Polytechnic University of Turin

Master's degree thesis

Title:

Enhancing Sustainable Practices in Adaptive Reuse: Integrating Energy Considerations into Renovation and Design Ex-Mercati Generali Torino

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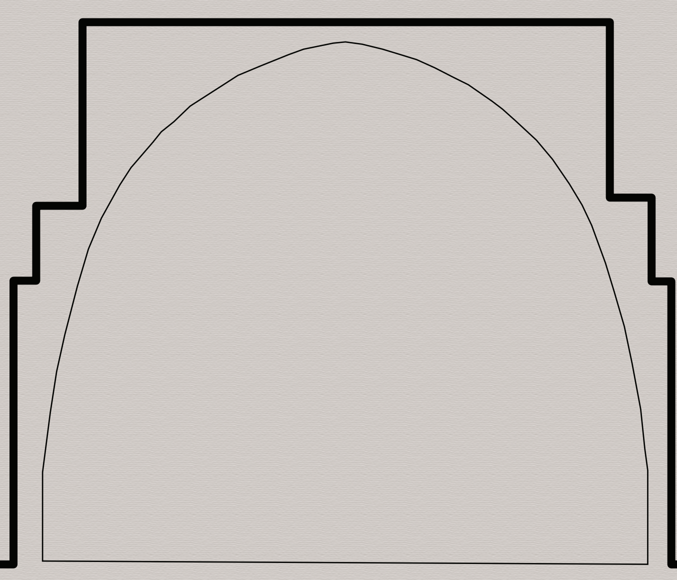

December

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To my father, Kambiz, your memory remains deeply cherished in my heart. Your kindness, love, and guidance continue to inspire me every day. I feel your presence by my side, and I am confident that from the heavens, you are watching over me with pride and unwavering support.

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I dedicate this thesis to my late father, whose memory continues to inspire and guide me, even in his absence.

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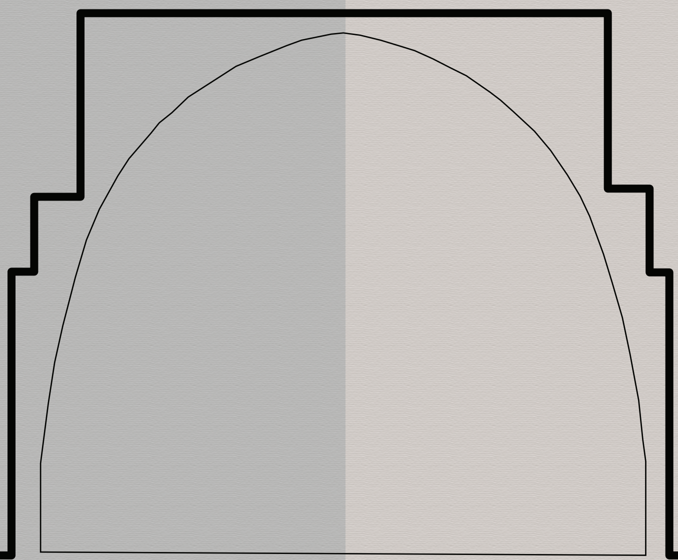


Introduction

1. Introduction

1.1 Background and rational

- **Overviews of adaptive re-use and sustainability in Architecture**

Figure 1 World Green Building Council is proud to support the UN's Sustainable Development Goals (SDGs)

Adaptive reuse is a practice that is broadly defined as the "Reuse of pre-existing structures for new purposes". While the first recorded use of this term is recent, the practice has its roots in ancient history, where reuse was often necessary because of a scarcity of resources. Within today's context of climate change, the term "adaptive reuse" is redefined, and in a significant manner. Adaptive reuse is one of three possible outcomes for existing structures. Despite preservation and demolition, it maintains the process of development and transformation. Routinely referred to as "transforming an unused building into one that serves a new use".

The practice of adaptive reuse is rich and varied and its importance includes not only the reuse of existing structures but also the reuse of materials, transformative interventions, and connections across the fabric of time and space.[1]

- **Adaptive reuse has benefits related to sustainability**

Environmental sustainability can be about reusing the existing buildings, preserving the resources, and reducing the waste that could be the result of demolition. By that, the need for new materials for the new construction will decrease. Thus, it can experience a lower carbon footprint. Cultural conservation and adaptive reuse preserve the historical and cultural identity of buildings, maintaining their value and their connection to the past. But, by adding a new meaning to them. Economic Efficiency is another positive impact of adaptive reuse especially for the historical buildings in dense urban settings. Because it can be more cost-effective than new construction. Urban regeneration, by converting abandoned buildings can revitalize urban areas and make them vibrant and useful again.

1. (LILIANE WONG STATES THAT THE TERM WAS FIRST NOTED AS BEING USED BY THE MARRIAM-WEBSTER DICTIONARY IN 1973. SEE LILIANE WONG, *ADAPTIVE REUSE: EXTENDING THE LIVES OF BUILDINGS* (BASEL: BIRKHAUSER, 2017), P. 30).

- **The role of sustainability in Architecture**

First, the meaning of sustainability and Architecture is crucial to analysis. Sustainability is "the quality of being able to continue over a period of time" and Architecture is "the style in which buildings are made" [2]. The term sustainability, as it refers to architecture, must be defined so that a subsequent conversation can progress with a full understanding of its meaning. More than just energy efficiency, it is an ecological approach to design. All the resources that go into a building: materials, fuels, and the understanding of the users' needs must be considered to create sustainable buildings. While there are many definitions of sustainability, it seems to be more of a process than a set of concrete ideas. The basic principles evolve as conditions, ideals, and technological capabilities change.[3]

- **Importance of Integrating energy into renovation and design**

According to the "Handbook of Energy Efficiency in Buildings: A Life Cycle Approach", buildings (residential and nonresidential) consume about 40% of final energy in the European Union (EU) and are responsible for about 36% of EU CO2 emissions. Buildings offer a large energy-savings potential. This has resulted in strong attention to the building sector in the EU energy and climate policies since the 1970s. Energy in buildings is mainly used for heating, cooling, ventilation, hot water production, lighting, and domestic appliances. Energy efficiency policies for the building sector target first, heating and cooling consumption, as this is by far the largest energy consumption in the building sector at the EU level. [4]

- **Challenges of energy efficiency in Historical buildings**

Unqualified materials are the first challenge in this matter. Historical materials and designs may not have been created for Energy efficiency. For instance, in adaptive reuse by calculating the U-value and R-value which are thermal transmittance and thermal resistance respectively, we can decide to change the wall, windows, etc. Another challenge that Energy efficiency may face is the limitations of re-design, adding or removing some elements. Whereas historical buildings have a crucial impact on their users, huge transformations could not occur. In some cases, we can only touch the internal parts and preserve the external parts as it is. Energy Efficiency has long-term benefits for buildings. By reducing energy consumption, the utility costs will decrease over time. As well as dropping greenhouse gas emissions, the building could be more resilient to climate related issues and require less maintenance.

1.2 Thesis objectives

Increasing concern about abandoned historical buildings has driven architects and heritage researchers to explore sustainable practices in adaptive reuse. The energy efficiency of these buildings is a critical aspect of this issue, especially in preserving their cultural and architectural value. This research estimates that integrating energy considerations into adaptive reuse can improve the sustainability of historical buildings and Ex-Mercati Generali Torino is selected as a case study.

2. KHAN, AHMED Z., AND KAREN ALLACKER. *ARCHITECTURE AND SUSTAINABILITY: CRITICAL PERSPECTIVES FOR INTEGRATED DESIGN*. KU LEUVEN FACULTY OF ARCHITECTURE CAMPUS SINT-LUCAS GHENT/BRUSSELS, 2015.

3. CORDERO, ELIZABETH. *SUSTAINABILITY IN ARCHITECTURE*. BACHELOR'S THESIS, CALIFORNIA STATE POLYTECHNIC UNIVERSITY, 1992. MASTER'S THESIS, DEPARTMENT OF ARCHITECTURE, MAY 24, 2001. MASTER OF SCIENCE IN ARCHITECTURE STUDIES IN BUILDING TECHNOLOGY, 11.

4. DESIDERI, UMBERTO, AND FRANCESCO ASDRUBALI, EDS. HANDBOOK OF ENERGY EFFICIENCY IN BUILDINGS: A LIFE CYCLE APPROACH. BUTTERWORTH-HEINEMANN, 2018.P.7

The way adaptive reuse is used to promote sustainability in architecture and reduce waste while conserving resources and extending the lifecycle of existing structures is examined in this study. The energy performance of Ex-Moi Generali Mercati will be evaluated and compared across three different periods—1933, the Olympic 2006 renovation phase, and the future design proposal—by analyzing metrics such as insulation quality with U-values and R-values and thermal conductivity along with the effect of architectural modifications on energy efficiency throughout these time frames. To estimate potential energy savings and reductions in maintenance costs and carbon emissions, a cost-benefit analysis is performed, which shows how these factors can importantly improve the overall effect. The research evaluates the ecological and economic benefits of sustainable interventions. The analysis draws attention to the feasibility of sustainable retrofitting for historical buildings and stresses the long-term benefits of these eco-friendly renovations. In addition, the study will suggest practical sustainable design interventions, developed with insights drawn from other theses to streamline the research process and enhance efficiency, that could further enhance the building's energy performance while maintaining its cultural integrity. Another objective is to introduce the active energy system selected for the project, calculate the energy produced by photovoltaic panels, and compare it with the building's energy requirements, exploring how active energy solutions can be incorporated within a historical framework without compromising its architectural aesthetic. Finally, this thesis will expand the case study's conclusions by illustrating how energy considerations could be included in similar adaptive reuse projects worldwide, providing a replicable framework for integrating sustainable practices into heritage conservation across diverse regional and cultural settings.

1.3 Case study: Ex-Moi Mercati Generali Torino

- **Introduction of site**

Ex-Moi Mercati Generali is an industrial heritage complex located in the southern part of Turin, Italy. The works were started at the end of August 1932 by Ing. Del Duca and Miccone (Architect Umberto Cuzzi). It is originally constructed at the end of December 1933.[5] The site served as a center for the wholesale market. It has a great role in the city's commercial and economic landscape. Its vast warehouses and industrial buildings reflect the architectural style and urban planning of its time.

- **Discuss the historical evolution**

Over the course of its existence, the Ex-Mercati Generali has undergone significant changes. The route of this architectural marvel was marred by the devastating effects of bombings: on August 17, 1943, RAF planes caused significant damage. And again in 1944, USAAF bombed the area, which led to a total collapse of some warehouses and the damage of sheds. Thus, the area was requiring extensive reconstruction between 1944 and 1945. Once the new market building in Turin was completed, it became the third-largest Agro-Food Center in Italy. [6]

2. KHAN, AHMED Z., AND KAREN ALLACKER. *ARCHITECTURE AND SUSTAINABILITY: CRITICAL PERSPECTIVES FOR INTEGRATED DESIGN*. KU LEUVEN FACULTY OF ARCHITECTURE CAMPUS SINT-LUCAS GHENT/BRUSSELS, 2015.
3. CORDERO, ELIZABETH. *SUSTAINABILITY IN ARCHITECTURE*. BACHELOR'S THESIS, CALIFORNIA STATE POLYTECHNIC UNIVERSITY, 1992. MASTER'S THESIS, DEPARTMENT OF ARCHITECTURE, MAY 24, 2001. MASTER OF SCIENCE IN ARCHITECTURE STUDIES IN BUILDING TECHNOLOGY, 11.
5. CERAGIOLO, MARIO. *"IL NUOVO MERCATO IN GROSSO ORTOFRUTTICOLO DELLA CITTA DI TORINO"*, 1933, P 1.
6. MUSEOTORINO "*BOMBINGS.*" GENERAL MARKETS. HTTPS://WWW.MUSEOTORINO.IT/VIEW/S/A9E0B7397BBE47FF84E91BF225B00A64#PAR_151939.

Following its relocation from Porta Palazzo, the General Markets served as CAAT's operating base from 1945 until 2001. On the other hand, CAAT's period at this facility ended in 2001. Over the years, several repairs and renovations were carried out until 2004–2006, when strategies to use the location as an athletes' village for the 2006 Winter Olympics were put forward, leading to a structural transformation phase. The architectural team led by architect Camerana was awarded the design and development of the new "Olympic district" by the Turin 2006 Agency through an international competition. The historically significant General Markets buildings are being restored and functionally renovated as part of this extensive architectural project.[7]

- **Architectural and cultural significant**

At Mercati Generali, innovation meets functionality. Two welcoming entrance buildings house essential services, including banks, restaurants, bars, day hotels, and conference spaces for the convenience of both employees and merchants. Adjacent to these, two elongated structures, extendable internally, serve as expansive warehouses for wholesalers. Upon entering, a grand 5,800 M2 atrium unfolds, leading to vast display rooms featuring symmetrical vaults parallel to the street. The shelters, extendable to a hundred meters, boast impressive 9-11 meter tall parabolic arches made of reinforced concrete, ensuring optimal natural light through large side windows even during winter. This architectural marvel is not just a market; it's a dynamic hub designed for the diverse needs of merchants and visitors, setting new standards for efficiency and convenience.

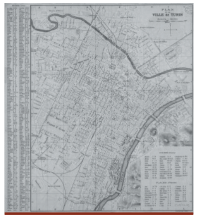
Unfortunately, today this building is underestimated. [8]

- **Provide an Overview of the Periods**

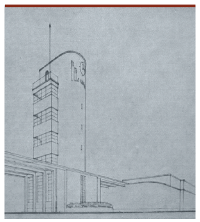
This thesis will analyze Ex-Moi Mercati Generali in three different periods: Construction in the early 20th century, the Winter olympic 2006 renovation phase, and the design proposal for the future. Each period has its architectural evolution in sustainability and Energy performances. This case study will examin the site's potential for adaptive reuse. Especially with the focus on, how energy considerations can be integrated into its renovation. By analyzing these three states, this research will suggest an understanding of how sustainable design could participate in the preservation and maintenance of historical buildings.

7. FILIPPI, M., F. MELLANO, M. FILIPPI, AND OTHERS. *AGENZIA PER LO SVOLGIMENTO DEI XX GIOCHI OLIMPICI INVERNALI TORINO 2006*: CANTIERI E OPERE. MILANO: ELECTA, 2006.
8. MORETTO, DAVIDE. "QUARTIERE FILADELFIA: NON-SOLO CALCIO." MASTER'S THESIS, POLYTECHNIC UNIVERSITY OF TURIN, 2012.

- **Historical Timeline**

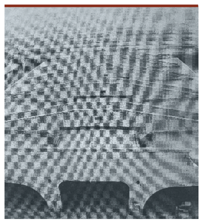


1928 — Brain storming of Market location



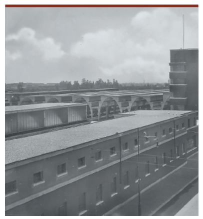
1931 — Competition Lunch

1933 — General Market’s construction



1936 — Addition of roof inside the central square

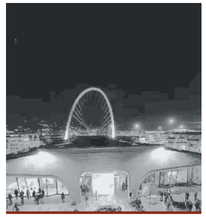
1943 — Bombing by RAF planes, and USAAF for the second time



1948 — Site re-construction After bombing

2002 — The market moved to Grugliasco area and new project started

2006 — Inauguration new Olympic village



2012 — Temporary exhibition area

2025 — Beyond Today

1.4 Methodology

This study used the mixed-methods approach, combining the qualitative analysis which is Historical and Architectural. And quantitative evaluation included the energy performance across three periods. The study aims to find out how adaptive reuse can relate to sustainable design and further interventions. This work has been done by gathering data through different Archives, historical records, articles, Theses, and original Architectural drawings. By considering all the information, this study will demonstrate how renovation and architectural design could improve over time. The initial resources have been gained from the "Archivio storico della citta di Torino", which holds extensive historical photographs, magazines, and original drawings.

1.5 Structure of the thesis

This thesis includes 6 chapters, and each chapter tries to indicate how energy considerations can enhance the sustainability of adaptive reuse projects, using Ex-Mercati Generali Torino as a case study. Below is a brief explanation of each part:

- **Chapter One: Introduction**

The first chapter, Introduction, is an overall overview of adaptive reuse in sustainable architecture, emphasizing the significance of adapting existing structures to reduce their negative environmental effects while maintaining its historical significance. The goals of the thesis are explained with a focus on integrating energy efficiency into adaptive reuse projects.

Ex-Mercati Generali Torino, the case study, is also introduced in this chapter, which ends with a thorough explanation of the research method used.

- **Chapter two: Literature review**

Chapter Two includes a comprehensive analysis of recent research relevant to the thesis topic, with a focus on adaptive reuse, sustainable design strategies, and energy considerations in building renovations. It begins with an investigation of adaptive reuse in architecture, demonstrating how the preservation of historical buildings can be integrated into modern functional requirements and environmental sustainability.

The chapter then focuses on sustainable design principles, emphasizing the significance of energy efficiency and the function of interior features in historical structures due to limits on exterior renovations. It then continues with a discussion of energy considerations in building renovation, pointing out key frameworks and best practices for integrating energy solutions while maintaining architectural integrity. In conclusion, the chapter discusses the integration of these concepts into heritage and historical structures, using the House Moroder case study to show effective retrofitting approaches that balance preservation with energy efficiency gains.

- **Chapter three: Ex-Moi Generali Mercati Torino; site analysis**

This chapter provides a full account of the Ex-Mercati Generali Torino, highlighting its historical significance, architectural features, and evolution during time. It explores into three essential times in the site's history (1933, 2006, and the design proposal), analyzing the building's original design, subsequent changes, and renovation design conditions. The research focuses on the structural and stylistic modifications made to the building to accommodate new uses, as well as its potential for adaptive reuse. The building's potential for continued restoration is pointed out with a discussion of how its architectural integrity and overall design might enable energy-efficient improvements while preserving its historical significance. This chapter offers the basis for the comparison of technologies and energy solutions discussed in the next parts.

- **Chapter four: Comparative analysis of the three periods**

In this chapter, I begin by comparing three significant periods which are the original construction in 1933, the transformation of 2006 due to the winter Olympics and my design proposal. This comparison includes not just the construction techniques used at each phase, but also any following changes and modifications. In addition, I analyze the materials used and their environmental impacts. In this analysis, I consider how the building's transformations and evolution contributed to energy efficiency, ultimately increasing the building's performance. While this chapter provides a broad overview of these developments, with an emphasis on their historical and environmental impacts, the following chapter explores more into the specifics of the energy analysis. There, I will provide a more complete analysis of how the building's energy performance has changed over time, focusing on strategies such as thermal insulation, energy use, and potential areas for improvement.

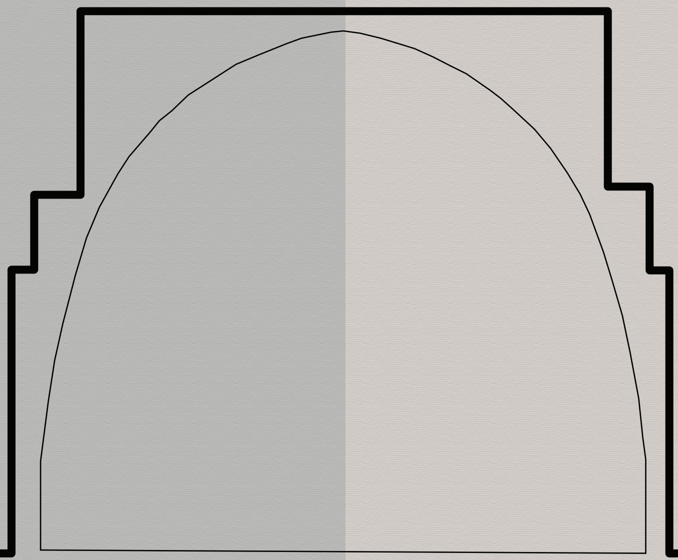
- **Chapter Five: Energy Analysis and Sustainable Design Integration**

Chapter 5 provides the building's energy performance via U-value and R-value estimates for external and interior walls, roofs, and windows. Based on such results, I provide design modifications and material selections that enhance energy efficiency while keeping cost-effective. To achieve a balance between maintenance and development, I prioritized the preservation of existing elements that have no impact on energy performance. Finally, the chapter reaches into additional steps to improve energy efficiency, which match with adaptive reuse aims and maintain the building's historical character while preparing it for future use.

- **Chapter six: Discussion**

This chapter presents the results and insights from the comprehensive analysis conducted by Ex-Mercati Generali Torino over its three mentioned periods. It examines the strategies through which these findings enhance sustainable design, energy efficiency, adaptive reuse, and environmental impact. This research underlines how sustainable interventions can preserve a site's historical importance while integrating modern sustainability practices by assessing the building's energy performance and architectural changes over time. The findings indicate that adaptive reuse can serve as an effective strategy for increasing energy efficiency and building performance, while also addressing the challenges of finding a balance between preservation and innovation.

02



Literature review

2. Literature review

2.1 Adaptive reuse in Architecture

Adaptive reuse of historical architecture aims to balance the preservation of existing structures and the necessity to adapt to modern requirements, mainly those related to financial and physical resources. Architectural heritage buildings can contribute significantly to a modern urban environment and meet its functional requirements while maintaining their original facades, historical patterns, layouts, architectural elements, and historical associations through acceptable reuse with suitable evaluation methods. A comprehensive, multi-interest process, the assessment of adaptive reuse of architectural heritage includes methods of planning and mid- to long-term development targets, in addition to maintaining historical, economic, scientific, and aesthetic qualities. The process of adaptive historical reuse improves a destination's value by providing tourists with recreational benefits. Preserving historical architecture, as well as other features, is an important part of increasing a destination's attractiveness. Natural landscapes are major tourist attractions, and to expect economic benefits, adaptive historical reuse methods need to keep into consideration the various dimensions of value as well as the need of providing visitors with an inviting place. Changes in a heritage site's landscape, from the process of demolition to adaptive historical reuse, transfer the location's value for the original users into a variety of values, including cultural, social, landscape, and environmental values—for new users.[9]

Adaptive reuse aims to reduce the demand for new materials by reusing existing building structures and shells, such as the outer layer, roof structure, and occasionally windows, as well as materials and infrastructure. Waste will be disposed in this case. This means that there will be less of an impact on the environment.

2.2 Sustainable design practices

Sustainable development was described in the 1987 Bruntland Commission's report (WCED, 1987) as, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [10] Based on statistics from "European commission", 85% of EU buildings were built before 2000 and amongst those, 75% have a poor energy performance. Acting on the energy efficiency of buildings is therefore key to saving energy and achieving zero-emission and fully decarbonized building stock by 2050.[11] While the building performance is completed, we should go to work on energy-related matters. These aspects can be divided into three categories: windows and glazing, building envelope, interior features, Interior lighting, mechanical and ventilation systems, and exterior materials and colors.[12] The study's emphasis will be mostly on interior features, technology, and materials considering the building is historical and there are restrictions on transforming the facade with respect to its current exterior.

9. TU, HUNG-MING. 2020. "*THE ATTRACTIVENESS OF ADAPTIVE HERITAGE REUSE: A THEORETICAL FRAMEWORK*" SUSTAINABILITY 12, NO. 6: 2372. P. 2 HTTPS://DOI.ORG/10.3390/SU12062372
10. GRIERSON, DAVID, AND CAROLYN MARY MOULTRIE. "*ARCHITECTURAL DESIGN PRINCIPLES AND PROCESSES FOR SUSTAINABILITY: TOWARDS A TYPOLOGY OF SUSTAINABLE BUILDING DESIGN.*" *DESIGN PRINCIPLES AND PRACTICES* (2011): 623-634.
11. EUROPEAN COMMISSION. "*ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE.*" ENERGY. LAST MODIFIED AUGUST 24, 2023. HTTPS://ENERGY.EC.EUROPA.EU/TOPICS/ENERGY-EFFICIENCY/ENERGY-EFFICIENT-BUILDINGS/ENERGY-PERFORMANCE-BUILDINGS-DIRECTIVE_EN.
12. FOURNIER, DONALD, AND KAREN ZIMNICKI. "INTEGRATING SUSTAINABLE DESIGN PRINCIPLES INTO THE ADAPTIVE REUSE OF HISTORICAL PROPERTIES." JOURNAL OF SUSTAINABLE DESIGN, MAY 1, 2004, 71.

2.3 Energy consideration in building renovation

Nowadays, building renovation is a global focus for reducing environmental impact. As a result, energy considerations play a major role in achieving this goal. By maintaining the existing structure, there is a great opportunity to upgrade the building's energy performance through various methods and technologies. Several frameworks and standards guide the integration of energy into building renovation. LEED (The Leadership in Energy and Environmental Design) developed in 2000 by the non-profit association USGBC - US Green Building Council (founded in 1993) for rating design and construction practices that would define a green building in the US. BREEAM (British Research Establishment Environmental Assessment Method) is also for buildings and large-scale developments.[13] This section will list the best practices for energy integration. In the case of study scenario, enhancing thermal insulation, particularly for interior components, is a crucial option. On the other hand, installing active solutions such as photovoltaic panels on rooftops and facades, with respect to the preservation of the original asset could help more in this matter. Another method is material selection, specifically choosing materials that are capable of being recycled.

13. MENSAH, SAMUEL K. OCCUPANT SATISFACTION WITH GREEN CERTIFIED BUILDINGS: A CASE STUDY OF ONE AIRPORT SQUARE. BACHELOR'S THESIS, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, DEPARTMENT OF CONSTRUCTION TECHNOLOGY AND MANAGEMENT, 2019. P.3

2.4 Relevance to heritage and historical buildings

- **Analysis of a Case study**

Although implementing these methods affects energy performance, there are challenges related to maintaining architectural integrity. In this study, I aimed to strike a balance between the dos and don'ts. As this case study holds a lot of historical and cultural value for its town, the preservation action is a priority. However, most of the heritage buildings were built before modernity so it causes the inefficiency of these properties. In this thesis, I cautiously chose the most effective techniques to keep the boundary between renovation and preservation. Fortunately, modern technology can be applied to heritage sites with no disruption to their values. I will explain them below. Energy-efficient glazing, thermal insulation materials, and renewable energy systems are some options we could use without breaking any rules. Here I want to mention a case study that matches the features referred to above. The case study is House Moroder, located in Bolzano Italy. The Architect Michael Tribus was built it in 1900s. This is a residential building with the Brick masonry wall type of construction. This area was expanded and the buildings reconstructed over the years, so that today the place is characterised by a colourful mix of buildings from different periods.

The renovation aimed to increase indoor comfort while respecting the building's architectural identity. Although this building was not registered, the owners want to maintain its architectural value. This was one of the few buildings in Bolzano that remained unchanged since its construction. The main goal of the refurbishment was to maximize the possibilities of maintaining the building while also achieving high levels of energy efficiency. The retrofit's aim was to reduce thermal losses through walls, windows, and thermal bridges while taking advantage of efficient technology to ensure a high level of indoor comfort with low energy consumption.[14]

Figure 2 South-West side

Figure 3 North facade

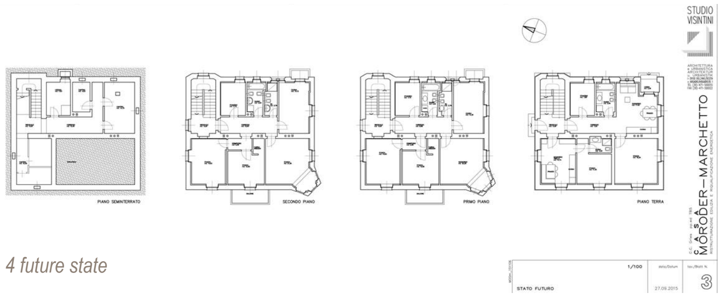


Figure 4 future state

Figure 5 The South view

Figure 6 The East view

Figure 7 The West view

Figure 8 The North view

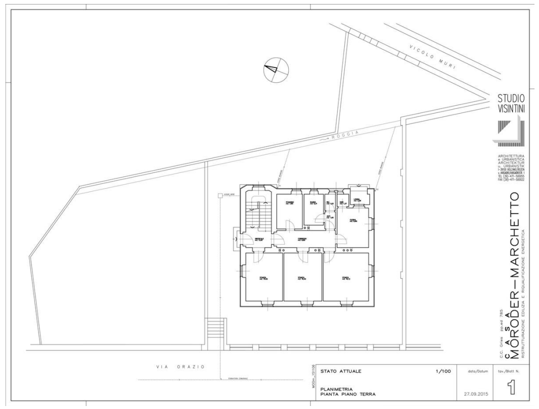


Figure 9 current status

14. HIBERATLAS. "HOUSE MORODER." HIBERATLAS, HTTPS://HIBERATLAS.EURAC.EDU/EN/HOUSE-MORODER--2-255.HTML. ACCESSED 12 SEPTEMBER 2024.

15. HIBERATLAS. "HOUSE MORODER." HIBERATLAS, HTTPS://HIBERATLAS.EURAC.EDU/EN/HOUSE-MORODER--2-255.HTML. ACCESSED 12 SEPTEMBER 2024.

To keep the facade untouched, 10-cm insulation was installed on the inside of all external walls. To prevent a thermal bridge, the floor was removed for a few centimeters along the wall joints, and the window frames have been modified to reduce heat loss. After calculating the initial U-value, the addition of an insulation layer to the internal side of the exterior walls resulted in a reduced U-value, enhancing the thermal performance of the building.[15] They measure the u-value of the window glass and frame individually. Modifying the window type and glazing results in a lower u-value and decreased thermal transmission. You can see the result below:

Existing window U-value Glass [W/m2K]:1,4

New window U-value Glass[W/m2K]:0,7

Existing window U-value Frame [W/m2K]:2,7

New window U-value Frame [W/m2K]:1,1

Renovated Windows	
New window type	Sash
New glazing type	Triple
New shading type	Outer shutter
New solar factor g	0.47

Existing Window	
Existing window type	Box-type
Existing glazing type	Single
Existing shading type	Outer shutter
Approximate installation year	1926


Figure 10 Window frame


Figure 11 Windows location

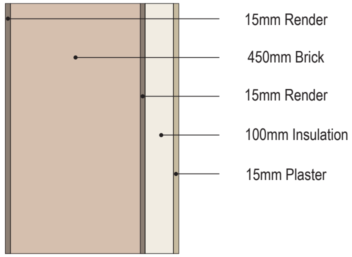


Figure 12 Retrofitted wall build up

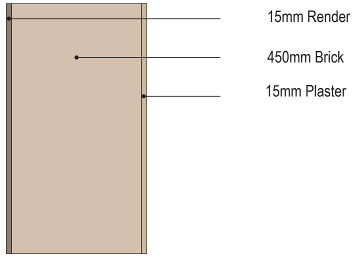
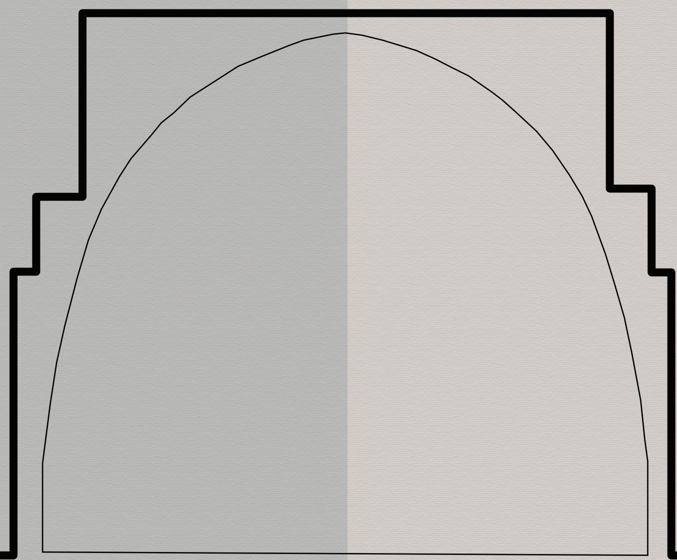


Figure 13 Original wall build up

03



Ex-Moi Mercati Generali Torino site analysis

3. Ex-Moi Mercati Generali Torino site analysis

3.1 Historical overview of the site

Turin's rapid population growth, combined with the inefficiency of numerous open-air markets, forced the construction of a new, organized market in the early twentieth century. The old markets, which lacked suitable frameworks, caused logistical difficulties and traffic jams, as well as increased the cost of goods. To solve these issues, the new market planned to upgrade the city's infrastructure, improve public hygiene, and simplify economic activity. This project was a critical component in Turin's urban growth, improving both functionality and aesthetic appeal.[16] Apart from the bombing time, the historical evolution of Ex-Moi Generali Mercati is characterized by three different periods. The initial one was designed for the wholesale market with wide openings, high ceilings, and large open spaces suitable for goods and people. After a long time of being unused, the city became the host for the Winter Olympics of 2006. This event affected the functionality of this site. Today, the Ex-Moi Generali Mercati property is abandoned and provides shelter for the homeless. Its outstanding cultural value has gone unnoticed for many years since multiple plans for restoration from various institutions have failed to occur. The location is currently used mostly as a pathway to reach Lingotto, with its potential largely disregarded.

16. CERAGIOLO, MARIO. "IL NUOVO MERCATO IN GROSSO ORTOFRUTTICOLO DELLA CITTA DI TORINO", 1933, P 4.


Figure 14 Construction phase,1933

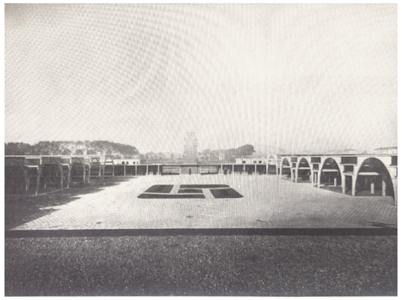


Figure 15 The central view,1933


Figure 16 The Interior view of the fruit stall,1933

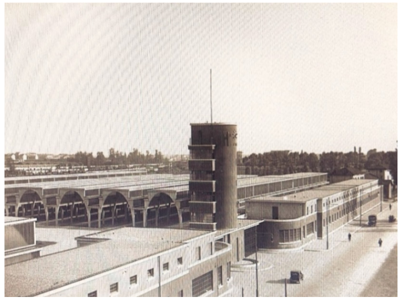


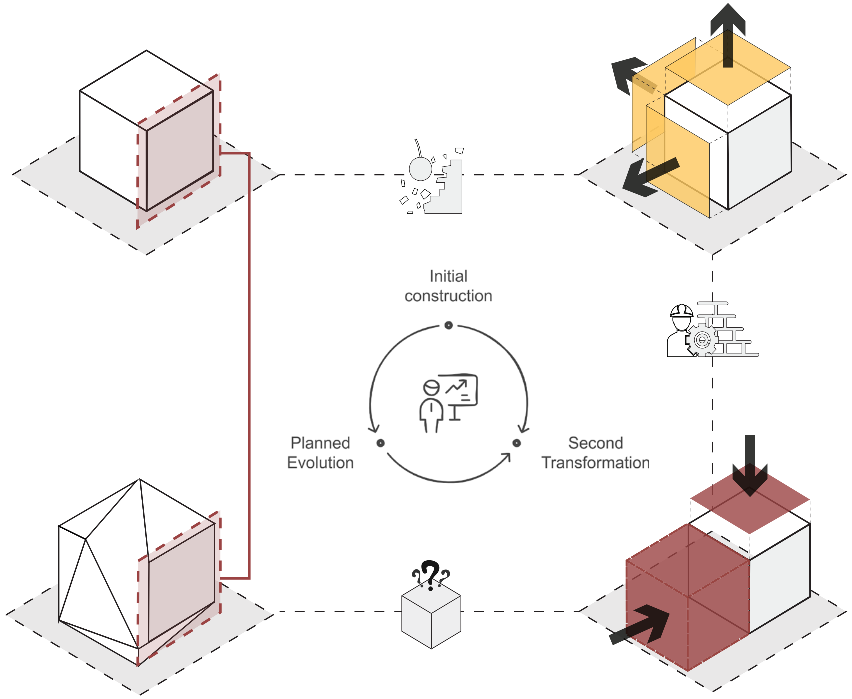
Figure 17 The North view,1933


Figure 18 The Arch view,1933

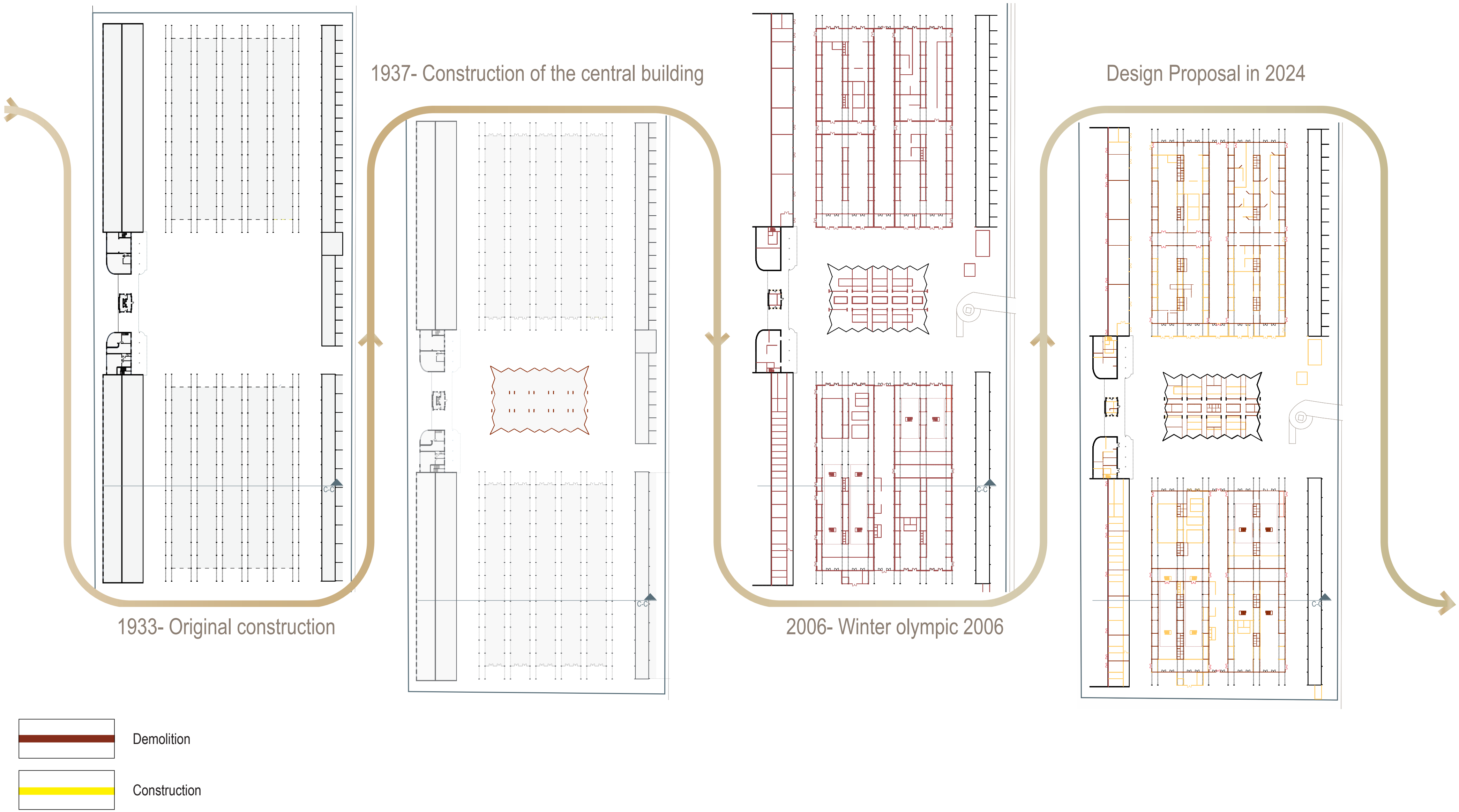

Figure 19 The interior view of Arch

3.2 Architectural Evolution over three periods

As mentioned in previous sections, the Ex-Moi Generali Mercati has witnessed two significant transformations. My design is to undergo a third phase of evolution, leading to the next phase in its development.



Infographic process




Original construction and design-1933

- **Period one: 1933-1945 - Original construction and design**

Del Duca e Miccone participated in the public competition for the construction of the Ex Moi Mercati-Generali and won. The project, designed by the Istrian architect Umberto Cuzzi, was completed as a significant architectural achievement of its time. The design enabled efficient market operations by allowing products to be unloaded directly from wagons onto the sales floor, with the market strategically located near customs and sorting stations. Strategic planning is evident in the alternating flat porches and seven canopies, creating a harmonious space for both pedestrians and goods. Specialized areas beneath these structures facilitate seamless loading, unloading, sorting, and trading processes, optimizing logistical efficiency. The market's layout defines distinct parking spaces and transit routes in covered and paved areas. The Mercati Generali goes beyond conventional markets, incorporating modern amenities like weighing stations, refrigerated chambers, and washing tanks. This architectural marvel is not just a market; it's a dynamic hub designed for the diverse needs of merchants and visitors, setting new standards for efficiency and convenience. Unfortunately, today this building is underestimated.[17]

Unfortunately, the impressive structure was significantly affected by the tragic impacts of World War II bombings. On August 17, 1943, RAF planes did significant damage, and in 1944, the USAAF occurred in the area again. This resulted in the entire collapse of some warehouses and damage to sheds. As a result, the area required considerable reconstruction between 1944 and 1945. Turin's new market building was completed, becoming Italy's third-largest Agro-food complex. Following the relocation from Porta Palazzo, the General Markets served as CAAT's operating base from 1945 until 2001, when the corporation's time at this facility ended.[18]

Below are some photos depicting the site during the bombing period.

Figure 20 Damage caused by bombing
Source: https://www.museotorino.it/


Figure 21 Damage caused by bombing
Source: https://www.museotorino.it/


Figure 22 Damage caused by bombing
Source: https://www.museotorino.it/

Figure 23 Damage caused by bombing
Source: https://www.museotorino.it/

17. MORETTO, DAVIDE. "*QUARTIERE FILADELFIA: NON-SOLO CALCIO.*" 2012.
18. M. FILIPPI, F. MELLANO, M. FILIPPI ET AL., AGENZIA PER LO SVOLGIMENTO DEI XX GIOCHI OLIMPICI INVERNALI TORINO 2006: CANTIERI E OPERE. MILANO: ELECTA, 2006, PRINT.

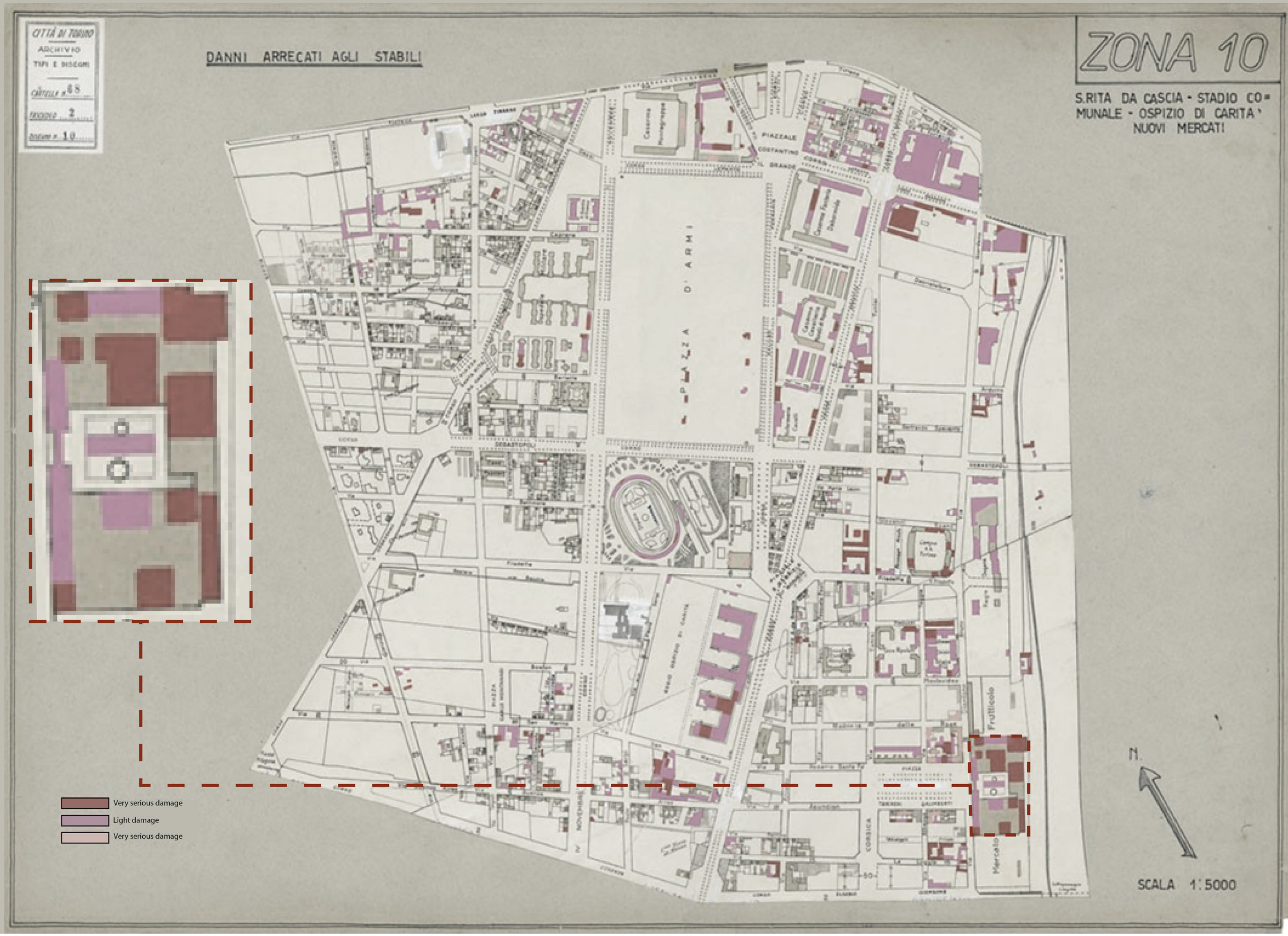


Figure 23 Damage caused by World War II bombings on the Mercati Generali. Source: MuseoTorino, Mercati Generali.


Olympic Torino- 2006

- **Period two: Olympic Torino- 2006**

The Winter Olympics 2006 was a fundamental moment for Turin, bringing international attention and needing extensive organization. This city hosted a wide range of events, athletes, and visitors from all over the world. To be prepared for this welcoming event, many developments have been made. Including the construction of new sports facilities and important changes to transportation systems. From the book "Torino Moi, from General Markets to Olympic Village" one could understand that the Investments made for this event would benefit the city long after the event was over. The Olympic Village's life center is designed with future adaptability in mind. All organizational elements are removable and changeable, allowing for post-Olympic reuse. This is the legacy that not only influences the physical infrastructure but also the improvement of the global face of Torino as a destination for tourism and other international events. Besides the economic aspect of this event, the Olympics has played an important role in shaping the cultural landscape of Torino. The city accepted various cultural events, exhibitions, and international cooperation among participants and visitors. Moreover, managing such a large-scale event has witnessed some challenges. For instance, logistical issues, financial considerations, and the most crucial one is the need to balance short-term goals with long-term sustainability. These challenges are valuable lessons for future hosts. Based on the book, there are many people and institutions involved in this project. I will mention a few of them, such as Benedetto Camerana who is the Architect, and Otto Steidle who was the specialist in town design and residential quarter projects. He contributed to the design of the residential quarter. Pietro Derossi Brought decades of experience in residential architecture to the project. Inarco, a consultancy from Torino that contributed to urban studies developed for the Lingotto area and collaborated on project engineering for structures. The team reached a conclusion on important matters such as the footbridge plan, the integration of the Olympic district into the city, and urban design. They planned to widen roads and establish market spaces. Disagreements arose over the master plan, with Steidle preferring a strict, clear layout and Derossi recommending architectural freedom. Steidle's checkerboard plan was eventually chosen, with 40 buildings packed along the urban front and equally divided elsewhere.[19]

- **Public Space and Urban Integration**

A large part of the outdoor space is public, with areas designated for pedestrian flows and parking.[20] The village's urban and environmental insertion considers both the athletes' needs and the wider public, integrating the site into the city's fabric.[21]

19. CITTÀ DI TORINO. TORINO MOI: FROM GENERAL MARKETS TO OLYMPIC VILLAGE. TURIN: 2005. P 86-105
20. CITTÀ DI TORINO. TORINO MOI: FROM GENERAL MARKETS TO OLYMPIC VILLAGE. TURIN: 2005. P 98,99
21. CAMERANA, BENEDETTO. VILLAGGIO OLIMPICO TORINO 2006. TORINO: CAMERANA & PARTNERS, 2005. P.30

Public Space and Urban Integration

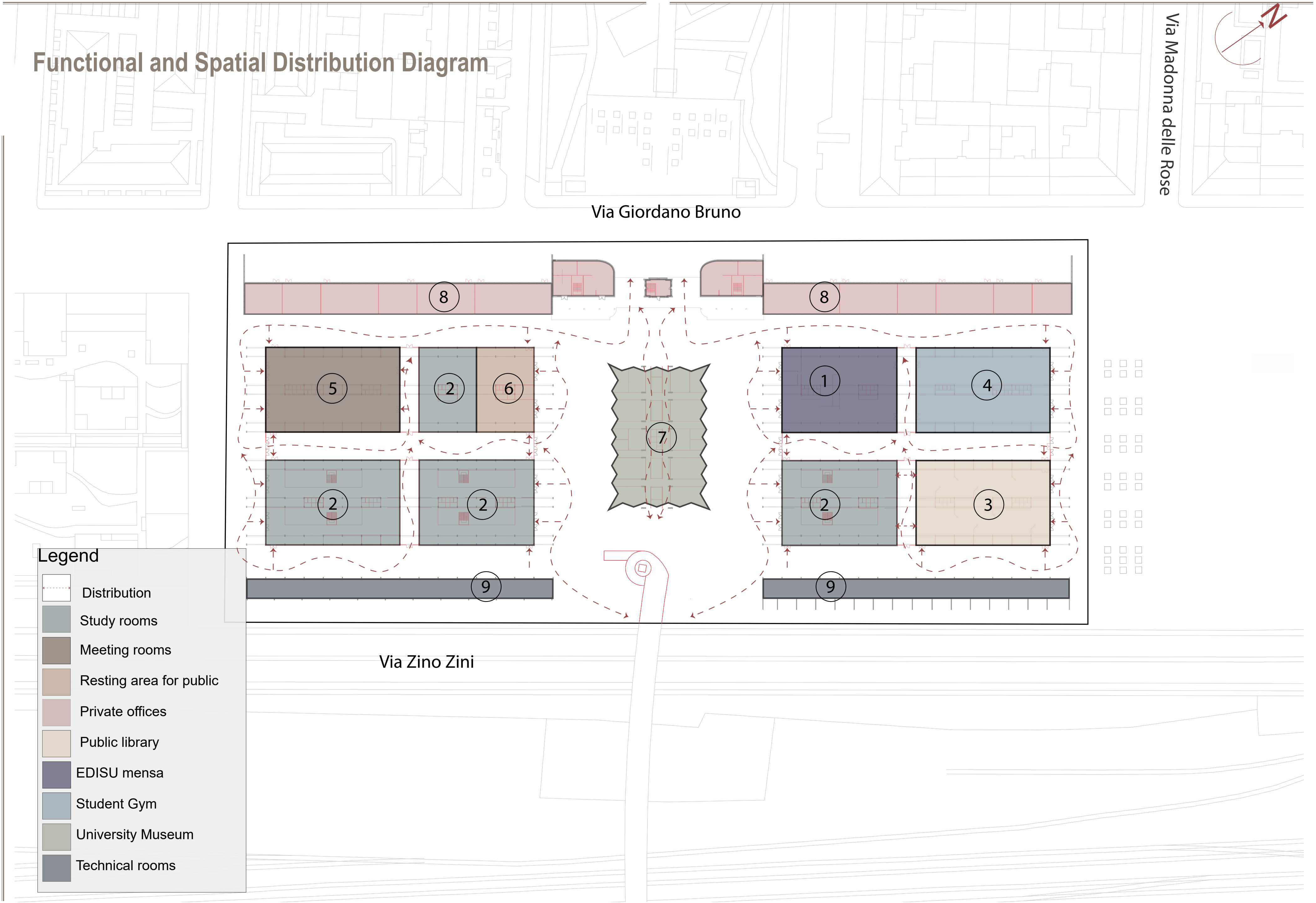
- **Period Three: Design proposal-2024**

The third stage reflects the building's design proposal state, emphasizing significant changes aimed at improving energy efficiency and reducing environmental impact. This phase of renovation focuses not only on preserving the building's historical and architectural integrity but also on incorporating sustainable techniques to ensure its viability for modern use. Insulation layers were added to the walls, floors, and roofs to enhance energy efficiency and reduce thermal loss. These renovations were designed to make the building more energy-efficient while adhering to preservation requirements due to its historical significance. Given the site's protected status, these upgrades were carefully integrated without altering exterior features, such as the façade and overall appearance of the structure. The new interventions preserve the building's original architectural elements, ensuring that its cultural and historical significance remains intact. At the same time, structural improvements have allowed for new functionalities that were logically chosen to meet future user demands. This comprehensive approach ensures the building is prepared for future reuse while remaining sustainable, demonstrating how modern energy solutions can be harmonized with historic architecture. The new features and proposed design will be discussed in detail in the sections that follow. These features were carefully designed based on a thorough investigation of the site and a thorough understanding of the users' future demands. The design approach tries to meet these needs by carefully integrating territorial, functional, and aesthetic features, ensuring that the space is adaptive and sustainable throughout time. The design aims to develop a flexible and durable solution that improves the entire experience of the site by taking into account both the users' immediate needs and long-term goals.

- **Design proposal area Identification**

1. An affiliated student canteen managed by the institution 'EDISU' for universities.
2. Spaces dedicated to coworking and study, such as study rooms.
3. A Public Library
4. a gym for students
5. Meeting areas
6. A refreshment area open to the public.
7. A museum centre
8. Private commercial premises (offices).
9. Technical rooms and a warehouse.

Functional and Spatial Distribution Diagram



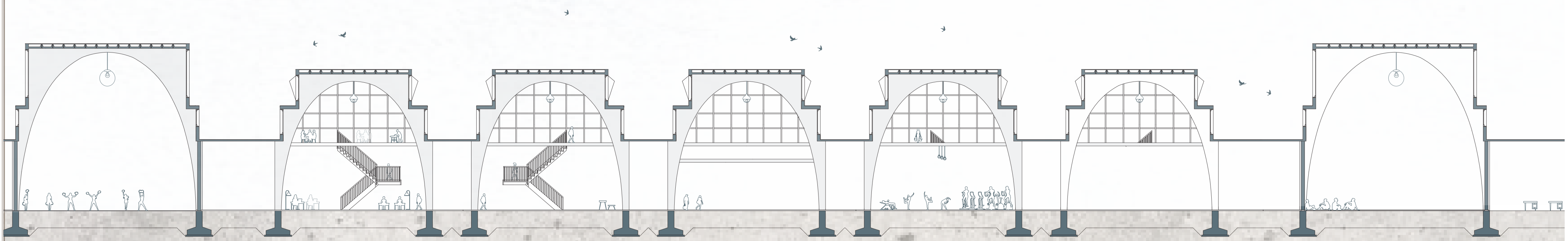
3.3 Selection of section for detailed study

The research will compare the site's architectural and energy performance over time and recommend improvements to these aspects. The portions chosen for analysis are significant within the site, with an emphasis on places that best indicate the evolution of the building's use and design. The transverse section under discussion focuses on the important arches, entrance buildings, and buildings next to the railway. That section crosses through the South-East 7 Arches, which have experienced numerous functional changes throughout the site's history. Each period of the structure's history brought transformation that changed both the design and energy efficiency of these arches, illustrating how the site modified to changing functional and ecological demands. To be more specific, the section illustrating the site's original state shows areas beneath the arches that were previously used for fruit sales. These places were active commercial centers where merchants operated. On the western side of the area, you can see the building dedicated to receiving goods that arrived via train wagons. This building was critical to the site's logistical operations since it was immediately connected to the railway network, enabling efficient transportation transit and distribution. This original layout not only represents the market's achievable architecture but also displays the site's strategic relationship with the railway, pointing out its importance as an important center for trade and commerce. The contrast between the commercial spaces under the arches and the logistical facility to the west emphasizes the space's architectural and functional efficiency during this time.

Section C-C
sc: 1:500

This section from 2006 highlights the important modifications made to accommodate the Olympic Games. Extensive interventions were carried out, including the creation of a new floor to the building and significant changes to the internal spaces. These improvements included reorganizing the internal parts by installing inner walls that divided open spaces into multiple functional zones. From this portion, we can see many features added to the southeast side of the structure. This consists of a fitness center, an athletes' relaxation lounge, the IOC Athlete Commission voting area, and the Chef de Mission meeting hall.

The spaces were created to fulfill the needs of athletes and authorities during the Olympic Games, indicating a significant shift in use from the site's original purpose. On the southwest side of the site, a polyclinic was built to provide athletes with essential healthcare. The addition of this facility demonstrates the site's flexibility to meet modern, large-scale requirements while maintaining structural integrity. This period of renovation demonstrates the building's ability to adapt, adding layers of functionality while maintaining historical value.[22]



Section C-C
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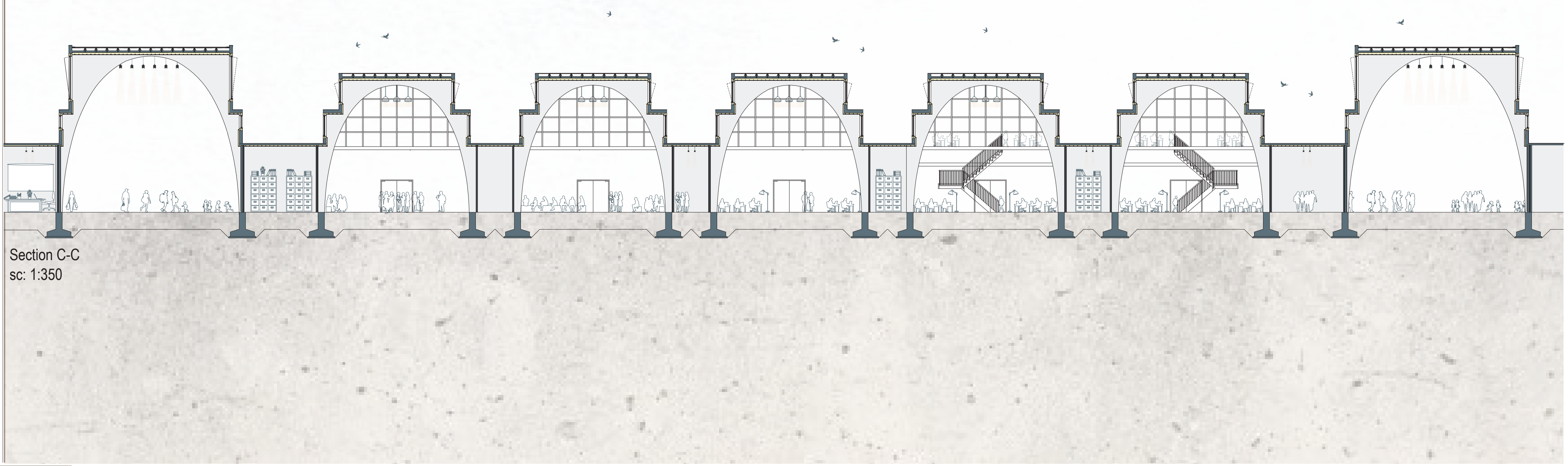
22. TORINO ORGANIZING COMMITTEE FOR THE XX OLYMPIC WINTER GAMES (TOROC). NOC CHEFS DE MISSION MANUAL: XX OLYMPIC WINTER GAMES, TORINO 2006. DECEMBER 2005.P.165

The last section presents my design proposal, which is inspired by a colleague's suggested design. But, in order to adapt it to the requirements of the project, I have made a lot of modifications and improvements. which includes interventions that show the needs of new users. The main aim of this phase is to minimize consumption of energy and improve the building's overall energy efficiency while the architectural value remains the same. As a result, the second floor, which was built during the 2006 Olympic modifications, remains untouched, however the function has been changed according to the needs of current users.

Plus, some modifications have been made to the walls, floors and roofs. The project demonstrates how planned improvements, particularly in terms of energy efficiency, can transform a historical building into a sustainable environment while maintaining architectural identity. The modifications are intended to preserve the building's historical value while providing a comfortable, energy-efficient environment for its new employees. In the following chapters, you will find the selected architectural sections detailed in chronological order, reflecting the changes across different periods.



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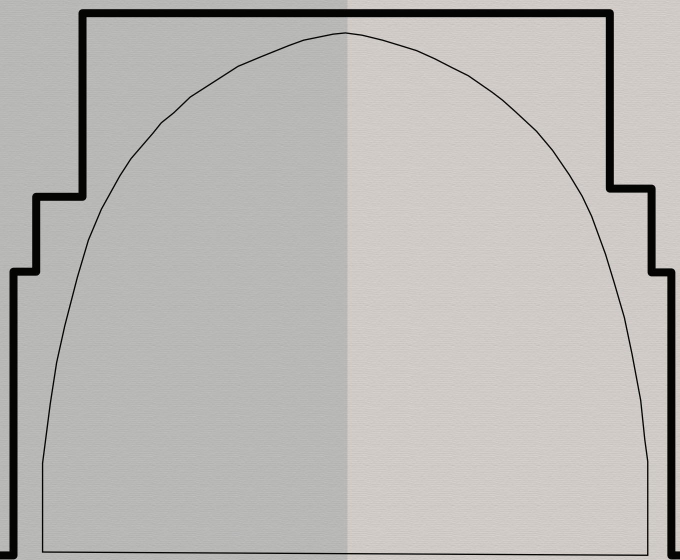


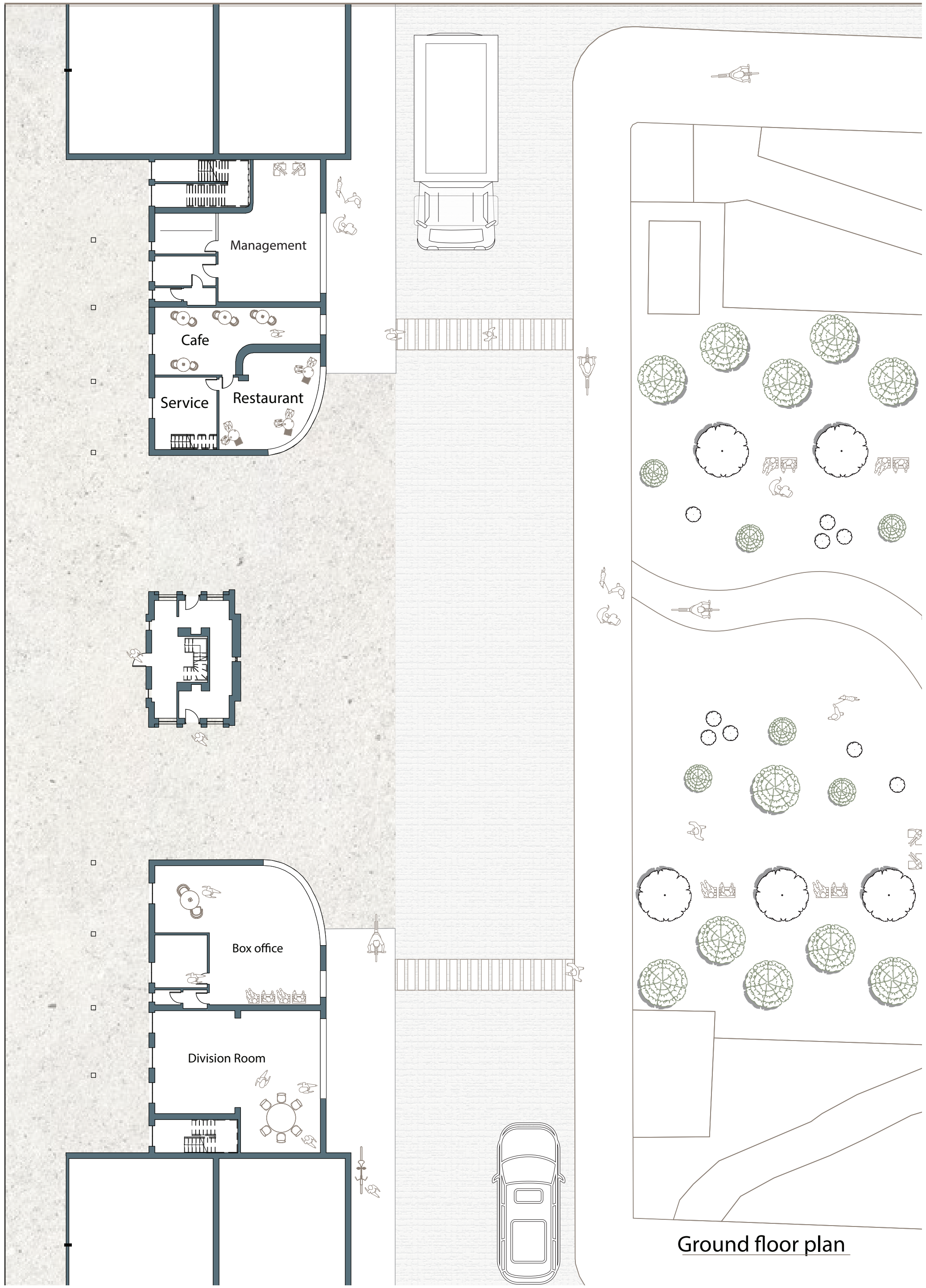
Comparative Analysis of the three periods

4. Comparative Analysis of the three periods

4.1 Period one: original design and use

In a document titled Il nuovo mercato in grosso ortofrutticolo della città di Torino, it is mentioned that the entrance to the Market was divided into two parts, each 9 meters wide and covered by a portico, separated by a 22-meter-high tower, which had two large luminous clocks on its top. On the ground floor of this tower, there were premises for entrance monitoring, which were closed by sliding gates. On each side of the entrance, there were two buildings, partially one-story and partially two-story. On the ground floor, there were areas such as a café and restaurant, post and telegraph service, the cash office, and a meeting hall for merchants. The first floor was divided into two parts: one part included some offices, and the other consisted of two small apartment units for the security staff. There was a basement that contained a day hotel with required facilities such as toilets, bathrooms, a tobacco shop, and a barbershop. All of these areas were paved and lined with washable materials. Additionally, the spaces were both mechanically and naturally heated and ventilated.The staircases are made of marble, and the rooms are simply decorated and heated by radiators. The paving of the uncovered central square and the two uncovered terminal streets are made of Balme syenite, laid in the same manner. The roofing of the roads and parking spaces is made of reinforced concrete, with arches 9 to 11 meters high, situated between the flat roofs of the warehouses.

22. TORINO ORGANIZING COMMITTEE FOR THE XX OLYMPIC WINTER GAMES (TOROC). NOC CHEFS DE MISSION MANUAL: XX OLYMPIC WINTER GAMES, TORINO 2006. DECEMBER 2005.P.165

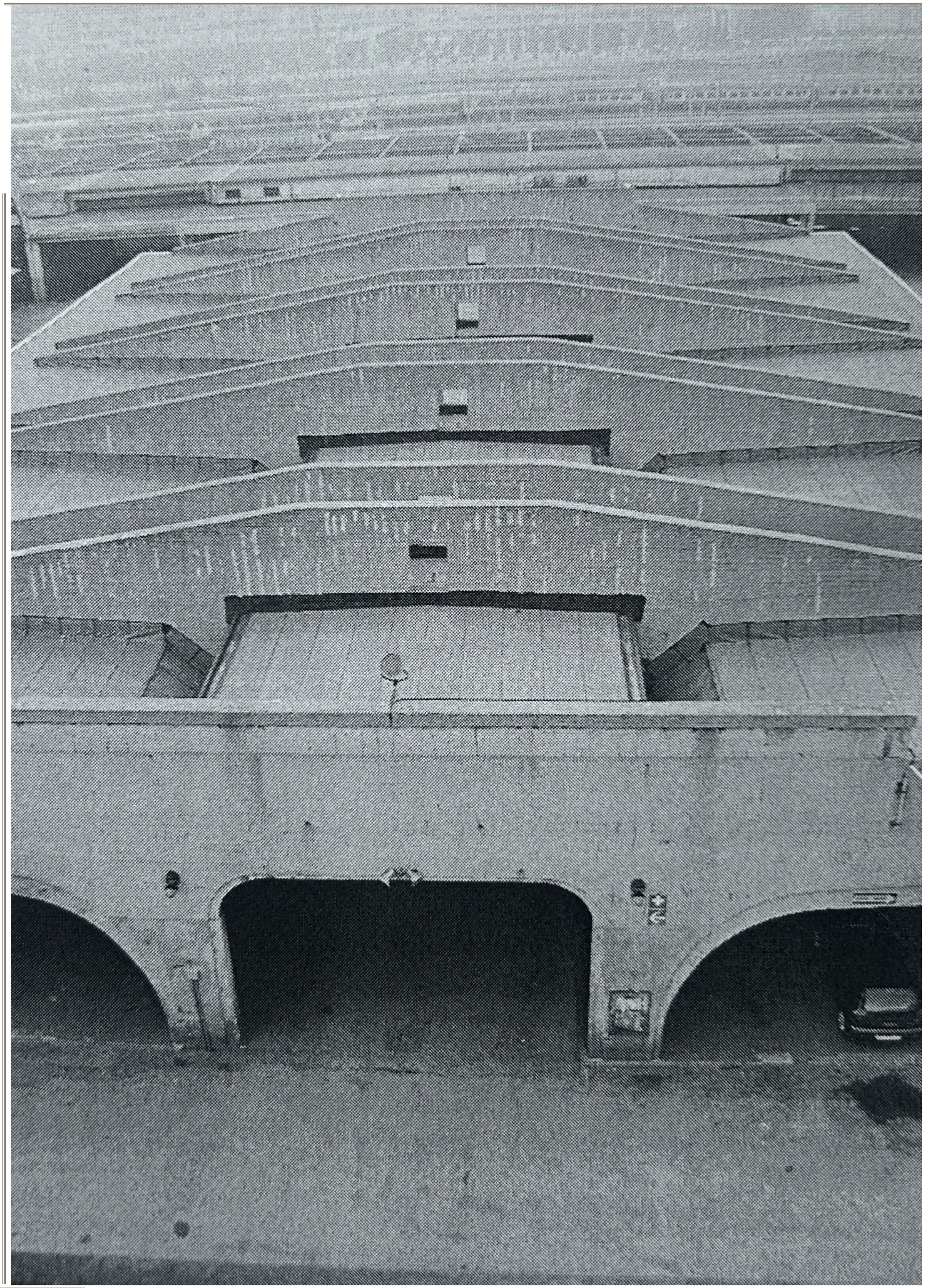


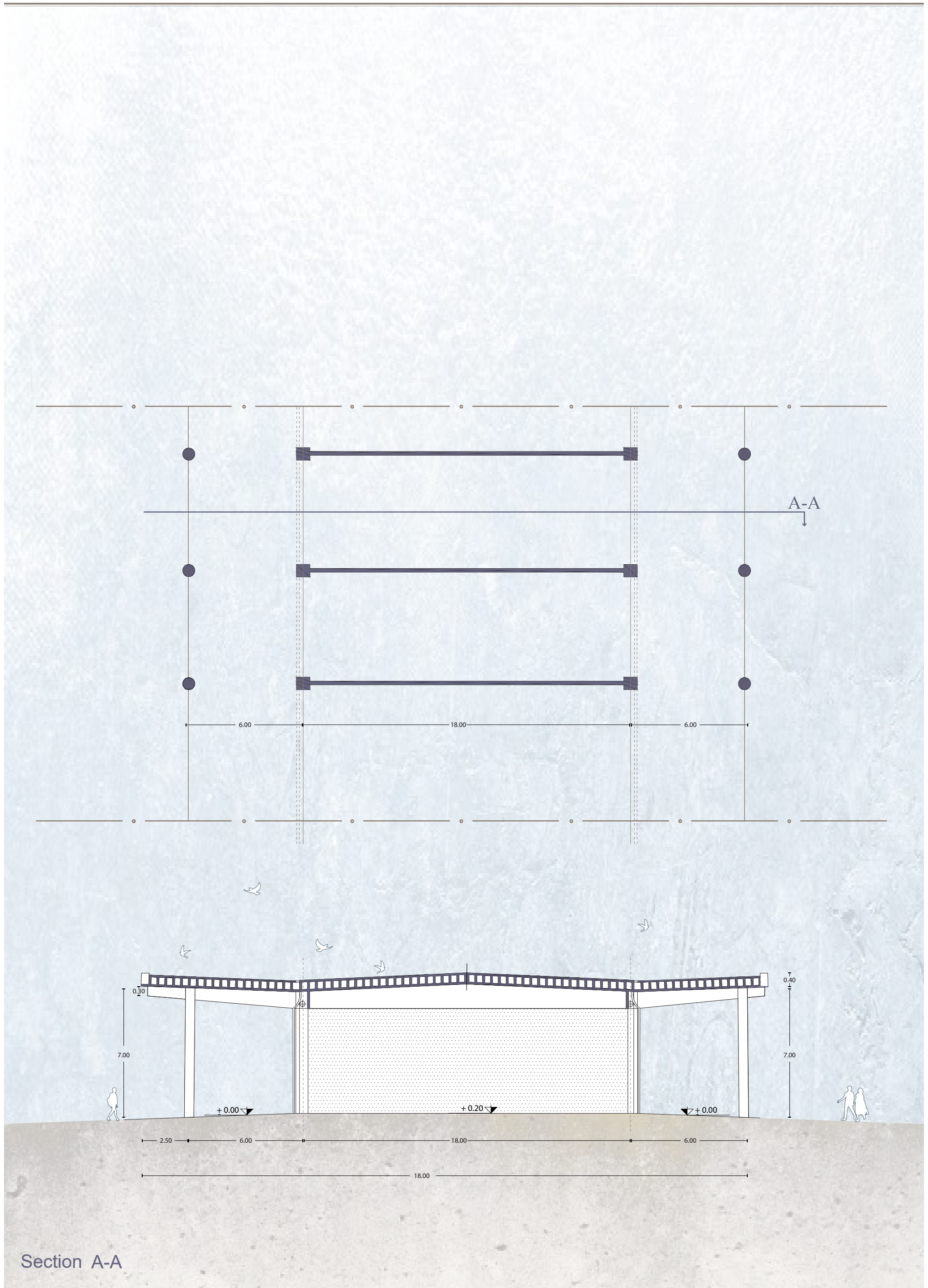
Ground floor plan

Additionally, a multi-layer waterproof covering of bituminous materials is spread over the floors. The flooring of the stands and pathways is made of stoneware tiles on a cementitious concrete substrate; hence it is perfectly washable. The tile organized clearly separates the parking zones, which are divided by handcart passages. These paths allow handcarts to deliver parking spaces while allowing customers to move freely. Despite its historical structure, the buildings are an excellent example of totally rational architecture that is fully responsive to its purpose and the structure is one of the first examples of the use of Zeiss-Dywidag patent, an engineering solution to achieve large spans for industrial, commercial and public structures. The Zeiss-Dywidag is the first time that shotcrete was used like construction method for engineering structures. Using the Zeiss-Dywadag System is capable of building structures of arches with 40 meters of spans in reinforced concrete. Air, light, and cleanliness are all given in various amounts. As a result of the canopies' orientation, the temperature remains several degrees lower than the outside temperature during the summer. It is important to point out that the features used at the time were significant in terms of functional needs and architectural styles. However, the lack of sufficient insulation materials has resulted in increased heat loss, reducing the building's overall performance. This issue highlights the necessity for current interventions to improve energy efficiency and increase building functionality in today's environment. The central building was built after construction due to the lack of parking spaces. The sheds were constructed with prefabricated reinforced concrete structures that were installed on-site. Each aisle is 120 meters long and 35 meters wide, with 20 parking spaces. The load-bearing structure, which consists of four rows of pillars, provides for mobility in the prefabricated panels that divide the various parking spaces, allowing the surface area to be modified. The shed's exterior includes a double canopy for unloading and selling which measures 8.50 meters. The minimum surface area of a parking space is 100 square meters. In addition to unloading roads, the project offers direct loading in sales paths, defined parking spots, and side roads to prevent obstacles during movement operations. To ensure safety, it is recommended that the market flooring be composed of non-slip materials. The project includes customers lots in front of and alongside the sales areas, as well as in the side lanes. Some warehouses are specifically constructed for loading and unloading by licensed operators and vehicles, as well as for car parking. Furthermore, an alternative location for repair and service stations is provided. In terms of management aspects, the management office area contains police stations, healthcare facilities, and a stock exchange for commodity transactions.[23] You can refer to the distribution diagram below for a clearer understanding of the entire system.[24]

22. TORINO ORGANIZING COMMITTEE FOR THE XX OLYMPIC WINTER GAMES (TOROC). NOC CHEFS DE MISSION MANUAL: XX OLYMPIC WINTER GAMES, TORINO 2006. DECEMBER 2005.P.165
23. CAIMOTTO, GIUSEPPE, AND PIER NATALE GUERCI. PROGETTO DI UN MERCATO ALL'INGROSSO DEI PRODOTTI ORTOFRUTTICOLI PER L'AREA TORINESE. 1977-1978. ARCHIVIO STORICO DELLA CITTÀ DI TORINO. ACCESSED APRIL 4, 2024.P 24.

24. CERAGIOLO, MARIO. "IL NUOVO MERCATO IN GROSSO ORTOFRUTTICOLO DELLA CITTA DI TORINO", INNER ROAD DIAGRAM, 1933, P 7.




A-A
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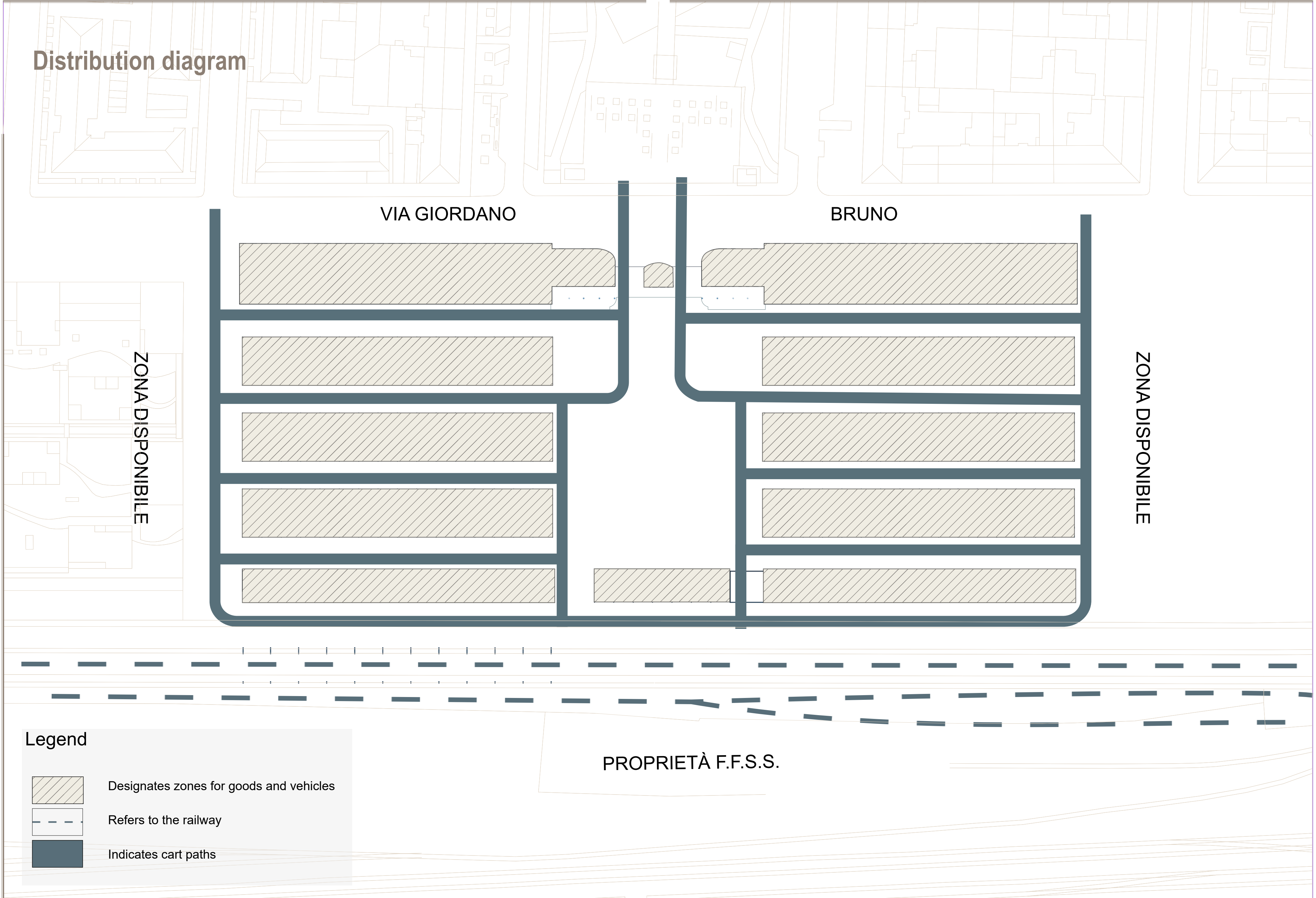
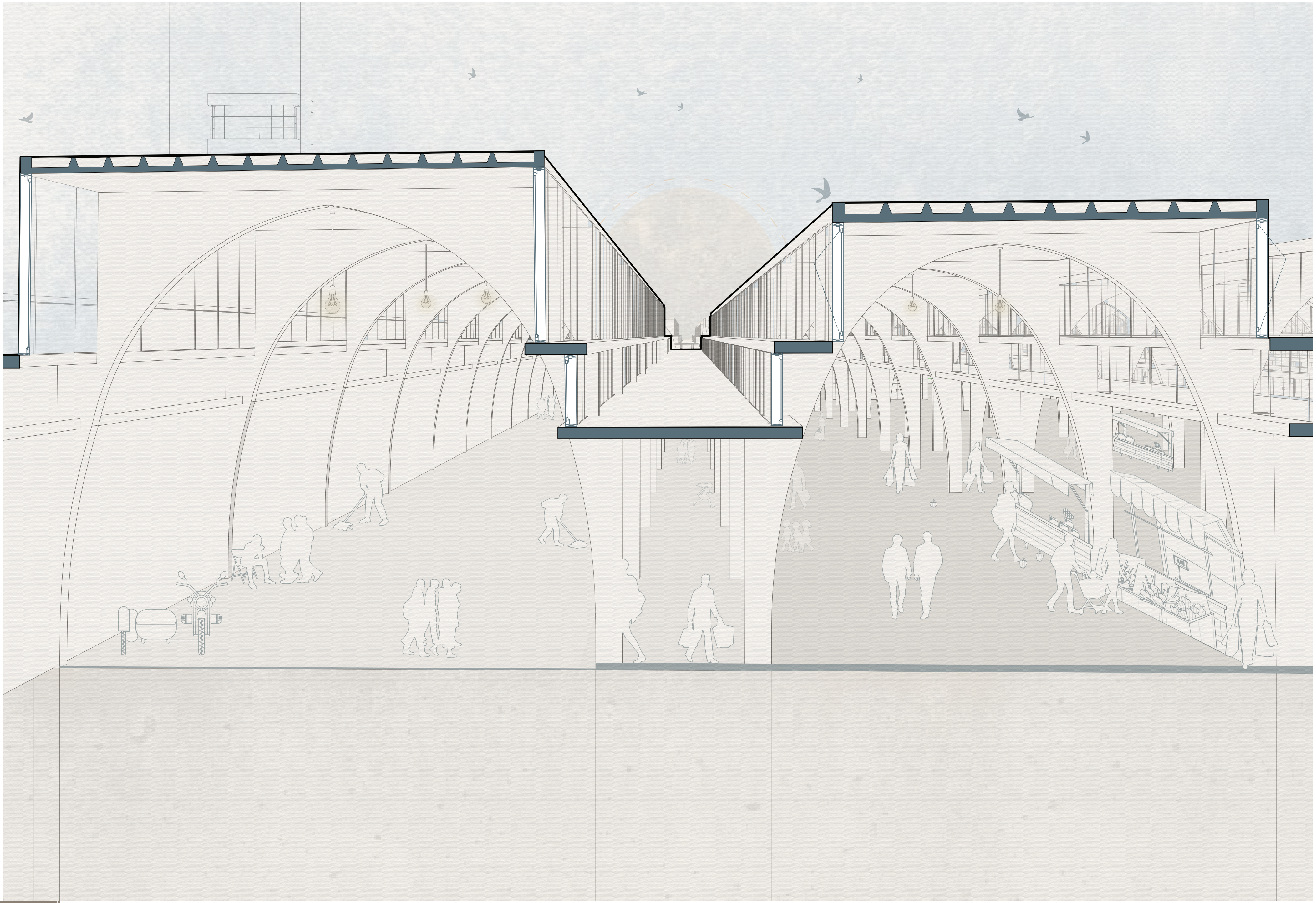
Section A-A

Distribution diagram



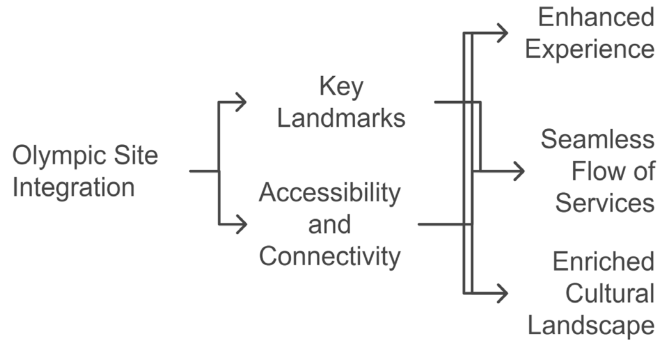


4.2 Period two: Olympic 2006

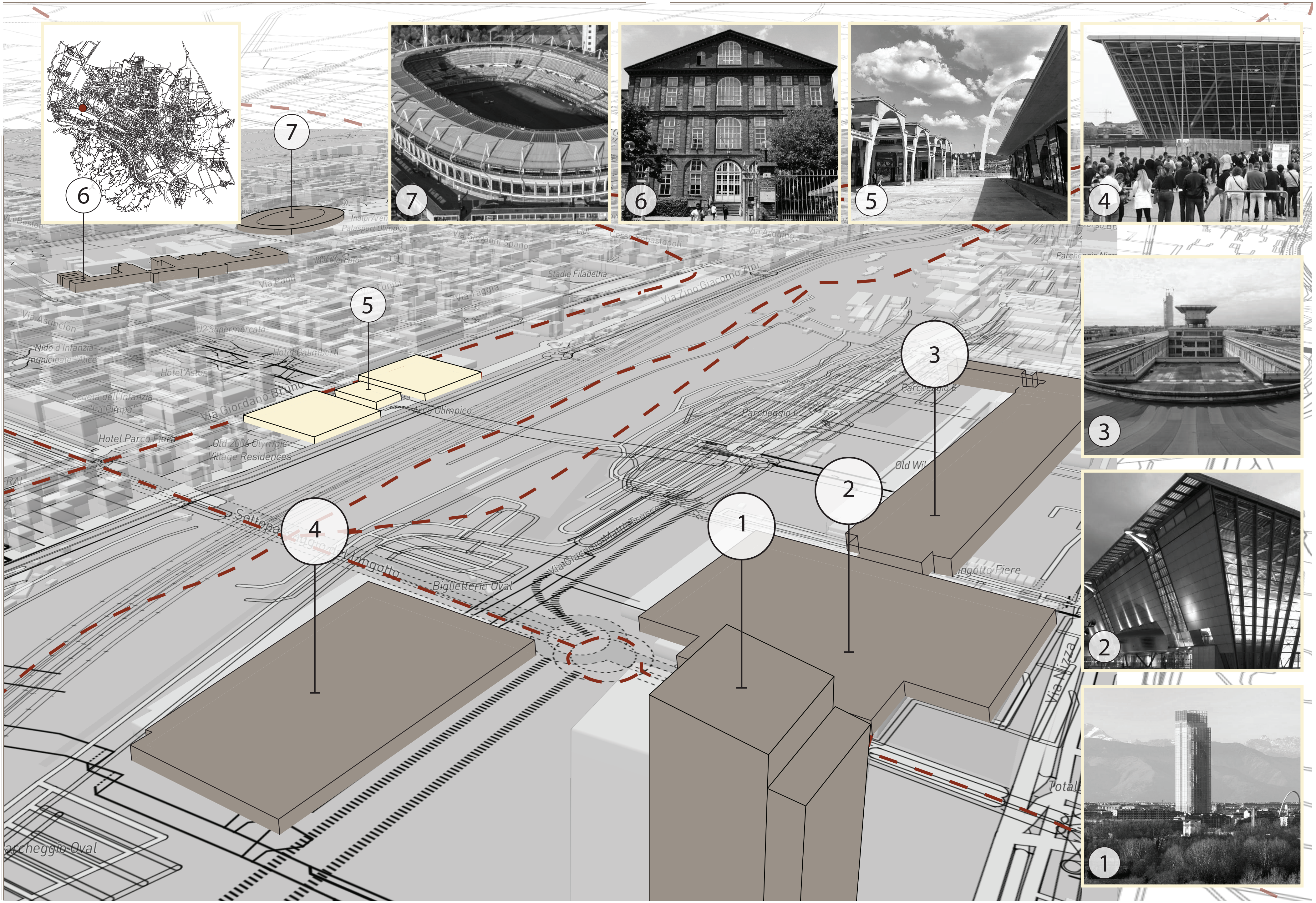
Following our discussion in Chapter 3 about the history of the Olympic Games 2006 and the key collaborators involved in this project, I would like to go deeper into the specific interventions that transformed the former Mercati Generali Torino into an Olympic place. In this section, I plan to explore into greater detail regarding these modifications, investigating how the renovations not only preserved the building's historical significance but also adapted it for modern use during the Games. "The Olympics mark a growth inside the city: a new quarter in a part of the city that at the beginning of the XX century ripens the passage from country to town". [25]

- **Olympic Site Integration with Turin's Key Landmarks**

The Olympic site, located Via Giordano Bruno 191 in Turin, was specifically planned to benefit from its accessibility to important landmarks and urban centers. The location is perfectly integrated into the city's wider transportation and mobility network, connecting athletes, visitors, and staff with significant destinations. Lingotto, a former industrial complex that has been reconstructed into a multifunctional center with shopping, offices, and a conference center, is one of the most visible sights nearby. The Olympic site's connection to Lingotto indicates a smooth flow of services and provides access to facilities for visitors to the Games. The Oval Lingotto, an Olympic site originally built for speed skating competitions, extends the site's urban connection further. Its close relationship with the Olympic site grows a partnership that enables productive cooperation between places; to guarantee events and people are efficiently extended over various areas. Torino Esposizioni, another architectural heritage with a long history, is also easily accessible. This structure, which is often used for exhibitions and large-scale events, complements the Olympic site by making a range of non-sporting activities during the Games. The location's near to these important icons not only helps accessibility, but also increases the Olympic venue's integration into the city's strong architectural and cultural heritage.



25. CRISTINA BIANCHETTI, ED., TORINO. IL VILLAGGIO OLIMPICO / THE OLYMPIC VILLAGE (ROME: OFFICINA EDIZIONI, 2005), P.63



7
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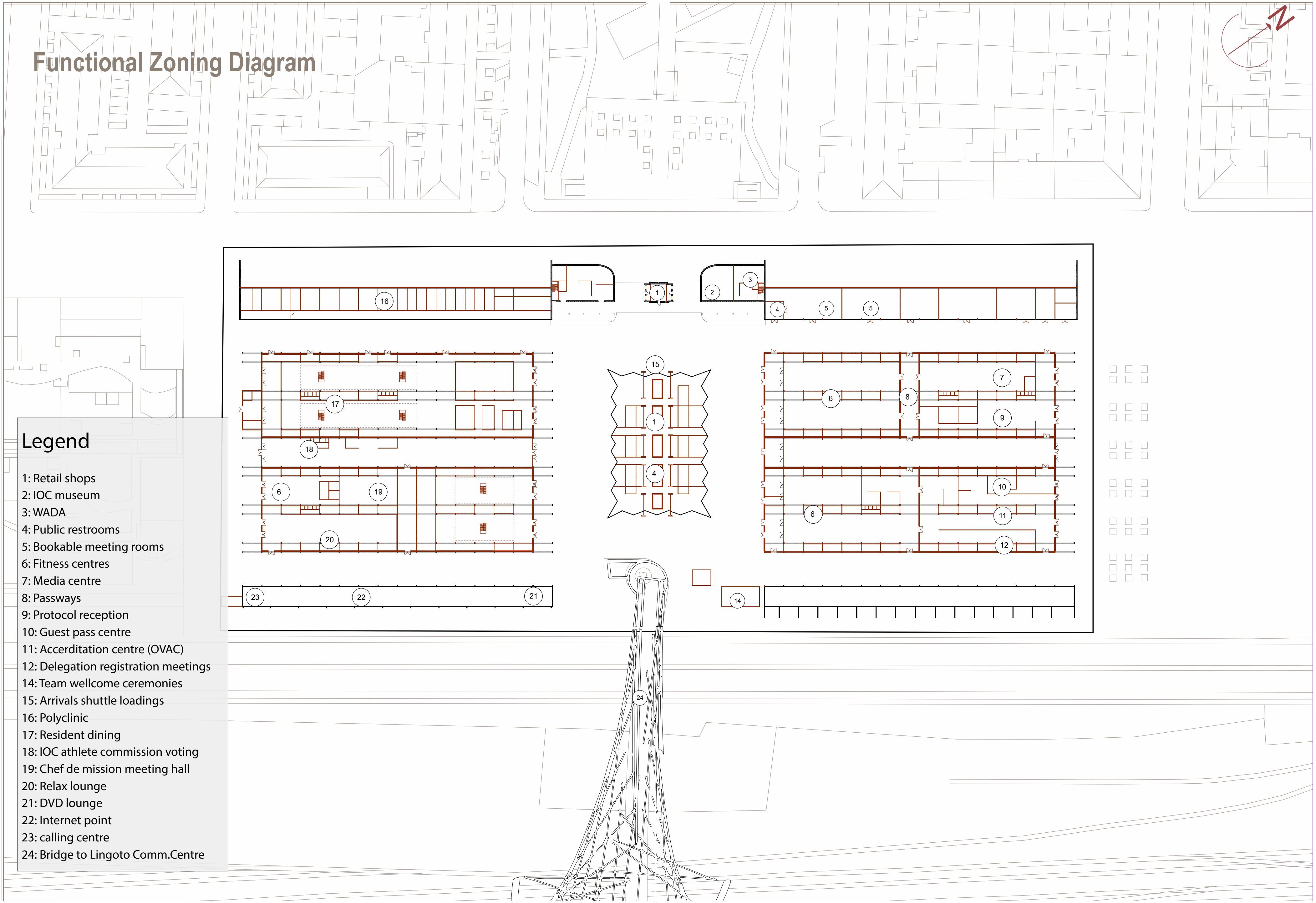
1
Palasport Olimpico
Via Giovanni Spano
Via Arduino
Stadio Filadelfia
Via Zino Giacomo Zini
Via Taggia
U2 Supermercato
Hotel Galimberti
Hotel Astor
Via Giordano Bruno
Arco Olimpico
Hotel Parco Fiera
Old 2006 Olympic Village Residences
Parcheggio E
Parcheggio L
Biglietteria Oval
Via Nizza

- **Functional Zoning and Spaces:**

The buildings are thoughtfully constructed to serve several needs, meeting the requirements of different groups of users such as athletes, visitors, and staff. Each building is designed to provide specific facilities and areas that guarantee efficiency and comfort for its users. Athletes, as case in point, may have access to locations for rest, recreation, and fitness, meanwhile visitors can take advantage of public spaces such as coffee shops, restaurants, and commercial areas. Staff facilities have been chosen in order that operations move smoothly and that all activities are coordinated. The diagram bellow includes a detailed overview of each building's individual functions and their role in assisting the system. The North Building has management offices, athlete and visitors permitted areas, as well as media equipment. The Central Building consists of operations spaces, small stores, information desks, and public recreation areas. The South Building, on the other hand, is specifically designed for athletes and includes a restaurant, relaxation services, massage rooms, cafés, recreational rooms, and a small meeting room. [26]

26. CAMERANA, BENEDETTO. VILLAGGIO OLIMPICO TORINO 2006. TORINO: CAMERANA & PARTNERS, 2005. P.30

Functional Zoning Diagram



Legend

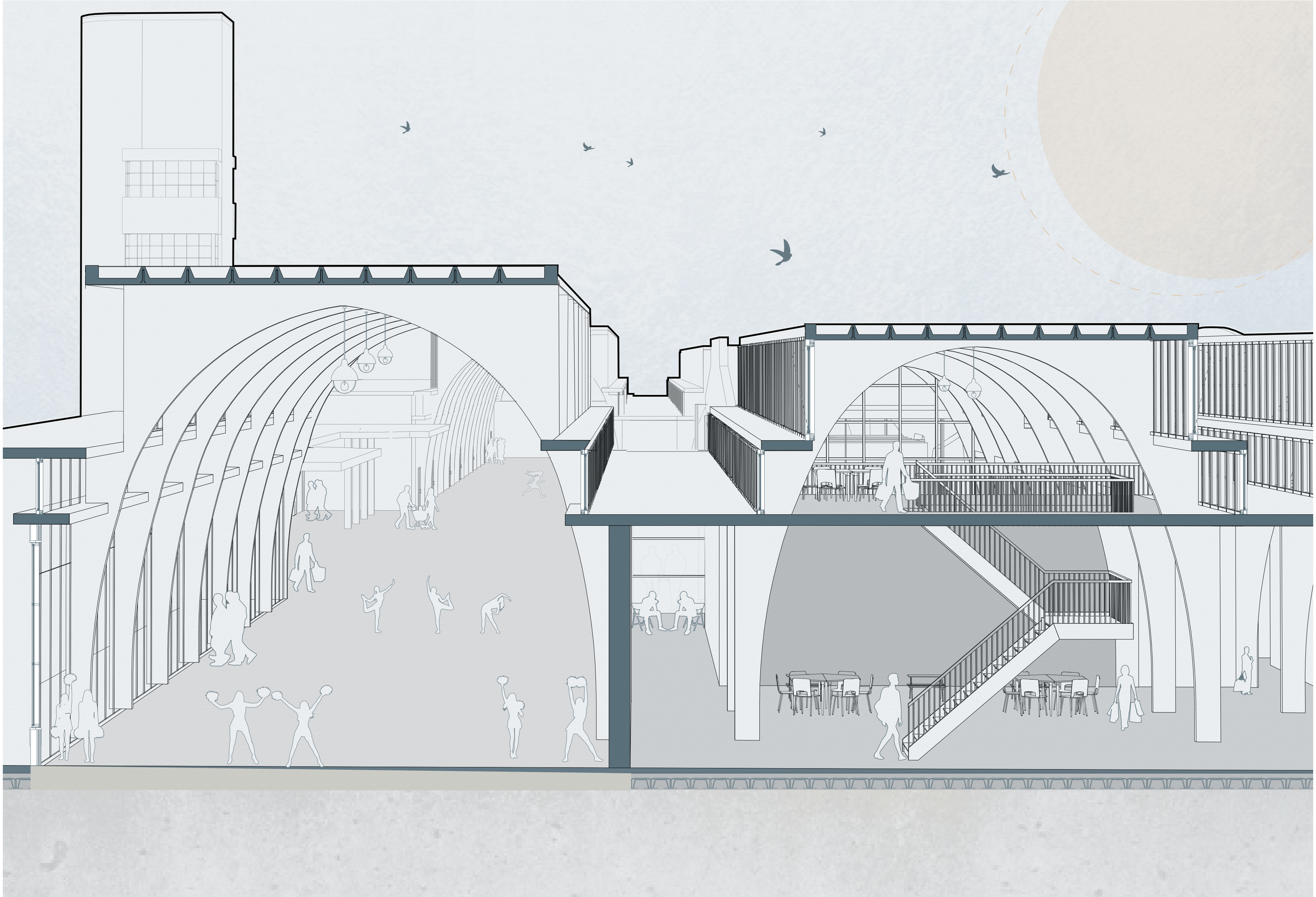
1: Retail shops
2: IOC museum
3: WADA
4: Public restrooms
5: Bookable meeting rooms
6: Fitness centres
7: Media centre
8: Passways
9: Protocol reception
10: Guest pass centre
11: Accerditation centre (OVAC)
12: Delegation registration meetings
14: Team wellcome ceremonies
15: Arrivals shuttle loadings
16: Polyclinic
17: Resident dining
18: IOC athlete commission voting
19: Chef de mission meeting hall
20: Relax lounge
21: DVD lounge
22: Internet point
23: calling centre
24: Bridge to Lingoto Comm.Centre

The project's materials were chosen for their clarity, which matched architect Cuzzi's refined and modest design language while maintaining consistency with the original components. Steel and glass are key features for the new façade facing the city, bringing modernization while maintaining the historical style (Figure 24). Geometric grills were added on the exterior to protect the railway, combining efficiency and design (Figure 25). Moreover, the previous roofs remained in both function and color, but substituted with smooth PVC surfaces and zinc finish, providing the structure with a modern touch while keeping its historic identity. [27]

Figure 24 Steel and glass façade, photographed by the author

Figure 25 Geometric grills façade, photographed by the author

27. CAMERANA, BENEDETTO. VILLAGGIO OLIMPICO TORINO 2006. TORINO: CAMERANA & PARTNERS, 2005. P.30



4.3 Period 3: Modern-day revvuse

The design wants to improve the building's energy efficiency while maintaining its architectural integrity. Renovations must not reduce the structure's historical value. Having this in mind, I thoroughly investigated the building's current state and former functions, particularly its participation during the 2006 Olympics. Since then, the structure has been abandoned until now. To cope with this, I began to examine other potential uses for the area. I was able to accelerate this process by taking inspiration from a colleague's proposal, which I modified significantly to correspond with my vision. Throughout, I wanted to keep as many of the building's original elements as possible in order to decrease its environmental impact and mark its past. If I want to explain in order, I started from the floor structure that I understand the common system in Italy is using the iglu system, the Iglu system (or crawl space ventilation) was introduced to improve airflow beneath the floors, reducing moisture and contributing to temperature regulation. [28] Given new functions, it became important to use the interior walls as partitions to effectively divide the space. These additions are carefully constructed to respect the existing structure while causing little impact to its overall structure.

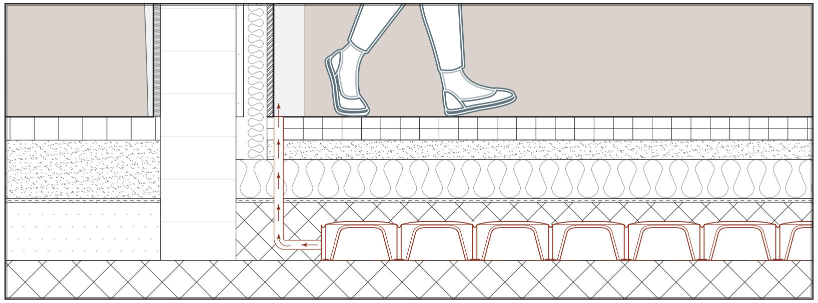


Figure 26 Detail of VENTILATED CRAWL SPACES, sc: 1:20

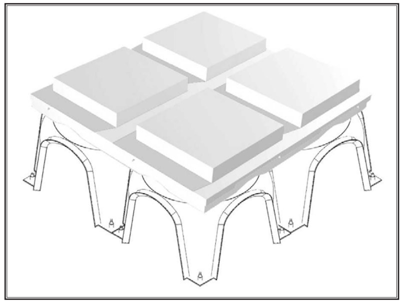


Figure 27 Iglu'® Plus element, showcasing its design for creating underfloor cavities and facilitating concrete casting

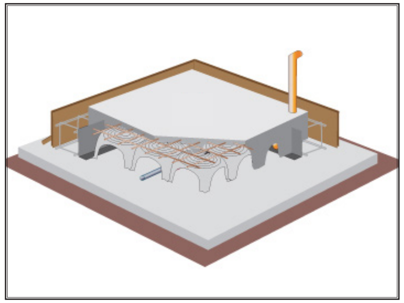


Figure 28 Concrete casting process starting from the center of the arc and flowing into the legs of the Iglu'® system

28. DALIFORM GROUP. PERMANENT FORMWORK FOR VENTILATED CRAWL SPACES. ENGLISH VERSION. MADE IN ITALY: DALIFORM GROUP SRL, 2023.

In my design strategy, I emphasize reusing many unused flat rooftops through the addition of green roofs and solar panels. I modified the roof's layering structure by installing green roofs in specific parts to provide natural insulation and reduce the consumption of energy. These green roofs are suitable for Turin's conditions since they help control heavy rainfall and summer heat, preserving the building's sustainability during the year. One of the main advantages of green roofs is their ability to retain water. They help to better drainage and lower the risk of floods, especially during Turin's rainy season. To prevent rain-related damage, I added layers of insulation and a water vapor barrier to the remaining rooftop surfaces that will not have green roofs. [29]

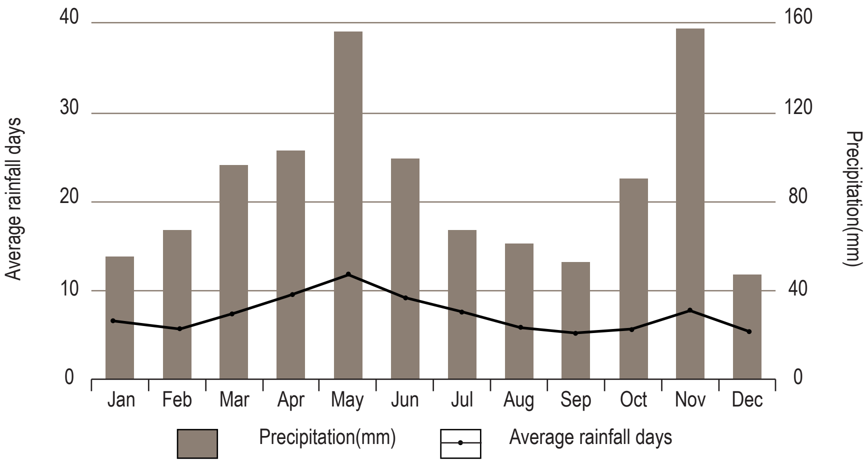
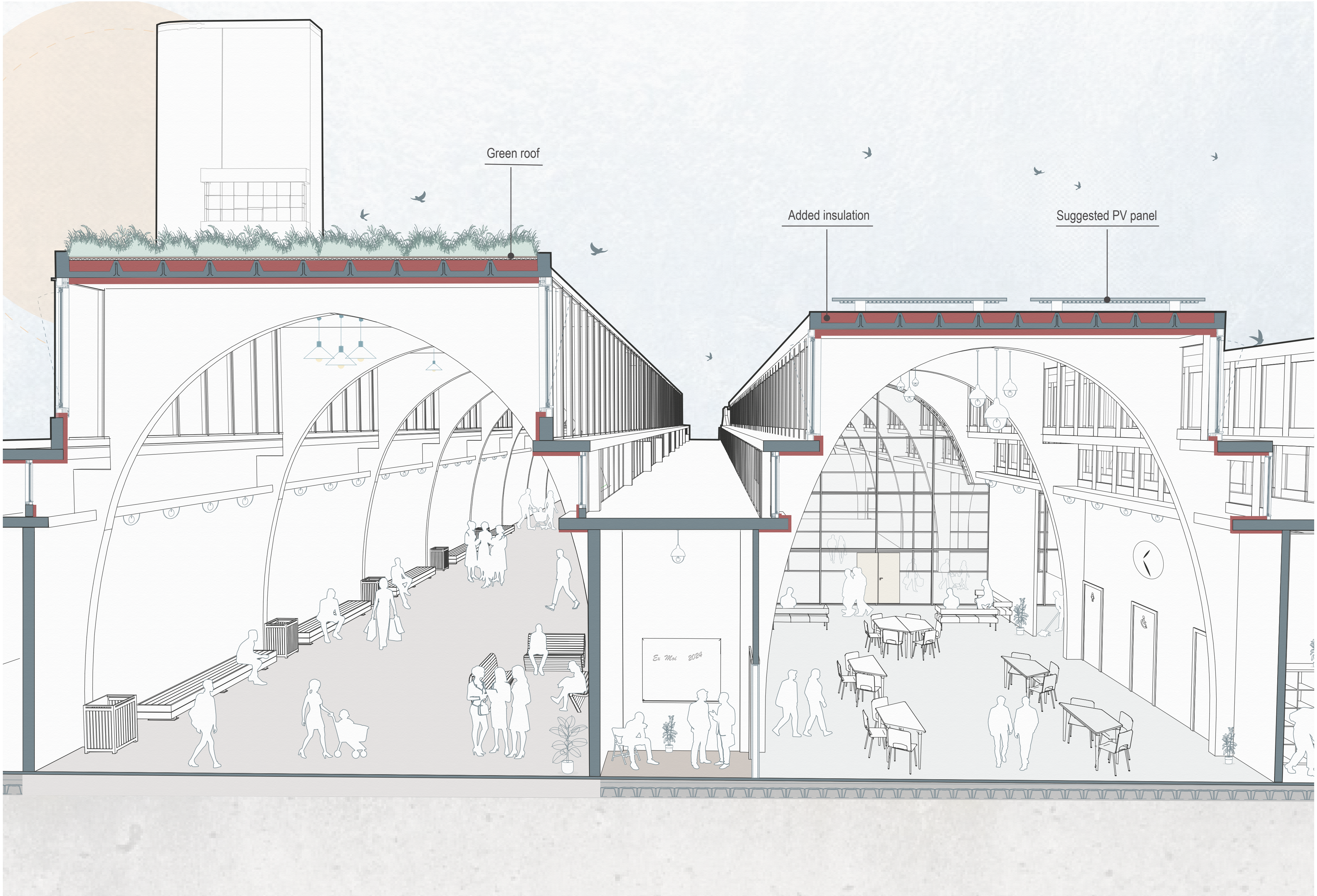
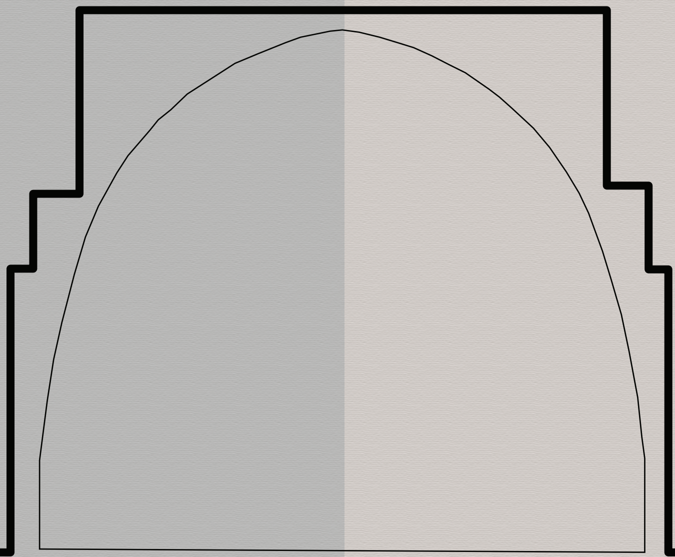


Figure 29 Average Rainfall for Turin

29. "Turin Weather Averages." World Weather Online. Accessed September 29, 2024. https://www.worldweatheronline.com/turin-weather-averages/piemonte/it.aspx.


Green roof
Added insulation
Suggested PV panel

05



Energy analysis and sustainable design integration

5. Energy analysis and sustainable design integration

The goal of this part is to evaluate energy performance of Ex-Moi Mercati Generali throughout three different time periods which are: its original design and construction 1933, the modifications made during the 2006 Olympic Games, and the design proposal. I will present a detailed comparison study for each time, considering energy efficiency, and insulation quality. This study will highlight how the building's energy consumption has changed over time, due to both technological advancements and changing functional requirements. Furthermore, based on the roles I have chosen for the building's adaptive reuse, I will give appropriate materials and technologies that may improve its sustainability. The initial phase in this research is to identify the materials used during each historical period, followed by calculating the U-value and R-value. Energy efficiency could be improved by focusing on these factors, especially by reducing the R-value while raising the U-value. As a result, the Ex Moi Generali Mercati has the opportunity to start a new chapter, with the ability to restore its vital values and serve as a dynamic public meeting place, as it did before.

5.1 Energy performance of each period

- **Period one: original design and use**

Ex Moi Mercati Generali's original design prioritized industrial and functional needs over energy efficiency. At the time, sustainable building practices were not widely adopted, mainly due to the lack of advanced technologies that could improve energy performance. The structure, built with masonry brick, concrete, and steel, was designed to be strong and durable; however, it lacked essential thermal insulation and energy-saving features. The absence of wall insulation resulted in significant heat losses during winter. The glazing method used during the period, which consisted of single-glazed windows, is an excellent case of inefficiency. These windows produced thermal bridges, resulting in significant heat loss and impacting the building's energy efficiency. According to the historical document *"Il nuovo Mercato in grosso ortofrutticolo della Città di Torino,"* [30] a mechanical heating and ventilation system was present in the entrance building, which housed service areas and a hotel in the basement. However, these systems were far from today's standards and would likely be insufficient by modern criteria. Despite this, the building's original function as a wholesale market meant that energy inefficiency had minimal impact on its overall operations. Additionally, this thesis focuses more on the architectural elements, specifically the arches, which played a crucial role in the building's design.

30. CERAGIOLO, MARIO. "*Il nuovo Mercato in grosso ortofrutticolo della Citta di Torino*", 1933, p.5

The tables lists the materials utilized during this timeframe. In the subsequent table, the U-values and R-values calculated for two different categories are presented which are Walls and Roofs. These calculations were conducted using the Excel document named CALCULATION OF DYNAMIC THERMAL CHARACTERISTICS AND OF HYGROTHERMAL PERFORMANCE OF BUILDING COMPONENTS, in compliance with the standards UNI EN ISO 13786:2018 and UNI EN ISO 13788:2013. This document was prepared by Professor Vincenzo Corrado.

The formula for calculating the R-value is:

R= d/λ

Where:

R= Thermal resistance (m²·K/W)

d= Thickness of the material (meters)

λ= Thermal conductivity of the material (W/m·K)

And the formula for calculating the U-value is:

U= 1/RTotal

Where:

U = Thermal transmittance (W/m²·K)

RTotal = Total thermal resistance of the building element (m²·K/W)

In the next tables there are material properties data where:

ρ (rho): Density

c: Specific heat capacity

λ (lambda): Thermal Conductivity

μ (mu): Thermal resistance

Table 1 demonstrates the material name and its properties, and table 2 illustrates the layers of the constructed building with the dimensions and its material properties.

Type of Material	Material	ρ	c	λ	μ
Intonaci e malte	Malta di calce o di calce e cemento	1800	840	0.9	24
68/ Laterizi	Mattoni pieni, forati, leggeri, ad alta resistenza	600	7	840	0.250
Intonaci e malte	Malta di calce o di calce e cemento	1800	840	0.9	24

Table 1

Exterior walls	*d*(cm)	ρ	μ	c	λ	*U*	*R*
plaster	0.2	1800	24	840	0.900	1.029 W/(m²K)	0.972 (m²K)/W
brick	19.5	600	7	840	0.250		
plaster	1.8	1800	24	840	0.900		

Table 2

Therefore, I have calculated the U-value and R-value of the exterior wall for the year of construction, as highlighted in Table 2. The next step is to calculate these values for the roofs. Based on the selected section, I identified two different types of roofs:

- The arch roof
- Roof between the arches (figure 30)

Since they have different structures, both must be considered in the calculations. Table 3 presents the material properties data for both the arch roof and the roof between the Arches, while Table 4 shows the layers, thickness, and the resulting U-value and R-value calculations for the roof between the arches. And table 5 indicates those information for Arch roof.

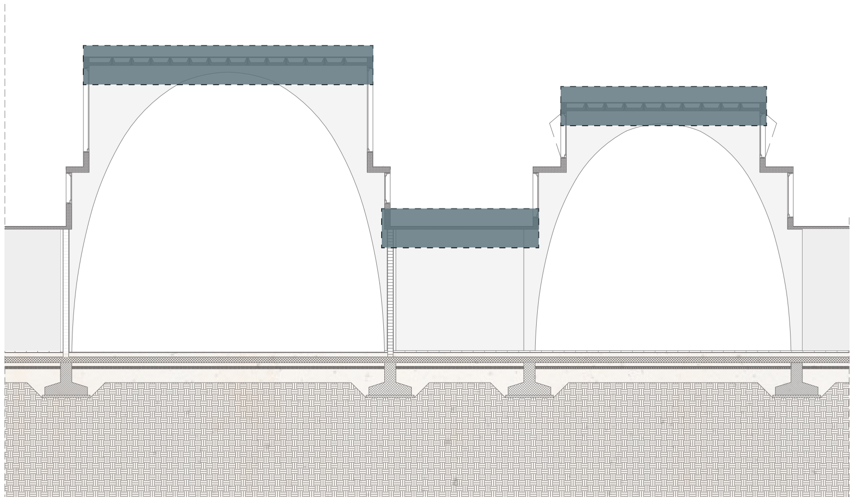


Figure 30 Detailed view of the specific section of the roof structure

Type of Material	Material	ρ	c	λ	μ
Materiali per impermeabilizzazioni	Bitume	1200	920	0.17	20491.8
Calcestruzzo	Calcestruzzo cellulare da autoclave	500	920	0.16	3
Materiali per impermeabilizzazioni	Asfalto	2100	920	0.7	21322.0

Table 3

Roof between Arch	*d*(cm)	ρ	μ	c	λ	*U*	*R*
Single Coat of Bituminous layer	0.5	1200	20491.8	920	0.17	1.298 W/(m²K)	0.770 (m²K)/W
Vapor barrier	0.5	2100	21322.0	920	0.7		
Reinforced concrete	9.5	500	3	920	24		

Table 4

Arch Roof	*d*(cm)	ρ	μ	c	λ	*U*	*R*
Single Coat of Bituminous layer	0.5	1200	20491.8	920	0.17	1.036 W/(m²K)	0.965 (m²K)/W
Autoclaved cellular concrete roof tile	1.5	400	4	840	0.15		
Concrete Slab	10	400	4	840	0.15		
Single Coat of Bituminous layer	0.5	1200	20491.8	920	0.17		

Table 5

Calculating the U-value and R-value for windows is different from other building components, such as walls or roofs, due to several unique characteristics of windows. These include their material composition and structure, thermal bridge effects, and the impact of air or gas layers in double-glazed or triple-glazed windows, and other items. Therefore, I have decided to dedicate a section to this topic. Consequently, the data related to the glazing system for each period will be presented at the end of this section named Windows thermal properties analysis.

- **Period two: Olympic 2006**

As time passed and technology evolved, the Ex-Moi Mercati Generali gained new responsibilities when Turin was picked to host the 2006 Winter Olympics. This historic structure, which had been abandoned for years, required significant modifications to hold the event. According to the documentation, "Recovering historical buildings was the most demanding job, both economically and spatially." The site contained around 20,000 square meters of buildings that required comprehensive restoration" (Alessandro Paglia). Benedetto Camerana, the architect in charge of the reconstruction process, approached the project with a precise balance between modernization and preservation. He explained: "The decision was to use invisible underground structural reinforcements to leave the historical structure's lightness untouched." This strategy protected the building's architectural integrity while providing structural modifications. The careful combination of old and modern parts assured that the Ex-Moi Mercati Generali was able to perform its new function in the 2006 Olympic Games while maintaining its historical value.[31] New areas have been developed to meet the needs of users and athletes. This time, energy efficiency has been prioritized by adding insulation to the existing walls, which now serve as exterior walls. Internal partition walls have been introduced to create distinct spaces. While the flooring has been renovated, the overall structure remains untouched. The incorporation of the IGLU'® ventilation system significantly enhanced energy efficiency during this renovation process. Some ineffective windows were demolished (or they have been demolished before), and new double-glazed curtain walls were added to improve the separation between the exterior and interior. By utilizing wall insulation, the Iglu system for floors, and double-glazed windows, energy loss has been considerably reduced compared to the previous period. However, there's always room for improvement! Therefore, I examined the U-value and R-value for the same section as of 2006. It is important to highlight that, due to insufficient information regarding the precise renovation materials at that time, I formulated a hypothesis about the insulation layers. Table 6 indicates the materials employed for the exterior wall interventions for the 2006 Olympics along with their respective properties. As you can see, I presumed that the walls retained their original masonry brick structure, and a layer of thermal insulation was subsequently added. Table 7 provides detailed data on the exterior walls, including the specific thickness of each layer.

31. CITTÀ DI TORINO. *TORINO MOI: FROM GENERAL MARKETS TO OLYMPIC VILLAGE.* TURIN: 2005. P 147

Type of Material	Material	ρ	c	λ	μ
Intonaci e malte	Malta di calce o di calce e cemento	1800	840	0.9	24
Materie plastiche cellulari	Polistirene espanso, in lastre stampate per termocompressione	20	1250	0.040	100.0
Pannelli e lastre varie	Pannelli di particelle pressati	600	2100	0.12	74.1
Aria	Aria in quiete	1.3	1000	0.026	1.0
68/ Laterizi	Mattoni pieni, forati, leggeri, ad alta resistenza	600	7	840	0.250
Intonaci e malte	Malta di calce o di calce e cemento	1800	840	0.9	24

Table 6

Exterior walls	*d*(cm)	ρ	μ	c	λ	*U*	*R*
plaster	1.8	1800	9	840	0.900	0.307 W/(m2K)	3.259 (m2K)/W
Expanded Polystyrene	6.0	20	100	1250	0.040		
Air Cavity	2.0	1	1	1000	0.026		
Brick	19.5	600	7	840	0.250		
Plaster	1.8	1800	9	840	0.900		

Table 7

The interior walls are excluded from this calculation because the internal area maintains consistent conditions, with no significant temperature difference across these walls. In the 2006 configuration, the interior walls are assumed to be constructed with plaster measuring 1.5cm, followed by gypsum board of 1.5 cm, insulation of 5 cm, and an additional layer of plaster measuring 1.5 cm. This composition reflects the typical materials and dimensions used for interior walls during that period. Up until now, the methods employed to improve the U-value and R-value for the exterior walls have submitted effective results, significantly enhancing the energy performance of the building envelope. As we move forward, the focus shifts to the next phase of analysis: examining the interior walls. In earlier chapters, it was established that the selected section of the project did not contain any interior walls in its original 1933 configuration. Therefore, the comparative analysis will be conducted between the existing data from the 2006 renovation and the proposed design for this phase of the project. In this part, the roofs are evaluated according to the categories defined by the construction year. Aluminum flashing has been applied as a protective layer to efficiently direct rainfall and stop water from penetrating into the roof. The basic structure of the roof remains untouched, but the bitumen layer and tiles have been upgraded with newer, more efficient materials. The materials used for both types of roofs are listed in table 8, and the precise details of each roof are provided in the following tables. Table 9 outlines the materials utilized in the layers of the arches' roof, including their matching thermal transmittance (U-value) and thermal resistance (R-value).

Type of Material	Material	ρ	c	λ	μ
Metalli	Alluminio	2700	960	220	2.1
Pannelli e lastre varie	Pannelli di particelle pressati	500	2100	0.10	74.1
Materiali per impermeabilizzazioni	Bitume	1200	920	0.17	20491.8
Calcestruzzo	Calcestruzzo a struttura chiusa confezionato con aggregati naturali	2000	880	1.16	69.0
Materie plastiche compatte	Polietilene (PE)	950	2100	0.35	53.3
Calcestruzzo	Calcestruzzo a struttura aperta di argille espanse	500	920	0.16	3.3

Table 8

Arch Roof	*d*(cm)	ρ	μ	c	λ	*U*	*R*
Alminum Flashing	0.1	2700	2	960	220	1.099 W/(m²K)	0.406 (m²K)/W
Composite Roof Tile	1.5	500	74	2100	0.1		
Single Coat of Bituminous layer	0.5	1200	20491.8	920	0.17		
Concrete Slab	10	2000	69	880	1.16		

Table 9

Roof between Arch	*d*(cm)	ρ	μ	c	λ	*U*	*R*
Alminum Flashing	0.1	2700	2	960	220	1.337 W/(m²K)	0.748 (m²K)/W
Vapor barrier	0.5	950	53	2100	0.35		
Reinforced Concrete	9.5	500	3	920	0.160		

Table 10

In a similar way, Table 10 listed comprehensive details about the roof situated between the arches, referencing the 2006 data and identifying the thickness and type of materials employed. This makes it simple to compare material choices and performance characteristics over the years. These values are important for evaluating the walls' performance in maintaining indoor thermal comfort while reducing energy consumption.

- **Period three: Modern-day reuse**

After the 2006 Olympics, the Ex Moi Mercati-Generali lost its use and became an abandoned place where homeless people took shelter. My thesis presents a great opportunity to study this valuable structure, understand its history, and its importance to the city of Turin. Considering this building as a heritage site requires me to be particularly careful in terms of material selection and energy strategies. The goal is to preserve the building's value as much as possible while making it sustainable and improving its performance. Additionally, I aim to choose functions that align with users' interests and are necessary to preserve the cultural aspects of this monument. This is a large-scale project, and I have decided to focus on a portion, similar to the previous sections, including both types of arches, and improve it until the results show that the renovation methods are effective. In this process, I start by analyzing the walls. Table 11 present the materials used for the exterior walls, along with their specific details, and the wall layer information with the corresponding results are places in Table 12, respectively.

Type of Material	Material	ρ	c	λ	μ
Intonaci e malte	Malta di calce o di calce e cemento	1800	840	0.9	24
Carta, cartone e derivati	Cartongesso in lastre	900	1090	0.21	8.7
Materie plastiche cellu-lari	Polistirene espanso, in lastre stampate per termocompressione	20	1250	0.040	100.0
Pannelli e lastre varie	Pannelli di particelle pressati	600	2100	0.12	74.1
Aria	Aria in quiete	1.3	1000	0.026	1.0
68/ Laterizi	Mattoni pieni, forati, leggeri, ad alta resis-tenza	600	7	840	0.250
Intonaci e malte	Malta di calce o di calce e cemento	1800	840	0.9	24

Table 11

Exterior wall	*d*(cm)	ρ	μ	c	λ	*U*	*R*
plaster	0.2	1800	9	840	0.900	0.263 W/(m²K)	3.795 (m²K)/W
Gypsum Board	1.5	900	9	1090	0.210		
Expanded Polystyrene	8.0	20	100	1250	0.040		
Air Cavity	2.0	1	1	1000	0.026		
Brick	19.5	600	7	840	0.250		
Plaster	0.2	1800	9	840	0.900		

Table 12

Most of the interior walls from 2006 remain unchanged. However, new walls added in the design proposal include 1.25 cm of acoustic drywall, 4.0 cm of acoustic foam, a 3.5 cm wall frame, and another 1.25 cm layer of acoustic drywall to enhance acoustic performance. These partitions are equipped with noise insulation to align the functional needs of the surrounding areas. Their main role is to create barriers that ensure individuals have quiet and comfortable environments. The building's historical value is preserved by these partitions, which also raise the interior layout by maintaining a simple transition between the old and new walls. Additionally, insulation helps control acoustics in public spaces, improving the atmosphere for various activities. It is obvious that the performance of these interior walls is better than that of the ones from 2006. However, from an economic perspective, I chose not to demolish the existing walls. I maintained the original walls, which are located exactly where the designed walls are, and placed the new walls in the required locations.

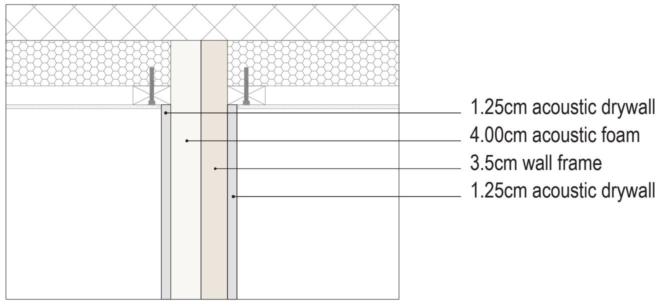


Figure 31 Detail of the interior wall, layers design proposal

The roofing construction materials are detailed in Table 13 and 14. As previously mentioned, I have decided not to change the building's main structure. Instead, the focus is to improve the existing roofing system using sustainable design principles and energy-efficient methods. As a result, I have two mains' recommendations for the arches roof. First, the installation of photovoltaic panels is advantageous due to the sufficient flat roof areas available for gaining solar energy (Roof 1). Second, I suggested the development of green roofs, as they can provide natural shade, moderate the urban heat island effect, and use water evaporation to cool the surrounding environment (Roof 2). In the next part, I will offer a comprehensive explanation of the proposed PV panels and their expected effects on energy efficiency. Furthermore, I will examine how these changes align with broader sustainability goals for adaptive reuse projects. After analyzing the materials and properties of the Arches roof, Table 17 presents the materials used for the roofs located between the arches, including their thicknesses and the calculated results. Similar to previous studies, the structure of these roofs is considered distinct from the main roof structure. However, the materials used are consistent with those listed in Tables 13,14.

Type of Material	Material	ρ	c	λ	μ
Metalli	Alluminio	2700	960	220	2.1
Pannelli e lastre varie	Pannelli di particelle pressati	500	2100	0.10	74.1
Materiali per imperme-abiliz-zazioni	Bitume	1200	920	0.17	20491.8
Materie plastiche cellu-lari	Polistirene espanso sinterizzato, in lastre ricavate da blocchi	10	1250	0.059	31.7
Calcestruzzo	Calcestruzzo a struttura chiusa confezion-ato con aggregati naturali	2000	880	1.16	69
Materiali per imperme-abiliz-zazioni	Asfalto	2100	920	0.7	21322
Legnami	Abete (flusso perpendicolare alle fibre)	450	2700	0.12	222.2
Intonaci e malte	Malta di calce o di calce e cemen-to	1800	840	0.9	24

Table 13

Type of Material	Material	ρ	c	λ	μ
Materiali sfusi e di riempi-mento	Perlite espansa in granuli da 0,1 a 2,3 mm	100	840	0.066	3.2
Materiali per imperme-abiliz-zazioni	Fogli di materiale sintetico	1100	1000	0.23	2666.7
Materie plastiche cellu-lari	Polistirene espanso sinterizzato, in lastre ricavate da blocchi	10	1250	0.059	31.7
Materiali per imperme-abiliz-zazioni	Bitume	1200	920	0.17	20491.8

Table 14

Arch Roof (1)	*d*(cm)	ρ	μ	c	λ	*U*	*R*
Alminum Flashing	0.1	2700	2	960	220		
Composite Roof Tile	1.5	500	74	2100	0.1		
Single Coat of Bitumi-nous layer	0.5	1200	20491.8	920	0.17		
Expanded polystyrene sin-tered foam	18	10	32	1250	0.059		
Concrete Slab	10	2000	69	880	1.16	0.152 W/(m^{2}K)	6.589 (m^{2}K)/W
Vapor Barrier	1	2100	21322	920	0.70		
Expanded polysty-rene, sintered Foam	17.3	10	32	1250	0.059		
Strapping	2.5	450	222	2700	0.120		
Plaster	0.5	1800	24	840	0.900		

Table 15

Arch Roof (2)	*d*(cm)	ρ	μ	c	λ	*U*	*R*
substrate	3.2	100	3	1250	0.38		
Synthetic material sheets	2.3	1100	2667	1000	0.23		
Drainage White, expand-ed polystyrene, sintered	2	10	32	1250	0.059		
Steam Barrier, Bitumen	2.5	1200	20492	920	0.17		
Expanded polystyrene, sin-tered Foam	18	10	32	1250	0.059	0.133 W/(m^{2}K)	7.508 (m^{2}K)/W
Concrete Slab	10	2000	69	880	1.16		
Vapor Barrier	1	2100	21322	920	0.70		
Expanded polystyrene, sin-tered Foam	17.3	10	32	1250	0.059		
Strapping	2.5	450	222	2700	0.120		
Plaster	0.5	1800	24	840	0.900		

Table 16

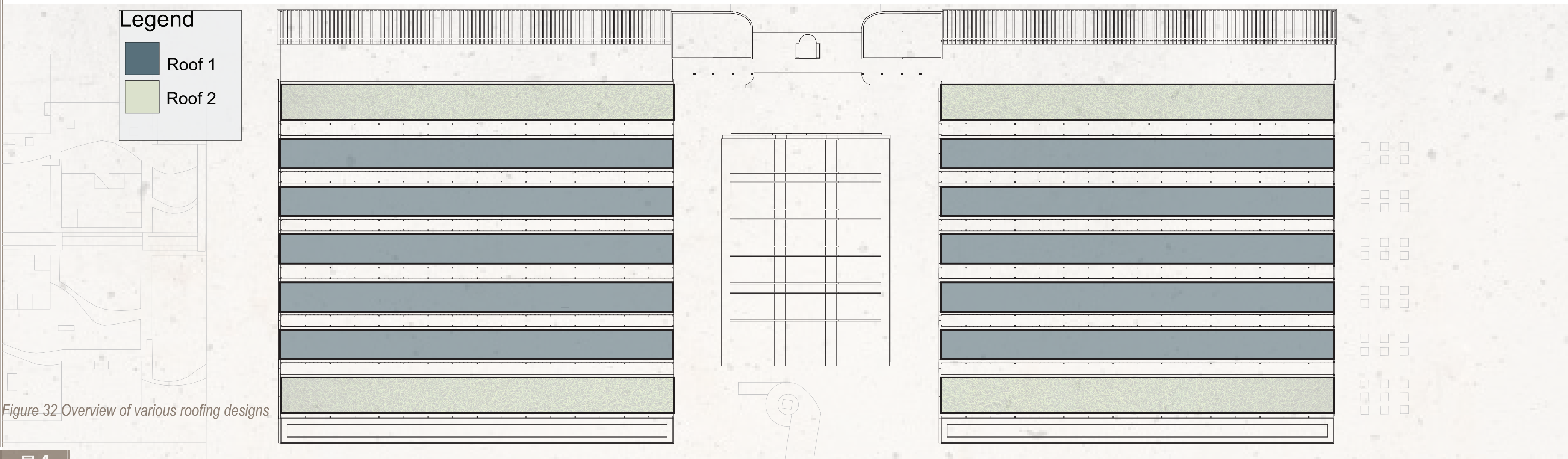


Figure 32 Overview of various roofing designs

Roof between Arch	*d*(cm)	ρ	μ	c	λ	*U*	*R*
Alminum Flashing	0.1	2700	2	960	220		
Vapor barrier	0.5	950	53	2100	0.35		
Reinforced Con-crete	9.5	500	3	920	0.160		
Expanded polysty-rene, sintered Foam	6.0	10	32	1250	0.059	0.505 W/(m²K)	1.979 (m²K)/W
Strapping	2.5	450	222	2700	0.120		
plaster	0.5	1800	9	840	0.900		

Table 17

Windows thermal properties analysis

- **Period one: original design and use**

In Italy throughout the 1930s, single-glazed systems were common in both commercial and residential structures [32] . Typically made of wood or metal, these types of windows offered minimum weather protection and transparency but lacked insulation since energy efficiency was not the focus. An illustration of a typical single-glazed window can be found in Figure 33.

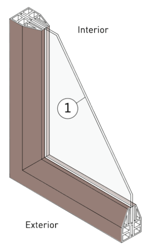


Figure 33 single glazed window

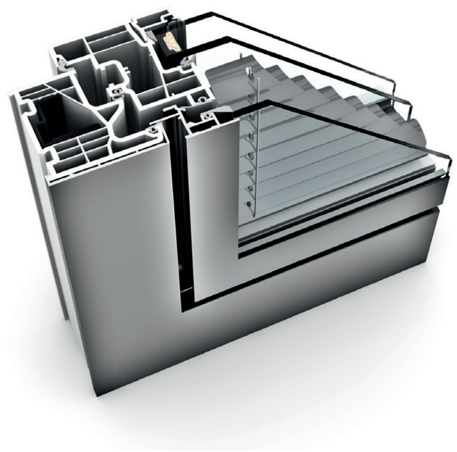
The modifications from the 1930s to 2006 will be examined in the parts that follow, with a focus on developments in materials and enhanced energy performance.

- **Period two, three: Olympic 2006, Modern-day reuse**

For the 2006 Winter Olympics, important renovations were carried out, including the change of windows. Based on personal observation of the Ex-Moi Mercati Generali building, it appears that areas previously fitted with single-glazed windows were upgraded to double-glazed systems. Instead of removing all the windows, I decided to use double-glazed windows wisely in particular spaces to improve energy efficiency and take financial limitations into consideration. This approach achieves a balance between lower expenses and efficiency benefits. This type of glass, manufactured in the UK between 1975 and 2000, offers enhanced insulation properties due to the gas-filled gap between panes, which acts as an effective thermal barrier. This gap reduces heat transfer through the window, decreasing the energy consumption in the building. Compared to single glazing system, double glazing reduces heat loss by almost 50%, while G-values and visible light transmittance are higher.[33] In this part, by considering the information about windows through the Ukinternorm websites, I gain the U values for the required windows. Figure 34 represented the data for the 2006 glazing system [34] and Figure 35 shows the design proposal [35]. According to European standards (EN ISO 10077-1) for the area 1.23m² the U values are calculated. As is shown in figures 36-39 there are different types of glasses therefore the U values are calculated based on each part.

32. SMRCEK, ANTONIN. "*EVOLUTION OF THE COMPOSITIONS OF COMMERCIAL GLASSES 1830 TO 1990. PART I. FLAT GLASS.*" TEPLICE, CZECH REPUBLIC: V U S U, 2004. PAGES 1–3.
33. AGUILAR-SANTANA, JORGE LUIS, ET AL. "*REVIEW ON WINDOW-GLAZING TECHNOLOGIES AND FUTURE PROSPECTS.*" INTERNATIONAL JOURNAL OF LOW-CARBON TECHNOLOGIES, VOL. 15, 2020, PP. 113–116.
34. INTERNORM WINDOWS UK. KV 350 UPVC/ALUMINIUM WINDOW WITH INTEGRATED BLINDS. UW AS LOW AS 0.79 W/(M²K). PDF, 2020.
35. INTERNORM WINDOWS UK. KF 410 UPVC/ALUMINIUM WINDOW. UW AS LOW AS 0.62 W/(M²K). PDF, 2020.

KV 350 UPVC/ALUMINIUM WINDOW WITH INTEGRATED BLINDS



PROPERTIES

Thermal insulation	U_w as low as 0.79 W/(m²K)
Sound reduction	up to 44 dB
Security	RC1N, RC2
Locking	concealed
Construction depth	74 mm

Sections

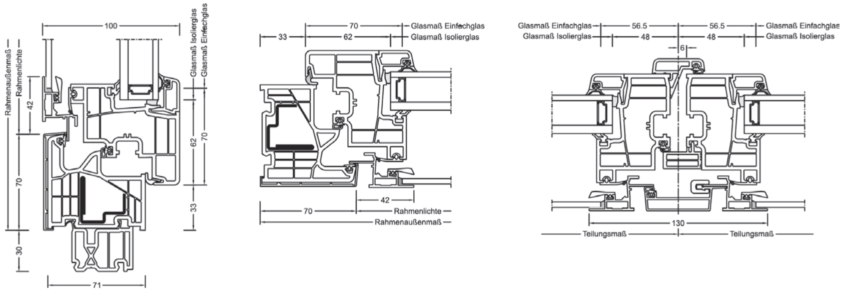
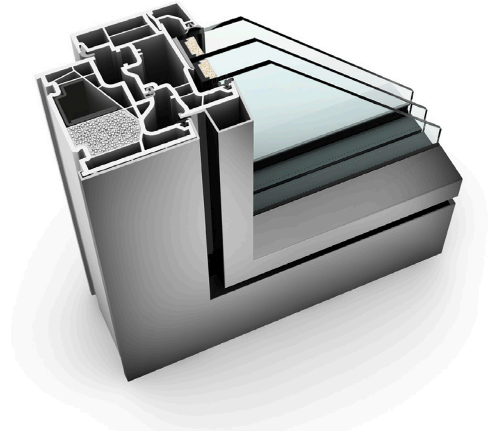


Figure 34 2006 glazing system

KF 410 UPVC/ALUMINIUM WINDOW



PROPERTIES

Thermal insulation	U_w as low as 0.62 W/(m²K)
Sound reduction	up to 45 dB
Security	RC1N, RC2
Locking	concealed
Construction depth	93 mm

Sections

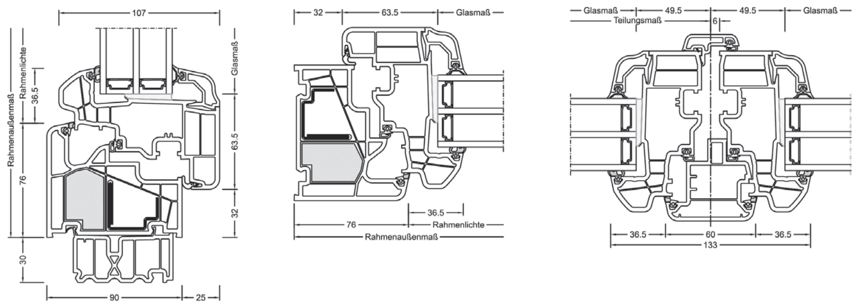
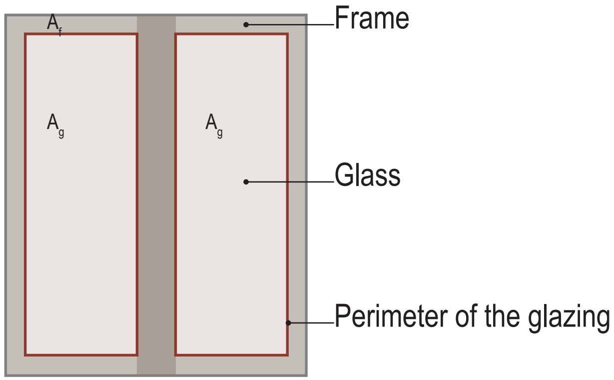


Figure 35 The design proposal glazing system

It is important to note that the calculation of U-values for windows differs from that of other building components. The formula below provides a method to determine these thermal properties:

$$U_w = \frac{(U_g.A_g)+(U_f.A_f)+\Psi.P}{A_g+A_f}$$

U_g :U-value of the glazing (W/m²·K).
A_g :Area of the glazing (m²).
U_f :U-value of the frame (W/m²·K).
A_f :Area of the frame (m²).
Ψ: Linear thermal transmittance of the edge spacer (W/m·K).
P: Perimeter of the glazing (m).



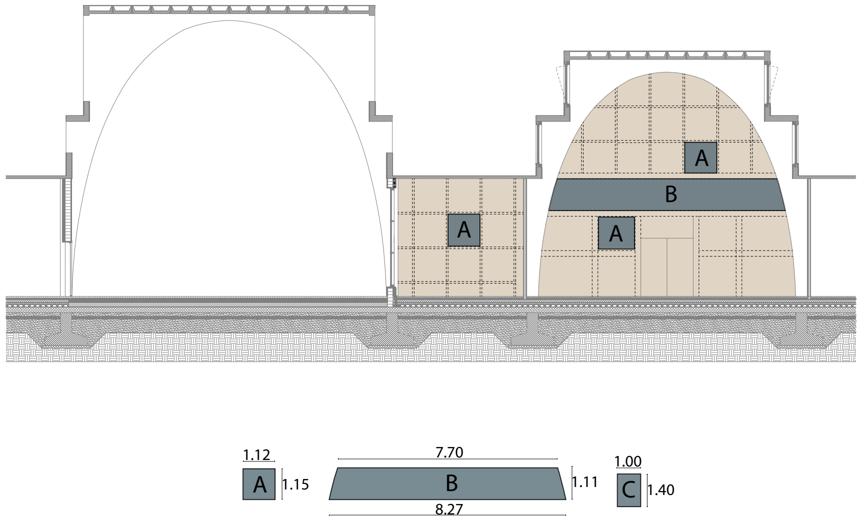


Figure 36 The South-West façade glazing, 2006

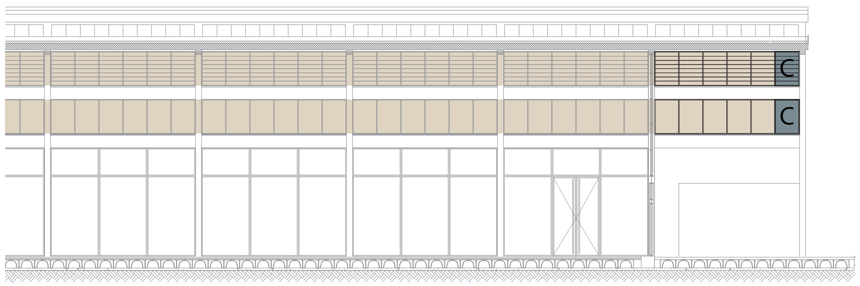


Figure 37 The West façade glazing, 2006

Olympic 2006	
Area	U_t value
Area (A): 1.28 m²	0.0583 (W/m²·K)
Area (B): 8.90 m²	0.822 (W/m²·K)
Area (C): 1.40 m²	0.144 (W/m²·K)

Table 18

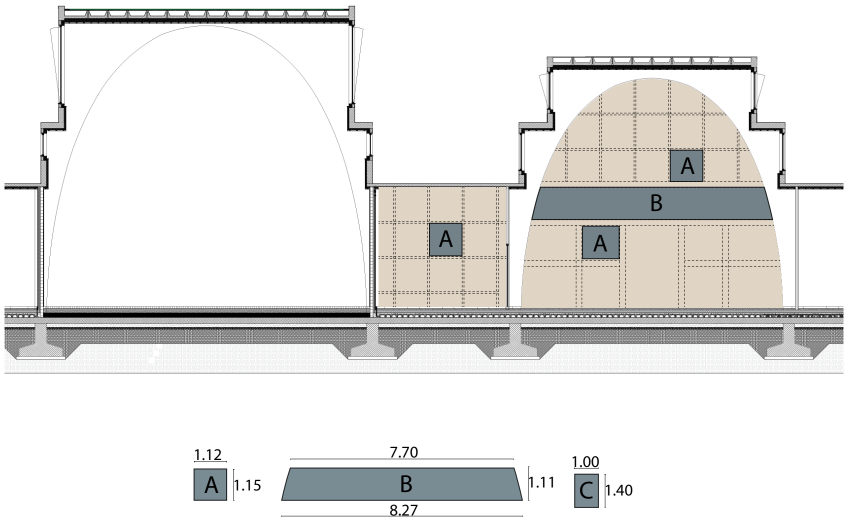


Figure 38 The South-West façade glazing, Design proposal

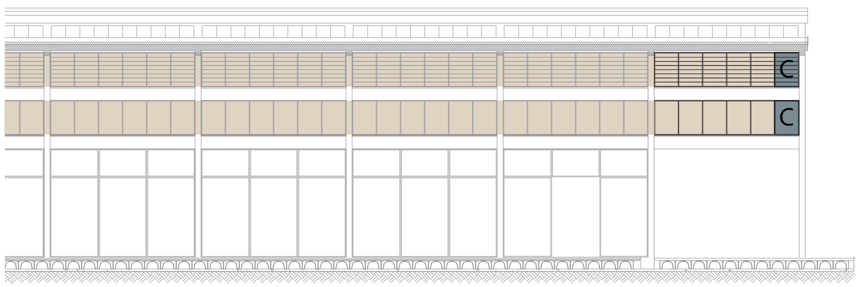


Figure 39 The West façade glazing, Design proposal

Design proposal	
Area	U_t value
Area (A): 1.28 m²	0.045 (W/m²·K)
Area (B): 8.90 m²	0.79 (W/m²·K)
Area (C): 1.40 m²	0.0056 (W/m²·K)

Table 19

In order to improve the building's energy efficiency, the original 2006-installed windows (Model K350) were switched out for more energy-efficient models (Model K410). Lower U-values, which indicate better thermal insulation and less heat transmission, were the goal of this improvement. In every area, the U-values of the existing windows were higher than they were when they were first installed. A considerable U-value reduction was attained across all defined glass areas by switching to the K410 type(Table 19), showing improved thermal insulation. By minimizing heat loss and improving indoor comfort, this upgrade assures a more energy-efficient building envelope. Furthermore, the K410 model has an aluminum frame, which provides a significant lifespan advantage. Aluminum is a sensible and environmentally friendly material because of its long lifespan and low maintenance needs. This further supports the project's objective of achieving a balance between sustainability and cost-effectiveness by lowering the frequency and expense of maintenance over the building's lifetime.

- **Technical sheets of finishing layers**

For this project, sustainable materials were chosen due to their feasibility and lower ecological impact. Being recyclable and easy to install and remove, each component was chosen to encourage flexibility and reduce potential waste during demolition or subsequent modifications.The circular approach is supported by the project's focus on recyclable materials, which allow components to be recycled or reused at the end of their life rather than ending up in landfills. This strategy ensures that materials support environmental sustainability and resource conservation in addition to achieving the project's functional and aesthetic goals. Using sustainably produced materials and incorporating ideas with low environmental impact, the project strives to meet modern standards for environmentally friendly design and construction. Technical sheets listing each material, along with relevant specifications such as suggested suppliers, product size, thickness, performance characteristics, and environmental impacts, are provided below. These sheets offer detailed insights into the internal and external finishing materials.[36]

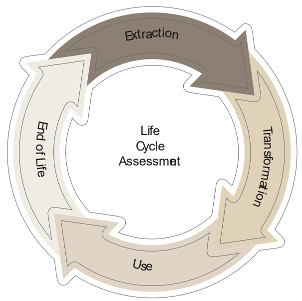


Figure 40 Life cycle assessment(LCA)

36. www.materialbank.eu

Flooring

Name of product: Lioz Sintra

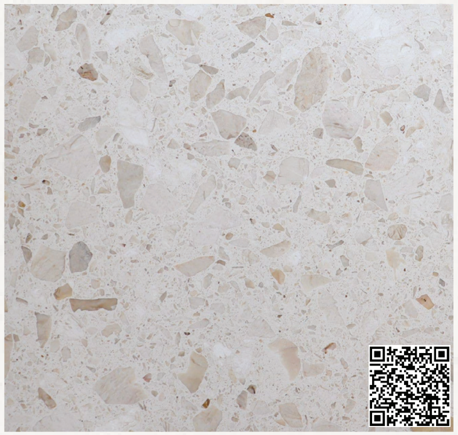
Description:

Timeless light beige colour with bigger beige stones. It is suitable for both traditional and modern designs.
Materials: Masonry & Stone/Stone
Collection Name: Original
Size Tiles: 300 mm x 300 mm, 600 mm x 300 mm, 600 mm x 600 mm; Slabs: 1830 mm x 1230 mm

Maintenance:

All products with NEUTRAL Ph; Cleaning Agent - CA1, Eurosurfaces CHS; Products suitable for the cleaning of natural marble or engineered marble (e.g. LEM 3 Bellinzoni, FILA Cleaner, StarWax Cleaner Reviver Marble, Diversay Cleaner, HG Stain Remover marble) 1230 mm

Product picture:



Environmental friendly:

Skillfully combines 95% natural marble with other materials to achieve high-quality products
Products manufactured from recycled raw material, respecting the 3R rule (reuse, reduce, recycle)

Characteristics:

Content: Marble
Finish: Aged; Honed; Polished; Satin; B.Hammered; Matt; Sandy
Construction: Engineered Marble Produced with Marble, Calcium Carbonate and Polyester Resin

Performance:

Fire Safety: Rated A1, A1fl (non-combustible).

Durability: Strong breaking strength (>1,500 N) and frost-resistant for internal and external applications.

Slip Resistance: Standard Dekton ranges (Rd < 15 or 15 < Rd < 35); Grip+ achieves R11 and >45 Rd for high slip resistance in wet or high-traffic areas.

Low Water Absorption: ≤ 0.5%, ensuring moisture and stain resistance.

Emissions: Very low cadmium (<0.02 mg/l) and lead (<0.2 mg/l) levels, suitable for populated spaces.

Company info: RMC
www.rmc.pt- info@rmc.pt- Eurosurfaces Portugal S.A

Name of product: Cosentino

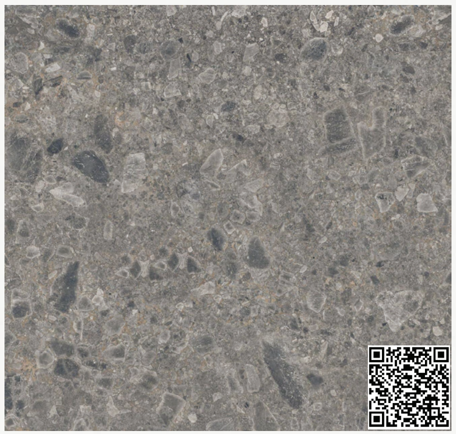
Description:

Materials: Surfaces/Sintered Stone
Collection Name: Pietra Kode
Sample Size: 10.2 cm x 15.2 cm
Size 142.2 cm x 320.0 cm
City of Origin: Macael
Warranty: 25-Year Limited Transferable Warranty

Maintenance:

Routine Cleaning and Maintenance
Dry Cleaning: Use a mop, vacuum, or broom without additives.
Wet Cleaning: Use a high-cleaning-power neutral detergent, avoiding acidic or abrasive products.
High-Traffic Areas: For spaces like shopping malls or airports, an automatic scrubber with adjustable pressure is recommended.

Product picture:



Environmental friendly:

LEED Contribution: Eligible for LEED credits and climate-compliant for sustainable projects.
Human Health Impact:
CDPH/CHPS 01350 compliant, Low VOC, certified for safe indoor air quality.
NSF/ANSI 51 certified for food safety, UL GREENGUARD, and GREENGUARD GOLD certified for low emissions.
Sustainable Composition:
Made with premium natural minerals and recycled materials.
Produced using HybriQ® technology, a sustainable process for eco-friendly surfaces.

Characteristics:

Please contact Cosentino for information

Performance:

Fire Safety: Rated A1, A1fl (non-combustible).

Durability: Strong breaking strength (>1,500 N) and frost-resistant for internal and external applications.

Slip Resistance: Standard Dekton ranges (Rd < 15 or 15 < Rd < 35); Grip+ achieves R11 and >45 Rd for high slip resistance in wet or high-traffic areas.

Low Water Absorption: ≤ 0.5%, ensuring moisture and stain resistance.

Emissions: Very low cadmium (<0.02 mg/l) and lead (<0.2 mg/l) levels, suitable for populated spaces.

Company info: Dekton
cosentino.com- Ctra. A334 Baza-Huércal Overa

Wall covering

Name of product: Granorte, 3D Forms Pyramid

Description:

3DFORMS modular cork tiles combine in various arrays to create unique three-dimensional patterns that add depth and identity to vertical surfaces. Delivering an endless amount of creative possibilities, 3DFORMS provides a one-of-a-kind texture and enhanced intrinsic acoustic and thermal properties.
Materials: Wallcovering/Natural Wallcovering
Collection Name: 3D Forms

Maintenance:

Regular Cleaning:
Dust periodically or use a vacuum with a soft brush attachment.
Remove stains promptly to prevent reaction with the wallcovering, especially from colored or solvent-based materials.

Product picture:

Environmental friendly:

Carbon Emissions Reduction: By participating in the Integrated Waste Management System (through Sociedade Ponto Verde, SPV), GRANORTE avoided emitting 790.57 kg CO_2 equivalent in 2022.
Equivalent Impact: This reduction is comparable to 7.91 thousand kilometers not driven by a car, highlighting the environmental benefit of the company's waste management practices.
Waste Management Approach: This impact is achieved by recycling, composting, and energy recovery (instead of landfill or simple incineration), focusing on material and energy recovery, which avoids additional emissions and reduces environmental impact.

Characteristics:

Content: Cork

Finish CORKGUARD: Aqueous dispersion based on SCOTCHGARD and a combination of resins

Performance:

Flammability: EN 13501-1 - Fire class E; EN ISO 11925-2 - Extent of flame < 150 mm. No flaming droplets

Emissions: EN 12149 - Fulfilled; Release of vinyl chloride monomer - EN 12149 Fulfilled; Heavy metals and specific elements - EN 12149 - Fulfilled; VOC: ISO 16000 parts 3, 6, 9 - Fulfilled AgBB scheme Fulfilled French Classification A+

Acoustics: Weighted Sound Absorption Coefficient: EN ISO 354 - αw - 0.1

Company info: GRANORTE

info@granorte.pt- GRANORTE - Revestimentos de Cortiça, Lda.

Name of product: Galileo

Description:

This leather has excellent softness despite its very high light and abrasion resistance. A wide range of colours makes it one of the most popular leathers.
Materials Leather/Leather Hide
Collection Name Galileo
Sample Size
10 cm x 12 cm

Maintenance:

To remove potential residual grime, it is enough using a damp cloth. For a perfect and long-lasting leather, above all in case of deeper stains, Maxpell offers a range of specific products for every kind of leather

Product picture:

Environmental friendly:

Human Health Impact REACH Compliant

Characteristics:

Content Italian Bull Leather
Finish Synthetic and vegetable oils
Construction Non-Woven

Performance:

Flammability BS 5852 schedule 4 part I source 0; BS 5852 schedule 5 part I source 1; CAL 117-2013; IMO FTPC part 8
Lightfastness UNI EN ISO 105-B02 - > 4/5 after 36 hours exposure

Company info: MAXPELL Italian Leather

nmonaco@maxpell.it- www.maxpell.it- Via Leonardo da Vinci, 4

Roof covering

Name of product: HERADESIGN® Plano

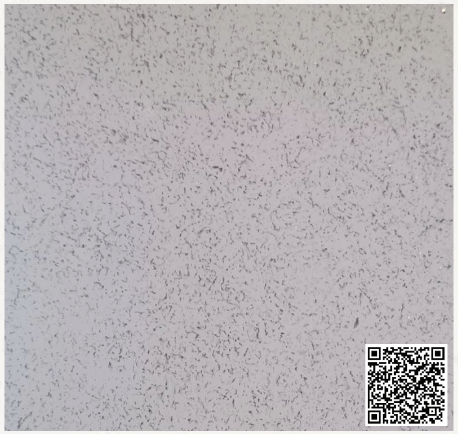
Description:

Furniture Fixtures And Equipment: Acoustical/Ceilings
Collection Name: HERADESIGN®
Sample Size: 195 mm x 145mm- Size 600 mm x 600 mm, 1200 mm x 600 mm
Custom Capabilities Special formats on request.
Maximum length available is 2400 mm; Maximum width available is 600 mm

Maintenance:

Soft Brush and Vacuum Cleaner

Product picture:



Environmental friendly:

Certifications: Cradle to Cradle Certified® Gold, Blue Angel, LEED®, BREEAM®, HQE™, DGNB, WELL, and FSC and PEFC certifications.

Sustainable Materials: Uses resource-saving, regenerative, natural, and health-safe materials.

Recyclability: Up to 100% recyclable, durable, and low-maintenance, with a closed production cycle.
Energy-Efficient Production: Manufactured under ISO 14001 (environmental management) and ISO 9001:2000 (quality assurance) standards.

Climate and Health Impact: Compliant with standards like EPD, Green Globes, CDPH/CHPS 01350, Low VOC, M1 Emissions, and WELL.

Characteristics:

Content: Magnesite-bonded wood wool
Surface Texture: Smooth
Thickness: 25 mm
Weight: 15.0 kg/m²
Color Options: Standard colors (white, beige) and additional options like granite, steel green, copper, oak, sandstone, and RAL/NCS custom colors

Performance:

Flammability: EN 13501-1 - B-s1, d0

Emissions: EN13964 - E1

Acoustics Sound Absorption: αw = up to 0.40

Performance: Thermal Conductivity: EN 12667 - λ = 0.10 W/mK

Company info: Knauf Ceiling Solutions

info.kcs@knauf.com-www.knaufceilingsolutions.com- Elsenthal 15 94481 Grafenau, Germany

Name of product: Armstrong METAL Rd 1522 with Fleece

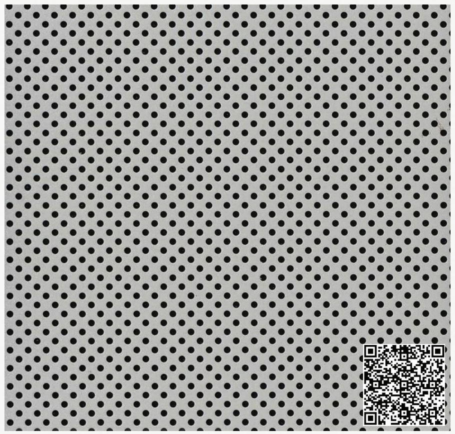
Description:

Furniture Fixtures And Equipment: Acoustical/Ceilings
Collection Name: Armstrong METAL
Sample Size: 205 mm x 145 mm
Size 600 mm x 600 mm, 625 mm x 625 mm, 1200 mm x 600 mm, 500 mm x 500 mm, 675 mm x 675 mm, 1200 mm x 300 mm, 750 mm x 750 mm

Maintenance:

Dusting: Use a soft brush or vacuum with a soft attachment.
Light Cleaning: Use lukewarm water with a mild cleaner and a soft sponge; dry afterward.
Deep Cleaning: Use a slightly damp cloth for stubborn areas, then dry with a soft cloth.
Compressed Air: For hard-to-reach spots, use compressed air or a steam cleaner (8 bar, 175ºC).

Product picture:



Environmental friendly:

LEED :May contribute to LEED credits
Climate Impact: BREEAM Compliant, 100% Recyclable, Environmental Product Declaration (EPD), FDES Certification, Green Globes Compliant, LEED Compliant, Oeko-Tex Certified, PVC free
Human Health Impact: CDPH / CHPS 01350 Compliant, Zero VOC

Characteristics:

Content: Post-coated galvanized steel, 0.5 - 0.7 mm thickness.
Surface Texture: Available in standard, micro-perforated, and extra-micro perforations, providing acoustic and visual variety.
Installation Options: Available as exposed, concealed grid, floating canopies, and wall solutions, allowing for design flexibility across ceiling and wall applications.

Performance:

Flammability: Euroclass A2-s2, d0

Emissions: EN13964 - E1

Acoustics Sound Absorption: EN ISO 354 - Class C, αw = 0.70; ASTM C 423 - NRC = 0.70; Sound Attenuation: EN ISO 10848-2 -Dn,f,w = 16 dB; Sound Reduction: EN ISO 10140-2 - Rw = 6 dB; CAC = 16 dB

Company info: Knauf Ceiling Solutions

info.kcs@knauf.com-www.knaufceilingsolutions.com- Elsenthal 15 94481 Grafenau, Germany

5.2 Proposed energy improvements for the future

The project's proposed energy improvements aim to transform the building into a more sustainable, energy-efficient structure while maintaining its architectural and historical value. One essential strategy for obtaining this goal is to reduce energy use. This significant strategy might ensure that the structure will remain environmentally sustainable and sufficiently adaptable to satisfy future energy requirements. To meet this energy goal, this project aims to strike a fair balance between new interventions and cultural feature conservation. The interventions will preserve the building's original materials, design, and cultural significance while also improving energy efficiency. The modifications proposed during the renovation focus on key elements such as insulation, material selection, and energy production through active systems like photovoltaic (PV) panels. The priority is installing high-performance insulation for walls, roofs, and floors. This insulation will minimize heat loss, helping to maintain a stable interior temperature. Additionally, acoustic insulation, applied primarily to partition walls, will reduce noise, creating a quieter, more focused atmosphere. The external walls are insulated with expanded polystyrene, along with a gypsum board, all backed by a sturdy masonry brick framework. [37]

- **Flooring system**

For the flooring insulation system as probably considered in 2006, the crawlspace is used. A ventilated under-floor cavity created with Iglù®. The air cavity formed by the Iglù® modules must be connected to the outside with simple pipes. This creates natural air flow that crosses the cavity and eliminates moisture and Radon gas (if present).[38] The ventilation process is gained in the proposed design by including the pipes in the flooring system. This method reduces the piping setup's visual presence while simultaneously raising airflow. By efficiently channeling air through these floor-integrated pipes, the Iglu system keeps the area's architectural integrity while producing efficient ventilation.

- **Roofing system**

Upgrading the roofing system with enhanced insulation will improve the building's overall energy performance. This proposal includes installing green roofs and PV-panel roofs in addition to adding thermal insulation to the roof layers. Green roofs provide an extra layer of insulation, aiding in the regulation of internal temperatures. By absorbing heat and releasing oxygen, they help lower the building's energy demand for cooling. The green roof system is designed according to DAKU standards, the Italian pioneer in green roofing(technical drawing are outlined in the appendix,see Appendix for more information), ensuring both energy efficiency and environmental compatibility.Providing the roofs with photovoltaic (PV) panels is a key strategy in meeting the energy goals of this project. The proposal assumes installing PV panels on the ten lower-arched roofs.

37. MADDALENA, RICCARDO, JENNIFER J. ROBERTS, AND ANDREA HAMILTON. "CAN PORTLAND CEMENT BE REPLACED BY LOW-CARBON ALTERNATIVE MATERIALS? A STUDY ON THE THERMAL PROPERTIES AND CARBON EMISSIONS OF INNOVATIVE CEMENTS." JOURNAL OF CLEANER PRODUCTION 186 (2018): 933-942.

38. DALIFORM GROUP. IGLU®: PERMANENT FORMWORK FOR VENTILATED CRAWL SPACES. ITALY: DALIFORM GROUP. ACCESSED [YEAR]. AVAILABLE AT WWW.DALIFORM.COM.

Although only this project will feature PV panels, the energy generated can benefit surrounding buildings through an energy-sharing community model. This means that while the surrounding residential buildings will not have PV panels themselves, they can use the energy produced by this project's system. By generating clean energy and sharing it with the local community, the project enhances sustainability and meets adaptive reuse goals while respecting the heritage status of the site and preserves the visual and historical integrity of this heritage site. Selecting the appropriate PV panel system requires clear alignment with the project's goals. The main target of this study is to respect the building's historical and architectural significance, which requires a PV system that is adaptable and less visible. While efficiency remains an essential factor, the substantial available roof space offers flexibility to achieve energy production targets, thereby addressing performance needs without risking the historical value of the structure.

- **Photovoltaic panel types**

In the table below, different types of PV panels are listed along with their characteristics. Based on this project's design proposal, the Monocrystalln PV panel type is determined to best meet its requirements. This conclusion was reached using the PVGIS platform, which provides essential calculations for solar irradiance and energy output, performance simulations, as well as system losses and efficiency. The main goal of this thesis, which is to maintain the building's architectural integrity, is closely connected with the selection of crystalline silicon PV panels. Crystalline silicon PV panels are more in line with the original design of the structure than thin-film or flexible PV panels, which may provide flexibility as well as price benefits. Its fixed shape allows integration without changing the building's skyline or profile, maintaining the architecture's visual. and historical value. In addition, even though the building's orientation is not the best for solar capture, all the surfaces could be used by installing the panels horizontally (with no slope and no azimuth revision). Although this approach reduces efficiency, it allows the installation of more panels without affecting design. Achieving sustainable energy performance while maintaining architectural value is a balance that supports the adaptive reuse thesis purpose. In the following sections, more specific data about the selected PV panel, its characteristics, and installation methods are presented.

Model	Pros	Cons
Monocrystalline	**• Highest efficiency • Longer lifespan (25+ years)**	**• Most expensive**
Polycrystalline	• balanced cost and efficiency • Long lifespan (25+ years)	• Lower efficiency than mono panels • Higher temperatures affect productivity and durability
Amorphous	• High temperatures only have a small impact on their productivity • Lightweight • Low cost • Flexible and adhesive panels available	• Low efficiency • Shorter lifespan than mono and poly panels
Crystalline Silicon	• High Efficiency • Long Lifespan • Mature Technology • Durability • Wide Availability	• Energy-Intensive Production • Performance Decline at High Temperatures • Bulkiness • Limited Flexibility

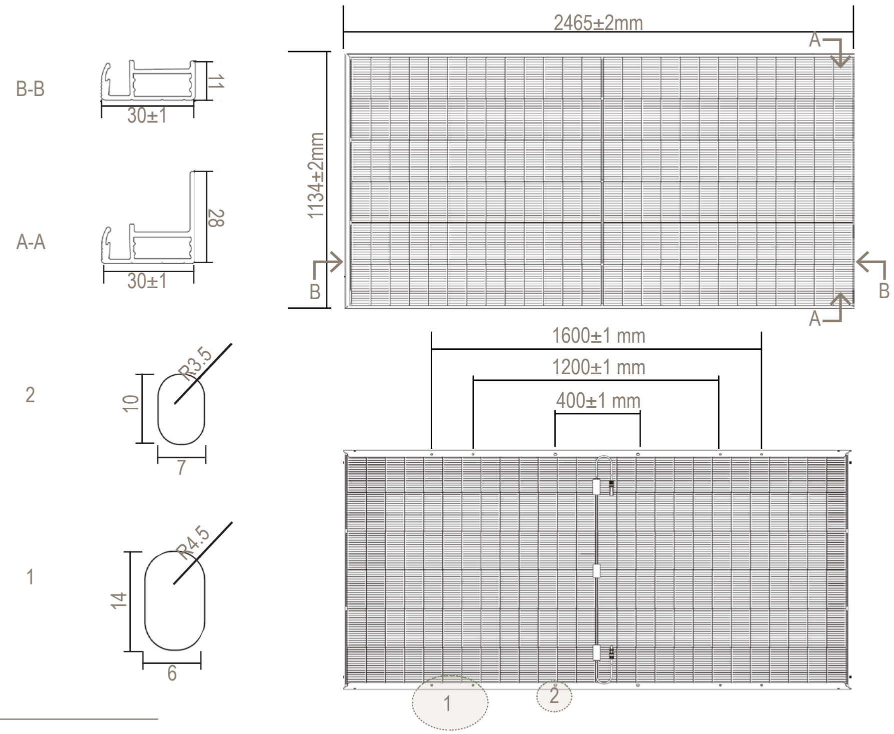
Table 20

5.3 Energy Performance Assessment of Crystalline Silicon PV Panels

A common type of photovoltaic solar panel is crystalline silicon, created mainly by silicon cells that absorb sunlight and convert it into electricity. These panels are available as monocrystalline and polycrystalline types, and their efficiencies differ. Due to their single-crystal structure, monocrystalline panels are typically more efficient, whereas polycrystalline panels use many silicon crystals and are therefore more economical. The main components of crystalline silicon photovoltaic panels are silicon cells that carry out the photoelectric function, protective external layers of glass or polymer, Ethyl Vinyl Acetate (EVA) as an encapsulant to guarantee durability, and electrical contacts composed of metals like copper or silver to promote energy transfer. While maintaining the panel's lightweight, an aluminum frame provides structural safety. Because of their complex material combination, they present recycling challenges requiring disassembling processes to efficiently recycle important components.[39] The table below displays the chosen photovoltaic (PV) panel model for this project, including its mechanical characteristics.[40]

Name	78HL4-BDV 625–650-Watt BIFACIAL MODULE WITH DUAL GLASS
Manufacturer	Jinko Solar
Model number	JKM625-650N-78HL4-BDV-F9-EN
Cell type	N- type Mono-crystalline
Dimensions (mm)	2465×1134×30
Module area (m2)	2.79
Weight (kg)	34
Front Glass	2.0 mm, Anti-reflection Coating
Back Glass	2.0 mm, Heat Strengthened Glass
Frame	Anodized Aluminum Alloy

Table 21



39. DIAS, PABLO RIBEIRO, MARIANA GONÇALVES BENEVIT, AND HUGO MARCELO VEIT. "PHOTOVOLTAIC SOLAR PANELS OF CRYSTALLINE SILICON: CHARACTERIZATION AND SEPARATION." WASTE MANAGEMENT & RESEARCH 34, NO. 3 (2016): 235-245. HTTPS://DOI.ORG/10.1177/0734242X15622812.

40. Jinko Solar Co., Ltd. JKM625-650N-78HL4-BDV-F9-EN Bifacial Module with Dual Glass: Product Datasheet. Accessed October 29, 2024. Jinko Solar.

N-type Technology

N-type modules with Tunnel Oxide Passivating Contacts (TOPcon) technology offer lower LID/LeTID degradation and better low light performance.

Dual-Sided Power Generation

Dual-sided power generation gain increases with backside exposure to light, significantly reducing LCOE.

SMBB Technology

Better light trapping and current collection to improve module power output and reliability.

HOT 3.0 Technology

N-type modules with JinkoSolar's HOT 3.0 technology offer better reliability and efficiency.

Mechanical Load Enhanced

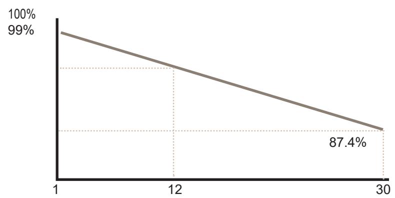
Certified to withstand:
5400 Pa front side max static test load
2400 Pa rear side max static test load

Anti-PID Guarantee

Minimizes the chance of degradation caused by PID phenomena through optimization of cell production technology and material control.

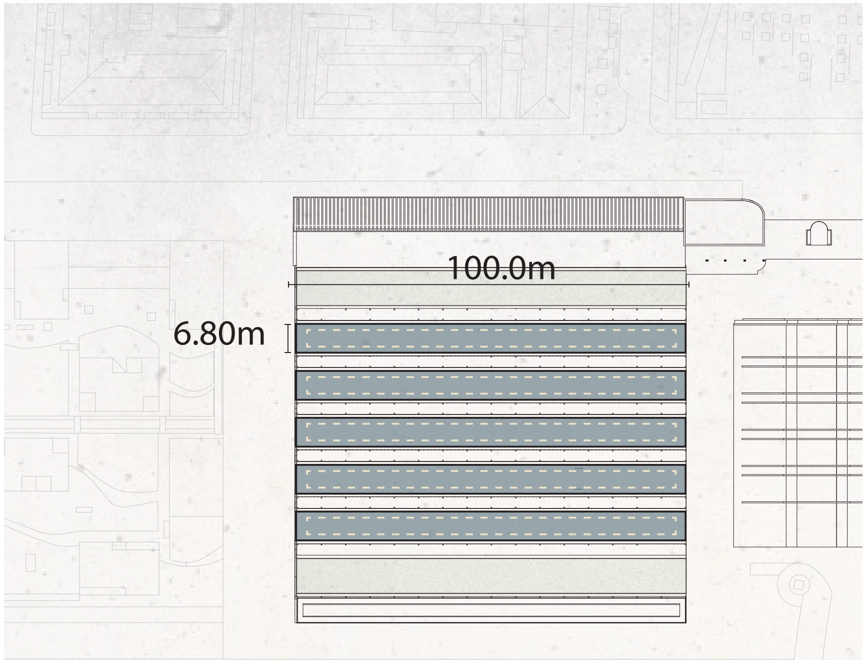
Adherence to Quality, Environmental, and Safety Management Standards:

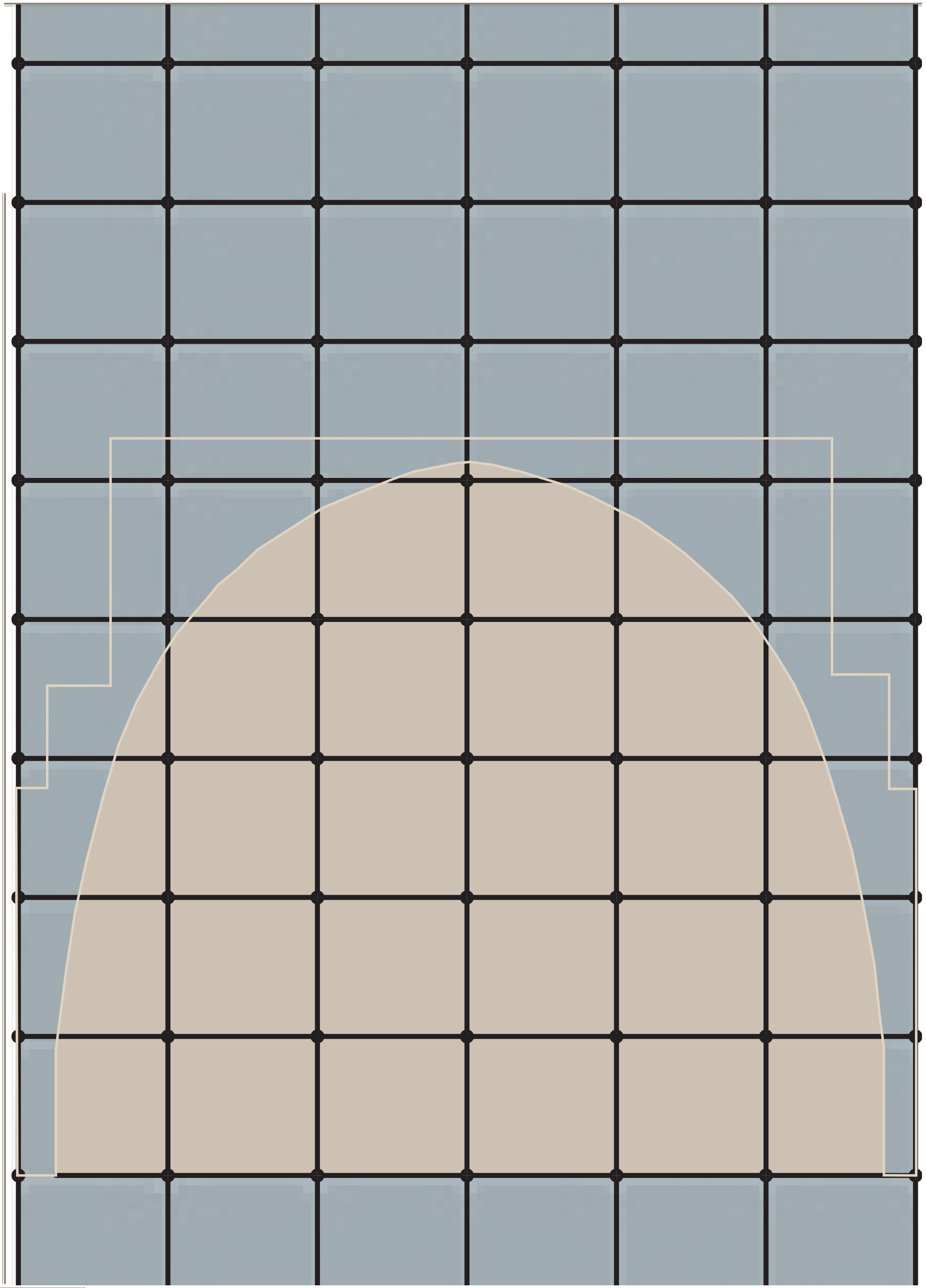
- IEC61215:2021 / IEC61730:2023
- IEC61701 / IEC62716 / IEC60068 / IEC62804
- ISO9001:2015: Quality Management System
- ISO14001:2015: Environment Management System
- ISO45001:2018: Occupational health and safety management systems



12Year	30Year	1%	0.40%
Product Warranty	Linear Power Warranty	First-year Degradation	Annual Degrdation Over 30 Years

The following step is to assess the energy efficiency of the chosen photovoltaic (PV) panel and understand the number of panels that can be fitted on the specified roofs. The initial calculations will be performed using the PVGIS website, and the results will be detailed in the next section. According to the dimensions of the chosen arched roof (width: 6.8 meters, length: 100 meters), I have organized 2 rows and 85 columns of photovoltaic (PV) panels, resulting in a total of 170 panels for each roof. To have the visual target, I considered an offset of 1 meter on each side of the width and 2 meters on each side of the length. This offset not only provides an organized and well-balanced visual effect but also maximizes the usable roof area for the installation of solar panels.





- PVGIS Analysis

The Photovoltaic Geographic Information System (PVGIS) is a web-based platform that delivers climate information and tools essential for evaluating the performance of photovoltaic (PV) technology across Europe. Geodatabases and simulation models are connected to the web interface, facilitating user-friendly access. Interactive maps are crucial for comprehending geographic variation in the performance of PV technology.[41] This useful tool enabled me to calculate the annual photovoltaic (PV) energy production (in kWh) of the PV panels for my project. I then applied these figures to estimate the installation's total energy output. After analyzing the data, I can confirm that the project has sufficient capacity to function as an energy community by comparing this output with the estimated energy demand of each area. This means it may generate additional power that could be shared among nearby buildings, thereby enhancing sustainability in the region and supporting the local energy network. Here are the PVGIS results. Table 22 shows total annual energy production, which is 1126.57 kWh, while Figure 41 breaks down monthly energy production. This chart highlights that energy output peaks in June, July, and August, indicating maximum production during these summer months. According to the number of PV panels required for each roof, 1700 PV panels are needed for the whole arches' roofs (10 roofs). The selected PV panel type produces 0.65 kWp power. Therefore, the total power production is 1105 kWp.

41. SURI, M., T. HULD, T. CEBECAUER, AND E. D. DUNLOP. "GEOGRAPHIC ASPECTS OF PHOTOVOLTAICS IN EUROPE: CONTRIBUTION OF THE PVGIS WEBSITE." IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING 1, NO. 1 (MARCH 2008): 34-41. HTTPS://DOI.ORG/10.1109/JSTARS.2008.2001431.

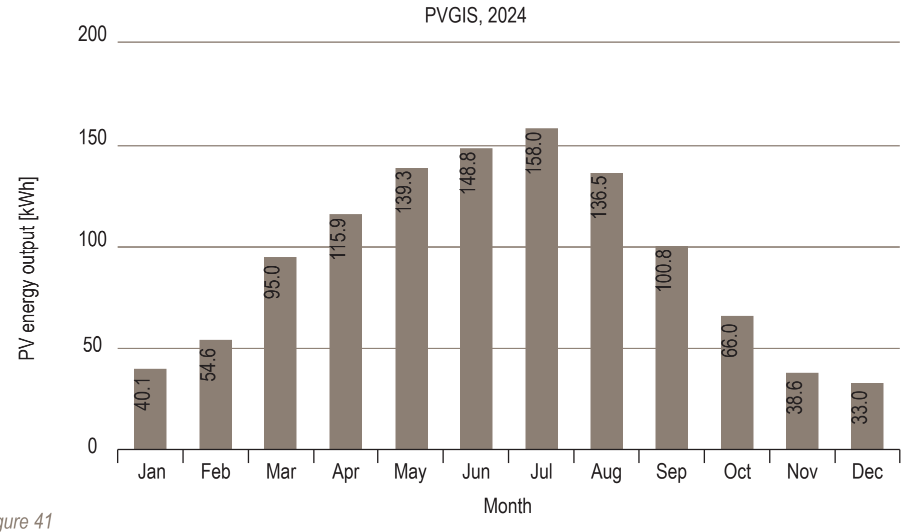


Figure 41

Provided inputs	
Location [Lat/Lon]	45.03255352203357, 7.657415068924144
Horizon	calculated
Database used	PVGIS-SARAH2
PV technology	CRYSTALLINE SILICON
PV installed [Wp]	1
System loss [%]	14
Simulation outputs	-
Slope angle [°]	0
Azimuth angle [°]	0
Yearly PV energy production [kWh]	**1126.57**
Yearly in-plane irradiation [kWh/m²]	1472
Year-to-year variability [kWh]	33.36
Changes in output due to	-
Angle of incidence [%]	-3.99
Spectral effects [%]	0.79
Temperature and low irradiance [%]	-8.04
Total loss [%]	-23.47

Table 22

- **Energy consumption of non-residential buildings**

The average specific energy consumption of non-residential buildings in Europe is approximately 280 kWh/m2, which is considerably 40% higher than that of residential buildings, according to a report by the Buildings Performance Institute Europe (BPIE). However, Because of differences in performance intensity and usage patterns, this figure can differ significantly across various types of non-residential buildings. The main sources of energy consumption are heating, cooling, and lighting technologies; considered as an entire unit, they demand the highest amounts of energy.[42] The services sector provided for 13.4% of the EU's total final energy consumption in 2022, as shown by recent data on final energy consumption for EU nations. In 2022, this sector contained a range of non-residential sectors like industries, hotels, hospitals, and schools, consumed 5,080 PJ total. The project's energy requirements were estimated using average data from EURAC Research (European Academy of Bolzano/Bozen) because precise data on building services energy usage was lacking. Among the functional areas included in the design plan are offices, study areas, and meeting rooms. Since these functions require almost the same amounts of energy as standard office spaces, EURAC Research's analysis of office building energy consumption data (EU-27)[43] has been used as a guide. Different energy categories are used in the computations, each having particular and overall consumption values listed in Table 23. The table indicates that the current heating demand is 161 kWh/m²/year. However, the design concept goals to improve the exterior walls with insulation in order to lower

42. ECONOMIDOU, MARINA, ET AL. EUROPE'S BUILDINGS UNDER THE MICROSCOPE: A COUNTRY-BY-COUNTRY REVIEW OF THE ENERGY PERFORMANCE OF BUILDINGS. BRUSSELS: BUILDINGS PERFORMANCE INSTITUTE EUROPE (BPIE), 2011.
43. Roberto Fedrizzi and Chiara Dipasquale, "Fabbisogni Energetici: Case e Uffici Sotto la Lente," Casa & Clima, no. 54 (2015): 10-12, European Academy of Bolzano/Bozen (EURAC).

this to 30 kWh/m²/year. This goal was selected in accordance with the project's huge glass surfaces. Using very high-performing windows would be necessary to achieve a heating energy consumption lower this, which would increase expenses considerably and go against the cost-effectiveness principle, which is an important aspect of sustainability. High-performance glass has already been integrated into the design concept in order to achieve a balance between affordability and energy efficiency, based on the U-value values examined in previous sections. Thus, Table 24 presents the data used for the energy consumption calculations.To calculate the energy usage of the project, the heated areas, representing the various functions, are considered as individual boxes (Figure 42).

Final use	Specific Consumption	Total Consumption
Heating (Riscaldamento)	161 kWh/m²/year	159 TWh/year
Cooling (Raffrescamento)	10 kWh/m²/year	7 TWh/year
Hot Water (ACS - Acqua Calda Sanitaria)	22 kWh/m²/year	18 TWh/year
Lighting (Illuminazione)	39 kWh/m²/year	42 TWh/year

Table 23

Final use	Specific Consumption
Heating (Riscaldamento)	30 kWh/m²/year
Cooling (Raffrescamento)	10 kWh/m²/year
Domestic Hot Water (ACS - Acqua Calda Sanitaria)	22 kWh/m²/year
Lighting (Illuminazione)	39 kWh/m²/year

Table 24

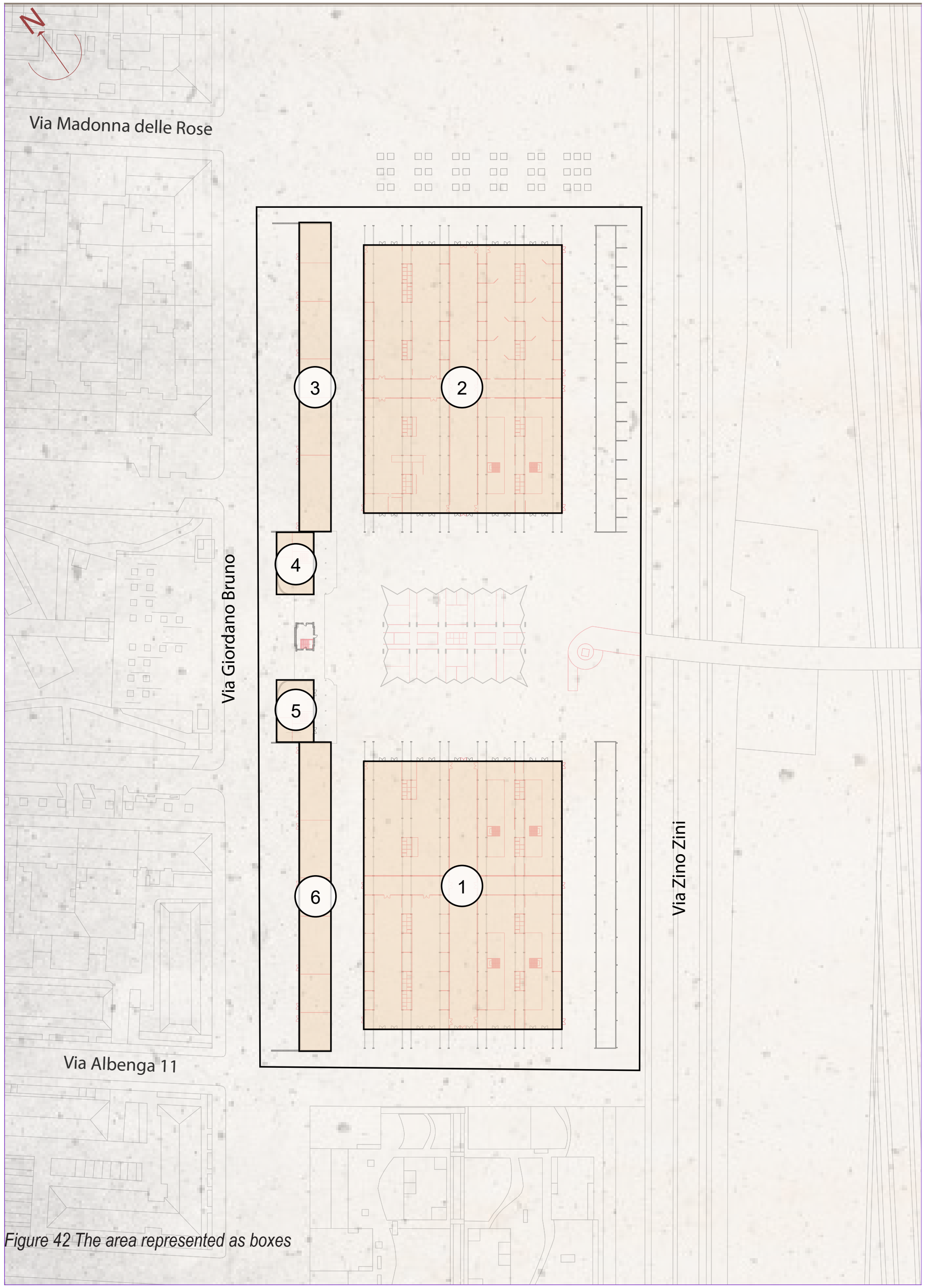


Figure 42 The area represented as boxes

Table 25 shows the area of each box in square meters. To determine the energy consumption for heating, cooling, domestic hot water (DHW), and electricity, it is necessary to know the total square meters of the heated area. It should be noted that heating and DHW are calculated together because they often share energy sources, operate within integrated systems, and are essential for evaluating overall building energy performance. Therefore, using a simple equation, the specific energy consumption for the designated square meters can be calculated.

Boxes	Area (m^2)
Box 1	5568
Box 2	5568
Box 3	1000
Box 4	240
Box 5	240
Box 6	1000
All boxes	13616

Table 24

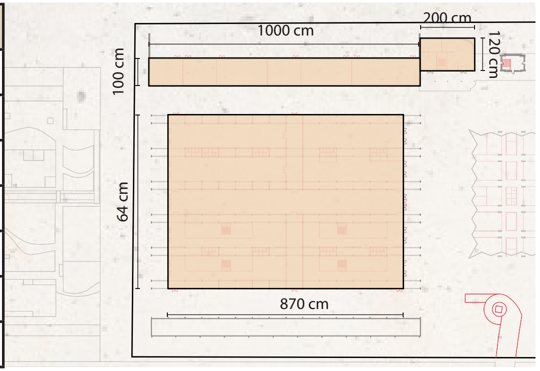


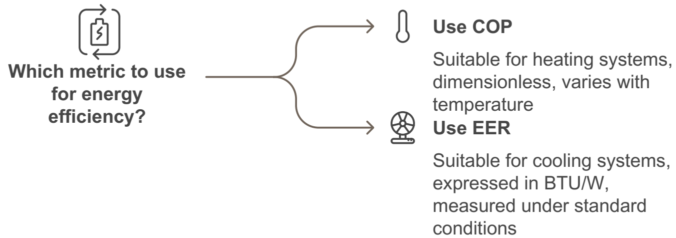
Figure 43 Dimensions of the area represented as boxes

Below is the process and the results for calculating the energy consumption of each building energy service:

- **Heating: 52 kWh/m^2 x 13616 m^2 = 708032 kWh/y**
- **Cooling: 10 kWh/m^2 x 13616 m^2 = 136160 kWh/y**
- **Lighting: 39 kWh/m^2 x 13616 m^2 = 531024 kWh/y**

- **COP and EER**

The coefficient of performance or COP measures the efficiency of appliances such as air conditioners and refrigerators and heat pumps. The useful heating or cooling output divided by the energy input represents what is produced when electricity or work is used. The ratio of a system's heat output to its energy consumption in heating applications is calculated by COP. The Energy Efficiency Ratio (EER) measures the cooling performance of air conditioners under controlled settings as it relates directly to the amount of heat the system removes and the energy required to achieve the cooling effect, making this measure important for understanding how effectively a cooling system or heat pump operates in specific situations. The calculation is influenced by the ratio of cooling capacity measured in BTUs per hour to electrical power input measured in watts and this relationship is important for understanding efficiency. COP applies to both heating and cooling systems but EER applies only to cooling systems and relies on fixed test conditions. Products can be compared by users based on their operating costs and potential energy savings because energy-efficient cooling devices are indicated by higher EER values and this comparison helps consumers make better decisions.[44]



44. Harvey S. Leff and William D. Teeters, "EER, COP, and the Second Law Efficiency for Air Conditioners," American Journal of Physics 46, no. 1 (1978): 19–22, https://doi.org/10.1119/1.11174.

According to the technical specifications outlined in TEON's datasheet for their Professional Series water-source heat pump systems,[45] the system selected is characterized by a high COP of 4.07 and EER of 5.27, ensuring efficient energy use for both heating and cooling calculations. To begin the process, the heating and cooling demands are divided by the COP and EER values, respectively:

- **The electricity need for heating = 173963.6 kWh**
- **The electricity need for cooling = 25836.81 kWh**

At this stage, the primary energy needs are determined by summing the energy requirements of all three building energy service categories. The total calculated energy is:

- **173963.6 + 25836.81 + 531024 = 730824.4 kWh**

Now, with the known power production of the PV panels at 0.65 kWp per panel and a total installed capacity of 1105 kWp, the total annual energy production (kWh) can be calculated using the following formulas:

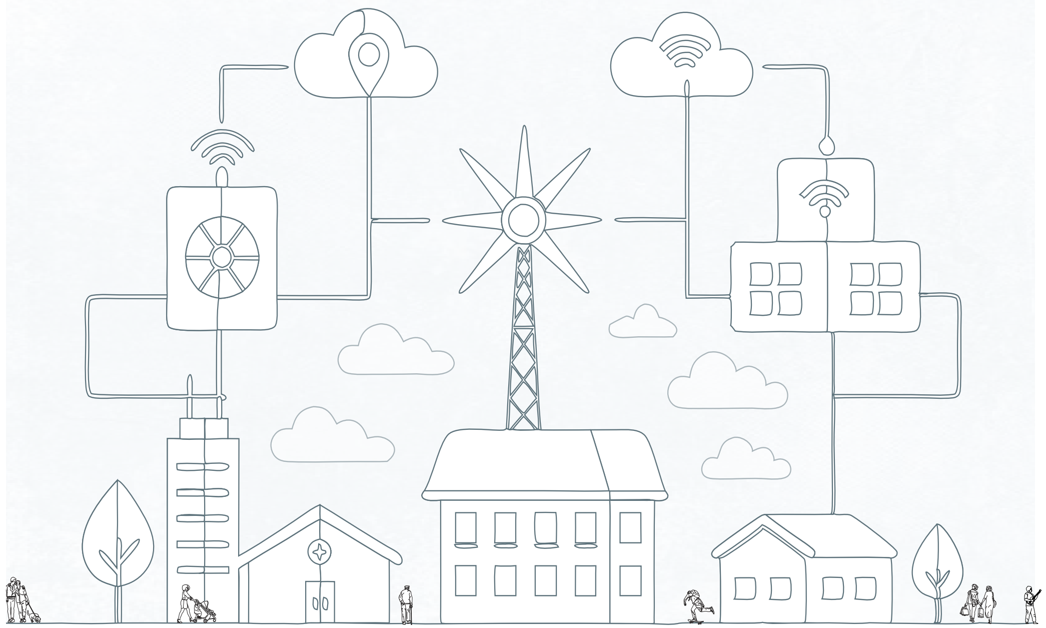
$$PR = \frac{\text{Yearly in-plane irradiation}}{\text{Installed capacity(kWp) x Yearly in-plane irradiation}}$$

Installed capacity(kWp) x Performance ratio(PR) x Yearly in-plane irradiation(kWh/m^2)

These calculations are based on the data provided in Table 22, which outlines the specifications and parameters used for determining the annual energy production of the PV system.

45. TEON. Scheda Tecnica: Gamma Professionale – Versione Water. Technical datasheet for water-source heat pump systems, including specifications and performance metrics.

With a Performance Ratio (PR) of 0.765, the total annual energy production is calculated as 112,608 kWh per kWp. For an installed capacity of 1105 kWp, this results in a total annual energy production of 1,242,432 kWh. At this stage, the coverage of the total annual energy production is analyzed in comparison with the total annual energy consumption. The coverage is calculated by dividing the total annual energy production by the PV panels by the total energy consumption. The result demonstrates that the energy produced by the PV panels not only cover the building's energy demands but also generates an additional 70% surplus energy that can be utilized by the energy community.



5.4 Heating and cooling technology

- **Heat pump technology**

An energy-efficient method for heating and cooling buildings is the heat pump. Heat pumps are significantly more effective than traditional heating techniques like gas boilers because they transfer heat from one place to another with a small amount of electricity, according to the International Energy Agency's "The Future of Heat Pumps Report." As an example, a standard heat pump can produce three to five times as much heat as it uses in electrical energy. Considering the worldwide energy and climate concerns, this technology is highly beneficial in reducing greenhouse gas emissions as well as decreasing consumption of fossil fuels. Heat pumps have positive and negative aspects like any other technology. The first benefit is that heat pumps are extremely efficient than older systems since they can provide both heating and cooling, avoiding the need for separate systems. In addition, they can save a lot of money and help reduce greenhouse gas emissions. However, this fact is unrelated to my design, heat pumps might be less effective in very cold climates. Other drawbacks include the possibility of leaks required for regular repair, and the complex installation requirements brought on by the large network of underground pipes.[46]
Complex energy systems must be stored and managed in technical rooms in commercial buildings. While keeping public and private areas apart to reduce disruptions and align with regulations, these places guarantee the correct operation, security, and effectiveness of important systems.Figure 44 is highlighted the technical rooms location in the project.

46. IEA. THE FUTURE OF HEAT PUMPS. PARIS: IEA, 2022. HTTPS://WWW.IEA.ORG/REPORTS/THE-FUTURE-OF-HEAT-PUMPS.

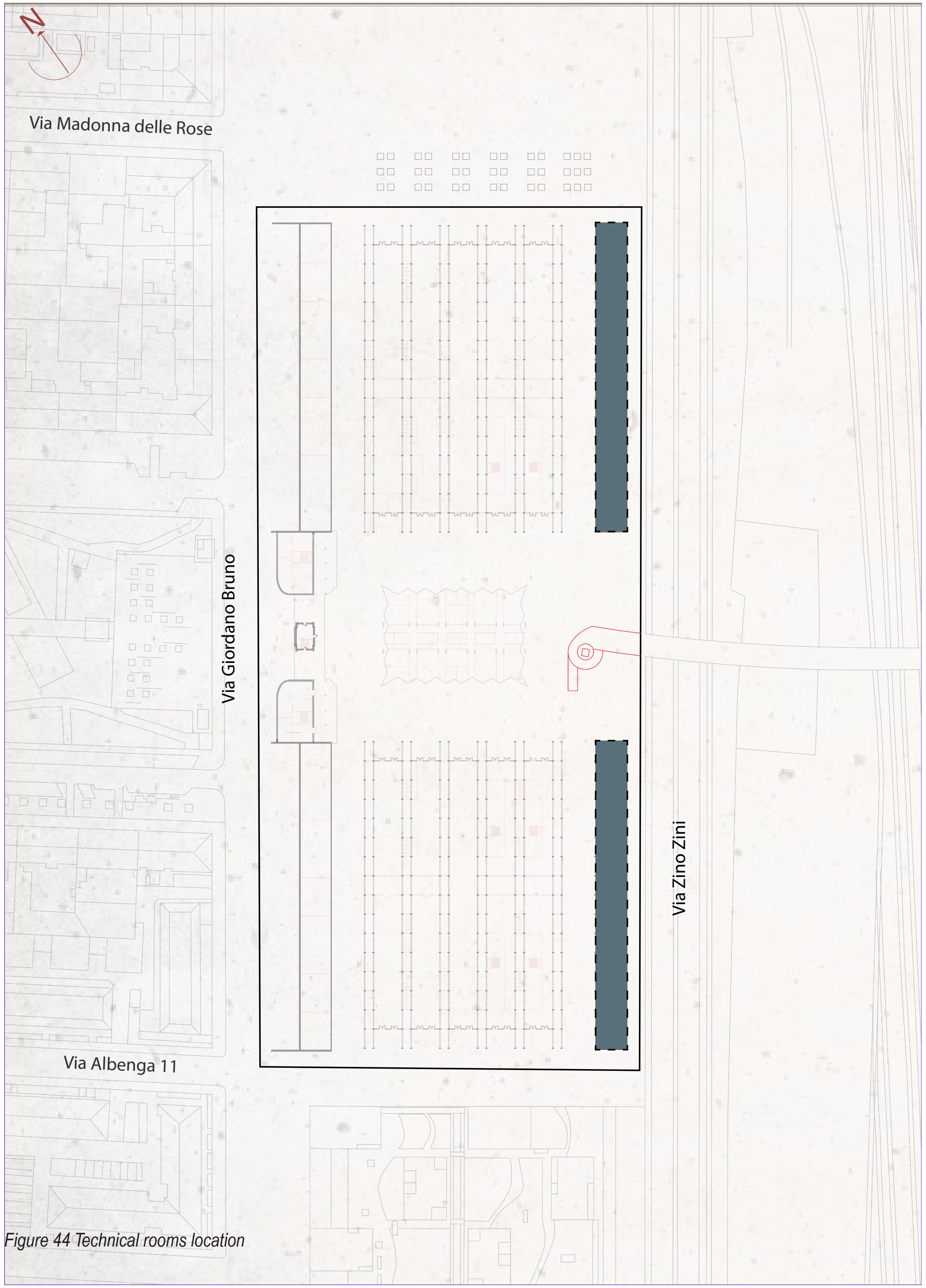
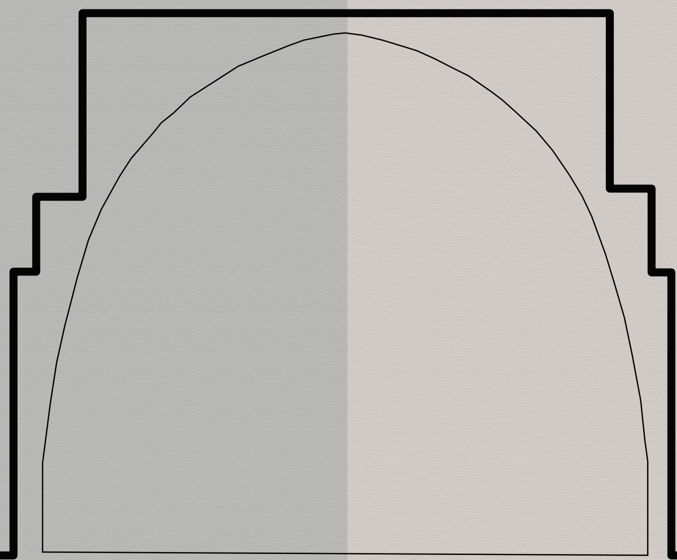


Figure 44 Technical rooms location

06



Discussion

6. Discussion

6.1 Key findings

The inclusive analysis of the Ex-Moi Mercati Generali structure has provided important insights into energy considerations in adaptive reuse projects. To begin with the first period, the original construction in 1933 prioritized functionality and durability. As a result, energy efficiency was not considered, leading to a lack of insulation and heat loss issues. The glazing system used at that time was single-glazed, and the walls consisted only of heavy brick masonry without any insulation barrier. This resulted in poor building performance, which was not a major concern due to the building's original function. In 2006, when Turin became the host of the Winter Olympics, energy principles gained importance. The technology was improved, new functions for the building required better energy efficiency methods. The integration of double-glazed windows, ventilated flooring systems like IGLU'®, enhanced insulation, and structural reinforcements aimed to improve performance while maintaining the building's historical value. The proposal's design team gives emphasis on sustainability and makes sure that the building's historical and ethnic value is maintained. The strategy seeks to minimize demolition and maximize reuse of existing materials for financial reasons. The roof has PV panels that produce power and green roofs that control the inside temperature by absorbing heat and releasing oxygen and the builders have kept the core structure of the floors while adding new finish layers. By implementing these steps, the overall energy use of the building is importantly reduced, which benefits both the environment and the occupants.

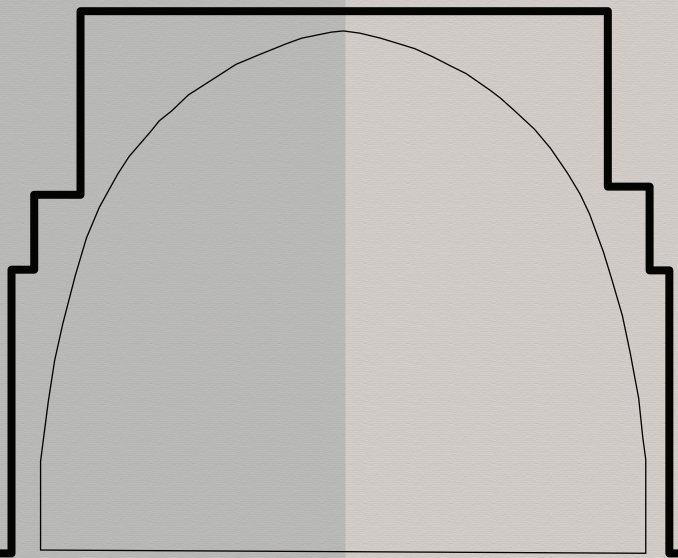
6.2 Implication for future adaptive reuse projects

In the Ex-Moi Mercati Generali case study, the integration of modern energy strategies into historical buildings was highlighted regarding challenges, limitations, and benefits. It is suggested by findings that important improvements in energy performance can be led by careful planning, and innovative design while the building's historical and cultural value is respected. This belief by professionals is regarded as important for future projects in historical sites. Balancing conservation with efficiency is often considered difficult. Energy analysis plays a key role in shaping design decisions as provided are detailed assessments for managing interventions that improve energy performance in design. For selecting materials and technologies that improve energy efficiency, understanding the thermal properties of building components is necessary without architectural heritage being compromised. For future projects, with energy efficiency considerations being incorporated early in planning, an information-based approach should be adopted from the start. As effective models for other adaptive reuse projects techniques represented in this research can serve, such as green roof installations, advanced glazing systems, and the use of photovoltaic panels for energy production, offering sustainable strategies to strengthen historical building.

6.3 Limitations of the research

This research relies on historical records and scientific articles and estimated material properties which introduce some uncertainties in energy performance calculations. Assumptions must reflect the materials and technologies used in the 2006 renovations and they may not show the actual choices made at that time. I cannot claim that those materials or technologies bear any resemblance to the ones that were used in 2006, and I believe important improvements have taken place since then. The study actively examines the technical aspects of a specific part of the Ex-Moi Mercati Generali site and highlights its importance. The findings are generally applicable, but this does not limit them. The selected section represents wider directions, and wide-ranging analysis has also been conducted for the entire site. The proposed design strategies and techniques were developed with current technologies and economic limitations in mind and the experimental performance of these strategies rely on financial resources and supervisory support. For future research, a cost-benefit analysis should be examined to better assess the sustainability and economic viability of these interventions and to allow for more informed decisions about adaptive reuse in similar projects.

07



Conclusion

7. Conclusion

7.1 Summary of contributions

This thesis investigated the adaptive reuse of historical buildings at the Ex Moi Mercati-Generali site in Turin, Italy, through the integration of sustainable principles. Several important topics were addressed by this research through a detailed analysis, providing an important understanding of accommodating modern energy efficiency needs in architectural heritage. Examined were the architectural details of the Ex Moi Mercati-Generali's structure, and extensively studied was the building's evolution over nearly a century. Historical data from archives were carefully gathered, personal site observations were conducted, and thorough research on early 20th-century design practices was engaged. The initial design from the 1930s served as a foundation for this thesis, highlighting how industrial functionality prioritized energy efficiency. Key features such as large parabolic concrete arches, wide open spaces, and uninsulated single-glazed windows were concentrated on in the analysis, which was state-of-the-art at that time. However, these features now create challenges as contemporary energy standards evolve. I estimated the growth of design practices, especially those renovations made for the 2006 Winter Olympics, showing both the limitations and opportunities that later renovations provided. Additionally, I have developed a thorough framework for energy analysis in adaptive reuse, which is an important contribution to this work. By comparing the energy performance of the building across three main periods—its original construction in 1933, the Olympic renovations in 2006, and the proposed modern design—this thesis provides a robust methodology for evaluating energy efficiency in heritage projects. The thermophysical design of the envelope and the analysis of the thermal requirements of the materials and components of walls, roofs, and windows, were pivotal in identifying energy losses and informing the selection of appropriate sustainable design interventions. Based on the calculated U-value and R-value, it can be concluded that there is a significant improvement in thermal performance indicators from the first period to the design proposal. The U-value has decreased, and the R-value has increased, both for walls and roofs, stating that the selected materials are effectively enhancing the building's thermal efficiency. These in-depth evaluations provided an understanding of how particular architectural elements influence energy efficiency across multiple periods and revealed the importance of design choices in sustainability. Solutions for energy efficiency were presented in the research and it presented how a historical building can be changed to meet contemporary ecological goals while not sacrificing its culture and architectural values. Green roofs will be installed for natural insulation and to reduce urban heat effects and photovoltaic panels will be added to generate renewable energy and respect the building's heritage status. According to the results, the energy production from the 170 PV panels installed in this project not only meets 100% of the building's energy demand but also generates an additional 70% surplus energy. By implementing appropriate strategies, this surplus energy could be distributed to nearby functional buildings, enhancing the overall energy efficiency of the surrounding area.

Planned enhancements such as better wall insulation and the preservation of key architectural features keep the building functional and energy efficient. These solutions exemplify how adaptive reuse projects can balance the preservation of historical value with modern sustainability standards, contributing to the broader discourse on energy-conscious design in heritage conservation. This thesis not only provides a blueprint for improving the Ex Moi Mercati-Generali's energy performance but also offers a replicable model for other heritage buildings. The findings demonstrate that with thoughtful planning and advanced energy modeling, heritage structures can be transformed into sustainable assets, setting a background for future architectural and urban planning initiatives.

7.2 Future directions

This thesis has created a strong foundation for understanding the energy performance of adaptive reuse projects. Areas where further research could be helpful have been identified. One exciting path for future research includes the use of advanced simulation software for more precise energy performance modeling in this project's context. A deeper understanding of design interventions affecting energy efficiency would be offered by such simulations enabling the improvement of sustainable design strategies. The effects of varying materials, and architectural modifications could be simulated by researchers, allowing outcomes to be predicted more precisely and data-driven decisions to be made for improving overall building performance. Moreover, costly understandings into the effectiveness of proposed design solutions over time can be gained through the implementation of a long-term monitoring approach, which is recommended. The identification of practical benefits and challenges of these interventions is made possible by continuous monitoring, providing a clearer picture of how adaptive reuse projects perform in real-world conditions. In this long-term study, aspects such as maintenance requirements, energy consumption, and occupant comfort will be evaluated which will provide a wide-ranging understanding of the sustainability of these projects over time. . Importantly contributing to the field, other historical sites with varied architectural styles, geographical locations, or climates are being included to expand the research area. A broader vision of the challenges and opportunities connected with preserving heritage while improving energy efficiency is gained by researchers through studying adaptive reuse projects from multiple perspectives. Patterns and best practices tailored to specific building types, or regional conditions are shown by comparative studies offering precious guidance for future projects, and urban planners worldwide. To the economic dimensions of adaptive reuse, greater attention should be paid to future research. Detailed cost-benefit analyses should be conducted to quantify financial implications of sustainable interventions, making it easier for investments in heritage conservation to be justified. Funding mechanisms and economic incentives supporting these projects must be examined, as decision-making often relies heavily on economic viability. Examining policy frameworks that encourage sustainable renovation should highlight stronger support for historic preservation efforts. Tax benefits, grants, or other incentives for energy-efficient renovations could be offered by policies to encourage a more compassionate setting for integrating sustainability into heritage architecture thereby promoting common adoption.

"As an architect, you design for the present, with an awareness of the past, for a future which is essentially unknown"

by architect and preservationist Sir Norman Foster

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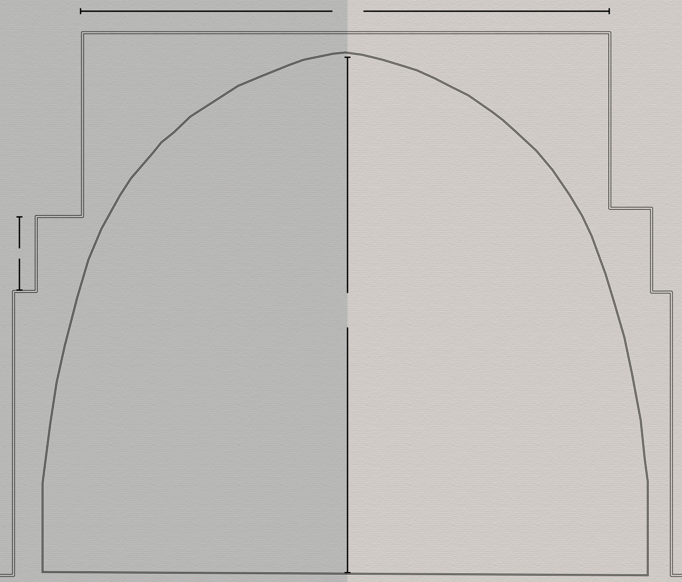
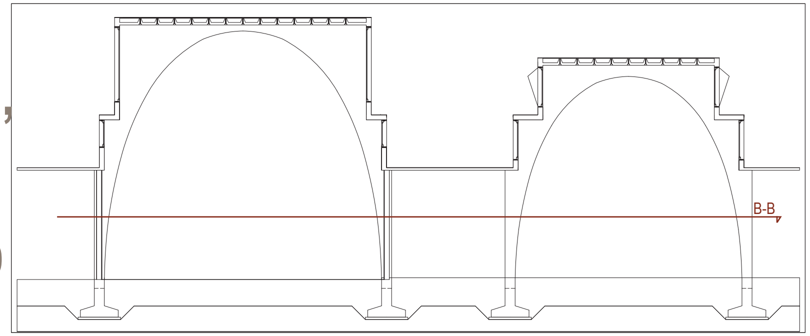
Appendix

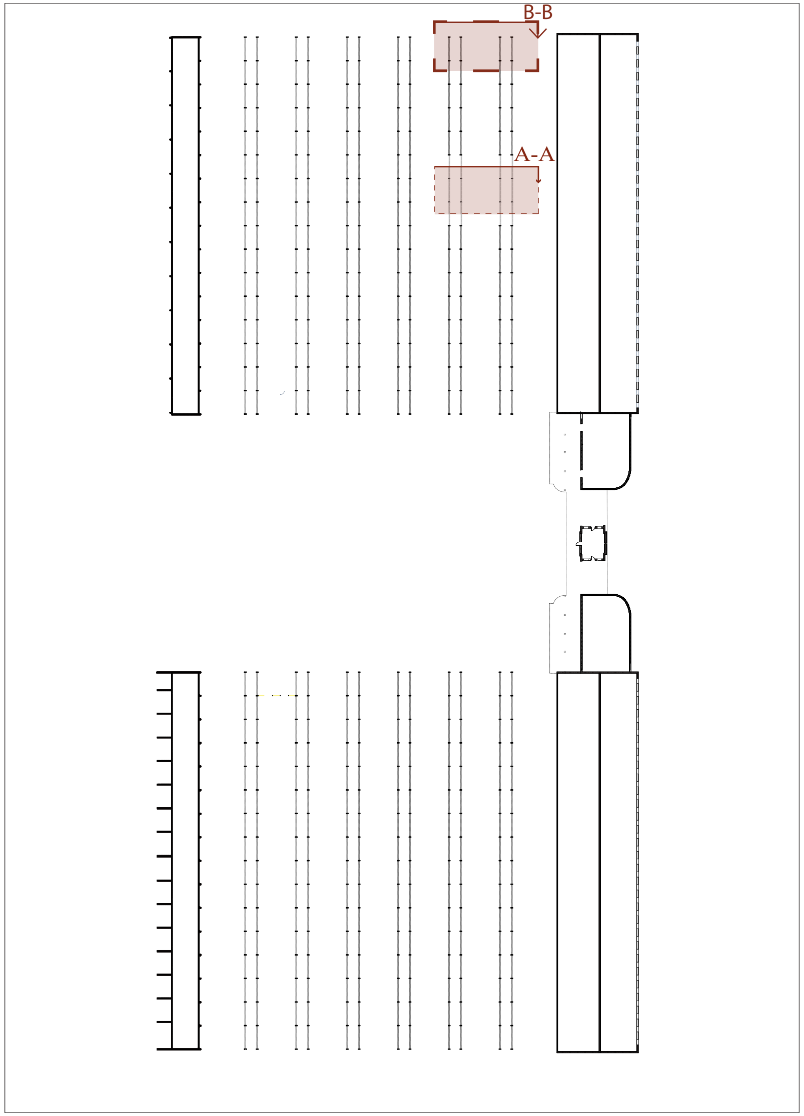
Technical drawings



Period one: Original design, 1933

Key section SC 1.300
Key plan SC 1:2000





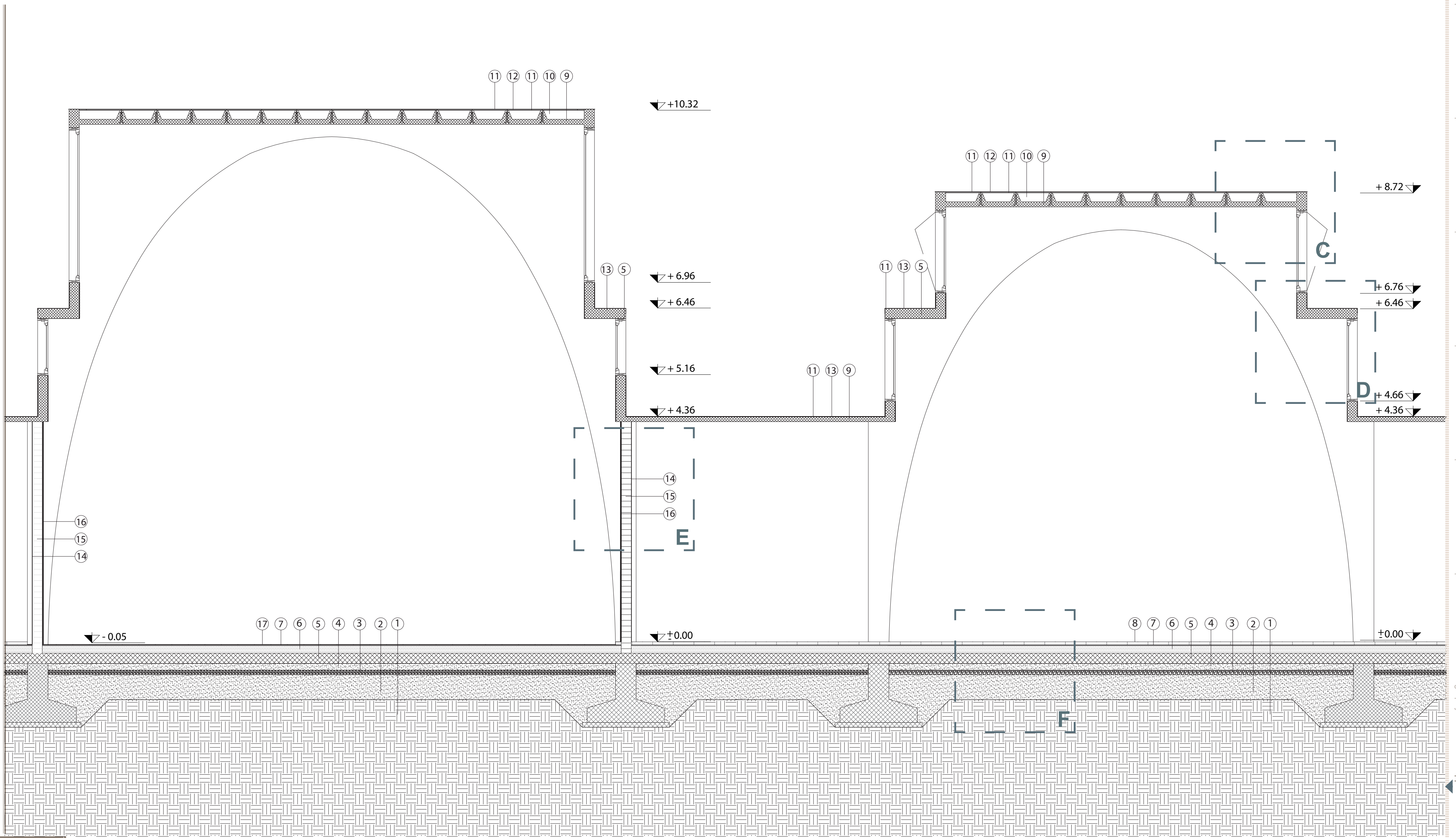
Legend

1: Natural Soil
2: Compact Soil
3: 90mm Gravel
4: 130mm Magrone
5: 200mm Concrete slab
6: 150mm Cemento
7: 10mm Thin-Set adhesive
8: 60mm Tile
9: 100mm Concrete slab
10: 170mm Cavity
11: 5mm single coat of Bitumen
12: 15mm Composite Roof Tiles (Synthetic)
13: 5mm Waterproofing membrane
14: 2mm Plaster
15: 195mm Masonry Brick
16: 18mm Plaster
17: 110mm Tile
18: 25mm Plaster
19: Reinforcement Detail

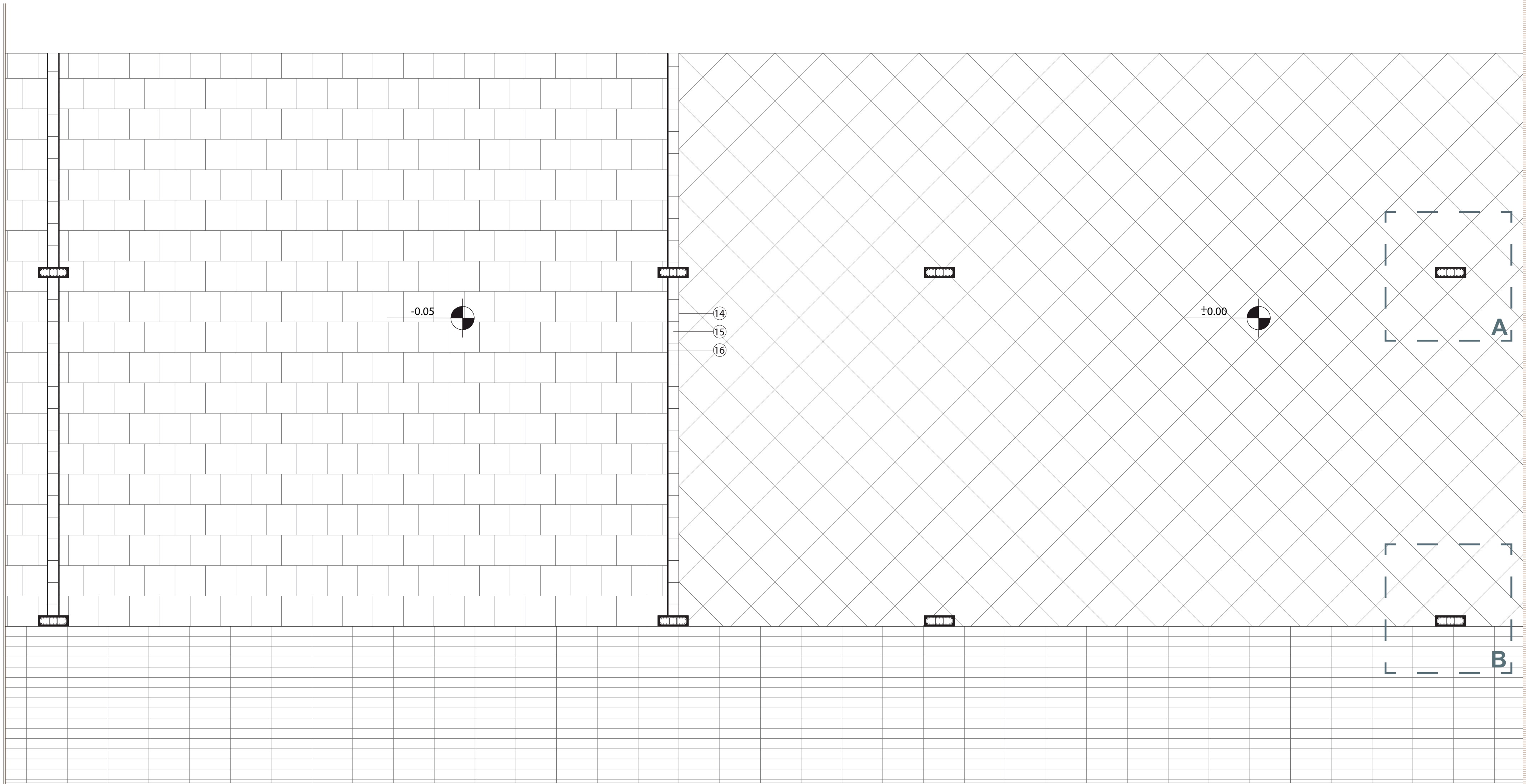
Structure projection

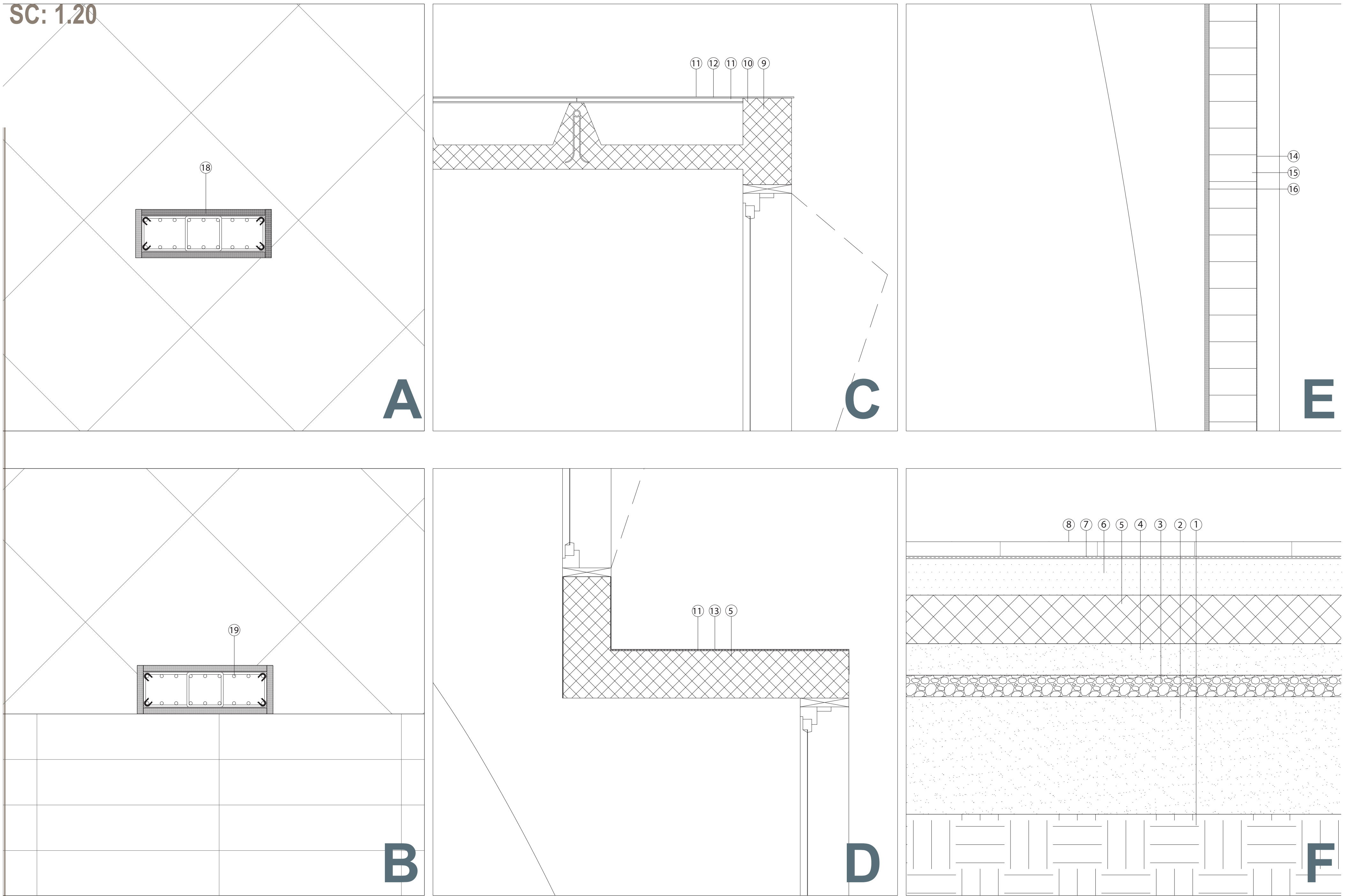
Roof Projection

Section A-A
SC: 1.100



Section B-B
SC: 1.100




SC: 1.20
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8 7 6 5 4 3 2 1
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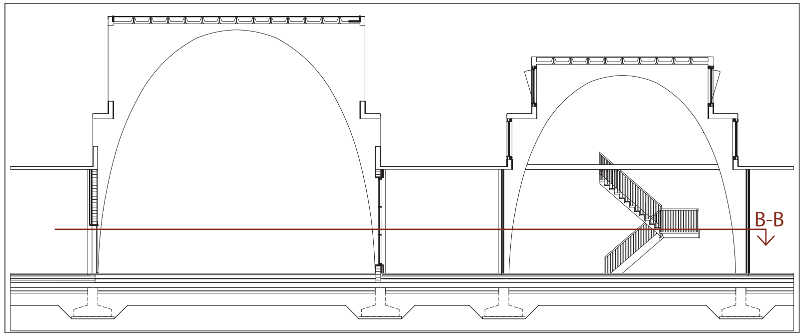
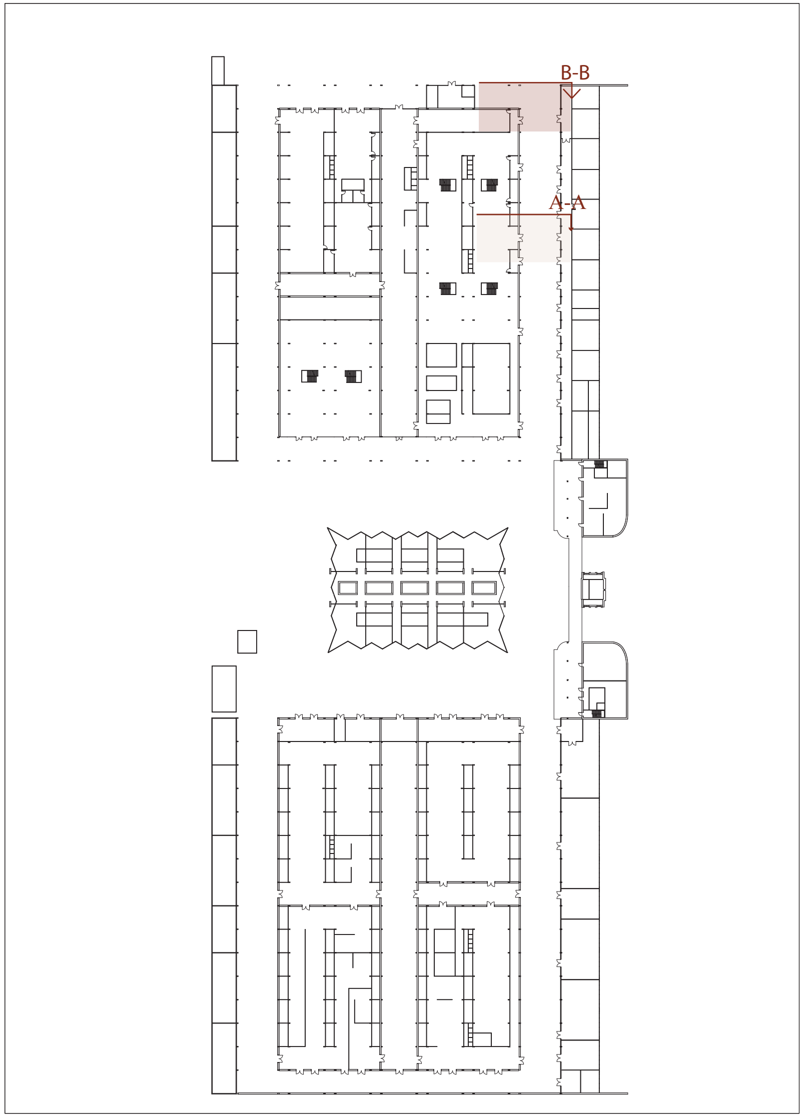
Period two: Winter Olympic, 2006

Key section SC 1.300
Key plan SC 1:2000





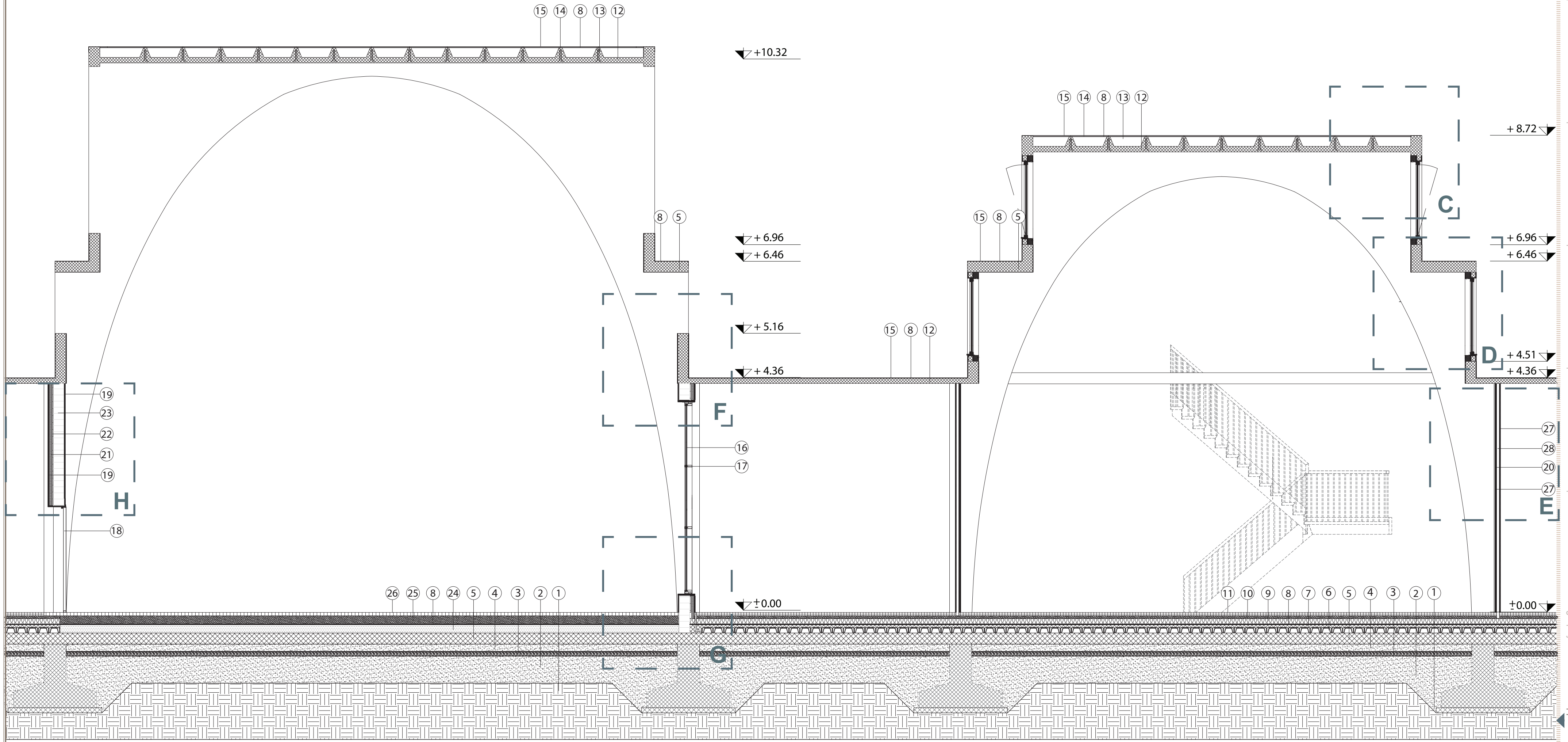
Legend

1: Natural Soil
2: Compact Soil
3: 90mm Gravel
4: 130mm Magrone
5: 200mm Concrete slab
6: 100mm IGLU'® FORMWORK
7: 50mm Concrete
8: 10mm Vapor barrier
9: 100mm thermal Insulation
10: 50mm Magrone
11: 60mm interior tile
12: 100mm Concrete slab
13: 170mm Cavity
14: 15mm Composite Roof Tiles
15: 0.6mm Aluminum Flashing
16: 4mm Insulated Glass Unit (IGU)
17: Aluminum mullion
18: Solid Wood Layer
19: 18mm Plaster
20: 15mm Gypsum board
21: 60mm Expanded Polystyrene
22: 20mm Air cavity
23: 112mm Masonry brick
24: 150mm Cemento
25: 150mm Magrone
26: 60mm Exterior tile
27: 15mm Plaster
28: 50mm Acoustic insulation
29: 25mm Plaster
30: Reinforcement Detail
31: Thermal bridge Insulation
32: Aluminum surface cover
33: Finishing plaster

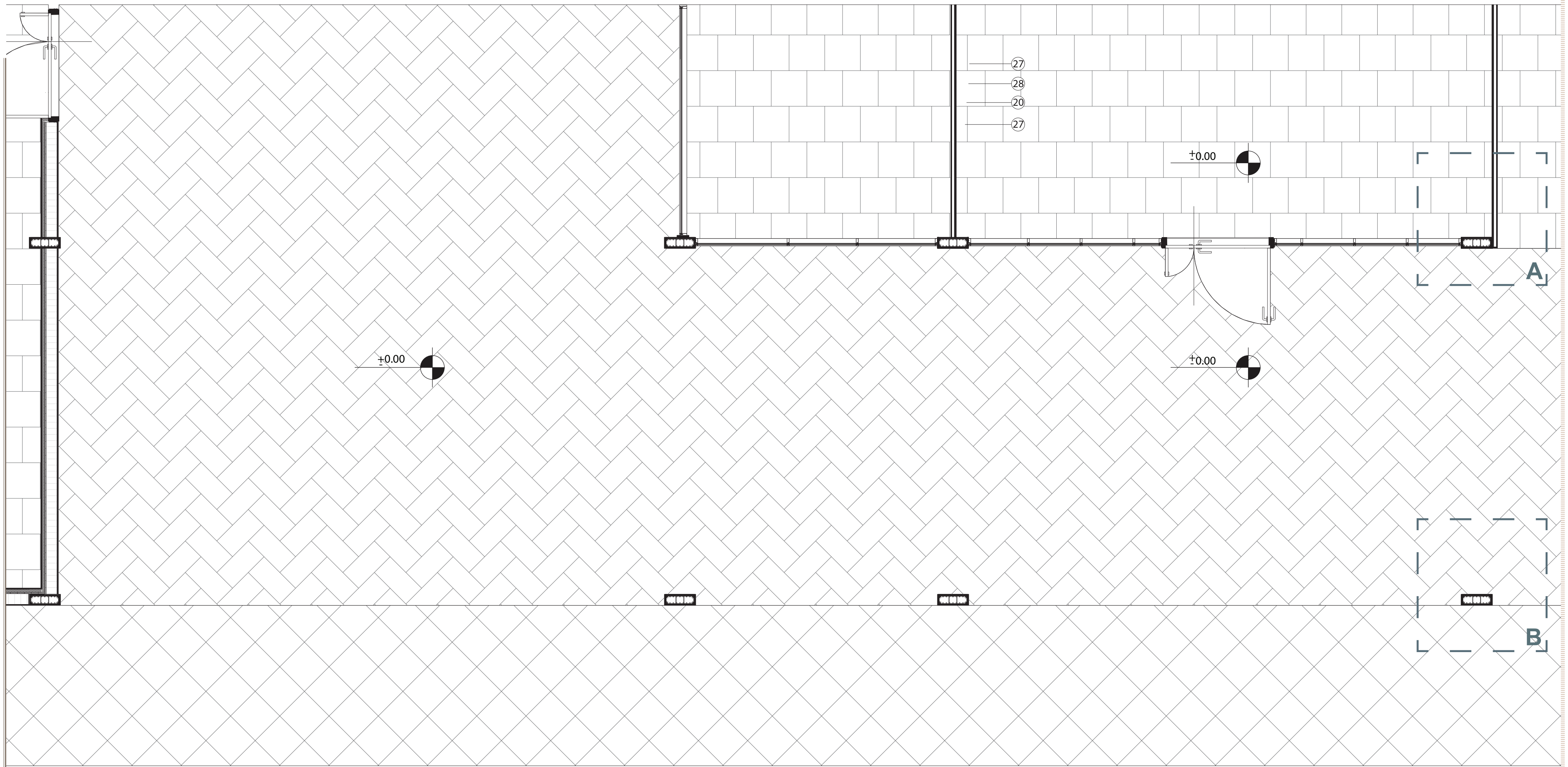
Structure projection

Roof Projection

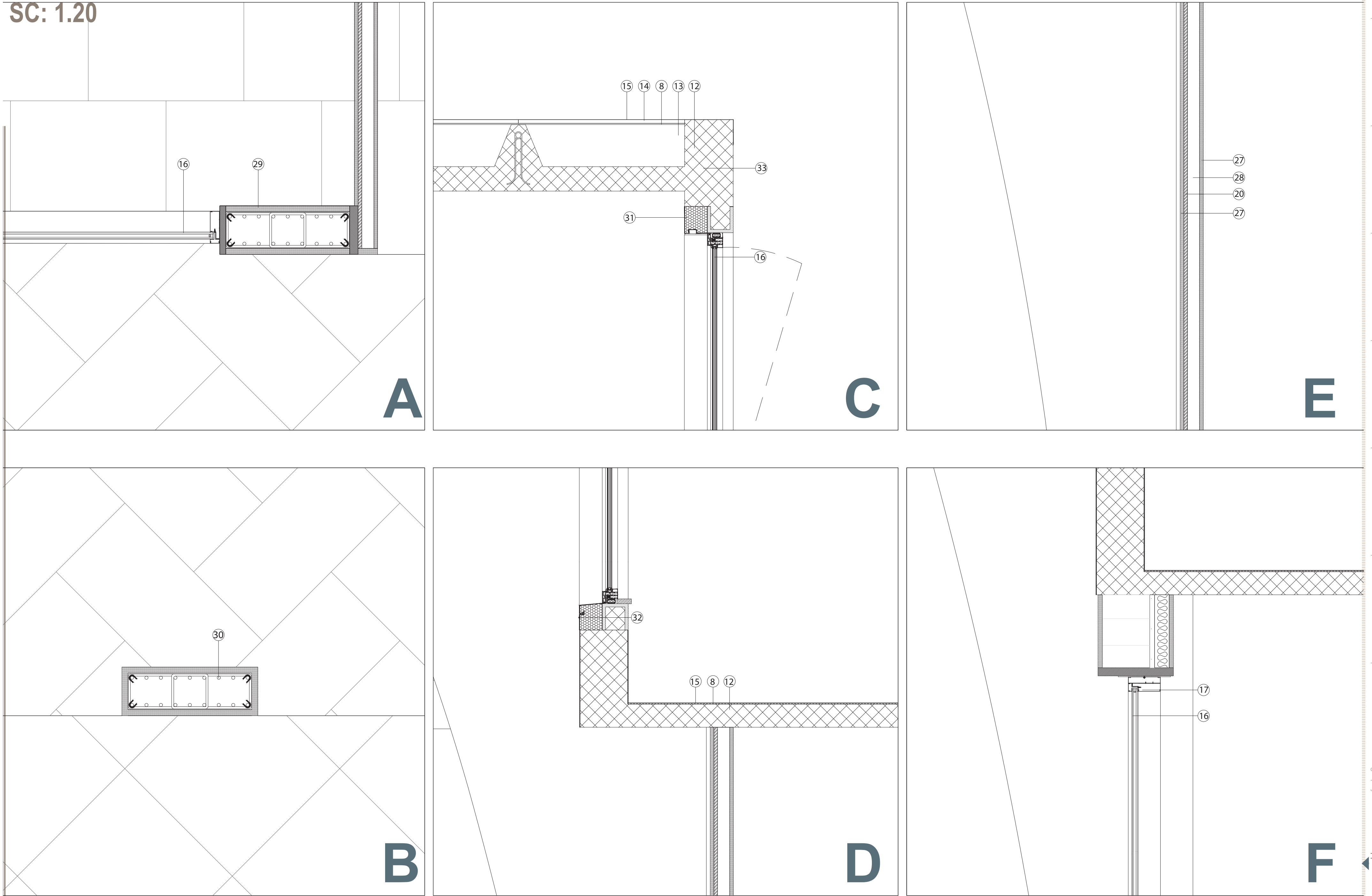
Section A-A
SC: 1.100



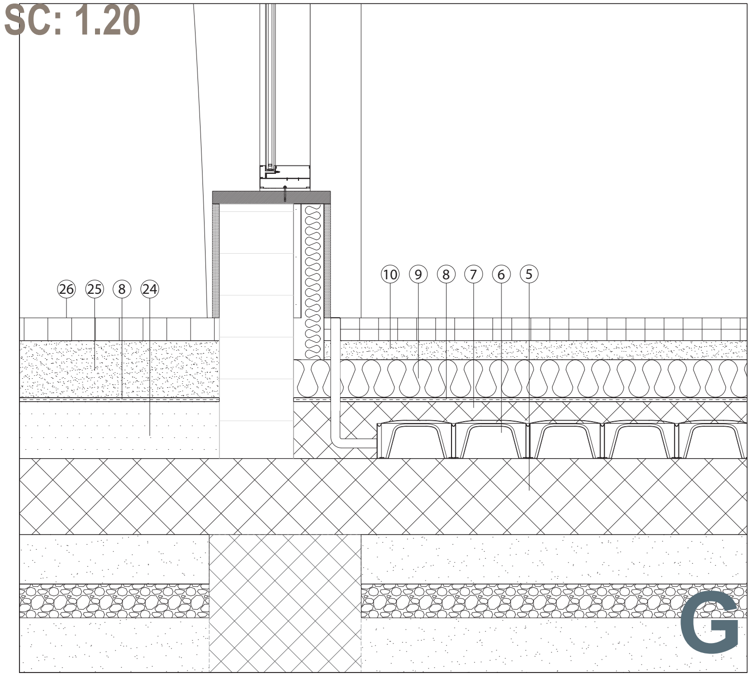
Section A-A
SC: 1.100

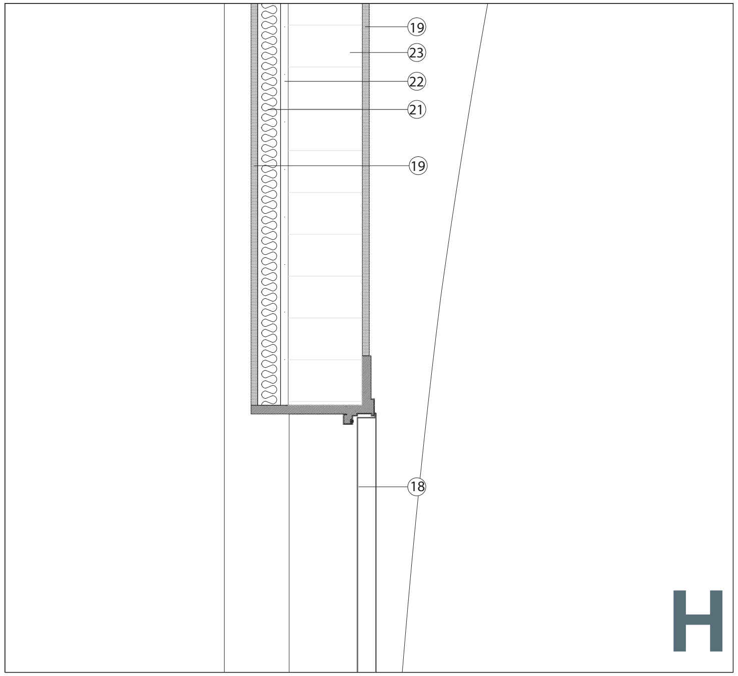


SC: 1.20



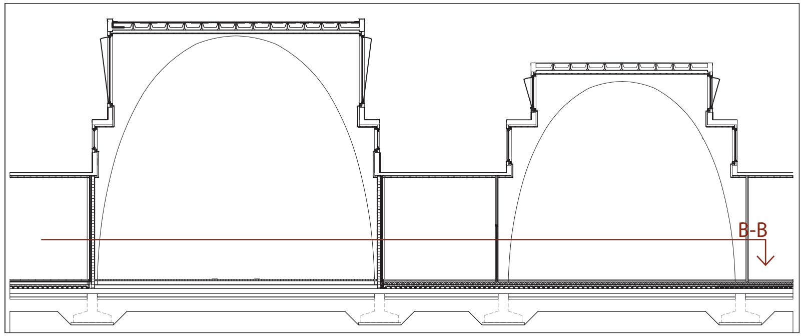
SC: 1.20

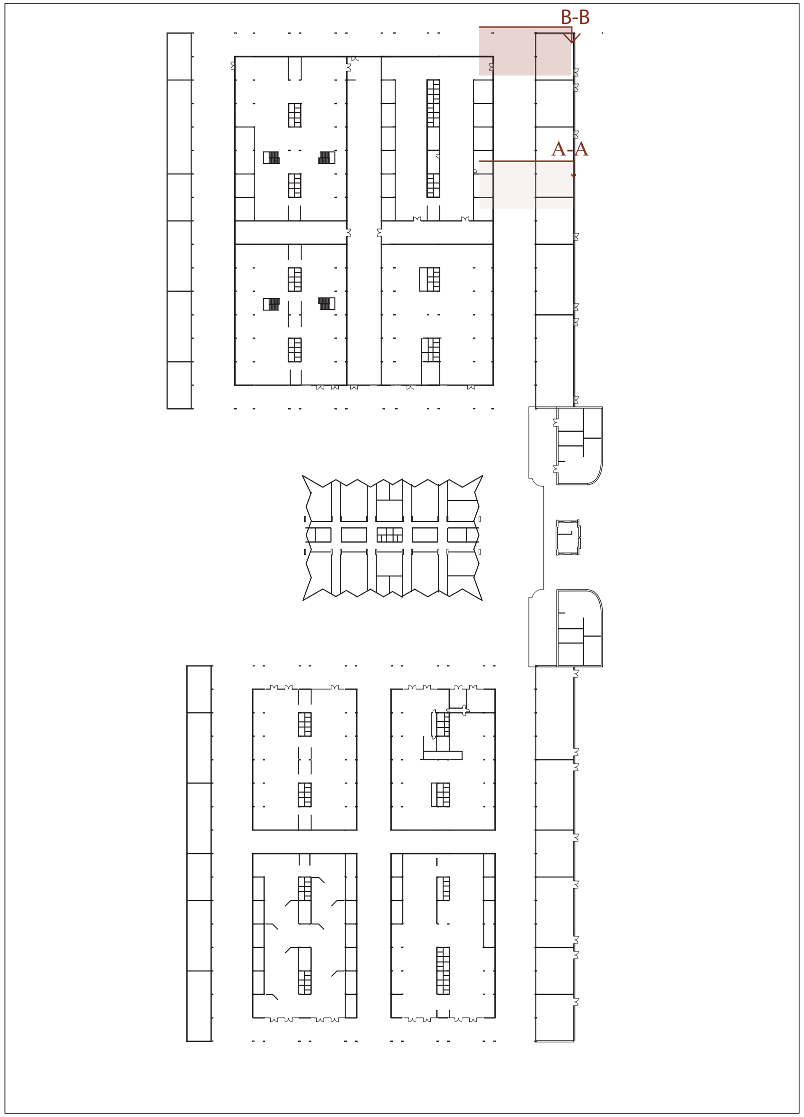




Period three: Design proposal, 2024

Key section SC 1.300
Key plan SC 1:2000



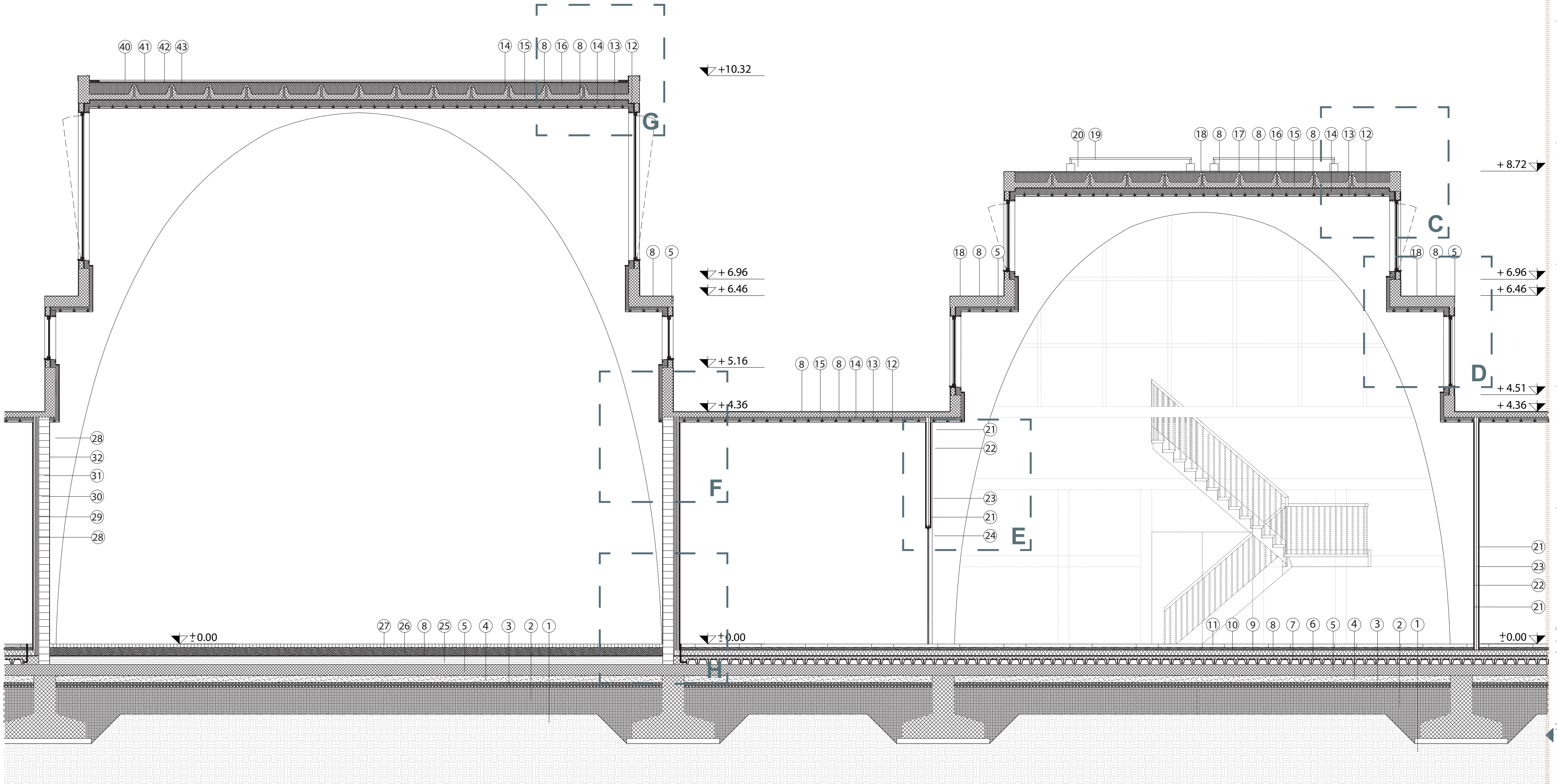


Legend

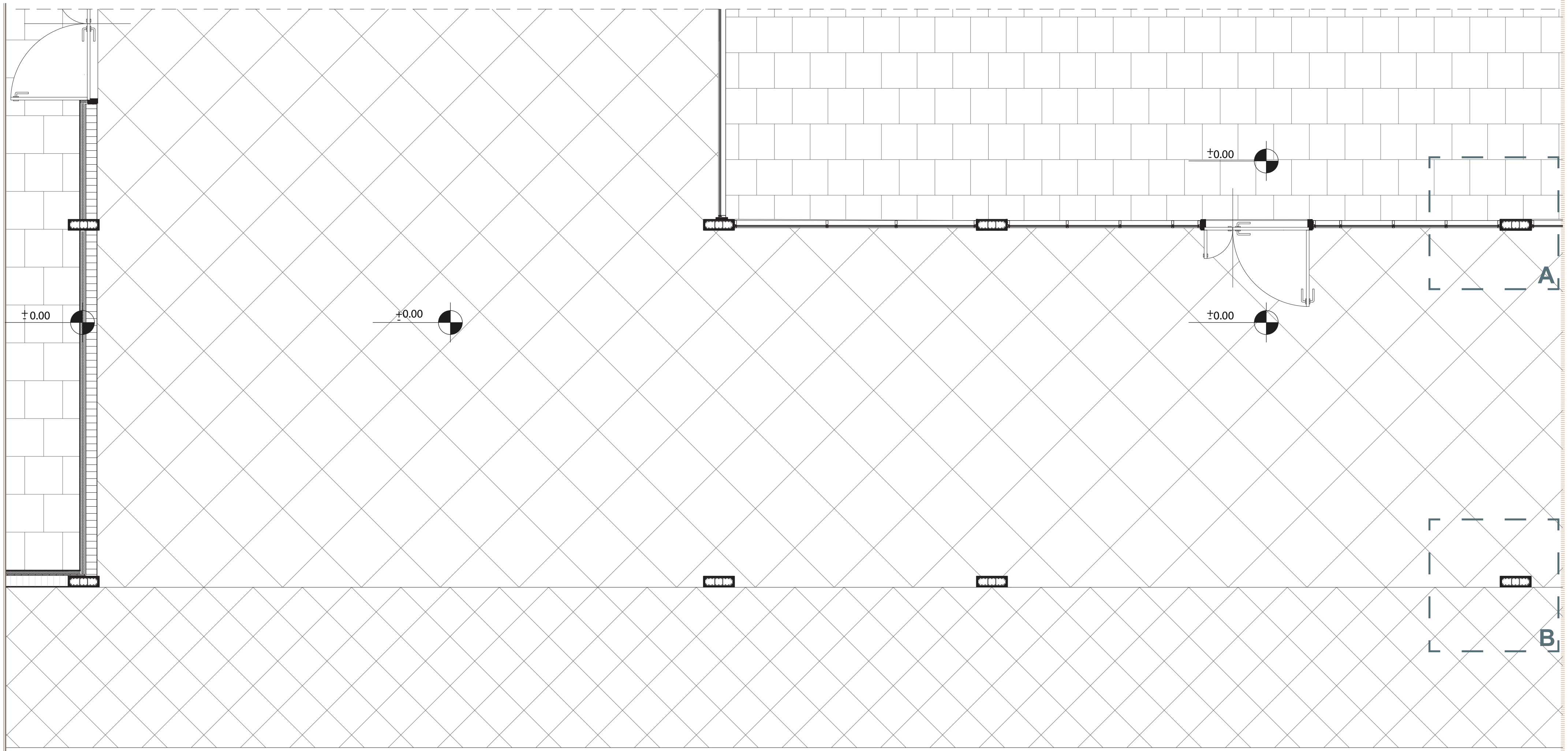
1: Natural Soil
2: Compact Soil
3: 90mm Gravel
4: 130mm Magrone
5: 200mm Concrete slab
6: 100mm IGLU'® FORMWORK
7: 50mm Concrete
8: 10mm Vapor barrier
9: 100mm thermal Insulation
10: 50mm Magrone
11: 60mm interior tile
12: 5mm Plaster
13: 25mm Strip
14: 118mm Expanded polystyrene, sintered Foam
15: 100mm Concrete slab
16:180mm Expanded polystyrene, sintered Foam
17: 15mm Composite Roof Tiles
18: 0.6mm Aluminum Flashing
19: PV panel
20: Concrete block
21: 1.3mm Acoustic drywall
22: 40mm Acoustic foam/ panel
23: 35mm Wall frame
24: Wooden frame
25: 150mm Cemento
26: 150mm Magrone
27: 60mm Exterior tile
28: 2mm plaster
29: 15mm Gypsum board
30: 80mm Expanded Polystyrene
31: 20mm Air Cavity
32: 195mm Masonry brick
33: 25mm Plaster
34: 25mm Closure Panel
35: 6 mm Acoustic Glass
36: Reinforcement Detail
37:Thermal bridge Insulation
38: Aluminum surface cover
39: Finishing plaster
40: 32mm substrate
41: 23mm Synthetic material sheets
42: Drainage White, Expanded polystyrene, sintered
43: 25mm Steam Barrier,Bitumen

Structure projection
Roof Projection

Section A-A
SC: 1.100



Section A-A
SC: 1.100



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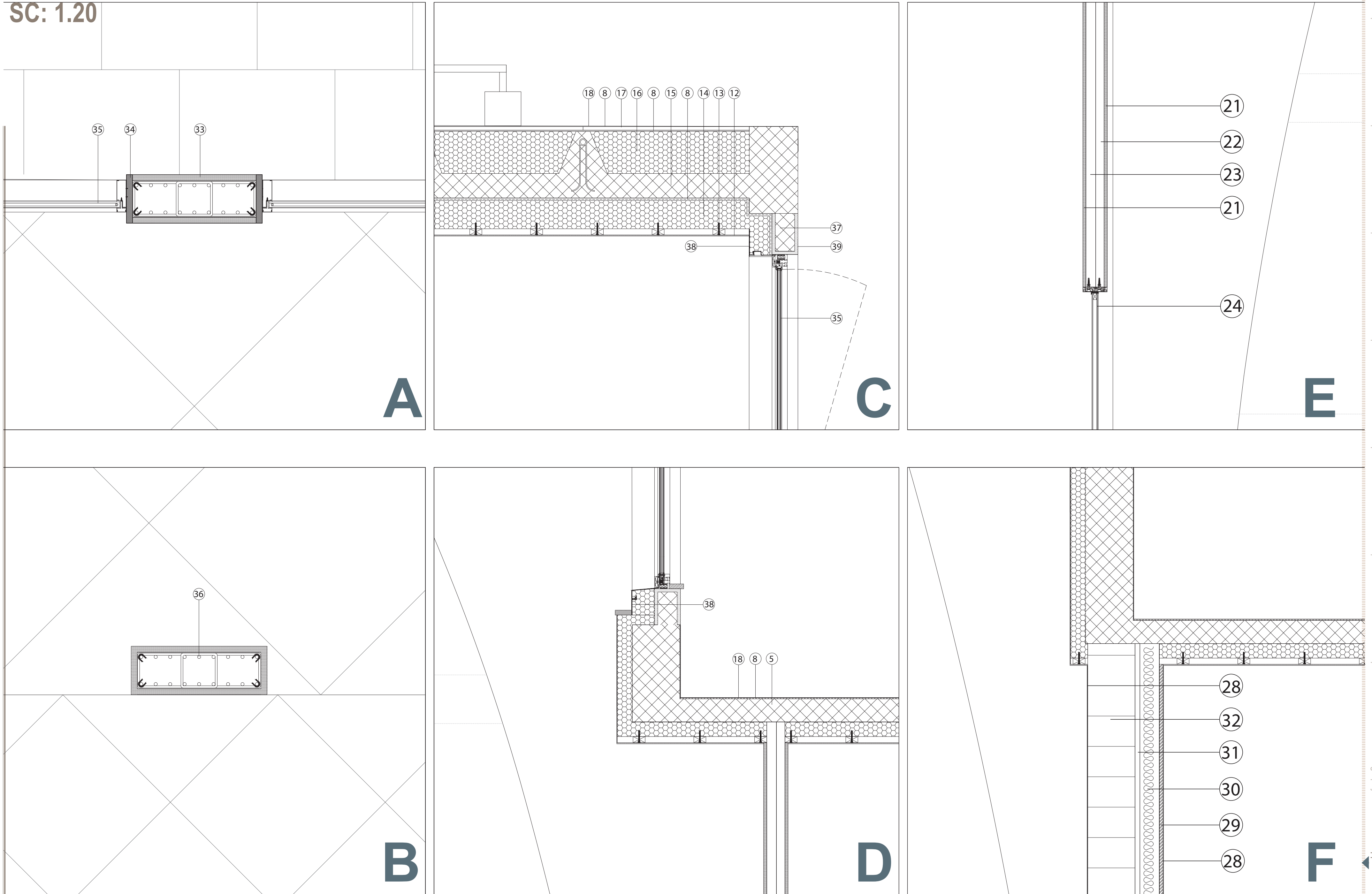

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SC: 1.20