal connection for non-inhabitants and inhabitants to eco-tourism activities, taking advantage of the Adda's Park proximity to the city, and its connectivity from the main gateways of the city.

Urban Intervention: Focused in two different scales. One focused on the public space use and redefinition and another towards the road intervention.

Public spaces:

- To enhance and redesign the considered "not well used" public spaces which are localized in strategic positions throughout the Eco-path and the city center
- To redefine the activities developed in the main public spaces which exist throughout the Eco-Path network.
- To redesign an existing area to become the new main cultural hub & entertainment center for the city

Road interventions:

- To redefine the use of the provincial road S342 considering the proposals given by the PTCP and the potentials and constrains of this node for the city.
- To solve the connectivity problem between different parts of the city in critical zones - such as some intersections in the provincial road S342.
- To provide a solution for the traffic problems presented in the city center due to heavy-traffic and light traffic that does not belong to the zone.

Architectural project:

- To design and conceptualize a multipurpose modular building which can host events of different nature from the parties of the country & concerts, dances, performances to public meetings with a capacity of not less than 300 seats.
- To create a pedestrian walkways network with the purpose of linking the area to the system of sustainable mobility at the urban scale and regional / provincial level.
- To generate outdoor areas and spaces directly related to the facility in order to host activities during specific periods of the year, especially during the summer.
- To redesign the existent public open spaces, their relationship with the country, with the existing public buildings and the surrounding historical presence.
- To reorganize the Children's area.
- To generate de expansion of existing facilities and bars.

Structural project:

- To develop a suitable structural solution for the facilities presented in the project, pointing out to the efficient use and implementation of materials and configurations that can provide intrinsic low CO2 emissions.
- To provide special structural solution for 20m and 30m single spans by using an affordable structural system that can satisfy lightness
- To provide and design structural systems that can minimize the material consumption and indirect energy expended on its manufacturing.

Technological project:

- To minimize the expected consumption of thermal energy, by means of providing technological solutions that in comparison with low thermal a performance building, can generate Energy saving values of up to 40%, aiming to decrease the energy needs, facilitating the sizing of renewable sources energy systems towards the achievement of a Zero Footprint building.

- To decrease the expected consumption of electrical energy by using high efficiency appliances.
- To design the systems of energy supply based on exclusively renewable sources, towards the classification of the Net Zero Foot Print standard.
- To decrease the expected consumption of potable supply water by providing a sustainable rain water recollection system able to satisfy the expected demand due to irrigation and toilets flushing mainly.
- To provide heat recovery systems that can lower the expected consumption of energy due to domestic hot water use.

ARCHITEC TURAL DESIGN

CHAPTER III: *ARCHITECTURAL DESIGN*

1. INTRODUCTION

Today, we are driven by a new sustainability ethic, necessarily systemic in scope. Carbon-neutrality is the rage, and location efficiency, clean energy and the return of neighborhood are the watchwords of change. Formulas and metrics, and new regulatory systems attempt results, and show the quest to measure how close we are to achieving ideal forms of location and development.

This section sets out in giving some general insight in the concept of social interaction. It describes different perspectives on the relation between the physical environment and social use. Finally an attempt is made to link these perspectives to the context of Calco and the area of San Vigilio.

This chapter aims to:

- Giving some general insight in the concept of sustainability in the context of urban design and the design of public spaces, focusing on the social aspect related.
- Stating a researchers' and users' perspective on sustainability in existing urban areas.
- Relating this perspective to the thesis proposal,
- Defining intervention patterns for the urban design proposal on two main scales – the city scale and intervention zone, and finally; presenting the proposed solution.

1.1. POLICIES AND GUIDELINES LEADING TO THE DEVELOPMENT OF THE AREA

As a first step toward the development of the urban approach for the thesis, the group concentrated on the study of the guidelines described for the area in terms of the Regional scale by means of the study of the PTCP (Piano Territoriale di Coordinamento Provinciale).

The Territorial Plan of Provincial Direction of the Lecco's province (PTCP -Piano Territoriale di Coordinamento Provinciale) is a legislative document elaborated by the territorial planning organism of the province of Lecco in the year 2004, with subsequent additions and final approval in 2009. This document contents a well structuralized analysis of the actual situation of the province in aspects such as urban and non urban areas morphology, socio-economical aspects, infrastructure development, energy sources, productive sectors, etc… Based on the actual situation of the province, the PTCP develops a series of strategies, policies and projects that will give a enhancement of the province in matter of territorial development and control in the following years.

The most important and significant objectives disposed by the PTCP can be summarized, and individualized as follows:

- To enhance the landscape, cultural qualities, and local identity of the Lecco's province: the use of Eco-museum project and the conception of Lombardia's lakes as high touristic attractive.
- To confirm the manufacturing vocation and to support the processes of innovation trough the province in related to this aspect.
- To improve the integration of Lecco and Brianza Lechesse in the urban network and extra-urban network: improvement of railway tracks and roadways connections.
- To encourage the development of a more integrated and sustainable mobility: realization of Bike and pedestrian ways network.
- To improve the functionality of the road system, in relation to the different settlements' functions (production, residence): comfort improvement, safety and paesagistic values.
- To protect the landscape: preserve natural and cultural context.
- To preserve the open space and the agricultural landscape, minimizing the land consumption: agricultural safeguarding and use of abandoned or unused land.
- To preserve the biodiversity and of green areas: to decrease the connection leak between green zones and safeguarding of rural areas to be used in touristic, and recreational applications with compatibility to the biodiversity and agricultural needs.
- To qualify the building industry towards the use of new technologies for bio-compatibility and energy saving: new regalement, energetic standards application and innovation.
- To improve the living conditions of the territory: formative, recreational and social services network.
- To ensure the security of the region with particular reference to the mountain: risk-management and mitigation, safe conditions for living.
- "To promote cooperation between local processes and the ability to self-representation and proposal of local systems." [9]

In the territorial and the urban issues, the PTCP prevents conditions and general regalements for the preservation and innovation of the internal productive patrimony, with the commitment of a new generation of productive areas ecologically equipped and the assessment of requalification of the actual productive settlements in matter of sustainability. However; the PTCP considers strictly the idea of the requalification of productive zones at the maximum possible to be taken only in-situ, avoiding possible abandoned and resettlements areas, which is considered a problem in matter of new conception and new plans for the use of the territory.[10]

[9] PROVINCIA DI LECCO. Piano Territoriale di Coordinamento Provinciale (PTCP): Monografia A- Obiettivi del PTCP e dimensione strattegica. 2008. p. 9-19.
[10] Ibíd. Piano Territoriale di Coordinamento Provinciale (PTCP): Norme di attuazione. 2008. p. 10.

2. STRATEGIC SCHEME

The PTCP divides in 4 main territories (regions) the Lecco's province in order to provide a more detailed formulation of strategies and projects related to the main territorial plan, in accordance to the needs, and the actual situation of each one of these regions, as it can be seen in the illustration11. (Brianza lecchese, Lecchese e Valle San Martino, Valsassina and Lario orientale.).

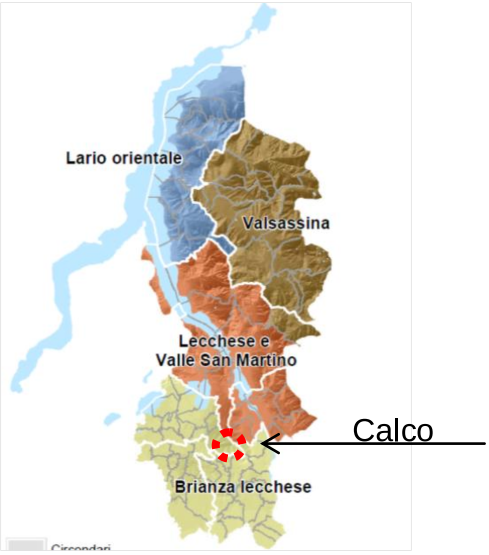


Illustration 6 Localization of calco within the 4 main territories. (extracted from Quadro Strattegico 2008)

According to the distribution stated above, a set of 10 projects have been proposed as a first instance of the strategies to be realized in matter of territory development and urban requalification. Some of these projects mentioned are part of the policy of the PTCP, which promotes the realization and inclusion of Projects of Urban Requalification and Territorial Innovation (PRINT-Progetti di Riqualificazione Urbana e Innovazione Territoriale) as follows: [12]

"…1. Regional nodal functions of the city of Lecco.
2. Eco-museum and cultural district of the Mountains and Lakes Briantei.
3. Cultural District of Valsassina.
4. Activation of the production division of Environment in the form Oggionese Ecologically Productive Area Equipped.
5. Expansion of the railway line Milan-Lecco-Sondrio and redevelopment of train stations with interchanging nodes.
6. Redevelopment and upgrading of the railway line Lecco-Molteno, Molteno- Monza and Lecco-Como: sector Carante to Airuno (14km) upgrading to double rail tracks
7. Integration of the foothill in the new Provincial roadway network.
8. Redevelopment, safety and protection of the scenic State Road 36 (Stretch-Nibionno-Civate).
9. Accessibility and redevelopment of the eastern shores of Como's Lake.
10. Upgrading of Meratese productive system and the fair-node of Osnago…."

These projects listed above, mainly have the aim to innovate the territorial settlements and infrastructure in the Lecco's province, with an interest on:

- The realization of new highway and railway connections and a requalification of high traffic conflict roads and rail tracks.

[11] Ibíd. Piano Territoriale di Coordinamento Provinciale (PTCP): Quadro strattegico territoriale. Scale 1:100000. 2008. p.1
[12] Ibíd. Piano Territoriale di Coordinamento Provinciale (PTCP): Norme di attuazione. 2008. p. 42.

- The realization of infrastructure to promote the touristic offer of the territory.
- Requalification and new system of productive nodes.
- The organization and system set up of heritage and environmental context.

2.1 ECOLOGICAL CORRIDORS: CONNECTION BETWEEN MAIN ECOLOGICAL CORRIDORS

Project: The Ecological network project aims at connecting (functionally) the most interesting natural areas through the upgrading of the environments affected by the urban development.
The PTCP promotes the development of this project for the following objectives:

- To counteract the process of environmental fragmentation of natural & semi-natural areas caused by the urban sprawl within these areas, & enhance the ecosystem in order to improve the ecological quality in the territory.
- Promote the preservation of native species & the prevention of any compromise to them or to the widespread ecological connection area.
- Promote opportunities for sustainable development & highlighting the importance of the natural & semi-natural areas & the proposed network; especially in the agricultural, forestry, tourism & environmental services.
- Reduce environmental discontinuity caused by infrastructural systems.
- Strengthen the role of streams (rivers & canals) in the ecological network, as well as recognizing the vital role of the rivers in the hydraulic & natural qualified landscaping systems.
- Promote the renewal of the ecological landscape for future urban projects in the area in order to control the impact of urban form, morphology & spatial distribution.

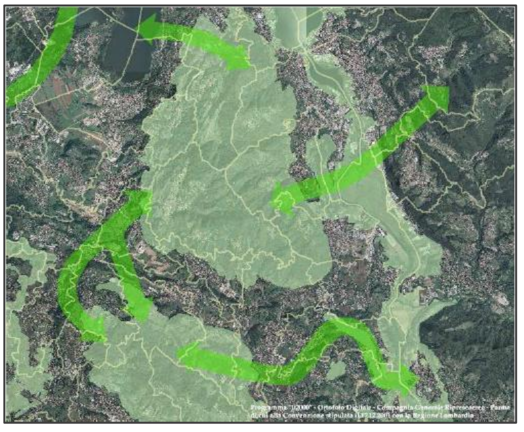


Illustration 7 Ecological network (extracted from (Quadro strattegico 2008)

2.2 ECO-MUSEUM DISTRICT OF THE MOUNTAINS AND LAKES OF BRIANTEI

Project: The eco-museum aims at providing awareness & rediscovery of the Brianza territories, its wealth of memories, tangible & intangible cultural & touristic assets, and of course its natural assets (Natural Parks & reserves…etc.)
It also studies the different approaches to market through different methods such as:

- Media animation sources in the municipalities & libraries - for didactic & informative reasons.
- The use of various technological tools such as websites.

This project also involves the construction of several pedestrian paths & the redevelopment of disused railway lines for the purpose of enjoyment and enhancement of the cultural heritage.
It promotes the development of the territory & its uniform identity in order to recover a sense of belonging, providing a model for dealing with cultural heritage of such interest.

For more information on the PTCP and the analysis made please refer to Annex 1, PTCP summary where we study these point into further detail and expand on other information regarding studies and statistics found on the PTCP.

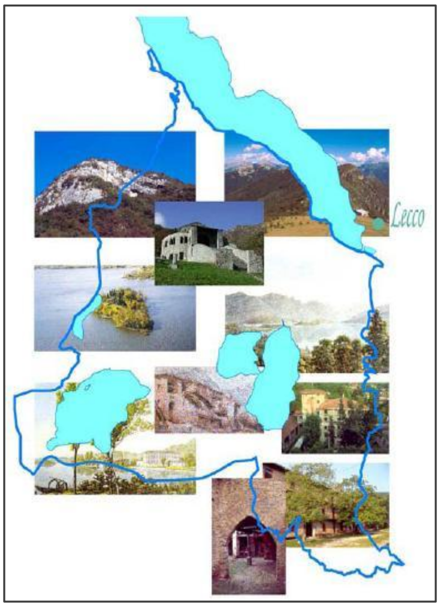


Illustration 8 Eco- museum path (extracted from (Quadro strattegico 2008)

3 INFORMATION ANALYSIS

The analysis of the urban context of the city of Calco was developed in this part of the thesis stands as the premise for the understanding of the focus that master plan should have. Through visits to the site and the connection of the different points of interest that we wanted to focus on gave us the tools for a better understanding of the problems of mobility and of use that were the main focus of the project initially.
Calco's growth over time and the overall physical expansion with respect to the neighbor towns resulted in the merger of the three towns as almost one. It is separated by big green protected areas and other natural elements but it has as a characteristic a very tangible proximity.

3.1. PREVIOUS STUDIES AND URBAN INTERVENTIONS

As part of the Analysis and recollection for the previous studies found for the commune and for the regional areas we focused also on the study of the Master plan for the Commune of Calco-Olgiate and Merate. From these we could subtract a series of studies related to the uses in the area of intervention such as Environmental and green areas, Historic centers and villas and historic parks, Residential, production, public interest and service settlements.
We also analyzed the importance of the street patterns, the landscape degradation and the relationship with the ecological corridors, bike paths and public transport schemes that are planned and also currently present in the area according to the PTCP.

3.1.1 Functional Use Analysis

For the consideration of the area in which we would start our urban analysis we decided to consider the whole span of area from the train station of Olgiate Molgora to the Adda Park.
This determined area allows us to understand the specific dimensions and urban spaces of the town and it allows us also to understand the relationship between the different uses that can be encountered in the city.

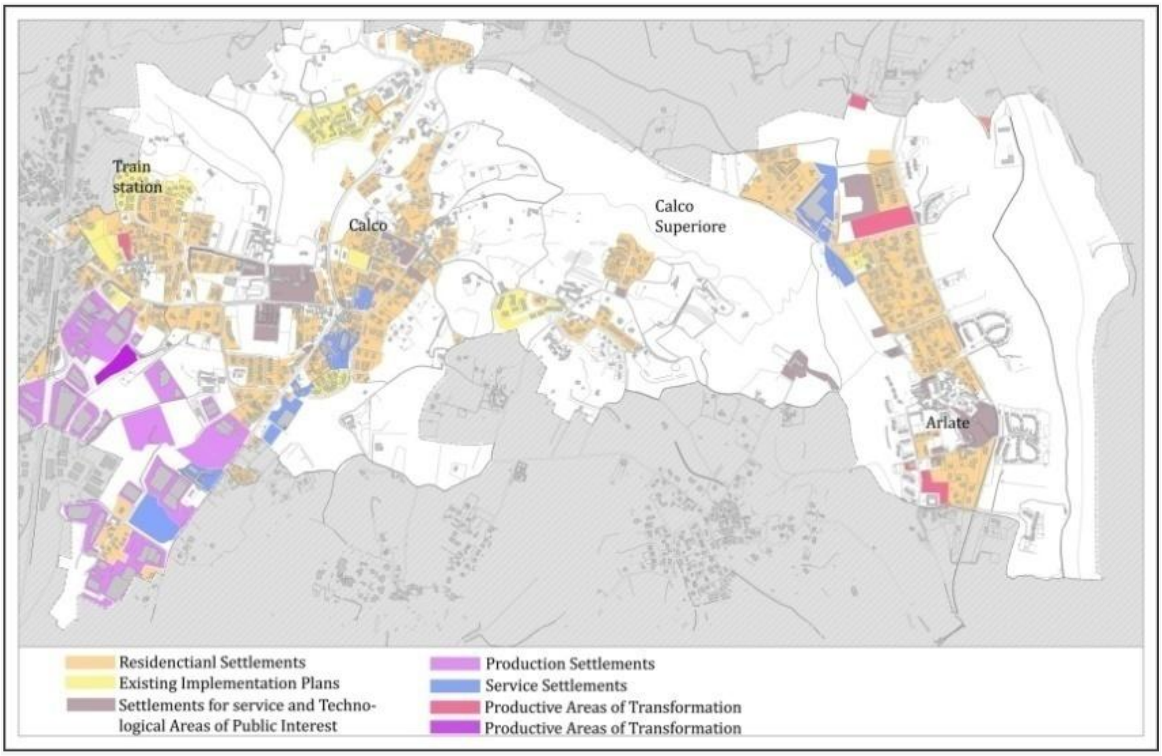


Illustration 9 Functional use analysis (extracted from master plan comune di calco)

As seen in illustration 4, the uses can be described as a mixture of residential, usually linked to the city centers and the main roads or connectivity nodes, Service settlements and production areas or small industries which are located mainly in the southern side specially linked to the statal Road Via Scagnello.

3.1.2 Street Patterns

Street pattern analysis in Calco resulted as a very important factor in the determination of the master plan. Mainly due to the fact the growth of the urban fabric and the relation of this to the Statal roads determine a lot of the qualities of the public space of Calco and its connectivity. The lack of public spaces and of sidewalks and other pedestrian friendly areas is evident by the configuration of the city with respect to the Statal roadsSS42.

Even the connectivity in the west-east direction is very limited and interrupted. The corridors and small pathways connecting east and west are all of no more than 5 km. This also affected by the fact that there is no determined street pattern and therefore it's commonly interrupted by natural elements or green protected areas.

In terms of connectivity and the resultant street patterns configuration and use it is very evident the influence that the statal road, and in general the connection with Milan and other parts of the region have in the urban configuration of Calco.

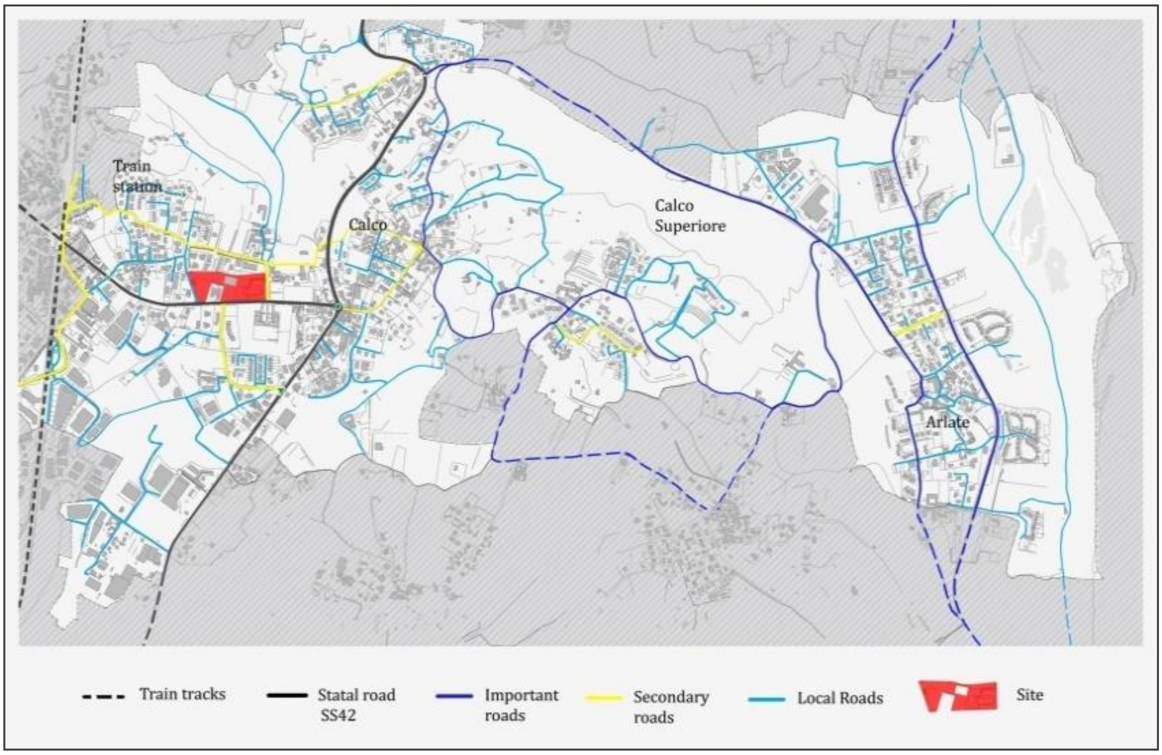


Illustration 10 street pattern analysis

3.1.3 Gateways And Thresholds

With the analysis for the gateways and thresholds of the city we encountered a good connectivity of the 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 the northern and southern parts of the region. However a good connection between east and west is lacking.

We identified as important gateways and thresholds of the area the train station. However this threshold is not used to its higher potential because of the poor street configuration towards the train station itself from the city.

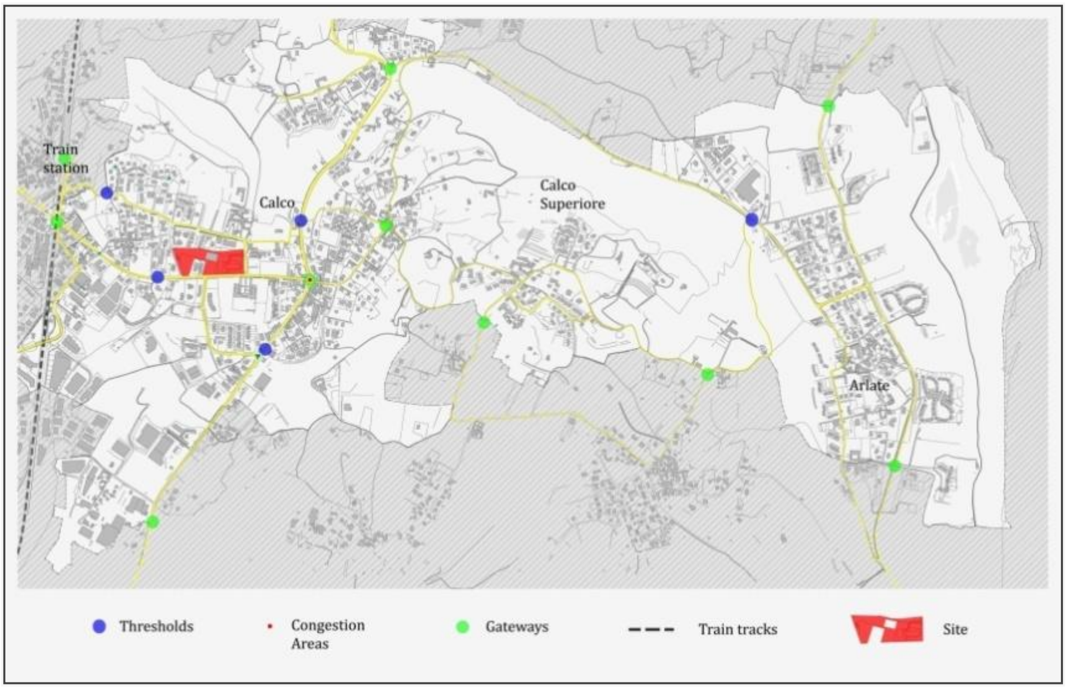


Illustration 11 gateways and thresholds analysis

3.1.4 Public Transport

The analysis of the public transport system is said to satisfy the demand specially the one focused to the transport of school kids. The train station of Olgiate is a very important asset for public transportation of the area, however the location of the train station itself and the accessibility form different parts of the zone by pedestrians or even by car is limited.

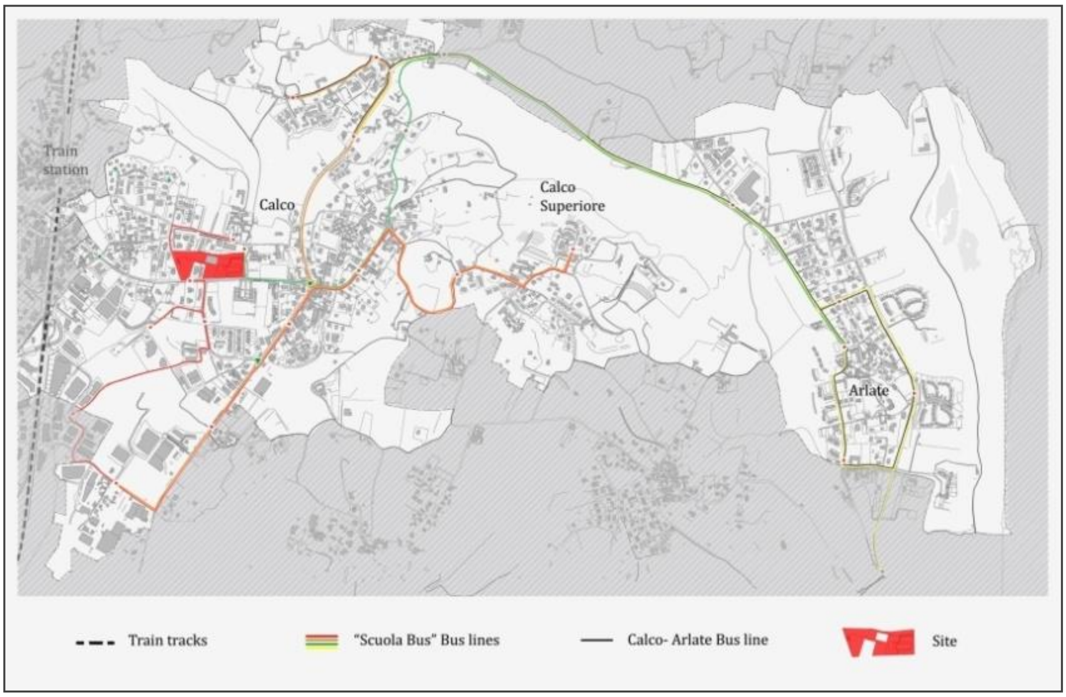


Illustration 12 public transport analysis

3.1.5 Solid And Voids

The commune of Calco is characterized by big open spaces that are protected by the local urban plans and are mainly constituted by protected green areas. There is a high dispersion of the urban settlements, which can be reflected in the low density and the high consume of territory. The new implementation regarding construction and land use given by the territorial land use plan for Calco are aimed towards the limitation of the urban expansion and the dispersion of the urban settlement.

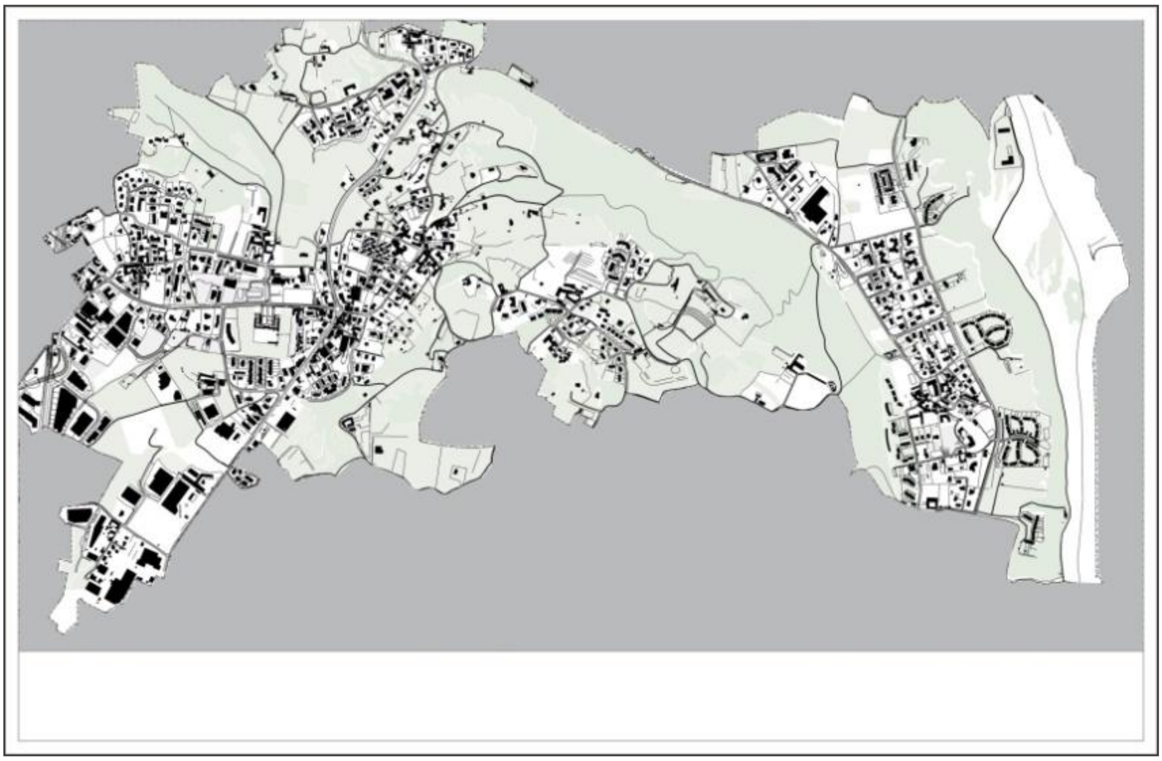


Illustration 13 solid and voids analysis

3.1.6 Historical Center

Calco has the presence of significant Historical centers and constructions within a close range of distance. These historical assets are again disconnected, lacking a public transportation method which doesn't allow them to explode the full historical and cultural potential.

In the PTCP it is stated that plans regarding the Valorization of touristic areas of natural landscape and cultural use are supported.

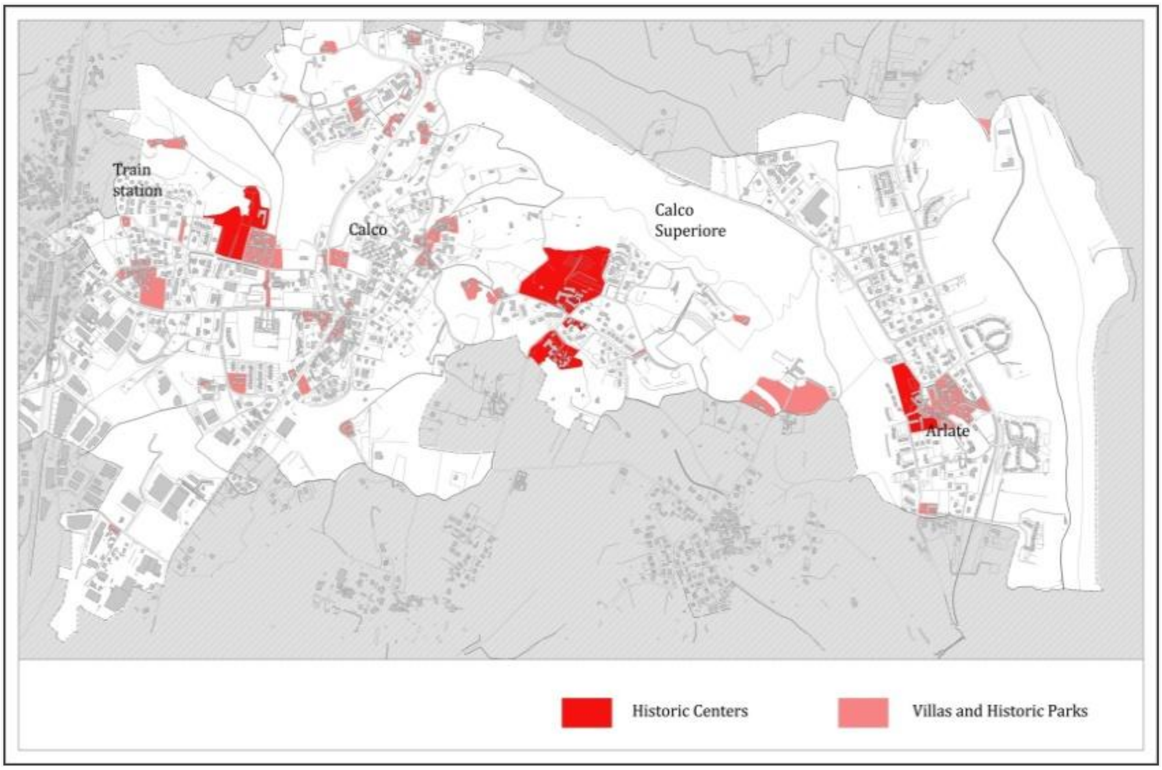


Illustration 14 historical centers (extracted from master plan comune di calco)

3.1.7 Green areas

The presence of many green protected areas is one of the main strongest characteristics of the area. Linked to this there is the proximity of the ecological networks proposed by the PTCP. Regarding the local Areas of Calco, the green areas are divided into different kinds of protected areas according to the local territorial plan and which range from Environmental protected areas, Forrest areas, gardens and orchards, and even agricultural areas.

These green areas are an important asset for the city, not only because of the quality of space that they give to the community but also due to the direct relation these have with other natural environment elements such as the Adda River.

During the Analysis of the green Areas we found a Disconnection between the different green Areas, similar to the one seen overall in the urban analysis. There is a lack of development of them towards new uses and the exploitation of its full potential. Also, the misuse of these open green areas leads to the creation of high levels of pollution inside of them and in their surroundings.

Considering all these factors and the importance of the green areas in the area, we took into consideration the policies of the PTCP that state that Ecological Network projects aiming at the functional connection of the most interesting natural areas of the region is under way. All This Considering those areas that are most affected by the urban development.

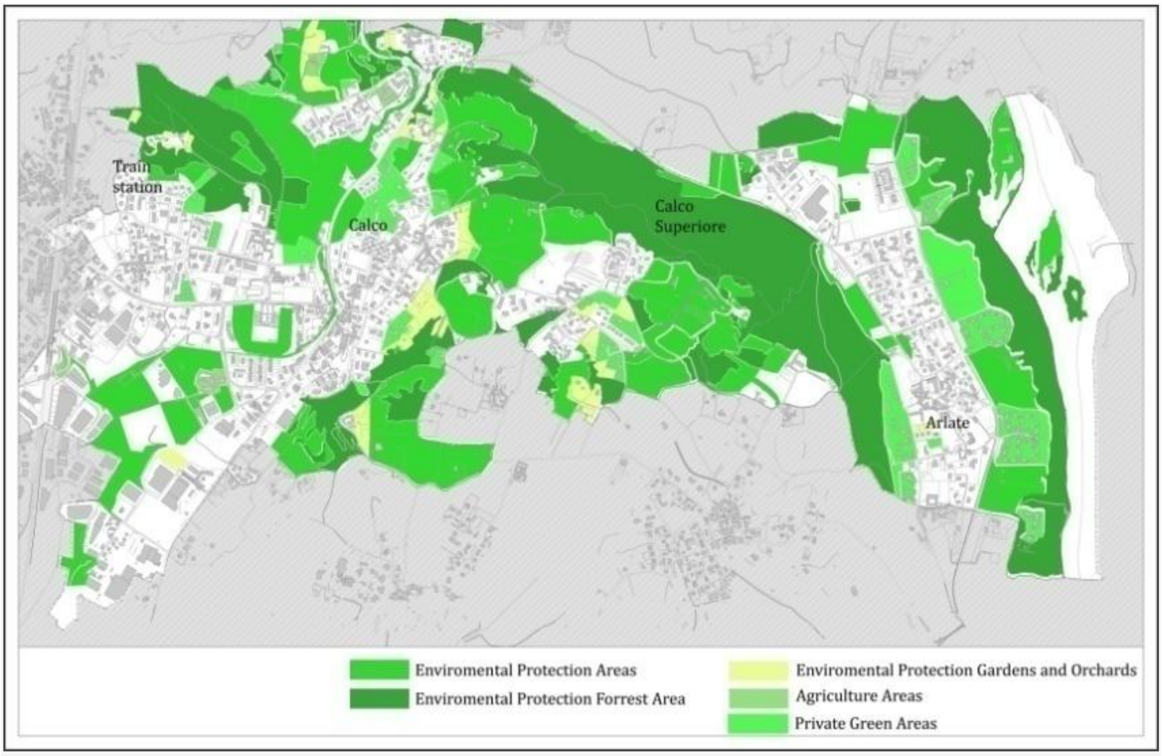


Illustration 15 Clasification of green areas (extracted from master plan comune di calco)

3.1.8 Scale comparison

To understand the scale we made a scale comparison study where we found out that the main city centers of the territory which we considered (Calco, Calco Superiore and Arlate) are spaced at a walking distance of maximum 0.7 kilometers. Also the proximity of the train station which is one of the most important thresholds with the Adda North Park was no longer than 4 kilometers. This means 1 hour walking or 20 minutes on bicycle more or less.

As a comparison scale we used the piazza Duomo to understand the distance referenced to a known distance. The result was that the total distance between the two points is more or less 7 times the length of Duomo in Milano.

Even though the distances between the different city centers and thresholds are a very considerably comfortable walking distance, the connection between them are not suited for the pedestrians and there is an overall lack of roadways in the east-west direction of the city.

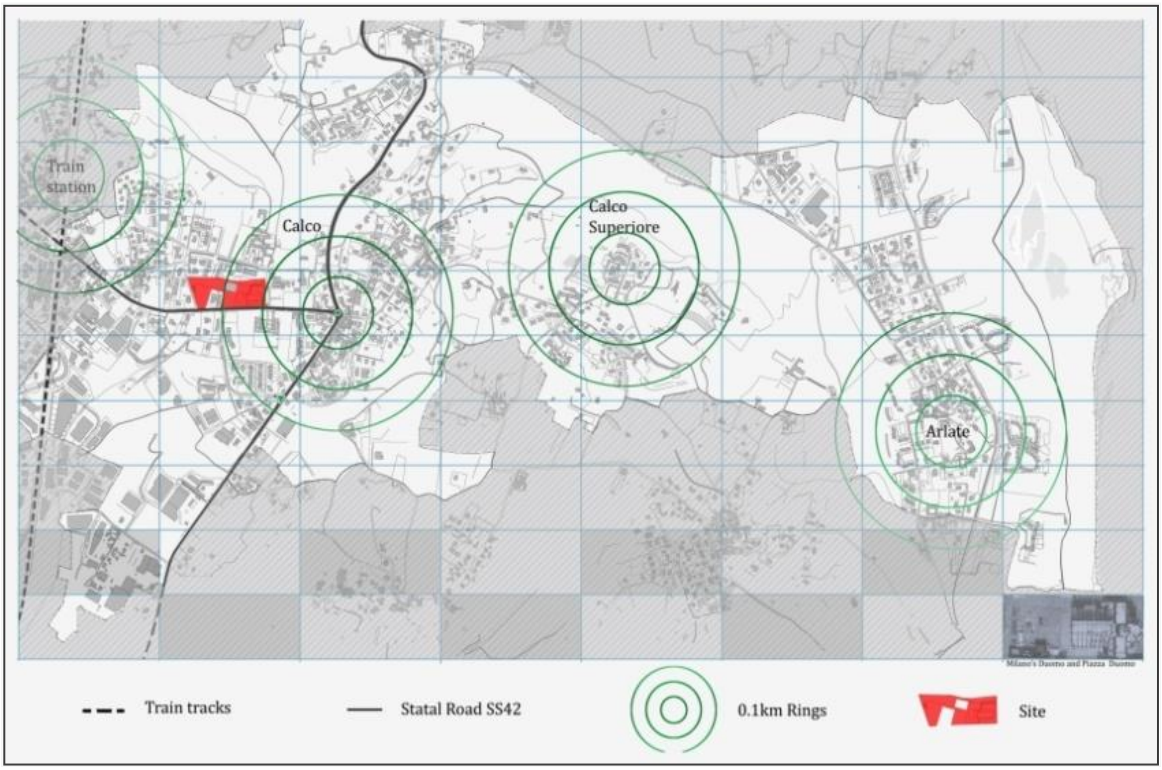
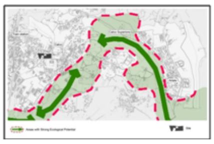
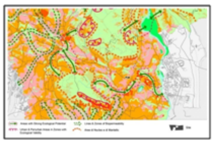
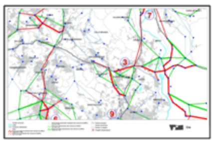
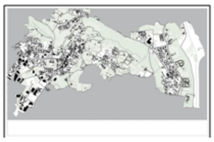
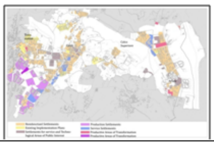
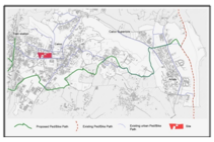
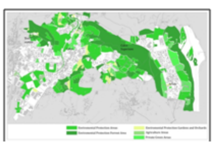


Illustration 16 scale comparison analysis

3.2. SWOT ANALYSIS:

Based on the basic analysis created from the study of the PTCP we created a Swot analysis matrix for each of the points analyzed.

STUDIES	STRENGHTS	WEAKNESSES	OPPORTUNITIES	THREATS
Landscape degradation 	• Presence of natural parks and the many different natural landscapes found in the area.	• Low preservation of landscape, and use of private patrimony.	• The PCTP proposes certain ways to compensate the environmental impact on landscape due to new infrastructure, and re-habilitation of the existing one.	• Reduction of biodiversity resulting in a loss of the variety of landscapes that constitutes the area.
Proposed Ecological Corridor 	• Great percentage of green protected areas in the zone, such as woods and the direct relation between these green areas and other natural presences such as the Adda River.	• Disconnection and fragmentation between the different areas and lack of development of them for new uses.	• Development of the plans of ecological corridors by the PTP at the Westside the Parco regionale MonteVecchia e della valle del curone, and on the Eastside the Parco regionale Adda Nord.	

Proposed Ecological Corridor large scale 	• Landscape variety in the province and the presence of landscape and environmental and natural elements.	• Disconnection and fragmentation between the different areas and lack of development of them for new uses.	• PCTP promotes the development of the ecological network thought out all the territory; safeguarding the continuity of the green disconnected by urban areas and infrastructure already built. • Integration of ecological and cultural offer through the Eco-museum project.	• Environmental crisis due to weak environmental sustainability policies.
Traffic volume and Mobility 	• Network available connects the city to the main cities of the province in corridors east to west Como-Bergamo) and north to south. (Lecco- Milan)	• Main mobility of the users is by car. • Main heavy traffic lines go inside the center and residential areas. • From the analysis of available data on the existing network in the Province of Lecco it can be deduced that the network of roads is not adequate for the complexity and intensity of reports generated by its residential and production structure.	• Policies set by PTCP in which the city centers and residential areas must be released from heavy traffic.	• Lecco's mobility infrastructure is continuously being related to the Milan urban area and gravitating into the orbit of the Milan subway system. As a result High traffic is induced in the corridor which goes through Calco.
Solids & Voids 	• Big open spaces to preserve.	• There is a high dispersion of the settlements. This is reflected in the low density and the high consume of territory.	• Limitation of the land use thanks to the implementation of the new territory land use plan for Calco.	
Historical centers 	• Presence of significant Historical centers and constructions in a close range of distance.	• Bad connection between them and the non-presence of good transport/public spaces between them to explode their touristic and cultural potential.	• PTCP states plans regarding the Valorization of touristic areas of natural, paesagistic and cultural use.	• Reduction of accessibility in the absence of rehabilitation of infrastructure projects.
Uses 	• Integration between residential and productive areas.	• Low quality of settlements and constructions.	• PTCP policies regarding productive settlements around train stations. Configuration of Calco agrees with this policy avoiding future re-settlements of productive areas.	
Public transport systems & mobility 	• Inter urban road transport system satisfies the demand of users, mainly scholars.	• Train system away from city center, parts of the Calco's territory (Calco superior, Arlate), and main park Adda. • Train system does not satisfy the actual demand. • Inter urban system only accessible to school's users. Lines Calco-Arlate only available on weekends. • Stops located in blind streets. • Corridors of Autobuses must go inside of private and blind roads.	• PTCP policies regarding enhancement of train stations and parking slots construction near to them. Intermodal change – Autobus or car to Train. • the public road traffic system must be facilitated • Provincial project of enhancement and increase of the capacity of the train system.	• There are not policies that facilitated the re-configuration of roadway public transport
Existing and proposed Pedestrian and bike paths 	• Plan connects the Main public transport system (train tracks) to the main touristic interest point of the zone (park of Adda)	• Existing pathways share the way with road traffic. • Poor development of bike roads which are not connected one to another.	• According to the policies on sustainable mobility given by the PTCP, the bike-pedestrian ways should be created in order to connect the main public interest places but also, residential and productive areas; it also should be used to develop the touristic and recreational activities by means of bike-roads and secondary pathways and roads.	• Existing proposal represents a Long pathway connecting the principal public and residential areas.
Green areas 	• Great percentage of green protected areas in the zone including the proximity of big ecological networks. • Presence of protected woods and the direct relation between these green areas and other natural presences such as the Adda River.	• Disconnection and fragmentation between the different areas and lack of development of them for new uses. • High Levels of Pollution of these alleged areas and their surroundings.	• Policies of the PTCP state that The Ecological network project aims at connecting (functionally) the most interesting natural areas through the upgrading of the environments affected by the urban development.	• Careless of landscape. • Reduction of biodiversity. • Further fragmentation of ecosystems due to new infrastructure. • Environmental crisis due to weak environmental sustainability policies.

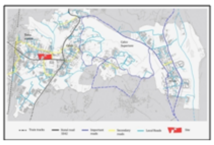
Street patterns 	• Corridors and small pathways connect the eastern and western parts of the city in a distance of no more than 5 km.	• High density of private roads inside the public road network. • Long local roads without intersections or exits to other roads. They only connect the city to specific private uses. • A not defined singular street pattern thought out the entire city, which difficulties the interconnectivity among the outer and the inner part of the city. • The current configuration of the Road system is greatly influenced by the proximity to Milan.	• PTCP states: To conserve the low-traffic roads which give access to environmental, paesagistic and touristic nodes, including also these paths in the conception of a wide circuit of bike-roads and pathways network for touristic and recreational use.	• Policies regarding changing in the configuration of road network avoided at the maximum in order to not get changes in the actual composition of the settlements and its organization.
Thresholds & Gateways 	• Access to the city can be done by means of train, car and Bus from northern, southern, eastern, and western gateways. This two last are not available for train system.	• The poor street configuration does not allow an easy access from the east to the western part of the city (From Calco superior and Calco, it is necessary either to go to southern cities or to go out of the territory in order to get to Arlate).		• There are no new accesses or infrastructure designated to this end in the proposed urban plan of the city.
Scale comparison 	• Main centers of the territory are spaced for a walking distance no more than 0.7 km. • Connection from main train system to the main touristic center (Park Adda) has a distance of no more than 4km. 1 hour by walking, 20 min by bicycle. It is equal to go 7 times through the Piazza of Duomo. (Milan)	• Main centers of the territory are spaced for a walking distance no more than 0.7 km but the connection between them cannot be guarantee in the special distance due to the lack of roadways connectivity in the corridor east-west of the city.		

Table 1 Urban SWOT analysis matrix

3.3. DEFINING THE AREA OF INTERVENTION

Considering as a starting point of the analysis of the urban intervention and after studying the potentials in terms of the region we made a series of visits to confront the information analyzed prior. The conclusions which helped us focus our area of intervention were basically those which we considered the lacking elements in site in terms of urban development. We found a lack of a correct use of the public space, as well as a lack of connectivity and discontinuity of the urban fabric between the three cities. Also, the presence of high speed roads passing through the city center was a big part of the definition of the level of intervention for our urban scheme.

Bearing in mind the historical value assets found in the area, and certain politics such as the PTCP Ecological path and the presence of the Adda Park as well as the existence of a great amount of natural protected green and agricultural areas in the zone we decided the intervention would be focused to the creation of a linear connection between the train station and the Adda Park, taking into account constrains such as the lack of space for new constructions or expansion of the public space and the presence of all these protected areas in which the construction is limited.

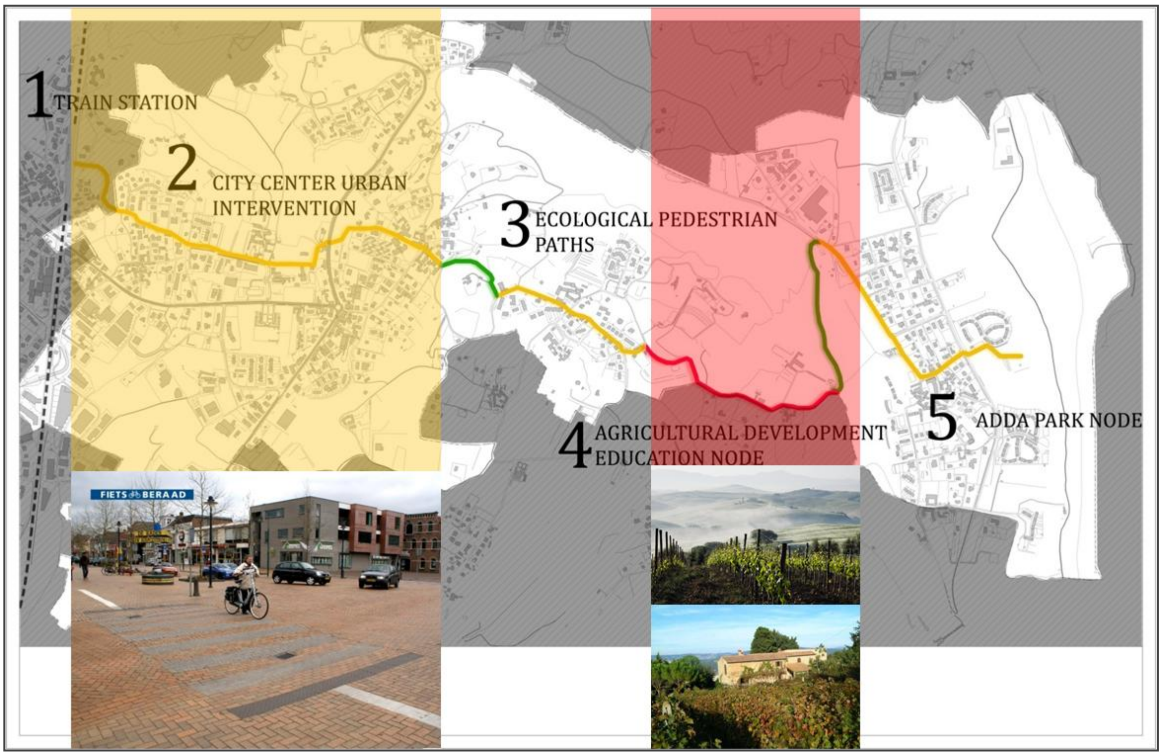


Illustration 17 Area of intervention

4 THEORETICAL FRAMEWORK

4.1 THE EVOLUTION OF PLACE… "CALCO… AN EVOLVING CITY"

The evolution of place is an interactive story; it's a mixture of many dimensions and is not to be confused to be a linear process.

> *"Time, of course, creates new and old approaches to the look and feel of habitation, workplace, and the transportation routes between. The elements of water and land interface and interact, sometimes together, with the built environment. Climate drives seasons and forms of building, access and the manipulation of light. And cultural approaches to ownership and stewardship modify these responses to climate, and create alternative forms of building on the ground"*[13]

The past century could be characterized by a series of rapid social, technical and economical changes and the development of globalized networks of communication and exchange. In many ways the rise and transformation of these networks have positively affected economic growth and social development. Unfortunately many negative aspects of modern days' organization of society can also be ascribed to these same processes, with environmental deterioration and loss of local identity and culture as some of the most prominent consequences (Held & McGrew, 2007). [14]

The key to evolution of place and sustainability is the context, and adaptation to a multi-environmental sense of place, associated imagery and sensation is an essential element of building design, urban development and innovation going forward; creating beautiful buildings that are able to work for the environment, or crafting appropriate enabling regulations, should also be considered as part of a broader, holistic effort.

This concept of movement of the future of the city of Calco was initiated by its municipality. Their intention was to change the current urban and building paradigm from its existing unhealthy "quoting their words" state to a sustainable one. Their concept was to evolve Calco into being a sustainable city, and at the same time, not jeopardizing its current cultural and natural – preserves and forests – states. Their dream was that this movement would induce positive emotions and dreams of the inhabitants of the city.

In order to describe the evolution of place, we pose a series of questions in an attempt to understanding and outlining the broad lines of this phenomenon.

[13] LENON, Chuck. URBAN DESIGN. (Available online). http://www.myurbanist.com ***/archives/3764***. 2011
[14] Held, D., McGrew, A., Globalization/Anti-Globalization:Beyond the Great Divide. Polity, Cambridge. 2007

Illustration 18 Seattle and sill wan panoramic view

What forces shape the look and feel of place?

Above, the context of a water-oriented urban skyline in modern America (Seattle) in comparison with today’s view of biblical legend, adjacent to the “Valley of Death” (Silwan, East Jerusalem). Interesting to be noted here is the severe contrast created by available building space, history and the local ecology of water.

Illustration 19 Masdar and Venezuela panoramic view

How to accommodate population density?

Could it be through the advantages of a planned city as in Masdar in Abu Dhabi, or through the improvised Barrios of Caracas, Venezuela?

Illustration 20 Universal studios, Tampa and Port Townsend, Washington panoramic view

What are the bases of cultural inspiration and sense of place?

Is it a false town (Universal Studios), or a real one (Port Townsend, Washington), this question highlights the importance of culture in working with the surrounding context.

Illustration 21 Universal studios, Tampa and Port Townsend, Washington panoramic view

What is the contrasting look and feel of public street space based on cultural expression, local economies and changing transportation modes? As shown, we can see vitality amid economic duress in the Middle East, and economic challenges of removal of parking and loading for bike lanes in the new, multi-modal America.

Illustration 22 Mexico city, Venezuela leisure/fight

How do people choose to "occupy" their familiar public spaces?
Leisure or fighting for a better life? In these two photos, two young people enjoy public space in a plaza in Mexico, in contrast to a group of Venezuelan students, who, in political protest, spell with their bodies the word "freedom" in the midst of a major thoroughfare.

Illustration 23 Interfaces

What additional interfaces exist between commercial settings and public spaces around the world?

In these pictures, we can distinguish the role of music and dining from the backdrop of a grand, public square, and an eatery amid public street-side darkness.


Illustration 24 Spaces in between

How is space between new and old buildings used in different places?
In the left image, we see access to a rear residence in a cultural context, compared with two modern towers flanking an older building which has fallen into non-use, as shown in the right image.


Illustration 25 Water bodies representation

In different contexts, how can bodies of water be used in urban areas?

Here, American recreation contrasts with gondolas, now also arguably recreation in today's Venice.

Illustration 26 Water bodies representation

What is the relationship between natural resources and urban settlement at the shoreline?
In one example, water, hills and towns blend together in form and function in Northern Italy and the Cyclades Islands of Greece. In the case of calco, the question could be more specified to focus on the relation between the natural preserves, the Adda Nord park, and the proposed intervention.

The aim of the previous questions is to clarify the need to access multidimensional memories of place to honor positive evolution in the design of new and redeveloped urban spaces more than emphasizing the history of place. Therefore, while every culture may provide different, contextual approaches, collectively these approaches should attempt a common goal: *human life in a better urban landscape.* All elements are required to be considered: the sense of place, climate, sound, population density, geographic orientation and, of course, neighbor buildings.

The higher goal of this research is to envision the recreation of the setting of the city of Calco in the Urban and Architectural scales while attempting to consider most of all of the previously mentioned elements hoping to reach a new and sustainably positive direction.

4.2 SUSTAINABILITY IN THE URBAN CONTEXT

Sustainability is a complex concept, interpreted and used differently and perhaps sometimes all too freely by different individuals. Many have expressed views on sustainable development; however, it is hardly available to find a ready for use set of guidelines for sustainable spatial planning and urban design. Also, attempting to develop this is far beyond the scope and scale of this thesis. It can be stated though, that sustainable planning in some manner tries to find a balance between social, economical and environmental issues.

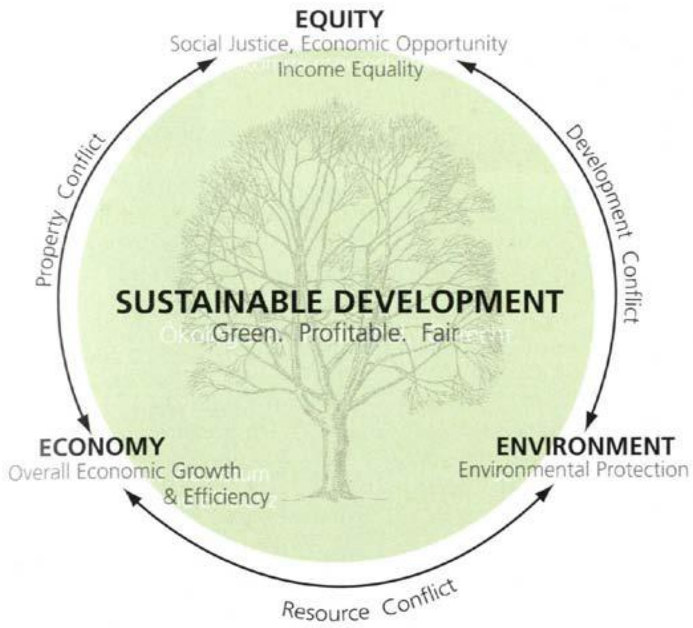


Illustration 27 sustainable development scheme (Campbell, 1996; Vallance et al., 2006).

In Calco, considering the limit on new constructions, and the desire of the municipality to preserve the density of the existing fabric, it is clear that when urban design aims to be sustainable, transformation of the existing urban areas is at the heart of the urban assignment of the 21st century.

4.2.1 Researchers' Perspective On Sustainability In The Context Of Existing Urban Areas

From the point of view of the researchers; Urban and Architectural design are tools for shaping –or reshaping- the built environment from an Environmental, Social and Economic perspective as shown in the following illustration. The aim of the thesis is to focus on the impact of the first two terms.

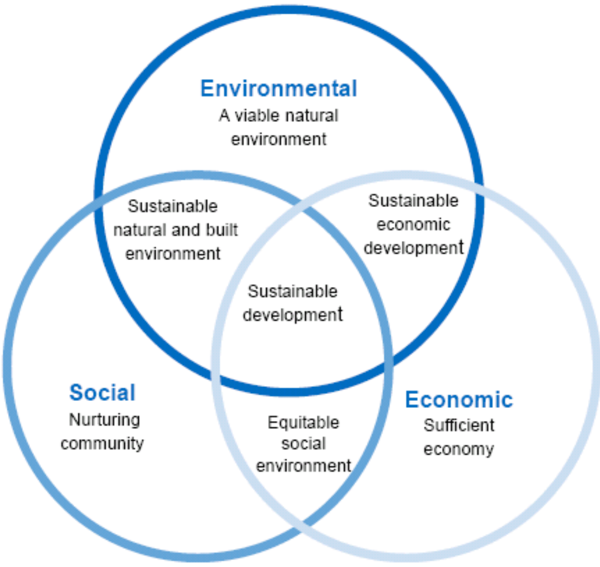


Illustration 28 Social, Economical and environmental transformation [15]

Sustainable transformation of the city can be is aimed to ensure the quality of life for both current and future generations.

Environmentally, this means that pollution and exhaustion of natural resources ought to be prevented. The environment influences the perception of individuals and creates or inhibits possibilities for different types of activities. In the same manner, it strongly affects the quality of life of the users of the different spaces. Aspects of ecology and biodiversity could also be related to technical environmental sustainability, since it could be interpreted as a natural resource.
Socially, this means that people should be given a chance to live and develop in a stimulating and safe environment.

Apart from user-oriented green structures and visually attractive species, it is more difficult to relate this to the communal interest of maintaining quality of life for people. In that respect it is probably not the most central sustainability aspect when dealing with transformation of existing cities and neighborhoods, but it does make sense to try and look for potential improvements in relation to other interventions. For example applying green roofs, environmental (air quality, water management), social (aesthetically pleasing, outdoor space) and ecological (plants, insects) improvements can be made.

Mainly, three aspects should be considered at all times when proposing spatial interventions… Time, Place and Scale…

[15] CIARAQUIN, J. Sustainability metrics. http://ciaraquinn.wordpress.com/2011/04 /12/week-10-sustainability-metrics/). 2011

- Time:

As far as time is concerned, this means that both short and long term usage and behavior should always be taken into account. Something which is considered as a sustainable solution today might not be sustainable for users in the future. Designing truly sustainable means that, a level of flexibility in planning must be put in, to provide for future developments and unforeseen outcomes.

- Place:

Urban sustainable design is strongly related to the place for three important reasons.
1) Factors in this context such as climate, landscape, infrastructure, also social networks and political decisions leads to the conclusion that, something that is sustainable for one locality might not be so for another.
2) Understanding the level of importance of different sustainability aspects in relation to one another.
3) *A local approach can provide many leads for a sustainable design*, by working from an analysis of locally available resources and qualities, better design solutions can be found.

- Scale:

Meaning that, time and energy have to be invested in determining the right level of scale for a certain intervention. Such an intervention in a city like Calco would be far different than another in Milan.

In many contexts, what sustainability and the environmental issues deal with can be controversial. According to Forrester (1999), these kinds of disputes can be characterized by a multitude of organized parties and issues, while rules and regulations offer little guidance to solve this. Top-down approaches can technically improve sustainability, but seem insufficient in dealing with disputes with those who believe that not enough is done ('the environmentalists') and those who feel that they are economically hindered by rules and regulations in this field (e.g. real estate developers). Mediation could provide a better framework in dealing with these kinds of problems.

Throughout this process, the mediator has a role in focusing attention on issues and substance and in this way enables a creative approach to solving the problem. Creating understanding for other viewpoints, an important part of collaborative planning, seems crucial in tackling sustainability issues.

4.2.2 Literature And Users' Level Perspective

From the literature studies concerning the city of Calco and the area of San Vigilio, through interviews and observations, as well as the guidelines induced from the PTCP, it became clear that many different paths could be taken towards putting sustainability theory into the urban practice of the city.

Both the living environment and the current users' perspectives are strong factors to be considered for sustainability.
Useful concepts to translate this idea into spatial interventions are *Social Sustainability* and C*onviviality of public spaces*.

Social sustainability is described by Goodland (2002) [16] as maintaining social capital, with social capital being described as investments and services that create the basic framework for society. It is an important facilitator for cooperation and trust.
Conviviality, on the other hand, is a subjective feeling, underpinned by, but not to be confused with, the actual physical state of a place. It can be described as the appreciation of the living environment by residents, a term which has become somewhat politicized in recent years.

The relationship between these two concepts has been described by many. Where they have noted that public spaces are important for health, wellbeing, learning, conflict resolution, tolerance and solidarity, to mention but a few benefits:

- **Health & Wellbeing:** Urban public spaces offer obvious health benefits insofar as city residents and workers can get fresh air and exercise in them. This requirement is for healthy spaces accessible to urban residents and workers is becoming critical in the light of increasing levels of heart disease and obesity, resulting from more sedentary lifestyles (National Heart Forum et al 2007, Ward Thompson and Travlou 2007). There is also a suggestion that they can promote mental health and wellbeing too (Guite et al 2006, Greenspace Sctoland 2004). Possibly as a result of our revolutionary heritage, humans seem to need both social contact with others and some access to greenery in order to maintain psychological balance (Wilson 1984, Kellert and Wilson 1993), both being provided by good public spaces.
- **Learning:** public spaces offer considerable social learning opportunities. Because by definition they are universally accessible, they offer one of the few opportunities for people to directly encounter other people with different norms, behaviors and cultures. In the more formal sense of 'learning', public spaces are often used as arenas for education (field visits) and research (the ubiquitous interviewer with a clipboard, found in so many urban spaces).
- **Conflict resolution, tolerance and solidarity:** Tolerance comes from close encounters with other citizens, rather than stereotyping them from monoculture enclaves. Public spaces also offer opportunities to build up a sense of solidarity with fellow citizens, both through ad-hoc encounters and through organized events such as festivals and demonstrations.

[16] Goodland, R., Sustainability: Human, Social, Economic and Environmental. [online] World Bank. Available at: http://www.wiley.co.uk/egec/pdf /GA811-W.PDF. 2002

- **Economic benefits:** Convivial spaces can generate financial benefits, both directly by making the towns where they are located more popular visitor attractions.
- **Urban security:** Well-used convivial places are the alternative to downtown areas abandoned to criminals and the socially rejected. This is based on the theories of having 'eyes on the streets', first espoused by Jane Jacobs (1961) and the presence of 'capable guardians' (Felson and Clarke 1998), i.e. crimes are less likely to occur if potential offenders are aware that there are law-abiding citizens in the area who could witness, report or intervene.
- **Democracy:** in democratic societies, public spaces are the gathering places where the citizenry can express their solidarity and also dissent.
- **History, politics and the law:** Since the ancient Greek agora, open public spaces have been at the heart of civilized urban life. Indeed, the quality and extent of urban spaces could be used as litmus test for the state of various societies 'public health' (think of the great parks of London in the 18th century and the reclaiming of Copenhagen's streets for pedestrians in the 20th century).

In summary, urban public spaces have huge social, political and economic value, the big ones, and small. The extent to which any town contains suitably convivial spaces is a reflection on how civilized it is.[17]

4.2.3 The Psychology of Public Space

The specific social science which studies the interaction between individuals and the environment is that of *environmental psychology.* The environment in that the field of study consists both of a social and a physical dimension. Research in the field of environmental psychology confirms that:

- There are strong links between the environment and behavior.
- It is difficult to establish the exact relation.

In terms of designing good public spaces, it helps to understand how people are likely to respond and relate to the space available and how they make space work for them. Some of this will relate to some basic human behavioral characteristics such as territoriality, interpersonal distance, distribution and the need for different types of observation and communication (Canter 1974). Other responses are to do with such psychological effects as interpretation, coherence, legibility, sense of safety, intrigue and curiosity. Here we highlight the ones most related to the proposal. [18]

- TERRITORIALITY:

[17] SHAFTOE, Henry. Convivial urban spaces: creating effective public. 2008 p .34
[18] Ibid. Convivial urban spaces: creating effective public. 2008 p .52

One of the most fundamental human traits (presumably from our tribal hunter-gatherer origins) is the need to mark and claim territory. This is potentially problematic in public open space, because in theory, it belongs to everyone and no one.

- INTERPERSONAL DISTANCE:

It's linked to territoriality, and it's the need to keep appropriate distance or proximity according to relationship.
As the space becomes more congested, people have to accommodate themselves gradually more closely to each other, but always according to some unwritten law about 'reasonable distance'.

- DISTRIBUTION:

There are certain preferred locations where people tend to cluster and others that people try to avoid. Generally, locations where one can observe others without being exposed from all sides oneself are preferred. This may explain the enduring attraction of ledges (where one's back is protected by the wall behind) and the avoidance or backless benches in the center of public spaces.

- THE NEED FOR DIFFERENT TYPES OF OBSERVATION AND COMMUNICATION:
- INTERPRETATION, LEGIBILITY AND COHERENCE:
- SENSE OF SAFETY:
- INTRIGUE AND CURIOSITY:

This is also an important factor in good park design – there is nothing more boring than a park or green space where you can immediately see everything that is there.

4.3 SUSTAINABILITY IN CALCO

4.3.1 Social Sustainability

As discussed previously, a sustainably convivial environment must meet standards for safety, health, interaction with the natural environment, control and the possibilities for finding or avoiding social interaction. Translating these concepts to the context of Calco, all of them could be considered relevant. However, from a current-user perspective there is one aspect that appears to be the most important:

Social interaction, as mentioned earlier in this chapter, there is a gap between underlying ideas and principles concerning diverse and social living environments and the physical translation of these ideas. This will be elaborated on in the next section.

4.3.2 The Concept Of A Social Interaction

As a general principle, the environment can be seen as a setting which either inhibits or provides affordances for different types of behavior, including social interaction[19].

> *"….social interactions are 'the acts, actions, or practices of two or more people mutually oriented towards each other, that is, any behavior that tries to affect or take into account each other's subjective experiences or intentions'. In his view this means that the different parties involved must also be aware of one another, but not necessarily in a physical sense. This means that friends writing an email to one another are also interacting socially. In the context of a neighborhood such a concept could be considered too broad…..".* [20]

Considering the analysis of Calco and San Vigilio, there are three relevant focus points as far as social interaction is concerned. These are:

- The improvement of possibilities to meet in public space;
- The improvement of possibilities to meet in public places such as cafes and restaurants;
- The improvements of the connections network between these spaces.

Simply put, an increase of liveliness and conviviality of a neighborhood improves the possibilities for social interaction, a self-reinforcing process.

4.4 CONVIVIAL PUBLIC SPACES IN CALCO

Designing successful convivial spaces reflects directly on the quality level of Calco city's social interaction, thus enhancing the quality of its spaces and the quality of life. As mentioned earlier, conviviality is a subjective feeling, underpinned by the actual physical state of a place. Ultimately, public spaces are about people. Without public spaces functioning as expected, the idea of social interaction will thus be annulled, breaking down with it the whole concept of sustainability in the designed area.
This sector discusses the concept of convivial public spaces as a linking part between the concept of sustainability in the urban design and public spaces; and the different levels of interventions proposed as a solution to the existing issues in the city of Calco and the area of San Vigilio.

[19] BELL, P.A., Green, T.C., Fisher, J.D. & Baum, A.. Environmental psychology. Mahway: Erlbaum, 2001. P132
[20] BRUI, Anne. Future proofing late postwar Neighbothoods: Urban patterns for a socially sustainable Zevenkamp. p .84

4.4.1 The Concept of Convivial Public Spaces

"Such places should consist of a rich, vibrant, mixed-use environment that does not die at night or at weekends and is visually stimulating and attractive to residents & visitors alike" Francis Tibbalds (1992). [21]

In order to give a more specific definition to conviviality of public spaces, we pose some questions which might clarify the meaning:

- Is the place enjoyable?
- Is it safe?
- Human in scale?
- With various uses?
- Is it environmentally friendly?
- Sunlit?
- Wind & pollution free?
- Is it memorable & identifiable?
- Distinctive?
- Is it appropriate?
- Does it relate to the context?
- Is access free available?
-

Christopher Alexander (The Timeless Way of Building [1979], A Pattern Language [1977]) suggests that we are better off 'growing' good places and spaces, rather than trying to build them from a blueprint. "I think", he follows "we have a lot to learn about how plants and natural environments grow, evolve and adapt to local circumstances and then to mirror this in the development of the built environment."

4.4.2 A Public Space for Calco

From the previous chapters, the decision from the Municipality of Calco to create a new social condenser which works as the city's main gathering area has proven to be very vital for the sustainability of the city; throughout the studies and analysis made by the researchers, as well as the guidelines and recommendations issued by the PTCP, all leads to the conclusion of the crucial need of Calco for having such a vital space.

4.4.2.1 Children and public spaces:

Healthy outdoor play has been weakened in many areas by adult preoccupations with health and safety, potential litigation, stranger danger, poor maintenance, economies in public services and even aesthetics. Despite various media-fuelled panics, children are in no more danger in public spaces than 30 years ago (Goodchild and Owen 2007). In fact, some commentators have noted, as mollycoddling parents keep their kids indoors and local

[21] SHAFTOE, Henry. Convivial urban spaces: creating effective public. 2008 p .43

authorities remove any trace of adventurous opportunities from the public realm, children are more likely to die of boredom than from any outdoor public danger.

A new approach in various parts of Europe is resulting in more vibrant play provision for children. Three features of this different approach are *integration into the townscape, mixed use and loose materials.*

4.4.2.2 Integration into the Townscape:

Children and their accompanying parents prefer short journeys to play areas and therefore it is likely that spaces will be better used if they are part of the neighborhood. This can also create livelier places for all.

4.4.2.3 Mixed use:

This feature highlights the value of having facilities for adults as well as children.

4.4.2.4 Loose Materials:

Children are more inclined to play with natural elements, such as water, sand and wood. This seems to allow them to be much more creative, which, after all, should be a valuable outcome of play.

In Germany (most notably in Freiburg and Berlin) play-space providers have wholeheartedly embraced this looser, more naturalistic approach, with the resulting playgrounds looking very different from the shiny metal and rubber-matted surfaces that characterize many British playgrounds.

Unpredictable Use: it has been noted by some play experts that children will often get the most out of play facilities when they use what is there in ways other than intended. This should be encouraged, or at least be allowed for, as it can lead to more creativity.

4.4.2.5 Young people and public spaces:

Young people and particularly adolescents are at a very vulnerable and influential development stage in their lives. What happens to them during these transitional years will influence their long-term physical and mental health. Repressing their natural inclinations to get out of their homes and learn to playfully socialize risks displacing their energies into the very things that concerned parents are trying to avoid, such as drug misuse, self-harm and delinquency.

The phenomenon of young people socializing in groups away from immediate adult supervision is an important developmental stage – moving from the family nest to independent adulthood (Waiton 2001).[22]

[22] SHAFTOE, Henry. Convivial urban spaces: creating effective public. 2008 p .104

We should be enabling this healthy socialization process by ensuring that there are places and spaces where youngsters can gather and ‘hang out’, and young people don’t want to be shunted into the margins of neighborhoods – they usually and rightly demand equal access to the prime sites such as town centers, parks, high streets and malls.

Some imaginative solutions to the need for young people to gather and ‘hang out’ include:

4.4.2.6 Youth shelters and sport systems:

Such as good quality structures where young people can gather without supervision and without causing annoyance to adult residents. Some shelters have been designed and even built by the target group of young people themselves. If young people have been involved in this or in other ways, they are more likely to safeguard their investment.

The location of such shelters is critical, they should be not so close to homes that adults become irritated, but not so isolated that young people are vulnerable to uncontrolled victimization. It is also important that they are regularly maintained; as if successful they are likely to experience a lot of wear and tear.

4.4.2.7 Adventure Playgrounds:

These rough, tough and tumble locations have mostly been emasculated by health and safety worries, with the result that many young people have fewer opportunities to experiment and take risks under benign adult supervision. Enterprising as they are, some young people have discovered that the entire urban realm is a potential adventure playground and, from its start in France, the *Parcours* or ‘free-running’ movement has burgeoned in many cities. This involves the use of walls and other built features as daring structures to jump over, between or from – a beautiful example of subverting the original intentions of the built environment to create a healthy (if dangerous and potentially illegal) activity.

4.4.2.8 Skateboarding, Stunt Bike and Rollerblading spaces:

Such places work best when young people have been involved in their design and location. An inspiring example can be found in central Brussels, where a site over the main railway line that cuts through the centre has been made into an urban space for all, with a built-in skateboarding to the specification of a group of local skaters. The space works as an attraction for young and old alike. [23]

In summary:

[23] SHAFTOE, Henry. Convivial urban spaces: creating effective public. 2008 p .34

- We need to 'design in' the facilities and locations where children and young people can meet, play and socialize in reasonable safety, without totally removing the excitement and 'buzz' that they need. On the other hand, we must minimize the danger and victimization that young people all too often experience in public spaces (Percy-Smith and Matthews 2001).[24]
- The Process of involvement is as important as the physical outcome. For example, involving young people in the choice and construction of the shelters increases the sense of belonging and responsibility towards these places.
- Young people are likely to want both structured and unstructured facilities and activities. Different groups and individuals will want different things. One size doesn't fit all (White 1998).[25]
- Teenagers don't want to be completely isolated from the general public.
- Young people probably feel safer in areas that are also accessible to adults, such as town squares, public car parks, footpaths and parks.

4.5 CONCLUSION

This chapter sets out in giving some general insight in the concept of sustainability in the context of urban design and the design of public spaces. As well as an overview of the framework as it was developed to approach sustainability in urban design in general, and Calco and the Area of San Vigilio specifically. These findings are followed by an analysis of the proposed intervention respecting the norms and ethics of the main concepts of evolution of place and sustainability.

[24] Ibid,. Convivial urban spaces: creating effective public. 2008 p .49
[25] Ibid,. Convivial urban spaces: creating effective public. 2008 p .109

5 INTERVENTION…

A bridge between theory and practice

5.1 INTRODUCTION

There are various aspects of the design and management of public spaces that affect how successful or problematic they may be.
A number of people have attempted to establish a set of ‘principles’ to inform the design and production of successful urban spaces. Francis Tibbalds (1989 p467), for example, suggested the following ‘Ten Commandments’ of urban design, most of which are directly applicable on public spaces:

1- Thou shalt consider places before buildings
2- Thou shalt have the humility to learn from the past and respect the context of buildings and sites
3- Thou shalt encourage the missing of uses in towns and cities
4- Thou shalt design on a human scale
5- Thou shalt encourage the freedom to walk about
6- Thou shalt cater for all sections of the community and consult with them
7- Thou shalt build legible environments
8- Thou shalt build to last and adapt
9- Thou shalt avoid change on too great a scale at any one time
10- Thou shalt, with all the means available, promote intricacy, joy and visual delight in the built environment. [26]

In this chapter, a number of intervention patterns in the urban scale have will be shown as an intermediate level between the theoretical approach and the practical proposal. The patterns will be sub-divided into two main scales:

1- The city scale:
2- The Intervention zone scale:
3-

Before starting with these patterns, we highlighted the bullet points in which our proposal revolves around:

5.1.1 Mixed Use And New Types Of Urbanism

The fundamental idea of the approach to mix uses together is to create more integrated neighborhoods which are more sustainable and capable of building ‘social capital’, as people are more likely to know each other and interact. Public spaces are a core part of this urbanism approach.

5.1.2 Legibility

A term originally coined, for urban design purposes, by Kevin Lynch (1960) [27]. He defines it as ‘the ease with which parts can be recognized and can be organized into a coherent pattern’. So, in terms of public spaces, it means:

[26] SHAFTOE, Henry. Convivial urban spaces: creating effective public. 2008 p .34

1) Knowing where you are,
2) Knowing how to get to where you want to be, and
3) Feeling that the space has visual coherence. Yet, as a result of accretions of street furniture and signs, many of our public spaces are incoherent and confusing.

5.1.3 Firmness or looseness?

The very thing that the evolution of convivial spaces requires is the allowance of much flexibility. Not doing so, would result in ending up with rigid designs that cannot easily be changed, once it is found they are not well adjusted for optimum use.
There are some objective underpinnings that can inform good design and management, based on the nature of human behavior and preference, many of which have been clarified with the help of environmental psychology.

5.1.4 **Aesthetics –** Sensing the Character of an Area

- The visual impression of place is likely to be the most powerful sensory experience for people with good sight.
- The feeling of warmth and coolness.
- Variations in shelter and shade can affect wind chill and the degree to which the warmth of the sun can penetrate.
- Finally, urban spaces can have some noticeable textural qualities, both in terms of the different types of surfacing underfoot and the qualities of built features and foliage, which, even if not actually touched, can be experienced.

If our understanding is limited to a visual understanding, we only concentrate on shapes. If, however, we go beyond appearances, we start a spatial understanding, a three dimensional experience. We can enter this space, rather than just see it. The same applies to the design of spaces. We do not create mere appearances but spaces that we can use for different purposes. (Madanipour 1996) [28]

Movement:
We generally experience the environment as we move between places. In relation to non-visual aesthetic experience, this will include the feeling of surfaces underfoot, the air or wind against our skin, and the effort of passing through a space, particularly if this entails climbing or descending.
We should optimize surface treatments, microclimates and gradients to provide the best sensory experiences.
The type of thoughtfully constructed floor-scape can also be a work of art that increases the pedestrian's enjoyment and awareness of the experience of

[27] SHAFTOE, Henry Who refers to Lyuch 1960. Convivial urban spaces: creating effective public. 2008 p .34
[28] Ibid, Who refers to Madanimpur 1996. Convivial urban spaces: creating effective public. 2008 p .34

walking. Each step is special and unique, and the effect, as in a Zen garden, is to focus attention on the present moment, the immediate sensory experience, the feel of the paving underfoot, the changing materials… this intensification of one's awareness of 'being here', in a pleasing environment intensifies one's sense of wellbeing.

The microclimate: generally in Northern Europe, we need to protect the people from the wind and cold and maximize access to daylight.

5.2 INTERVENTION PATTERNS

- **A-** Intervention aimed at improving **Visibility** of the environment.
- **B-** Intervention aimed at improving **Legibility** of the environment
- **C-** Intervention aimed at improving **Accessibility** of the environment
- **D-** Intervention aimed at improving the **Aesthetics** of the environment
- **E-** Intervention aimed at **Gathering People** and events in time and space
- **F-** Intervention aimed at **Integration of Functions**.

5.2.1 City scale:

5.2.1.1 Various architectural typologies:

Diversity in architectural typologies ensures that the needs of different types of people are met. Serving to only one type of residents largely prevents social exchange through shared use of facilities such as a sports center or some shops. On the other hand, too much diversity in residents can lead to social irritation.

Proposal: Within San Vigilio, diversity was achieved through the creation of a multi-purpose hall that acts as a social attracting engine. Furthermore, other services for catering to people with different lifestyles, such as the bars, gallery and restaurent.

Intervention Group: B, D & E

Illustration 29 Architectural typologies

5.2.1.2 Different materials:

The facades of built-up areas of Calco city are mainly made of brick and render for walls, and tiles for pitched roofs. Brickwork and tiled roofs give these neighborhoods a softer and small scale appearance. This materialization is a defining characteristic of this city.
Unfortunately this singular application of material and style leads to an unlivable image, and Calco appears to be somewhat stuck in the past. In other words, the image of the city has become somewhat bland.

Proposal: Apply more diverse materials such as COR-TEN Steel and ETFE transparent systems, for both technological and conceptual reasons in relation with the global concept of evolving the city of Calco.

Intervention Group: A, B & D

Illustration 30 New materials

5.2.1.3 Edible Green And Agritourism

Many successful examples show that urban agriculture provides a meaningful contribution to a number of sustainability aspects, such as reduced energy use for transport. Also, considering the low biodiversity of certain green areas, such as lawns, urban agriculture can provide a meaningful addition to this as well. Furthermore, urban agricultural areas can have an educational and social function, when local residents become involved in their development and maintenance. It provides them with an activity which they can undertake to stay in public space, and have social interaction with their neighbors.

Proposal: Transform unused green areas into urban agricultural lands
Intervention Group: **B, E & F**

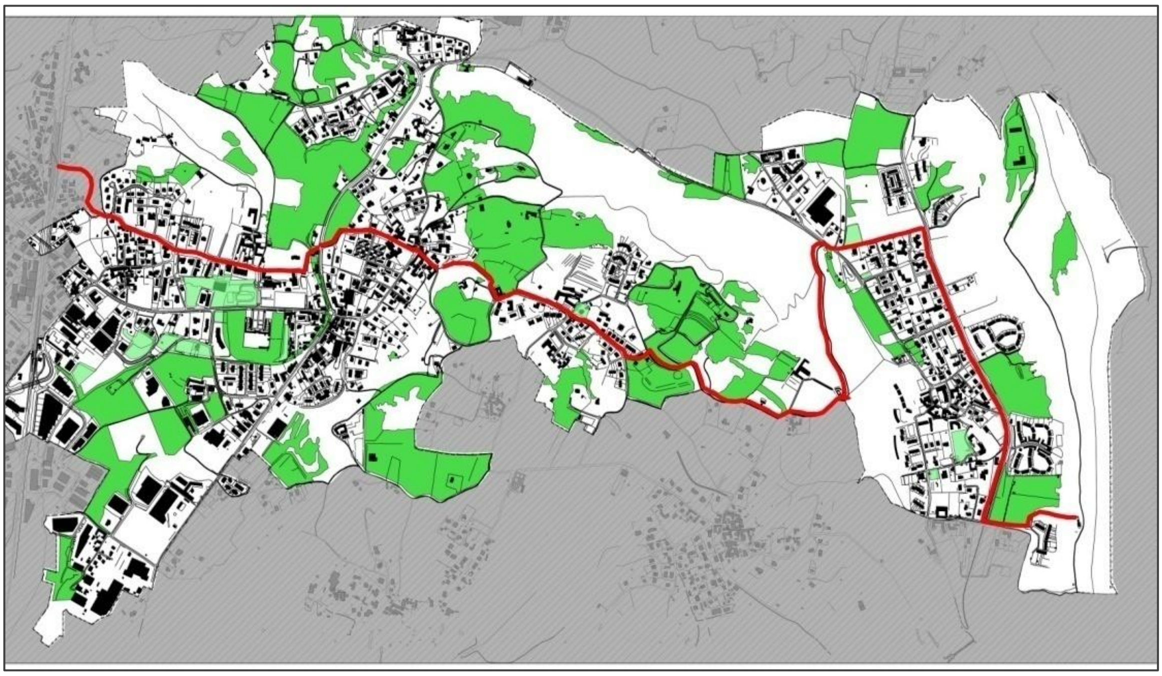


Illustration 31 Relationship between protect agricultural green areas and main urban intervention.

5.2.1.4 Natural Green

Natural green provides more affordances for social interaction than an empty field does. Natural green provides more opportunities for social interaction than an empty field does, in particular in supporting play activities. Natural playgrounds provide better affordance for construction and fantasy play, compared to traditional playgrounds. Furthermore, natural green areas can support a higher biodiversity.

Proposal: Develop plans for the development of a number of natural green areas, specifically mentioning in this case the San Vigilio Park intervention.
Intervention Group: **A, B, C, D, E & F**

Illustration 32 Relationship between protected natural green areas and forest and main urban intervention

5.2.1.5 Accessible public transport

Public transport stations need to be activity nodes with a good density and diversity of program, to ensure socially safe access both day and night. Good public transport access is crucial for any neighborhood, ensuring possibilities for social traffic, in particular for lower income groups, elderly and youths. However, public transport is also associated with socially unsafe in the evening.

Proposal: Enhancing existing bus lines and adding new routes to enhance connectivity between different parts of the city.
Intervention Group: C, E & F

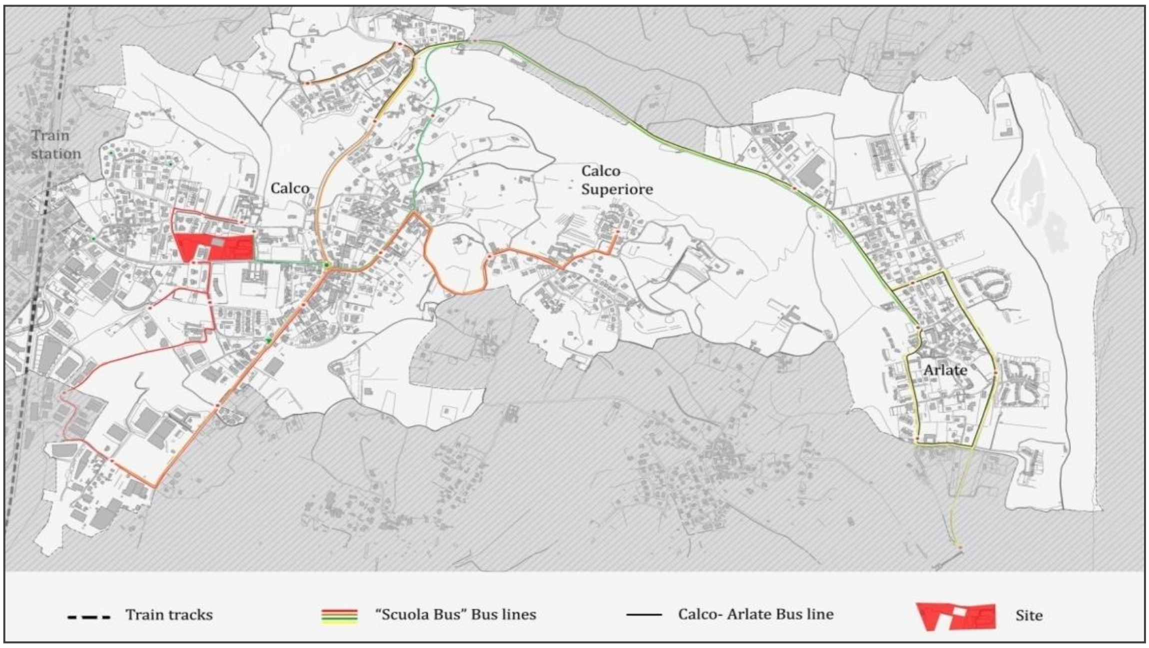


Illustration 33 present Public transportation scheme city of Calco

5.2.1.6 Shared space

Sharing space can greatly improve the social quality of public space. Traffic guidelines have become the determinant factor in how many public spaces are shaped. In this manner the traffic function is well taken care of, but the visual quality is in general rather poor, and possibilities for social interaction are being undermined due to a thinning of users of public space.

Illustration 34 Public space example. (Taken from "Shared space room for everyone") [29]

[29] KEUNING INSTITUUT, GROININGEN. Shared Space: Ruimte voor iedereen. 2005. P. 5.

Shared space provides and alternative approach. It uses visual information to guide use, and strives to combine the different functions of public space. The experience with pilot projects shows that socially successful places can be created, without compromising on traffic safety.

The balance of the traffic functions and other functions of public spaces is every time less equivalent. This is due to the fact that demarcation and the quality of the public space is every time less appropriate. Streets have very important functions that can be globally grouped in two main categories: the movement and also as the social interaction between the user. Before, the civic functions were more important than the transportation, however there was a turning point in which this informal coexistence of both functions was overthrown and the civic space came to a secondary position. Understanding the importance of these interactions is the key point of our intervention: recuperating the complementary use of the street providing spaces that are more “pedestrian user friendly”.

There is the understanding that the need of highways is important. However the characteristics of these spaces are linear and systematic. The control of the rules is given by the state. The public whelm and public space is quite opposite to the characteristics of high-speed, car mobility. The characteristics of the public realm are described as defined by the culture of their users, not by the law enforcement. It has a very personal and special definition, it is multipurpose and it has a very important characteristic which is that it is under constant change. This makes the public realm something totally unpredictable and it is important therefore to explain the importance of the cultural and social rules that govern it. The communication skills that are necessary in the use of the public realm contrast totally with the ones that are used in traffic oriented spaces such as the signs and markings.

The overlapping of these two different scenarios gives as a result low quality public spaces and unsafe highways or motorways. [30]

Searching for referents to this kind of approach we investigated different examples of “Shared spaces”. The focus was directed towards the creation of a space that wasn’t principally a traffic function oriented space but rather a space also envisioned to create a safe space for pedestrians and a comfortable space for other functions of public use. Therefore the shared space philosophy begins as the counterpart of the traditional scheme of public space design. Instead of having a partition of the spaces depending of their function, there should be a single space that mixed the functions. This was a great asset for our project due to the fact that the lack of space and the narrow dimension of the streets due to the growth of the city gave us the opportunity to create a new scheme using this approach.

[30] SHARED SPACE PROJECT. Web based videos. Online web content. http://www.shared-space.org/default.asp?ObjectID=18445

The use of shared space policies have proven to have good results in public space in terms of:

- Reduction of car speed
- Reduction of accident numbers
- Improvement in traffic flow
- Enhancement if the public space use.[31]

Illustration 35 Example of shared space[32]

The concept of shared space public areas must be considered a project that involves more than just the street design and the resulting "streetscape". Shared paces are also focused towards the creation of new policies and in general the implementation of a new attitude of the community that uses the space in terms of social interaction, own responsibility concept and risk perception. Therefore it could be concluded that it involves rather an adoption of new attitudes and the end of familiar practices.[33]

> *"…The expert team discovered that the main question in Shared Space is not, 'How should we organize a particular space?' but, rather, the more strategic question, 'What opportunities does this space offer the community?' - not just from a traffic engineering or an environmental or landscape perspective, but from a collective cross-divisional vision…"* [34]

After the participation of the community stakeholders and the administration has been competed there is another big element of the design process of the shared spaces. After the shared vision is defined, the location is chosen with a

[31] INSTITUUT, GROININGEN. Shared Space: Van project naar process. 2008. P. 11
[32] KEUNING INSTITUUT, GROININGEN. Shared Space: Ruimte voor iedereen. 2005. P.12.
[33] Ibid. Shared Space: Ruimte voor iedereen. 2005. P. 9.
[34] INSTITUUT, GROININGEN. Shared Space: Van project naar process. 2008. P. 12

certain significance and history. The analysis and interpretation for data of the site or sites in which the shared space is to be developed is important to determine what is to be preserved of the exiting public space. The creation of mental maps of the community evidencing those elements of the public space or of the city in general which are to be maintained. Furthermore, how the new shared space can enhance this identify elements in the city.[35]

The shared space focuses on the implementation of policies and design strategies that facilitate people activities instead of restricting them. Therefore there must be an interaction between the concept of public space and the service it provides; whether it is for the observation or lingering or the movement, motorized or non-motorized. The balance between the traffic and human exchange are in balance with other special functions creating a new diverse and more flexible and friendly environment. It focuses on restoring the idea of public space instead of just a traffic mobilization space in the urban fabric. This marks therefore a differentiation between the public space and the highways. In cities such as Calco, there is no differentiation between traffic areas which are design for rapid movement and the public space. Therefore we wanted to propose a new space that mixed both creating a new type of urban scheme and giving new types of behavior.

Illustration 36 Shared space in Amsterdam (Taken from internet)

With the introduction of the car into consolidated urban spaces, the concept of traffic and movement and displacement changed the way the public space was

[35] Ibid. INSTITTUT GROININIGGEN. Shared Space: Van project naar process. 2008. P. 14-17

designed and used. Cars became the main influence in the design and use of the public space. As a result we have public spaces that are depending on the main purpose of movement and subordinated at the same time to the influence of the car and motorized traffic. There is a separation of the uses.

The solutions that have been adopted in the implementation of shared spaces are very different depending on the space in which it applied. However we studied certain guidelines which make the ideas described in the theory of shared spaces more tangible and can be seen in some examples found of the theory applied.

A clear strategy in the implementation of a new shared space is to create a space with no traditional “technical” traffic tools”. Instead the uses of special elements which can hint the new public use of the space are recommended.
For example there should not be any use of speed bumps, traffic lights or Central Island since they are immediately related to the traffic use and will not help to the creation of a new use of the space.

Illustration 37 Example of Harem City Center. Before and After intervention. .36

It is also encouraged to reduce the regulating of the use of the space by signs but rather to appeal to the users self-regulation capacity.

Another important approach to consider in the design of the shared spaces is the materials used in the project. This refers to the different textures and the colors that will guide the users in the space and can give hints of the way ti should be used. Also the furniture and characteristics of the space should be according to the architecture and landscape of the area.

It is also considered at the moment of designing to not separate the uses. An apparently “unsafe” space in which different users are mixed (cars pedestrians and bikes) may actually be safer due to the fact that the mixture of all the different types of users create a reduction in speed; whereas the separation of the different types of flows result in higher speeds and therefore more risks of accidents.

[36] INSTITUUT, GROININGEN. Shared Space: Van project naar process. 2008. P. 37

Proposal: In view of the lack of space that we have left for intervention and the existing urban fabric of small narrow and principally car-oriented streets we focused on the creation of this linear connection between the Calco train Station and the Adda Nord Park. The lack of existence of sidewalks and in general space to implement a intervention for the urban linear park made us consider he maximization of the public spaces and in particular the optimization of the use of the street as a space that can host both automobile and pedestrians in the same importance. Applying shared space principles, using materialization and furnishing to slow traffic movements, and combining different traffic flows, would form the main intervention element in the urban proposal on the city scale.

Intervention Group: **A, B, C, D, E & F**

Illustration 38 shared space vies proposal concept. Before and after.

5.2.1.7 Landmark (theater, church, park)

The city of Calco needs more landmarks to improve the legibility. Landmarks are physical elements, which for a variety of reasons may contrast with their background. This can be for example due to form, size, color or age. Together with well designed paths, edges, districts and nodes, landmarks are important elements of a legible environment and are important for orientation and way finding (Lynch, 1960). [37]

Proposal: Adding the new buildings requested by the Municipality of Calco to the intervention site, which clearly stand out due to materialization, size and form.
Intervention Group: **A, B D & F**

[37] LYNCH, K. The Image of the city. 1960. P 32

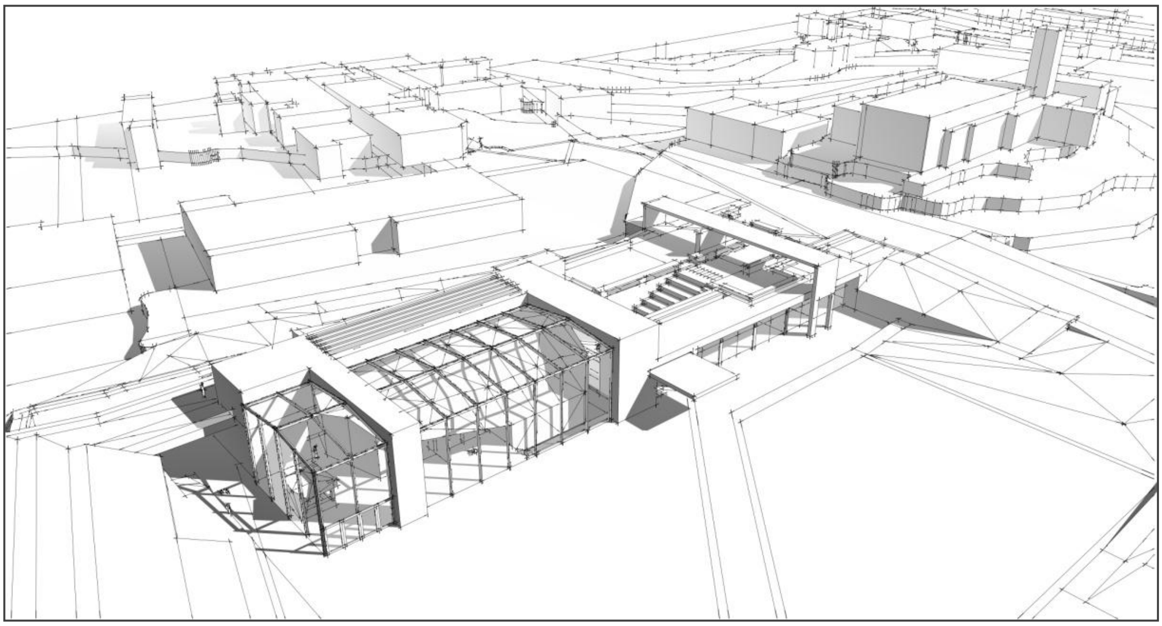


Illustration 39 The intervention as a Landmark

5.2.2 "San vigilio park" scale:

5.2.2.1 Main park entrances

The intervention zone entrances are important structuring elements to mark the neighborhood territory. The entrances to a certain neighborhood are important elements that influence the relation between this neighborhood and a city it is a part of. They ought to function as a clear marking of the neighborhood territory.

Entrances should clearly communicate that this is a separate territory. This can aid a sense of character of this zone.

Proposal:In the specific situation of San Vigilio, there are three main entrances to the site. All linked by a single line with a different paving material connecting the whole area in an unconventional manner, emphasizing the evolution of the space lining and the innovation of the language of the urban intervention.

Intervention Group: **A, B, C & D**

Illustration 40 Park Entrances

5.2.2.2 Materialization in the public space

Materialization is an important factor in supporting intended social use of public space. Aesthetic appeal of the public space is an important component of the physical preconditions for social safety and possibilities for social interaction.
In the context of Calco some particular problems can be identified as far as the aesthetic appeal is concerned, and much of that has to do with the materialization of public space. The same kind of materials are applied across the intervention zone (Normal scattered stone tiles, sand or concrete for paths), which have a high level of technical sustainability, but which are nothing short of an eyesore.

Furthermore, applying more differentiated materials can also aid social use, such as defining gradients in the hierarchy of use of the public space.

Proposal: Apply more diverse materials in the public spaces, in particular to differentiate between spaces with different levels of public-ness and accessibility. Concentrate more attractive materials, with different colors, in the most vitally used areas, such as the centre, and along important axes.

Intervention Group: A, B & D

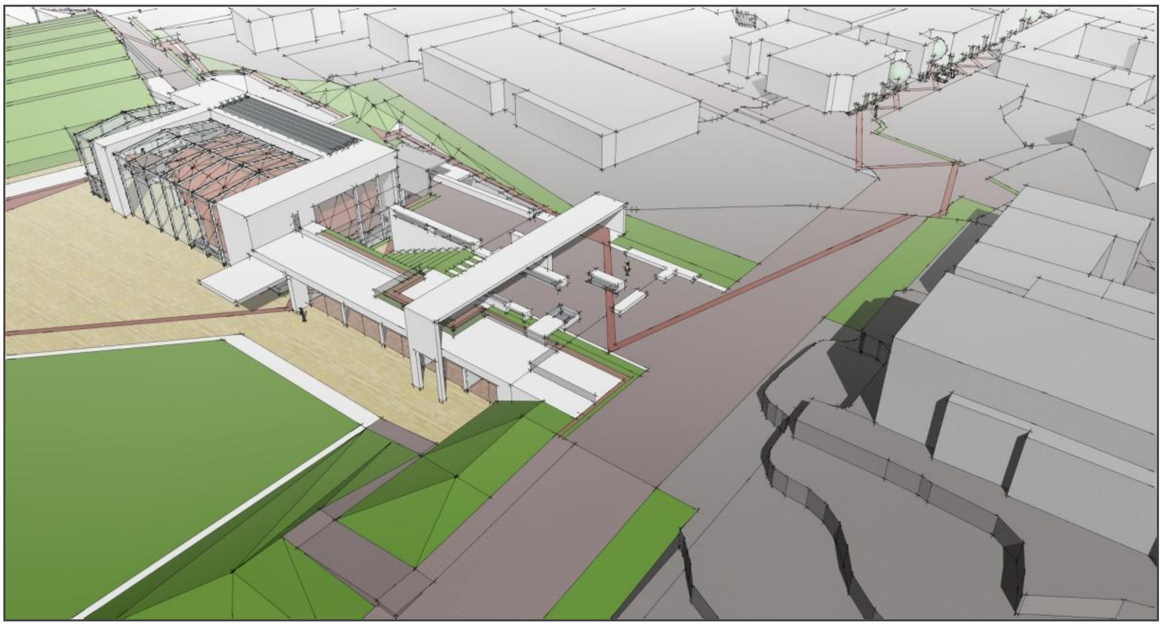


Illustration 41 materials used in the public spaces and their connectivity at different levels

5.2.2.3 Landscape connection

The connection to the surrounding landscape is the most important green structure of a neighborhood.

Proposal: Redesign the connection(s) between the defined zone of intervention and the existing green spaces, as part of the completion of the PTCP plan goals with clear direct paths and direct sight lines with an emphasis on materialization used in those paths.

Intervention Group:
A, B, C & D

Illustration 42 An explanatory diagram showing the desire of having unity and landscape connection with existing green in the new proposal

5.2.2.4 Legible public space

Public space needs to be legible to provide affordances for undertaking activities in public space, and to provide the physical prerequisites for a socially safe environment.

According to Lynch (1961), the ease at which different parts of a city image can be organized in a coherent pattern is an important property of a beautiful city. This characteristic is called legibility, and is influenced by the design of the paths, edges, districts, nodes and landmarks. A highly legible environment provides its users with a clear mental image, which not only provides emotional security, but which is also crucial for orientation through an area. Furthermore, if an environment is perceived as attractive, it becomes easier for residents to care about it.

Proposal: Redesign the San Vigilio public space with the provision for 'stay' quality by programming green structures, improving sitting possibilities, and enhance social interaction through improved aesthetic appearance, visibility, legibility and coherence of the main traffic structures and the neighborhood centre through interventions in the structure and materialization of public space.

Intervention Group:
A, B, C, D, E & F

Illustration 43 Public space intervention

5.2.2.5 Living walls (historic center)

Walls are an effective means to shield off individual territory from public space, and can be used for playing ball by children. Unfortunately long blind walls have a large negative visual impact on the adjoining public space. Specifically mentioning San Vigilio, the historic center is the link between the park greenery and the natural green areas in the north.

Proposal: Replace walls with hedges or grow plants on the walls.
Intervention Group: A, B, C, D & F

Illustration 44 wall treatment in the historic center, and strengthening of the green connection from North to the park

5.2.2.6 Attractive elements

Visually attractive elements in public space are important for triggering positive emotions, and they can give observers something to talk about with one another. Aesthetic quality is judged differently by individuals, but people feel uncomfortable if an environment does not fit their cultural expectations and personal identity. Some universal values do hold; natural elements such as greens and sunshine are generally appreciated, whereas large-scale open spaces make people feel small and unsafe. Having something attractive to look at provides people with an activity to undertake in public space.

Proposal: In the context of San Vigilio, we added some new elements such as the unconventional skylights/seating places in front of the church, and also the stepping paths leading to absolute green in the linear park zone.

Intervention Group: A, D & F

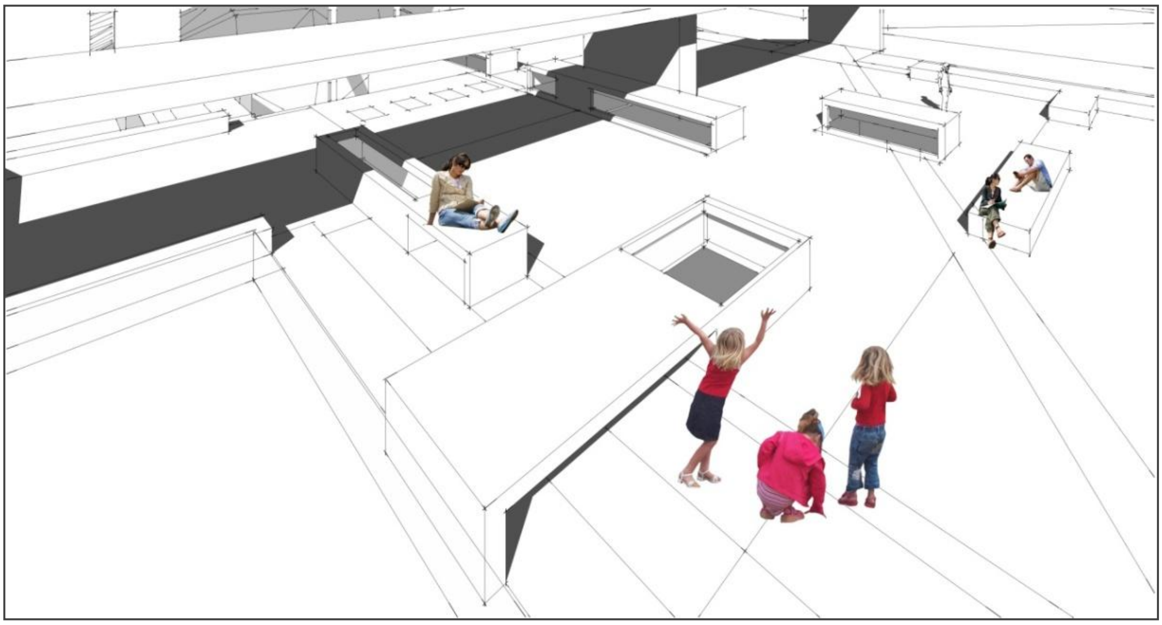


Illustration 45 Skylights/seating functionality of elements

5.2.2.7 Sitting everywhere

Opportunities for sitting in public space should be provided for as much as possible**.** Sitting is an important manner in which the duration of staying in public space can be elongated. Apart from benches, which are not so attractive when they are not being used, many additional affordances for sitting can be provided. Certain objects are perceived to be useful and comfortable for sitting, in particular sufficiently large, elevated horizontal planes. Building ledges, bridges, steps, flower pots etcetera, can all hold such a function, but often these objects are not designed with possible sitting in mind, and this is a missed opportunity (Whyte, 1980).[38]

The concept emerges also from the chair sharing project applied in Modena in which movable chairs with Wi-Fi were used to enhance the usage of public space in a neighborhood that was just transitional and enhance the use of public space in order to boost the overall usage of the sector. This idea of flexibility and movility within an appropriate open public space give dynamism to the urban context and has direct repercussion on social behaviors and economic activity.[39]

[38] WHYTE, W.H., *The Social Life of Small Urban Spaces.* New York: Project for Public Spaces. 1980. 125 p.
[39] BRAVO BORDAS, David. Chair sharing, Modena Italia 2010. [on-line] Spain. [Reviewed on the 23 May 2011]. http://www.publicspace.org/es/obras/f264-chairsharing

Proposal: The design of the San Vigilio Park allows for maximum sitting areas all around the site, the elevated green surfaces with various levels, the unorthodox benches/skylights in the public space in front of the San Vigilio church, as well as the introduction of both, the red line, which changes its form to host different functions, such as seating benches, and the chair sharing concept which add another dimension to the usage of space. In this manner, the space use isn't bound by physical limitations and is constantly changing.

Intervention Group: A, B, D, E & F

Illustration 46 "Modena Cambia Faccia" Chair sharing project images.[40]

5.2.2.8 Youth zone

Youths are an important user group of public space, and the design of public space should acknowledge that. The negative attitude of adults towards loitering youths is partially justifiable due to social nuisance and vandalism caused by some of them, but youths need a place to stay as well. Even when they are not causing any trouble in a particular place, they are asked to leave.

Proposal: Designating, areas in the San Vigilio Park a zone equipped for the use of the youngsters, as well as mingling these spaces as part of the Mixed Uses areas, and provide them with necessary facilities. Also, covering the palazzo dello sport with a stepped green roof is meant to provoke the energy of the curious youth to try new urban and highly active sports such as Parcours.

Intervention Group:
A, B, D, E & F

[40] BRAVO BORDAS, David. Chair sharing, Modena Italia 2010. [available on-line] .http://www.publicspace.org/es/obras/f264-chairsharing

Illustration 47 conceptual sketch youngsters' zone

5.2.2.9 Aesthetically appealing parking space

Parking should not just be a waste of space**.** Availability of parking close to the site, and easily accessible could be considered as an essential quality in the area. However, parking makes a tremendous spatial claim on the living environment and in its normal layout it has a large negative impact on both the social and visual quality of public space. Furthermore, large amounts of hardened surfaces contribute to high surface water run-off.

Proposal: Adding a green roof on top of the parking area, in order to enhance the image of the space as well as making it a part of the green network.

Intervention Group: A, C, D & F

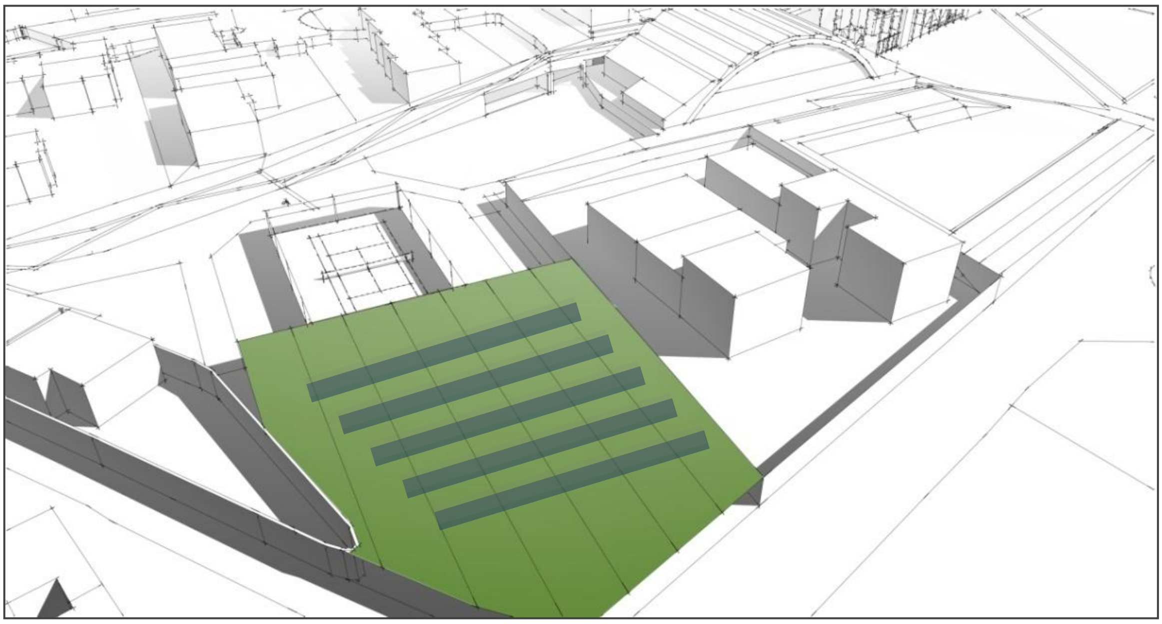


Illustration 48 treatment of the parking space roof (green roof) with PV panels.

5.2.2.10 Trees

Trees can improve structural cohesion and visual attractivity of public space and support stay-quality of a place. If they are well-chosen and well-placed, trees can improve structural cohesion and visual attractivity of public space (Lynch, 1960). Furthermore, trees can strengthen stay quality of a place by providing a sense of shelter for people. Trees can help damper local climatic fluctuations, providing much needed cooling in the summer (Whyte, 1980). Finally, trees can strengthen the identity of place, with old trees being valued greatly.

Proposal: Develop a coherent tree plan, maintaining unique trees, especially on the sides of the intervention zone, and placed on different levels of greens, simulating the natural forests passing between Calco and Arlate.

Intervention Group: A, B & D

Illustration 49 The green character in the Lombardy area

5.2.2.11 Mixed use of public spaces

A neighborhood with limit program is not a convivial neighborhood.

Proposal: The design of the park zones is described to be a one giant mixed use space with various weights of usages for each little zone. This is to ensure the sustainability and flexibility of the whole area.

Intervention Group: A, B, C, D, E & F

5.2.2.12 Nightlife

The presence of evening functions is a prerequisite for a convivial zone. Having evening functions in an area, leads to an increased use of public space in the evening, in that manner strengthening social safety (Jacobs, 1961).[41]

Proposal: The functions used in the architectural design such as bars and galleries around the main public spaces.

Intervention Group: A, B, D & E

[41] JACOBS, J., Death and Life of Great American Cities. NewYork: Modern Library Edition. 1961. P 47

6 PROPOSAL

6.1 URBAN APPROACH

6.1.1 Road Intervention

In order to achieve the described policies and design strategies for the new public space, we realized the necessity of creating a new scheme of roads which would allow us the reduction of car traffic inside the urban limits of Calco.

For this part the proposal of intervention includes the relocation of high speed traffic on a new part of the road that would be located following the train tracks. This way we would reduce traffic flows thin the city and make it possible to apply the shared spaces criteria without affecting the traffic flow of the region which is so important in this part of the Province and in general due to the localization of Calco within the overall road system of the region.

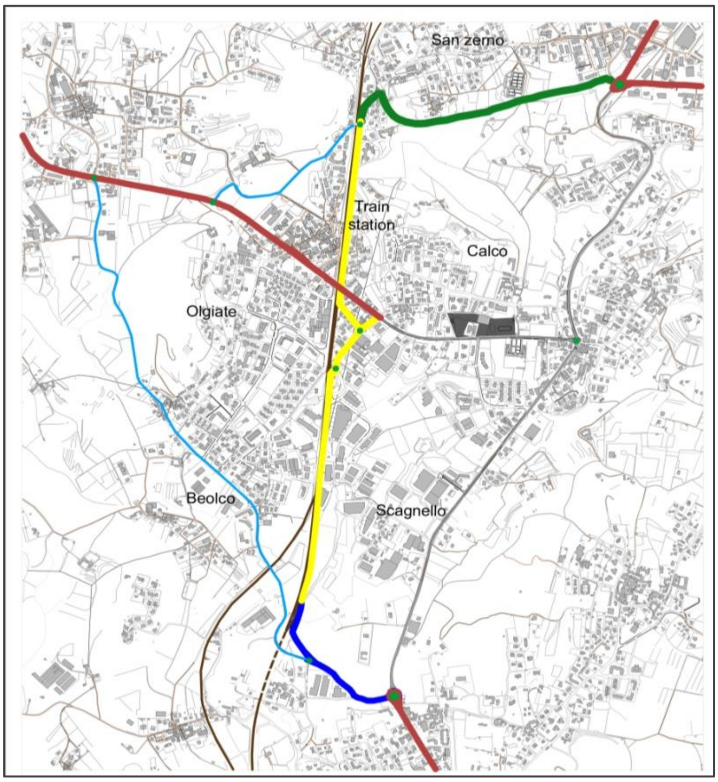


Illustration 50 New Roads General Scheme

There are 5 main nodes that are of vital importance for the connections of this new road intervention with the existing one. They are the ones that ensure the deviation of the high speed traffic.

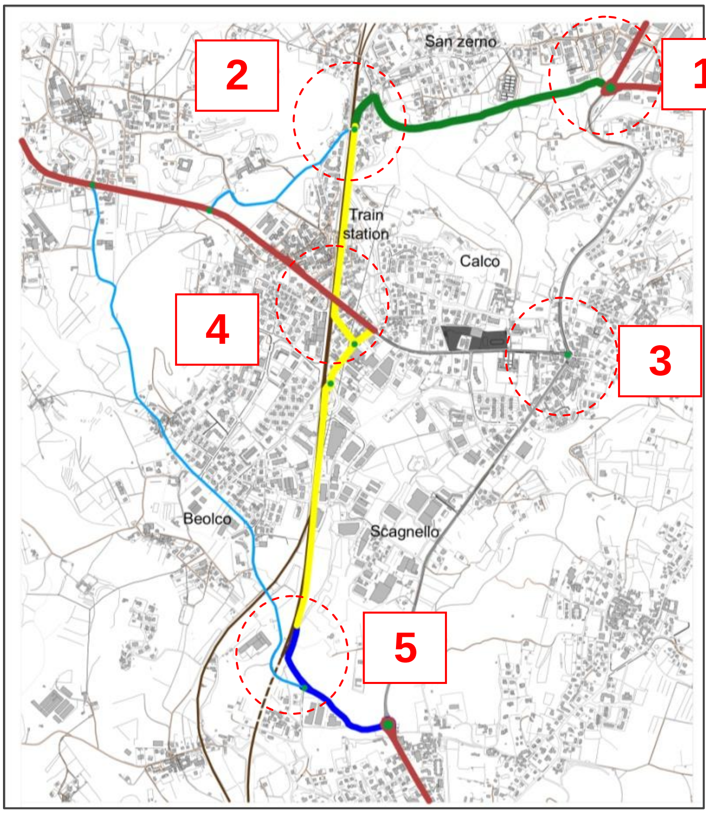


Illustration 51 Location of the nodes of intervention.

Node 1

The new road intervention coming from north to south starts at the round about that joins SP 72 with SP 342. From here heavy and speed traffic flows are proposed to deviate towards the west until hitting the train track from where a parallel road to this element is to be created.

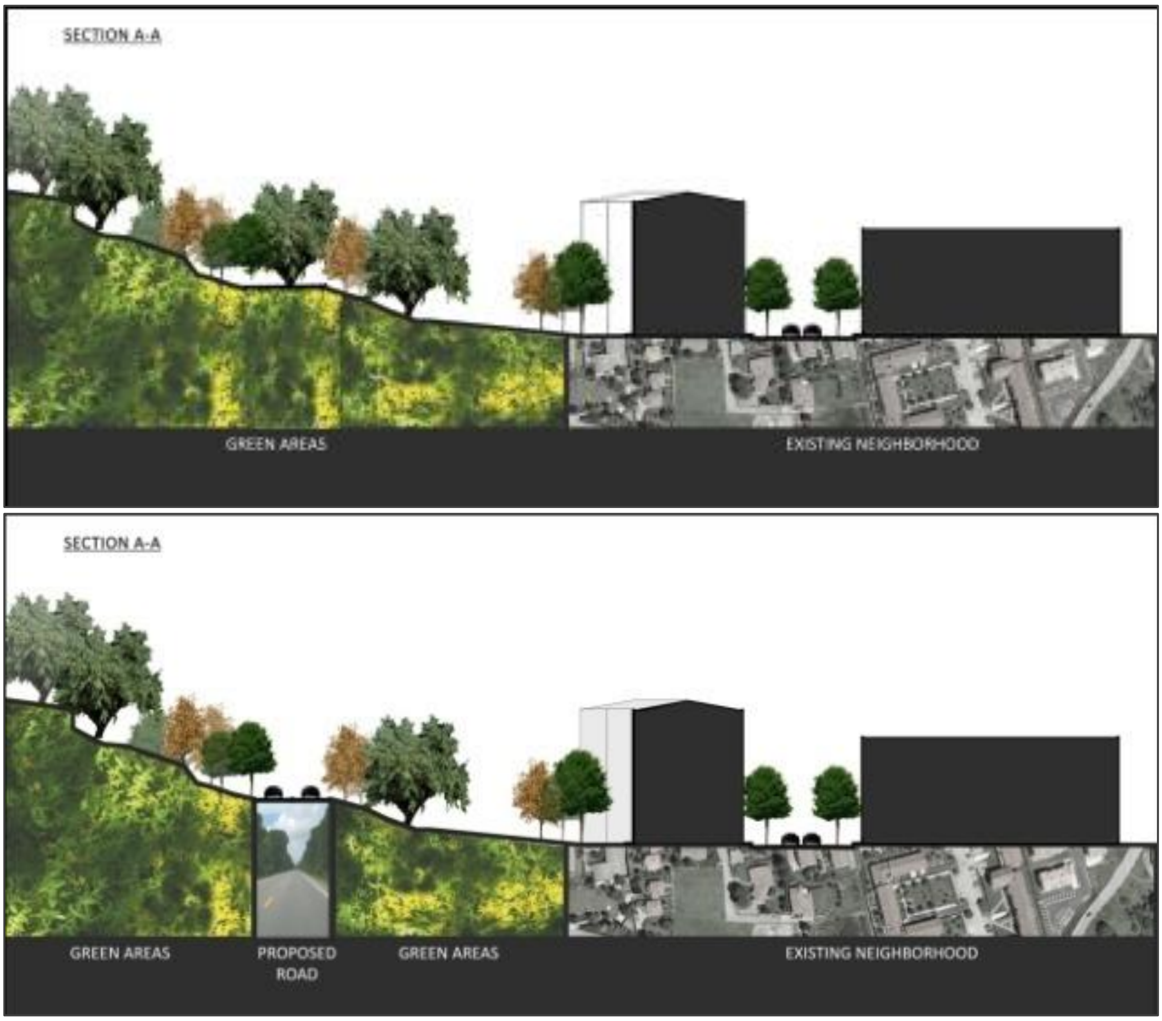


Illustration 52 New Road Intervention Node 1 Before/After

Node 2

Via Cesare Cantu is another important junction between the new proposed road, the train tracks and the existing neighborhood before arriving to the train station. In this junction there is a roundabout over the train tracks which are below street level to allow the traffic flows both in the sense of the new road and also towards the east on Via San Primo.

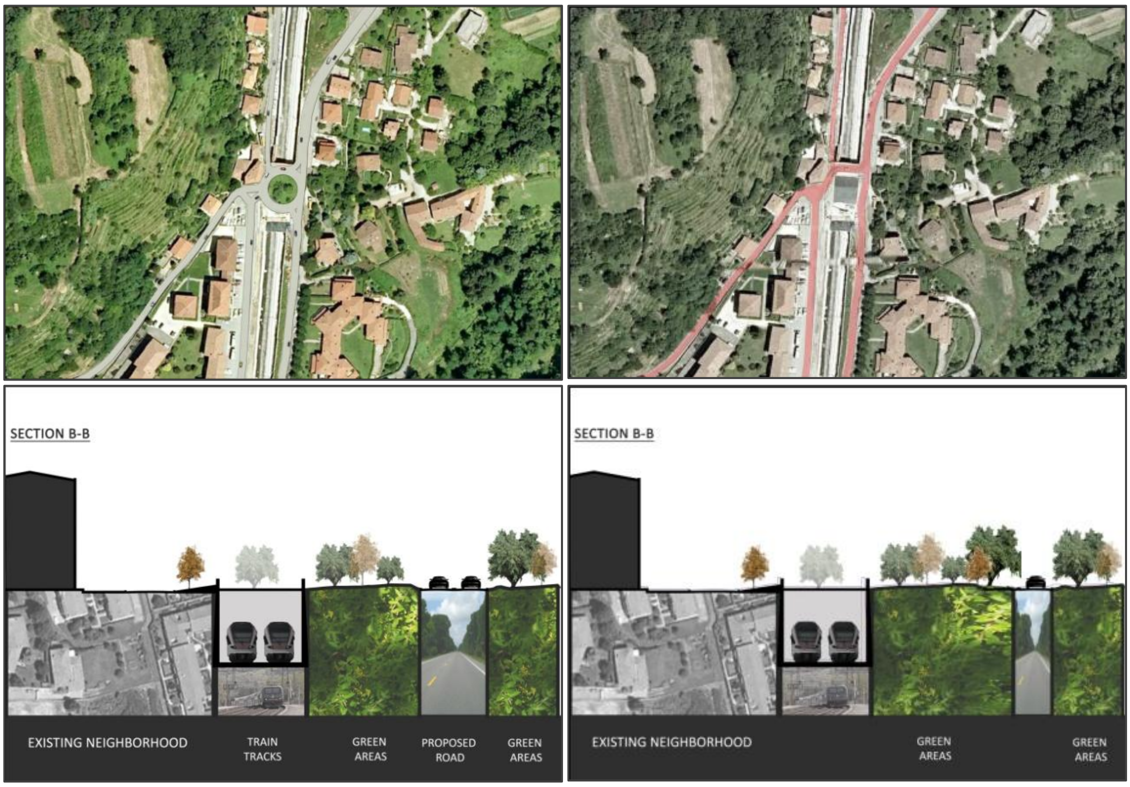


Illustration 53 New Road Intervention Node 2 Before/After

Node 3

Heavy traffic flows are then passing on Via Independenza within the Urban Limits of Calco. Two roundabouts were designed to control the junction between this heavy flow of traffic in the north-south direction and the inner urban fabric in east-west direction.

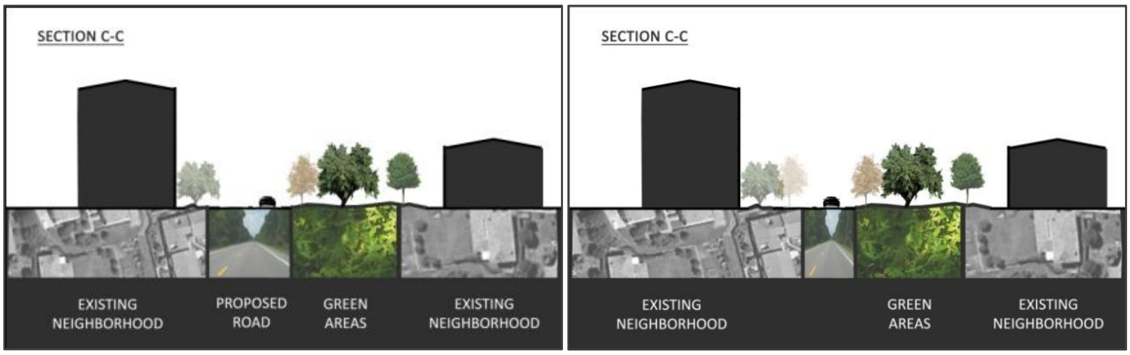


Illustration 54 New Road Intervention Node 3 Before/After

Node 4

On the edge of Calendoni Area, the merger between the bridge connecting the two sides of the train tracks and the new proposed intervention was also studied.

Illustration 55 New Road Intervention Node 4

Node 5

The final node of intervention was considered at the junction of Via del Calendone and the Via Statale SP342. Its main goal is to achieve the deviation of heavy traffic flows onto the proposed parallel road located next to the train tracks as shown in the following images.

Illustration 56 New Road Intervention Node 5 Before/After

STRATEGY OF INTERVENTION

6.1.2 Connectivity and enhancement of public spaces.

After the consolidation of the wider scale intervention for the roads, the main ecological mixed used path that would become our main urban intervention was divided into nodes of connectivity where the enhancement of the public spaces would take place. These nodes would each have a different characteristic depending of their urban and landscape context. However the major link in all of them was the idea of the enhancement of the public space and the implementation of the theoretical analysis of the model described prior towards the creation of a new public space use in the city.

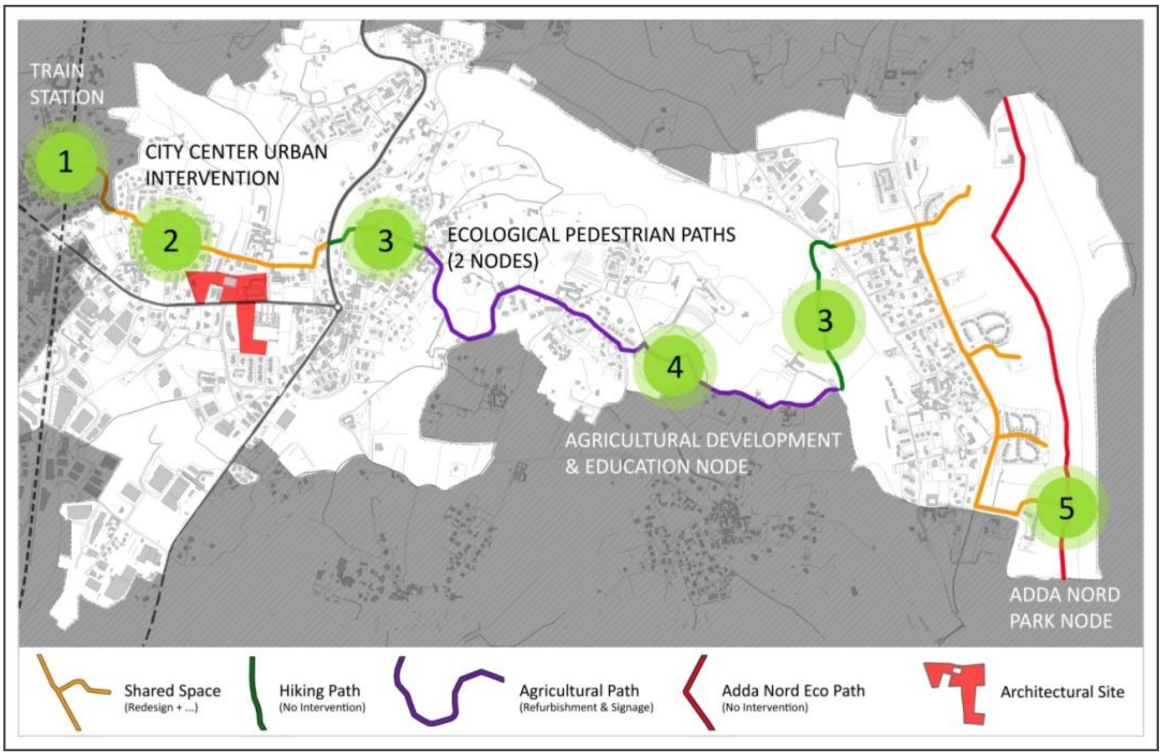


Illustration 57 Main intervention Nodes scheme

NODES INTERCONNECTIVITY

- The train Station as an important gateway that would be the link for the corridor to the region and as the start of this ecological mixed use public space.
- A city center intervention that would create a new public space that would bring the use of the street back to pedestrian and other uses and not limiting it to the use of car exclusively which was the situation occurring currently.
- Ecological and Hiking paths corresponding to the protected green areas and forests that are present in the area and which are one of the biggest potentials.
- An agricultural and potentially educational node related also to the agricultural use of the land determined by the territorial pan for some of the parts of the ecological corridor.
- The Node of the Adda Park is in itself one of the biggest potential of the zone along with the ecological corridor policies.

The following studies were taken specifically focusing on the main city center node and the train station node, due to the fact that it was the most related to our site. The design of the urban project in this part was especially concentrated in the part of the design of the shared space and how this is connected to our architectural project.

TRAIN STATION NODE

The starting point of the Calco shared space public area is the train station which hold a very important use to the city in terms of transportation and connection to the Province and the Region in general. The shared space has its beginning at this point.

Illustration 58 Train Station Node Plan

MAIN SHARED SPACE AROUND THE SITE

The site is surrounded by shared spaces which link the public space created to the main transversal pedestrian-mixed used connection between the train station and the Adda Park.

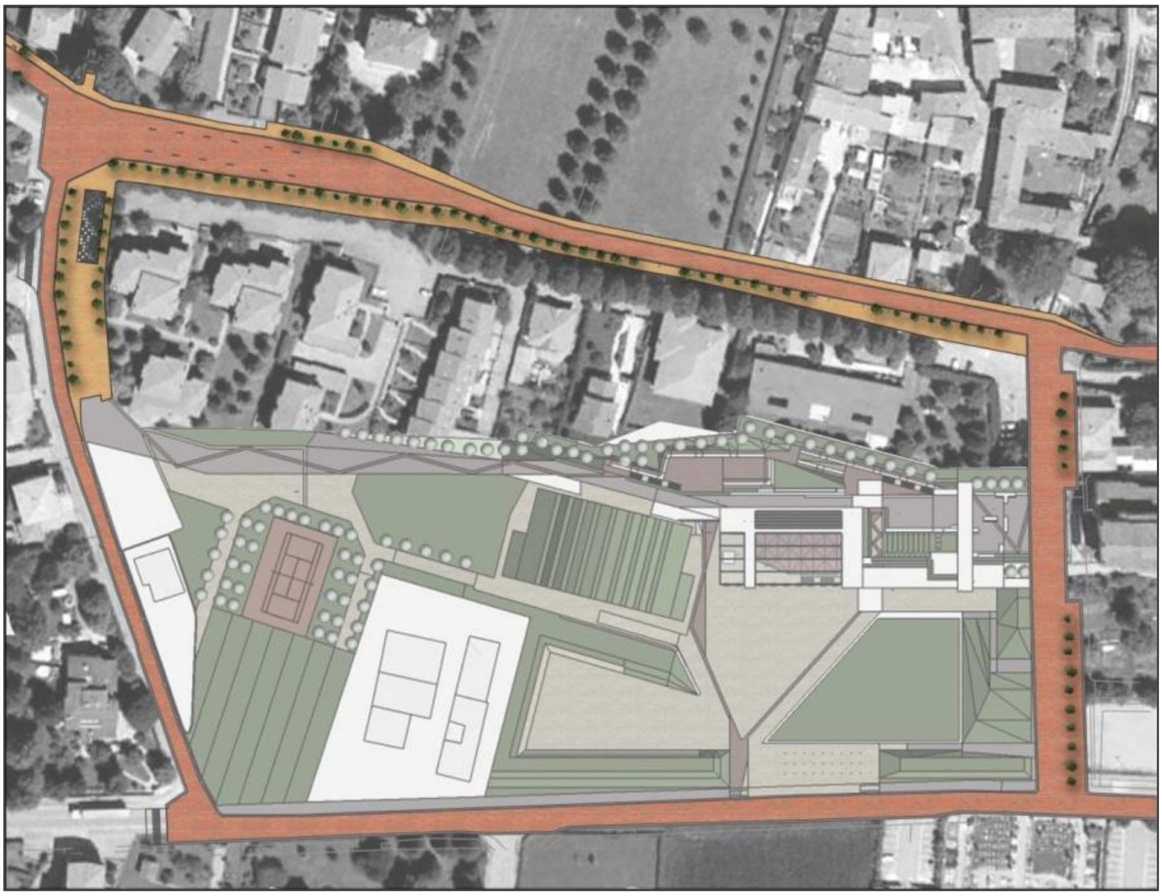


Illustration 59 Shared Spaces Around the site

North-Western shared space junction

The city center node of the urban intervention connects with the train station towards the west and to the widest spam of open public shared space of the whole project. This connection is important because of the convergence of different street sizes and patterns into this new multiple use space.

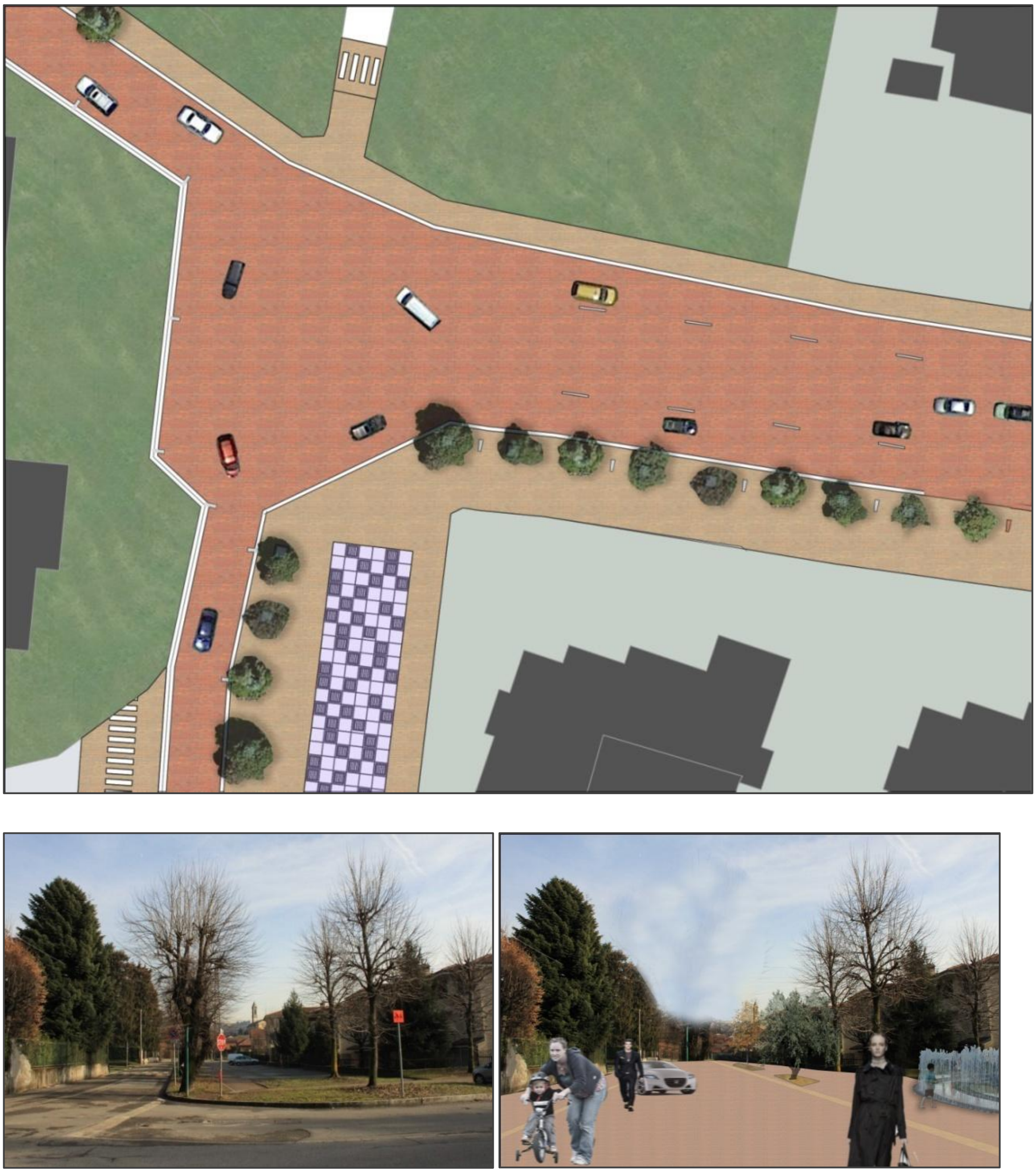


Illustration 60 North-western shared space connection to Site. Plan and Before and After Shots.

The same behavior can be seen in the shared space scheme in the north eastern part where there is a connection to a narrow part of the shared space connecting to the eastern ecological part of the corridor. This node is especially important because of the presence of the church and the connection to the historical center in the north street. Also, the school plays an important role in the design of the public space with regards to the shared space.

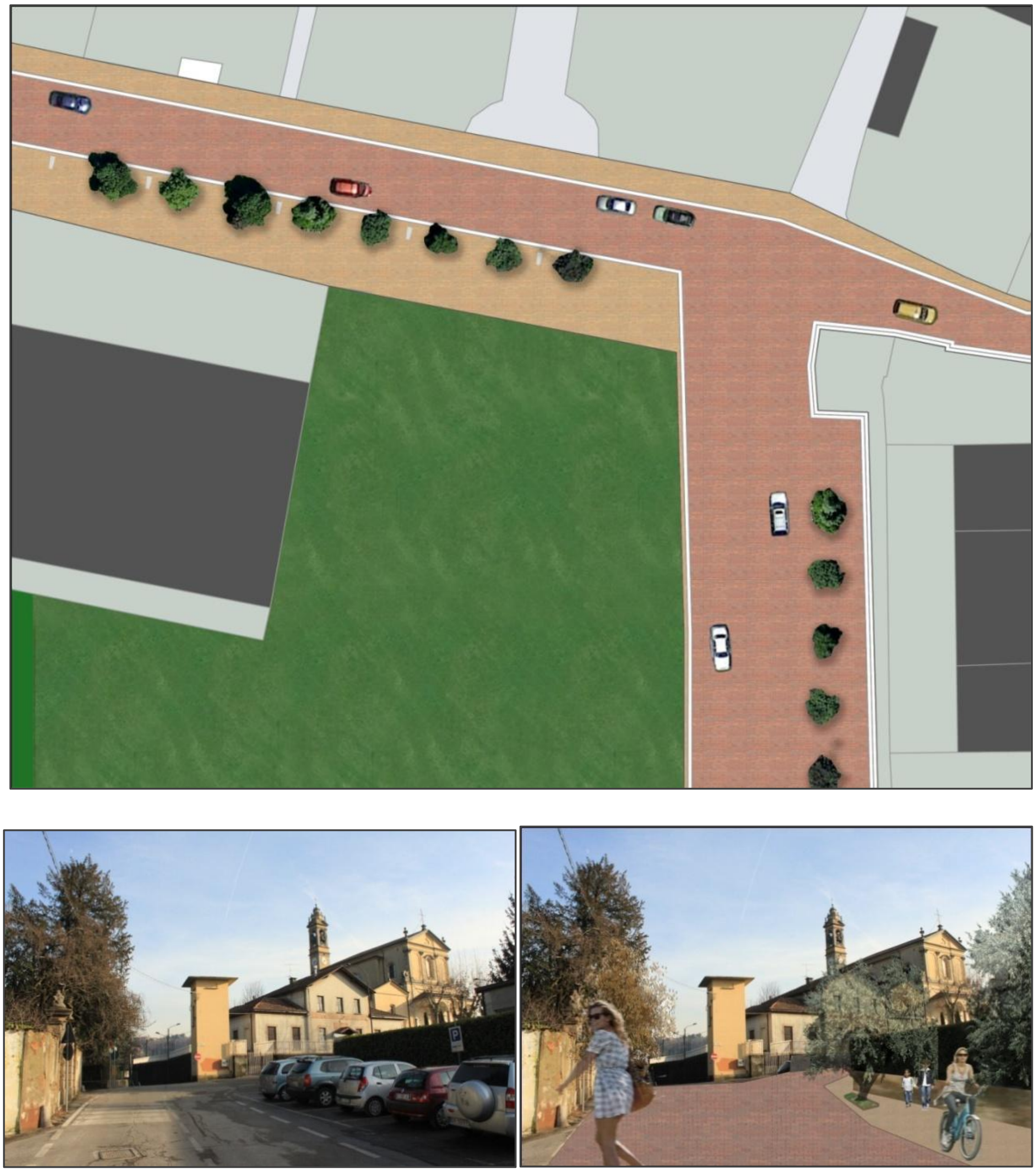


Illustration 61 North-eastern shared space connection to Site.
Plan and Before and After Shots.

Another important aspect of the design strategy was to define crossroads between the shared spaces and streets with other types of characteristics, which is the case of the crossing between the proposed shared space and the existing SP 342.

Even though the high traffic is proposed to be deviated from this main road, the flow that is left in it is one of very different characteristics to that of the shared public space.

Different materials treatment will allow the users to understand the use of this new interconnection space and the flows of all kinds of users (pedestrian, cars and bicycles) should be able to merge in this point.

Illustration 62 Connection Shared spaces with Road SP340

6.1.3 "San Vigilio Park" Scale

SAN VIGILIO AREA… A CITY NUCLEUS**:**

Located in a vital location within the city of Calco –according to Convivial Spaces-, with regard to the scale of the city, this zone is clearly different within the prevailing context in the rest of the city. Its location, in addition to its connection to the surrounding functions and accessibility to the rest of the parts of the city makes it crucial to notice the volume, scale and shape of the new construction.

6.1.3.1 Study Area Analysis

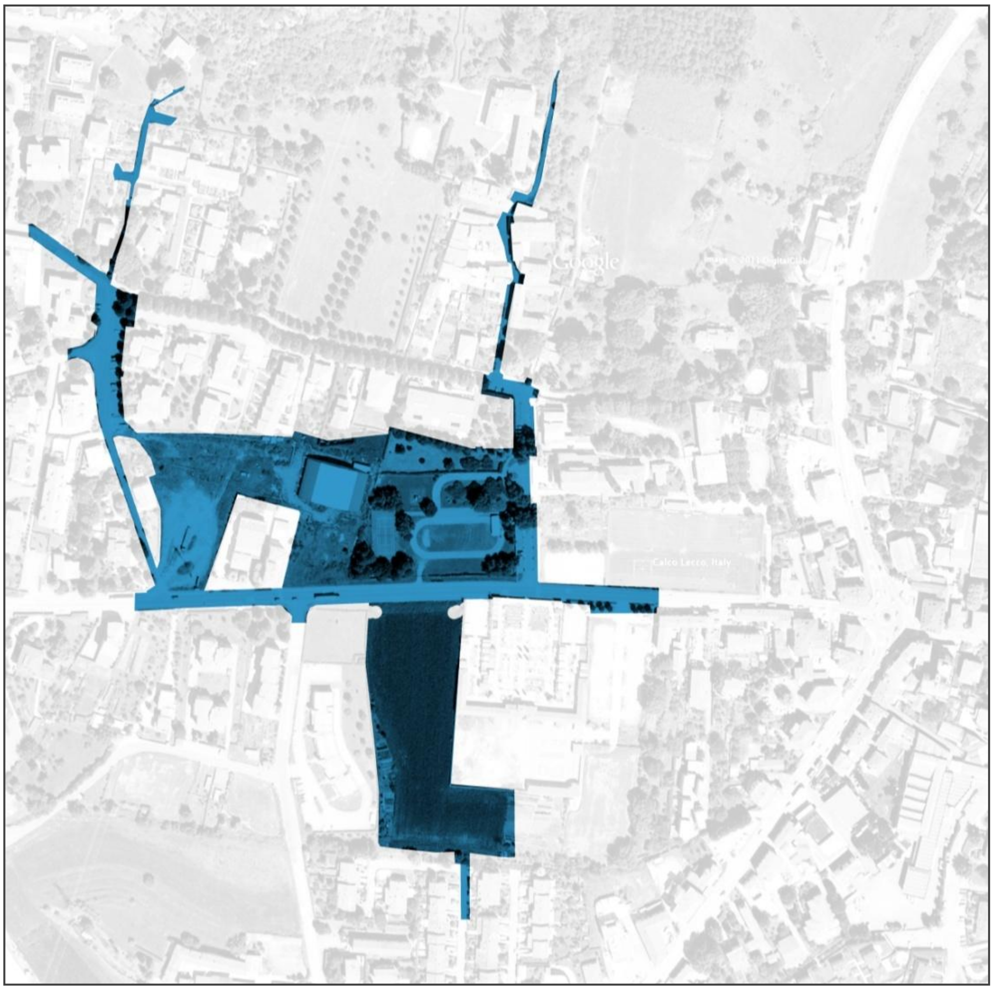


Illustration 63 Zone of intervention

The chosen site for the architectural project in San Vigilio Area is 41,200m^2 with a parameter of 1690m, with a lot of scattered green areas, most of them not well used, especially the ones close to the cemetery.

SURROUNDINGS:

Illustration 64 Site and significant surrounding structures

The site is surrounded by various architectural typologies, the majority of the functions attached or directly related to the site are residential, follows that the historic buildings, and last we find the two independent functions of the Palazzo dello sport and the school.

The site is characterized with complexity in the parameter geometry. Three points are considered to be crucial in solving the connection problem between the different areas within the site:

1- The entrances from both the church and the western end of the site.
2- The palazzo dello sport area with the two narrow open spaces around it.
3- The connection of the northern and southern parts of the park through the street, and how this space will be treated.

SAN VIGILIO SITE… EXISTING SITUATION

The open areas within the San Vigilio area are characterized by major separation, physically and psychologically, it could be described as a plot of 12 small, scattered and poorly used spaces.

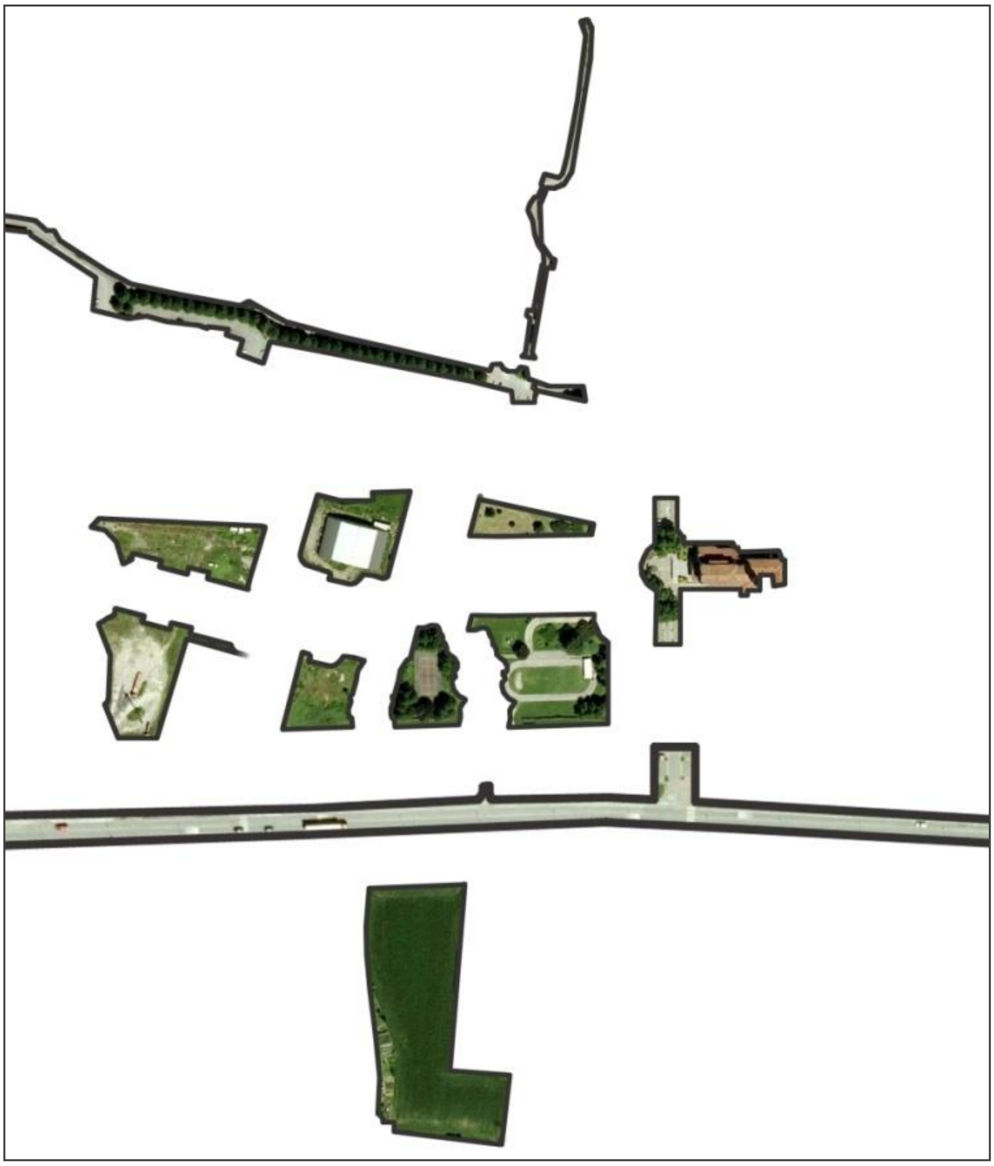


Illustration 65 Separation in the existing situation

Each space either has one specific function, or has no function at all. To be named, the 12 spaces are:

1- The San Vigilio Church
2- The Children Zone
3- Palazzo dello Sport
4- Tennis Court
5- Unused area between the school and the children zone, fenced by greenery.

6- Unused space between the residential block, the Palazzo dello Sport and the Tennis court.
7- Unmaintained open space on the left side of the residential block in the site (currently used as an unofficial parking spot)
8- Unused space between the palazzo dello sport and the non-formal parking.
9- The Highway road cutting through the site and continuing to branch out in the commercial center.
10- Unused linear green space beside the cemetery
11- Small street passing through the historic center (no sidewalks)
12- The back street, with either miniature or no sidewalks. This street leads directly to the train station from one side, passing through the preserved forest through the existing hiking path, and finally reaching Arlate city center.

Illustration 66 separation & uninhabited spaces in the existing state in Calco

This separation is a main factor in the misuse – or lack of use – of the public spaces in this zone. From its high point, the site slopes steeply to the north and east and gradually to the west and south. Prevailing sun come from the south and provides heating throughout the year. Views are excellent in all directions, suggesting that primary consideration should be about the light, solar orientation, and cooling breezes.

6.1.3.2 Conceptual approach

SAN VIGILIO AS A SUSTAINABLE CENTER

Illustration 67 The proposed concept of a sustainable green and socially rich center for Calco

The city of Calco, Italy, needs a public space. This project is the first attempt to create an enjoyable, socially and sustainably healthy public space. This public space represents the centric node for future developments to renew and integrate the public spaces and the services to the neighborhood. The existing lack of public spaces generate an absolute degrade of the entire area, and the neighborhood has become an unsustainable place. For this reason the project amplifies the idea of a relational space filling the social void with explosive, playful, sensorial and interactive intimate elements, and it’s constantly in tension between artificial and natural elements.

It is a space in which users and citizens can find the joy of life, love and get to know each other again and become comfortable with the entire area, thus renewing the social sustainability of this site in Calco.

CONCEPTUAL DIAGRAMS

Illustration 68 Layers of the proposed concept evolution

The main concept is made of 5 main layers:

1- Two green hills softly moving on different levels, which try to simulate the characteristics and visual of the forestry cutting through the city.
2- Pathways stitching the different parts of the two green belts.

3- The urban streets and shared spaces.
4- The layer of masses. Emerging from the green hills to minimize its artificial impact within the surroundings.
5- The red line. A direct expression which creates an unorthodox movement for the users within the different spaces and zones.

The five layers have one message; creating places and spaces that are evolved from the existing spaces and functions, not in any way an imposition of a newly different design. In other words, to have projects that is:

Illustration 69 Overlapped layers of the new concept of intervention

Evolved… Not Designed…

As for the public spaces, the idea was to create one main big space with mixed uses with different ratios of importance to each zone. This point will be discussed a bit further.

One Space… Many uses.

SITE NEW ENTRANCES

Illustration 70 Entrances to and within the main park area

SITE STREETS HEIRARCHY AND FUNCTION

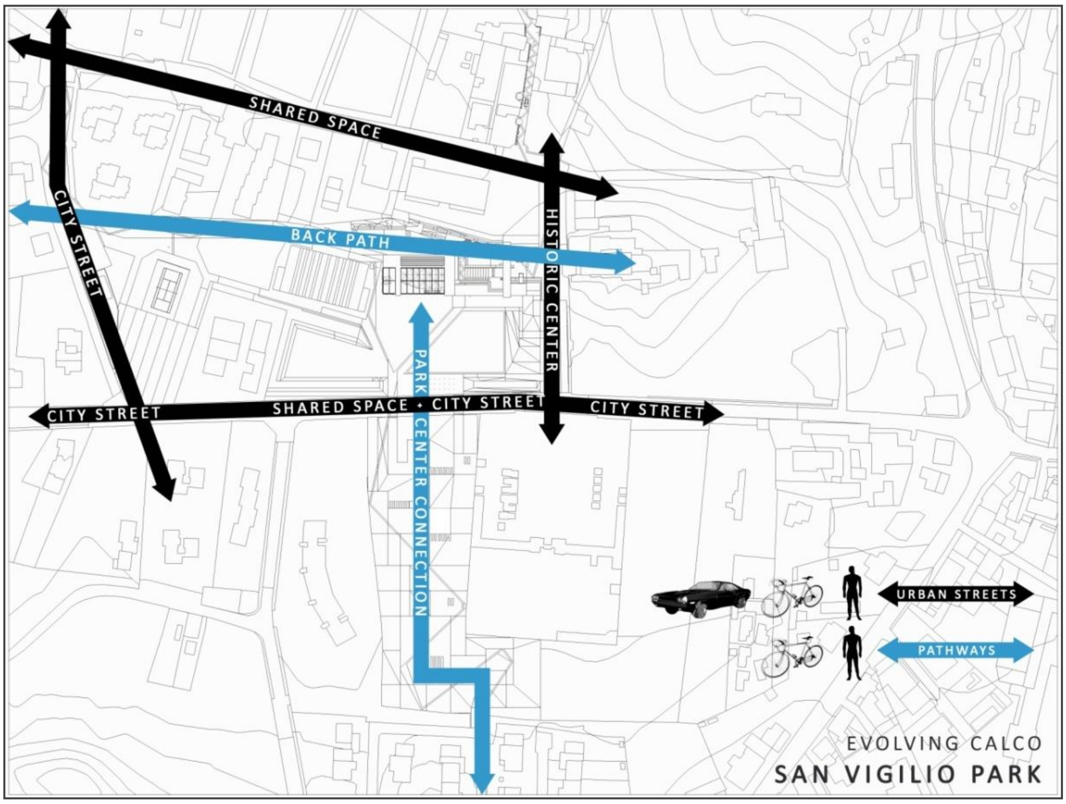


Illustration 71 New Hierarchy of the streets, paths and shared spaces within the site

CONCEPT DEVELOPMENT

Illustration 72 Green hills and spaces layer

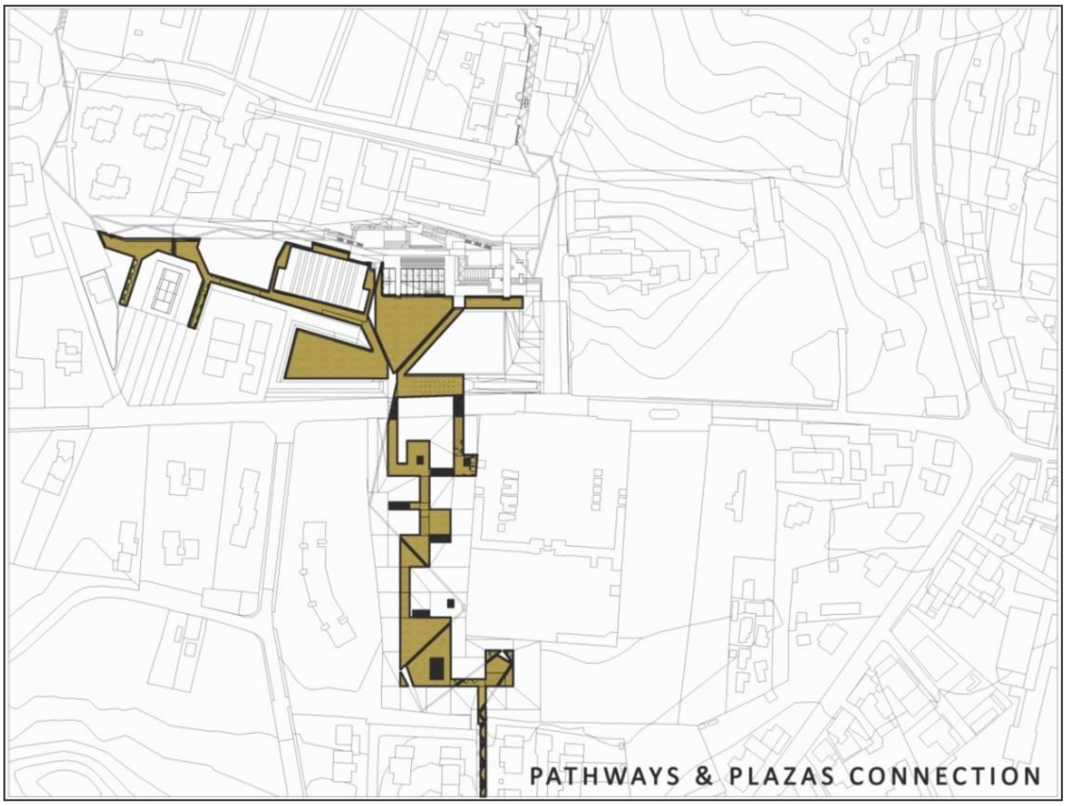


Illustration 73 Paths within the site layer

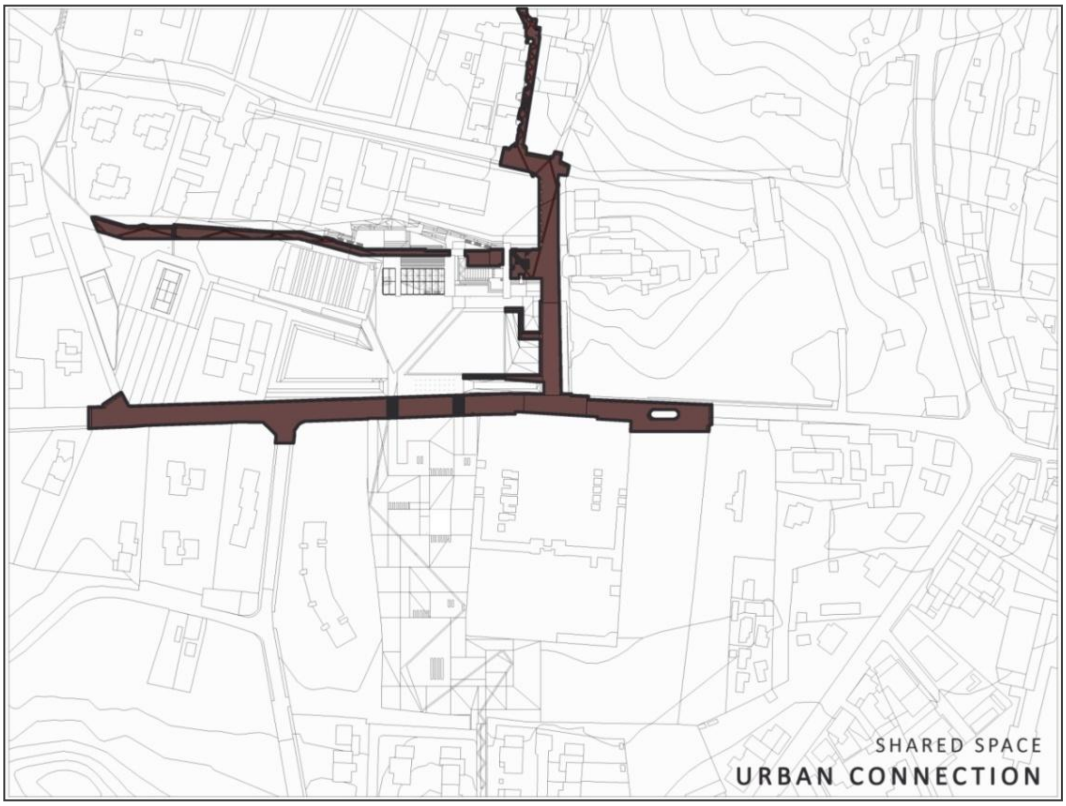


Illustration 74 Urban shared streets and paths layer

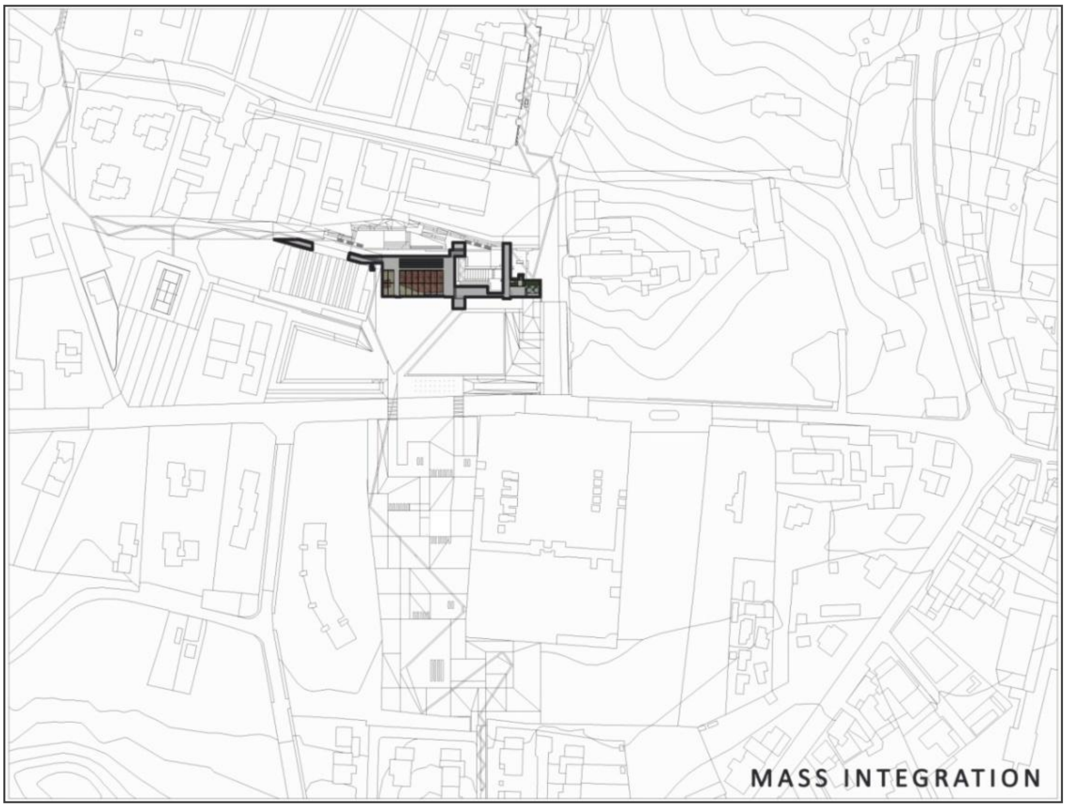


Illustration 75 Building layer

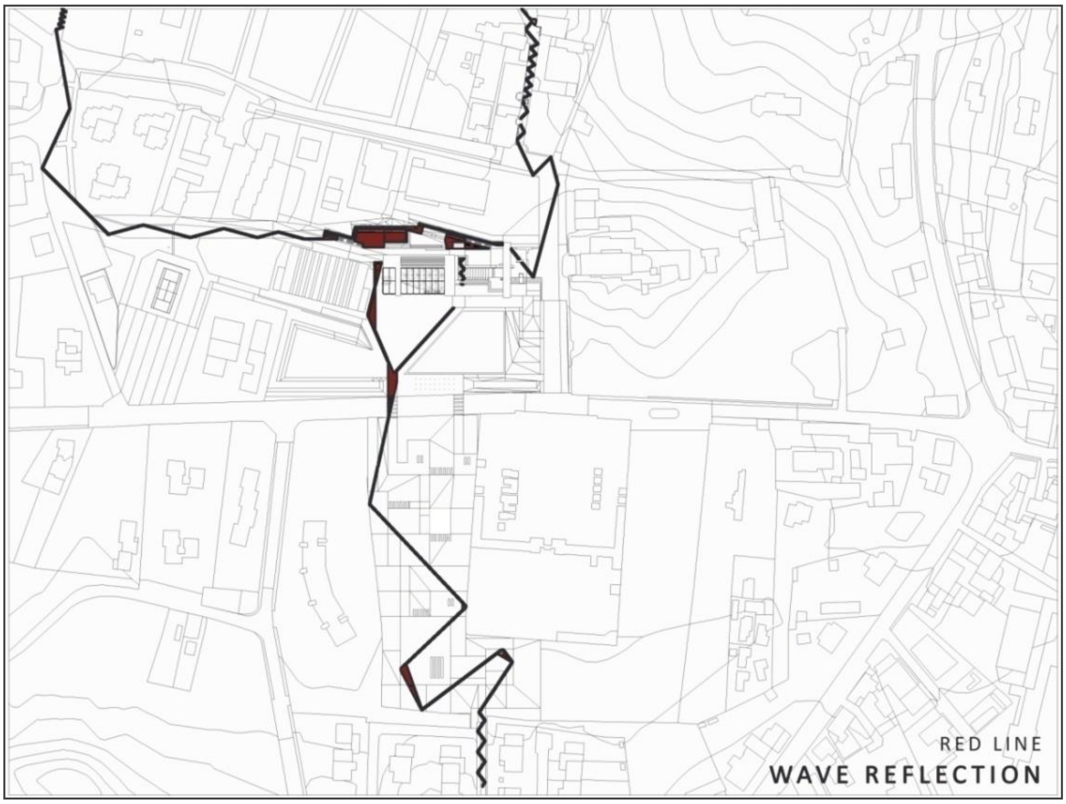


Illustration 76 Red line layer

THE RED LINE CONNECTION

How do you create a solid and open framework that can satisfy the wishes and needs of a developing culture and thousands of individuals from inside Calco and outside? Citizens and tourists?

This expression of a bold linear connection is not a finalized piece but an open creation that will receive content and shape through the dialogue with the users within the spaces. The choice of colors and materials begin as neutral to language and culture but acquire a meaning over time as they are used in the city-space and populated by the inhabitants. The different surfaces, colors and geometry of the line in contrast with its surroundings are integrated so that they become a backdrop for a variety of objects chosen by the designers. This backdrop is at the same time neutral, distinctive and discreet.

The line reflectance follows the same rules of a sound reflecting wave, thus, symbolically resembling the function of the main mass in the project which is the multi-purpose Auditorium/Hall of San Vigilio. The line is an eccentric element in both its movement path (it’s not related to the modularity/geometry of the existing pathways and green areas), and it’s morphing function, for sometimes it is merely a different color cutting through the paths, and in others it’s a bench for sitting down, or a raised flower pot…etc. this provoking explosion of many uses of the same element in the San Vigilio Red Line helps achieve another aim of making the neighborhood become the center of innovative urban spaces of local and international standards which can be an inspiration for other cities and neighborhoods.

Illustration 77 conceptual final outcome of the new proposal

The goal of the project is to invite users to a path in which the scene is always changing. The user will have the sensation of discovering an always-different space but with the same kind of characteristic. The five human senses are a theme of the space; the materials and vegetation relates to them. The user does not have an entire look over the park, but he will do through a series of the different senses. The variation of height, inclination, and dimensional games is part of the lucid peculiarity of the park; these views will be clearly shown in the final images in the end of this chapter.

The balanced blend of the natural essences (trees, shrubs and flowers) and the artificial elements (cement and resin) make the San Vigilio Park not only easy to maintain but also simultaneously durable and mutable.

RESULTING FUNCTIONAL ZONES

The new design has turned the twelve separate uses within the intervention area into three main interconnected zones with flexibility in usage and space configuration.
This project proposes a responsible urbanism based on the heterogeneity of the program, on the urban porosity and on the adaptability to the different situations and events.

We didn´t want an intervention that was working only in moments of concerts and festivals, we wanted a fabric that was forming a part of the day after day of the city offering daily spaces to the habitants of Calco.

The project develops along 3 main perpendicular axes in an extension of more than 41,000m2 meeting different situations of contour, which do that the action divides in three differentiated zones:

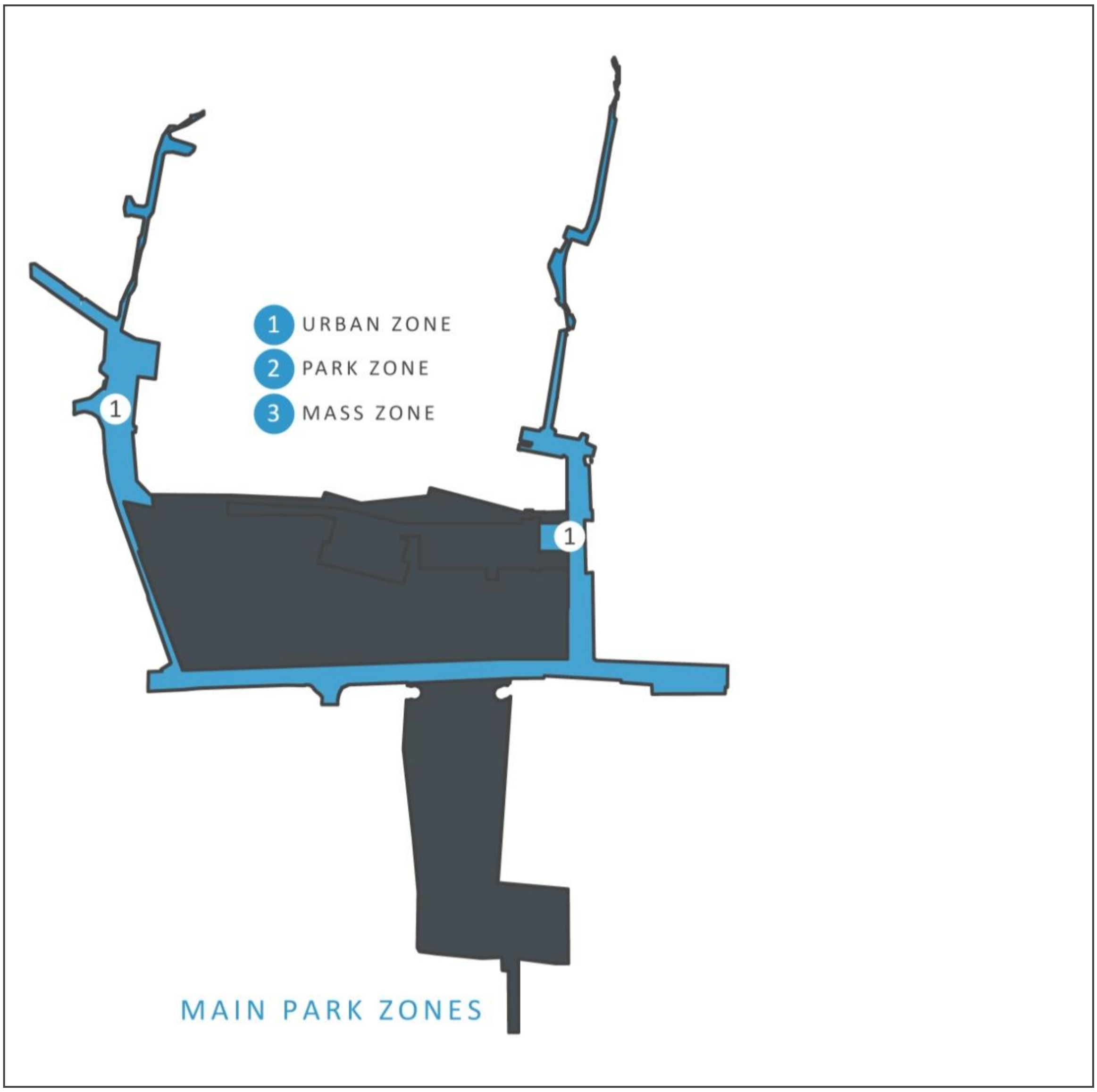


Illustration 78 The Urban Zone (Shared spaces) cutting through the site

Urban Zone

Consists on…

- The Historic Path (passes through the small historical center and reaching to the church and cemetery)

- Main Public Nodes (New enlarged Church Piazza, Entrance to site and to main paths nodes…etc.)
- Shared Paths

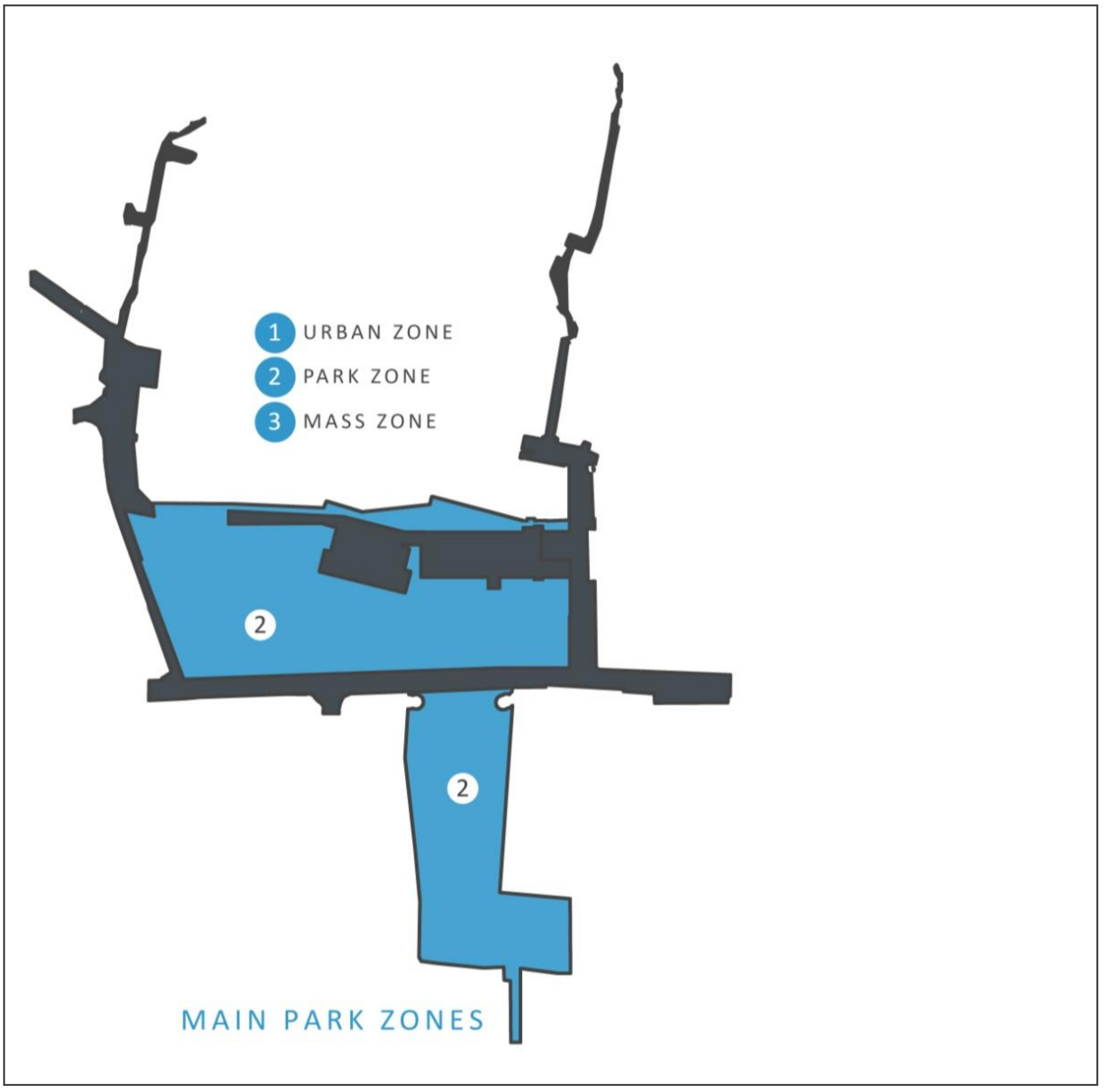


Illustration 79 The Park Zone within the site

Park Zone

Consists of one big mixed use space with varying ratios of usage proportions, these spaces can be verbally mentioned as follows…

- Linear Park (Starts from the Historic Center and the other end of the project and reaches to the lower part of the project)
- Leisure (Bars, Restaurant and Theater Zone) + Children's Area… Both areas are together to increase the safety factor in the physical and psychological sense.
- Active Zone (Youngsters' zone)
- Sports Zone (with a small bar serving that side of the project)

- Linking Paths

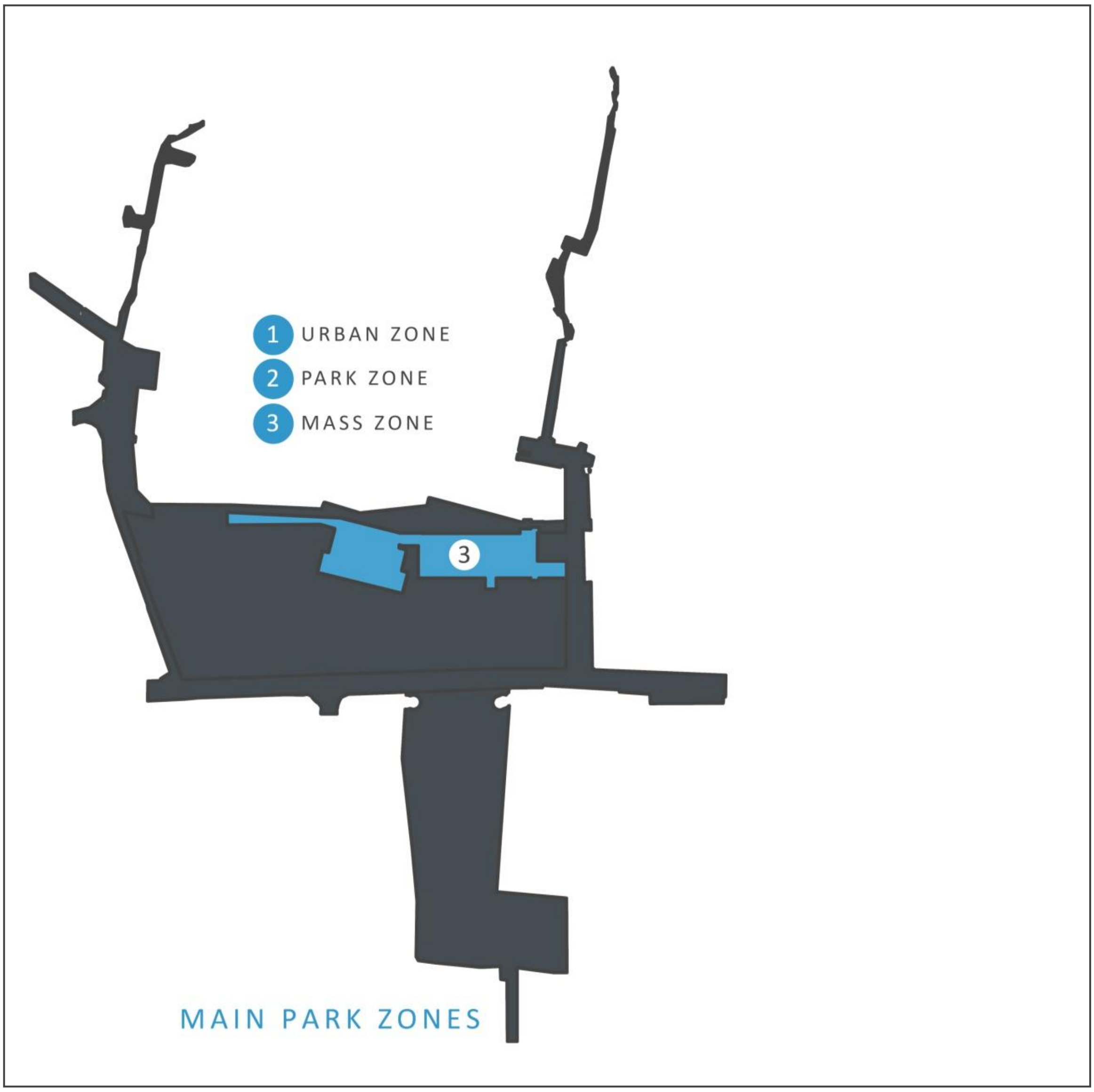


Illustration 80 The Mass Zone emerging from the site

Mass Zone

Consists of two main masses connected with an urban bridge/path/link and shading elements that tie the project horizontally. It's a path that connects the shared streets passing beside the site, the new masses, and also the palazzo dello sport.

The functions of the Mass zone can be generally divided into three main zones:

- Multi-Purpose Auditorium/hall
- Bars, Gallery/Store and Restaurant.
- Services

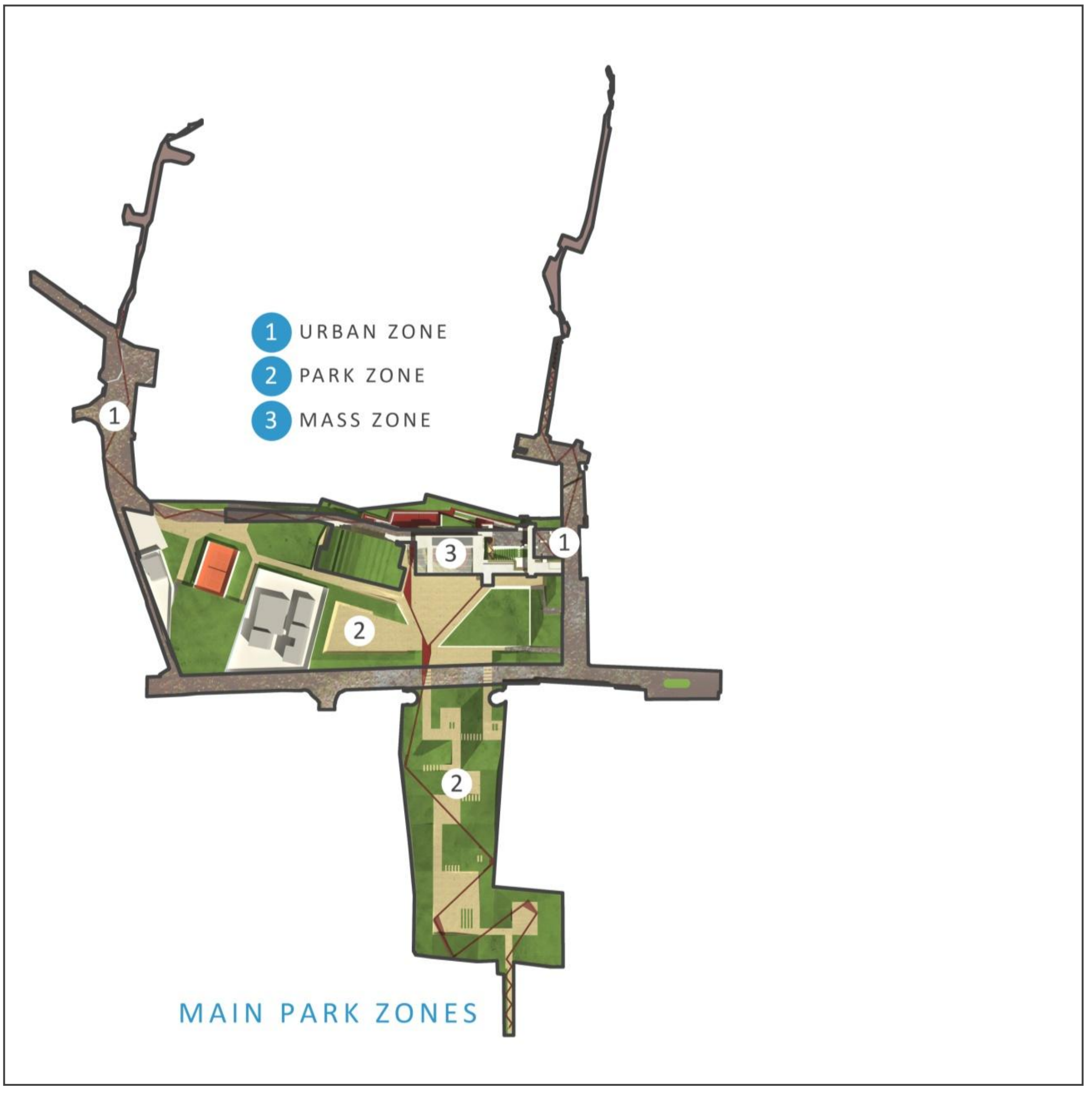


Illustration 81 The three zones overlapped, showing the final result

The project aims at getting its character from the use that the people of Calco does to it, and for how the project gradually is incorporated into the city as a living place, full of life and of possibilities of use and enjoyment.

The site presents a very singular situation. It's defined by a protective slope of trees and plants that form a hill located at a higher level than the surrounding streets and spaces. One consequence of this is that most of the building is buried behind this hill. This strategy allows the natural massive green slope to keep being the image and character of the urban net in this area of the city. The part of the building that stands out above the massive volume of trees and plants is therefore not very high.

6.1.3.3 Final layout

Illustration 82 Final layout proposal integrated within the context

Illustration 83 Final layout proposal integrated within the context

6.2 ARCHITECTURAL DESIGN

6.2.1 Study area analysis

PROGRAM

The basic program called for is:

- The Reorganization of the children playing area.
- The Expansion of existing facilities and bars.
- The Construction of a multipurpose modular building to replace the existing function with a space which can host events of different nature from the parties of the country & concerts, dances, performances to public meetings with a capacity of not less than 300 seats. Also to be held in high esteem the ability to have outdoor areas directly related to the facility to host activities in support during specific periods of the year, especially during the summer.
- The Redesigning of public open spaces, their relationship with the country, with the existing public buildings and the surrounding historical presence.
- The Connection with the pedestrian walkways network and the purpose of linking the area to the system of sustainable mobility at the urban scale and regional / provincial level.
- The Redesigning of parking spaces in line with the system of public spaces and the structure of urban mobility.

The aim of the project is to define a new city center that can have the same function also within a wide geographical area.

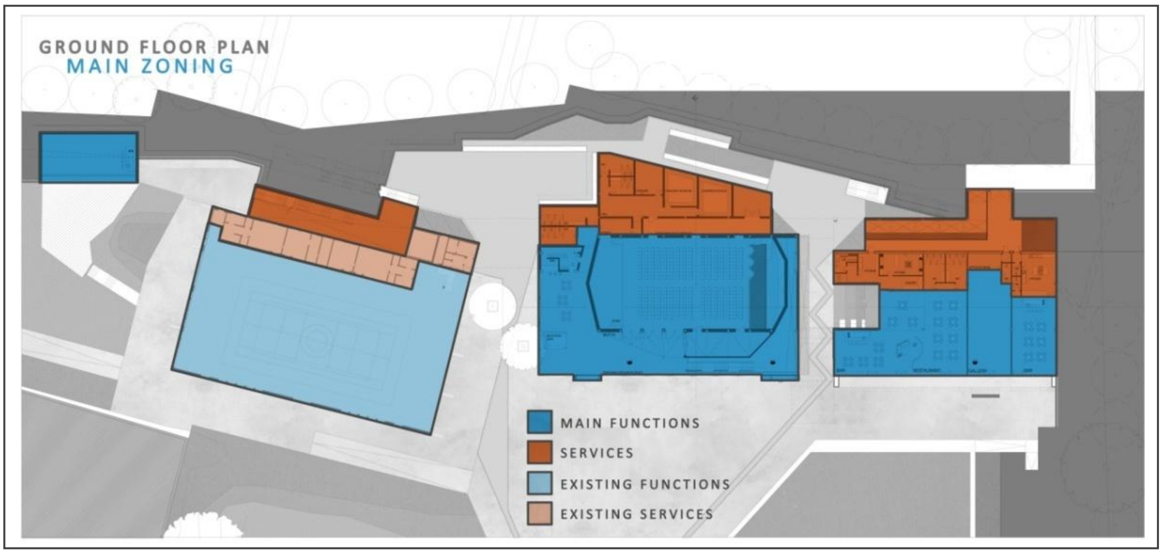


Illustration 84 Main zoning areas in relation with the site

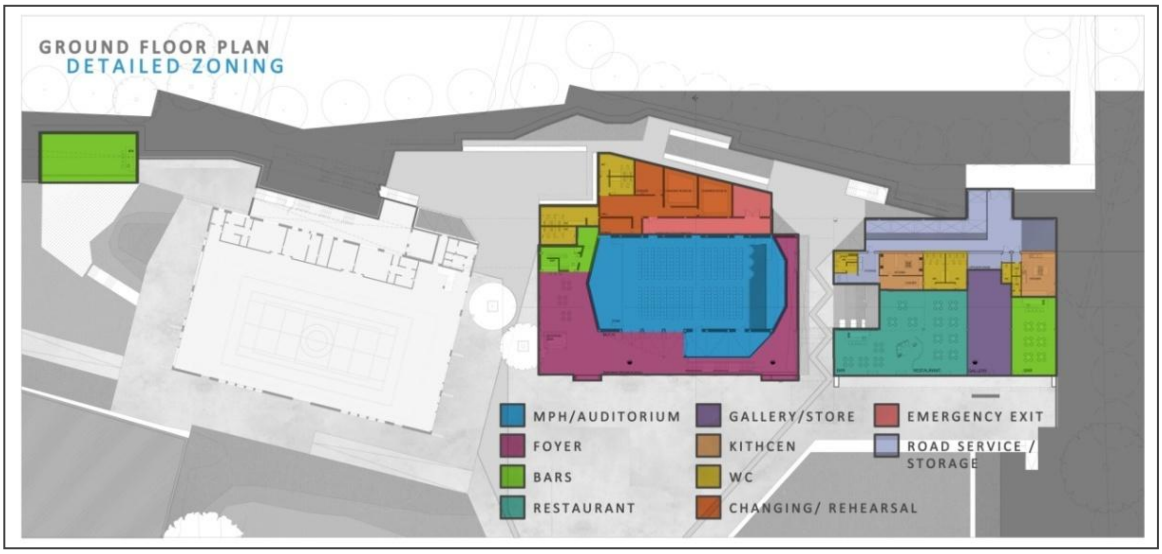


Illustration 85 Detailed zoning of the intervention area

6.2.2 Design

The building employs concrete surface smoothly growing out of the terrain to provide a platform that raises the glass structure from underground. By careful placement and design, these walls minimize the physical impact on the site. The main body of the complex is a linear construction oriented on an east-west axis. This linear organization allows almost all of the spaces of the complex to have sun exposure (other than the services).

Also, the rectangular shape has also been cited as an important part of the mass security (better perimeter control) and to improve internal circulations.

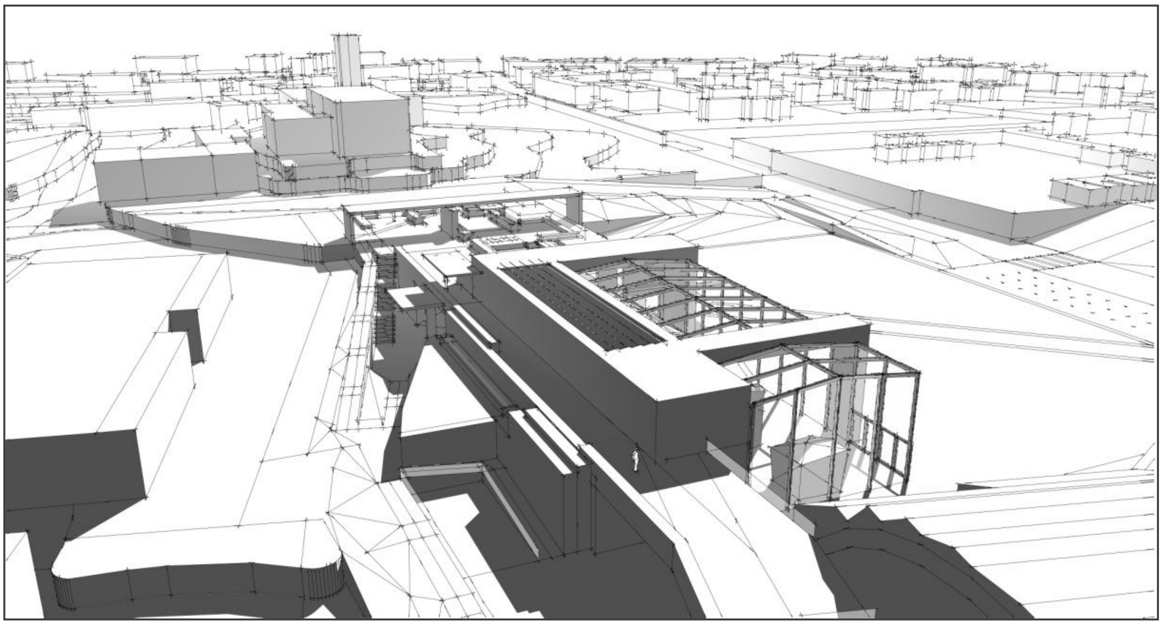


Illustration 86 Project's View.

6.2.3 Sustainability

The linear nature of the design maximizes the north/south exposures. Although the glass area on the south elevation is significant, the mullions within the glazing system (Okalux) and the pattern within, provide sun shading. Low e-glass and ETFE Cushions are used throughout. A linear slot of operable windows, at a height of five meters along the southern elevation, provides natural cooling from breezes in the summer. Additional insulation in the walls and roof provide excellent insulation and protection from the outer environment in both summer and winter.

Beyond the efficiency of the natural systems that the architectural design could achieve alone, the San Vigilio Complex takes into consideration environmentally conscious choices in energy efficiency, renewable energy, water efficiency, air quality, recycled materials and renewable resources, which will be discusses further in detail in the next chapters.

Preserving materials and resources was an initiative of the design in this project. Waste production from demolition and construction is aimed to be diverted from landfills by recycling and is meant also to continue to participate in routine recycling. A percentage of the materials have been chosen to be materials with recycled content. Other materials are directed towards renewable material.

Finally, each of the environmentally conscious and elements that went into the design of the building, are intended to be put into a case study and signage program throughout the site for visitors, clients and the occupants themselves to use as an educational tool and test subject to experiment with future green building products and initiatives; and minimizing the buildings impact on its environment.

6.2.4 Conceptual Approach

It's a "relations factory" for the city… A social condenser… A space to do things… anything! Simply do things … A place to communicate. Communicate with the World … To Know … To learn in a fun way!

The architectural design is merely a continuation of the urban and public spaces concept and strategy. The main approach of intervention is to evolve what exists rather than design something new from the beginning, this approach started by taking advantage of the context, for example, the terrain, and the level difference between the San Vigilio Church and the lower level green space (6.00m difference).
Note: The site area levels vary in a range of approximately 6-7m. The highest point of the site in the terrain is the San Vigilio Church base (+6.00m from the 0.00 level), and the lowest is the level of the cemetery open green margin (0.00 Level).

It is a building that dialogues with the city; a regular block, which gently lands on the land. It's a kind of constant sensory challenge that appeals to the discovery, experimentation, to a new way of experiencing Calco city!, a space where the physical boundaries of the site are diluted within the geometry of the shape and permeability zones created, reinforcing and contrasting with the fluidity of the surrounding urban space.

The building looks like a neat linear form, merging with the site in a way to easily seize the attention at both car speed and able to stimulate the curiosity of a walking passersby, in a constant game of seduction between "show" and "hide".

The interior is thought of as a kind of continuous linear functional series of spaces, except for the Auditorium/Hall where a geometrically morphing mass is born within a clear protecting box, exploring an idea of transparency, diluted within the structure, making the perception of different spaces possible and be a constant invitation to the movement and the discovery of spaces that are visible.

The intention is to "design something that differs in pace, but not so much in scale, from the rest of the city. We aim that when people enter the San Vigilio Zone, they would automatically slow your pace and behavior and switch to a different position due to the physical restrictions that makes up the space."

6.2.5 Accessibility (Horizontal + Vertical) and Main Entrances:

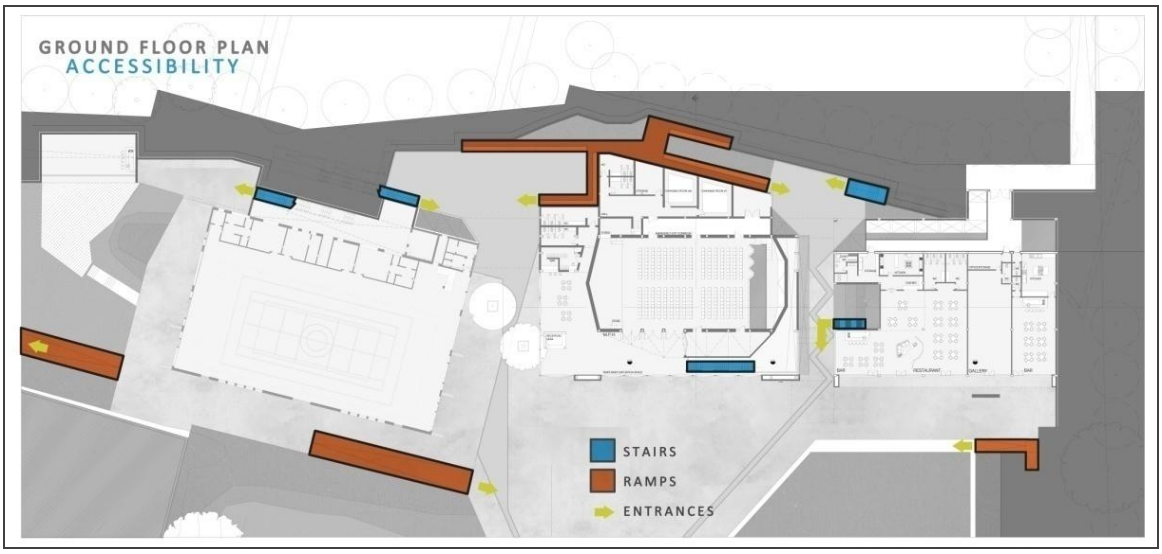


Illustration 87 Accessibility diagram

6.2.5.1 Form blow up:

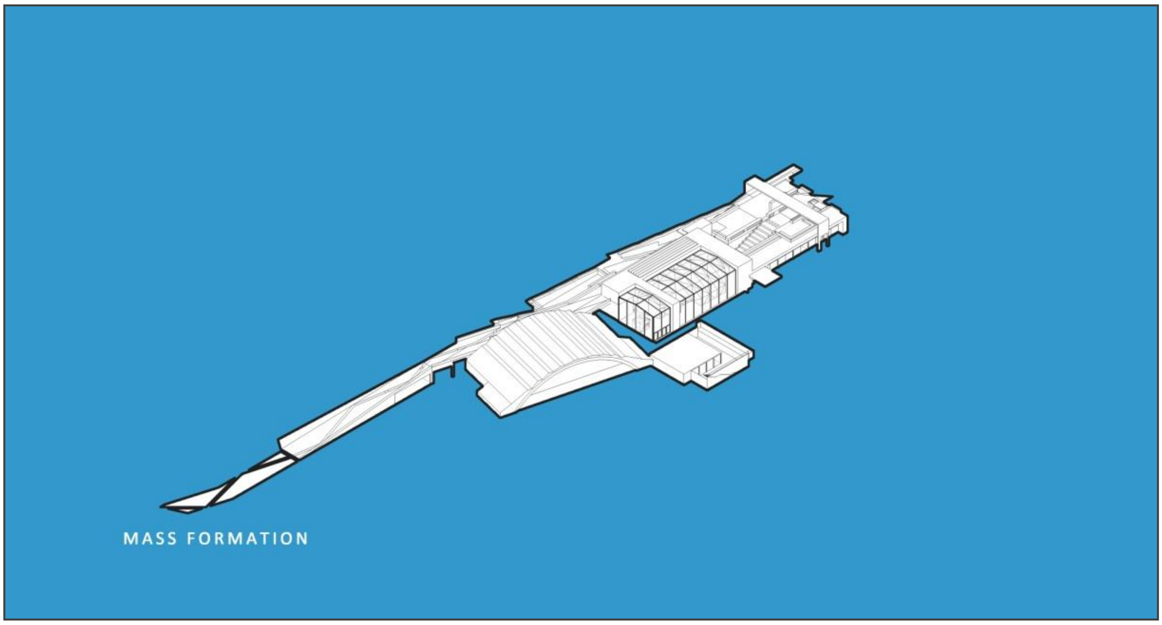


Illustration 88 Study of the whole structure morphology

The division of the single space aims at a non-minimalistic and lively sequence of confined and airy spaces, interiors and exteriors, horizontal and vertical views as well as carefully framed views of the site. The continuous interior space is opening up to the park open spaces, to the transitional zone (in the Auditorium/hall zone), and to the sky above (with Skylights).

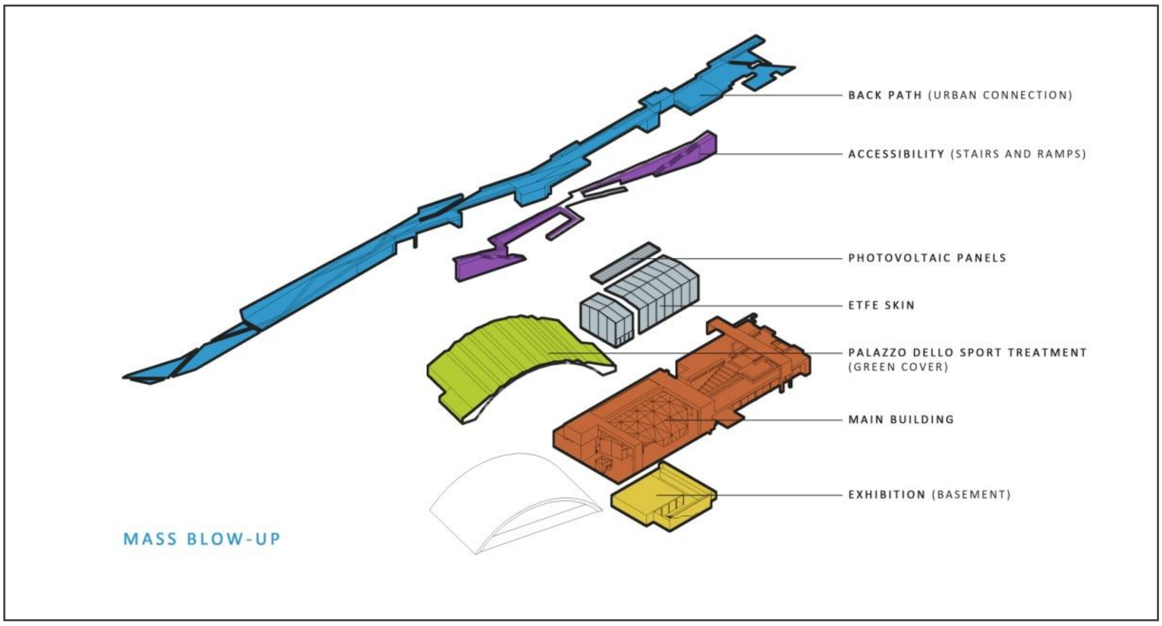


Illustration 89 Study of the blow up of all the masses design within the site

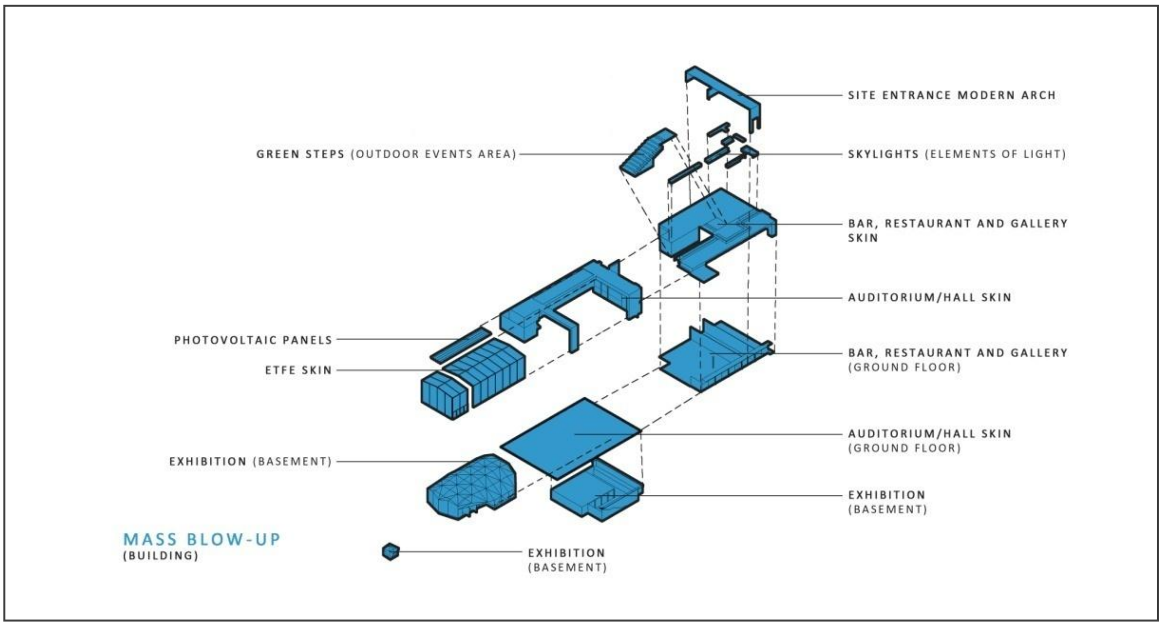


Illustration 90 Study of the blow up of the main two buildings (MPH / Auditorium and the Restaurant, Bar and Gallery Zones)

The openness to all directions generates a building both iconic and transparent. All facades are treated equally in terms of transparency and opacity, exposing the interior and offering views through the building with similar apertures whether on the south, east or west fronts.

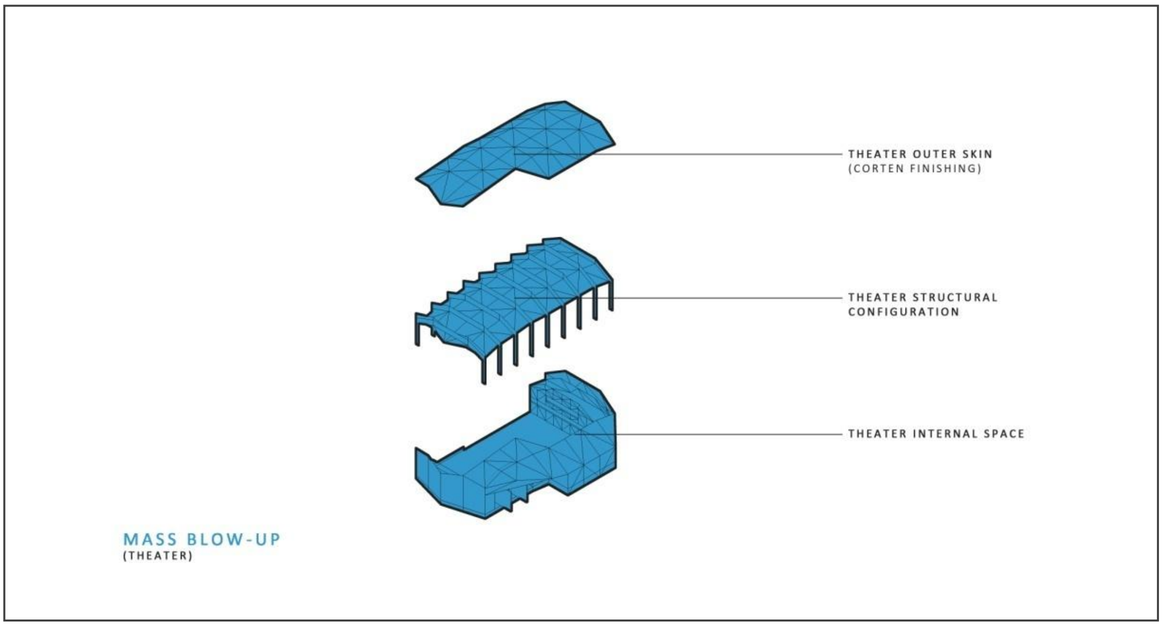


Illustration 91 Study of the blow up of the main space in the project (MPH / Auditorium)

6.2.6 Skyline, greenline and groundline:

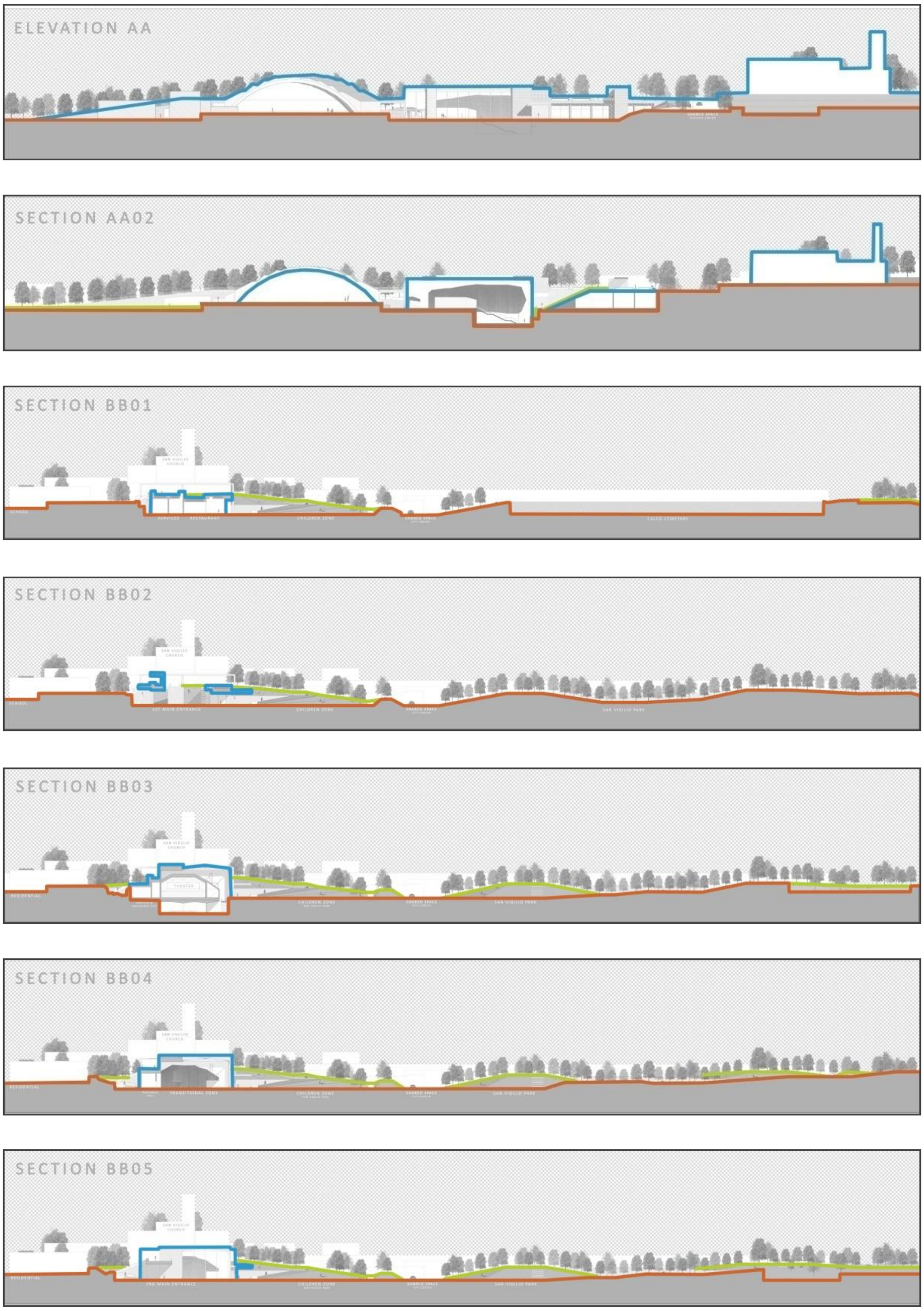


Illustration 92 relation between the groundline, skyline and greenlines in various sections in the project

6.2.7 Design proposal

6.2.7.1 Layout

The proposal of the San Vigilio Park aims at creating an environment for free and safe interactions that can also be a space for culture and learning. This design is aimed to pose a question… How to intervene an emblematic, new, yet not an invasive formation in such a complex site, and at the same time provide safe and socially active public spaces in the city?

The San Vigilio site possesses unique characteristics in the city, not only because of the historic church in the background, but also because it acts as an urban centrality, and because of its singular morphology, which gives it a 180 degree front, but a 360 degree usage. Programs such as a children space, and the multi-purpose space, which allows for community work, complements the given program of the Palazzo dello sport, bar/cafe, exhibition hall, lobby and outdoor spaces.

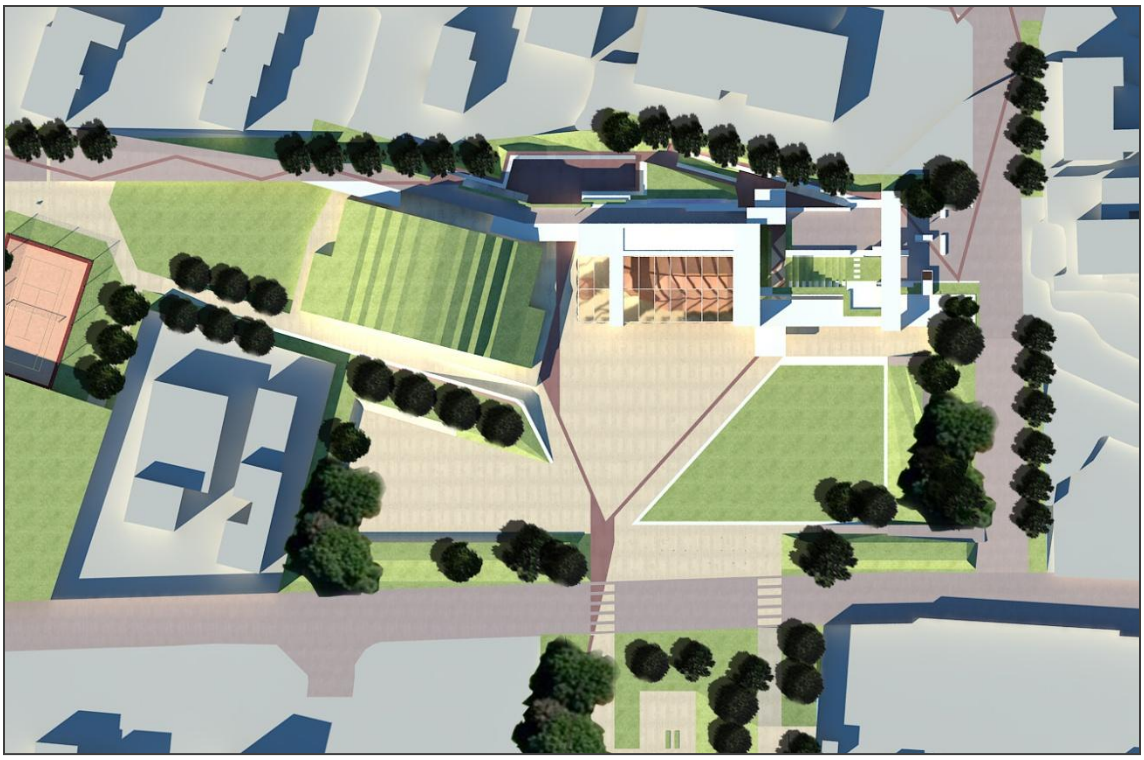


Illustration 93 Final Proposed Layout

The project aims to preserve the historical value and prominence of the original historical district by smoothly integrating it to the new proposed complex. The new building is a linear sequence of masses. Its thread of volumes not only has a light footprint but also confers an interweaving rhythm to its linear promenade. The space divisions functionally conform to all aspects comprised in the program. Interior and exterior, empty space and exhibit space, nature and building are connected through a series of passages, ramps and crossovers. The interiors offer interesting views and spatial experiences by playing with light. The skylights use light diffusers that take into account insulation and energetic resource preservation. The ends of the museum stretching out into the water shores integrate the experience of nature to the exhibit space.

6.2.7.2 Plan

In plan, the floor is split in two halves perpendicularly by the entrances to the site, in which their origin is the continuous ramp that starts from the church area and that links each level of each building. A backbone linear service blocks through the masses of each plan plate that contains egress and building support.

A linear scheme, makes an easy visual domain, both towards the inside and outside, by the visitor possible, approaching a real public social system; this scheme is completed by generating connections and slopes of accessibility facing both forward and backward, and visually penetrating transparent vertical surfaces, turning it into a backless building.

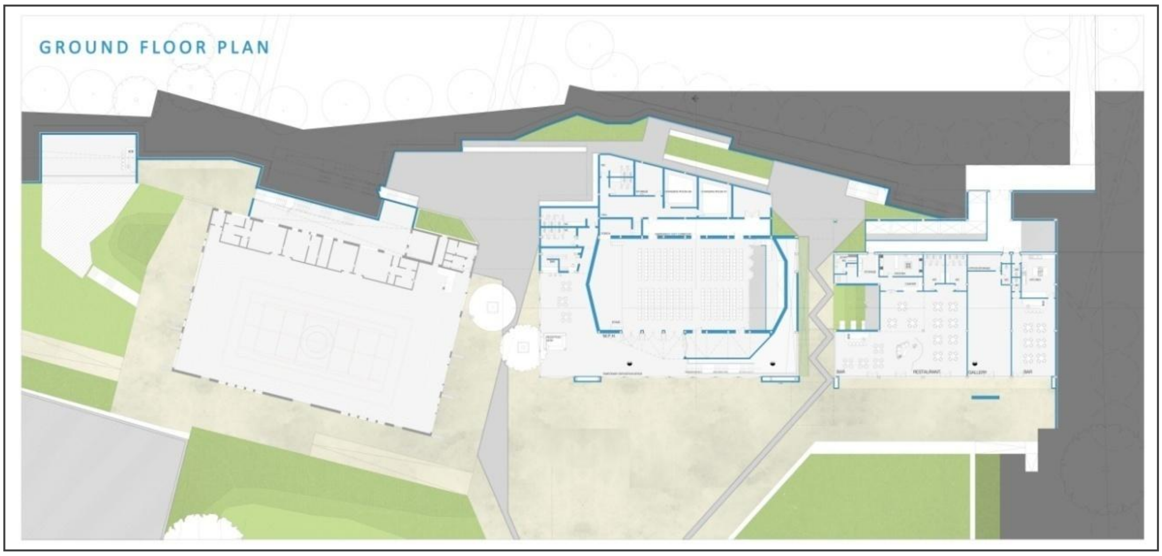


Illustration 94 Final Proposal Plan

Finally, the restaurant, bar and gallery of public use articulates the linearity of the different parts of the program, allowing a constant and balanced flow of activities: an active and programmed circulation acting as leisure, stroll and/or rest space, which, given its stretched linear form, allows the safe monitoring of the children space in front of it. Main plaza in front of the multi-purpose space, and platform parallel to the linear gallery and perpendicular to the linear park penetrating path let visitors and passers-by alike go through the space freely, connecting the whole project to the surrounding streets, and introducing true public space into the project.

6.2.7.3 *Sections & Elevations*

In section, each floor is aligned on split levels adding greater hierarchy to the whole project. The designed program efficiently makes the project permeable, which coupled with a subtracting operation on part of the more recent buildings, allows for a passive touching and articulation of the only two existing buildings on the site (Church & Palazzo).

Illustration 95 Horizontal Section Lines

Illustration 96 Final Proposal South Elevation

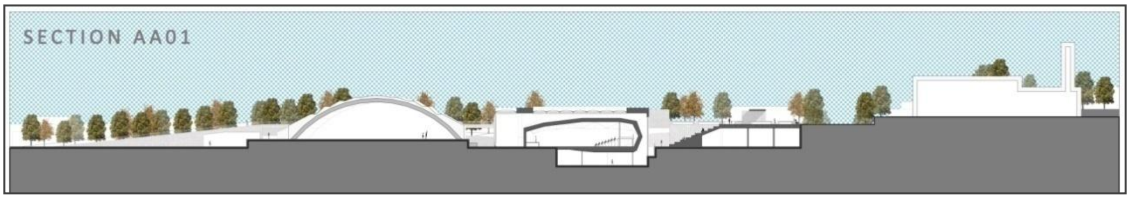


Illustration 97 Final Proposal Section AA01

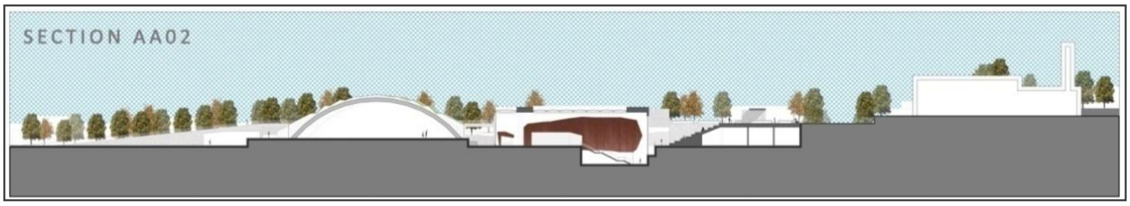


Illustration 98 Final Proposal Section AA02

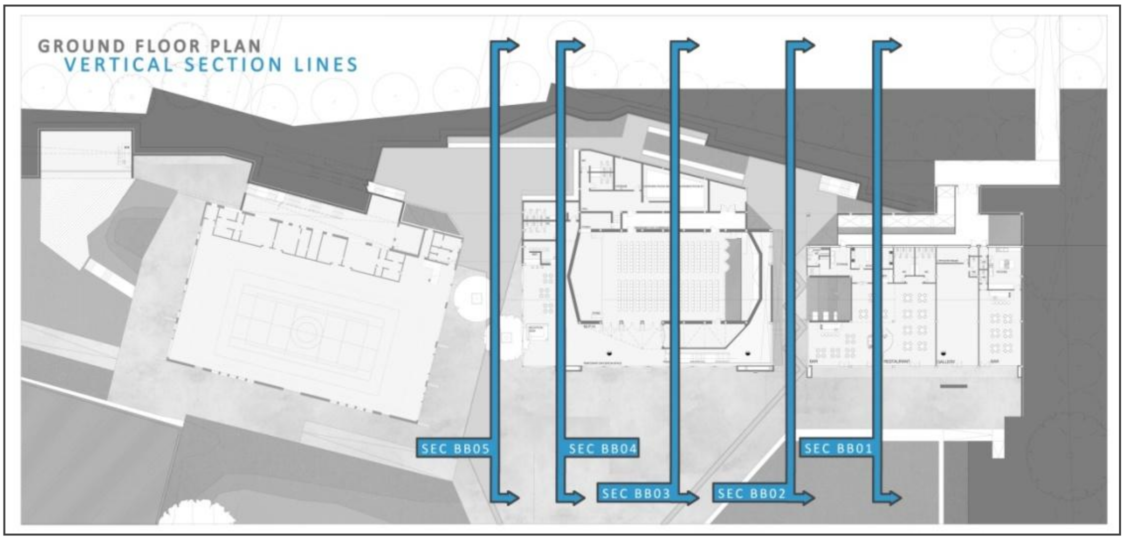


Illustration 99 Vertical Section Lines

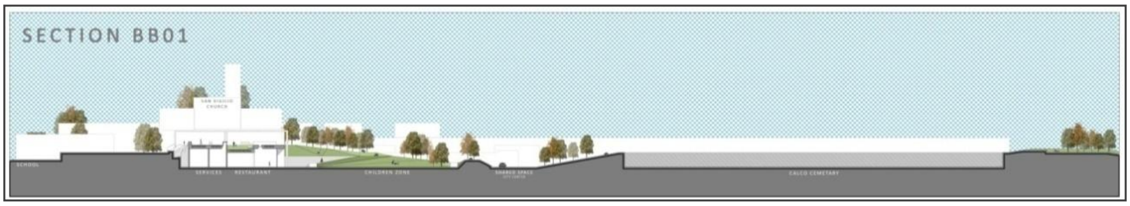


Illustration 100 Final Proposal Section BB01

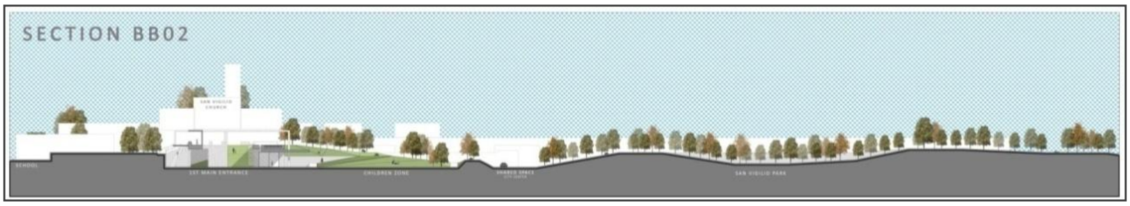


Illustration 101 Final Proposal Section BB02 / West Elevation 01

Illustration 102 Final Proposal Section BB03

Illustration 103 Final Proposal Section BB04

Illustration 104 Final Proposal Section BB05 / West Elevation 02

6.2.7.4 Final results

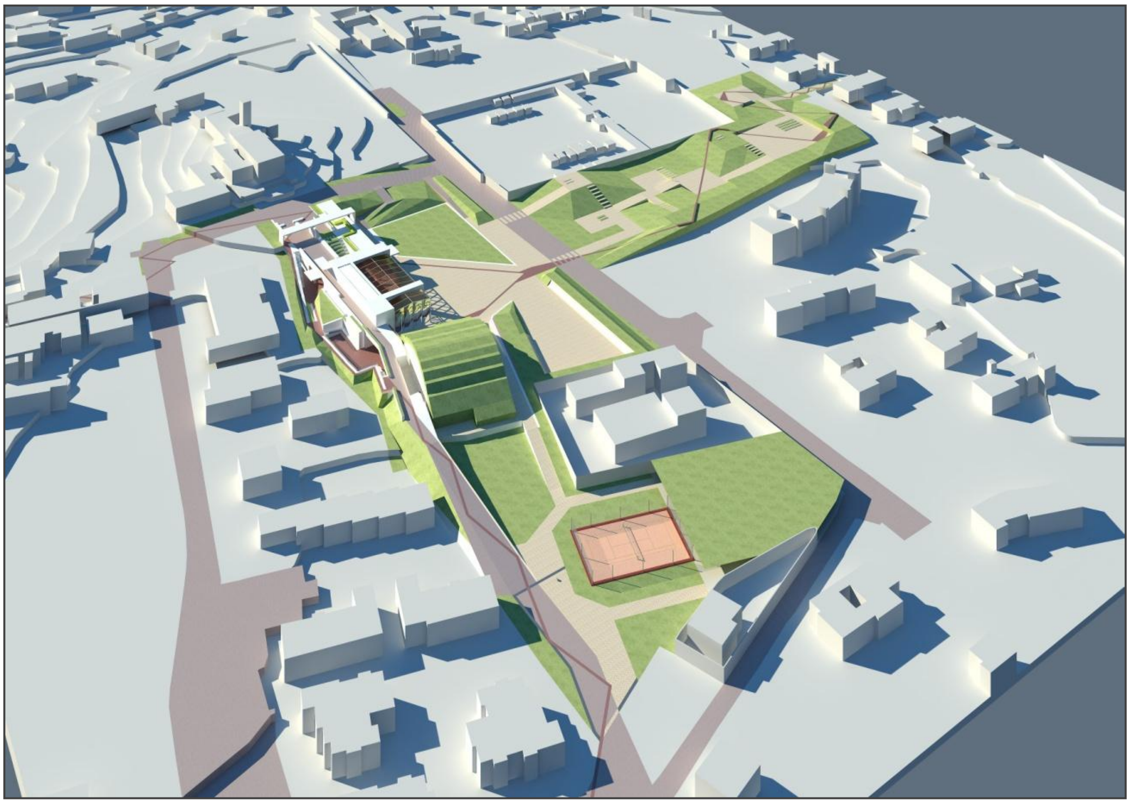


Illustration 105 Full San Vigilio Intervention Proposal

Illustration 106 Shot showing the relation between the project and the existing context

ETFE…..As it is just a cover for the internal spaces, its transparency (plastic) allows the evolving mass behind it to be part of the intervention and fully visible from all over the square and all around its zone, and at the same time, creating not invading the current urban structure surrounding it.

During the day, the sunlight of Calco, passing through the semi-translucent ETFE Fabric, makes the internal morphing mass a mystery element that attracts the eye to see what's behind the curtain, while at night, the texture if the COR-TEN steel with the direct and indirect lighting makes it glow red and reveals the expressive projections of the structure's shadows. At night, when the events take place, the theater is illuminated into a sinuous frame of red-brown light.

The system of operable ETFE hydraulic screens on the exterior of the building encloses theater and exhibition spaces. These screens act as filters for both light and view. Easily operable, these screens can be raised to allow for more porosity or kept in place for visual interest.

When opened (mainly in the summer and spring seasons) the screens act as a vertically cantilevered canopy. As the light moves across the screens shadows slide across surfaces creating an ever-changing façade. Also, the landscape becomes an extension of the intermediate area. The material of the interior and exterior faces blend together and the natural greens of the surrounding hills become one with the structure.

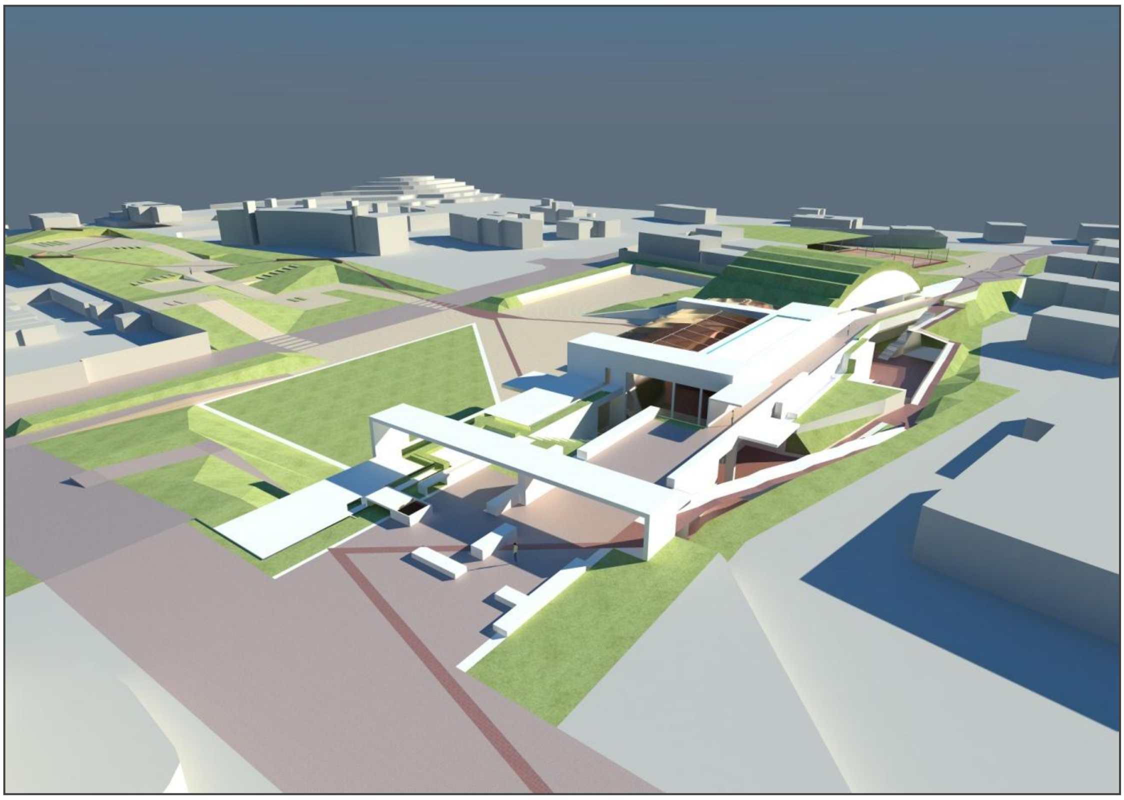


Illustration 107 View from the Church (Bird's Eye)

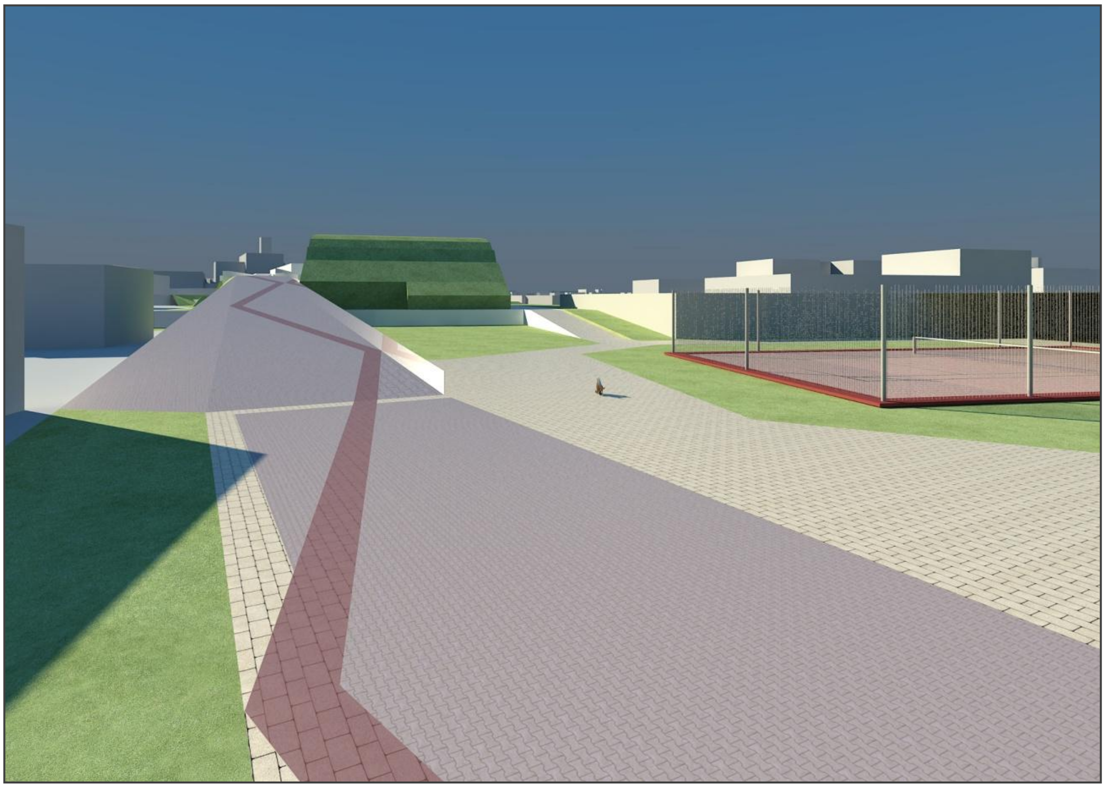


Illustration 108 View from the West end of the project, highlighting the visual relation between the back path and the church, as well as the functional relation with the rest of the project

The back path of the San Vigilio Complex is a unique architectural and urban element in that the basis of its proposition is an exchange of transit medium, an urban connection of both ends of the site, and an architectural feature that links the different parts of the project to form a necklace of functions and spaces.
Given this transformation, the project envisions a potential larger than a pure connector. The proposed Path works as a spatial mediator between urban spaces and functions allowing east and west to become a singular meandering public space. With this perspective, the proposal is better understood less as a bridge and more as an urban intervention.

The alignment of this urban intervention simultaneously considers orientation and views during the procession, and frames of view toward the park and auditorium as an artistic object itself. Circulation of pedestrians and cyclists through the bridge is thought of as a series of tentacles gathering and dispersing users from numerous regions and directions.

The east side of the bridge splinters into varying directions indicating subtle axis towards the main park axis. The west side is mediated with the quiet side of the park, and parking space, plus that it connects to the shared space that orients travelers in two different directions, north or south.
Circulation to/from the linear park zone occurs through a newly created urban pedestrian (taking into consideration the disabled) and cycling entrances along the north side of the auditorium. The urban path is situated to directly connect with the mixed-use spaces to the south and is perpendicular to the main park spine, denoting an exit to the to the west end of the project.

The morphology of the urban intervention is characterized directly by the program considerations, orientation of access, views (urban and natural), and the relation between the history of the city and province and the future of innovation. The uniqueness of the bridge form itself benefits the city less of an object and more of an intervention into the landscape of the city with programmatic elements that serve the city in all four seasons. The urban intervention is also immersed within dual colors of synthesizing traditional materials of stone.

6.2.8 Project View Analysis

6.2.8.1 From church

The first thing that was thought about in redefining this open space was in terms of scale and visual attraction. The proposal was to enlarge the open space in front of the church in order to give a more coherent proportion of width to height (plaza to church), and to add attracting elements, mini landmarks that would work as technological elements (Skylights), as well as social elements (Seating places) and aesthetically appealing.

"Elements of Light", as we call it, has been placed in the main plaza area (which coincides with the bar, gallery and restaurant in the lower level). What we mean by the "Elements of Light" are rectangular, cubic light-wells of different shapes, with mono neutral color and facing different directions in the high ceiling bringing in various "lights" into the interior space, changing with the time and the seasons.

The users may be able to feel the changes of these "lights", and interact with them in different ways, and to enjoy this gift of "light" in their daily activities.
Furthermore, the shape of the "Elements of Light" may be seen from the outside as its unique silhouettes are outlined against the new urban scenery, providing it with a little more character.

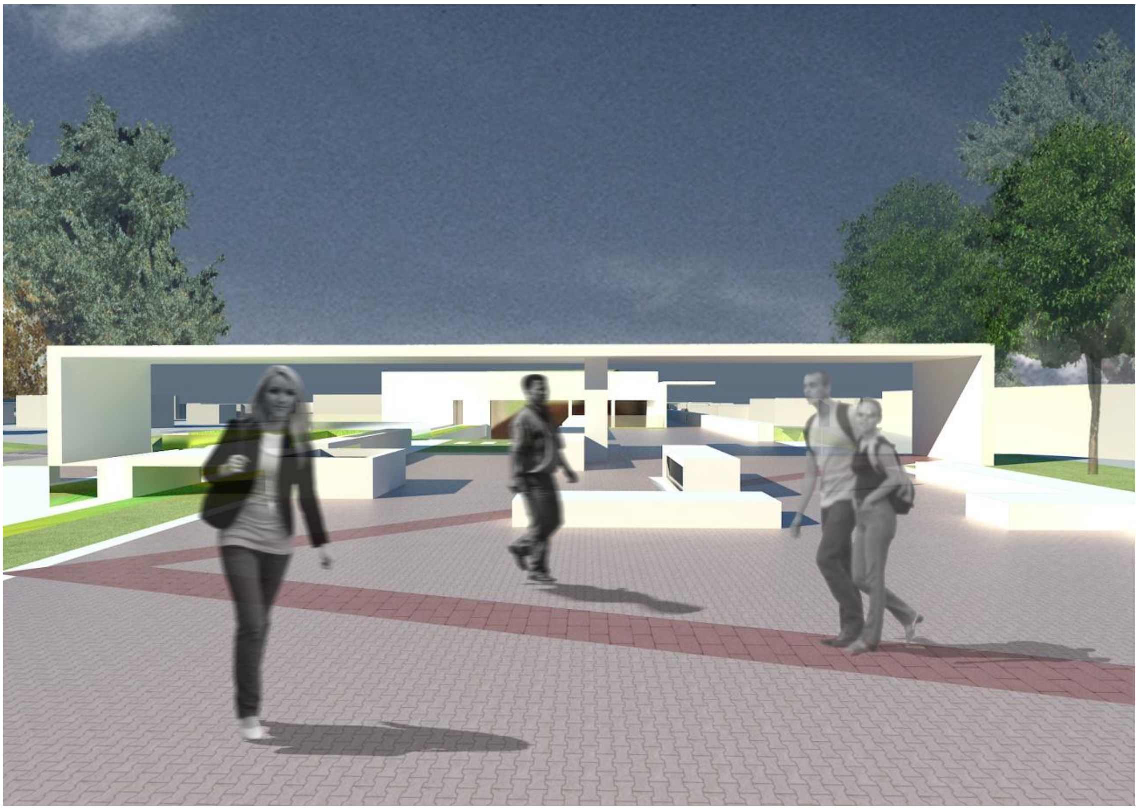


Illustration 109 Shot from the San Vigilio Church Entrance

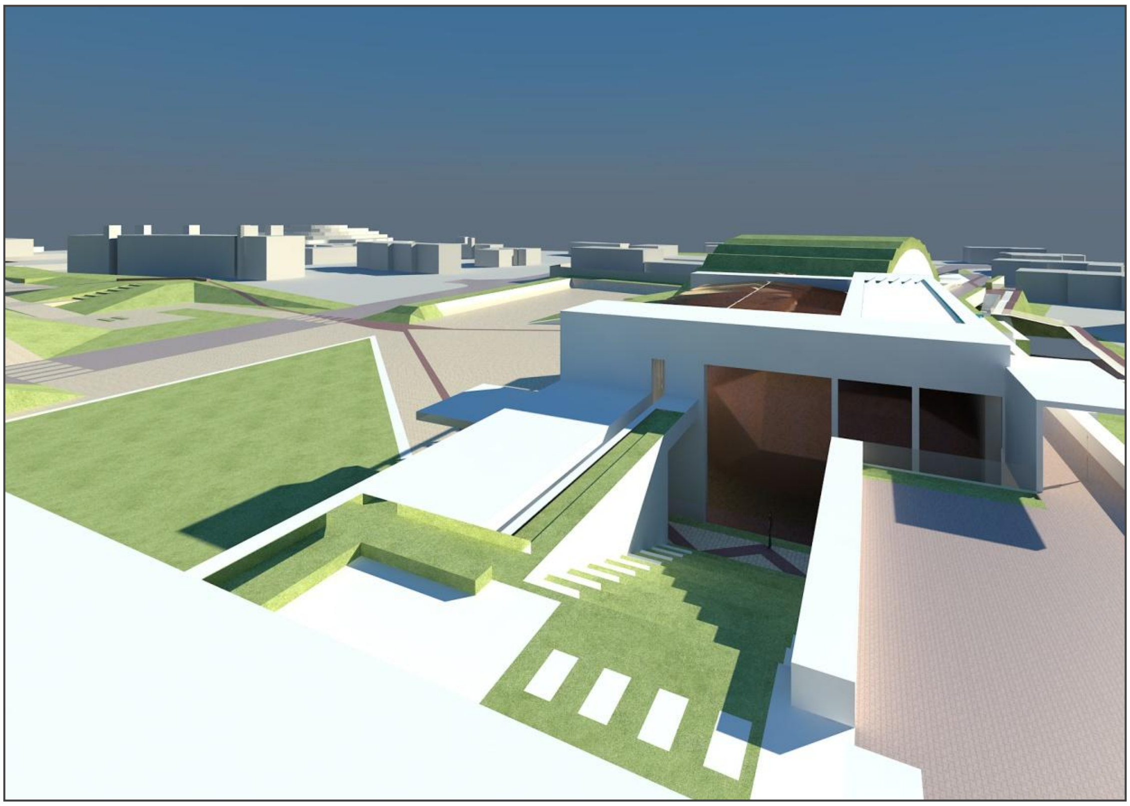


Illustration 110 interconnection in accessibility and functional relations

6.2.8.2 Back path and main entrances:

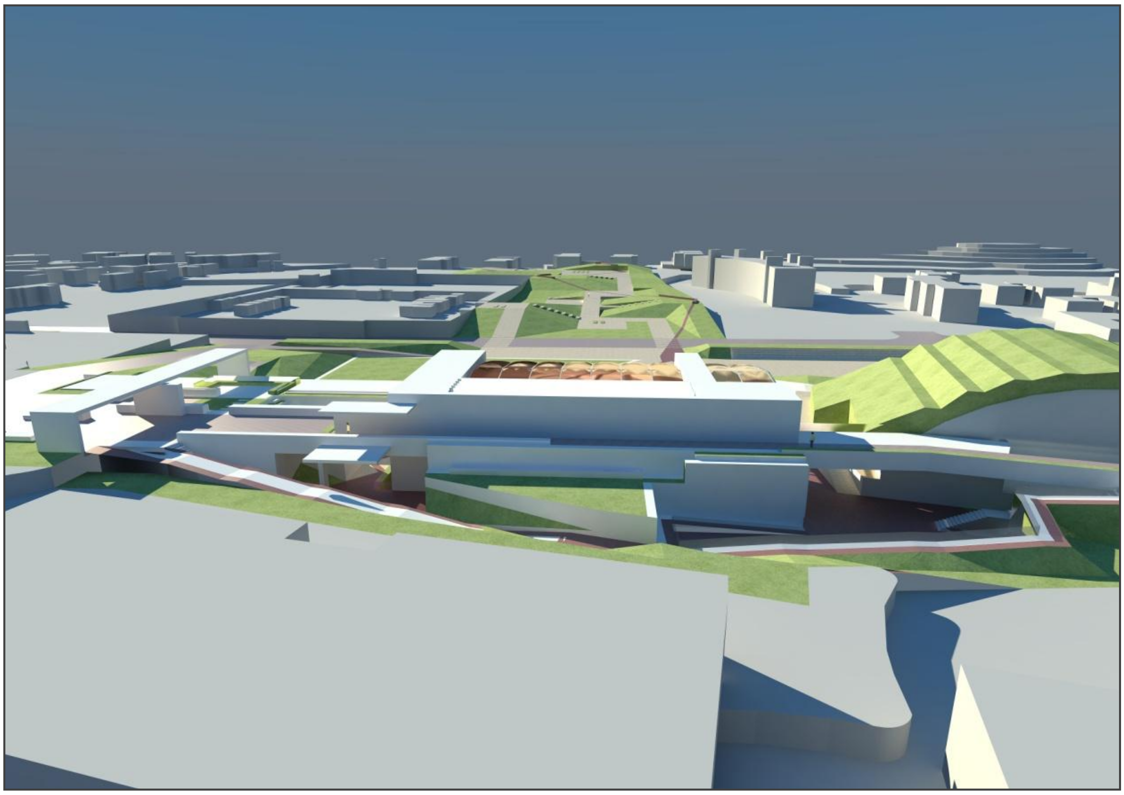


Illustration 111 back path and main entrances to the site

The back path (placed in the north of the project) acts as an urban link between the eastern and western parts of the project. This link incorporates the main entrances to the newly “evolved” building, as well as links to the palazzo dello sport audience entrance to watch the games.

The overall massing and orientation of the complex aim to connect its inhabitants to the surrounding environment by linking the exterior space with the buildings’ spaces. This, coupled with the linear internal approach to the building, is a fundamental break from the past that serves to marry contemporary ideas of promenade and aesthetics with the machine-like function and economic derivation that forms the conventional buildings within the site.

6.2.8.3 Leisure Children Zone

Illustration 112 relation between the children zone and the catering zone

6.2.8.4 Youngsters area

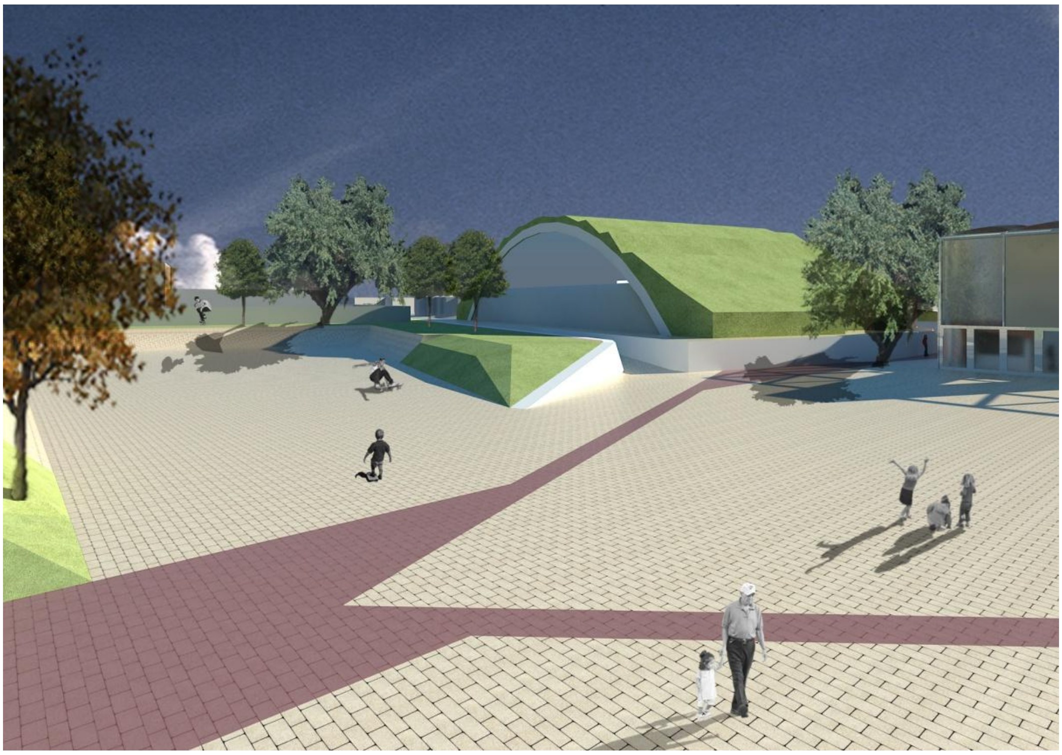


Illustration 113 relation of the youngsters zone with the palazzo dello sport and the Auditorium Zone

6.2.8.5 Sports zone + bar

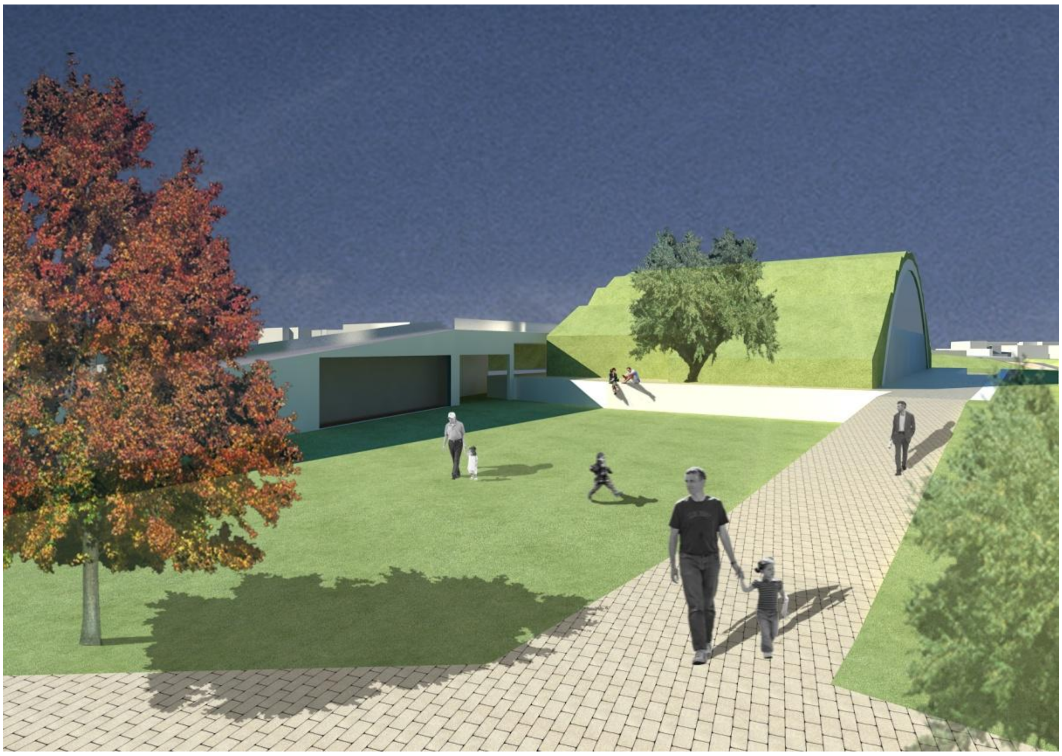


Illustration 114 relation between the back path, bar and the palazzo

6.2.8.6 San Vigilio park

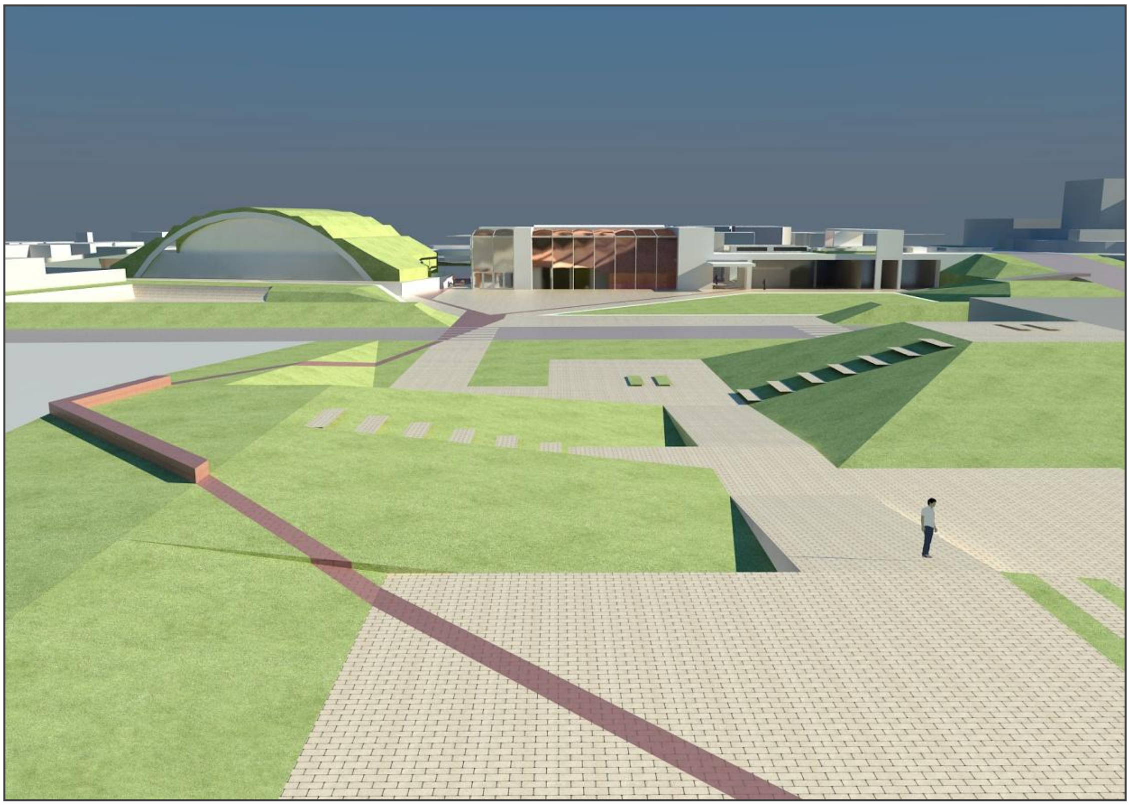


Illustration 115 A view from the linear park (Facing North – San Vigilio on the right)

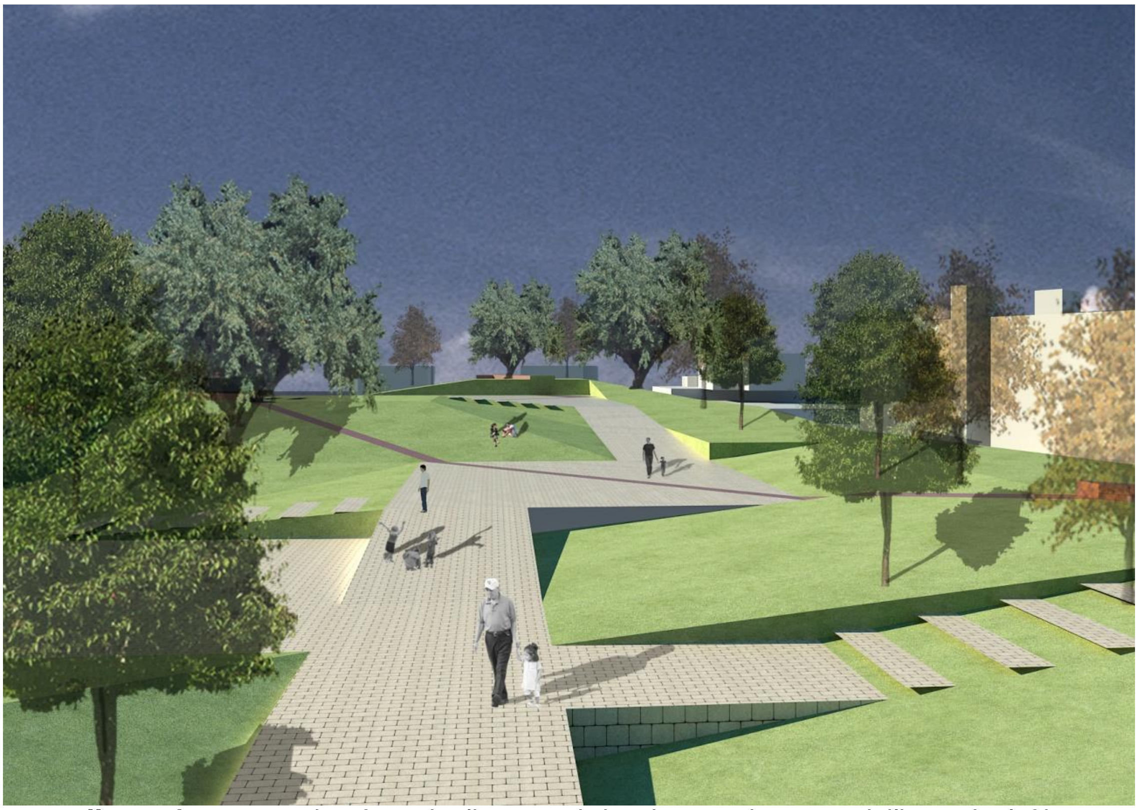


Illustration 116 A view from the linear park (Facing South – San Vigilio on the left)

6.2.8.7 Small street treatment

Illustration 117 Green walls and Red Line treatment in the small historic center street

6.2.8.8 Transitional zone and theater

The rustic COR-TEN steel material used as the theater cladding system resembles a modern abstraction of the regular and popularly used pitched roof tiles in the city of Calco. The form of the Theater represents a freed expression from the constrained norms of construction but with a sense of origin, that was shown through the geometrical triangular lines creating the final morphing mass.

The big volumetric scale of the theater, with this COR-TEN structure (made out of prefabricated modular parts), was designed to impose itself as both an architectonic and an urban iconic catalyzer while retaining and respecting the consolidated spatial hierarchy of the surrounding buildings and context. At the same time, it takes advantage of the use of color as an urban activator contrasting with the subdued color and materials of the surrounding spaces.

As for the stage and seating places, they were designed to be intangible and flexible, and to mingle with the people and the city. Therefore, a flexible seating system was incorporated in the design of the space which can be easily retracted when is not needed, in which complies with the request from the municipality to have a flexible space, as well as serves the concept of the space and place evolution in terms of usage, materials and elements.

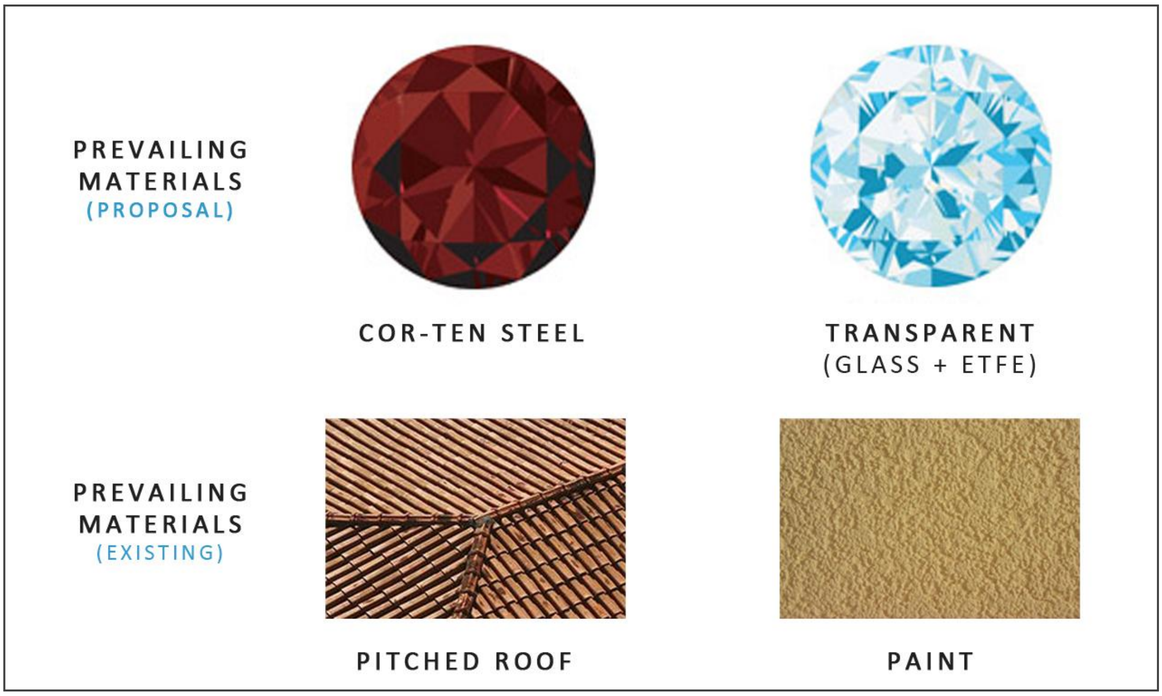


Illustration 118 abstraction of the prevailing materials in the existing situation and the new proposal

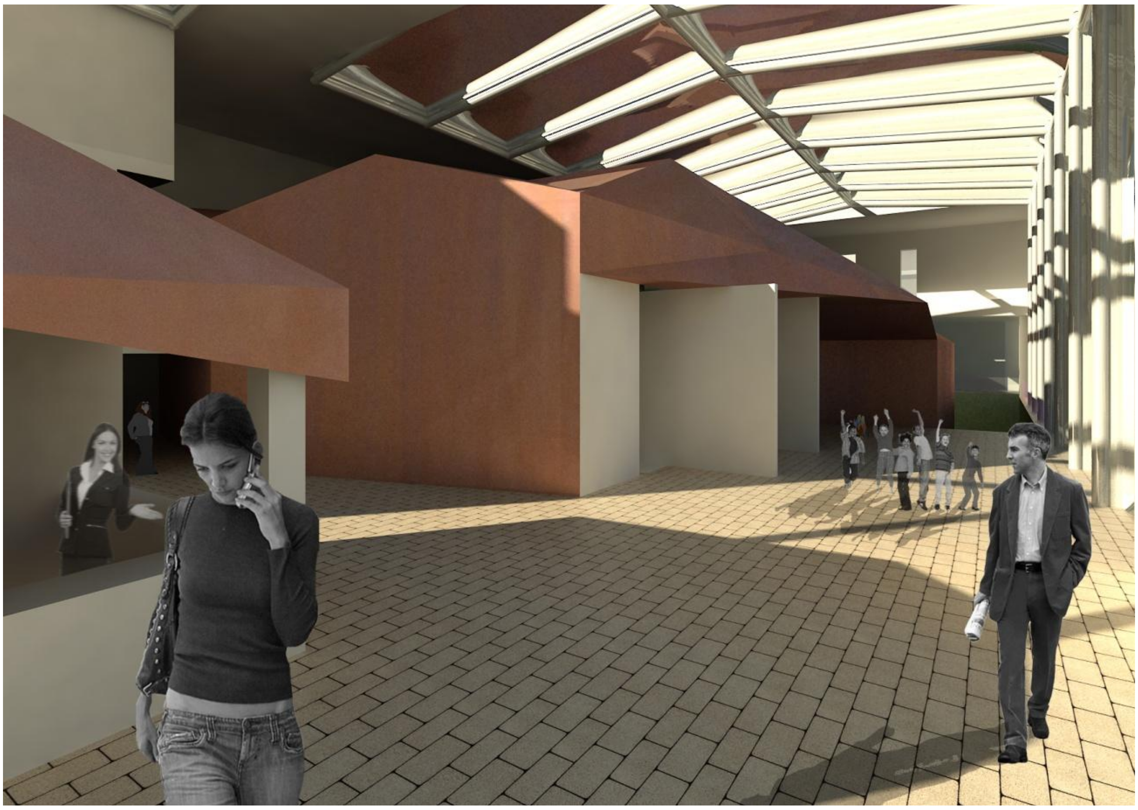


Illustration 119 Interior shot of the Multi-purpose Auditorium/Hall Zone

In the following chapters, it will be explored the efficiency of the design in accordance with its characteristics of the site, building design and its surroundings in terms of thermal behavior, energy conservation and sustainability.

STRUCTURAL DESIGN

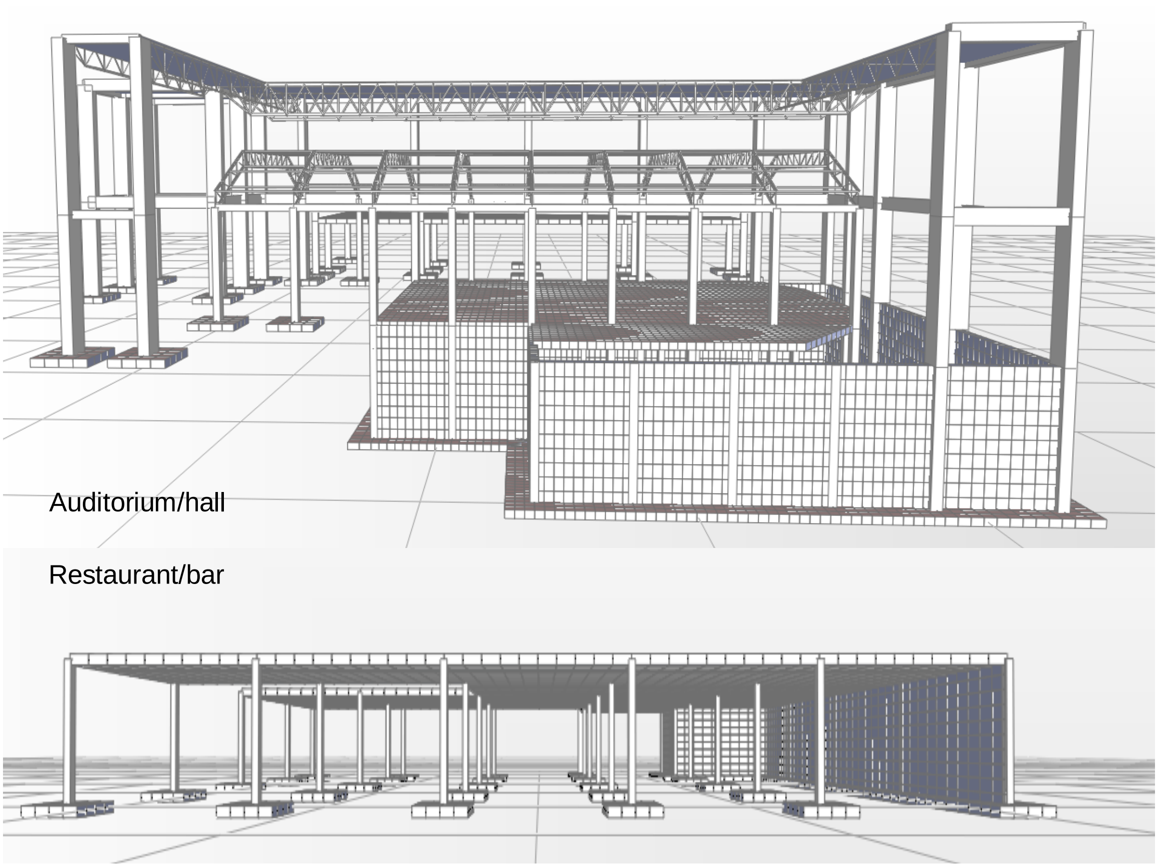
CHAPTER IV: *STRUCTURAL DESIGN*

1. INTRODUCTION

The present document represents the study, analysis and design of the elements that satisfy the structural integrity of all the building and/or series of buildings, contemplated inside the project of current discussion.

1.1 DIMENSION AND USES

The project designed for the area of San Vigilio, in the municipality of Calco consists into two main structures expected to work away one from the other for structural simplicity purposes, as it can be seen in the next scheme.



Graphic 3 Buildings structural distribution and uses

The project is composed by two main areas: the area on the upper part of the graphic shows a multipurpose scenario which will hold mainly cultural activities, including concerts, fairs, public events and general activities related. The area on the right side is expected to hold activities related to gastronomy. In particular this last building will have constant access to the all extension of its roof by visitors, being one of the main entrances to the complex. The multipurpose area is not expected to hold traffic on its roof, but only for maintenance proposes.

According to the statement presented above, the Auditorium/hall area can hold classifications C2, C3, C4, C5, according to the possible variety of activities proposed for the spaces ,however it has been selected the category of load C5 which is the more unfavorable for the structure. On the other hand the building which mainly will be composed by restaurants and bars fits into the category of uses C1. [42]

1.2 SOIL CHARACTERISTICS AND STUDIES

According to the geotechnical study realized in the zone of the project in 2003[43]; the soil in the area of Sanvigilio-Calco, is characterized by glacial pluvial-glacial formations with limited slope. In detail, the area of study is particularly described by a succession of glacial related forms (mostly found in hilly areas), and the action of river water flows (in areas that slope gently to the west, towards the Calendone canal bed). From the morphologic point of view, the area consist on mainly gravel and sand with pebbles of different nature (crystalline and calcareous) often embedded in large black limo-clay matrixes. The soil particles are generally angular, and its dimensions can vary from one centimeter up to several decimeters. In the zone of the project, the main existence of soil is of sand with scattered pebbles. [44]

The next series of graphics show the stratigraphy of the ground for the location of the project, even when this study was not straightly realized for this area, it is aimed to be used as a guide for the future decisions to be made into the structural design of the building. It is worth to underline that the geotechnical study was realized at a distance of 20 meters far away from the project's site.

[42] EUROCODE 1. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. Table 6.1 categories of use. prEN: 1991-1-1-2001.
[43] I PENATI Maurizio, TODESCHINI, Marialuisa. Indagine geologico tecnico ai sensi del D.M. 11.3 nel comune di Calco (Lc). 2003.
[44] Ibid. Indagine geologia tecnica ai sensi del D.M. 11.3 nel comune di Calco (Lc). 2003. P 15.

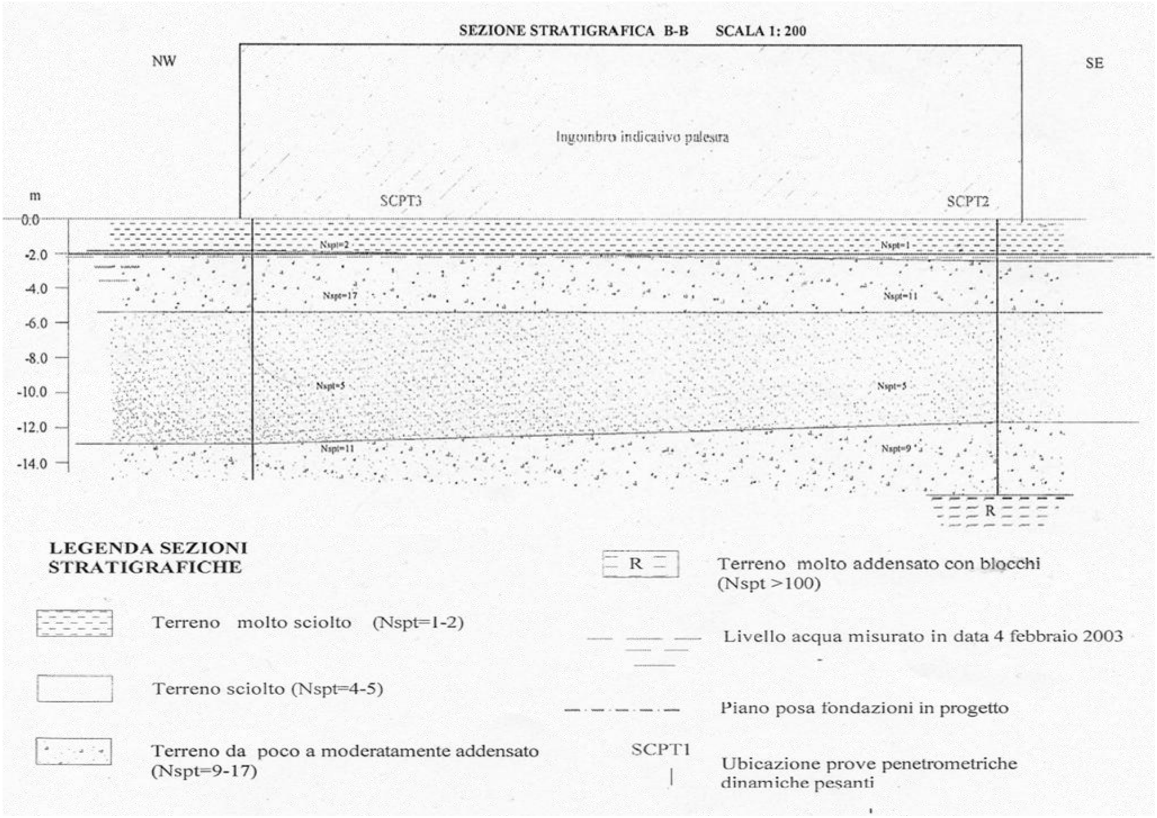


Illustration 120 Project expected ground stratigraphy (Extracted from PENATI) [45]

1.2.1 Proposed shallow foundation design

According to the data obtained and described above, the geotechnical studies propose the dimensions for square footings of side B, taking into account a safe factor = 3, and the suitable foundation levels of – 2.0 atl and - 2.7 a.t.l. However it is recommended to realize the foundation at levels below - 2.0 a.t.l in order to reduce settlement actions below level at – 2.1 a.t.l.

B (m)	Qadm (t/m²)	Qtot (t)	S (cm)
1.5	8.0	18.00	4.5
2.0	8.5	34.00	5.6
2.5	9.0	56.25	6.6
3.0	9.5	85.50	8.0
3.5	10.0	122.5	9.4

B(m)	Qadm (t/m²)	Qtot (t)	S (cm)
1.5	10	22.5	2.1
2.0	11	44.0	3.2
2.5	12	75.0	4.4
3.0	13	117.0	5.7
3.5	14	171.5	6.8

Where: B = Side square footing, Qadm = Admissible footing bearing capacity. Qtot = Total load including footing self weight. S = expected settlement.

Table 2 Proposed footing dimensions according to bearing load for foundations levels at -2.0 a.t.l and - 2.7 a.t.l (Extracted from PENATI) [46]

[45] Ibid. Indagine geologia tecnica ai sensi del D.M. 11.3 nel comune di Calco (Lc). 2003. P 14.
[46] Ibid. Indagine geologia tecnica ai sensi del D.M. 11.3 nel comune di Calco (Lc). 2003. P 16-17

1.2.2 Proposed deep foundation design

On another hand, if the loads considered in the building could not be satisfied by the bearing capacity given by the footing foundation; It is recommended to transfer the loads to levels lower than – 13 a.t.l. by using piling systems with a pile cap at – 2.0 a.t.l. The proposed dimensions and bearing capacity for this system are presented in the next table:

L (m)	Φ (cm)	Qt (t/pile)
13	30	23-25
13	40	38-40
15	30	28-30
15	40	46-48

Where: L = Length of piles, Φ = Diameter of piles, Qtot = Total load including footing self weight.

Table 3 Proposed piling dimensions according to bearing load for foundation level at -2.0 a.t.l (Extracted from PENATI)[47]

1.3 NORMATIVE

The main normative and calculation methodologies for the design are driven according to the considerations and instances of the EUROCODE Chapters 1, 2, 3, 7 and 8. Moreover, further normative is implemented such as the Italian structural design code (Norme techniche per le costruzioni-2008).

[47] Ibid. Indagine geologia tecnica ai sensi del D.M. 11.3 nel commune di Calco (Lc). 2003. P 18

2. STRATEGY

2.1 ENERGY EFFICIENT MATERIAL'S OPTIMIZATION/ IMPLEMENTATION

2.1.1 Concrete mixtures with Fly-ash based Cement.

Fly ash is defined as the residue resulting from the combustion of ground or powdered coal, being a byproduct of coal burning energy widely produced in the world. In the past, fly ash was released after regular production into the atmosphere; although, worldwide policies prohibited its releasing due to widely known contamination issues, limiting its disposal to landfill deposits and ash pounds (around 60% of European production is disposed so, meaning around 25.000 ton of fly ash waste per year only in Europe)[48]

Fly ash can be reused in certain proportions as a cementitious material, which as well as most of the pozzolans can present beneficial properties in addition to the Portland cement, improving the performance and quality of concrete. Specifically, Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration; but also, it increases strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphates resistance, and reduces alkali-aggregate reaction. [49]

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. In figures for every ton of fly ash/ton of Portland cement, 1 ton of CO_2 is reduced to be released into the atmosphere. [50]

2.1.2 High strength Concrete

On the other hand, the use of high strength concrete provides a solution for high load requirements in the structure, avoiding the need of using higher sections of slabs, walls, beams and columns in order to satisfy these structural requirements. According to the NCMA [51], high strength concrete can be obtained starting from a compressive strength of 40 MPa or higher tested in cylinders of a ratio 1:2 of proportion. In order to obtain this resistance, higher amounts of cementitious material are proportioned in parts with the inclusion of Fly-ash or other pozzolans materials,

[48] ACAA USA Adavancing the management and use of coal combustion products. ECOBA 2006 CCP production & survey Europe (article available on-line). http://www.acaa-usa.org/associations/ 8003/files/ECOBA_Stat_2006_EU15.pdf p1.
[49] SOUSTAINABLE SOURCES. Flyash concrete (article available on-line). http://flyash.sustainablesource s.com/#USE. 2011
[50] NRCMA. Concrete in practice (article available on-line). http://www.nrmca.org/aboutconcrete/cips/33p.pdf.2011.
[51] ACAA USA Sustainable construction with coal combustion products. (article available on-line). http://www.acaa-usa.org/associations/8003/files/Sustainability_Construction_w_CCPs%28 Consolidated%29.pdf. 2011. p8.

2.2 STRUCTURAL TECHNOLOGIES:

2.2.1 Biaxial hollow slabs

The core hollow slab is a technology newly implemented in the construction sector as an excellent pre-fabricated solution for the raising of lightweight structures, and buildings that required nowadays even more efficient ratio slab height/span. This technology consist basically on leaving out great amounts of the mass of concrete required for a flat-plate slab while keeping part of the flexural and shear strength of the system, and allowing a biaxial transfer of the load. The system is composed by voids in the midst of bottom and top reinforcement that displace concrete reducing the self weight of the structure and then the size of it needed to resist static forces.

The biaxial hollow light concrete slabs, can be calculated and design with the same provisions given by full section concrete slabs, with a difference that the next advantages will be presented:

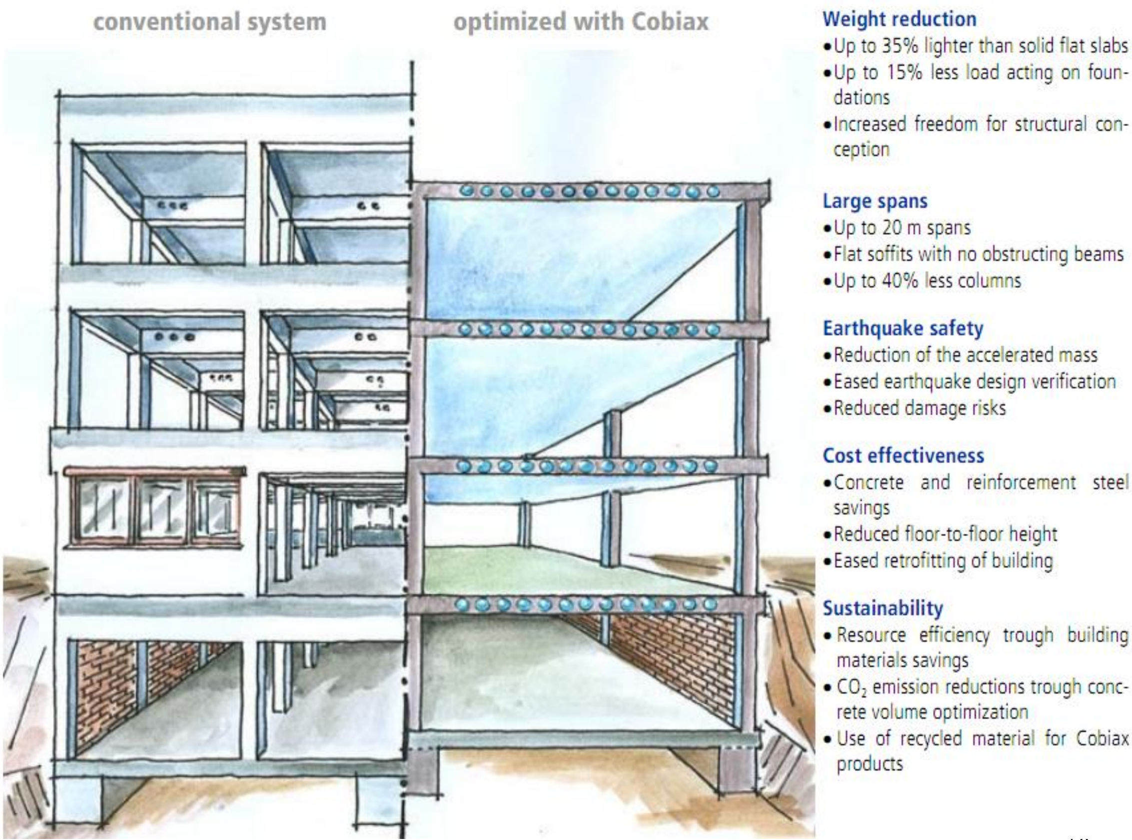


Illustration 121 Comparison conventional system/hollow slab (Extracted from COBIAX) [52]

[52] COBIAX S.A. Benefits of the Cobiax slab technology. (Content Available On-line). http://www.cobiax.ch/downloads /english /Cobiax_Brochure_E_2010.pdf.

2.2.2 Open Steel web joist

Open web steel joist are prefabricated trusses constructed under specific specifications to withstand high loads (Industrial and mechanical equipment) in particularly long span applications. Its classification varies according to the height and load that the system is designed for (K,LH,DLH,SLH) and thus, the maximum span that they can withstand as it is hereafter presented:

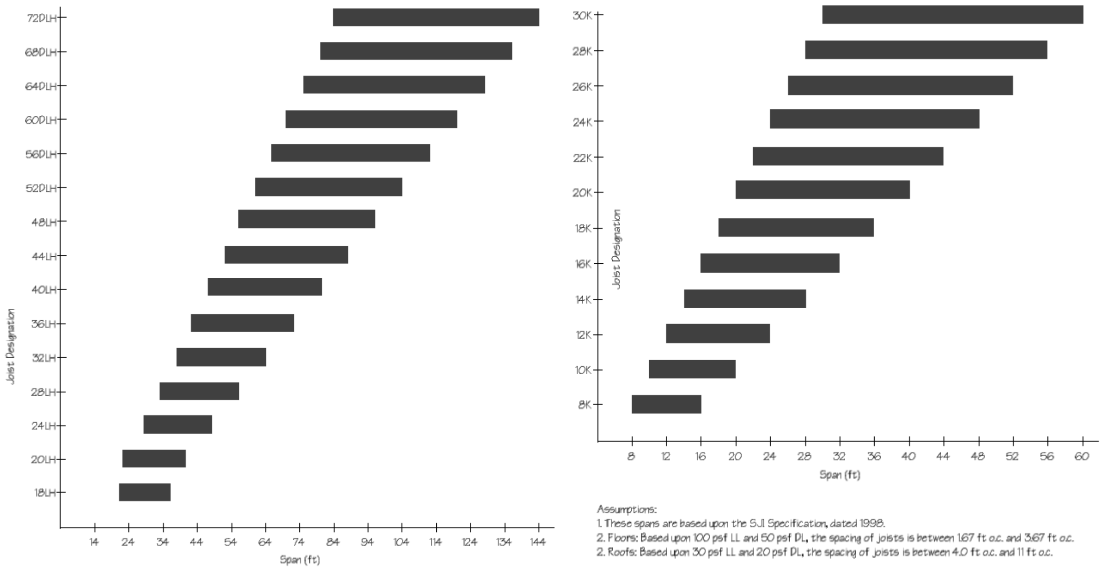


Illustration 122 Maximum span according to open web steel joist classification (Extracted from VULCRAFT)[53]

A conventional open web joist is composed by single angular elements made of structural steel which are spaced according to the loads in the system and the height of the beam as it is shown in the next illustration.

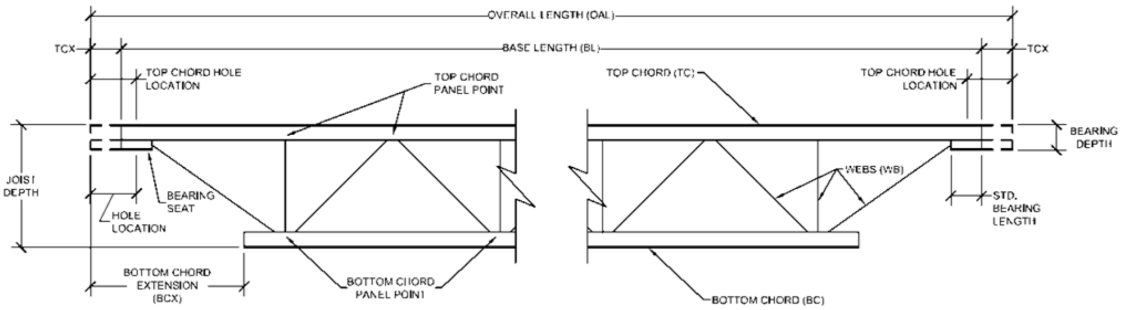


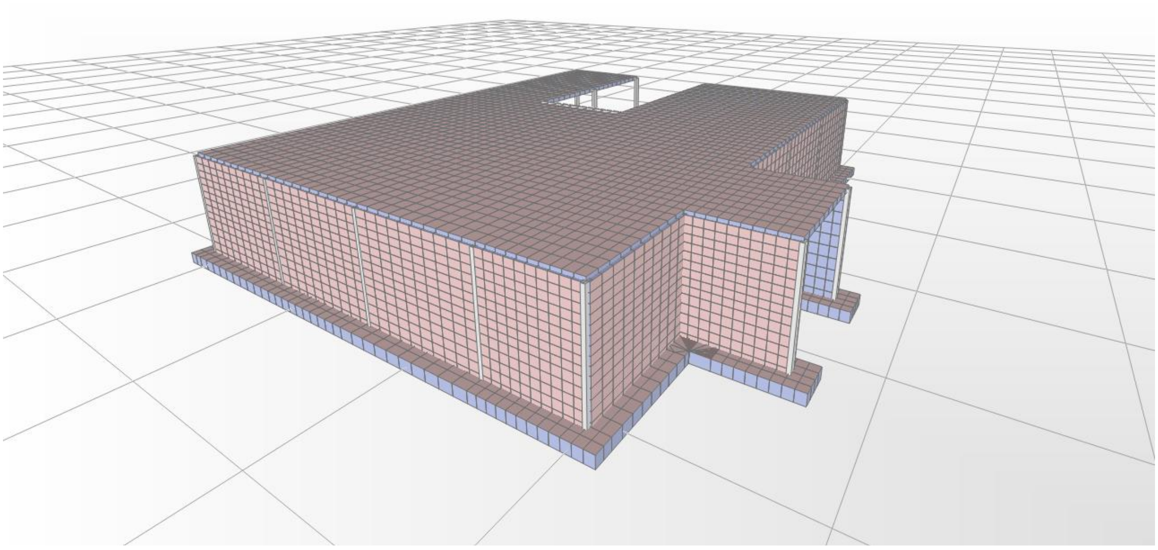
Illustration 123 Open web steel joist conventional configuration (Extracted from VULCRAFT)[54]

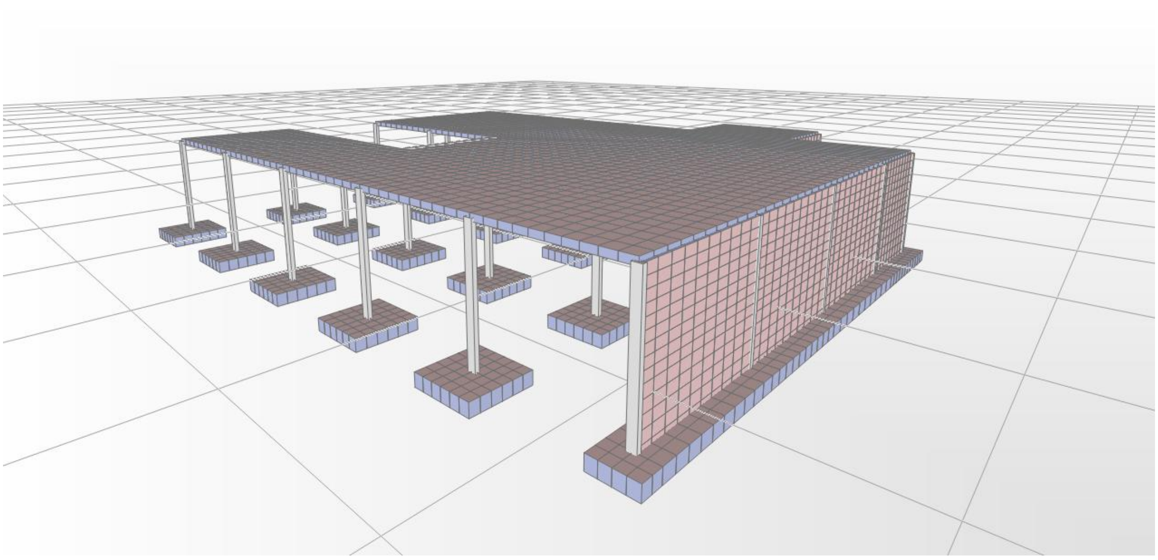
[53] VULCRAFT. Steel Joists and Joist Girders – Steel Joist Institute. P. 32. 2001
[54] Ibid. Steel Joists and Joist Girders – Steel Joist Institute. P. 44 . 2001

3. DESIGN

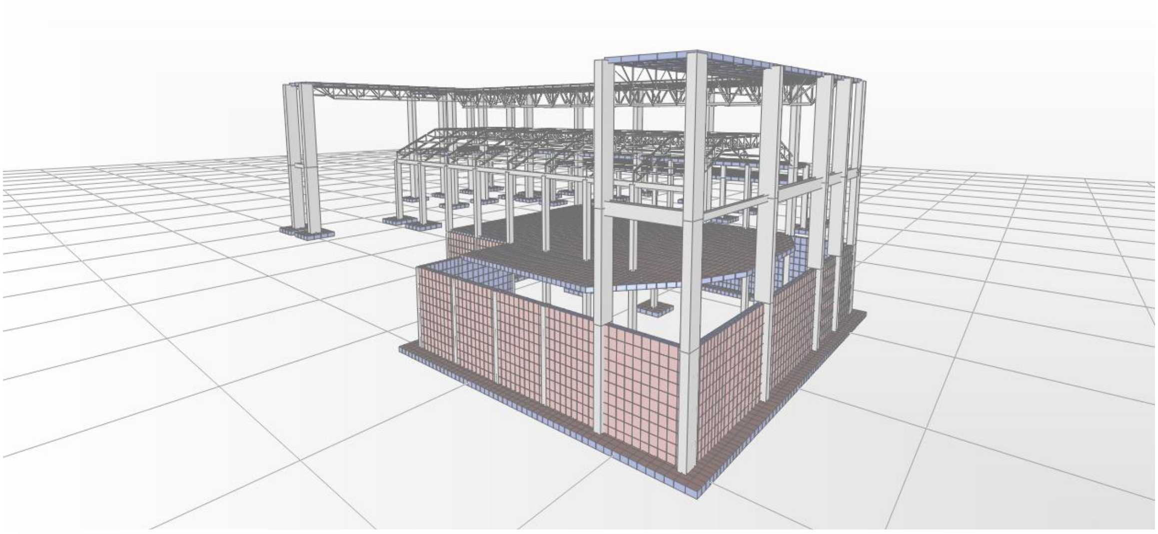
3.1 NUMERICAL MODEL

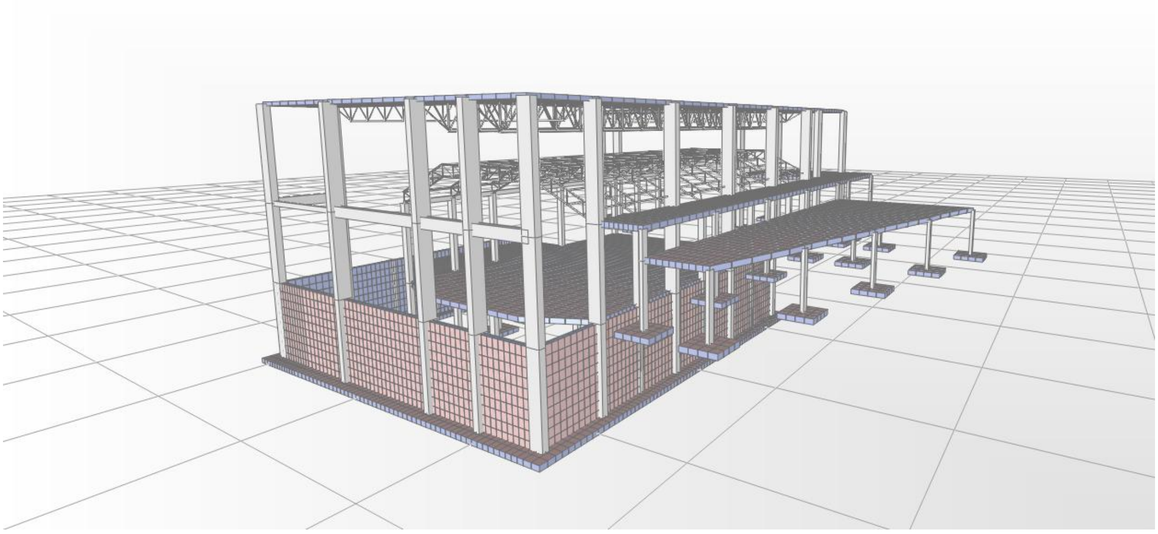
The model of the structure has been done by means of the Software SAP2000, using Finite elements (Shell) in order to represent retaining walls, slabs, stairs and foundations. On the other hand elements type frame has been used in order to represent linear elements such as ties, girders, beams and columns. Concrete beams used in order to maintain the structural integrity of the foundation and avoid differential settlements are not modeled due to its minimum contribution in terms of resistance.

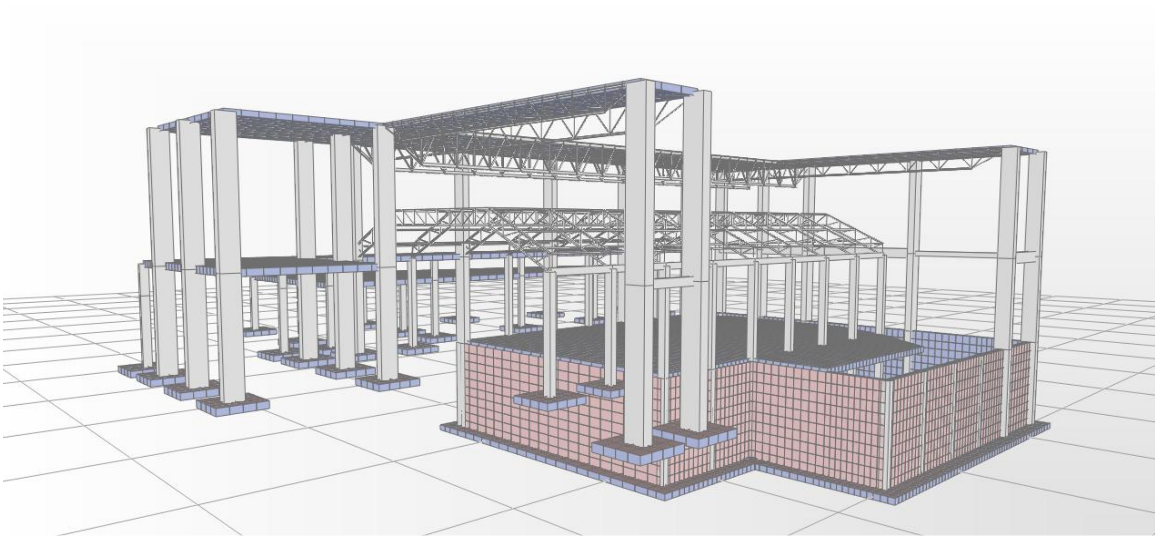


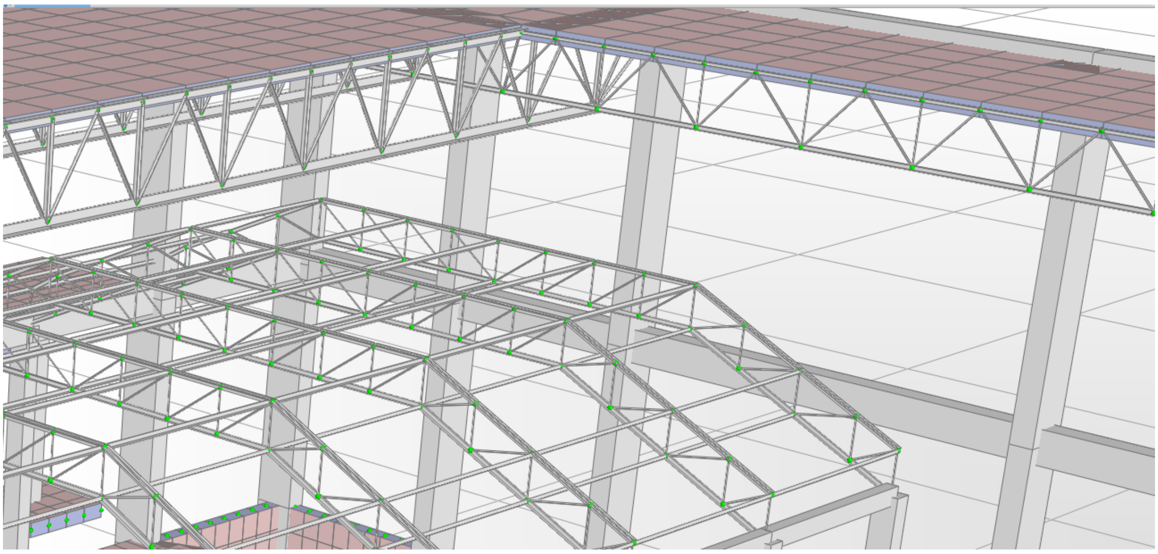


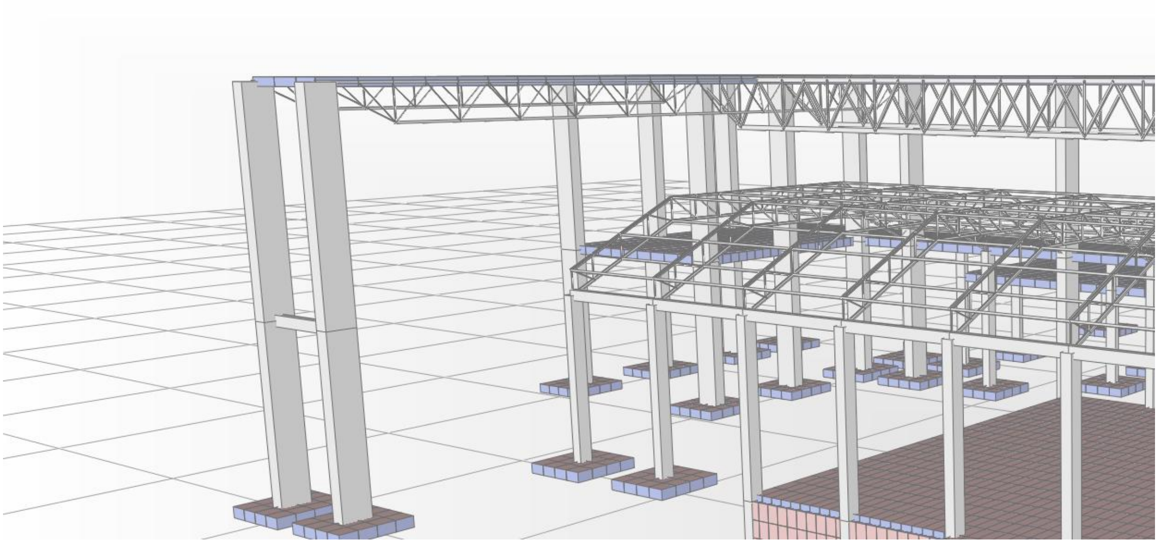
Graphic 4 Analytical model Restaurant/bar in SAP 2000.

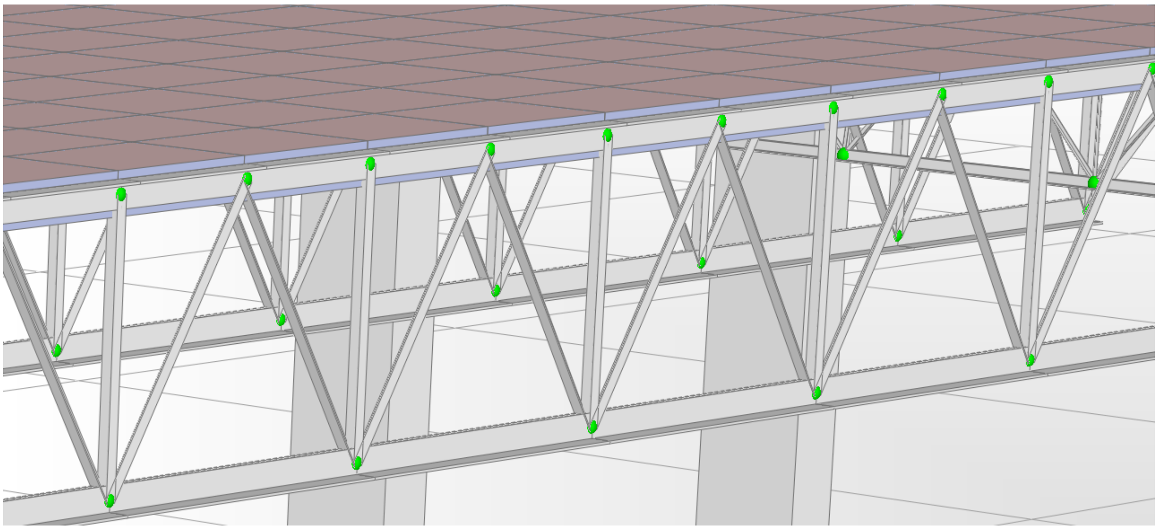


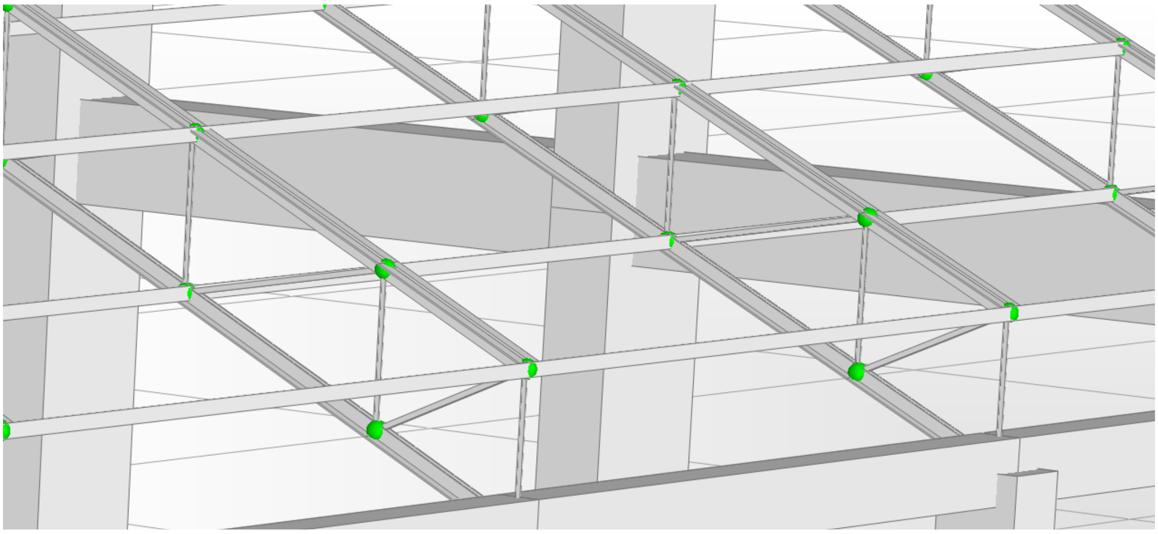












Graphic 5 Analytical model Auditorium/hall in SAP 2000.

3.2 MATERIALS

Reinforced Concrete: C50/60 for all structural elements except Slabs C35/45

$$fck = 50\ \text{N/mm2} \quad fcd = 35\ \text{N/mm2}$$
$$fck = 35\ \text{N/mm2} \quad fcd = 20\ \text{N/mm2}$$
$$\varepsilon c2 = 0.002$$
$$\varepsilon cu = 0.0035$$

Reinforcement: type B500 for all reinforced concrete structural elements.

$$fyk = 500\ \text{N/mm2}$$
$$fyd = 435\ \text{N/mm2}$$
$$\text{E}s = 200\ \text{KN/mm2}$$
$$\varepsilon yd = 0.00217$$

Structural steel: For roof trusses and other structural elements.

$$fu = 430\ \text{N/mm2}$$
$$fy = 275\ \text{N/mm2}$$
$$\text{E}s = 210\ \text{KN/mm2}$$

3.3 GEOTECHNICAL PROPERTIES

The next parameters are extracted from the geological studies realized in the zone by PENATI[55]

$$\gamma t = 1.65\ t/m^3$$
$$\varphi = 23^{o}$$
$$K_0 = 1 - \sin(\varphi) = 0.61$$
$$Level\ of\ water = -2\ m\ below\ terrain\ level.$$

3.4 ANALYSIS METHOD

It has been decided to use the limit state methodology which multiplies the working loads by partial factors of safety, and also divides materials' ultimate strengths by further factors of safety, being a method of analysis suitable for its application in reinforced concrete and steel structures.

3.5 LOADS ASSESSMENT

The load assessment and estimation is here after presented according to the actions that the structure will withstand during its service life.

- Permanent actions (G): permanent actions are those actions which the structure will be normally subject at, during its whole life. These actions include:

  - Self weight (G_1) of all the structural elements.
  - Self weight (G_2) of all non structural elements such as exterior cladding, permanent partitions and fixtures, ceilings and static machinery.
  - Expected differential settlements and deformations loads. (not expected in this case)
  - Self weight soil(G_2)

- Variable actions (Q): Variable actions are known to be difficult to calculate accurately due to the wide "load's *variability*" during time that a structure can present along all its service life. These actions include:

  - Weight due to occupancy and maintenance actions (Q_1).
  - Movable partitions (Q_2).
  - Weight of Snow (Q_3 = S).
  - Thermal expansion and shrinkage of concrete
  - Pressure of wind : The assessment of horizontal and vertical wind load is neglected in the present analysis due to the next instances: a. The low ranges of wind velocities presented in the zone and described in the chapter 4, do not represent a threat for the safety

[55] Ibid. Indagine geologia tecnica ai sensi del D.M. 11.3 nel comune di Calco (Lc). 2003. P 16-17

of the structure, taking into account the use of non-lightweight elements in the main direction of the wind, and a framed stiff structural system. b. Low height of the buildings considered (5m-7m)

- Hydrostatic pressure (Q_4): due to the level of water = -2 m.a.t.l.
- Surcharge (Q_5).
- Sub-pressure: Sub pressure in the Auditorium/Hall structural foundation slab has been subjected due to the assumption that the weight of the structure distributed around all the area of the building will avoid the possible “swing pool” effect due to increase in the water level.

- Accidental actions (A): Accidental actions are considered to be presented under exceptional conditions during the structure’s life. *(to be not considered for this analysis).*

- Seismic actions (E): Actions due to horizontal deformation – forces induced by an earthquake. According to the data obtained from the INGV[56] for the coordinates 45°43'32"25 N, 09°24'42"28 E (Project’s location) where the value of the pseudo acceleration is A(g) =0.06 and the importance factor is equal to γ_I = 1.2 (importance category II); Calco is located in a “Low seismicity region” (A(g)* γ_I = 0.072g<=0.1g). In this way, the analysis of the seismic load for the project can be neglected as well.[57]

3.5.1 Permanent actions (G)

3.5.1.1 Self weight (G_1)

The self weight of the structural elements is calculated by using the automatic computation given by the software SAP2000 where the structural analysis of the buildings is developed. However the weight of the slabs and the ETFE façade system is not taken into account in the program, so it is loaded manually.

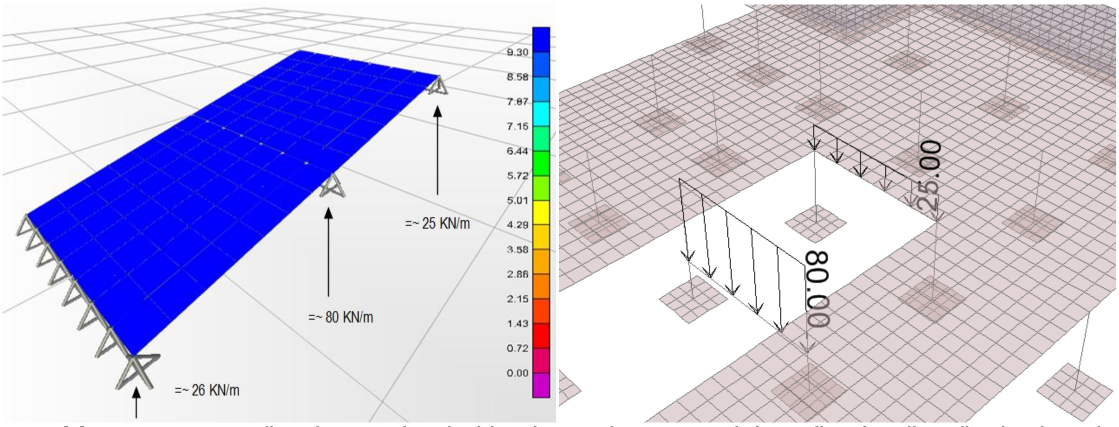
3.5.1.2 Self weight (G_2)

For permanent partitions, it is considered to add a load equal to q_k = 0.5 kN/m^2, considering a self weight of these partitions not higher than 1.0 KN/m.[58]

The load due to the staircase for the restaurant/bar building has been extracted by modeling a planar-tilted weightless slab subjected under the G2 type of load.

[56] INSTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA. Zone sismiche regionali Italia. http://zonesismiche.mi.ingv.it/
[57] EUROCODE 8. Design of structures for earthquake resistance. Pr EN: 1998-1-2003. P12
[58] Ibid. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. PrEN: 1991-1-1-2003. P23

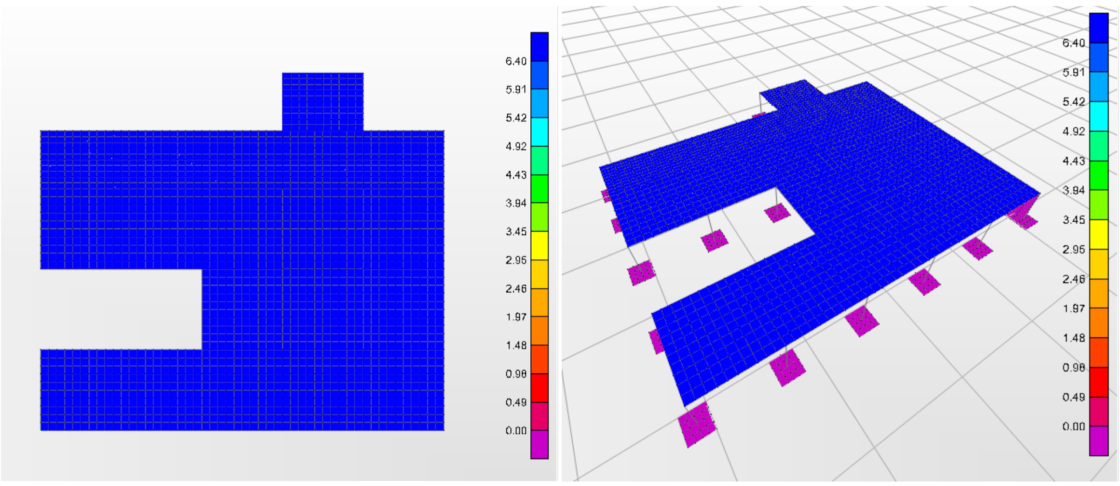
The reactions in the supports (which are considered to simulate the bearing beams of the staircase) are considered to be distributed loads in the beams; this distributed load is loaded in the final model, its calculation is made by the sum of all the reactions divided by the total width of the slab.



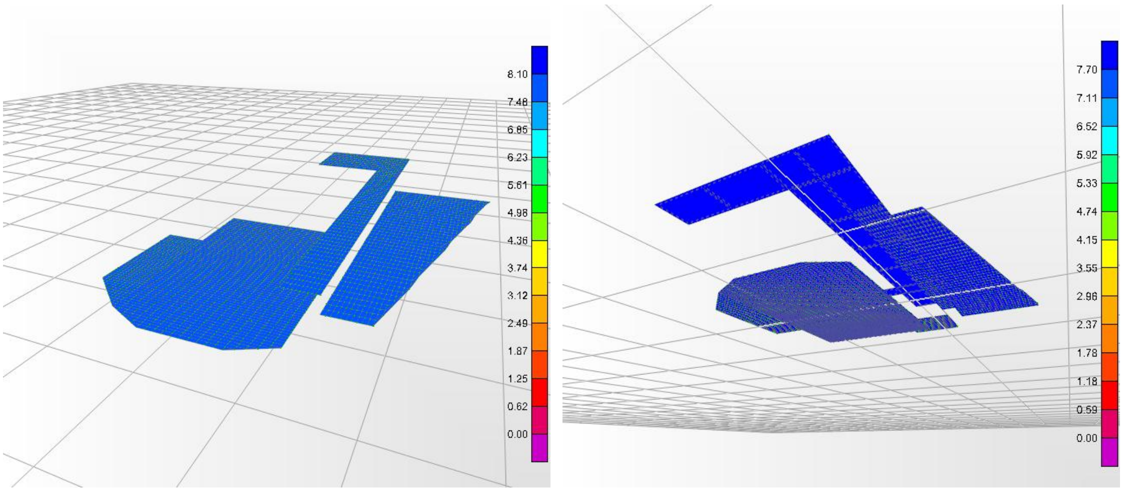
Graphic 6 Restaurant/bar beams loaded by the Staircase model G2 first loading (kN/m2) and reactions (kN/m)

LAYERS	Thickness (m)	Density (kN/m3)	Load (kN/m2)
Floor finishing pack - Impermeabilization	-	-	1.8
Concrete staircase	0.3	24	7.2
Ceiling + self structure	-	-	0.2
TOTAL			9.2

Table 4 Restaurant/bar Staircase model G2 loading



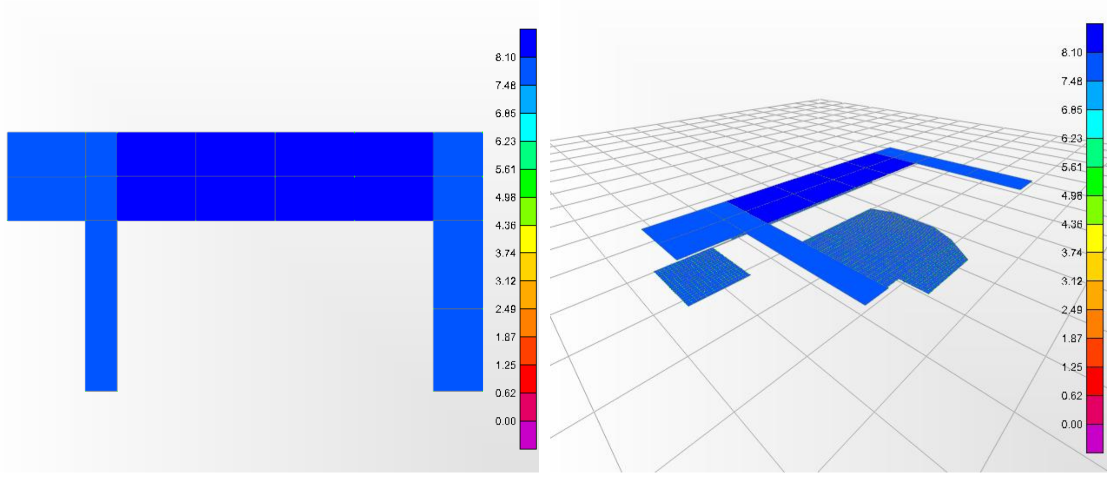
Graphic 7 Restaurant/bar ceiling slab G2 loading (kN/m2)



Graphic 8 Auditorium/hall Slabs G2 loading (kN/m2)

LAYERS	Thickness (m)	Load (kN/m3)	Load (kN/m2)
Floor finishing pack - Impermeabilization	-		1.8
Concrete hollowed	0.34	16.1	5.5
Mechanical systems	-	-	0.3
Ceiling + self structure	-	-	0.2
TOTAL			**7.7**

Table 5 Restaurant/bar and Auditorium/hall slabs G2 load.



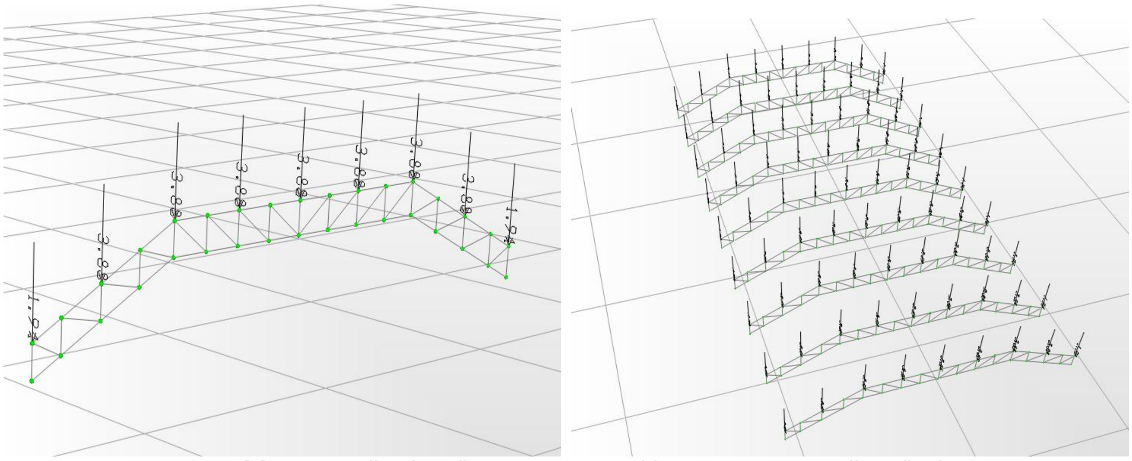
Graphic 9 Auditorium/hall External Ceiling – G2 Machinery loading (kN/m2)

Machinery	Load (kN/m2)
PV Monocrystaline panels + Structure	0.2
Solar standard collector + Structure	0.2

Table 6 Auditorium/hall External Ceiling – Machinery loads (Extracted form UNIRAC) [59]

[59] UNIRAC. Code compliant installation manual. Pag 4. 2011

On the other hand, the calculation of the dead loads for the auditorium internal roof is done by dividing the load carried by the areas adjacent to the rafters, these rafters will transfer the load to the truss, as it is calculated in the next scheme.

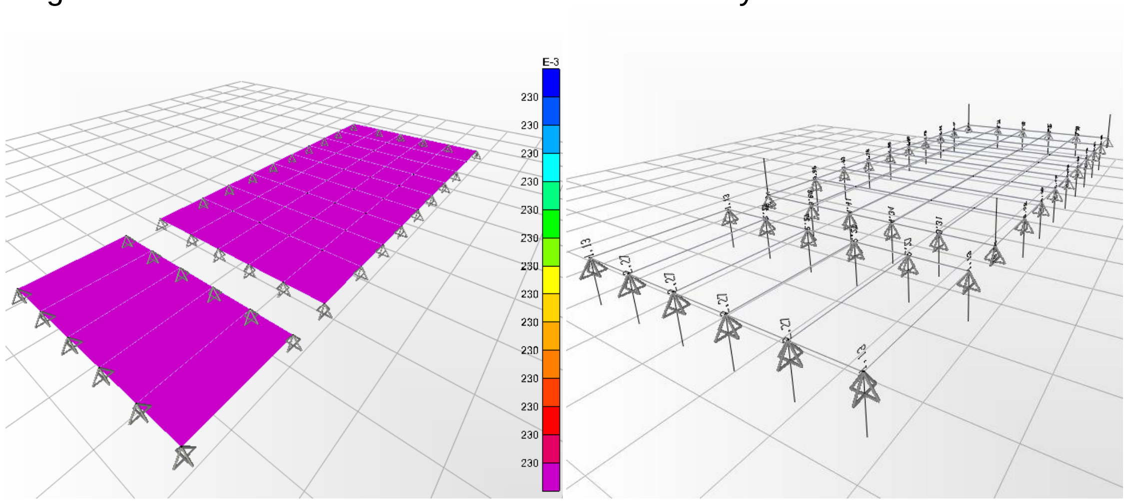


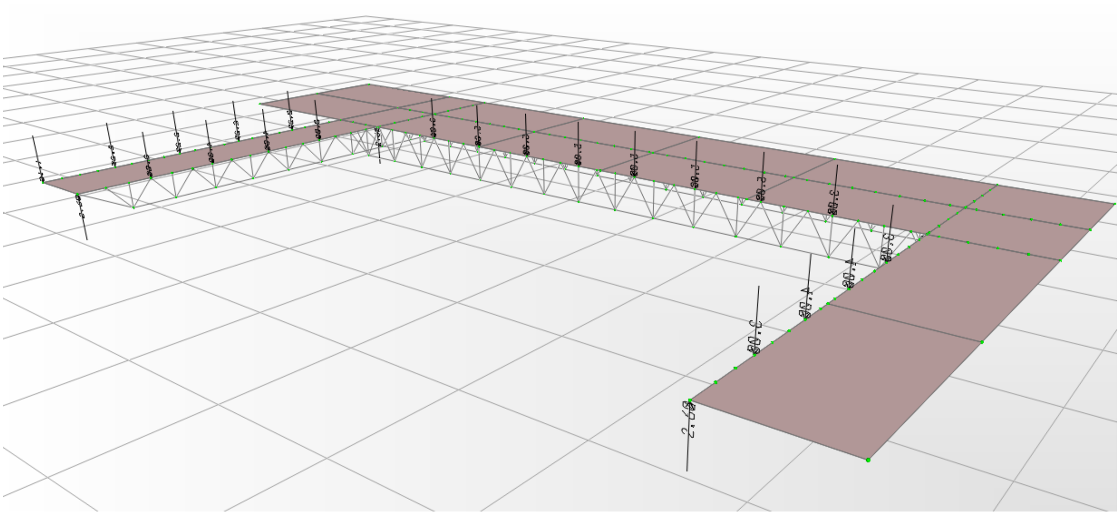
Graphic 10 Auditorium/hall Internal Ceiling truss G2 loading (kN)

LAYERS	Load (kN/m2)	Rafters (un)	Ly (m)	Trusses (un)	Aproximate roof Area (m2)	Load to Internal joint (KN)	Load to External joint (KN)
Metalic Cladding + self structure	0.3	9	15.2	9	413.44	0.97	0.48
Mechanical system (ducts + recovery chamber)	0.3	9	15.2	9	413.44	0.97	0.48
Insulation + self structure (rafters @ 1m)	0.2	9	15.2	9	413.44	0.65	0.32
Ceiling + self structure	0.2	9	15.2	9	413.44	0.65	0.32
Acustic panels	0.2	9	15.2	9	413.44	0.65	0.32
TOTAL						3.88	1.94

Table 7 Auditorium/hall Internal Ceiling – Metal

On the other hand, in order to calculate the load that the ETFE panels will transfer to the structure, it has been modeled an infinitesimal weightless slab that simulates the support conditions of the façade and ceiling made out of this material. The conditions given are an approximation similarly as it was done for the staircase of the restaurant for simplification purposes. The resultants of this model are a combination of punctual and distributed loads that are applied into the general model for the different load of cases analyzed.





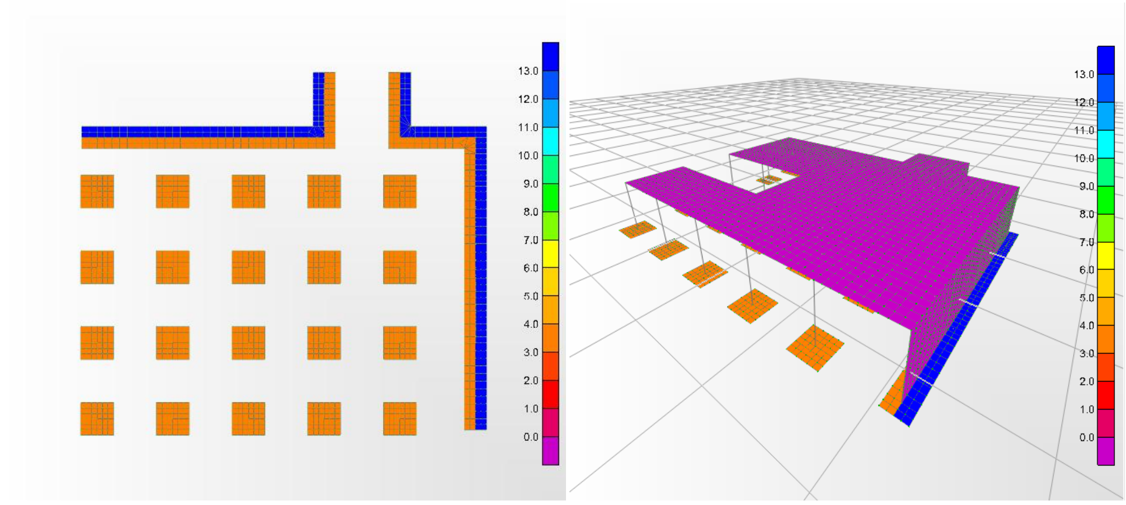
Graphic 11 Auditorium/hall External Ceiling – ETFE G2 first loading (kN/m2), reactions (kN) and second loading.

LAYERS	Load (kN/m2)
ETFE panel triple layer	0.01
Self structure	0.22
TOTAL	**0.23**

Table 8 Auditorium/hall External Ceiling – ETFE (Extracted form MAKMAX)[60]

3.5.1.3 Soil pressure (G_3)

According to the distribution of the soil that should be in one part contained by the retaining wall, there is another part that will generate an extra weight at the foundation level.



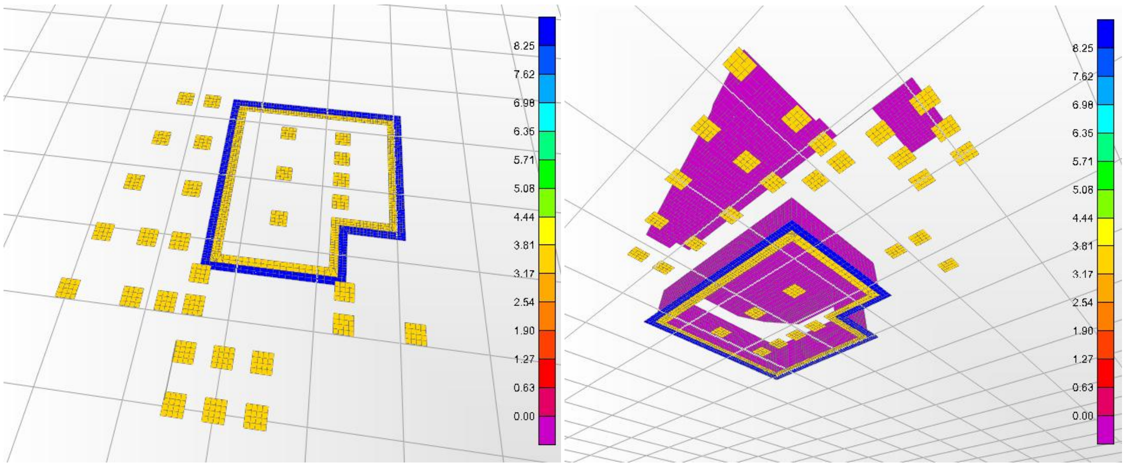
[60] MAKMAX. ETFE Panels solutions. (Available ON-line). http://www.makmax.com/business/etfe_brochure.pdf . 2011

Graphic 12 Restaurant/bar Footing G3 loading (ton/m2)

$$G3\ footing\ retaining\ wall = h * \gamma t = 8 * 1.65 = 13\ Ton/m2$$

$$G3\ footing\ columns = h * \gamma t = 2 * 1.65 = 3.3\ Ton/m2$$

Equation 1 Restaurant/bar Footing G3 loading



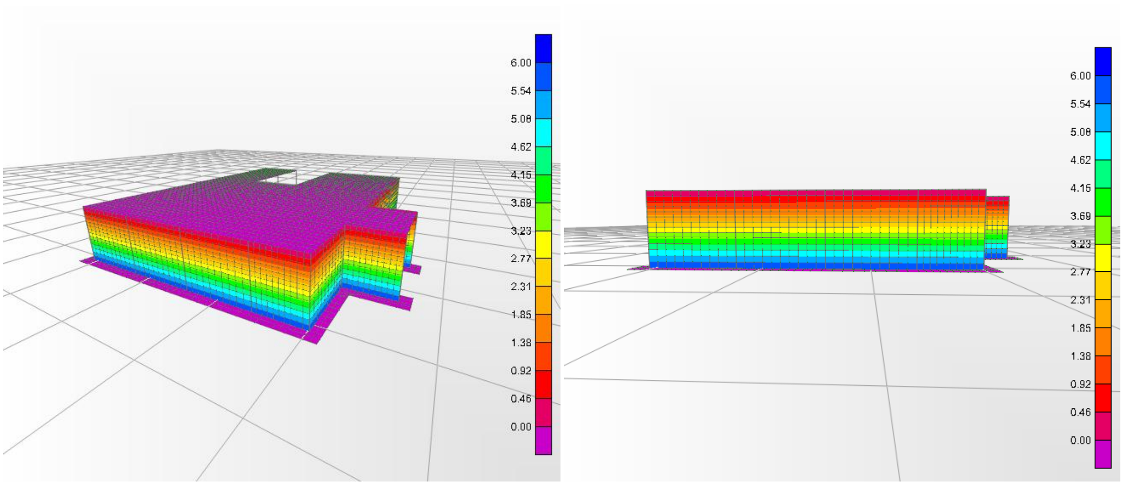
Graphic 13 Auditorium/hall Footing G3 loading (kN/m2)

$$G3\ footing\ retaining\ wall = h * \gamma t = 5 * 1.65 = 8.25\ Ton/m2$$

$$G3\ footing\ columns = h * \gamma t = 2 * 1.65 = 3.3\ Ton/m2$$

Equation 2 Auditorium/hall Footing G3 loading

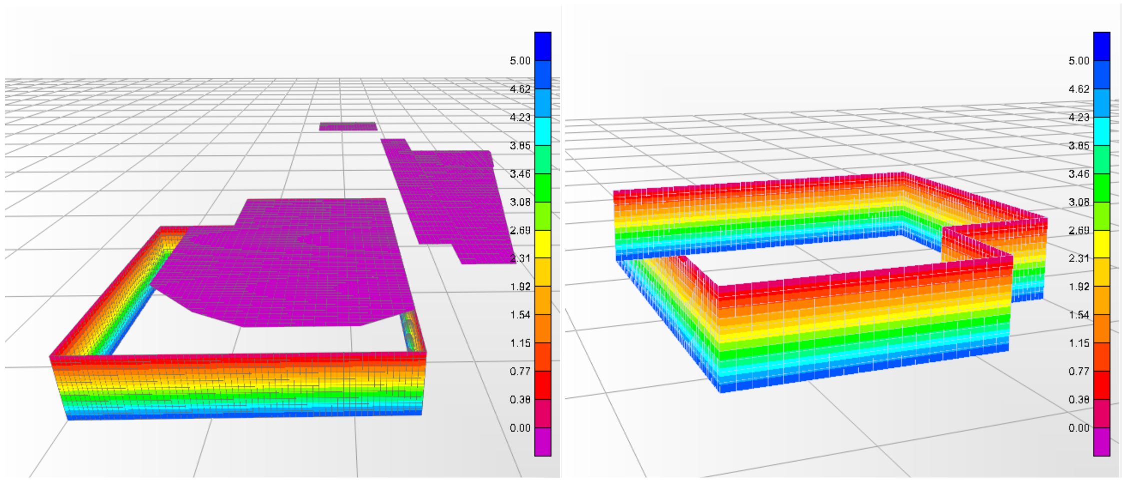
On the other hand the horizontal pressure of soil is here after presented:



Graphic 14 Restaurant/bar retaining wall G3 loading (Ton/m2)

$$G3 = \gamma t * K_o * h = 1.65 * 0.61 * 6 = 6\ \ Ton/m2$$

Equation 3 Restaurant/bar retaining wall G3 loading



Graphic 15 Auditorium/hall retaining wall G3 loading (Ton/m2)

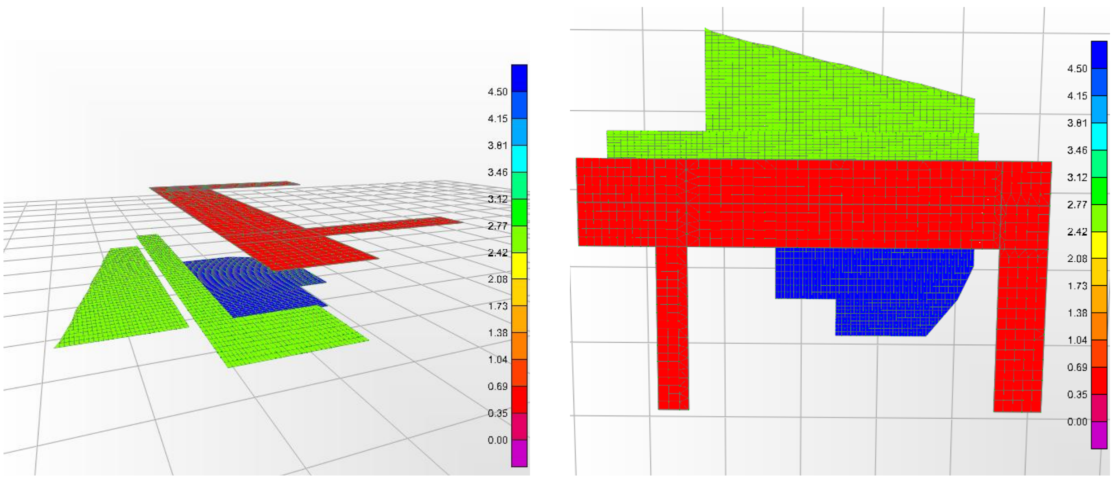
$$G3_{unconf} = \gamma t * K_o * h = 1.65 * 0.61 * 5 = 4.9 \ \text{Ton/m2}$$

Equation 4 Auditorium/hall retaining wall G3 loading

3.5.2 Variable actions (Q)

3.5.2.1 Occupancy (Q_1)

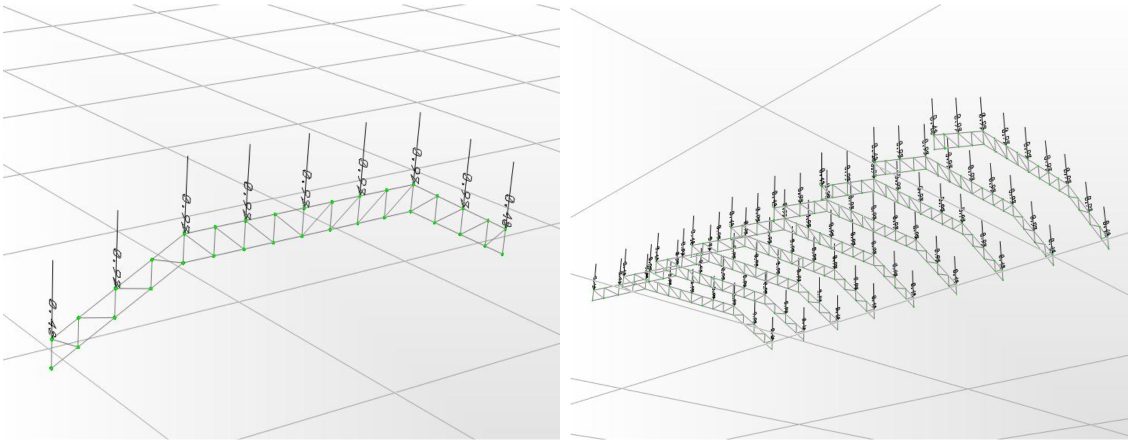
For floors, stairs and balconies, according to the wide range of uses to be hold in the Auditorium/hall area (C2-C4), it is considered the most unfavorable load condition C4; however, taking into account the expected probability for the structure to hold activities related to a use C4[61] (30%-50% of the time) we consider a value of load of qk = 4.5 kN/m2, out of a range of 4.5 – 5.0 kN/m2. However the roof of the changing rooms and the passage over the building is expected to have a live load of 2.5 kN/m2.



Graphic 16 Auditorium/hall slabs Q1 loading (kN/m2)

[61] EUROCODE 1. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. Table 6.2 imposed floors in balconies, floors and stairs of buildings. prEN: 1991-1-1-2001. p22

For restaurants and bar, the category of use is C1, which means an average live load for slabs, stairs and balconies equal to: qk = 2.5 kN/m2. [62]. Both internal and external ceiling/roof of the Auditorium/hall area building is expected to have an average load due to occasional maintenance (Category H) of qk = 0.4 kN/m2.

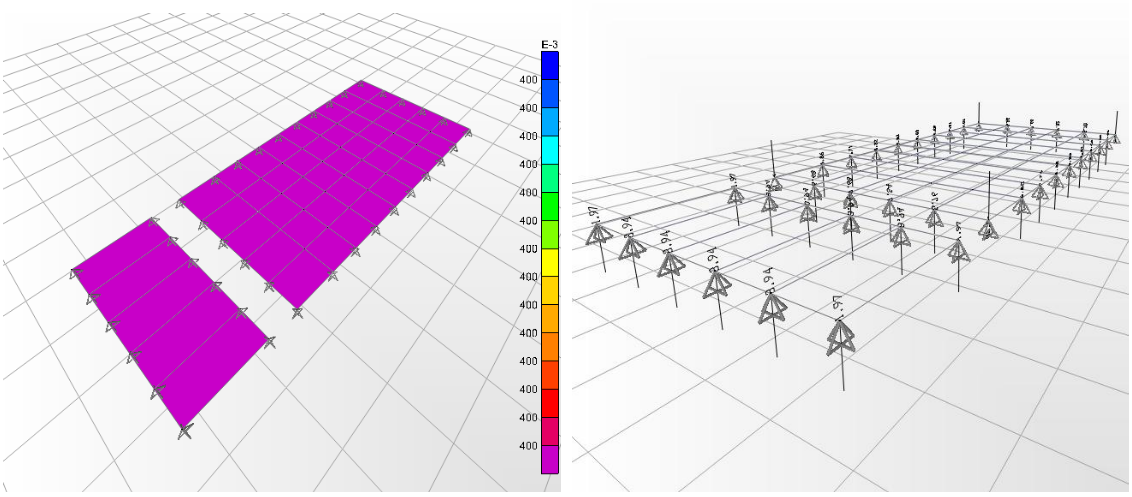


Graphic 17 Auditorium/hall internal ceiling truss Q1 loading (kN)

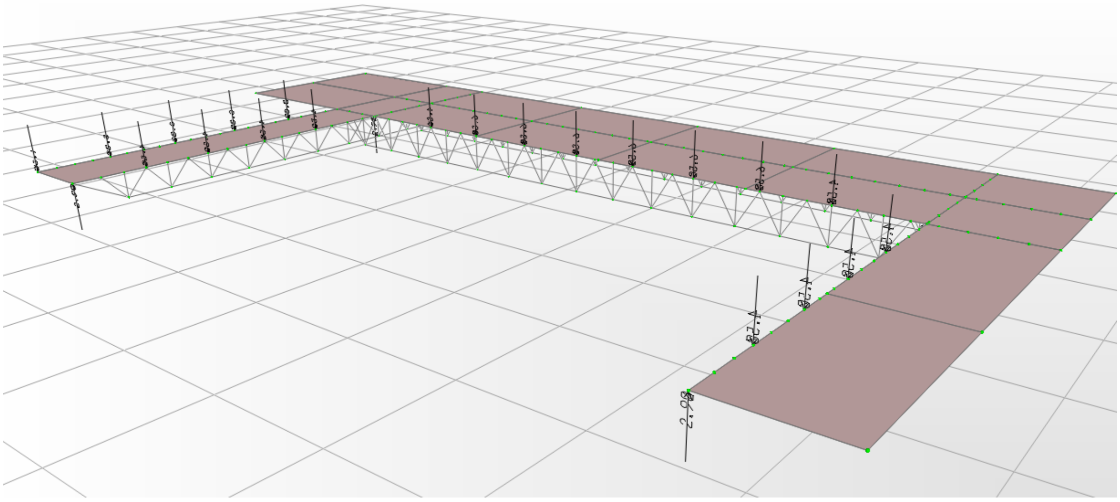
$$Q1_{\text{int joint}} = qk * \frac{\frac{A * (\text{Raft} - 1)}{\text{Truss} - 1}}{2} = 0.4 * \frac{\frac{413 * (9 - 1)}{9 - 1}}{2} = 1.29\ \text{kN}$$

$$Q1_{\text{ext joint}} = qk * \frac{\frac{A * (\text{Raft} - 1)}{\text{Truss} - 1}}{4} = 0.4 * \frac{\frac{413 * (9 - 1)}{9 - 1}}{4} = 0.65\text{kN}$$

Equation 5 Auditorium/hall Internal Ceiling – loading equation Q1

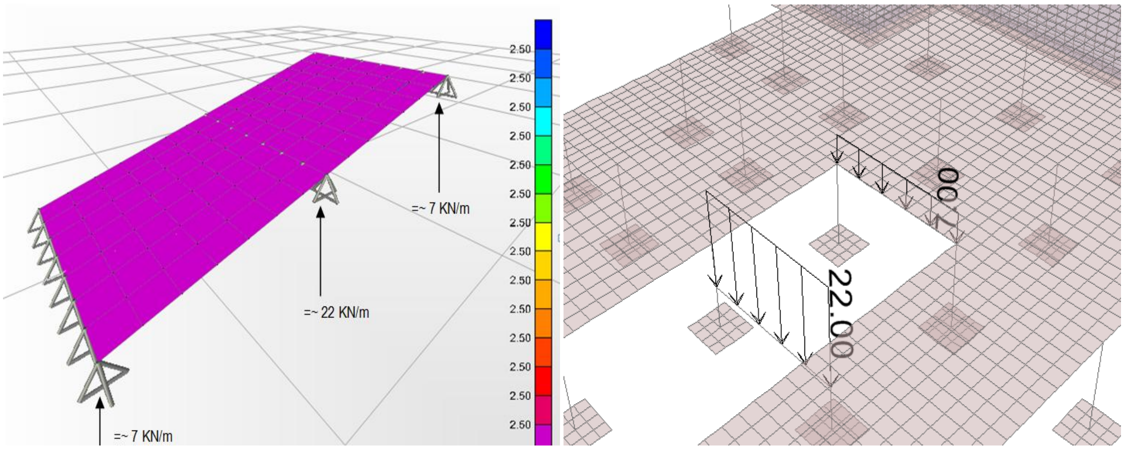


[62] Ibid. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. Table 6.2 imposed floors in balconies, floors and stairs of buildings prEN: 1991-1-1-2001. P23



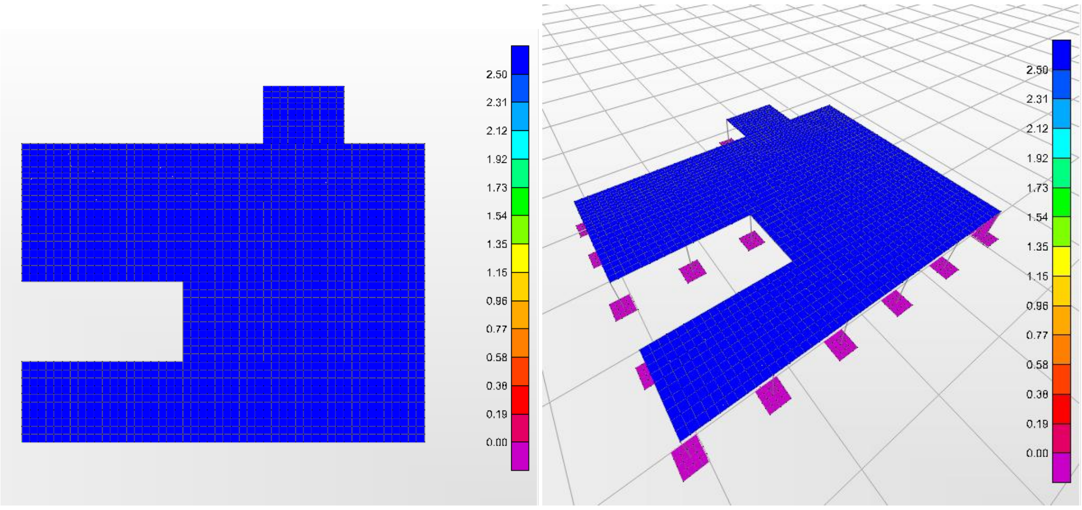
Graphic 18 Auditorium/hall External Ceiling – ETFE Q1 first loading (kN/m2), reactions (kN) and second loading.

On the other hand, the roof of the single story building (restaurant/bar) is expected to have a constant load according to the use of the building (category C1-I). qk = 2.5 kN/m2.[63] In the same way, the loading of beams and elements is given by:



Graphic 19 Restaurant/bar beams loaded by the Staircase model Q1 first loading (kN/m2) and reactions (kN/m)

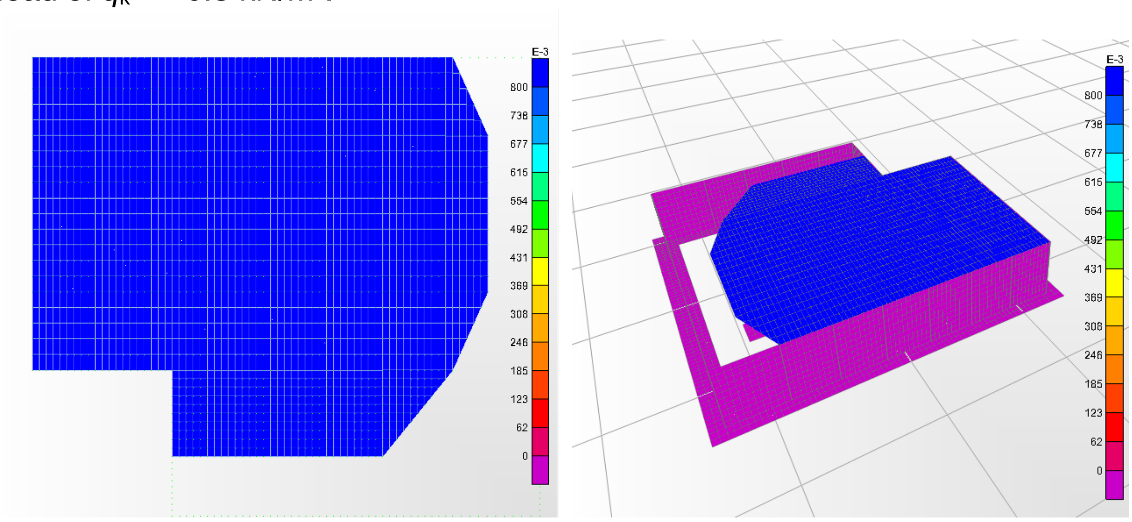
[63] Ibid. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. prEN: 1991-1-1-2001. P29



Graphic 20 Restaurant/bar ceiling slab Q1 loading (kN/m2)

3.5.2.2 Movable partitions (Q_2)

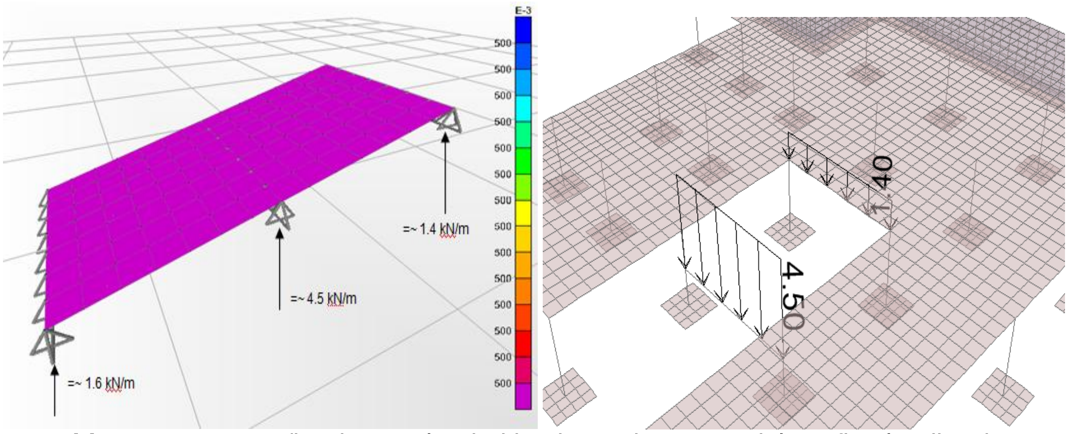
Movable partitions such as the stage, auditorium folding seats system, and possible reorganization of the area for temporary expositions, represent an extra lateral distribution of loads that should be considered inside the design. Thus the Auditorium/hall ground floor area will be subjected to an extra variable load of q_k = 0.8 kN/m^2. [64]



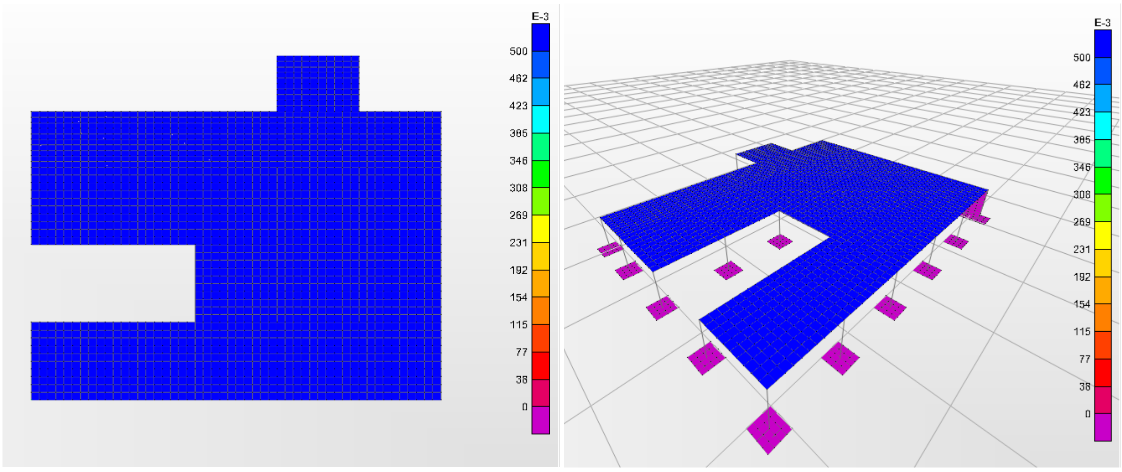
Graphic 21 Auditorium/ hall first floor slab Q2 loading (x10^-3 kN/m2)

In the case of the restaurant and bar it has been considered the loads due to the paesagistic organization of the main square and the staircase with movable furniture, adding a load distribution of q_k = 0.5 kN/m^2, In the same way, the loading of beams and elements is given by:

[64] Ibid. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings. PrEN: 1991-1-1-2001. P23

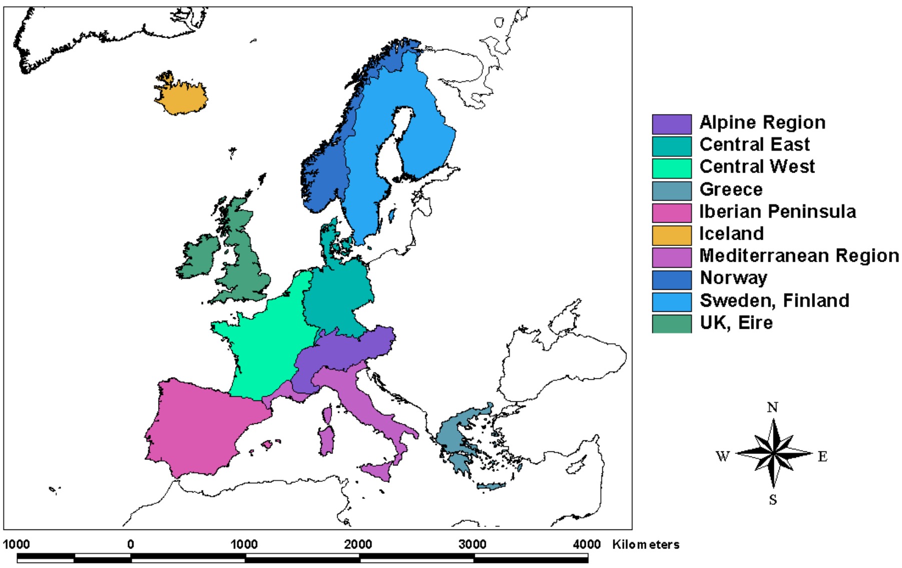


Graphic 22 Restaurant/bar beams loaded by the Staircase model Q2 first loading (x10^-3kN/m2) and reactions (kN/m)



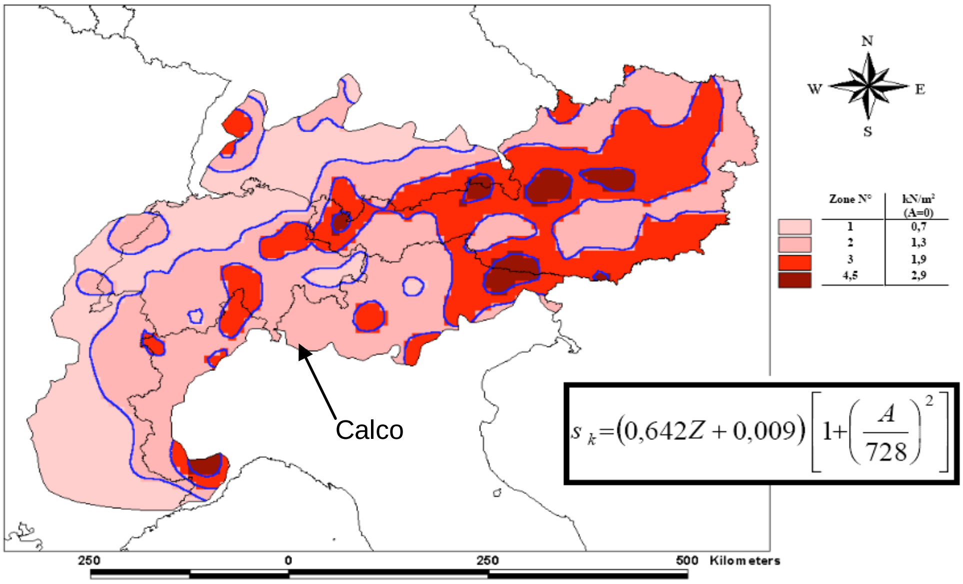
Graphic 23 Restaurant/bar ceiling slab Q2 loading (x10^-3 kN/m2)

3.5.2.3 *Snow Load (Q_3 =S)*



llustration 124 European snow map (Extracted from EUROCODE1-3) [65]

The expected load due to snow is given according to the EUROCODE EN1-3 1990[66].



Where:

s_k	is the characteristic snow load on the ground [kN/m^2]
A	is the site altitude above Sea Level [m]
Z	is the zone number given on the map.

Illustration 125 Snow load at sea level for Alpide zone (Extracted from EUROCODE1-3) [67]

Due to the approximated location of Calco inside the Alpine zone as it was described at the beginning of this chapter; the formula and graphic given in the next illustration, is the starting point for the characteristic snow load (Sk) calculation as follows:

$$\mathrm{Sk} = (0.642\ (2) + 0.009)\left[1 + (\frac{286}{728})^2\right] = 1.5\ \mathrm{kN/m2}$$

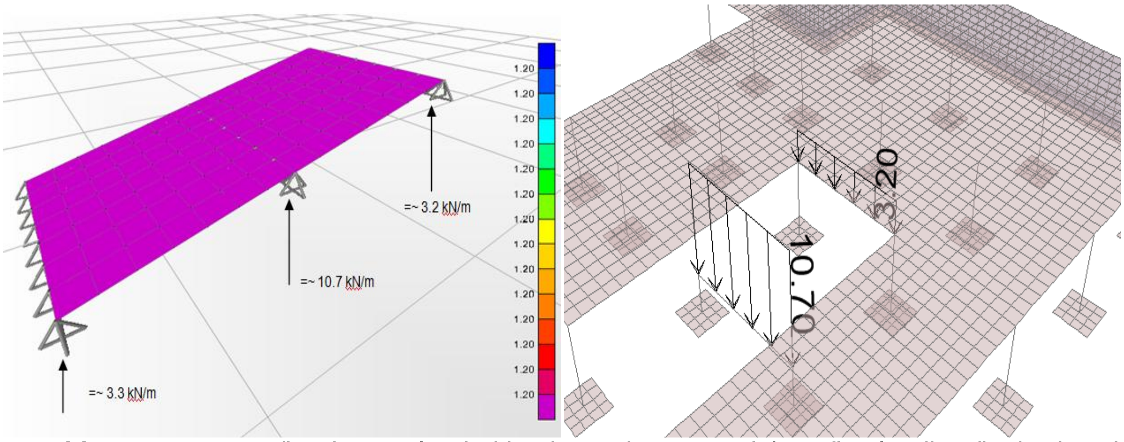
Equation 6 Characteristic Snow load for roof.

The total snow load will be given by the next equation, where U1 = 0.8 (flat roof), Ce = 1 (normal shelter), Ct = 1 (roof with U<=1 Wm^2/°K). [68]

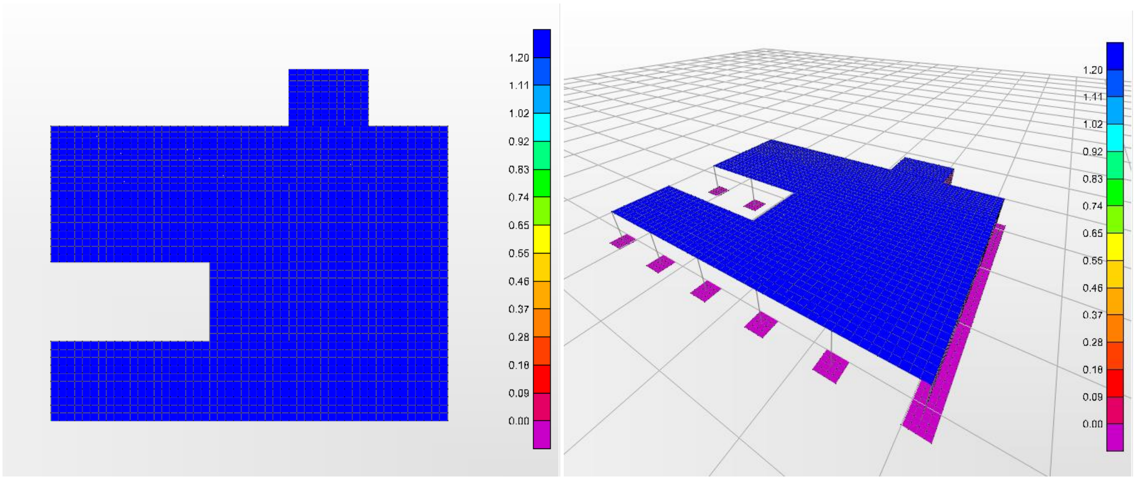
$$\mathrm{S} = \mu_1 * \mathrm{C_e} * \mathrm{C_t} * \mathrm{Sk} = 1.2\ \mathrm{kN/m2}$$

Equation 7 Snow load for roof

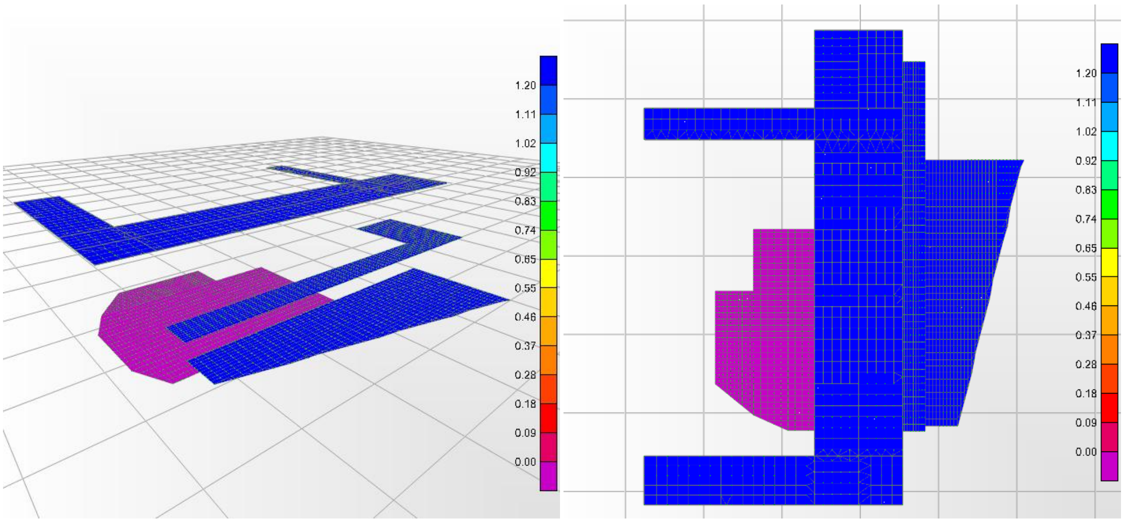
[65] Ibid. Actions on structures - Part 1-3: General actions - Snow loads. prEN: 1991-1-3-2001. P39
[66] Ibid. Actions on structures - Part 1-3: General actions - Snow loads. prEN: 1991-1-3-2001. P29
[67] Ibid. Actions on structures - Part 1-3: General actions - Snow loads. prEN: 1991-1-3-2001. P39
[68] Ibid. Actions on structures - Part 1-3: General actions - Snow loads. prEN: 1991-1-3-2001. P18-20



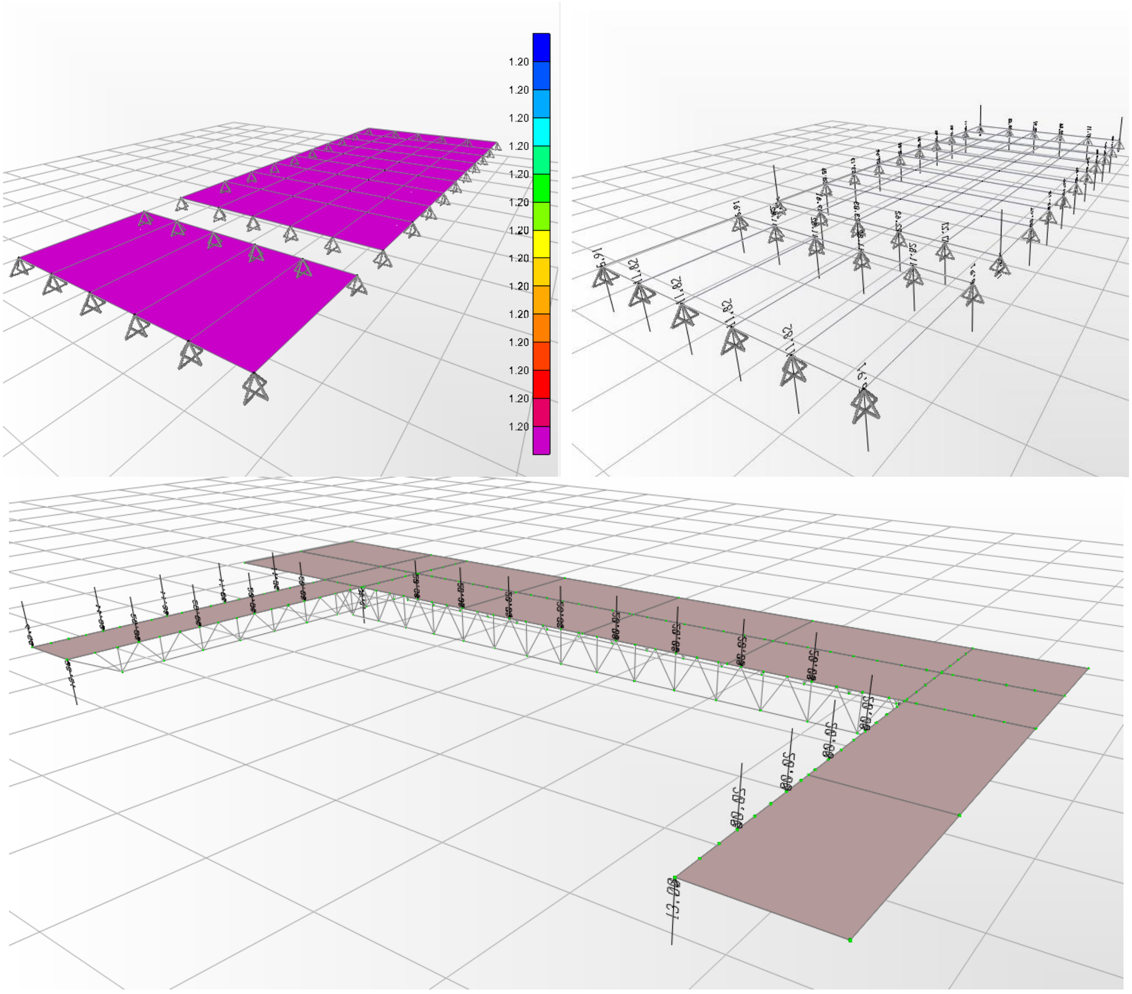
Graphic 24 Restaurant/bar beams loaded by the Staircase model Q3 first loading (kN/m2) and reactions (kN/m)



Graphic 25 Restaurant/bar ceiling slab Q3 loading (kN/m2)



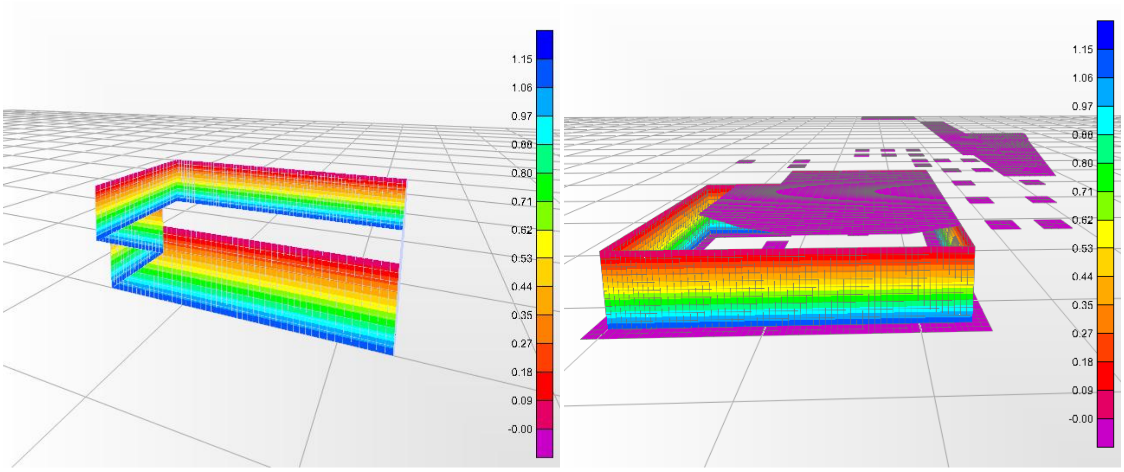
Graphic 26 Auditorium/Hall External ceiling and slabs Q3 loading (kN/m2)



Graphic 27 Auditorium/hall External Ceiling – ETFE Q3 first loading (kN/m2), reactions (kN) and second loading.

3.5.2.4 Hydrostatic pressure (Q_4)

The load due to hydrostatic pressure will be given to the retaining wail located in the basement of the auditorium/hall building. Its calculation is given considering the soil equivalence when it has presence of water, and when it is dry (Confined, unconfined)



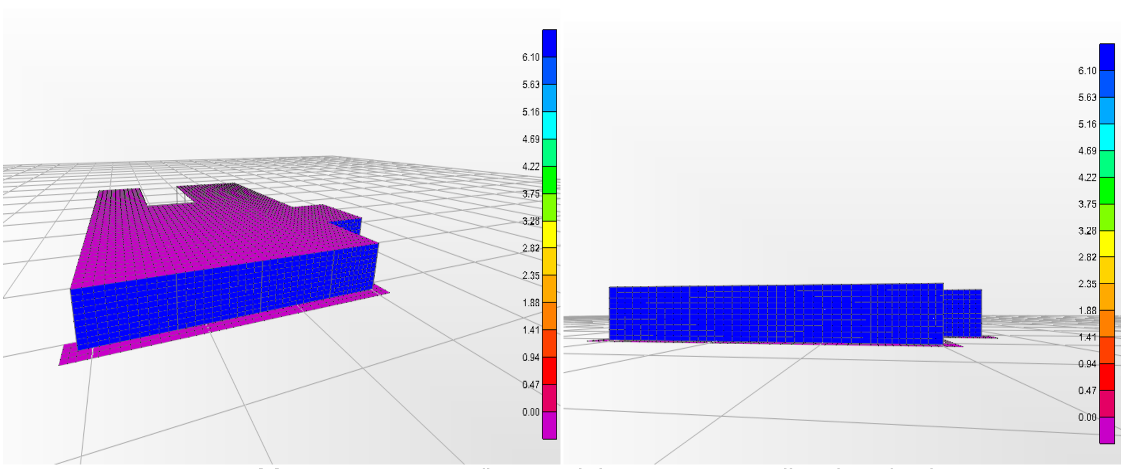
Graphic 28 Auditorium/ hall retaining wall Q4 loading (Ton/m2)

$$G3_{conf} = \gamma t * K_o * hw + [(\gamma t - \gamma w) * K_o + 1] * (h - hw)$$
$$G3_{conf} = 1.65 * 0.61 * 2 + [(1.65 - 1) * 0.61 + 1] * (5 - 2) = 6.05 \ \text{Ton/m2}$$
$$Q4 = G3_{conf} - G3_{unconf} = 6.05 - 4.9 = 1.15 \ \text{Ton/m2}$$

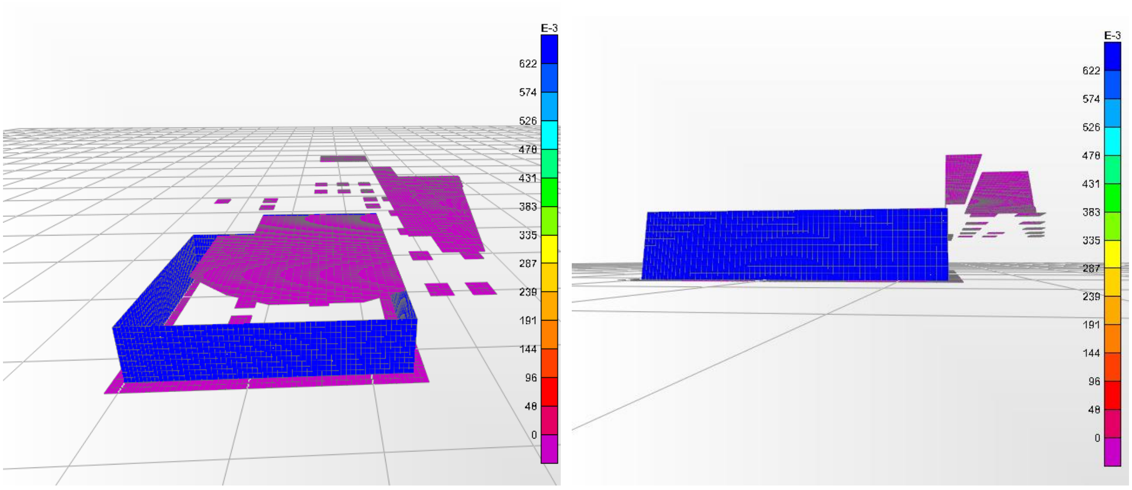
Equation 8 Auditorium/hall retaining wall G3 loading

3.5.2.5 Surcharge (Q_5)

It is considered the analysis of the model with an overload of 10KN/m2 perpendicular to the terrain surface that is contented by the soil, obtaining:



Graphic 29 Restaurant/bar retaining wall Q5 loading (Ton/m2)



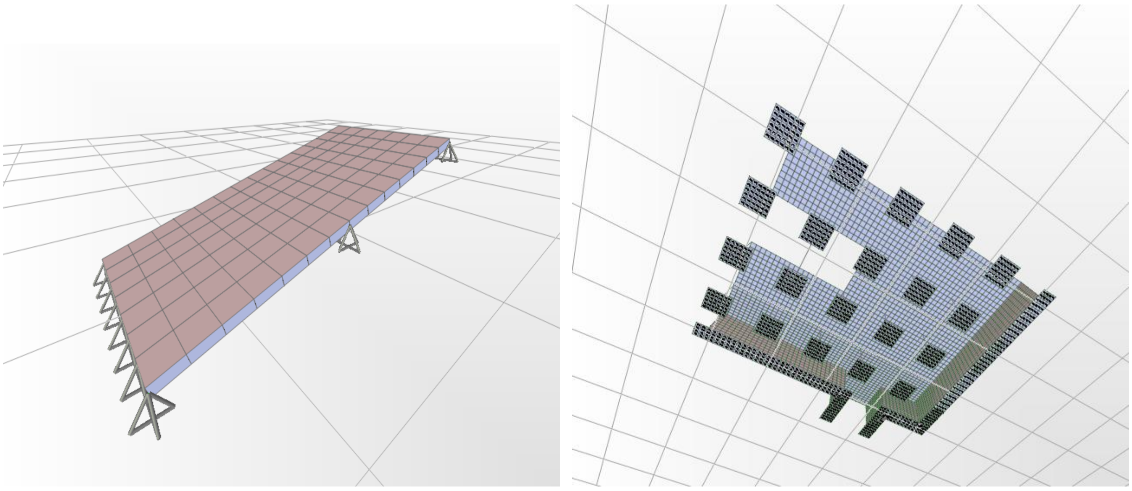
Graphic 30 Restaurant/bar retaining wall Q5 loading (x10^-3Ton/m2)

$$Q_5 = K_o * 10 = 6.1 \text{ kN/m2}$$

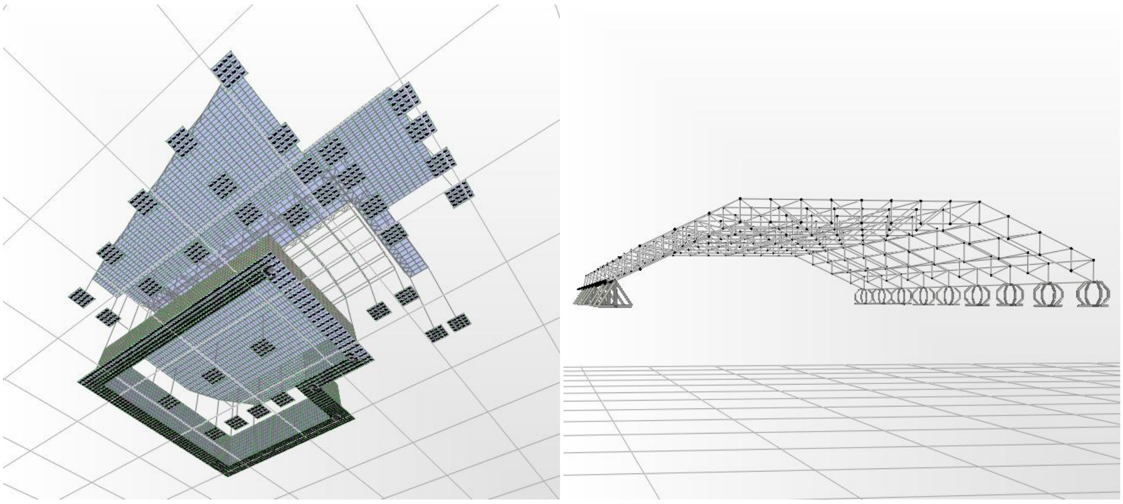
Equation 9 Auditorium/hall and restaurant bar retaining wall G3 loading

3.6 RESTRICTIONS AND SUPPORTS

According to the characteristics of the soil, it has been decided to support the structure considering a spring constant of Ks=1000 ton/m3. Stairs are modeled to be supported over pinned supports which will simulate the bearing beams in which the stair is hanging on. On the other hand the structure of the ceiling of the auditorium/theater has been modeled with a 1st and 2nd degree supports to allow the lateral movement of the structure under constant temperature changes.



Graphic 31 Restaurant/bar elements restrictions and supports



Graphic 32 Auditorium/hall foundation restrictions and supports of internal ceiling structure

3.7 LOADS COMBINATIONS

The main concept of loads combinations is to represent the maximum state of stresses that represent the most unfavorable condition[69] for the structure, taking into account the probability of occurrence and combination of these loads in a single instant. According to the methodology selected, partial factors (γ_f) will be applied for safety reasons to the characteristic actions obtained in the last chapters; 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.

3.7.1 Ultimate limit state

$$E_d = \sum_{j=1}^{n} \gamma_{G,j} * G_{k,j} + \gamma_{Q,1} * Q_{k,1} + \sum_{i=1}^{n} \gamma_{Q,i} * \Psi_{0,i} * Q_{k,i}$$

$$E_d = 1.35\,(G_1 + G_2 + G_3) + 1.5 * (Q_{1,1} + Q_{2,1}) + 1.5 * \left(0.5 * S_i + 0.7 * Q_{4,i} + 0.7 * Q_{5,i}\right)$$

Equation 10 Design load for persistent and transient design loads for Ultimate limit state.

[69] EUROCODE 1. Actions on structures - Part 1-1: General actions - densities, self-weight, imposed loads for buildings . prEN: 1991-1-1-2001. p22

Persistent or transient design situation	Permanent actions (G_k)		Leading variable action ($Q_{k,1}$)		Accompanying variable actions ($Q_{k,i}$)	
	Unfavourable	Favourable	Unfavourable	Favourable	Unfavourable	Favourable
(a) For checking the static equilibrium of a building structure	1.10	0.90	1.50	0	1.50	0
(b) For the design of structural members (excluding geotechnical actions)	1.35	1.00	1.50	0	1.50	0
(c) As an alternative to (a) and (b) above to design for both situations with one set of calculations	1.35	1.15	1.50	0	1.50	0

Illustration 126 partial safety factor at ultimate limit state, γ_g and γ_Q values. (Extracted from Mosley et al)[70]

Action	Combination Ψ_0	Frequent Ψ_1	Quasi-permanent Ψ_2
Imposed load 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, 30 kN < vehicle weight < 160 kN	0.7	0.5	0.3
Category H: roofs	0.7	0	0
Snow loads on buildings (see EN 1991-1-3)			
For sites located at altitude $H > 1000$ m above sea level	0.7	0.5	0.2
For sites located at altitude $H \leq 1000$ m above sea level	0.5	0.2	0

Illustration 127 ψ_0, ψ_1 and ψ_2 values for different load combinations (Extracted from Mosley et al)[71]

3.7.2 Serviceability limit state

$$E_d = \sum_{j=1}^{n} G_{k,j} + Q_{k,1} + \sum_{i=1}^{n} \gamma_{Q,i} * \Psi_{0,i} * Q_{k,i}$$

$$SLS = (G_1 + G_2 + G_3) + (Q_{1,1} + Q_{2,1}) + (0.5 * S_i + 0.7 * Q_{4,i} + 0.7 * Q_{5,i})$$

Equation 11 Design load under normal conditions of loads for serviceability limit state.

3.8 ULS and SLS DESIGN

3.8.1 Slabs:

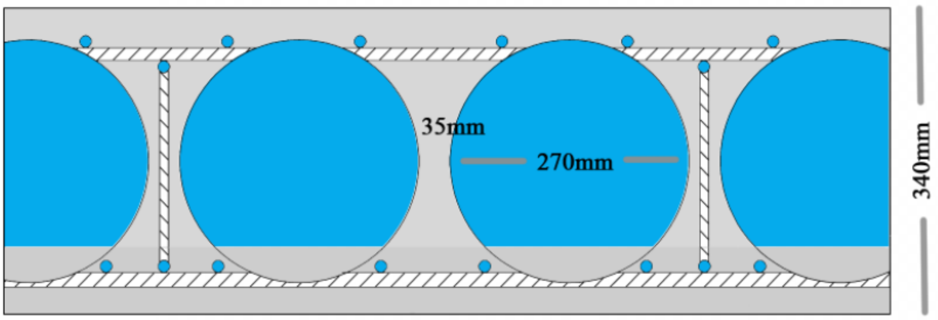
[70] MOSLEY Bill Et al.. Reinforced concrete design to Eurocode 2. Sixth edition. 2007 p.20
[71] Ibid.. Reinforced concrete design to Eurocode 2. Sixth edition. 2007 p.24

3.8.1.1 Sizing:

The sizing of the slabs is given according to the estimated simple supported and continuous span width. It is used the table of the manufacturer as a guide to get a preliminary design as follows

Version	Slab Thickness	Bubbles	Span (Multiple bays)	Cantilever Maximum Length	Span (Single bays)	Completed Slab Mass	Site Concrete Quantity
	mm	mm	metres	metres	metres	Kg/m²	m³/m²
BD230	230	Ø 180	5 – 8.1	≤ 2.2	5 – 6.3	370	0.11
BD280	280	Ø 225	7 – 10.1	≤ 2.7	6 – 7.8	460	0.14
BD340	340	Ø 270	9 – 12.5	≤ 3.3	7 – 9.6	550	0.18
BD390	390	Ø 315	10 – 14.4	≤ 3.8	9 – 11.1	640	0.21
BD450	450	Ø 360	11 – 16.7	≤ 4.5	10 – 12.5	730	0.25

Graphic 33 Manufacturer proposed dimensions for slabs



Graphic 34 Restaurant/bar – ceiling slab dimensioning

3.8.1.2 Bending moment design:

The hollow slab can be designed with conventional structural analysis of a full section, if the next criterion is followed (DIN 1045-1, DIN 1045).

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/m²]

Graphic 35 Flexion requirements (Extracted from Bubble deck) [72]

where

$$m_{sd} = \frac{M_{Ed}}{bd}$$

[72] BUBBLE DECK. The biaxial Hollow deck- design guide. [Available on-line] http://www.bubbledeck.com/download/BD_INT_DesignGuide.pdf. 2011.

Steps:

1. The bending reinforcement of a full section slab is given by: considering the level arm = 0.90 d nad b =1m

$$A_s = \frac{M_{Ed}}{0.9 f_{yd} bd}$$

2. Reinforcement details and rules: for bt the mean width of the tensile section. It is considered a 0,5 of the full section as an approximation. bt = 0.5 (1m).

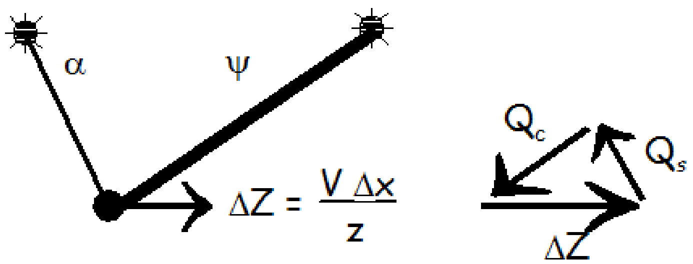
$$A_{min} = \frac{0.26 f_{cmt} b_t \, d}{f_{yk}} \geq 0.0013 b_t \, d$$

$$A_{max} = 0.04 b \, h$$

3. The steps from 1 to 3 are repeated for bottom and top reinforcement, but also for both x and y directions.

3.8.1.3 Shear design:

A Hollow slab type Bubble-deck is considered to provide a reduced resistance to shear than a flat concrete slab due to the bearing condition of a section directly dependent of its concrete amount. The reduction in concrete reduces approximately the shear resistance in 40%.[73] The methodology of calculation is the indicated in the Eurocode 2 part 1-1 1993-202 taking into account the recommendations for Bubble-deck slabs extracted from the Dutch standard NEN 6720.



Steps:

1. The ultimate design shear force without need of reinforcement for shear is given by: where b = 1m

[73] Ibid. The biaxial Hollow deck- design guide. [Available on-line] http://www.bubbledeck.com/download/BD _INT_DesignGuide.pdf. 2011.

$$v_{Ed} = \frac{V_{Ed}}{bd} \leq \; v_{Rd} = \frac{V_{Rd}}{bd}$$

2. Checking reinforcement need from the empirical formula: for bw = 1m. And affecting the shear of the whole section by 0.6, according to the shear capacity reduction due to the voids of the bubble-deck.

$$v_{rd,c1} = \frac{V_{rd,c}}{bd} = 0.60\left[0.12k\left(100\rho_1 f_{ck}\right)^{1/3}\right] > V_{Ed}$$

With a minimum of

$$v_{rd,c1} = \frac{V_{rd,c}}{bd} = 0.60[0.035k^{3/2}(f_{ck})^{1/2}] > V_{Ed}$$

Where:

$$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.0\,, \;\; \rho_1 = \frac{A_{sl}}{b_w d} \leq 0.02$$

3. If shear reinforcement is not required, distribution reinforcement should be provided on top and bottom of the slab.

A_{smin} = 0.0013bd (mm2/m) with b = 0.3m
$A_{max} = 0.04bh$ with b = 0.3m

4. Design of shear reinforcement when needed from the empirical formula: for b =0.3*b(1m), and considering tilted shear reinforcement α = 45°,(two diagonal legs of the BV-girder that form a triangle together, only one diagonal should be applied as shear force reinforcement. Of this diagonal only 75% of the cross area is considered according to the standard)., the shear resistance is the minimum value of the equations:

$$V_{Rd,s2} = 0.75 * 0.9d\frac{A_{sw}}{s}\; f_{ywd}(\cot(\alpha) + \cot(\Psi))\sin(\alpha)$$

And:

$$V_{Rd,max2} = 0.3 * 0.9bd\; \mathrm{v} f_{cd}(\cot(\alpha) + \cot(\Psi))\sin^2(\Psi)$$

Where:

$$\mathrm{v} = 0.5 \text{ for italy}$$
$$\Theta = 45$$
$$\frac{1}{1 + \cot(\Psi)} = \frac{0.75 A_{sw} f_{yd} \mathrm{Sin}\,(\alpha)}{0.3bs\mathrm{v} f_{cd}}$$

5. The shear resistance must satisfy the relationship:

$$v_{Ed} = \frac{V_{Ed}}{bd} \leq \; v_{Rd1+}v_{Rd2}$$

6. Reinforcement ratio verification: the maximum amount of reinforcement in the section both for flexion + shear (BV-girders added) must satisfy the relation ships:

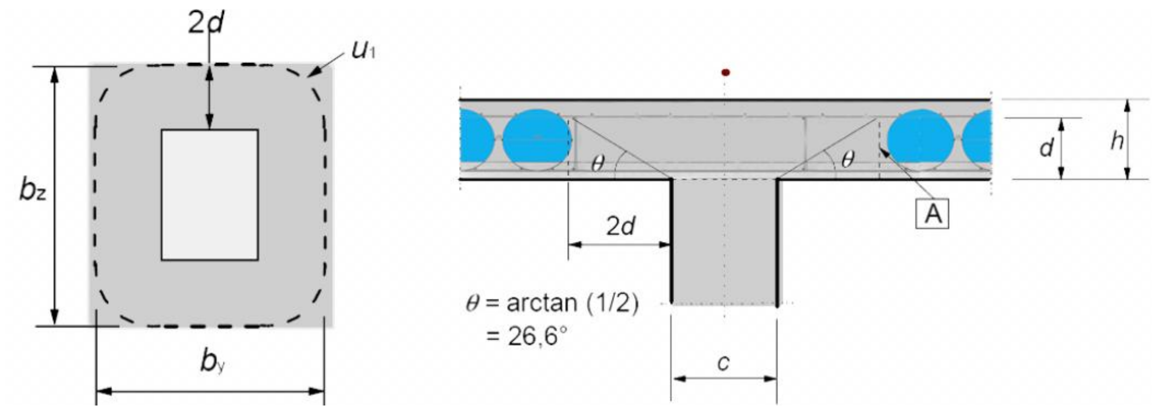
$$A_{ws} + Asl < A_{max} = 0.04b\ h \text{ with b = 0.3m}$$

3.8.1.4 Punching design:

According to the Dutch standard, the Bubble-deck slab behaves in the same way as a solid slab in terms of punching. On the other hand, the standard of reference states:

"…There are no test results available to prove that the influence of punch reinforcement in BubbleDeck floors could be determined in the same way as for solid floors. The contribution of punch reinforcement can therefore be left out of consideration. This is not a problem because punch reinforcement is impractical and anyway by leaving some spheres out the punch criterion can be satisfied. In this case the requirements for punch…"(CUR)[74]

In this way it is considered that the section will not have spheres in the control section, to be able to behave as a full solid slab for punching requirements.



Graphic 36 Restaurant/bar –ceiling slab effective area punching model

1. The ultimate shear stress is given by the load concentrated in the control perimeter given by the combination of loads:

$$\mathrm{V_{ed}} = \mathrm{E_d} * Acon = \left(1.35\ (\mathrm{G_2}) + 1.5 * (\mathrm{Q_{1,1}} + \mathrm{Q_{2,1}})\ +\ 1.5 * 0.5 * \mathrm{S_i}\right) * \mathrm{Ac}$$

$$\mathrm{V_{ed}} = 41.5\text{kN}$$

Where:

$$Acon = (4d + b) * (4d + h)$$

2. The ultimate shear stress in the control perimeter is given by:

[74] CUR CENTER FOR CIVIL ENGINEERING RESEARCH AND CODES- Bubble deck floors, supplementary regulations to NEN 6720 : 1995.

$$v_{ed} = \beta \frac{V_{ed}}{u_i d} \leq v_{rd}, c$$

Where:

$$\beta = 1.15 \; for \; Internal \; columns,$$
$$\beta = 1.4 - 1.5 \; for \; Edge \; columns$$

It is considered to apply an approximate method to define β due to the similitude in continuous spans, and taking into account that the lateral stability of the structure does not depend on frame action between slabs and columns, but also by the foundation and retaining walls actions.

3. The resistant for punching without considering shear reinforcement, according to the statement given above is:

$$v_{Rd,c} = \left[0.12k\left(100\rho_1 f_{ck}\right)^{1/3}\right] + 0.10\sigma_{cp} > v_{ed}$$

With a minimum of

$$v_{Rd,c} = \left[0.035k^{\frac{3}{2}}(f_{ck})^{\frac{1}{2}}\right] + 0.10\sigma_{cp} > v_{ed}$$

Where:

$$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.0\,, \;\; \rho_1 = \sqrt{\rho_x * \rho_y} \leq 0.02$$

$$\sigma_{cp} = \frac{\frac{N_{ed,x}}{Ac} + \frac{N_{ed,z}}{Ac}}{2},$$

Ned,x and Ned,z are the longitudinal forces across the full bay for internal columns and the longitudinal force across the control section for edge columns. The force may be from a load or pre-stressing action. *A*c is the area of concrete according to the definition of *N*ed.

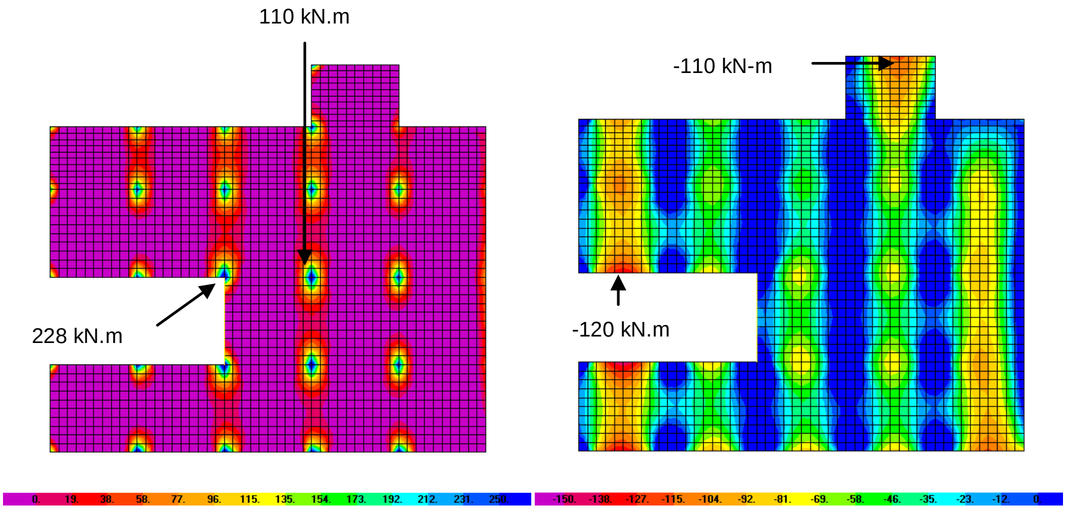
3.8.1.5 Serviceability limit state:

The serviceability limit state verification is done by the control of the maximum deflection in the lowest point of the slab. The deflection should not be higher than:

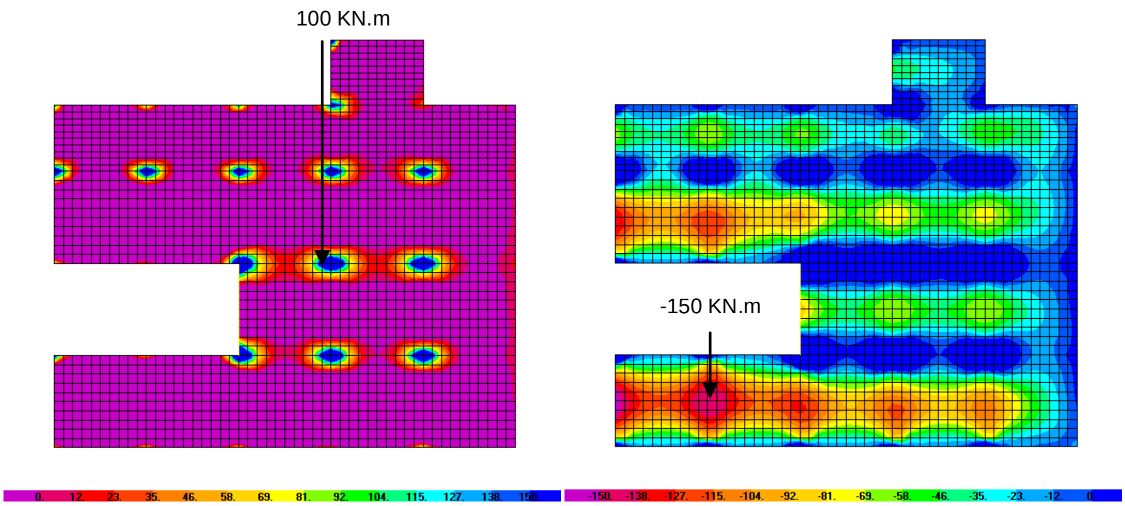
$$\alpha_z \leq L/250$$

3.8.1.6 Internal Forces and Reactions:

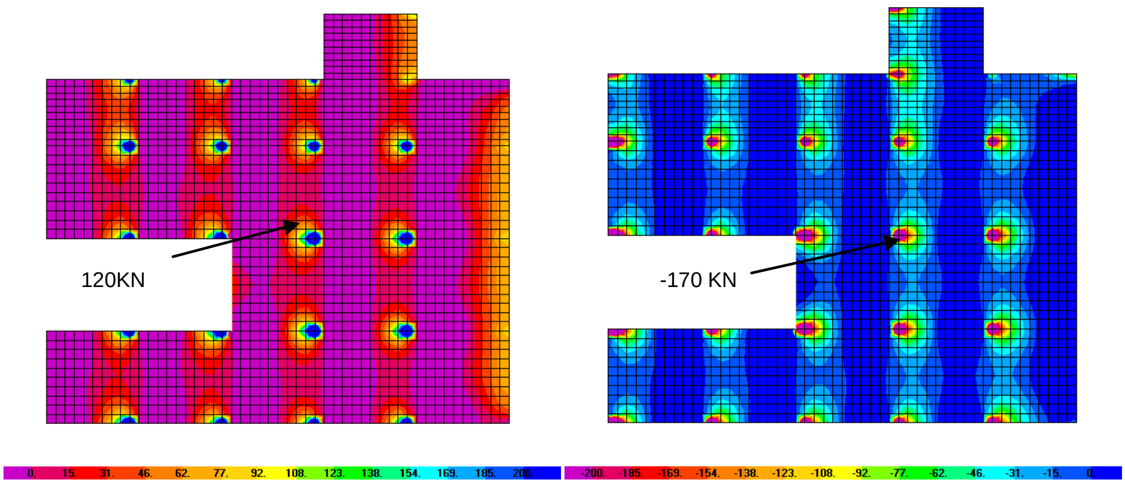
For simplification purposes it has been decided to analyze the slab of the restaurant as the one with highest loading of all the existent in the structural system.



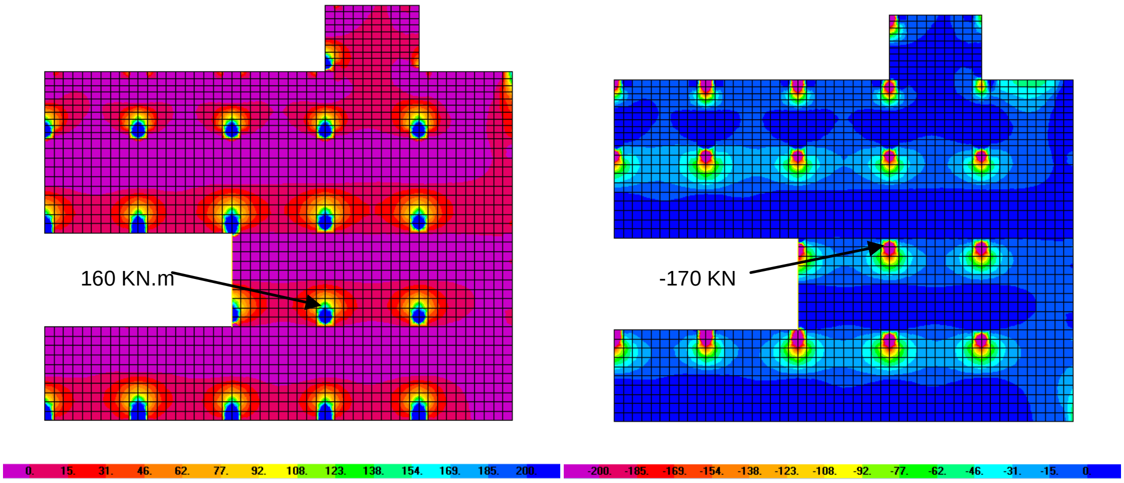
Graphic 37 Restaurant/bar – Reactions M11 ceiling slab ENV-ULS.



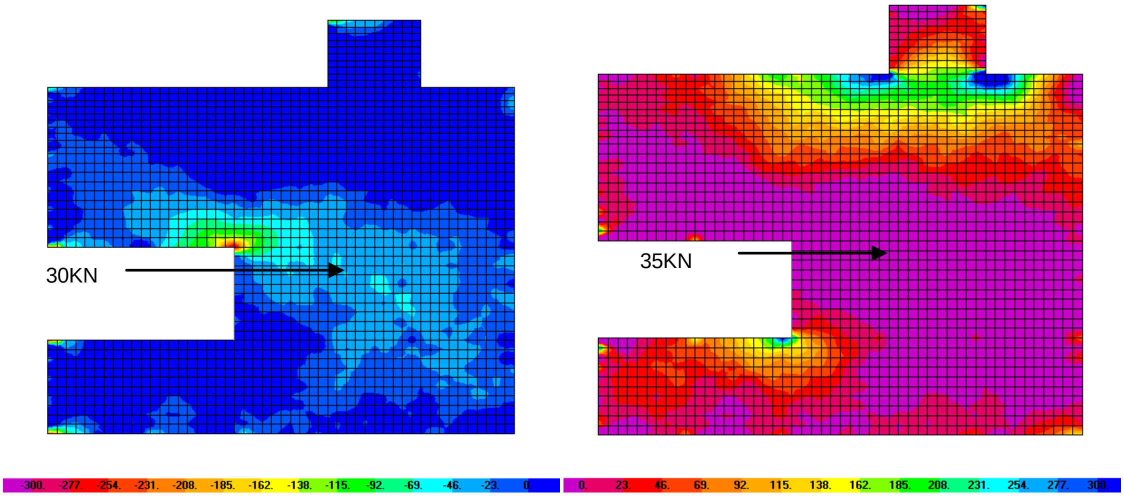
Graphic 38 Restaurant/bar – Reactions M22 ceiling slab ENV-ULS.



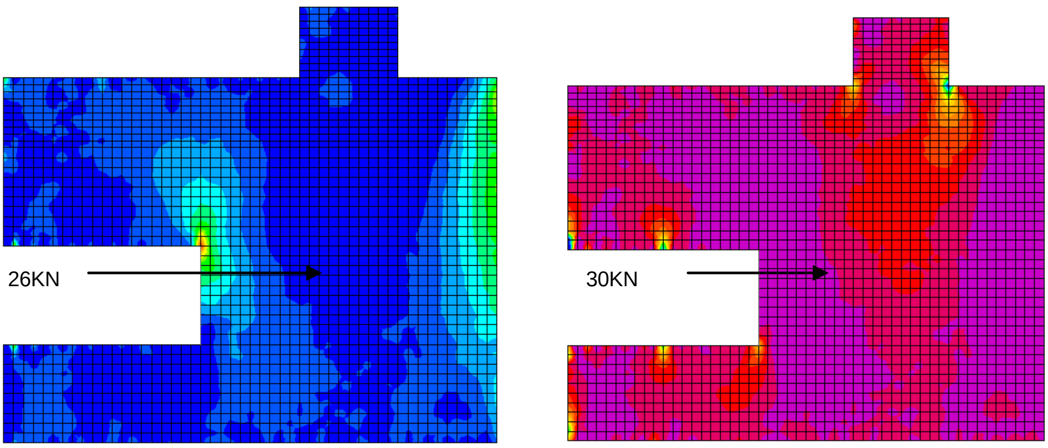
Graphic 39 Restaurant/bar – Reactions V12 ceiling slab ENV-ULS.



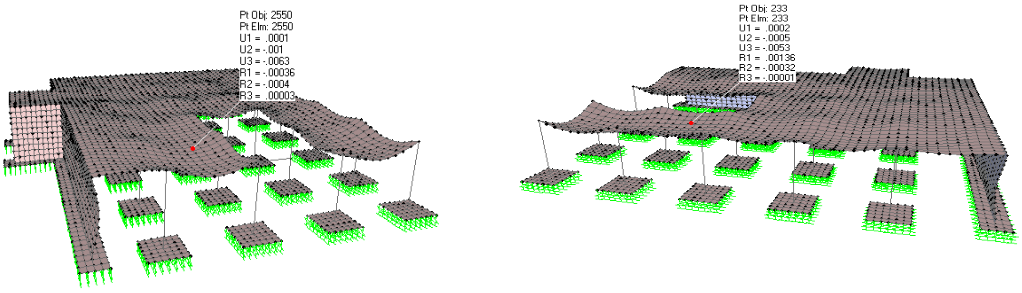
Graphic 40 Restaurant/bar – Reactions V23 ceiling slab ENV-ULS.



Graphic 41 Restaurant/bar – Minimum axial Reactions F11 ceiling slab ENV-ULS.



Graphic 42 Restaurant/bar – Minimum axial Reactions F22 ceiling slab ENV-ULS.



Graphic 43 Restaurant/bar – Maximum deflections slab ENV-SLS.

3.8.1.7 Results:

DESIGN SHEET- Slab restaurant

Maximum internal forces

Top reinforcement	
M11 + (kN.m)	110
M22 + (kN.m)	100

Top reinforcement	
V12 + (kN)	180
V23 + (kN)	160

Botton reinforcement	
M11 - (kN.m)	120
M22 - (kN.m)	150

Botton reinforcement	
V12 - (kN)	170
V23 - (kN.m)	170

Punching internal forces

F11ed- kN	30
F22ed- kN	26

V - (kN)	39

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C35/45				REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fctm(N/mm2)	fyk (N/mm2)	Es (N/mm2)
9917	35	0.002	4.1	500	200000
C (mm)	fcd(N/mm2)	εcu2(N/mm2)		fyd (N/mm2)	εyd
50	20	0.0035		435	0.00217

Element properties in y-y

b (mm)	h (mm)	d (mm) y-y	d' (mm)
1000	340	310	30

Checking according to DIN 1045

Msd (MN/m)	Dbd (m)	db (m)	fck (MN/m2)	μsds
0.484	0.27	0.34	35	0.2

μsds<=0.2
OK!

Flexion design

	d' (mm)	d (mm)	Asl (mm2)/m	Asl min (mm2)/m	Asl min (mm2)/m
M11 + (kN.m)	30	310	907	165	101
M22 + (kN.m)	35	305	838	163	99
M11 - (kN.m)	35	305	1005	163	99
M22 - (kN.m)	30	310	1237	165	101

Asl < Asmx
OK!
OK!
OK!
OK!

	As (mm2)/m	Re-bar φ	ırea rebar (mm2	Separation m
M11 + (kN.m)	907	14	154	0.160
M22 + (kN.m)	838	14	154	0.180
M11 - (kN.m)	1005	16	201	0.190
M22 - (kN.m)	1237	16	201	0.160

Shear assesment

	ved (kN/m2)	k	ρ1	vrd,c1 (kN/m2)	vrd,c1min (kN/m2)
M11 - (kN.m)	581	1.80	0.0066	370	301
M22 - (kN.m)	548	1.80	0.0080	394	301

vrd,c > ved
NEED OF REINFORCEMENT
NEED OF REINFORCEMENT

Shear reinforcement M11

# BV girders.m	Re-bar φ	Asw (mm2)	s (mm)	ϴ	ψ
2	14	308	460	45	57

vrd,c1+vrd,s2 > ved
OK!

vrd,s2 (kN/m2)	vrd,c2 (kN/m2)
228	3113

Aws+Asl < Asmx
OK!

Shear reinforcement M12

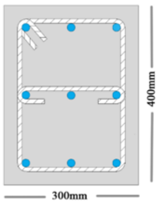
# BV girders.m	Re-bar φ	Asw (mm2)	s (mm)	ϴ	ψ
2	12	226	460	45	57

vrd,c1+vrd,s2 > ved
OK!

vrd,s2 (kN/m2)	vrd,c2 (kN/m2)
168	3113

Aws+Asl < Asmx
OK!

Punching design



Type of colum	β	υ (mm)
Internal	1.15	5421

b (mm)	h (mm)	deff (mm) y-y	d' (mm)
300	400	320	30

Maximum forces in the perimeter

Nedyy kN	Nedxx kN	σcp kN/mm2	Ved kN	ved (kN/m2)
30	26	0.36	38.7	23.03

Punching assesment

Asl xx(mm2)	ρx	ρ	k	Crd,c	vrd,c (kN/m2)	vrd,cmin (kN/m2)
1005	0.0030	0.00328	1.79	0.12	520.53	531.96
Asl yy(mm2)	**ρy**					
1237	0.0036					

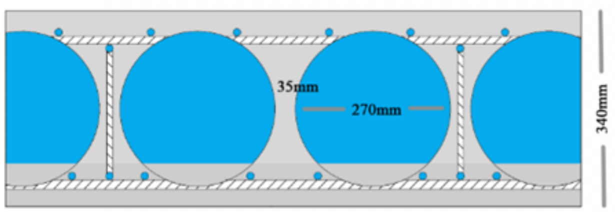
vrd,c> ved
OK!

Serviceability limit state

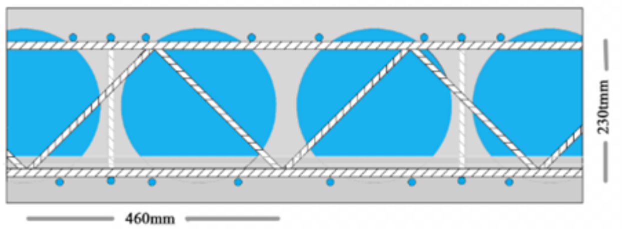
Span length (m)	α (m)
7	0.006

α<=L/250
ok!!!

FINAL DESIGN TABLE		
Longitudinal reinforcement		
	Re-bar φ	Separation m
M11 +	14	0.160
M22 +	14	0.180
M11 -	16	0.190
M22 -	16	0.160



Bv girders		
	# BV girders.m	Re-bar φ
M11 +	2	14
M11 +	2	12



3.8.2 Retaining wall:

The procedure for the design of a retaining wall can be done by means of the application of the equations previously stated for the design of a full slab and a column, taking into account that the axial forces prevail in the element as well as the shear and flexion moment.

3.8.2.1 Stability Analysis:

As an approximation, the stability of the structure in terms of overturning and sliding is meant to be satisfied by the slab-column structural system of the building. It is stated that the system will provide enough stiffness in to the system at the – 6 m and 0 m points of the wall "simulating" barely a simple supported wall in the horizontal direction. Considering that the failure mode of stability due to overturning and sliding is more predominant in the design for cantiliever retaining walls, which case is not presented in this problem as it was presented above. However, during construction it should be taking into account that the retaining wall should be casted at the same time or having the horizontal support of the slab-column system.

3.8.2.2 Bending moment design:

This type of retaining wall can be designed with the methodology applied for the design of a full concrete-section slab.

Steps:

4. The bending reinforcement of a full section slab is given by: considering the level arm = 0.90 d nad b =1m

$$A_s = \frac{M_{Ed}}{0.9 f_{yd} b d}$$

5. Reinforcement details and rules: for bt the mean width of the tensile section. bt = 1m

$$A_{min} = \frac{0.26 f_{cmt} b_t\ d}{f_{yk}} \geq 0.0013 b_t\ d$$

$$A_{max} = 0.04 b\ h$$

6. The steps from 1 to 3 are repeated for bottom and top reinforcement, but also for both x and y directions.

3.8.2.3 Shear design:

Steps:

1. The ultimate design shear force without the need of reinforcement for shear is given by: where b = 1m

$$v_{Ed} = \frac{V_{Ed}}{bd} \leq v_{Rd} = \frac{V_{Rd}}{bd}$$

2. Checking reinforcement need from the empirical formula: for bw = 1m.

$$v_{rd,c1} = \frac{V_{rd,c}}{bd} = \left[0.12k\left(100\rho_1 f_{ck}\right)^{1/3} + 0.15\sigma_{cp}\right] > v_{Ed}$$

With a minimum of

$$v_{rd,c1} = \frac{V_{rd,c}}{bd} = \left[0.035k^{\frac{3}{2}}(f_{ck})^{\frac{1}{2}} + 0.15\sigma_{cp}\right] > v_{Ed}$$

Where:

$$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.0\ , \quad \rho_1 = \frac{A_{sl}}{b_w d} \leq 0.02$$

3. When shear reinforcement is not required, distribution reinforcement should be provided on both sides of the wall.

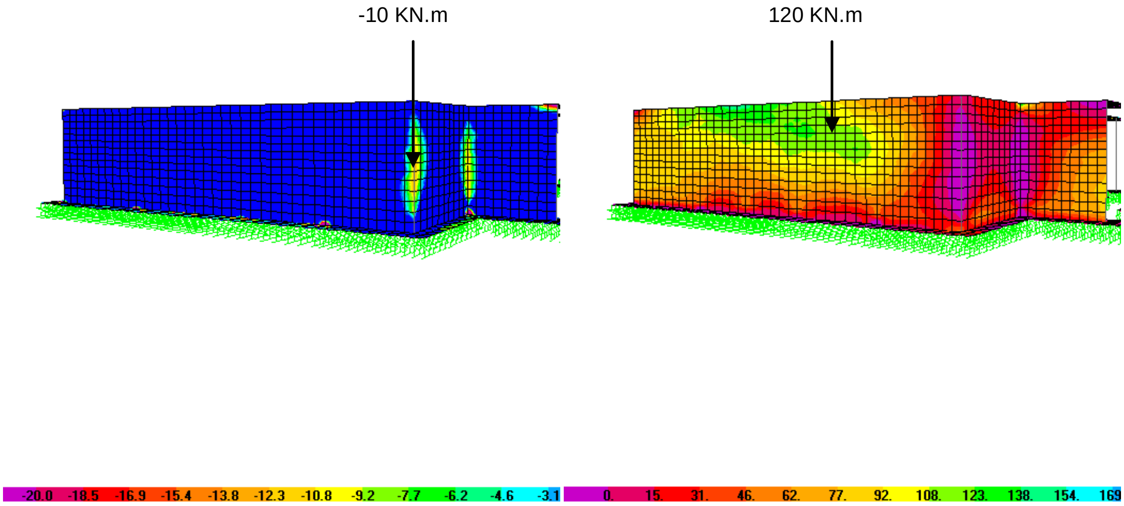
A_{smin} = 0.0013bd (mm2/m)

$$A_{max} = 0.04b\ h$$

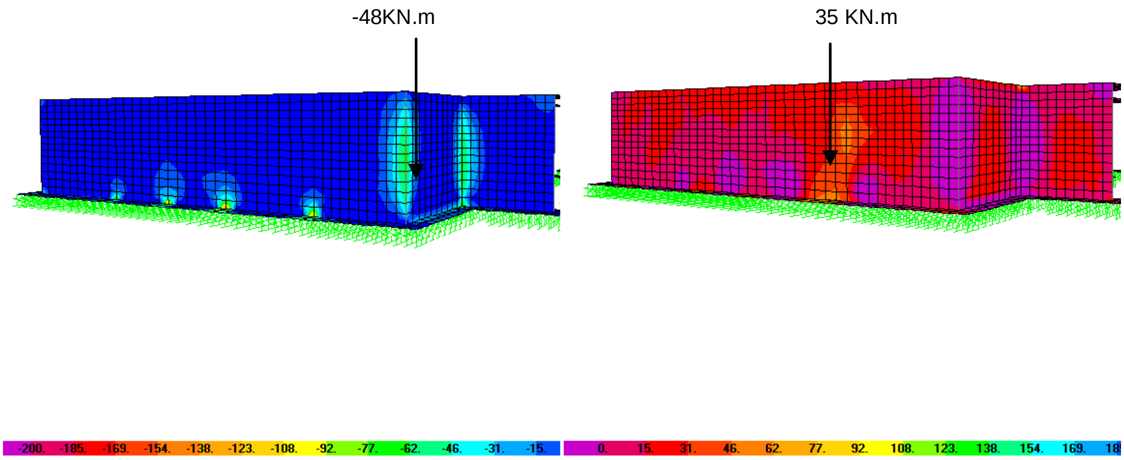
Confinement reinforcement should be given with hoops of 10mm spaced every 30cm max when shear reinforcement is not required.

3.8.2.4 Internal Forces and Reactions:

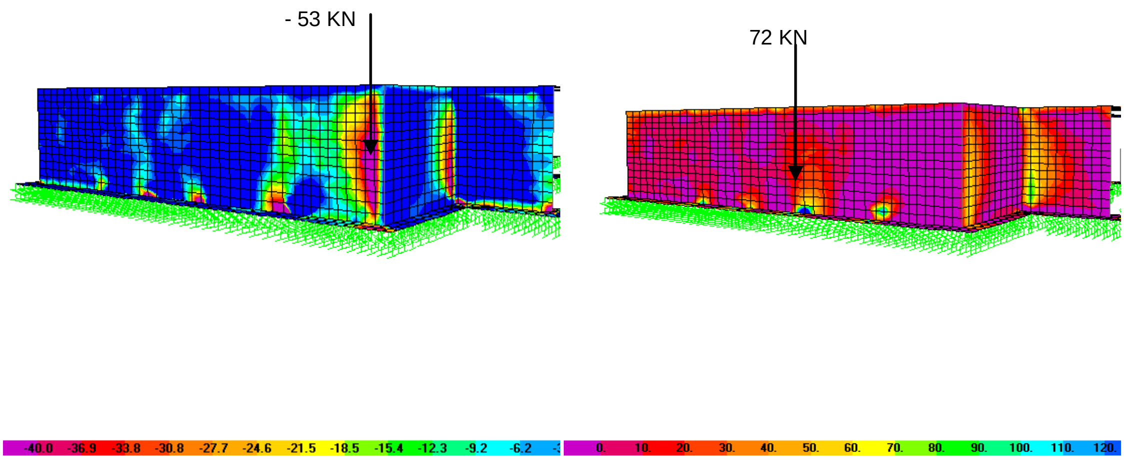
For simplification purposes it has been decided to analyze the retaining wall of the restaurant as the one with highest loading of all the existent in the structural system. Thus all the retaining walls in the compound of buildings will be given by the output of this design.



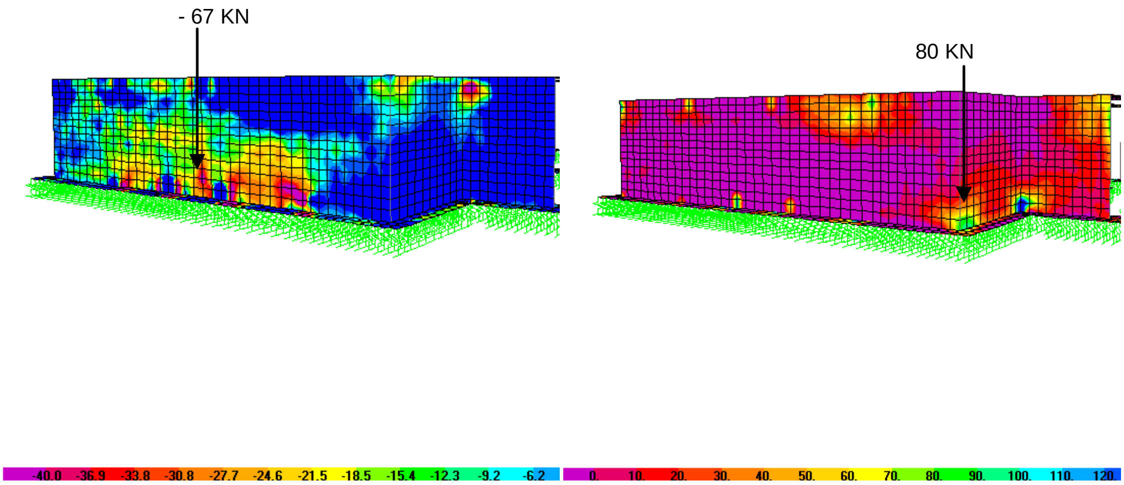
Graphic 44 Restaurant/bar – Reactions M11 retaining wall ENV-ULS.



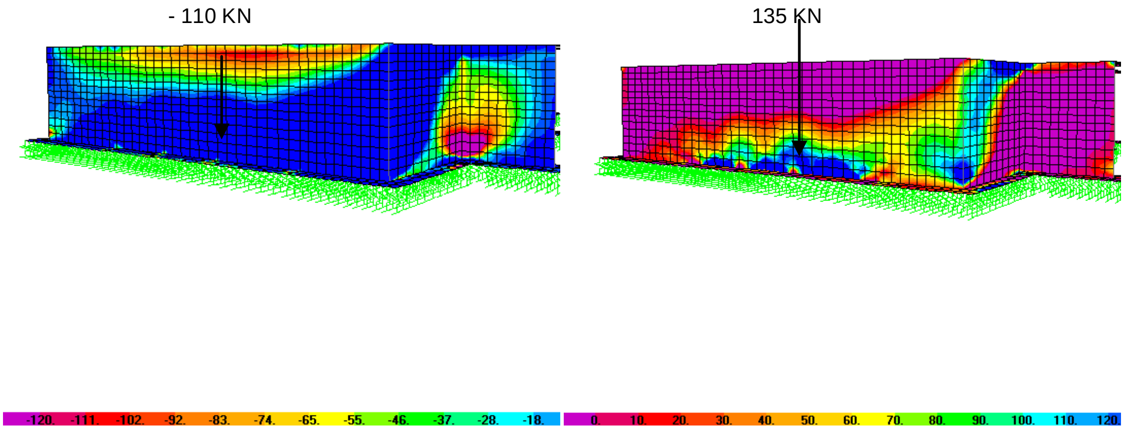
Graphic 45 Restaurant/bar – Reactions M22 ceiling slab ENV-ULS.



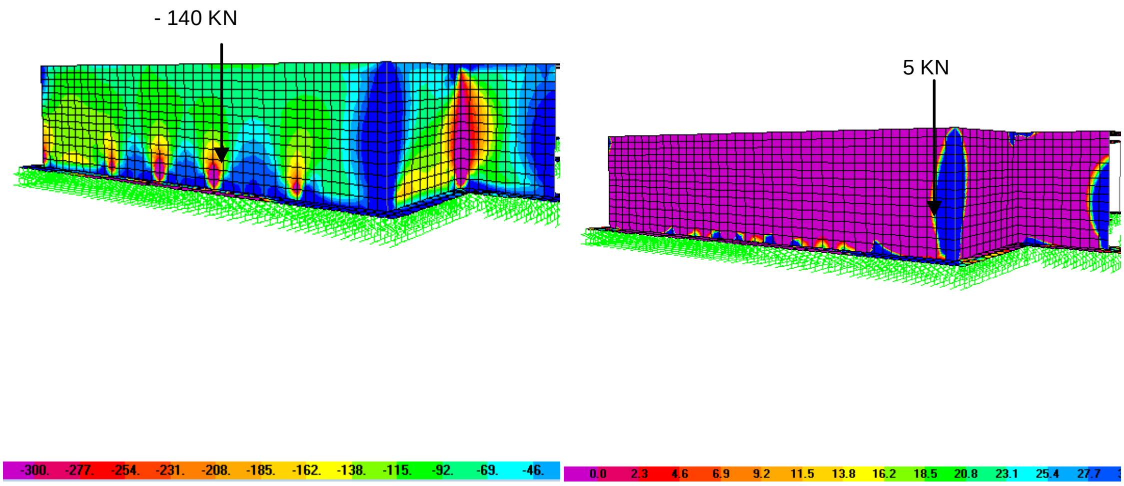
Graphic 46 Restaurant/bar – Reactions V12 ceiling slab ENV-ULS.



Graphic 47 Restaurant/bar – Reactions V23 ceiling slab ENV-ULS.



Graphic 48 Restaurant/bar – Reactions F11 ceiling slab ENV-ULS.



Graphic 49 Restaurant/bar – Reactions F22 ceiling slab ENV-ULS.

3.8.2.5 Results:

DESIGN SHEET- Retaining wall restaurant.

Maximum internal forces

Top reinforcement

M11 + (kN.m)	120
M22 + (kN.m)	35

Botton reinforcement

M11 - (kN.m)	10
M22 - (kN.m)	48

Punching internal forces

F11ed- kN	110
F22ed- kN	140

Top reinforcement

V12 + (kN)	72
V23 + (kN)	80

Botton reinforcement

V12 - (kN)	53
V23 - (kN.m)	67

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C35/45				REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fctm(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	4.1	500	200000
C (mm)	fcd(N/mm2)	εcu2(N/mm2)		fyd (N/mm2)	εyd
50	28	0.0035		435	0.00217

Element properties in y-y

b (mm)	h (mm)	d (mm) y-y	d' (mm)
1000	250	220	30

Flexion design

	d' (mm)	d (mm)	Asl (mm2)/m	Asl min (mm2)/m	Asl min (mm2)/m
M11 + (kN.m)	30	220	1394	235	143
M22 + (kN.m)	35	215	416	229	140
M11 - (kN.m)	35	215	119	229	140
M22 - (kN.m)	30	220	558	235	143

Asl < Asmx
OK!
OK!
OK!
OK!

	As (mm2)/m	Re-bar φ	Area rebar (mm2)	Separation m
M11 + (kN.m)	1394	18	254	0.180
M22 + (kN.m)	416	12	113	0.270
M11 - (kN.m)	229	10	79	0.340
M22 - (kN.m)	558	14	154	0.270

Shear assesment

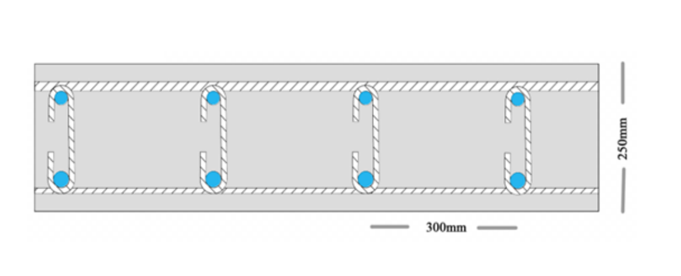
	ved (kN/m2)	k	ρ1	vrd,c1 (kN/m2)	vrd,c1min (kN/m2)
M11 - (kN.m)	327	1.95	0.0011	409	676
M22 - (kN.m)	364	1.95	0.0025	547	676

vrd,c > ved
OK!
OK!

Asl < Asmx
OK!

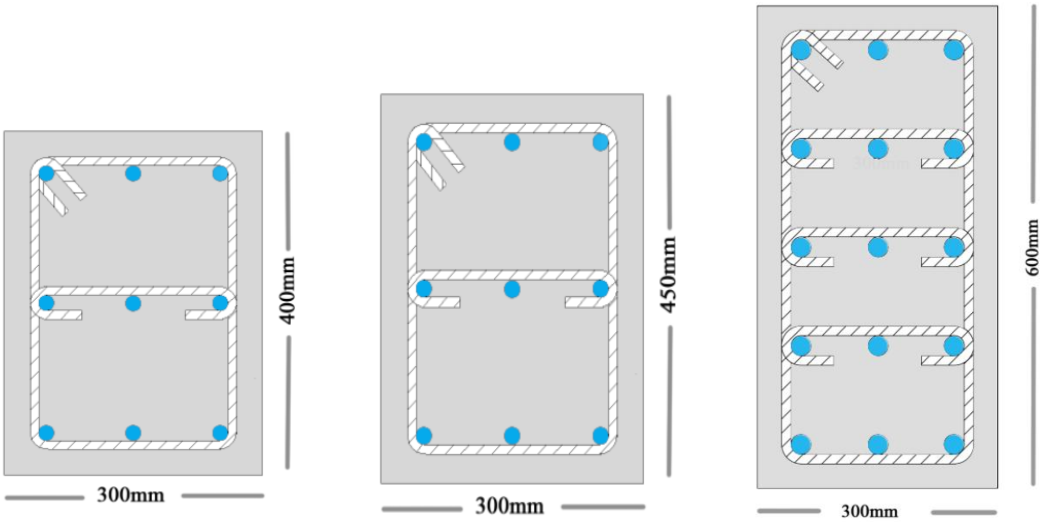
FINAL DESIGN TABLE		
Longitudinal reinforcement		
	Re-bar φ	Separation m
M11 +	18	0.180
M22 +	12	0.270
M11 -	10	0.340
M22 -	14	0.270

Longitudinal reinforcement
Stirrups # 10 Every 30cm.



3.8.3 Columns

3.8.3.1 Sizing and slenderness:



Graphic 50– Internal and external column section of characteristic columns.

The columns of all the system have to be analyzed for a failure mode due to slenderness, being characterized by their height without bracing and high axial loads. this failure mode can be analyzed as follows:

Steps:

1. The slenderness of a braced column such as the ones having on the design is given by:

$$\lambda = \frac{l_0}{\sqrt{\frac{I}{A_c}}}$$

Where:

$$l_0 = 0.5l\sqrt{\left(1+\frac{k1}{0.45+k1}\right)\left(1+\frac{k2}{0.45+k2}\right)}, k = \frac{Column\ stiff}{Beam\ stiff}$$

For this case it is considered to have a stiffness given by the Bubbledeck slab, which will be approximately equal to de stiffness of a solid slab at both rotation ends of the column, with a width equal to the dimension of the column considered in that direction. As a result:

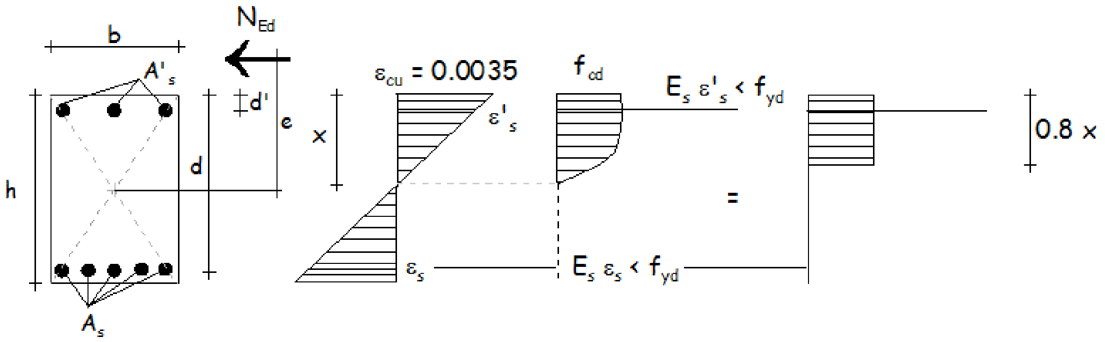
$$k1 = k2 = k = \frac{\frac{E_c}{l}Ic}{4\frac{E_c}{l_{span}}I_s}$$

2. The slender limit of any element is given by:

$$\lambda_{lim} = \frac{20 * 0.7 * B * C}{n} > \lambda$$

$$\mathrm{n} = \sqrt{\frac{\mathrm{N_{Ed}}}{\mathrm{A_c f_{cd}}}}, \mathrm{B} = \sqrt{1 + 2\frac{\mathrm{A_s f_{yd}}}{\mathrm{A_c f_{cd}}}}, \mathrm{C} = 1.7 - \frac{\mathrm{M_{minx}}}{\mathrm{M_{maxy}}}$$

3.8.3.2 Bending and axial load design M-N diagram:



Steps:

1. If the column is not slender, it can be designed as a non slender column (short column, by traditional methods). A M-N diagram can be constructed at which it will be analyzed all the possible maximum M-N combinations that can lead to the next cases of failure:

Tension Failure: x = d
Tension/Compresion Failure x =2.63d'
Balanced failure: x = xbal = 0.62d,
Compression Failure: x = d
Compression Failure: x = h
Compression Failure: x > h

Plastical centroid due to a not square section:

$$\mathrm{Xp} = \frac{\left(f_{cd}\mathrm{b}\frac{\mathrm{h}^2}{2} + f_{yd}A_s{}'d' + f_{yd}A_s d\right)}{f_{cd}\mathrm{bh} + f_{yd}A_s{}' + f_{yd}A_s}$$

Linear strain distribution:

For 0 < x < h

$$\varepsilon_{s'} = 0.0035\left(\frac{x-d'}{x}\right),\ \varepsilon_s = 0.0035\left(\frac{d-x}{x}\right)$$

For X>>>h

$$\varepsilon_{s'} = 0.002\left(\frac{7(x-d')}{7x-3h}\right),\ \varepsilon_s = 0.002\left(\frac{7(x-d)}{7x-3h}\right)$$

Axial force and moment equations:

For $0 < 0.8x < h$

$$\mathrm{N_{Ed}} = 0.8 f_{cd}\mathrm{Xb} + f_s' A_s' + f_s A_s$$

$$\mathrm{M_{Ed}} = 0.8 f_{cd}\mathrm{Xb}(\mathrm{Xp} - 0.4\mathrm{X}) + f_s' A_s'(\mathrm{Xp} - d') - f_s A_s(\mathrm{d} - \mathrm{Xp})$$

For $0.8x >= h$

$$\mathrm{N_{Ed}} = f_{cd}\mathrm{bh} + f_s' A_s' + f_s A_s$$

$$\mathrm{M_{Ed}} = f_{cd}\mathrm{bh}\left(\mathrm{Xp} - \frac{\mathrm{h}}{2}\right) + f_s' A_s'(\mathrm{Xp} - d') - f_s A_s(\mathrm{d} - \mathrm{Xp})$$

Where:

$$\varepsilon \geq \varepsilon_y = 0.00217, \quad f_s = f_{yd}$$
$$\varepsilon < \varepsilon_y = 0.00217, \quad f_s = E\varepsilon$$

2. The reinforcement detailing of the column should be:

$$Asl_{min} = \frac{0.10N_{ed}}{f_{yd}} \geq 0.002A_c$$

$$Asl_{max} < 0.08A_c$$

The design will be driven by considering all the possible combinations of Moments and axial load that can be presented during the Ultimate limit state combinations of loads.

3. The biaxial bending effect should be considered if the next relationship is not fulfilled: (for simplification purposes the section has been designed to achieve this requirement)

$$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^a + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^a \leq 1{,}0$$

3.8.3.3 Shear design:

1. The shear resistance of the full cross section without considering shear reinforcement, according to the statement given above is:

$$V_{Rd,c} = \left[0.12k\left(100\rho_1 f_{ck}\right)^{1/3} + 0.15\sigma_{cp}\right]bd > V_{ed}$$

With a minimum of

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

Where:

$$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.0\,, \quad \rho_1 = \frac{A_{sl}}{bd}$$

$$\sigma_{cp} = \frac{N_{ed}}{Ac} < 0.2f_{cd}$$

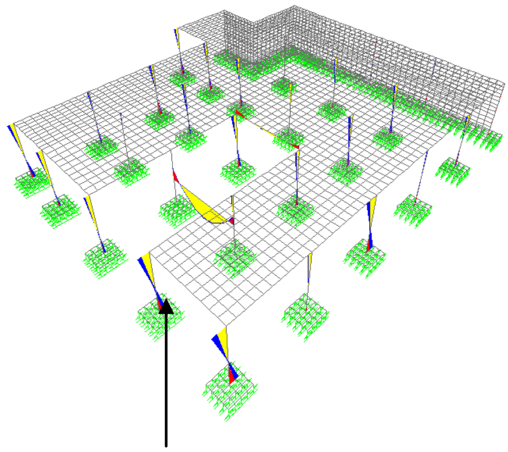
For the kind of columns considered not subjected to external horizontal loads that could generate exceptional conditions of shear stress in the section, It has been considered to design the section to be inside the limits of shear strength without necessary reinforcement, more than the given by:

Aws min to provide confinement= 10mm stirrups @ 240mm in confinement zone and @400mm in the rest of the section.

For practical purposes it is going to be analyzed the columns which present the highest internal forces as a driven factor that will generalized the design of the system.

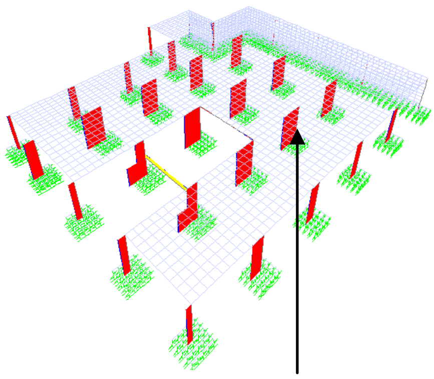
3.8.3.4 Internal Forces and Reactions:

Due to the high amount of vertical elements that compose the restaurant/bar structure, it has been decided to analyze for practical purposes the internal and external column of the restaurant with the highest loads that will be considered the characteristic columns of all the structural system.



Highest loaded external Column
ULS: maximum envelope values

Ned = -265 kN.m
Ved2 = - 60 kN
Ved3 = 32 kN
Med2 = 99.4 kN.m
Med3 = 311 kN.m
Ted = 4 kN.m - neglected

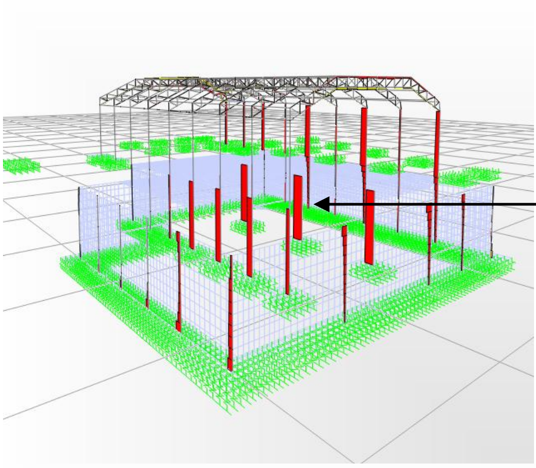


Highest loaded Internal Column
ULS: maximum envelope values

Ned = -1288 kN.m
Ved2 = - 51 kN
Ved3 = 1.3 kN
Med2 = 4.65 kN.m
Med3 = 177.1 kN.m
Ted = 0.1 kN.m - neglected

Graphic 51 Restaurant/bar –Characteristic column internal forces at ULS and SLS (view of M22 and Axial loads)

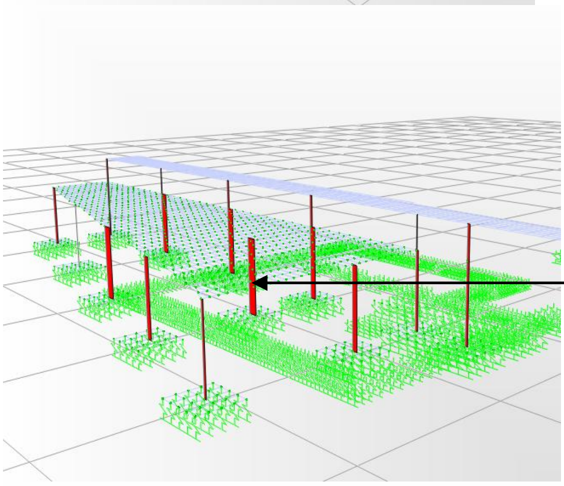
On the other hand, the elements that compose the auditorium hall building, have not close similitude to the restaurant structure in terms of support conditions and structural system regularity both in plan and in section. For this reason it has been decided to divide this building into zones that have an apparent similitude in terms of the conditions stated above. As a result:



Basement/theater Columns - highest loaded Element

ULS: maximum envelope values

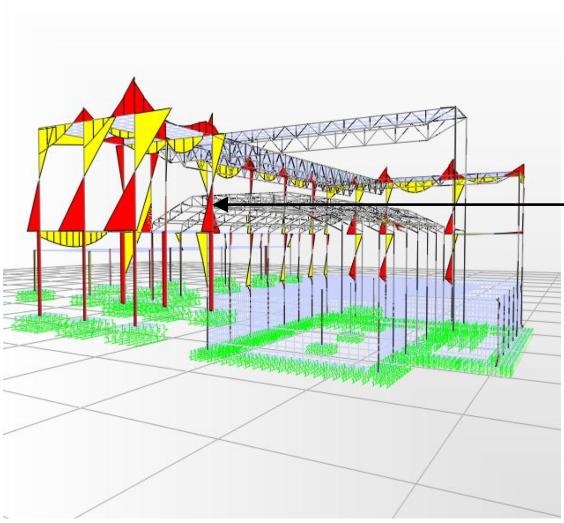
Ned = - 920 kN.m
Ved2 = 7.9 e-10 kN
Ved3 = 2.15e-10 kN
Med2 = 4.65 kN.m
Med3 = 1.4 kN.m
Ted = 7 kN.m - neglected



Changing rooms Columns - highest loaded Element

ULS: maximum envelope values

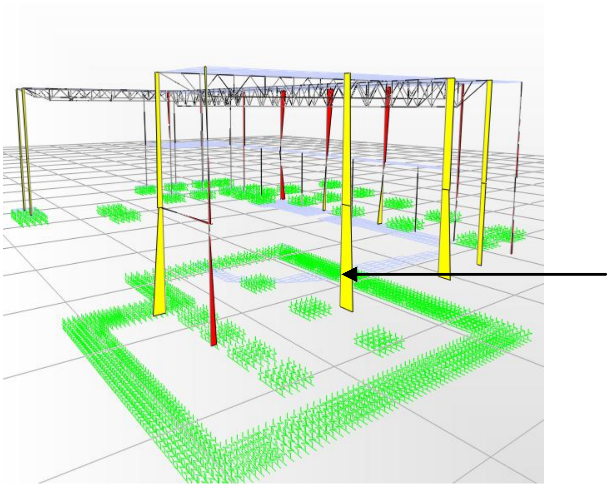
Ned = - 460 kN.m
Ved2 = 8.07 e-11 kN
Ved3 = 1.76e-11 kN
Med2 = 0.9 kN.m
Med3 = 1.27 kN.m
Ted = 1.6 kN.m - neglected



Internal skin - highest loaded Element

ULS: maximum envelope values

Ned = 1050 kN.m
Ved2 = 21 kN
Ved3 = 90 kN
Med2 = 448 kN.m
Med3 = 84 kN.m
Ted = 2.1 kN.m – neglected



External Skin - highest loaded Element

ULS: maximum envelope values

Ned = 840 kN.m
Ved2 = 34 kN
Ved3 = 78 kN
Med2 = 793 kN.m
Med3 = 93 kN.m
Ted = 12 kN.m – neglected

Graphic 52 Auditorium/hall – Characteristic column internal forces at ULS (view of Axial loads and M22)

3.8.3.5 Results:

DESIGN SHEET-Internal Column-Restaurant/bar

Maximum internal forces

Ped kN	Med 33-yy kN.m	Med 22-xx kN.m	Ved 33-yy kN	Ved 22-xx kN
1288	177	4.7	1.3	51

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C50/60			REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	500	200000
50	28	0.0035	435	0.00217

Element properties in y-y

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	400	120000	1145.11	1145.11	370	30

Asmin<As>=0.002Acc
OK!

Element properties In x-x

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
400	300	120000	1145.11	1145.11	270	30

Asmax/Ac<0.08
OK!

Slenderness checking x-x- braced column

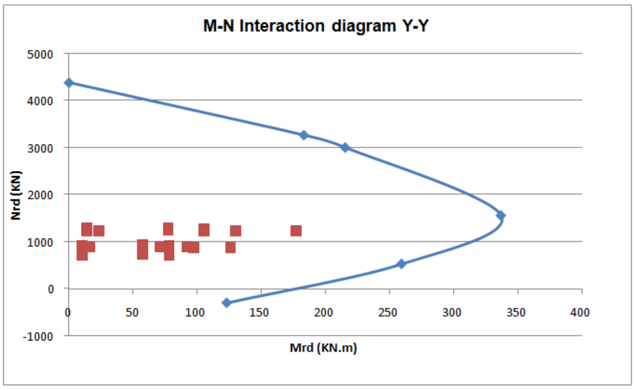
L (mm)	I (mm4)	i (mm)	k1	k2	l0(mm)	l
6000	1600000000	115.5	0.8503	0.6378	4859	42.08

n	B	C	llim
0.62	1.26	1.67	47.94

l<llim

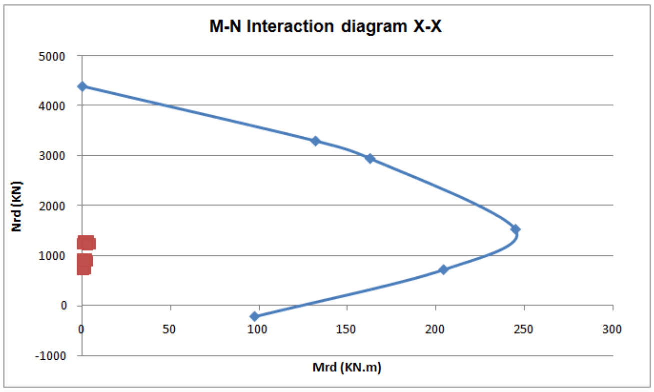
Interaction diagram In direction Y-Y

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	200	0.00000	0.03967	0	-435	-294	123
Tension failure x =2.63d'	78.9	200	0.00217	0.01291	434	-435	535	259
Xbal = 0.62d	229.4	200	0.00304	0.00215	435	-429	1567	337
Compression failure x =d	370	200	0.00322	0.00000	435	0	3014	215
Compression failure x =h	400	200	0.00324	-0.00026	435	53	3278	183
Compression failure x >h	1E+25	200	0.00217	0.00217	435	435	4396	0



Interaction diagram In direction X-X

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-226	97
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	714	204
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	1524	245
Compression failure x =d	270	150	0.00311	0.00000	435	0	2946	163
Compression failure x =h	300	150	0.00315	-0.00035	435	70	3298	132
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	4396	0.0



Biaxial Bending Assessment

Ned (KN)	Nrd (KN)	Med x- x (KN.m)	Mrd x-x (KN.m)	Med y- y (KN.m)	Mrd y-y (KN.m)	a
1288	4396	4.7	59	177	185	1.3

Confirmation
OK!

Shear Assesment in Y-Y

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
1.3	1145.110522	1.74	0.15	0.12	300	370

Vrd,c (KN)	ρ1	σcp N/mm2
265	0.010316311	10.7

Ved<Vrd,c
Minimum As is needed

Shear Assesment in X-X

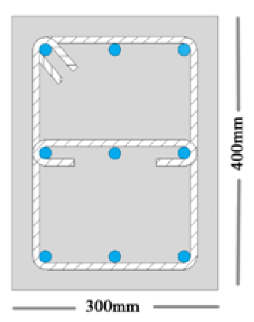
Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
51	1145.110522	2	0.15	0.12	400	270

Vrd,c (KN)	ρ1	σcp N/mm2
264.47	0.010602875	10.7

Ved<Vrd,c
Minimum As is needed

FINAL DESIGN TABLE

Stirrups		
As min	s confinement (mm)	s (mm)
stirrup 10 mm	240	400
Longitudinal reinforcement		
As		
9 bars H18		



DESIGN SHEET- Corner Column-Restaurant/bar

Maximum internal forces

Ped kN	Med 33-yy kN.m	Med 22-xx kN.m	Ved 33-yy kN	Ved 22-xx kN
265	311	99.0	32.0	60

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C50/60			REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	500	200000
50	28	0.0035	435	0.00217

Element properties in y-y

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	400	120000	2208.93	2208.93	370	30

Asmin<As>=0.002Acc
OK!

Element properties In x-x

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
400	300	120000	2208.93	2208.93	270	30

Asmax/Ac<0.08
OK!

Slenderness checking x-x- braced column

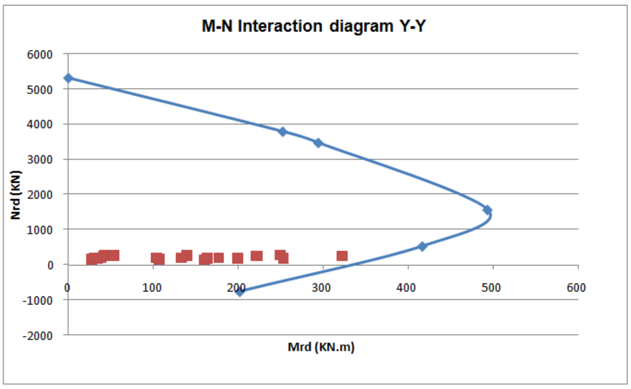
L (mm)	I (mm4)	i (mm)	k1	k2	l0(mm)	l
6000	1600000000	115.5	0.8503	0.6378	4859	42.08

n	B	C	llim
0.28	1.46	1.38	101.12

l<llim
OK!

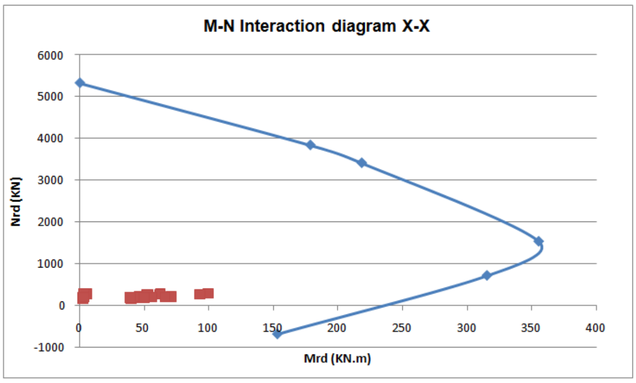
Interaction diagram In direction Y-Y

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	200	0.00000	0.03967	0	-435	-756	202
Tension failure x =2.63d'	78.9	200	0.00217	0.01291	434	-435	534	417
Xbal = 0.62d	229.4	200	0.00304	0.00215	435	-429	1573	493
Compression failure x =d	370	200	0.00322	0.00000	435	0	3476	294
Compression failure x =h	400	200	0.00324	-0.00026	435	53	3796	252
Compression failure x >h	1E+25	200	0.00217	0.00217	435	435	5321	0



Interaction diagram In direction X-X

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-688	153
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	713	315
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	1530	355
Compression failure x =d	270	150	0.00311	0.00000	435	0	3408	218
Compression failure x =h	300	150	0.00315	-0.00035	435	70	3835	178
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	5321	0.0



Biaxial Bending Assessment

Ned (KN)	Nrd (KN)	Med x- x (KN.m)	Mrd x-x (KN.m)	Med y- y (KN.m)	Mrd y-y (KN.m)	a
265	5321	99.0	240	311	325	1

Confirmation
OK!

Shear Assesment in Y-Y

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
32.0	2208.932335	1.74	0.15	0.12	300	370

Vrd,c (KN)	ρ1	σcp N/mm2
144	0.019900291	2.2

Ved<Vrd,c
Minimum As is needed

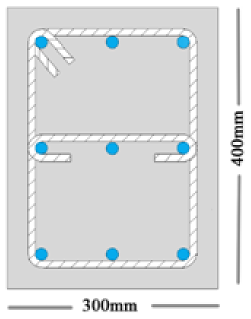
Shear Assesment in X-X

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
60	2208.932335	2	0.15	0.12	400	270

Vrd,c (KN)	ρ1	σcp N/mm2
148.54	0.020453077	2.2

Ved<Vrd,c
Minimum As is needed

FINAL DESIGN TABLE		
Stirrups		
As min	s confinement (mm)	s (mm)
stirrup 10 mm	240	400
Longitudinal reinforcement		
As		
9 bars H25		



DESIGN SHEET- Basement/theater Column-Auditorium/hall

Maximum internal forces

Ped kN	Med 33-yy kN.m	Med 22-xx kN.m	Ved 33-yy kN	Ved 22-xx kN
940	1	2.2	0.0	0

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C50/60			REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	500	200000
50	28	0.0035	435	0.00217

Element properties in y-y

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	400	120000	1145.11	1145.11	370	30

Element properties In x-x

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
400	300	120000	1145.11	1145.11	270	30

Asmin<As>=0.002Acc
OK!

Asmax/Ac<0.08
OK!

Slenderness checking x-x- braced column

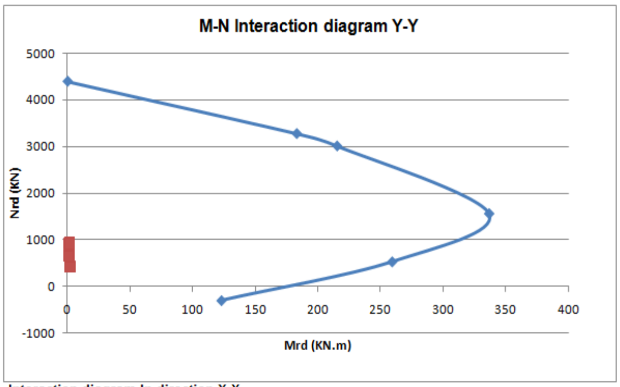
L (mm)	I (mm4)	i (mm)	k1	k2	l0(mm)	l
5000	1600000000	115.5	1.0204	0.7653	4154	35.97

n	B	C	llim
0.53	1.26	1.09	36.57

l<llim
OK!

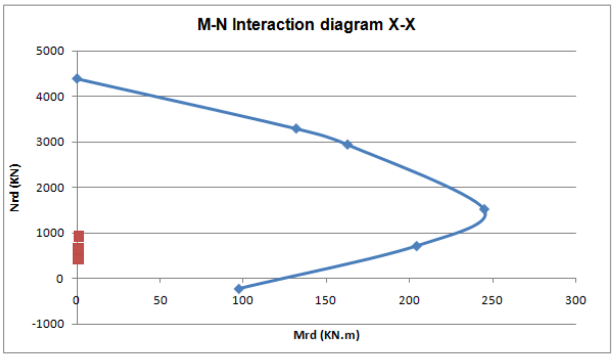
Interaction diagram In direction Y-Y

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	200	0.00000	0.03967	0	-435	-294	123
Tension failure x =2.63d'	78.9	200	0.00217	0.01291	434	-435	535	259
Xbal = 0.62d	229.4	200	0.00304	0.00215	435	-429	1567	337
Compression failure x =d	370	200	0.00322	0.00000	435	0	3014	215
Compression failure x =h	400	200	0.00324	-0.00026	435	53	3278	183
Compression failure x >h	1E+25	200	0.00217	0.00217	435	435	4396	0



Interaction diagram In direction X-X

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-226	97
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	714	204
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	1524	245
Compression failure x =d	270	150	0.00311	0.00000	435	0	2946	163
Compression failure x =h	300	150	0.00315	-0.00035	435	70	3298	132
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	4396	0.0



Biaxial Bending Assessment

Ned (KN)	Nrd (KN)	Med x- x (KN.m)	Mrd x-x (KN.m)	Med y- y (KN.m)	Mrd y-y (KN.m)	a
940	4396	2.2	800	1	290	1

Confirmation
OK!

Shear Assesment in Y-Y

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
0.0	1145.110522	2.00	0.15	0.12	300	370

Vrd,c (KN)	ρ1	σcp N/mm2
230	0.010316311	7.8

Ved<Vrd,c
Minimum As is needed

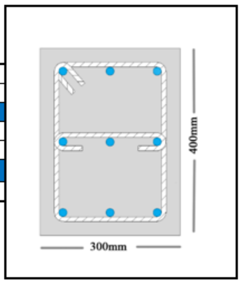
Shear Assesment in X-X

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
0	1145.11	2	0.15	0.12	400	270

Vrd,c (KN)	ρ1	σcp N/mm2
217.46	0.010602875	7.8

Ved<Vrd,c
Minimum As is needed

FINAL DESIGN TABLE		
Stirrups		
As min	s confinement (mm)	s (mm)
stirrup 12 mm	240	400
Longitudinal reinforcement		
As		
9 bars H18		



DESIGN SHEET- Changing room Column-Auditorium/hall

Maximum internal forces

Ped kN	Med 33-yy kN.m	Med 22-xx kN.m	Ved 33-yy kN	Ved 22-xx kN
491	1	0.9	0.0	0

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C50/60			REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	500	200000
50	28	0.0035	435	0.00217

Element properties in y-y

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	300	90000	1154.54	1154.54	270	30

Asmin<As>=0.002Acc
OK!

Element properties In x-x

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	300	90000	1154.54	1154.54	270	30

Asmax/Ac<0.08
OK!

Slenderness checking x-x- braced column

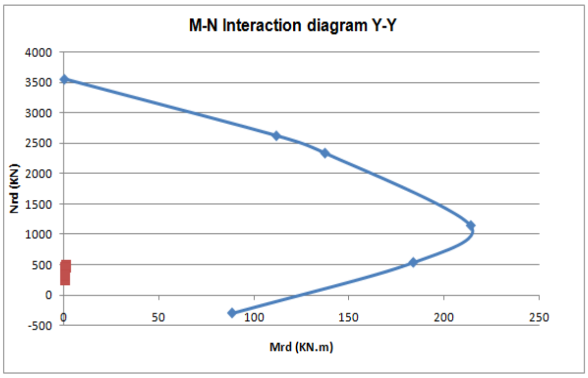
L (mm)	I (mm4)	i (mm)	k1	k2	l0(mm)	l
3500	675000000	86.6	0.6150	0.6150	2761	31.88

n	B	C	llim
0.44	1.34	0.98	41.93

l<llim
OK!

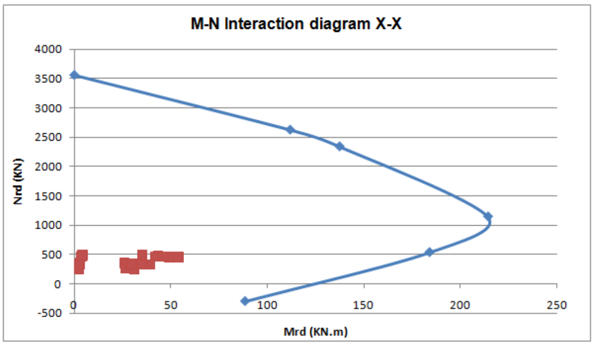
Interaction diagram In direction Y-Y

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-298	88
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	535	184
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	1145	214
Compression failure x =d	270	150	0.00311	0.00000	435	0	2338	137
Compression failure x =h	300	150	0.00315	-0.00035	435	70	2623	112
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	3554	0



Interaction diagram In direction X-X

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-298	88
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	535	184
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	1145	214
Compression failure x =d	270	150	0.00311	0.00000	435	0	2338	137
Compression failure x =h	300	150	0.00315	-0.00035	435	70	2623	112
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	3554	0.0



Biaxial Bending Assessment

Ned (KN)	Nrd (KN)	Med x- x (KN.m)	Mrd x-x (KN.m)	Med y- y (KN.m)	Mrd y-y (KN.m)	a
491	3554	0.9	110	1	110	1

Confirmation
OK!

Shear Assesment in Y-Y

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
0.0	1154.5353	1.86	0.15	0.12	300	270

Vrd,c (KN)	ρ1	σcp N/mm2
141	0.014253522	5.5

Ved<Vrd,c
Minimum As is needed

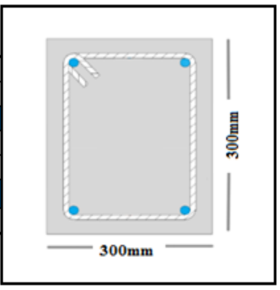
Shear Assesment in X-X

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
0	1154.54	2	0.15	0.12	300	270

Vrd,c (KN)	ρ1	σcp N/mm2
141.22	0.014253522	5.5

Ved<Vrd,c
Minimum As is needed

FINAL DESIGN TABLE		
Stirrups		
As min	s confinement (mm)	s (mm)
stirrup 12 mm	240	400
Longitudinal reinforcement		
As		
4 bars H14		



DESIGN SHEET- Internal skin Column-Auditorium/hall

Maximum internal forces

Ped kN	Med 33-yy kN.m	Med 22-xx kN.m	Ved 33-yy kN	Ved 22-xx kN
1098	89	541.3	89.7	25

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C50/60			REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	500	200000
50	28	0.0035	435	0.00217

Element properties in y-y

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	600	180000	3681.55	3681.55	570	30

Asmin<As>=0.002Acc
OK!

Element properties In x-x

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
600	300	180000	3681.55	3681.55	270	30

Asmax/Ac<0.08
OK!

Slenderness checking x-x- braced column

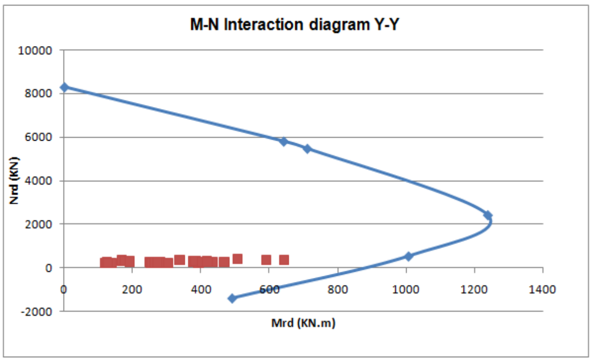
L (mm)	I (mm4)	i (mm)	k1	k2	l0(mm)	l
5000	5400000000	173.2	3.4439	1.7219	4595	26.53

n	B	C	llim
0.46	1.50	1.54	69.61

l<llim
OK!

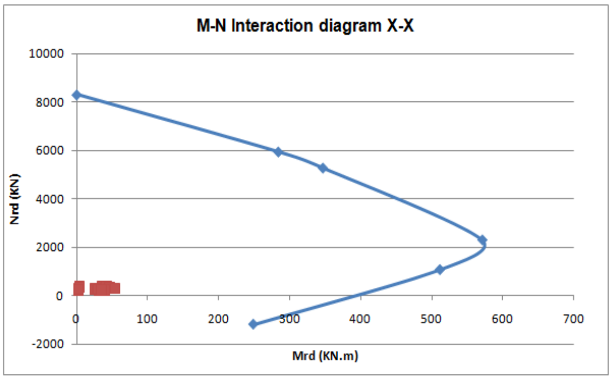
Interaction diagram In direction Y-Y

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	300	0.00000	0.06300	0	-435	-1397	491
Tension failure x =2.63d'	78.9	300	0.00217	0.02179	434	-435	533	1007
Xbal = 0.62d	353.4	300	0.00320	0.00215	435	-429	2424	1240
Compression failure x =d	570	300	0.00332	0.00000	435	0	5477	711
Compression failure x =h	600	300	0.00333	-0.00018	435	35	5810	642
Compression failure x >h	1E+25	300	0.00217	0.00217	435	435	8301	0



Interaction diagram in direction X-X

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-1193	248
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	1070	511
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	2298	571
Compression failure x =d	270	150	0.00311	0.00000	435	0	5273	346
Compression failure x =h	300	150	0.00315	-0.00035	435	70	5938	284
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	8301	0.0



Biaxial Bending Assessment

Ned (KN)	Nrd (KN)	Med x- x (KN.m)	Mrd x-x (KN.m)	Med y- y (KN.m)	Mrd y-y (KN.m)	a
1098	8301	541.3	900	89	400	1

Confirmation
OK!

Shear Assesment in Y-Y

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
89.7	3681.553891	1.59	0.15	0.12	300	570

Vrd,c (KN)	ρ1	σcp N/mm2
312	0.021529555	6.1

Ved<Vrd,c
Minimum As is needed

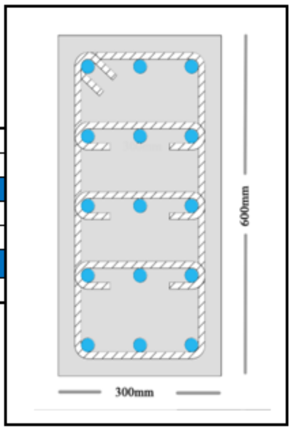
Shear Assesment in X-X

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
25	3681.55	2	0.15	0.12	600	270

Vrd,c (KN)	ρ1	σcp N/mm2
323.47	0.022725641	6.1

Ved<Vrd,c
Minimum As is needed

FINAL DESIGN TABLE		
Stirrups		
As min	s confinement (mm)	s (mm)
stirrup 12 mm	240	400
Longitudinal reinforcement		
As		
15 bars H25		



DESIGN SHEET- External skin Column-Auditorium/hall

Maximum internal forces

Ped kN	Med 33-yy kN.m	Med 22-xx kN.m	Ved 33-yy kN	Ved 22-xx kN
396	54	642.9	90.2	20

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C50/60			REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	500	200000
50	28	0.0035	435	0.00217

Element properties in y-y

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
300	600	180000	3681.55	3681.55	570	30

Asmin<As>=0.002Acc
OK!

Element properties In x-x

b (mm)	h (mm)	Acc (mm2)	As' (mm2)	As (mm2)	d (mm) y-y	d' (mm)
600	300	180000	3681.55	3681.55	270	30

Asmax/Ac<0.08
OK!

Slenderness checking x-x- braced column

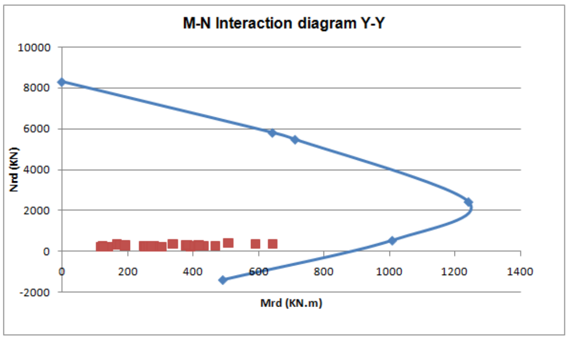
L (mm)	I (mm4)	i (mm)	k1	k2	l0(mm)	l
5000	5400000000	173.2	3.4439	1.7219	4595	26.53

n	B	C	llim
0.28	1.50	1.62	121.98

l<llim
OK!

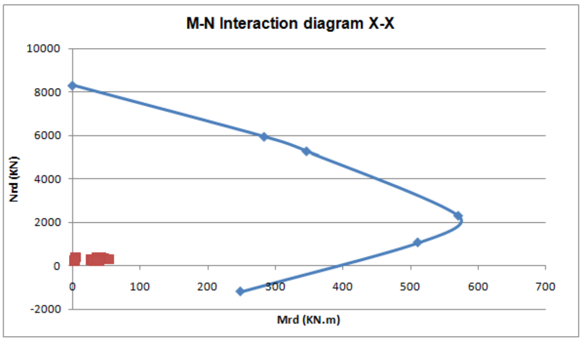
Interaction diagram In direction Y-Y

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	300	0.00000	0.06300	0	-435	-1397	491
Tension failure x =2.63d'	78.9	300	0.00217	0.02179	434	-435	533	1007
Xbal = 0.62d	353.4	300	0.00320	0.00215	435	-429	2424	1240
Compression failure x =d	570	300	0.00332	0.00000	435	0	5477	711
Compression failure x =h	600	300	0.00333	-0.00018	435	35	5810	642
Compression failure x >h	1E+25	300	0.00217	0.00217	435	435	8301	0



Interaction diagram In direction X-X

Failure Condition	x (mm)	xp (mm)	εs'	εs	fs'	fs	Nrd (KN)	Mrd (KN.m)
Tension failure x = d'	30	150	0.00000	0.02800	0	-435	-1193	248
Tension failure x =2.63d'	78.9	150	0.00217	0.00848	434	-435	1070	511
Xbal = 0.62d	167.4	150	0.00287	0.00215	435	-429	2298	571
Compression failure x =d	270	150	0.00311	0.00000	435	0	5273	346
Compression failure x =h	300	150	0.00315	-0.00035	435	70	5938	284
Compression failure x >h	1E+25	150	0.00217	0.00217	435	435	8301	0.0



Biaxial Bending Assessment

Ned (KN)	Nrd (KN)	Med x- x (KN.m)	Mrd x-x (KN.m)	Med y- y (KN.m)	Mrd y-y (KN.m)	a
396	8301	642.9	800	54	290	1

Confirmation
OK!

Shear Assesment in Y-Y

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
90.2	3681.553891	1.59	0.15	0.12	300	570

Vrd,c (KN)	ρ1	σcp N/mm2
212	0.021529555	2.2

Ved<Vrd,c
Minimum As is needed

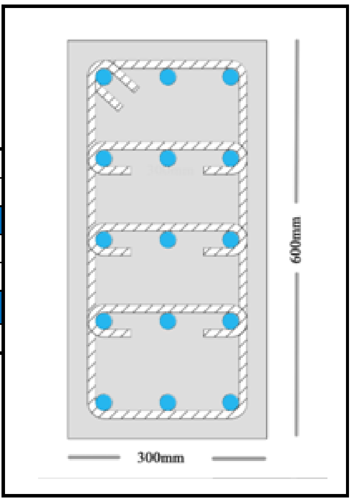
Shear Assesment in X-X

Ved (KN)	Asl (mm2)	k	k1	Crd,c	bw (mm)	d (mm)
20	3681.55	2	0.15	0.12	600	270

Vrd,c (KN)	ρ1	σcp N/mm2
228.63	0.022725641	2.2

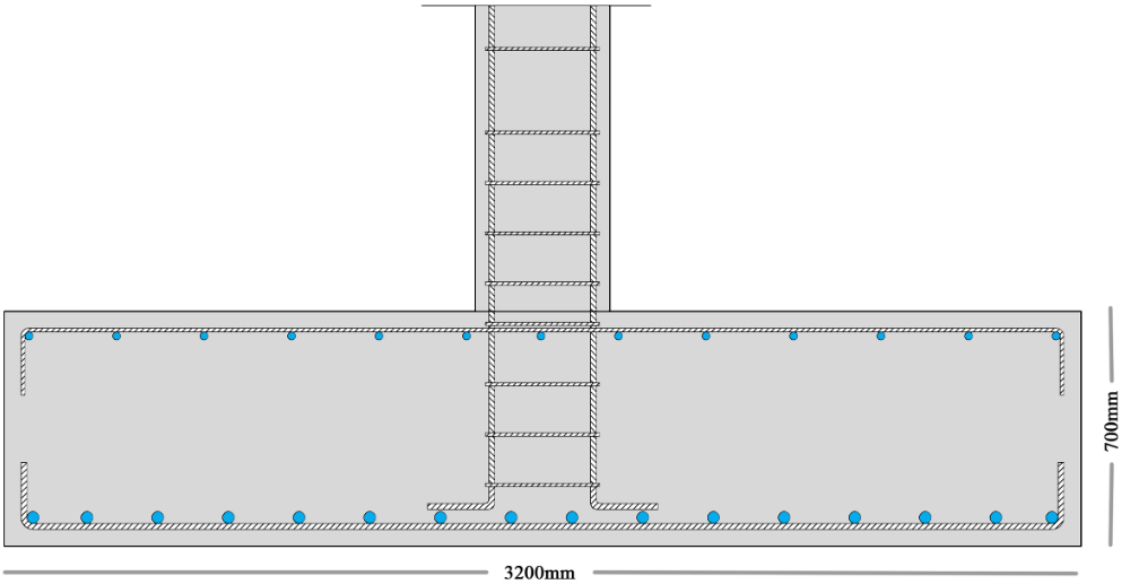
Ved<Vrd,c
Minimum As is needed

FINAL DESIGN TABLE		
Stirrups		
As min	s confinement (mm)	s (mm)
stirrup 12 mm	240	400
Longitudinal reinforcement		
As		
15 bars H25		



3.8.4 Footing

3.8.4.1 Sizing



Graphic 53 Restaurant/bar – Footing of Internal column section

The sizing of the footing is made according to the values of maximum Qtot load that a footing section can resist for serviceability limit state according to the strength of the system obtained by geotechnical design. For a Ned = W tot = 920 kN. Interpolating we get a footing of 3.2 m wide.

B (m)	Qadm (t/m^2)	Qtot (t)	S (cm)
1.5	8.0	18.00	4.5
2.0	8.5	34.00	5.6
2.5	9.0	56.25	6.6
3.0	9.5	85.50	8.0
3.5	10.0	122.5	9.4

Where: B = Side square footing, Qadm = Admissible footing bearing capacity. Qtot = Total load including footing self weight. S = expected settlement.

Table 9 Proposed footing dimensions according to bearing load for foundations levels at -2.0 a.t.l (Extracted from PENATI) [75]

3.8.4.2 Shear design:

Steps:

1. If the free length of the footing is less than two times d, a strut/tie model has to be followed where the maximum resistance to shear is given by the minimum of the next values:

$$P_{Rd,s} = \frac{A_s F_{yd}}{ctg\Psi^2} \geq v_{Rd} = \frac{V_{Rd}}{bd}$$

$$P_{Rd,c} = 0.4bdsin\Psi^2 F_{yd} \geq v_{Rd} = \frac{V_{Rd}}{bd}$$

In this case, L/d = 1.4/.60 considering a r' = 5cm, is > 2. In this way:

2. The ultimate design shear force without the need of reinforcement for shear is given by: where b = 1m

$$v_{Ed} = \frac{V_{Ed}}{bd} \leq v_{Rd} = \frac{V_{Rd}}{bd}$$

3. Checking reinforcement need from the empirical formula: for b = 1m.

$$v_{rd,c1} = \frac{V_{rd,c}}{bd} = \left[0.12k\left(100\rho_1 f_{ck}\right)^{1/3}\right] > v_{Ed}$$

With a minimum of

$$v_{rd,c1} = \frac{V_{rd,c}}{bd} = \left[0.035k^{\frac{3}{2}}(f_{ck})^{\frac{1}{2}}\right] > v_{Ed}$$

Where:

[75] Ibid. Indagine geologia tecnica ai sensi del D.M. 11.3 nel comune di Calco (Lc). 2003. P 16-17

$$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.0\ ,\ \ \rho_1 = \frac{A_{sl}}{b_w d} \leq 0.02$$

4. When shear reinforcement is not required, distribution reinforcement should be provided on both sides of the wall.

A_{smin} = 0.0013bd (mm2/m)

$$A_{max} = 0.04b\ h$$

3.8.4.3 Bending moment design:

This type of retaining wall can be designed with the methodology applied for the design of a full concrete-section slab.

Steps:

1. The bending reinforcement of a full section slab is given by: considering the level arm = 0.90 and b =1m

$$A_s = \frac{M_{Ed}}{0.9 f_{yd} bd}$$

2. Reinforcement details and rules: for bt the mean width of the tensile section. bt = 1m

$$A_{min} = \frac{0.26 f_{cmt} b_t\ d}{f_{yk}} \geq 0.0013 b_t\ d$$

$$A_{max} = 0.04b\ h$$

3. The steps from 1 to 3 are repeated for bottom and top reinforcement, but also for both x and y directions.

3.8.4.4 Punching design:

1. The ultimate shear stress is given by the load concentrated that is transmitted to the footing by the column.

$$\mathrm{V_{ed}} = \mathrm{N_{ed}} = 1288\ \mathrm{kN}$$

Where:

$$Acon = (4d + b) * (4d + h)$$

2. The ultimate shear stress in the control perimeter is given by:

$$v_{ed} = \frac{V_{ed}}{u_i d} \leq v_{rd}, c$$

Where:

3. The resistant for punching without considering shear reinforcement, according to the statement given above is:

$$v_{Rd,c} = \left[0.12k\left(100\rho_1 f_{ck}\right)^{1/3}\right] > v_{ed}$$

With a minimum of

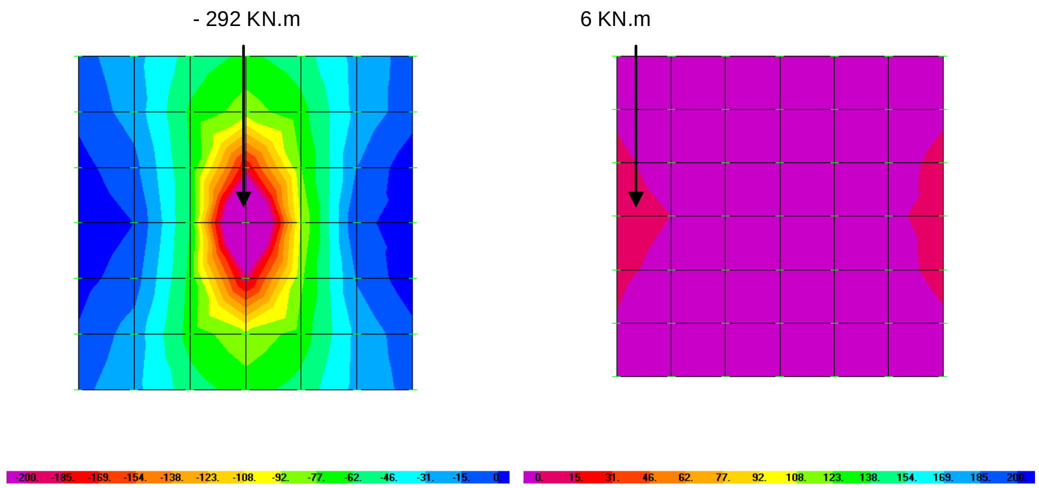
$$v_{Rd,c} = \left[0.035k^{\frac{3}{2}}(f_{ck})^{\frac{1}{2}}\right] > v_{ed}$$

Where:

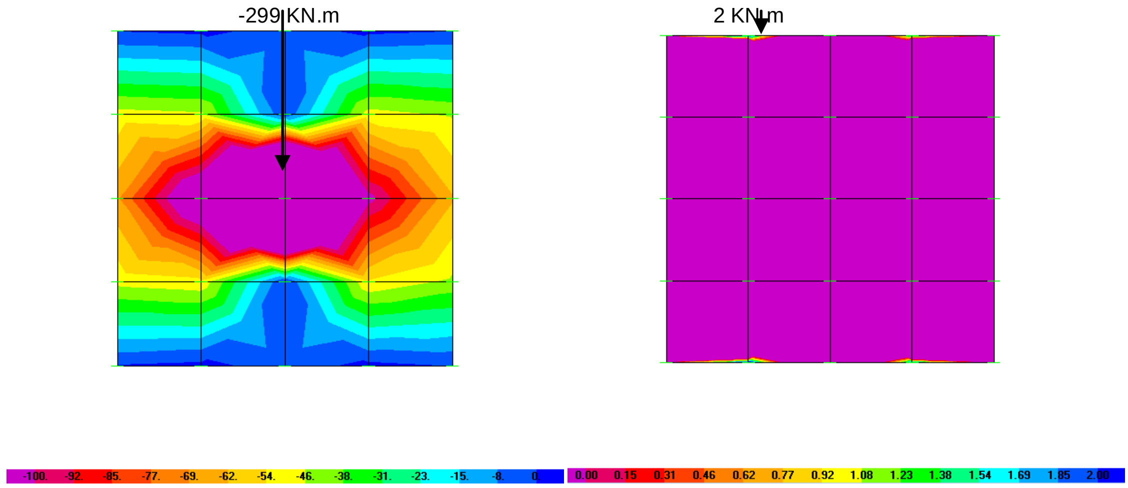
$$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.0\,, \quad \rho_1 = \sqrt{\rho_x * \rho_y} \leq 0.02$$

3.8.4.5 Internal Forces and Reactions:

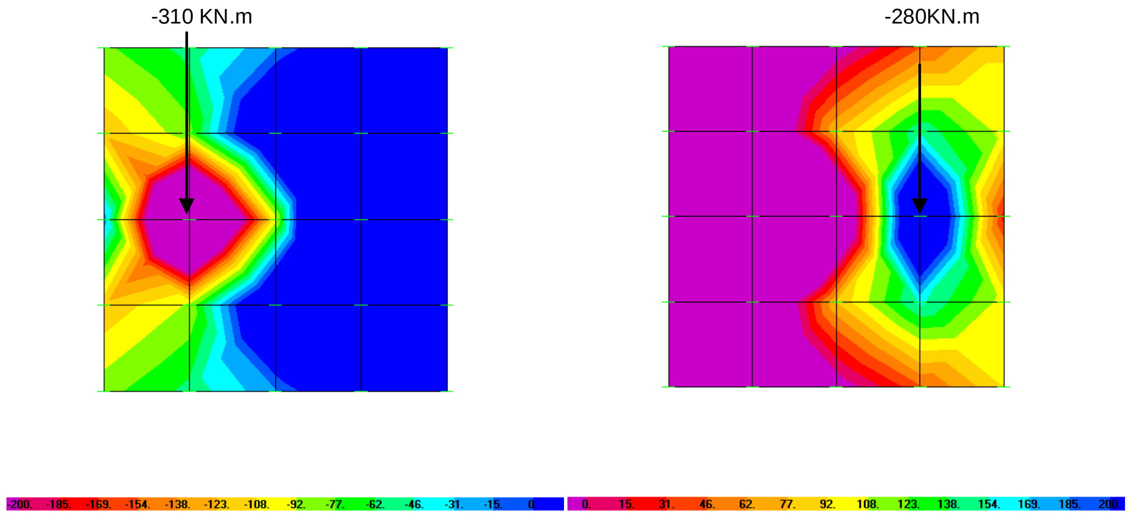
For simplification purposes it is going to be designed the footing that receives the maximum axial load, as the one representative of the foundation system of the structure. However the size of the multiple footing around the structure is given by means of the geotechnical beating capacity area needed according to the load that every column is withstanding.



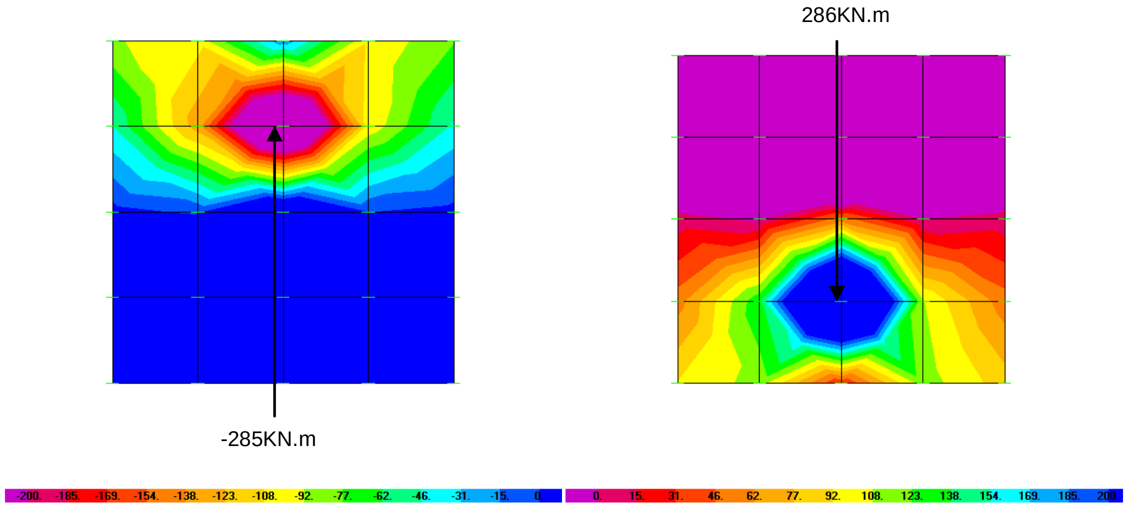
Graphic 54 Restaurant/bar – Reactions M11 Footing critical internal column ENV-ULS.



Graphic 55 Restaurant/bar – Reactions M22 Footing critical internal column ENV-ULS.



Graphic 56 Restaurant/bar – Reactions V12 Footing critical internal column ENV-ULS.



Graphic 57 Restaurant/bar – Reactions V23 Footing critical internal column ENV-ULS.

3.8.4.6 Results:

DESIGN SHEET- Footing

Maximum internal forces

Top reinforcement

M11 + (kN.m)	6
M22 + (kN.m)	2

Botton reinforcement

M11 - (kN.m)	292
M22 - (kN.m)	299

Punching internal forces

Ned kN	1288

Top reinforcement

V12 + (kN)	280
V23 + (kN)	286

Botton reinforcement

V12 - (kN)	310
V23 - (kN.m)	285

Partial factors

Partial Factors	Value
gc	1.5
gcc	0.85
αct	1
gs	1.15

Material properties

Concrete C35/45				REBAR B500	
Ec (N/mm2)	fck(N/mm2)	εc2(N/mm2)	fctm(N/mm2)	fyk (N/mm2)	Es (N/mm2)
14167	50	0.002	4.1	500	200000
C (mm)	fcd(N/mm2)	εcu2(N/mm2)		fyd (N/mm2)	εyd
50	28	0.0035		435	0.00217

Element properties in y-y

b (mm)	h (mm)	d (mm) y-y	d' (mm)
1000	700	650	50

Flexion design

	d' (mm)	d (mm)	Asl (mm2)/m	Asl min (mm2)/m	Asl min (mm2)/m
M11 + (kN.m)	50	650	24	346	423
M22 + (kN.m)	55	645	8	344	419
M11 - (kN.m)	55	645	1157	344	419
M22 - (kN.m)	50	650	1176	346	423

Asl < Asmx
OK!
OK!
OK!
OK!

	As (mm2)/m	Re-bar φ	Area rebar (mm2)	Separation m
M11 + (kN.m)	423	12	113	0.260
M22 + (kN.m)	419	12	113	0.260
M11 - (kN.m)	1157	18	254	0.210
M22 - (kN.m)	1176	18	254	0.210

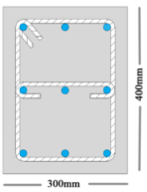
Asl < Asmx
OK!

Shear assesment

	ved (kN/m2)	k	ρ1	vrd,c1 (kN/m2)	vrd,c1min (kN/m2)
M11 (kN.m)	477	1.55	0.0018	388	480
M22 (kN.m)	440	1.55	0.0018	389	480

vrd,c > ved
OK!
OK!

Punching design



Type of colum	β	υ (mm)
Internal	1	5421

b (mm)	h (mm)	deff (mm) y-y	d' (mm)
300	400	320	30

Maximum forces in the perimeter

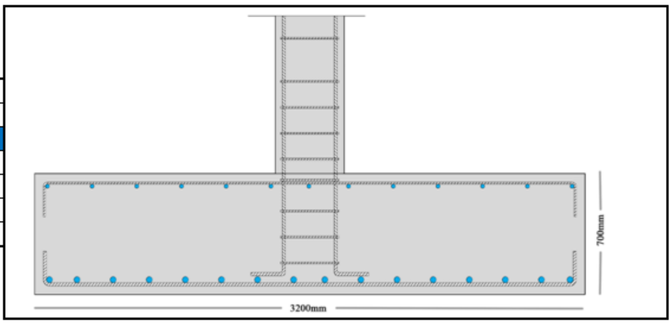
Ved kN	ved (kN/m2)
1288.0	365.51

Punching assesment

Asl xx(mm2)	ρx	ρ	k	Crd,c	vrd,c (kN/m2)	vrd,cmin (kN/m2)
1157	0.0017	0.00167	1.79	0.12	435.57	592.98
Asl yy(mm2)	ρy					
1176	0.0017					

vrd,c> ved
OK!

FINAL DESIGN TABLE		
Longitudinal reinforcement		
	Re-bar φ	Separation m
M11 +	12	0.260
M22 +	12	0.260
M11 -	18	0.210
M22 -	18	0.210



3.8.5 Open web Joist 36m span- Auditorium/hall External roof

The design of a 36m single span component constitutes one of the most challenging ideas inside the structural solution proposed for the Auditorium/hall area of the building. The selection of an alternative widely used such as the Steel open web joist is given according to the utility of these kind of systems for large open areas subjected in almost all the cases, to industrial loads; in this example it is presented the design of the largest and more loaded Steel open web joist out of 5 total present in the structure.

3.8.5.1 Sizing

The composition of the structure is given by welded L channels to be subjected to Tension and compression stresses. The size of the structure is given according to the simplified-empirical methodology given by the manufacturer Vulcraft and the Steel Joist Institute[76] as it is hence presented.

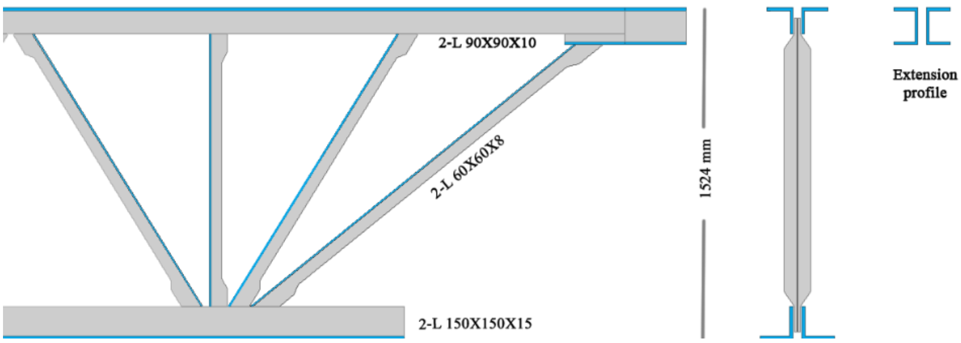
The height of the Open web joist can be established according to the previously estimated values of Imposed load (kN/m) and Permanent load (kN/m) that the element is subjected to. These values are compared to the maximum values that any element can support calculated for an L/360 maximum deflection and given in the table below. As a result it is chosen a 60DLH18 open web joist.

STANDARD LOAD TABLES IN METRIC UNITS/LONGSPAN STEEL JOISTS, **DLH**-SERIES
SAFE UNIFORM DISTRIBUTED LOAD IN KILONEWTONS/METER

Joist Designation	Approx. Mass (kN / m)	Approx. Mass (kg / m)	Depth (mm)	SAFE LOAD* In kN Between		CLEAR SPAN (mm)															
				21336-30175	30480-31699	32003	32308	32613	32918	33223	33528	33832	34137	34442	34747	35052	35356	35661	35966	36271	36576
60DLH12	0.42	43	1524	138.3	138.3	4.30	4.21	4.14	4.07	3.99	3.94	3.86	3.80	3.73	3.67	3.61	3.56	3.50	3.44	3.38	3.32
						2.45	2.37	2.30	2.24	2.18	2.13	2.07	2.01	1.95	1.91	1.86	1.80	1.76	1.72	1.67	1.64
60DLH13	0.51	52	1524	168.1	168.1	5.22	5.12	5.03	4.94	4.85	4.77	4.69	4.61	4.53	4.46	4.39	4.31	4.24	4.17	4.11	4.04
						2.96	2.87	2.78	2.72	2.64	2.56	2.49	2.43	2.37	2.30	2.24	2.20	2.14	2.08	2.02	1.97
60DLH14	0.58	60	1524	186.8	186.8	5.80	5.70	5.58	5.48	5.39	5.29	5.19	5.10	5.02	4.93	4.84	4.77	4.68	4.61	4.52	4.45
						3.15	3.06	2.99	2.90	2.81	2.75	2.67	2.59	2.52	2.48	2.40	2.34	2.27	2.21	2.17	2.11
60DLH15	0.63	64	1524	219.2	219.2	6.81	6.68	6.56	6.45	6.33	6.23	6.11	6.01	5.91	5.80	5.72	5.61	5.53	5.44	5.35	5.26
						3.72	3.61	3.53	3.42	3.32	3.25	3.15	3.06	2.99	2.91	2.83	2.77	2.69	2.62	2.55	2.49
60DLH16	0.67	68	1524	241.0	241.0	7.48	7.35	7.20	7.07	6.94	6.82	6.71	6.58	6.47	6.36	6.24	6.14	6.04	5.93	5.83	5.73
						4.15	4.04	3.92	3.82	3.72	3.60	3.51	3.42	3.32	3.25	3.16	3.07	3.00	2.93	2.86	2.77
60DLH17	0.76	77	1524	277.1	277.1	8.61	8.44	8.3	8.14	7.99	7.85	7.72	7.57	7.44	7.31	7.19	7.06	6.94	6.82	6.71	6.61
						4.72	4.59	4.46	4.34	4.23	4.13	4.01	3.89	3.8	3.70	3.60	3.51	3.42	3.32	3.25	3.16
60DLH18	0.86	88	1524	319.8	319.8	9.93	9.74	9.57	9.39	9.22	9.06	8.9	8.74	8.59	8.43	8.28	8.15	8.01	7.88	7.74	7.61
						5.34	5.21	5.04	4.91	4.77	4.65	4.52	4.42	4.29	4.17	4.07	3.96	3.88	3.77	3.67	3.59

Graphic 58 Manufacturer proposed dimensions for Steel open web joist.

[76] VULCRAFT. Steel Joists and Joists Girders. SJI- Steel joist girder institute. 2001. P42.



Graphic 59 Auditorium/hall – Open web joist external ceiling sizing.

3.8.5.2 Design of elements subjected to Tension.

The axial resistance force in welded elements class 3 subjected to tension due to plastic and local buckling resistance is given by the minimum value of the next compound of equations:

$$N_{p1,Rd} = A * \frac{f_y}{\gamma_{M0}}$$

And, $\leq N_{ed,T}$

$$N_{u,Rd} = 0.9 * A * \frac{f_u}{\gamma_{M2}}$$

3.8.5.3 Design of elements subjected to Compression.

The axial resistance force in welded elements class 3 subjected to compression due to plastic and ultimate resistance at the connection point is given by the minimum value of the next compound of equations:

$$N_{p,Rd} = A * \frac{f_y}{\gamma_{M0}}$$

And, $\leq N_{ed,c}$

$$N_{u,Rd} = A * \frac{f_y}{\gamma_{M1}}$$

It has to be verified also that the critical load applied that can lead to a failure due to buckling doesn't exceed the next values.

$$N_{b,rd} = \lambda * A * \frac{f_y}{\gamma_{M1}} \leq N_{cr} = \frac{\pi^2 EI}{L^2}$$

Where:

$$\lambda = \frac{1}{\Phi + \sqrt{\Phi^2 - \chi^2}}, \quad \chi = \sqrt{\frac{A * f_y}{N_{cr}}}$$

$$\Phi = 0.5[1 + \alpha(\lambda - 0.2) + \chi^2] \text{ , } \alpha = 0.34 \; for\ class\ 3\ profiles$$

3.8.5.4 Stability and Slenderness ratio verification

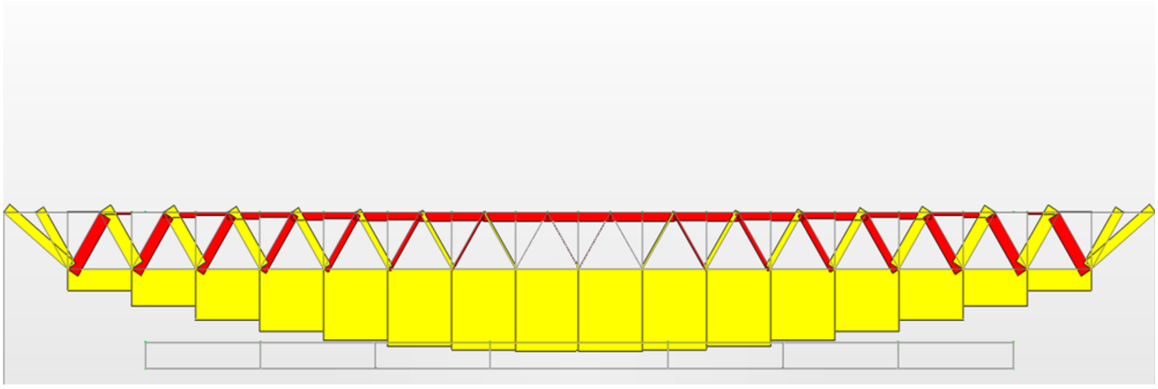
For elements subjected to tension stresses, the slenderness should not exceed the next values:

$$\lambda = \frac{L}{r} \leq 250$$

For elements subjected to compression stresses, the critical load should not exceed the next values:

$$\alpha_{cr} = \frac{N_{cr}}{N_{ed,c}} \leq 10$$

3.8.5.5 Internal Forces and Reactions:



ULS: maximum envelope values

Max Ned Bottom Chord-T = 2212 kN.
Max Ned Tie Chord-T = 122 kN.
Max Ned Diagonal Chord-T = 455 kN.
Max Ned Top Chord-C = 255 kN
Max Ned Tie Chord-C = 25.9 kN.
Max Ned Diagonal Chord-C = 380 kN.

SLS - NC: maximum envelope values

Max Ned Bottom Chord-T = 1599 kN.
Max Ned Tie Chord-T = 89 kN
Max Ned Diagonal Chord-T = 330 kN
Max Ned Top Chord-C = 183 kN
Max Ned Tie Chord-C = 21 kN
Max Ned Diagonal Chord-C = 278 kN

Graphic 60 External roof –Critical Internal forces at ULS and SLS (view of axial internal forces)

3.8.5.6 Results:

<u>DESIGN SHEET- Open Web joist</u>

ULTIMATE LIMITI STATES Partial factors & Material properties.

Partial Factors	Value
γM0	1
γM1	1.1
γM2	1.25

E (KN/mm2)	fu(N/mm2)	fy (N/mm2)
210	430	275

Maximum Reactions in the Elements

	Eed ULS	
Characteristic element	Ned (KN)	State
Bottom Chord	2200	T
Tie	122	T
Diagonal Tie	455	T
Top Chord	255	C
Strut	25.9	C
Diagonal Strut	380	C

Properties characteristic elements

Welded connections ,class 3

Characteristic element	Le (mm)	# Angles	Angle selection	Class	Ag=Aeff =Anet (mm2)	b (mm)	b/t	Iz=Iy (x10^4 mm4)	iz=iy (mm)
Bottom Chord	940	2	L150 x 150 x 15	3	8600	150	10.0	1796.2	45.7
Tie	1500	2	L40 x 40 x 5	3	758	4	0.8	10.86	12.0
Diagonal Tie	1794	2	L60 x 60 x 8	3	1806	60	7.5	58.3	18.0
Top Chord	940	2	L90 x 90 x 10	3	3420	90	9.0	253.8	27.2
Strut	1500	2	L60 x 60 x 8	3	1806	60	7.5	58.3	18.0
Diagonal Strut	1794	2	L120 x 120 x 15	3	6780	120	8.0	889.8	36.2

ULS - Resistance of cross section for elements in TENSION - Plastic and local buckling resistance

Characteristic element	Np1,Rd (KN)	Nu,Rd (KN)	Nt,Rd (KN)
Bottom Chord	2365	2663	2365
Tie	208	235	208
Diagonal Tie	497	559	497

Ned < Nt,Rd
OK!
OK!
OK!

ULS - Resistance of cross section for elements in COMPRESION - Plastic and lultimate ressitance at the connection point.

Characteristic element	Np,Rd (KN)	Nc,Rd (KN)	Nc,Rd (KN)
Top Chord	941	855	855
Strut	497	452	452
Diagonal Strut	1865	1695	1695

Ned < Nc,Rd
OK!
OK!
OK!

ULS - Resistance of cross section for elements in COMPRESION to buckling

Characteristic element	Ncr (KN)	α	λ–	Φ	χ	Nb,Rd (KN)
Top Chord	5953	0.34	0.40	0.61	0.93	793
Strut	537	0.34	0.96	1.09	0.62	281
Diagonal Strut	5730	0.34	0.57	0.73	0.85	1444

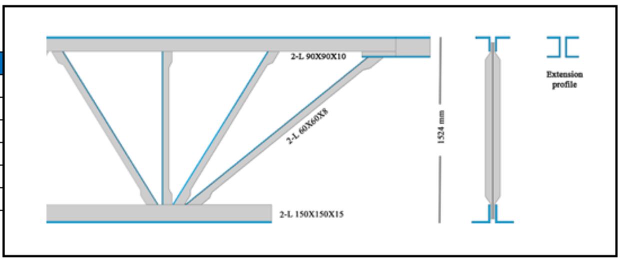
Ned < Nb,Rd
OK!
OK!
OK!

ULS - Stability and slenderness ratio verification.

Characteristic element	λ
Bottom Chord	21
Tie	125
Diagonal Tie	100
Characteristic element	**αcr**
Top Chord	23.3
Strut	20.7
Diagonal Strut	15.1

λ < 250
OK!
OK!
OK!
αcr >=10
OK!
OK!
OK!

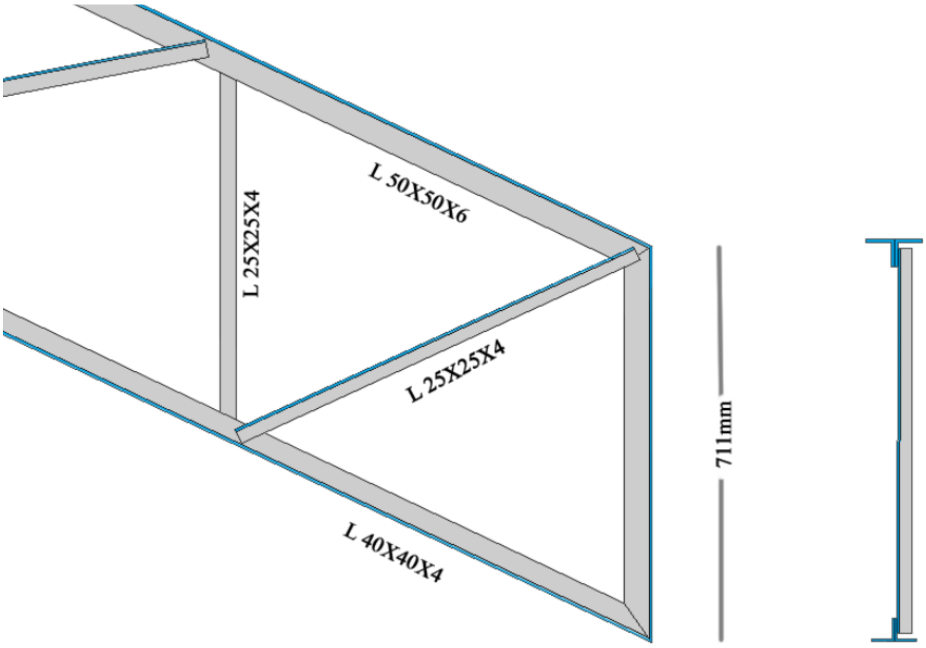
Characteristic element	Le (mm)	# Angles	Angle selection
Bottom Chord	940	2	L150 x 150 x 15
Tie	1500	2	L40 x 40 x 5
Diagonal Tie	1794	2	L60 x 60 x 8
Top Chord	940	2	L90 x 90 x 10
Strut	1500	2	L60 x 60 x 8
Diagonal Strut	1794	2	L120 x 120 x 15



3.8.6 Truss 15.2m span - Auditorium/hall internal roof

3.8.6.1 Sizing

The composition of the structure is given by welded L channels to be subjected to Tension and compression stresses. The size of the structure is given according to the rule L/20 for steel trusses as an approximation to the expected deflection of the expected system.



Graphic 61 Auditorium/hall – Internal ceiling sizing

3.8.6.2 Design of elements subjected to Tension.

The axial resistance force in welded elements class 3 subjected to tension due to plastic and local buckling resistance is given by the minimum value of the next compound of equations:

$$N_{p1,Rd} = A * \frac{f_y}{\gamma_{M0}}$$

And, $\leq N_{ed,T}$

$$N_{u,Rd} = 0.9 * A * \frac{f_u}{\gamma_{M2}}$$

3.8.6.3 Design of elements subjected to Compression.

The axial resistance force in welded elements class 3 subjected to compression due to plastic and ultimate resistance at the connection point is given by the minimum value of the next compound of equations:

$$N_{p,Rd} = A * \frac{f_y}{\gamma_{M0}}$$

And, $\leq N_{ed,c}$

$$N_{u,Rd} = A * \frac{f_y}{\gamma_{M1}}$$

It has to be verified also that the critical load applied that can lead to a failure due to buckling doesn't exceed the next values.

$$N_{b,rd} = \lambda * A * \frac{f_y}{\gamma_{M1}} \leq N_{cr} = \frac{\pi^2 EI}{L^2}$$

Where:

$$\lambda = \frac{1}{\Phi + \sqrt{\Phi^2 - \chi^2}}, \quad \chi = \sqrt{\frac{A * f_y}{N_{cr}}}$$

$$\Phi = 0.5[1 + \alpha(\lambda - 0.2) + \chi^2] \text{ , } \alpha = 0.34 \; for \; class \; 3 \; profiles$$

3.8.6.4 Stability and Slenderness ratio verification

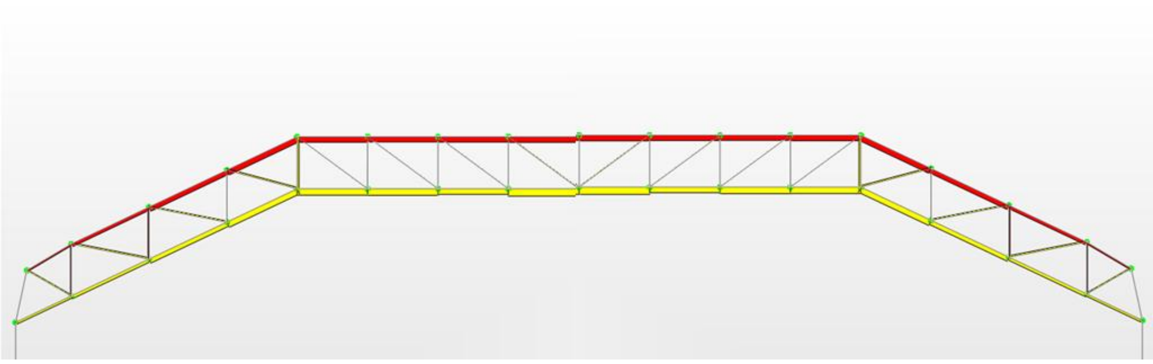
For elements subjected to tension stresses, the slenderness should not exceed the next values:

$$\lambda = \frac{L}{r} \leq 250$$

For elements subjected to compression stresses, the critical load should not exceed the next values:

$$\alpha_{cr} = \frac{N_{cr}}{N_{ed,c}} \leq 10$$

3.8.6.5 Internal Forces and Reactions:



ULS: maximum envelope values

Max Ned Bottom Chord-T = 120 kN.
Max Ned Tie Chord-T = 22 kN.
Max Ned Diagonal Chord-T = 73 kN.
Max Ned Top Chord-C = 103 kN
Max Ned Tie Chord-C = 87 kN.
Max Ned Diagonal Chord-C = 12 kN.

SLS - NC: maximum envelope values

Max Ned Bottom Chord-T = 89 kN.
Max Ned Tie Chord-T = 16 kN
Max Ned Diagonal Chord-T = 53 kN
Max Ned Top Chord-C = 74 kN
Max Ned Tie Chord-C = 41 kN
Max Ned Diagonal Chord-C = 8 kN

Graphic 62 Internal roof –Critical Internal forces at ULS and SLS (view of axial internal forces)

3.8.6.6 Results:

DESIGN SHEET- Internal roof truss

ULTIMATE LIMITI STATES Partial factors & Material properties.

Partial Factors	Value
γM0	1
γM1	1.1
γM2	1.25

E (KN/mm2)	fu(N/mm2)	fy (N/mm2)
210	430	275

Maximum Reactions in the Elements

	Eed ULS	
Characteristic element	Ned (KN)	State
Bottom Chord	120	T
Tie	22	T
Diagonal Tie	73	T
Top Chord	103	C
Strut	87	C
Diagonal Strut	12	C

Properties characteristic elements

Welded connections ,class 3

Characteristic element	Le (mm)	# Angles	Angle selection	Class	Ag=Aeff =Anet (mm2)	b (mm)	b/t	Iz=Iy (x10^4	iz=iy (mm)
Bottom Chord	700	2	L40 x 40 x 4	3	616	40	10.0	8.94	12.0
Tie	700	1	L25 x 25 x 4	3	185	25	6.3	1.01	7.4
Diagonal Tie	1026	1	L40 x 40 x 5	3	379	4	0.8	5.43	12.0
Top Chord	700	2	L50 x 50 x 6	3	1138	50	8.3	25.68	15.0
Strut	700	1	L60 x 60 x 6	3	691	60	10.0	22.79	18.2
Diagonal Strut	1026	1	L45 x 45 x 4.5	3	390	45	10.0	7.15	13.5

ULS - Resistance of cross section for elements in TENSION - Plastic and local buckling resistance

Characteristic element	Np1,Rd (KN)	Nu,Rd (KN)	Nt,Rd (KN)
Bottom Chord	169	191	169
Tie	51	57	51
Diagonal Tie	104	117	104

Ned < Nt,Rd
OK!
OK!
OK!

ULS - Resistance of cross section for elements in COMPRESION - Plastic and lultimate ressitance at the connection point.

Characteristic element	Np,Rd (KN)	Nc,Rd (KN)	Nc,Rd (KN)
Top Chord	313	285	285
Strut	190	173	173
Diagonal Strut	107	98	98

Ned < Nc,Rd
OK!
OK!
OK!

ULS - Resistance of cross section for elements in COMPRESION to buckling

Characteristic element	Ncr (KN)	α	λ–	Φ	χ	Nb,Rd (KN)
Top Chord	1086	0.34	0.54	0.70	0.87	247
Strut	964	0.34	0.44	0.64	0.91	157
Diagonal Strut	141	0.34	0.87	1.00	0.68	66

Ned < Nb,Rd
OK!
OK!
OK!

ULS - Stability and slenderness ratio verification.

Characteristic element	λ
Bottom Chord	58
Tie	95
Diagonal Tie	86
Characteristic element	αcr
Top Chord	10.5
Strut	11.1
Diagonal Strut	11.7

λ < 250
OK!
OK!
OK!
αcr >=10
OK!
OK!
OK!

Characteristic element	Le (mm)	# Angles	Angle selection
Bottom Chord	700	2	L40 x 40 x 4
Tie	700	1	L25 x 25 x 4
Diagonal Tie	1026	1	L40 x 40 x 5
Top Chord	700	2	L50 x 50 x 6
Strut	700	1	L60 x 60 x 6
Diagonal Strut	1026	1	L45 x 45 x 4.5