SCIENCE ISLAND

INTERNATIONAL DESIGN CONTEST

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POLITECNICO MILANO 1863

POLO TERRITORIALE DI LECCO

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KAUNAS, LITHUANIA

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|ABSTRACT|

Formerly known as an industrial centre and interwar capital of Lithuania, Kaunas has reinvented itself as a diverse academic and business-focused city attuned to innovation and economic and cultural growth.

Science Island, an International design competition from 2016, was intended to further develop Kaunas' profile as one of the Baltic's key knowledge and cultural hubs and as an increasingly popular visitor destination. The contest sought design concepts for a National Science and Innovation Centre, which will focus on 3 interconnecting themes: Human, Machine and Nature, along with an urban integration plan for Nemunas Island.

In the form of "Science Island", the competition challenges us to foster and advance the development of science and culture in Kaunas, and in Lithuania as a whole.

The Nemunas island, with river views, green and open space, and close proximity to the popular visitor areas was chosen for the planned Science centre. The building and the master plan spans over an area of 13,000 square meters. To have a keystone value on the cultural image of the city, building was expected to have a landmark value.

During the 7 months of design process, comprehensive studies were made. Beginning with urban analysis, followed by site visit, conceptual and technical studies including energy and daylight analysis, structural designing and detailed architectural design was carried out.

These multi-disciplinary studies were a result of an extensive research and integrated technical studies, in parallel with spatial and technical aspects. Memory of the location has been retained in the concepts, studied with physical models in urban and building scales. Fundamental concepts of science and inspirations from classical monuments were effectively applied, which evolved into a refined design fitting the context.

As a result of this strict concept-technique related approach, challenging envelope geometry over conventional structural logic was achieved. Cooperation between concept, life, functions, and technical solutions were achieved by developing a design philosophy which is explained deeply over the concept of "Journey".

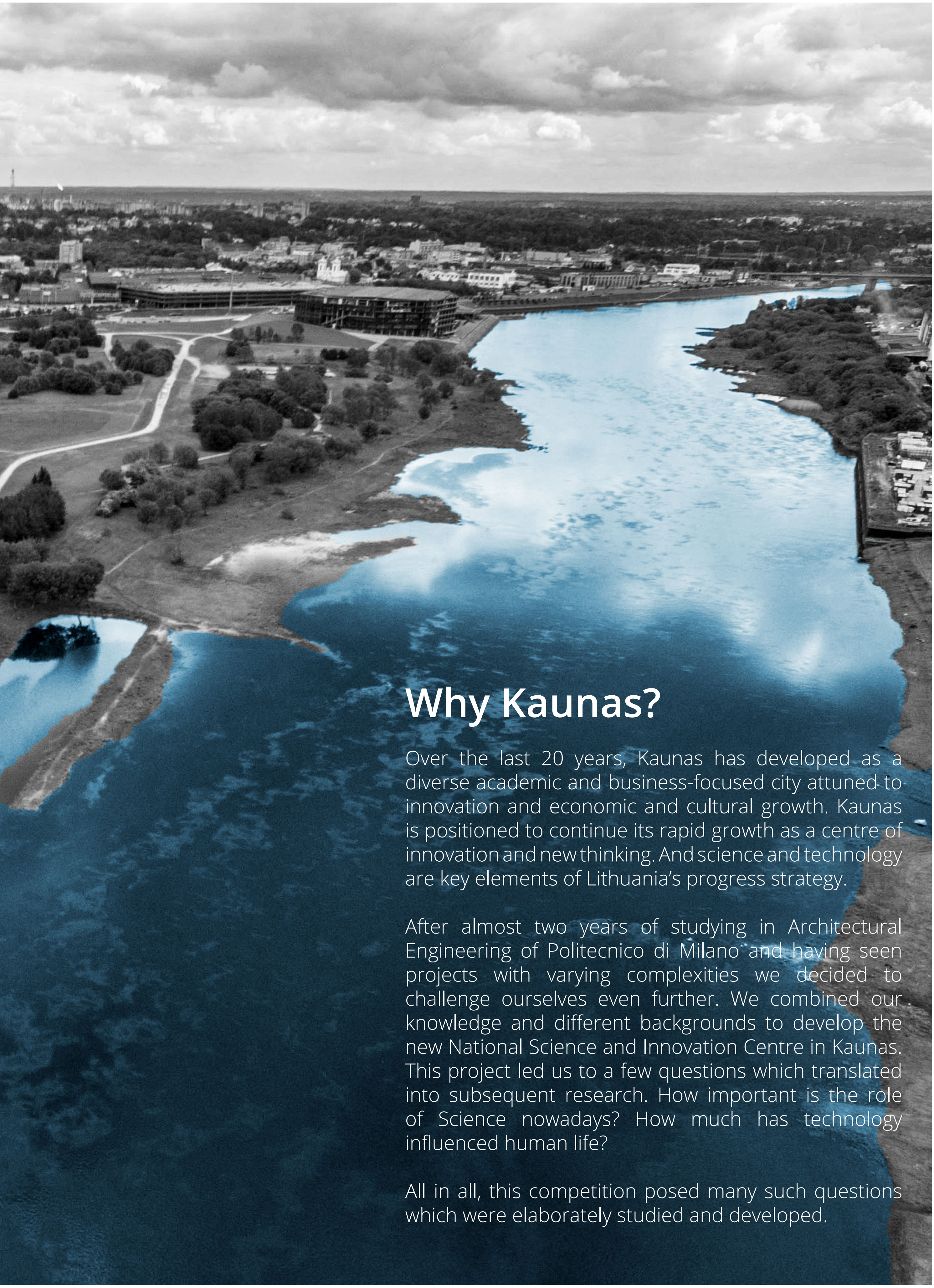
As a result, beginning with the common origin of Human, Machine and Nature, simple masses have evolved to a building which shares the DNA of the context with the potential of strong landmark in the cultural image of Kaunas.

|CONTENTS|

INTRODUCTION

SCIENCE ISLAND

The rationale of the new National Science and Innovation Centre – Science Island aim is to inspire new audiences, young and old: fostering an enduring relationship with science and innovation, communicating knowledge and expanding understanding through hands-on activities and play.



Why Kaunas?

Over the last 20 years, Kaunas has developed as a diverse academic and business-focused city attuned to innovation and economic and cultural growth. Kaunas is positioned to continue its rapid growth as a centre of innovation and new thinking. And science and technology are key elements of Lithuania's progress strategy.

After almost two years of studying in Architectural Engineering of Politecnico di Milano and having seen projects with varying complexities we decided to challenge ourselves even further. We combined our knowledge and different backgrounds to develop the new National Science and Innovation Centre in Kaunas. This project led us to a few questions which translated into subsequent research. How important is the role of Science nowadays? How much has technology influenced human life?

All in all, this competition posed many such questions which were elaborately studied and developed.

"The architectural quality of the new Centre is a key project value, given Kaunas' architectural heritage"

The Science Island attraction is intended to further develop Kaunas' profile as one of the Baltic's key knowledge and cultural hubs and as an increasingly popular visitor destination, creating a landmark for the city.

Science Island's perspective on three interrelated scientific themes, the Human, the Machine and Ecology/Nature, will be framed by the future: the most likely outcomes for the world, alternative possible scenarios, and the extent to which each of us is part of that unfolding process. The project's overall aim is to foster and advance the development of science and culture in Kaunas, and in Lithuania as a whole.

An initial feasibility study identified the 33 hectare Nemunas Island in Kaunas – with its central, accessible location, river views and green, open space – as the site for the planned National Science and Innovation Centre. The Island, which is owned by Kaunas City Municipality, is currently used as an outdoor recreational and leisure space within the city, and is also home to Žalgiris Arena, Lithuania's largest sports and entertainment arena.

The new Centre can be located anywhere within Nemunas Island, with a total site area of up to 13,000 square metres, which includes 9,000 square metres for the Science and Innovation Centre building.

The architectural quality of the new Centre is a key project value, given Kaunas' architectural heritage.

The new Centre will include a mixture of permanent and temporary galleries, a virtual planetarium, an 'Experimentorium', research laboratories, a cafeteria, and a flexible events space. It is foreseen that circa 4,000 square metres of outdoor space around the Centre on the Island could be used as external exhibition space, creating an attractive green space in the city. Visitors to Science Island are anticipated to number circa 300,000 per year.

As one of the key aims of the Centre is to promote visitors' active engagement with renewable energy, the jury would give special attention to the functionality, innovation and energy-efficiency of the design; this should achieve the best use of natural and renewable resources.

| MISSION |

The national Science and innovation center's mission is to:

1
Promote creative and innovative thinking – contributing to the increase of critical scientific thinking abilities of the citizens of Kaunas.

2
Develop Kaunas as the scientific and cultural capital of Lithuania.

3
Match and exceed other regional popular Science Centres in content and reputation.

4
Lead in improving environmental awareness.

The purpose of the design cintest was to:

1
Develop an urban integration plan that identifies a suitable area on Nemunas Island for the new National Science and Innovation Centre and establishes a compelling setting and identity for the project;

2
Create a concept design for the new National Science and Innovation Centre.

|PROJECT AIMS|

The design of the new building should:

1
Be an exemplar of sustainability;

2
Sit comfortably within the Island and landscaped setting, retaining the Island's panoramic views;

3
Be an original and distinctive architectural composition which could become a symbol of the Island;

4
Fit naturally within the urban grain of Kaunas, located in this strategic position within the city;

5
Enhance the image of Kaunas, becoming a part of the city's identity;

6
Create harmony with the existing Arena, and develop a compositional relationship with the Naujamiestis and Aleksotas areas;

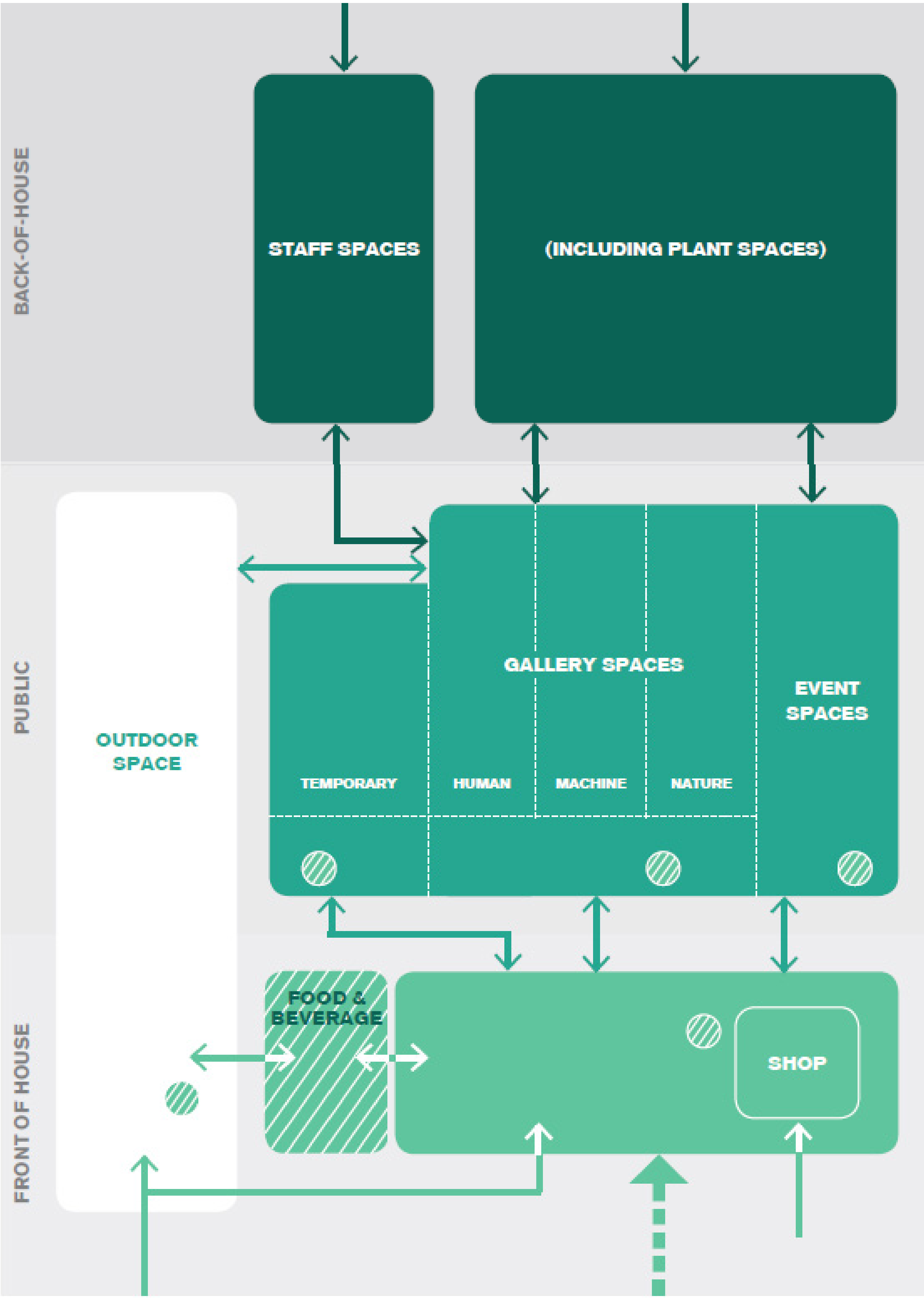
7
Consider routes through the Island to a potential new bridge link to the proposed concert and convention centre located on the south bank of the Nemunas River in Aleksotas.

|SCHEDULE|

The Science and Innovation Centre complex will be up to **13,000** square metres in size. The building is anticipated to be **9,000** square metres, with an additional **4,000** square metres for external space associated with the Centre, including for public access and threshold, visitor amenities and outdoor exhibits.

The proposed building footprint for the Science and Innovation Centre is anticipated at 5,000 square metres with a maximum permissible height above typical island surface level of 25 metres.

The breakdown for the building program requirements of the project is provided in the area schedule below and described in the subsequent pen portraits of each space.


BACK-OF-HOUSE
PUBLIC
FRONT OF HOUSE
STAFF SPACES
(INCLUDING PLANT SPACES)
OUTDOOR SPACE
GALLERY SPACES
EVENT SPACES
TEMPORARY
HUMAN
MACHINE
NATURE
FOOD & BEVERAGE
SHOP

SPACE TYPE		SPACE TYPE AREA (M²)	BREAKDOWN	BREAKDOWN AREA (M²)
FRONT OF HOUSE		950	Entrance Hall (including orientation space)	600
			Information Centre/Reception/Ticketing	30
			Security	20
			Cloakrooms	200
			Sanitation facilities	85
			First Aid Room	15
VISITOR AMENITIES	RETAIL SPACE	150	Science Centre souvenir shop	110
			Shop office	10
			Shop storage	30
	FOOD & BEVERAGE	500	Cafeteria	265
			Refreshment stations	20
			Sanitation facilities	65
			Main Kitchen	120
			Kitchen storage	30
TEMPORARY GALLERIES		700	Introductory Space	100
			Main Space	600
PERMANENT GALLERIES		2,450	Introductory/Show Space	200
			Gallery 1 - 'Human'	750
			Gallery 2 - 'Machine'	750
			Gallery 3 - 'Nature/Ecology'	750
EVENT SPACES		1,000	'Black Box' flexible space	250
			'Virtual' Planetarium	300
			Research Laboratories	250
			Experimentorium	200
BACK-OF-HOUSE	STAFF SPACES	770	Meeting Rooms	65
			Copy/Resource Room	15
			Local archive storage	20
			Coffee/Staff Room	25
			Sanitation facilities	25
			Hot-desking/break-out space	50
			Lunch Room	30
			Staff and service entrance	40
	BACK-OF-HOUSE	1,230	Security	30
			Loading Bay	125
			Delivery, packing, crate storage	150
			Exhibition, preparation space and storage	350
			Workshops	250
			Workshop storage	50
			Workshop office	25
			Furniture storage	50
			Cleaner's room(s)	25
			Refuse room and recycling room	35
			IT Room	100
	PLANT SPACES	1,250	Plant rooms, ducts, etc.	1,250
TOTAL - MAIN BUILDING		**9,000**		**9,000**
OTHER		4,000	External exhibition and visitor amenity space	4,000
TOTAL - OVERALL (inc. landscape)		**13,000**		**13,000**

CONTEXT

"Science and technology are key elements of Lithuania's Progress Strategy"

Geographically the largest of the Baltic States, Lithuania is located on the eastern coast of the Baltic Sea and borders Latvia, Belarus, Poland and Russia (Kaliningrad). Throughout its history, it has established itself as an independent state.

The nation has the most diverse economies of the Baltic States and one of the fastest growing in the European Union, with an average real GDP growth of 2.5% over the past three years. It is rated first in the EU for ease of starting a business, and with incentives such as a 15% flat rate of corporation tax, and with seven areas (including Kaunas) designated as free economic zones (FEZ), it has attracted a diverse range of new and established businesses over the past six years; indeed, the community of foreign nationals living in Lithuania has grown five-fold since 2010.

Science and technology are key elements of Lithuania's Progress Strategy, and it has already established itself as a European leader in fibre optic internet development, a world leader in the provision of public internet and communication technologies, and also in producing the highest number of science graduates relative to the general population.

Following a history of being 'Lithuania's merchant prince' – dominated by trade and industrial activity – Kaunas, Lithuania's second largest city, has recently gained a growing reputation as one of the Baltic's key knowledge and cultural hubs.

Historically, it has played a significant role in national defence. From 1882 until the end of the First World War, it was surrounded by a ring of fortifications and batteries; Kaunas Castle is the most complete surviving example of this era.

With nearly 50 museums, a botanical garden, and Lithuania's only zoo, Kaunas is becoming an increasingly popular visitor destination. As Lithuania's leading academic city, it has an enviably vibrant atmosphere largely shaped by the 56,000 young people who are seeking higher education at its eight universities. The availability of young, highly-skilled specialists along with exceptional connectivity – most of Lithuania's nearly three million residents live less than an hour's drive away – has attracted an influx of innovative companies to the city.

In 2015, Kaunas was designated as a UNESCO Creative City and IN 2016 it hosted a Design Week and Architecture Festival (KAFe).

Figure 2.1 Lithuania.

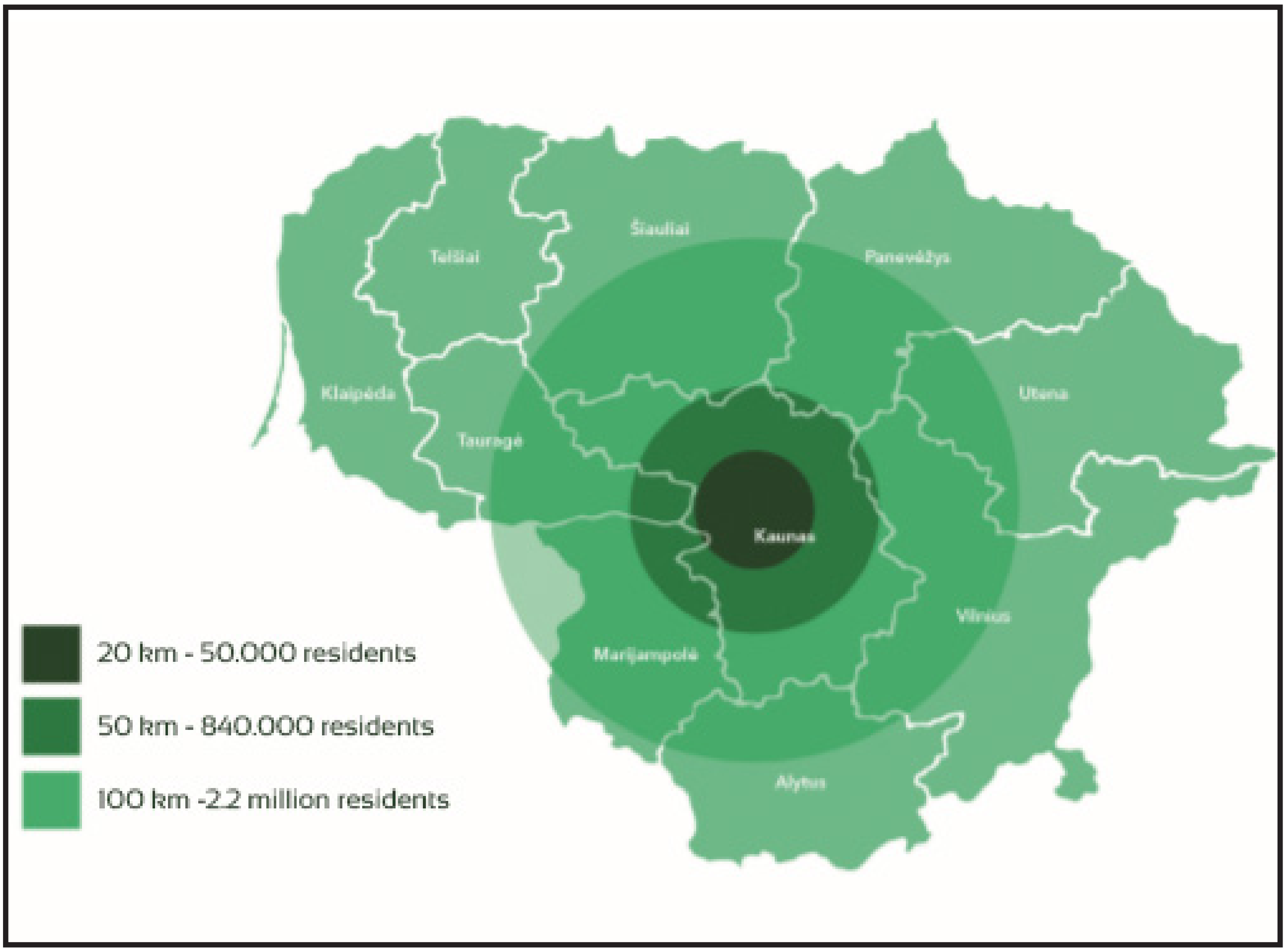


Figure 2.2 Kaunas distance diagram.

|ARCHITECTURAL HERITAGE|

"Architecturally these Soviet "dream cities" look very similar to each other"

INTERWAR ARCHITECTURE IN LITHUANIA (1918 – 1944):

Rebirth of independent Lithuania in 1918 gave a new impetus on construction. Initially, the earlier historicist trends were continued. This changed soon and the most productive decade of interwar architecture (1930s) was heavily influenced by **art deco style** and **Bauhaus** movement. It saw a reduction of architectural detail. But while there were no more bas-reliefs or statues adorning the facades there were still many large over-arching architectural motives that make the architecture of this period attractive. Typically these Lithuanian buildings include both **sharp and curved corners**, although some follow art deco style throughout and omit curved lines.

Borough of Žaliakalnis (planned by interwar urbanists for the detached homes of the elite) and the New Town (the heart of interwar Kaunas) are the **districts most saturated with art deco architecture.** The most visible landmark of this so-called Smetonic era (after the interwar president Antanas Smetona) is the Church of Christ Ressurection in Žaliakalnis (Kaunas). Other major examples of large scale interwar architecture exist in the New Town of Kaunas: the War Museum, Central post building, Pienocentras HQ.

Vilnius was a backwater of the Polish state at this time and therefore has relatively few interwar buildings for its major size.

SOVIET FUNCTIONALISM ARCHITECTURE IN LITHUANIA (1955-1994):

The late Soviet era is arguably the **most visible** one in Lithuanian cities. This was the era of great urban redevelopment and expansion, with a strong preference for **quantity over quality**.

This architectural era began in when 1955 all "unnecessary architectural details" were forbidden, effectively banning the previously-official Stalinist architecture. Rapid urbanization of the 1960s-1980s also changed the Soviet urban planning policy. The natural city centers were no longer expanded. Instead, new so-called "**micro-districts**" or "sleeping districts" were constructed away from the downtowns all over the Soviet Union. These areas were meant to be self-sufficient with shops, schools, and kindergartens in their centers and parks on their flanks.

Architecturally these Soviet "dream cities" look very similar to each other. Multi-storey apartment blocks surround large open spaces presently overfilled with cars. There are few interesting buildings as hundreds of white apartment blocks used to be built on the **same design,** devoid of any unique details.

Nevertheless, for a person outside the former Iron Curtain, it may be interesting to explore at least a single such zone.

To the adherents of functionalist architecture, the answer in the question “But which is more important, the function or the appearance? “ is clear: **buildings are defined first and foremost by their purpose,** and that’s exactly how they should appear.

Functionalism, in terms of aesthetics, is characterized by **low levels of ornamentation and extraneous decoration, as well as a prominent display of raw materials.** Following the idea that function comes first, the building materials used to make a structure are often left **uncovered** and **undecorated**. This means that flat concrete slabs, steel sheets, and even wood beams or floors are left exposed, meant to be viewed exactly as they are.

"A unique concentration of Modernist architecture, drawing on international style tendencies"

As the provisional capital of a newly-independent Lithuania between 1919 and 1939, Kaunas saw rapid growth and investment. Russian and European architects and engineers flocked to the city, and the result was an extraordinary era of cultural creativity which gave Kaunas a remarkable legacy: a unique concentration of Modernist architecture, drawing on international style tendencies – such as Bauhaus – as well as the Lithuanian national style. This demonstration of architectural and visual flair was not unprecedented, as indicated by surviving examples of Gothic, Renaissance and Baroque buildings in the Old Town, all now part of Kaunas' rich heritage.

Key buildings include:

CENTRAL POST OFFICE

The most significant functional building of interwar Lithuania, the Central Post Office is a vivid statement of national identity. Lithuanian themes are conveyed through the way the façade (which reminds visitors of local sandstone) has been worked, and the decorations around the windows and cement cornices bring to mind wooden folk sculptures. Construction began in 1930, which was designated as the Year of Vytautas the Great, and finished the following year.

CHRIST'S RESURRECTION BASILICA

A symbol of the nation's rebirth and independence, this is the most famous sacred building of Lithuania's interwar period. The architecture reveals an interaction between conservatism and modernity, combining the basilica-like volume of the structure with sharp, rectangular forms. Its tower rises to a height of 63 metres. In 1952 it was reconstituted as a radio factory before being restored to its religious uses in 1988. It underwent a period of rebuilding from 1989 to 2006.

FIREFIGHTER'S BUILDING

Built from 1929-30 in the Modernist style, with some decorative elements in the Art Deco style. The curved front of the Firefighter's Building was dictated by the practical need to maximise the space for fire engines, but was hugely influential in introducing architectural diversity and modernity to the New Town.

KAUNAS TOWN HALL

Known as the 'White Swan', the Town Hall, dating from the 16th century, stands in the middle of the Town Hall Square in Kaunas' Old Town. At 53 metres, the building's tower is the highest structure in the district. Subsequent reconstructions include those of 1638 (Renaissance), 1771-5 (Baroque and Classicism), 1836 (where it was made residence for the Russian Tsars), 1973, and finally, 2005.

KAUNAS CASTLE

Located strategically on a rise on the banks of the Nemunas River (near its confluence with the Neris) Kaunas Castle is currently a tourist attraction and art gallery. Archaeological evidence suggests that the Castle was originally built in the mid-14th century in the Gothic style, and today roughly one-third of the original structure still stands.

KAUNAS STATE THEATRE

The first municipal Theatre, of which few signs remain, was built in 1891. The reconstruction from 1922 to 1925 gave the Theatre its Neo-Baroque centre, which exemplifies the style of national architecture during this period. All of the interior ornamentation, stylised in the Art Deco style, followed the traditions of Lithuanian woodcarving. An expansion in 1930 created a new façade on Kestusis Street, which has elements of Modernist architecture.

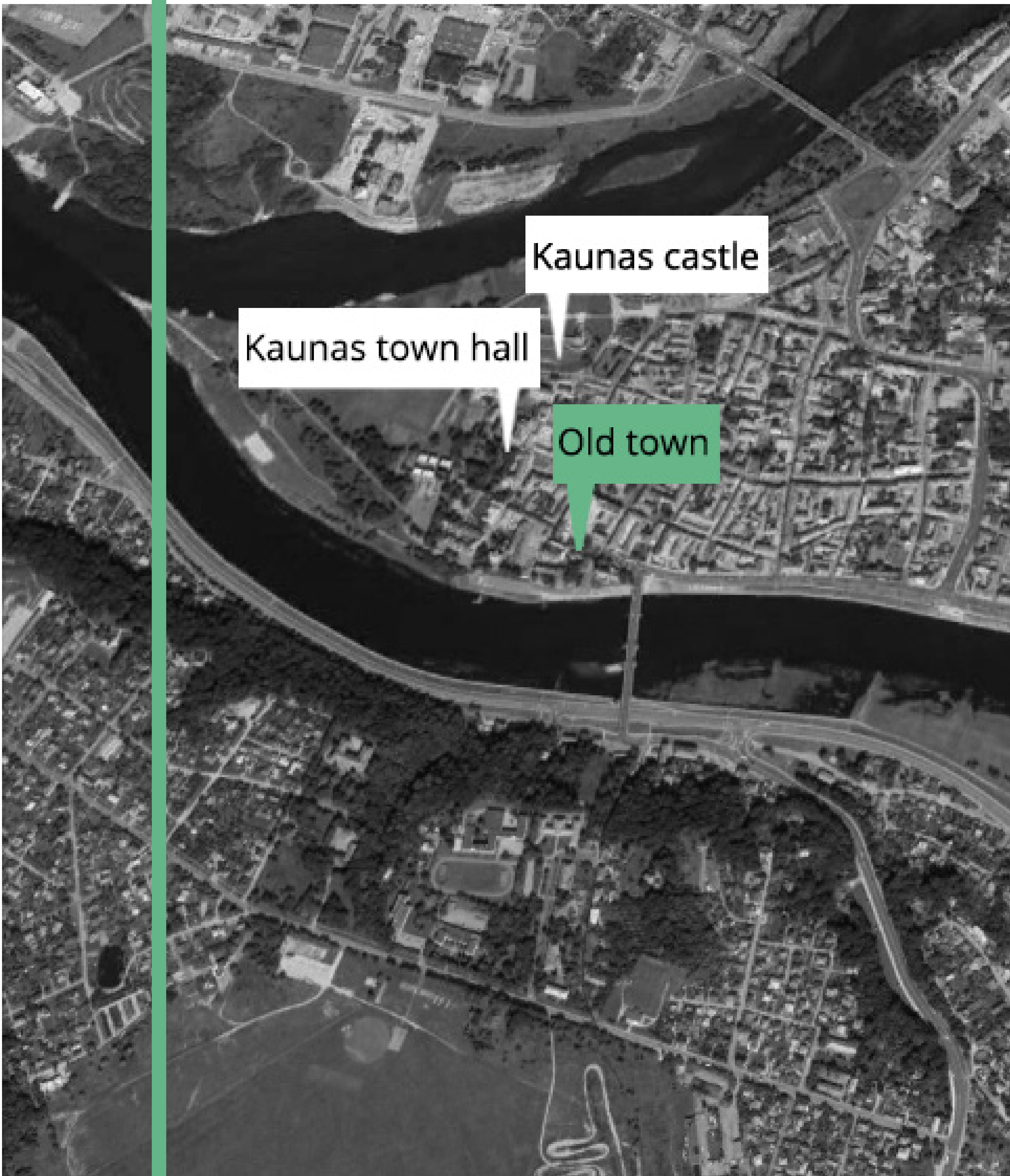
MILITARY MUSEUM OF VYTAUTAS THE GREAT

Originally planned as a 'museum of museums', the construction of the Military Museum was one of the most important architectural events of interwar Lithuania. With its harmonious interaction between tradition and modernity, it arguably represents the specific character of Kaunas' interwar architecture in the best and most clear way, with spaces and plans being structured to emphasise compositional axes and symmetry.

ST MICHAEL THE ARCHANGEL CHURCH

Located at the eastern end of Laisvės alėja, this Roman Catholic Church was built between 1891 and 1895, when Lithuania was part of the Russian Empire. It is notable for its size – designed to accommodate 2,000 worshippers – and unusual architecture, which employs triple Corinthian columns in an otherwise typical Neo-Byzantine five-dome design.

|LANDMARKS|



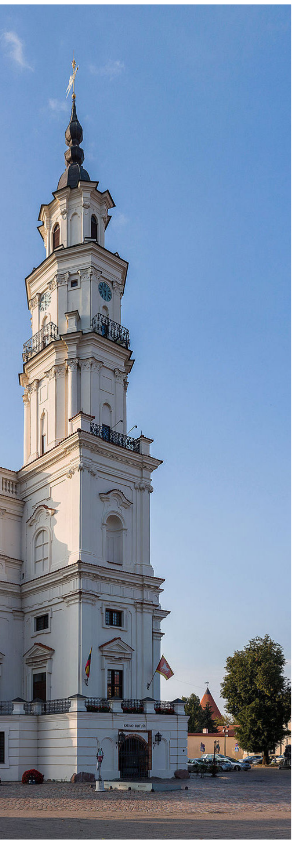

Christ's Resurrection Basilica
Military Museum of Vytautas the Great
New town
Firefighters Building
State theater
St Michael the Archangel Church
Žalgiris Arena

Figure 2.3 Old Town

Figure 2.5

Figure 2.4 Christ's resurrection basilica

Figure 2.6 M.K. National Art Museum



Kaunas town hall

Figure 2.7 Firefighters building KaunaS

Figure 2.8 Kaunas Castle

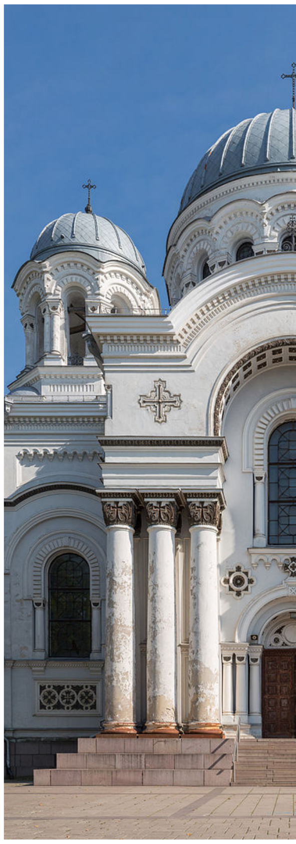
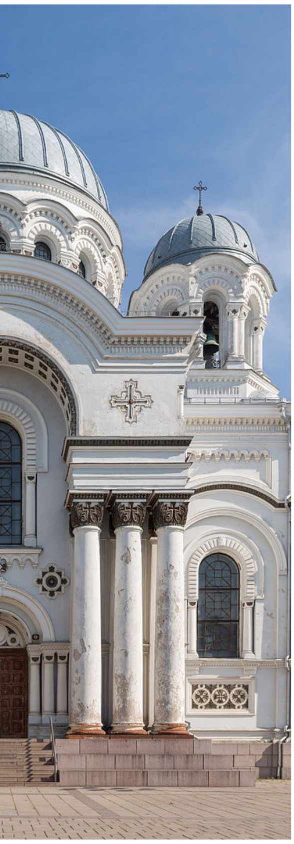


Figure 2.10 St Micha

Figure 2.9 Military museum of Vytautas Kaunas

Figure 2.11 Kaunas state theatre



el the Archangel Kaunas

Figure 2.12 Žalgiris arena

|SCIENCE AND INNOVATION CENTRE|

Museums have undergone an unbroken boom period for many decades now - globally as well as in Europe. New buildings are being constructed unceasingly, while existing ones are spruced up and equipped to meet other functions. Building stock which originally served a different purpose is at the same are being rennovated and converted into exhibition facilities. The museum has for some time now emerged as by far the most popular of all cultural institutions. The number of visitos which exceed by a long way those of other facilities, such as concert halls or theaters, also underlines this fact. It almost seems to be the case that our increasingly digitalised world awakens in many people the need to engage with the authentic object, whether in the form of a work of art or a historical document.

The past decades have at the same time seen a profound change in the museum as an institution, At the end of 1970s, the Centre Pompidou in Paris stepped up to the place with a revolutionary concept. It only presented itself as a spectacular exhibition machine, but also as a public forum which fast became one of the major focal points of the city. Since then, the tried-and-tested offerings have in recent times no longer proved sufficient for the majority of the museums. The established tasks of collecting, preserving, researching and presenting are augmented by a wide range of other ones.

The building increasingly become an event venue and meeting place (for dining) or a commercial marketplace with their ever-larfer shops. However, it is primarily exhibition concepts which are changing: for example, the former endless long showcases (with exotic insects) in a natural history museum have long become outdated. Today, the sheer volume of objects is cohesively replaced by multimedia presentations and the observer interactively integrated. In so doing, the entertainment aspect also gains increasing importance. Irrespective of whether the museum exhibits works of the visual arts or of the history of technology, whether is displays natural history or ethnological collections, the current trend is shifting from the former sublime temple of learning towards a dazzling world of experiences courting an increasingly spoiled audience's favour with special effects. This is often augmented by another task, not least owing to Frank O.Gehry's Guggenheim Museum and the associated Bilbao effect: museums are becoming the important pillars of city marketing or even landmark of an entire region. The approach calls for freestanding buildings which clamour for attention and not infrequently compete with the exhibited objects. In extreme cases, sometimes visitors come not only because of the art presented within, but more because of the building itself.

Museums, in general, can be divided into four main groups:

Art museum,

Territorial museum,

Event museum,

Science museum,

What connects plankton and eagles, homo erectus and Hitler, Ferraris and Maseratis? Well, the science museum knows the answer to this question, which lies in establishing links between its exhibitis. In so doing, the intrinsic logic of teaching runs a tight ship which also dominates the architecture. **Externaly, it has to stimulate interest in the topic. Internally,the design of the floor plan is tightly dedicated by it.** A word of caution : many an enternal truth is an illusion! In order to maintain the science museum in a maner permitting further development, its special storage facilities ought not to be tightly designed.

"By their spectacular visual apperance alone, museums become more and more expressive sculptures intended to attract streams of tourists"

Designing exhibitions and presentations is as fascinating as it represents the current hot topic for architects and designers. The exhibitng of authentic objects as means of feedback with the physical world or as conveyor of interrelations of cause and effect receives special significance, especially in a world becoming more and more complex and full of digital stimuli and manipulated images. This is, for one, valid for the cultural sector, ie the presentation of works of arts or signs of the times, but the commercial sector as well. At the same time, within the perpetual competition with the leisure industry, the requirements that exhibitions have to meet are increasing in order to seduce the audience or offer a special experience. Architecture marks the beginning of this process more than once: By their spectacular visual apperance alone, museums become more and more expressive sculptures intended to attract streams of tourists.

Designing exhibitions comprises the spatial-visual implementation of a concept developed by a designer in close collaboration with curators and scientists or marketing experts. Communication with the observer and/or transmission of messages is a central goal. Architecture, regardless if exclusively designed for this purpose or already existant, plays a decisive role in this context. It sets the stage; ideally, it corresponds to the context of the presentation. Spatial compositions and proportions, illumination and visual realations can support the choreography of an exhibition.

Each exhibition places the objects on display in a new context and thus reinterprets them. The mode of presentation significantly influences its message, whether the object is a painting, an ethnological or natural historic artifact, or a merchandise for sale.

The type of dramatization, the selected colors and materials, the lighting design, explanatory graphics, as well as giudance systems, but most of all the individual compilation of exhibits greatly influence how visitors conmprehend an exhibition. A conceptual central theme is of particular importance in this situation: it can be based on chronology or topic, or be constructed as narrative - an increasing common strategy in recent time. The exhibited objects are thus-contextualised or grouped according to their topic in order for them to tell a story and create suspense, similar to a good story, capturing the audience. Which path may be the better depends on the particular situation, the subject, but also the purpose and function of an exhibition.

Electronic media become increasingly signifcant. Even today, there is hardly any exhibition without audio guides or video projections. For designers and curators, rhe task arises to adequately integrate these media and prevent digital museums from being autoreferential. Or, as a critic once stated to prevent that visiting museums becomes nothing other than "public television".

"I think the future of museums will be a lot more personalised than the current one-fits-all visitor experience, with technology allowing people with different interests to each have a tailored experience"

-JIM RICHARDSON, FOUNDER OF MUSEUM NEXT AND SUMO DESIGN-

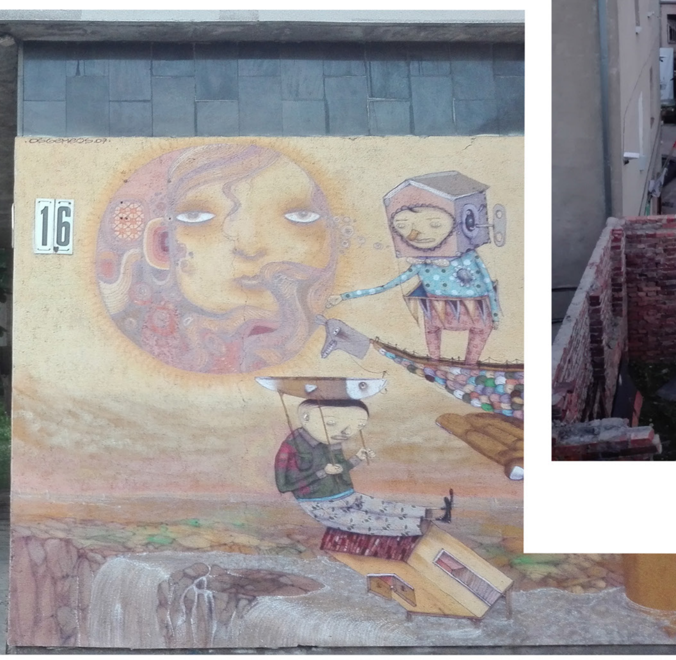
As we live increasingly mobile, digital and virtual lives - with personalised user-experiences and services at our fingertips- museums will have to find new ways to tell stories and engage theri audiences. **As digital experiences and physical spaces merge, who will be the audience and who the curator?** WIll museums function exclusively in the cultural sector or continue to expand into other markets? How and where will the contect be delivered?

Over the past 20 years, changes in society and technology have reshaped **how museums function, how they deliver experiences and how ther spaces are designed.** Over the coming decades, securing access to funding, attracting broader audiences and serving alternative forms of culture will all place pressure on museums to innovate and adapt to changing user needs and economic realities.

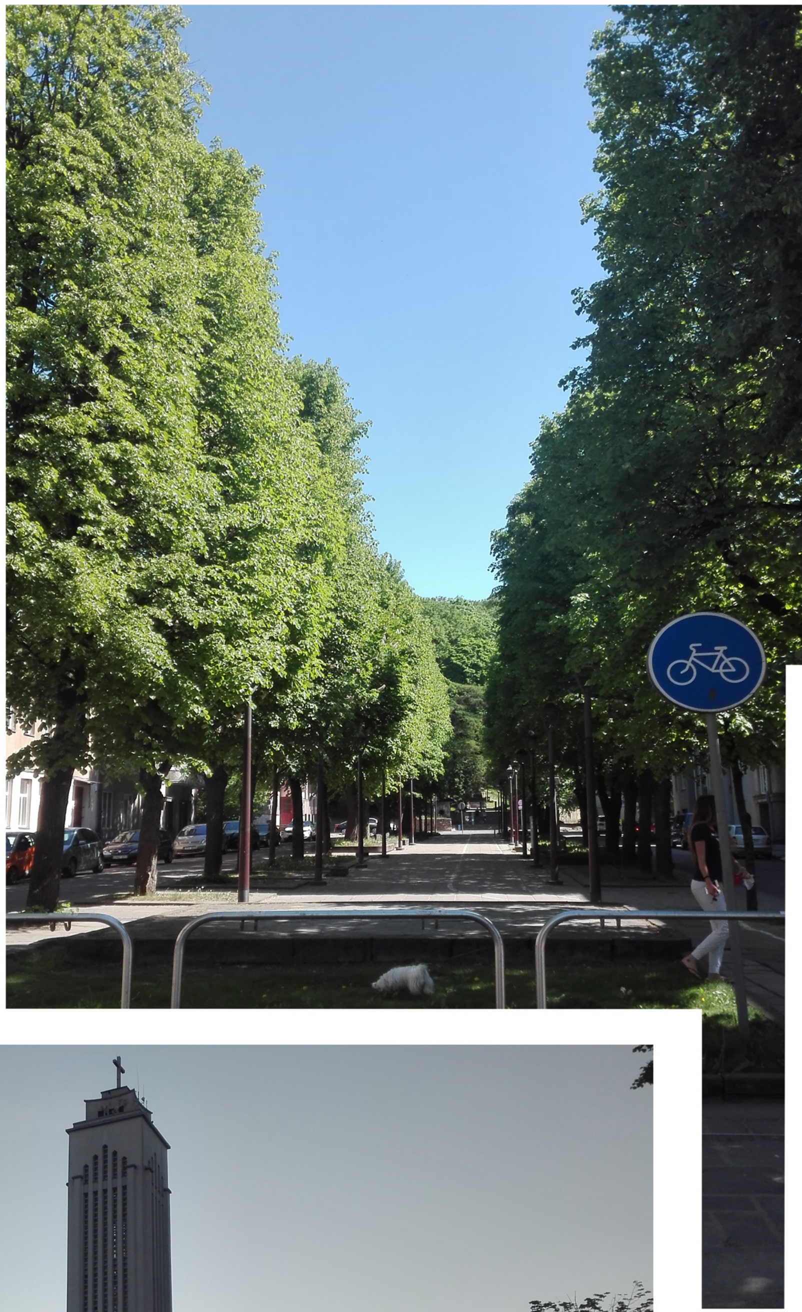
In the future, museums will continue to be shaped by a wide variety of trends and drivers, new technologies like augmented reality are changning how and where we can have museum-like experiences. Social and cultural shifts are influencing what type of experiences people will expect, while restrictions to funding will continue to out pressure on some museums to be both profitable and more inclusive at the same time.

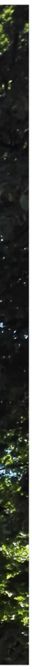
|SITE VISIT|

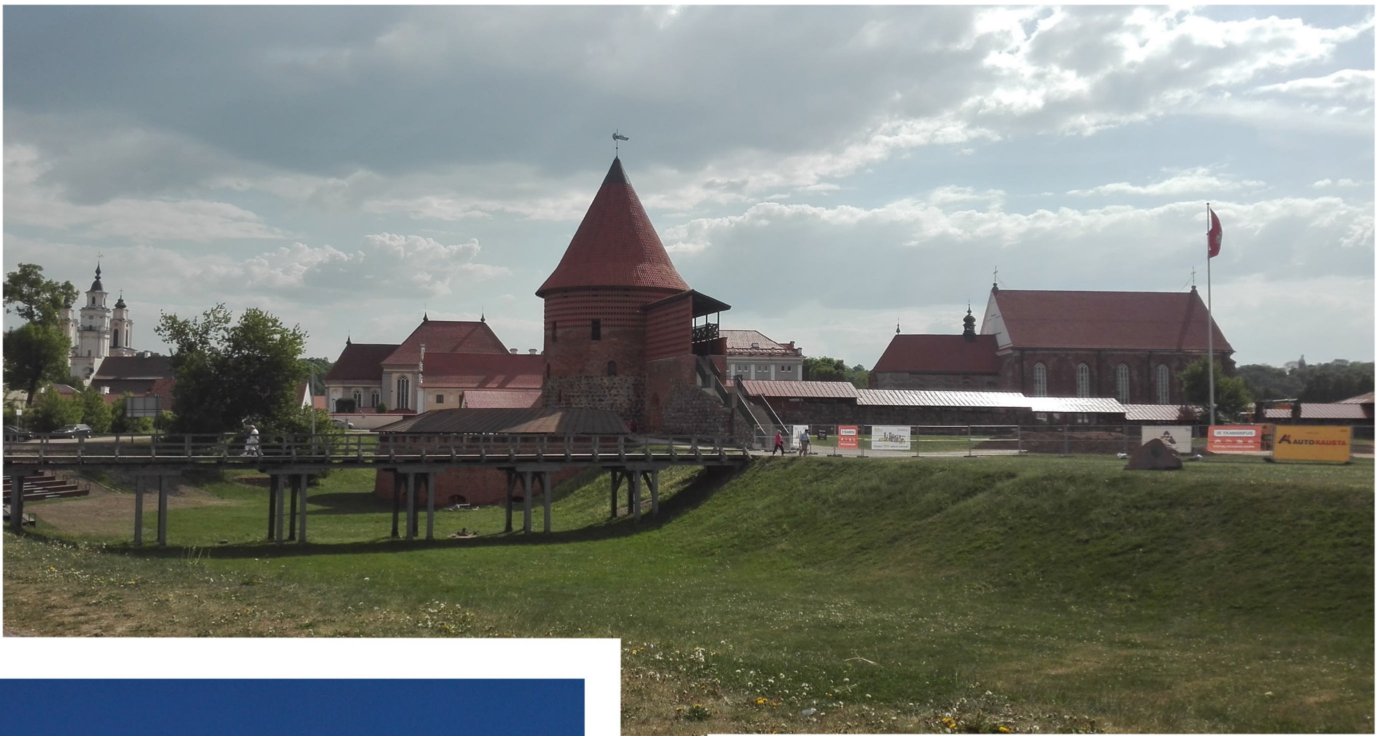
|ATMOSPHERE OF KAUNAS|



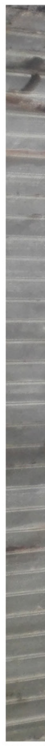
|NORTH PART OF KAUNAS - LANDMARKS|







|SOUTH PART OF KAUNAS|



| NEMUNAS ISLAND |

SITE VISIT

Site visit was a really important step in our design procedure. After two months of studying the context of the city, the architectural heritage and trying to identify the existing functions, a trip to Kaunas was arranged in order to testify our first results.

The visit helped to understand much better the **atmosphere** of Kaunas, the structure of the city and finally see the Nemunas island.

A few words to be said, the city can be characterised as a student city that provides young activities, with graffities playing a prime role in it. The **north** part of Kaunas, where the old and new centre of the city lies, has all of the landmarks and the existing green corridor.

Meanwhile, the **south** part of the city seemed rather isolated and mostly industrial. Between these two, Nemunas river divides the city in two parts with **Nemunas island** located right in the middle. On the island, Žalgiris Arena is the only existing building. Besides this, the island is full of natural elements, trees, outdoors activities, and people occassionally swimming in the river.

URBAN ANALYSIS

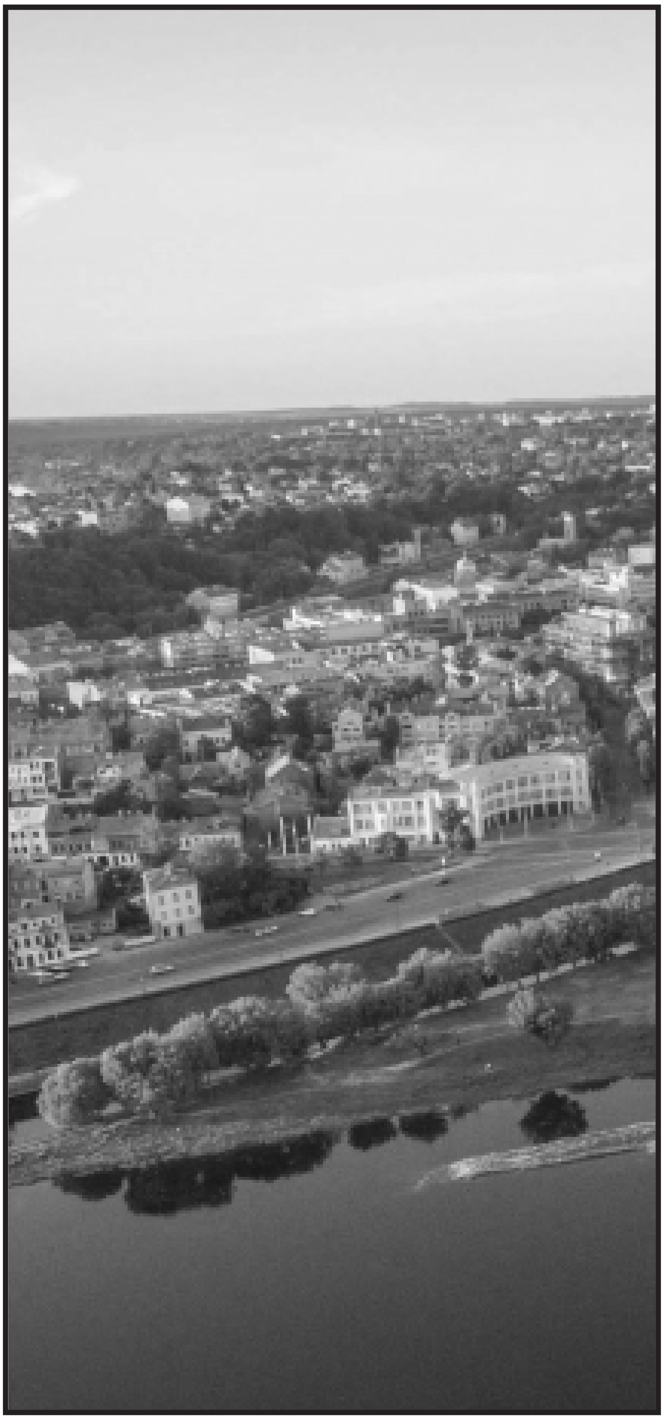
|NEMUNAS ISLAND|

"The 33 hectare island is located on the Nemunas River in the heart of Kaunas"

In January 2016 a Working Group established by the Ministry of Science and Education gave their recommendation to site the National Science and Innovation Centre at Nemunas Island. The 33 hectare island is located on the Nemunas River in the heart of Kaunas, in close proximity to the popular visitor areas of the historic Old Town, Laisvės Avenue – notable for its numerous cafés, restaurants and cultural institutions – and the Akropolis shopping centre.

The Island, which is owned by Kaunas City Municipality, is currently used as an outdoor recreational and leisure space within the city, where visitors enjoy activities such as walking, volleyball, and to enjoy the panoramic views around the city and its landscape. It is also home to Žaligiris Arena, Lithuania's largest sports and entertainment arena, which opened
in 2011.

Competitors should also note that the Science and Innovation Centre is anticipated to be the final building planned for Nemunas Island, and the area will remain a recreational zone for use as Kaunas' citizens desire.



|SCALE COMPARISON|

Figure 3.1 Scale comparison between the cities of Houston, Kaunas and Rome.

Trying to understand the city context better, the city of Kaunas was compared with other cities that are crossed by rivers. Houston and Rome were selected in order to show that Kaunas is in the “middle“ of these two in the sense that the city’s density is much higher than low-densed Houston but also much less than highly-densed Rome.

|URBAN INTEGRATION|

"Competitors are asked to illustrate how their design fits in its context and to provide an urban integration plan for the whole Island"

The Science and Innovation Centre can be located anywhere within Nemunas Island, and it is permitted for concept designs to connect to the island's surrounding territories, e.g. stepping into the river. The siting of the building, and its related facilities, should be considered at two key scales: **at the level of the city,** demonstrating how the building fits into the wider existing and potential future urban context of the city of Kaunas; and a**t the level of the Island itself**. Competitors are asked to illustrate how their design fits in its context and to provide an urban integration plan for the whole Island.

Notice to be taken into account:

The Žaligiris Arena, also located on Nemunas Island at its eastern end, will remain operational.

The new Science and Innovation Centre should not affect the functioning of the Arena and its supporting requirements and facilities, such as access, servicing and parking.

The location of the existing pedestrian and vehicular bridge links between the Island and the city.

The potential likely location of any new pedestrian bridge link between Nemunas Island and the proposed new convention centre on the south bank of the Nemunas River.

The diagram below highlights some of these issues and constraints.

Figure 3.2 Issues and constaints

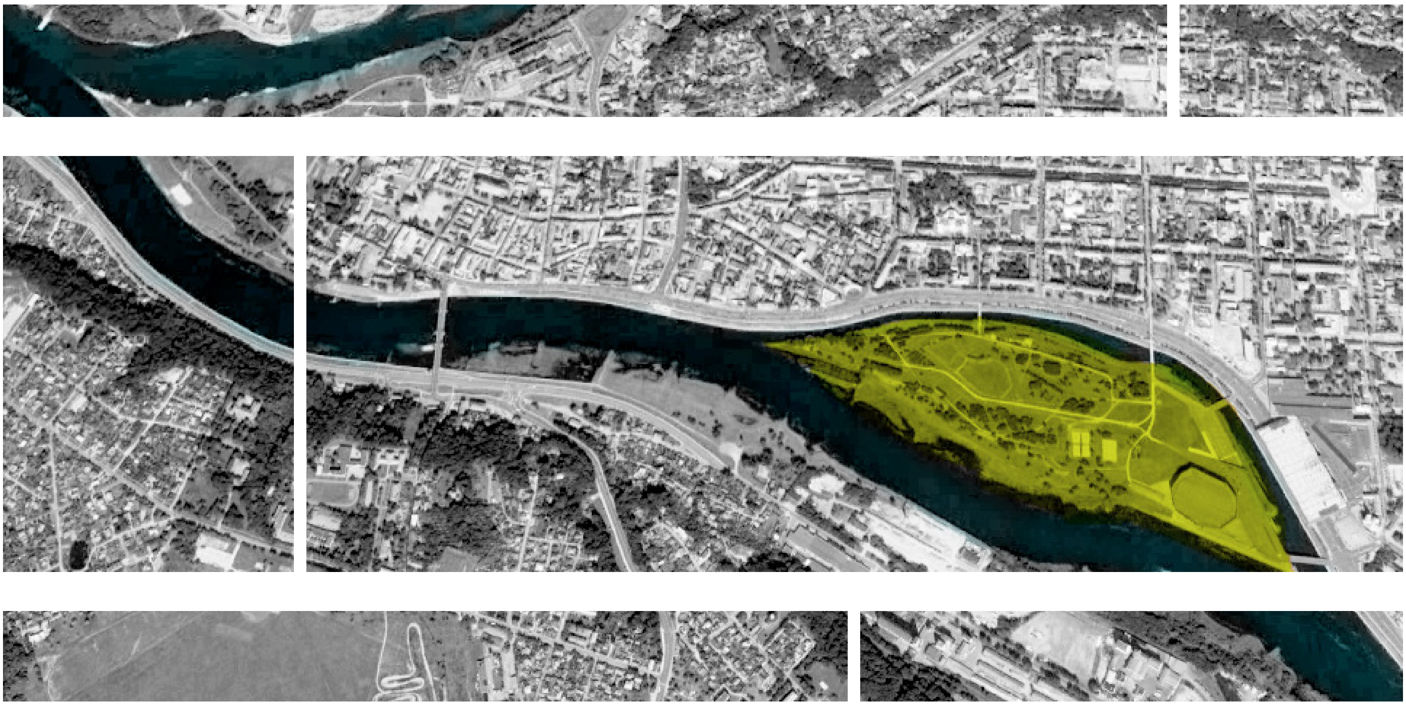


Figure 3.3 Urban Plan

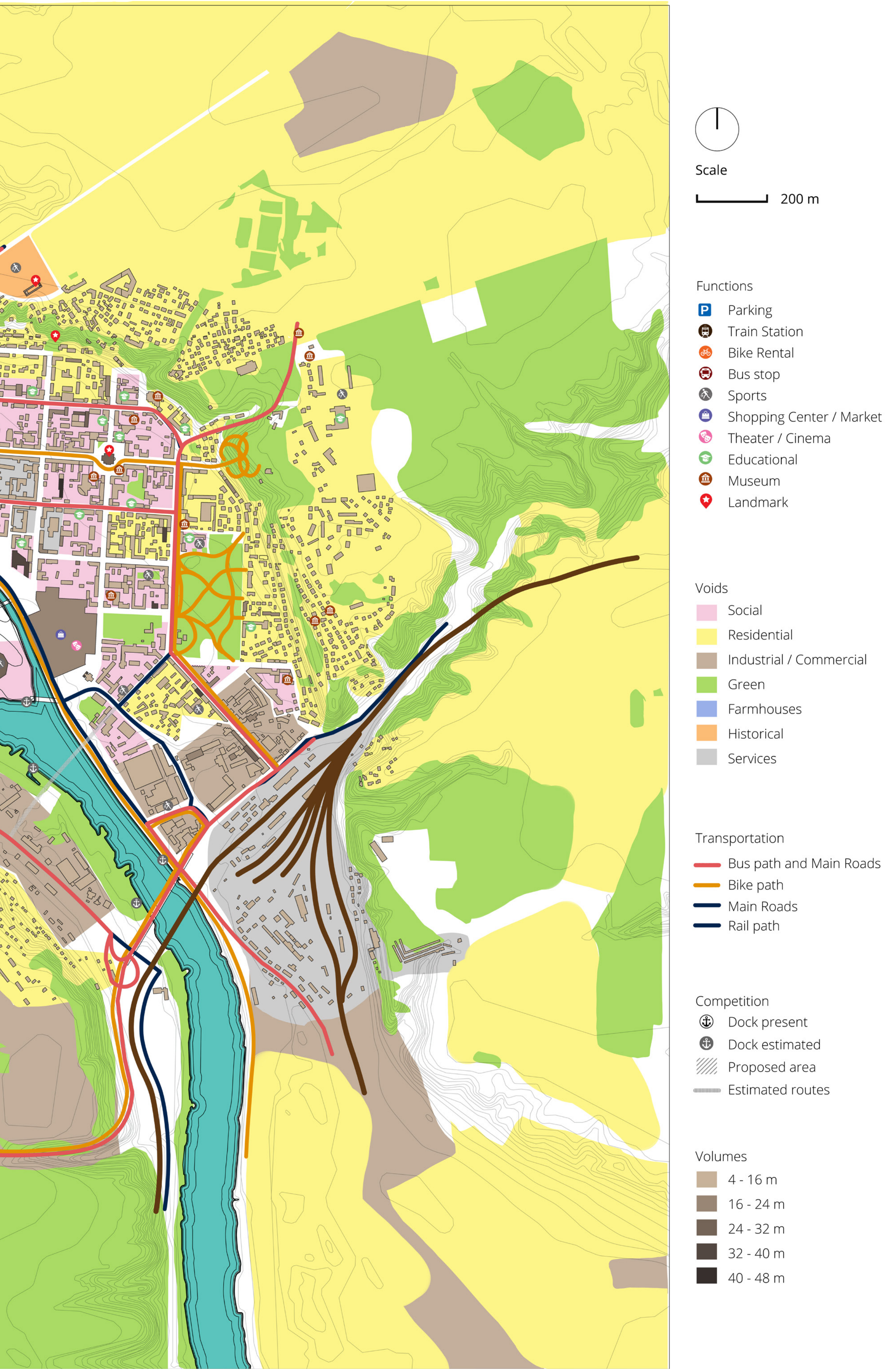
The **strategic position** of the island captured our attention. Under the right interventions, the island could work as a catalyst for the city of Kaunas.

After studying the characteristics and the position of landmarks of the city, we started our Urban Analysis in order to understand what exists in the contect of the city, the differences between the north and south part, the role of the water and the existing transportation systems.

The freedom of the competition regarding the **placing of the Museum** led us to investigate the city's characteristics, so that the choise of the positioning will help whole Kaunas

In order to better understand the context of the city, the Urban texture of it was analysed. **Volumes, Voids, Functions and Transportation** were identified.

|URBAN FUNCTIONS|


Scale
200 m
Functions
Parking
Train Station
Bike Rental
Bus stop
Sports
Shopping Center / Market
Theater / Cinema
Educational
Museum
Landmark
Voids
Social
Residential
Industrial / Commercial
Green
Farmhouses
Historical
Services
Transportation
Bus path and Main Roads
Bike path
Main Roads
Rail path
Competition
Dock present
Dock estimated
Proposed area
Estimated routes
Volumes
4 - 16 m
16 - 24 m
24 - 32 m
32 - 40 m
40 - 48 m

|ROLE OF THE RIVER|

"River should be considered an axis and not a border of the city"

The **role** of **rivers** in city centres is **multi-faceted**. Quite roughly, it can be classified by the main object of interest:

a) **functional** role of the river,
b) **social** role of the river;
c) the **ecological** role of river;
d) **visual** role of the river for the city centre.

In the course of history, political and sociocultural events always have influence on urban development and shape of the city. Such events also affected the river role for the city centre, as well as influenced the relationships between river and human. Depending on that, usually one of the four dimensions (functional, social, ecological or visual) of river role was dominating.

According to the literature analysis and empirical researches, **the function of the river is not clear in the centres of Lithuanian cities nowadays.** Also, weak social, visual, ecological and identity formation factors led up to the lost role of the river in urban and social context.

Comparing foreign projects of riversides revitalization with the Lithuanian ones, it is obvious that **the potential of the river here is untapped and managed insufficiently**. All the dimensions of river role (functional, social, ecological and visual) should be developed equally, without overwhelming each other, in order to achieve the most optimal results of riverside regeneration.

On the basis of the implemented riversides' projects abroad the management tendencies of rivers and riversides in the city centre can be distinguished: the river is interpreted as an important **axis** of city centre with **strong visual and ecological role in urban space.** Also, aspects of sustainability and riversides adapted for social place are the trend of river management nowadays.

|HEATMAPS|

Figure 3.4 Heatmap Walking Activity

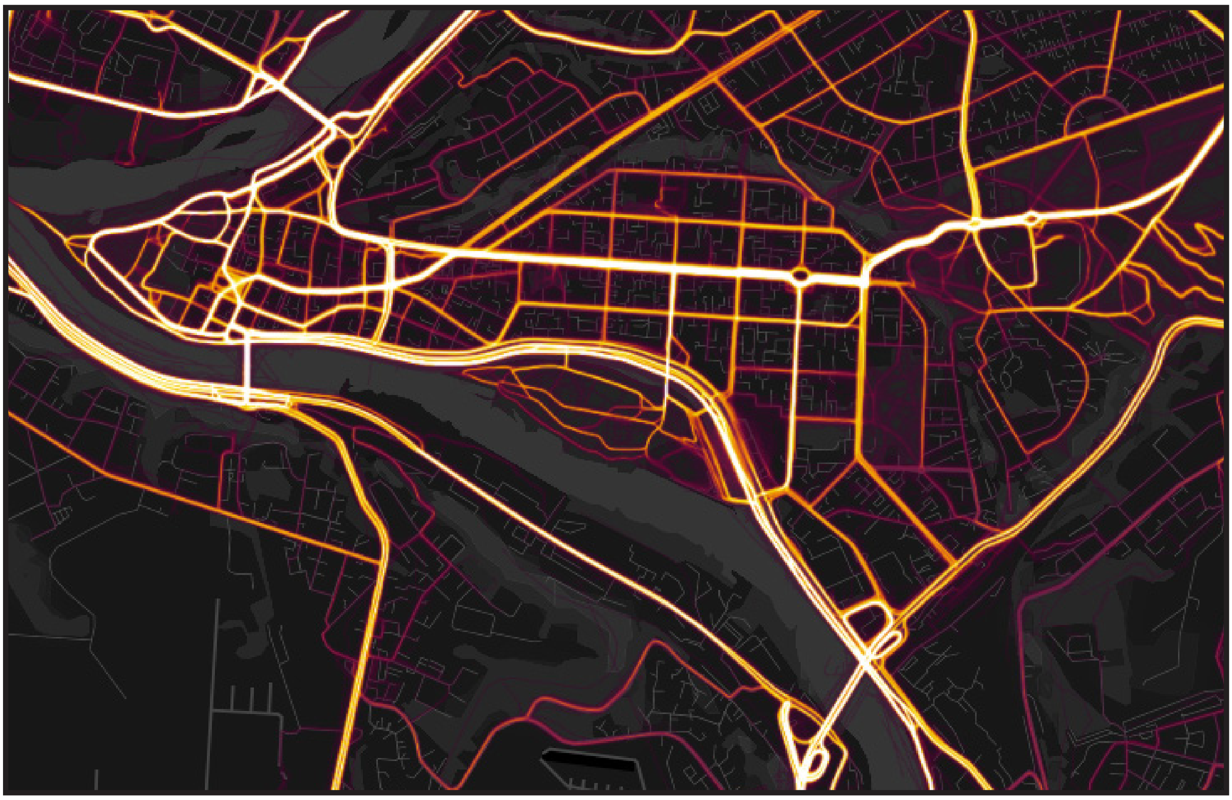


Figure 3.5 Heatmap Rides Activity

Heatmaps of walking and rides activity give us a first impression of the density distribution of Kaunas' citizens. The reason these two maps were chosen was that by combining them we may understand **the already existing main network** used. Strong and weak points can be identified. Areas where both walking and riding activities are already high, were those where ways to **reduce people's density** could be found. Areas where both walking and rides activity are relatively low, werethose where **functions should be introduced**. All these parts of the existing network may boost island's position to create an even stronger network of the city, where the island connects the existing habitats.

As shown in the two previous maps, **most** of walking and riding **activity** is concentrated in the **north** part of the city, where the old and new city exists. In the **south** part of the island both activities present **low** percentages of **activity** underlying the low connectivity between the south and north parts of the city.

The high concentration of activities in the north led us to search a possible **Green Corridor** in the city. The possible integration of Nemunas Island in the Green Corridor and the potential connection of the two parts of the city would be interesting, giving even more significance in the **positioning** of the island.

In order to achieve this, the Urban Functions in the center of the city were studied, keeping in mind the needed connections between Nemunas and Kunas and finally combined the two heatmaps, trying to link the main streets with the island, and also how the **south** part of Kaunas could be integrated, which seemed to have a weak connection with the rest of the city.

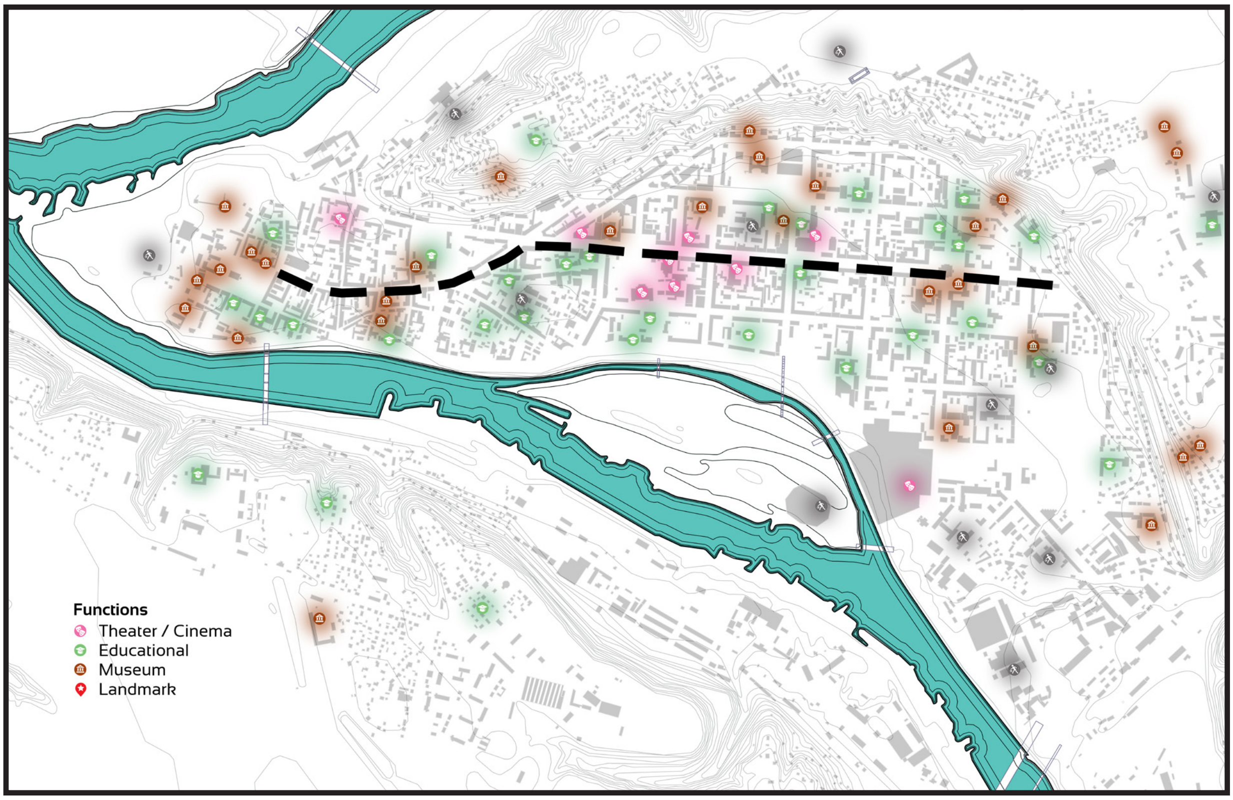


Figure 3.6 Distribution of Urban Functions

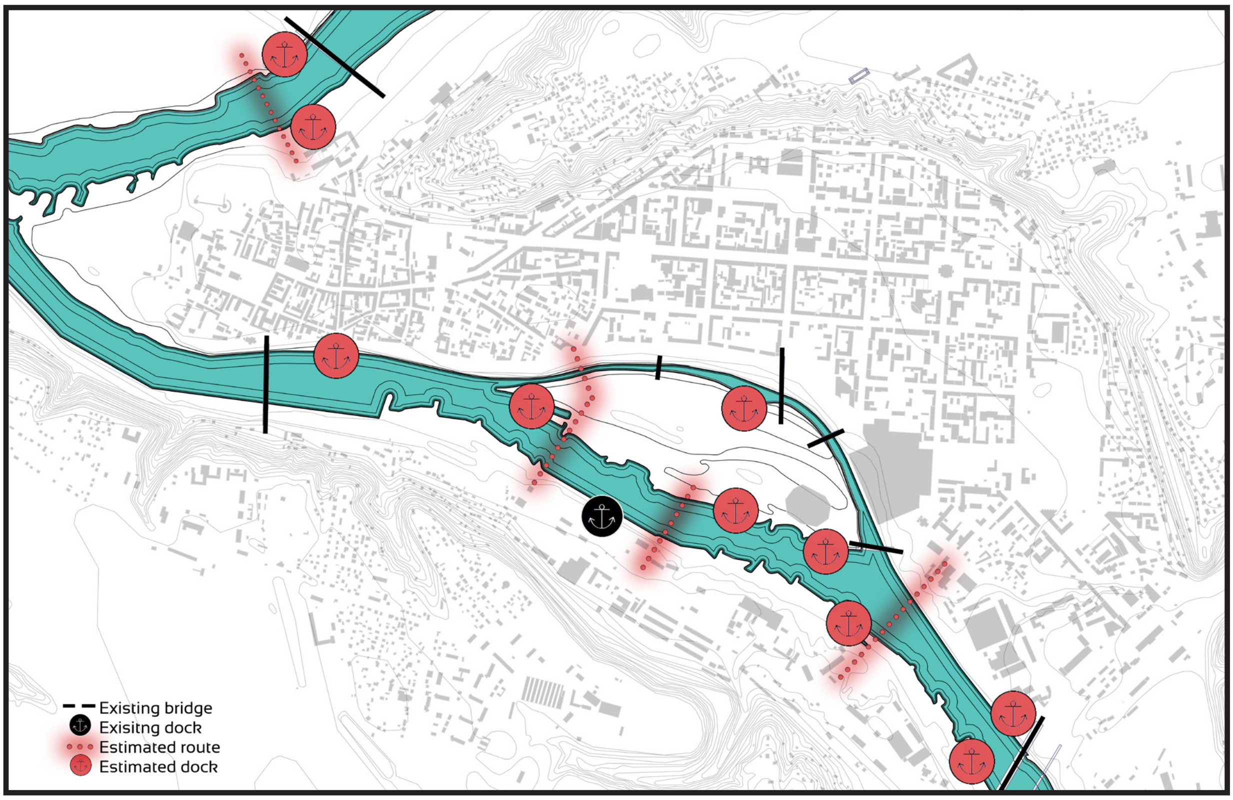


Figure 3.7 Existing and proposed connections

|GREEN CORRIDOR|

"Green Corridors should be viewed as a part of the overall network of habitats throughout the city"

A thin strip of land that provides sufficient habitat to support wildlife, often within an urban environment, thus allowing the movement of wildlife along it.

Green Corridors are an essential component of the cities' ecological networks; they are a strong response to environmental problems. They have a **dual purpose.** In addition to their ecological role in creating a pure vision, and helping people to live in better communities, they provide **access routes**, and **improve the quality of life,** particularly social life. Therefore, they should be viewed as part of the overall network of habitats throughout the city.

BENEFITS

Ecologically, Green Corridors include high quality habitats and ecosystems, especially the natural corridors such as riparian corridors, waterways and aquatic habitats. They prevent soil erosion and they absorb rainwater, thereby improving drainage, and protect against the urban heat island effect The diversity of activities through them ameliorates the ecological consequences, such as greening urban areas, agriculture, forestry, and recreation facilities. Finally, Green Corridors and their inhabitants are good **indicators of the overall ecological health of the ecosystem**

Socially, Green Corridors have recreational uses: a place to play, meditate, gather, or rest. They give people the sense of place, of identity and of belonging, and enhance feelings of family kinship and solidarity. They provide the opportunity to reflect on personal and social values, promote culture and spiritual growth, and increase the sense of commnity. In general, Green Corridors **allow users to feel free in a more structured environment**.

Environmentally, Green Corridors provide a high quality life through **integrating nature into the urban environment** and stimulating the senses with their simple colour, sound, smell, and motions. They play an important role in reshaping the urban spatial pattern and establishing connectivity for a wide variety context across the city. Loops and intersections produce a variety of routes and greenways that help to increase accessibility and forming or transforming the city form by delimiting its land use.

VISION

This vision aims to achieve four main objectives: (a) maintain and improve **environmental quality** through nature protection, (b) increase **economic development** through appropriate tourist activities, recreation development and historic conservation, (c) create **high land value potential** through having a welldistributed population, (d) create a **dynamic network** to provide sustainable transportation through walking and finding the right of use of riding, cycling, and light motorized transportation.

Figure 3.8 Overlay of heatmaps

Figure 3.9 Old Town

Figure 3.10 New town

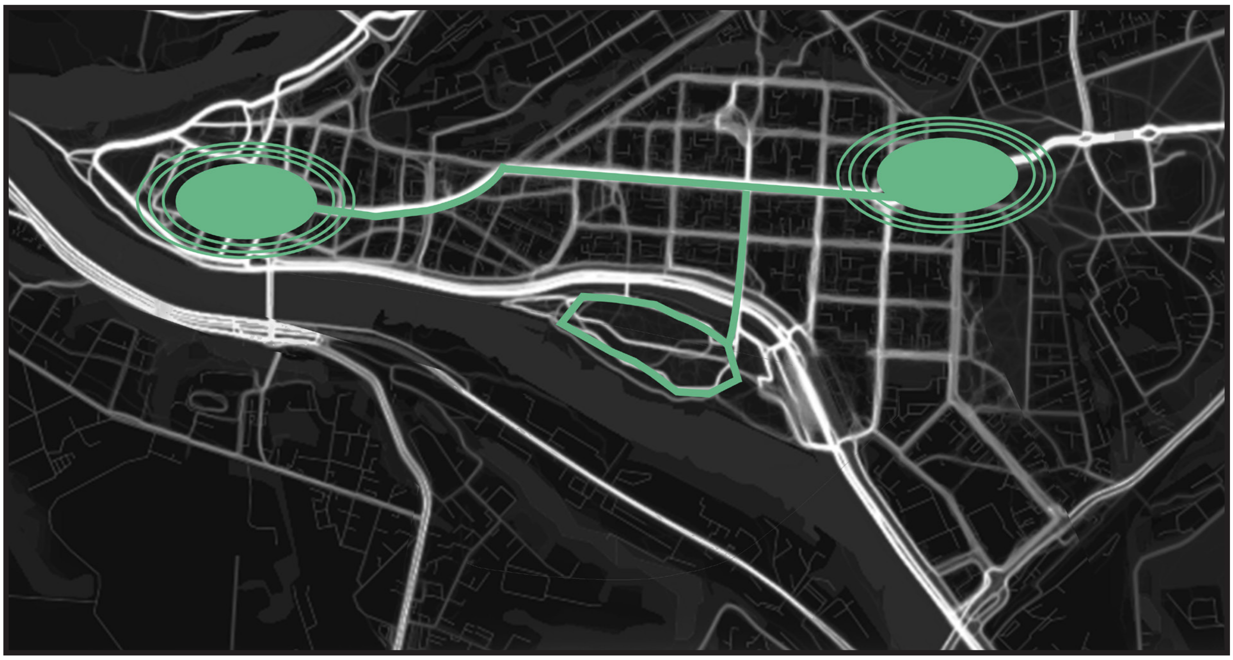


Figure 3.11 Main connections between the city and the island

Figure 3.12 Weak South part

Figure 3.13 Possible connection with the island

Figure 3.14 Integration of South part in the existing Corridor

After analysing the data, it was proven that the streets with high walking and riding activity in the center connecting the old and new center of the city created a **Green Corridor of 2.9 km**.

In order to improve the people's accessibility to the south part of Kaunas, it was suggested to introduce **two new bridges** through Nemunas island to connect the south with the isand and the existing Corridor.

|SWOT ANALYSIS|

STRENGTH

Public green areas.
Presence of educational museums and cultural facilities.
Historical and social coexistence.
Parking areas.
Balanced green density throughout the city.
Proximity to rail, bus station.
Long term strategies regarding public transportation.
Access of public transportation on project area.
Greenhouses, proximity to local food resources.
Old town center gives another perspective to the city.
Strong contrast in the urban texture.

WEAKNESS

Lack of bus stops in city centre.
Not well connected pedestrian and bike paths.
Ground inclination is not in favor of bike use.
River is considered a border and the axis of the city.
Rainy weather and high humidity thoughout the year

OPPORTUNITIES

Free public transportation future policy.
Strong existence of natural elements.
Science and sport coexistence.
Lack of landmarks and not a strong/modern image of the city.
Connection of North and South part of the city.
Location and orientation of the island.
Proposed construction of docks.
Youth integration.
Creation of green corridor.

THREATS

Rise of water level.
Safety provided in island.
Destroying the ecology/current identity.

The analysis of the urban texture underlined the **differences** between **north** and **south**. In the north part of Kaunas there is a strong coexistence of Social Spaces and Services. On the west part of the city there is a Historical Center and in the east one the Industrial and Commercial Buildings. The Residential part of the city starts right above the Social one, as one heads out of the city.

The island is mostly covered by Green spaces and hosts the Zalgiris Arena on the east end. Meanwhile, the south part of the island is departed by Social and Industrial places which lie right in front of the waterfront, with residential and farming houses following as one heads outside of the city.

Regarding the transportation system most of the city is covered by Bus and Bike paths, with the Railway being in the east edge of Kaunas.

|INTERVENTIONS|

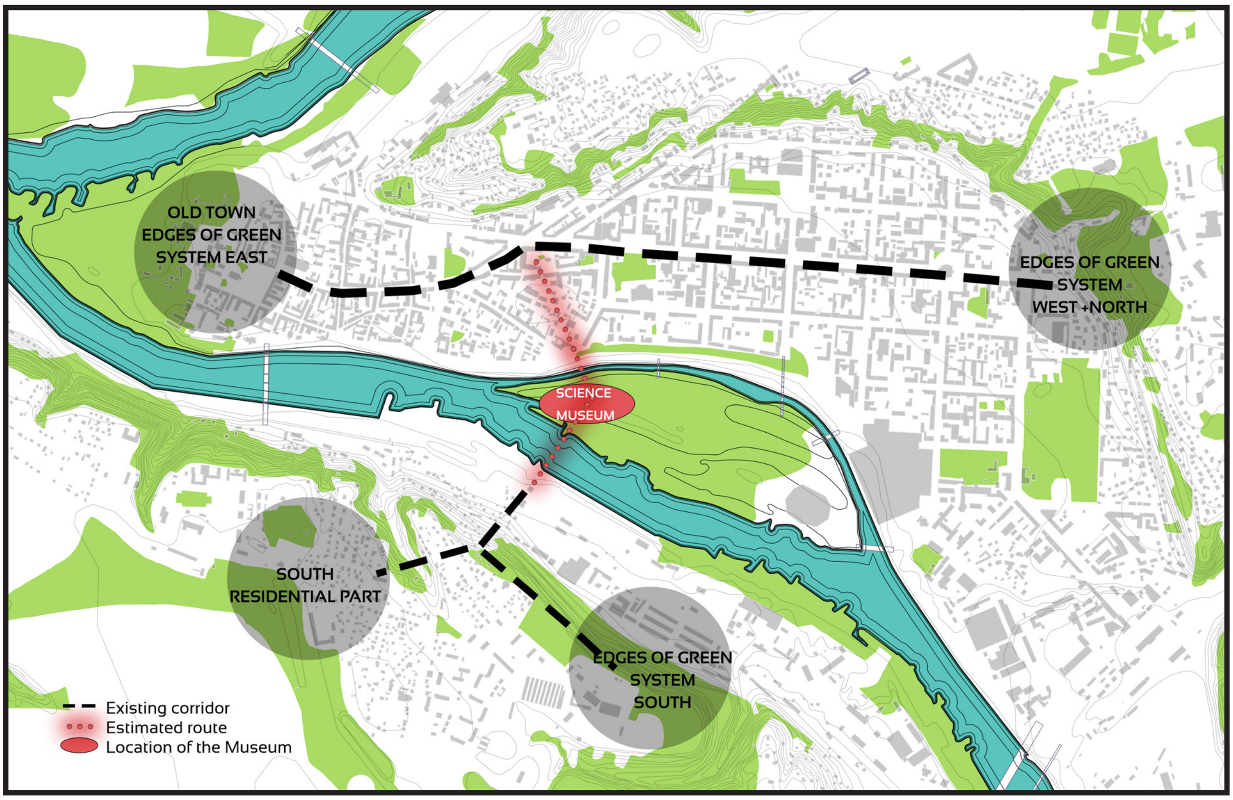


Figure 3.15 City Integration and placing of the Museum

After identifying the Urban texture, the distribution of the functions and the density of the people, taking under consideration the possible connections, the placing of the museum was established.

The **placement** of the Museum was made in a way that the connections of the island will connect the south part with the already existing Green Corridor of the city.

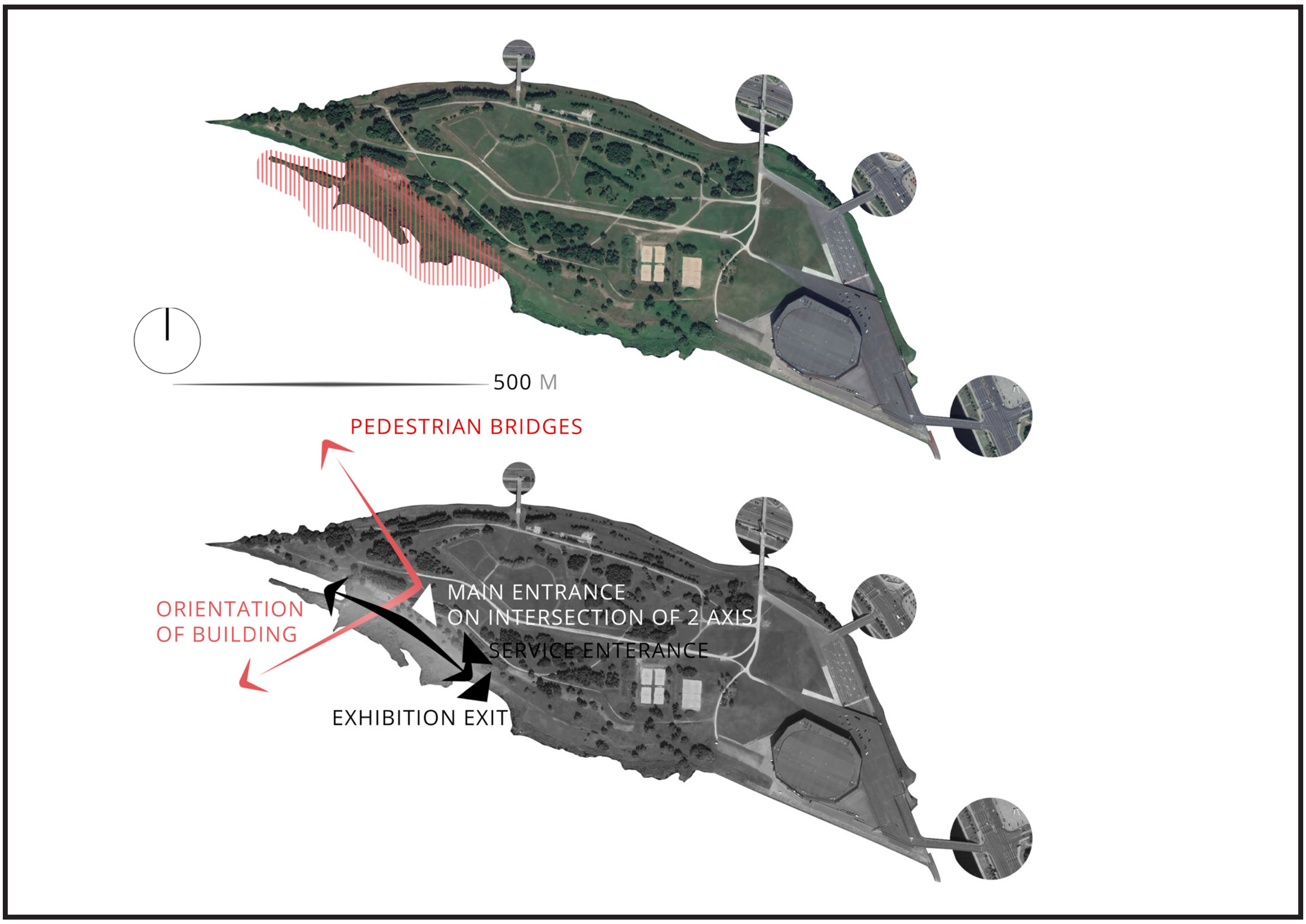


Figure 3.16 Links - Orientation -Principal Decisions.

DESIGN PRINCIPLES

- Preservation of public green space.

- Improving the pedestrian path.

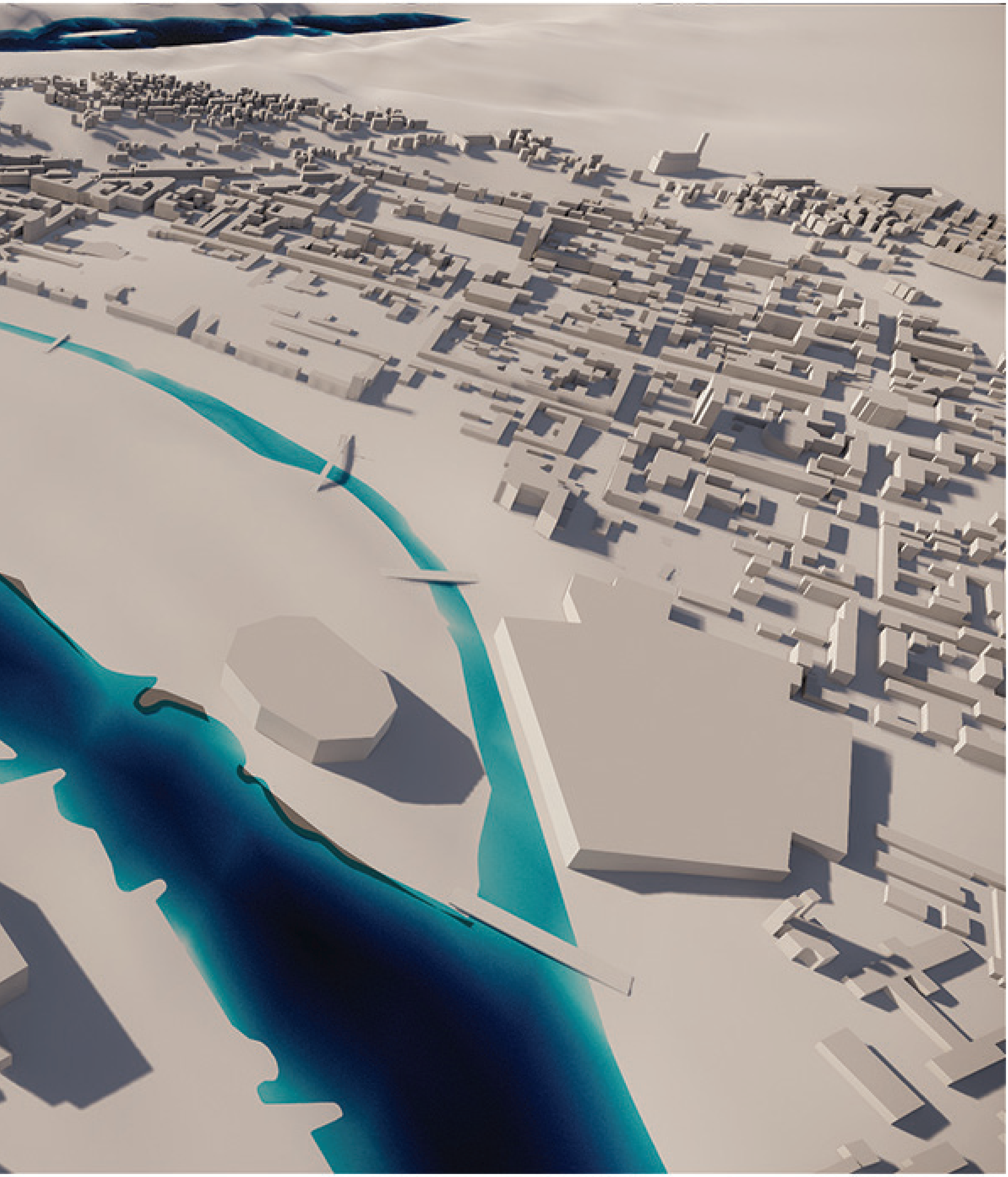
- Integration of walking , cycling and dock links.

- Exploiting the potential island views.

- Definition on the city sillhouettte.

|POSITIONING OF SCIENCE CENTRE|

Figure 3.17 Placing of Science Centre.

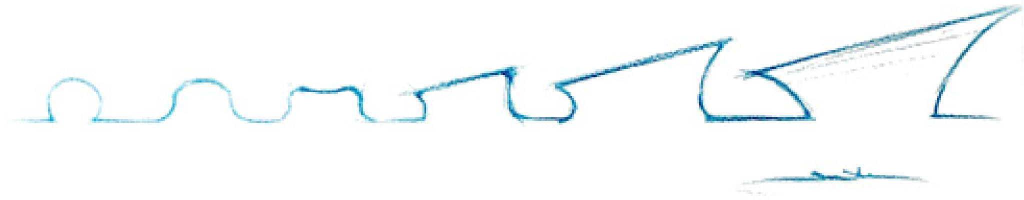


ARCHITECTURAL DESIGN

|CONCEPTUAL EVOLUTION|

JOURNEY.

CONCEPTUAL KEYS.



Evolution

Metamorphosis

Transformation

Transition

Process

Links

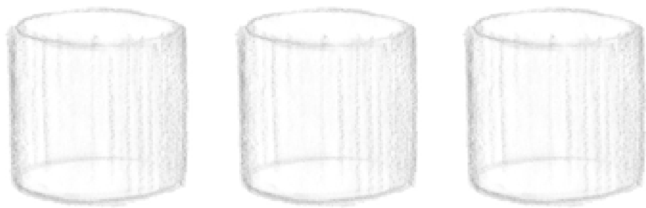
Journey

Memory

“There are infinite links and everlasting transformation between existence in the universe.”

-Emphasis on common matter-

2- INITIATION; GIVEN CONCEPTS; NATURE, HUMAN, MACHINE.

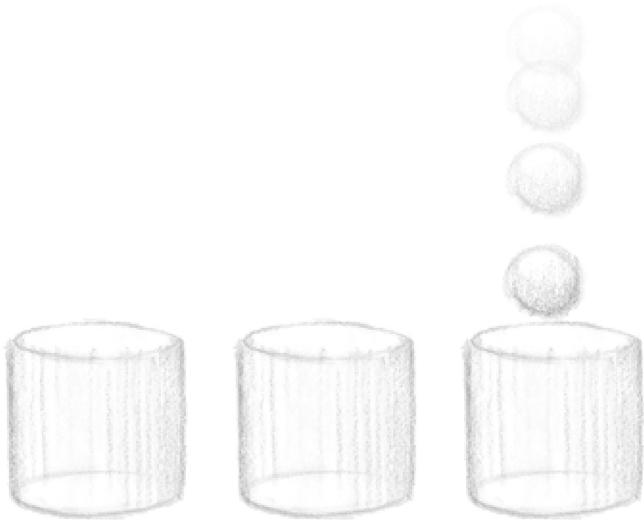


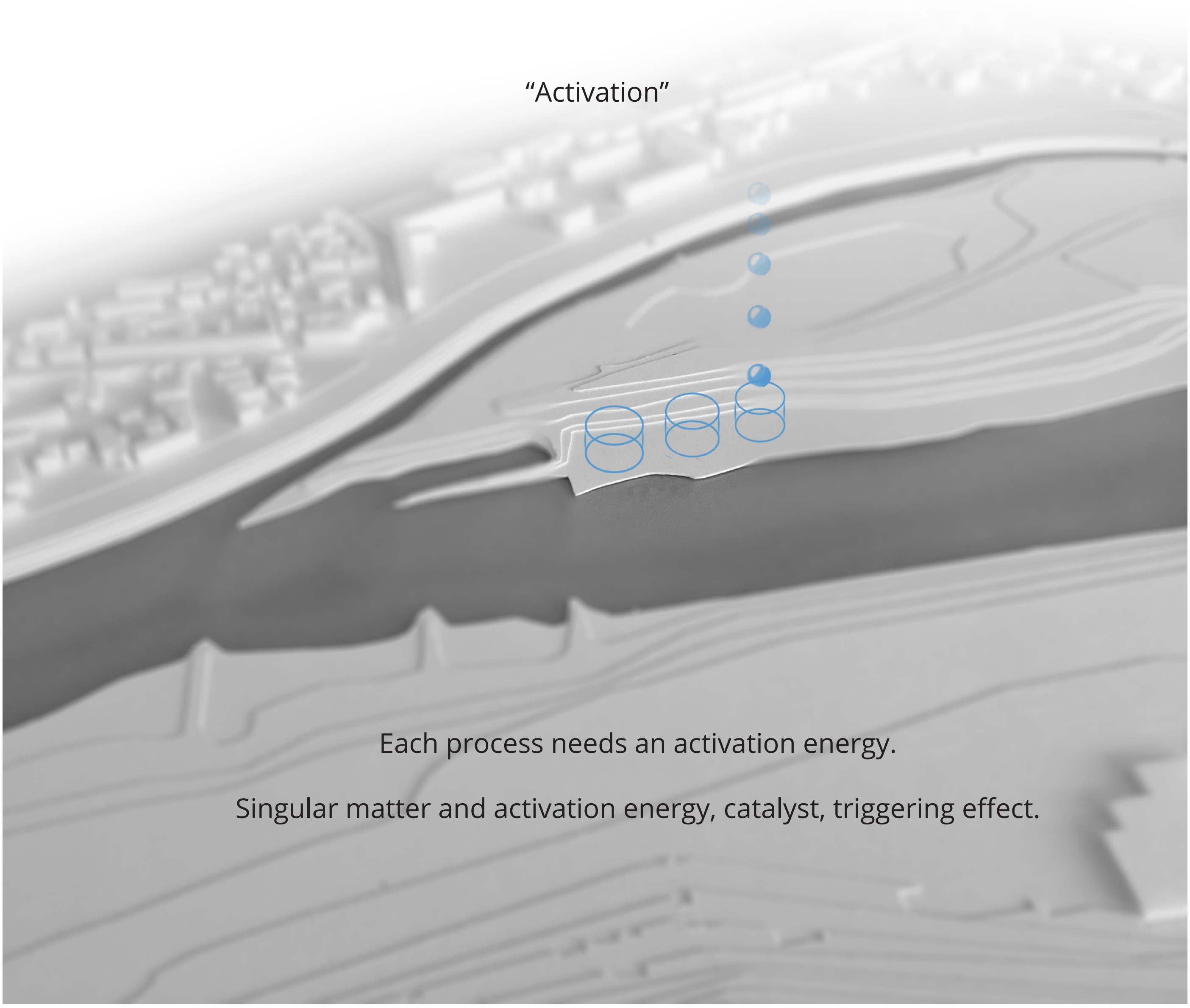
"Repetition"

Three different form of development, derived from 3 same origins.
In our case; the shared form is going to transform into a building which shares a DNA from Kaunas.

Journey is about the begin.

3- PROCESS.



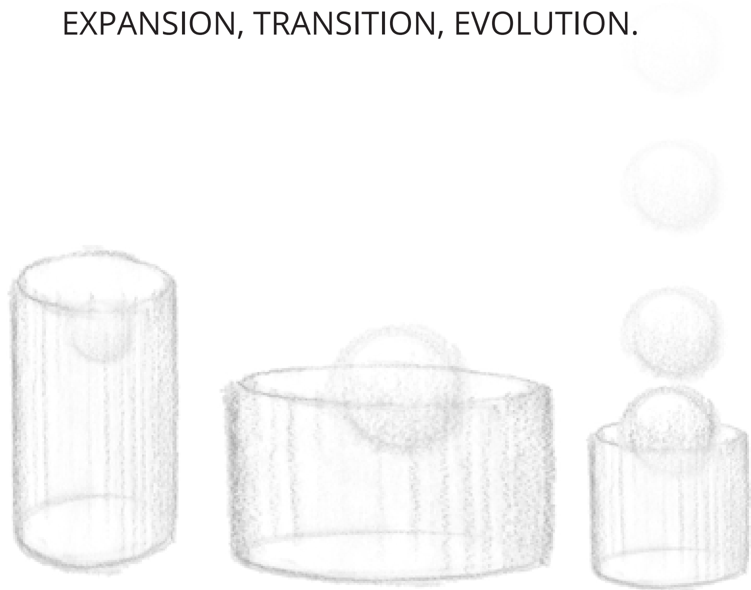


"Activation"

Each process needs an activation energy.

Singular matter and activation energy, catalyst, triggering effect.

EXPANSION, TRANSITION, EVOLUTION.



"Rhytmn, Analogy".

Energy doesn't dissappear in space but transforms.

Transformation happens under external and internal driving forces; location, functions, hierachy.

Evolution and development process as a conceptual analogy for transiton.

Transitions, expansions and contractions happen in multiple dimensions.

MEMORY.

"Hierarchy".

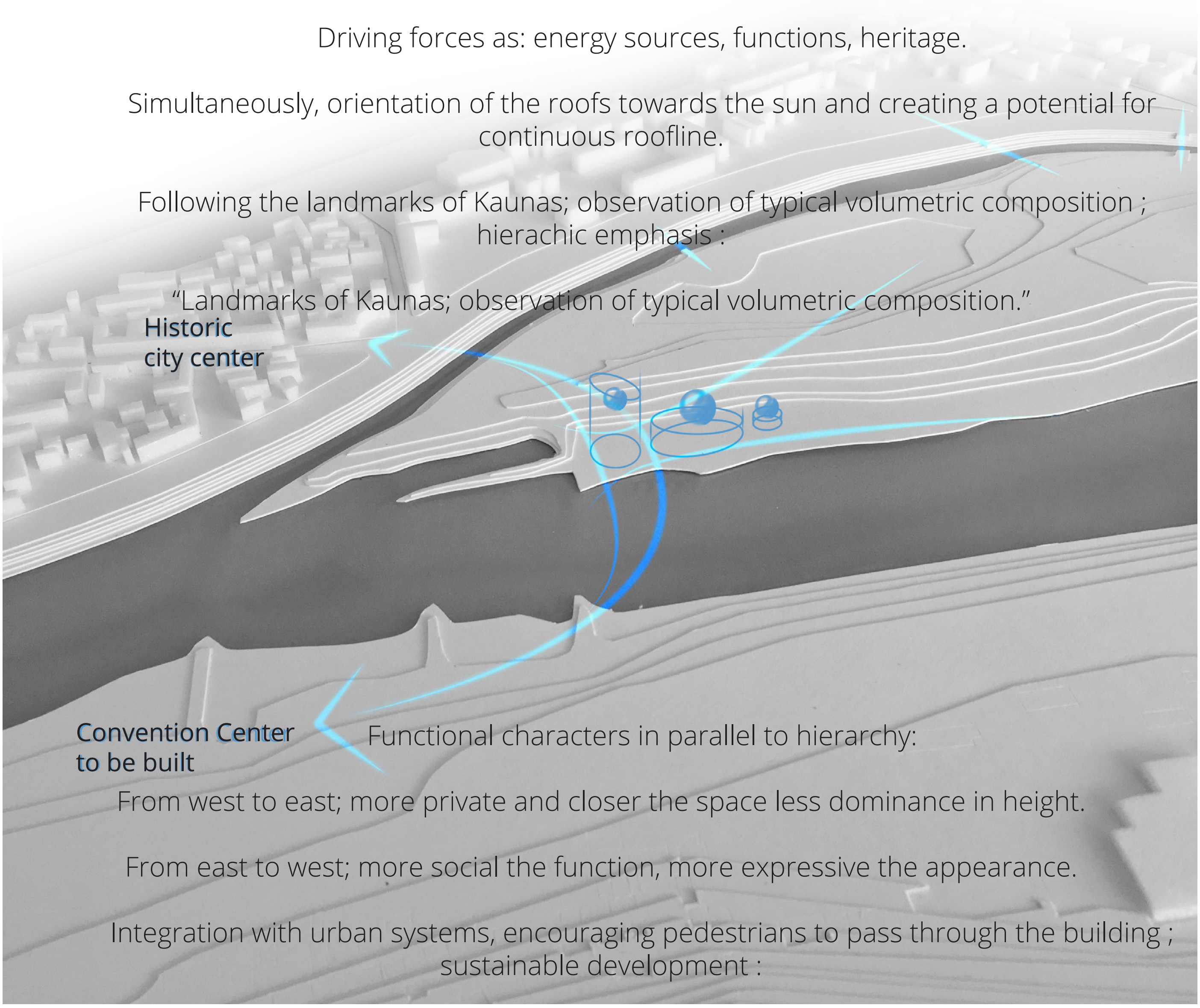
- Advanced adaptation to local conditions in time.

Driving forces as: energy sources, functions, heritage.

Simultaneously, orientation of the roofs towards the sun and creating a potential for continuous roofline.

Following the landmarks of Kaunas; observation of typical volumetric composition ; hierachic emphasis :

"Landmarks of Kaunas; observation of typical volumetric composition."



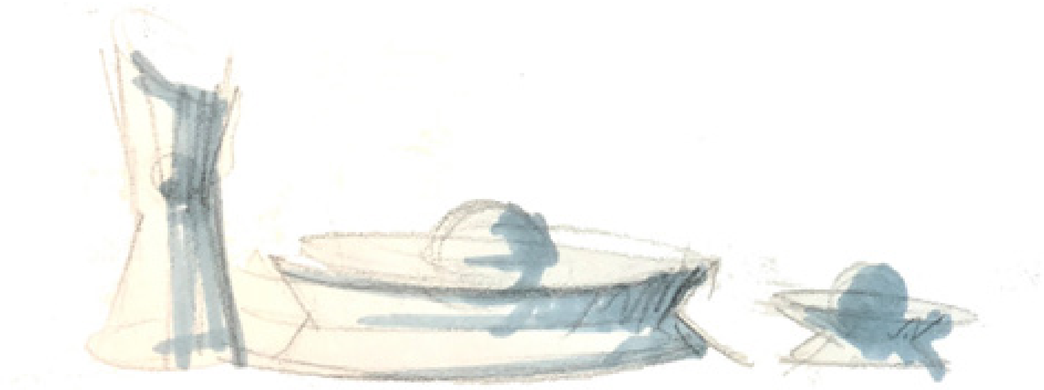
Functional characters in parallel to hierarchy:

From west to east; more private and closer the space less dominance in height.

From east to west; more social the function, more expressive the appearance.

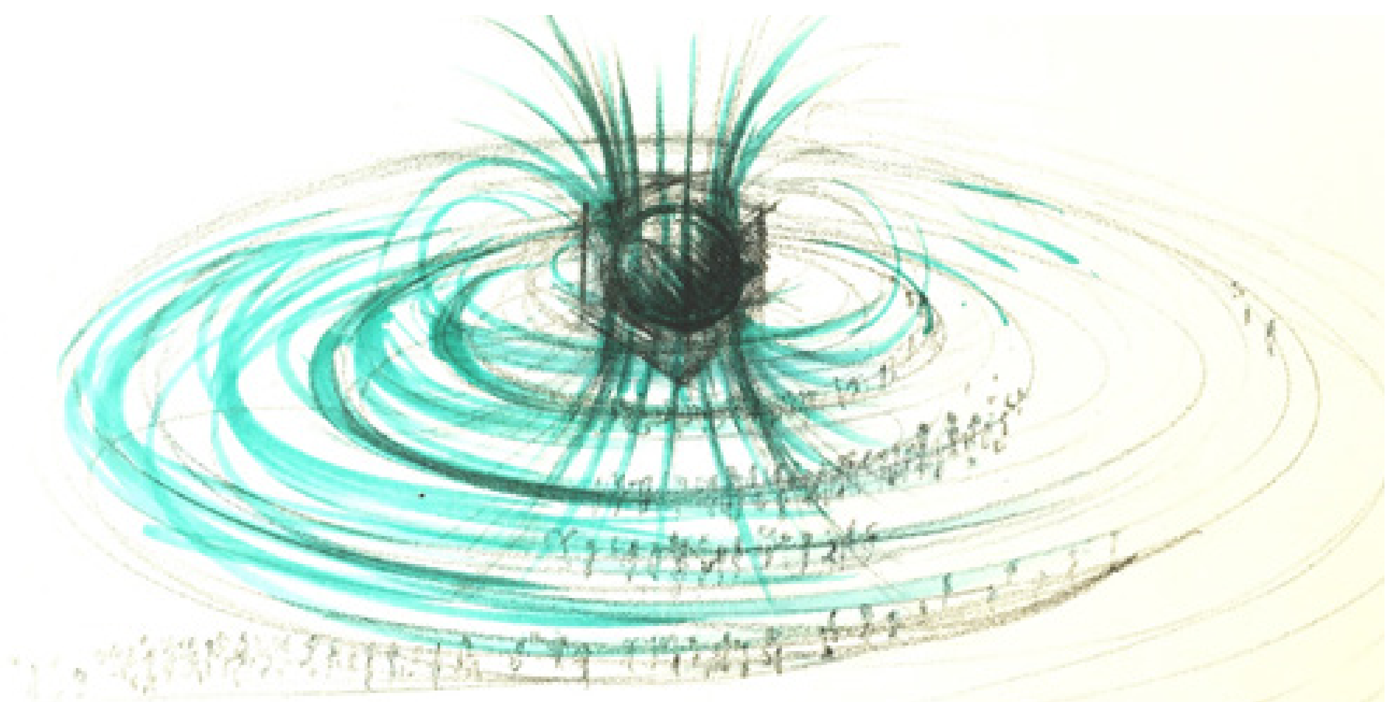
Integration with urban systems, encouraging pedestrians to pass through the building ; sustainable development :

INSPIRATION.



"Analogy".

Conceptual references in transition; continuous transition in the form of expansion, contraction and circles in the cosmos.

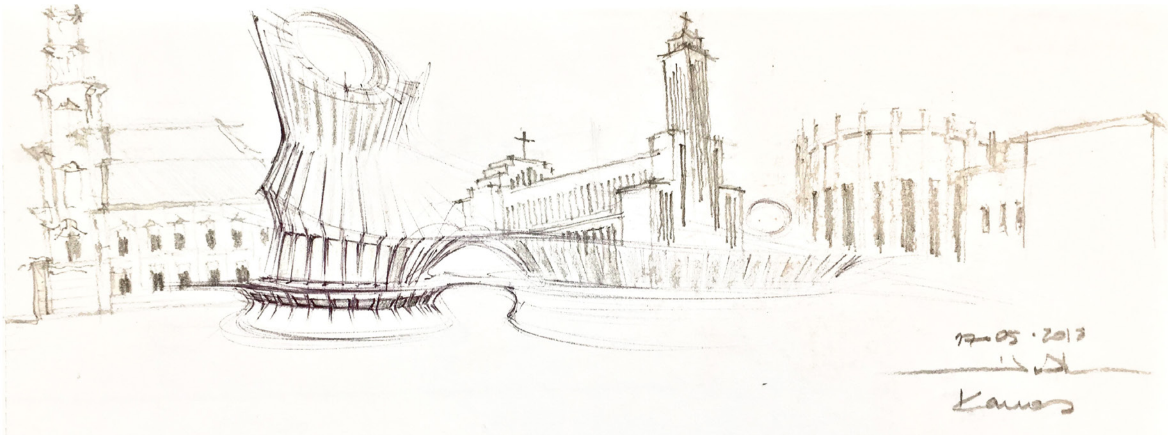


LINKS.

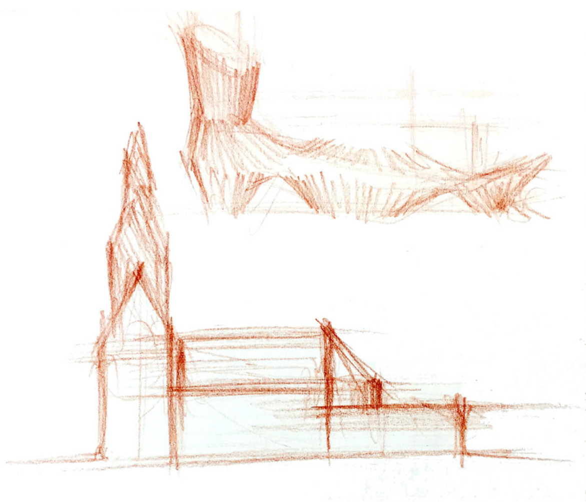
"Analogy".

Physical links and permeability of masses.

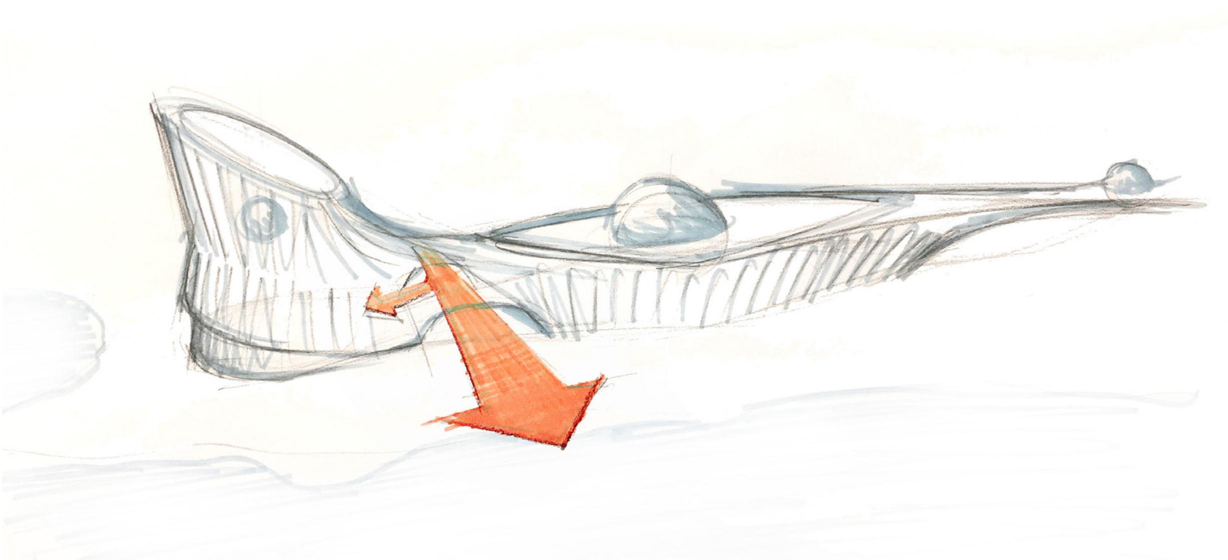
"Observation of the "White swan" analogies for the landmarks, pure and vertical expressions in the Baltic texture."



City Hall, Conceptual Sketch for Science Museum, Christ's Resurrection Church, Art Museum.



REFINEMENT PROCESS; ORDER, CIRCULATION, MASSIVE DIVISION, FUNCTIONS.



Driving forces as; functions, energy strategies, spatial requirements, principal orders.
Refining after energy studies;
Three major spatial composition; Tower, Bridge, Longitudinal Expansion (exhibition spaces).

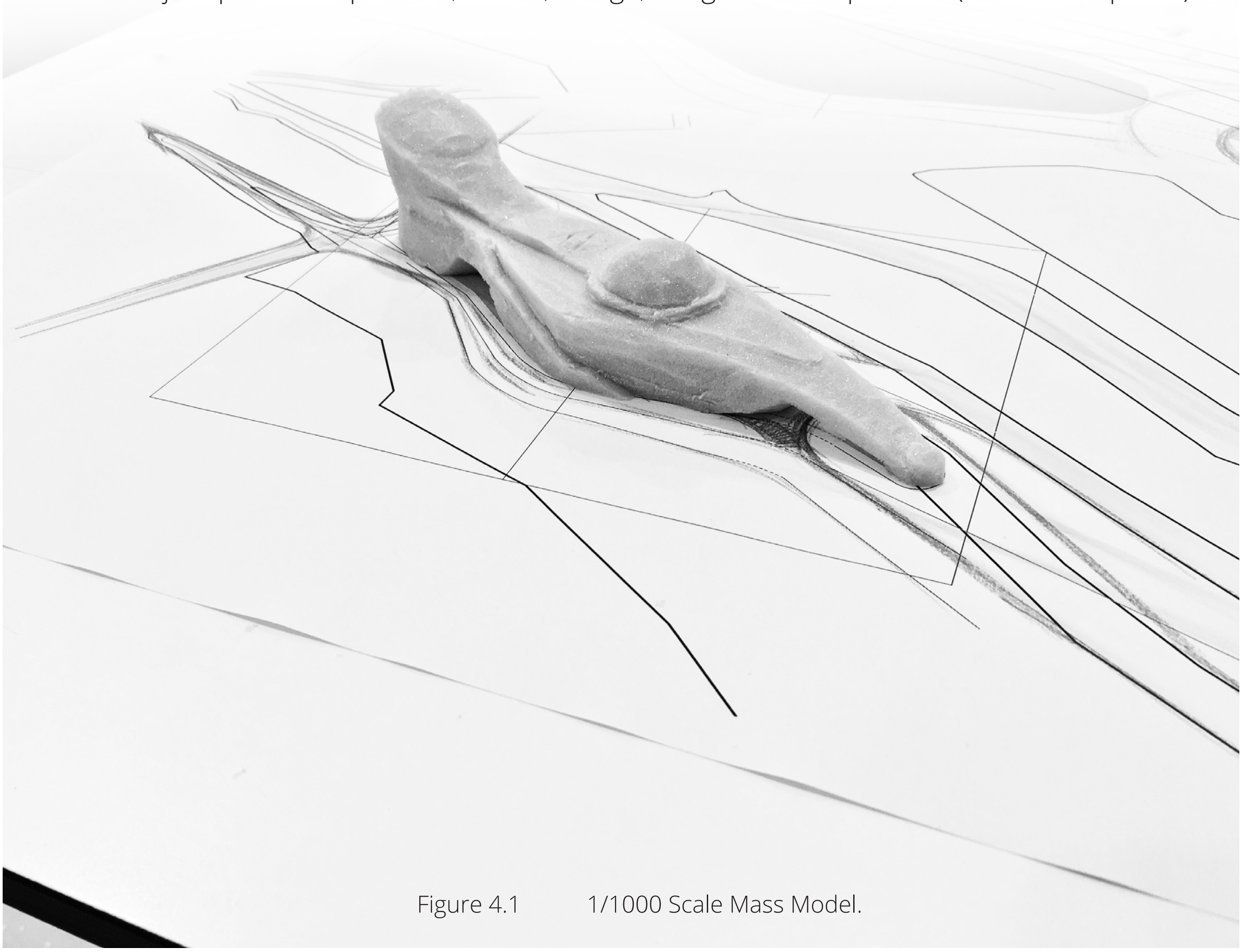
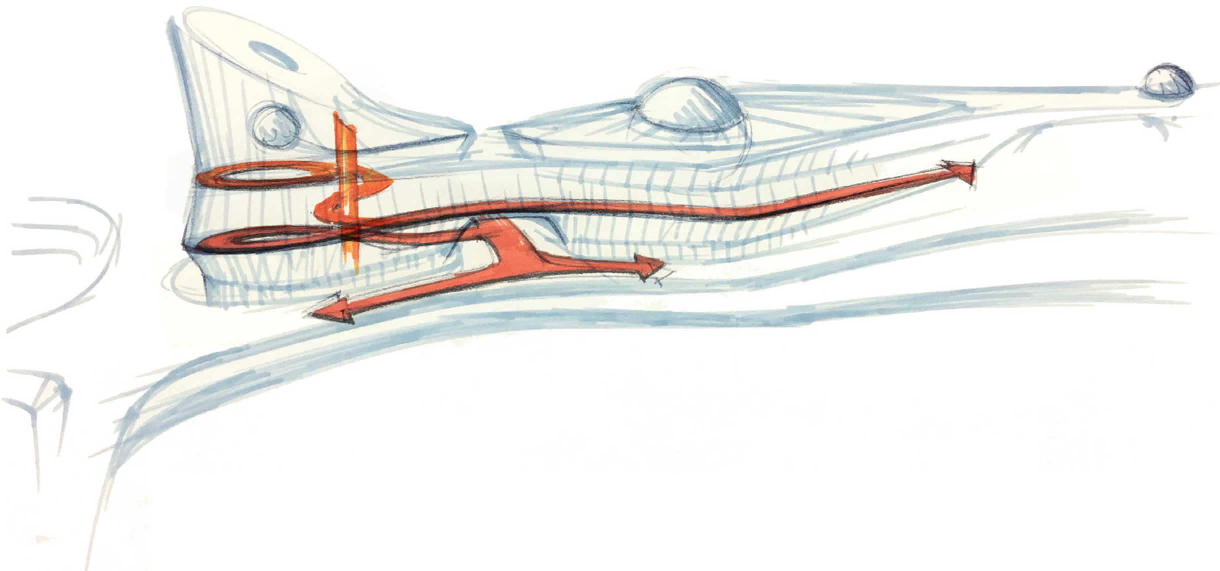


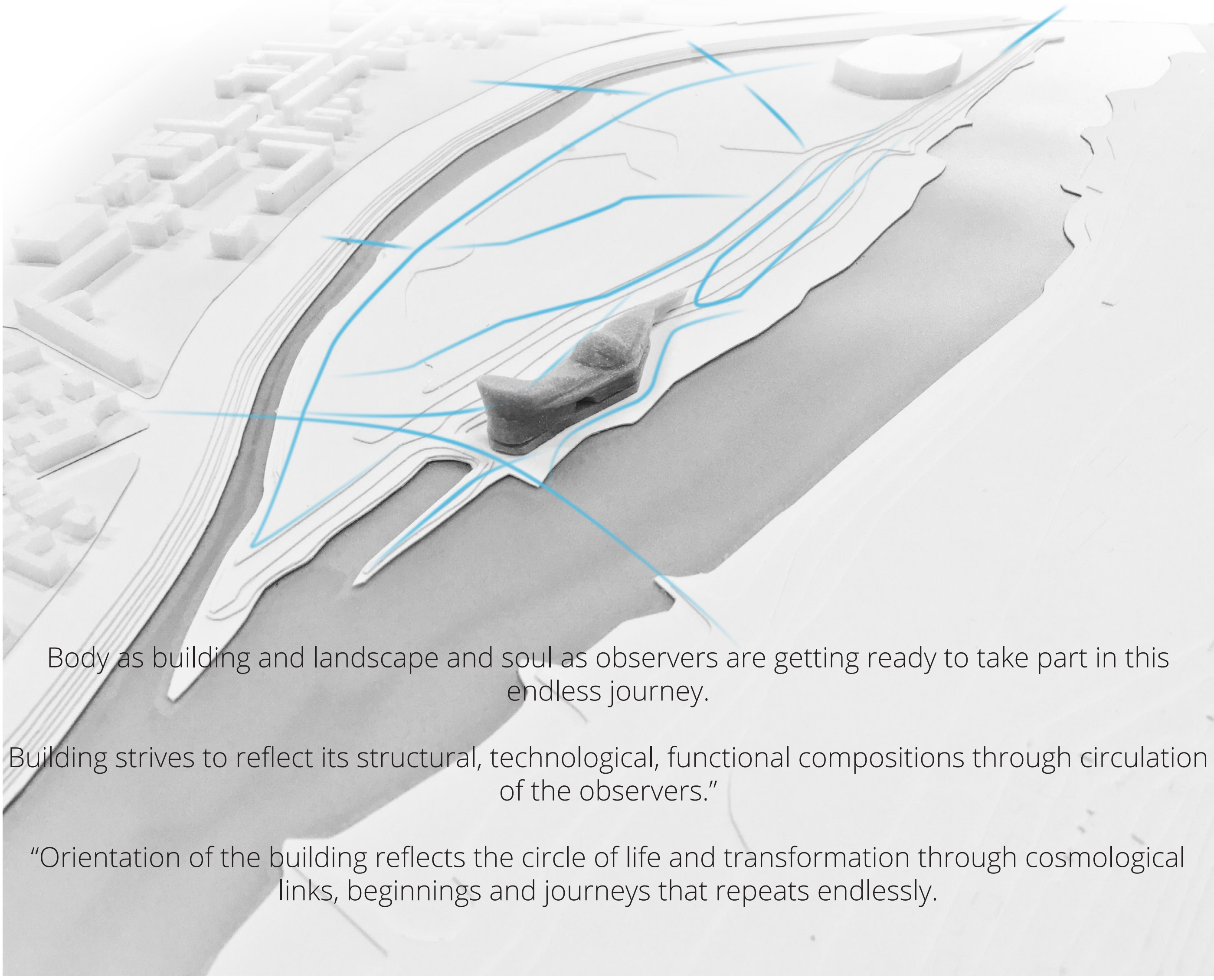
Figure 4.1 1/1000 Scale Mass Model.

REFINEMENT, INTEGRATION OF ELEMENTS, TRANSITION, JOURNEY.



Driving forces as; Structure, Circulation, Daylight, Spatial Requirements.

"Evolution process improves the integration; in terms of interactions. Interaction of location, building, environment and observer."

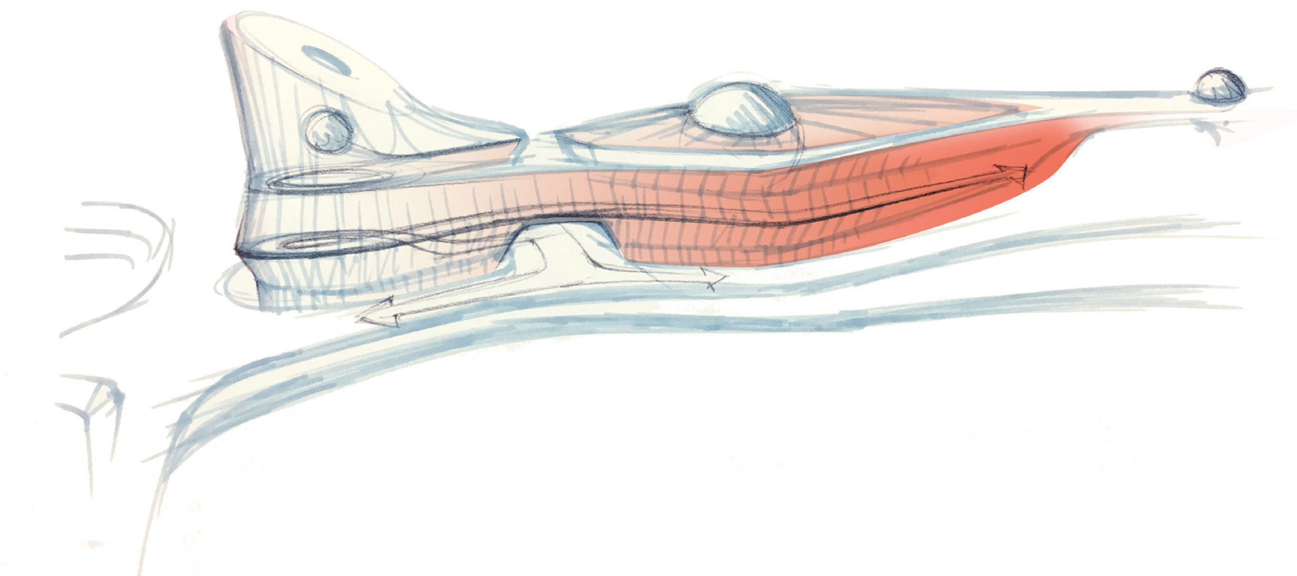


Body as building and landscape and soul as observers are getting ready to take part in this endless journey.

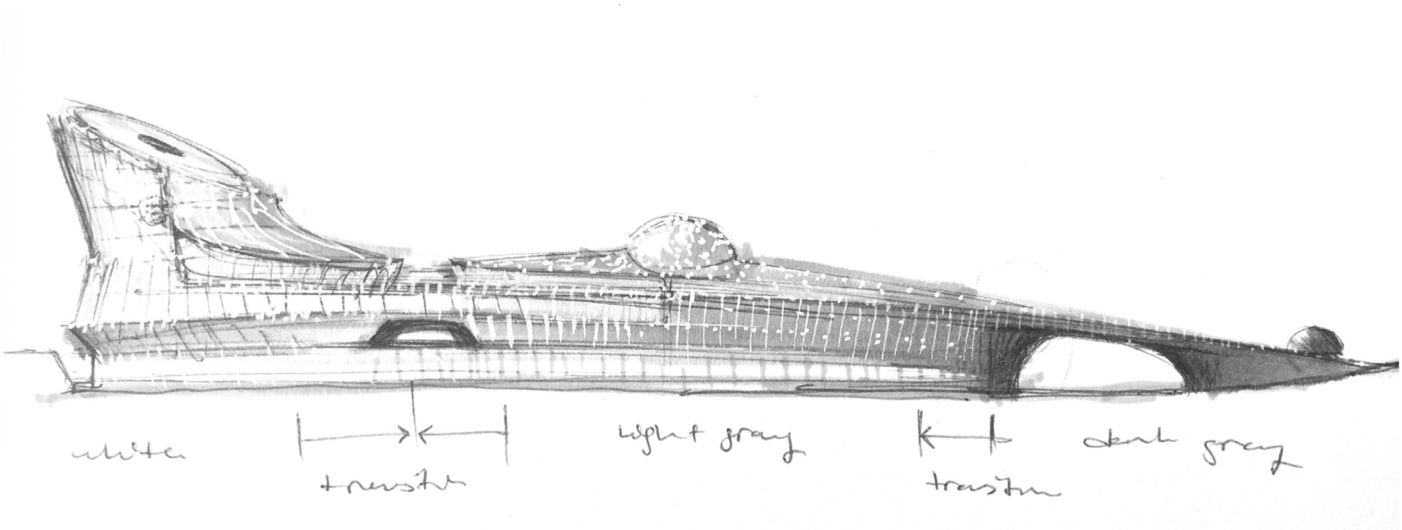
Building strives to reflect its structural, technological, functional compositions through circulation of the observers."

"Orientation of the building reflects the circle of life and transformation through cosmological links, beginnings and journeys that repeats endlessly.

MAIN PRINCIPLES AFTER EVOLUTION PROCESS.



Building adapts itself to the location through landscape and connections, maturity of the composition evolves towards final building, all the pieces are being brought together around holistic design principles.

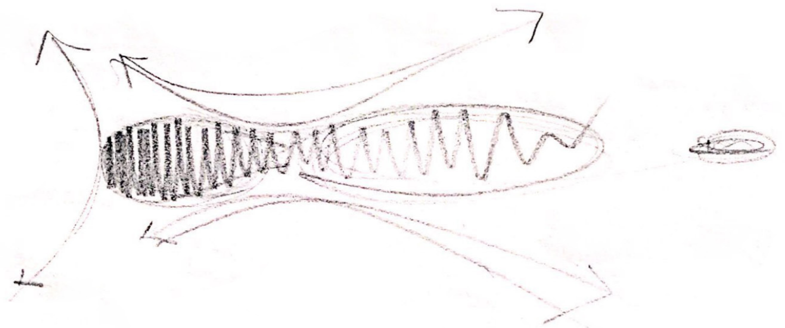


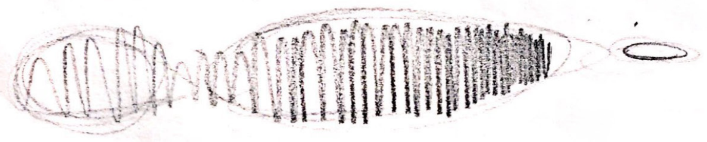
“Transition” begins from east to west through “expansion”, therefore, density of the mass decreases, with transition of grey tones to white between 3 major tones; dark grey, light grey and white.

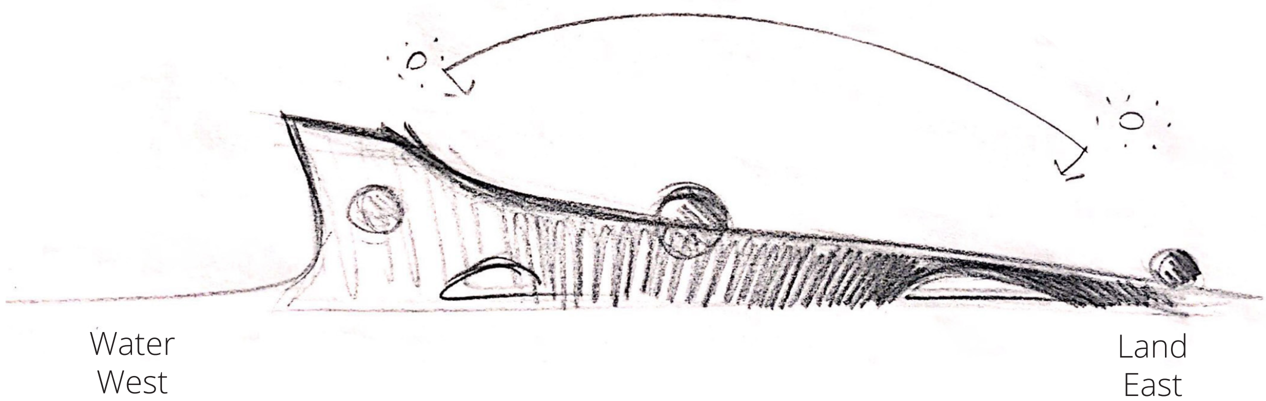
This transition also effects the transparency ratio by increasing from east to west, in parallel to private/social space transition, as it increases the height of the building. As a result; building prioritize its social side and welcomes visitors, attracts the citizens towards this composition of hierarchy, inspired by their city, Kaunas...

SOCIAL BEHAVIOUR THROUGH PRICNCIPLES.

“Transition and Graduality focal regions”.



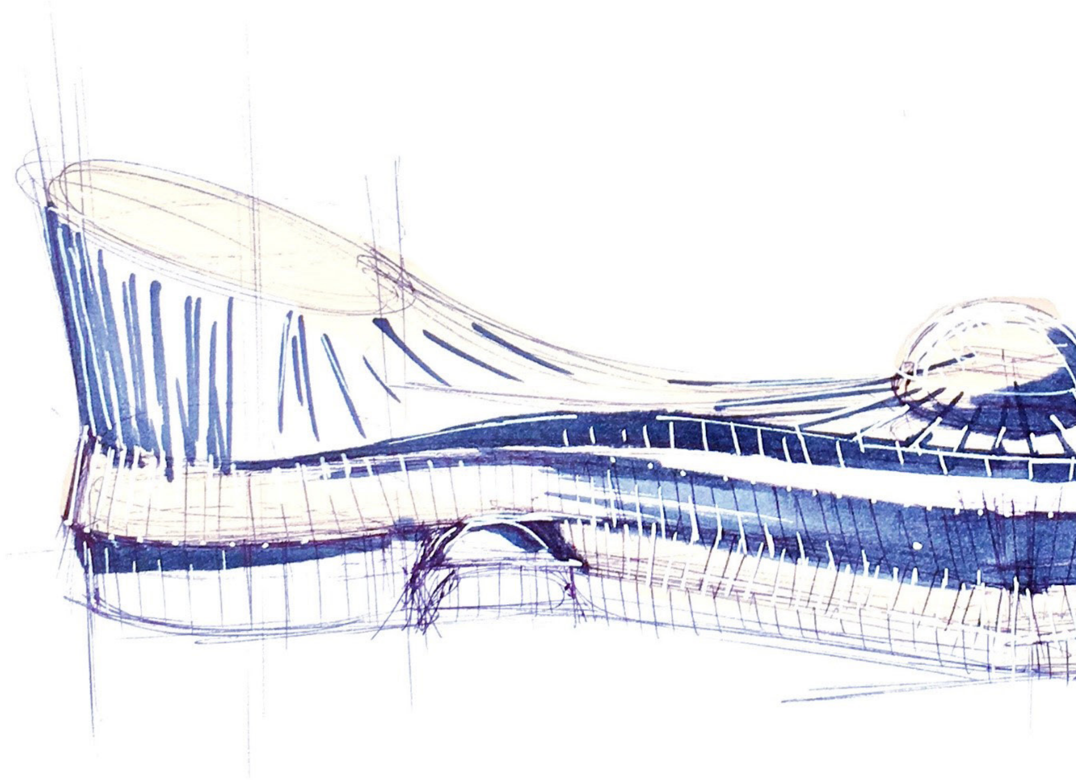


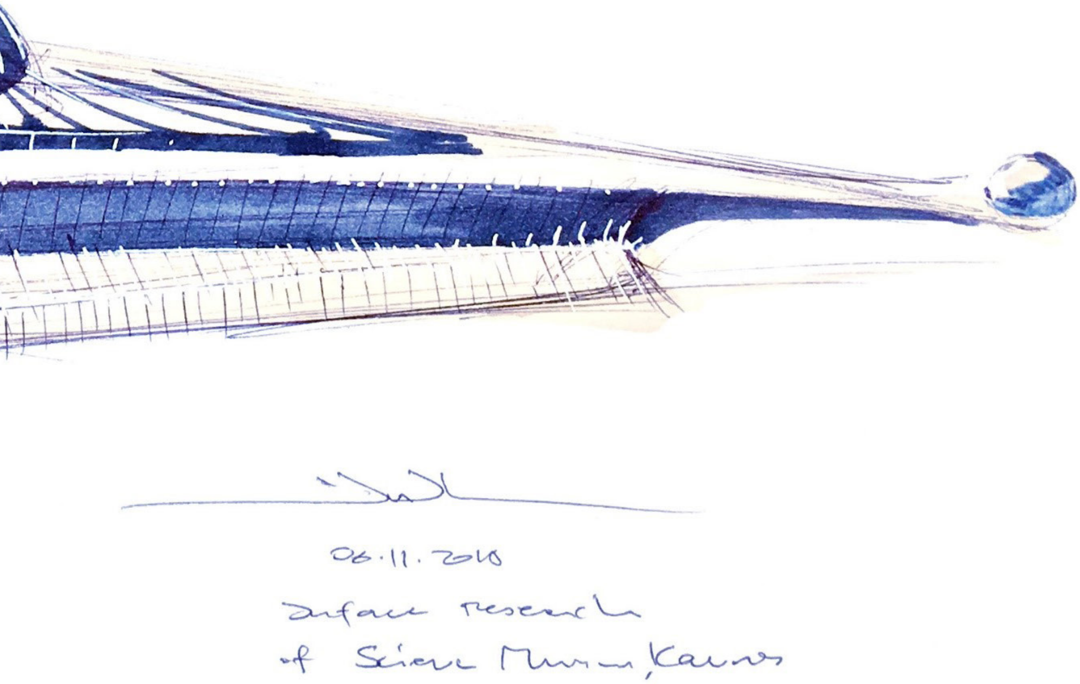


“MACHINE, HUMAN, NATURE”

Final principal composition within the Journey.

From nature to machine, back to the water in an invasive behaviour, message of cycles from east to west, transition between different forms of common matter.

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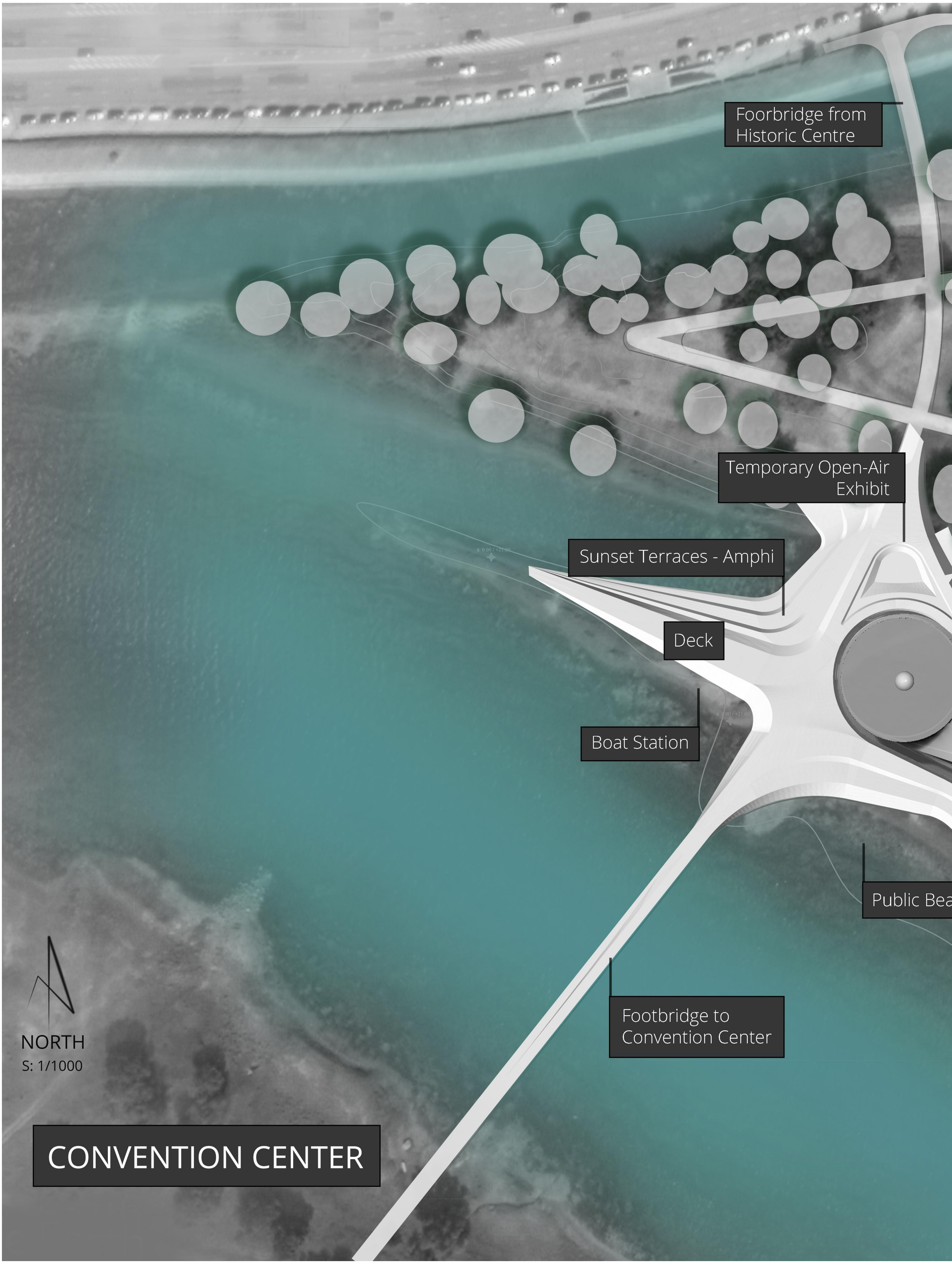
|MASTER PLAN|


Foorbridge from
Historic Centre
Temporary Open-Air
Exhibit
Sunset Terraces - Amphi
Deck
Boat Station
Public Bea
Footbridge to
Convention Center
NORTH
S: 1/1000
CONVENTION CENTER


Foorbridge from
Commercial Centre
NEMUNAS ISLAND
Open-Air Exhibition;
Staff Entrance
Main Entrance
Service Area
Accessible Roof
Info-point
SCIENCE CENTRE
ach
Loading Bay Entrance
East Amphi
Theatre

|BUILDING OPTIONEERING|

Evolving from the architectural concept, the first step in the design process took into account the fundamental ratio between envelope surface (S) and volume of the building (V). This ratio, together with the use of energy performance parameters, helped in defining the optimal shape of the building to reduce the energy consumption.

Naturally the design has to take into account the architectural requirements, urban interventions and the site characteristics. Therefore, the procedure followed three steps:
- Design choice for the shape of the mass.
- Optioneering for massing and window-to-wall ratio.
- Optimization of the energy performance.

The process aimed to improve the results, done with the use of Ladybug and Honeybee tools for Grasshopper (Rhino5). For better optioneering, Design Explorer has been used. Developed by CORE studio, Design Explorer, is an open source tool for exploring design spaces on the web. It is an interface that lets us visualize and filter groups of iterations - sets of design solutions that are both intimately related, and potentially scattered across a vast, high-dimensional possibility space.

In this regard, the following inputs were given with the mentioned range:
- Radius of building A (12 – 20 m)
- Height of building A (32 – 40 m)
- Radius of building B (32 – 38 m)
- Height of building B (16 – 24 m)
- Bridge Depth (8 – 16 m)
- Window-to-wall ratio (0.0 – 0.8)

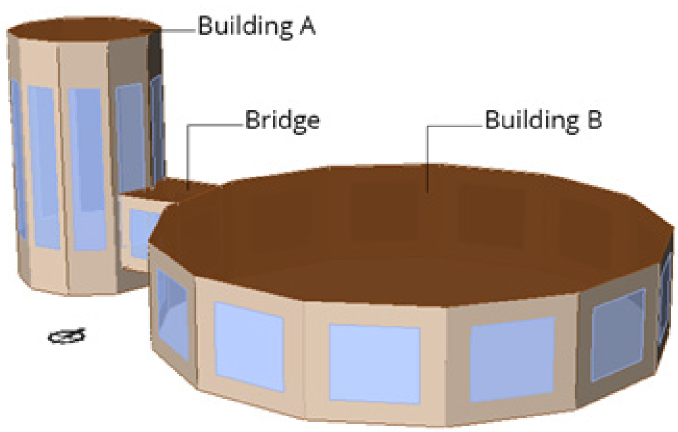
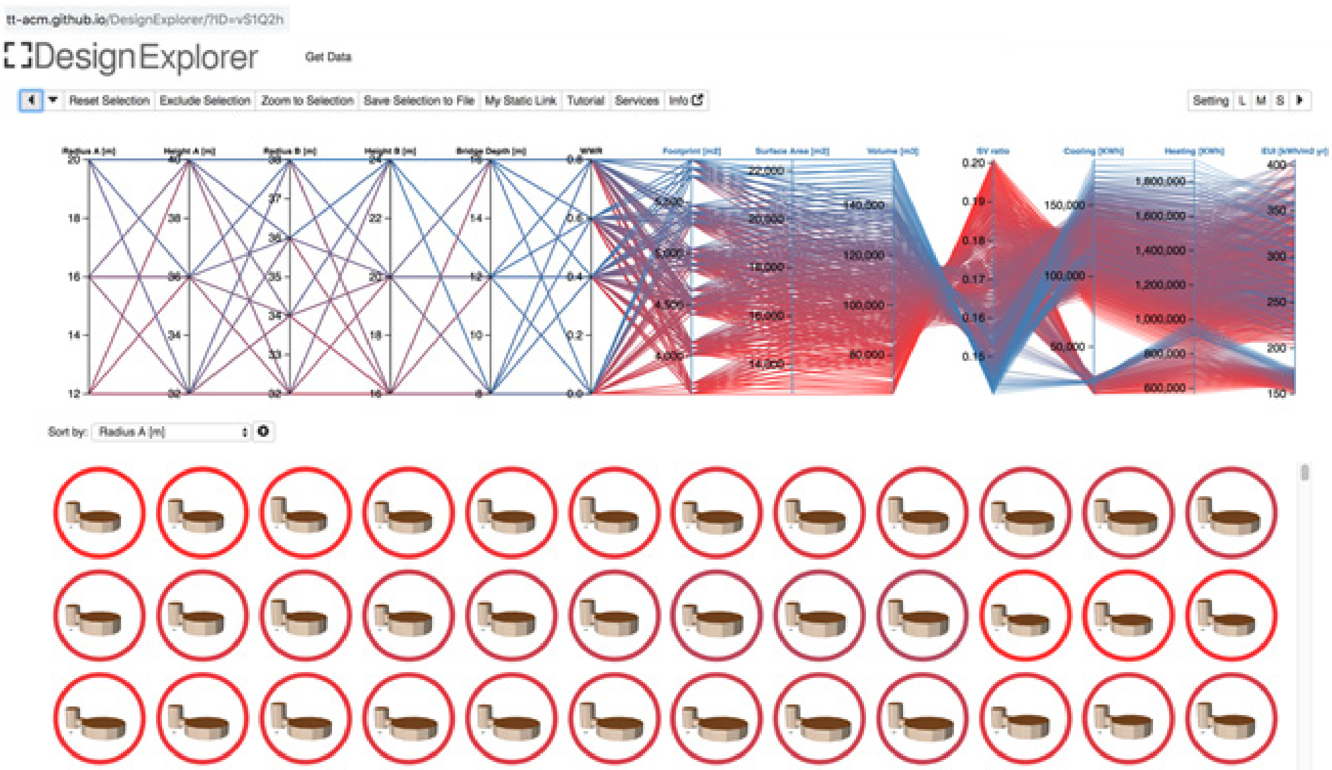


Figure 4.2 Scheme of building model.

And the following outputs were extracted:
- Footprint (m2)
- Total Surface Area (m2)
- Total Volume (m2)
- SV ratio
- Cooling Load (kWh)
- Heating Load (kWh)
- Energy Use Intensity (EUI) (kWh/m2.yr)
- Total Solar Radiation (kWh).

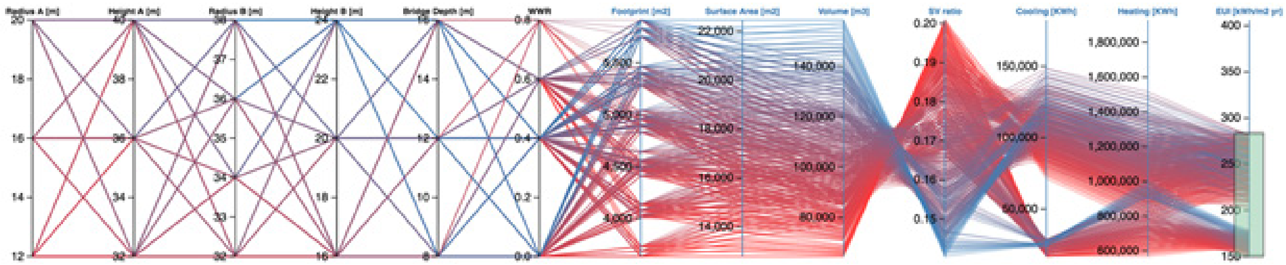
The results for this optioneering are freely available online on this link:
https://goo.gl/vS1Q2h, or this QR code.

The Design Explorer interface is quite user-friendly and allows easy filtering and sorting within different input and output groups.



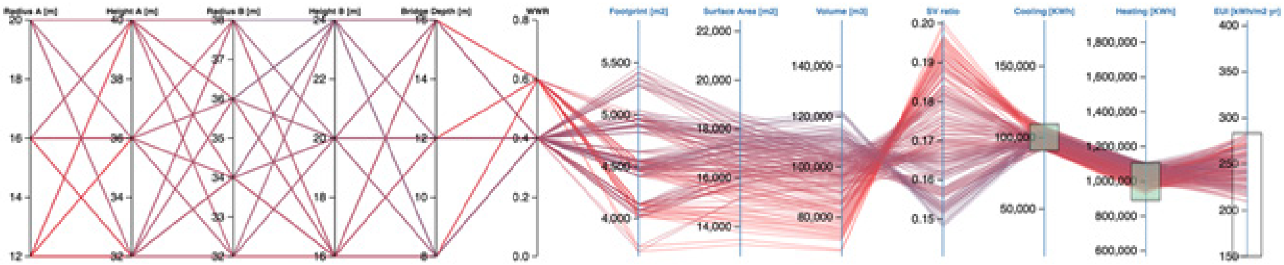
OPTIONEERING 1

For relatively better energy performance, EUI between 150 – 270 kWh/m2.yr



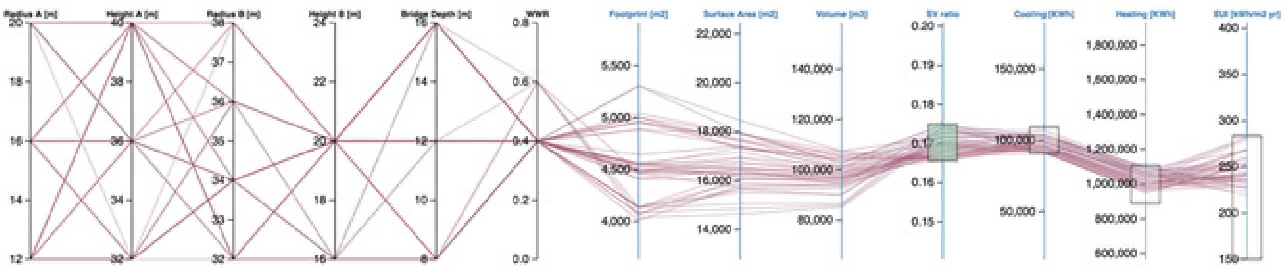
OPTIONEERING 2:

For reducing overall cooling and heating loads. Cooling load between (90,000 kWh – 110,000 kWh), and heating load between (900,000 – 1,100,000 kWh)



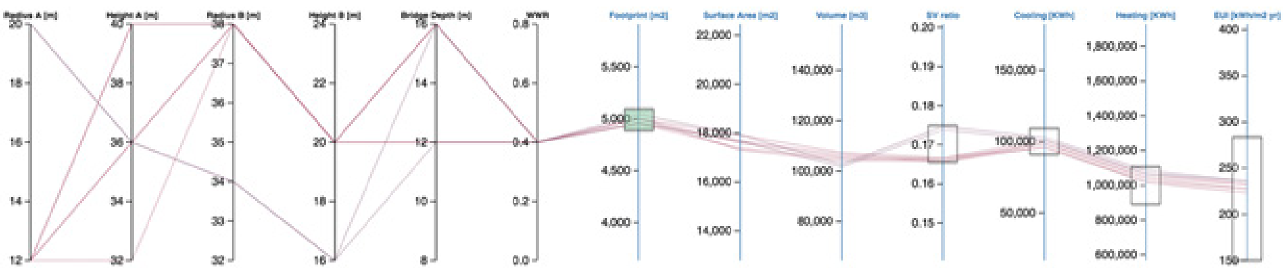
OPTIONEERING 3

SV ratio between 16.5 – 17.5

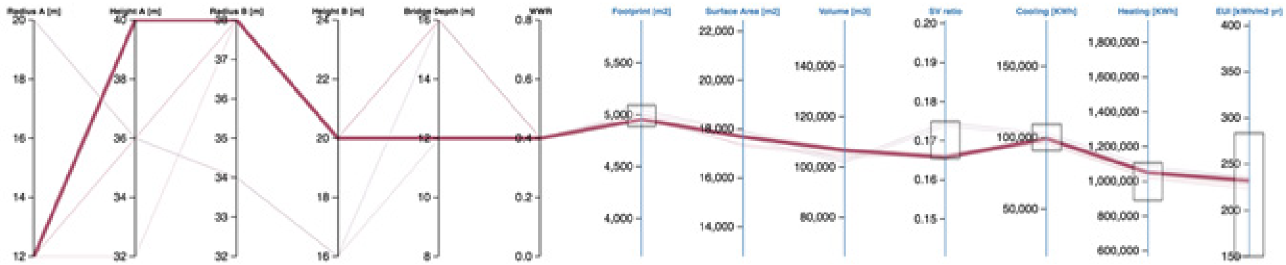


OPTIONEERING 4:

Footprint ~ 5000 m2, based on design brief.



Final choice: considering the optioneering results and architectural requirements, the following option was deemed most suitable.



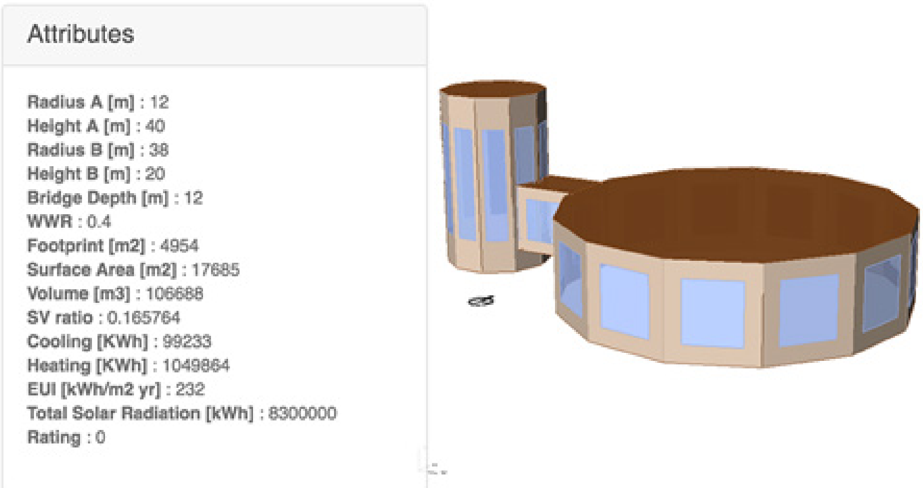


Figure 4.3 Final attributes given to the building.

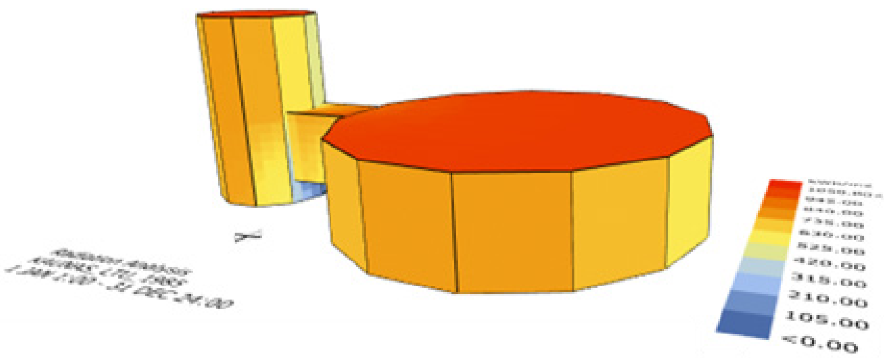


Figure 4.4 Annual solar radiation analysis.

This analysis contributed in understanding the general energy performance for this complex mass. The heating loads are rather high, which is addressed later in the analysis for HVAC systems. Also different strategies are used to reduce the high EUI value.

|SPACE OPTIMIZATION|

"Configuration as the way spaces are related to each other in order to serve a functional purpose is the very nature of architecture"

A design methodology and a toolkit developed as a parametric CAD program for configurative design of architectural plan layouts, Space Syntax, was used. From an analytical point of view, the theory of Space Syntax provides a comprehensive and consistent framework for understanding spatial arrangements and their likely human effects, which we can be termed as social performance of the buildings. Using this toolkit, designers can start plan layout process with sketching the way functional spaces need to connect to each other.

. The tool draws an interactive bubble diagram and a set of tools reveal feasible geometric interpretations of the proposed bubble diagram in terms of plan layout graphs. It offers real-time analyses, and provides feedback on the spatial performance, which is translatable into the likely social performance of the plan layout patterns.

For the purpose of this project, this tool was used to understand the social performance of spaces for the services floor and optimise the distribution based on the various indices it calculates.

STEP 1: PREPARING THE INPUT

The process starts by making a number of arbitrary points for defining the centre of functional spaces along with a corresponding list of area values and spatial labels for them.

0: Office space 1, 200sqm
1: Office space 2, 124sqm
2: Office space 3, 124sqm
3: Office space 4, 188sqm
4: Meeting Rooms, 76sqm
5: Copy/Resource Room, 18sqm
6: Local archive storage, 24sqm
7: Coffee/Staff Room, 30sqm
8: Sanitation 1, 36sqm
9: Sanitation 2, service shaft, 70sqm
10: Hot-desking space, 58sqm
11: Lunch Room, 36sqm
12: Staff-service entrance, 46sqm
13: Security, 36sqm
14: Loading Bay, 146sqm
15: Delivery, packing, crate storage, 176sqm
16: Exhibition, preparation, storage, 412sqm
17: Workshops, 294sqm
18: Workshop storage, 58sqm
19: Workshop office, 30sqm
20: Furniture storage, 58sqm
21: Cleaner's room(s), 58sqm
22: Refuse, recycling room, 42sqm
23: IT Room, 118sqm
24: HVAC, 588sqm
25: Buffer Zone, 46sqm
26: Research lab, 294sqm

Figure 4.5 Function and area of spaces on the services floor.

STEP 2: PRODUCING A CONNECTIVITY GRAPH

These points (representing functions) are connected using a line, based on their linkages as per architectural requirements. These links eventually would need the rooms to be adjacent to one another in order to be accessible immediately. This is to say that a set of connectivity requirements can be thought of as a subset of an adjacency requirements set.

Figure 4.6 Links between functions.

STEP 3: SPACE SYNTAX ANALYSIS

The theory of space syntax is focused on how spatial units relate to one another in buildings and built environments. In the tool suite, a few measures have been implemented which help in understanding the privacy/communality, spatial articulation and other spatial qualities, by using the following representations and indices:

Depth map: shows how many topological steps a single space is away from another one. A distance measured between two nodes on a graph is called the graph theoretical distance between them.

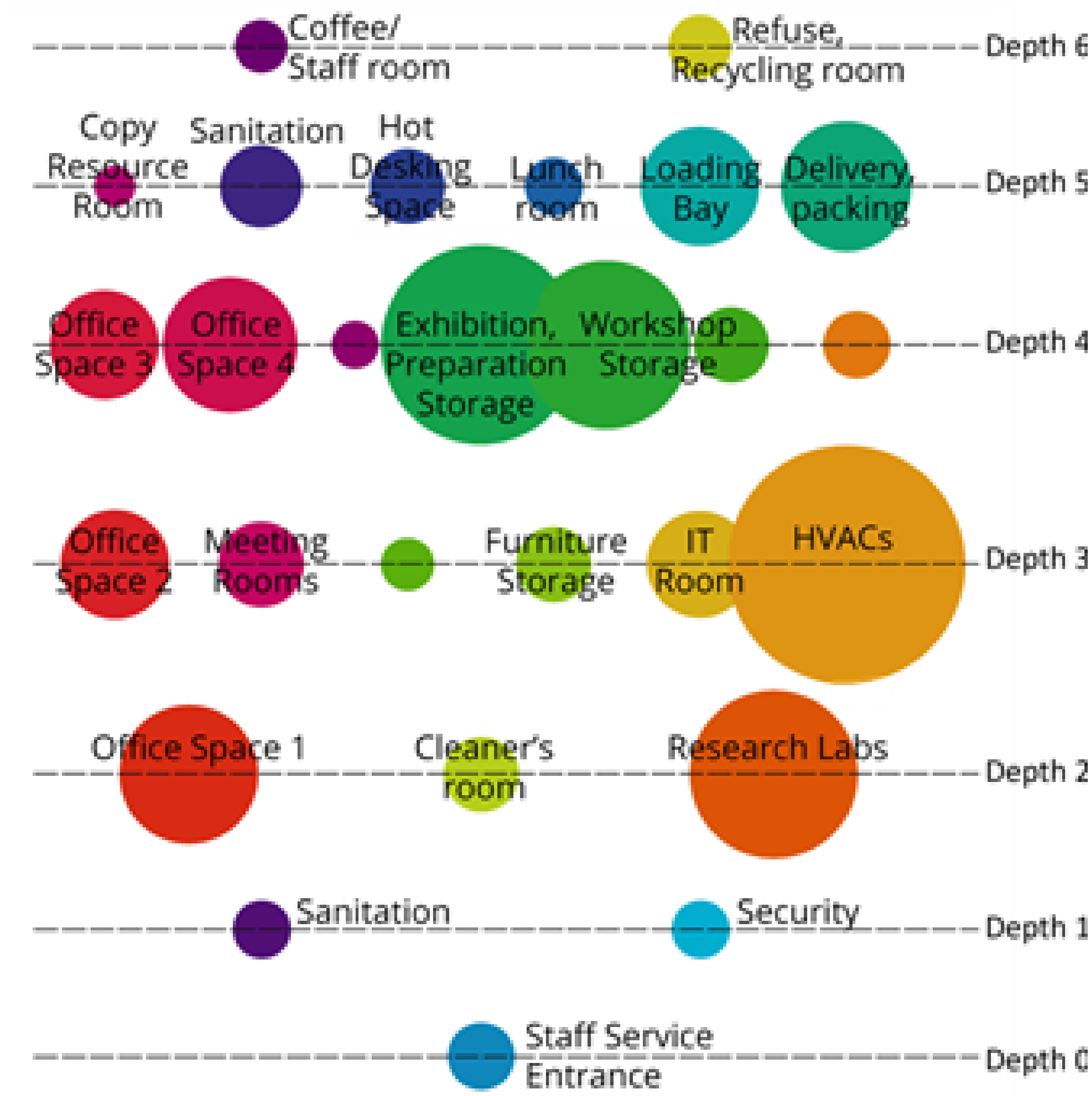


Figure 4.7 Death map from the point of view of staff and service entrance.

Integration: Integration is a measure of centrality that indicates how likely it is for a space to be private or communal. Higher the integration value, the more likely for a space to be communal, and lower the integration value, more private the space.

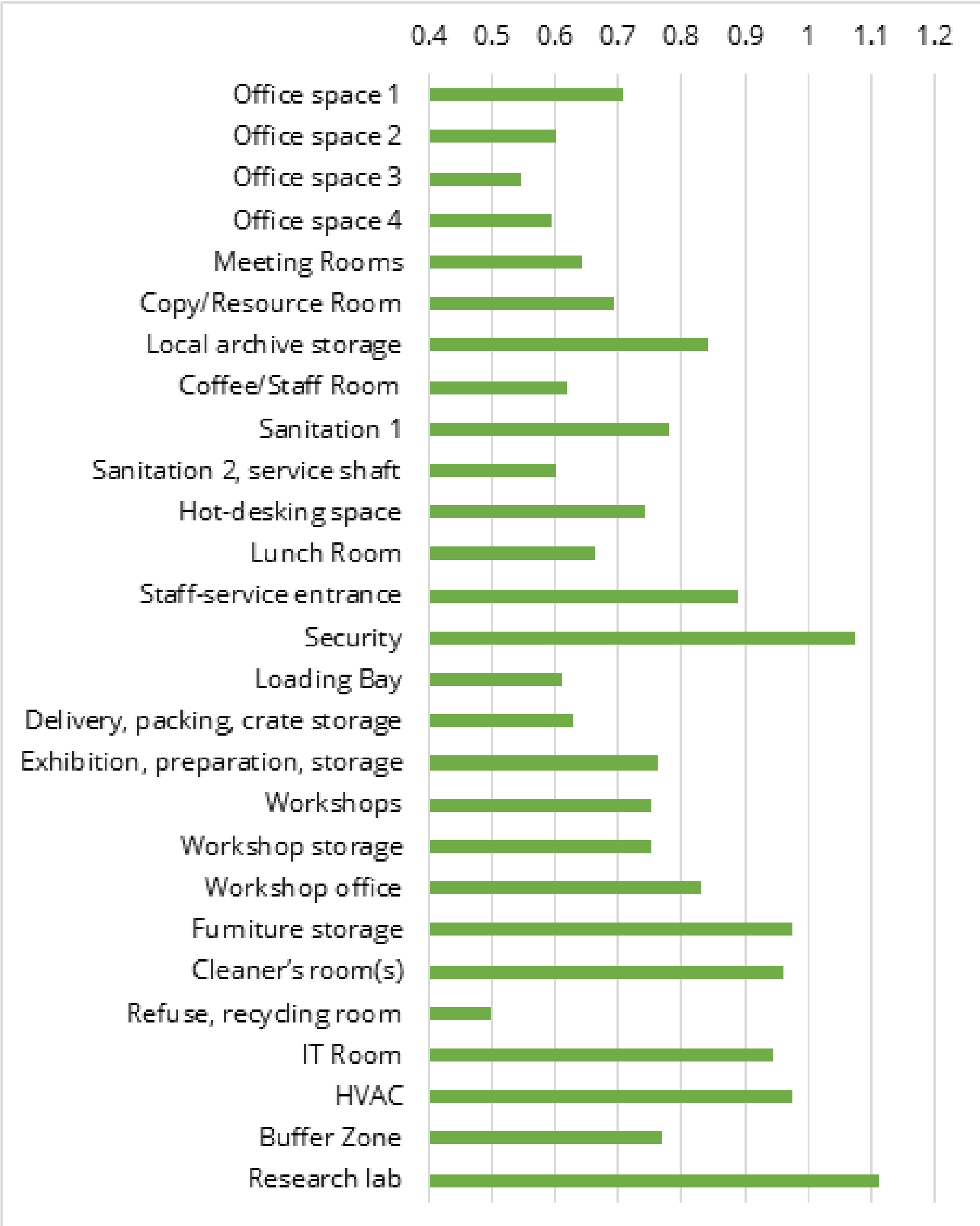


Figure 4.8 Integration values.

- The Office space 3 could be used for the museum director, since its integration value is relatively low and makes it appropriate for the chief.
- The staff-service entrance hall, which is the interface between staff spaces and back-of-the-house spaces, is comparatively communal.

CONTROL VALUE

Indicates how strongly a vertex in a graph (a space in a configuration) is linked to other points in a superior manner.

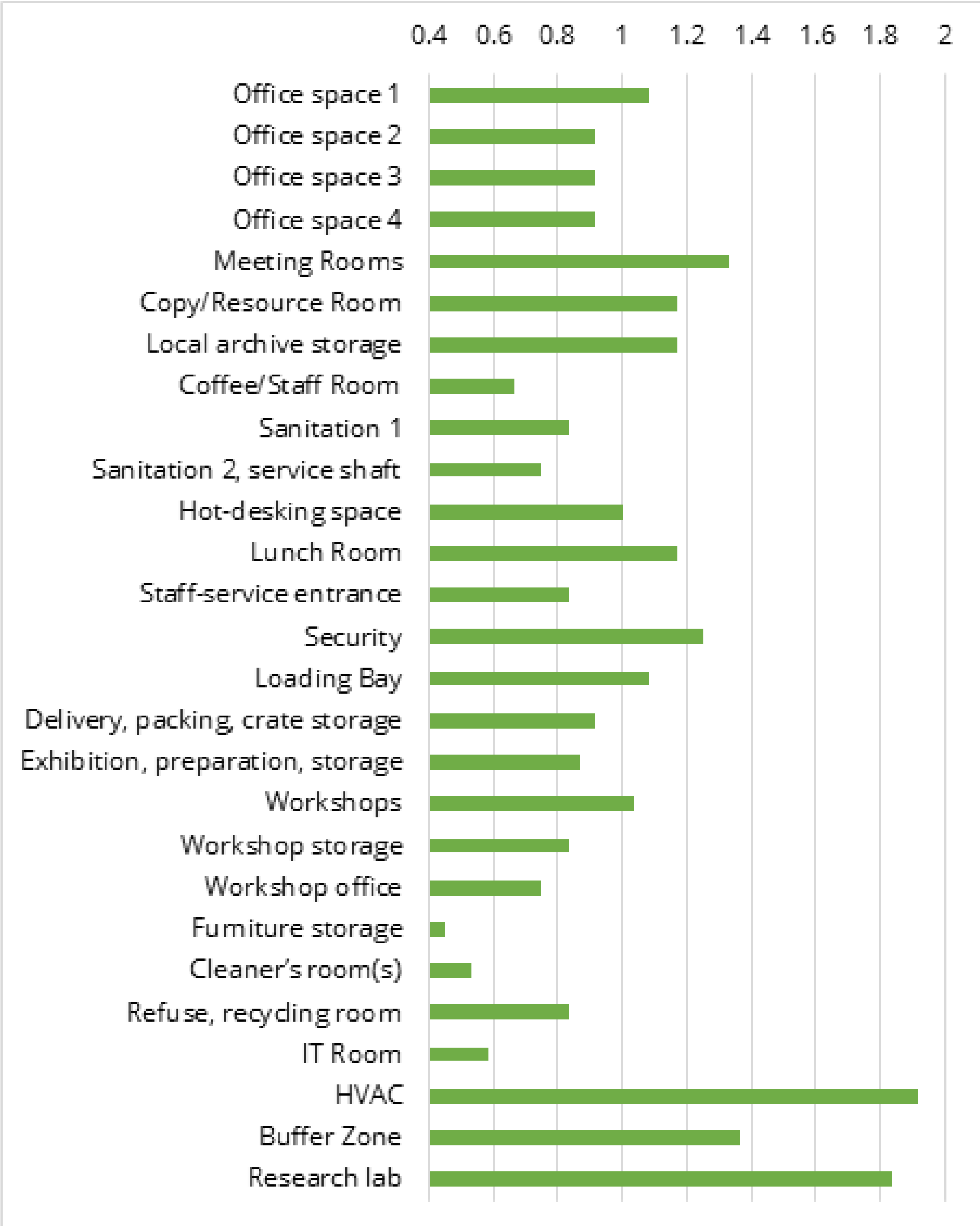


Figure 4.9 Control Value.

- The security room is well linked with other node, so it is easier to reach other spaces from this space and vice-versa.
- The meeting rooms are also better connected to the other spaces.

CHOICE OR BETWEENNESS

Choice is a measure of importance of a node within a configuration. That literally tells how many times a node happens to be in the shortest paths between all other nodes.

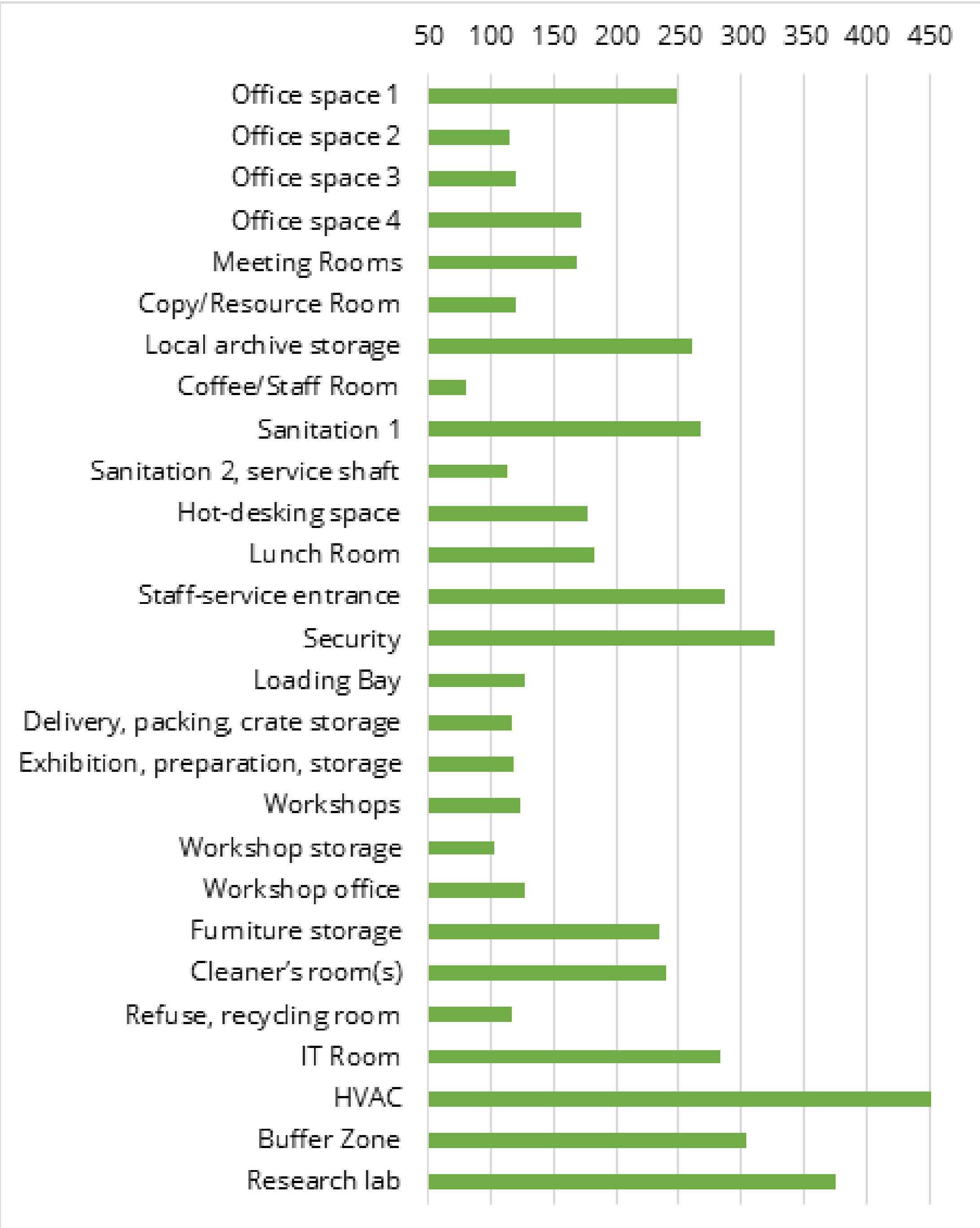


Figure 4.10 Choice values.

- The workshops, which are provided for woodwork, metalwork and finishing are secluded from the other spaces, and so are the other storage spaces.
- The security room happens to be in the shortest paths between other nodes.

STEP 4: PRODUCING A UNIQUE CONVEX EMBEDDING OF THE CONNECTIVITY GRAPH

The topological embedding indicates how the vertices of a graph are connected to one another on a surface. It is usually expressed in terms of 'face' descriptions.

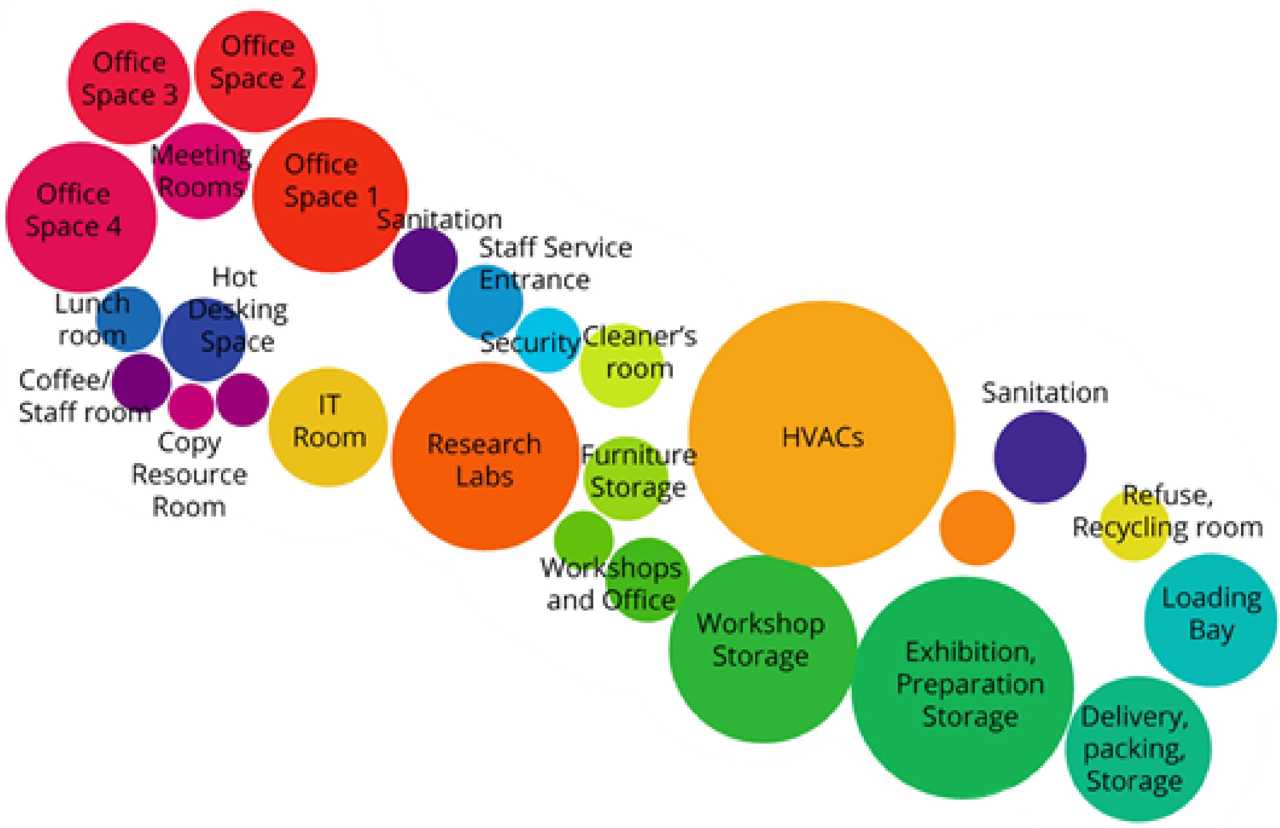


Figure 4.11 Bubble diagram of functions.

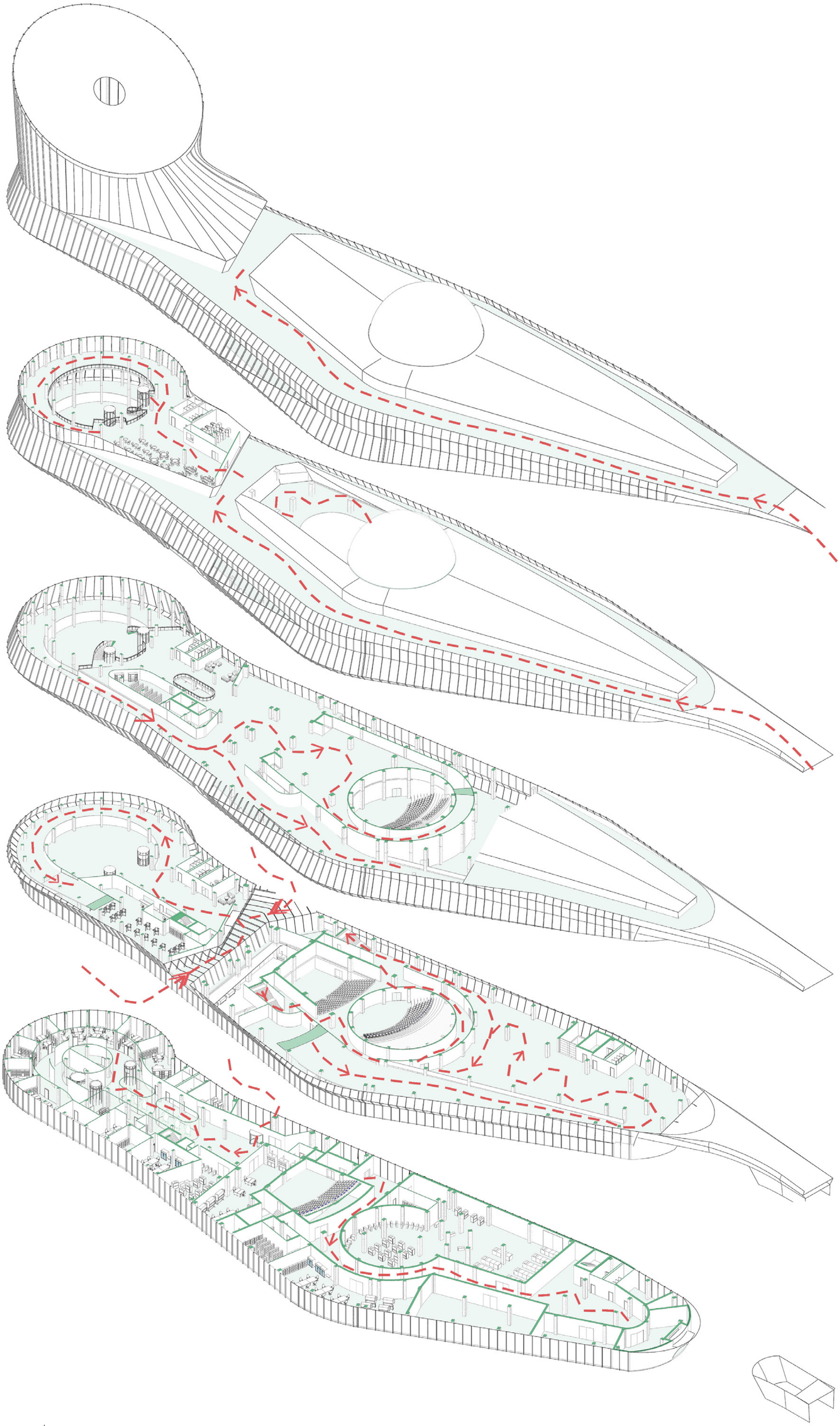
STEP 5: FORCE-DIRECTED GRAPH DRAWING

This tool is quite intuitive and shows in real-time bubble diagrams neatly according to the specified areas and the connectivity graph

Figure 4.12 Force-Directed Graph Drawing.

Using this tool, the relation of one space with the other was analysed in terms of syntactic measures. This helped to look at the spaces individually and focus on their morphological aspects and their geometrical state of being. Moreover, the use of various indices helped in understanding if the proposed plan in terms of a bubble diagram actually matches with the requirements on privacy/ community, spatial articulation and other spatial qualities.

|CIRCULATION|



Movement

Figure 4.13 irculation diagrams

The movement within the building is mostly **peripheral**, through open spaces that lead the visitors by the main axis of the science center in the commercial tower and exhibition part.

On the ground floor, the Services are located in order to place the offices and installation rooms needed. An entrance for the employees is distinctively provided, along with an area of 1,200m^2 for mechanical equipment on the same level. The **main entrance** to the Science Centre is located at the level of +5.50m. The visitors have access to the **Tower part**, where the reception is. The **ramp** from the entrance guide the visitors to the exhibition spaces through the circumference of the tower with view directed towards the west. As they initiate this journey, they are led to the south river facing part and entering the introductory space., which lands on the height of +10.00m.
I
Here the visitors are given a choice to enter the **temporary or permanent galleries**. The temporary galleries are connected to the event spaces for short excursions or special events. The route to the permanent gallery begins with the **Nature gallery**, gradually going down the ramp to the other permanent galleries, **first Human and subsequently Machine**. These spaces then direct the visitors to the Experimentorium and Planetarium where the visitors head again to the Tower part in order to reach the Souverni Shop and Restaurant. At the Restaurant level they have the chance of expriencing the **panoramic view** of the city.

The **roof is accessible** from the ground up until the restaurant where independent events can be organised.

Movement through and orientation within the Science and Innovation Centre is natural and intuitive, without the need to rely on excessive signage and wayfinding devices. The building enables ease of use, access, movement and orientation, with minimal cross-overs, obstacles, impediments to visual and physical connections throughout.

In organising the building and associated landscape, three separate movement paths (and associated entrances) are provided for the smooth operation of the building:

Visitor paths: The layout of the front-of-house and public spaces is logically arranged to facilitate visitor orientation and movement, and is designed to avoid potential conflicts or specific areas on the public routes where visitors may congregate and thereby create congestion. A separate public entrance for group visits (e.g. schools) is considered within the design. The back-of-house and staff areas are off limits to the public.

Employee paths: Separate paths are provided for staff, and these paths do not conflict with or cross-over visitor routes.

Exhibit paths: Secure, dedicated, uninterrupted, covered and appropriately conditioned routes for exhibits are provided so these exhibits can be delivered, stored and displayed at the Science Centre as and when required. These are staff only spaces, where deliveries can be supervised and adequately designed to accommodate objects of 4 metres x 5 metres x 4 metres in size.

|FUNCTIONAL LAYOUT|

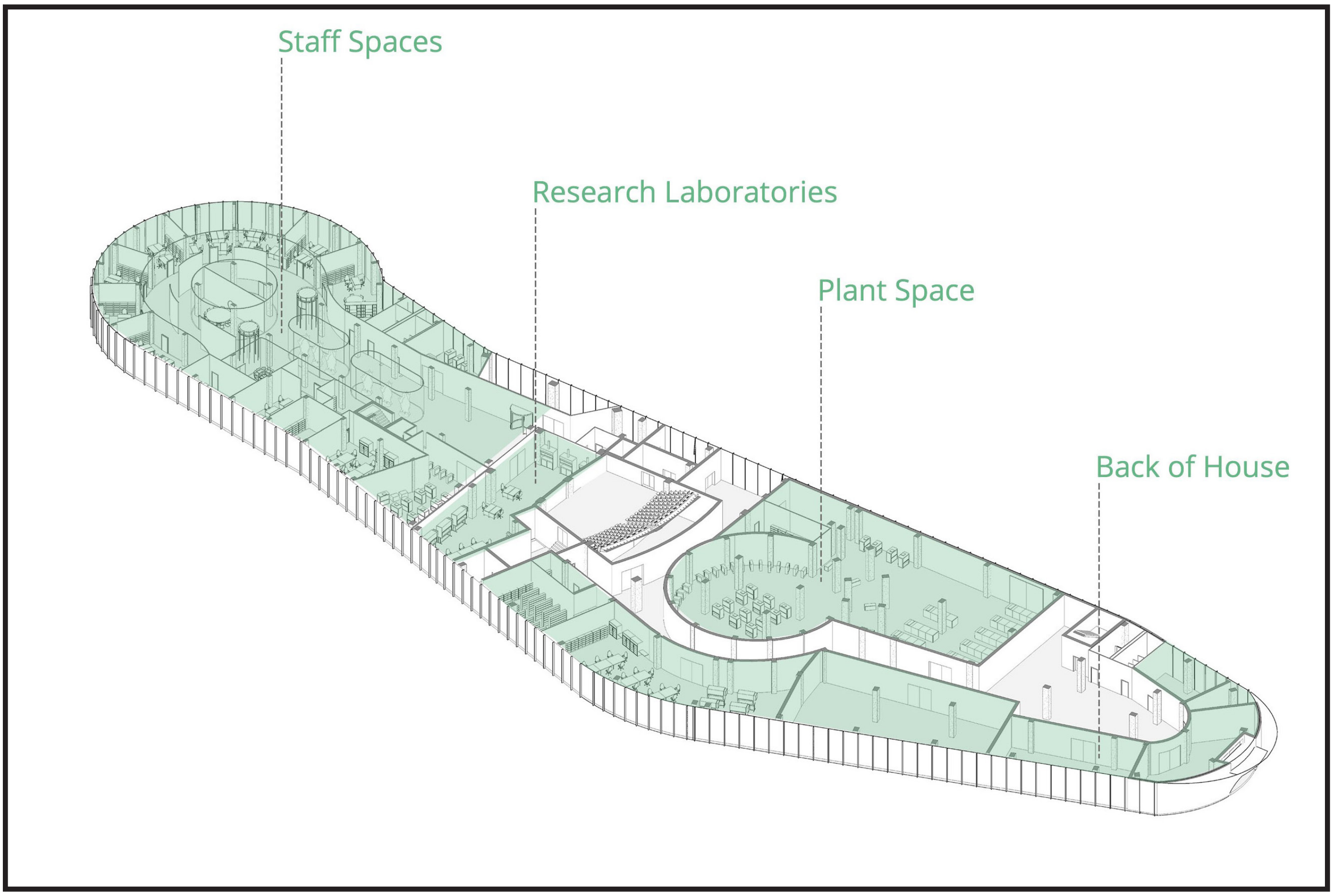


Figure 4.14 Functions on Services Floor.

STAFF SPACES

Spaces where an expert and administrative team can assemble to curate, manage and operate the Science and Innovation Centre. The offices and supporting staff spaces are carefully sited, located within relatively close proximity to the galleries as well as the front and back-of-house facilities. Permanent workspaces are provided for up to 60 staff.

RESEARCH LABORATORIES

The research laboratories, covering scientific domains like biology, chemistry, physics and robotic engineering, are provided. These laboratories are accessed by invitation only and aimed at serious academic research, predominantly aligned with the national curriculum for STEM (Science, Technology, Engineering and Mathematics) for school aged visitors.
The laboratories have appropriate ventilation provision, modern equipment and incoming service provision.

PLANT SPACE

Adequate service space for plant rooms and equipment, and vertical risers and ducts are provided, and sited in efficient locations to service the building.

BACK OF HOUSE

The arrangement of back-of-house facilities, to service and support building operations, is as important as the more high-profile front-of-house spaces. A loading bay is provided for both exhibition and day-to-day deliveries providing the service entrance to the Science Centre. This is covered with the adequate swing space. Equipment, workshop, furniture, refuse, recycling and general stores are located in close proximity to the loading bay, as the delivery, main packing and unpacking space for exhibitions.

Adequate space is provided for exhibition preparation and storage, as well as workshops for the repair and fabrication of exhibits.

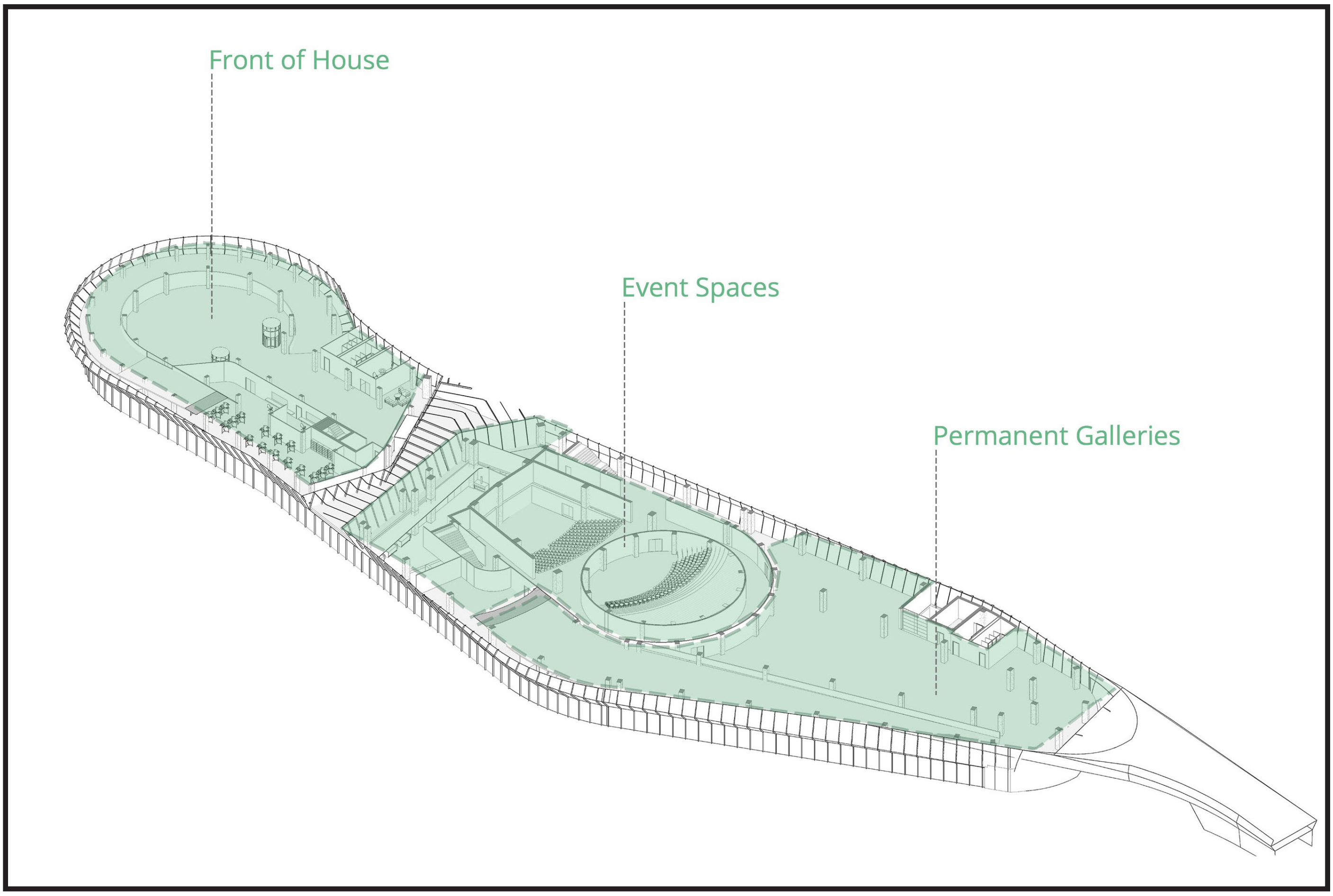


Figure 4.15 Functions on Entrance Floor.

FRONT OF HOUSE

The main entrance hall is the visitors' first experience of, and engagement with, the Centre. It is the main entry, orientation and security point. However, it also provides space to pause, reflect and relax within.

From outside the entrance announces itself through the clarity of its architecture. Once inside, the visitor finds the entrance hall bright, inviting and impactful, with a generosity of scale and space. Natural light, and visual connection to the outside, is essential. Again, there is minimal reliance on wayfinding devices, with a clear and intuitive hierarchy of routes to adjoining spaces.

The main reception, ticketing and information point for the Science Centre is located within the hall, with clear visual and physical connection between it, the entrance and other public functions and visitor amenities. This accommodates three information staff, three ticketing staff and include a small resource room/space (for printers, scanners, storage, etc.).

Other front of house facilities, such as the cloakroom, sanitation and first aid facilities are clearly demarcated and easily accessible from the entrance hall, but o not compete with the main reception, ticketing and information point. The cloakroom has capacity for 300 items, as well as a locker room/space for 100.

EVENT SPACES

Flexible Event Space: A flexible multi-purpose event space is provided for a range of activities, including projections, lectures, symposiums, etc. In the form of an auditorium, it is capable of seating up to 200 visitors. It provides a 'black box' environment, with high quality audio-visual equipment. A technical room and equipment storage room is also provided as part of the flexible event space.

Virtual' Planetarium: A 'virtual' planetarium is provided. This is a multi-media room, for up to 100 visitors, providing a 3D/4D experience within the Science Centre. This could also have a separately ticketed offer for the visitors who choose to take short excursions.

PERMANENT GALLERIES

The Science and Innovation Centre presents the earth, its environment and eco-systems through the prism of the impact that humankind has had upon it, including through the development of technology.

The permanent galleries focus on three inter-connecting themes: the Human, the Machine and Nature/Ecology. A fourth, introductory gallery introduces the three themes and acts as a lobby or atrium to the three main galleries. It also includes a small show space, to facilitate informal demonstrations or introductory films.

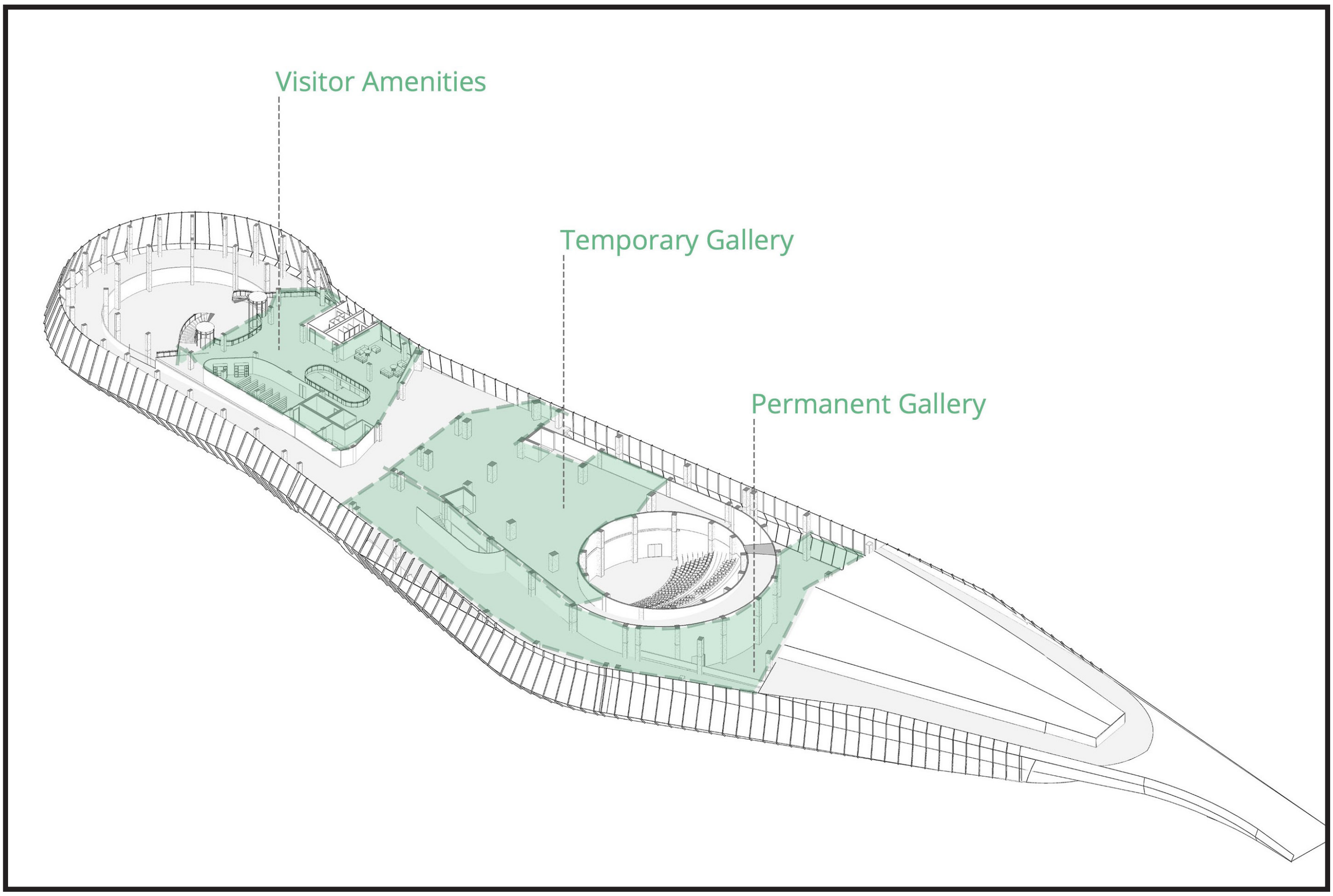


Figure 4.16 Functions on Exhibition Floor.

The Science and Innovation Centre does not have a permanent collection of objects. Instead it is anticipated that the galleries will present their themes largely through interactive exhibits, enabling visitors to engage and interact with the exhibits, supplemented, where required and possible, by other physical and/or audio-visual conten.

VISITOR AMENITIES

Retail space: A shop selling Science Centre merchandise and promotional materials, as well as books and other related publications, is located on the floor above the entrance and catches people as they are leaving the exhibition spaces. A small shop storage room and office is also co-located with the shop.

TEMPORARY GALLERIES

A highly flexible temporary gallery space is provided to cater for the loan of significant international travelling exhibitions, related to the overall themes of the Science and Innovation Centre. This is designed to international standards for climate control, lighting, security and fire control. It is capable of multiple arrangements, either as one large volume or sub-divided as required.

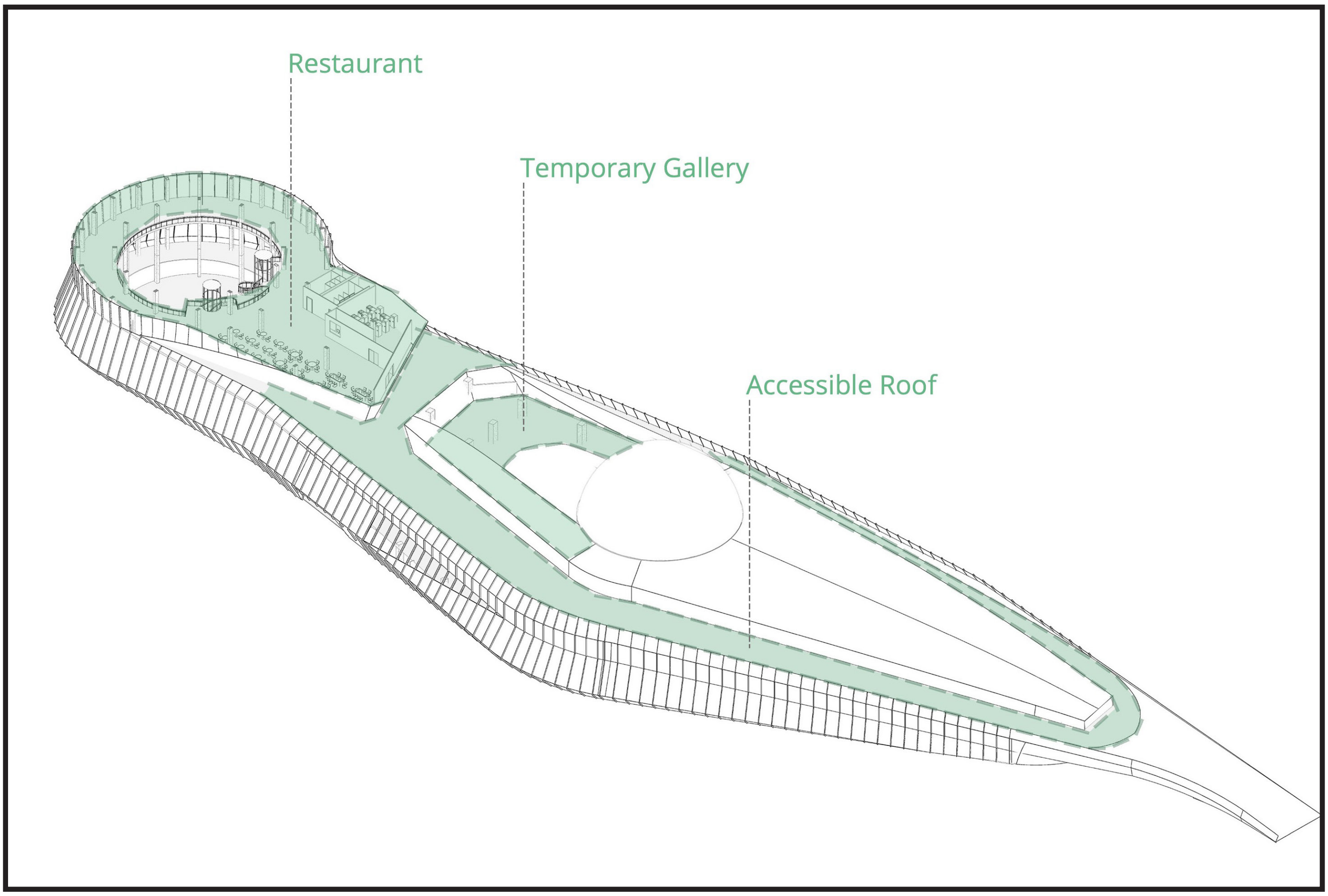


Figure 4.17 Functions on Restaurant-Mezannine floor.

RESTAURANT

Food and Beverage: A cafeteria, serving up to 60 people, is provided. This presents a highly social and relaxed atmosphere, and is envisaged as an **important meeting place within the city of Kaunas**. It takes advantage of important views and natural daylight.

The cafeteria includes a servery counter, which can transform into a bar in the evenings for events on the roof, a main kitchen and kitchen store.

As with the shop, a separate entrance is considered. The cafeteria also has **direct access** to a dedicated external area, to serve up to 50 covers. Careful consideration of the siting of the cafeteria within the building has been made, to facilitate separate access, dedicated external space and direct and dedicated access for deliveries and waste disposal.

ACCESIBLE ROOF

An accessible roof is provided on the top of the exhibition spaces. It gives the chance for the building to be **better and strongly integrated with the city.** The public has the chance to access the roof in order to experience the events held in restaurant area by enjoying the view of the city.

|ARCHITECTURAL PLANS|

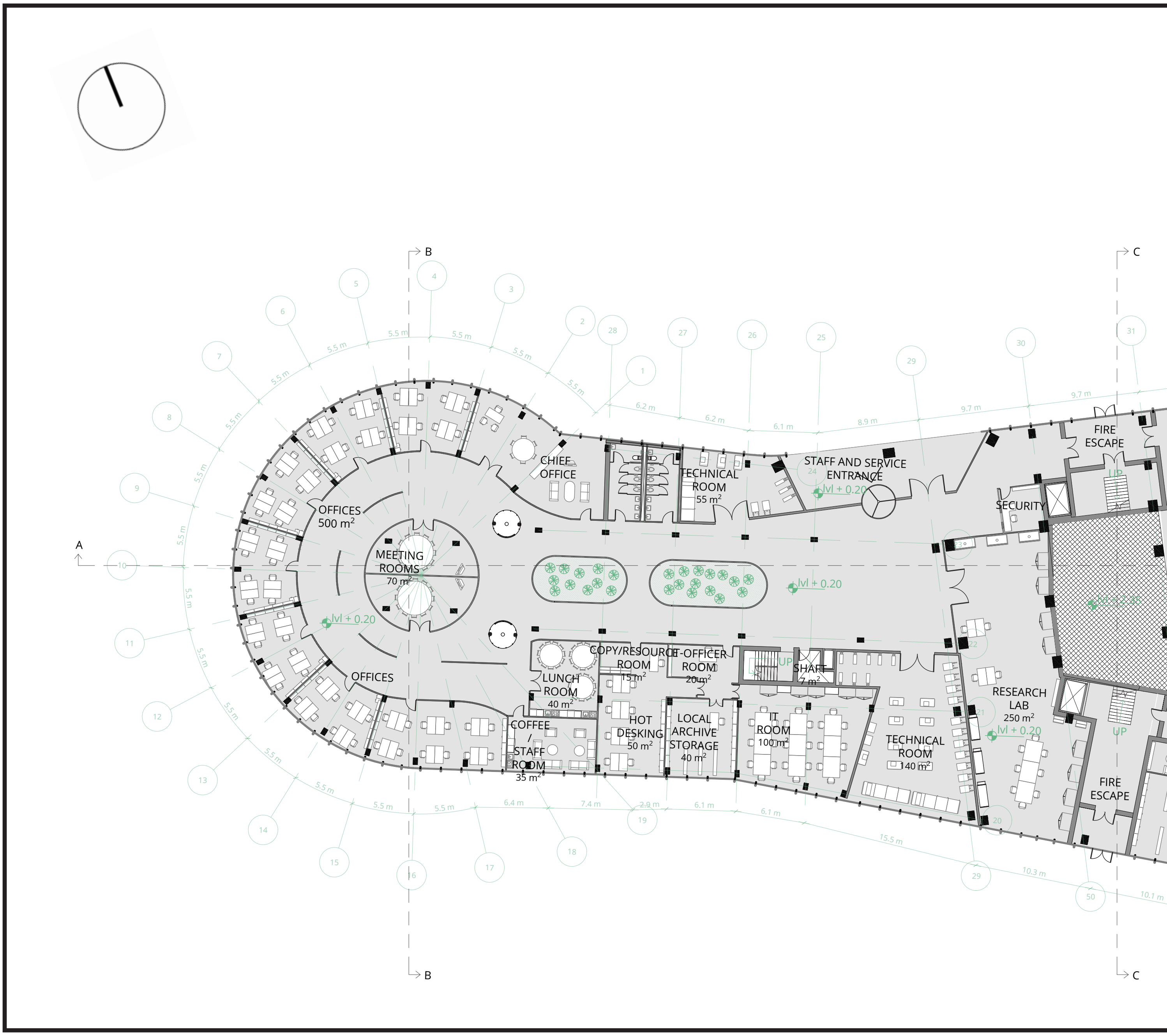
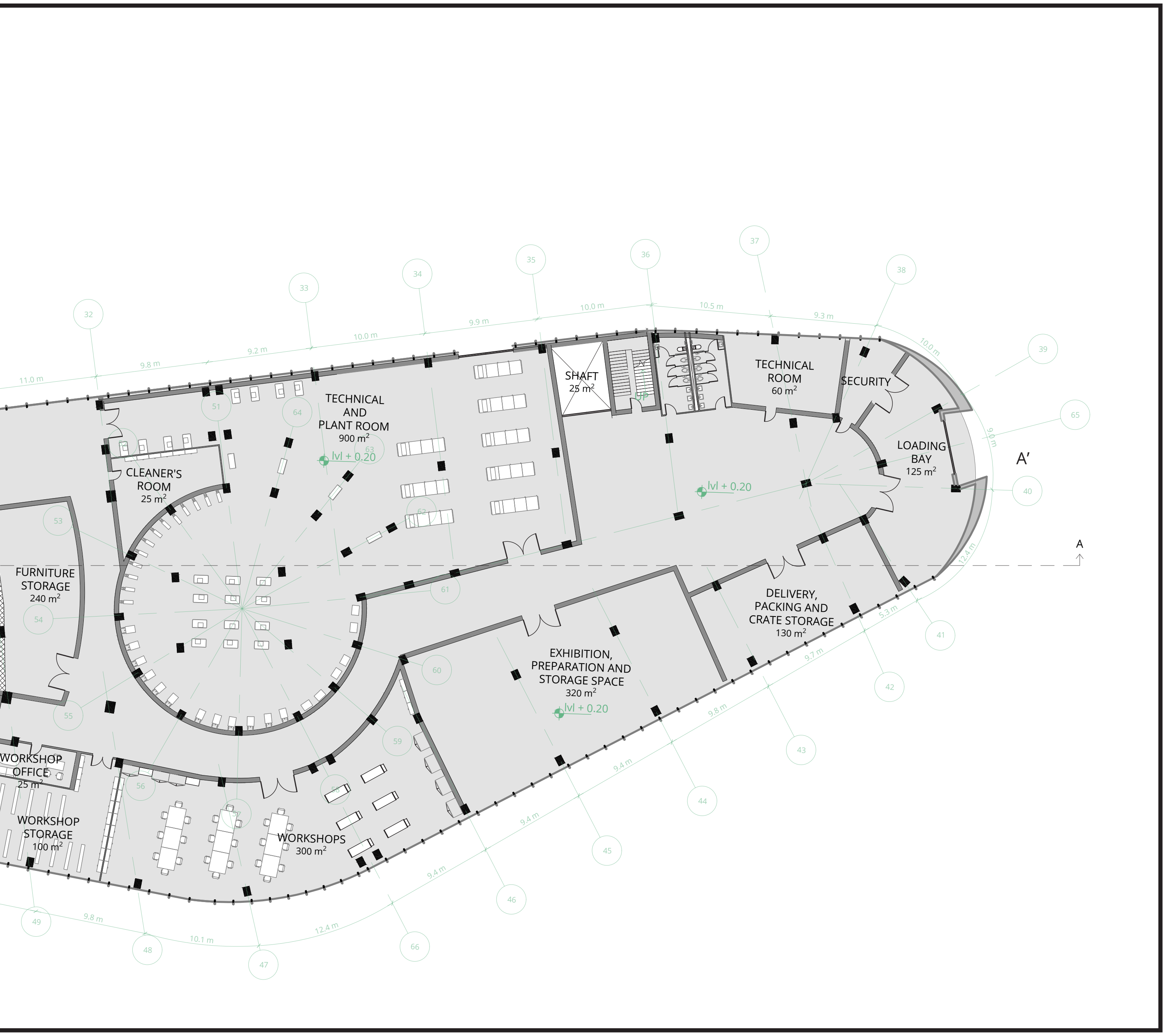


Figure 4.18 Layout of services floor (Level 0.20m)
Scale 1:500.


TECHNICAL AND PLANT ROOM
900 m²
lvl + 0.20
SHAFT
25 m²
UP
TECHNICAL ROOM
60 m²
SECURITY
LOADING BAY
125 m²
lvl + 0.20
A'
A
CLEANER'S ROOM
25 m²
FURNITURE STORAGE
240 m²
DELIVERY, PACKING AND CRATE STORAGE
130 m²
EXHIBITION, PREPARATION AND STORAGE SPACE
320 m²
lvl + 0.20
WORKSHOP OFFICE
25 m²
WORKSHOP STORAGE
100 m²
WORKSHOPS
300 m²

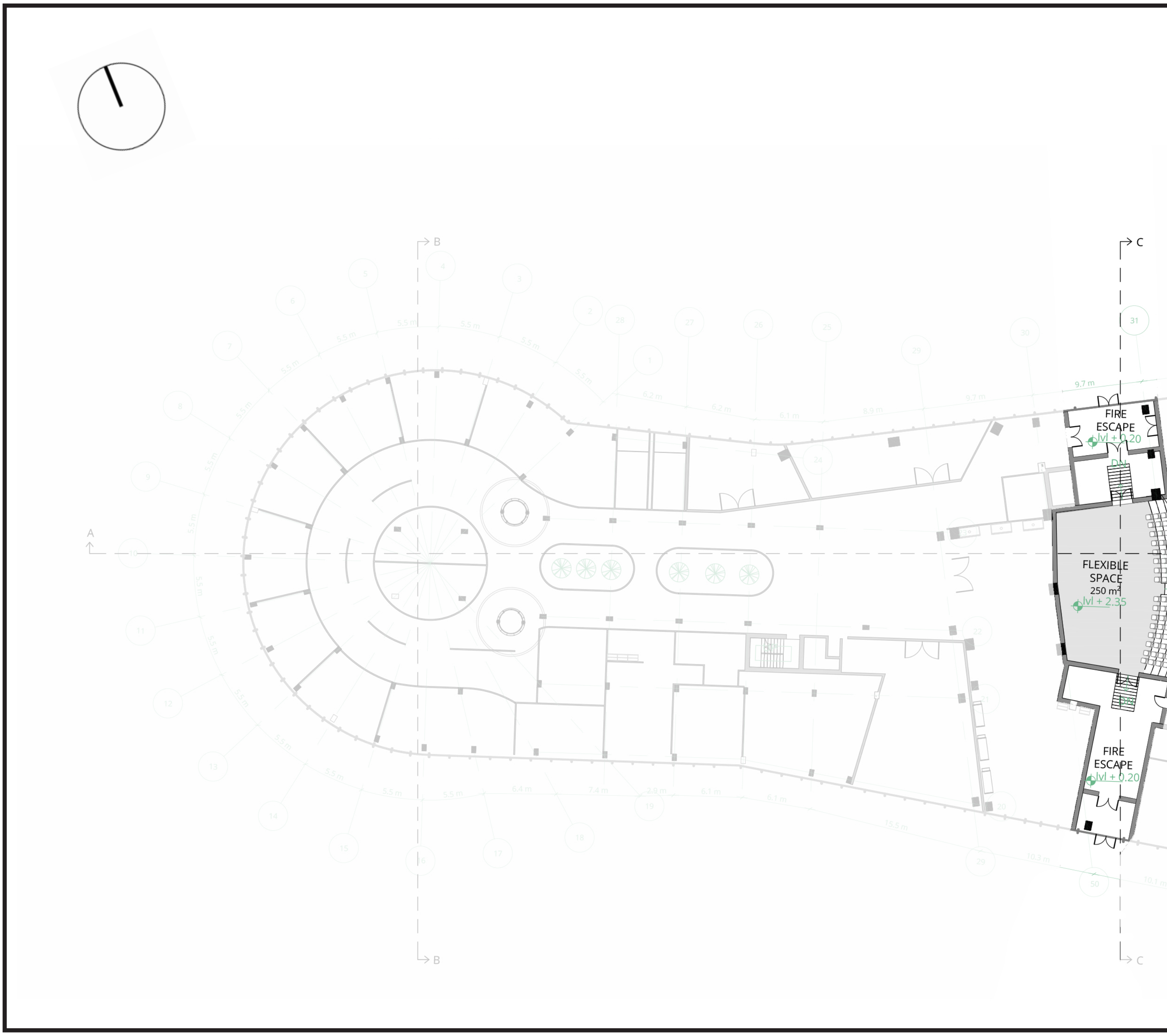
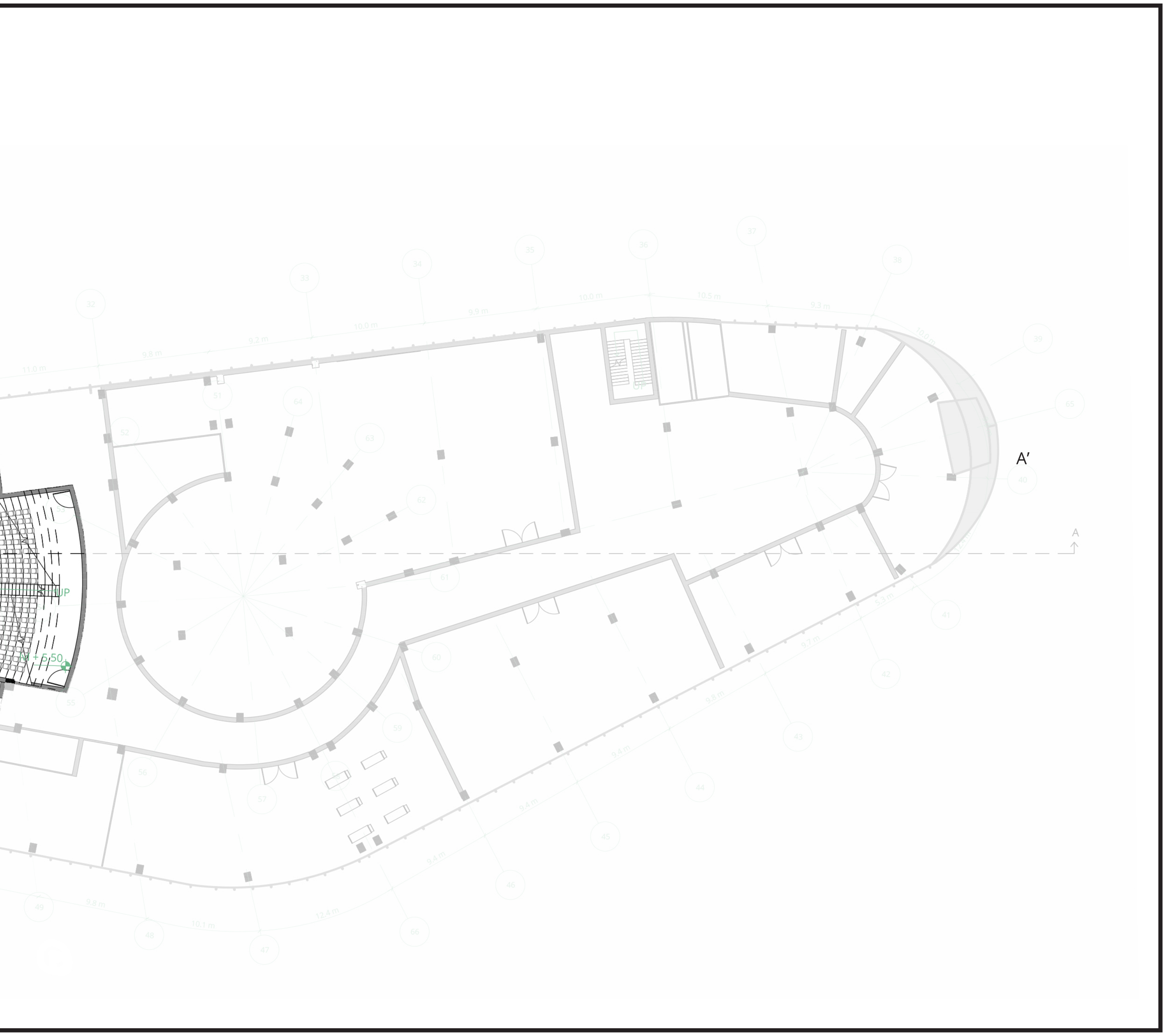


Figure 4.19 Layout of services floor (Level +2.35m). Scale 1:500.


A'
A
UP
+5.50

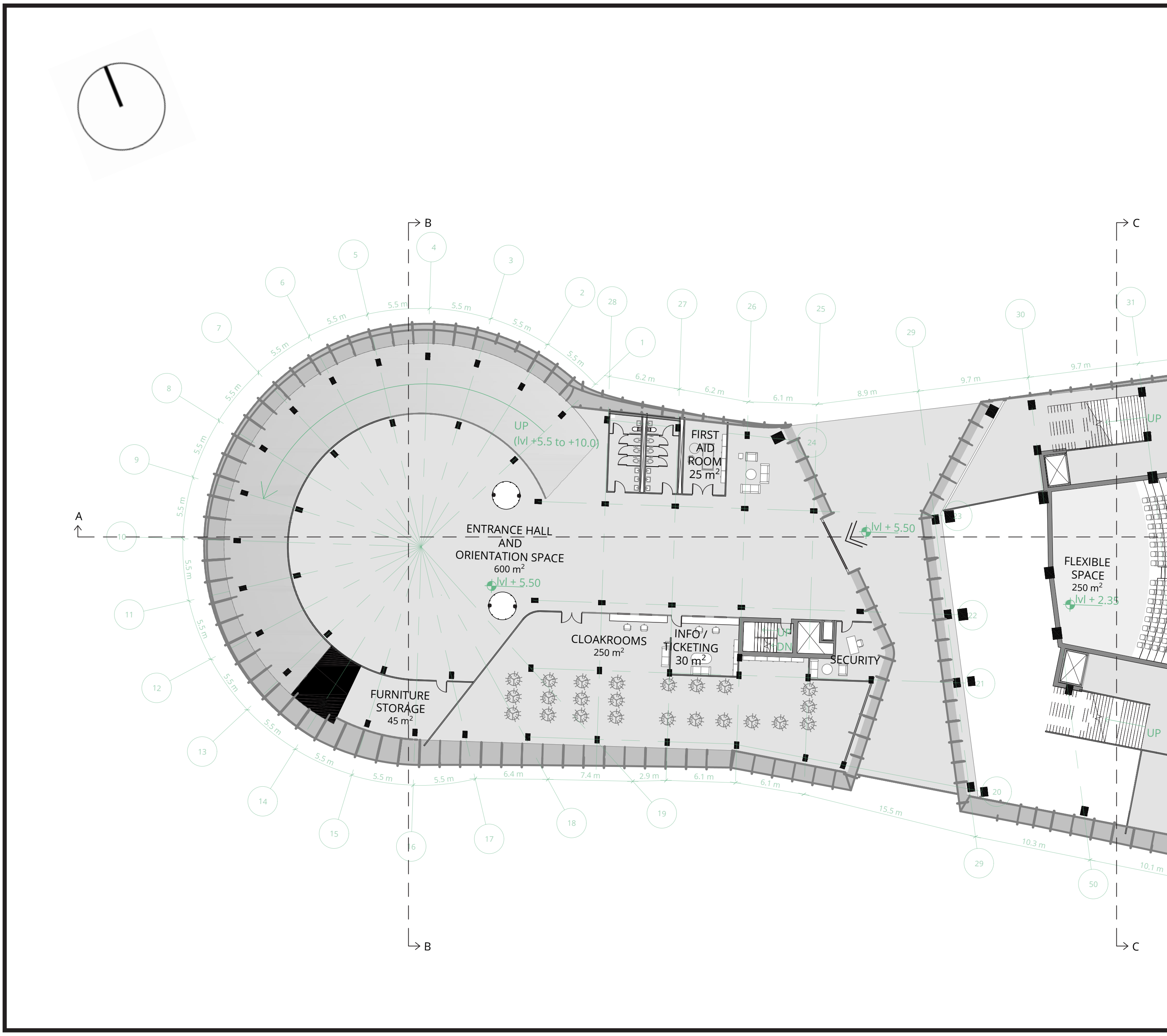
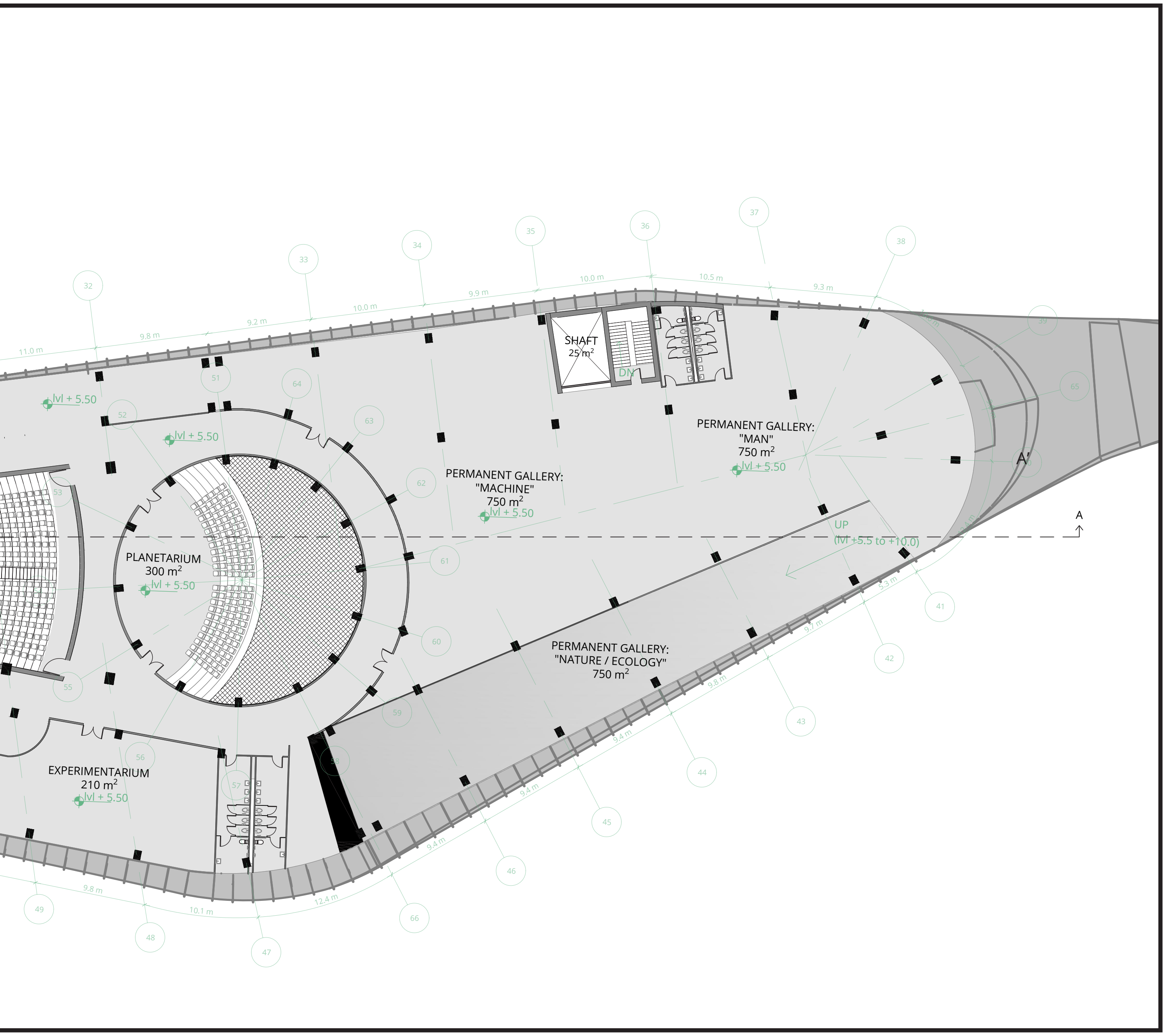


Figure 4.20 Layout of entrance (Level +5.50m). Scale 1:500.


SHAFT
25 m²
DN
PERMANENT GALLERY:
"MAN"
750 m²
lvl + 5.50
PERMANENT GALLERY:
"MACHINE"
750 m²
lvl + 5.50
PLANETARIUM
300 m²
lvl + 5.50
UP
(lvl +5.5 to +10.0)
PERMANENT GALLERY:
"NATURE / ECOLOGY"
750 m²
EXPERIMENTARIUM
210 m²
lvl + 5.50
A

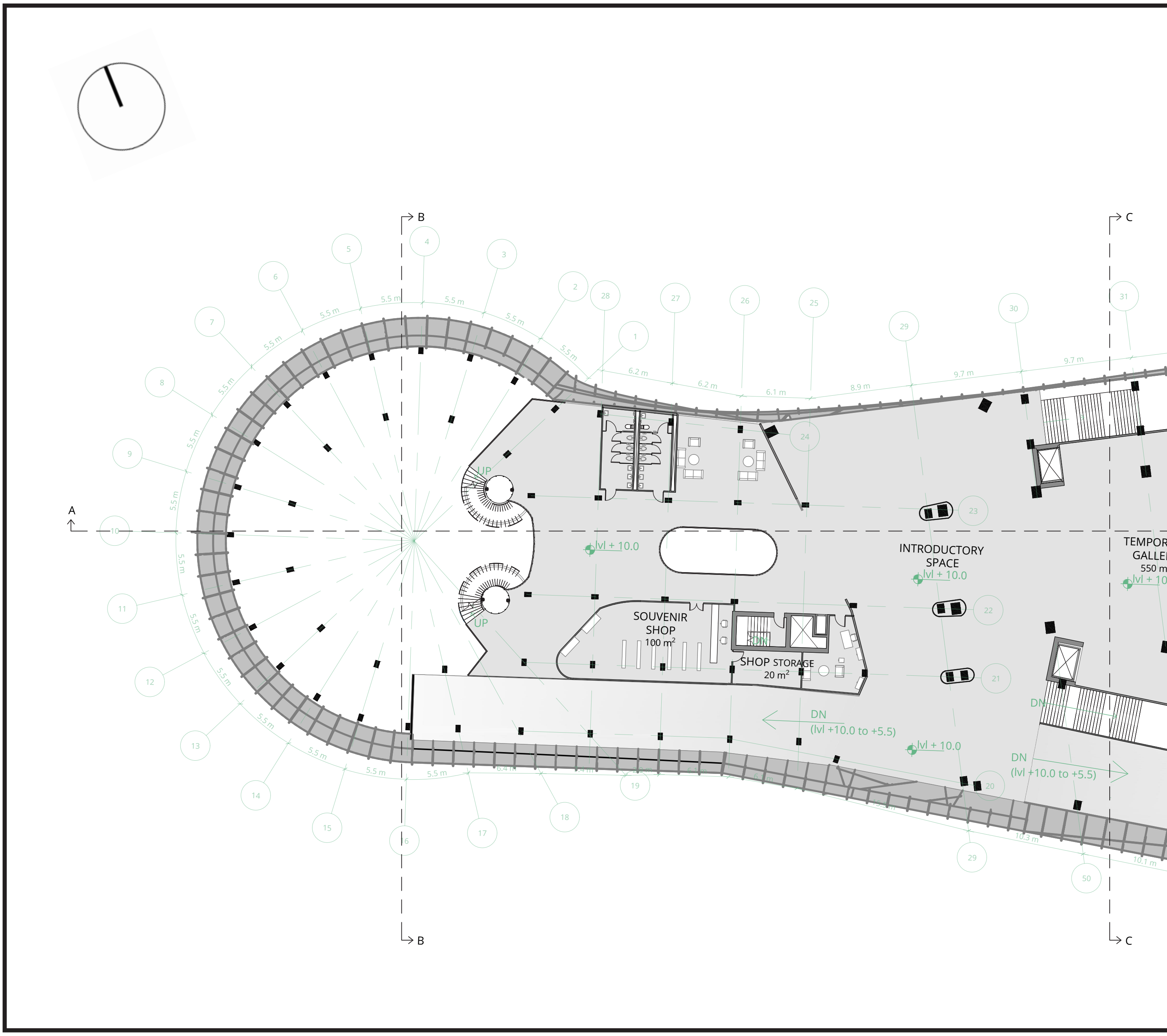
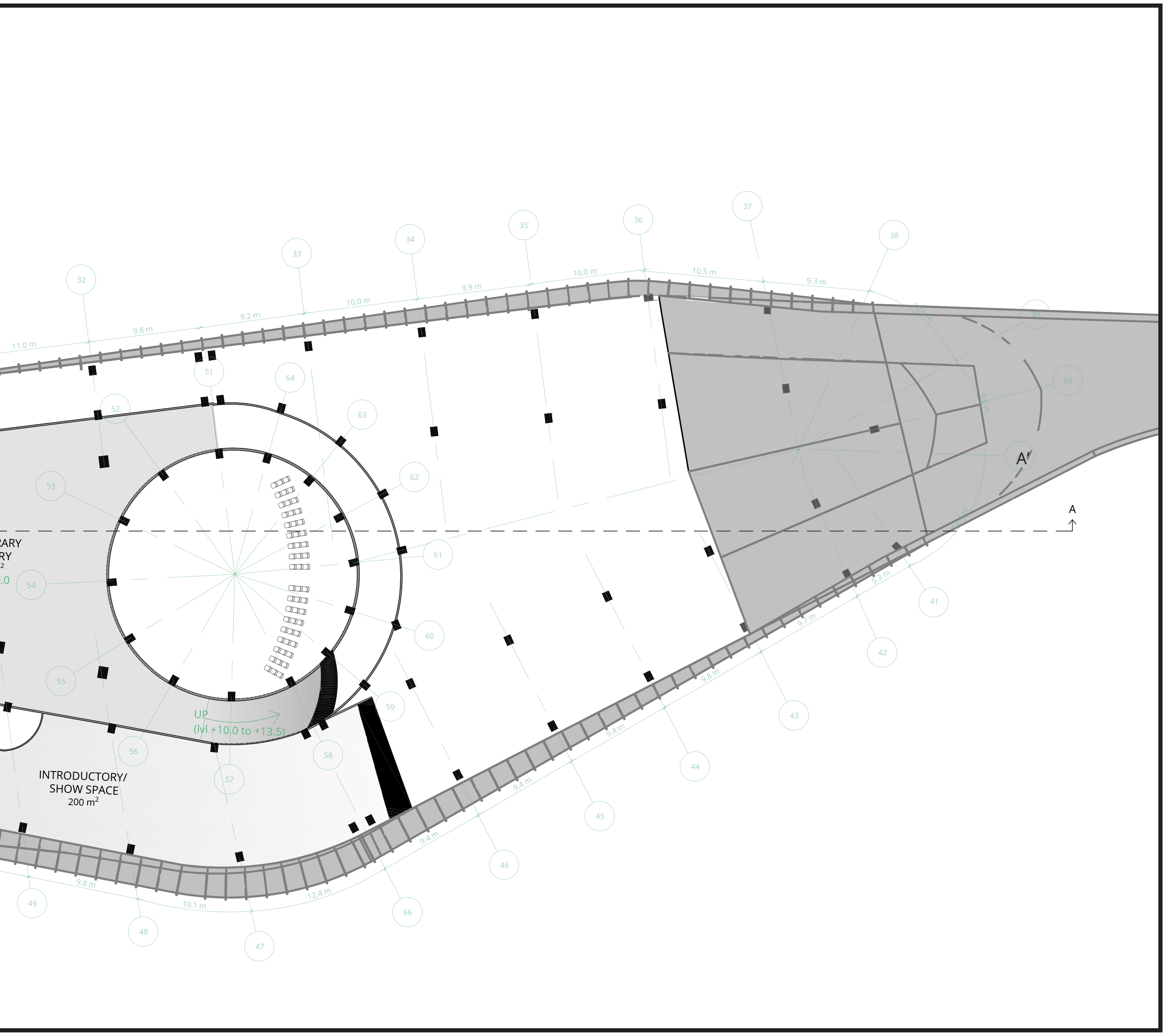


Figure 4.21 Layout of Exhibition floor (Level +10.0m)
Scale 1:500.


INTRODUCTORY/
SHOW SPACE
200 m²
UP
(lvl +10.0 to +13.5)
A
A'

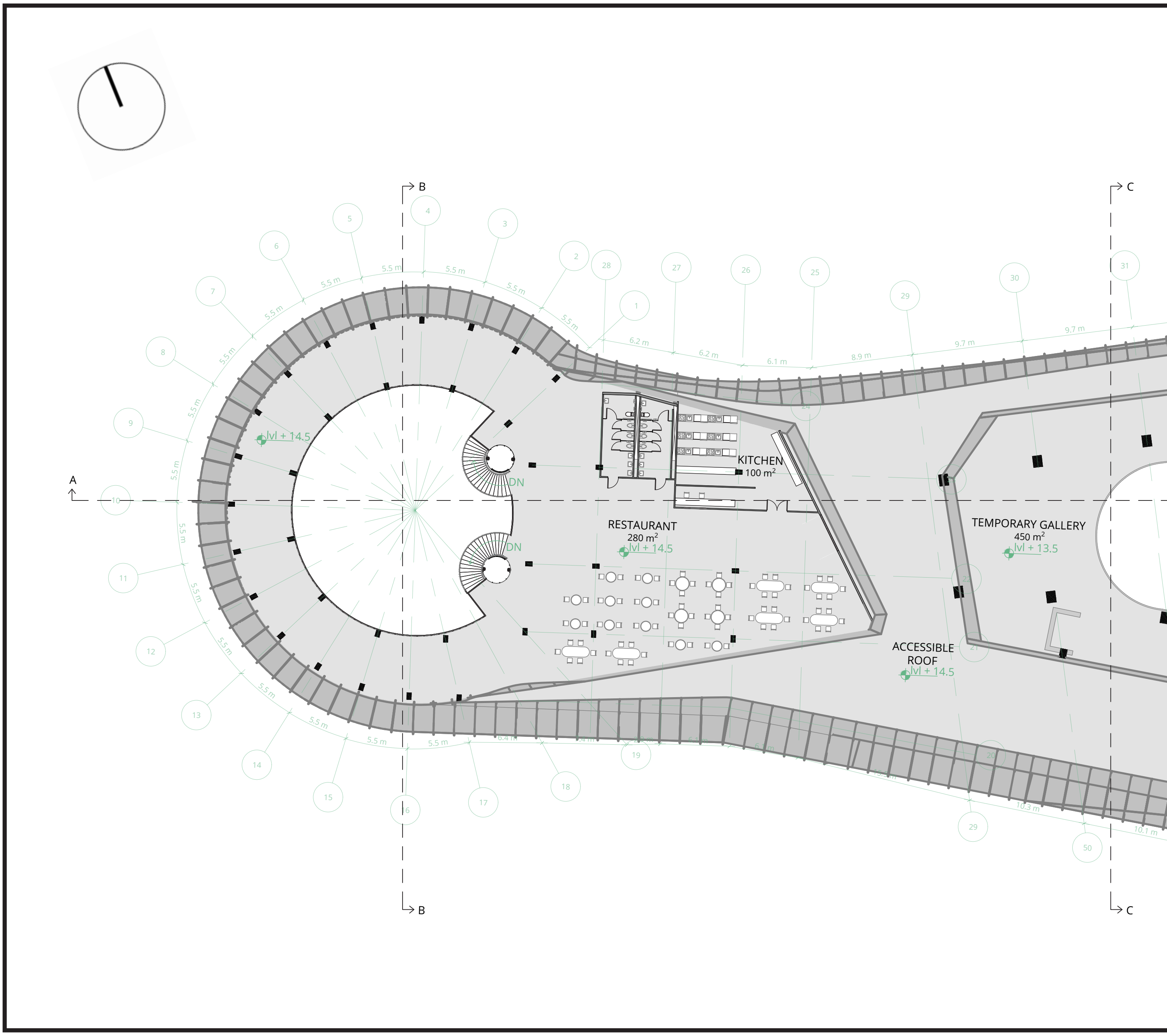
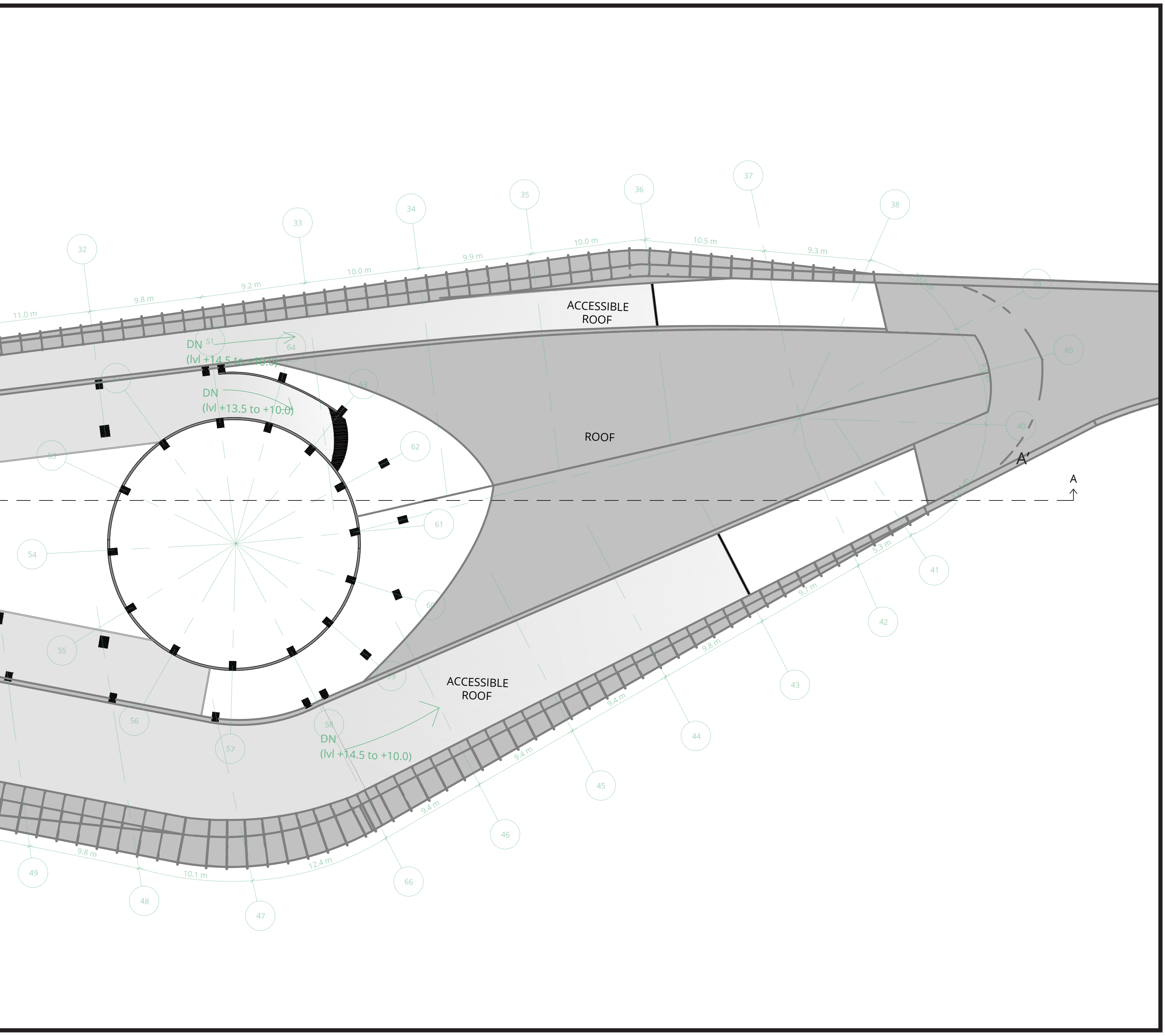


Figure 4.22 Layout of Restaurant (Level +13.50m) - Mezannine (Level+14.50m). Scale 1:500.


ACCESSIBLE ROOF
ROOF
ACCESSIBLE ROOF
DN
(lvl +14.5 to +10.0)
DN
(lvl +13.5 to +10.0)
DN
(lvl +14.5 to +10.0)
A
A'

|SECTIONS|

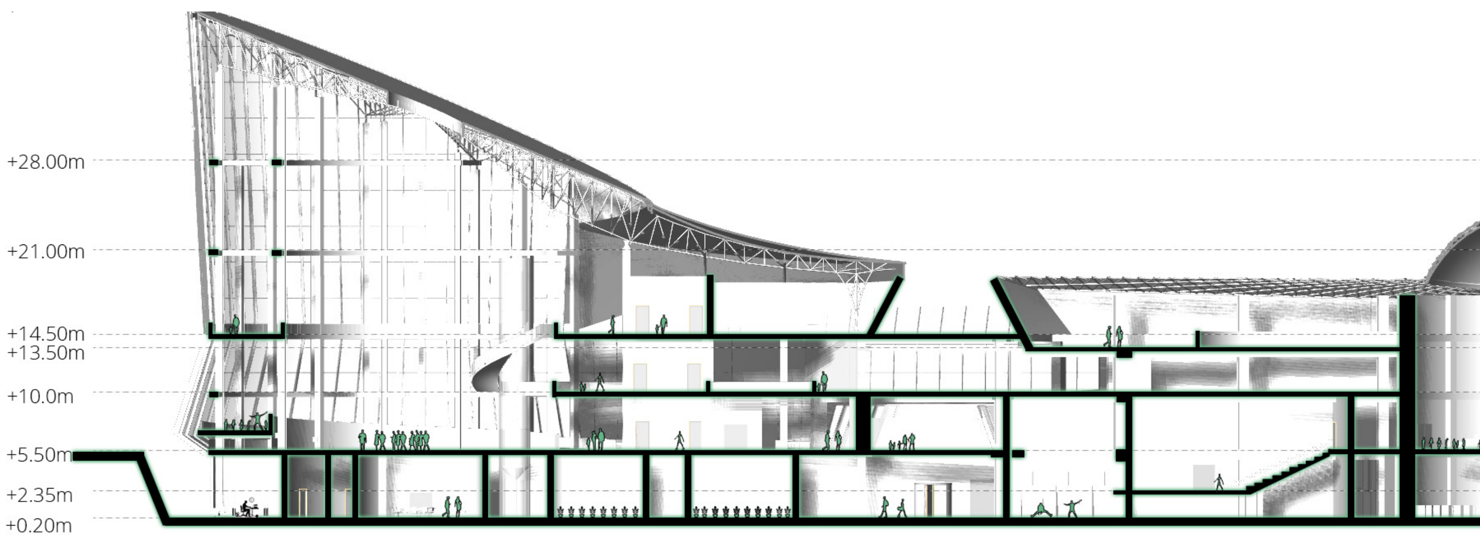
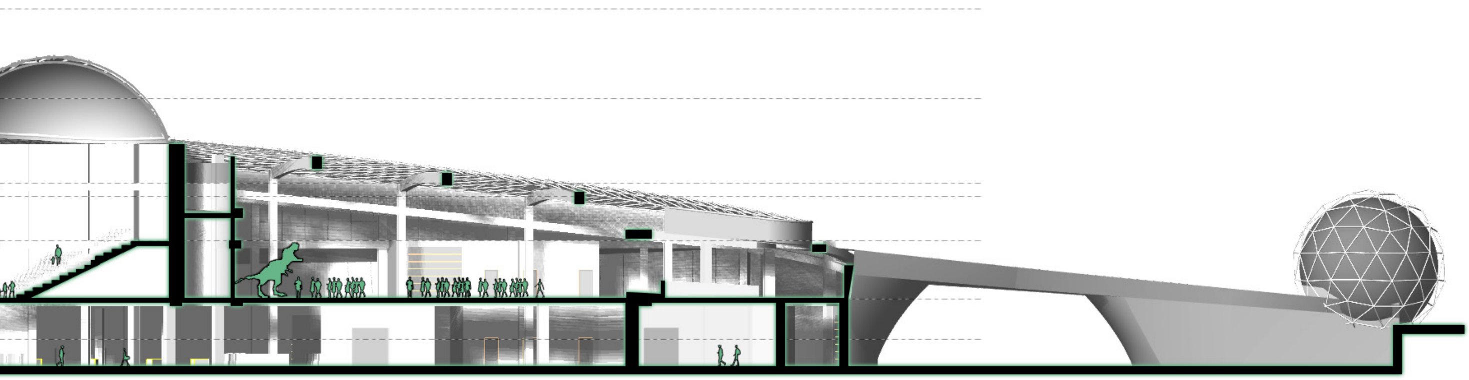


Figure 4.23 Section AA.



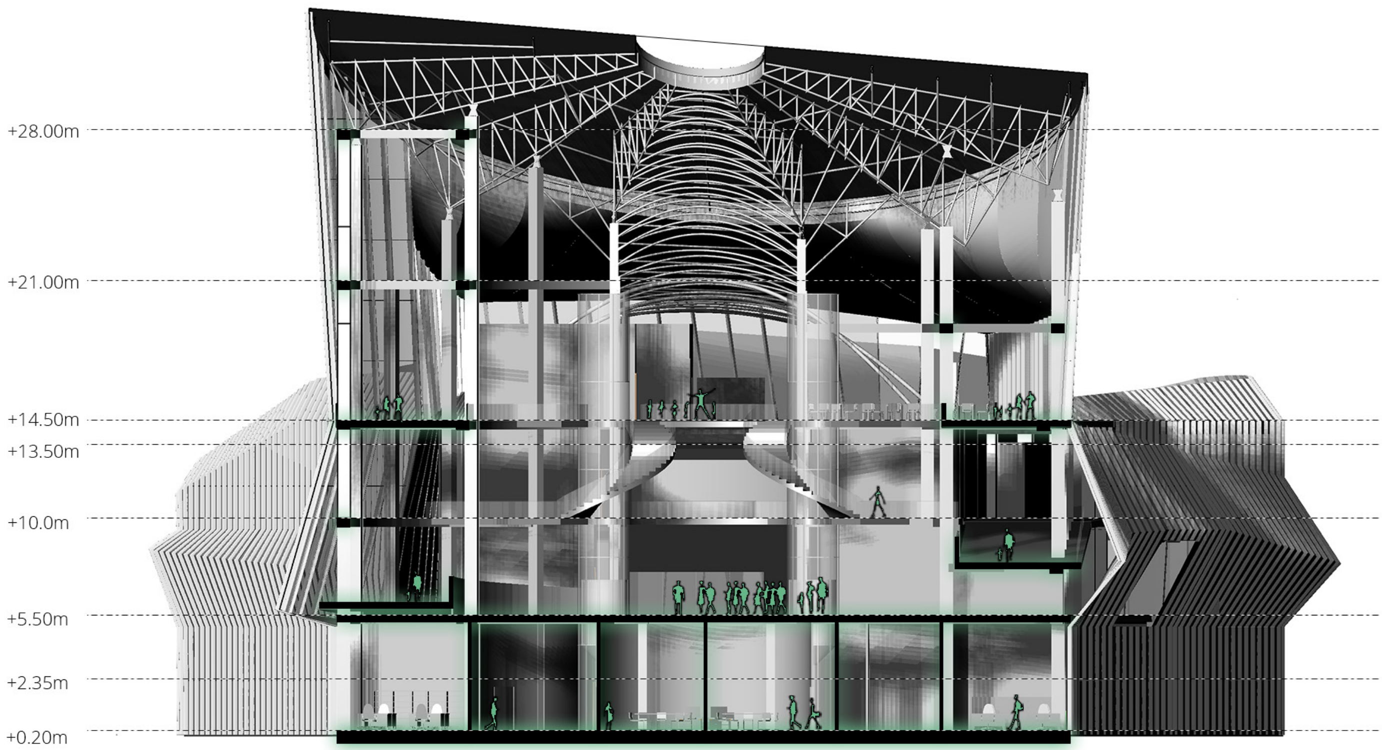


Figure 4.24 Section BB.

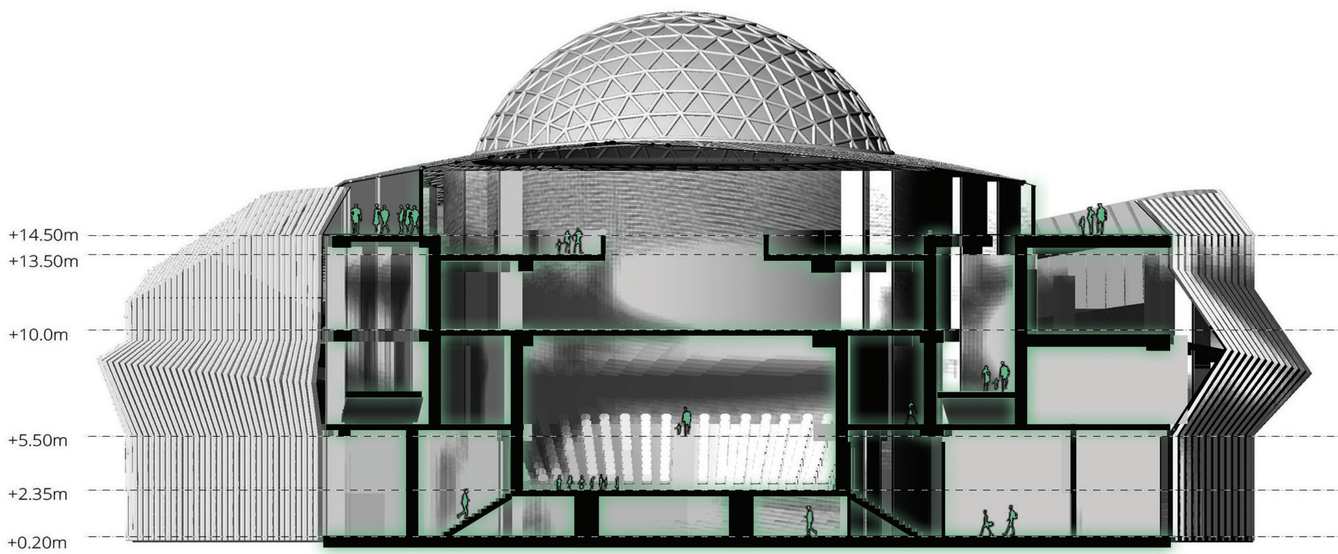


Figure 4.25 Section CC.

|ELEVATIONS|

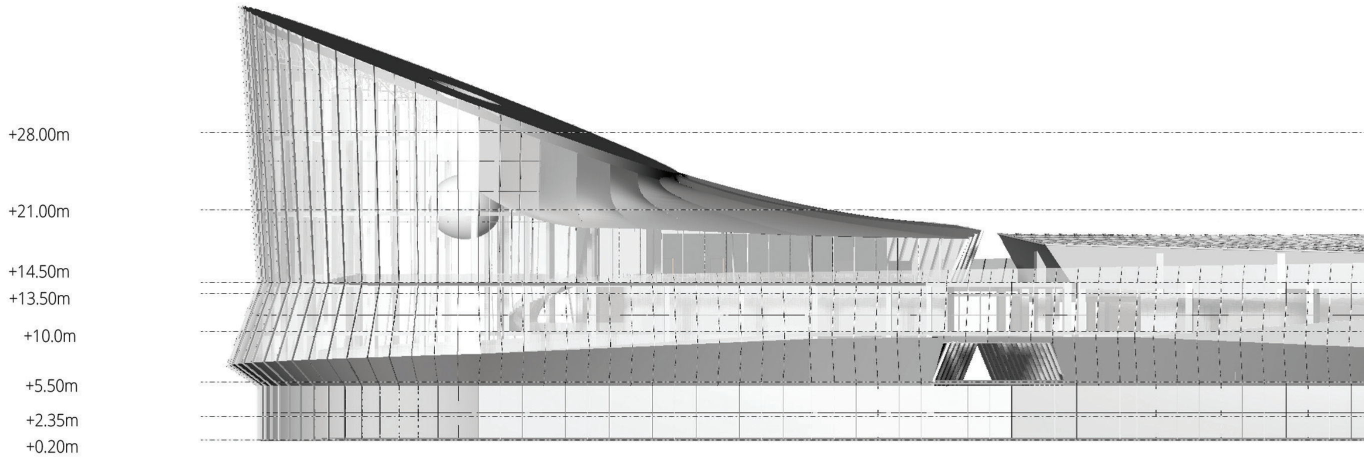


Figure 4.26 South Elevation

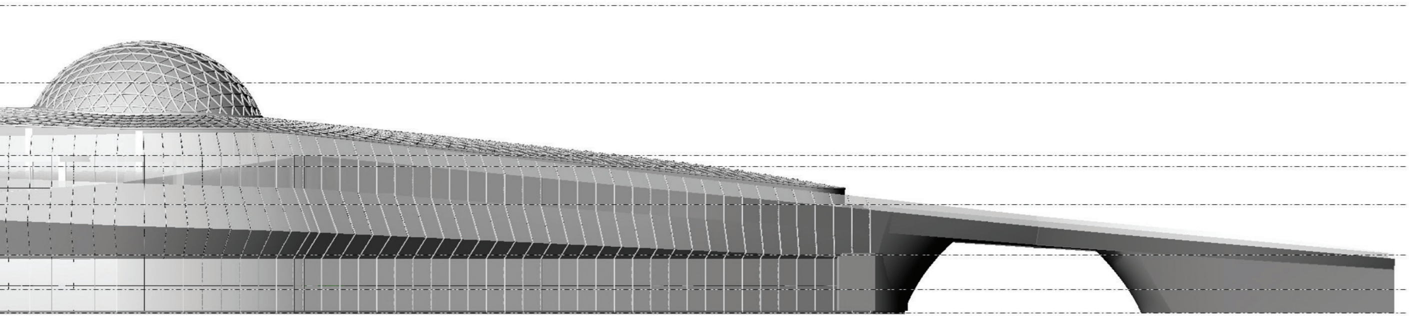
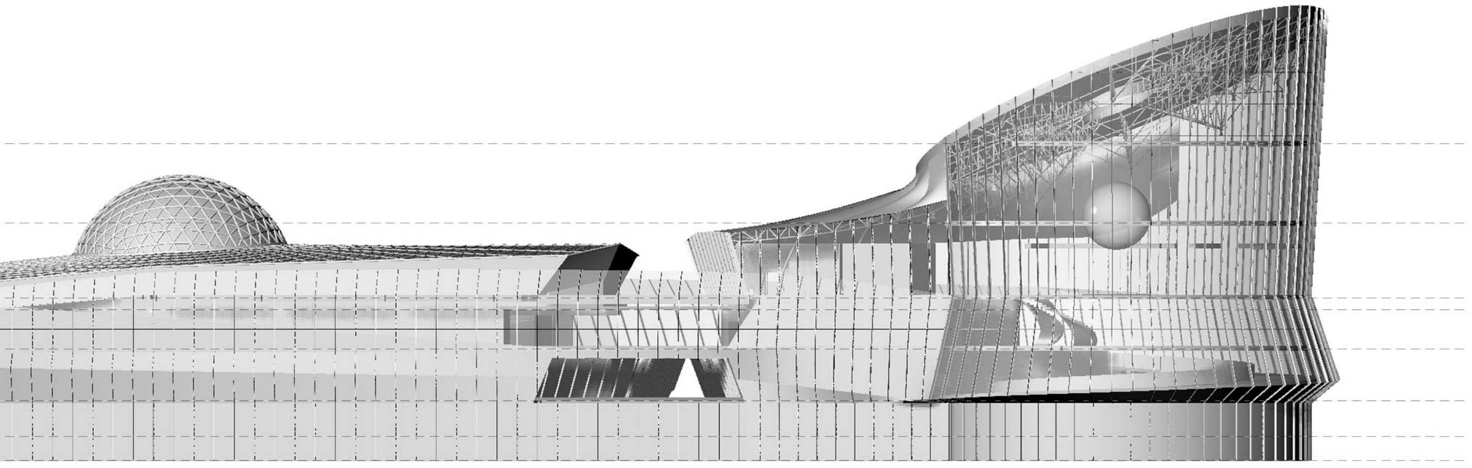


Figure 4.27 North Elevation



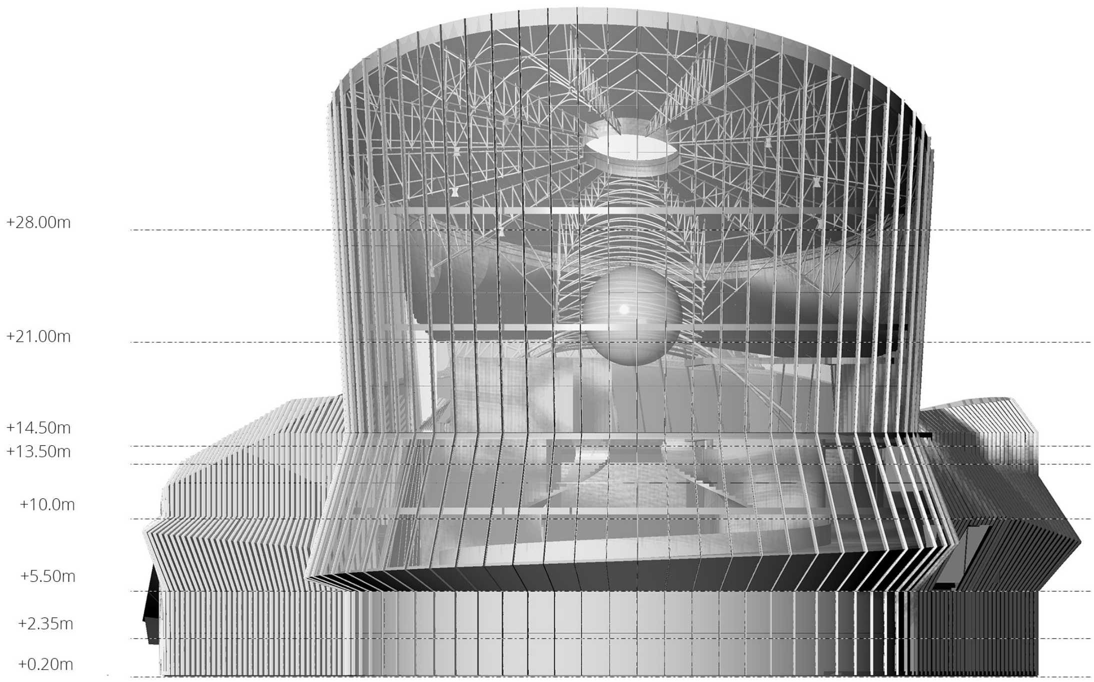


Figure 4.28 West Elevation.

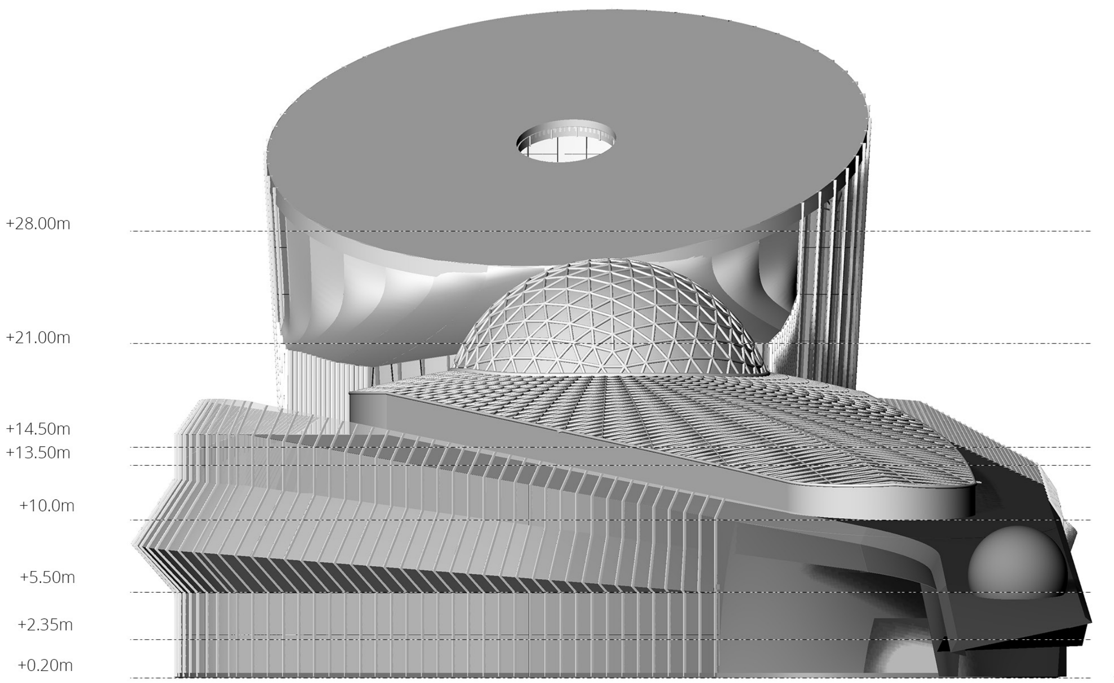
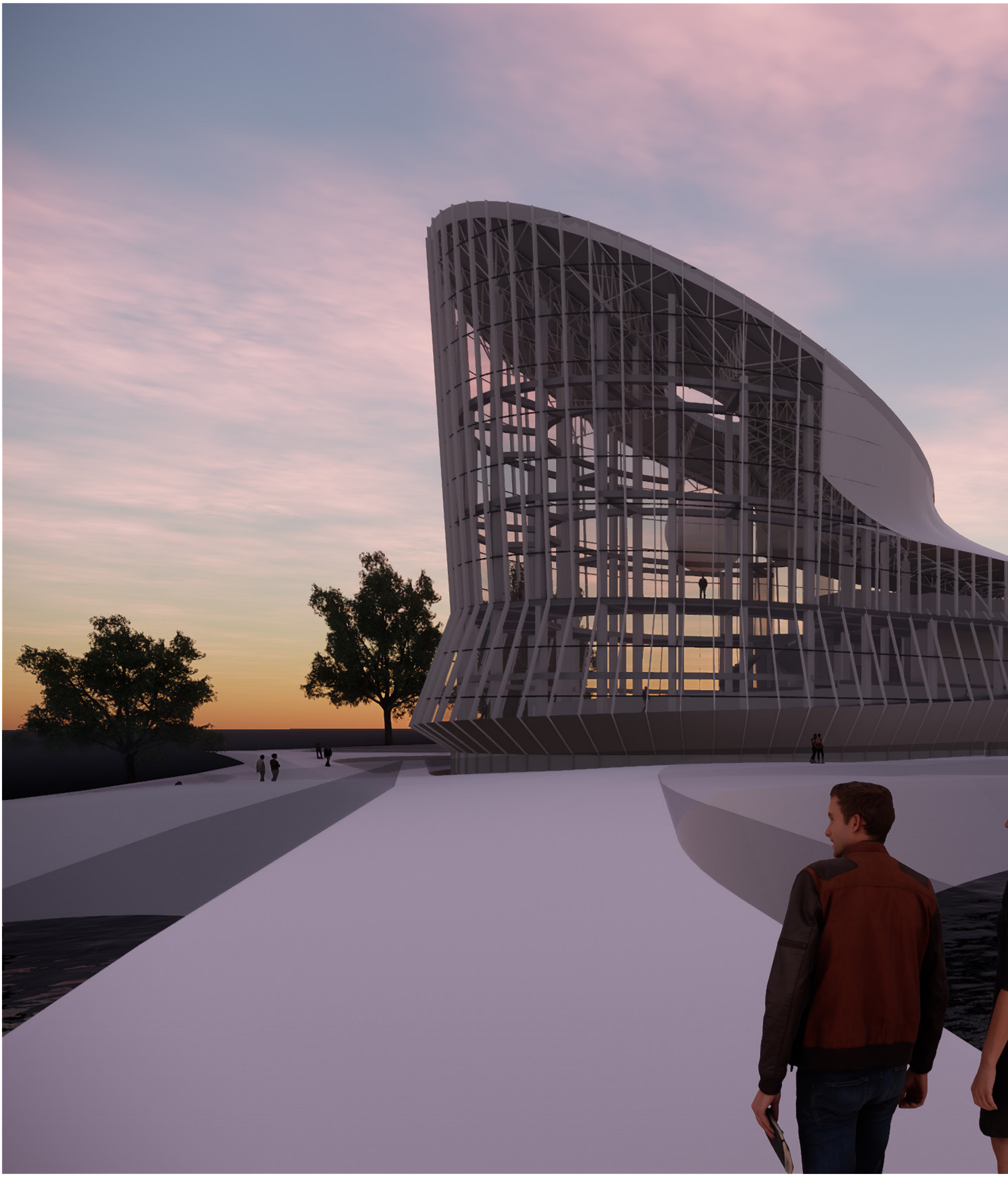
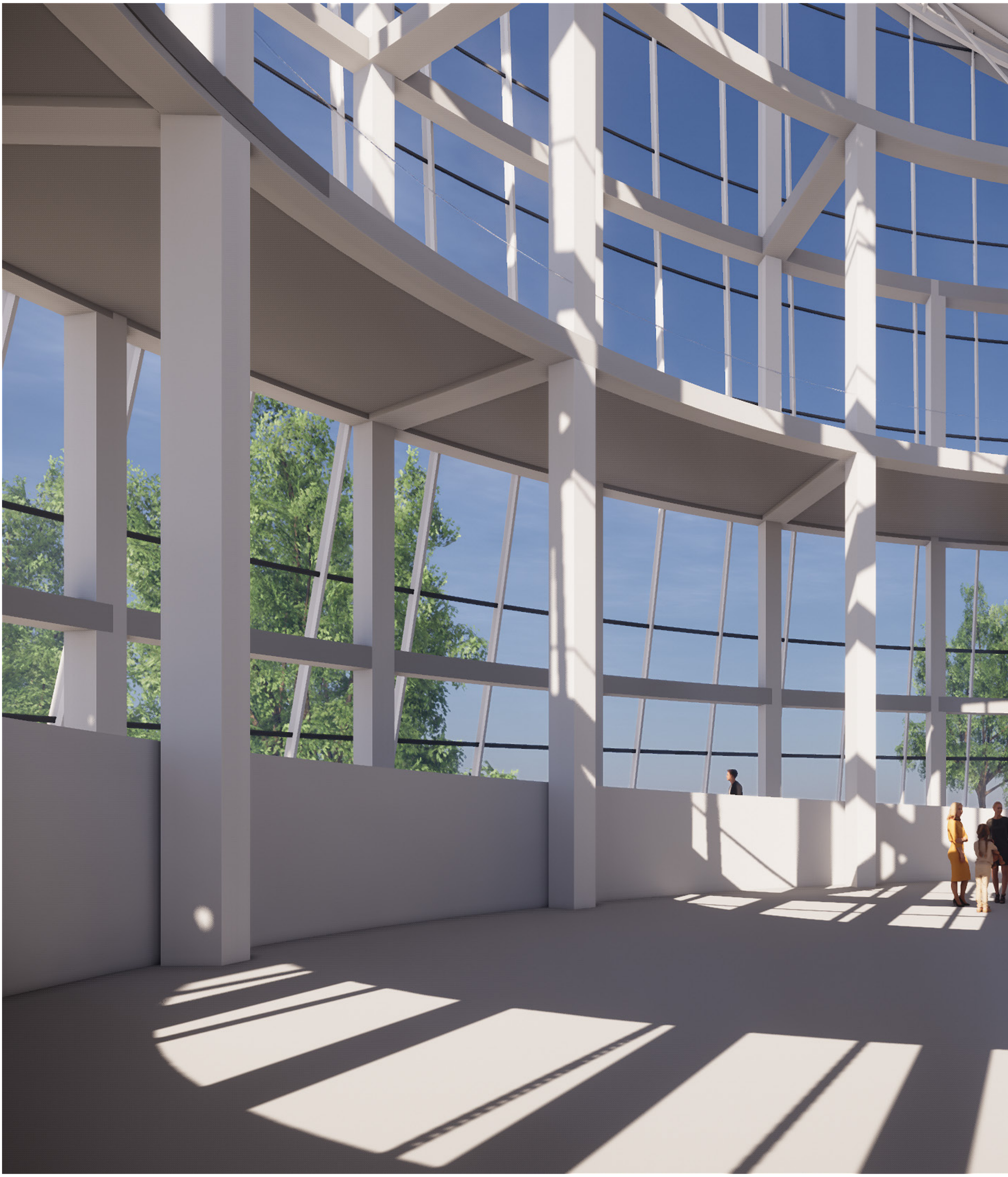
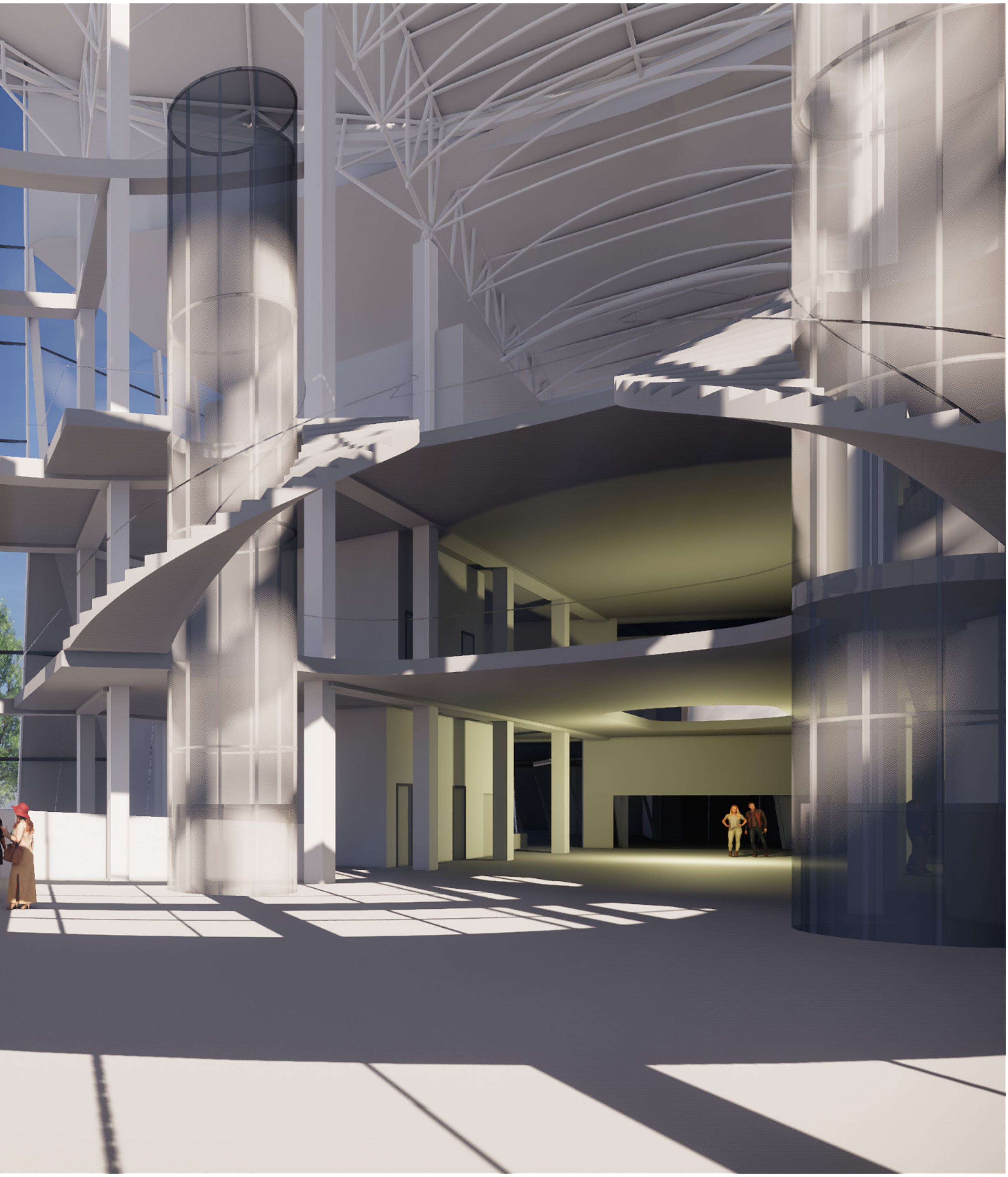


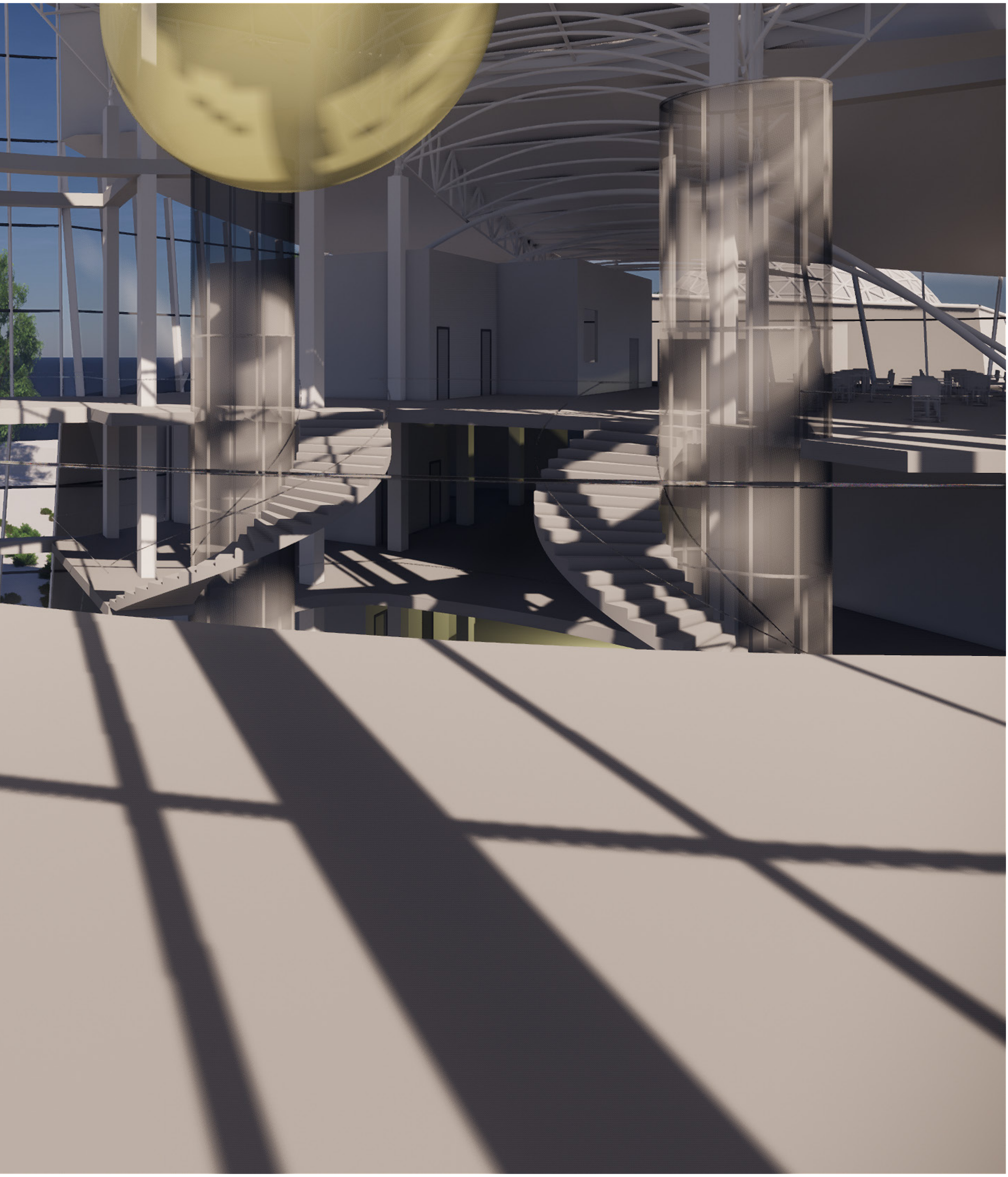
Figure 4.29 East Elevation.

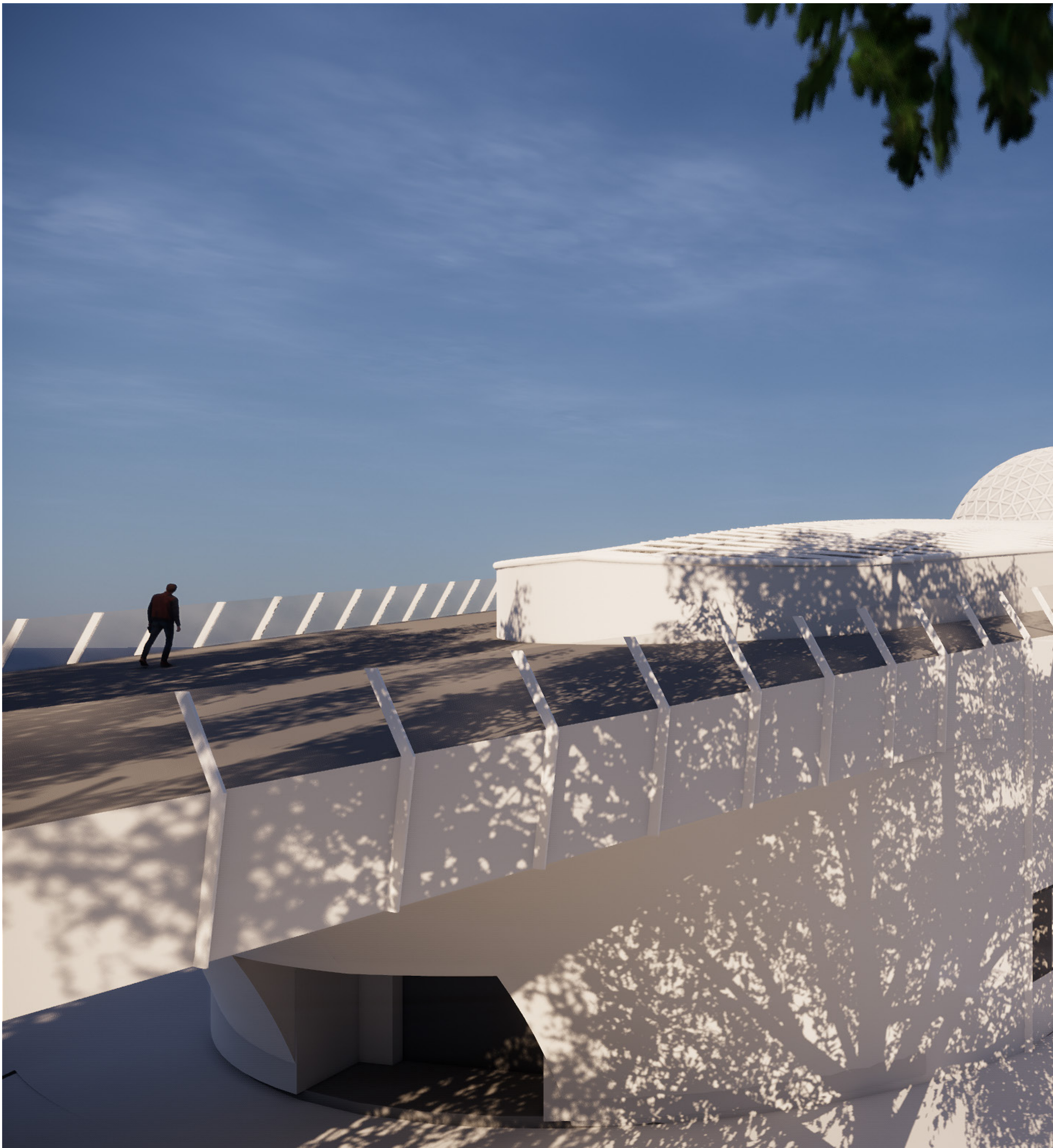
|RENDERS|

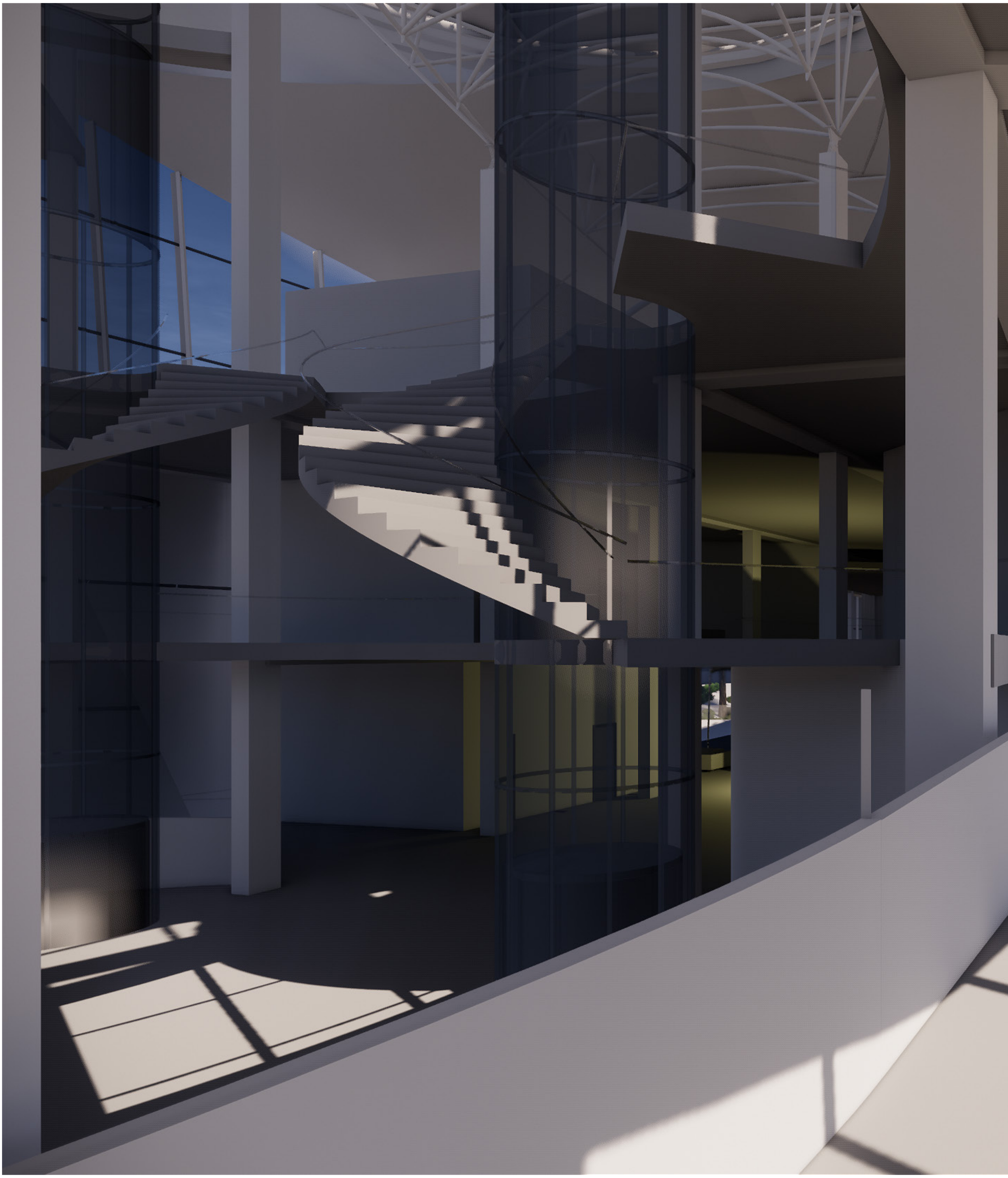


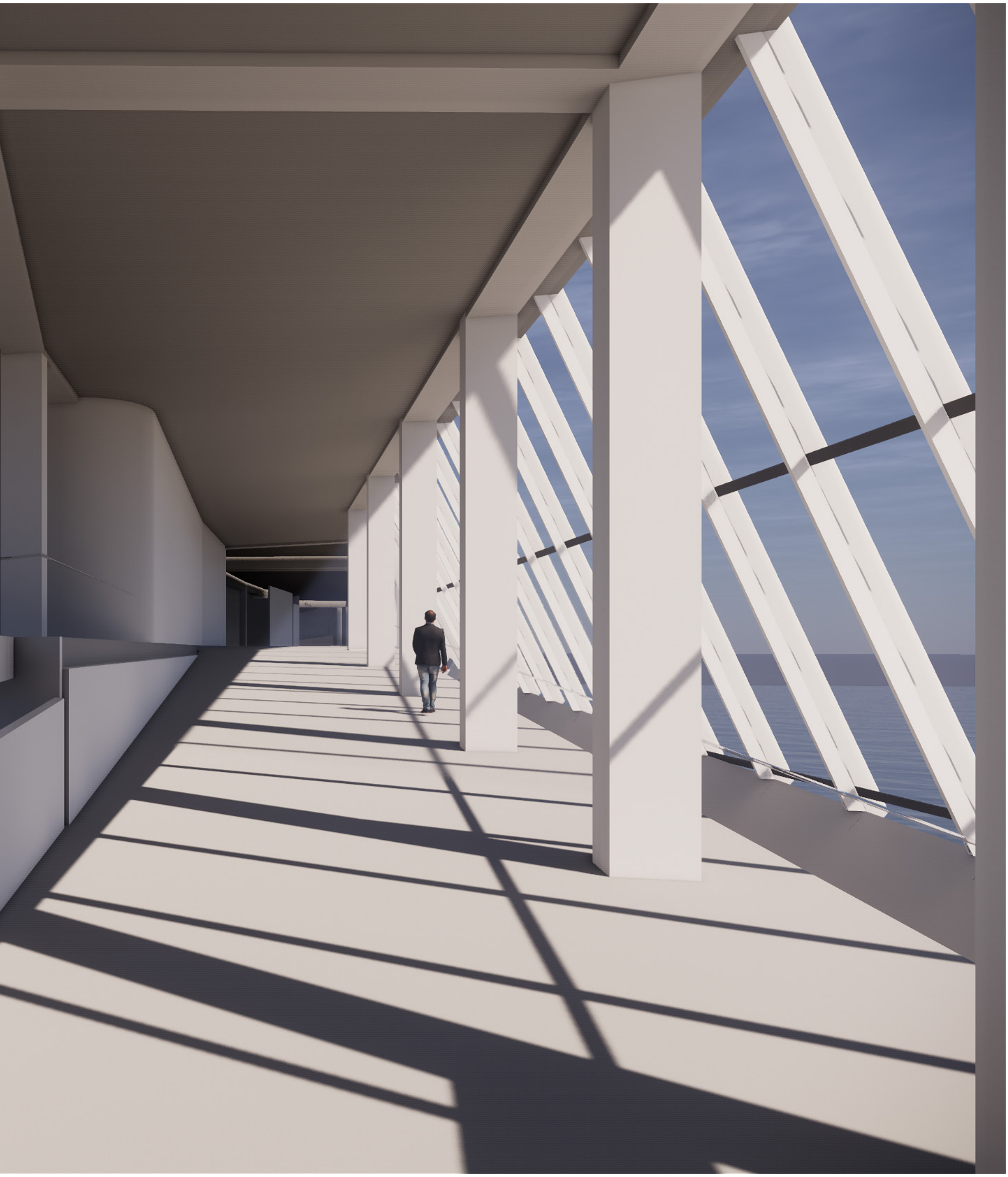












SUSTAINABLE BUILDING TECHNOLOGIES

|SUN PATH ANALYSIS|

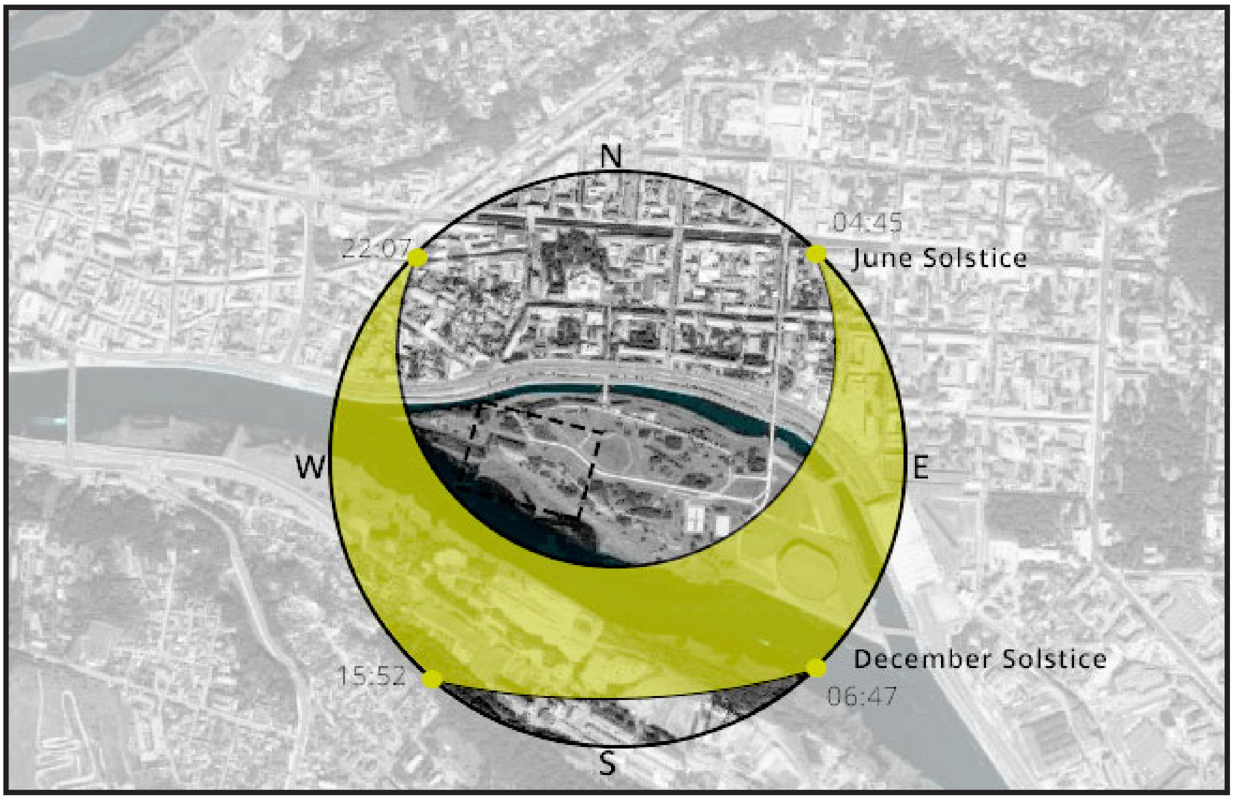


Figure 5.1 Annual Sun Path in Kaunas.

June Solstice:

Sun hrs: 17hr18min
Rise: NE
Set: NW

December Solstice:

Sun hrs: 9hr08min
Rise: SE
Set: SW

The longer portion of the site is oriented towards SE and NW.

In summer, the sun rises from NE and sets in NW with relatively long days reaching maximum of around 15hrs. In winter, with shorter days the sun becomes lower and rises from SE and sets in SW.

Target was to place the museum in such a position that the **maximum solar radiation exposure is achieved.** The tower was decided to be placed on the **edge of the island**, in order to highlight its role as a **landmark** of the city. Moreover, the solar radiation and the presence of the river contributed in having **most of the transparent elements on the south part of the Science Centre.** The absence of surrounding buildings made the **shadows analysis not important** for our designing.

|WEATHER ANALYSIS|

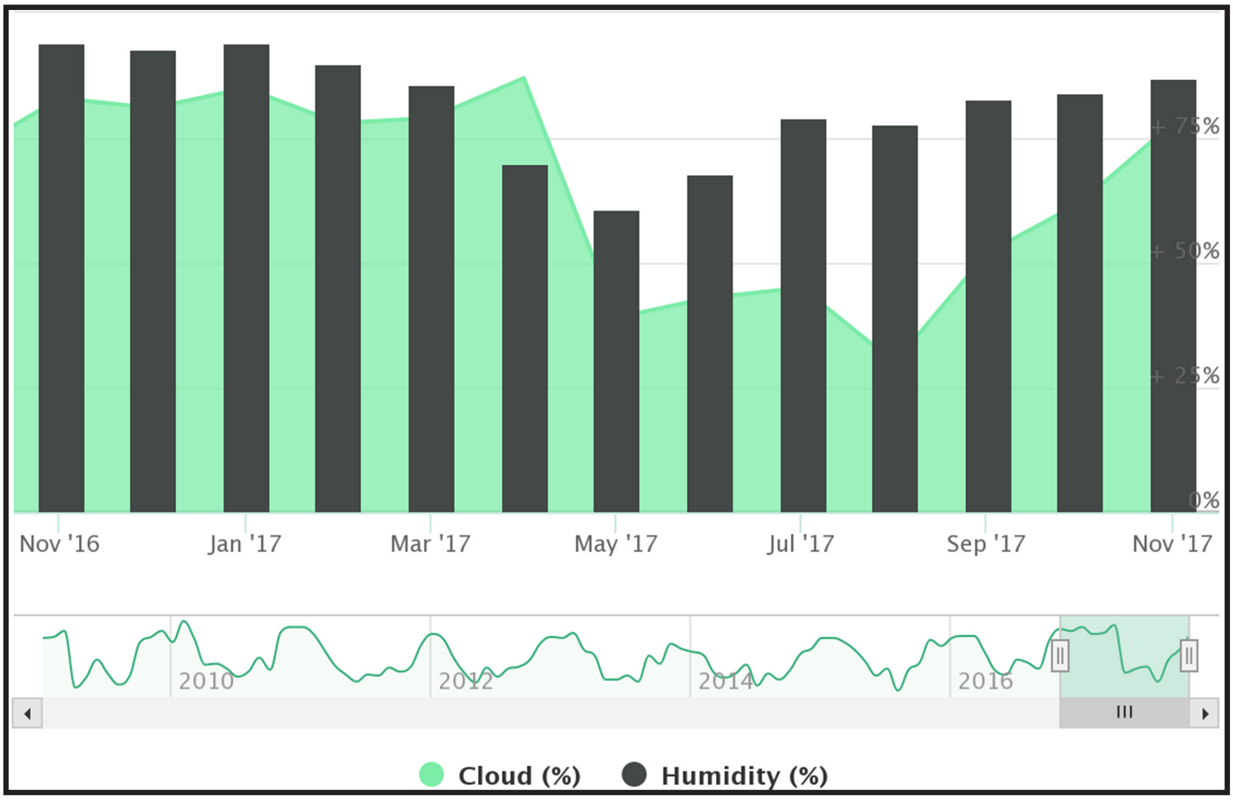


Figure 5.2 Cloud and humidity

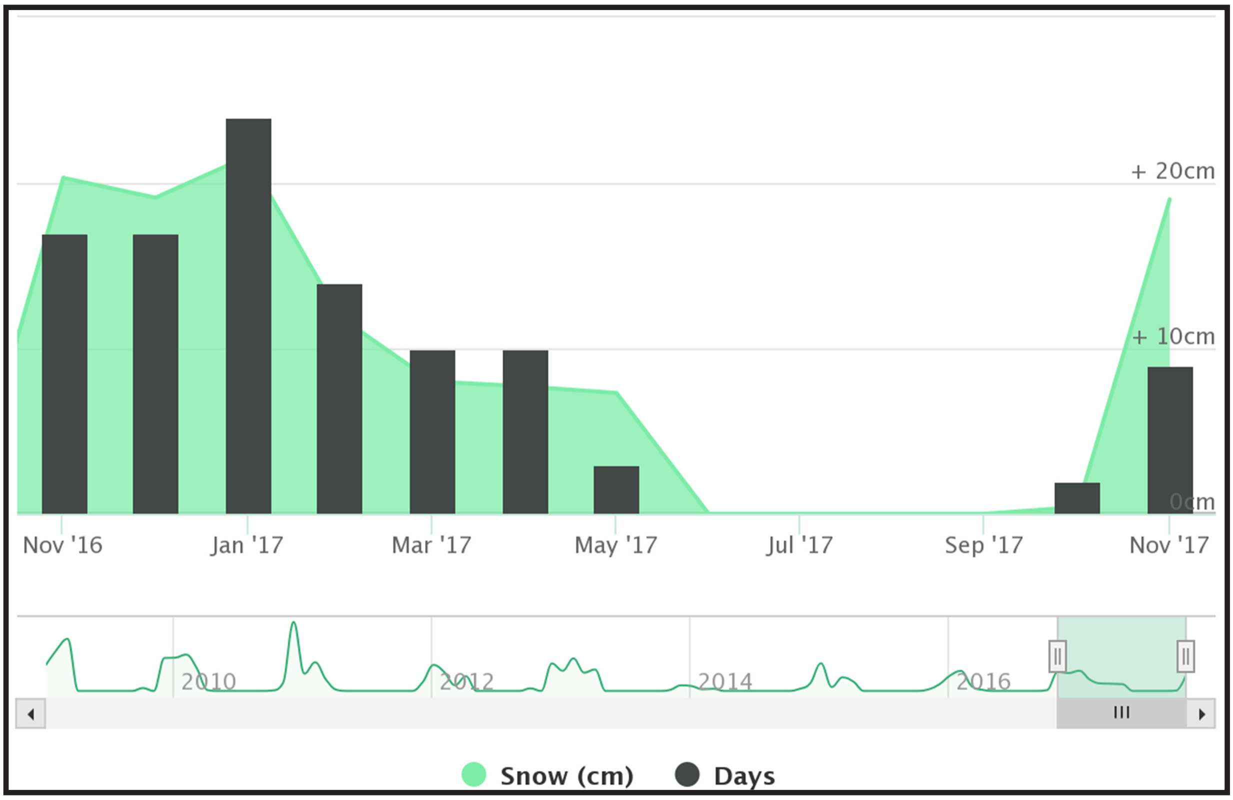


Figure 5.3 Snowfall and Snow Days

Source: WorldWeatherOnline.com

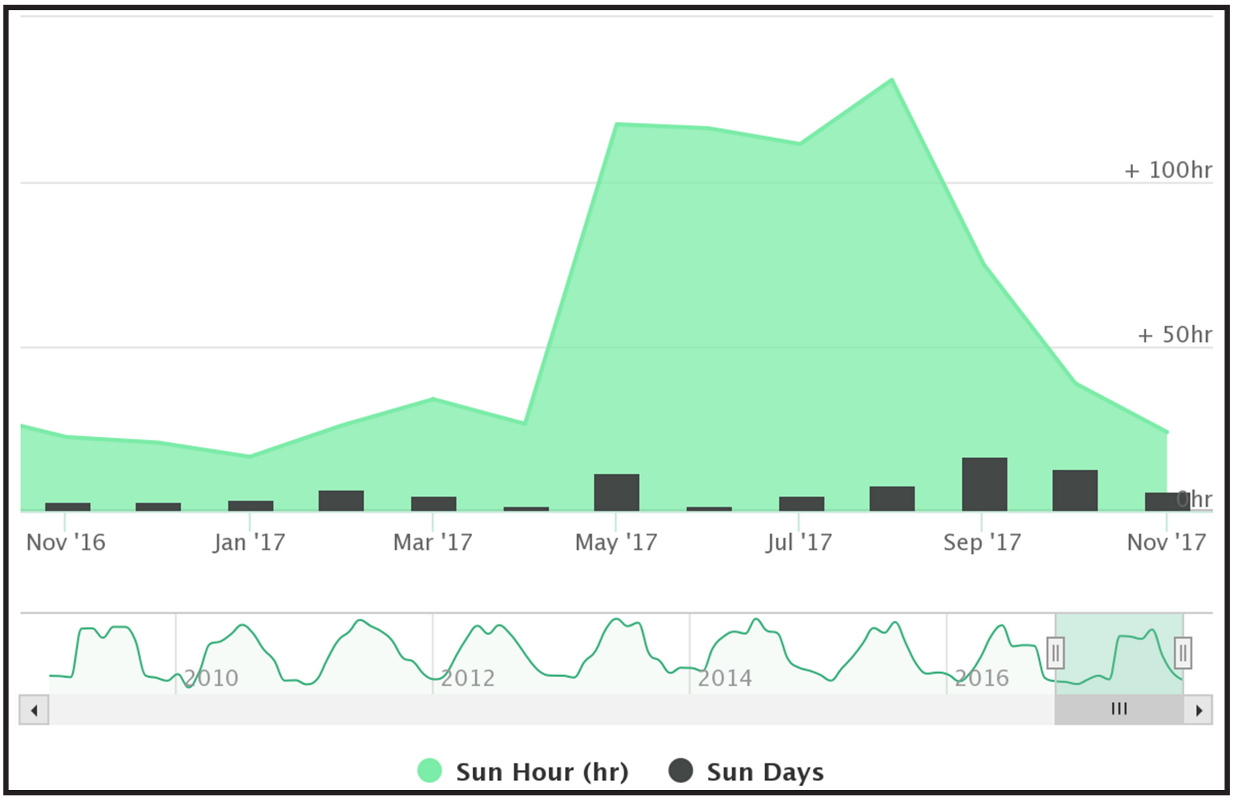


Figure 5.4 Sun Hours and Sun Days

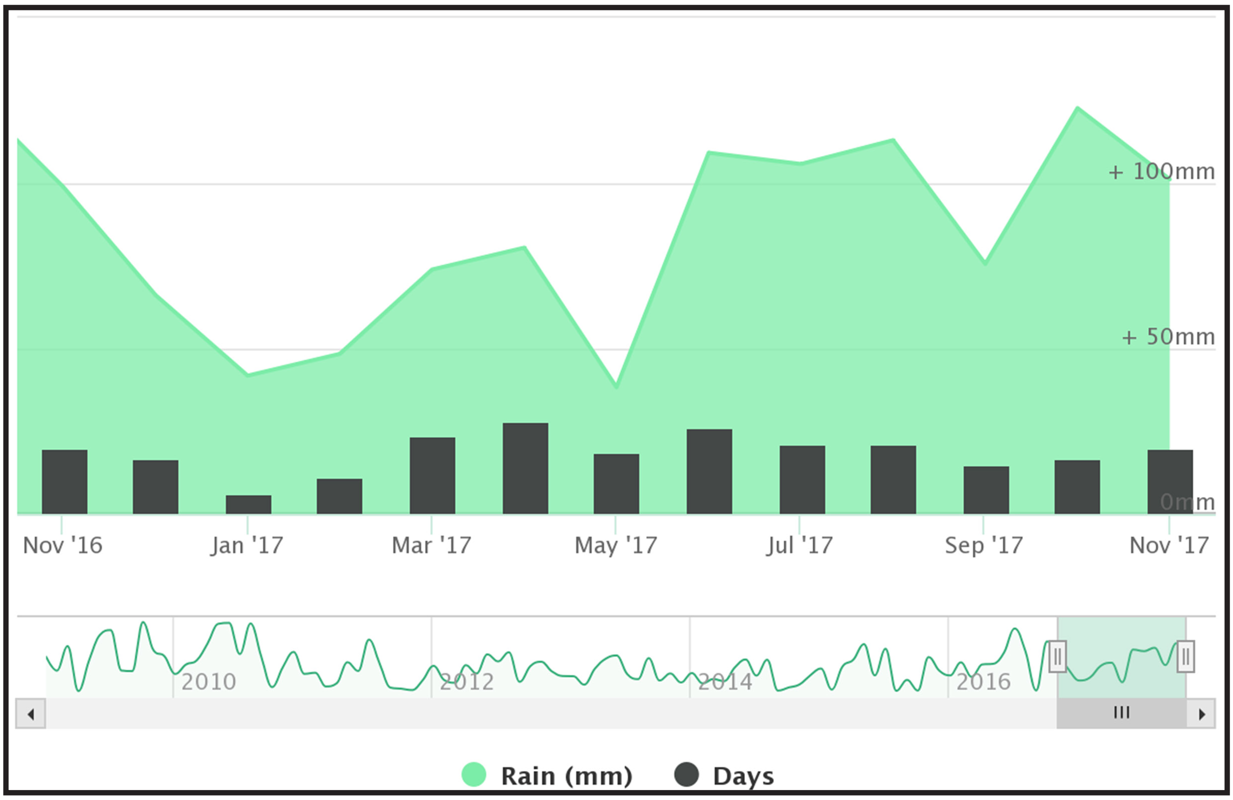


Figure 5.5 Rainfall and Rain days

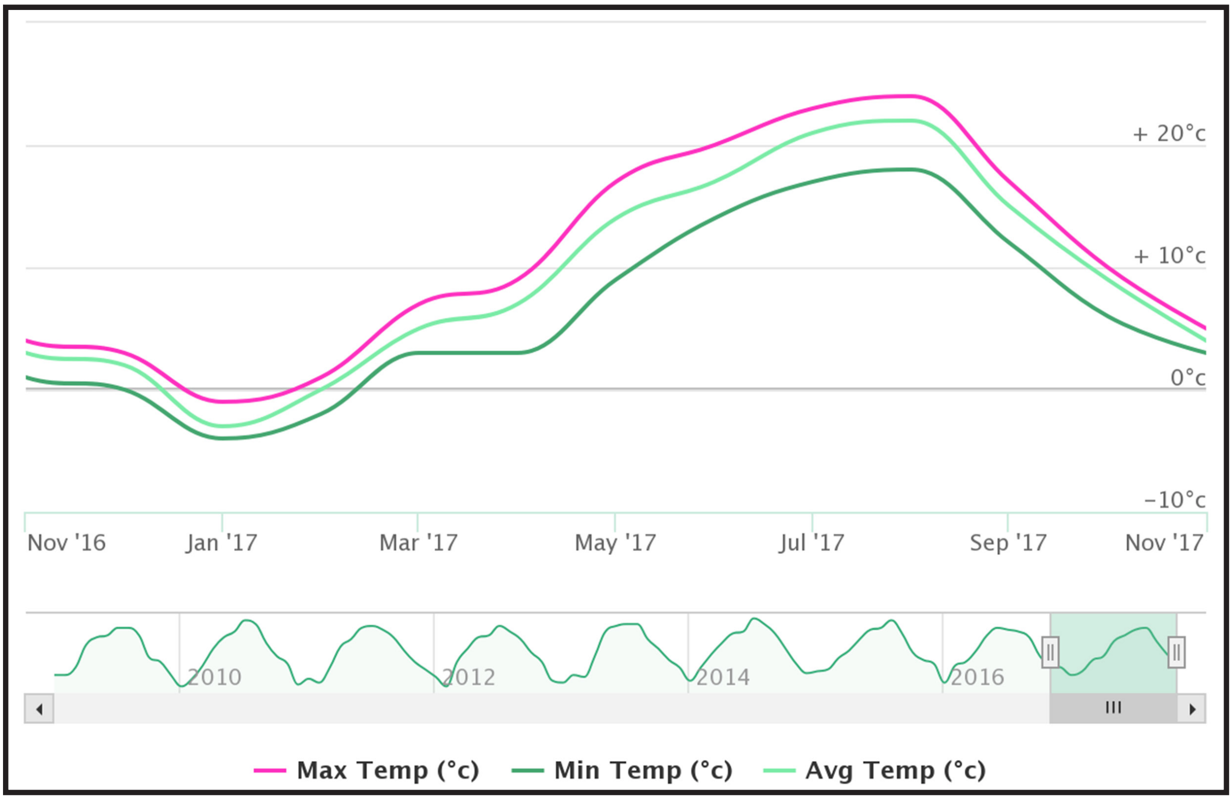


Figure 5.6 Max, Min and Average Temperature

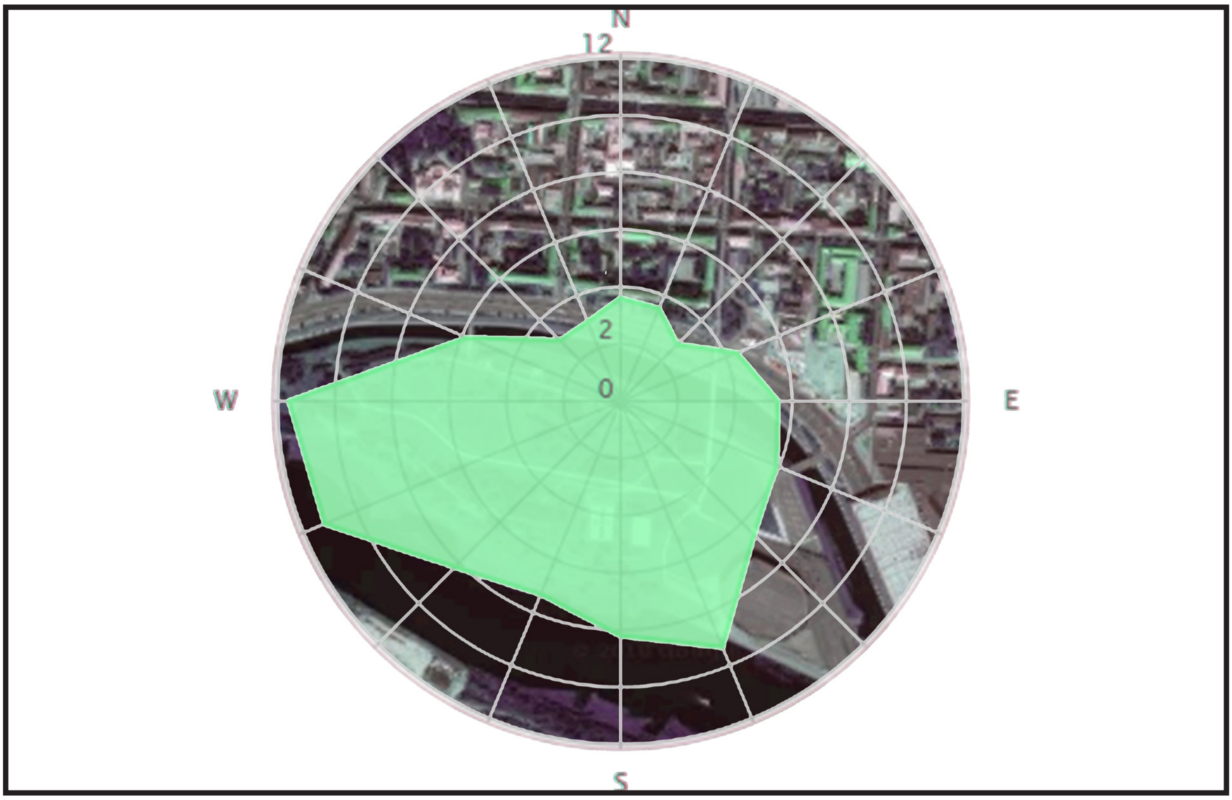


Figure 5.7 Wind distribution

Source: WorldWeatherOnline.com

"The climate in Kaunas is relatively mild compared to other locations in similar latitudes, mainly because of the Baltic Sea."

Lithuania's climate can be described as a typical European continental influenced climate. It is characterised by seasonal weather changes and has become warmer in recent decades.

The average annual temperature in the whole territory is 6.5-7.9° C. The warmest month of the year is July (with an average temperature of about 19.7°C, and a maximum of over 30°C), and the coldest is January (with an average temperature of about -2.9°C, and a lowest temperature during occasional severe frosts of below -30° C). Heavy snowfall or even snowstorms are also possible on some days.

The weather is often breezy and humid due to the proximity of the Baltic Sea. The most rainfall is recorded from April to October (60-65% of annual rainfall). Heavy rains are common nearly every summer with precipitation exceeding 30mm per day.

Despite its northern location, the climate in Kaunas is relatively mild compared to other locations in similar latitudes, mainly because of the Baltic Sea. The Kazlų Rūda Forest, west of Kaunas, create a microclimate around the city, regulating humidity and temperature of the air, and protecting it from strong western winds. Some characteristics based on the diagrams presented are:

- High percentages of humidity throughout the whole year and high cloud concentration during autumn, winter and spring.

- High amount of solar radiation during summer and really low during the other period of the year.

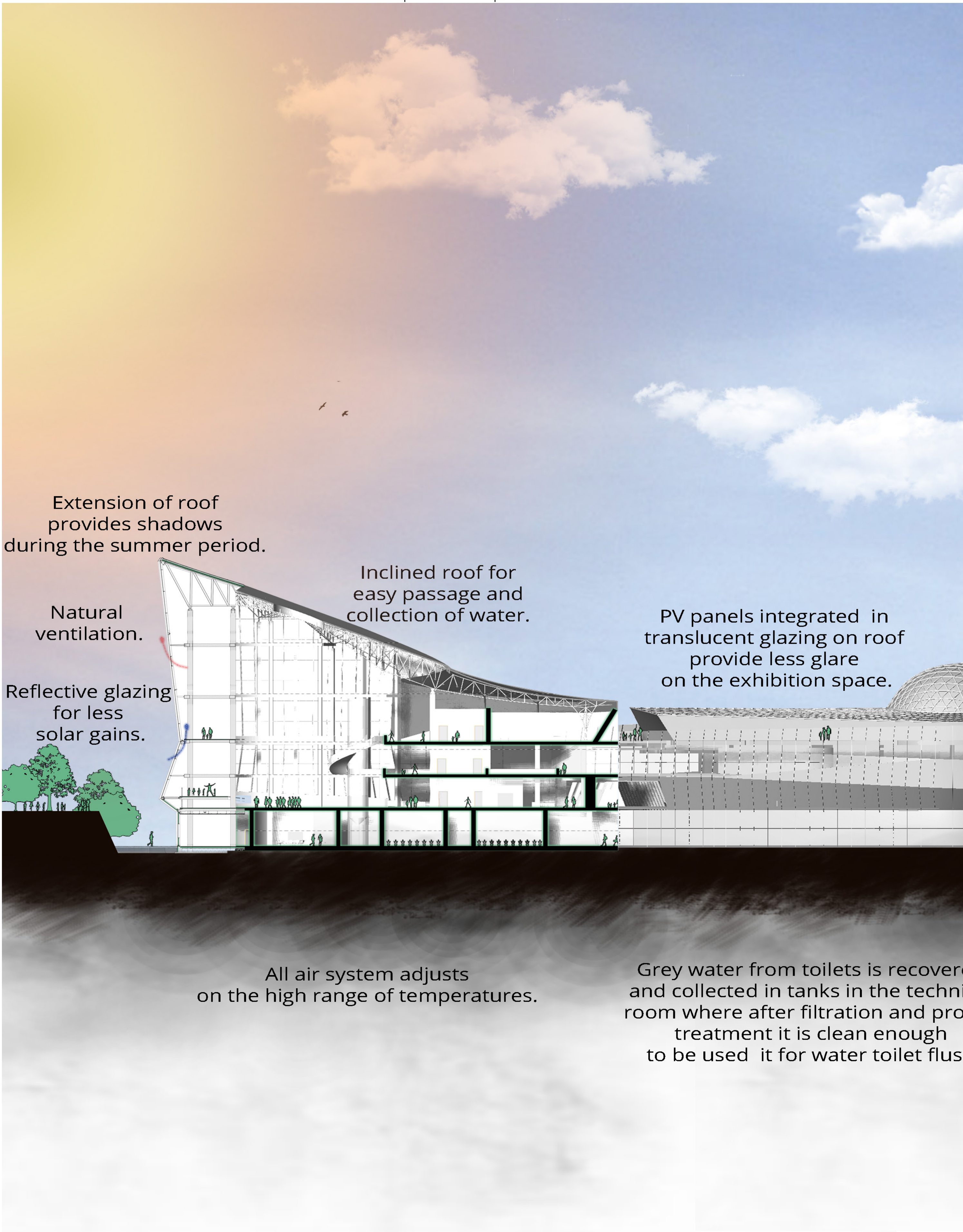
WEATHER ANALYSIS CONCLUSIONS

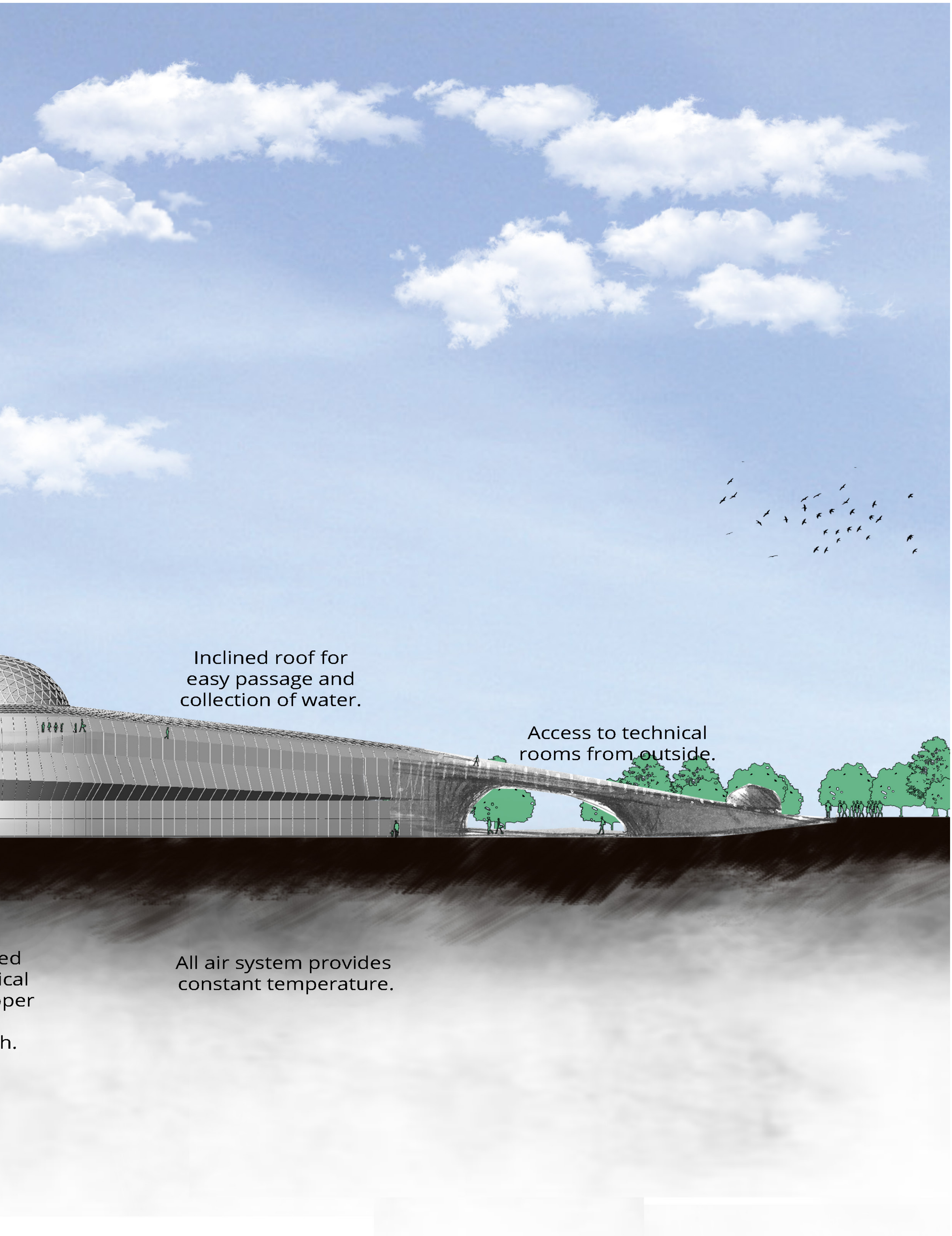
Weather's characteristics of Kaunas city will influence the design procedure of our thesis project. Hot summer periods, really cold winter, high amount of rainfall and snow will define the functions placed on the Project Area. Besides that, the characteristics of the building, like openings, shading, materials' choice, inclinations etc, are totally influenced by these climatical conditions.

On the other hand, wind speed is characterised as "Gentle breeze", which means that is not going to influence the architectural design in a primary way.

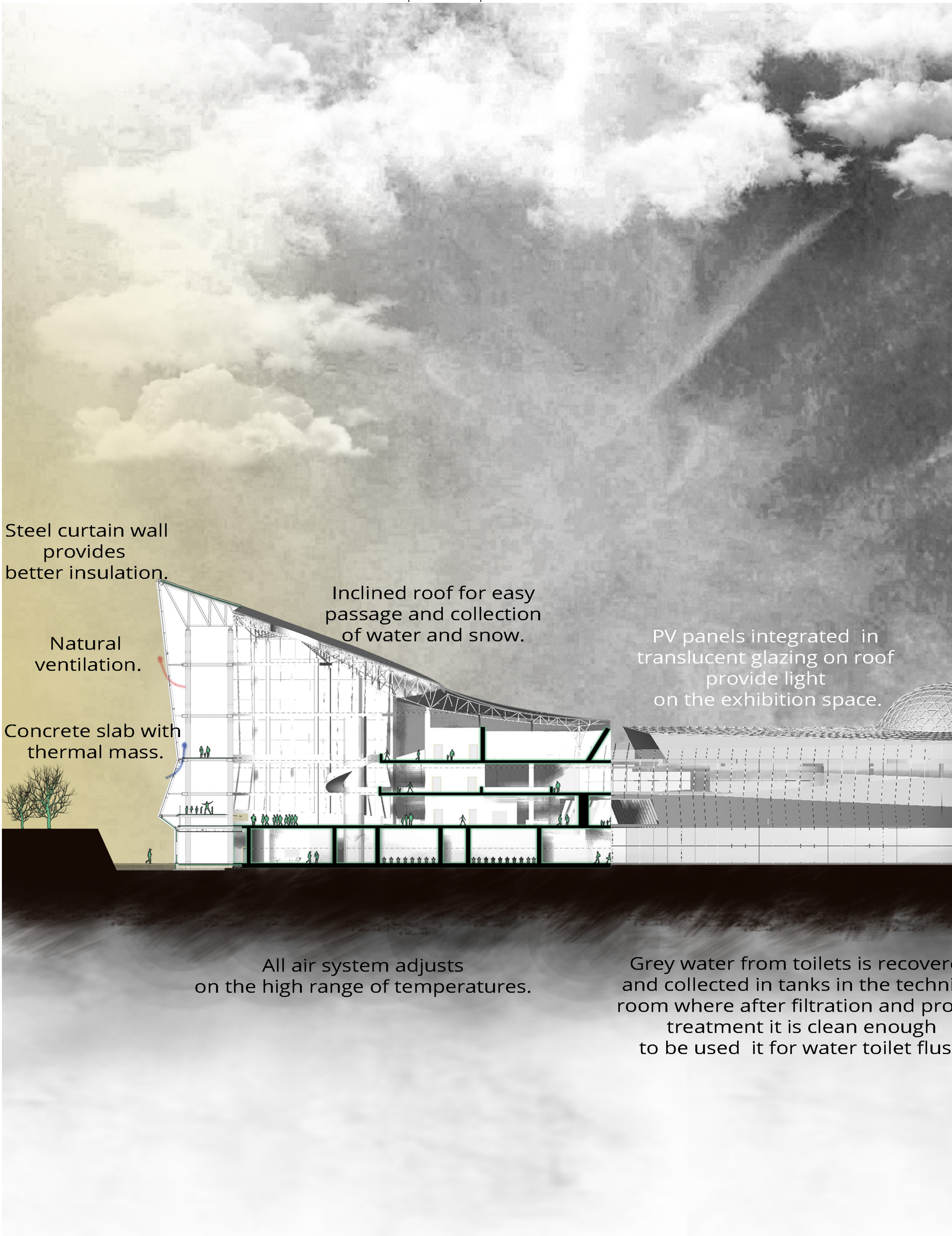
|GREEN STRATEGIES|

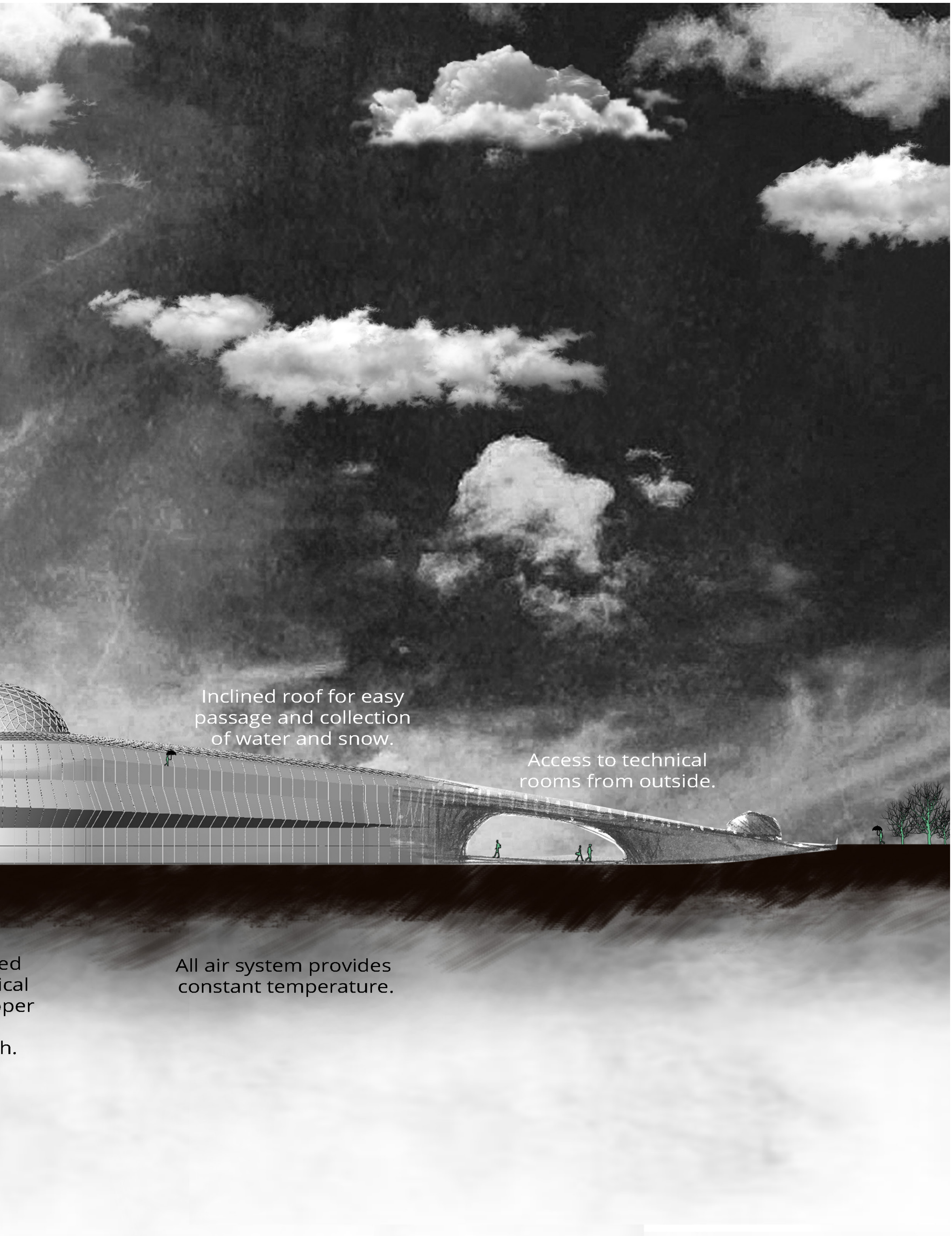
|Summer|




Inclined roof for easy passage and collection of water.
Access to technical rooms from outside.
All air system provides constant temperature.

|Winter|


Steel curtain wall
provides
better insulation.
Natural
ventilation.
Concrete slab with
thermal mass.
Inclined roof for easy
passage and collection
of water and snow.
PV panels integrated in
translucent glazing on roof
provide light
on the exhibition space.
All air system adjusts
on the high range of temperatures.
Grey water from toilets is recovere
and collected in tanks in the techni
room where after filtration and pro
treatment it is clean enough
to be used it for water toilet flus


Inclined roof for easy passage and collection of water and snow.
Access to technical rooms from outside.
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ical
per
h.
All air system provides constant temperature.

|DAYLIGHT VISUALISATION|

WHERE DOES THE MUSEUM AND THE OUTSIDE WORD BEGIN?

Museums present challenges to glazing designs, given the tight environmental conditions that must be met. Consideration must be given to many parameters, often conflicting, including:

- quality and quantity of light,
- ultraviolet resistance,
- aesthetics,
- thermal performance,
- condensation resistance, strength,
- security performance,
- safety and cost.

For a best-practice curatorial environment, temperature and humidity must be contained within a tight band of 18° to 22° Celcius and 45% to 60% relative humidity year-round. Artifacts and artwork must also be protected from UV and visible solar radiation at the same time as being displayed in “natural” light.

WHAT ARE THE STANDARDS FOR MUSEUMS?

There are several different organizations defining light standards for museums. To mention a few, there is International Council of Museums (ICOM), Illuminating Engineering Society (IES), the British organization The Society of Light and Lighting, and the European standard DS/EN 12464-1.

Figure 5.7 from the European standard DS/EN 12464-1, gives the lighting schedule for different rooms and activities based on their function and requirement. It lists downs the maintained illuminance E_m and Unified Glare Rating limit (UGRL), but there is no value given for museums, because of their subjective and sensitive nature. In most office buildings, there is a need for light levels in task areas between 50 and 5000 lux according to DS/EN 12464-1, with a minimum of 300 lux.

Those light levels are too high to fulfill preservation requirements. For exhibition requirements, light levels are restricted to between 50 and 200 lux for light sensitive works. Light sensitive works include paintings, carpets, sculptures, artefacts among other items. Furthermore, restrictions are given for the amount of time light sensitive works are exposed to light.

Because of this sensitive nature of the items displayed in museums, a low natural daylight is needed.

5.5	**Museums**				
Ref. no.	**Type of interior, task or activity**	$\bar{E}_m$ lx	UGR_L -	R_a -	**Remarks**
5.5.1	Exhibits, insensitive to light				Lighting is determined by the display requirements.
5.5.2	Light sensitive exhibits				1. Lighting is determined by the display requirements. 2. Protection against damaging radiation is paramount.

Figure 5.8 Lighting schedule for different rooms and activities based on their function and requirement.

After analysing the site conditions and introducing the design principles for the placing of windows, each part of the museum is presented with its function, specific lighting requirements, and architectural consideration regarding the required natural lighting.

By mentioning the various influences (architectural, technical and performance) in one chapter, the aim was to **communicate the design as a compromise between various influences.**

SITE CONDITION

The Science Center is located on an **island with no buildings** in close vicinity but surrounded by **trees** on the North and East, blocking incoming solar radiations. At the south and west flows the **Nemunas river.**

The Science Center has a limited opening time, which makes utilizing thermal mass for heat storage into the evening hours less attractive.

The placing of the glazing therefore followed considerations of indoor visual comfort and diffused daylighting rather than that of a sophisticated energy balance.

To inform the placing of windows and other transparent elements of the center's envelop, extended analysis with Grasshopper (Ladybug and Honeybee tools) as plug-in for Rhino 5 has been carried out.

The general procedure was to determine the required amount of glazing and solar transmittance on each orientation to achieve the optimum level of daylight for the exhibitions and visual comfort for the visitiors.

INPUTS:

-Daylight factor (%) and illuminance (lux) was analysed for the tower, bridge and the exhibition spaces of the Science Center.

-At every orientation, 3 values of window-to-wall ratio were analysed: 25%, 50%, and 75%. Figure 5.8 shows the Grasshopper model for 25% and 50% WWR.

-Illuminance analysis was performed with a 2D analysis grid, placed on all the floors, 0.76m above the floor plane. The grid size was 1m x 1m encompassing all the interior areas except the service floor.

-For each scenario, an illuminance analysis is conducted at **1pm t**o represent summer solstice, fall equinox, and winter solstice (**June 21 , September 21 , and December 21**). This resulted in a total of 9 simulation runs for this experiment.

-The figure 5.9 shows the occupancy hours throughout the year. The Science center in Kaunas is open from Tuesday to Sunday, from 10am to 5pm.

Subsequently a balance was made between the architectural concepts for each exhibition hall and other closed spaces, and the amount of glazed surfaces were calculated.

The chosen solutions have been analyzed again to guarantee proper lighting in all parts of the structure.

OUTPUTS:

The following values were calculated for each floor in each zone.

-Daylight Factor average: a ratio that represents the amount of illumination available indoors relative to the illumination present outdoors at the same time under overcast skies.

-Illuminance (lux): measures the amount of light falling onto and spreading over a given surface area.

- sDA: spatial dayilght autonomy describes how much of a space receives sufficient daylight. Specifically, it describes the percentage of floor area that receives at least 300 lux for at least 50% of the annual occupied hours.

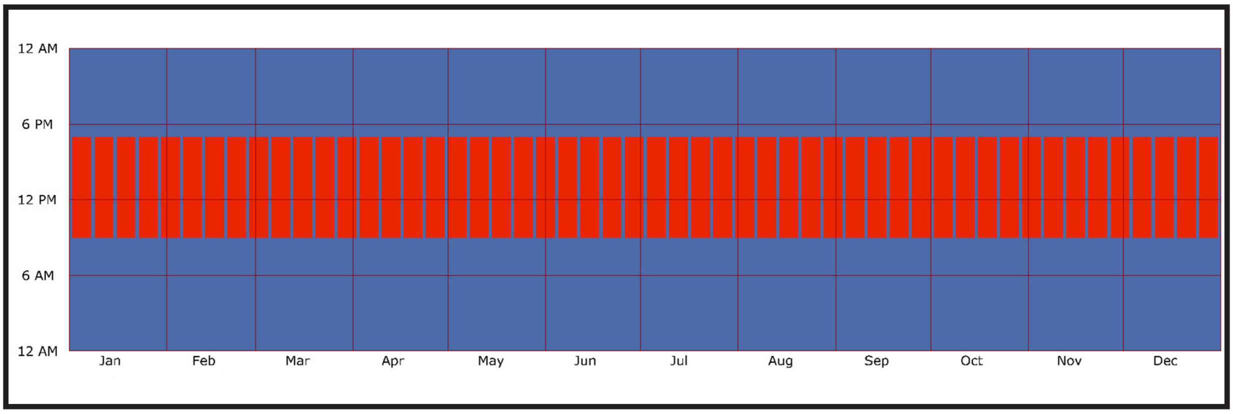


Figure 5.9 Occupancy hours throughout the year.function and requirement.

The Science Center is analysed for daylighting on the following floor levels:

	Tower and Bridge	Exhibition Spaces
Floor 0	Entrance, Info point, Ticketing	Permanent Gallery - Man, Machine; Research Lab, Exploratorium, Planetarium
Floor 1	Shop, Introduction space	Permanent Gallery - Nature; Temporary Gallery
Floor 2	Restaurant	Temporary Gallery extension

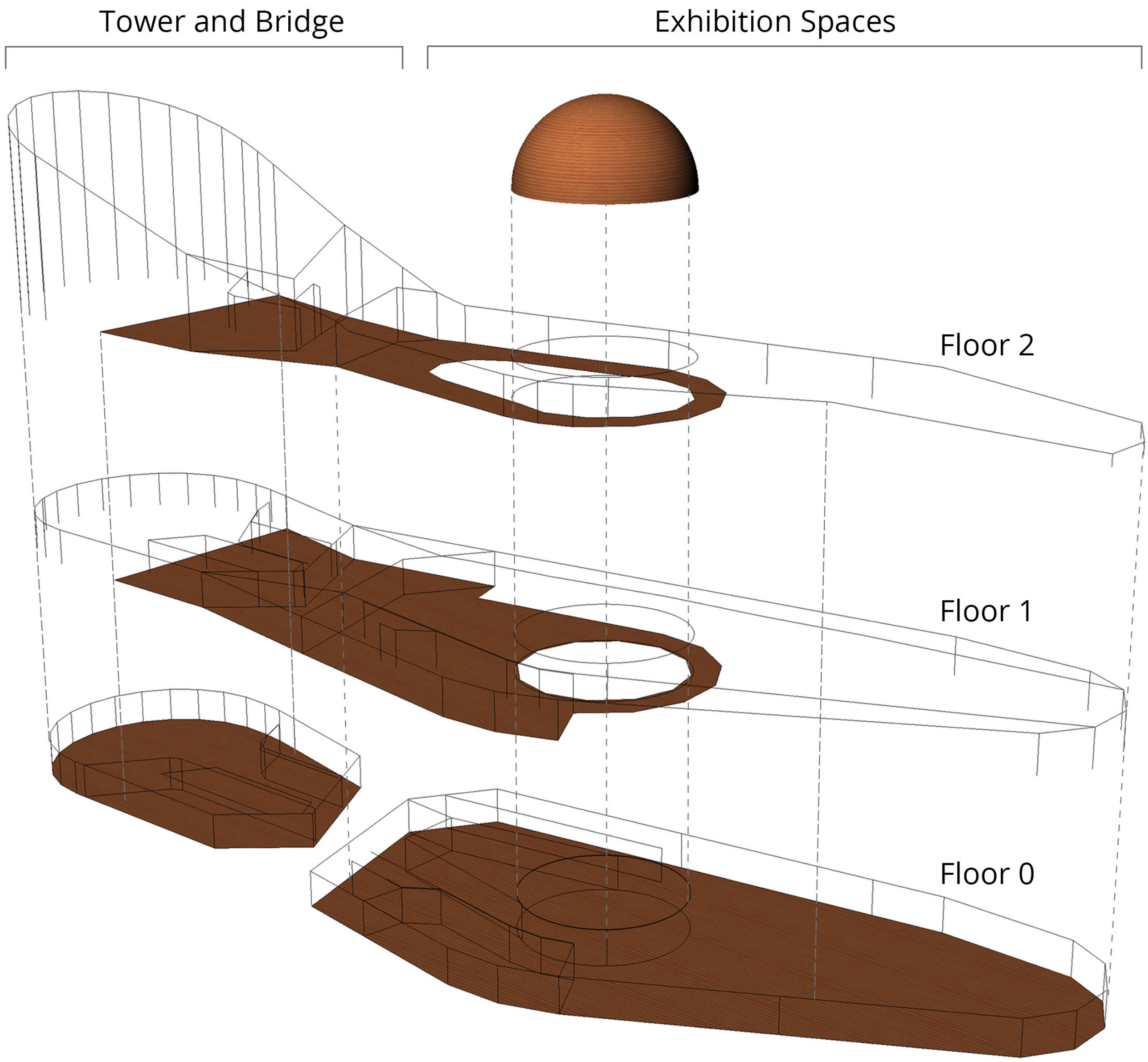


Figure 5.10 Floors to be analysed.

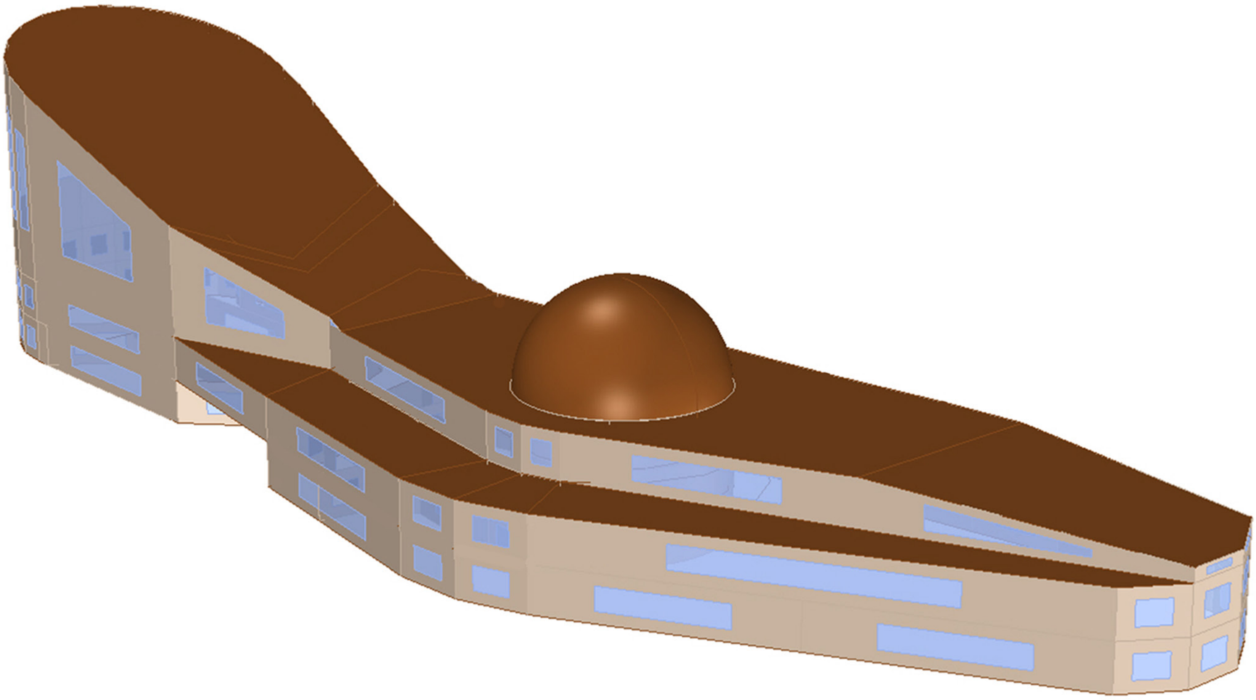


Figure 5.11 25% Window to Wall Ratio.

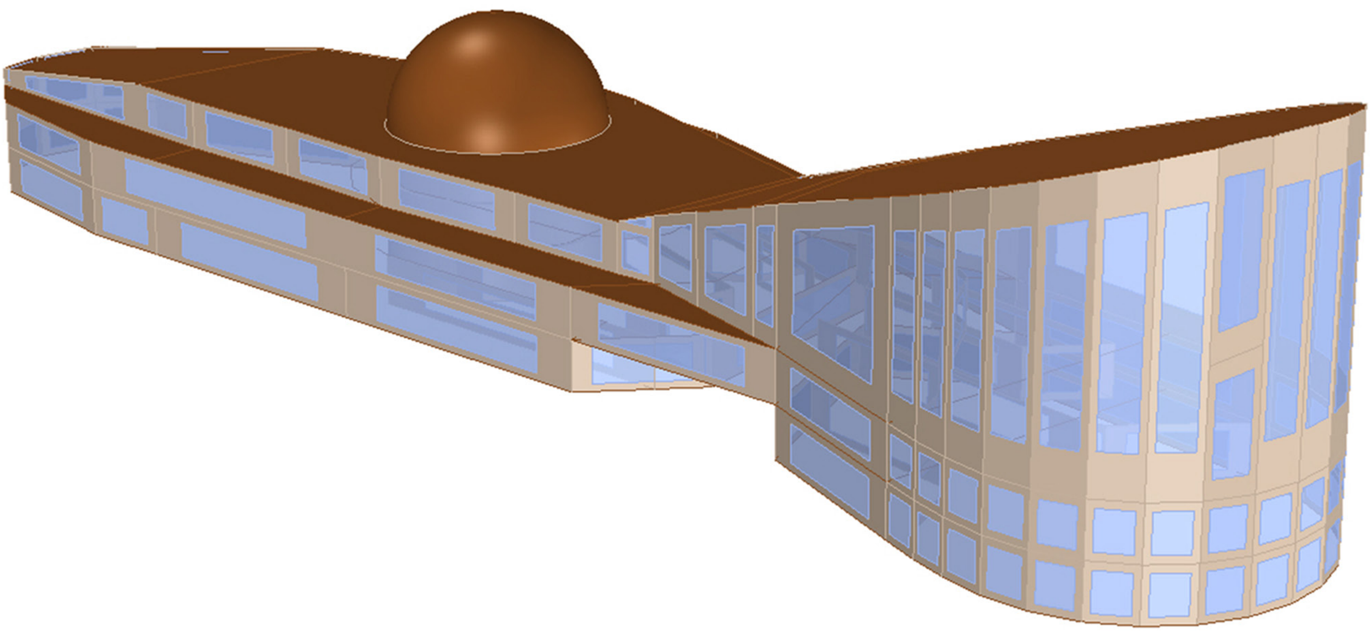
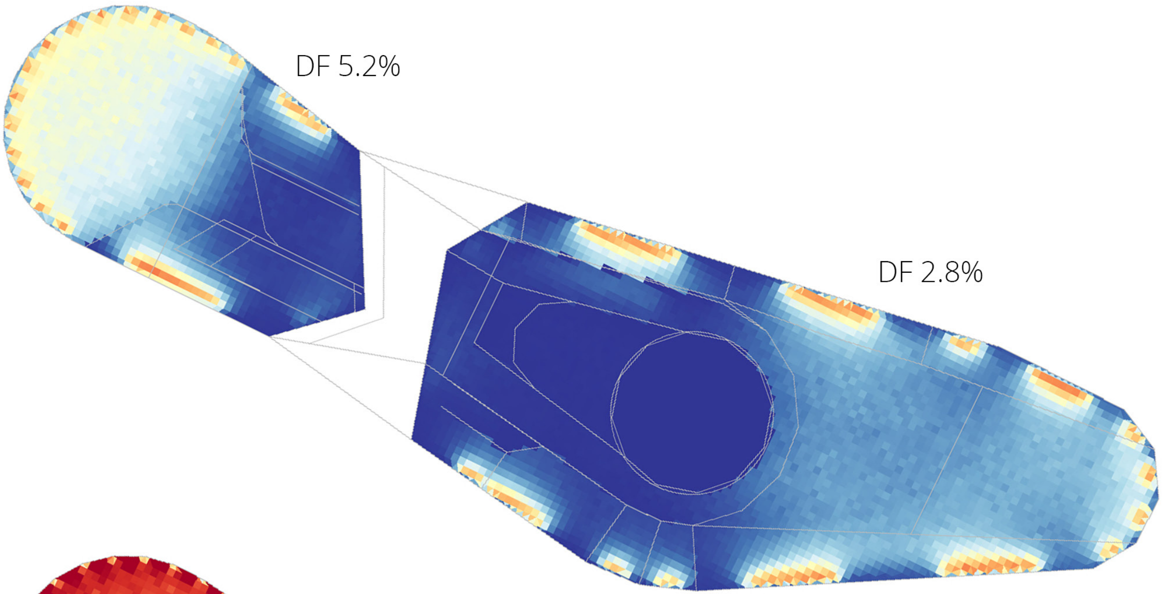


Figure 5.12 50% Window to Wall Ratio

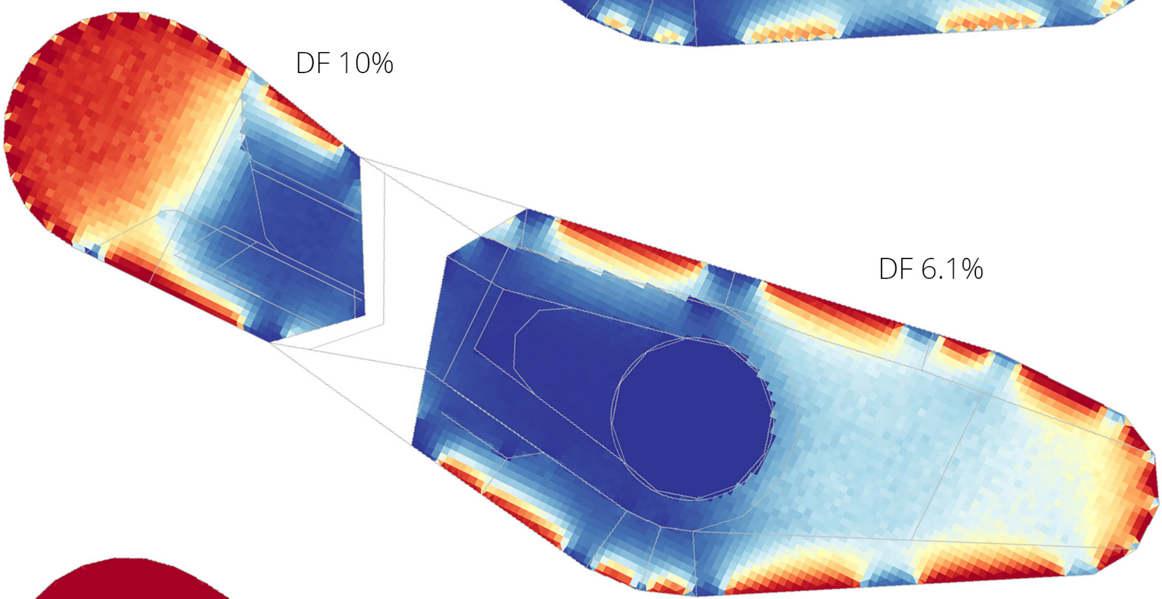
|DAYLIGHT FACTOR|

Floor 0

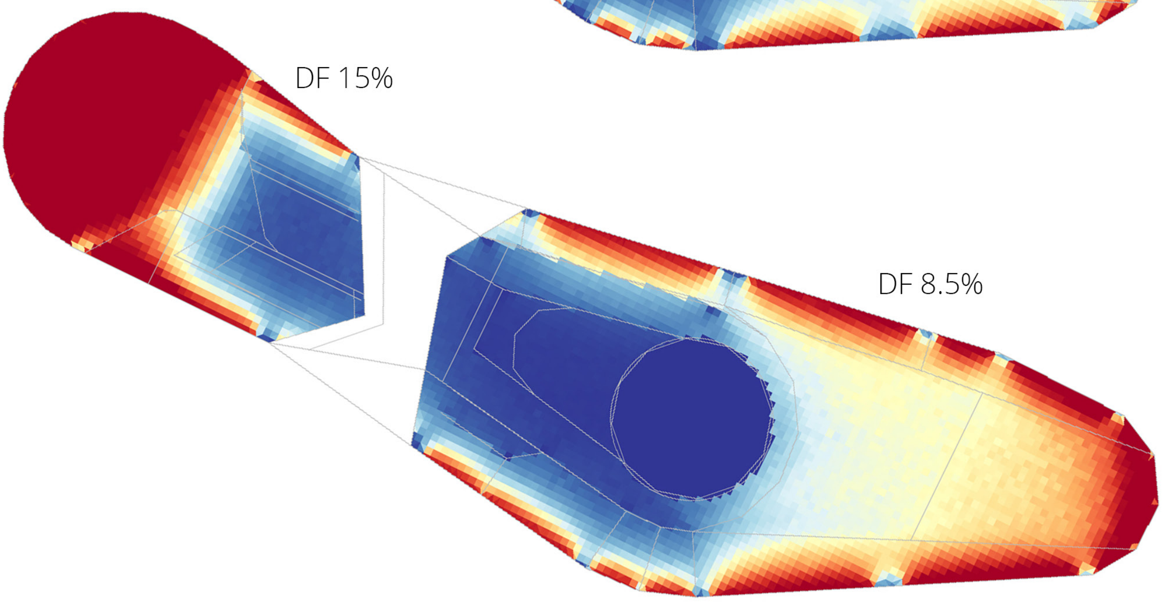
25 percent Glazing

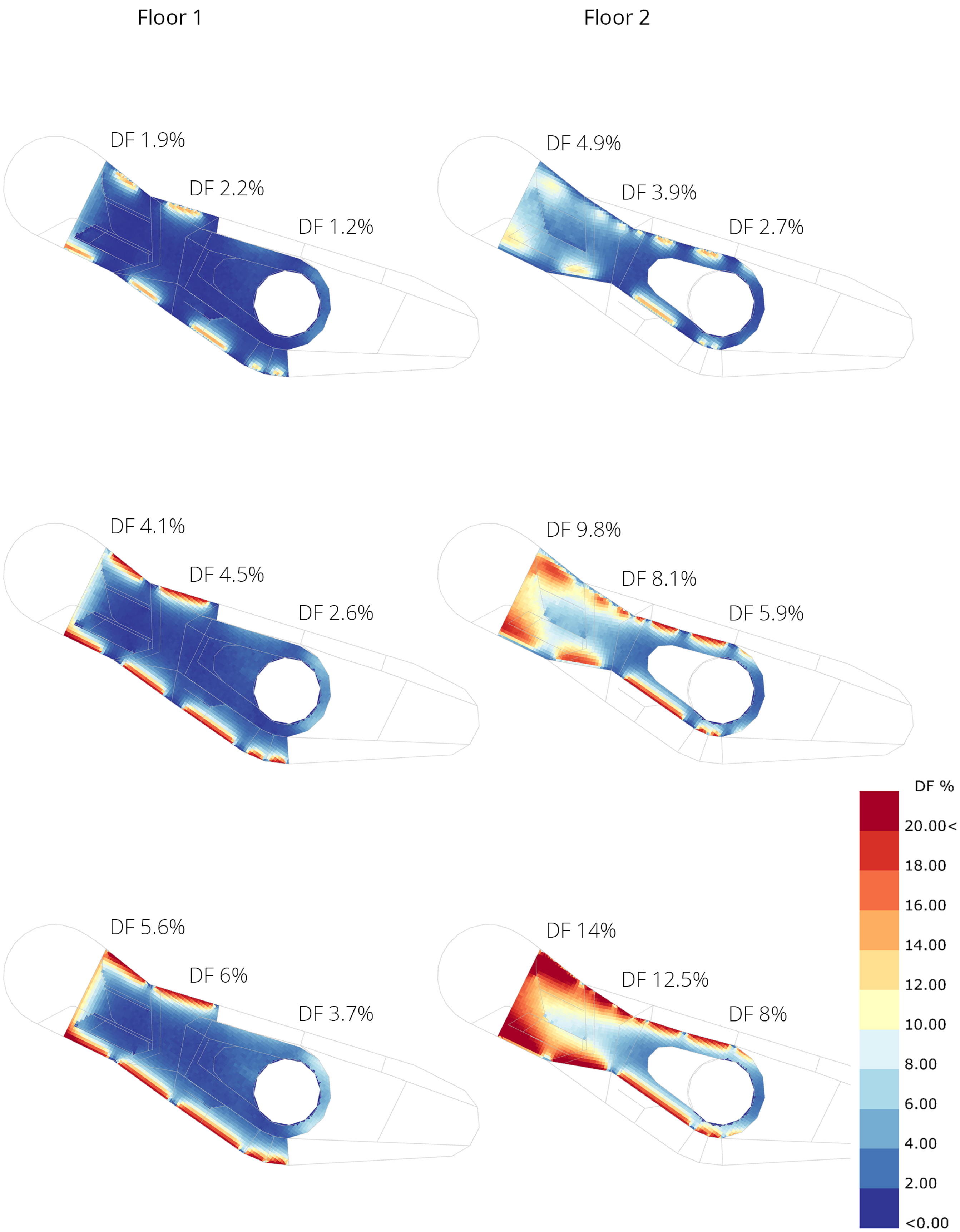


50 percent Glazing



75 percent Glazing

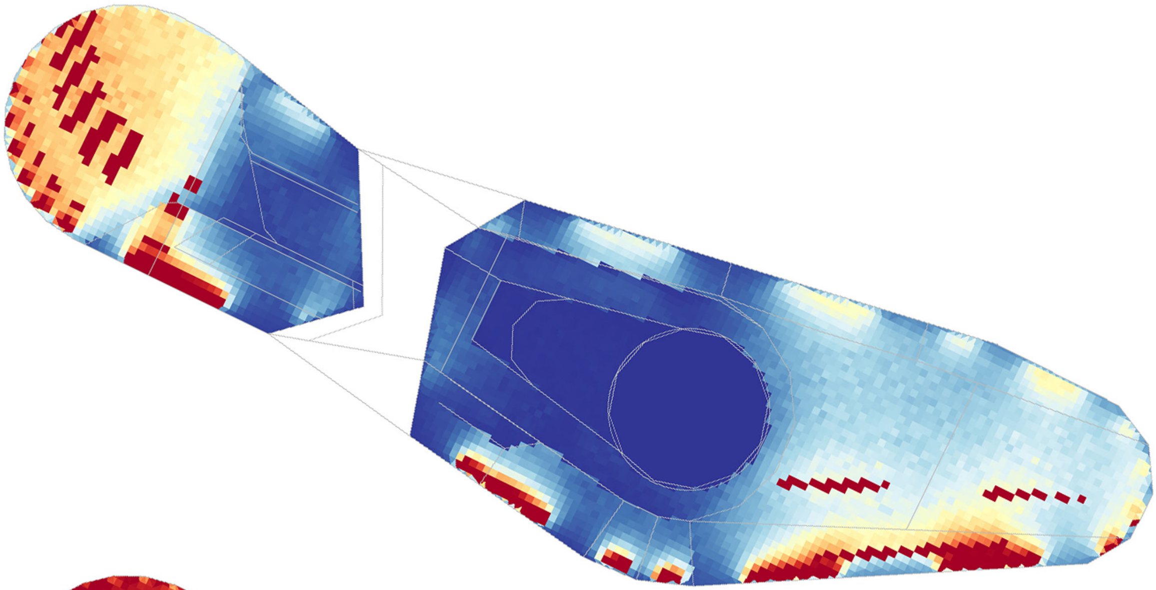



Floor 1
Floor 2
DF 1.9%
DF 2.2%
DF 1.2%
DF 4.9%
DF 3.9%
DF 2.7%
DF 4.1%
DF 4.5%
DF 2.6%
DF 9.8%
DF 8.1%
DF 5.9%
DF 5.6%
DF 6%
DF 3.7%
DF 14%
DF 12.5%
DF 8%
DF %
20.00<
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
<0.00

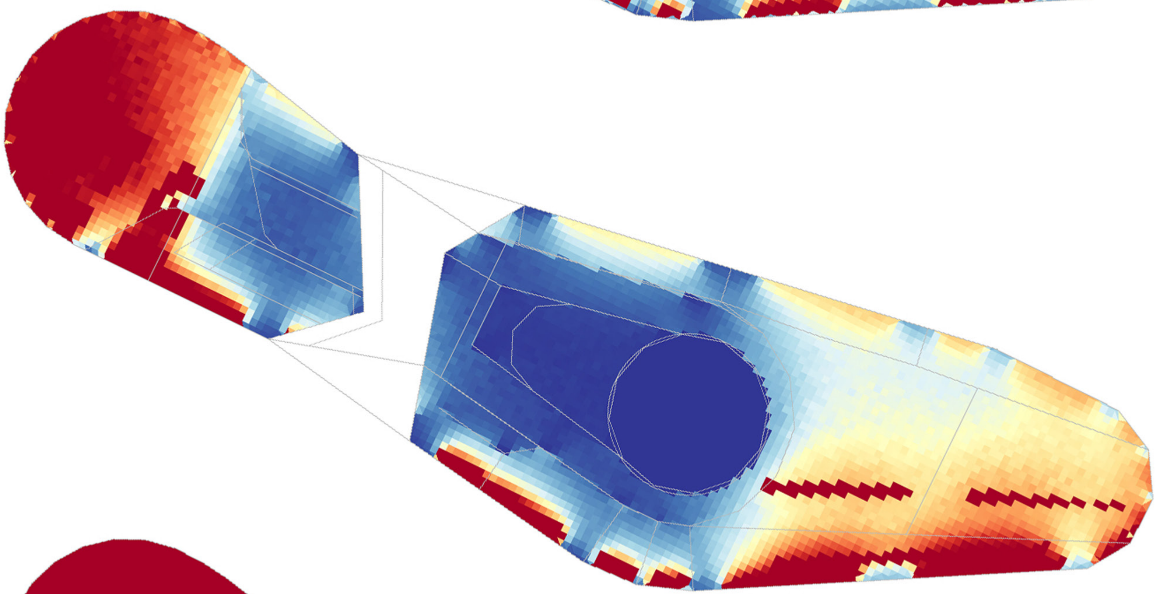
|Illuminance Analysis - June 21 - 1PM|

Floor 0

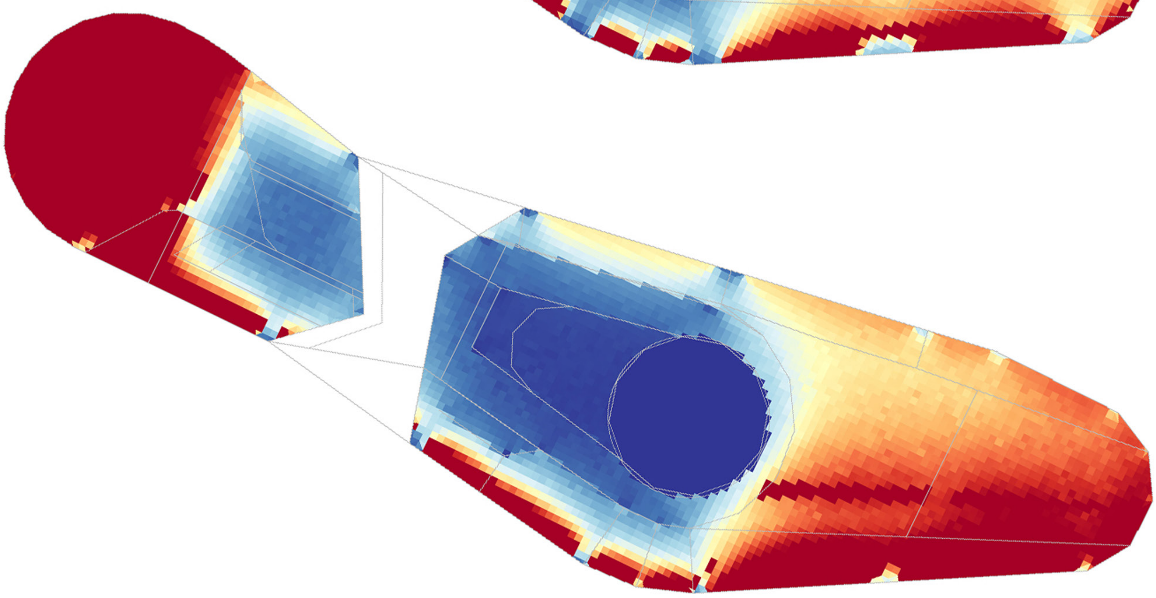
25 percent Glazing



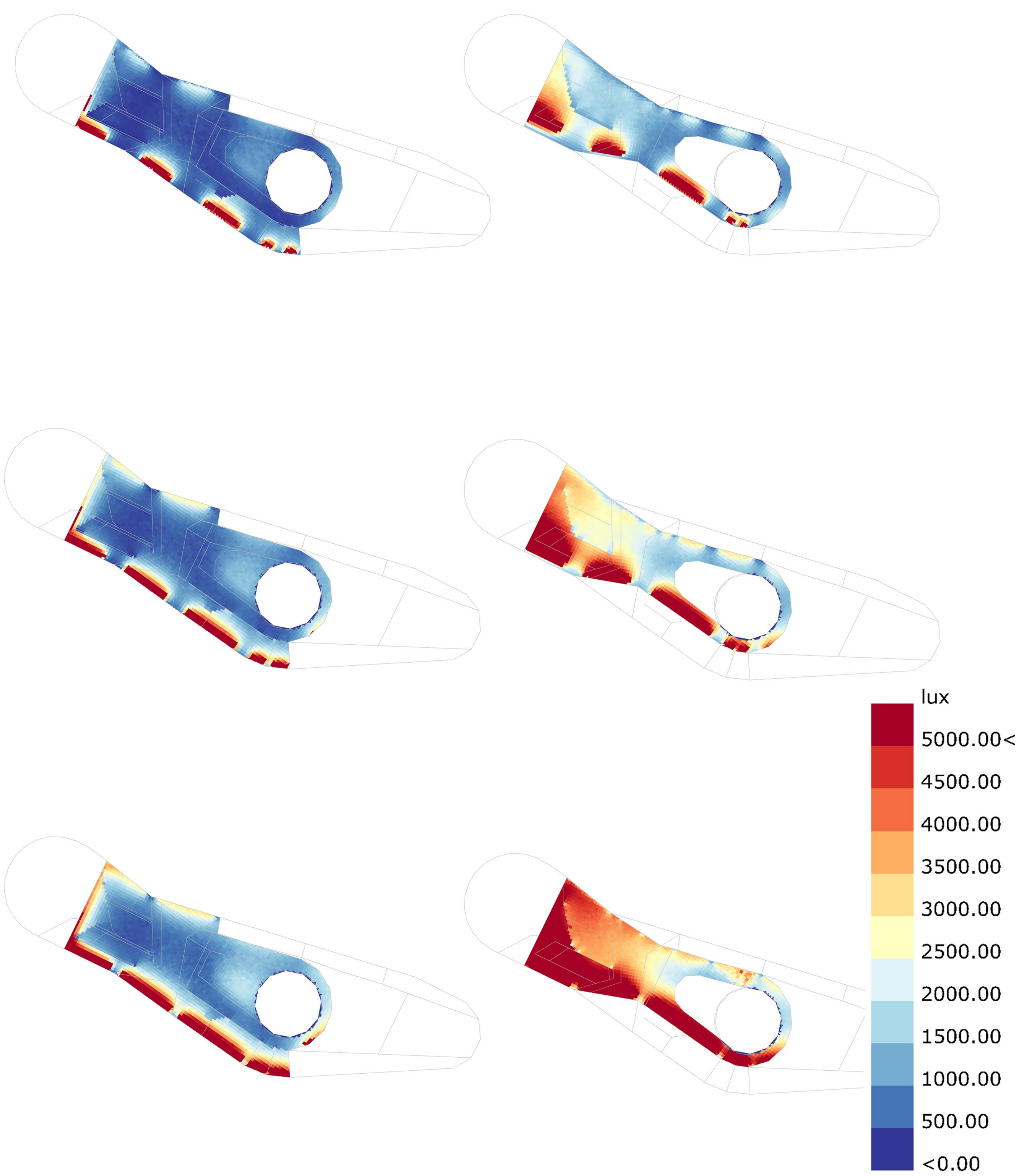
50 percent Glazing



75 percent Glazing



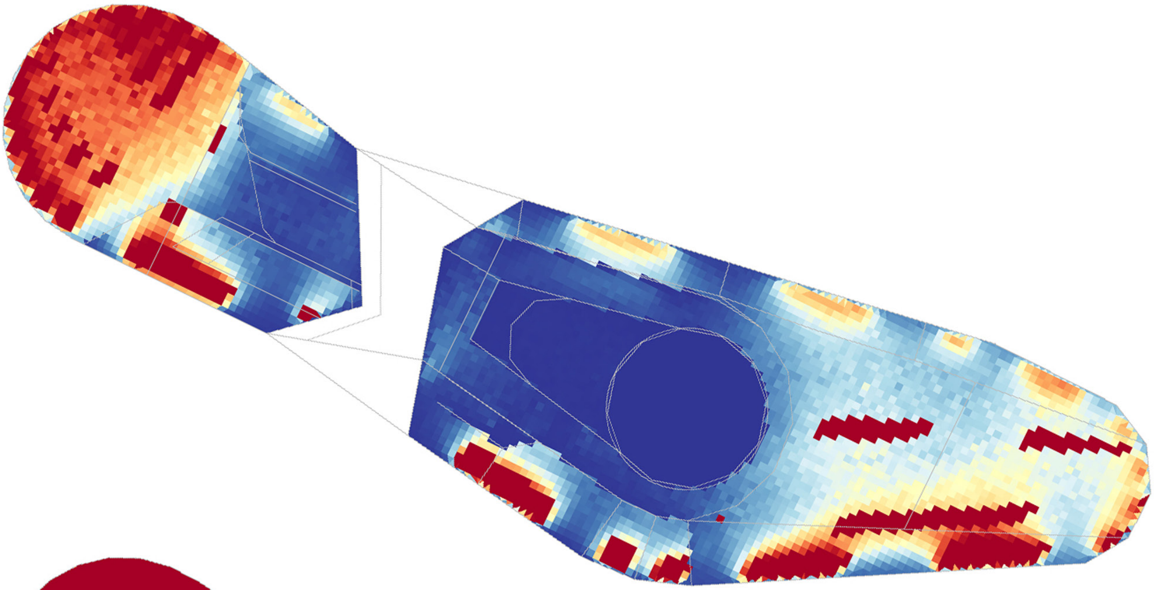
Floor 1 Floor 2



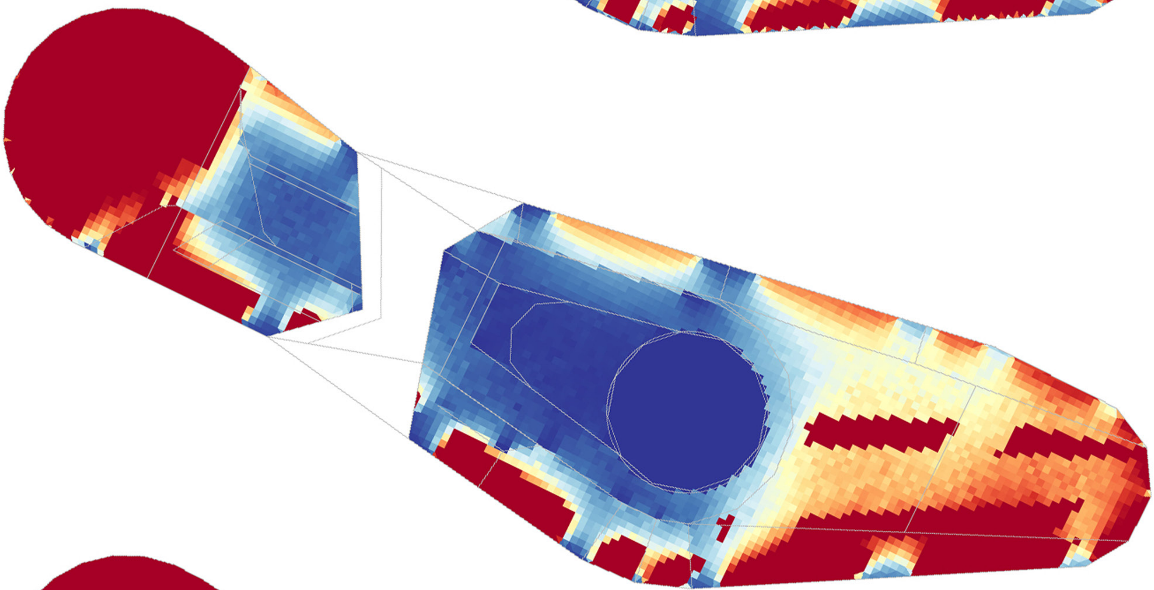
|Illuminance Analysis - Sep 21 - 1PM|

Floor 0

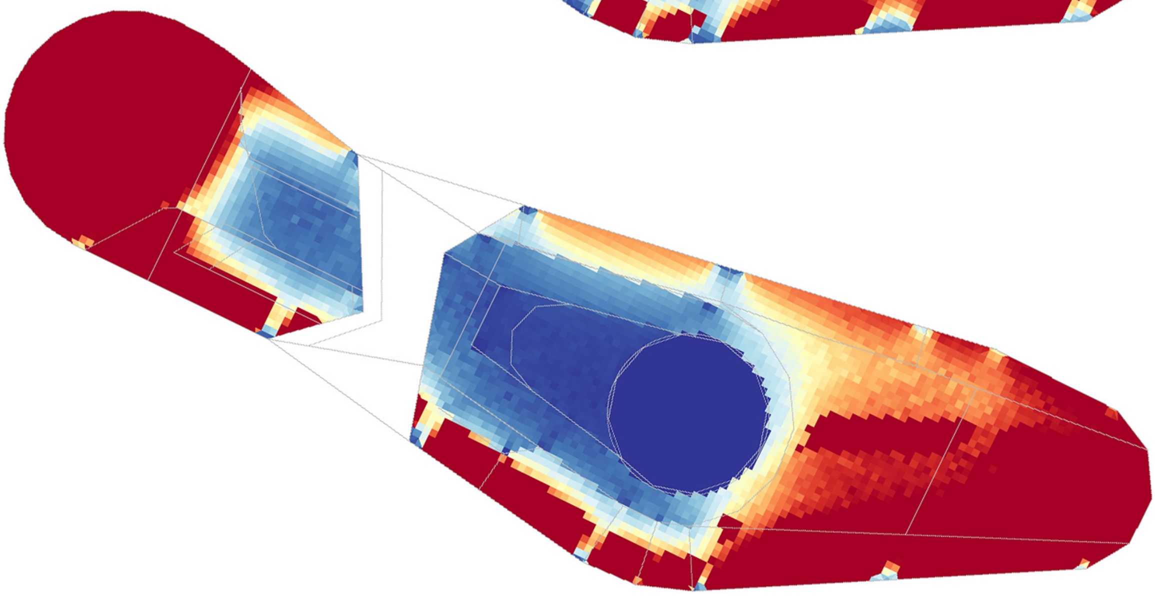
25 percent Glazing



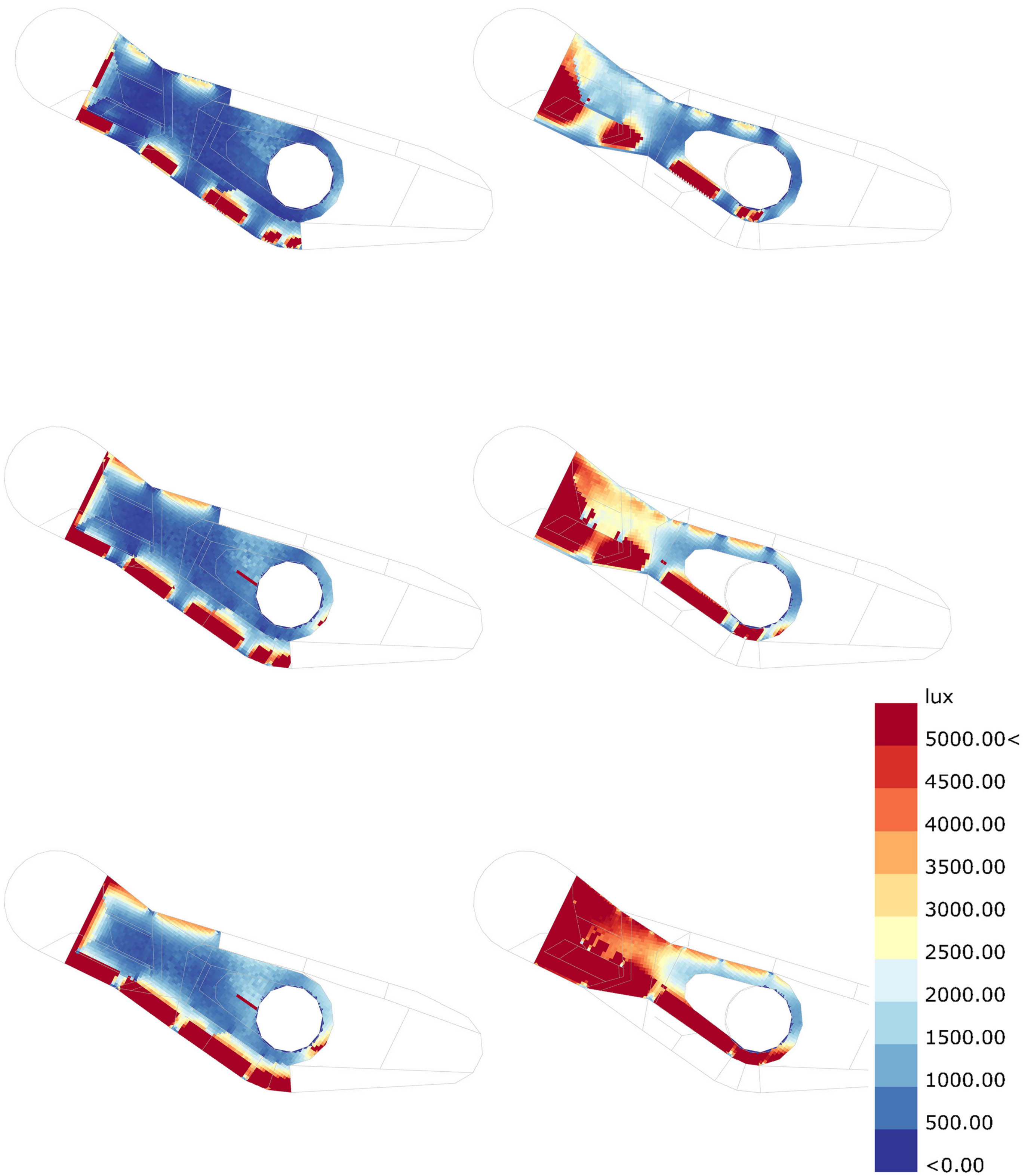
50 percent Glazing



75 percent Glazing



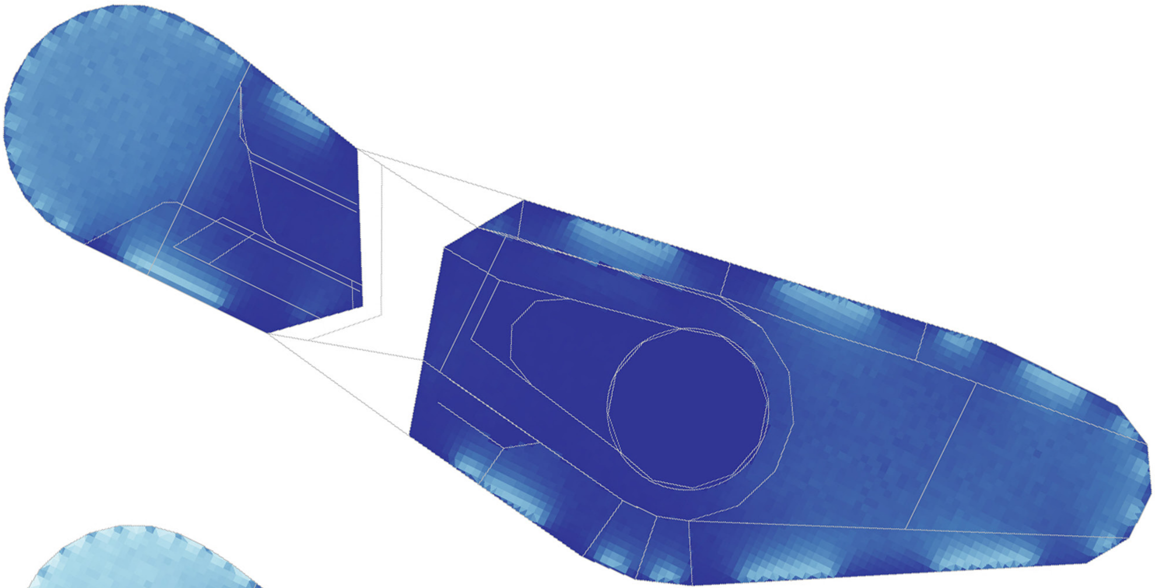
Floor 1 Floor 2



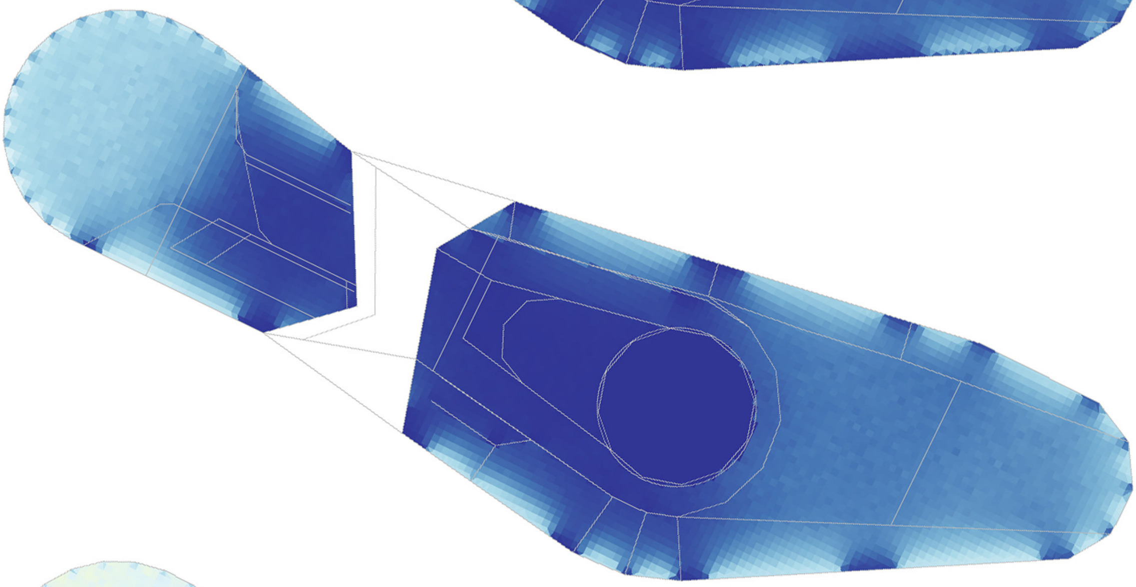
|Illuminance Analysis - Dec 21 - 1PM|

Floor 0

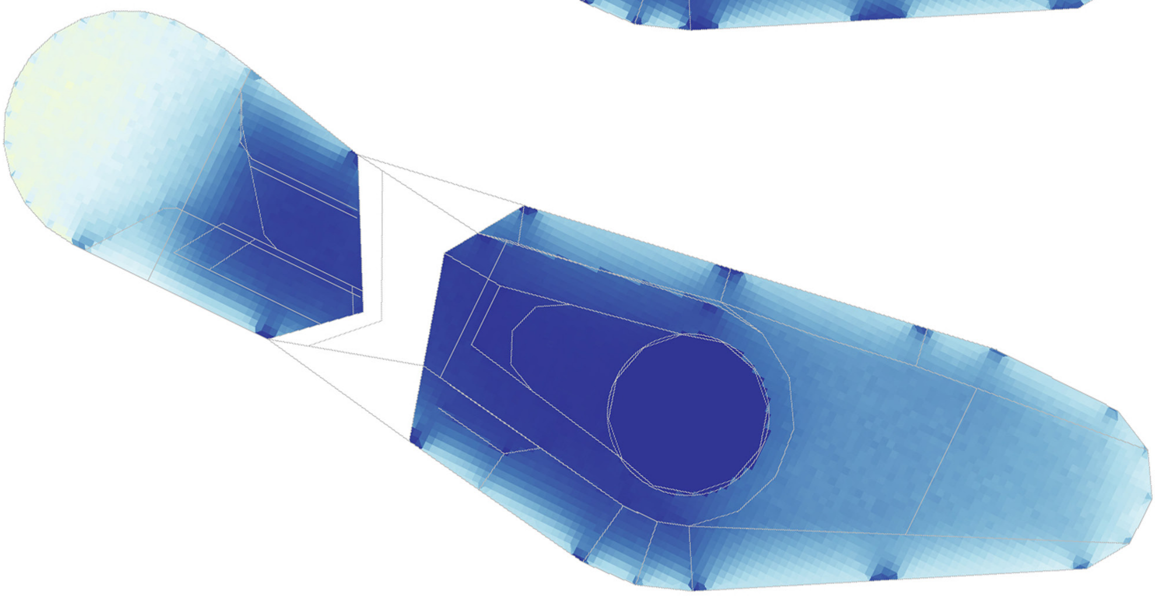
25 percent Glazing



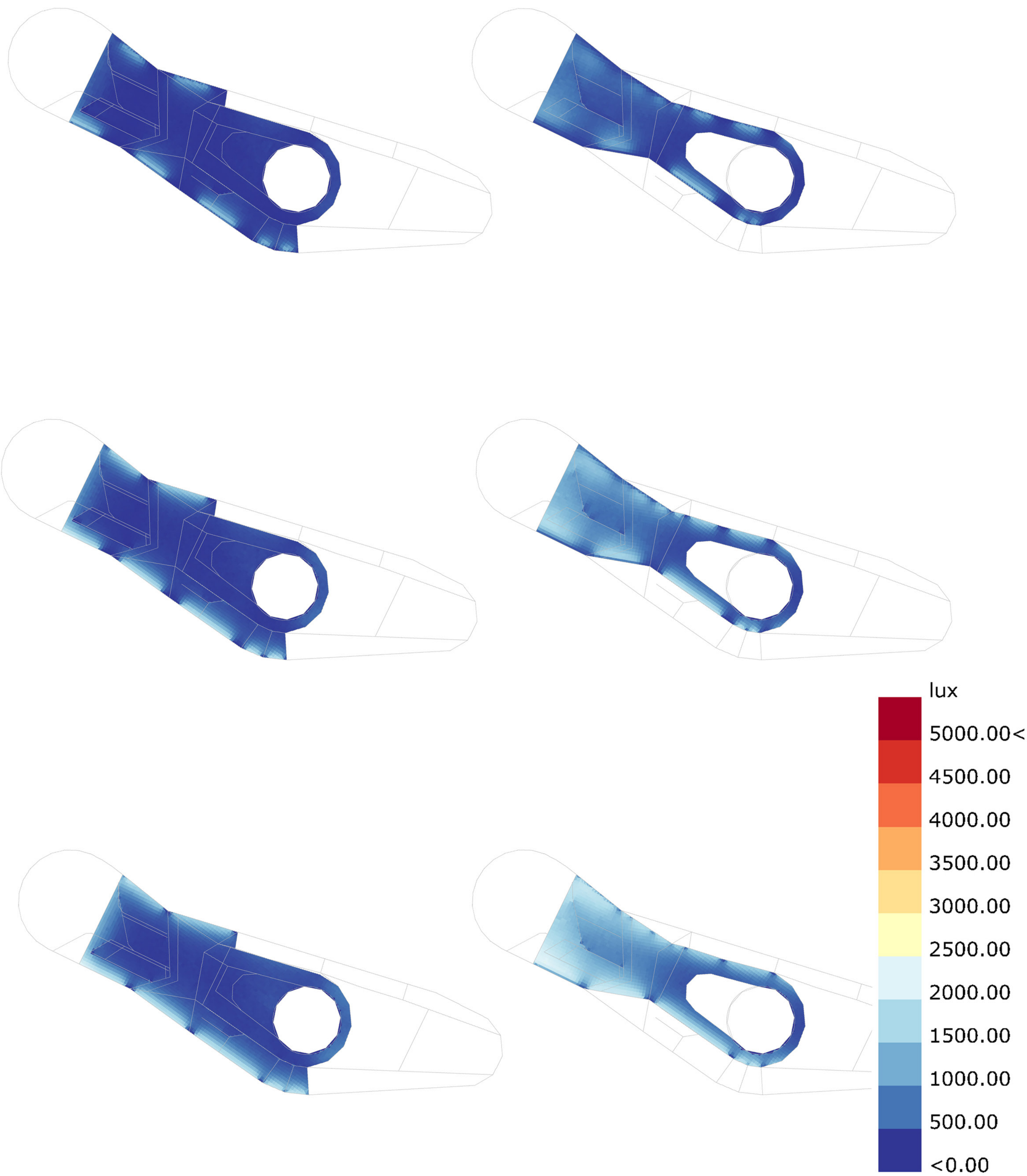
50 percent Glazing



75 percent Glazing



Floor 1 Floor 2



|OPTIONEERING 1|

The window-to-wall ratios are chosen based on the daylight factor and illuminance values for each floor, specific lighting requirements and architectural considerations regarding natural daylighting.

Skylight on the roof is also introduced in the exhibition spaces. This skylight will be translucent material with integrated solar panels to let in diffused light.

The tower which is a landmark for the city, will have a higher glazing area.

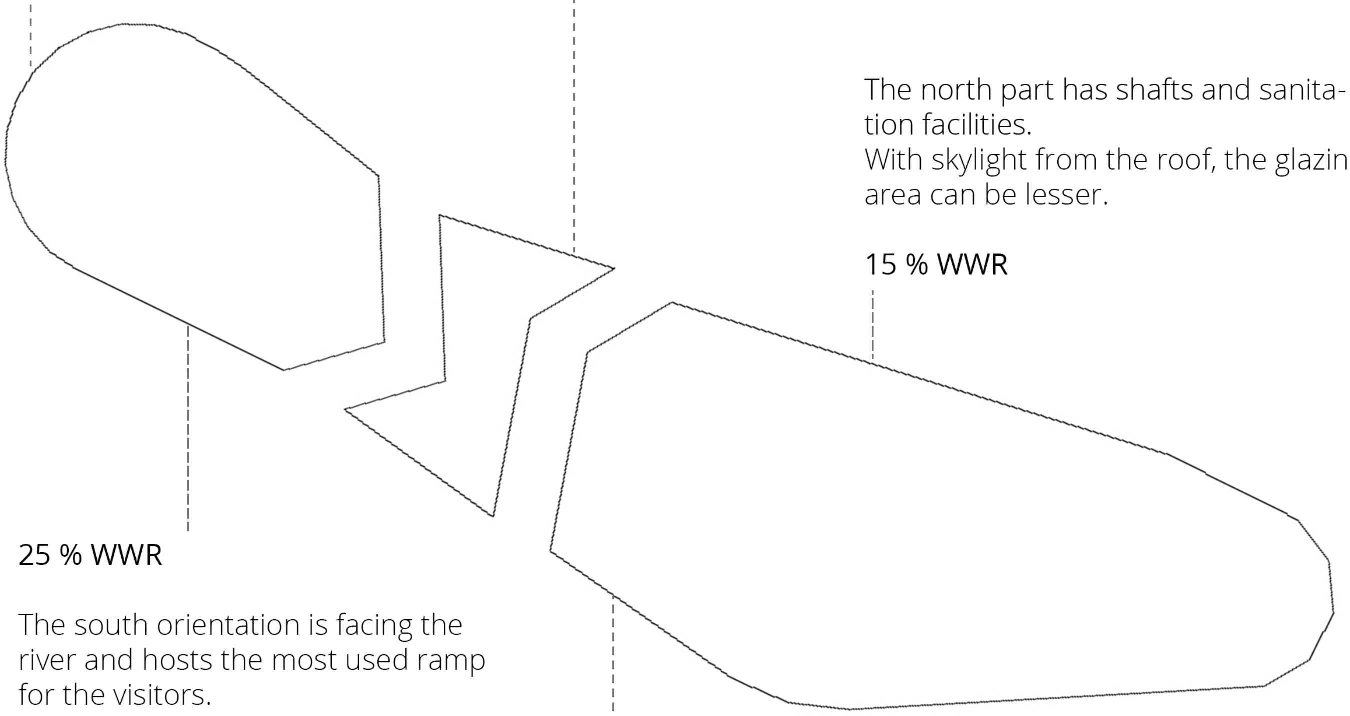
50 % window to wall ratio.

The north side has the view of the island and the north part of the city.

25 % WWR

The north part has shafts and sanitation facilities.
With skylight from the roof, the glazing area can be lesser.

15 % WWR



25 % WWR

The south orientation is facing the river and hosts the most used ramp for the visitors.
The east side is covered by the bridge but has the entrance.

15 % WWR

This part hosts the exhibitions, and many closed spaces, with gradual change in transparency as we go west.

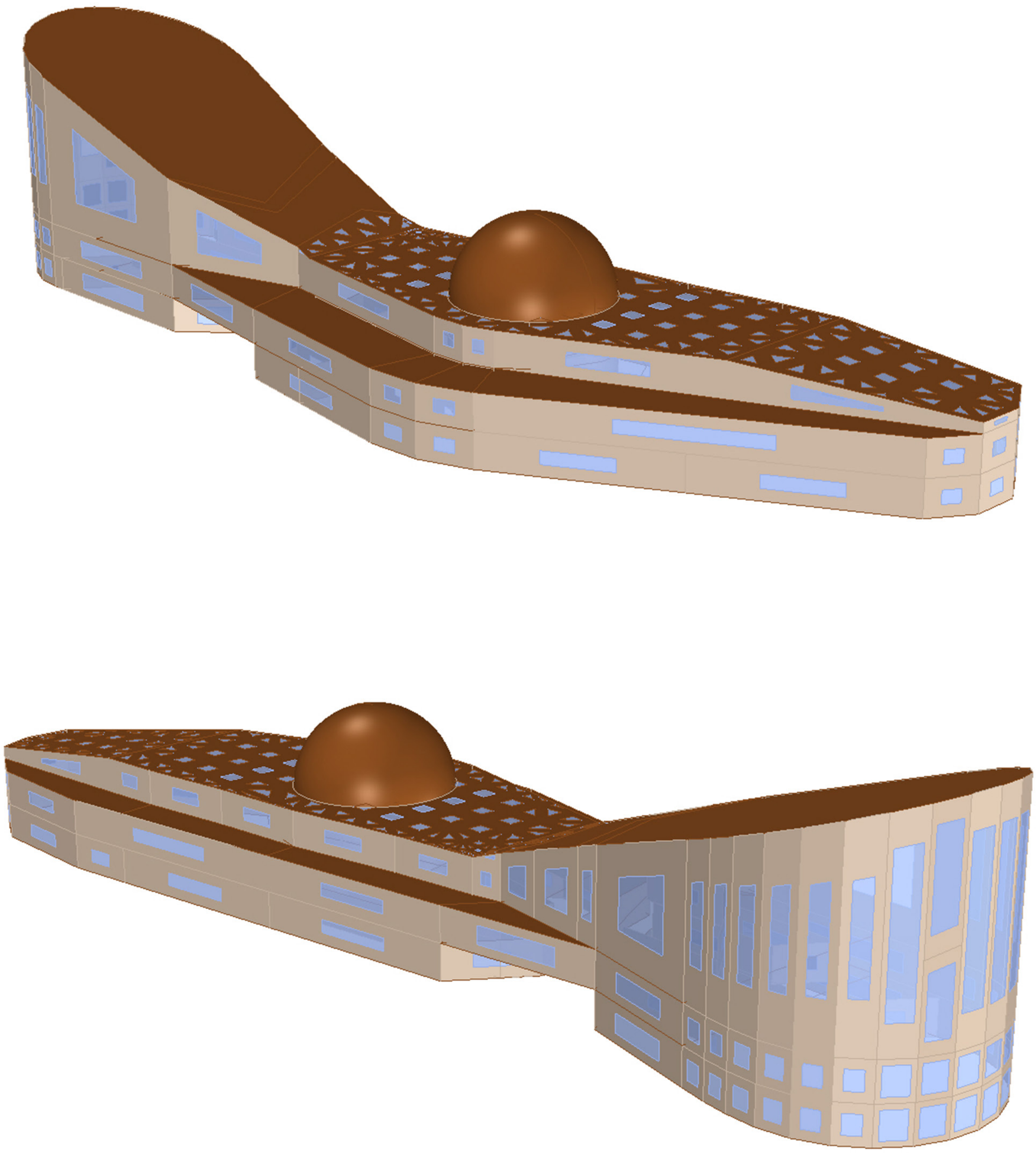
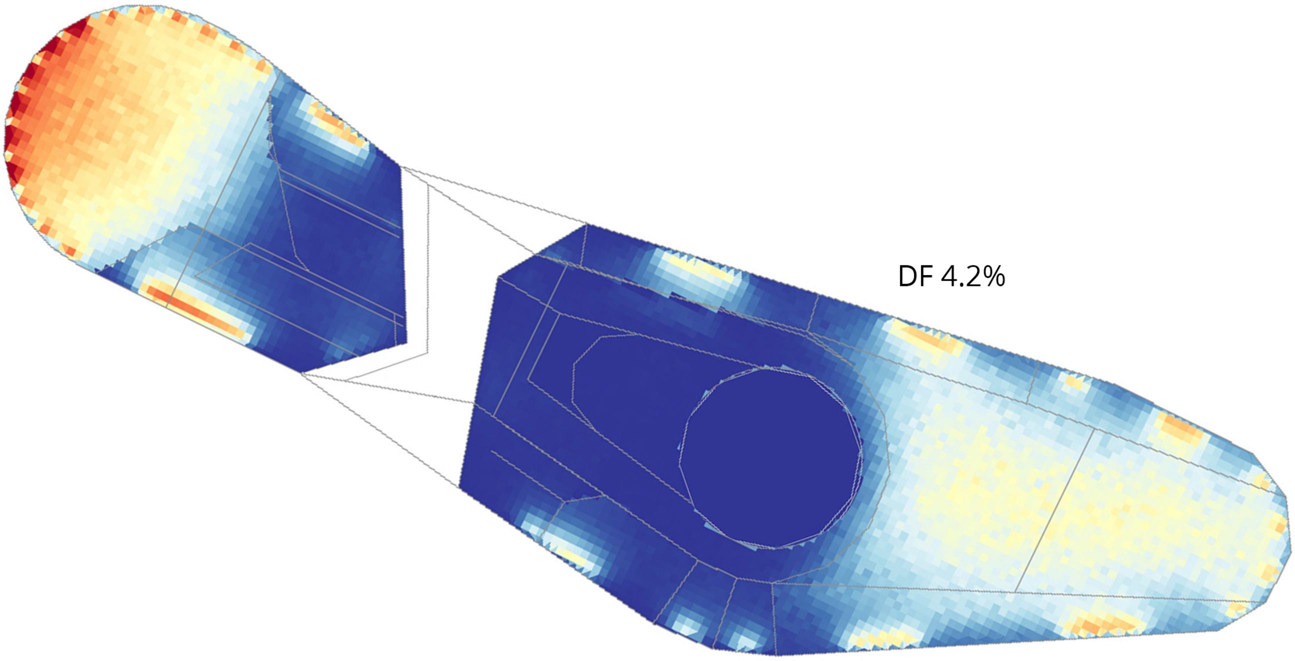


Figure 5.13 Optioneering 1 Analysis Model.

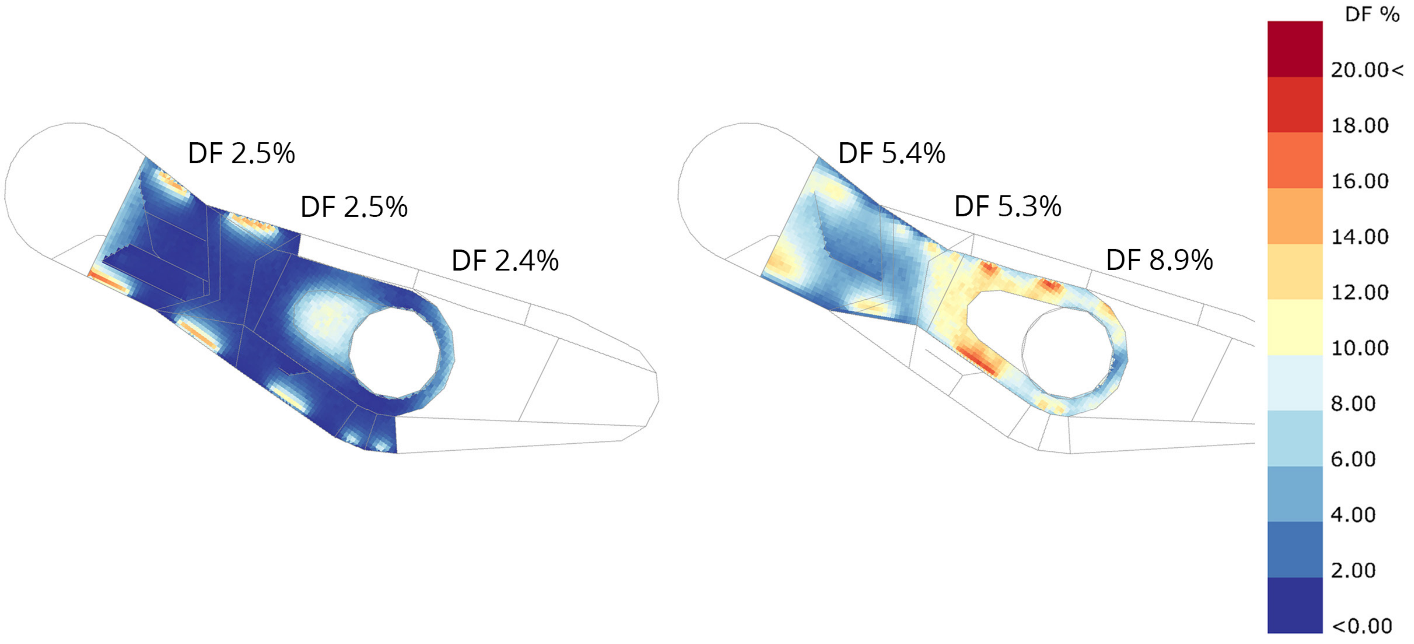
|OPTIONEERING 1 - DF RESULTS|



After running the analysis of the model with the previous W/W ratios, the above results were obtained. On the ground floor of the tower part, a value of 7% DF was achieved which created concerns regarding the glare and the heating consequences of the spaces.

OPTIONEERING 2

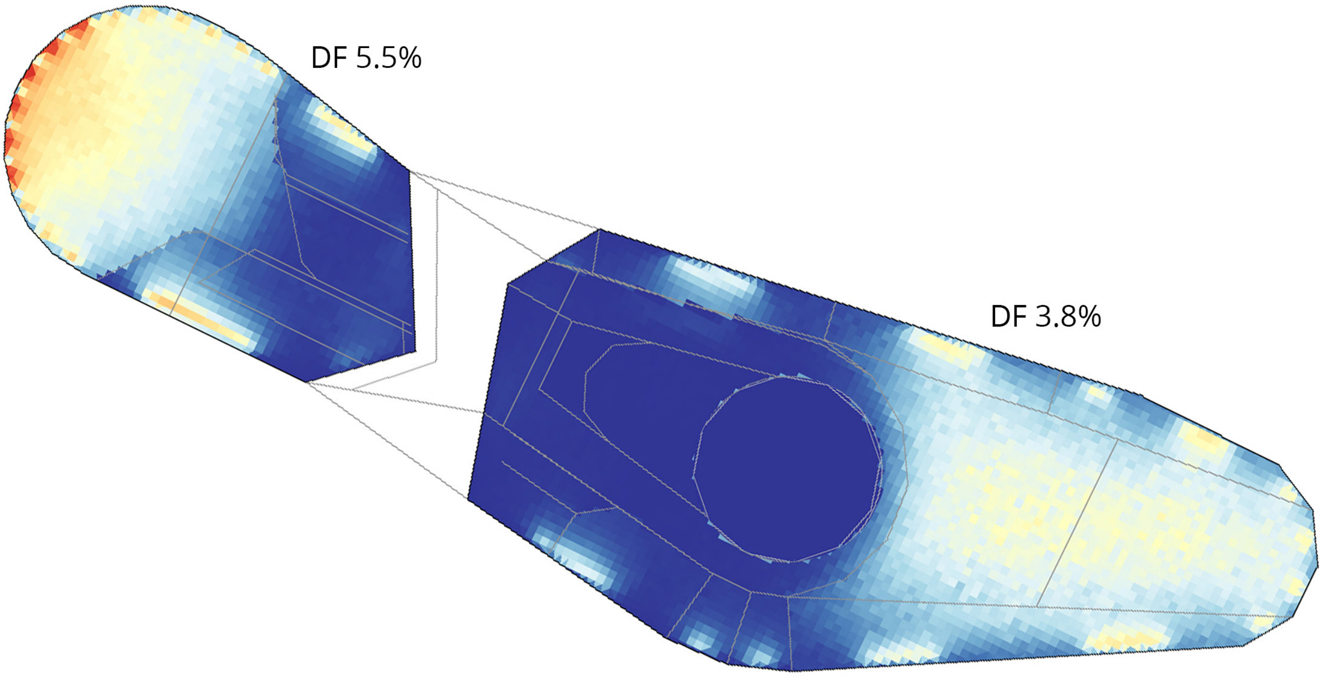
Consequently, the value of **50% of W/W** were kept the same for the following optioneering. The percentages of Reflectivity and Light Transmittance were changed in order to achieve better DF and Illuminance results. **Reflectivity was increased by 25% and Light Transmittance was set up to 60%**



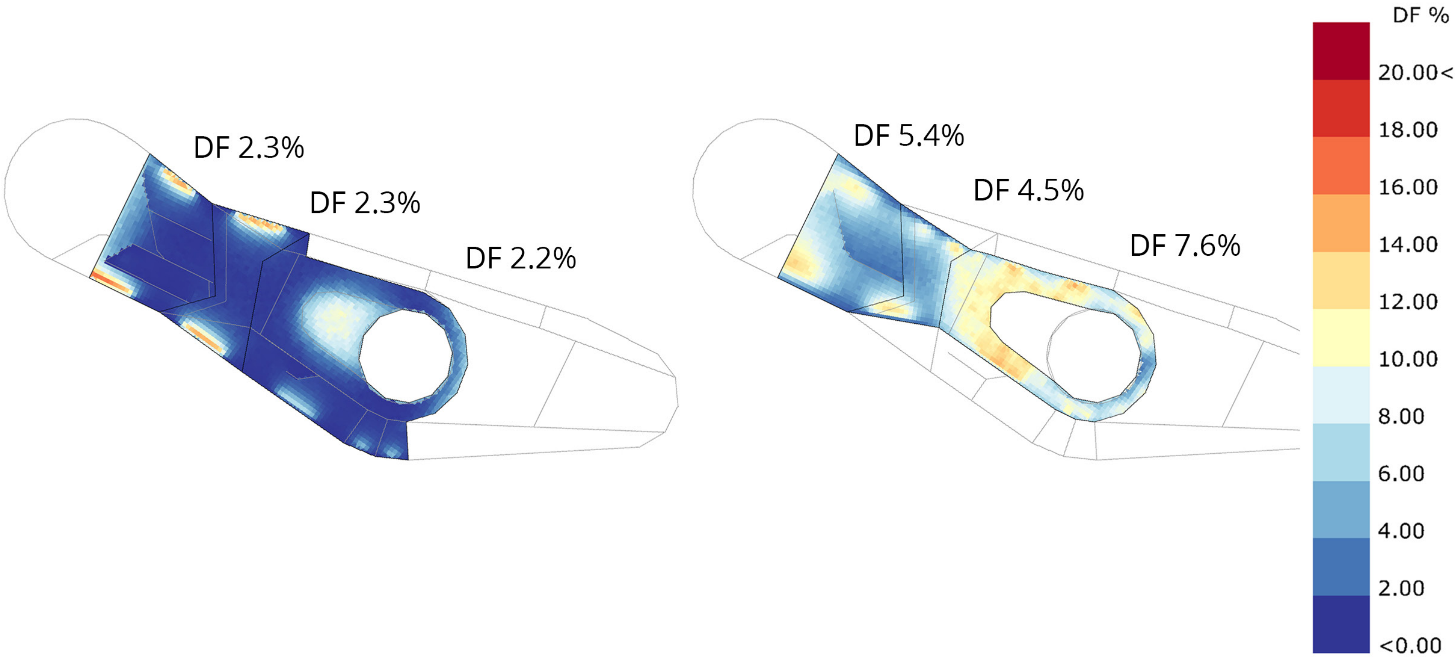
On the ground floor of the exhibition part the value 4.2% of DF showed that proper lighting conditions are already acquired. The same can be observed for the floors above, except for the part of mezannine where the DF reaches almost 9%. Regarding the functions needed to be placed, the DF can be reduced, so **most of the transparent elements are placed on the skylight of the exhibition space (Optioneering 2).**

Moreover, lower values of Illuminance and glare should be achieved, since the exhibition conditions are really specific (avoiding shadows, glare, etc.)

|OPTIONEERING 2 - DF RESULTS|



The second run of analysis created the values presented above. A decrease of the values is noticed both in tower and exhibition spaces. A value **5.5%** is considered already better since less glare values are noticed at the same time.



In the first and second floors, the results behave in the same way. A small reduction is noticed providing the adequate Daylighting conditions needed for the Science Center. Especially, in the second floor where the Restaurant and Mezannine are placed, the results are still high but **the functions placed have completetly different character**. The Mezannine level is more bright after passing through the darkspaces of the exhibitions. By placing the translucent glazing roof, the visitor is slowly connected with the outside part again. The Restaurant has higher DF values since the goal is to achieve proper interaction with the city.

Subsequently, the values of ASE and Illuminace were examined in order to secure the glare conditions.

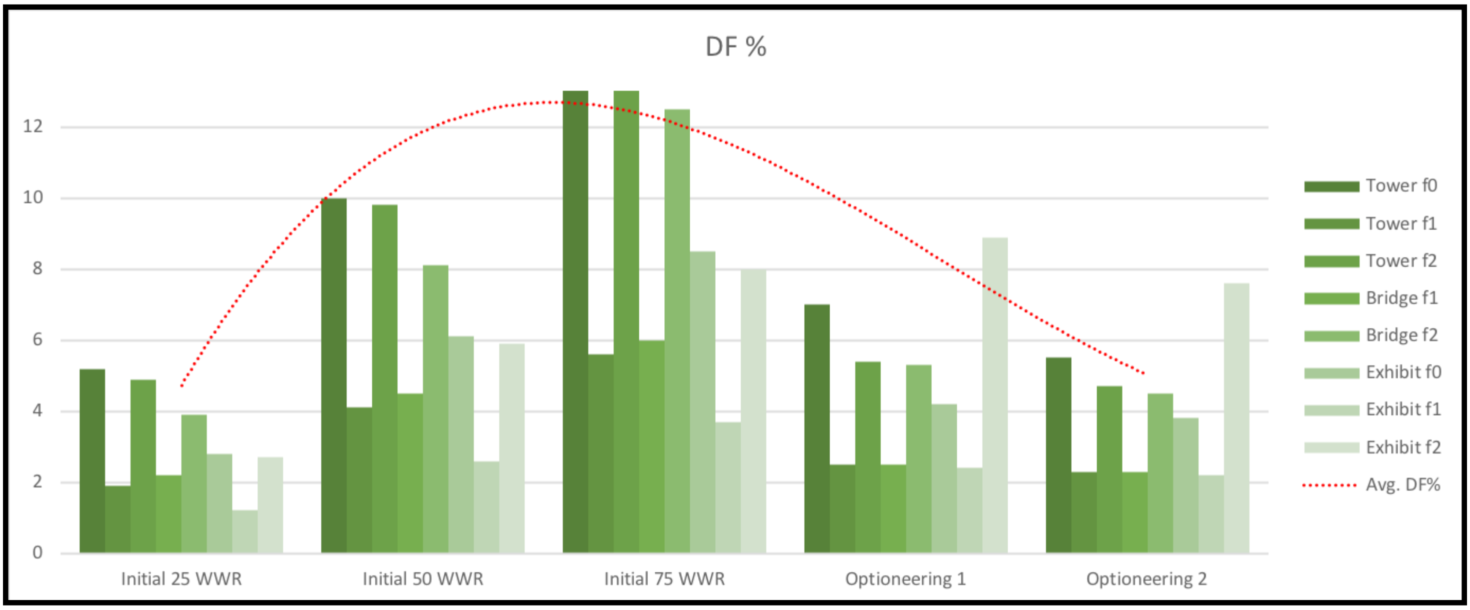


Figure 5.14 Daylight factor results Comparison.

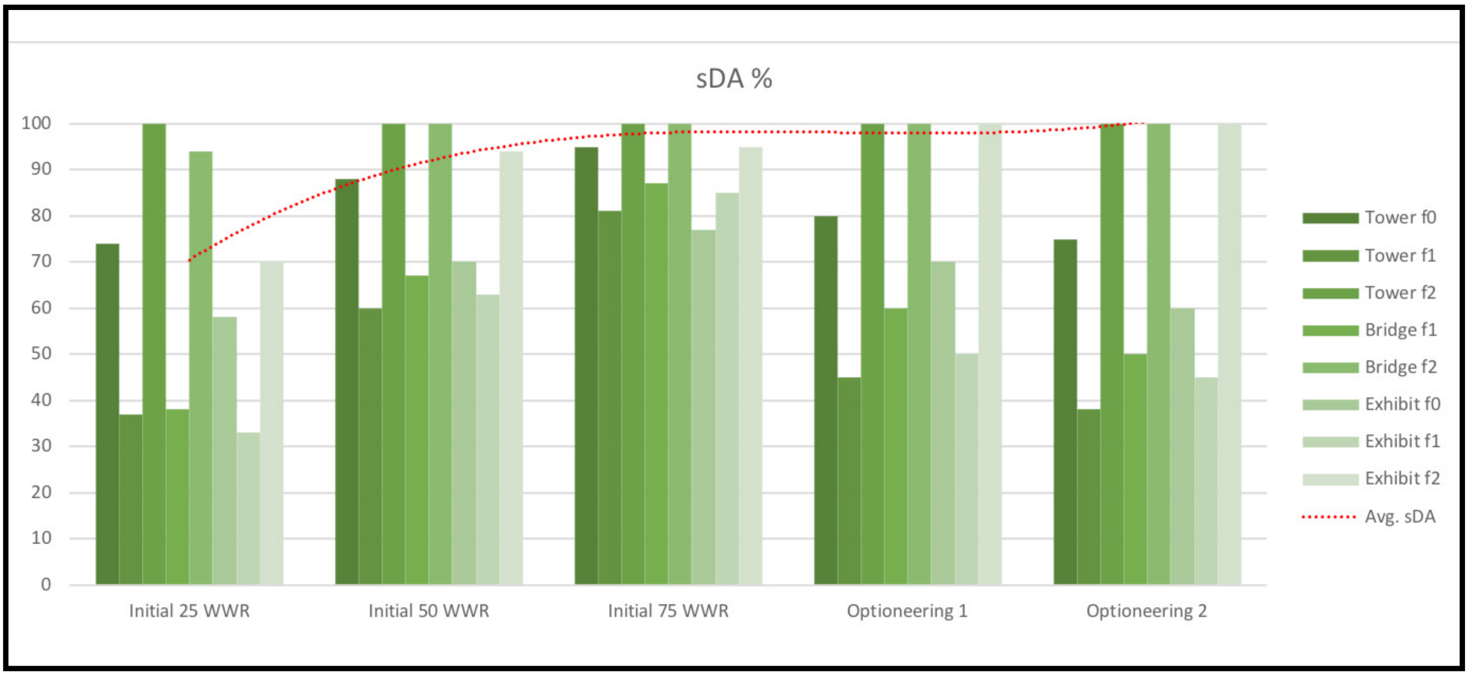


Figure 5.15 sDA% results Comparison.

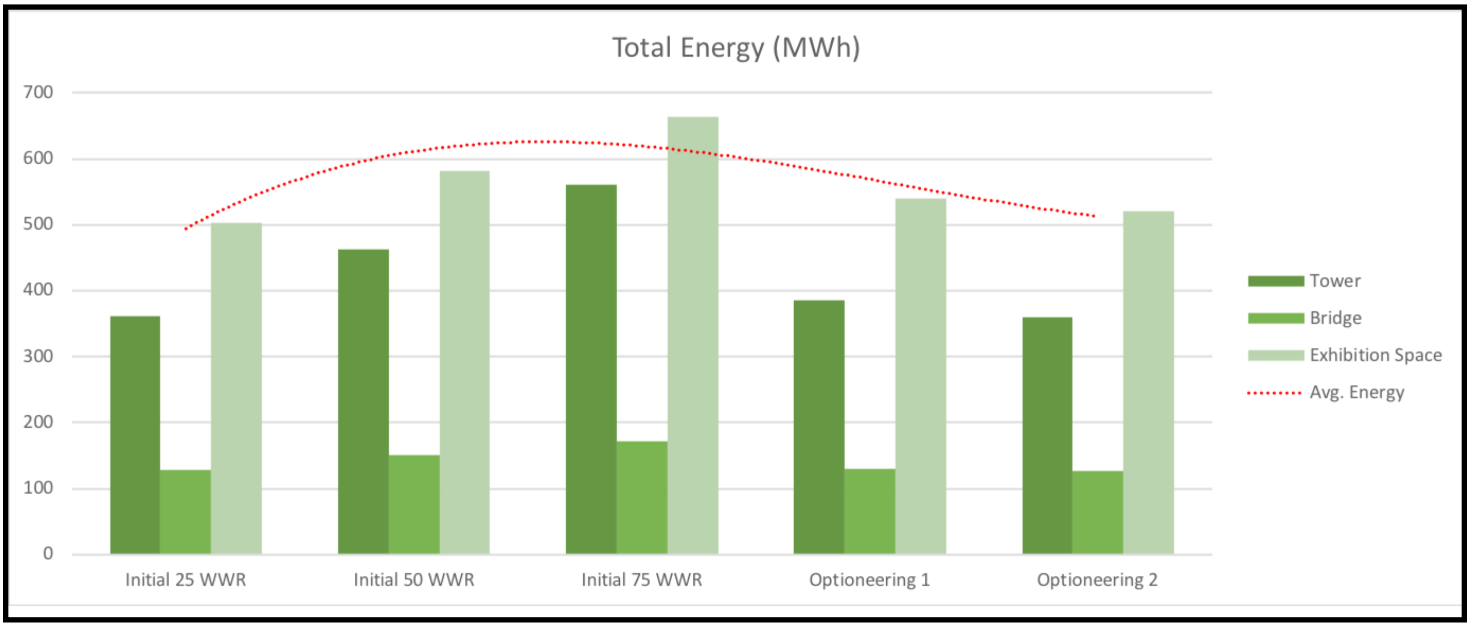


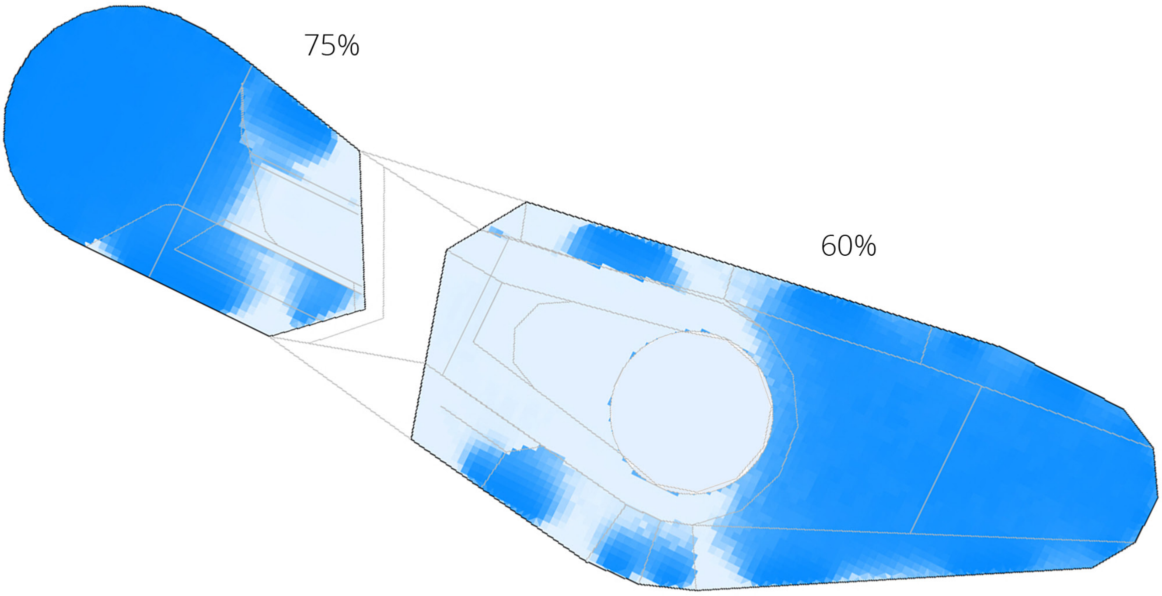
Figure 5.16 Energy results Comparison.

Summarising, by comparing the fist initial rations and the two optionsoneering modeled it is clear that the results after optioneering 2 have better values.

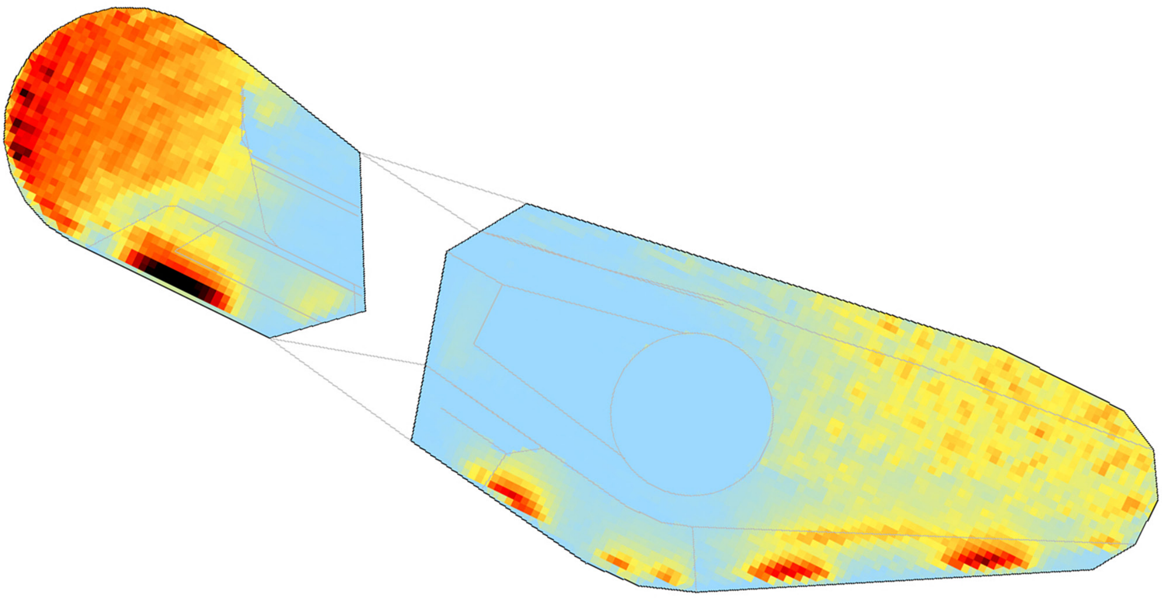
The ratio is not analogous for each Vector, with the DF and Total Enrgy presenting higher fluctuations compared with the values of sDA (%).

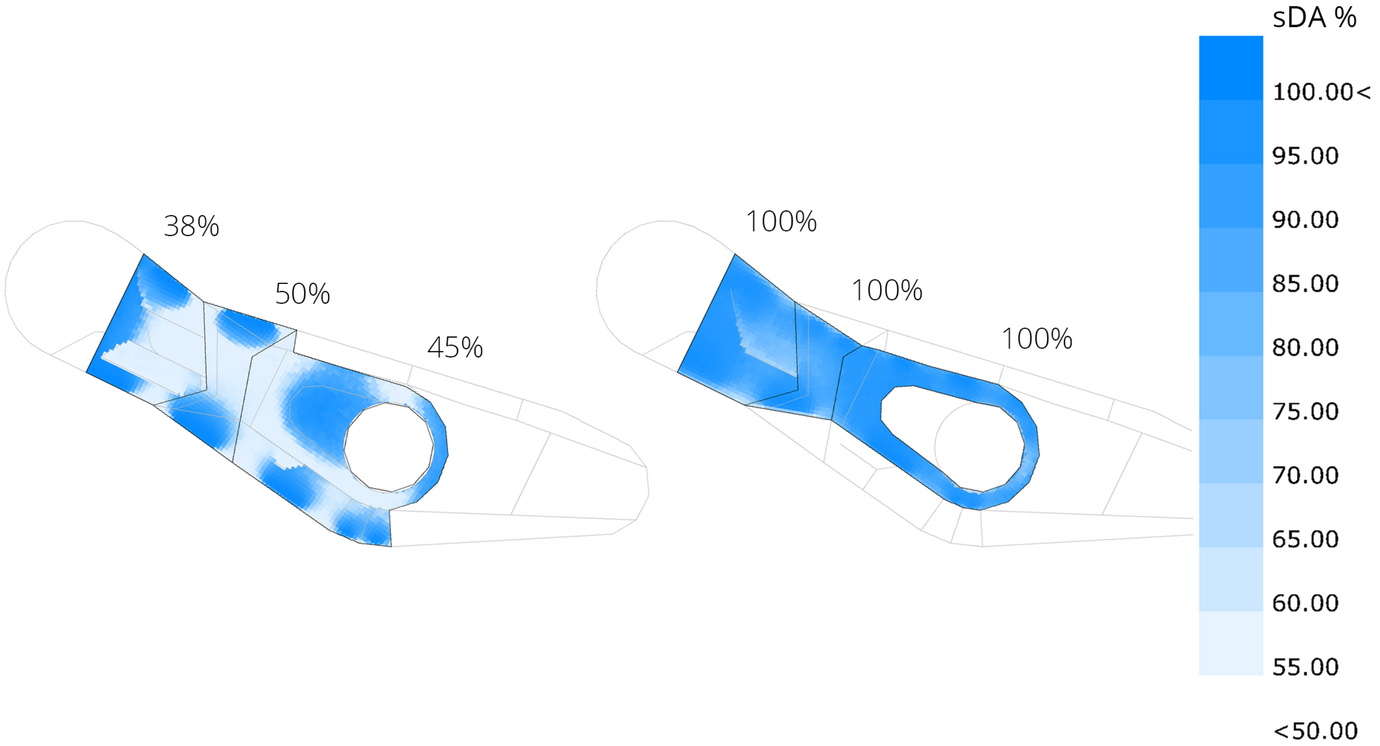
|OPTIONEERING 2 FINAL RESULTS|

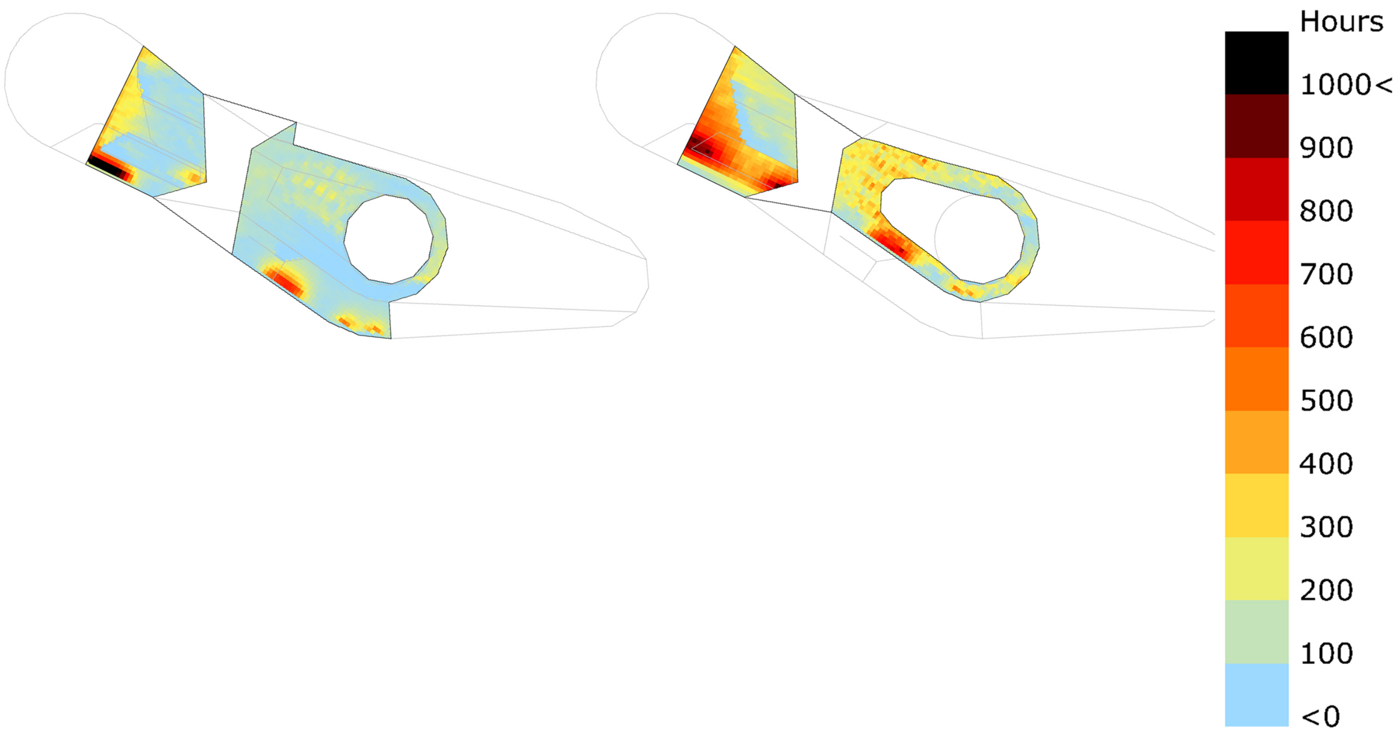
sDA %



ASE




38%
50%
45%
100%
100%
100%
sDA %
100.00<
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
<50.00


Hours
1000<
900
800
700
600
500
400
300
200
100
<0

|ENERGY PERFORMANCE|

"Due to the discontinuous flow of people, a significant and sudden change of the microclimatic parameters in the museum environment can be caused"

MICROCLIMATIC CONTROL IN MUSEUMS

Interactions between the museum and the outside environment, if not properly controlled, may accelerate the processes of deterioration, often irreversible, of both the building envelope itself and the artworks within.

The main agents responsible for the degradation processes of historical buildings and artworks are:
-thermal-hygrometric conditions and vertical thermal distribution of air masses;
-velocity of the air in contact with the object;
- indoor air quality and pollutant concentration;
-electromagnetic radiations coming from sources of natural and artificial light.
-Their synergic effect can affect degradation too.

While low temperatures are not particularly dangerous for the artworks, **on increasing temperature degradation processes accelerate, with consequent risk for conservation.** Moreover, RH exceeding 65% associated to T in excess of 20 degree C increases the development of mycete colonies and accelerates the life cycles of damaging insects.

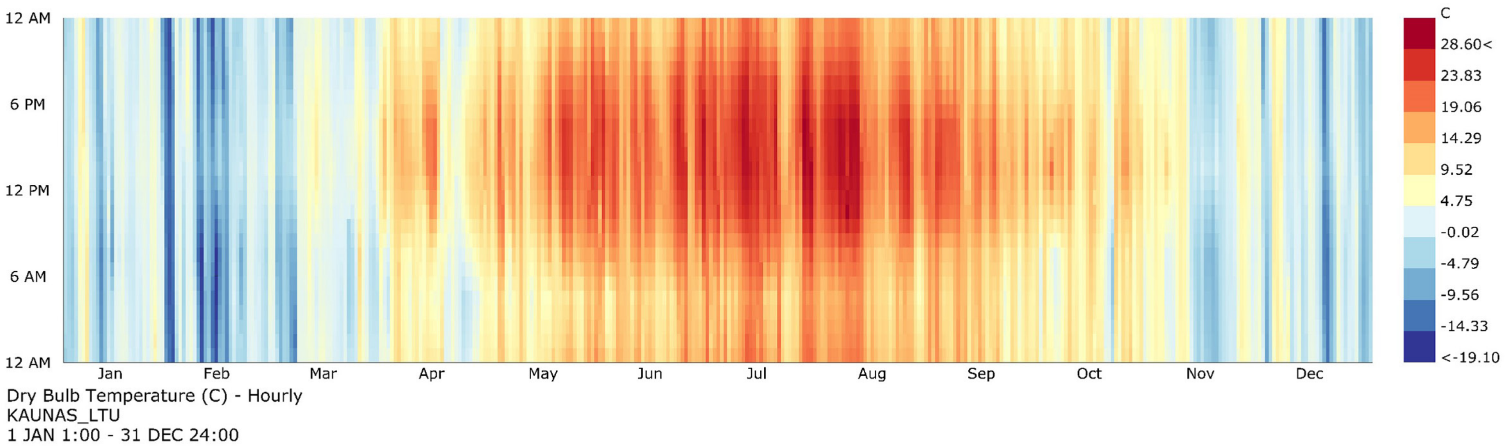


Figure 5.17 Dry Bulb Temp (°C).

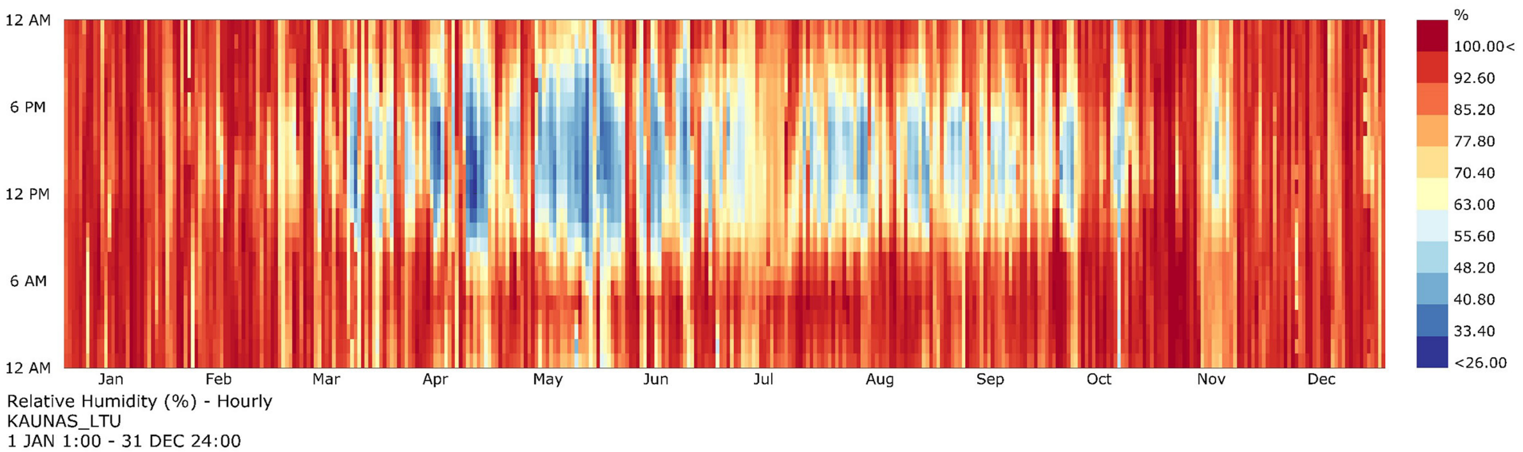


Figure 5.18 Relative Humidity (%).

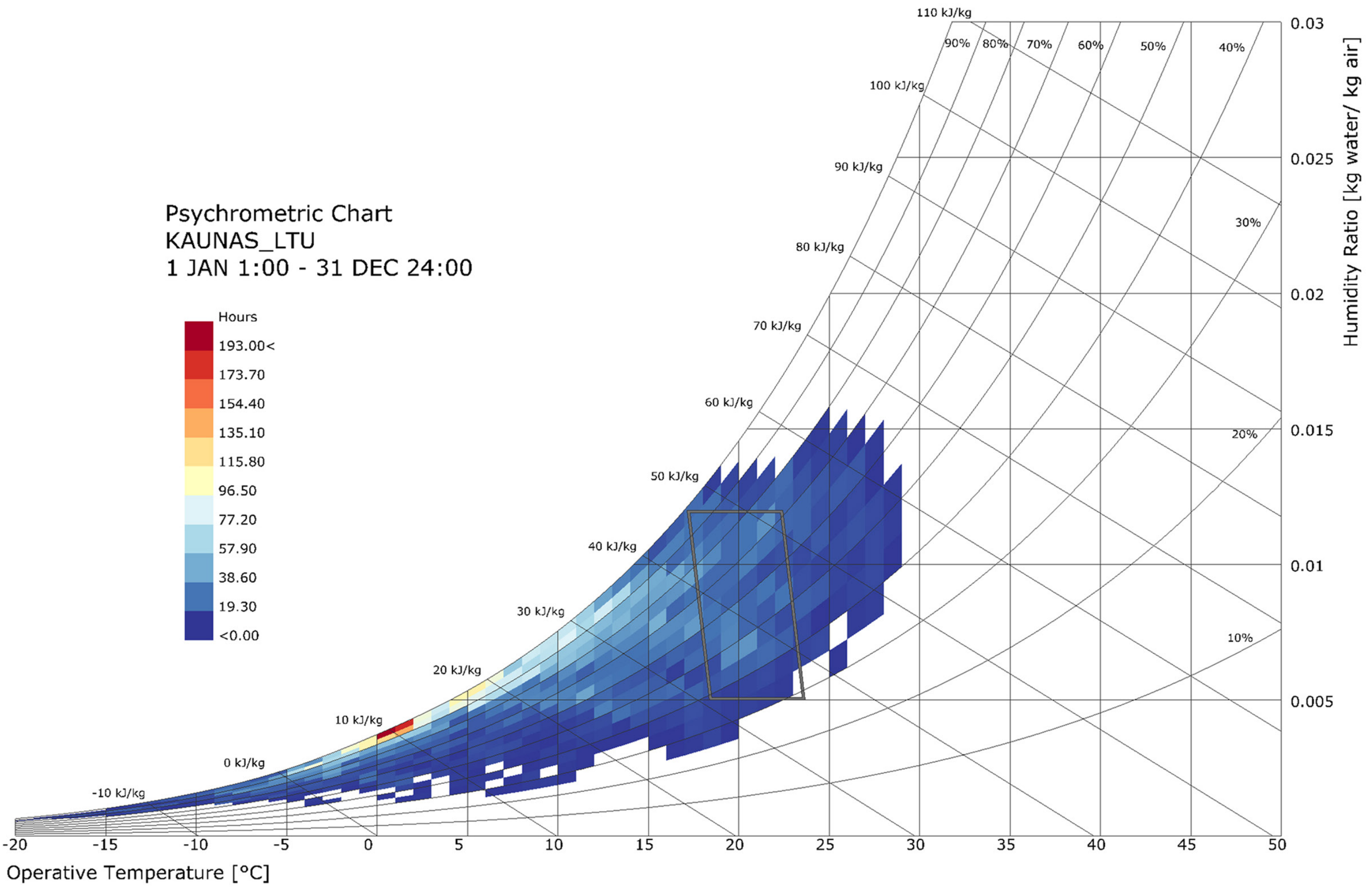


Figure 5.19 Psychometric Chart for Kaunas, Lithuania. (1JAN-31 DEC))

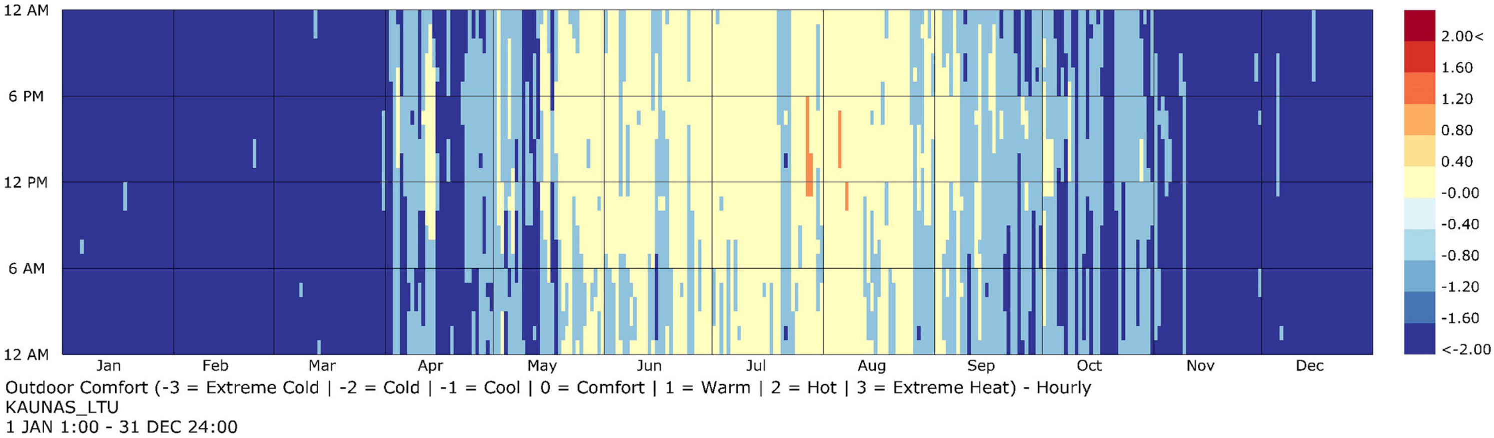


Figure 5.20 Universal Thermal Climate Index (UTCI).

Universal Thermal Climate Index (UTCI)

Perhaps the most familiar application of Univeral Thermal Climate Index (UTCI) is the temperature given by TV weathermen and women when they say that, "even though the dry bulb temperature outside is a certain value, the temperature actually "feels like" something higher or lower."

UTCI is this temperature of what the weather "feels like" and it takes into account the radiant temperature (sometimes including solar radiation), relative humidity, and wind speed. UTCI uses these variables in a human energy balance model to give a temperature value that is indicative of the heat stress or cold stress felt by a human body in the outdoors.

A UTCI between 9 and 26 degrees Celcius indicates no thermal stress or comfortable conditions outdoors. A UTCI between 26 and 28 degrees Celcius indicates slight heat stress (comfortable for short periods of time). Between 28 and 32 degrees, UTCI indicates moderate heat stress (hot but not dangerous). Between 32 and 38 degrees, UTCI indicates strong heat stress (dangerous beyond short periods of time). Above 38, UTCI indicates very strong to extreme heat stress (very dangerous). A UTCI between 0 and 9 degrees Celcius indicates slight cold stress (comfortable for short periods of time). Between 0 and -13 degrees, UTCI indicates moderate cold stress (cold but not dangerous). Between -13 and -27 degrees, UTCI indicates strong cold stress (dangerous beyond short periods of time). Below -27, UTCI indicates very stong to extreme cold stress (very dangerous).
UTCI is result of the world's leading comfort specailists' attempt to make an interational standard of outdoor temperature sensation that fills the follwoing requirements:
1) Thermo-physiological significance in the whole range of heat exchange conditions of existing thermal environments
2) Valid in all climates, seasons, and scales
3) Useful for key applications in human biometeorology.

|HVAC SYSTEM|

The HVAC system must guarantee the indoor design microclimatic conditions, controlling the transient phenomena and, at the same time, it should be well integrated in the building structure. Due to the discontinuous flow of people, a significant and sudden change of the microclimatic parameters in the museum environment can be caused; **so the reaction of the HVAC system must be quick and effective in order to restore the design values of the thermal-hygrometric conditions.**

In order to provide a uniform environment for avoiding deterioration of the items and the ambient conditions be kept stable in the time, it is necessary that HVAC systems remain constantly operating, during all the year and 24 hours per day. So, the adoption of suitable techniques is useful to obtain considerable energy savings.

Moreover, in order to reduce the transient phenomenon period, minimum airflow rate values should vary from 6 to 8 air changes per hour; thus, a constant-volume HVAC system is preferred.

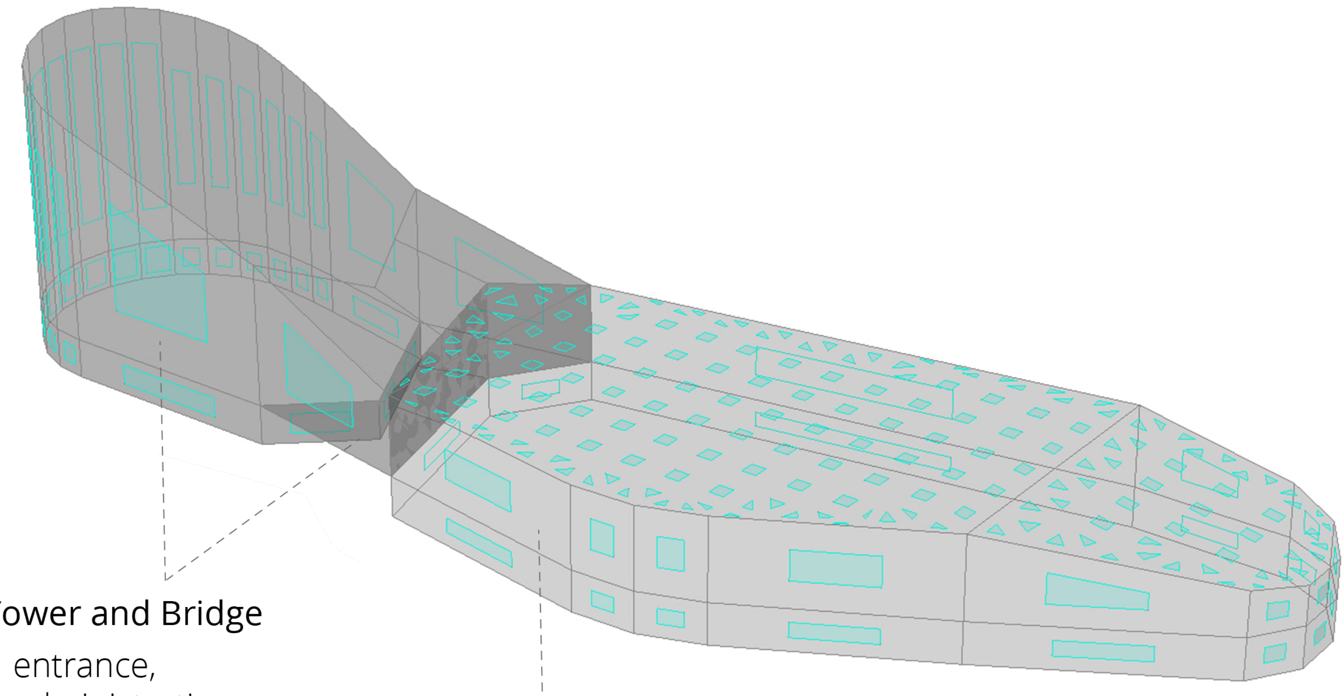
In order to achieve the project goals before described, **all-air systems is used:** a centralised air-handling unit keeps equipment, maintenance and monitoring at some distance from the collections.

The adoption of absorption dehumidification systems will be useful too, as it allows the reduction of the humidity. This dehumidification type is better also in terms of hygiene as the absence of condensed water greatly reduces the presence of bacteria, fungi and microbes.

|HVAC SYSTEM ANALYSIS|

The Science Center is divided into 2 zones:

1. Tower and Bridge: with entrance, administrative, info/ticketing, souvenir shop, restaurant and introduction space.
2. Exhibition spaces: with permanent and temporary galleries, research labs, experimentorium, planetarium and flexible event spaces.



Tower and Bridge

entrance,
administrative,
info/ticketing,
souvenir shop,
restaurant and
introduction space.

Exhibition Spaces

permanent and temporary galleries,
research labs, experimentorium,
planetarium and flexible event spaces.

- **Heating set point temperature**: 21°C
- **Cooling setback temperature:** 24 °C
- **RH range:** 45% to 55%
- **Air changes**: 7 per hour
- **Occupancy Hours:** every day 10 am - 5 pm,
  Monday (closed)

Figure 5.21 Two main zones for HVAC Analysis.

These 2 zones behave differently in terms of functions. The tower and bridge zone doesn't include things of high sensitivity and can be shut off during closed-hours of the museum. On the other hand, the exhibition space zone houses all the items of display and must be kept under uniform conditions of temperature and RH.

The attention has been focused on the exhibition space, because of the interest both in the artwork conservation and in the comfort for occupants. Particular feature of the exhibition space is the presence of skylight, which allow diffused light through translucent glass.

Design Parameters:
The following design parameters were considered according to 2015 ASHREA Handbook for HVAC Applications:

- Heating set point temperature 21°C

- Cooling setback temperature: 24 °C

- RH range: 45% to 55%

- Occupancy Hours: The occupancy schedule is the same throughout the year; the museum is open every day from 10 a.m. to 5 p.m., except on Monday (closed)

- Based on the comfort analysis, the building needs mostly heating, throughout the year.

- Air changes every hour: 7

TYPES OF SYSTEMS

The type of HVAC system used is critical to achieving project environmental goals.
Based on this source. These systems have been suggested in the 2015 ASHRAE Handbook:

-Constant-Volume Reheat: A constant-volume reheat system can present problems if improperly applied. In many institutions, terminal reheat with steam or hot-water coils located near or over collection spaces cause chronic problems from steam and water leaks. Efficient zone-level humidification often suggests placing the humidifier downstream from the reheat coil; if the reheat coil is located near or over collection spaces, preventive maintenance on humidifiers further complicates maintenance problems. Constant- volume reheat systems are very effective when reheat coils and humidifiers are installed entirely within the mechanical space, instead of at the terminal, feeding through what is effectively a multizone distribution system.

- Multizone System: A multizone air handler with zone reheat and zone humidification can be a stable and relatively energy- efficient solution. However, multizone systems without individual zone reheat and individual zone humidification have proved problematic in many institutions, requiring retrofit of zone equipment for stable humidity control. With proper layout and equipment complement, a multizone system can reduce the amount of reheat and be very energy efficient.

- Dehumidification Coil: An important feature of multizone and dual-duct air handlers is a separate dehumidification coil up-stream of both the hot and cold decks. This separate cooling coil, distinct from the one in the cold deck, is used during dehumidification demand. Air can be cooled to dew point even if it eventually flows through the hot deck. Without this feature, moist return air could be warmed in the hot deck and delivered back to the room without being dehumidified. An alternative is to locate a single cooling coil upstream of both decks, where the cold deck simply bypasses the hot deck, although this configuration can increase energy use.

- Fan-Coil Units: Fan-coil units have been problematic when placed in and above collection areas. Fan-coil units expand and decentralize maintenance, requiring maintenance in collection areas and a net increase in overall facility maintenance. Because they cool locally, they need condensate drains, which can leak or back up over time. As all-water systems, they require four pressurized- water pipes to each unit, increasing the chance of piping leaks in collection areas.

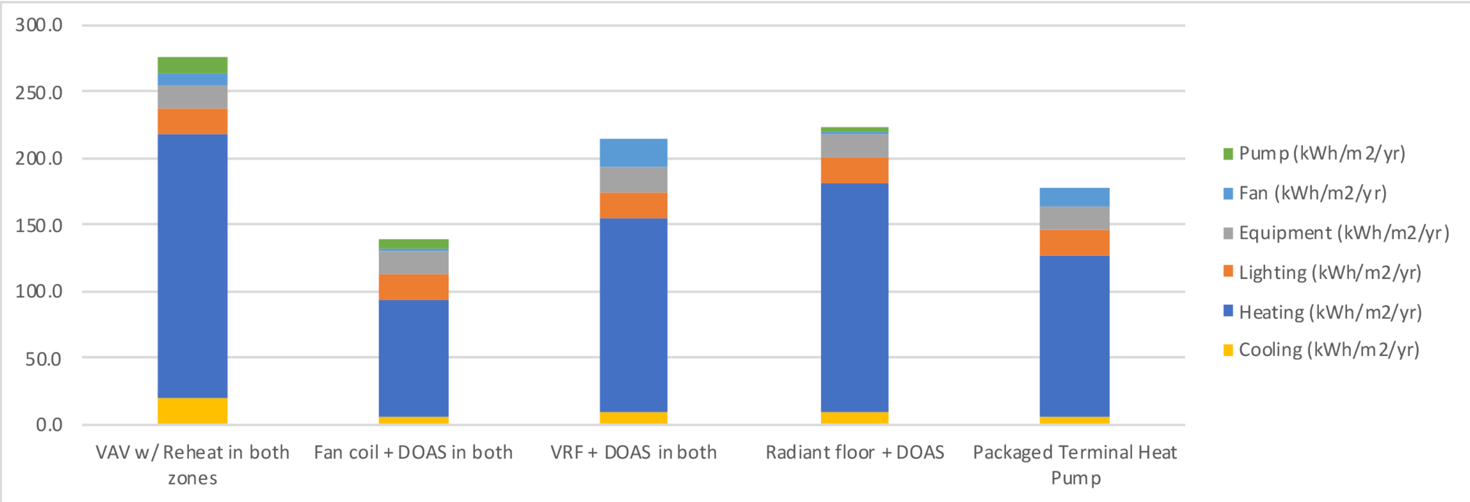


Figure 5.22 Energy Comparison for different HVAC Systems.

The parameter **"Unmet Load Hours" (UMLH)** is also used as a criterion for picking the most suitable HVAC system. The concept of unmet load hours applies to individual thermal zones but is summed for hours whenever any thermal zone in the building has unmet loads. For a thermal zone, it represents the number of hours during a year when the HVAC system serving the thermal zone is unable to maintain the set point temperatures for heating and/or cooling. During periods of unmet loads, the space temperature drifts above the cooling setpoint or below the heating setpoint. A thermal zone is considered to have an unmet load hour if the space is outside the throttling range for heating or cooling.

An unmet load hour can occur only during periods when the HVAC system is scheduled to operate. Unmet load hours are accounted for in each zone of the building. For energy simulations, the schedule of heating and cooling point was set to 'always on' for the exhibition space, where as for the tower and bridge the schedule was according to the occupancy hours.

Unmet load hours can occur because fans, air flows, coils, furnaces, air conditioners or other equipment is undersized. Unmet load hours can also occur due to user errors including mismatches between the thermostat setpoint schedules and HVAC operating schedules or from other input errors, for instance, high internal gains or occupant loads. The term, as used in this manual, only addresses equipment that is undersized. It is the responsibility of the user to address other causes of unmet load hours in the proposed design.

No zone in the building can exceed the maximum allowed unmet load hours. ASHRAE Standard 90.1-2007 Appendix G imposes limits on unmet load hours when using the Performance Rating Method in section G3.1.2.2 Equipment Capacities.

Unmet load hours for the proposed design or baseline building designs shall not exceed 300 (of the 8760 hours simulated), and unmet load hours for the proposed design shall not exceed the number of unmet load hours for the baseline building design by more than 50.

If unmet load hours in the proposed design exceed the unmet load hours in the baseline building by more than **50**, simulated capacities in the baseline building shall be decreased incrementally and the building resimulated until the unmet load hours are within 50 of the unmet load hours of the proposed design. If unmet load hours for the proposed design or baseline building design exceed **300**, simulated capacities shall be increased incrementally and the building with unmet loads resimulated until unmet load hours are reduced to **300** or less. Alternatively, unmet load hours exceeding these limits may be accepted at the discretion of the rating authority provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads."

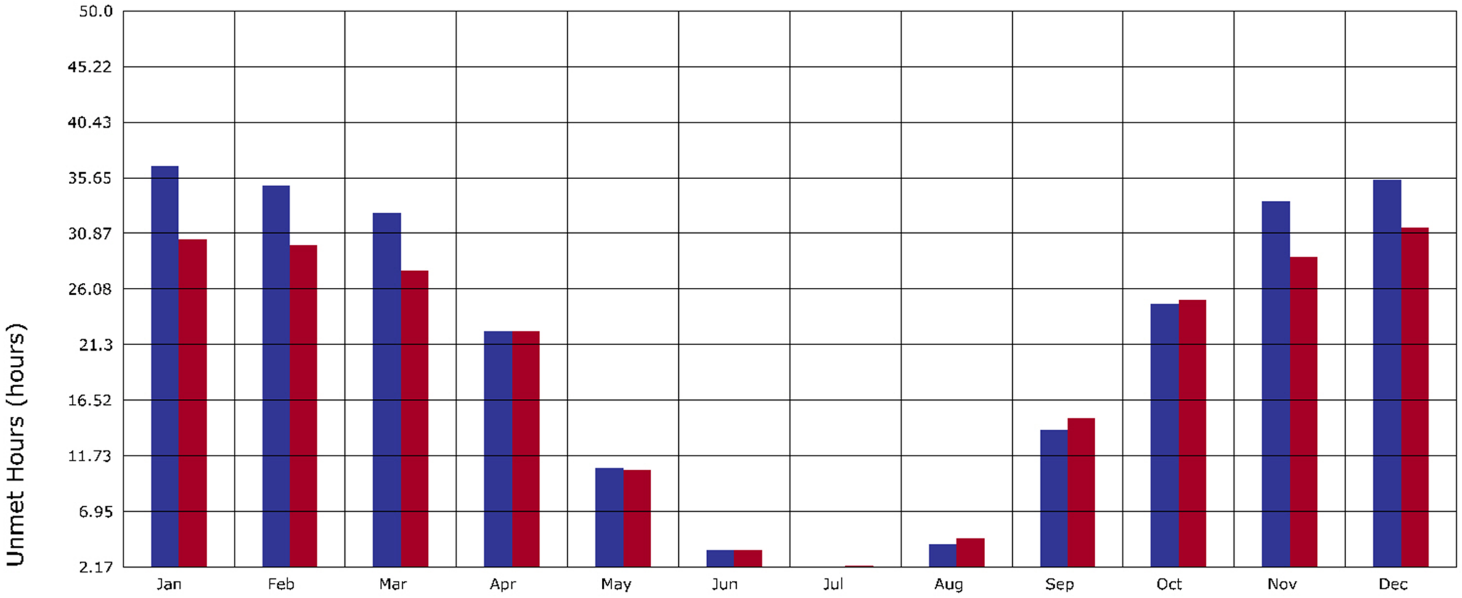


Figure 5.23 Fan coil + DOAS in both zones.

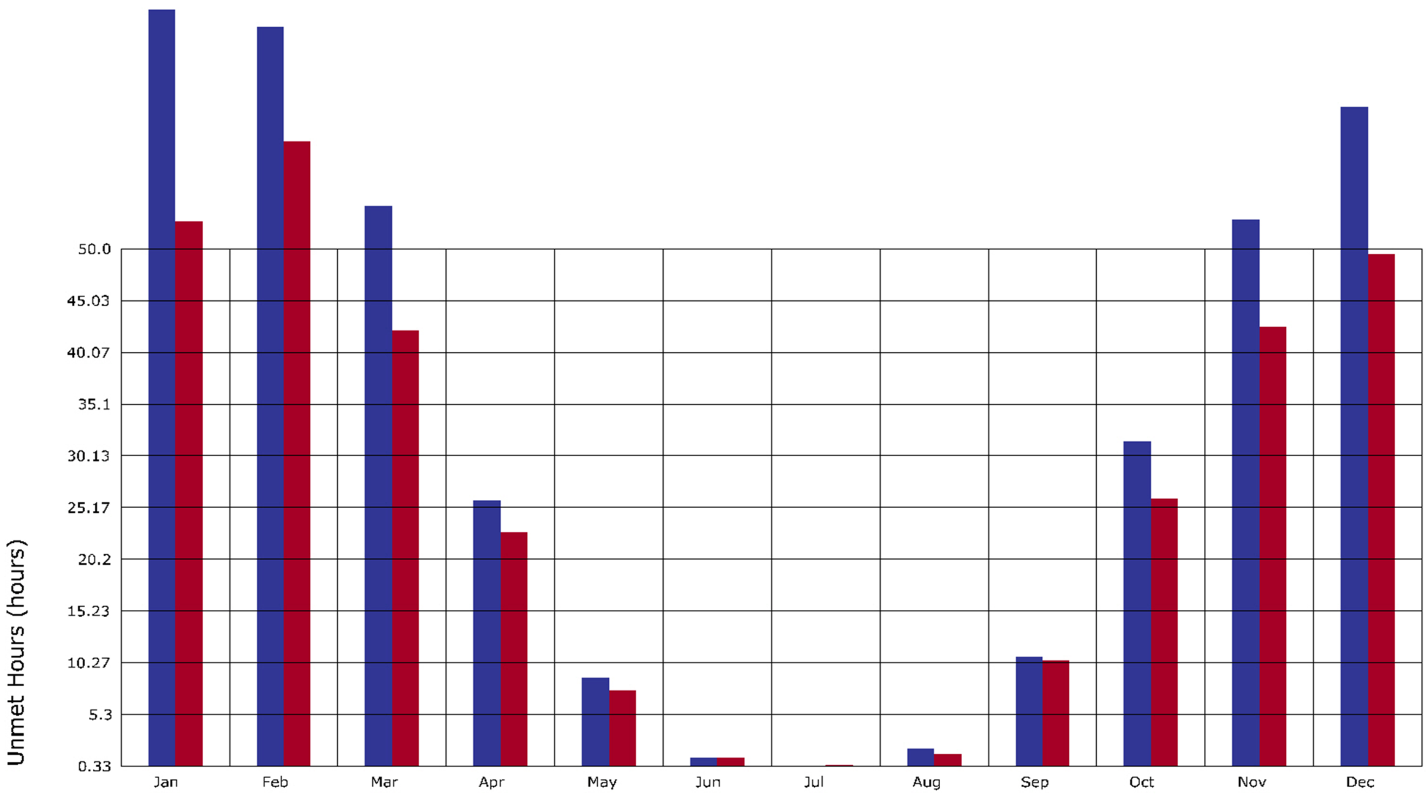


Figure 5.24 VRF + DOAS in both zones.

Following the literature review from 2015 ASHREA Handbook for HVAC Applications and the paper: "Energy saving strategies in air-conditioning for museums" by Fabrizio Ascione, Laura Bellia, Alfonso Capozzoli, Francesco Minichiello, **a constant air volume system** would provide the performance in terms of dynamic thermal-hygrometric control and an optimal control of temperature.

The best performance in RH control, generally more critical for summer conditions, has been obtained by the system with a desiccant dehumidifier.

Using condenser heat to provide reheat for **dehumidification** can increase efficiency and can substantially reduce dehumidification energy cost. Although an air-side economizer can cause problems, a water-side economizer can allow efficient winter cooling using condenser water. Because load varies between day and night operations, particularly in museums, night cooling loads are sometimes best met with a smaller off-hours chiller. Similarly, primary-secondary pumping with two-way control valves can be useful as loads vary over the day and across areas.

SYSTEM WITH DESICCANT MODULE

The paper by Ascione, Bellia and Minichiello indicatd CAV-DW, as in the figure below, is characterized by adsorption dehumidification obtained with a desiccant wheel. The desiccant module presents also a regeneration coil, a sensible heat exchanger and an evaporative cooler.

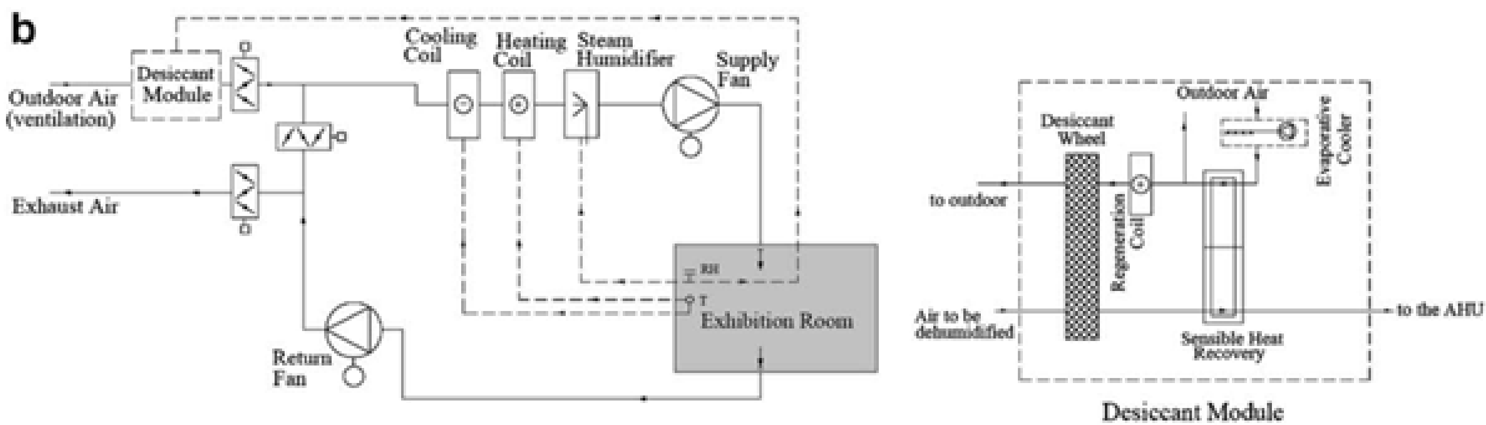
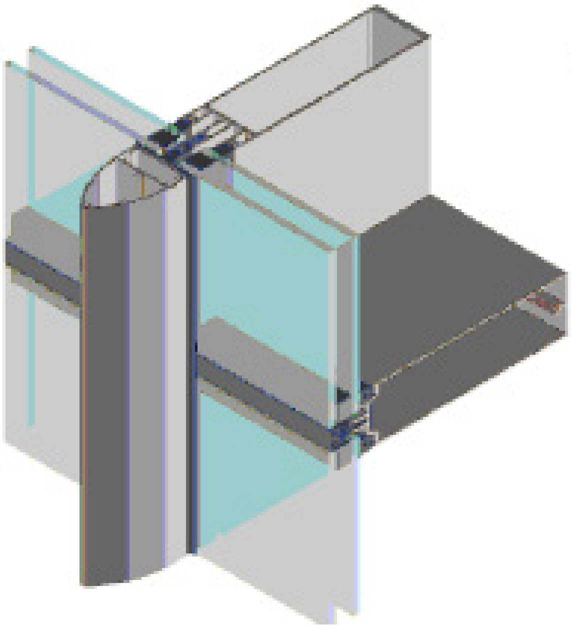


Figure 5.25 System with desiccant module.

|TRANSPARENT ELEMENTS|
FRAMING DETAILS

Exhibition Curtain Wall
Double Glazing Window



EFP 50 TVS
Fixed Curtain Wall
Material : Aluminium
U_f = 1.2 W/(m²K)
Two Sided Structural Glazing

Tower Curtain Wall
Double Glazing Window

Stavalux ZL-S
Fixed Curtain Wall
Material : Steel
U_f = 0.67 W/(m²K)
Providing a much larger continuous glass surface.

Source : European Facade Products, Kawneer, Schüco

Curtain Wall
Sliding Door

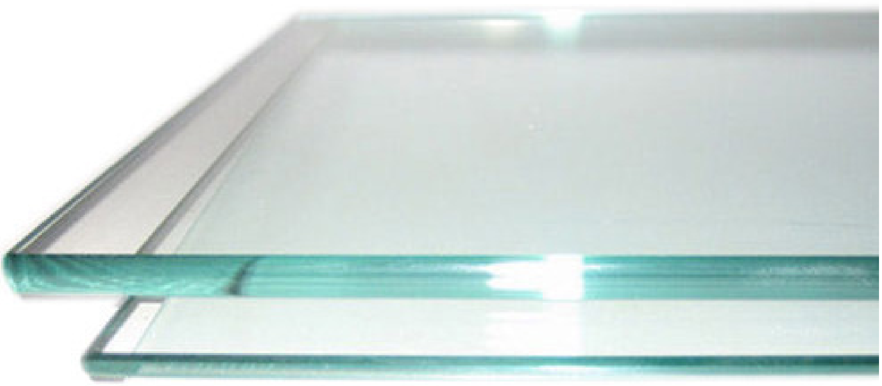
ASS 70.HI
Double Glazing WIndow
Material : Aluminium
U_f = 1.6 W/(m²K)
Minimum face width : 100 mm

Exhibition Glazing
Double Glazing Window

GLASSvent™ UT
Operable Windows
Material : Aluminium
U_f = 1.6 W/(m²K)
Outswing Casement Windows

GLAZING DETAILS

Double Glazing Window



SGG COOL-LITE XTREME 60/28
Fixed Windows
Light Transmittance LT (%) : 60
Solar Factor - g value : 0.28
U_g - 16mm argon : 1.0 [W/m².K]

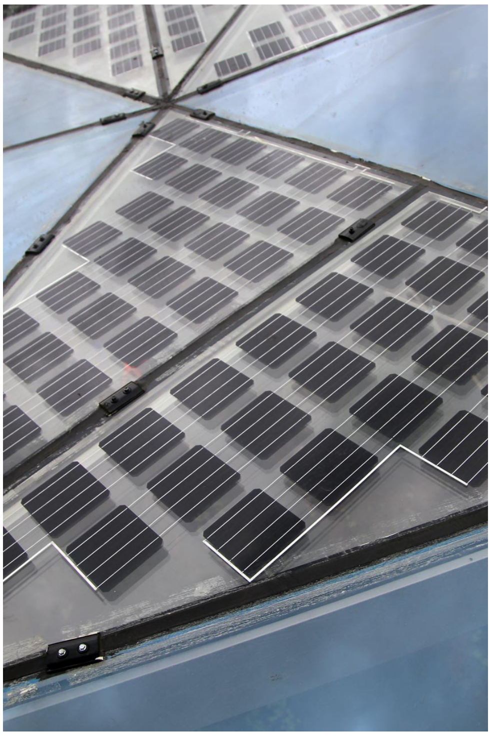
Single Glazing Window

SGG EMALIT Evolution
Opaque Coloured Glass
Maximum dimensions : 3600x2080mm
U_g = 3.7 W/(m²K)
Enamelled heat-treated outer glass pane

Source : Saint-Gobain

Curtain Wall

Sliding Door

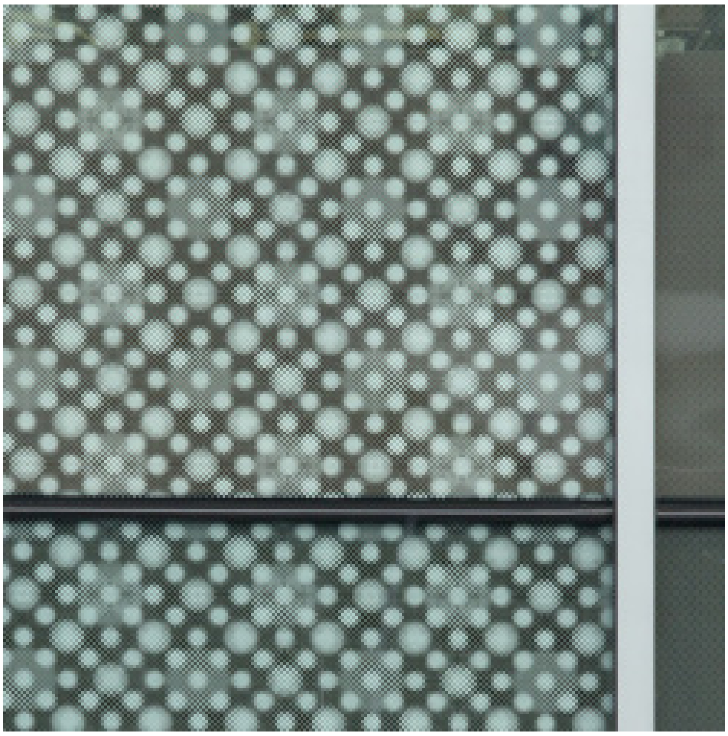


SG Solar Suneka®
On roof Solar Module
High solar transmission glass and an anodized aluminium-framed module.

Translucent Glazing Window

OPALIT Evolution
Thickness : 6mm
Maximum dimensions : 3300x2000mm
U_g - 16mm argon : 1.0 [W/m².K]
Toughened, translucent enamelled glass

Double Glazing Window

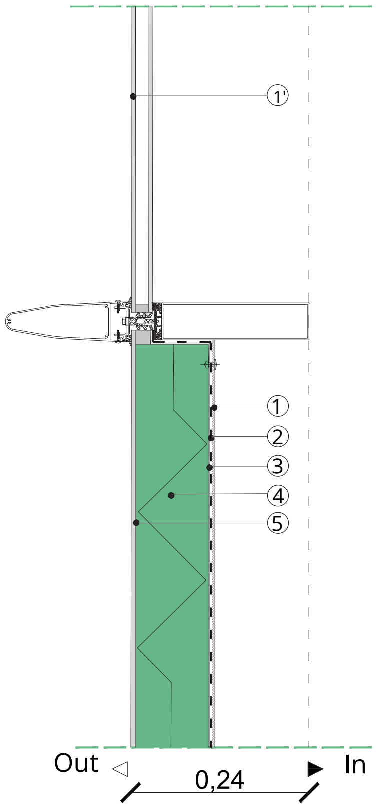


Silkscreened Ceramic Frit
Restaurant Curtain Wall
Any combination of flat glass 3mm-19mm
Enamel ink that is applied to the glass

Source : Goldray Glass

|TECHNICAL LAYERS|

External wall
Transparent-Opaque Connection



Horizontal Section

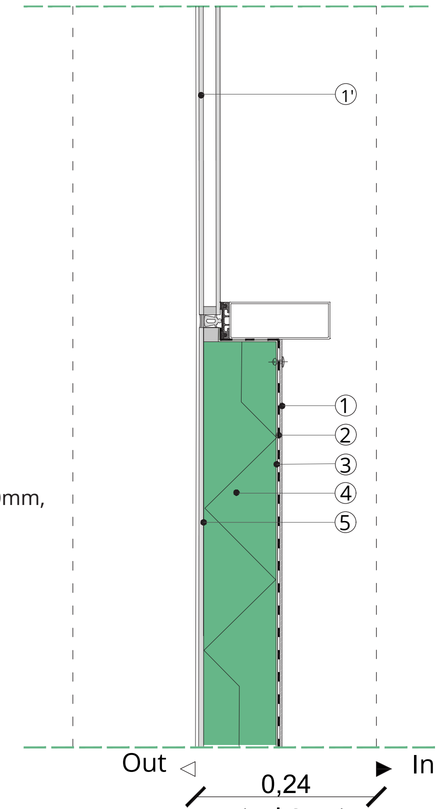
① Double glazing 6+16+6mm,
dim. 1800mmx2200mm

Uvalue = 1.091 W/m^{2}K

① Polycarbonate sheet 3mm
② Vapor barrier 1mm
③ Steel back pan 2mm
④ Expanded polysteryne 100mm
⑤ Enamelled heat-treated outer glass pane, 40mm, dim. 1800mm X 2220mm

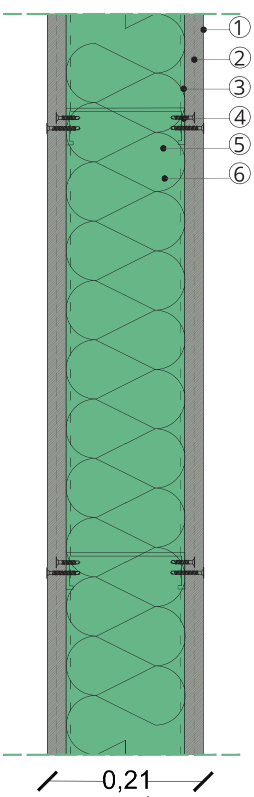
Uvalue = 0.281 W/m^{2}K

External wall
Transparent-Opaque Connection



Vertical Section

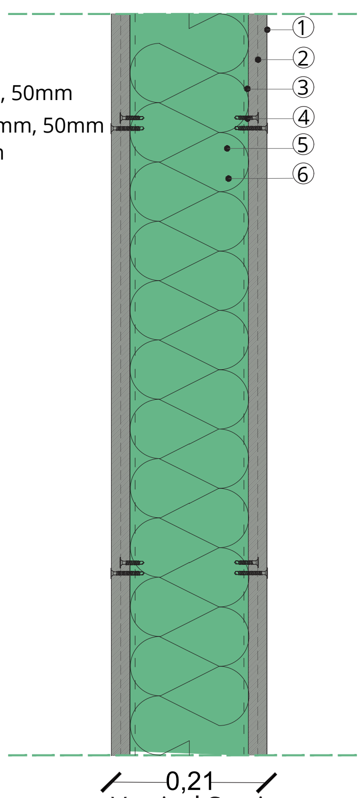
Internal accoustic wall



Horizontal Section

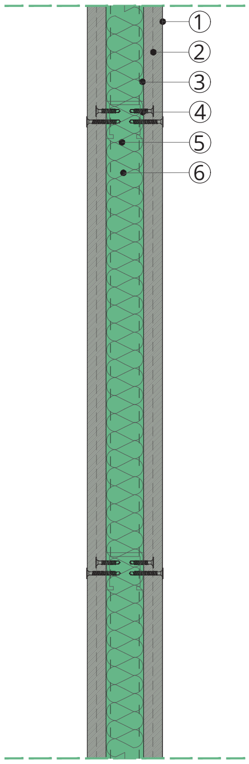
① Washable paint based on acrylic resin
② Double plasterboard slab 2x12.5mm
③ Vertical galvalised steel profile "C" dim 140mm, 50mm
④ Horizontal galvalised steel profile "U" dim 160mm, 50mm
⑤ Acoustic insulation in rock wool panels 160mm
⑥ Double plasterboard slab 2x12.5mm

Internal accoustic wall



Vertical Section

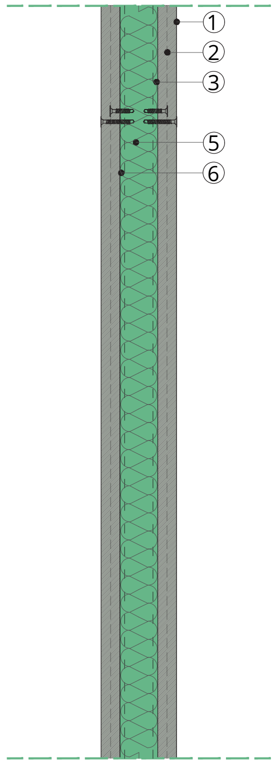
Internal wall



0,1
Horizontal Section

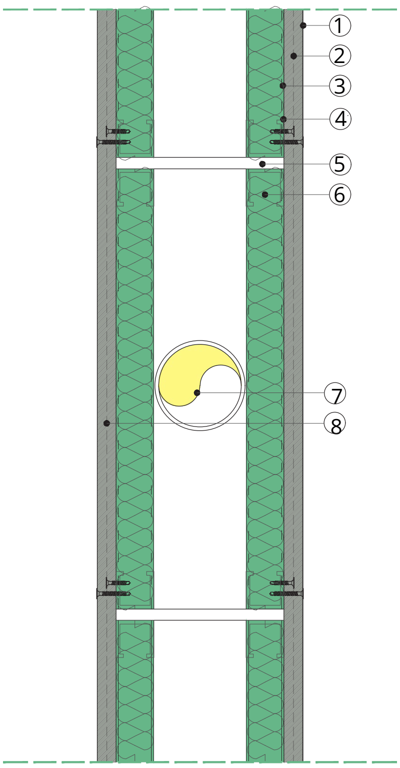
1. Washable paint based on acrylic resin
2. Double plasterboard slab d 2x12.5mm
3. Vertical galvalised steel profile "C" dim 50mm, 50mm
4. Horizontal galvalised steel profile "U" dim 80mm, 50mm
5. Acoustic insulation in rock wool panels d. 50 mm
6. Double plasterboard slab d. 2x12.5mm

Internal wall



0,1
Vertical Section

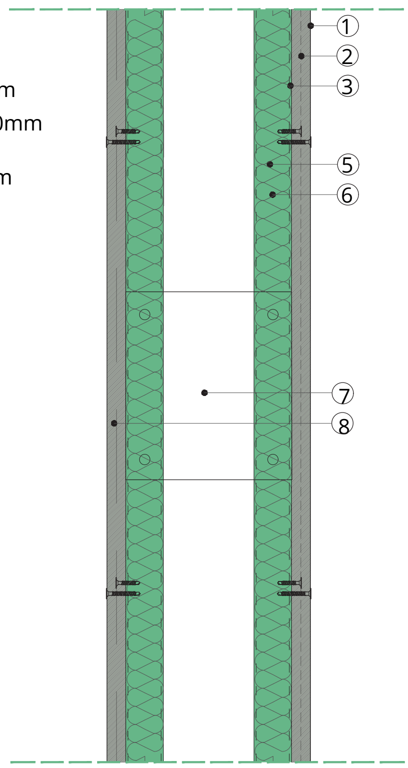
Internal wall with cavity



0,27
Horizontal Section

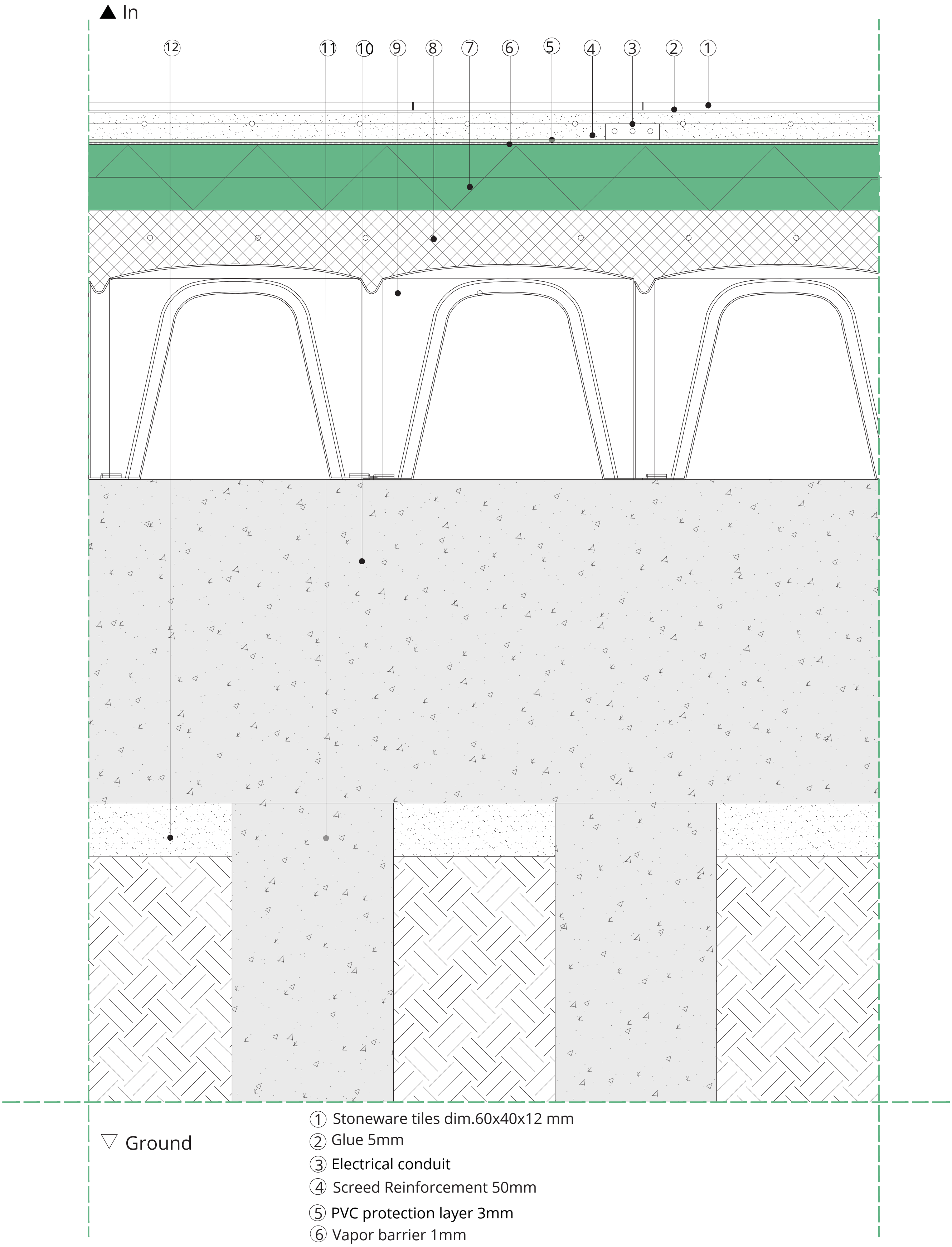
1. Washable paint based on acrylic resin
2. Double plasterboard slab d 2x12.5mm
3. Vertical galvalised steel profile "C" dim 50mm, 50mm
4. Horizontal galvalised steel profile "U" dim 80mm, 50mm
5. Chipboard d.15mm h. 300mm
6. Acoustic insulation in rock wool panels d. 50 + 50mm
7. Equipped cavity d. 120mm
8. Double plasterboard slab d. 2x12.5mm

Internal wall with cavity



0,27
Vertical Section

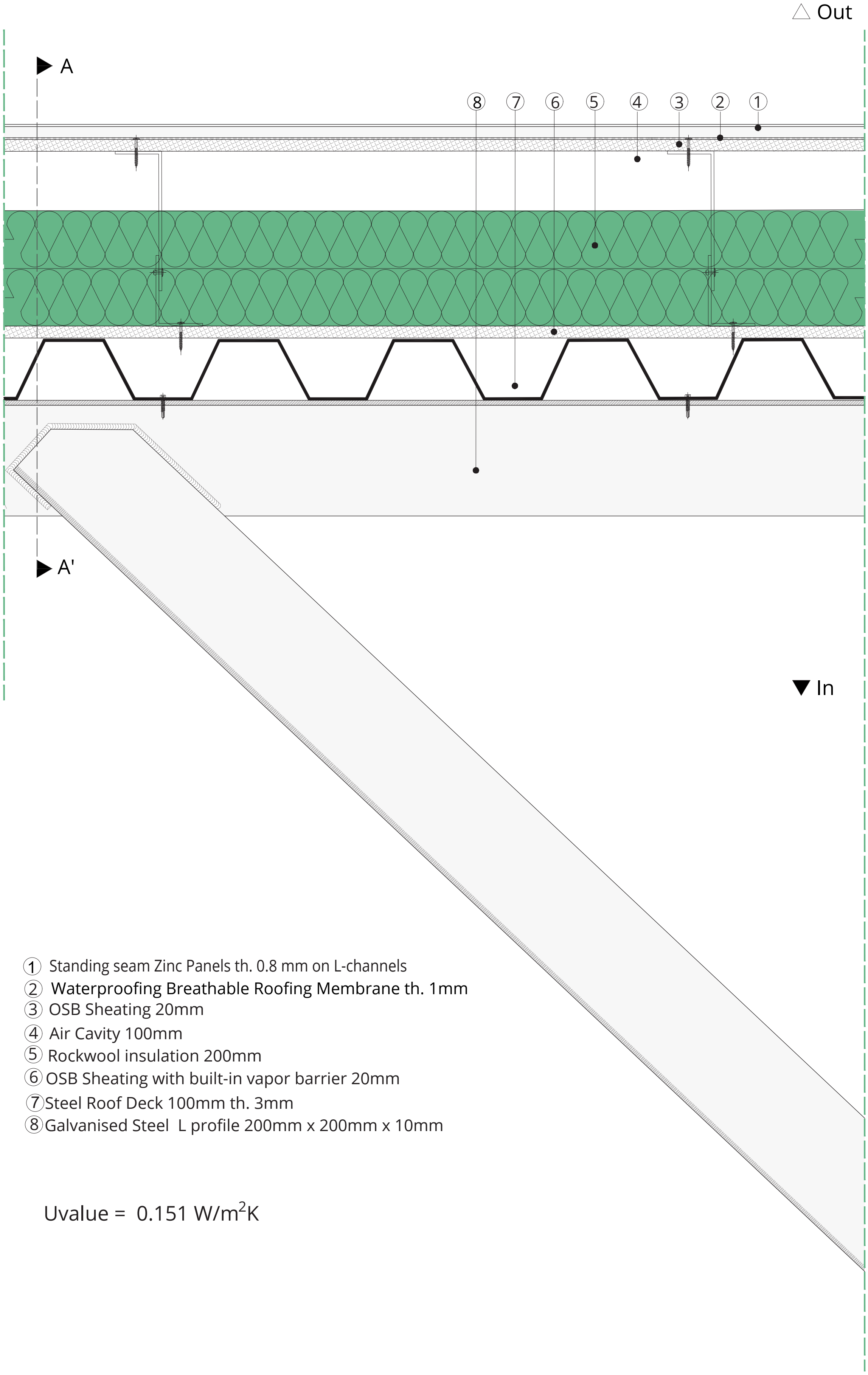
Floor in contact with the Ground



1. Stoneware tiles dim.60x40x12 mm
2. Glue 5mm
3. Electrical conduit
4. Screed Reinforcement 50mm
5. PVC protection layer 3mm
6. Vapor barrier 1mm
7. Thermal insulation in expanded polystyrene 120mm
8. Pouring concrete 100 mm
9. Ventilated underground cavity with igloo 300mm
10. Reinforced Concrete bed 600mm reacting as pile cap
11. Reinforced Pile 300x300mm leading to rock soil
12. Oversite concrete 100 mm

Uvalue = 0.170 W/m^2K

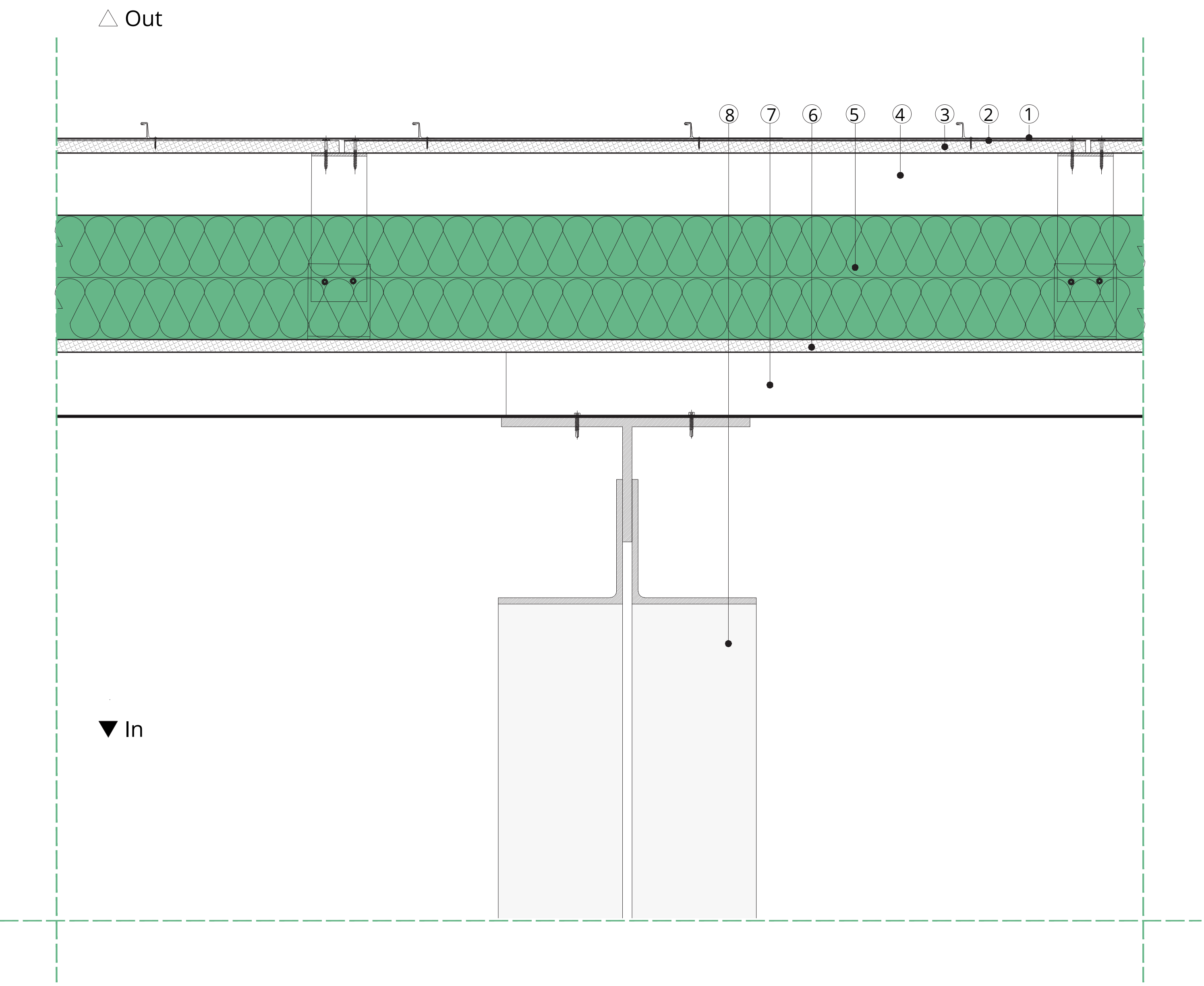
Tower Roof



1. Standing seam Zinc Panels th. 0.8 mm on L-channels
2. Waterproofing Breathable Roofing Membrane th. 1mm
3. OSB Sheating 20mm
4. Air Cavity 100mm
5. Rockwool insulation 200mm
6. OSB Sheating with built-in vapor barrier 20mm
7. Steel Roof Deck 100mm th. 3mm
8. Galvanised Steel L profile 200mm x 200mm x 10mm

Uvalue = 0.151 W/m^2K

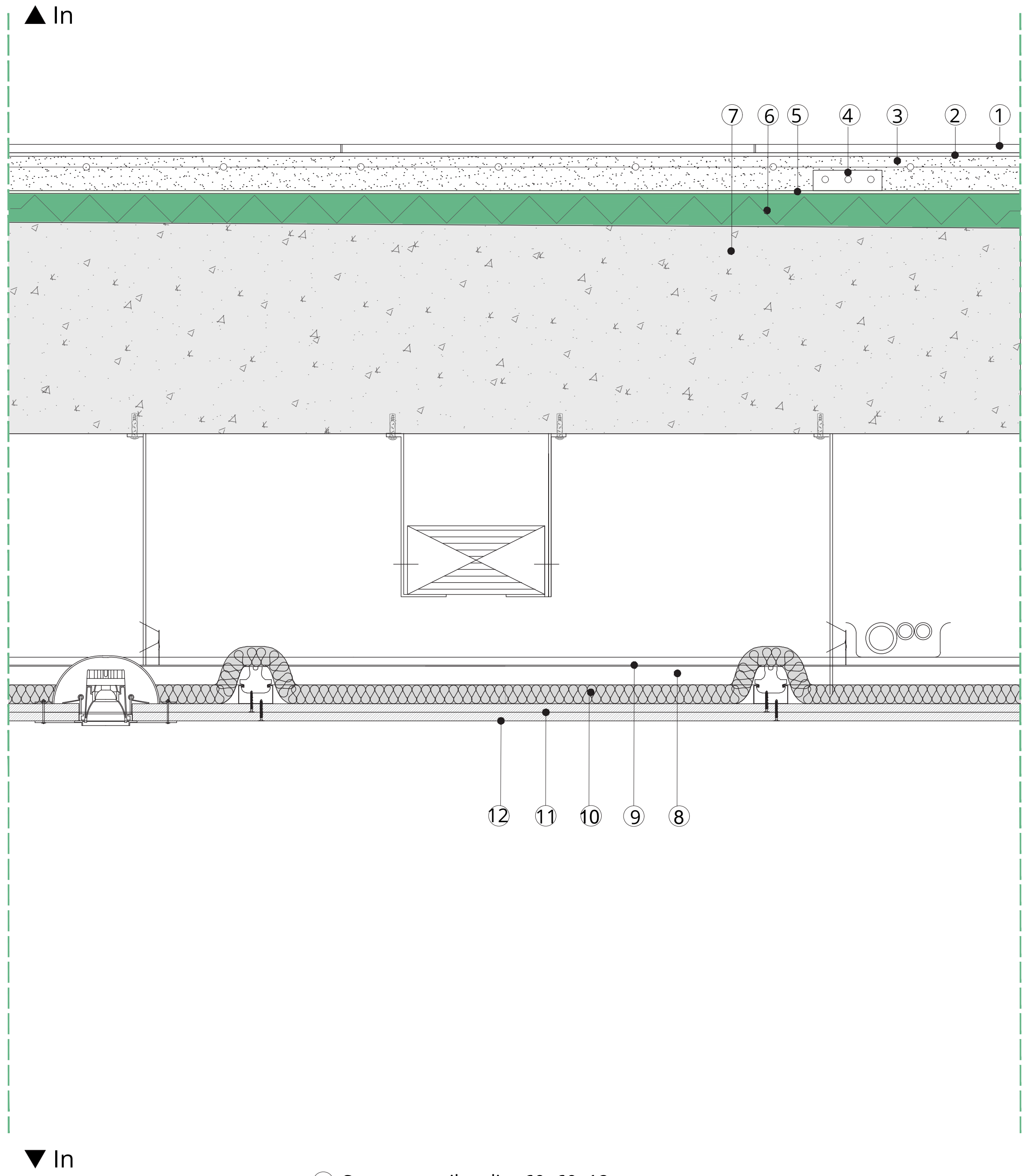
Tower Roof - AA' Section



1. Standing seam Zinc Panels th. 0.8 mm on L-channels
2. Waterproofing Breathable Roofing Membrane th. 1mm
3. OSB Sheating 20mm
4. Air Cavity 100mm
5. Rockwool insulation 200mm
6. OSB Sheating with built-in vapor barrier 20mm
7. Steel Roof Deck 100mm th. 3mm
8. Galvanised Steel L profile 200mm x 200mm x 10mm

Uvalue = 0.151 W/m^2K

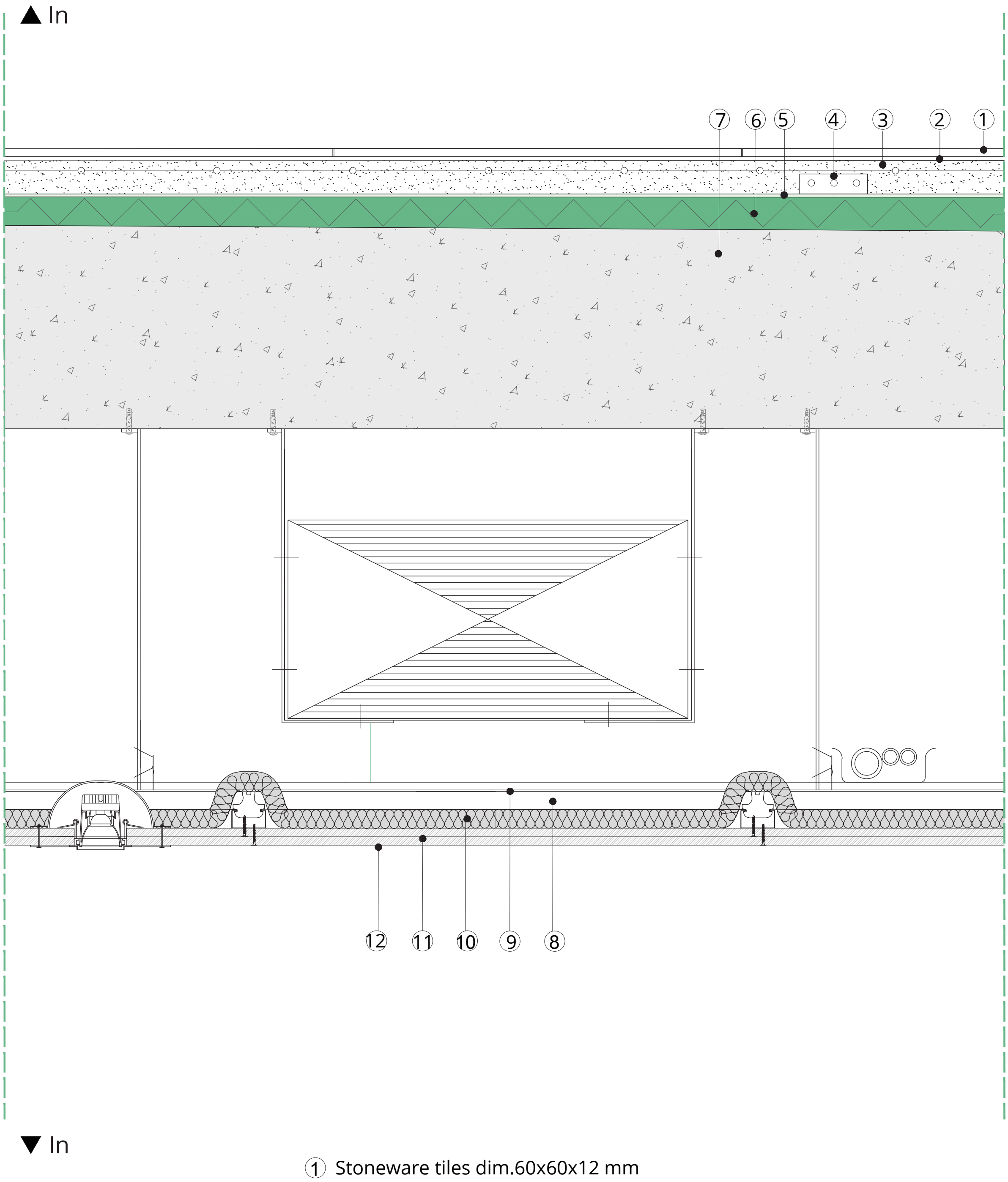
Interior floor of tower



1. Stoneware tiles dim.60x60x12 mm
2. Glue 5 mm
3. Screed reinforcement 50mm
4. Electrical conduit
5. PVC protection layer 3mm
6. Expanded polysteryne 50 mm
7. Slab in RC 300 mm
8. Equipped cavity 330 mm
9. False ceiling with galvanized steel "C" profiles dim. 50x27x0.6 mm
10. Acoustic insulation in rock wool panels 30 mm
11. Double plasterboard slab 2x12.5mm
12. Washable paint based on acrylic resin

Uvalue = 0.191W/m^{2}K

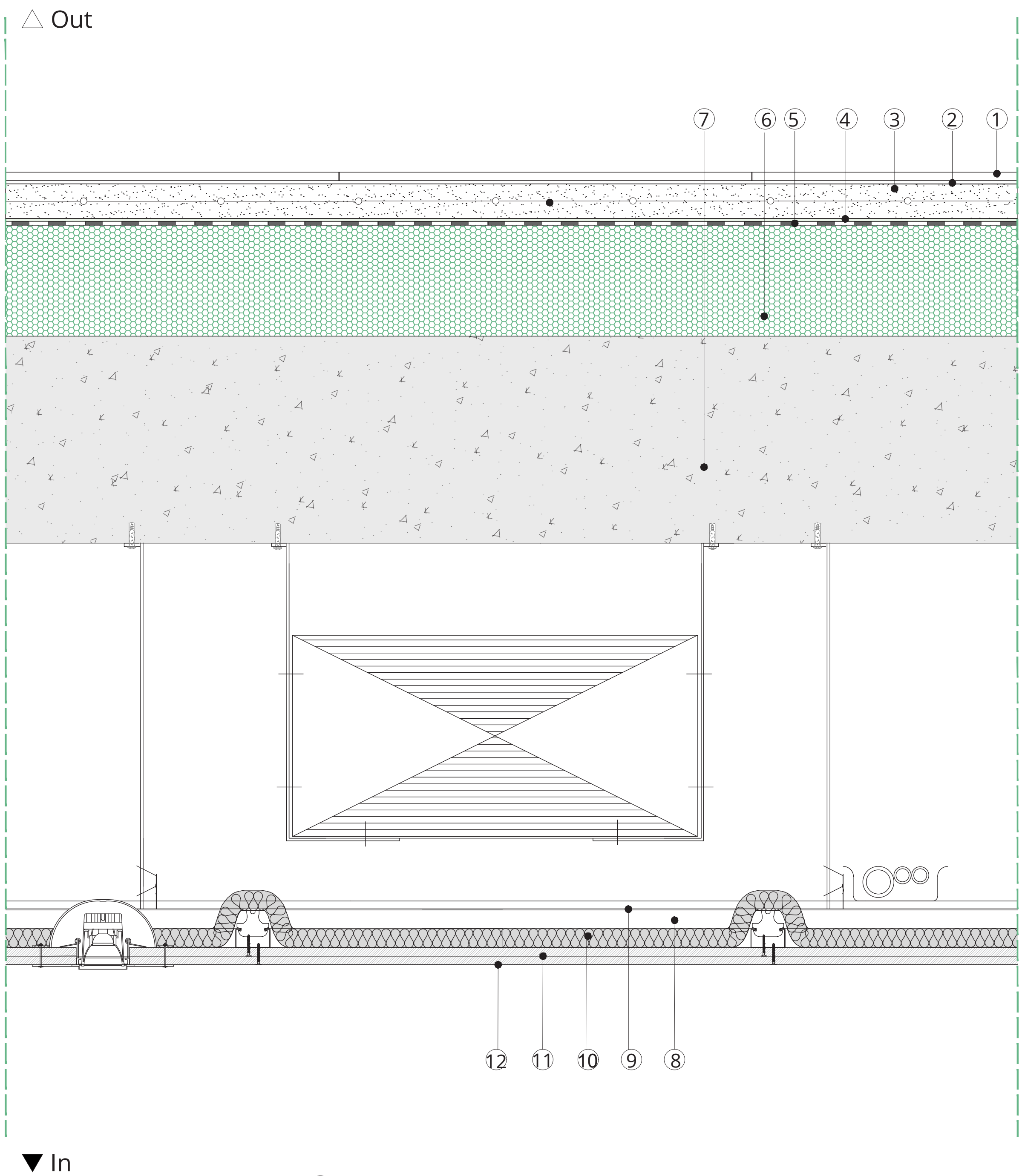
Interior floor of exhibition space



1 Stoneware tiles dim.60x60x12 mm
2 Glue 5 mm
3 Screed reinforcement 50mm
4 Electrical conduit
5 PVC protection layer 3mm
6 Expanded polysteryne 50 mm
7 Slab in RC 300 mm
8 Equipped cavity 560 mm
9 False ceiling with galvanized steel "C" profiles dim. 50x27x0.6 mm
10 Acoustic insulation in rock wool panels 30 mm
11 Double plasterboard slab 2x12.5mm
12 Washable paint based on acrylic resin

Uvalue = 0.176 W/m^2K

Accessible Roof of exhibition space



1. Stoneware tiles dim.60x60x12 mm
2. Glue 5mm
3. Screed reinforcement 50mm
4. PVC protection layer 3mm
5. Waterproof membrane, bitumen sheets 5 mm
6. Insulation slab FOAMGLAS type placed with hot-bitumen 160 mm
7. Slab in RC 300 mm
8. Equipped cavity 560 mm
9. False ceiling with galvanized steel "C" profiles dim. 50x27x0.6 mm
10. Acoustic insulation in rock wool panels 30 mm
11. Double plasterboard slab 2x12.5mm
12. Washable paint based on acrylic resin

Uvalue = 0.221 W/m^{2}K

| U-Values |

Spandrel

Material	Thickness [m]	Conductivity [W/mK]	Conductance [W/m²K]	Heat Resistance [m²K/W]
Single plasterboard	0.0125	0.200	16.000	0.063
Vapor barrier	0.001	0.160	160.000	0.006
Steel back pan	0.002	50.200	25100.000	0.000
Expanded polysterine	0.100	0.031	0.310	3.226
SGG EMALIT EVOLUTION				0.270
			Uvalue	0.281

Soil floor

Material	Thickness [m]	Conductivity [W/mK]	Conductance [W/m²K]	Heat Resistance [m²K/W]
stoneware tiles	0.012	0.374	31.167	0.032
glue	0.005	0.037	7.400	0.135
Screed reinforcement	0.050	0.090	1.800	0.556
PVC protective layer	0.003	0.190	63.333	0.016
vapor barrier	0.001	0.170	170.000	0.006
expanded polystyrene	0.120	0.031	0.258	3.871
pouring concrete	0.100	1.350	13.500	0.074
ventilation cavity	0.300	0.500	1.667	0.600
concrete bed	0.600	1.160	1.933	0.517
oversite concrete	0.100	1.350	13.500	0.074
			Uvalue	0.170

Accessible roof

Material	Thickness [m]	Conductivity [W/mK]	Conductance [W/m²K]	Heat Resistance [m²K/W]
Stoneware tiles	0.012	0.374	31.167	0.032
Glue	0.005	0.037	7.400	0.135
Reinforced screed	0.05	0.090	1.800	0.556
PVC protective layer	0.003	0.190	63.333	0.016
Waterproof Membrane	0.005	0.170	34.000	0.029
FOAMGLAS	0.016	0.036	2.250	0.444
Slab in RC	0.300	0.260	0.867	1.154
equipped cavity	0.560	0.500	0.893	1.120
rock wool panels	0.030	0.033	1.100	0.909
double plasterbord slab	0.025	0.200	8.000	0.125
			Uvalue	0.221

Interior floor of tower

Material	Thickness [m]	Conductivity [W/mK]	Conductance [W/m^{2}K]	Heat Resistance [m^{2}K/W]
Stoneware tiles	0.012	0.150	12.500	0.080
glue	0.005	0.037	7.400	0.135
expanded polystyrene	0.050	0.031	0.620	1.613
slab in RC	0.300	0.260	0.867	1.154
equipped cavity	0.330	0.500	1.515	0.660
expanded polystyrene	0.130	0.031	0.238	4.194
rock wool panels	0.030	0.033	1.100	0.909
double plasterbord slab	0.025	0.200	8.000	0.125
			Uvalue	0.113

Interior floor of exhibition

Material	Thickness [m]	Conductivity [W/mK]	Conductance [W/m^{2}K]	Heat Resistance [m^{2}K/W]
Stoneware tiles	0.012	0.150	12.500	0.080
glue	0.005	0.037	7.400	0.135
expanded polystyrene	0.050	0.031	0.620	1.613
slab in RC	0.300	0.260	0.867	1.154
equipped cavity	0.560	0.500	0.893	1.120
expanded polystyrene	0.130	0.031	0.238	4.194
rock wool panels	0.030	0.033	1.100	0.909
double plasterbord slab	0.025	0.200	8.000	0.125
			Uvalue	0.107

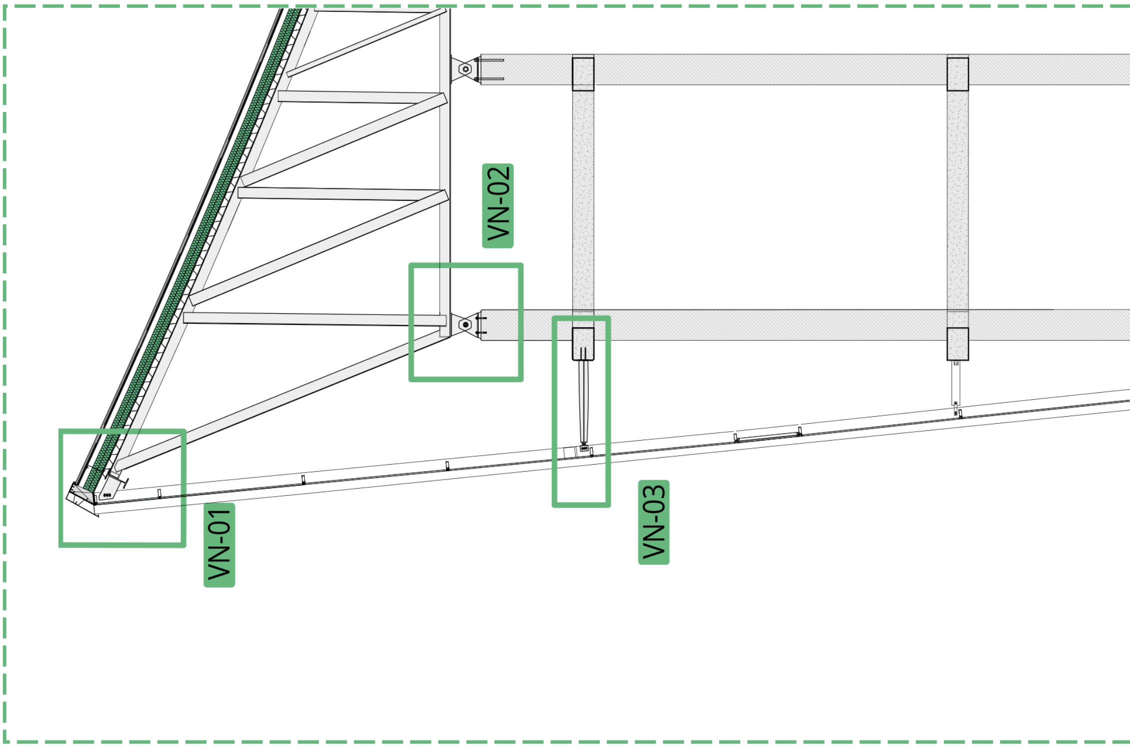
Tower roof

Material	Thickness [m]	Conductivity [W/mK]	Conductance [W/m^{2}K]	Heat Resistance [m^{2}K/W]
Zinc Panels	0.0008	0.270	337.500	0.003
Breathable Membrane	0.001	0.033	33.000	0.030
OSB Sheating	0.020	0.130	6.500	0.154
Air Cavity	0.100	0.500	5.000	0.200
Rock wool insulation	0.200	0.033	0.165	6.061
OSB Sheating	0.020	0.130	6.500	0.154
			Uvalue	0.151

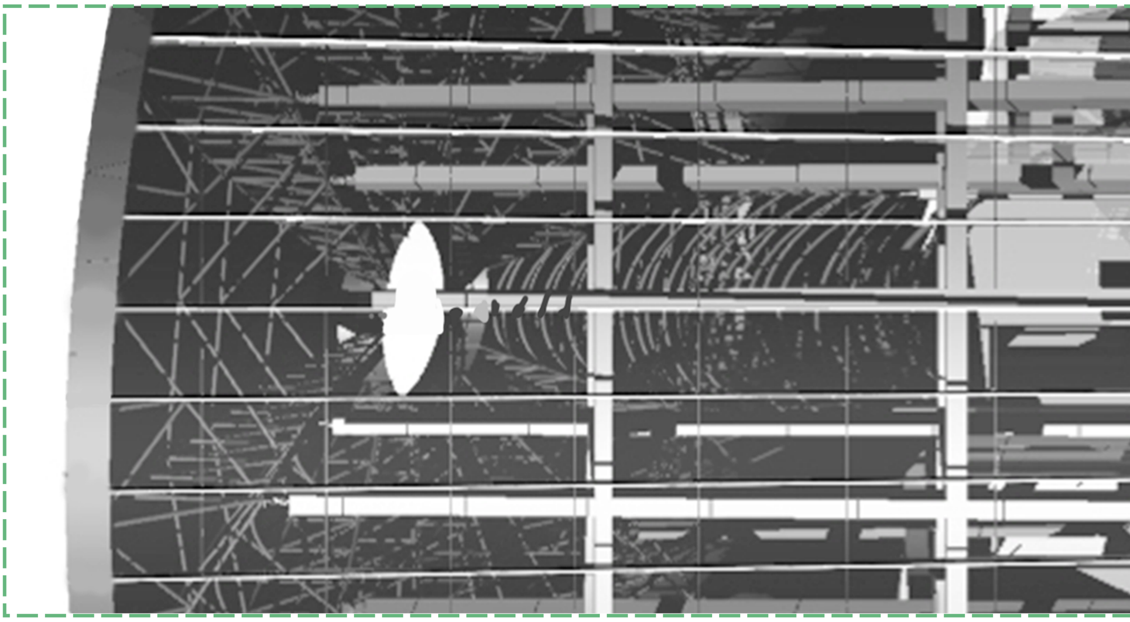
Instance	Frame Code	Glazing Code	Dim. [m]	Dim. [m]	Uw [W/m²K]	Ag [m²]	Ug [W/m²K]	Af [m²]	Uf [W/m²K]	Lg [m]	Ψg [W/mK]
Tower Curtain Wall	STABAL UX ZL-S	SGG COOL-LITE XTREME 60/28	1.8	2.2	1.064	3.76	1.00	0.20	0.67	8.0	0.04
Exhibition Curtain Wall	EFP 50 TSV	SGG COOL-LITE XTREME 60/28	1.8	2.2	1.091	3.76	1.00	0.20	1.20	8.0	0.04
Operable Window	GLASS vent™ UT	SGG COOL-LITE XTREME 60/28	1.2	1.2	1.183	1.32	1.00	0.12	1.60	4.8	0.04
Sliding Door	ASS 70.HI	SGG COOL-LITE XTREME 60/28	3.5	2.2	1.081	7.42	1.00	0.29	1.60	11.4	0.04

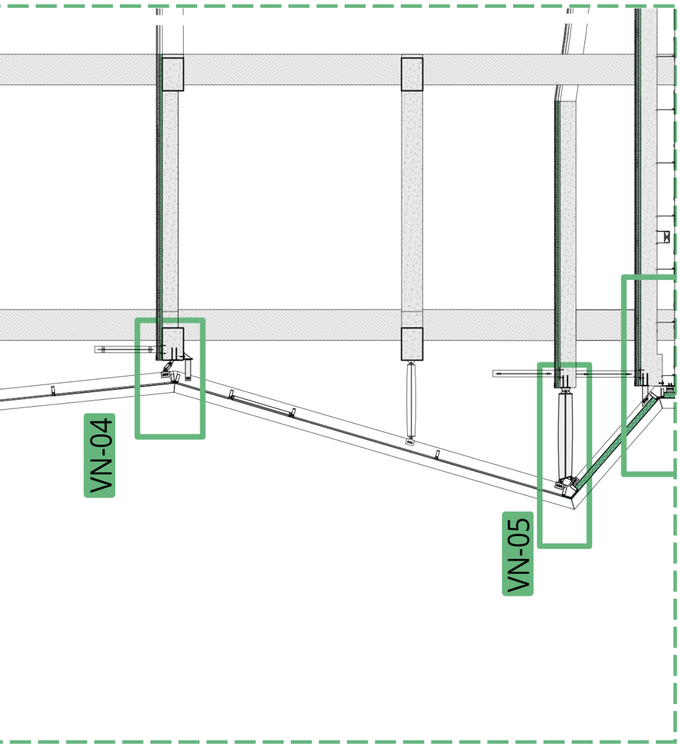
|BLOW UPS & NODES |

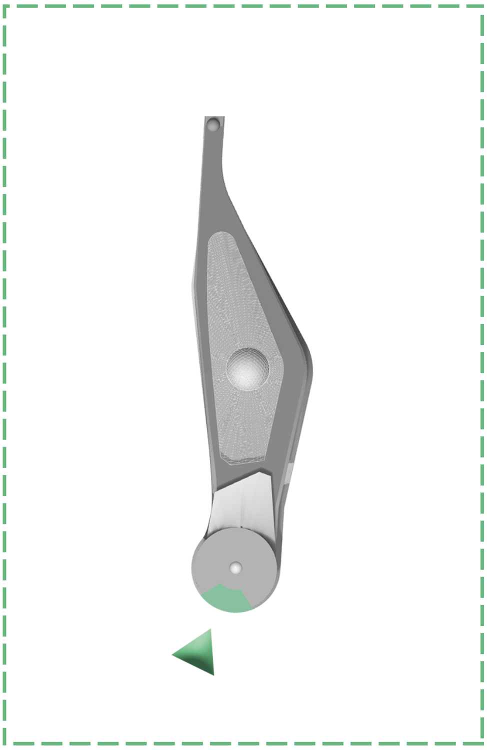
VERTICAL SECTION
Scale 1:130

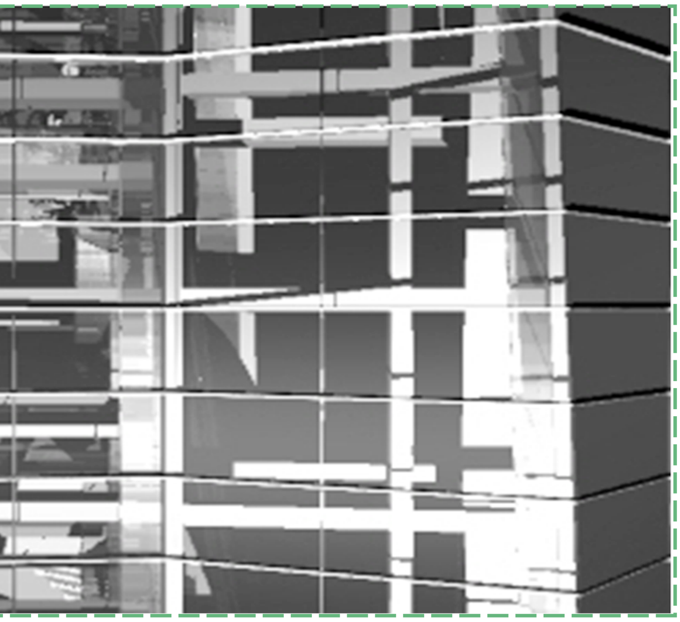


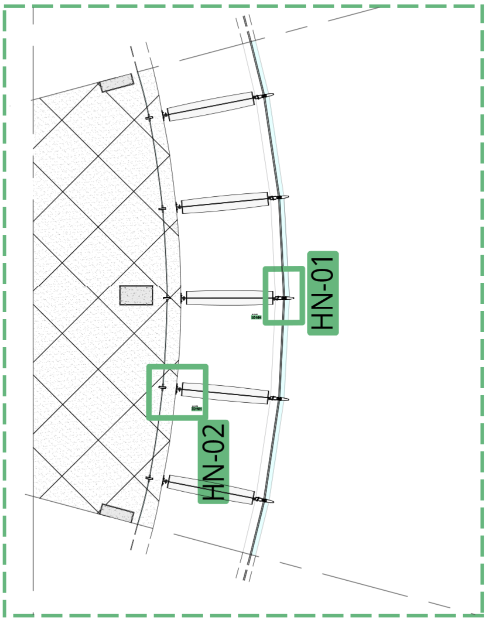
ELEVATION
Scale 1:130



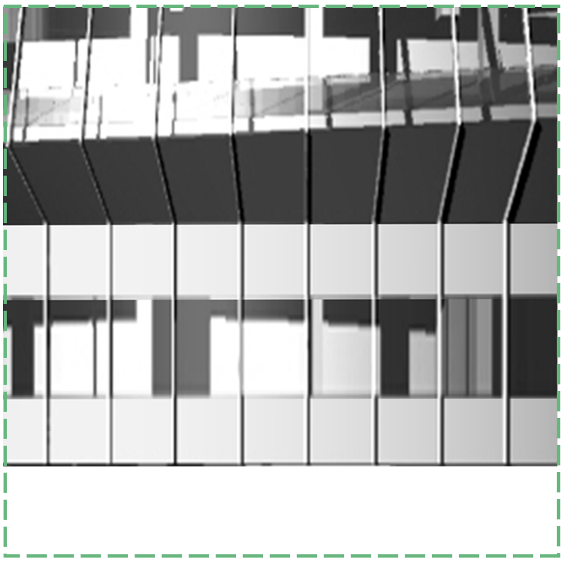




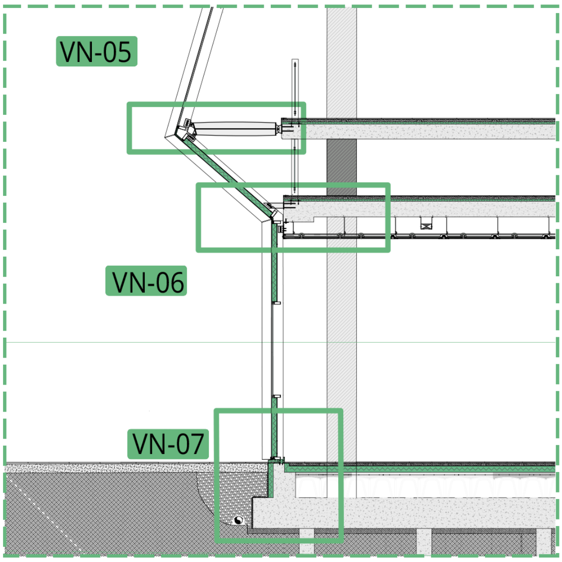




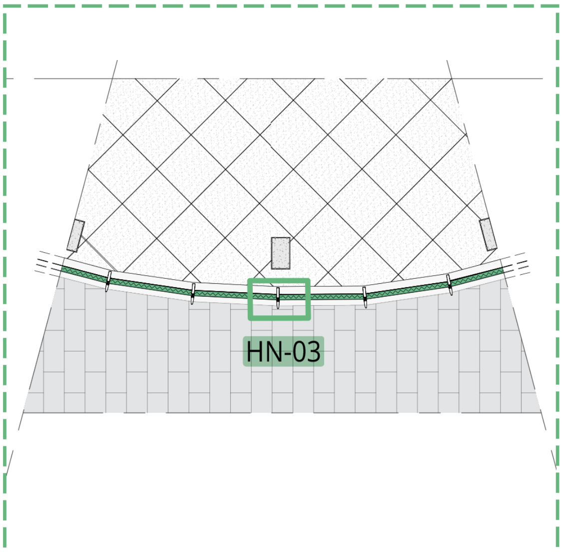
HORIZONTAL SECTION
Scale 1:130



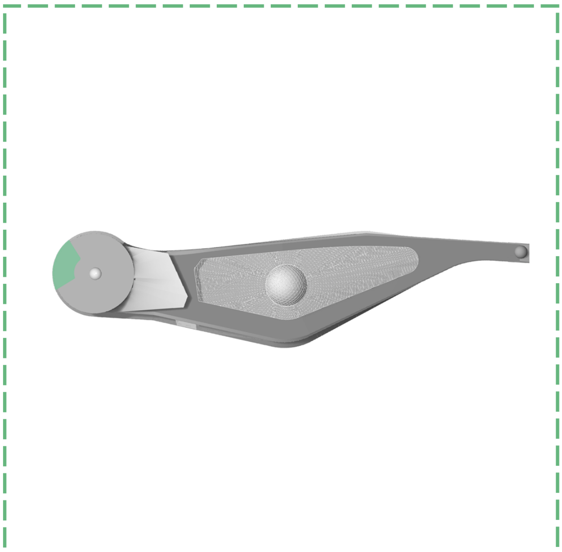
ELEVATION
Scale 1:130



VERTICAL SECTION
Scale 1:130

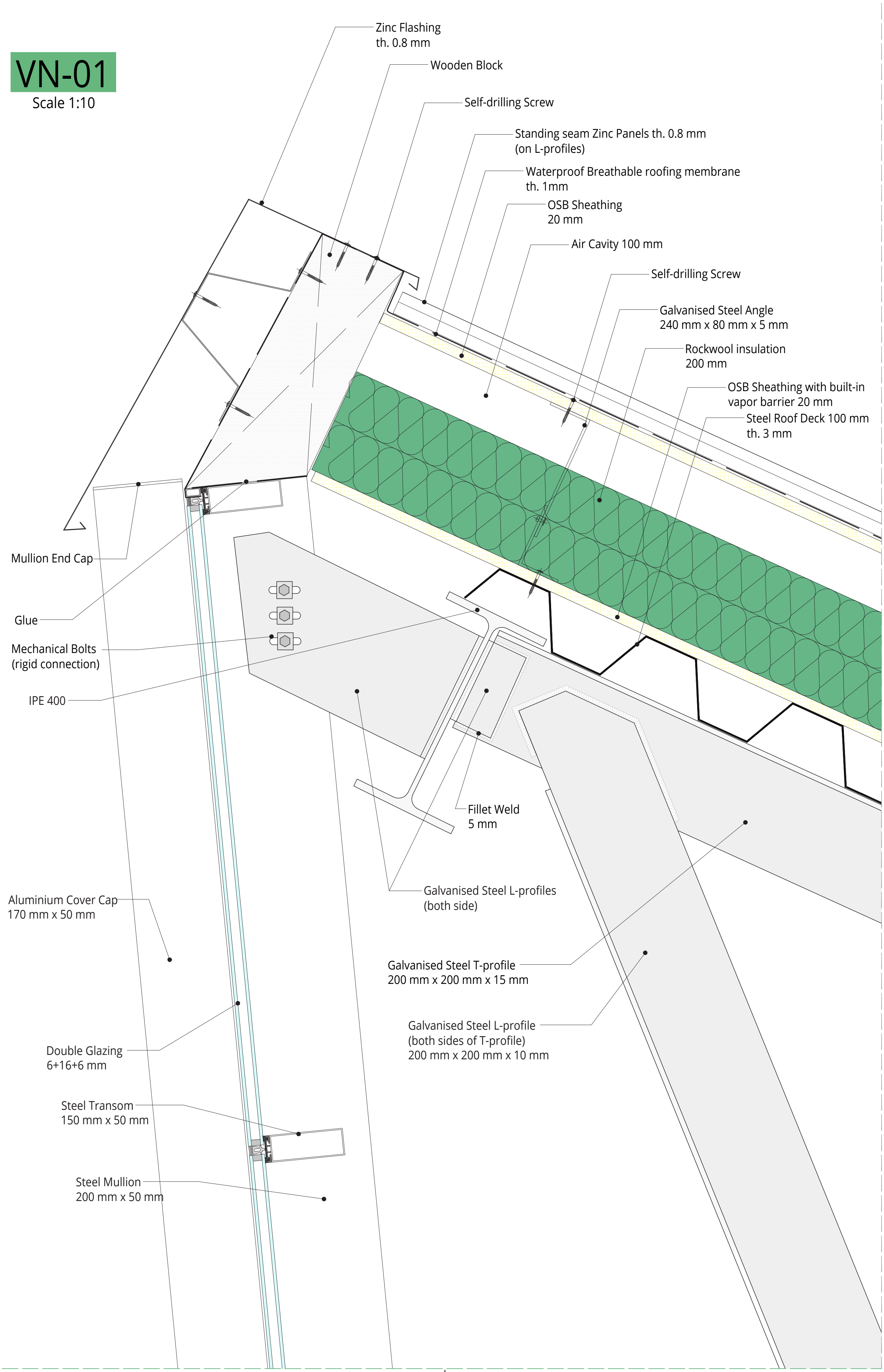


HORIZONTAL SECTION
Scale 1:130



VN-01

Scale 1:10



VN-02
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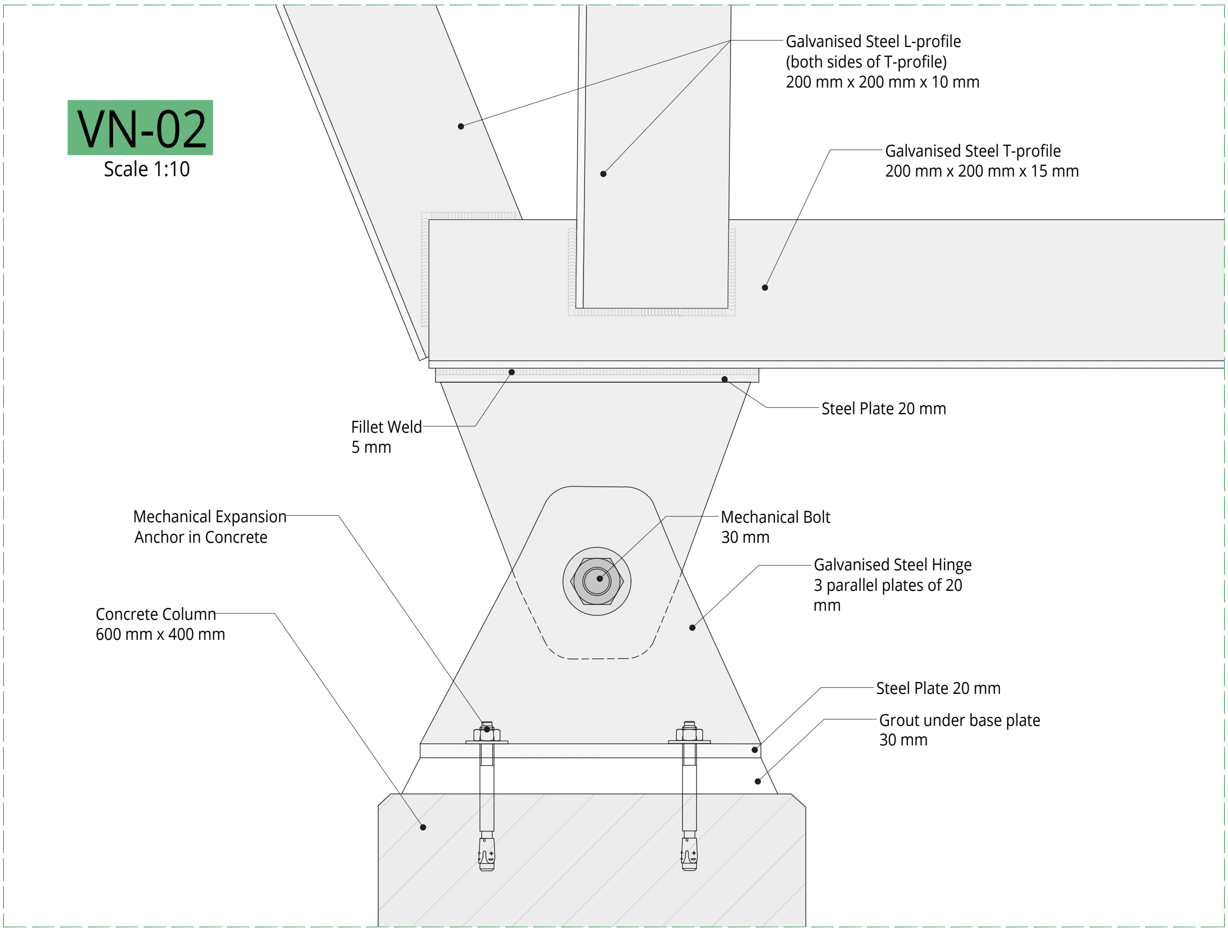
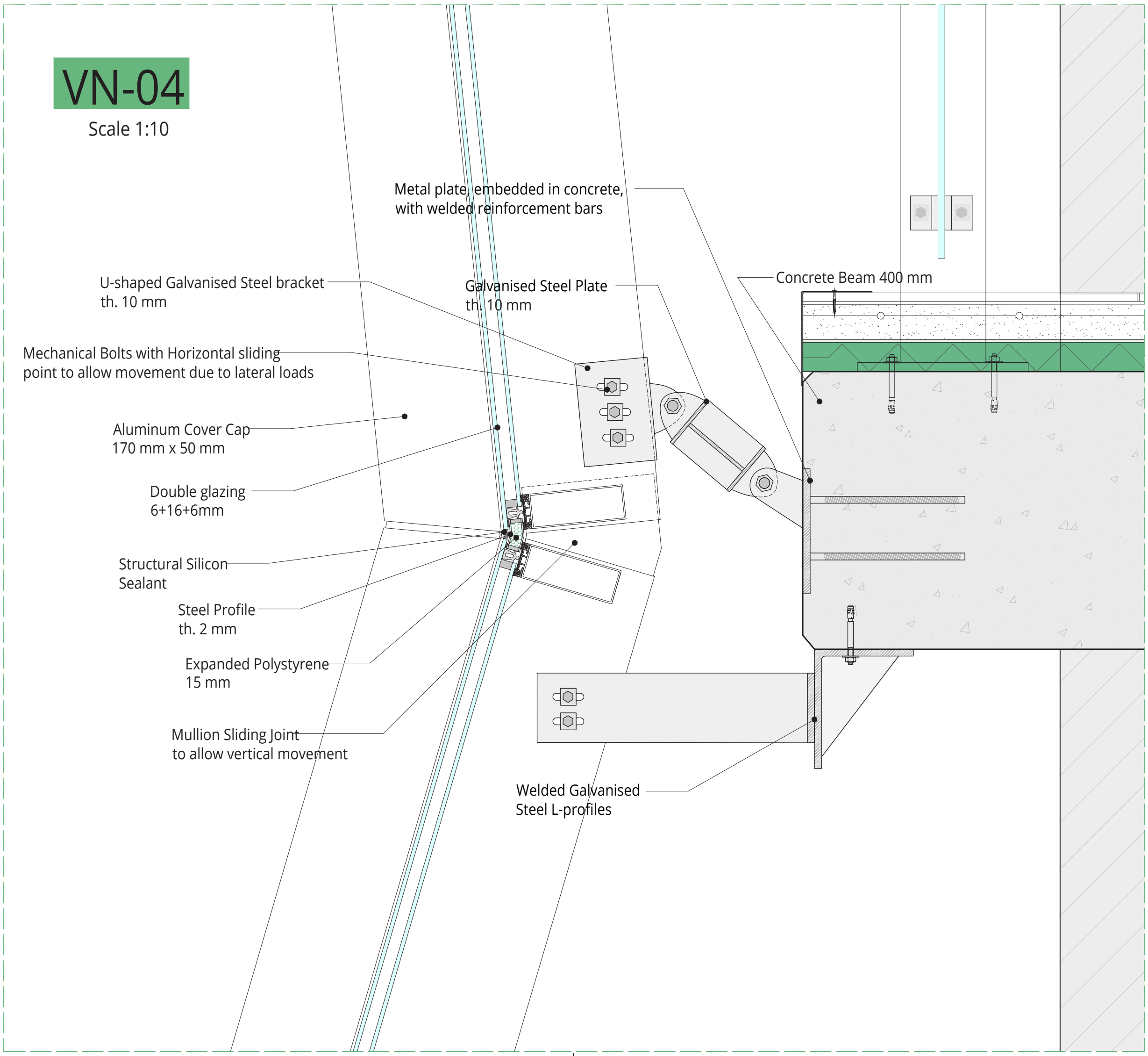
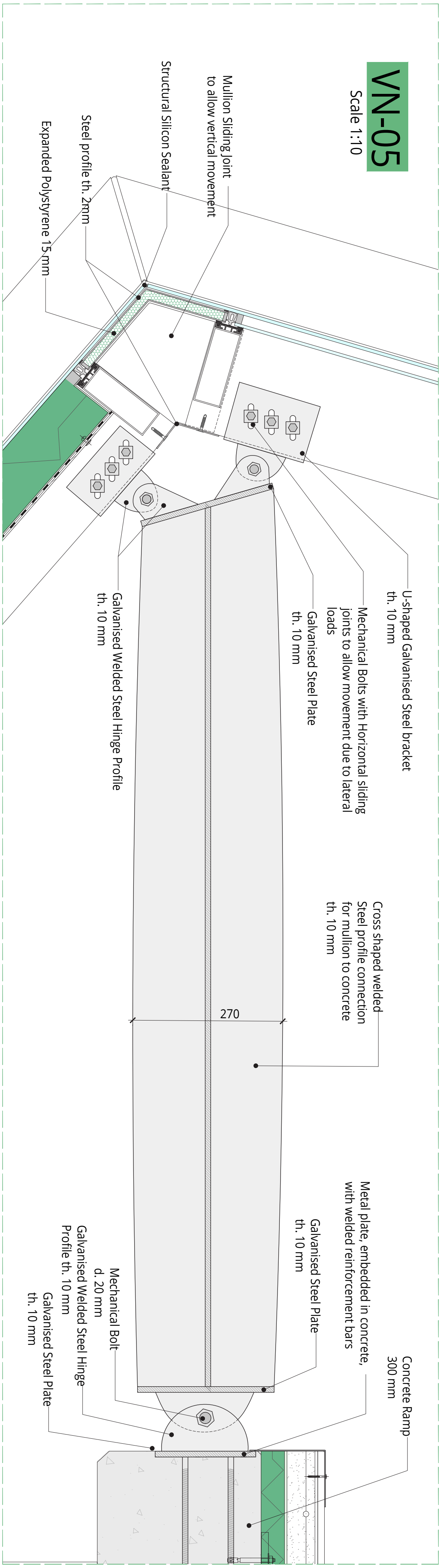
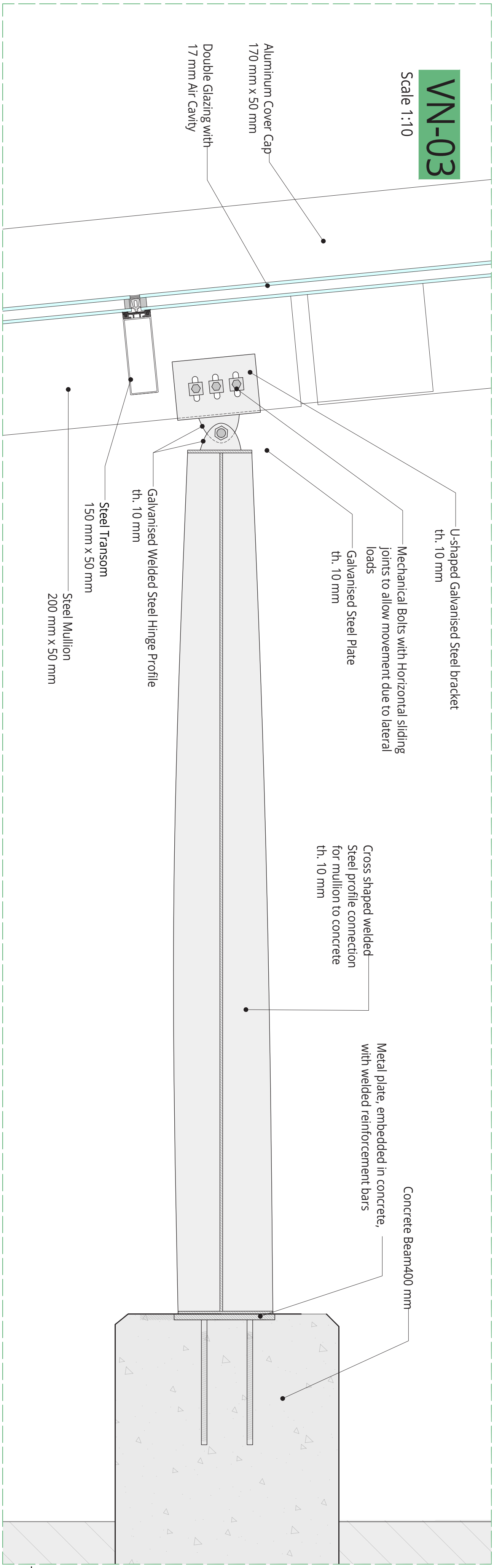
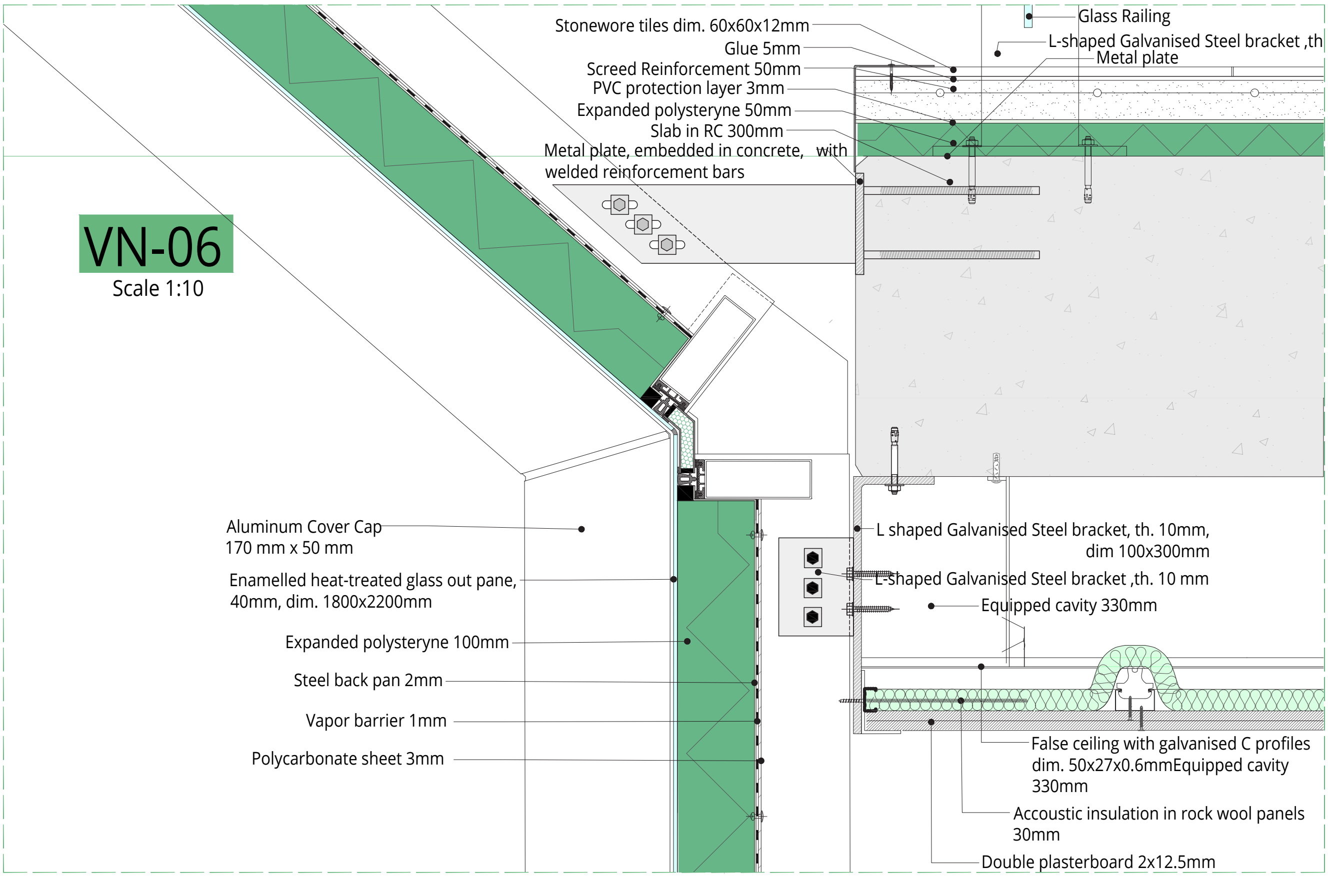


VN-04
Scale 1:10

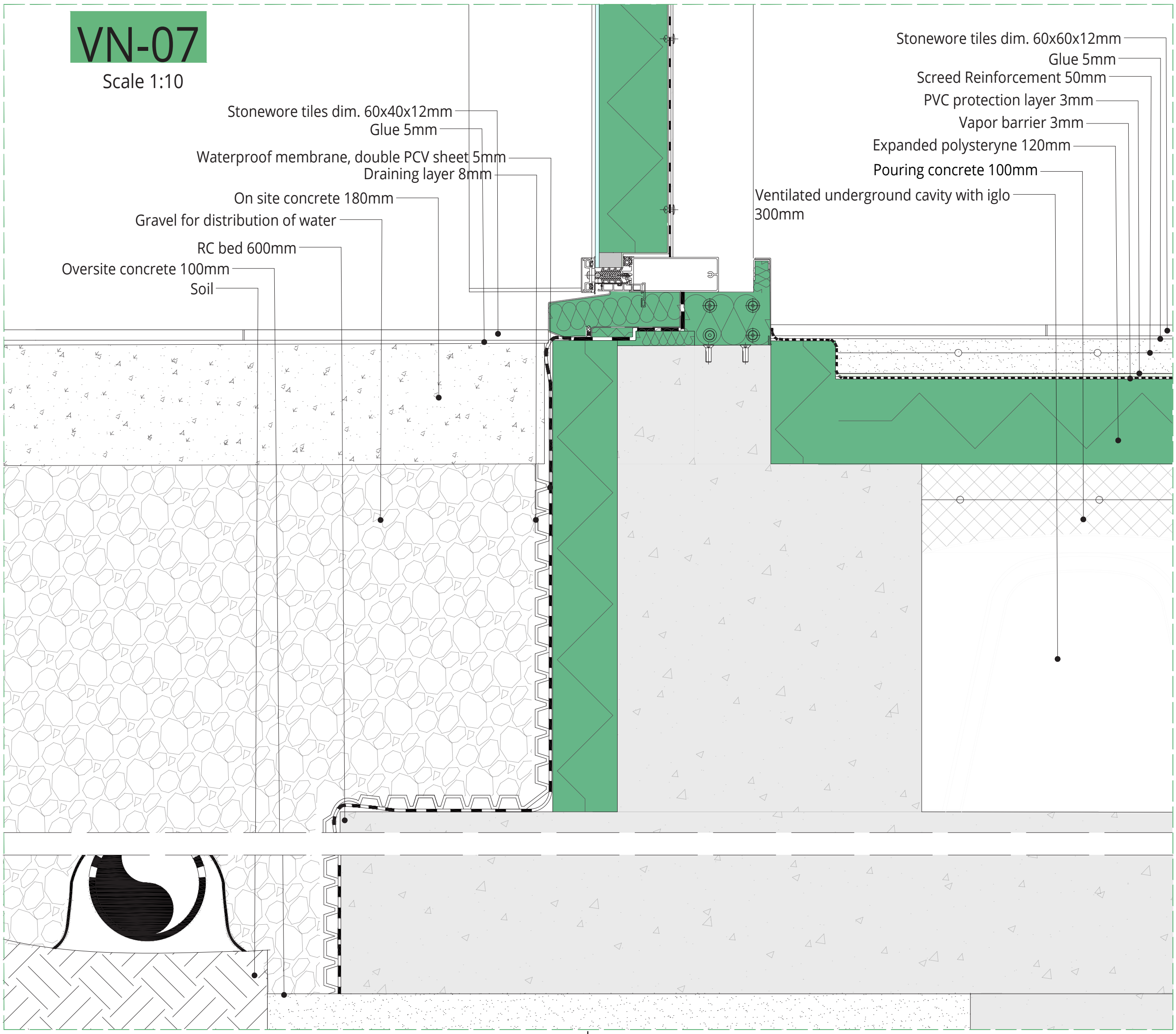



VN-05
Scale 1:10
Mullion Sliding Joint
to allow vertical movement
Structural Silicon Sealant
Steel profile th. 2mm
Expanded Polystyrene 15 mm
U-shaped Galvanised Steel bracket
th. 10 mm
Mechanical Bolts with Horizontal sliding
joints to allow movement due to lateral
loads
Galvanised Steel Plate
th. 10 mm
Galvanised Welded Steel Hinge Profile
th. 10 mm
Cross shaped welded
Steel profile connection
for mullion to concrete
th. 10 mm
270
Concrete Ramp
300 mm
Metal plate, embedded in concrete,
with welded reinforcement bars
Galvanised Steel Plate
th. 10 mm
Mechanical Bolt
d. 20 mm
Galvanised Welded Steel Hinge
Profile th. 10 mm
Galvanised Steel Plate
th. 10 mm

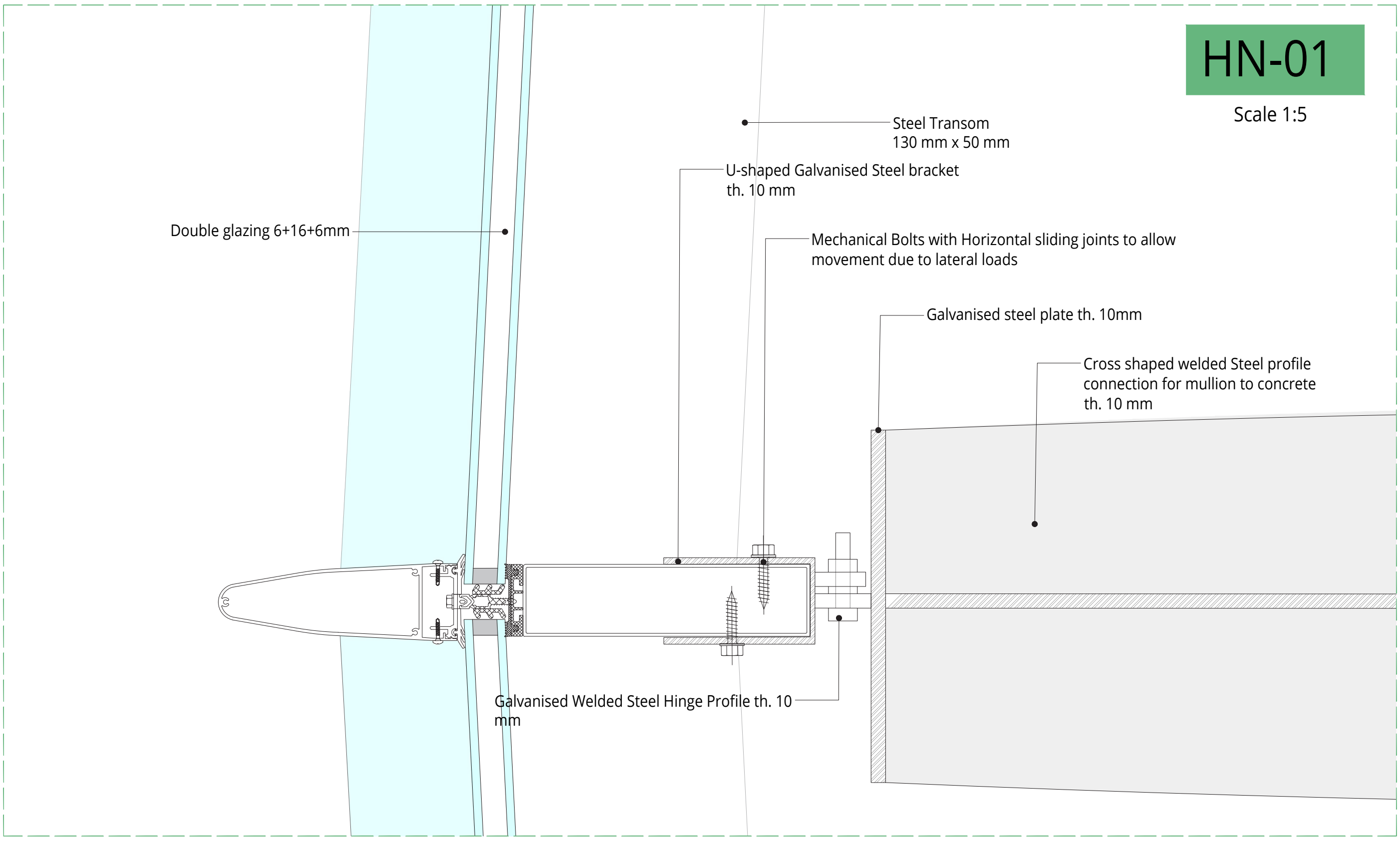

VN-03
Scale 1:10
Aluminum Cover Cap
170 mm x 50 mm
Double Glazing with
17 mm Air Cavity
U-shaped Galvanised Steel bracket
th. 10 mm
Mechanical Bolts with Horizontal sliding
joints to allow movement due to lateral
loads
Galvanised Steel Plate
th. 10 mm
Galvanised Welded Steel Hinge Profile
th. 10 mm
Steel Transom
150 mm x 50 mm
Steel Mullion
200 mm x 50 mm
Cross shaped welded
Steel profile connection
for mullion to concrete
th. 10 mm
Metal plate, embedded in concrete,
with welded reinforcement bars
Concrete Beam400 mm

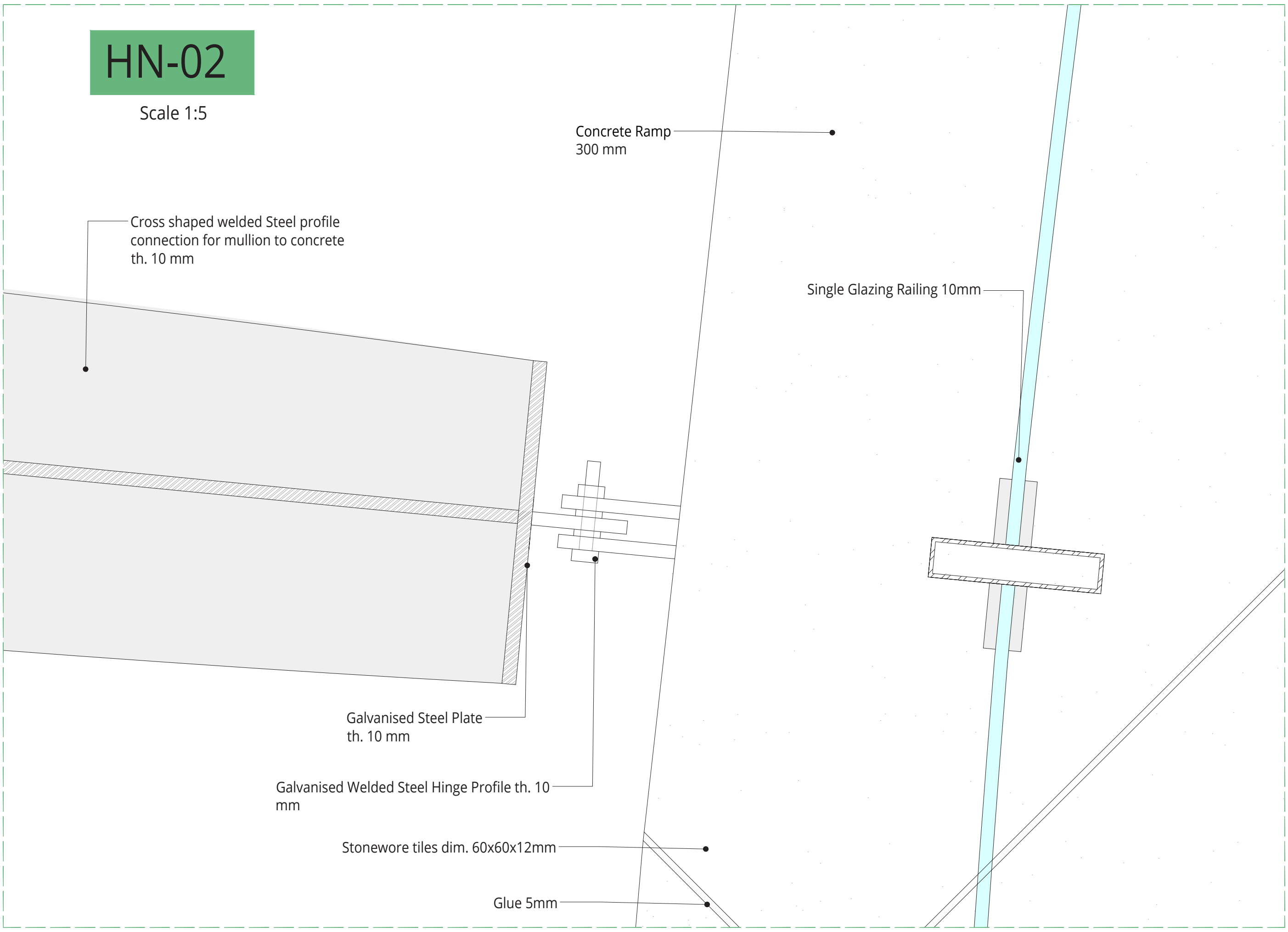


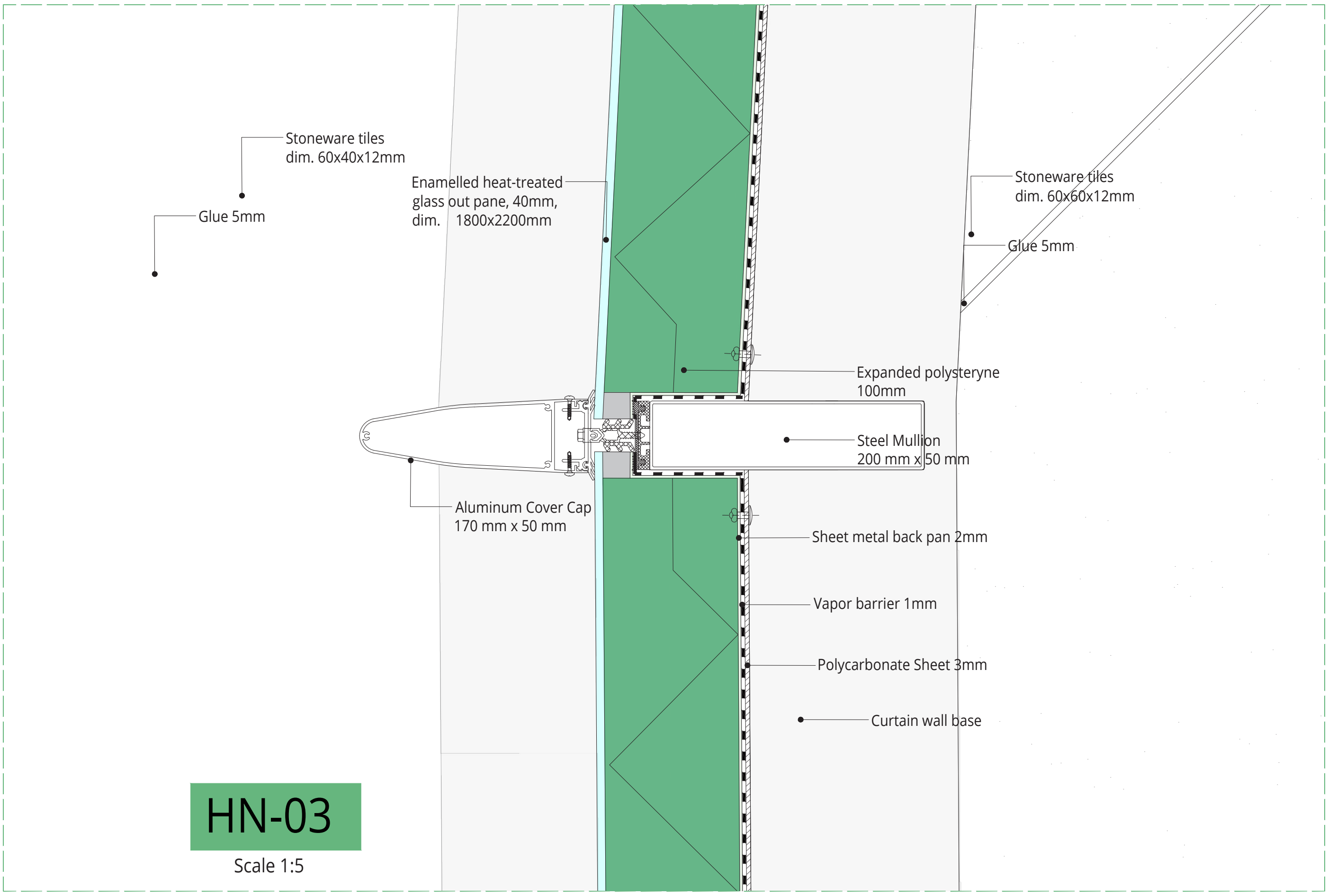
VN-06
Scale 1:10
Stonewore tiles dim. 60x60x12mm
Glue 5mm
Screed Reinforcement 50mm
PVC protection layer 3mm
Expanded polysteryne 50mm
Slab in RC 300mm
Metal plate, embedded in concrete, with welded reinforcement bars
Glass Railing
L-shaped Galvanised Steel bracket ,th
Metal plate
Aluminum Cover Cap 170 mm x 50 mm
Enamelled heat-treated glass out pane, 40mm, dim. 1800x2200mm
Expanded polysteryne 100mm
Steel back pan 2mm
Vapor barrier 1mm
Polycarbonate sheet 3mm
L shaped Galvanised Steel bracket, th. 10mm, dim 100x300mm
L-shaped Galvanised Steel bracket ,th. 10 mm
Equipped cavity 330mm
False ceiling with galvanised C profiles dim. 50x27x0.6mmEquipped cavity 330mm
Accoustic insulation in rock wool panels 30mm
Double plasterboard 2x12.5mm



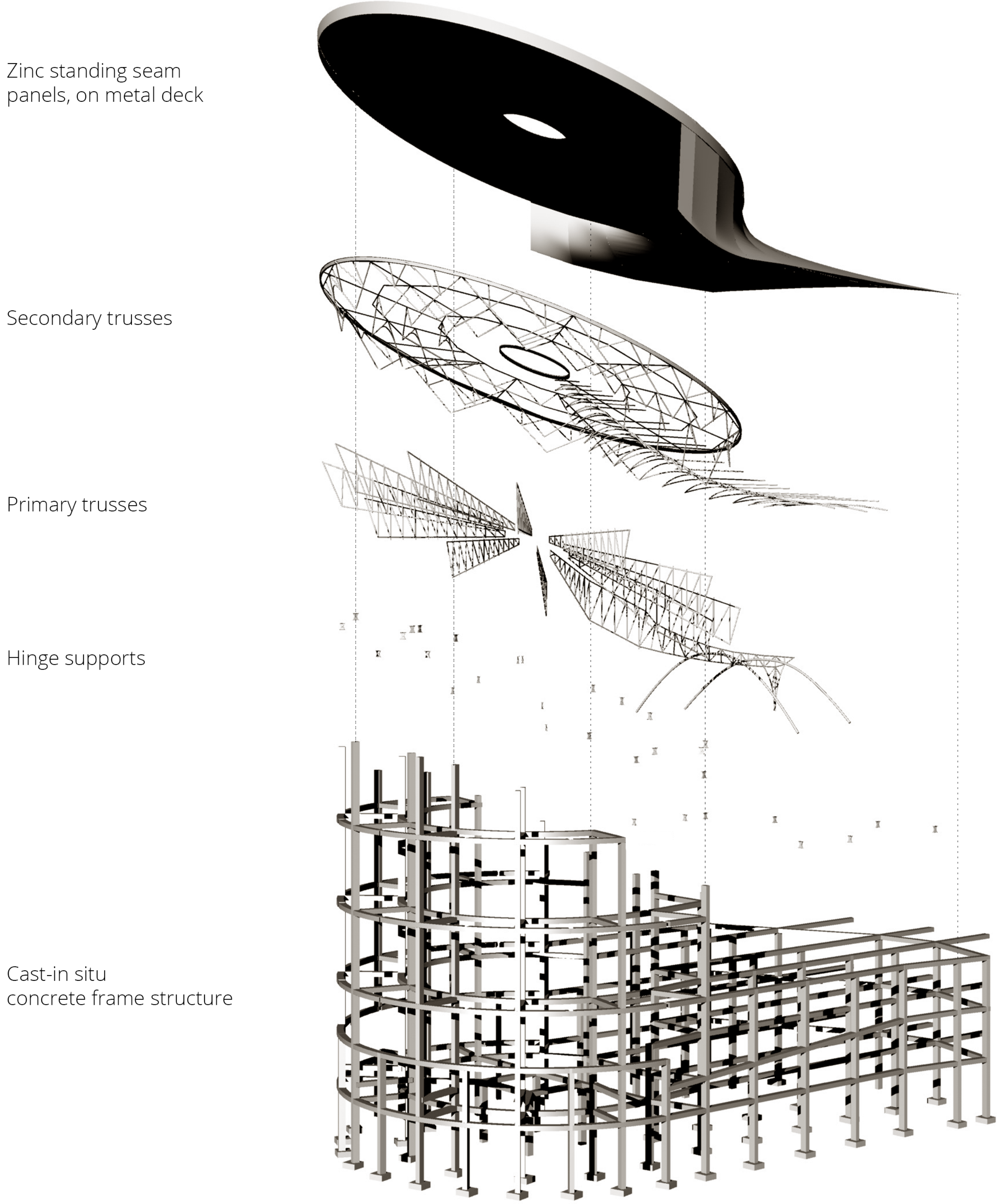
VN-07
Scale 1:10
Stonewore tiles dim. 60x40x12mm
Glue 5mm
Waterproof membrane, double PCV sheet 5mm
Draining layer 8mm
On site concrete 180mm
Gravel for distribution of water
RC bed 600mm
Oversite concrete 100mm
Soil
Stonewore tiles dim. 60x60x12mm
Glue 5mm
Screed Reinforcement 50mm
PVC protection layer 3mm
Vapor barrier 3mm
Expanded polysteryne 120mm
Pouring concrete 100mm
Ventilated underground cavity with iglo 300mm


HN-01
Scale 1:5
Steel Transom
130 mm x 50 mm
U-shaped Galvanised Steel bracket
th. 10 mm
Double glazing 6+16+6mm
Mechanical Bolts with Horizontal sliding joints to allow
movement due to lateral loads
Galvanised steel plate th. 10mm
Cross shaped welded Steel profile
connection for mullion to concrete
th. 10 mm
Galvanised Welded Steel Hinge Profile th. 10
mm


HN-02
Scale 1:5
Concrete Ramp
300 mm
Cross shaped welded Steel profile
connection for mullion to concrete
th. 10 mm
Single Glazing Railing 10mm
Galvanised Steel Plate
th. 10 mm
Galvanised Welded Steel Hinge Profile th. 10
mm
Stonewore tiles dim. 60x60x12mm
Glue 5mm


Stoneware tiles
dim. 60x40x12mm
Glue 5mm
Enamelled heat-treated
glass out pane, 40mm,
dim. 1800x2200mm
Stoneware tiles
dim. 60x60x12mm
Glue 5mm
Expanded polysteryne
100mm
Steel Mullion
200 mm x 50 mm
Aluminum Cover Cap
170 mm x 50 mm
Sheet metal back pan 2mm
Vapor barrier 1mm
Polycarbonate Sheet 3mm
Curtain wall base
HN-03
Scale 1:5

|ROOF STRUCTURE OF TOWER|



|CASE STUDY - ROOF OF EXHIBITION'S SPACE|

Figure 5.26 Zaryadye Park, Moscow.

THE LOAD BEARING GRID SHELL STRUCTURE OF ZARYADYE PARK IN MOSCOW, RUSSIA.

The canopy structure is situated short distance from Red Square and the Kremlin. Structural glass beams, 72 in total, are connected into the main undulating steel grid shell structure which measures approximately 120m long and 60m wide. The beams themselves vary in length according to the geometry but are generally 3m long, 0.2m deep. The beams meet each other and the main steel structure at bespoke stainless steel nodes, and are topped by triangular glass roof panels. The glass beams were designed to accommodate Moscow's extreme weather conditions, with drifted snow loads of up to 350 kg/m2.

Differential movement of the main structure was another challenge and required linear analysis with over 150 load combinations. The resulting movements called for further development of the nodal connections and non-linear nalysis of their performance.

Due to a lack of legislation covering structural glass in Russia a so called 'Special Technical Standard' was required. This document was written with significant input and covers the technical aspects of glass and its performance. A full scale mock-up of one roof panel, complete with beams and node connections, was constructed and tested to gain approvals from the authorities.

GLASS ANALYSIS

- Geometry,

Geometry was a significant factor in the analysis, much of the stress is a result of nodal deformations and thus implicitly tied to the geometry.

- Material,

The glass beams are laminated from 5 pieces of 10mm toughened glass. A two-part silicone was required due to the size of the bite being used.

- Loading,

19 separate loads were considered, ranging from 0.25kPa for the lightest wind load to 3.36kPa for a rather more onerous Snow load.

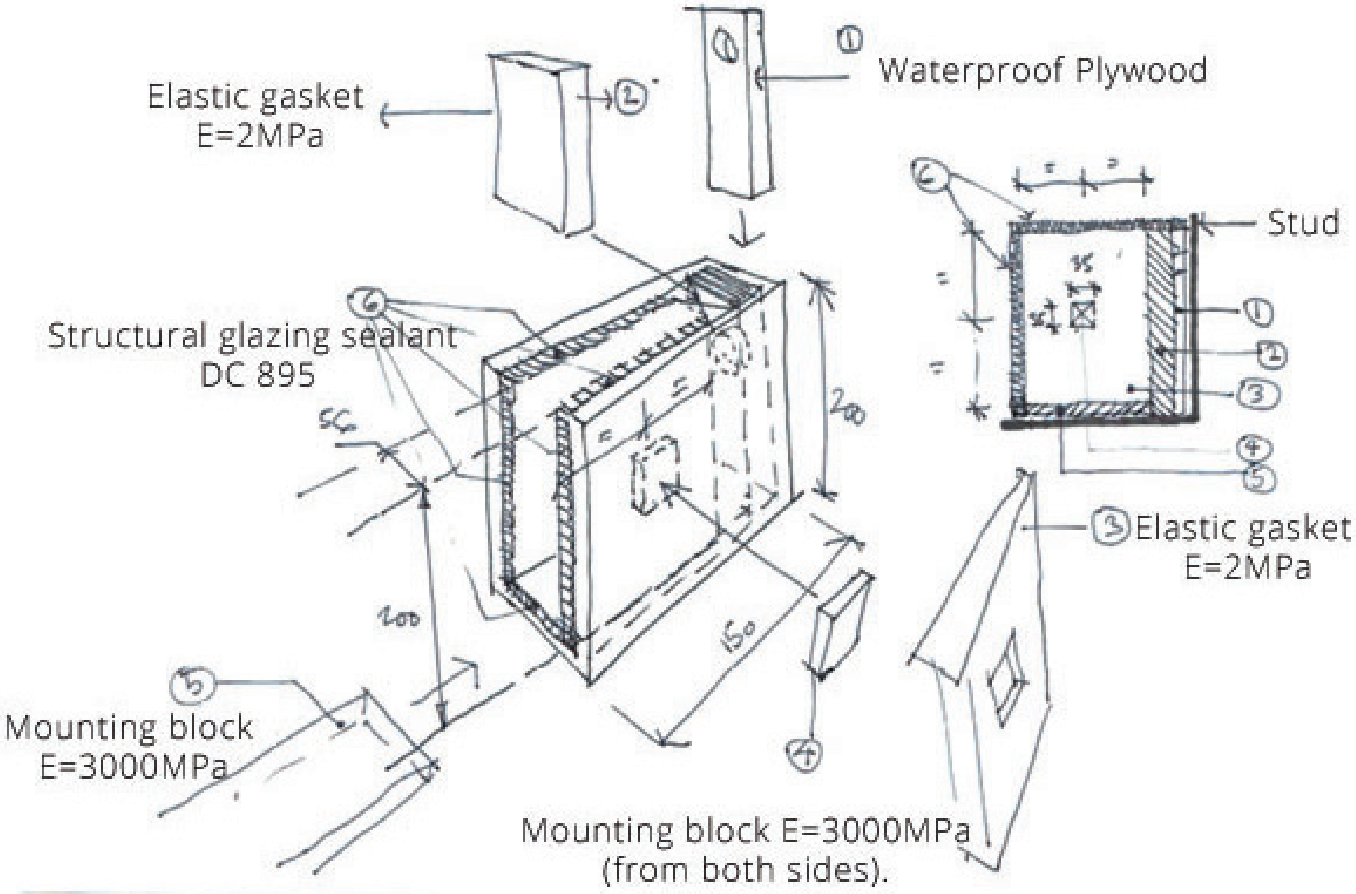


Figure 5.27 Detailing of the Silicone Connections.

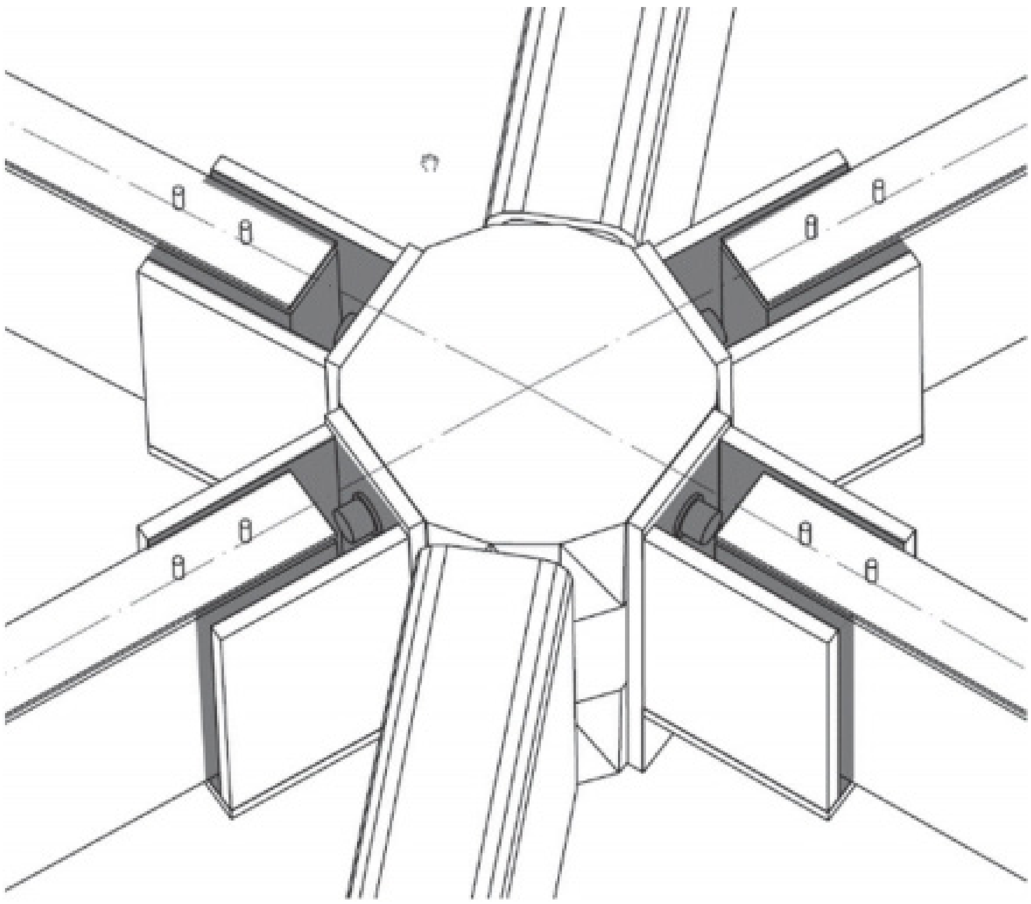


Figure 5.28 Typical joint detail.

Figure 5.29 Typical joint .

STRUCTURAL DESIGN

|MATERIAL OPTIMIZATION|

The **different characteristics** of the two studied areas - Tower and Exhibition - created **different needs.** The **Tower** is mostly **transparent** with long mullions and high inclinations, meanwhile the **Exhibition Space** is mainly **opaque** with smaller inclination and shorter mulliions.

In order to understand which material should be chosen, the following scenarios for the choice of curtain wall mullion were made:

- Aluminium profile of 250mm x 50mm,

- Steel profile of 200mm x 50mm.

The scenario of having a steel mullion profile of 150mm x 50mm was rejected since the **structural solution for the connection of the spandrel to the slabs and beams needed a mullion of at least 200mm.** In this case there is an **appropriate space for the brackets to be hanged on the mullions of curtain walls.**

The analysis presenting next, shows the procedure which was followed.

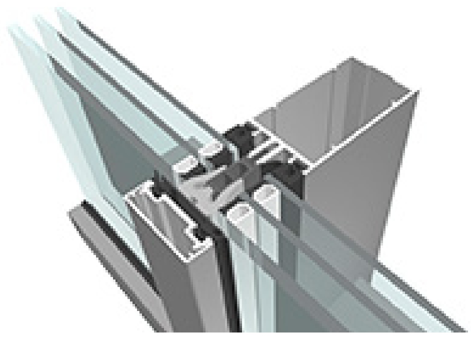


Figure 6.1 Aluminium Mullion.

Figure 6.2 Steel Mulion.

"Steel curtain wall system has been selected for the Tower part and aluminium profiles for the Exhibitions space."

Material	λ [W/(mk)] (20°C)	ρ [kg/m^{3}]	Thermal expansion °C range:(20-100°C) [m/(m°C)]	Corrosion [mm/year]	E [N/mm^{2}]	U Value [W/(m^{2}k)]
Aluminium	204	2710	23.6x10^{-6}	Low	70000	1.2
Steel	50	9850	13x10^{-6}	High	205000	0.67

Figure 6.3 Properties comparison between Aluminium and Steel.

Comparing the two basic materials the upcoming conclusions were made:

- The thermal conductivity of aluminium is much higher than steel. Based on the fact that our glazing area in the tower part is significantly high, this characteristic becomes crucial. A quick comparison between the two choosen frames, one aluminium (EFP 50 TSV) and one steel framing (STABALUX ZL-S) showed that the **reduction of Uvalue after using steel frame is 55%. Taking in mind that most of the Tower's surface is glazing, one can understand the reduction of thermal losses that will follow.**

- Steel is three times denser than aluminium, which makes it much heavier. Meanwhile, it is almost **four times stiffer**, offering the possibility to deform less than the aluminium Characteristically, the steel deflection is up to 1/3 compared with the one of the aluminium

-Steel is strong and less likely to warp, deform or bend under weight, force or heat.

.

- Aluminium's corrosion rates are lower than those of steel. Taking in mind the high percentages of RH (%) high attention should be paid in the cossorion resistance of steel. What is worth to be refered is that **even with the possibility of corrosion, steel is harder than aluminum.** Most spinnable tempers and alloys of aluminum dent, ding or scratch more easily as compared to steel.

Subsequently, steel curtain wall system has been selected for the tower part and aluminium profiles for the exhibition.

|STEEL CURTAIN WALL|

"Steel is approximately three times stiffer than aluminum"

CURTAIN WALLS OF STEEL

Lightweight, versatile and rust resistant, aluminum had surpassed steel as the curtainwall framing material of choice for decades. This is what happened also in our case. First material chosen for our project was aluminium. **Looking closely at the characteristics of the Tower part and the challenges of our design, steel curtain wall system was chosen. It should also be highlighted that steel curtain wall was chosen for the Tower part and aluminum curtain wall for the Exhibitions space. The long spans and big inclinations of curtain wall were made possible using steel mullion.**

Using a rollforming technique in which continuous steel coils are forced through dies and then laser-welded, **manufacturers can produce steel window frame members in long lengths and various complex shapes.** Compared to traditional steel and aluminum assemblies, the new generation of steel frames are **much narrower**, can have **sharp edges** rather than rounded profiles, and can have corner joints with no visible weld beads or fasteners. The result is **slender, strong frame components** that can stretch across building exteriors or be used to separate interior spaces-all with **larger glass areas and less visible members.**

KEY DESIGN CONSIDERATIONS FOR UTILIZING NEW GENERATION STEEL FRAMING IN CURTAINWALL SYSTEMS.

UTILIZE STEEL'S STRENGTH

Modern manufacturing processes enable steel frames to have an **aesthetic** and system design similar to aluminum. However, **since steel is inherently stronger than aluminum, it can support greater free spans than an aluminum system of similar dimensions and applied loads.**

The length of the steel mullions can be increased to span almost 9m, a **30 percent increase over their aluminum counterparts**. In some instances, appropriately designed curtainwall systems incorporating long, continuous steel back mullions can handle up to 12m free spans in a single member without splicing. Steel also provides the necessary support for heavy double- or triple-glazed units (up to 7cm thick).

Another benefit of steel is its ability to meet necessary load and deflection requirements with less material than aluminum, which **reduces frame dimension size by approximately 25 percent.** Aesthetically, reducing frame profile size helps accentuate the minimalist appearance of modern curtainwalls by shifting the visual focus off the frames and onto the glazing.

GO MODULAR

Advanced steel curtainwall systems overcome the challenge of fixed back mullions through a 'steel veneer,' or glazing adaptor. The glazing adaptor can overlay onto nearly any modular back mullion system, enabling it to receive glass or any other glazing material. Since the steel veneer is fastened through a 'plugand- screw' connection to the structural back member, it can attach to virtually any structural component that can support the curtainwall system's weight and imposed glazing loads (e.g. wind and snow loads).

Additional design freedom is possible with **structural silicone glazed-steel curtainwalls.** Similar to veneer curtainwall systems, the structural silicone glazed lites are structurally attached with silicone to the front of the stainless steel back mullions or to aluminum adaptors. Steel mullions can also function as the structural component in point-supported glazing systems using custom connectors such as "spiders," which in turn structurally attach to the steel supporting member.

DESIGN FOR DURABILITY

Some steel curtainwall systems offer high anti-corrosion protection-such as a double-sided pre-galvanization with a factory-applied curable primer and finish color-to further protect against corrosion. After the framing components are fabricated and before they are installed, they can be either powder- or wet-coated to match any desired color scheme. In addition, numerous stainless steel options are available, which is a common desire for high-end storefronts or applications in coastal areas.

Advanced steel curtainwall systems include a continuous gasket across the full width of the frames to help prevent water from coming into direct contact with the steel back members. Back mullions are typically made of carbon or stainless steel, and **cover caps** made of rolled stainless steel or **aluminum extrusions.** The installer can further prevent water intrusion for a long-lasting system by sealing the lapped joints at the horizontal-to-vertical connections

|CORROSION'S CHALLENGE|

Due to its strength, **steel is able to support larger free spans of glazing than traditional aluminum assemblies.** But for years, corrosion concerns prevented architects and design professionals from utilizing its strength in curtain-wall systems. **Steel rusts in the presence of moisture and oxygen,** which is a seemingly irreconcilable problem since many curtain walls serve as the divider between exterior and interior spaces.

Thanks to manufacturing and fabrication advances, steel frames can now complement stunning expanses of glass for years to come, without corrosion.

POWDER COATING

Properly trained powder coating screws can reduce coating errors, improve quality and streamline delivery. One of the most important parts of the powder coating process is the **initial frame preparation.** Soils and surface imperfections impact the powder coat's ability to adhere to the metal. As such, it is important to properly prepare and seal the substrate.

Fabricators can prepare the substrate manually or with automated cleaning systems. The manual process requires hand wiping the metal with a solvent, sandblasting and then hand sanding the surface. Although that is effective, automated cleaning systems provide many benefits for fabricators and suppliers. These include reducing heavy lifting, minimizing damage during natural handling, eliminating air-born contaminates and improving coating adhesion.

After the steel has been thoroughly cleaned and sealed, it can be powder coated. The best practice is to apply the powder in a controlled environment to prevent air born contaminants. A single coat of powder is sufficient for many applications.

The final step in the powder coating process is to thermally cure the frames and components. While liquid-applied paint can take up to 30 days to achieve a full cure, powder coatings are fully cured upon removal from the furnace. Compared to wet coating, this improves operating efficiency, expedites the assembly process and allows fabricators to improve project lead times.

HOW DO STEEL CURTAIN-WALL SYSTEMS PROTECT AGAINST MOISTURE INTRUSION?

Curtain-wall systems must protect against dynamic and static water penetration, regardless of the material. Advanced steel curtain-wall systems are available with a **continuous gasket across the full width of the steel frame.** This gasketing prevents water in the glazing cavity from coming into direct contact with the steel back members. It also keeps water off the tops of insulated glass units and directs it to the verticals. As such, glaziers and installers do not need to zone dam each glazed lite to help manage water flow within the curtain-wall system.

Basic steel system components for a 'plug-and-screw' connection of framing components utilize a shear block-type assembly. They allow the framing joints to be watertight and readily assembled without welding. The installer must seal the lapped gasket joints at the horizontal-to-vertical connections to prevent water intrusion to the steel back members and interior occupied spaces.

"To help protect against rust and preserve the steel's appearance, double-sided pregalvanization can be applied to the raw material"

HOW ARE STEEL CURTAIN-WALL SYSTEMS PROTECTED AGAINST CORROSION?

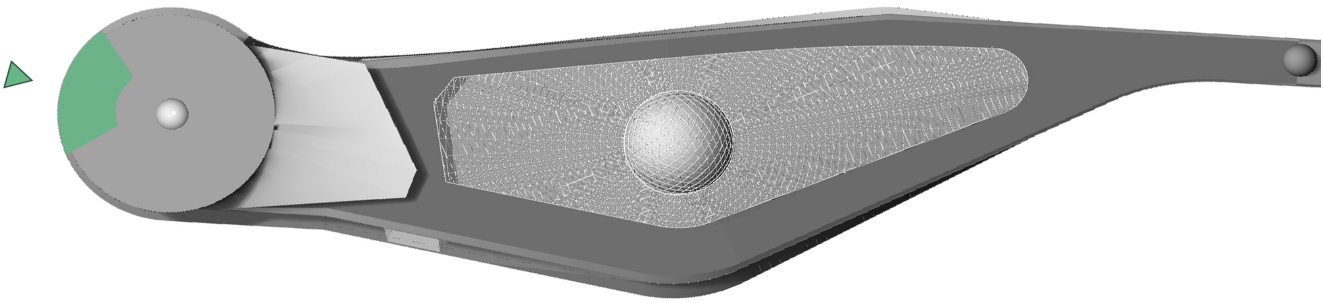
Steel frames are unique in that they do not require cladding or reinforcement to support expansive captured and non-captured curtain-wall systems; when properly sized, **the primary frame members can act as structural elements.** They typically can be finished, thereby serving as the finished, exposed material. **To help protect against rust and preserve the steel's appearance, double-sided pregalvanization can be applied to the raw material** (prior to forming and finishing).

Also, steel framings can be prefinished and top-coated with a factory-applied curable primer and finish color to match virtually any design scheme. **No special coatings beyond these are required to prevent corrosion.** For high-end storefronts or applications in coastal areas, the exterior caps or interior back mullions can be made from stainless steel. Depending on the material thickness, stainless steel finishes can be brushed or bead-blasted.

Generally, galvanic action in steel curtain-wall assemblies requires steel and aluminum components (or two other dissimilar metals) to be in direct contact with each other. The configuration of advanced steel curtain-wall systems can help prevent such contact. **Stainless steel screws indirectly connect the aluminum pressure plates to steel back members.** Since stainless steel and aluminum have similar anodic polarity, **this reduces the potential for corrosion to occur**.

|CURTAIN WALL ANALYSIS|

For analysing the curtain wall, the highlighted part is considered on the west orientation. This part is the most critical in the building becase of its elevation being the highest.



Codes and Standards

S.No		Code Name	Description
1	Aluminium	BS 8118 : 1:91	British standard for structural use
2	Glass	ASTM E 1300- 02	American standard for glass
3	Steel	BS 5950:Part1	British standard for structural use of Steel
4	Wind	EN.1.1.4	Eurocode for Wind pressure calculation

Aluminium specifications:

Modulus of Elasticity, E	=	7000	N/mm^2
Density	=	2710	kg/m^3
Modulus of rigidity	=	26600	N/mm^2
Poisson's ratio	=	0.3	
Bending strength (Alloy 6063 T6)	=	160	N/mm^2

Glass specifications:

Modulus of Elasticity, E	=	71700	N/mm^2
Density	=	2500	kg/m^3
Poisson's ratio	=	0.25	
Allowable bending stress	=	90	N/mm^2

Steel specifications:

Modulus of Elasticity, E	=	205000	N/mm^2
Density	=	9850	kg/m^3
Poisson's ratio	=	0.3	
Design strength (S275)	=	275	N/mm^2

Deflection criteria

Element	Loadings	Deflection limit
Mullion and transom	Wind load	L/175 for L≤4.1 m
Glass	Wind load	L/60

Wind Pressue Calculations

w_e wind pressure on external surfaces = 809.3 N/m^2

Refer to Load Calculation for Wind Loads

Structural Analysis for Glass

Size and Thickness of Glass

Insulated glazing unit th. = 28 mm

Inner panel FT th. = 6 mm

Air space th. = 16 mm

Outer Panel FT th. = 6 mm

Maximum panel size (worst case) = 3000 x 1800 mm

a Max glass size (Longer side) = 3000 mm

b Max glass size (Shorter side) = 1800 mm

Maximum wind pressure = 809.3 N/m^2

= 0.809 kPa

Calculations using ASTM E-1330-02

TABLE 2 Glass Type Factors (GTF) for Double Glazed Insulating Glass (IG), Short Duration Load

Lite No. 1 Monolithic Glass or Laminated Glass Type	Lite No. 2 Monolithic Glass or Laminated Glass Type					
	AN		HS		FT	
	GTF1	GTF2	GTF1	GTF2	GTF1	GTF2
AN	0.9	0.9	1.0	1.9	1.0	3.8
HS	1.9	1.0	1.8	1.8	1.9	3.8
FT	3.8	1.0	3.8	1.9	3.6	3.6

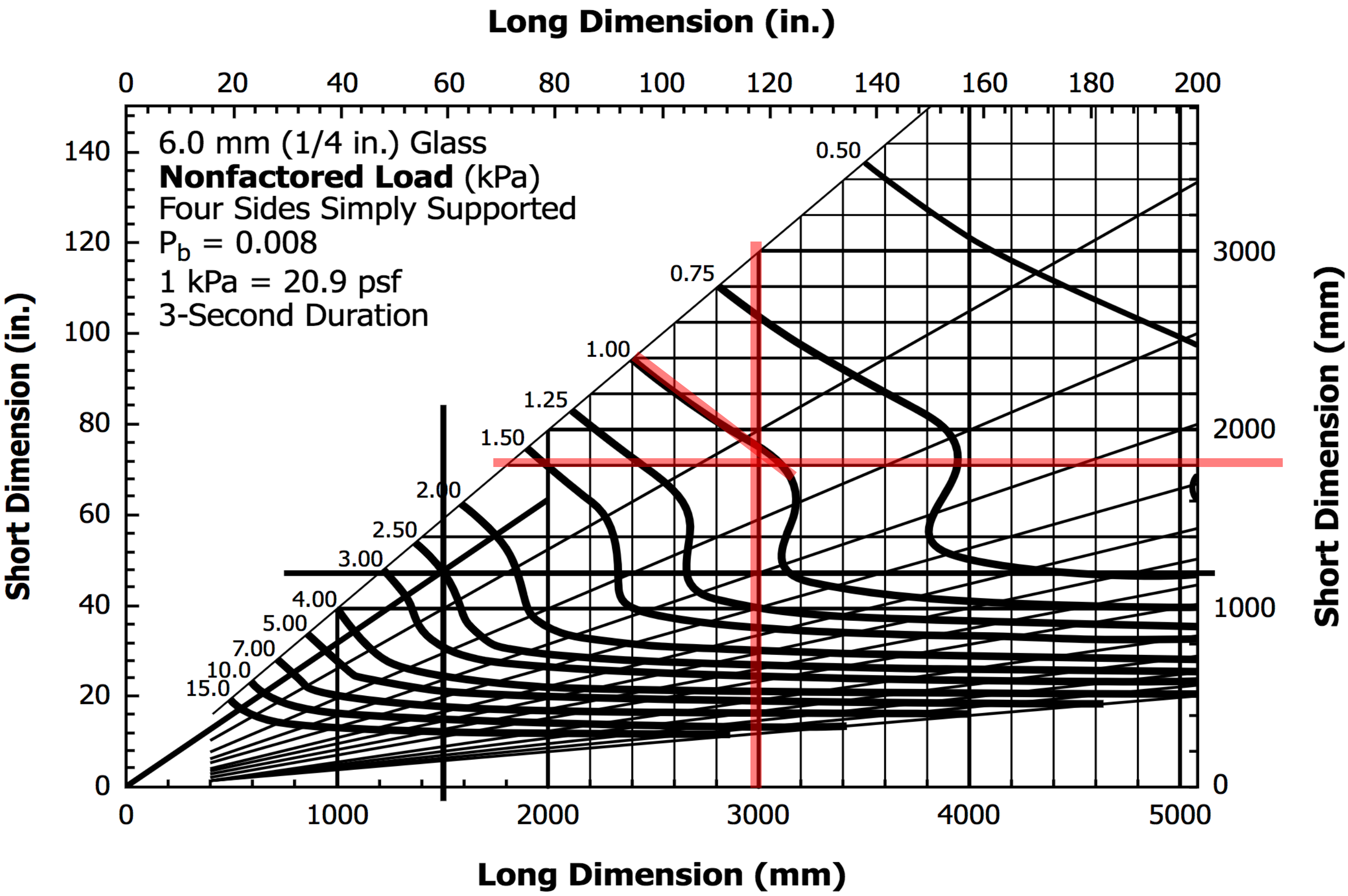
GTF Glass type factor (Fully Tampered FT) = 3.6

TABLE 5 Load Share (LS) Factors for Insulating Glass (IG) Units

NOTE 1—Lite No. 1 Monolithic glass, Lite No. 2 Monolithic glass, short or long duration load, or Lite No. 1 Monolithic glass, Lite No. 2 Laminated glass, short duration load only, or Lite No. 1 Laminated Glass, Lite No. 2 Laminated Glass, short or long duration load.

Lite No. 1		Lite No. 2																					
Monolithic Glass		Monolithic Glass, Short or Long Duration Load or Laminated Glass, Short Duration Load Only																					
Nominal Thickness		2.5 (3/32)		2.7 (lami)		3 (1/8)		4 (5/32)		5 (3/16)		6 (1/4)		8 (5/16)		10 (3/8)		12 (1/2)		16 (5/8)		19 (3/4)	
mm	(in.)	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2
2.5	(3/32)	2.00	2.00	2.73	1.58	3.48	1.40	6.39	1.19	10.5	1.11	18.1	1.06	41.5	1.02	73.8	1.01	169.	1.01	344.	1.00	606.	1.00
2.7	(lami)	1.58	2.73	2.00	2.00	2.43	1.70	4.12	1.32	6.50	1.18	10.9	1.10	24.5	1.04	43.2	1.02	98.2	1.01	199.	1.01	351.	1.00
3	(1/8)	1.40	3.48	1.70	2.43	2.00	2.00	3.18	1.46	4.83	1.26	7.91	1.14	17.4	1.06	30.4	1.03	68.8	1.01	140.	1.01	245.	1.00
4	(5/32)	1.19	6.39	1.32	4.12	1.46	3.18	2.00	2.00	2.76	1.57	4.18	1.31	8.53	1.13	14.5	1.07	32.2	1.03	64.7	1.02	113.	1.01
5	(3/16)	1.11	10.5	1.18	6.50	1.26	4.83	1.57	2.76	2.00	2.00	2.80	1.56	5.27	1.23	8.67	1.13	18.7	1.06	37.1	1.03	64.7	1.02
6	(1/4)	1.06	18.1	1.10	10.9	1.14	7.91	1.31	4.18	1.56	2.80	2.00	2.00	3.37	1.42	5.26	1.23	10.8	1.10	21.1	1.05	36.4	1.03
8	(5/16)	1.02	41.5	1.04	24.5	1.06	17.4	1.13	8.53	1.23	5.27	1.42	3.37	2.00	2.00	2.80	1.56	5.14	1.24	9.46	1.12	15.9	1.07
10	(3/8)	1.01	73.8	1.02	43.2	1.03	30.4	1.07	14.5	1.13	8.67	1.23	5.26	1.56	2.80	2.00	2.00	3.31	1.43	5.71	1.21	9.31	1.12
12	(1/2)	1.01	169.	1.01	98.2	1.01	68.8	1.03	32.2	1.06	18.7	1.10	10.8	1.24	5.14	1.43	3.31	2.00	2.00	3.04	1.49	4.60	1.28
16	(5/8)	1.00	344.	1.01	199.	1.01	140.	1.02	64.7	1.03	37.1	1.05	21.1	1.12	9.46	1.21	5.71	1.49	3.04	2.00	2.00	2.76	1.57
19	(3/4)	1.00	606.	1.00	351.	1.00	245.	1.01	113.	1.02	64.7	1.03	36.4	1.07	15.9	1.12	9.31	1.28	4.60	1.57	2.76	2.00	2.00

LS Load share factor = 2



NFL Non factored load = 1 kPa

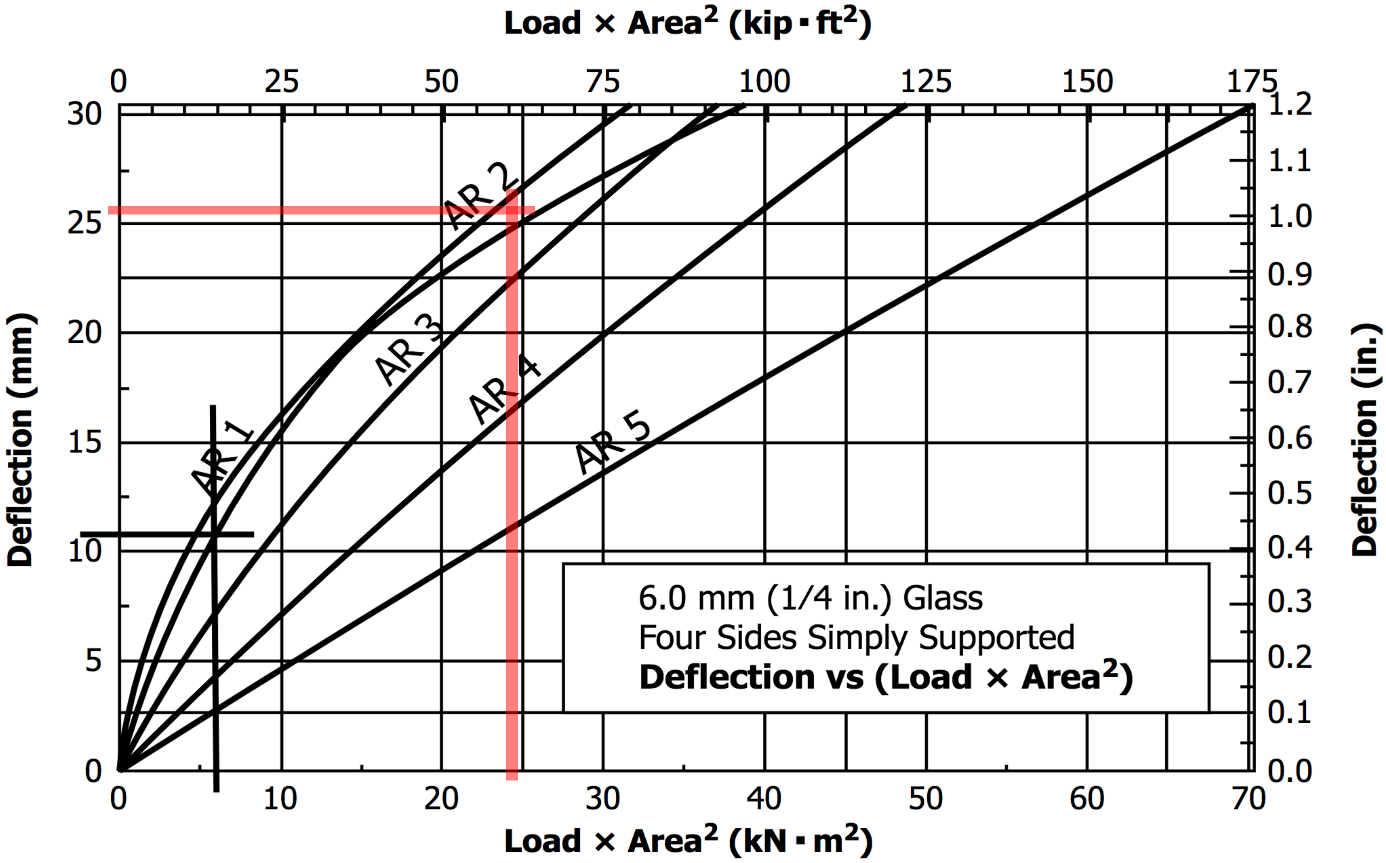
Load capacity of double glass
= NFL * LS * GTF = 7.2 kPa

W Wind load acting on glass = 0.809 kPa

The wind load acting on the glass is less than the capacity of glass.

Deflection Check

AR	Aspect Ratio	=a/b	=	1.67	
A	Area of glass panel	=a*b	=	5.4	m^2
w	Max wind load in single glass	=W / LS	=	0.405	kPa
	Load * $Area^2$	=W * A^2	=	23.60	$kN.m^2$



d	deflection on the glass	=	26 mm
d_{lim}	delection Limit of four side supported	=	30 mm

Ratio of deflection to limit = d/d_{lim} = 0.87 <1

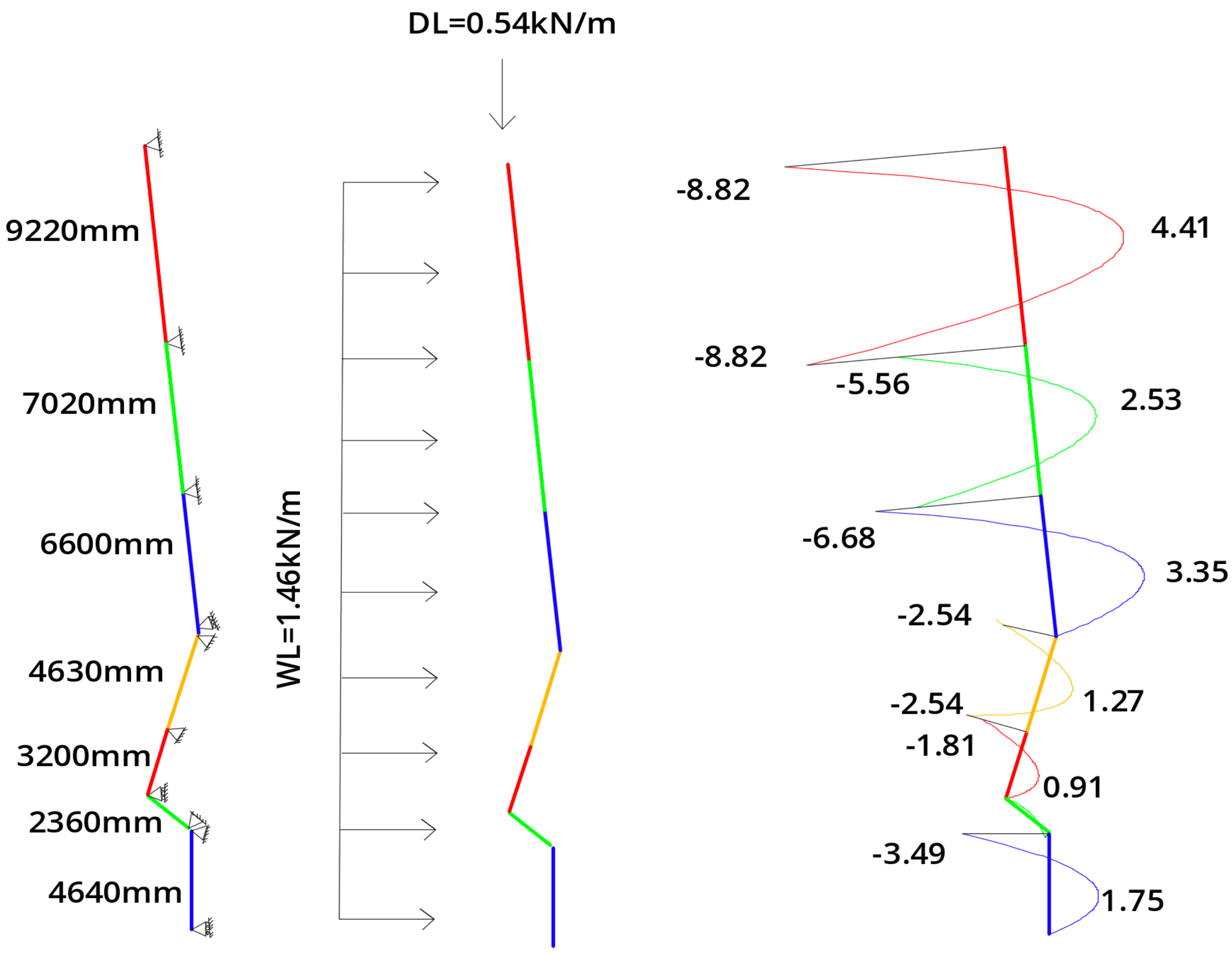
Hence the glass is safe against deflection

So 6mm + 16mm + 6 mm Double Glazing is structurally stable for curtain wall.

Structural Analysis for Mullion

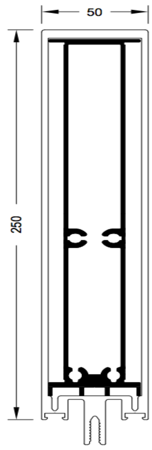
Design loads on the mullion

t_g	Effective Glass thickness = 6 + 6 mm	=	12	mm
ρ_g	Density of glass	=	25	kN/m^3
D_L	Dead load from glass = $t_g * \rho_g$	=	0.3	kN/m^2
WL	Max. Wind Pressure	=	0.809	kN/m^2
w	Effective module width	=	1.8	m
W_D	Dead load on the mullion = D_L * w	=	0.54	kN/m
W_L	Wind load on the mullion = WL * w	=	1.46	kN/m

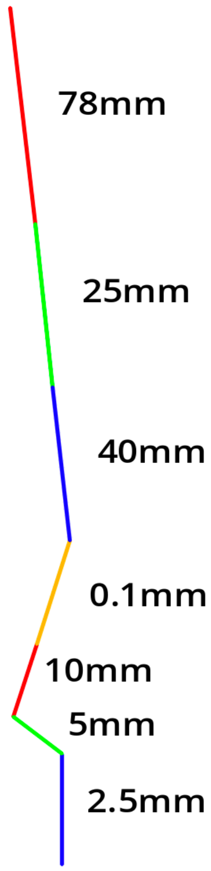


Karamba model — Loads — Moment diagram

Aluminium Mullion



A	Area of cross-section	=	1620 mm^2
I_{xx}	Moment of inertia about X axis	=	5602500 mm^4
I_{yy}	Moment of inertia about Y axis	=	183100 mm^4
x	Distance from N.A (Y-axis) to edge	=	25 mm
y	Distance from N.A (X-axis) to edge	=	133 mm
Z_{xx}	Section modulus about X axis = I_{xx} / y	=	42124.1 mm^3
Z_{yy}	Section modulus about y axis = I_{yy} / x	=	7324 mm^3



Deflections

Karamba Analysis of Aluminium Mullion

L	Maximum span of mullion	=	9260 mm
M_x	Maximum Bending moment (x axis)	=	8.82 kN.m
d	Maximum Deflection on mullion	=	67.6 mm

Bending moment check

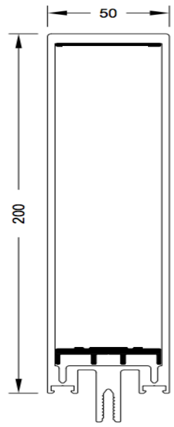
Q_{mx}	Bending stress on mullion = M_x / Z_{xx}	=	209.38 MPa
P_a	Aluminium limiting stress = 160/1.15	=	139.13 MPa
	Stress ratio = Q_{mx} / P_a	=	$1.50 \nless 1$

Deflection check

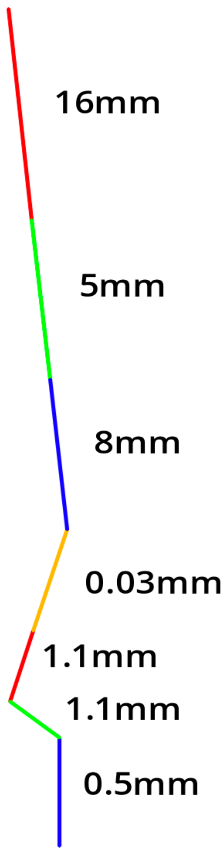
d_{lim}	Delfection limit of mullion = L /240	=	38.58 mm
	Ratio of deflection = d / d_{lim}	=	$1.75 \nless 1$

Hence the Aluminium mullion is **not safe** against wind load.

Steel Mullion



A	Area of cross-section	=	1325 mm^2
I_{xx}	Moment of inertia about X axis	=	4032600 mm^4
I_{yy}	Moment of inertia about Y axis	=	166000 mm^4
x	Distance from N.A (Y-axis) to edge	=	25 mm
y	Distance from N.A (X-axis) to edge	=	108 mm
Z_{xx}	Section modulus about X axis = I_{xx}/y	=	37338.89 mm^3
Z_{yy}	Section modulus about y axis = I_{yy}/x	=	6640 mm^3



Deflections

Karamba Analysis of Steel Mullion

L	Maximum span of mullion	=	9260 mm
M_x	Maximum Bending moment (x axis)	=	8.82 kN.m
d	Maximum Deflection on mullion	=	16 mm

Bending moment check

Q_{mx}	Bending stress on mullion = M_x / Z_{xx}	=	236.21	MPa
P_s	Steel limiting stress = 275/1.15	=	247.75	MPa
	Stress ratio = Q_{mx} / P_s	=	0.95	<1

Deflection check

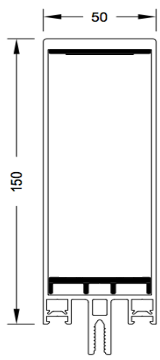
d_{lim}	Delfection limit of mullion = L /240	=	38.58	mm
	Ratio of deflection = d / d_{lim}	=	0.41	<1

Hence the Steel mullion is safe against wind load.

Structural Analysis for Transom

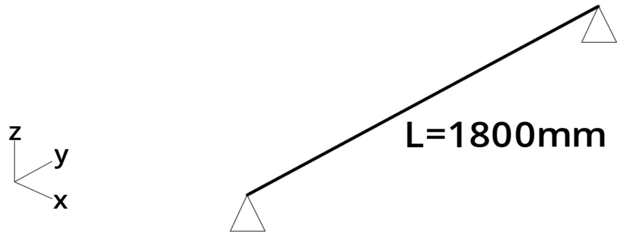
Design loads on the transom

t_g	Effective Glass thickness = 6 + 6 mm	=	12	mm
ρ_g	Density of glass	=	25	kN/m^3
D_L	dead load from glass = t_g * ρ_g	=	0.3	kN/m^2
WL	Max. Wind Pressure	=	0.809	kN/m^2
s	Maximum transom spacing	=	3	m
W_D	Dead load on the transom = D_L * s	=	0.9	kN/m
W_L	Wind load on the transom = WL * s	=	2.43	kN/m

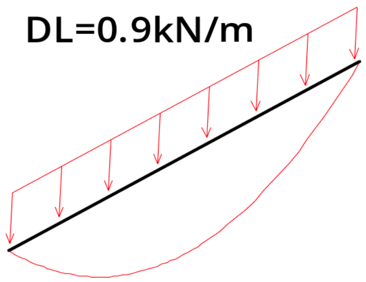


Steel Transom

A	Area of cross-section	=	1070	mm^2
I_{xx}	Moment of inertia about X axis	=	2265100	mm^4
I_{yy}	Moment of inertia about Y axis	=	191200	mm^4
x	Distance from N.A (Y-axis) to edge	=	25	mm
y	Distance from N.A (X-axis) to edge	=	83	mm
Z_{xx}	Section modulus about X axis = I_{xx}/y	=	27290.36	mm^3
Z_{yy}	Section modulus about y axis = I_{yy}/x	=	7648	mm^3



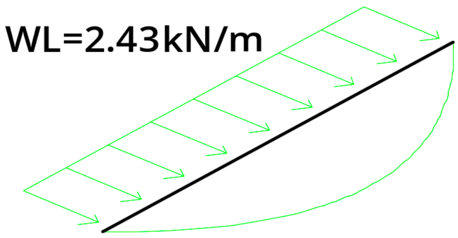
Model



Mx=0.36kNm

dx=1.47mm

Along x axis



My=0.98kNm

dy=0.55mm

Along y axis

Karamba Analysis of Steel transom

L	Maximum span of transom	=	1800 mm
M_x	Maximum Bending moment (x axis)	=	0.36 kN.m
M_y	Maximum Bending moment (y axis)	=	0.98 kN.m
d	Maximum Deflection on transom	=	1.47 mm

Bending moment check

Q_{mx}	Bending stress on transom = M_x / Z_{xx}	=	13.19 MPa
Q_{my}	Bending stress on transom = M_y / Z_{yy}	=	128.14 MPa
Q	Combined stress = $Q_{mx} + Q_{my}$	=	141.33 MPa
P_s	Steel limiting stress = 275/1.15	=	239.13 MPa
	Stress ratio = Q / P_s	=	0.59 <1

Deflection check

d_{lim}	Delfection limit of mullion = L /175	=	10.29 mm
	Ratio of deflection = d / d_{lim}	=	0.14 <1

Hence the Steel transom is safe against wind load.

MATERIALS

Concrete strength class: C30/37

f_{ck}	characteristic cylinder compressive strength (28d)	=	30	N/mm^2
γ_c	partial safety coefficient concrete	=	1.5	
α_{cc}	coefficient considering creep of concrete	=	0.85	
f_{cd}	design compressive strength = $(\alpha_{cc} \cdot f_{ck})/\gamma_c$	=	17	N/mm^2
$\sigma_{c,adm}$	allowable compressive stress under characteristic combination of actions = $k_1 \cdot f_{ck}$	=	18	N/mm^2
f_{ctm}	medium tensile strength = $0.3(f_{ck})^{2/3}$	=	2.90	N/mm^2
$f_{ctk;0.05}$	characteristic tensile strength = $0.7f_{ctm}$	=	2.03	N/mm^2
f_{ctd}	design tensile strength = $(\alpha_{cc} \cdot f_{ctk;0.05})/\gamma_c$	=	1.35	N/mm^2
E_{cm}	secant modulus of elasticity = $22(0.1(f_{ck} + 8))^{0.3}$	=	32837	N/mm^2

High ductility steel type: B450C

f_{yk}	characteristic yield strength	≥	450	N/mm^2
γ_s	partial safety coefficient steel	=	1.35	
f_{yd}	design yield strength steel = f_{yk}/γ_s	=	333	N/mm^2
$\sigma_{s,adm}$	admissible stress under characteristic combination of	=	360	N/mm^2
E_s	modulus of elasticity	=	200000	N/mm^2
ρ_s	density	=	9850	kg/m^3
ν	poisson's ratio	=	0.3	

LOADS

Self-weight of structural and non-structural elements

Vertical closures

The average weight of a glass curtain wall is 400 to 600 N/m^2	=	600 N/m^2
Weight of steel mullion per unit length	=	70 N/m
Typical Floor height	=	5 m
Linear weight of the Curtain Wall	=	3000 N/m
	=	3 kN/m

The load of the external curtain walls is directly applied on the roof along the perimeter.

Inside partitions

The classical solution of a single-masonry is used for the purpose of this analysis:
Plaster-Masonry-Plaster

Weight	=	1.7 kN/m^2
Assuming a net floor height	=	5 m
Linear weight of the Interior Wall	=	8.5 kN/m

In case of partitions with linear self-weight exceeding 3.0 kN/m EN 1991-1-1 [6.3.1.2(9)] recommends to consider the effective position of the load on the slab.
However, the load of inside walls is hereby considered to be uniformly distributed in order to avoid further calculations in case of a possible change of disposition of partitions during the design working life of the building.

Assuming a span between inside walls	=	2.5 m

In accordance with the assumptions of EN 1991-1-1,

The correspondent equivalent uniformly distributed load is	=	3.4 kN/m^2

Typical floor

The slab is a tile-lintel floor made of concrete joists, 100 mm wide and 200 mm high every 500 mm, and a superior reinforced concrete slab 40 mm thick, formed up with lightened bricks (200 mm x 400 mm).

Tile-lintel floor self-weight	=	5.3 kN/m^2
Finishes	=	2 kN/m^2

Roof

The weight of the roof will be considered as uniformly distributed all over the last slab.

For a truss system with standing seam zinc panels:

Weight of truss	=	2 kN/m^2
Zinc standing seam panels + other layers	=	0.1 kN/m^2
The equivalent uniformly distributed load	=	2.1 kN/m^2

Imposed Loads

The imposed load for floors in residential buildings is [EN 1991-1-1 : 6.3.1.2, Tables 6.1 and 6.2, in accordance with National Annex]

For museums, exhibition halls (category: C3)	=	5 kN/m^2

Snow Loads

For persistent design situation, the snow load on the roof is expressed by the formula:

$$s = \mu_i \cdot C_e \cdot C_t \cdot s_k$$

μ_i	snow load shape coefficient (0° < angle < 30°)	=	0.8
C_e	exposure coefficient of the site topography	=	1
C_t	thermal coefficient (ISO-4355) (for inclined glass roof)	=	0.9
s_k	characteristic value of snow load on the ground	=	2.85 kN/m^2
s	snow load	=	2.05 kN/m^2

Wind Loads

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

Terrain category: II

z_0	roughness length	=	0.05 m
z_{min}	minimum height defined in Table 4.1 EC 1.1.4	=	2 m
z_{max}	default maximum height EC 1.1.4	=	200 m
$z_{0,II}$	(default from EC 1.1.4)	=	0.05 m
k_r	terrain factor depending on the roughness length	=	0.19

$$k_r = 0.19\left(\frac{z_0}{z_{0,II}}\right)^{0.07}$$

z	reference height for calculation	=	20	
$c_o(z)$	orography coefficient	=	1	
$c_r(z)$	roughness coefficient	=	1.138	

$$c_r(z) = k_r \ln\left(\frac{z}{z_0}\right) \quad \text{for } z_{min} \leq z \leq z_{max}$$

Basic values

c_{dir}	directional factor	=	1	
c_{season}	seasonal factor	=	1	
$v_{b,0}$	fundamental value of basic wind velocity (lithuania)	=	24	m/s
v_b	basic wind velocity	=	24	m/s

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$$

Basic velocity pressure

ρ_{air}	air density	=	1.25	kg/m^3
q_b	basic velocity pressure	=	360	N/m^2

$$q_b = \frac{1}{2}\rho_{air} v_b^2$$

Turbulence Intensity

k_I	turbulence factor	=	1	
$I_v(z)$	turbulence intensity at height z	=	0.167	

$$I_v(z) = \frac{k_I}{c_o(z)\ln(\frac{z}{z_0})} \quad \text{for } z_{min} \leq z \leq z_{max}$$

Peak pressure

$v_m(z)$	mean wind velocity	=	27.32	m/s

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

$c_e(z)$	exposure coefficient	=	2.81	

$$c_e(z) = [1 + 7I_v(z)]\, c_r(z)^2\; c_o(z)^2$$

$q_p(z)$	peak velocity pressure at height z	=	1011.6	N/m^2
		=	1.012	kN/m^2

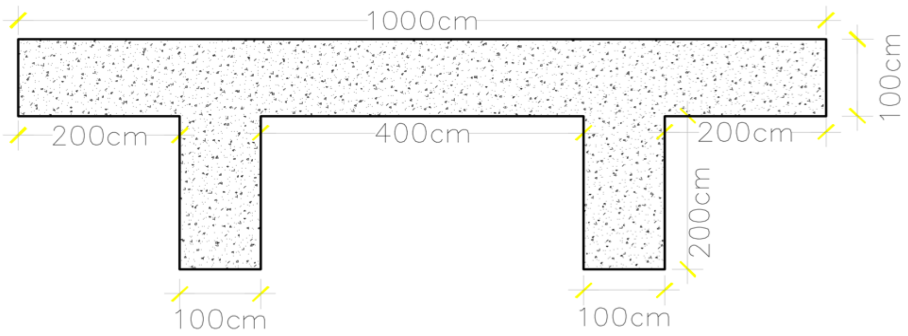
$$\begin{aligned} q_p(z) &= [1 + 7I_v(z)]\, \frac{1}{2}\rho_{air}\, v_m(z)^2 \\ &= [1 + 7I_v(z)]\, \frac{1}{2}\rho_{air}\; c_r(z)^2\; c_o(z)^2\; v_b^2 \\ &= c_e(z)\; q_b \end{aligned}$$

Wind pressure on surfaces

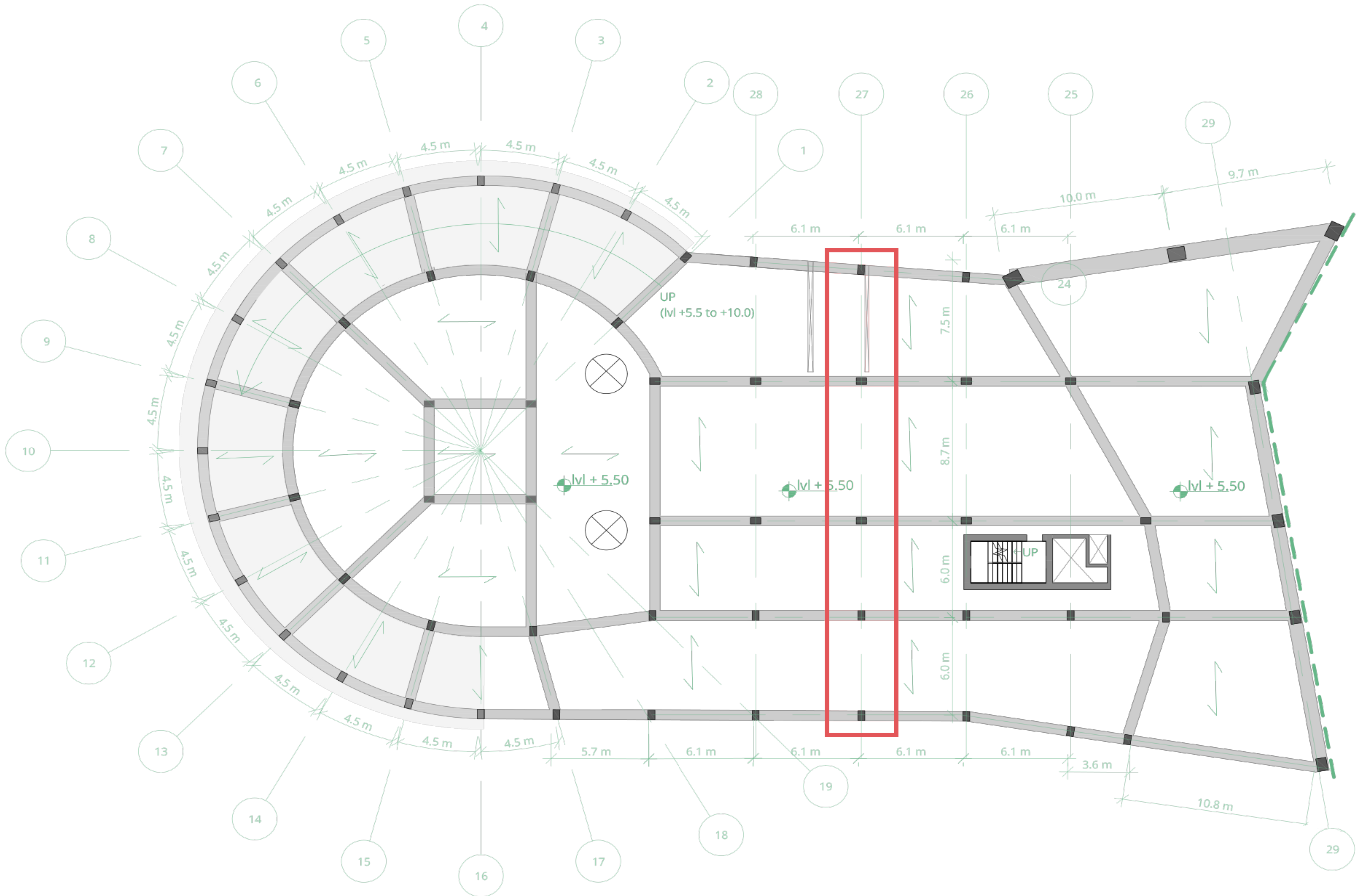
b	width of building face (wall)	=	42 m
h	height of wall	=	20 m
d	dimension of building parallel to the wind direction	=	30 m
h/d	(for calculating c_{pe})	=	0.67
Since h<b;	$z_e = h$ (figure 7.4, EN.1.1.4)		
z_e	reference height for calculation	=	20 m
w_e	wind pressure on external surfaces	=	**809.27 N/m²**
	$w_e = c_{pe} \cdot q_p(z_e)$	=	**0.809265 kN/m²**
c_{pe}	pressure coefficient — windward wall	=	0.8
	leeward wall	=	-0.483
A_i	influence area on wall	=	30 m^2
$c_s \cdot c_d$	structural factor	=	1
F_w	wind force	=	24277.95 N
	$F_w = c_s \cdot c_d \cdot \Sigma_i (w_{ei} \cdot A_i)$	=	**24.28** kN
OR	uniform load on column = w_e * (3+3)	=	4.86 kN/m
F_w	total load on column = uniform load * floor height	=	24.28 kN

|SLABS|

A typical **one-way joist slab** system, made of concrete joists and bricks with a concrete topping, is chosen since it performs better for wide spans.



The calculated slab is located on the entrance level (+5.5 m).
It spans mono dimensionally.
The column supports are locate at grid lines 20, 21, 22, 23 and 24.
The calculation is done for a 1 meter segment of the slab, being treated as continuous beam over four fields.



Structural plans (lvl +5.5m)

The design of the slab is made considering a strip of width = 1 m

Permanent actions:

G_1	tile-lintel floor self-weight	=	5.3	kN/run m
G2	other permanent loads (finishes..)	=	2	kN/run m

Variable actions:

Q_1	live load (museums)	=	5	kN/run m
Q_2	inside partitions self-weight	=	3.4	kN/run m

Partial Factors for Actions

γ_G	partial factor for permanent action	=	1.35
γ_Q	partial factor for variable action	=	1.5

Permanent Actions = $\Sigma\gamma_{G,j} \cdot G_{k,j}$	=	9.86	kN/run m
Variable Actions = $\gamma_{Q,1} \cdot Q_{k,1}$	=	12.60	kN/run m

Ultimate Limit State

Permanent loads + Variable loads

$$\Sigma\gamma_{G,j} \cdot G_{k,j} + \gamma_{Q,1} \cdot Q_{k,1}$$

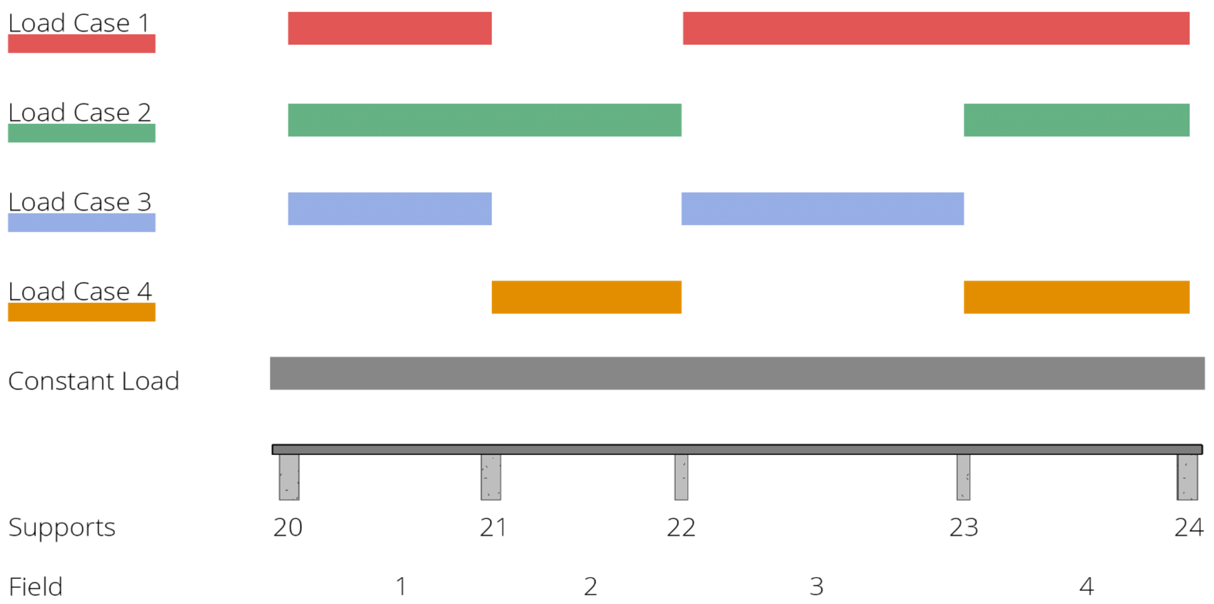
$$\gamma_G \cdot (G_1 + G_1) + \gamma_Q \cdot (Q_1 + Q_2)$$

$$1.35 \cdot (G_1 + G_1) + 1.5 \cdot (Q_1 + Q_2)$$

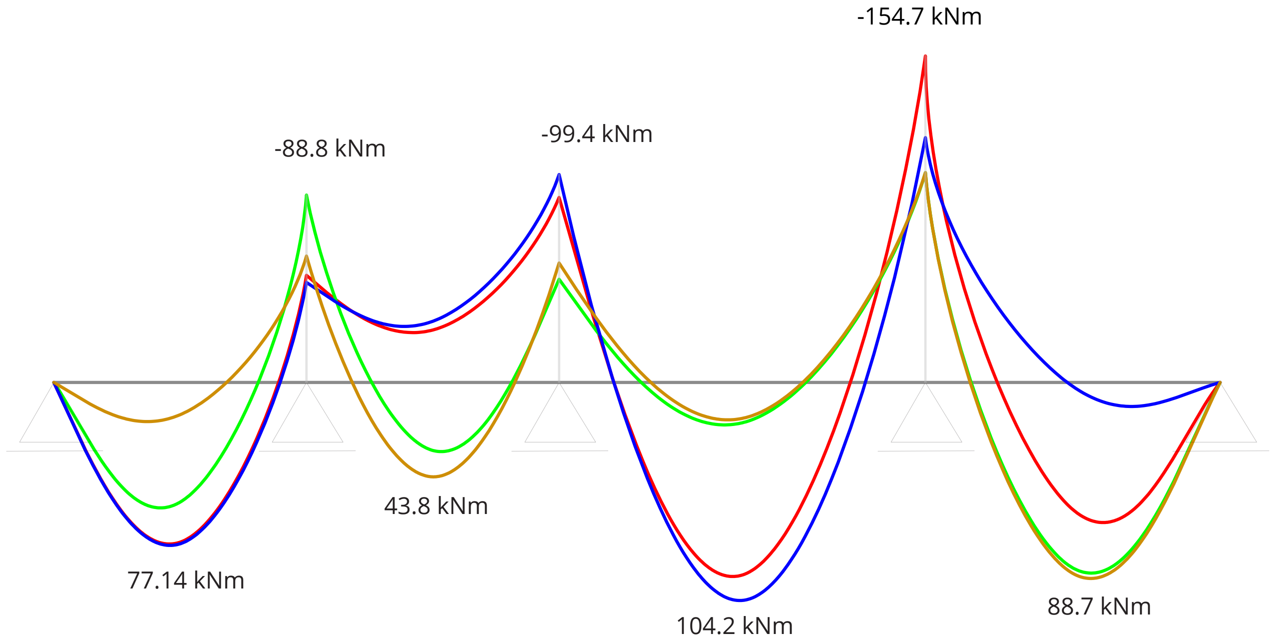
$$9.86 + 12.60$$

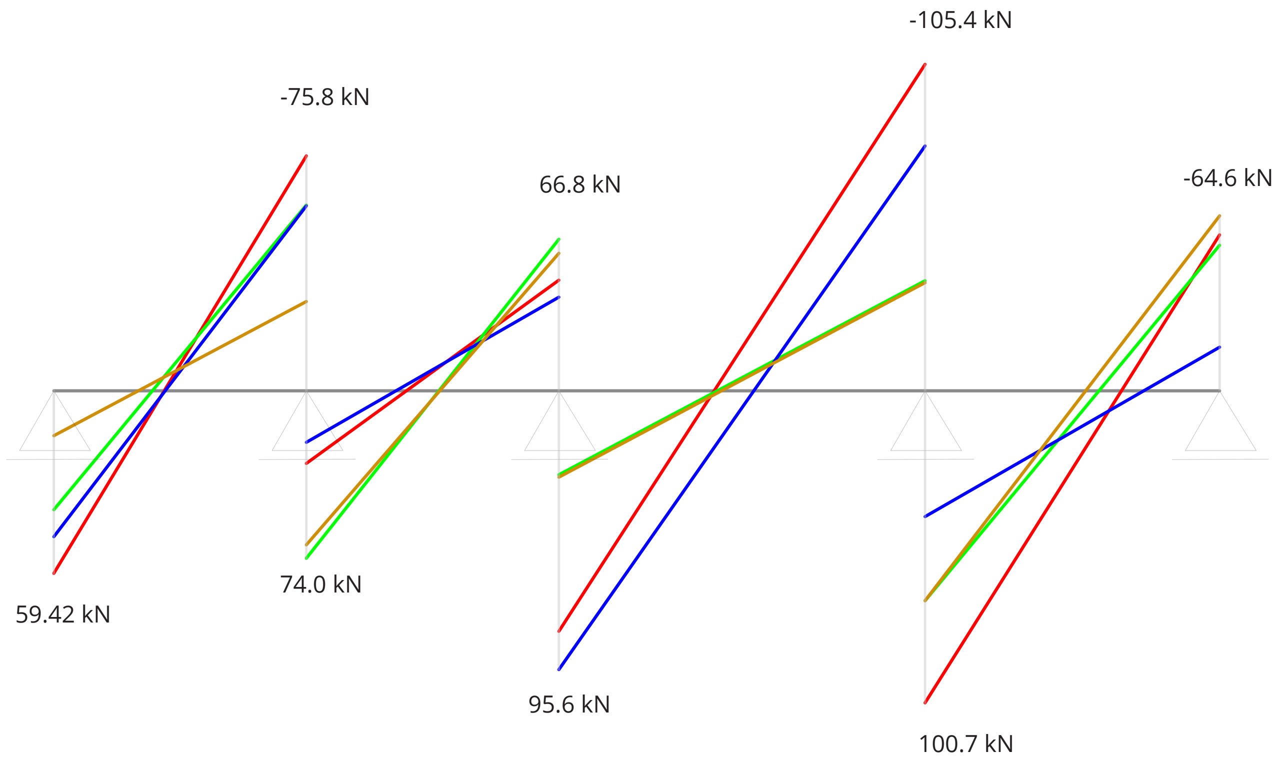
Load Combinations:

Combination of load case 1, 2, 3 or 4 with dead load provide maximum stress resultants in fields and at mid support.

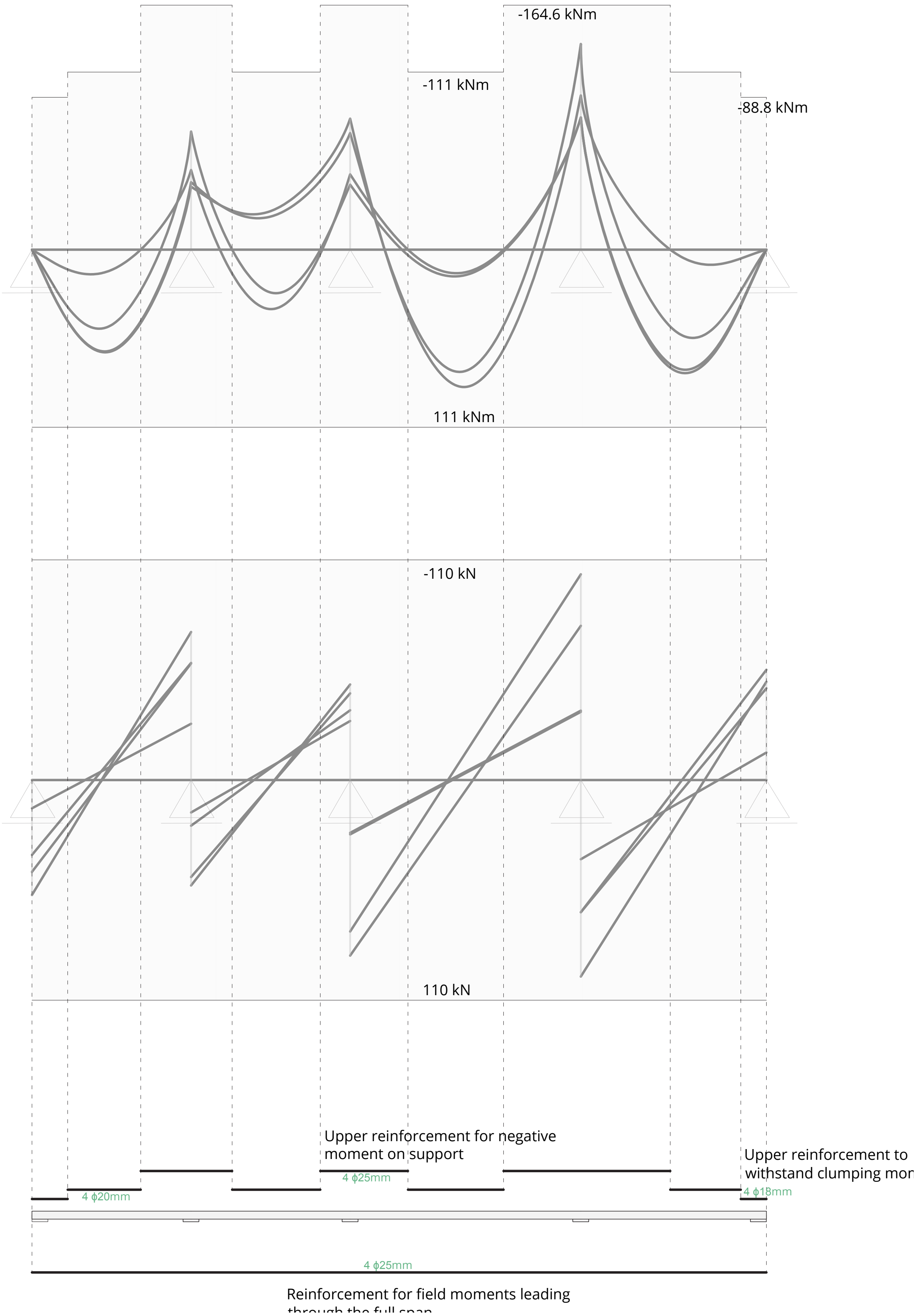


MAXIMUM VALUES OF MOMENT AND SHEAR:
Superposition of four load cases for moment and shear to reach values determining the design.





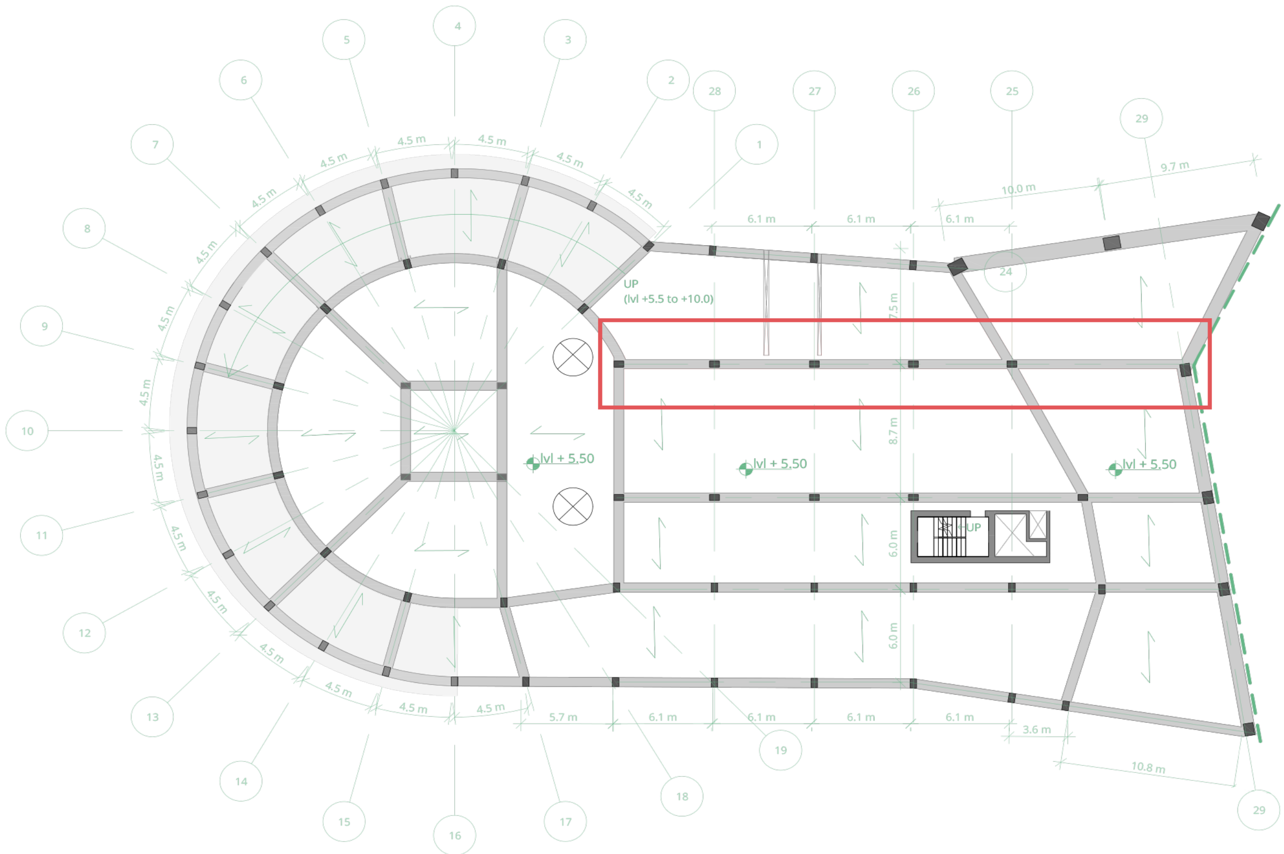
Schematic display of reinforcement capacity.



|BEAMS|

The calculated beam is located on the entrance level (+5.5 m).
It spans over 5 fields.

The first and the last span are treated as if they would both span over 9.5 m.
Therefore slightly higher stress resultants are assigned to the first span, compared to the actual situation.
This creates a symmetrical system, mirrored in the middle of the third beam.



Structural plans (lvl +5.5m)

Width of influence area	=	9	m
Beam height	=	400	mm
Beam width	=	600	mm

Permanent actions:

G_{slab}	slab self-weight = slab structural load · 9	=	47.34	kN/m
G_{beam}	beam self-weight = 0.6 · 0.8 · 25	=	12	kN/m
G_1	structural self-weight = $G_{slab} + G_{beam}$	=	59.34	kN/m

G_2 other permanent load = 18 kN/m
= slab finishes load · 9

Variable actions:

Q_1 live load = imposed load · 9 = 45 kN/m

Q_2 inside partition self-weight = 30.6 kN/m
= inside partition load · 9

Partial Factors for Actions

γ_G partial factor for permanent action = 1.35

γ_Q partial factor for variable action = 1.5

Permanent Actions = $\Sigma \gamma_{G,j} \cdot G_{k,j}$ = 104.41 kN/run m

Variable Actions = $\gamma_{Q,1} \cdot Q_{k,1}$ = 113.40 kN/run m

Ultimate Limit State

$$\Sigma \gamma_{G,j} \cdot G_{k,j} \quad + \quad \gamma_{Q,1} \cdot Q_{k,1}$$

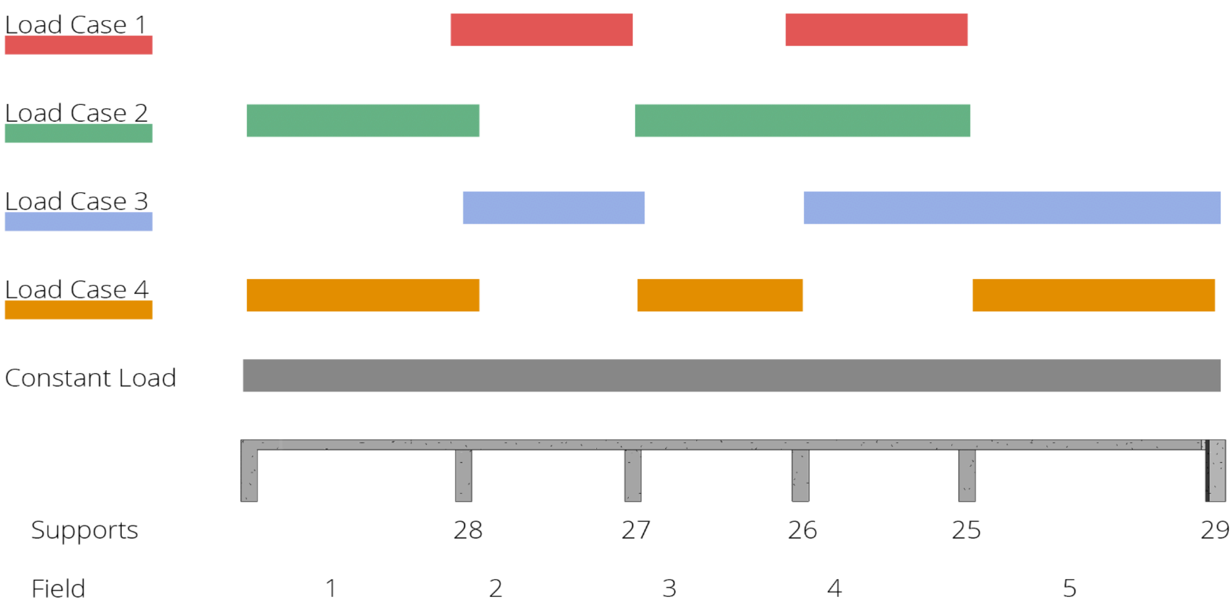
$$\gamma_G \cdot (G_1 + G_2) \quad + \quad \gamma_Q \cdot (Q_1 + Q_2)$$

$$1.35 \cdot (G_1 + G_2) + \quad 1.5 \cdot (Q_1 + Q_2)$$

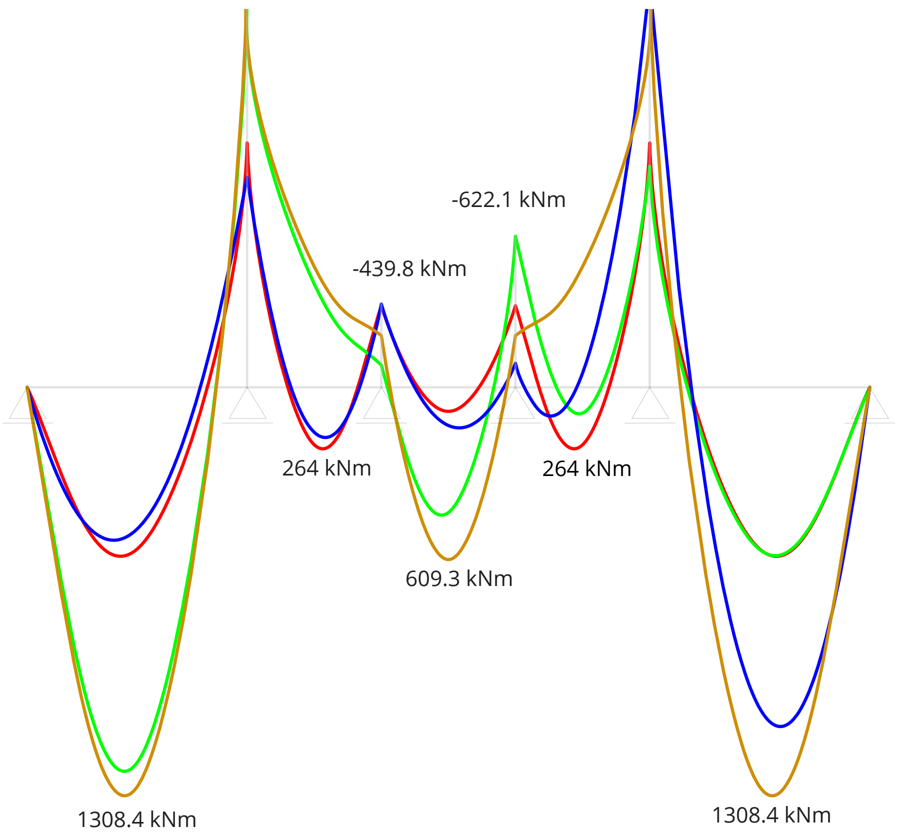
$$104.41 \quad + \quad 113.40$$

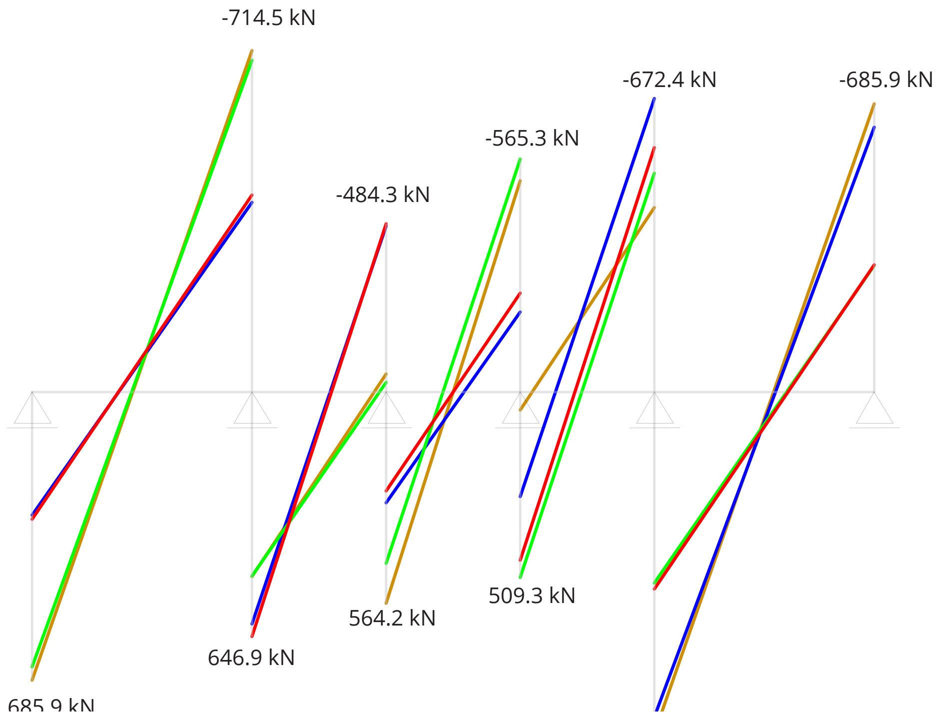
Load Combinations:

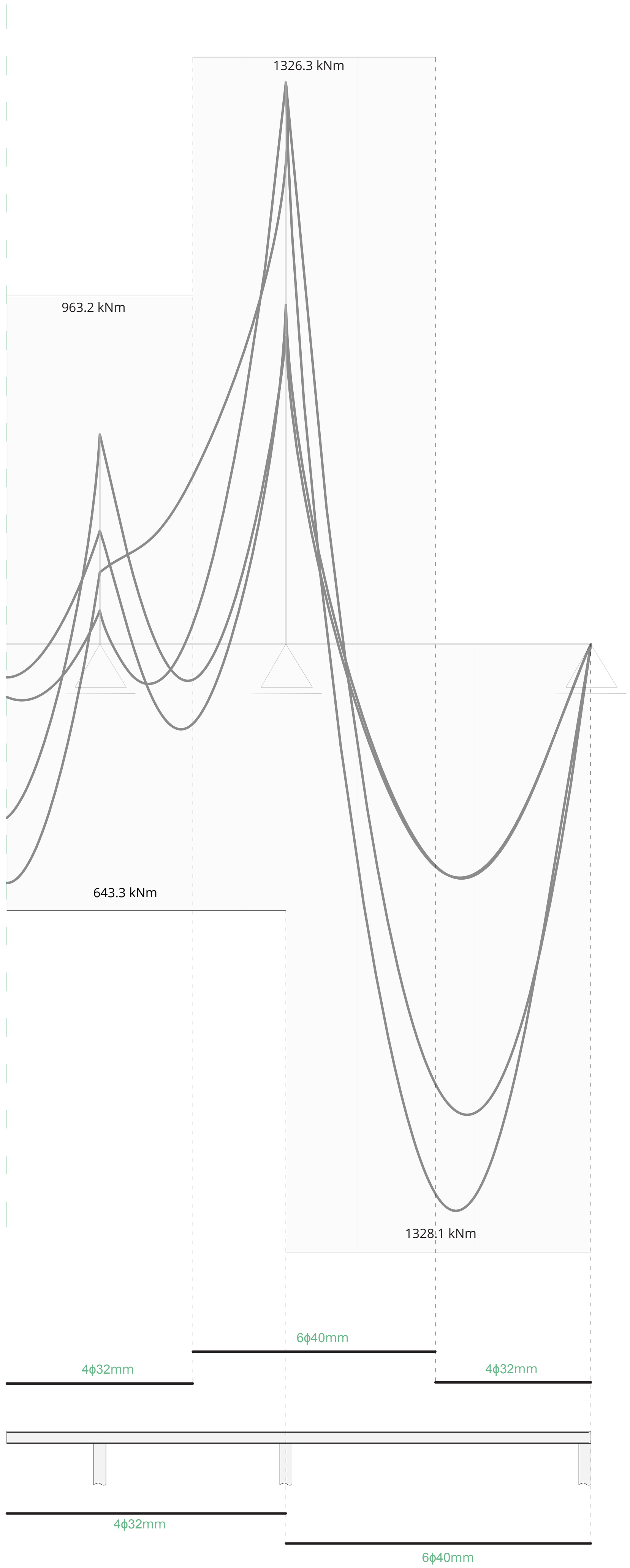
Combination of load case 1, 2, 3 or 4 with dead load provide maximum stress resultants in fields and at mid support.



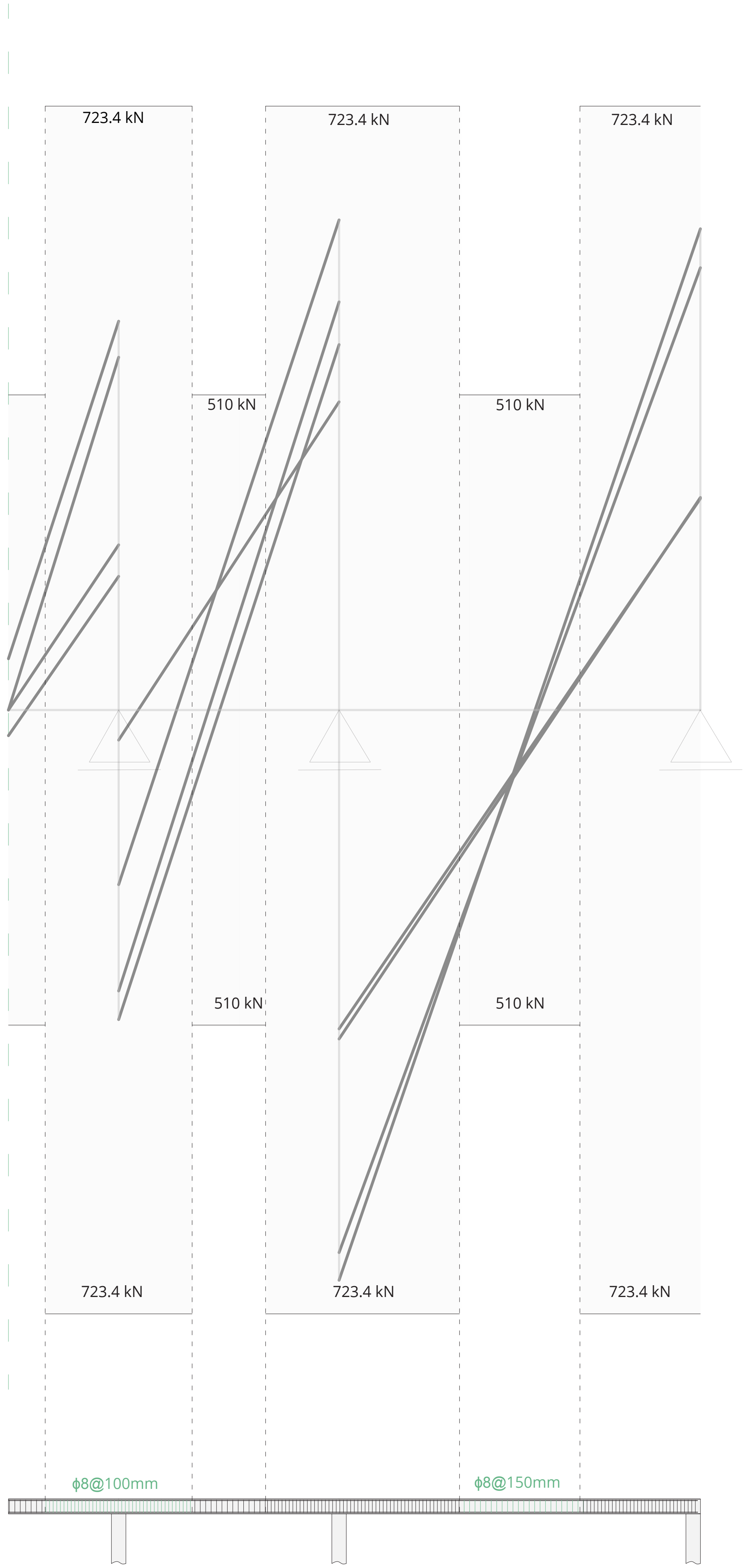
MAXIMUM VALUES OF MOMENT AND SHEAR:
Superposition of four load cases for moment and shear to reach values determining the design.



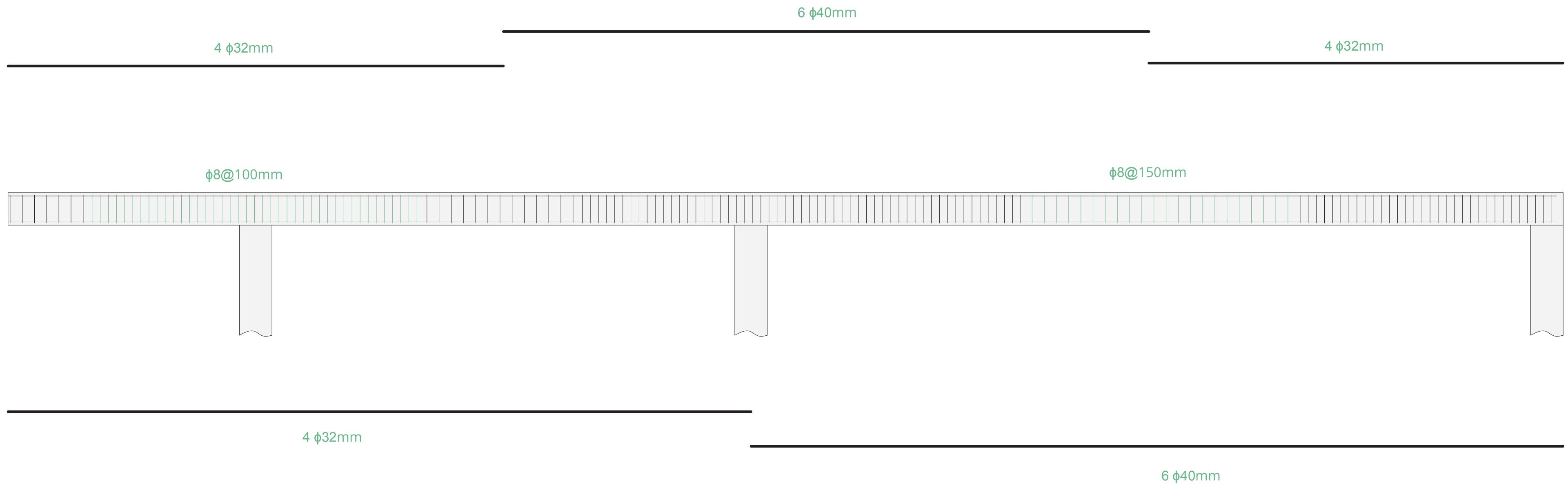



1326.3 kNm
963.2 kNm
643.3 kNm
1328.1 kNm
6ϕ40mm
4ϕ32mm
4ϕ32mm
4ϕ32mm
6ϕ40mm

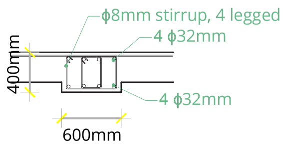
Schematic display of transversal reinforcement capacity



Detailed beam section

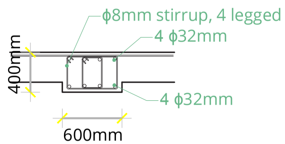


Field 3



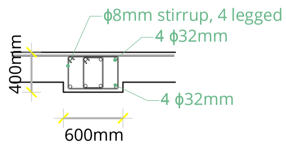
M_{Ed}=609.3kNm
M_{Rd}=643.3kNm
V_{Ed}=134kN
V_{Rd}=510kN

Support 27,26



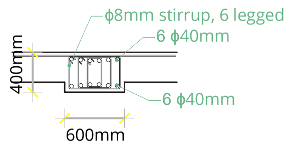
M_{Ed}=-622.1kNm
M_{Rd}=-963.2kNm
V_{Ed}=-714.5kN
V_{Rd}=-723.4kN

Field 2,4



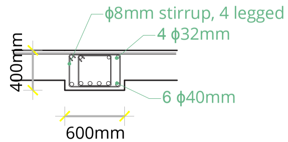
M_{Ed}=264kNm
M_{Rd}=674.6kNm
V_{Ed}=176kN
V_{Rd}=510kN

Support 28,25



M_{Ed}=-1314.4kNm
M_{Rd}=-1326.1kNm
V_{Ed}=-672.4kN
V_{Rd}=-723.4kN

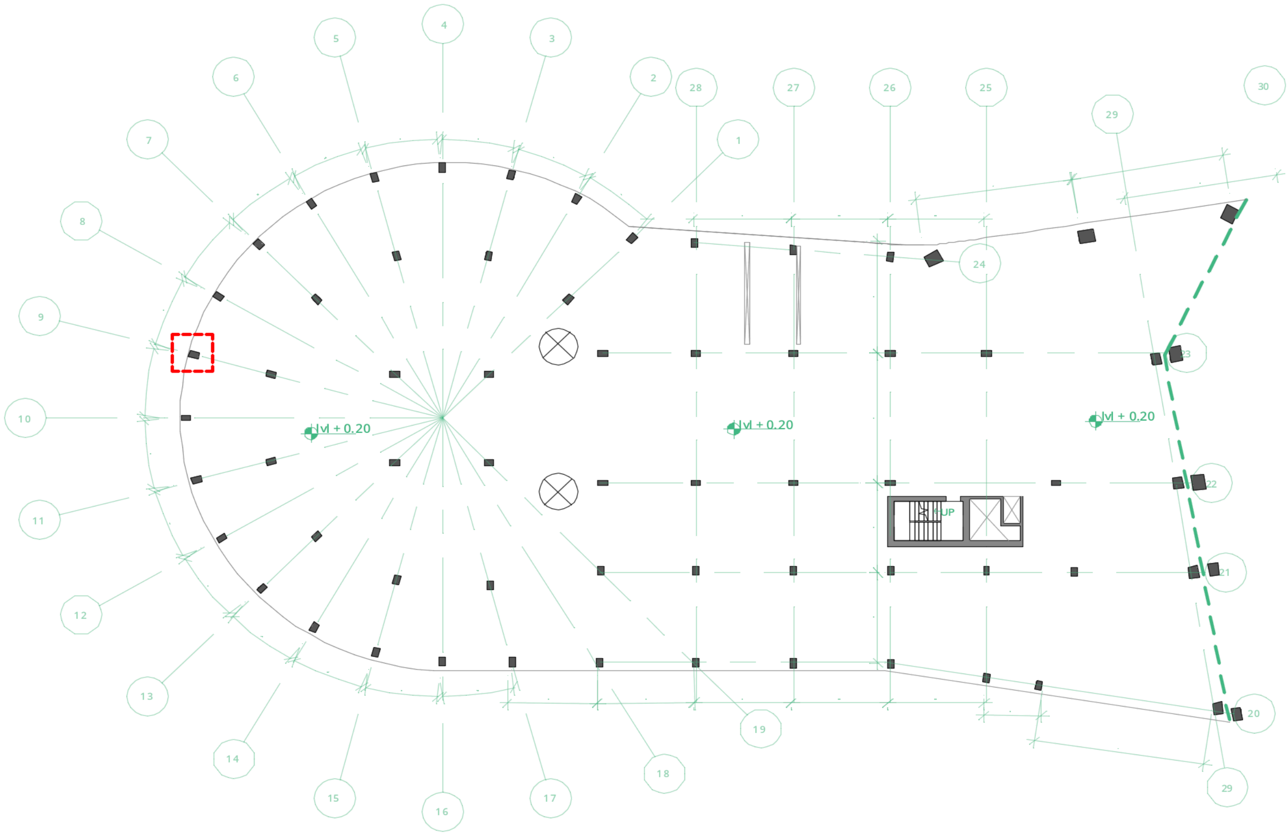
Field 1,5



M_{Ed}=1308kNm
M_{Rd}=1328.1kNm
V_{Ed}=148kN
V_{Rd}=510kN

|COLUMNS|

The calculated column supports the entrance floor. It is footed in the foundation and rises 5.3 m up.
The column has a rectangular section of 60 cm * 40 cm.
The load which needs to be carried by the column is rather large; and the column is also challenged by actions due to the wind.

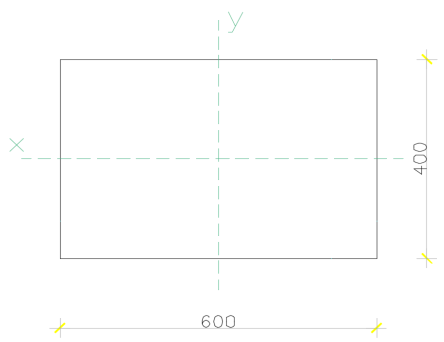


Influence area	=	18 m^2
Roof Loads:		
Number of mullions in the influence area	=	4
Height of mullion from the ground	=	40 m
Weight of mullions	=	11.2 kN
Weight of glass panels	=	108 kN
Weight of Curtain wall	=	119.2 kN
Trusses and finishing layers	=	37.8 kN
Total roof load	=	157 kN
Weight of the rib of the beam (redundancy coefficient = 0.9) = $0.9 \cdot 6 \cdot 1.2 \cdot 0.45 \cdot 25 kN/m^3$	=	72.9 kN
Snow	=	36.9 kN
Typical floor loads:		
Slab self-weight	=	131.4 kN
Variable loads (inside partitions included):	=	151.2 kN

Weight of external curtain wall		=	13.5 kN
Weight of the rib of the beam (redundancy coefficient = 0.9) = 0.9 · 6 · 1.2 · 0.45 · 25kN/m^3		=	72.9 kN

Column pre-dimensions

b	Column width	=	0.6 m
d	Column depth	=	0.4 m
Column self-weight = b · d · floor height · 25kN/m^3		=	30 kN



Verification for Buckling:

l	floor height	=	5300 mm
l_0	effective length = 0.7 l	=	3710 mm
A	column cross-section area	=	240000 mm^2
I	moment of inertia = b h^3 /12		
I_x	moment of inertia about x	=	3200000000 mm^4
I_y	moment of inertia about y	=	7200000000 mm^4
r	radius of gyration = √(I / A)		
r_x	radius of gyration about x	=	115.47 mm
r_y	radius of gyration about y	=	173.21 mm
λ_x	slenderness ratio about x = l_0 / r_x	=	32.13
λ_y	slenderness ratio about y = l_0 / r_y	=	21.42
λ	= max (λ_x , λ_y)	=	32.13 about x
F_{cr}	critical load = (E I_x pi^2) / l_0^2	=	75269531.88 N
		=	75269.5 kN
σ_{cr}	critical stress = F_{cr} / A	=	313.62 N/mm^2

Loads on every storey are:

Roof

G_k	permanent loads	=	267.7 kN
Q_k	variable loads	=	36.9 kN

3rd floor

G_k	permanent loads	=	217.8 kN
Q_k	variable loads	=	151.2 kN

2nd floor

G_k	permanent loads	=	217.8 kN
Q_k	variable loads	=	151.2 kN

1st floor

G_k	permanent loads	=	217.8 kN
Q_k	variable loads	=	151.2 kN

Ground floor

G_k	permanent loads	=	217.8 kN
Q_k	variable loads	=	151.2 kN

γ_g	partial factor for permanent action	=	1.35
γ_q	partial factor for variable action	=	1.5

γ_f $(\gamma_g \cdot G_k + \gamma_q \cdot Q_k) / (G_k + Q_k)$ = 1.41

Column	F_k	N (kN)	$N_{Ed} = \gamma_f \cdot N$	$A_{c,0} = N_{Ed} / f_{cd}$	b · d	A_c
	(kN)	$N = \Sigma F_{kj}$	(kN)	(mm^2)	(mm^2)	(mm^2)
3rd floor	334.6	334.6	472.3	27784	600 x 400	240000
2nd floor	399	733.6	1035.5	60912	600 x 400	240000
1st floor	399	1132.6	1598.7	94040	600 x 400	240000
Ground floor	399	1531.6	2161.8	127168	600 x 400	240000

Pre-dimensioning for centred axial load and self-weight influence

Column	A_c	$A_{s\,min}$ (mm^2)	$A_{s\,min}$ (mm^2)	10 Φ 16	A_s (mm^2)	A_s
	(mm^2)	$\rho_s = 0.3\%$	$= 0.10 N_{Ed}/f_{yd}$	(mm^2)	(mm^2)	(mm^2)
3rd floor	240000	720	141.7	2010	2010	10 Φ 16
2nd floor	240000	720	310.7	2010	2010	10 Φ 16
1st floor	240000	720	479.6	2010	2010	10 Φ 16
Ground floor	240000	720	648.6	2010	2010	10 Φ 16

Pre-dimensioning of longitudinal reinforcement

Under the hypothesis of plane sections (Eulero-Bernoulli), same strain in steel and surrounding concrete (εc = εs) and elastic materials, it is σs = αe σc, where the ratio between the modulus of elasticity αe is assumed equal to 15 in order to take into account the time dependent behaviour of concrete.

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

$A_{ie} = A_c + \alpha_e A_s$

$\alpha_e = 15$

$\sigma_c = N / A_{ie} \leq \sigma_{c,adm} (= 0.6 f_{ck} = 18 \text{ N/mm}^2)$

Column	A_c (mm^2)	A_s (mm^2)	A_{ie} (mm^2)	N (kN)	σ_c (N/mm^2)	< $\sigma_{c,adm}$?
3rd floor	240000	2010	270144	335	1.24	Yes
2nd floor	240000	2010	270144	734	2.72	Yes
1st floor	240000	2010	270144	1133	4.19	Yes
Ground floor	240000	2010	270144	1532	5.67	Yes

SLS verification

The translational equilibrium for ULS is

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

Column	A_c (mm^2)	A_s (mm^2)	N_{ed} (kN)	N_{Rd} (kN)	N_{Rd} / N_{Ed}
3rd floor	240000	2010	472.3	4750	10.1
2nd floor	240000	2010	1035.5	4750	4.6
1st floor	240000	2010	1598.7	4750	3.0
Ground floor	240000	2010	2161.8	4750	2.2

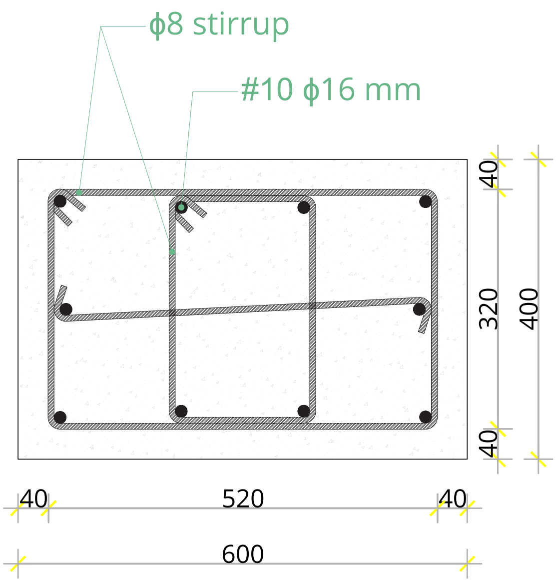
ULS verification

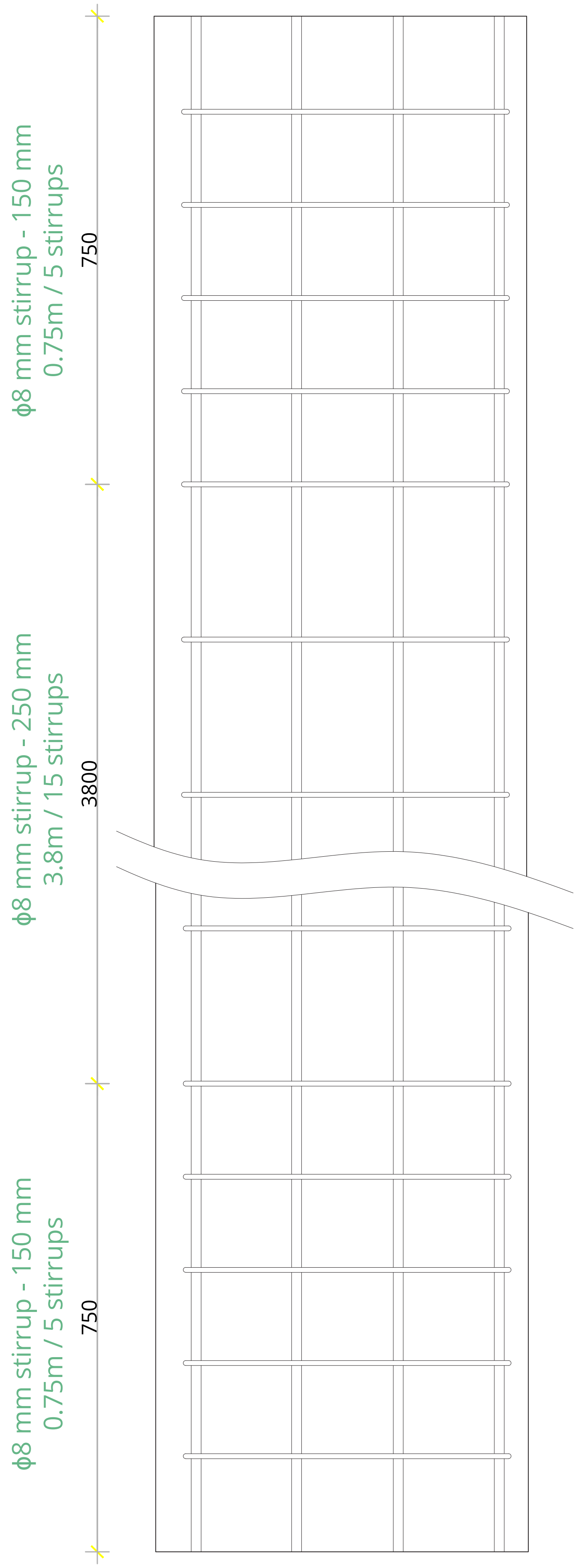
Using the prescriptions from Eurocode 2, the reinforcements are outlined:

Diameter of transversal bars = 8 mm

Spacing between transverse reinforcements = 250 mm

Stirrups Φ8/250 will be provided along all the columns, whereas at the bottom and the top of the columns for a distance equal to 750 mm stirrups Φ8/150 will be provided.


ϕ8 stirrup
#10 ϕ16 mm
40
320
400
40
40
520
40
600


ϕ8 mm stirrup - 150 mm
0.75m / 5 stirrups
750
ϕ8 mm stirrup - 250 mm
3.8m / 15 stirrups
3800
ϕ8 mm stirrup - 150 mm
0.75m / 5 stirrups
750

|STRUCTURAL PLANS|

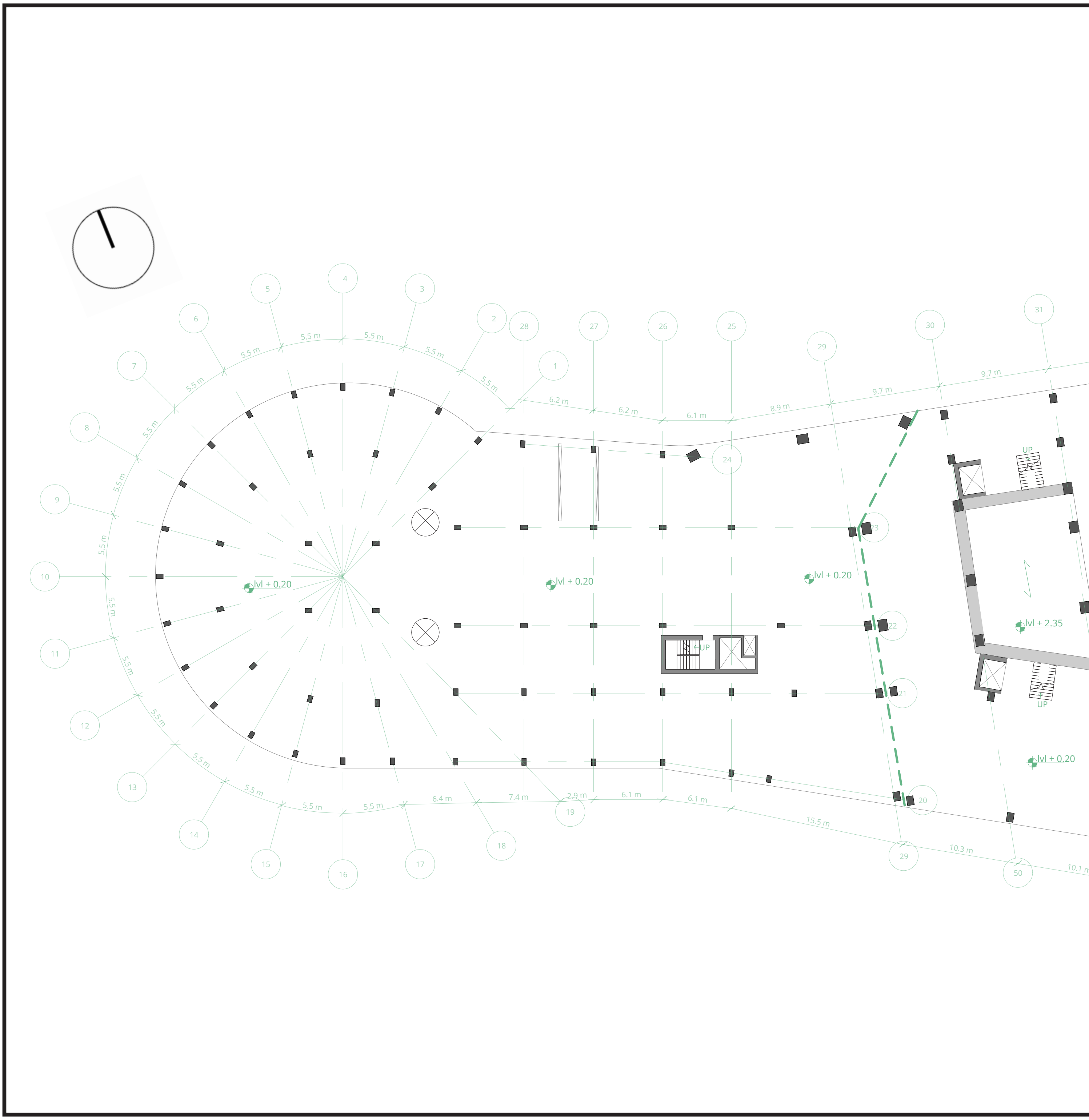
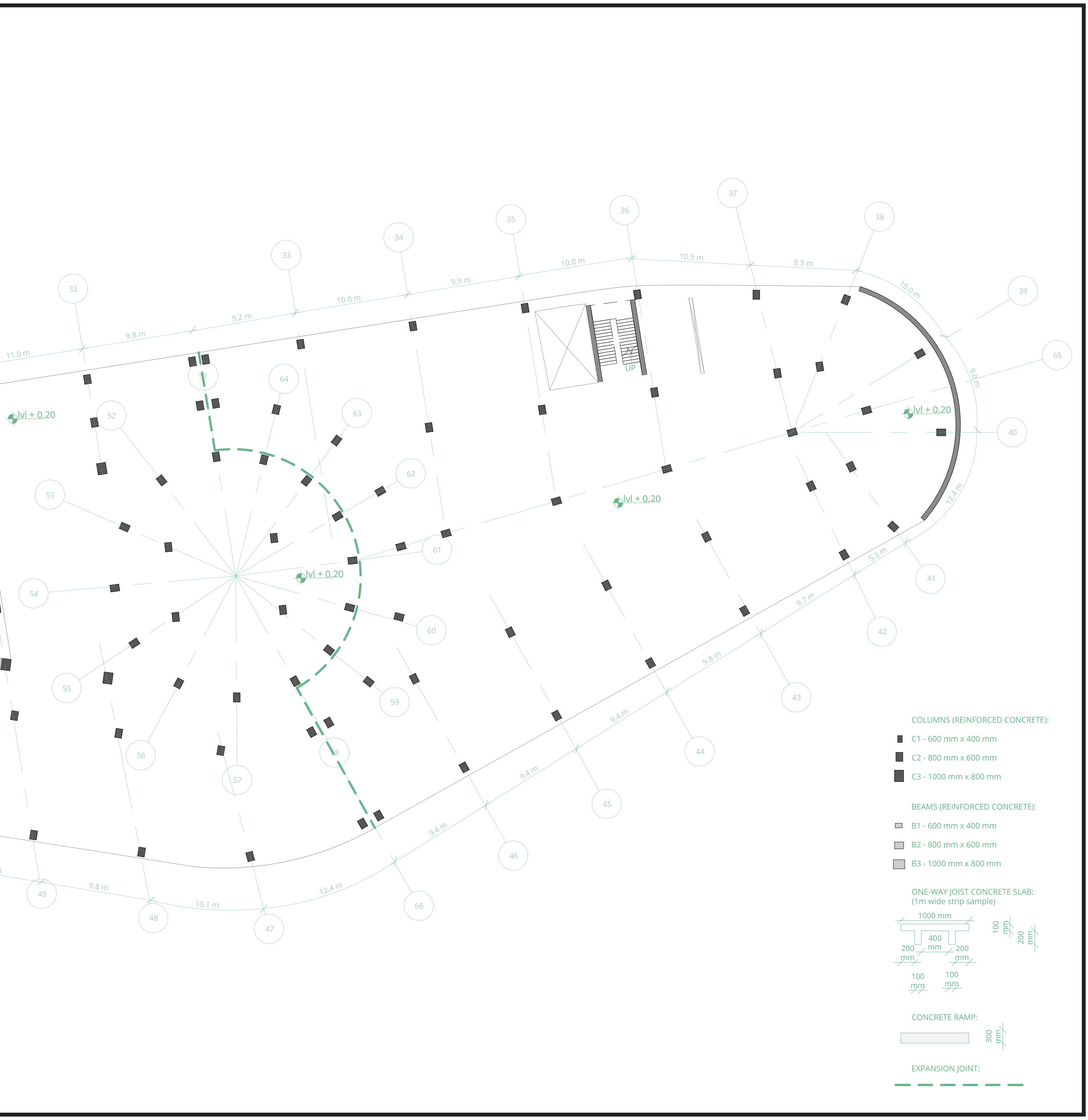


Figure 6.4 Structural plan of services floor (Level 0.20m)
Scale 1:500.


lvl + 0,20
lvl + 0,20
lvl + 0,20
lvl + 0,20
UP
COLUMNS (REINFORCED CONCRETE):
C1 - 600 mm x 400 mm
C2 - 800 mm x 600 mm
C3 - 1000 mm x 800 mm
BEAMS (REINFORCED CONCRETE):
B1 - 600 mm x 400 mm
B2 - 800 mm x 600 mm
B3 - 1000 mm x 800 mm
ONE-WAY JOIST CONCRETE SLAB:
(1m wide strip sample)
1000 mm
400 mm
200 mm
200 mm
100 mm
100 mm
100 mm
200 mm
CONCRETE RAMP:
300 mm
EXPANSION JOINT:

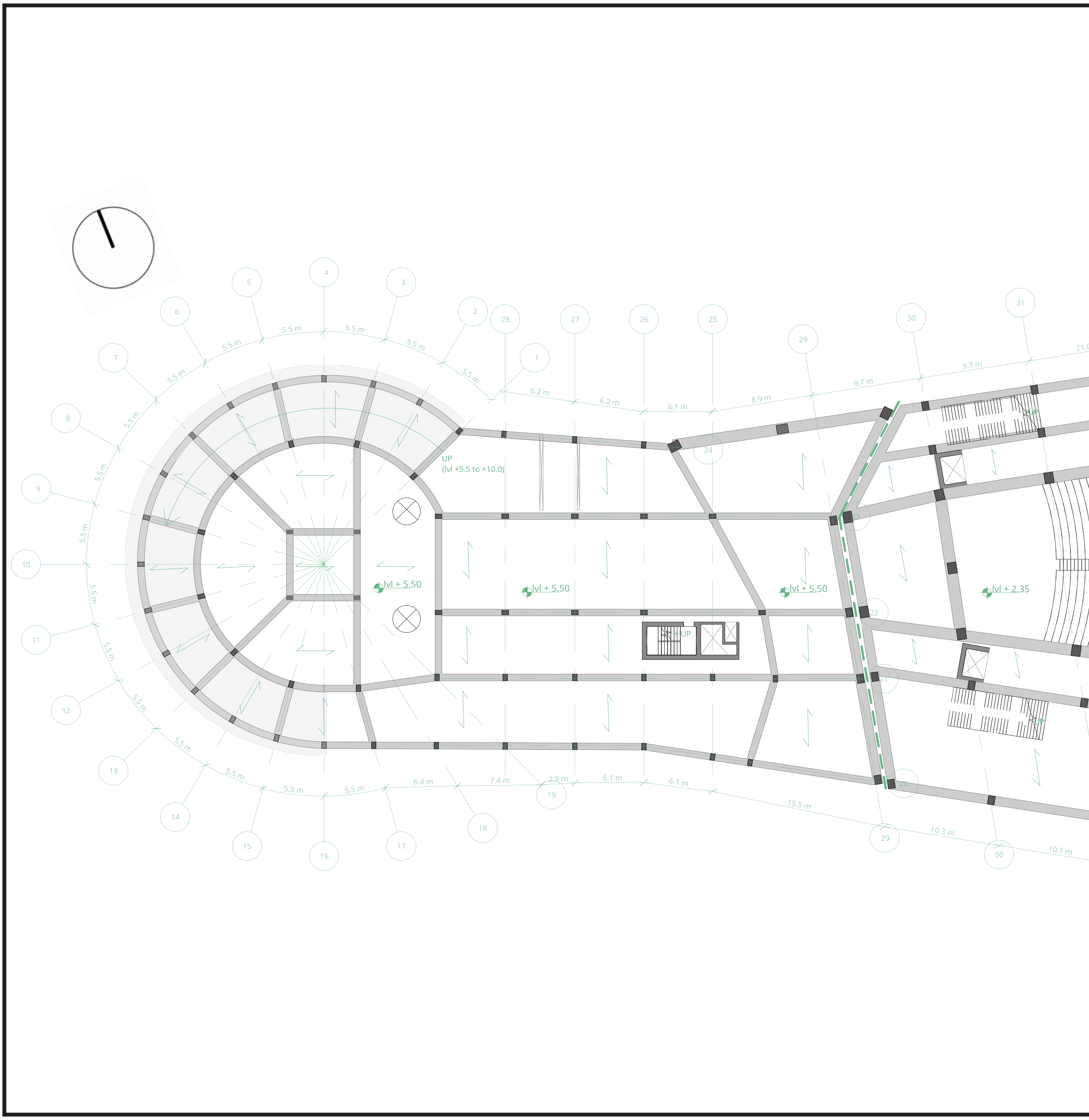
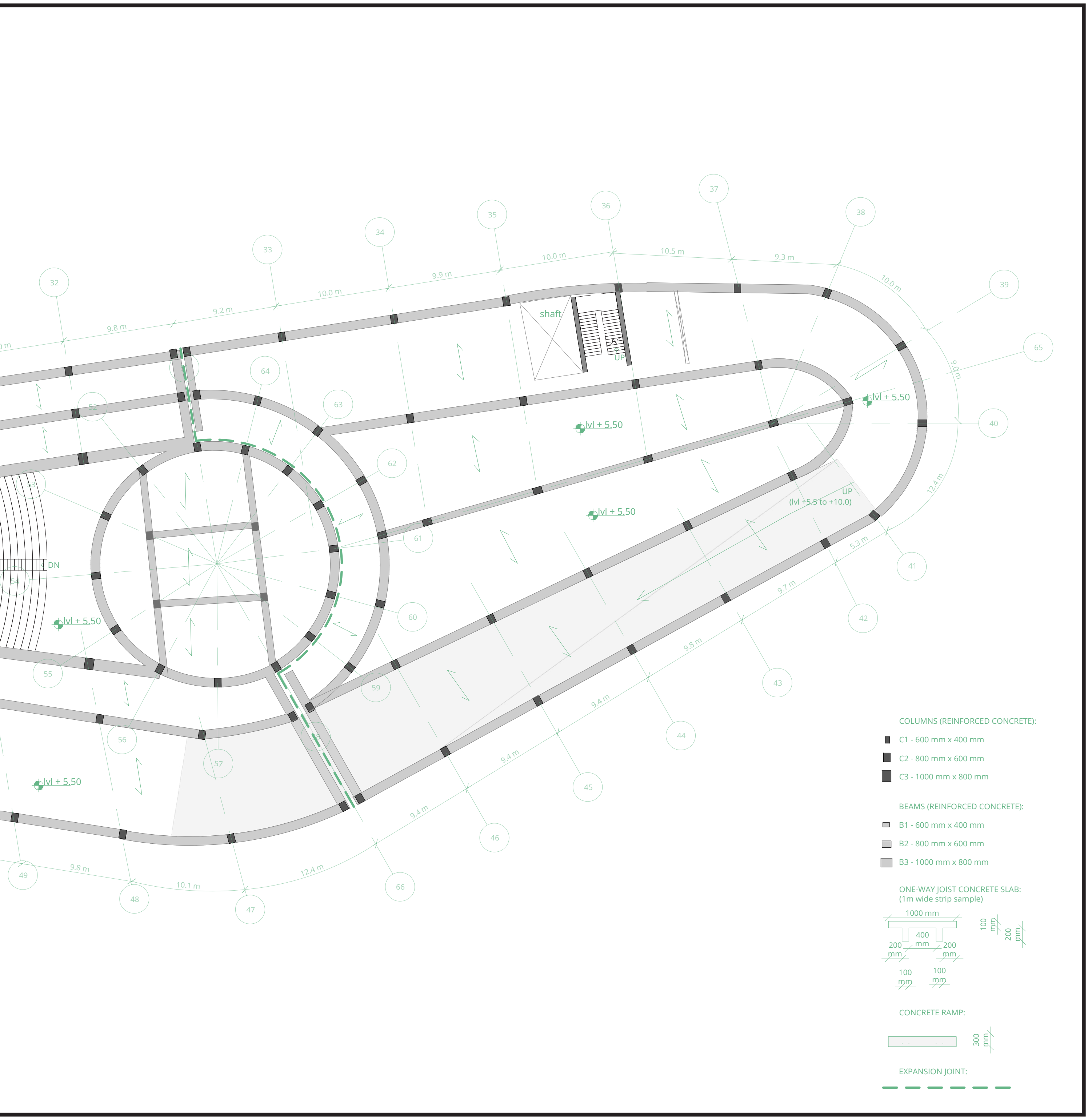


Figure 6.5 Structural plan of entrance (Level 5.50m)
Scale 1:500.


shaft
UP
lvl + 5,50
UP
(lvl +5.5 to +10.0)
DN
10.0 m
10.5 m
9.3 m
9.9 m
10.0 m
9.2 m
9.8 m
9.0 m
12.4 m
5.3 m
9.7 m
9.8 m
9.4 m
9.4 m
9.4 m
12.4 m
10.1 m
9.8 m
COLUMNS (REINFORCED CONCRETE):
C1 - 600 mm x 400 mm
C2 - 800 mm x 600 mm
C3 - 1000 mm x 800 mm
BEAMS (REINFORCED CONCRETE):
B1 - 600 mm x 400 mm
B2 - 800 mm x 600 mm
B3 - 1000 mm x 800 mm
ONE-WAY JOIST CONCRETE SLAB:
(1m wide strip sample)
1000 mm
400 mm
200 mm
200 mm
100 mm
100 mm
100 mm
200 mm
CONCRETE RAMP:
300 mm
EXPANSION JOINT:

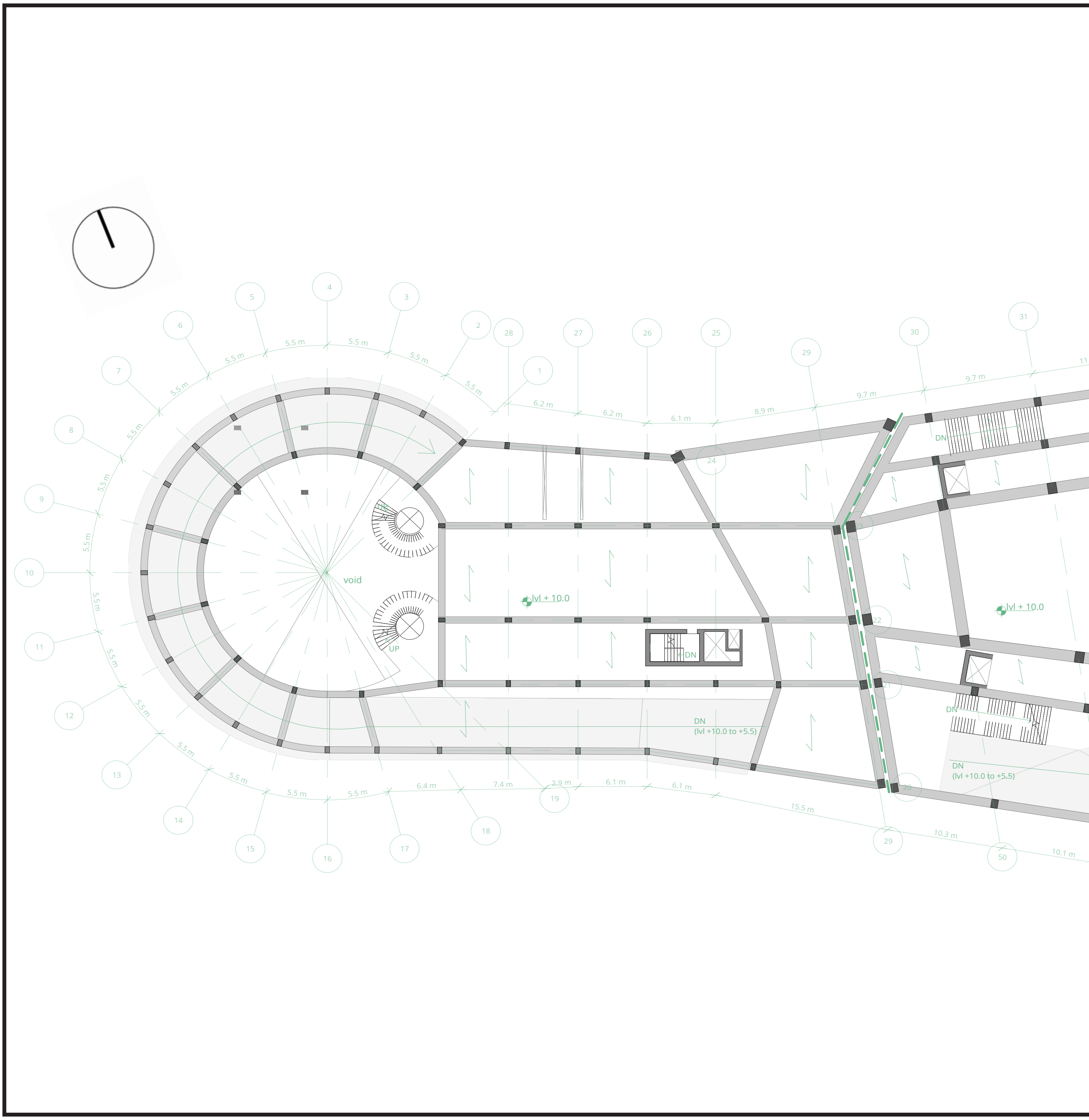
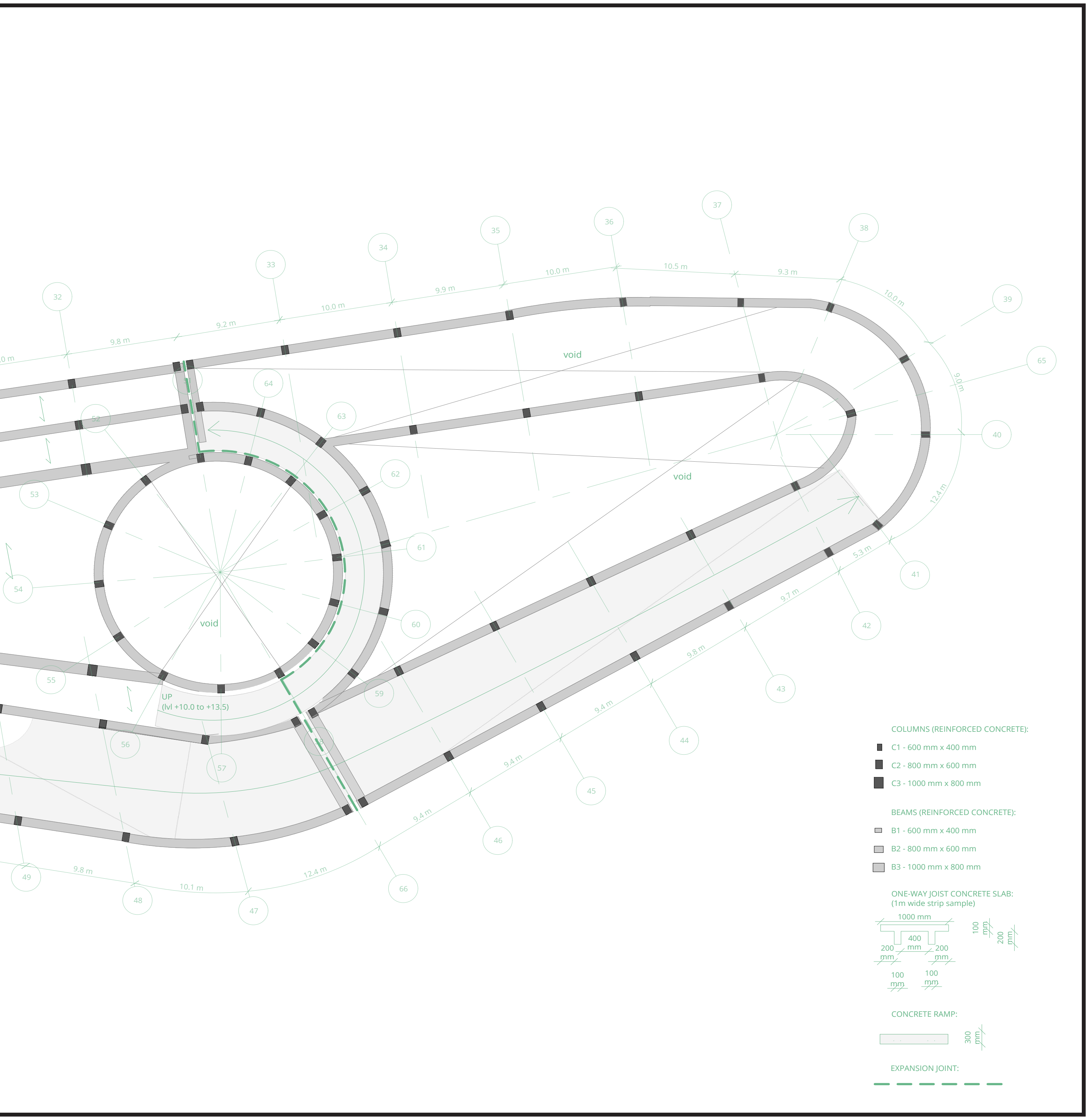


Figure 6.6 Structural plan of exhibition (Level 10.00m)
Scale 1:500.


void
void
void
UP
(lvl +10.0 to +13.5)
COLUMNS (REINFORCED CONCRETE):
C1 - 600 mm x 400 mm
C2 - 800 mm x 600 mm
C3 - 1000 mm x 800 mm
BEAMS (REINFORCED CONCRETE):
B1 - 600 mm x 400 mm
B2 - 800 mm x 600 mm
B3 - 1000 mm x 800 mm
ONE-WAY JOIST CONCRETE SLAB:
(1m wide strip sample)
1000 mm
400 mm
200 mm
200 mm
100 mm
100 mm
100 mm
200 mm
CONCRETE RAMP:
300 mm
EXPANSION JOINT:

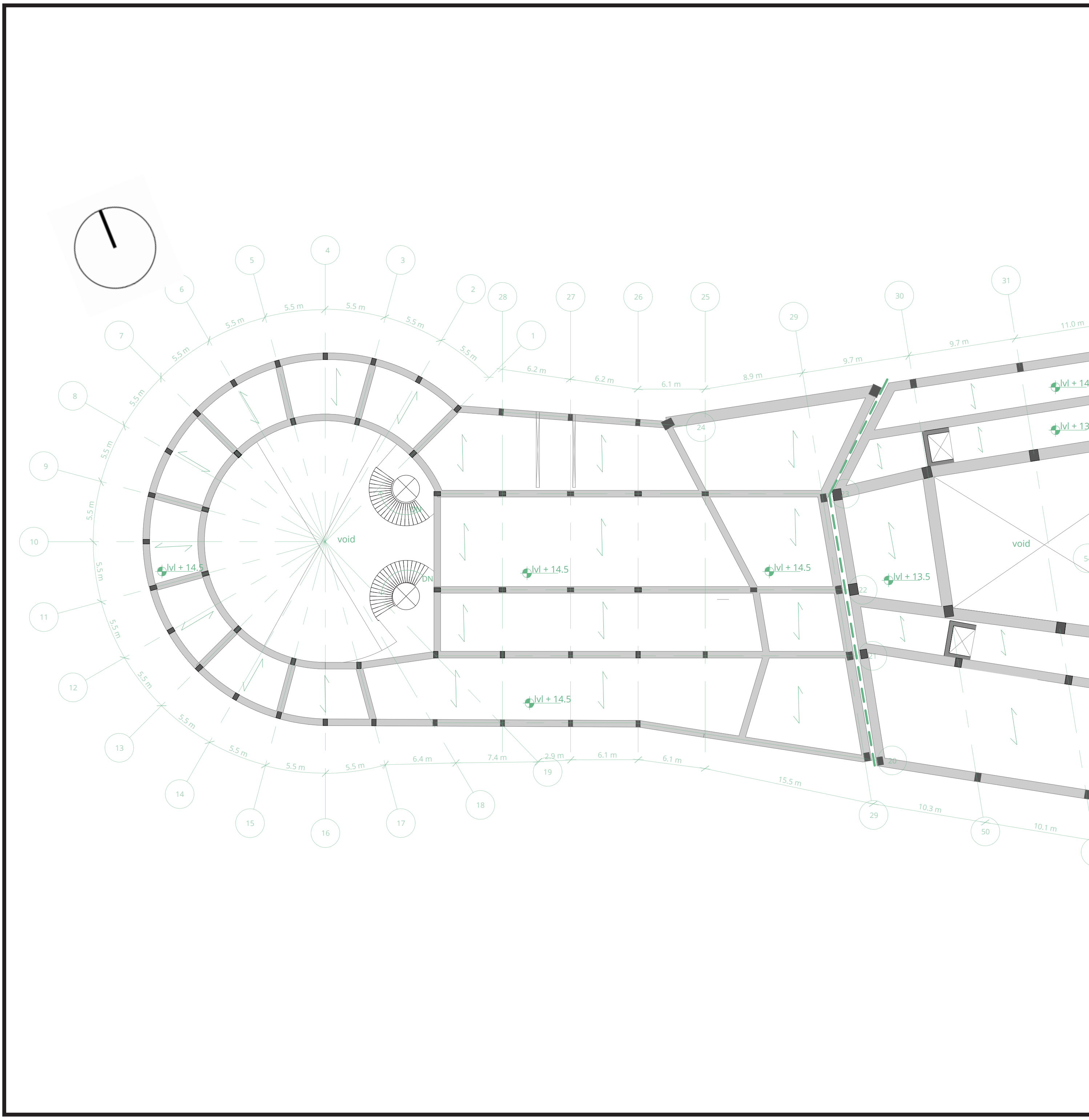
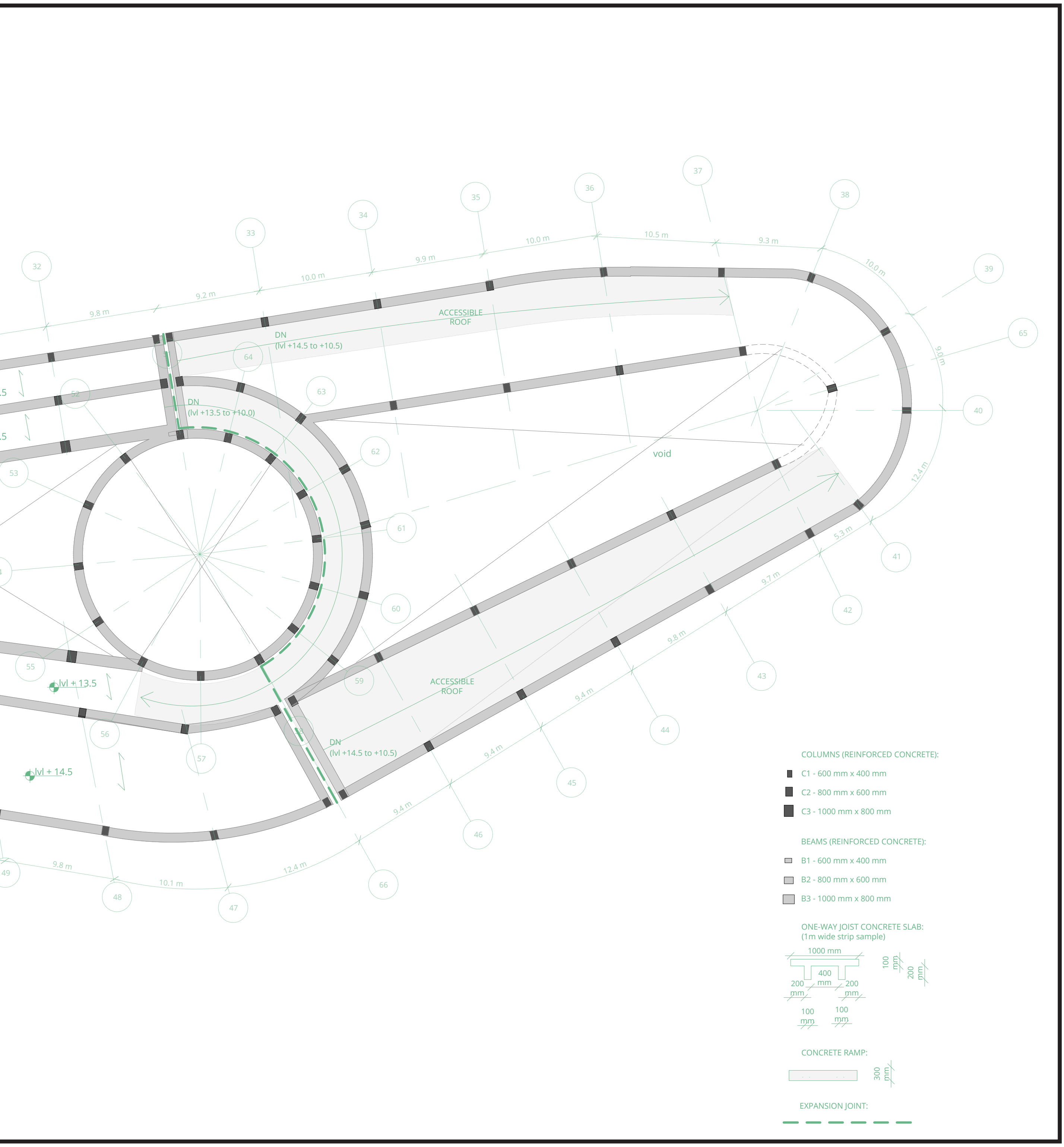


Figure 6.7 Structural plan of Restaurant (Level +13.50m) - Mezannine (Level+14.50m).

Figure 6.8 Scale 1:500.


ACCESSIBLE ROOF
DN (lvl +14.5 to +10.5)
DN (lvl +13.5 to +10.0)
void
ACCESSIBLE ROOF
DN (lvl +14.5 to +10.5)
lvl + 13.5
lvl + 14.5
COLUMNS (REINFORCED CONCRETE):
C1 - 600 mm x 400 mm
C2 - 800 mm x 600 mm
C3 - 1000 mm x 800 mm
BEAMS (REINFORCED CONCRETE):
B1 - 600 mm x 400 mm
B2 - 800 mm x 600 mm
B3 - 1000 mm x 800 mm
ONE-WAY JOIST CONCRETE SLAB:
(1m wide strip sample)
1000 mm
400 mm
200 mm
200 mm
100 mm
100 mm
100 mm
200 mm
CONCRETE RAMP:
300 mm
EXPANSION JOINT:

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THE END.