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VI FACULTY OF ENGINEERING
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MASTER OF SCIENCE IN ARCHITECTURAL ENGINEERING

MASTER THESIS

The New Qualia

An Experimental Transit
Malmi, Finland

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Abstract

What is the main goal of a train station? Is it just a place for transportation from one place to another? Or is a center point around which cities are created? Or is it an attraction point for commercial activities to flourish around?

In the contemporary way of thinking, A train station is much more than that, it can be a cultural spot from which journeys start, a platform on which different activities and uses merge in a perfect harmony due to the diversity of the users. These activities and cultural aspirations start to form a solid core for an integrated community that expands to form a city.

A city where the history of its land and people create the milestone for the approached development in culture, technology, arts,….etc. a city that manifests the evolution of space and architecture through time ,

That's the idea of this thesis is to apply this contemporary evolutionary idea on how the city is formed, starting from the history to understand how it all started and gradually reaching the current status with all the challenges facing the new developments and how they merge with the old settlements. By making these analyses we proposed the design solutions to overcome the gap created between the old and the new which is very obvious in the case of the city of Malmi, Helsinki, which is exposed to a great and fast wheel of change which can be seen in city center of Helsinki.
Since the Malmi train station is considered the core around which the city has evolved it had already maintained its importance as the main city center, but unfortunately it had also arrived to be the separation point between the Ala Malmi and the Yla Malmi, leaving the city in a state of undefined identity.

From that, our design is a proposal of creating a platform that doesn't only connect between the old and the new but to introduce new ways of connection, by creating new spaces, new activities, and therefore new experiences.

These new experiences as well have to be presented in a modern up to date approach introducing new technologies and respecting the new considerations of the architectural world, therefore our design includes the technological solution and methodologies we seek to apply starting from the walls, floors, roofs to the integrated building systems that control the performance of the whole building,

With this new experiences offered by our design, different users find the chance to share their knowledge, their experiences as well as their aspirations, which is the milestone of the cultural bridge between the past and the present , hopefully creating a path to follow to avoid another gap between the present and the future.

CONTENTS

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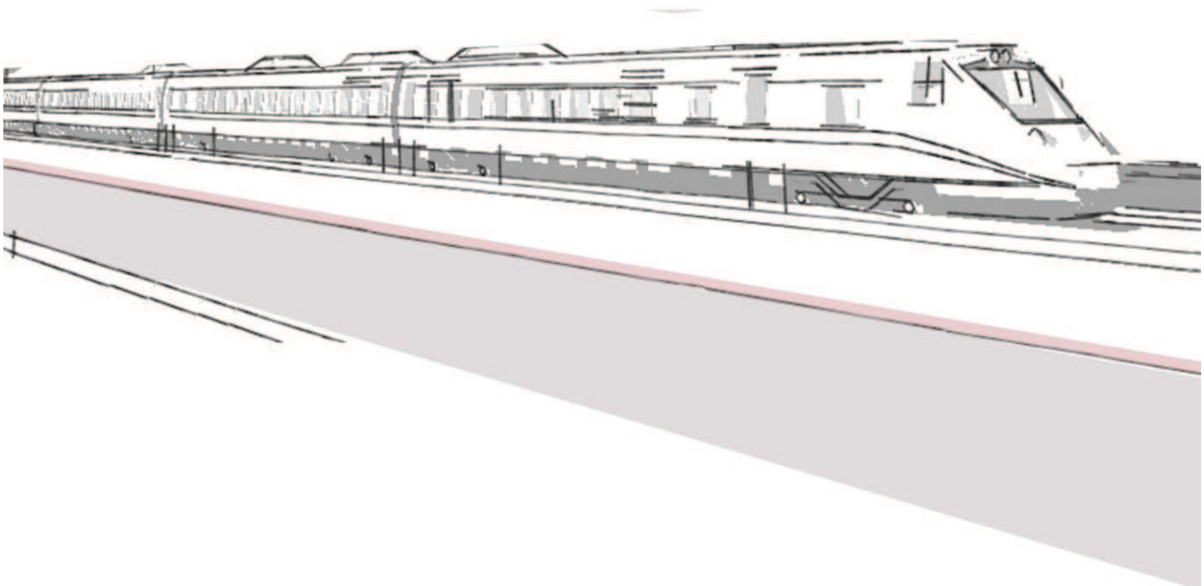
1.0 INTRODUCTION



1.1 Competition

1.1.1 Competition Brief

Figure 1.1– Competition Poster 1

The competition brief is related to transit areas and the train station area of Malmi in Helsinki. The aim of the competition is thinking about the "Arrival to Malmi" by 5 different means: train, bus, car, bicycle and walking.

Each of the means of arrival has specific areas to be addressed. However the concept should also address the challenge on a general level, in which the emphasis should be placed on the overall concept.

Reference: http://bullhorn.cembrit.com/bullhorn-27000.aspx

1.1.2 About the Area

- The Malmi station area is a typical example of a busy transit hub that has become worn out and where the overall appearance and functionality need improvement.
- One of the major transit hubs in Helsinki, over 6 million people each year use the railway that passes through Malmi, and almost 4 million people each year step in and out at trains at the Malmi station
- The organizers are looking for ideas that can transform the unappealing transit areas into outstanding experiential landmarks for urban commuters, creating ideas that will improve the quality of life for thousands of people each day.

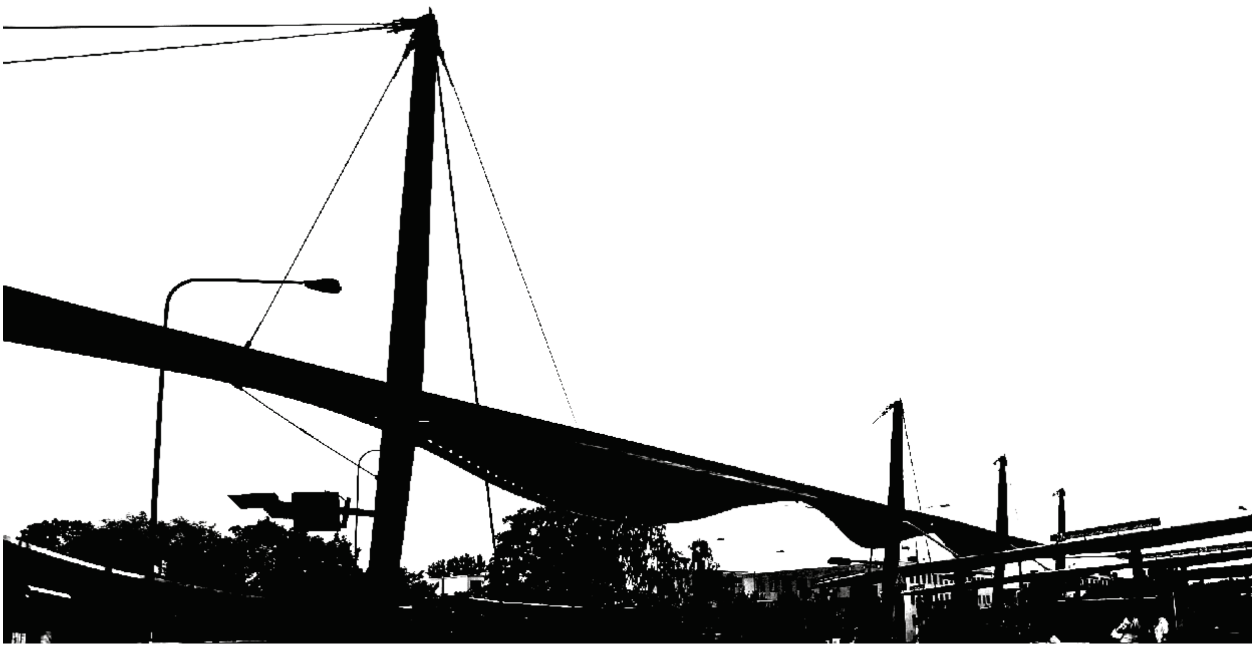


Figure 1.2 – Competition poster 2

1.1.3 Objective

- Finding a concept level solutions for the improvement of the quality of a transit area and its surrounding environment by using a fiber cement as a material
- Finding a universally applicable ways to improve the attractiveness of suburbs
- Providing different ideas that can transform the unappealing transit areas into outstanding experiential landmarks for urban commuters, creating ideas that will improve the quality of life for thousands of people each day.

1.1.4 Goals

- Ideas that transform the unappealing transit areas into outstanding experiential land marks for urban commuters
- Ideas that improve the quality of outstanding life settings
- Addressing solutions for urban transit problem
- Increasing the attractiveness of the area
- Improving the feeling of safety and access f life for thousands of people each day.
- Supporting the identity of the area
- Thinking about Malmi as a functional (transit and committing), mental (orientation and identity of the area) and visual experience
- Using fiber cement in improving the quality of the environment
- Transit areas are becoming important identity building elements in urban environments
- Flexibility in the concept
- The station areas are complex with various tenants- public and private – heavy usage and a tendency to be exposed to vandalism
- Role of private business should be considered and development of the station
- Supporting business activity in transit area
    - Concentrating the functions close to the station
    - It is crucial for commercial activity that public services are intertwined with commercial services that will allow station to become local village centers.
- The quality of the city space
    - Facades on pedestrian
    - Quality of space for pedestrian and the experience in shopping
    - Lighting. Accessibility and organization of bicycle parking
    - Negative influence on apartments close to the station to be expensive whereas apartments located in walking distance benefit from good Connections

1.2 Location

1.2.1 Finland - Malmi

The Competition site is located in Finland in a city called "Malmi", which is famous to be an industrialized city.

Figure 1.5 - Finland

Figure 1.3 – Finland Location

Figure 1.6 – Vantaa Airport

Figure 1.4 – Finland Location

Figure 1.7 – Helsinki

In Figure 1.8, It is shown that the Site is centered between Vantaa airport,

Helsinki airport and Helsinki the capital.

Vantaa Airport is considered to be the main airport in Finland, but Helsinki airport is for military services.

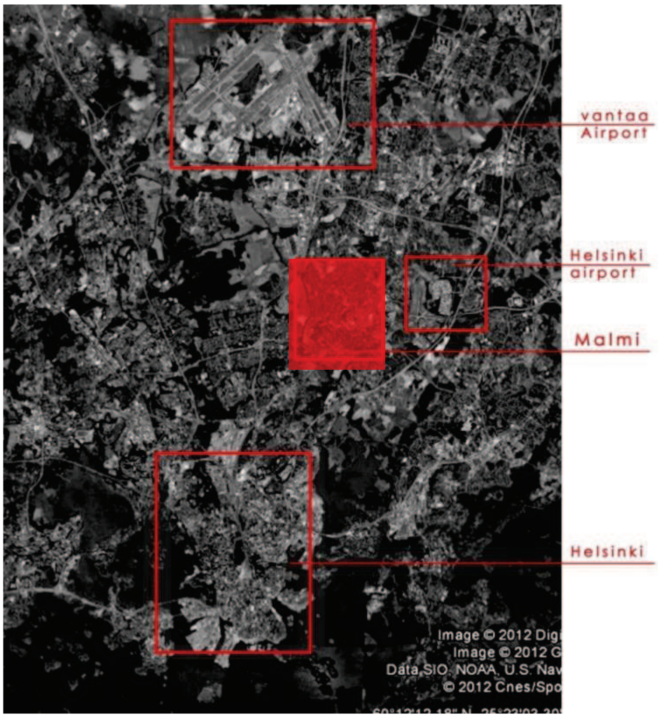


Figure 1.8–Malmi in relation with Helsinki and the airport

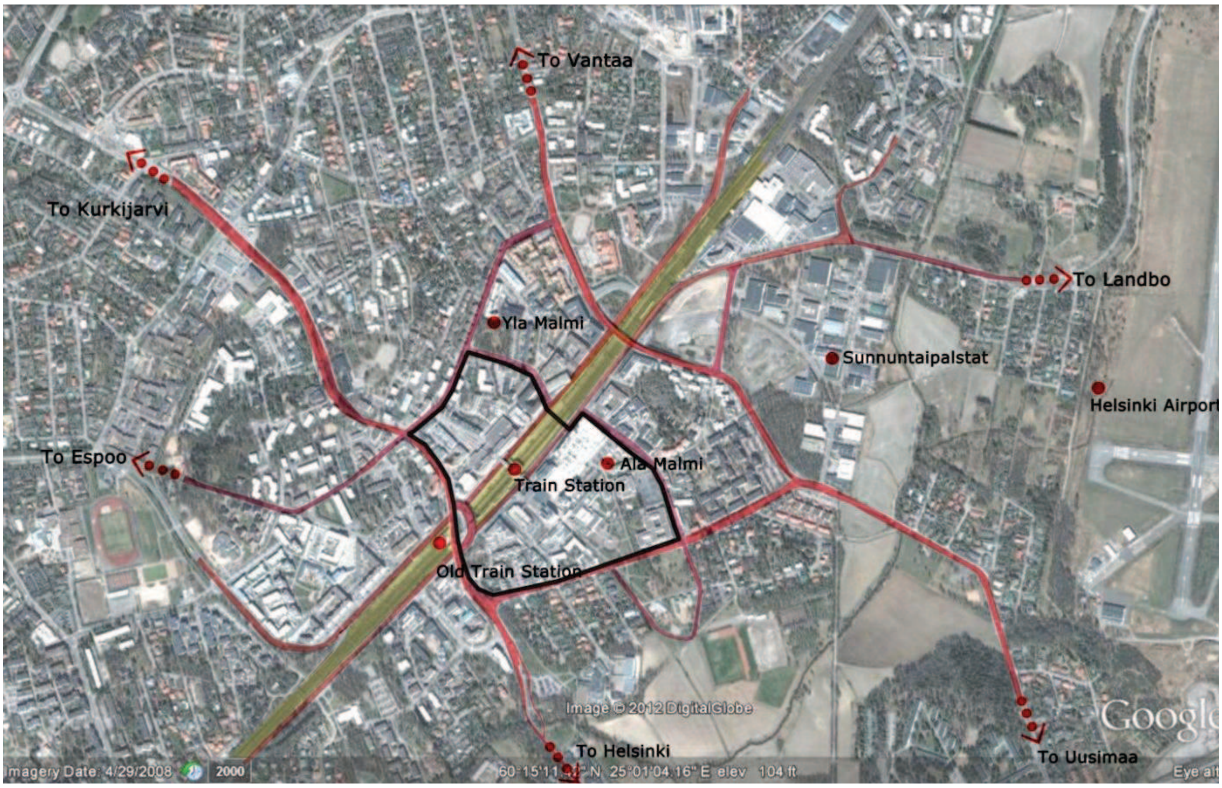


Figure 1.9– Site Roads Accessibility

1.2.2 Site Boundaries

As mentioned before the target of the competition was to design different approaches arriving to the station with new experiences every day. It wasn't specified a specific site, but the main concentration was on the area of the train station.

Train Station

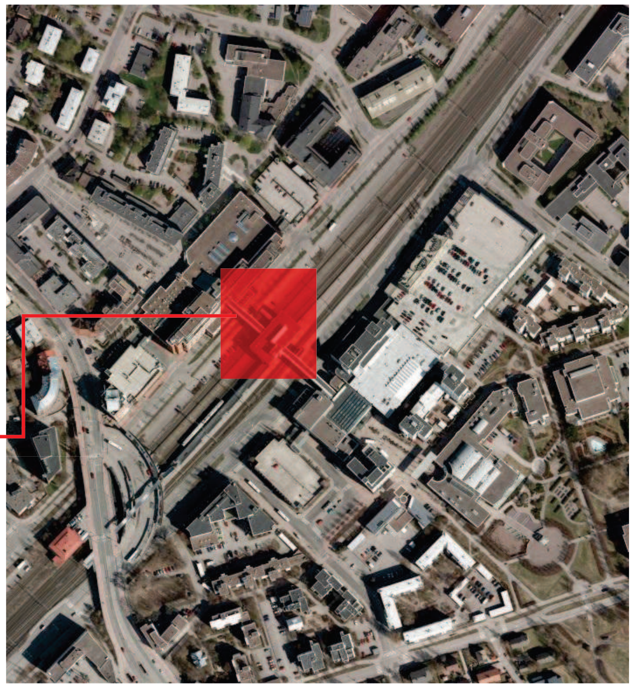


Figure 1.10– Site Surroundings

For our project we decided to have two main site boundaries:

- **Urban boundaries** figure 1.11: Related to the experiences that people will pass through every day.
- **Architecture Boundaries** figure 1.12 : Related to the upgrading of the station within the surrounding buildings

Figure 1.11 -Urban Site Boundaries
239184.806 m^2

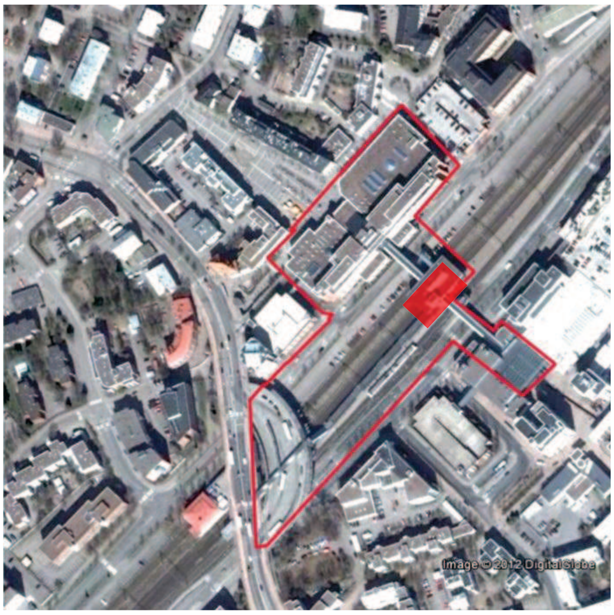
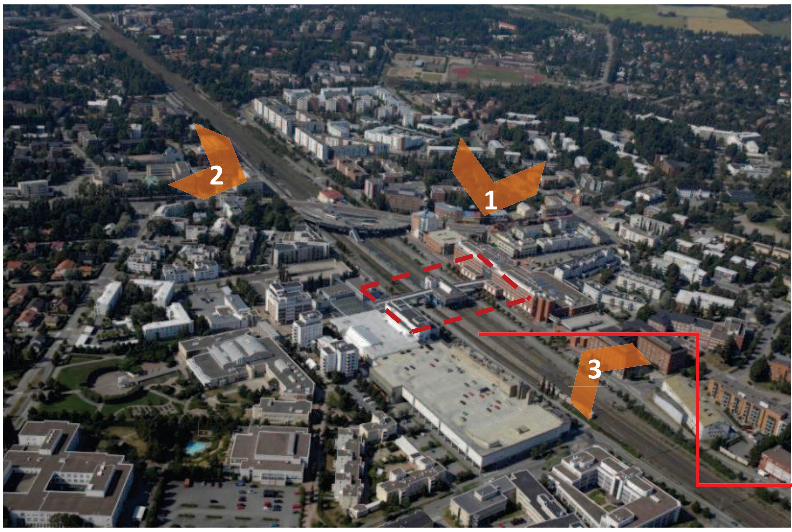


Figure 1.12 – Architecture Site Boundaries
36141.648m^2

1.2.3 Aerial views for the Site

The site is mainly the train station shown in figure 1.13 with a red highlight. But according to the brief and to our approach we wanted to merge the train station with the surrounding building and with the transportation network.



In the competition Brief, Aerial views of the area were provided. The view in Figure 1.13 shows the surrounding area around the train station.

Figure 1.13 – Aerial view of the Area

Figure 1.14 – view 1

Figure 1.15 – view 2

Figure 1.16– View 3

1.3 Winning Prizes

The results of the competition were different from what we thought, as none of them didn't think of the new experiences that the competition asked for, instead they used the fiber cement material to cover some parts of the building and to make it more appealing.

In our visit to the site we had the chance to interview one of the juries and their judgment was according to the possibility of constructing the design in reality and the three prizes were chosen according to the best technical solution that was constructed easily.

First Prize
Inspiration was taken from a swarm of butterflies. They added a third dimension to fiber-cement boards and from that created a modular system of fiber-cement butterflies.

The basic component is a three-dimensional fiber-cement triangle. With the organic form and colors of the components, "Papilio" brings natural and lively shapes into the rough station environment.

Figure 1.17– First Prize

Second Prize

The second-placed entry, "Malmi waffles", by Swedish Arklab Sthlm, strives to highlight the high level of energy in a station area and to bring in "soft design". The proposal is based on re-inventing the use of the classic corrugated roofing sheets, which is a 100 year old industrial design icon.

Figure 1.18– Second Prize

Resources: http://bullhorn.cembrit.com/Helsinki_2012-28250.aspx

Third Prize

A variety of travel and movement related symbolisms can be found – seagulls, clouds, flight. In the modular shelter system, fiber-cement boards have been used as a surface material and, according to the jury, it has its strength in the very clean design and firm repetition which in a very elegant way covers large areas such as station platforms.

Figure 1.19– Third Prize

1.4 Finland

1.4.1 Background & Geography

Finland is the Republic of Finland, is a Nordic country situated in the Fennoscandian region of Northern Europe. It is bordered by Sweden in the west, Norway in the north and Russia in the east, while Estonia lies to its south across the Gulf of Finland.

Finland is a parliamentary republic with a central government based in Helsinki and local governments in 336 municipalities

About one million residents live in the Greater Helsinki area, which consists of Helsinki, Espoo, Kauniainen and Vantaa, and a third of the country's GDP is produced there. Other larger cities include Tampere, Turku, Oulu, Jyväskylä, Lahti and Kuopio.

Area: 338,424 km² (131,985 square miles),
The fifth-largest country in Western Europe
Greatest length from north to south: 1,160 km (720 miles)
Greatest width from east to west:: 540 km (335 mi)

Figure 1.20– Finland

Resources: http://www.squidoo.com/finish-people-and-life-style
http://www.matitjamaijat.fi/english/index.htm

1.4.2 History

1550

Sweden's King Gustavus Vasa founded Helsinki on the mouth of VantaanjokiRiver to compete with Tallinn for Baltic Sea trade.

1600

The town grew slowly however, and the center of Helsinki was moved to its current location.

1748

Sweden began construction of the Suomenlinna Maritime Fortress off the coast of Helsinki to counter the growing threat from Russia. The massive project brought additional wealth, inhabitants and merchants to the town.

1809

Russia conquered Finland. The status of Helsinki was raised to capital of the autonomous Grand Duchy of Finland three years later. A monumental Empire-style city plan was drawn up to reflect the power of Russia and the Tsar.

1812

Emperor Alexander I promoted Helsinki to the capital of the Grand Duchy. The Guard of Finland is established. Helsinki is an outpost of St. Petersburg.

1819

The Government Council, later renamed the Imperial Senate of Finland, and all its central bureaus are relocated to Helsinki.

1820

From the 1820s onwards the city administrative court leases land bordering the Turku and Häme roadways for agricultural use, grassland, and for building sites for factories and villas.

1828

The seat of the county governor is transferred to Helsinki. The province of Häme-Uusimaa is divided into two separate provinces in 1831.

Resources: http://www.visithelsinki.fi/en/come/welcome-helsinki/history-helsinki-in-nutshell

1837

Steamboat traffic begins, connecting Stockholm, Helsinki, and St. Petersburg.

1862

Finland's first railway line is opened between Helsinki and Hämeenlinna.

1867 – 1868

The last years of severe hunger in Finland. During the famine years, eight percent of the Finnish population died of hunger.

1870

In the 1870s, Helsinki had begun to grow in earnest as a capital city.

1884

The electricity company is founded. The city is developed and modelled after cities in Central Europe, Germany in particular. Urban conveniences such as gas, water, electricity and public transport are quickly adopted in Helsinki and other major cities.

1900

The turn of the century was the period of Jugendstil architecture in Helsinki.

1903

The coastal railway connection (Rantarata) between Helsinki and Karjaa is completed.

1906

Meilahti and Toukola become part of Helsinki.

1907

The population of Helsinki crosses the 100,000 mark; it is now a miniature metropolis.

1912

The new town plan is completed. Eliel Saarinen's designs for the city were based on Helsinki's first ever planning architect Bertel Jung's draft town plan of 1911, where the city and its surrounding areas were seen as part of a single, larger entity.

1917

Finland became independent, and Helsinki assumed the demanding new role of capital of the young republic. City planning was characterized by Classicism and Functionalism.

1918
26 January 1918 Civil war breaks out in Finland. Helsinki is the capital of “red” Finland, and Vaasa the capital of the “whites”.

1938
1938 Malmi airfield and the Olympic Stadium are completed. Helsinki is selected as host of the 1940 Summer Olympics, which are later cancelled when war breaks out.

1939 – 1940
30 November 1939 – 13 March 1940 The Winter War is fought between Finland and the Soviet Union, which results in the deaths of 23,000 soldiers and 1000 civilians.

1941 – 1944
The Continuation War. The Soviet Union bombards Helsinki through the entire duration of the war, with the worst damage being caused by three large-scale bombardments in February of 1944.

1947
In the Paris Peace Treaties of 1947, Finland loses twelve per cent of its territory to the Soviet Union.

1952
Recovering from the hardships of war, Helsinki hosted the Summer Olympics. The games created an international reputation for Helsinki as an efficient and friendly host city.

1956

The Soviet Union’s lease on Porkkala ends and the region is returned to Finland.

1960

The age of prefabricated buildings. Industrialization exerts a heavy influence on housing construction methods, creating a need for new funding methods that are developed from the 1960s onwards. In 1966 the parish of Vuosaari is made part of the city of Helsinki, and a major new harbor and power plant are planned for the new district.

1961

Architect Alvar Aalto unveils his town plan for the center of Helsinki.

1975
Helsinki is recognized as a city in which many differing views can interact in a constructive atmosphere. The Finland Hall has hosted many international summit meetings, including the Conference for Security and Co-operation in Europe.

1995
Finland became an EU Member State.

2000
Helsinki was one of nine European Cities of Culture

2006
Helsinki hosted the ASEM6 Summit, the largest meeting held in Finland to date.

2008

The new Vuosaari Harbour comes into use.

2009

Parts of Vantaa and Sipoo are amalgamated into Helsinki.

2012
World Design Capital Helsinki 2012. The aim of the World Design Capital year is to improve the residents' everyday lives and living environment, to promote international business opportunities and to foster the economy through design.

1.4.3 People

1.4.3.1 Population

About 5.6 million in Finland, 15.7 inhabitants per km2 (40.2 per square mile) with the majority concentrated in the southern region.

Population in Helsinki the capital is about 1.3 million and there are actually four separate cities, Helsinki, Espoo, Vantaa and kauniainen. Approximately one quarter of Finns live in the metropolitan areas as well as the majority of non-nationals living in Finland.

Life expectancy: Men 76 years, women 83 years

Languages: Official languages are Finnish (spoken by 91%) and Swedish (5.4%). Sámi is the mother tongue of about 1,700 people, members of the indigenous Sámi people of northern Lapland

Religion: 80.7% Lutheran and about 1.1% Orthodox. In practice society is fairly secularized

1.4.3.2 Culture

Finland has managed to blend these different cultural influences in a very harmonious way, adopting various habits and customs originating from the neighboring countries. The unique location of the country, which lies above the Arctic Circle, is naturally reflected in the culture and traditions, the character of its residents and their way of life.

The people are environmentally friendly, and
support eco Efficiency; also Finland is the country with the least pollution, and one of the
most competitive countries in the world.

The good development of the country and its willingness to invest to culture come from the good levels of the education system and the efficient and innovative environment.

Figure 1.21

Figure 1.22

Resources : http://www.squidoo.com/finish-people-and-life-style

There are numerous festivals taking place in Finland all year long; Mid-summer is known as the period of summer solstice; the emphasis is given to the celebrations of June 24th when the Finns celebrate sunlight, building large Bonfires by the lakes, letting the thing burn down.

Mayday is also a great day in Finland; it is the festival of spring and drinking, which takes a big part in the Finnish culture. Starting on April 30th, there are numerous festivals and celebrations in every city and town of the country.

1.4.3.3 Attractions & Sports

Finland is mostly famous for its rivers and lakes, which make it a true center of boating and fishing in Europe, as well as its carefully protected nature, wonderful wildlife and excellent opportunities for winter sports.

During the summer, magnificent shores of the Baltic Sea and thousands of lakes provide good opportunities for swimming, hiking, cycling and hunting.

Helsinki is also famous for its fresh air and beautiful scenery combined with exciting "northern" architecture. The most famous architectural ensemble of the Finnish capital is a complex of buildings in the Empire style in the Senate Square: the Cathedral, The State Council, the University, etc. Not too far from the Senate Square you will find the Market Square the most vivid and vibrant place in Helsinki, the Presidential Palace, City Hall, Esplanadna Park (Espa) and the symbol of the city – a fountain with a bronze sculpture "Havis Amanda "(1908).

Figure 1.23

Figure 1.24

Figure 1.25

Resources: http://www.gofinland.org/visit-finland/finland-attractions/t

1.4.3.4 Economy

Finland has a highly industrialized, mixed economy with that of other western economies such as France, Germany, Sweden or the United Kingdom. The largest sector of the economy is services at 65.7 percent, followed by manufacturing and refining at 31.4 percent.

Primary production is 2.9 percent, with respect to foreign trade, the key economic sector is manufacturing. The largest industries are electronics (21.6 percent), machinery, vehicles and other engineered metal products (21.1 percent), forest industry (13.1 percent), and chemicals (10.9 percent). Finland has timber and several mineral and freshwater resources.

High standard of education, social security and healthcare, all financed by the state.

Main exports:

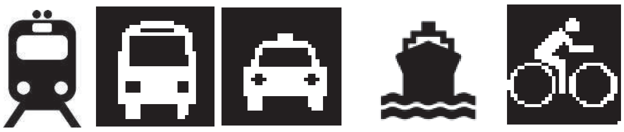
- Electro technical goods
- metal products, machinery
- Transport equipment
- Wood
- paper products
- chemicals

Main imports:

- Raw materials,
- investment goods,
- energy,
- consumer goods (for example cars and textiles)

Resources : http://www.hsl.fi/EN/passengersguide/Pages/cycling.aspx

1.4.4 Transportation - Helsinki



Bus, tram, metro, train, and ferry services. The system is managed by Helsinki Region Transport (HRT). The diverse public transport system of Helsinki region consists of trams, suburban metro railways, the subway, bus lines and two ferry lines.

1.4.4.1 Tram

The tram is considered to be one of the major and important transportation in Finland. It is a part of their urban lives and the city morphology.

Figure 1.27

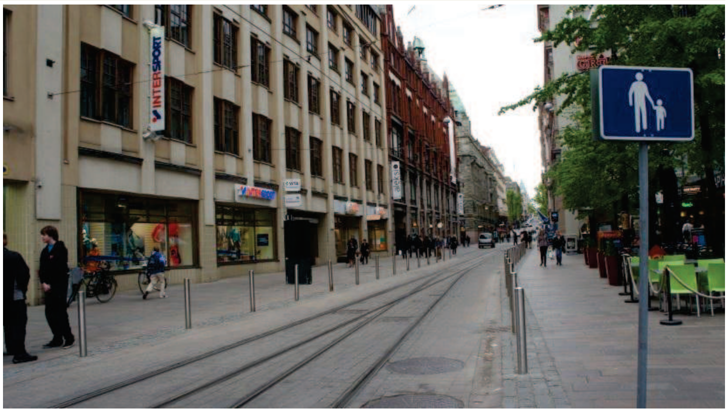


Figure 1.26

The relation between our site and Helsinki is shown in figure 28. The tram is almost configured in all Helsinki regions but there is no connection to our site. In future plans it is considered to connect malmi and Helsinki with tram connections as shown in figures below

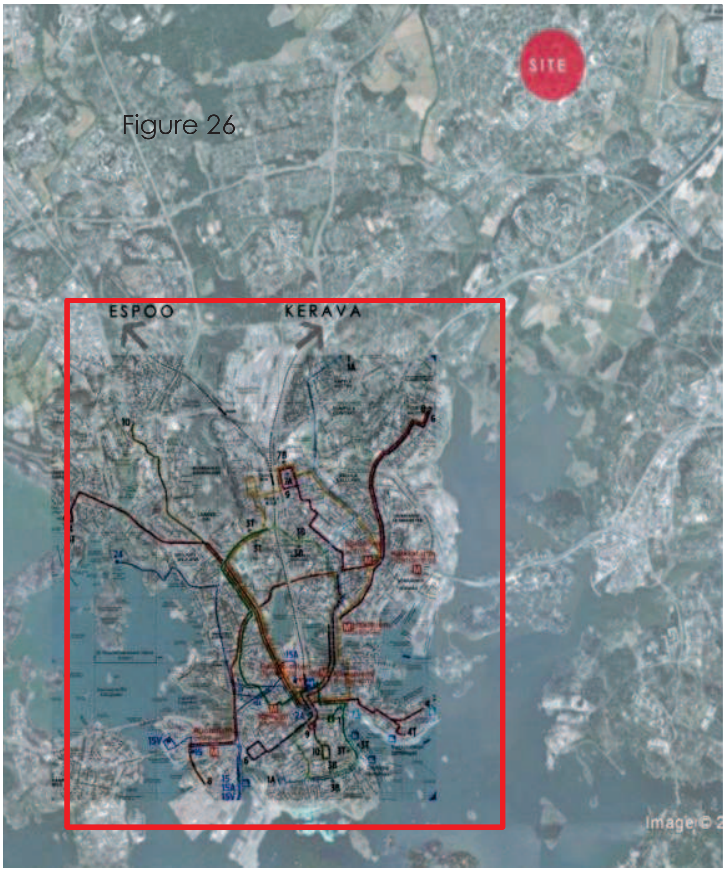


Figure 1.28- Tram Flow

Figure 26

Figure 1.29 – Zoomed figure

Figure 1.30 – Future Plans connecting Malmi to Helsinki

Resources: http://teamhelsinki.blogspot.it/2007_01_01_archive.html

1.4.4.2 Metro

Figure 1.31— Metro Interior

The Helsinki Metro, opened in 1982, was the first, and so far the only, subway-system in all of Finland. For the first 16 years of its existence, the line was topologically only one straight line, but in 1998 a fork with three stations each was added at the eastern end of the line.

Also in the metro there is no connection between malmi and helsinki, but for future plans will be considered future Plans connecting the train to other parts of Finland, our site is included also

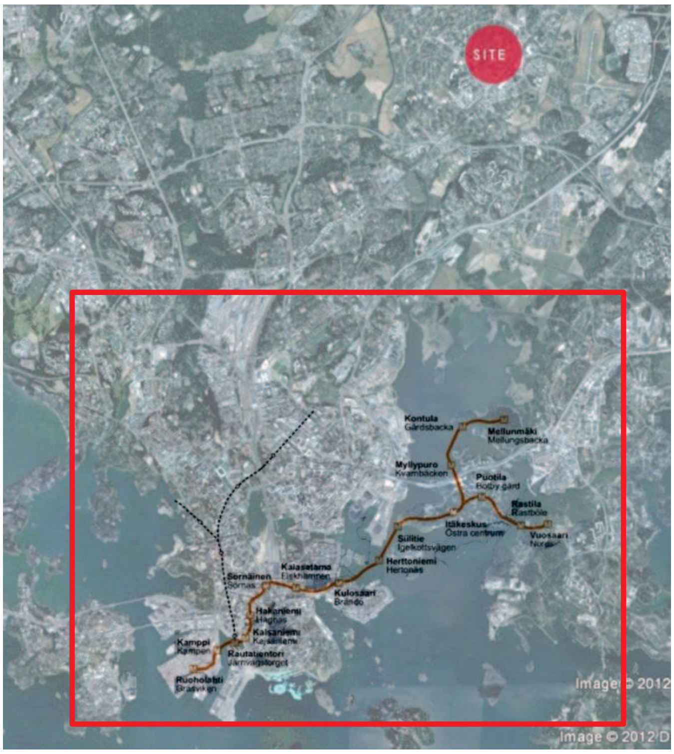


Figure 1.32— Metro Map

Figure 1.33— Zoomed Metro Map

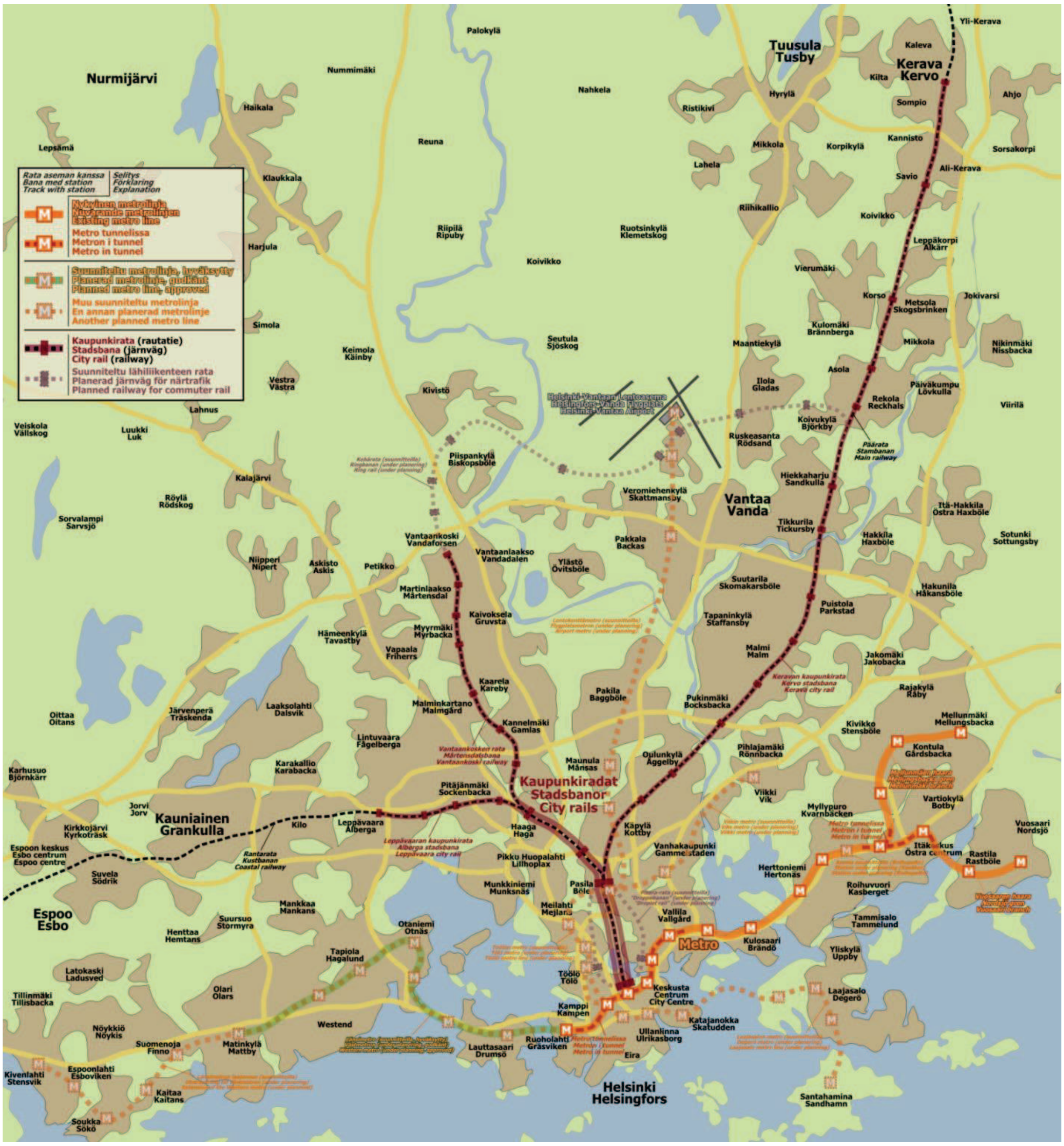


Figure 1.34— Future Plans Map

1.4.4.3 Train

Trains depart from the Central Railway Station and Pasila (Böle) station to destinations across Finland.

Pendolinos offer higher speed (up to 220 km/h) connections to major cities, as do Intercity and Intercity trains at slightly slower speeds, and regional and suburban trains cover all of the capital region and smaller cities and towns as far north as Riihimäki and Lahti, and as far west as Karis (Karjaa). A tunnel has been proposed to connect Helsinki with Tallinn, though the proposal is still in the investigation phase.

Ring Rail Line (Kehärata-Ringbanan), a project to connect Helsinki-Vantaa Airport with the national rail network and downtown Helsinki, has been approved and construction should be completed by 2013.

Figure 1.35— Helsinki Train Station

Figure 1.36— Helsinki Train Station

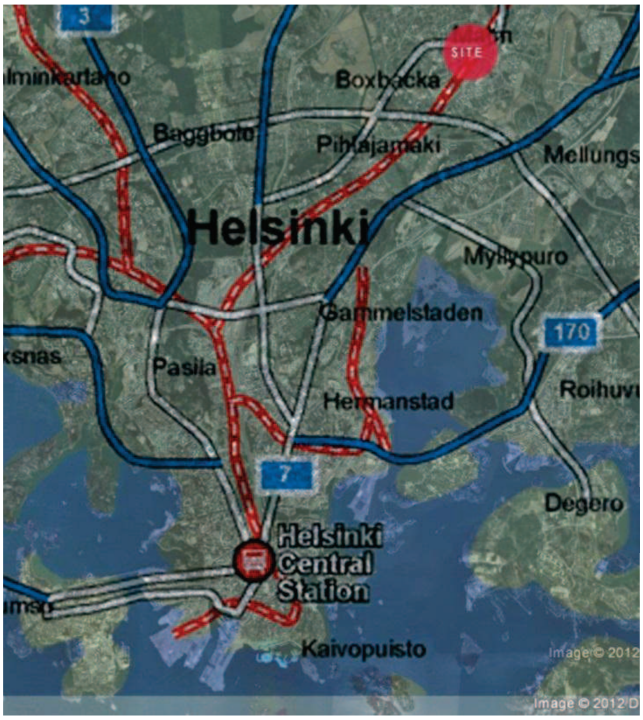


Figure 1.38— Helsinki Train Map

Figure 1.37— Helsinki Train Station

1.5 Malmi

1.5.1 Geography

Malmi is a regional center and a major district on the north-eastern part of Helsinki, Finland.

Malmi (*Malminkaupunginosa*) is divided into six subareas, which are *Ylä-Malmi*, *Ala-Malmi*, *Pihlajamäki*, *Tattariharju*, *Malminlentokenttä* (Malmi airport) and *Pihlajisto*.

Malminperuspiiri is a related but distinct subdivision of Helsinki (used for certain administrative purposes) which does not include Pihlajamäki and Pihlajisto, but instead includes *Tapanila* and *Tapaninvainio*.

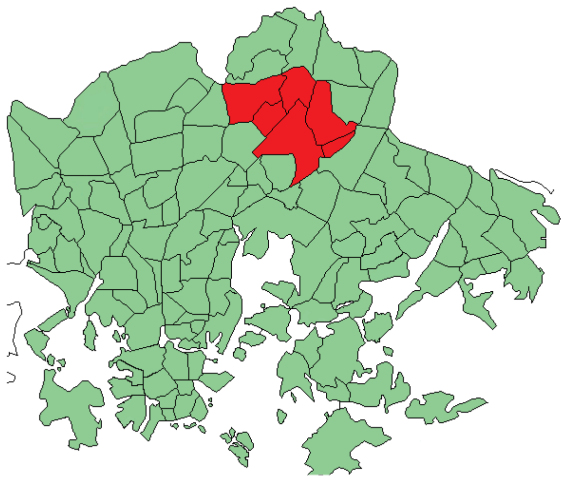


Figure 1.39 -Population change in Helsinki by district jn 2005 -2008

1.5.2 History

1871
The beginning of Malmi, The opening of the railway station in 1871 drew a large number of residents as well as industry to Malmi.
(Malmi cemetery)

1933
First and largest airport of Finland Helsinki City Council decided to locate the airport at Tattarisuo, a swampy area two kilometer east that was known to be extremely poor building ground

1936
Helsinki Airport with its shining white, perfectly round main building became operational in December 1936

1938
Helsinki Airport was officially inaugurated on 15 May 1938 in a ceremony that gathered a huge, proud audience of 25000 people from near and far.

1946
Originally, it served as the center of what was then the township of Helsinki until 1946 when the area was consolidated to the City of Helsinki.

1952
Until the opening of the Helsinki-Vantaa Airport Helsinki Olympic Games in 1952 it was the main airport of Helsinki and all Finland. Today, the airport is still actively used in general aviation and flight raining. It still is the second busiest airport in Finland after Helsinki-Vantaa Airport, as measured by the number of landings.

1953
The period following the consolidation to Helsinki also saw the beginning of new zoning projects: the west side of the railway tracks (Malmi, Tapaninkylä) received its first town plan.

1972:
Second district center of Helsinki
the City Council resolved that Malmi would be designated as the second district center of Helsinki, which sparked a new zoning process in the Malmi district. The new railway station over the railway tracks was completed in 1986 and was connected to the pedestrian and bicycle ways on both sides of the tracks with bridges. The most important commercial and public services were positioned around the squares at the ends of the bridges. Office buildings were constructed along the roads flanking the main railway line. Later development of the district center has followed along these lines. As was the case with the first town plan, the new plan took into account the existing network of streets, which is why Malmi took its current form. Additionally, conscious efforts were made to preserve as much of the old building stock as possible.

2012
Heart of north-eastern Helsinki
After the consolidation, Malmi became, for all practical purposes, the heart of north-eastern Helsinki, which has been its role to this day. Today, Malmi is also one of the two district centres in Helsinki.

1.5.3 Climate

Helsinki's climate is typical of its northerly situation. Its intermediate climate combines characteristics of both a maritime and a continental climate. The proximity of the Arctic Ocean and the North Atlantic creates cold weather, while the Gulf Stream brings in warmer air.

Seasons
The summer in Helsinki is bright. The days are at their longest in the second half of June, when the sun stays above the horizon for 19 hours.

The evenings grow cool towards the end of September, and the days grow noticeably shorter as winter approaches. The crisp air is spiced with the colors of the splendid autumn foliage.

The winter begins in either November or December depending on the year. The temperature fluctuates either side of 0°C. The first snowfall makes the city look picture perfect. The average temperature between December and February is around -4°C.
The coldest time of the year is usually at the end of January, when the mercury can fall to below -15°C and the ground is covered by snow. The sea usually freezes over in the heart of winter.

The lowest temperature ever recorded in Helsinki was -34.3°C in 1987.
If the winter is sufficiently cold, the splendid Northern Lights or Aurora Borealis that can often be seen in Northern Finland make an appearance in Helsinki.
Spring arrives in Helsinki usually sometime in April. The days grow rapidly longer and warmer, attracting people to the city while the nature blossoms all around.

Average temperatures in Helsinki

- entire year +5.0°C
- warmest month, June +21.7°C
- coldest month, January -10.4°C

1.5.4 Transportation -Malmi

Malmi has comprehensive transport system including its own railway station and an airport. There is no tram Transportation but its planned in the future plans.

Buses, Train, bicycles are the main transportation elements. Since Malmi is a small city, there were no documents found to show different routes of bicycles, bus and trains. We worked on the analysis of these transportations in our site which will be provided in next chapter.

1.5.5 Population

The population of this area is approximately 27,800.

1.5.6 Building Architectural Style

In the interview with the municipality of malmi. They stated that it is allowed for anyone to design a building even if he/she doesn't have a degree. That's the reason that the buildings are not consistent in the design but have homogenous materials and heights

Since Malmi is an industrial city, most building types of buildings are commercial, residential, industrial, public services.

In figure 40, is shown a commercial building using red bricks material.

Figure 1.40

In figure 41, is shown a cultural center aslo using the red brick material, steel
And Glass.

Figure 1.41

In figure 42, is shown a bridge connection between commercial buildings using glass and steel.

Figure 1.42

As shown in figures 43, 44 are examples of residential buildings that have the same red bricks materials.

Figure 1.43- Residential Buildings

Figure 1.44- Residential and commercial

As for the residential building in figure 45, glass and paint were used
But still they are homogenous with the other surrounding materials.

Figure 1.45- Residential Buildings

1.5.7 Vegetation

Finland is the most densely forested nation in Europe, the majority coniferous. Trees include pine, spruce and birch. There are over 1,200 species of plants and ferns and 1,000 varieties of lichens. Many herbs grow wild in the fields of Finland including: thyme, alliums, yarrow and hops.


Figure 1.46 - Coniferous

Maximum 80 meters


Figure 1.47- Spruce

Up to 30 meters


Figure 1.48- Pine

Up to 20 meters


Figure 1.49- Birch

Up to 30 meters


Figure 1.50 - Thyme

Up to 0.5 meters


Figure 1.51 - alliums

Up to 1.5 meters


Figure 1.52 - Yarrow

Up to 1 meter


Figure 1.53- Hops

Up to 7 meters

1.6 Interview with Municipality

Elias Rainio is urban planner at Helsinki City Planning Department. Working with urban renewal of suburban areas. One of his main goals is to develop and activate areas nearby public transport, such as the Malmi station.

Elias has past experience on development of similar size transit areas. We have asked Elias about the identity of malmi, and problems concerning the area.

Elias Rainio was also one of jury in the competition and he is really concerned about malmi and its identity.

Figure 1.54-Architect
Elias Rainio
City planning
department

Also we had the opportunity to Mrs. Maria works in the Municipality of Malmi, introduced t us history about Malmi and its station. We went with her in a site tour in the site and its Surroundings

Figure 1.55- Maria
City planning department

The interview was held in the site, we walked in the site and in the surrounding areas of the train station. It was very helpful to understand the experiences that people pass through and the difficulties that people suffer from. We also understood the difference between Helsinki and malmi.
As a summary of the interview, we concluded the following:

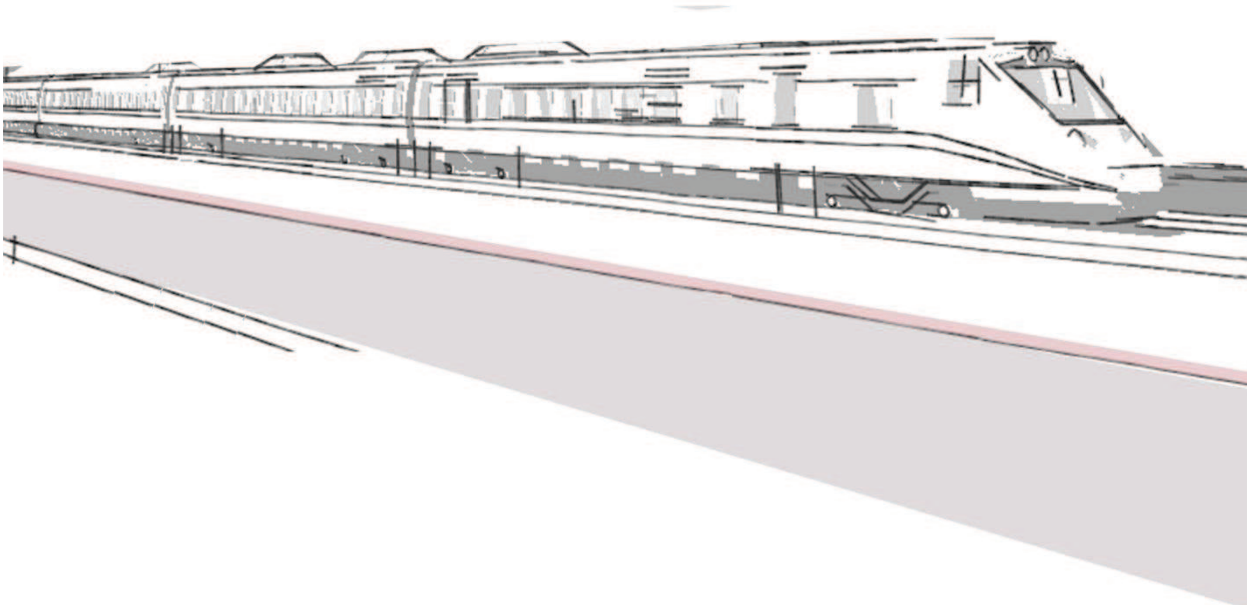
- The train station is owned by three different companies which is always hard to get an approval to change something.
- Malmi is divided to “Yla Malmi” and “Ala Malmi”(old and new malmi) , where the tracks of the trains separate them form each other by 100 m
- There was a funeral train arrives to a grave yard which is considered the largest grave yard in Helsinki
- There used to be an old station that is now used as a glass factory, but it’s in a very bad condition and the municipality is thinking to do change the function as a bicycle parking.
- In winter the people waiting for the train on the platforms suffer from a high speed wind.
- It is very difficult to get people to buy from merchants and it’s a new activity in finland.
- There should be parking places with any new building built by law.
- There is no actual ticket office, and people always gets confused from where to buy the ticket

- The road that has the drop off for the buses is a very important road that exists from the past, and there is a new transportation bus lines is going to be established.
- There is an abandoned platform that needs to be reused with an activity.
- Indoors activities are more important than outdoors because of the weather.
- Malmi has always been as a big center.

1.7 Our Project Goals

- Merging ala Malmi and yla Malmi
- Redefinition of the Malmi train station
- Creating new experiences for the users
- Redefinition of street markets
- Introducing new technologies
- Redefinition of the Malmi train station as a the new city center
- Rehabilitation of the cultural activities both indoors and outdoors

2.0 URBAN DESIGN



2.1 History of urban development of the site and its surroundings

2.1.1 Urban development

Before the Second World War, Malmi was a part of vanta.

In 1946, malmi became a part of Helsinki to be an independent as an industrial agriculture city.

Malmi used to be divided into agriculture lands and farms. They used to have a very small railway (Red line) in 1883 as shown in figure 2.1.

As was shown in the introduction chapter Malmi is situated between Helsinki and Vantaa, a main road connecting both pass on our site which is over the rail way station " kirkonkyantie" indicated on figure (yellow line).

Figure 2.1

Our Site

Main Road Connecting Vantaa and Helsinki passing through malmi

Railway

Figure 2.2

In 1887 main railways has been established.

Our Site

Main Road Connecting Vantaa and Helsinki passing through malmi

Railway

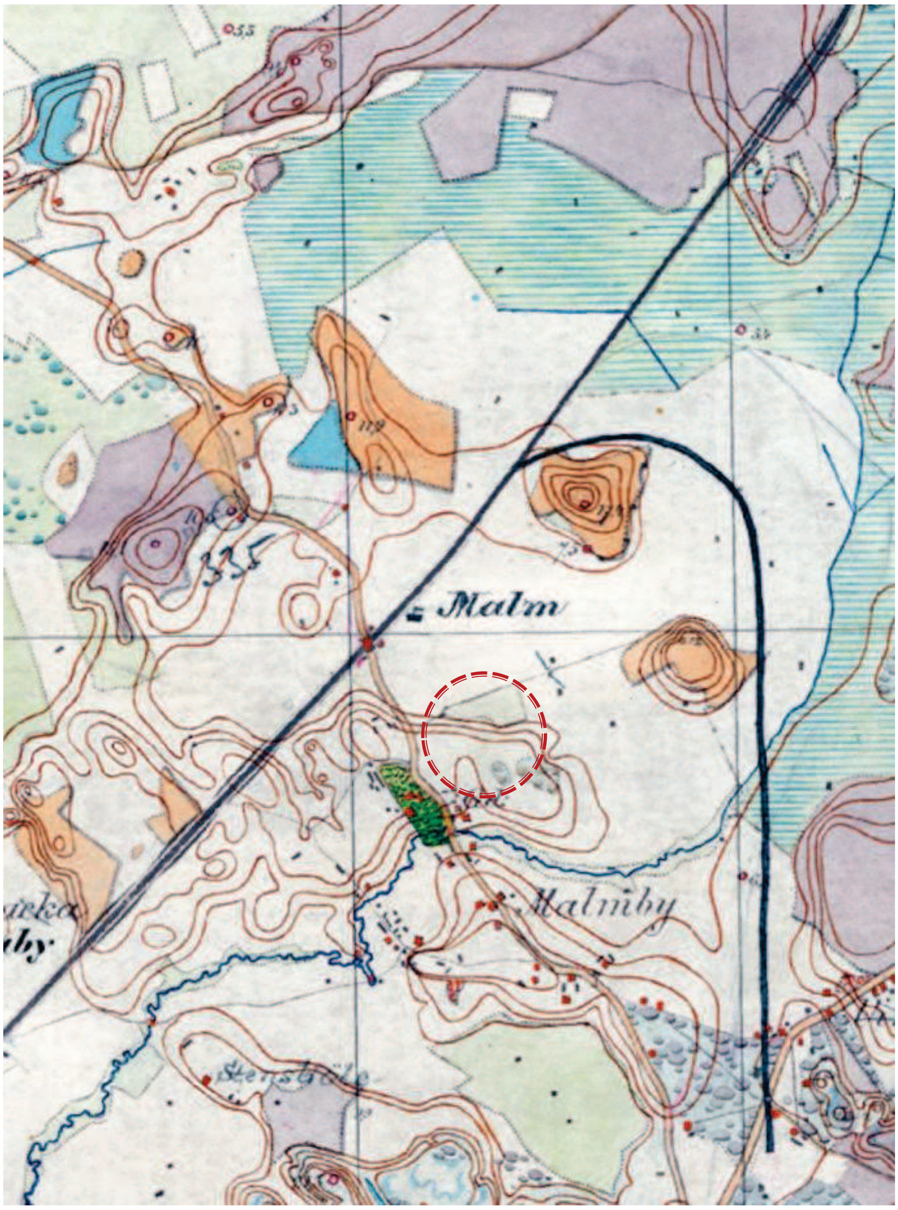


Figure 2.3 -1872 Train Station

Figure 2.4 - Train Station

In this map figure 2.5, more urban development in malmi occurred that allowed us to trace our existing site in urban and architecture, tracing also the two main elements that was seen in all the historical maps (railway and the main road)

In 1933 there was a funeral train that arrives to the main grave yard, but it doesn't exist now although still this graveyard is considered the biggest one in Finland.

Train Station Building

Urban Site

Architecture Site

Main Road Connecting Vantaa and Helsinki passing through malmi

Railway

Figure 2.5 – 1933 map

Figure 2.6

In 1933 a building was established as the station, but now this building is glass factory and it is in a very bad condition.

In figure 2.7, it shows the main road that was mentioned before. Also it shows the separation that occurred in malmi due to the train station. It divided malmi into two parts Ala Malmi and yala malmi with 100 m

Figure 2.7

2.1.2 Current Condition

In figure 2.8, it is shown the current condition of the site noticing the two main elements that we saw in the previous maps which are
The railway station and the main road

Railway

Main Road

Figure 2.8 – Current Condition

2.2 Site Analysis

2.2.1 Site Surroundings

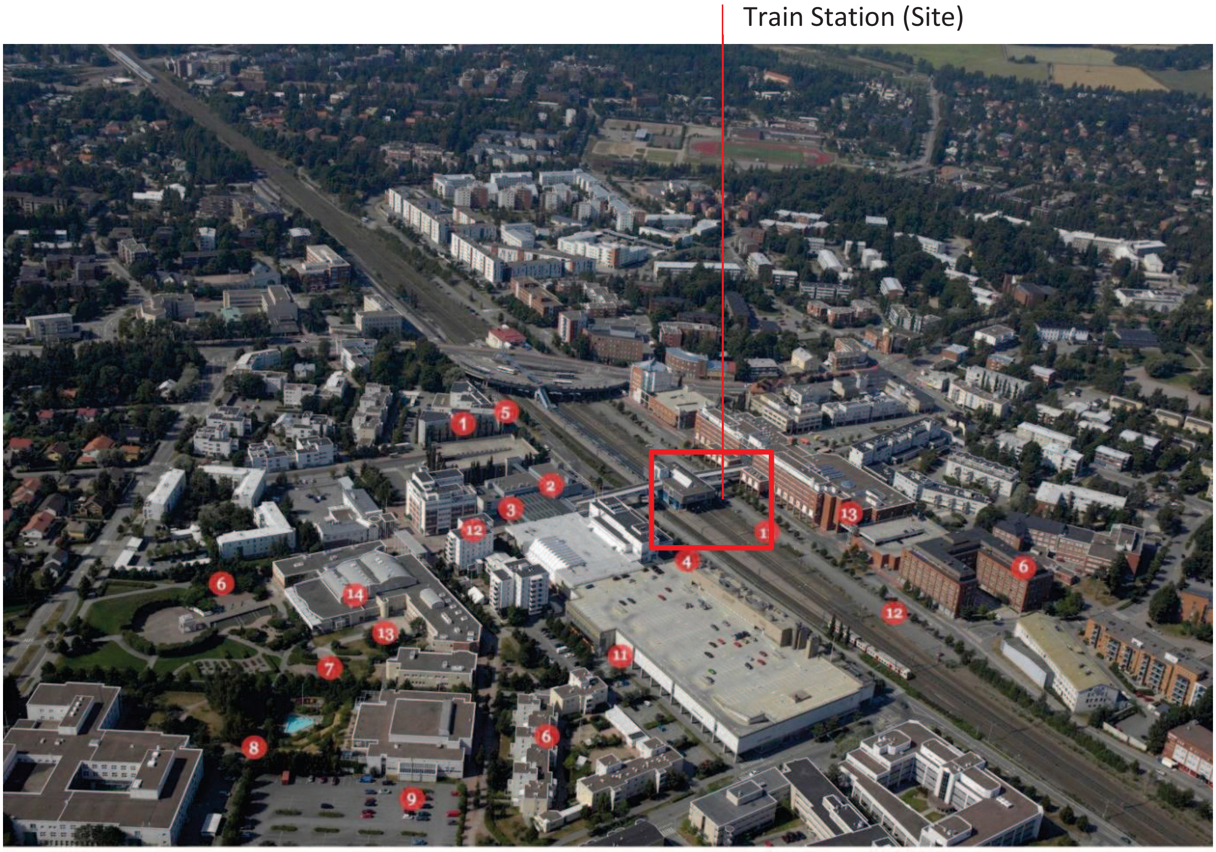


Figure 2.9- Site Surroundings

2.2.2 Site Boundaries

The Competition Site boundaries are as shown in figure the white dotted line.

We decided to enlarge the borders of the site for urban considerations.

Competition Site Boundaries

Our Boundaries

Architecture Site (Train Station)

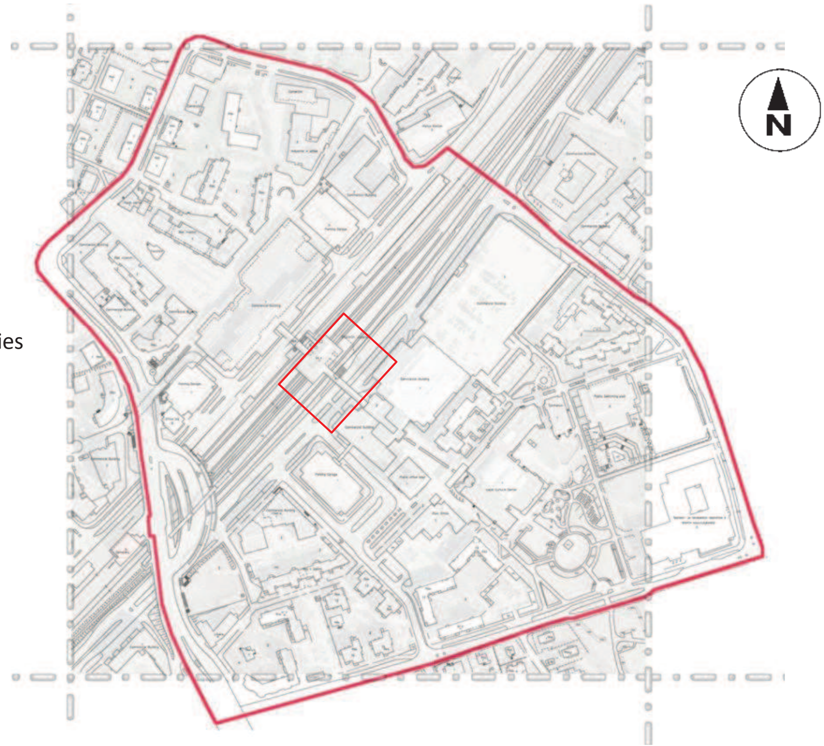


Figure 2.10- Site Boundaries

2.2.3 Existing Site analysis

2.2.3.1 Urban Fabric

Tracing the urban fabric of the site lead to the understanding that there wasn't a consistent fabric for the area, and that was due to the presence in the past of fire that lead to the loss of the fabric.

The undefined fabric caused a lot of lost spaces within the buildings. It is also shown in figure 2.11 that the railway caused more problem of the un integrated fabric and the loss of connection.

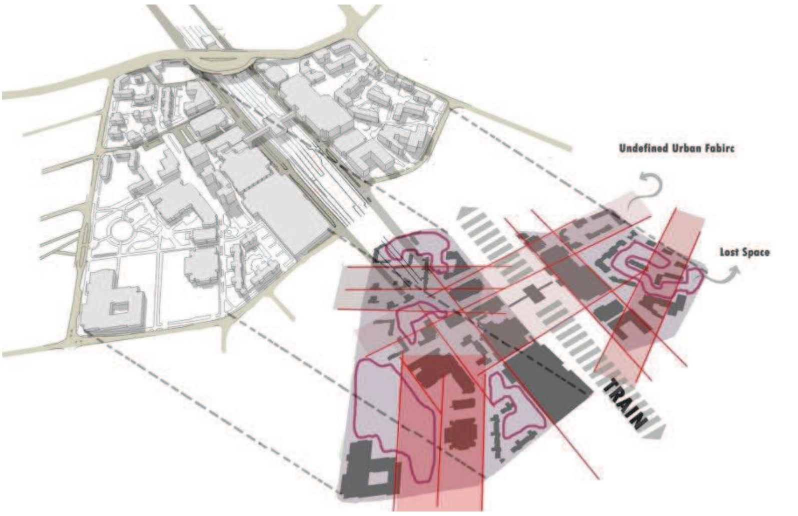


Figure 2.11- Urban Fabric

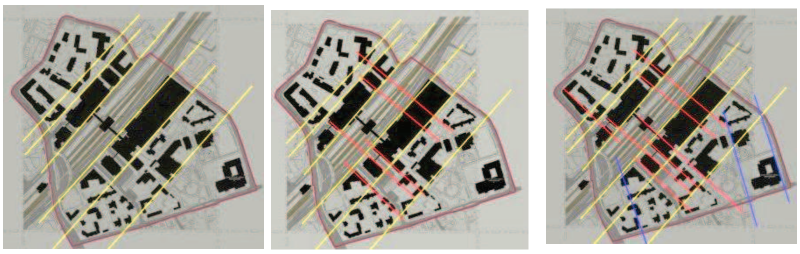


Figure 2.12- Tracing of Urban Fabric

2.2.3.2 Solid & Void

The analysis of solid and void explain the spaces within a building and an open space.

The space between two solids it is passive, and when it occurs as a removal, or subtraction, from a solid, the void is active.

In figure 2.13, it shows the different spaces within the solids

Figure 2.13- Solid and void

2.2.3.3 Greens

Figure 2.14- Greens

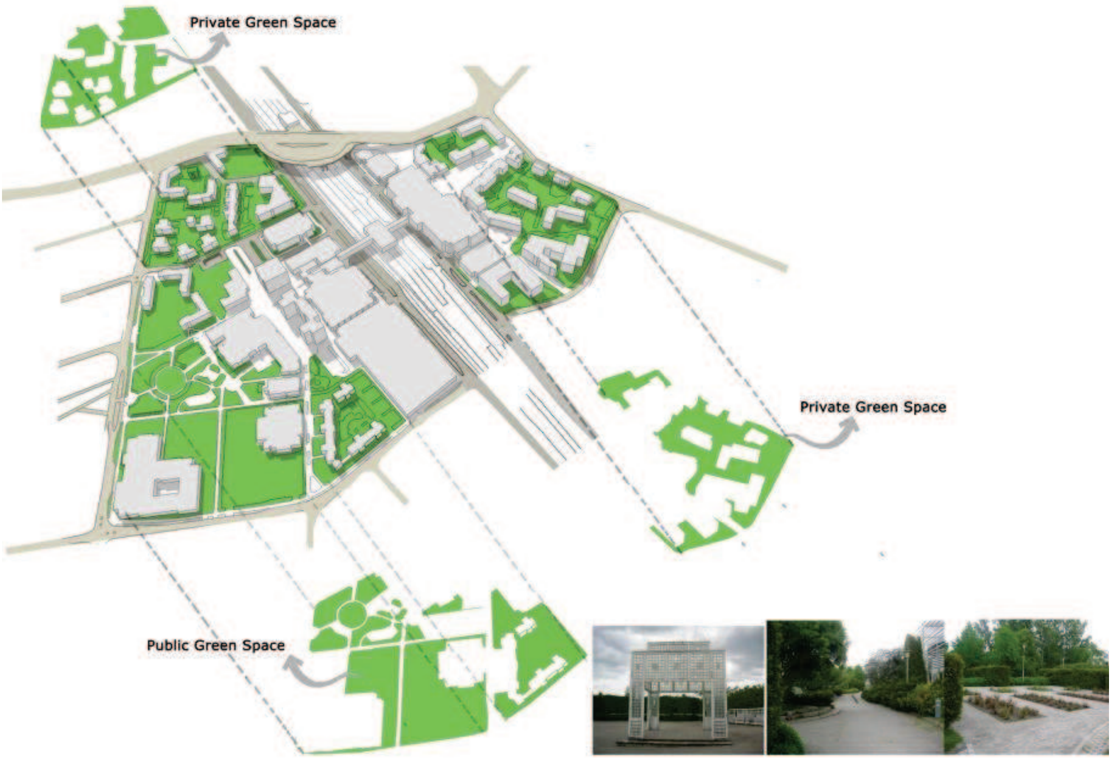


Figure 2.15- Greens (Public and private)

2.2.3.4 Pedestrian

Figure 2.16- Pedestrian

2.2.3.5 Mobility

Bus

Pedestrian

Bicycle and cars (Separate lanes)

Mobility around the train station in figure 2.17 shows a good flow around the station.

All kinds of transportation surrounds the railway station to arrive the railway station very easily, but the problem arriving to the station approaching the city it is not linked very well.

Figure 2.17- Mobility

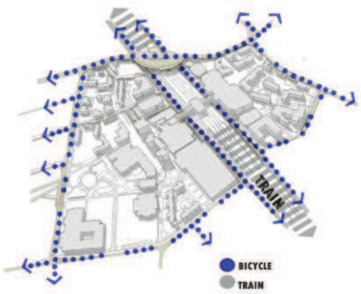


Figure 2.18- Mobility

Figure 2.19- Mobility

Figure 2.20- Mobility

For the bus line, it arrive the drop off and directly access the platform in a very primitive, uninteresting flow.

There is a lot of pedestrian areas but also the problem of the railway separates the flow of the people. It is true that there is a connection above the railways but it is in a very bad condition and most homeless people sit their which is a very new phenomenon in Finland they want to avoid.

2.2.3.6 Arrivals to the station

2.2.3.6.1 Arrival by Bus – Bus Drop Off

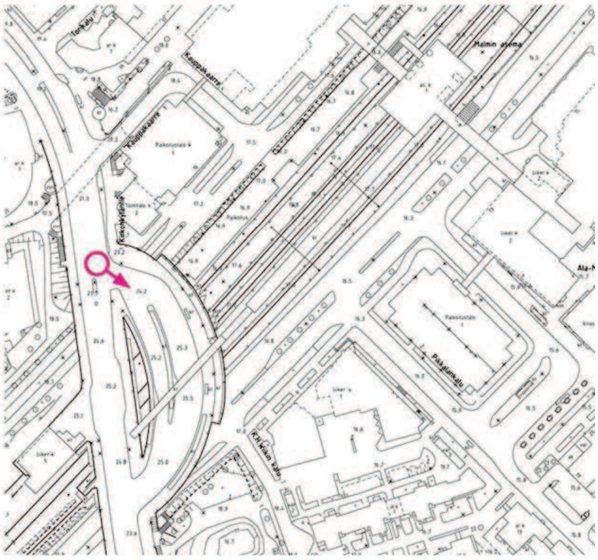


Figure 2.21- Arrival by Bus (drop off)

Bus Stops on the high way bridge over the train station, the bus drop is running efficiently.

The design style is not integrated with the train station. We are thinking to redesign the bus drop to take full use of it and merge it into the new train station plan

Canopies over the connection between stops
Escalator from bus drop to the train station

Figure 2.22- Bus drop off

Figure 2.23- Bus drop off

Figure 2.24- Entrance to platform

2.2.3.6.2 Arrival by Train

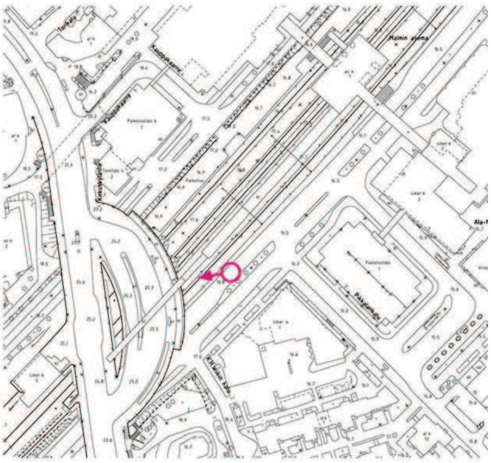


Figure 2.25- Arrival by train

Figure 2.26- Arrival by train

Figure 2.27 Building bore by the railway

Figure 2.28- Platform

Figure 2.29- Relation between drop off to platform

2.2.3.6.3 Arrival by Car

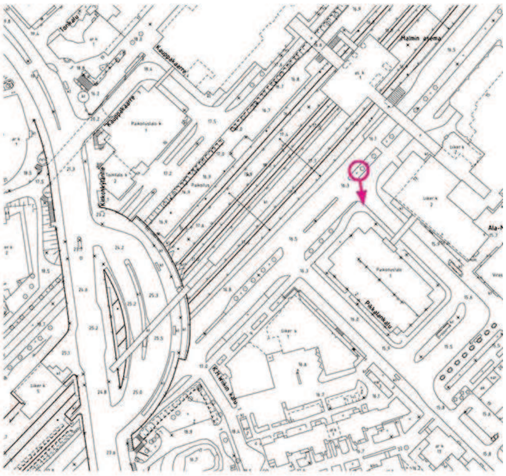


Figure 2.30 Arrival by car

Figure 2.31

.There is another platform for the old train station now is abandoned

Figure 2.32

Figure 2.33

2.2.3.6.4 Arrival by Bicycle

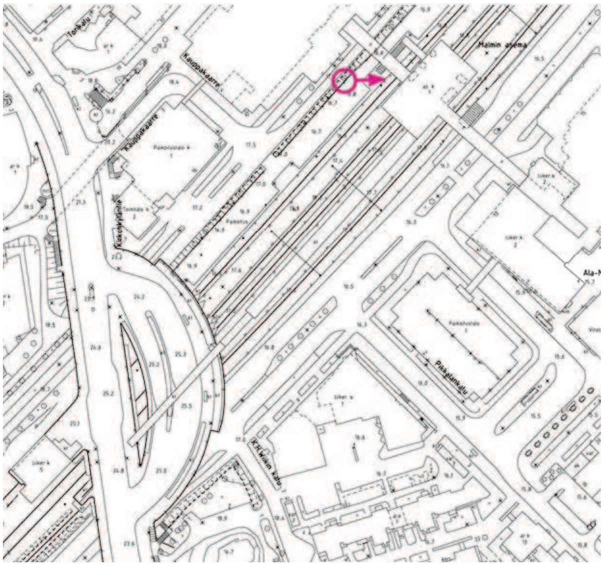


Figure 2.34 – Arrival by bicycle

Figure 2.35

Figure 2.36

Figure 2.37

Figure 2.39

Figure 2.38

2.2.3.6.5 by Foot

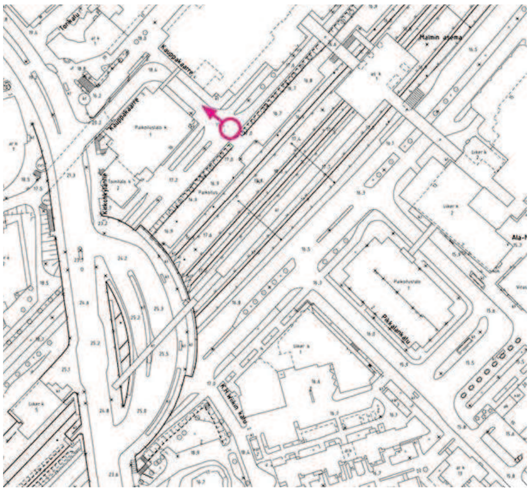


Figure 2.40 – Arrival by foot

Figure 2.41

Figure 2.42

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2.2.3.7 Land use

Figure 2.43 - Landuse

2.2.3.8 Nodes

As shown in figure 2.44 , there are there main nodes on the same axis of the train station
Node 1 : M ain piazza

These three nodes are along the pedestrian area which is a very good opportunity to link them with the train station with the pedestrian area.

Figure 2.44 - Nodes

2.2.3.8.1 Node 1: Main Piazza

1 Statue
2 Bicycle Parking
3 Merchants
4 Commercial building
5 Shops arcade

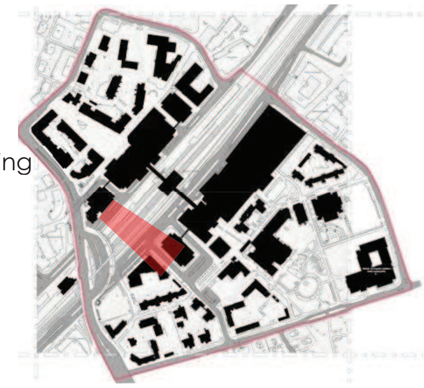


Figure 2.45 – Main Piazza Location

It's the main piazza approaching to the train station through a commercial building. It is located in Ala malmi side .It and represents one of the most important node in the project as it acts as one of the main entrances to the train station.

When we visited the site, we understood Some problems that are summarized in
- unorganized space
- mixed activities
- bicycles parking in the piazza
- Unconnected to surrounding area.

Figure 2.46 – Main piazza location

Figure 2.47 – Bicycle parking and shopping arcade

Figure 2.48 – Floor pattern in the piazza
That we are going to keep for it directionality
To the train station

Figure 2.49 – Sculpture

2.2.3.8.2 Node 2: Small Piazza

1 Fountain
2 Cultural Center
3 Piazza
4 Commercial building

Figure 2.50 – Small Piazza Location

This is another piazza on the other Side of the malmi (yla Malmi). It has a small But it's not working, and there is no Other activities, it represents a Circulation node as it is surrounded By cultural , commercial and office buildings

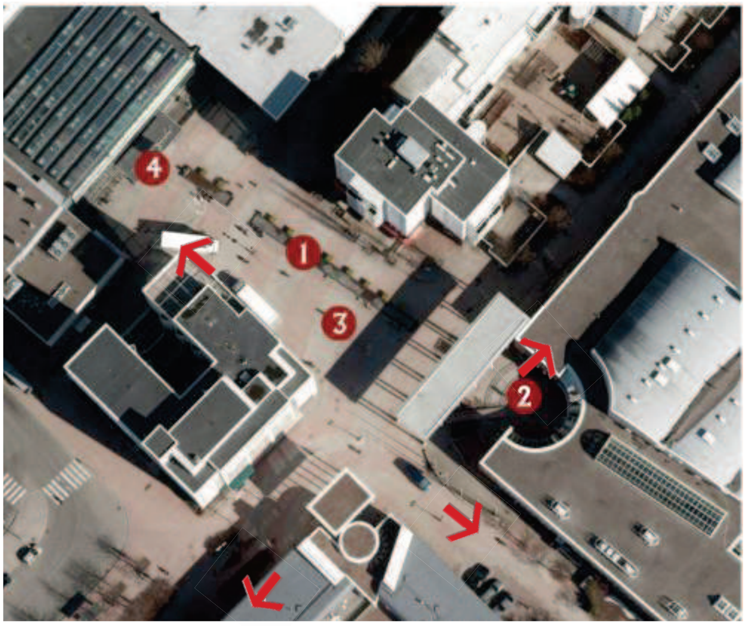


Figure 2.51 –small piazza

Figure 2.52

2.2.3.8.3 Node 3: Park

The last node is the park which is Surrounded by recreational Buildings.

The park has lots of potentials, but Since it has no activities and Disconnected from the pedestrian And the surroundings.

1 Pedestrian
2 Kiosk
3 Carports
4 Indoor Swimming pool
5 Residential area
6 Park

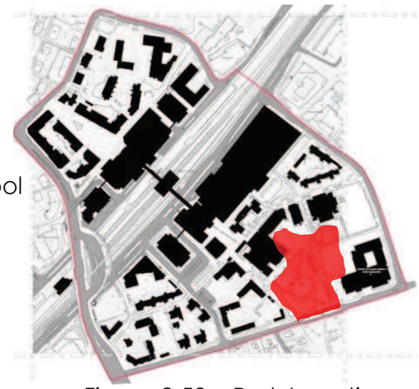


Figure 2.53 – Park Location

Figure 2.54 – Code plan for park

0

Figure 2.55 – Seating areas in the park

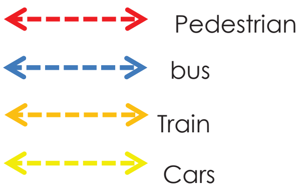
Figure 2.56 – Pathways

Figure 2.57 – Flower boxes

2.2.3.9 Densities

In figure 2.58, it shows people Densities arriving and leaving the train station that highlights again the axis perpendicular to the train Station linking both sides of malmi.

Flow of people's arrival and departure from and to the train with different transportations



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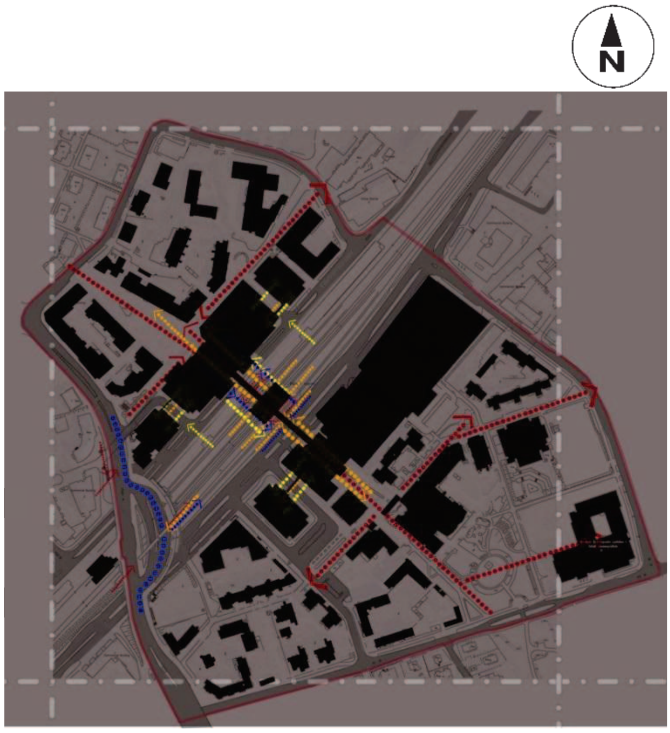


Figure 2.58 – Densities

2.2.3.10 Skyline

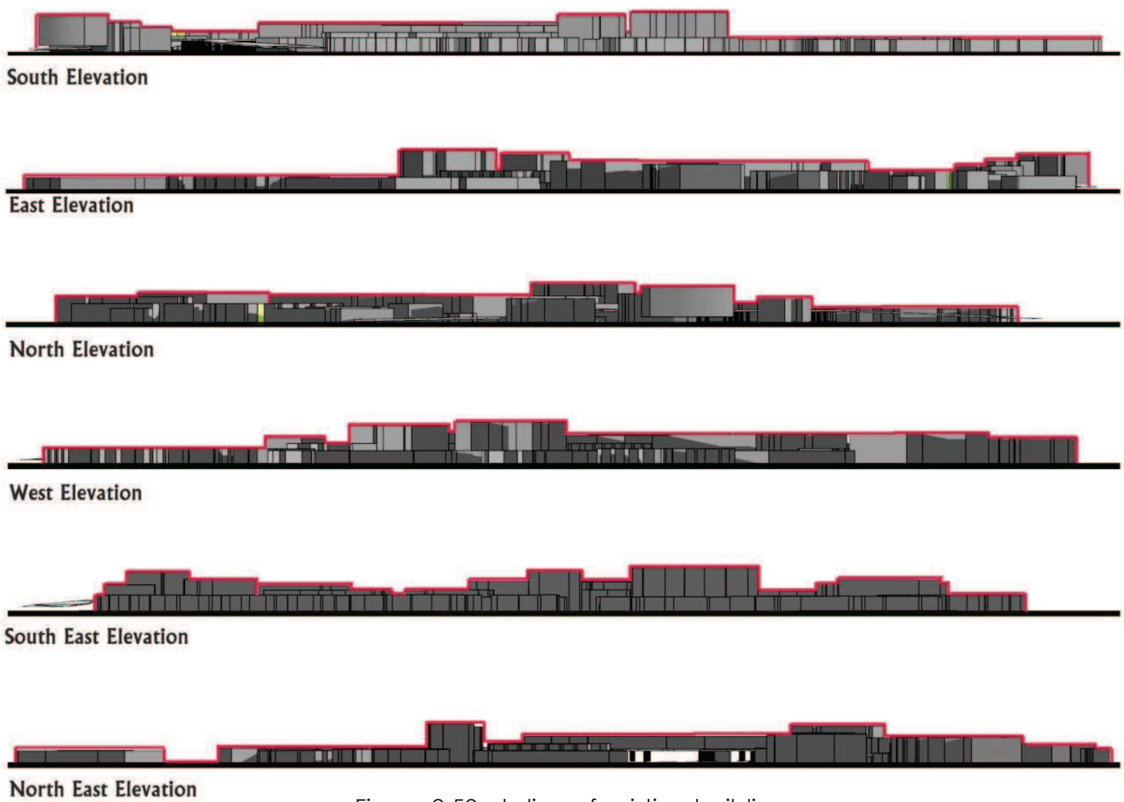


Figure 2.59- skyline of existing buildings

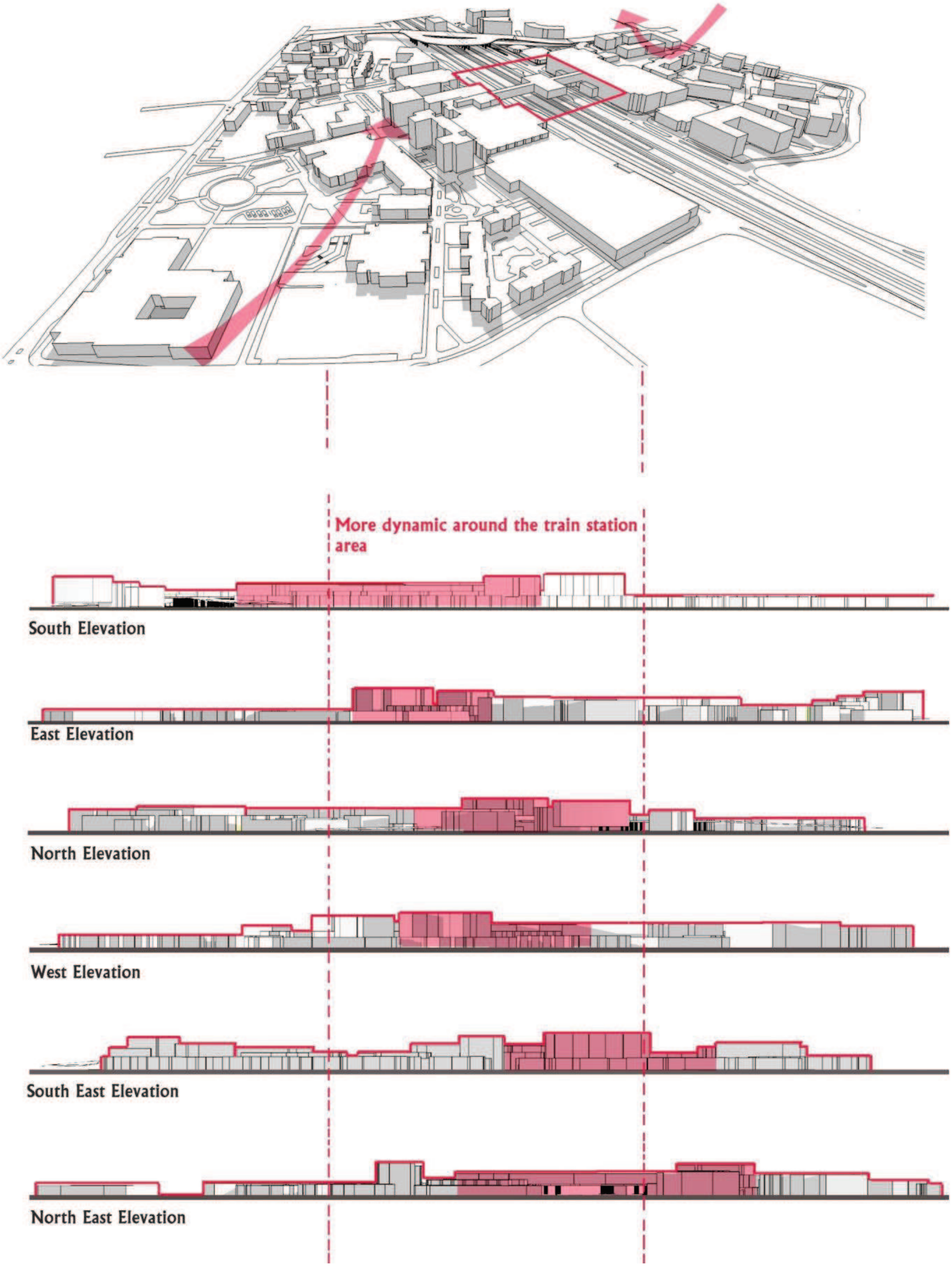


Figure 2.60- skyline Analysis

2.2.4 Summary

2.2.4.1 SWOT Analysis

Figure 2.61Strength map

Strength

- The drop off of the buses is at a higher level +9.00 m above of the tracks.
- Most of the surrounding area around the train station is pedestrian.
- Streets are well designed having lanes for pedestrian, cars and bicycles.
- Residential area surrounding the commercial area.

Weakness

- The area around the old station is abandoned
- The new use of the old station is a function irrelevant to the surrounding area "Glass factory" and it's in a very bad condition
- The core have a lot of entrances from all sides and represents very packed circulation
- Connection to the platform directly without an introductory space
- No space for bicycle parking, and bicycles are located everywhere
- Vendors are located in the piazza and in the bridge connecting the station with the commercial buildings which are unwelcomed from the government and the people
- Railways lead to separation of Malmi to Ala and Yla Malmi.
- Discontinuity of pedestrian
-

Figure 2.62- Opportunity map

Opportunities

- Pedestrian areas
- Park
- Recreational building around the park
- New bus line will be active this year reaches the drop off
- Commercial buildings
- The possibility of designing with the present technology due to the governmental regulations

Threats

- The growth of the separation between ala Malmi and yla Malmi
- The chaos and loss of value due to street venders

2.3.1 The Conceptual Proposal

2.3.1 Theoretical Concept

In phenomenology, the environment is concretely defined as "the place," and the things which occur there "take place." The place is not as simple as the locality, but consists of concrete things which have material substance, shape, texture, and color, and together coalesce to form the environment's character, or atmosphere. It is this atmosphere which allows certain spaces, with similar or even identical functions, to embody very different properties, in accord with the unique cultural and environmental conditions of the place which they exist.
The man-made components of the environment become the settlements of differing scales, some large - like cities, and some small - like the house. The paths between these settlements and the various elements which create the cultural environment become the secondary defining characteristics of the place.
The distinction of natural and manmade offers us 3 steps:

1. The phenomenological approach.
2. Qualification of inside and outside, or of the relationship of earth-sky.
3. Assessing character, or how things are made and exist as participants in their environment.

2.3.1.1 The phenomenological approach

The quality or nature of a given experience is often referred to by the term **QUALIA**, whose archetypical exemplar is "redness". For example, we might ask, "Is my experience of redness the same as yours?"
That's why in our concept we decided to activate an operative process that interprets the city not through our eyes but through the eyes of others (users)
Having different types of users between:

- <u>Categeory1</u>: the users living in Malmi and pass through the station to reach another destination,
- <u>Categeory2</u>: the visitors coming from other destinations ,
- <u>Categeory3</u>: the transit users who are staying in the station for short period
- <u>Categeory4:</u> the users who work in the station every day.

The interpretation becomes rich with two new elements:

<u>First: Speed</u> which is based on the time spent by the user in the station and thus the amount of details absorbed by the conscience. For example, if we consider user in cat.3 whose time spent in the station is relatively short spent between waiting areas, shops or sometimes just the platforms, in this case, the <u>qualia</u> of this experience for the user is brief and can only be perceived by quick direct messages, on the other hand, the user from cat.1, the qualia of his experience can turn into a full transformation of space and lifestyle, as the time spent in the project is long enough to capture the qualia of most of the project if not all.

<u>Second: Knowledge</u> which is not based on the categories of users with respect to their destination, but on their age group. For different generations have different expectations of a given space which are results of growing knowledge of and therefore different reactions in the behavior or lifestyle.

2.3.1.2 Qualification of inside and outside, or of the relationship of earth-sky

The material expression of the human life-world is constructed by establishing patterns oriented through, and by, the earth-sky relation.
Human socio-cultural praxes manifest spatially through establishing the fundamental spatiality, "a level" an equilibrium that is formed through the collusion of the upright posture of the lived-body and the earthly horizon, marking the measure of the earth-sky relation and human experience.
In our concept, the relation between earth-sky is uninterrupted through transitional spaces but with different experiences of the lived body through introducing different activities stimulating the energies of the users with continuous diversity in the vertical dimension of the project through ramps, and the diversity of ideas of the built environment by changing the scenes between man-made materials and green nature within the architecture of the project, so the relation between inside and outside is rich and regenerative.

2.3.1.3 Assessing character, or how things are made and exist as participants in their

Every single element in the space including the user is considered a participant in the perceived qualia of this given space. The body stands between this fundamental distinction between subject and object, ambiguously existing as both. Our concept is how to weave the relation between having the person as a user of space and being a dynamic part of this space.
These assessments of the role of the character in the project is a mutual relation between the user benefiting from a space and performing activities and another user who is attracted to this same environment and maybe the same activity. So in other words creating a successful activity in a space can be as attractive as good architecture attracting users to get involved. Therefor the elements of a space include walls, furniture, roof, sky, greens and users.
the concept of **INTERSUBJECTIVITY** is often used as a mechanism for understanding how it is that humans are able to empathize with one another's experiences, and indeed to engage in meaningful communication about them. The phenomenological formulation of **BEING-IN-THE-WORLD**, where person and world are mutually constitutive, is central here.

2.3.2 Summary

So as a conclusion we realize that a focal point like the Malmi station can be an opportunity to act as a factor with lots of diversities, therefore it's our aim to realize new experiments which can be expressed by creating new forms of belonging through two steps:

First: interpreting the existing complex fabrics through narration process to reflect the identity of existing diverse city, **how it evolved?**

Second: introducing other approaches to rethink the city through eliminating the logical space boundaries formed in our minds. This is expressed by exploring the new unlimited possibilities of the form of a space creating new spaces with new experiences (qualia) and thus raising the question of **how to be involved?**

2.4. Urban Design Proposal

2.4.1 Conceptual Approach

Our conceptual approach is related to the history, the idea that Malmi used to be a united city, and after the railway construction it was divided to two parts. The idea of merging Malmi to have its own identity. Another aspect was realizing that Malmi lies between Vantaa and Helsinki shown in figure that are two important cities complemented the idea of how we can demonstrates the history of the 3 cities.

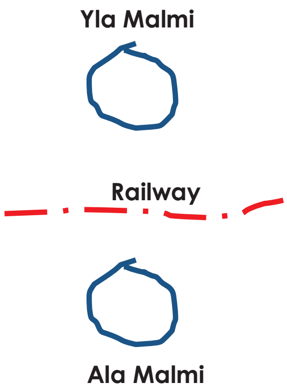


Figure 2.63

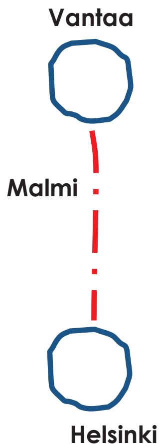


Figure 2.64

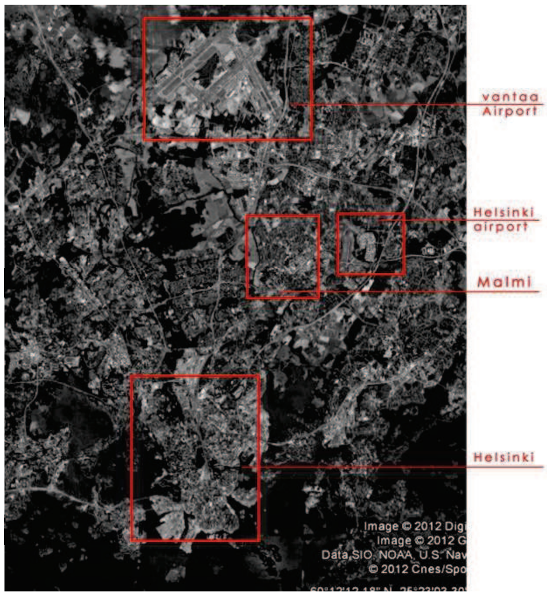


Figure 2.65

Analyzing the two sketches that explain:

- In figure 2.63 , The railway is the intersection point between Ala and Yla Malmi, where combining these two sides form the new qualia "Malmi"
- In figure 2.64 Malmi is the intersection point between Vantaa and Helsinki, where connecting both intersects as well with "Malmi "

Concluding the two sketches, result the figure 2.66

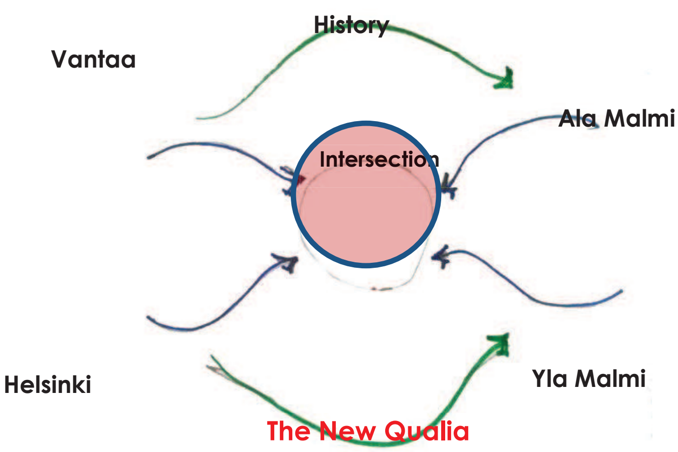


Figure 2.66

As shown in figure 2.67 Demonstrating the connection path in the site using the core of the station is the intersection point that will create the new qualia.

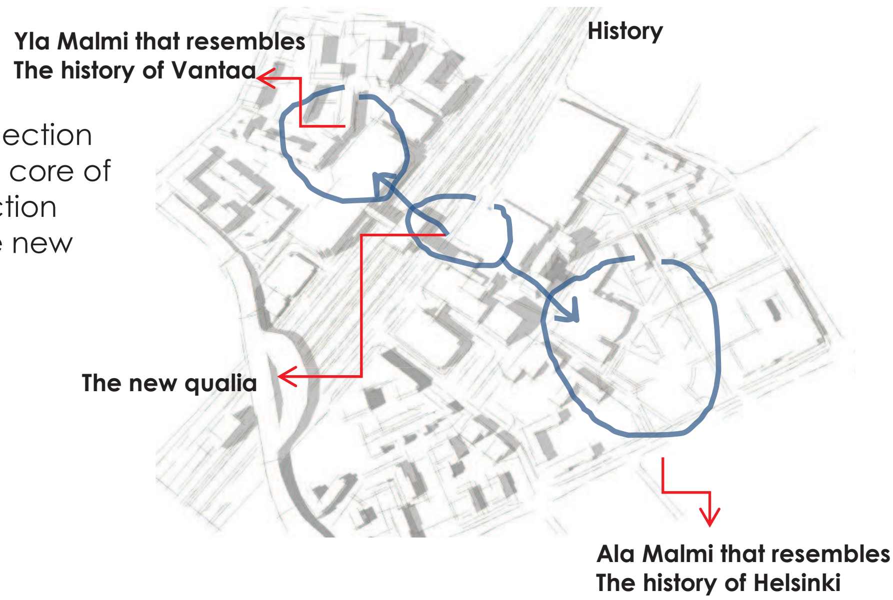


Figure 2.67

As shown in figure 2.68, we noticed that the drop off existed in all the historical maps and it is always the link between Vantaa and Helsinki, that's why we decided to keep it to be one of the main entrances to the new qualia

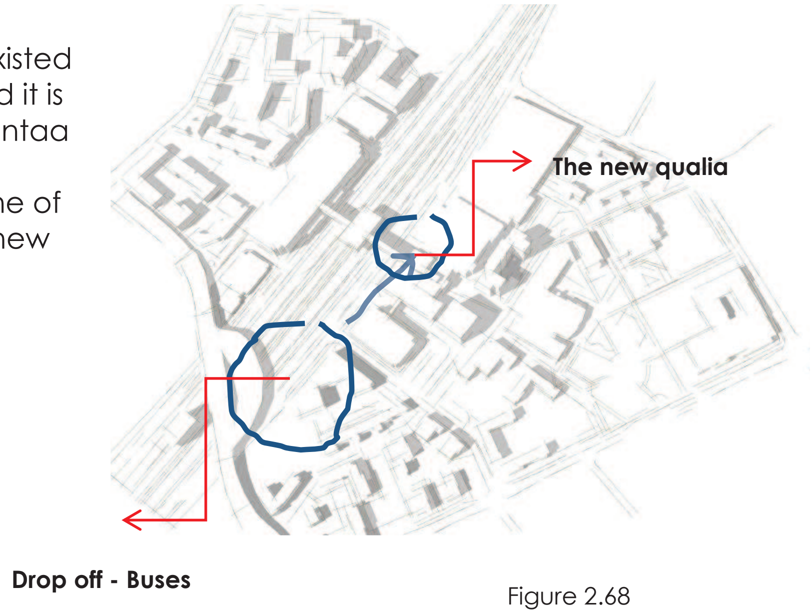


Figure 2.68

2.4.2 Methodology

The methodology achieving our conceptual approach is mainly traced form the existing site in the following steps:

1. Summary

The understanding of the site morphology, nodes, peoples flow around and through the train station, lead to focus on:

A. Four important nodes:

1. Main Piazza
2. Train Station
3. Small Piazza
4. Park

B. Main Road

The high way main road that was seen in all the historical maps And its the link between Vantaa and Helsinki and also direct existing entrance to the train station

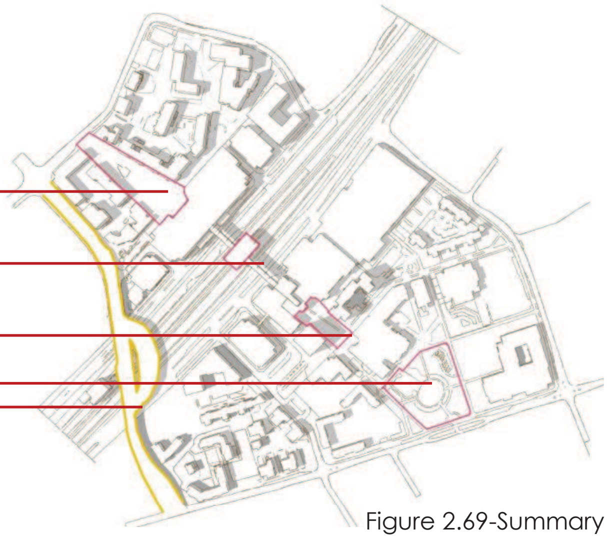


Figure 2.69-Summary

2. Connecting

Accordingly we decided to connect the important nodes in the site and we took the opportunity of two things, first thing that they most of them lie on the same axis, second thing that a lot of recreational activates also lie on the same axis which brought the idea of creating “A Cultural experimental Spine” that the station will be a part of it, a part of the experience that will allow people enjoy their time passing through in transit time, arriving or departure from the station.

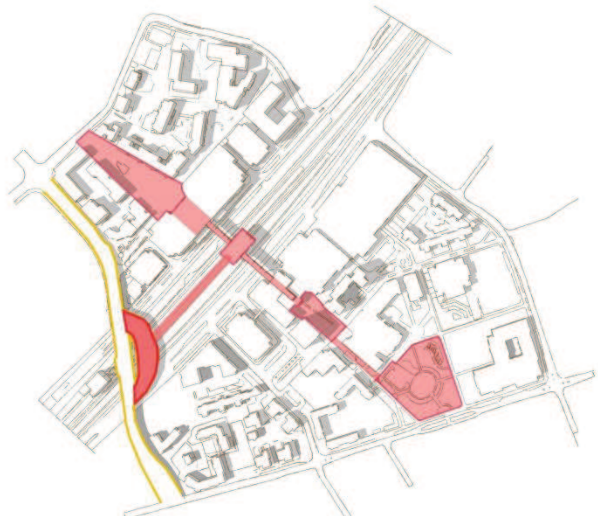


Figure 2.70-Connecting

3. Tracing

Connecting this spine to the surroundings, we traced the existing urban fabric which has a dynamic grid and it was also a good potential of the experience we want to achieve. Also the existing pedestrian areas were good potential to use it and extended to create a pedestrian platform surrounding the train station.

Figure 2.71 - Tracing

4. Merging

Concluding the summary, connecting and tracing, we understood the existing locating of the train station has the best location as it acts as the focal point of the area as shown in figure 2.73, and since the existing station is just acting like a core and it's a circulation building that is in a very bad condition, we decided to remove it and design a new dynamic station that will complete the new culture experience in malmi.

Figure 2.72 - Merging

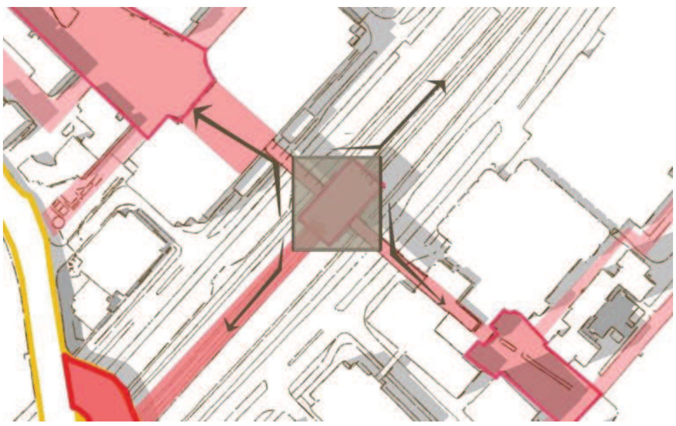


Figure 2.73 – Focal point

2.4.3 Urban Design Proposal

2.4.2.1 Master Plan – Zero Level – Railway Level

2.4.3.2 Master Plan - Level +9

1 Main Piazza
2 Building 1
3 Platform
4 Connection
5 Park
6 outdoor seating
7 Reused building -Hotel
8 Residential Area
9 Museum (Old Station)
10 Residential Parking
11 Railway

Access from Drop off to the Site

Entrances to the spine

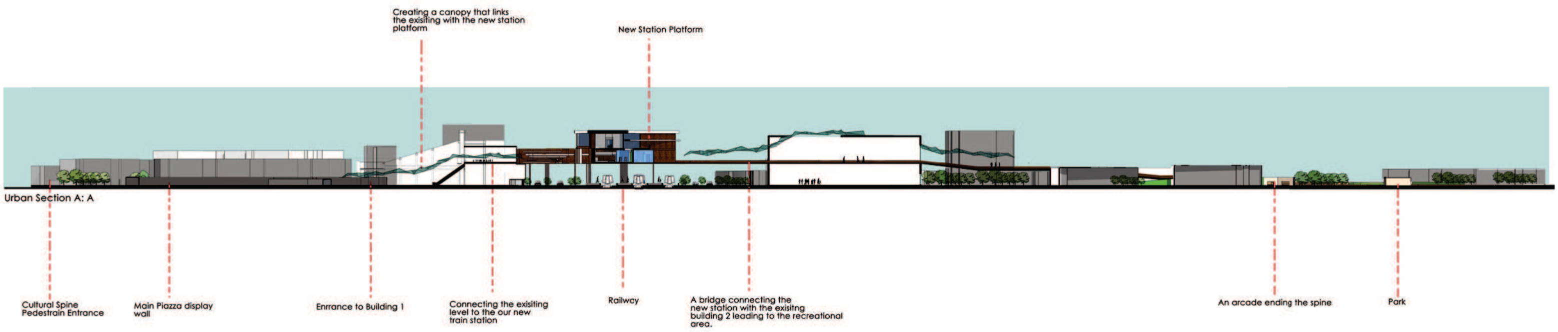
2.4.2.2 Master Plan – +9 Level – The new train station (The new qualia)

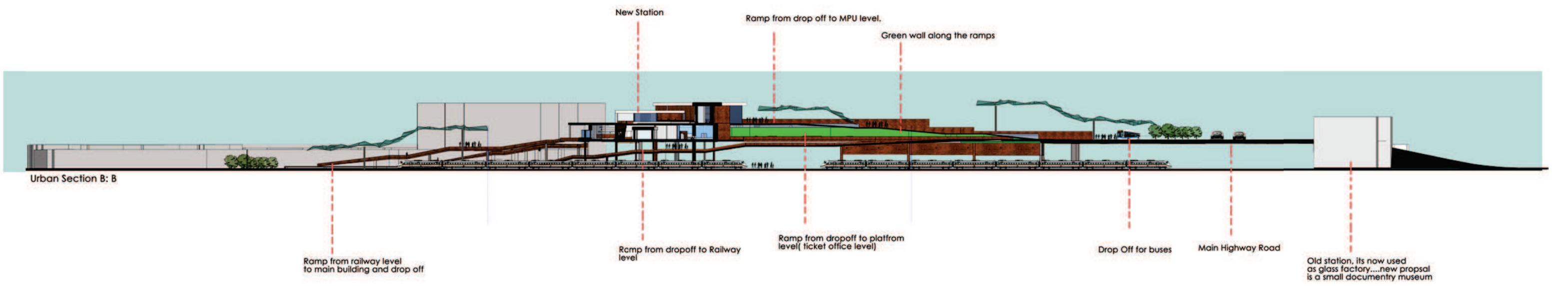
2.4.3.2 Master Plan - Level +9

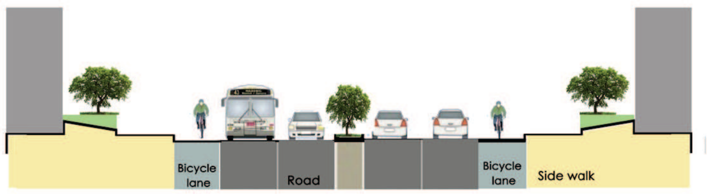
2.4.3.3 Urban Sections

2.4.3.3 Urban sections

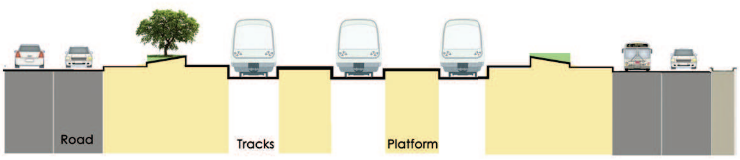
scale 1/1000







road section 2



road section 1

2.4.4 The New Qualia

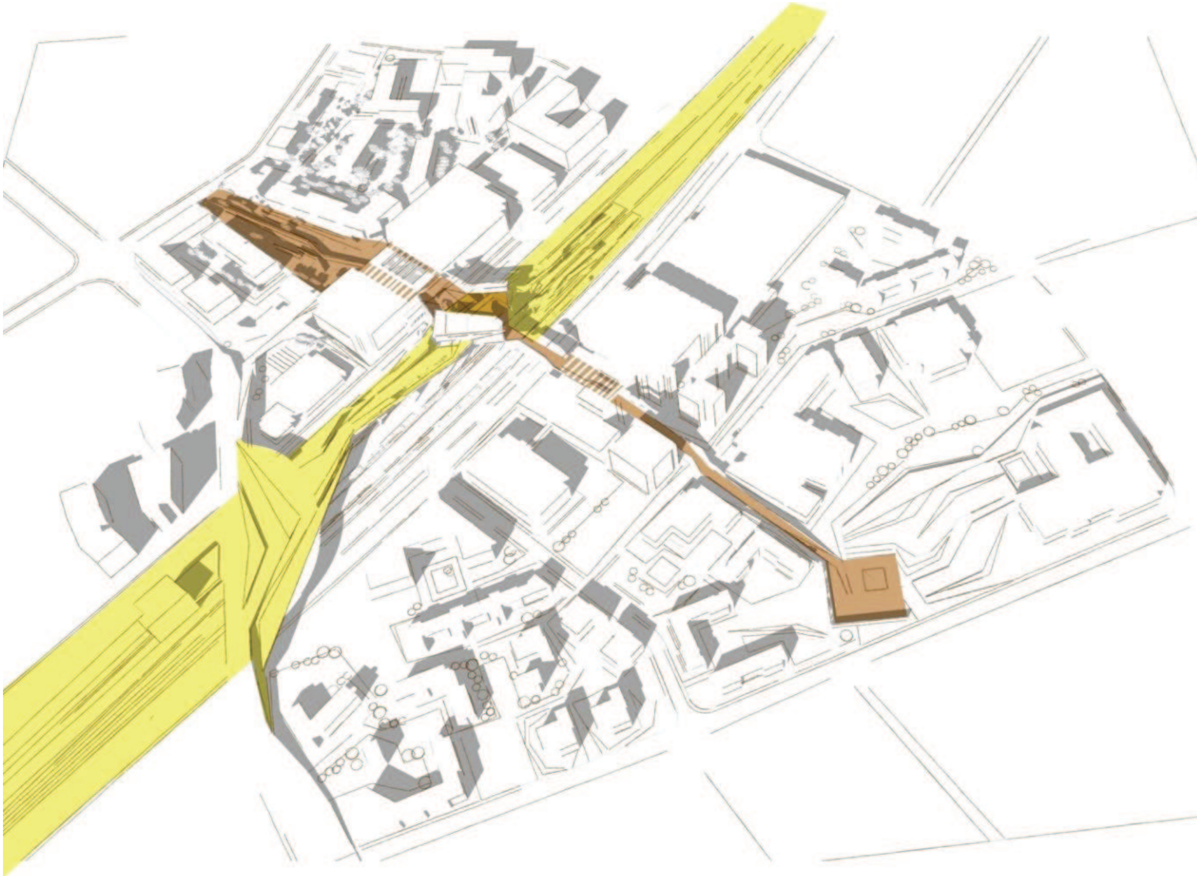
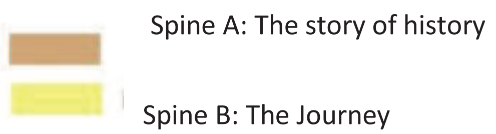


Figure 2.74– Spines codes



The New qualia (the new train station platform) are the intersection of both spines as shown in figure 2.74.

2.4.4.1 Spine A: The Story

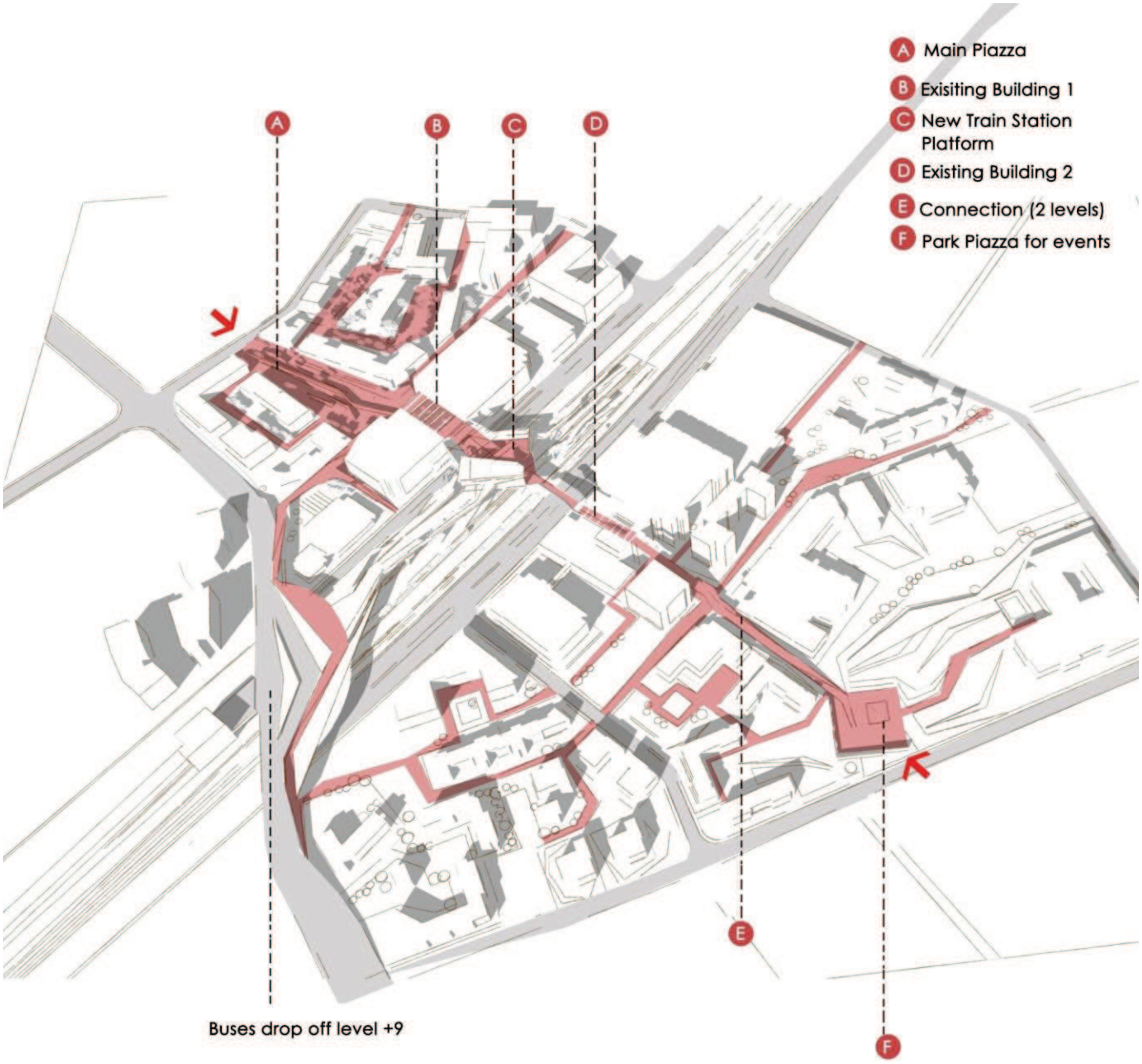


Figure 2.75– Spine A code

A. Main Piazza (History of Vantaa)

Figure 2.76 – Main Piazza Proposal

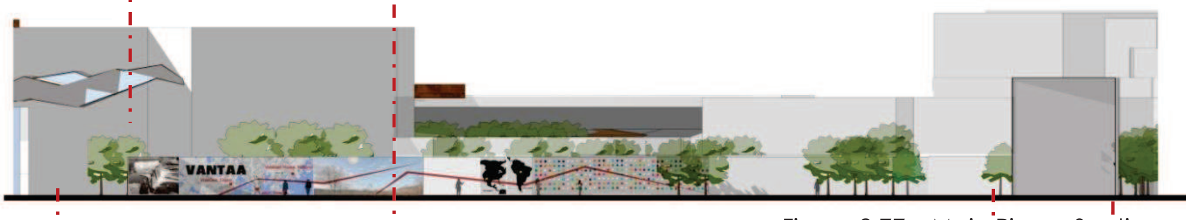


Figure 2.77 – Main Piazza Section

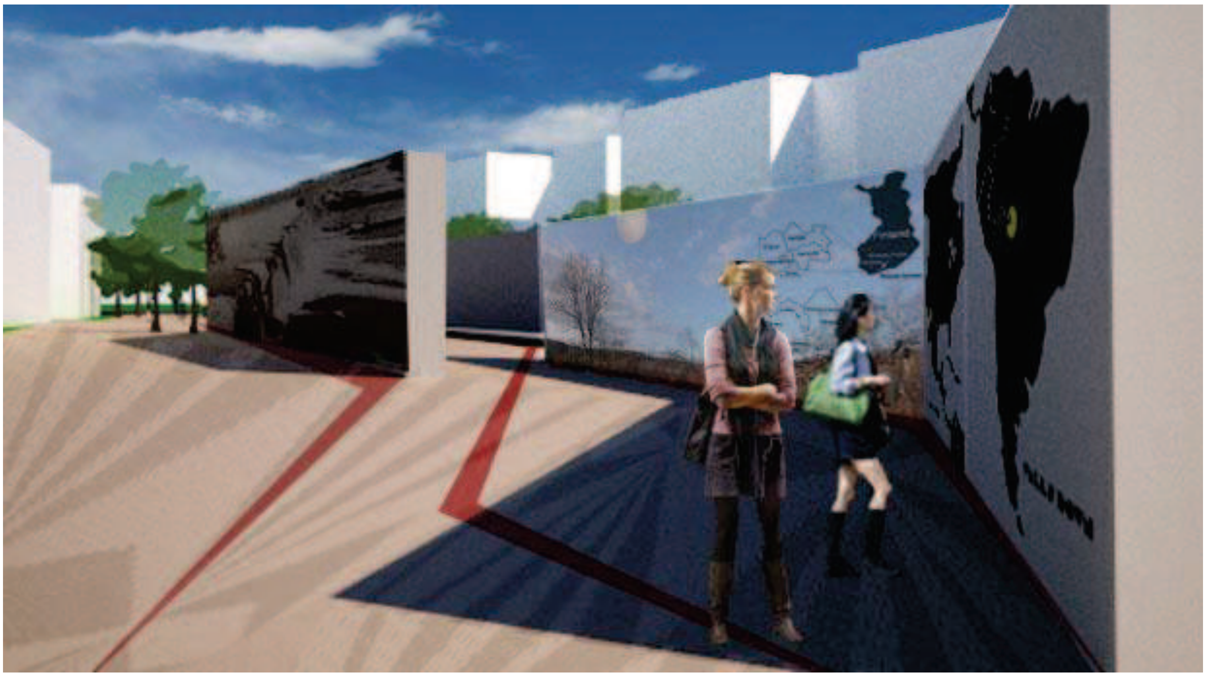


Figure 2.78 – Main Piazza

Figure 2.79 – Main Piazza

The idea is to divide the wall so that vendors could drag them out to sell their products, and when they leave the wall could be returned back to be used for the display.

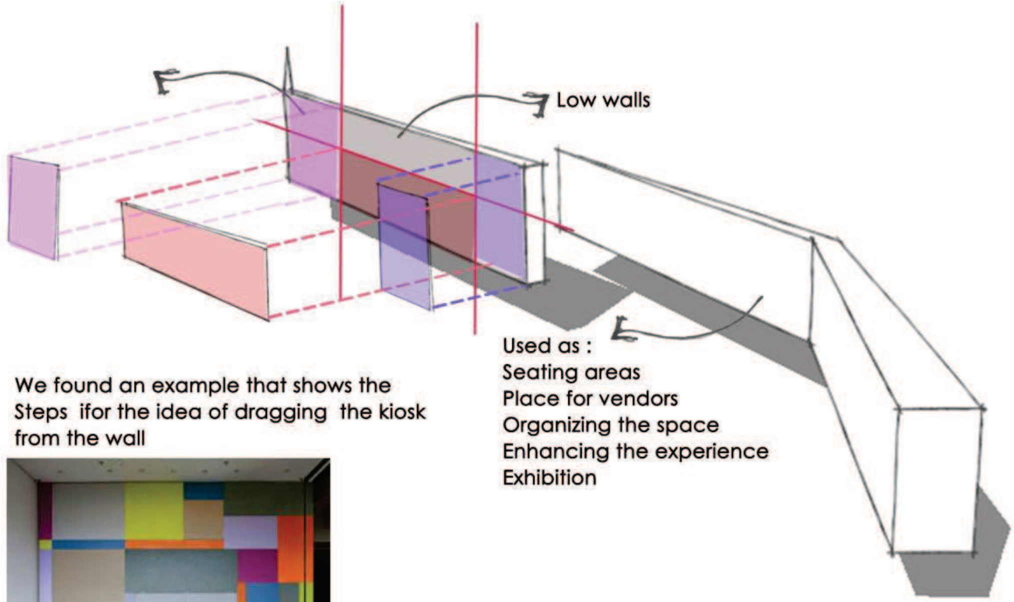


Figure 2.80 – Low wall idea

We found an example that shows the Steps ifor the idea of dragging the kiosk from the wall

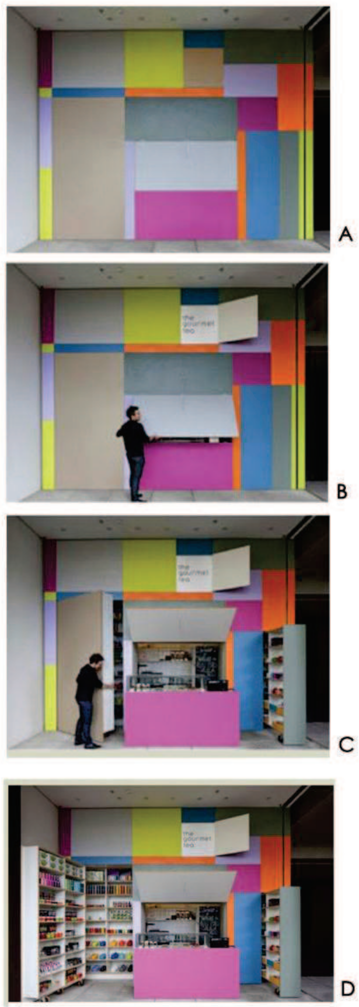


Figure 2.81 – An example

B. Existing Building 1

Passing from History of Vantaa going to history of malmi, a pathway through an existing building is designed for the spine continuity.

Achieving this pathway, a small intervention in the skylight fo the building is modified, and a modern canopy is attached for a physical and visual connection to people to continue in the spine to arrive the main train station "History of malmi"

Figure 2.82– Entrance to existing building

C. The new station Platform (History of Malmi)

The story continues after people pass through existing building 1 entering the history of malmi which is our main architecture project. We designed an entrance cube that represents the gateway between the history of Vantaa to history of Malmi.

The scope of new station platform will be explained in details in the architecture chapter.

Figure 2.83 – New station platform "The new Qualia

D. Existing building 2

The experience continuous to the other side which is linked with a bridge connecting the new station platform to the existing building 2, this link continues inside the building going to the park.

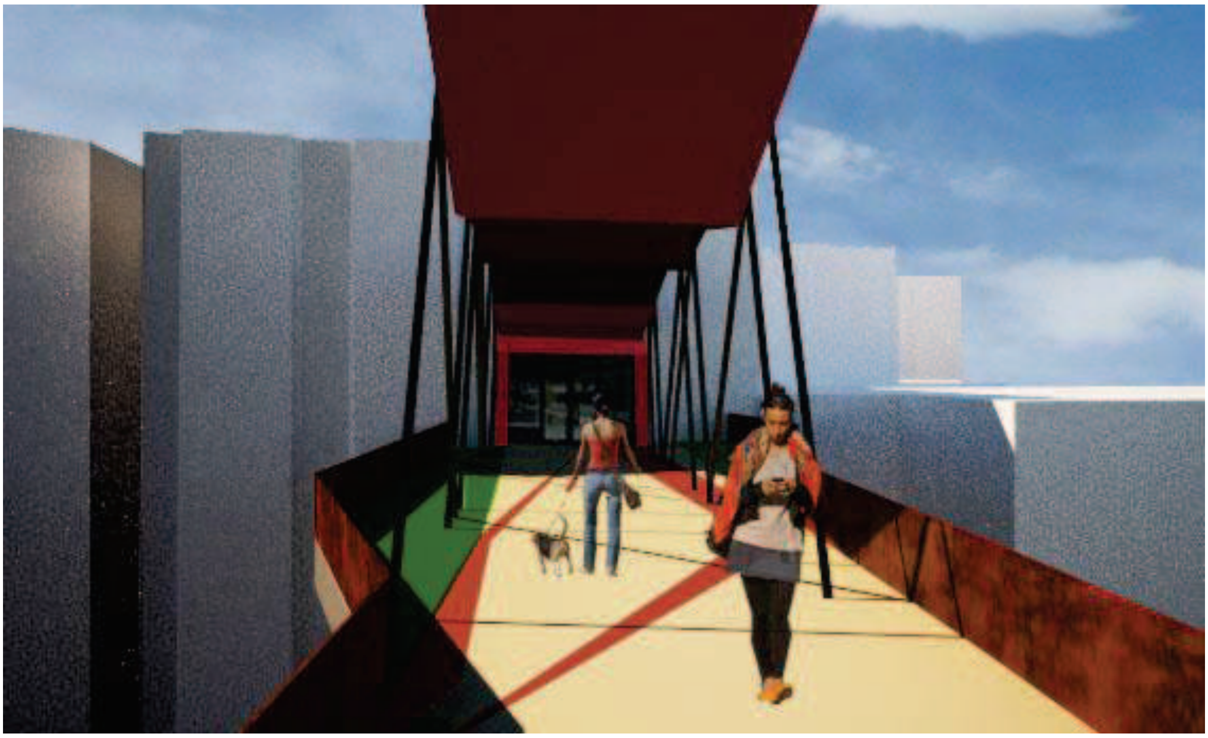


Figure 2.84– Pathway to existing building 2

E. The connection (Ground Level + Bridge level)

Figure 2.85– connection from existing building 2 to Park

Pathway under the bridge

Connection bridge

The connection leading from the existing building 2 to the park is designed so that there is two pathways one above the bridge and one under to access the residential area.

F. Park (History of Helsinki)

The story ends with a recreational area, an entertaining public area that resembles the history of Helsinki. It is a public park that is surrounded by a lot of recreational existing buildings: health center, indoor swimming pool, conference hall, and cultural center.

Our approach to the park was mainly concentrated on the landscape without demolishing any of the existing, and refurbished the existing small kiosk for outdoor events.

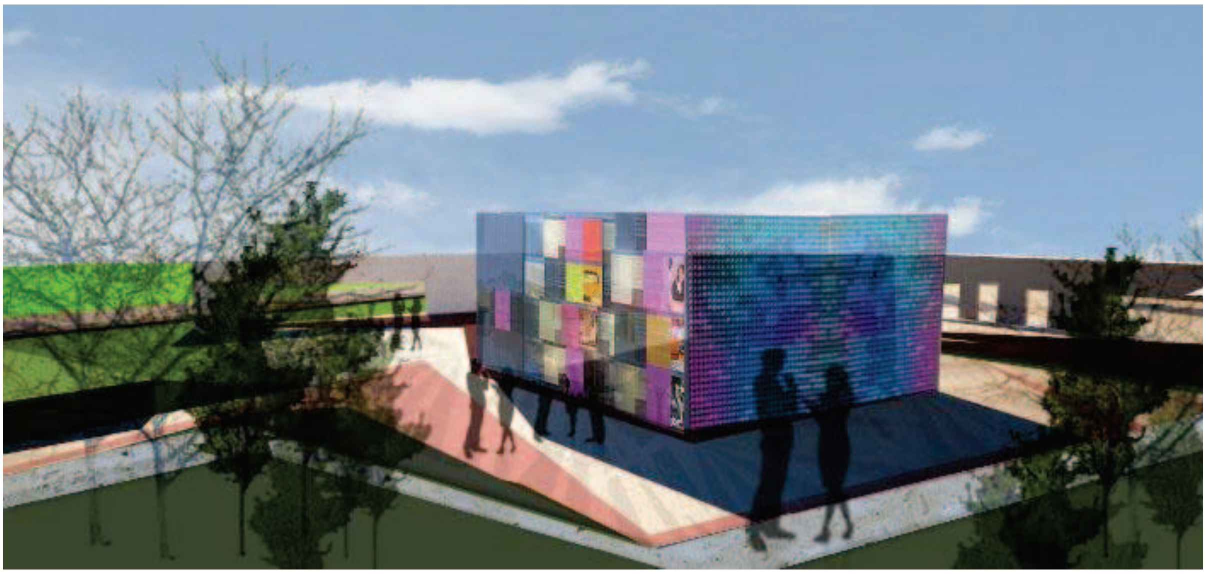


Figure 2.86– Kiosk in the park , led screens displaying history of helsiniki

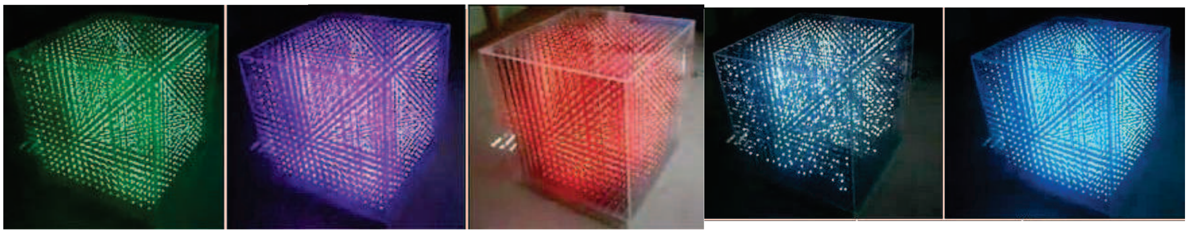


Figure 2.87– Different shades of led screens

2.4.4.2 Spine B: The Journey

The journey spine is the one perpendicular to spine A. this spine reassembles the journey of the people from the drop off that is the starting point to different levels and place

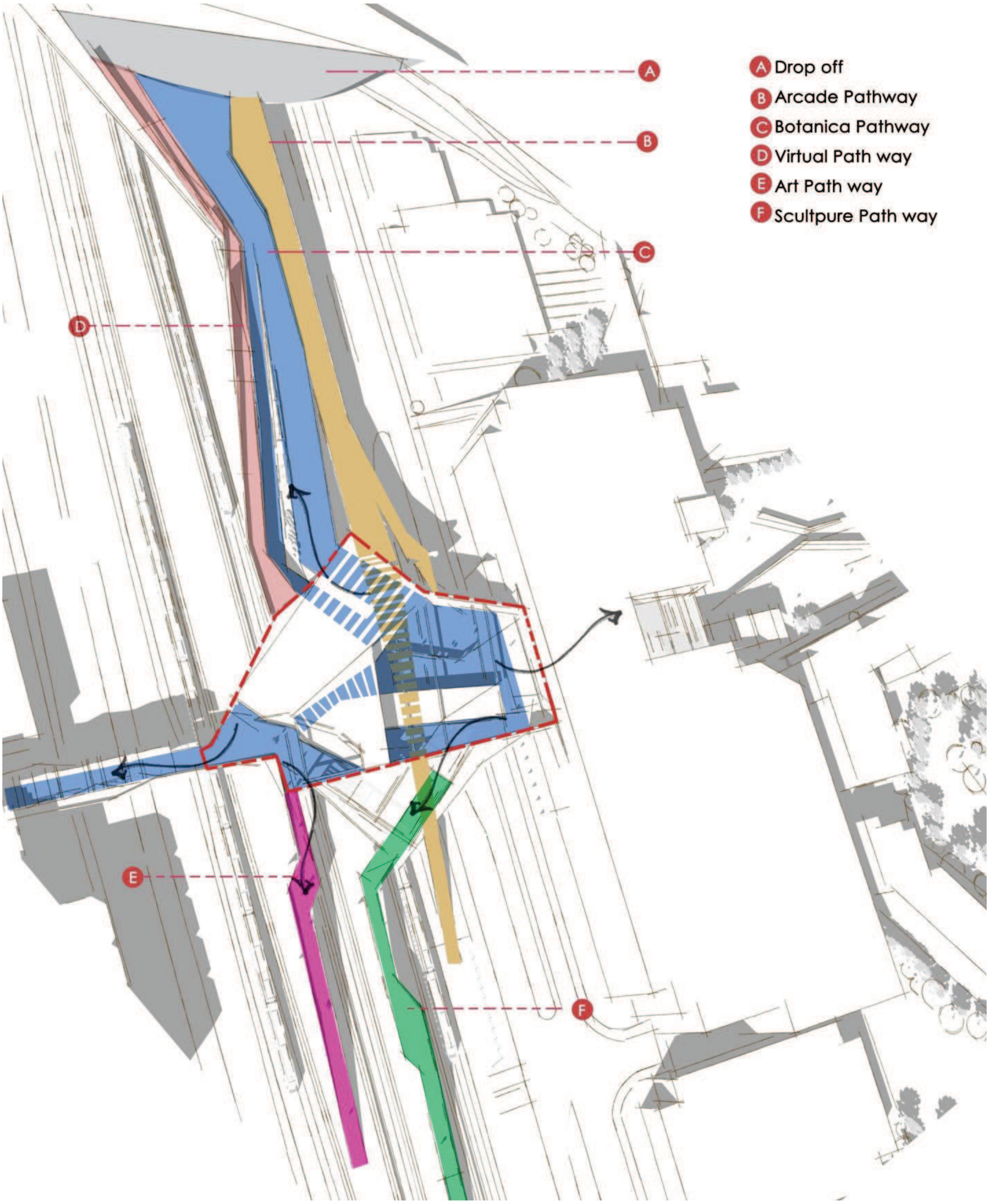


Figure 2.88– Ramps code

A. Drop off

The drop off represent the starting point of the journey, as it's the main stop of the buses arrivals to the train station.

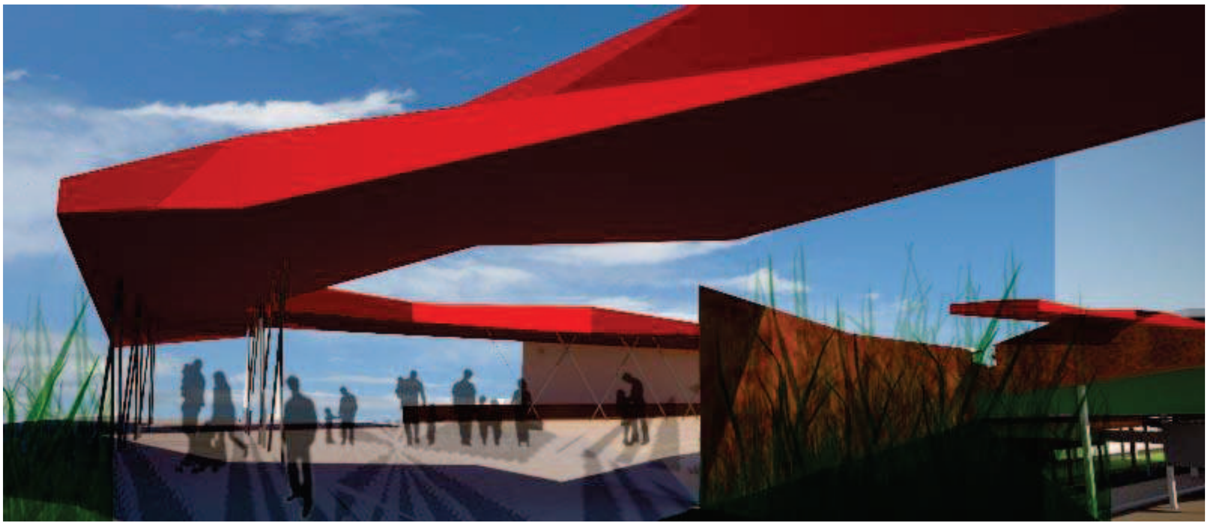


Figure 2.89– Drop off

Figure 2.90– Relation of drop off to the ramps

B. Arcade Pathway (Shadows of the past)
Theme:

Figure 2.91

First journey that is the shadows of the past, where there is a relation between the user, the space and his reflections on the space. It has access to both the platform and to the main platform building.

The ramp is embraced by irregular arcade, that forms different shadows by the user in the morning and in the night led light is used.

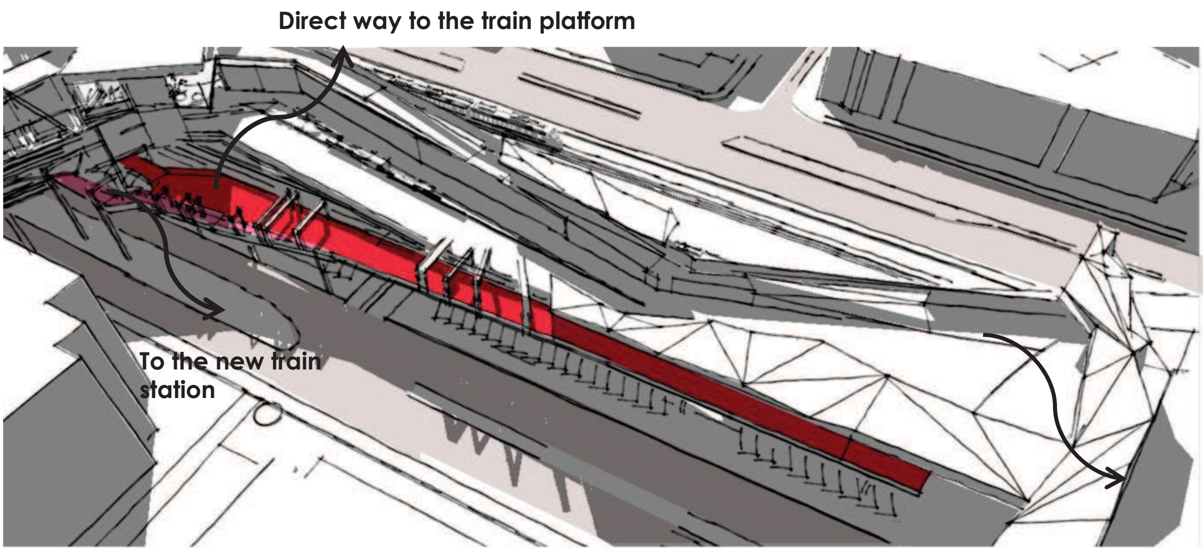


Figure 2.92 Drop off- Journey starting point

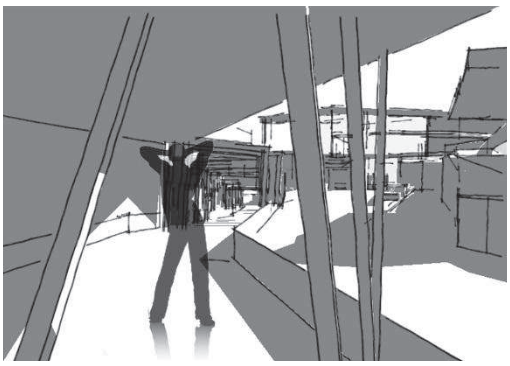


Figure 2.93

Figure 2.94

B, Botanical Pathway Theme:

Figure 2.95

Allium Flower are plants of beauty in both flower and leaf,. They are easy-to-grow with different palette of colors, heights, bloom times and flower forms.

They make excellent cut flowers for fresh or dried bouquets, they don't take much space, and they are planted once a year, and stay the whole year in a perfect shape as long as they are well drained

Also another advantage that this flower has various colors that would complement the pathway with interesting variations of shades,

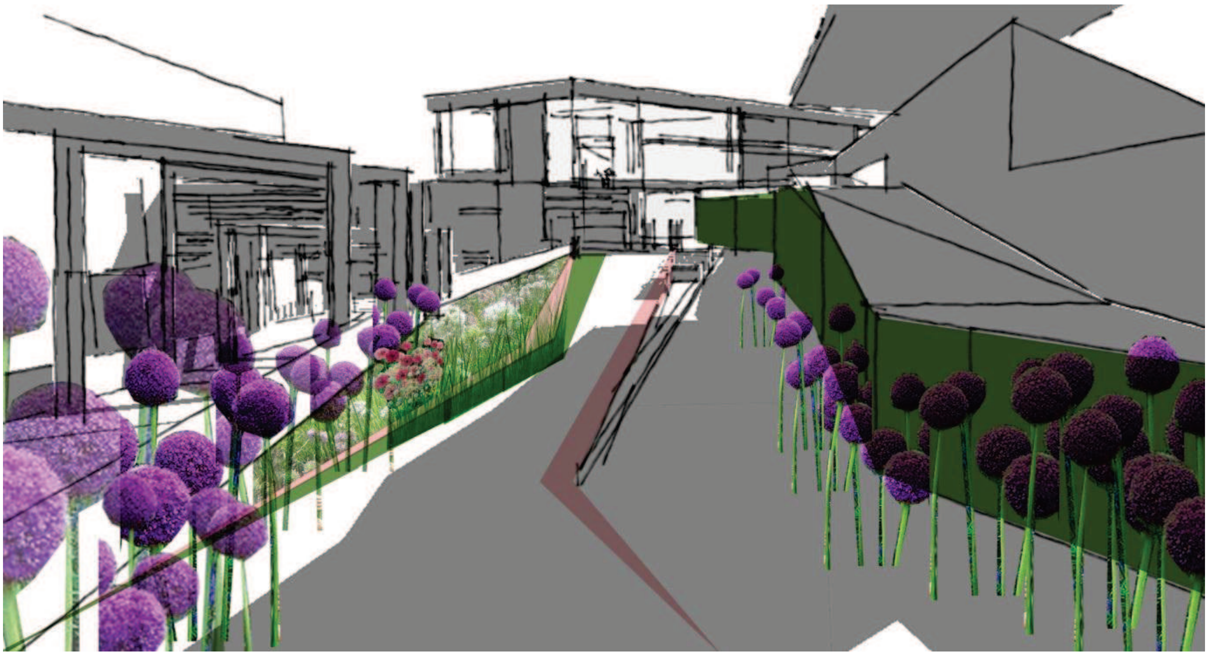


Figure 2.96

This journey leads to the level of the new train station platform.

C. Virtual Pathway

Theme:

Figure 2.97

This pathway leads to the highest level which is the M.PU Hall, its represents virtually and technology. Applying virtually resembles the relation of the user between sky and earth and the feeling of freedom.

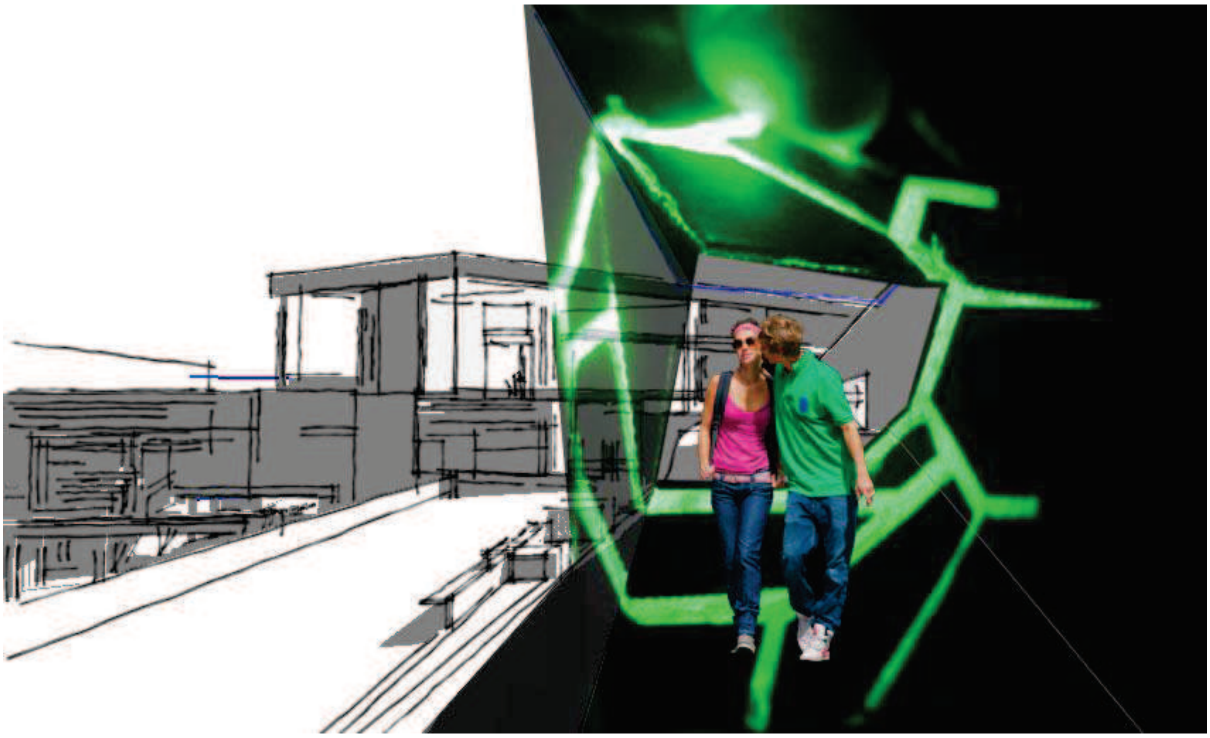


Figure 2.98

These two pathways start from a different starting point which is the new qualia, and the journey becomes more physical, as they reach the final destination and back to reality. Artists and sculptures have the chance to perform their designs and interact with people

D. Art and sculpture Pathways

E. Theme

Figure 2.99

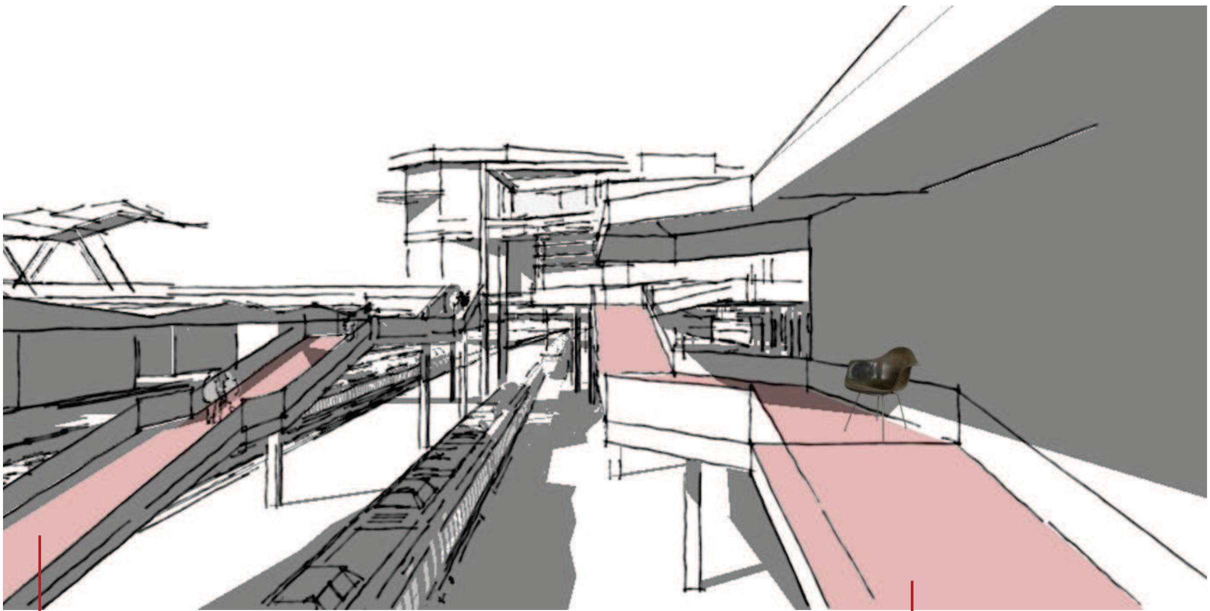


Figure 2.100

Art Pathway

Sculpture Pathway

Figure 2.101

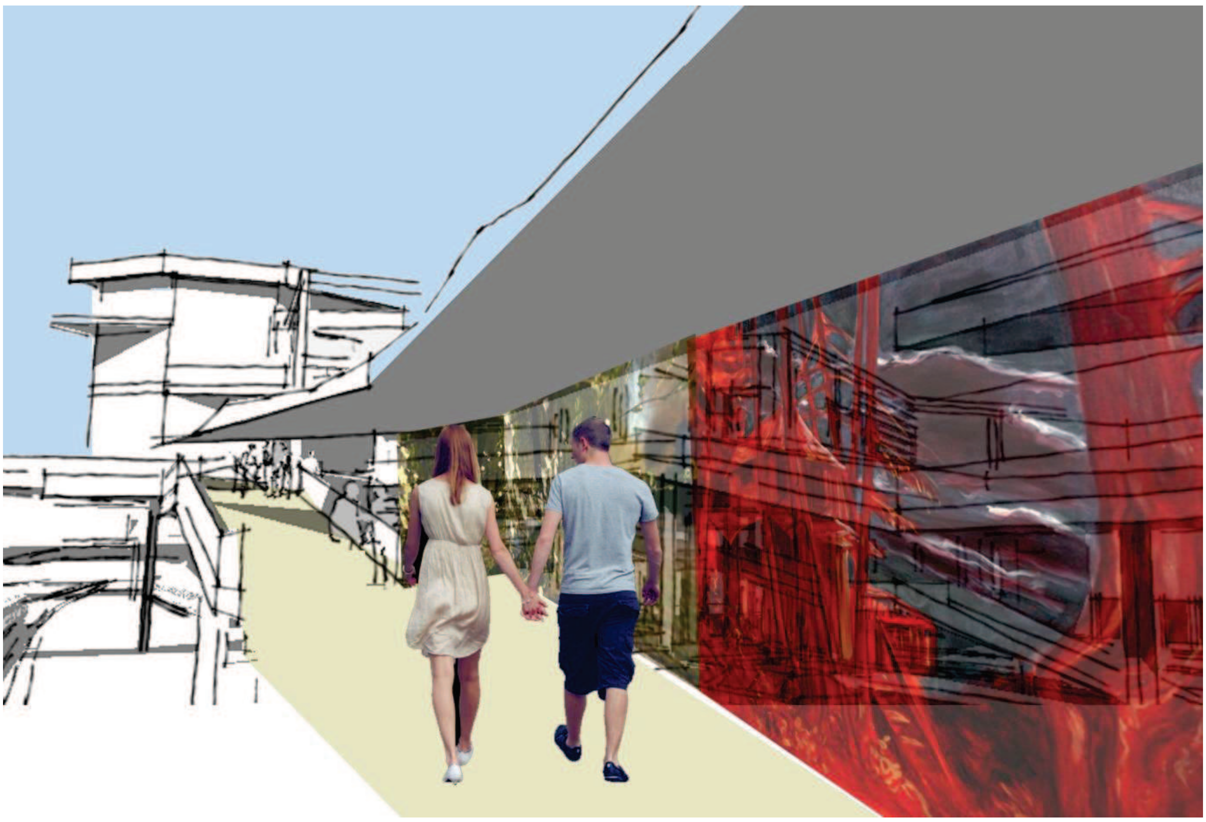
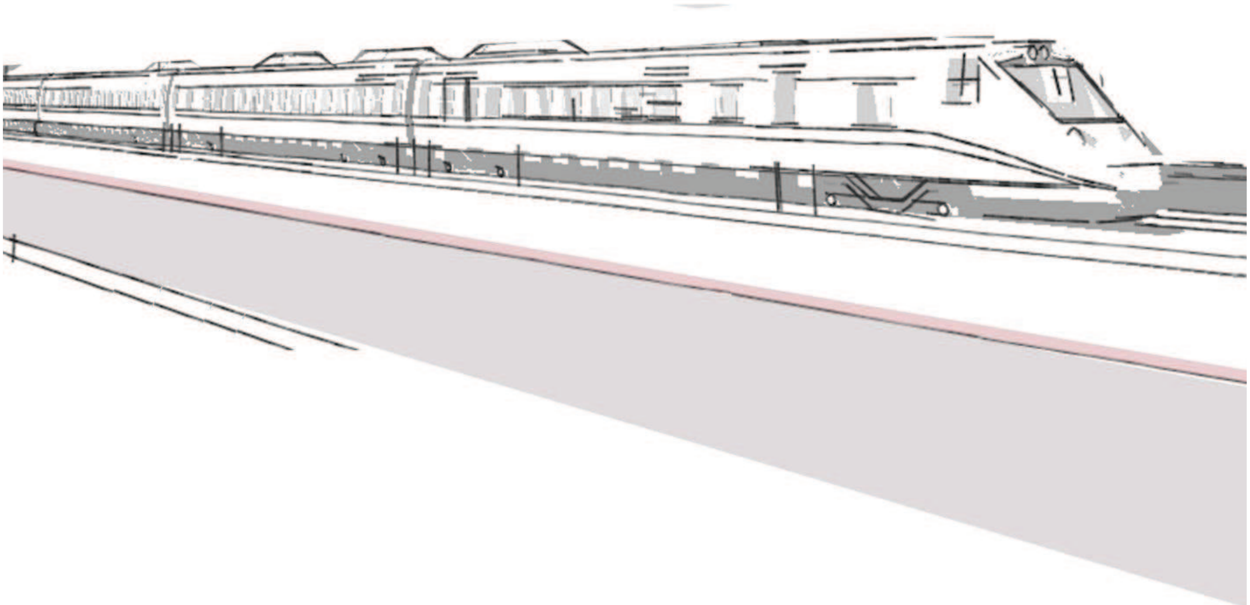


Figure 2.102

3.0 ARCHITECTURAL DESIGN



3.1 Architectural concept

3.1.1 Concept statement

To apply the concept of the new qualia in the architecture of our project we considered the bigger urban scale as the lens through which the user identifies every space, thus forming the mental unique qualia of his experience.

So starting from where our urban lines ended we picked up the paths forming the shape of the main platform (the new building) and the interventions in the existing buildings (refurbishment scope) to serve the main urban concept of continuity.

3.1.2 Morphological concept

From the previous urban analysis we realized that our project is not only about a building its more like a platform where the all the users meet and in the same time where all the users disperse into different directions seeking different activities

so based on the optimum shape that governs that the two spines realized from the urban concept, a perfect square was found to fulfill the idea with all its aspects due to the diverse directionality derived from its geometry.

Directionality of a square

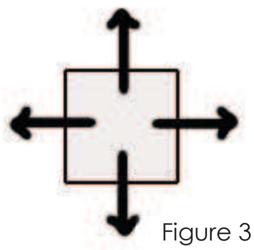


Figure 3.1

Collective space

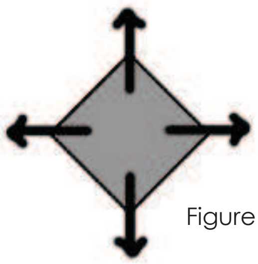


Figure 3.2

Exit / entrance points

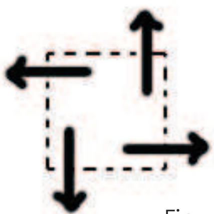


Figure 3.3

Nontraditional directionality

Based on the functionality of the platform, and its position above the train railway station besides the ramps realized from the urban concept:

- **Main connection points forming the intersection point between 2 spines**

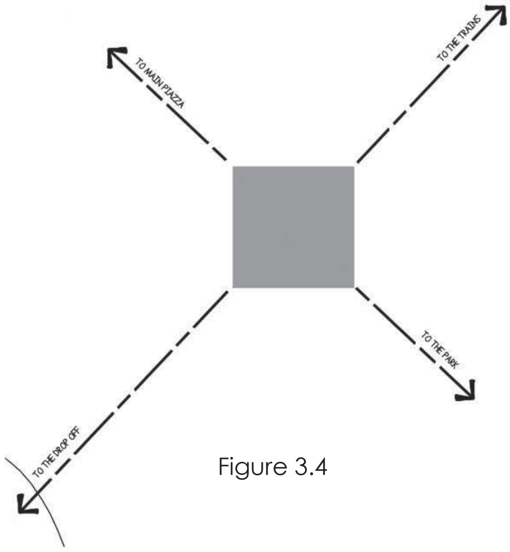


Figure 3.4

- **Main exit points from the platform were determined according to functionality of the building**

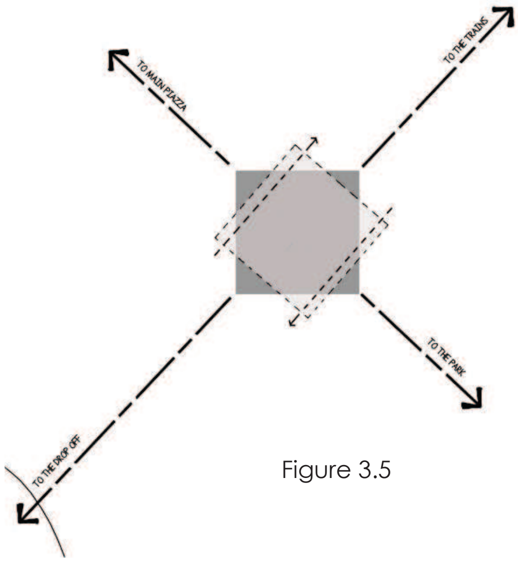


Figure 3.5

- **Nontraditional directionality applied according to architectural concept**

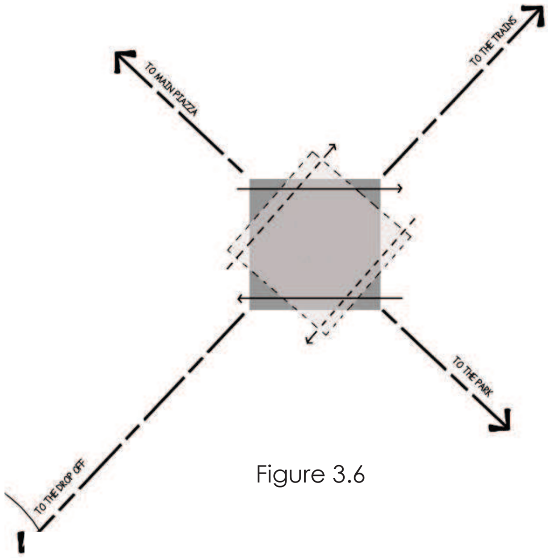


Figure 3.6

- **Realization of main lines of the platform by overlapping the previous stages**

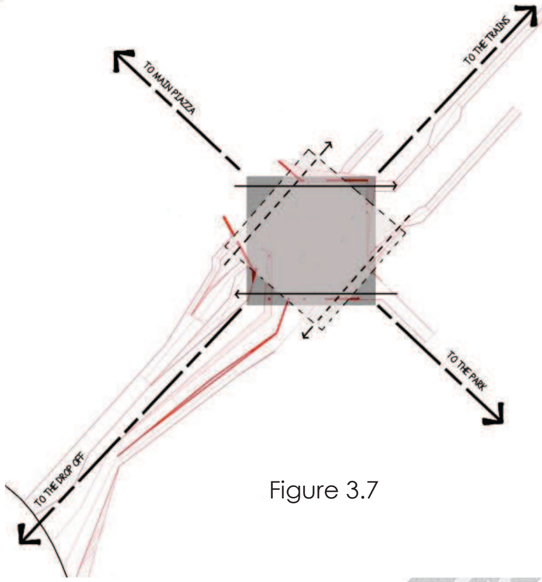


Figure 3.7

- **Realization of platform plan**

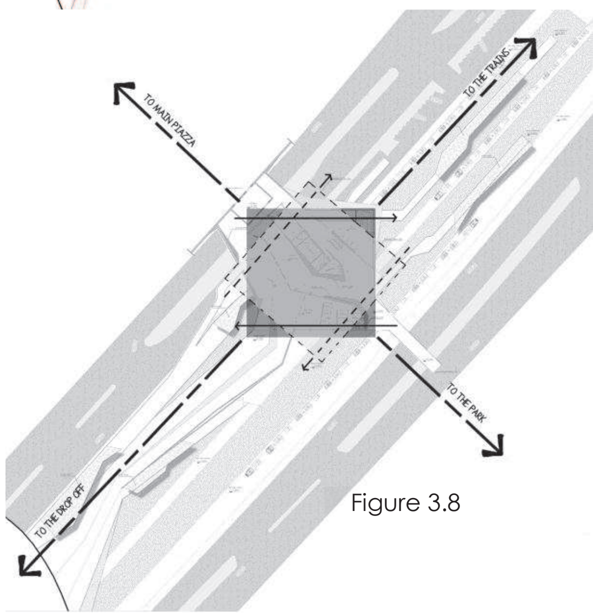


Figure 3.8

3.2 Scope of work

3.2.1 New building

3.2.1.1 Design sketches

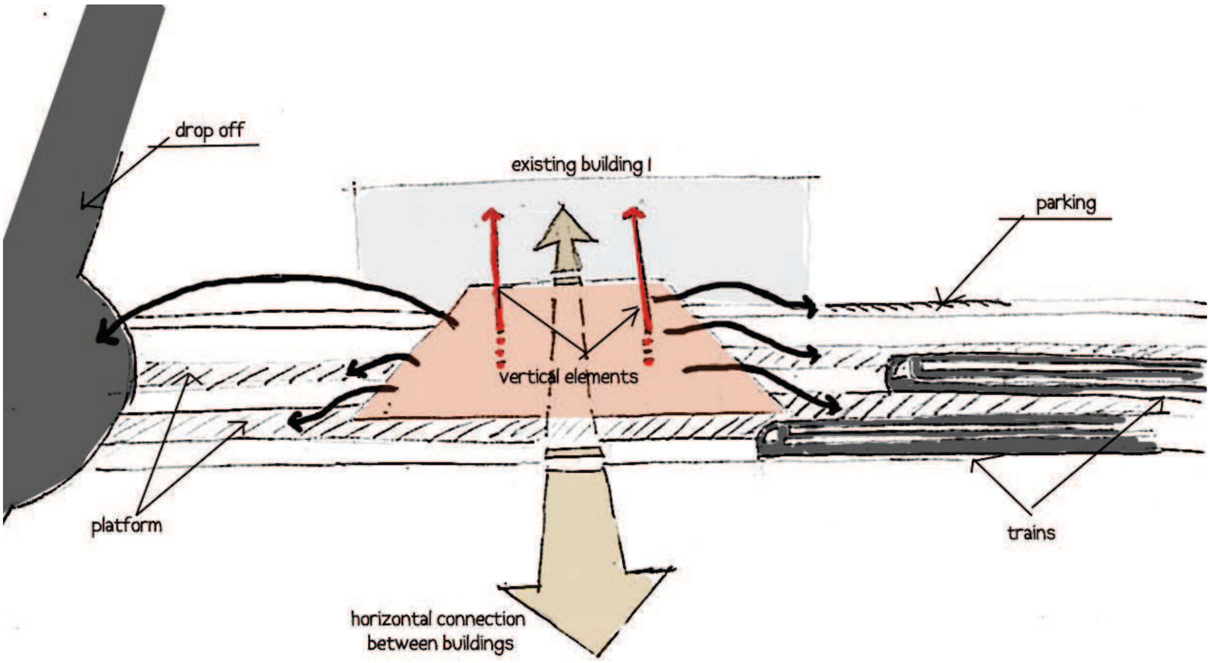


Figure 3.9 Design Sketch for main platform

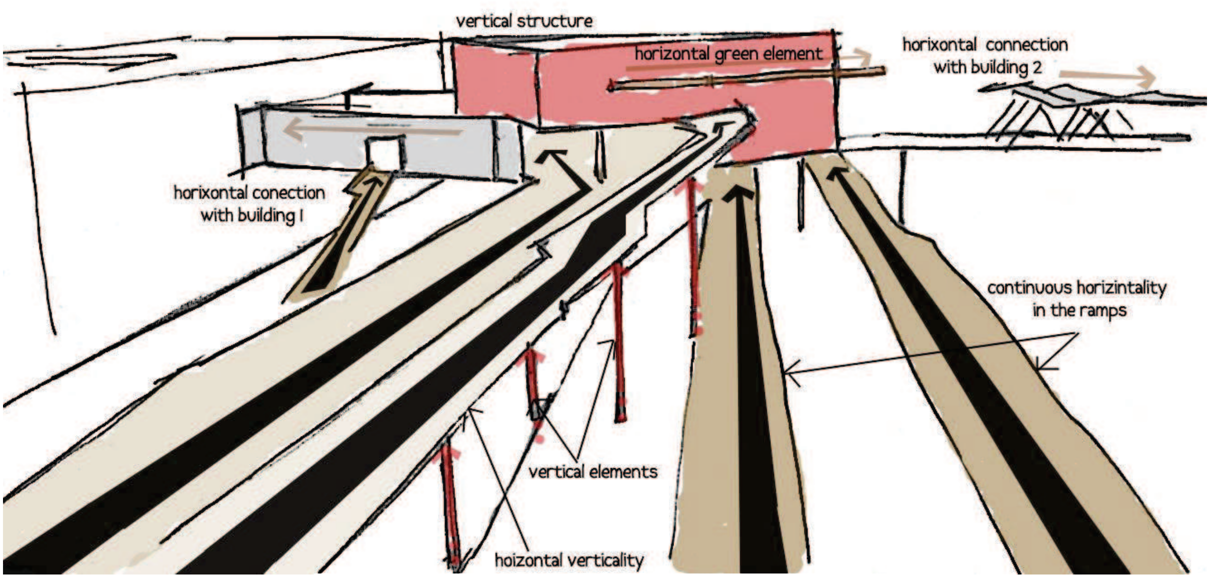


Figure 3.10 Design Sketch for main building

3.2.1.2 Zoning

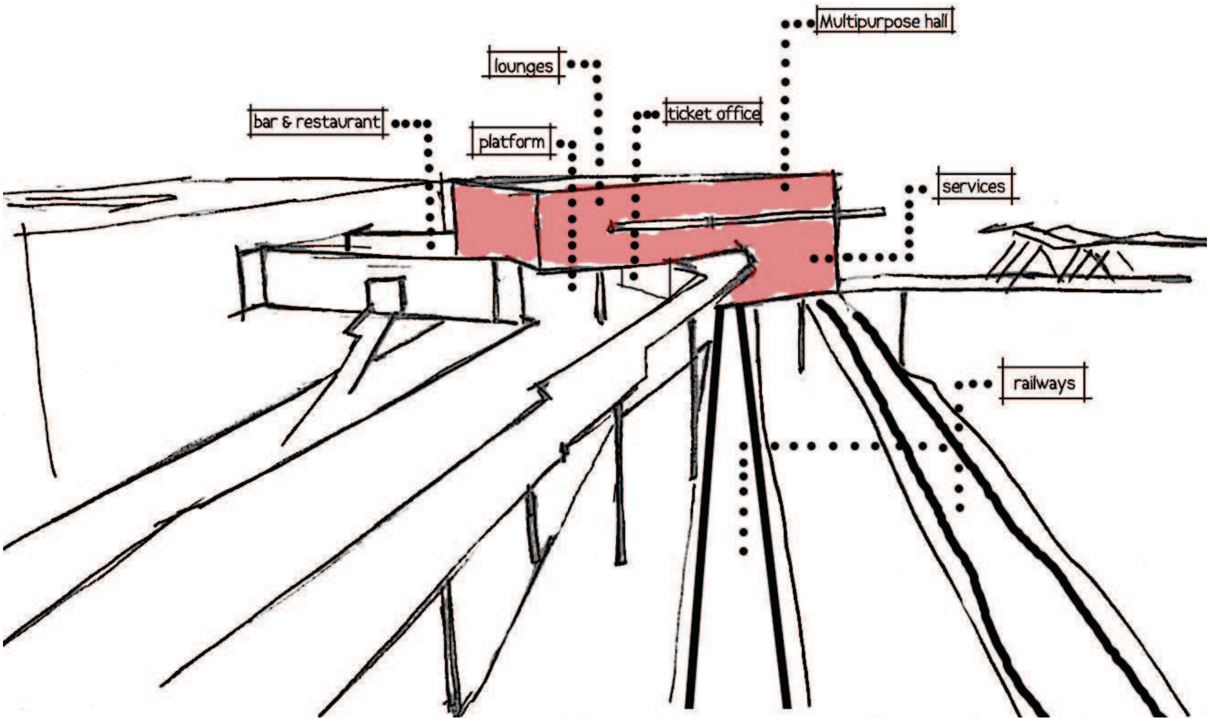
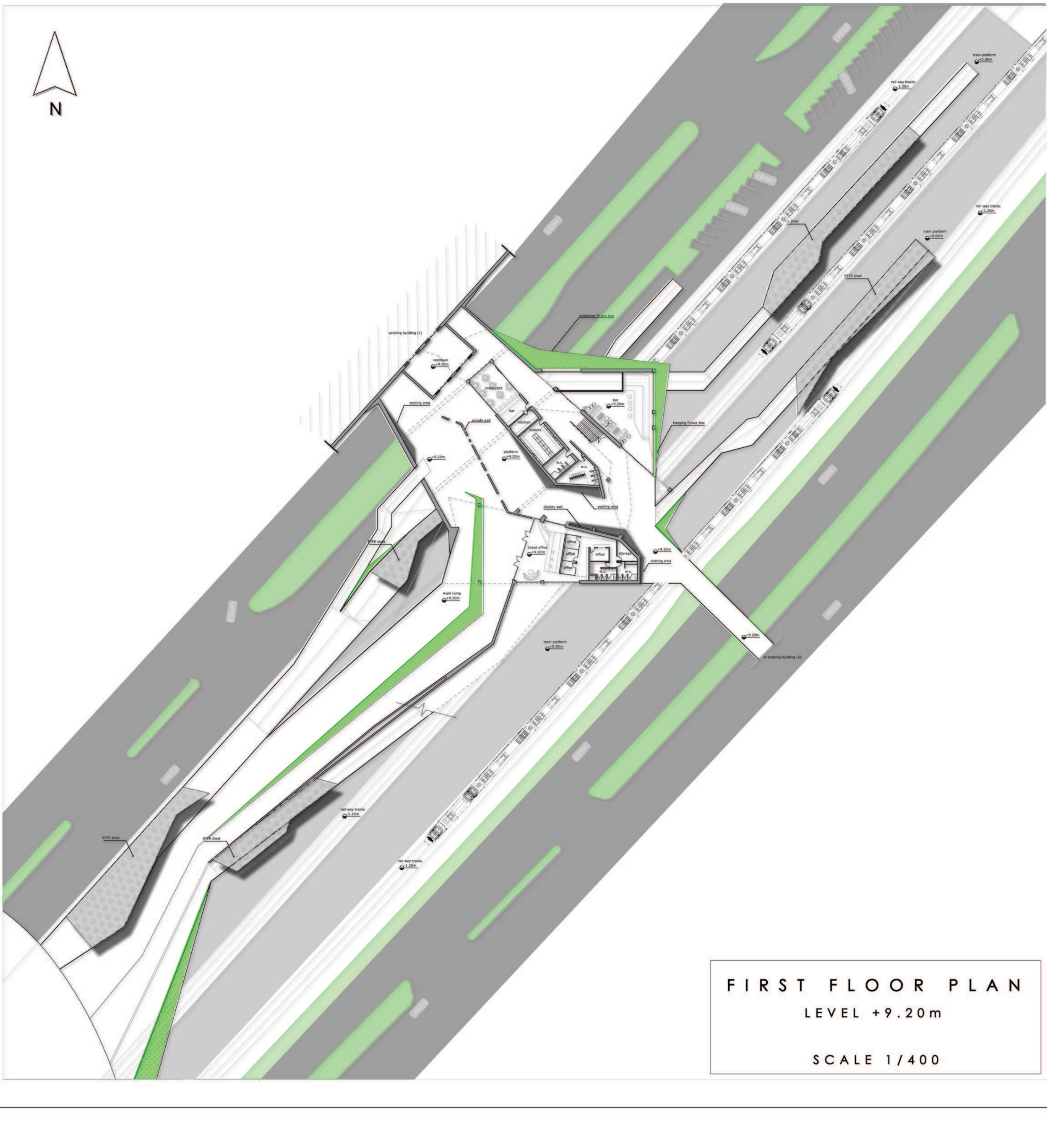
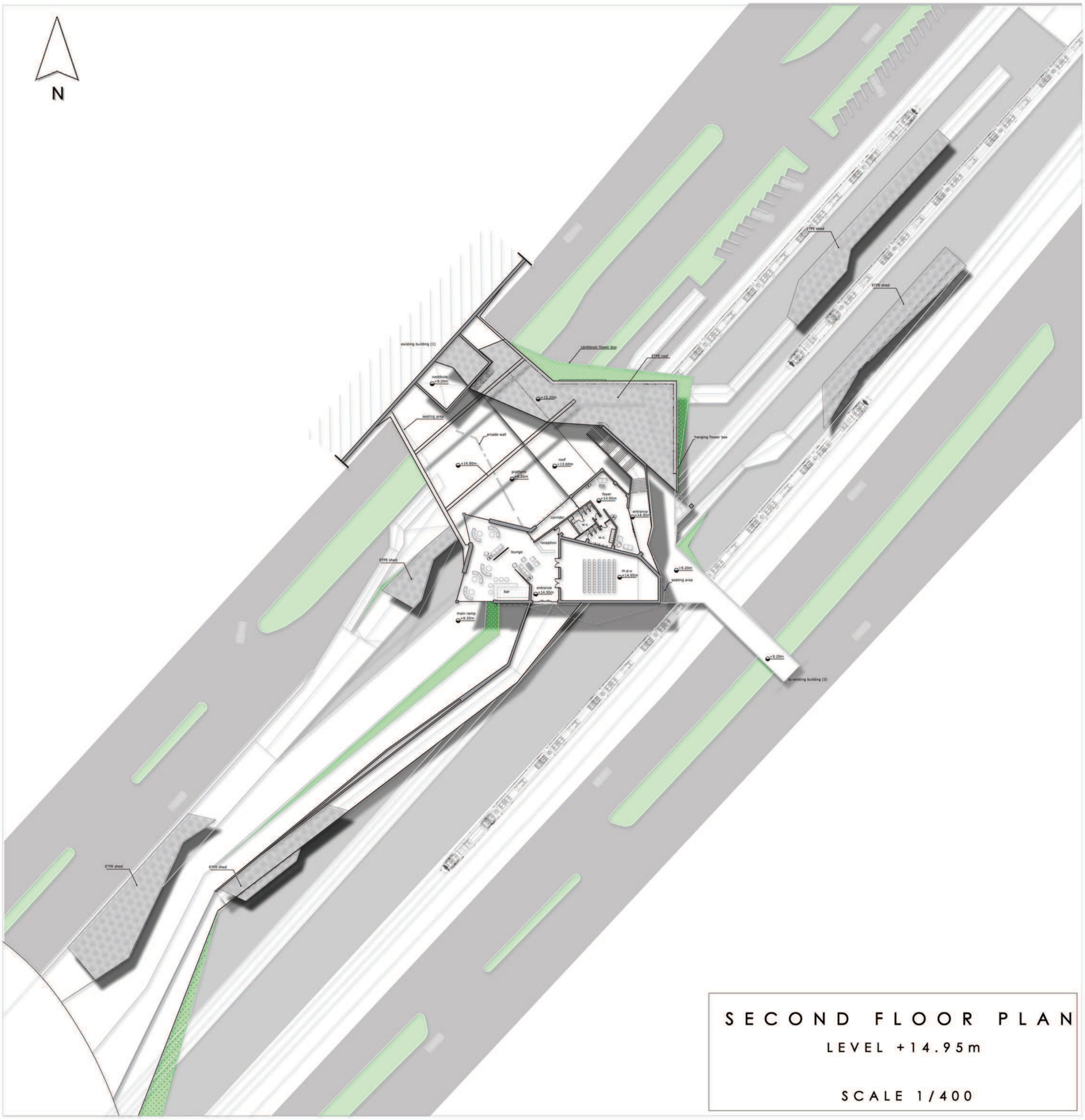


Figure 3.11 Sketch of zoning

3.2.1.3 Architectural drawings

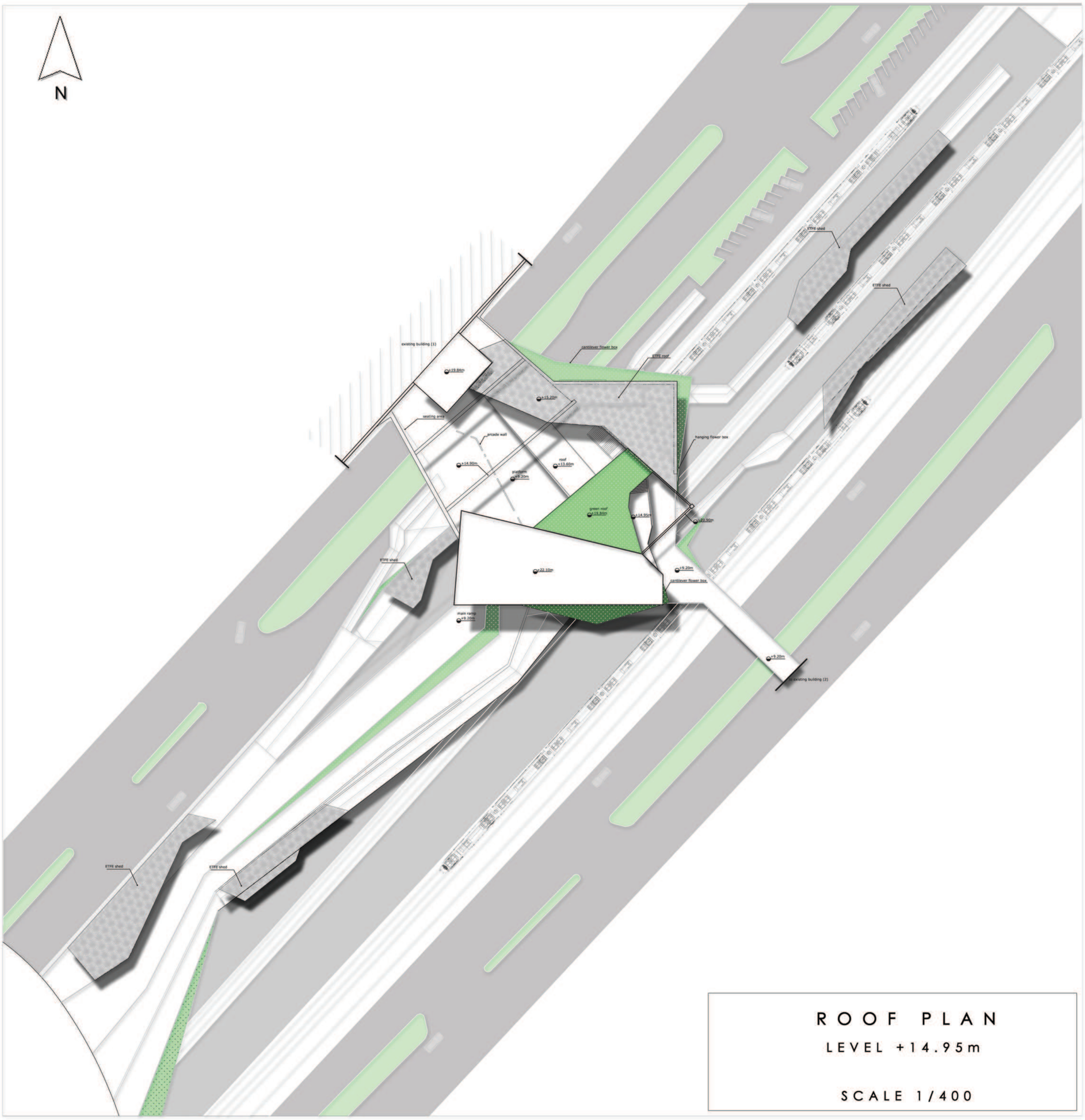

N
FIRST FLOOR PLAN
LEVEL +9.20m
SCALE 1/400



SECOND FLOOR PLAN

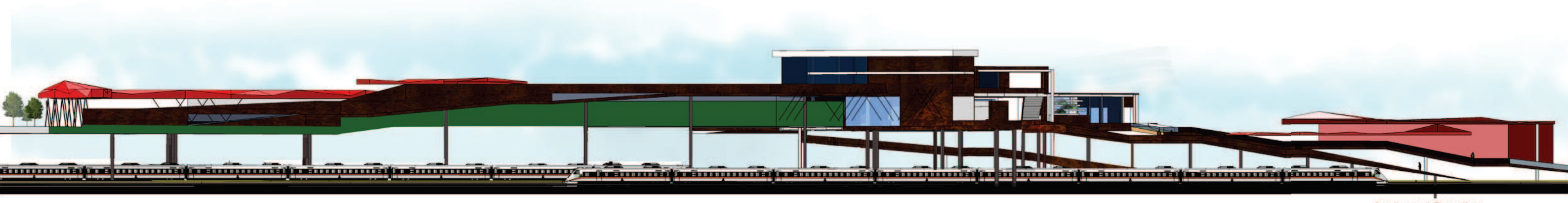
LEVEL +14.95m

SCALE 1/400

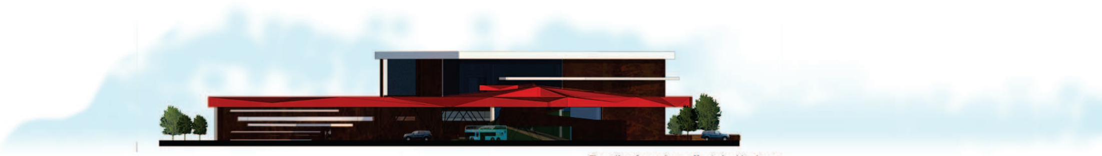

N
existing building (1)
+19.84m
cantilever flower box
ETFE roof
+15.20m
seating area
arcade wall
hanging flower box
+14.90m
roof
+13.60m
platform
+9.20m
green roof
+19.84m
+14.95m
+20.90m
ETFE shed
+22.10m
+9.20m
cantilever flower box
main ramp
+9.20m
ETFE shed
ETFE shed
+9.20m
existing building (2)
ETFE shed
ETFE shed
ROOF PLAN
LEVEL +14.95m
SCALE 1/400

ELEVATIONS

scale 1/400



South west Elevation
Scale 1 :400



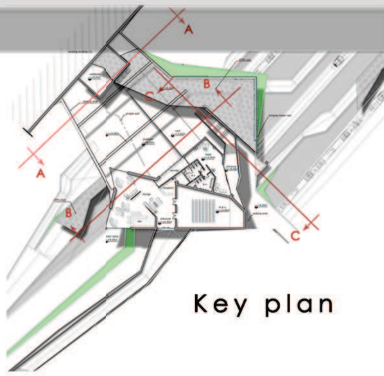
Elevation from drop pff - Arrival by buses
South East Elevation
Scale 1 : 400

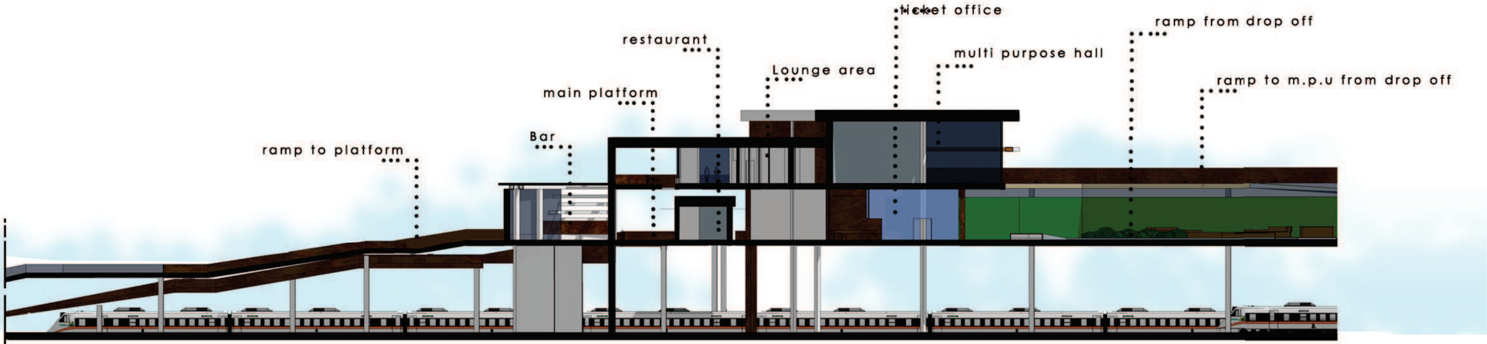
North East Elevation
Scale 1 :400

North West Elevation
Scale 1 :400

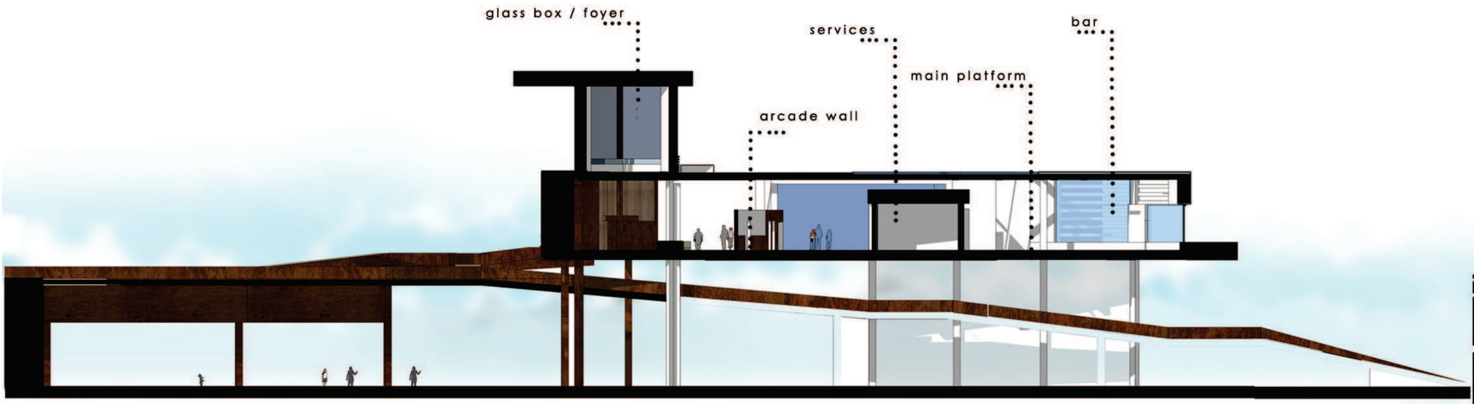
Elevations

scale 1/400

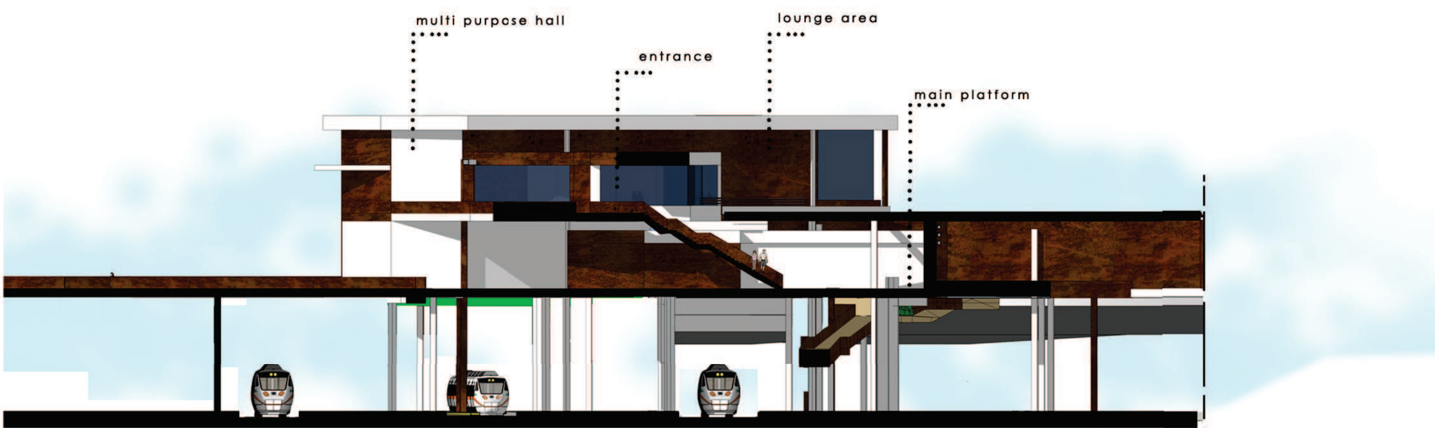




Section A : A
Scale 1:400



Section B : B
Scale 1:400



Section C:C
Scale 1:400

Rendered shots:

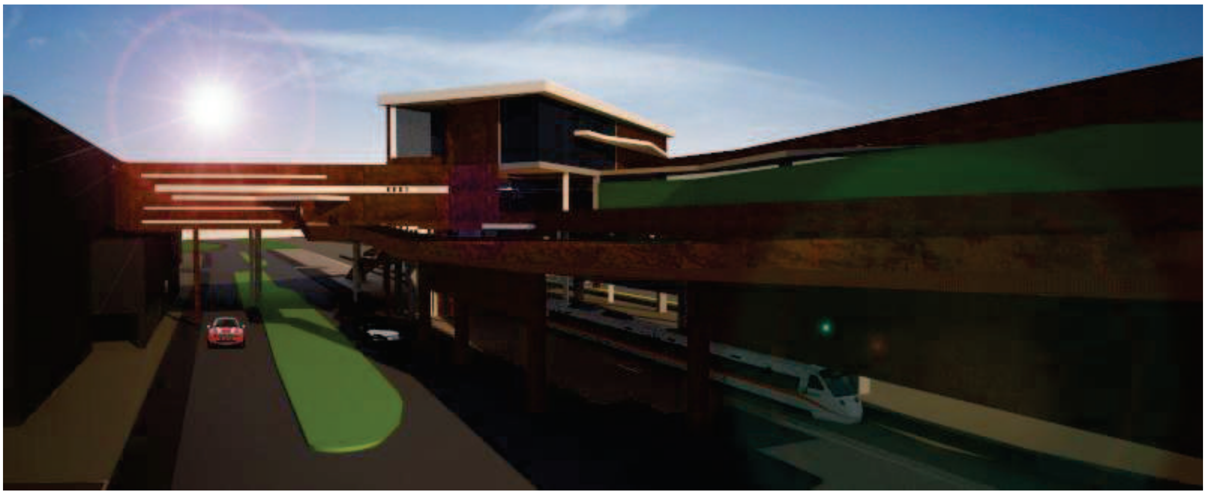


Figure 3.12 – Architectural building proposal

Figure 3.13- Architectural building proposal

Figure 3.14

Figure 3.15

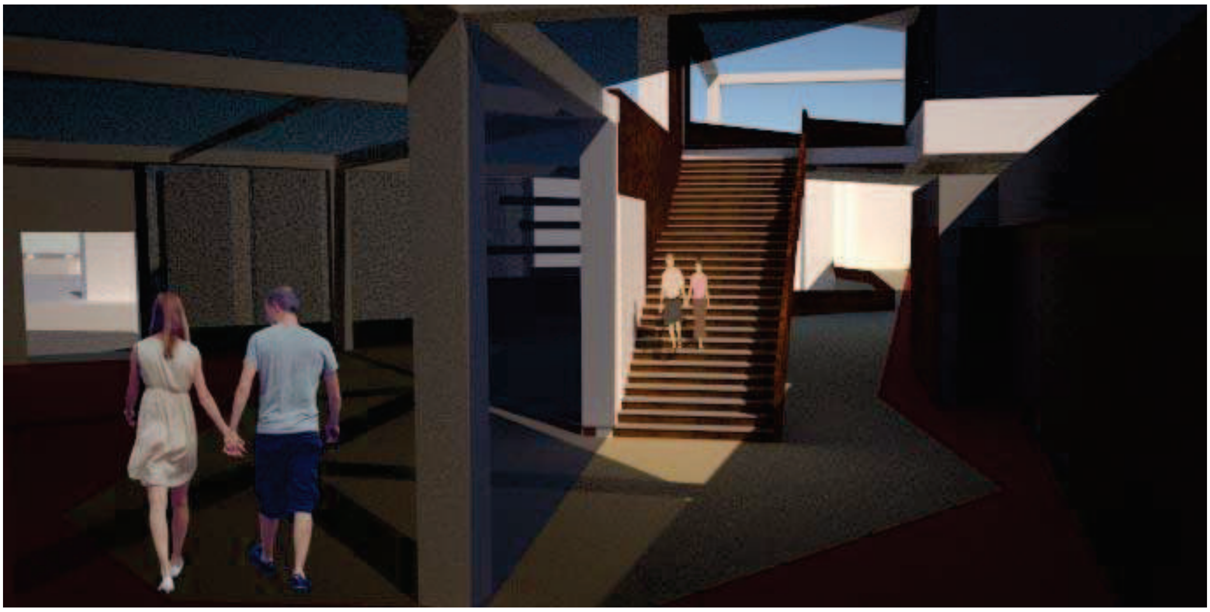


Figure 3.16

3.2.2 Refurbishment scope

3.2.2.1 Building (1)

Existing status:

Foot print: 7592 m2
Function:
- passage to train station from main piazza
- Commercial

Building materials:
- Facade finish: brick cladding
- Structure: reinforced concrete
- Glazing: double glazing
- skylight: fixed double glazing

Condition: Medium

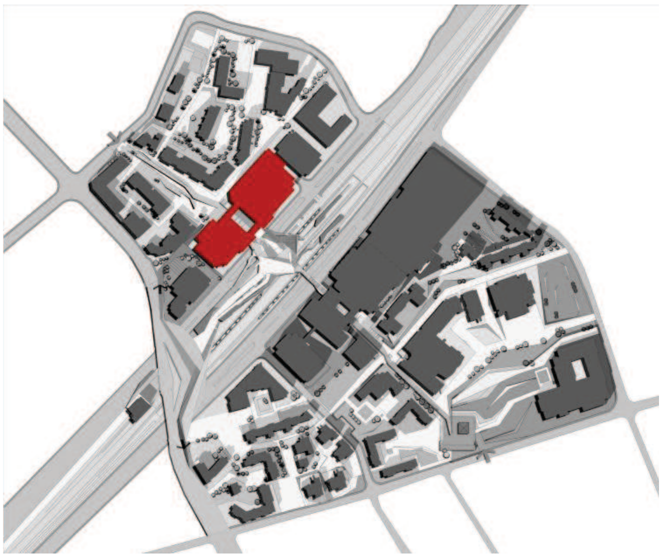


Figure 3.17 - Key plan

Photos:

Figure 3.18
view from main piazza

Figure 3.19
Close up on the entrance

Figure 3.20 interior shot 1
Main atrium

Figure 3.21interior shot 2
Second floor

Figure 2.22 interior shot 3
Shops on the second floor

Figure 2.23 interior shot 4
Corridor of elevator

Existing plans: scale 1/1000

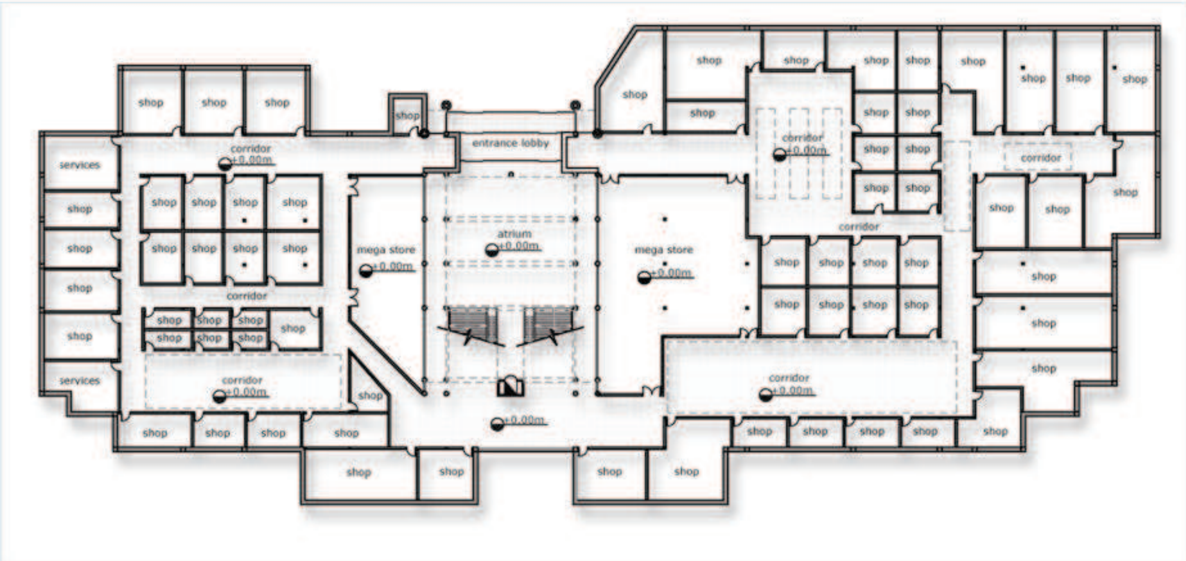


Figure3.24 Ground floor plan

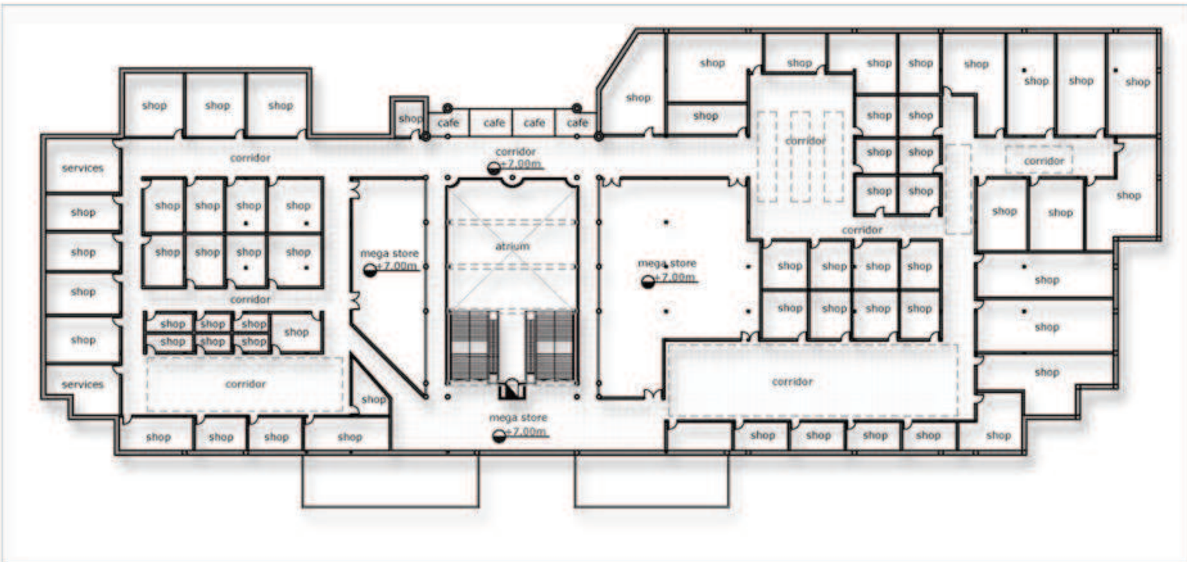


Figure3.25 First floor plan

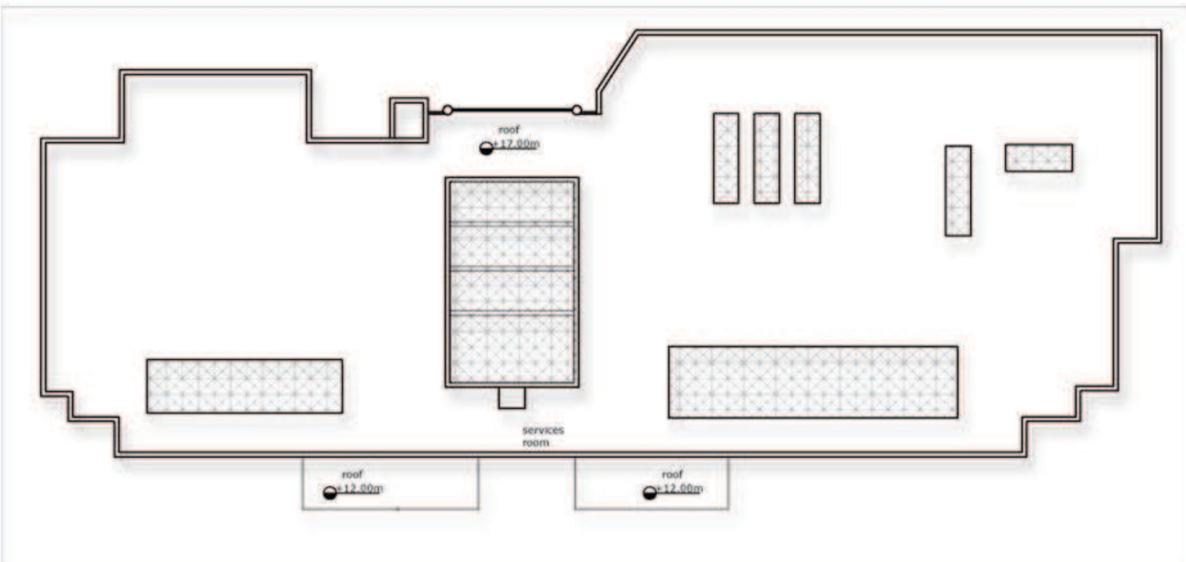


Figure3.26 Roof floor plan

Plan of intervention:

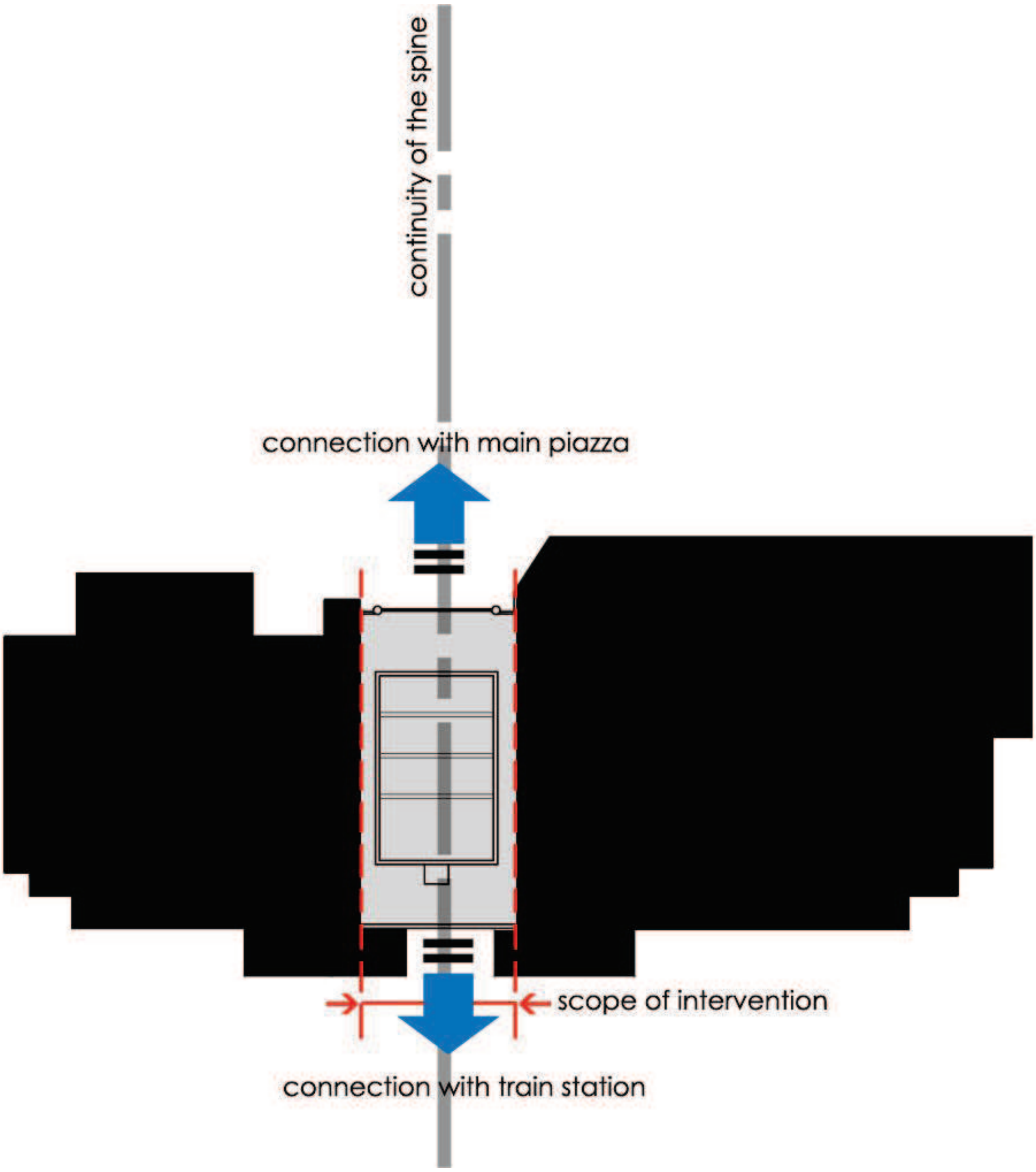


Figure 3.27 Plan of intervention

Main goals of intervention:

- Emphasizing continuity of the spine by creating the continuous ETFE shed
- Installing triple glazing glass façade
- Installing ETFE as a material for glass roof above atrium
- Creating a transitional vestibule for exit for train station

Proposal Design sketches:

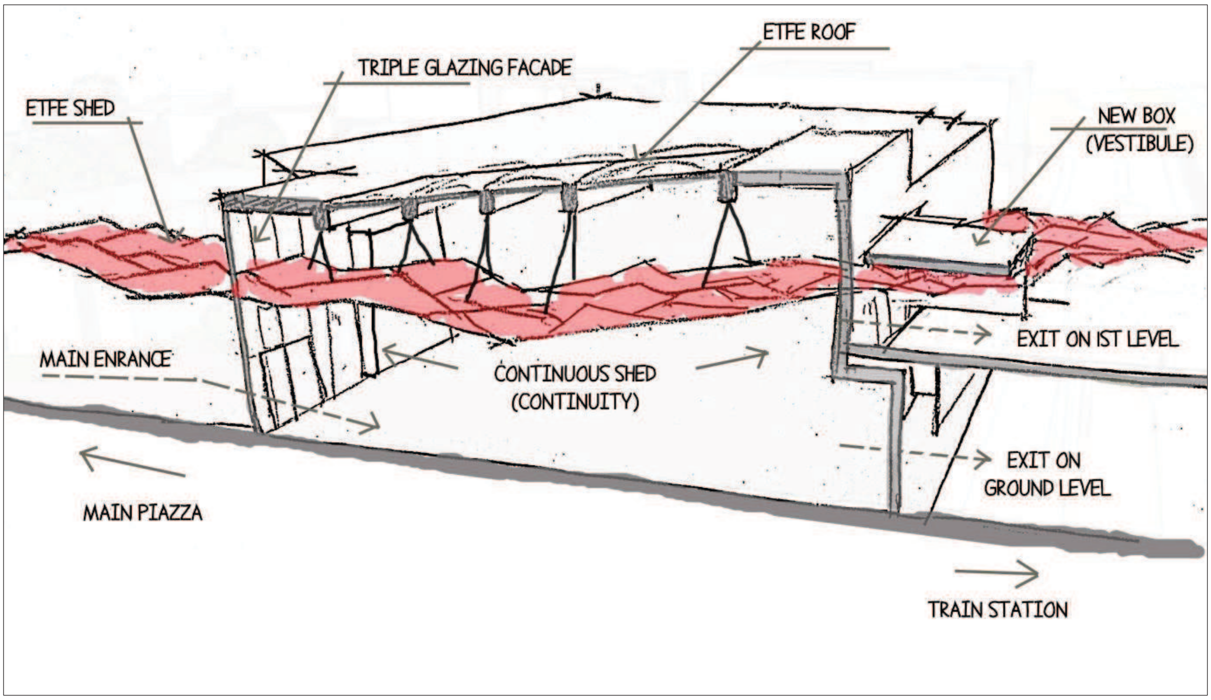


Figure3.28 Sketch of intervention

Refurbished plans:

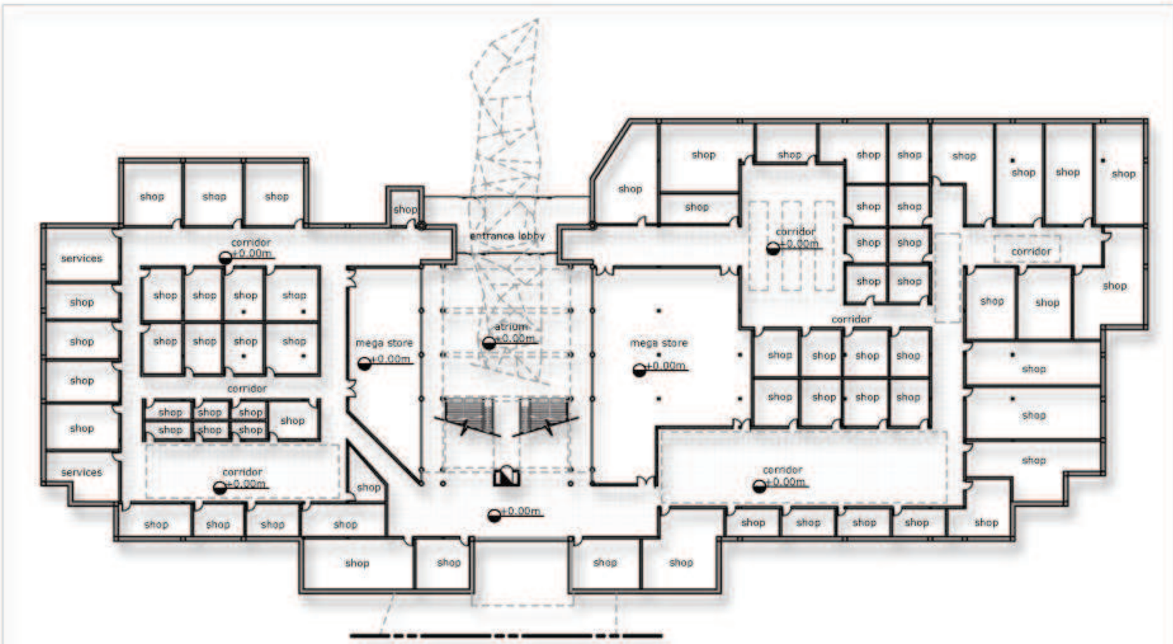


Figure3.30 Ground floor plan

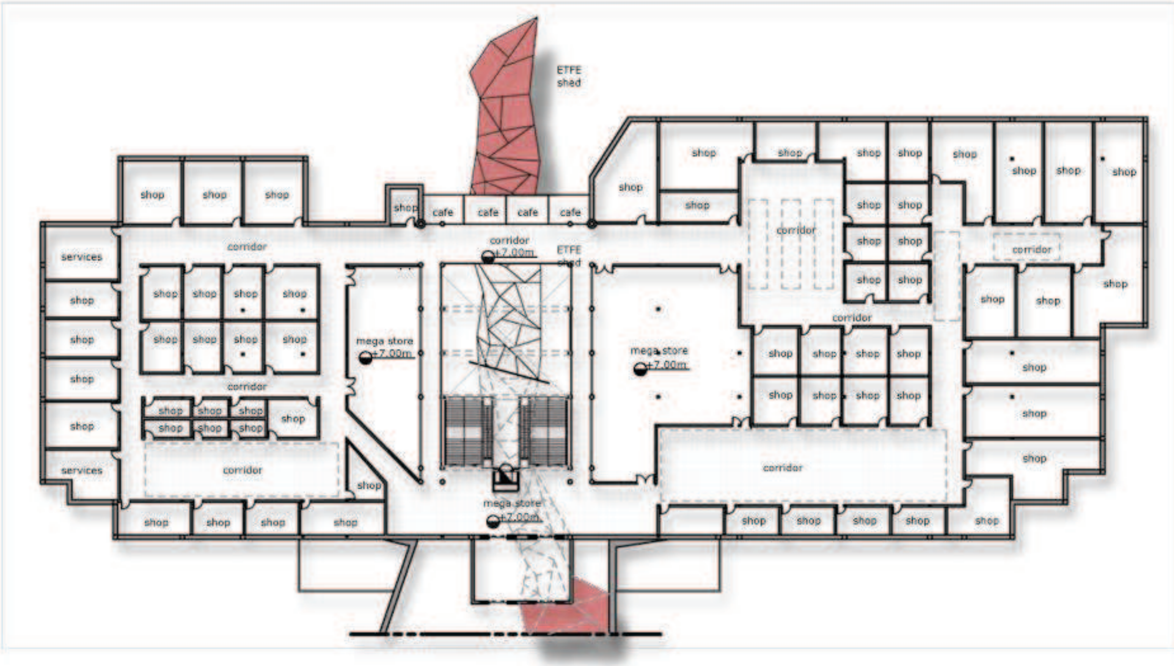


Figure 3.31First floor plan

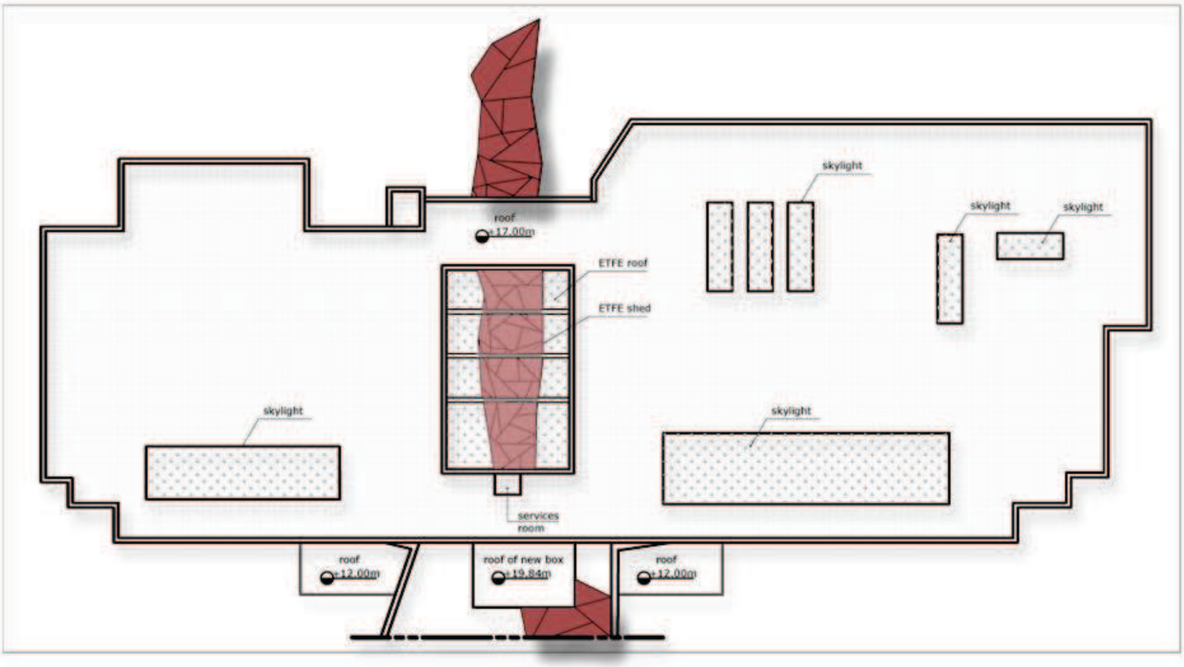


Figure3.32 Roof floor plan

3.2.2.2 Building (2)

Existing status:

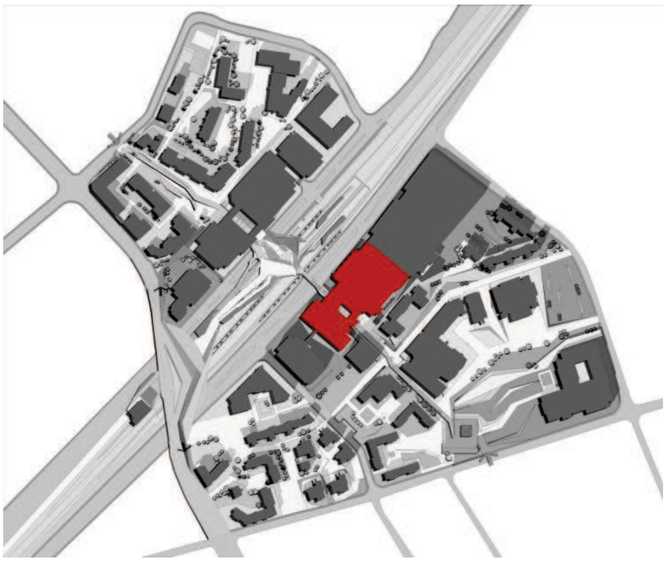


Figure3.33 - Key plan

Foot print: 18,488 m2
Function:
- passage to train station from recreational piazza
- Commercial
- Parking on the roof

Building materials:
- Facade finish: metal cladding
- Structure: Steel
- Glazing: triple glazing

Condition: Good (fairly new)

Photos

Figure 3.34
Entrance 1

Figure 3.35
Close up on entrance 1

Figure 3.36
Entrance 2

Figure 3.37
Interior shot - atrium

Plan of intervention:

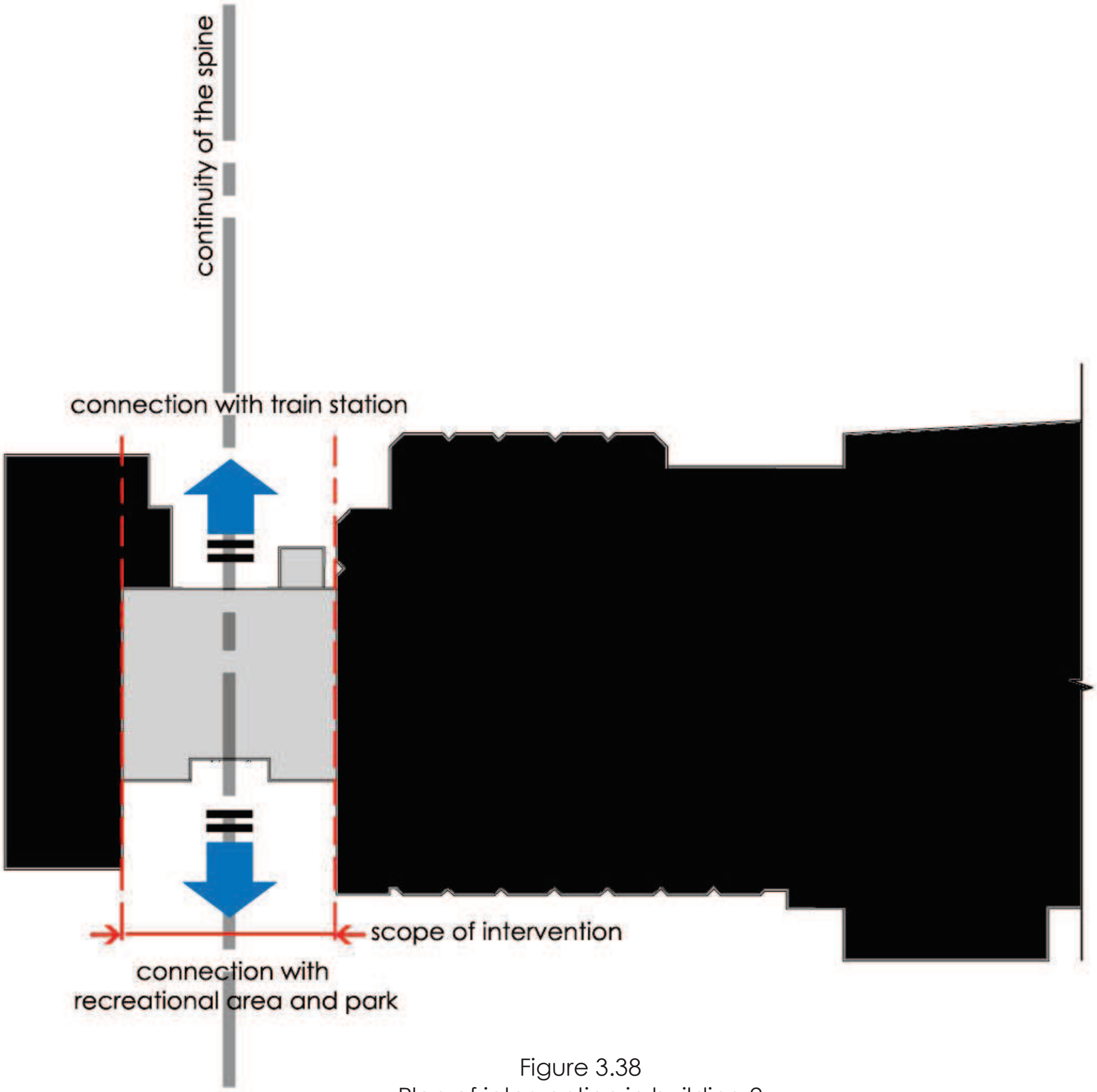


Figure 3.38
Plan of intervention in building 2

Main goals of intervention:

- Emphasizing continuity of the spine by creating the continuous ETFE shed
- Installing triple glazing glass façade
- Raising a new roof in the middle portion
- Installing ETFE as a material for glass roof above atrium

Proposal Design sketches:

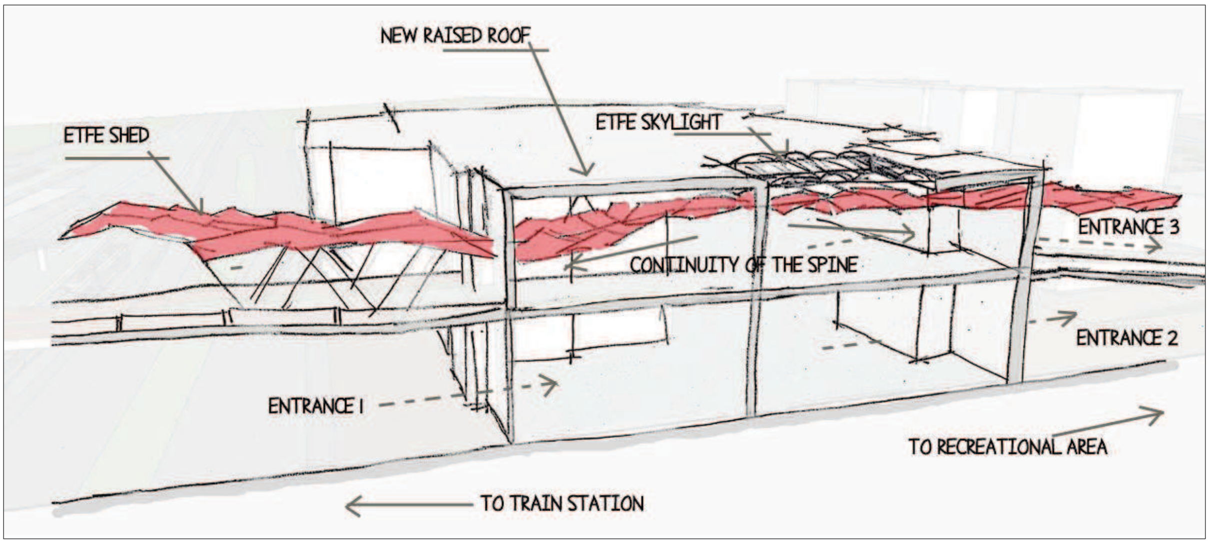
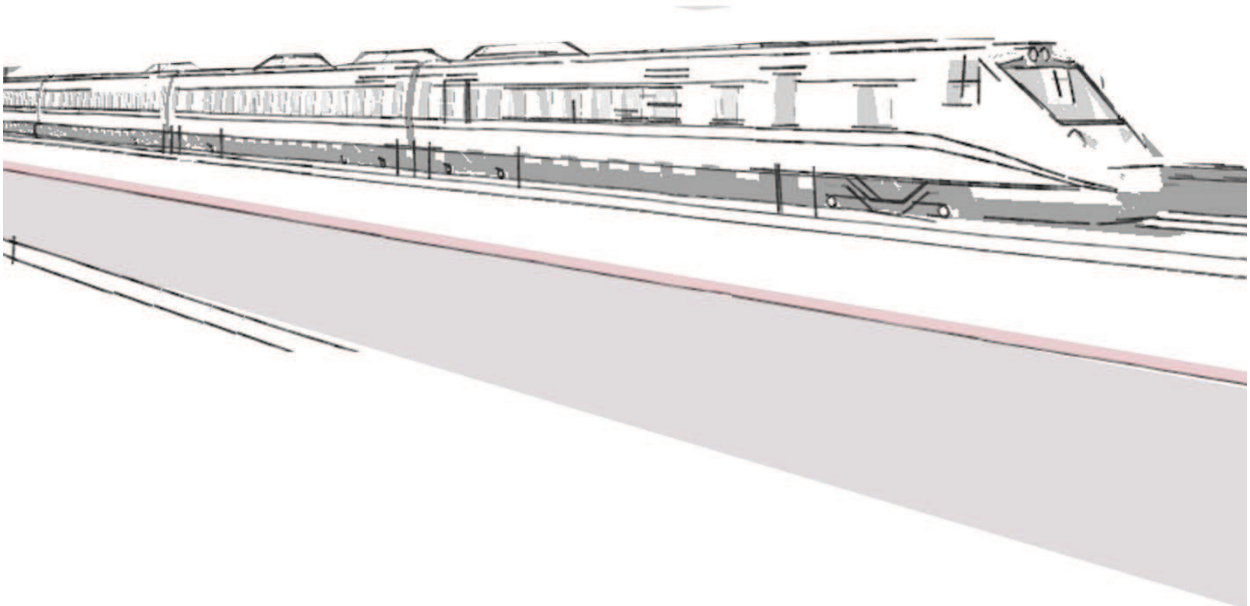


Figure 3.39
Sketch of intervention in building 2

refursbished plan:

Figure 3.40
Roof floor plan

4.0 STRUCTURAL DESIGN



4.1 Introduction

4.1.1 General Statement

As an initial procedure in the building design process, structural design ensure the building within standing as it is designed and guarantees its safety without failure. In the structural design, many factors should be taken into consideration: the materials of components, the forms of the structure, the condition of the site, the climate, the seismic fortification and so on.
The site of this project locates at a train hub, and our building is designed as a train station so several critics on local regulations of rail-way should be considered in our design, especially for the structure design. For example, there are some provision on the structure clearance of the construction for rail-way, which restricts the plans and elevations of buildings structure. And also problems, for example, the vibration to the structure caused by the rails, have made more challenges to our design.
Considering all the problems and challenges, we have chosen the steel frame structural system as the main support element for our building. This decision is based on the fact that we need a light weight structure, the building has a somewhat irregular shape and it needs to be light and structurally sound. Another reason why we have chosen the steel frame system is that the light weight and flexibility of the building would contribute a lot to the damping and noise considering that our site locates at a train station where there is the vibration and noise occurred ,which would be problems for our building and the multifunctional hall on the top floor.
Moreover, to reduce the impaction of the vibration from the tracks, we have introduced the concept of base isolation into our design of structure, which is usually used in the seismic design.

4.1.2 Advantages and disadvantages of steel frame structure

4.1.2.1Advantages

Larger Clear Spans:
Structural steel framing easily and economically accommodates 40' x 40' (12m x 12m) and larger clear spaces, which gives an owner more flexibility with office layouts.

Smaller Columns:
Steel columns are smaller than concrete columns, which mean more useable space and less visual obstructions.

Economical Design Flexibility:
Clear spans, cantilevers, skewed walls; sloping surfaces, curved framing, atria, floor openings, special aesthetic features, and unusual loadings are all easily and economically accommodated with steel.

Simple Modification and Renovation:
If additional loads are added to the structure sometime in the future, steel can be easily reinforced to handle the weight. Likewise, new floor openings for elevators, stairwells and architectural or mechanical requirements can be easily accommodated.

Reduced Construction Time:
Steel framing can be rapidly purchased, fabricated and erected. Steel´s ease of design and construction readily lends itself to fast-track construction.

Reduced Foundation Costs:
Steel lighter weight allows for a smaller less expensive foundation.

Reduced Construction Financing Costs:
Steel can be erected more quickly and the building can be occupied sooner, which reduces interest costs on construction financing. And if there is leasable space included in the project, cash flows starts flowing sooner.

Superior Seismic Performance:
Steel´s ductility makes it the premiere structural material for economically resisting earthquakes. An owner needs to consider both life safety and how much of the structure is recoverable after a seismic event. Steel framing maximizes both of these factors.

Complete Recyclability:
Most steel sold today has been recycled, and nearly all steel taken from demolition projects is 100% recycled.

(Source: http://EzineArticles.com/67769)

Above all, strength is a major plus for steel. Steel structures can withstand unfavorable weather conditions such as hurricanes, high winds, heavy snow and even earthquakes. They are also resistant to termites, creeping, cracks, splitting and rotting, thus increasing durability.

4.1.2.2Disadvantages

Although considered as a reliable structure, steel buildings have some disadvantages. These disadvantages are critical and must always be remedied to ensure a steel building's structural stability.

Thermal Conductivity:
Steel buildings have a poor resistance to heat. Heat conductivity has always been a common problem of steel buildings. Steel is a good conductor of heat, thus making

it more susceptible to thermal bridging, according to Infoforbuilding.com. Thermal breaks and external insulators are required to prevent this, adding to the cost of construction.

Corrosion:

Steel components have a tendency to corrode, especially in marine climates, according to Infoforbuilding.com. When steel comes in contact with water, the iron part of the steel chemically reacts to the oxygen contained in the water. This reaction is the main reason why rust forms in steel buildings, according to Corrosionist.com. Because the atmosphere contains all the necessary elements to form water, corrosion in steel buildings is common, especially in places with high humidity.

Prone to Fracture:

Just like most construction materials, steel is prone to fracture. Constant tension and stress caused by the overall weight of a building contributes to the wear and tear of the steel. However, it can be resolved by including additional support systems. These systems range from additional steel columns to complex brace systems, ensuring the stability and strength of steel buildings.

(Source: http://www.ehow.co.uk/list_7456025_disadvantages-steel-buildings.html)

4.2Structural configuration

4.2.1Structural plan

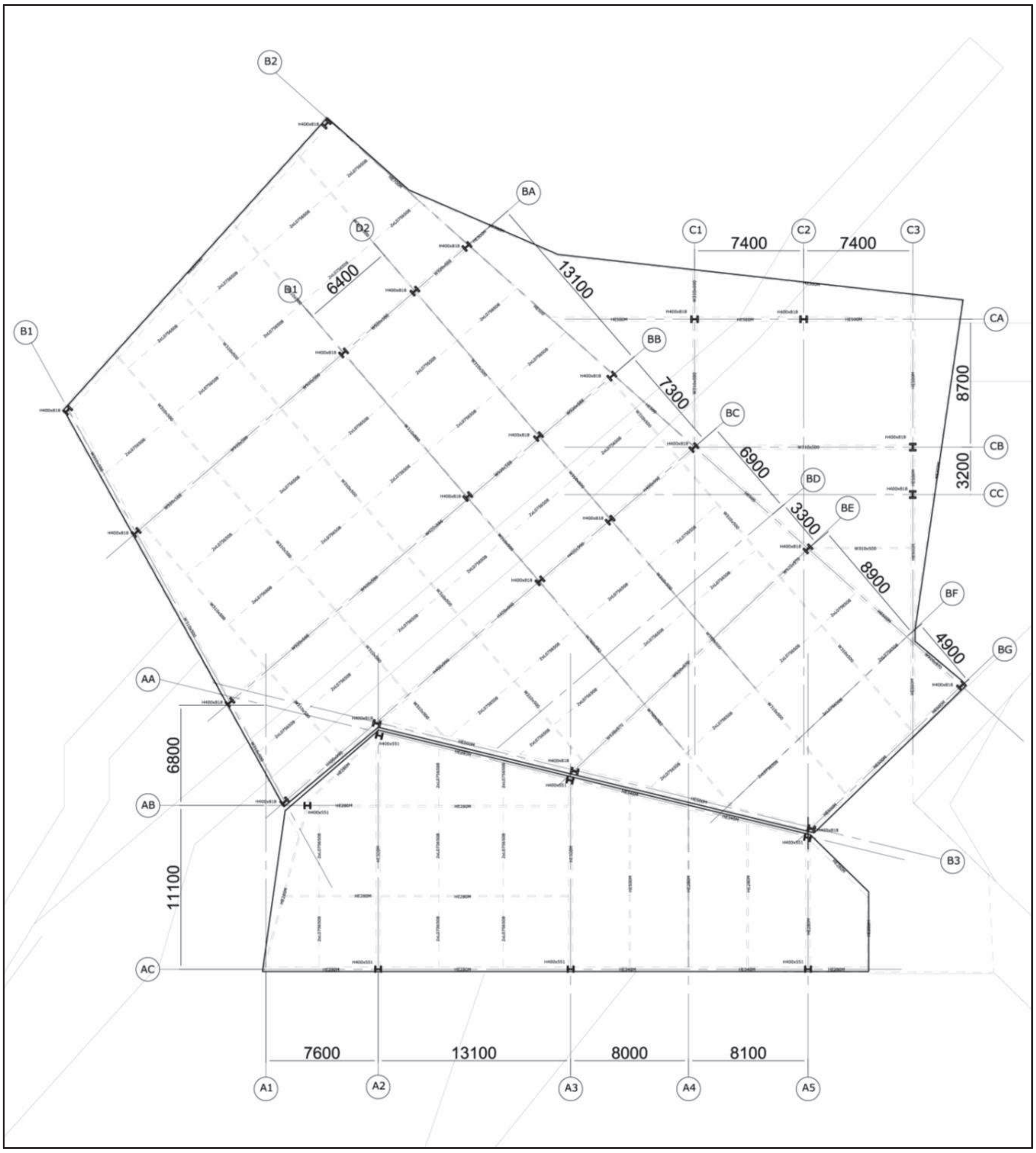


Fig4.1 Structural plan (mm)

4.2.2 Critics on structure design for train station

Because the railway design is related to our project, several critics on structural plan should be concerned.

According to '*Finnish Railway Network Statement 2013*', a Finnish national standard by *The Finnish Transport Agency*. The form and dimensions of the structure gauge (ATU) on a straight track, on open line and in the railway yard are shown in Figure 4.2. The space required for the mounting of the catenary structure and for the passage of the pantograph on electrified lines is marked by the broken line D-E-F-G-H-L.

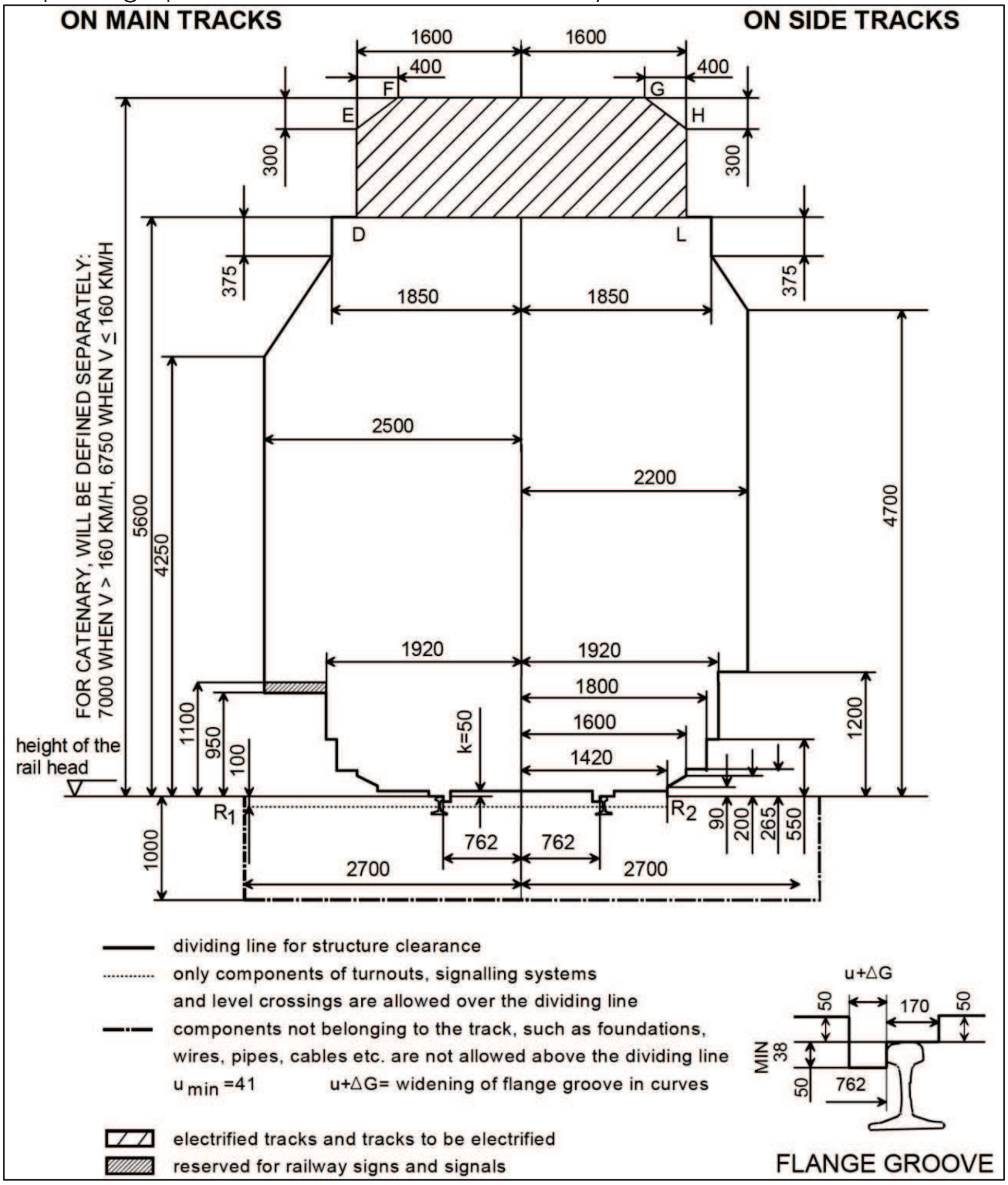


Fig 4.2 Principal dimensions of the structure gauge in Finland

(Source: 'Finnish Railway Network Statement 2013', Finnish national standard by *The Finnish Transport Agency)*

Respecting to the Finland national standard for dimensions of the structure gauge, we have made our structure plan. The Fig 4.3 shows the design details about the clearances of rail-way going under our building structure.

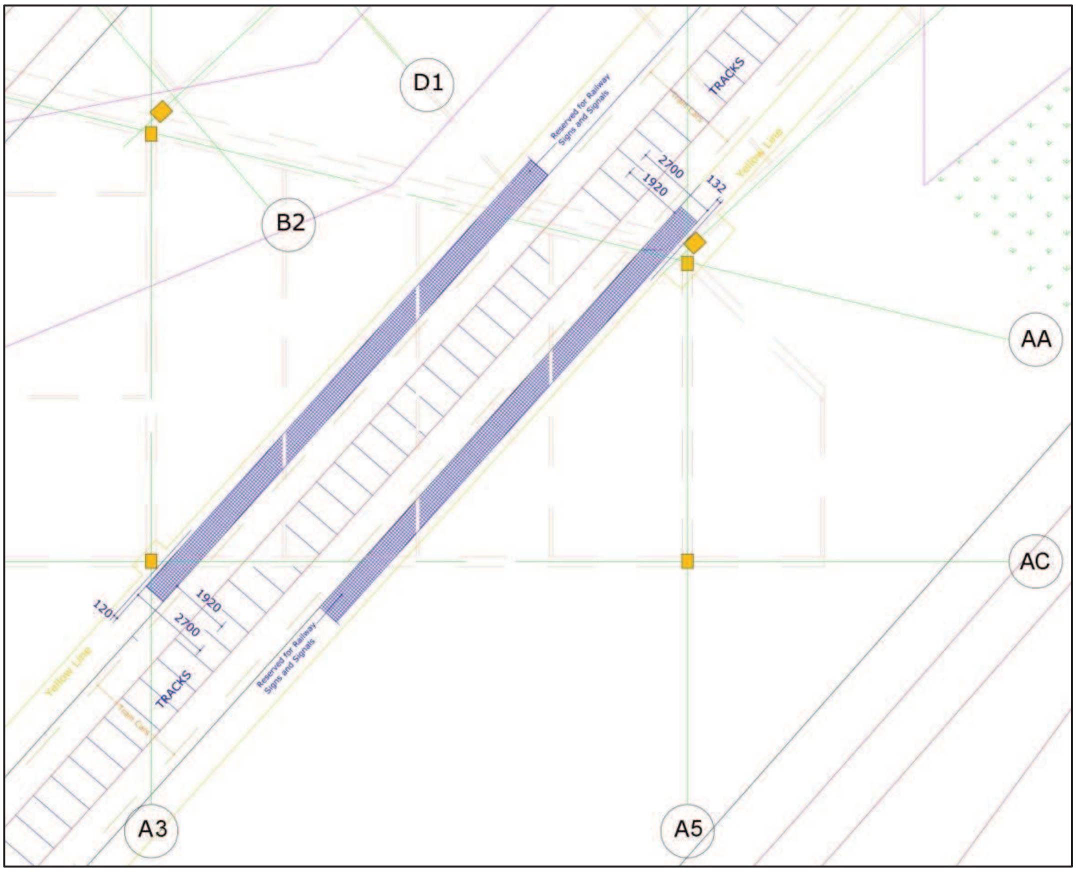


Fig 4.3The place where the clearances of structure is least

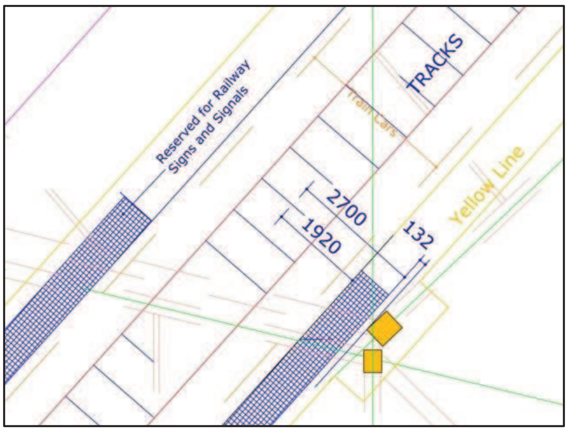


Fig 4.3 .1 Clearances beside A3AC column   Fig 4.3 .2 Clearances beside A5AA column

As figures shown above, our structure plans meet the requirements of Finland national standard for clearance of the structure gauge.

4.2.3 Structural Scheme

Due to different building functions and different building geometry, we decided to split the structure into two parts. So for multifunctional building, semi-open platform are being proposed different structures according to their volume. We set a double structure with a 10cm gap between each other respecting to the different vibration models and expansion joints.
For modeling & structural analysis purpose we have chosen SAP2000 (Structural Software).

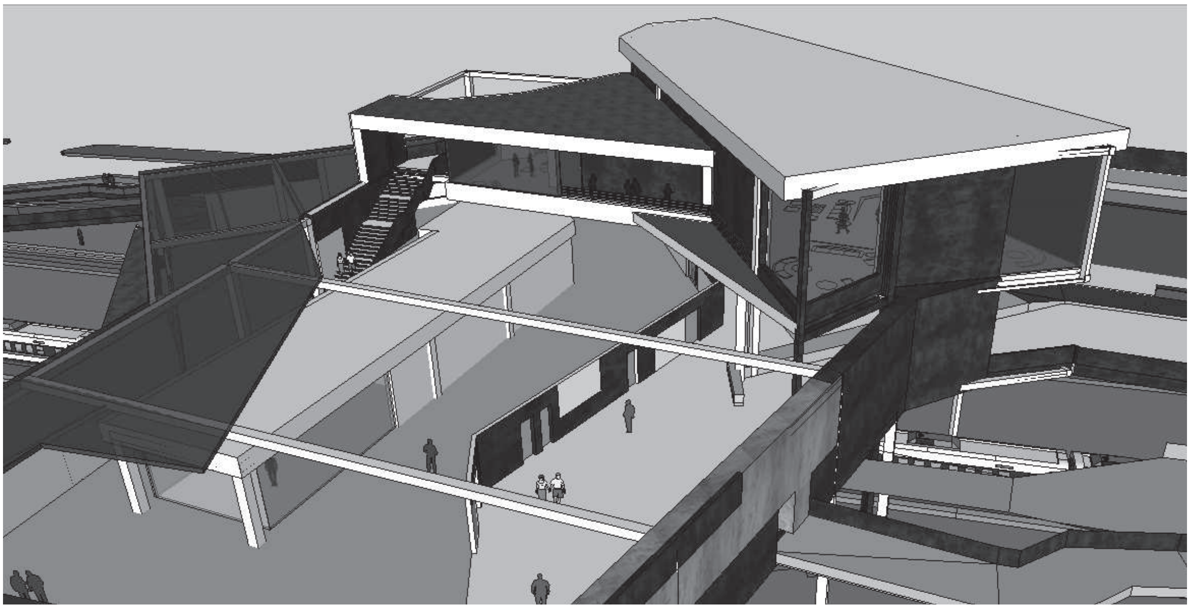


Fig 4.43D Model of the building

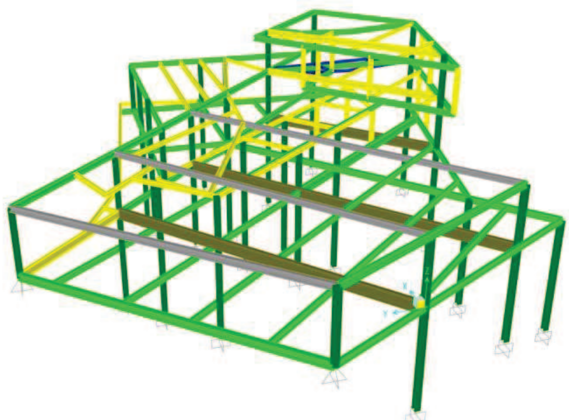
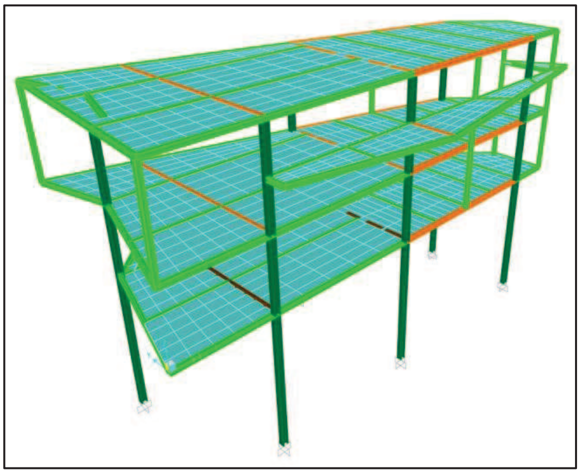


Fig 4.5 Main frames of the semi-open platform

Fig 4.6 Main frames of multifunctional building

4.2.3.1Structural design of multifunctional building

The plan of multifunctional building is designed as a maximum 41.10 meters long (along Axis AC) and maximum 16.43 meters wide (along Axis A2) irregular hexagon. According to the architecture elevation, the height of each storey is 9 meters for the underground, 5.8 meters for the first floor and 7.4 meters for the second floor. In the meanwhile, the bottom columns are connected with the foundation system, which is restricted by the '*Finnish Railway Network Statement 2013*', so the columns for underground part are extended 2.36 meters to be 11.36 meters long to meet the requirement that 'no foundation belonged to other structure above the 1 meter under the level of the rail head'. The green shading is set as a cantilever on the main structure of multifunctional building.



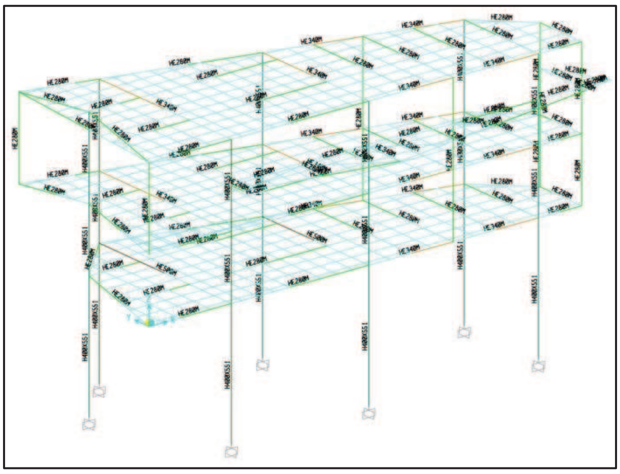


Fig 4.7Simulated Structural model of multifunctional building in SAP2000

4.2.3.2Structural design of the semi-open platform

The plan of platform is in an extremely irregular shape. The maximum length is 57.87 meters(along Axis B2) and the maximum width is 52.87 meters(along Axis BC). The height of each storey is 9 meters for the underground, 5.8 meters for the first floor and 7.4 meters for the second floor. The edge of the platform is supported by the structure of existing building. Some parts of underground columns that are closed to the rail area are extended into 11.36 meters long to reach the deeply-set pile foundations. On the platform, there is a small structure for the lockers room, and the net height of these columns for it is 4.3 meters high.

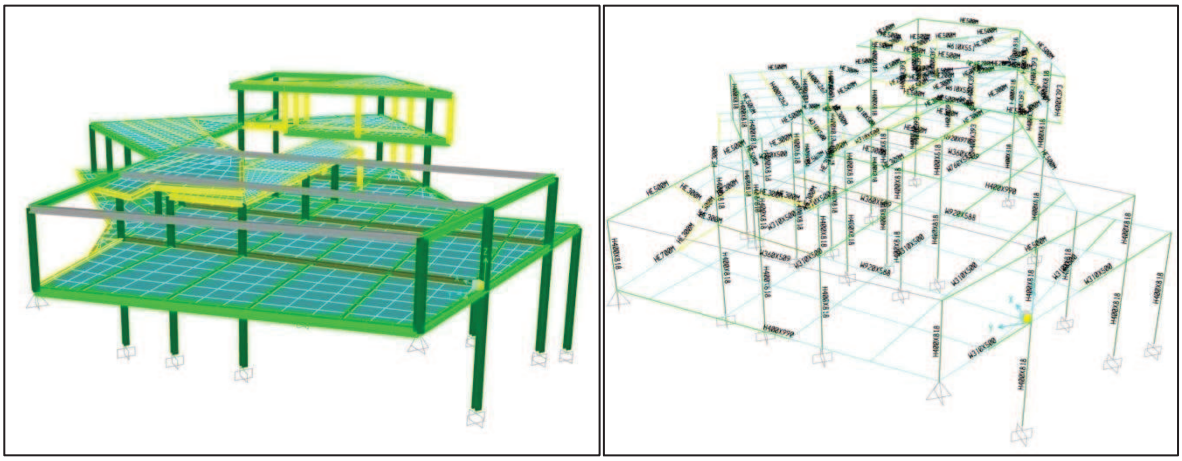


Fig 4.8 Simulated structural model of The semi-open platform in SAP2000

4.3Load estimation and design

According to construction experience on structure design, firstly, we made choice on the sections of structural element and the forms of connection between each component. Then as illustrated before, we have taken use of SAP2000 as a simulation tool to model the structures and calculate the inner forces (axial force, shear force and bending moment), stresses and displacement under the effect of different load combinations and the loads that have been taken into consideration are dead load, live load, snow load and wind load.
Since the seismic risks of Finland are really at low level, this country is considered as a ideal place for storing nuclear weapons and other nuclear equipment. The ever greatest earthquake in Finland recorded is Richter Level 4.7 in 1898. So the seismic impact on structures in Finland is negligible. And our building is just 3 storeys structure of which height is at average level in Finland. Respecting those reasons above, we have not use seismic load into the load combination. But still ,we have done some seismic designs-base isolation-thereby guarantee the safety of building in case of rear situation as well as the vibration due to the train tracks, which is going to be discussed in later chapters of structure design.
It should be demonstrated that the building has been divided into two independent structural parts. This allows difference on deformations of the two parts caused by structure arrangement and load distribution as well as change on temperature.

Some of the applicable Euro codes for the project are listed below, and all the analysis
and estimations are done on the basis of Euro codes.

Euro code 0 (EN 1990): Basis of structural design
Eurocode 1 (EN 1991): General actions on structures
Eurocode 3 (EN 1993): Design of steel structures
Eurocode 4 (EN 1994): Design of composite steel and concrete structures

4.3.1Material Properties

The table below lists the mechanical properties of the steel

Steel grade S 450	t ≤ 40 mm	40 mm <t ≤ 80 mm
F_{yk} [N/mm^2]	440	420
f_{tk} [N/mm^2]	550	550
(ft /fyk)k (minimum)	1.25	1.31
Es [KN/mm^2]	210	210

Table 4.1 Steel properties

4.3.2Load estimation

4.3.2.1Dead load calculations

No.	Layers	Thickness (m)	Avg. height (m)	Specific weight (KN/m^3)	Linear weight (KN/m)
1	Exterior façade plaster	0.0035	6	0.15	0.00315
2	Fiberglass mesh	0.002	6	0.02	0.00024
3	EPS thermal insulation	0.05	6	0.2	0.06
4	Fibercement board	0.015	6	15	1.35
5	Double layer rock wool	0.2	6	0.01	0.012
6	Double layer gypsum board wall	0.03	6	5.88	1.0584
				Total	2.48379

Table 4.2 Dead load- External ventilated wall

No.	Layers	Thickness (m)	Specific weight (KN/m^3)	Weight (KN/m^2)
1	Marble	0.02	27	0.54
2	Flexible Tile Adhesive (Grout)	0.009	10	0.09
3	Bituminous sheets	0.006	76	0.456
4	Electric Heating cable	0.003	0.01	0.00003
5	Osb	0.025	6	0.15
6	Double Rock Wool	0.15	0.01	0.0015
5	Vapor Barrier	0.002	11	0.022
6	Osb	0.05	6	0.3
8	Mineral Wool	0.025	0.01	0.00025
			Total	1.55978

Table 4.3 Dead load- intermediate slab

No.	Layers	Thickness (m)	Specific weight (KN/m³)	Weight (KN/m²)
1	Polished concrete flooring	0.1	18	1.8
2	Cellulose - Acoustical layer	0.015	0.55	0.00825
3	Screed	0.07	20	1.4
4	Polymer bitumen waterproofing membrane	0.006	11	0.066
5	Extruded Polystyrene board (xps)	0.04	0.2	0.008
6	Reinforced Concrete	0.13	22	2.86
7	Corrugated sheets	0.001	18	0.018
			Total	6.16025

Table 4.4 Dead load- platform slab

No.	Layers	Thickness (m)	Specific weight (KN/m³)	Weight (KN/m²)
1	Screed	0.015	20	0.3
2	Bituminous sheets	0.008	11	0.088
3	Osb	0.05	6	0.3
4	Aluminum bubble film insulation	0.006	0.1	0.0006
5	OSB	0.05	6	0.3
6	Double Rock wool Insulation	0.15	22	3.3
7	Vapor barrier	0.002	11	0.022
8	Osb	0.05	6	0.3
9	Double Rock wool Insulation	0.025	0.01	0.00025
			Total	4.61085

Table 4.5 Dead load- roof

4.3.2.2Live load

Live loads are a result of the occupancy of a structure. EN1991-1-1: section 6 specifies C2: Areas with fixed seats(e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms).Since the building mainly has rooms with fixed seats, such as multi-functional hall and waiting rooms, we used $4KN/m^2$ for institutions. For the other rooms with unfixed seats, we used $3KN/m^2$. In the open space, platform for example, $2KN/m^2$ has been used as the live load, according to the EN1991-1-1: section 6.

4.3.2.3Wind load calculation

The wind load calculations have been conducted according to EN-1991-1-4, which deals with the determination of natural wind actions for the structural design of buildings and civil engineering works. The code is applicable to buildings and civil engineering works with heights up to 200 m, thus for the buildings under the scope of this study, wind actions can be determined according to this part of the Euro code.

Calculation of MeanWind Velocity:

Due to lack of the data of national code of Finland for wind design, which leads to great difficulty on using the method in EN1991-1-4-Wind actions to calculate the Mean wind velocity, we have decided to use the data from an experiment (**Pori, Finland – Case study** *Energi- ogMiljødata, NielsJernesvej 10, DK-9220 Aalborg O – Tel: +45 96835 4444, Fax: +45 9635 4446, Mail: emd@emd.dk, Web: www.emd.dk*) to make the mean wind speed $V_m = 6.5\ m/s$

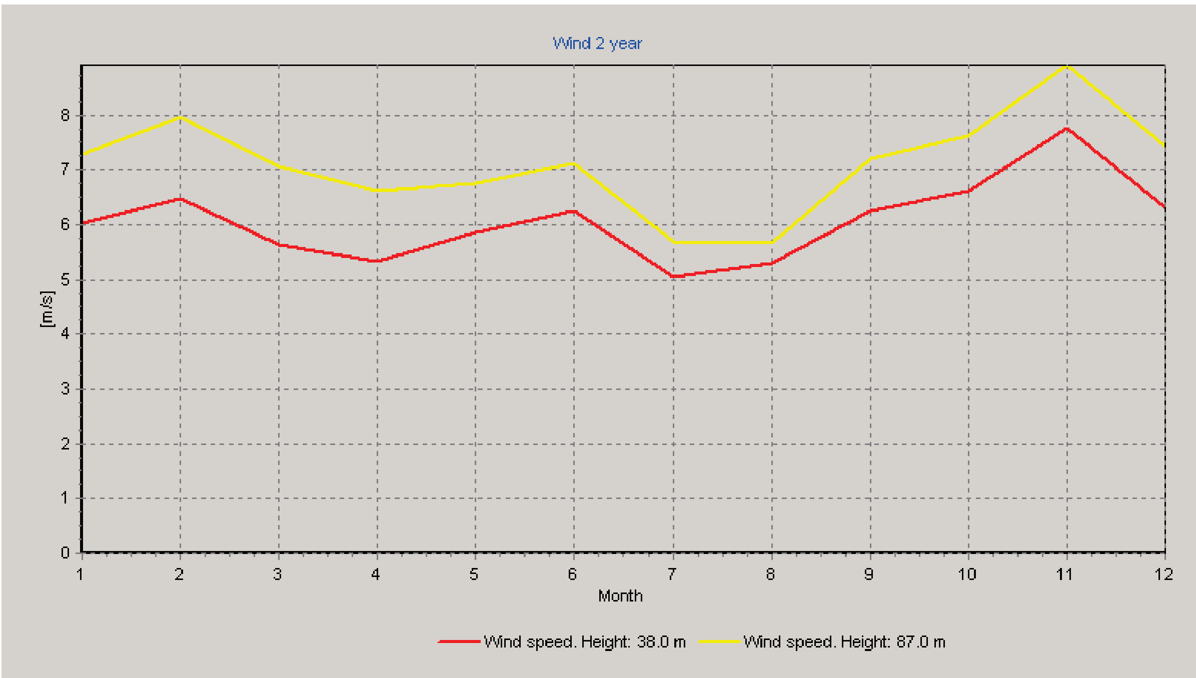


Fig 4.6 Graph showing the mean wind speed at the heights 38 m (red) and 87 m (yellow).

Calculation of Wind Turbulence, I_v (z):

$K_r = 0.19(Z_0 / Z_{0,\ IV})^{0.07}$

Where,

Z_0 is the roughness length

K_r is the terrain factor depending on the roughness length Z_0.$Z_{0, IV}$= 1 m (the value for terrain category IV given in Table 4.1 of EN 1991-1-4)
Z_{min} is the minimum height defined in Table 4.1
Z_{max} is to be taken as 200 m, unless otherwise specified in the National Annex
Source of table 5.6
NTC, Table 3.3.I
Z_0, Z_{min} depend on the terrain category, Table 4.1 of EN 1991-1-4 also provides the recommended values for Z_0, Z_{min} depending on five representative terrain categories.
Accordingly;

Table 4.1 — Terrain categories and terrain parameters

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
NOTE: The terrain categories are illustrated in A.1.			

Fig 4.10Table 4.1from EN 1991-1-4

Z_0 = 1 m
Z_{min} = 10 m

$k_r = 0.19 . (40/ 1)^{0.07}$
$k_r = 0.246$

$I_v (z) = v / v_m (z)$ for $z_{min} < z < z_{max}$
$I_v (z) = I_v (z_{min})$ for $z < z_{min}$
${}^{\delta}v = k_r. V_b. k_l$

Source of table 5.7
EN 1991-1-4, Table 4.1
Where,
k_r is the terrain factor calculated above,
V_b is the basic wind velocity calculated above,
k_l is the turbulence factor, which is recommended to be taken as 1,0 by EN 1991-1-4.

$^{\delta}v = (0.246)\ (6.5)\ (1)$
$^{\delta}v = 1.599$

Calculation of Peak Velocity Pressure, q_p (z):

$q_p (z) = [1 + 7.I_v (z)] \ .\ ½\ .\rho\ .\ v_m^2 (z)$

Where,
ρ is the air density which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms. The recommended value is 1.20 kg/m^3 in EN 1991-1-4.

Peak velocity pressure, q_p (z) will be:
$I_v (z) = {}^{\delta}v / V_m$
= 1.599 / 6.5 = 0.246
q_p (z) = 69 N/m^2

Determination of Pressure Coefficient, c_{pe}:
The external pressure coefficients c_{pe} for buildings and parts of buildings depend on the size of the loaded area A, which is the area of the structure that produces the wind action in the section to be calculated. The external pressure coefficients are given for loaded areas A of 1 m^2 and 10 m^2 in the tables for the appropriate building configurations as c_{pe1}, for local coefficients, and c_{pe10}, for overall coefficients, respectively.
Since the pressure coefficients for vertical walls and flat roof vary through the wall and roof surface, the calculation is made considering geometry of the structure, the aspect ratio (h/d) and wind direction.

$C_{pe} = C_{pe,\,1}$, for $A \le 1\ m^2$
$C_{pe} = C_{pe,\,1} - (C_{pe,\,10} - C_{pe,\,1}) \log 10\ A$, for $1 < A < 10m^2$
$C_{pe} = C_{pe,\,10}$, for $A > 10m^2$

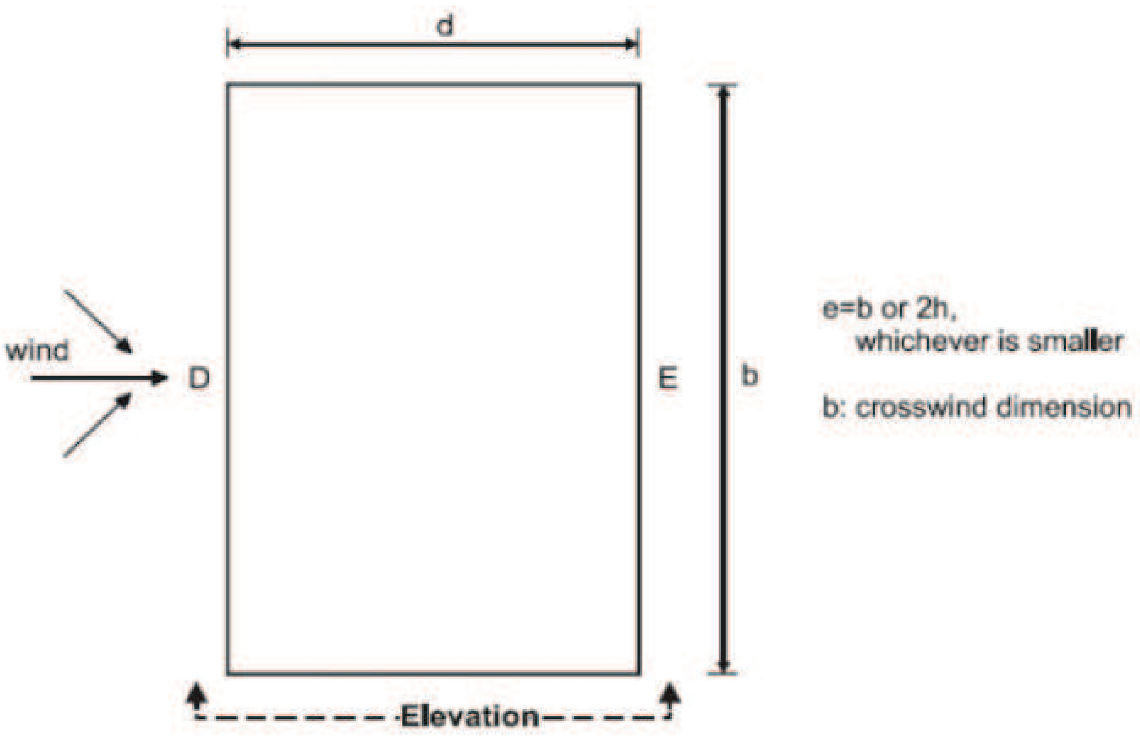


Fig 4.11 Pressure coefficient for vertical wall

(Source: EN 1991-1-4 Figure 7.5 - Key for vertical walls)

The area is greater A > 10 m^2 in all the cases hence the wind pressure on the surfaces is calculated from the peak velocity pressure q_p (z), and external pressure coefficient to be used will be $C_{pe,10}$. Multiplying this coefficient by the characteristic peak velocity pressure (q_p) we obtain the external wind pressure we. Finally to obtain the wind force acting on the area is used the equation:

$F_w = c_s\, c_d c_f q_p\, (ze)\, A_{ref}$

Where,

c_{scd}, structural factor, defined as 1.0 according to section 6

c_f, force coefficient for the element, defined as 1.0 according to section 7

q_p(ze), characteristic peak velocity pressure at height ze, calculated before

A_{ref}, reference area of the structural element.

By this we obtain all the forces that will be acting on the building, and are distributed on the elements for their analysis.

For main building:

Zone	Cpe,10(Overall Co-efficient)	q_p(Peak velocity Pressure) N/m2	Area	We(Wind pressure on surface) N/m2	F(Wind Force) KN)
A	-1.2	69	93.738	-82.8	-7.76
B	-0.8	69	90.361	-55.2	-4.99

Table 4.6 Wind forces on wall and 0° wind direction

Zone	Cpe,10(Overall Co-efficient)	q_p(Peak velocity Pressure) N/m2	Area	We(Wind pressure on surface) N/m2	F(Wind Force) KN)
A	-1.2	69	388.464	-82.8	-32.16

Table 4.7 Wind forces on wall and 90° wind direction

Zone	Cpe,10(Overall Co-efficient)	q_p(Peak velocity Pressure) N/m2	Area	We(Wind pressure on surface) N/m2	F(Wind Force) KN)
F	-1.8	69	28.8	-124.2	-3.58
G	-1.2	69	69.7512	-82.8	-5.78
H	-0.7	69	394.2048	-48.3	-19.04
I	-0.2	69	41.063	-13.8	-0.57

Table 4.8 Wind forces on flat roof

For other part:

Zone	Cpe,10(Overall Co-efficient)	qp(Peak velocity Pressure) N/m2	Area	We(Wind pressure on surface) N/m2	F(Wind Force) KN)
A	-1.2	69	279.205	-82.8	-23.12
B	-0.8	69	261.483	-55.2	-14.43

Table 4.9 Wind forces on wall and 90° wind direction

Zone	Cpe,10(Overall Co-efficient)	qp(Peak velocity Pressure) N/m2	Area	We(Wind pressure on surface) N/m2	F(Wind Force) KN)
F	-1.4	69	14.8	-96.6	-1.43
G	-0.9	69	47.82	-62.1	-2.97
H	-0.7	69	274.48	-48.3	-13.26
I	-0.2	69	343.1	-13.8	-4.73

Table 4.10 Wind forces on flat roof

Area description	Height(m)	Z/Z0	Cr	$^{\delta}$V	Iv(z)	Vm (Z) m/s	q p (Z) N/m2	q p (Z) KN/m2
Platform Wall	11.5	1150	1.19	4.23	0.14	29.78	1060.33	1.06
Main Building	18.5	1850	1.27	4.23	0.13	31.78	1170.16	1.17

Table 4.11 Vertical distribution of wind pressure

4.3.2.4Snow load calculation

The characteristic values of the minimum ground snow load are given in EurocodeEN1991-1-3:2003 and NTC.

<u>Zone - Sweden and Finland</u>

Altitude relationship for Sweden:

$$\boldsymbol{S_k = 0.790Z + 0.375 + A / 336}$$

Where: Z is the Zone Number & A is the altitude

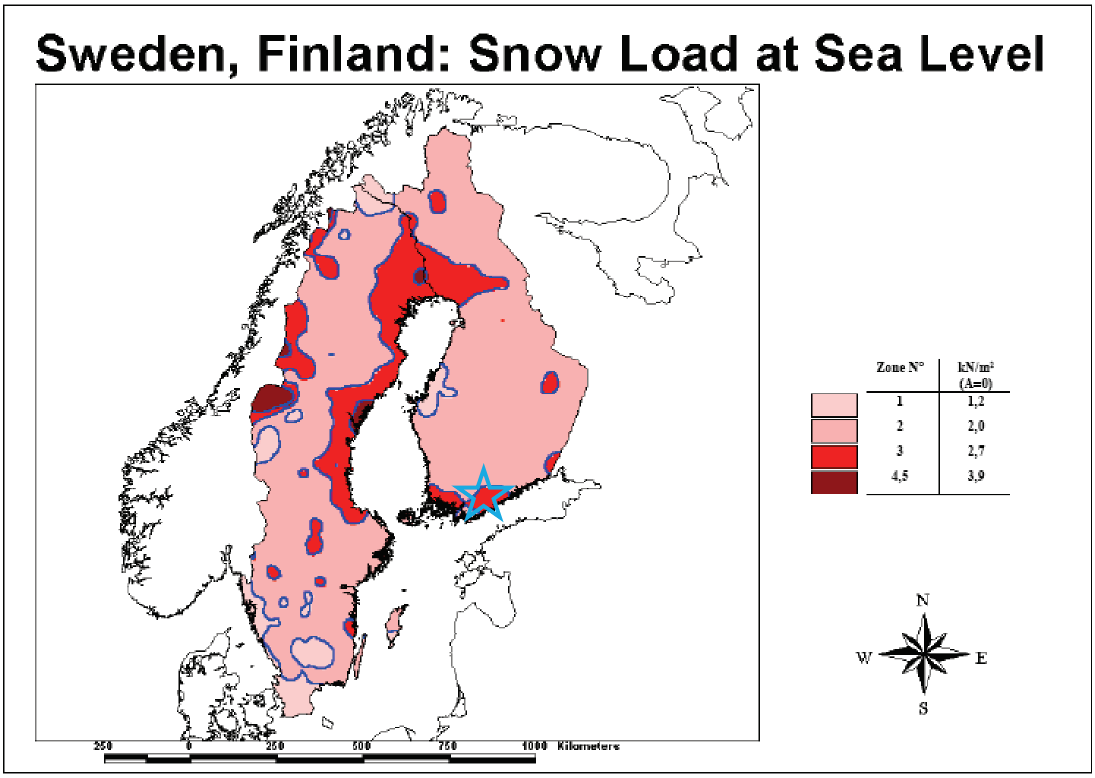


Fig 4.12 Snow load zone map of Sweden and Finland, NTC

(Source:EN1991-1-3:2003)

The altitude of the site is **28 m**and the zone number can be obtained from the figure above, which is**3**. Therefore the characteristic value of snow load on the ground at the relevant site is taken as,

$$S_k = 0.790 \times 3 + 0.375 + 25 / 336 = 2.819\ KN / m^2$$

So taking in to account the effect of other factors, the load is calculated by;

$$\boldsymbol{s = \mu_i . C_e . C_t . s_k}$$

Where,
μ_1 is the snow load shape coefficient
s_k is the characteristic value of snow load on the ground,
C_e is the exposure coefficient
C_t is the thermal coefficient.
C_e should be taken as 1.0 unless otherwise specified for different topographies.

Determination of snow load shape coefficient:
Inclination of the flat roof is taken as 3° for drainage purposes hence; it is assumed that the snow is not prevented from slipping. If the lower end of the water ends with a guardrail, barrier or other obstruction, then the form factor cannot be taken less than 0.8 regardless of the angle .In the table below 1 is given as 0.8 for the angles between 0° and 30°.
Therefore; the calculation is summarized as:
Snow load on the ground: $s_k = 2.819\ KN/m^2$
The snow load shape coefficient: $\mu_l = 0.8$
Exposure coefficient: $C_e = 1$
Thermal coefficient: $C_t = 1$
$s = \mu_l . C_e . C_t . s_k$
$\boldsymbol{s = 0.8 \times 1 \times 1 \times 2.819 = 2.256\ KN/m^2}$

4.3.2.5Earthquake design concepts

Finland is situated on the Baltic shield, which is the one of the seismically quietest areas in the world. So the seismic hazard in Finland is very weak. The Figure 4.8 indicates the Seismicity Map - 1900 to Present in Finland, which illustrates rare earthquakes happened as recorded. Usually, the seismic design was not considered in the structural design, which helped designers to achieve good and Economical designs.

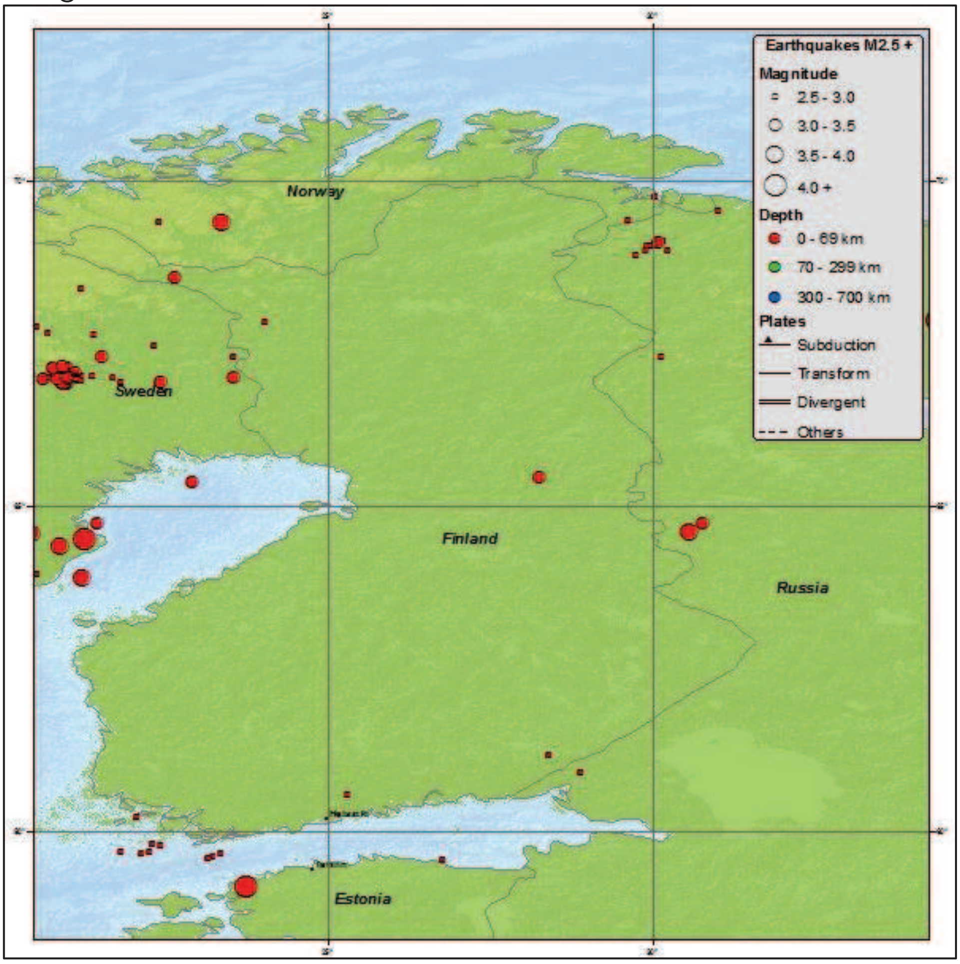


Fig 4.13 Seismicity Map - 1900 to Present in Finland
(Source: http://earthquake.usgs.gov/earthquakes/world/finland/seismicity.php)

However, our project is located at a transport hub, mechanical vibrations caused by the trains would impact the structure at a considerable level. To solve this problem that may cause trouble to our project as well as to reduce the incidental seismic hazards on our buildings, we have used the concept of seismic base isolation in seismic design.

Base isolation, also known as seismic base isolation or base isolation system, is one of the most popular means of protecting a structure against earthquake forces .It is a collection of structural elements which should substantially decouple a superstructure from its substructure resting on a shaking ground thus protecting a building or non-building structure’s integrity.

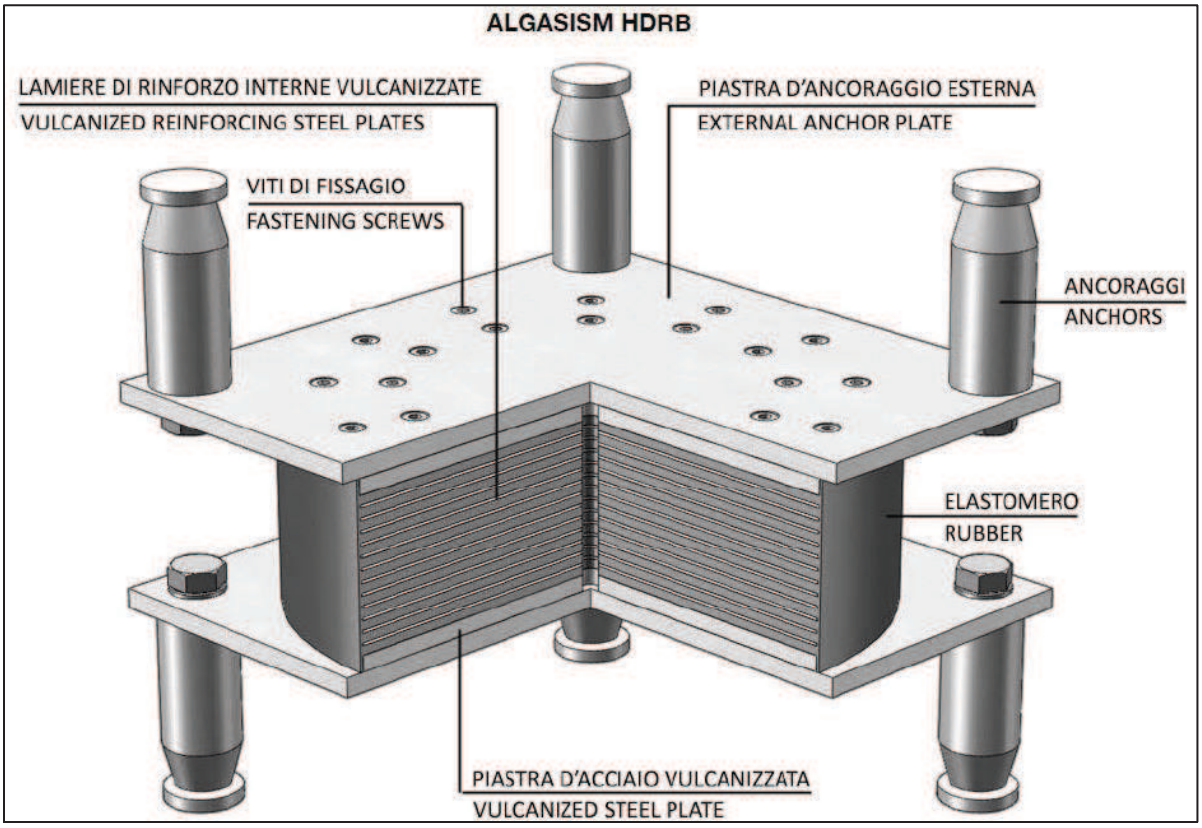


Fig 4.14 High Damping Rubber Bearings / Lead Rubber Bearings

'*Technical Thinking*'- Algasism- www.alga.it

We have chosed the HDH700X140 , whose viscous damping of the rubber is 16%.

The technical data is shown below:

HDH 700X140	V_{max}	V_{sism}	K_r	H	t_e	S_{max}
	[KN]	[KN]	[KN/mm]	mm	mm	mm
Value	17900	10900	3.85	302	140	280

Table 4.12 Technical data for HDH700X140

Where:

$V_{max}$is Max vertical load at ULS (Ultimate Limit State) with zero displacement

$V_{sism}$is Vertical load under seismic conditions

$K_r$is Horizontal stiffness (elastomer contribution)

K_{lead} is Horizontal stiffness (lead core contribution)

F_y is Yield point load for lead core

K_{eff} is Effective horizontal stiffness

H is Overall height of the isolator

t_e is Thickness of the elastomer

S_{max} is Design displacement

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Many tests and practices shows that base isolation is an effective strategy to enhance the seismic structural performance also for relatively flexible framed systems at serviceability and ultimate limit states. It is demonstrated that although the base-isolated and the fixed base construction may undergo the same maximum accelerations the structural and non-structural damage are prevented in the frame resting on rubber devices. Savings of about 40% were estimated for percentage of steel reinforcement to be used for the columns and beams of the base isolated frame.

As a second solution to the seismic design , we have proposed the bracing systems between some columns to enhence the seismic performance of building. For examle, along Axis AA between Axis A3 and Axis A5, along AxisB3 between Axis BE and Axis BG and so on. In the simulation by SAP2000, we neglect the effects provided by bracing system, somehow that makes the main structre to have a stronger solustion and to improve the safety factors, though we have proposed the bracing systems into our structure design.

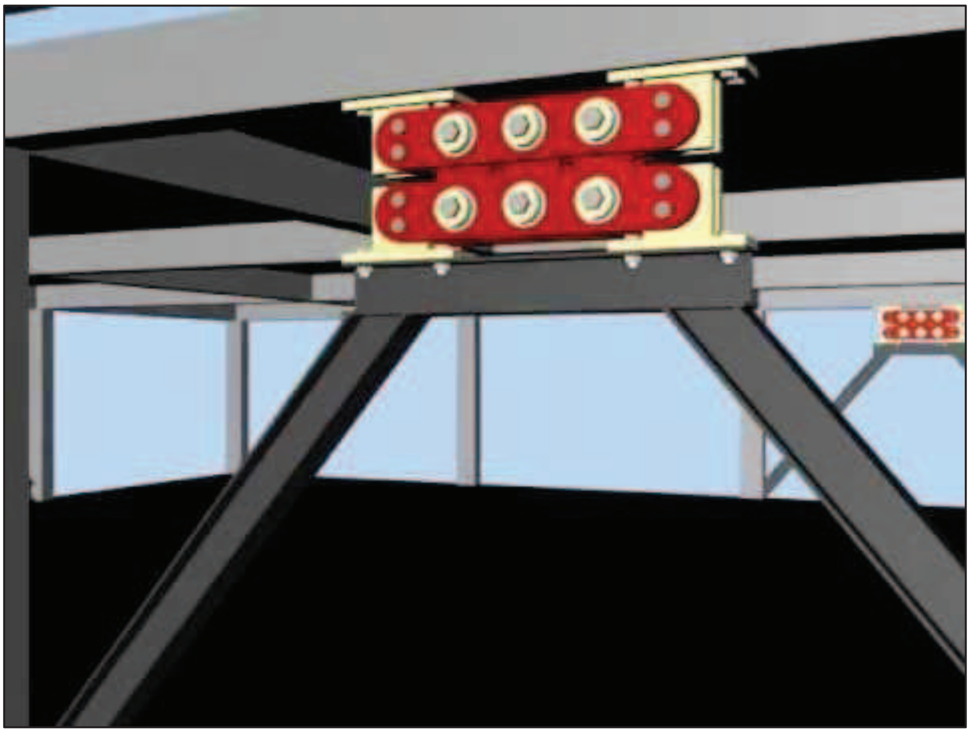


Fig 4.15 Bracing systems

4.4 Predesign of sections

4.4.1 Column sections

Multifunctional Building:

Fig 4.16 Structure plan for Pre-design of sections

Here we take a column at A5-AC as reference where the loads are at the maximum level in the building duo to a big cantiler in the plan.
Due to the irregular shape of plan and to guarantee the safety, we enlarge the effectice area of a 6m X 9m rectangular with dash lines, as shown in Fig 4.16.

So the Loads on the column A5-AC on the ground floor:

$Q_d = Q_{roof} + Q_{slab} \times 2 + Q_{walls}$

$= 4.61 \times 54 + 6.16 \times 54 \times 2 + 2.48 \times 14 \times 2$

$= 983.66\ KN$

$N_{d,column} = Q_d \times /2 = 491.83\ KN$, $N_{combo,column} = 3 \times N_{d,column} = 1475.49KN$

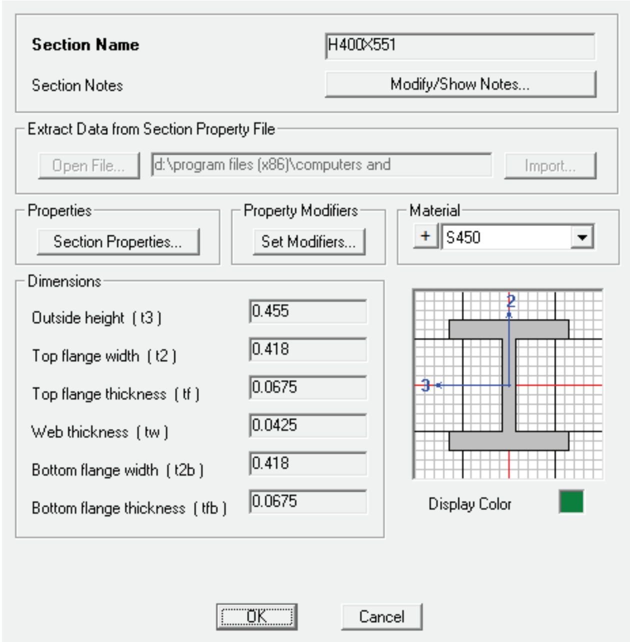
$A_o = N_{column} / F_{yk} = 1475.49 \times 10^3 / 420 = 3513\ mm^2$.

So predesign of column sections can be obtained:

$A_{pre} = A_o / (\rho_{pnc}\beta_{pnt}) = 3513 / (0.5 \times 0.125) = 56280\ mm^2$

Here we can find the $A_{H400X551} = 70000\ mm^2$, which is apropriate for $A_{pre} = 56280\ mm^2$, *so* H400X551is **SATISFIED**.

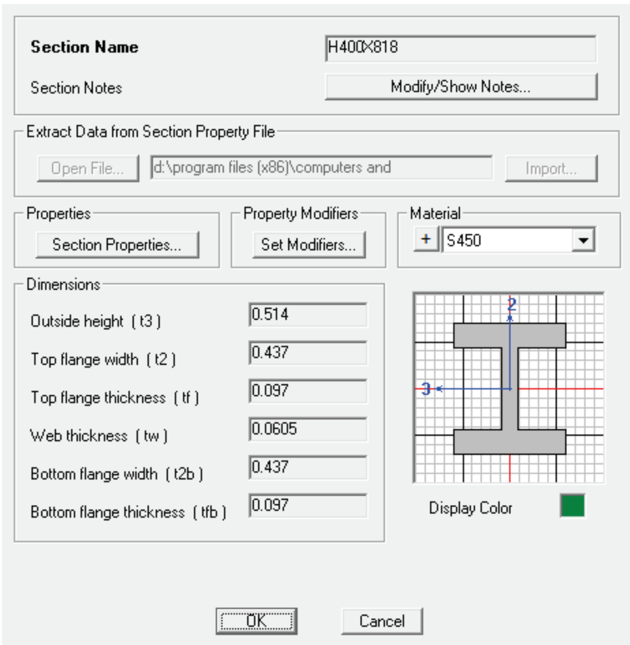
Therefore, in multifunctional buildins area we have used H400X551 as main section



H400X551, d= 45.5cm, W_f= 41.8cm, t_f= 6.75 cm, t_w = 4.25cm

<u>The semi-open platform:</u>

Due to larger loads and larger pans on semi-open platform, we have used a larger cross section form columns, which isH400X818.



H400x818, d= 51.4cm, W_f= 43.7cm, t_f= 9.7 cm, t_w = 6.05cm

4.4.2 Beam section

Multifunctional Building:

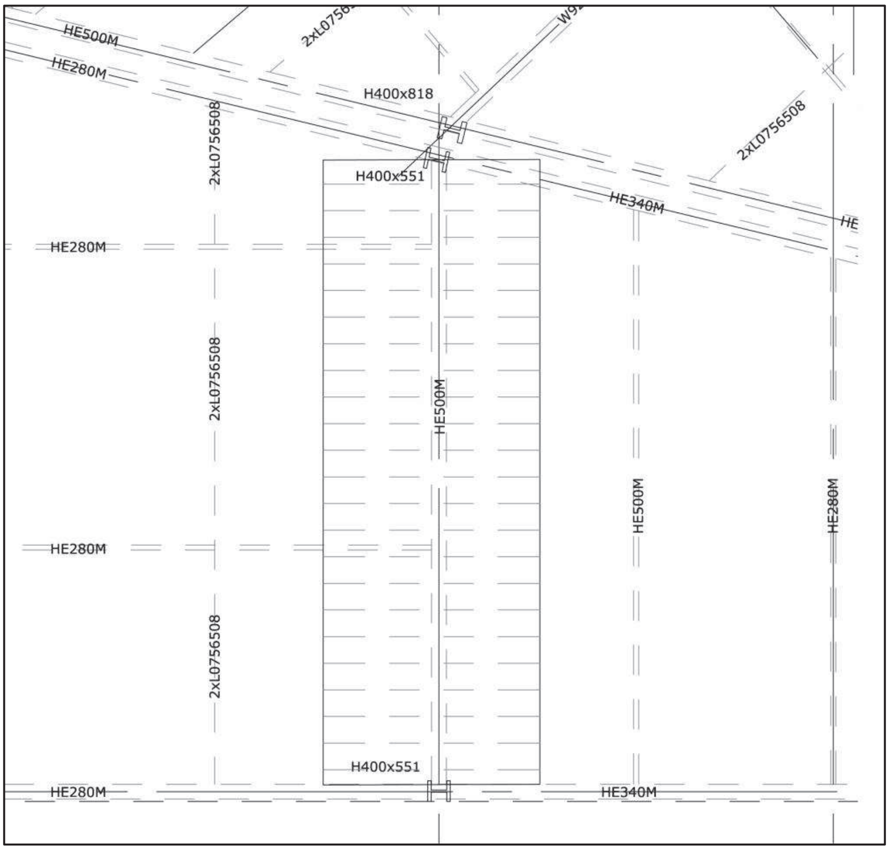
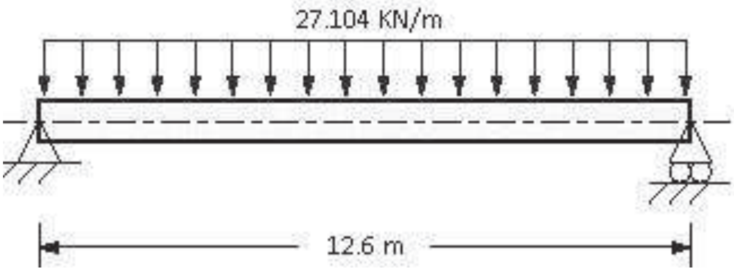


Fig 4.17 Structure plan for Pre-design of sections

Here we take a beam along A3 as reference where the loads are large and the plan is long.
Due to the irregular shape of plan and to guarantee the safety, we enlarge the effectice area of a 4.4m X 12.6m rectangular with dash lines, as shown in Fig 4.10.
So the Loads on the beam along A3 on the ground floor:
q= 6.16 x 4.4 = 27.104 KN/m



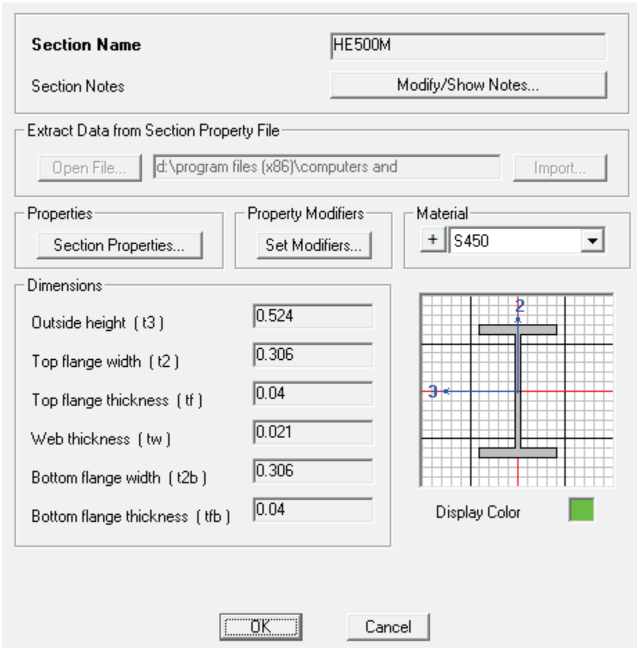
In calculation, we rougly conside it as simply supported beam,
Md = qL^2 / 8 = 27.104 x 12.6^2/ 8= 537.88 KN ▪ m

We assume : Mcombo =3 Md = 1613.64 KN ▪ m

We assume F_b = 0.5, F_y = 141.12 KN / mm^2

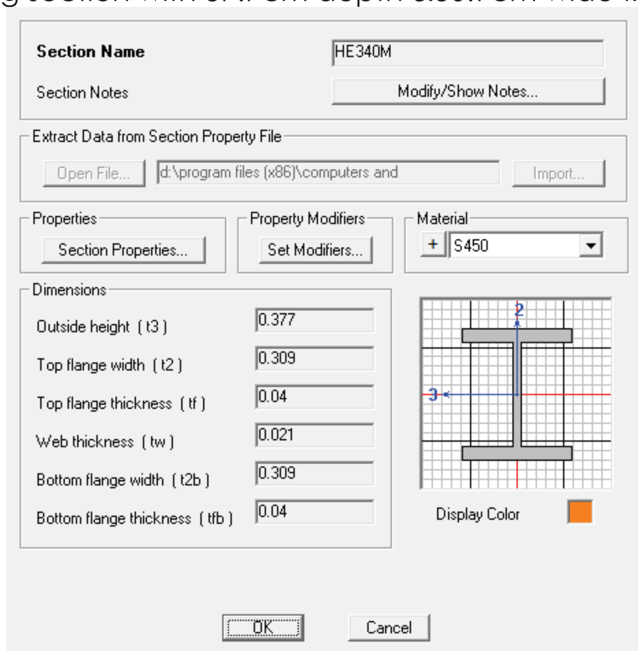
Ao= Mcombo / F_y = 1613.64 x 103/141.12 = 11428 mm^2

A_{pre} = A_o /F_b = 11428 / 0.5 = 22856 mm^2
So we use HE 500M, whose cross section is 34400 mm^2, **SATISFIED**



HE 500 M

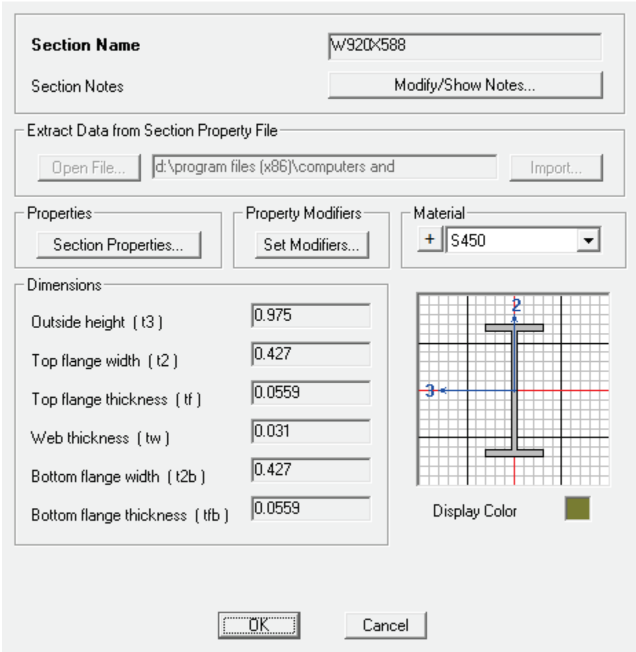
For the other area, where the load is less and the span is shorter, I section Beam is having section with 37.7cm depth &30.9cm wide flange.



HE 340 M

<u>For semi-open platform:</u>

and for the platform where the span is quite lang and the load is very large, we have usedW920X588 section with 97.5cm depth &42.7cm wide flange.



W920X588

At some areas, to reduce the span of slab to less than 4m , we have proposed 2xL0756508 as couping beams supported by secondary beams surrounded.

4.4.3 Load combinations

Combo11.35DL+1.5LL

Combo21.35DL+1.05SL+1.5LL

Combo31.35DL+1.5LL+1.05SL+1.05WLX

Combo41.35DL+1.5LL+1.05SL+(-1.05)WLX

Combo51.35DL+1.5LL+1.05SL+1.05WLY

Combo61.35DL+1.35LL+1.05SL+(-1.05)WLY

4.5 Structural analysis

This whole analysis is made on software SPA2000. Although some manual checks have also been applied to confirm the software results. Some assumptions which are made before starting analysis are

- Euro code 3-1993 is being used to run the analysis.
- The analysis is made for all three buildings separately so we are presenting results of courts building due to its higher volume.

4.5.1 Bending moment diagram

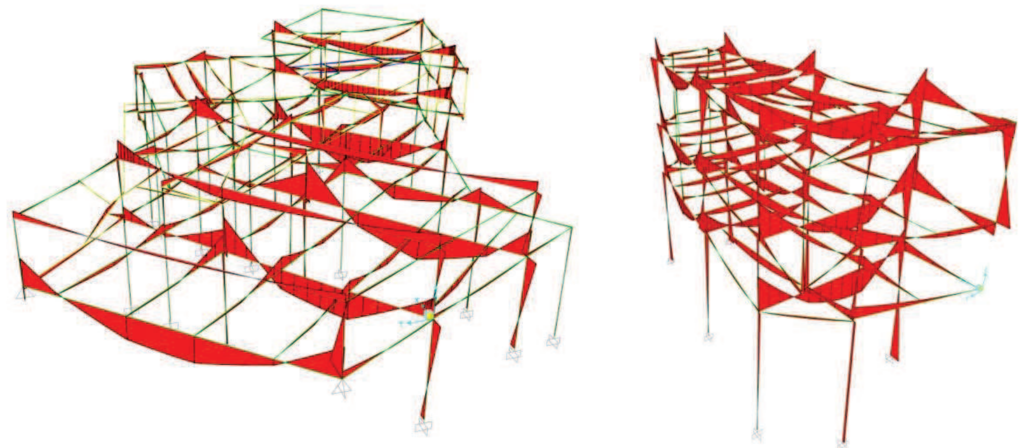


Fig 4.18 3D view of bending moment diagram of frames in SAP2000

BM diagram 1:

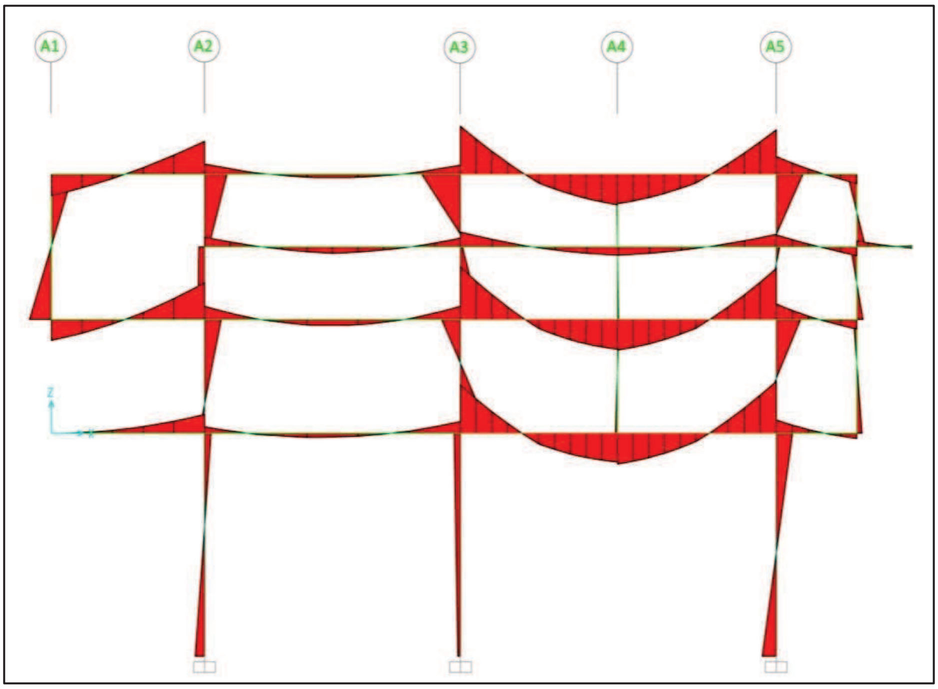


Fig 4.19BM diagram of multifunctional building on Axis AC (KN/M/C)

This is bending moment diagram of one of multifunctional building completely exposed to wind. In this frame trusses are perpendicular to face of this frame. This bending moment diagram is with load combination 3 giving the maximum value of moments.

BM diagram 2

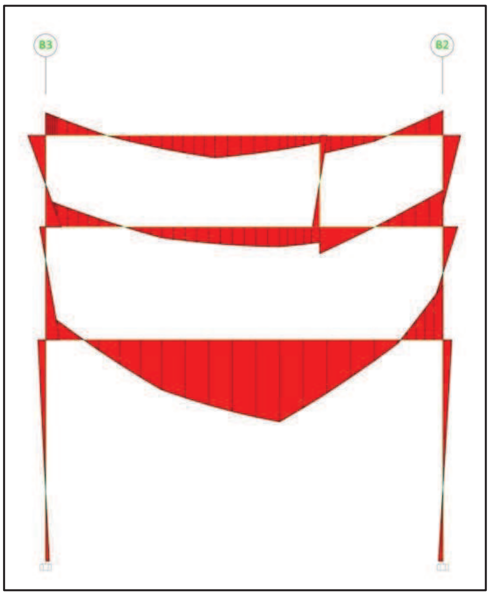


Fig 4.20BM diagram of semi-open platform on Axis BE (KN/M/C)

This bending moment diagram is with load combination 4 giving the maximum value of moments. (Three are the secondary structures supported in the middle of this frame above, which are not shown in the figure)

BM diagram 3

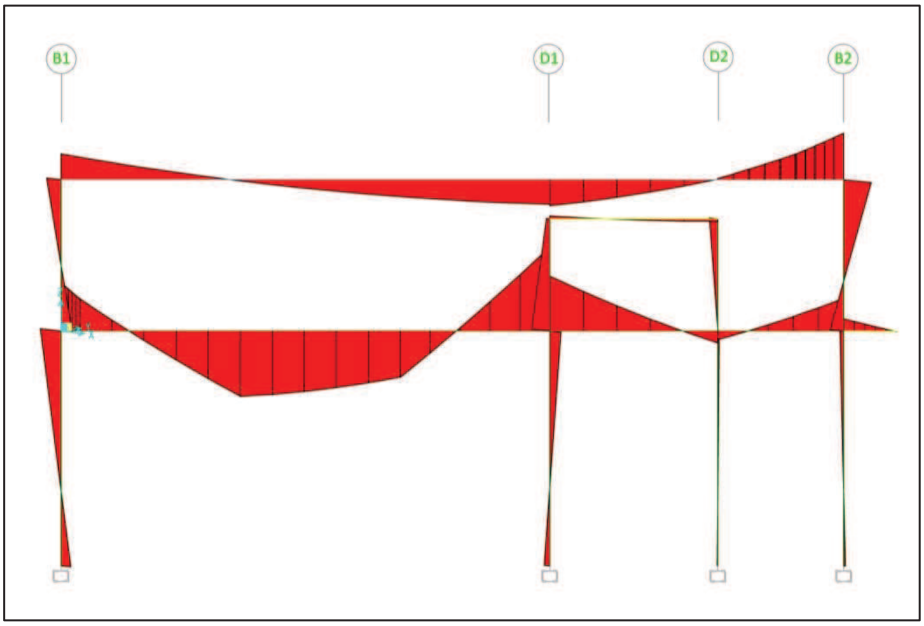


Fig 4.21 BM diagram of semi-open platform on Axis BA (KN/M/C)

This bending moment diagram is with load combination 3 giving the maximum value of moments. (Three are the secondary structures supported in the middle of this frame above, which are not shown in the figure)

4.5.2 Shear force diagram

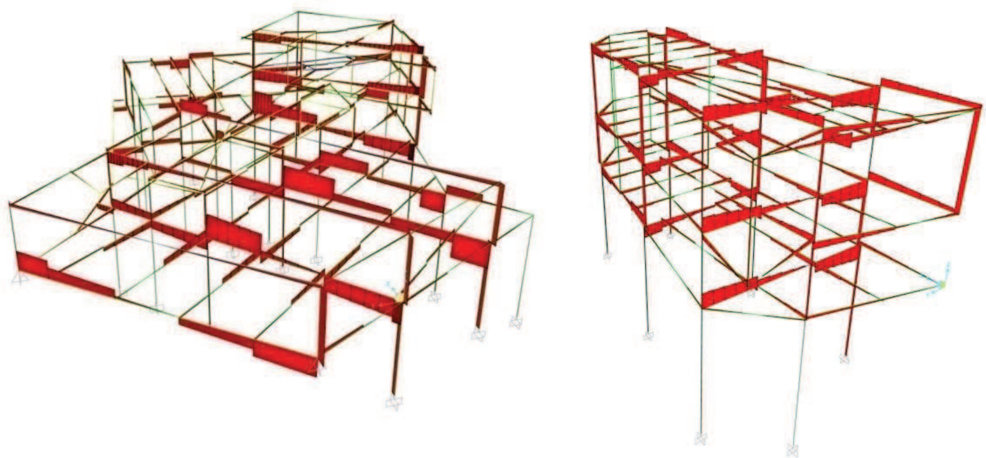


Fig 4.22 3D view of shear force diagram of frames in SAP2000

SF diagram 1:

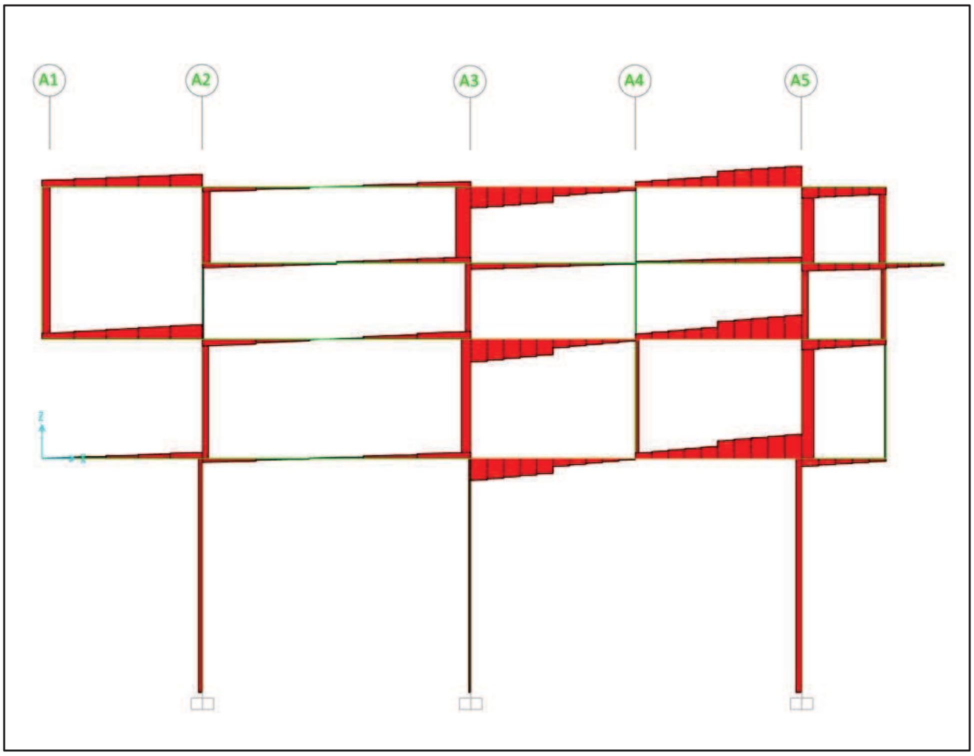


Fig 4.23 SF diagram of multifunctional building on Axis AC (KN/M/C)

This shear force diagram is with load combination 3 giving the maximum value of shear forces.

SF diagram 2:

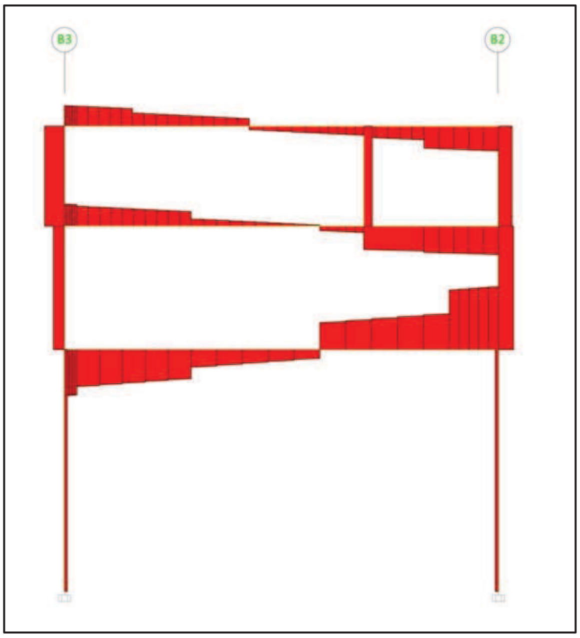


Fig 4.24 SF diagram of semi-open platform on Axis BE (KN/M/C)

This shear force diagram is with load combination 3 giving the maximum value of shear forces. (Three are the secondary structures supported in the middle of this frame above, which are not shown in the figure)

SF diagram 3

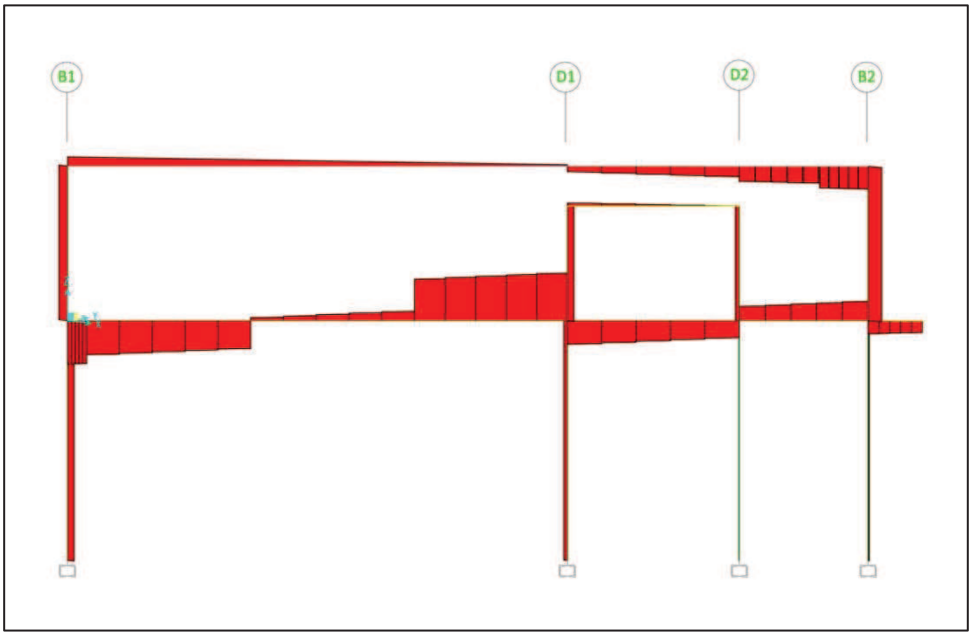


Fig 4.25 SF diagram of semi-open platform on Axis BA (KN/M/C)

This shear force diagram is with load combination 3 giving the maximum value of shear forces. (Three are the secondary structures supported in the middle of this frame above, which are not shown in the figure)

4.5.3 Axial force diagram

Fig 4.26 3D view of axial force diagram of frames in SAP2000

AF diagram 1:

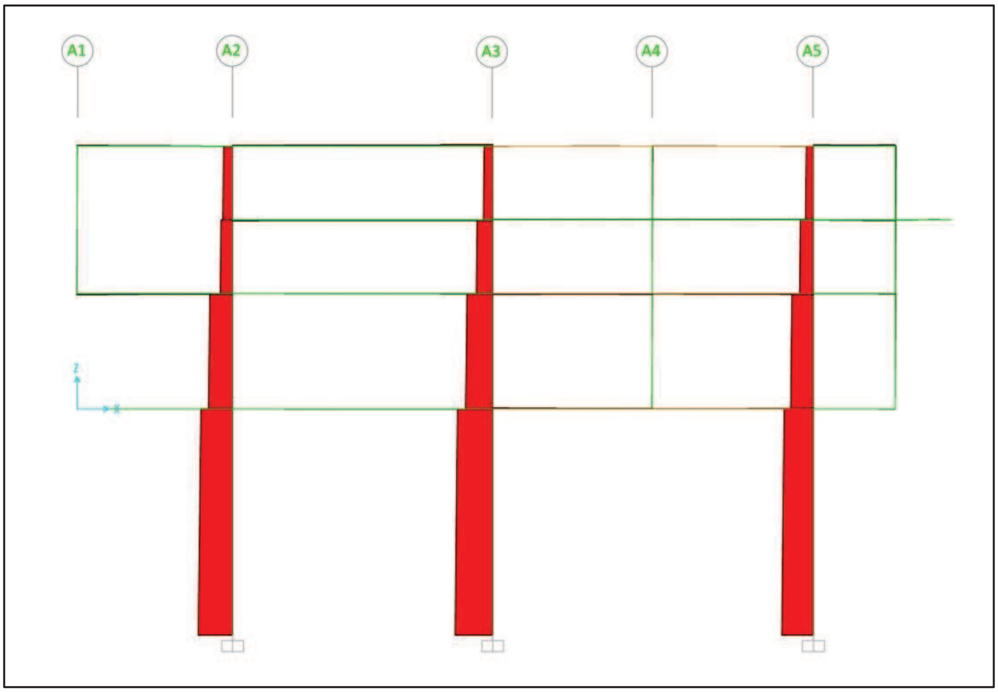


Fig 4.27AF diagram of multifunctional building on Axis AC (KN/M/C)

This axial force diagram is with load combination 3 giving the maximum value of axial forces. Due to low value on the connection columns that are not continuous to the ground, the axial force diagram on them is not readable.

AF diagram 2:

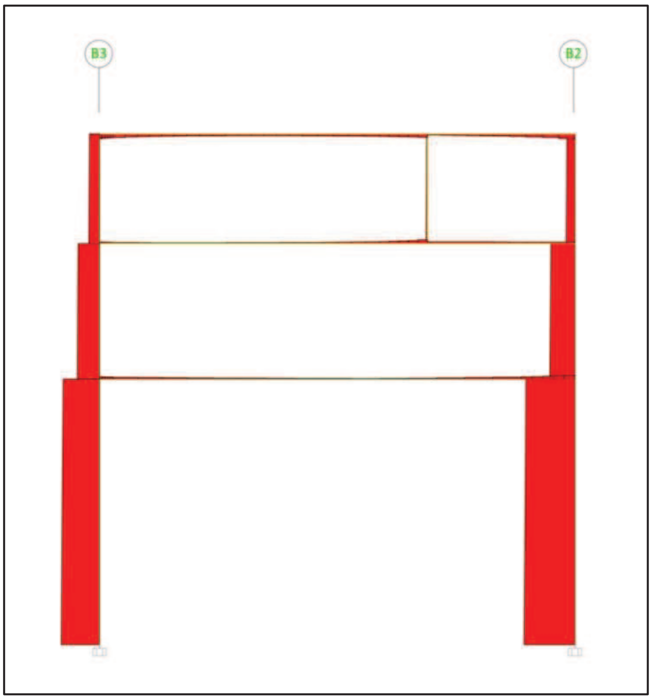


Fig 4.28AF diagram of multifunctional building on Axis BE (KN/M/C)

This axial force diagram is with load combination 3 giving the maximum value of axial forces.

AF diagram 3:

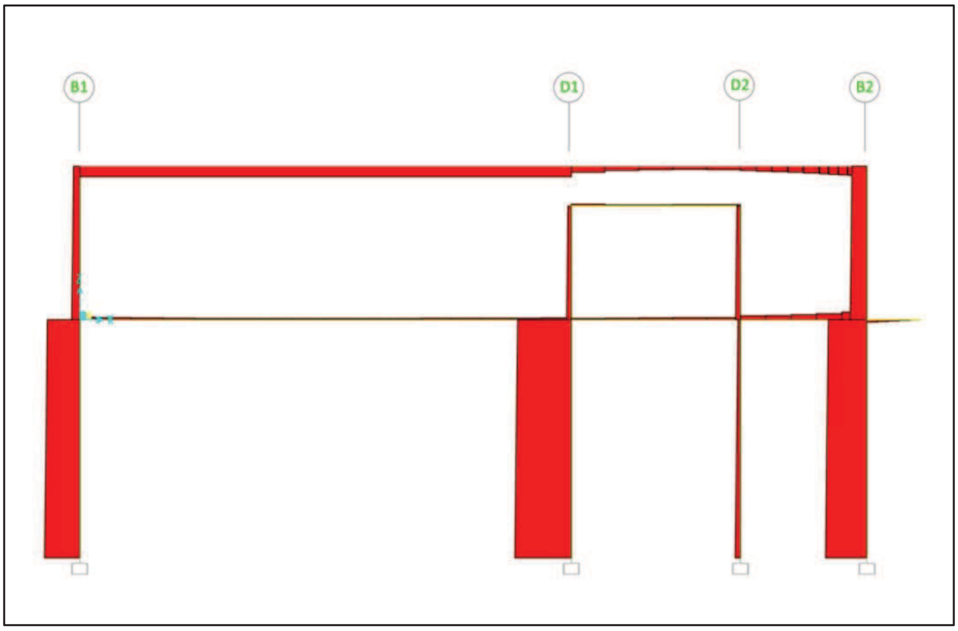


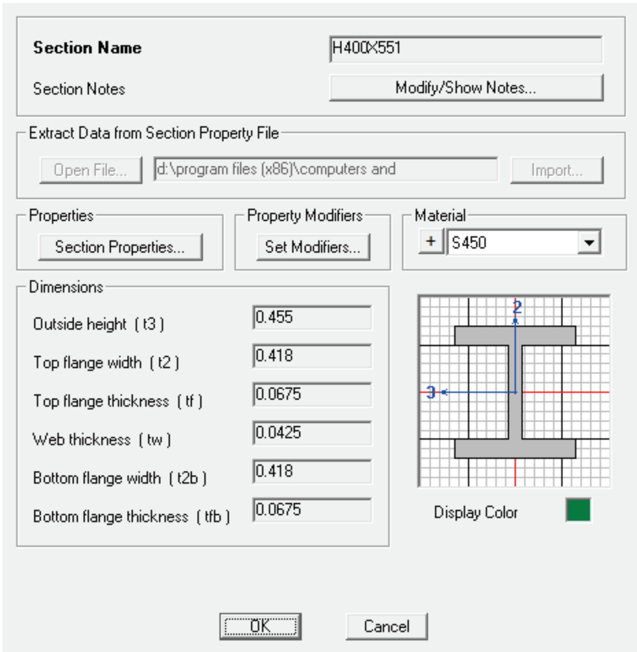
Fig 4.29AF diagram of multifunctional building on Axis BA (KN/M/C)

This axial force diagram is with load combination 3 giving the maximum value of axial forces.

4.6 Designing of structural members

4.6.1 Column design 1-Column 12 H400X551

<u>Section dimensions:</u>



Section Name H400X551

Section Notes — Modify/Show Notes...

Extract Data from Section Property File — Open File... d:\program files (x86)\computers and — Import...

Properties: Section Properties...

Property Modifiers: Set Modifiers...

Material: S450

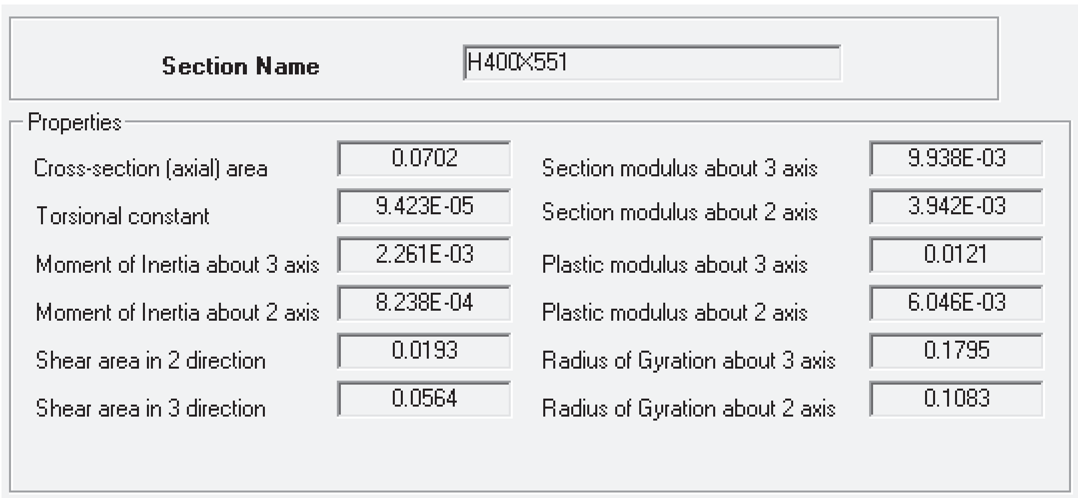
Dimensions

Outside height (t3)	0.455
Top flange width (t2)	0.418
Top flange thickness (tf)	0.0675
Web thickness (tw)	0.0425
Bottom flange width (t2b)	0.418
Bottom flange thickness (tfb)	0.0675

Display Color

OK Cancel

<u>Section Properties:</u>



Section Name H400X551

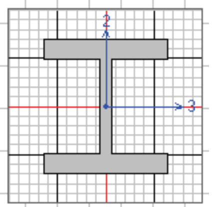
Properties

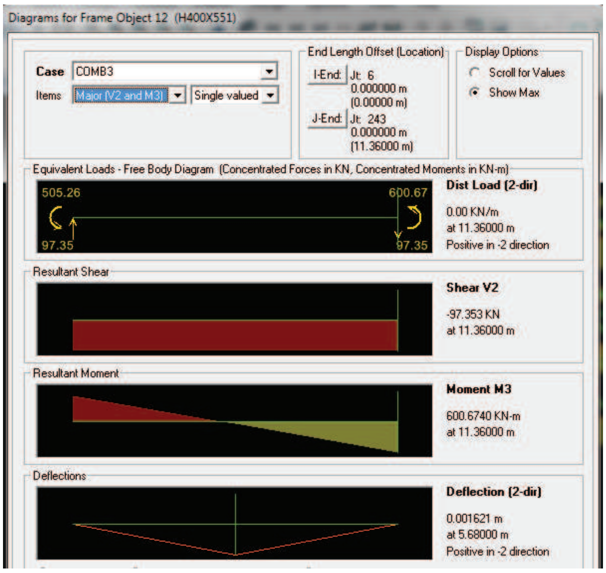
Cross-section (axial) area	0.0702	Section modulus about 3 axis	9.938E-03
Torsional constant	9.423E-05	Section modulus about 2 axis	3.942E-03
Moment of Inertia about 3 axis	2.261E-03	Plastic modulus about 3 axis	0.0121
Moment of Inertia about 2 axis	8.238E-04	Plastic modulus about 2 axis	6.046E-03
Shear area in 2 direction	0.0193	Radius of Gyration about 3 axis	0.1795
Shear area in 3 direction	0.0564	Radius of Gyration about 2 axis	0.1083

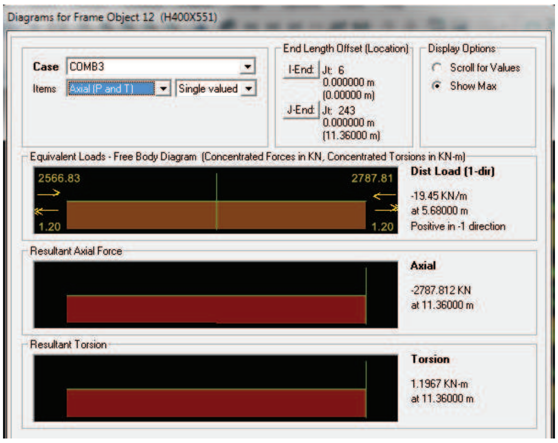
Moment , SF & Axial force Values from software after analysis:

Units KN, m, C

```
Frame   : 12            Design Sect: H400X551
X Mid   : 36.956        Design Type: Column
Y Mid   : 0.000         Frame Type : Moment Resisting Frame
Z Mid   : -5.680        Sect Class : Compact
Length  : 11.360        Major Axis : 0.000 degrees counterclockwise from local 3
Loc     : 11.360        RLLF       : 1.000

Area    : 0.070         SMajor : 0.010       rMajor : 0.179        AVMajor: 0.019
IMajor  : 0.002         SMinor : 0.004       rMinor : 0.108        AVMinor: 0.056
IMinor  : 8.238E-04     ZMajor : 0.012       E      : 210000000.00
Ixy     : 0.000         ZMinor : 0.006       Fy     : 440000.000

STRESS CHECK FORCES & MOMENTS
    Location          Pu        Mu33        Mu22        Vu2         Vu3        Tu
    11.360     -1386.485     649.519    -697.823     -97.878     102.801     1.528

PMM DEMAND/CAPACITY RATIO
    Governing       Total          P      MMajor      MMinor       Ratio     Status
    Equation        Ratio      Ratio       Ratio       Ratio       Limit      Check
    (H1-1a)         0.789  =   0.403   +   0.121   +   0.265       0.950         OK

AXIAL FORCE DESIGN
                      Pu    phi*Pnc     phi*Pnt
                   Force   Capacity    Capacity
    Axial      -1386.485   3439.977   27799.200

MOMENT DESIGN
                      Mu    phi*Mn       Cm      B1      B2       K       L      Cb
                  Moment  Capacity   Factor  Factor  Factor  Factor  Factor  Factor
    Major Moment 649.519  4771.800    0.315   1.000   1.000   1.560   1.000   2.215
    Minor Moment -697.823 2341.326    0.331   1.000   1.000   1.693   1.000

SHEAR DESIGN
                      Vu     phi*Vn      Stress     Status        Tu
                   Force   Capacity       Ratio      Check   Torsion
    Major Shear   97.878   4594.590       0.021         OK     0.000
    Minor Shear  102.801  13407.768       0.008         OK     0.000
```







N_{Ed} = 2787.81 KN

M_{Ed} =600.67KN ·m

V_{Ed} = 97.35 KN

H400X551 wide flange section is selected.

Section properties for H400X551:

h = 455 mm A = 70100 mm^2
b = 418 mm I_y = 2260 x 10^6 mm^4
t_w = 42.5 mm $W_{el,y}$ = 9938 x 10^3 mm^3
t_f = 67.6 mm $W_{pl,y}$ = 12100 x10^3 mm^3
r = 15 mm h_w = 319.8 mm

For the verification of the section class, the selected section is checked according to table provided by Eurocode 3.

For flange:
$c = (b - t_w - 2r) / 2$
$c = 172.8\ mm$
$c / t_f = 2.56$
$\epsilon = \sqrt{235/fy} = 0.731$
$c / t_f < 9\ \epsilon$
2.56<6.577SATISFIED

For web:
$c = (h - 2\ t_f - 2r) / 2$
$c = 144.9\ mm$
$c / t_w = 3.409$
$c / t_w < 72\ \epsilon$
3.409<52.632SATISFIED
The section is Class-1 as assumed

Compression resistance of cross section:
$N_{Ed} / N_{c,\ Rd} < 1.0$
$N_{cl,\ Rd} = A\ .f_y\ /\ \Upsilon_{M0} = 29442\ KN$
N_{Ed}<$N_{c,\ Rd}$ SATISFIED

Bending resistance of cross section:
$M_{c,\ Rd\ (pl)} = W_{pl} x\ f_y / \Upsilon_{M0}$ = 5082KN ·m
M_{Ed}<$M_{c,\ Rd(pl)}$ SATISFIED

Shear resistance of cross section:
$V_{Ed} / V_{c,\ Rd} < 1.0$
$V_{pl,\ Rd} = A_v\ .\ (f_y/\sqrt{3})\ /\ \Upsilon_{M0}$
A_v for hot rolled I and H sections is calculated as;
$A_v = A - 2\cdot b \cdot t_f + (t_w + 2r).\ t_f$
$A_v = 0.0185\ m^2$
$f_y = 420\ MPa\ ,\ \Upsilon_{M0} = 1.00$

$V_{pl,\,Rd}$ = 4486 KN >97.35 KN SATISFIED

Combined bending and axial resistance of cross section

$M_{Ed} \leq M_{N,Rd}$

$M_{N,Rd} = M_{pl,Rd}[\ 1-\ (N_{Ed}\ /\ N_{c,Rd})] = 4600.8KN\cdot m$

M_{Ed}<$M_{N,Rd}$SATISFIED

Buckling resistance of cross section

$N_{Ed}\ /\ N_{b,Rd} \leq 1.0$

$N_{b,\,Rd} = \chi\ .A\ .f_y /\ \gamma_{M0}$

$\lambda_1 = 93\ \epsilon = 67.983$

$\lambda y = \lambda z = L_{cr}\ /\ i\ /\ \lambda_1$

$\lambda y = \lambda z = 2470/108.5/67.983 = 0.34$

Buckling curve: Type a for = 0.34

$$\chi = \frac{1}{\phi + (\phi^2 - \bar{\lambda}^2)^{0.5}} \leq 1$$

$$\phi = 0.5(1 + \alpha(\bar{\lambda} - 0.2) + \bar{\lambda}^2)$$

$\phi = 0.573$

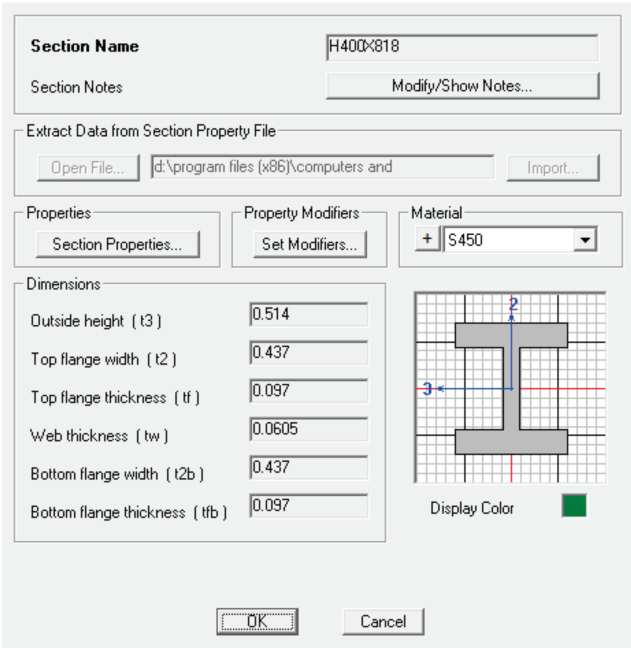
$\chi\ = 0.97 < 1$

$N_{b,Rd} = 28486.5\ KN$

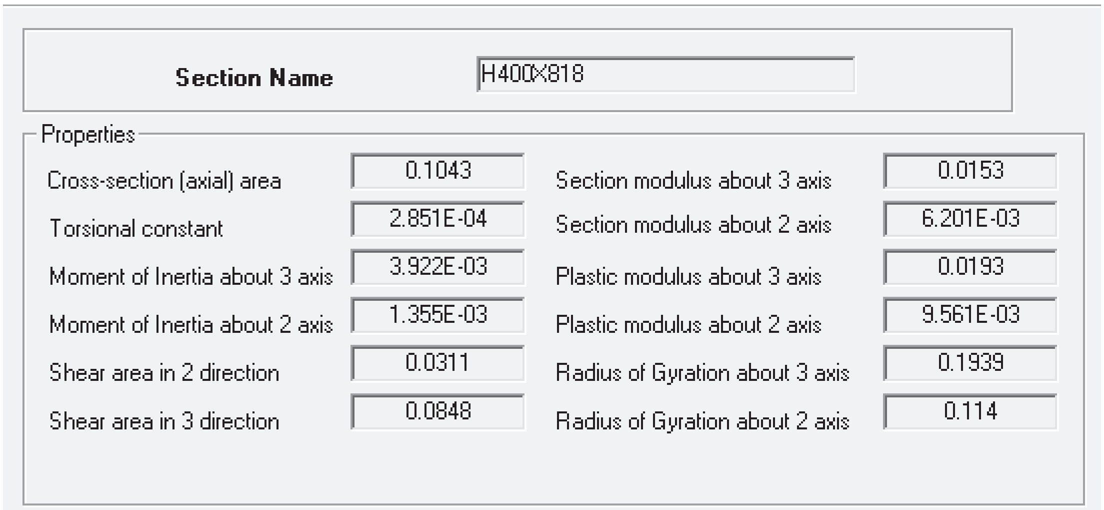
N_{Ed}<$N_{b,Rd}$SATISFIED

4.6.2 Column design 2-Culumn C33 H400X818

Section Dimensions:

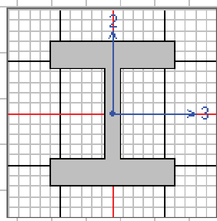


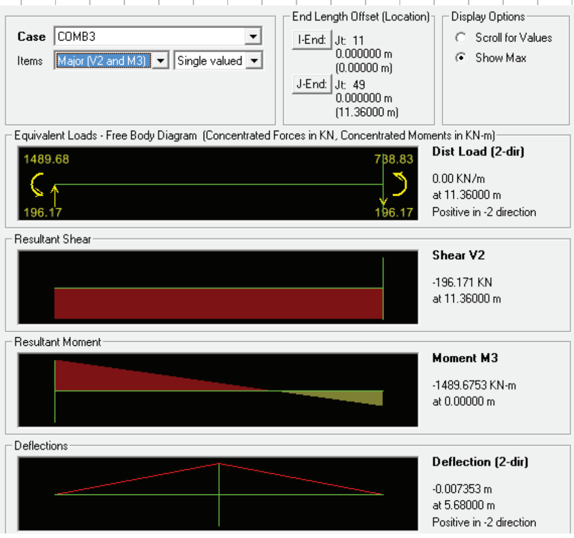
Section Properties:

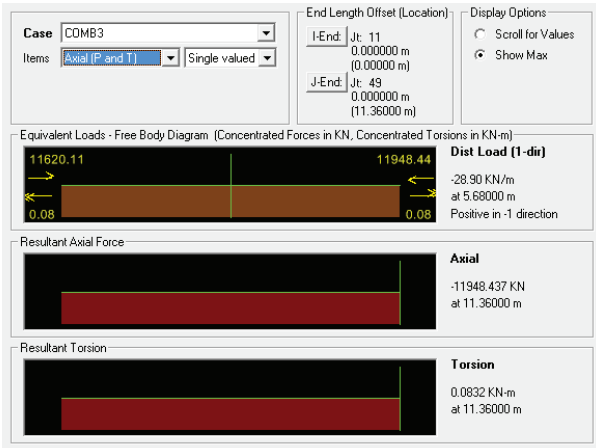


Moment , SF & axial force values from software after analysis:

```
Frame   : 33            Design Sect: H400X818                                          Units KN, m, C
X Mid   : 45.566        Design Type: Column
Y Mid   : -1.093        Frame Type : Moment Resisting Frame
Z Mid   : -5.680        Sect Class : Compact
Length  : 11.360        Major Axis : 0.000 degrees counterclockwise from local 3
Loc     : 0.000         RLLF       : 1.000

Area    : 0.104         SMajor : 0.015          rMajor  : 0.194         AVMajor:
IMajor  : 0.004         SMinor : 0.006          rMinor  : 0.114         AVMinor:
IMinor  : 0.001         ZMajor : 0.019          E       : 210000000.00
Ixy     : 0.000         ZMinor : 0.010          Fy      : 440000.000

STRESS CHECK FORCES & MOMENTS
    Location            Pu         Mu33         Mu22          Vu2          Vu3           Tu
    0.000        -5914.773     -817.325      693.080     -107.579       91.792        0.043

PMM DEMAND/CAPACITY RATIO
    Governing        Total            P       MMajor       MMinor        Ratio       Status
    Equation         Ratio        Ratio        Ratio        Ratio        Limit        Check
    (H1-1a)          0.861   =    0.599   +    0.095   +    0.167        0.950           OK

AXIAL FORCE DESIGN
                        Pu      phi*Pnc      phi*Pnt
                     Force     Capacity     Capacity
    Axial        -5914.773     9877.344    41302.800

MOMENT DESIGN
                        Mu      phi*Mn       Cm        B1        B2        K         L        Cb
                    Moment    Capacity    Factor    Factor    Factor    Factor    Factor    Factor
    Major Moment  -817.325    7626.960    0.402     1.000     1.000     1.447     1.000     2.173
    Minor Moment   693.080    3683.616    0.398     1.000     1.000     1.282     1.000

SHEAR DESIGN
                        Vu      phi*Vn       Stress       Status          Tu
                     Force    Capacity        Ratio        Check     Torsion
    Major Shear    107.579    7388.647        0.015           OK       0.000
    Minor Shear     91.792   20143.253        0.005           OK       0.000
```







N_{Ed} = 11948 KN
M_{Ed} = 1490KNm
V_{Ed} = 196 KN

H400X818 wide flange section is selected.

Section Properties for H400X818:

h = 514 mm A = 104 x 10^3 mm^2

b = 437 mm I_y = 3920 x 10^6 mm^4

t_w = 60.5 mm $W_{el,y}$ = 15300 x 10^3 mm^3

t_f = 97 mm $W_{pl,y}$ = 19300 x10^3 mm^3

r = 15 mm h_w = 320 mm

For the verification of the section class, the selected section is checked according to table provided by Eurocode 3.

For flange:

$c = (b – t_w– 2r) / 2 = ((437 – 60.5 – 2(15)) / 2$

c = 173.25 mm

c / t_f= 173.25 / 97 = 1.786

$\varepsilon = \sqrt{235/fy}= \sqrt{235/420} = 0.748$

$c / t_f< 9\ \varepsilon$

$9\ \varepsilon = 9\ (0.748) = 6.73$

1.786<6.73 SATISFIED

For web:

$c = (h - 2\ t_f - 2r) / 2 = ((514 – 2(97) – 2(15)) / 2$

c = 145 mm

c / t_w= 145 / 60.5 = 2.40

$\varepsilon = \sqrt{235/fy} = \sqrt{235/420} = 0.748$

$c / t_w< 72\ \varepsilon$

$72\ \varepsilon = 72\ (0.748) = 53.86$

2.4<53.86SATISFIED

The section is Class-1 as assumed

Compression resistance of cross section:

$N_{Ed}/ N_{c,\ Rd} < 1.0$

$N_{cl,\ Rd} = A{\cdot}f_y/\gamma M_0$ = 43.68 x 10^3 KN

N_{Ed} = 11948 KN

soN_{Ed}<$N_{cl,\ Rd}$ SATISFIED

Bending resistance of cross section:

$M_{c,\ Rd\ (pl)} = W_{pl}{\cdot}f_y/\ \gamma M_0$ = 8106KN ·m

M_{Ed} = 1490KN ·m

soM_{Ed}<$M_{c,\ Rd(pl)}$SATISFIED

Shear resistance of cross section:

$V_{Ed}\ /\ V_{c,\ Rd} < 1.0$

$V_{c,\ Rd} = A_v{\cdot}\ (f_y/\sqrt{3})\ /\ \Upsilon_{M0}$

A_v for hot rolled I and H sections is calculated as;

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

$A_v = 104000 - 2(437)\ (97) + (60.5+2(15))97$

$A_v = 28 \times 10^{-3}\ m^2$

$f_y = 420Mpa$, $\gamma_{M0} = 1.00$

$V_{pl,\ Rd} = 6790$ KN

$V_{Ed} = 196$ KN

so $V_{Ed} < V_{pl,\ Rd}$ SATISFIED

Combined bending and axial resistance of cross section:

$M_{Ed} \leq M_{N,Rd}$

$M_{N,Rd} = M_{pl,Rd}[\ 1 - (N_{Ed}\ /\ N_{c,Rd})] = 5889KN \cdot m$

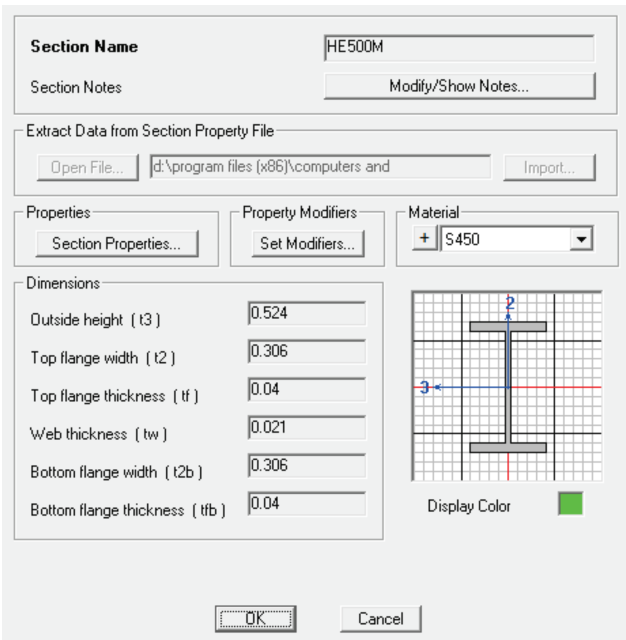
$M_{Ed} = 1490KN \cdot m$

$M_{Ed} < M_{N,Rd}$ SATISFIED

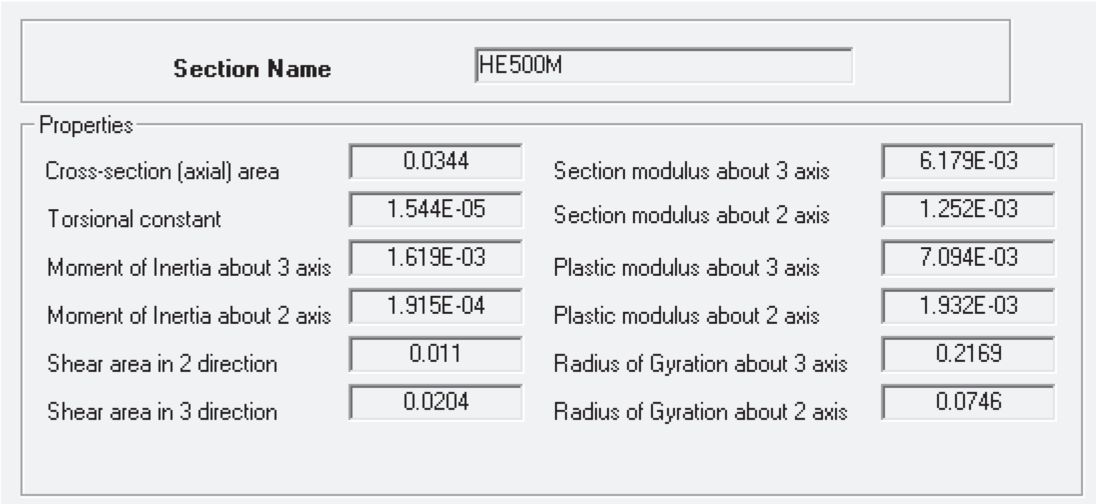
4.6.3 Beam design -Beam 72 HE500M

After analyzing the structure for different combination cases, we take one beam from the frame to design

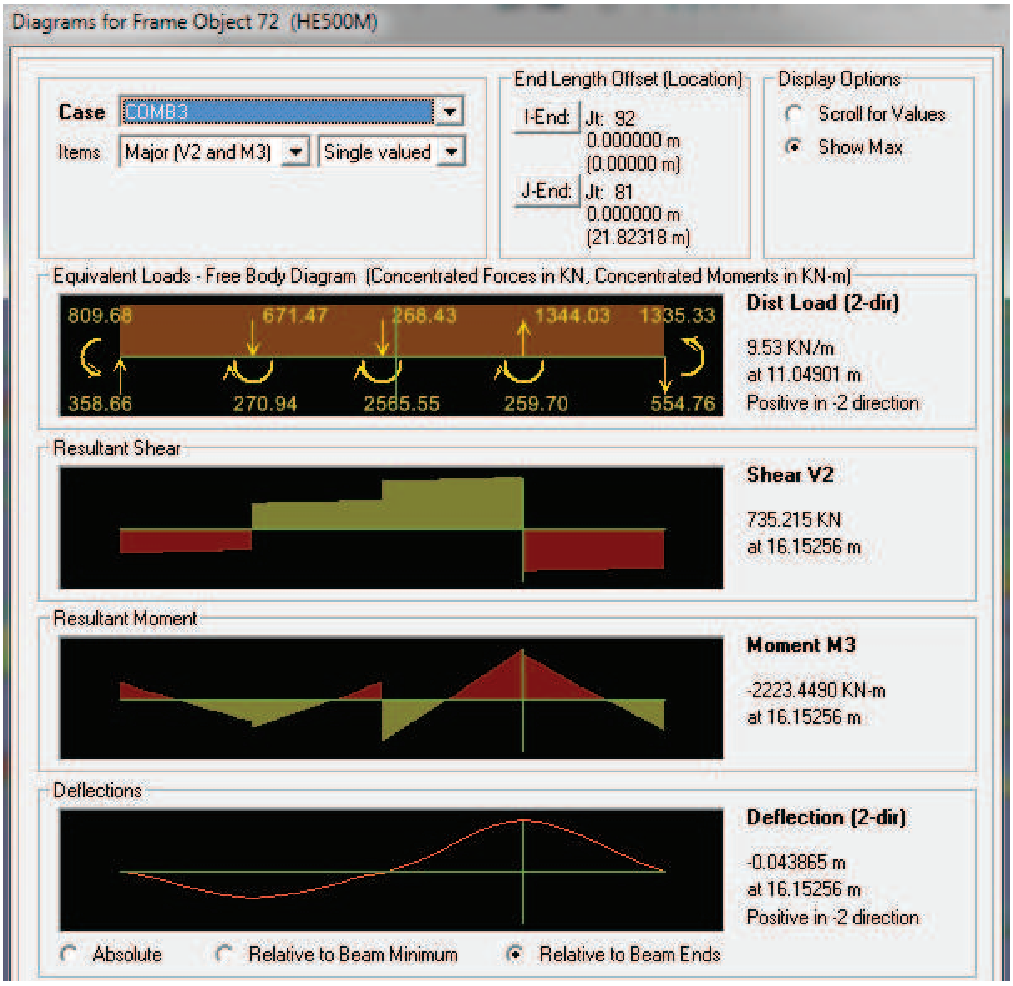
Section Dimensions:



Section Properties:



Moment & SF values from software after analysis:



M_{Ed} = 2223.45KN ·m
V_{Ed} = 735.22 KN

HE 500 M wide flange section is selected.

Section Properties for HE 500M:

h = 524 mm A = 34.4 x 10^3 mm^2
b = 306 mm I_y = 1620 x 10^6 mm^4
t_w = 21 mm $W_{el,y}$ = 6180 x 10^3 mm^3
t_f = 40 mm $W_{pl,y}$ = 7090 x10^3 mm^3
r = 27 mm h_w = 470 mm

For flange:
$c = (b - t_w - 2r) / 2 = (306 - 21 - 2(27)) / 2$
c = 115.5 mm
c / t_f= 115.5 / 40 = 2.89
$\varepsilon = \sqrt{235/\text{fy}} = \sqrt{235/420} = 0.748$
$c / t_f < 9\ \varepsilon$
9 ε = 9 (0.748) = 6.732
2.89< 7.326 SATISFIED

For web:
$c = (h - 2\ t_f - 2r) / 2 = (524 - 2(40) - 2(27)) / 2$
c = 195 mm
c / t_w= 195 / 21 = 9.29
$\varepsilon = \sqrt{235/\text{fy}} = \sqrt{235/420} = 0.748$
$c / t_w < 72\ \varepsilon$
72 ε = 72 (0.748) = 53.856
9.29< 53.856SATISFIED
The section is Class-1 as assumed

Shear resistance of cross section:
$V_{Ed} / V_{c,\ Rd} < 1.0$
$V_{pl,\ Rd} = A_v \cdot (f_y/\sqrt{3}) / \gamma_{M0}$
A_v for hot rolled I and H sections is calculated as;
$A_v = A - 2 \cdot b \cdot t_f + (t_w + 2r) \cdot t_f$
$A_v = 34400 - 2(306)\ (40) + (21+2(27))40$
$A_v = 12.92 \times 10^{-3}\ m^2$
f_y= 420Mpa , γ_{M0} = 1.00
$V_{pl,\ Rd}$ = 3132.9 KN
V_{Ed}= 735.22 KN
V_{Ed}<$V_{pl,\ Rd}$SATISFIED

But $V_{pl,\ Rd}$ /2 = 1566.45 KN
$V_{pl,\ Rd}$ /2 >V_{Ed}
So no check is required for combined shear and bending

Shear buckling resistance:

h_w / t_w< 72 ε / η   (η = 1)

h_w / t_w= 470 / 21 = 22.38

72 ε = 72 (0.748) = 53.856

h_w / t_w< 72 ε

So no check required for shear buckling

Deflection check:

M_{max} = 2223.45KN·m

$M_{c, Rd}$ = Elastic resistance of section = W_{ely} .f_y / γ_{M0} = 2595.6 KN

M_{max}<$M_{c, Rd}$ SATISFIED

Elastic calculation:

Span / 250 = 16.15 / 250 = 0.0646 m

Max deflection = 0.0439 m

Max deflection < Span / 250 SATISFIED

4.6.4 Base plate design and base isolation design

For the columns H400x818, the cross section = 514 mm x 437 mm x 97 mm, and the critical inner forces are:

M_{sd} = 1490KN·m

N_{sd} = 11948 KN

V_{sd} = 196 KN

Material strength

Steel grade S450 M, f_y = 420 N/mm^2

Concrete grade C 40/50, f_{ck} = 40 N/mm^2

Size of base isolation HDH700X140 is 800mm X 800mm X 326mm, the technical date is below:

HDH 700X140	V_{max}	V_{sism}	K_r	H	t_e	S_{max}
	[KN]	[KN]	[KN/mm]	mm	mm	mm
Value	17900	10900	3.85	302	140	280

Table 4.13 Technical data for HDH700X140

The thickness of base plate should not be less than the thickness of the column flange.

Therefore use base plate thickness, t_p>t_f, i.e. 97mm (assumption). We consider **t_f = 100 mm.**according to the code,

c= $t_i \sqrt{\frac{fy}{3fb}}$

where

$f_b$bearing stress of supporting material, for base isolation we have f_b = f_y

soc = *100* x $\sqrt{\frac{1}{3}}$ = *57.74 mm*

now we just make a pre-design on dimension of base plate
minimum width of plate = $b + 2c = 437 + 2 \times 57.74 = 552.48$ mm
Minimum depth of plate = $d + 2c = 514 + 2 \times 57.74 = 629.48$ mm

according to the size of base isolation : 750mm x 750 mm, which is satisfied with the minimum width of plate, then we design a base plate 750 mm x 750 mm x 100 mm and check it:

<u>Axial resistance:</u>
As V_{max}, max vertical load, provided by the base isolation HDH700X140 is 17900KN,
$V_{max} > N_{sd} = 11948$ KN SATISFIED

<u>Shear resistance:</u>
For base of column:
when the applied shear force is less than 20% of the applied vertical load, no special provisions are necessary for the transfer of the shear force from the base plate to the foundation.
N_{sd} = 11948 KN
Therefore, 20% of N_{sd} = 2389.6KN
V_{sd} = 196 KN
So V_{sd}< 20% of N_{sd}
As V_{sism}, max horizontal load, provided by the base isolation HDH700X140 is 10900 KN,
$V_{sism} > 196$ KN SATISFIED

For base isolaton:
$V_{BI} = \frac{KrxSmax}{Ri}$
where Ri is a reduced factor that accounts for ductility in the structure, here for cantilever steel isolated column, Ri = 1.4
so $V_{BI} = \frac{3.85 \times 280}{1.4} = 770$ KN
***then $V_{BI} > V_{sd} = 196$ KN* SATISFIED**

<u>Bending moment resistance:</u>
the moment at the top and bottom of an elasomeric isolation bearing is :
$M_{BI} = \frac{1}{2} (V_B H + PS_{max})$
where :
H is the total height of the bearing
P the vertical load concurrent with V_B
so $M_{BI} = \frac{1}{2} (V_B H + PS_{max}) = \frac{1}{2} (10900 \times 0.302 + 17900 \times 0.280) = 4151.9$ KN·M
then$M_{sd} = 1490$KN·m<4151.9 KN·M = M_{BI} SATISFIED

Design of base plate and base isolation:
Due to the check on resistance of bending moment, axial force and shear force, **750 mm × 750 mm × 100 mm** thick grade S 450 M steel base plate has been used, the base isolations **HDH700X140** have been used.

4.6.5 Design of bolts

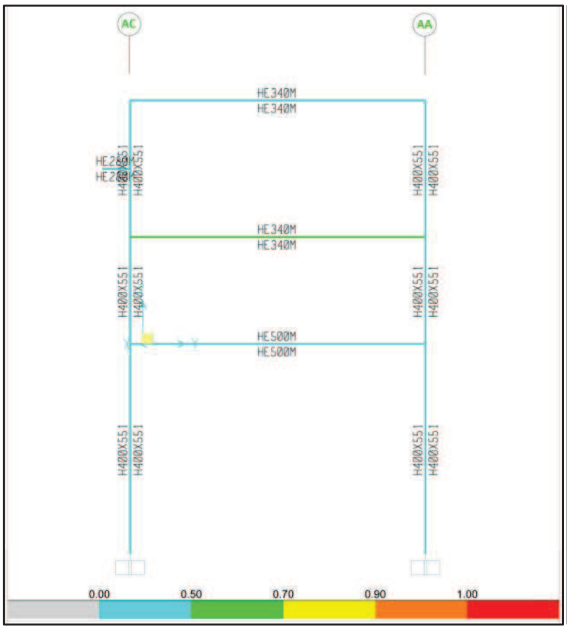
Plate size = 750 mm x 750 mm x 100 mm
Bolts M 20 Grade 8.8, f_{yb} = 640 N/mm^2, f_{ub} = 800 N/mm^2, Diameter 30 mm.

Bolt area at the bottom of the thread: A_s = 561 mm^2
Diameter of holes $d_0 = d + 2 = 30 + 2 = 32$ *mm*.
Minimum edge distance, $e_1 = 1.2\ d0 = 1.2 \times 32 = 38.4$ *mm*
Minimum hole distance, $p_1 = 2.5\ d0 = 2.5 \times 32 = 80$ *mm*
Maximum edge distance, $e_1 = 12\ t = 12 \times 100 = 1200$ *mm*
Maximum hole distance, $p_1 = 14\ t = 14 \times 100 = 1400$ *mm*

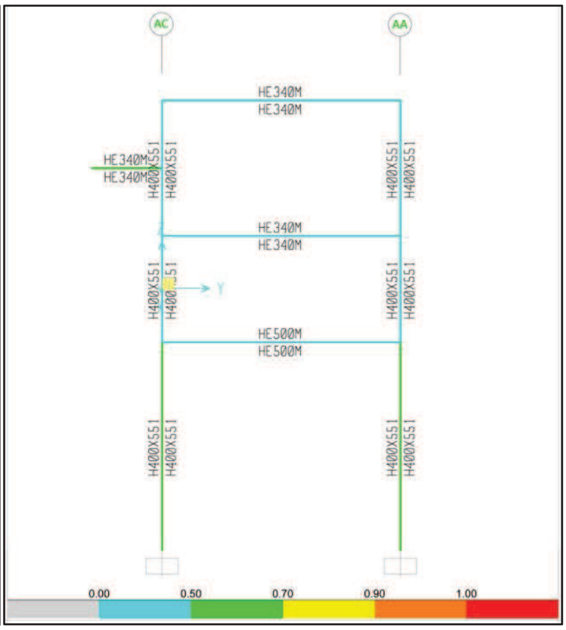
Shear resistance of bolts
Assumptions: One shear area per bolt and threads area in the shear plane.
Hence the shear capacity of the bolts is given by:
v = 0.6 for classes 4.6, 5.6 and 8.8:
$F_{v,\,Rd} = (0.6)(800)(561)(10^{-3})\ /\ 1.25 = 215.4\ KN > N_{Ed}\ /\ 2t_p = 11948/\ (2 \times 100) = 59.74KN$
SATISFIED

4.7 Verification of sections provided in structure

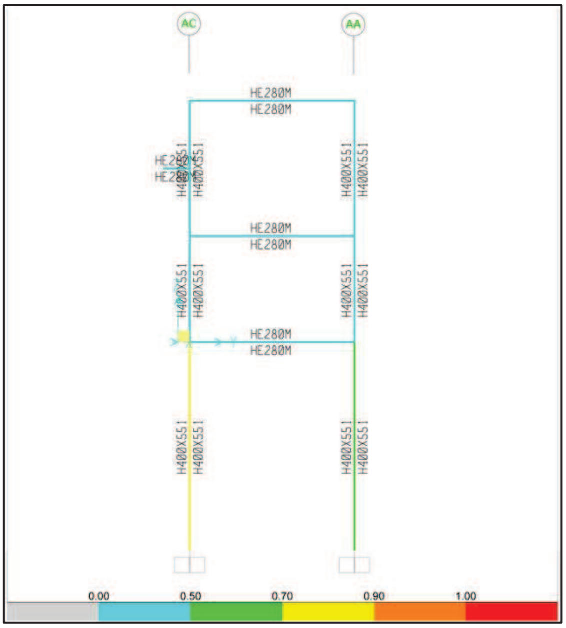
Here we are verifying the rest sections.
Frames of multifunctional building frames:



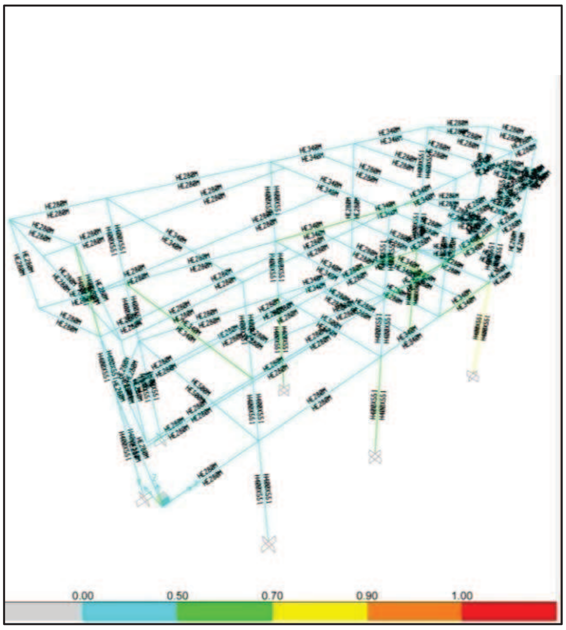
Frame on axisA2 (for most frames,stress limit ratio is below 0.50, for the beam on the second floor, it is between 0.50 and 0.70)



Frame on axisA3 (for most frames,stress limit ratio is below 0.50, for two columns on the ground floor, it is between 0.50 and 0.70)

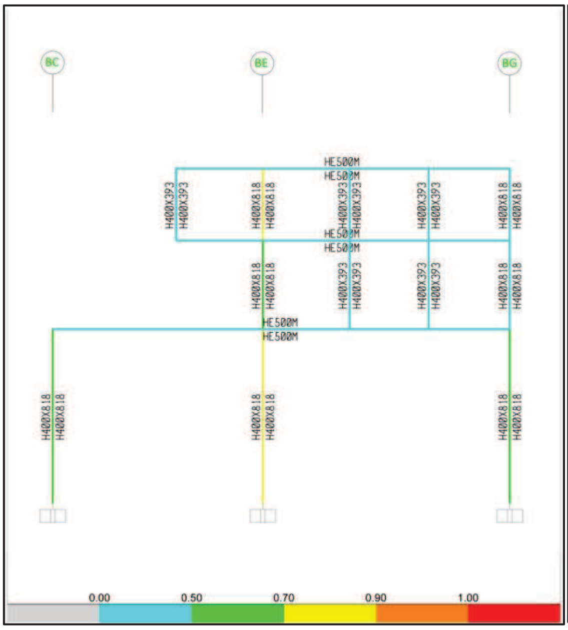


Frame on axisA5 (for most frames,stress limit ratio is below 0.50, for two columns on the ground floor, it is between 0.50 and 0.90)

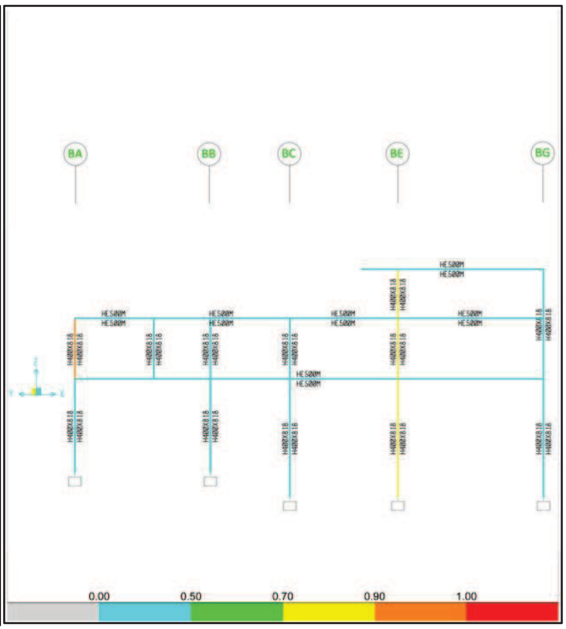


3D view of stress limit ratio on the multifunctional building. Due to irregular shape and less the types of steel, the general ratios mainly stay below 0.50 in order to guarantee the safety of other frames applied with heavy loads.

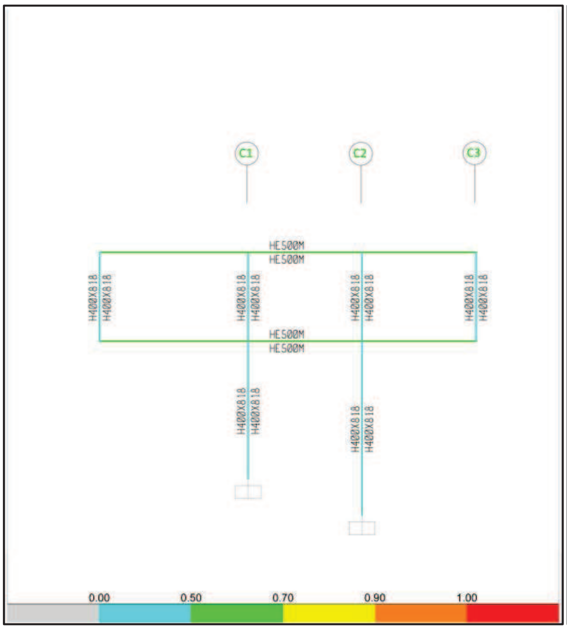
Frames of semi-open platform frames:



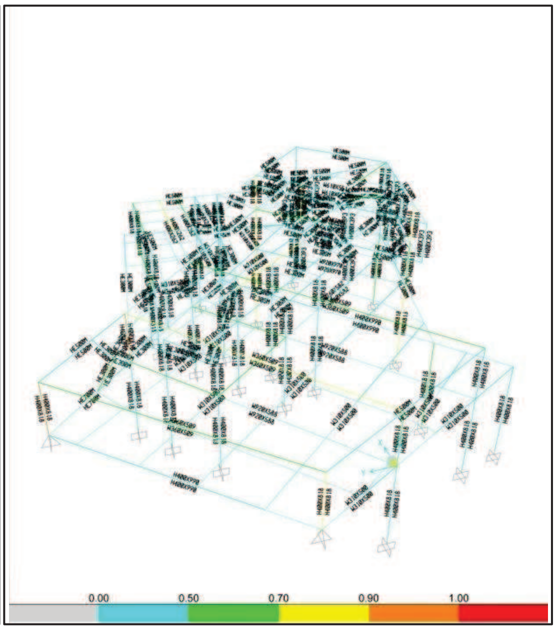
Frame on axisB3 (for most frames, stress limit ratio is below 0.50, for three columns on the ground floor, it is between 0.50 and 0.90)



Frame on axisB2 (for most frames, stress limit ratio is below 0.50, for columns on the axis BE, it is between 0.50 and 0.90, for one short column on axis BA ,it is between 0.90 and 1.00)



Frame on axisCA (for columns, stress limit ratio is below 0.50, for beams, it is between 0.50 and 0.90)



3D view of stress limit ratio on the multifunctional building. Due to irregular shape and less the types of steel, the general ratios mainly stay below 0.50 in order to guarantee the safety of other frames applied with heavy loads.

4.8 Foundation Design

Base on the site visit to Malmi, Helsinki, the type of the base soil in our project we got to know is clay with rock layers in deeper base. Though we have not exact data of geological survey, which is usually obtained by series of base tests, frequent values of technical parameters for clay base have been taken into consideration in calculation.
According to this clay base, we have proposed a foundation plan for our design - Pile Foundations. More specifically, excavation pile foundations have been used in this system.

4.8.1 Materials

Base rock: standard value of uniaxial compressive strength f_{rc}- *10MPa*
Concrete: pile - C40/C50 , coating wall of pile - C30/C37
Steel bar: longitudinal reinforcement - S355 , Transverse stirrups - S275

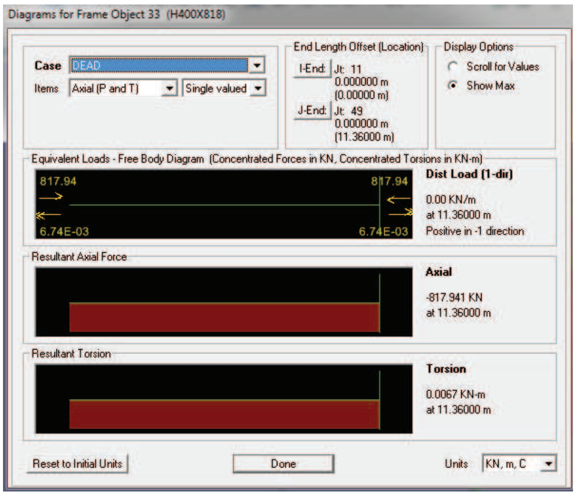
4.8.2 Choice of excavation piles

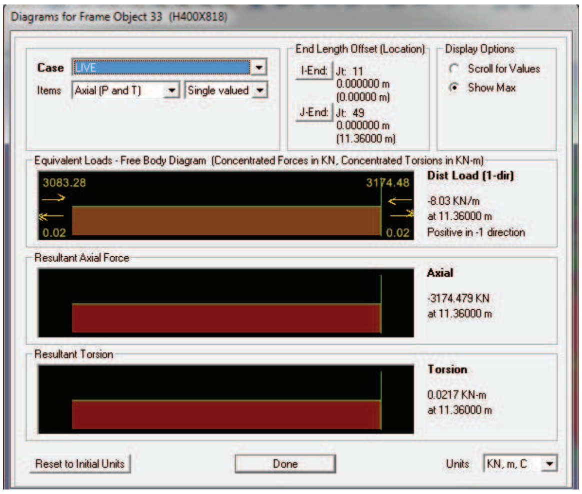
Diameter of cross section - *1200mm*

4.8.3 Load Capacity Design

According to ' *JGJ 94-2008*', chapter - 5.2
when the column and pile are concentric, axial force:
$Q_{ek} \leq 1.25R_a$
Vertically bearing capacity eigen value：
$R_a = Q_{uk} / K$
where:
Q_{uk} : Standard value of the ultimate bearing capacity
K : Safety factor , $K = 2$
lateral side fraction : $Q_{uk}= Q_{rk} = \xi r f_{rc} A_p,$

<u>For Column 33:</u>





$Q_k = Q_{kD} + Q_{kL} = 817.941 + 3174.48 = 3992.421\ KN$

Vertically bearing capacity value:

$R_a = Q_{uk} / K = Q_{rk} / K = \xi_r f_{rc} A_{p,} / K$
$\quad = 0.95 \times 10 \times 10^3 \times 3.14 \times 0.6^2 \times 1.2/2$
$\quad = 6443.28\ KN$

note :$f_{rc} = 10MPa < 15MPa$, the rock is soft rock, Rocksocketed depth$h_r = D$, $f_{rc} = 10MPa$, according to rules in the standard, $\xi_r = 0.95$.

Check:
$Q_k = 3992.421 \ < 1.25\ R_a = 1.25 \times 6643.28 = 8054.1\ KN$

Calculation of bearing capacity of piles:
$Q \leq \ A f_c \Psi_c$

where$Q$ is the load to the top of pile from the column

for Non-extrusionpiles with slurry Wall $\Psi_c = 0.8$
Q = 11948 KN, which is got from the result of maximum inner force calculation with load combination 3.

$A f_c \Psi_c = 3.14 \times 0.6^2 \times 14.3 \times 0.9 \times 10^3 = 14548KN > Q = 11948\ KN$, **SATISFIED**.

Construct Reinforcement Design:
According to ' *JGJ 94-2008* ' , the reinforcement ratio must be larger than *0.2% - 0.65%* .

Reinforcement Design:

Name	Section and number	A_s (mm^2)	ρ
WI1	18Φ16	3619.8	0.32%

Table 4.14 Reinforcement design for piles

For the region of pile above 5D from the top of pile, the additional stirrups should be used, which is Φ10@100. For the remaining region of pile ,stirrups is Φ10@200.

Anchor Calculation For Reinforcement:

$l_a = ad\, f_y / f_t = 0.14 \times 20 \times 345 / 2.5 = 387mm$

to guarantee the safety , $l_{ae} = 400mm$,which is the length of anchor for inserted reinforcement.

4.8.4 Spiral indirect reinforcement

According to ' *JGJ 94-2008*', the bearing capacity of Local compression should be satisfied by :
$Q \leq 0.9\ (\ \beta_c\ \beta_l f_c + 2a\rho_l\ \beta_{cor} f_y\ )\ A_{ln}$

<u>Calculation for spiral reinforcement:</u>

$\beta_{cor} = \beta_l$, A_{ln} = 562500 mm^2 (area of base isolation bottom), $a = 1.0$, $S = 50mm$,
$\rho_v = 4A_{ssl} / (d_{cor}S) = 4 \times 3.14 \times 0.6^2 \times /[\ (1200\text{-}32\text{-}80\ ) \times 50] = 0.83\% \geq 0.5\%$,
so$Q = 1.1948 \times 10^4 KN < 0.9 \times (\ 1.0 \times \sqrt{3.14} \times 19.1 + 2 \times 1.0 \times \sqrt{3.14} \times 0.83\% \times 275) \times 0.5625 \times 10^6 = 2.125 \times 10^4 KN$

Therefore $\boldsymbol{Q \leq 0.9\ (\ \beta_c\ \beta_l f_c + 2a\rho_l\ \beta_{cor} f_y\ )\ A_{ln}}$ **SATISFIED .**

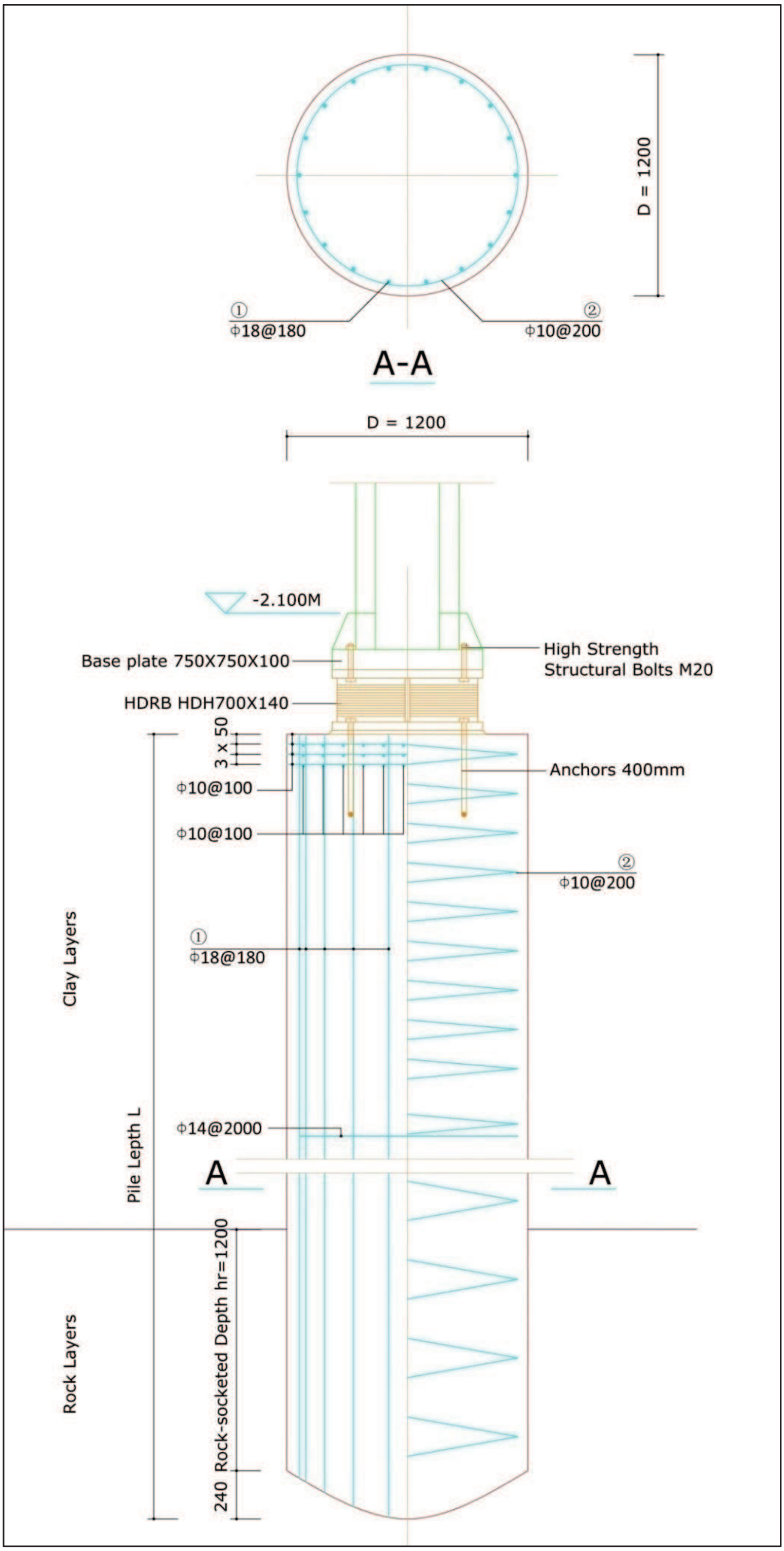


Fig 4.30 Design of Pile Foundations

4.9 Conceptual Structure Design of Ramps

In this chapter, we only discuss the concept of structure design of ramps, due to the similar steel frames system of ramps to the main building structure. And we have used the SAP2000 as a structural analysis tool to design the structure of ramps.

4.9.1 Plans

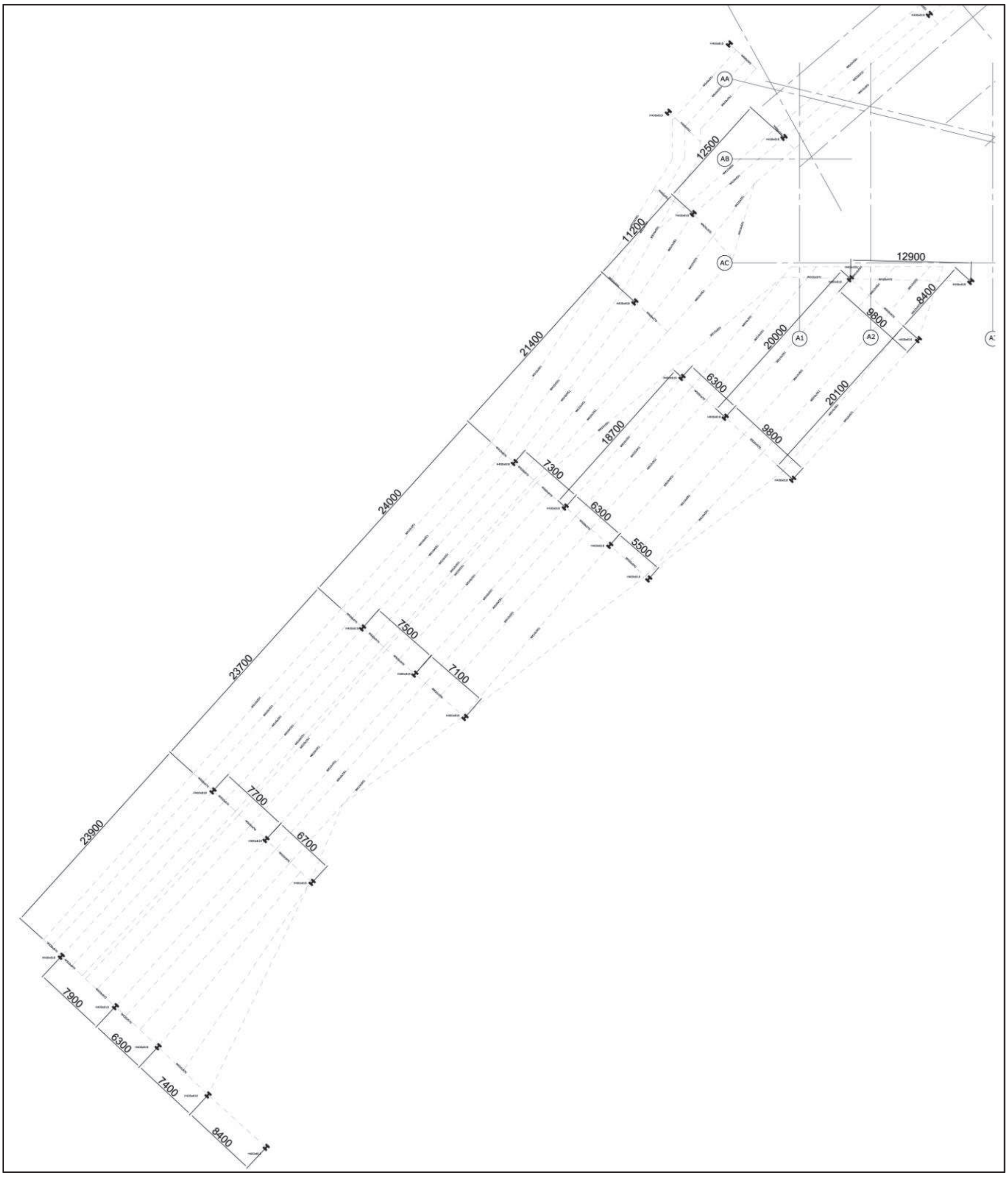


Fig 4.31 Structure Plan of Ramps (mm)

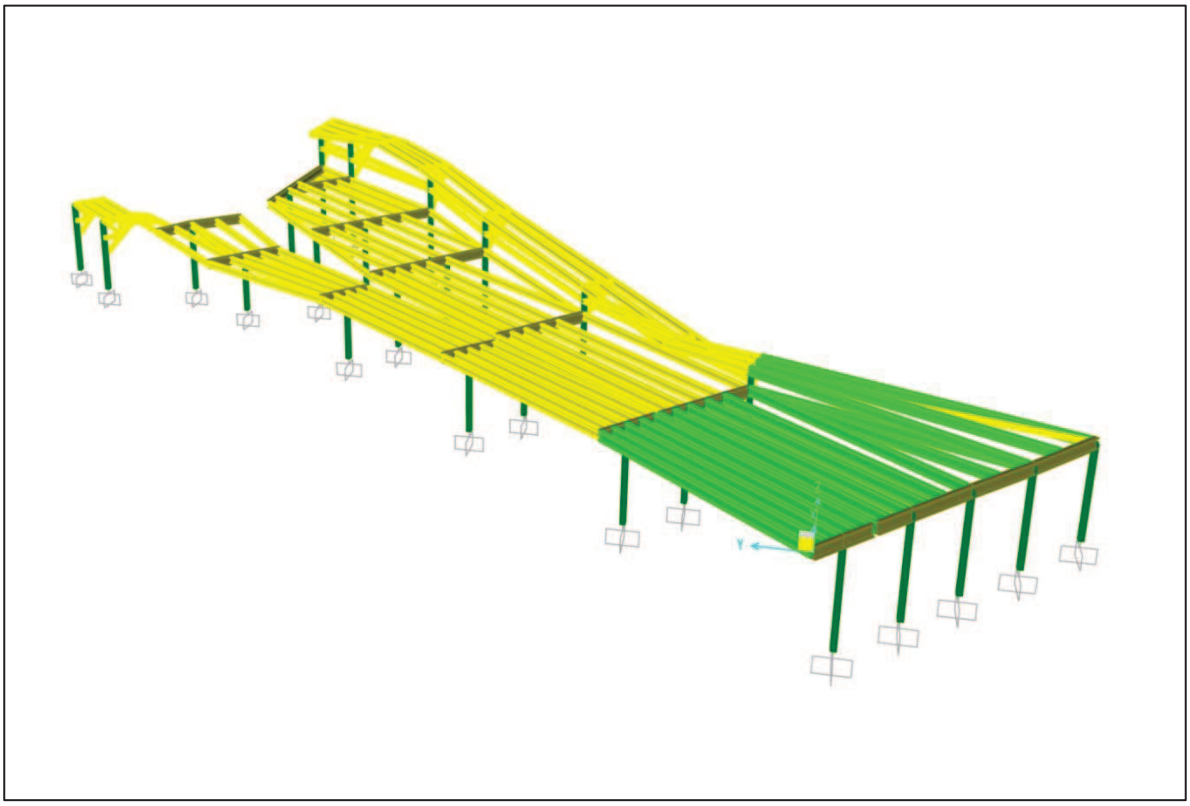


Fig 4.32 Structural mode of ramps

4.9.2 Loads Calculation

Dead loads:
Here we have used the same slabs as the intermediate floor used in platform, so we have a area dead load of ,*1.864 KN/m²*. And the span of slabs here is 1.5 m, then we get a continues linear load on the main beams ***Q_{LD} = 1.845 x 1.5 = 2.77 KN/m***.

Live loads:
According to the .EN1991-1-1: section 6, the area load for the ramps is *2KN/m²*.And the effective area for each beam is *1.5m,*
So ***Q_{LL}= 2 x 1.5 = 3 KN/m***

Snow loads:
Base on the Chapter 4.3.2.4, we know the area snow load here is *2.256 KN/m²*. Considering the effective area for each beam is *1.5m,*
So ***Q_{LS}= 2.256 x 1.5 = 3.384 KN/m***

4.9.3 Results of Calculation

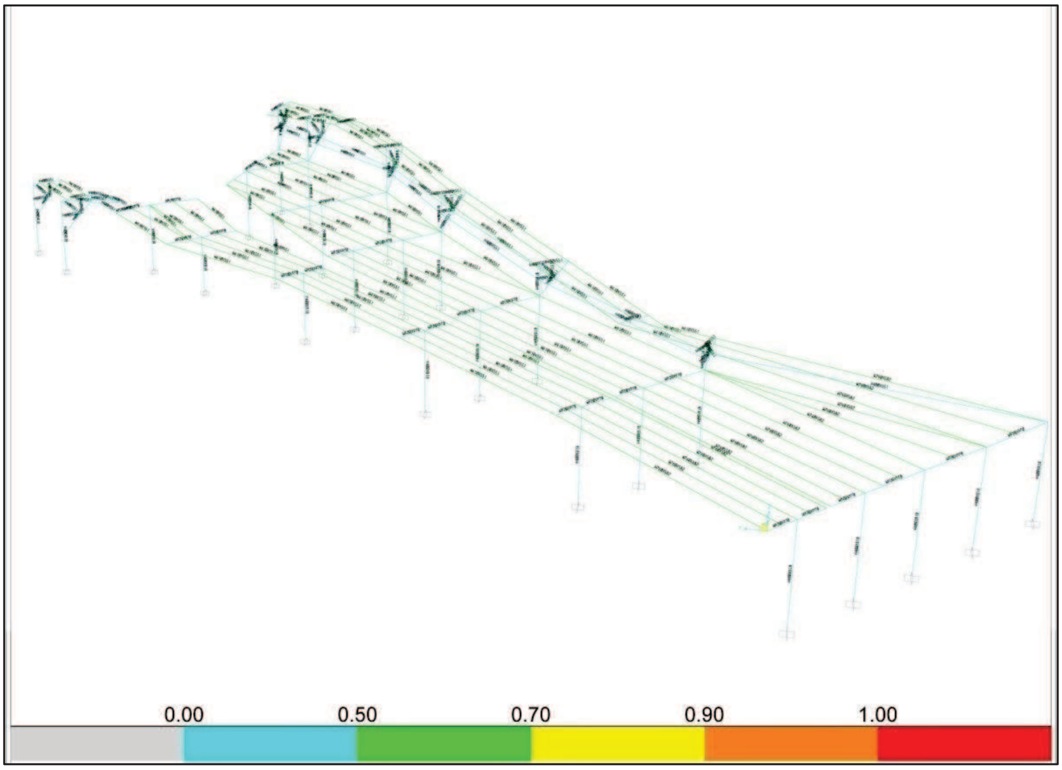


Fig 4.33 3D view of stress limit ratio on the ramps.

The stress limit ratio mainly is between 0.50 and 0.70, especially for the beams. And for the columns and short beams, the ratio is below 0.50.

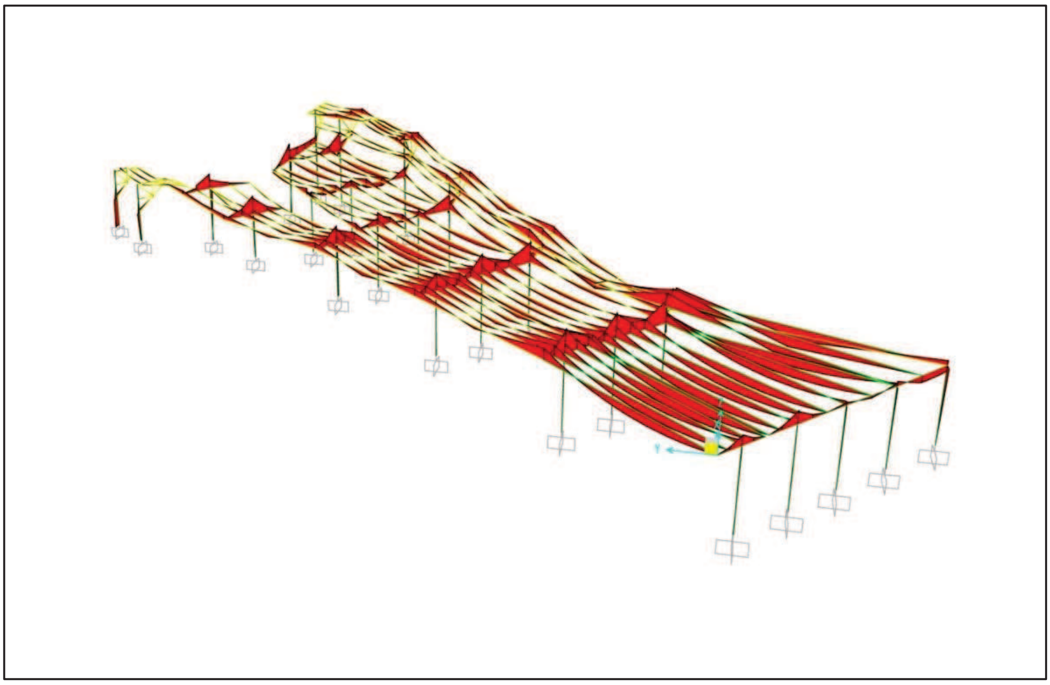
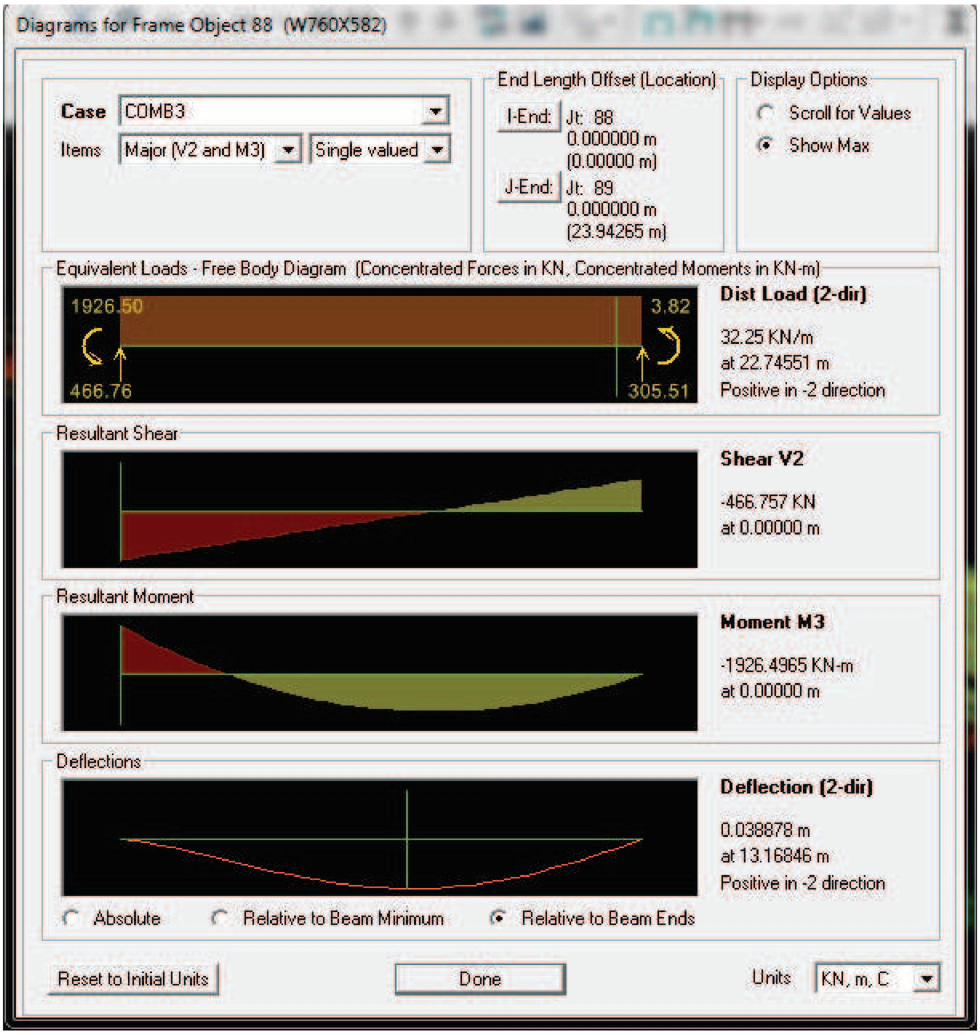


Fig 4.34 3D view of bending moment diagram on the ramps

According to the simulated result obtained from the SAP2000, the structure of ramps is satisfied by assessments.

4.9.4 Simple Check on Elastic calculation

Here we choose a specific Beam 88, which has the largest deformation among all the beams, to check.

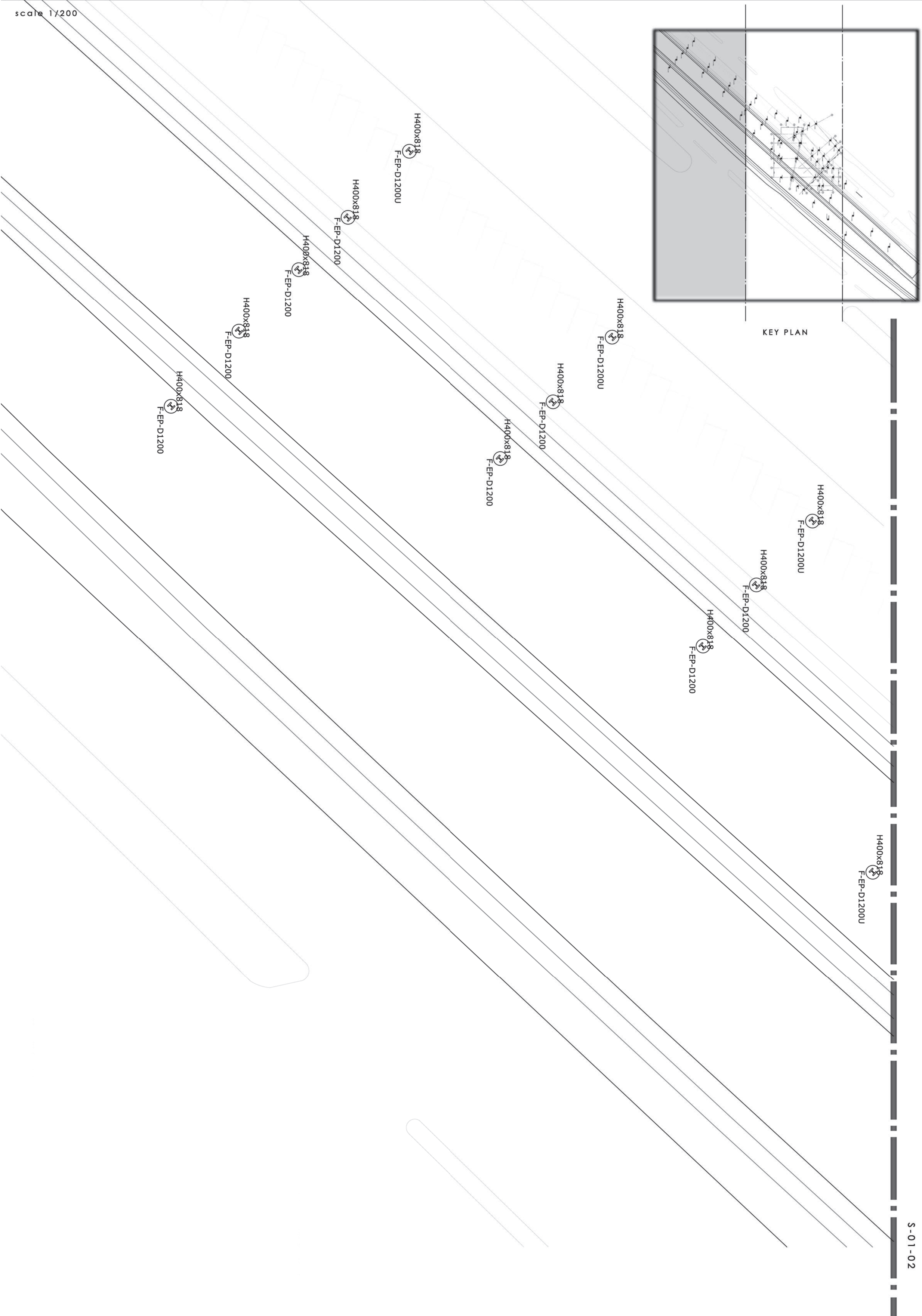


according to the Euro Codes:
Span / 250 = 13.168 / 250 = 0.0527 m
Max deflection = 0.03888 m
Max deflection < Span / 250 SATISFIED.

4.10 Structural figures

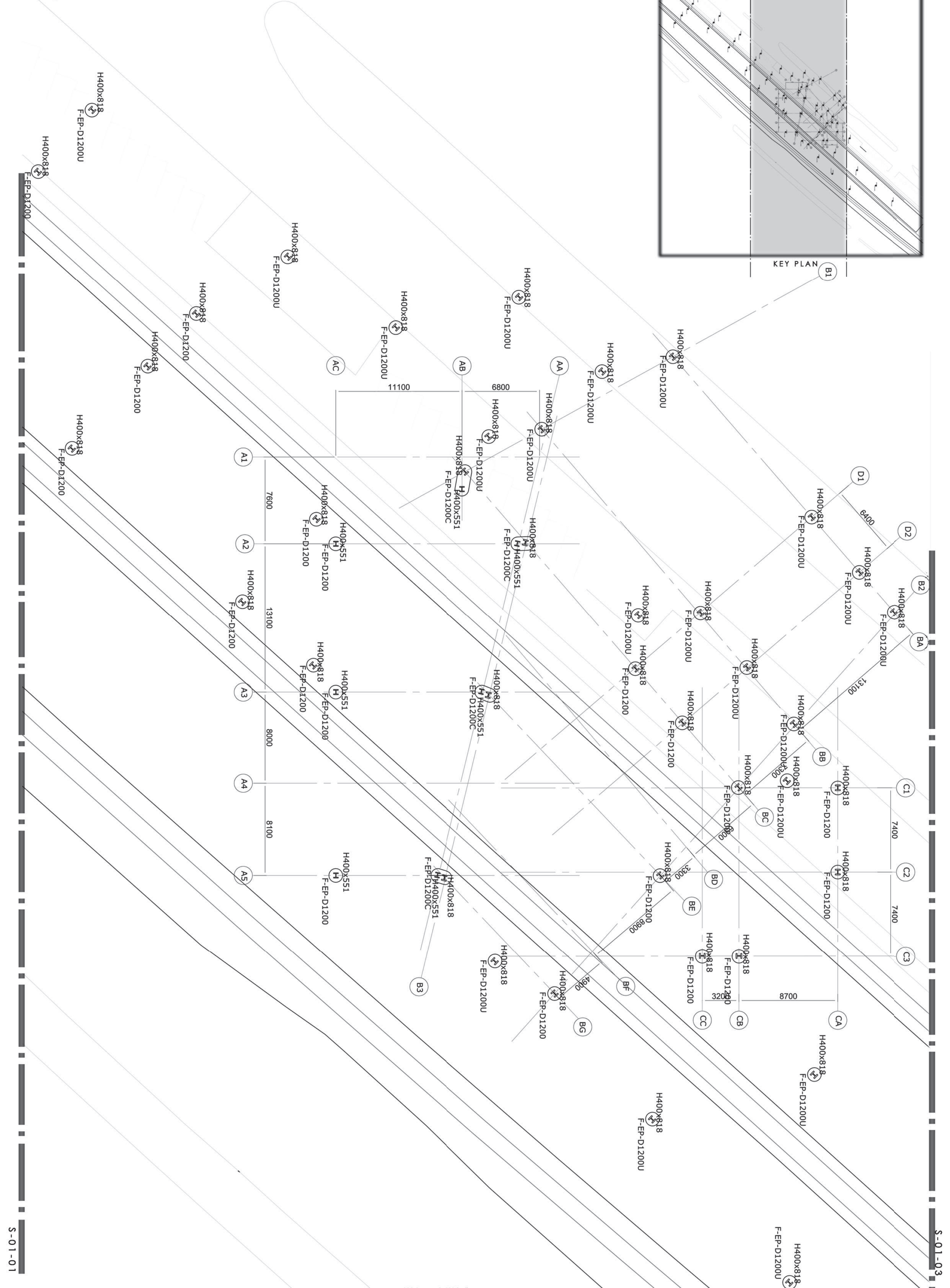
S-01-01: STRUCTURE PLAN AT GROUND FLOOR LEVEL (± 0.000M)

scale 1/200

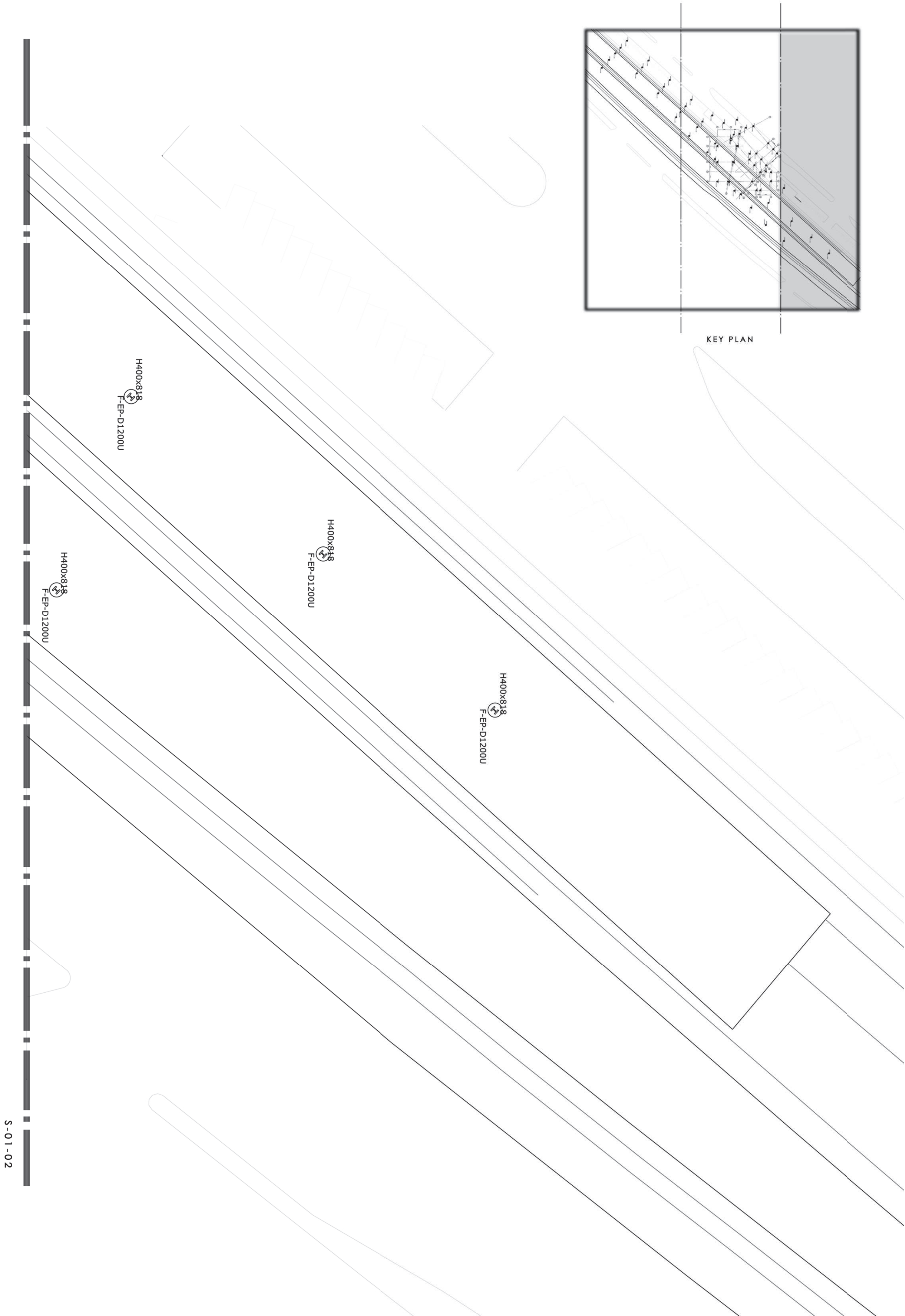


S-01-02: STRUCTURE PLAN AT GROUND FLOOR LEVEL (± 0.000M)

scale 1/200



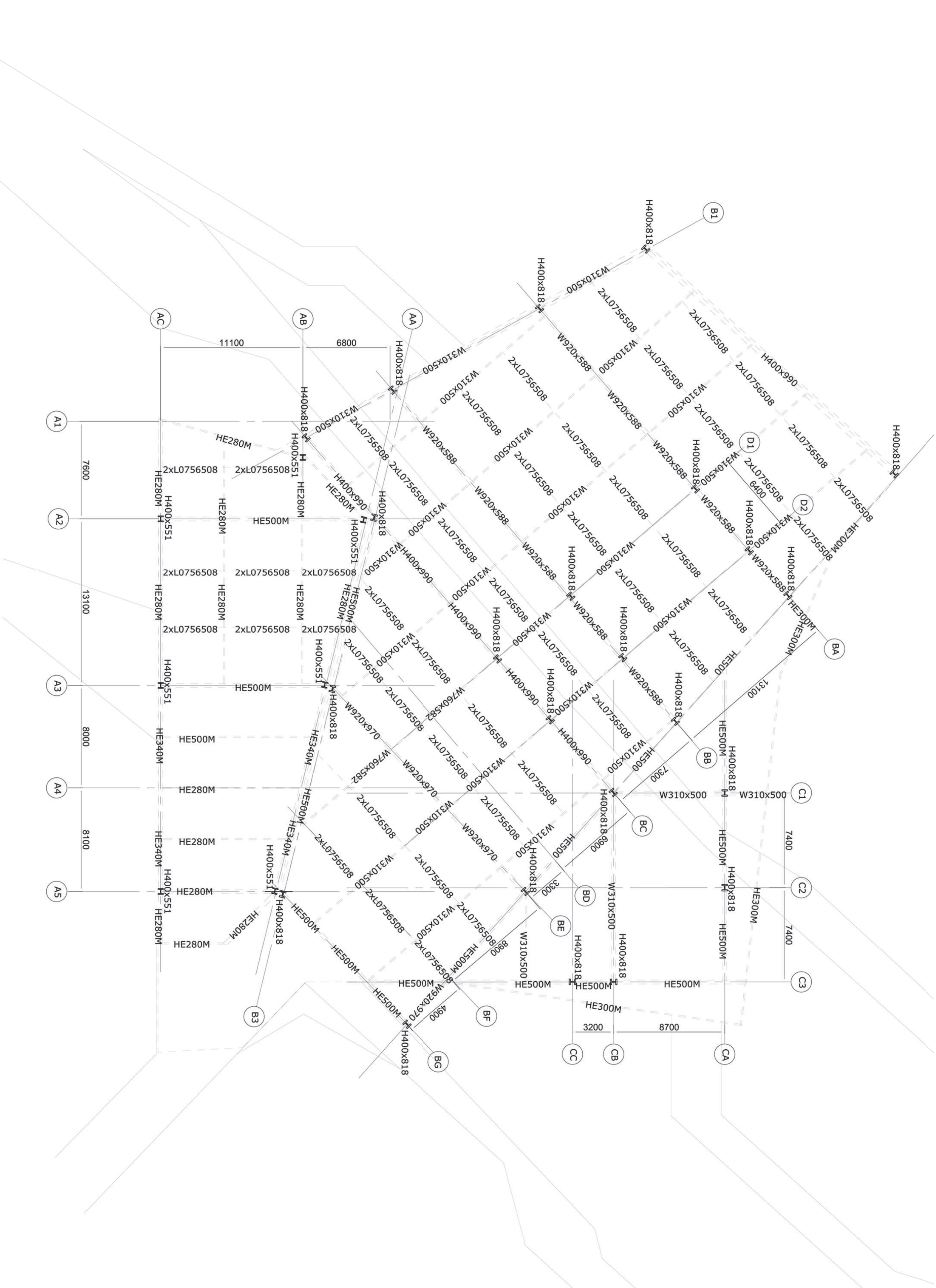
scale 1/200



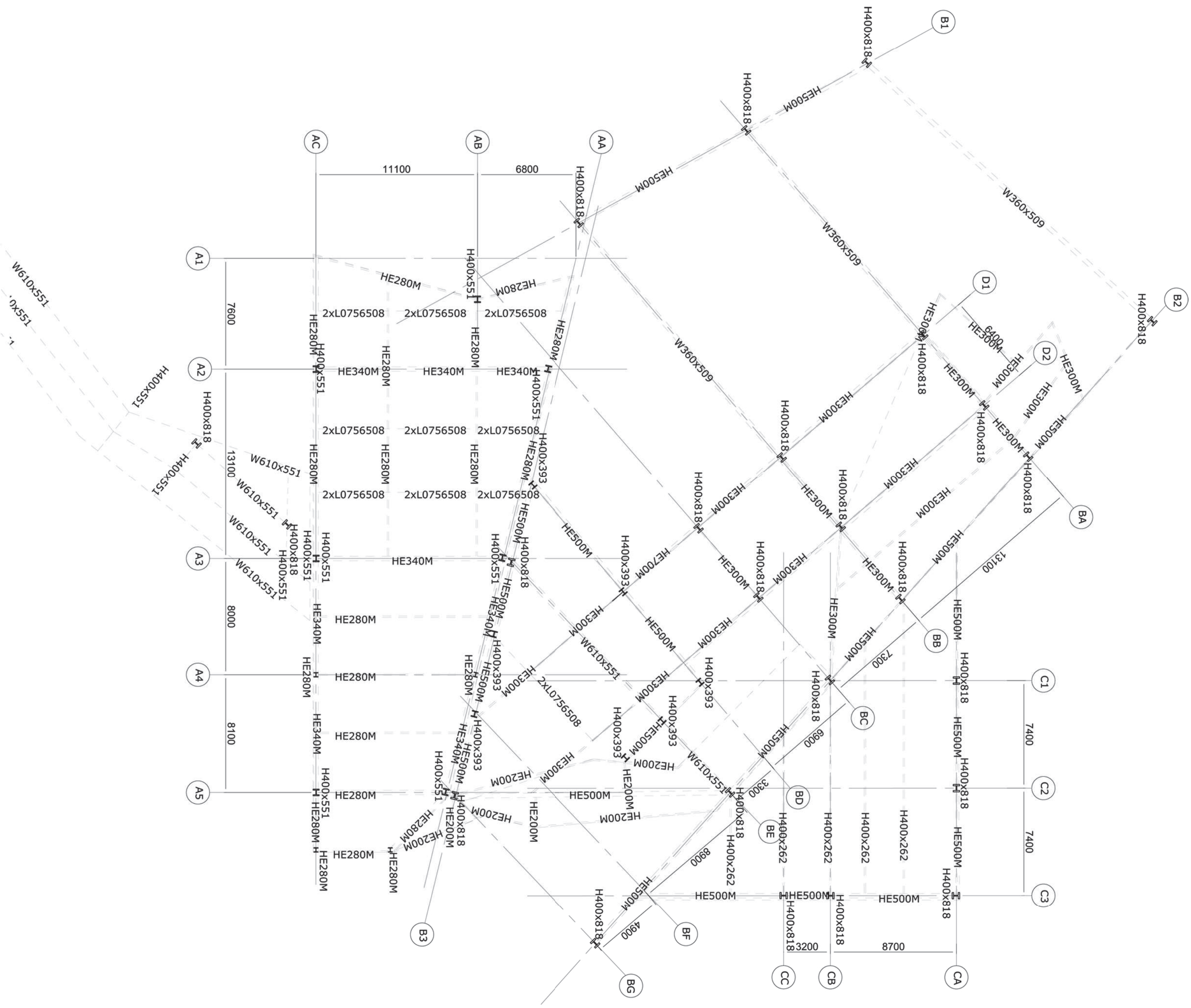
KEY PLAN
H400x818
F-EP-D1200U
H400x818
F-EP-D1200U
H400x818
F-EP-D1200U
H400x818
F-EP-D1200U
S-01-02

S-02-01: STRUCTURE PLAN AT 1ST FLOOR LEVEL (+ 9.000M)

scale 1/200



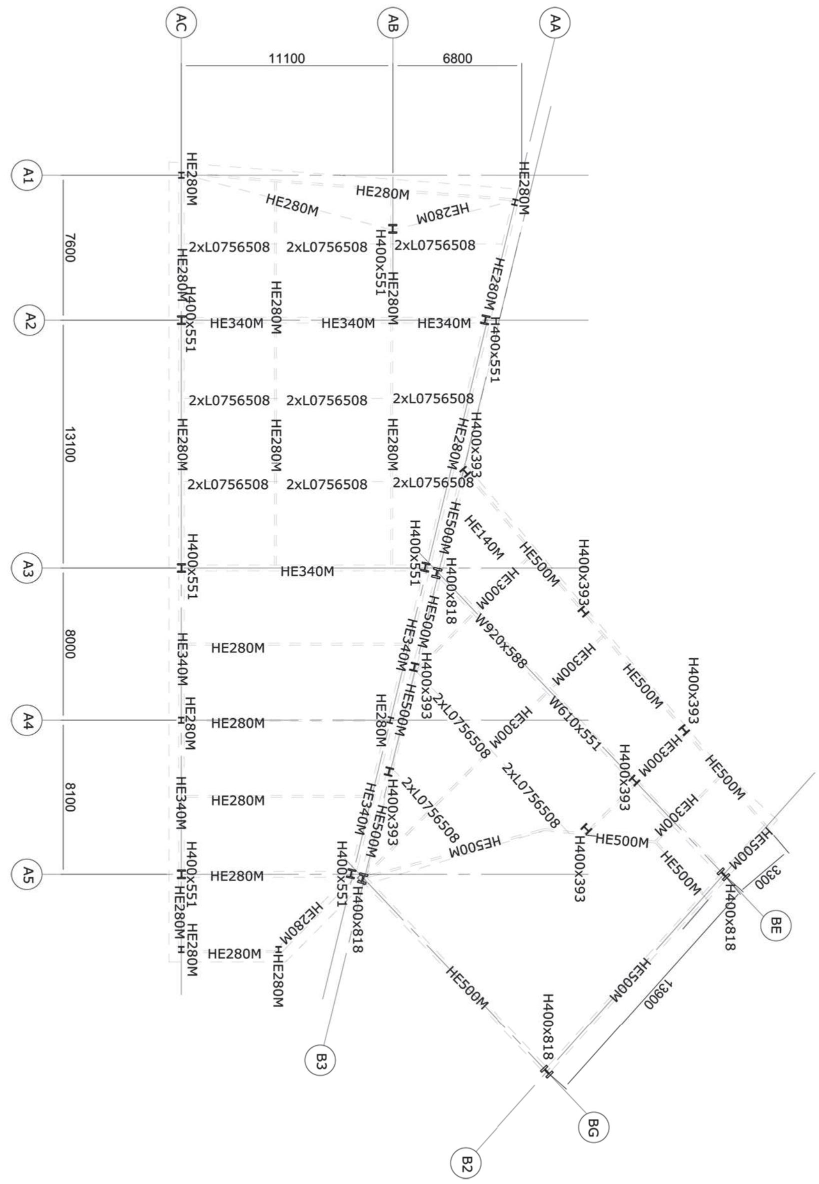
scale 1/200



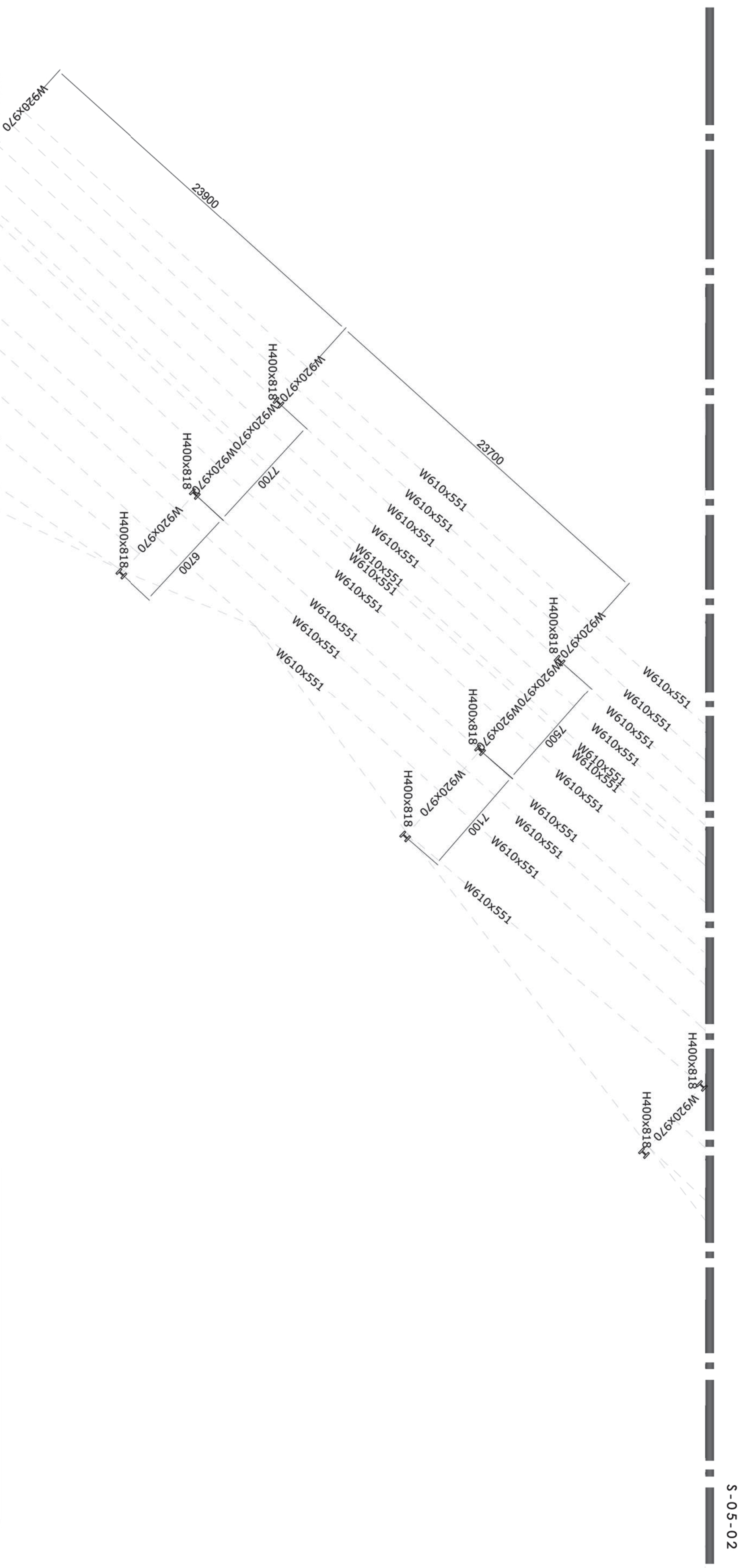
AC
AB
AA
11100
6800
A1
A2
A3
A4
A5
B1
B2
B3
D1
D2
BA
BB
BC
BD
BE
BF
BG
C1
C2
C3
CA
CB
CC
7600
13100
8000
8100
7400
7400
3200
8700
13100
7300
6400
4900
HE280M
HE340M
HE500M
HE300M
HE200M
HE700M
H400x818
H400x551
H400x393
H400x262
W610x551
W360x509
2xL0756508

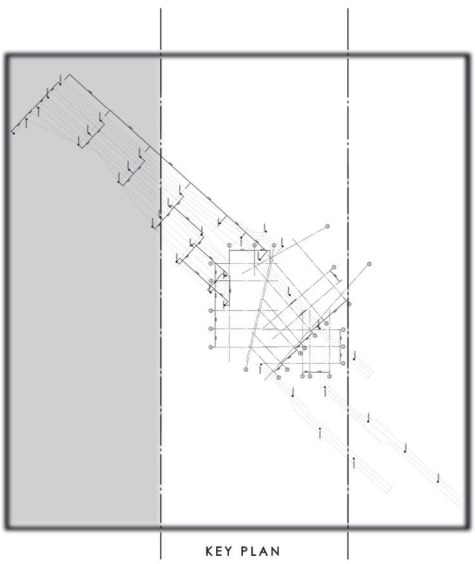
S-04-01: STRUCTURE PLAN AT ROOF LEVEL (+22.200)

scale 1/200



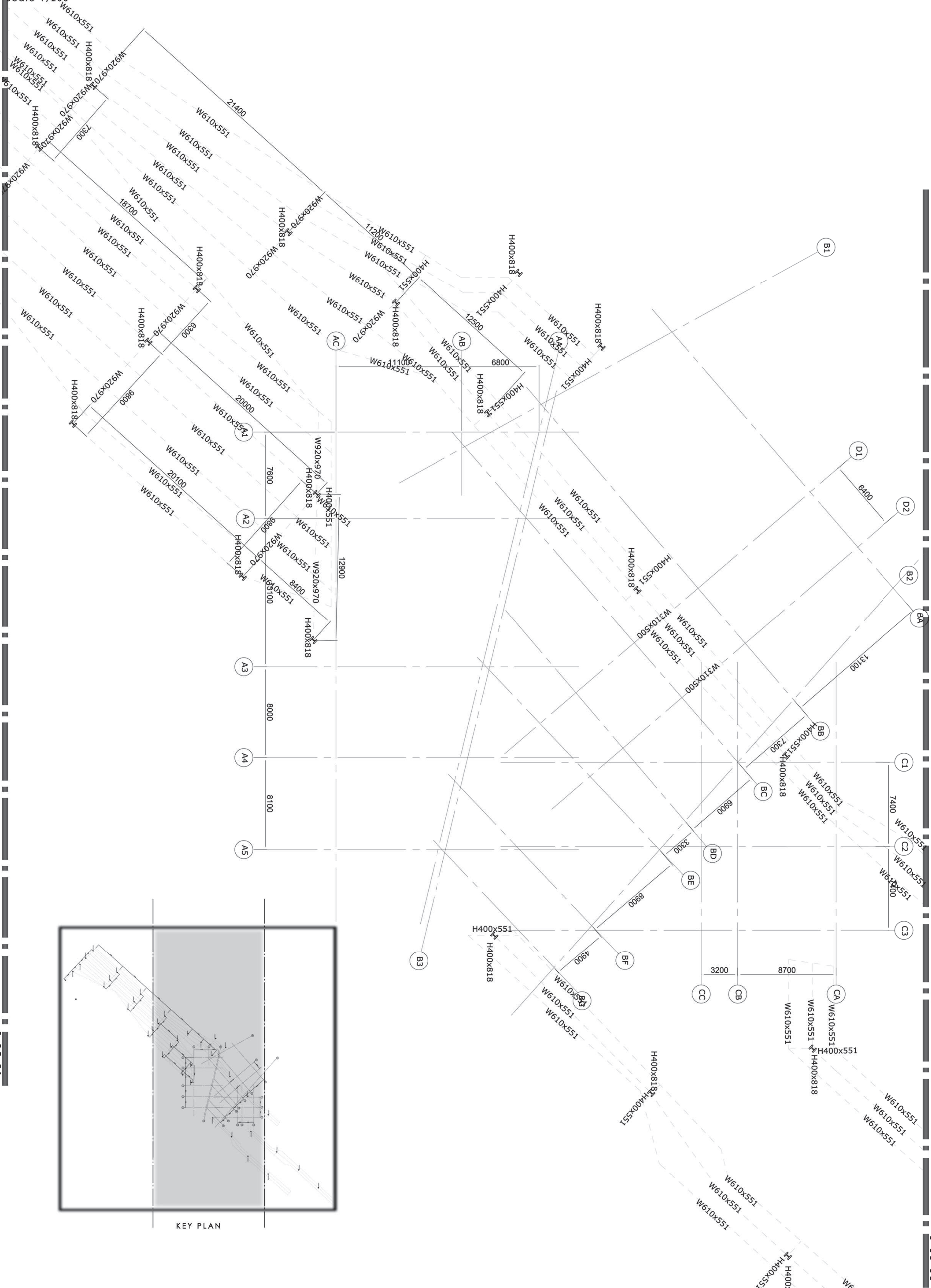
scale 1/200





KEY PLAN

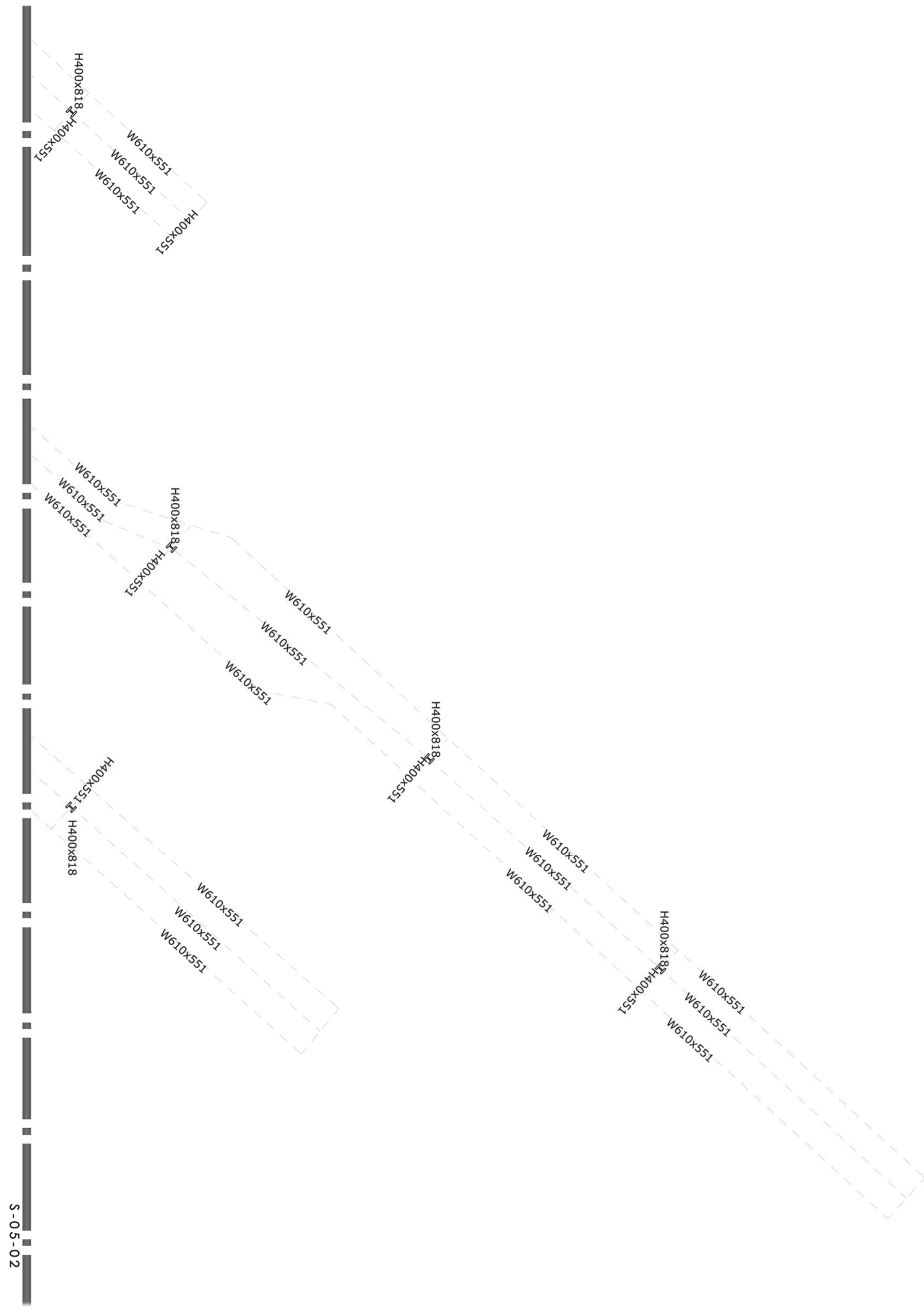
scale 1/200

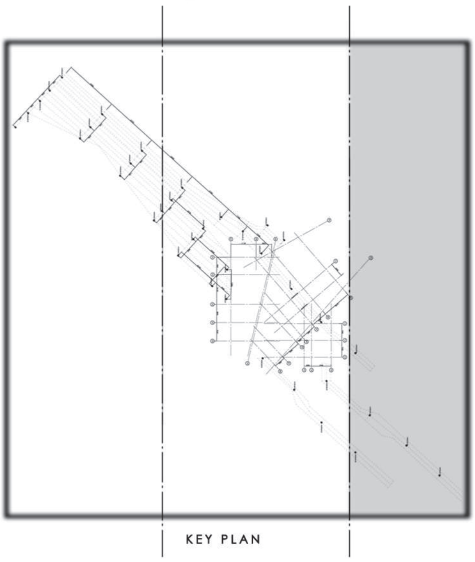


S-05-01
S-05-03

S-05-03: STRUCTURE PLAN OF RAMPS AT 1ST FLOOR LEVEL (+9.00M)

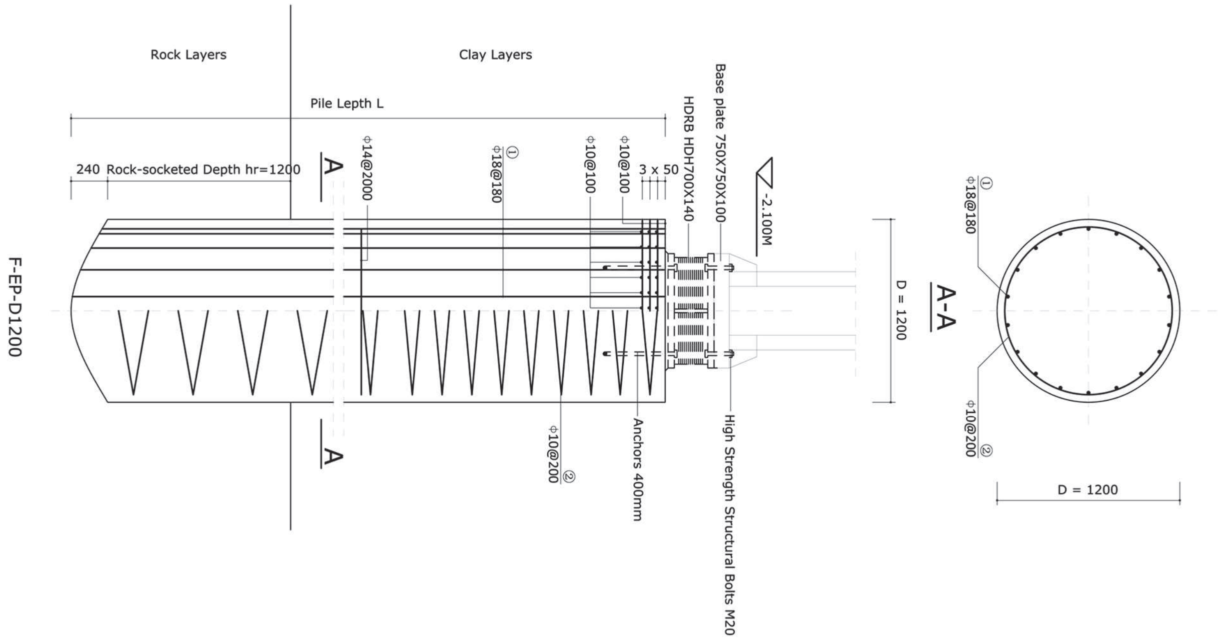
scale 1/200

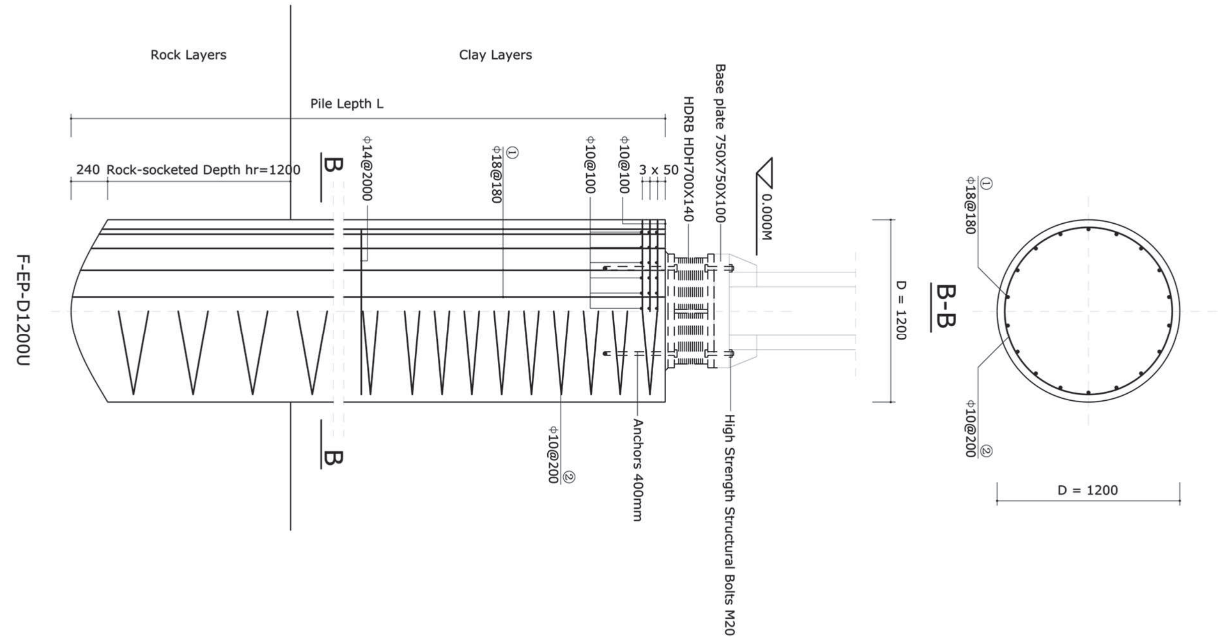




KEY PLAN

scale 1/25


F-EP-D1200
Rock Layers
Clay Layers
Pile Lepth L
240 Rock-socketed Depth hr=1200
A
A
Φ14@2000
① Φ18@180
Φ10@100
Φ10@100
3 x 50
HDRB HDH700X140
Base plate 750X750X100
-2.100M
② Φ10@200
Anchors 400mm
High Strength Structural Bolts M20
D = 1200
A-A
① Φ18@180
② Φ10@200
D = 1200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Rock Layers
Clay Layers
Pile Lepth L
240 Rock-socketed Depth hr=1200
B
B
Φ14@2000
① Φ18@180
Φ10@100
Φ10@100
3 x 50
HDRB HDH700X140
Base plate 750X750X100
0.000M
② Φ10@200
Anchors 400mm
High Strength Structural Bolts M20
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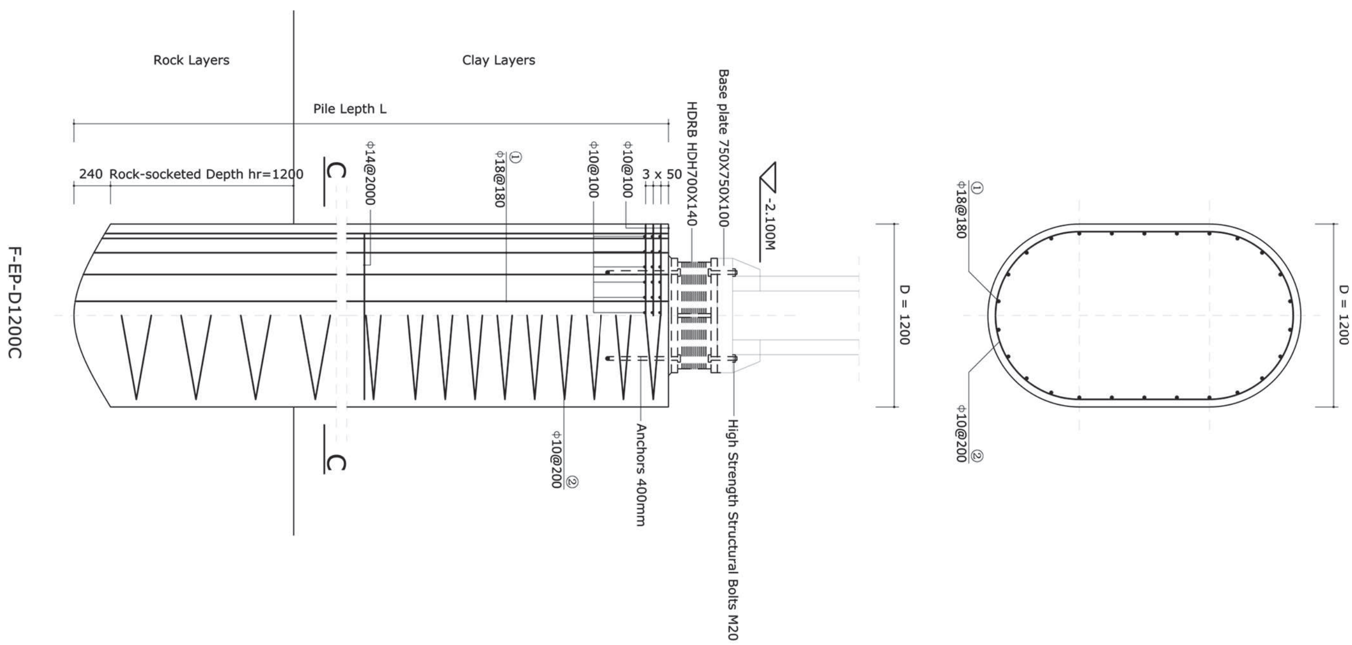
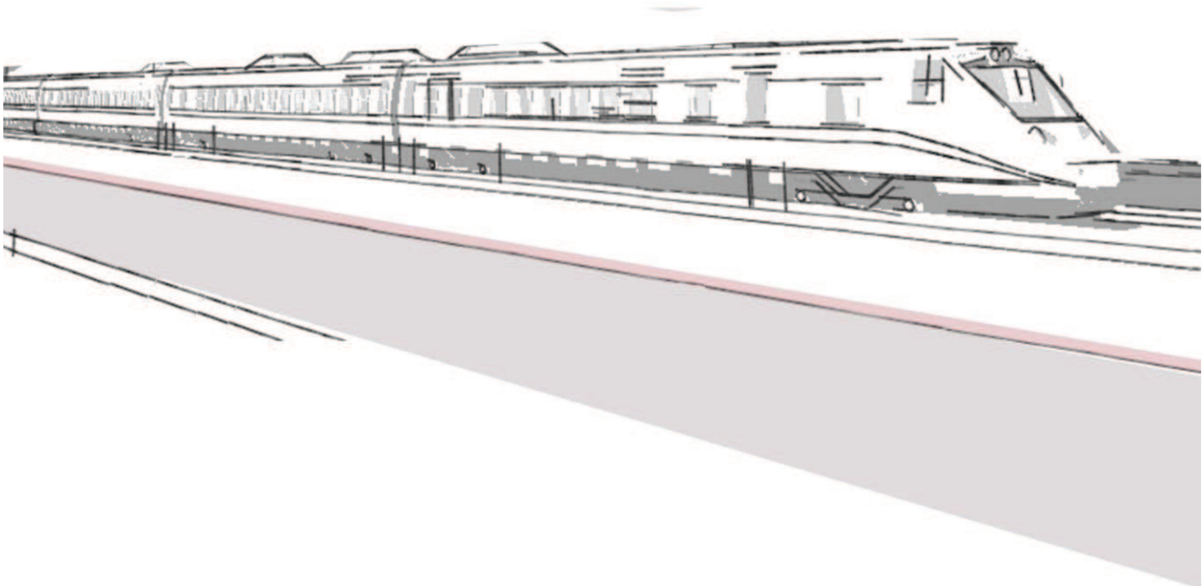
② Φ10@200
D = 1200


F-EP-D1200C
Rock Layers
Clay Layers
Pile Lepth L
240 Rock-socketed Depth hr=1200
C
C
Φ14@2000
① Φ18@180
Φ10@100
Φ10@100
3 x 50
HDRB HDH700X140
Base plate 750X750X100
-2.100M
② Φ10@200
Anchors 400mm
High Strength Structural Bolts M20
D = 1200
① Φ18@180
② Φ10@200
D = 1200

5.0 TECHNOLOGICAL DESIGN



5.1 Introduction

5.1.1 Vision Statement

Finland is a North European country with unique climate and unique geological environment. Accordingly, the Finnish design regulations for buildings are different from other regulations in central Europe, some of which, a relatively low 45% temperature efficiency of heating recovery system for example, are not understood in other parts of Europe. So in our design process of this project, we respect a lot to Finnish codes for buildings, especially the requirement on energy aspects. In the following chapters of technology design, we will demonstrate the rules of Finnish National Codes that we have taken as references.

As an international trend, sustainability has been becoming a hot topic and a general goal for buildings constructions. In our project, we mainly want to achieve a more sustainable solution for our design. After setting this goal, we have focused on sustainability issues in very early design steps (architecture design).

Considering the unique the geographical environment in Malmi, Helsinki, the measures for sustainable design is different from the ones in somewhere else. From general point of view, achieving sustainability requires us to live within the limits of the earth's capacity to provide the materials for our activities and to absorb the waste and pollution that our activities generate. And buildings and the built environment will therefore increasingly be required to satisfy a number of criteria, including that they should:

- Enhance biodiversity – not use materials from threatened species or environments and improve natural habitats where possible through appropriate planting and water use.
- Support communities – identify and meet the real needs, requirements and aspirations of communities and stakeholders and involve them in key decisions.
- Use resources effectively – not consume a disproportionate amount of resources, including money and land during material sourcing, construction, use or disposal; not cause unnecessary waste of energy, water or materials due to short life, poor design, inefficiency, or less than ideal construction and manufacturing procedures. Buildings have to be affordable, manageable and maintainable in use.
- Minimize pollution – create minimum dependence on polluting products and materials, management practices, energy, power and forms of transport.
- Create healthy environments – enhance living, leisure and work environments; and not endanger the health of the builders or occupants, or any other parties, through exposure to pollutants, the use of toxic materials or providing host environments to harmful organisms.
- Manage the process – stewardship of projects is a vital and overarching aspect in delivering sustainable projects, both in the first instance and also in ensuring their performance over time. This requires us to identify appropriate targets, tools and benchmarks, and manage their delivery.

In our design, we take specific measures to achieve a good performance on sustainability issue as much as possible. Main sustainable solutions would be focused on several aspects: basic material selection (high efficiency insulation), low-impact construction, airtight envelop, passive solar measures (heating and ventilation), lighting and day-lighting, renewable technology, water and sewage management.

To sum up, to achieve the prospective goal on sustainable design, we have made comprehensive analysis of the survey on the site of our project and have referred a lot from the Finnish National Codes, then we get proper solutions to improve the buildings performance with relatively low demand for energy and with less impact on the surrounding environment.

5.1.2 Geological information of Malmi

5.1.2.1 Project localization

Finland is a country of lush forests and vast woodlands. Finland's 800-mile border with Russia gives it a unique position as a gateway to the east. The country's excellent infrastructure and transportation system, its geographical location, and its understanding of how to do business in Russia and the Baltic states mean that many foreign companies. Finland is also a country of thousands of lakes and islands; 187,888 lakes (larger than 500 m²) and 179,584 islands to be precise. One of these lakes, Saimaa, is the fifth largest in Europe.

Figure 5.1 Satellite map of Finland

The Finnish landscape is mostly flat with few hills. Its highest point, the Haiti at 1,324 meters, is found in the extreme north of Lapland at the border between Finland and Norway. Finland is very green, with approximately seventy-five percent of its land area covered by coniferous taiga forests, with littlearable land. Moraine or till is the most common type of soil, covered by a thin layer of humus of biological origin. The most common type of rock is granite, which is visible everywhere there is no soil cover.

5.1.2.2 Description about terrain of Malmi

Figure 5.2 Satellite map of Malmi, Helsinki

Located at 28 meters of altitude, the town of Malmi has the following coordinates60.25 ° north, 25.05 °east. Average altitude here is 28m above the sea level. The mail soil type here is clay. More in detail, flatland is the main terrain type in Malmi. Between the downtown and the Airport-Malmi, Helsinki, there is small hill that is the highest point on the terrain, which is 20 meters higher than the average.

5.1.3 General information of Climate

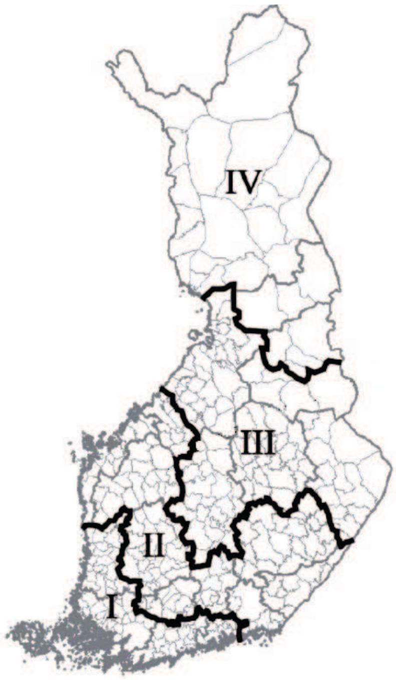


Figure 5.3 Weather zones in Finland, National Building Code of Finland, D4, Figure L 1.1

Finland is located at the Baltic Sea coast, the climate is classified as the transition climate from ocean zone to continent zone.

Malmi, Helsinki has a humid and cool semi-continental climate, characterized by warm summers and freezing winters. Winters of southern Finland are usually 4 months long, and the snow typically covers the land from middle of December to early April. During the early winter, it can melt many times, and then come again. Arctic tundra proper is not found here; even the latitude is so northern

The main factor influencing the Malmi's climate is the country's geographical position between the 60th and 70th northern parallels in the Eurasian continent's coastal zone, which shows characteristics of both a maritime and a continental climate, depending on the direction of air flow. Malmi is near enough to the Atlantic Ocean to be continuously warmed by the Gulf Stream, which explains the unusually warm climate considering the absolute latitude.
(Source: http://en.wikipedia.org/wiki/Finland#Climate)

Correspondingly, in the National Building Code of Finland, the country is divided into four weather zones (Zone I, Zone II, Zone III, Zone IV). In the code, regulations in different zones are not the same due to the differences among each region.

Our site is located in Zone I which is characterized by fairly warm climate similar to the Central Europe.

5.1.3.1Statistic Date of Temperate and Climate Based on Analysis Tools of ECOTECT

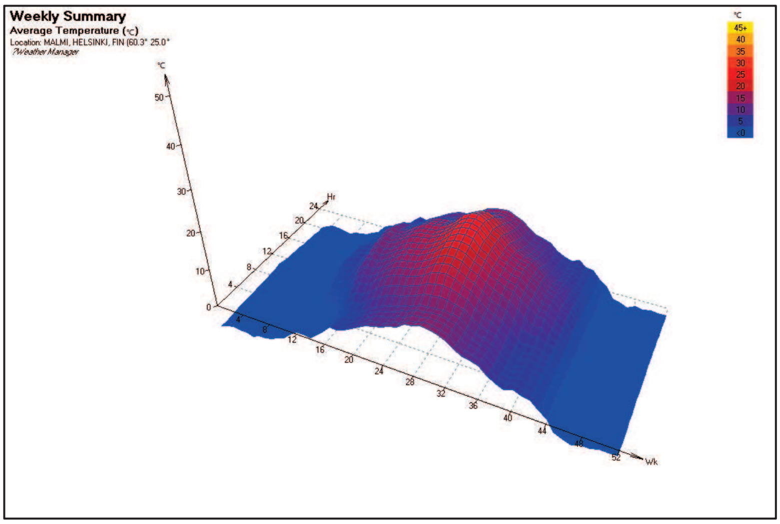


Figure 5.4 Average Temperatures in Malmi, Helsinki

Figure 5.4 shows a color coded graph of the average temperature of Malmi, Helsinki in a year on a weekly basis. The darkest color - Blue depicts temperatures of around 00C, representing the lower limit of the color spectrum. The color spectrum then increases with increments of 5 until reaching the brightest color - Yellow that portrays temperatures of around 450C. The X-Axis shows the number of weeks. The Y-Axis is the hour axis that ends at 24 which shows the number of hours each day. Both the X and Y axes increase in steps of 4. The value of temperature in each month is shown in the table below:

Average Temperature ℃	-6	-6.5	-4	3	9	14	18	16	12	6	1	-3
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

Table 5.1

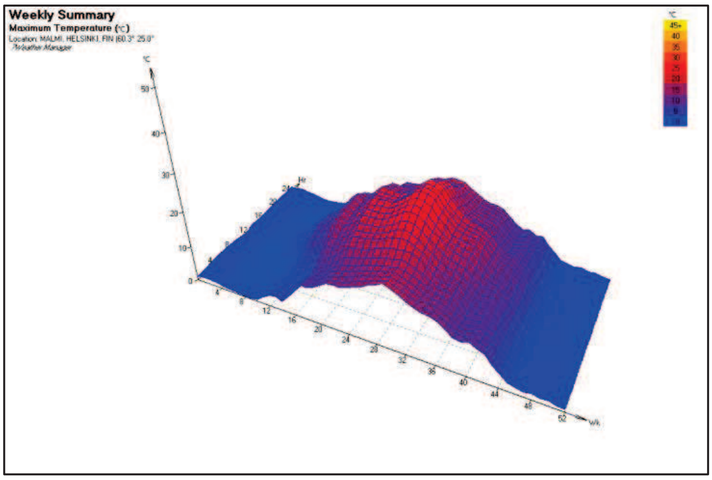


Figure 5.5 Maximum Temperature in Malmi, Helsinki

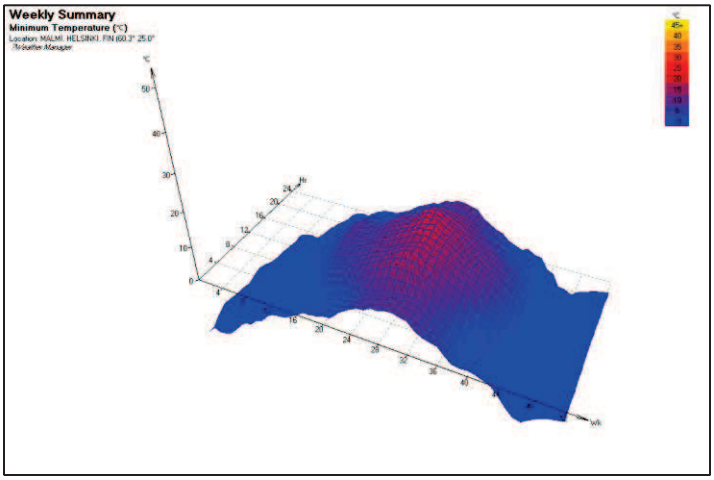


Figure 5.6 Minimum Temperature in Malmi, Helsinki

As they are shown in Figure 5.5 and Figure 5.6, the maximum temperature and minimum temperature are concluded in the table 5.02, the difference between the maximum and minimum value is included, as well.

Average Maximum Temperature ℃	-3	-4	0	6	14	19	22	20	15	8	3	-1
Average Minimum Temperature ℃	-9	-9	-7	-1	4	9	13	12	8	3	-1	-5
Difference between Max and Min ℃	6	5	7	7	10	10	9	8	7	5	4	4
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

Table 5.2

5.1.3.2Statistic Date of Relative Humidity Based on Analysis Tools of ECOTECT

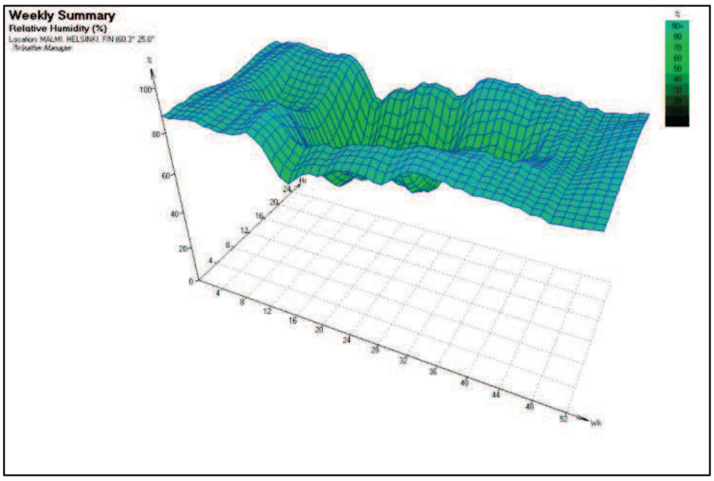


Figure 5.7 Relative Humidity in Malmi, Helsinki

Figure 5.07 shows a color coded graph of the relative humidity in Malmi, Helsinki in a year on a weekly basis. The darkest color - dark Green depicts relative humidity of around 0% and above, representing the lower limit of the color spectrum. The color spectrum then increases with increments of 10% until reaching the brightest color - Bright almost bluish Green that portrays Relative humidity of around 90%. The figure 5.4 gives us an underlying idea of how our space should be treated in terms of relative humidity. The figure 5.07 demonstrates that the relative humidity in Malmi remains at the level of around 80% in a long period of a year, only in summer months it drops below 80% to minimum 64% in the relative hottest days. Table 5.3 is a conclusion based on the Figure 5.7.

Relative Humidity %	89	88	78	75	64	64	70	77	85	89	89	91
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

Table 5.3

5.1.3.3 Precipitation Rate

Precipitation has multiple effects on the environment, society and human life. Intense rainfall increases soil erosion, chemical leaching and the amount of urban waste and nutrients carried from catchments into watercourses and coastal waters. Especially in urban areas, heavy rainfall can cause flooding, and rainwater can inundate streets and cellars. On the other hand, rainfall is very efficient in cleaning the air of pollen and contaminants.

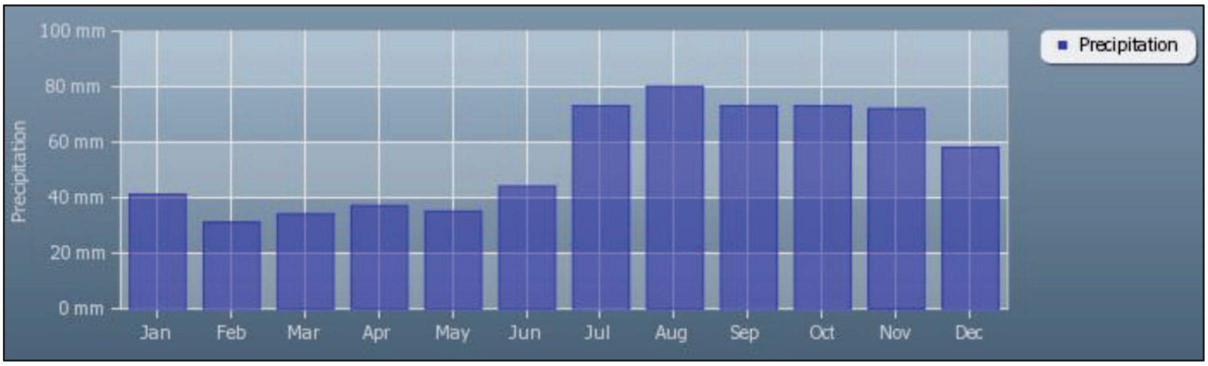


FIGURE. 5.8 Average monthly precipitation over the year (rainfall, snow)

(Source:http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Helsinki, Finland)

As shown in the Figure 5.8, the rainfall is concentrated in the latter half of a year. Records indicate that in May the rain events are relative long-lasting but the rain rate is low, which makes the 37mm rainfall in this month. In June, with 44mm rainfall, convection starts in the earnest and the rain is heaviest in the afternoon. In July the rain events last for a short time, but can be very intensive. In August, the month with the most precipitation of 80mm, the diurnal cycle is strongest and the rain rate is high. In September the fraction of wet spells is greatest, and the rain events are long lasting and weak intensity.

5.1.3.4 Wind Characteristics

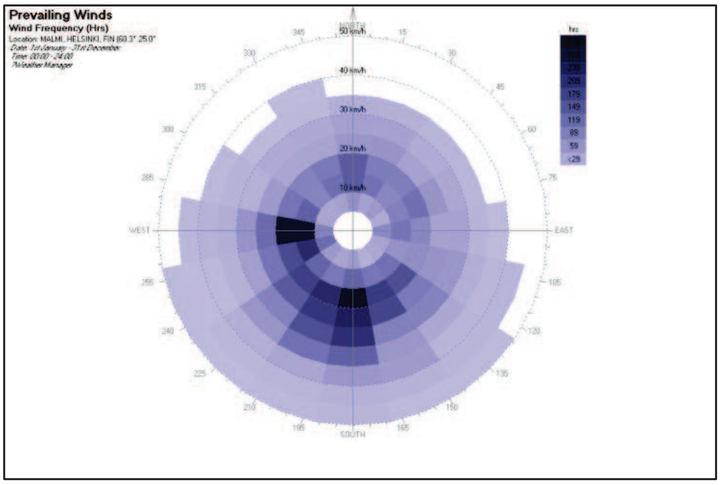


Figure 5.9 Prevailing Wind in Malmi, Helsinki

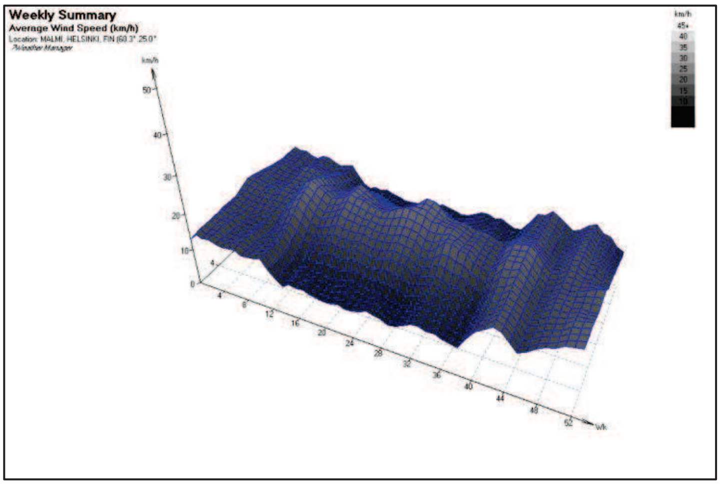


Figure 5.10 Wind Speed in Malmi, Helsinki

According to Figure 5.9 and Figure 5.10, we can understand that the most frequent winds to Malmi is from the South, and the average of wind speed is at the level of around 18KM/h with slightly variation during a whole year.

5.1.3.5 Solar Radiation

In figure5.11it is shown that the direct solar radiation in Malmi, Helsinki region receives on a weekly basis. Particularly during the months April through August, more than 400 W/m2 of solar radiation is incident from the hours of 8 AM through 3 PM. This particular behavior gives us the opportunity to make use of the radiation towards day lighting.

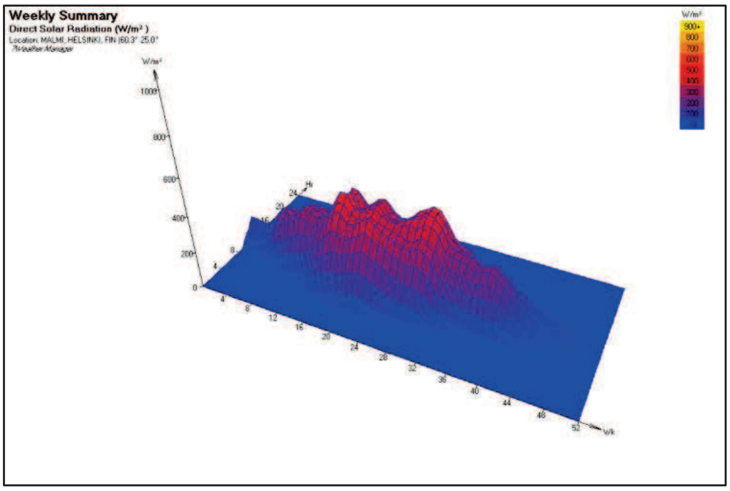


Figure 5.11 Direct Solar Radiation in Malmi, Helsinki

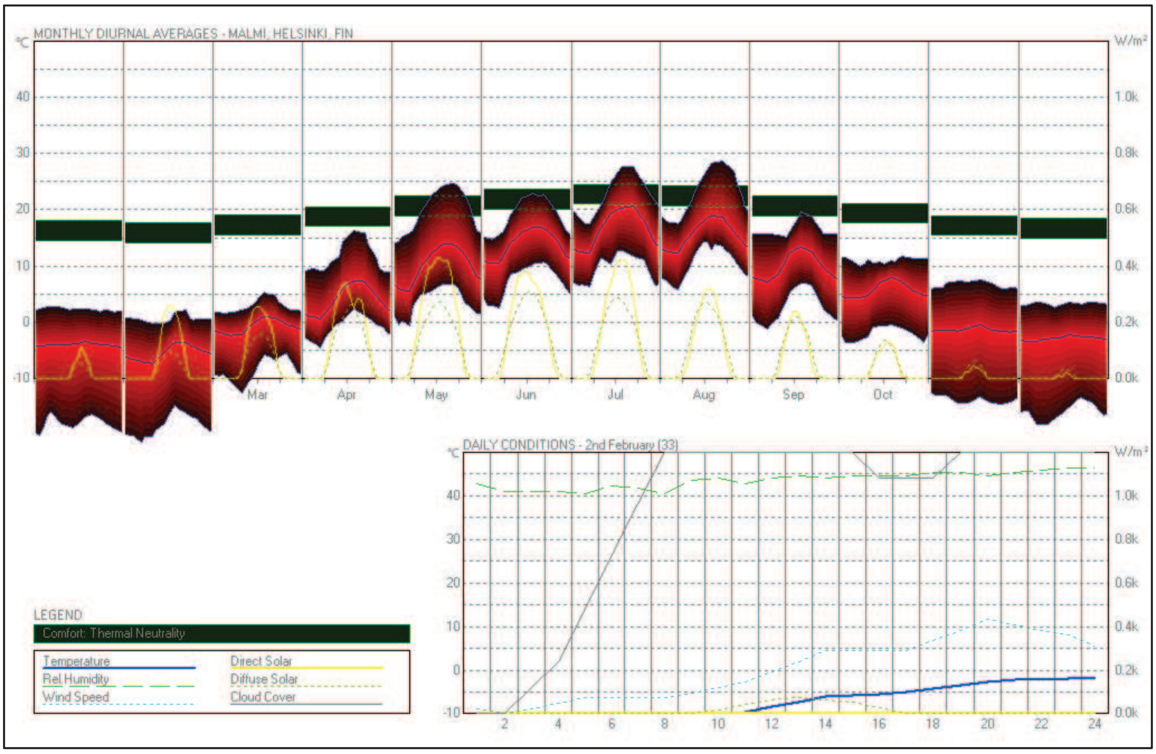


Figure 5.12 Daily conditions of climate on 2nd of August in Malmi, Helsinki

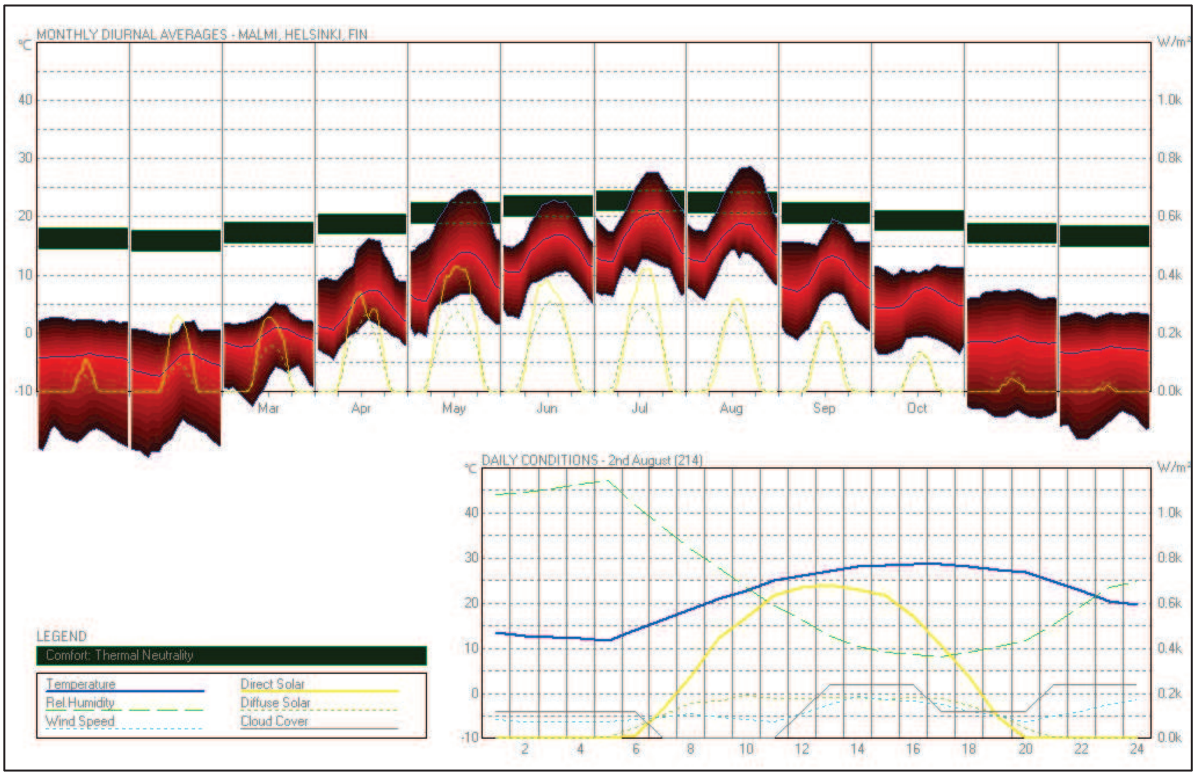


Figure 5.13 Daily conditions of climate on 2nd of February in Malmi, Helsinki

The weather data is summarized based on the summer and winter peaks that occur on the 2nd of August and 2nd of February, respectively. Figures 5.12 and 5.13 basically show the maximum, minimum and average monthly temperatures in Malmi, Helsinki. In addition to that the dotted green line shows the relative humidity while the solid green area shows the comfort zones for the particular months. The graphs on the bottom right hand corner show the daily details for the summer peak, 2nd of August and for the winter peak, 2nd of February. The figures also tell that from September through May heating is required, while, the cooling measures are not necessary due to the low temperature in summer time.

5.1.3.6 Psychrometric charts for summer time

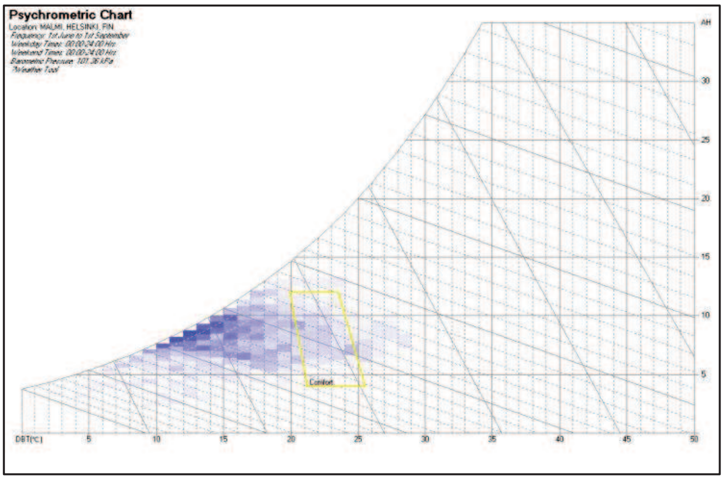


Figure 5.14 Psychometric charts in summer time

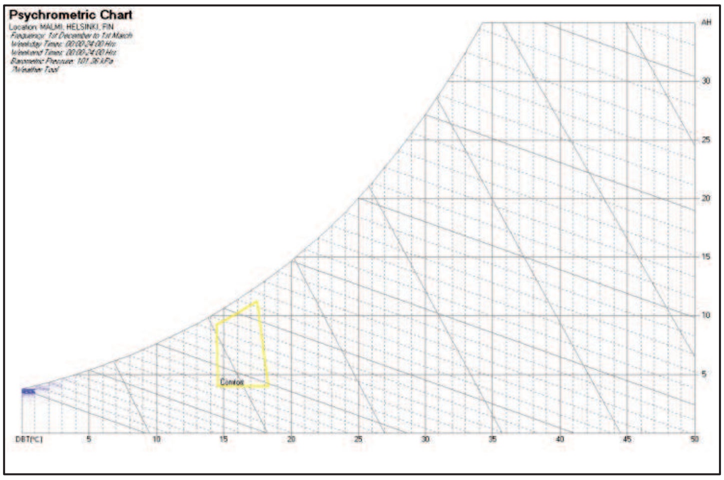


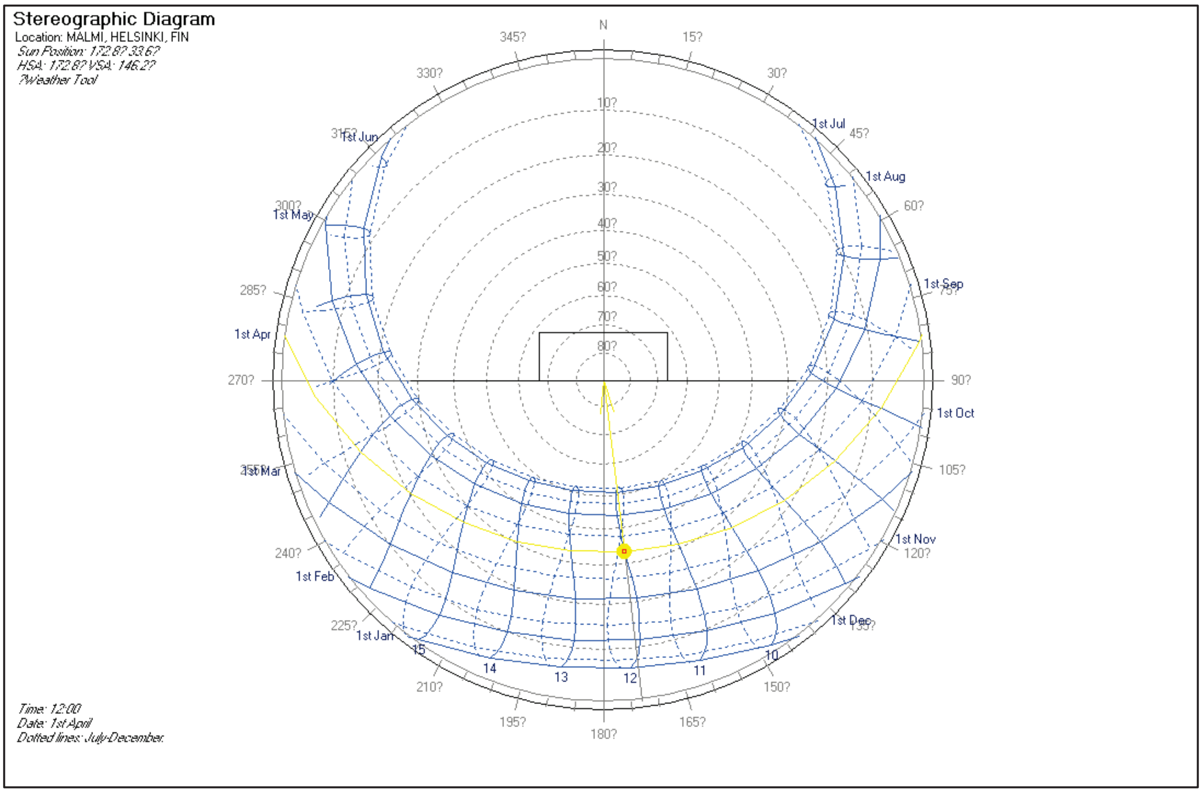
Figure 5.15 Psychometric charts in winter time

From the summer comfort zone it is readily understandable the cumulative frequency of the temperature remains outside the comfort band while relative humidity remains inside the comfort band for the most part during summer. This also leads us to believe that during summer months we should mainly consider cooling

Our site is characterized by little or no humidification during the days. And if required, some dehumidification of incoming air during the mornings could be a welcome addition. The morning air tends to be cooler and can be further cooled for daytime use while simultaneously dehumidifying it could prove beneficial and energy conscious.

Psychometric charts that show us a comfort band that we shall assay to achieve through our designs. The figures 5.14 and 5.15 show us where the comfort zone lies for medium/low activity zones in Malmi, Helsinki for summer and winter respectively. From the summer comfort zone it is clear that the cumulative frequency of the temperature remains between 15° C and 20 ° C and the relative humidity also remains outside the comfort band with 50 to 60 % for the most days of the summer. This indicates summer cooling in our site is not required, but the dehumidification measures during the days are necessary. For the winter comfort zone the cumulative frequency for temperature fall down below the comfort band and the relative humidity on the other hand stays above the comfort level at around 80 to 90 %. Therefore in winter we are required to heat the incoming air while also at the same time dehumidify it to the required level.

5.1.3.7 Stereographic Diagram



Tabulated Daily Solar Data

Latitude: 60.3°
Longitude: 25.0°
Timezone: 30.0° [+2.0hrs]
Orientation: 0.0°

Date: 1st April
Julian Date: 91
Sunrise: 05:55
Sunset: 18:52

Local Correction: -23.9 mins
Equation of Time: -3.9 mins
Declination: 4.1°

Local	(Solar)	Azimuth	Altitude	HSA	VSA
06:00	(05:36)	82.8°	0.6°	82.8	4.8
06:30	(06:06)	89.3°	4.3°	89.3	80.8
07:00	(06:36)	95.8°	8.0°	95.8	125.8
07:30	(07:06)	102.5°	11.7°	102.5	136.2
08:00	(07:36)	109.2°	15.3°	109.2	140.4
08:30	(08:06)	116.2°	18.7°	116.2	142.5
09:00	(08:36)	123.4°	21.9°	123.4	143.8
09:30	(09:06)	130.9°	24.9°	130.9	144.7
10:00	(09:36)	138.7°	27.5°	138.7	145.3
10:30	(10:06)	146.8°	29.8°	146.8	145.7
11:00	(10:36)	155.2°	31.6°	155.2	145.9
11:30	(11:06)	163.9°	32.8°	163.9	146.1
12:00	(11:36)	172.8°	33.6°	172.8	146.2
12:30	(12:06)	-178.2°	33.8°	-178.2	146.2
13:00	(12:36)	-169.2°	33.4°	-169.2	146.2
13:30	(13:06)	-160.4°	32.4°	-160.4	146.0
14:00	(13:36)	-151.8°	30.9°	-151.8	145.8
14:30	(14:06)	-143.4°	28.9°	-143.4	145.5
15:00	(14:36)	-135.4°	26.5°	-135.4	145.1
15:30	(15:06)	-127.8°	23.7°	-127.8	144.4
16:00	(15:36)	-120.4°	20.6°	-120.4	143.4
16:30	(16:06)	-113.3°	17.3°	-113.3	141.8
17:00	(16:36)	-106.4°	13.8°	-106.4	139.0
17:30	(17:06)	-99.7°	10.2°	-99.7	133.3
18:00	(17:36)	-93.2°	6.5°	-93.2	115.8
18:30	(18:06)	-86.6°	2.8°	-86.6	39.8

Figure 5.16 Stereographic diagram

5.2Strategy

5.2.1 Policies and Guidelines

- The National Building Code of Finland, C3 Thermal insulation in a building Regulations 2010
- The National Building Code of Finland, C4 Thermal insulation
- The National Building Code of Finland, D2 Indoor climate and ventilation of buildings Regulations and guidelines 2010
- The National Building Code of Finland, D3 Energy management in buildings Regulations and guidelines 2010
- The National Building Code of Finland, D5 Calculation of power and energy needs for heating of buildings Guidelines 2007
- Standard SFS EN 15316-4-6:2007, Heating systems in buildings - Method for calculation of energy requirements and the yield of the plant - Part 4-6: Heat generation systems, photovoltaic systems
- SBI, European Strategies to move towards very low energy buildings , 2008

5.2.2Target design

Main design goals:

- To reduce energy consumption to range from 50 to 80 KW
- Installing Active systems to support at least 30% of total energy consumption of the building
- Reduction of water consumption by Optimization of grey water system
- Optimization of day light factor
- Optimization of indoor Air quality
- Optimization of shadow design for both indoors and outdoors

5.3Thermal Design of Building Envelope

5.3.1Technical Data

According to National Code of Finland, D5, Table L 1.1, in the calculation we have set the outdoor temperature is -26°C, and the inside temperature set is 20°C. On the other hand, due to stable Relative Humidity of around 80% all the year round, as it illustrated by the Table 5.03, the outside Relative Humidity in calculation has been assigned as 80%.

5.3.2 Technological choices

As it is restricted by National Code of Finland, C3, Chapter 3.2.1, for the heated or especially warm space, the thermal transmittances U for building components must not exceed the following values:

- wall 0.25 W/m^2K
- roof or base floor 0.16 W/m^2K
- building component against the ground 0.25 W/m^2K
- window 1.0 W/m^2K
- skylight 1.5 W/m^2K

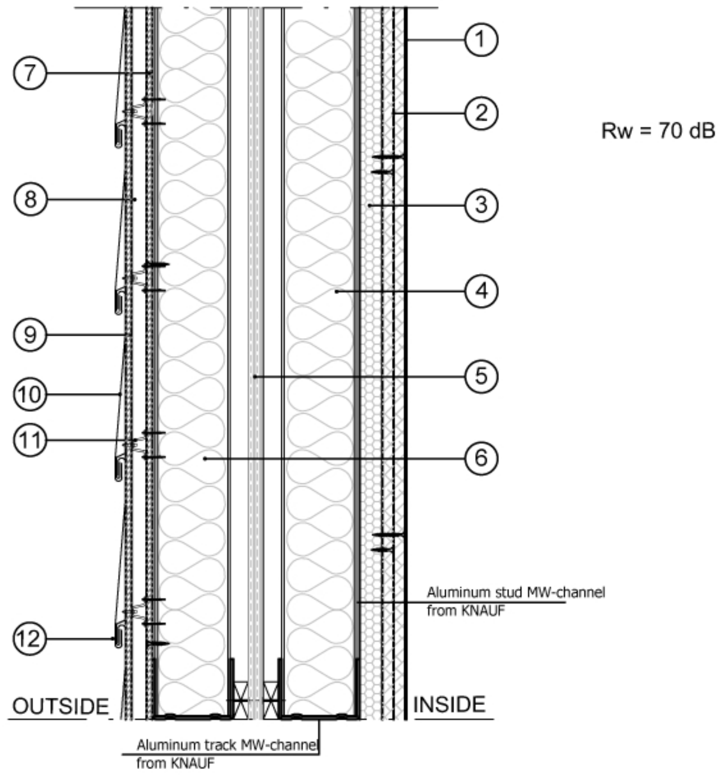
Generally, we have taken these values as references to design the envelopes. Due to the balance of U-value among each component, we have chosen double glazing and triple glazing with similar U-value to walls and roofs for design of windows.

5.3.2.1 Wall types

5.3.2.1 Wall types (T-05)

T_05_01: M.P.U. wall with Paint finish

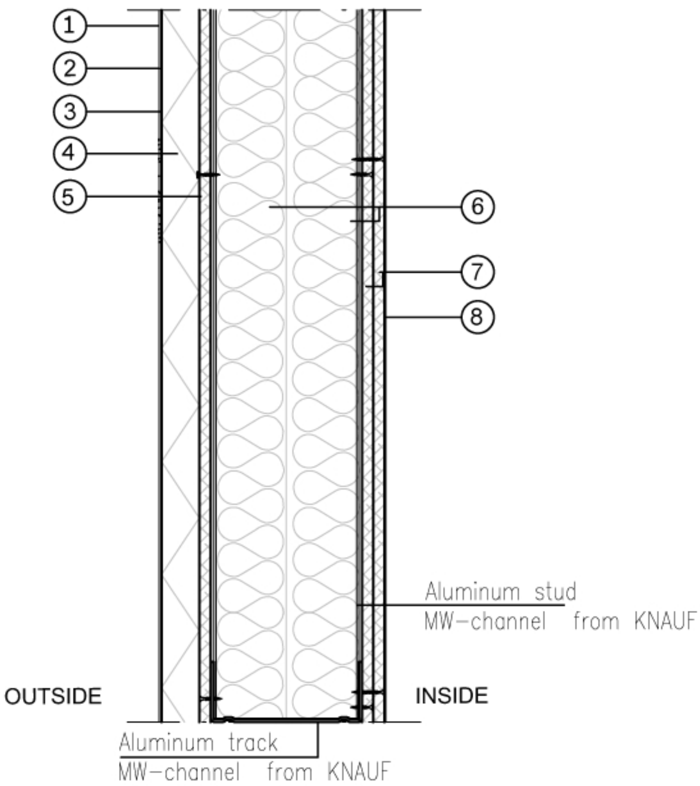
SCALE 1/10



1	Acrylic bonded water based paint	
2	Double gypsum board	30mm
3	Composite polyurethane foam board	30mm
4	Rockwool insulation	100mm
5	ACTIS insulation sheet with metallic internal reflective films	22mm
6	Rockwool insulation	100mm
7	Fibrecement board	15 mm
8	Air Gap	20 mm
9	Fibrecement board	15 mm
10	Flat Lock Tiles made of Cort-en A	8 mm
11	wooden block	
12	Flat Lock Clips	

T_05_02: Typical wall with Paint finish

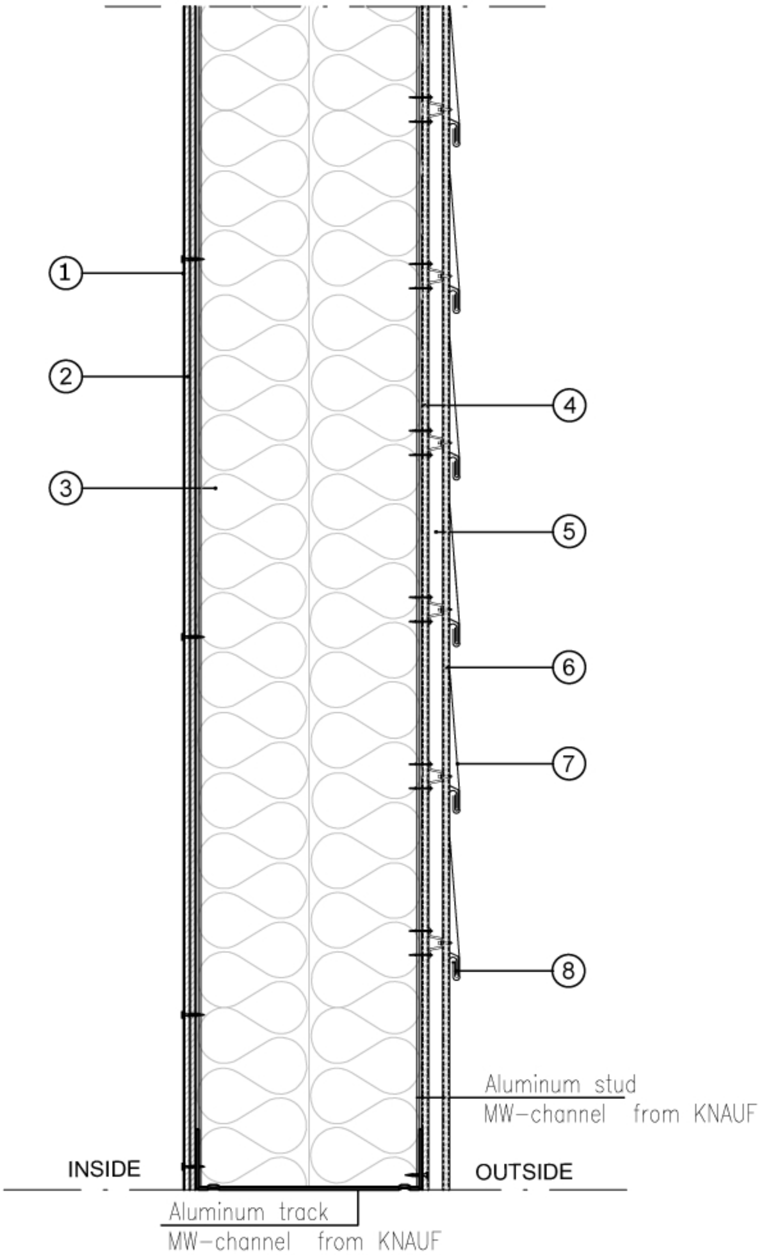
SCALE 1/10



1	Acrylic bonded water based exterior façade paint	
2	Exterior façade plaster	3.5 mm
3	Fiberglass mesh	2 mm
4	EPS thermal insulation	50 mm
5	Fibrecement board	15 mm
6	Double layer rock wool insulation	100+100 mm
7	Double layer gypsum board wall	15+15 mm
8	Acrylic bonded water based paint	

T_05_03: Typical wall with Cor-ten cladding

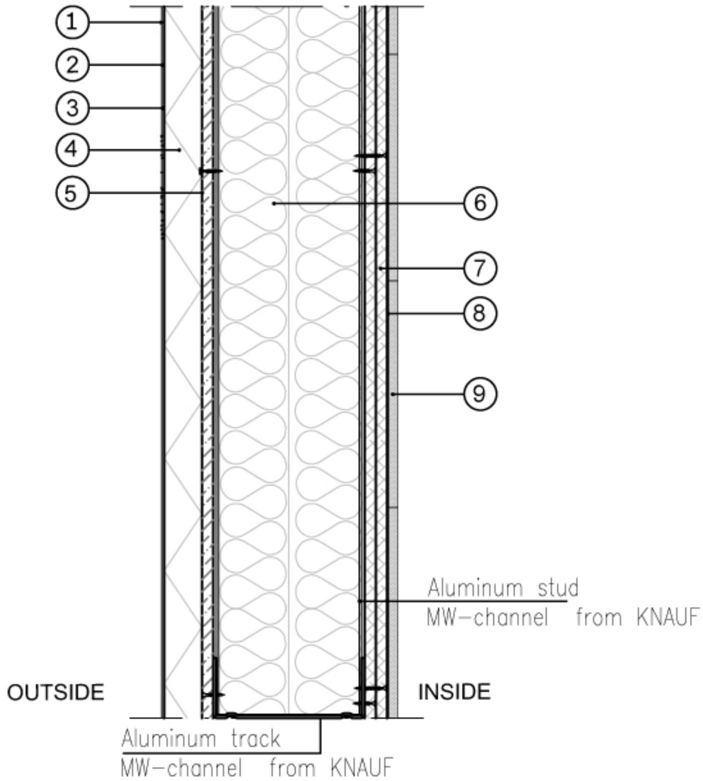
SCALE 1/10



1	Acrylic bonded water based exterior façade paint	
2	Double Fibrecement board	15 mm
3	Rockwall insulation	
4	Fibrecement board	7.5 mm
5	Air Gap	20 mm
6	Fibrecement board	7.5 mm
7	Flat Lock Tiles made of Cort-en A	8 mm
8	Flat Lock Clips	

T_05_04: Typical wall with ceramic finish

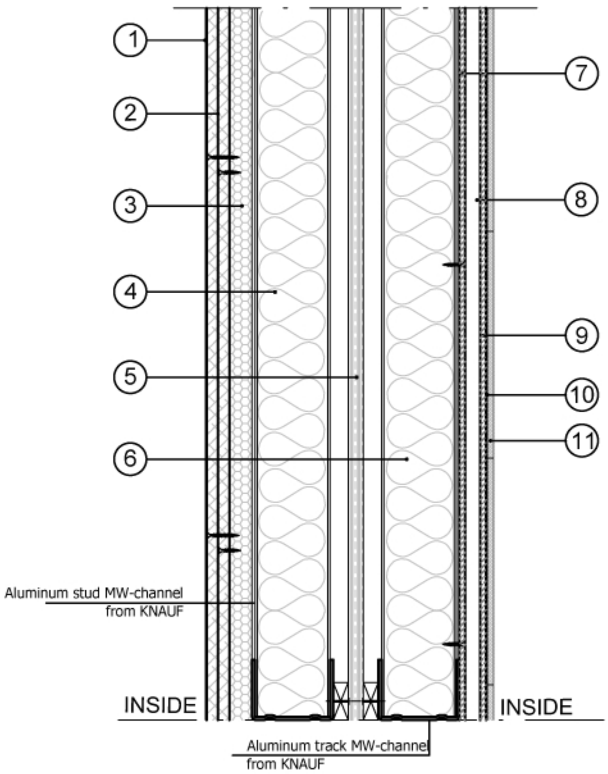
SCALE 1/10



1	Acrylic bonded water based exterior façade paint	
2	Exterior façade plaster	3.5 mm
3	Fiberglass mesh	2 mm
4	EPS thermal insulation	50 mm
5	Fibrecement board	15 mm
6	Double layer rock wool insulation	100+100 mm
7	Double layer Aqua panel board	15+15 mm
8	Adhesive grout	
9	Ceramic tiles 300*200*12mm	

T_05_05: M.P.U / W.C. wall

SCALE 1/10

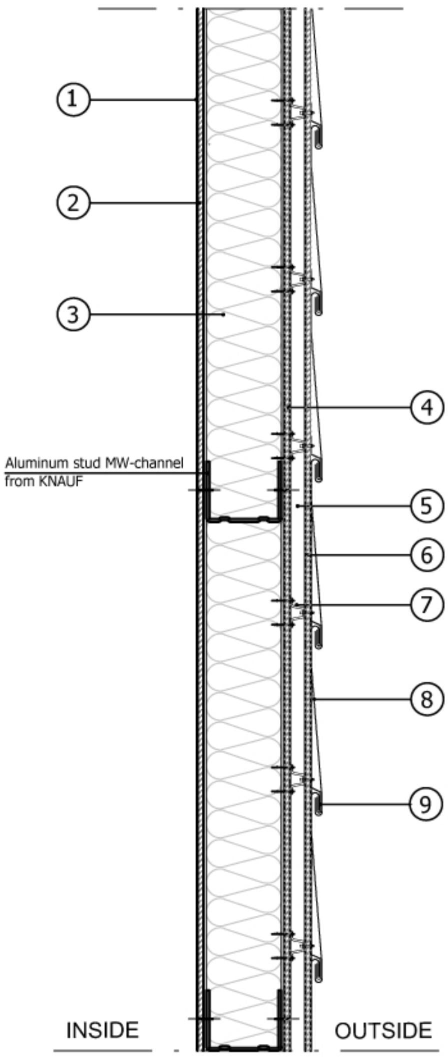


Rw = 70 dB

1	Acrylic bonded water based paint	
2	Double gypsum board	30mm
3	Composite polyurethane foam board	30mm
4	Rockwool insulation	100mm
5	ACTIS insulation sheet with metallic internal reflective films	22mm
6	Rockwool insulation	100mm
7	Fibrecement board	15 mm
8	Air Gap	20 mm
9	Fibrecement board	15 mm
10	Adhesive Grout	
11	Ceramic tiles 300*500*12mm	

T_05_06: Skin Wall

SCALE 1/10



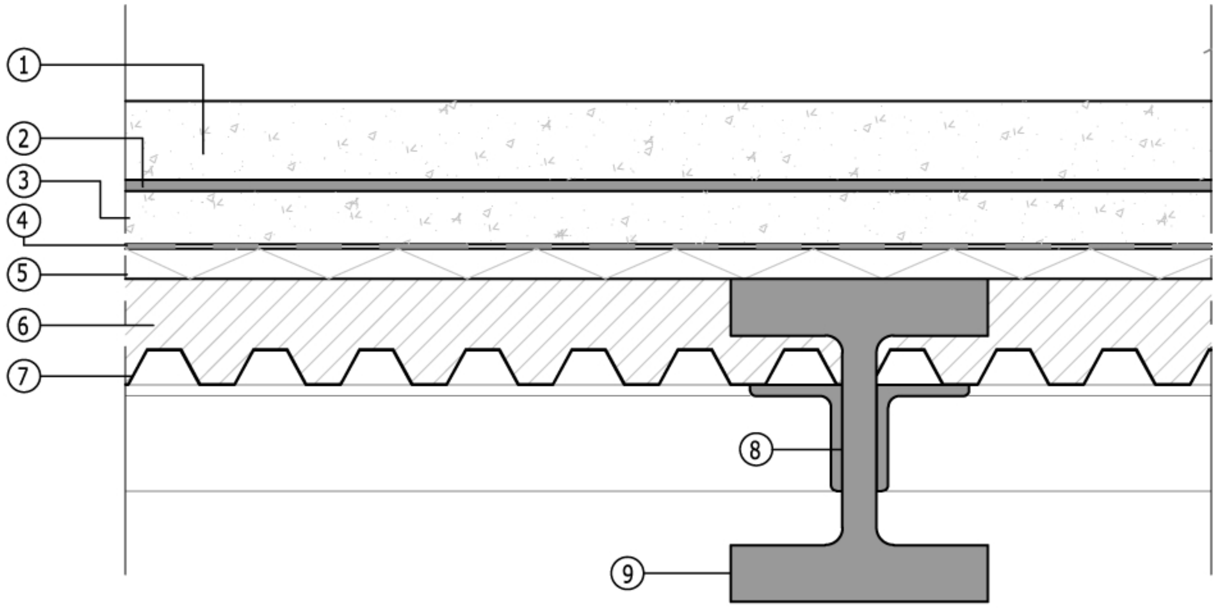
1	Acrylic bonded water based exterior façade paint	
2	Fibrecement board	7 mm
3	Rockwool insulation	
4	Fibrecement board	7.5 mm
5	Air gap	20mm
6	Fibrecement board	7.5 mm
7	wooden block	
8	Flat Lock Tiles made of Cort-en A	8 mm
9	Flat Lock Clips	

5.3.2.2 Floor types

5.3.2.2 Floor types (T-06)

T-06-01: Platform with polished concrete finish

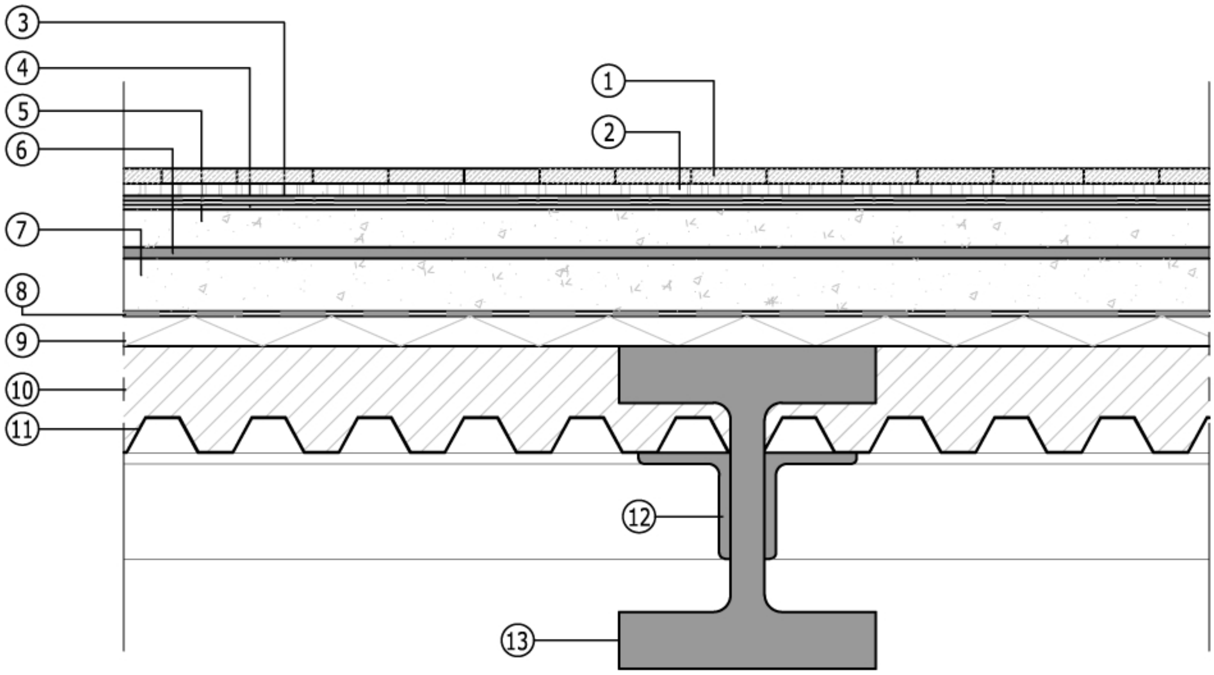
SCALE 1/10



1	Polished concrete flooring	100 mm
2	Cellulose - Acoustical layer	15 mm
3	Screed	70 mm
4	Polymer bitumen waterproofing membrane	6mm
5	Extruded Polystyrene board (xps)	40 mm
6	Reinforced Concrete	130mm
7	Corrugated sheets	H = 50 mm
8	L-shape steel angle	
9	Secondary structural steel beam W310*500	
10	Main structural steel beam W920*585	

T-06-02: Platform with marble finish

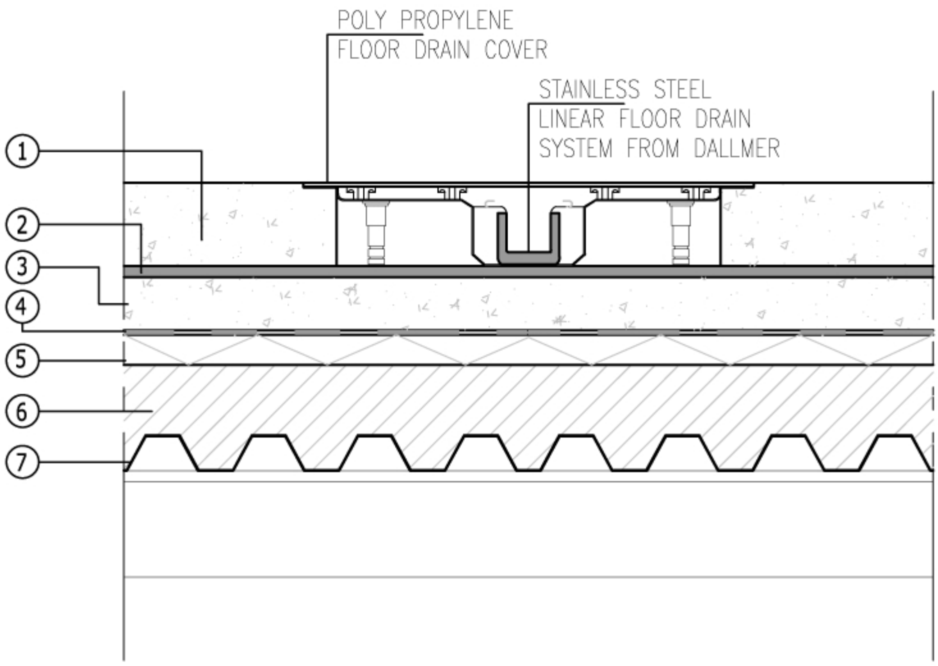
SCALE 1/10



1	Marble	20 mm
2	Flexible Tile Adhesive (Grout)	8.5mm
3	Bituminous sheets	6 mm
4	Electric Heating cable	3 mm
5	Screed	50 mm
6	Cellulose - Acoustical layer	15 mm
7	Screed	70 mm
8	Extruded Polystyrene board (xps)	40 mm
9	Reinforced Concrete	130mm
10	Corrugated sheets	H = 50 mm
11	L-shape steel angle	
12	structural steel beam	

T-06-03: Platform gutter detail

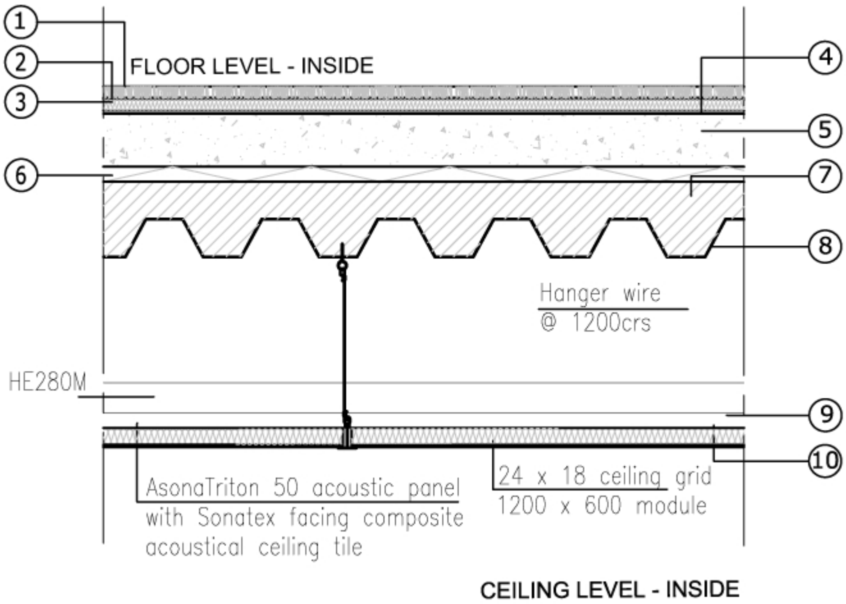
SCALE 1/10



1	Polished concrete flooring	70 mm
2	Cellulose - Acoustical layer	15 mm
3	Screed	70 mm
4	Polymer bitumen waterproofing membrane	6mm
5	Extruded Polystyrene board (xps)	40 mm
6	Reinforced Concrete	130mm
7	Corrugated sheets	H = 50 mm
8	L-shape steel angle	

T-06-04: Intermediate slab with carpet finish

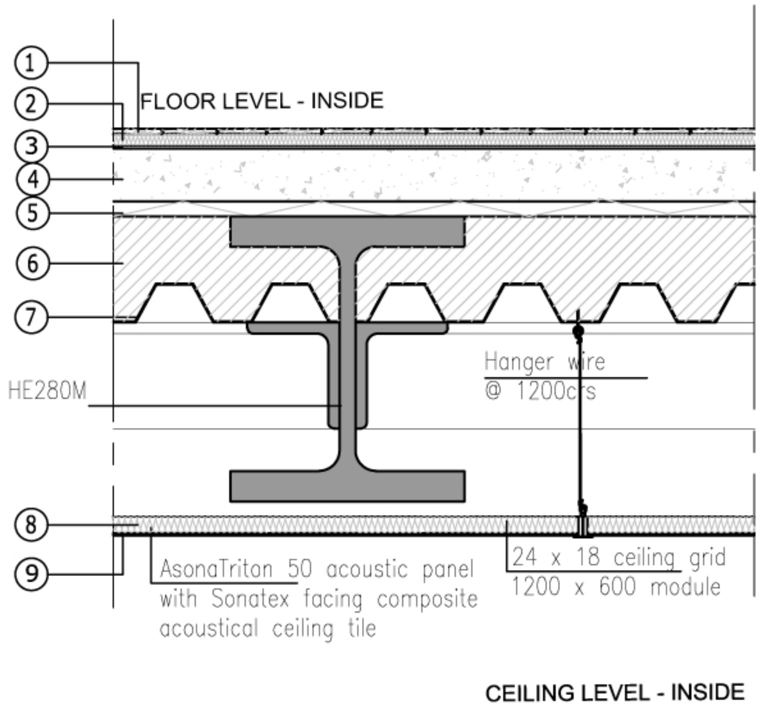
SCALE 1/10



1	Carpet	15 mm
2	Adhesive	2 mm
3	Cellulose - Acoustical layer	15 mm
4	Polyester vapor Barrier for carbon film heating systems	4mm
5	Leveling concrete (light weight)	70 mm
6	Extruded Polystyrene board (xps)	20 mm
7	Reinforced Concrete	120mm
8	Corrugated sheets	H = 50 mm
9	Mineral wool Insulation 22 mm	Dual layer composite acoustical facer laminated to high density resin bonded bio soluble glass fibre absorber 25 mm
10	Soft fibre high sound absorbing tiles	

T-06-05: Intermediate slab with HPL finish

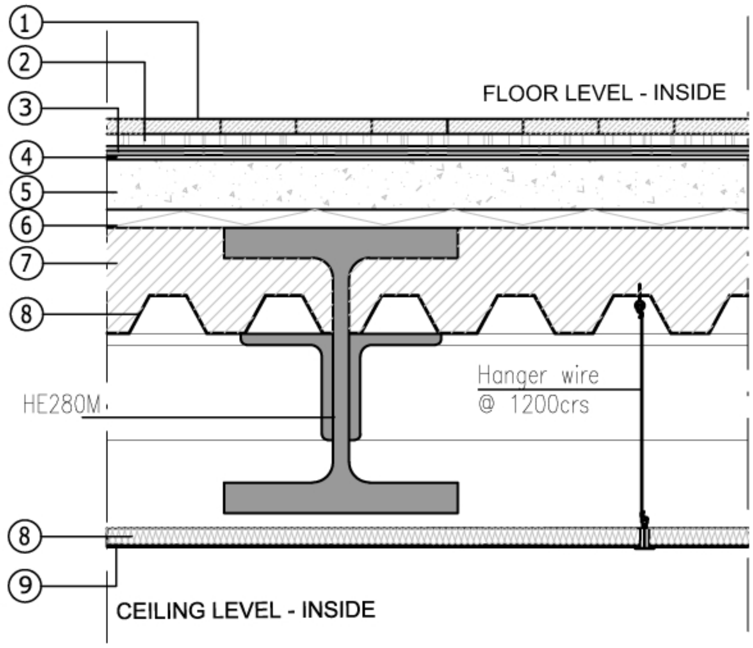
SCALE 1/10



1	HPL Heavy durty accoustical panels	15 mm
2	Cellulose - Acoustical layer	15 mm
3	Polyester vapor Barrier for carbon film heating systems	4mm
4	Leveling concrete (light weight)	70 mm
5	Extruded Polystyrene board (xps)	20 mm
6	Reinforced Concrete	120mm
7	Corrugated shee	H = 50 mm
8	Mineral wool Insulation 22 mm — Dual layer composite acoustical facer laminated to high density resin bonded bio soluble glass fibre absorber	25 mm
9	Soft fibre high sound absorbing tiles	

T-06-06: Intermediate slab with marble finish

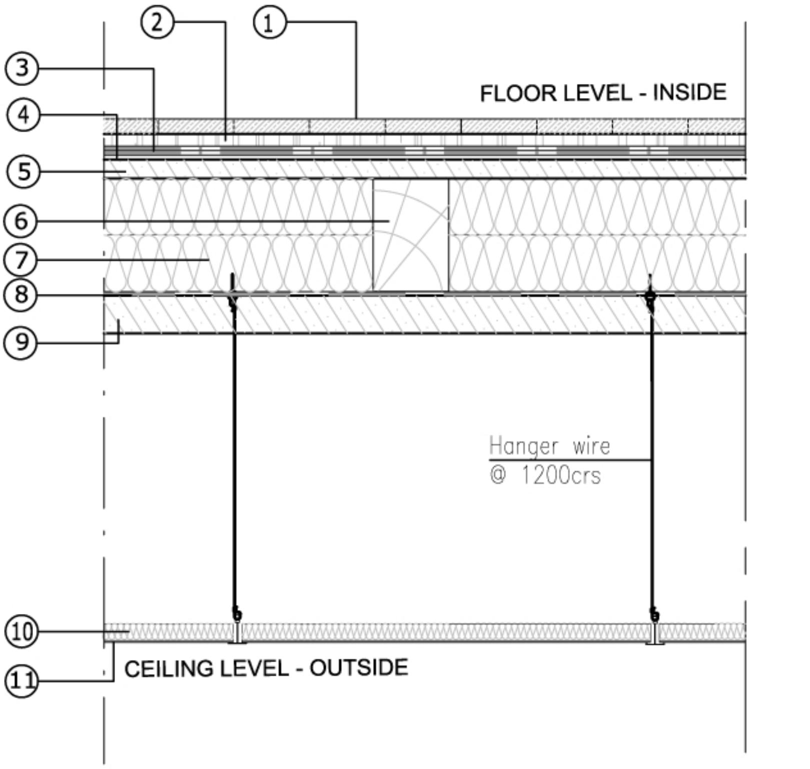
SCALE 1/10



1	Marble		20 mm
2	Flexible Tile Adhesive (Grout)		8.5mm
3	Bituminous sheets		6 mm
4	Electric Heating cable		3 mm
5	Leveling concrete (Light Weight)		50 mm
6	Extruded Polystyrene board (xps)		20 mm
7	Reinforced Concrete		120mm
8	Corrugated sheet		H = 50 mm
9	Mineral wool Insulation 22 mm	Dual layer composite acoustical facer laminated to high density resin bonded bio soluble glass fibre absorber	25 mm
10	Soft fibre high sound absorbing tiles		

T-06-07: Intermediate slab above platform

SCALE 1/10



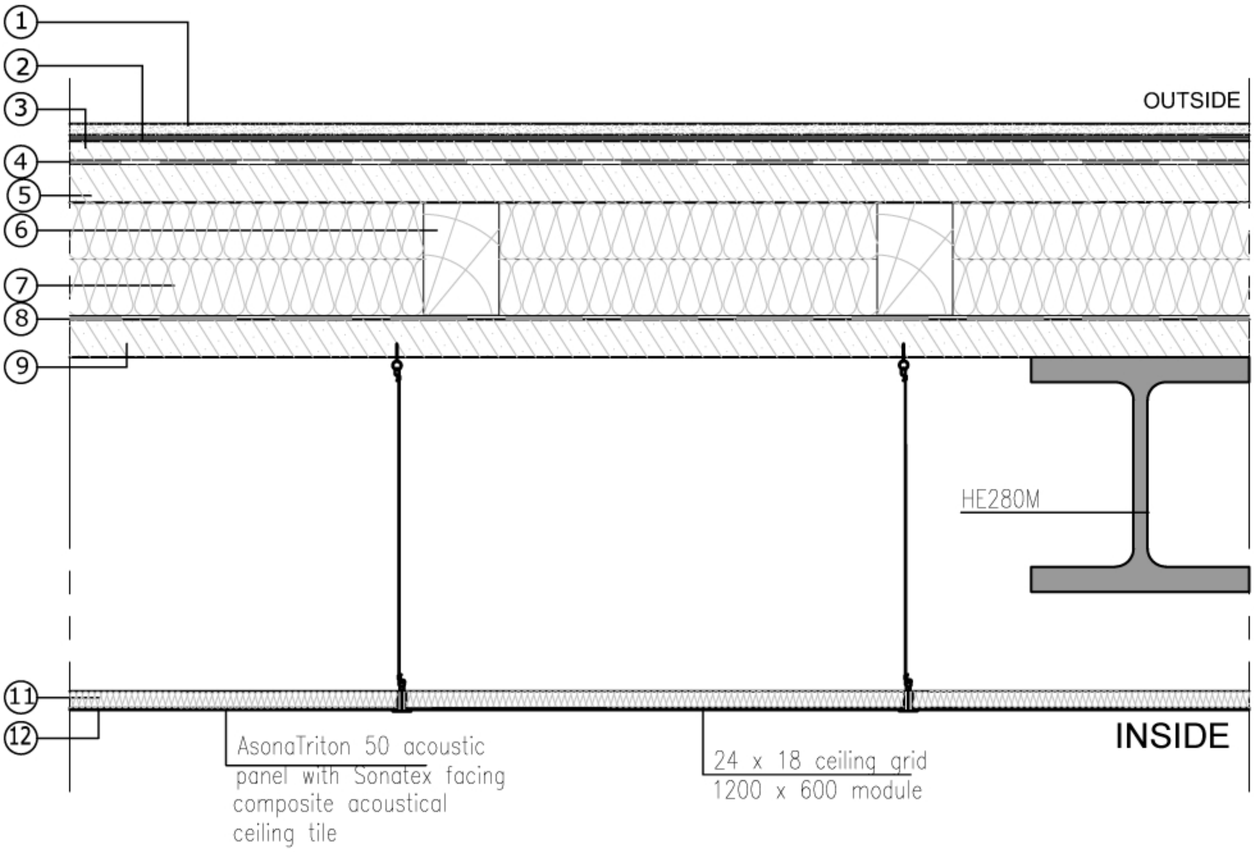
1	Marble		20 mm
2	Flexible Tile Adhesive (Grout)		8.5mm
3	Bituminous sheets		6 mm
4	Electric Heating cable		3 mm
5	Osb		25 mm
6	Wooden studs 150*100mm		
7	Double Rock wool Insulation		150 mm
8	Vapor barrier		2mm
9	Osb		50 mm
10	Mineral wool Insulation 22 mm	Dual layer composite acoustical facer laminated to high density resin bonded bio soluble glass fibre absorber	25 mm
11	Soft fibre high sound absorbing tiles		

5.3.2.3 Roof types

5.3.2.3 Roof types (T-07)

T-07-01: Typical Flat roof

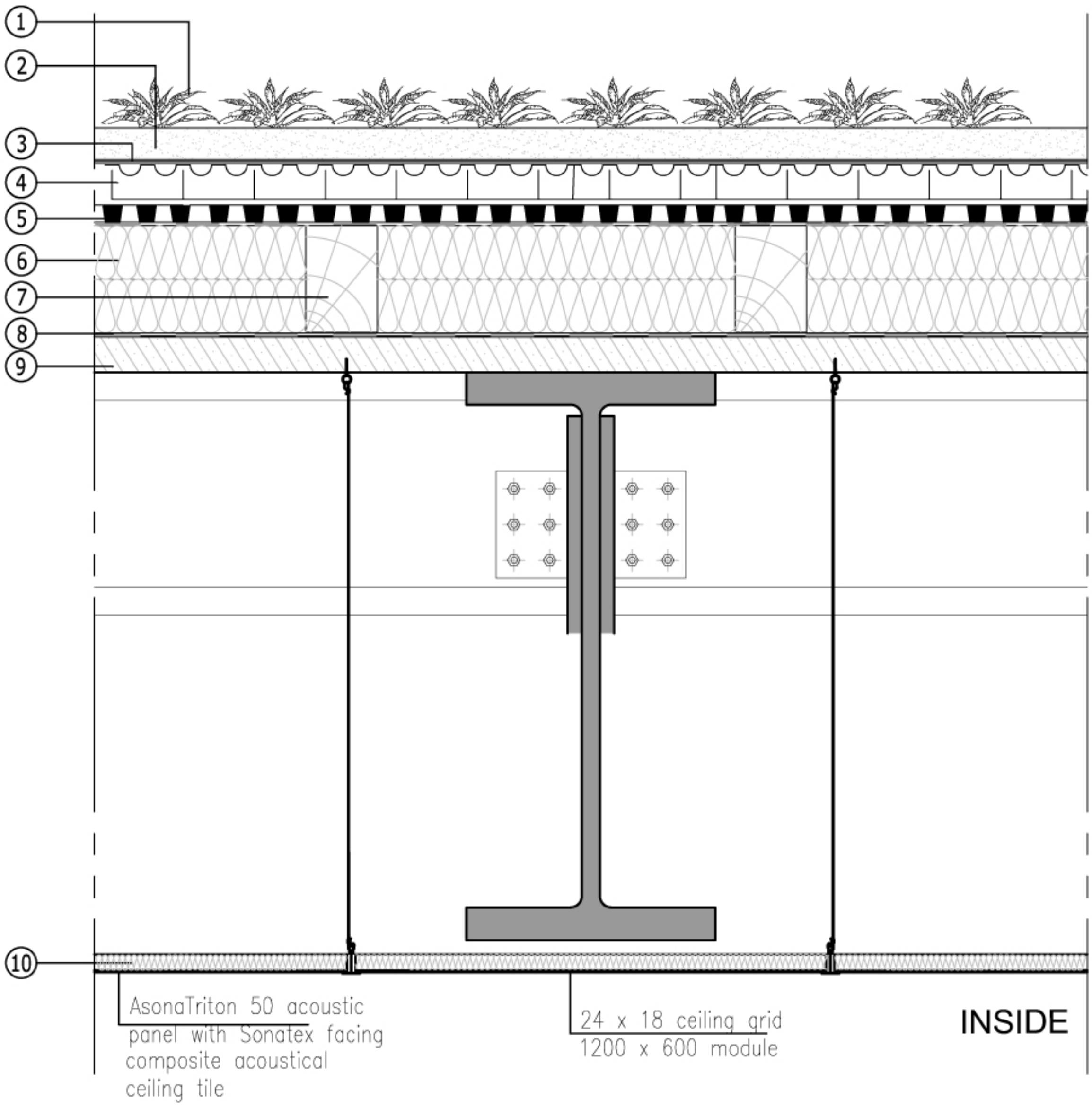
SCALE 1/10



1	Screed	15 mm
2	Bituminous sheets	4 + 4 mm
3	Osb	50 mm
4	Aluminum bubble film insulation	6 mm
5	Osb	50 mm
6	Wooden studs 150*100mm	
7	Double Rock wool Insulation	150 mm
8	Vapor barrier	2mm
9	Osb	50 mm
10	Steel I beam HE280M 288x310	
11	Rock wool Insulation 22 mm	Dual layer composite acoustical facer laminated to high density resin bonded bio soluble glass fibre absorber
12	Soft fibre high sound absorbing tiles	25 mm

T-07-02: Green roof

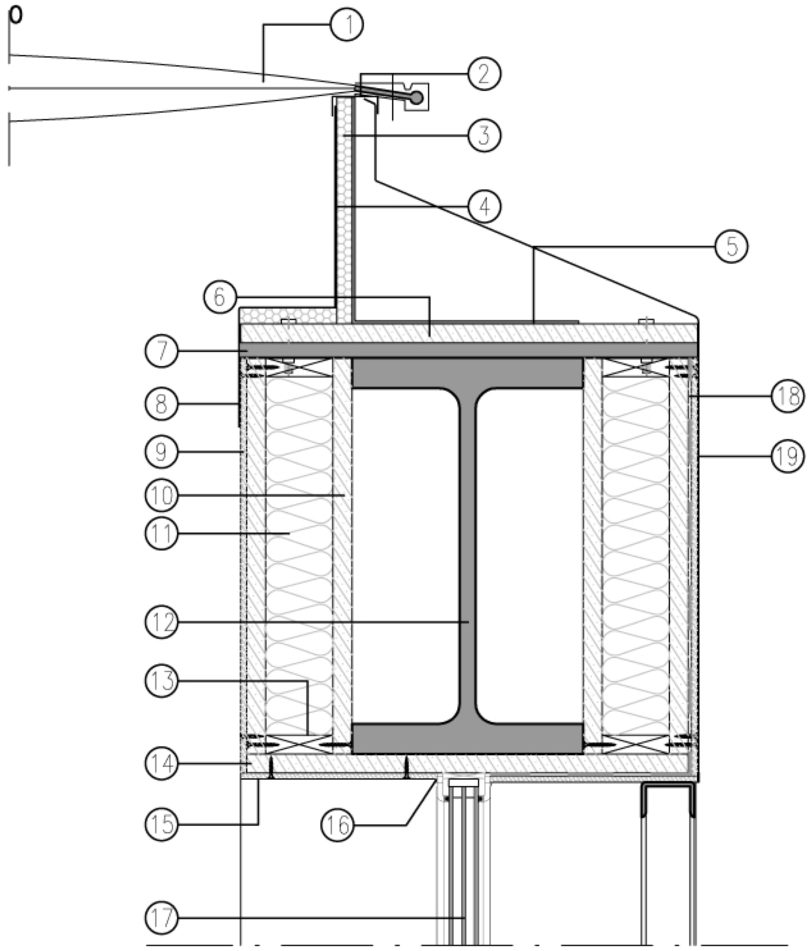
SCALE 1/10



1	Vegetation(Roof Garden)	
2	Sand/Clay layer (Bed)	40 mm
3	Stab-Filter Layer,Polypropylene fiber	1 mm
4	Water Drainage/Storage Element DAKU FSD20 (1250x100x80)	
5	Anti-Root & Rot waterproofing membrane	4mm
6	Rockwool Thermal Insulation	150 mm
7	wooden stud 150*100mm	
8	vapor barrier	2mm
9	OBS board	50mm
10	Gypsum Plaster board	15 mm

T-07-03: ETFE roof column connection

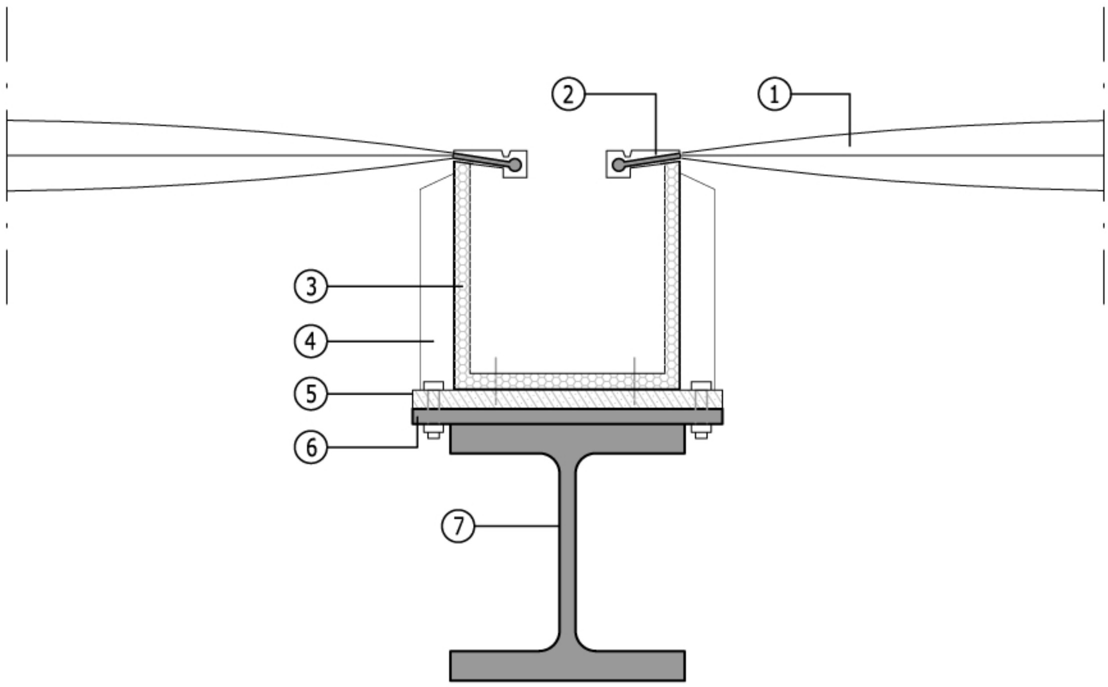
SCALE 1/10



1	ETFE cushion	
2	PVC under alloy	
3	pvc gutter lining	
4	Insulated cor-ten flashing	
5	steel bracket	
6	OBS board	25mm
7	steel plate	
8	insulated cor-ten flashing	
9	Aqua panel board	8mm
10	OBS board	25mm
11	Rockwool insulation	80mm
12	Main steel structure HE500M	
13	wooden block	
14	OBS board	25mm
15	Aqua panel board	8mm
16	sealant	
17	triple glazing panel	
18	Bituminous sheet	4mm
19	insulated cor-ten flashing	

T-07-04: ETFE roof beam connection

SCALE 1/10



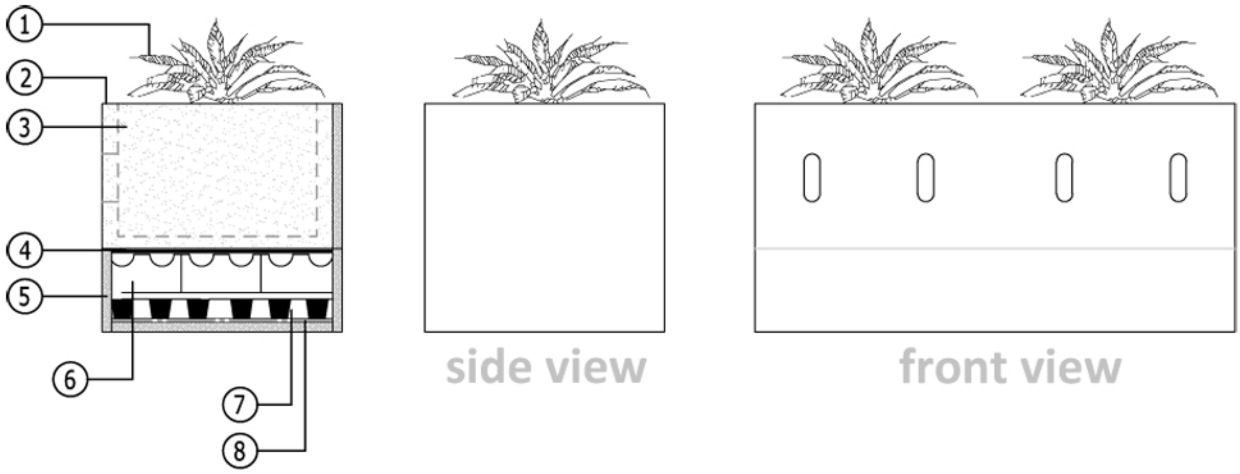
1. ETFE cushion
2. PVC under alloy
3. pvc gutter lining
4. steel bracket
5. osb board 25mm
6. steel plate
7. steel structure

5.3.2.4 General details

5.3.2.4 General details (T-09)

T_09_01: Flower box

SCALE 1/10



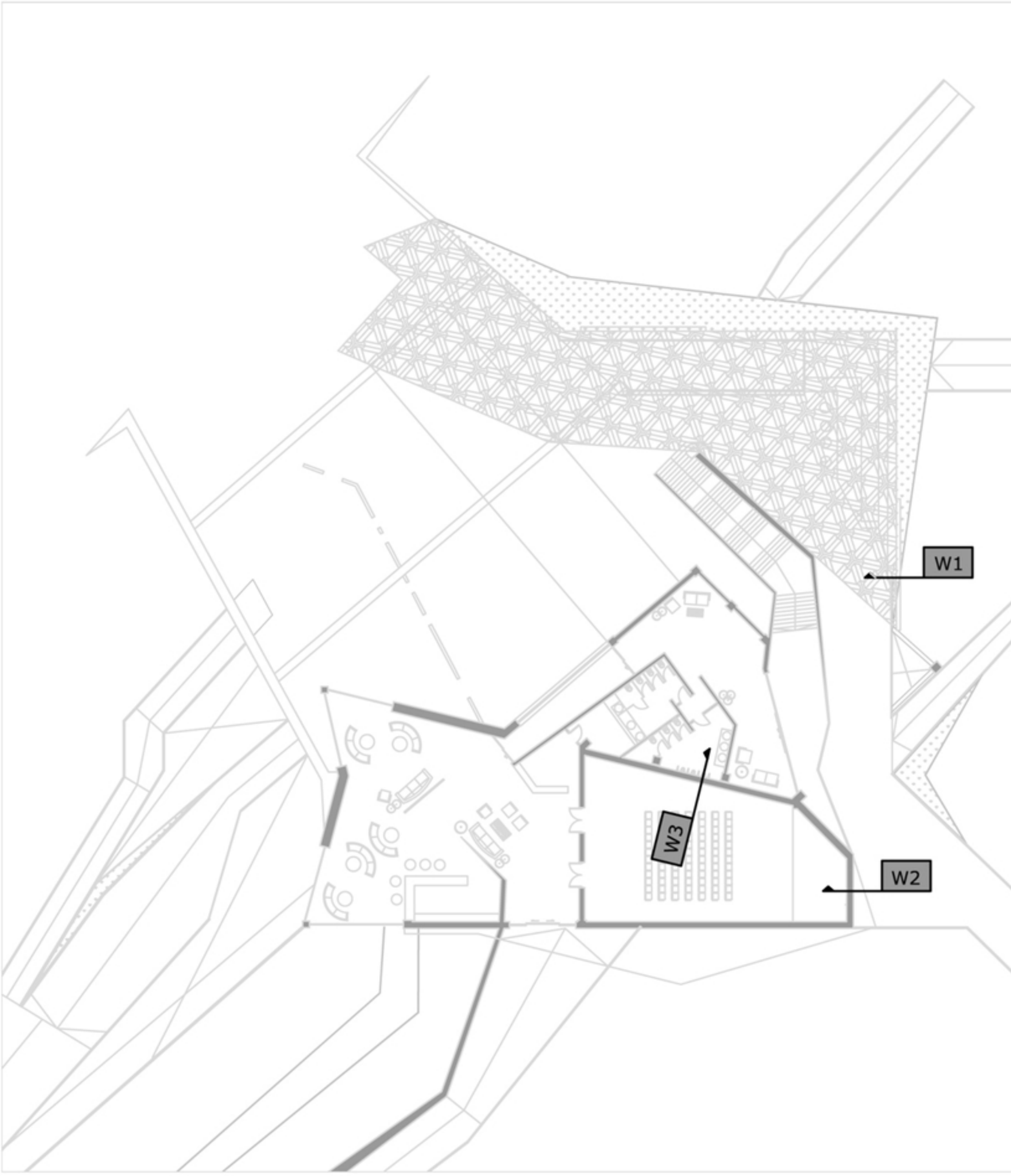
1	Vegetation(Roof Garden)	
2	extruded polystyrene module	
3	Sand/Clay layer (Bed)	40 mm
4	Stab-Filter Layer,Polypropylene fiber	1 mm
5	plaster board	
6	Water Drainage/Storage Element DAKU FSD20 (1250x100x80)	
7	Anti-Root & Rot waterproofing membrane	4mm
8	waterproofing membrane	4mm

5.3.2.5 Wall sections

5.3.2.5 Wall sections (T-10)

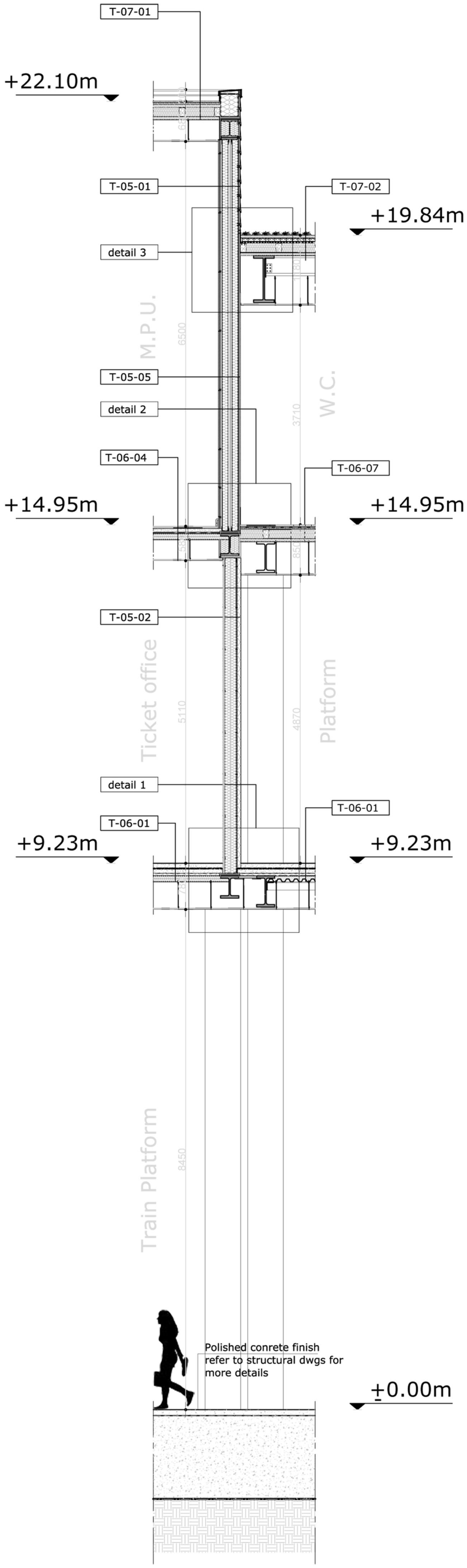
wall section key plan

SCALE 1/500

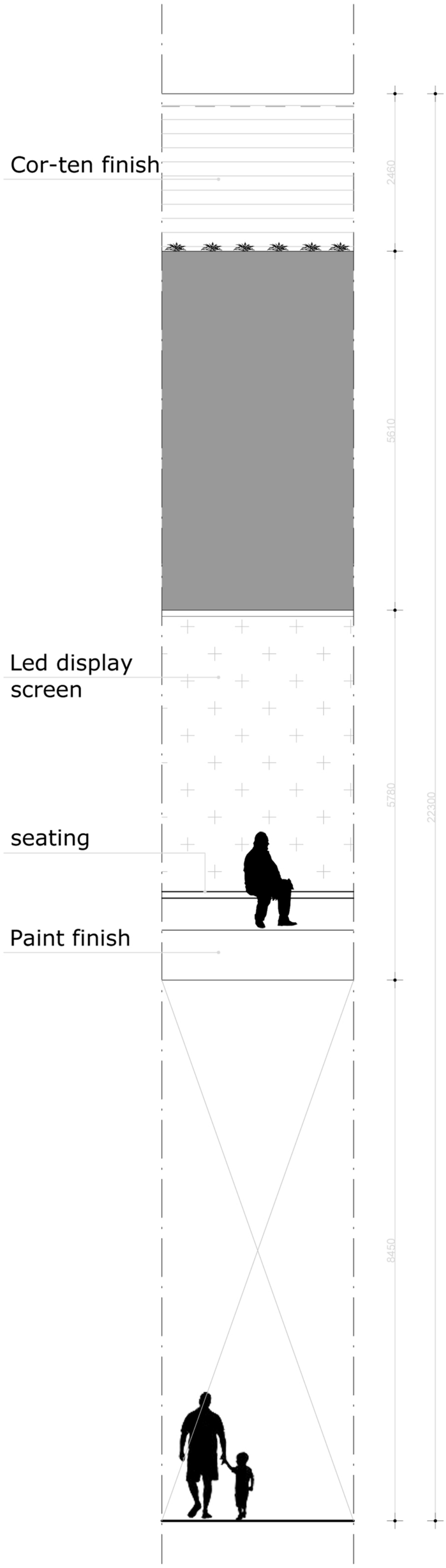


T-10-01: Wall section 1

scale 1/50



Section

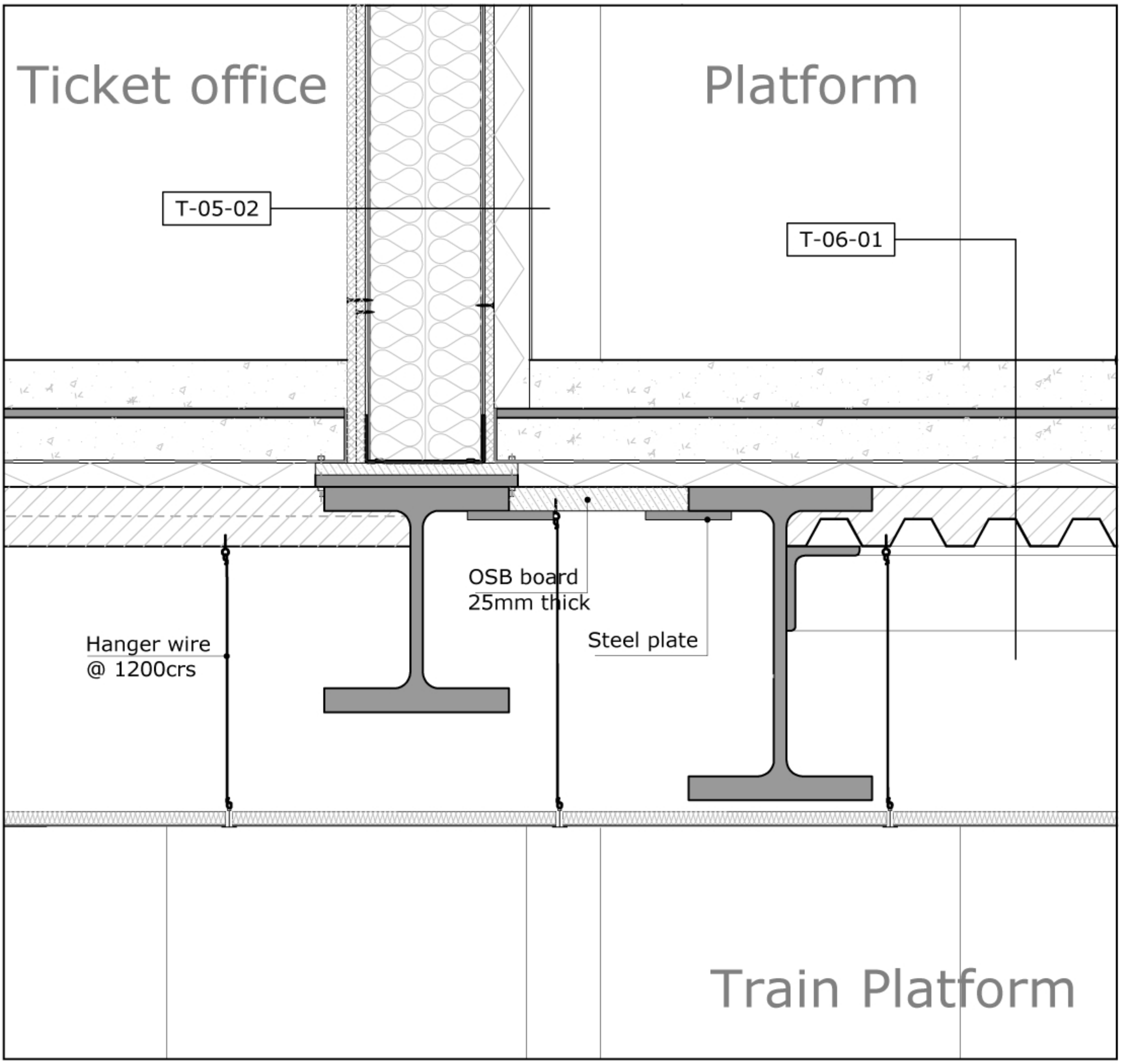


elevation

Wall section 1

T-10-01A: Detail 1

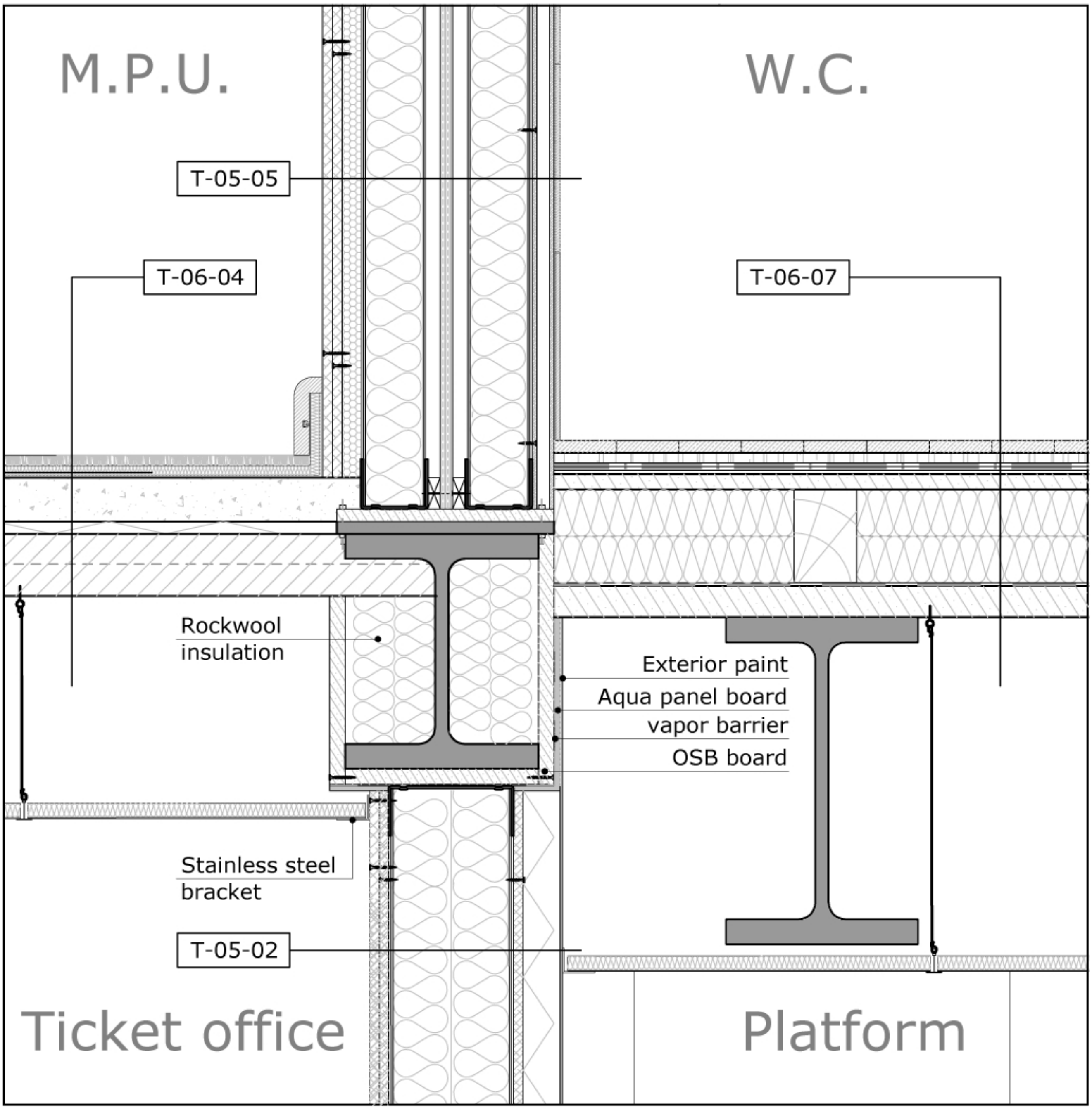
SCALE 1/10



Wall section 1

T-10-01B: Detail 2

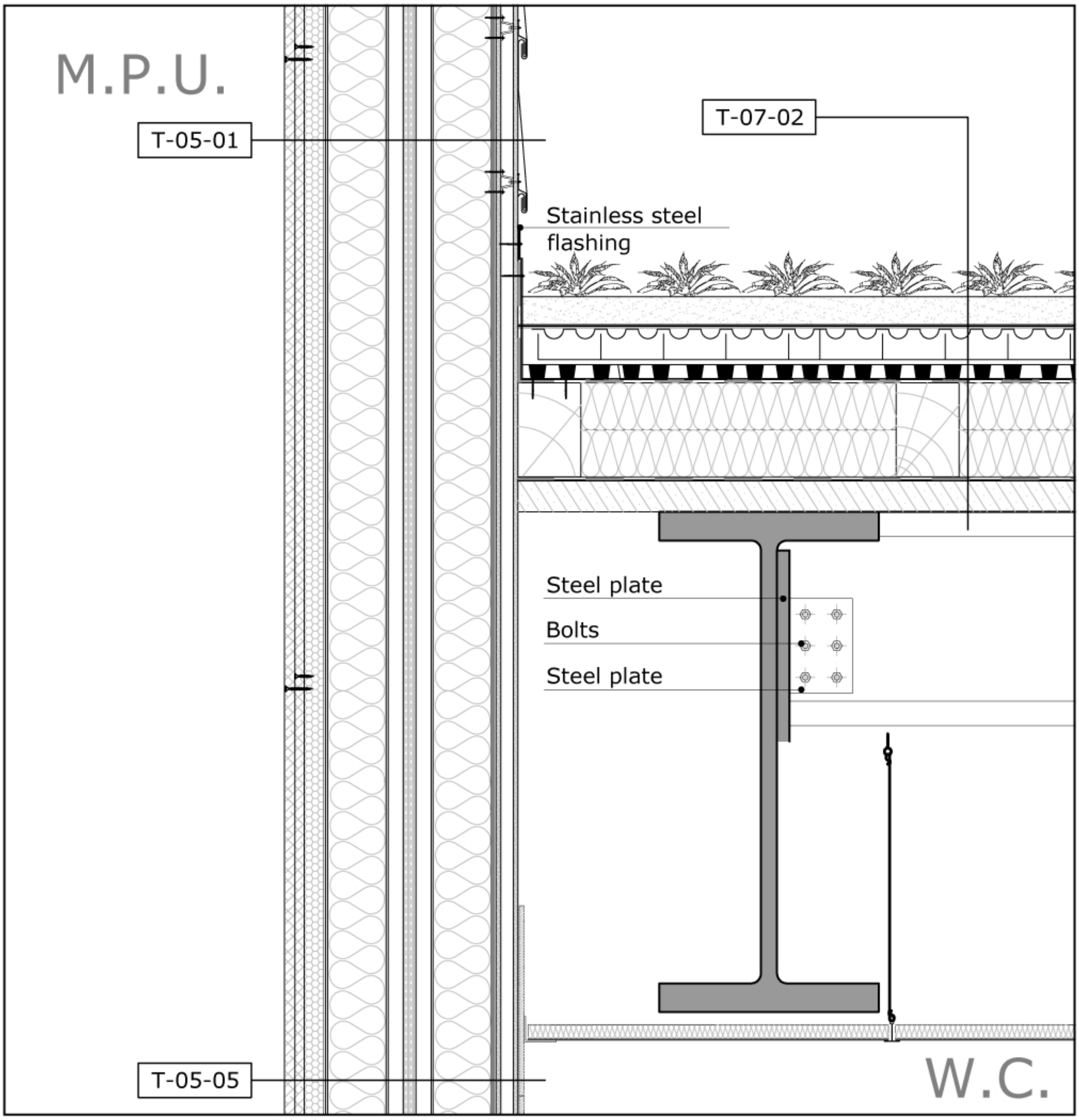
SCALE 1/10



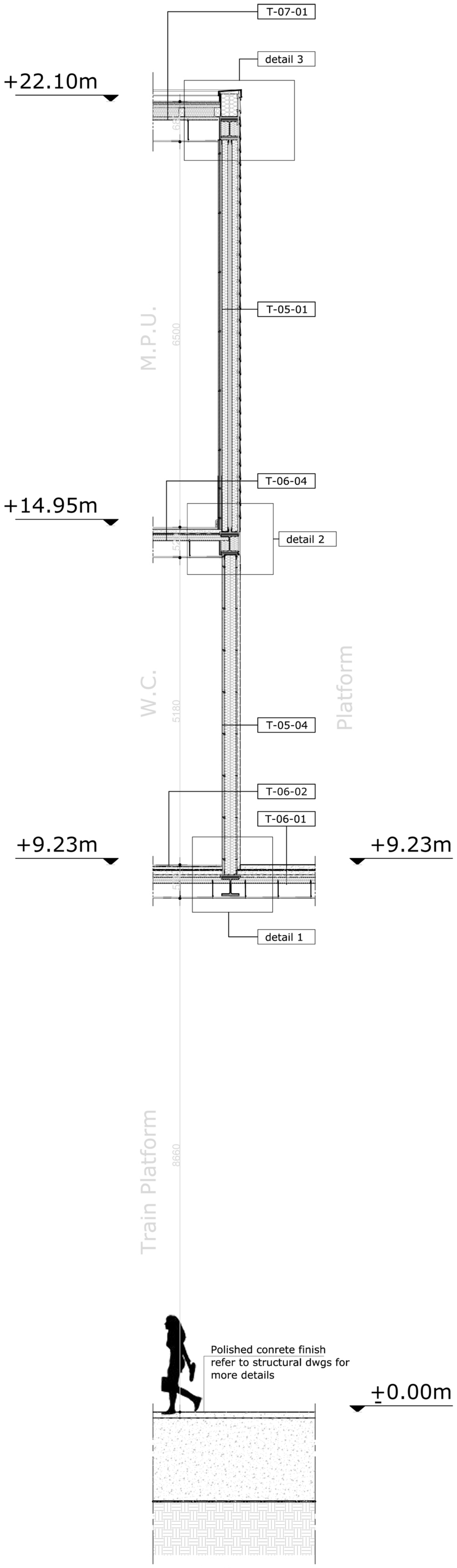
Wall section 1

T-10-01C: Detail 3

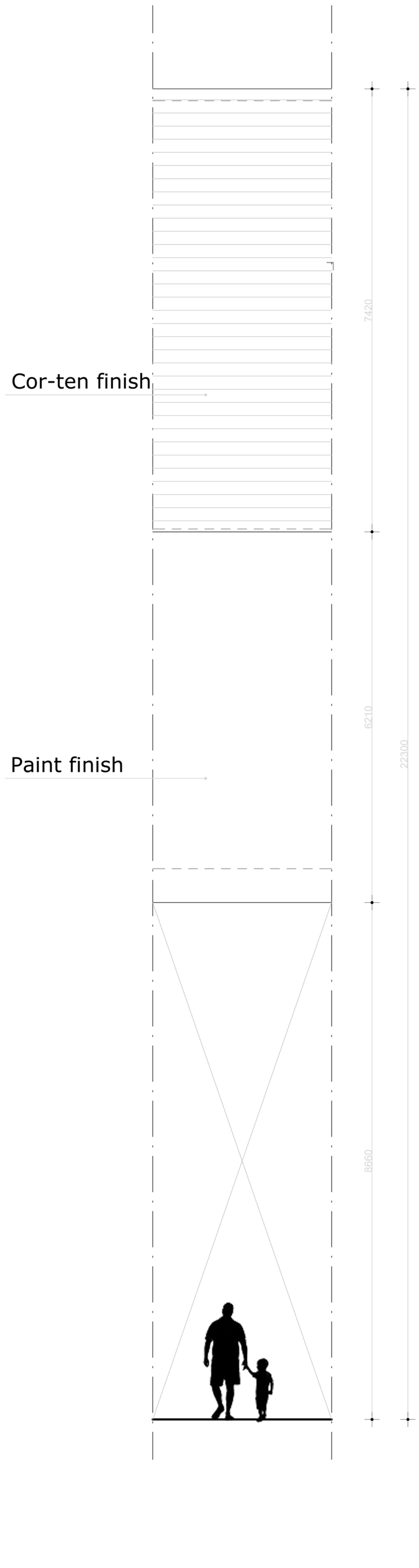
SCALE 1/10



scale 1/50



Section

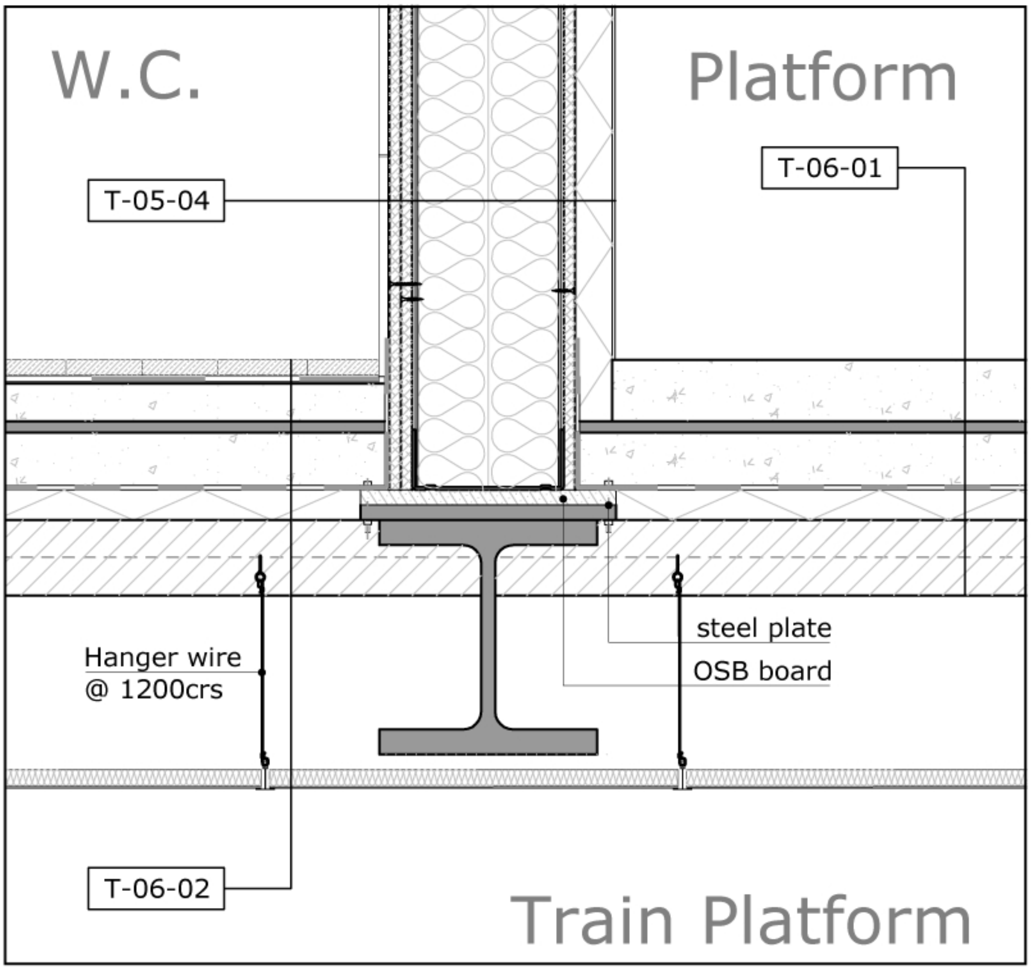


elevation

Wall section 2

T-10-02A: Detail 1

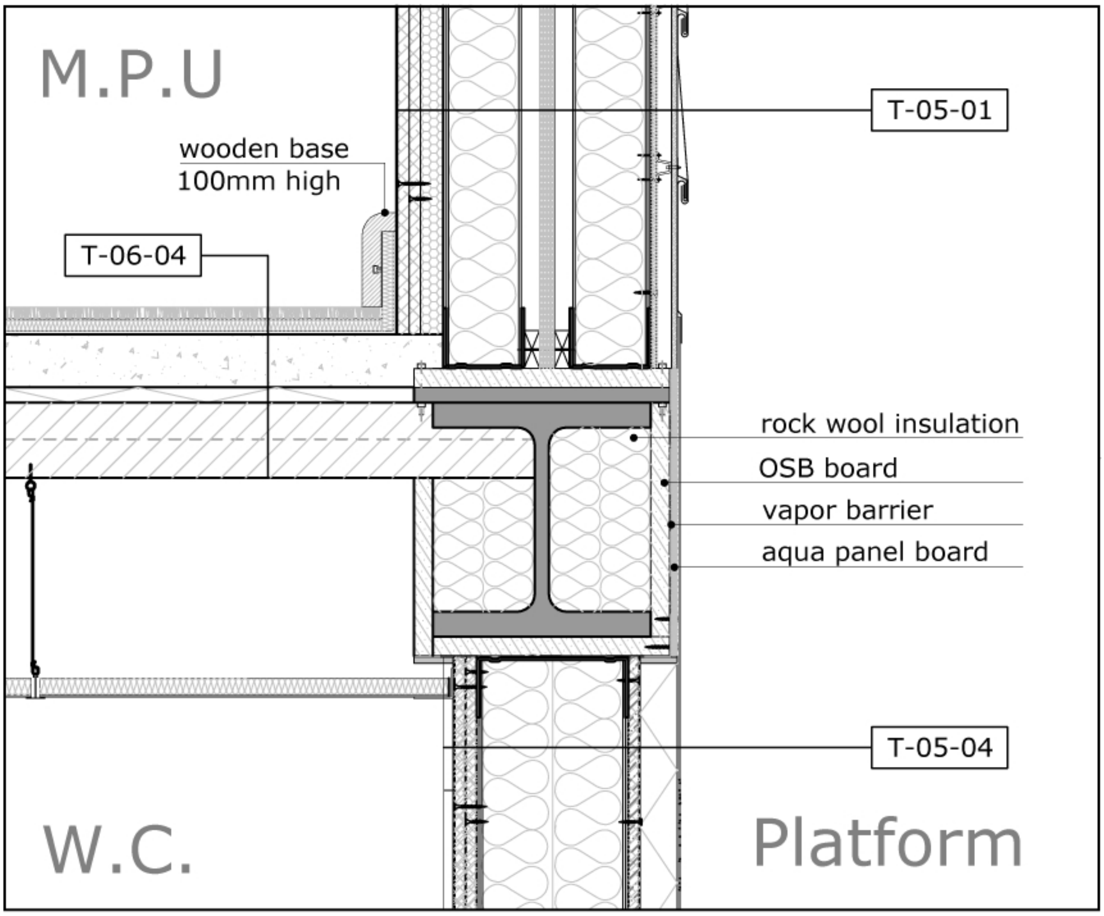
SCALE 1/10



Wall section 2

T-10-02B: Detail 2

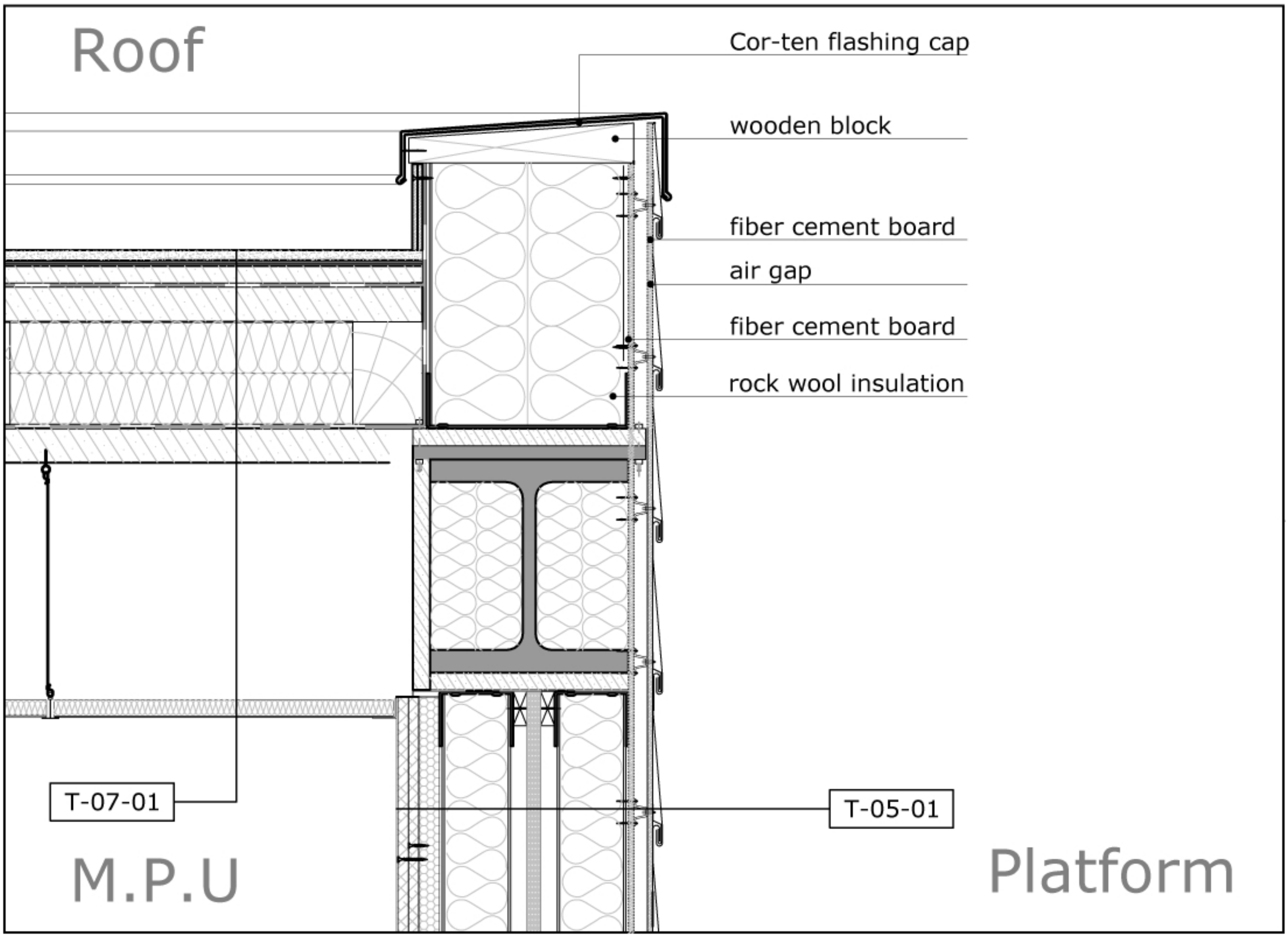
SCALE 1/10



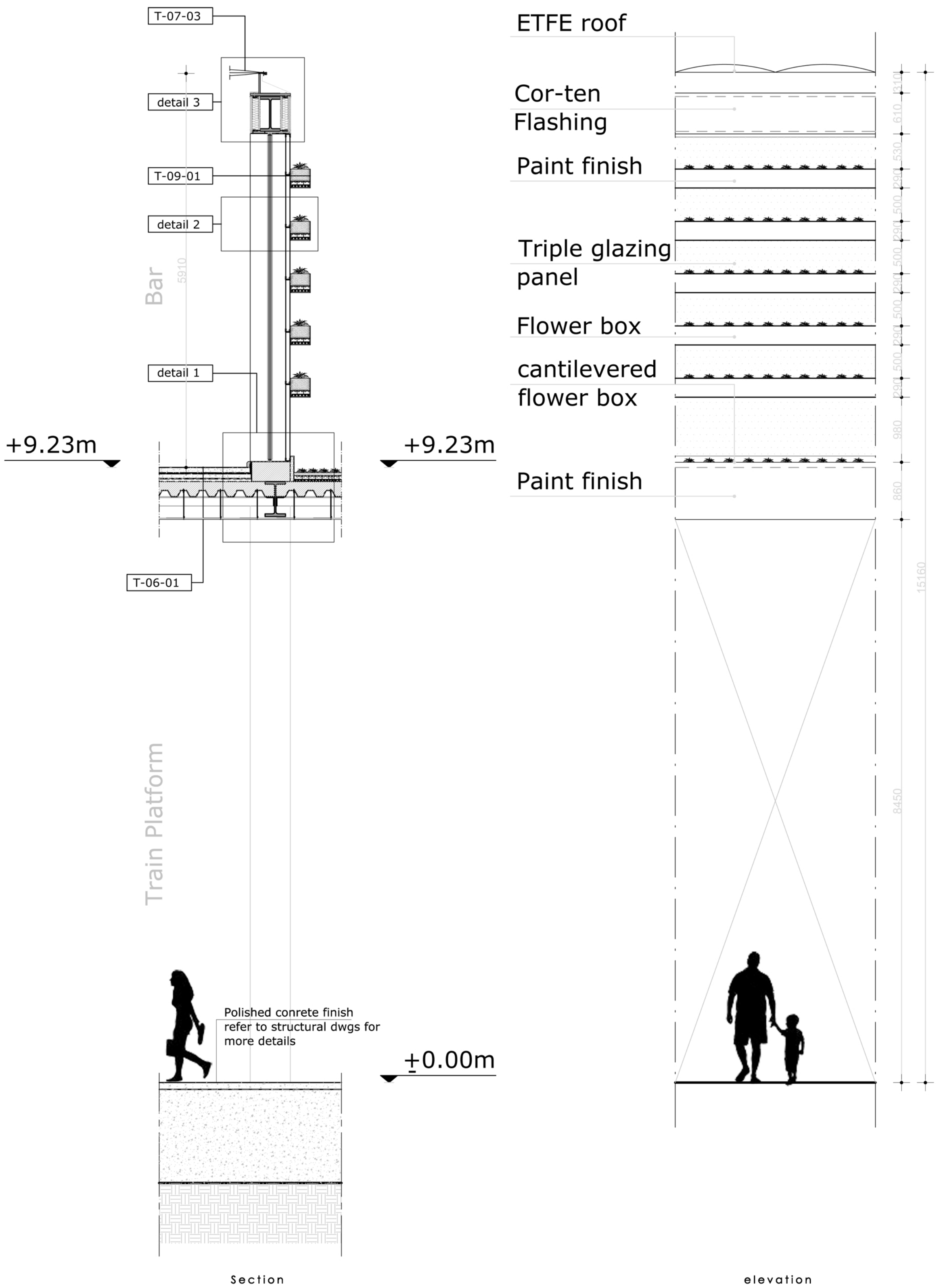
Wall section 2

T-10-02C: Detail 3

SCALE 1/10



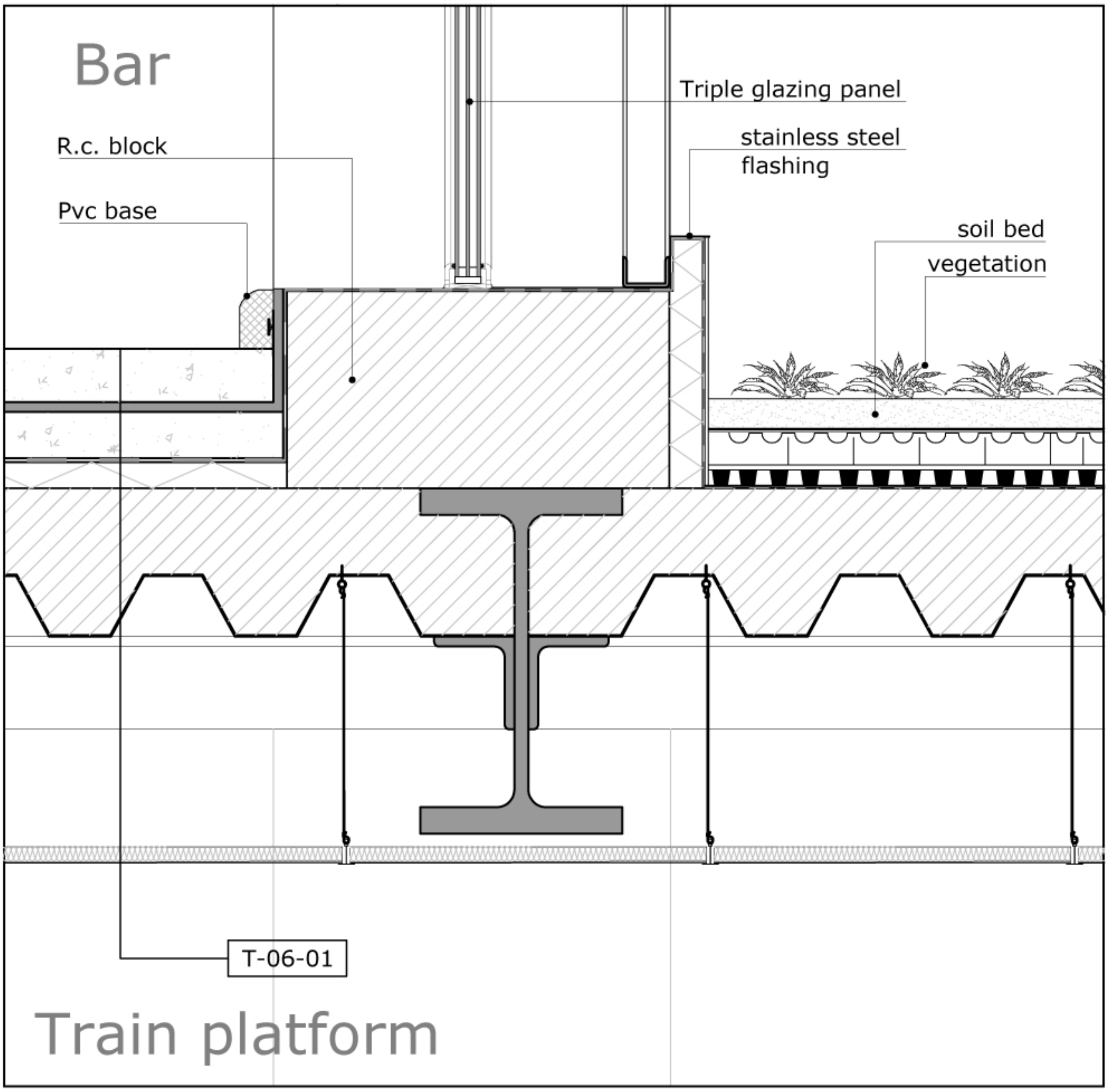
scale 1/50


T-07-03
detail 3
T-09-01
detail 2
Bar
5910
detail 1
+9.23m
+9.23m
T-06-01
Train Platform
Polished conrete finish
refer to structural dwgs for
more details
±0.00m
ETFE roof
Cor-ten
Flashing
Paint finish
Triple glazing
panel
Flower box
cantilevered
flower box
Paint finish
980
860
8450
15160
Section
elevation

Wall section 3

T-10-03A: Detail 1

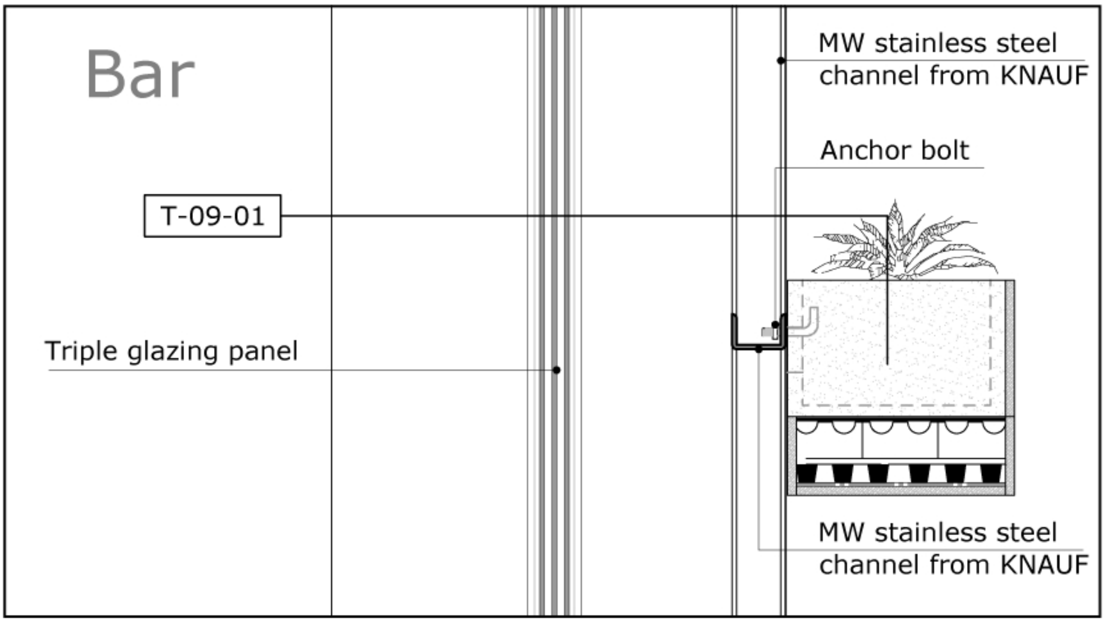
SCALE 1/10



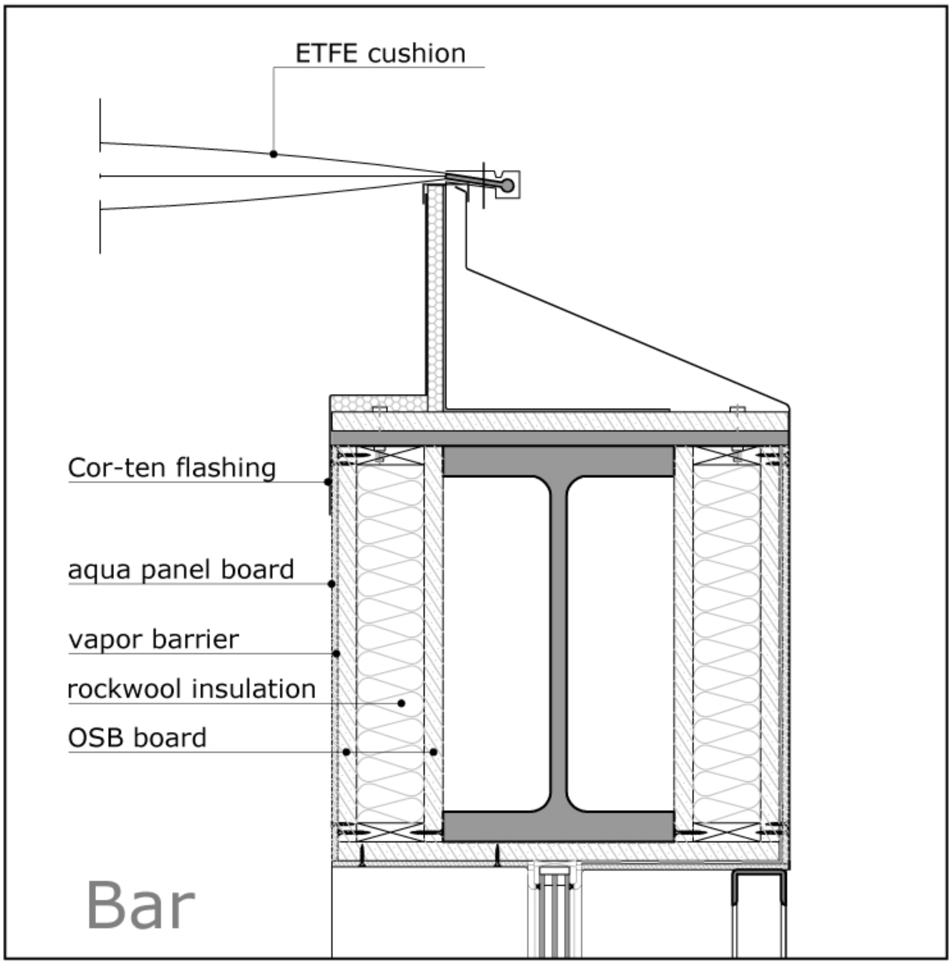
Wall section 3

T-10-03B: Detail 2

SCALE 1/10



T-10-03C: Detail 3



5.3.3Condensation risk analysis

5.3.3.1U-Value Calculation

The U-value (or U-factor), more correctly called the overall heat transfer coefficient, describes how well a building element conducts heat. It measures the rate of heat transfer through a building element over a given area, under standardized conditions. The usual standard is at a temperature gradient of 20 °C, at 60% humidity with no wind (a smaller U-value is better).
U is the inverse of R (resistance) with SI units of W/(m²K).

If the wall is multi-layer:
$U = 1 / (1/h_i + \Sigma s/\lambda + 1/h_e)$
where the sum regards all of the layers.

If the wall includes air cavities, the expression of U becomes:

$$U = 1 \big/ \left(1/h_i + \Sigma s/\lambda + 1/C + 1/h_e\right) \quad [\mathrm{W/m^2K}]$$

with C being the thermal conductance of the cavity
with h being the convective coefficients [m²K/W] of the internal and external surfaces
given by :

Cavity	Thickness : 1cm		Thickness : 2-10cm	
	Conductance C	*Resistance 1/C*	*Conductance C*	*Resistance 1/C*
Vertical layer of air	7.5	0.133	6.4	0.156
Horizontal layer of air (upward flux)	7.5	0.133	7.0	0.143
Horizontal layer of air (downward flux)	7.5	0.133	5.2	0.192

Table 5.4

	Internal: $1/h_i$	External: $1/h_e$
Vertical layer of air	0.13	0.04
Horizontal layer of air (upward flux)	0.10	0.04
Horizontal layer of air (downward flux)	0.17	0.04

Table 5.5

Forms of calculations:

Code	T_05_01		1/hi =	0.130
Designation	MPU wall		1/he =	0.040
Layers (ext -->int)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Flat Lock Tiles made of Cort-en A	0.008	16.000	0.001
2	Fibrecement board	0.015	0.180	0.083
3	Air Gap	0.020	C	0.156
4	Fibrecement board	0.015	0.180	0.083
5	Rock wool	0.100	0.040	2.500
6	ACTIS insulation sheet with metallic internal reflective films	0.022	0.040	0.550
7	Rock wool	0.100	0.038	2.632
8	Composite polyurethane foam board	0.030	0.025	1.200
9	Gypsum board wall	0.030	0.210	0.143
	Total thickness =	0.340	**U-value**	0.133

Table 5.6

Code	T_05_02,T_05_04		1/hi =	0.130
Designation	Typical wall(Paint Finish, Ceramic finish)		1/he =	0.040
Layers (ext -->int)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Exterior façade plaster	0.004	0.480	0.007
2	Fiberglass mesh	0.002	0.035	0.057
3	EPS thermal insulation	0.050	0.034	1.471
4	Fibrecement board	0.015	0.180	0.083
5	Double layer rock wool	0.200	0.040	5.000
6	Double layer gypsum board wall	0.030	0.210	0.143
	Total thickness =	0.301	**U-value**	0.144

Table 5.7

Code	T_05_03		1/hi =	0.130
Designation	Typical wall with corten cladding		1/he =	0.040
Layers (ext -->int)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Flat Lock Tiles made of Cort-en A	0.008	16.000	0.001
2	Fibrecement board	0.008	0.180	0.044
3	Air Gap	0.020	C	0.156
4	Fibrecement board	0.008	0.180	0.044
5	Double layer rock wool	0.300	0.038	7.895
6	Double Fibrecement board	0.015	0.180	0.083
	Total thickness =	0.359	**U-value**	0.119

Table 5.8

Code	T_05_05		1/hi =	0.130
Designation	MPU wall		1/he =	0.040
Layers (ext -->int)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Double gypsum board	0.030	0.210	0.143
2	Composite polyurethane foam board	0.030	0.025	1.200
3	Rock wool	0.100	0.040	2.500
4	ACTIS insulation sheet with metallic internal reflective films	0.022	0.040	0.550
5	Rock wool	0.100	0.040	2.500
6	Fibrecement board	0.015	0.180	0.083
7	Air gap	0.020	C	0.156
8	Fibrecement board	0.015	0.180	0.083
	Total thickness =	0.332	**U-value**	0.135

Table 5.9

Code	T_06_01		1/hi =	0.170
Designation	Main platform(anti slipppery polished)		1/he =	0.040
Layers (top -->bott)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Polished concrete flooring	0.100	1.130	0.088
2	Cellulose - Acoustical layer	0.015	0.040	0.375
3	Screed	0.070	0.410	0.171
4	Polymer bitumen waterproofing membrane	0.006	0.047	0.128
5	Extruded Polystyrene board (xps)	0.040	0.029	1.379
6	Reinforced Concrete	0.130	1.130	0.115
7	Corrugated sheets	0.001	204.000	0.000
	Total thickness =	0.362	**U-value**	0.405

Table 5.10

Code	T_06_02		1/hi =	0.170
Designation	Main platform(Marble finish)		1/he =	0.040
Layers (top -->bott)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Marble	0.020	2.500	0.008
2	Flexible Tile Adhesive (Grout)	0.009	1.730	0.005
3	Bituminous sheets	0.006	0.200	0.030
4	Electric Heating cable	0.003	50.000	0.000
5	Screed	0.050	0.410	0.122
6	Cellulose - Acoustical layer	0.015	0.040	0.375
7	Screed	0.070	0.410	0.171
8	Extruded Polystyrene board (xps)	0.040	0.029	1.379
9	Reinforced Concrete	0.130	1.130	0.115
10	Corrugated sheets	0.001	204.000	0.000
	Total thickness =	0.309	**U-value**	0.414

Table 5.11

Code Designation	T_06_04		1/hi =	0.170
	Intermediate slab(carpet Finish)		1/he =	0.170
Layers (top -->bott)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Carpet	0.015	0.056	0.268
2	Adhesive	0.002	1.730	0.001
3	Cellulose - Acoustical layer	0.015	0.040	0.375
4	Polyester vapor Barrier for carbon film heating systems	0.004	0.330	0.012
5	Leveling concrete (light weight)	0.070	0.380	0.184
6	Extruded Polystyrene board (xps)	0.020	0.029	0.690
7	Reinforced Concrete	0.120	1.130	0.106
8	Corrugated sheets	0.001	204.000	0.000
	Total thickness =	0.246	**U-value**	0.506

Table 5.12

Code Designation	T_06_05		1/hi =	0.170
	Intermediate slab(HPL finish)		1/he =	0.170
Layers (top -->bott)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	HPL Heavy durty acoustical panels	0.015	0.035	0.429
2	Cellulose - Acoustical layer	0.015	0.040	0.375
3	Polyester vapor Barrier for carbon film heating systems	0.004	0.330	0.012
4	Leveling Reinforced concrete (light weight)	0.070	0.380	0.184
5	Extruded Polystyrene board (xps)	0.020	0.029	0.690
6	Reinforced Concrete	0.120	1.130	0.106
7	Corrugated sheets	0.001	204.000	0.000
	Total thickness =	0.244	**U-value**	0.468

Table 5.13

Code Designation	T_06_06		1/hi =	0.170
	Intermediate slab(Marble Finish)		1/he =	0.170
Layers (top -->bott)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Marble	0.020	2.500	0.008
2	Flexible Tile Adhesive (Grout)	0.009	1.730	0.005
3	Bituminous sheets	0.006	0.200	0.030
4	Electric Heating cable	0.003	50.000	0.000
5	Leveling Reinforced concrete (Light Weight)	0.050	0.380	0.132
6	Extruded Polystyrene board (xps)	0.020	0.029	0.690
7	Reinforced Concrete	0.120	1.130	0.106
8	Corrugated sheets	0.001	204.000	0.000
	Total thickness =	0.228	**U-value**	0.763

Table 5.14

Code	T_06_07		1/hi =	0.170
Designation	Intermediate slab(above platform)		1/he =	0.040
Layers (top -->bott)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Marble	0.020	2.500	0.008
2	Flexible Tile Adhesive (Grout)	0.009	1.730	0.005
3	Bituminous sheets	0.006	0.200	0.030
4	Electric Heating cable	0.003	50.000	0.000
5	Osb	0.025	0.110	0.227
6	Double Rock Wool	0.150	0.040	3.750
5	Vapor Barrier	0.002	0.330	0.006
6	Osb	0.050	0.110	0.455
8	Mineral Wool	0.025	0.038	0.658
	Total thickness =	0.290	**U-value**	0.187

Table 5.15

Code	T_07_01		1/hi =	0.100
Designation	Flat Roof		1/he =	0.040
Layers (ext -->int)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Screed	0.015	0.410	0.037
2	Bituminous sheets	0.008	0.2	0.040
3	Osb	0.050	0.110	0.455
4	Aluminum bubble film insulation	0.006	0.032	0.188
5	OSB	0.050	0.110	0.455
6	Double Rock wool Insulation	0.150	0.040	3.750
7	Vapor barrier	0.002	0.330	0.006
8	Osb	0.050	0.11	0.455
9	Double Rock wool Insulation	0.025	0.040	0.625
	Total thickness =	0.356	**U-value**	0.163

Table 5.16

Code	T_07_02		1/hi =	0.100
Designation	Green Roof		1/he =	0.040
Layers (ext -->int)	**Name**	**Thickness s [m]**	**Conductivity λ [W/mK]**	**Resistivity s/λ [m²K/W]**
1	Sand/Clay layer (Bed)	0.040	0.900	0.044
2	Stab-Filter Layer,Polypropylene fiber	0.001	0.137	0.007
3	Water Drainage/Storage Element DAKU FSD20	0.080	0.040	2.000
4	Anti-Root & Rot waterproofing membrane	0.004	0.200	0.020
5	Polystrene Foam boards	0.150	0.025	6.000
6	Polyster reinforced Waterproofing membrane	0.002	0.200	0.010
7	Vapor barrier	0.002	0.330	0.006
8	Osb	0.050	0.11	0.455
9	Gypsum Plaster board	0.015	0.210	0.071
	Total thickness =	0.344	**U-value**	0.114

Table 5.17

5.3.3.2Glazer diagram

Glaser diagram representing P_v and P_s can be traced to assess the risk of condensation. Condensation is tolerated if materials are not deteriorated by condensed water, and if this can evaporate completely during the warm season.

Temperature distribution curve:

Ti= Ti-1– (ΔT/Ki) U

where:

ΔT = Difference in Temperature between the two sides of the Section (T int - T ext);

Tint = Internal temperature, 20°C

Text = external Temperature -26 °C

K_i = λ/s is the thermal Conductivity of the i-th layer;

U= Thermal conductivity of whole section (W/m^2 K)

To calculate the internal Surface temperature

Φ = U S Δ T

Φ= Heat flux (W)

U= Thermal conductivity of whole section (W/m^2 K)

S= Total thickness of Section (m)

T_{pi}= T_i– (Φ/S)(1/h_i)

T_{pi}= Internal Surface Temperature (°C)

T_i= Internal ambient temperature (°C)

S= Total thickness of Section (m)

H_i= Internal Convective co-efficient

Pressure distribution curve:

The risk of condensation can be assessed by tracing the Glaser diagram: in every point, P_v curve should remain below Ps curve. If the distribution of temperatures through the wall is known, saturation pressure can be determined by specific charts, while partial vapor pressure can be calculated from:

P_i= P_{i-1}– (ΔP/ρ_{tot}) ρ_i

Where,

ΔP = Difference in vapor pressure between the two sides of the section (P_{int} - P_{ext});

P_{int} = Internal Pressure at 20°C Temp & 50% R_h(Calculated through Psychometric chart)

P_{ext} = external Pressure at -5 °C Temp & 80% R_h(Calculated through Psychometric chart)

ρ_i = s_j/$\delta_j$is the resistance to vapor diffusion of the i-th layer;

δj is vapour permeability of the i-th layer (see UNI 10351 or DIN 4108);

ρ_{tot} is the resistance (diffusivity) to vapour diffusion of the whole wall and is calculated as:

ρ_{tot} = Σρ_j

outside temperature (°C)	-26
inside temperature (°C)	20
Temperature difference (°C)	25
Outside relative humidity (%)	80
Inside relative humidity (%)	60

Table 5.18

5.3.3.3Condensation

A Section separates two environments with different concentrations of water vapor, a vapor flow will start between the two (higher to lower concentration). The highest partial vapor pressure P_V is generally to be found where temperature is higher. If at some point of the wall, P_V reaches the saturation value Ps, condensation occurs. As a rule, condensation does not occur in single-layer, homogeneous walls, while it is very likely if the inner layers are insulating and with small resistance to the passage of vapor.

<u>Condensation should be avoided because:</u>
• It decreases the durability of materials;
• If it happens in insulating materials, it makes them ineffective (condensed water fills the air gaps).

<u>Two ways to avoid condensation:</u>
• Raising the saturation value P_S: this happens if the inner surface temperature is higher, that is, working on the insulation level;
• Lowering the partial pressure P_V: this can be obtained inserting in the wall -towards the warm environment - a layer with high resistance to vapor flow (vapor barrier - polyethylene or aluminum sheet)

In the calculation, we mainly focus on the condensation risk on the walls, floors and roofs at MPU.

- **Calculation for Temperature & Pressure distribution in the wall T_05_02**

Inside temperature [°C]	20
Outside temperature [°C]	-26
Temperature difference	46
Inside relative humidity	60%
Outside relative humidity	80%

To calculate T at the interface

$T_i = T_{i-1} - \rho_i*(\Delta T/\rho_{tot})$

To calculate Pv:

$|n_a| = W\ |\Delta P_a|$

$P_i = P_{i-1} - \rho_i*(\Delta P/\rho_{tot})$

To calculate Ps:

$P_s = \exp\ (26{,}23 - [5416/(T+273{,}15)])$

Pve	59.92
Pvi	1,166.39

Layers	Name	Cumulated thickness	T [°C] at the end of the layer	Vapour permeability $\delta_u .10^{12}$ [kg/msPa]	Resistance to vapour diffusion ρ_i	Ps [Pa]	Pv [Pa]
	Exterior	0.000	-26.00			74.90	59.92
	On the surface	0.000	-25.73			76.68	59.92
1	Exterior façade plaster	0.004	-25.69	15.00	0.000233	77.01	61.10
2	Fiberglass mesh	0.006	-25.31	-	0.000000	79.64	61.10
3	EPS thermal insulation	0.056	-15.55	3.00	0.016667	182.25	145.15
4	Fibrecement board	0.071	-14.99	15.00	0.001000	190.65	150.19
5	Double layer rock wool	0.271	18.19	1.00	0.200000	2,079.71	1,158.83
6	Double layer gypsum board wall	0.301	19.14	20.00	0.001500	2,208.97	1,166.39
	Interior	0.301	20.00		0.000000	2,332.78	1,166.39

Table 5.19

OUTSIDE INSIDE

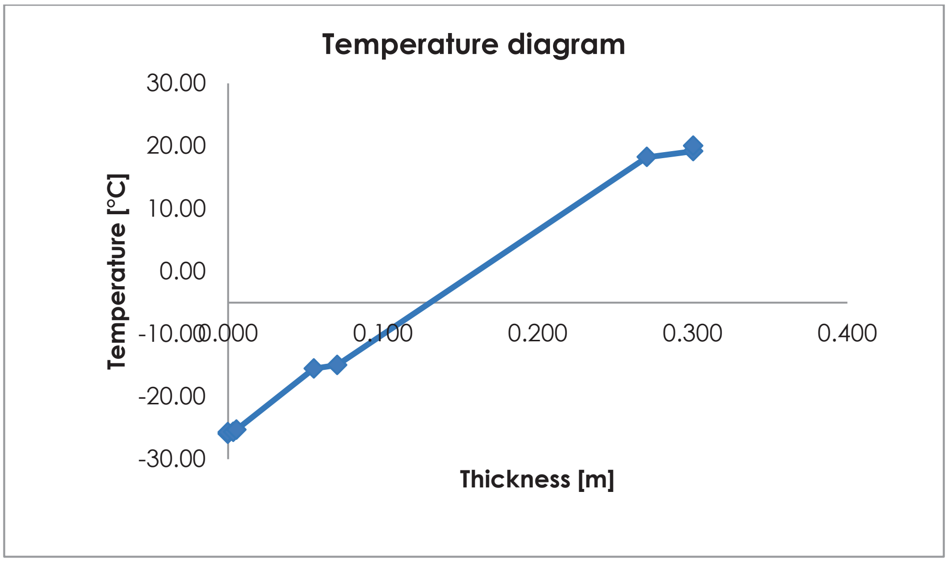


Figure 5.18

OUTSIDE INSIDE

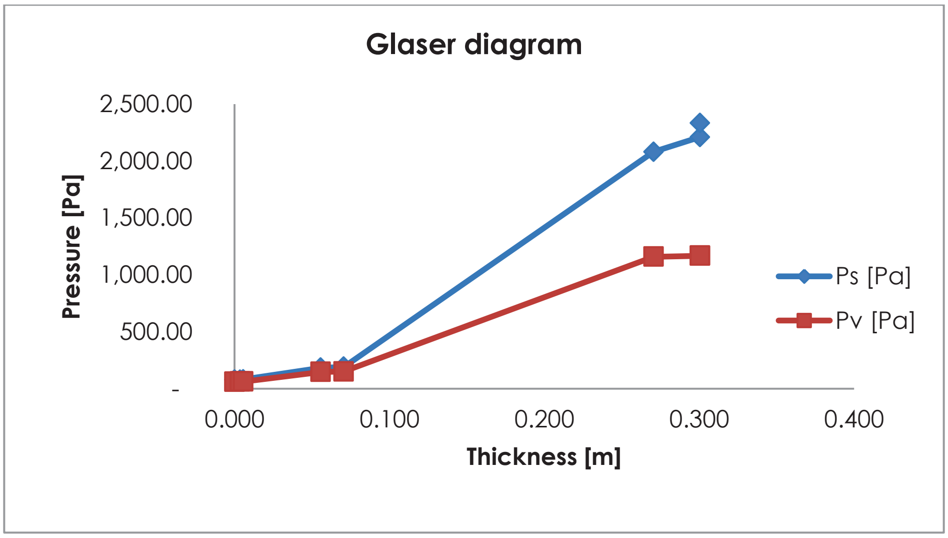


Figure 5.19

Due to saturated pressure is more than vapor pressure for every layer, there is no condensation risk in the wall T_05_02.

- **Calculation for Temperature & Pressure distribution in the floor T_06_07**

Inside temperature [°C]	20
Outside temperature [°C]	-26
Temperature difference	46
Inside relative humidity	60%
Outside relative humidity	80%

To calculate T at the interface

$T_i = T_{i-1} - \rho_i*(\Delta T/\rho_{tot})$

To calculate Pv:

$|n_a| = W\ |\Delta P_a|$

$P_i = P_{i-1} - \rho_i*(\Delta P/\rho_{tot})$

To calculate Ps:

Ps = exp (26,23 - [5416/(T+273,15)])

Pve	59.92
Pvi	1,166.39

Layers	Name	Cumulated thickness	T [°C] at the end of the layer	Vapour permeability $\delta_u \cdot 10^{12}$ [kg/msPa]	Resistance to vapour diffusion ρ_i	Ps [Pa]	Pv [Pa]
	Exterior	0.000	-26.00			74.90	59.92
	On the surface	0.000	-25.66			77.22	59.92
1	Marble	0.020	-25.59	-	0.000000	77.69	59.92
2	Flexible Tile Adhesive (Grout)	0.029	-25.54	20.00	0.000450	78.00	62.17
3	Bituminous sheets	0.035	-25.28	0.00	0.000000	79.79	62.17
4	Electric Heating cable	0.038	-25.28	-	0.000000	79.80	62.17
5	Osb	0.063	-23.33	4.50	0.005556	94.67	89.90
6	Double Rock Wool	0.213	8.92	36.00	0.004167	1,128.95	110.69
7	Vapor Barrier	0.215	8.97	0.01	0.200000	1,132.96	1,108.95
8	Osb	0.265	12.88	4.50	0.011111	1,472.84	166.15
9	Mineral Wool	0.290	18.54	63.00	0.000397	2,126.47	112.67
	Interior	0.290	20.00		0.000000	2,332.78	112.67

Table 5.20

OUTSIDE INSIDE

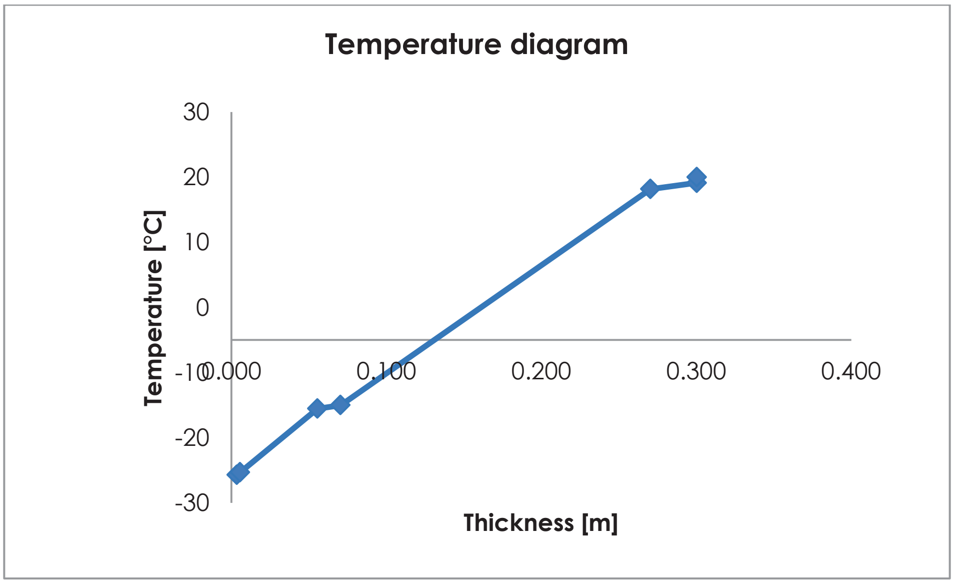


Figure 5.20

OUTSIDE INSIDE

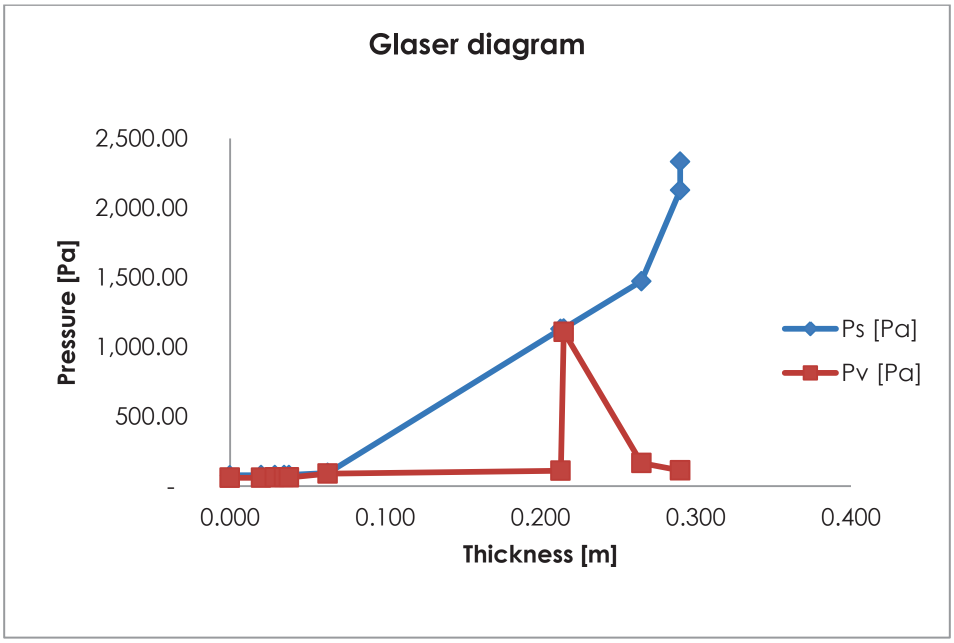


Figure 5.21

Due to saturated pressure is more than vapor pressure for every layer, there is no condensation risk in the floor T_06_07.

- **Calculation for Temperature & Pressure distribution in the roof T_07_01**

Inside temperature [°C]	20
Outside temperature [°C]	-26
Temperature difference	46
Inside relative humidity	60%
Outside relative humidity	80%

To calculate T at the interface

$T_i = T_{i-1} - \rho_i*(\Delta T/\rho_{tot})$

To calculate Pv:

$|n_a| = W\ |\Delta P_a|$

$P_i = P_{i-1} - \rho_i*(\Delta P/\rho_{tot})$

To calculate Ps:

Ps = exp (26,23 - [5416/(T+273,15)])

Pve	59.92
Pvi	1,166.72

Layers	Name	Cumulated thickness	T [°C] at the end of the layer	Vapour permeability $\delta_u . 10^{12}$ [kg/msPa]	Resistance to vapour diffusion ρ_i	Ps [Pa]	Pv [Pa]
	Exterior	0.000	-26.00			74.90	59.92
	On the surface	0.000	-25.70			76.91	59.92
1	Screed	0.015	-25.43	14.00	0.001071	78.80	62.55
2	Bituminous sheets	0.023	-25.13	0	0.000000	80.90	62.55
3	Osb	0.073	-21.73	4.50	0.011111	108.70	89.82
4	Aluminum bubble film insulation	0.079	-20.32	0.5	0.012000	122.50	119.27
5	OSB	0.129	-16.92	4.50	0.011111	162.78	146.54
6	Double Rock wool Insulation	0.279	11.13	36.00	0.004167	1,310.78	156.77
7	Vapor barrier	0.281	11.18	0.01	0.400000	1,314.77	1,138.48
8	Osb	0.331	14.58	4.50	0.011111	1,646.73	1,165.75
9	Mineral wool Insulation	0.356	19.25	63.00	0.000397	2,225.08	1,166.72
	Interior	0.356	20.00			2,333.44	1,166.72

Table 5.21

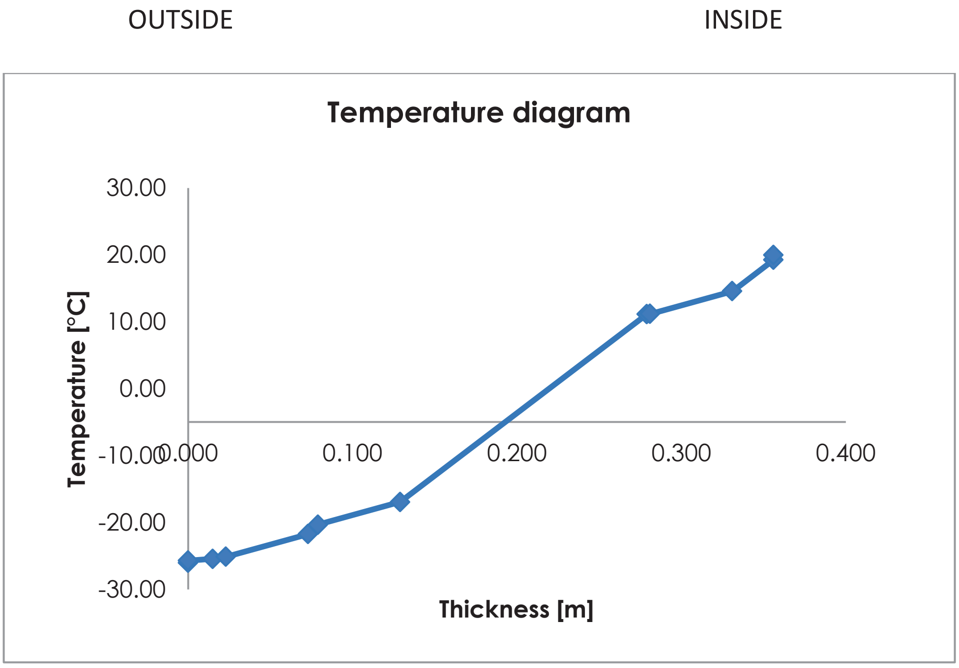


Figure 5.22

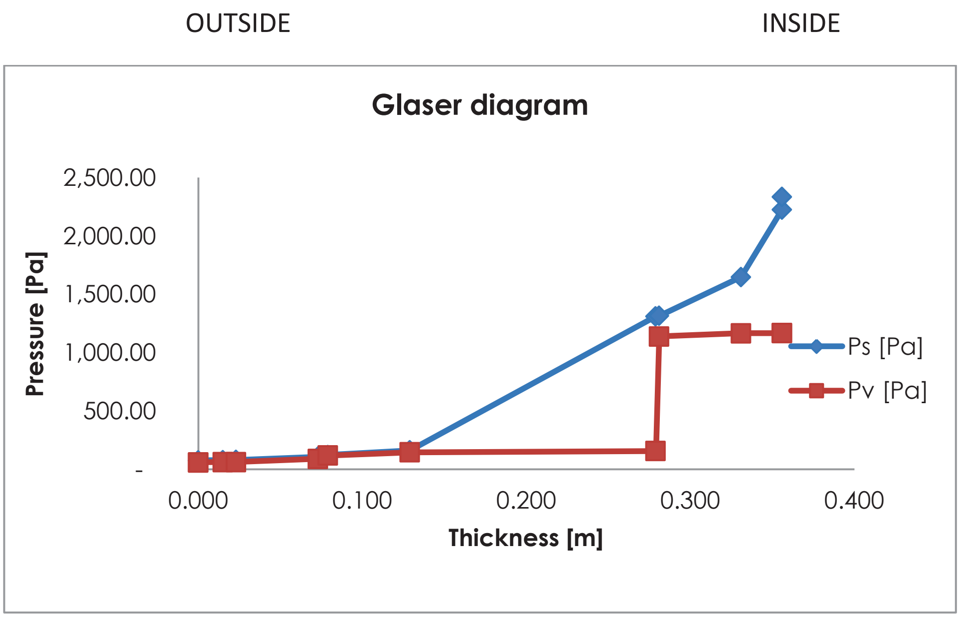


Figure 5.23

Due to saturated pressure is more than vapor pressure for every layer, there is no condensation risk in the roof T_07_01.

- **Calculation for Temperature & Pressure distribution in the roof T_07_02:**

Inside temperature [°C]	20
Outside temperature [°C]	-26
Temperature difference	46
Inside relative humidity	60%
Outside relative humidity	80%

To calculate T at the interface

$T_i = T_{i-1} - \rho_i * (\Delta T / \rho_{tot})$

To calculate Pv:

$|n_a| = W \ |\Delta P_a|$

$P_i = P_{i-1} - \rho_i * (\Delta P / \rho_{tot})$

To calculate Ps:

Ps = exp (26,23 - [5416/(T+273,15)])

Pve	59.92
Pvi	1,166.39

Layers	Name	Cumulated thickness	T [°C] at the end of the layer	Vapour permeability $\delta_v .10^{12}$ [kg/msPa]	Resistance to vapour diffusion ρ_i	Ps [Pa]	Pv [Pa]
	Exterior	0.000	-26.00			74.90	59.92
	On the surface	0.000	-25.79			76.31	59.92
1	Sand/Clay layer (Bed)	0.040	-25.56	200.00	0.000200	77.90	60.36
2	Stab-Filter Layer,Polypropylene fiber	0.041	-25.52	3.90	0.000256	78.17	60.93
3	Water Drainage/Storage Element DAKU FSD20	0.121	-15.01	5.00	0.016000	190.43	96.32
4	Anti-Root & Rot waterproofing membrane	0.125	-14.90	0.60	0.006667	192.06	111.07
5	Polystrene Foam boards	0.275	16.63	2.30	0.065217	1,881.29	255.33
6	Polyster reinforced Waterproofing membrane	0.277	16.68	0.01	0.200000	1,887.68	697.74
7	Vapor barrier	0.279	16.71	0.01	0.200000	1,891.56	1,140.15
8	Osb	0.329	19.10	4.50	0.011111	2,203.65	1,164.73
9	Gypsum Plaster board	0.344	19.47	20.00	0.000750	2,256.66	1,166.39
	Interior	0.344	20.00			2,332.78	1,166.39

Table 5.22

OUTSIDE INSIDE

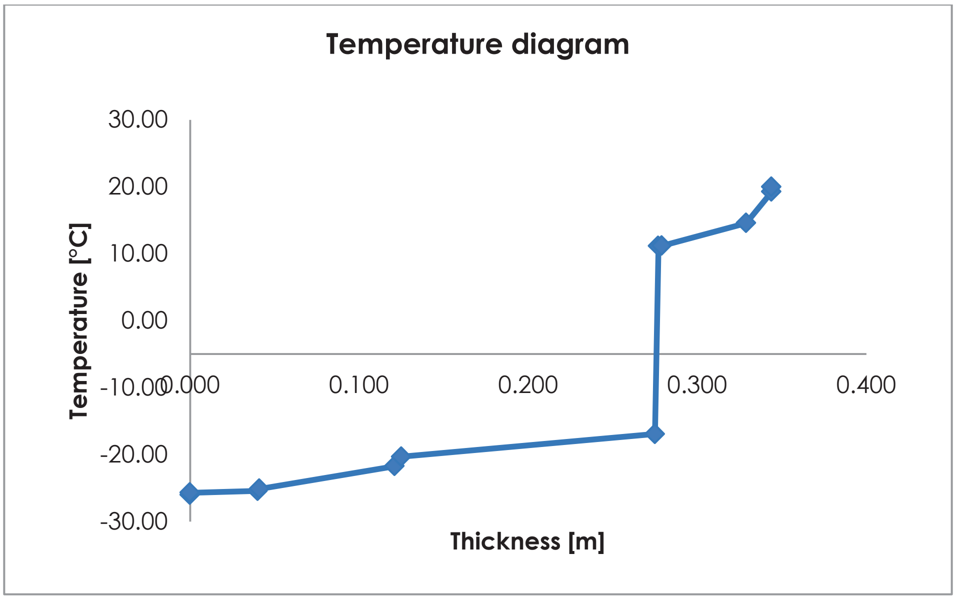


Figure 5.24

00 OUTSIDE INSIDE

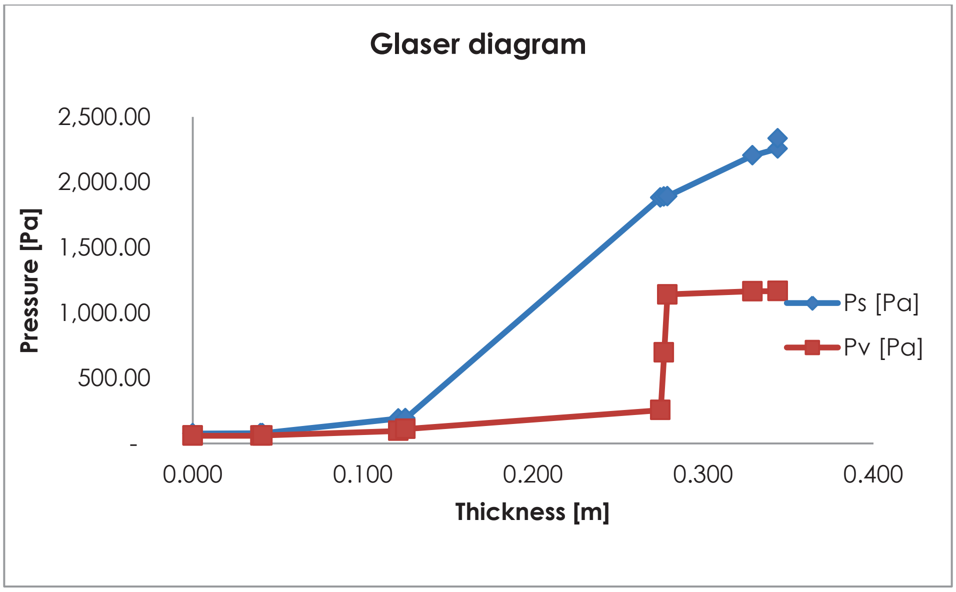


Figure 5.25

Due to saturated pressure is more than vapor pressure for every layer, there is no condensation risk in the roof T_07_02.

5.4Thermal Analysis

5.4.1 Introduction

In this chapter, we have mainly used the analysis tool - Autodesk Ecotect Analysis, which allows us to simulate building performance right from the earliest stages of conceptual design. In addition to the calculation of energy demands required by the building including heating and cooling loads, ventilation, allowing an overall assessment on our technological solutions and the perceive results.

5.4.2 Building Thermal Performance Simulation

5.4.2.1Considerations for the demand of the various zones

Zone Properties:

ZONE	HOURS OF OPERTAION	TERMALSTAT RANG	TYPES OF SYSTEM	EFFICIENCY
TICKET OFFICE WAITING ROOM	8:00-19:00	18°C-25°C	MIXED MODE	95%
MPU	13:00-24:00 (WEEKENDS:9:00-24:00)	20°C-25°C	MIXED MODE	95%
FOYER	13:00-24:00 (WEEKENDS:9:00-24:00)	20°C-25°C	MIXED MODE	95%
SEATING AREA	7:00-23:00 (WEEKENDS:9:00-23:00)	20°C-25°C	MIXED MODE	95%
SERVICES	9:00-23:00	18°C-25°C	MIXED MODE	95%
LOCKERS	9:00-23:00	18°C-25°C	MIXED MODE	95%

Table 5.23

Components properties:

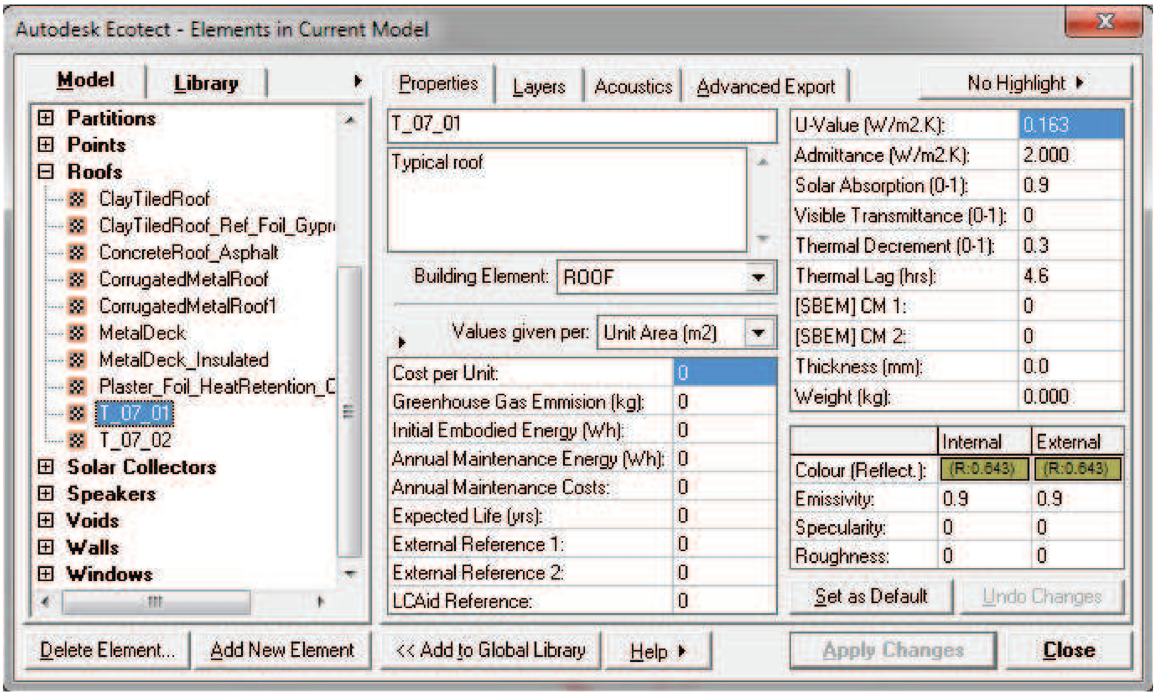


Figure 5.26

TYPES	CODES	U-value
WALL	T_05_01	0.133 W/m²K
WALL	T_05_02	0.144 W/m²K
WALL	T_05_03	0.119 W/m²K
WALL	T_05_04	0.144 W/m²K
WALL	T_05_05	0.135 W/m²K

Table5.24

TYPES	CODES	U-value
FLOOR	T_06_01	0.405 W/m²K
FLOOR	T_06_02	0.414 W/m²K
FLOOR	T_06_04	0.506 W/m²K
FLOOR	T_06_05	0.468 W/m²K
FLOOR	T_06_06	0.763 W/m²K
FLOOR	T_06_07	0.187 W/m²K

Table5.25

TYPES	CODES	U-value
ROOF	T_07_01	0.163 W/m²K
ROOF	T_07_02	0.114 W/m²K
TRIPLE GLAZING	T_08_01	0.170 W/m²K
DOUBLE GLAZING	T_08_02	0.27 W/m²K

Table5.26

5.4.2.2Heating & Cooling Loads

All Visible Thermal Zones

Comfort: Zonal Bands
Max Heating: 178046 W at 16:00 on 12th January
Max Cooling: 26850 W at 13:00 on 4th August

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	39113588	0	39113588
Feb	34916452	0	34916452
Mar	31643952	0	31643952
Apr	17410550	0	17410550
May	7555932	0	7555932
Jun	3260965	0	3260965
Jul	1770659	0	1770659
Aug	2316142	53715	2369856
Sep	8251688	0	8251688
Oct	18469806	0	18469806
Nov	31962656	0	31962656
Dec	40164820	0	40164820
TOTAL	236837216	53715	236890928
PER M^2	163636	37	163673

Floor Area:	1447.339 m^2

Table5.27

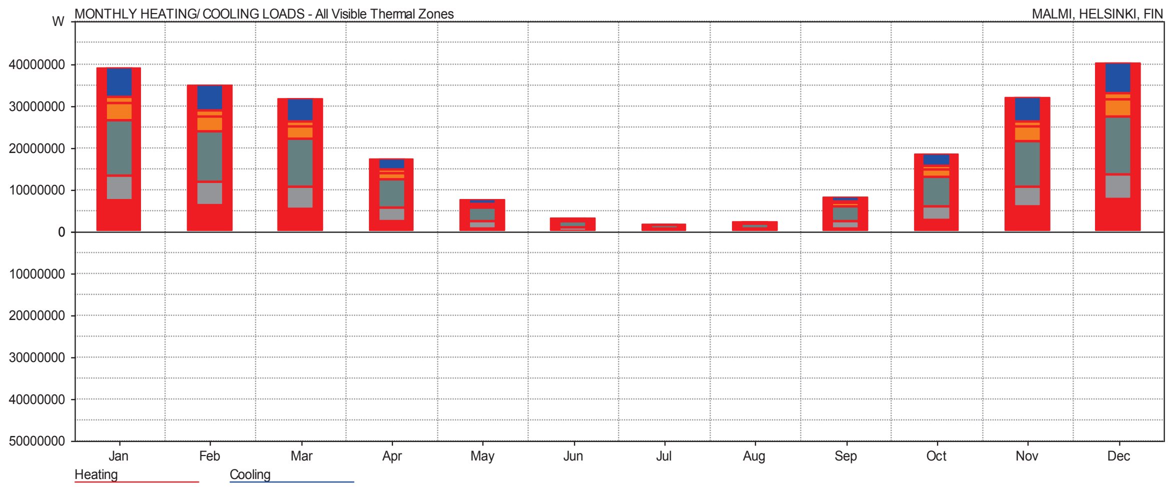


Figure 5.27

Zone: Ticket Office

Operation: Weekdays 08-19, Weekends 08-19.
Thermostat Settings: 18.0 - 25.0 C
Max Heating: 40665 W at 09:00 on 12th January
Max Cooling: 15977 W at 13:00 on 4th August

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	7278446	0	7278446
Feb	6149118	0	6149118
Mar	5298144	0	5298144
Apr	2264950	0	2264950
May	479634	0	479634
Jun	108731	0	108731
Jul	16595	0	16595
Aug	35794	31664	67458
Sep	661141	0	661141
Oct	2711265	0	2711265
Nov	5774341	0	5774341
Dec	7480864	0	7480864
TOTAL	38259028	31664	38290692
PER M^2	71966	60	72026
Floor Area:	531.623 m^2		

Table5.28

Zone: MPU

Operation: Weekdays 13-24, Weekends 09-24.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 29470 W at 16:00 on 12th January
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	5896727	0	5896727
Feb	5516226	0	5516226
Mar	5213998	0	5213998
Apr	3360050	0	3360050
May	1827872	0	1827872
Jun	900470	0	900470
Jul	477430	0	477430
Aug	612512	0	612512
Sep	1789776	0	1789776
Oct	3170874	0	3170874
Nov	4872760	0	4872760
Dec	6010288	0	6010288
TOTAL	39648984	0	39648984
PER M^2	183952	0	183952
Floor Area:	215.540 m^2		

Table5.29

Zone: Foyer

Operation: Weekdays 13-24, Weekends 09-24.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 64113 W at 16:00 on 12th January
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	13202481	0	13202481
Feb	12197715	0	12197715
Mar	11380816	0	11380816
Apr	6726596	0	6726596
May	3295080	0	3295080
Jun	1451068	0	1451068
Jul	902089	0	902089
Aug	1154416	0	1154416
Sep	3532340	0	3532340
Oct	6950188	0	6950188
Nov	10829561	0	10829561
Dec	13642561	0	13642561
TOTAL	85264912	0	85264912
PER M^2	286810	0	286810
Floor Area:	297.287 m^2		

Table5.30

Zone: Seating Area

Operation: Weekdays 07-23, Weekends 09-23.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 16446 W at 08:00 on 7th February
Max Cooling: 11177 W at 14:00 on 4th August

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	4050004	0	4050004
Feb	3307524	0	3307524
Mar	2907418	0	2907418
Apr	1397670	0	1397670
May	578466	0	578466
Jun	281736	0	281736
Jul	162147	0	162147
Aug	231107	22050	253157
Sep	773140	0	773140
Oct	1827646	0	1827646
Nov	3391501	0	3391501
Dec	4202804	0	4202804
TOTAL	23111164	22050	23133214
PER M^2	236119	225	236345
Floor Area:	97.879 m^2		

Table5.30

Zone: Services

Operation: Weekdays 09-23, Weekends 09-23.

Thermostat Settings: 18.0 - 25.0 C

Max Heating: 9576 W at 10:00 on 8th February

Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	1610700	0	1610700
Feb	1539524	0	1539524
Mar	1364934	0	1364934
Apr	776172	0	776172
May	300090	0	300090
Jun	91737	0	91737
Jul	32467	0	32467
Aug	35447	0	35447
Sep	281810	0	281810
Oct	718651	0	718651
Nov	1298504	0	1298504
Dec	1599644	0	1599644
TOTAL	9649682	0	9649682
PER M^2	129260	0	129260
Floor Area:	74.653 m^2		

Table5.31

Zone: Lockers

Operation: Weekdays 09-23, Weekends 09-23.

Thermostat Settings: 18.0 - 25.0 C

Max Heating: 28712 W at 19:00 on 7th February

Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	7075256	0	7075256
Feb	6206294	0	6206294
Mar	5478632	0	5478632
Apr	2885115	0	2885115
May	1074794	0	1074794
Jun	427223	0	427223
Jul	179930	0	179930
Aug	246867	0	246867
Sep	1213483	0	1213483
Oct	3091203	0	3091203
Nov	5795992	0	5795992
Dec	7228685	0	7228685
TOTAL	40903476	0	40903476
PER M^2	177566	0	177566
Floor Area:	230.356 m^2		

Table5.32

As it is shown above, the simulated results obtained from ECOTECT indicate that it is unnecessary to take measures on cooling. So, the following chapters will not refer any cooling demand. On the other hand, according to the data on the heating raise demand, several problems have been raised in some design zones. The National roadmaps towards nearly zero energy buildings of Finland(Sources: Motiva Oy, Rakennuslehti, The National Building Code of Finland) regulates that the space heating demand for new buildings in 2012 should reduce 20% of the standard heating demand in 2010, which is 70-105kW/m^{2}a. That is to say, the energy on space heating should not exceed the value **56-84 kW/m^{2}a**. So the thermal design in some zones should be optimized to reach the standard values.

In the following chapter, we will propose several measures to reduce the heating demand, thereby optimizing our design.

5.4.2.3Optimization on thermal design

- <u>**Reducing Air Leakage: air-tight envelope**</u>

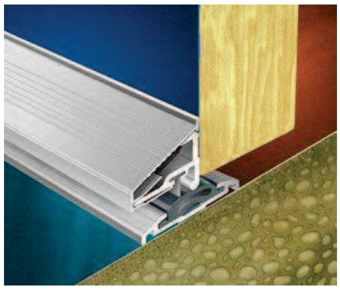
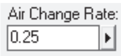


Figure 5.28 Air barrier at the window frame

Warm air leaking out through gaps in a building's external envelope is a major cause of heat loss and, consequently, wasted energy. Improving air-tightness in buildings reduces the uncontrolled flow of air through gaps and cracks in the external fabric. The air barrier is a continuous line around the building which separates heated and unheated spaces.

In ECOTECT, for the airtight zones, we set the 'Infiltration Rate' as AIRTIGHT - 0.25ach(

).This measure can be taken into some closed zones, for example : Zone MPU, Zone Foyer, Zone Seating Room, Zone Service Room, Zone Lockers.

- <u>**Reuse of heat: Ventilation with Heat Recovery**</u>

Figure 5.29 Airstreams through heat pipes

Heat recovery is a process of continuously preheating incoming cool supply air by warming it with the outgoing exhaust air. Warm air is not simply exhausted through the open window but transfers most of its heat to supply air in a highly efficient heat recovery exchanger before being exhausted. At no time do the airstreams mix as the heat radiates through the plates of the exchanger. This heat recovery process is called Heat recovery ventilation (HRV), which provides fresh air and improved climate control, while also saving energy by reducing heating requirements.

There are a number of types of heat exchanger that can be used in Heat recovery ventilation-HRV devices, in our design however, we propose a solution of heat pipe.

The heat energy in waste air is valuable. With a heat pipe, the most heat energy in waste air can be recovered for free. The heat pipe extracts heat from the waste air stream and adds it to the incoming stream. The effectiveness of this process can be as high as 75%, yet the running costs are nil and the set-up costs are minimal.

Much of that energy escapes with waste gases and liquids. A heat pipe can recover and recycle that heat without fear of contamination from the waste product itself. What's more, a heat pipe can be treated to withstand corrosive environments with minimal loss of effectiveness.

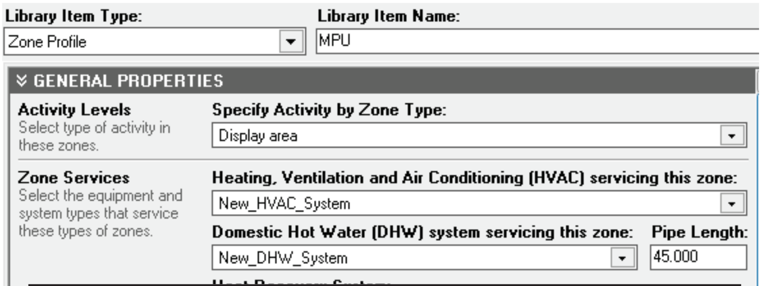


Figure 5.30 Simulation of heat recovery in ECOTECT

This measure has been used in most zones, except for Ticket Office.

(source:http://www.spcoils.co.uk/Products/HeatPipes/HeatPipesforHeatRecovery.aspx)

Post application calculations

- **Zone Ticket Office**: renovations are not applied in this zone due to the reasons demonstrated above.
- **Zone MPU:**

Operation: Weekdays 13-24, Weekends 09-24.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 14323 W at 10:00 on 14th January
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	2385861	0	2385861
Feb	2234336	0	2234336
Mar	2009966	0	2009966
Apr	1266524	0	1266524
May	576131	0	576131
Jun	213168	0	213168
Jul	86817	0	86817
Aug	108761	0	108761
Sep	578712	0	578712
Oct	1178614	0	1178614
Nov	1976987	0	1976987
Dec	2368896	0	2368896
TOTAL	14984774	0	14984774
PER M^2	69522	0	69522
Floor Area:	215.540 m^2		

Table5.33

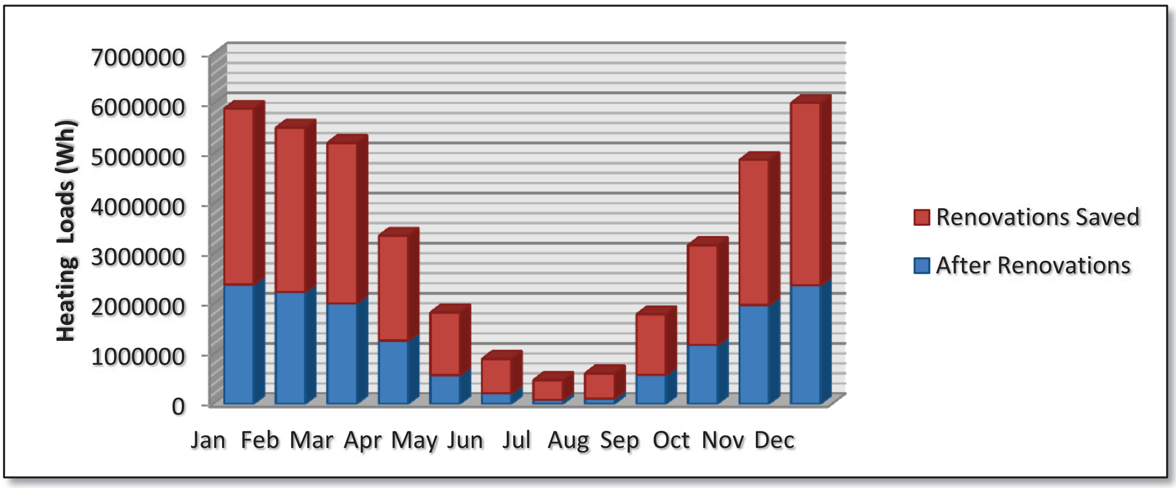


Figure 5.31

Comparing to loads 183952 W/ M² ·a before renovations, the heating loads in Zone MPU has dropped to 69522 W/ M²· a. The **62.2%** of heating loads are saved after renovations.

- **Zone Foyer:**

MONTHLY HEATING/COOLING LOADS
Zone: Foyer
Operation: Weekdays 13-21, Weekends 09-21.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 25824 W at 15:00 on 12th January
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	4153973	0	4153973
Feb	3722111	0	3722111
Mar	3095722	0	3095722
Apr	1430203	0	1430203
May	381611	0	381611
Jun	119206	0	119206
Jul	53282	0	53282
Aug	120633	0	120633
Sep	660231	0	660231
Oct	1840003	0	1840003
Nov	3403989	0	3403989
Dec	4206967	0	4206967
TOTAL	23187932	0	23187932
PER M²	77999	0	77999
Floor Area:	297.287 m²		

Table5.34

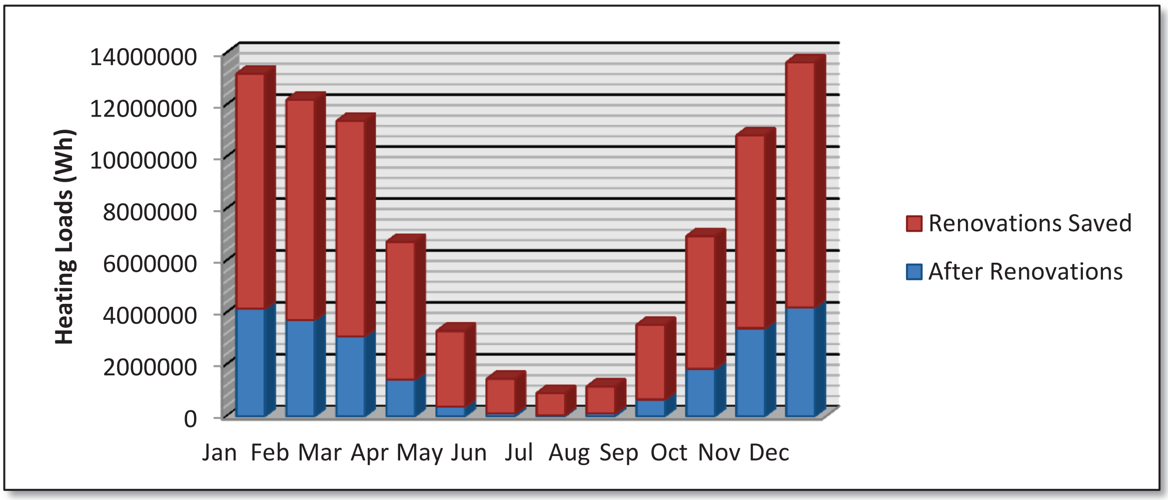


Figure 5.32

Comparing to loads 286810 W/ M^2 ·a before renovations, the heating loads in Zone Foyer has dropped to 77999 W/ M^2· a. The **72.8%** of heating loads are saved after renovations.

- **<u>Zone Seating Area:</u>**

MONTHLY HEATING/COOLING LOADS
Zone: Seating Area
Operation: Weekdays 07-21, Weekends 09-21.
Thermostat Settings: 20.0 - 25.0 C
Max Heating: 8352 W at 08:00 on 8th February
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	1485419	0	1485419
Feb	1107733	0	1107733
Mar	832661	0	832661
Apr	292742	0	292742
May	80825	0	80825
Jun	25844	0	25844
Jul	9753	0	9753
Aug	26834	0	26834
Sep	151849	0	151849
Oct	517057	0	517057
Nov	1272002	0	1272002
Dec	1576431	0	1576431
TOTAL	7379151	0	7379151
PER M^2	75390	0	75390
Floor Area:	97.879 m^2		

Table5.35

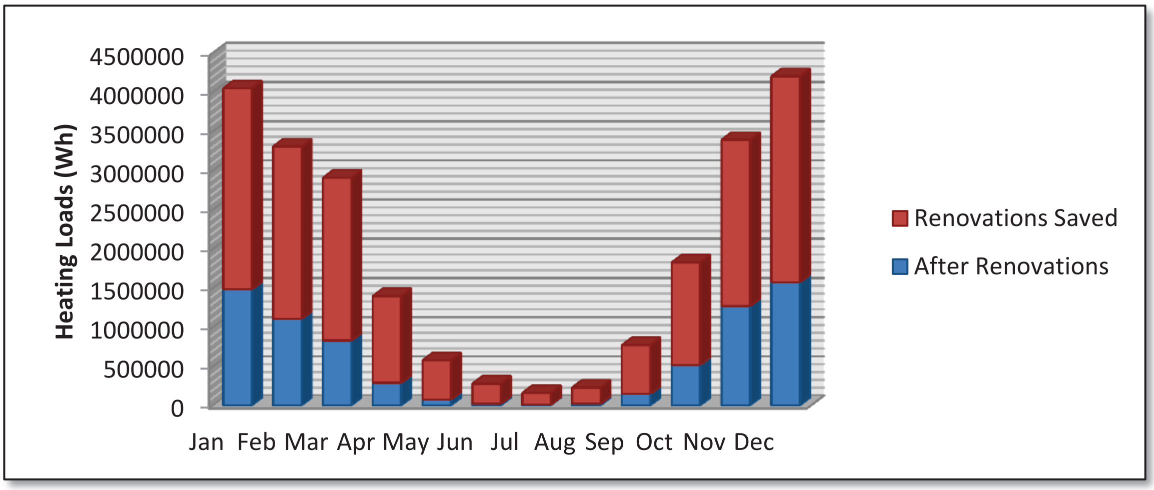


Figure 5.33

Comparing to loads 236119 W/ M²·a before renovations, the heating loads in Zone Seating Area has dropped to 75390 W/ M²· a. The **68.1%** of heating loads are saved after renovations.

- **Zone Services**:

Operation: Weekdays 09-23, Weekends 09-23.
Thermostat Settings: 18.0 - 25.0 C
Max Heating: 6105 W at 10:00 on 9th February
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	710719	0	710719
Feb	688615	0	688615
Mar	560651	0	560651
Apr	286668	0	286668
May	79857	0	79857
Jun	17586	0	17586
Jul	4833	0	4833
Aug	4769	0	4769
Sep	73965	0	73965
Oct	243053	0	243053
Nov	563040	0	563040
Dec	690031	0	690031
TOTAL	3923790	0	3923790
PER M²	52560	0	52560
Floor Area:	74.653 m²		

Table5.36

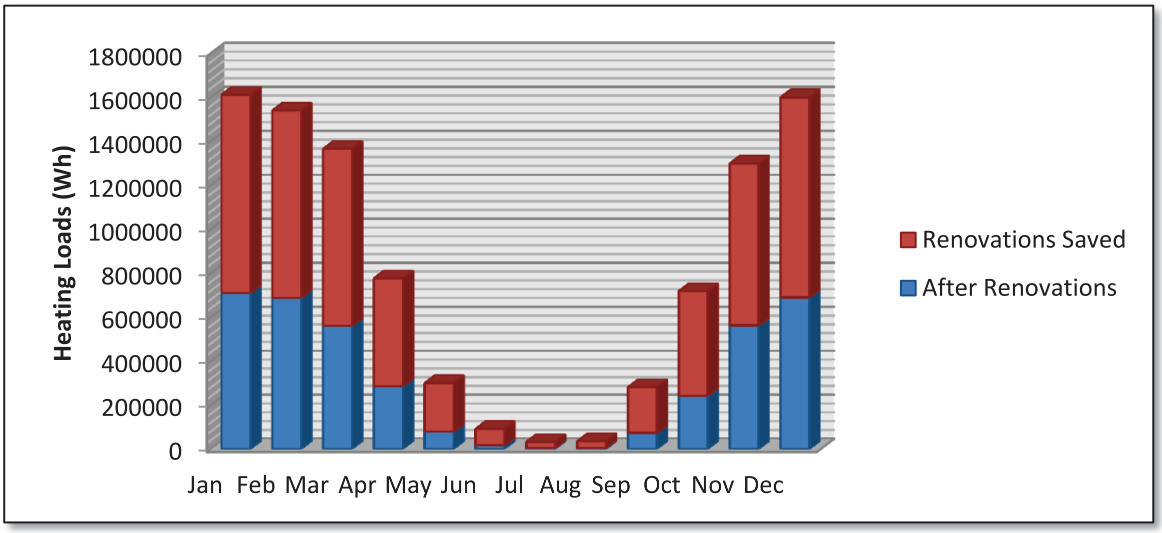


Figure 5.34

Comparing to loads 129260 W/ M^2 ·a before renovations, the heating loads in Zone Services has dropped to 52560 W/ M^2· a. The **59.3%** of heating loads are saved after renovations.

- **Lockers:**

Operation: Weekdays 09-23, Weekends 09-23.
Thermostat Settings: 18.0 - 25.0 C
Max Heating: 12156 W at 15:00 on 12th January
Max Cooling: 0.0 C - No Cooling.

	HEATING	COOLING	TOTAL
MONTH	(Wh)	(Wh)	(Wh)
Jan	2909347	0	2909347
Feb	2386633	0	2386633
Mar	1980833	0	1980833
Apr	883822	0	883822
May	278369	0	278369
Jun	76024	0	76024
Jul	28700	0	28700
Aug	36476	0	36476
Sep	336744	0	336744
Oct	1048635	0	1048635
Nov	2431080	0	2431080
Dec	2976187	0	2976187
TOTAL	15372851	0	15372851
PER M^2	66735	0	66735
Floor Area:	230.356 m^2		

Table5.37

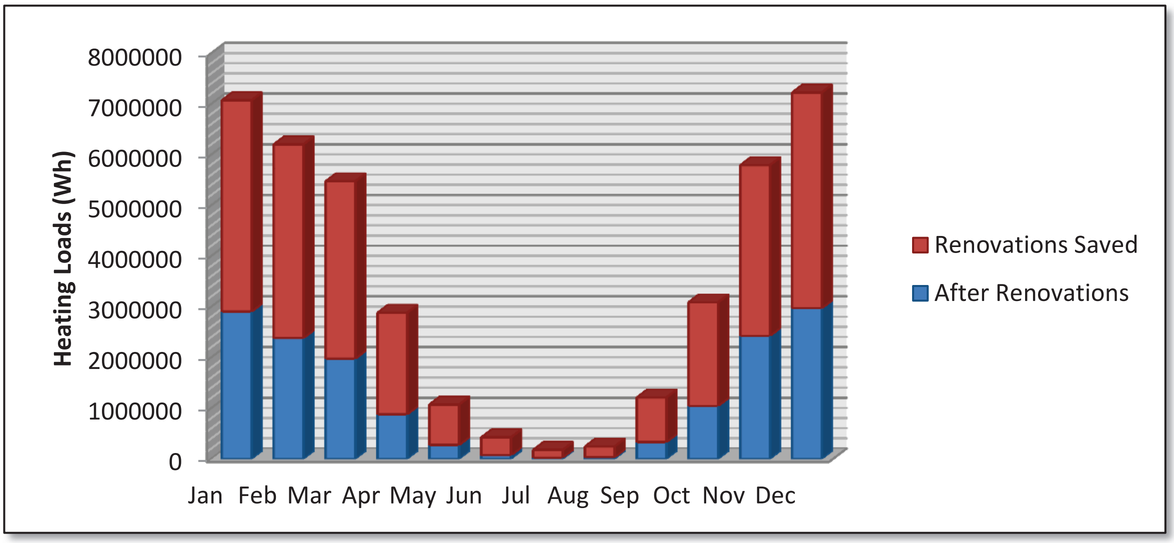


Figure 5.35

Comparing to loads 129260 W/ M^2 ·a before renovations, the heating loads in Zone Services has dropped to 52560 W/ M^2· a. The **59.3%** of heating loads are saved after renovations.

- **All visible zones:**

MONTHLY HEATING/COOLING LOADS
All Visible Thermal Zones
Comfort: Zonal Bands
Max Heating: 95754 W at 16:00 on 12th January
Max Cooling: 0.0 C - No Cooling.

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	18883076	0	18883076
Feb	16248548	0	16248548
Mar	13735367	0	13735367
Apr	6391194	0	6391194
May	1851043	0	1851043
Jun	542937	0	542937
Jul	185853	0	185853
Aug	299178	0	299178
Sep	2436367	0	2436367
Oct	7498901	0	7498901
Nov	15382717	0	15382717
Dec	19257214	0	19257214
TOTAL	102712400	0	102712400
PER M^2	70966	0	70966
Floor Area:	1447.339 m2		

Table5.38

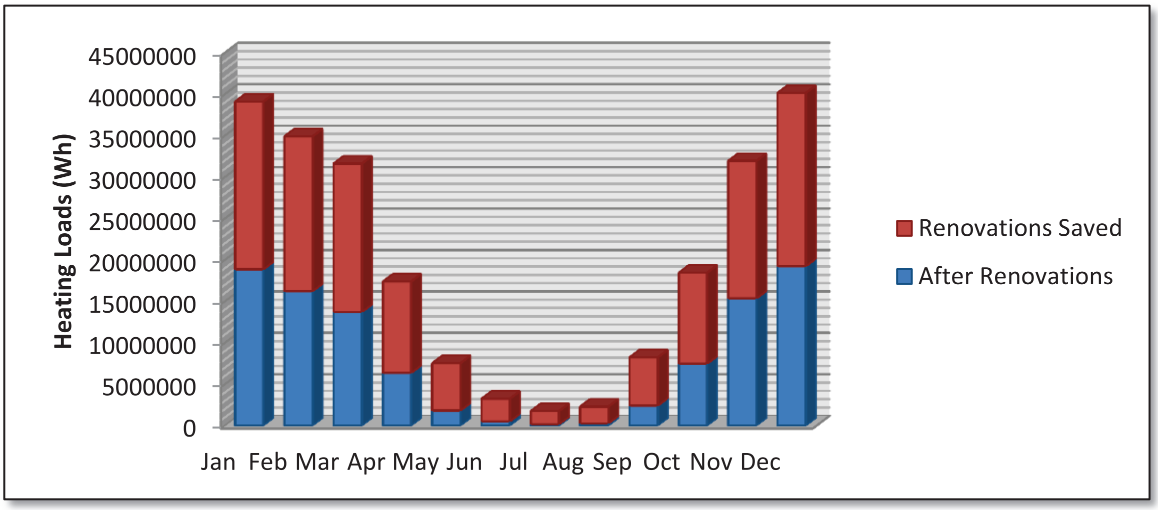


Figure 5.36

For the total heating loads in all visible zones, the heating loads drops from 163636 W/ M^2·a to 70966 W/ M^2 · a. Generally , the **56.6%** of energy has been reduced. In the mean while, we have achieved the goal that the energy on space heating should not exceed the value 56-84 kW/M^2 ·a (solution value: **70.966 kW/M^2 · a**)- a national standard of Finland for the low energy buildings according to National Building Code of Finland.

5.4.2.4Conclusion

The energy performance includes energy consumption on space and ventilation heating, hot water heating , fans and pumps, lighting, applicants and so on. As we have obtained the energy on space heating, we can roughly estimate the total energy consumed in our project, as shown below:

$Q_{space\ heating}$ = *102712.4 kWh /a*

Consider the space heating as 40% of total energy demand,

Q_{total} = *102712.4 / 40% = 256781kWh / a.*

To sum up, our building can be defined as **Low Energy Building** in Finland. What is more, due to the relatively high U-values of floors exposed to outdoor we are using in this project, there is still such potential to improve the energy saving performance on heating demand by replacing the floors with lower U-values, *0.25 W/m²K* for example.

5.5Lighting Design

5.5.1 Shadow analysis

As shadows and reflections are an important aspect of building design, shadow analysis enables an understanding of the extent to which shadows from other local structures affect the specific property that is being designed. This helps to take the right decisions regarding placement of Glazing panels and artificial lighting devices. Viewing shadows in this manner allows the designers to focus on specific objects that can hinder or support some of the functional aspects of the design, or quickly see the location of sun-patches as they travel across the floor and up a wall.

5.5.1.1General information about our site

The place is closed to Arctic Circle, In bright and warm summers Finland can have nearly 24 hours of daylight a day. But in the winter, it can be just about 8-10 hours. And in the Fall and in the Spring, it's about 14 hours.

And the shortest daytime happens in January, while the longest is in July. Since the sunlight is always needed for buildings in Malmi, Helsinki all the year around, and the maximum value of solar gain is in July and the minimum value occurs in January.

- **impact from surrounding - good location selected**

The only two surrounding buildings locate in the northwest and the southeast, respectively. The Nova Malmi, which is in the southeast of site is less than 22 meters, while another one in the northwest is less than 23 meters. Due to the high latitude of Malmi (60 degree North) and the long distance between the building site to the nearest two buildings is 50 meters, the shadow caused by surrounding buildings do not block the sunlight to our site of building. That is to say, the site is absolutely exposed to the sun in the day time. The passive gain for solar energy of the building on the site can reach the maximum value. So we can say that it is a perfect prospect site for building from the point of view on passive energy strategies.

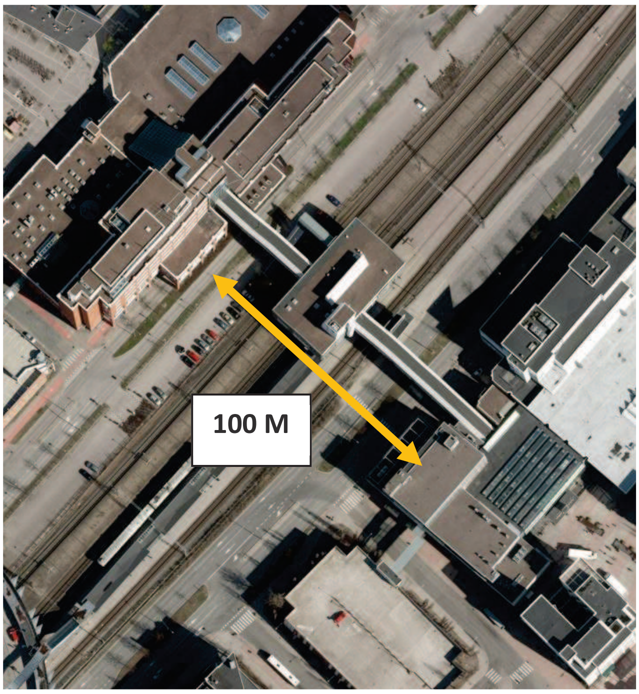


figure 5.37

Shadow Analysis on the Building

` **5.5.1.2 Shadow range of building in a day catalogues by seasons**

Shadows at 9:00:

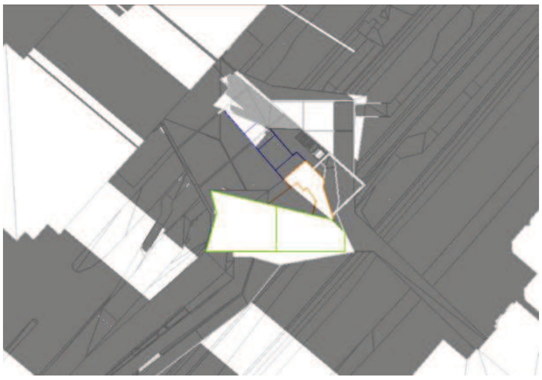
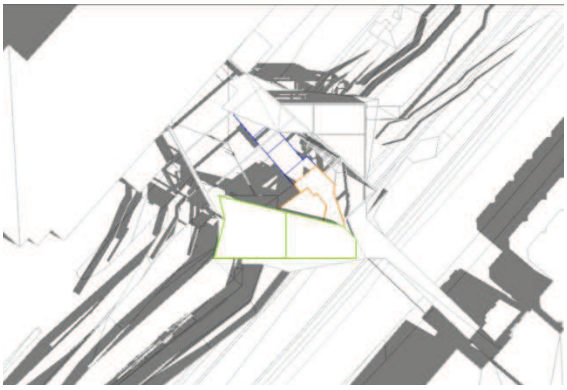


Figure 5.38 : February



Fgure5.39: May

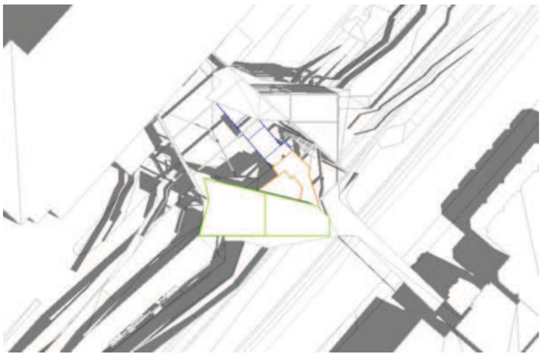


Figure 5.40: August

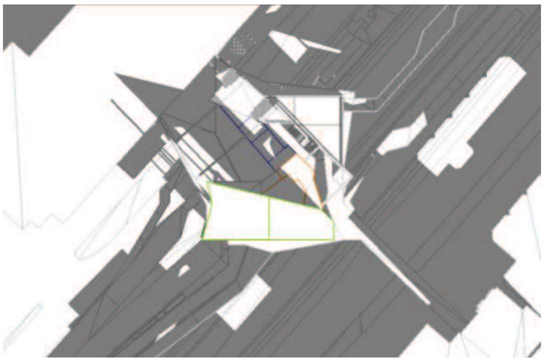


Figure5.41: November

Fig 5.38 shows in February, shadow on the building in the morning with sun towards south east. It is evident that a long shadow will be formed due to lowest sun height about the horizon and the sunrays will almost penetrate inside the building. The most part of platform including the room of lockers are in the shadow of MPU(highlighted by green lines) and Foyer of Seating Area(highlighted by orange lines). In the meant while, the sunlight enters into the main entrance of Foyer of Seating Area, and the multifunctional building (MPU) is exposed into sunshine.

Fig 5.40 showsin August, shadow on the building in the morning with sun towards south east. However, contrary to winter solstice the sun is at the highest point about the horizon and the sun rays will be almost perpendicular to the building so the shadow will be very short as shown in the figure. Summer solstice is the longest day of the year with maximun sun exposure.

Fig 5.39 and 5.41 shows shadow in May and November respectively. It is to be noted that the main buildings (MPU, Foyer of Seating Area) are exposed in the sunshine all the time in the morning, which gain solar radiation at a maximum level, which benefits for the passive energy performance on those buildings.

Shadows a12:00 :

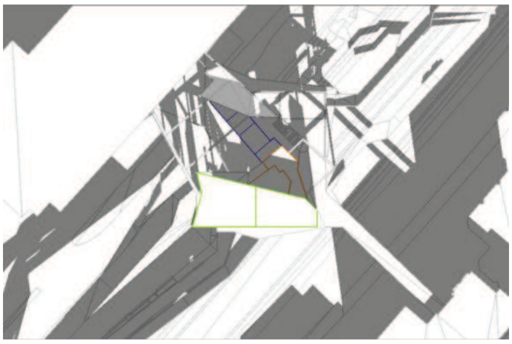


Figure 5.42: February

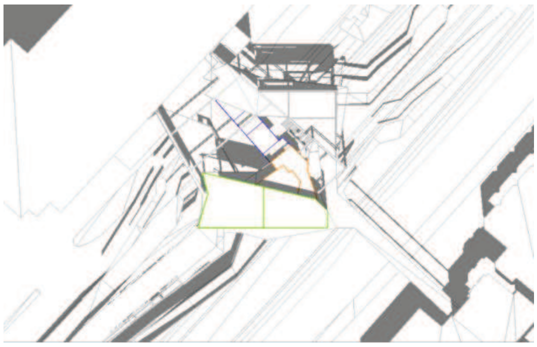


Figure5.43: May

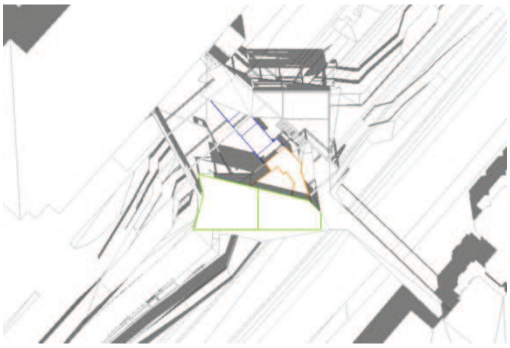


Figure 5.44: August

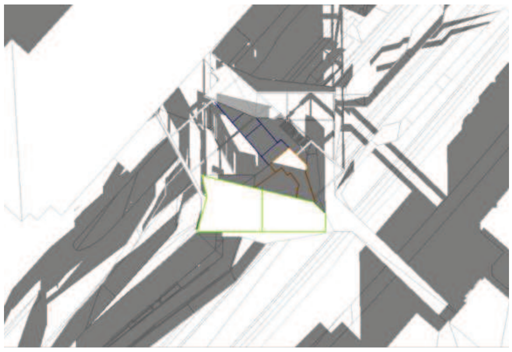


Figure5.45: November

All the above figures shows the different shadow of analysis of the same building with different sun positions in February, March, August, November, respectively. The phenomenon has been explained above. The only difference is the time of the day. These shadow analysis are for noon i.e. 12:00 pm or at "Zenith". In winter solar radiations are entering the building as its southern façade with lot of glazed area. The sunlight is necessary even in summer time, while due to the low solar angle in winter, there may be such need to protect the so shining direct sunshine into windows.

Shadows at 16:00 :

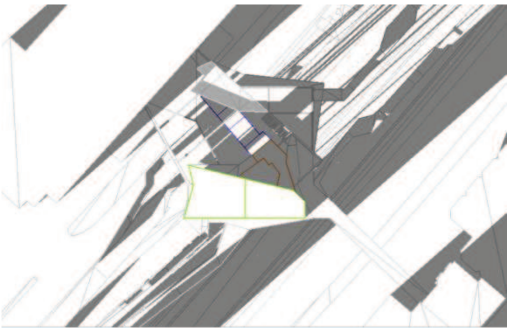


Figure 5.46 : February

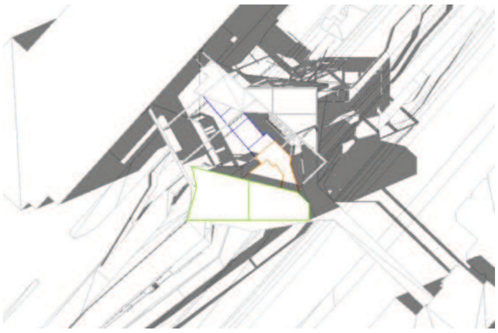


Figure5.47: May

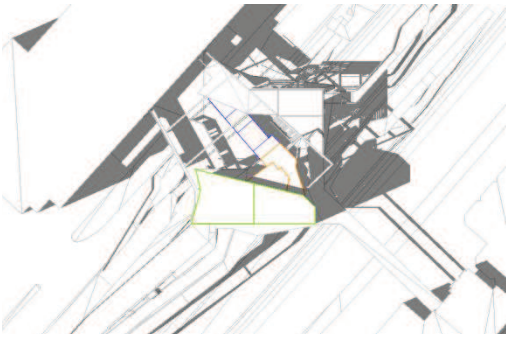


Figure 5.48: August

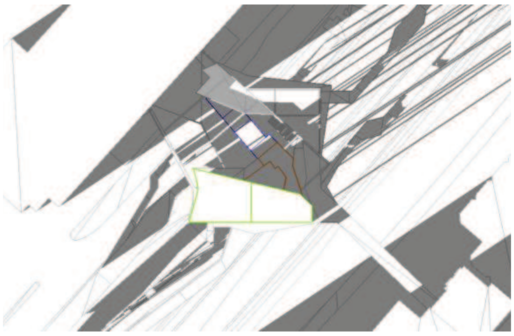


Figure5.49: November

Fig 5.46, 5.47, 5.48 and 5.49 shows the different shadow of analysis of the same building with different sun positions in February, May, August and November, respectively. The phenomenon has been explained above. The only difference is the time of the day. These shadow analysis are for 16:00 when sun is at lower position and penetrating the building from Western so we may need protection for sight of people from direct solar rays.

5.5.1.3Shadow range of building in a day catalogued by seasons

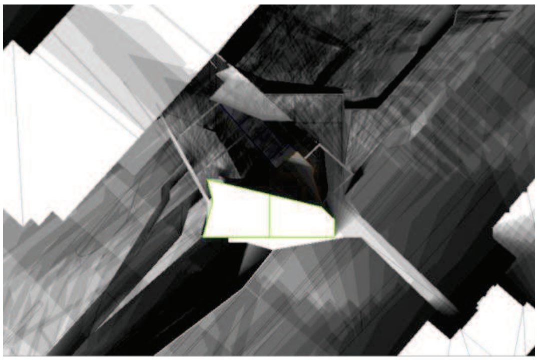


Figure 5.50 : February

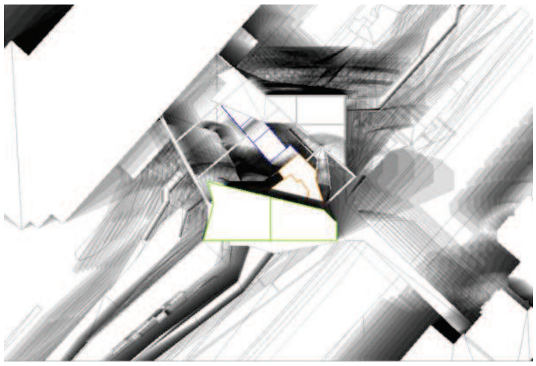


Figure5.51: May

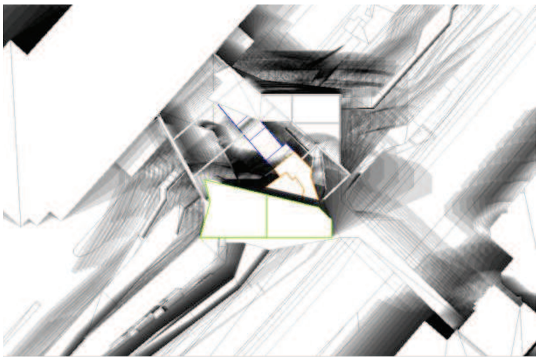


Figure 5.52: August

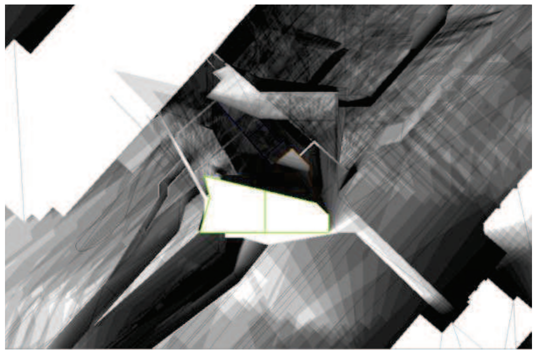


Figure5.53: November

This analysis explains the shadow range of the building. We can see that in Fig 5.50 the shadow is the longest one which is due to winter season. Fig 5.52 has the shortest shadow in summer because the sun is at the highest altitude. Fig 5.51&5.53 has moderate shadows due to May and November when the position of the sun is intermediate.

5.5.1.4Comparison between primary and final form of the building

Shadow range on 2nd February

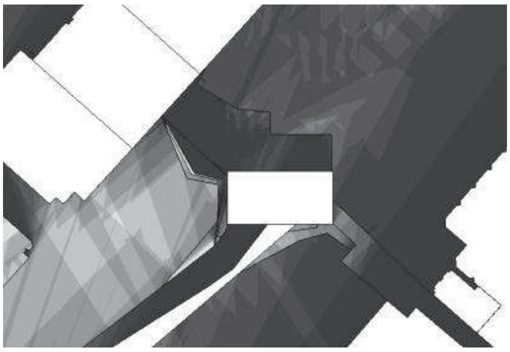


Figure 5.54 Primary form

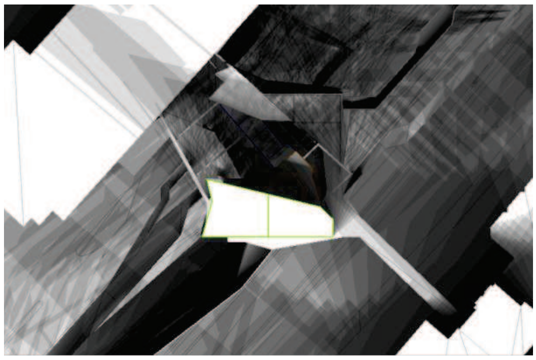


Figure 5.55 Final form

Shadow range on 2nd August

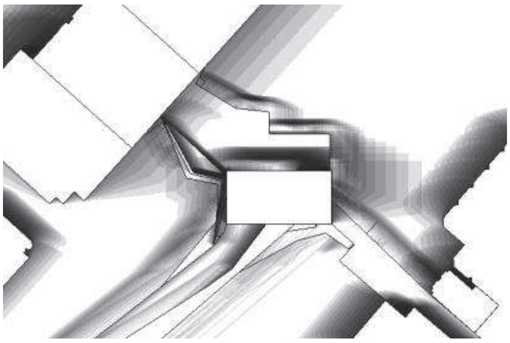


Figure 5.56 Primary form

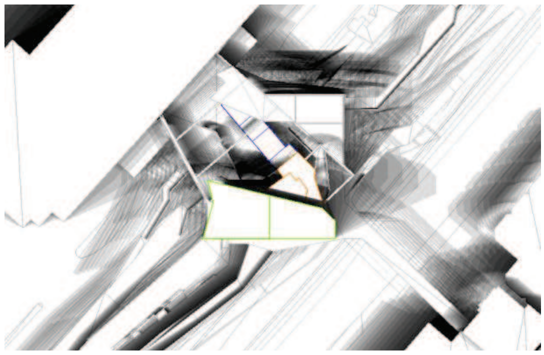


Figure5.57 Final form

After comparison between the two concepts, we have conclusions below :

Both concepts consider the best orientation of main facade of building, which achieve good passive solar performance in both solutions. On the other hand, because of the variation of shape in plan, shadow range in each season on the final concept gain more visible interests from an architectural point of view, which would leave more special impression to people in the building and attract more attention from people. So we can say that, the final concept appears to be a better solution to our project.

`
5.5.2Calculation of daylight factor

The use of natural light or day lighting has traditionally been a desirable building feature and a hallmark of good design. It is the practice of bringing light into a building interior and distributing it in a way that provides more desirable and better quality illumination than artificial light sources. This reduces the need for electrical light sources, thus cutting down on electricity use and its associated costs and pollution.

We introduced daylight that creates an ambience of quiet contemplation and visual comfort by the correct placement of openings in the building envelope to allow light penetration while providing adequate distribution and diffusion of the light. Our building system also avoids excessive thermal gains and excessive brightness resulting from direct sunlight, which can impair vision and cause discomfort using shades.

Standards for Daylight factor calculation:

Average DF	Appearance	Energy implications
< 2%	Room looks gloomy	Electric lighting needed most of the day.
2% to 5%	Predominantly daylight appearance, supplementary artificial lighting is needed	Good balance between lighting and thermal aspects.
> 6%	Room appears strongly daylight	Daytime electric lighting rarely needed, but potential for thermal problems due to overheating in summer and heat losses in

Table 5.39

<u>Day light factor (Split flux method):</u>

In the method, the room is considered as a closed box into which light is admitted through an aperture that can be a window or a door. The various ways the light can enter the room is basically distinguished into three categories:

<u>Sky component (SC):</u>

The Sky Component (SC), light coming from the visible part of the sky.

- On BRS protractor SC is calculated only above 1m.

  Final SC = SC * Correction Factor

Externally reflected component (ERC):

The Externally reflected component (ERC), light reflected from opposing surfaces.

- In our project calculation, we considered ERC as zero as around building huge area is allocated for landscaping & height of boundary wall is less.

Internally reflected component (IRC):

The Internally reflected component (IRC), light arriving from infinite possible paths.

A= Window area/ Total Surface area(Ceiling+ walls+ Floor area)

Average Reflectance = All Walls area/ Total surface area
B = Value from table against average reflectance value & 70% (As color of external walls is white so they reflect more light).
C & D scales are used if there is any obstruction.

DF Equation:
Finally, Daylight Factor
(DF) = SC + ERC + IRC.

With the use of the set of protractors developed by the building research station we are able to calculate the Sky Component (SC).
DF = (SC + ERC + IRC) x M x G x B
where,
M: maintenance factor
G: glass factor
B: bars or framing factor

<u>Ecotect simulation:</u>
<u>Foyer</u>

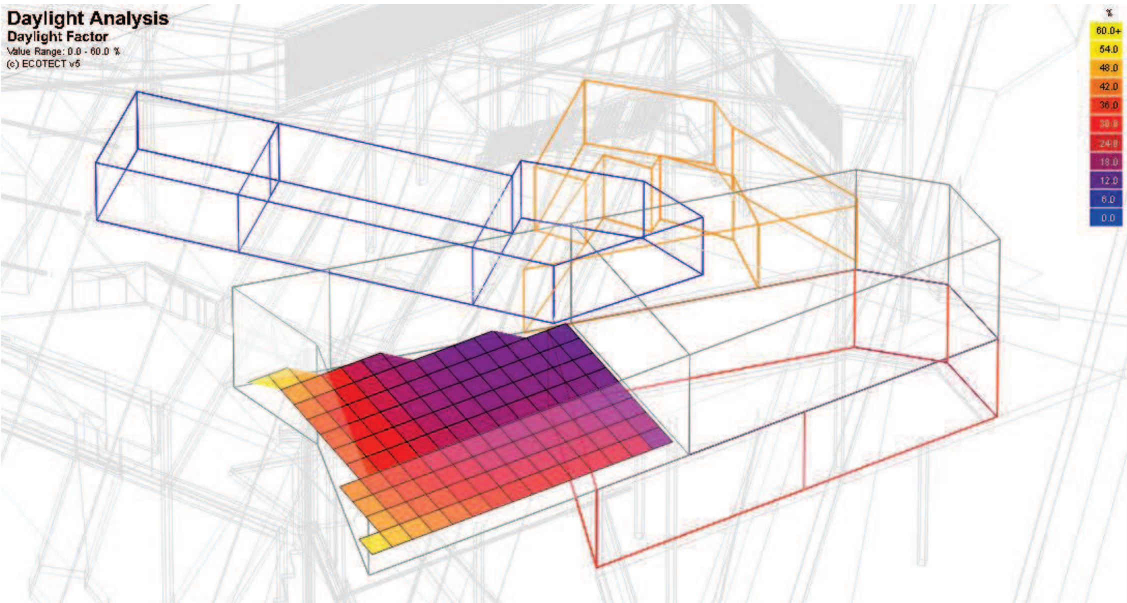


Figure 5.58

Average value of DLF = 18%, Min value of DLF = 6%, Max value of DLF = 60.0%

The foyer of multifunctional building is designed as a glazing box, which has a great view on surrounding scene. But somehow ,the maximum value of daylight factor is up to 60%, that may be too much for daylight in the room. On the other hand, the solar energy carried by solar

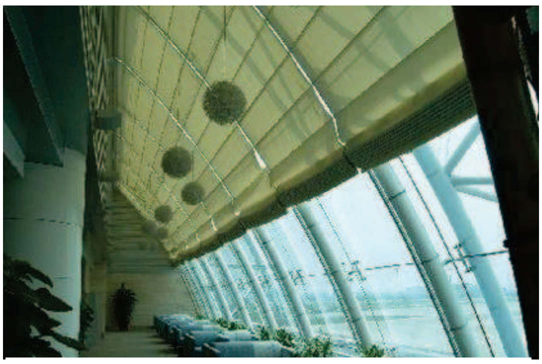


Figure 5.59 Automatic curtains system

raysbenefits for the passive energy performance, so we proposed indoor curtains system to reduce the so much daylight when it is necessary and minimize the impact on solar energy gain into inner space.

Ticket Office

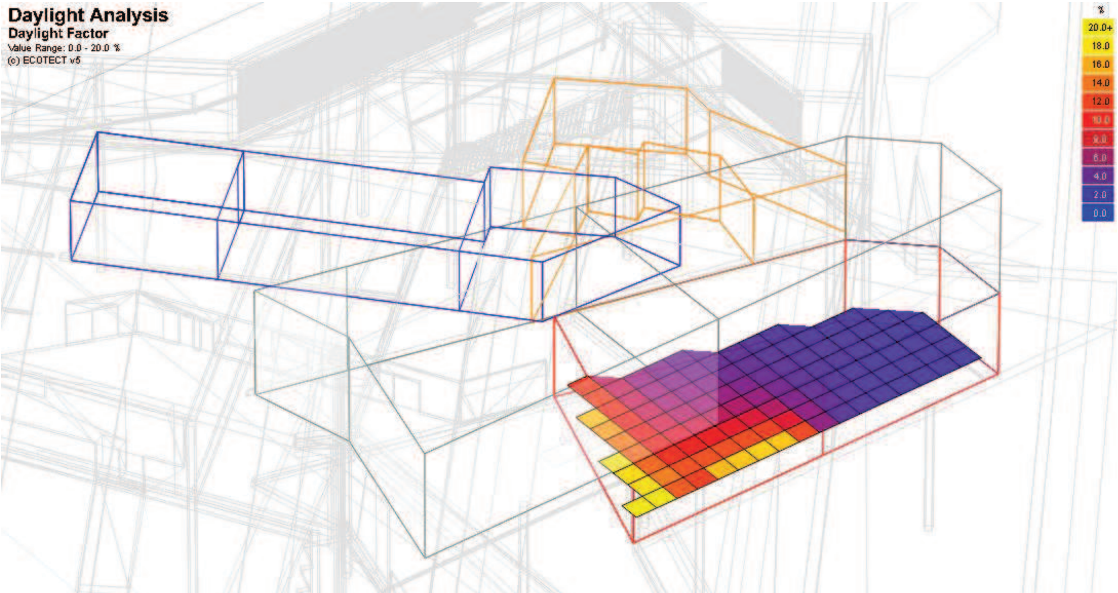


Figure 5.60

Average value of DLF = 8.0%, Min value of DLF = 2.0%, Max value of DLF = 20.0%
The ticket office has large scale of glazing on the west facade and half of the south facade. Considering the high value of daylight factor (20%), automatic curtains system is also proposed to be installed on the inner side of glazing.

Seating Area

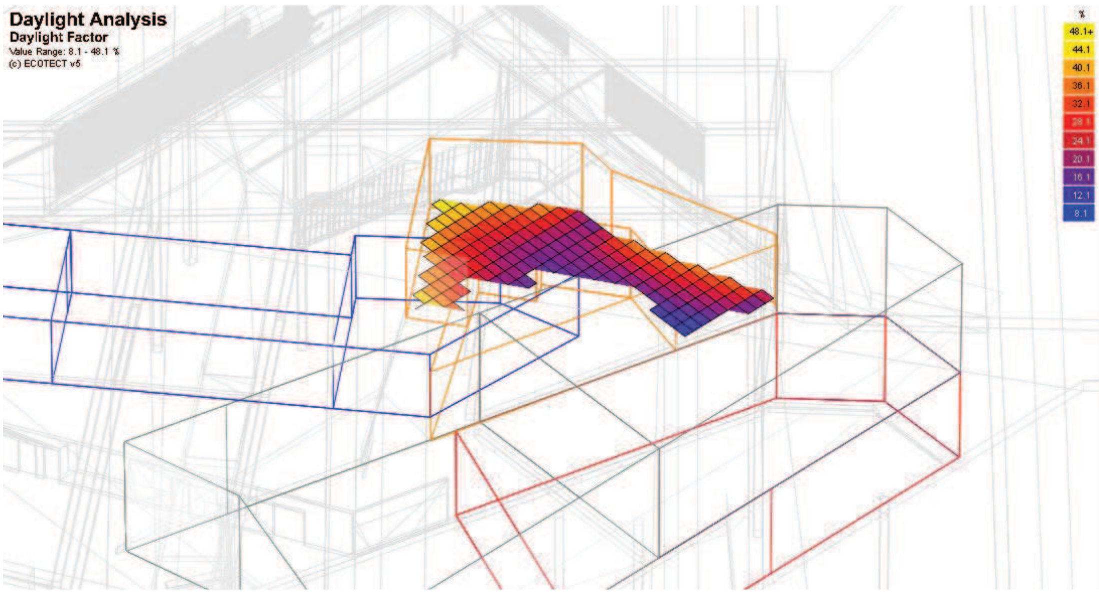


Figure 5.61

Average value of DLF = 24.1%, Min value of DLF = 12.1%, Max value of DLF = 48.1%

The foyer of seating area is designed as glazing box with large glazing facade. Considering the high value of daylight factor (48.1%), automatic curtains system is also proposed to be installed on the inner side of glazing, as well.

Lockers

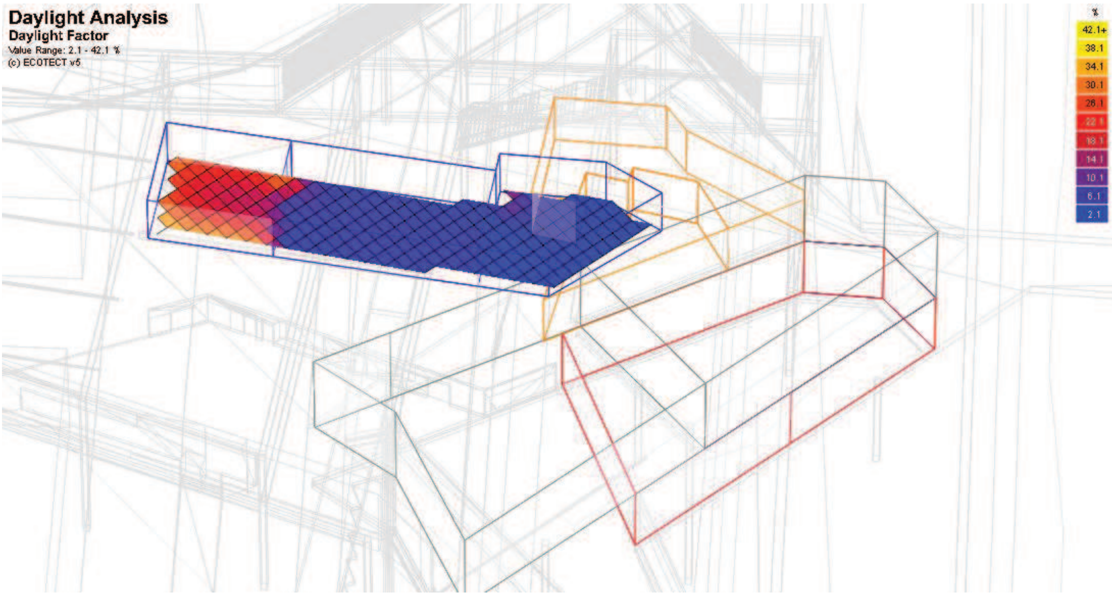


Figure 5.62

<u>For glazing room</u>:
Average value of DLF = 18.1%, Min value of DLF = 14.1%, Max value of DLF = 34.1%
The so called glazing room is a glazing box, due to high value of daylight factor (341%), automatic curtains system is also proposed to be installed on the inner side of glazing, as well.

<u>For inner rooms</u>:
Average value of DLF = 6.1%, Min value of DLF = 2.1%, Max value of DLF = 10.1%
For the inner rooms in this zone, the daylight factor is quite appropriate.

5.6Integrated building systems

5.6.1PV system

Most commonly known as "solar cells," PV systems are already an important part of our lives. The simplest systems power many of the small calculators and wrist watches we use every day. More complicated systems provide electricity for pumping water, powering communications equipment, and even lighting our homes and running our appliances. In a surprising number of cases, PV power is the cheapest form of electricity for performing these tasks.

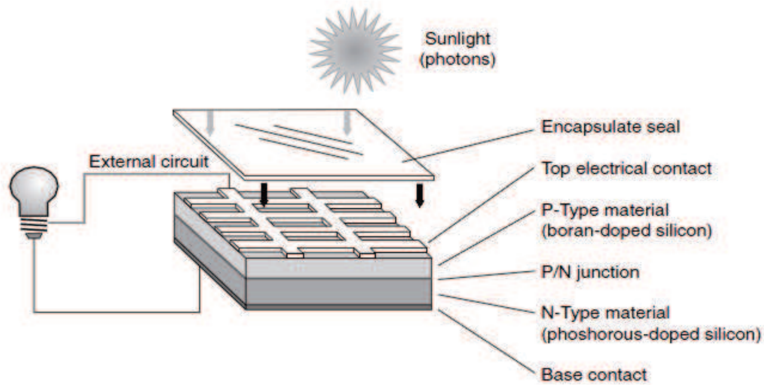


Figure 5.63 Basic solar cell construction

PV cells convert sunlight directly into electricity without creating any air or water pollution. PV cells are made of at least two layers of semi conductor material. One layer has a positive charge, the other negative. When light enters the cell, some of the photons from the light are absorbed by the semi conductor atoms, freeing electrons from the cell's negative layer to flow through an external circuit and back into the positive layer. This flow of electrons produces electric current.

<u>In our project</u>, we proposed a grid-connected system.

A grid connected system is connected to a large independent grid (typically the public electricity grid) and feeds power either directly into a residential or commercial building or back into the grid. This is a form of decentralized electricity generation. In the case of building mounted grid connected PV systems, the power generated is fed into the building, and any additional power needed beyond what is being produced by the system is delivered by the grid. If power is produced in excess of what is needed by the building, it is fed back into the grid. The feeding of electricity into the grid requires the transformation of DC into AC by a special, grid-controlled solar inverter.

5.6.1.1Pre design analysis

Conceptual analysis

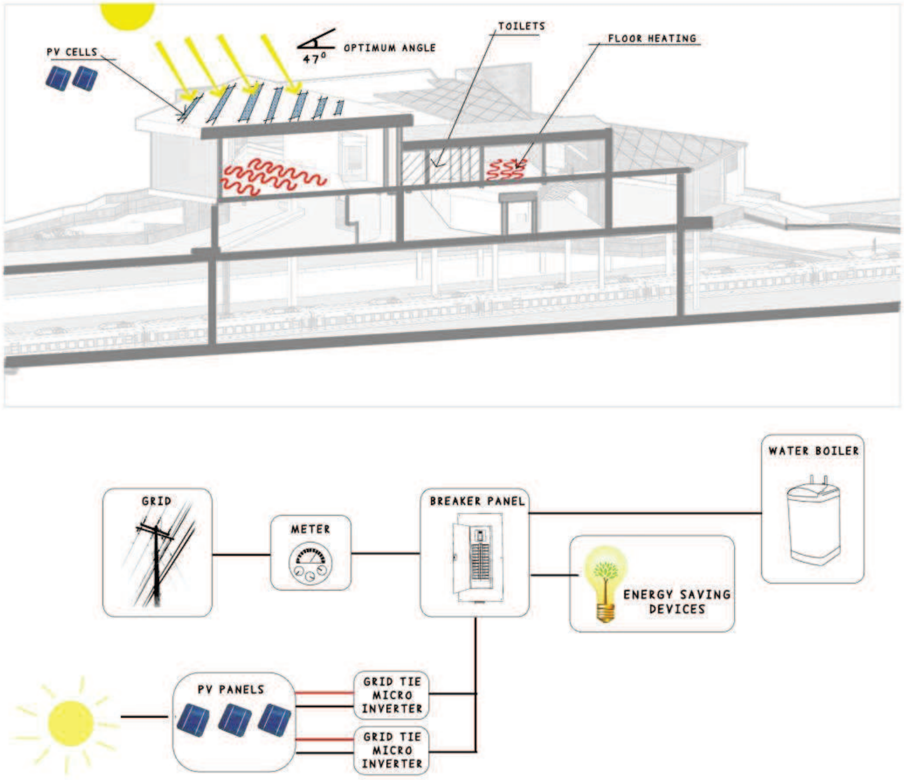


Figure 5.64 Schematic for PV system-grid connection

Solar exposure analysis

Main focus on the solar access on the roof of MPU, to check the potential solar energy obtained where the PVP system is going to be installed.

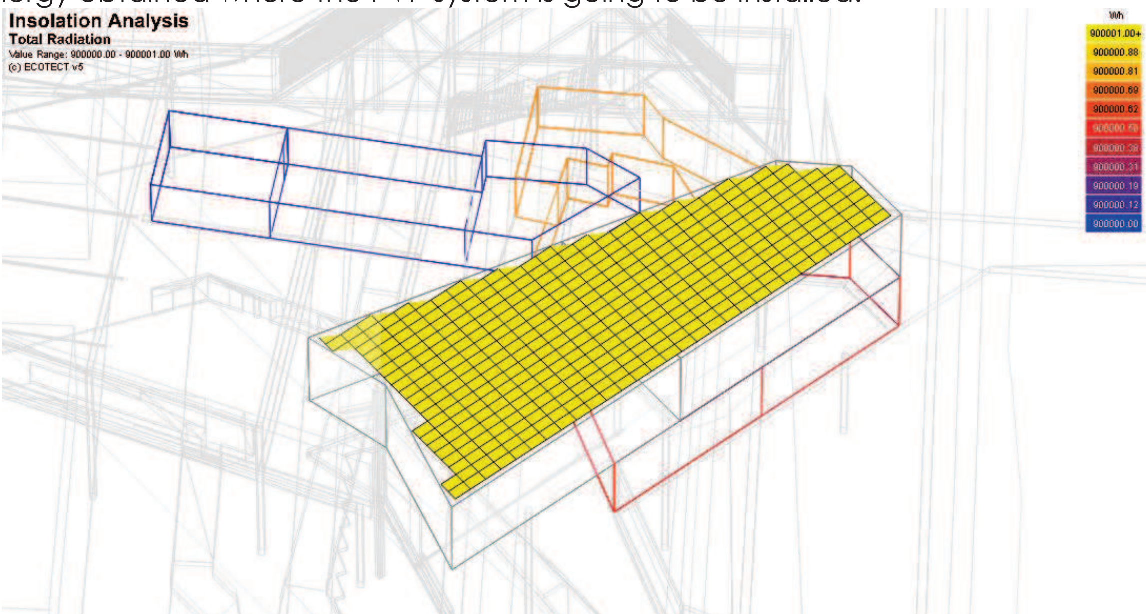


Figure5.65 Solar exposure analysis for MPU roof

Area = 513M^2
Total Radiation Gain 900000Wh per unit area per year, that is to say 900 kWh/m^{2}. A

5.5.4.3Design process

We proposed PV cells system as our additional energy supplier. According to Standard SFS EN 15316-4-6:2007, we can calculate the electric energy $E_{s,pv,out}$ [kWh/a] produced by a photovoltaic system connected to the building:

$$E_{s,pv,out} = \frac{Esol * Pmax * Fusage}{Iref}$$

$E_{sol}$is the annual radiant energy directed at photovoltaic cells [kWh/m$^2 \cdot$ a]
P_{max} is maximum electric power produced by photovoltaic cells whose cells produce in reference
radiation (I_{ref}=1 kW/m^2, at reference temperature 25 ˚C) [kW]
F_{usage} performance factor for the usage scenario [-]
I_{ref} reference radiation [1 kWh/m^2]

The solar radiation directed at the cells during a year is calculated using Equation below:
$E_{sol} = E_{sol,hor} \times F_{position}$

where:
$E_{sol,hor}$ is the annual amount of total solar radiant energy directed at a horizontal area which is
dependent on the building location [kWh/m^2,a]. From Tables 5.40
$F_{position}$ correction factor for photovoltaic cell direction and inclination angle [-]. From Tables 5.40

The maximum electric power P_{max} produced by the photovoltaic cells is the device's tested power under
standard conditions. The method is described in standard EN61829. If a test result is not available, P_{max}
is calculated using Equation below:

$P_{max} = K_{max} A$

where:
$K_{max}$is the maximum power coefficient, which depends on the solar cell type. [kW/m^2] From Tables 5.40
The correction factor $F_{position}$ for compass direction and inclination angle is calculated using Equation below:

$F_{position} = F_1 \times F_2$
whereF_1 is the factor for the compass direction
whereF_2 is the factor for inclination angle

F_1 is the factor for the compass direction (-).

Facing	F1
south/southeast/southwest	1
east/west	0.8
north/northeast/northwest	0.6

F_2 is the factor for inclination angle (-)

Inclination angle	Factor
<30°	1
30°...70°	1.2
>70°	1

Maximum power coefficient K_{max}, which depends on the photovoltaic cell type (kW/m^2

Photovoltaic cell type	Maximum power coefficient K_{max} kW/m^2
Monocrystalline silicon cells *	0.12...0.18
Multicrystalline silicon cells *	0.10...0.16
Thin-film silicon cells	0.04...0.08
Other thin-film cells	0.035
Thin-film $CuInGaSe_2$ solar cell	0.105
Thin-film CdTe solar cell	0.095
* Packing density >80 %	

Performance factor for the usage scenario F_{usage}[-]

Installation method for the photovoltaic cell	Performance factor for the usage scenario F_{usage}[-]
Module without ventilation	0.70
Module with light ventilation	0.75
Module with heavy ventilation or mechanical ventilation	0.80

Tables 5.40

$E_{sol,hor}$ = 900 kWh/m^2 a
Faceing : south - F_1 =1 ,inclination angle : 47° - F_2 = 1.2 , so $F_{position}$ = 1 x 1.2 =1.2.
then we get E_{sol} = $E_{sol,hor}$ x $F_{position}$ = 900 * 1.2 = 1080 kWh/m^2 a

Monocrystalline silicon cells :Kmax = 0.18 kW/m^2 , A = 1447 m^2. So P_{max} = 0.18 x 513 = 92.34 kW.
Module with heavy ventilation: F_{Usage} = 0.8

so we have :

$$E_{s,pv,out} = \frac{Esol * Pmax * Fusage}{Iref} = \frac{1080 * 92.34 * 0.8}{1} = 79781.76\ kW/a.$$

which is the energy produced from PV cells system.

5.6.1.3Energy efficiency of proposed system

Total Energy generated	*79781.76*	KWh/a
Heating load demand	*102712.4*	KWh/a
Total energy demand	*256781*	KWh/a
Efficiency in terms of total energy demand	31.1	%

Table 5.41 Energy efficiency

From the Table 5.29 ,we finally get the efficiency of proposed system is 31.1%. That is to say, the energy from exterior suppliers is *256781 * (1- 31.1%)* = 176999 KWh/a, in unit area :176999/ 1147 = 154.3 KWh/m^2·a. So the total primary energy demand from public power suppliers is **154.3 KWh/m² · a**, which is lower than a code requirement of 170 KWh/m² · a.

5.6.2 Rain Water collection System

Conceptual analysis

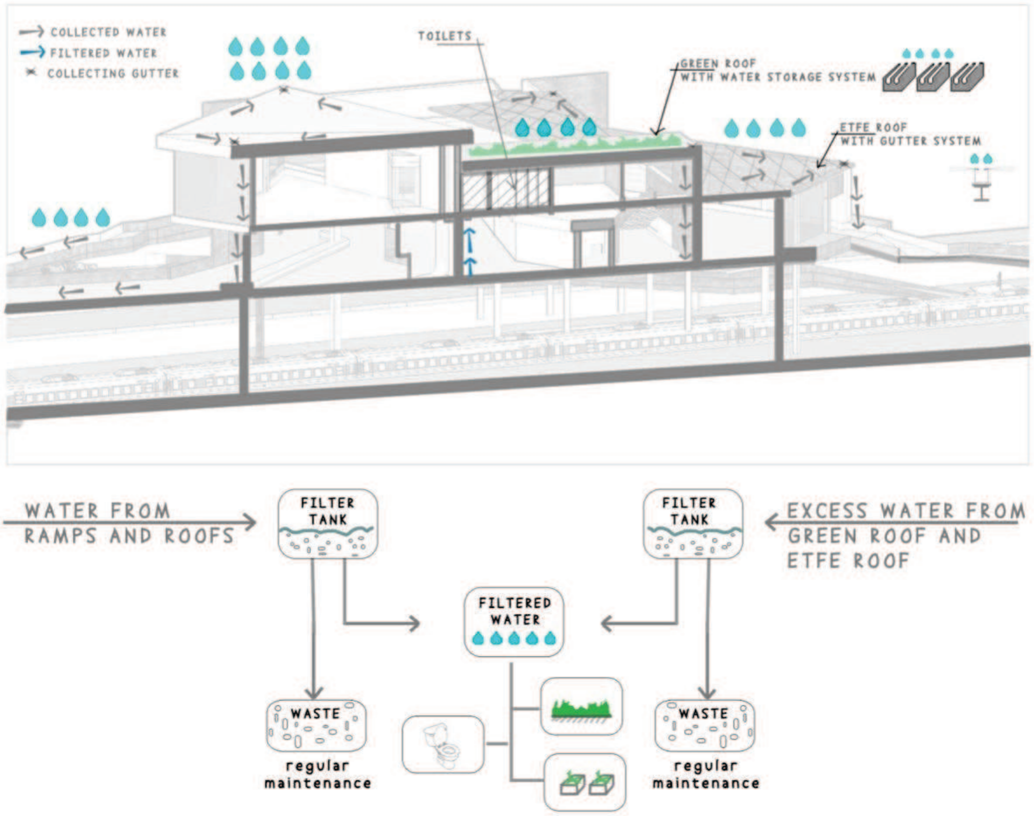


Figure 5.66 Schematic diagrams for rain collection system

5.6.3 HVAC system

5.6.3.1 Radiant floor heating system

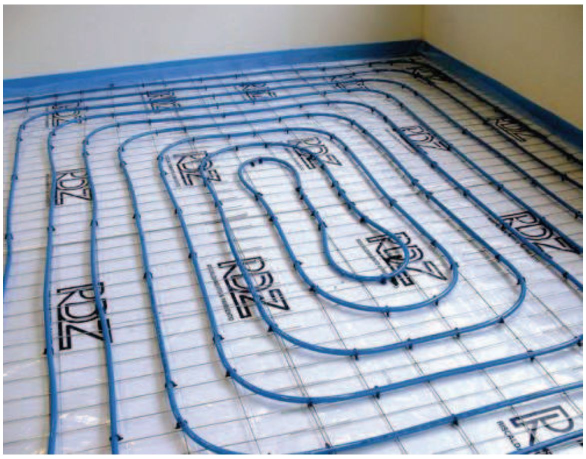


Fig. 5.67 heating wires system

Under floor heating and cooling is a form of central heating and cooling which achieves indoor climate control for thermal comfort using conduction, radiation and convection. The terms radiant heating and radiant cooling are commonly used to describe this approach because radiation is responsible for a significant portion of the resulting thermal comfort but this usage is technically correct only when radiation composes more than 50% of the heat exchanged between the floor and the rest of the space.

Modern under-floor heating systems use either electrical resistance elements ("electric systems") to heat the floor. Either type can be installed as the primary, whole-building heating system or as localized floor heating for thermal comfort.

In our project, we proposed the electrical systems. Because electrical resistance can only be used for heating and we do not have such need for cooling. Other applications for which either electric or systems are suited include snow/ice melting for walks, driveways and landing pads, turf conditioning of football and soccer fields and frost prevention in freezers and skating rinks.

Electric heating elements can be cast in a concrete floor slab ("poured floor system" or "wet system"). They can also be placed under the floor covering ("dry system") or attached directly to a wood sub floor ("sub floor system" or "dry system").

(source: http://en.wikipedia.org/wiki/Underfloor_heating)

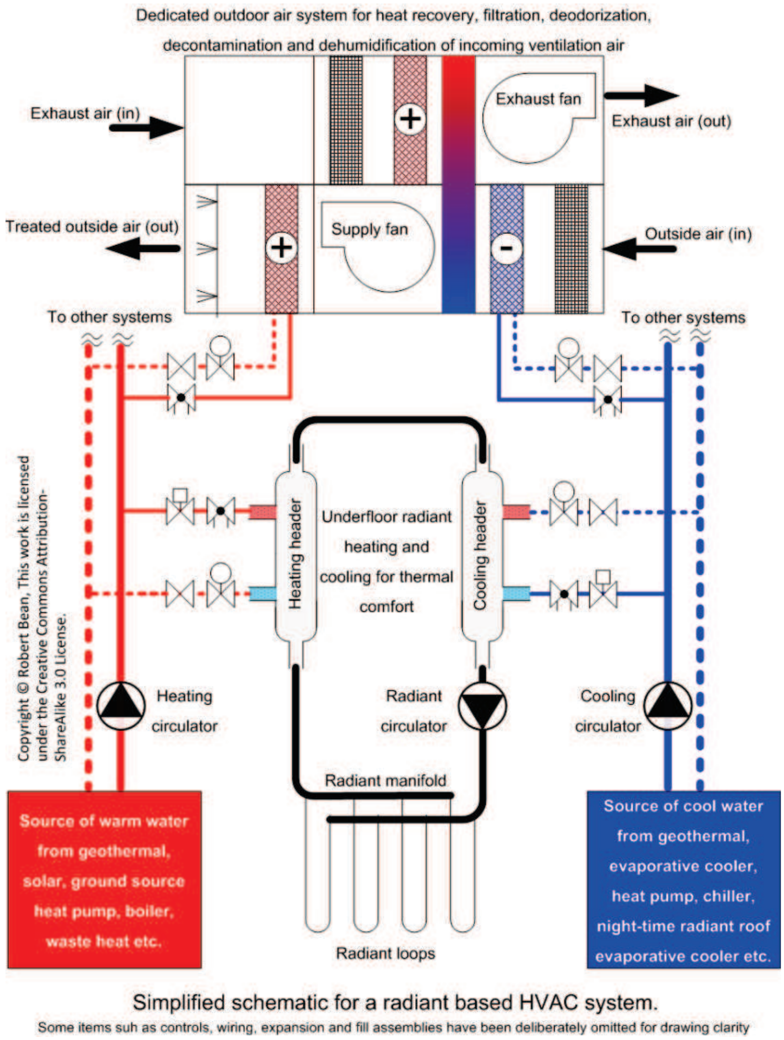


Fig. 5.68 Radiant based HVAC system for heating

5.6.3.2Heat recovery system

In heating, ventilation and air-conditioning systems, HVAC, heat pipes are positioned within the supply and exhaust air streams of an air handling system, or in the exhaust gases of an industrial process, in order to recover the heat energy.

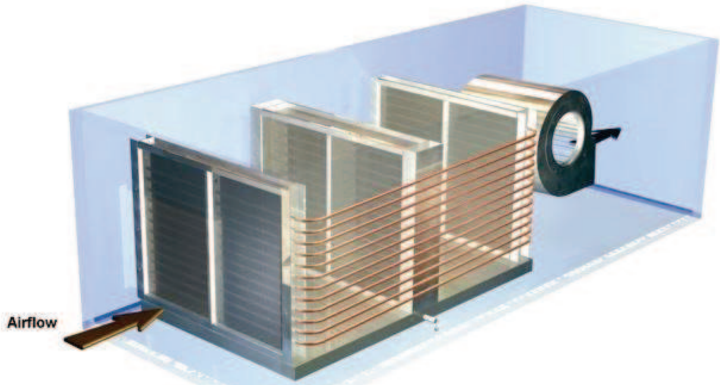


Fig. 5.69 Heat pipes for energy recovery

The device consists of a battery of multi-row finned heat pipe tubes located within both the supply and exhaust air streams. Within the exhaust air side of the heat pipe, the refrigerant evaporates, taking its heat from the extract air. The refrigerant vapor moves towards the cooler end of the tube, within the supply air side of the device, where it condenses and gives up its heat. The condensed refrigerant returns by a combination of gravity and capillary action in the wick. Thus heat is transferred from the exhaust air stream through the tube wall to the refrigerant, and then from the refrigerant through the tube wall to the supply air stream.

Because of the characteristics of the device, better efficiencies are obtained when the unit is positioned upright with the supply air side mounted over the exhaust air side, this allows the liquid refrigerant to flow quickly under gravity back to the evaporator. Generally, gross heat transfer efficiencies of up to 75% are claimed by manufacturers.

Heat pipes significantly improve the effectiveness of dehumidification systems. They can double the moisture extraction rate while improving the quality of the recycled air. And it's all done at zero running cost.

The heat pipe advantage:

- No moving parts
- No direct energy input
- Totally passive
- Up to twice as much moisture extraction
- No need for reheat or desiccant systems
- Easy drainage of condensation
- Long-lasting – may well outlast the air conditioning system
- Virtually maintenance-free
- Environmentally safe

(source: http://en.wikipedia.org/wiki/Heat

Appendix 1

Performance of Grid-connected PV

PVGIS estimates of solar electricity generation

Location: 60°15'3" North, 25°0'38" East, Elevation: 15 m a.s.l.,
Solar radiation database used: PVGIS-classic

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 7.4% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.0%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 22.7%

	Fixed system: inclination=40 deg., orientation=0 deg. (Optimum at given orientation)			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	0.50	15.4	0.57	17.6
Feb	1.63	45.8	1.90	53.1
Mar	2.53	78.5	3.05	94.6
Apr	3.65	110	4.63	139
May	4.24	131	5.58	173
Jun	4.14	124	5.61	168
Jul	4.13	128	5.66	175
Aug	3.21	99.5	4.33	134
Sep	2.25	67.4	2.90	87.1
Oct	1.29	40.1	1.59	49.3
Nov	0.50	14.9	0.59	17.6
Dec	0.28	8.56	0.32	9.82
Year	2.36	71.9	3.07	93.3
Total for year		863		1120

	Inclined axis tracking system optimal inclination=47°			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	0.58	17.9	0.65	20.2
Feb	2.05	57.3	2.38	66.5
Mar	3.30	102	3.97	123
Apr	5.12	154	6.41	192
May	6.31	195	8.12	252
Jun	6.12	184	8.06	242
Jul	6.10	189	8.15	253
Aug	4.33	134	5.74	178
Sep	2.86	85.8	3.66	110
Oct	1.57	48.6	1.92	59.4
Nov	0.57	17.1	0.67	19.9
Dec	0.31	9.75	0.36	11.1
Year	3.27	99.6	4.18	127
Total for year		1190		1530

Ed: Average daily electricity production from the given system (kWh)

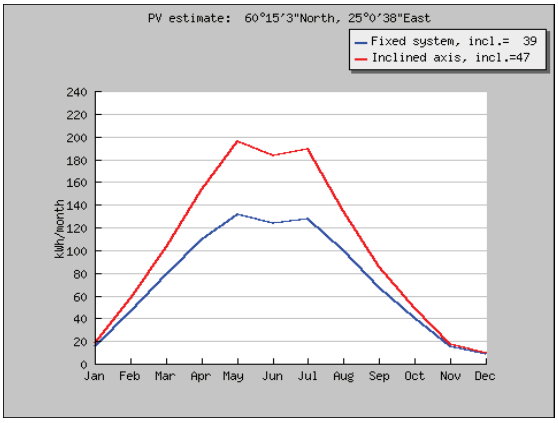
Em: Average monthly electricity production from the given system (kWh)

Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

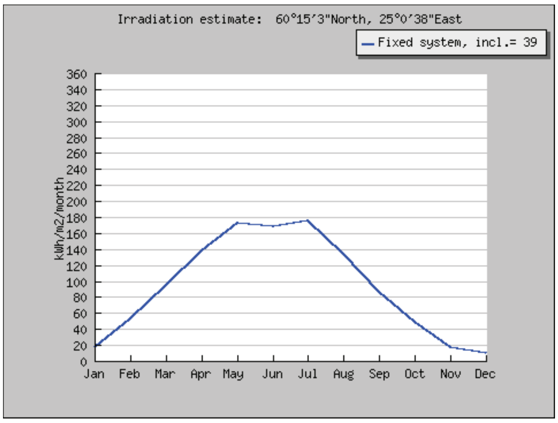
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Photovoltaic Geographical Information System

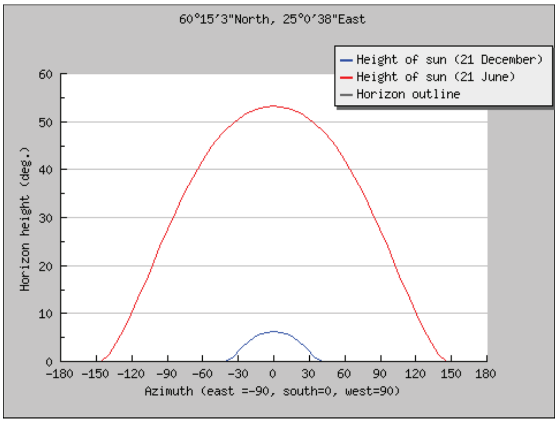
European Commission
Joint Research Centre
Ispra, Italy



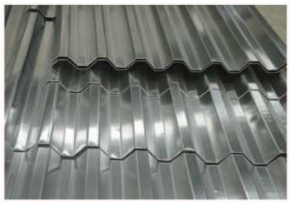
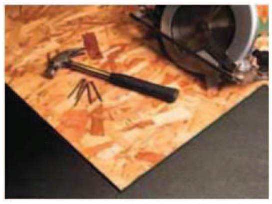
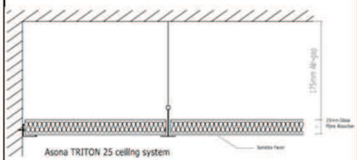
Monthly energy output from fixed-angle PV system



Monthly in-plane irradiation for fixed angle



Outline of horizon with sun path for winter and summer solstice

LIST OF MANFACTURERS					
MATERIAL	**USED IN**	**DIMENSIONS**	**SPECIFICATION**	**MANFACTURE NAME**	**IMAGE**
Construction materials					
Fibrecement Board	Walls	Up to 4000 x 5000 mm and 150-180 mm in thickness	*U value:0.8-1.2 W/m2K *Density:350-400 kg/m3	Cembrit	
Waterproof Membrane	Foundation. Slabs and roofs	6 mm in thickness	*High elasticity *-40ºC to +70ºC	Sika	
Corrugated Metal Sheet	Slabs	1 mm in thickness	*Lightweight *High strength *Easy installation *High durability	Kalzip	
OSB board	Slabs	25mm - 50mm in thickness	*The thermal conductivity (λ)+0.13 W/m.K *The value of the water vapour resistance factor (μ) 30 to 40	GLUNZ	
Finishing materials					
Composite Glass Acoustical Panel	Suspended Ceiling	300-1200 mm in Width 400-2400 mm in Length	*Density :48 kg / m3 *Class A high sound absorbing glass fibre	asona	
XPS	Slabs Walls	600 x 1250 x 50 mm	*U value:0.011 W/m2K *High moisture resistance and compressive strength	DOW	
Ceramic	Bathroom	*Unit size of 200 x 200 mm	*Mediterraneo blue	VitrA Bathroom Culture	
Paint	Walls		*Life span up to 20 years *High UV resistance *Water and moisture resistance	JOTUN	
Cor-ten steel	Walls	var.	*cor-ten A for thick ≤ 16mm *cor-ten B for thickness ≥16mm	Proteus ENGINEERED FACADE TECHNOLOGY