POLITECNICO DI MILANO

Corso di Laurea Magistrale in Building and Architectural Engineering

MASTER GRADUATION THESIS

BEIRUT'S PORT: ANALYSIS OF PORT LOGISTICS, MODULAR CONSTRUCTION, ENERGY EFFICIENCY AND STRUCTURAL & ARCHITECTURAL INTEGRITY

Supervisor: Professor Gabriele Masera

Lorenzo Bavelloni

Margrét Halla Valdimarsdóttir

Academic Year: 2022/2023

MASTER'S THESIS

Master's thesis for Building and Architectural Engineering

Politecnico di Milano

Polo territoriale di Lecco

Authors:
Lorenzo Bavelloni
Margrét Halla Valdimarsdóttir

Supervisor:
Gabriele Masera

POLITECNICO
MILANO 1863

ACKNOWLEDGEMENT

We express our heartfelt gratitude and appreciation for all we have learned throughout our studies at PoliMi, without all of which we could never have undertaken a project such as this. We want to further extend our sincerest thanks to our supervisor, Professor Gabriele Masera, whose valuable feedback and suggestions have been instrumental in refining all aspects of our design. We'd also like to extend our gratitude to Rachid Khalil an architect from Beirut who gave us a deeper understanding of the subject area and advised us in what elements to prioritize within the master plan.

We would like to extend our sincere thanks to Michalis Hadjistyllis, Senior Associate at OMA. Mr. Hadjistyllis, your expertise in urban planning and architectural design has been invaluable to our thesis. We are grateful for the opportunity to have benefitted from your knowledge and guidance throughout this journey.

Furthermore, we would like to thank Nuno Carvalho, Manager at Tesla. Mr. Carvalho, your emphasis on the importance of BIM management helped us understand the significance of integrating these disciplines into architectural design and greatly benefited us during the structural design.

In conclusion, we are immensely grateful for the opportunity to have collaborated with such distinguished individuals throughout our thesis journey. Their collective wisdom, expertise, and inspiration have contributed significantly to the quality and depth of our research. We are confident that the knowledge and skills we have gained through this process will serve us well in our future endeavours of innovation in the built environment.

ABSTRACT ENGLISH

In this master thesis we designed a new master plan in the downtown harbour area of Beirut, the capital of Lebanon before fully designing a building located within said master plan.

The thesis consists of 6 chapters. The first is a concise analysis of Beirut and its history, with a special focus on the port neighbourhood which constitutes our design area. In order for our design to fit into its environment it was necessary to understand the climate, cultural-, and architectural history of the area. In this chapter we also perform a SWOT analysis which deepened our understanding of the area and guided us in the design of the master plan.

The second chapter presents our master plan. First, we introduce the concepts we followed throughout the design of this extensive master plan, then we gradually explain each step of our decision making. The aim of the design was raising land value and strengthening public spaces and the waterfront connection as well as implementing innovative programs to protect and enhance the natural environment and present a strong foundation for battling the environmental challenges of the foreseeable future.

The third chapter is dedicated to the architectural design of the building we chose to fully develop within the master plan. We explain our choice of location and which building we decided to develop further and show the references and inspirations we built upon while designing it.

The fourth chapter focuses on the engineering, how we analysed and optimized the energy performance across a multitude of standardized metrics. And how we brought that together with our ideas for the building's design, with respect to the façade, lighting considerations and more.

In the fifth chapter we detail the construction plans of the building, the panelization and the details. The sixth and final chapter is then dedicated to the structural analysis of our building

ABSTRACT ITALIAN

In questa tesi di laurea abbiamo progettato un nuovo piano generale nell'area portuale del centro di Beirut, la capitale del Libano, prima di progettare completamente un edificio situato all'interno di detto piano generale.

La tesi si compone di 6 capitoli. La prima è una sintetica analisi di Beirut e della sua storia, con un focus particolare sul quartiere portuale che costituisce la nostra area progettuale. Affinché il nostro progetto si adattasse al suo ambiente, era necessario comprendere il clima, la storia culturale e architettonica dell'area. In questo capitolo eseguiamo anche un'analisi SWOT che ha approfondito la nostra comprensione dell'area e ci ha guidato nella progettazione del piano generale.

Il secondo capitolo presenta il nostro piano generale. In primo luogo, introduciamo i concetti che abbiamo seguito durante la progettazione di questo ampio piano generale, quindi spieghiamo gradualmente ogni fase del nostro processo decisionale. Lo scopo del progetto era aumentare il valore del terreno e rafforzare gli spazi pubblici e il collegamento con il lungomare, nonché implementare programmi innovativi per proteggere e migliorare l'ambiente naturale e presentare una solida base per combattere le sfide ambientali del prossimo futuro.

Il terzo capitolo è dedicato al progetto architettonico dell'edificio che abbiamo scelto di sviluppare integralmente all'interno del masterplan. Spieghiamo la nostra scelta del luogo e quale edificio abbiamo deciso di sviluppare ulteriormente e mostriamo i riferimenti e le ispirazioni su cui ci siamo basati durante la progettazione.

Il quarto capitolo si concentra sull'ingegneria, su come abbiamo analizzato e ottimizzato le prestazioni energetiche attraverso una moltitudine di metriche standardizzate. E come l'abbiamo unito alle nostre idee per il design dell'edificio, per quanto riguarda la facciata, le considerazioni sull'illuminazione e altro ancora.

Nel quinto capitolo dettagliamo i piani costruttivi dell'edificio, la pannellatura ei dettagli di costruzioni. Il sesto ed ultimo capitolo è poi dedicato all'analisi strutturale del nostro edificio.

TABLE OF CONTENTS

ANALYSIS + MASTERPLAN

ARCHITECTURE

TABLE OF CONTENTS

DAYLIGHT & ENERGY

BUILDING TECHNOLOGIES & STRUCTURES

ANALYSIS

INTRODUCTION

Architectural competition

Our project stems from our participation in the "Beirut port competition" hosted by Inspireli. Students were invited to rethink the future port of Beirut that stands to be rebuilt after a devastating explosion in the year 2020 which caused immense destruction and over 200 fatalities.

Location

The project is located in the downtown harbour area of Beirut, the capital of Lebanon. Beirut is often recognized for its harbour which has been seen as a focal point in the Middle East that connected the region to each neighbouring continents. However, the city has now been left without a functioning port, thus unable to fulfil its former role in the economy.

Projects requirements

Participants of the competition were challenged to not only think of the new area as a visually pleasing piece of architectural artwork but to design with the context of the lost infrastructure in mind. It was very important that the new development utilize the valuable land for the benefit of the economy and commerce by restoring storage areas while also taking into account other functions of an efficient, sustainable port. In addition to functional requirements the orchestrators also requested that various social aspects be considered.

Being the site for a catastrophe, a memorial was strongly encouraged. The port had also been disconnected from the city in the past, so creating greater synergy with its surrounding by incentivizing pedestrian traffic and including cultural, leisure and commercial functions in the design was also requested. [1]

Short history of Beirut

Before embarking on a design project of this scale one must familiarize oneself with the location's history. Beirut is a complicated city with a tumultuous history. It has been occupied by Phoenicians, Greeks, Romans, Byzantines, Arabs, Medieval crusaders, Ottoman and French. All these settlers have left their mark on the city, with many iterations of destruction and reconstruction the city's urban matrix has become an amalgamation of the styles of its former inhabitants. [2]

References

[1] https://www.inspireli.com/en/awards/beirut-documents.
[2] https://www.area-arch.it/en/beirut-city-of-clusters-planned-city-and-urban-chaos/

Figure 1: Beirut's Port

INTRODUCTION

Building development

Transitioning to a smaller scale, Beirut had no official building code before the 1940s. Largely, the neighbourhoods received their character from individual buildings, many of which were built by the skilled masons of the Ottoman or were constructions of the Mandate period set forth by the League of Nations after the first World War. Dwellings were intermixed with commercial functions and large entryways & open staircases functioned as natural expansions of the public streets. This status quo prevailed until the real-estate bubble, which is widely regarded as having started in 2005 and which saw the collapse of Lebanon's economy. The end the housing boom resulted in a litter of unfinished, half-empty projects throughout the city. [1]

Our project goals

We participated with the goal of fulfilling the requirements outlined above by making our design with sustainability and multiplicity of functions at the forefront. We placed an emphasis on connecting the harbour to other parts of the city, allowing the public to enjoy various activities along the waterfront. Alongside this effort we decided to increase green areas, following guidance laid out by common practices of UGBI (Urban Green Blue Infrastructure). By analysing UGBI at multiple scales we ensure a connection to nature at the smaller scale while also promoting safety, accessibility, physical-, and emotional comfort in a manner that is sustainable and easily maintainable. A closely related goal was to reduce the need for private transportation while maintaining the infrastructure necessary for the port. As part of making the area more inviting for the pedestrian, we took great care to reintroduce the human scale by keeping buildings on the waterfront low-rise and inviting. We concurred with the competition description that a memorial would be important to preserve the sites history, so we highlight it as an important node of our walkway network. Throughout these modifications to the previous schema, we utilize technological advances in an effort to reduce the area necessary to reinstate the port's functions.

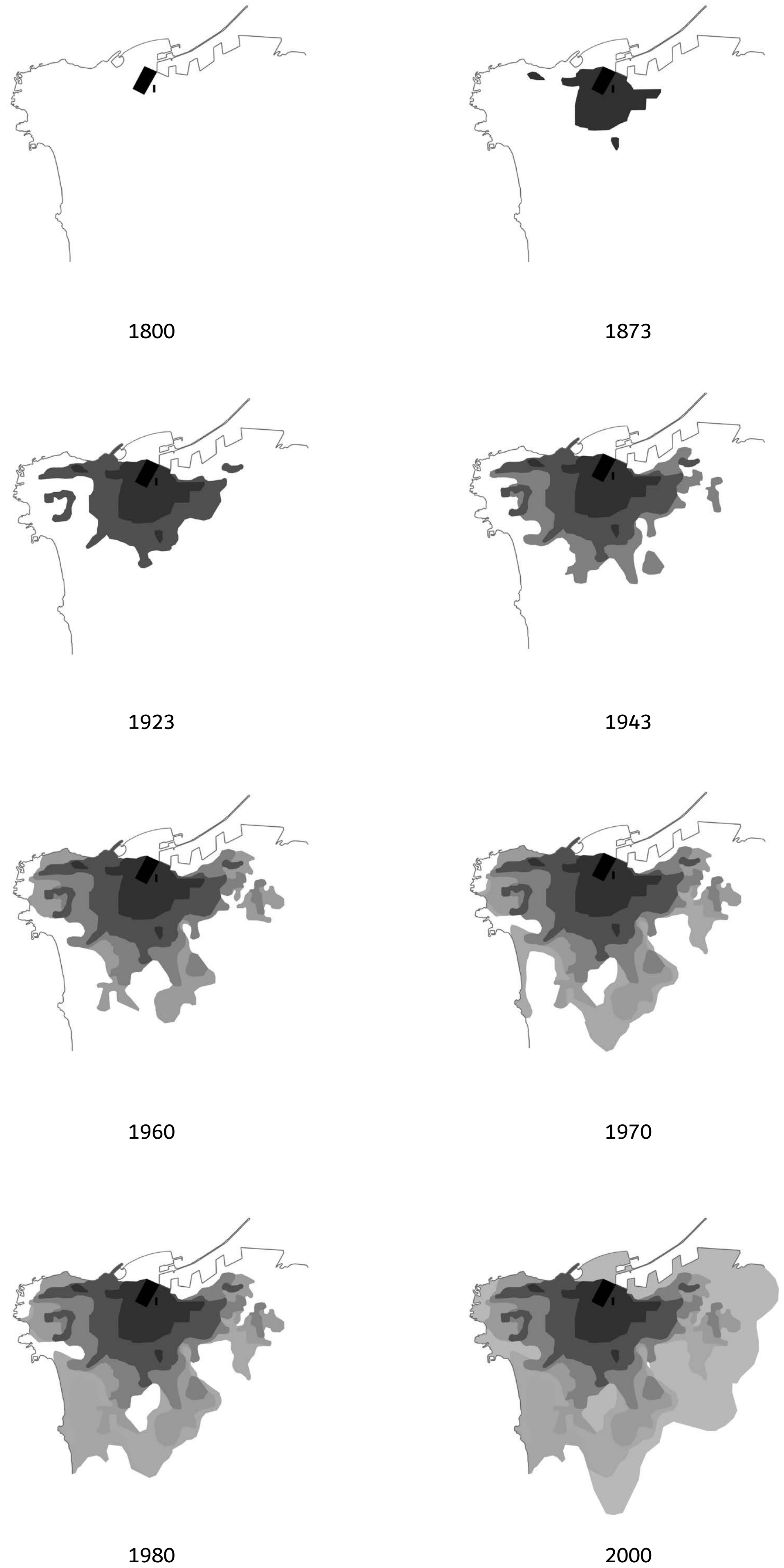
Beirut's port

Serving a crucial part of the economics of the city, the country even, and thus our master plan is the port. As mentioned above, the port has long served as a central element in the nation's trade industries and naval activity. It had stood in it's pre-explosion state since the 1880s, when the Ottoman empire allowed a proprietary company to fortify its grounds there. So, out-of-date at best. It lies at 35 57' E and 35 15' N, right at the junction of Europe, Asia, and Africa, an obviously important trade route. As such it has always functioned as a commercial hotspot, and since the 70's has provided a crucial transport layer to the surrounding countries in the middle east. [2] [3]

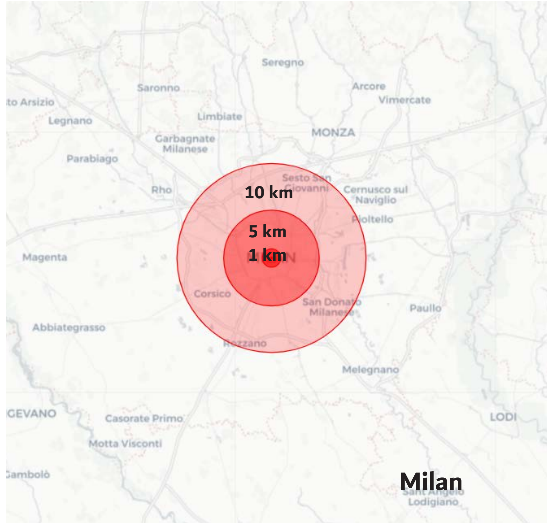
References:

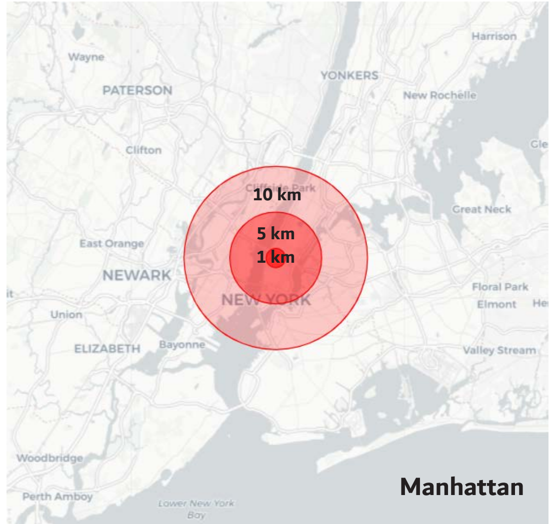
[1] https://beirutshiftinggrounds.com/Architecture
[2] http://www.worldportsource.com/ports/review/LBN_Port_of_Beirut_26.php
[3] http://www.portdebeyrouth.com/index.php/en/

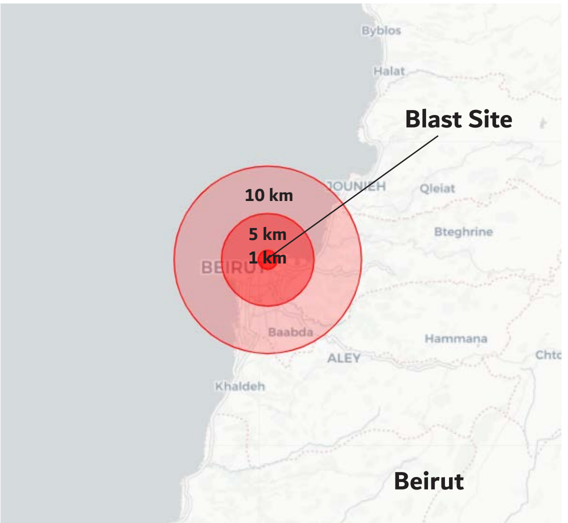
BEIRUT'S GROWTH - FROM 1800-2000



EXPLOSION





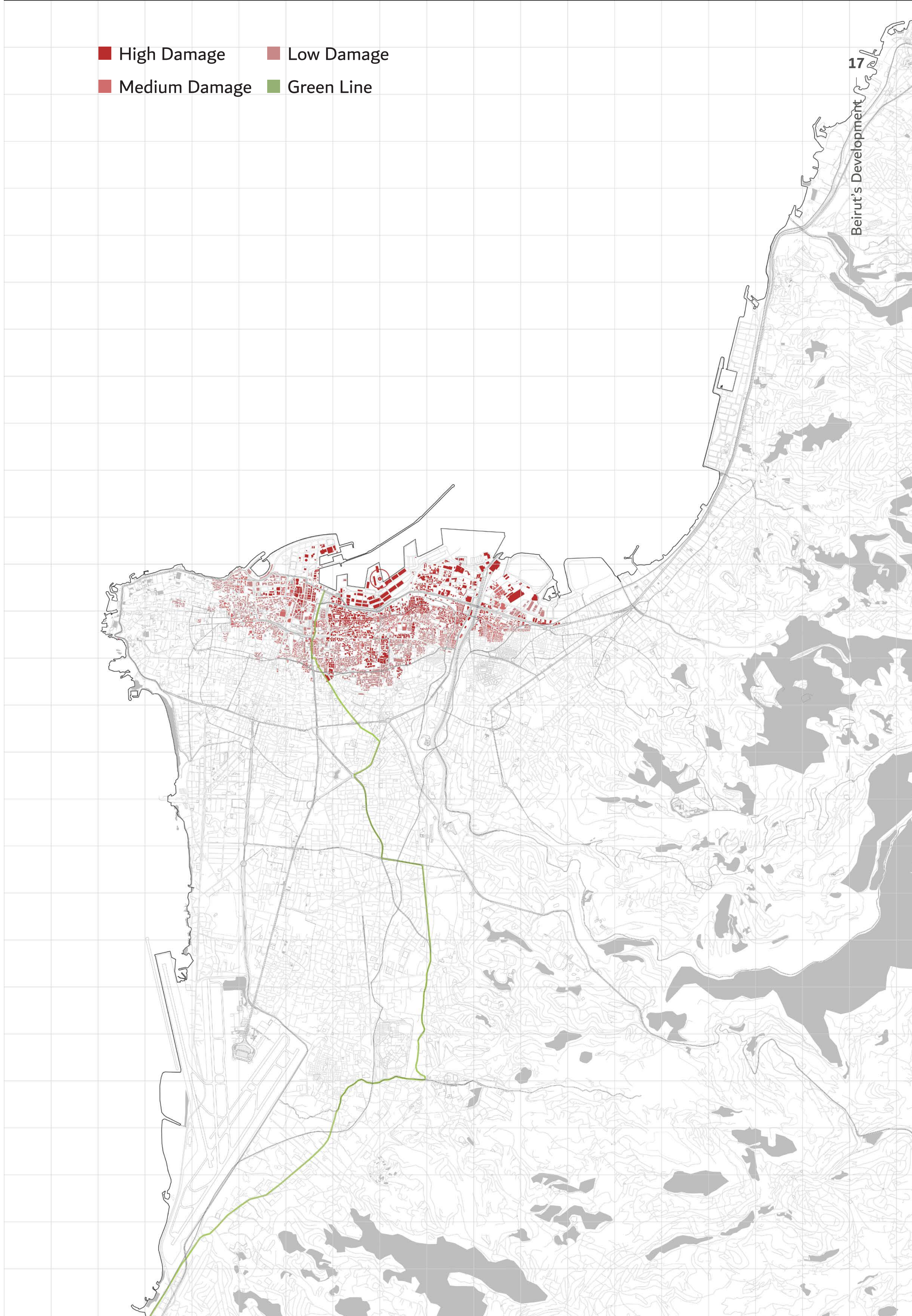


The explosion in 2020 is believed to have been caused by the ignition of 2,750 tons of ammonium nitrate, which had been stored in a warehouse at the city's port for years. [1] It caused severe damage to the surrounding area and was felt as far as 240 km away in Cyprus and measured as a 4.5 magnitude earthquake on the Richter scale by researchers in Jordan. [2]

On the left you can see a size comparison between Beirut, Milano and Manhattan, damaged houses were reported within the 10 km radius. [3]

References:

[1] https://www.wionews.com/world/social-media-users-inlay-beirut-blast-radius-over-their-cities-to-contextualise-the-disaster-319023
[2] https://www.jordantimes.com/news/local/beirut-blast-similar-quake-45-magnitude-%E2%80%94-jso
[3] https://edition.cnn.com/2020/08/04/middleeast/beirut-explosion-port-intl/index.html



WEATHER ANALYSIS

Average high and low temperature in Beirut

"The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures." [1]

Humidity comfort levels in Beirut

"The percentage of time spent at various humidity comfort levels, categorized by dew point." [1]

Average monthly rainfall in Beirut

"The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average snowfall." [1]

Daily chance of precipitation in beirut

"The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day)." [1]

Wind direction in Beirut

"The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 1.0 mph. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest)."[1]

Average wind speed in Beirut

"The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands." [1]

Hours of daylight and twilight in Beirut

"The number of hours during which the Sun is visible (black line). From bottom (most yellow) to top (most gray), the color bands indicate: full daylight, twilight (civil, nautical, and astronomical), and full night." [1]

Cloud cover categories in Beirut

"The percentage of time spent in-each cloud cover band, categorized by the percentage of the sky covered by clouds." [1]

References:

[1] https://weatherspark.com/y/99217/Average-Weather-in-Beirut-Lebanon-Year-Round

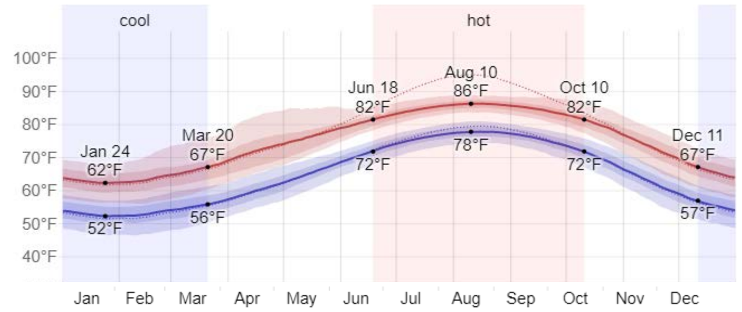


Figure 2: Average High and Low Temperature in Beirut

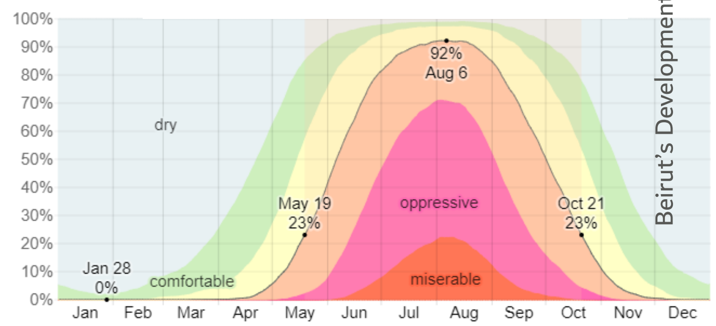


Figure 3: Humidity Comfort Levels in Beirut

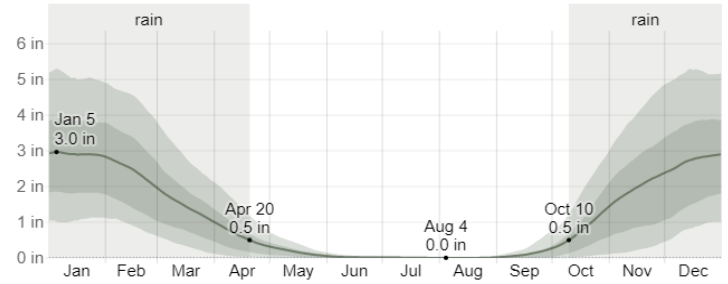


Figure 4: Average Monthly Rainfall in Beirut

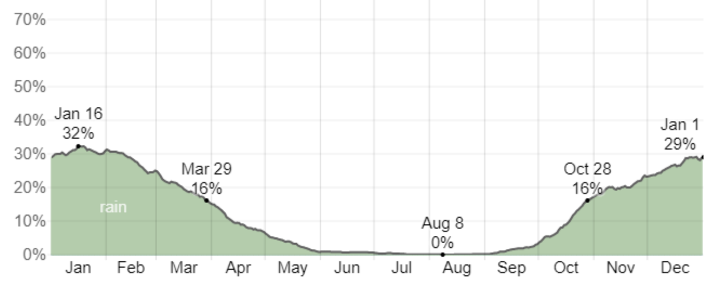


Figure 5: Daily Chance of Precipitation in Beirut

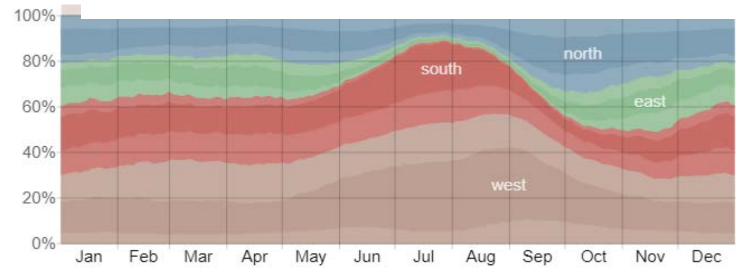


Figure 6: Wind Direction in Beirut

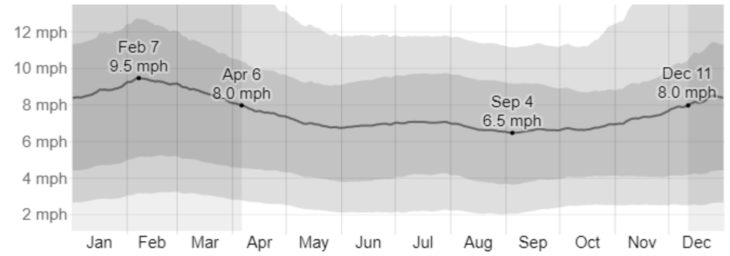


Figure 7: Average Wind Speed in Beirut

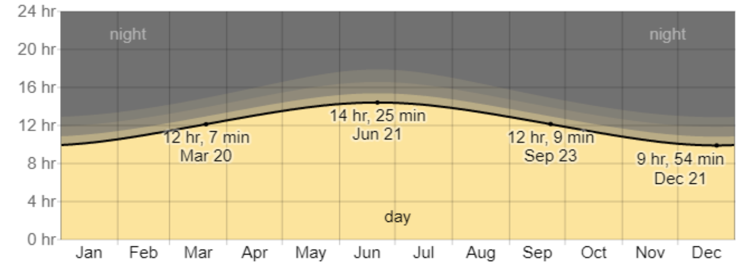


Figure 8: Hours of Daylight and Twilight in Beirut

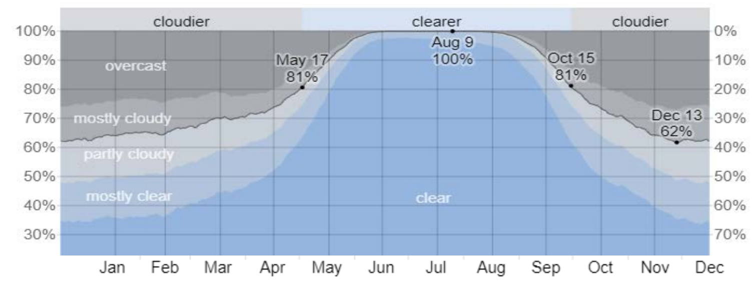


Figure 9: Cloud Cover Categories in Beirut

SWOT ANALYSIS

STRENGTH:

High connectivity to sea Port
High connectivity to the old city center
Sea barrier against flooding
Yacht club + port
Highway

High proximity of public functions:
-Gym
-Governmental office
-Mosque
-Theater
-Mall
-Roman ruins
-Historical plaza
-Hospital

OPPORTUNITIES:

Reimagining of the sea port
Highway redevelopment
Remodelling of open air and underground parking
Utilization of newly refurbished roads within the masterplan boundaries
New waterfront activities

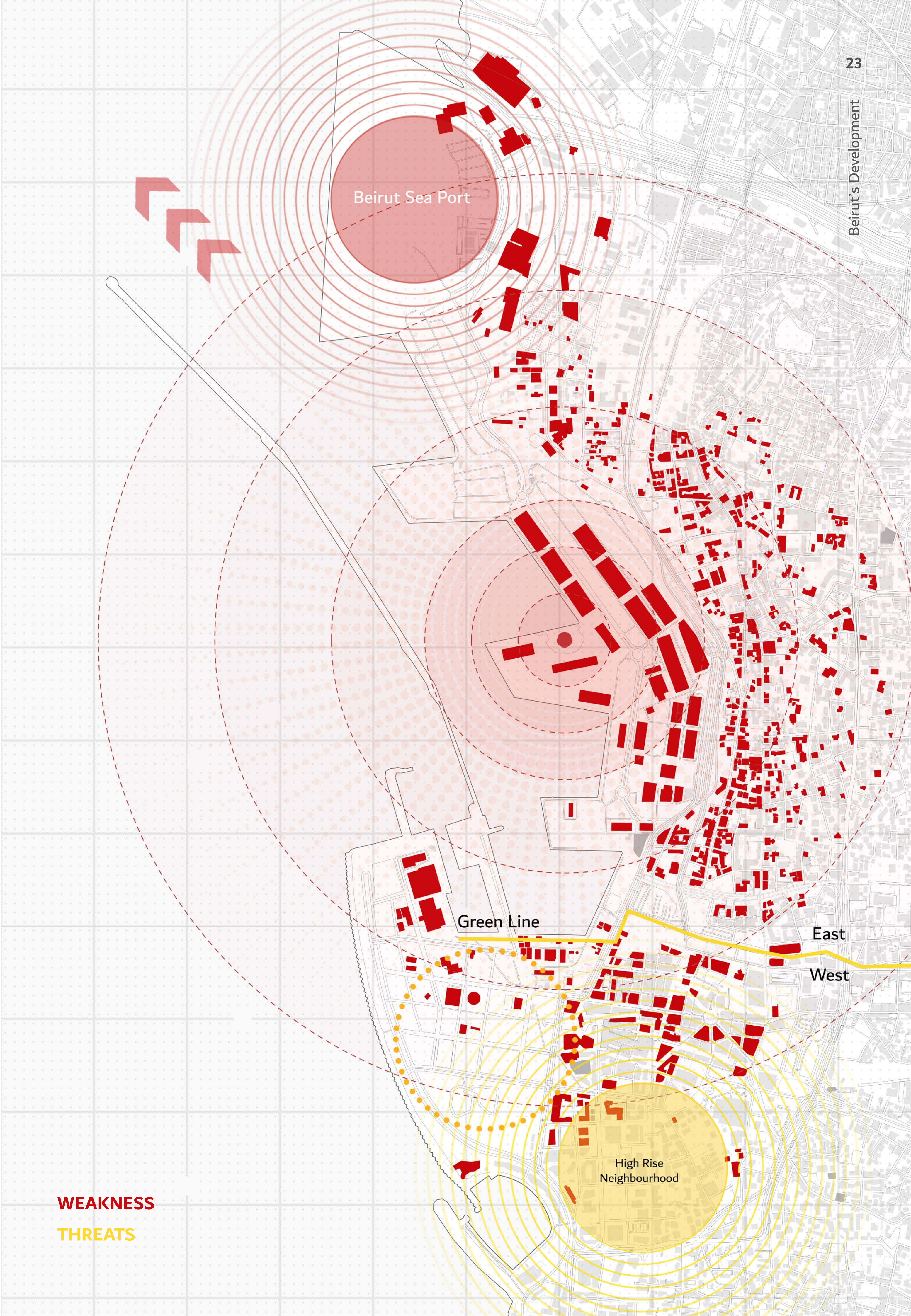
SWOT ANALYSIS

WEAKNESS:

Recent explosion
Lack of green spaces
Insufficient water and electricity infrastructure
Port's absence from the economy
Low connectivity between functions
Debilitating level of building damage

THREATS:

Exacerbated division accross the Green line, between East and West
Social-cultural disparities
Rapid urbanization
High-rise neighbourhood gentrification
Rising sea level
Taxing energy demands



GOALS

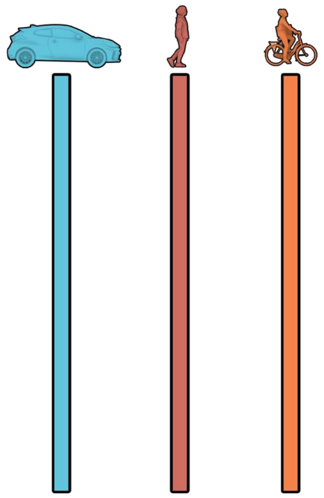
GOALS	STRATEGIES
1. Reclaim the port as a civic space	**1.1** Preserve the identity of the port area **1.2** Design public spaces and introduce new activities that attract the public **1.3** Activate the waterfront
2. Provide safe and attractive spaces for the port	**2.1** Increase pedestrian and cycling paths **2.2** Promote public transportation **2.3** Limit vehicle access to improve pedestrian safety **2.4** Improve street lighting by using LED lights **2.5** Insert attractive urban furnitures
3. Insert green areas to improve public space quality	**3.1** Implement continuous water-front connection with permeable pavement and green spaces **3.2** Design green buffer zones to reduce the noise from the highway **3.3** Introduce green roofs

ACTIONS

- Create new activites that attracts both local citizens and international tourists
- Invite tourism with the introduction of a new cruise terminal
- Divide the port into different zones, zones related to the public needs and zones related to the container terminal
- Make sure that the container terminal works efficiently with new smart technology
- Design new green and recreational spaces which are easily accessible
- Improve the connection to the waterfront
- Dedicate the area where the silos were located to a new historical center
- Design wide pedestrian and bicycle paths with great connection to greenery
- Activate the ground floors of buildings in the master plan in order to provide more interesting street connections

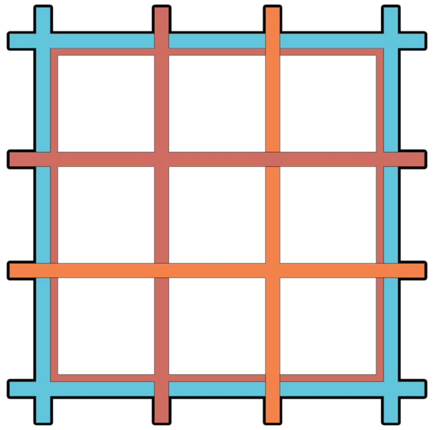
MASTERPLAN

GENERAL CONCEPT



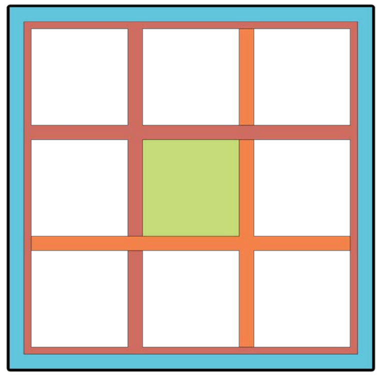
Mobility

For decades streets have been designed mainly for cars but the proposed design prioritizes pedestrians and bicycles. The three colours represent different mobility; for cars, pedestrians and bikes.



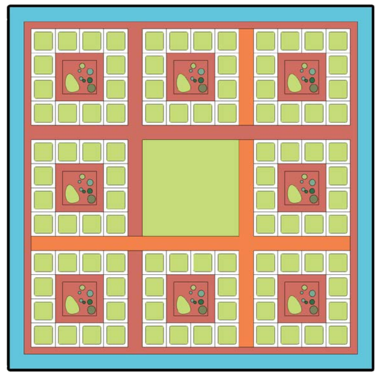
The grid

A 3x3 block grid was used in the proposed master plan. Each block is 10x10 meters.



Central courtyard

The buildings were designed around a central courtyard.



Roof gardens

The vegetation was maximized by adding roof gardens to the buildings.

IMM METHODOLOGY

The Integrated Modification Methodology (IMM) is a design methodology that is based on a specific process with the primary goal of improving complex adaptive systems' energy performance by modifying their constituents and optimizing their ligand's architecture. IMM is fundamentally holistic, multi-layered, and multi-scale, it analyses the relationships between urban morphology, energy consumption, and environmental performance. The methodology primarily focuses on the "Subsystems". IMM's approach to sustainability is aligned with the 17 UN Sustainable Development Goals 2030, in particular Goal 11 - Sustainable Cities and Communities.

IMM Key Categories

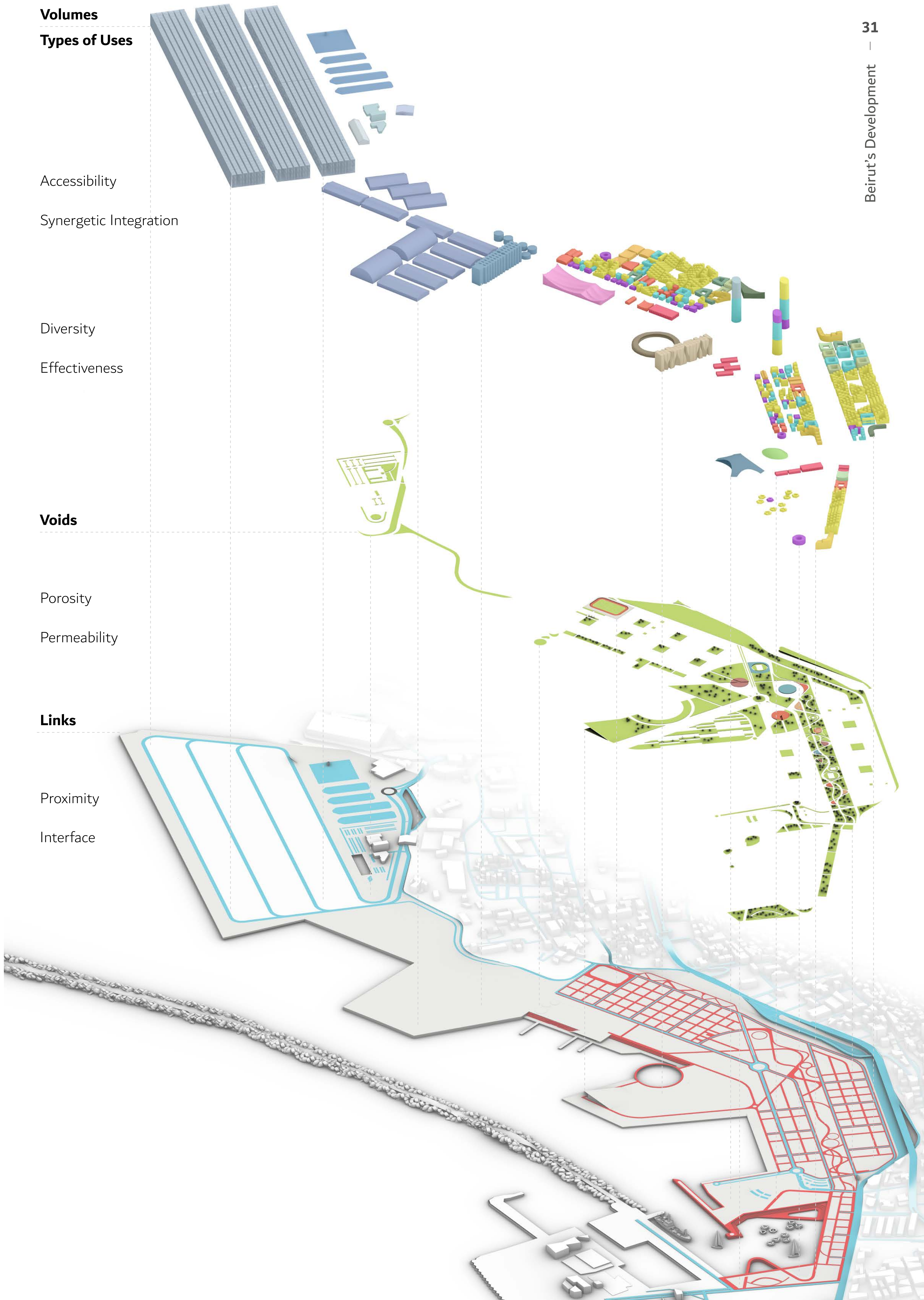
The principal categories IMM advises one to inspect/analyse are: Porosity, Permeability, Proximity, Diversity, Interface, Accessibility, and Effectiveness. These categories form the basis of the IMM methodology and are used to analyze and optimize complex adaptive systems. Porosity refers to the degree of openness in a system, while permeability represents the ability of a system to allow the movement of energy and resources. Proximity encapsulates the closeness of different elements in a system, while diversity analyses the variety of elements in a system. Interface refers to the interaction between different elements in a system, while accessibility studies the ease of movement within a system. Finally, effectiveness examines the overall performance of a system in terms of energy efficiency and sustainability.

However, we couldn't just apply the IMM principles from the onset, on account of the explosion. The majority of the area we were supposed to design was severely damaged, so we had to approach the area in a different way, initially. We used the IMM methodology to understand the connection between the port and the other parts of the city, as well as to analyse the roads which had been recently refurbished. However, we integrated IMM when analysing our master plan design when it was nearly finished in order to understand if it worked with respect to each of the key categories: porosity, permeability, etc. [1]

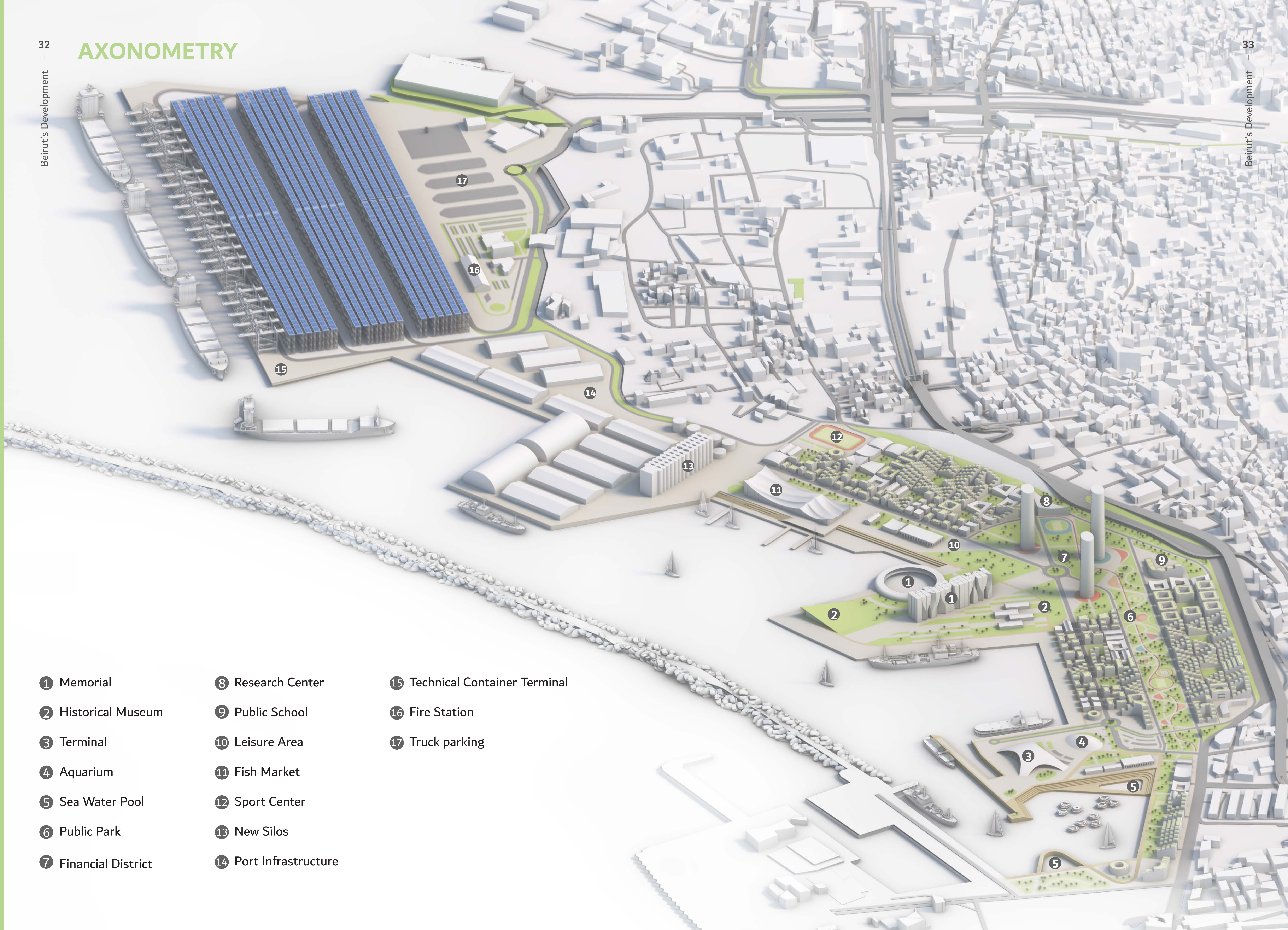
From the beginning we focused on understanding how to divide the master plan into volumes and voids for maximum effect. The voids were just as important as the volumes, as Beirut lacks greenery and therefore our goal was to it as much as possible. Using the IMM methodology we maximised the effectiveness of the whole project. As the port has different zones with different functions it was important to understand their interfaces clearly, how the public transportation works in Beirut which enabled us to limit the car and promote pedestrian and bicycle infrastructure.

References

[1] http://www.immdesignlab.com/informazioni/



AXONOMETRY



1 Memorial
2 Historical Museum
3 Terminal
4 Aquarium
5 Sea Water Pool
6 Public Park
7 Financial District
8 Research Center
9 Public School
10 Leisure Area
11 Fish Market
12 Sport Center
13 New Silos
14 Port Infrastructure
15 Technical Container Terminal
16 Fire Station
17 Truck parking

MASTERPLAN

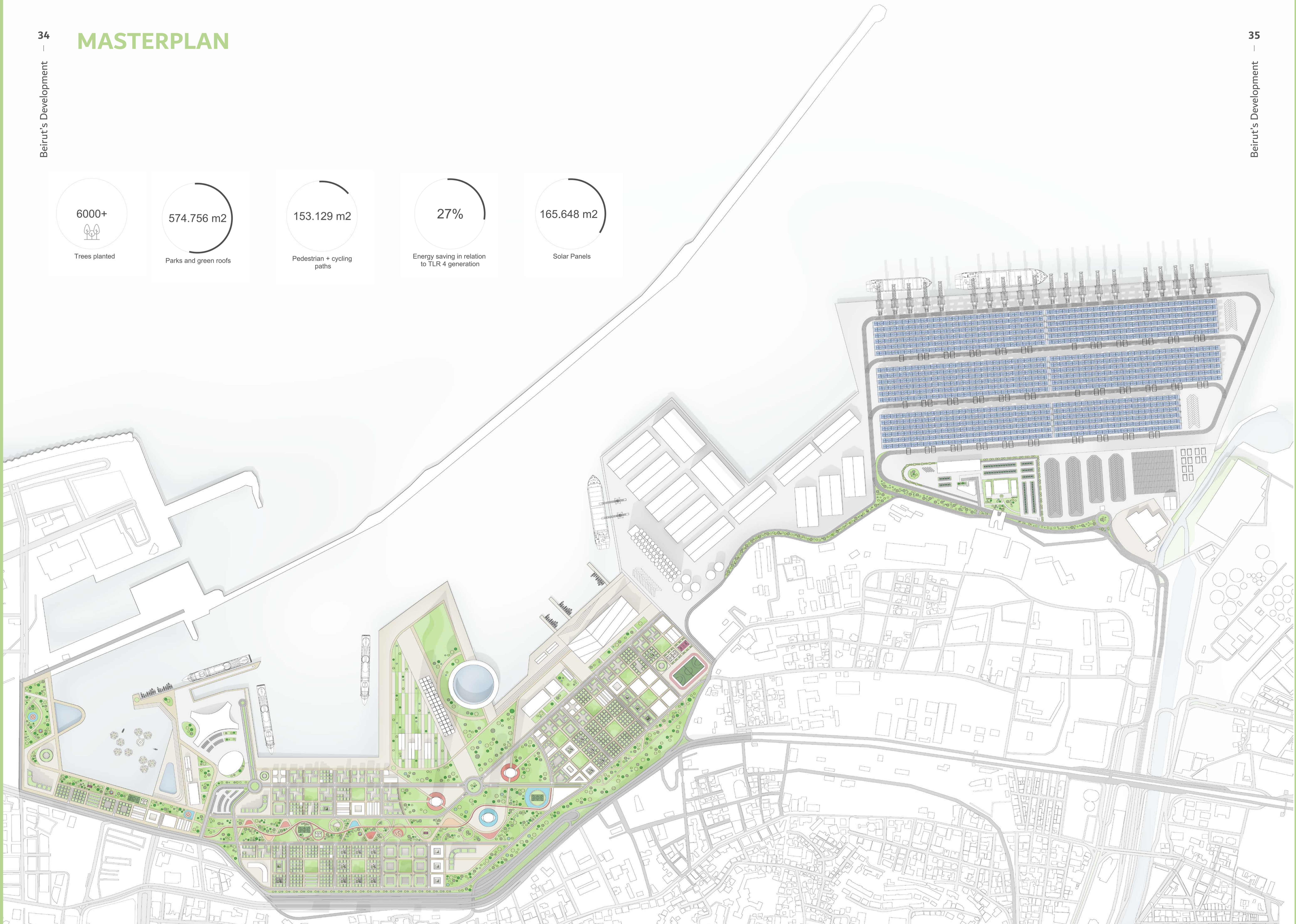
6000+
Trees planted

574.756 m2
Parks and green roofs

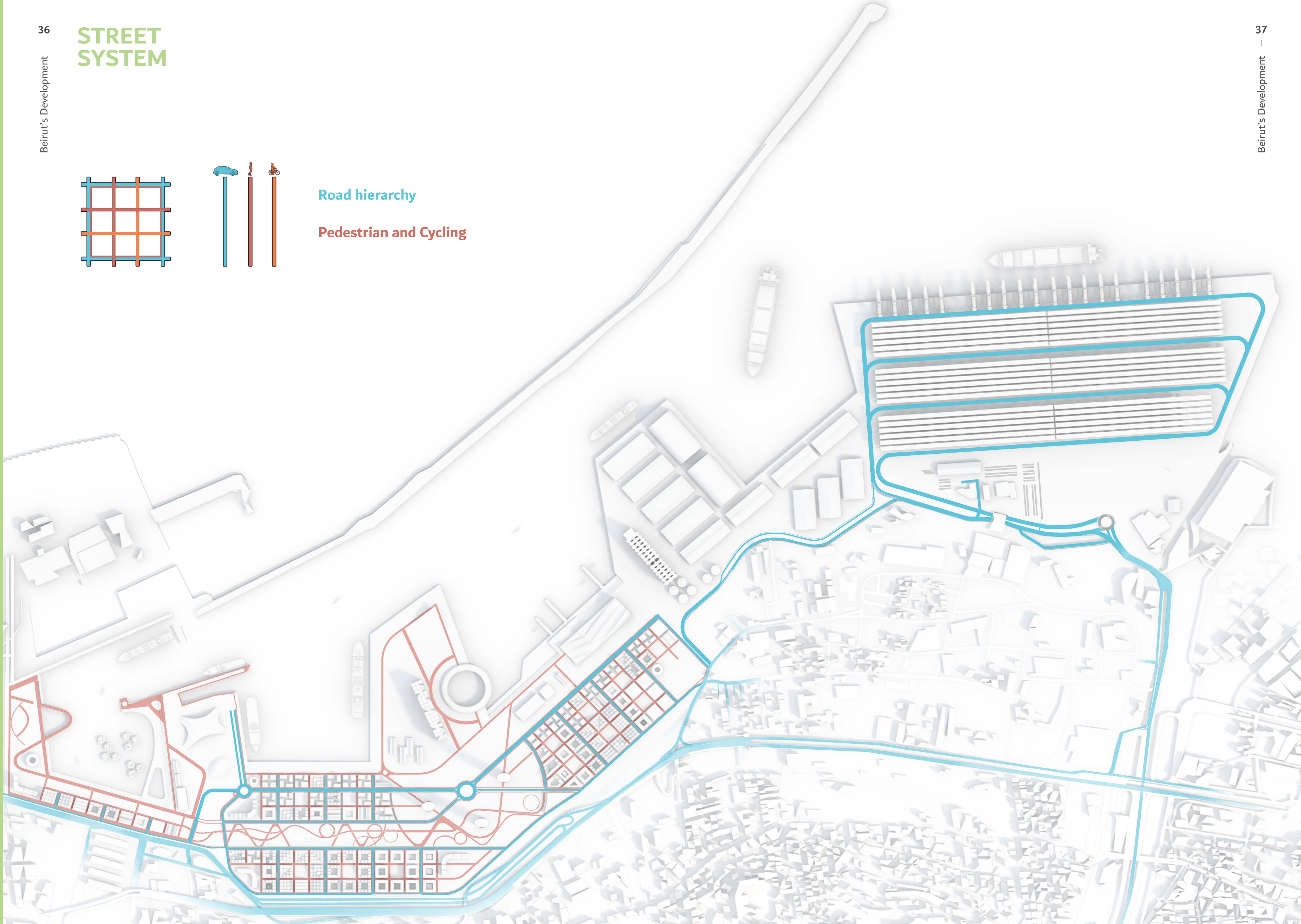
153.129 m2
Pedestrian + cycling paths

27%
Energy saving in relation to TLR 4 generation

165.648 m2
Solar Panels



STREET SYSTEM

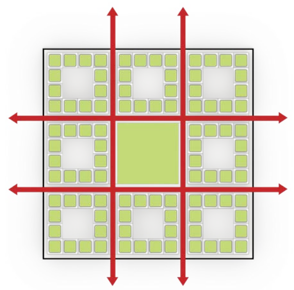


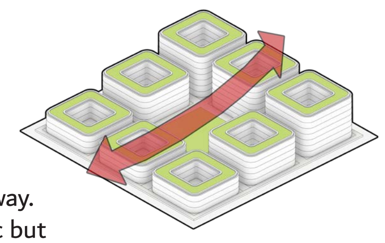
CONCEPT

Our Beirut master plan combines innovation, respect, and technology with the planning principles of traditional Beirut architectural morphology with the vision of creating a sustainable and equal community that aims to be carbon neutral with zero waste. The master plan which encompasses 120.0000 m2 is focused on renewable energy and clean technology within a modular grid system solution that is resilient to the global warming crisis. The waterfront and the different parts of the master plan will become symbols of rebirth, advancement, equality, evolution, and energy production for a circular economy. With the ambition of attracting the most talented professionals both from Beirut, and from around the globe. A mixed use low-rise, low-density development with central towers connected by a sustainable green network that generates an urban fabric able to provide a sense of place. Furthermore, it offers comfortably shaded spaces for walking, biking, and meandering between the functions of the waterfront. Numerous courtyards, terraces, parks, and pools create an inviting place for recreation, reflection, and relaxation. The master plan is designed to be highly flexible in terms of development expansion, phases, and climate change responses. Arising from the grid system the project envisioned catalytic landmarks for generating a stronger sense identity and a richer cultural atmosphere.

Access

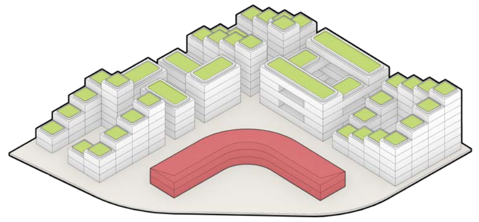
Different access points to enter the communal courtyard.





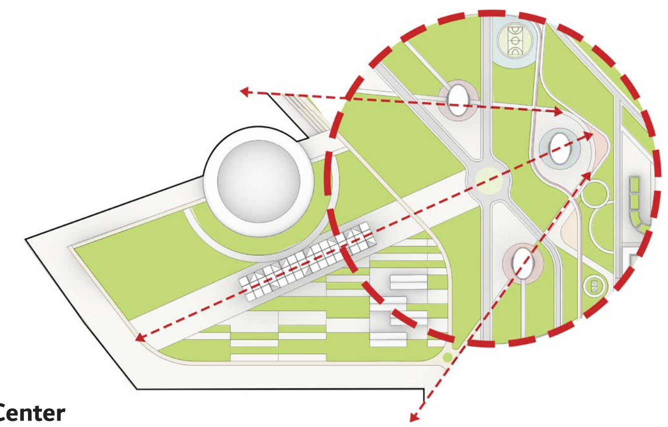
Height

Progressively ascending height towards the highway. This seperates the traffic but preserves the human scale.



Corner

Encompasing the structured grids we placed curved buildings intended to house various society sustaining functions.

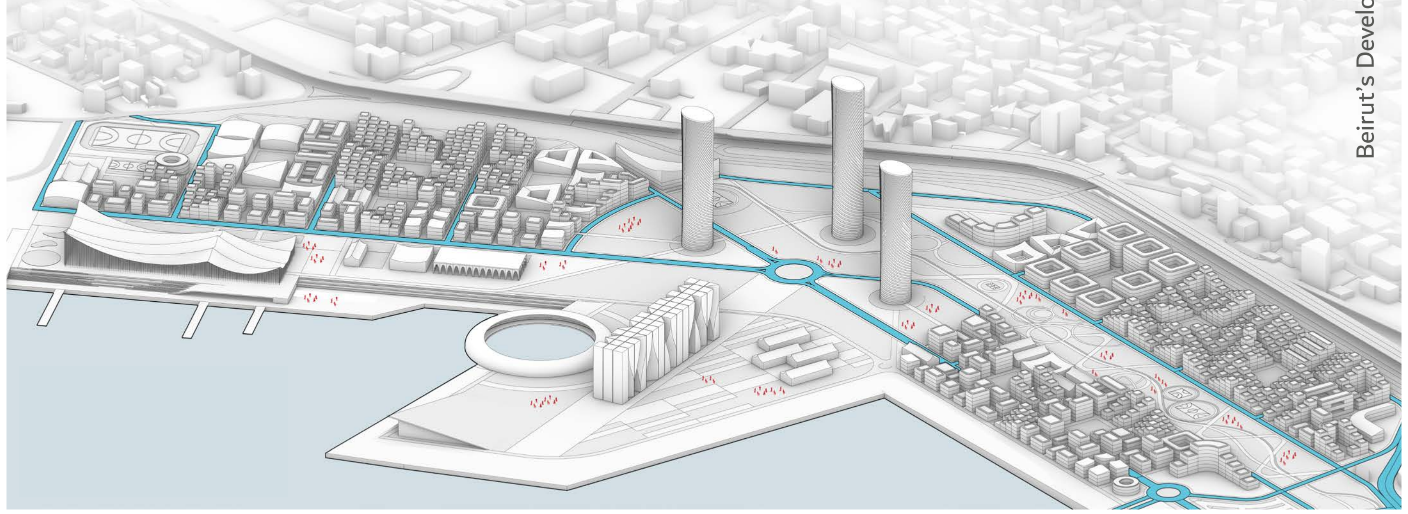


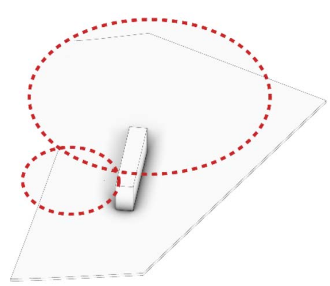
Center

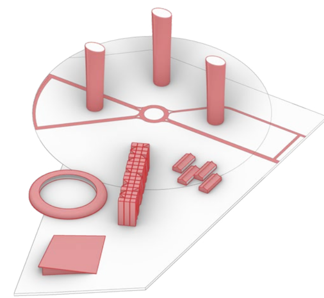
The design is centered around the focus point depicted in the image above. It contains the financial district and has strong connections to the surrounding grids and the memorial.

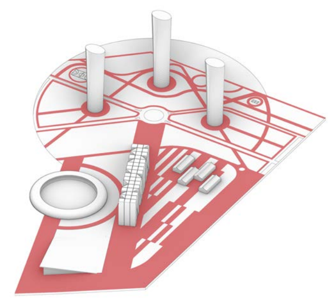
Roadway Hierarchy

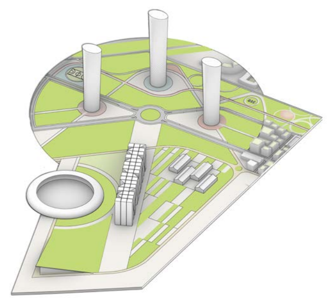
By carefully designing the road system we were able to limit the car's pervasiveness, returning ownership of the environment to pedestrians and bicyclist.











Radius

We incorporated the concept of the disastrous blast radius into our design, in an effort to give the people of Beirut an opportunity to reclaim their city while still remembering the fateful incident.

Volume

The volume was split between to principal areas, the financial district and the memorial site which houses the museum and other displays in memoriam of the accident.

Pedestrian Path

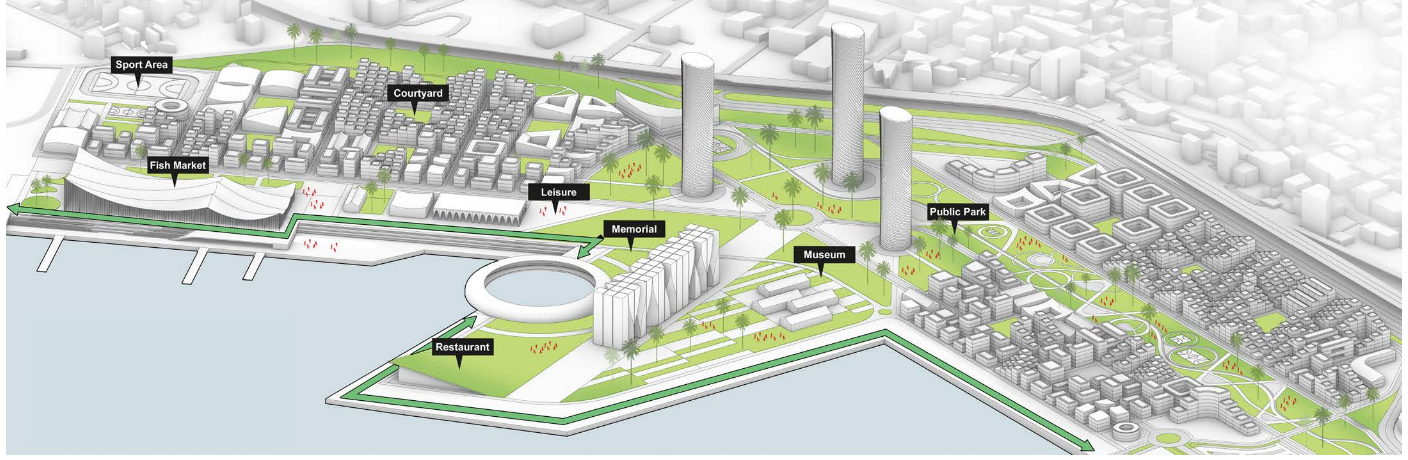
Engaging paths lead pedestrians on an adventure through the open space.

Green ways

Enhancing the playful paths, green areas are spread throughout beckoning passersby to visit and sojourn.

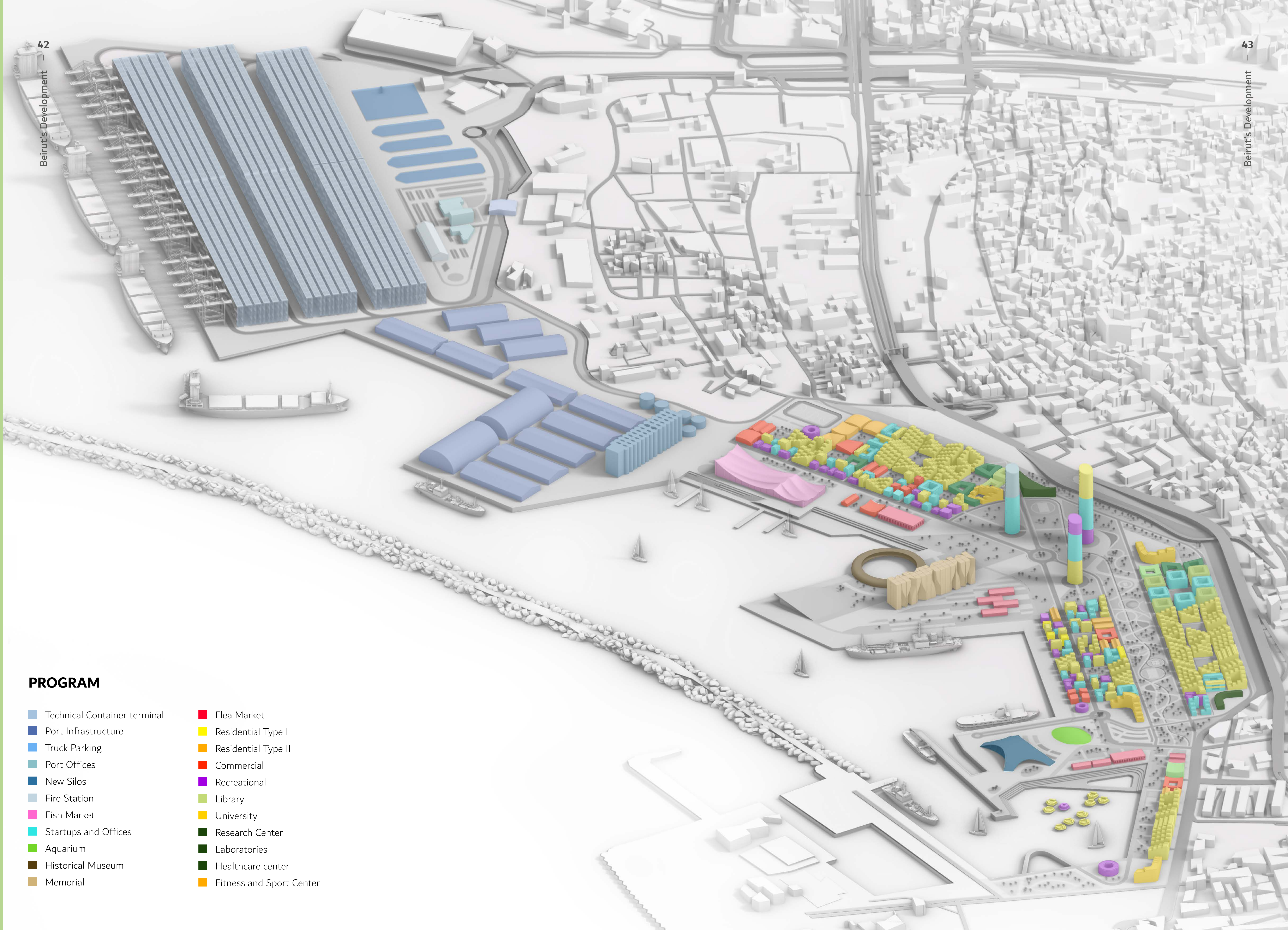
Active Waterfront

Various functions along the seaside increase the engagement on the waterfront walk. Flowing naturally from the paths leading through the public park, the way lends a connection to nature to each and every district in the area.



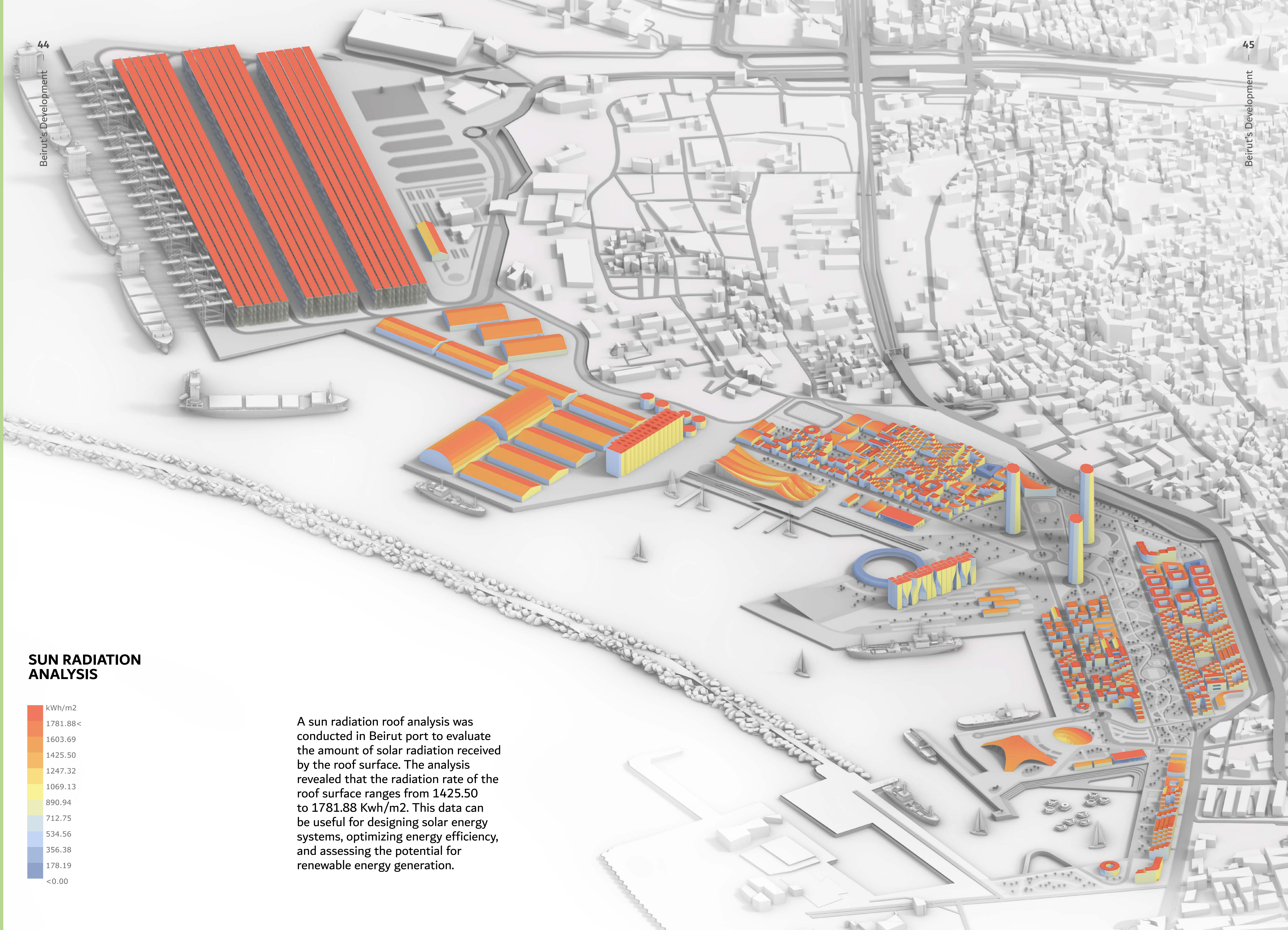
MEMORIAL

On the 4th of August 2020 the city of Beirut was left shattered after the explosion caused by improperly stored ammonium nitrate at Beirut’s port. The memorial complex is dedicated to the 200 people who lost their lives, the 1000 injured, and to the over 300.000 who lost their homes. The design is centered on dynamic connectivity, sensitivity, and spirituality. The new memorial is emerging out of the ruins, highlighting the vast green area that melts with the museum. The emptiness of the destroyed zone is framed by the ring that symbolizes balance and unity.



PROGRAM

- Technical Container terminal
- Port Infrastructure
- Truck Parking
- Port Offices
- New Silos
- Fire Station
- Fish Market
- Startups and Offices
- Aquarium
- Historical Museum
- Memorial
- Flea Market
- Residential Type I
- Residential Type II
- Commercial
- Recreational
- Library
- University
- Research Center
- Laboratories
- Healthcare center
- Fitness and Sport Center



SUN RADIATION ANALYSIS

A sun radiation roof analysis was conducted in Beirut port to evaluate the amount of solar radiation received by the roof surface. The analysis revealed that the radiation rate of the roof surface ranges from 1425.50 to 1781.88 Kwh/m2. This data can be useful for designing solar energy systems, optimizing energy efficiency, and assessing the potential for renewable energy generation.

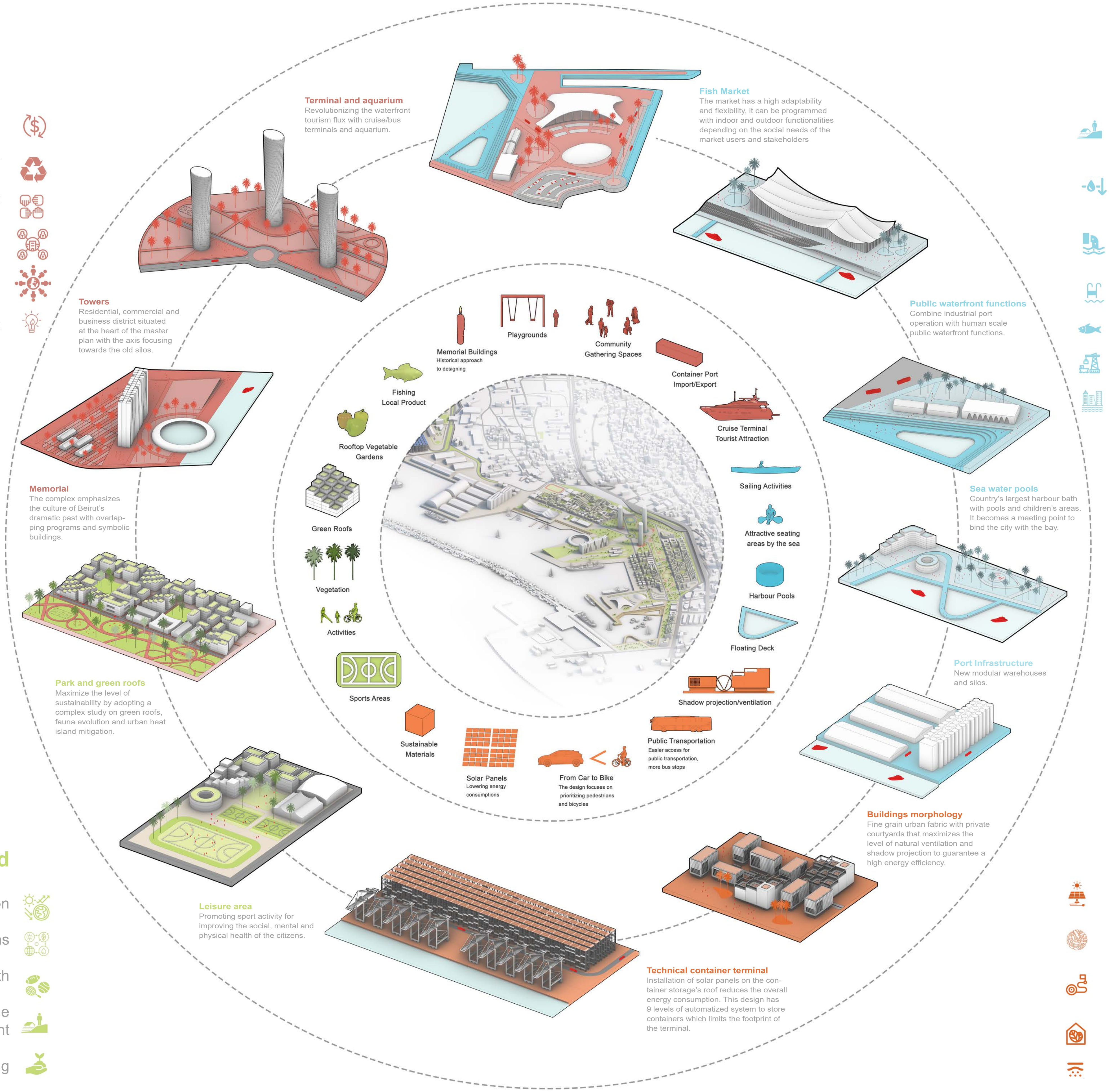
FISH MARKET

The design is reminiscent of the waves of the sea that try to embrace the market archetype with a focus on flexibility, connectivity between the functions allowing the public indirect participation in the building program. The project also pushes sustainable strategies to the forefront by managing biofiltration, grey water recycling and, mechanical filtration system.

CONCEPT DIAGRAM

Economy and culture

- Circular economy promotion
- Zero waste city
- Social support with citizen/tourist participation
- Promotion of local associations
- Promotion of citizen participation
- Synergy between industrial and cultural port



Sustainability, health and food

- Heat island effect reduction
- Improving biodiversity and green connections
- Sport activities to improve citizens health
- Prevention against flooding with permeable pavement
- Local production of food, urban farming

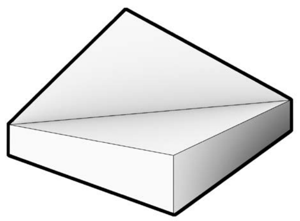
Waterfront connection

- Flooding prevention with permeable and vegetative surfaces.
- Floodwater protection wall with topographical intervention
- Flooding prevention with underground drainage system
- Sea water pools
- Fish market
- Port infrastructure
- Public waterfront functions

Energy and mobility

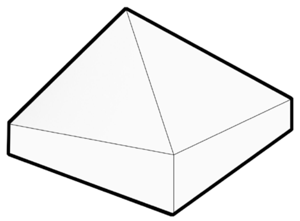
- Automatized solar energy system container storage
- Building morphology
- Reducing congestion with multi-layered street networks
- Sustainable building materials
- Building envelope protection

BUILDING TYPES



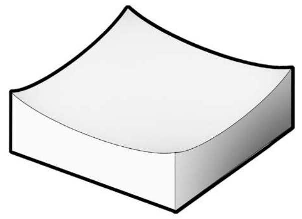
Building 1 Type A I

Building type quantity: 1
Total Area: 3200 m^2 / 32 units
Offices: 1200 m^2
Hospitality: 1000 m^2
Leisure: 1000 m^2



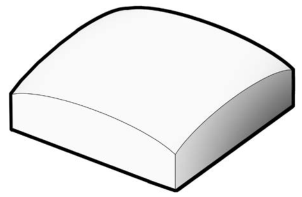
Building 2 Type A I

Building type quantity: 1
Total Area: 3200 m^2 / 32 units
Retail: 1200 m^2
Offices: 1000 m^2
Hospitality: 1000 m^2



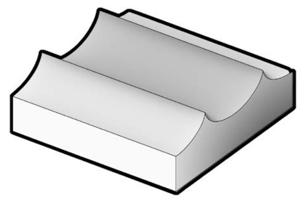
Building 3 Type A I

Building type quantity: 3
Total Area: 1600 m^2 / 16 units
Retail: 1200 m^2
Offices: 200 m^2
Leisure: 10 m^2



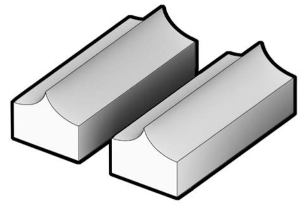
Building 4 Type A I

Building type quantity: 3
Total Area: 1600 m^2 / 16 units
Leisure: 1400 m^2
Hospitality: 200 m^2



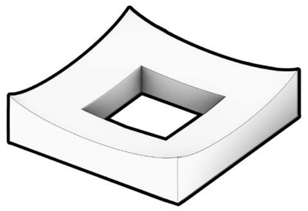
Building 5 Type A II

Building type quantity: 1
Total Area: 1600 m^2 / 16 units
Leisure: 1300 m^2
Hospitality: 200 m^2
Offices: 100 m^2



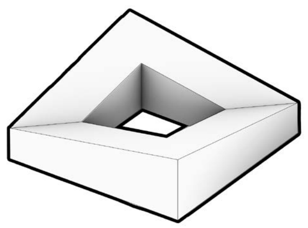
Building 6 Type A II

Building type quantity: 5
Green area: 300 m^2
Total Area: 1300 m^2 / 13 units
Retail: 800 m^2
Hospitality: 500 m^2



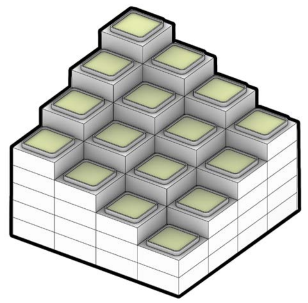
Building 7 Type A III

Building type quantity: 4
Green area: 400 m^2
Total Area: 2400 m^2 / 24 units
Offices: 400 m^2
Hospitality: 200 m^2
Education: 1200 m^2



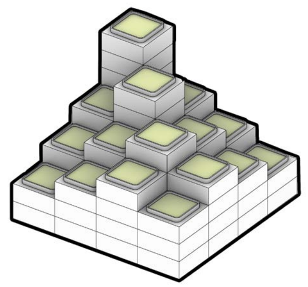
Building 8 Type A III

Building type quantity: 5
Green area: 400 m^2
Total Area: 2400 m^2 / 24 units
Offices: 1200 m^2
Hospitality: 200 m^2
Education: 1000 m^2



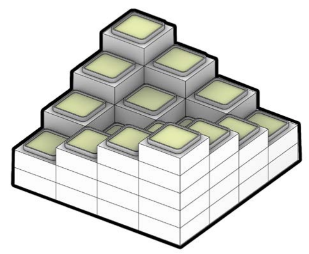
Building 9 Type B I

Building type quantity: 8
Green area: 1600 m^2
Total Area: 9000 m^2 / 90 units
Retail: 400 m^2
Offices: 400 m^2
Leisure: 800 m^2
Residential: 7400 m^2



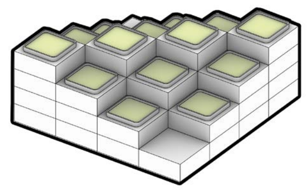
Building 10 Type B I

Building type quantity: 1
Green area: 1600 m^2
Total Area: 8000 m^2 / 80 units
Retail: 1000 m^2
Hospitality: 600 m^2
Residential: 6400 m^2



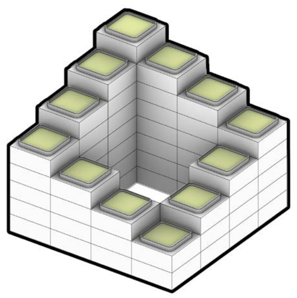
Building 11 Type B I

Building type quantity: 10
Green area: 1600 m^2
Total Area: 6100 m^2 / 61 units
Retail: 600 m^2
Hospitality: 1000 m^2
Residential: 4500 m^2



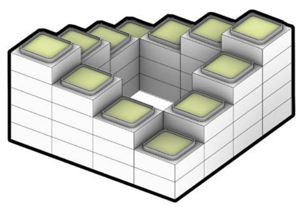
Building 12 Type B I

Building type quantity: 3
Green area: 1600 m^2
Total Area: 4400 m^2 / 44 units
Retail: 400 m^2
Leisure: 600 m^2
Hospitality: 600 m^2
Residential: 2800 m^2



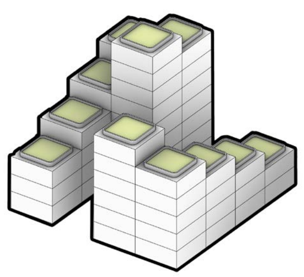
Building 13 Type B II

Building type quantity: 7
Green area: 1600 m^2
Total Area: 6000 m^2 / 60 units
Leisure: 600 m^2
Hospitality: 600 m^2
Residential: 4800 m^2



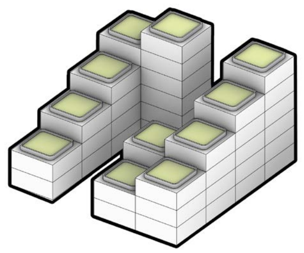
Building 14 Type B II

Building type quantity: 7
Green area: 1600 m^2
Total Area: 4200 m^2 / 42 units
Leisure: 600 m^2
Hospitality: 600 m^2
Residential: 3000 m^2



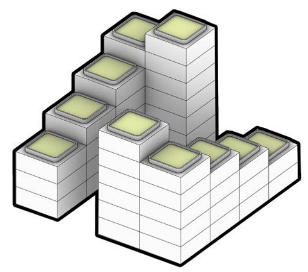
Building 15 Type C I

Building type quantity:
Green area: 1600 m^2
Total Area: 6000 m^2 / 60 units
Leisure: 600 m^2
Hospitality: 700 m^2
Residential: 4700 m^2



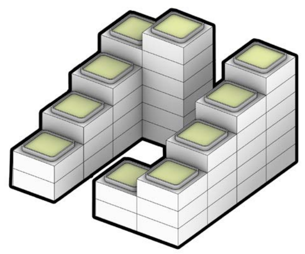
Building 16 Type C I

Building type quantity: 2
Green area: 1600 m^2
Total Area: 5000 m^2 / 50 units
Leisure: 400 m^2
Retail: 400 m^2
Residential: 4200 m^2



Building 17 Type C I

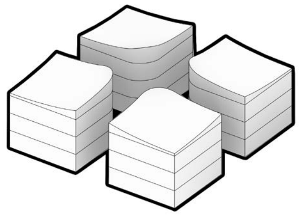
Building type quantity: 3
Green area: 1600 m^2
Total Area: 5000 m^2 / 50 units
Leisure: 200 m^2
Residential: 4800 m^2



Building 18 Type C I

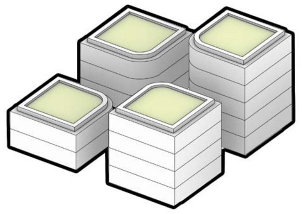
Building type quantity: 2
Green area: 1600 m^2
Total Area: 4000 m^2 / 40 units
Retail: 400 m^2
Leisure: 400 m^2
Residential: 3200 m^2

BUILDING TYPES



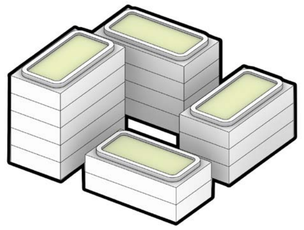
Building 18 Type D I

Building type quantity: 2.5
Total Area: 4800 m^2 / 48 units
Retail: 2000 m^2
Offices: 2000
Hospitality: 800 m^2



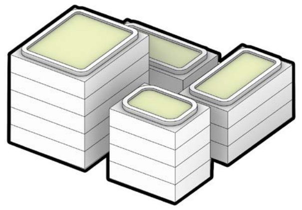
Building 19 Type D I

Building type quantity: 4
Green area: 1800 m^2
Total Area: 7200 m^2 / 72 units
Retail: 800 m^2
Offices: 1000 m^2
Residential: 5400 m^2



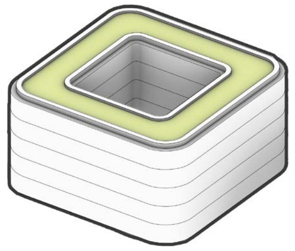
Building 20 Type D II

Building type quantity: 10
Green area: 1700 m^2
Total Area: 7000 m^2 / 70 units
Leisure: 800 m^2
Retail: 400 m^2
Residential: 5800 m^2



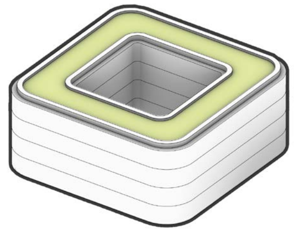
Building 21 Type D II

Building type quantity: 7
Green area: 1600 m^2
Total Area: 7000 m^2 / 70 units
Retail: 1000 m^2
Offices: 1000 m^2
Residential: 5000 m^2



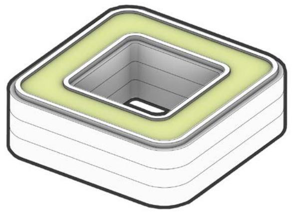
Building 22 Type E I

Building type quantity: 3
Green area: 1600 m^2
Total Area: 6000 m^2 / 60 units
Offices: 500 m^2
Hospitality: 500 m^2
Residential: 5000 m^2



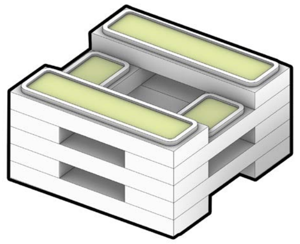
Building 23 Type E I

Building type quantity: 3
Green area: 1600 m^2
Total Area: 4800 m^2 / 48 units
Leisure: 400 m^2
Hospitality: 400 m^2
Residential: 4000 m^2



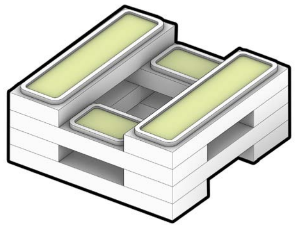
Building 24 Type E I

Building type quantity: 4
Green area: 1600 m^2
Total Area: 3600 m^2 / 36 units
Leisure: 300 m^2
Hospitality: 300 m^2
Residential: 3000 m^2



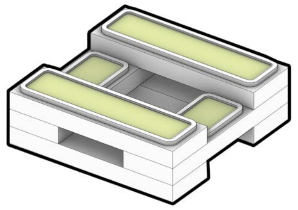
Building 25 Type F I

Building type quantity: 3
Green area: 3200 m^2
Total Area: 4000 m^2 / 40 units
Offices: 400 m^2
Hospitality: 400 m^2
Residential: 3200 m^2



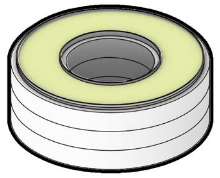
Building 26 Type F I

Building type quantity: 1
Green area: 2400 m^2
Total Area: 4200 m^2 / 42 units
Leisure: 200 m^2
Residential: 4000 m^2



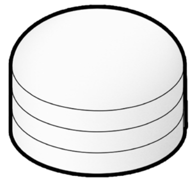
Building 27 Type F I

Building type quantity: 1
Green area: 2000 m^2
Total Area: 2400 m^2 / 24 units
Leisure: 400 m^2
Hospitality: 400 m^2
Residential: 1800 m^2



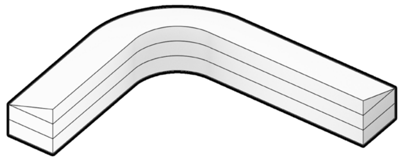
Building 28 Type G I

Building type quantity: 3
Green area: 480 m^2
Total Area: 1400 m^2 / 14 units
Residential: 1400 m^2



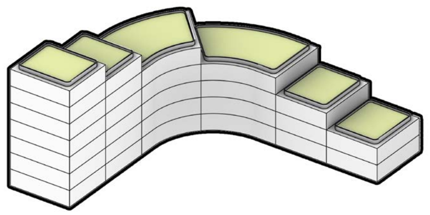
Building 29 Type G I

Building type quantity: 1
Total Area: 1400 m^2 / 14 units
Leisure: 1400 m^2



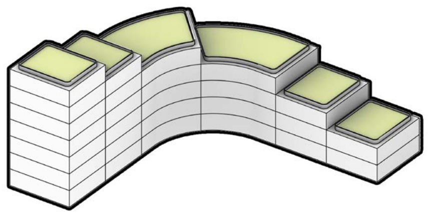
Building 30 Type H I

Building type quantity: 1
Total Area: 4800 m^2 / 48 units
Leisure: 1000 m^2
Offices: 3000
Hospitality: 800 m^2



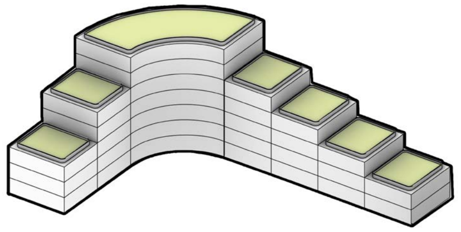
Building 31 Type H II

Building type quantity:
Green area: 1800 m^2
Total Area: 7200 m^2 / 72 units
Offices: 800 m^2
Retail: 100 m^2
Residential: 6300 m^2



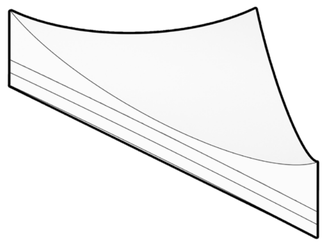
Building 32 Type H II

Building type quantity: 1
Green area: 1600 m^2
Total Area: 7000 m^2 / 70 units
Retail: 400 m^2
Hospitality: 5400 m^2
Leisure: 1200 m^2



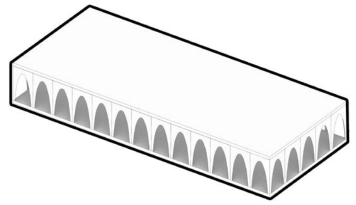
Building 33 Type H II

Building type quantity: 1
Green area: 1600 m^2
Total Area: 7000 m^2 / 70 units
Retail: 1200 m^2
Leisure: 400 m^2
Residential: 5400 m^2



Building 34 Type I I

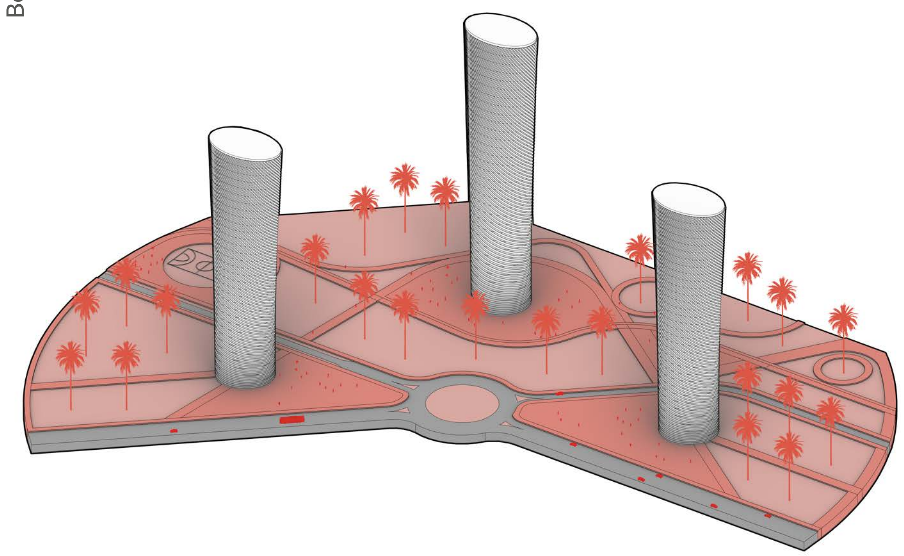
Building type quantity: 1
Total Area: 5000 m^2 / 50 units
Offices: 2500 m^2
Education: 2500 m^2



Building 35 Type J I

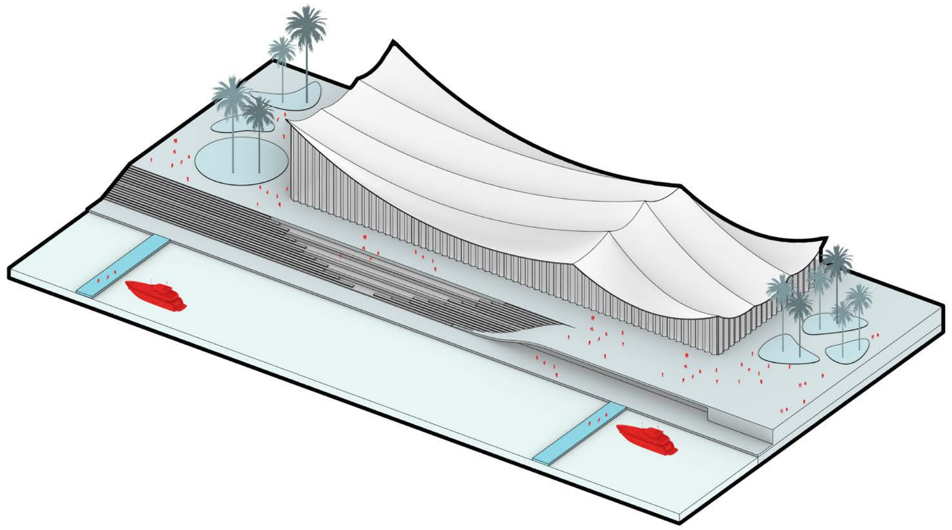
Building type quantity: 2
Total Area: 3500 m^2 / 35 units
Retail: 2500 m^2
Offices: 1000 m^2

BUILDING TYPES



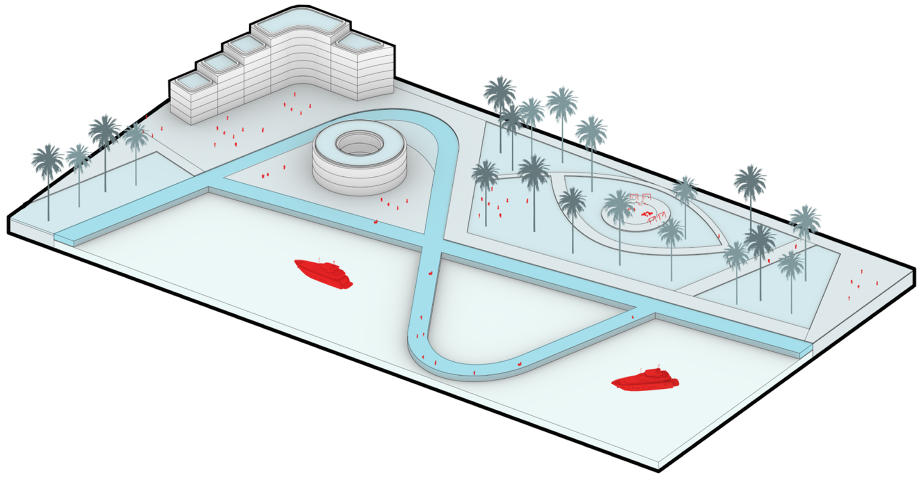
Tower Complex

Green area: 130.000 m²
Total Area: 87.000 m²
Tower 1: 28.000 m²
Tower 2: 28.000 m²
Tower 3: 31.000 m²



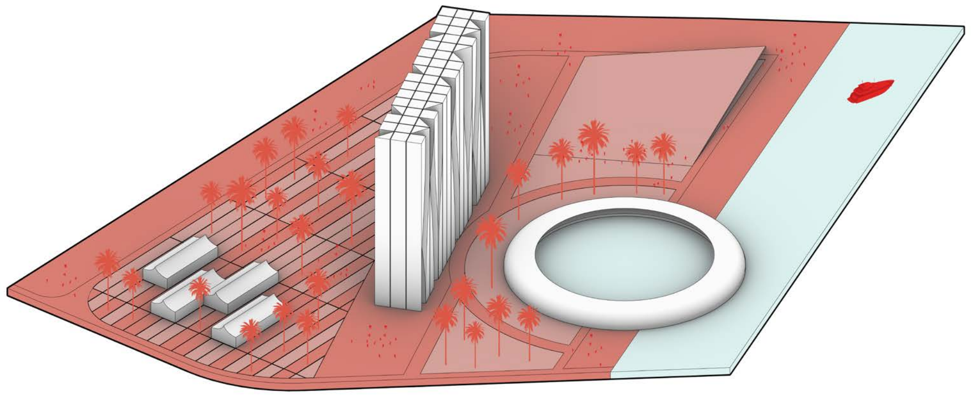
Fish Market

Green area: 4000 m²
Total Area: 17.000 m² / 170 units
Retail: 10.000 m²
Hospitality: 5000 m²
Leisure: 2000 m²



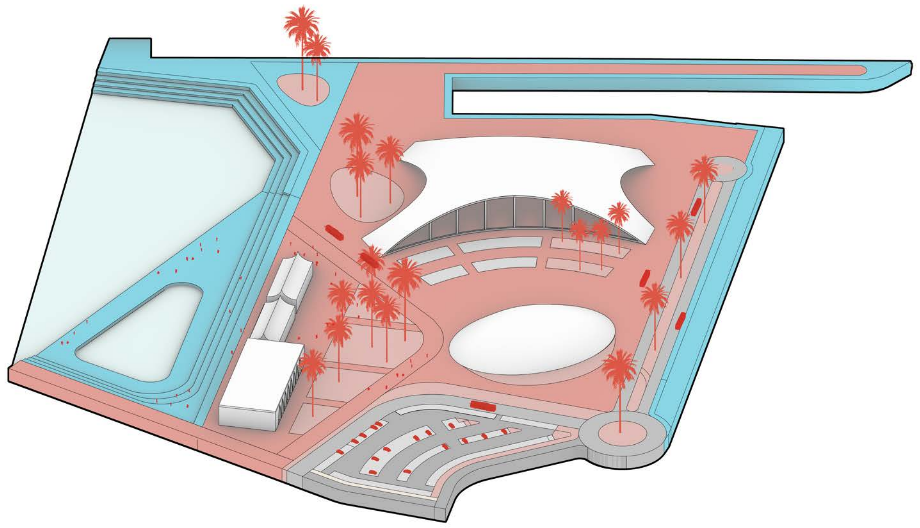
Exterior pool complex

Green area: 20.000 m²
Total Area: 6000 m²



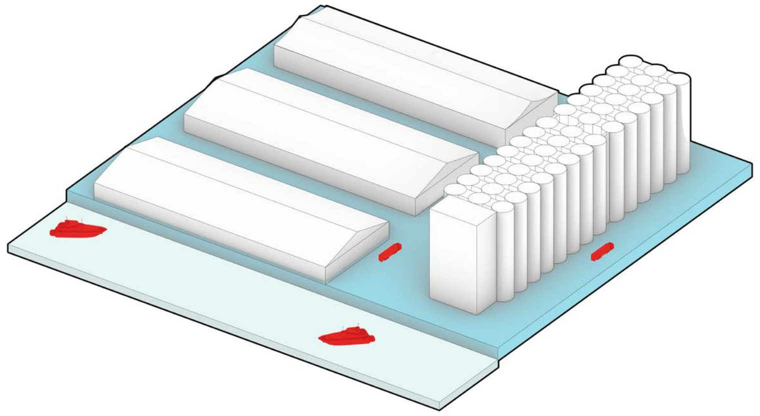
Memorial

Green area: 100.000 m²
Total Area: 43.100 m²
Circular memorial: 8400 m²
Silos renovation: 6700 m²
Museum: 28.000 m²



Terminal & Aquarium

Green area: 2000 m²
Total Area: 14000 m²
Terminal: 9000 m²
Aquarium: 5000 m²



Port Infrastructure

Total Area: 1.112.2914 m²

TOWERS

The towers will host company headquarters and startup incubators able to adapt to the post-covid situation. They are connected to the downtown districts and lead towards the memorial site with a geometrical and respectful axis. The tower facades invoke recollection of the water with their marine grade aluminium cladding designed in response to the sun with profiles that generate shading from the harsh sunlight and improve the energy efficiency of the buildings. The buildings framing the towers feature an ultra-high performance concrete, lightweight and low carbon molded concrete panels that guarantee a high thermal mass, enhanced by the windows shading system that gives a strong identity and improves the thermal comfort by minimizing the solar radiation.

SERVICES FOR ALL

Mobility

Promoting the use of public transportation and alternative modes of transportation. This goal aims to reduce the carbon footprint of the port and the city by encouraging people to use public transportation options such as buses, trains, and bicycles. This would not only reduce traffic congestion but also improve air quality.

Energy

The plan aims to harness renewable energy sources such as solar and wind power to reduce the reliance on fossil fuels and minimize the environmental impact of the port.

Smart port Logistics

The Master plan aims to use technology to optimize logistics operations, reduce waste, and improve efficiency. This includes using sensors and automation technologies to track cargo and minimize delays.

Fish market

Creating a sustainable fish market. This goal aims to encourage sustainable fishing practices and provide a market for locally caught seafood. This would help support local fishermen and reduce the reliance on imported seafood.

IOT

Digitizing the Masterplan. The Masterplan will be digitized to facilitate easy access to information and enable stakeholders to participate in the planning process.

Health care

Promoting physical and mental well-being. The port will provide recreational areas and activities to promote physical and mental well-being for the port workers and the local community.

Education

Improving the knowledge economy. The Masterplan aims to establish a knowledge-based economy by encouraging research and development in areas such as logistics, renewable energy, and sustainable development.

Finance

With all the enhancements made to the port we saw the opportunity to place the financial sector close by. With increased growth we foresee a new awakening for the entire downtown area, as the increased functioning of the port will bring more financial activity.

Safety and security

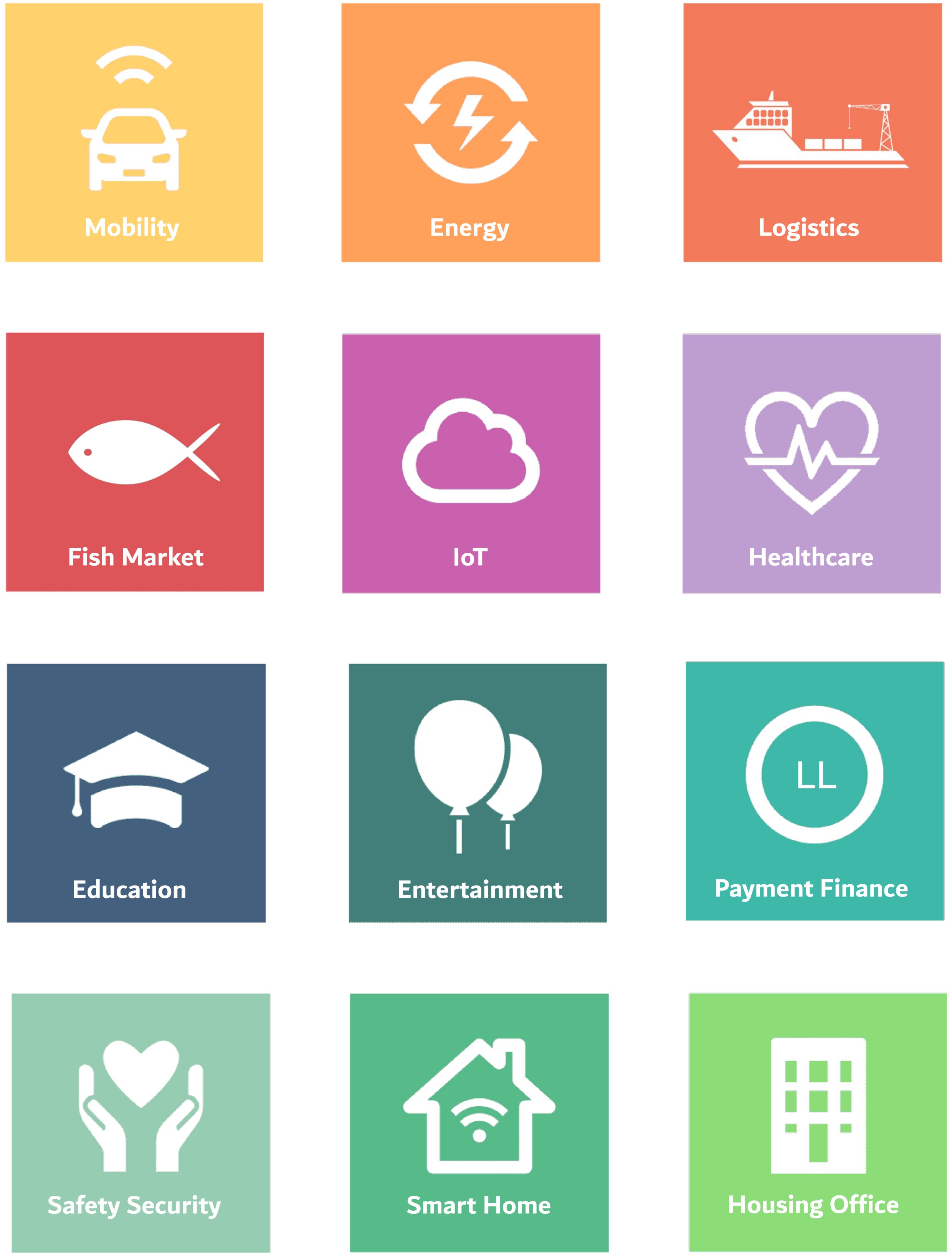
Enhancing safety and security measures. The plan aims to enhance safety and security measures to protect the port and the local community from potential risks.

Smart Home

The proximity of residential real estate to the port offers all manner of resource sharing, excess energy from the port area can be drawn, used and even stored at the residential level. Further increasing potential for smart-home solutions.

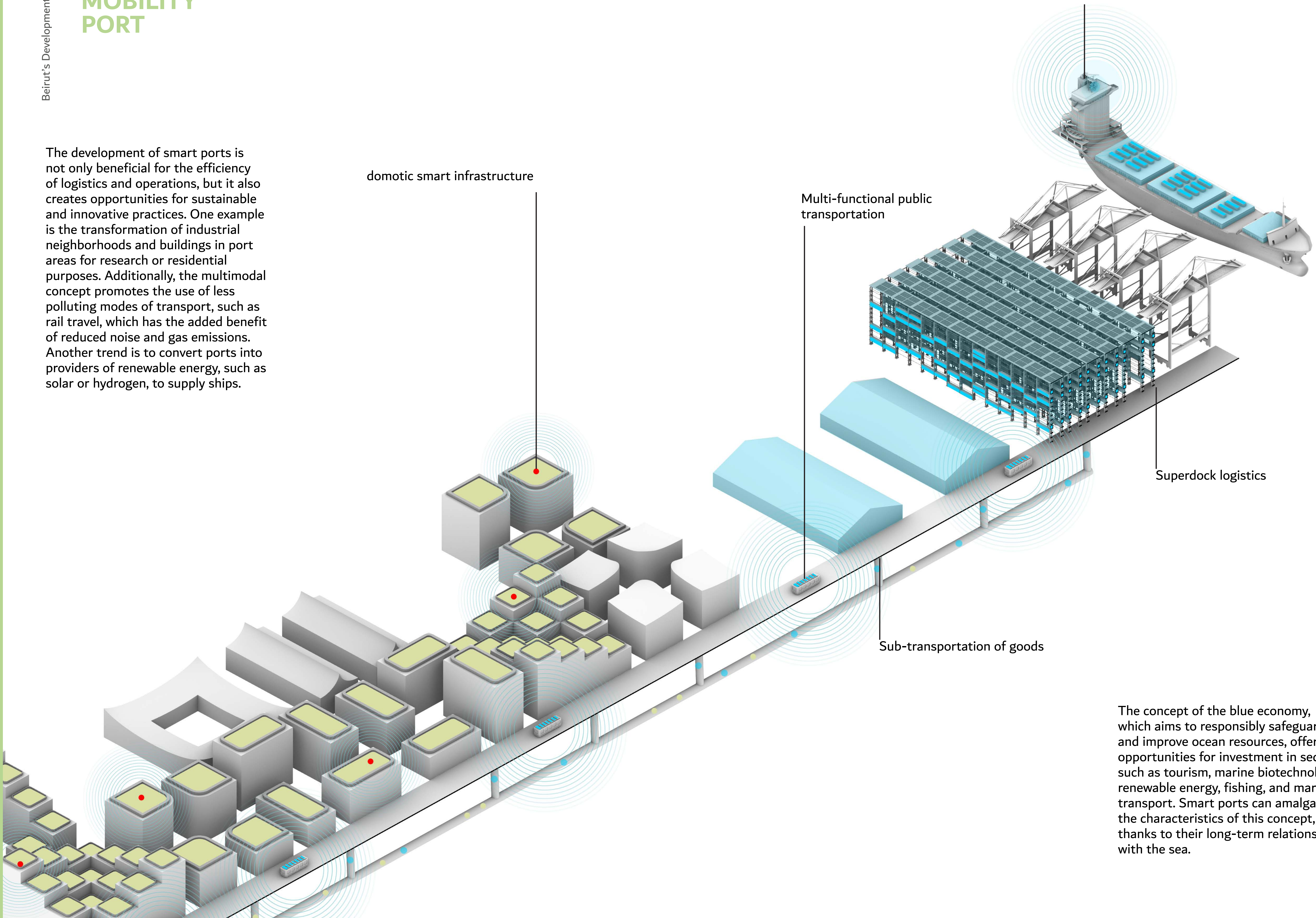
Modular & social housing

The port will provide modular social housing to address the housing shortage in the city and provide affordable housing options for the local community.



SMART MOBILITY PORT

The development of smart ports is not only beneficial for the efficiency of logistics and operations, but it also creates opportunities for sustainable and innovative practices. One example is the transformation of industrial neighborhoods and buildings in port areas for research or residential purposes. Additionally, the multimodal concept promotes the use of less polluting modes of transport, such as rail travel, which has the added benefit of reduced noise and gas emissions. Another trend is to convert ports into providers of renewable energy, such as solar or hydrogen, to supply ships.



The concept of the blue economy, which aims to responsibly safeguard and improve ocean resources, offers opportunities for investment in sectors such as tourism, marine biotechnology, renewable energy, fishing, and maritime transport. Smart ports can amalgamate the characteristics of this concept, thanks to their long-term relationship with the sea.

SMART MOBILITY PORT

Main features and benefits of smart ports

Smart ports are designed to improve efficiency, transparency, safety, and security for port users. They achieve this through the use of technology and data collection to manage operations and share information with stakeholders. By integrating with smart transport infrastructures, smart ports offer various benefits such as reduced costs and improved efficiency [2]. One way smart ports seek to increase their handling capacity is through the automatic identification of containers [1]. Smart ports also address sustainability, productivity, communication, and transparency, and can detect risks in maritime transport while streamlining collaboration [2]. Additionally, the digitalization of port assets has allowed ports to significantly reduce their carbon output, making them more environmentally friendly [2].

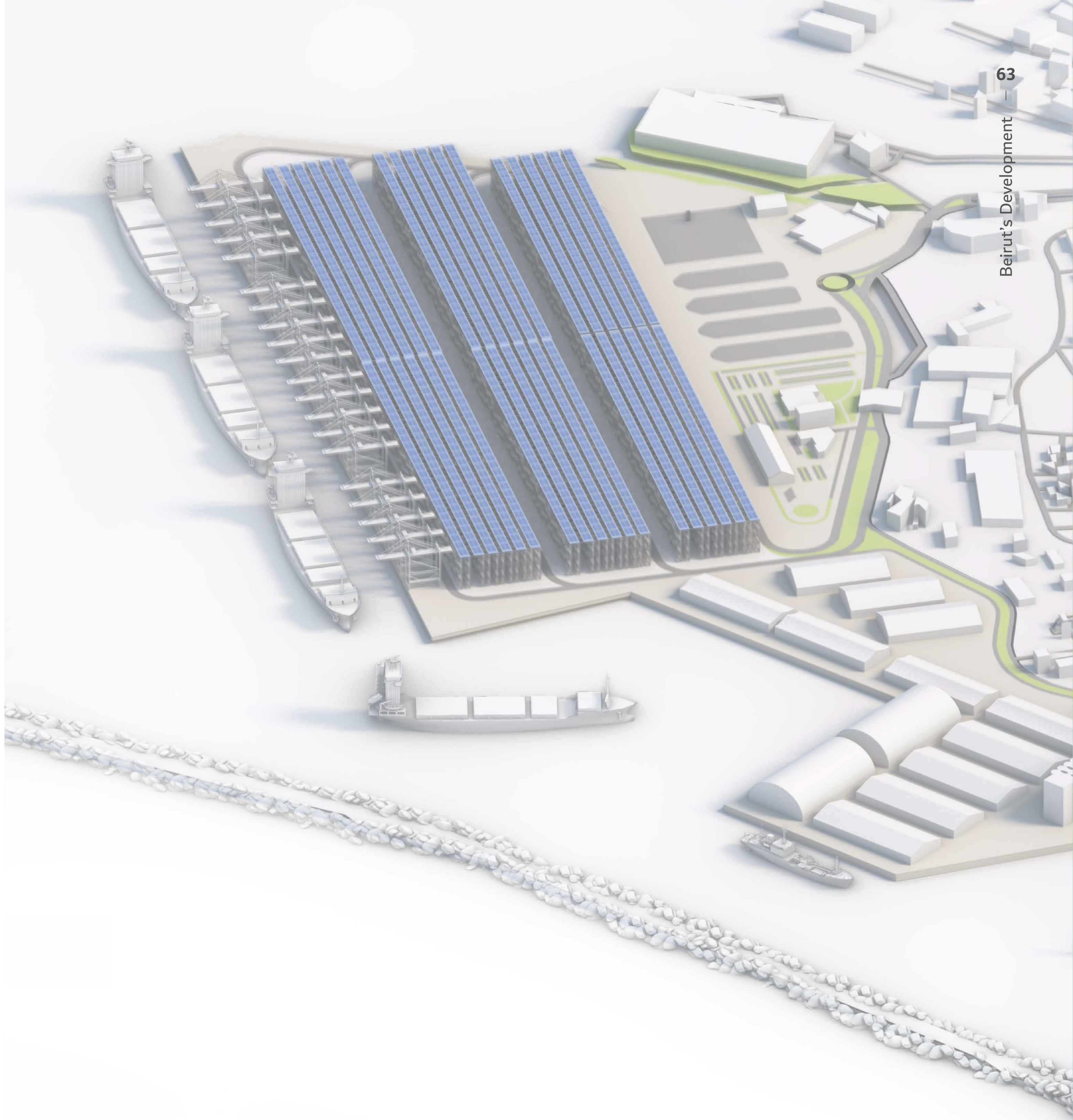
Always Beta

Smart ports are a new and exciting development in the world of logistics and operations. They offer a range of benefits, from increased efficiency to more sustainable practices. One of the key advantages of smart ports is their ability to integrate digitalization and 4th industrial revolution (4IR) technology, such as AI, IoT, Cloud, Big Data, and Blockchain. These technologies can help ports cope with changing environments and requirements, and ensure that they remain competitive in an increasingly digital world.

Another benefit of smart ports is their ability to support the blue economy. This concept refers to the sustainable use of ocean resources, and includes sectors such as tourism, marine biotechnology, renewable energy, fishing, and maritime transport.
However, in order to be successful, smart ports must prioritize adaptability, sustainability, and community engagement. This means building facilities that can evolve and change over time, in response to the needs of the community and the changing demands of the market. Finally, community engagement is crucial, as it ensures that the needs and concerns of local residents are taken into account and that the port is seen as a positive and valuable asset to the community. [3]

Modern Solutions

A key feature of our design was to create an energy efficient port. We did this by utilizing solar panels on roofs, using fully electrically driven machinery with power regeneration and automized systems reducing the need for carbon-powered, human controlled machinery. This technology allowed us to limit the land use of the container port, resulting in a smaller terminal footprint which introduced more flexibility. A variety of solutions on the market are made expressly for this purpose, one of which is BOXBAY it allows terminal operators a more sustainable use of the limited space in ports. Their High Bay Storage solution enables capacity increases without the need of extra land by extending storage space vertically instead of horizontally. We also foresee employing green wall cladding which both enhances the aesthetic appeal by introducing more nature but also helps improve air quality and mitigate the urban heat island effect. [4]



References:
[1] 13 Smart Port Benefits to Increase ROI, Safety, and Smarter ...
[2] What is a Smart Port? - Port Technology International
[3] SOLVED: What Is a Smart Port? Port Digitalization - Sinay
[4] https://www.boxbay.com/

7th Annual

INSPIRELI AWARDS

CERTIFICATE

FOR

FINALIST

Lorenzo Bavelloni
Margrét Halla Valdimarsdóttir

in Category: ARCHITECTURE

AIA International Region

The American Institite of Architects Continental Europe hereby wishes to congratulate you on your outstanding achievement with a formal invitation to join our institute upon successful completion of your diploma in architecture.

Ing. arch. Otto Dvořák	Ing. Karel Smejkal, Ph.D.	Lester Korzilius, FAIA, RIBA	Arch. Victor Leonel Miguel
AIA Chairman of the INSPIRELI AWARDS jury	Intl Assoc. AIA President of the INSPIRELI AWARDS	President, AIA International Region	President of the Africa Union of Architects

CTU in PRAGUE, 2022

7th Annual

INSPIRELI AWARDS

CERTIFICATE

FOR

FINALIST

Lorenzo Bavelloni
Margrét Halla Valdimarsdóttir

in Category: URBAN DESIGN

AIA International Region

The American Institite of Architects Continental Europe hereby wishes to congratulate you on your outstanding achievement with a formal invitation to join our institute upon successful completion of your diploma in architecture.

Ing. arch. Otto Dvořák	Ing. Karel Smejkal, Ph.D.	Lester Korzilius, FAIA, RIBA	Arch. Victor Leonel Miguel
AIA Chairman of the INSPIRELI AWARDS jury	Intl Assoc. AIA President of the INSPIRELI AWARDS	President, AIA International Region	President of the Africa Union of Architects

CTU in PRAGUE, 2022

ARCHITECTURE

ARCHITECTURAL CONTEXT BEIRUT

The architecture of Beirut is characterized by a unique blend of ancient and modern styles, with influences from Ottoman, French, and Arab cultures. Having passed through the hands of so many different inhabitants, it is only natural that the city's landmarks bare the fingerprints of each of its residing populus. Each change of power saw the need for a new defining landmark, and each landmark made its mark. This, among other factors, made Beirut a hotspot for innovations in architecture and placed it among the forefront of the world's cities with respect to intellectualism, design and culture. Beirut has also drawn the attention of modern designers e.g., Herzog & de Meyron, Soma Architects and Zaha Hadid have recently turned their eyes towards the thriving city. Beirut boasts a diverse range of buildings, from traditional Lebanese houses to contemporary high-rise towers. [1]

The materials used in Beirut's architecture also vary widely, depending on the era in which the buildings were constructed. Traditional Lebanese houses were typically built using stone, while more modern structures are often made of concrete and glass. The use of modern materials has enabled architects to create innovative designs that have transformed Beirut's skyline. [2]

At first glance the buildings portrayed on the right seem relatively disconnected design wise. Upon further analysis certain elements appear which create a more cohesive image. In a way the speak the same architectural language, from the Roman Beirytus to Lina's Stone Garden one can discern a methodical rythm to the interplay of volumes and voids.

This corner stone of design can often present a balancing challenge, especially in warmer climates but we immediately felt it was a feature we wanted to wrestle with and these references gave us a deep understanding of the panorama we were creating an addition to.

References:

[1] https://architizer.com/blog/inspiration/collections/modern-beirut-architecture/

[2] https://www.aub.edu.lb/nyo/news/Pages/The-Beiruti-Building.aspx

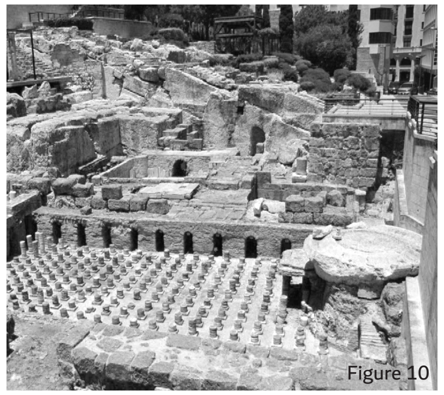


Figure 10

Roman Berytus (Roman Baths), 1st century AD

Figure 11

Bayt Beirut Ruin, Youssef Aftimus, 1924

Figure 12

Nejmeh Square, Camille Duraffourd, 1926

Figure 13

Sursock Museum, Jean-Michel Wilmotte, 1961

Figure 14

Holiday Inn Beirut Ruin, André Wogenscky, 1971

Figure 15

Beirut Souks , Shopping Mall, Rafael Moneo, 1995

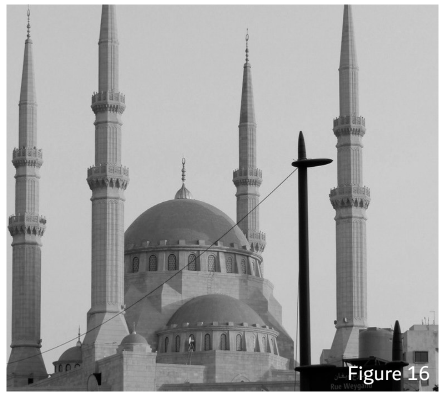


Figure 16

Mohammad Al-Amin Mosque, Ottoman Architecture, 2008

Figure 17

Beirut Terraces, Herzog & de Meuron, 2009

Figure 18

Issam Fares Institute – American University of Beirut , Zaha Hadid Architects, 2014

Figure 19

Plot # 1282 ,Bernard Khoury ,DW5, 2017

Figure 20

Stone Garden Apartment Building, Lina Ghotmeh Architecture, 2020

Figure 21

Beirut Port Silos Ruin, 2020

ARCHITECTURAL REFERENCES

Cube and the Box

“Simplicity can be quite complex” a statement which seems paradoxical but portrays a very important truth. As mentioned above, Beirut is in great need of new development particularly because of the housing crisis exacerbated by the explosion. This coupled with the coupled economic constraints necessitates the use of efficient solutions. As part of the process we felt it necessary to deepen our understanding of Beirut's architectural history and explore the adventures of others into the concept of simplicity in architectural design. Our first foray into the space was an investigation of the perfect cube, a form comprised of six surfaces, each with the same side lengths and 90° corners. We pondered how best to incorporate this alluring, simple form without designing something boring, uninteresting and uncreative. This was a great challenge to overcome before starting the design process, as we wanted our building to circumscribe simplicity, with a twist.

A space defined by right angles is in a sense perfectly poised to minimize wasted space, another key principle of our goals. Furthermore, our building should be relatively straight forward to manufacture and construct. Modular design accomplished these two goals and brought the further advantages of cost efficiency, increased sustainability, and providing the option of flexible redesign in coming years. Mass production, standardization and the modular systems present in modern building technologies create a perfect ground for sustainable building solutions without hindering interesting, technical simplicity of construction.

The cube is the perfect form to unify ergonomics and economics. Before venturing into the third dimension, we explored the second, we used the square to form a grid which gave us the floorplan and perimeter of our building. The bounded form gave us a strong foundation to experiment with the extrusion. Simple design can create complex and interesting spaces which is why we decided to continue with the idea of the cube and the grid. Rather than escaping its boundary, we embraced its limits and approached each frame as a tabula rasa for our creativity. [1] [2]

Cubic Block and Rational repetition

We began our journey into the cube by investigating Modena Cemetery. At the center of the cemetery, one is met with a big, terracotta colored cube which functions as an ossuary. The clear lines and rhythmic placement of the openings are an instant identifying characteristic.

There is a clear contrast between the solid and the voids. The empty holes in Rossi's cube, even though square, have been said to be analogues to the empty round holes in the Roman tomb. [3]
It is very interesting how Rossi, with his simple form of solidity and voids can be so poetic in the concept of death. With the cube he is somehow able to invoke so many ideas and contemplations.
We encounter a very interesting spatial shape in Rossi's cube where the perimeter is very clear, but still he was able to reach much further through his marriage of space and death within the openings of the building. [4]
(Figure 22, page 71)


Figure 22


Figure 23


Figure 24

ARCHITECTURAL REFERENCES

Another interesting cubic building which we decided to analyse is the Casa del Fascio. The building is located in Como, Italy and is considered one of the masterpieces of Italian Modern Architecture, designed by the Italian architect Giuseppe Terragni. The building was planned within a perfect square, the height of the building is half of the width, so it is in a way the half of a cube. Even though the four facades of the building are equal in size they are quite diverse with respect to the contrast between solids and voids. Each side clearly indicates the function and internal layout of the building. There is however a very logical rhythm to the building and the use of the same materials gives lends it a strong self-coherence. [5]
(Figure 24, page 71)

We found it very informative to compare Rossi's and Terragni's cubes. They both have strict rhythmic elements, however they manage to be playful at the same time, each giving their own interpretation of the cube.

Mass subtraction, Openings and Daylight

Looking at Beirut's architectural diversity we were astounded by Lina Ghotmeh's architecture which was exposed at the Architecture Biennale 2021 lead by Rem Koolhaas. The building is a 4200 m2, mixed-use tower, which houses an art gallery, residential-, and commercial functions. It's situated in an industrial area by the harbour, in great proximity to the center of the blast, but somehow it withstood the explosion. What makes it so interesting is the playfulness of the solids and voids, especially how the differently sized windows grant it enhanced depth. The materialistic/textural effect which comes from a mixture of cement and local soil, which was hand-combed by artisans gives the building a stunning aesthetic, enabling the solid to have even greater complexity and depth. The choice of materials gives one the feeling that the building just rose out of the earth lending a tactile connection to nature. The contrast between the voids and solid gets even more interesting with Lina's addition of vegetation to the balconies. This building was a strong inspiration to us while designing our building. [6]
(Figure 28, page 75)

As suggested by our discussion so far, we felt it was important for us to understand the contrast between the solid and voids before we began experimenting with it. Our third subject was the Therme Vals by Peter Zumthor. Its openings helped us find the balance between volumes and voids. We wanted to induce a feeling of an inviting ground floor which guided people effortlessly to the entrance. This was ascertained by introducing a grand entrance to the building which had a double height and was partly sheltered from the sun, which also gave a playful effect.
(Figure 26, page 73)

Another important reference for the openings on the ground floor in our building was deeply inspired by Aravena's office building in the Novartis Campus in Shanghai.
(Figure 25, page 73)

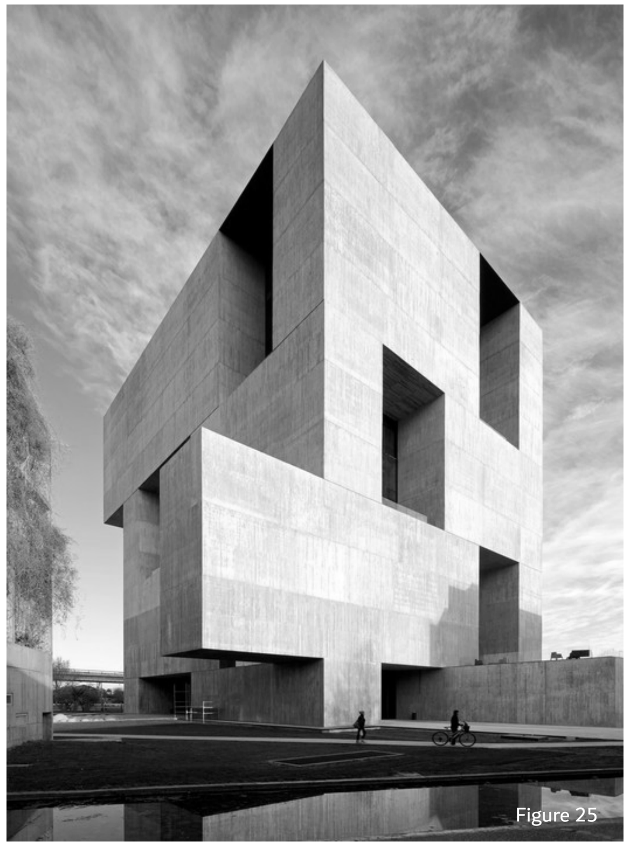


Figure 25


Figure 26


Figure 27

ARCHITECTURAL REFERENCES

Rationalism vs Deconstructivism

Our final example, the last piece of the puzzle, led us in the exploration of rationalism versus deconstructivism. The Zollverein Cube, a white cubic structure designed by the Japanese architectural duo SANAA, is very interesting and effortlessly draws the eye. It's defining characteristic is the playfulness of the voids and the windows. At first their placement may seem random or purely aesthetic, but their size and placement are in fact dictated to a large extend by their functions. The building houses, amongst others, a library, computer workstation, conference room, each with openings carefully chosen to suit each room. The placement is intriguing, it invites curiosity as to why they are placed as they are. The façade is also so interesting as you don't notice that the cube spans multiple levels, it looks like a giant cube with no separation, this gives a feeling of mass, which is further highlighted by the concrete. Nonetheless, many openings give it more lightness. [7]
(Figure 27, page 73)

Deconstructivism is neither a completely novel style, nor an objection to architectural norms. It is not characterized by any "rules" of specific aesthetics. It is, perhaps most succinctly put, "the unleashing of infinite possibilities of playing around with forms and volumes". [8] [9]

Some further references we explored to a lesser extent are the following: De Rotterdam (Monumental Voids), Blox (Overlapped program) , Norra Tornen (Modularity and durability), Timmerhuis (Pixellated grid). (Figure 29, page 75)

In the case of Beirut, the city's diversity and traumas can be expressed through deconstructionism, which embraces complexity and conflict as part of the human experience. Ultimately, a successful multifunctional building must prioritize adaptability, sustainability, and community engagement in order to meet the evolving needs of the community over time.

Oasis

We decided to name our building Oasis as it rises, resembling a graceful sand dune, from the otherwise low-rise area and as it is decorated with a variety of vegetation, we felt it was reminiscent of an oasis in the desert.

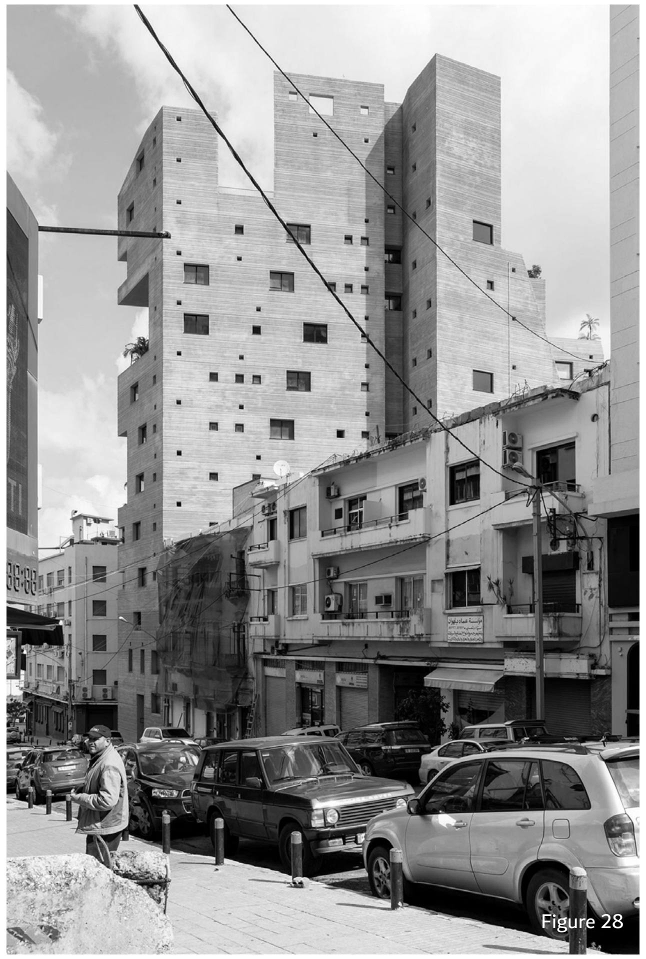


Figure 28


Figure 29

References:
[1] Renier de graft, Four Walls and a Roof: The Complex Nature of a Simple Profession, Inevitable box chapter 9

[2] https://www.architectural-review.com/archive/notopia-archive/the-inevitable-box-architectures-main-achievement-and-its-main-trauma

[3] https://www.jstor.org/stable/989761?seq=8]

[4] L'architettura della città, Aldo Rossi, I Saggiatore

[5] https://www.archdaily.com/312877/ad-classics-casa-del-fascio-giuseppe-terragni

[6] https://www.dezeen.com/2020/10/18/lina-ghotmeh-stone-garden-beirut-architecture/

[7] https://architectuul.com/architecture/zollverein-cube

[8] Deconstructivist architecture. Philip Johnson and Mark Wigley. Author. Johnson, Philip, 1906-2005. Date. 1988. Publisher. The Museum of Modern Art

[9] https://www.archdaily.com/899645/what-is-deconstructivism

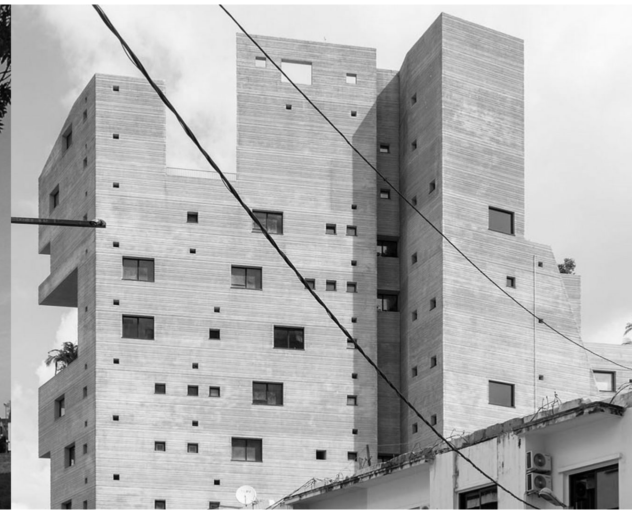
ARCHITECTURAL REFERENCES DIAGRAM

San Cataldo Cemetery, Modena, Italy.
1971
Postmodernism
Aldo Rossi

Figure 30

Thermal baths, Vals, Switzerland.
1996
Swiss Minimalism
Peter Zumthor

Zollverein Cube, Essen, Germany.
2006
Japanese Minimalism
SANAA



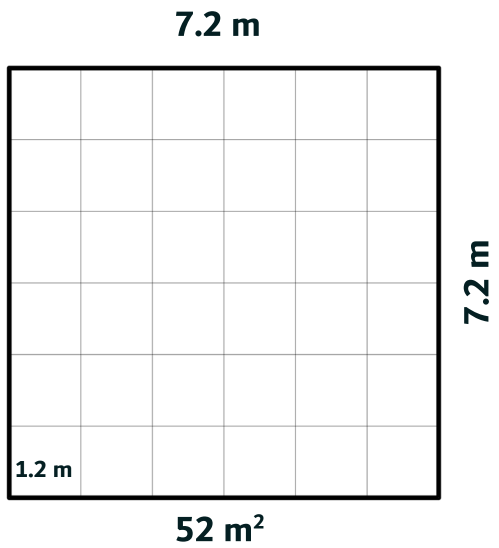
Stone Garden, Beirut, Lebanon.
2020
Deconstructivism/Minimalism
Lina Ghotmeh

Oasis, Beirut, Lebanon.
-
Deconstructivism/Minimalism

GRID

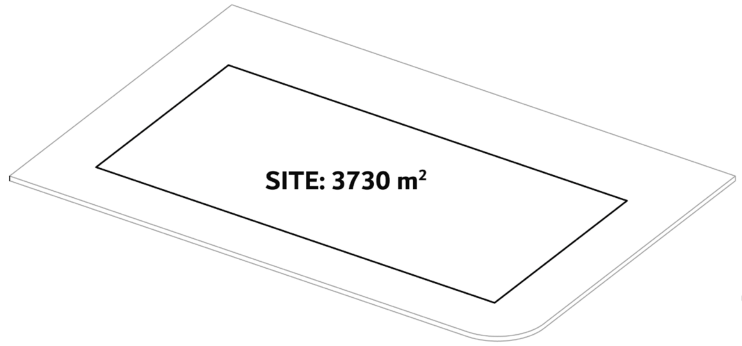
The building's geometry is broken down to a grid of 7.2x7.2 meters. Inside this grid we introduce a sub-grid where the 7.2 meters are divided into 6 parts, each a square with sides of 1.2 meters. This will be further discussed later in the thesis, but it was necessary to design this sub-grid early in the process to understand how we would place and organize the modular panels for the facade. The highest floor is the ground floor, which has a height of 6 meters while all the other floors are 3.5 meters high. The length of the building is spanned by 12 grid cubes, each 7.2 meters long, giving a total of 86.4m. The width is then half this length, or 6 cubes making 43.2m.

The idea of the grid came from our masterplan development in which we used another type of grid for a similar purpose. The site area of our building is a total of 3,730 m2 and it has a strong connection to a large public park. We wanted to create a delicate transition from the natural environment and into the building which gave us the idea of the vertical garden. It was important to us to introduce as much greenery as possible and we could achieve that with the help of verticality.



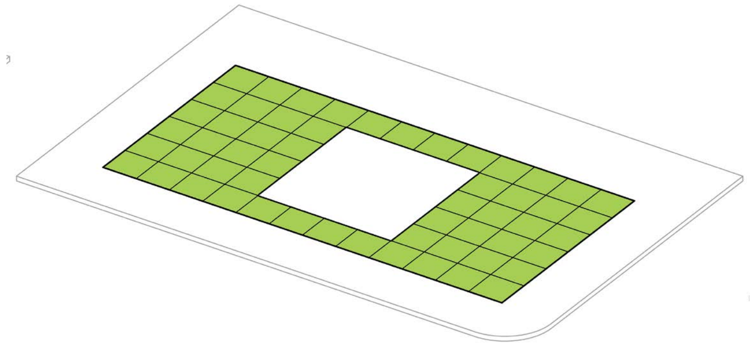
SITE

The site is a total of 3730 m². It is in great connection to a large public park.



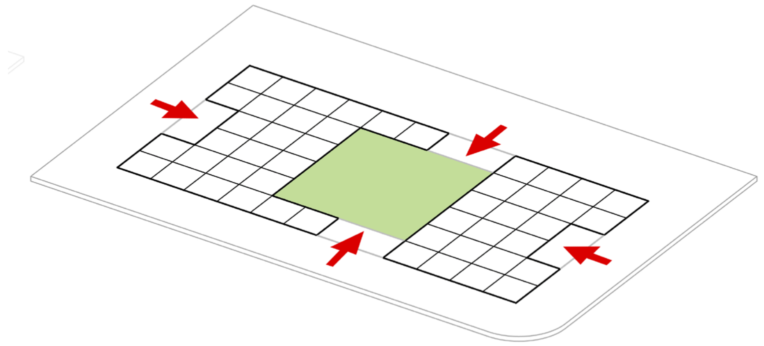
GRID

A grid of 7.2x7.2 m squares was used to form the building.



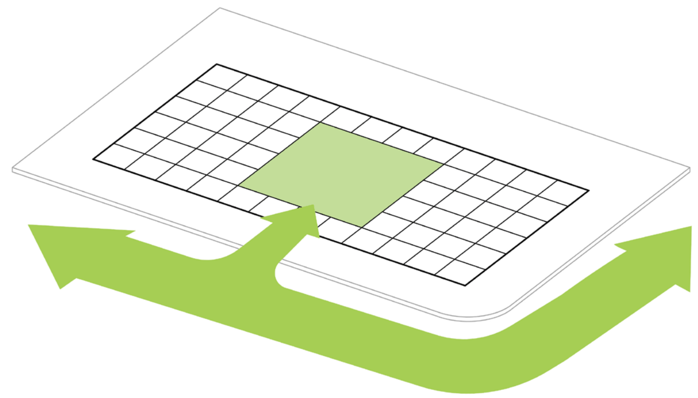
OPENINGS

Openings were created on the ground floor in order to introduce better connection to the surrounding.



GREEN CONNECTION

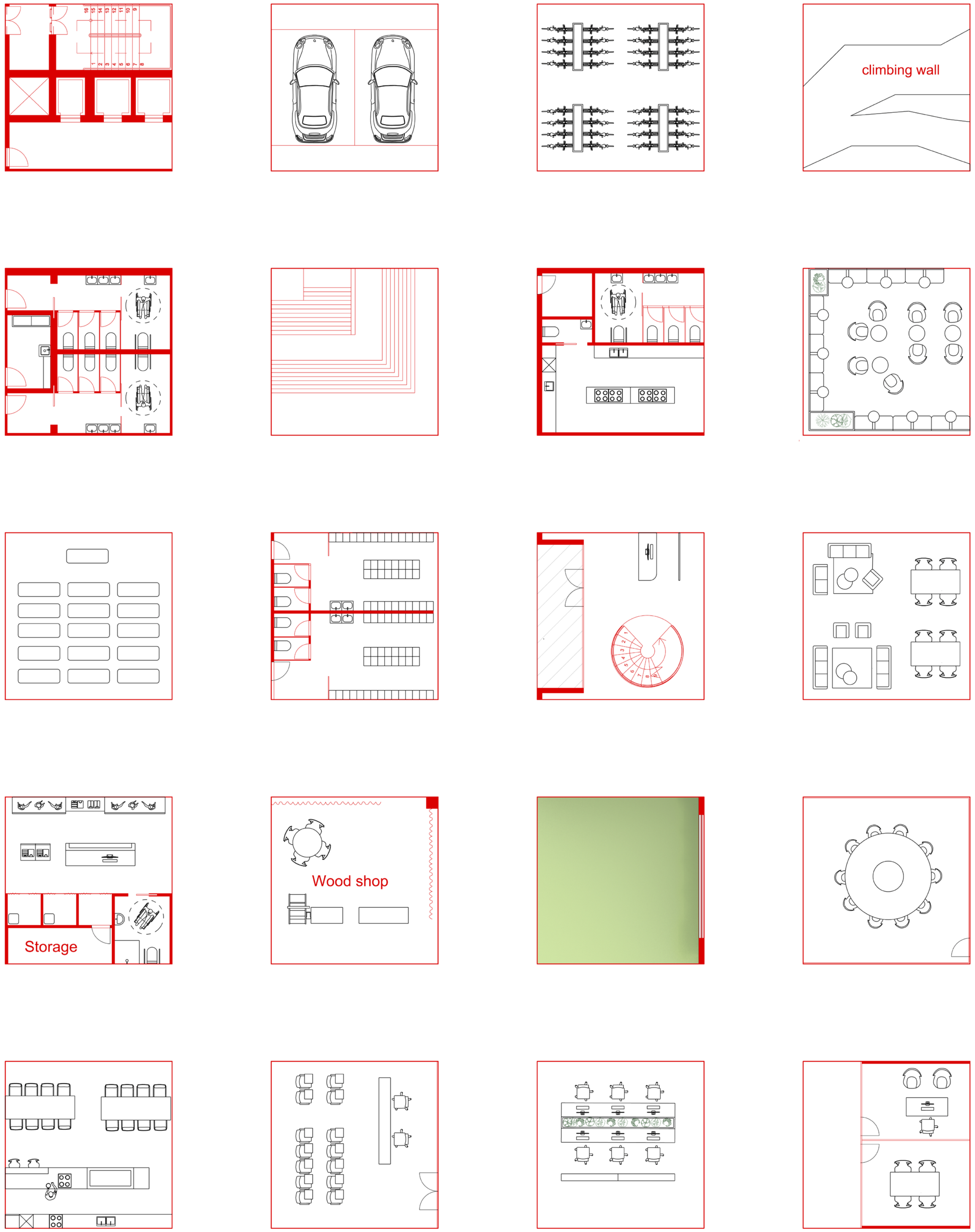
The design includes a big courtyard and many terraces in order to create a delicate transition between the surrounding area and the building.



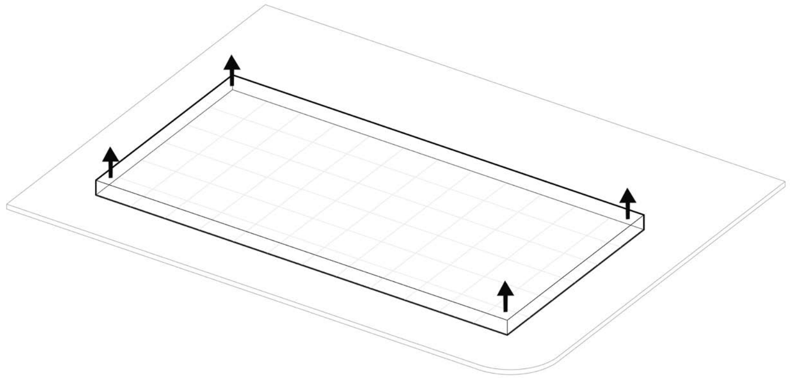
GRID

As the building is quite deep, we wanted to design a big courtyard of 4 x 4 grid cubes which enabled us to bring more daylight into the building. This was a part of our plan for the building from the very beginning, we then further developed it by creating more openings of double height on the ground floor in order to connect it more to the surrounding neighbourhood and create grand openings which gives the building a more dramatic effect. During this transformation we followed the grid carefully and it gave us a better understanding how much volume we could remove or add. In the beginning we started with a fully extruded cube made of smaller cubes of 7.2m. As mentioned earlier, the initial concept was to have a large courtyard which already changed this cube fairly drastically. We then experimented with removing the sub-cubes one by one to find the pixelated shape we were after while making sure that the removal would fit the program, we envisioned for each of the floors.

With the help of the grid, we were able to design the building appearance with the pixelated form we were looking for. The removal of cubes at each floor both enhanced the pixelated appearance and created terraces. We were careful while thinking of the exterior to also think about how it would work in the plan, with all the different functions inside the building. The idea of the grid also came from wanting to create a modular building which could adapt to future changes, and which would be easy to maintain. Following the grid, we managed to plan the interiors and give the opportunity for the spaces to change in functions in the coming years. For example, the residential units could be changed into offices or vice versa. The grid was also fun to play with while designing the plans as each grid cell was given a deep meaning even if it was just placing desks for offices or designing the central core. Even though we followed this rigid grid we introduced flexibility in the plans, for example with the open floor plan system of the offices there is great possibility for adaptation of each inhabiting company. The sub-grid was used to plan and design the façade, and this also helped us understand where to place the windows with maximum impact. This was also very important to follow in the interior design as daylight has such an immense effect on how spaces are perceived.

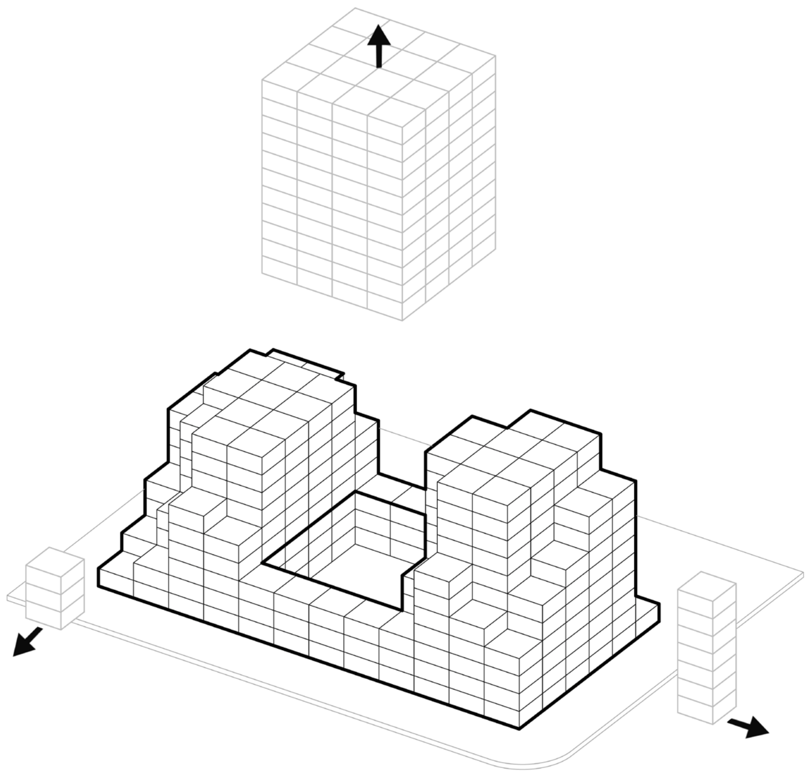


SHAPE EVOLUTION



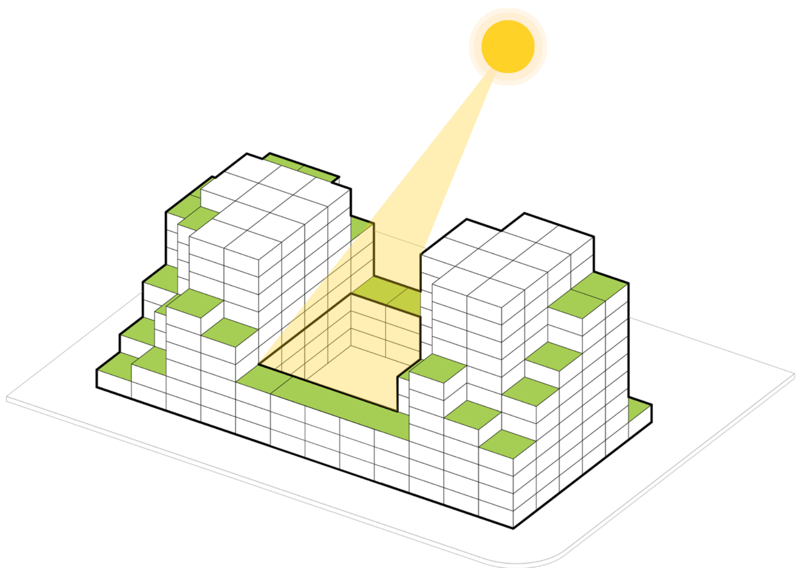
01 EXTRUDE

We used the grid of 7.2 times 7.2 meters to divide the site into different cells. We took great care while orienting the building that it would be in such a manner to minimize the energy expenditure.



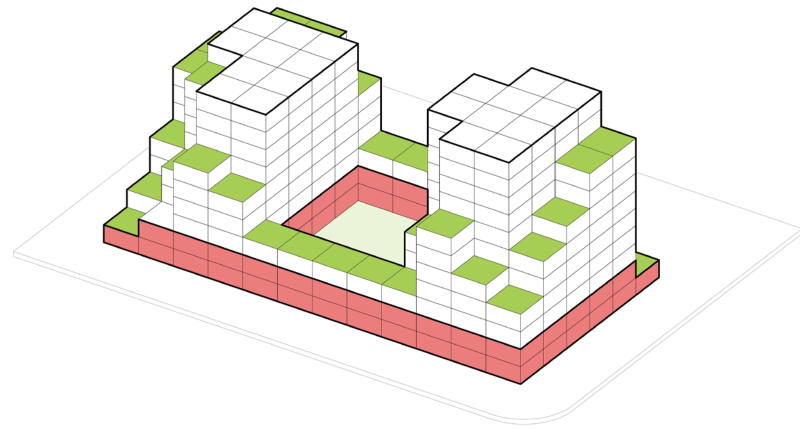
02 CARVE

The next step was to remove the central core from the overall mass in order to design a big atrium which would allow us to maximize the daylight. Addititonal cubes were then removed in order to create terraces.



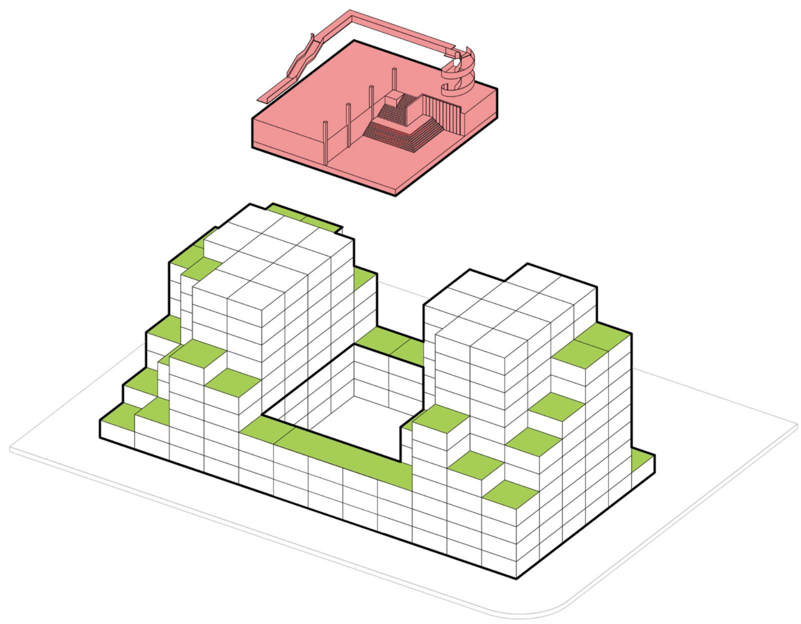
03 DAYLIGHT AND TERRACES

The big atrium helped us to introduce more natural lighting into the building. The terraces will host various plants.



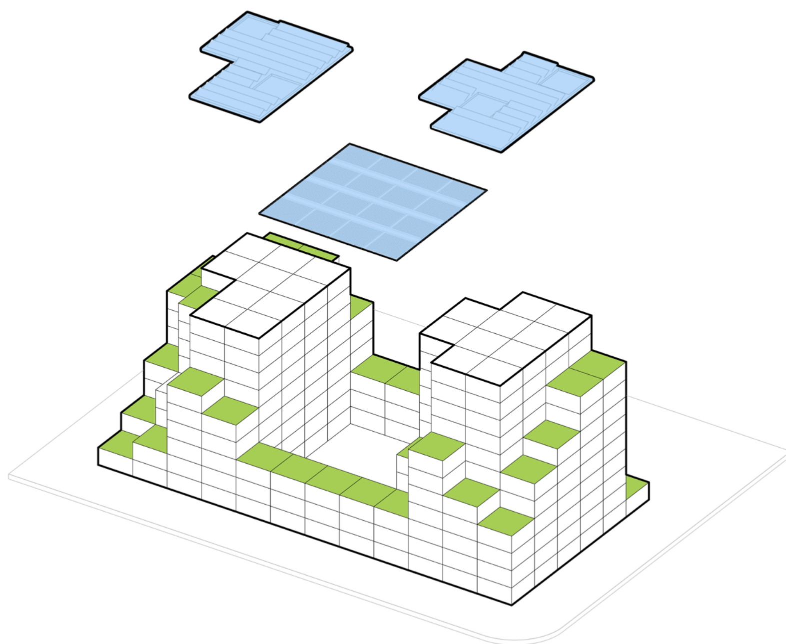
04 ACTIVE GROUNDFLOOR

With an active ground floor we encourage pedestrian movement and enhanced urban experiance.



05 COURTYARD

The courtyard will work as a central navigational part of the building and can be used for numerous activities.



06 SOLAR PANELS

Solar panels were added on the roof and also over the courtyard to provide an internal source of energy.

SITE PLAN

Location:

The site is located in Beirut Port, which is situated in the western part of the city, overlooking the Mediterranean Sea. The site is easily accessible by road and sea transport, which makes it an ideal location for a multifunctional project. However, it is essential to consider the impact of the busy port area on the site's development.

Site Characteristics:

The site is relatively flat and rectangular in shape, with a total area of several hectares. The site's grid system-based master plan can provide an efficient use of the available space, considering the large complexity and size of the project. The project's first phase will include a combination of offices, residential buildings, agricultural land, and parks. The agricultural system, in particular, will create new jobs and opportunities for research and economic improvement while utilizing the available land close to the sea.

The agriculture close to the seacoast of Lebanon typically involves the cultivation of crops that are adapted to the Mediterranean climate, such as olive trees, citrus trees, grapes, vegetables, and almond trees. Traditional farming techniques and organic farming practices are often used to maximize land use and maintain soil health. [1]

Site Divisions:

1. Offices-Research Lab Plot: This plot will house the project's administrative offices and research labs.

2. Residential-Offices Plot (Building): The residential and office buildings are the primary functional spaces of the project.

3. Energy Biomass Crops: This division will focus on cultivating crops specifically for producing energy.

4. Automated Farming: The automated farming division will utilize advanced technology to cultivate crops with minimal human intervention.

5. Selections of Fruit Tree: This division will focus on cultivating fruit trees.

6. Agricultural Land: The agricultural land division will use traditional farming techniques to cultivate crops.

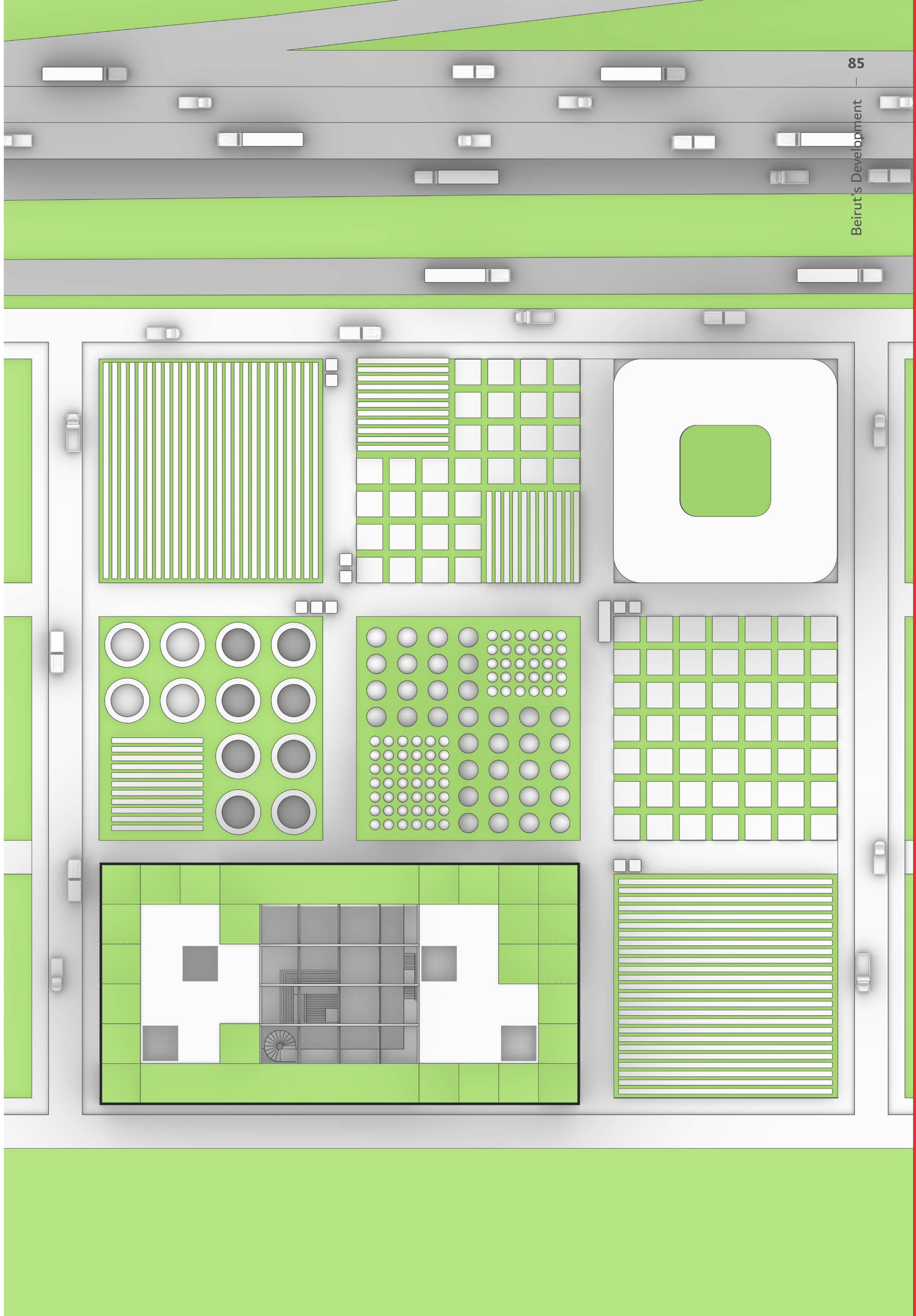
7. Farming for Residences: This division will focus on cultivating crops specifically for the residential buildings.

8. Parks with Sports Functions: This division will provide open green spaces for leisure and sports activities.

Overall, the site analysis suggests that the project's grid system-based master plan will provide an efficient use of the available space. Careful selection of locations for each site division can ensure optimal functionality and collaboration among the various components of the project. Additionally, the integration of the agricultural system can contribute to the project's economic growth and research opportunities.

References:

[1] https://www.sciencedirect.com/science/article/pii/S2212682112000078



PROGRAM

As urban areas continue to grow and evolve, the project program design has to meet the changing needs of communities while still respecting local traditions and culture. This is particularly true in cities like Beirut, where a complex mix of cultural and historical influences has created a unique urban landscape.

One approach to designing buildings that can adapt to changing needs while still respecting community traditions is to create multifunctional structures that can serve a variety of different purposes. By incorporating municipal services, offices, and residential units into a single building, in order to create a dynamic and flexible structure that can respond to the needs of the community over time.

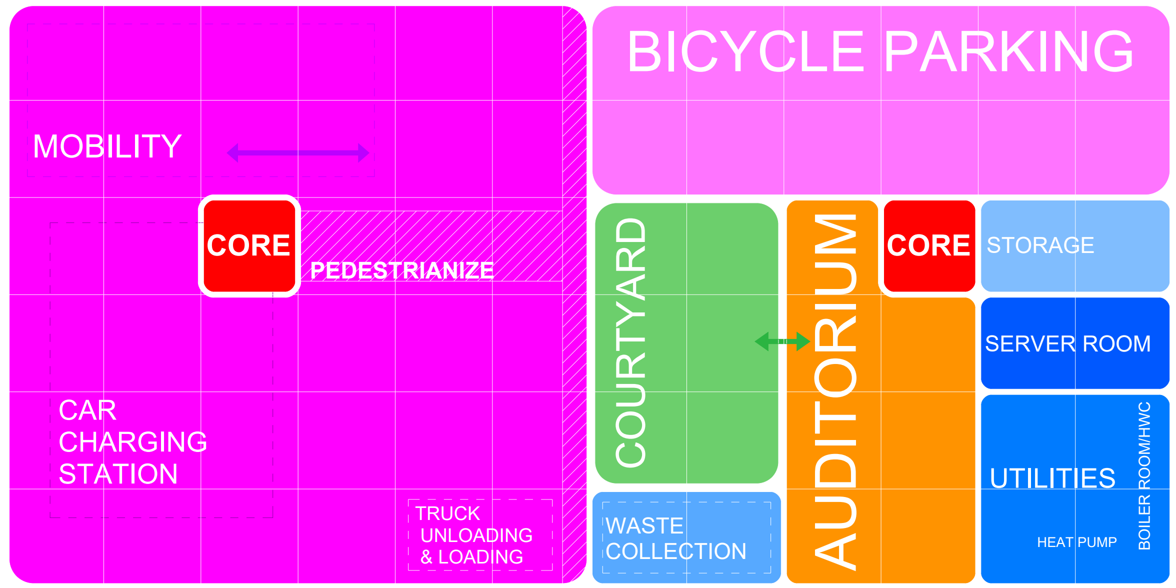
Our program works in synergy with the structural grid. This system is based on a modular design that allows for easy expansion and adaptation, making it an ideal choice for buildings that need to be able to evolve over time. The modular design also allows for efficient use of space, which is especially important in densely populated areas like Beirut. In addition to adaptability and sustainability, community engagement should also be a key consideration in the design of multifunctional buildings.

The program analysis was shaped by local residents needs and preferences, and to ensure that the building serves the community in a meaningful way.

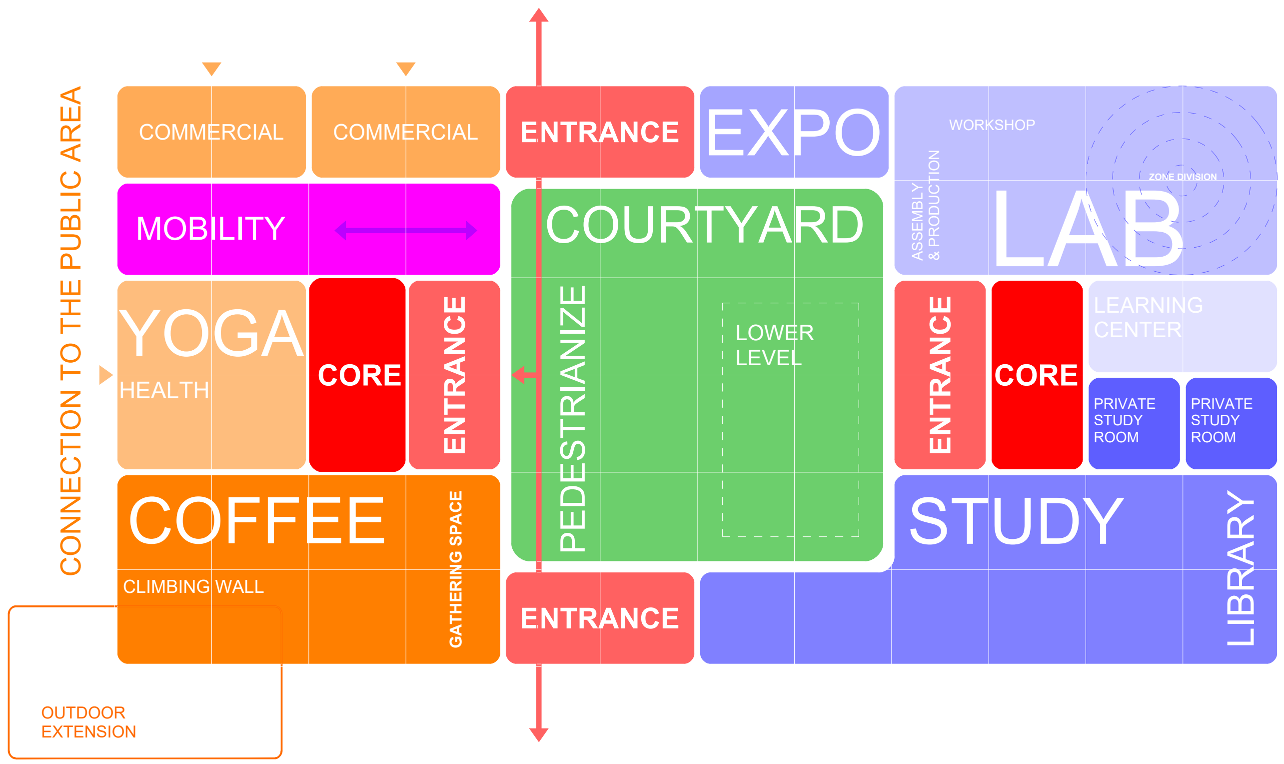
One way to achieve this is by designing smaller cells within the larger structure that are tailored to specific community needs. For example, a residential cell could be designed to meet the needs of families, while an office cell could be tailored to the needs of small businesses.

When viewed from the Beirut port, these smaller cells can come together to form an impressive and cohesive structure that reflects the community's unique character.

By designing structures that are flexible, sustainable, and community-oriented, architects and urban planners can create buildings that are not only functional but also meaningful and impactful. As Rem Koolhaas emphasized in his program analysis of Delirious New York, it is important to consider the social and cultural context in which a building is situated in order to create structures that truly serve the needs of the community.



BASEMENT



GROUND FLOOR

PROGRAM

RESIDENCE:
7940 m2
Student housing: 880 m2
Apartments: 7060 m2

STARTUP:
1090 m2

OFFICES:
3160 m2

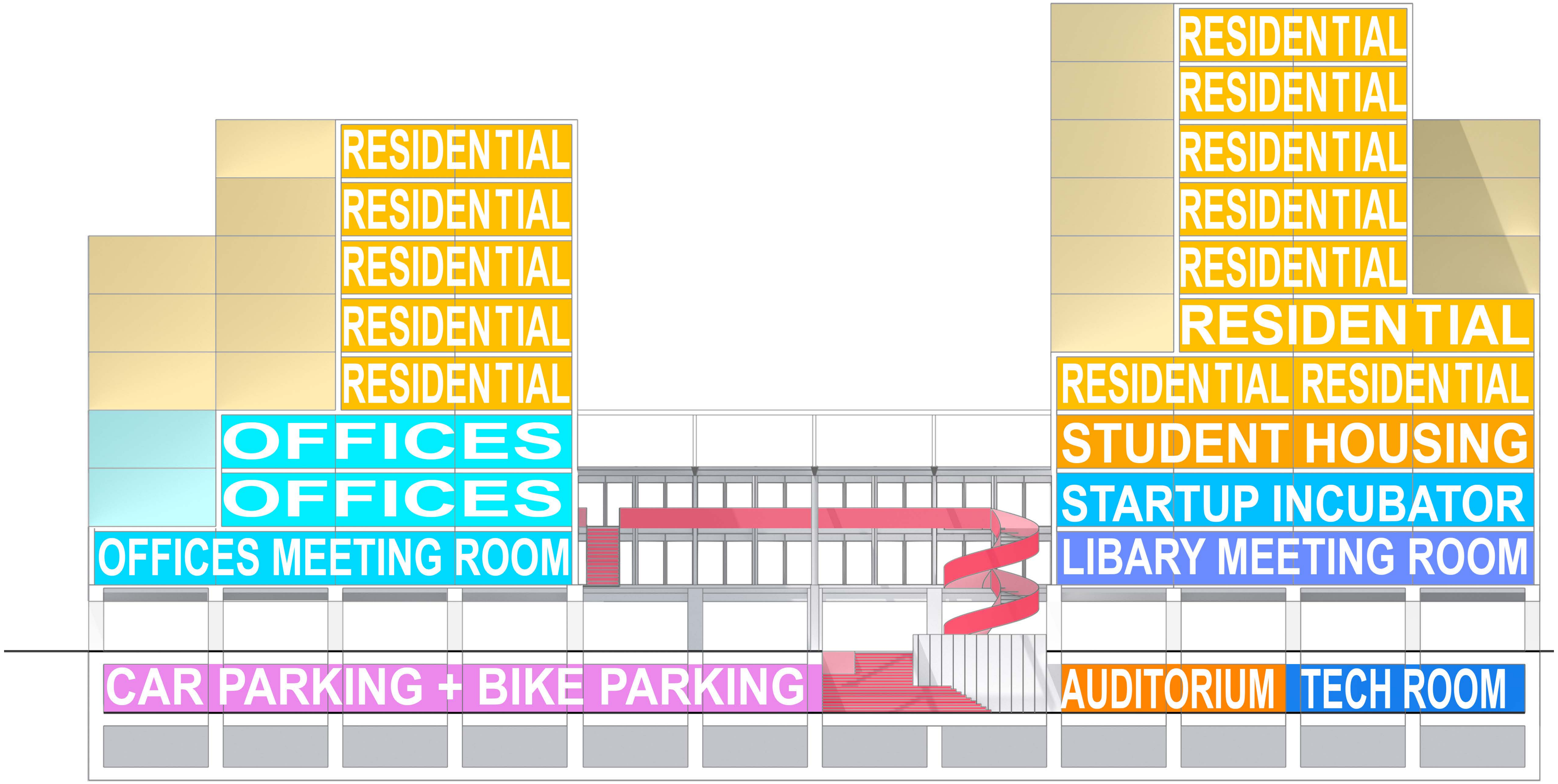
LEARNING CENTER
& LAB: 1900 m2

LEISURE/COMMERCIAL:
1490 m2

GREEN AREA: 2810 m2
Terraces: 2020 m2
Courtyard: 790 m2

BIKE: 600 m2

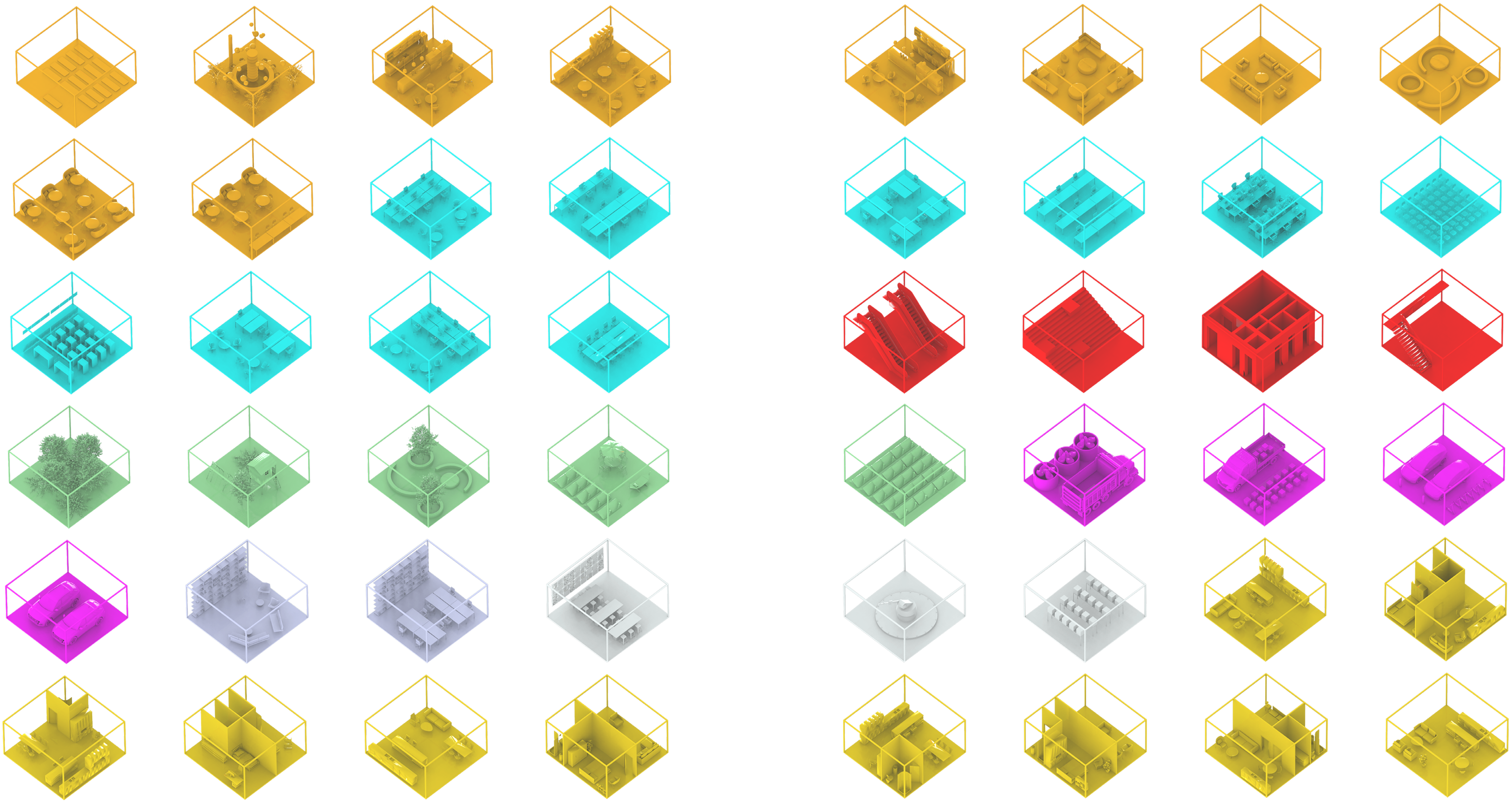
MOBILITY: 5270 m2



PROJECT AREA: 3732 m^2
COURTYARD: 790 m^2

PROGRAM

- LEISURE
- STARTUP & OFFICES
- CORE AND STAIRCASES
- GREEN AREA
- MOBILITY
- LEARNING CENTER
- LABORATORY
- RESIDENTIAL



ATRIUM

The central core of the project is the atrium that stands as the heart of the multifunctional building providing a blend of different spaces and functions within one structure. The atrium combines a central courtyard space with various retail, office or residential spaces around the perimeter. The use of atrium has several advantages, including improved daylight optimization and natural ventilation through stack effect.

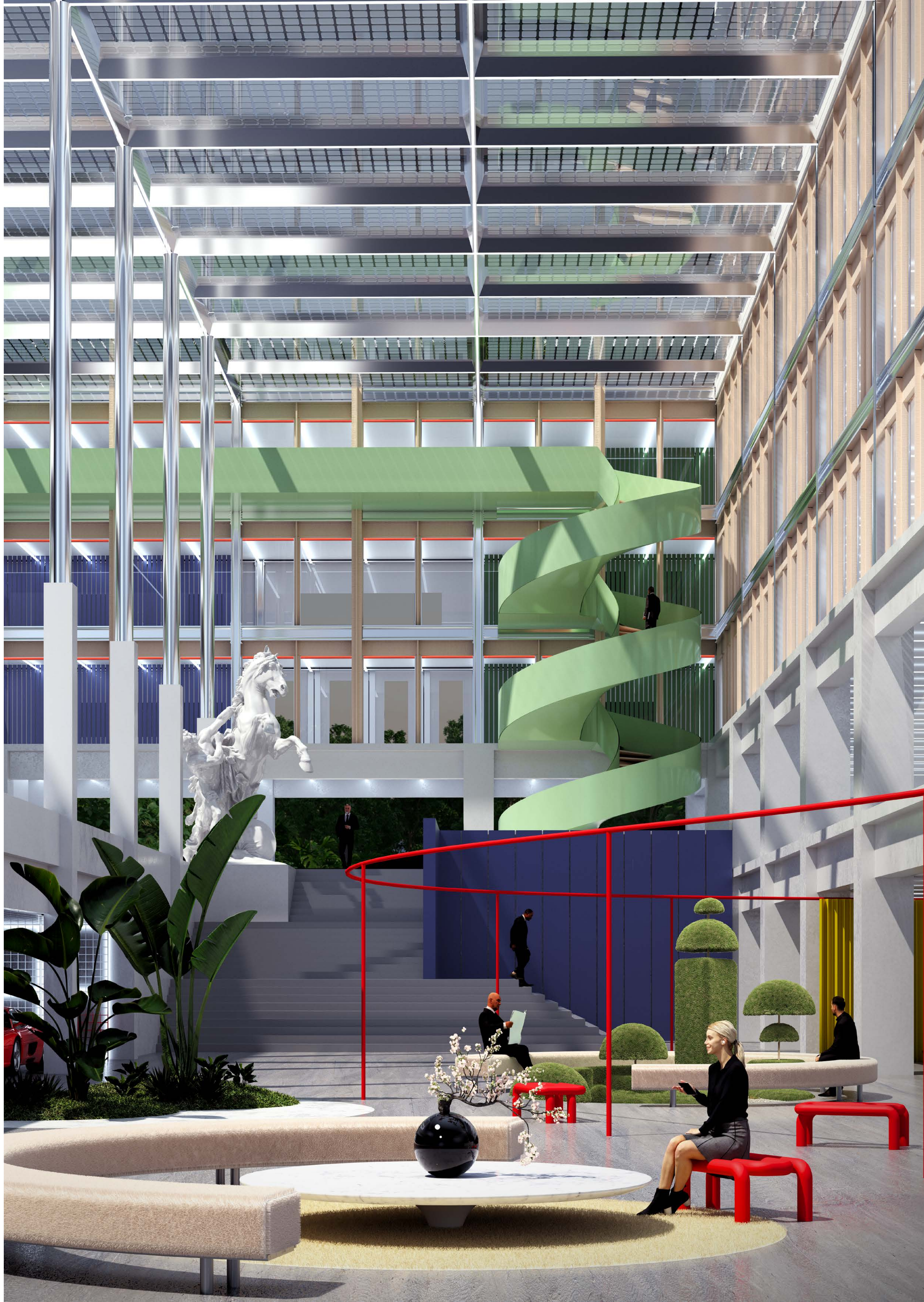
Daylight optimization is a crucial factor in creating a comfortable and sustainable indoor environment. The use of the atrium allows for the introduction of natural light deep into the building, reducing the need for artificial lighting and energy consumption. The central courtyard space of the atrium acts as a light well, distributing natural light to the surrounding spaces. This not only provides a more pleasant working or living environment but also enhances the visual appeal of the building.

Natural ventilation is another key factor in creating a comfortable and healthy indoor environment. One way to achieve this is through stack effect, which is the natural movement of air caused by differences in temperature and pressure. The use of atrium design can help to promote this effect, with air being drawn in at the lower levels of the building and expelled at the upper levels. This provides a constant supply of fresh air throughout the building, reducing the need for mechanical ventilation and improving indoor air quality.

The interior design of the 80's has emerged as a significant source of inspiration. The 80's was a decade of bold colors, geometric shapes, and futuristic designs, which have been updated and reinterpreted to suit modern tastes. The interior design of the 80's is characterized by the use of neon colors, metallic finishes, and bold patterns, which we have incorporated into our atrium design to create a vibrant and dynamic environment.

The use of bold colors is a key feature of 80s-inspired design, with bright pinks, greens, and blues being popular choices. These colors can be used to create a sense of energy and vibrancy within the atrium. Metallic finishes, such as gold and silver, can be used to add a touch of glamour and sophistication to the space, while bold patterns can be used to create interest and texture.

In conclusion, the combination of these elements can result in a multifunctional building that not only meets the practical needs of its inhabitants but also provides an enjoyable and visually appealing environment in which to work or live.



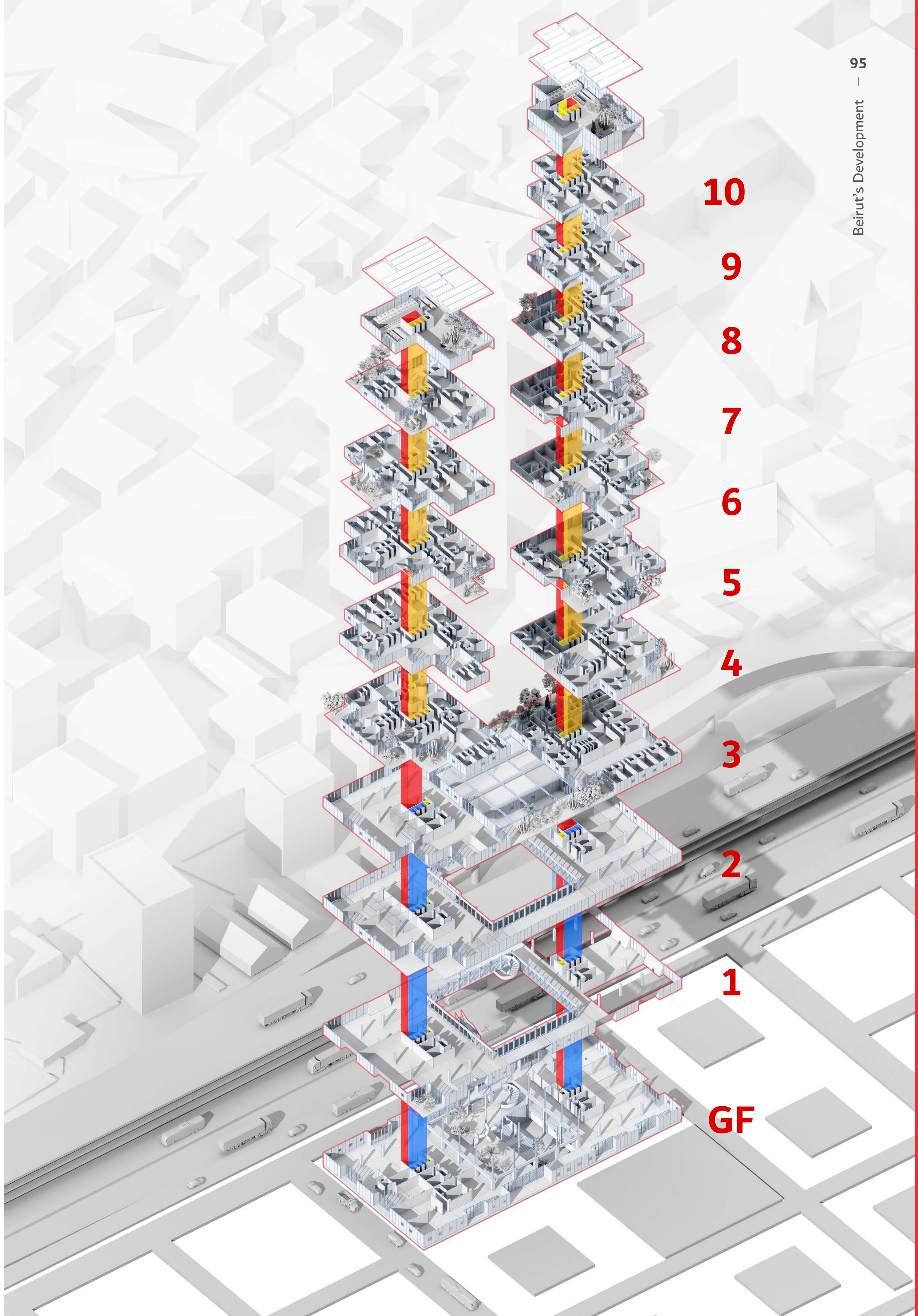
PLANS

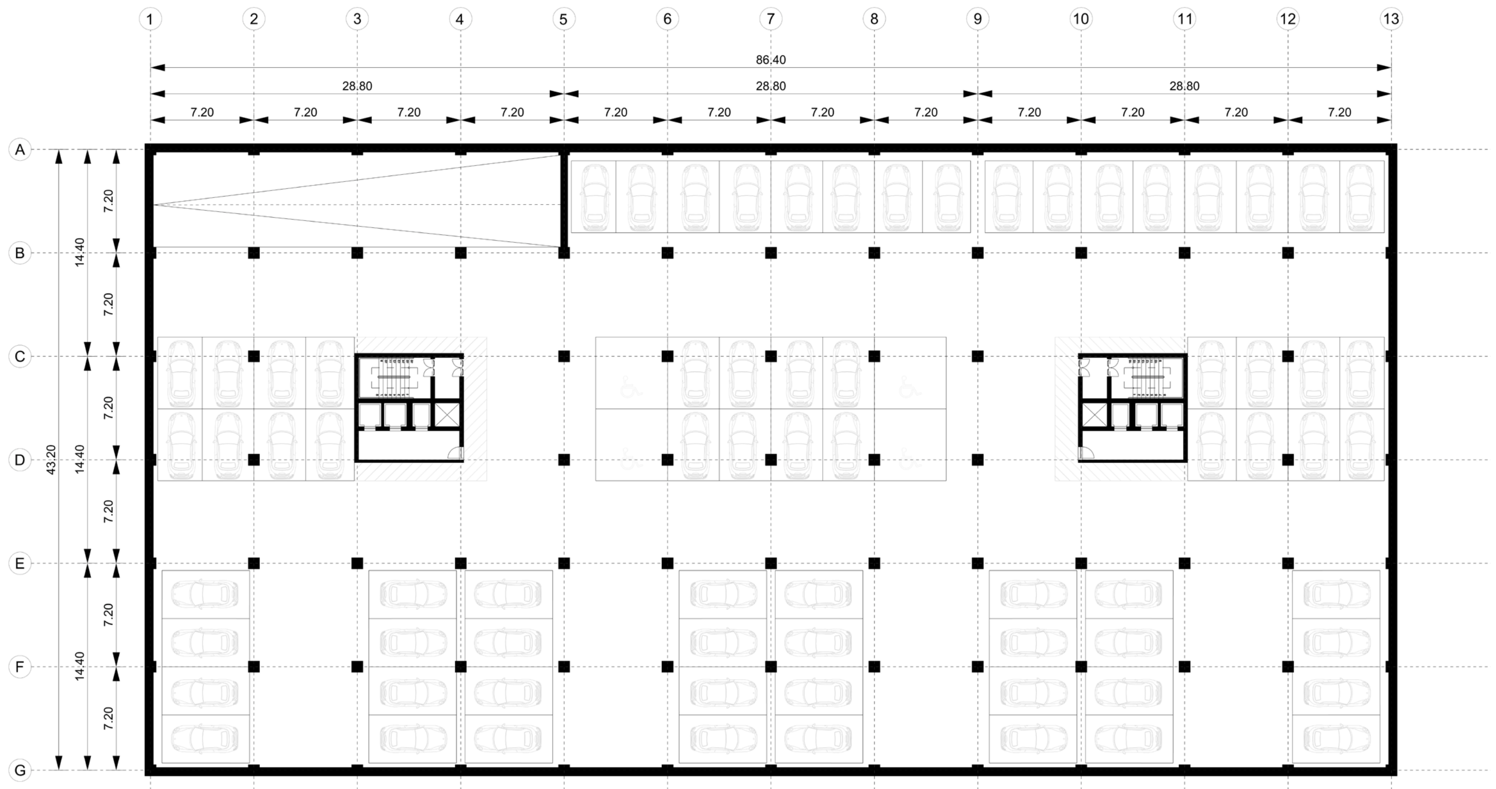
With the help of the 7.2x7.2m unit grid it was easier to organize how to translate the program into the building plans. From the start of the design, the ground floor was intended to house a collection of different functions that would entice a multitude of visitors. Creating a continuity of the surrounding spaces to the inside of our building was paramount to that effect the building has grand openings of double height. Upon entering the building one is met by a large atrium leading to a spacious courtyard which will receive a lot of daylight, which is a great source of natural light to the building. The courtyard not only introduces this light but will also function as a central part of the structure, easing the cognitive load of navigation throughout the building. Furthermore, it will be a place where people can gather on any number of occasions, giving it a diverse role.

As Beirut is sorely lacking greenery the design had to include naturalistic elements such as the trees, bushes and other foliage in the courtyard. We extend this idea of greenery further by introducing terraces on each floor, which will be discussed in greater detail later. The courtyard is divided amongst two floors, the -1 basement grants people entrance to the car park as well as a large auditorium. The auditorium has large glass walls which lends great connection to the courtyard and is partly operable, so it can be extended into the outdoor area. On the ground floor one can visit a large learning center which offers free entrance to a public space to either study or work in. In the learning center there is also a lecture hall that can be rented out for larger events. The building is meant to function as a place fostering creativity, so connected to the learning center there will be a laboratory equipped with various technologies in order to aid people working on a great number of projects. The laboratory is envisioned as the main node of production and development and will be in strong connection to the start-up spaces on the first floor. People working in the lab will also have the opportunity to showcase their innovations in the gallery which is located to the left of the lab.

To further increase diversity of visitors the ground floor will house a café which is not entirely ordinary as it sports a section of climbing walls to create flow and give a different atmosphere throughout the hours of the day. Focusing more on activity and health we also introduce a yoga studio with two differently sized rooms and accompanying changing rooms. There is also a part of the ground floor dedicated to commercial functions.

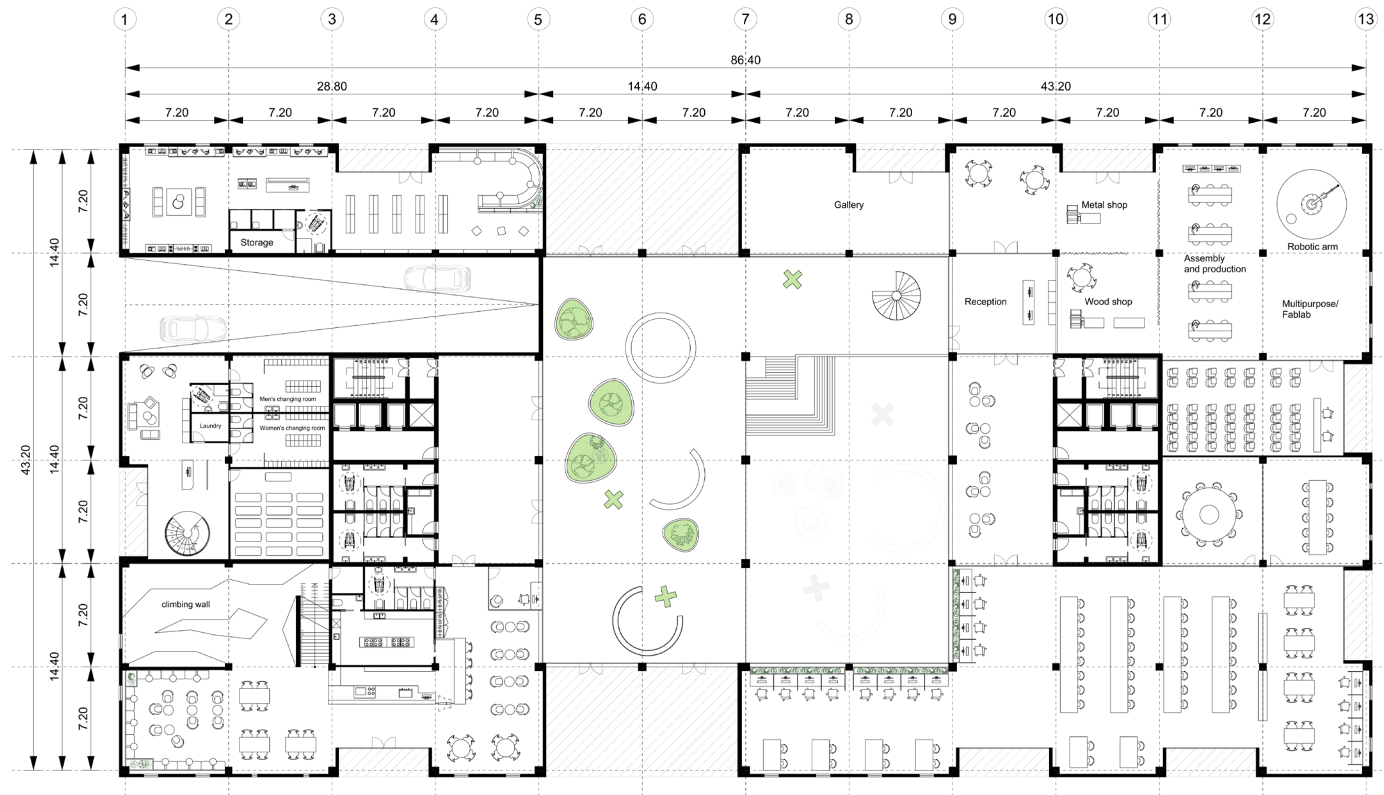
The first floor can be reached through the main cores which in both the West and Eastwing of the building. From the 1st floor to the 4th there are 2 pairs of lavatory spaces that contain 3 stalls and a disabled bathroom as part of the core that are easily reachable from the entirety of each floor. The first floor functions as an extension of the learning center and has a large area dedicated to a start-up incubator. This space contains rentable tables so that budding entrepreneurs have an opportunity to work on their businesses while intermingling, which is known to foster more creativity. The yoga center, the gallery and the coffee house also take up part of the first floor. The coffee house can be further extended to the terrace.



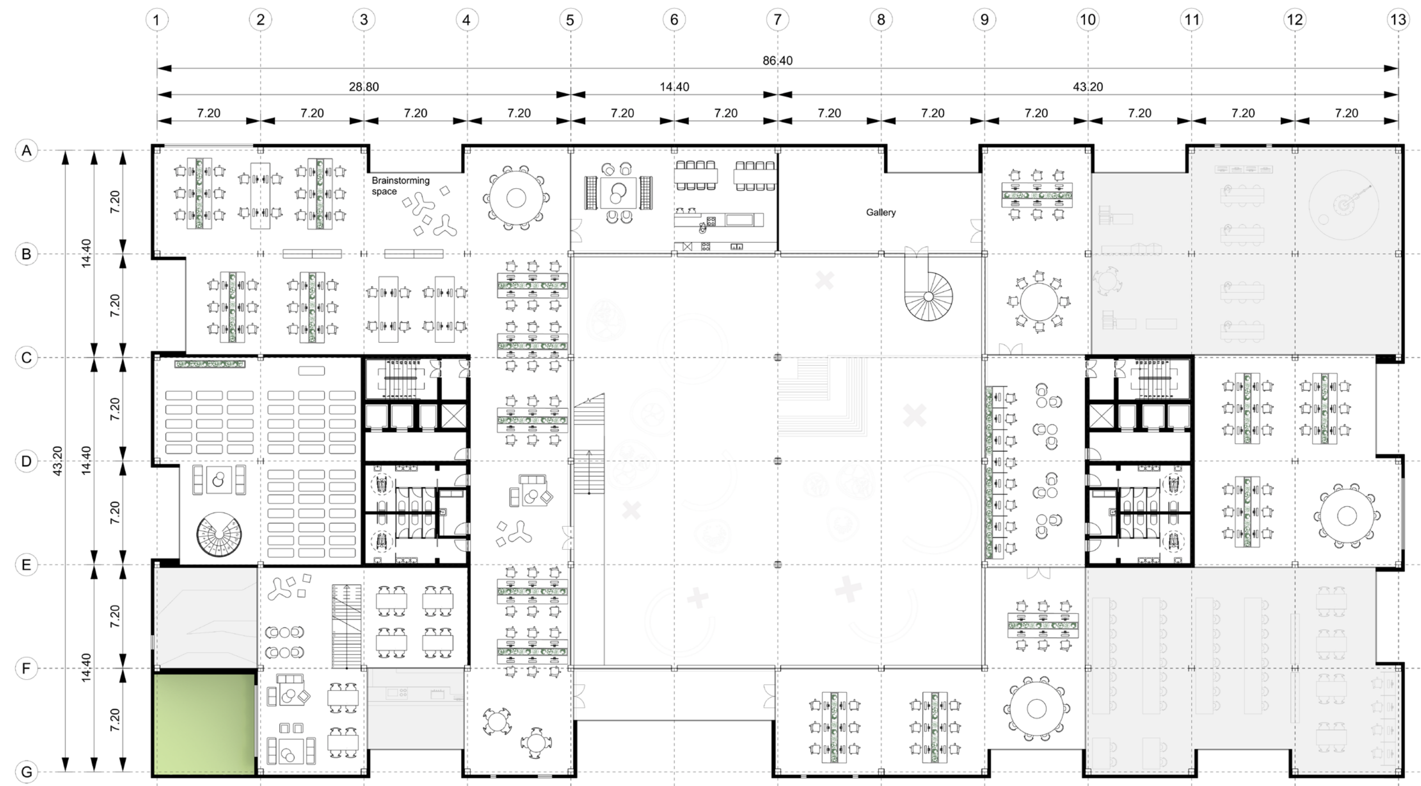


BASEMENT -2

BASEMENT -1



GROUND FLOOR



1ST FLOOR

PLANS

The second floor is reserved for offices and will have an open floor space encouraging more interaction between people. There are designated meeting rooms that are available to everyone by means of a shared scheduling system. There are also small rooms which will be quiet zones for those who want to work in a more secluded environment. The offices have access to green terraces, enhancing a closeness to nature has been proven to have a positive effect on mental health and increase productivity.

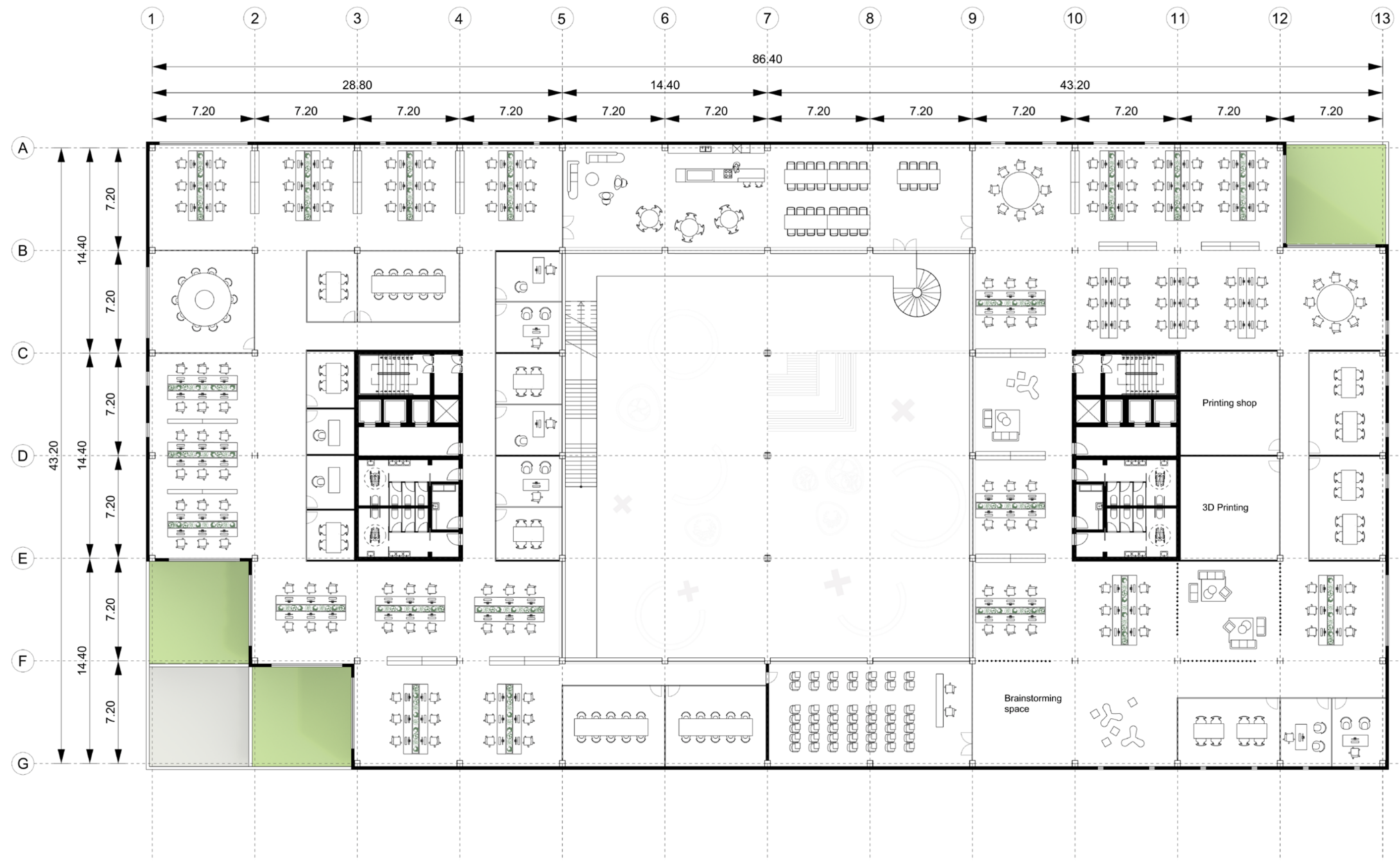
The open floor system of the office is divided into different zones following the 7.2 x 7.2 m grid. There are meeting rooms, brainstorming areas, a lounge where people can relax and communicate in a more leisurely way. The kitchen is fitted with big windows with visibility over the courtyard. The external staircases provide another entryway to the courtyard from the office floor. The flexibility of the open floor system has been carefully thought out and Covid has also encouraged us to think of the office space in a different way.

Dividing the floor into different zones creates a more dynamic, healthier workplace where people are granted greater initiative. We want to design offices where the coming generation of workers can thrive by designing environments which encourage people to come back to the workplace instead of working from home. We underline this design philosophy by introducing the green connection of the terraces, the optional quiet zones, the accessible brainstorming area and the communal lounge areas. The printing spaces are situated next to the core in order to avoid disturbing the office workers, this also allows us to use this darker space for a function that doesn't require daylight without posing an issue as most often workers won't spend a lot of time there.

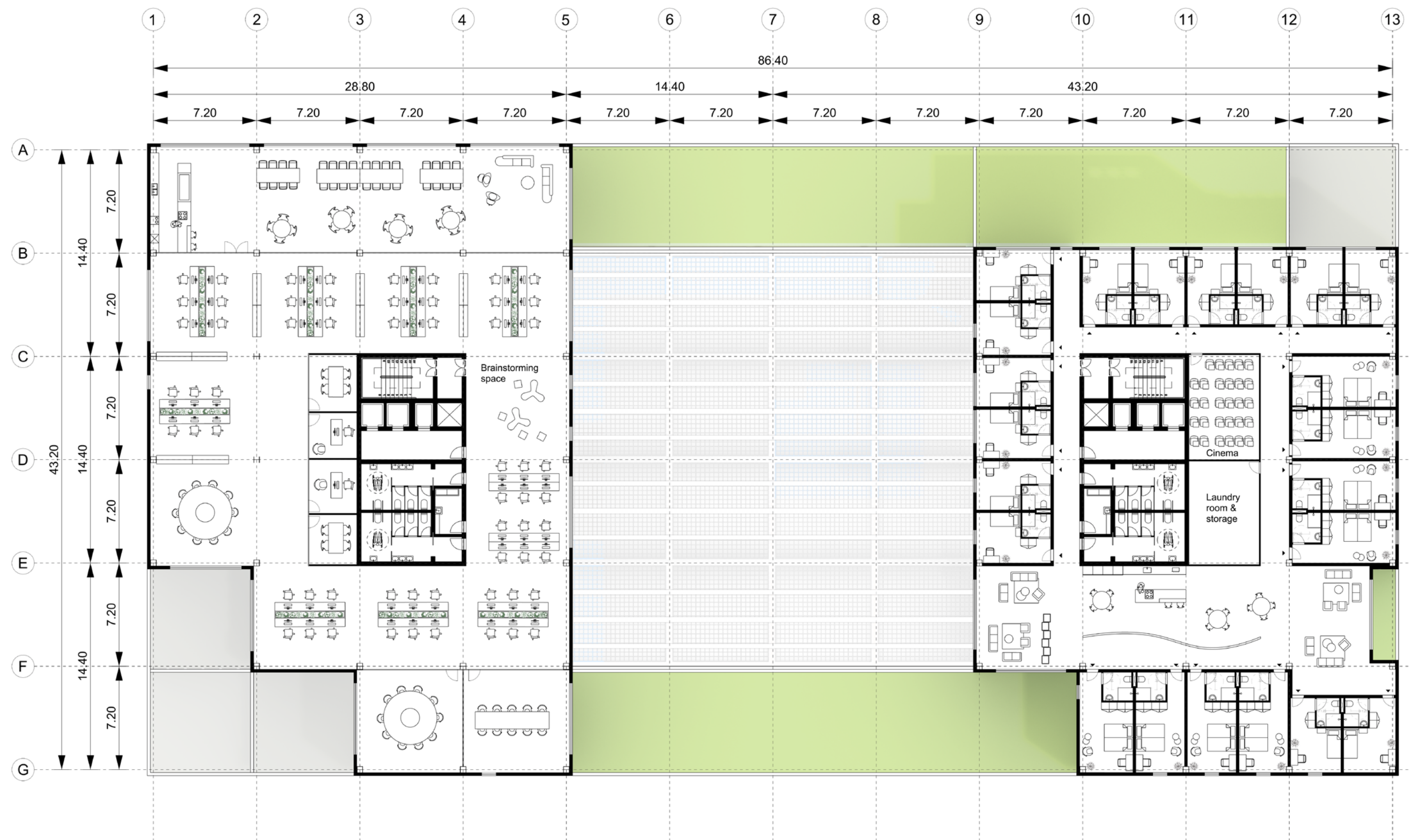
We use plants to separate desks to create an attractive and pleasant workspace which continues our idea of bringing biophilia into the occupants' day. In the courtyard we placed stimulating staircases that connect the office floors to the central part of the building. The gallery's main entrance on the second floor is also reachable by the spiral staircases.

The third floor is divided in two, we have dedicated the West wing of the building to offices but the right wing to student housing. The two wings are separated by large terraces and the courtyard. The idea of the open floor system continues for the offices with different zones where people can work more efficiently.

The student housing is made up of 22 units, a large lounge and kitchen area, laundry room and storage as well as a small cinema. There are two different types of units, the first one is 15 m2 and is intended for a single inhabitant but the other type is 20 m2 which can accommodate two occupants. The lounge and kitchen area are shared spaces with a lot of natural light and connection to the terraces.



2ND FLOOR



3RD FLOOR

PLANS

4TH FLOOR

6TH FLOOR

5TH FLOOR

7TH FLOOR

PLANS

The need and demand for affordable housing in Beirut has increased enormously in the last years. Therefore, floors 4 through 10 offer 93 residential units of 14 different types. It was important to us that we facilitated a diverse array of familial units which is why we dedicated such a large part of the building to these residences and introduced a separate level of parking spaces reserved for these units.

The ground floor will not only be a place for the public, but it will also act as a social space for the residents and includes a child friendly playing area. The terraces will function as vertical gardens as they ascend from the first floor all the way through to the top floor. This creates a delicate transition between the surrounding area and the building.

Each of the residential floors follows a differently sized rectangular plan. With each ascending floor we try to introduce more terraces in an effort to create an interesting geometry and of course maximize the daylight within without risking too much thermal radiation which would increase energy use for cooling. The variety of trees and plants on each floor will create the feeling of being on the ground in nature even though you are situated on one of the higher floors. As the greenery will mature over the years, the building's green elements will increase significantly, acting even better as a sun-shading element with the added benefit of providing privacy. Another idea behind the residential units was to use the duality of open and closed spaces, and with the help of the terraces it was easier to bring daylight to the deeper apartments.

The open plan living, and the terraces provide shade and comfortable outdoor living areas which enhance sustainable living. The apartments are accessible from the central core which works as a circulation space. The openness of the apartments will also add to the sense of spatial abundance. No two floors are exactly alike which ensures that the living experience is unique both on the inside and the outside.

Some units include a diagonal interior wall, this intervention is intended to maximize the natural light as these units also have a deep plan. All units irrespective of size were fitted with large storage space in the form of closets, cabinets, and storage rooms. Bathrooms and other spaces that don't require as much natural light were carefully placed in darker areas so that other rooms, which usually see more use, would enjoy more daylight.

A special emphasis was placed on opening up the living room by connecting them to a large kitchen area thus granting both spaces more light. It was crucial for our design to create a liveable space where big families can enjoy being together. This idea was also adopted from the design of the offices even though the scale is much smaller. Dividing the open floor plan into different zones so in the living room is comprised of the entrance, kitchen, and the primary living area which can be further divided into zones by the occupants.

8TH FLOOR

9TH FLOOR

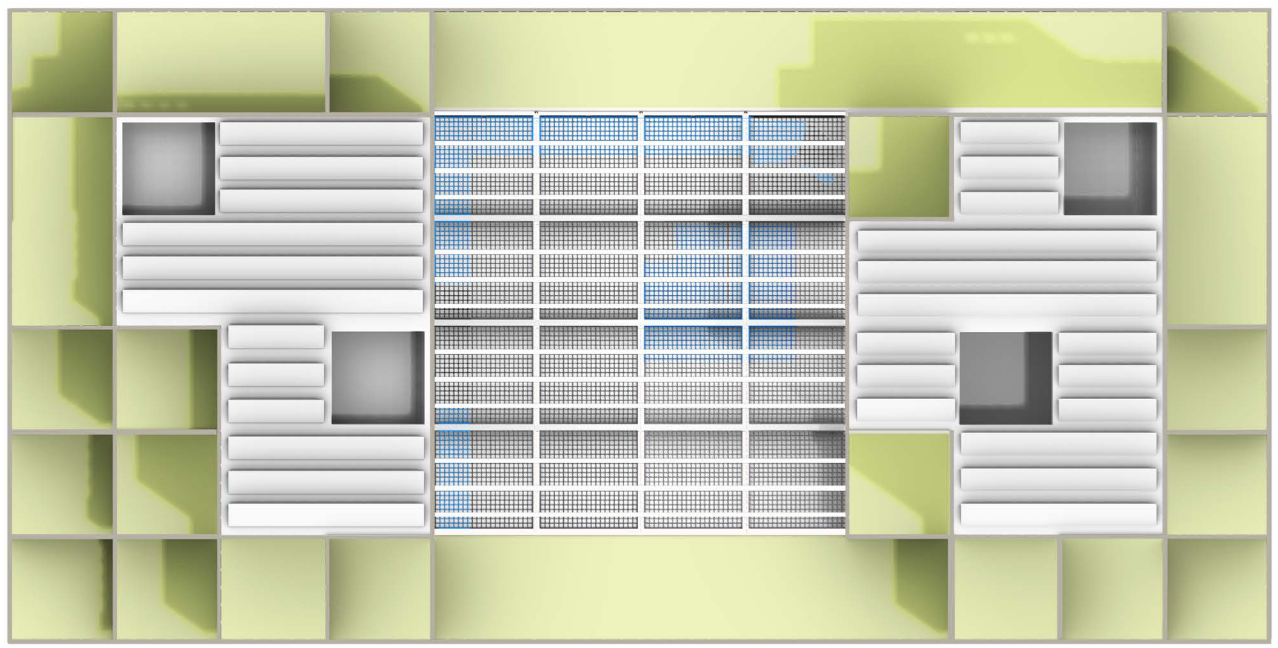
PLANS

The grid was an essential part in understanding the organization of the zones. The terraces also introduce flexibility into the residential units. The decision of having different sizes of units within each of the floors was to introduce a variety of family sizes to each floor. It also helped organizing the units so as to better maximize the amount of daylight in each one.

The East wing of the building has 10 floors but the West one has 8 floors. To increase sustainability of the building, the roof's surface will be populated with solar panels, and the courtyard will be covered with transparent solar panel. The predefined grid was particularly helpful when placing the residential units and gave us a great tool to maximize the utilized space of each one.

The flooring will be in light parquet which keeps the bright feeling we designed for the exterior. The vision was to have a sleek and modern interior design which was also practical. Light colours also enable residents to add furniture to their liking with less risk of the colours mismatching with the interior design. Introducing a functional and practical base of materials and colours also allows for more flexibility.

10TH FLOOR



ROOF

MODULARITY

Modularity in architectural design has become increasingly popular due to its cost-effectiveness and flexibility. The Beirut port project is a perfect example of how modularity can be used to create a sustainable and functional building. The project uses various modular elements that are integrated into the design, resulting in a building that is easy to construct, maintain, and upgrade.

The first aspect of modularity in the Beirut port project is the use of facade modules. The facade cladding panels are made up of modules that are 1.2 meters by 3.5 meters in size, which allows for quick and easy installation. The panels are also made of fiber c material, which provides excellent thermal insulation and is resistant to weathering. The use of standardized modules for the facade also allows for flexibility in design, as different patterns and textures can be achieved by simply rearranging the modules.

The second aspect of modularity in the project is the use of standardized construction elements, including fiber c panels, triple glazing, and photovoltaic panels. These elements are pre-fabricated off-site, which reduces construction time and costs. The use of standardized elements also ensures consistency in quality and performance, as all the elements are tested and certified before installation.

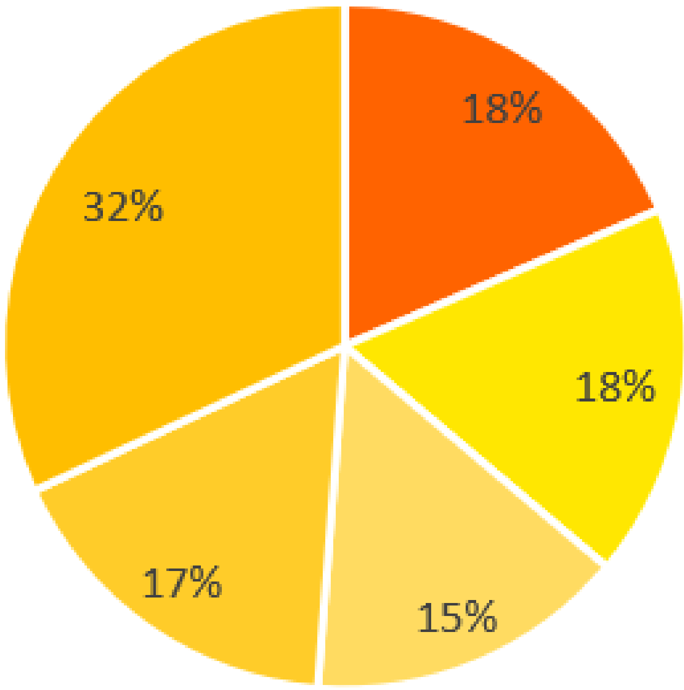
The benefits of modularity in the Beirut port project are numerous. Firstly, it is a cost-effective method of construction, as it reduces labor costs and allows for quicker construction times. The use of standardized elements also reduces the need for skilled labor, which can be in short supply in some areas. Secondly, modularity allows for flexibility in design, as the building can be easily modified or expanded in the future. The use of standardized elements also makes it easier to maintain and upgrade the building over time.

Finally, the concept of using containers is also incorporated into the design of the Beirut port project. This is particularly relevant given the location of the project, which is in a port area where containers are a common sight.

References:

Krygiel, E., & Nies, B. (2017). Architectural detailing: Function, constructibility, aesthetics. John Wiley & Sons.
Salingaros, N. A. (2017). Principles of urban structure. Sustasis Press.
Turrin, M., & Zordan, M. (2018). Sustainable modular housing: a case study. Procedia engineering, 212, 1197-1204.

- **STUDENT HOUSING 15-20 m²**
- **STUDIO 35 m²**
- **MONO-BILOCALI 50 m²**
- **BI-TRILOCALI 75 m²**
- **QUADRI-TRILOCALI 100-150 m²**



According to the United Nations the average Lebanese family has **3.9 people per household**. This is why we thought it was important to design more residential units of tri- & quadrilocali in order to provide as much housing as possible.

MODULARITY

There are 7 floors of residential units, floors 4 through 10 offer 93 residential units of 14 different types. The units are divided into different categories by the number of people each unit can accommodate. It was important to us to design fewer types of higher quality in order to facilitate an easier, cost effective, installation on the work site. These modular units are lend themselves to off-site production which most often provides higher quality at lower costs. This will also facilitate maintenance and offer greater flexibility to change the function of these units in the future. The aim with these low cost and easy installation units is to increase sustainability but also to ensure that people have access to affordable housing while maintaining quality. We introduce units facilitating 5 differing types of familial units. The Oasis project is meant to be a socially inclusive architectural work which welcomes all ages, sexes and ability levels. It is also intended to provide diversity and an overall interesting and welcoming atmosphere.

STUDENT HOUSING 15-20 m²

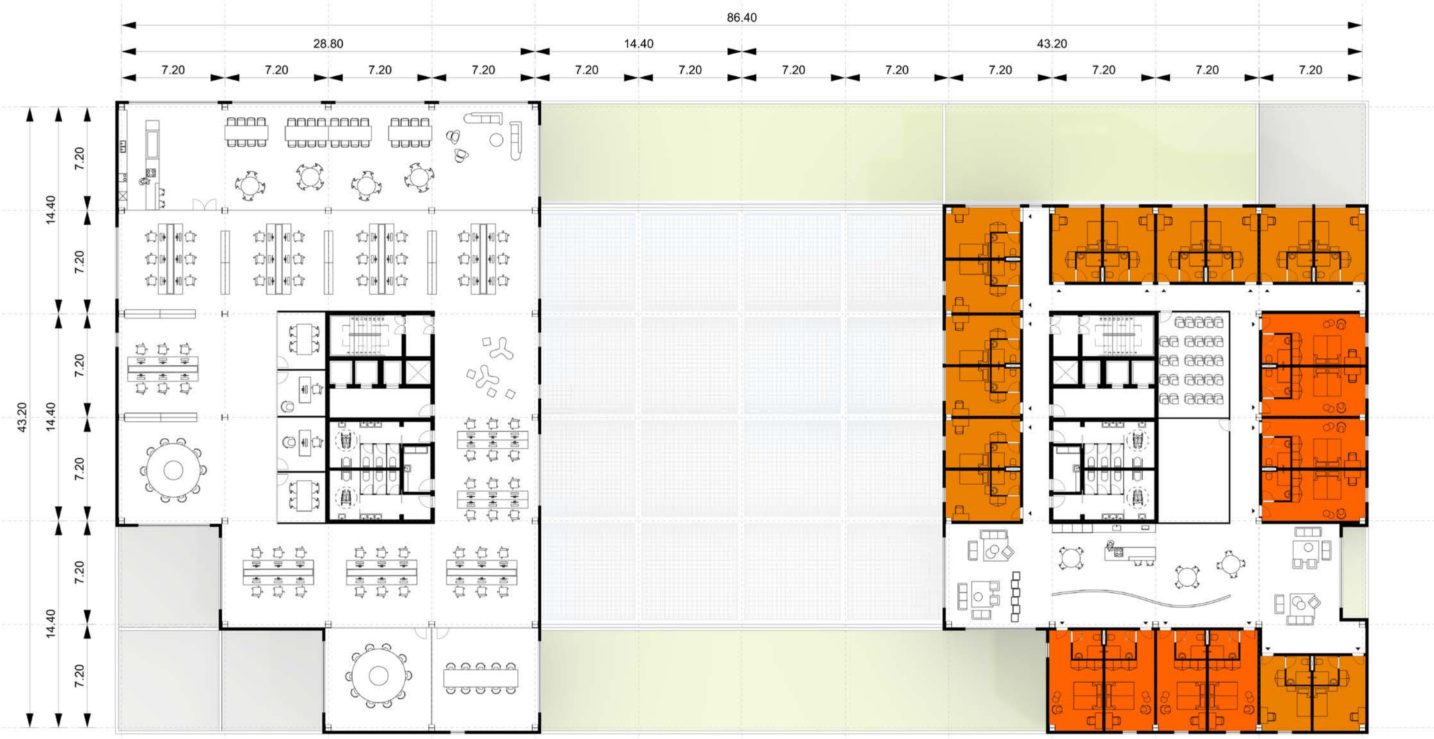
STUDIO 35 m²

MONO-BILOCALI 50 m²

BI-TRILOCALI 75 m²

QUADRI-TRILOCALI 100-150 m²

RESIDENTIAL UNITS



3RD FLOOR

4TH FLOOR

- STUDENT HOUSING 15-20 m²
- STUDIO 35 m²
- MONO-BILOCALI 50 m²
- BI-TRILOCALI 75 m²
- QUADRI-TRILOCALI 100-150 m²

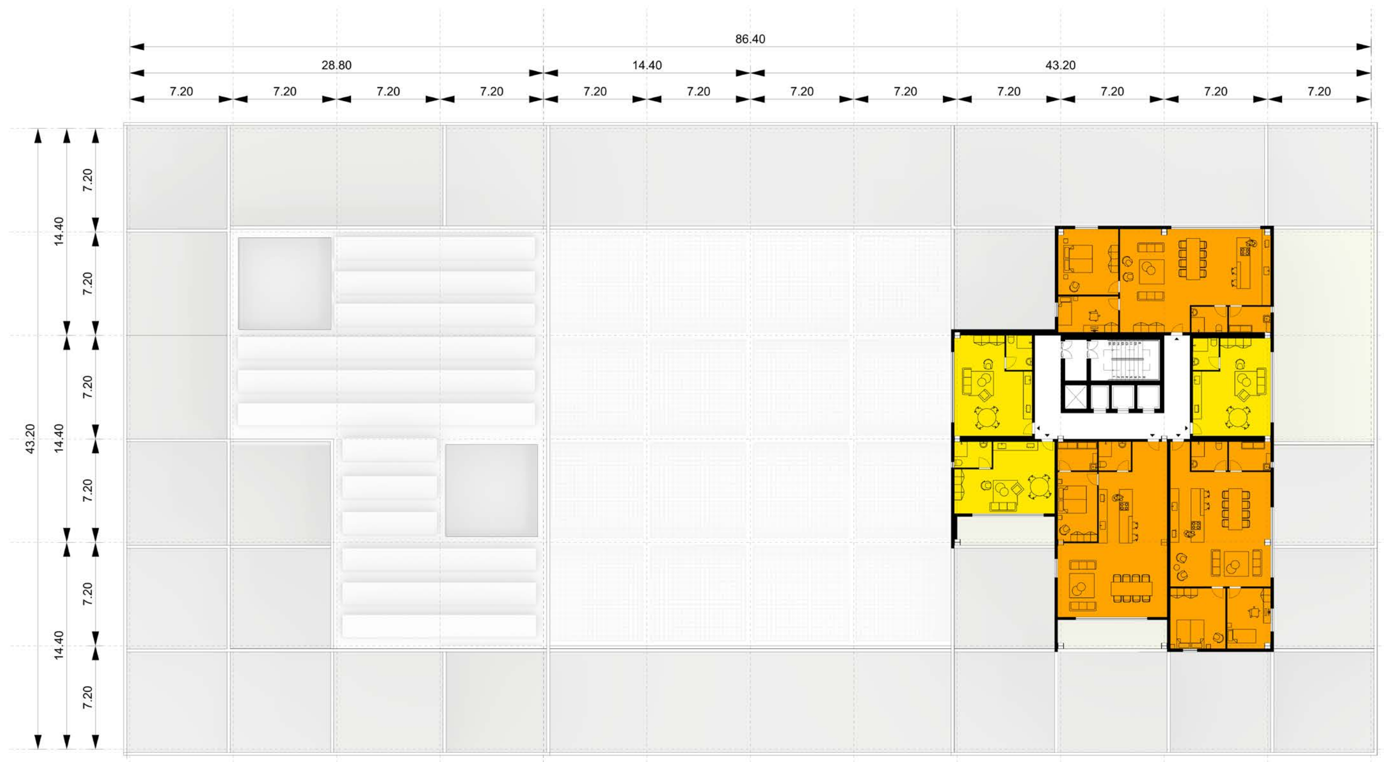
5TH FLOOR

6TH FLOOR

RESIDENTIAL UNITS

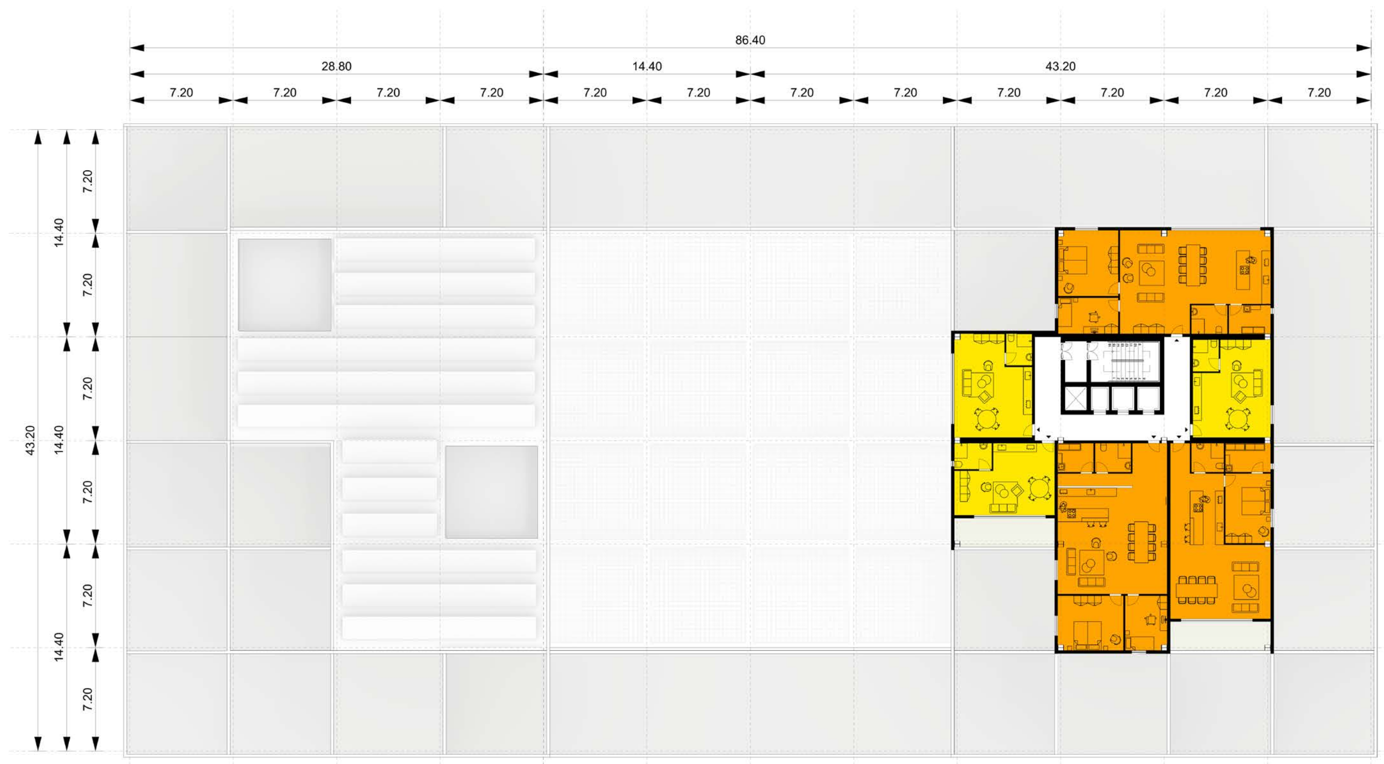
- STUDENT HOUSING 15-20 m²
- STUDIO 35 m²
- MONO-BILOCALI 50 m²
- BI-TRILOCALI 75 m²
- QUADRI-TRILOCALI 100-150 m²

7TH FLOOR



9TH FLOOR

8TH FLOOR

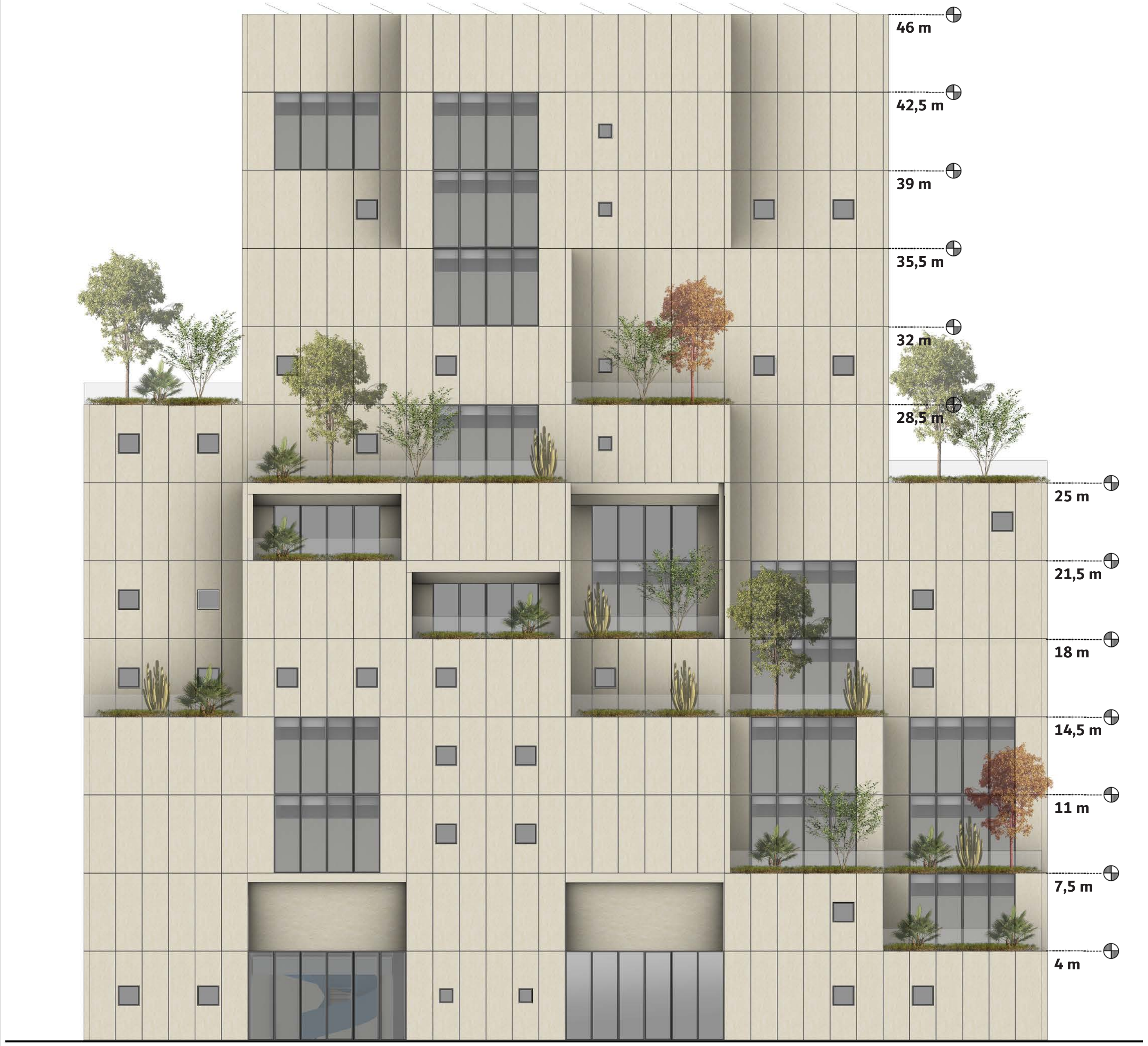


10TH FLOOR

ELEVATION SOUTH

The façade of the building is designed to fit into its environment as effortlessly as possible. It is rich with lightly coloured fiber c panels which form a contiguous shape. The façade is made of 3 different types of panels, fiber c, triple glazing and photovoltaic panels. The panels were placed carefully according to our aesthetic, energy consumption and natural lighting requirements. Because of the region's climate it was important to keep the building as opaque as possible without losing to much of the daylight.

ELEVATION WEST



The critical sides; South, East and West have been designed with careful thought of minimizing energy loss through the facade without limiting daylight. Therefore, these sides are made up of many opaque panels, however with the installation of small windows we are able to introduce a good amount of daylight. The vegetation on the terraces and in the courtyard work as powerful shading systems which enable us to have large glass panels on critical sides without adversely affecting the energy too much.

ELEVATION EAST

The ground and first floors have large openings of glass panels which are offset towards the inside to provide shading. The playfully but functionally positioned terraces gives the elevation a pixelated look. The smaller terraces are offset to the inside which lends the elevations as a whole greater depth. Even though the building is quite massive the terraces help to reduce that feeling and instead gives people walking past the building a better connection to it, it enters better into the human scale and allows people to fully grasp the building when approaching it and gives the feeling of a vertical garden.

ELEVATION NORTH

The size of the courtyard also reduces the feeling of massiveness, and it lets each tower stand out by itself but also creates a connection between them. The fiber c panels give the building a unique look and depth as the colour of the stone like panels changes throughout the sunlit hours of the day through to the night. The low position of the sun will create longer shadows and bring out the detail of textures. The North facade has the most amount of glass panels as it requires less shading. This creates a great contrast between the South and the North side

Regarding the South side the focus was on having as much opaque panels as possible but placing the smaller windows in a playful yet organized way, so as to feel more natural and less manufactured. The width to height ratio of the panels is 1.2x3.5m, this coupled with the small gaps between panels introduces a feeling of verticality and drags the eye of the visitor to the upper floors and thus connects the ground floor to the top floor in a manner.

MATERIALS

The façade of a building is one of the most important elements of its design. Not only does it play a crucial role in the building's aesthetic appeal, but it also serves as a barrier between the inside and outside environment, protecting the interior from the elements. In recent years, the use of prefabricated fiber C material cladding solutions has become increasingly popular in building design due to their high thermal resistance and aesthetic value.

Despite its minimum thickness, this material contributes significantly to the thermal insulation of the building. This means that it can help to reduce energy consumption in the building by maintaining a comfortable temperature inside, regardless of the weather conditions outside. As a result, it can help to reduce energy costs and improve the overall sustainability of the building.

PRODUCT: concrete skin,
öko skin, formparts sharp edge
COLOUR: sandstone
TEXTURE: standard
SURFACE: ferro plus

Another advantage of prefabricated fiber c material cladding is its aesthetic value. With a wide range of colors and finishes available, this material can be used to create a unique and visually striking facade.

In the context of Beirut, the importance of facade materiality cannot be overstated. As a result, there is a strong emphasis on preserving the city's architectural heritage while also incorporating modern design elements. Prefabricated fiber c material cladding solutions offer an ideal solution for balancing the preservation of the city's architectural heritage with modern design elements.

References:

https://www.rieder.cc/en/product/standard-sandstone-ferro-plus/

DAYLIGHT & ENERGY

DAYLIGHT TASK INTRO

Daylight and energy performance are critical aspects of our building located in Beirut Port that have a significant impact on the comfort, health, and productivity of building occupants, as well as on the environment.

1. Massing and orientation optimization:
The first step in optimizing daylight performance is to ensure that the building massing and orientation are optimized to maximize the amount of natural light that enters the building. The building is oriented in a way that the main façade faces south, while the shorter facades face east and west. This orientation and features optimize solar gain throughout the winter and summer months.

2. Window opening-size optimization:
The next step is to optimize the size and placement of windows to ensure that natural light enters the building and illuminates the interior spaces adequately. The window openings have been strategically placed and sized to balance the amount of natural light entering the building while minimizing heat gain and glare.

3. Terraces and vegetation (Shaders) Optimization:
The building's terraces have been designed to provide shading for the interior spaces during the hottest times of the day, reducing the amount of direct sunlight entering the building. Vegetation has been incorporated into the terraces to provide additional shading and improve the building's overall aesthetic.

4. Daylight analysis based on thermal and light comfort in terms of sDA, ASE and LUX:
The building's daylight performance has been analyzed using various metrics, including spatial Daylight Autonomy (sDA), Annual Sunlight Exposure (ASE), and LUX levels. Our analysis, which follows on the next pages, shows that the building meets the recommended daylight levels for optimal occupant comfort and productivity while reducing energy consumption by minimizing the need for artificial lighting.

ENERGY TASK INTRO

1. Envelope optimization-facade construction study & Panel thermal resistance:
The building's envelope has been optimized to minimize heat gain and loss, and to maximize energy efficiency. The facade has been constructed using high-performance panels with a high thermal resistance, reducing the building's energy consumption and improving its overall energy performance.

2. Facade Optimization-Daylight study:
The optimization of the building's facade for daylight performance also contributes to its overall energy performance. By maximizing the amount of natural light that enters the building, the need for artificial lighting is minimized, reducing energy consumption.

3. Natural Ventilation and light:
Natural ventilation and light are important components of the building's energy performance. The building has been designed to maximize natural ventilation and lighting, reducing the need for mechanical ventilation and artificial lighting.

4. Smart HVAC System:
The building's HVAC system has been optimized for energy efficiency, with the use of a smart system that controls temperature and airflow which takes into account the occupancy levels and weather conditions.

5. Water system analysis:
The building's water system has been designed to minimize water consumption, with the use of low-flow fixtures and a rainwater harvesting system that collects and recycles rainwater for irrigation and other non-potable uses.

6. Smart Lighting system & sensors:
The building's lighting system has been optimized for energy efficiency, with the use of a smart system that controls lighting based on occupancy levels and natural light levels. Motion sensors are also used to turn off lights in unoccupied areas, reducing energy consumption. Systems such as DALI (Digital Addressable Lighting Interface) can be used to benefit the circadian rhythm by manipulating the power and color temperature of connected lighting devices to suit the hour of the day and external lighting conditions.

7. Renewable Energy-PV panels analysis:
The building incorporates renewable energy sources, including photovoltaic (PV) panels that generate electricity from sunlight. An analysis of the PV panels shows that they provide a significant portion of the building's energy needs, reducing its carbon footprint and energy costs.

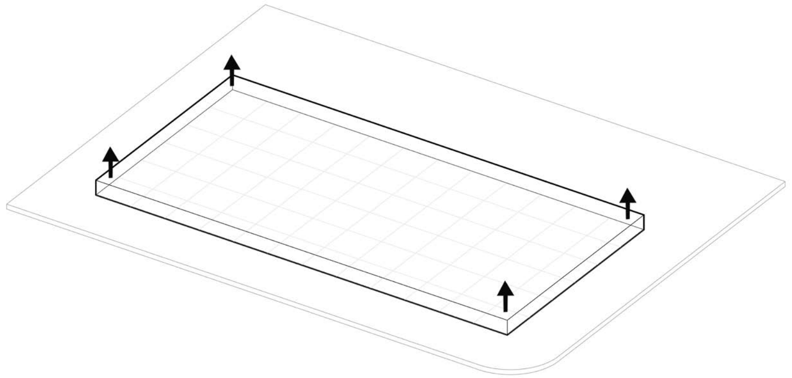
8. CO2 saved:
The building's energy-efficient design and use of renewable energy sources contribute to significant CO2 savings, reducing its impact on the environment.

9. EUI, CO2 saved, Energy cost.

SCHEMATIC DESIGN/ MASSING

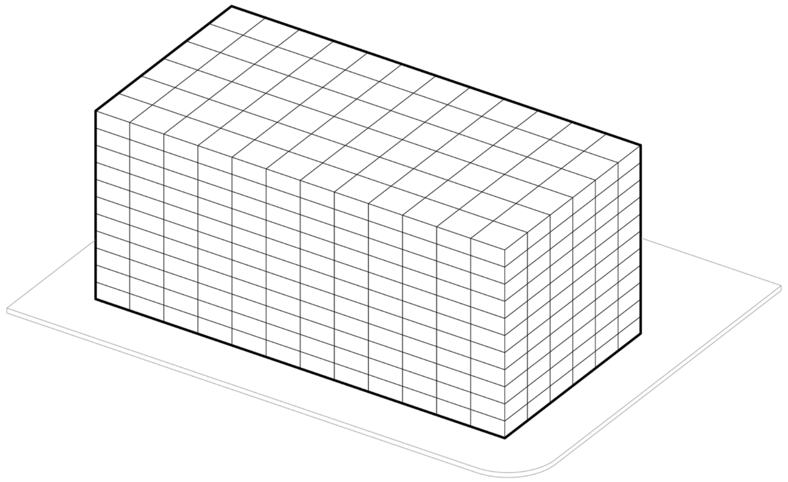
01 EXTRUDE

We used the grid of 7.2 times 7.2 meters to divide the site into different cells. We took great care while orienting the building that it would be in such a manner to minimize the energy expenditure.



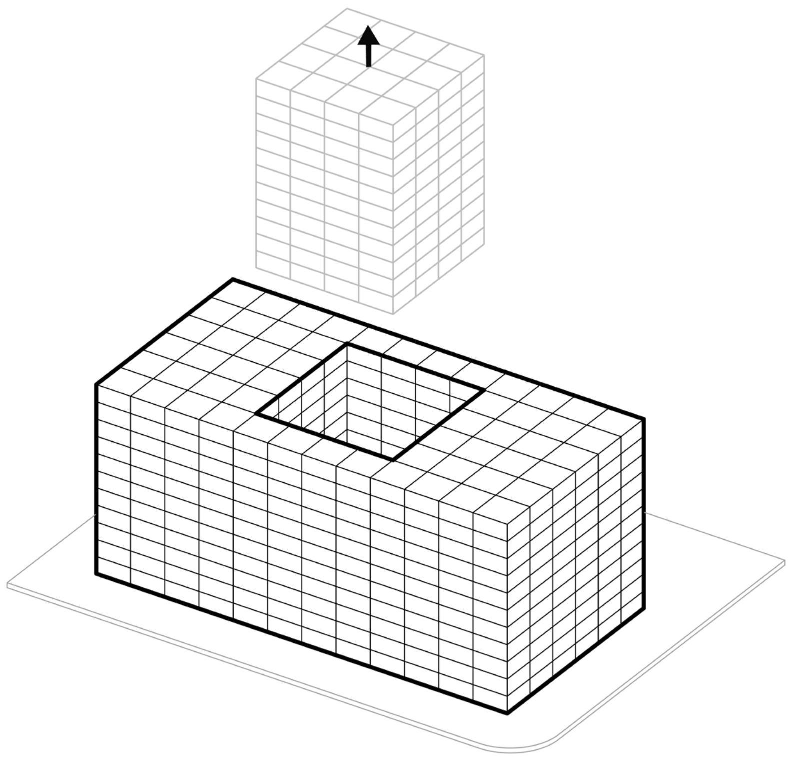
02 MASSING

We created one mass to represent the overall building shell.



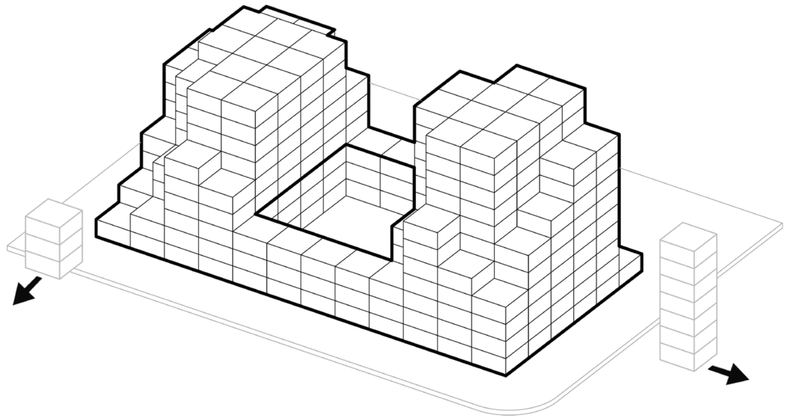
03 CARVE

The next step was to remove the central core from the overall mass in order to design a big atrium which would allow us to maximize the daylight.



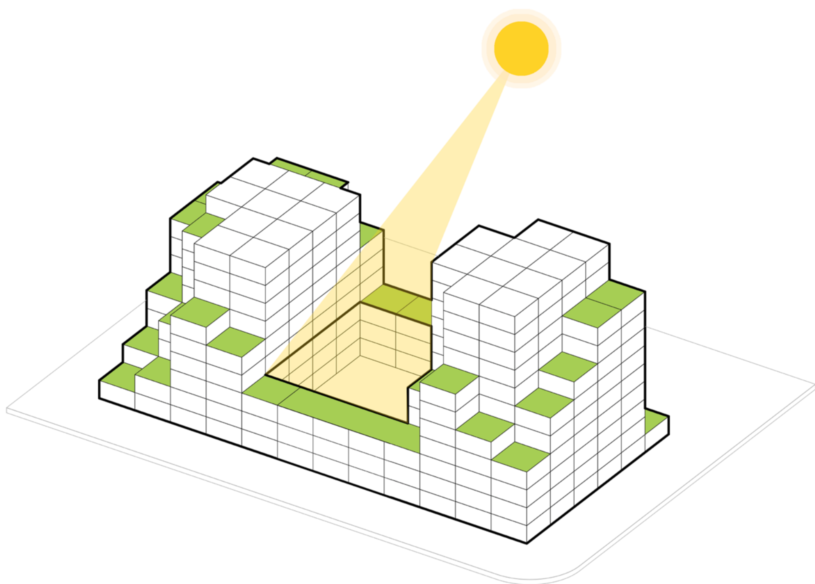
04 TERRACES

Addititonal cubes were then removed in order to create terraces and internal voids in order to minimalize the ASE and maximize the sDA.



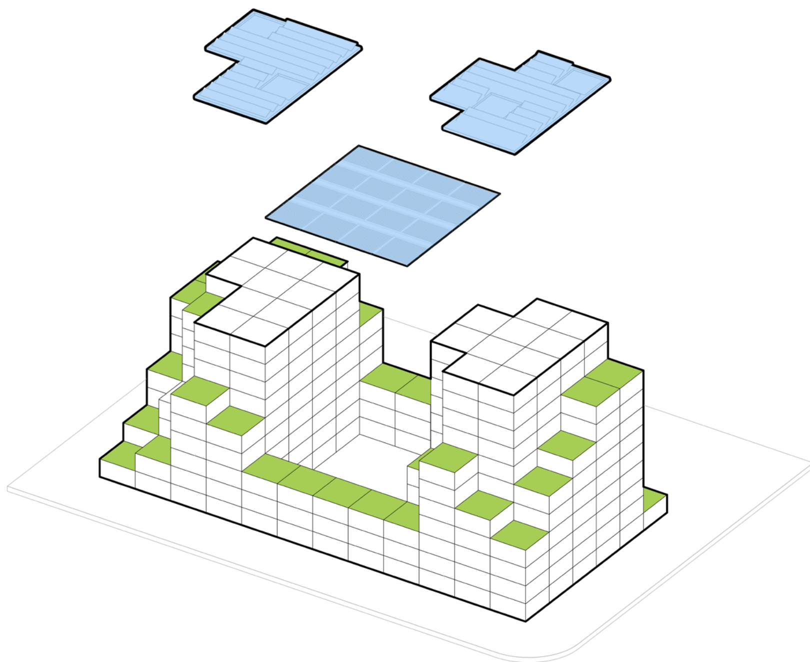
05 NATURAL SHADING

Terraces were extensively used to provide shading. During winter the terraces are used to increase the natural light and in summer to minimize the energy losses. The surface areas exposed to sun at different times of day, the building height, and building width were all optimized for passive comfort.



06 SOLAR PANELS

Solar panels were added on the roof and also over the courtyard to provide an internal source of energy.



SUSTAINABILITY STRATEGY

Green roof Rainwater management

The combination of a green roof and retention of rainwater can protect the municipal sewers from overloading, especially during heavy rain events. In order to reduce the need for fresh water, rainwater and gray water will be used for flushing toilets and watering the green areas.

Mechanical ventilation

Use of displacement air system with highly efficient heat recovery and needs-based Co2 control. With heat and cold recovery from the ventilation system, the need for electricity for air circulation can be saved in the transitional seasons with the help of the smart facade.

Controlled atrium ventilation

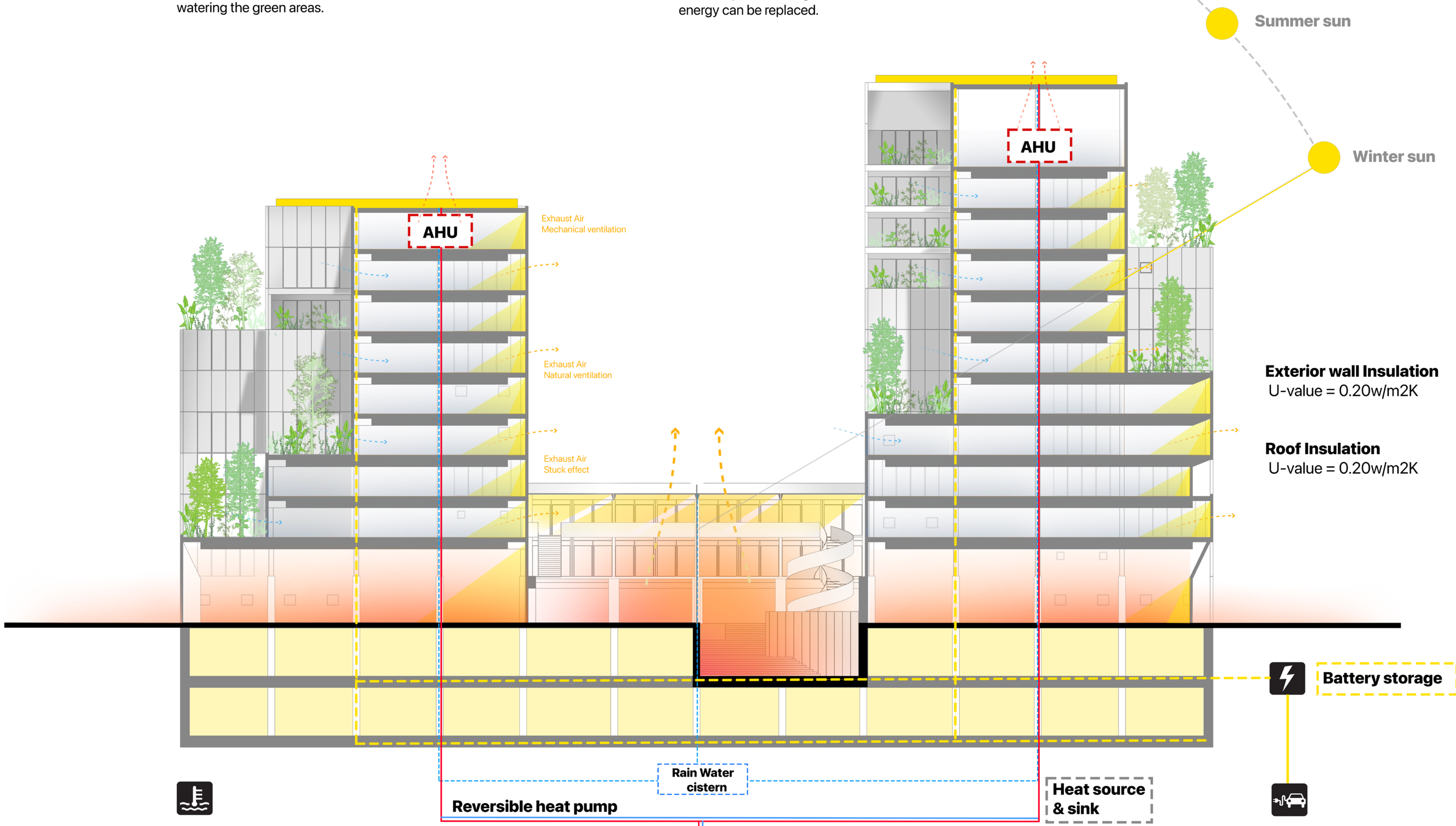
daylight is achieved through the use of atriums. Ventilation on the floors is supported by the resulting thermal lift in the atrium and internal areas are also supplied with sufficient fresh air. With mild outside temperatures or at night, part of the required cooling energy can be replaced.

Photovoltaic panels

Depending on the installed capacity and energy consumption of the building (excluding Dta-server storage), the large-scale use of photovoltaic modules on the roofs can generate more energy than is consumed on an annual basis.

Natural Ventilation

With the help of terraces and sensors in the façade for air temperature, wind speed and volume, the user is shown when it makes more energy sense to ventilate naturally.



Exterior wall Insulation
U-value = 0.20w/m2K

Roof Insulation
U-value = 0.20w/m2K

Geothermal

Due to the grid distribution of the buildings, geothermal probes can be used evenly across the district. In winter, heat is withdrawn from the ground. This makes it cooler. The cold is then used in summer.

Automated parking

The batteries of the electric vehicles and bicycles, as well as stationary batteries, serve as electrical buffer storage for the photovoltaic systems.

CLIMATE ANALYSIS BEIRUT

Psychometric Chart Analysis

The city of Beirut experiences a Mediterranean climate, characterized by hot, dry summers and mild, rainy winters. To understand the climatic conditions of the city, psychometric chart analysis can be used. According to [1], psychometric chart analysis is a graphical representation of the thermodynamic properties of air. The chart provides information on temperature, humidity, and other properties of air. In Beirut, the air temperature during summers ranges from 30°C to 35°C, while the humidity ranges from 50% to 70%. During winters, the temperature drops to 10°C to 15°C, while the humidity ranges from 60% to 80%.

Wind Rose

Beirut is located on the eastern Mediterranean coast, making it susceptible to strong winds. A wind rose is a graphical representation of the frequency and intensity of winds from different directions. According to [1], the prevailing wind direction in Beirut is from the northwest, with a frequency of 45%. The average wind speed during the day is 9.8 km/h, while at night, it is 6.0 km/h. During the summer months, the wind speed can reach up to 25 km/h, while in winter, it drops to 5 km/h.

Sunpath

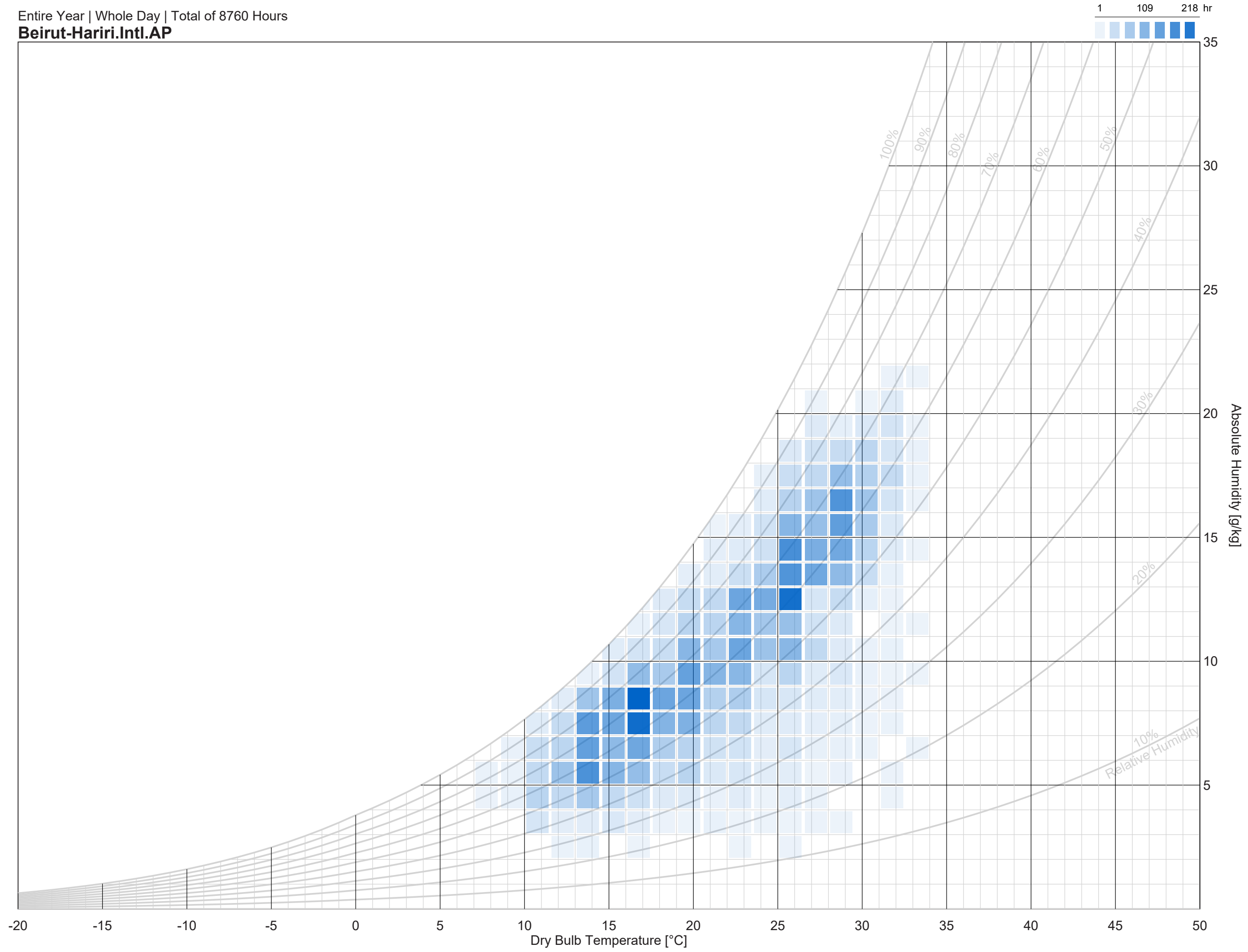
The sunpath is a graphical representation of the position of the sun throughout the year. In Beirut, the sun is high in the sky during the summer months, while in winter, it is low. According to [1], the angle of the sun's rays during the summer months is between 50° and 70°, while during the winter months, it is between 20° and 40°. The amount of solar radiation received in Beirut is high, with an average of 5.2 kWh/m2 per day.

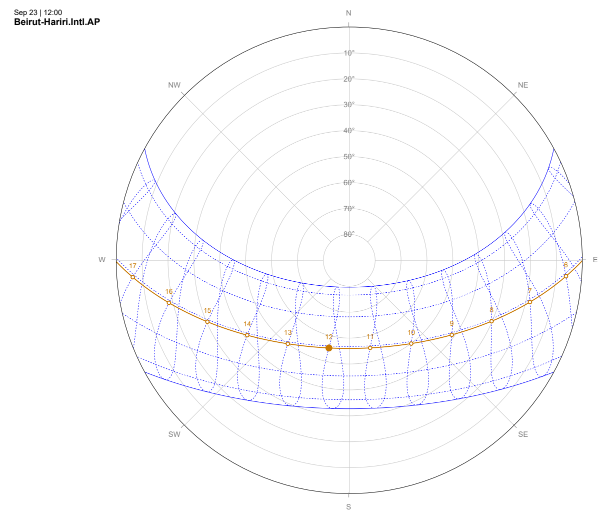
In conclusion, Beirut experiences a Mediterranean climate with hot, dry summers and mild, rainy winters. The prevailing wind direction is from the northwest, with an average wind speed of 9.8 km/h during the day. The sun is high in the sky during summers, while in winter, it is low. The city receives a high amount of solar radiation, making it a suitable location for solar energy projects. By analyzing the psychometric chart, wind rose, and sunpath, we can understand the climatic conditions of Beirut better.

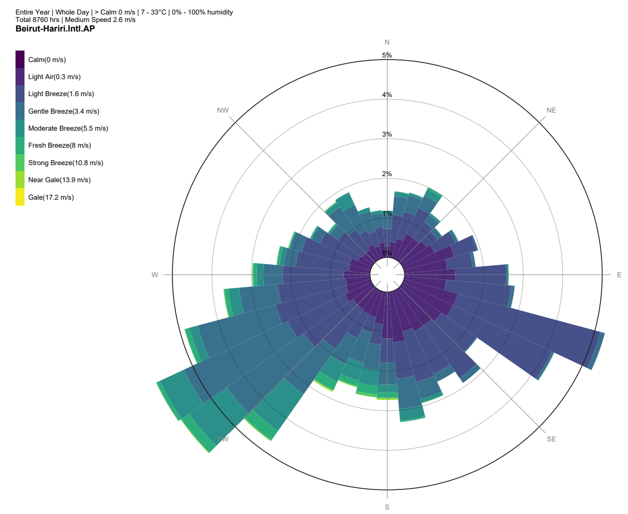
References:

[1] Achieving Building Comfort by Natural Means

Program: Solemma







CLIMATE ANALYSIS BEIRUT

Direct Nominal Radiation

Beirut, the capital of Lebanon, is located on the eastern shore of the Mediterranean Sea. The city has a Mediterranean climate with hot and dry summers and mild and rainy winters . The direct nominal radiation in Beirut varies throughout the year, with the highest values observed in July and August and the lowest values in December and January . The average daily direct nominal radiation in Beirut is around 5.5 kWh/m² [2].

Rain and Humidity

The city of Beirut experiences a Mediterranean climate, with rainfall occurring mainly in the winter months from November to March . The average annual precipitation in Beirut is around 825 mm [1]. The relative humidity in Beirut is generally high, reaching up to 80% in the early morning hours

UTCI

The Universal Thermal Climate Index (UTCI) is used to evaluate the thermal comfort conditions in Beirut. The UTCI values in Beirut range from -2°C to 35°C . During the summer months, from June to September, the UTCI values in Beirut are usually above 26°C, indicating that the thermal comfort conditions are not suitable for outdoor activities [1].

Heat Index

The Heat Index is another important measure of thermal comfort in Beirut. The Heat Index takes into account both temperature and humidity to determine how hot it feels . The highest Heat Index values in Beirut are usually observed in August and September, with values exceeding 40°C [1].

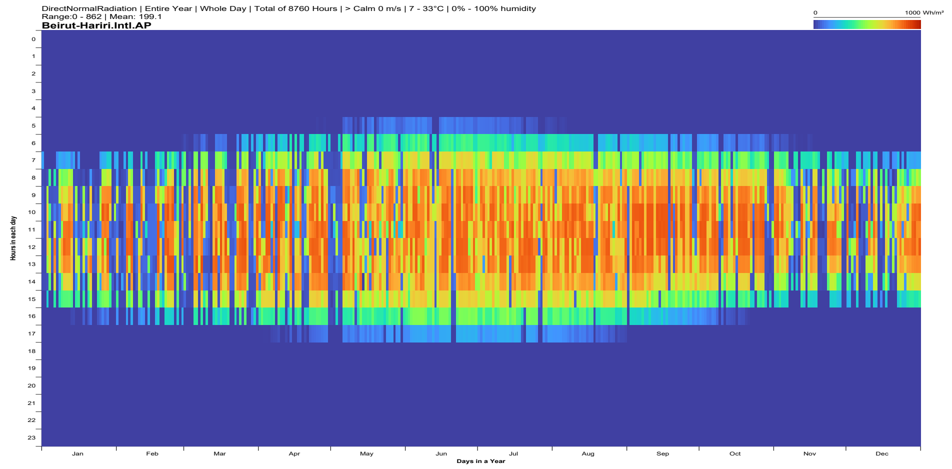
In conclusion, the direct nominal radiation in Beirut varies throughout the year, with the highest values observed in July and August and the lowest values in December and January. The city experiences high relative humidity in the early morning hours, and rainfall mainly occurs in the winter months. The UTCI values in Beirut indicate that the thermal comfort conditions are not suitable for outdoor activities during the summer months. The Heat Index values in Beirut are usually highest in August and September.

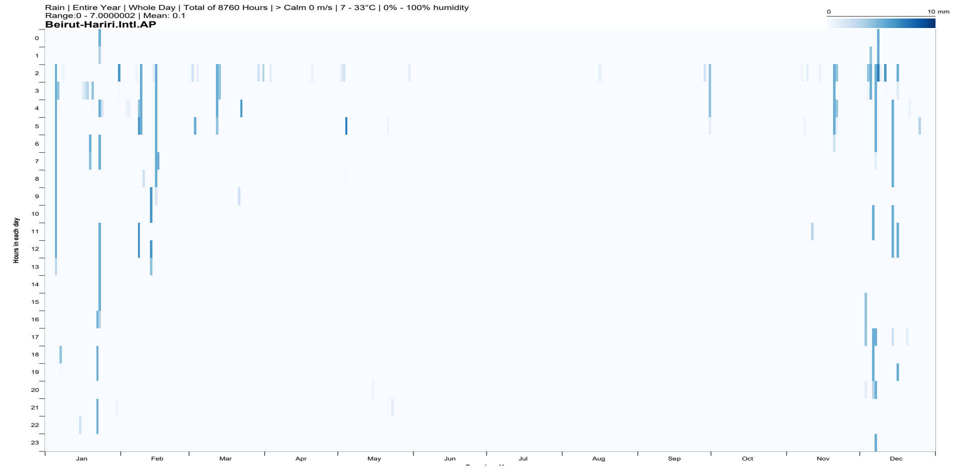
References:

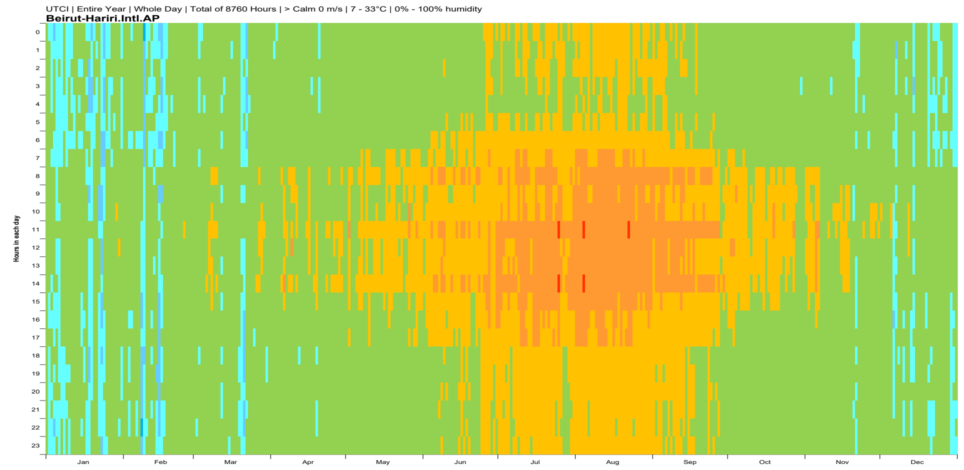
[1] Roaf, S., & Finlayson, W. (2009). Proceedings of the 1st International Conference on Comfort at the Extremes: Energy, Economy and Climate.

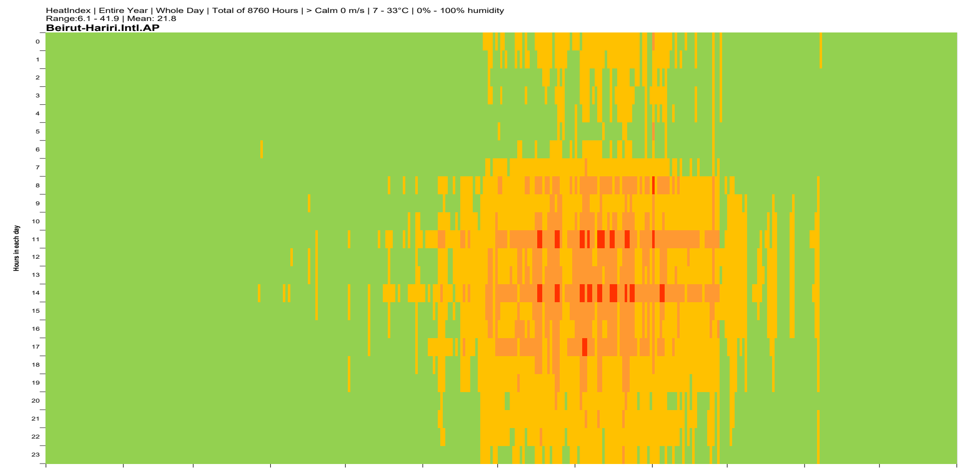
[2] The Daily Star. (2018, June 15). Lebanon's Energy Crisis: A Status Report. The Daily Star. https://www.dailystar.com.lb/News/Lebanon-News/2018/Jun-15/453139-lebanons-energy-crisis-a-status-report.ashx.

Program: Solemma









DAYLIGHT THEORY

Introduction

Daylight analysis is a crucial aspect of building design, especially in a multi-functional buildings that serve both residential and commercial purposes. The building has a total of 10 floors, with the first four floors dedicated to commercial use, while the rest of the floors are for residential purposes. Using BIM, we analyse the building's daylight performance by simulating the sun's movement at different times of the day and year. The analysis helped identify areas of the building that receive adequate daylight and those that required additional lighting. Thus it helped us to optimize the building's energy consumption by reducing the need for artificial lighting during the day. The daylight analysis showed that the building has a good overall daylight performance, with most of the rooms receiving adequate natural light. By designing buildings with proper daylighting, we can create more sustainable and comfortable living spaces.

Spatial Daylight Autonomy

"Spatial Daylight Autonomy (sDA) examines whether a space receives enough daylight during standard operating hours (8 a.m. to 6 p.m.) on an annual basis using hourly illuminance grids on the horizontal work plane. Floor areas, or grid points, in the building model that achieve 300 lux for at least half of the analysis hours count as meeting the daylighting threshold. As a result, sDA values can range from zero to 100 percent of the floor area in question. An sDA value of 75 percent indicates a space in which daylighting is "preferred" by occupants; that is, occupants would be able to work comfortably there without the use of any electric lights, and find the daylight levels to be sufficient. An sDA value between 55 percent and 74 percent indicates a space in which daylighting is "nominally accepted" by occupants. Lighting designers, therefore, should aim to achieve sDA values of 75 percent or higher in regularly occupied spaces, such as an open-plan office or classroom, and at least 55 percent in areas where some daylight is important." [1]

Annual Solar Exposure (ASE)

"With higher levels of daylight sufficiency comes the potential for glare and solar heat gain. That's where Annual Sunlight Exposure (ASE) steps in. Meant to complement sDA, ASE is intended to help designers limit excessive sunlight in a space. While ASE is a crude proxy for glare phenomena, it measures the presence of sunlight using annual hourly horizontal illuminance grids rather than luminance measures, so it is technically not a glare metric."

"ASE uses a simulated 1,000 lux as an indicator value for sunlight, but the simulated value can differ significantly from what is measured in the physical world, which considers secondary bounce-off surfaces. Like sDA, ASE values range from zero to 100 percent, with the latter suggesting that the entire floor area of the space in question exceeds the simulated value of 1,000 lux for at least 250 hours per year. Thus, to reduce the potential for glare and thermal stress, designers should aim for low ASE values." [1]

Useful Daylight Illuminance (UDI)

"Useful daylight illuminance (UDI) is a daylight availability metric that corresponds to the percentage of the occupied time when a target range of illuminances at a point in a space is met by daylight."

"Daylight illuminances in the range 100 to 300 lux are considered effective either as the sole source of illumination or in conjunction with artificial lighting. Daylight illuminances in the range 300 to around 3 000 lux are often perceived as desirable (Mardaljevic et al, 2012)." [2]

Daylight Factor (DF)

"Daylight factor (DF) is a daylight availability metric that expresses as a percentage the amount of daylight available inside a room (on a work plane) compared to the amount of unobstructed daylight available outside under overcast sky conditions (Hopkins,1963). The key building properties that determine the magnitude and distribution of the daylight factor in a space are (Mardaljevic, J. (2012)):

- The size, distribution, location, and transmission properties of the facade and roof windows.
- The size and configuration of the space.
- The reflective properties of the internal and external surfaces.
- The degree to which external structures obscure the view of the sky."

"The higher the DF, the more daylight is available in the room. Rooms with an average DF of 2% or more can be considered daylit, but electric lighting may still be needed to perform visual tasks. A room will appear strongly daylit when the average DF is 5% or more, in which case electric lighting will most likely not be used during daytime (CIBSE, 2002)." [2]

References:

[1] https://www.architectmagazine.com/technology/lighting/annual-daylighting-performance-metrics-explained_o
[2] https://www.velux.com/

Spatial Daylight Autonomy (sDA)	
0 to 55%	Not acceptable
55 to 75%	Acceptable level
>75%	Optimum level

Annual Sunlight Exposure (ASE)	
0 to 10%	Comfortable
>10%	May result in visual discomfort

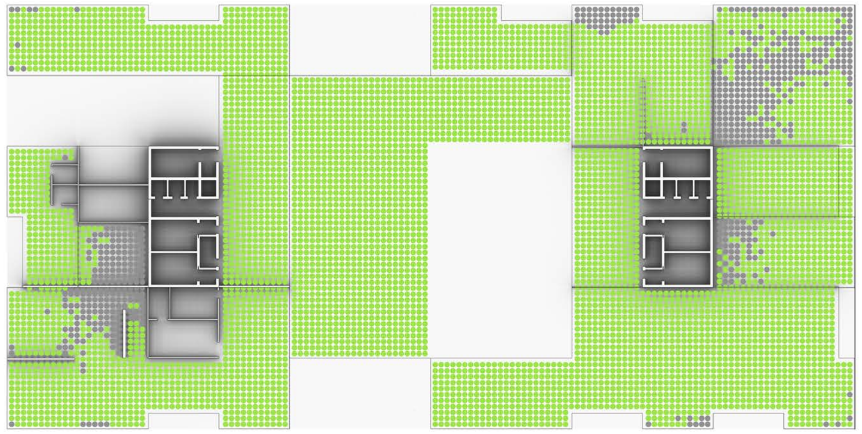
Useful Daylight Autonomy (UDI)	
0 to 100 lux	Not effective
100-300 lux	Effective
300 to 3000 lux	Desirable

Daylight Factor (DF)	
<2%	Not adequately lit
2 to 5%	Adequately lit
>5%	Well lit

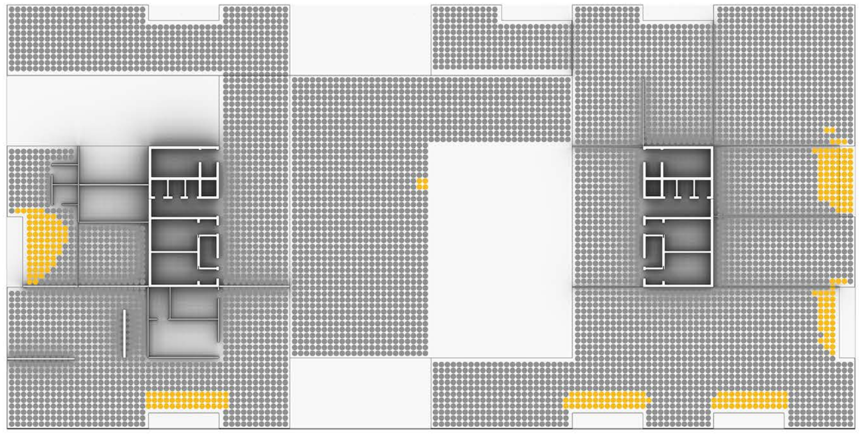
DAYLIGHT ANALYSIS

GF Floor Multifunction

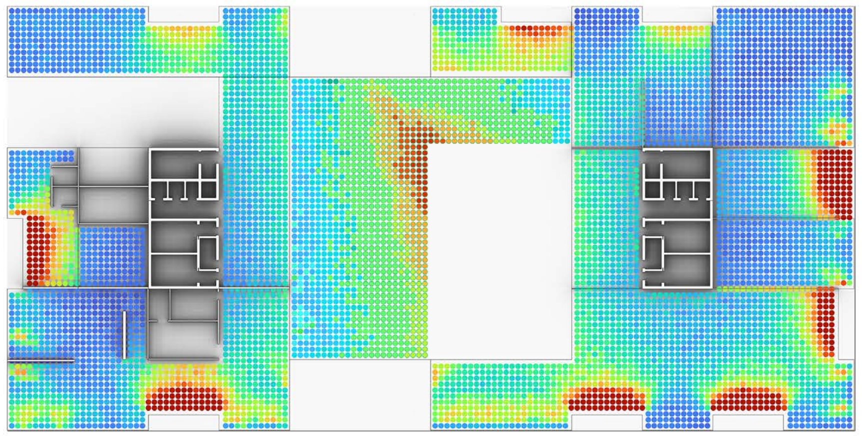
sDA
88.93 %



ASE
5.15%



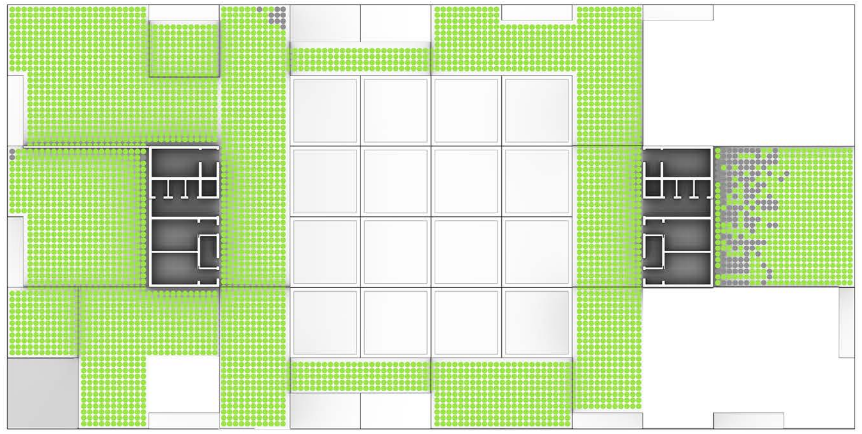
LUX
983
Avg. LUX



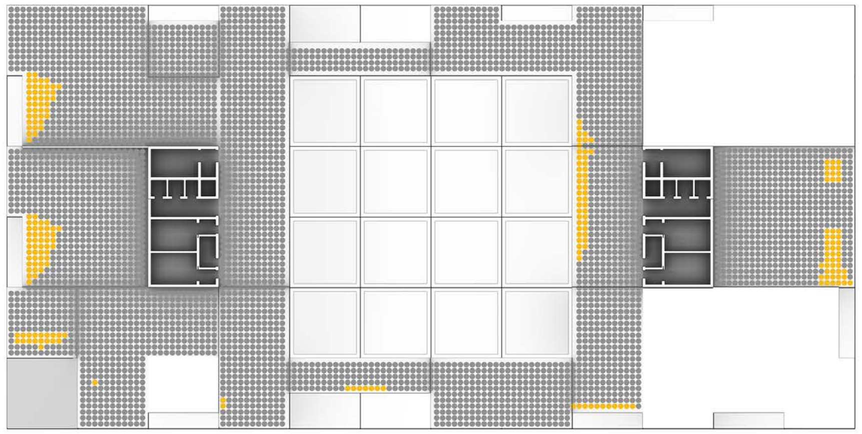
Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

1st Floor Offices-Startups

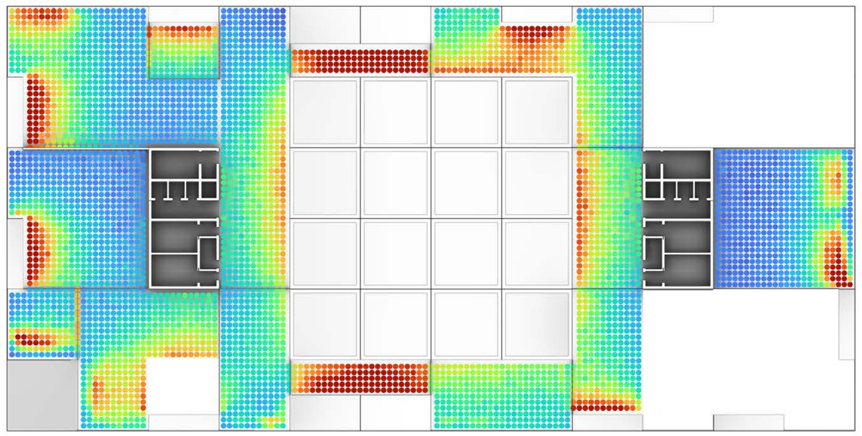
sDA
90.63 %



ASE
4.30%



LUX
983
Avg. LUX



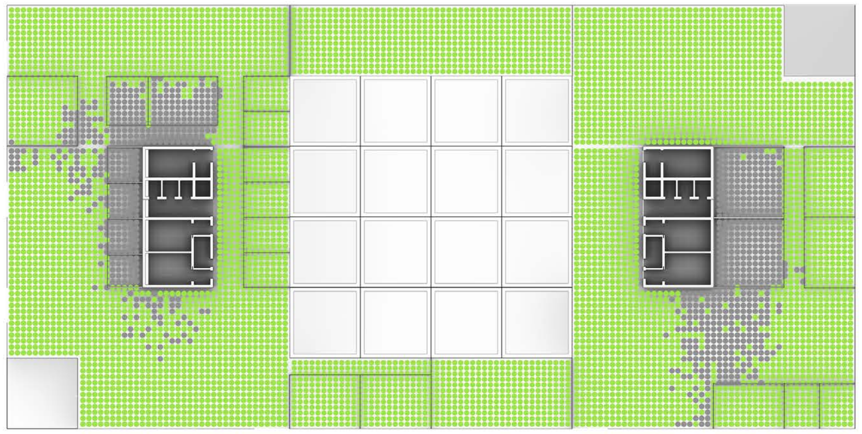
Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

DAYLIGHT ANALYSIS

2nd Floor Offices-Startups

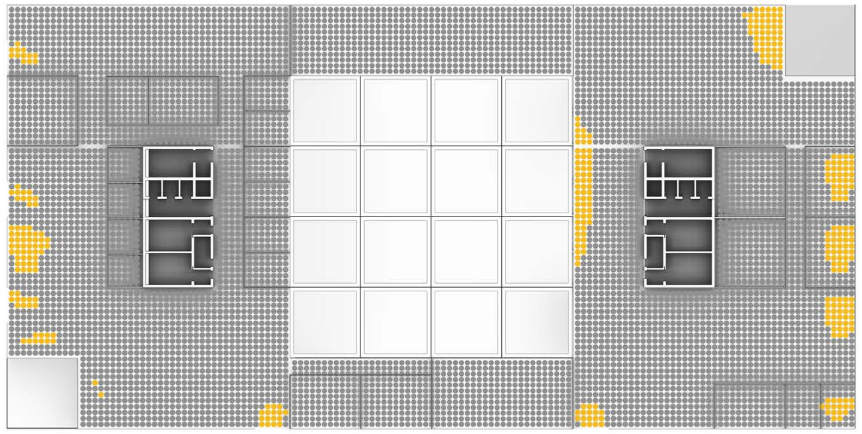
sDA

84.45 %



ASE

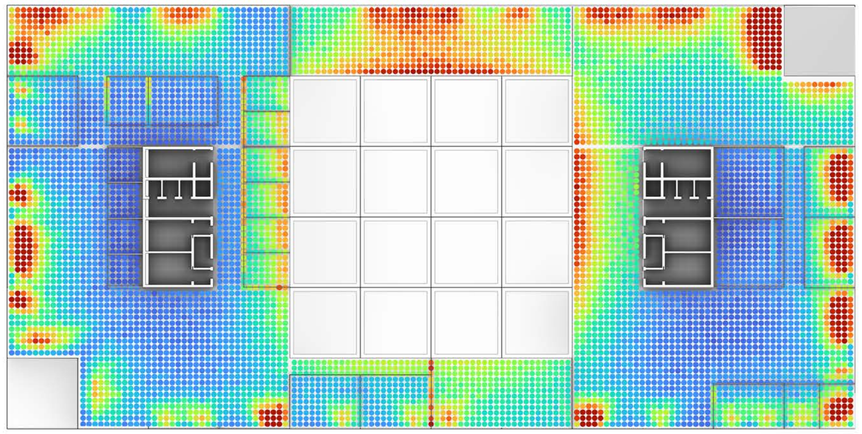
8.80%



LUX

983

Avg. LUX

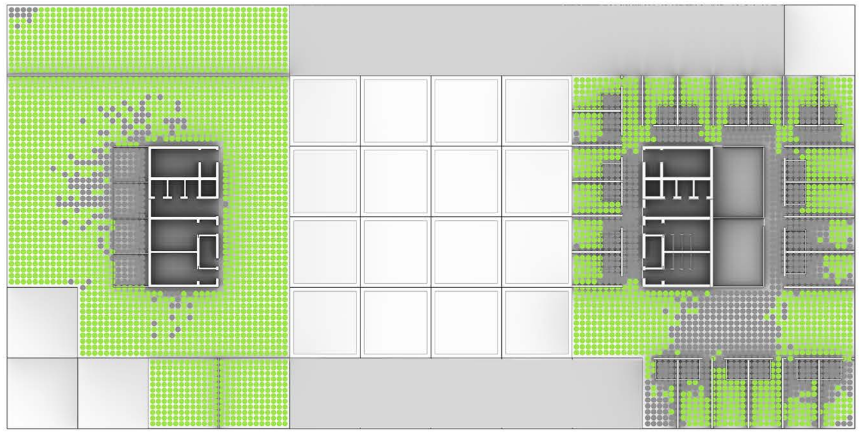


Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

3rdFloor Residencial-Offices

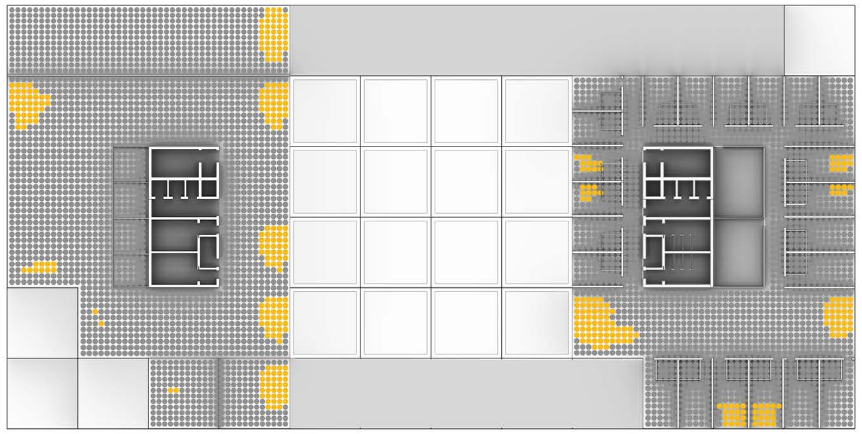
sDA

69.27 %



ASE

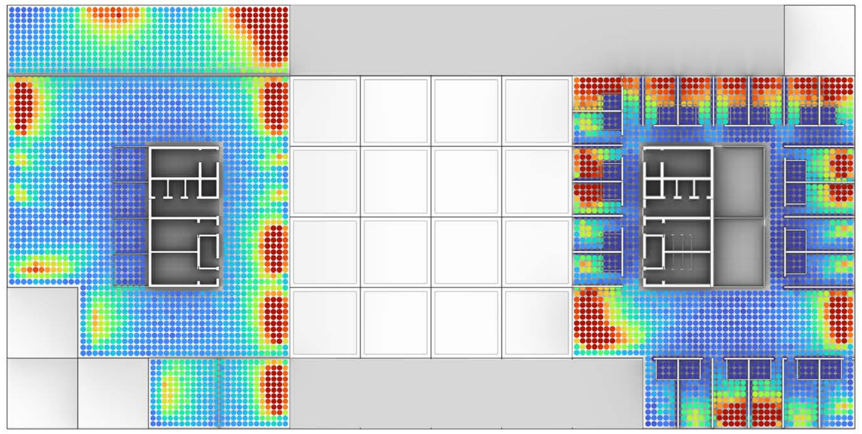
8.51%



LUX

983

Avg. LUX

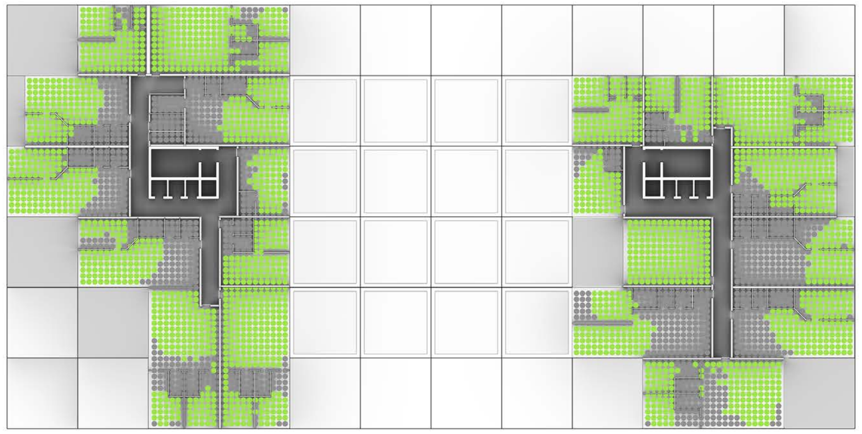


Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

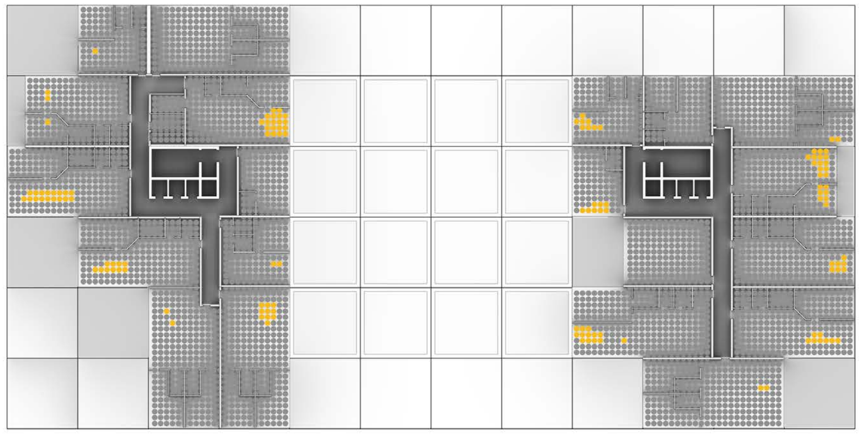
DAYLIGHT ANALYSIS

4th Floor Residencial

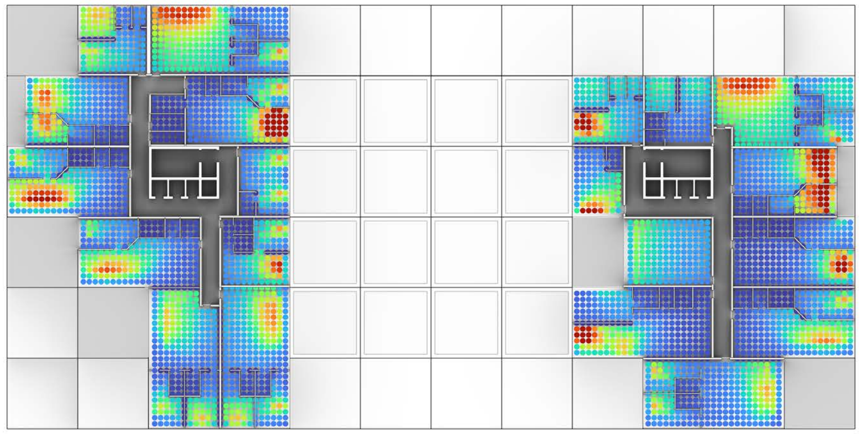
sDA
64.61 %



ASE
3.49%



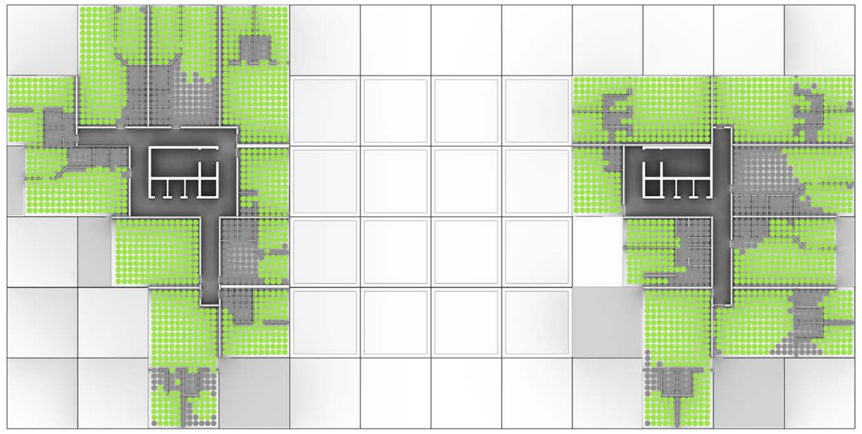
LUX
893
Avg. LUX for all residencial units



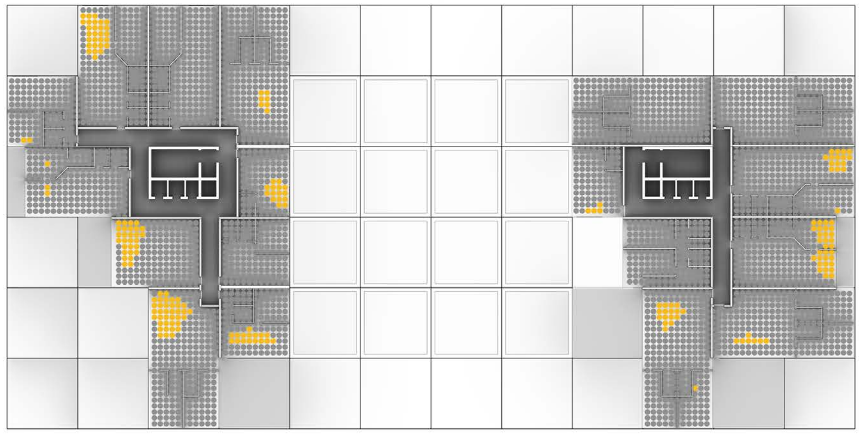
Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

5th Floor Residencial

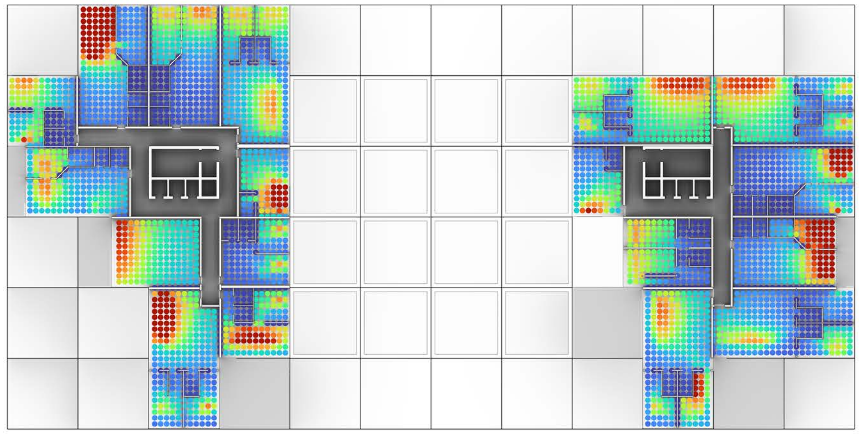
sDA
72.29 %



ASE
5.9%



LUX
893
Avg. LUX for all residencial units

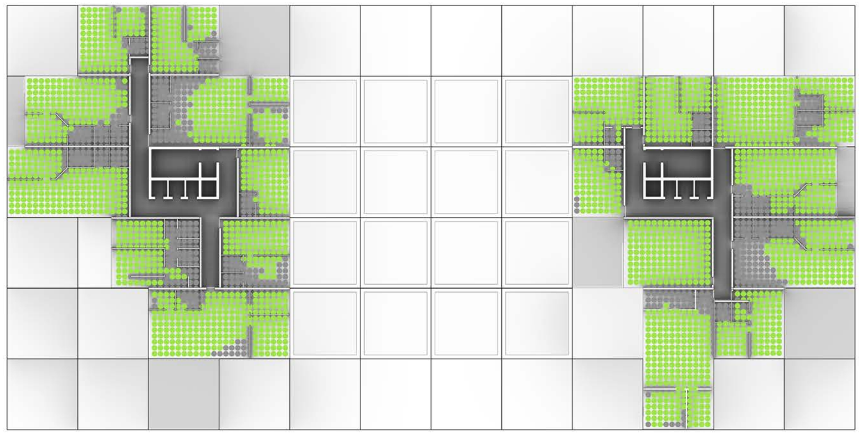


Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

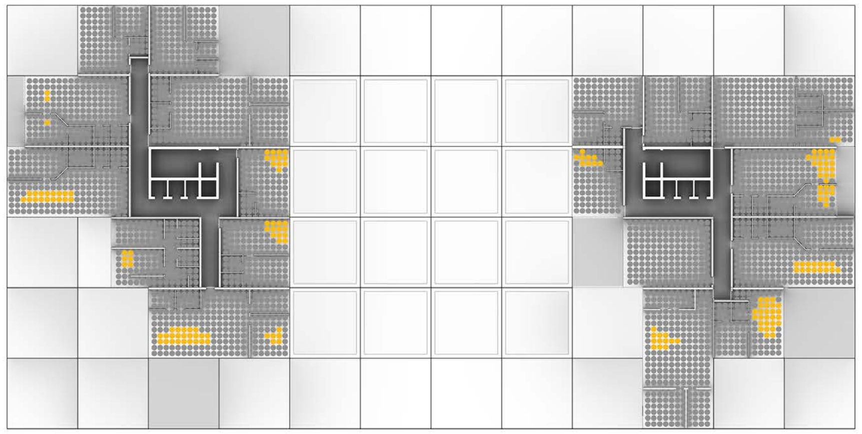
DAYLIGHT ANALYSIS

6th Floor Residencial

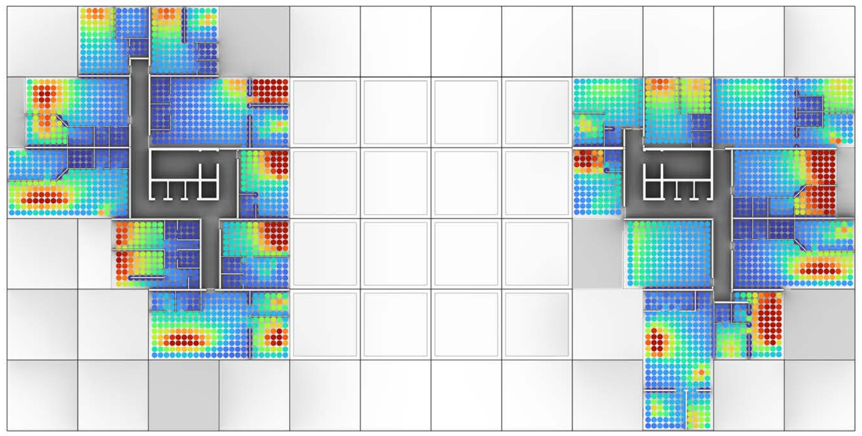
sDA
76.24 %



ASE
5.24%



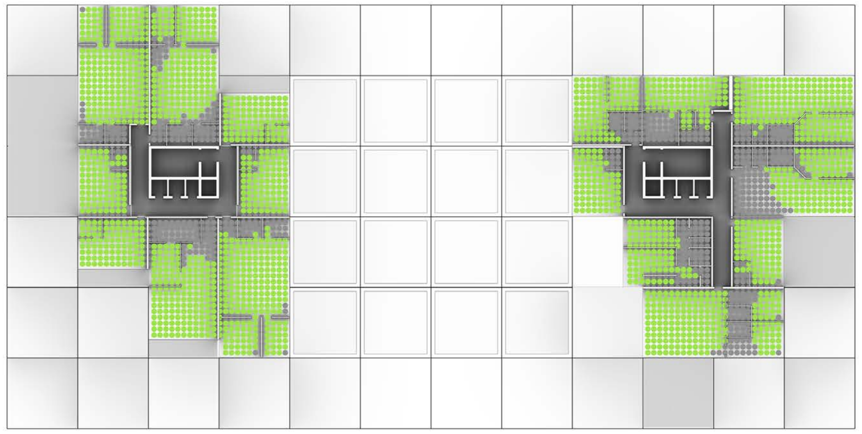
LUX
893
Avg. LUX for all residencial units



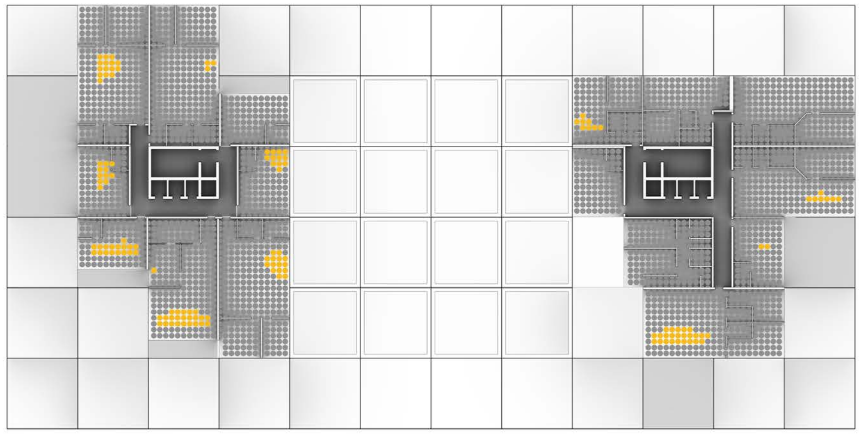
Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

7th Floor Residencial

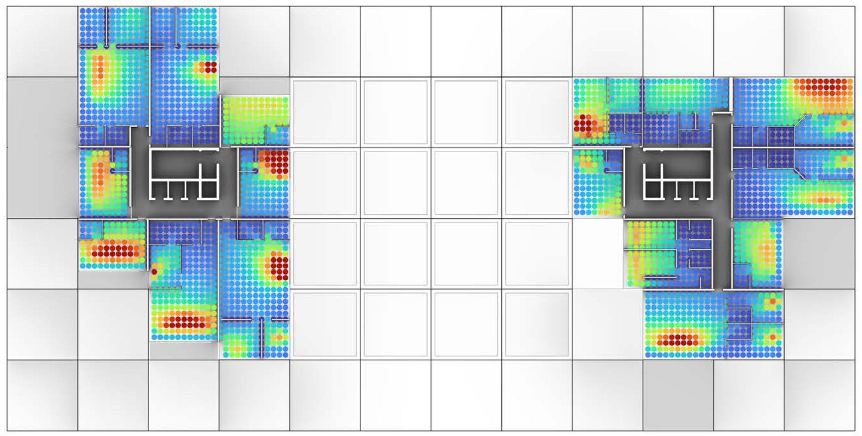
sDA
75.32 %



ASE
4.95%



LUX
893
Avg. LUX for all residencial units

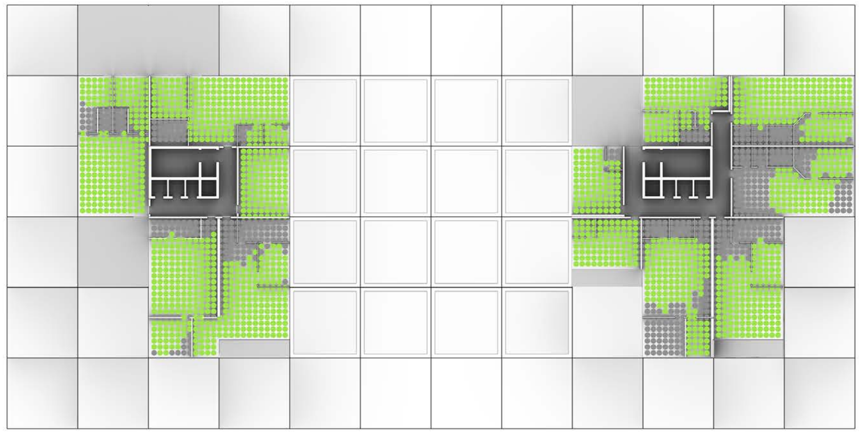


Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

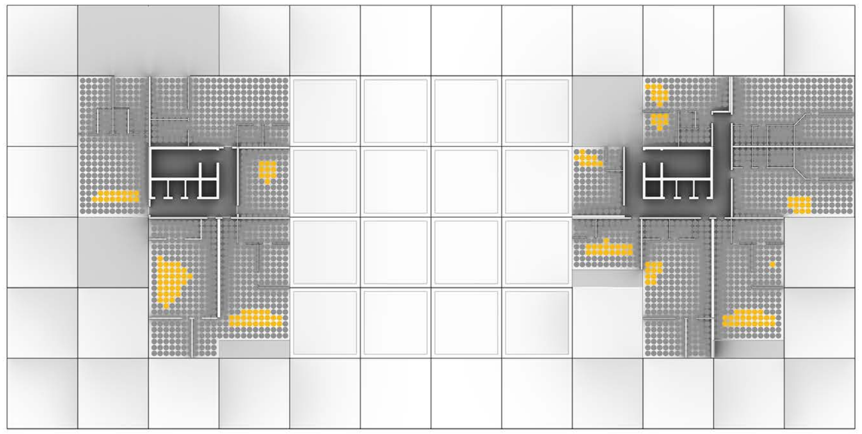
DAYLIGHT ANALYSIS

8th Floor Residencial

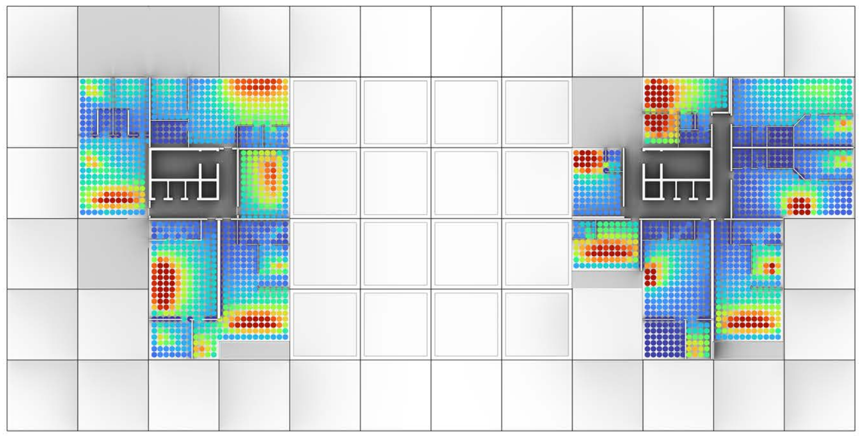
sDA
78.16 %



ASE
6.87%



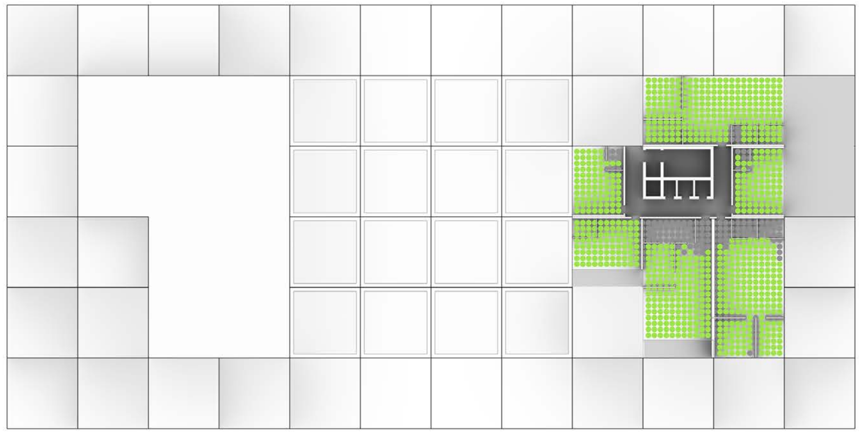
LUX
893
Avg. LUX for all residencial units



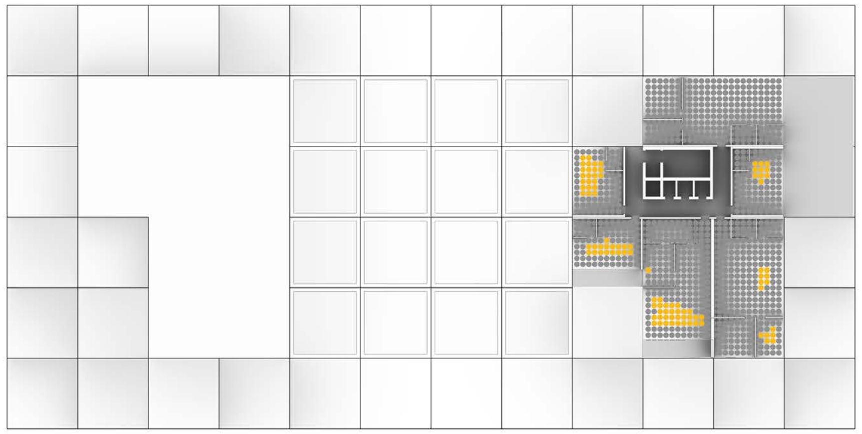
Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

9th Floor Residencial

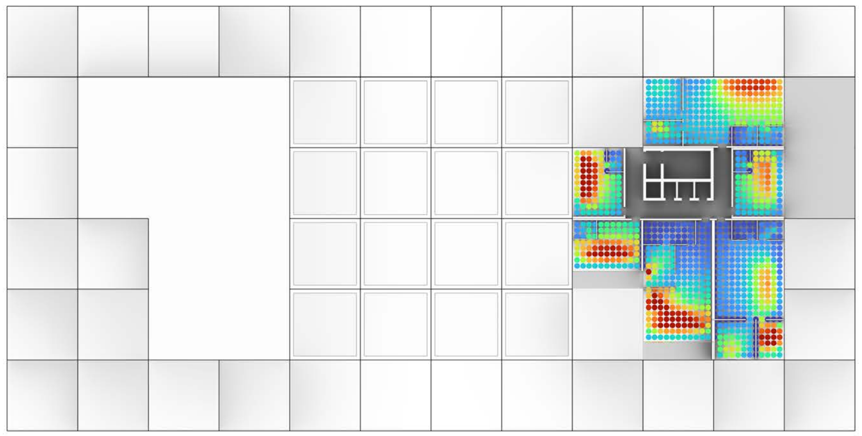
sDA
82.15 %



ASE
6.72%



LUX
893
Avg. LUX for all residencial units



Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

DAYLIGHT ANALYSIS

Description of plans

Analysing the daylight performance of a multifunctional building in Beirut, several parameters were considered, including sDA, ASE, and LUX. These parameters provided a comprehensive understanding of the building's daylighting conditions, allowing for targeted improvements to optimize energy efficiency and occupants' well-being.

The ground, first, and second floors of the building showed good overall performance in terms of daylighting, with sufficient natural light penetrating the space. The third and forth floors also achieved high values and with further development could be maximized by analysing more in detail the interior size and orientation of the building, its shape, or the presence of surrounding buildings that block natural light.

The fifth to ninth floors of the building had good sDA values, indicating that natural light was effectively penetrating the space. However, the tenth floor showed a quite high ASE value, which means that there is a higher potential for glare easily countered by common residential shading solutions.

Ground Floor: sDA 88.93 %, ASE 5.15%,LUX983

1st Floor: sDA 90.63 %, ASE 4.30%,LUX983

2nd Floor: sDA 84.45 %, ASE 8.80%,LUX983

3rdFloor: sDA 69.27 %, ASE 8.51%,LUX983

4th Floor : sDA 64.61 %, ASE 3.49%,LUX893

5th Floor: sDA 72.29 %, ASE 5.9%,LUX893

6th Floor: sDA 76.24 %, ASE 5.24%,LUX893

7th Floor: sDA 75.32 %, ASE 4.95%,LUX893

8th Floor: sDA 78.16 %, ASE 6.82%,LUX893

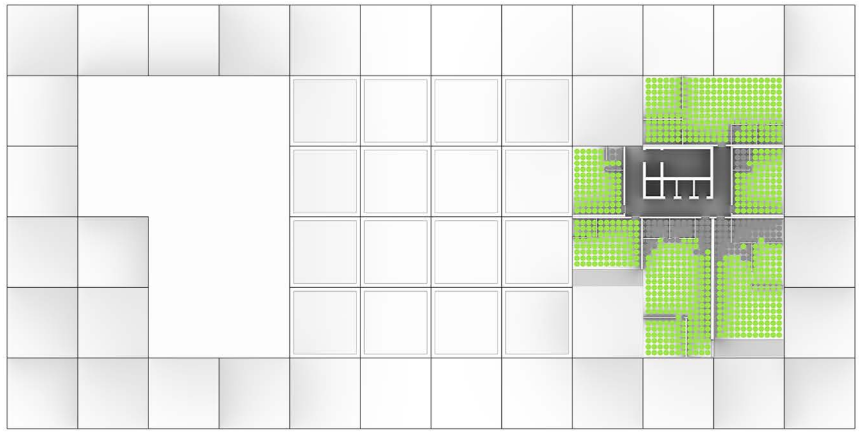
9th Floor: sDA 82.15 %, ASE 6.72%,LUX893

10th Floor: sDA 82.44 %, ASE 9.12%,LUX893

10th Floor Residencial

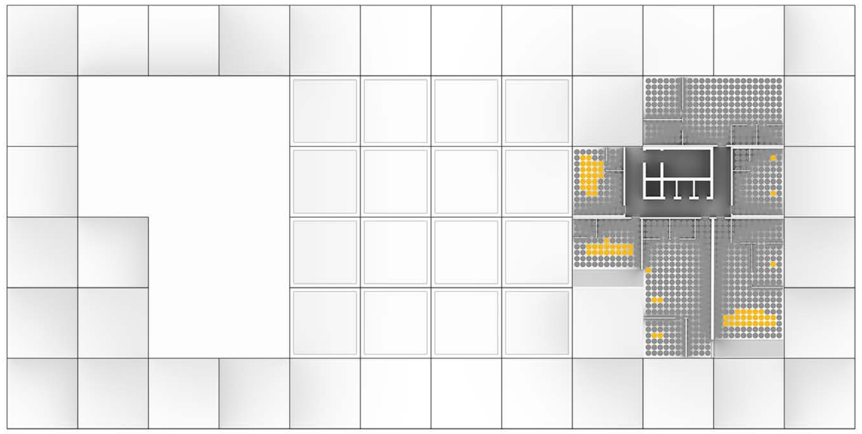
sDA

82.44 %



ASE

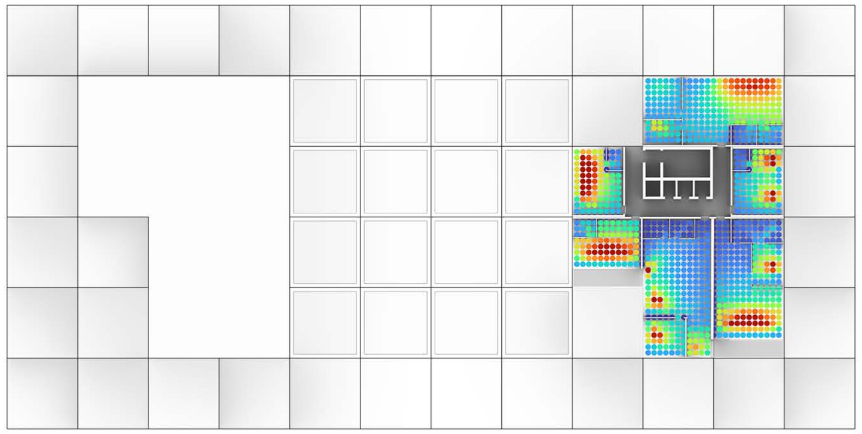
9.12 %



LUX

893

Avg. LUX for all residencial units



Engine: Radiance 5.3
Weather: LBN_BA_Beirut
North Offset: 0°
Ambient Bounces: 6

DAYLIGHT ANALYSIS

Conclusion

In conclusion, additional lighting fixtures may need to be installed on the second and third floors to improve the overall lighting conditions. However, thanks to the atrium and double high of the first floors of the multifunctional building in Beirut play a crucial role in maximizing the daylight factors such as sDA, ASE, and LUX. These design features allow natural light to penetrate deeper into the building's interiors, providing a well-lit and comfortable environment for the occupants.

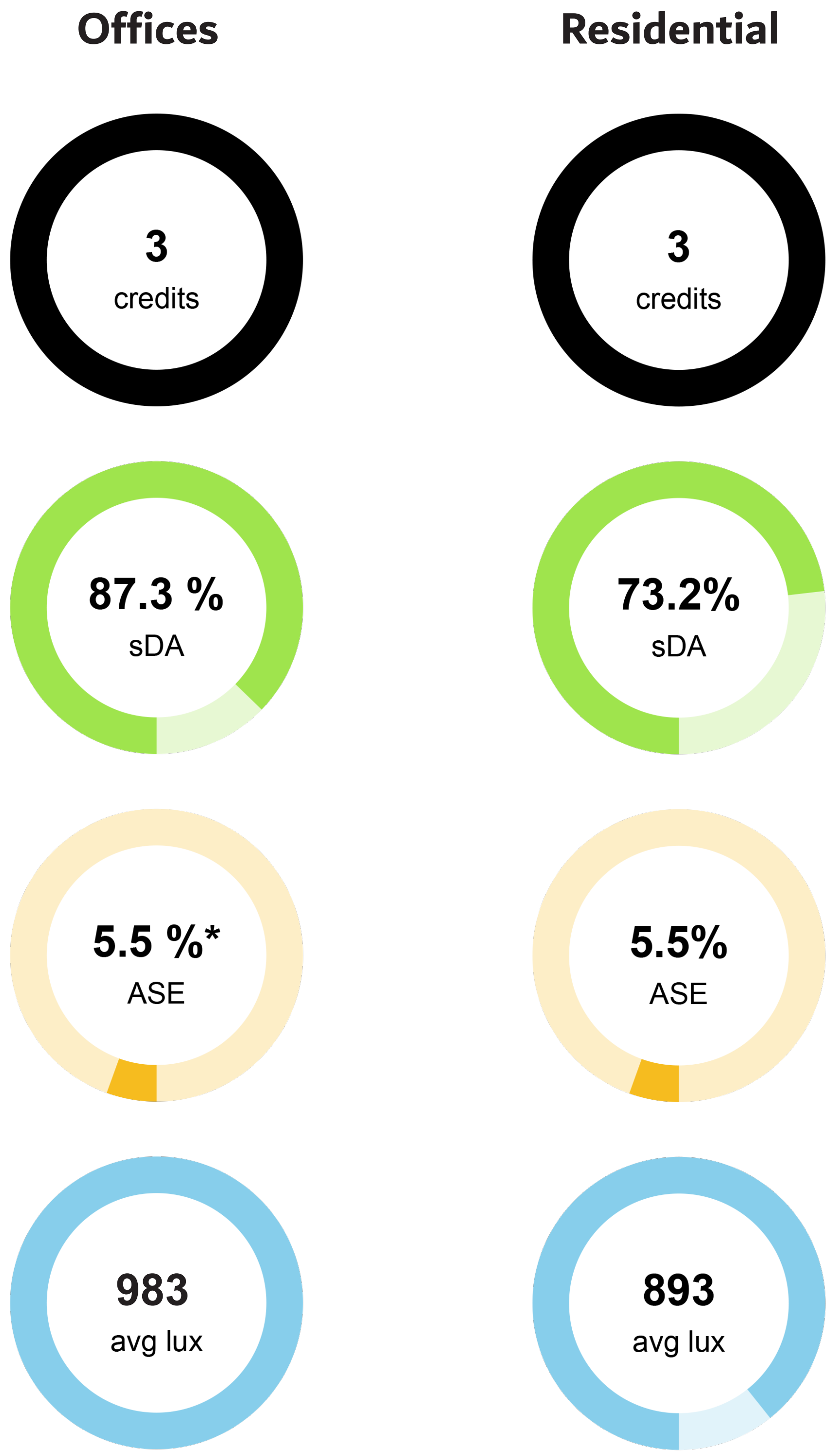
The atrium, a central "open" space that connects multiple floors, acts as a light well, drawing in natural light and distributing it throughout the surrounding spaces. This design feature allows the first-floor spaces to benefit from a higher sDA and lower ASE value, as they receive direct and indirect sunlight for a longer duration. The double-height space further amplifies the effect of the atrium by extending the height of the floor-to-ceiling glazing, increasing the amount of natural light that enters the space.

The use of high-performance glazing further enhances the daylight performance of the first floors. The glazing allows for maximum daylight transmission while minimizing heat gain, thereby reducing the need for artificial lighting and cooling during the day.

Overall, Daylight analysis is an essential aspect of building design, as it can significantly impact the energy efficiency, occupant comfort, and well-being of the building's occupants. One critical element of daylight analysis is the careful consideration of windows' orientation and opening, as well as the impact on terraces and natural vegetation shading.

We used terraces and natural vegetation shading because it is known to have a significant impact on building's daylight performance and occupant comfort. Terraces provided shading and reduced the amount of direct sunlight entering the space, filtering and diffusing sunlight, reducing glare. Moreover, the atrium and double-height space of the first floors contribute to the building's daylight performance and energy efficiency and occupants' well-being.

To achieve 3 stars in LEED daylight analysis for building performance, we took several factors into account. According to [1], achieving economic and environmental performance require a good daylight analysis, the guide recommends using an hourly time-step analysis based on typical meteorological year data, or an equivalent, for the nearest available weather station. Secondly, Building orientation and windows opening should be carefully analysed according to climate data. [2]. Additionally, it is important to ensure that any permanent shading devices (terraces and deep voids) are accounted for in the analysis. Finally, those main drivers were implemented to resilient and healthy strategies to realize a sustainable masterplan in terms of environment, economic, social and community. By following these guidelines, a building can achieve a 3-star rating in LEED daylight analysis for building performance.



References:

[1] LEED v4: Building Design + Construction Guide

[2] Daylight | U.S. Green Building Council

ENERGY

Introduction

In this chapter, we analyse our building with respect to energy consumption following the established design regulations. We employed the European Standard "EN 15251" to ensure thermal & air quality, and acoustic & visual comfort.

The energy consumption of the building is calculated by energy simulations performed in the software Solemma and algorithms created in Grasshopper. The application demonstrates the energy demands of the building for general equipment, heating, cooling, and lighting.

In the energy simulations, the conditions of the climate of Beirut were considered by observing the energy demands of the seaside port area, and this meant taking into account the prevalence of heating energy demand. Further, considerations of the space uses in the building were made as well as lighting needs following the standarts ASHRAE 55, ASHRAE 62, UNI 10339, EN 12464 and 12193.

Building energy performance requirements in Beirut are essential for reducing the energy demand of buildings, mitigating climate change, and ensuring the comfort of occupants. The building category and total energy requirements are two significant factors to consider when analysing the energy performance requirements of a building in Beirut.

Building Category:

The building category is an important parameter that determines the energy performance standards for a building. Buildings in Beirut are categorized based on their use and function, such as residential, commercial, educational, healthcare, and industrial buildings. Each building category has different energy performance requirements, which are determined by the Ministry of Energy and Water in Lebanon. The energy performance requirements for each category are based on the type and amount of energy consumed, the size and height of the building, and the level of occupancy.

Total Energy Requirements:

The total energy requirements for buildings in Beirut are determined by the total energy consumed for heating, cooling, and lighting the building. The energy consumed is measured in kWh/m2 per year, and the energy performance requirements vary based on the building category. The energy performance requirements are more stringent for buildings with higher energy consumption.

Building Envelope:

The building envelope plays a crucial role in reducing the energy consumption of buildings. The envelope should be designed to minimize heat gain during summers and heat loss during winters. The envelope should be well-insulated with high-performance materials, such as double-glazed windows, insulated walls, and roofs.

HVAC Systems:

The HVAC system is responsible for heating, ventilation, and air-conditioning of the building. HVAC systems should be designed to be energy-efficient, with high-efficiency equipment and controls. The system should be regularly maintained and serviced to ensure maximum efficiency.

Lighting:

Lighting is a significant energy consumer in buildings. Energy-efficient lighting systems, such as LED lights, should be used to reduce energy consumption.

Systems such as DALI (Digital Addressable Lighting Interface) can be used to benefit the circadian rhythm by manipulating the power and color temperature of connected lighting devices to suit the hour of the day and external lighting conditions.

https://www.dali-alliance.org/dali/

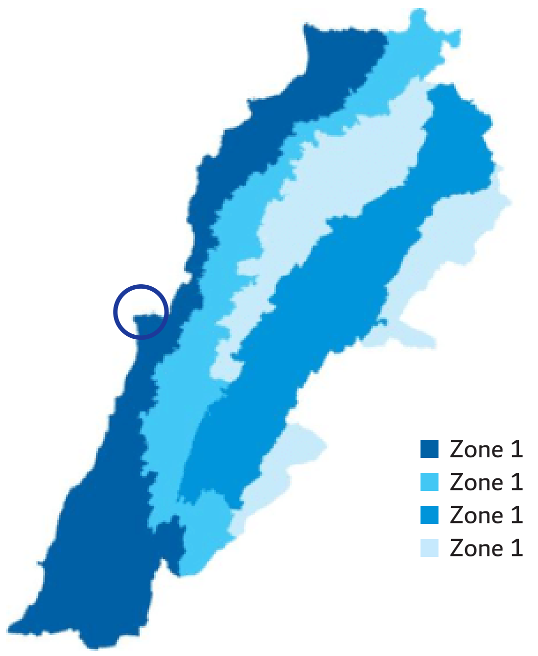
Renewable Energy:

Renewable energy sources, such as solar panels, can be used to generate electricity and reduce the energy demand of buildings. On account of the opportunities offered by the climate, new construction in Beirut should be designed to incorporate renewable energy sources, such as solar panels, wherever possible.

Energy performance requirements for buildings in Beirut are crucial for reducing energy demand, mitigating climate change, and ensuring occupant comfort. The building category and total energy requirements are key factors to consider when analyzing the energy performance requirements of buildings in Beirut. Technical guidelines, such as optimizing the building envelope, using energy-efficient HVAC systems and lighting, and incorporating renewable energy sources, should be followed to achieve maximum energy efficiency.

THERMAL STANDARDS

ENVELOPE



CLIMATE ZONES

Zone 1 -Coastal
Zone 2 - Western Mid-mountain
Zone 3 - Inland Plateau
Zone 4 - High Mountain

Climatic Zone	Climatic Sub-zone	Winter	Summer	Daily Gap
1 Coastal	**1A** Altitude < 400 m	Warm and short	Hot and humid	Small all year
	1B Altitude > 400 m	Cold and long increasing with altitude	Hot and humid with maximum daily temperature differing slightly from 1A	

The maximum reference U-values for roofs, walls, glazing and exposed and semi-exposed floors are presented in Table 3.

Table 3: Reference Thermal Transmittance Values per Component U-ref (W/m²K) vs. climatic zone

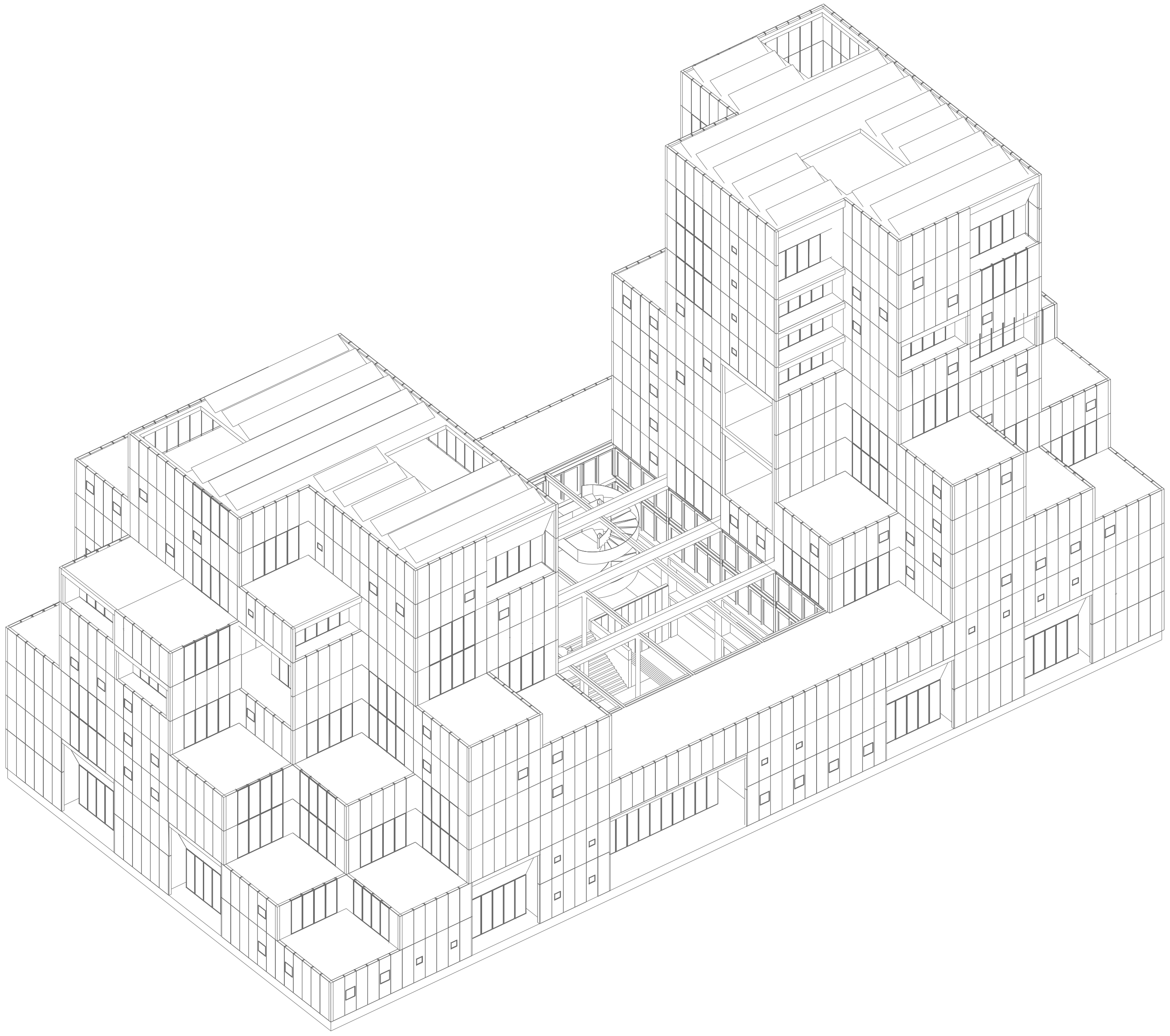
Climatic Zone	Building category	U-value Roof	U-value Wall	U-value Window	U value Ground Floor Exposed*	Semi-exposed**
1 Coastal	**1 Residential**	0.71	1.60	5.80	1.70	2.00
	2 N Residential	0.71	1.26	5.80	1.70	2.00

* Exposed: ground floor in direct contact with the exterior air.
** Semi-exposed: ground floor above a non air-conditioned space.

Values we used:

Element	U W/m^2K
Fiber c panel	1.8 W/m²K
Glass panel	1.2
Roof	0.71

References:
https://docplayer.net/146656135-Thermal-standard-for-buildings-in-lebanon-for-new-residential-and-non-residential-buildings.html



ENERGY

Energy Use Intensity (EUI)

The Project EUI of the multifunctional building located in Beirut is 96.72 Kwh/m2/Year, before energy optimization.

This value is calculated by dividing the total annual energy consumption (in KWh) by the total floor area (in square meters) of the building.

Therefore, the EUI of 96.72 KWh/m2/Year for the multifunctional building in Beirut indicates that it consumes 96.72 kilowatt-hours of energy per square meter of floor area per year. This value is below the average EUI for similar buildings in the region, which suggests that the building is operating efficiently.

Energy Gains and Losses

The main energy losses in the building occur during the summer months when the building requires cooling to maintain a comfortable indoor environment.
The mechanical ventilation system is responsible for most of these losses.
The energy consumption of the mechanical ventilation system increases significantly during the summer months. As you can see from the table, the energy consumption of the mechanical ventilation system increases significantly from June to August, when the outdoor temperatures are highest.
This is because the system has to work harder to maintain a comfortable indoor temperature during these months.

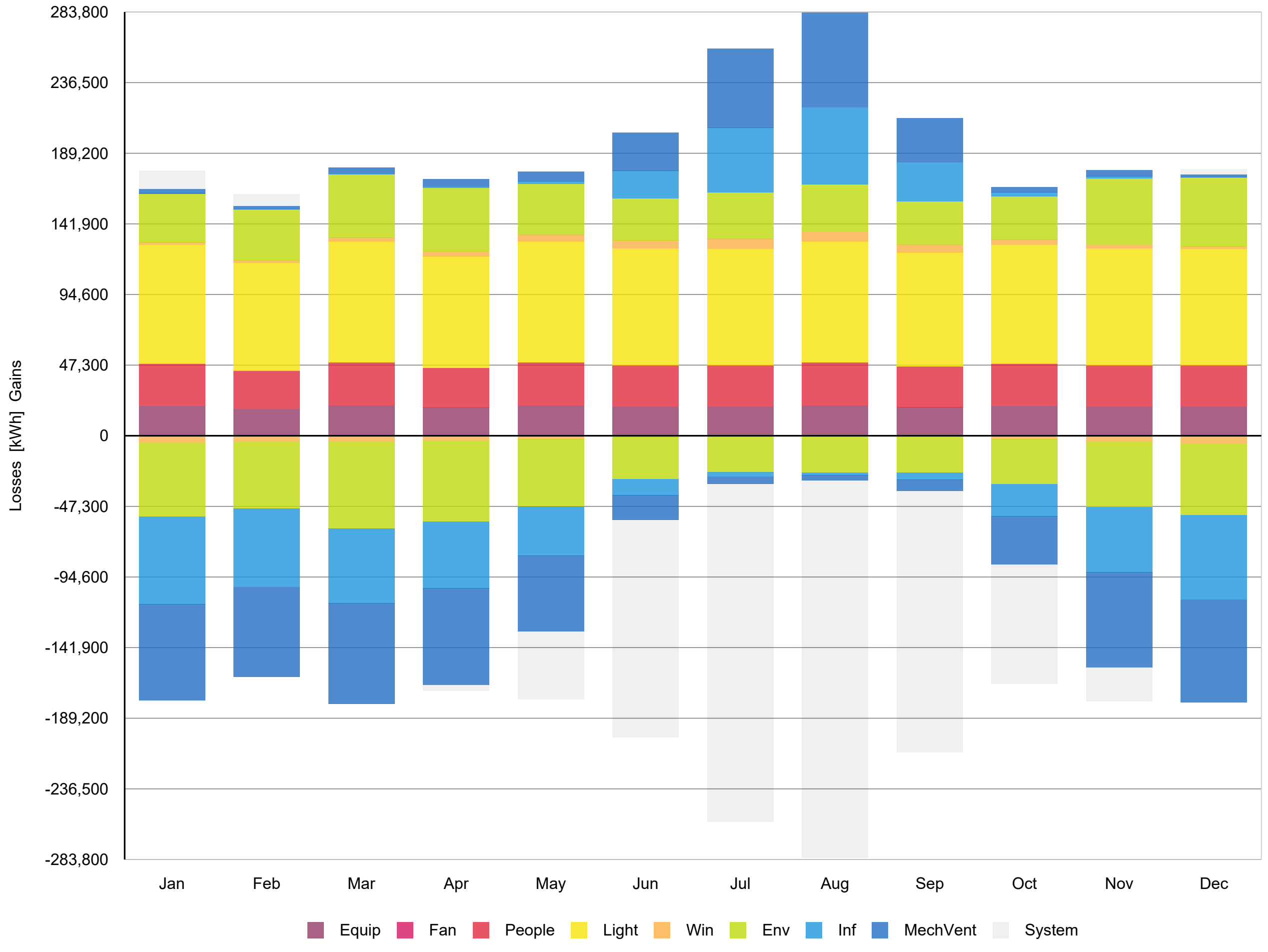
Other energy losses in the building are more homogeneous over the year and include equipment, lighting, domestic hot water, and fans. To reduce these losses, the building could adopt energy-efficient technologies and systems.

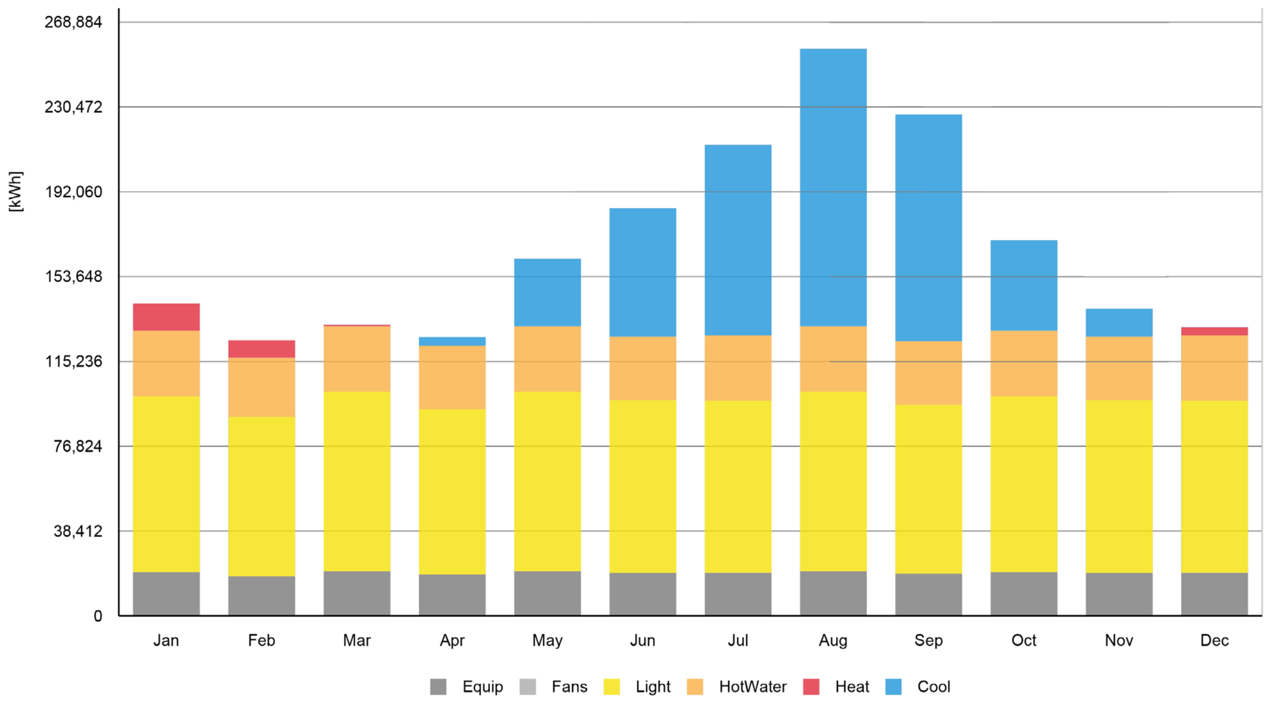
Passive Strategies to Decrease Mechanical Ventilation

One strategy for reducing the energy consumption of the mechanical ventilation system is to adopt passive strategies for natural ventilation. The building has a central atrium that works with the stack effect to promote natural ventilation. The central atrium has a height of 14 meters and a 790 cross-sectional area of square meters. The temperature difference between the bottom and top of the atrium is approximately 3 degrees Celsius. This creates a natural flow of air through the atrium, as warm air rises and is expelled through the vents at the top, while cooler air is drawn in from the surrounding spaces.
Another strategy for reducing the energy consumption of the building is to install terraces with vegetation. The building has three terraces, each with an area of 52 square meters. The vegetation on the terraces reduces glare and heat gain from direct sunlight, which reduces the cooling load on the building. The vegetation also promotes natural ventilation, as the movement of air around the plants helps to cool the surrounding spaces.

Before optimization:

EUI 96.72 Kwh/m²





ENERGY

Relative Humidity, T-MRT, T-Air, T-Operative

The multifunctional project located in Beirut, Lebanon, is a large-scale development that combines residential, commercial, and office spaces. The building was designed to be energy-efficient, taking into consideration the unique climate of Beirut. The building's energy performance was monitored over a one-year period, with specific attention given to relative humidity, T-MRT, T-Air, and T-Operative.

Relative humidity is an important factor to consider when designing energy-efficient buildings in hot and humid climates like Beirut. High humidity levels can lead to discomfort, indoor air quality issues, and increased energy consumption due to increased demand for air conditioning. The relative humidity levels in the building were monitored and kept within the recommended range of 40-60%.

T-MRT, or mean radiant temperature, is a measure of the average temperature of all surfaces in a space that radiate heat. T-Air is the air temperature, and T-Operative is the average of T-MRT and T-Air. Monitoring these three parameters is crucial for maintaining a comfortable indoor environment and minimizing energy consumption. The T-MRT, T-Air, and T-Operative were all kept within recommended ranges throughout the year, with the building's design and insulation playing a significant role in achieving this.

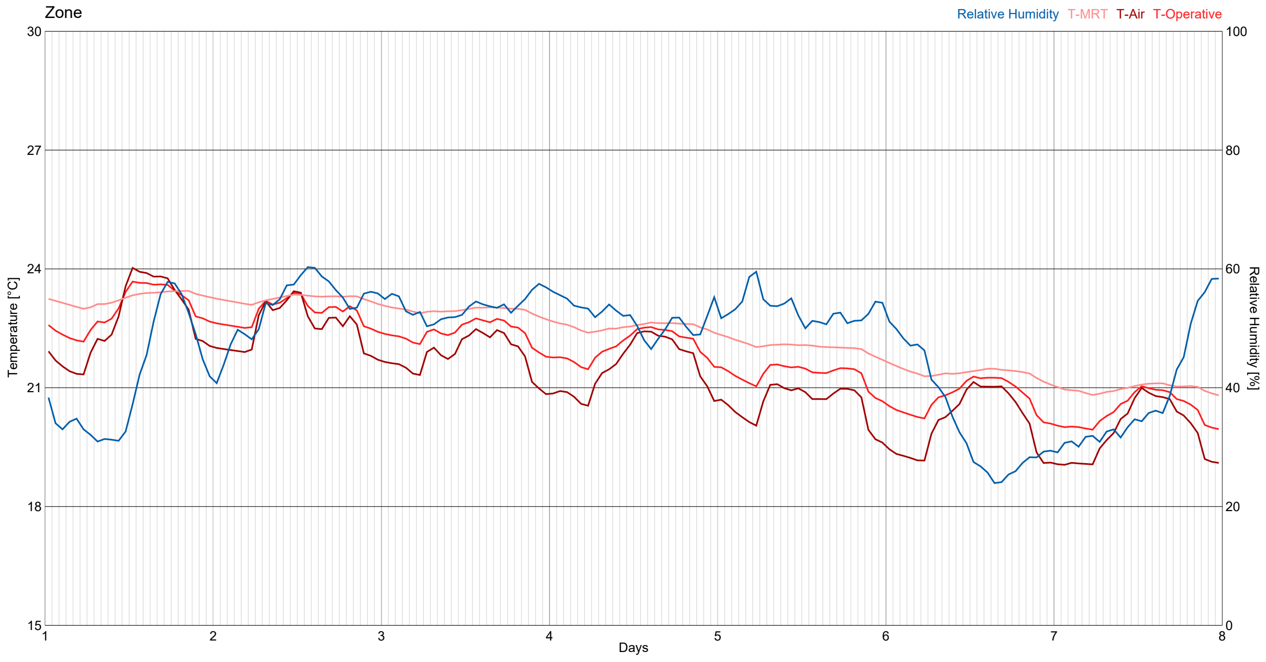
Heat Transfer Summer-Winter of Equipment, Lights, People, Ventilation, Infiltration Envelope, and Windows

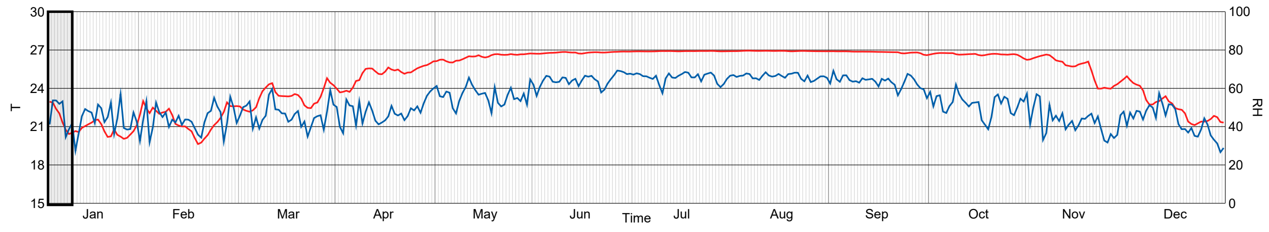
The multifunctional project located in Beirut was designed to be energy-efficient in both summer and winter. The building's energy performance was monitored over a one-year period, with specific attention given to heat transfer from equipment, lights, people, ventilation, infiltration, envelope, and windows.

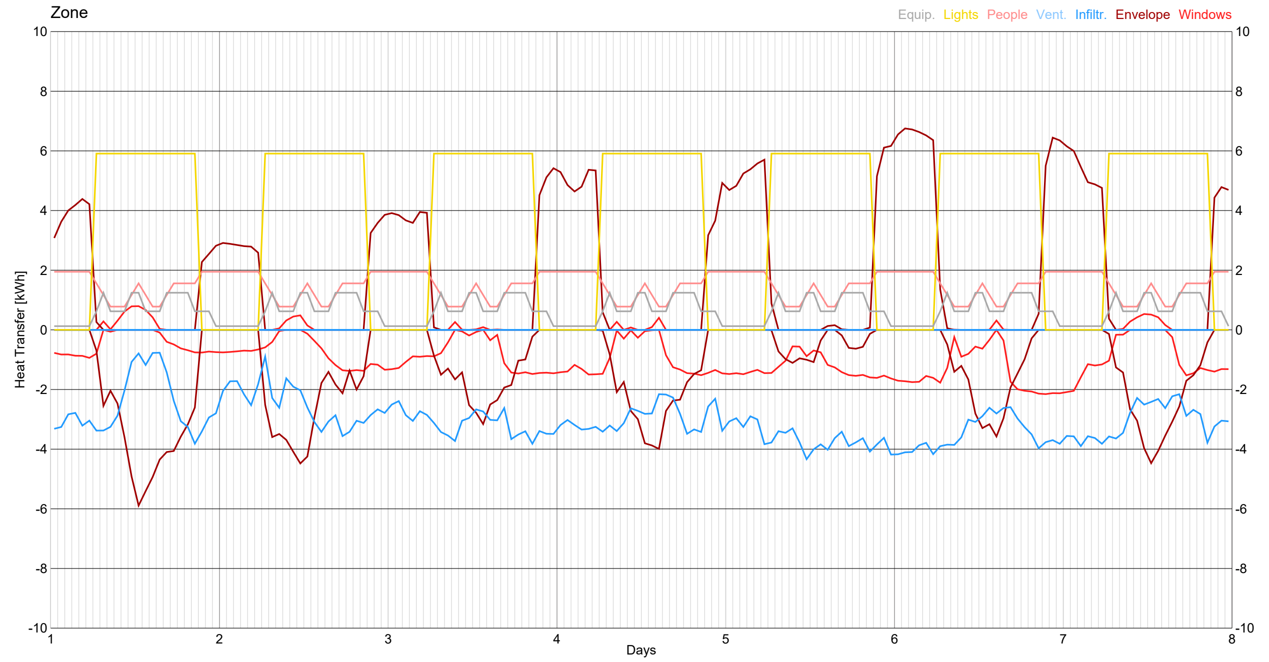
Equipment and lighting are major sources of heat gain in buildings. The building's design incorporated energy-efficient lighting fixtures and equipment, such as HVAC systems with high SEER ratings, to minimize the heat gain from these sources. People also contribute to heat gain in buildings. The building's design included measures to reduce heat gain from occupants, such as shading devices and reflective surfaces to reduce the impact of the sun's rays.

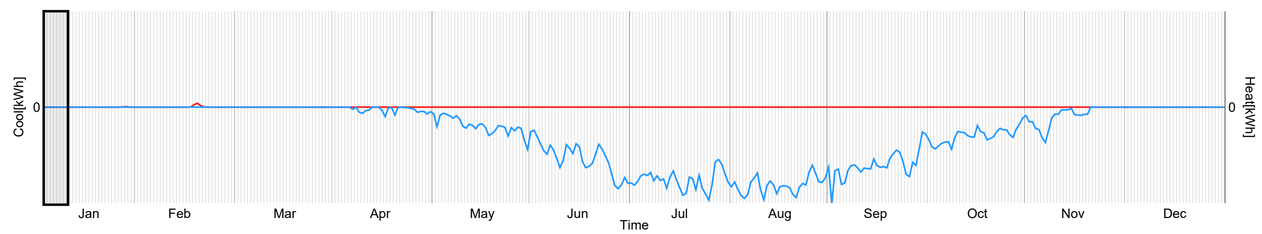
Ventilation and infiltration are essential for maintaining indoor air quality, but they also contribute to heat gain in buildings. The building's design included mechanical ventilation systems with energy recovery capabilities to minimize the energy required to maintain indoor air quality.

The building envelope and windows play a significant role in controlling heat transfer between the interior and exterior of a building. The building's design incorporated high-performance windows with low-e coatings and insulated frames to reduce heat gain in the summer and heat loss in the winter.









SOLAR PANELS

Solar Panel Specifications:
The SunPower Maxeon solar panels on the roofs have a total area of 872 m2, with a power of 440 W and an efficiency of 22.8%. The transparent PV glass in the atrium covers an area of 790 m2, with a power of 120 W and an efficiency of 30%.

Energy Production Calculation:
Using the annual solar radiation in Beirut of approximately 1863 kWh/m2/year, the energy production of the solar panels can be calculated as follows:
Total Energy Produced by Roof Solar Panels = Area x Power x Efficiency x Annual Solar Radiation

Roofs:
Total energy produced = 872 m2 x 440 W x 0.228 x 1863 kWh/m2/year = 795,783 kWh/year

Atrium:
Total energy produced = 790 m2 x 120 W x 0.30 x 1863 kWh/m2/year = 42,429 kWh/year

Total energy produced by both solar panel types = 838,212 kWh/year

Energy Savings Calculation:
The EUI is the amount of energy used per square meter of the building per year. In this case, the EUI of the building is 71.78 kWh/m2/year, and the total area of the building is 17,708 m2. Therefore, the total energy consumption of the building without the solar panels can be calculated as follows:
Total energy consumption = EUI x total area = 71.78 kWh/m2/year x 17,708 m2 = **1,270,603 kWh/year**

With the solar panels, the total energy consumption of the building can be reduced by the amount of energy produced by the solar panels. Therefore, the energy savings can be calculated as follows:

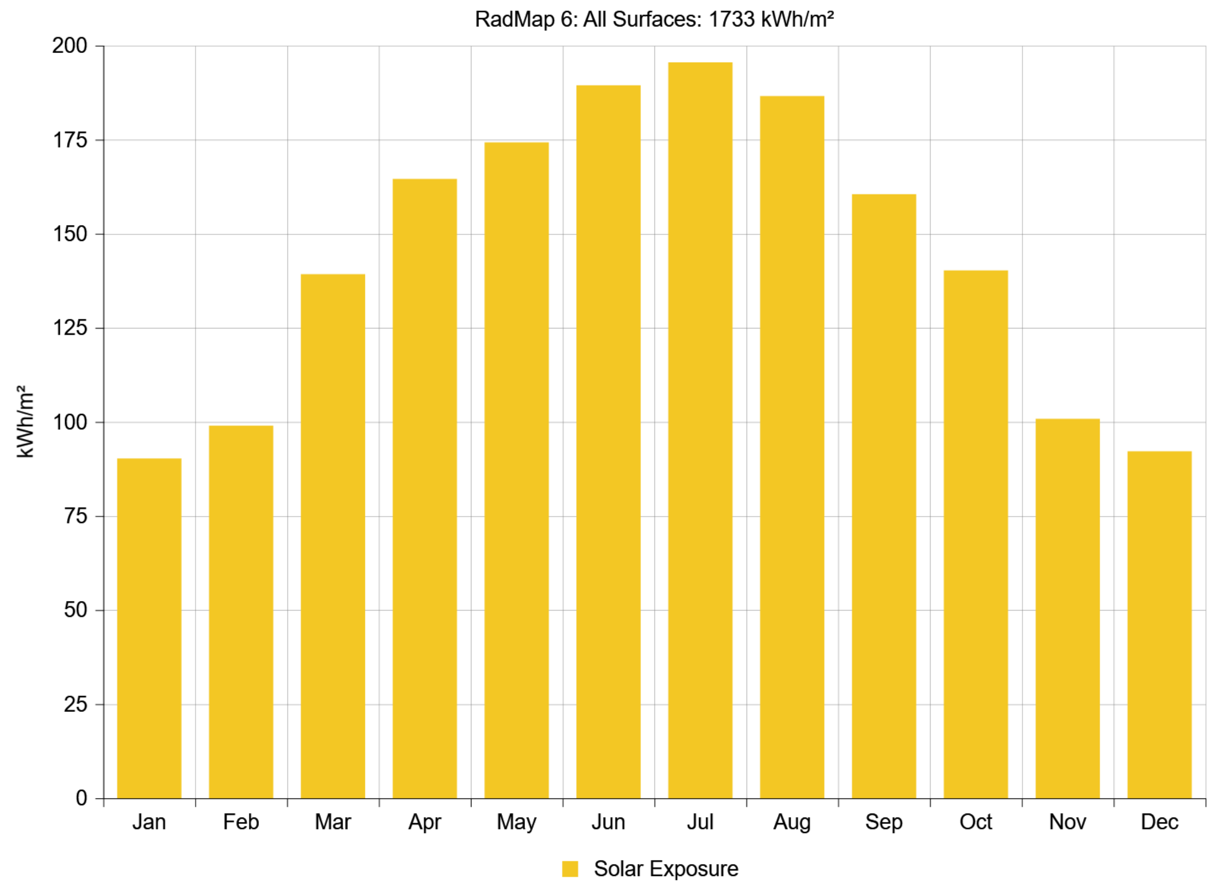
Energy savings = total energy produced by solar panels - total energy consumption without solar panels = 838,212 kWh/year - 1,270,603 kWh/year = **-432,391 kWh/year**

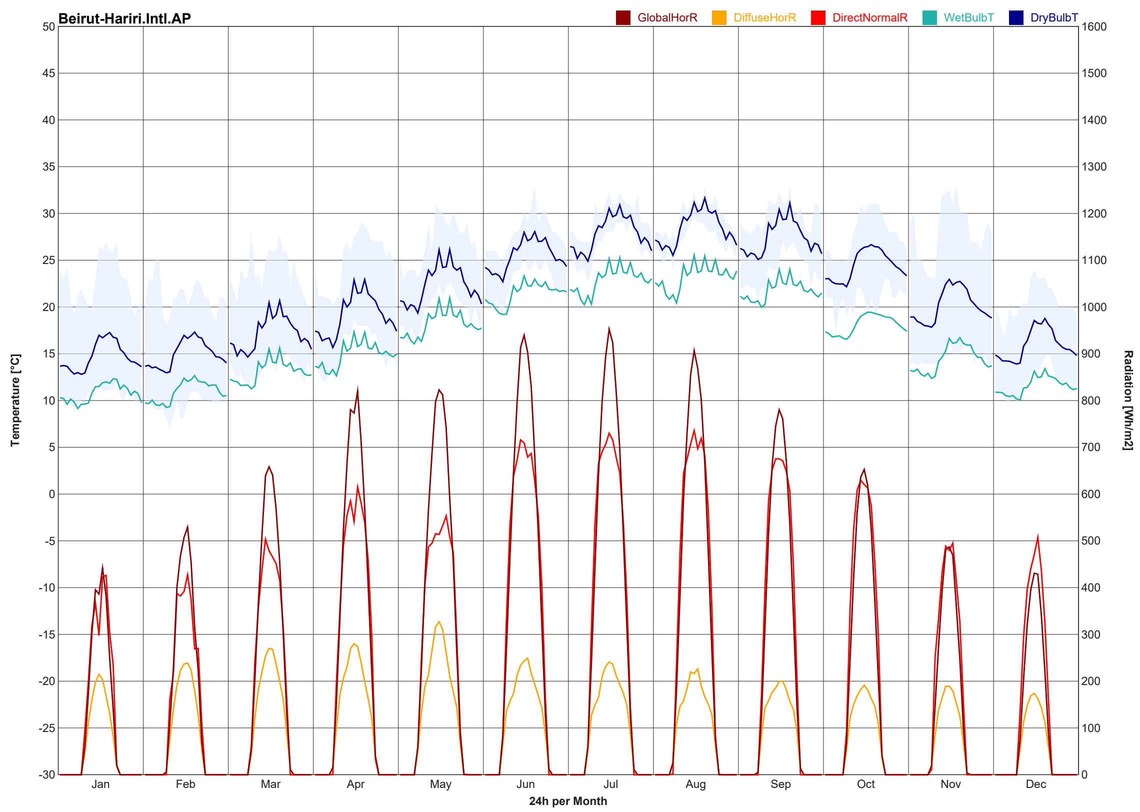
New EUI with PV panels:
New EUI = (Total energy consumption - Total energy savings from solar panels) / Total area of the building

Total energy consumption = EUI * Total area of the building Total energy consumption = 71.78 * 17,708 m2 Total energy consumption = 1,271,168 kWh

New EUI = (1,271,168 kWh - 115,608 kWh) / 17,708 m2 New EUI = 61.8 kWh/m2
Percentage reduction = ((Old EUI - New EUI) / Old EUI) * 100 Percentage reduction = ((71.78 - 61.8) / 71.78) * 100 Percentage reduction = 13.9%

Therefore, the new EUI of the building is **61.8 kWh/m2** and there has been a **13.9%** reduction in EUI after installing the solar panels.





ATRIUM OPTIMIZATION

The energy performance of an atrium in a building can be greatly affected by its integration and operation in hot and humid climates like Beirut. One of the key factors that influence energy performance is the use of natural ventilation and irradiation in the atrium. Natural ventilation can help to reduce the negative effects of overheating in internal spaces by allowing the heat at the top of the atrium to exit through the wind driving force and stack effect.

Stack effect is the phenomenon where hot air rises and is removed from the top section of the atrium through the openings located at the roof or sides. This can help to improve thermal comfort and indoor air quality for occupants. However, the hot air at the top of the atrium can cause unpleasant thermal conditions for occupants of the top floors. To address this, additional insulation and operable windows will be placed on the perimeter of the atrium's upper floors to reduce heat transfer.

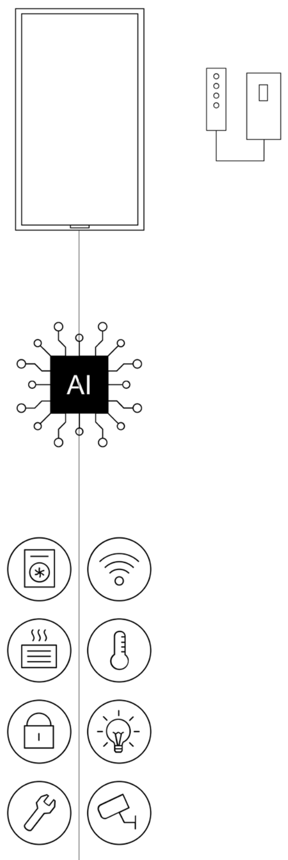
As a second step to improve the energy performance of the atrium we used Computational Fluid Dynamics (CFD) analysis. CFD is a numerical simulation technique that can help to predict the airflow and thermal behaviour of the atrium. By using CFD, we optimize the atrium airflow design to maximize natural ventilation and reduce energy consumption.

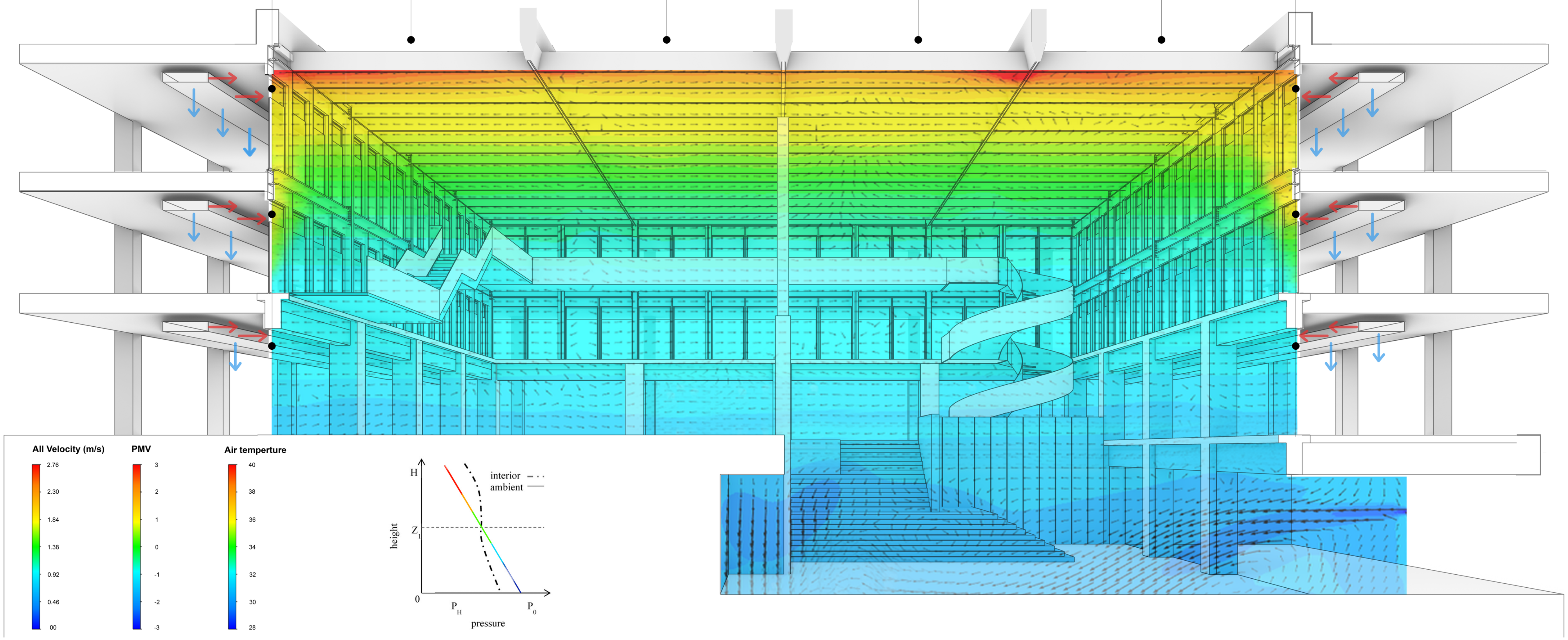
In this project, the top glazed surfaces of the atrium were covered by automatic operable transparent PV to increase natural daylight and improve thermal comfort, especially during summer working hours with stack effect. The study used the software Simscale for the airflow and Thermal Comfort Assessment with simulations. The analysis indicated higher atrium air temperature tolerance in the model below, with a range of 36.45°C to 39.12°C, while most of the atrium spaces in the side-lit atrium were 32°C. Overall, the integration of the atrium in the building can increase its performance in terms of daylight, air flows, Thermal Comfort and HVAC system of the offices, and decrease the overall energy use intensity (EUI) by up to 8% with the use of sensors connected to an automatic system.

Glazed interior façade + Atrium roof glass operable panels
Sensors
1-Internal Brightness
2-Room humidity, Pressure and temperature
3-Co2
4-noise
5-Internal radiation and surface temperature

Computerized Central Automation
1- Pressure sensors
2- Temperature/irradiation sensors
3- Thermal comfort satisfaction rate

Building Management System
1- HVAC automated control
2- Heat pump automated control
3- Security accesses
4- Monitoring maintainance
5- Climate datas integrated
6- Automated temperature
7- Artificial light savings
8- Security cameras





CO_2

CO2 Emissions Reduction Building optimization:

The CO2 emissions reduction can be calculated based on the amount of energy saved by the solar panels and the CO2 emissions factor of the energy source used to cover the remaining 34% of the building's energy needs. Assuming a CO2 emissions factor of 0.698 kg CO2/kWh for the energy source, the CO2 emissions reduction can be calculated as follows:

Total energy consumption = EUI * Total area of the building

Not optimized Building

Total energy consumption = 96.72 * 17,708 m2 = 1,712,717 kWh

Optimized building

Total energy consumption = 58.4 * 17,708 m2 = 1,034,147.2 kWh

Energy Saving

1,712,717 kWh - 1,034,147.2 kWh = 678,569.8 kWh

CO2 emissions reduction = Energy saving x CO2 emissions factor

= -678,569.8 kWh/year x 0.698 kg CO2/kWh = -473,641.72 kg CO2/year

Trees:
According to the United States Environmental Protection Agency (EPA), https://www.epa.gov/, in average a tree can absorb 21.8 kilograms of CO2 per year.

Our project, Oasis has a total of 80 trees just in building site (without counting external parks)

CO2 emissions reduction

= N trees x CO2 absorption

= 83 trees x 21.8 Kg= - 1,809.4 kg CO2/year

It is also important to note that the amount of CO2 absorbed by a tree can decrease over time as the tree ages, and that planting trees alone is not enough to fully mitigate the effects of greenhouse gas emissions on the environment. It is important to reduce our carbon footprint through other means, such as using renewable energy sources and practicing energy efficiency.

Green Roofs:

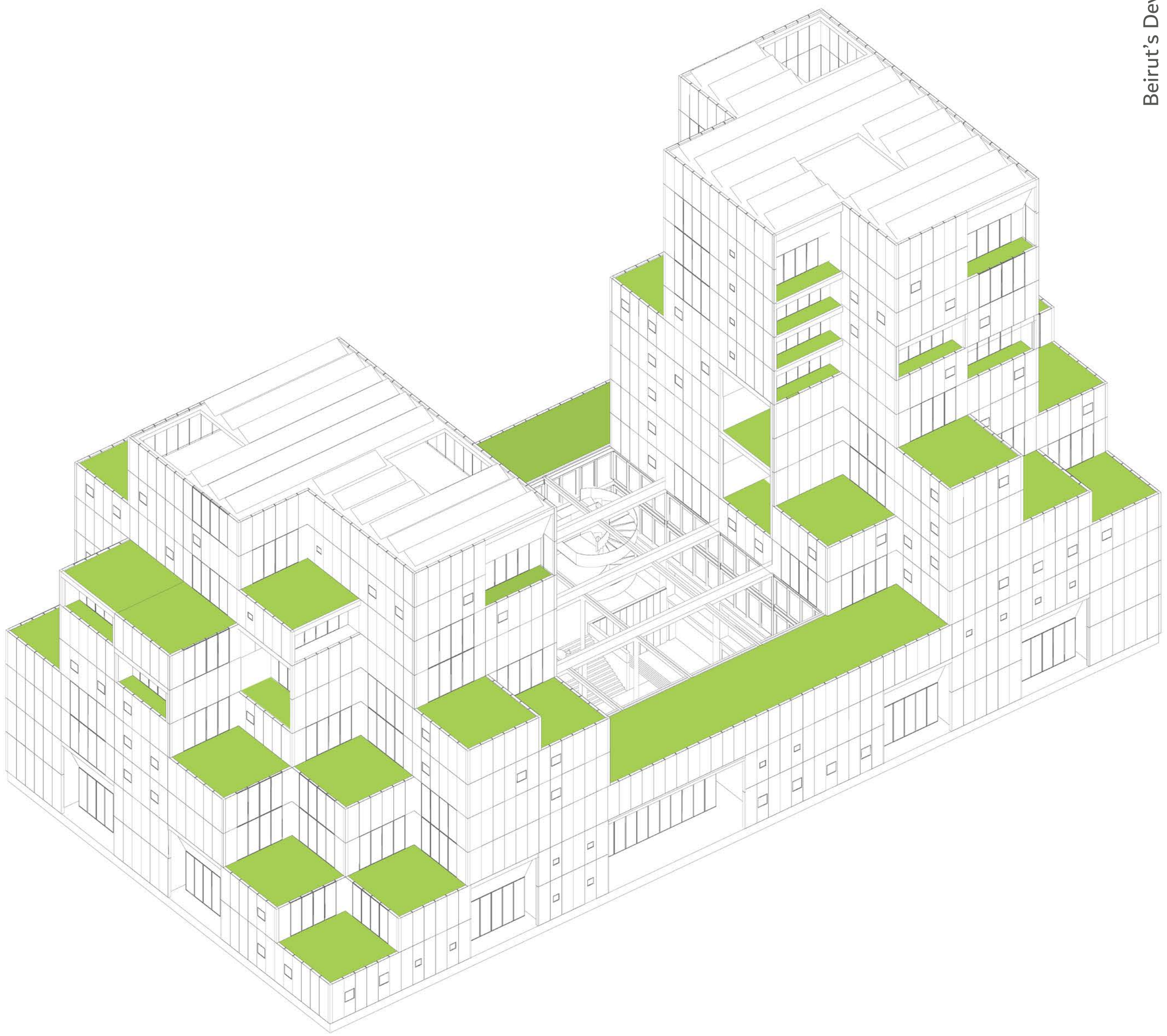
According to a study by the Green Roofs for Healthy Cities organization, a green roof with 75% coverage can absorb up to 208 grams of CO2 per square meter per year. Therefore, for a project with 39 green terraces totaling 2020 square meters, the total CO2 absorption would be approximately:

2020 m2 x 0.75 (coverage) x 208 g CO2/m2 = 316,800 g CO2/year

To convert grams to kilograms, we can divide by 1000:

316,800 g CO2/year ÷ 1000 = 316.8 kg CO2/year

Therefore, the estimated, direct CO2 reduction of this project would be approximately 316.8 kg CO2 per year.



Conclusion:

Our building has a total Co2 reduction of :

- CO2 Emissions Reduction Building optimization - Trees CO2 absorption - green roof CO2 absorption =

-473,641.72 - 1,809.4 - 316.8 =

-480,020.32 kg CO2/year

References:

United States Environmental Protection Agency (EPA). (2016). Carbon dioxide equivalents. Retrieved from https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Green Roofs for Healthy Cities. (2019). The Green Roof Industry Survey. Retrieved from https://greenroofs.org/2019-industry-survey/

DAYLIGHT ENERGY OPTIMIZATION

CO2	EUI	ENERGY COST
-480,020.32 kg/CO_2 year	58.4 kWh/m^2	€ 279,889.10

Smart HVAC System:

The Carrier i-Vu Building Automation System optimizes energy consumption while maintaining indoor comfort by remotely monitoring and controlling temperature and airflow based on occupancy and weather conditions.

Smart Lighting System:

The Philips Hue Smart Lighting or Dali system (Digital Addressable Lighting Interface). System adjusts lighting levels based on occupancy and natural daylight and can be remotely controlled, increasing energy efficiency and flexibility.

Automated Window Shades:

The Somfy Automated Window Shades reduce heat gain from direct sunlight, decreasing the need for artificial cooling and energy consumption. The system can be remotely controlled.

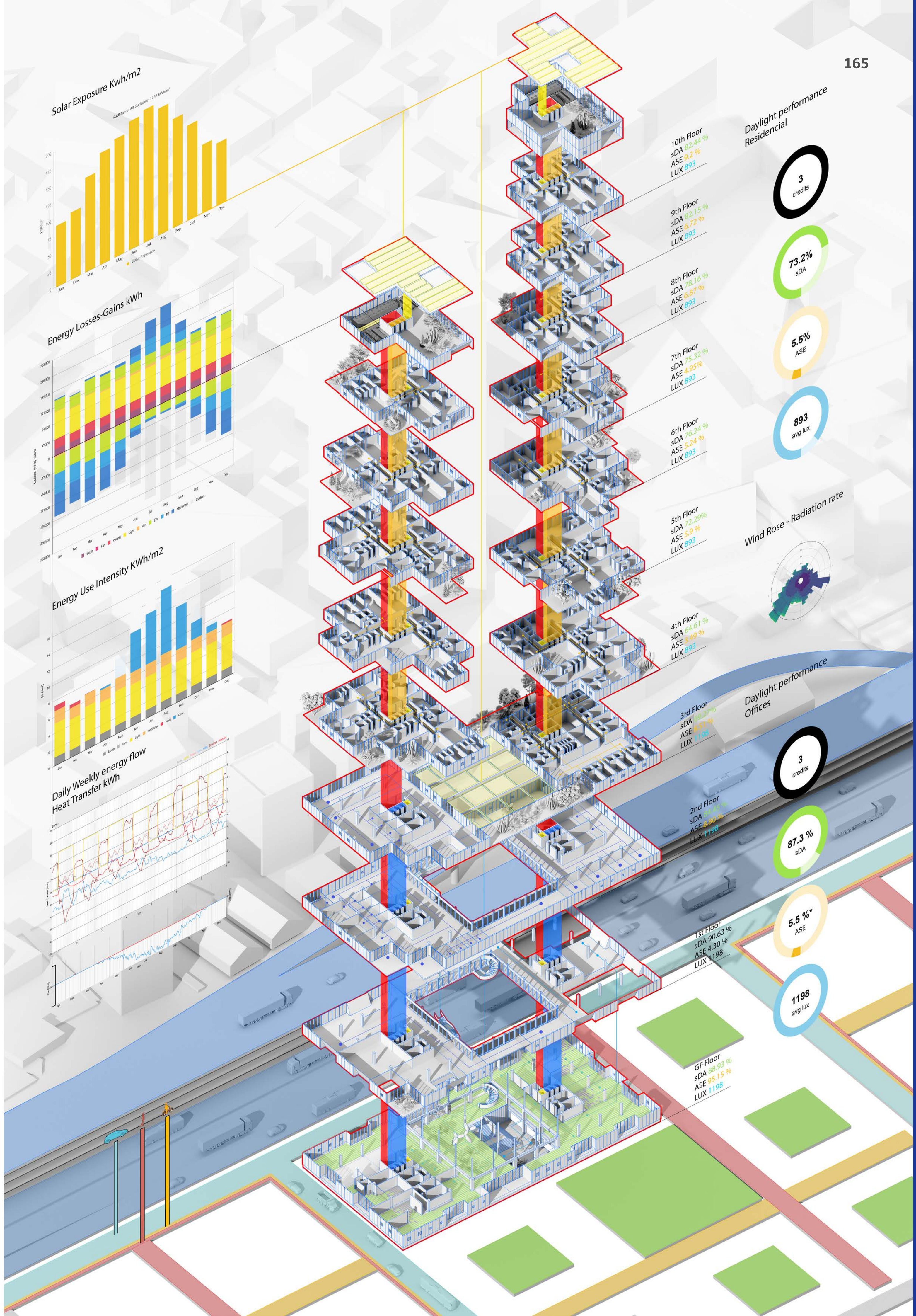
Smart Sensors:

Honeywell CO2 Sensors detect high levels of CO2 allowing the centralized system to increase fresh air intake, improving indoor air quality.

Energy Management System:

The Siemens Desigo CC Energy Management System monitors and controls all building systems, providing real-time data on energy consumption and identifying areas for energy savings, improving energy efficiency and reducing operating costs.

Type	%	EUI	Energy cost €
Basic Building		96.72	462,433.79
Automated window shades	-1	95.75	457,796.07
Envelope Optimization	-2	93.80	448,472.80
Smart Lighting system	-6	88.17	421,554.87
Smart HVAC System & Smart Sensors	-7	81.99	392,007.30
Water Optimization	-6	77.07	368,484.00
Terraces & natural shaders	-1	76.29	364,754.69
Energy Management System (domotic)	-3	74.01	353,853.65
Solar panels renewable energy	-14	63.64	304,273.02
Atrium Optimization	-8	58.54	279,889.10



BUILDING TECHNOLOGIES

CONSTRUCTION DETAILS

Introduction

Modular construction has become a popular choice for building projects due to its many advantages, including cost-effectiveness, speed, and sustainability. In the context of our project located in Beirut's Port, the use of modular construction offers several benefits.

1. Unitized System

Unitized panels are pre-assembled in the factory, with all components including glazing, framing, and insulation, fully integrated into the panel. This means that the panel is a complete unit, ready for installation on the building façade. The use of unitized panel technology in the Beirut Port project reduces installation time and costs as the pre-assembled panels can be installed quickly and easily on-site. This is particularly important in urban areas where access and space are limited. Furthermore, the pre-assembly of the panels in a controlled environment ensures high-quality construction and reduces the risk of errors or defects during the installation process. Unitized panel technology also offers advantages in terms of energy efficiency. The pre-assembled panels can be designed to incorporate high-performance glazing and insulation, which helps to reduce energy consumption and improve the overall energy efficiency of the building. However, the use of unitized panel technology also poses challenges in terms of transportation and logistics. The panels are large and heavy, and careful planning and coordination are required to ensure safe and efficient transportation to the construction site. The installation process also requires careful planning to ensure the correct placement and alignment of the panels.

2. Speed of Construction

Modular construction is a faster construction method than traditional methods. Building components, including panels, are manufactured off-site in a controlled environment, which allows for parallel construction processes to take place, reducing overall construction time. This is particularly important in the context of the Beirut Port project, where the need for new construction is immense in light of current events.

3. Cost-Effective

Modular construction can be a cost-effective option for building projects. Since the panels and their systems are assembled in the factory, installation times and costs are reduced during the on-site installation. This is particularly important in the context of Beirut Port project, where cost-effectiveness is a key consideration.

4. High Thermal Resistance

The use of high-performance panels in the façade and cladding systems of the Beirut Port project offers several benefits, including high thermal resistance. The panels contribute to the thermal insulation of the building despite their minimum thickness, which helps to reduce energy consumption and improve the overall efficiency of the building.

5. Aesthetic Value

The use of large-format natural panels can create a visually striking and attractive building façade, which can help to enhance the overall design of the project.

FIBER C PANELS

References:

https://www.rieder.cc/wp-content/uploads/2020/11/facades-guide-11_2020.pdf

Technical specifications | **fibreC**

Areas of application[1]

- Facade cladding with rear ventilation
- Inclined facades
- Weatherboarding
- Outer planking of prefabricated composite elements
- Cornice coverings
- Cladding of window reveals
- Cladding of window and door lintels
- Fascia
- Balcony cladding (with restrictions)
- Base, pillar and column cladding (half-shells)
- Solar protection elements
- Roof coverings
- Wall cladding
- Interior wall cladding/room divider
- Floor covering
- Kitchens, furniture fronts
- Work surfaces/bar toppings
- Furniture
- Verge and eaves ends
- Portal construction

Formats

Characteristics	
Special formats	upon request
Dimensional deviation Length	± 1 mm/m
Dimensional deviation Width (1.2 m)	± 2 mm
Diagonal difference up to 1.5 m | over 1.5 m	± 3.5 mm | ± 4 mm
Diagonal difference up to 2.5 m | over 3.6 m	± 5 mm | ± 6 mm

Thickness

13 mm		
Thickness tolerance	± 10 %	EN 12467
Edge straightness (level 1)	± 0.1 %	EN 12467
Perpendicularity (level 1)	± 2 mm/m	EN 12467

Physical characteristics

Characteristics		
Flatness tolerances up to 0.6 | 1.2 | 2.4 | 3.6 m	± 2 mm | ± 4 mm | ± 6 mm | ± 8 mm	
Raw density (13 mm)	2.0 - 2.42 kg/dm³	EN 12467
Flexural strength[2]	> 18 N/mm²	EN 12467, class 4
Young's modulus for deformation calculation	approx. 10.000 N/mm²	Reference to German approval
Young's modulus for constraint calculation	approx. 30.000 N/mm²	Reference to German approval
Dead load/weight per unit area (13 mm)	26 - 31.5 kg/m²	
Coefficient of thermal expansion	approx. 10 x 10^{-6} 1/K	DIN 51045
Classification of fire behaviour	A1 - non-combustible | A2-s1,d0 - non-combustible	EN 13501-1
Temperature stability	depending on core moisture up to 350 °C	
Specific thermal capacity	approx. 1,000 joules/(kg*K)	
Thermal conductivity	lambda: approx. 2.0 W/(m*K)	
Humidity expansion	0.05 %	EN 12467

Weather resistance

Characteristics		
Impermeable to	water	EN 12467
Heat/rain cycle test	given	EN 12467
Frost resistance	given	EN 12467
Freeze-thaw cycle test	given	EN 12467
UV light resistance	UV-resistant colour pigments	DIN 12878
Wet-storage resistance	given; efflorescence may occur	EN 12467
Hot water resistance	given	EN 12467

Mounting

Characteristics	
Visible mounting	rivets, screws
Concealed mounting	bonding, undercut anchor, Rieder Power Anchor
Substructure	aluminium, steel
Joint width	at least 8 mm recommended; The maximum joint width depends on the respective applicable national regulation.

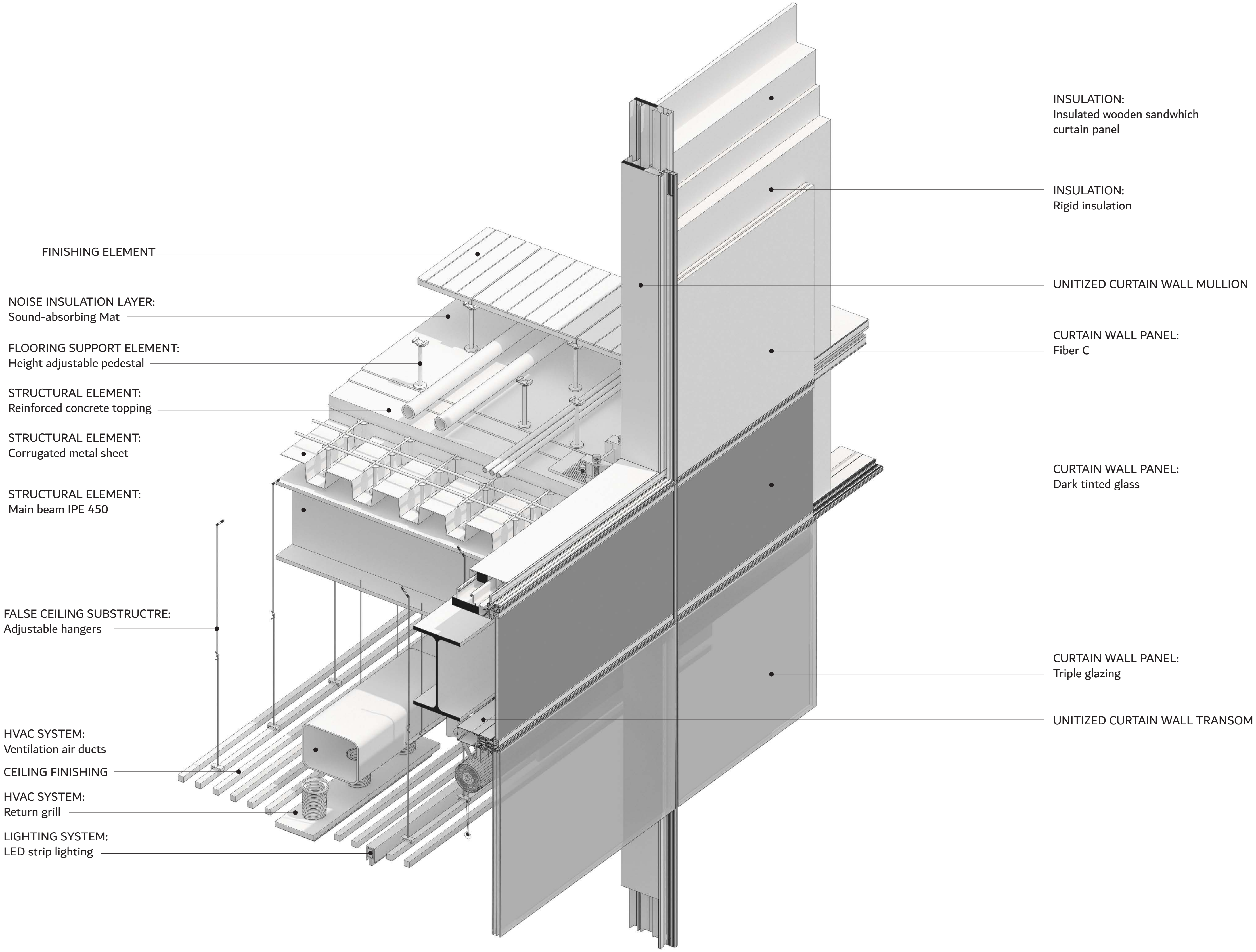
Further specifications

Characteristics	
Reinforcement	through glassfibre textile fabric approved by the building authorities
Edge formation	cutting edges are unfinished and sharp-edged with a roughness of approx. 1 mm on the visible side. Glassfibres may protrude at the edges. The rear side may have recesses
Colours[3]	solid colouring of the entire panel; 23 standard colours; special colours on request
Surfaces[3]	matt: matt or brushed surface ferro light: lightly blasted surface ferro: blasted surface
Surface protection	protection against environmental and weather influences

1) If fibreC products are installed as an alternative, specific regulations must be observed for the respective application. More detailed information on the respective area of application is available on request. It should be noted that certain applications, such as roofing or bar topping, may result in greater discoloration and soiling, as the protective layer is subject to greater wear on sloping or horizontal surfaces.

2) MOR (Modulus of rupture): Design values deviate from MOR according to national regulations. The national certifications and regulations for calculating the rated resistance apply.

3) Due to the natural product concrete, every glassfibre reinforced concrete panel is regarded as a unique piece. Differences in colour, structure and texture are characteristic. Efflorescence or small visible pores are not defects. Light resistance varies depending on the colour. Differences in the surface appearance, which do not affect the serviceability of the panels, are permissible. 02/2004 Leaflet on exposed concrete EN 12467 [publisher: BDZ/DBV].

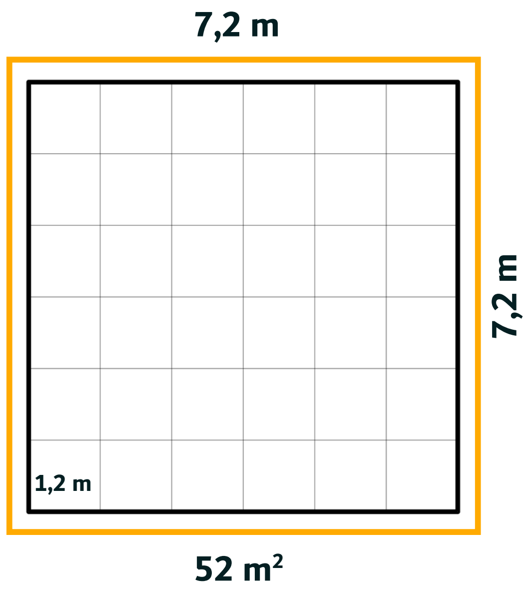

INSULATION:
Insulated wooden sandwhich curtain panel
INSULATION:
Rigid insulation
UNITIZED CURTAIN WALL MULLION
CURTAIN WALL PANEL:
Fiber C
CURTAIN WALL PANEL:
Dark tinted glass
CURTAIN WALL PANEL:
Triple glazing
UNITIZED CURTAIN WALL TRANSOM
FINISHING ELEMENT
NOISE INSULATION LAYER:
Sound-absorbing Mat
FLOORING SUPPORT ELEMENT:
Height adjustable pedestal
STRUCTURAL ELEMENT:
Reinforced concrete topping
STRUCTURAL ELEMENT:
Corrugated metal sheet
STRUCTURAL ELEMENT:
Main beam IPE 450
FALSE CEILING SUBSTRUCTRE:
Adjustable hangers
HVAC SYSTEM:
Ventilation air ducts
CEILING FINISHING
HVAC SYSTEM:
Return grill
LIGHTING SYSTEM:
LED strip lighting

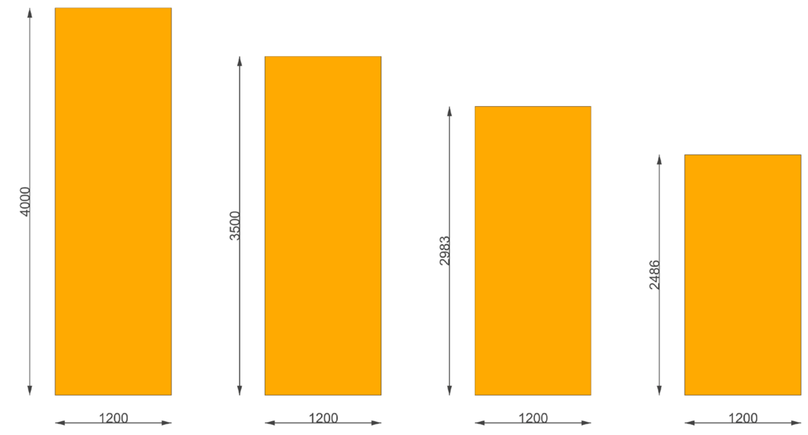
PANEL TYPES

The implementation of unitized panel technology in our building, Oasis, offers significant advantages in construction precision, energy efficiency, and other factors. However, careful planning and coordination is required to overcome the challenges associated with transportation and installation to ensure the successful implementation of this technology.

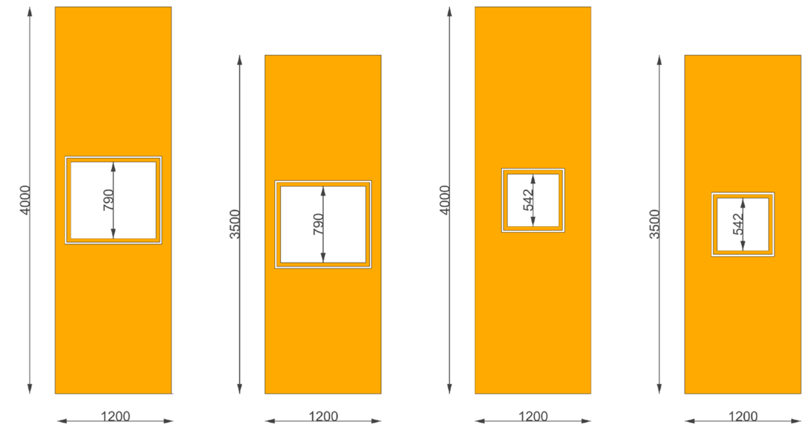
As stated above the building's geometry is broken down to a grid of 7.2x7.2 meters. Inside this grid we introduce a sub-grid where the 7,2 meters are divided into 6 parts, each a square with sides of 1,2 meters which is used for the width of panels without exception. Because the building has a small variation in height of the different floors, the height of the panels also differs slightly, this creates different types of panels which can then be further subcategorized into opaque, transparent or semi-transparent.

The panels used in the project are divided into 3 primary types, type A, B and W. W being the window type also encompasses type C. The C-type glazing has a dark tinted glass which hides the slab from external view. The A-type panels are fully opaque ceramic panels. We have four different sizes of panels where the height is the only variable factor, the width and depth stay the same. The B-type panels are partly opaque and partly transparent made of a ceramic material with inlaid windows of 2 different sizes. The last type which is the W-type or window type also comes in four different sizes, again, only varying in height. In total that means that aesthetically we have 12 different panel designs. See "Family types" below for further detail on the cladding pattern codification.

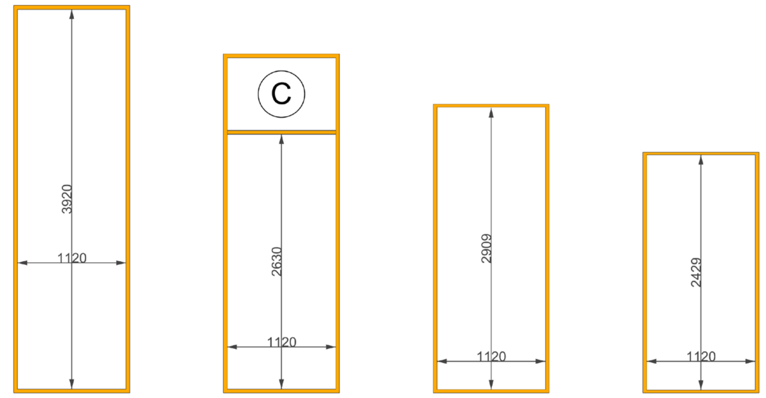




A-TYPE PANELS



B-TYPE PANELS

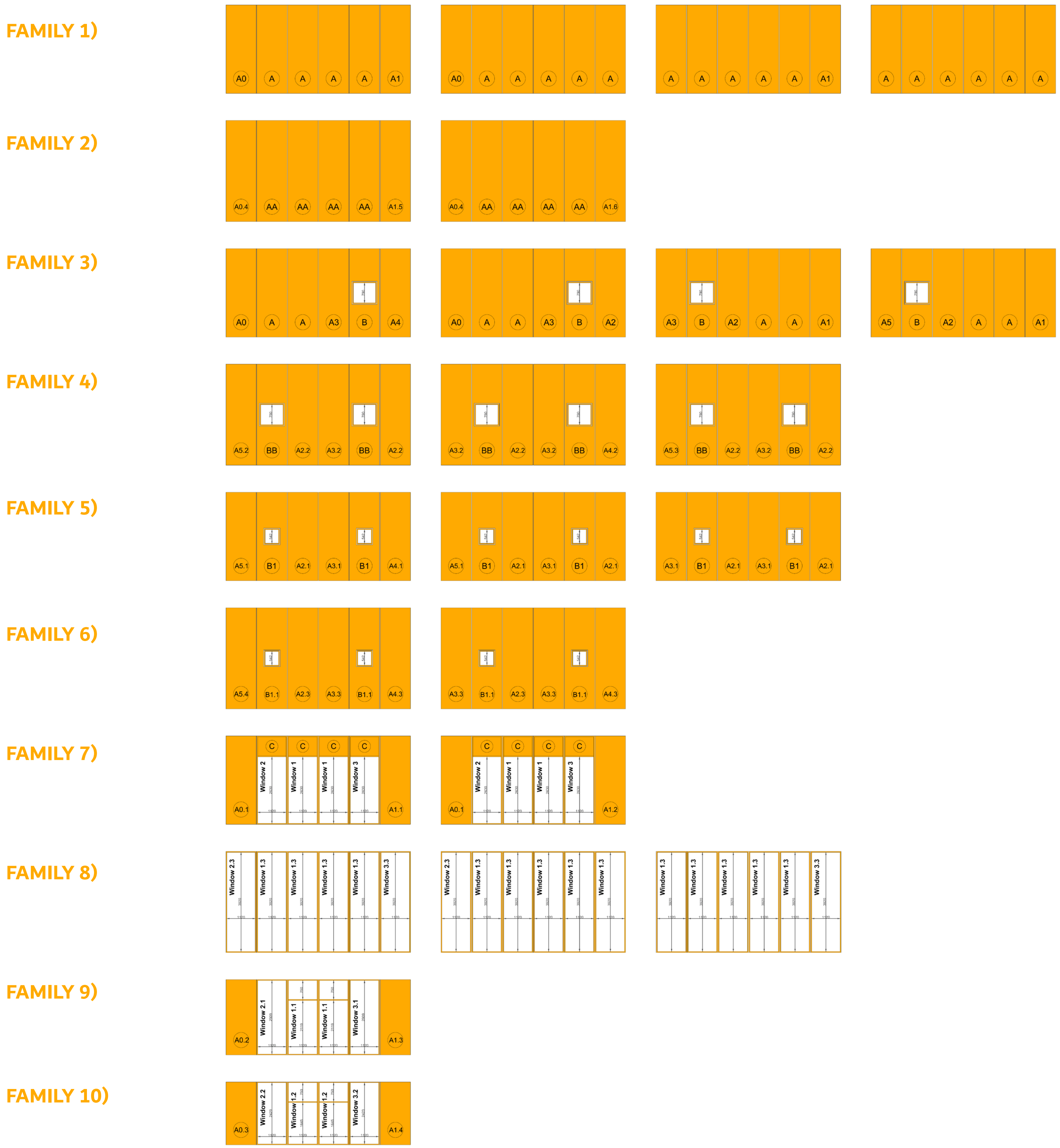


GLASS-PANELS

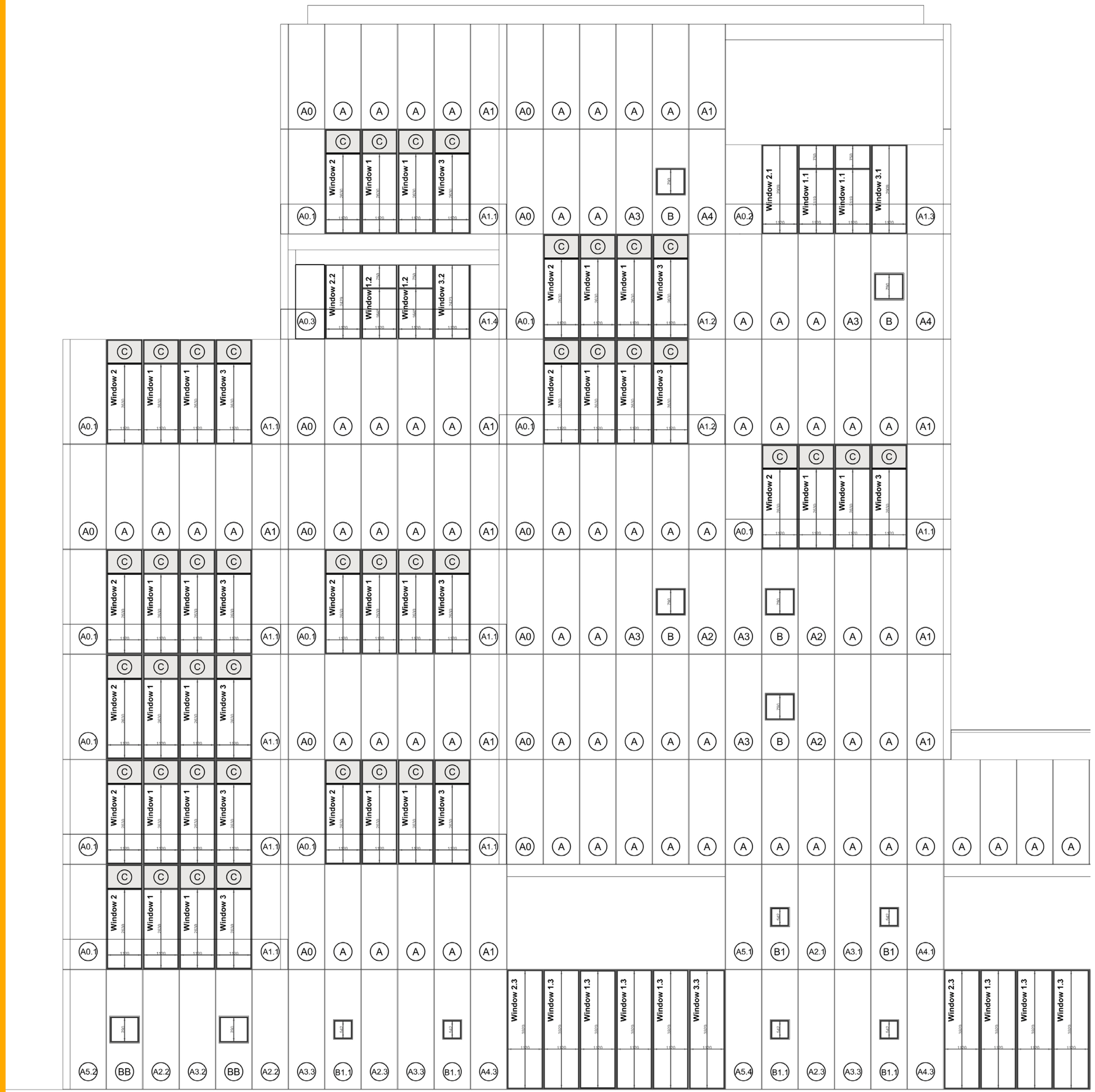
FAMILY TYPES

Our project is based on “façade families” that can be place with ease inside our grid system, thanks to their modularity and flexibility. The first two families show two different heights of completely opaque ceramic panels. The reason for having four types in family 1) and two in family 2) is that they have differing construction connection mechanisms. A panel has a specific number according to its appearance in conjunction with which type of panel it is connected to, i.e., whether it is connected to 2 opaque panels or to an opaque on the left side but to a glass panel on the right. This concept applies to all the families. As demonstration of the utility of this design; the most common type of panel was the A-type which appears 170 times on the South side alone, which we believe enforces the idea that the design is well suited to the off-site manufacturing, on-site installation framework.

PANEL FAMILIES TYPES OF 7,2 METERS WIDTH



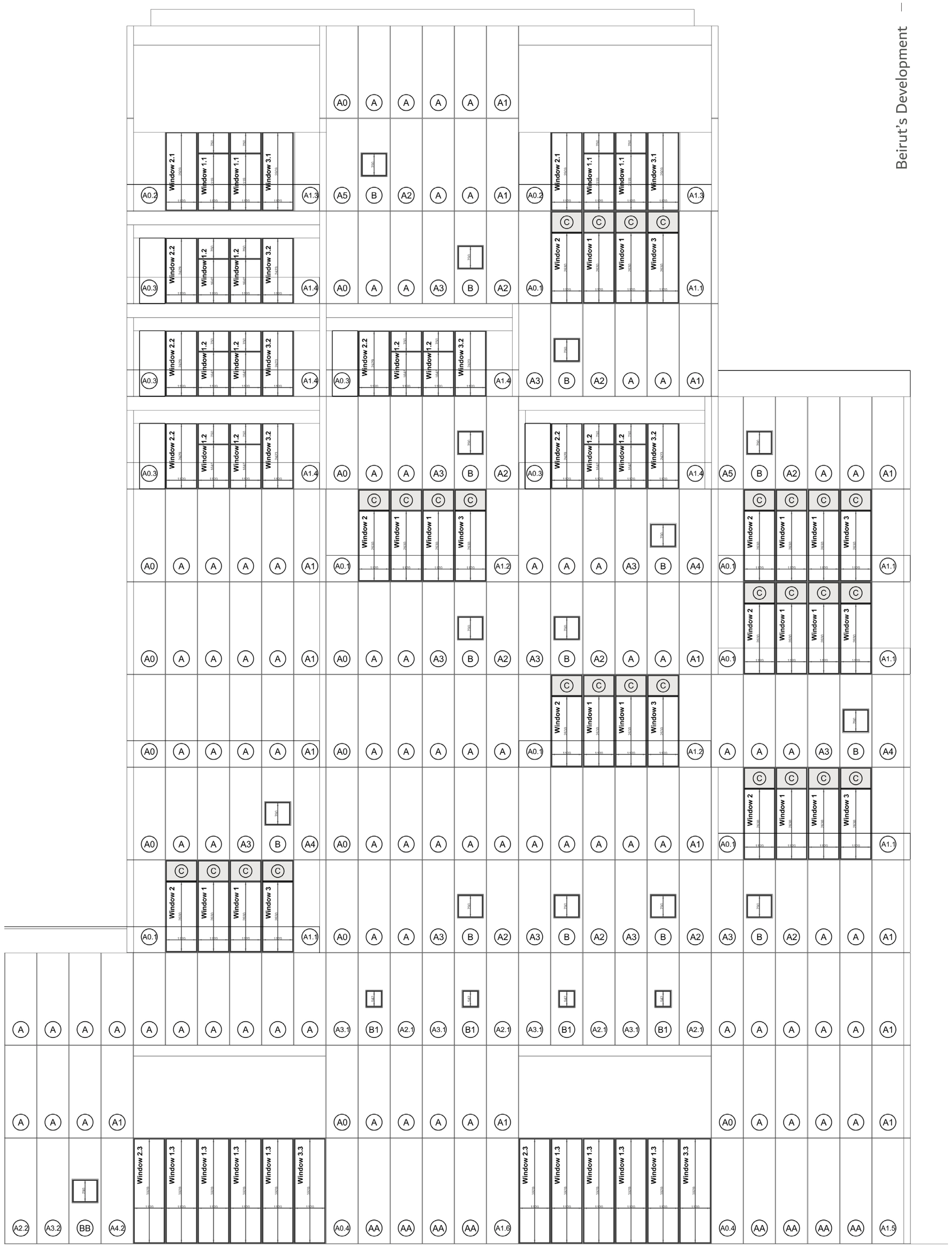
PANELIZATION SOUTH SITE

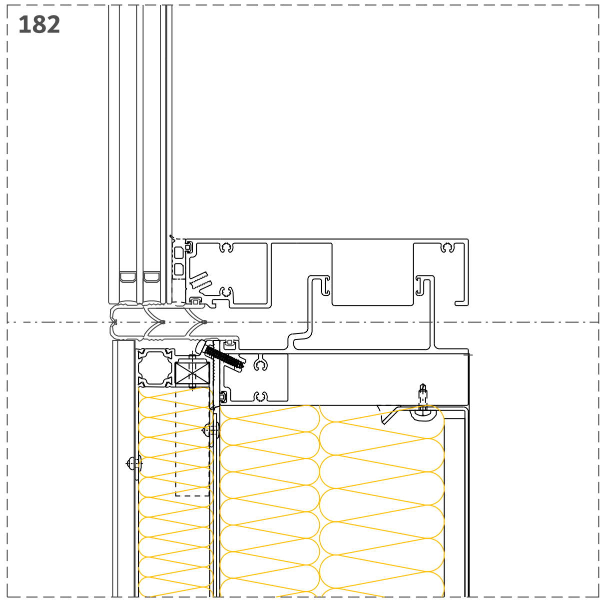


	Dimensions	Quantity	TYPE
A	1,2 m x 3,5 m	170 on South side	Ceramic Panel
AA	1,2 m x 4 m	8 on South side	Ceramic Panel
A0	1,2 m x 3,5 m	25 on South side	Ceramic Panel
A0.1	1,2 m x 3,5 m	18 on South side	Ceramic Panel
A0.2	1,2 m x 2,9 m	3 on South side	Ceramic Panel
A0.3	1,2 m x 2,5 m	6 on South side	Ceramic Panel
A0.4	1,2 m x 4 m	2 on South side	Ceramic Panel
A1	1,2 m x 3,5 m	24 on South side	Ceramic Panel
A1.1	1,2 m x 3,5 m	14 on South side	Ceramic Panel
A1.2	1,2 m x 3,5 m	4 on South side	Ceramic Panel
A1.3	1,2 m x 2,9 m	3 on South side	Ceramic Panel
A1.4	1,2 m x 2,5 m	6 on South side	Ceramic Panel
A1.5	1,2 m x 4 m	1 on South side	Ceramic Panel
A1.6	1,2 m x 4 m	1 on South side	Ceramic Panel
A2	1,2 m x 3,5 m	14 on South side	Ceramic Panel
A2.1	1,2 m x 3,5 m	7 on South side	Ceramic Panel
A2.2	1,2 m x 4 m	5 on South side	Ceramic Panel
A2.3	1,2 m x 4 m	2 on South side	Ceramic Panel
A3	1,2 m x 3,5 m	17 on South side	Ceramic Panel
A3.1	1,2 m x 3,5 m	6 on South side	Ceramic Panel
A3.2	1,2 m x 4 m	4 on South side	Ceramic Panel
A3.3	1,2 m x 4 m	3 on South side	Ceramic Panel
A4	1,2 m x 3,5 m	5 on South side	Ceramic Panel
A4.1	1,2 m x 3,5 m	1 on South side	Ceramic Panel
A4.2	1,2 m x 4 m	1 on South side	Ceramic Panel
A4.3	1,2 m x 4 m	1 on South side	Ceramic Panel
A5	1,2 m x 3,5 m	2 on South side	Ceramic Panel
A5.1	1,2 m x 3,5 m	2 on South side	Ceramic Panel
A5.2	1,2 m x 4 m	1 on South side	Ceramic Panel
A5.3	1,2 m x 4 m	1 on South side	Ceramic Panel
A5.4	1,2 m x 4 m	1 on South side	Ceramic Panel
B	1,2 m x 3,5 m	19 on South side	CP w/window
BB	1,2 m x 4 m	6 on South side	CP w/window
B1	1,2 m x 3,5 m	8 on South side	CP w/window
B1.1	1,2 m x 4 m	4 on South side	CP w/window
C	0,75 m x 1,12 m	72 on South side	Dark tinted glass
W1	1,12 m x 2,63 m	36 on South side	Glass Panel
W1.1	1,12 m x 2,63 m	6 on South side	Glass Panel
W1.2	1,12 m x 2,63 m	12 on South side	Glass Panel
W1.3	1,12 m x 3,92 m	22 on South side	Glass Panel
W2	1,12 m x 2,63 m	18 on South side	Glass Panel
W2.1	1,12 m x 2,91 m	3 on South side	Glass Panel
W2.2	1,12 m x 2,43 m	6 on South side	Glass Panel
W2.3	1,12 m x 3,92 m	4 on South side	Glass Panel
W3	1,12 m x 2,63 m	18 on South side	Glass Panel
W3.1	1,12 m x 2,91 m	3 on South side	Glass Panel
W3.2	1,12 m x 2,43 m	6 on South side	Glass Panel
W3.3	1,12 m x 3,92 m	4 on South side	Glass Panel

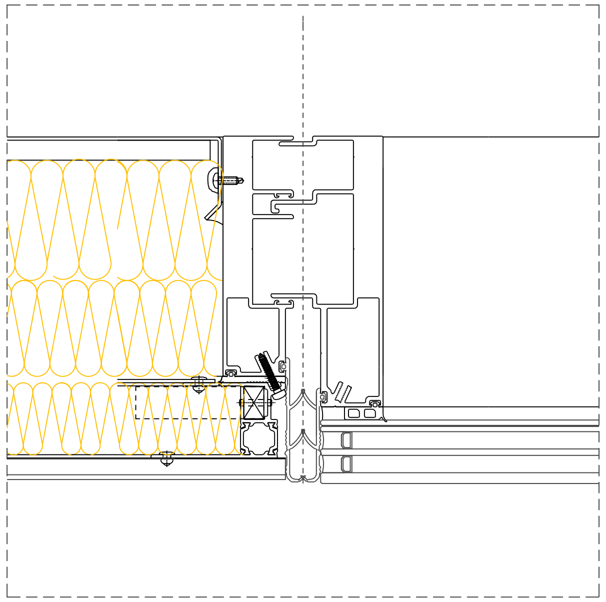
PANELIZATION SOUTH SITE

	Dimensions	Quantity	TYPE
A	1,2 m x 3,5 m	170 on South side	Ceramic Panel
AA	1,2 m x 4 m	8 on South side	Ceramic Panel
A0	1,2 m x 3,5 m	25 on South side	Ceramic Panel
A0.1	1,2 m x 3,5 m	18 on South side	Ceramic Panel
A0.2	1,2 m x 2,9 m	3 on South side	Ceramic Panel
A0.3	1,2 m x 2,5 m	6 on South side	Ceramic Panel
A0.4	1,2 m x 4 m	2 on South side	Ceramic Panel
A1	1,2 m x 3,5 m	24 on South side	Ceramic Panel
A1.1	1,2 m x 3,5 m	14 on South side	Ceramic Panel
A1.2	1,2 m x 3,5 m	4 on South side	Ceramic Panel
A1.3	1,2 m x 2,9 m	3 on South side	Ceramic Panel
A1.4	1,2 m x 2,5 m	6 on South side	Ceramic Panel
A1.5	1,2 m x 4 m	1 on South side	Ceramic Panel
A1.6	1,2 m x 4 m	1 on South side	Ceramic Panel
A2	1,2 m x 3,5 m	14 on South side	Ceramic Panel
A2.1	1,2 m x 3,5 m	7 on South side	Ceramic Panel
A2.2	1,2 m x 4 m	5 on South side	Ceramic Panel
A2.3	1,2 m x 4 m	2 on South side	Ceramic Panel
A3	1,2 m x 3,5 m	17 on South side	Ceramic Panel
A3.1	1,2 m x 3,5 m	6 on South side	Ceramic Panel
A3.2	1,2 m x 4 m	4 on South side	Ceramic Panel
A3.3	1,2 m x 4 m	3 on South side	Ceramic Panel
A4	1,2 m x 3,5 m	5 on South side	Ceramic Panel
A4.1	1,2 m x 3,5 m	1 on South side	Ceramic Panel
A4.2	1,2 m x 4 m	1 on South side	Ceramic Panel
A4.3	1,2 m x 4 m	1 on South side	Ceramic Panel
A5	1,2 m x 3,5 m	2 on South side	Ceramic Panel
A5.1	1,2 m x 3,5 m	2 on South side	Ceramic Panel
A5.2	1,2 m x 4 m	1 on South side	Ceramic Panel
A5.3	1,2 m x 4 m	1 on South side	Ceramic Panel
A5.4	1,2 m x 4 m	1 on South side	Ceramic Panel
B	1,2 m x 3,5 m	19 on South side	CP w/window
BB	1,2 m x 4 m	6 on South side	CP w/window
B1	1,2 m x 3,5 m	8 on South side	CP w/window
B1.1	1,2 m x 4 m	4 on South side	CP w/window
C	0,75 m x 1,12 m	72 on South side	Dark tinted glass
W1	1,12 m x 2,63 m	36 on South side	Glass Panel
W1.1	1,12 m x 2,63 m	6 on South side	Glass Panel
W1.2	1,12 m x 2,63 m	12 on South side	Glass Panel
W1.3	1,12 m x 3,92 m	22 on South side	Glass Panel
W2	1,12 m x 2,63 m	18 on South side	Glass Panel
W2.1	1,12 m x 2,91 m	3 on South side	Glass Panel
W2.2	1,12 m x 2,43 m	6 on South side	Glass Panel
W2.3	1,12 m x 3,92 m	4 on South side	Glass Panel
W3	1,12 m x 2,63 m	18 on South side	Glass Panel
W3.1	1,12 m x 2,91 m	3 on South side	Glass Panel
W3.2	1,12 m x 2,43 m	6 on South side	Glass Panel
W3.3	1,12 m x 3,92 m	4 on South side	Glass Panel

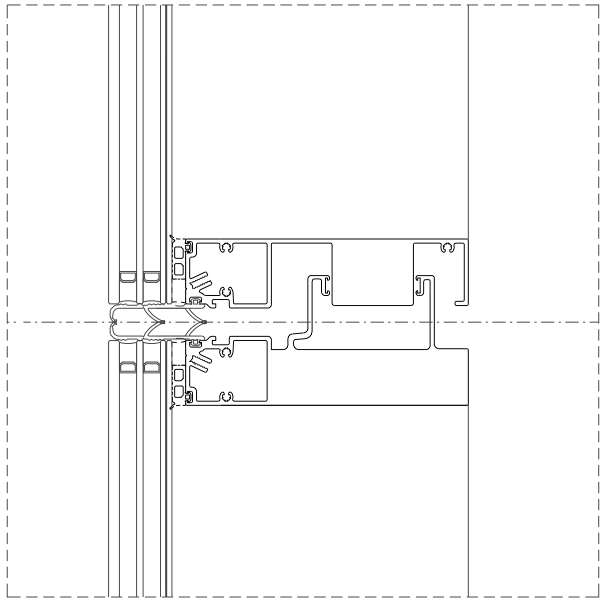




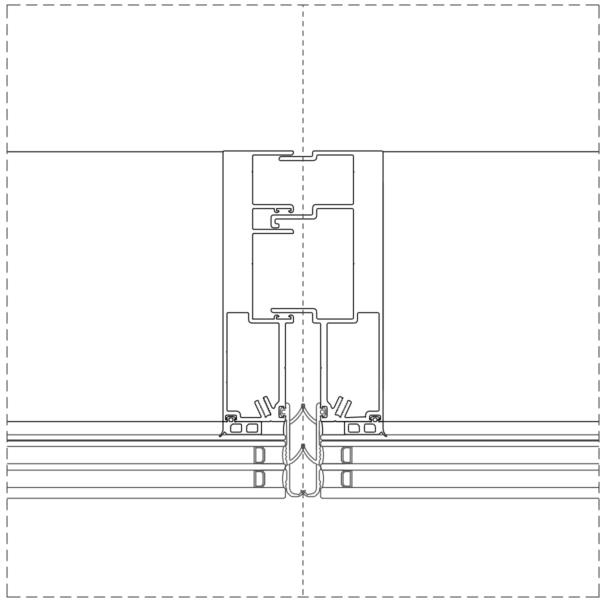
Unitized Facade Horizontal Section
Opaque/glass joint



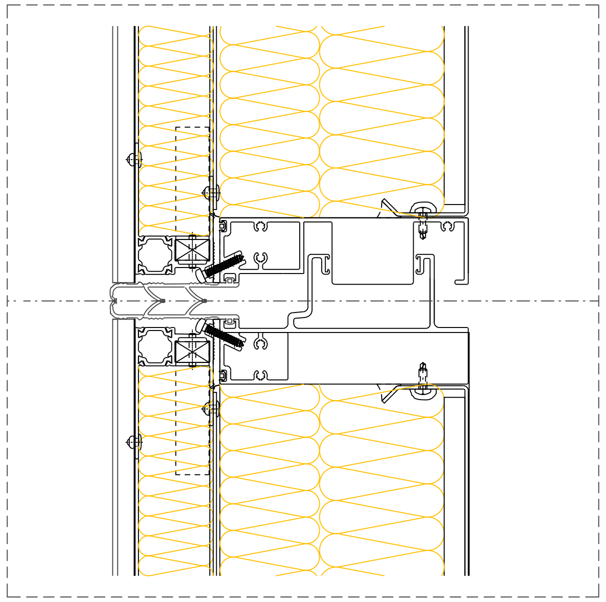
Unitized Facade Horizontal Section
Opaque/glass joint



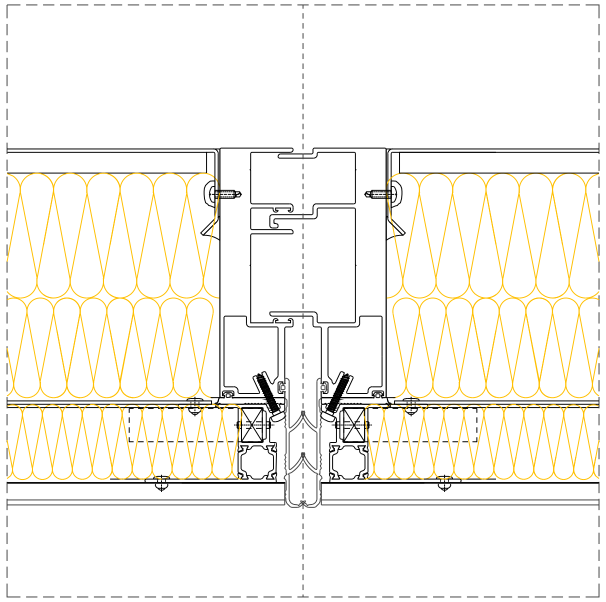
Unitized Facade Horizontal Section
Glass/glass joint



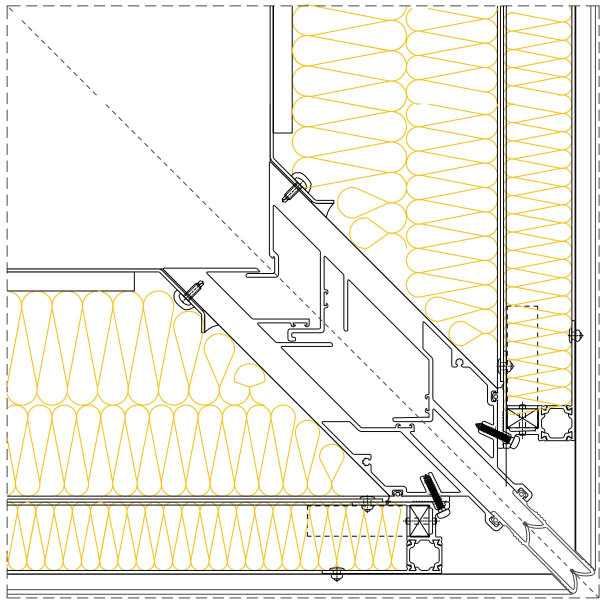
Unitized Facade Horizontal Section
Glass/glass joint



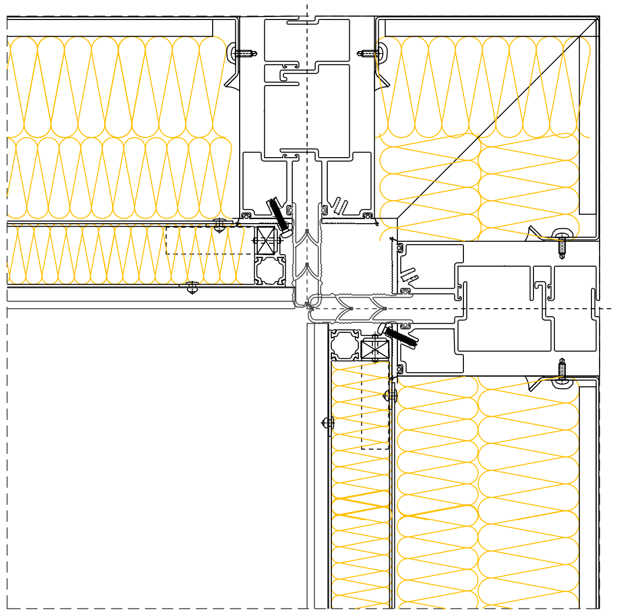
Unitized Facade Horizontal Section
Opaque/opaque joint



Unitized Facade Horizontal Section
Opaque/opaque joint

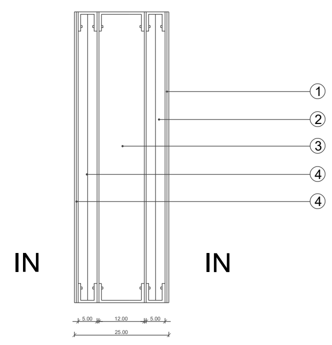


Horizontal Angled Section External



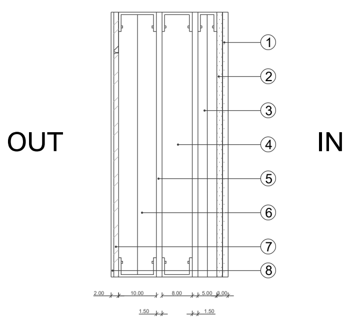
Horizontal Angled Section Internal

Bathroom Partition Wall



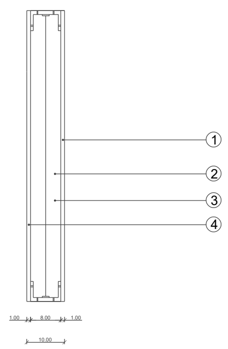
1.INTERNAL FINISHING, Plasterboard, 2 x 0,5 cm
2.INSULATION, Mineral Wool, Thickness: 5 cm
3.CAVITY, Thickness: 12 cm
4.INSULATION, Mineral Wool, Thickness: 5 cm
5.INTERNAL FINISHING, Plasterboard, 2 x 0,5 cm

External Wall



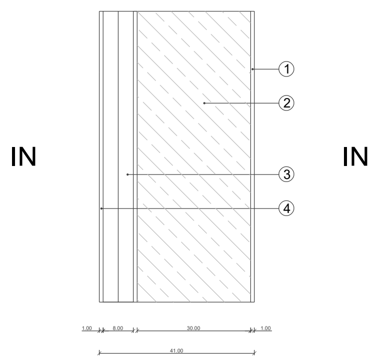
1.INTERNAL FINISHING, Plasterboard
2.INTERNAL PLASTERBOARD
3.THERMAL INSULATION, Expanded Polystrene (EPS) ,Thickness: 5 cm
4.CAVITY, Thickness: 8 cm
5.STRUCTURAL ELEMENT, Metal C Profile
6.THERMAL INSULATION, Expanded Polystrene (EPS), Thickness: 10 cm
7.EXTERNAL PLASTERBOARD
8.EXTERNAL FINISHING ?????

Internal Partition Wall



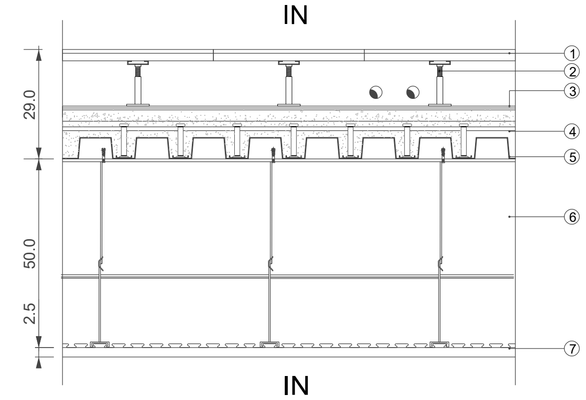
1.INTERNAL FINISHING, Plasterboard
2.STRUCTURAL ELEMENT, Metal C Profile
3.ACOUSTIC INSULATION, Mineral Wool, Thickness: 8 cm
4.INTERNAL FINISHING, Plasterboard

Internal Core Wall



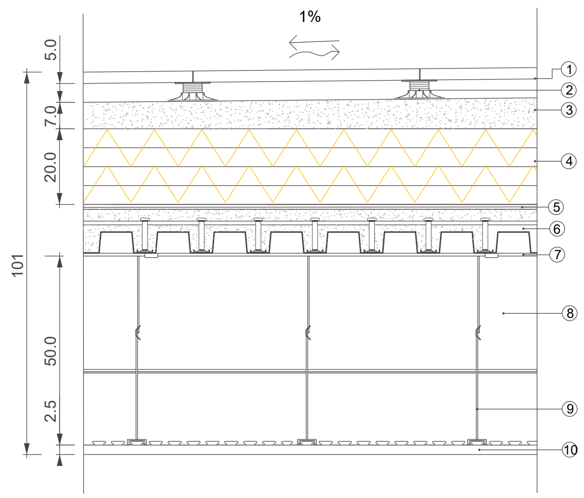
1.INTERNAL FINISHING, plaster
2.STRUCTURAL ELEMENT, RC wall, Thickness: 30 cm
3.THERMAL INSULATION, Expanded Polystrene (EPS), Thickness: 8 cm
4.INTERNAL FINISHING, plaster

Intermediate Floor



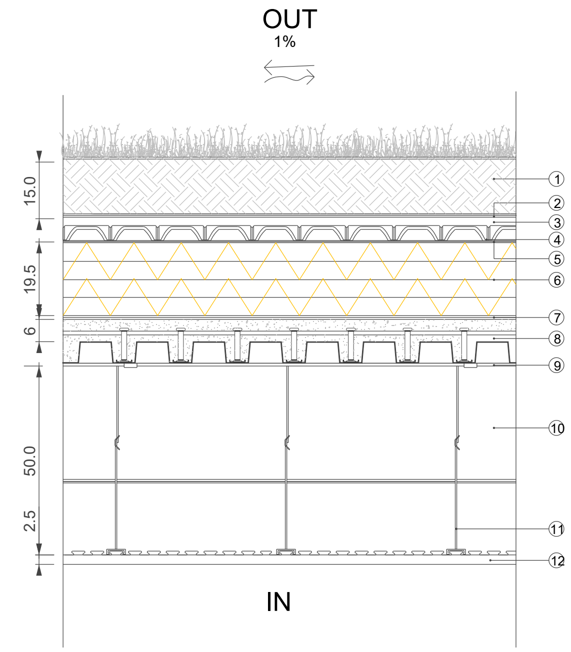
1.FINISHING ELEMENT, stoneware flooring glued to a chipboard panel
Thickness 4.8 cm
2.FLOORING SUPPORT ELEMENT, height-adjustable base for floating floors
3.NOISE INSULATION LAYER FROM CAPLESTIO, sound-absorbing mat
Thickness 1 cm
4.STRUCTURAL LAYER, corrugated sheet + collaborating hood
5.METALLIC STRUCTURE, profiles and guides for false ceilings
6.STRUCTURAL ELEMENT, Steel Beam, IPE 300
7.FINISHING LAYER, Acoustic Gypsum Plasterboard Panels, Thickness: 2.5 cm

Roof

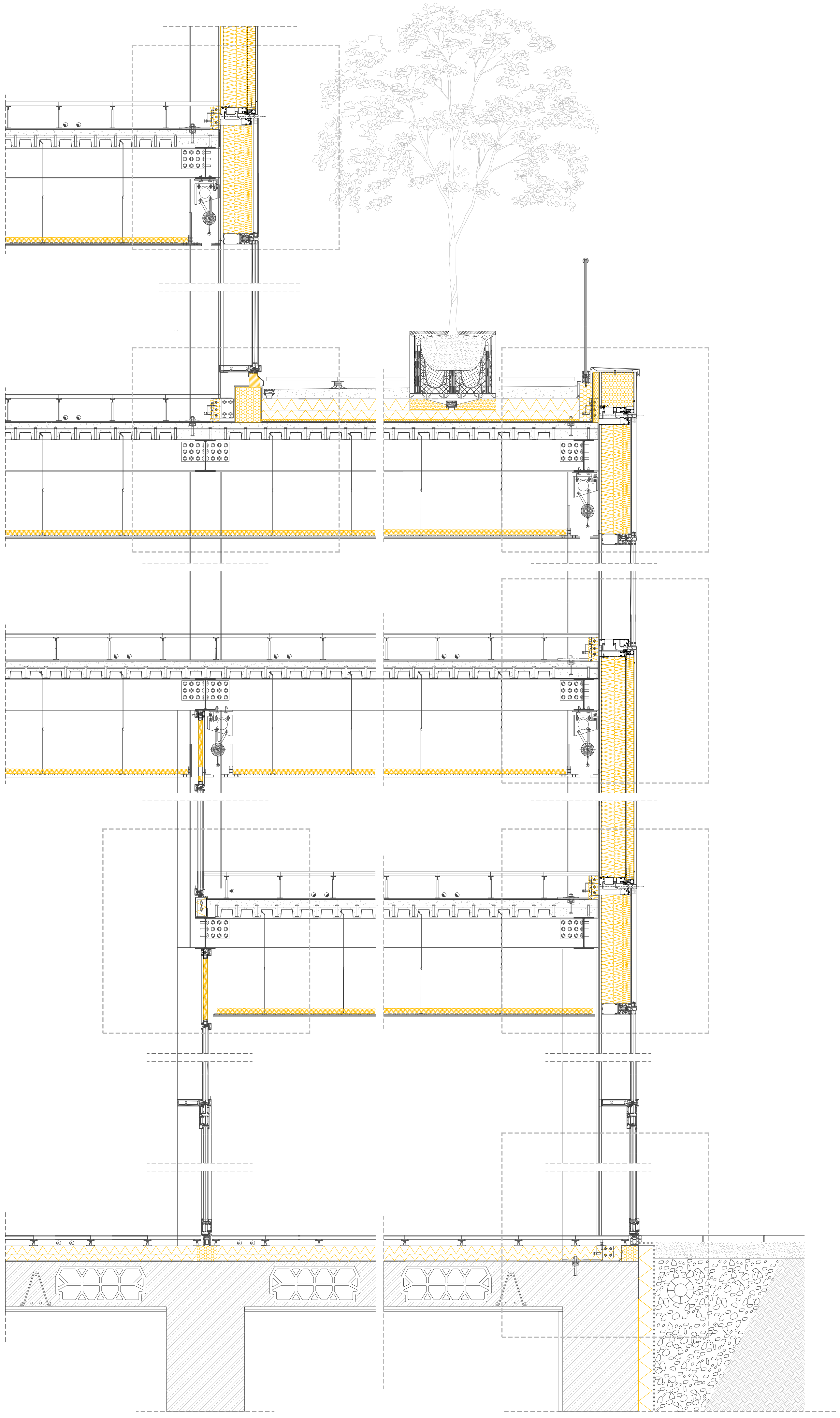


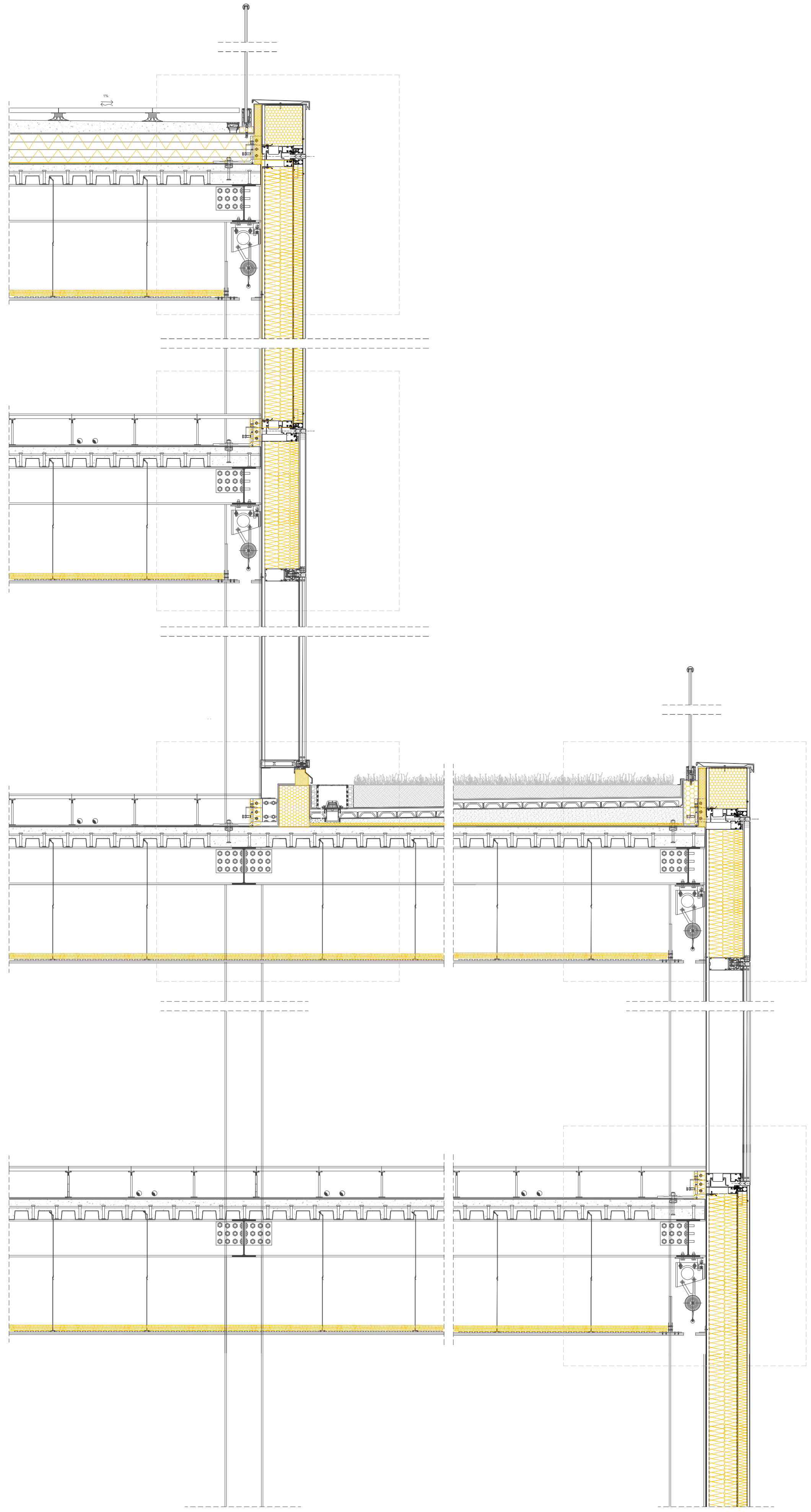
1.FINISHING ELEMENT, Natural Stone, Marble, Thickness: 3 cm
2.FLOORING FIXING ELEMENT ,Height Adjustable Pedestal, Height : 5 cm
3.SLOPING CONCRETE - 1% min. 7 cm
4.THERMAL INSULATION, Extruded Polystrene (XPS), 2 layers 10 cm + 10 cm
5.WATERPROOFING, EPDM Membrane
6.STRUCTURAL ELEMENT, Corrugated Metal Sheet + Collaborating Hood
7.METALLIC STRUCTURE, profiles and guides for false ceilings
8.STRUCTURAL ELEMENT, Steel Beam, IPE 300
9.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
10.FINISHING LAYER, Acoustic Gypsum Plasterboard Panels, Thickness: 2.5 cm

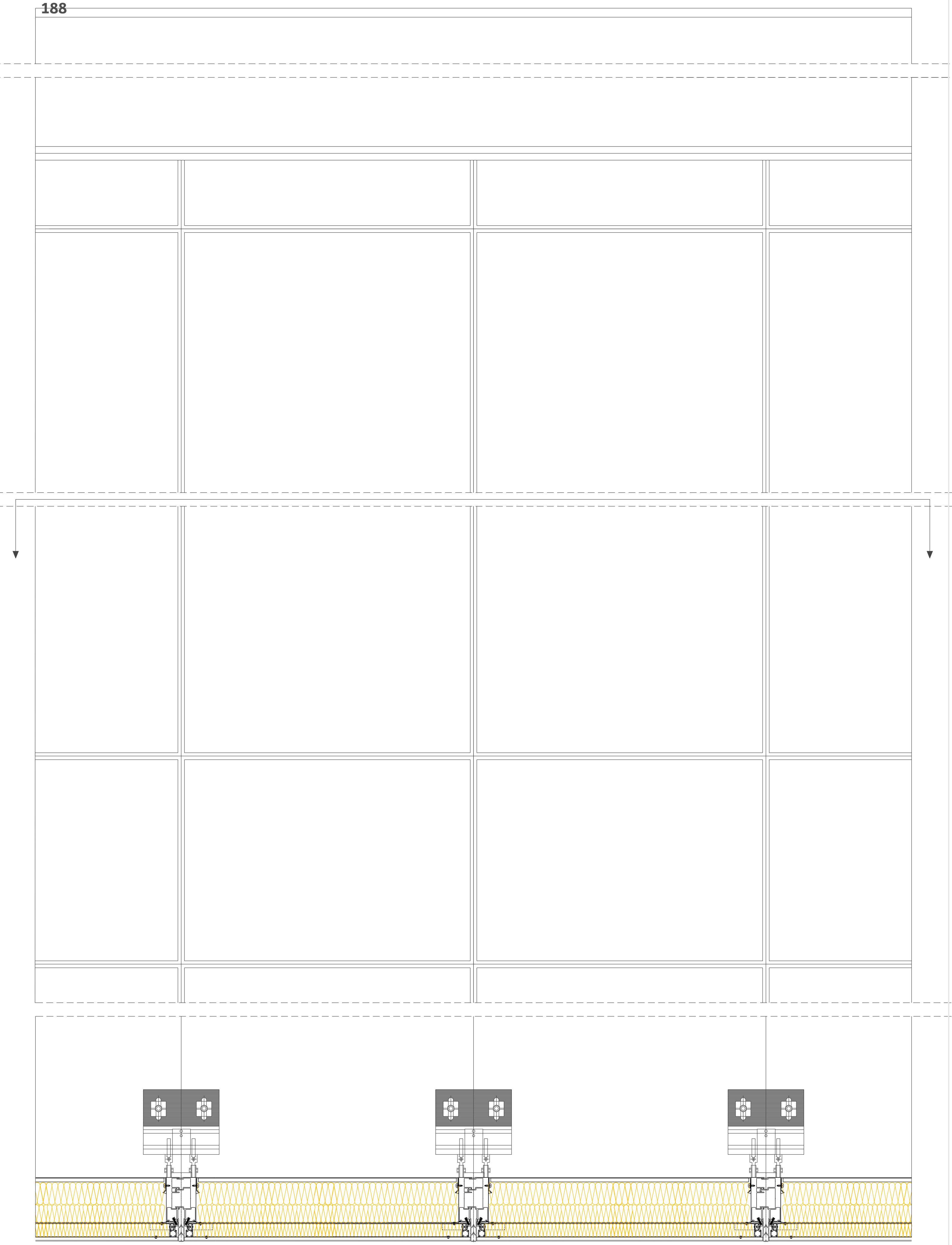
Green Roof

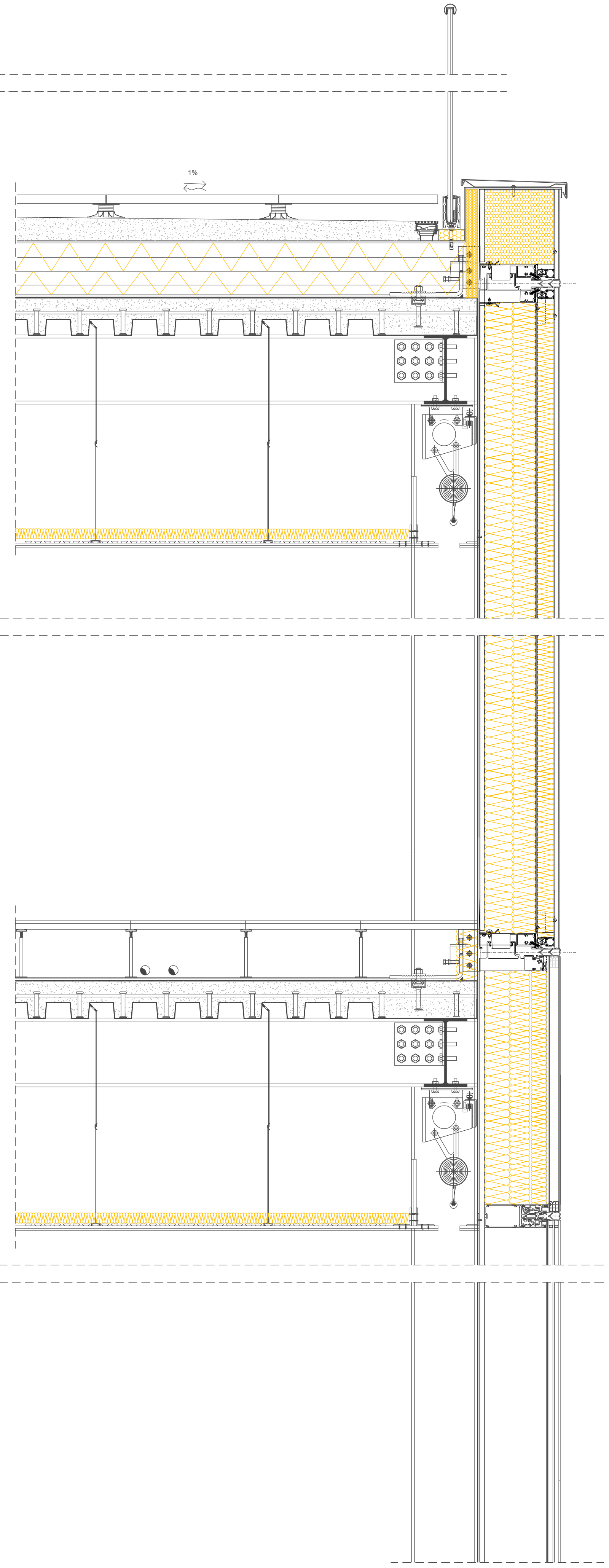


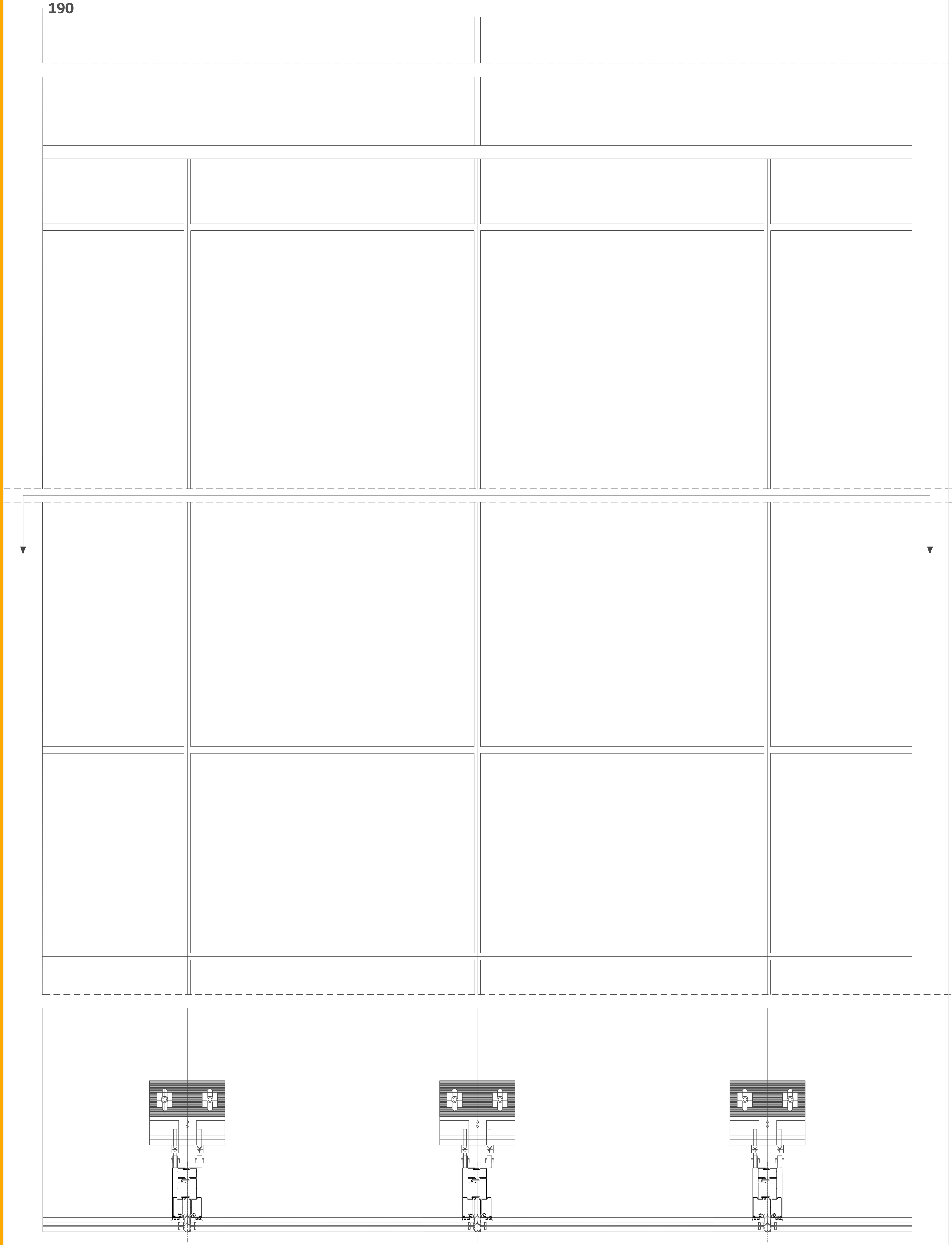
1.CULTIVATION LAYER, soil
Thickness: 15 cm
2.SLIDING LAYER, pointed non-woven geotextile in white polyester
Thickness: 0.05 cm
3.DRAINING LAYER, expanded clay for roofing.
Thickness: 2 cm
4.DRAINING AND WATER RESERVE LAYER, formwork for hanging gardens
Formwork height: 4 cm
5.WATERPROOFING LAYER, solvent-free single-component paste, based on synthetic resins in water dispersion, extremely fast drying.
Thickness 0.3 cm
6.THERMAL INSULATION LAYER + 1% SLOPE LAYER, Extruded Polystrene (XPS),Thickness: 10 + 10 cm
7.ANTICONDENSATION LAYER, Vapor Barrier, PE Membrane
Thickness: 0.02 cm
8.STRUCTURAL LAYER, corrugated sheet + collaborating hood
9.METALLIC STRUCTURE, profiles and guides for false ceilings
10.STRUCTURAL ELEMENT, Steel Beam, IPE 300
11.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
12.FINISHING LAYER, Acoustic Gypsum Plasterboard Panels, Thickness: 2.5cm

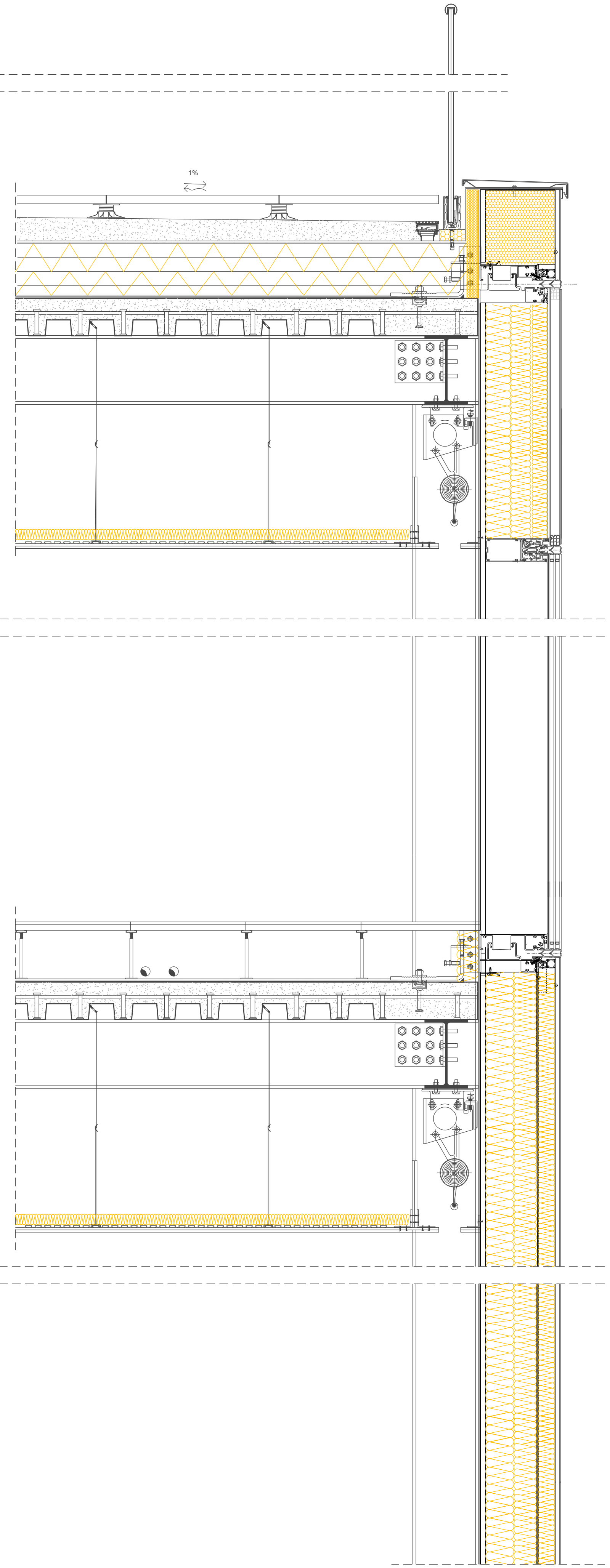


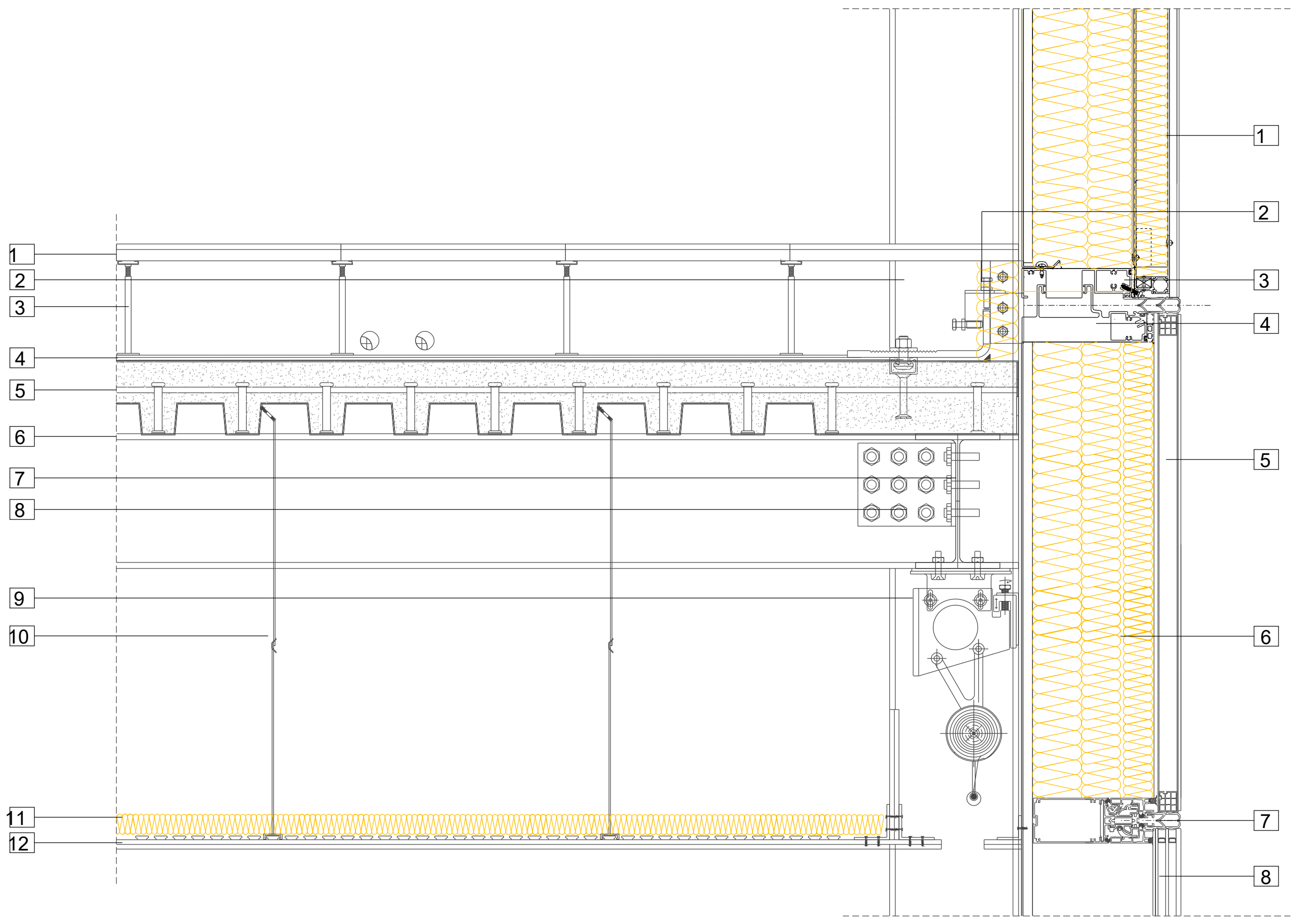









1%

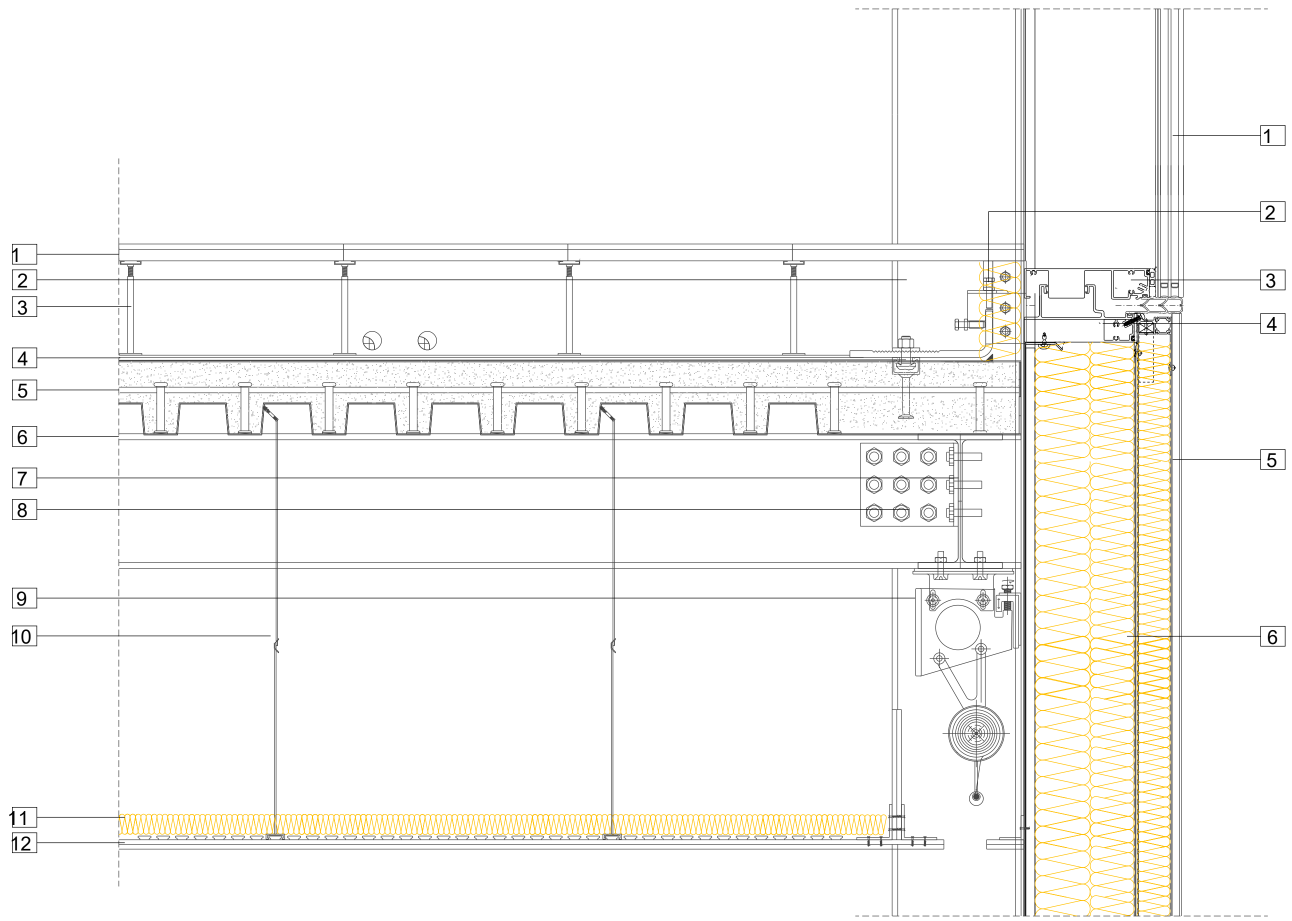


INTERMEDIATE FLOOR SYSTEM

1.FINISHING ELEMENT, Stoneware Flooring glued to a chipboard panel,Thickness 3 cm
2.STRUCTURAL ELEMENT, Column, HEA 300 Steel Profile
3.FLOORING SUPPORT ELEMENT, Height-adjustable Pedestal
4.NOISE INSULATION LAYER, sound-absorbing mat, Thickness 1 cm
5.STRUCTURAL LAYER, corrugated sheet + collaborating hood
6.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
7.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
8.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
9.CURTAIN SYSTEM attached to main structure
10.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
11.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
12.FINISHING LAYER, Acoustic False Ceiling Panels

UNITISED SYSTEM - CURTAIN WALL FACADE

1.CLOSING ELEMENT, Fiber C, Natural Sand colourblushing effect alkali-resistant glassfibres (AR glass), UV - hydrophobicity protection
2.STRUCTURAL ELEMENT, Aluminum Fixing Bracket for Curtian systems, Fixed to Structural reiforced slab
3.STRUCTURAL ELEMENT OPAQUE, Curtain Wall Transom, 80x250 mm
4.STRUCTURAL ELEMENT GLASS, Curtain Wall Transom, 80x250 mm
5.CLOSING ELEMENT, Insulated sandwich panel with reflective finishing
6.THERMAL INSULATION, Insulated Wooden Sandwich Curtain Panel
7.STRUCTURAL ELEMENT, Aluminum Glass Fixing t for Curtian systems,
8.CURTAIN WALL PANEL, Triple Glazing

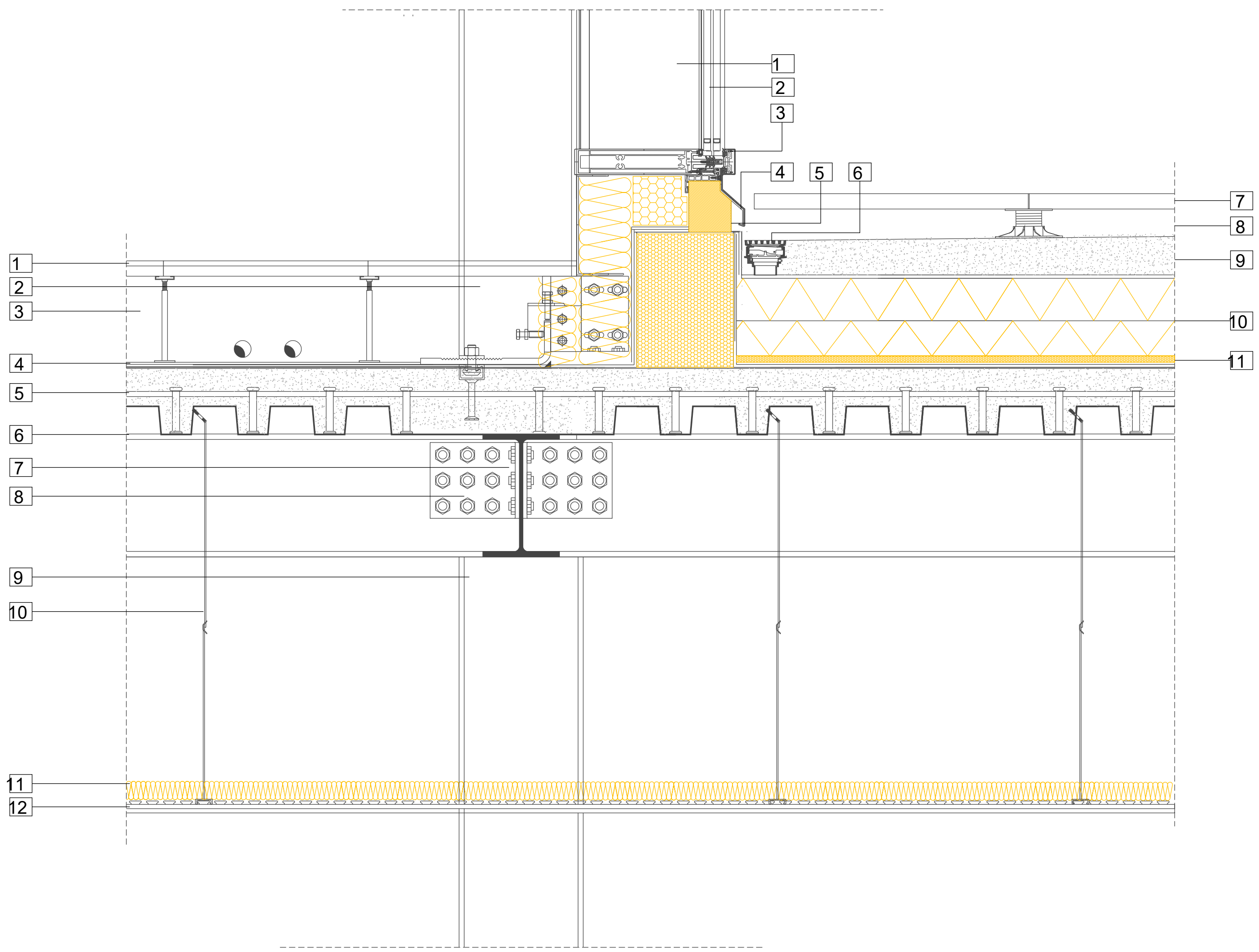


INTERMEDIATE FLOOR SYSTEM

1.FINISHING ELEMENT, Stoneware Flooring glued to a chipboard panel,Thickness 3 cm
2.STRUCTURAL ELEMENT, Column, HEA 300 Steel Profile
3.FLOORING SUPPORT ELEMENT, Height-adjustable Pedestal
4.NOISE INSULATION LAYER, sound-absorbing mat, Thickness 1 cm
5.STRUCTURAL LAYER, corrugated sheet + collaborating hood
6.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
7.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
8.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
9.CURTAIN SYSTEM attached to main structure
10.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
11.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
12.FINISHING LAYER, Acoustic False Ceiling Panels

UNITISED SYSTEM - CURTAIN WALL FACADE

1.CURTAIN WALL PANEL, Triple Glazing
2.STRUCTURAL ELEMENT, Aluminum Fixing Bracket for Curtian systems, Fixed to Structural reiforced slab
3.STRUCTURAL ELEMENT GLASS, Curtain Wall Transom, 80x250 mm
4.STRUCTURAL ELEMENT OPAQUE, Curtain Wall Transom, 80x250 mm
5.CLOSING ELEMENT, Fiber C, Natural Sand colourblushing effect alkali-resistant glassfibres (AR glass), UV - hydrophobicity protection
6.THERMAL INSULATION, Insulated Wooden Sandwich Curtain Panel

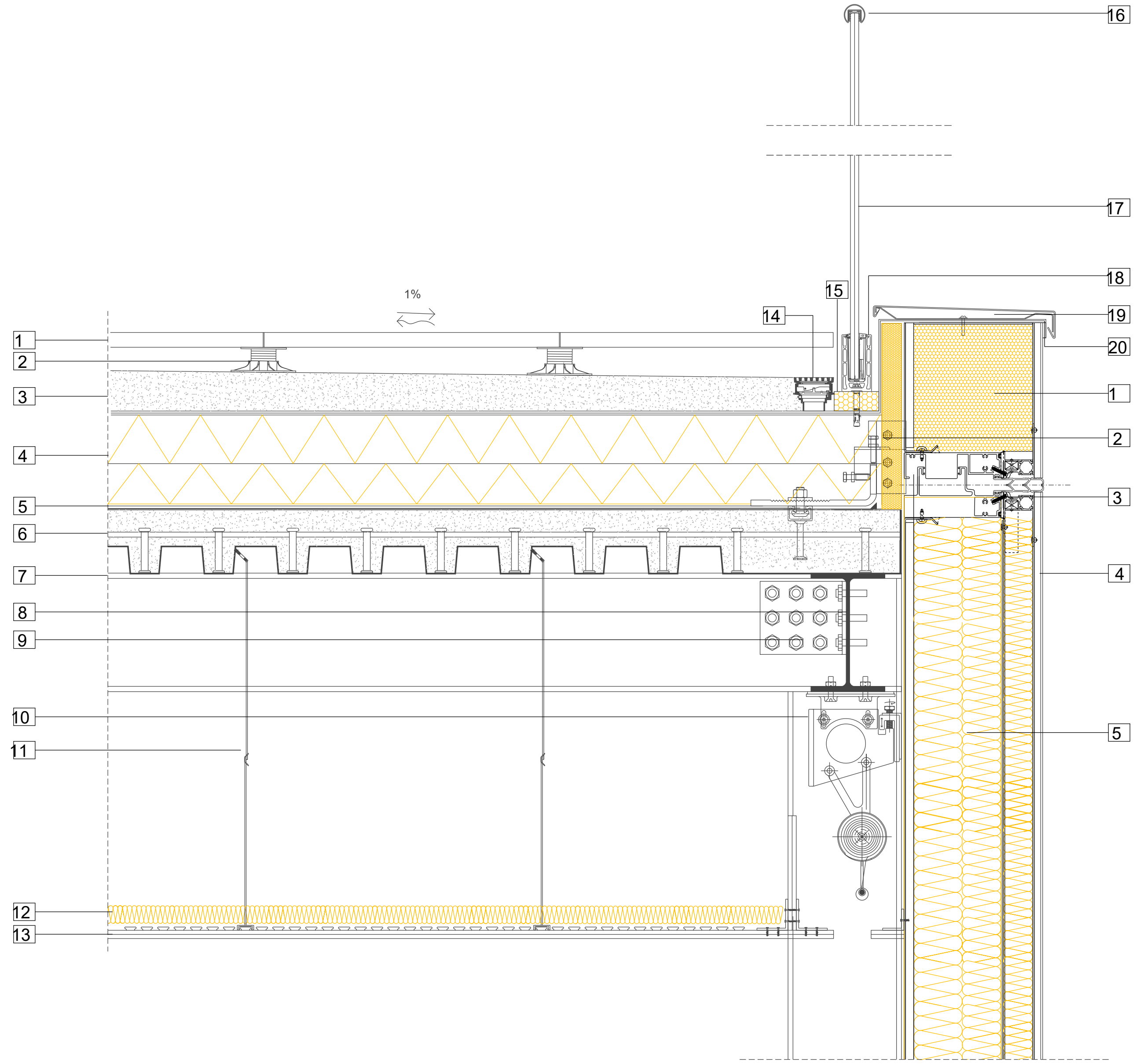


INTERMEDIATE FLOOR SYSTEM

1.FINISHING ELEMENT, Stoneware Flooring glued to a chipboard panel,Thickness 3 cm
2.STRUCTURAL ELEMENT, Column, HEA 300 Steel Profile
3.FLOORING SUPPORT ELEMENT, Height-adjustable Pedestal
4.NOISE INSULATION LAYER, sound-absorbing mat, Thickness 1 cm
5.STRUCTURAL LAYER, corrugated sheet + collaborating hood
6.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
7.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
8.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
9.CURTAIN SYSTEM attached to main structure
10.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
11.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
12.FINISHING LAYER, Acoustic False Ceiling Panels

INTERMEDIATE ROOF-TERRACE SYSTEM

1.STRUCTURAL ELEMENT, Curtain Wall Mullion, 50x270 mm
2.CURTAIN WALL PANEL, Triple Glazing
3.STRUCTURAL ELEMENT, Curtain Wall Transom, 50x270 mm
4.SUPPORT BLOCK
5.FLASHING, Alluminum Profile with J Trim Drip Edge, 5% Slope
6.DRAINAGE
7.FINISHING ELEMENT, Natural Stone, Marble, Thickness: 3 cm
8.FLOORING FIXING ELEMENT ,Height Adjustable Pedestal, Height : 5 cm
9.SLOPING CONCRETE - 1% min. 7 cm
10.THERMAL INSULATION, Extruded Polystrene (XPS), 2 layers 10cm+10cm
11.WATERPROOFING, EPDM Membrane

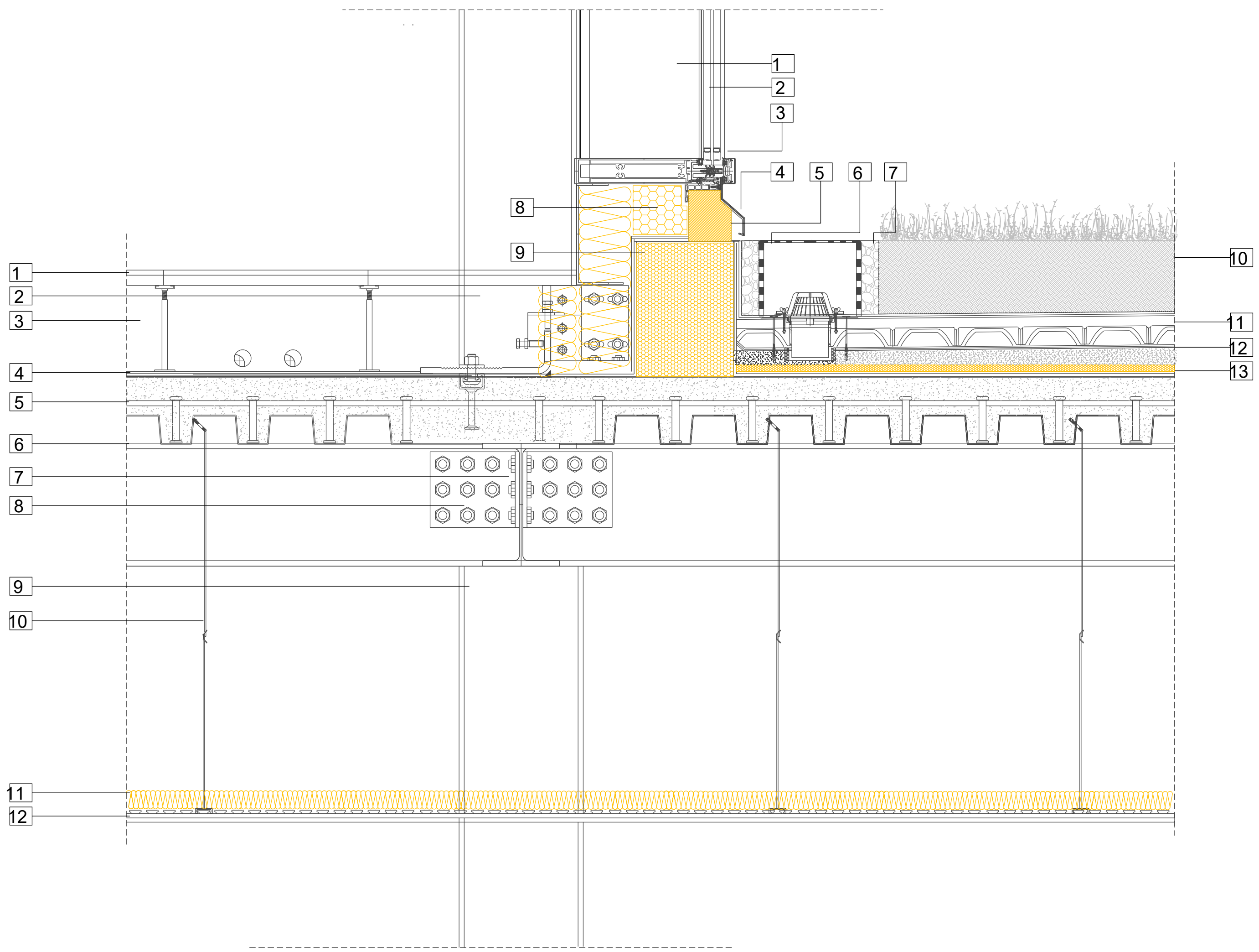


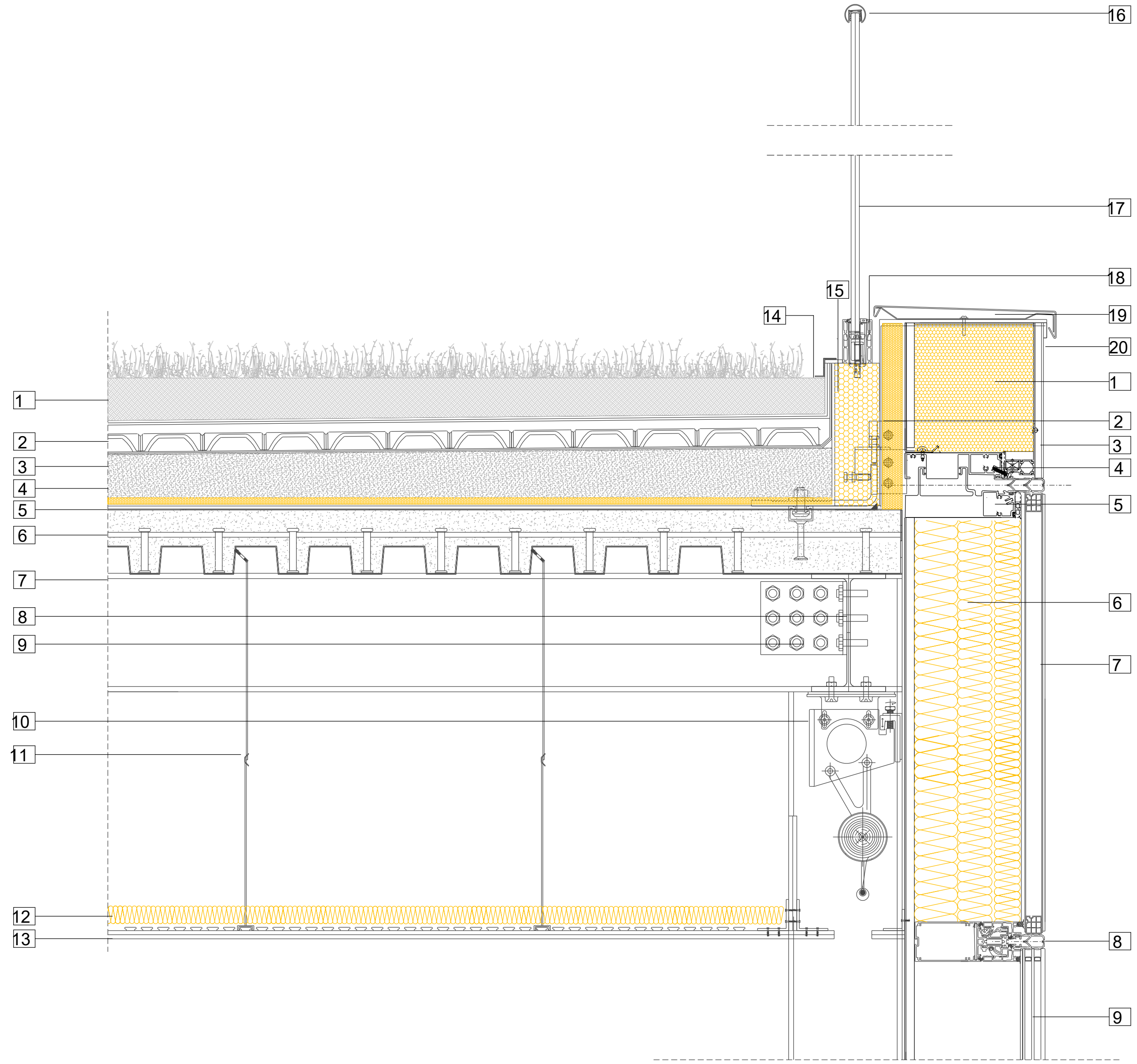
INTERMEDIATE ROOF-TERRACE SYSTEM

1.FINISHING ELEMENT, Natural Stone, Marble, Thickness: 3 cm
2.FLOORING FIXING ELEMENT ,Height Adjustable Pedestal, Height : 5 cm
3.SLOPING CONCRETE - 1% min. 7 cm
4.THERMAL INSULATION, Extruded Polystrene (XPS), 2 layers 10cm+10cm
5.WATERPROOFING, EPDM Membrane
6.STRUCTURAL LAYER, corrugated sheet + collaborating hood
7.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
8.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
9.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
10.CURTAIN SYSTEM attached to main structure
11.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
12.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
13.FINISHING LAYER, Acoustic False Ceiling Panels
14. DRAINAGE
15.RIGID INSULATION
16.RAILING, Aluminum Circular Railing Cap
17.RAILING, Glazing
18.BALLUSTRADE FIXING, Steel Side Mount Anchor
19.FLASHING, Alluminum Profile with J Trim Drip Edge, 5% Slope
20.WATERPROFING, Grooved Air and Water Barrier

UNITISED SYSTEM - CURTAIN WALL FACADE

1.THERMAL INSULATION, Rigid Stone Wool curtain panel finishing, Thickness 20 cm
2.STRUCTURAL ELEMENT, Aluminum Fixing Bracket for Curtian systems, Fixed to Structural reinforced slab
3.STRUCTURAL ELEMENT OPAQUE, Curtain Wall Transom, 80x250 mm
4.CLOSING ELEMENT, Fiber C, Natural Sand colourblushing effect alkali-resistant glassfibres (AR glass), UV - hydrophobicity protection
5.THERMAL INSULATION, Insulated Wooden Sandwich Curtain Panel





INTERMEDIATE FLOOR SYSTEM

1.FINISHING ELEMENT, Stoneware Flooring glued to a chipboard panel,Thickness 3 cm
2.STRUCTURAL ELEMENT, Column, HEA 300 Steel Profile
3.FLOORING SUPPORT ELEMENT, Height-adjustable Pedestal
4.NOISE INSULATION LAYER, sound-absorbing mat, Thickness 1 cm
5.STRUCTURAL LAYER, corrugated sheet + collaborating hood
6.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
7.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
8.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
9.CURTAIN SYSTEM attached to main structure
10.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
11.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
12.FINISHING LAYER, Acoustic False Ceiling Panels

INTERMEDIATE ROOF-TERRACE SYSTEM

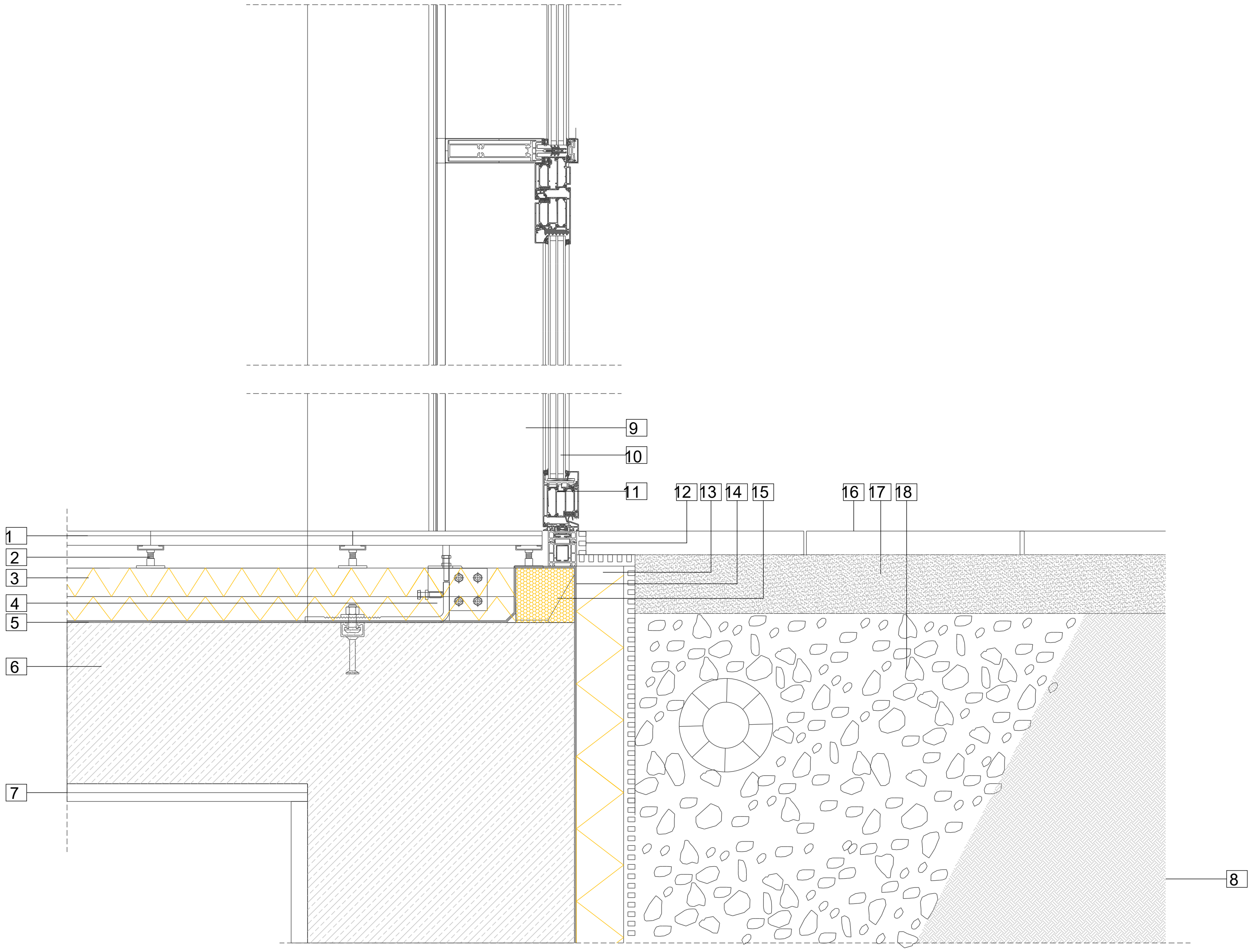
1.STRUCTURAL ELEMENT, Curtain Wall Mullion, 50x270 mm
2.CURTAIN WALL PANEL, Triple Glazing
3.STRUCTURAL ELEMENT, Curtain Wall Transom, 50x270 mm
4.SUPPORT BLOCK
5.FLASHING, Alluminum Profile with J Trim Drip Edge, 5% Slope
6.DRAINAGE
7. Drainage gravels protection
8.CULTIVATION LAYER, Soil, Thickness: 5 cm
9.SLIDING LAYER, Pointed non-woven geotextile in white polyester, Thickness: 0.05 cm
10.DRAINING AND WATER RESERVE LAYER, Formwork for gardens, Formwork height: 4 cm, Total height: 6 cm
11.WATERPROOFING LAYER, Solvent-free Single-Component Paste, based on synthetic resins in water dispersion, extremely fast drying, Thickness 3 mm
12.THERMAL INSULATION, Expanded Polystrene Boards, Thickness: 10 cm min., Sloped 1%
13.ANTI-CONDENSATION LAYER, Vapor Barrier, PE Membrane, Thickness: 2 mm

INTERMEDIATE ROOF-TERRACE SYSTEM

1.DRAINING AND WATER RESERVE LAYER, Formwork for gardens, Formwork height: 4 cm, Total height: 6 cm
2.WATERPROOFING LAYER, Solvent-free Single-Component Paste, based on synthetic resins in water dispersion, extremely fast drying, Thickness 3 mm
3.SLOPING CONCRETE - 1% min. 7 cm
4.THERMAL INSULATION, Expanded Polystrene Boards, Thickness: 10 cm min., Sloped 1%
5.ANTI-CONDENSATION LAYER, Vapor Barrier, PE Membrane, Thickness: 2 mm
6.STRUCTURAL LAYER, corrugated sheet + collaborating hood
7.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
8.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
9.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
10.CURTAIN SYSTEM attached to main structure
11.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
12.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
13.FINISHING LAYER, Acoustic False Ceiling Panels
14. FINISHING LAYER, Flashing Railing
15.RIGID INSULATION
16.RAILING, Aluminum Circular Railing Cap
17.RAILING, Glazing
18.BALLUSTRADE FIXING, Steel Side Mount Anchor
19.FLASHING, Alluminum Profile with J Trim Drip Edge, 5% Slope
20.WATERPROFING, Grooved Air and Water Barrier

UNITISED SYSTEM - CURTAIN WALL FACADE

1.THERMAL INSULATION, Rigid Stone Wool curtain panel finishing, Thickness 20 cm
2.STRUCTURAL ELEMENT, Aluminum Fixing Bracket for Curtian systems, Fixed to Structural reinforced slab
3.CLOSING ELEMENT, Fiber C, Natural Sand colourblushing effect alkali-resistant glassfibres (AR glass), UV - hydrophobicity protection
4.STRUCTURAL ELEMENT OPAQUE, Curtain Wall Transom, 80x250 mm
5.STRUCTURAL ELEMENT GLASS, Curtain Wall Transom, 80x250 mm
6.THERMAL INSULATION, Insulated Wooden Sandwich Curtain Panel
7.CLOSING ELEMENT, Insulated sandwich panel with reflective finishing
8.STRUCTURAL ELEMENT, Aluminum Glass Fixing t for Curtian systems,
9.CURTAIN WALL PANEL, Triple Glazing

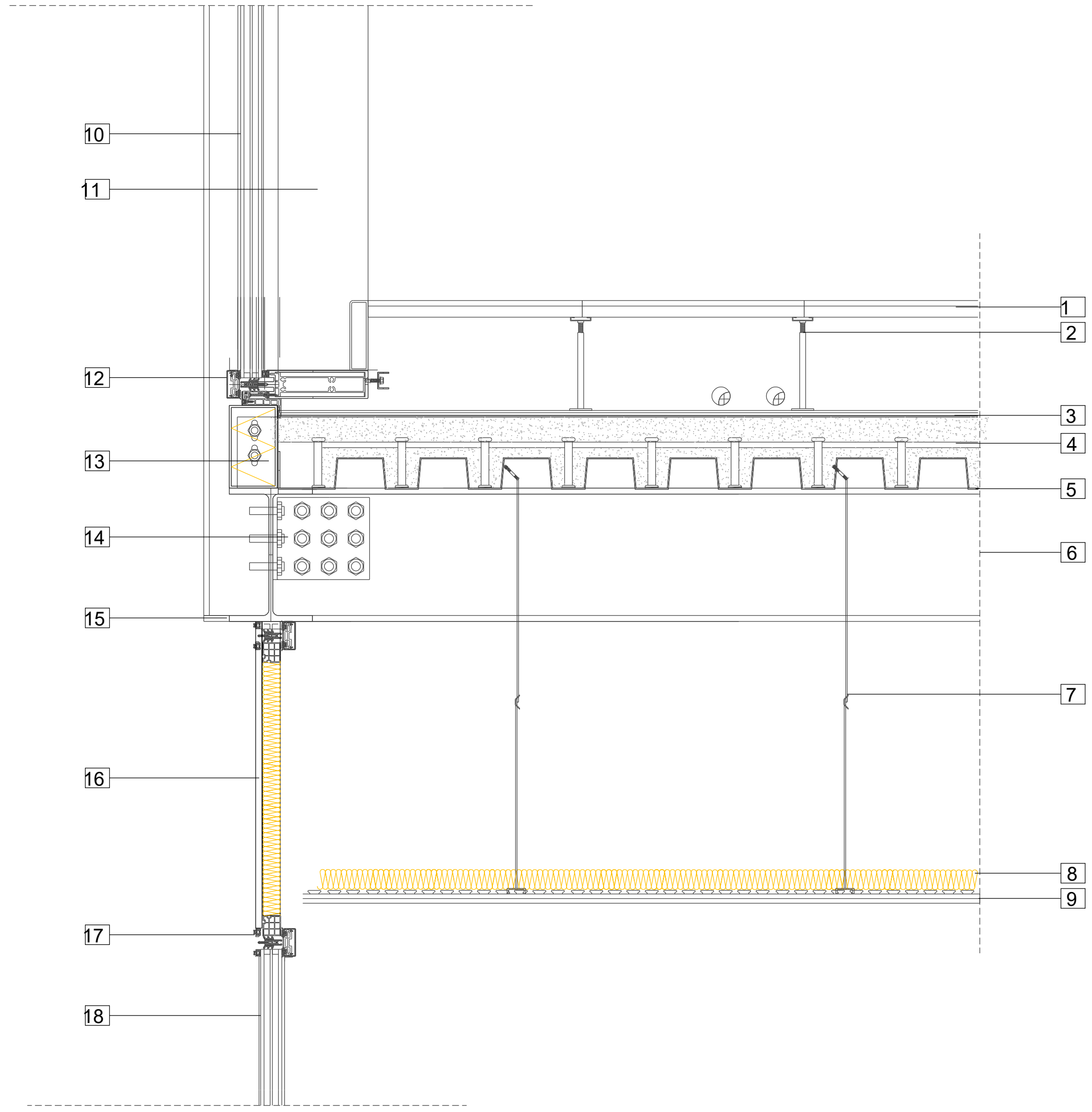


FLOOR ON FOUNDATION

1.FINISHING ELEMENT, Stoneware Flooring glued to a chipboard panel,Thickness 3 cm
2.FLOORING SUPPORT ELEMENT, Height-adjustable
3.THERMAL INSULATION, XPS Board, Thickness: 10 cm
4.STRUCTURAL ELEMENT, Curtain Wall Fixing Anchor
5.WATERPROOFING, Bituminous Membrane, Thickness: 1.5 mm
6.STRUCTURAL ELEMENT, Reinforced Concrete Raft Foundation, Thickness: 100 cm
7.FINISHING CONCRETE
8.Earth

FOUNDATION - EXTERNAL FLOOR SYSTEM

9.STRUCTURAL ELEMENT, Curtain Wall Mullion, 50x270 Mm
10.CURTAIN WALL DOOR PANEL, Triple glazing
11.STRUCTURAL ELEMENT, Curtain Wall Door Profile
12.PROTECTION LAYER, Geotextile Mat
13.PROTECTION LAYER, Expanded Polystrene
14.WATERPROOFING, Bituminous Membrane, Thickness: 1.5 mm
15.SUPPORT BLOCK, Foam Glass
16.PAVEMENT, Natural Stone Blocks with sand swept joints, Travertine, Thickness: 5 cm
17.SANDBED, Thickness: 10 cm
18.GRAVEL



INTERMEDIATE FLOOR SYSTEM

1.FINISHING ELEMENT, Stoneware Flooring glued to a chipboard panel,Thickness 3 cm
2.FLOORING SUPPORT ELEMENT, Height-adjustable Pedestal
3.NOISE INSULATION LAYER, sound-absorbing mat, Thickness 1 cm
5.STRUCTURAL LAYER, collaborating hood
5.STRUCTURAL LAYER, corrugated sheet
6.STRUCTURAL ELEMENT, Secondary Beam, IPE 180 Steel Profile
7.FALSE CEILING SUBSTRUCTURE, Adjustable Hangers
8.ACOUSTIC INSULATION, Stone Wool, Thickness: 3 cm
9.FINISHING LAYER, Acoustic False Ceiling Panels
10.STRUCTURAL ELEMENT, Curtain Window Mullion, 50x270 mm
11.CURTAIN WALL DOOR PANEL, Triple glazing
12.STRUCTURAL ELEMENT, Curtain Wall Door Profile
13.INTERNAL FINISHING, Aluminum Composite Panels
14.STRUCTURAL ELEMENT, Main Beam, IPE 240 Steel Profile
15.STRUCTURAL ELEMENT, Steel Anchoring Bracket + Steel Bolts: Ø32,4mm x 9
16.CURTAIN WALL PANEL, Insulated Wooden Sandwich Panel
17.STRUCTURAL ELEMENT, Curtain Wall Door Profile
18.CURTAIN WALL DOOR PANEL, Triple glazing

STRUCTURES

STRUCTURAL DESIGN

Structural system

We chose a steel structure as the main loadbearing element; it consists of primary and secondary beams raised on columns and equipped with a floor system with corrugated sheet of Metecno HI-BOND A55 / P600 type.

In the plan views, reinforced concrete members are indicated in the foundation and ground story while the steel members are used for all upper floors.

The structure is divided into three independent parts with expansion joints which securely holds the separate parts together while safely absorbing vibrations and withstanding temperature-induced expansion. For the concrete part, a floor system with predalles type slabs was used.

Concrete

Strength class C30/37

Concrete characteristic cylindrical compressive strength: f_{ck} = 30 MPa

Concrete characteristic cubic compressive strength: R_{ck} = 37 MPa

Design compressive strength:

$$f_{cd} = \alpha_{cc}\,\frac{f_{ck}}{\gamma_c} = 0{,}85\frac{f_{ck}}{1{,}5} \Rightarrow f_{cd} = 0{,}85\,\frac{30}{1{,}5} = 17\ MPa$$

Steel

The steel chosen for the reinforced part: B450C,

Characteristic strength f_{tk} = 540 MPa

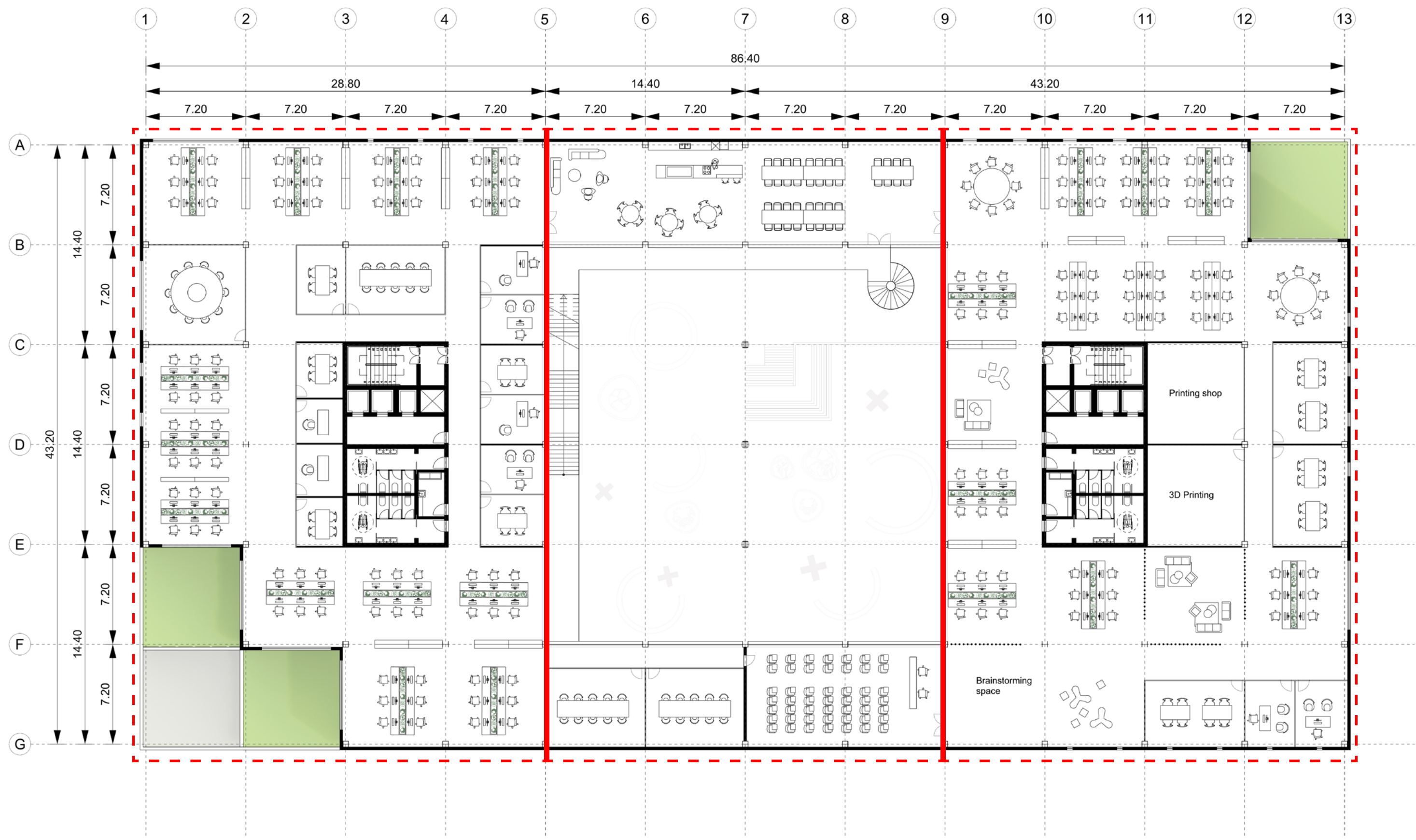
Steel characteristic yielding strength for the bar: f_{yk} = 450 MPa

Design yield strength $f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{450}{1{,}15} = 391\ MPa$

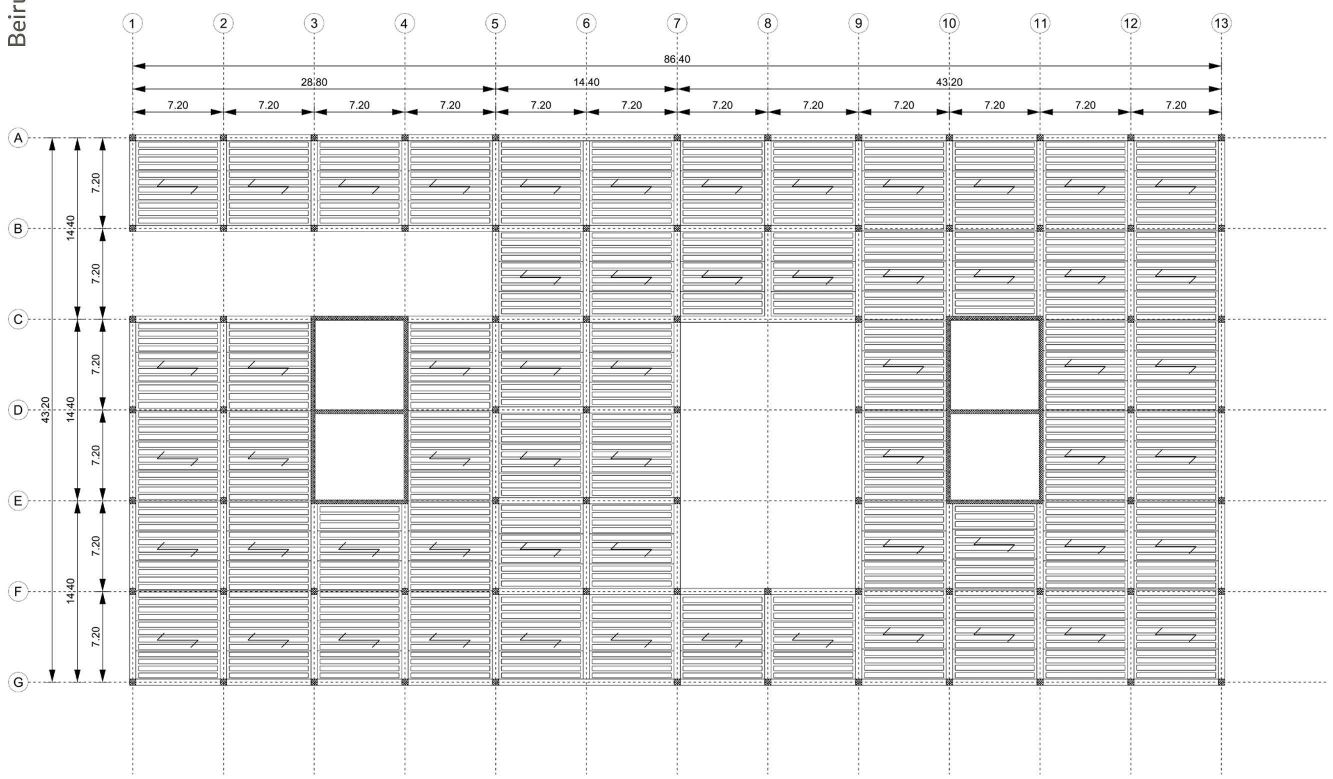
Modulus of elasticity Es = 210000 MPa

The steel profile used: Class S275

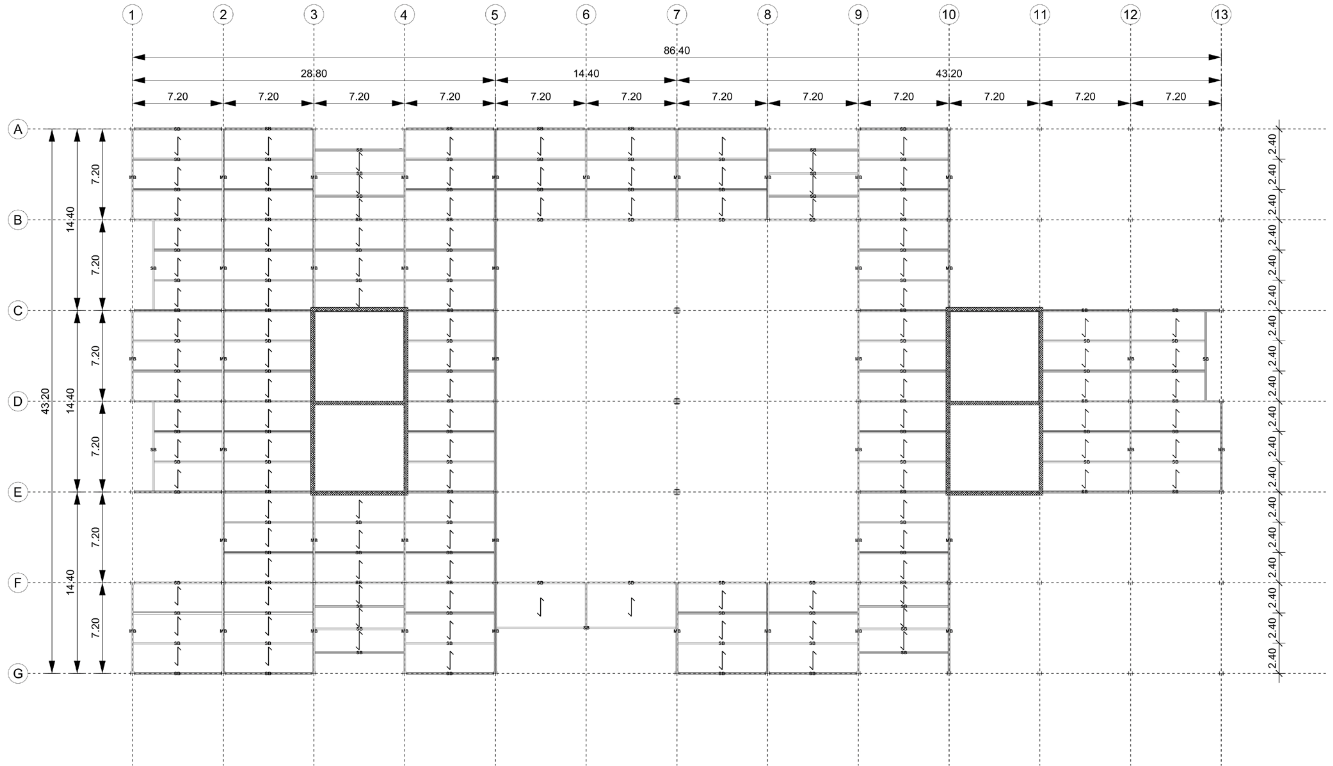
Expansion joints



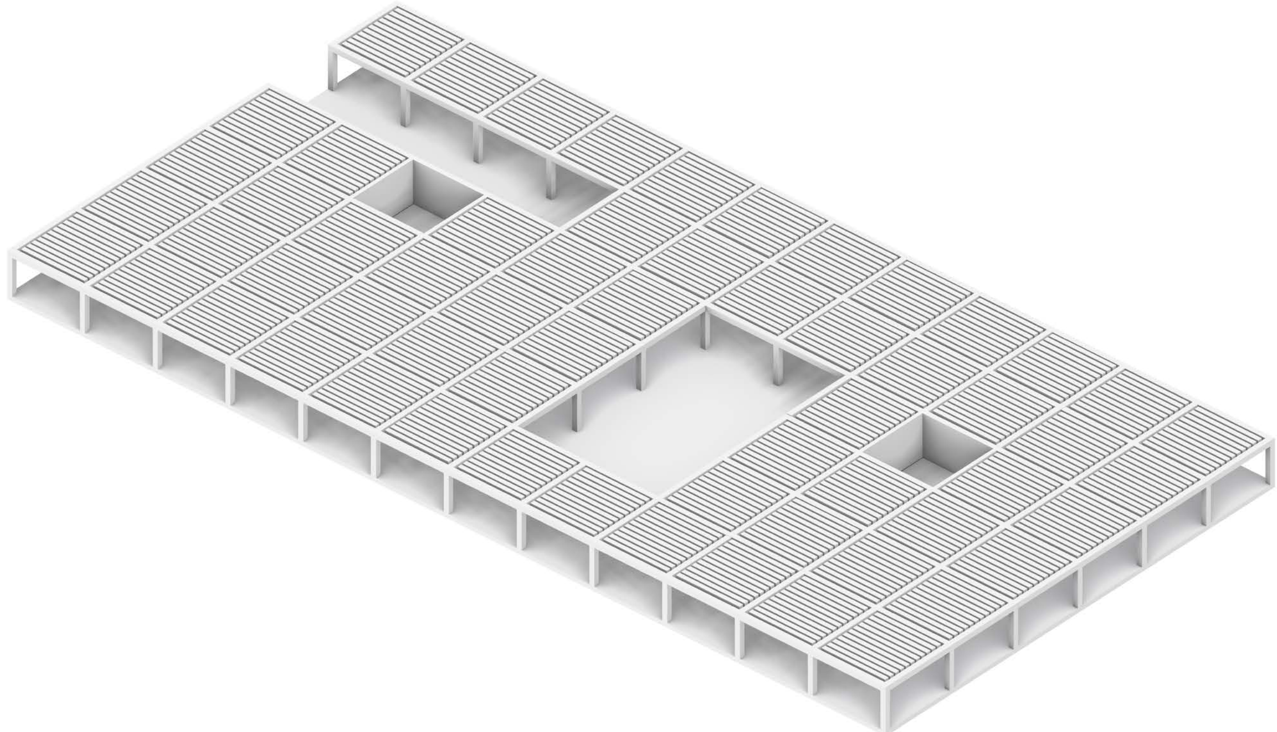
STRUCTURAL SCHEMES

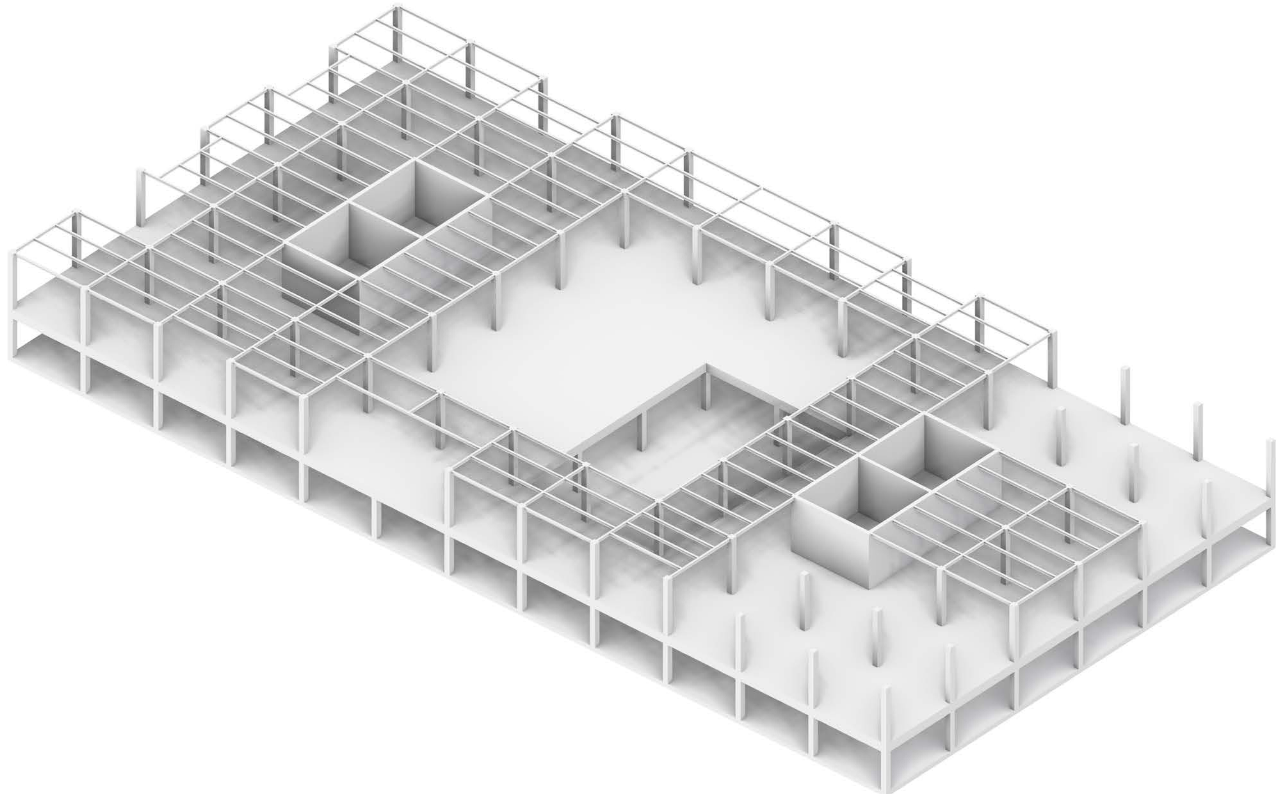


GROUND FLOOR

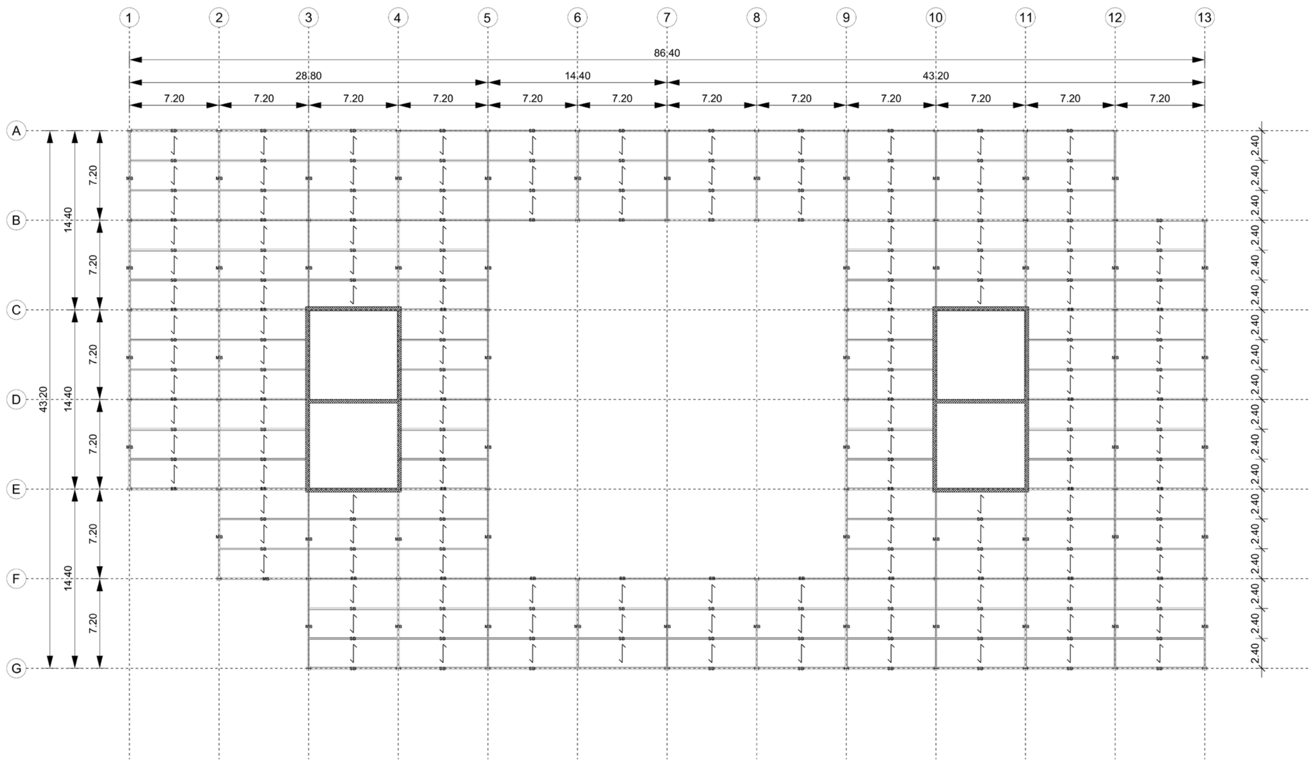


1ST FLOOR

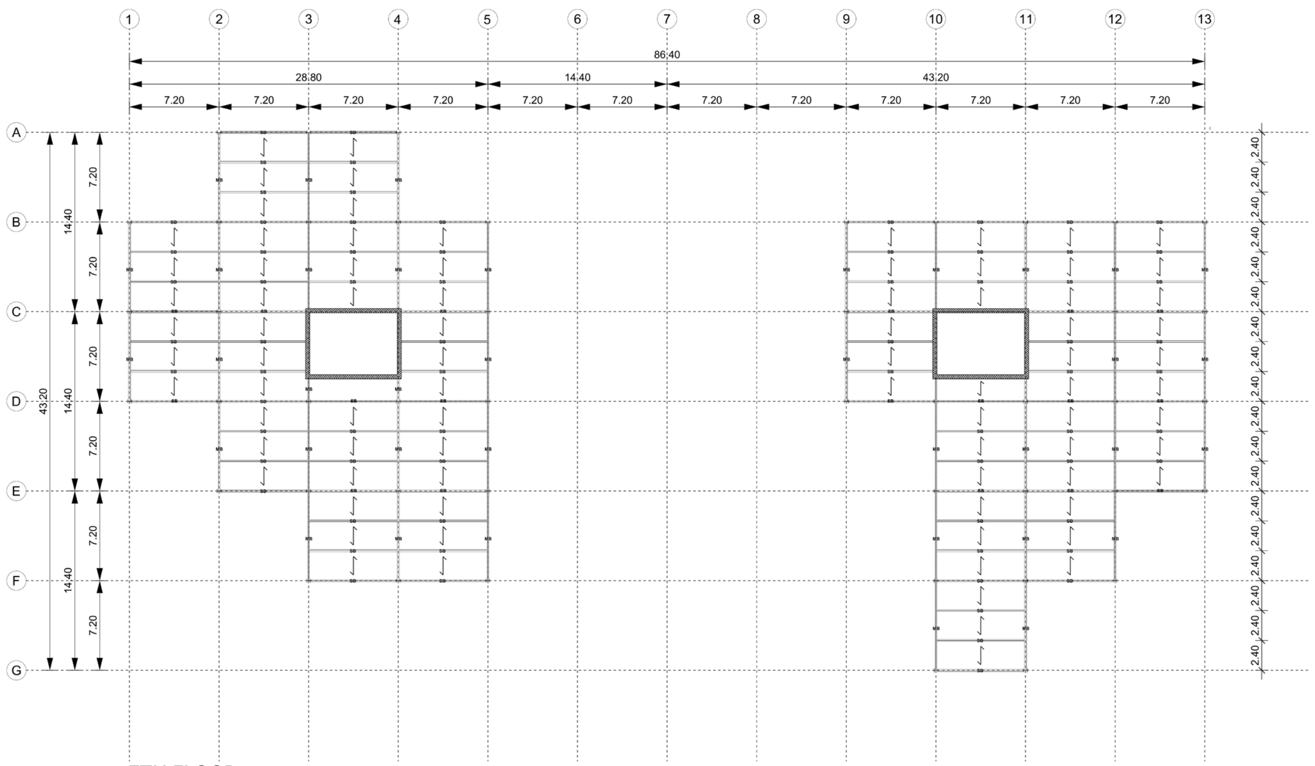




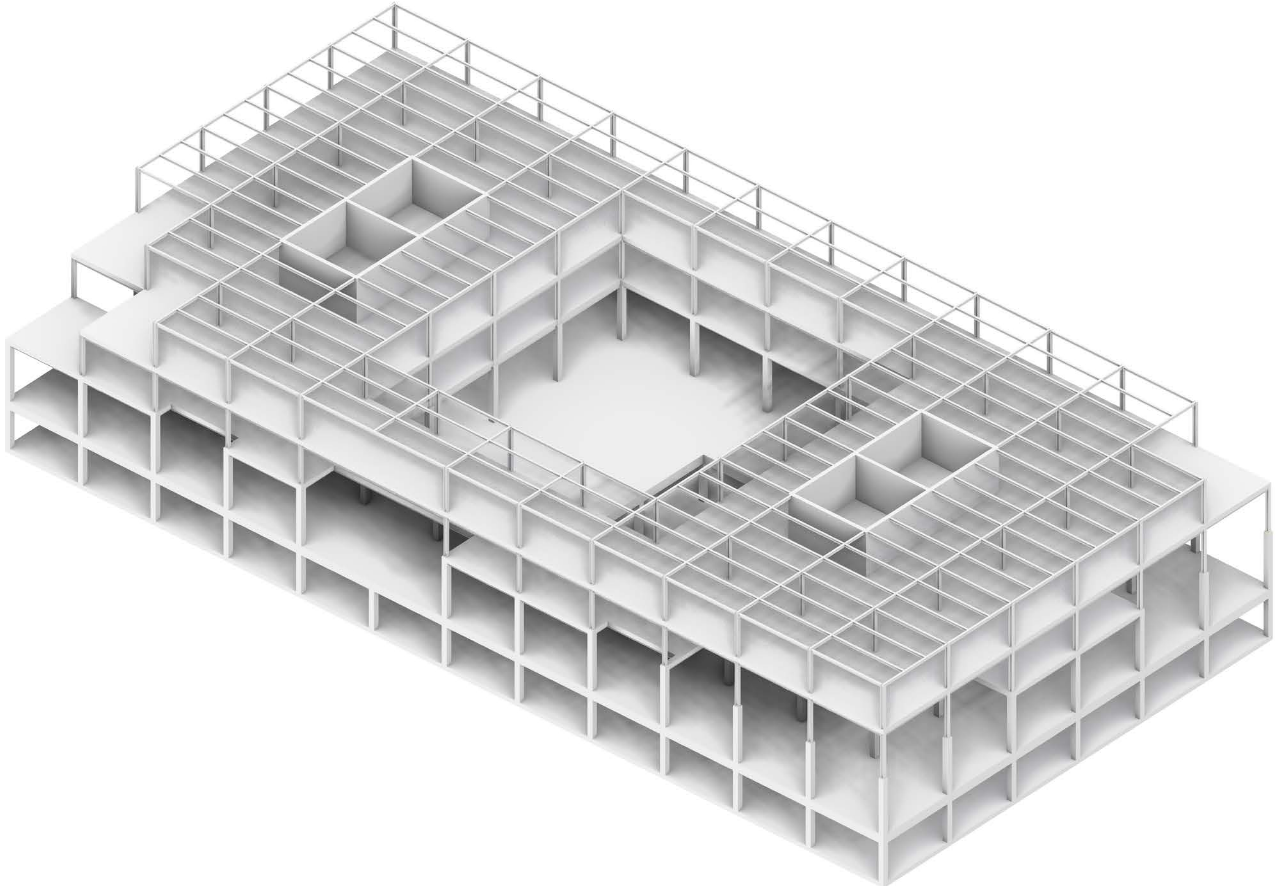
STRUCTURAL SCHEMES

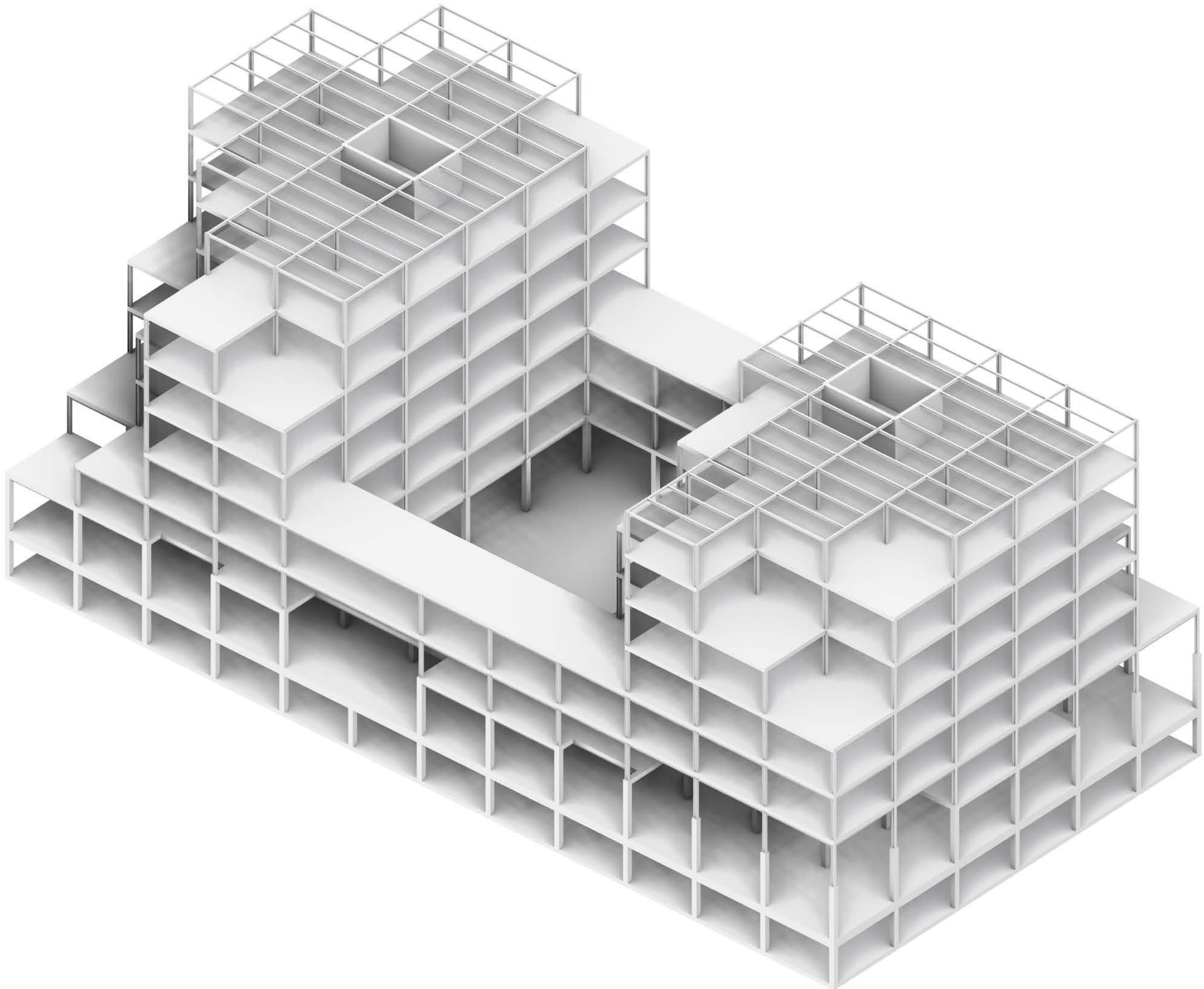


3RD FLOOR

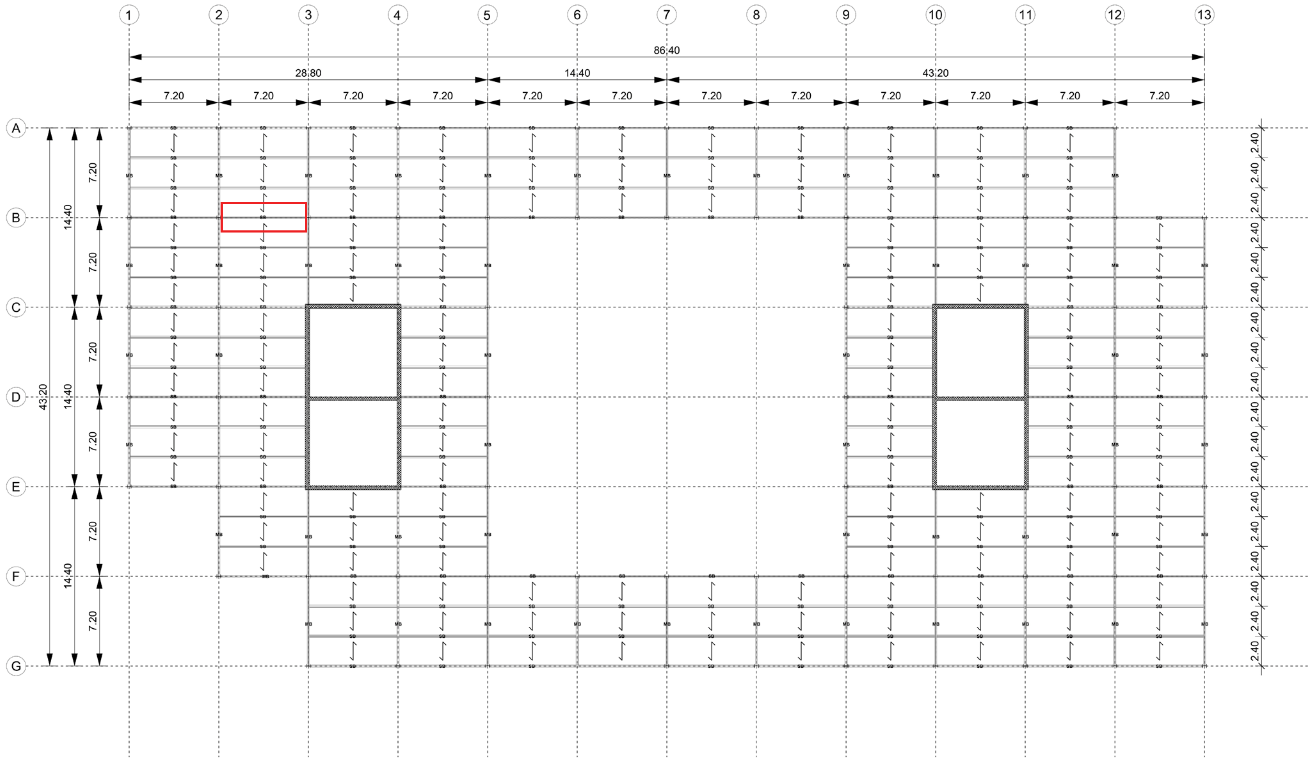


7TH FLOOR

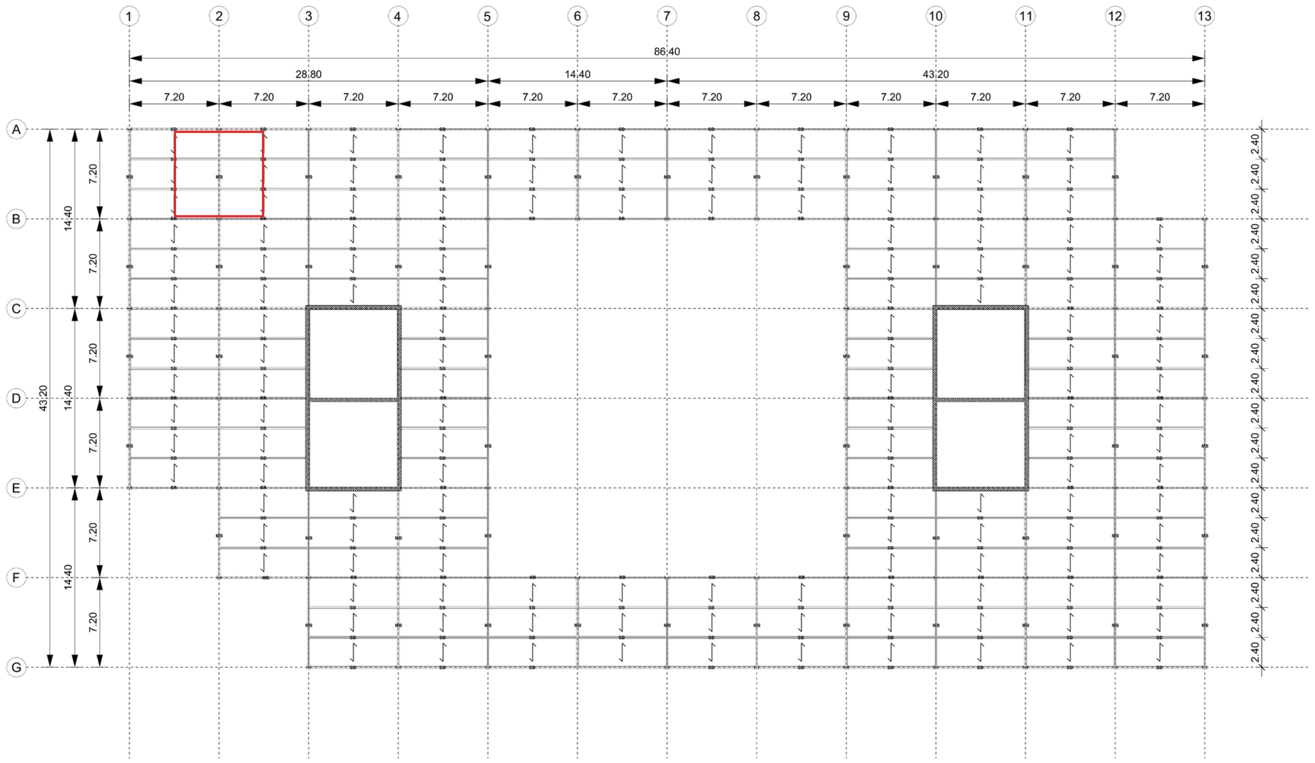




STEEL



SECONDARY BEAM



PRIMARY BEAM

In the part covered with steel beams, the floor is made up of a corrugated sheet of type Metecno HI-BOND A55 / P600.

13	265	0,70	4,48	659,76	2209,28	77,43	1460
		0,80	4,71	726,89	2313,67	87,71	
		1,00	5,11	849,32	2491,55	107,69	
		1,20	5,45	958,20	2639,26	126,84	

Weight		ULS		SLS	
		Favorable	Unfavorable	Favorable	Unfavorable
G1	2,65 $[kN/m^2]$	2,65 $[kN/m^2]$	3,45 $[kN/m^2]$	2,65 $[kN/m^2]$	2,65 $[kN/m^2]$
G2	0,977+0,8=1,78	0 $[kN/m^2]$	2,67 $[kN/m^2]$	0 $[kN/m^2]$	1,78 $[kN/m^2]$
Q	2 $[kN/m^2]$	0 $[kN/m^2]$	3,00 $[kN/m^2]$	0 $[kN/m^2]$	3,00 $[kN/m^2]$

G2 = weight of floors + weight internal partitions = 0,977 + 0.8 = 1,78 kN/m^2

Q= 2 kN/m^2 (standard for residential use)

Secondary Beam

We analyzed the 4th floor for dimensioning and choosing the correct profile for secondary and main beam.

Pre-dimensioning

The height of the secondary beam was calculated as 1/25 of the maximum span present.

Therefore: $h_t = \frac{1}{25} \times l_{max} = \frac{1}{25} \times 7{,}2 = 0{,}288\ m = 288\ mm$

From these calculations we hypothesized that the secondary beam is an IPE 360. The maximum deflection of the secondary beam was calculated as 1/250 of the maximum span present.

Therefore: $f_{max} = \frac{1}{250} \times l_{max} = \frac{1}{250} \times 7{,}2 = 0{,}0288\ m = 28{,}8\ mm$

Type of load	Value	ULS	SLS
G1	$2{,}65 \frac{kN}{m^2} \times 2{,}4 \times 1{,}15 = 7{,}3\ kN/m$	$7{,}3 \frac{kN}{m} \times 1{,}3 = 9{,}5\ kN/m$	$7{,}3\ kN/m$
G2	$1{,}78 \frac{kN}{m^2} \times 2{,}4 = 4{,}3\ kN/m$	$4{,}3 \frac{kN}{m} \times 1{,}5 = 6{,}5\ kN/m$	$4{,}3\ kN/m$
Q_K	$2 \frac{kN}{m^2} \times 2{,}4 = 4{,}8\ kN/m$	$4{,}8 \frac{kN}{m} \times 1{,}5 = 7{,}2\ kN/m$	$4{,}8 \frac{kN}{m} \times 1{,}5 = 7{,}2\ kN/m$

Combination of actions:

ULS: $\gamma_{G1} \times G_1 + \gamma_{G2} \times G_2 + \gamma_0 \times Q = 1{,}3 \times 7{,}3 + 1{,}5 \times 4{,}3 + 1{,}5 \times 4{,}8 = 23{,}2\ \mathrm{kN/m}$

SLS (rare): $G_1 + G_2 + Q = 7{,}3 + 4{,}3 + 4{,}8 = 16{,}4\ kN/m$

SLS check

$$f = \frac{5}{384} \times \frac{Q_{SLS\ (rare)} \times span^4}{EI} = \frac{5}{384} \times \frac{16{,}4 \times 7200^4}{210000 \times I}$$

Considering a IPE 360 beam as previously assumed, a value of I = 16270 cm4 is obtained. Therefore:

$$f = \frac{5}{384} \times \frac{13{,}7 \times 7200^4}{210000 \times 16270} = 140308 = 14{,}03\ mm\ < f_{max}\ = 28{,}8 \longrightarrow$$ Verified

ULS check

$$M_{max,ULS} = \frac{1}{8} ql^2 = \frac{1}{8} \times 23{,}2 \times 7{,}2^2 = 150{,}34\ kNm$$

$$V_{max,ULS} = \frac{1}{2} ql = \frac{1}{2} \times 23{,}2 \times 7{,}2 = 83{,}52\ kNm$$

S275	W_{pl} max $[cm^3]$	h $[mm]$	b $[mm]$	r $[mm]$	d $[mm]$	t_w $[mm]$	c_w $[mm]$	t_f $[mm]$	c_f $[mm]$	$\varepsilon = (\sqrt{\frac{235}{f_y}})$	$X' = c_w/t_w$	$X'' = c_f/t_f$
IPE 360	974	360	170	18	298,6	8	298,6	12,7	63	0,92	37,33	4,96

S275	Bending web class	Compression web class		Bending flanges class	Compression flanges class
	Class1: X' <72ε	Class1: X' <33ε	Class3: X' <42ε	Class1: X'' <9ε	Class1: X'' <9ε
IPE 360	37,33 < 66,24	Useless	37,33 < 38,64	4,96 < 8,28	4,96 < 8,28

S275		Web	Flanges	Section
IPE 360	Bending	Class 1	Class 2	Class 1
	Compression	Class 3	Class 1	Class 3

Bending verification:

According to the Eurocodes, bending moment must be verified in ULS, so increased by partial coefficients and with worst case scenario load distributions. In this case the design value of bending

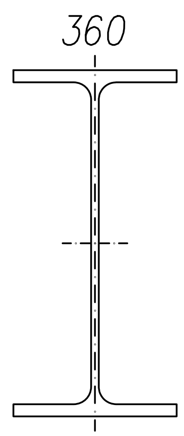
$$\frac{M_{Ed}}{Mc{,}Rd} \leq 1$$

$$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} \times f_{yk}}{\gamma_{M0}}$$

Bending verification							
S275	W_{pl} max $[cm^3]$	f_y $[N/mm^2]$	γ_{M0}	$M_{c,Rd}$ $[kNm]$	M_{Ed} $[kNm]$	$\frac{M_{Ed}}{Mc,Rd} \leq 1$	
IPE 360	974	275	1,05	255,10	150,34	0,59	ok

Shear verification:

According to the Eurocode, the design value of the shear force V_{Ed} at each cross-section shall satisfy:



$$\frac{V_{Ed}}{Vc{,}Rd} \leq 1$$

$$V_{pl,Rd} = \frac{A_v \times (f_y \times \sqrt{3})}{\gamma_{M0}}$$

$$A_v = A - 2 \times b \times t_f + (t_w + 2 \times r) \times t_f$$

Shear verification								
S275	A $[mm^2]$	A_v $[mm^2]$	f_y $[N/mm^2]$	γ_{M0}	$V_{c,Rd}$ $[kNm]$	V_{Ed} $[kNm]$	$\frac{V_{Ed}}{Vc,Rd} \leq 1$	
IPE 360	7273	3514	275	1,05	159,4	83,52	0,52	ok

PRIMARY BEAM

Pre-dimensioning

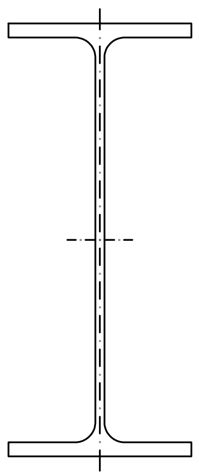
The height of the primary beam was calculated as 1/20 of the maximum span present.

Therefore: $h_t = \frac{1}{20} \times l_{max} = \frac{1}{20} \times 7{,}2 = 0{,}36\ m = 360\ mm$

From these calculations I hypothesized that the secondary beam is an IPE 450. The maximum deflection of the secondary beam was calculated as 1/250 of the maximum span present.

Therefore: $f_{max} = \frac{1}{250} \times l_{max} = \frac{1}{250} \times 7{,}2 = 0{,}0288\ m = 28{,}8\ mm$

Type of load	Value	ULS	SLS
G1	$2{,}65 \frac{kN}{m^2} \times 7{,}2 \times 1{,}15 = 21{,}9\ kN/m$	$21{,}9 \frac{kN}{m} \times 1{,}3 = 28{,}5\ kN/m$	$21{,}9\ kN/m$
G2	$1{,}78 \frac{kN}{m^2} \times 2{,}4 = 4{,}3\ kN/m$	$4{,}3 \frac{kN}{m} \times 1{,}5 = 6{,}5\ kN/m$	$4{,}3\ kN/m$
Q_K	$2 \frac{kN}{m^2} \times 2{,}4 = 4{,}8\ kN/m$	$4{,}8 \frac{kN}{m} \times 1{,}5 = 7{,}2\ kN/m$	$4{,}8 \frac{kN}{m} \times 1{,}5 = 7{,}2\ kN/m$



SLS check

$$f = \frac{5}{384} \times \frac{Q_{SLS\,(rare)} \times span^4}{EI} = \frac{5}{384} \times \frac{16{,}4 \times 7200^4}{210000 \times I}$$

Considering a HEB 360 beam as previously assumed, a value of I = 33740 cm4 is obtained. Therefore:

$f = \frac{5}{384} \times \frac{13{,}7 \times 7200^4}{210000 \times 33740} = 67658 = 6{,}8\ mm < f_{max} = 28{,}8$ ⟶ Verified

ULS check

$$M_{max,ULS} = \frac{1}{8} q l^2 = \frac{1}{8} \times 42{,}1 \times 7{,}2^2 = 272{,}81\ kNm$$

$$V_{max,ULS} = \frac{1}{2} q l = \frac{1}{2} \times 42{,}1 \times 7{,}2 = 151{,}56\ kNm$$

S275	W_{pl} max $[cm^3]$	h $[mm]$	b $[mm]$	r $[mm]$	d $[mm]$	t_w $[mm]$	c_w $[mm]$	t_f $[mm]$	c_f $[mm]$	$\varepsilon = (\sqrt{\frac{235}{f_y}})$	$X' = c_w/t_w$	$X'' = c_f/t_f$
IPE 450	1624	450	190	21	378,8	9,4	378,8	14,6	69,3	0,92	40,32	4,34

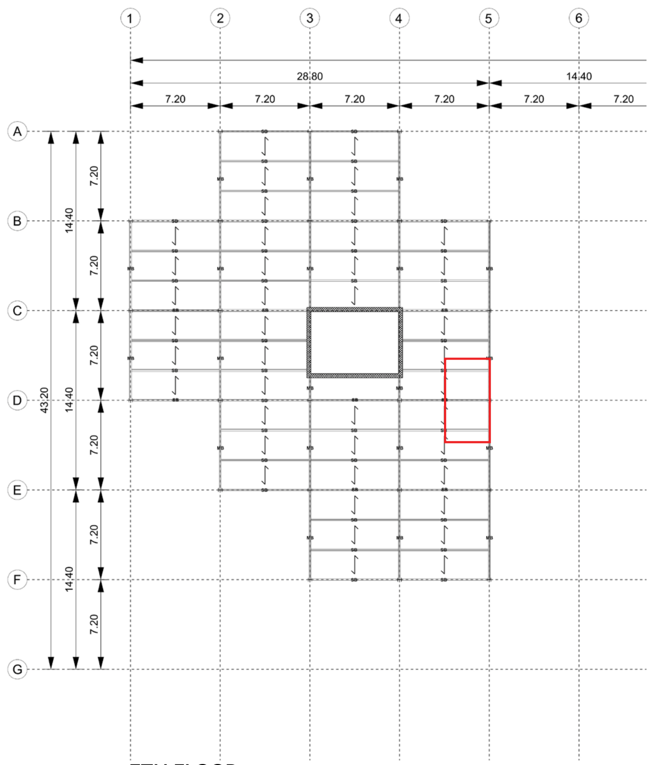
S275	Bending web class	Compression web class	Bending flanges class	Compression flanges class
	Class1: X' <72ε	Class 4	Class1: X'' <9ε	Class 1
IPE 450	40,32 < 66,24		4,34 < 8,28	

S275		Web	Flanges	Section
IPE 450	Bending	1	1	1
	Compression		1	

Bending verification							
S275	W_{pl} max $[cm^3]$	f_y $[N/mm^2]$	γ_{M0}	$M_{c,Rd}$ $[kNm]$	M_{Ed} $[kNm]$	$\frac{M_{Ed}}{Mc,Rd} \leq 1$	
IPE 450	1624	275	1,05	425,33	272,81	0,64	ok

Shear verification								
S275	A $[mm^2]$	A_v $[mm^2]$	f_y $[N/mm^2]$	γ_{M0}	$V_{c,Rd}$ $[kNm]$	V_{Ed} $[kNm]$	$\frac{V_{Ed}}{Vc,Rd} \leq 1$	
IPE 450	9882	5084	275	1,05	230,63	151,56	0,66	ok

PILLAR



7TH FLOOR
LEFT WING

Area: 7,2 m x 3,6 m = 25,92

Roof	Distributed load $[kN/m^2]$	Area of influence $[m^2]$	Total load $[kN]$	ULS load $[kN]$	Total distributed load ULS $[kN]$
G1	2,65	25,92	68,7	89,3	251,5
G2	2,97		77,0	115,5	
Q_s	1,2		31,1	46,7	
This is the axial load N of the column from 8th - Roof					

8th floor		Distributed load $[kN/m^2]$	Area of influence $[m^2]$	Total load $[kN]$	ULS load $[kN]$	Total distributed load ULS $[kN]$	Total load
Distributed load	G1	2,65	25,92	68,7	89,3	236,2	318,7
	G2	0,977+0,80 = 1,78		46,1	69,2		
	Q	2		51,8	77,7		
7th floor		Linear load $[kN/m]$	Length of beam $[m]$	Total load $[kN]$	ULS load $[kN]$	Total linear load ULS $[kN]$	
Linear load	G1	0				82,5	
	G2	2,45x4,5=11	5	55	82,5		
	Q	0					
Total load for the 7th – 8th floor column = 318,7 + 251,5 = 570,2							

G2=0,977+internal partition for residential

7th floor	Same analysis as 8th floor, load = 318,7
Total load for 6th-7th floor column = 570,2 + 318,7 = 888,9	

6th floor	Same analysis as 8th floor, load = 318,7
Total load for 5th-6th floor column = 888,9 + 318,7 = 1207,6	

5th floor	Same analysis as 8th floor, load = 318,7
Total load for 4th-5th floor column = 1207,6 + 318,7 = 1526,3	

4th floor	Same analysis as 8th floor, load = 318,7
Total load for 3rd-4th floor column = 1526,3 + 318,7 = 1844,7	

3rd floor	Same analysis as 8th floor, load = 318,7
Total load for 2nd-3rd floor column = 1844,7 + 318,7 = 2163,4	

2nd floor	Same analysis as 8th floor, load = 318,7
Total load for 1st-2nd floor column = 2163,4 + 318,7 = 2482,1	

Column 8th floor-Roof

Data		
N_{Ed}	251,5	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$
	χ	<1	0,36	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	2666	mm^2	$\frac{N_{Ed}}{\chi\times f_{yd}}$
	A	78,08	cm^2	**HEB 200**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	λ = h/I_z	5,07	78,9	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,91	<1,38
	Description	Formula		Φ	Verification
	Φ	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$		1,1	<1,74
	Description	Formula		χ	Verification
	χ	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,58	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd}=\chi\times A\times f_{yd}$	1186,5	251,5	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\frac{N_{Ed}}{N_{c,Rd}}\leq 1$	0,21	The column is correctly dimensioned	

Column 7th floor - 8th floor

Data		
N_{Ed}	570,2	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$
	χ	<1	0,36	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	6045	mm^2	$\frac{N_{Ed}}{\chi\times f_{yd}}$
	A	78,08	cm^2	**HEB 200**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	λ = h/I_z	5,07	78,9	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,91	<1,38
	Description	Formula		Φ	Verification
	Φ	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$		1,1	<1,74
	Description	Formula		χ	Verification
	χ	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,58	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd}=\chi\times A\times f_{yd}$	1186,5	570,2	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\frac{N_{Ed}}{N_{c,Rd}}\leq 1$	0,48	The column is correctly dimensioned	

Column 6th floor - 7th floor

Data		
N_{Ed}	888,9	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0,5[1+\alpha(\bar{\lambda}-0,2)+\bar{\lambda}^2]$
	χ	<1	0,36	$\chi = \frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	9424	mm^2	$\frac{N_{Ed}}{\chi \times f_{yd}}$
	A	149,1	cm^2	**HEB 300**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	λ = h/I_z	7,58	52,7	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,61	<1,38
	Description	Formula		Φ	Verification
	Φ	$0,5[1+\alpha(\bar{\lambda}-0,2)+\bar{\lambda}^2]$		0,79	<1,74
	Description	Formula		χ	Verification
	χ	$\chi = \frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,77	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd} = \chi \times A \times f_{yd}$	3007,9	888,9	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\frac{N_{Ed}}{N_{c,Rd}} \leq 1$	0,30	The column is correctly dimensioned	

Column 5th floor - 6th floor

Data		
N_{Ed}	1207,6	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0,5[1+\alpha(\bar{\lambda}-0,2)+\bar{\lambda}^2]$
	χ	<1	0,36	$\chi = \frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	12803	mm^2	$\frac{N_{Ed}}{\chi \times f_{yd}}$
	A	149,1	cm^2	**HEB 300**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	λ = h/I_z	7,58	52,7	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,61	<1,38
	Description	Formula		Φ	Verification
	Φ	$0,5[1+\alpha(\bar{\lambda}-0,2)+\bar{\lambda}^2]$		0,79	<1,74
	Description	Formula		χ	Verification
	χ	$\chi = \frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,77	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd} = \chi \times A \times f_{yd}$	3007,9	1207,6	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\frac{N_{Ed}}{N_{c,Rd}} \leq 1$	0,40	The column is correctly dimensioned	

Column 4th floor – 5th floor

Data		
N_{Ed}	1526,3	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$
	χ	<1	0,36	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	16182	mm²	$\frac{N_{Ed}}{\chi\times f_{yd}}$
	A	197,8	cm²	**HEB 400**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	λ = h/I_z	7,40	54,1	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,62	<1,38
	Description	Formula		Φ	Verification
	Φ	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$		0,80	<1,74
	Description	Formula		χ	Verification
	χ	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,77	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd}=\chi\times A\times f_{yd}$	3990,4	1526,3	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\frac{N_{Ed}}{N_{c,Rd}}\leq 1$	0,38	The column is correctly dimensioned	

Column 3rd floor – 4th floor

Data		
N_{Ed}	1844,7	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$
	χ	<1	0,36	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	19558	mm²	$\frac{N_{Ed}}{\chi\times f_{yd}}$
	A	218	cm²	**HEB 450**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	λ = h/I_z	7,33	54,6	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,63	<1,38
	Description	Formula		Φ	Verification
	Φ	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$		0,80	<1,74
	Description	Formula		χ	Verification
	χ	$\chi=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,77	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd}=\chi\times A\times f_{yd}$	4398,0	1844,7	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\frac{N_{Ed}}{N_{c,Rd}}\leq 1$	0,42	The column is correctly dimensioned	

Column 2nd floor – 3rd floor

Data		
N_{Ed}	2163,4	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$
	χ	<1	0,36	$\chi=\dfrac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	22937	mm^2	$\dfrac{N_{Ed}}{\chi\times f_{yd}}$
	A	254,1	cm^2	**HEB 550**

f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	$\lambda = h/I_z$	7,17	55,8	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,64	<1,38
	Description	Formula		Φ	Verification
	Φ	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$		0,81	<1,74
	Description	Formula		χ	Verification
	χ	$\chi=\dfrac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,77	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd} = \chi \times A \times f_{yd}$	5126,0	2163,4	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\dfrac{N_{Ed}}{N_{c,Rd}} \leq 1$	0,42	The column is correctly dimensioned	

Column 1st floor – 2nd floor

Data		
N_{Ed}	2482,1	kN
h	400	cm

Pre-dimensioning				
	Description	Value		Note:
0	Slenderness	80 < λ <120		Limits
1	Hypothesis	λ	120	λ_{max} from the code < 200
2	$\bar{\lambda}$	λ/87	1,38	87 determined from material use (S275)
3	Curve C	α	0,49	From NTC
	Φ	> λ	1,74	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$
	χ	<1	0,36	$\chi=\dfrac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$
4	A_{min}	26316	mm^2	$\dfrac{N_{Ed}}{\chi\times f_{yd}}$
	A	270,0	cm^2	**HEB 600**

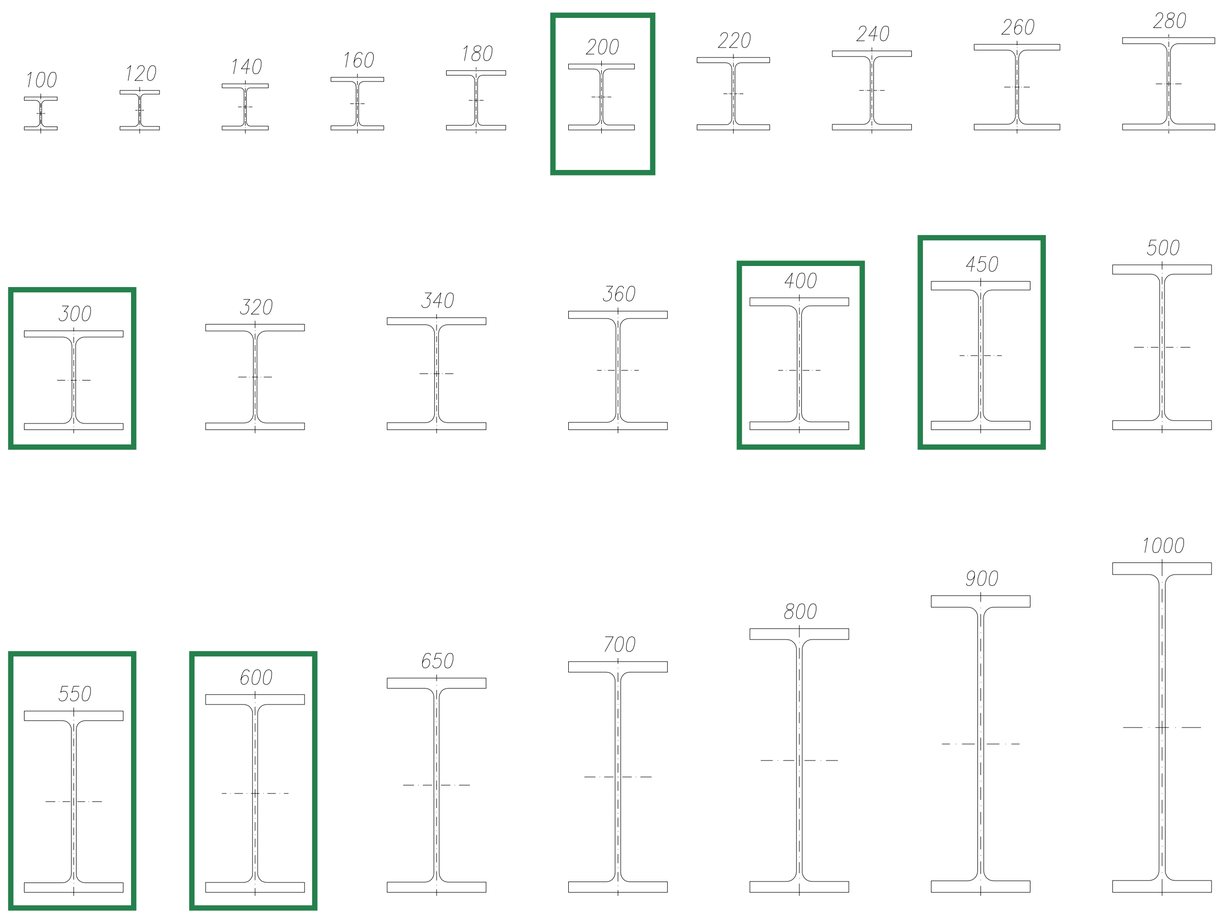
f_{yd} = Design yield strength (f_{yd}= f_{yk}/γ_{M0}=262 MPa) • f_{yk}= Characteristic yield strength (275 N/mm²)

Verifications					
	Description	Formula	I_z $[cm^4]$	λ	Verification
5	λ_z	$\lambda = h/I_z$	7,08	56,5	<120
	Description	Formula		$\bar{\lambda}$	Verification
	$\bar{\lambda}$	λ/87		0,65	<1,38
	Description	Formula		Φ	Verification
	Φ	$0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$		0,82	<1,74
	Description	Formula		χ	Verification
	χ	$\chi=\dfrac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$		0,76	<1
	Description	Formula	$N_{b,Rd}$ $[kN]$	N_{Ed} $[kN]$	Verification
6	$N_{b,Rd}$	$N_{b,Rd} = \chi \times A \times f_{yd}$	5376,2	2482,1	$N_{b,Rd}$ > N_{Ed}
	Description	Formula	Result	Comment	
	Demand capacity ratio	$\dfrac{N_{Ed}}{N_{c,Rd}} \leq 1$	0,46	The column is correctly dimensioned	

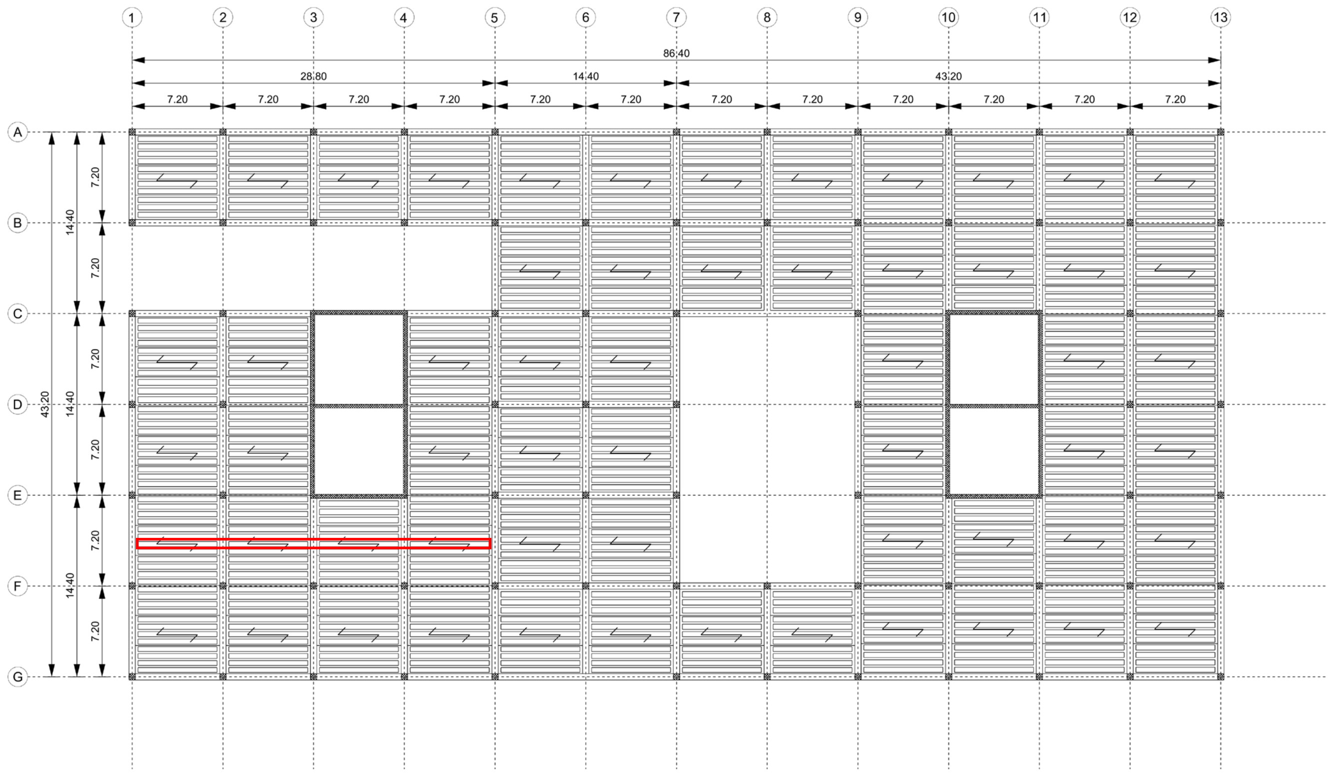
Column dimensions											
S275	h [mm]	b [mm]	r [mm]	d [mm]	t_w [mm]	c_w [mm]	t_f [mm]	c_f [mm]	ε ($\sqrt{235/f_y}$)	X' = c_w/t_w	X'' = c_f/t_f
HEB 200	200	200	18	134	9	134	15	77,5	0,92	14,9	5,2
HEB 300	300	300	27	208	11	208	19	117,5	0,92	19	6,2
HEB 400	300	400	27	198	13,5	198	24	166,3	0,92	14,7	6,9
HEB 450	300	450	27	194	14	194	26	191	0,92	13,9	7,3
HEB 550	300	550	27	188	15	188	29	240,5	0,92	12,5	8,3
HEB 600	300	600	27	186	15,5	186	30	265,3	0,92	12	8,8

Classes						
S275	Bending web class	Compression web class	Bending flanges class	Bending flanges class	Compression flanges class	Compression flanges class
	Class1: X' <72ε	Class1: X' <33ε	Class1: X'' <9ε	Class2: X'' <10ε	Class1: X'' <9ε	Class2: X'' <10ε
HEB 200	14,9 < 66,24	14,9 < 30,36	5,2 < 8,28	Useless	5,2 < 8,28	Useless
HEB 300	19 < 66,24	19 < 30,36	6,2 < 8,28	Useless	6,2 < 8,28	Useless
HEB 400	14,7 < 66,24	14,7 < 30,36	6,9 < 8,28	Useless	6,9 < 8,28	Useless
HEB 450	13,9 < 66,24	13,9 < 30,36	7,3 < 8,28	Useless	7,3 < 8,28	Useless
HEB 550	12,5 < 66,24	12,5 < 30,36	Useless	8,3 < 9,2	Useless	8,3 < 9,2
HEB 600	12 < 66,24	12 < 30,36	Useless	8,8 < 9,2	Useless	8,8 < 9,2

S275	Bending web class	Compression web class	Bending flanges class	Compression flanges class
HEB 200	Class 1	Class 1	Class 1	Class 1
HEB 300	Class 1	Class 1	Class 1	Class 1
HEB 400	Class 1	Class 1	Class 1	Class 1
HEB 450	Class 1	Class 1	Class 1	Class 1
HEB 550	Class 1	Class 1	Class 2	Class 2
HEB 600	Class 1	Class 1	Class 2	Class 2



REINFORCED CONCRETE SLAB



GROUND FLOOR

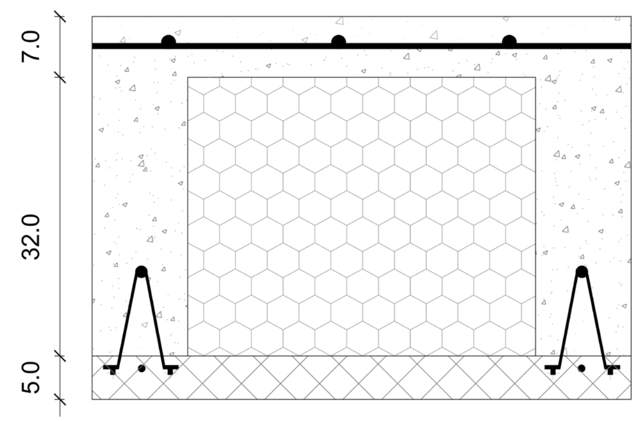
Type of load	Value	ULS	SLS
G1	$6{,}18\,\frac{kN}{m^2} \times 0{,}6 = 3{,}7\ kN/m$	$3{,}7\,\frac{kN}{m} \times 1{,}3 = 4{,}8\ kN/m$	$3{,}7\ kN/m$
G2	$2{,}5\,\frac{kN}{m^2} \times 0{,}6 = 1{,}5\ kN/m$	$1{,}5\,\frac{kN}{m} \times 1{,}5 = 2{,}25\ kN/m$	$1{,}5\ kN/m$
Q_K	$2\,\frac{kN}{m^2} \times 0{,}6 = 1{,}2\ kN/m$	$1{,}2\,\frac{kN}{m} \times 1{,}5 = 1{,}8\ kN/m$	$1{,}2\,\frac{kN}{m} \times 1{,}5 = 1{,}8\ kN/m$

Horizontal Partitions

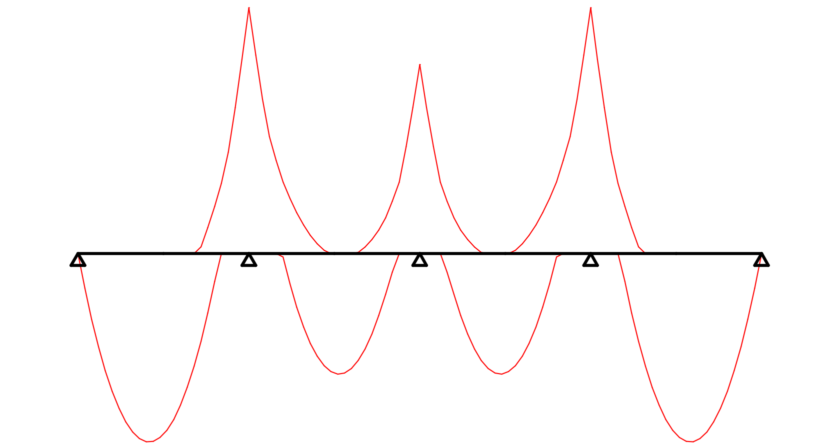
Extracted from a technical data sheet for predalles floor. The table below shows some typical slab sections.

Effective floor height (cm)	Slab in concrete thickness (cm)	Polystyrene thickness (cm)	Reinforced concrete hood thickness (cm)	Predalles weight $[kN/m^2]$
20	5	10	5	3,42
22	5	12	5	3,60
24	5	14	5	3,78
26	5	16	5	3,97
28	5	18	5	4,15
30	5	18	7	4,52
32	5	22	5	4,65
34	5	24	5	4,70
36	5	24	7	5,20
38	5	26	7	5,38
40	5	28	7	5,57
42	5	30	7	5,75
45	5	32	7	6,18

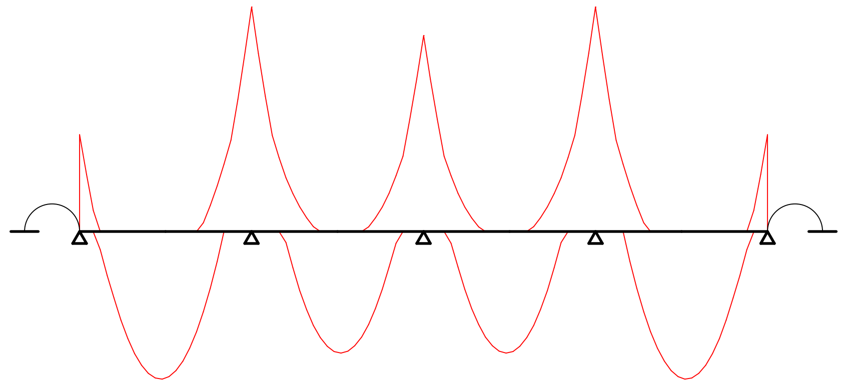
Following the pre-dimensioning shown above, for which the effective floor height is equal to 45 cm, you choose a predalles, composed of a base slab in concrete with a thickness of 5 cm, 32 cm thick polystyrene slabs and 7 cm thick reinforced concrete hood.



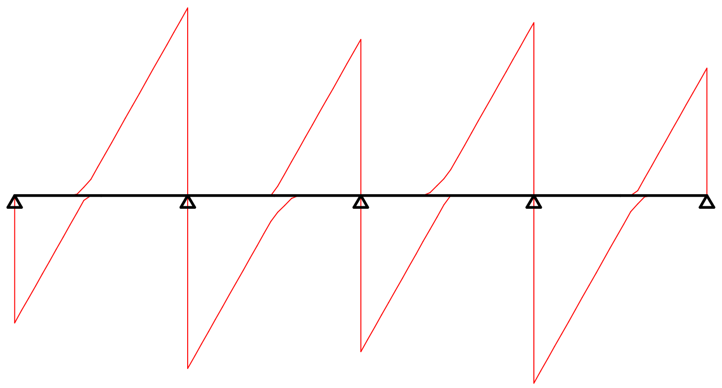
ULS LOAD COMBINATIONS



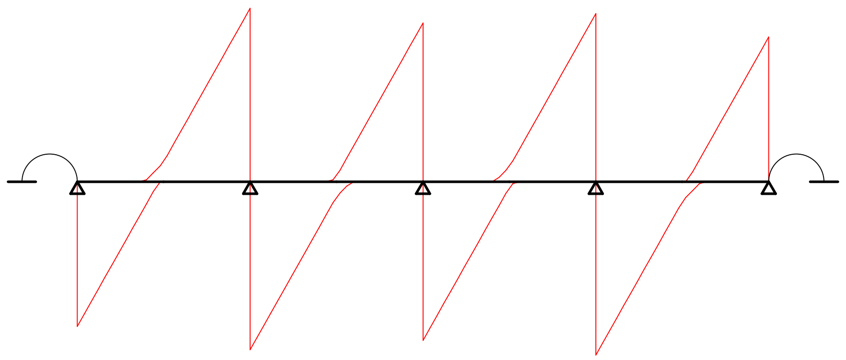
M min	0		-51,86		-39,86		-51,86		-2,530E-05
M max		39,66		25,39		25,39		39,66	
R max	26,53		75,11		65,11		75,11		26,53
R min	12,81		39,35		27,88		39,35		12,81



M min	-20,27		-46,99		-41,02		-46,99		-20,27
M max		30,90		25,47		25,47		30,90	
R max	30,12		71,06		66,08		71,06		30,12
R min	14,14		36,86		30,19		36,86		14,14

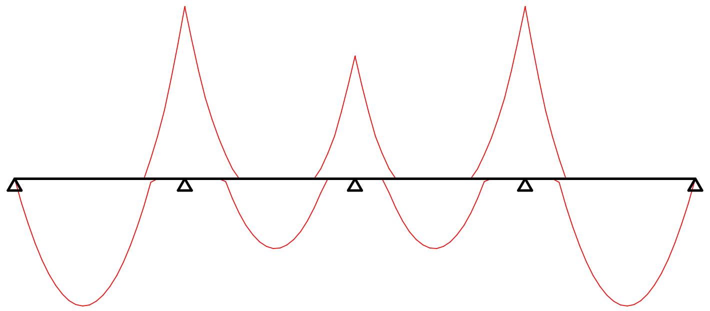


T maxs	0		-39,10		-32,56		-36,01		-26,53
T maxd	26,53		36,01		32,56		39,10		0
Luci		7,2		7,2		7,2		7,2	
G1		3,7		3,7		3,7		3,7	
G2		1,5		1,5		1,5		1,5	
Q1		1,2		1,2		1,2		1,2	
Q2		0		0		0		0	

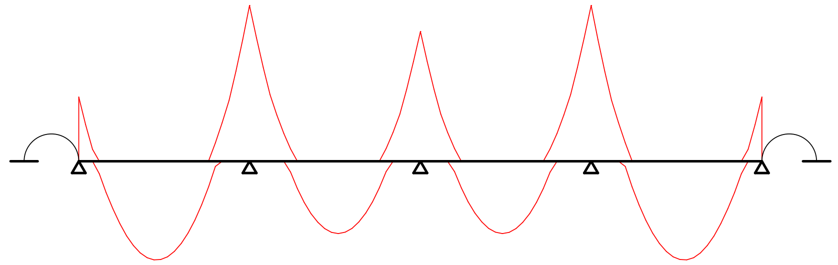


T maxs	0		-36,09		-33,04		-34,97		-30,12
T maxd	30,12		34,97		33,04		36,09		0
Luci		7,2		7,2		7,2		7,2	
G1		3,7		3,7		3,7		3,7	
G2		1,5		1,5		1,5		1,5	
Q1		1,2		1,2		1,2		1,2	
Q2		0		0		0		0	

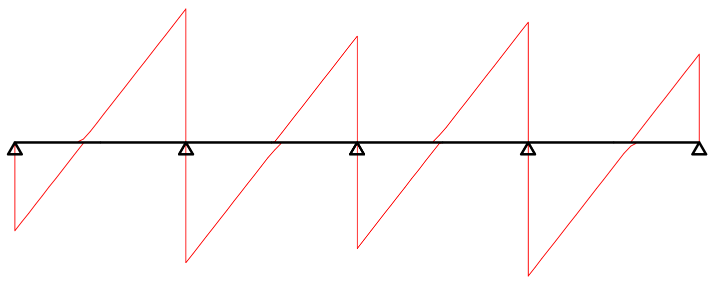
SLS LOAD COMBINATIONS



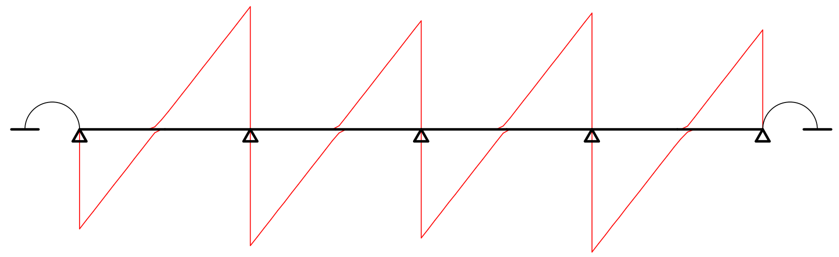
M min	0		-36,38		-25,92		-36,38		-1,771E-05
M max		26,93		14,77		14,77		26,93	
R max	18,57		53,36		44,64		53,36		18,57
R min	14,25		42,09		32,91		42,09		14,25



M min	-13,52		-32,81		-27,30		-32,81		-13,52
M max		20,80		15,25		15,25		20,80	
R max	20,97		50,38		45,79		50,38		20,97
R min	15,94		39,61		34,49		39,61		15,94



T maxs	0		-28,09		-22,32		-25,26		-18,57
T maxd	18,57		25,26		22,32		28,09		0
Luci		7,2		7,2		7,2		7,2	
G1		3,7		3,7		3,7		3,7	
G2		1,5		1,5		1,5		1,5	
Q1		1,2		1,2		1,2		1,2	
Q2		0		0		0		0	



T maxs	0		-25,87		-22,90		-24,51		-20,97
T maxd	20,97		24,51		22,90		25,87		0
Luci		7,2		7,2		7,2		7,2	
G1		3,7		3,7		3,7		3,7	
G2		1,5		1,5		1,5		1,5	
Q1		1,2		1,2		1,2		1,2	
Q2		0		0		0		0	

DIMENSIONING LONGITUDINAL BARS

	SLS	ULS
σ_s $[MPa]$	240	391
d $[mm]$	260	260

ULS

Section	M $[kNm]$	A_s $[mm^2]$ $A_s = M/(\sigma_s \times 0{,}9xd)$	Single bar surface $[mm^2]$	Ø$[mm]$	Ø$[mm]$ nominal	Nominal surfaces $[mm^2]$	N° of bars
A	-20,27	140,5	46,8	7,7	12	339,3	3
A'	39,66	274,9	68,7	9,4	12	452,4	4
B	-51,86	359,4	89,9	10,7	12	452,4	4
B'	25,47	176,5	58,8	8,7	12	339,3	3
C	-41,02	284,3	94,8	11,0	12	339,3	3
C'	25,47	176,5	58,8	8,7	12	339,3	3
D	-51,86	359,4	89,9	10,7	12	452,4	4
D'	39,66	274,9	91,6	10,8	12	339,3	3
E	-20,27	140,5	46,8	7,7	12	339,3	3

SLS

Section	M $[kNm]$	A_s $[mm^2]$ $A_s = M/(\sigma_s \times 0{,}9xd)$	Single bar surface $[mm^2]$	Ø$[mm]$	Ø$[mm]$ nominal	Nominal surfaces $[mm^2]$	N° of bars
A	-13,52	152,7	76,3	9,9	12	226,2	2
A'	26,93	304,1	101,4	11,4	12	339,3	3
B	-36,38	410,8	102,7	11,4	12	452,4	4
B'	15,25	172,2	86,1	10,5	12	226,2	2
C	-27,30	308,3	102,8	11,4	12	339,3	3
C'	15,25	172,2	86,1	10,5	12	226,2	2
D	-36,38	410,8	102,7	11,4	12	452,4	4
D'	26,93	304,1	101,4	11,4	12	339,3	3
E	-13,52	152,7	76,3	9,9	12	226,2	2

The calculation of the anchorage length of the reinforcement for each part of the system was carried out using the formula: $l_b = \frac{Ø \times \sigma_{sd}}{4 \times f_{bd}}$

Where:

$f_{bd} = \eta_1 \eta_2 \times 2{,}25 \times f_{ctd}$ adhesion force between steel and concrete

f_{ctd} = 1,35 for C30/37

η_1 = 1 if adherence is good but η_1 = 0,7 if adherence is bad

η_2 = 1 if diameter is less than 32 mm

Anchorage Length - ULS

Section	Nominal surfaces $[mm^2]$	Ø$[mm]$ nominal	N° of bars	η_1	η_2	f_{bd} $[MPa]$	l_b $[cm]$
A	339,3	12	3	1	1	3,04	38,6
A'	452,4	12	4	1	1	3,04	38,6
B	452,4	12	4	1	1	3,04	38,6
B'	339,3	12	3	1	1	3,04	38,6
C	339,3	12	3	1	1	3,04	38,6
C'	339,3	12	3	1	1	3,04	38,6
D	452,4	12	4	1	1	3,04	38,6
D'	339,3	12	3	1	1	3,04	38,6
E	339,3	12	3	1	1	3,04	38,6

Anchorage Length - SLS

Section	Nominal surfaces $[mm^2]$	Ø$[mm]$ nominal	N° of bars	η_1	η_2	f_{bd} $[MPa]$	l_b $[cm]$
A	226,2	12	2	1	1	3,04	23,7
A'	339,3	12	3	1	1	3,04	23,7
B	452,4	12	4	1	1	3,04	23,7
B'	226,2	12	2	1	1	3,04	23,7
C	339,3	12	3	1	1	3,04	23,7
C'	226,2	12	2	1	1	3,04	23,7
D	452,4	12	4	1	1	3,04	23,7
D'	339,3	12	3	1	1	3,04	23,7
E	226,2	12	2	1	1	3,04	23,7

SLS BENDING VERIFICATION

$$X = \frac{m \times A_s}{b} \times \left[-1 + \sqrt{1 + \frac{2b \times d}{m \times A_s}}\right] where\ m = 15 = E_s/E_c = 15\ homogenization\ coefficient$$

If x<h where h = 70 mm then we use these equations:

$$\sigma_c = \frac{M}{\frac{1}{2} \times b \times x(d - \frac{x}{3})}$$

$$\sigma_s = m \times \sigma_c \times \frac{(d - x)}{x}$$

If x>h where h = 70 mm then we need to calculate x using the first equation and σ_c using the second equation (in the table below the numbers highlighted with yellow are calculated using these equations):

$$\frac{1}{2} b_w x^2 + (mA_s bh - b_w h)x - mA_s d - \frac{1}{2}(b - b_w)h^2 = 0$$

$$\sigma_c = \frac{M \times x}{\frac{bh^3}{12} + bh(x - \frac{h}{2})^2 + \frac{b_w(x-h)^3}{3} + mA_s(d - x)^2}$$

$$\sigma_s = m \times \sigma_c \times \frac{(d - x)}{x}$$

Max values:

$\sigma_c \leq 0{,}6 \times f_{ck} = 0{,}6 \times 30 = 18\ MPa$ $\sigma_s \leq 0{,}8 \times f_{yk} = 0{,}8 \times 450 = 360\ MPa$

Section	b [mm]	d [mm]	b_w [mm]	h [mm]	M [$N \times mm$]	A_s [mm^2]	X [mm]	σ_c [MPa]	Check	σ_s [MPa]	Check
A	600	410	200	70	13520000	226,2	62,7	1,8	ok	153,6	ok
A'	600	410	200	70	26930000	339,3	75,3	3,1	ok	206,2	ok
B	600	410	200	70	36380000	452,4	85,7	3,7	ok	210,8	ok
B'	600	410	200	70	15250000	226,2	62,7	2,1	ok	173,3	ok
C	600	410	200	70	27300000	339,3	75,3	3,1	ok	209,1	ok
C'	600	410	200	70	15250000	226,2	62,7	2,1	ok	173,3	ok
D	600	410	200	70	36380000	452,4	85,7	3,7	ok	210,8	ok
D'	600	410	200	70	26930000	339,3	75,3	3,1	ok	206,2	ok
E	600	410	200	70	13520000	226,2	62,7	1,8	ok	153,6	ok

ULS BENDING VERIFICATION

$x = (A_s \times f_{yd})/(f_{cd} \times k_1 \times b)$ $where\ f_{cd} = 22{,}7\ MPa\ and\ k_1 = 0{,}8$

$\varepsilon_s = \varepsilon_{cu} \times \frac{(d-x)}{x}$ $where\ \varepsilon_{cu} = 0{,}0035$ $\varepsilon_s \geq 0{,}2\%$

$M_{RD} = A_s \times f_{yd} \times (d - k_2 \times x) > M_{ED}$ $where\ k_2 = 0{,}4$

Section	b [mm]	d [mm]	b_w [mm]	h [mm]	A_s [mm^2]	x [mm]	M_{RD} kN × mm	M_{ED} kN × mm	check	ε_s	%	check
A	600	410	200	70	339,3	16,26	53,5	20,27	ok	0,085	9	ok
A'	600	410	200	70	452,4	21,68	71,0	39,66	ok	0,063	6	ok
B	600	410	200	70	452,4	21,68	71,0	51,86	ok	0,063	6	ok
B'	600	410	200	70	339,3	16,26	53,5	25,47	ok	0,085	9	ok
C	600	410	200	70	339,3	16,26	53,5	41,02	ok	0,085	9	ok
C'	600	410	200	70	339,3	16,26	53,5	25,47	ok	0,085	9	ok
D	600	410	200	70	452,4	21,68	71,0	51,86	ok	0,063	6	ok
D'	600	410	200	70	339,3	16,26	53,5	39,66	ok	0,085	9	ok
E	600	410	200	70	339,3	16,26	53,5	20,27	ok	0,085	9	ok

SHEAR VERIFICATION

$k = 1 + \sqrt{\frac{200}{d}} \leq 2{,}0$ $\rho_l = \frac{A_s}{b_w \times d}$ $\gamma_c = 1{,}5$

$$V_{Rd,c} = \frac{0{,}18}{\gamma_c} \times \left(1 + \sqrt{\frac{200}{d}}\right) \times (100\rho_l f_{ck})^{\frac{1}{3}} \times b_w \times d$$

$$V_{min} = 0{,}035 \times \left(1 + \sqrt{\frac{200}{d}}\right)^{\frac{3}{2}} \times \sqrt{f}_{ck} \times b_w \times d$$

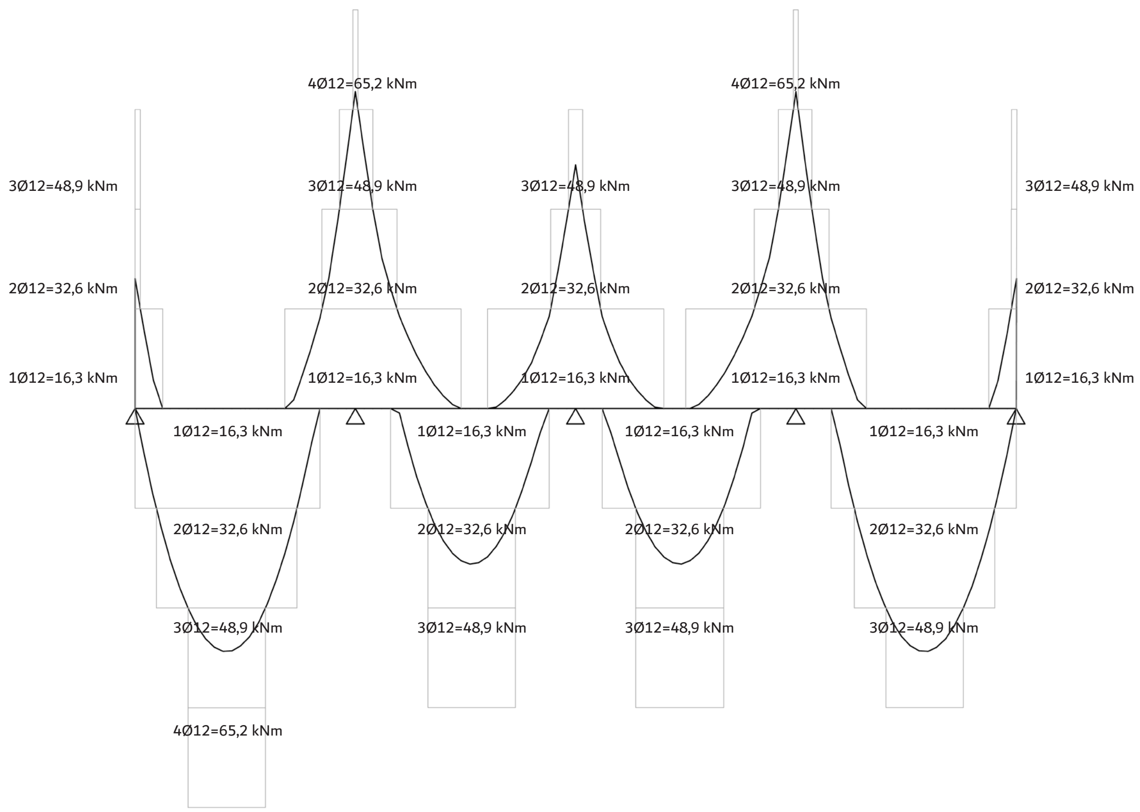
Section	k	f_{ck} [MPa]	b_w [mm]	d [mm]	ρ_l	A_s [mm^2]	V_{RD} [kN]		V_{ED} [kN]	check
Point A right	1,7	30	200	410	0,0041	339,3	38,7	34,8	30,1	ok
Point B left	1,7	30	200	410	0,0055	452,4	42,6	34,8	39,1	ok
Point B right	1,7	30	200	410	0,0055	452,4	42,6	34,8	36,0	ok
Point C left	1,7	30	200	410	0,0041	339,3	38,7	34,8	33,0	ok
Point C right	1,7	30	200	410	0,0041	339,3	38,7	34,8	33,0	ok
Point D left	1,7	30	200	410	0,0041	339,3	38,7	34,8	36,0	ok
Point D right	1,7	30	200	410	0,0055	452,4	42,6	34,8	39,1	ok
Point E left	1,7	30	200	410	0,0041	339,3	38,7	34,8	30,1	ok

CALCULATION OF RESISTING MOMENT

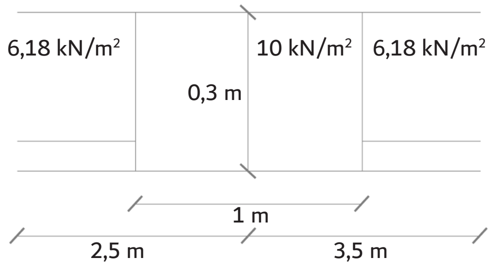
$$M = A_s \times 0{,}9 \times d \times \sigma_s$$

Section	Single bar surfaces	N° of rebars	Single resistant moment	Total moment
A	113,1	3	16,3	48,9
A'	113,1	4	16,3	65,2
B	113,1	4	16,3	65,2
B'	113,1	3	16,3	48,9
C	113,1	3	16,3	48,9
C'	113,1	3	16,3	48,9
D	113,1	4	16,3	65,2
D'	113,1	3	16,3	48,9
E	113,1	3	16,3	48,9

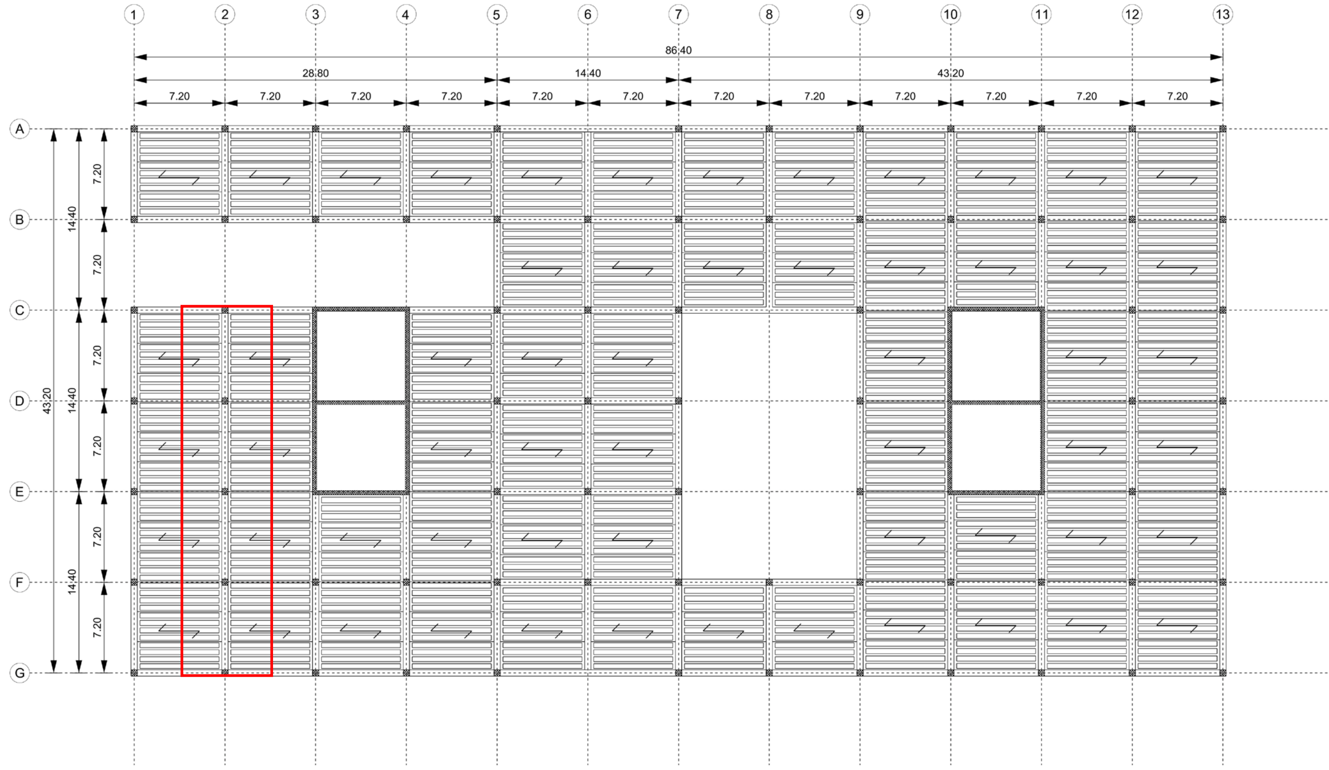
The excess rebars are there to account for what is needed to ensure passing shear validation.



REINFORCED CONCRETE BEAM

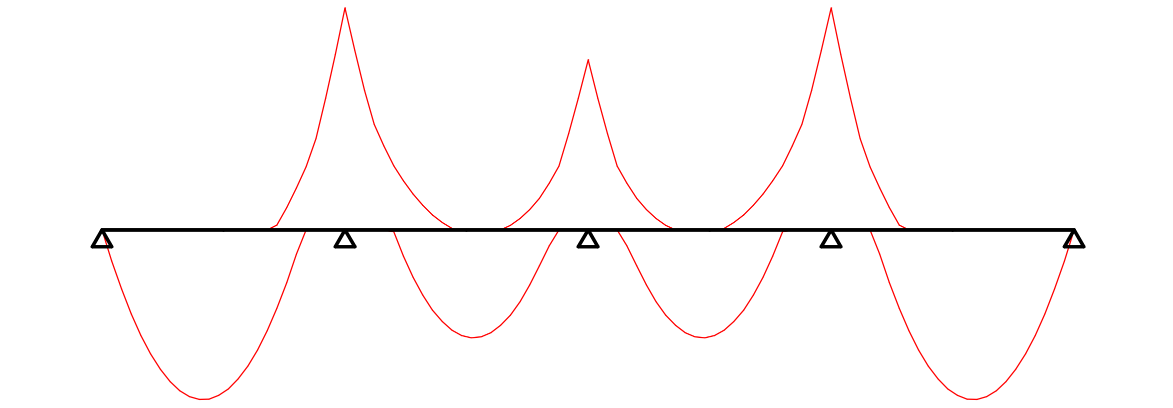


(6,18x(2+2,75)+10x1)/5,75 = 6,8 kN/m²

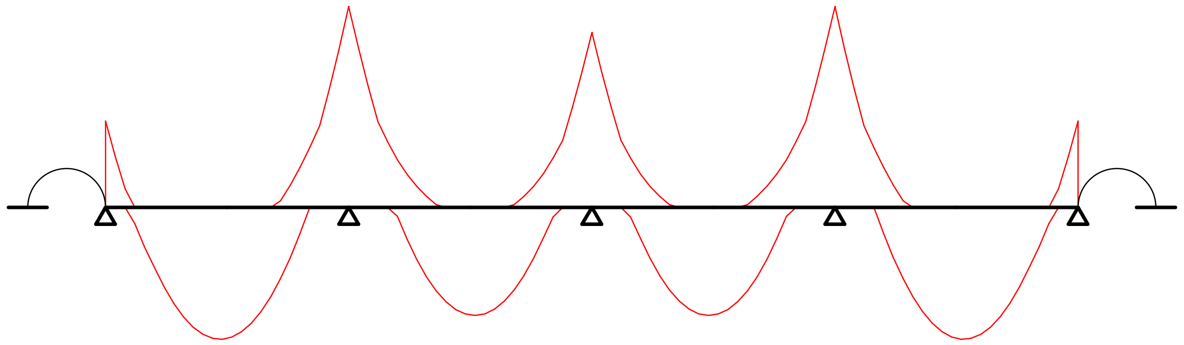


Type of load	Value	ULS	SLS
G1	$6{,}8\frac{kN}{m^2} \times 7{,}2 = 49\ kN/m$	$46\frac{kN}{m} \times 1{,}3 = 63{,}7\ kN/m$	$49\ kN/m$
G2	$2{,}5\frac{kN}{m^2} \times 7{,}2 = 18\ kN/m$	$18\frac{kN}{m} \times 1{,}5 = 27\ kN/m$	$14{,}4\ kN/m$
Q_K	$2\frac{kN}{m^2} \times 7{,}2 = 14{,}4\ kN/m$	$14{,}4\frac{kN}{m} \times 1{,}5 = 21{,}6\ kN/m$	$14{,}4\frac{kN}{m} \times 1{,}5 = 21{,}6\ kN/m$

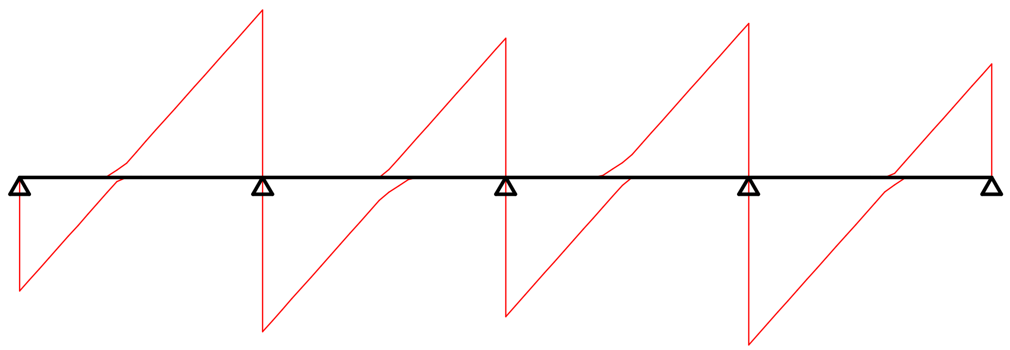
ULS LOADCOMBINATIONS



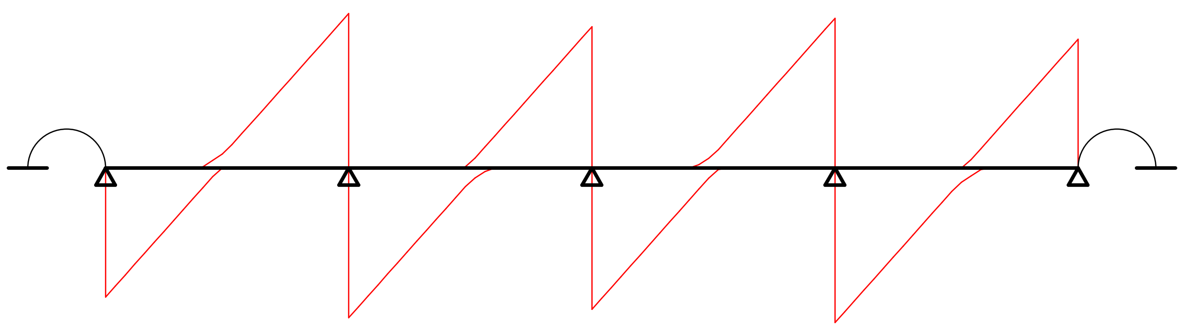
M min	0		-656,4		-503,0		-656,4		-3,203E-04
M max		501,4		319,0		319,0		501,4	
R max	335,8		951,3		823,5		951,3		335,8
R min	166,3		509,3		363,2		509,3		166,3



M min	-256,1		-594,7		-518,1		-594,7		-256,1
M max		390,5		320,4		320,4		390,5	
R max	381,1		899,9		836,0		899,9		381,1
R min	183,6		477,1		392,4		477,1		183,6

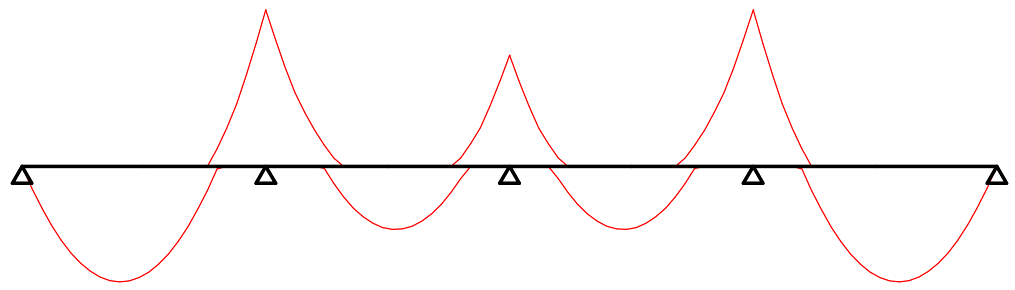


T maxs	0		-495,5		-411,7		-455,9		-335,8
T maxd	335,8		455,9		411,7		495,5		0
Luci		7,2		7,2		7,2		7,2	
G1		49		49		49		49	
G2		18		18		18		18	
Q1		14,4		14,4		14,4		14,4	
Q2		0		0		0		0	

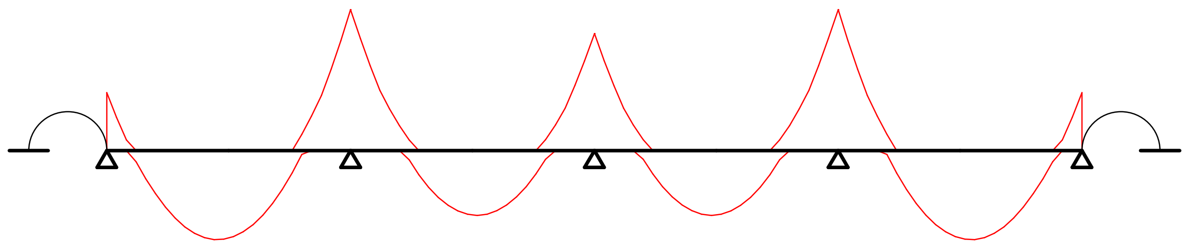


T maxs	0		-457,2		-418,0		-442,7		-381,1
T maxd	381,1		442,7		418,0		457,2		0
Luci		7,2		7,2		7,2		7,2	
G1		49		49		49		49	
G2		18		18		18		18	
Q1		14,4		14,4		14,4		14,4	
Q2		0		0		0		0	

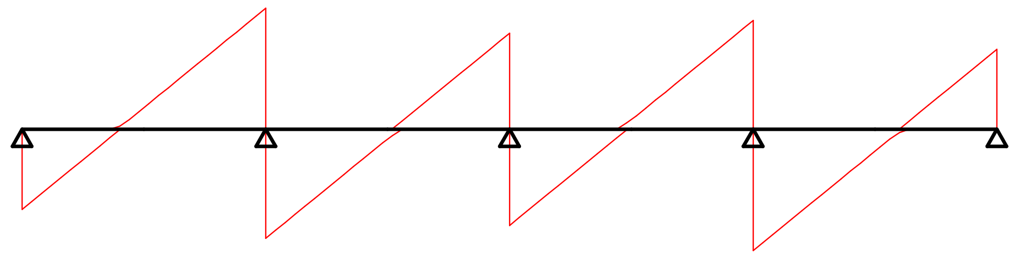
SLS LOADCOMBINATIONS



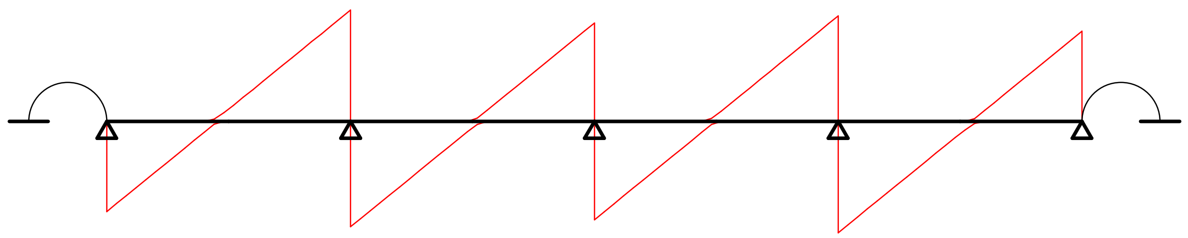
M min	0		-462,1		-328,1		-462,1		-2,249E-04
M max		341,5		185,9		185,9		341,5	
R max	235,8		678,1		566,4		678,1		235,8
R min	184,0		543,0		425,7		543,0		184,0



M min	-171,3		-416,7		-346,0		-416,7		-171,3
M max		263,7		192,2		192,2		263,7	
R max	266,3		640,3		581,4		640,3		266,3
R min	205,9		511,0		445,7		511,0		205,9



T maxs	0		-357,2		-283,2		-320,9		-235,8
T maxd	235,8		320,9		283,2		357,2		0
Luci		7,2		7,2		7,2		7,2	
G1		49		49		49		49	
G2		18		18		18		18	
Q1		14,4		14,4		14,4		14,4	
Q2		0		0		0		0	



T maxs	0		-328,9		-290,7		-311,3		-266,3
T maxd	266,3		311,3		290,7		328,9		0
Luci		7,2		7,2		7,2		7,2	
G1		49		49		49		49	
G2		18		18		18		18	
Q1		14,4		14,4		14,4		14,4	
Q2		0		0		0		0	

DIMENSIONING LONGITUDINAL BARS

	SLS	ULS
σ_s $[MPa]$	240	391
d $[mm]$	260	260

ULS

Section	M $[kNm]$	A_s $[mm^2]$ $A_s = M/(\sigma_s \times 0{,}9xd)$	Single bar surface $[mm^2]$	$Ø[mm]$	$Ø[mm]$ nominal	Nominal surfaces $[mm^2]$	N° of bars
A	-256,1	1775,0	443,8	23,8	26	2123,7	4
A'	501,4	3475,2	496,5	25,1	26	3716,5	7
B	-656,4	4549,5	505,5	25,4	26	4778,4	9
B'	320,4	2220,7	444,1	23,8	26	2654,6	5
C	-518,1	3591,0	513,0	25,6	26	3716,5	7
C'	320,4	2220,7	444,1	23,8	26	2654,6	5
D	-656,4	4549,5	505,5	25,4	26	4778,4	9
D'	501,4	3475,2	496,5	25,1	26	3716,5	7
E	-256,1	1775,0	443,8	23,8	26	2123,7	4

SLS

Section	M $[kNm]$	A_s $[mm^2]$ $A_s = M/(\sigma_s \times 0{,}9xd)$	Single bar surface $[mm^2]$	$Ø[mm]$	$Ø[mm]$ nominal	Nominal surfaces $[mm^2]$	N° of bars
A	-171,3	1187,3	395,8	22,4	26	1592,8	3
A'	341,5	2366,9	473,4	24,6	26	2654,6	5
B	-462,1	3202,8	457,5	24,1	26	3716,5	7
B'	192,2	1332,1	444,0	23,8	26	1592,8	3
C	-346,0	2398,1	479,6	22,6	26	2654,6	6
C'	192,2	1332,1	444,0	23,8	26	1592,8	3
D	-462,1	3202,8	457,5	24,1	26	3716,5	7
D'	341,5	2366,9	473,4	24,6	26	2654,6	5
E	-171,3	1187,3	395,8	22,4	26	1592,8	3

The calculation of the anchorage length of the reinforcement for each part of the system was carried out using the formula: $l_b = \frac{Ø \times \sigma_{sd}}{4 \times f_{bd}}$

Where:

$f_{bd} = \eta_1 \eta_2 \times 2{,}25 \times f_{ctd}$ adhesion force between steel and concrete

$f_{ctd} = 1{,}35$ for C30/37

$\eta_1 = 1$ if adherence is good but $\eta_1 = 0{,}7$ if adherence is bad

$\eta_2 = 1$ if diameter is less than 32 mm

Anchorage Length - ULS

Section	Nominal surfaces $[mm^2]$	$Ø[mm]$ nominal	N° of bars	η_1	η_2	f_{bd} $[MPa]$	l_b $[cm]$
A	2123,7	26	4	1	1	3,04	83,6
A'	3716,5	26	7	1	1	3,04	83,6
B	4778,4	26	9	1	1	3,04	83,6
B'	2654,6	26	5	1	1	3,04	83,6
C	3716,5	26	7	1	1	3,04	83,6
C'	2654,6	26	5	1	1	3,04	83,6
D	4778,4	26	9	1	1	3,04	83,6
D'	3716,5	26	7	1	1	3,04	83,6
E	2123,7	26	4	1	1	3,04	83,6

Anchorage Length - SLS

Section	Nominal surfaces $[mm^2]$	$Ø[mm]$ nominal	N° of bars	η_1	η_2	f_{bd} $[MPa]$	l_b $[cm]$
A	1592,8	26	3	1	1	3,04	51,3
A'	2654,6	26	5	1	1	3,04	51,3
B	3716,5	26	7	1	1	3,04	51,3
B'	1592,8	26	3	1	1	3,04	51,3
C	2654,6	26	6	1	1	3,04	51,3
C'	1592,8	26	3	1	1	3,04	51,3
D	3716,5	26	7	1	1	3,04	51,3
D'	2654,6	26	5	1	1	3,04	51,3
E	1592,8	26	3	1	1	3,04	51,3

SLS BENDING VERIFICATION

Max values:

$\sigma_c \leq 0,6 \times f_{ck} = 0,6 \times 40 = 24\ MPa$ $\quad \sigma_s \leq 0,8 \times f_{yk} = 0,8 \times 450 = 360\ MPa$

Section	b $[mm]$	d $[mm]$	h $[mm]$	M $[N \times mm]$	A_s $[mm^2]$	X $[mm]$	σ_c $[MPa]$	Check	σ_s $[MPa]$	Check
A	1000	410	450	171,3	1592,8	118,1	7,8	ok	290,2	ok
A'	1000	410	450	341,5	2654,6	145,2	13,0	ok	355,8	ok
B	1000	410	450	462,1	3716,5	165,2	15,8	ok	350,3	ok
B'	1000	410	450	192,2	1592,8	118,1	8,8	ok	325,6	ok
C	1000	410	450	346,0	2654,6	155,8	12,4	ok	303,4	ok
C'	1000	410	450	192,2	1592,8	118,1	8,8	ok	325,6	ok
D	1000	410	450	462,1	3716,5	165,2	15,8	ok	350,3	ok
D'	1000	410	450	341,5	2654,6	145,2	13,0	ok	355,8	ok
E	1000	410	450	171,3	1592,8	118,1	7,8	ok	290,2	ok

ULS BENDING VERIFICATION

$x = (A_s \times f_{yd})/(f_{cd} \times k_1 \times b) \quad where\ f_{cd} = 17\ MPa\ and\ k_1 = 0,8$

$\varepsilon_s = \varepsilon_{cu} \times \frac{(d-x)}{x} \quad where\ \varepsilon_{cu} = 0,0035 \quad \varepsilon_s \geq 0,2\%$

$M_{RD} = A_s \times f_{yd} \times (d - k_2 \times x) > M_{ED} \quad where\ k_2 = 0,4$

Section	b $[mm]$	d $[mm]$	h $[mm]$	A_s $[mm^2]$	x $[mm]$	M_{RD} kN × mm	M_{ED} kN × mm	check	ε_s	%	check
A	1000	410	450	2123,7	61,06	320,2	256,1	ok	0,020	2	ok
A'	1000	410	450	3716,5	106,85	533,7	501,4	ok	0,010	1	ok
B	1000	410	450	4778,4	137,38	663,4	656,4	ok	0,007	1	ok
B'	1000	410	450	2654,6	76,32	393,9	320,4	ok	0,015	2	ok
C	1000	410	450	3716,5	106,85	533,7	518,1	ok	0,010	1	ok
C'	1000	410	450	2654,6	76,32	393,9	320,4	ok	0,015	2	ok
D	1000	410	450	4778,4	137,38	663,4	656,4	ok	0,007	1	ok
D'	1000	410	450	3716,5	106,85	533,7	501,4	ok	0,010	1	ok
E	1000	410	450	2123,7	61,06	320,2	256,1	ok	0,020	2	ok

SHEAR VERIFICATION

$k = 1 + \sqrt{\frac{200}{d}} \leq 2,0 \qquad \rho_l = \frac{A_s}{b_w \times d} \qquad \gamma_c = 1,5$

$V_{min} = 0,035 \times \left(1 + \sqrt{\frac{200}{d}}\right)^{\frac{3}{2}} \times \sqrt{f_{ck}} \times b_w \times d \qquad V_{Rd,c} = \frac{0,18}{\gamma_c} \times \left(1 + \sqrt{\frac{200}{d}}\right) \times \left(100\rho_l f_{ck}\right)^{\frac{1}{3}} \times b_w \times d$

Section	k	f_{ck} $[MPa]$	b_w $[mm]$	d $[mm]$	ρ_l	A_s $[mm^2]$	V_{RD} $[kN]$		V_{ED} $[kN]$	check
Point A right	1,7	30	1000	410	0,0052	2123,7	208,5	174	381,1	no
Point B left	1,7	30	1000	410	0,0091	3716,5	251,3	174	495,5	no
Point B right	1,7	30	1000	410	0,0117	4778,4	273,2	174	455,9	no
Point C left	1,7	30	1000	410	0,0065	2654,6	224,6	174	418,0	no
Point C right	1,7	30	1000	410	0,0091	3716,5	251,3	174	418,0	no
Point D left	1,7	30	1000	410	0,0065	2654,6	224,6	174	455,9	no
Point D right	1,7	30	1000	410	0,0117	4778,4	273,2	174	495,5	no
Point E left	1,7	30	1000	410	0,0091	3716,5	251,3	174	381,1	no

In order to make these sections capable of withstanding the design stresses V_{Ed}, it will therefore be necessary to insert shear resistant transversal reinforcement.

Assuming to insert ϕ8 brackets with four arms A_{sw}=2.01 cm2 , we want to determine the pitch s of the stirrups:

$s = \frac{A_{sw} \times f_{yd}}{b \times \omega_{sw} \times f_{cd}} \qquad t_{Ed} = \frac{V_{Ed}}{b \times d^* \times 0,85 \times f_{cd}} \qquad A_{sw} = 201\ mm^2: Area\ with\ 4\emptyset 8$

$\omega_{sw} = \frac{A_{sw} \times f_{yd}}{b \times s \times f_{cd}} = \frac{t_{Ed}}{cot\theta}$ with $cot\theta = 2,5$ (precautionary value required by law)

Section	A_{sw} $[mm^2]$	$d^*[mm]$	t_{Ed}	ω_{sw}	s $[mm]$
Point A right	200,96	369	0,061	0,024	192,6
Point B left	200,96	369	0,079	0,0316	146,3
Point B right	200,96	369	0,073	0,029	159,4
Point C left	200,96	369	0,067	0,027	171,2
Point C right	200,96	369	0,067	0,027	171,2
Point D left	200,96	369	0,073	0,029	159,4
Point D right	200,96	369	0,079	0,0316	146,3
Point E left	200,96	369	0,061	0,024	192,6

d $[cm]$	b_w $[cm]$	A_{st} $[mm^2/m]$	$n_{st} = A_{st}/201$ $[mm^2/m]$	$s=100/n_{st}$ $[cm]$	S=0,8d $[cm]$	S=100/3 $[cm]$
41,0	100	1500	7,46	13,4	32,8	33,33

SHEAR VERIFICATION

The shear check is now carried out with the transversal reinforcement assumed above:

$V_{Ed} < \min\left(V_{Rsd}, V_{Rcd}\right)$

With:

$$V_{Rsd} = d^* \times \frac{A_{sw}}{s} \times f_{yd} \times (cot\alpha + cot\theta) \times sin\alpha$$

$$V_{Rcd} = d^* \times b_w \times \alpha_c \times 0{,}5 \times f_{cd} \times \frac{cot\alpha + cot\theta}{1 + cot^2\theta}$$

Where $\alpha_c = 1$

$\alpha = 90°$ angle of inclination of the transverse reinforcement

$cot\theta = \sqrt{\frac{0{,}5 \times \alpha_c}{\omega_{sw}} - 1}$ $\quad 1 \le cot\theta \le 2{,}5$ "in case cot θ exceeds the extreme values to the right or left, then it will have to be considered equal to nearest extreme value."

$$\omega_{sw} = \frac{A_{sw} \times f_{yd}}{b \times s \times f_{cd}}$$

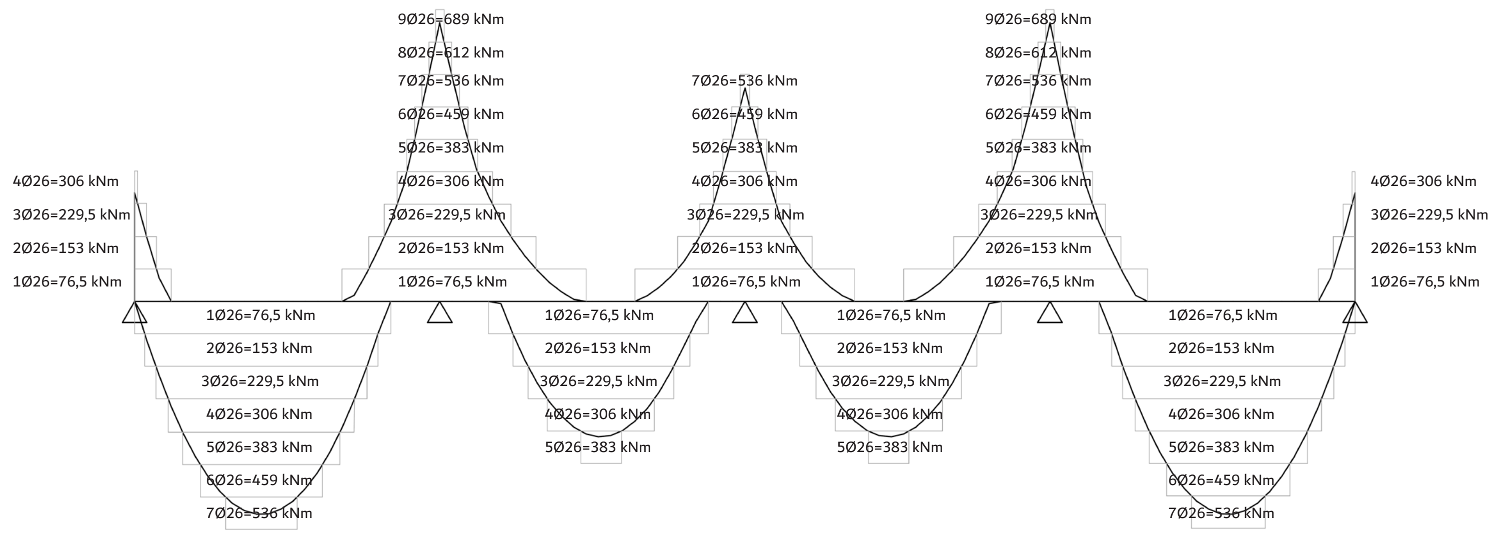
A_{sw} $[cm^2]$	4Ø8	2,0096
S $[cm]$	10	

Section	ω_{sw}	$cot\theta$	V_{Rsd} $[kN]$	V_{Rcd} $[kN]$	V_{min} $[kN]$	V_{Ed} $[kN]$	$V_{Ed} < V_{min}$
Point A right	0,046	2,50	725,1	1081,5	725,1	381,1	ok
Point B left	0,046	2,50	725,1	1081,5	725,1	495,5	ok
Point B right	0,046	2,50	725,1	1081,5	725,1	455,9	ok
Point C left	0,046	2,50	725,1	1081,5	725,1	418,0	ok
Point C right	0,046	2,50	725,1	1081,5	725,1	418,0	ok
Point D left	0,046	2,50	725,1	1081,5	725,1	455,9	ok
Point D right	0,046	2,50	725,1	1081,5	725,1	495,5	ok
Point E left	0,046	2,50	725,1	1081,5	725,1	381,1	ok

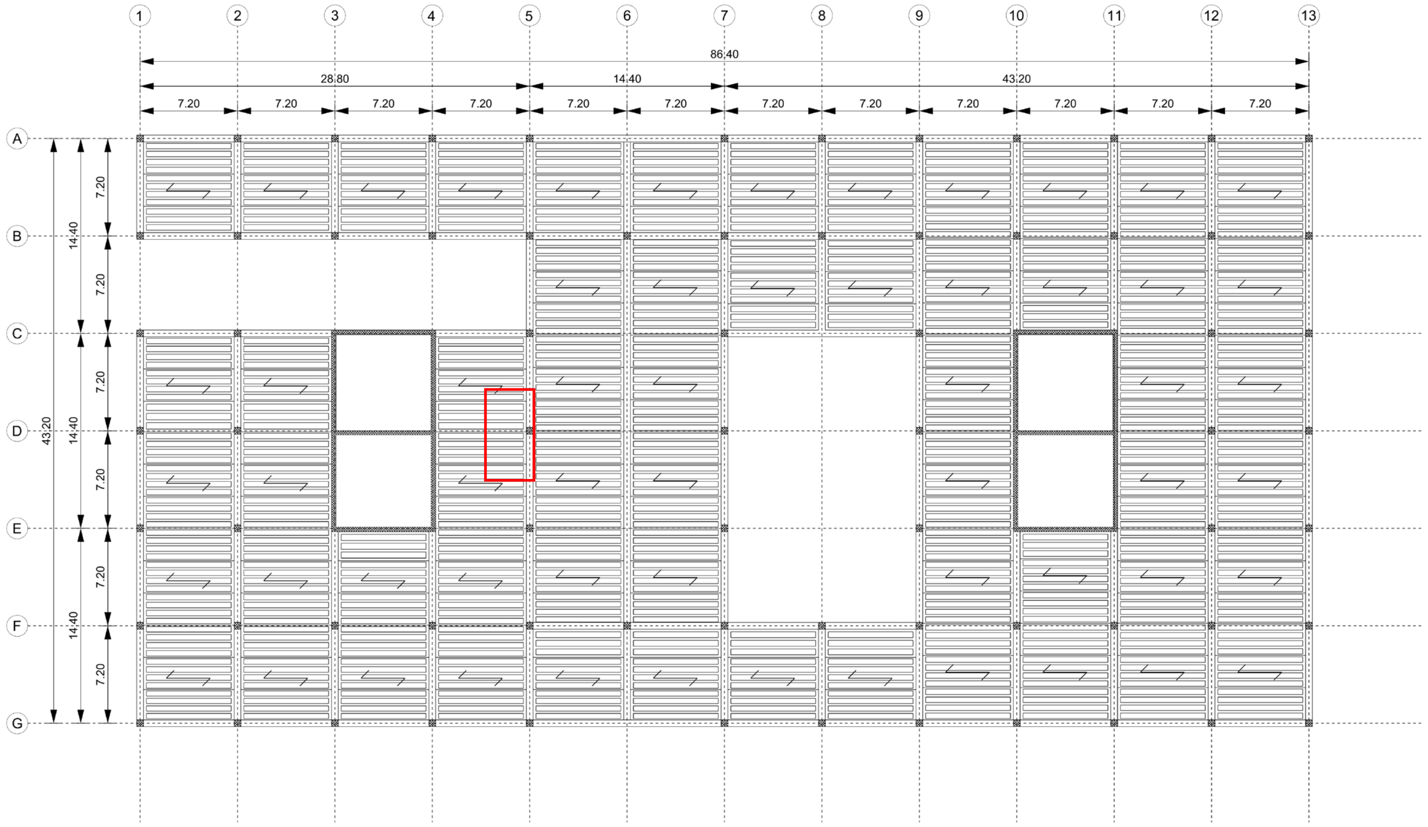
CALCULATION OF RESISTING MOMENT

$$M = A_s \times 0{,}9 \times d \times \sigma_s$$

Section	Single bar surfaces	N° of rebars	Single resistant moment	Total moment
A	530,93	4	76,5	306
A'	530,93	7	76,5	536
B	530,93	9	76,5	689
B'	530,93	5	76,5	383
C	530,93	7	76,5	536
C'	530,93	5	76,5	383
D	530,93	9	76,5	689
D'	530,93	7	76,5	536
E	530,93	4	76,5	306



REINFORCED CONCRETE COLUMN



The area of influence of the column is obtained by taking half of the floor on each side of the column. The value corresponding to this surface will then be multiplied by a correction coefficient equal to 1.44, which takes into account any behavior given by the hyperstatic nature of the structure.

A_{inf}=7,2×3,6=25,92 m²

F_k load from upper floors

$A_{co} = \frac{N_{Ed}}{f'_{cd}}$ *where* $f'_{cd} = 0{,}8 \times f_{cd}$

A_{so} minimum area of steel rebars. Formula: $A_{so} = \frac{0{,}1 \times N_{Ed}}{f'_{cd}}$ at least 1% of A_{co}

A_s (chosen area of steel), $A_s \geq A_{so}$

A_c (chosen area of concrete) = $a \times b$, $A_c \geq$

a & b are the column's dimensions

	F_k $[kN]$	N_{Ed} $[kN]$	$A_{c,o}$ $[cm^2]$	a $[cm]$	b $[cm]$	A_c $[cm^2]$	A_{so} $[mm^2]$	n	ϕ	A_s $[mm^2]$
1st floor	2428	2428	1785	70	70	4900	4900	10	26	5306
Ground floor	442,3	2870	2111	75	75	5625	5625	11	26	5837
Underground floor	442,3	3313	2436	80	80	6400	6400	12	26	6367

SLS Verification								
	N $[kN]$	$A_i = A_c + \alpha_{Ec} \times A_s$ $[cm^2]$	$\sigma_c = N/A_i$ $[MPa]$	$\sigma_c * = f_{ck} \times 0{,}45$ $[MPa]$	Result	$\sigma_s = \alpha_E \times \sigma_c$ $[MPa]$	$\sigma_s *$ $[MPa]$	Result
1st floor	2428	5695	4,26	13,5	ok	63,9	240	ok
Ground floor	2870	6500	4,42	13,5	ok	66,3	240	ok
Underground floor	3313	7355	4,50	13,5	ok	67,5	240	ok

Where:

$A_i = A_c + \alpha_{Ec} \times A_s$ is the ideal area of the columns with homogenization factor $\alpha_{Ec} = 15$ for elastic calculation

$\sigma_c = N/A_i$ tension in columns

ULS Verification							
	f_{cd}	A_c $[cm^2]$	f_{yd}	A_s $[mm^2]$	N_{rd} $[kN]$	N_{Ed} $[kN]$	Result
1st floor	17	4900	391	5306	9155	2428	ok
Ground floor	17	5625	391	5837	10410	2870	ok
Underground floor	17	6400	391	6367	11738	3313	ok

$N_{Rd} = f'_{cd} \times A_{ir} = 0{,}85 \times A_c \times f_{cd} + A_s \times f_{yd} = total\ resistance\ value$

$\frac{N_{Rd}}{N_k} < 1$

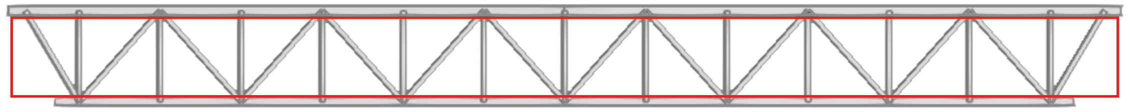
Stirrups design						
	H_{cr} $[mm]$	ϕ_{sr} $[mm]$	S_{max} $[mm]$	$S_{cr,max}$ $[mm]$	S_{eff} $[mm]$	$S_{cr,eff}$ $[mm]$
Formula	max [450, H/6]	max [6,ϕ/4]	min [12ϕ,250]	min [b/2, 175, 8ϕ, 24ϕ$_{sr}$]		
1st floor	583	6,5	250	156	20	10
Ground floor	667	6,5	250	156	20	10
Underground floor	583	6,5	250	156	20	10

Where stirrups minimum diameter shall be ϕ_{st} = 8 mm (A_{st} = 50,24 mm²).

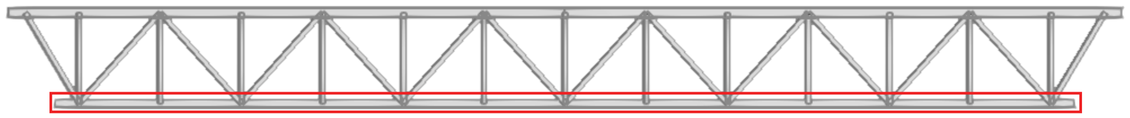
TRUSSES COURTYARD

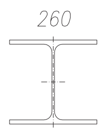
Main loads:

Roof load: 4 kN/m²
Other (maintainence etc.)**: 1 kN/m²**

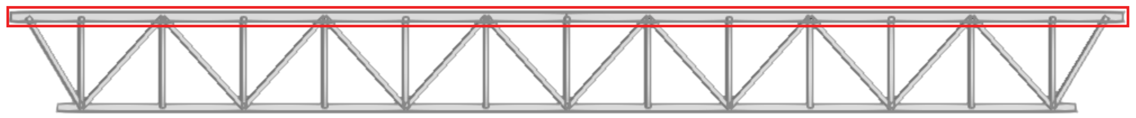


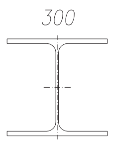
Diagonal Beam and vertical: VKR140
Material: S275





Bottom Beam: HEA 260
Material: S275



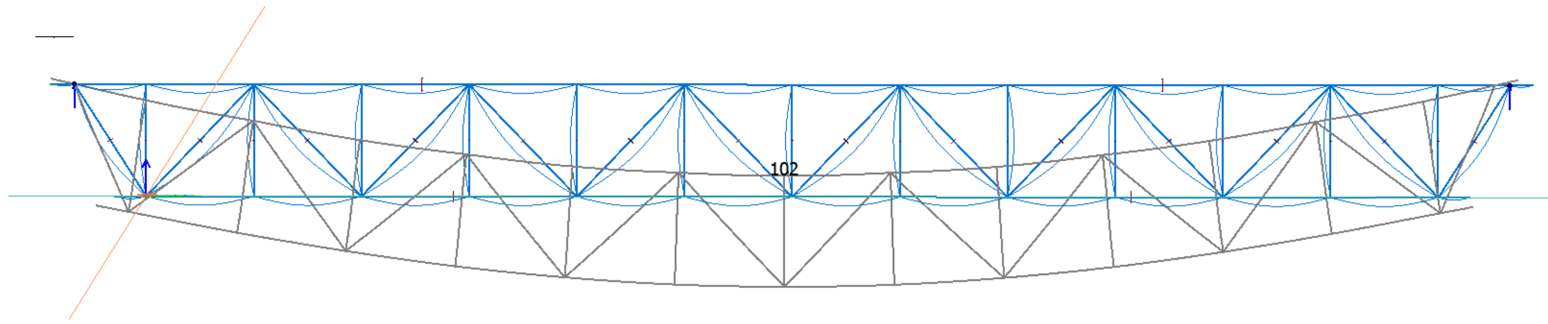


Top Beam: HEA 300
Material: S275

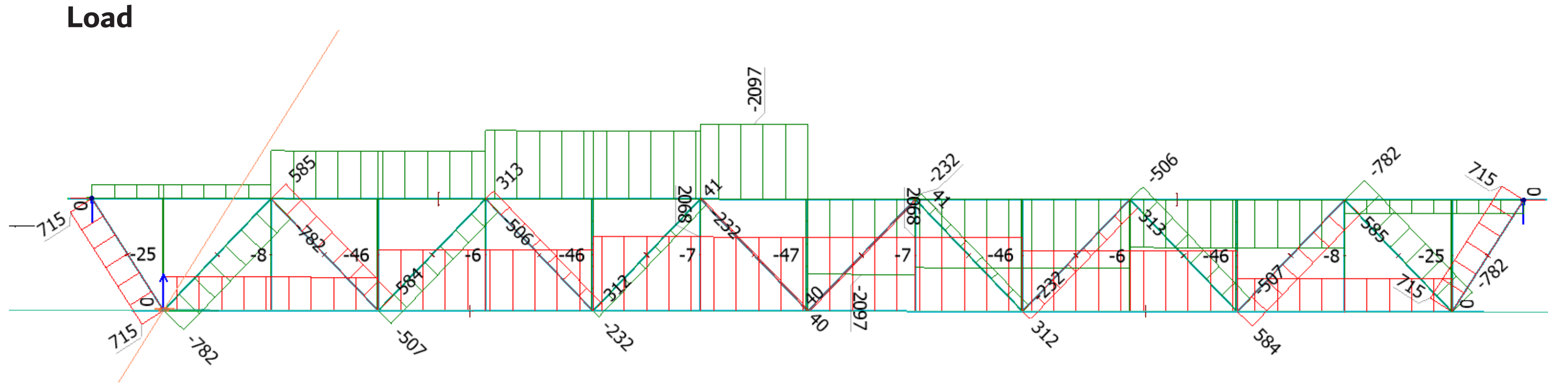
Deflection

Limit deflection: 28800/250 = 115

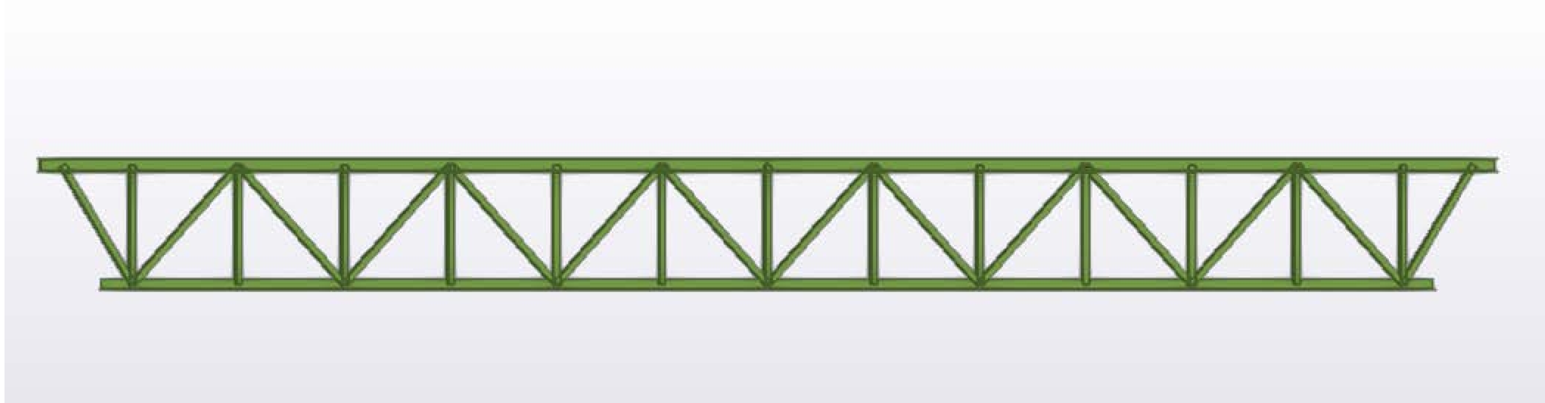
From our calculation we get the deflection = 102 which is under our limit



Load



Final Truss Design



LIST OF FIGURES