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MASTER THESIS

CITY, CULTURE AND TRADITION: RENOVATION OF THE HANDCRAFT MARKET OF MEXICO CITY, AND
ITS CONNECTION WITH THE HISTORIC CENTER.

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Abstract

This thesis follows the complete process of development of an architectural project, applied to the refurbishment and rehabilitation of the San Juan Market of handcraft and its surroundings, located in Mexico City. Along this work the authors put in practice the different methods of analysis and problem solution oriented to the user experience.

A holistic approach leads the present project, starting from a general analysis of the physical, historic, and economic context; the traditions and identity of the site guide the architectural and urban design, after the details of service, comfort and structure systems are presented. Photographs, plans, schemes and renders illustrate the process and final result. All the solutions proposed are ecofriendly oriented and expect to be a reference for future studies and design projects.

Acknowledgments

We would like to thank Prof. Gabrielle Masera and Prof. Paolo Martinelli for the support and advice given along the development of the present project, without their constant guidance and feedback none of this could be possible.

Besides, we thank all the professors of the faculty of Architectural Engineering of the Politecnico di Milano Campus Lecco, their teaching has been an important part of this work.

Furthermore, we want to recognize the support, motivation and experience of our friends, they are also part of this achievement.

Finally, a special recognition to our families whom despite the distance has always been there for us.

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Preface

The aim of this thesis work is to present the process followed to develop the project: City, Culture and Tradition: Renovation of the Handcraft Market of Mexico City, and its Connection with the Historic Center.

It is well known that no design project can be done without the consideration, since its early phases, a complete study of the context and history of site, the technical solution that can be adopted, and specially the necessities of the users, no matter if they are residents or casual visitors. A synergetic approach leads the following work, along the text the reader will find a series of solutions that are the summary of the academic courses taking during the Master of Science, passing through the design, energy and efficiency analysis, and structural design.

We can roughly divide the structure of the following report in two main parts, the first related to the design based on the function and comfort of the users. We resorted to analyze the site and the context, referring to the work of other architects that had worked already in the city we took the ideas and they were complemented by the knowledge obtained in the Ms. Of Sc. Architectural Engineering course, to illustrate all this process images and diagrams to support our decisions are important part of this work. This first stage contents the Urban and Architectural proposals, as an interconnected development, looking forward to find a common identity and functionality.

Then the specific technical solutions are developed, where we find first the technologies applied in the building in order to reach the ecological and efficiency approach. Later, with all the non-structural elements already chosen and located, we develop the structural analysis and design, following the guidelines stablished by the Eurocode and the local code of construction of Mexico City for critic considerations, in each section a complete description of the resources, codes, and technical data consulted is shown.

In order to show clearly the ideas, proposals and final decisions we use photographs, diagrams, tables and infographics that also give the user a quick understanding of the book just in a quick look. The images and diagrams used are original creations or Creative Commons licensed.

Some tools, although not used as a direct reference, where important such as the following websites: Pinterest, Wikipedia, Flickr, Google search engine and Linguee. During the conduction of the present material the software used were: MS Office, SketchUp, Autodesk Revit, Autocad, Ecotect, Vasari, Velux, Climate Consultant, Robot Structural Design, Adobe Photoshop and Illustrator. The material and knowledge developed along the Master of Science were important source of information and experience. The rest of the material and references are specified along the report when is necessary.

We hope the reader find this work clear and easy to follow, but especially that can be used as a tool for future projects.

1

SAN JUAN
Mercado de Artesanías

This chapter provides the description and requirements stated in the project brief, along with the vision, general objective and specific objectives intended to achieve with the development of the proposal.

Chapter 1: Introduction

1.1 Project

The local authorities through “Escuela Digital” (digital design center, calls students and young students to the 4th International Competition of Architectural Ideas Urban Intervention of San Juan Square – China Town and Handcraft Market, Historic Center of Mexico City” in order to develop a proposal for enhancing the public space, contributing to a new culture.

The project consists on the Urban Intervention of San Juan Square – China Town in the Historic Center of Mexico City. It should make explicit the use of design alternatives that lead to a socially inclusive urban space, economically prosperous and environmentally sustainable, through a sustainable design program that links to its context in a harmonious, aesthetic and comprehensive.

1.2 Requirements

1- Create a link between San Juan Square and China Town

The proposal has to consider the renewal of public space, street furniture, flooring, finishes, lighting, landscaping, etc. Propose a solution for pedestrian and vehicular traffic between Chinatown and Plaza de San Juan (sidewalks, pedestrian street crossing, vehicular traffic, lighting, furniture, etc.

2- Renovation of Crafts Market

The design most create a contemporary concept of selling, keeping the original structure, where visitors and tourists who wish to purchase crafts from around the country found a new buying experience with the reorganization and renovation of architectural spaces.

Levels	Space	Area	m2	Notes
Parking level	Parking area	3261.70	m2	With 104 parking spaces for cars
	Motorcycle space	98.08	m2	
	Service rooms	100.90	m2	
Ground floor	Library + café	259.59	m2	
	Commercial space / stands	698.96	m2	S1 = 9.14 m2
				S2 = 29.10 m2
	WC	41.69	m2	Ladies
		27.07	m2	Gentlemen
	Boutique space	205.80	m2	3 boutiques with 68.60 m2 each
	Courtyard	243.79	m2	Free area / expositions
	Corridors	1279.03	m2	
First level	Special exposition area	245.70	m2	
	Commercial space / stands	775.43	m2	S1 = 9.14 m2
				S2 = 29.10 m2
	WC	41.69	m2	For girls WC
		27.07	m2	For boys WC
	Multipurpose rooms	201.13	m2	2 multipurpose rooms with 100.567m2 each
	Corridors	928.54	m2	
Second level	Green roof	1502.00	m2	
	Terrace	790.47	m2	
	Office	90.06	m2	
	Workshop area	266.06	m2	3 workshop rooms with 87.98m2 each
	Total area	11084.76	m2	

Table 1- 1 Required Areas and spaces

1.3 Vision

Diversity

The main objective of the project is to encourage the community development by promoting the acceptance of diversity presents in this district of the city by the creation of anew attracting and evolving configuration of the urban space, taking the current individual elements of identity and merging them into a new image to the inhabitants and the visitors.

1.4 General Objective

With the highest degree of permeability and connection, integrate the historical city center, reclaiming lost spaces and upgrading areas without clear identity in order to provide the community with a place where the people can enjoy an area where culture, commerce, recreation and public services are combined.

1.5 Specific Objectives

• To make a proposal to transform the public space that is formed between the San Juan Market and Chinatown, including the Plaza del San Juan.

• To develop various hot spots that would allow better movement, interaction and usage of the outside urban pubic space where design can be enhanced to attract new businesses and protect existing businesses.

• To enhance the appearance of the built handcrafts market in order to enrich an ambience of pleasant commercial experience, interconnection and dynamic exchange of ideas between the different communities on the area.

2

ANALYSIS

This chapter provides the preliminary analysis held in order to develop the architectural, urban and technological proposal.
The descriptions of the site, historical context, landmarks and green areas are presented first with a global approach, followed by a scale comparison, which takes us to the local analysis of the land use and the accessibility. Finally, a summary of the results is synthetized in the strengths, weaknesses, opportunities and threats analysis.

Chapter 2: Analysis

2.1 Physical context

2.1.1 Location

The site of this project is located in Mexico City's (Distrito Federal) Cuauhtémoc borough, the principal of the sixteen boroughs in the city, due to host the main public administrative buildings of the city and the country, the specific district is known as "Centro Historico – Alameda Central".

Figure 2- 1 Location of the site

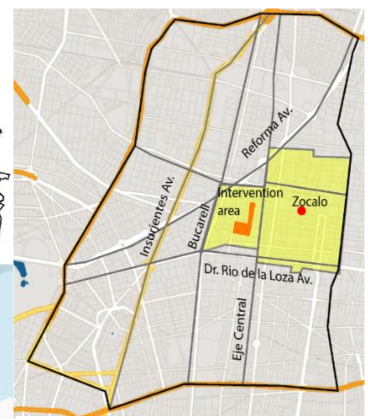


Figure 2- 2 Location of Mexico City

Site	Mexico City	
Latitude	19° N	
Longitude	99.1° W	
Climate Classification	Humid Subtropical Climate (CWa)	
Temperature	Min 8°C	Av 15-20°C
	Max 29°C	
Precipitation	762 mm	
Wind	West winds.	
Psychometrics	Need of solar radiation in winter	
	Natural ventilation for summer	
	Many days in comfort zone	

Table 2- 1 Location profile

Mexico City is located in the Valley of Mexico (Anahuac) a large valley in the high plateaus at the center of Mexico, at an altitude of 2,244 meters, surrounded by mountains and volcanoes that reach elevations of over 5,000 meters.

This valley has no natural drainage outlet for the waters that flow from the mountainsides, making the city vulnerable to flooding. Drainage was engineered through the use of canals and tunnels starting in the 17th century. The city primarily rests on what was Lake Texcoco that was drained since 17th century reason why the city rests on the lake bed's heavily saturated clay. This soft base is collapsing due to the over-extraction of groundwater, called groundwater-related subsidence. Since the beginning of the 20th century, the city has sunk as much as nine meters in some areas. Seismic activity is frequent here (Wikimedia Foundation, 2014).

2.1.2 Geography

According to the Koppen-Geiger climate classification (Peel, Finlayson, & McMahon, 2007), Mexico City has a subtropical highland climate, due to its tropical location and high elevation. The lower region of the valley receives less rainfall than the upper regions of the south; the average annual temperature varies from 12 to 16 °C. The temperature is rarely below 3 °C or above 30 °C. The lowest temperature ever registered was −4.4 °C, and the highest temperature on record is 33.9 °C.

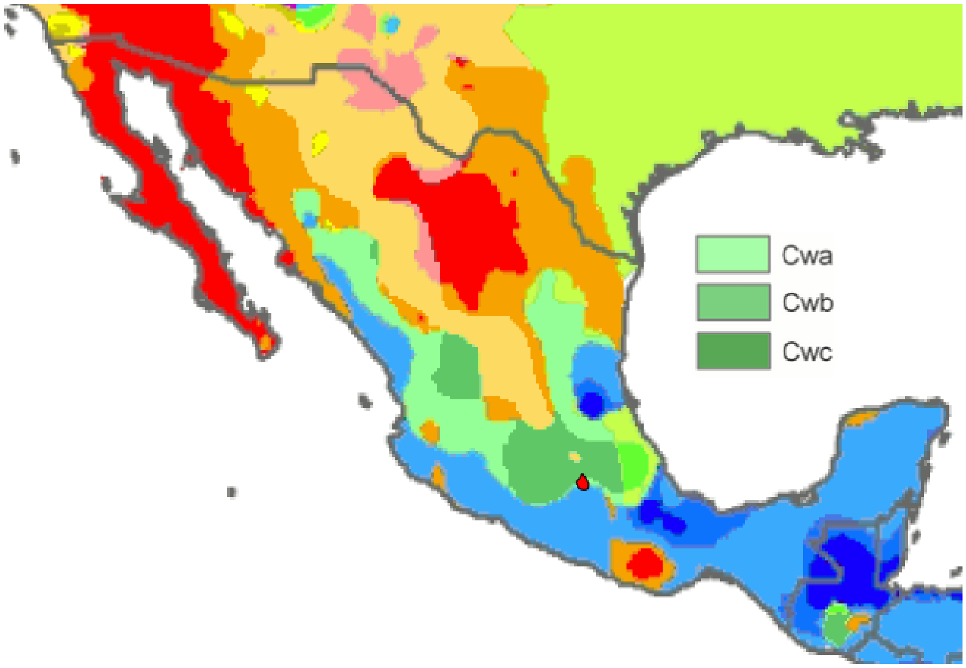


Figure 2- 5 Mexico's map of the Köppen-Geiger Climate Classification

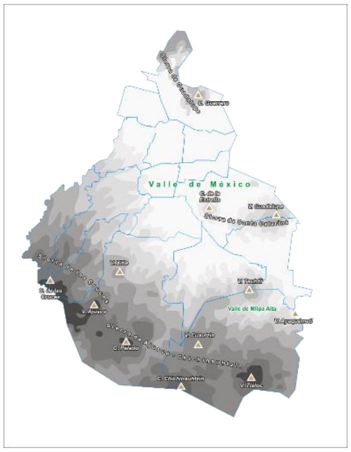


Figure 2- 6 Topography map of Mexico City

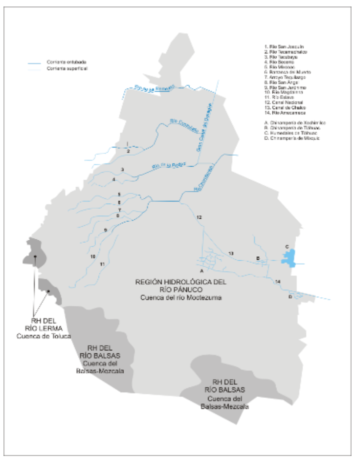


Figure 2- 10 Hydrology map of Mexico City

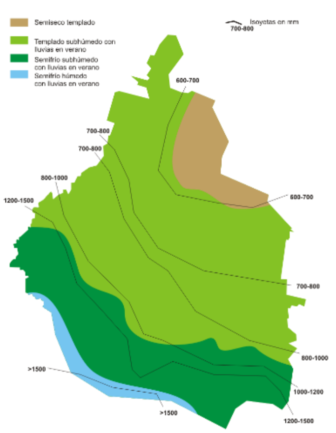


Figure 2- 13 Climate pattern map of Mexico City

The area receives about 762 mm of annual rainfall, which is concentrated from July, with 160 mm of precipitation, through September/October with little or no precipitation the remainder of the year. The month with the least precipitation on average is December with an average of 5.1 mm. In terms of liquid precipitation, there are an average of 80.0 days of rain, with the most rain occurring in July with 16.8 days of rain, and the least rain occurring in December with 1.0 days of rain (Weather Base, 2014). The area has two main seasons. The rainy season runs from June to October when winds bring in tropical moisture from the sea. The dry season runs from November to May, when the air is relatively drier. This dry season subdivides into a cold period and a warm period. The cold period spans from November to February when polar air masses push down from the north and keep the air fairly dry. The warm period extends from March to May when tropical winds again dominate but do not yet carry enough moisture for rain. The region of the Valley of Mexico receives anti-cyclonic systems. The weak winds of these systems do not allow for the dispersion, outside the basin, of the air pollutants which are produced by the 50,000 industries and 4 million vehicles operating in and around the metropolitan area.

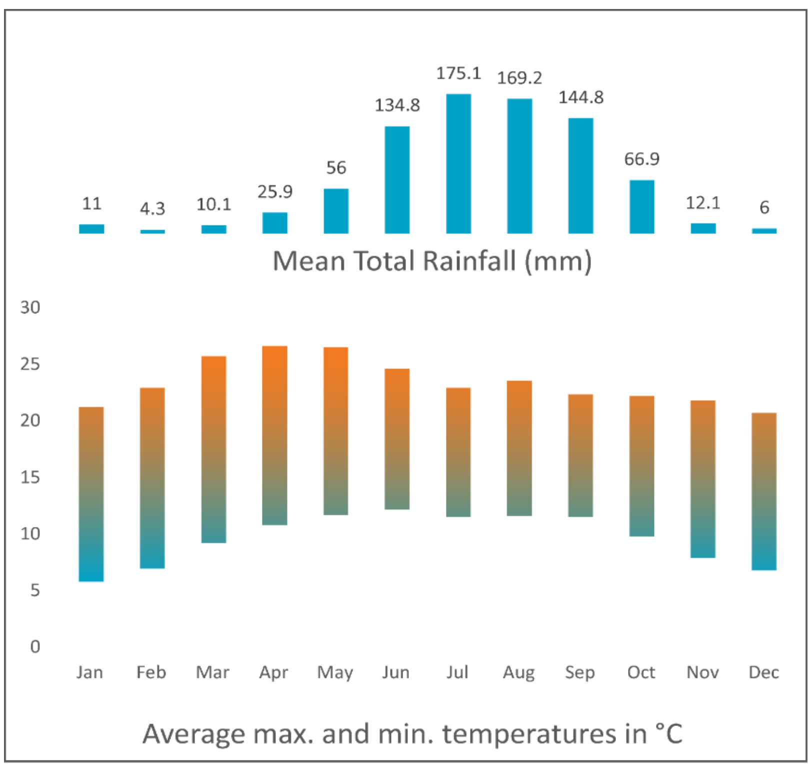


Figure 2- 9Mean total rainfall and average maximum and minimum temperature

Figure 2- 17 Model of Tenochtitlan

Figure 2- 14 Templo Mayor ruins, in the middle of Zocalo

Figure 2- 18 Reuse of prehispanic stone in colonial building

Figure 2- 19 Mexico City's Cathedral

Figure 2- 20 National Palace

2.2 Historical context

Mexico City as capital of Mexico is the center of politics, commerce, culture and education of the country a condition dated from its foundation 7 centuries ago.

The city was founded by the Aztec civilization on the Valley of Mexico that lies at 2244 m above sea level, surrounded by high mountains, some of them active volcanoes. The water coursing down in stream from these mountains created a series of lakes that provide a rich source force natural life. Today al this area has been completely dried due to the human occupation (Wikimedia Foundation, 2014).

About the 1325 AD the Aztecs founded their capital, Tenochtitlan, in a place where a great eagle was perched on a cactus killing a snake. This place, smack dab in the middle of a marsh with no proper ground at all, but this apparently unfortunate position facilitated economic connections and protection.

The city grew rapidly, with palaces and well-organized residential areas and aqueducts providing fresh water to the city from the mountains. At the center of the city stood the sacred precinct with ball courts, schools for nobles, and priests' quarters. The ceremonial heart of the city and of the whole empire was the Great Temple of Mexico-Tenochtitlan, known as the "Templo Mayor" (the Great House of the Gods), which it ruins still remain there (Maestri, 2014).

When Spanish arrived in 1520 AD, found one of the largest cities in the world.

After the conquer of Mexico, the Spanish empire called the region Nueva España (New Spain) and the colonial process took part in the actual country for the next 300 years, from 1521 in the fall of Tenochtitlan until 1821 with the Mexican independence. As Baxter (1901)describe in "Spanish-colonial architecture in

Figure 2- 23 La Santísima Trinidad church

Figure 2- 25 Santo Domingo church

Figure 2- 24 San Ildefonso College

Figure 2- 26 Iturbide Palace

Mexico" this period represents not only the first, but the most important development of the depictive arts in the New World under European influences. Most of the building from that period where Catholic Churches and palaces for the Spanish aristocracy, this architecture was particularized by the use of domes, glazed tiles for exterior decoration, a high contrast of ornamentation for facades, relief work and the adoption of the local techniques for stone cutting and ornamentation, in some cases the same stones used for antique temples where re use for colonial buildings.

The main styles observed are Spanish Renaissance, especially the Baroque and the Churriguresque. The most important buildings are the Cathedral, National Palace, the Church of La Santisima Trinidad, the Church of Santo Domingo, Former College of San Ildefonso, Iturbide Palace and the Institute of Mines among many others.

After the Mexican independence in 1821 the Spanish styles and uses of buildings remain the same until the end of the "Reforma War" when the government took the control of many properties under the control of the church and started a new use for monasteries and palaces, transforming them into Universities, hospitals and public offices. After the period of war until the Mexican Revolution (1865-1910) a new architecture started supported by the economic and social stabilization of the country, the use of new materials such as iron, marble, granite and copper. In other hand the use new technologies gave the opportunity of create new spaces. All these new constructions are inspired by European an American architecture, with new departmental buildings, pavilion based solutions and new public palaces as prove of economic power and progress (Velazquez Nuñes, 2010).

From this period we can find buildings like the Palace of Communications, the Boker Building, Post Palace and the revitalization of Paseo de la Reforma.

Some other projects that where finish after the Mexican revolution where started in this time like Palace of Fine Arts and Mexican Congress Palace (actual Revolution Monument).

After the Revolution Mexico city started a new process of modernization mixed with nationalism (Piña Olivares, 2014). The use of colonial and pre-Columbian elements with Decó are characteristic, also the use of mural painting in new and old buildings with cultural purposes. It's important to mention the proliferation of urban housing in the historical center with the model of "Vecindades", multi familiar units with central courtyards where many families share spaces and facilities.

Some examples are: Hotel Majestic, Bank of Mexico Building and La Nacional Building (Romero Moreno, 2005).

After the 30's the construction of new buildings in the historical center decayed and some of the old buildings were bought and refurbished for different uses, is important to highlight the construction of the 1st skyscraper of Latin America in this area in 1956: Latinoamericana Tower (Torre Latino, 2014).

Around the city many different projects were developed but the historical source of the center was preserved until nowadays.

2.3 Landmarks

In the Historic Center as core of the city many public spaces can be found, squares, parks, banks, markets, museums and schools.

Through different official decrees, have been catalogued and protected (Conaculta, 2014):

- 67 religious monuments
- 129 civil monuments
- 743 buildings historic and important buildings to be preserved
- 111 buildings with environmental value
- 6 modern temples
- 17 buildings with link to historic facts and figures
- 78 squares and gardens
- 19 religious cloister
- 26 fountains and memorials
- 13 museums
- 12 sites and buildings with mural painting

Figure 2- 27 Institute of Mines

Figure 2- 28 Communications Palace

Figure 2- 29 Boker Building

Figure 2- 30 Post Palace

Bellow some of the most characteristic.

Figure 2- 31 Paseo de la Reforma

Public Buildings

In the zone many official buildings are part of the urban life like: National Palace, Chamber of Senators, Bank of Mexico, Ministry of Foreign Affairs, Ministry of Public Education and Mexico City Hall, most of these buildings come from the colony.

Squares

Figure 2- 32 Palace of Fine Arts

Since the colonial period many squares were created in concordance with the Spanish style, some of these have had an important relevance along the Mexican history.

The most important is the Constitution Square (Zocalo) one of the largest squares in the world, also we can mention: Garibaldi, Santo Domingo and Tres Culturas (Ciudad de Mexico, 2009).

Figure 2- 33 Revolution Monument

2.4 Education and Culture

Mexico City is the city with most museums in the world (Bolaños Sanchez, 2006) and especially the Historic Center has a high concentration of cultural centers of any kind: Schools, Museums, Galleries, Exposition Centers, Theaters and Libraries. The most important cultural spots that are even close to our project site are:

Figure 2- 34 Vecindad

- Palace of Mines
- Sor Juana University
- Vizcaínas University
- Escuela Libre de Derecho (Laws Faculty)
- Mexico City Museum
- National Museum of Arts
- National Museum of Architecture
- Fine Arts Palace
- Iturbide Palace
- Hidalgo Theater
- National Library Jose Vasconselos
- Markets / Commerce

Figure 2- 35 Majestic Hotel

Figure 2- 36 Zocalo

Figure 2- 39 Bank of Mexico building

In Mexico the markets are more than just a place to buy and sell: they are places where the culture and tradition come alive, where the flavors, colors and essences of the country meet each other. Some of the traditional markets have a pre-Columbian origin. Two kind of markets are present in the day life of the residents of Mexico City, those established in a specific building and open every day (Mercado) and the Tianguis a provisional market that just open in a street one day a week (Visit Mexico, 2012).

Figure 2- 40 La Nacional Building and Latinoamericana tower

Mercados

Fifteen markets are located in the Hisctoric Center of Mexico City, that's why one of the most important characteristics of our site is the presence of 3 markets, those that are included in the project are: Market of Traditional Handcraft, Market of Flowers and Gourmet Market of San Juan. Some others are Merced, Lagunilla, Sonora and Jamaica (Ciudad de Mexico, 2009).

Figure 2- 41 Chamber of Senators

Tianguis

Some street markets are close to the site but they have lost the original tradition of the markets. Some examples are Tepito and Lagunilla.

It is important mention that near to the project site there is an important technological pole in the city, a district specialized in the commerce of IT solutions, videogames, multimedia and electronic, this area is composed by many shopping and thematic buildings like: Technology Shopping Center, Mobile Phone Shopping Center, Anime and video mall and Meave Shopping Center (specialized in videogames and electronics).

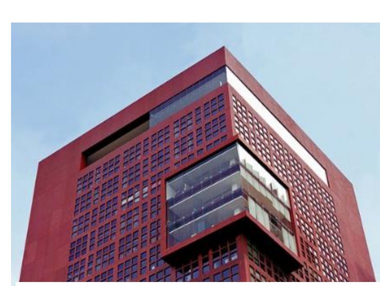


Figure 2- 42 Ministry of Foreign Affairs

Figure 2- 43 Ministry of Public Education

2.5 Green areas

According to the local legislation a green area is “every surface covered by vegetation, natural or induced located in the Federal District (Mexico City)” the control and maintenance of these areas is given by the Borough Urban Development Program (Secretaria del Medio Ambiente, 2010). The Green City Index includes Mexico City in the average score of green cities (Siemens AG, 2012), even though the specific district, where the project is located, has a reduced green coverage.

The local Environment Ministry has quantified in Cuauhtémoc borough 1.81 km^2 of green areas that represent just 5.5% of the extension of the borough. Next a comparison between the borough with most green areas (Coyoacán), Cuauhtémoc and total for the City (Secretaria del Medio Ambiente, 2010).

The figure XXX compares the percentage of green area of our borough, the greenest borough of the city, the average in Mexico City and a reference green city, Vienna (Skyscrapercity, 2015). From this graphic we observe the lack of green spaces, in the urban design chapter we analyze how to improve this characteristic in order to enhance the area.

The most important green areas around the site are: Alameda Central, Alameda de Santa Maria and San Juan Park. In addition some other areas are scattered along the city, most of them trees along some small private areas an avenues (Reforma Avenue).

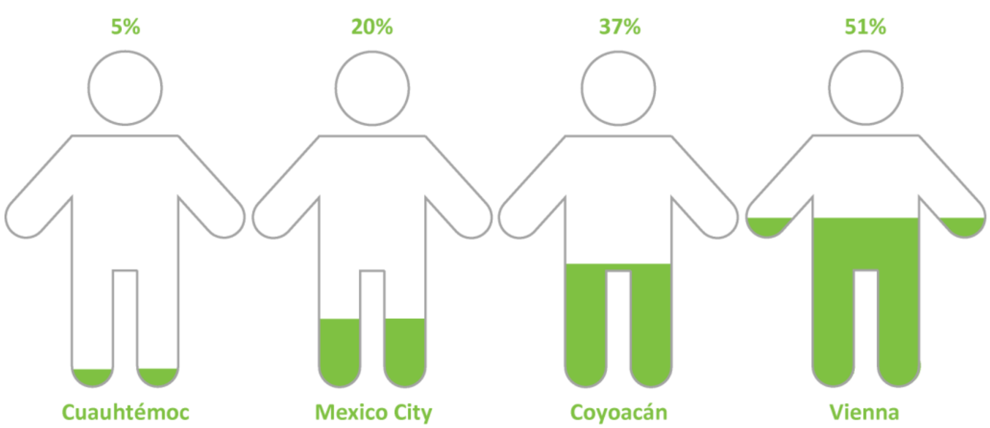


Figure 2- 49 Percentage of green area per capita in different cities

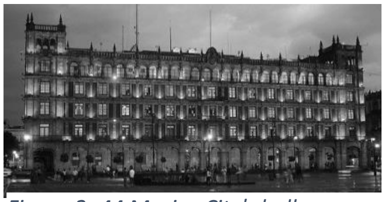


Figure 2- 44 Mexico City's hall

Figure 2- 45 Garibaldi Square

Figure 2- 46 Tres Culturas Square

Figure 2- 47 Market of Traditional Handcraft

Figure 2- 48 Gourmet Market of San Juan

Borough	Area km²	Green Area Km²	Green Area %	Trees Areas %	Grass and bush Areas %	Green Area per inhabitant m²	Trees Area per inhabitant	Population millions
Coyoacán	54.01	20.13	37.3	76.7	23.3	31.4	24.1	0.6
Cuauhtémoc	32.67	1.81	5.5	74.0	26.0	3.5	2.6	0.5
Distrito Federal	632.6	128.2	20.4	55.9	44.1	15.1	8.4	8.8

Table 2- 2 Green areas

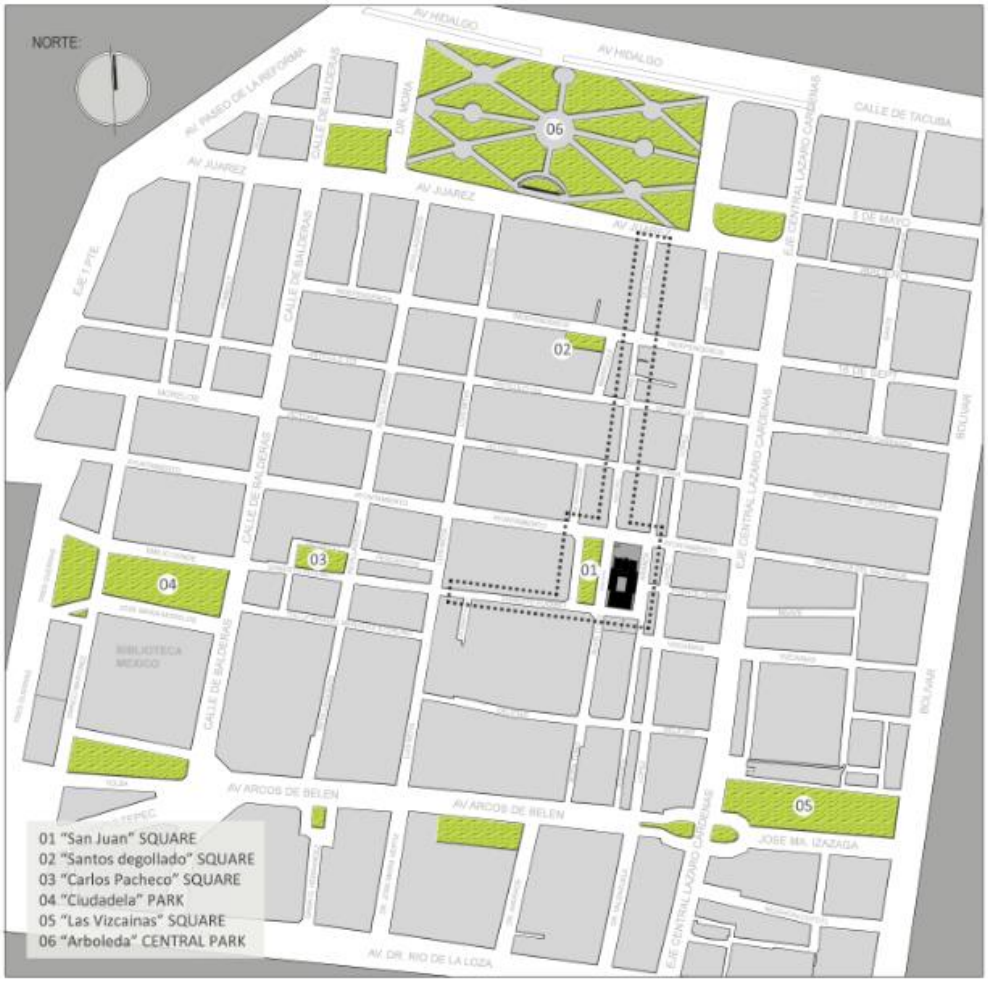


Figure 2- 51 Green areas around the site

Figure 2- 50 Alameda Central

Figure 2- 52 Alameda Santa María

2.6 Scale comparison

In order to present to the reader of this document a reference of the intervention area the FIGURE XXX, shows the area of intervention compared with a well-known landmark in Italy, the Duomo and its square, in the left it is observed the main square and the streets that take part in the competition, in the right we highline the area of the San Juan park and surrounding streets (area un blue) and the location of the handcraft market (central area in pink) that is similar in size with the Duomo's transept.

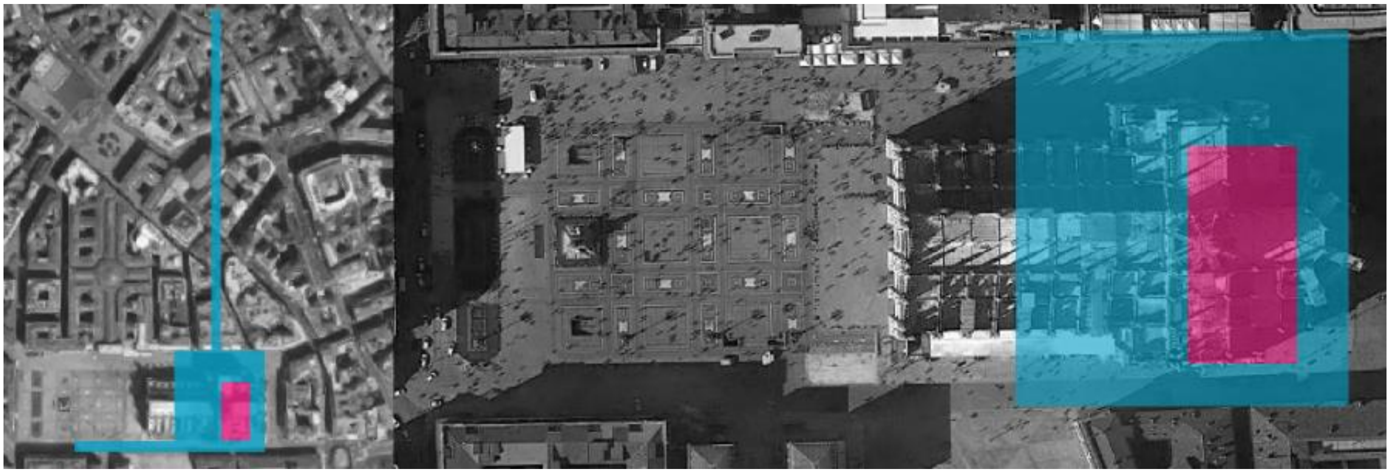


Figure 2- 53 Scale comparison with Duomo of Milan and the Piazza

2.7 Skyline

Figure 2- 54 Skyline, the white lines define our building shape

2.8 Land use

The area of our site is the west extreme part of the historical center, is a place of transition and mix of culture in the city. In the old history of the city this district was the limit of the political center and the entrance to the residential area, due to this antecedent some neighborhoods still been considered traditional. A short description of the streets along the site (Dolores and Ernesto Pugibet) starting from the north: we enter on Dolores St. Corner with Juarez Av., behind the Palace of Fine arts an Alameda Central Park are the link with the traditional touristic spot. The importance of the area is clear in the first block where the main building of the Ministry of Foreign Affairs is located, along the street we can find many stores and some buildings with residential purpose.

Figure 2- 55 Land Use

Further starts the China Town, where the Chinese community established since the 60's, this area is a traditional sector for the locals as a pole for shopping and leisure activities, this two block of Chinese thematic flank a total pedestrian street.

After the Chinese part a new commerce street starts, here the shops are specialized on lighting system and electric supplies, all these activity produces a heavy traffic, a deficient image and damaged street. This specialized section ends in the corner with Ayuntamiento St.

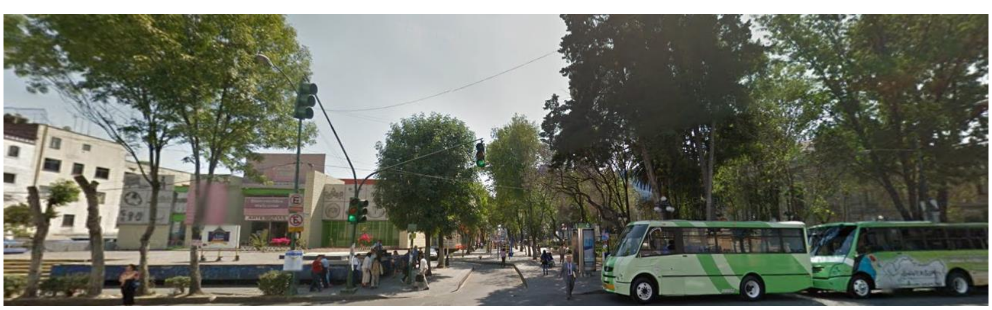


Figure 2- 56 View of the Market and San Juan Square

At this point we find the San Juan park and the Market of Traditional Handcraft, coming out from Dolores St. means arrive to an interesting semi open space, where the area of the market and park mix in a big pedestrian area, in order to continue with the route for pedestrians is better to cross the space between these points until Ernesto Pugibet St. where the main path turns to the right.

Along Ernesto P. St. office buildings are located and the traditional gourmet Market San Juan, that although its importance and fame is not easy to identify and doesn't have an attractive image to the people passing around. Further at the end of the site of intervention we find the Flower Market.

All these buildings and streets show a high degree of decay in image and some cases structural.

Close to the site is important the presence of other commercial areas and streets, like Eje Central that concentrates many shopping centers of computer, electronic and multimedia. Eje Central runs parallel to all Dolores Street the longest path of our intervention area, also represents the main origin of visitor because of the public transport stations on this avenue.

2.9 Accessibility

The site of intervention due to been centrically located has many options for accessing. Flanked by important the avenues Juarez in the north, Eje Central to the east , Arcos de Belen in the south and Balderas in the west; and also other important throughways like Reforma and Insurgentes are close giving multiple options for reaching the site and its surroundings bye car. About public transportation this specific district of the city has many Metro (Subway), Trolebus (electric bus) and Metrobus (Bus Rapid Transit) stations.

Metro: the subway of Mexico City has more than 200 km of double rail, 12 lines 195 stations and moves more than 4 million people a day (STCM, 2014) a map of the lines is annexed (AN01). Four subway lines surround the project site (Lines 1, 2, 3 and 8) that practically bring visitors, workers and students from all the city each day. The stations that serve to this zone are: Hidalgo (lines 2 and 3), Bellas Artes (lines 2 and 8) San Juan de Letran (line 8), Salto del Agua (lines 1 and 8), Balderas (line 1 and 3) and Juarez (line 3).

Metrobus: this system is based on high technology buses, automatized system of payment, five lines serve the city (Metro Bus, 2014). Along the site from west to east five stations of line 4 South cross the Ayuntamiento Avenue. The stations are: Juarez, Mercado de San Juan and Eje Central. A general view of the system is shown in AN02.

Ecobici: is the local system of shared public bikes of the City, for enhancing the mobility on the downtown, it started in 2010now has 3600 bicycles, 275 stations along 21 km^2 (Ecobici, 2014).

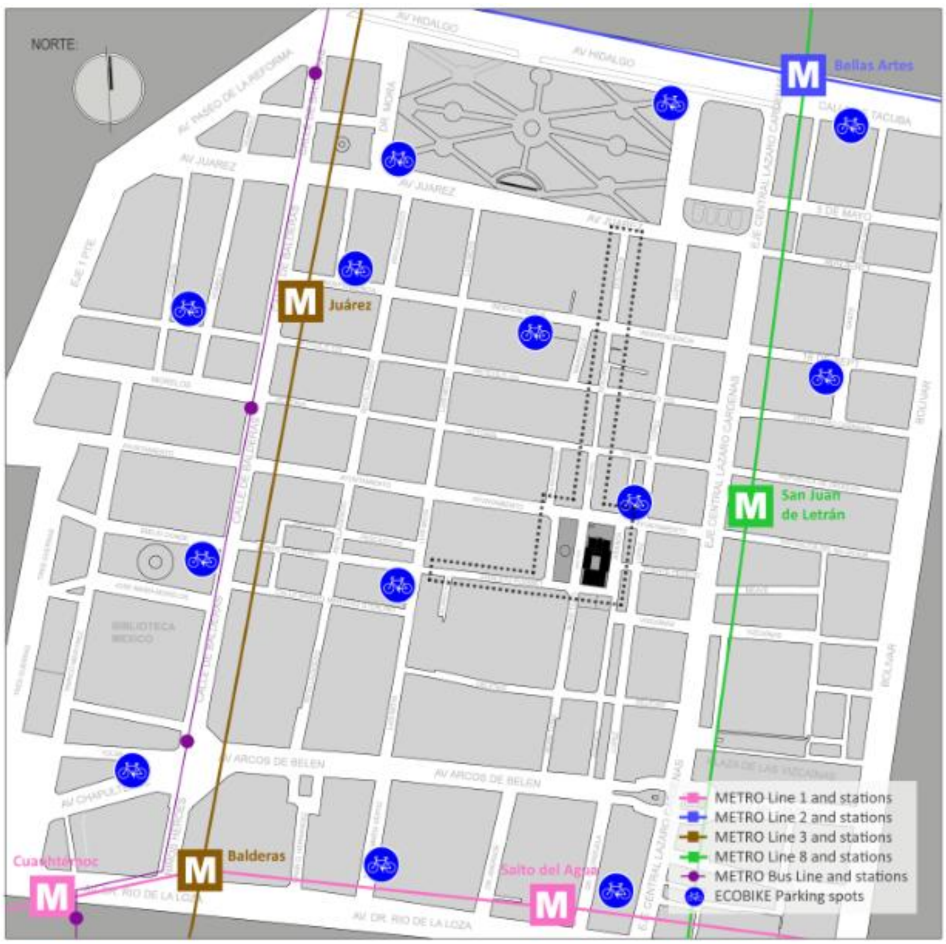
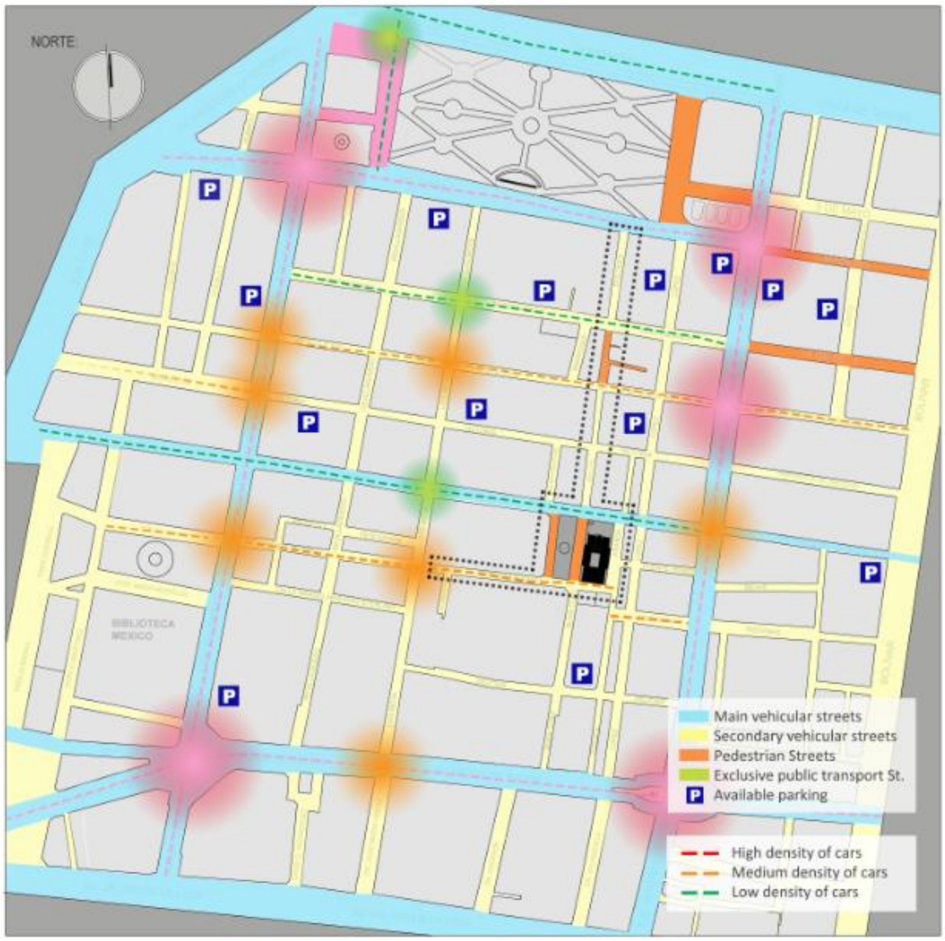


Figure 2- 57 Accessibility (Public transportation)

Pedestrian: The flow of people coming from the area around can reach by many accesses from the other parts of historic center, special important have the pedestrian streets Madero and 16 de Septiembre. The local government started in 2009 a program for getting mack the streets to the users (Blanco, 2014), and there are many plans for make streets and paths totally or partially (local vehicles and public transportation) pedestrian. Bellow a map with the actual pedestrian streets.

Traffic: the inhabitants of Mexico City suffer the longest time in transportation between home, work and school in the world (IBM, 2011), 23 hours a month in traffic. Many factors contribute to this (bad conditions of the ways, over population, bad urban design, limited and relative expensive public transportation and finally the schedules of school and business star and end at the same time. The drivers spend 1:20 hours and those who use public transport 2:08 hours going to work and education enters (Seriña Garza, 2014). According to the Ministry of Transport and Highways two of the avenues with more traffic in the city in the peak times (2014), these avenues are in first place Eje Central (image XX) and in second instance Eje 1 Poniente. An analysis of the traffic is show in the section XXX.

Figure 2- 58 Traffic Analysis



2.10 NOLY

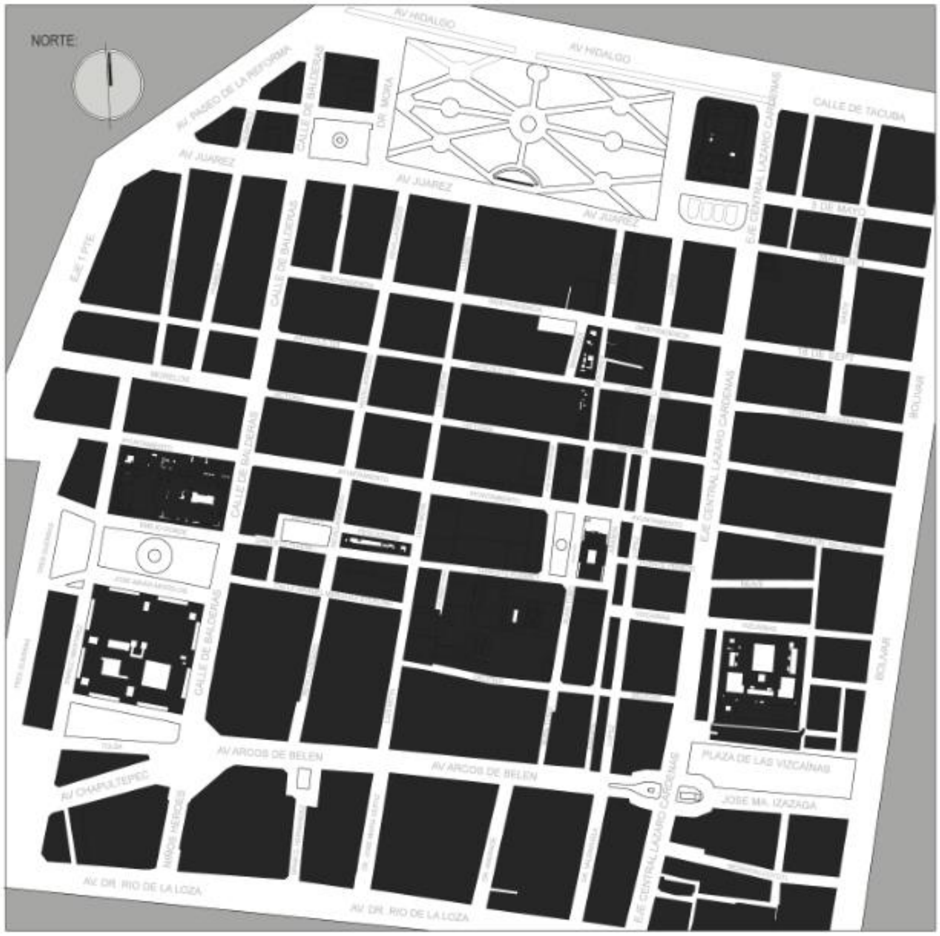


Figure 2- 59 NOLY

2.11 SWOT analysis

A main part of any design, after gartering all the information of the project available, is the analysis of all the elements that composed the space, area and context in which we plan to develop our work. One common way to do the analyses is with a SWOT, by the initial letter for Strengths-Weakness-Opportunities-Threats.

It is not a simple study to carry it out fast, and with no conscious about the area, as many aspects may fit in one, two or even three categories. In spite of that, to study the strengths and opportunities may give us the advantages of elements to incorporate the space better into an urban project, and therefore the weakness and threats represent the areas and aspect to be careful and focus more in avoid/correct when designing.

For this report we represent the SWOT in two different ways, graphically to be more explicit in the analysis, and as a table with the influence of each aspect in our design work.

Primary Analysis - Site analysis

After the location of the site, it is necessary an understanding of the interaction between the area and the site itself; is a starting point to any of the further analysis. In the *image 1* we can see the area of work, color in grey, in the center of a piece of the city that can be in context because of the proximity with the project. This scale of the city was defined according to the possible relevance and influence in the Urban and Architectural design of the project.

The buildings that may represent an influence in the project are mark with their respective name-use, to create a link in terms of visibility and compatibility with the new urban spaces created around the main building of the project. Base plan, land use, relevant building occupancy, and street hierarchy. The basic nodes (when two street of relative important meet) were analyzed according to the occupancy and the possible problematic that can be, in terms of vehicular and pedestrian accessibility.

The most conflict points are identify with a red spot, while the less conflict points with a green color. As well as did with the hierarchy of the streets mark with dot lines.

The land use is really vast in this part of the city, as it is represented in the *Image 1* with the land use plan, giving to the project a very high flexibility in order to create different functions in one architectural space.

- Area of the project – Individual analysis.

Not all the analysis can be done in a general scale, that means that a close up in the area of the project need to be carried out to fully understand how is the behavior and the main advantages of the surroundings. The next scheme shows in a more graphical way the most important aspects.

The main problems the area is affected by can be listed as follow:

- The lack of maintenance of the streets; the area is full of commerce in bad state, and the informal market most of the times block partially or completely the visibility, access, and make the transition between the recently renovated city center with the rest of the old center part almost impossible.
- The circulation along the street is difficult due to a number of factors; the vehicular circulation in most of the small street is block by informal parking, signs placed wrongly in the street by the business, informal trade blocking the sides of the road.
- Insecurity in the area; the obstruction that the informal trade represent in the street generate small corridors, lack of visibility, difficult transit, etc., conditions that the burglars take as an advantage for illegal activities and commit thefts.

Finally we can put together all the aspect to create the SWOT.

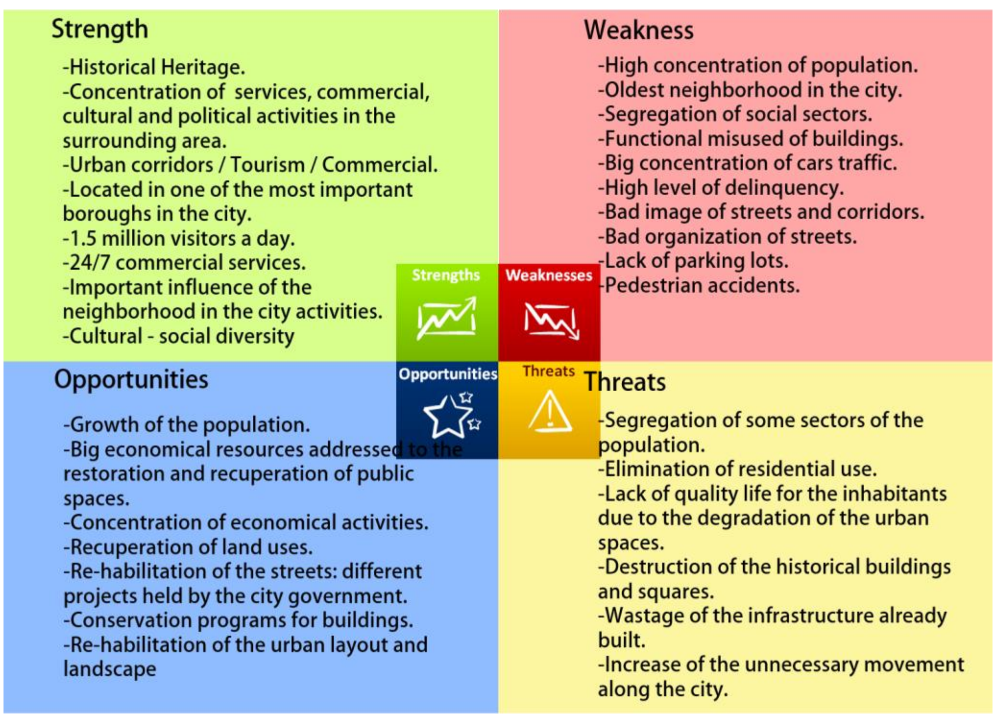


Figure 2- 60 SWOT

3

URBAN DESIGN

This chapter specifies all the primary process that was followed to develop the urban proposal.
The descriptions of the design process, the concept plan and sketches which led to the final Master Plan are presented; plans, section, details and perspectives are shown as support of the design outcome.

Chapter 3: Urban Design

3.1 Introduction

The importance of the urban design as a part of the architectural design lies in the necessity of linking the private with the public spaces, in the different fields of architectural design the urban design has the greatest impact in the city life and its nature, due to this relevance many different fields of study are involve in the efficient and harmonic performance of the public space (Lang, 2005).

The urban design is a complex mix of different elements, between: buildings, squares, streets, parks, etc., when a new element is planned all the urban factors must be taken in consideration in order to not interfere with the harmony of the site, or like in our case to enhance the current conditions of life and joy.

The most important aspect of the urban design is its public character and how all the elements listed before can work together and enrich the experience of the users, for this matter the design has to take in consideration also the connectivity between the different urban units, the understanding of the natural elements; such as sunlight, weather conditions, environment, and social context.

The refurbishment of "San Juan Market" is more than the simple reuse of a building, as part of an important district of the city, for his role in history and now in commerce is concern of the designers to build a plan that considers its connection with the city and how this intervention con match with the city and the future urban plans considered by the local authorities. As we analyzed in the Chapter two, our site goes from two important landmarks: the Palace of Fine Arts and the Alameda, the first green public space in the continent after the colonization. It is fundamental to consider the rich context of the site; we cross one of the most touristic areas of the City, passing through the mix of cultures (Chinatown meets one of the most characteristic specialized commercial streets of the city) and finally we find our main site, where "San Juan" square works as a meeting point for all the elements, this large public space is the heart of our urban design that influence the flux of people and even the new design of the handcraft market.

As part of the courses taken in the Architectural Engineering program the sustainable design is an important consideration for all the phases of design. The first step is to consider a City as an ecosystem, that lives and evolves in time and that any decision taken for a single element of it will change the complete environment, and our aim is to make this change in a way that not only don't disturb the previous harmony but also brings something to the site.

In Urban Design, a Typology of Procedures and Products, Lang (2005) divides the urban design work in four generic types:

1 Total urban design, the designer is part of project from inception to completion.

2 All-of-a-piece urban design, where an urban design team creates a master plan and parameters that is divided in components.

3 Piece-by-piece urban design, general policies and procedures are applied to a precint of a city in order to steer development in specific directions.

4 Plug-in-urban design, here the infrastructure is supplied and then the subsequent developments can plug in to it.

In our case, we can identify our project in the third one, where the government already has started a program with specific guidelines and our development is part of it.

We highlight that the local government has already started a plan for transform the Historical center into a free car zone, enhance the pedestrian mobility and provide more sustainable options of transportation. The streets of our site are considered for future interventions and our design follows in the details the local codes for urban design (sidewalks, bicycle paths, urban furniture, etc.).

The authorities and regulations involve in this kind of development are:

- General Program of Urban Development of DF

- Criteria for the Public Space Design of DF: vegetation treatment

- Criteria for the Public Space Design of DF: refurbishment of small structures, urban furniture and advertisement

- Criteria for the Public Space Design of DF: urban horizontal and vertical signals

- Criteria for the Public Space Design of DF: sidewalks

- Management plan of bicycle paths in DF

- Ministry of Social Development: urban road planning

- Construction normativity of the public administration of DF

As independent references we consulted:

- Guide of strategies for the reduction of car use in Mexican Cities, by the British Embassy in Mexico and Institute of Transport and Development Policies in Mexico

- Manual for the bicycle paths, by BiciRed and World Bank

- Traffic calming: 16th de Septiembre Street study case, by Urban Blog

- Manual for pedestrian crossing

Our global vision of the project is an inclusive approach, it is clear that the site is full of elements that define its character and this reach context must be kept, bellow a description of the process followed is explained as well as the linkage between the site and the city.

3.2 Design process

The base of the process is the definition of our site as a piece of the city that interacts with the surroundings, while it is true that there are not define boundaries we can identify some characteristics inside the site that create an identity. The building type, morphology of the street grid, the commercial activities and in this specific case a clash of two different cultures. Along 700m (Dolores Street) the visitor goes from one of the most touristic districts of the city, cross the Chinatown, later a commercial street and ends in a park and a handcraft market, a place where the traditional objects from all the country are exhibit and offer. This contrast has been part of the history of the site and can't be ignored, on the contrary is an aspect to be exploited in order to attract visitors and enhance the life of inhabitants and regular users by a pleasant experience in safe, enjoyable and well maintained facilities and services (Lang, 2005).

By this point of the project we already have analyzed the prerequisites of the client adding suggestions that are not part of the competition; a complete analysis has been accomplished drawn from a research of the history of the area, this knowledge was gathered from the architectural evolution of the city till the current conditions.

The chapter two resumes the nature of the place, urban texture, patterns, functions, building typology and components, street network, public spaces, commercial places, and mobility. The information collected by the urban design team creates a framework of knowledge for starting the design itself (Palazzo & Steiner, 2011). The SWOT analysis presented in the previous chapter shows the synthesis of this information, in addition a scale comparison and skyline diagram was shown.

The synthesis of the analysis is represented in the following Opportunities and Constraints Map.

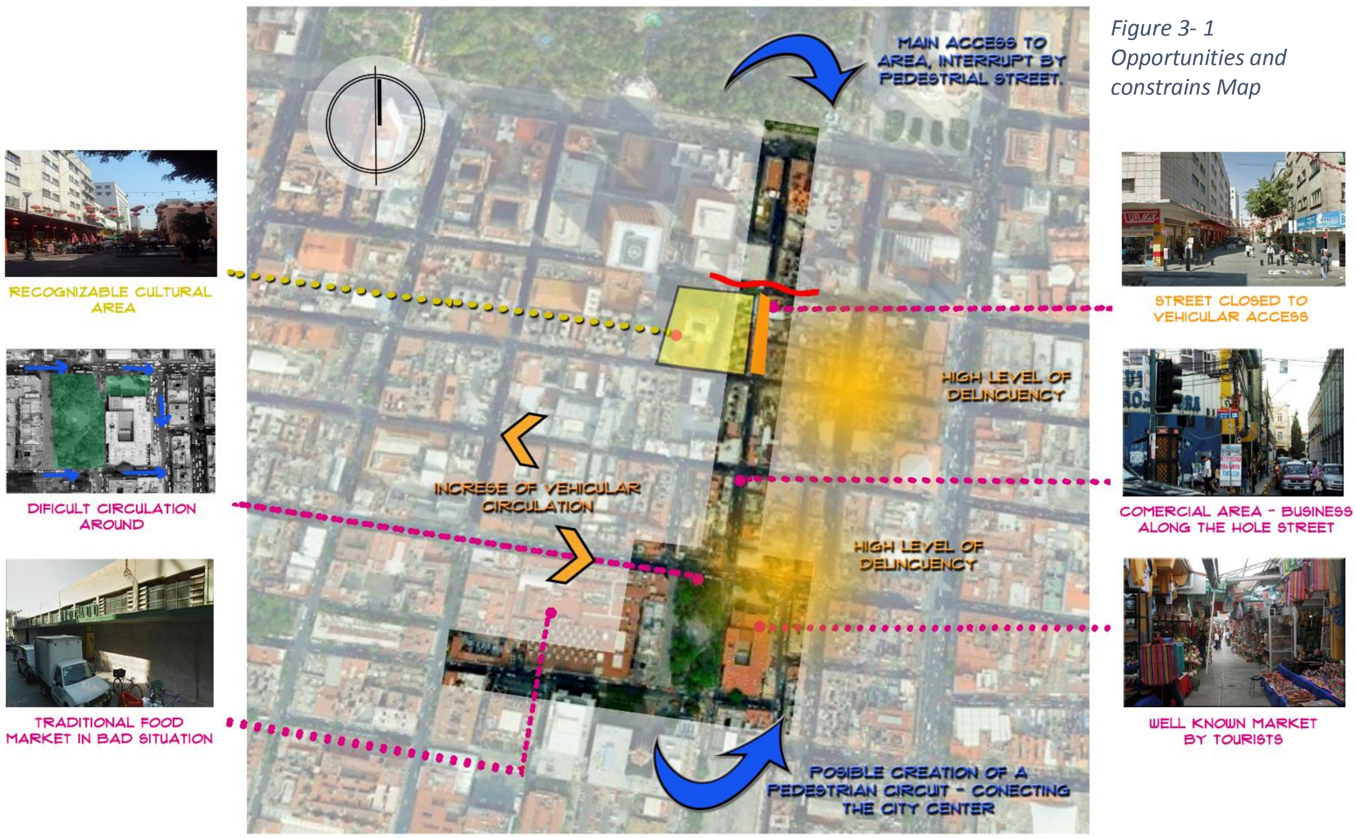


Figure 3- 1 Opportunities and constrains Map

3.3 Concept

The first condition in every urban project is establish a grouped participation in the process of intervention, without a share vision between the stakeholders of the urban project is difficult to held a project for more that the first ideas and interest. Create a share vision and guidelines make sustainable the urban development and multiply the project intervention, in a good track, and hence long terms decision easier to integrate the public and urban works.

Figure 3- 2 Example of Tree of Life

Re-create an Urban Space inside a city, such as Mexico City, require many skills and full attention in the aims that are wanted to achieve. Practically, for the starting point of the design we consider all the aspect the city can offer to the users and what is the most important lack of coverage.

As it happens in any big city, there are areas that are so full of services, business, users, urban elements, and activities in general, that sooner or later it start losing the identity in which it was conceived in the first place. It is even more visible if you have in the same area of intervention, like our area, a well know quarter like China Town, and a few hundred meters away a traditional market of handcrafts of all the country.

To make a connection between the two main important identities we are going to take as a basic concept the idea of a "Tree of life", a typical handcraft made in the center of Mexico that represent the union between different parts of life, or different world, as its branches connect together. Many representations and names have been given to this handcraft as the culture has been changing since remote times. The tradition of this tree of life appeared in Mexico in the art and traditions of the cultures like Mayan, Aztecs, and Olmecs.

The "World Tree" (as it's called in Europe) incorporates in its design the four cardinal points, what represent in the same time the nature of a tree as a central axis for the world, connecting symbolically the planes of the heaven and the underworld with the earth.

Now a days the representation has been turn into a representation of all the aspects of life with a strong influence of the catholic church, using vivid colors, typical from the Mexican culture, with figures and physical representation of each region, festival of the season, religious representations, or even a signature or a distinctive of the family that make the handcraft.

The reason of choosing this singular item of the Mexican culture is mainly because of the evolution that followed it, and the facility to relate the image to different aspect of life. The main figure is base in a main axis, the trunk of the tree, and the branches always go to a central point, without losing relations between themselves;

this is the way a city must be related, and connected within so that all the urban context become one and the people living on that space can have the feeling of belonging, a feeling of unity and order.

The area has as well a main axis, the street of Dolores that connect all the interventions part, and it connects them to a central point, the heart of the project chosen to be the Handcraft Market, with some other branches like business, stores, services, all the street surrounding that in a certain way are independent from each other but connected with the city.

All the intervention in the Urban Scale needs to be carry out from a conscious state of evolution of the city and the constant changing that a city of this type represent, as every year, month, day changes occurs as the people living in, are in a continuous movement that does not stop.

The two predominant cultures that strongly are rooted in the area, the Chinese culture with the Chinatown, and all the business around it like restaurant, shops, bookshops; and the Mexican with the Hand Craft Market, the couple of churches, and the food market, need to be connected to create a unify image to all the project, and in this way implement to the users, workers and people in the city the sensation of own that space, to make them feel like home even though they are just passing by. This is a task only achievable if the project itself can develop over time a transition between the two cultures and be adaptable to any change that they can suffer in time.

Create a link between not only the spaces, but between the cultures, is one of the main aims of the planned urban intervention in this project. In order to achieve that, the starting point is the recognition of the elements that most represent both cultures:

The dragon, for the Chinese, as it is always present in the Asiatic mythology.

The Quetzalcoatl, for the Mexican, as it is one the most import antique gods.

We use this two characteristic fantastic elements to create a green meandering path all along Dolores Street from Chinatown until San Juan Market; furthermore, the luminaries selected for this pedestrian street are inspired in both cultures elements.

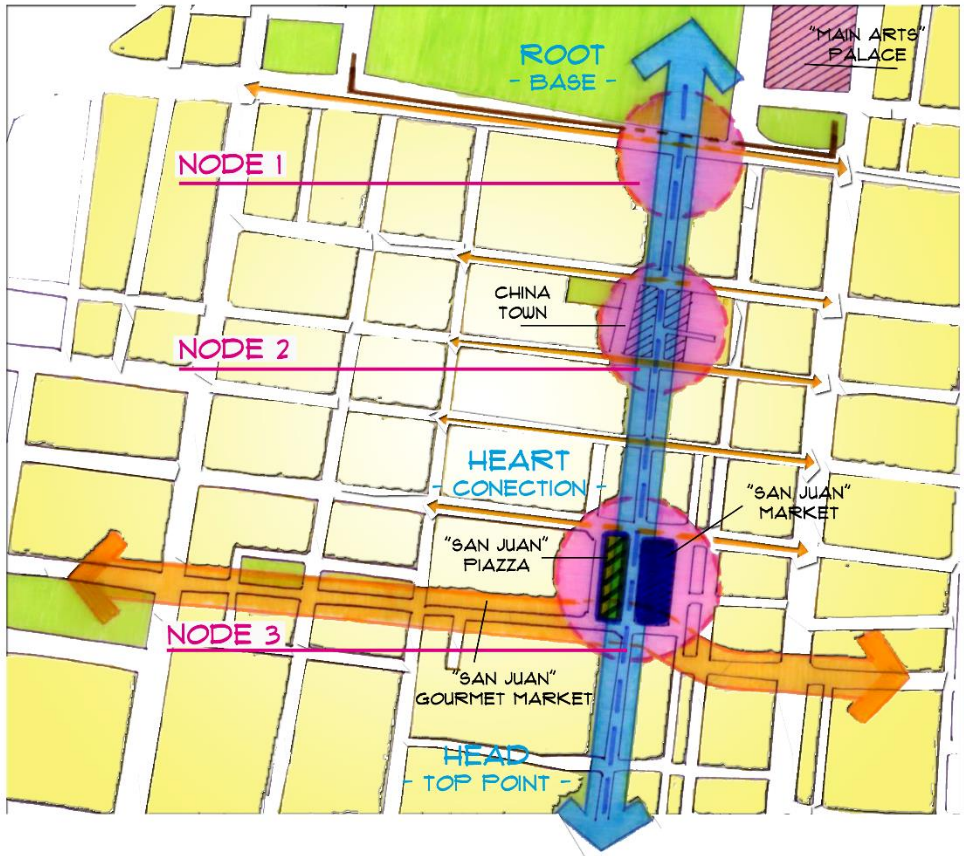


Figure 3- 3 Concept Plan

3.4 Master plan

The master plan is the final result of the urban project, an organized way to put together all the decisions from the previous steps. The masterplan describes and maps the concept, land-use and public spaces (Palazzo & Steiner, 2011). The masterplan presented in this chapter is a general view of our vision for the site, we can appreciate the new pedestrian street, the redesign of the landscape in our park and how the intervention interacts with the other elements. The other important item is the building that hosts the market, the new architecture of the building aims a better integration with urban grid and the new landscape, more details are presented in the next chapter.

After the global masterplan, we present a zoom in divided in two closer views.

Figure 3- 4 Master Plan, main concepts

Figure 3- 5 Master Plan

3.5 Plans and Sections

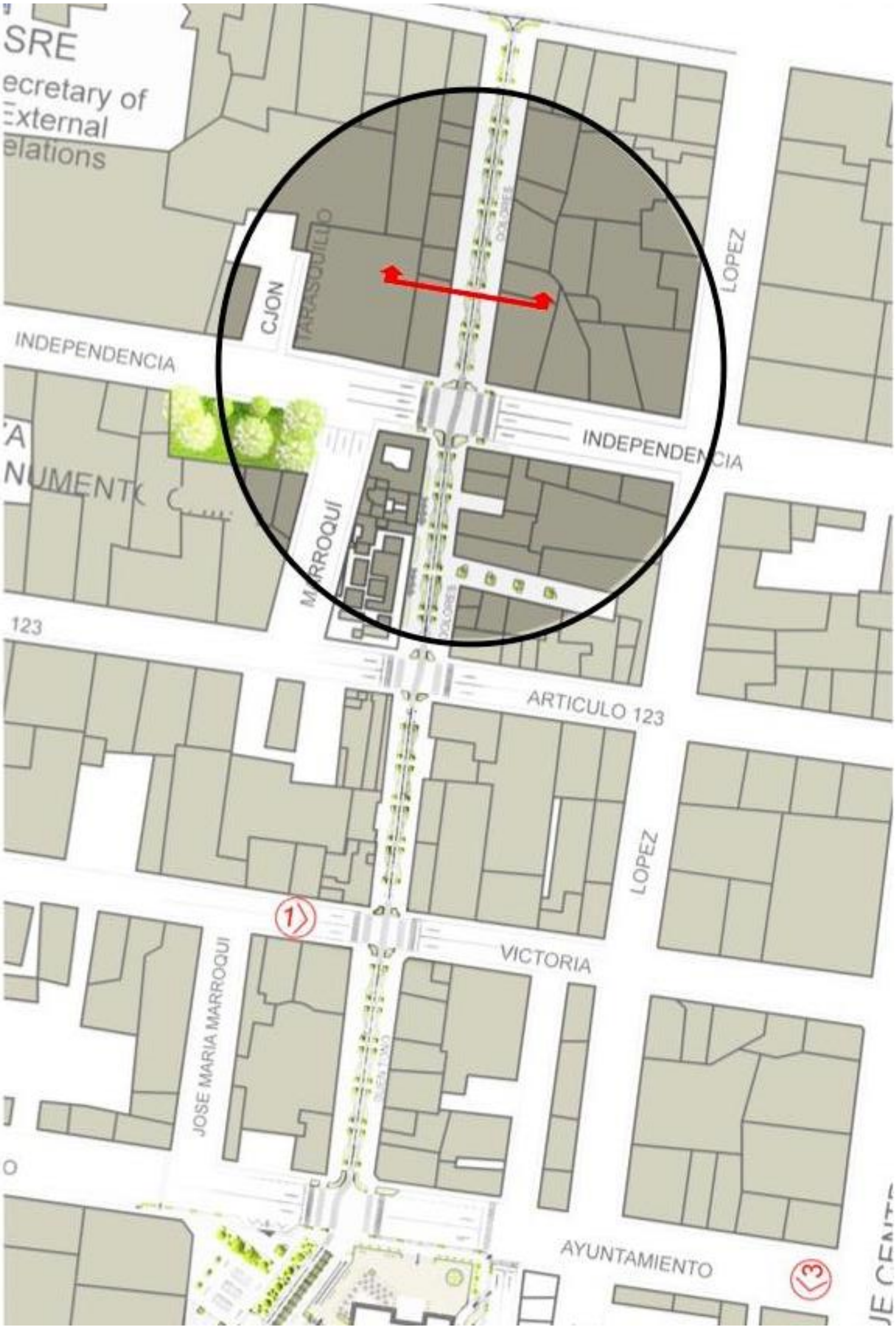


Figure 3- 6 Dolores Street

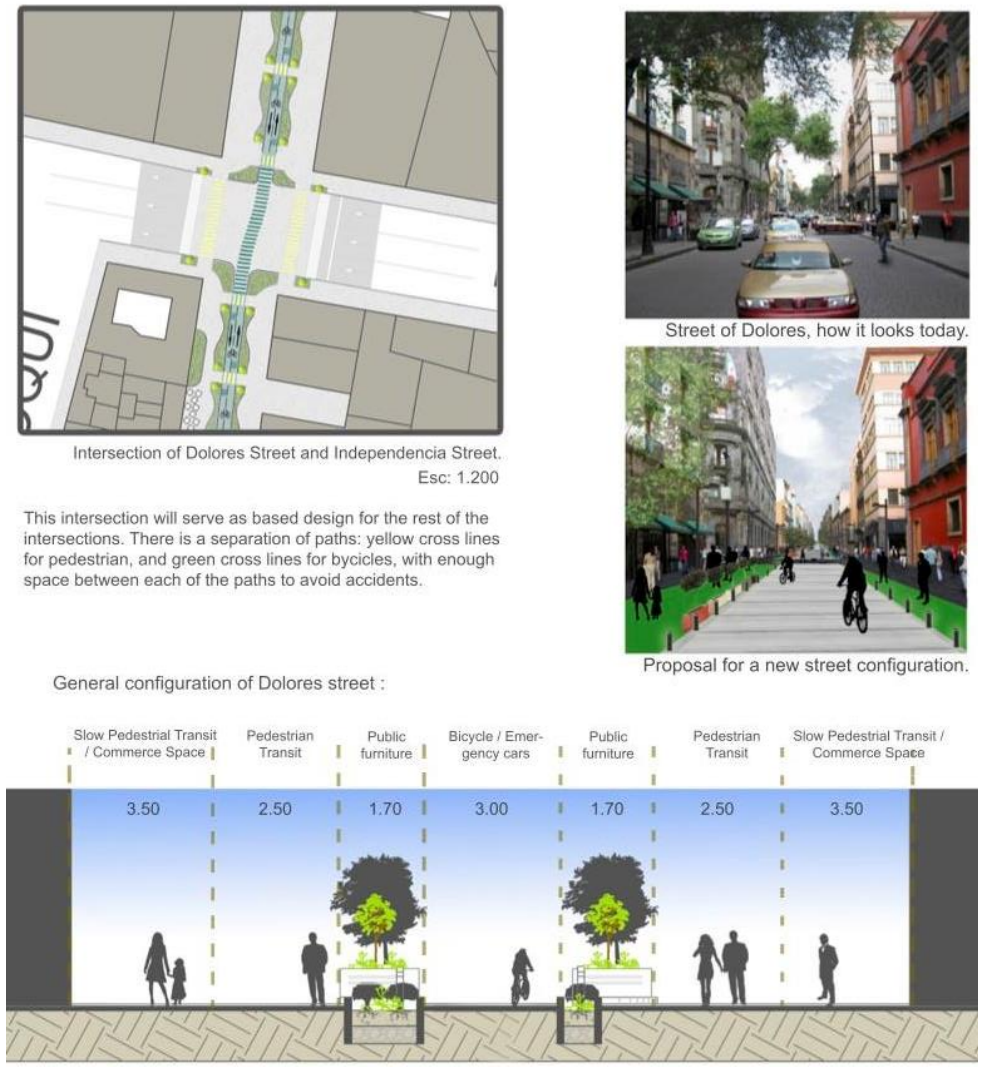


Figure 3- 7 Dolores and Independencia streets intersection, details of the proposed changes in wiews and section

Our proposal includes a new design and use for the Dolores Street, this changes are a radical but necessary decision to transform the experience of the users, passing from a chaotic area with high levels of traffic to an organized space that accomplish both, commercial and the new touristic, aims. To present in more detail the final design we create two characteristic typologies of street, plans and sections are shown below.

Figure 3- 8 Section types, the curve shape represent the union between Chinese and Mexican culture

3.6 Design Guidelines

This section define a series of details that complement the previous plans and diagrams. For the luminaires, as mention before, we suggest a mix of Chinese and Mexican characteristic decorative lamps along the street that connects both cultural poles.

The sustainable approach of this project, considers the proper reuse of materials in the site (more details are described in the Technological Design Chapter), to accomplish this, the debris generated in the demolition of some parts of the market are use as fill of gabion furniture, we can see one example in figure XXX.

About the vegetation, first we keep the actual trees in the area, for the new landscape we use native spices, with to basic aims, first the ecologic restoration of the site. Mexico has suffered extended alterations in the natural ecologic communities, although many forestation programs has been created usually these programs include exotic plants that transform the original nature. The national government has a project for the correct ecological restoration, in order to recover the principal functions of the original ecosystems, fertility of soils and hydrologic cycle (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad).

The plants suggested are:

Name	Type
Quercus rugosa Née	Trees of 20 m heigh, important to the restoration of green areas
Senna multiglandulosa	Butch or short tree, native ornamental plant with flowers
Buddleia cordata Kunth	Butch or short tree, native ornamental plant with flowers
Prunus serotina ssp. capuli	Trees of 15 m heigh and white flowers, useful for recovery of soil and provides food to natural wildlife
Jacaranda mimosifolia	Well adapted exotic tree, absorbs pollutants of the soil

Table 3- 1 Suggested plants for the ecological restoration

Figure 3- 9 Quercus rugosa Née

Figure 3- 10 Senna multiglandulosa

Figure 3- 11 Buddleia cordata Kunth

Figure 3- 13 Prunus serotina ssp. capuli

Figure 3- 12 Jacaranda mimosifolia

3.7 Sketches

In order to illustrate our vision we present the following renders and sketches, these images transmit the idea of modernization of a traditional public space, with a sustainable approach incorporating passive strategies for efficiency, keeping and strengthening the traditional elements through materials and atmosphere while the visitor walks. The urban and architectural design are, thus, tools to integrate and enhance the interaction between people and the city and its components (malls, squares, streets, etc.).

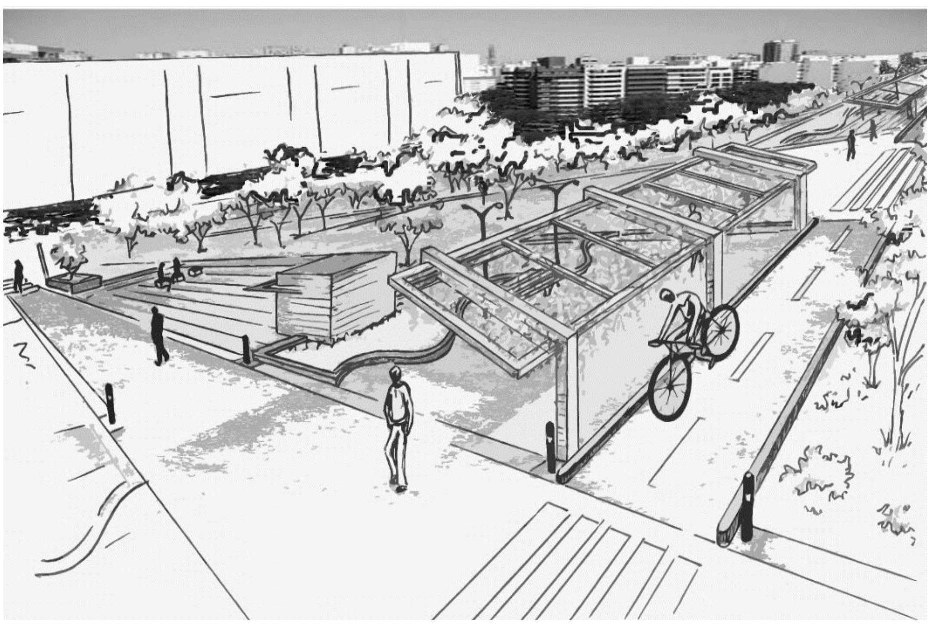


Figure 3- 14 View of San Juan Park

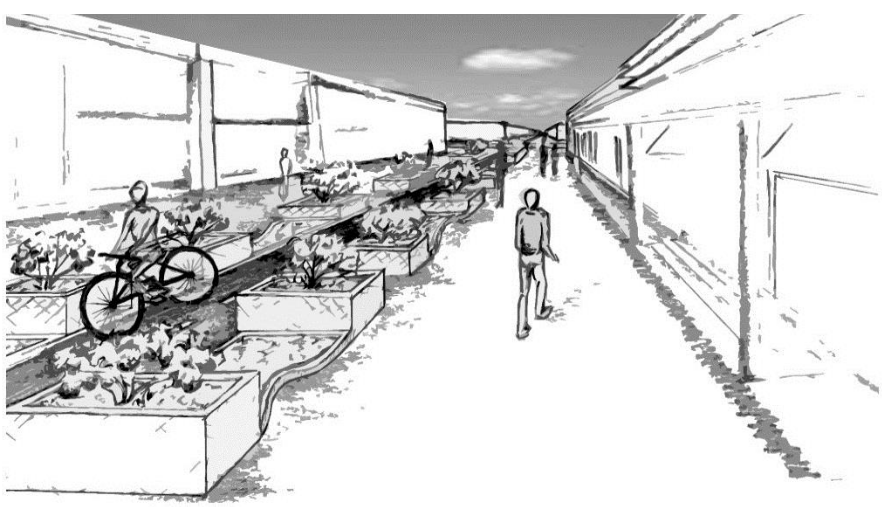


Figure 3- 15 View of Dolores Street, and its new pedestrian function

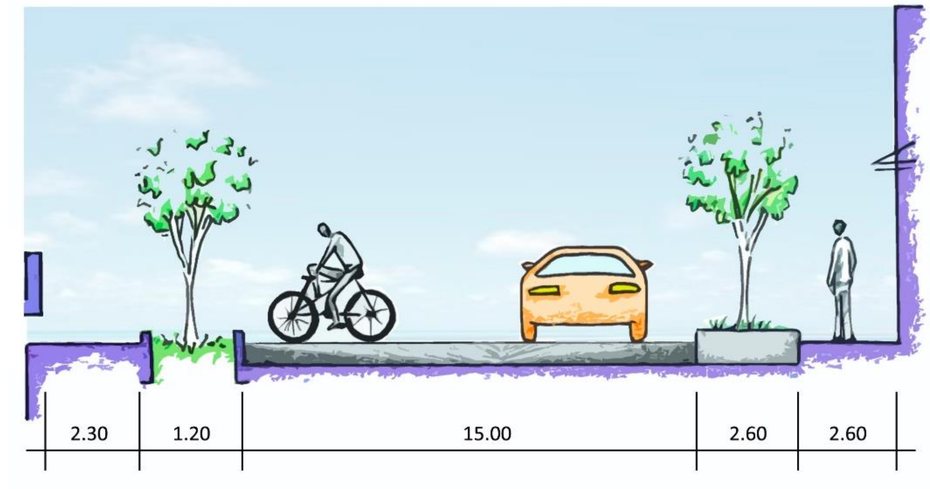


Figure 3- 16 Section of mix used street

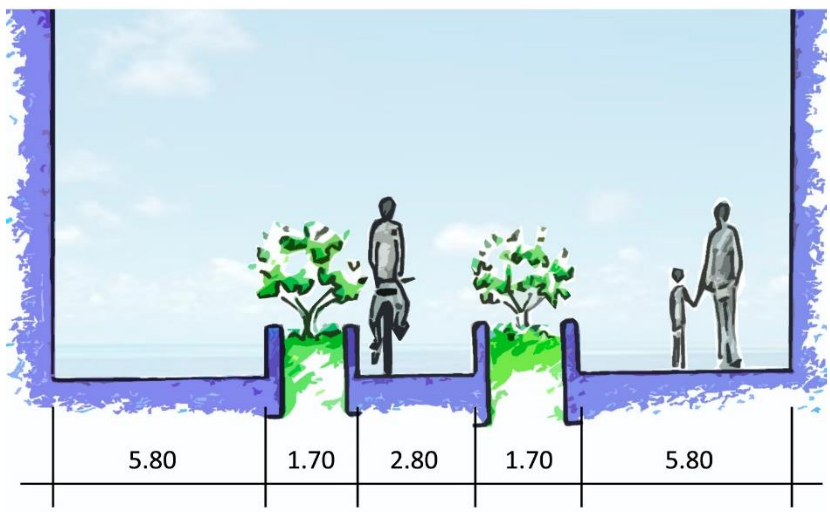


Figure 3- 17 Section of pedestrian - bike street

4

ARCHITECTURAL DESIGN

This chapter specifies the process followed to develop the architectural proposal. Starting from the investigation and analysis of national references, and followed by the geometrical and physical analysis of the original volume improving its spatial quality; plans, sections, elevations and renders are presented as support of the design outcome.

Chapter 4: Architectural Design

4.1 Introduction

Davies and Jokiniemi, in "Dictionary of Architecture and Building Construction" (2008), defined architecture as the art and science of producing built form, the product and study of this. These two words, art and science, resume all the different techniques and disciplines involve in the design process. Since early human constructions it was obvious for the architects that a building is more than a simple container of people and functions, it is also a part of the artificial environment that a city hosts, and this is almost as important as containing and housing.

When we talk about art, to our minds comes the term aesthetics concern with beauty; a new building or a major intervention, as it is our case, must consider that the work planned will modify the total appearance of site, and is matter of the design team to make this irruption a successful project.

The size, scale and proportion, have to harmonize in some measure with the actual expectations of people and the surroundings. To achieve this harmony the architects based their designs on basic forms, in other words: geometry applied for the purpose of design (Sebestyen, 2003).

Color, light and shadow, has an important impact on appearance, the correct use of this factor can create a better atmosphere, and enjoyable place to be, and can even enforce the identity of the construction, divide spaces beyond physical borders.

The science is the tool to bring the building to reality, extending the techniques to withstand the elements, forces and pass of time, and science is not only an answer to durability but also a way to give the users and their activities the proper conditions to live, work and joy.

Materials and their behavior, energy supply, human comfort and lighting conditions in addition to the previous aspects are the main topic of this chapter, the reader will understand from the studies made in chapter two, and the urban solutions obtained in chapter four; how the Handcraft Market evolves, the importance of all the conditions (physical, social, economic and technological).

As the new times required, an architectural project must consider and take as main guideline to design the relation of the buildings with the conditions where it is projected. When the term "sustainable" is applied to architecture, immediately the idea that comes is environmental sustainability, however, is also a concern of social and economic sustainability (Hagan, 2001).

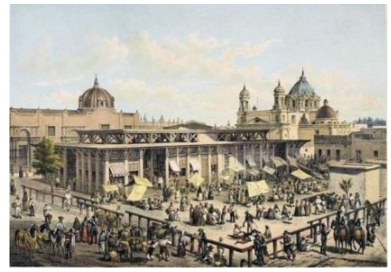


Figure 4- 1 Iturbide Market in 1869 (former San Juan Market)

Figure 4- 2 Handcaft Market in 1964

4.2 Background

The handcraft market of "San Juan" has a history that dates backs to 1562 with the Tianguis (traditional street market) of "San Juan Moyotlan" located just two blocks from the actual site. The first stablished building was constructed in the 19th century and stayed there until the 60's due to the construction of the subway station of Salto del Agua. According to Rafael Acosta Sanchez, chronicler of the area, the building that nowadays accommodates the market was originally a pavilion in Tokyo, where it used to be a museum (Solis, 2014) , the building was part of the reorganization of the markets made in the 60's by the local government.

Figure 4- 3 Variety of mexican handcraft, wooden toys

Figure 4- 4 Fabric dolls

The architectural project consist in the refurbishment of the building, keeping as much as possible the existing installations and structure, but providing new spaces and services for the necessities of the vendors, modernization of the market to new conditions, economic and sustainable, but not putting apart the importance of the market in the community, pass and for the future both.

4.3 Design process

We part from the fact that this building concentrates a wide variety of examples of the culture from all over the country; a rich concentration of colors, materials and forms (FIG) is the main inspiration for us. Satisfy the client with an attractive and useful market models the basic form of the building.

Figure 4- 5 Silver sculpture

We keep the straight geometric lines we inherited, include new shapes and give a teaser of the colors that we have inside, in the façade. Also, as an inclusive development, we enhance the experience by the green spaces and views.

Figure 4- 6 Hacienda Gogorron

4.4 References

After a simple view over the original building, we can make an analogy with a characteristic typical kind of structure in Mexico: the Hacienda.

The typical Spanish house was similar to the houses they found in Mexico, the main characteristics were: generally two stories, simple facades y surrounded by exterior gardens. General shaped in square, L or U form. The rooms used to be located around a courtyard, shading loggias and often a fountain. This last element in addition to the large windows all around the rooms facing the courtyard facilitate the cross ventilation, refreshing naturally the ambient. Large open space in the middle of the building brings natural light to the rest of it. In some cases in the north of Mexico (with a deserted climate) is know that the roof was covered with vegetation for insulation purposes.

Passive design is a main characteristic of this type of architecture, we analyze the solutions used in haciendas and later they are compared with our own proposals.

Insulation was supplied by thick adobe or stone walls (30 cm), covered with a mix of mortar of limestone in order to protect against humidity. The loggia brings shading and keeps fresh the rooms in summer season.

The openings in the rooms creates cross ventilation, where the wind flows from the outside to the central yard. The fountains in the central part of the building has an important role, refreshing by evaporation (Ruiz, 2011).

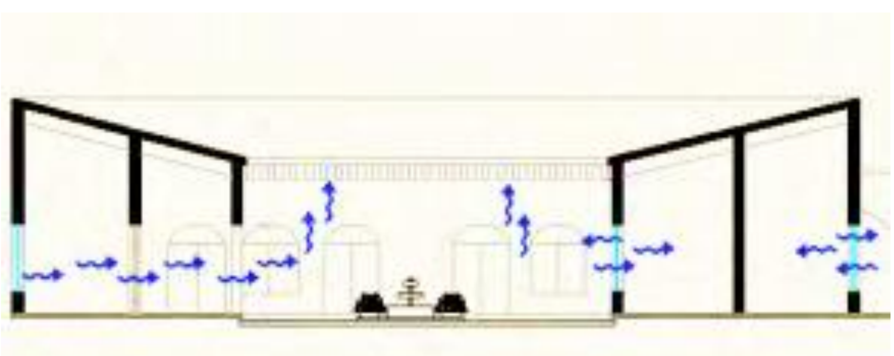


Figure 4- 7 Plan of the "Casa de los Perros" Hacienda

Figure 4- 8 Cross ventilation diagram in "Casa de los Perros" Hacienda

4.5 Study cases

Luis Barragán Gilardi House

Figure 4- 9 Corridor in "Casa Gilardi"

This architect is an obligated reference in the architecture, although most of his work was applied to small scale (houses) he included on it the principles of the traditional design, incorporating colors and materials, bring to the present the solutions of the past.

The "Casa Gilardi" is a perfect example of the use of simple elements to create ambient and feelings, passing from room to room the user find himself in new and rich atmosphere.

Figure 4- 10 Cortyard of "Casa Gilardi"

This house is located in Mexico City, a narrow land hosts a house divided in a two volumes building, the front part as the provide space and in the back the social one, linked by a characteristic corridor. In the middle a courtyard with a Jacaranda tree (Ruiz, 2011).

Thanks to the location, it's easy to design based in natural ventilation and passive principles, Barragán used thick walls for thermal and acoustic insulation, at the same time recreates the traditional architecture. As the old Haciendas the courtyard has an important paper in the natural ventilation and gives a nice interior view. The plans and water containers help to refresh the ambient. The architect looks for a passive solution to the comfort requirements and at the same time provides a beautiful view and traditional design.

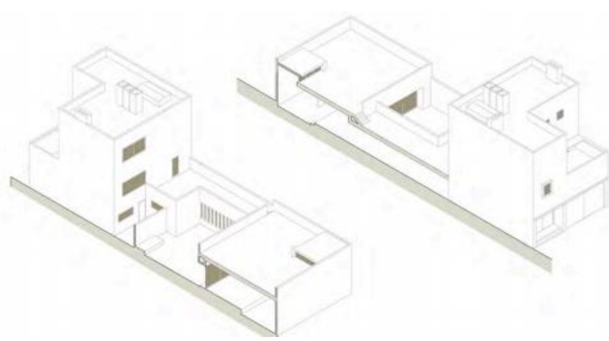


Figure 4- 12 Isometrics of "Casa Gilardi"

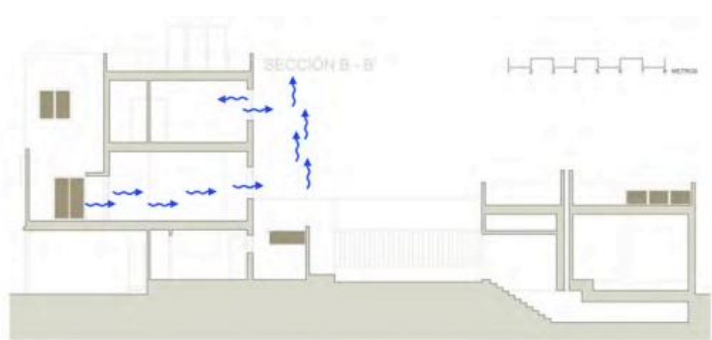


Figure 4- 11 Section and cross ventilation of "Casa Gilardi"

Figure 4- 13 Exterior of the National Anthropology Museum

Figure 4- 14 Courtyard of the National Anthropology Museum

Figure 4- 15 "The Umbrella" at interior of the National Anthropology Museum

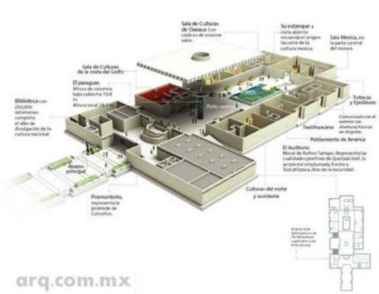


Figure 4- 16 Diagram of the National Anthropology Museum

Pedro Ramírez Vázquez National Anthropology Museum

We selected the Anthropology Museum as a reference for one important reason, this important an iconic building of the city hosts a rich variety of the history and culture of all the country, like our market, the visitors have to enjoy with many different rooms, exposition centers, and research or work.

The main criteria for the design was:

a) Register, conservation and management of the cultural heritage of Mexico.
b) Production and divulgation of knowledge.
c) Bring over the indigenous world to everyone.

This was multidisciplinary project with experts in: anthropology, archeology and history; education, museography, art and model building, and architecture (Museo Nacional de Antropología, 2015).

Its location is in the middle of the Chapultepec urban forest with a strong relation with the natural environment. The design respect the tradition of the Mexican cultures adding the work of many plastic artist. The form consist in a rectangular shape, divided in spaces with different functions and sensations. The criteria followed by Ramírez was "visitor user" and "visitor protagonist", it was necessary a harmonic game between exhibition rooms and gardens, light, dimensions and materials. We can see the following elements:

- Façade and access square: big open space, glazed doors and linked to the outer space.
- Atrium: to orient and distribute visitors, library and research rooms.
- Central courtyard: the core from all the rooms are arranged, the "umbrella" fountain is the most visible structure, also a large pond reminds the lake past of the city

As the architect mentioned in an interview in 1985 when talking about the location of the main entrance, not facing the most important avenue of the city:

"… decrease the fluency. The gate can be in the side and still being important."

(Ramírez Vázquez, 1985)

The design team created a museum that integrates culture, knowledge and leisure.

Dr. Manuel Gea González Hospital

Figure 4- 17 Main Facade made of TiOx panels of the Dr. Manuel Gea

For the last decades Mexico has made many improvements in order to clean the air from toxic pollutants, one of the last solutions to this problem can be find in the Dr. Manuel Gea hospital, that has the capacity of depollute the air.

Using the German system Prosolve370e, the design studio Elegant Embellishments, has created a 100 m screen that covers one of the façades of the hospital, this product can absorb the toxic chemist produced by 8750 cars per day (Abilia, 2013). The modules are covered by a pigment made of titanium dioxide, that port from reflecting the sunlight reacts with the nitrogen dioxide and other volatile organic components (VOC's) and divides this particles in less toxic molecules.

The new second skin, provides a characteristic identity to the building and at the same time has a functional purpose, it is important to create a useful and attractive building, that not just sum volume to the site but brings benefits to all the community.

Learnings

These basic principles are taken in to our design, first we keep the courtyard, but we open totally the access to it, now the building has just a direct way to the central yard (FIG XX); by the information given in the brief, we know that the wall are not structural elements and we have a plan of disposal for debris. The building has now a water body that is usually dry, we will keep it with some modifications, and the air will be refreshed with the inclusion of plants inside the courtyard.

To provide insulation in summer season to the south and west façade we select autoclaved aerated concrete, a light material with insulation properties, and an aluminum cladding is selected to protect the inner wall. This aluminum layer works also as a reflective material, the standard and easy installation with the wide range of colors was also important to consider this option, also the systems

Figure 4- 18 Interior courtyard of the "San Juan Market"

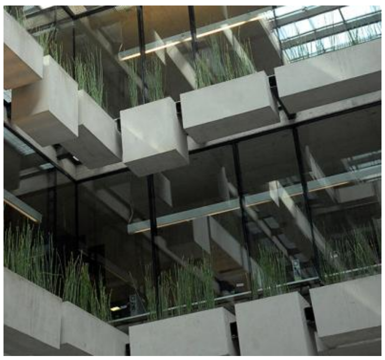


Figure 4- 19 Interior of the Nicanor Parra Library in Chile

Figure 4- 20 Green roof example

Figure 4- 21 proSolve370e 420Series panel

by blocks makes easy possible changes and reparation. The insulation in the roof is a green layer that also is an open space for the workers.

The colors are and important characteristic of Mexican architecture, we selected some of the most typical colors in handcraft and modern Mexican architecture, both with a light tone, just to invite the user to get inside and enjoy these powerful colors but from the craft offered by the artisans. Some details in deeper tonalities make a contrast.

For us was important to create a link between the public space in the park, and the market, we transform a closed private mall into a semi open building, where the landscape of the park defines also the building. It was strongly important to connect the people with the new green space, for that we provide a curtain wall in the west façade, and the new main entrance faces this part. Another consideration from this big glass wall is the high level of solar light that in summers can overheat the west wing of the market. To solve the problem of radiation, first we use glass with a coating layer, but most important is the new second façade that diffuses the light and that is shaped to give the building a distinctive architectural element; this new layer is made of panels that all together form a honeycomb shaped structure, this strong and defined geometry is similar to those used in the traditional fabrics that can be found inside the market. This new element goes all along the curtain wall and turns over the roof and covers also the courtyard. The material selected for the panels is recycled plastic covered by titanium oxide (TiOx) that gives this white color. The TiOx has also the role of air cleaning device, reacting with the sunlight and changing air pollutants into less dangerous molecules. The hexagon shape and the TiOx both have been used in Mexico before, as seen in the reference cases. For the faces with direct sunlight, although the windows are narrow form external appearance, a closer view shows that in fact part of it is covered by a perforated aluminum sheet, this panel lets the wind to pass but reduce the among of sunlight.

Having selected a second façade as a solution for the comfort performance of the building, we can take advantage of it in order to enrich the architecture; we must look beyond the physical necessity of structure towards its function and aesthetics (Charleson, 2005), being more than just a static element and contributing to the global experience, in this case bringing a game of lights and shape. Modulation generates patterns that creates the possibility of variety, makes the construction easier and cheaper and makes easier the future maintenance. In order to offer not only a visually attractive and functional structure, but also safe we consider the equilibrium, to stand applied forces; stability to preserve its form and strength; we explain better how it works in chapter seven. The structure consist basically in a metal grid in r form, that carries the hexagonal panels, and in the case of horizontal cover also an expanded metal layer.

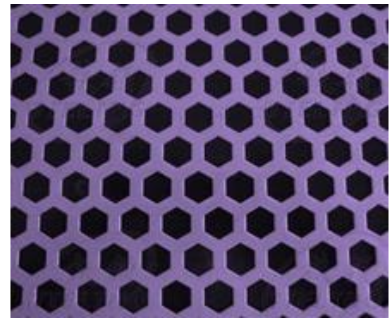


Figure 4- 22 Aluminium perforated sheet

Figure 4- 23 National Cinematheque in Mexico City, example of structure as ornament and function

4.6 Shape - Volume

Our structure is a simple rectangular plan building, we increase part of the volume to the west side, added a new level and a second skin as shading system.

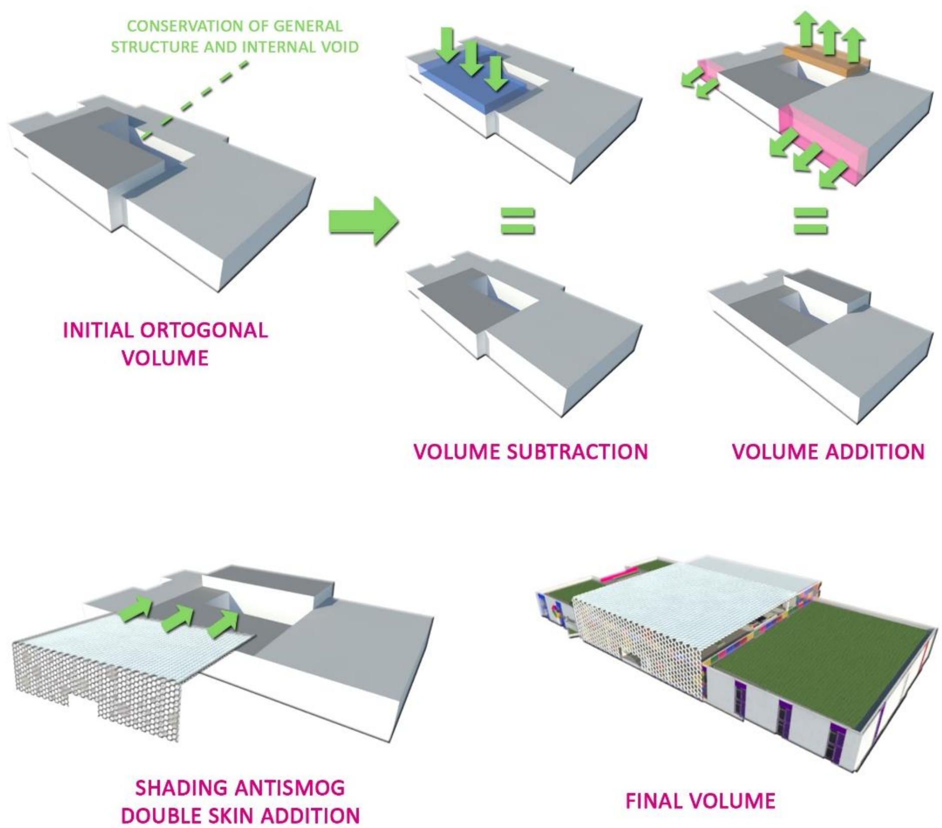


Figure 4- 24 Shape and volume

4.7 Orientation

Since we work in building already constructed, we have limitations in the decision of the orientation, as we mention before the building itself was brought from other location and accommodated in space, without a proper consideration of the environment and context. Because of these conditions the corridors are not well illuminated and wastes the opportunity of linking a green open space with the interiors.

We try to open more the windows, offering a view to the exterior and derationing a new flux not only for the immediate area, but also from other important landmarks.

4.8 Zoning and, Horizontal and Vertical Movement

The new design keeps the same number of locals, and also give new uses for old empty spaces. The new level add extra space for administration offices and the new layout also include the commercial necessities. The big open spaces in the interiors allow easy mobility and the inclusion of new stars in the courtyard and elevator enhance the vertical movement, also it is important to mention the new scape stairs in the south part of the building.

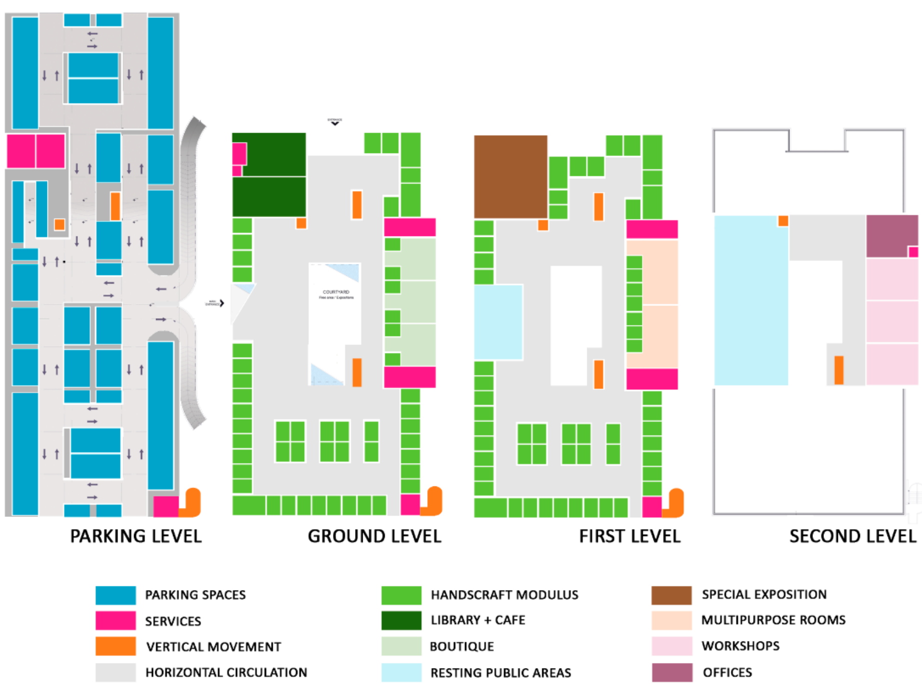


Figure 4- 25 Zoning and movement

4.9 Architectural Plans

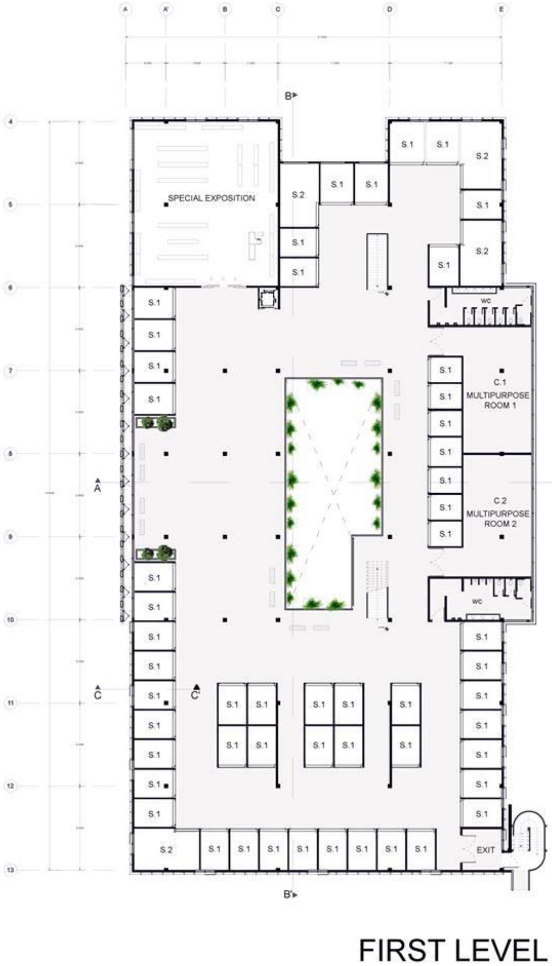
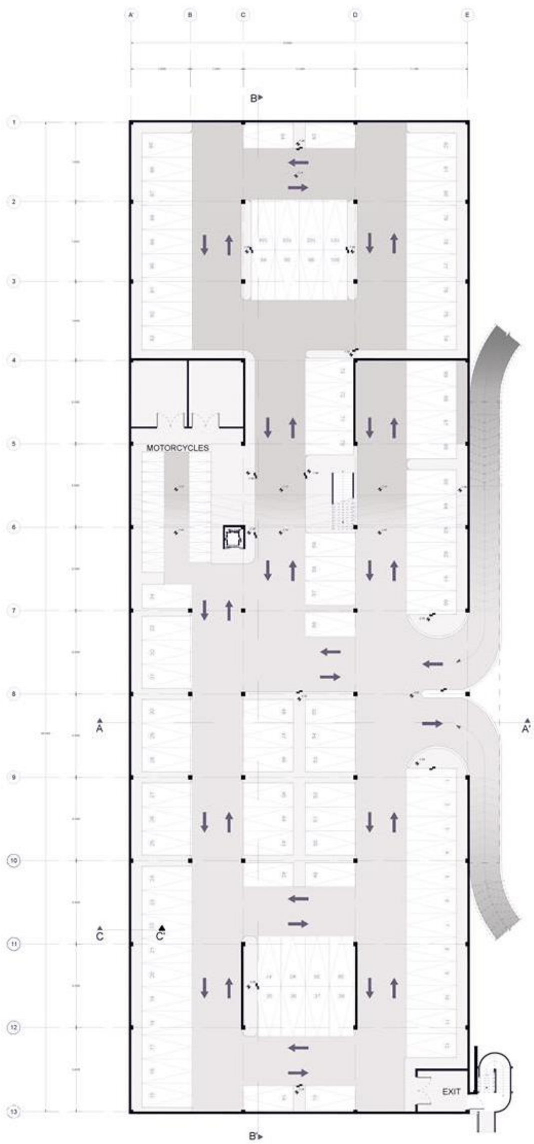


Figure 4- 26 First level plan

Figure 4- 27 Second level plan

Figure 4- 29 Parking Plan



PARKING LEVEL

Figure 4- 28 Ground level plan

GROUND LEVEL

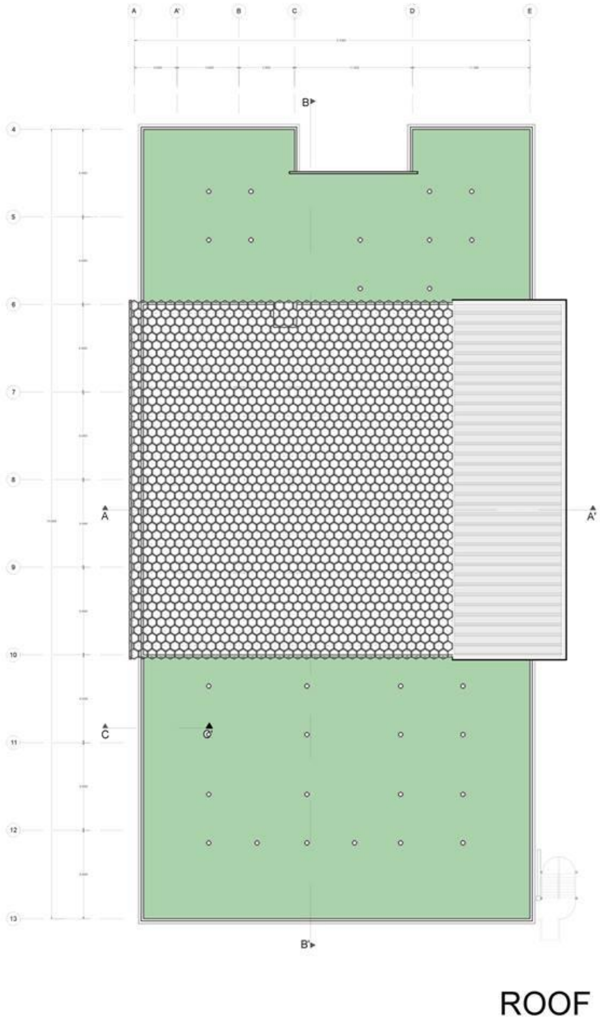
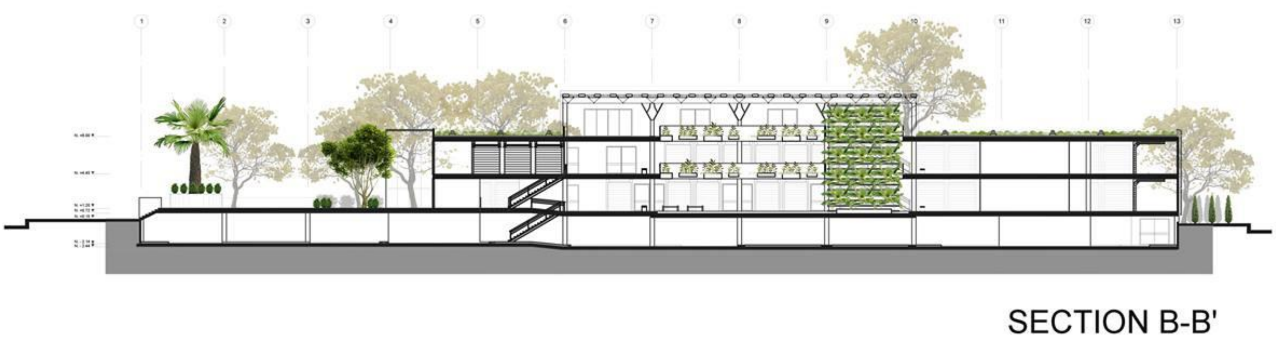
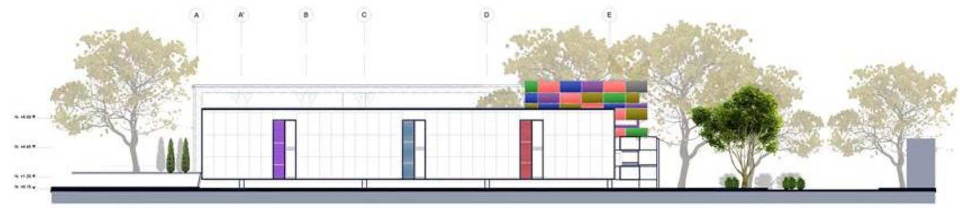


Figure 4- 30 Top plan view

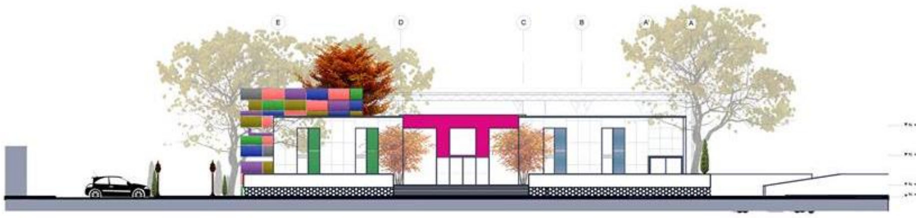
4.10 Architectural Sections and Elevations

Figure 4- 31 Sections

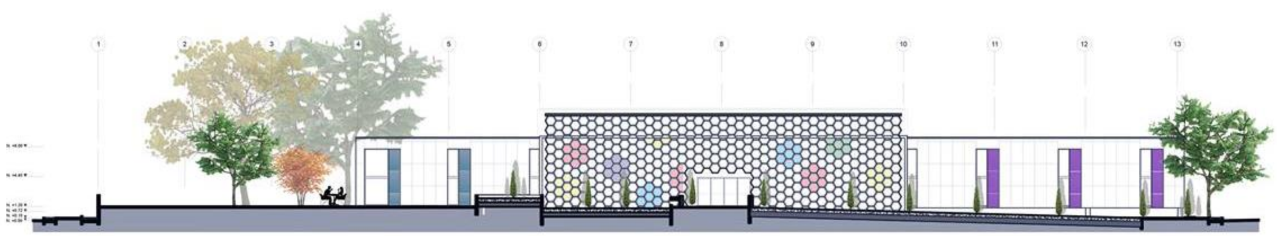




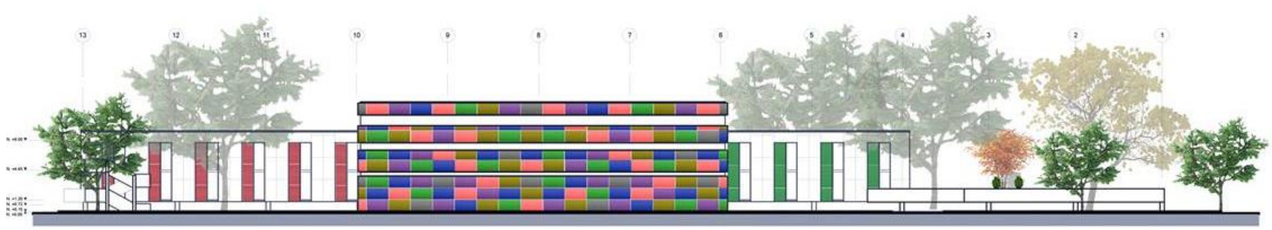
SOUTH FACADE



NORTH FACADE



WEST FACADE



EAST FACADE

Figure 4- 32 Elevations

4.11 Renders

Figure 4- 33 West view

Figure 4- 34 East view

Figure 4- 36 San Juan Park and Market

Figure 4- 35 North view

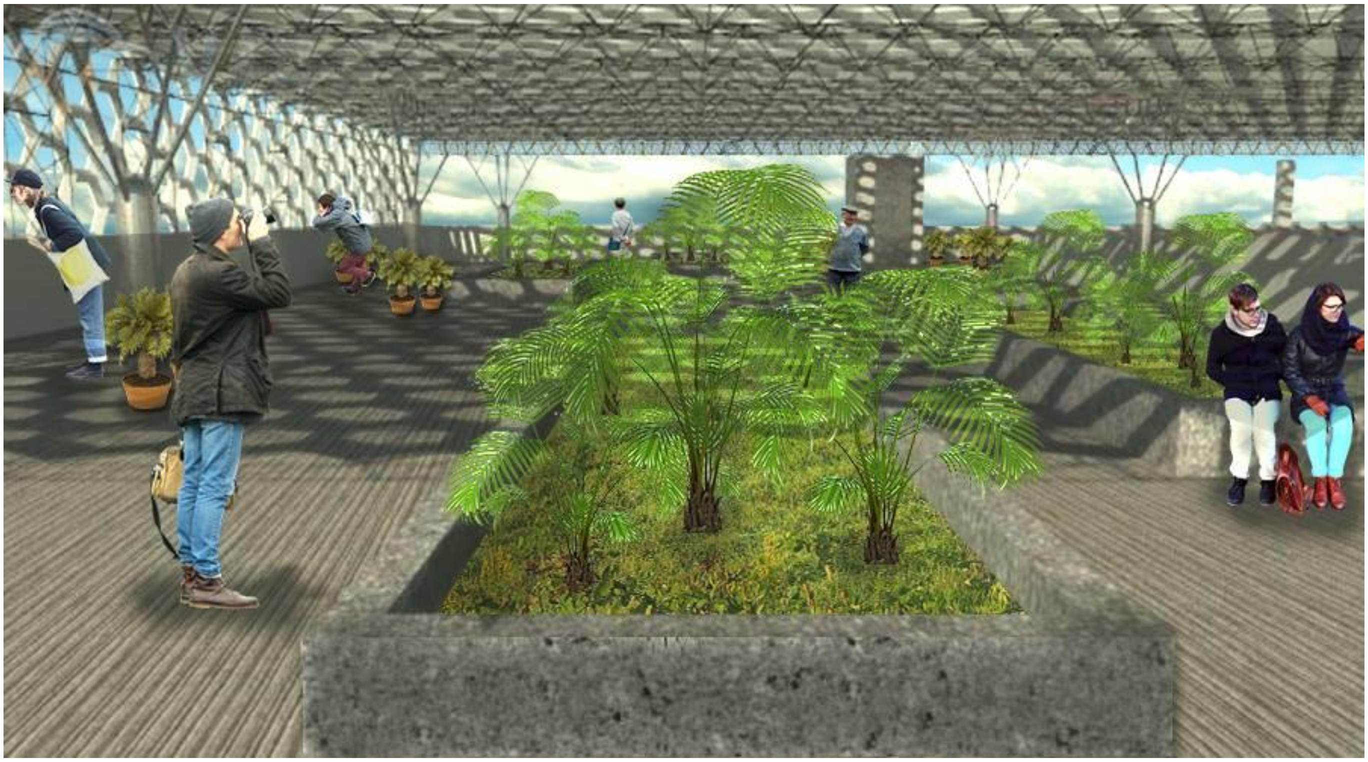


Figure 4- 37 New green and walkable roof

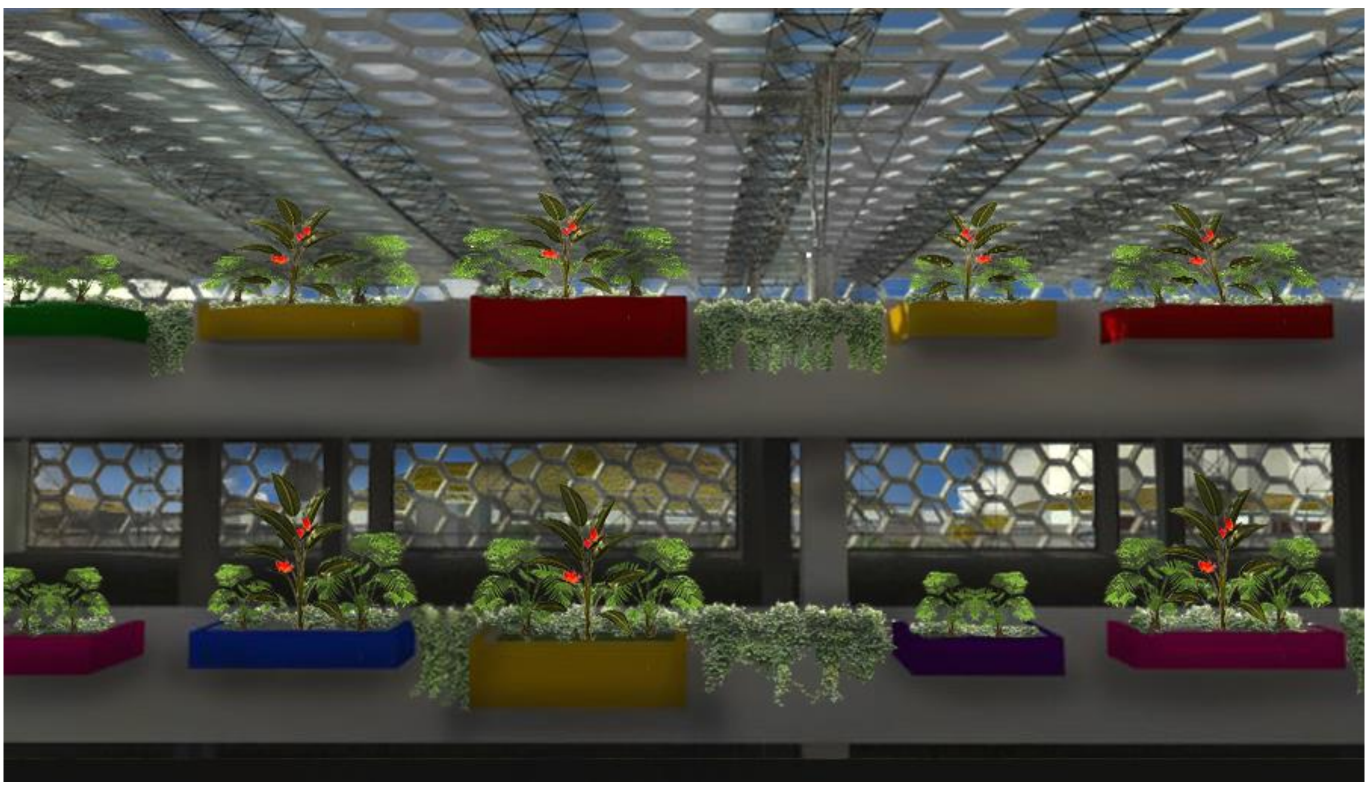


Figure 4- 38 Interior courtyard

5

TECHNOLOGICAL DESIGN

This chapter offers the technological solutions adopted in order to follow with the ecological approach and comfort aspects for the current and future users.
Along with the technological details, wind, weather, shadow and lighting analysis are presented as support of the final outcome.

Chapter 5: Technological Design

5.1 Introduction

This section can be divided in two categories, the first one contains the technological proposals for the project that will reduce the negative impact on the environment, both passive and active. For this first approach we consider some of the guidelines recommended by the worldwide recognized certifications systems, especially those from the U. S. Green building Council (USGBC).

About the second part, it includes the different construction system and solutions, with details, sections, plans and elevations that show how the building is integrated, the analysis and studies made for the design are also included in this section.

5.2 Sustainable and Energy Approach

In order to create an integrated intervention not only architectural aspects must be considered, to apply strategies in order to decrease the negative impact of human activity an also provide a comfortable space for the users an visitors is one of the aims of these project. Integrate harmonically the different activities of the site requires to enhance the image and experience along the walk through for visitors and better life and work conditions for inhabitants and workers.

The Leadership in Energy & Environmental Design (LEED) certification program is classified according to the type of construction to be made, in our case the category is New Construction and Major Renovation. This category consider the following sub categories:

-Sustainable Sites (SS)

-Water Efficiency (WE)

-Energy and Atmosphere (EA)

-Materials and Resources (MR)

-Indoor Environmental Quality (IEQ)

-Innovation in Design (ID)

-Regional Priority (RP)

The system consist in accumulate a certain number of points to achieve one of the four certifications. A copy of the checklist and the specific point given to the compliance of the requirements is included in the annexes.

We shall describe and discuss each point in order to apply the proper technologies to achieve each category points.

I.	Project Site Factors	=
II.	Water Management	=
III.	Project Systems and Energy Impacts	=
IV.	Acquisition, Installation, and Management of Project Materials	=
V.	Improvements to the Indoor Environment	=
VI.	Stakeholder Involvement in Innovation	=
VII.	Project Surroundings and Public Outreach	=

Table 5- 1 LEED approach

Sustainable sites

This topic starts with the prevention of pollution by controlling soil erosion, water sedimentation and air pollutants; for this a plan of construction is required and must comply with the local regulations in this matter. Later it is important to select a proper site that not create a negative environmental impact, the fact that our project is the refurbishment of an existing building ensure we accomplish this part. The next point is also related to the type of project, building in a developed area take advantage of the existing infrastructure, our site has a strong development density and high community connectivity.

Another important aspect for the site selection are the transport alternatives in order to reduce the impact from automobile use. As we analyze in previous chapters the site is really well connected to the rest of the city and is easy to reach from all the city by many transportation options, in addition to this some of our proposals like provide more Ecobici stations, electric taxis facilities and avoiding more parking.

Our project provides a 50% of green areas (with local vegetation that requires less care and water supply), increase the permeable surfaces. The design of the landscape invites the user to walk through the complete development by increasing the pedestrians and green areas. Between Juarez and Ayuntamiento avenues Dolores St. has no green areas and is a congested street. The integration of green paths along the sidewalks will help to increase the vegetation, this solution is just possible if we change the use of the street into a semi pedestrian one (in accordance with the local authority's pedestrian approach of decrease the vehicular circulation in the center), and with this action we can increase the size of the sidewalks for the better pass of people and implement green spaces.

The control and use of stormwater must be done by reducing impervious cover, provide permeable areas and reduce the pollutants of stormwater runoff.

For the LEED certification is important to minimize the heat islands, this is possible if to the 50% of the hardscape is composed by trees shade, solar thermal collectors, evacuated tube collector, its efficiency is constant in different temperatures, the architectural surfaces have a solar reflectance index (SRI) of at least 29. It's also useful to have the parking spaces under cover. For roof, the SRI must be at least 78 for at least 75% of the area or install a vegetated surface of 50% of total roof area. The market will use a combination of both solutions proposed above.

The building should have a low impact in the light pollution, by controlling the nonemergency luminaires a nights. Our building is in the zone LZ4 by the Illuminating Engineering Society of North America (IESNA), thus the exterior lighting should not be greater than 0.60 horizontal and vertical candles. To reach these levels we proposed cutoff luminaries and low-angle spotlights.

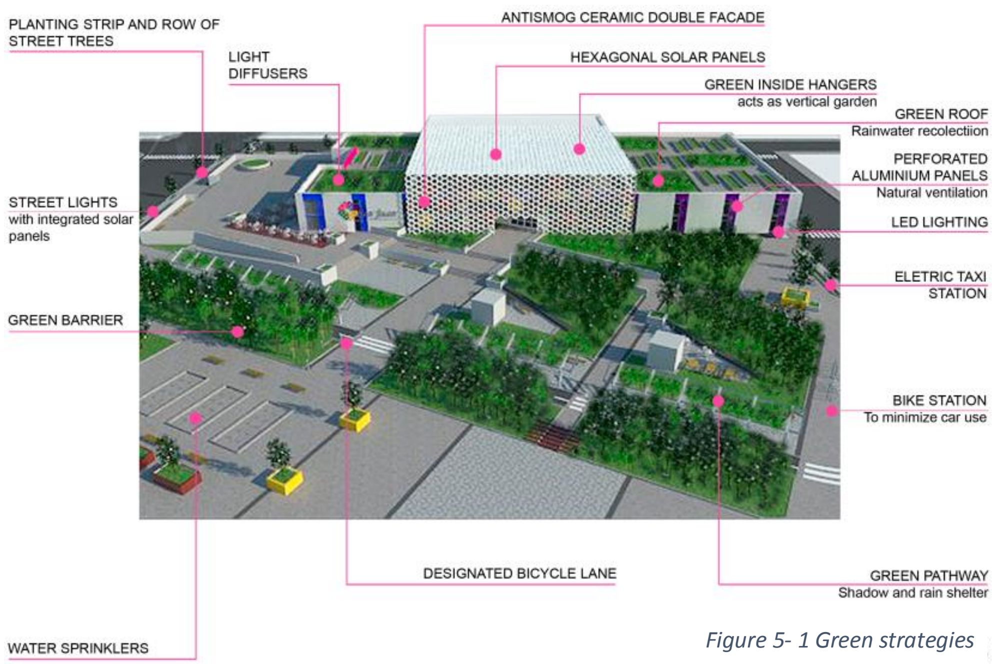


Figure 5- 1 Green strategies

Water efficiency

In order to determine savings in water use, it is necessary to know the standard water use (without irrigation) showed below:

The target in this section is to reduce the use of water by 20%, the possible aspects to consider are: to reduce or eliminate the use of potable water for irrigation, in our case we will totally avoid the use of potable water for this purpose, by harvesting rainwater in addition to install landscaping that does not requires permanent irrigation systems. Also a reed bed system will be installed to recycle the water used in the building to use it later in gardens and re infiltration. Another important reduction of water is achieved with water conserving fixtures to reduce waste water volumes.

Commercial Fixtures, Fittings, and Appliances	Current Baseline
Commercial toilets	1.6 gallons per flush (gpf) Except blow-out fixtures: 3.5 (gpf)
Commercial urinals	1.0 (gpf)
Commercial lavatory (restroom) faucets	2.2 gallons per minute (gpm) at 60 pounds per square inch (psi), private applications only (hotel or motel guest rooms, hospital patient rooms) 0.5 (gpm) at 60 (psi)** all others except private applications 0.25 gallons per cycle for metering faucets
Commercial prerinse spray valves (for food service applications)	flow rate ≤ 1.6 (gpm) (no pressure specified; no performance requirement)

Table 5- 2 Commercial water use baselines

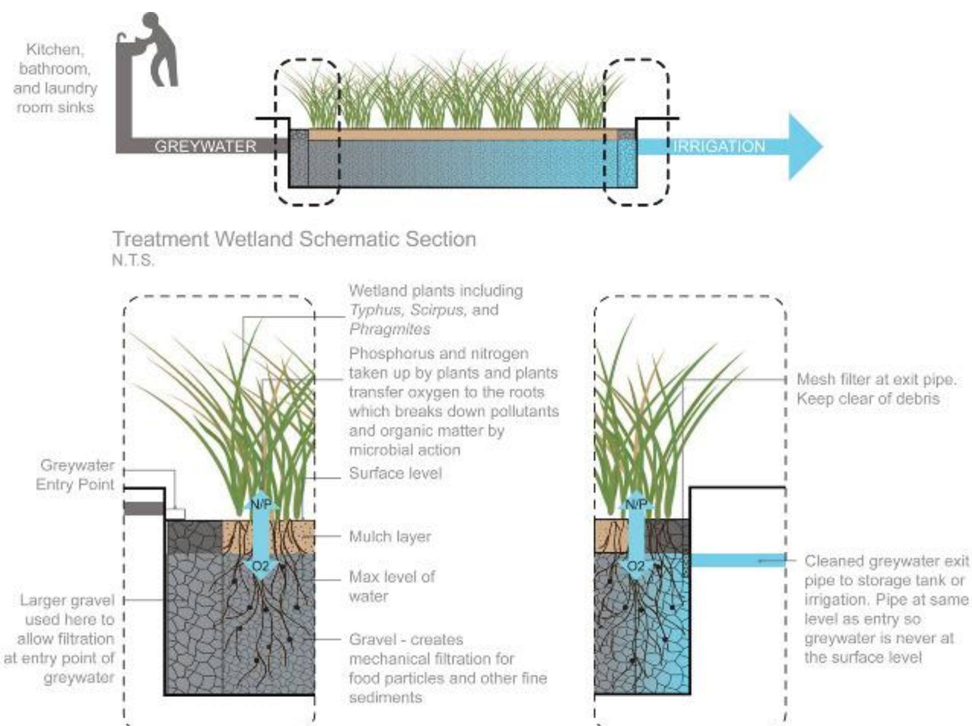


Figure 5- 2 Reed bed water treatment system

Energy and Atmosphere

Running tests of performance before construction let the designers to know the possible treat and areas to improve in design, we create a model to be sure that the building provides the user the comfort conditions with the less active systems.

An important advantage of the location is the low necessity of install HVAC equipment, in the case of closed boutiques the mechanical units must avoid the use

Figure 5- 3 Autoclaved aerated concrete

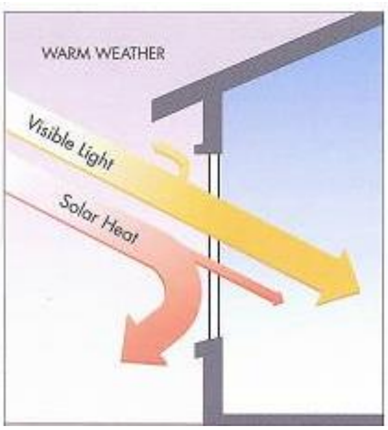


Figure 5- 4 Low E coating layer on glass

Figure 5- 5 White water proof layer made of recycled tires

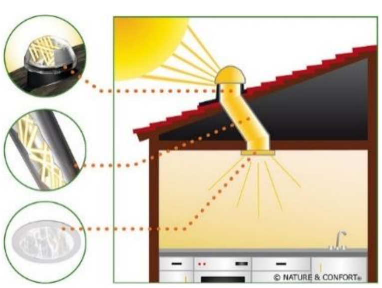


Figure 5- 6 Solar tunnel

of chlorofluocarbon based refrigerants. The architectural design itself bring important contributions to this aspect for example, the cross ventilation in the building helps to ovoid mechanical systems; the internal courtyard with pools and vegetation creates a natural cooling zone. This building has high roof and just one floor is used for commerce, in summer season the heat from the bottom goes up till the roof where some openings let it flow, for the winter these openings must be closed for avoiding the loses and the system is used for ventilation with a heat recovery system.

Another passive elements that help to keep the comfort conditions are the insulated walls made of autoclaved concrete and the use of windows with a low emission coating, for insulating the roof surface we install an extensive green roof, that consist in a thin layer of soil an vegetation, the thickness goes up to 15 cm and is suitable for limited human access zones (Iannaccocone, Imperadori, & Gabriele, 2014); and for the walkable area a coated roof with a water proof layer made of recycled tires in light-color in order to achieve higher reflectance value . In the areas where the glass openings are big we provide a shading system.

The other aspect that increase the energy efficiency is the use of on-site renewable energy. In our case we have solar collectors installed in the roof to provide hot water. The luminaries used in parks and streets will be solar powered, and for interiors we give preference to natural lighting; this last aspect was enhance form the original building by providing a hybrid solar lighting system that combines the use channeled sunlight through fiber optic cable bundles, where the openings of the building are not enough, supplementing this natural light with artificial source, in our case LED lamps as required. For the upper level we implement solar tunnels to allow the higher level of natural light to get inside. In addition to the previous solutions we plan to install high efficiency luminaires and appliances, in Mexico the Ministry of Energy grants the seal FIDE A to appliances that according to the local requirement guarantees energy savings.

Materials and resources

One way to make a building eco-friendly and reduce its impact around the site the LEED guidelines recommend to store and collect recyclables, providing and specific area for this that must be easily accessible. Other credit that suits our project is the use of existing structures, and the most is re use the biggest is the benefit. Also we plan to integrate the non-hazardous debris into the site, using it as a fill material in landscape and as gabion fill in some urban furniture.

LEED certification considers also important not only to recycle site materials, but also to include in the design to include recycled materials, our project will use for flooring: recycled glass tiles, the shading façade is composed by plastic panels that are also recycled, and the impervious layer of the roof is made of particles obtained from tires. None of the previous solutions has an important effect if the transportation of the materials has a high impact in the environment; the LEED certification requires a minimum of 10% or 20% of the materials to be extracted, harvested or recovered, as well as manufactured, within 800 km from the project site. The materials must be also rapidly renewable, giving preference to natural materials. Finally in the case of wood, this has to be certified according to the Forest Stewardship Council (FSC).

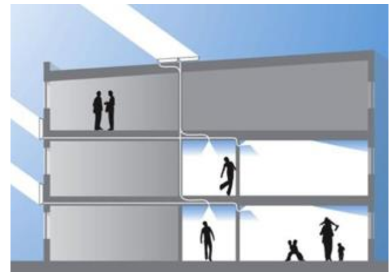


Figure 5- 7 Diagram of a fiber optic daylighting system

Figure 5- 8 Gabion furniture

Indoor Environmental Quality

According to the ASHRAE Standard 62.1-2007 paragraph 5.5, the natural ventilation system should be able to work also with mechanical ventilation systems. The openings must be at least 8m long and with an area of 4% of net floor area. It’s necessary to have permanent unobstructed openings of 8% of the room area between interior rooms, and these openings shall be accessible to building occupants. The interior courtyard helps to increase the cross ventilation, the east winds enters through the façade openings and the stack effect offered by the interior open space takes out the heat; the system is complemented by two water bodies and vegetation in the courtyard.

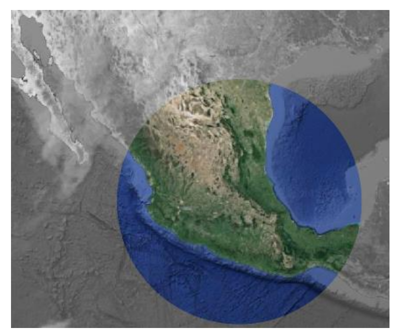


Figure 5- 9 Materials must come from a distance equal to 800 km from project site

By law in Mexico City, and in concordance with the guidelines of LEED, it is prohibited to smoke inside public buildings. The materials chosen for the project also fulfil the requirements of emissivity of pollutant particles and Volatile organic compounds (VOC). A list of this limits is included in the appendix XXX.

The quality of environment includes also the controllability of systems, for lighting 90% and thermal comfort 50% control. Along the day use, a proper daylight and view has to be provided to the users, this is achieved by a combination of side and top opening where possible to get at least 75% light form this source of occupied spaces. The comfort conditions for the users include provide an appropriated view to the exterior spaces, this is achieved with totally a totally open building to the interior courtyard, and a curtain wall in the west façade facing the redesigned park. In order to protect this space form overheating and sunlight, we propose a second façade that reduces the direct light on the glass skin in addition to the low emissivity coating.

Innovation in Design

Our building has the mission of recover a decaying structure, where the main consideration is the positive impact in the area with the minimum impact in the environment. One of the guidelines stablished by the team is to have the less use of water and energy with the combination of multiple technologies. As a complement of the savings, to reduce the pollutants and waste in every way we create systems to prevent it.

Mexico City had an important problem of air pollution along the last decade of the XX century, although that issue has been attacked still now the city has in some days high degrees of particles in the air, in order to help the reduction of them we plan to install a new ceramic material covered by Titanium Oxides that in exposure of UV rays transform the contaminants into non dangerous gases.

To avoid an estrange object in the city, some design solutions are suitable for the project, for example install as part of the façade of the buildings and as ornamental elements in the park.

Regional Priority

This project has an special importance for the development of the area, in first instance the refurbishment of the market pursuits to attract tourist, in a urban scale the enhance of the area not only represents a reason to visitors to come, but also increase the quality life of the residents and work spaces for this commerce area. As part of the global project of recovering pedestrian spaces in the historical center this project complements the actions in the borough.

5.3 Weather analysis

The weather information is shown below.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	28	29	33.3	33	33.9	33.5	30	28.4	28.5	29	29.3	28	33.9
Average high °C	22	23	25.7	27	26.8	25.3	23.8	23.9	23.3	23	22.9	22	24
Daily mean °C	15	16	18.1	20	20	19.4	18.2	18.3	18	17	16.3	15	17.5
Average low °C	7.4	8.5	10.4	12	13.2	13.5	12.5	12.7	12.7	11	9.7	8.1	11
Record low °C	−4.1	−4.4	−4	−0.6	3.7	4.5	5.3	6	1.6	0	−3	−3	−4.4
Precipitation mm	11	4.3	10.1	26	56	135	175	169	145	67	12.1	6	816
Avg. precipitation days (≥ 0.1 mm)	2.2	2.5	4.1	6.8	12.9	18.7	23.2	20.9	18.2	9.6	3.8	2	125
% humidity	51	47	41	43	51	63	69	69	70	64	57	54	56
Mean monthly sunshine hours	240	234	268	232	225	183	176	176	157	194	232	236	2,555

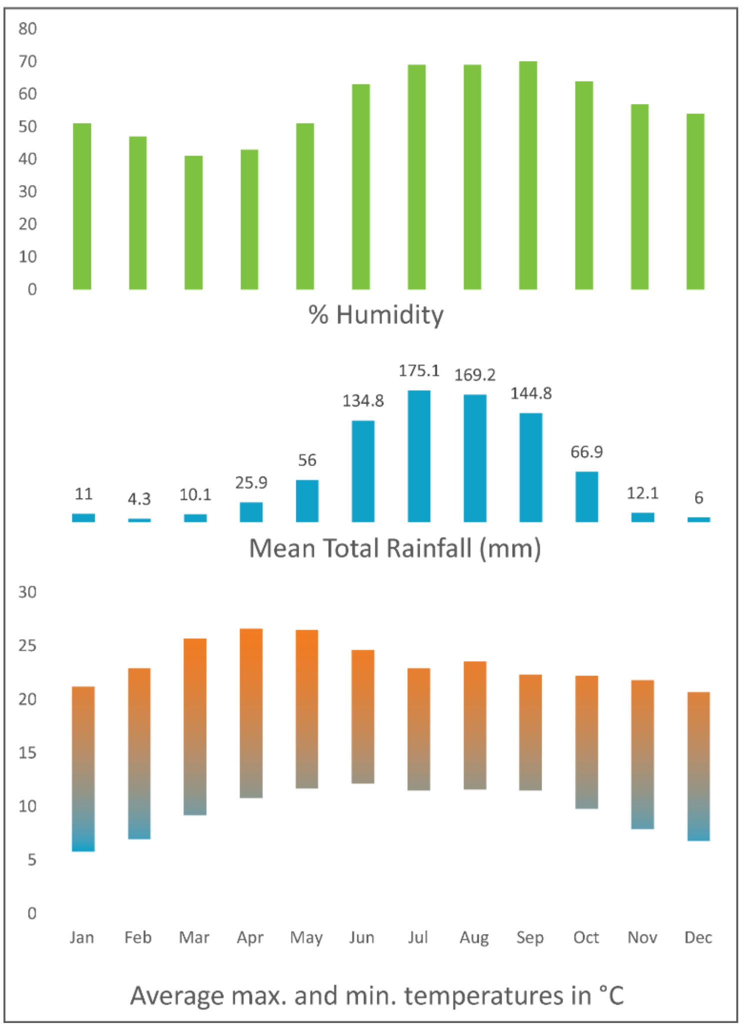


Figure 5- 10 % Humidity, Mean total rainfall and average max. and min.

The lighting conditions are presented in the following graphics.

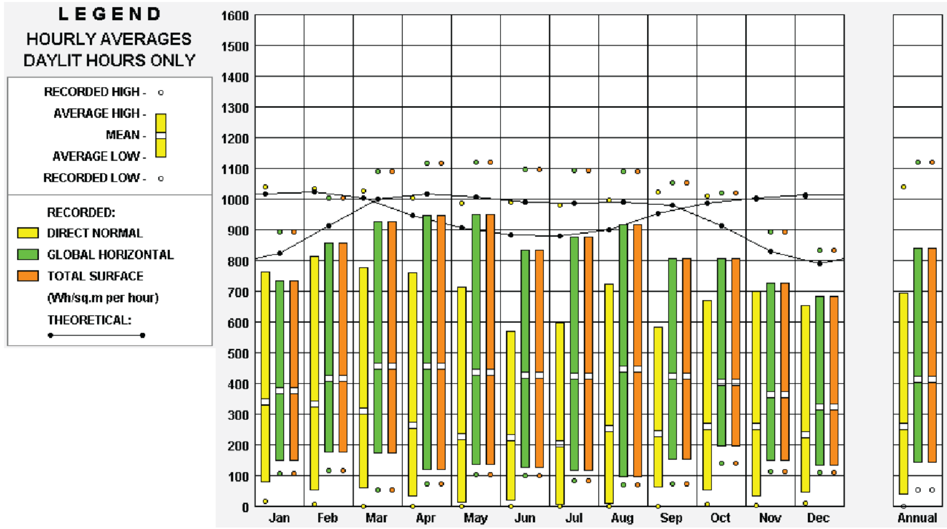


Figure 5- 11 Daylight hours

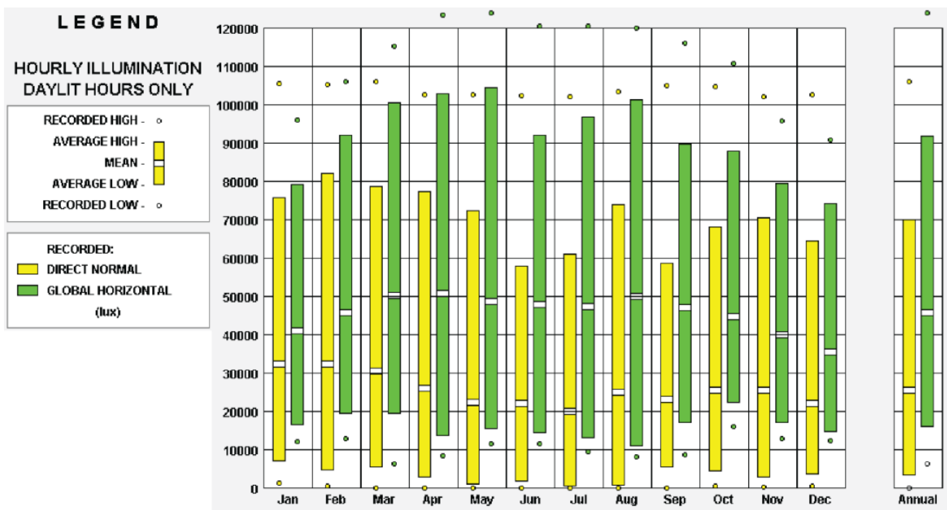


Figure 5- 12 Illumination conditions

Ground temperature.

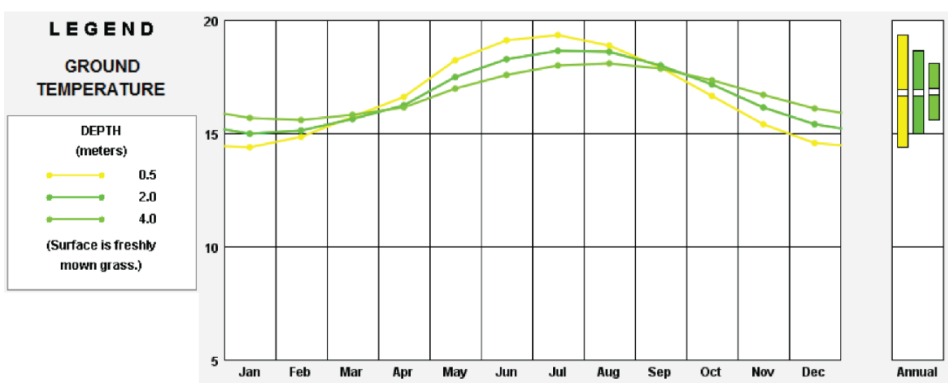


Figure 5- 13 Ground temperature

5.4 Comfort conditions

From Ecotect Weather Tool we can see that the comfort zone is in the conditions of the site

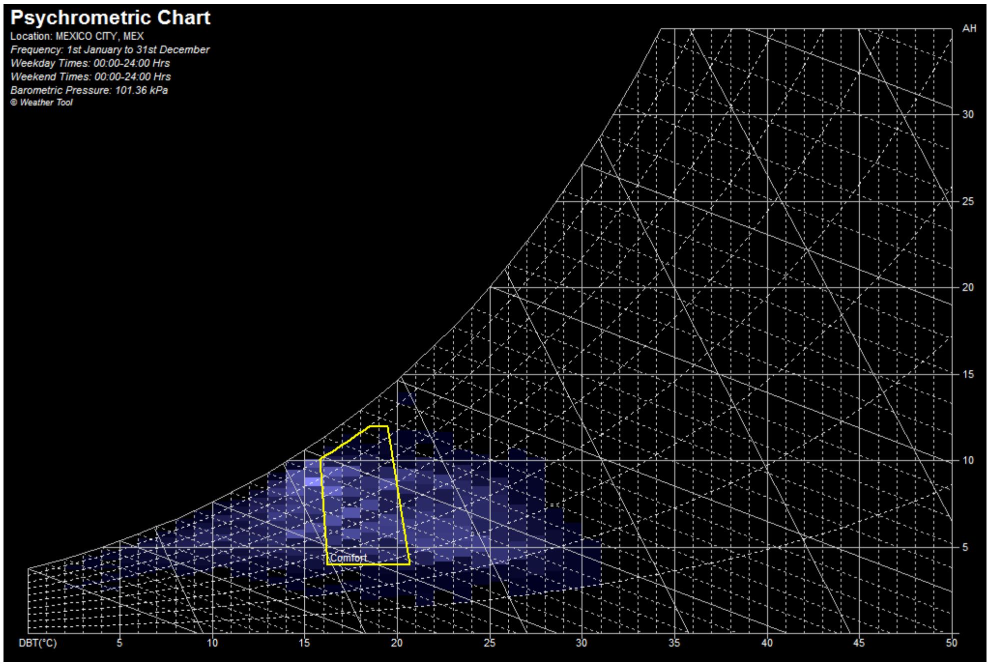


Figure 5- 14 Comfort zone

If we apply natural ventilation the comfort zone increases its range.

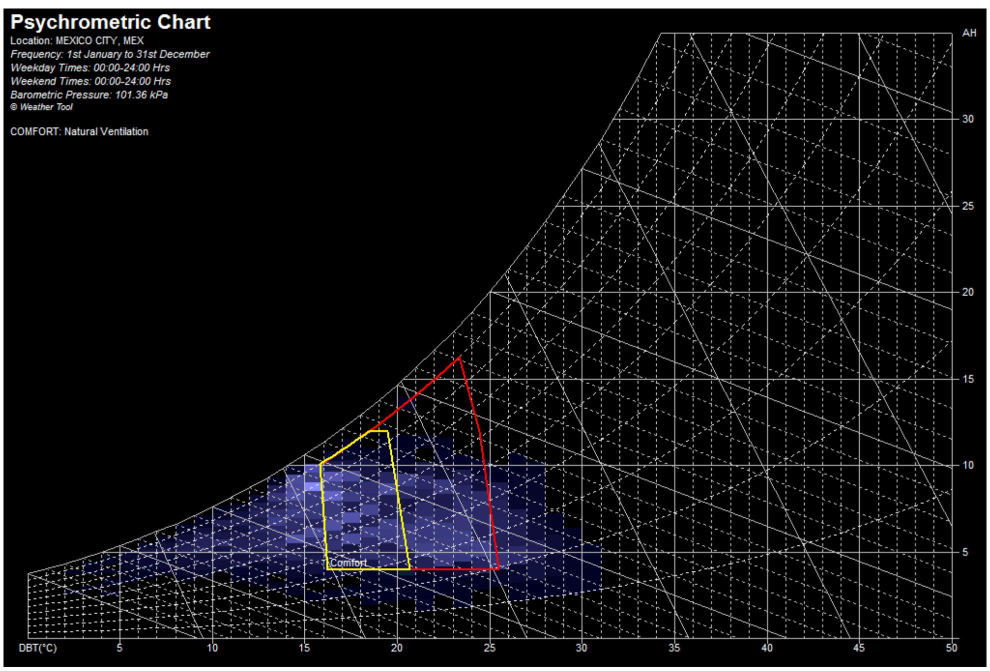


Figure 5- 15 Effect of natural ventilation in the comfort zone

The Weather tool also allows us to apply other passive strategies to see the effect on the comfort zone. First the thermal mass effect.

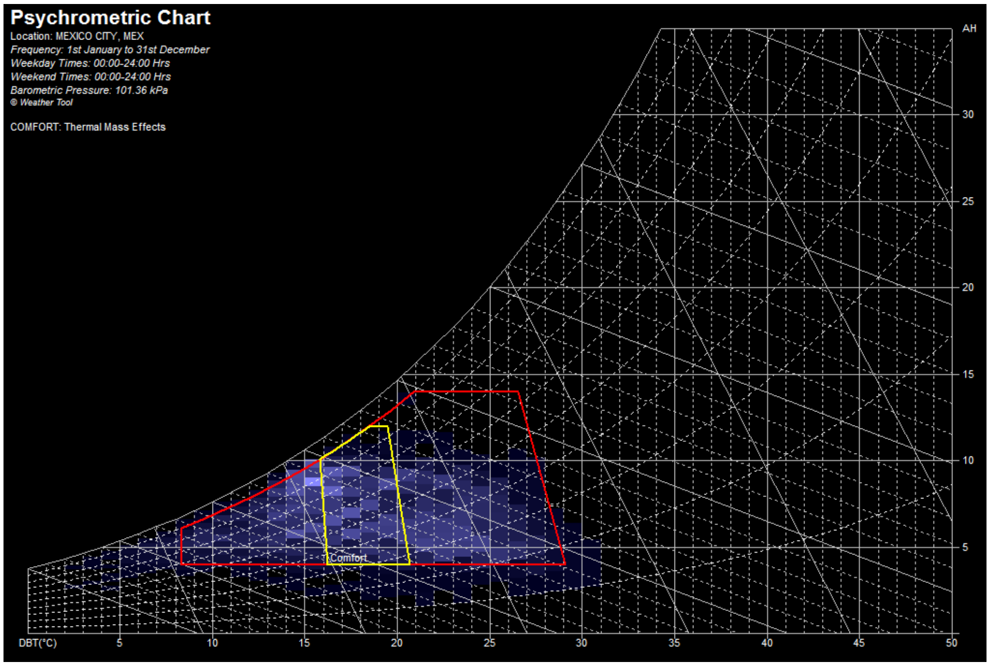


Figure 5- 16 Thermal mass effect in the comfort zone

Finally if we combine both strategies, the comfort zone cover all the conditions.

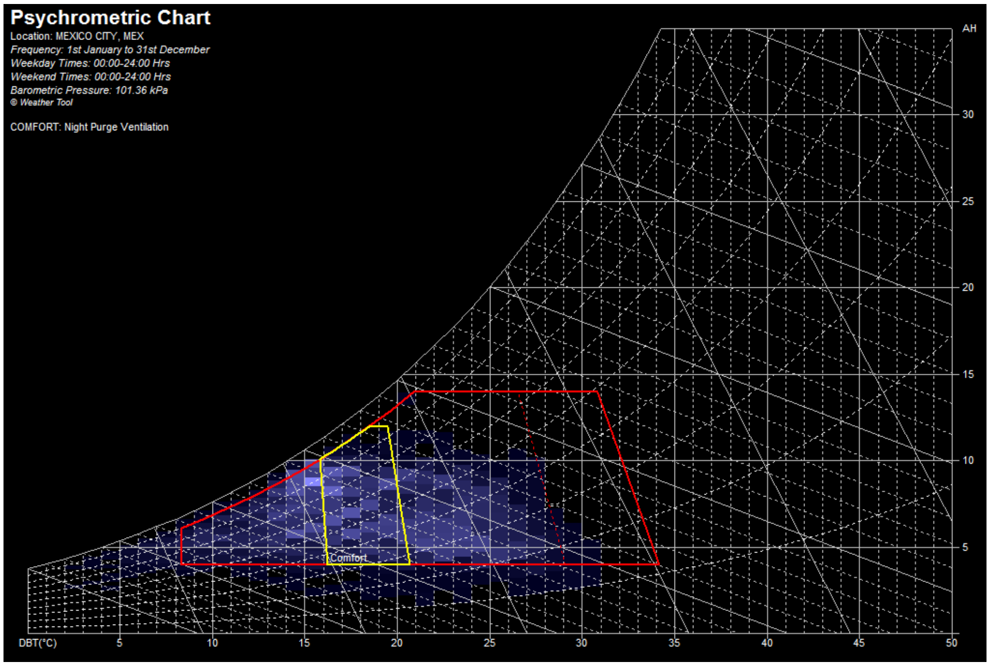


Figure 5- 17 Thermal mass and natural ventilation effects

5.5 Wind analysis

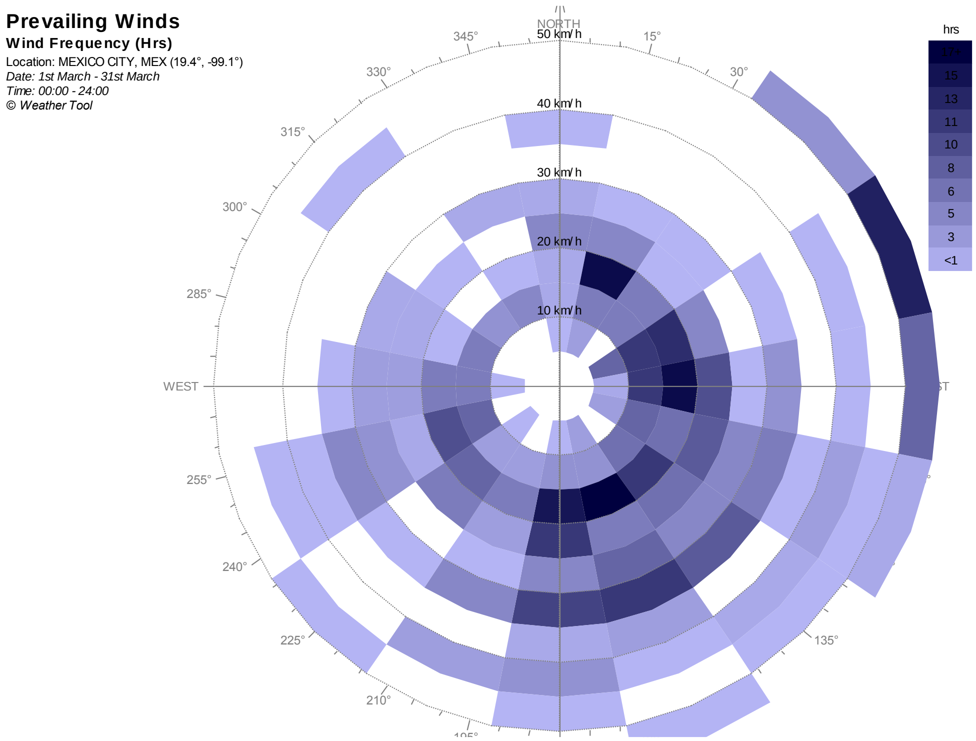


Figure 5- 18 Winds in spring

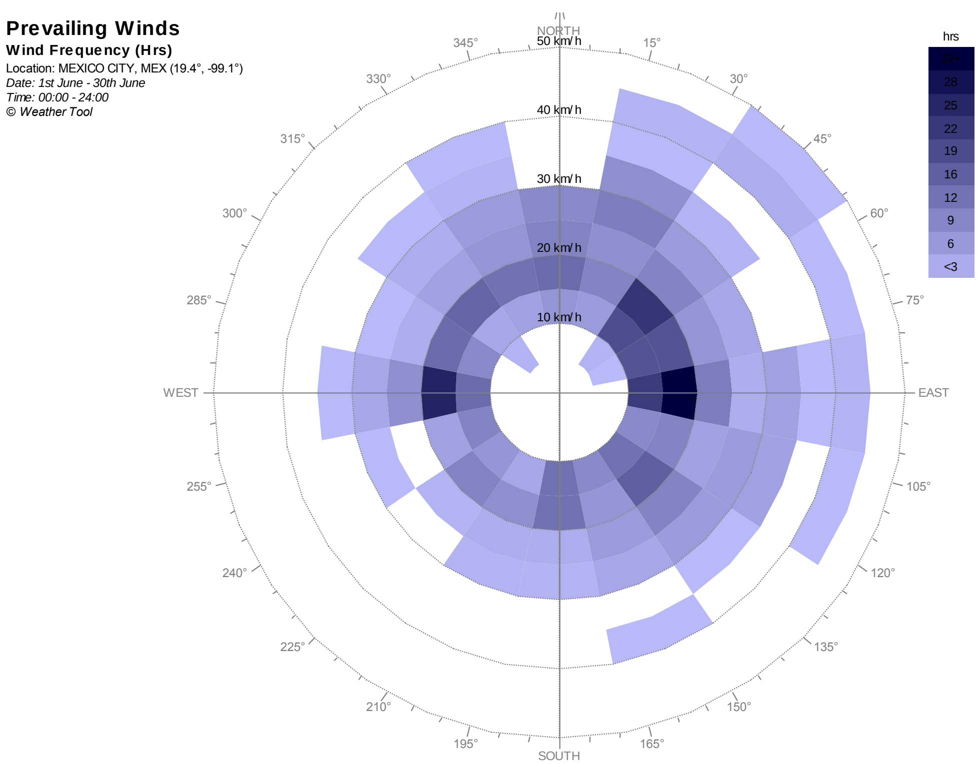
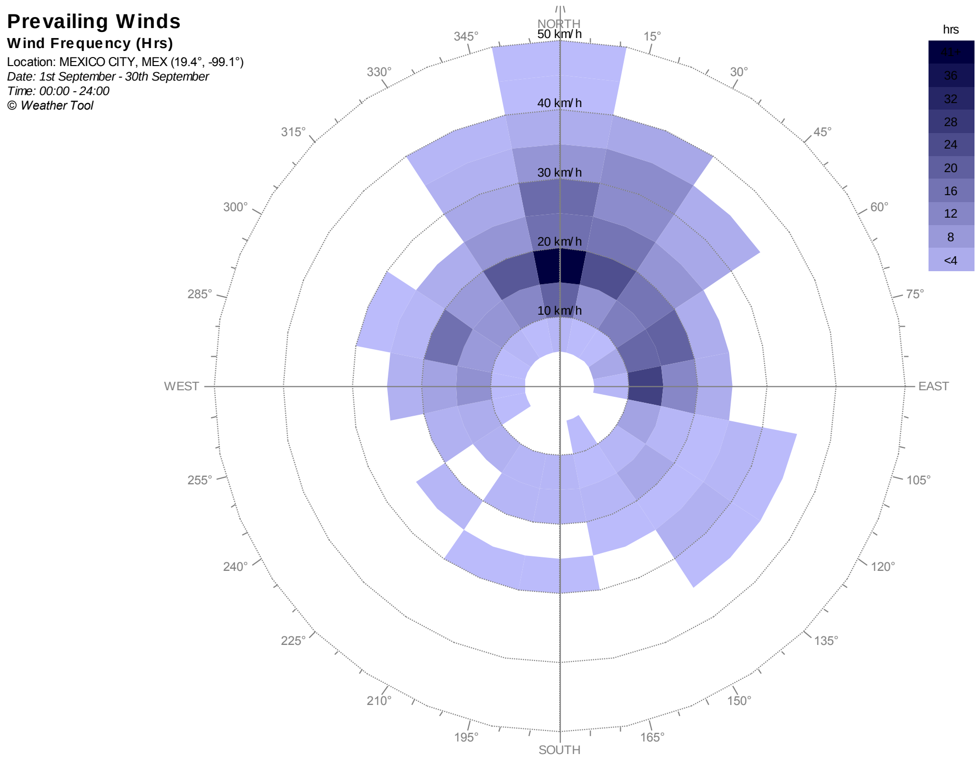


Figure 5- 19 Winds in summer

Figure 5- 20 Winds in fall



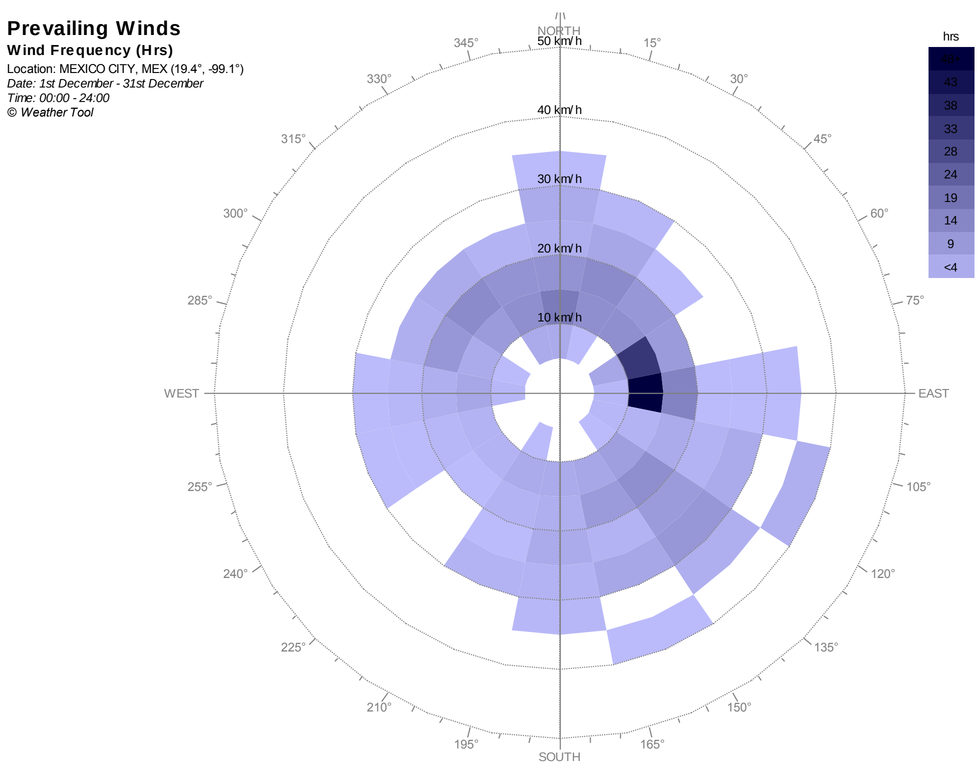


Figure 5- 21 Winds in winter

5.6 Shadow analysis

The fact that the building is located in the middle of an open space allows a constant daylight over the building, this aspect is important for the design of the openings, the west façade has a large curtain wall that is protected by the second façade.

The protection given to the south face is made of perforated aluminum panels, this allows diffuse light and the pass of air for the natural ventilation.

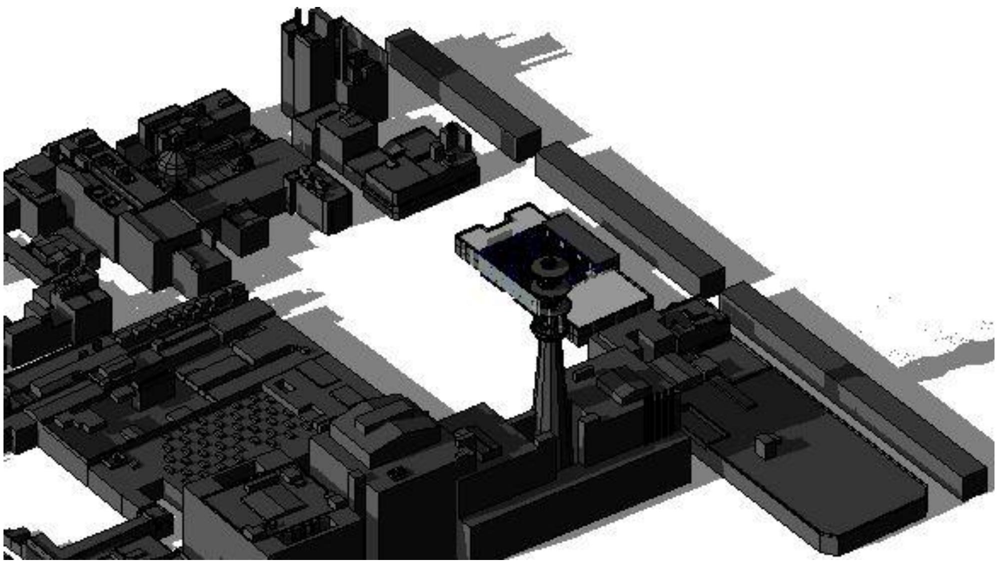


Figure 5- 22 Shadows viewed from south

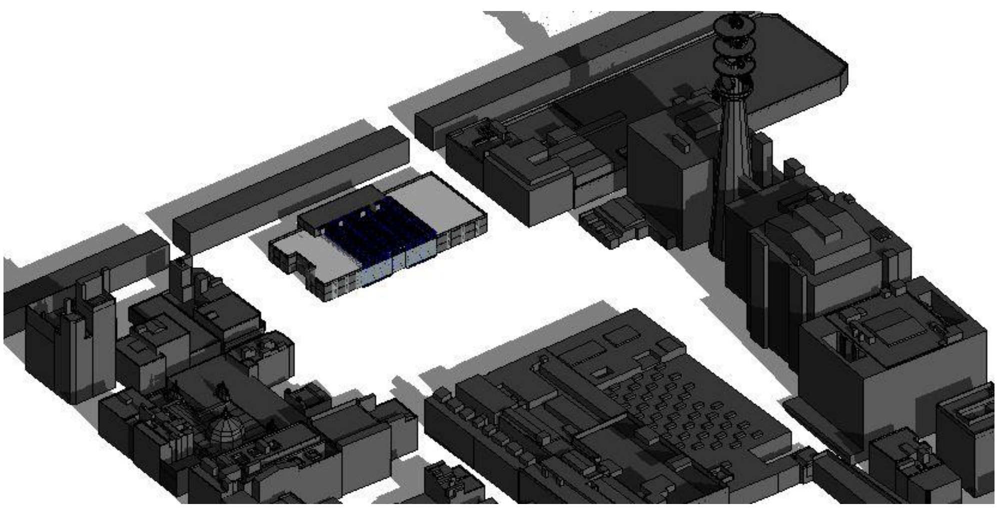


Figure 5- 23 Shadows viewed from west

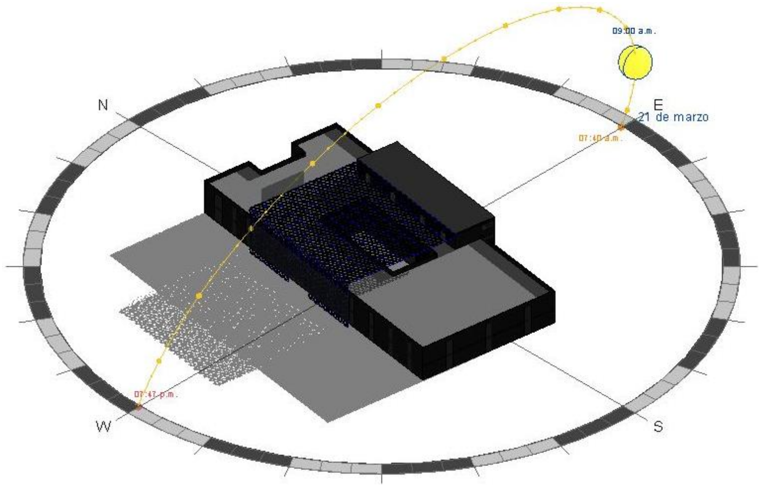


Figure 5- 24 Mid-season 9:00

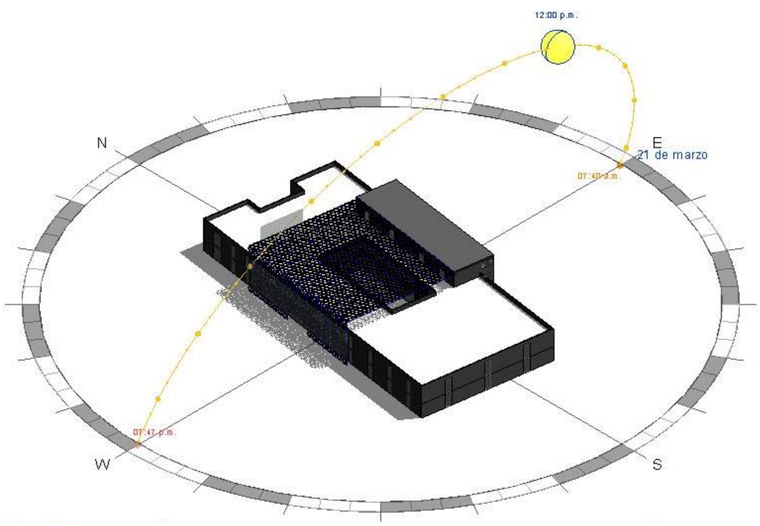


Figure 5- 25 Mid-season 12:00

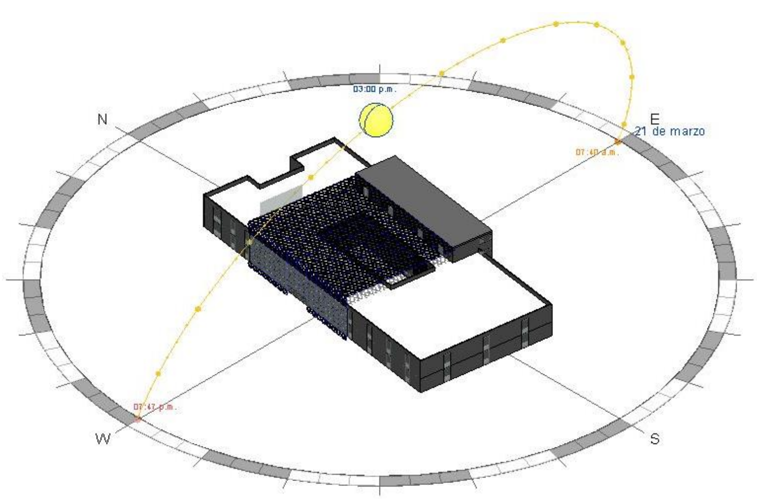


Figure 5- 26 Mid-season 15:00

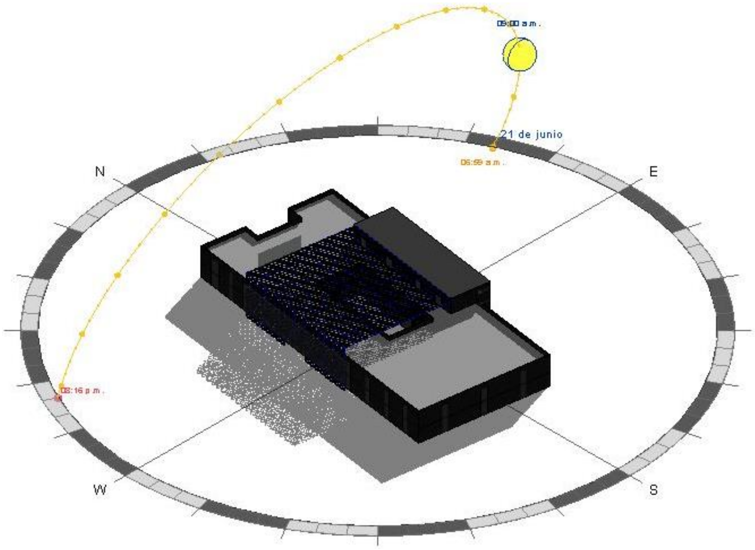


Figure 5- 27 Summer 9:00

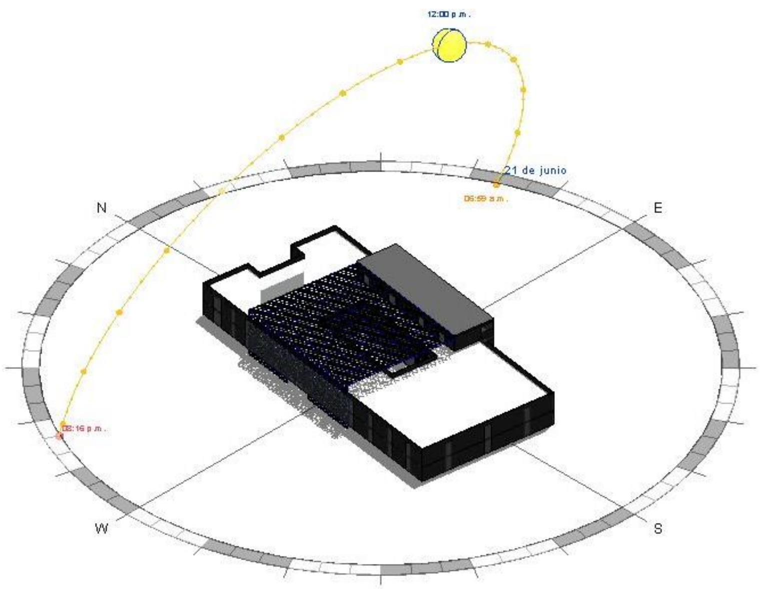


Figure 5- 28 Summer 12:00

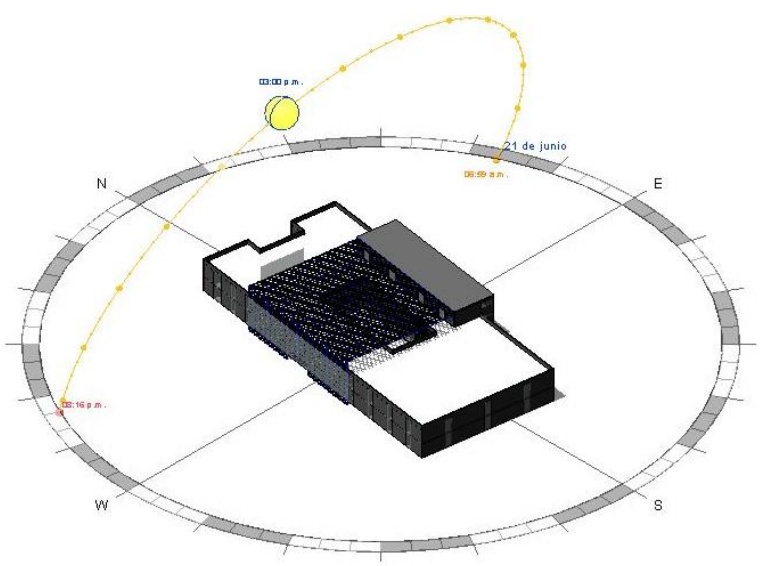


Figure 5- 29 Summer 15:00

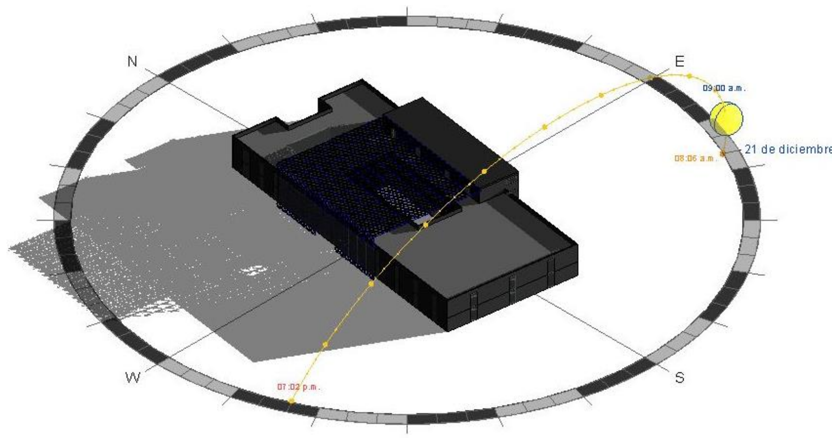


Figure 5- 30 Winter 9:00

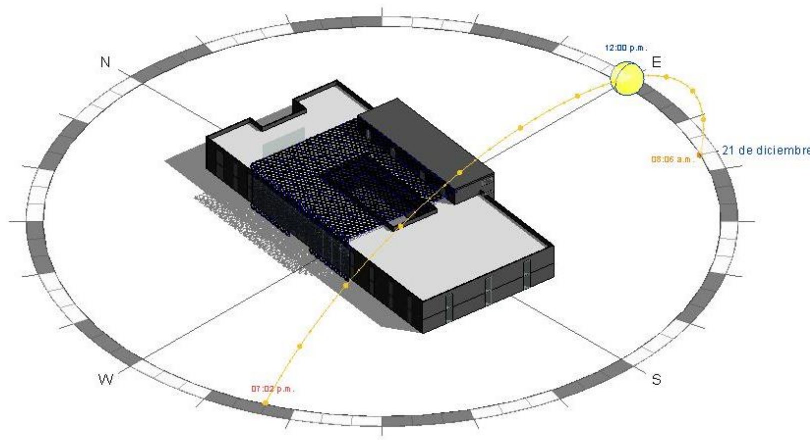


Figure 5- 31 Winter 12:00

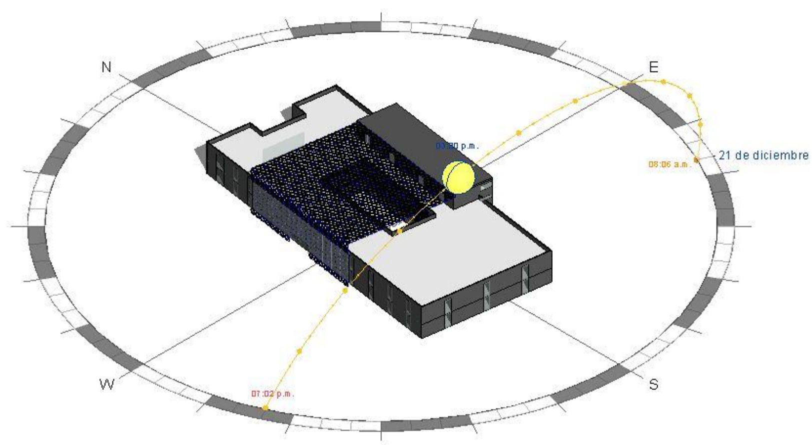


Figure 5- 32 Winter 15:00

5.7 Solar Radiation

From the study of the solar radiation over the surfaces, we can see that along the year the levels of radiation are high, the following images show the accumulated radiation of characteristic days in the year.

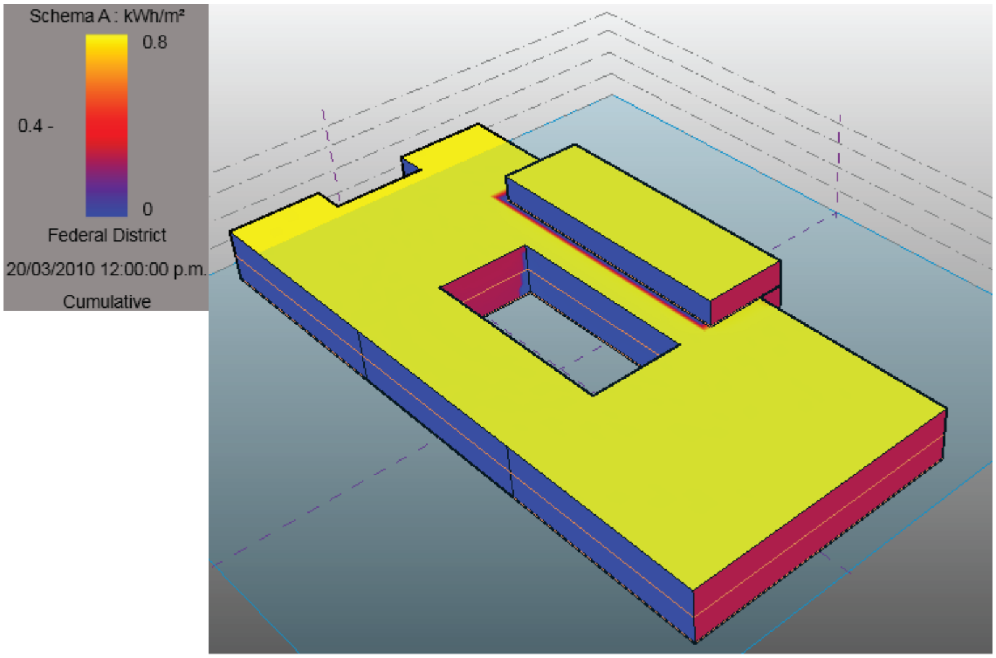


Figure 5- 33 Radiationon spring

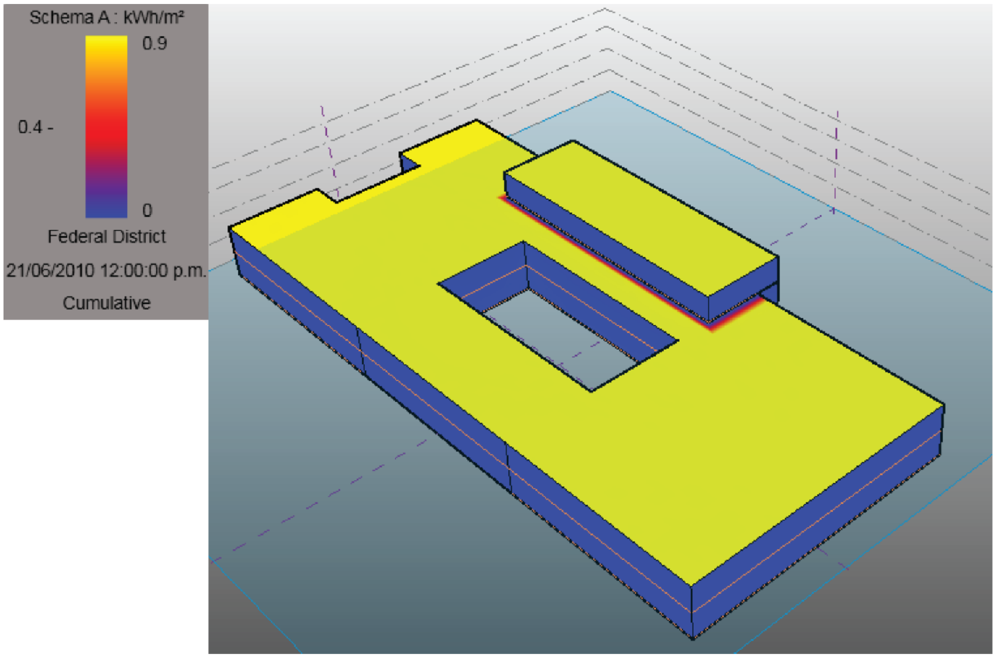


Figure 5- 34 Radiation summerr

The mid-seasons present similar values of radition, meanwhile in winter the radiation is half that the one presented on summer. Altohuf the west surface is faced to the sun the radiation is not as high as to be an important problem.

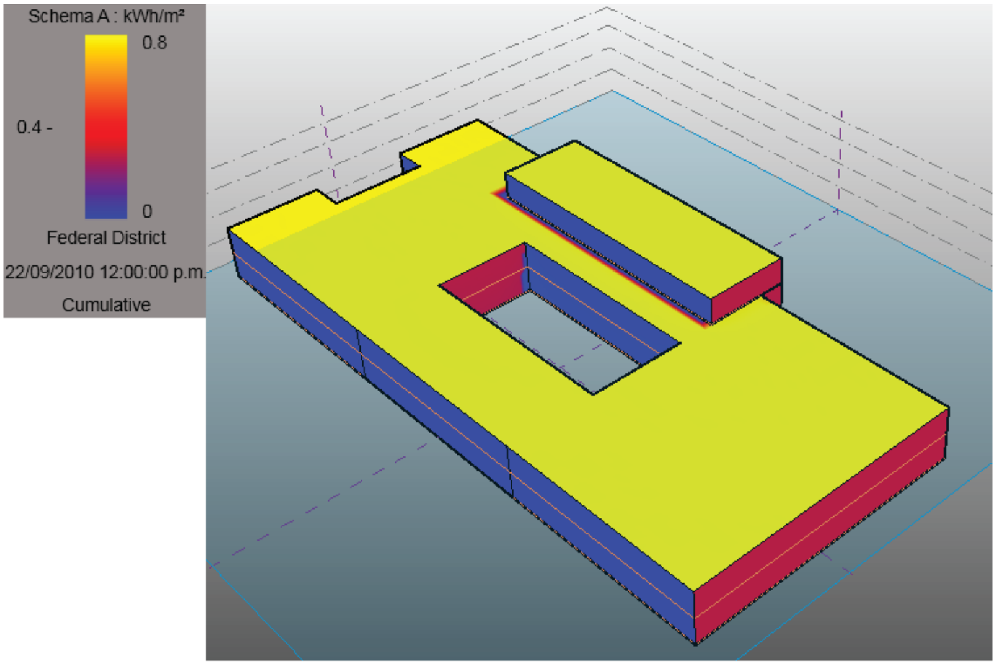


Figure 5- 35 Radiation fall

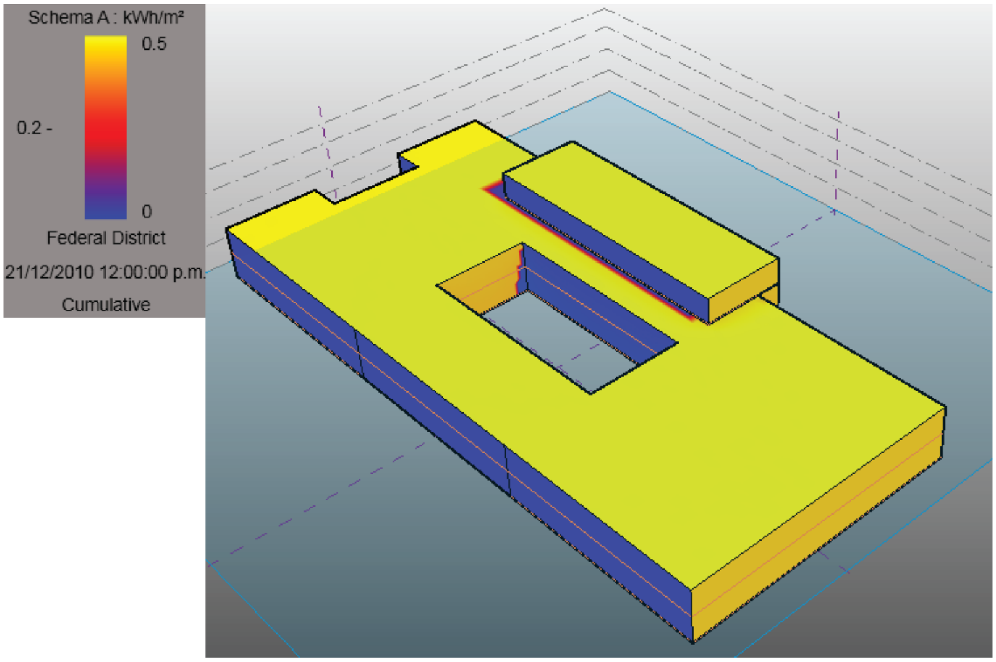


Figure 5- 36 Radiation winter

The total radiation is 1586 kWh/m^2 over the roof along the year, thus the solutions taken will decrease the possible heat transmitted to the interior.

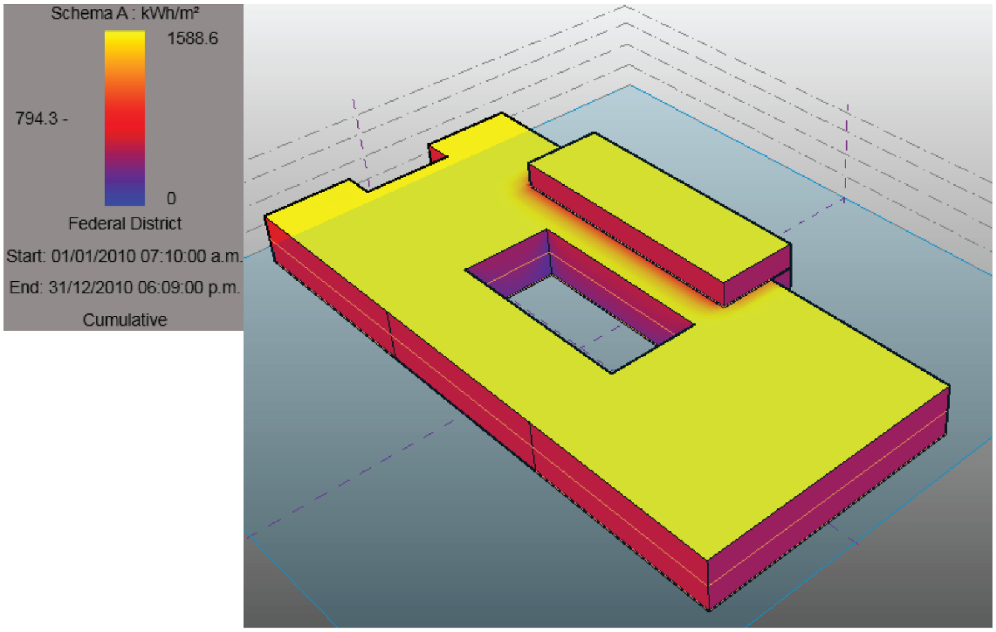


Figure 5- 37 Radiation accumulated

5.8 Lighting analysis

In this project we have two main contrasting situations, the hall that faces the park is really well illuminated. From this analysis we know if natural light is enough or if artificial source is needed and where.

We use the illuminance of the building to evaluate the importance of daylight, this analysis shows also, the luminous intensity in candela (cd) and the illuminance (lux) in specific sections of the building.

First the hall facing the park then, the corridors in the south part of the building are darker, we have suggested solar tunnels and hybrid lighting system to increase the access to light. These studies are presented in the next pages for characteristic dates (summer, winter and midseason).

As a conclusion, artificial light is needed due to the inherited problem, we chose a hybrid system for ground floor and openings on the roof for second floor.

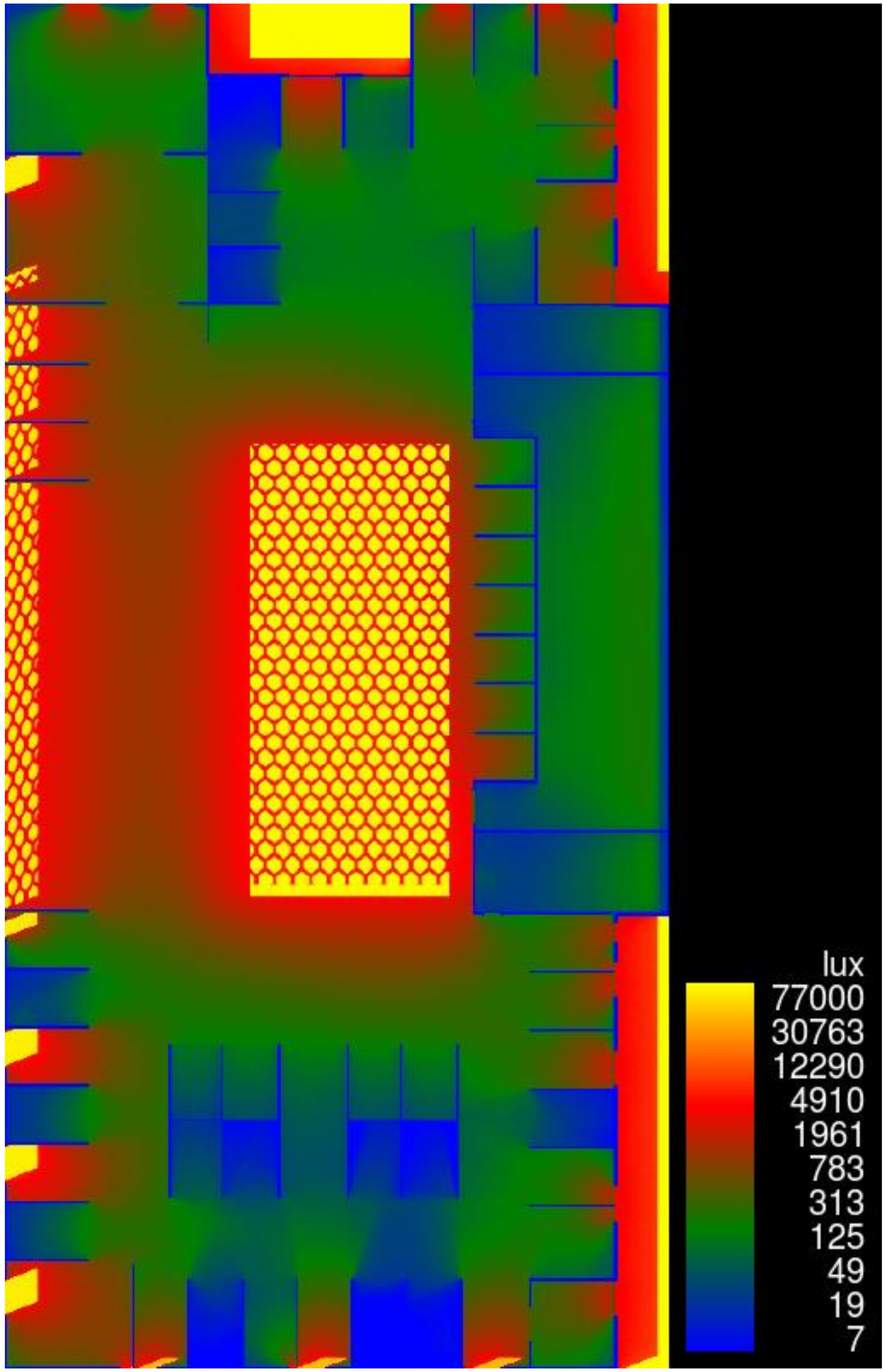


Figure 5- 38 Illuminance in typical floor

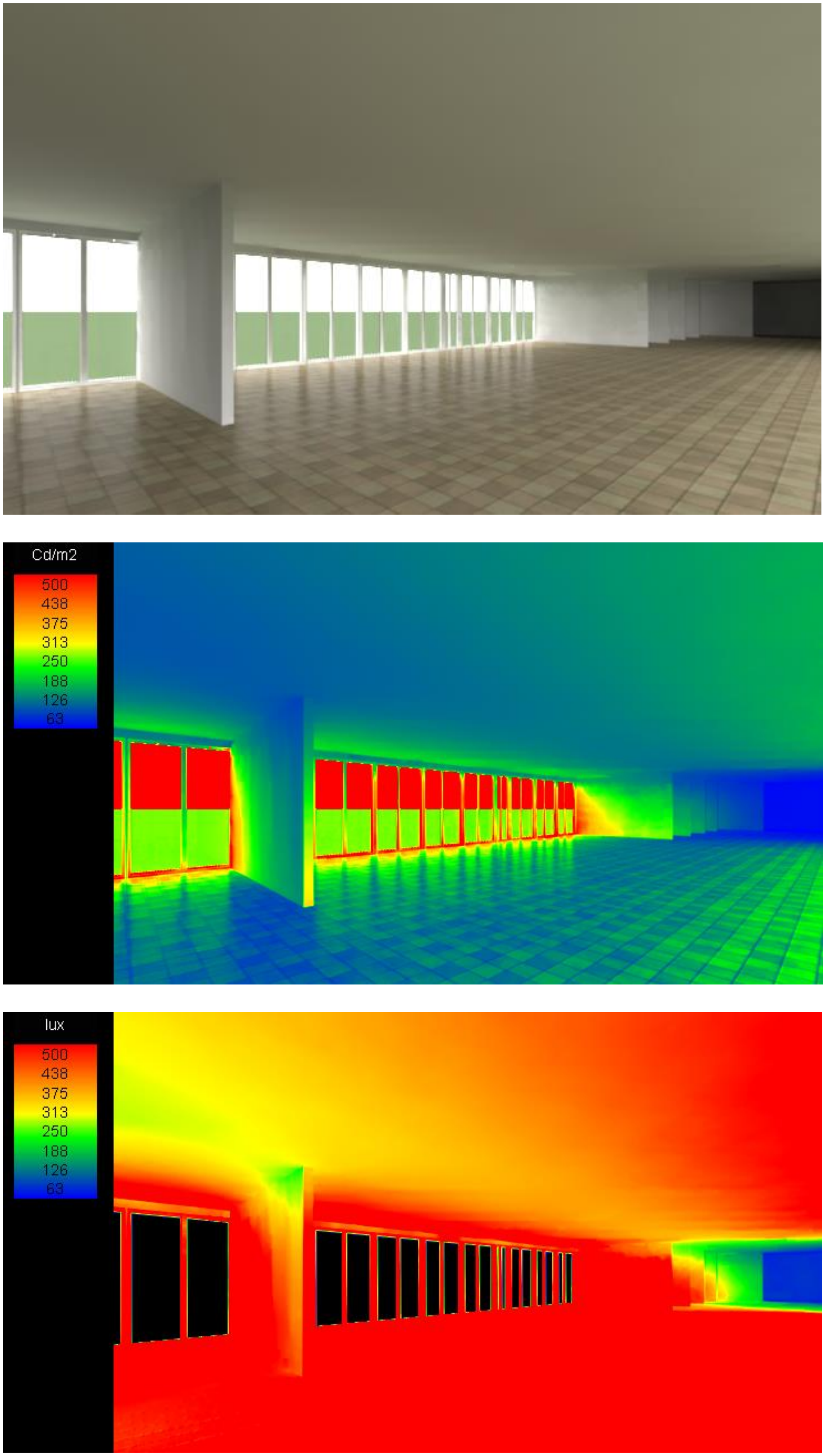


Figure 5- 39 Summer solar study in main entrance a) Simulation b) Luminance c) Illuminance

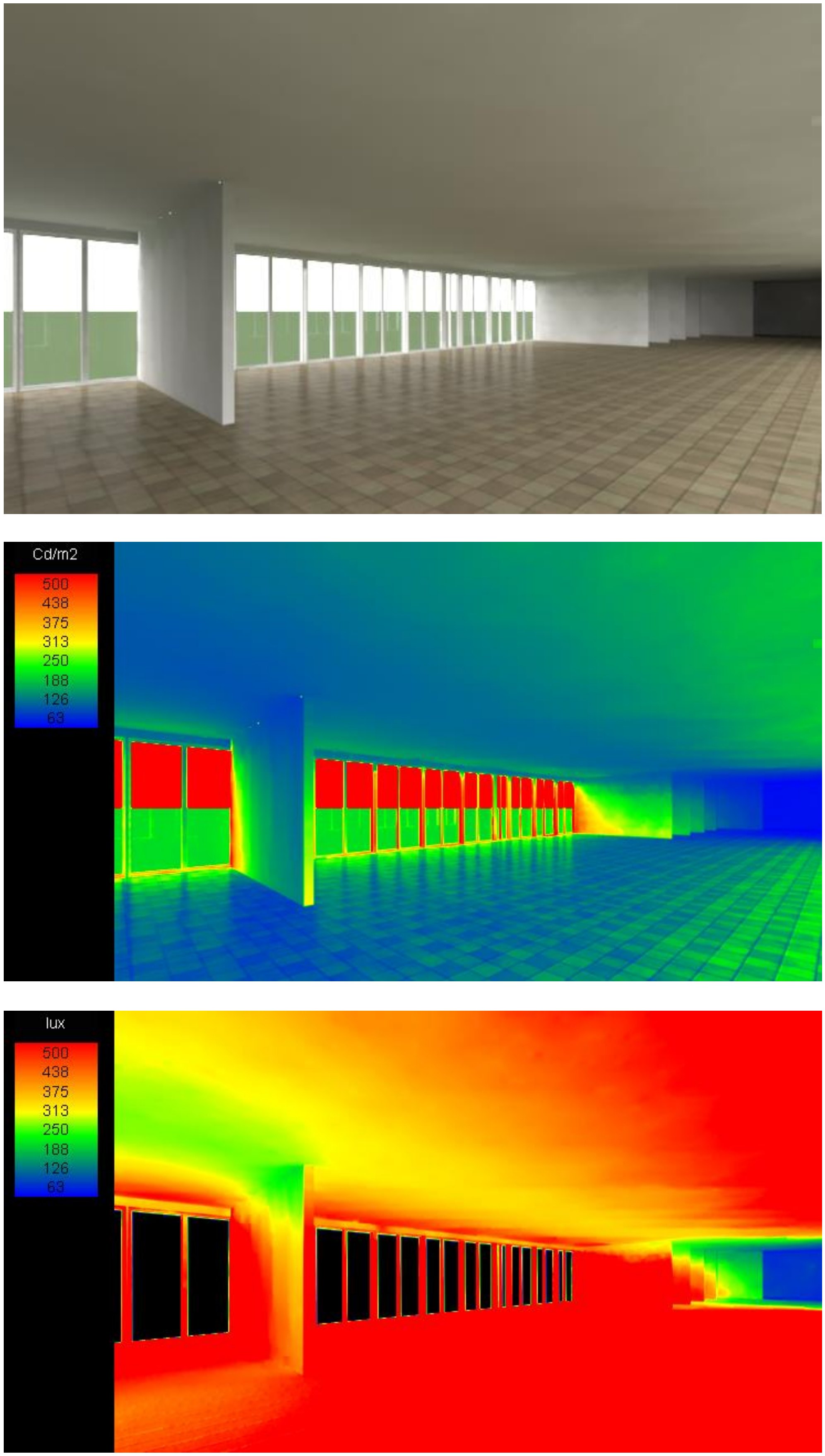


Figure 5- 40 Figure 5- 39 Winter solar study in main entrance a) Simulation b) Luminance c) Illuminance

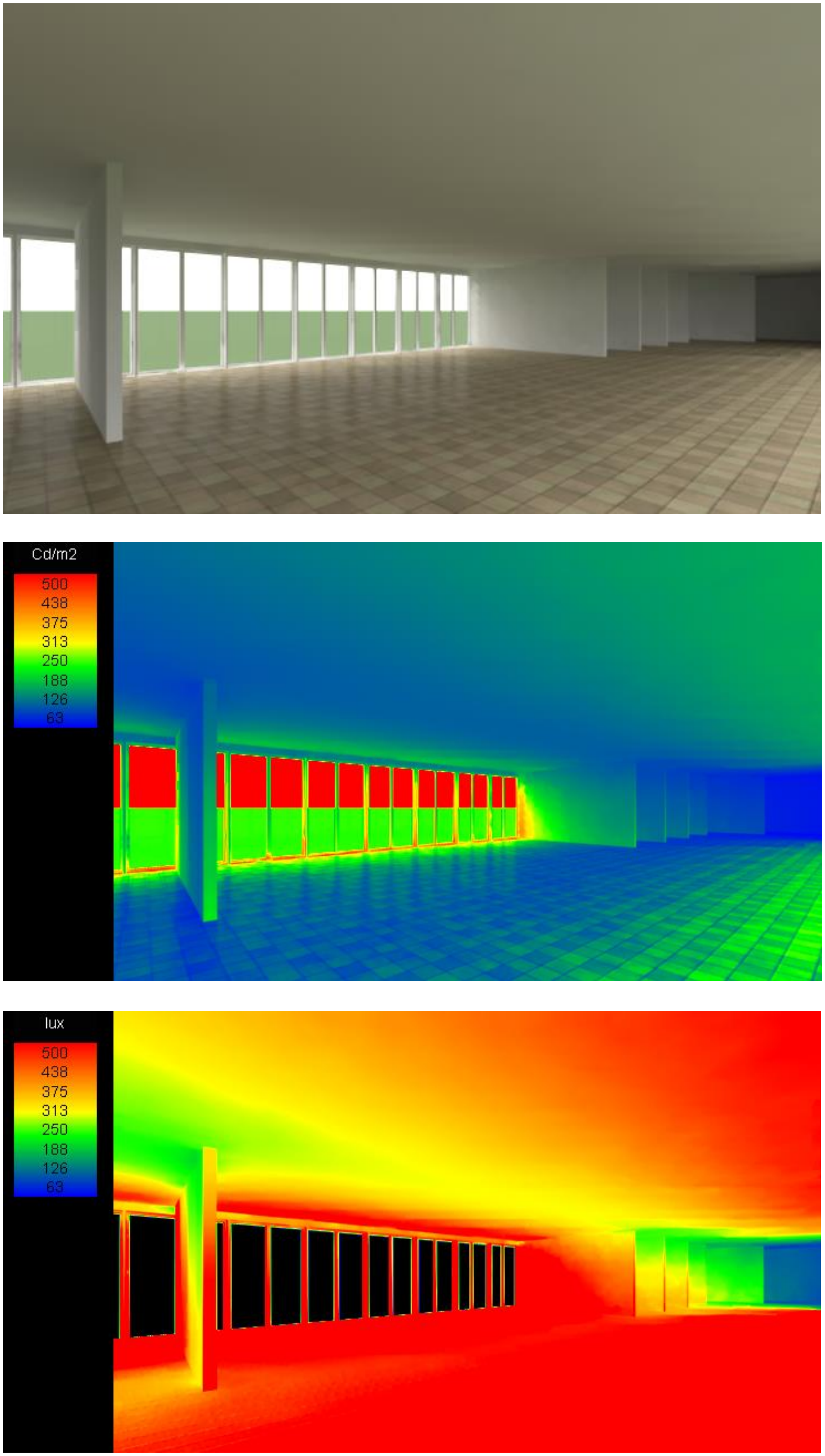


Figure 5- 41 Mid-season solar study in main entrance a) Simulation b) Luminance c) Illuminance

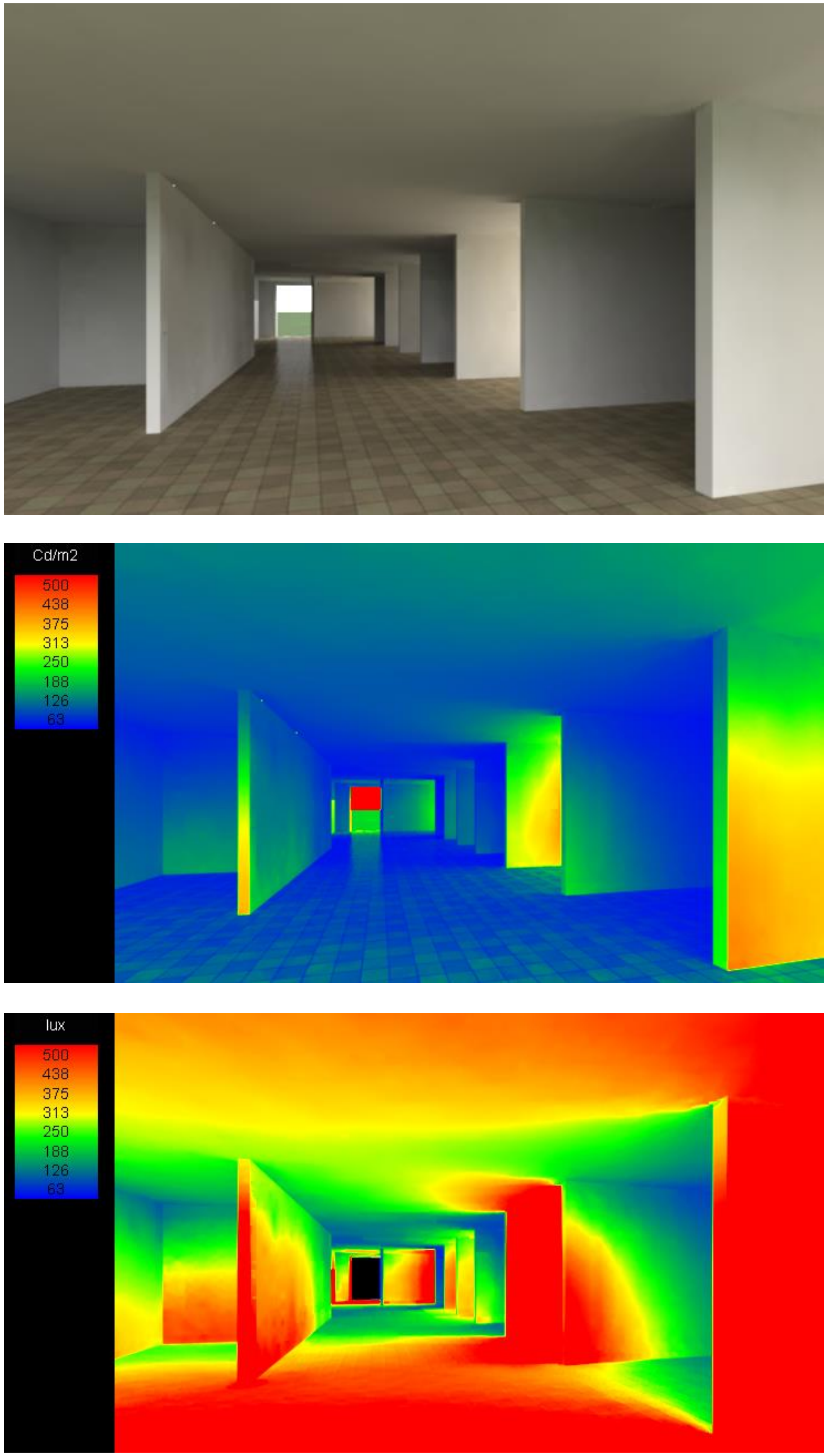


Figure 5- 42 Summer solar study in corridor a) Simulation b) Luminance c) Illuminance

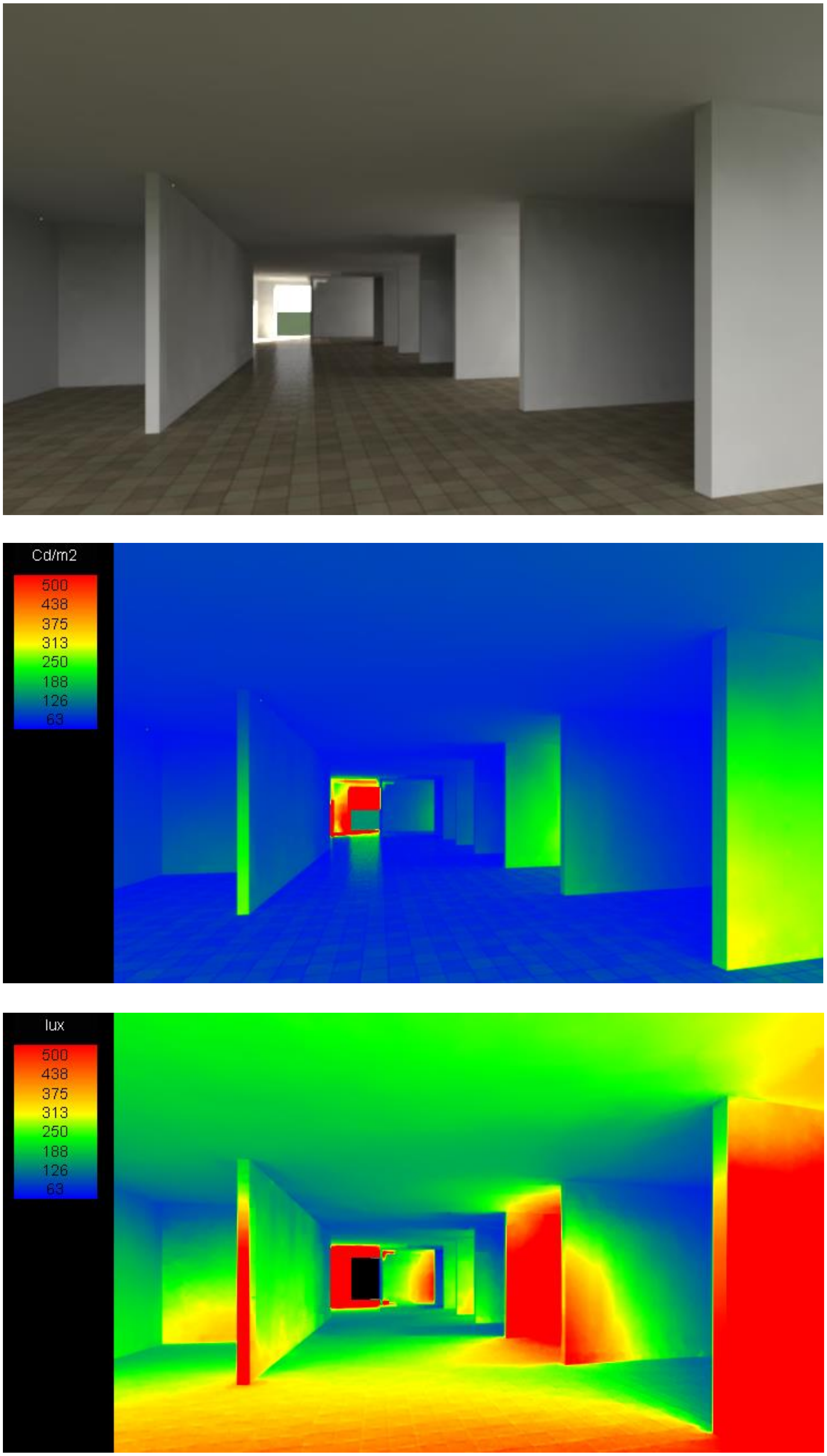


Figure 5- 43 Winter solar study in corridor a) Simulation b) Luminance c) Illuminance

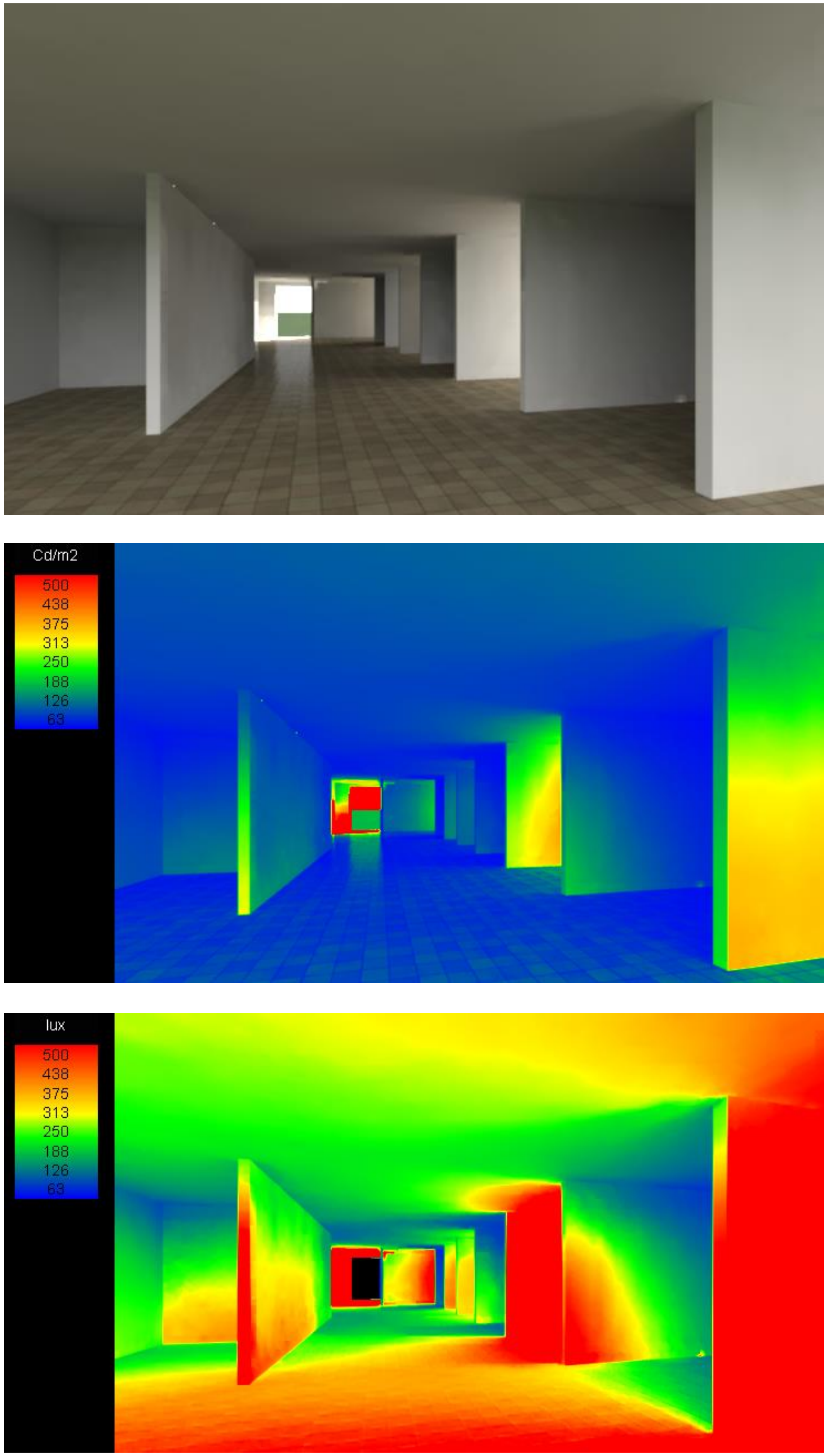
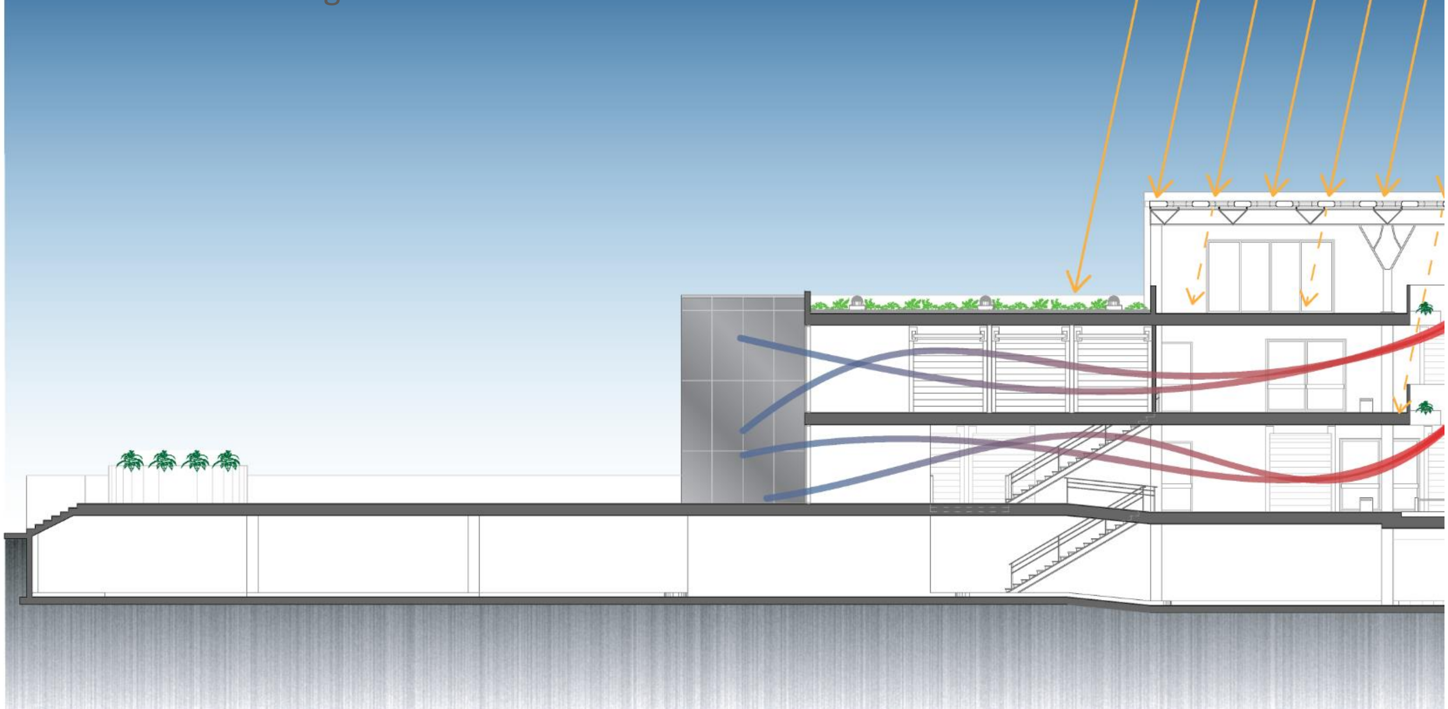
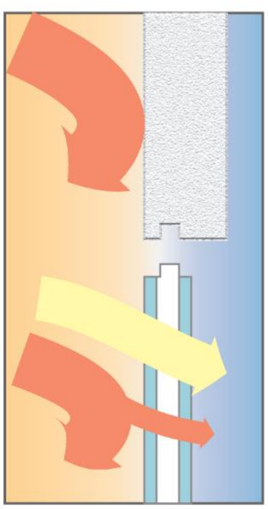


Figure 5- 44 Mid-season solar study in corridor a) Simulation b) Luminance c) Illuminance

5.9 Green strategies - Schemes



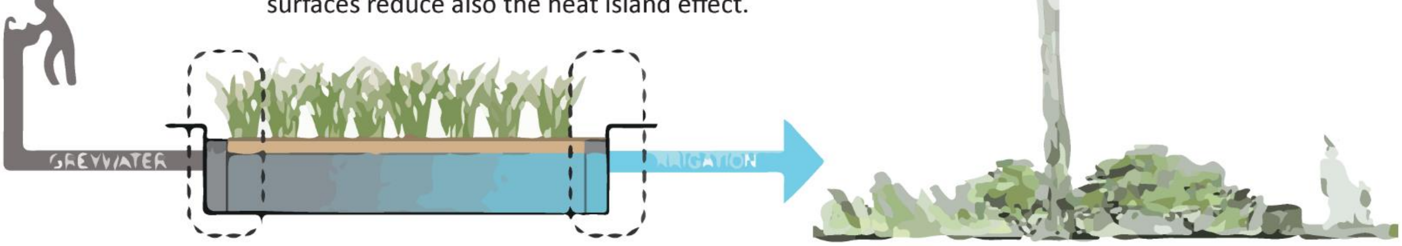
This scheme shows the effect of the of the shading system made of hexagonal panels in addition to an expanded metal layer below, the sunlight is diffused and it reaches the ground less intense.
In order to refresh the whole building we take advantage of the natural ventilation from the north-east, the big interior openings let the air flow easily through the market.

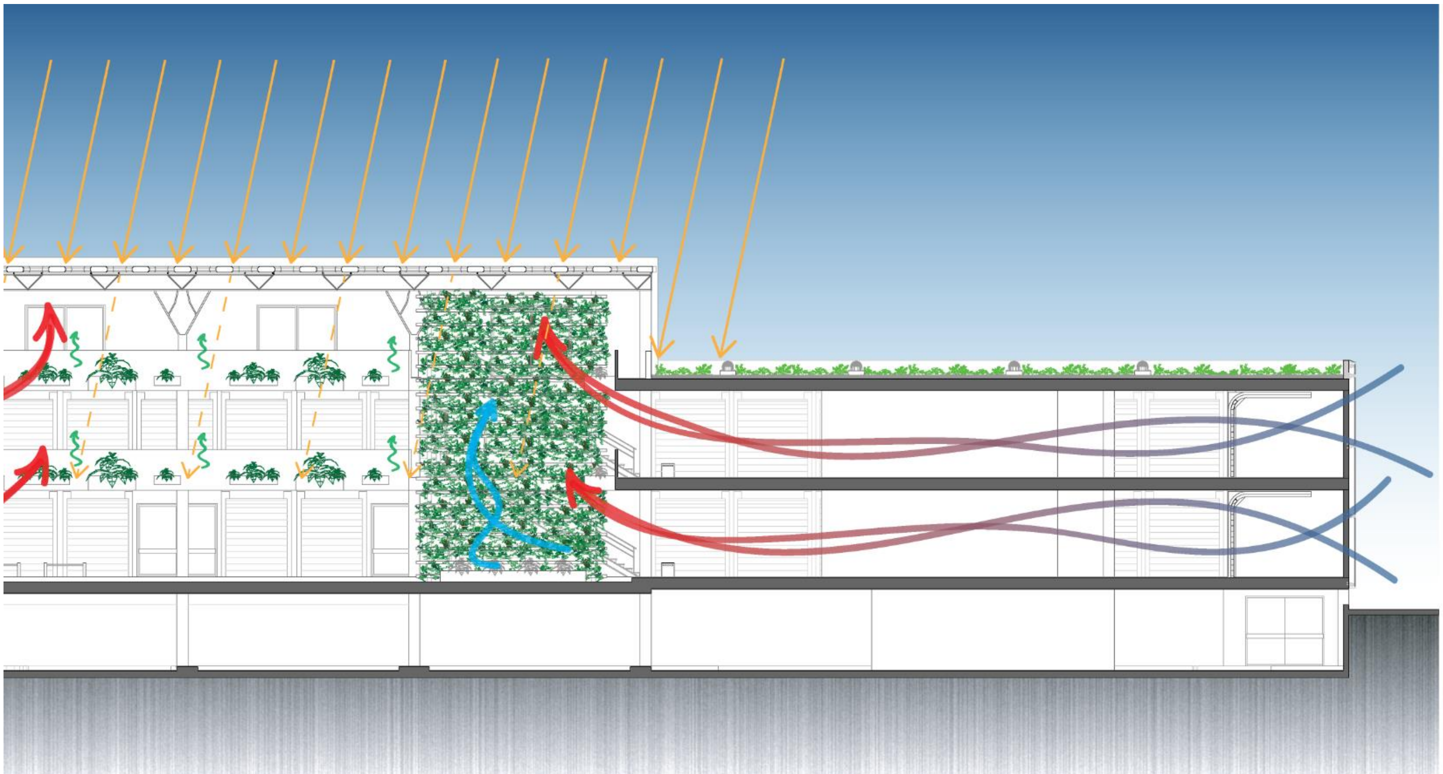


In order to reduce the energy necessities we have described and located along the project, in the diagram we can see how the light enters into the building, the daylight analysis shows the lack of internal lighting, to solve this issue we provide a system that captures and directs the rays of the sun. The process starts with a receiver on the outside, cables (optic fiber) that transport the light through the property and reach the luminaries that spreads the light inside. The lamps have a support system made of LEDs. The upper level is illuminated by solar tunnels in the roof.

The façade facing the park is a curtain wall, where the glass is coated by a E-low coating, this prevent the overheating letting the light pass, to reduce the bright the second façade works as a shading system.
The other element that prevents the heat entering the market is self-insulated walls, made of autoclaved aerated concrete, this material is protected to the exterior elements by an aluminum panel cladding that in part reflects the heat from the sun.

The water efficiency is increased collecting the stormwater and using it to irrigate the vegetated areas, to complement the system and in order to clean the waste water used in the market, we install a reedbed system, the water obtained by both sources will help to increase the infiltration to the ground and prevent to the latent problem of soil settlements, erosion and the pervious surfaces reduce also the heat island effect.





To refresh the air, the courtyard collects the warm air and this raises the top of the building, sucking up the interior streams, including vegetation and a water body in the courtyard helps by the evaporation effect. Ventilation in the parking is possible due to the fact that the floor over it is above the street level arond 1m and is open to the exterior.

Solar thermal collectors (Evacuated tubes) are installed over the offices level, the diurnal function of the market reduces the need of extra lighting at nights, the water supplied by the thermal collectros is used in toilets and caffeteria. Some extra PV panels are used for the hybrid ligthing system in corridors.

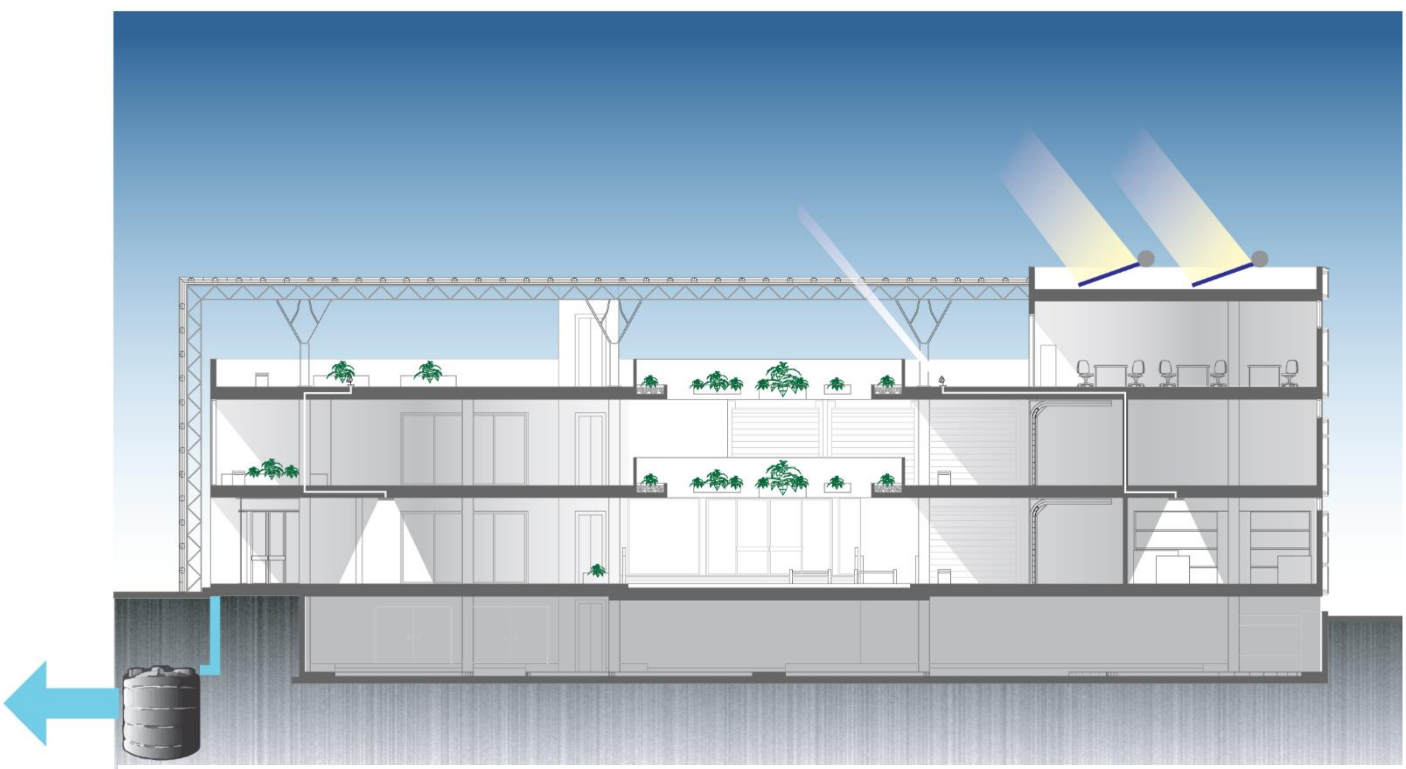


Figure 5- 45 Description and location of the green strategies

5.10 Blow up's sections

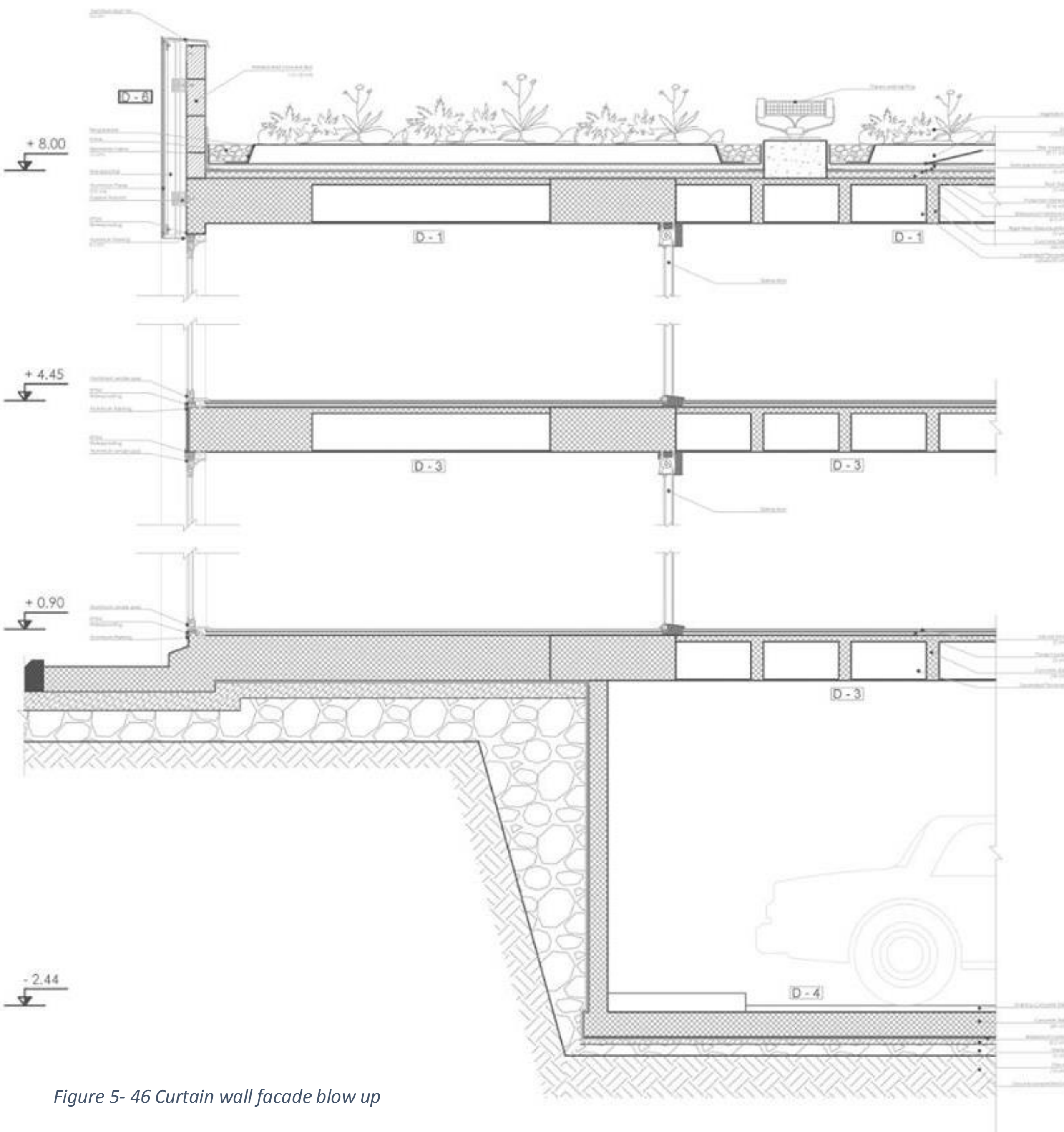


Figure 5- 46 Curtain wall facade blow up

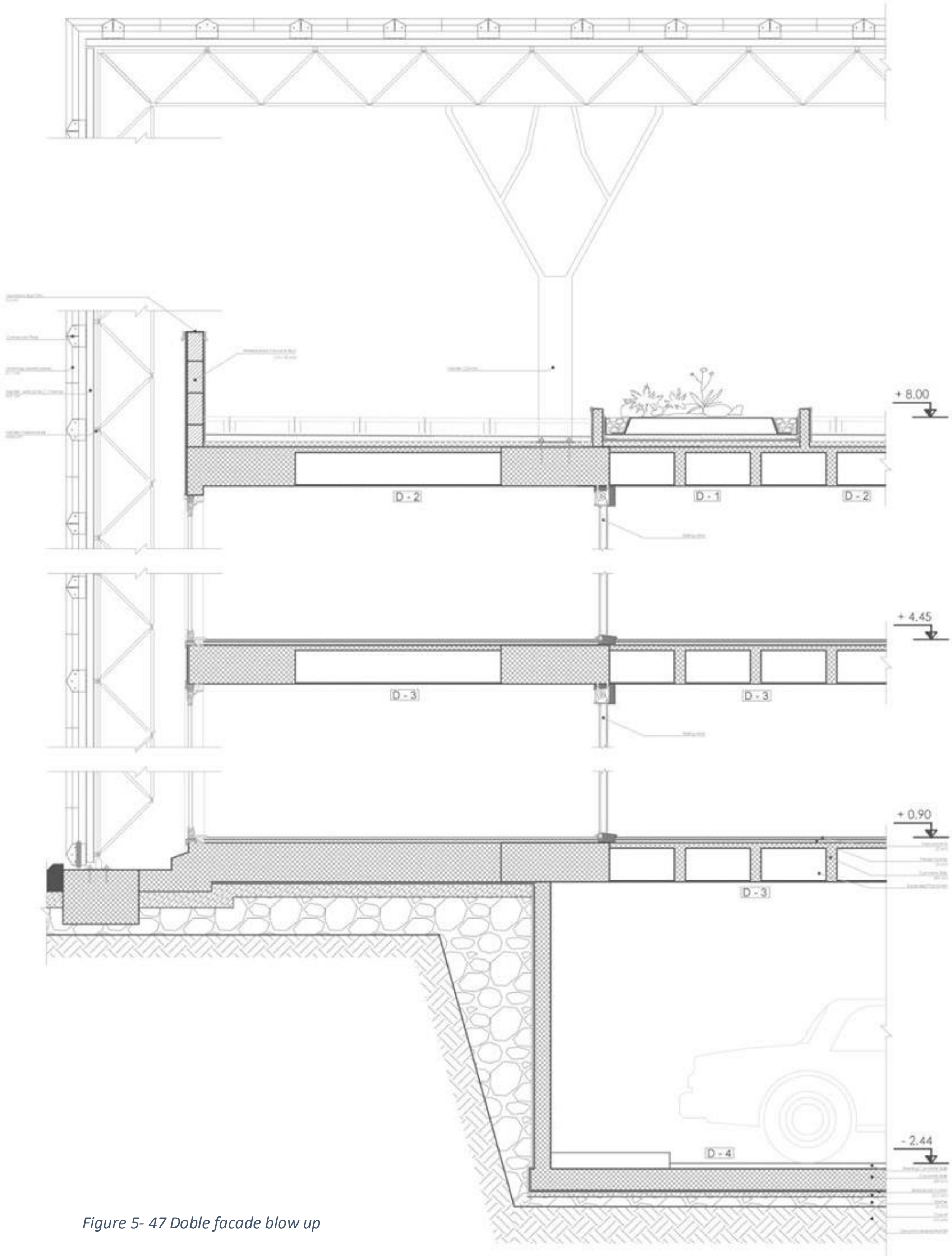


Figure 5- 47 Doble facade blow up

5.11 Technological details (walls, floors, roofs)

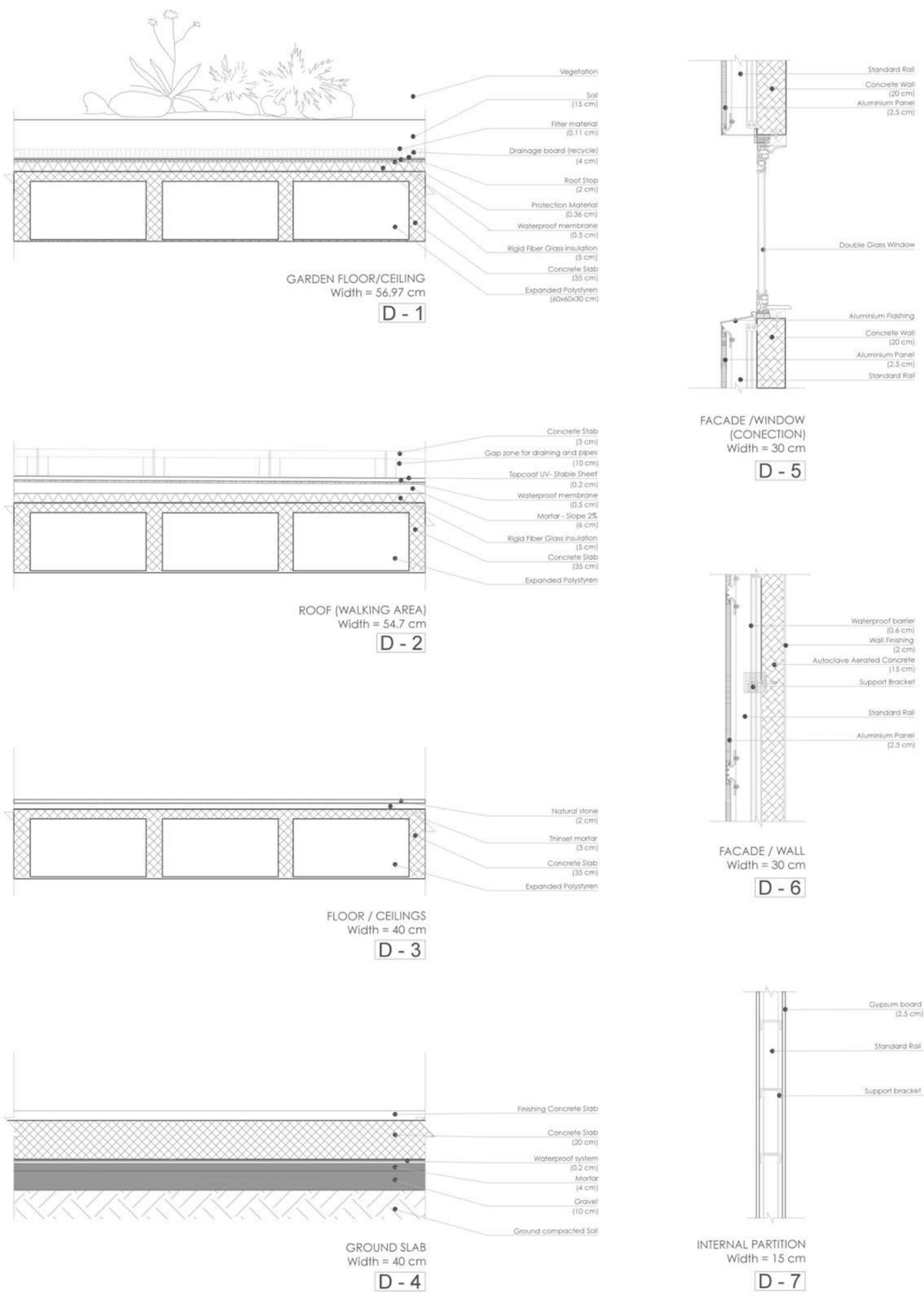


Figure 5- 48 Details

STRUCTURAL DESIGN

6

This chapter provides the structural design of the building starting from the load analysis and reaching the structural design of the critical elements of the building.
Finally, a summary of the results is synthetized in the structural plan and the reinforcement details; renderings are shown as graphic support of the previous.

Chapter 6: Structural Design

6.1 Introduction

The “San Juan Handcraft Market” is the main architectural and structural subject of study in the development of the present thesis. The building is a concrete structure, originally a three levels construction, our design keeps this configuration and adds an upper new level constructed with light materials. The distribution of levels is the following: an underground level for services and parking, then in the surface is the ground level of the building with an internal courtyard; a square is located in the north and is over part of the underground level. The first level keeps the same dimension as the previous and finally a second level for offices and workshops.

The underground and ground slabs have a surface of 98.5m x 40.2m and 2.9m high, the building has a plan of 74.8m x 40.2m, finally the new structure we propose is 33.2m x 10m; these last floors have a height of 3.3m. Plans and cross section are illustrated in last section of this chapter.

Due to the conditions of the competition, the approach of the present report is to analyze an existing structure; some of the properties of structural elements as well as the construction system are given. The main structural elements are: lightened slab with polystyrene working in the shortest direction of the main panels, all interior floors are covered by tiles and some areas of the roof will have vegetation, the primary beams are have the height of the slab and transmit the vertical forces to square shape columns, to the foundations that are made up of a perimeter wall to resist ground actions and under each column a group of piles will transmit the vertical loads to the ground. And in order to resist lateral incident forces four shear walls are proposed, the external walls made up autoclave aerated concrete are not design as bearing load elements and serve for supporting the exterior aluminum panels in the façade.

As a new element to the building a shading system will cover part of the west façade and roof, this new structure is a steel truss, which supports are in the ground and over the top of the columns in the roof. This truss won’t be analyzed in the present work, but the loads that transmit to the columns are considered in the design of these last ones.

The development of this analysis follows the Eurocode normative, the “Reglamento de Construcciones para el Distrito Federal y sus Normas Técnicas Complementarias” (RCDF and NTC are the Mexico city’s local codes for construction), and American Concrete Institute (ACI) recommendations, besides the above mentioned regulations different literature was consulted.

6.2 Materials

Concrete strength class: C25/30

Characteristic cylinder compressive strength

$$f_{ck} = 25\ N/mm^2$$

Design compressive strength [EC2-3.1.6 (1) Table 2.1N for γ_c]

$$f_{cd} = \alpha_{cc}\frac{f_{ck}}{\gamma_c} = 0.85 \cdot \frac{25}{1.5} = 14.2\ N/mm^2$$

Allowable compressive stress under combination of actions [EC2-7.2(2)]

$$\sigma_{c,amd} = k_1 f_{ck} = 0.6 \cdot 25 = 15\ N/mm^2$$

Medium tensile strength [EC2-Table 3.1]

$$f_{ctm} = 0.3(f_{ck})^{2/3} = 2.6\ N/mm^2$$

Characteristic tensile strength [EC2-Table 3.1]

$$f_{ctk;0.5} = 0.7 f_{ctm} = 1.8\ N/mm^2$$

Design tensile strength [EC2-3.1.6(2) and Table 2.1N for γ_c]

$$f_{ctd} = \alpha_{ct}\frac{f_{ctk;0.5}}{\gamma_c} = 1.2\ N/mm^2$$

Secant modulus of elasticity [EC2- Table 3.1]

$$E_{cm} = 22\left(\frac{f_{cm}}{10}\right)^{0.3} = 31000\ N/mm^2$$

High ductility steel type B450C

Characteristic yield strength

$$f_{yk} \geq 450\ N/mm^2$$

Design yield strength [EC2- 3.2.7 and Table 2.1N for γ_s]

$$f_{sd} = \frac{f_{yk}}{\gamma_s} = 391 \text{ N/mm}^2$$

Admissible stress under characteristic combination of action [EC2-7.2(5)]

$$\sigma_{s,adm} = k_3 f_{yk} = 360\ N/mm^2$$

Modulus of elasticity [EC2-3.2.7(4)]

$$E_s = 200000\ N/mm^2$$

The data related to the nominal dimensions of structural rebar used in this project is shown below in accordance to the standard EN 10080 (Steel Rebar, 2014):

Metric	Mass per unit length	Nominal Diameter	Cross Sectional
Bar Size	(kg/m)	(mm)	Area (mm^2)
6.0	0.222	6	28.3
8.0	0.395	8	50.3
10.0	0.617	10	78.5
12.0	0.888	12	113
14.0	1.21	14	154
16.0	1.579	16	201
20.0	2.467	20	314
25.0	3.855	25	491
28.0	4.83	28	616
32.0	6.316	32	804
40.0	9.868	40	1257
50.0	15.413	50	1963

Table 6- 1 Rebar sizes

6.3 Loads Analysis

6.3.1 Self-weight of a typical floor per square meter.

Vertical closures

For the external walls was chosen Autoclave Aerated Concrete a diagram is shown in figure below.

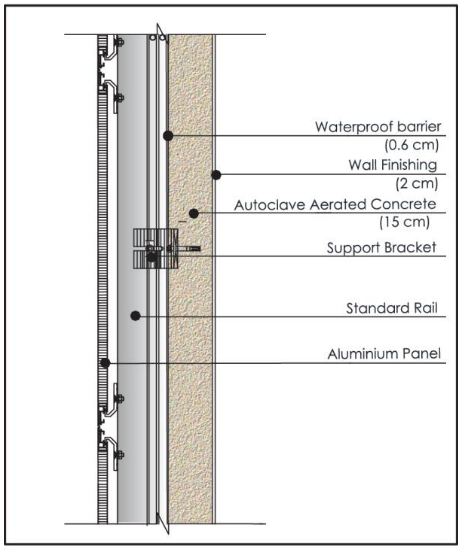


Figure 6- 1 Exterior wall

Layer	Thickness [cm]	Weight [kN/m]
Façade Panels	-	0.82
Wall	15	2.75
Plaster	2	0.73
Waterproof barrier	0.6	0.03
	Total	4.34

Table 6- 2 Exterior wall loads

The construction system selected for façade considers the same weight for windows and aluminum panels. This load is applied along the perimeter beams, and do not affect the slab loads.

In side partitions

Typical section is shown below.

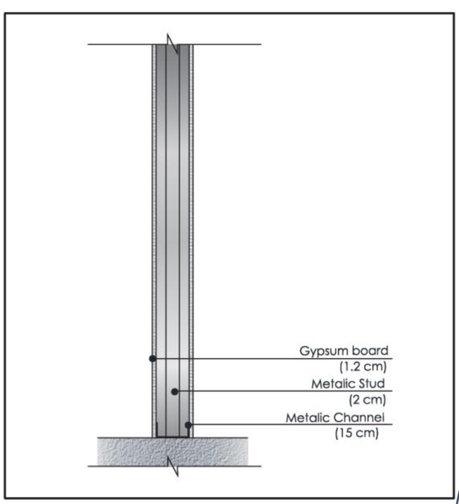


Figure 6- 2 Interior wall

Layer	Thickness [cm]	Weight [kN/m]
Gypsum board	2x1.2	0.38
Metallic stud	-	0.07
Channel	-	0.02
Joins	-	0.05
	Total	0.538

Table 6- 3 Interior wall loads

According to EN 1991-1-1[EC1 6.3.1.2(8)] it is possible to distribute the loads due to internal partitions over the floor. The equivalent distributed load is:

$$0.538/2.5 = 0.2152\ kN/m^2$$

This load is considered as a live load with a safe factor of γ_c=1.5 for Ultimate Limit State (ULS) combinations and coefficients ψ_0=ψ_1=ψ_2=1.0 Serviceability Limit State (SLS) combinations.

Typical floor

The slab is formed by recycled glass tiles with especial adhesive mortar, the joist are 100 mm wide and 300 mm height, the slab is 50 mm thick reinforce concrete, with expanded polystyrene as lightener with a section of 600 mm by 300 mm. The slab configuration is shown next:

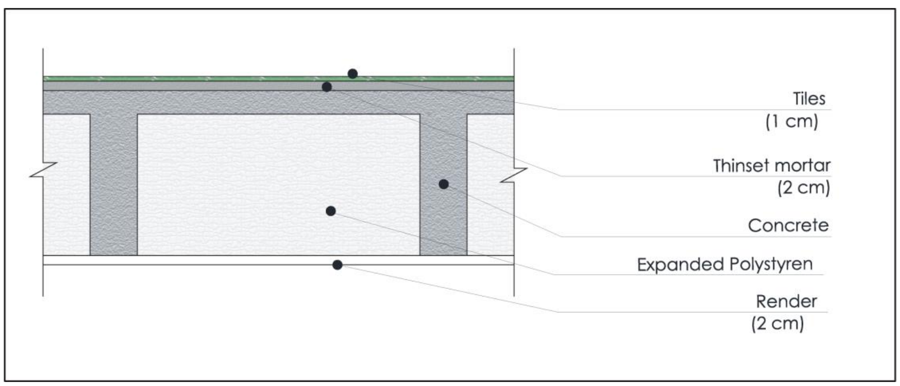


Figure 6- 3 Slab section

Layer	Thickness [cm]	Weight [kN/m²]
Topping	5	1.17
Ribs	6	2.53
Polystyrene	24	0.02
	Total	3.73

Table 6- 4 Floor slab loads

For typical interior floor we have also to consider the finishing:

Layer	Thickness [cm]	Weight [kN/m^2]
Mortar	2	0.27
Tiles	1	0.40
Ceiling plaster	2	0.24
Installations	-	0.40
	Total	1.33

Table 6- 5 Flooring loads

For the zone with green roof:

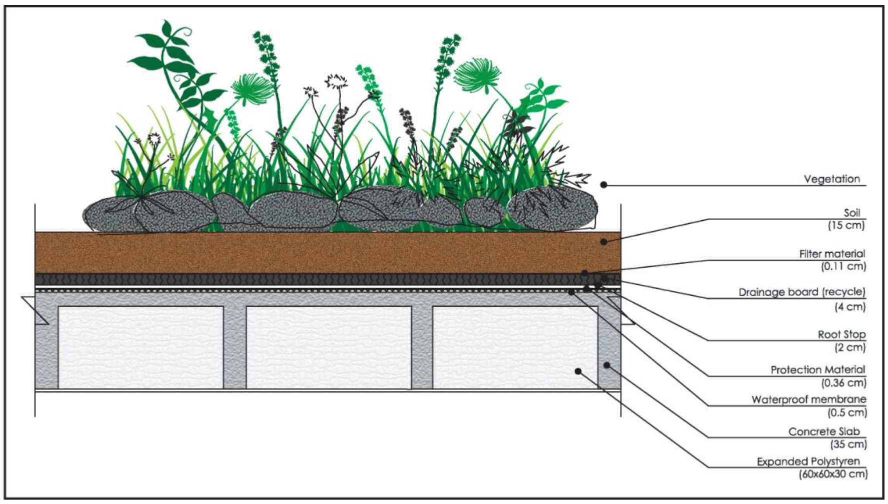


Figure 6- 4 Green roof section

Layer	Thickness [cm]	Weight [kN/m^2]
Vegetation	-	0.30
Soil	15	2.21
Filter material	1.1	0.001
Drainage board	4	0.02
Protection material	0.36	0.003
Waterproof membrane	0.5	0.005
	Total	2.554

Table 6- 6 Green roof slab loads

Thus:

Internal flooring total weight: 5.24 kN/m^2

Roof total weight: 7.79 kN/m^2

6.3.2 Live loads

According to the RCDF [c. V Art 199 – V] the live loads for commercial buildings are:

Live loads	Incidental	Gravitational
Meeting Areas	2.54	3.56
Roof	0.71	1.01

Table 6- 7 Live loads

6.4 Slab

For the design of the slabs is considered a strip 1 m wide, and analyzed a beam.

Applied loads:

Permanent actions

- Floor self-weight: G_1= 3.73 kN/m
- Other permanents: G_2= 1.33 kN/m

Variable actions

- Live load: Q_1= 3.56 kN/m
- Inside partitions: Q_2= 0.21 kN/m

6.4.1 Structural Analysis

The present structural analysis will be done using linear analysis considering the combination of actions from [EC2-5.1.3(1)], the load factors and combinations are defined by [EC0- Expression 6.10]:

$$\sum_{j\geq 1} \gamma_{Gj} G_{kj} + \gamma_{Q1} Q_{k1} + \sum_{i>1} \gamma_{Qi}\, \psi_{01} Q_{k1}$$

Combination 1 (Minimum moment at the continuity support)

Permanent loads: $\gamma_G(G_1+G_2)$= 1.35 (G_1+G_2)

Variable loads: $\gamma_Q(Q_1+Q_2)$= 1.5 (Q_1+Q_2)

For this case this loads will be applied on both spans.

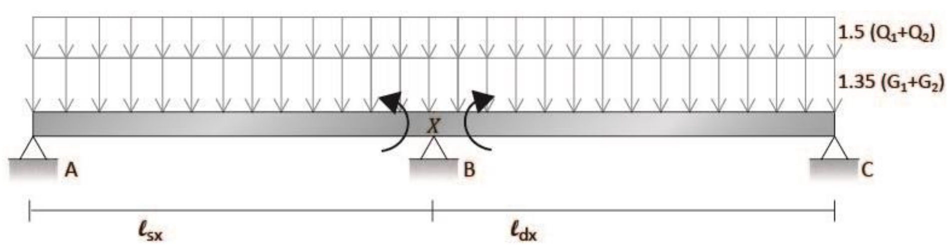


Figure 6- 5 Combination 1

For solving this beam it is used the Flexibility Method.

Congruence equation: $\varphi_{11}X+\varphi_{11}=0$

$$\varphi_{11} = \frac{l_{sx}}{3EI} + \frac{l_{dx}}{3EI} = \frac{16.6}{3EI}\ (where\ l_{sx} = l_{sd} = 11.2\ m)$$

$$\varphi_{10} = \left[\gamma_G(G_1 + G_2) + \gamma_Q(Q_1 + Q_2)\right]\left(\frac{l_{sx}^3 + l_{dx}^3}{24EI}\right)$$

$$X = -\frac{\varphi_{10}}{\varphi_{11}} = -\left[\gamma_G(G_1 + G_2) + \gamma_Q(Q_1 + Q_2)\right]\frac{l^2}{8}$$

$$X = -195.22\ kNm$$

X represents the minimum moment at the continuity support.

Support reactions:

$$R_A = R_C = \left[\gamma_G(G_1 + G_2) + \gamma_Q(Q_1 + Q_2)\right]\frac{l}{2} - \frac{X}{l} = 87.15\ kN$$

$$R_B = \left[\gamma_G(G_1 + G_2) + \gamma_Q(Q_1 + Q_2)\right]l + 2\frac{X}{l} = 104.58\ kN$$

Analytical expressions for shear and moment (the beam is symmetric):

$M(x) = 87.15x\text{-}6.22x^2$

$V(x) = 87.15\text{-}12.45x$

The position of the maximum moment along the span is:

$$x_{Mmax} = \frac{R_A}{\left[\gamma_G(G_1 + G_2) + \gamma_Q(Q_1 + Q_2)\right]} = 7m$$

The maximum moment is:

$$M_{\max} = R_A x_{Mmax} - 0.5\left[\gamma_G(G_1 + G_2) + \gamma_Q(Q_1 + Q_2)\right]x_{Mmax}^2 = 305.03\ kNm$$

Combination 2 (Maximum moment in the left span)

The loads are the following:

Permanent loads: $\gamma_G(G_1+G_2)= 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2)= 1.5\ (Q_1+Q_2)$

The permanent loads will be applied over both spans and the left just in the left. A diagram of this combination is showed bellow

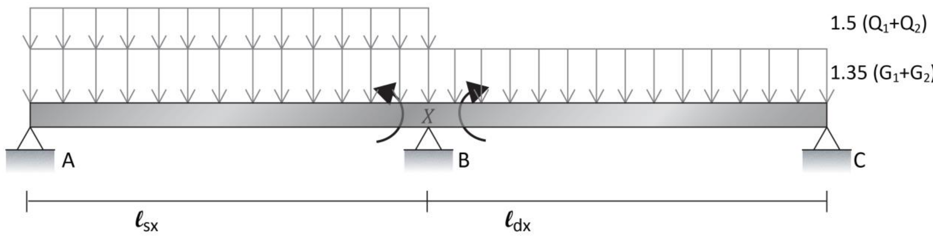


Figure 6- 6 Combination 2

The same steps used before are now apply to this configuration of loads.

The analytical expressions for shear and moment are shown below for the left span:

$M(x) = 83.22x\text{-}6.22x^2$

$V(x) = 83.22\text{-}12.45x$

The position of the maximum moment along the span is:

$$x_{Mmax} = \frac{R_A}{[\gamma_G(G_1+G_2)+\gamma_Q(Q_1+Q_2)]} = 6.68m$$

The maximum moment is:

$$M_{\max} = R_A x_{Mmax} - 0.5[\gamma_G(G_1+G_2)+\gamma_Q(Q_1+Q_2)]x_{Mmax}^2 = 278.16\ kNm$$

For right span:

$M(x) = 78.81x\text{-}3.42x^2$

$V(x) = 78.81\text{-}6.84x$

The position of the maximum moment along the span is:

$$x_{Mmax} = \frac{R_A}{[\gamma_G(G_1+G_2)+\gamma_Q(Q_1+Q_2)]} = 3.62\ m$$

The maximum moment is:

$$M_{\max} = R_A x_{Mmax} - 0.5[\gamma_G(G_1+G_2)+\gamma_Q(Q_1+Q_2)]x_{Mmax}^2 = 240.80\ kNm$$

Combination 3 (Maximum moment in the left span)

This combination is symmetric to the combination 2. The values used are those calculated previously.

Combination 4 (Minimum moment at support A)

To calculate the negative moment presented at the ends of the slab, produced by the constrain of the beams, we fix the extreme supports as shown in figure XXX:

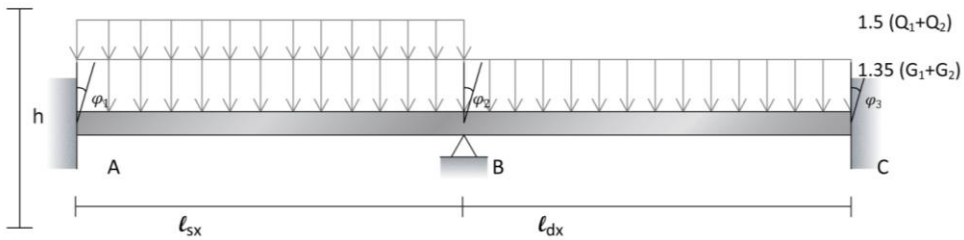


Figure 6- 7 Combintation 4

The stiffness of the column I^*_{col}, is calculated with a section of 500 mm x 500 mm, and the average spacing of 2.3 m.

$$I*_{col} = \frac{500^4}{12} \cdot \frac{1}{2.3} = 1.736x10^9 mm^4$$

The moment of inertia of the cross section of slab is:

$$I_{cs} = 5.45x10^9 mm^4$$

When stiffness of slab is calculated, the rigidity of ends is not considered. The barycenter of cross section, of characteristic slab stripe (Fig XXX) is:

$$y_G = \frac{1000 \cdot 50 \cdot 25 + 2 \cdot 300 \cdot 100 \cdot 200}{100 \cdot 50 + 2 \cdot 300 \cdot 100} = 120.45\ mm$$

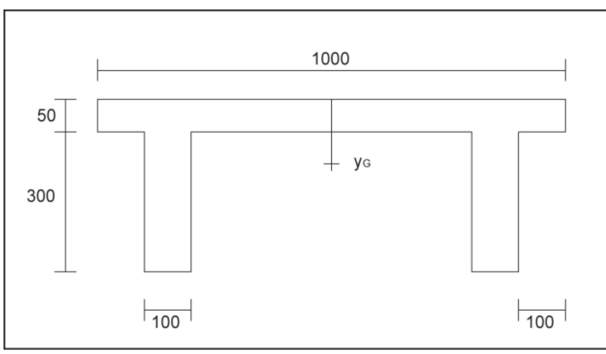


Figure 6- 8 Barycentre of the slab section

The loads are:

Permanent loads: $\gamma_G(G_1+G_2) = 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2) = 1.5\ (Q_1+Q_2)$

Where, permanent load is applied in both spans and variable on left only.

In order to calculate the beam proposed stiffness Method is used.

$$\begin{cases} m_{11}\varphi_1 + m_{12}\varphi_2 + m_{13}\varphi_3 + m_{10} = 0 \\ m_{21}\varphi_1 + m_{22}\varphi_2 + m_{23}\varphi_3 + m_{20} = 0 \\ m_{31}\varphi_1 + m_{32}\varphi_2 + m_{33}\varphi_3 + m_{30} = 0 \end{cases}$$

$$\begin{bmatrix} 1.631 & 0.178 & 0 \\ 0.178 & 0.714 & 0.178 \\ 0 & 0.178 & 1.631 \end{bmatrix} * \begin{Bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \end{Bmatrix} + \begin{bmatrix} -130.148 \\ 58.638 \\ 71.509 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\varphi_1 = 90.334 \frac{kNm^2}{EI_{cs}}$$

$$\varphi_1 = -96.354 \frac{kNm^2}{EI_{cs}}$$

$$\varphi_1 = -33.290 \frac{kNm^2}{EI_{cs}}$$

Thus the values of the moment at the ends of the slab sections are:

$M_A =$ -115.092 kNm

$M_B =$ -111.867 kNm

$M_C =$ -35.499 kNm

The reactions in the nodes A and C are:

$R_A = 38.59\ kN$

$R_C = 31.49\ kN$

The analytical expressions for shear and moment are shown below for the left span:

$M(x) = -115.09+38.59x-6.22x^2$

$V(x) = 38.59-12.45x$

The analytical expressions for shear and moment are shown below for the right span:

$M(x) = -35.49+31.49x-3.42x^2$

$V(x) = 31.49-6.84x$

Combination 5 (Minimum moment at C)

This combination is symmetric to the combination 4. The values used are those calculated previously.

6.4.2 Envelope of bending moment

The following diagram shows the bending moment calculated before.

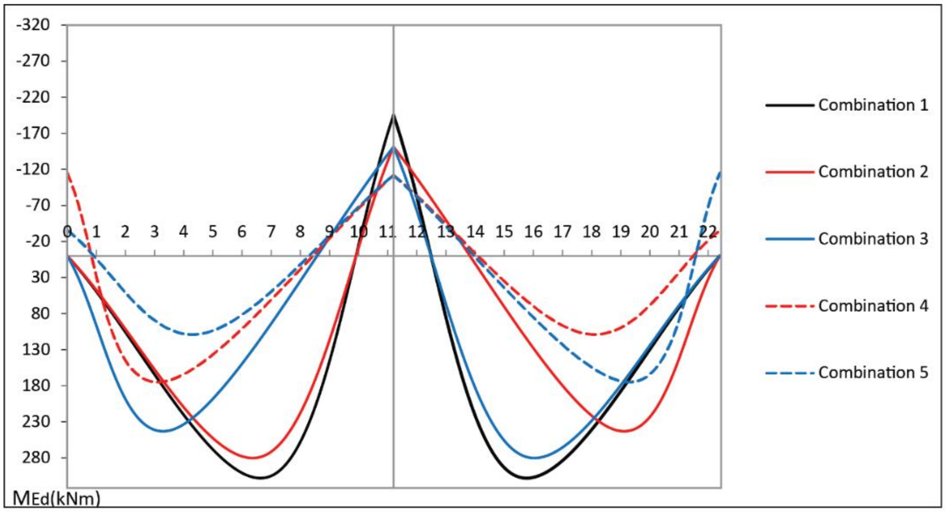


Figure 6- 9 Envelope od moments

According to [EC2-6.2.2(5)] an effective depth is necessary for shifting the diagram in the most unfavorable direction.

$d = h - c - \phi/2$

where,

h : depth of cross section

c : concrete cover

ϕ : longitudinal bar diameter

The cover thickness is calculated according to EN 1992-1-1 § 4.4.1; the nominal cover is a minimum cover, c_{min}, plus an allowance, Δc_{dev} [Expression 4.1-EC2]

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

where,

$c_{min} = \phi = 14\ \mathrm{mm}$

$c_{min,b\ dur} = 10\ \mathrm{mm}$ according to EN 1992-1-1 § 4.4.2(5)-EC2 and Table 4.4 N-EC2 when there is not risk of corrosion.

$\Delta c_{\gamma} = 0$ from EN 1992-1-1 § 4.4.2(6)-EC2

$\Delta c_{dur,st} = \Delta c_{dur,add} = 0$, since no special steel is used [EN 1992-1-1 § 4.4.2(7-8)-EC2]

The minimum cover is:

$c_{min} = (14\ mm, 10\ mm, 10\ mm) = 14\ mm$

$\Delta c_{dev} = 10\ mm$ from EC2 § 4.4.1.3], thus the nominal concrete cover is:

$c_{nom} = 24\ mm$

And the effective depth is:

$d = 319\ mm$

The moments to verify after considering the shifted envelope of diagram of moment are:

Section	Description	M_{ED} [kNm]
A	Solid section at beginning	-115.092
A'	Change from solid to ribbed section	-100.649
S	Ribbed section with maximum moment	305.035
B'	Change from ribbed section to solid section	-195.222
B	Solid section	-135.295

Table 6- 8 Design moments along the slab

4.4.3 Reinforcement pre-dimensioning

For the present design we assume:

- Only tension reinforcement is considered

- Rectangular stress distribution is assumed for concrete in compression [EC2-3.1.7(3)], λ= 0.8 [EC-Expression 3.21] and η= 1.0 [EC2-Expression 3.21]

The rotational equilibrium about the barycenter of the tension reinforcement is:

$0.8 b\, x\, f_{cd}\, (d - 0.4x) = M_{Ed}$

From the previous expression the neutral axis x is unknown.

The translational equilibrium, under the hypothesis of yielded tension reinforcement is:

$0.8 b\, x\, f_{cd} - A_s f_{yd} = 0$

The required reinforcement area is:

$$A_s = \frac{0.8b\ x\ f_{cd}}{f_{yd}}$$

The hypothesis of yielded steel is:

$$\xi = \frac{x}{d} \leq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} = \frac{3.5}{3.5 + 1.96} = 0.641$$

The EC2-9.2.1.1, Expression 9.1N recommends that the reinforcement area needs to be higher than:

$$A_{s,min} = 0.26\frac{f_{ctm}}{f_{yk}}b_t\ d$$

The Table (ULS pre-dimensioning) shows the calculations for the effective area of longitudinal reinforcement.

Section	M_{Ed} [kNm]	B [mm]	X [mm]	x/d	A_{sr} [mm^2]	b_t [mm]	A_{sm} [mm^2]	ϕ	No	A [mm^2]
A (-)	115.092	1000	18.958	0.059	550.809	1000	479.2089	14	4	616.00
A' (-)	100.649	200	88.958	0.278	516.913	800	383.3671	14	4	616.00
S (+)	305.035	1000	23.333	0.073	677.919	200	95.84178	16	4	804.00
B' (-)	135.295	200	148.750	0.466	751.022	800	383.3671	16	4	804.00
B (-)	195.222	1000	36.458	0.114	1092.788	1000	479.2089	16	6	1884.00

Table 6- 9 Calculation of steel

6.4.4 Bending Ultimate Limit State verification

- *Section A*

This is a section with a width b = 1000 mm and depth d = 319 mm, as seen in figure X. We assume that the concrete in compression reaches its maximum strain and the steel is yielded.

$$\xi = \frac{x}{d} \leq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} = \frac{3.5}{3.5 + 1.96} = 0.641$$

The translational equilibrium follows the expression:

$$b\lambda x\eta f_{cd} - A_s f_{yd} = 0.8bxf_{cd} - A_s f_{yd} = 0$$

Where:

$$x = \frac{A_s f_{yd}}{0.8bf_{cd}} = 27.672\ mm\ \rightarrow\ \xi = 0.086 < 0.641$$

The resistant moment of the section with the reinforcement given is obtained by the rotational equilibrium:

$$M_{Rd} = A_s f_{yd}\left(d - \frac{\lambda x}{2}\right) = A_s f_{yd}(d - 0.4x) = 115.705\ kNm > 115.092\ kNm$$

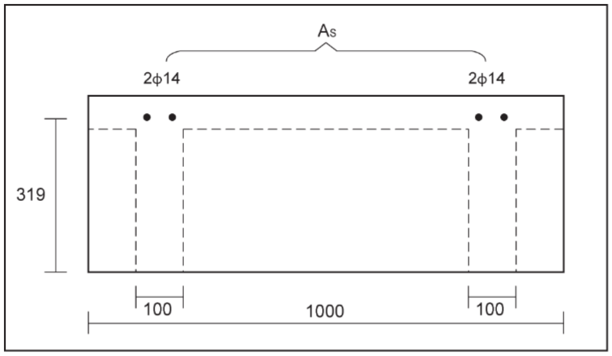


Figure 6- 10 Section A

- Section A’

This section is ribbed, with a b = 200 mm and d = 319 mm (Fig X). The process for the ULS revision is the same used for section A.

$$x = 138.364\ mm\ \rightarrow \xi = 0.443 < 0.641$$

The resistant moment of the section:

$$M_{Rd} = 100.847\ kNm > 100.649\ kNm$$

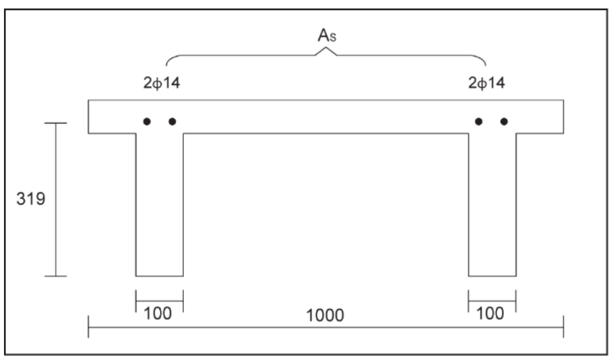


Figure 6- 11 Section A’

- Section B

Solid section at the end of the slab strip (Fig X), like in section A we have b = 1000 mm and d = 319 mm. The process for the ULS revision is the same used in the previous section.

$$x = 64.845\ mm\ \rightarrow \xi = 0.203 < 0.641$$

The resistant moment of the section:

$$M_{Rd} = 215.882\ kNm > 195.222\ kNm$$

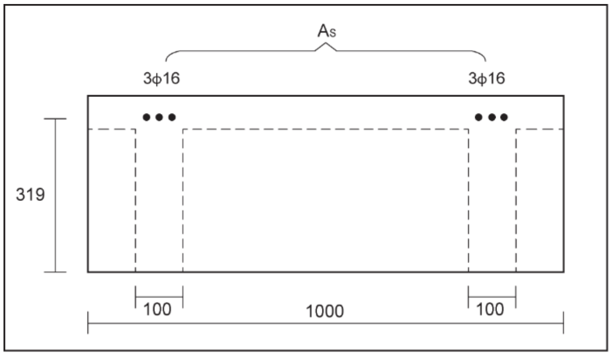


Figure 6- 12 Section B

- *Section B'*

This section is ribbed, with a b = 200 mm and d = 319 mm (Fig X). The process for the ULS revision is the same used in the previous section.

$$x = 138.364\,mm\ \rightarrow \xi = 0.433 < 0.641$$

The resistant moment of the section:

$$M_{Rd} = 154.633\,kNm > 135.295\,kNm$$

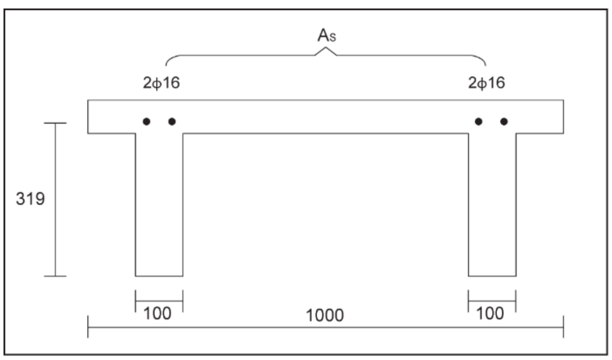


Figure 6- 13 Section B'

- *Section S*

Due to the positive moment in this section, the topping is in compression and the steel reinforcement is supply in the bottom part:

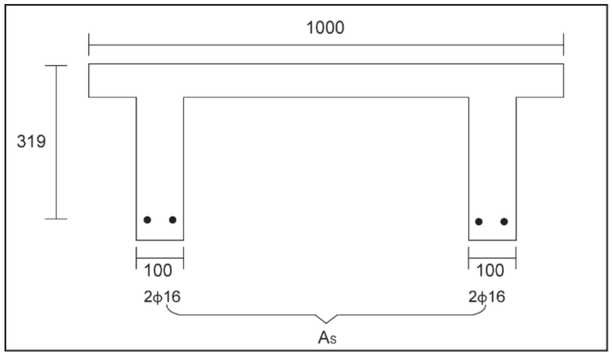


Figure 6- 14 Section S

Like in the previous revisions the following assumption is consider:

$$\xi = \frac{x}{d} \leq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} = \frac{3.5}{3.5 + 1.96} = 0.641$$

The effective width of the flange is calculated with EC2 – Expression 5.7 and figures 5.2, 5.3.

$$b_{eff} = \sum b_{eff,i} + b_w \leq i$$

Where

$$b_{eff,i} = 0.2b_i + 0.1l_0 \leq 0.2l_0$$

And

$$b_{eff,i} \leq b_i$$

The distance between ribs $i = 700\ mm$ and $l_0 = 0.85l = 9520\ mm$, the effective flange width is:

$$b_{eff,i} = 1072mm < 2240mm$$

$$b_{eff} = 2244mm > 700mm$$

The depth of the neutral axis is assumed less than the topping thickness and the reference section is b = 1000 mm, acting as a rectangular section.

$$\xi = \frac{x}{d} < \frac{t}{d} = \frac{50}{319} = 0.156$$

The translational equilibrium follows the expression:

$$0.8bxf_{cd} - A_sf_{yd} = 0$$

Where:

$$x = \frac{A_s f_{yd}}{0.8 b f_{cd}} = 27.672\ mm\ \rightarrow\ \xi = 0.086 < 0.641$$

The resistant moment of the section with the reinforcement given is obtained by the rotational equilibrium:

$$M_{Rd} = 968.023\ kNm > 305.035\ kNm$$

6.4.5 Shear Ultimate Limit State Verification

The following verification omits the solid sections at the end of the slab strip due to its large width which can stand high resistance to shear.

In the figure X the envelope of shear is shown.

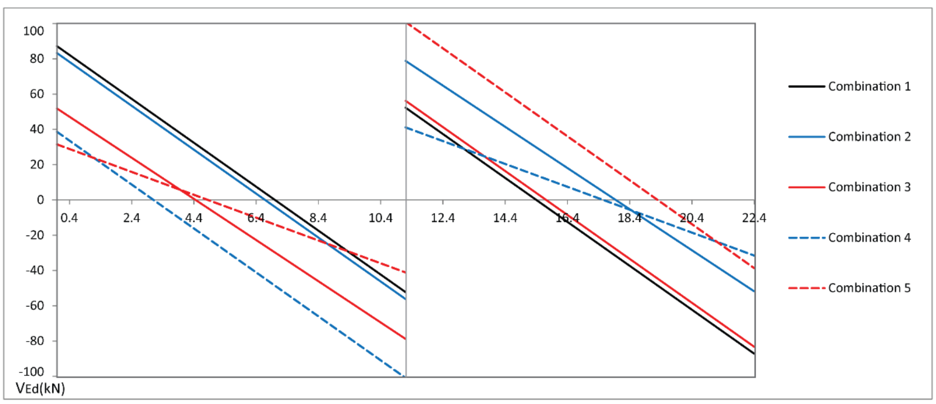


Figure 6- 15 Envelope of shear

We calculated the resistance to shear without reinforcement using [EC2 – Expression 6.2a]:

$$V_{Rd,c} = \frac{C_{Rcd}}{\gamma_c}\left[\left(1 + \sqrt{\frac{200}{d}}\right)(100\rho_1 f_{ck})^{1/3}\right] b_w d$$

Where

$$\rho_1 = \frac{A_{sl}}{bd}$$

For the zone with positive moment:

$A_{sl} = 616mm^2$ $\qquad \rho_l = 0.0096 \qquad V_{Rdc} = 39.645\ kN$

And for the negative moment zone:

$A_{sl} = 804mm^2 \qquad \rho_l = 0.0126 \quad V_{Rdc} = 43.326\ kN$

When the previous resistant shears are overlapped on the envelope we can obtain the areas where shear reinforcement is not necessary, this is observed in the center of the span.

The reinforcement propose for these section is inclined at α = 45°, thus the portion of slab interested is given by (truss system is shown in Fig.6-16):

$$\Delta x = z(cot\alpha + cot\theta) = 861.3mm$$

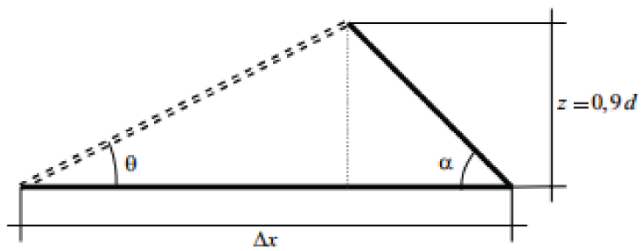


Figure 6- 16 Truss system scheme

For those areas where shear reinforcement is supply we consider 1+1ϕ12 inclined bars that provide the following shear resistance:

Applied shear near end supports:

$$V_{Rds} = \frac{A_{sw}}{\Delta x} z f_{ywd}(cot\theta + cot\alpha)sin\alpha = 159.861\ kN > V_{Ed} = 68.564\ kN$$

Applied shear near continuity support:

$$V_{Rds} = 159.861kN > V_{Ed} = 95.298kN$$

Finally the resistance to compression of the truss must be checked with [EC2 – Expression 6.14].

$$V_{Rd,max} = \alpha_{cw} b_w z v_1 f_{cd} \frac{cot\theta + cot\alpha}{1 + \cot^2\theta}$$

$$V_{Rd,max} = 308.207kN > V_{Ed}$$

6.4.6 Reinforcement arrangement

The total length of the reinforcement bars we use [EC2 – Expression 8.3] to know the basic required anchorage:

$$l_{b,rqd} = \frac{\phi}{4}\frac{\sigma_s}{f_{bd}}$$

Where:

σ_s = design stress of the bar (f_{yd})

$f_{bd} = 2.5\eta_1 \eta_2 f_{ctd}$, ultimate bond stress

η_1 = 1.0 for good bond conditions

η_2 = 1.0 for ϕ < 32 mm

f_{ctd} = 1.2 N/mm^2

$l_{b,req}$ = 506.8 mm for ϕ 14

$l_{b,req}$ = 579.2 mm for ϕ 16

From [EC2 – Expression 8.4] the design length of anchorage is:

$$l_{bd} = \alpha_1 \alpha_2 \alpha_3 \alpha_4 \alpha_5 l_{b,req}$$

Where:

α_1 = 1.0 for straight bars

α_2 = 1-0.15 $1 - 0.15 \frac{c_d - \phi}{\phi} \leq 1.0$ in tension

where: c_d = min (a/2, c, c_1)

a = max (20 mm, ϕ, d_g + 5 mm)

d_g = 20 mm

c = 24 mm

$c_1 = b_w - 2\phi - a > 23.5$ mm

α_2 = 1.0 in compression

α_3 = 1.0 if no confinement by transverse reinforcement

α_4 = 1.0 if not welded transverse bars

α_5 = 1.0 if not more evaluation of pressure

Thus:

l_{bd} = 506.8 mm for ϕ 14

l_{bd} = 579.2 mm for ϕ 16

FIG SOMETHING: REINFORCEMENT ARRANGEMENT ☹

6.4.7 Serviceability Limit State

For this evaluations we referred to [EC0 – Expression 6.14b]:

$$\Sigma_{j\geq1}G_{kj} + Q_{lk} + \Sigma_{j\geq1}\psi_{0i}Q_{ik}$$

The combinations of actions are calculated bellow. The structural analysis is done following the same procedure used in the previous sections, and just the analytical expressions will be shown.

Combination 1 (Minimum moment at the continuity support)

Permanent loads: $(G_1+G_2) = (G_1+G_2) = 5.067$ kN/m

Variable loads: $(Q_1+Q_2) = (Q_1+Q_2) = 3.739$ kN/m

For this case this loads will be applied on both spans.

The analytical expressions for moment is shown below (the beam is symmetric):

$M(x) = 39.98x - 4.40x^2$

Combination 2 (Maximum moment in the left span)

The loads are the following:

Permanent loads: $(G_1+G_2) = (G_1+G_2) = 5.067$ kN/m

Variable loads: $(Q_1+Q_2) = (Q_1+Q_2) = 3.739$ kN/m

The analytical expressions for moment is shown below:

Left span	Right span:
$M(x) = 59.44x - 4.4x^2$	$M(x) = 58.37x - 2.53x^2$

Combination 3 (Maximum moment in the left span)

This combination is symmetric to the combination 2. The values used are those calculated previously.

Combination 4 (Minimum moment at support A)

Permanent loads: $(G_1+G_2) = (G_1+G_2) = 5.067$ kN/m

Variable loads: $(Q_1+Q_2) = (Q_1+Q_2) = 3.739$ kN/m

To calculate the negative moment presented at the ends of the slab, produced by the constrain of the beams, we fix the extreme supports.

The analytical expression moment is shown below for the left span:

$M(x) = -82.20 + 27.56x - 4.40x^2$

The analytical expression moment is shown below for the right span:

$M(x) = -35.49 + 22.49x - 2.53x^2$

Combination 5 (Minimum moment at C)

This combination is symmetric to the combination 4. The values used are those calculated previously.

6.4.8 SLS Verifications: Stress limitation and crack control

The analysis will follow the same assumptions considered for the part 4.4.4 of this chapter.

Steel and concrete have elastic behavior with $\alpha_e = E_s/E_c$, this calculations are presented first: showing the mathematical expressions, in order to calculate the translational equilibrium, and then a table with the results after applying the formulas.

Example of reinforcement in the upper part.

- *Section A*

$$\frac{1}{2}\sigma_c bx - \sigma_s A_s = 0$$

$$\sigma_s = \alpha_e \sigma_c \frac{d-x}{x}$$

The rotational equilibrium about the tension barycenter is:

$$\frac{1}{2}\sigma_c bx\left(d - \frac{x}{3}\right) = M$$

The maximum stress in concrete is according with [EC2 – 7.2(2)] expression:

$$\sigma_c = \frac{2M}{bx\left(d - \frac{x}{3}\right)} < 0.6f_{ck} = 15MPa$$

The reinforcement is object of the following stress as [EC2 – 7.2(5)] requires:

$$\sigma_s = \alpha_e \sigma_c \frac{d-x}{x} < 0.8f_{yk} = 360N/mm^2$$

Bellow the verifications are shown for the important sections.

Section	M_{ED} [kNm]	A_s [mm^2]	b [mm]	x [mm]	σ_{cmax} [MPa]	< 0.6f_{ck} 15MPa	σ_s [MPa]	< 0.8f_{yk} 360N/mm^2
A	-82.200	616	1000	100.4	5.730	✓	186.953	✓
A'	-33.584	616	200	179.5	7.218	✓	84.146	✓
S	64.260	804	1000	111.7	4.080	✓	113.474	✓
B'	-81.432	804	200	194.0	14.183	✓	136.943	✓
B'	-104.160	1884	1000	153.1	5.077	✓	82.528	✓

Table 6- 10 Verification of steel reinforcement

From [EC2 – Table 7.2N] we can verify that cracks are under the limits without making direct calculation.

6.4.9 SLS verifications: Deflection

If the ratio between span and effective depth is less than [EC2 – Expression 7.16a], EC2 allows not to calculate the deflections.

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right]$$

Where:

K = 1.3 [EC2 – Table 7.4N]

ρ_0 = 0.005 ρ = 0.003

Thus

$\frac{l}{d} = 32.107$ According to [EC2 – 7.4.2(2)] this value is multiplied by 0.8 factor

$$\left(\frac{l}{d}\right)_{lim} = 25.686 < 26.018$$

The direct calculation of deflections is omitted.

6.5 Beams

6.5.1 Interior beam

The beam selected for this analysis first is located in. From the plans given in the competition we know that the beams are rectangular shape with a height equal to the slab thickness, 350 mm, and a width of 1000 mm. The loads, permanent and variable, are transferred from the slab.

6.5.1.1 Loads

Structural self-weight G_1 Other permanent loads G_2

G_1 = 52.253 kN/m G_2 = 18.688 kN/m

4.5.2 Variable loads

Live load Q_1 Inside partition self-weight Q_2

Q_1 = 49.931 kN/m Q_2 = 2.425 kN/m

As has been done for the slab analysis the combinations include the maximum moment along thee span, modeling the beam as simple support and negative moments with fixed ends.

The expression [EC0 – Expression 6.10] is used:

$$\sum_{j\geq 1} \gamma_{Gj} G_{kj} + \gamma_{Q1} Q_{k1} + \sum_{i>1} \gamma_{Qi}\, \psi_{01} \mathrm{Q}_{\mathrm{k}1}$$

6.5.1.2 Combinations

The procedure followed is the same used in the structural analysis of the slab, and the spans of it are the same with the beam ones. Below is shown and schematic drawing of the loads over the beams.

Combination 1 (Minimum moment at the continuity support)

Permanent loads: $\gamma_G(G_1+G_2)$= 1.35 (G_1+G_2)

Variable loads: $\gamma_Q(Q_1+Q_2)$= 1.5 (Q_1+Q_2)

For this case this loads will be applied on both spans.

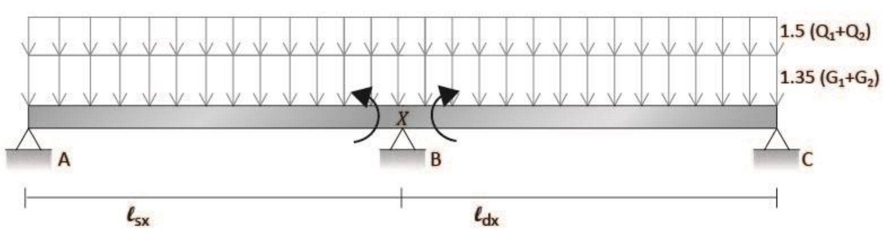


Figure 6- 17 Combination 1

The analytical expressions for shear and moment are shown below (the beam is symmetric):

$M(x) = 732.08x - 87.15x^2$

$V(x) = 732.085 - 174.306x$

Continuity moment:

$M(11.2m) = -2732.742$ kNm

$M_{max}(4.2m) = 732.08$ kNm

Combination 2 (Maximum moment in the left span)

The loads are the following:

Permanent loads: $\gamma_G(G_1+G_2) = 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2) = 1.5\ (Q_1+Q_2)$

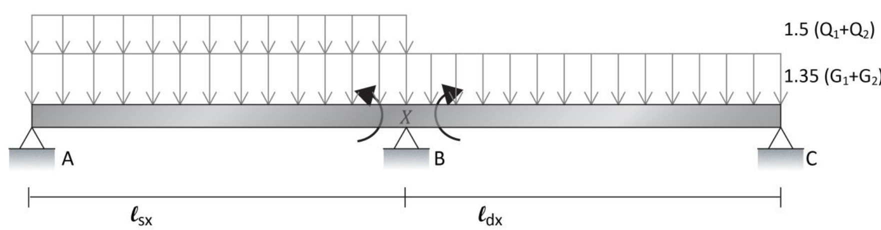


Figure 6- 18 Combination 2

The permanent loads will be applied over both spans and the left just in the left.

The analytical expressions for shear and moment are shown below (left span):

$M(x) = 787.05x - 87.15x^2$

$V(x) = 787.05 - 174.306x$

Maximum moment along the span:

$M_{max}(4.51m) = 1776.955$ kNm

For the right span:

$M(x) = 725.52x - 47.85x^2$

$V(x) = 725.52 - 95.77x$

Maximum moment along the span:

$M_{max}(7.57m) = 767.111$ kNm

Combination 3 (Maximum moment in the left span)

This combination is symmetric to the combination 2. The values used are those calculated previously.

Combination 4 (Minimum moment at support A)

To calculate the negative moment presented at the ends of the slab, produced by the constrain of the beams, we fix the extreme supports.

The loads are:

Permanent loads: $\gamma_G(G_1+G_2)= 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2)= 1.5\ (Q_1+Q_2)$

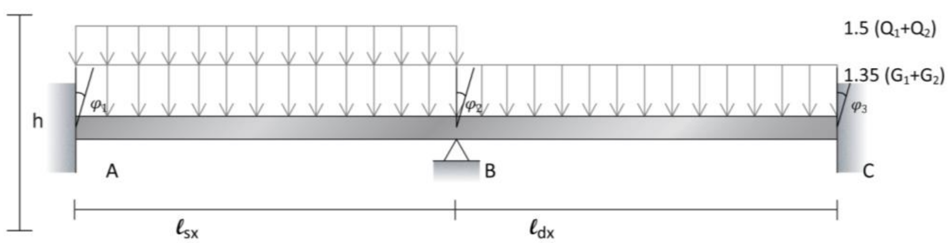


Figure 6- 19 Combination 4

The analytical expressions for shear and moment are shown below for the left span:

$M(x) = -2087.32+1047.16x - 87.153x^2$

$V(x) = 1047.16 - 174.305x$

The analytical expressions for shear and moment are shown below for the right span:

$M(x) = -437.29 + 320.99x - 39.26x^2$

$V(x) = 320.99 - 78.53x$

Combination 5 (Minimum moment at C)

This combination is symmetric to the combination 4. The values used are those calculated previously.

6.5.1.3 Envelope of moment

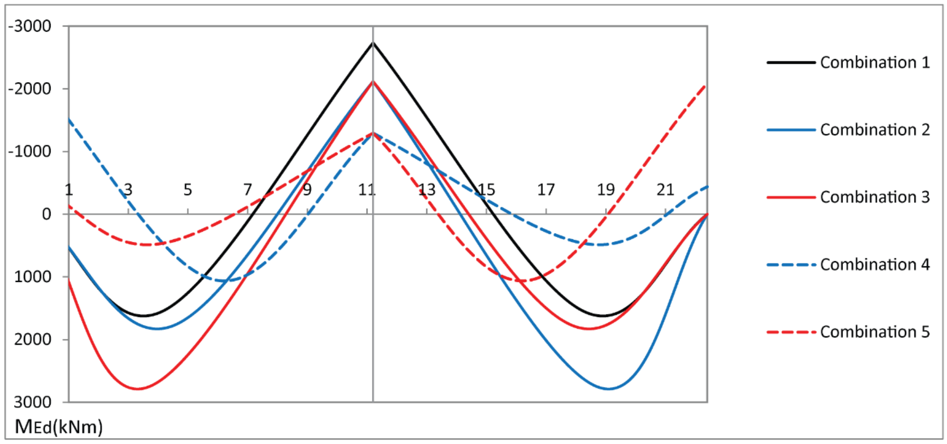


Figure 6- 20 Emvelope of moments

In the table below the significant sections and their actions are highlighted:

Section	Position [m]	M_{Ed} [kNm]
A	0	-2087.3
S	3.7	2749.8
B	11.2	-2732.8
D	18.7	2749.8
C	22.4	-2087.3

Table 6- 11 Design moment along the beam

6.5.1.4 Pre - dimensioning of reinforcement

The process and expressions used in the previous section of this chapter are the same, and the results obtained are expressed below.

Section	M_{Ed} [kNm]	b [mm]	x [mm]	x/d	$A_{s,req}$ [mm²]	b_t [mm]	$A_{s,min}$ [mm²]	ϕ	No bars	A_s [mm²]
A	-2087.3	1000	103.1	0.332	2997.645	1000	535.9591	20	10	3140
S	2749.8	1000	128.6	0.414	3737.469	1000	535.9591	20	12	3768
B	-2732.8	1000	135.6	0.437	3939.828	1000	535.9591	20	13	4082
D	2749.8	1000	128.6	0.414	3737.469	1000	535.9591	20	12	3768
C	-2087.3	1000	103.17	0.332	2997.645	1000	535.9591	20	10	3140

Table 6- 12 Pre dimension of steel reinforcement for beam

6.5.1.5 Ultimate Limit State: Bending verification

Compression steel is proposed to simplify some calculations $A'_s = 4\ \phi\ 20 = 1256\ mm^2$ for both spans.

The equation that computes the translational equilibrium is:

$$0.8bxf_{cd} + \sigma_s' A_s' - f_{yd} A_s = 0$$

$$\sigma_s' = E_s \varepsilon_{cu} \frac{x - d'}{x} \leq f_{yd}$$

Where: $d' = h - d = 40mm$

The limit of the neutral axis is given by:

$$\frac{x}{d} \leq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} = 0.641$$

$$\frac{x}{d'} \leq \frac{\varepsilon_{cu}}{\varepsilon_{cu} - \varepsilon_{yd}} = 2.273$$

Resistant moment:

$$M_{Rd} = 0.8bxf_{cd}(d - 0.4x) + \sigma_s' A_s'(d - d')$$

Below the table presents the results of these calculations:

Section	A_s [mm^2]	A'_s [mm^2]	x [mm]	x/d	σ'_s [N/mm^2]	M_{Rd} [kNm]	M_{Ed} [kNm]	M_{Rd}/M_{Ed}
A	3140	1256	73.69	0.237	231.25	3602.45	2087.32	1.73
S	3768	1256	91.88	0.296	356.07	4630.17	2749.83	1.68
B	4082	1256	96.86	0.312	390.22	4904.99	2732.80	1.79
D	3768	1256	91.88	0.296	356.07	4630.17	2749.83	1.68
C	3140	1256	73.69	0.237	231.25	3602.45	2087.32	1.73

Table 6- 13 Calculation of the resistant moments

6.5.1.6 Ultimate Limit State: Shear analysis

The envelope of shear from the structural analysis made previously on this section:

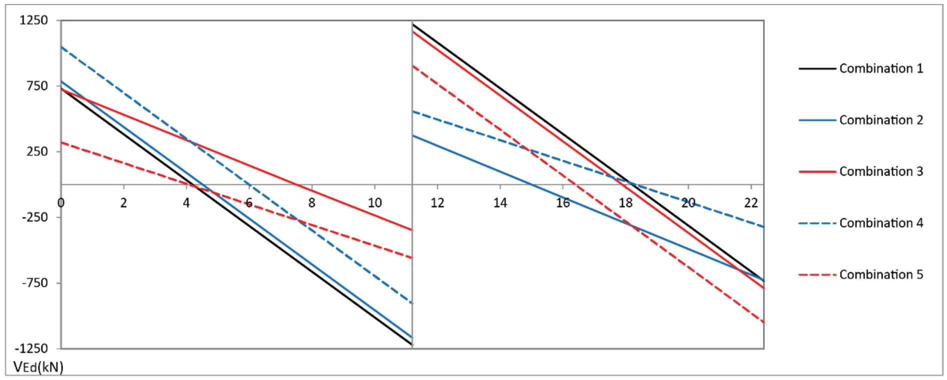


Figure 6- 21 Envelope of shear

The limits for the shear reinforcement are given in [EC2 – Expression 9.5N]

$$\rho_{sw} = \frac{A_{sw}}{b_w s} \geq 0.08 \frac{\sqrt{f_{ck}}}{f_{yk}} = 9 \cdot 10^{-4} = \rho_{sw,min}$$

[EC2 – 9.2.2(6) & Expression 9.6N] stablish the maximum spaces for longitudinal space between stirrups:

$$s_{l,max} = 0.75d(1 + cot\alpha) = 232.5mm$$

The transversal distance is limited by [EC2 – 9.2.2(8) & Expression 9.8N]:

$$s_{t,max} = 0.75d = 232.5mm < 600mm$$

For this beam we assume 10 legs of ϕ10/140 mm (after compering different values of spacing):

$$\rho_{sw} = 0.0056 > \rho_{sw,min}$$

[EC2 – Expression 6.8] defines the resistance value as:

$$V_{Rd,s} = 0.9 d b_w \rho_{sw} f_{ywd} ctg\theta = 1223.355\ kN > V_{Ed}$$

The maximum value of shear comes from the mathematical expression obtain from the structural analysis.

$$V_{Ed} = 1176.57\ kN$$

The resistance of the compression strut as [EC2 – Expression 6.9] describes is:

$$V_{Rd,max} = \alpha_{cw} b_w z v_1 f_{cd} \frac{cot\theta + cot\alpha}{1 + \cot^2\theta} = 1247.967\ kN > V_{Ed}$$

6.5.1.7 Serviceability Limit States: structural analysis

In order to evaluate the serviceability limits states the [EC2 – Expression 6.14b] gives the following combination of actions:

$$\Sigma_{j\geq 1} G_{kj} + Q_{lk} + \Sigma_{j\geq 1} \psi_{0i} Q_{ik}$$

The combinations of actions are calculated bellow. The structural analysis is done following the same procedure used in the previous sections, and just the analytical expressions will be shown.

Combination 1 (Minimum moment at the continuity support)

For this case this loads will be applied on both spans.

The analytical expressions for moment is shown below (the beam is symmetric):

$M(x) = 522.91x - 61.64x^2$

Continuity moment:

$M(11.2) = -2732.742\ kNm$

Maximum moment along the span:

$M_{max} = 1537.423\ kNm$

Combination 2 (Maximum moment in the left span)

The loads are the following:

The analytical expressions for moment is shown below:

Left span	Right span:
$M(x) = 59.44x - 4.4x^2$	$M(x) = 58.37x - 2.53x^2$
$M_{max} = 1776.955\ kNm$	$M_{max} = 767.111\ kNm$

Combination 3 (Maximum moment in the left span)

This combination is symmetric to the combination 2. The values used are those calculated previously.

Combination 4 (Minimum moment at support A)

To calculate the negative moment presented at the ends of the slab, produced by the constrain of the beams, we fix the extreme supports.

The analytical expression moment is shown below for the left span:

$M(x) = -82.20 + 27.56x - 4.40x^2$

The analytical expression moment is shown below for the right span:

$M(x) = -35.49 + 22.49x - 2.53x^2$

Combination 5 (Minimum moment at C)

This combination is symmetric to the combination 4. The values used are those calculated previously.

6.5.1.8 SLS: Tension Limitation and Crack control

As the beam has reinforcement at the top and the bottom, the equation for translational equilibrium is:

$$\frac{1}{2}\sigma_c bx + \sigma_s' A_s' - A_s\sigma_s = 0$$

The ratio stress/strain between concrete and steel is:

$$\sigma_s = \alpha_e\sigma_c\frac{d-x}{x}$$

$$\sigma_s' = \alpha_e\sigma_c\frac{x-d'}{x}$$

Thus:

$$b\frac{x^2}{2} + \alpha_e(A_s - A_s')x - \alpha_e(A_s d + A_s' d') = 0$$

From where we obtained the value of the neutral axis.

The following expression is the moment of inertia of the cracked section:

$$I_{ci}^* = b\frac{x^3}{3} + \alpha_e A_s(d-x)^2 + \alpha_e A_s'(x-d')^2$$

Maximum compression in concrete:

$$\sigma_c = \frac{M}{I_{ci}^*}x$$

The maximum stress in concrete is according with [EC2 – 7.2(2)] expression:

$$\sigma_c = \frac{2M}{bx\left(d - \frac{x}{3}\right)} < 0.6f_{ck} = 15MPa$$

The reinforcement is object of the following stress as [EC2 – 7.2(5)] requires:

$$\sigma_s = \alpha_e \sigma_c \frac{d-x}{x} < 0.8 f_{yk} = 360N/mm^2$$

Bellow the verifications are shown for the important sections.

Section	M_{ED} [kNm]	A_s [mm²]	A'_s [mm²]	x [mm]	σ_{cmax} [MPa]	$<\sigma_{cadm}$ 15MPa	σ_s [MPa]	$<\sigma_{cadm}$ 360MPa	σ'_s [MPa]
A	-1490.94	3140	1256	34.0	14.07	✔	171.38	✔	37.20
S	1281.62	3768	1256	36.0	10.83	✔	123.67	✔	18.02
B	-1875.53	4082	1256	36.9	15.11	✔	167.63	✔	18.89
D	1281.62	3768	1256	36.0	10.83	✔	123.67	✔	18.02
C	-1490.94	3140	1256	34.0	14.07	✔	171.38	✔	37.20

Table 6- 14 Tension and crack verification

From [EC2 – Table 7.2N] we can verify that cracks are under the limits without making direct calculation.

5.5.1.9 SLS: Deflection

If the ratio between span and effective depth is less than [EC2 – Expression 7.16a], EC2 allows not to calculate the deflections.

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right]$$

Where:

K = 1.3 [EC2 – Table 7.4N]

ρ_0 = 0.005 ρ = 0.003

Thus

$\frac{l}{d} = 24$

According to [EC2 – Expression 7.17]:

$$\frac{\sigma_s}{310} = \frac{500 A_{s,prov}}{f_{yk} A_{s,req}} = 1.120$$

$$\left(\frac{l}{d}\right)_{lim} = 24.2 < 24$$

The direct calculation of deflections is omitted.

6.5.1.10 Punching verification

First we calculate the effective depth:

$$d = \frac{d_y + d_z}{2}$$

Where:

d_y = effective depth in beam direction

d_z = effective depth in slab direction

$$d = 314.5\ mm$$

The area susceptible to fail due to punching is defined by the control perimeter u_l, considered at a distance twice d (Fig XX).

$$u_1 = [2 * (500 + 500) + 2\pi * 314.5] = 5952.123\ mm$$

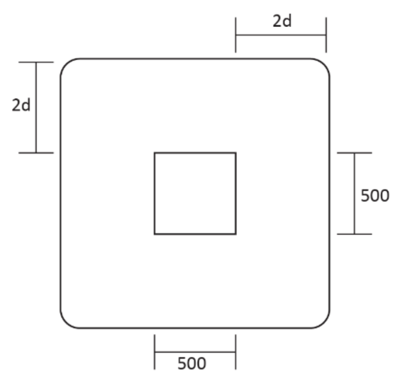


Figure 6- 22 Control perimeter

The design shear value:

For the end in internal column $$v_{E,d} = \frac{V_{Ed}}{u_1 d} = 0.66 \frac{N}{mm^2}$$

For the end in external column $$v_{E,d} = \frac{V_{Ed}}{u_1 d} = 0.56 \frac{N}{mm^2}$$

The shear at the perimeter is given by [EC2 – 6.4.5(3)]:

$$v_{Ed} = \frac{V_{Ed}}{u_0 d}$$

For the end in internal column $$v_{Ed} = \frac{V_{Ed}}{u_0 d} = 1.96 \frac{N}{mm^2}$$

For the end in external column $$v_{Ed} = \frac{V_{Ed}}{u_0 d} = 2.25 \frac{N}{mm^2}$$

$u_0 = 2000\ mm$

This value of design must be lower than the resistance shear of the member in order to satisfy the basic perimeter performance:

$$v_{Rd,max}x = 0.5\nu f_{cd} = 4.47\frac{N}{mm^2} > v_{E,d}$$

The punching resistance is calculated with [EC2 – Expression 6.47]

$$v_{Rd,c} = \frac{0.18}{\gamma_c}\left(1 + \sqrt{\frac{200}{d}}\right)(100\rho_1 f_{ck})^{\frac{1}{3}}$$

Where:

$\rho_1 = \sqrt{\rho_y \rho_z}$

$\rho_y =$ Reinforcement ratio in the beam direction

$\rho_z =$ Reinforcement ratio in the slab direction

For internal column:

$\rho_y = 0.013$

$\rho_z = 0.003$

$\rho_1 = 0.0072$

$$v_{Rd,c} = 0.567\frac{N}{mm^2} < v_{Ed} = 1.968\frac{N}{mm^2}$$

It is necessary to provide reinforcement, [EC2 – 6.4.5(1)] assumes $d/s_r = 0.67$.

The required steel area is:

$$A_{sw} = \frac{(v_{Ed} - 0.75v_{Rdc})u_1 d}{1.5 \cdot 0.67 sin\alpha f_{ywd,ef}} = 859.97mm^2$$

The proposed stirrups are: 3ϕ20

$$A_{sw} = 942mm^2$$

For external column:

$\rho_y = 0.010$

$\rho_z = 0.004$

$\rho_1 = 0.0064$

$$v_{Rd,c} = 0.551 \frac{N}{mm^2} < v_{Ed} = 2.25 \frac{N}{mm^2}$$

It is necessary to provide reinforcement, [EC2 – 6.4.5(1)] assumes $d/s_r = 0.67$.

The required steel area is:

$$A_{sw} = \frac{(v_{Ed} - 0.75 v_{Rdc}) u_1 d}{1.5 \cdot 0.67 sin\alpha f_{ywd,ef}} = 996.35 mm^2$$

The proposed stirrups are: 4ϕ20

$$A_{sw} = 1256 mm^2$$

6.5.2 Edge Beam

The procedure of the edge beam is the same followed in the interior beam, the important factor to consider is that the only loads considered are those from façade elements.

The beam selected for this analysis first is located in between the columns E-10 and E-11, plans are at the end of this chapter. From the plans given in the competition we know that the beams are rectangular shape with a height equal to the slab thickness, 350 mm, and a width of 1000 mm. The loads, permanent and variable, are transferred from the slab.

6.5.2.1 Permanent loads

Structural self-weight G_1

$G_1 = 4.34$ kN/m

6.5.2.2 Pre - dimensioning of reinforcement

The process and expressions used in the previous section of this chapter are the same, and the results obtained are expressed below.

Section	M_{Ed} [kNm]	b [mm]	x [mm]	x/d	$A_{s,req}$ [mm^2]	b_t [mm]	$A_{s,min}$ [mm^2]	ϕ	No bars	A_s [mm^2]
A	-626.196	400	82.540	0.266	959.246	400	214.383	20	4	1256
S	824.951	400	102.912	0.331	1195.99	400	214.383	20	4	1256
B	-819.84	400	108.484	0.349	1260.745	400	214.383	20	5	1570
D	824.951	400	102.912	0.331	1195.99	400	214.383	20	4	1256
C	-626.196	400	82.540	0.266	959.246	400	214.383	20	4	1256

Table 6- 15 Pre dimesioning of steel reinforcement for edge beam

6.5.2.3 Ultimate Limit State: Bending verification

Below the table presents the results of the calculations:

Section	A_s [mm^2]	A'_s [mm^2]	x [mm]	x/d	σ'_s [N/mm^2]	M_{Rd} [kNm]	M_{Ed} [kNm]	M_{Rd}/M_{Ed}
A	1256	1256	58.957	0.190	130.102	1371.583	626.196	2.19
S	1256	1256	73.508	0.237	229.960	1795.806	824.951	2.18
B	1570	1256	77.488	0.249	257.274	1909.831	819.842	2.33
D	1256	1256	73.508	0.237	229.960	1795.806	824.951	2.18
C	1256	1256	58.957	0.190	130.102	1371.583	626.196	2.19

Table 6- 16 ULS verification

6.5.2.4 Ultimate Limit State: Shear analysis

The limits for the shear reinforcement are given in [EC2 – Expression 9.5N]

$$\rho_{sw} = \frac{A_{sw}}{b_w s} \geq 0.08\frac{\sqrt{f_{ck}}}{f_{yk}} = 9 \cdot 10^{-4} = \rho_{sw,min}$$

[EC2 – 9.2.2(6) & Expression 9.6N] stablish the maximum spaces for longitudinal space between stirrups:

$$s_{l,max} = 0.75d(1 + cot\alpha) = 232.5mm$$

The transversal distance is limited by [EC2 – 9.2.2(8) & Expression 9.8N]:

$$s_{t,max} = 0.75d = 232.5mm < 600mm$$

For this beam we assume 10 legs of ϕ10/140 mm (after compering different values of spacing):

$$\rho_{sw} = 0.0056 > \rho_{sw,min}$$

[EC2 – Expression 6.8] defines the resistance value as:

$$V_{Rd,s} = 0.9 d b_w \rho_{sw} f_{ywd} ctg\theta = 1223.355\ kN > V_{Ed}$$

The maximum value of shear comes from the mathematical expression obtain from the structural analysis.

$$V_{Ed} = 1176.57\ kN$$

The resistance of the compression strut as [EC2 – Expression 6.9] describes is:

$$V_{Rd,max} = \alpha_{cw} b_w z v_1 f_{cd} \frac{cot\theta + cot\alpha}{1 + \cot^2\theta} = 1247.967\ kN > V_{Ed}$$

6.5.2.5 Serviceability Limit States

Bellow the verifications are shown for the important sections.

Section	M_{ED} [kNm]	A_s [mm²]	A'_s [mm²]	x [mm]	σ_{cmax} [MPa]	$<\sigma_{cadm}$ 15MPa	σ_s [MPa]	$<\sigma_{cadm}$ 360MPa	σ'_s [MPa]
A	-1490.94	3140	1256	34.0	14.07	✓	171.38	✓	37.20
S	1281.62	3768	1256	36.0	10.83	✓	123.67	✓	18.02
B	-1875.53	4082	1256	36.9	15.11	✓	167.63	✓	18.89
D	1281.62	3768	1256	36.0	10.83	✓	123.67	✓	18.02
C	-1490.94	3140	1256	34.0	14.07	✓	171.38	✓	37.20

Table 6- 17 SLS verification

From [EC2 – Table 7.2N] we can verify that cracks are under the limits without making direct calculation.

6.5.2.6 SLS: Deflection

If the ratio between span and effective depth is less than [EC2 – Expression 7.16a], EC2 allows not to calculate the deflections.

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right]$$

Where:

K = 1.3 [EC2 – Table 7.4N]

$\rho_0 = 0.005$ $\rho = 0.003$

Thus

$\frac{l}{d} = 24$

According to [EC2 – Expression 7.17]:

$$\frac{\sigma_s}{310} = \frac{500A_{s,prov}}{f_{yk}A_{s,req}} = 1.120$$

$$\left(\frac{l}{d}\right)_{lim} = 24.2 < 24$$

The direct calculation of deflections is omitted.

6.6 Columns

6.6.1 Border Column

The interior column studied in this chapter is located in D-5, where just axial forces are considered. As was mention in the introduction, the competition brief stablishes dimensions for the structural members, the main purpose of the following calculations is to corroborate the resistance of the concrete section and calculate de proper steel reinforcement for the actions applied.

6.6.1.1 Pre-dimensioning

The influence area over the column is:

$8.3 * 11.2 = 92.96\ m^2$

a coefficient of 1.4 is used

$92.96 * 1.4 = 130.144\ m^2$

Loads

A reduction factor defined by [EC1 – 16.3.2(10)] can be applied to the calculation of columns:

$$\alpha_A = \frac{5}{7}\psi_0 + \frac{A_0}{A} \leq 1.0$$

Where $\psi_0 = 0.7$

$A_0 = 10\ m^2$

$A = influence\ area\ of\ the\ column$

$$\alpha_A = 0.576$$

The loads after the reduction factor:

	Roof loads	Typical floor loads
Permanent	928.908 kN	497.703 kN
Variable	94.726 kN	197.256 kN

For the Ultimate Limit State combination of actions a factor γ_F is obtained from γ_G and γ_Q:

$$\gamma_F^* = \frac{\gamma_G G_k + \gamma_Q Q_k}{G_k + Q_k} = 1.392$$

The next table computes the pre-dimensioning of the geometry. F_k represent the axial load on each floor, N is the sum of the axial loads, and the next column is the result of the previous force multiplied by the factor calculated before. In order to estimate the necessary concrete area the axial force is divided by the compression strength of the concrete. We use the section given by the project and is compared with the section area needed.

Column	F_k [kN]	$N=\Sigma F_{kj}$ [kN]	$N_{Ed}=\gamma_F$*N [kN]	$A_{c0}=N_{Ed}/f_{cd}$ [mm^2]	bxh [mm]	A_c [mm^2]
1° Floor	1023.63	1023.635	1425.489	100386.5	500x500	250000
Ground F	694.96	1718.595	2393.273	168540.4	500x500	250000
Basement	694.96	2413.555	3361.058	236694.2	500x500	250000

Table 6- 18 Axial load resistance of concrete section

The weight of the column is shown below:

Column self-weight	
1° Floor	18.75 kN
Ground floor	18.75 kN
Basement	18.75 kN

Table 6- 19 Columns sel-weight

Considering these extra loads the table below is updated to consider the columns action.

Column	F_k [kN]	$N=\Sigma F_{kj}$ [kN]	$N_{Ed}=\gamma_F$*N [kN]	$A_{c0}=N_{Ed}/f_{cd}$ [mm^2]	bxh [mm]	A_c [mm^2]
1° Floor	1042.385	1042.385	1451.6	102225.3	500x500	250000
Ground F	713.710	1756.095	2445.4	172218	500x500	250000
Basement	713.710	2469.805	3439.3	242210.6	500x500	250000

Table 6- 20 Total axial loads

6.6.1.2 Reinforcement pre-dimensioning

[EC2] stablish the following rules for minimum and maximum amounts of reinforcement to use in columns:

- a minimum of four bars is required in a rectangular column, in each corner, and de diameter should not be less than 12 mm.

- the minimum area of steel follows the expression:

$$A_s \geq 0.003A_c$$

- the maximum area of steel is:

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

From the rules listed above, we propose the pre-dimensioning shown in the table:

Column	A_c [mm²]	$A_{s\ min}$ ρ_s=0.3% [mm²]	$A_{s\ min}$ [mm²]	4ϕ12 [mm²]	n°xϕ	A_s [mm²]
1° Floor	250000	750	371.25	452	4ϕ16	804
Ground F	250000	750	625.44	452	4ϕ16	804
Basement	250000	750	879.63	452	4ϕ20	1256

Table 6- 21 Pre dimensioning of steel reinforcement for axial loads

6.6.1.3 Serviceability Limit State Verification

The translational equilibrium is defined by:

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

Assuming that the strain in steel and concrete is equal and reminds elastic the ratio between the modulus of elasticity of both materials α_e = 15, thus $\sigma_s = \alpha_e \sigma_c$, the equation is modified as follows:

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

The stress on the concrete should be:

$$\sigma_c = \frac{N}{A_{ie}} \leq \sigma_{c\ adm} = 0.6f_{ck} = 15\ N/mm^2$$

The table contents the SLS revision.

Column	A_c [mm²]	A_s [mm²]	A_{ie} [mm²]	N [kN]	σ_c [N/mm²]	<σ_{cadm}
1° Floor	250000	804	262060	848.13	3.236	✓
Ground F	250000	804	262060	1572.35	5.999	✓
Basement	250000	1256	268840	2296.57	8.542	✓

Table 6- 22 SLS revision

6.6.1.4 Ultimate Limit State Revision

The equation of translational equilibrium is:

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

The table shows the ULS revision.

Column	A_c [mm²]	A_s [mm²]	N_{Ed} [kN]	N_{Rd} [kN]	N_{Rd}/N_{Ed}
1° Floor	250000	804	1182.44	3864.36	3.268
Ground F	250000	804	2192.14	3864.36	1.762
Basement	250000	1256	3201.83	4041.09	1.262

Table 6- 23 ULS revision

6.6.2 Exterior Column

The exterior column studied in this chapter is E-5, where axial forces are considered and the existence of eccentric loads creates a bending moment. As was mention in the introduction, the competition brief stablishes dimensions for the structural members, the main purpose of the following calculations is to corroborate the resistance of the concrete section and calculate de proper steel reinforcement for the actions applied.

6.6.2.1 Pre-dimensioning

The influence area over the column is:

$4.6 * 11.2 = 51.52\ m^2$

a coefficient of 1.0 is used

Loads

A reduction factor defined by [EC1 – 16.3.2(10)] can be applied to the calculation of columns:

$$\alpha_A = \frac{5}{7}\psi_0 + \frac{A_0}{A} \leq 1.0$$

Where $\psi_0 = 0.7$

$A_0 = 10\ m^2$

$A = influence\ area\ of\ the\ column$

$$\alpha_A = 0.576$$

The loads after the reduction factor:

	Roof loads	Typical floor loads
Permanent	525.765 kN	280.516 kN
Variable	52.498 kN	131.546 kN

For the Ultimate Limit State combination of actions a factor γ_F is obtained from γ_G and γ_Q:

$$\gamma_F^* = \frac{\gamma_G G_k + \gamma_Q Q_k}{G_k + Q_k} = 1.397$$

The next table computes the pre-dimensioning of the geometry. F_k represent the axial load on each floor, N is the sum of the axial loads, and the next column is the result of the previous force multiplied by the factor calculated before. In order to estimate the necessary concrete area the axial force is divided by the compression strength of the concrete. We use the section given by the project and is compared with the section area needed.

Column	F_k [kN]	$N=\Sigma F_{kj}$ [kN]	$N_{Ed}= \gamma_F$*N [kN]	$A_{c0}=N_{Ed}/f_{cd}$ [mm^2]	bxh [mm]	A_c [mm^2]
1° Floor	578.265	578.265	808.348	56925.91	500x500	250000
Ground F	412.063	990.327	1384.365	97490.47	500x500	250000
Basement	412.063	1402.390	1960.382	138055	500x500	250000

Table 6- 24 Pre dimensioning of edge column

The weight of the column is shown below:

Column self-weight	
1° Floor	18.75 kN
Ground floor	18.75 kN
Basement	18.75 kN

Table 6- 25 Self-weight of column

Considering these extra loads' the table below considers the columns action.

Column	F_k [kN]	$N=\Sigma F_{kj}$ [kN]	$N_{Ed}= \gamma_F$*N [kN]	$A_{c0}=N_{Ed}/f_{cd}$ [mm^2]	bxh [mm]	A_c [mm^2]
1° Floor	597.015	597.015	834.558	58771.714	500x500	250000
Ground F	430.813	1027.827	1436.785	101182.075	500x500	250000
Basement	430.813	1458.640	2039.013	143592.435	500x500	250000

Table 6- 26 Total axial load on edge column

6.6.2.2 Reinforcement Pre-dimensioning

[EC2] stablish the following rules for minimum and maximum amounts of reinforcement to use in columns:

- a minimum of four bars is required in a rectangular column, in each corner, and de diameter should not be less than 12 mm.

- the minimum area of steel follows the expression:

$$A_s \geq 0.003A_c$$

- the maximum area of steel is:

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

From the rules listed above, we propose the pre-dimensioning shown in table:

Column	A_c [mm^2]	$A_{s\,min}$ ρ_s=0.3% [mm^2]	$A_{s\,min}$ [mm^2]	4ϕ12 [mm^2]	n°xϕ	A_s [mm^2]
1° Floor	250000	750	213.442	452	4ϕ16	804
Ground F	250000	750	367.464	452	4ϕ16	804
Basement	250000	750	521.487	452	4ϕ20	1256

Table 6- 27 Pre dimension of steel reinforcemetn

6.6.2.3 Serviceability Limit State Verification

The translational equilibrium is defined by:

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

Assuming that the strain in steel and concrete is equal and reminds elastic the ratio between the modulus of elasticity of both materials α_e = 15, thus $\sigma_s = \alpha_e \sigma_c$, the equation is modified as follows:

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

The stress on the concrete should be:

$$\sigma_c = \frac{N}{A_{ie}} \leq \sigma_{c\,adm} = 0.6f_{ck} = 15\,N/mm^2$$

The table contents the SLS revision.

Column	A_c [mm^2]	A_s [mm^2]	A_{ie} [mm^2]	N [kN]	σ_c [N/mm^2]	<σ_{cadm}
1° Floor	250000	804	262060	848.135	3.236	✔
Ground F	250000	804	262060	1572.355	6.000	✔
Basement	250000	804	262060	2296.575	8.764	✔

Table 6- 28 SLS Revision of edge column

6.6.2.4 Ultimate Limit State Revision

The equation of translational equilibrium is:

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

The table contents the ULS revision.

Column	A_c [mm²]	A_s [mm²]	N_{Ed} [kN]	N_{Rd} [kN]	N_{Rd}/N_{Ed}
1st Floor	250000	804	1182.449	3864.364	3.268
Ground F	250000	804	2192.140	3864.364	1.762
Basement	250000	804	3201.831	3864.364	1.206

Table 6- 29 ULS rvision of edge column

6.6.2.5 Second Order Effects

According to [EC2 – 5.8.3.3] the global second effects in a building may be ignored if [EC2 - 5.8.3.3 Expression (5.18)] is satisfied:

$$F_{V,Ed} \leq k_1 \frac{n_s}{n_s + 1.6} \frac{\sum E_{cd} I_c}{L^2}$$

Where:

$F_{V,Ed}$ total vertical load

n_s number of storey

L total height

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

I_c second moment of area of bracing members

k_1 0.31 is recommended

This expression is valid if:

- Torsional instability is not governing
- Global shear deformations are negligible
- Bracing members are fixed at base
- Stiffness is constant along the height the loads increase by the same amount per storey

Thus:

$$k_1 \frac{n_s}{n_s + 1.6} \frac{\sum E_{cd} I_c}{L^2} = 986270 \ kN \gg F_{V,Ed} = 85401.41 \ kN$$

And second order effects can be ignored.

6.6.2.6 Effects of Beams

- Structural analysis

A simplified scheme is used in order to calculate the axial loads and bending moments acting on the columns. The horizontal displacements are considered neglectable.

The stiffness of the structural elements are:

Column	$I_c = 5.21 \cdot 10^9$	
Beam	$I_b = 2.57 \cdot 10^9$	$0.686\ I_c$
Wall	$I_w = 1.24 \cdot 10^{10}$	$2.376\ I_c$

The loads acting on the structure are:

Location	Type	Load [kN/m]	Partial factor	Load ULS [kN/m]
Green roof	Gr	32.32	1.35	33.944
Structural s-w	G1	24.22	1.35	32.709
Other permanent	G2	11.03	1.35	14.902
Imposed Variable	Q1	14.774	1.5	22.161
Inside partitions	Q2	4.15	1.5	6.225

Table 6- 30 Loads acting on the column for secon order effect calculations

The combination selected is:

Permanent loads: $\gamma_G(G_1+G_2)= 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2)= 1.5\ (Q_1+Q_2)$

On both spans, on every storey.

A diagram of the combinations is presented next:

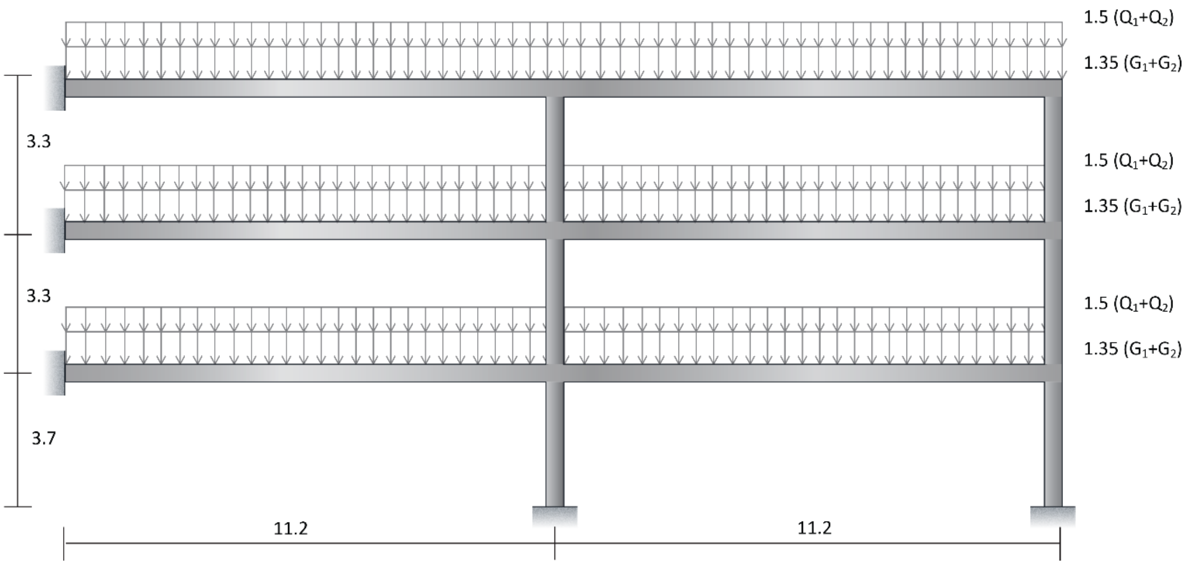


Figure 6- 23 Combination of actions

Verifications

USL verification

We make the same assumptions made before for previous analysis.

-We consider that in the section the concrete is broken in compression reaching ultimate strain, the steel behaves is yielded in top and bottom.

The neutral axis X is calculated from the translational equilibrium.

$$0.8bxf_{cd} + f_{yd}A_s' - f_{yd}A_s = N_{Ed}$$

The rotational equilibrium about the barycentre of gross area defines the value of the resisting moment of the member.

$$0.8bxf_{cd}(0.5h - 0.4x) + f_{yd}A_s'(0.5h - d') - f_{yd}A_s(d - 0.5h) = M_{Rd}$$

-For the section where the concrete is broken in compression reaching ultimate strain, the steel behaves elastic in top and is yielded in bottom.

The translational equilibrium is:

$$0.8bxf_{cd} + \sigma_s' A_s' - f_{yd}A_s = N_{Ed}$$

$$\sigma_s' = E_s \varepsilon_{cu} \frac{x - d'}{x}$$

The rotational equilibrium:

$$0.8bxf_{cd}(0.5h - 0.4x) + \sigma_s' A_s'(0.5h - d') - f_{yd}A_s(d - 0.5h) = M_{Rd}$$

- For the section where the concrete is broken in compression reaching ultimate strain, the steel behaves yielded in top and is elastic in bottom.

$$0.8bxf_{cd} + f_{yd}A_s' - \sigma_s' A_s = N_{Ed}$$

$$\sigma_s' = E_s \varepsilon_{cu} \frac{d - x}{x}$$

The rotational equilibrium:

$$0.8bxf_{cd}(0.5h - 0.4x) + f_{yd}A_s'(0.5h - d') - \sigma_s' A_s(d - 0.5h) = M_{Rd}$$

The inferior reinforcement is yielded if:

$$x \geq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} d = 294.86\ mm$$

And superior reinforcement is yielded if:

$$x \geq \frac{\varepsilon_{cu}}{\varepsilon_{cu} - \varepsilon_{yd}} d' = 90.92\ mm$$

$e_0 = 20\ mm$

Column	N_{Ed} [kN]	M_{Ed} [kNm]	$N_{Ed}xe_o$ [kNm]	X [mm]	M_{Rd} [kNm]
1st Floor	444.87	16.32	8.897	39.161	32.476
Ground Floor	834.34	14.55	16.686	73.445	61.214
Basement	1200.15	22.44	24.003	105.647	71.483

Table 6- 31 ULS verification for bending moment on edge column

SLS verification

The stresses in the materials can be calculated with the following expressions:

$$\sigma_c = \frac{N_{Ed}}{\frac{bx^2}{2} + \alpha_e A_s'(x - d') - \alpha_e A_s(d - x)} x$$

$$\sigma_s = \alpha_e \sigma_c \frac{d - x}{x}$$

$$\sigma_s' = \alpha_e \sigma_c \frac{x - d'}{x}$$

We use $\sigma_c = 15$, as the ratio between the modulus of elasticity of steel and concrete.

Column	N_{Ed} [kN]	M_{Ed} [kNm]	e=M/N	x [mm]	σ_c [N/mm^2]	σ_s [N/mm^2]	σ'_s [N/mm^2]
1st Floor	342.20	12.55	36.6	30.1	3.955	36.687	38.901
Ground Floor	641.80	11.19	17.4	32.5	8.143	106.785	111.020
Basement	923.19	17.26	18.6	37.5	13.928	156.545	161.092

Table 6- 32 SLS on edge column from bending moment actions

6.6.3 Corner Column

The corner column studied in this section is E-4, where axial forces are considered and the existence of eccentric loads creates a bending moment, these loads are in both directions X and Y, thus the flexural moment must be considered in both. As was mention in the introduction, the competition brief stablishes dimensions for the structural members, the main purpose of the following calculations is to corroborate the resistance of the concrete section and calculate de proper steel reinforcement for the actions applied.

6.6.3.1 Pre-dimensioning

The influence area over the column is:

$4.6 * 5.6 = 25.76\ m^2$

a coefficient of 1.0 is used

Loads

A reduction factor defined by [EC1 – 16.3.2(10)] can be applied to the calculation of columns:

$$\alpha_A = \frac{5}{7}\psi_0 + \frac{A_0}{A} \leq 1.0$$

Where $\psi_0 = 0.7$

$A_0 = 10\ m^2$

$A = influence\ area\ of\ the\ column$

$$\alpha_A = 0.888$$

The loads after the reduction factor:

	Roof loads	Typical floor loads
Permanent	325.095 kN	145.508 kN
Variable	26.249 kN	84.166 kN

For the Ultimate Limit State combination of actions a factor γ_F is obtained from γ_G and γ_Q:

$$\gamma_F^* = \frac{\gamma_G G_k + \gamma_Q Q_k}{G_k + Q_k} = 1.404$$

The next table computes the pre-dimensioning of the geometry. F_k represent the axial load on each floor, N is the sum of the axial loads, and the next column is the result of the previous force multiplied by the factor calculated before. In order to estimate the necessary concrete area the axial force is divided by the compression strength of the concrete. We use the section given by the project and is compared with the section area needed.

Column	F_k [kN]	$N=\Sigma F_{kj}$ [kN]	$N_{Ed}= \gamma_F*N$ [kN]	$A_{c0}=N_{Ed}/f_{cd}$ [mm²]	bxh [mm]	A_c [mm²]
1° Floor	351.344	351.344	493.628	34762.57	500x500	250000
Ground F	229.674	581.019	816.313	57486.89	500x500	250000
Basement	229.674	810.693	1138.99	80211.21	500x500	250000

Table 6- 33 Pre dimension of the cross section of the column

The weight of the column is shown below:

Column self-weight	
1° Floor	18.75 kN
Ground floor	18.75 kN
Basement	18.75 kN

Table 6- 34 Self-weight of corner column

Considering these extra loads the table below is updated to consider the columns action.

Column	F_k [kN]	$N=\Sigma F_{kj}$ [kN]	$N_{Ed}= \gamma_F*N$ [kN]	$A_{c0}=N_{Ed}/f_{cd}$ [mm²]	bxh [mm]	A_c [mm²]
1° Floor	370.094	370.094	519.971	36617.73	500x500	250000
Ground F	248.424	618.519	869.000	61197.19	500x500	250000
Basement	248.424	866.943	1218.029	85776.66	500x500	250000

Table 6- 35 Cross section after considering self-weight

6.6.3.2 Reinforcement Pre-dimensioning

[EC2] stablish the following rules for minimum and maximum amounts of reinforcement to use in columns:

- a minimum of four bars is required in a rectangular column, in each corner, and de diameter should not be less than 12 mm.

- the minimum area of steel follows the expression:

$$A_s \geq 0.003A_c$$

- the maximum area of steel is:

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

From the rules listed above, we propose the pre-dimensioning shown in the table:

Column	A_c [mm^2]	$A_{s\,min}$ ρ_s=0.3% [mm^2]	$A_{s\,min}$ [mm^2]	4ϕ12 [mm^2]	n°xϕ	A_s [mm^2]
1° Floor	250000	750	132.985	452	4ϕ16	804
Ground F	250000	750	222.250	452	4ϕ16	804
Basement	250000	750	311.516	452	4ϕ16	804

Table 6- 36 Pre dimension of steel reinforcement for axial load of corner column

6.6.3.3 Serviceability Limit State Verification

The translational equilibrium is defined by:

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

Assuming that the strain in steel and concrete is equal and reminds elastic the ratio between the modulus of elasticity of both materials α_e = 15, thus $\sigma_s = \alpha_e \sigma_c$, the equation is modified as follows:

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

The stress on the concrete should be:

$$\sigma_c = \frac{N}{A_{ie}} \leq \sigma_{c\,adm} = 0.6f_{ck} = 15\ N/mm^2$$

The table contents the SLS revision.

Column	A_c [mm^2]	A_s [mm^2]	A_{ie} [mm^2]	N [kN]	σ_c [N/mm^2]	$<\sigma_{cadm}$
1° Floor	250000	804	262060	848.135	3.236	✓
Ground F	250000	804	262060	1572.355	6.000	✓
Basement	250000	804	262060	2296.575	8.764	✓

Table 6- 37 SLS revision for corner column

6.6.3.4 Ultimate Limit State Revision

The equation of translational equilibrium is:

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

The table contents the ULS revision.

Column	A_c [mm^2]	A_s [mm^2]	N_{Ed} [kN]	N_{Rd} [kN]	N_{Rd}/N_{Ed}
1st Floor	250000	804	1182.449	3864.364	3.268
Ground F	250000	804	2192.140	3864.364	1.762
Basement	250000	804	3201.831	3864.364	1.206

Table 6- 38 ULS revison of corner column

6.6.3.5 Second Order Effects

According to [EC2 – 5.8.3.3] the global second effects in a building may be ignored if [EC2 - 5.8.3.3 Expression (5.18)] is satisfied:

$$F_{V,Ed} \leq k_1 \frac{n_s}{n_s + 1.6} \frac{\sum E_{cd} I_c}{L^2}$$

Where:

$F_{V,Ed}$ total vertical load

n_s number of storey

L total height

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

I_c second moment of area of bracing members

k_1 0.31 is recommended

This expression is valid if:

- Torsional instability is not governing

- Global shear deformations are negligible
- Bracing members are fixed at base
- Stiffness is constant along the height the loads increase by the same amount per story

Thus:

$$k_1 \frac{n_s}{n_s + 1.6} \frac{\sum E_{cd} I_c}{L^2} = 986270\ kN \gg F_{V,Ed} = 85401.41\ kN$$

And second order effects can be ignored.

6.6.3.6 Effects of Beams (X direction)

- *Structural analysis*

A simplified scheme is used in order to calculate the axial loads and bending moments acting on the columns. The horizontal displacements are considered neglectable.

The stiffness of the structural elements are:

Column $I_c = 5.21 \cdot 10^9$

Beam $I_b = 2.57 \cdot 10^9$ $0.686\ I_c$

Wall $I_w = 1.24 \cdot 10^{10}$ $2.376\ I_c$

The loads acting on the structure are:

Location	Type	Load [kN/m]	Partial factor	Load ULS [kN/m]
Green roof	Gr	32.32	1.35	33.944
Structural s-w	G1	24.22	1.35	32.709
Other permanent	G2	11.03	1.35	14.902
Imposed Variable	Q1	14.774	1.5	22.161
Inside partitions	Q2	4.15	1.5	6.225

Table 6- 39 Loads acting from X direction

The combination selected is:

Permanent loads: $\gamma_G(G_1+G_2)= 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2)= 1.5\ (Q_1+Q_2)$

On both spans, on every story.

A diagram of the combinations is presented in the following figure:

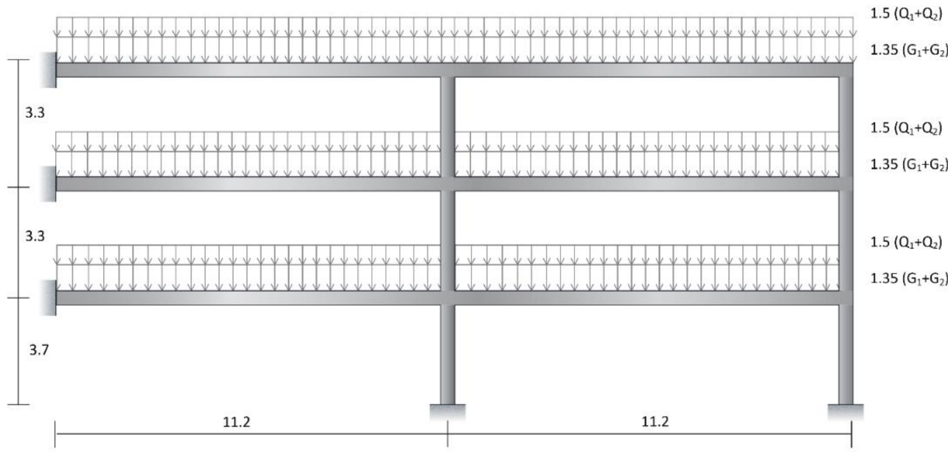


Figure 6- 24 Combination of actions corner column X axis

- *Verifications*

USL verification

We make the same assumptions made before for previous analysis.

-We consider that in the section the concrete is broken in compression reaching ultimate strain, the steel behaves is yielded in top and bottom.

The neutral axis X is calculated from the translational equilibrium.

$$0.8bxf_{cd} + f_{yd}A'_s - f_{yd}A_s = N_{Ed}$$

The rotational equilibrium about the barycenter of gross area defines the value of the resisting moment of the member.

$$0.8bxf_{cd}(0.5h - 0.4x) + f_{yd}A'_s(0.5h - d') - f_{yd}A_s(d - 0.5h) = M_{Rd}$$

-For the section where the concrete is broken in compression reaching ultimate strain, the steel behaves elastic in top and is yielded in bottom.

The translational equilibrium is:

$$0.8bxf_{cd} + \sigma'_s A'_s - f_{yd}A_s = N_{Ed}$$

$$\sigma'_s = E_s \varepsilon_{cu} \frac{x - d'}{x}$$

The rotational equilibrium:

$$0.8bxf_{cd}(0.5h - 0.4x) + \sigma'_s A'_s(0.5h - d') - f_{yd}A_s(d - 0.5h) = M_{Rd}$$

- For the section where the concrete is broken in compression reaching ultimate strain, the steel behaves yielded in top and is elastic in bottom.

$$0.8bxf_{cd} + f_{yd}A_s' - \sigma_s' A_s = N_{Ed}$$

$$\sigma_s' = E_s \varepsilon_{cu} \frac{d - x}{x}$$

The rotational equilibrium:

$$0.8bxf_{cd}(0.5h - 0.4x) + f_{yd}A_s'(0.5h - d') - \sigma_s' A_s(d - 0.5h) = M_{Rd}$$

The inferior reinforcement is yielded if:

$$x \geq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} d = 294.86\ mm$$

And superior reinforcement is yielded if:

$$x \geq \frac{\varepsilon_{cu}}{\varepsilon_{cu} - \varepsilon_{yd}} d' = 90.92\ mm$$

$e_0 = 20\ mm$

Column	N_{Ed} [kN]	M_{Ed} [kNm]	$N_{Ed}xe_o$ [kNm]	X [mm]	M_{Rd} [kNm]
1st Floor	222.435	10.58	8.897	19.580	14.207
Ground Floor	417.17	12.95	16.686	36.722	28.425
Basement	600.075	20.28	24.003	52.823	48.321

Table 6- 40 ULS verification

SLS verification

The stresses in the materials can be calculated with the following expressions:

$$\sigma_c = \frac{N_{Ed}}{\frac{bx^2}{2} + \alpha_e A_s'(x - d') - \alpha_e A_s(d - x)} x$$

$$\sigma_s = \alpha_e \sigma_c \frac{d - x}{x}$$

$$\sigma_s' = \alpha_e \sigma_c \frac{x - d'}{x}$$

We use $\sigma_c = 15$, as the ratio between the E of steel and concrete.

Column	N_{Ed} [kN]	M_{Ed} [kNm]	e=M/N	X [mm]	σ_c [N/mm^2]	σ_s [N/mm^2]	σ'_s [N/mm^2]
1st Floor	171.10	10.98	73.36	15.061	0.913	17.535	45.361
Ground Floor	320.90	10.19	34.88	32.594	4.071	53.392	55.510
Basement	461.59	13.58	37.39	37.585	6.964	78.272	80.546

Table 6- 41 SLS verification

6.6.3.7 Effects of Beams (Y direction)

For this direction the same procedure was followed, only the final results are shown.

- Structural analysis

A simplified scheme is used in order to calculate the axial loads and bending moments acting on the columns. The horizontal displacements are considered neglectable.

The stiffness of the structural elements are:

Column $I_c = 5.21 \cdot 10^9$

Beam $I_b = 2.57 \cdot 10^9$ $0.686\ I_c$

Wall $I_w = 1.24 \cdot 10^{10}$ $2.376\ I_c$

The loads acting on the structure are:

Location	Type	Load [kN/m]	Partial factor	Load ULS [kN/m]
Green roof	Gr	32.32	1.35	33.944
Structural s-w	G1	24.22	1.35	32.709
Other permanent	G2	11.03	1.35	14.902
Imposed Variable	Q1	14.774	1.5	22.161
Inside partitions	Q2	4.15	1.5	6.225

Table 6- 42 Loads acting from Y direction

The combination selected is:

Permanent loads: $\gamma_G(G_1+G_2)= 1.35\ (G_1+G_2)$

Variable loads: $\gamma_Q(Q_1+Q_2)= 1.5\ (Q_1+Q_2)$

On both spans, on every storey.

A diagram of the combinations is presented the next figure:

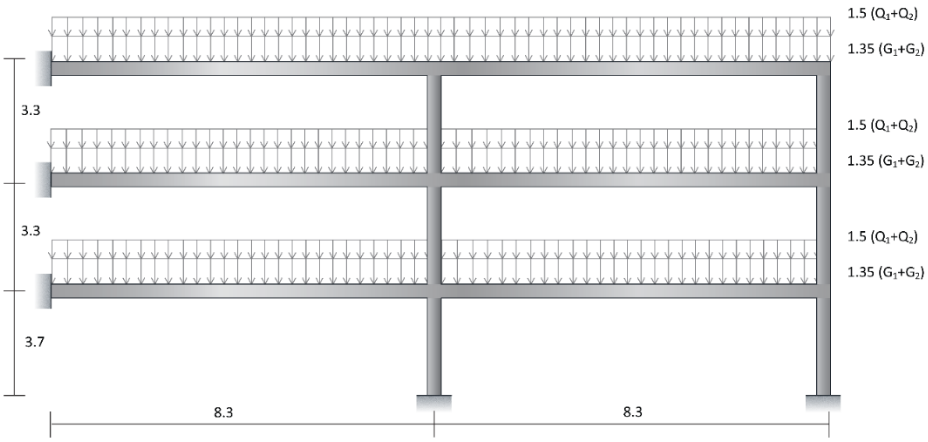


Figure 6- 25 Combination of actions corner column Y axis

- *Verifications*

USL verification

$$e_0 = 20\ mm$$

Column	N_{Ed} [kN]	M_{Ed} [kNm]	$N_{Ed}xe_o$ [kNm]	X [mm]	M_{Rd} [kNm]
1st Floor	222.435	10.88	8.897	19.580	14.207
Ground Floor	417.17	9.70	16.686	36.722	28.425
Basement	600.075	14.96	24.003	52.823	48.321

Table 6- 43 ULS verification

SLS verification

We use $\sigma_c = 15$, as the ratio between the modulus of elasticity of steel and concrete.

Column	N_{Ed} [kN]	M_{Ed} [kNm]	e=M/N	x [mm]	σ_c [N/mm²]	σ_s [N/mm²]	σ'_s [N/mm²]
1st Floor	171.10	9.415	55.027	12.049	0.720	17.404	50.122
Ground Floor	320.90	7.835	24.417	22.598	2.669	51.662	123.318
Basement	461.59	12.083	26.176	32.506	5.838	76.777	242.241

Table 6- 44 SLS verification

6.7 Other considerations

6.7.1 Incidental Actions

The lateral forces can be as relevant as the gravitational ones, the incidental action of wind, snow and earthquake must be considered according to the conditions of the building. In this project the most important horizontal action is due to the earthquake, been in a zone with high seismic activity and plastic soils, make any project vulnerable to this forces.

This building has a history of almost 50 years in the site, it is clear that its structural design was accurate, since the opening of the market has stood an earthquake of 8.1 degrees and more than 15 higher than 7. Situated atop three of the large tectonic plates that constitute the earth's surface, Mexico is one of the most seismologically active regions on earth. The motion of these plates causes earthquakes and volcanic activity.

Seismic Design Manual of the Federal Electricity Commission

The present code is wide use in Mexico since is the result of the Commission activities along the country, it describes a probabilistic procedure for calculating the seismic hazard in Mexico. The seismic hazard usually shows profiles that describe the seismic intensity in specific return periods. As a complement to the code is used the software PRODISIS in order to obtain the Peak Accelerations and design spectrums. Next a calculation of the forces using this manual as a guide. Shear walls are not calculated, but a roughly description is given at the end.

Classification of buildings by importance and type.

Group	Description
A+	High important structures. Their failure means loss of thousands of lives. Dams, nuclear energy plants.
A	High security level needed, importance. The failure of these structures means risk for a high number of people, economic or cultural. Bridges, water supply, electric stations, telecommunication stations, temples, schools, deposits of toxics and transport hubs.
B	Conventional level of security, moderate loses. Industrial buildings, low use housing and offices.

Table 6- 45 Group categories of construction accordingt to risk by CFE

Type 1	Building structures
Type 2	Inverted pendulum
Type 3	Retaining wall
Type 4	Chimney
Type 5	Tanks
Type 6	Industrial plant
Type 7	Bridges
Type 8	Pipelines
Type 9	Dams
Type 10	Seismic insulationn and energy dissipation
Type 11	Telecommunication towers
Type 12	Tunnels
Type 13	Foundation

Table 6- 46 Type of construction according to CFE

Optimum values for design spectrum in Ultimate limit state for rocky soils for Group B structures were obtained.

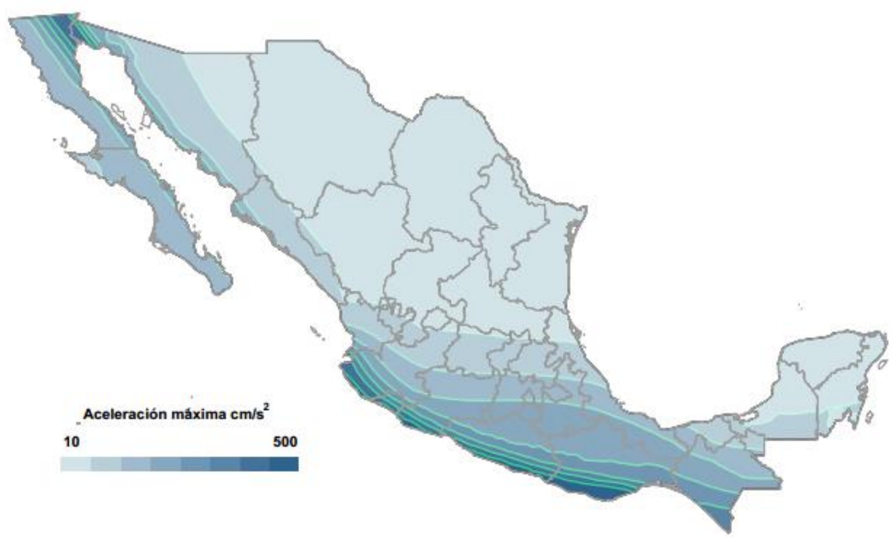


Figure 6- 26 Map of Accelerations of the ground in Mexico

For structures in group A, a 1.5 factor must multiply the spectral values of the ultimate limit state of Group B.

Design spectra is calculated by the following expression:

$$a = \frac{Sa(T_e)}{g} = \begin{cases} a_0 + (\beta c - a_0)\frac{T_e}{T_a} & \text{si } T_e < T_a \\ \beta c & \text{si } T_a \le T_e < T_b \\ \beta c\left(\frac{T_b}{T_e}\right)^r & \text{si } T_b \le T_e < T_c \\ \beta c\left(\frac{T_b}{T_c}\right)^r\left[k + (1-k)\left(\frac{T_c}{T_e}\right)^2\right]\left(\frac{T_c}{T_e}\right)^2 & \text{si } T_e \ge T_c \end{cases}$$

Where:

a = acceleration
T_e = structural period
T_a = inferior limit of spectra
T_b = superior limit of spectra
T_c = start of the descendant part
r & k = control of descendant ordinates
β = damping factor
a_o = maximum acceleration
c = design coefficient

A spectra of acceleration for the three types of soil in Mexico City is show below:

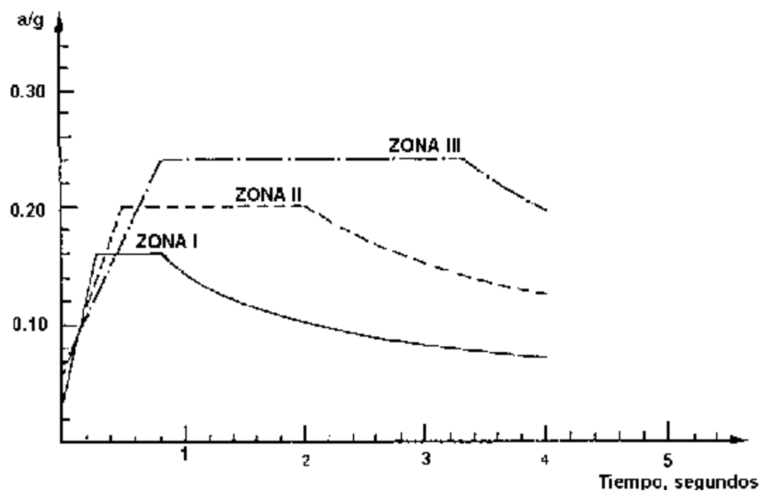


Figure 6- 27 Design spectra for the three types of soil in Mexico City

The type of structure (regular structure and height less than 30 m), according to the code, allows to make a static analysis where the use of coefficients that correspond to an acceleration varies in linear way, thus the shear V divided by the total weight W is equal to the seismic coefficient C.

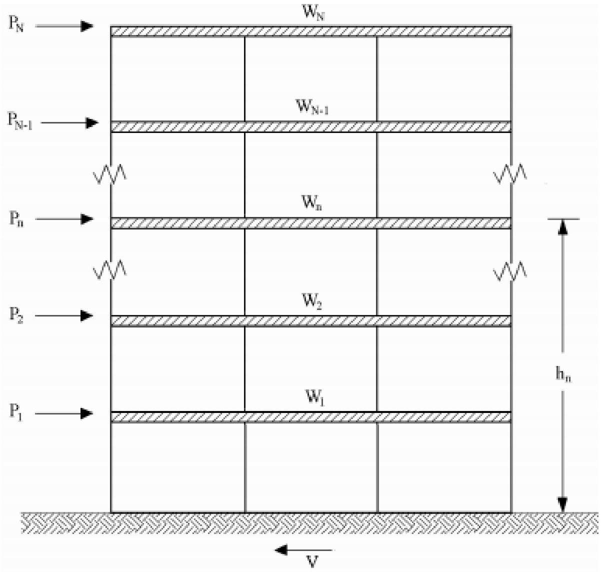


Figure 6- 28 Schematic diagram of lateral equivalent forces

$$P_n = \alpha_f W_n h_n$$

Where:

W_n = weight of each floor

H_n = height of each floor

The coefficient C:

$$\frac{V}{W} = \frac{c\beta}{Q'R\rho}$$

Where:

Q' = reduction factor due to ductility

Tb = inferior limit of the design spectra

c = seismic coefficient

β = damping factor

$$\alpha_f = \frac{\sum_{n=1}^{N_e} W_n}{\sum_{n=1}^{N_e} W_n h_n} \frac{c\beta}{Q'R\rho}$$

And finally:

$$P_n = W_n h_n \frac{\sum_{n=1}^{N_e} W_n}{\sum_{n=1}^{N_e} W_n h_n} \frac{c\beta}{Q'R\rho}$$

Level	Weight [kN]	Height [m]	Pn [kN]
2nd R	958.5529	10.3	2310.05
1st R	30056.14	7.2	50632.93
1st F	22206.47	4.1	21302.51
Gr F	27445.96	1	6421.64

Table 6- 47 Weight and statical equivalent forces for each level

The previous table shows the force over each floor, the lower value in the roof of second floor is due to the smaller area.

In order to stand the horizontal forces we need to provide structural elements to resist them, we use shear walls. This walls generally start at the foundation level and continue up to the roof, recommended thickness is higher than 150 mm and are provided in both directions. Doors and window can be part of the shear wall, but with a small size.

Shear walls in building must be symmetrically located in plan to reduce ill-effects of twist, and are more effective when located in exterior or the further to the center and like other reinforced concrete elements is better to design them ductile. The reinforcement bars have to have a minimum area of 0.0025 times the cross section (IITK, 2014).

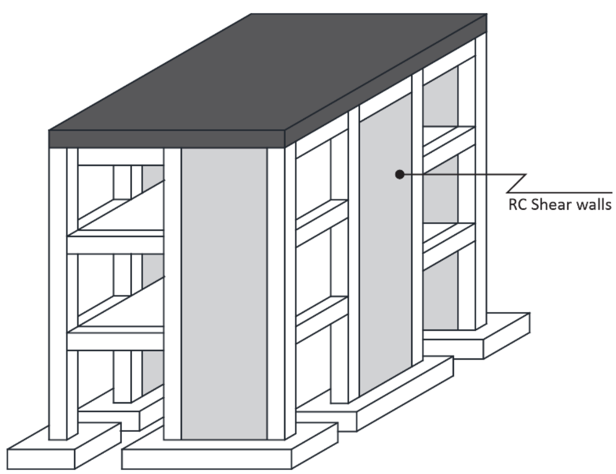
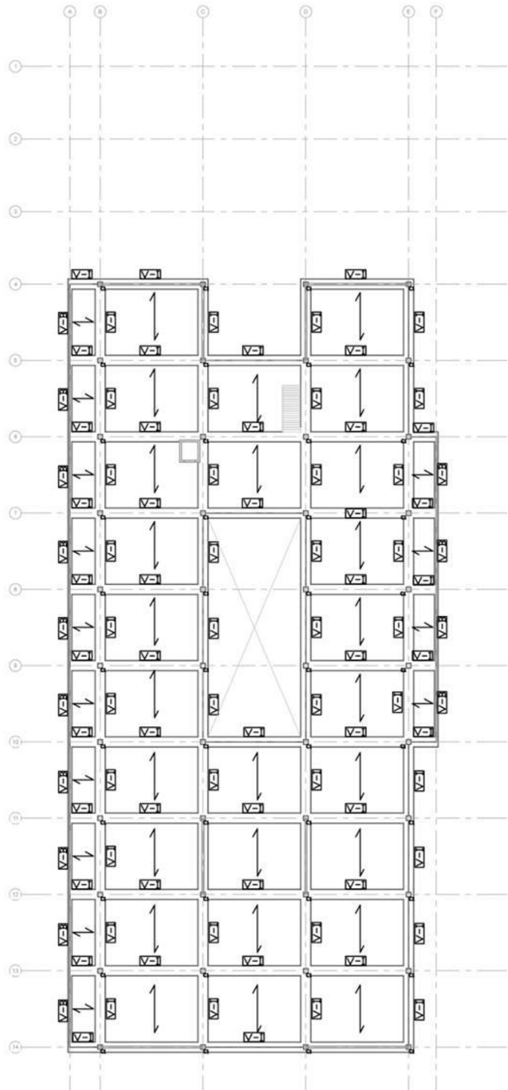


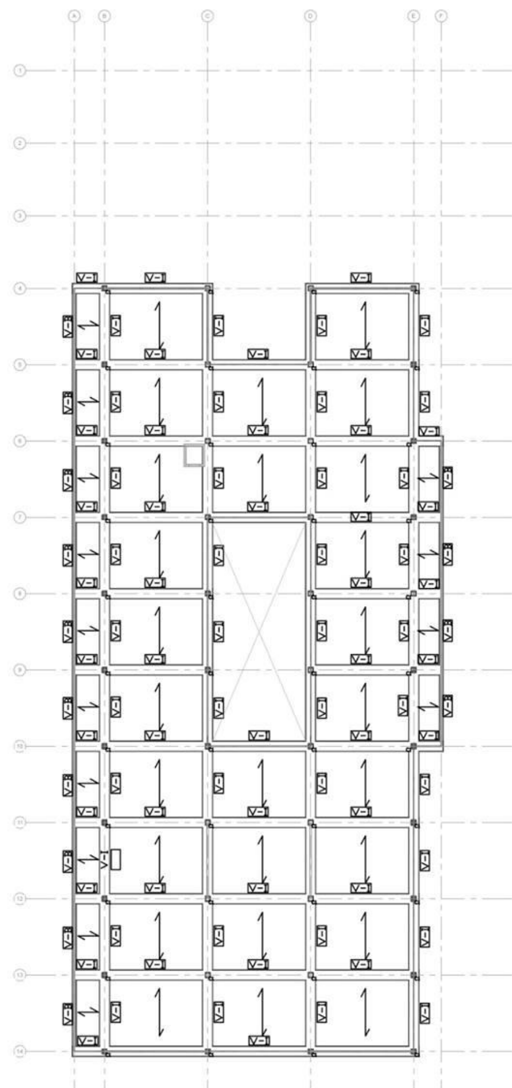
Figure 6- 29 Schematic location of shear walls

6.8 Plans and Reinforcement



Structural Plan First Floor

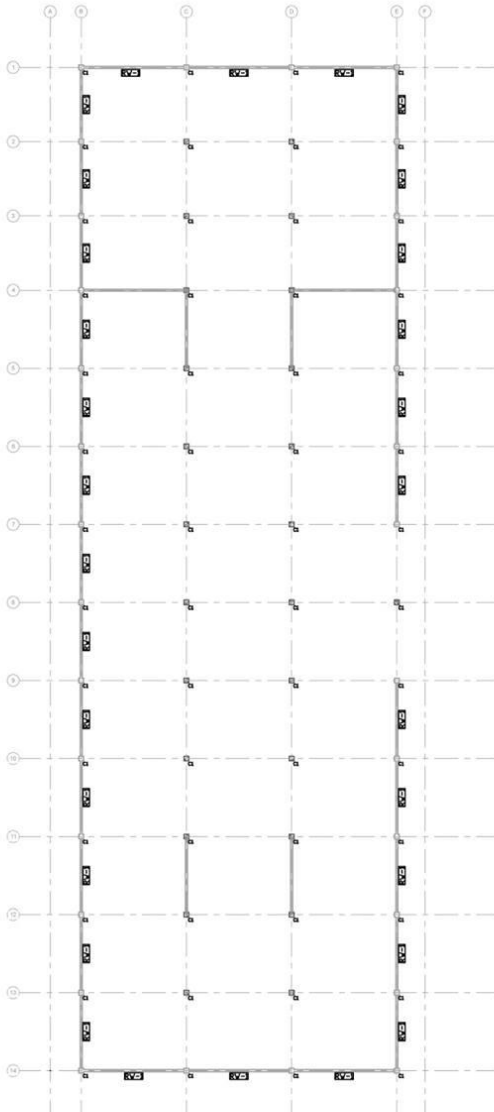
Column C1 50x50
Interior Beam V-I 100x35
Edge Beam V-B 40x35
Shear Walls R-W1 Thickness 20cm



Structural Plan Second Floor

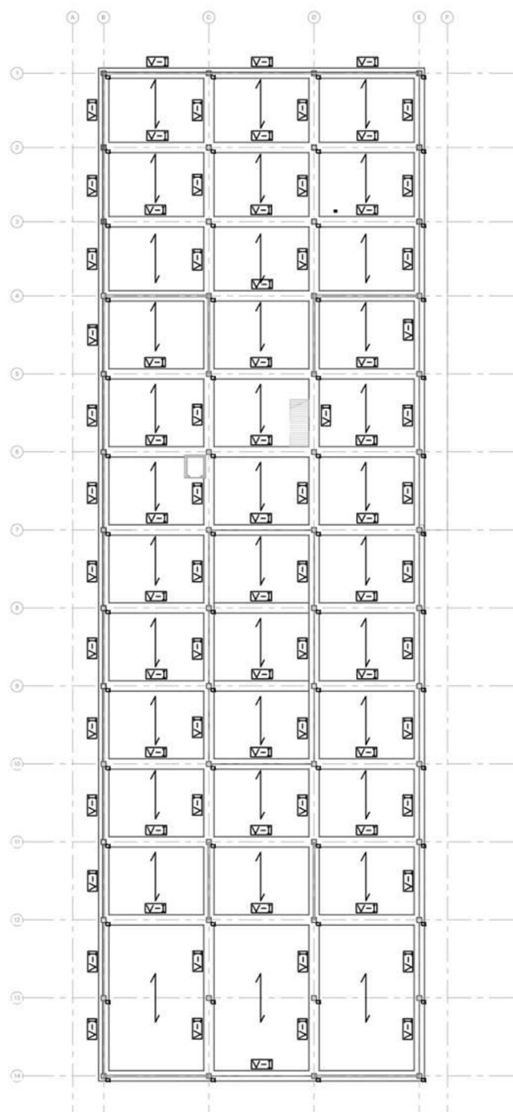
Column C1 50x50
Interior Beam V-I 100x35
Edge Beam V-B 40x35
Shear Walls R-W1 Thickness 20cm

Figure 6- 30 First and second floors plans



Structural Plan Parking

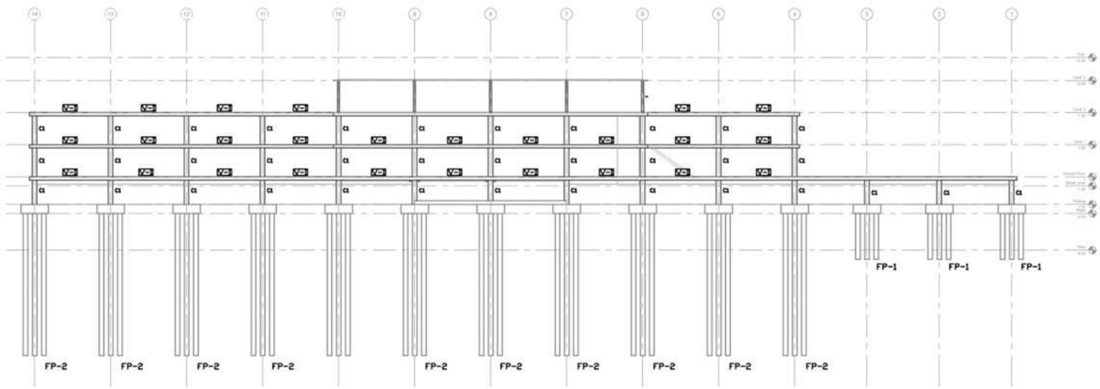
Column C1 50x50
Foundation slab 40cm Thickness
Shear Walls R-W1 Thickness 20cm



Structural Plan Ground Floor

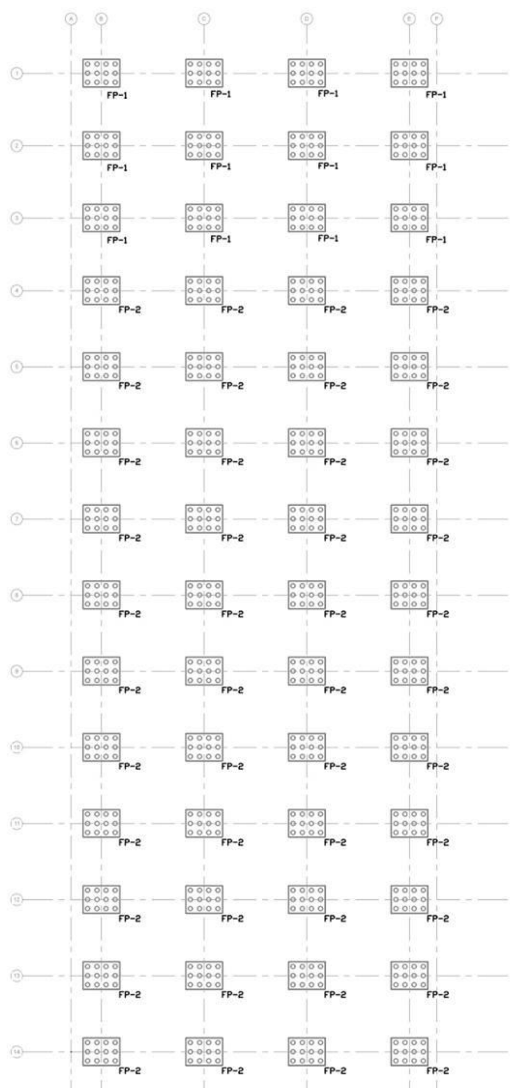
Figure 6- 31 Parking and ground floor plans

Foundation slab 40cm Thickness
Interior Beam V-I 100x35
Shear Walls R-W1 Thickness 20cm



Structural Plan East Elevation

Column C1 50x50
Interior Beam V-I 100x35
Edge Beam V-B 40x35
Shear Walls R-W1 Thickness 20cm



Foundation

Plinth 400x300x100
Pile Group FP-1 Ø 50cm 5m Depth
Pile Group FP-2 Ø 50cm 15m Depth

Figure 6- 32 Foundation plan and east elevation

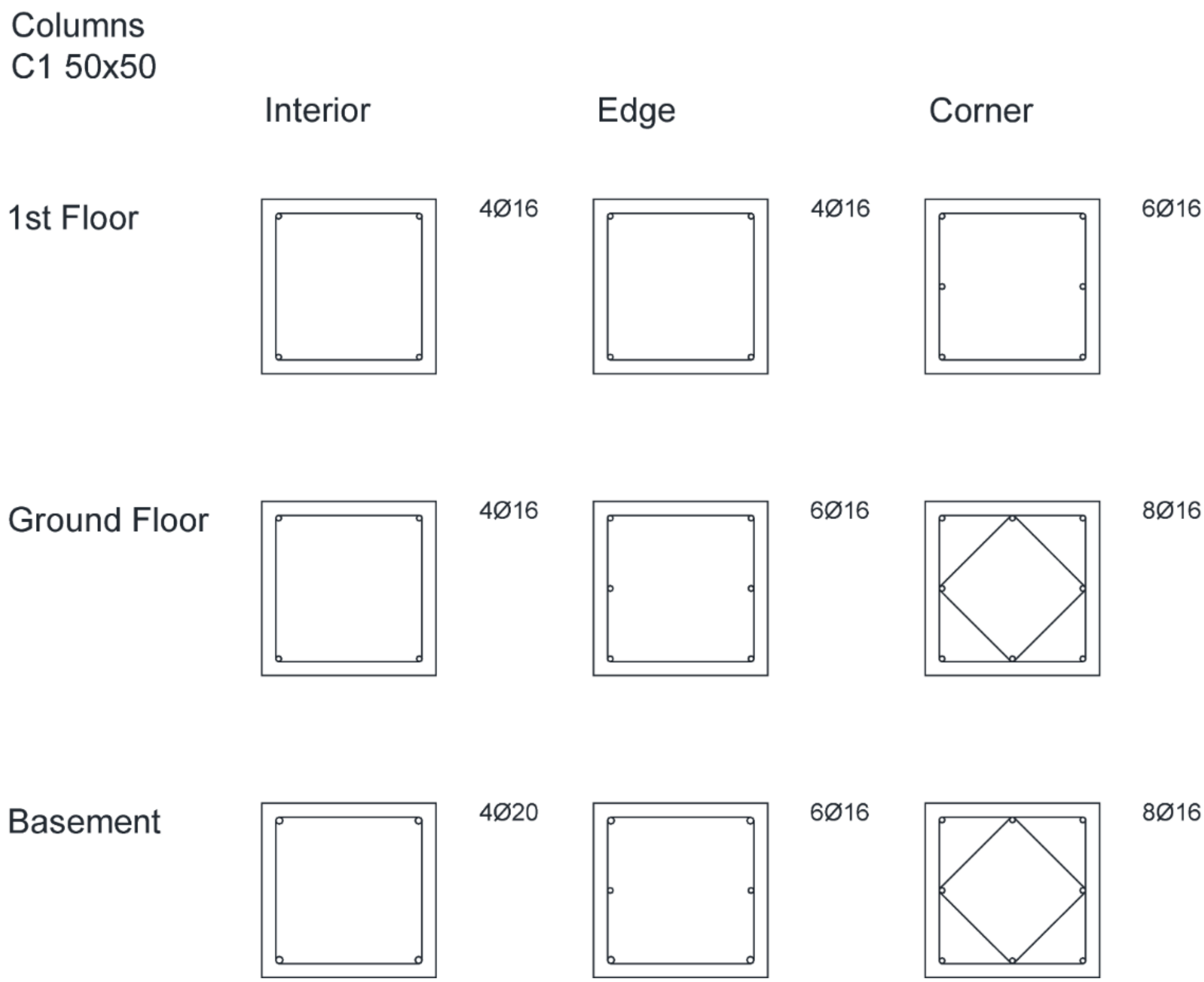


Figure 6- 33 Columns reinforcement

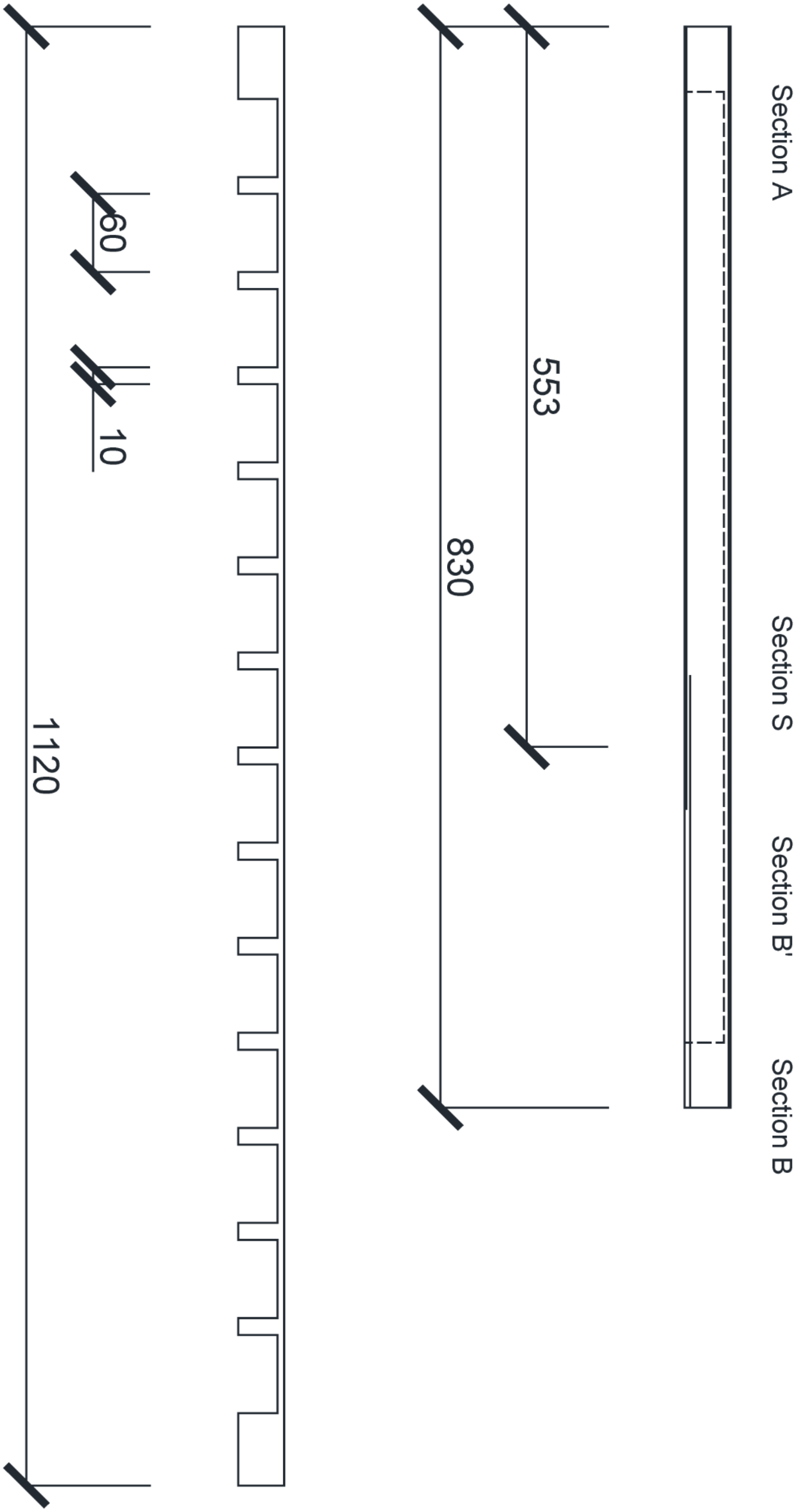


Figure 6- 34 Slab reinforcement

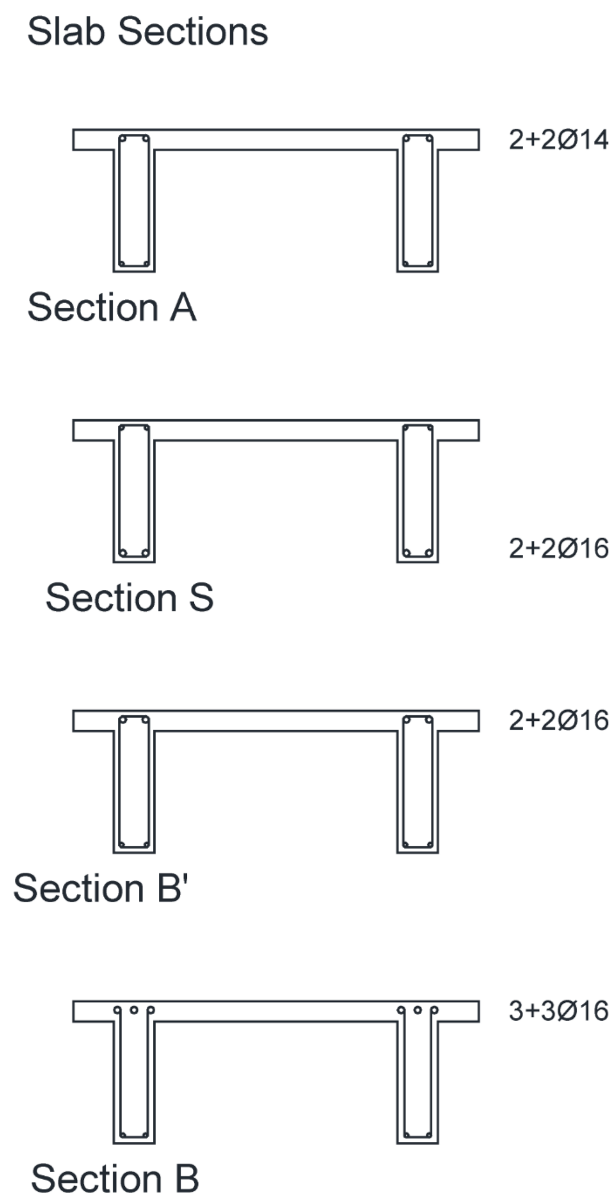


Figure 6- 35 Slab sections

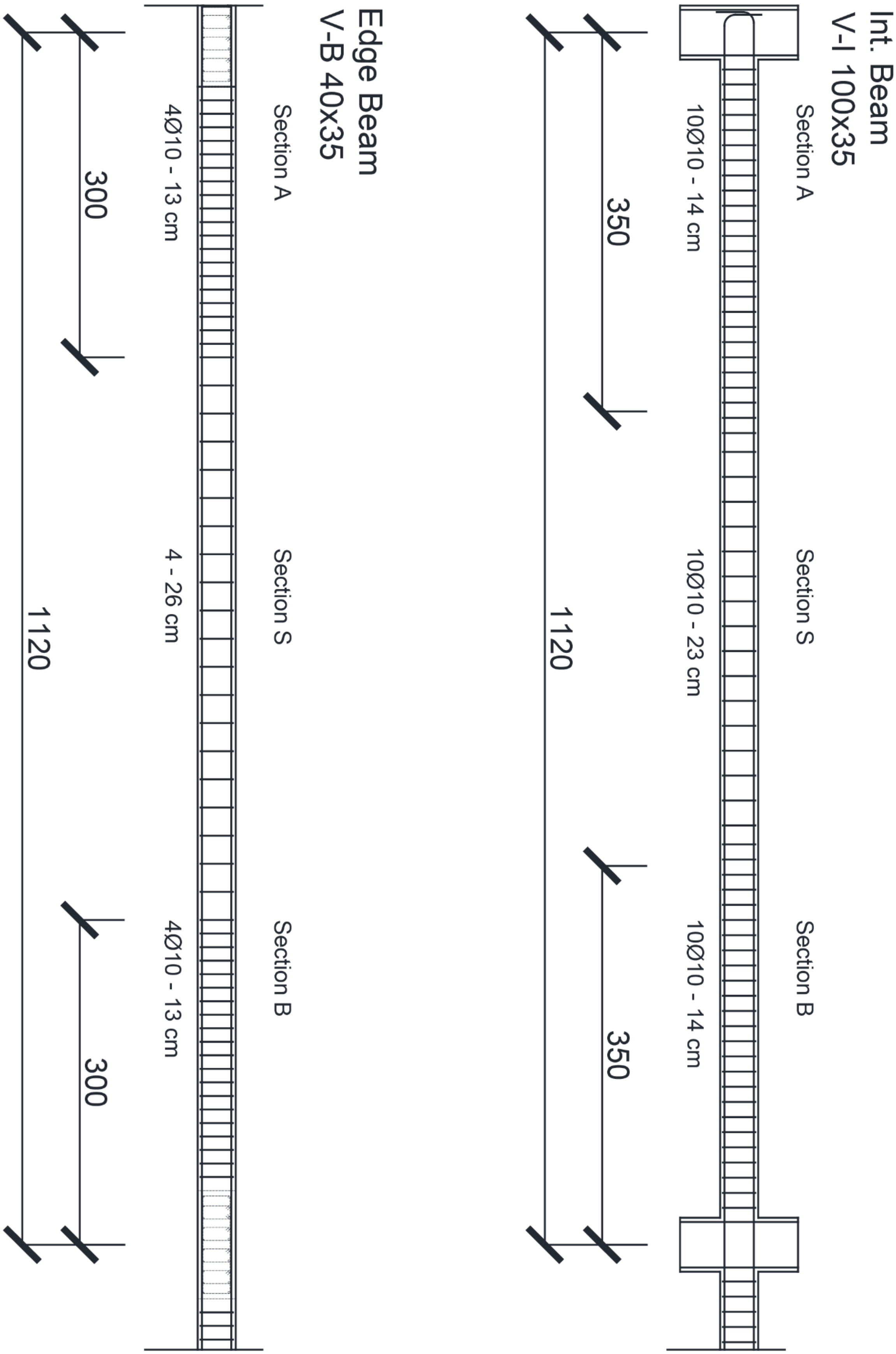


Figure 6- 36 Beam reinforcement

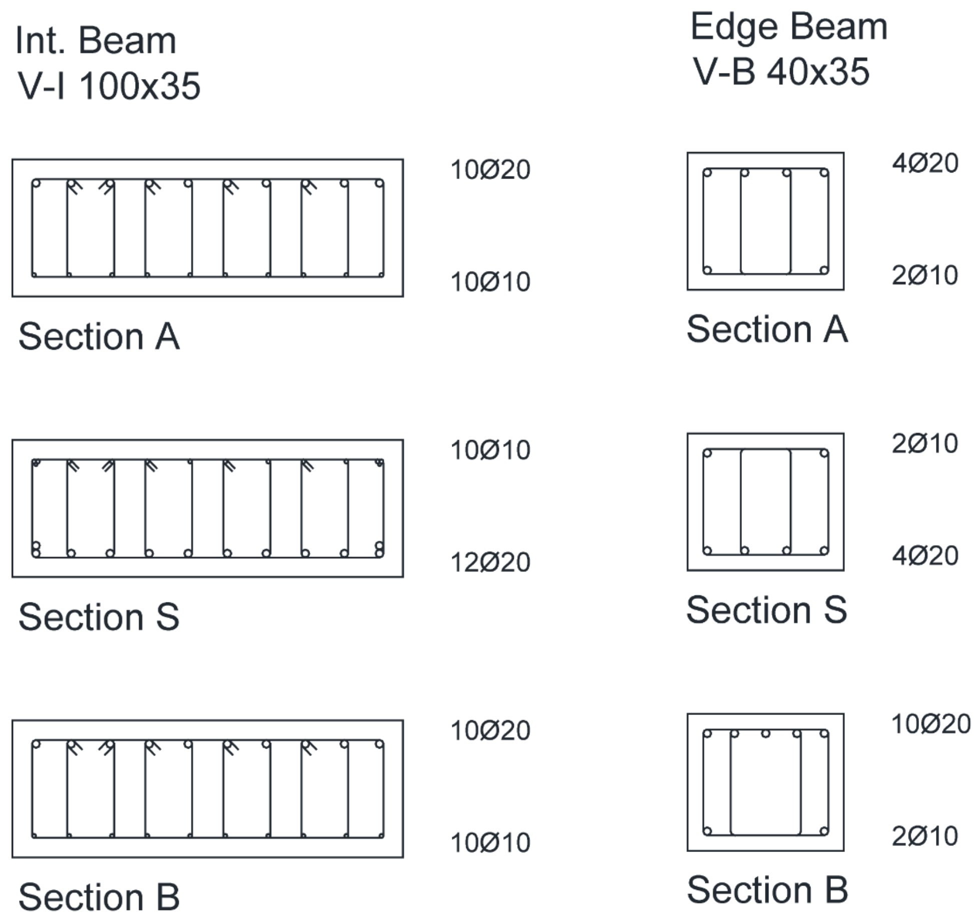


Figure 6- 37 Beam sections

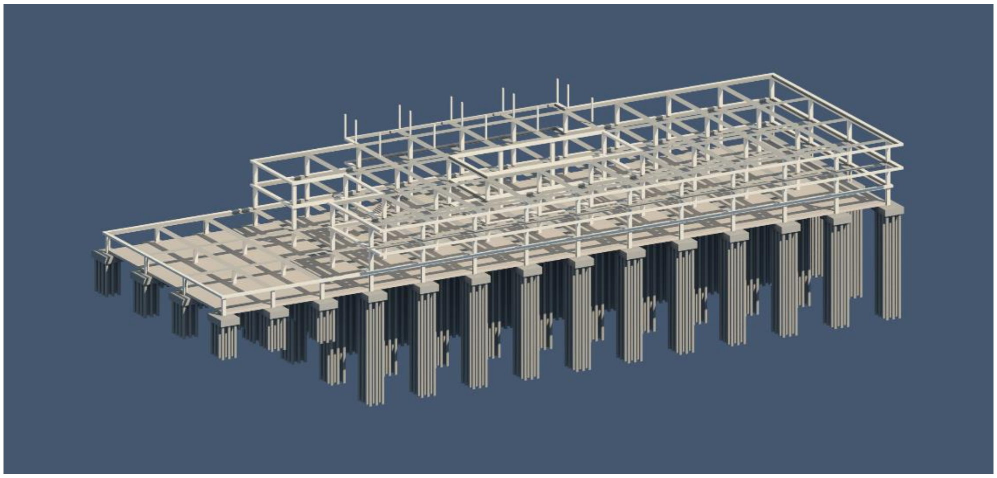


Figure 6- 38 3D view of beams and columns

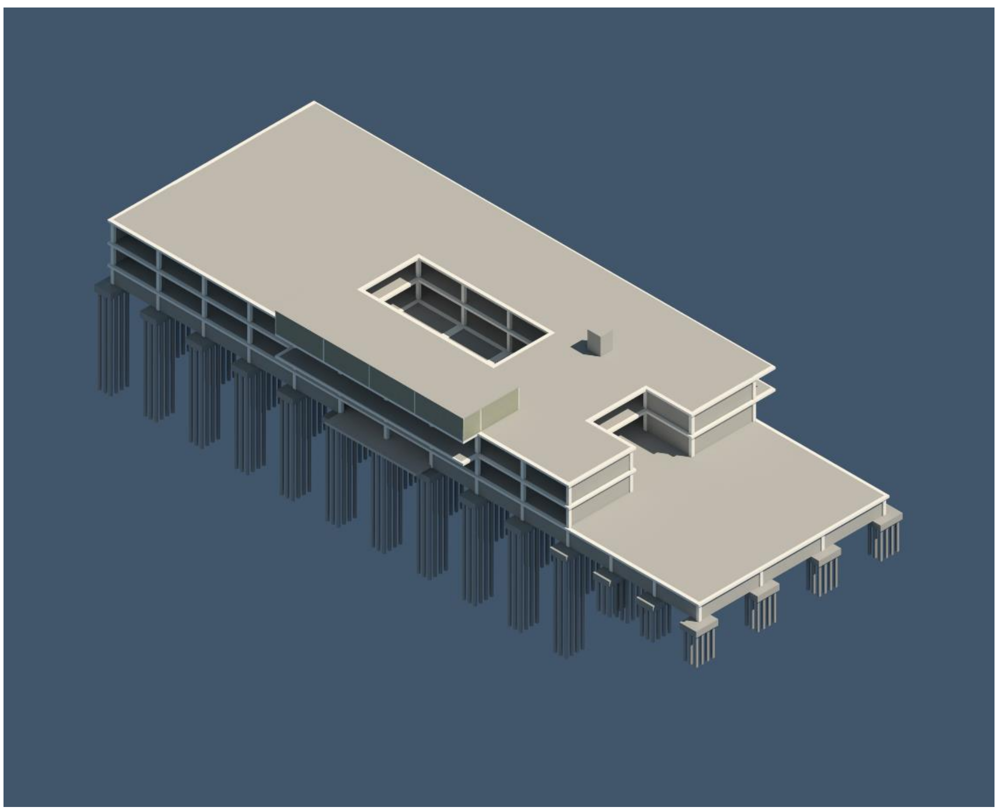


Figure 6- 39 3D view of slabs

7 FINAL THOUGHTS

Chapter 7: Final Thoughts

During this Master's course, we were able to understand the importance of synchronization of different disciplines with which we interacted, and that made us grow as people and professionals, valuing teamwork. The formation of a team of professionals capable of managing a comprehensive project is essential for the progress in our countries.

As a result of the design process carried for the Market, after applying the tools offered by our teachers, and from a theoretical perspective, we obtained results that allows us to introduce the following set of conclusions:

As for the cultural aspects we see that the project is the representation of the manifestations of traditions and local knowledge of Mexico City. The lack of awareness of designers, directly influences the design and functionality of architectural and urban spaces, which makes it possible to have shortcomings when hosting the general population. These needs must be solved on short term because it makes impossible the proper use of this facilities and does not contribute to environmental care

Most problems and needs detected in the building are due to the lack of detailed analysis prior to construction, as there are many elements that must be changed because they do not meet the ideal characteristics required for a bioclimatic comfort. Among others, we can find the unification and reorganization of existing furniture and the implementation of techniques and strategies that go in line with the technological advances and which always take into consideration functionality, practicality, safety and economy in design.

We can see that it is much more efficient and cheaper to initially plan and design a building considering all bioclimatic comfort criteria and especially the needs and characteristics of those who will make use of the spaces, than to redesign and readjust an existing building such as the Handcraft Market of Mexico City. However, it remains difficult for certain companies and users to face an initial outlay like this.

References

Abilia. (2013, April 4). *Conciencia Sustentable*. Retrieved from Cobertura de edificio en forma de panal combate el smog en México DF: http://conciencia-sustentable.abilia.mx/cobertura-de-edificio-en-forma-de-panal-combate-el-smog-en-mexico-df/

American Concrete Institute. (2008). *Requisitos de Reglamento para Concreto Estructural.* Farmington Hills: IMCYC.

Baxter, S. (1901). *Spanish-colonial architecture in Mexico.* Boston: J. B. Millet.

Blanco, M. (2014, February 10). *Calles semipeatonales*. Retrieved from Atraccion 360: http://www.atraccion360.com/calles-semipeatonales-el-nuevo-camino-de-la-movilidad

Bolaños Sanchez, A. (2006, November 26). *El DF, la ciudad con más museos en el mundo*. Retrieved from La Jornada Online: http://www.jornada.unam.mx/2006/11/24/index.php?section=capital&article=047n1cap

Charleson, A. (2005). *Structure as architecture.* Oxford: Elsevier.

Ciudad de Mexico. (2009). *Mercados*. Retrieved from Ciudad de Mexico: http://www.ciudadmexico.com.mx/compras/mercados.htm

Ciudad de Mexico. (2009). *Parques y Plazas Centro Historico*. Retrieved from Ciudad de Mexico: http://www.mexicocity.gob.mx/contenido.php?cat=30600&sub=1

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. (n.d.). *Arboles y arbustos nativos potencialmente valiosos para la restauración ecológica y la reforestación.* Mexico: Institute of Ecology, UNAM.

Conaculta. (2014, February 2). *Centro Histórico de la ciudad de México*. Retrieved from Turismo Cultural: http://www.conaculta.gob.mx/turismocultural/destino_mes/cd_mexico/

Davies, K., & Jokiniemi, E. (2008). *Dictionary of Architecture and Building Construction.* Oxford: Architectural Press.

Ecobici. (2014, February 15). *¿Qué es Ecobici?* Retrieved from Ecobici: https://www.ecobici.df.gob.mx/es/informacion-del-servicio/que-es-ecobici

European Committee for Standardisation. (2008). Eurocode 2 : design of concrete structures. European Committee for Standardisation.

Hagan, S. (2001). *Taking Shape, A new contract between architecture and nature.* Oxford: Architectural Press.

Iannaccocone, G., Imperadori, M., & Gabriele, M. (2014). *Smart-ECO Buildings Towards 2020/2030.* Milan: Springer.

IBM. (2011, September 8). *IBM Global Commuter Pain Survey: Traffic Congestion Down, Pain Way Up*. Retrieved from IBM Press: http://www-03.ibm.com/press/us/en/pressrelease/35359.wss

IITK. (2014). *Learning Earthquake Design and Construction.* Retrieved from Why are Buildings with Shear Walls preferred in Seismic Regions?: http://www.iitk.ac.in/nicee/EQTips/EQTip23.pdf

Lang, J. (2005). *Urban Design: A Typology of Procedures and Products.* Sydney: Elsevier.

Maestri, N. (2014, February 5). *Aztec Origins*. Retrieved from About Archeology: http://archaeology.about.com/od/aztecarchaeology/a/aztec_origins.htm

Metro Bus. (2014, February 15). *¿Qué es MetroBus?* Retrieved from Metro Bus: http://www.metrobus.df.gob.mx/que_es_metrobus.html

Museo Nacional de Antropología. (2015). *Museo Nacional de Antropología*. Retrieved from Historia del Museo: http://www.mna.inah.gob.mx/museo/historia/historia-del-museo.html

Palazzo, D., & Steiner, F. (2011). *Urban Ecological Design.* Washington: Island Press.

Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Koppen-Geiger climate classification. *Hydrology and Earth System Sciences*.

Piña Olivares, G. (2014). Arquitectura Postrevolucionaria. In G. Piña Olivares, *Historia de la Arquitectura Mexicana II.* Pachuca: Universidad Autonoma del Estado de Hidalgo.

Ramírez Vázquez, P. (1985, September 16). Ramírez Vázquez y la historia del Museo de Antropología. (A. Ponce, Interviewer)

Romero Moreno, G. (2005). *Tendencias Actuales de la Arquitectura Mexicana.* Hermosillo: UniSon.

Ruiz, P. (2011). *Arquitectura de la Haciendas Caloniales de México.* Barcelona: UPC.

Sebestyen, G. (2003). *New Architecture and Technology.* Oxford: Architectural Press.

Secretaria de Transporte y Vialidad. (2014). *Vialidades con mayor y menor saturación vehicular en la Ciudad de México*. Retrieved from Secretaria de Transporte y Vialidad: http://www.setravi.df.gob.mx/wb/stv/vialidades_con_mayor_y_menor_saturacion_vehicular_

Secretaria del Medio Ambiente. (2010). *Areas Verdes Urbanas*. Retrieved from Secretaria de Medio Ambiente del Distrito Federal: http://www.sma.df.gob.mx/avu

Seriña Garza, A. (2014). *El trafico es un tema muy complejo*. Retrieved from Tu Discovery: http://vroom.tudiscovery.com/el-trafico-es-un-tema-muy-complejo-para-los-habitantes-de-la-ciudad-de-mexico/

Siemens AG. (2012). *Green City Index.* Munich: Siemens AG.

Skyscrapercity. (2015). *Cities with the most % of public green space*. Retrieved from Skyscrepercity.com: http://www.skyscrapercity.com/showthread.php?t=1660203

Solis, V. (2014). *Mx-Df*. Retrieved from Mercado de Artesanías San Juan: Un mercado de curiosidades y tradiciones mexicanas: http://www.mx-df.net/2014/04/mercado-de-artesanias-san-juan-un-mercado-de-curiosidades-y-tradiciones-mexicanas/

STCM. (2014, February 10). *Actualidad*. Retrieved from Metro Distrito Federal: http://www.metro.df.gob.mx/organismo/pendon4.html

Steel Rebar. (2014). *Steel Rebar Sizes*. Retrieved from Steel Rabar: http://steel-rebar.com/Steel-Rebar-Sizes.html

Torre Latino. (2014, February 3). *Museos*. Retrieved from Torre Latino: http://www.torrelatino.com

Velazquez Nuñes, L. A. (2010). La Arquitectura del Porfiriato. *Historia Critica de la Arquitectura y el Arte*.

Visit Mexico. (2012). *Mercados Tradicionales*. Retrieved from visit Mexico.

Weather Base. (2014, February 14). *Climate Summary Mexico City, Centro*. Retrieved from Weather Base Mexico City: http://www.weatherbase.com/weather/weather-summary.php3?s=989033&cityname=Mexico+City+-+Centro%2C+Distrito+Federal%2C+Mexico&units=

Wight, J., & MacGregor, J. (2009). *Reinforced Concrete, Mechanics & Design.* Ney Jersey: Pearson.

Wikimedia Foundation. (2014, February 3). *Mexico City*. Retrieved from Wikipedia: http://en.wikipedia.org/wiki/Mexico_City

LEED 2009 FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS PROJECT CHECKLIST

Sustainable Sites			**26 Possible Points**
☑	Prerequisite 1	Construction Activity Pollution Prevention	Required
☐	Credit 1	Site Selection	1
☐	Credit 2	Development Density and Community Connectivity	5
☐	Credit 3	Brownfield Redevelopment	1
☐	Credit 4.1	Alternative Transportation—Public Transportation Access	6
☐	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
☐	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
☐	Credit 4.4	Alternative Transportation—Parking Capacity	2
☐	Credit 5.1	Site Development—Protect or Restore Habitat	1
☐	Credit 5.2	Site Development—Maximize Open Space	1
☐	Credit 6.1	Stormwater Design—Quantity Control	1
☐	Credit 6.2	Stormwater Design—Quality Control	1
☐	Credit 7.1	Heat Island Effect—Nonroof	1
☐	Credit 7.2	Heat Island Effect—Roof	1
☐	Credit 8	Light Pollution Reduction	1
Water Efficiency			**10 Possible Points**
☑	Prerequisite 1	Water Use Reduction	Required
☐	Credit 1	Water Efficient Landscaping	2-4
☐	Credit 2	Innovative Wastewater Technologies	2
☐	Credit 3	Water Use Reduction	2-4
Energy and Atmosphere			**35 Possible Points**
☑	Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required
☑	Prerequisite 2	Minimum Energy Performance	Required
☑	Prerequisite 3	Fundamental Refrigerant Management	Required
☐	Credit 1	Optimize Energy Performance	1–19
☐	Credit 2	On-site Renewable Energy	1–7
☐	Credit 3	Enhanced Commissioning	2
☐	Credit 4	Enhanced Refrigerant Management	2
☐	Credit 5	Measurement and Verification	3
☐	Credit 6	Green Power	2
Materials and Resources			**14 Possible Points**
☑	Prerequisite 1	Storage and Collection of Recyclables	Required
☐	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors and Roof	1-3
☐	Credit 1.2	Building Reuse—Maintain Existing Interior Nonstructural Elements	1
☐	Credit 2	Construction Waste Management	1-2
☐	Credit 3	Materials Reuse	1-2
☐	Credit 4	Recycled Content	1-2

☐	Credit 5	Regional Materials	1-2
☐	Credit 6	Rapidly Renewable Materials	1
☐	Credit 7	Certified Wood	1

Indoor Environmental Quality			**15 Possible Points**
☑	Prerequisite 1	Minimum Indoor Air Quality Performance	Required
☑	Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Required
☐	Credit 1	Outdoor Air Delivery Monitoring	1
☐	Credit 2	Increased Ventilation	1
☐	Credit 3.1	Construction Indoor Air Quality Management Plan—During Construction	1
☐	Credit 3.2	Construction Indoor Air Quality Management Plan—Before Occupancy	1
☐	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
☐	Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
☐	Credit 4.3	Low-Emitting Materials—Flooring Systems	1
☐	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
☐	Credit 5	Indoor Chemical and Pollutant Source Control	1
☐	Credit 6.1	Controllability of Systems—Lighting	1
☐	Credit 6.2	Controllability of Systems—Thermal Comfort	1
☐	Credit 7.1	Thermal Comfort—Design	1
☐	Credit 7.2	Thermal Comfort—Verification	1
☐	Credit 8.1	Daylight and Views—Daylight	1
☐	Credit 8.2	Daylight and Views—Views	1

Innovation in Design			**6 Possible Points**
☐	Credit 1	Innovation in Design	1-5
☐	Credit 2	LEED Accredited Professional	1

Regional Priority			**4 Possible Points**
☐	Credit 1	Regional Priority	1-4

LEED 2009 for New Construction and Major Renovations

100 base points; 6 possible Innovation in Design and 4 Regional Priority points

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above