POLITECNICO DI MILANO

VI FACULTY OF ENGINEERING
POLO REGIONALE DI LECCO

MASTER OF SCIENCE IN ARCHITECTURAL ENGINEERING

MASTER THESIS

Designing of Transitional Confluence:

Davutpasa Auditorium

Istanbul, Turkey

Relatore: Professor Massimo Tadi
Correlatore: Gabriele Masera

Master Thesis of
Ali Mahroo 767228
Yunus Cem Duran 765129
Nancy Guddi Tirkey 767065

April 2013

Acknowledgements

We would like to gratefully acknowledge our following Professors for their flexibility, invaluable time and guidelines which provided us a continuous stimulus by paving our task in a smoother way.

Professor Massimo Tadi

Professor Gabriele Masera

Professor Liberato Ferrara

We would also like to thank our family and friends for their loving support and motivation. Last but not the least our University Politecnico di Milano staffs for providing us help in the administrative formalities for submission of the work.

Ali Mahroo
Yunus Cem Duran
Nancy Guddi Tirkey

April 2013

Abstract

The ambience of the university campus has a special resonance. Apart from the functional necessity, the building and the landscape forms the heart and soul of the institution. The purpose of this project is to design and utilize the campus derelict land asset to its full potential. Through adroit planning choice, the entire environment can be shaped into an expression of institutional identity and ambition. We have chosen a competition in Istanbul, Turkey, which constitute of urban, architectural, structural and technological aspects. The aspect of the competition is provided in chapter 1.

Davutpasa campus is a part of Yildiz Technical University which has a noteworthy historical landmark and we designed a cultural space for linking the fragmented active faculty department and also the urban fabric with the institution. Our concept is based more on architectural and landscape design which offers great opportunity for requalification and transitional confluence. Initially, for developing the concept we analyzed the site and its circumference, then incorporated these analysis into the architectural design of auditorium in a sustainable way. Structural modeling is accomplished with the help of SAP 2000 software, and necessary design checks are done manually. Heating and cooling load analysis, light analysis, shadow analysis and sun path diagram is developed in Ecotect software for the Technological section.

In the following chapters we have explained the details and design procedure along with the drawings to cover every related topics. Subsequently we have taken care of the standards and codes to fulfill the requirements.

Keywords: *Auditorium, campus, landscape concept, design, requalification, linking, confluence*

CONTENT

CHAPTER 1

INTRODUCING DAVUTPASA COMPETITION

1.1 Competition Brief

1.1.1 Objective

By this competition it has been aimed to encourage architecture students to produce inventive ideas to create spaces in which university ceremonies, spring festivals, and concerts can be held, while taking into account the historical context of Davutpasa Barracks being located at the center of the campus. Competitors are expected to have designs that are;

- Capable of sustaining various activities throughout the year
- In harmony with the natural environment inside the campus
- Offering temporary and/or permanent construction processes for different activities
- Considering the durability and economical aspects of these temporary and/or permanent constructions
- Compatible to the surroundings within campus

1.1.2 Competition Requirements

Activity area is predicted to be used for ceremonies, festivals, concerts, and exhibitions that will be held by the University. Graduation ceremonies that take place in summer should also be taken into account.

Competitors are expected to consider the relation of the ceremony area with inside and outside the University campus (public transportation spots, etc.). The bus park that is located inside the competition area is not to be considered due to the assumption of it being relocated. Supposing that the need of car parking is satisfied with the existing car parking lots all over the campus; it is not mandatory for competitors to make a proposal for that.

Area: Yildiz Technical University, Davutpasa Campus (44470 m2)

Number of Spectators: Activity area for 5000 among which 1000 people will be seated

Stage: 200-300 m2, the floor should be fixed.

Seating area and the Enclosure: Whether the seating area is enclosed totally or not, is up to the competitor. Seating area can be temporary or permanent.

Café: Should be adoptable to be used in daily campus life, providing closed space for 60-75 people and open space for 100 people

Stalls: Temporary or permanent and to be used in activities.

1.2 Location

1.2.1 About Istanbul

Istanbul is the capital of Turkey, which had been an attractive settlement for various civilizations since ancient times. It is located at 41.01 º North and 28.97 º East co-ordinates. The city lies at a point where Asia and Europe are separated by a narrow strait - the Bosphorus. Istanbul has a history of over 2,500 years, and ever since its establishment on this strategic junction of lands and seas, the city has been a crucial trade center.

Figure 1.1- location of Istanbul in Turkey

Figure 1.2- Province of Istanbul

The historic peninsula is flanked on three sides by the Sea of Marmara, the Bosphorus and the Golden Horn. It had been the capital of three great empires, the Roman, Byzantine and Ottoman for more than 1,600 years. During its development, the city was enlarged four times, and each time the city walls being rebuilt further to the west stretching over seven hills. It has a unique blend of modern and traditional architecture representing rich cultural diversity.

Figure 1.3- Historic peninsula of Istanbul

Figure 1.4- Panoramic view of Istanbul city

In 1923 Istanbul became a part of the Republic of Turkey, and was not the capital city of the new republic. During the early years of its formation, Istanbul was overlooked and the investment went into the new centrally located capital Ankara. In the 1940 to 1950, Istanbul re-emerged new public squares, boulevards, and avenues were constructed.

In the last few decades the city green areas have been developed for housing, commercial centers, subway system, and sea routes for transportations. Also Istanbul's many historical areas were added to the UNESCO World Heritage list in 1985.

1.2.2 Davutpasa Campus & Its Location

Yildiz Technical University has three different campuses in three districts of Istanbul. The main campus is on the border of Beşiktaş district, the other two campuses are Maslak and Davutpaşa on the borders of Şişli and Esenler districts. Davutpaşa Campus which is the largest out of these three campuses stretches across 130 hectare and consists of some historical buildings reflecting traditional Ottoman Empire architecture. It has several historical buildings in which some departments of the University have been fulfilling their missions in university education. It has been planned to construct new buildings for the departments demanding more rooms and offices. Some of the constructions have been completed while some are incomplete.

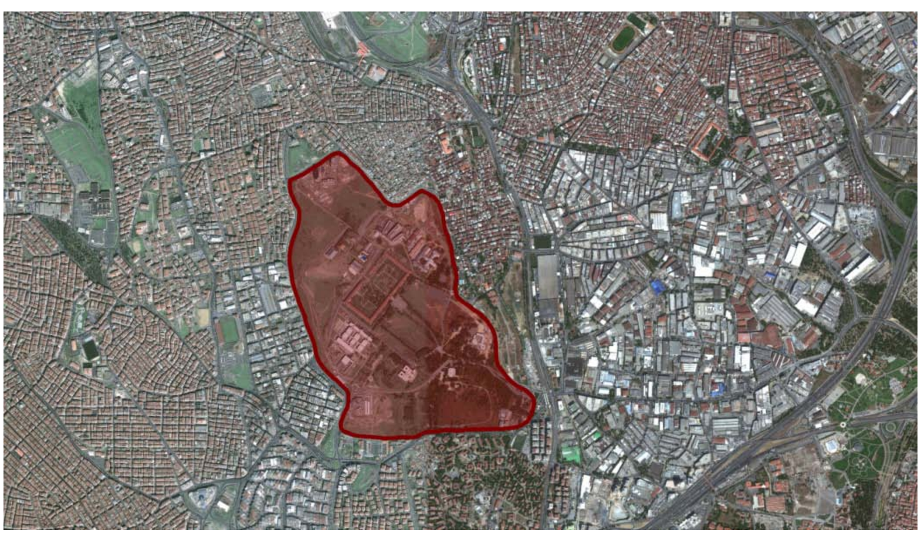


Figure 1.5- *Davutpasa University Campus in Istanbul*

1.2.3 Demographics

Istanbul bears unique testimony to the Byzantine and Ottoman civilization. It was built at the crossroads of two continents; it was successively the capital of the Eastern Roman Empire, the Byzantine Empire and the Ottoman Empire, and it has constantly been associated with major events in political history, religious history and art history in Europe and Asia for some 20 centuries. Istanbul is a large metropolis, and the province has been divided into 39 districts. This historic city has undergone population growth in the past 30 years with its population of 13.26 million inhabitants until 2010.

Yildiz technical university is located in Esenler district, and the population of this district is compared with the surrounding districts are shown.

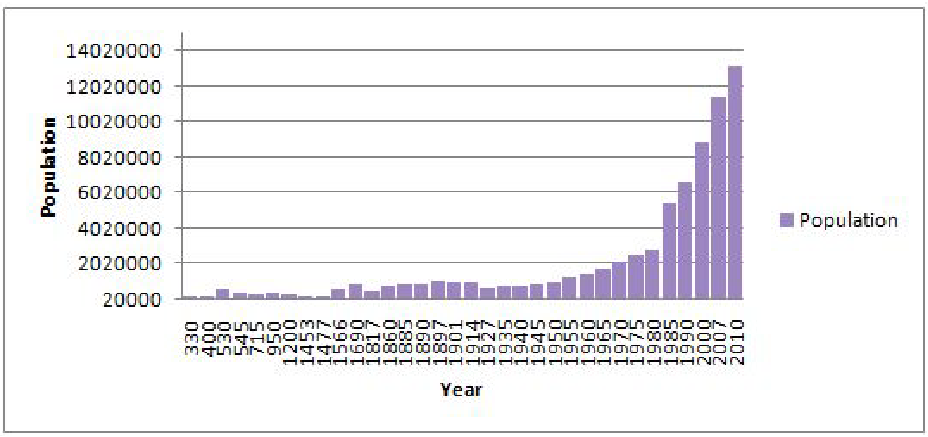


Figure 1.6- Population of Istanbul

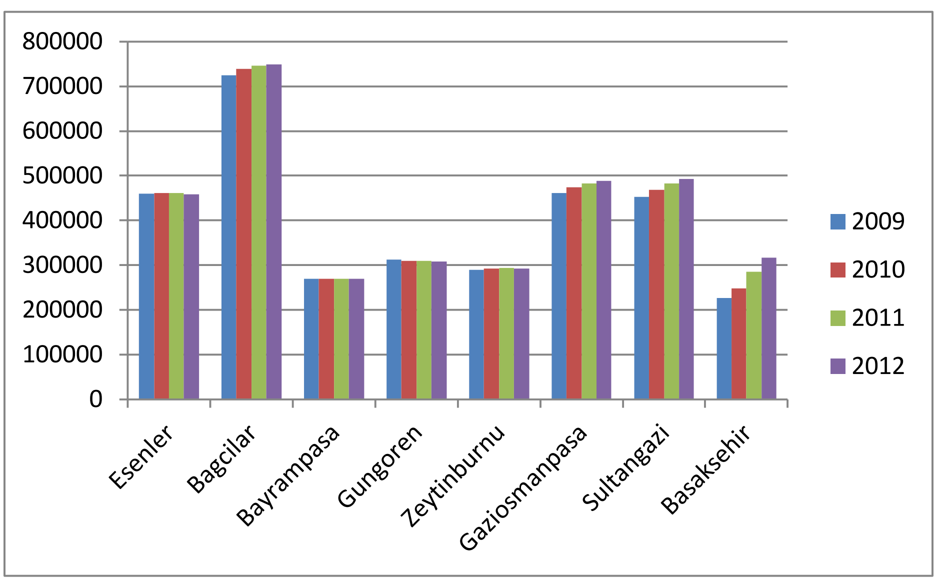


Figure 1.7- Comparison of Esenler district population with the neighboring districts

1.2.4 Historical Context

According to the history the military settlement in this area such as the old Davutpaşa Military Barracks dates back to the Byzantine era. The building of the Davutpaşa Barracks was ordered by Sultan Mahmut II and the construction, started in 1826, opening for use in 1832 during the conquest of Istanbul. The barracks sustained its function in the Ottoman era, until the end of the 1990s. Krikor Balyan is thought to have been the architect of the barracks that was used as a military hospital during World War I. In the process leading up to the 12 September 1980 coup d'état and in its aftermath, the former barracks served as a military prison where trade unionists and members of leftwing organizations and associations were interrogated, tortured and detained for long periods before their trials were concluded. In 1999, the Davutpaşa Barracks was assigned to the use of Yıldız Technical University.

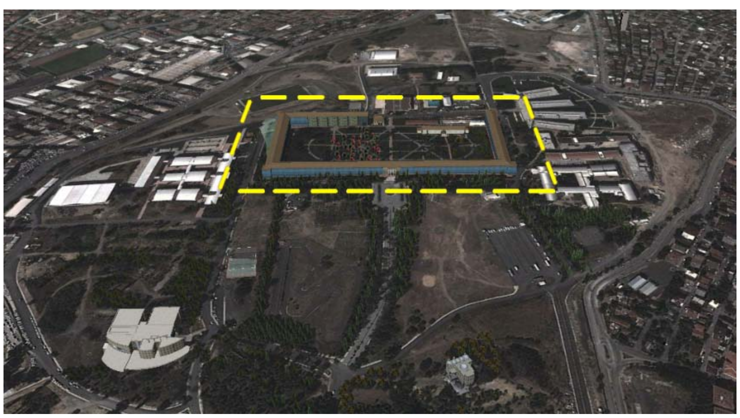
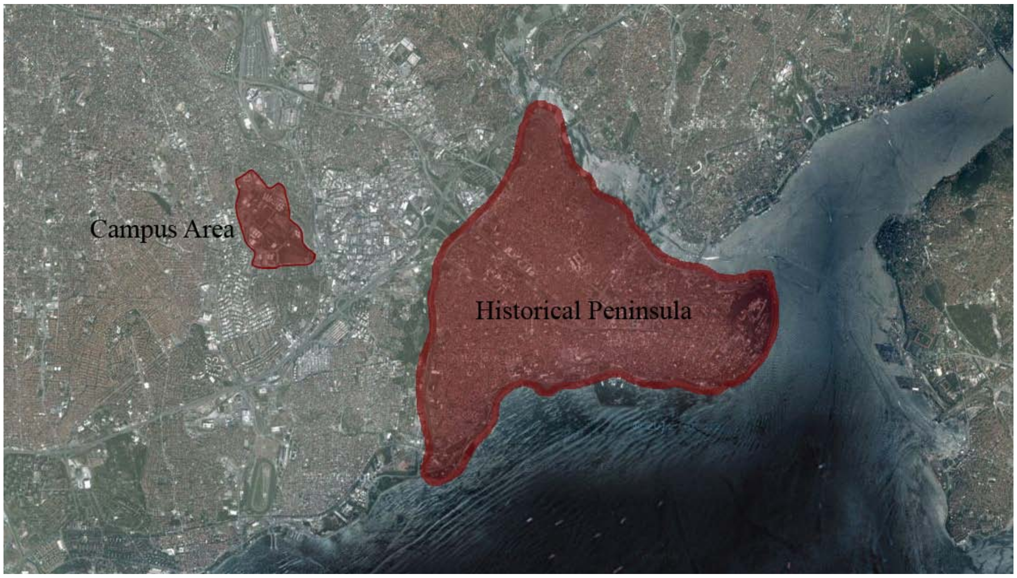


Figure 1.8- Location of Military Barrack in the campus

Figure 1.9- Entrance of Military Barrack



1.10- Distance of Campus area to historical peninsula is 5 km

Yildiz technical university is one of the 3rd oldest universities in Turkey, with its history dating back to 1911. The university has a distinguished past which is outlined below:

1911 - Conductors (Technicians) School of Higher Education was founded to meet the "science officer" (known previously as conductors, and today as technicians) requirement of the Municipality Public Works Section. The school was modeled on the syllabus of the "Ecole de Conducteur" and was affiliated with the Ministry of Public Works.

1922 - Under the direction of the Ministry of Construction, it was renamed as "Construction and Science School" (Nafia Fen Mektebi).

1931 – The Course duration was set at 3 years.

1937 - Nafia Fen Mektebi was abolished and the "Technical School" was established under the Ministry of Construction. The Science Department (2 year course) and the Mechanical Engineering Department (4 year course) were introduced. The university moved from the Health Museum to the present main campus location in Besiktas.

1941 - Control of the Technical School was transferred to the Ministry of Education. The Electrical Engineering Department and an independent Faculty of Architecture were founded. The system of preparatory classes was abandoned.

1943 - The status of a 4 year Higher Education Institution was granted.

1960 - Graduate programmes were introduced.

1969 - The Technical School was renamed as "Istanbul State Academy of Engineering and Architecture", *ISAEA*.

1971 - With the nationalisation of the private high schools, Galatasaray, Işık, Kadıköy and Vatan Engineering High Schools were incorporated into *ISAEA*.

1982 - *ISAEA* was reorganized and renamed Yıldız University. It comprised 4 faculties; the Faculty of Engineering, the Faculty of Engineering, the Faculty of Architecture, the Faculty of Arts and Sciences.

1992 - It was renamed as "Yıldız Technical University" with the addition of five more faculties; Electrical and Electronic Engineering, Civil Engineering, Chemical and Metallurgical Engineering, Mechanical Engineering, and Economic and Administrative Sciences.

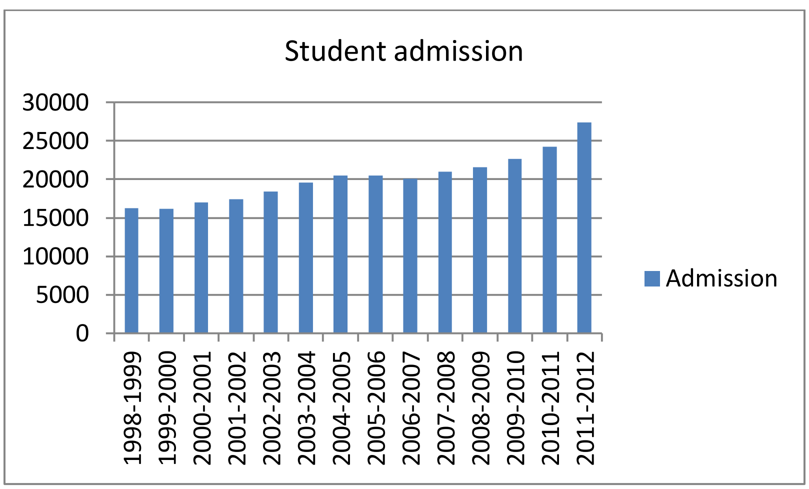
1997 - The Faculty of Art and Design was established.

1998 - The School of Foreign Languages was established.

1999 - Renovation began at the historical Davutpaşa campus.

2000 - Faculties of Science and Literature, and Chemical and Metallurgical Engineering were opened at Davupaşa campus.

The figure shows the graphical analysis of student intake every year which has been increasing every year.



1.11- No. of Student intake in the University

CHAPTER 2

URBAN STUDIES

2.1 Aim of Project

The aims of our project are as follows:

- To create a prominent pedestrian and bike starting from the main university entrance gate until the project site, being the focal point for both transitional and meeting area
- To provide a safe and car free zone and enhance the path way activity
- Redefining identity of the site
- Connecting the detached faculty buildings through this converging point

2.2 Case Studies

The urban case studies of the university enabled us to understand the typology of existing institutional building with relations to the surrounding urban land uses and within the campus boundary.

The project site is located in university campus, so the process involved various questions which were sorted out to finalize the better solution before any planning and drafting of drawings were taken up. Case studies were done to find out what type of campus is Yildiz technical university. Accordingly various case studies were selected mostly relating to our project site to compare the connectivity and land use infrastructural pattern within the campus. The campus has all the facilities inside the campus boundary and is self sufficient to support the students and staff living in the hostels and staff quarters. Here are the following selected cases:

2.2.1 Anadolu University

Anadolu University is located in Eskisehir, a city that is close to the capital of Turkey. The campus is very much like the Davutpasa campus of Yildiz Technical University in terms of being closed to outside and a self sufficient cluster of educational facilities.

Figure 2.1-Image showing the boundary of the campus

Figure 2.2- Image showing road network

The road network around the campus that is showing a similar accessibility to Davutpasa campus which is in reach of people via all types of municipal public transportations thanks to the destination points situated close to the main gate.

Figure2.3- Image showing the vehicular circulation inside the campus

In-campus circulation shows a similar problem that is present in Davutpasa campus due to non-arriving cut roads.

Figure 2.4- Land use analysis

Image showing the land-use analysis that once more can be traced in Davutpasa land-use map in terms of the way they both are zoned.

Figure 2.5- Image showing the green-spaces and parks

It is widely known that the campus is being appreciated generously by the students for having a nicely planned out parks. This strength of the campus only exists as an opportunity in Yildiz Technical University Davutpasa Campus.

2.2.2 *Eastern Mediterranean University*

Eastern Mediterranean University (EMU) is located in Famagusta, a city in North Cyprus.

Figure 2.6- Image showing the boundary

Positive aspects:

- Campus zoning is justified
- Position of the green square is meaningful because it is very near to the main entrance and used for the cultural activities

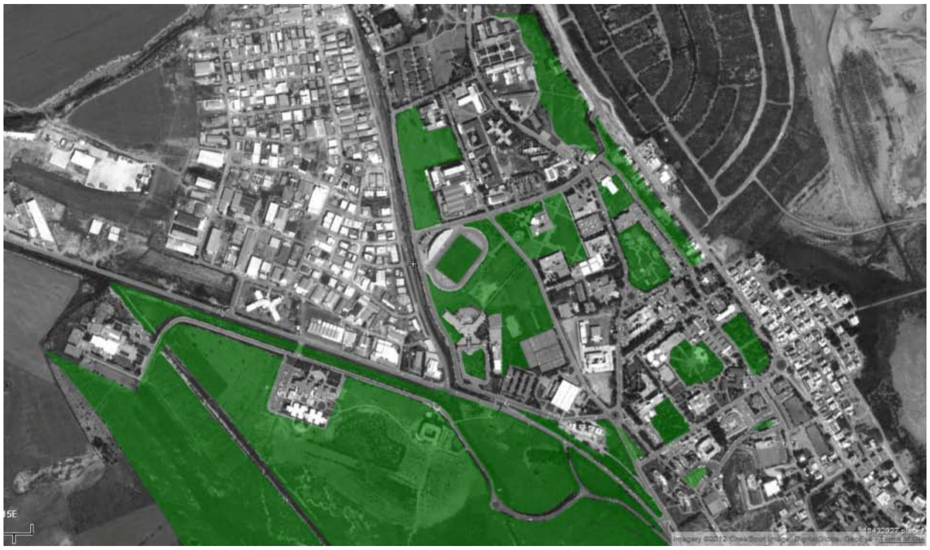


Figure 2.7- Image showing Green spaces

Negative aspects:

- The main entrance not well defined
- The main building square is obstructed by the other department building
- It has a very weak axes

Figure 2.8- Image showing functional layout

Figure 2.9- Image showing road network

Conclusion:

From the above case study we can conclude that the EMU (Eastern Military University) campus does not have a specific or well defined cultural activity center. It uses the sport centre as a temporary medium for fulfilling their occasional events.

2.3 Davutpasa Campus Analyses

The connectivity pattern to the campus and the significance of the historical barrack helped to redefine and propose better solution for the new cultural center. The following aspects has been the mainly considered to analyze the existing project site of the campus.

2.3.1 Land use pattern

The precise characteristic of land use planning varies from country to country due to its cultural, climatic, political reason.

The plan below shows the functional use of the land within the university. The university campus facilities are not well integrated and have variable building typology.

Figure 2.10- Image showing the functional layout

2.3.2 Road network

Roads contribute to the enhancement of life and activity. Reaching the university is very easily accessible by trains, metro and bus. But within the campus the circulation system i.e. the main road and pathways are not well defined.

Figure 2.11- Showing the existing road

2.3.3 Solid and void

This gives the general idea of the density of the built up areas within the campus. It is immediately recognized from the map shown below, that the built up infrastructure is fragmented from each other and also has maximum free space for future development.

Figure 2.12- Showing the Solid and Void

2.3.4 Green Area

The university campus has lot of green / free space which maximizes the scope to extend the existing infrastructure facility and services. On the other hand it can be left green with an effort to make a link between the ecological dispersion. In the south direction of the campus, a technological park construction is under progress.

Figure 2.13- Green spaces

2.3.5 Urban morphology

Understanding the morphology is an essential step to decode the urban landscape and the relationship between patterns and forms. We analyzed the urban morphology in the reduced scale with respect to only the university buildings. The existing form of the building corresponds to totally different structural and functional units having diverse characteristic. The only thing common in all of the building is that it faces towards the military barrack. It is interesting that the building we design follows the landscape and genuinely satisfies its presence without obstructing the view of the barrack.

2.3.6 S.W.O.T Analysis

This method was done with help of some research work on internet and discussion with friends to evaluate the potential of the project. The following table addresses the strength, weakness, opportunity, threat is as follow:

Strength	***Weakness***
i) Decent topography of the land. ii) Availability of Green space within the campus.	i) Facilities in the campus are fragmented. ii) Campus boundary not well defined.
Opportunity	***Threat***
i) Located near the historical peninsula.	i) Existing Concert hall in the surrounding area.

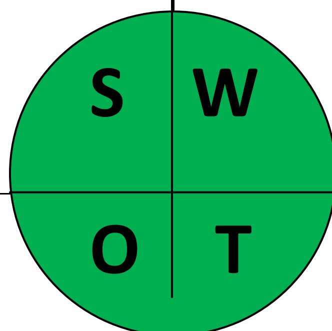


Table 2.1- S.WO.T Analysis

2.4 Urban implementation

The three focal nodes is figured out which connects the main university entrance gate to the project center and also it stands as a strong node. The center road line is kept free of any vehicles. Some hand sketch drawing below represents the urban thought processing for defining the pathway from the university main gate until the Auditorium area.

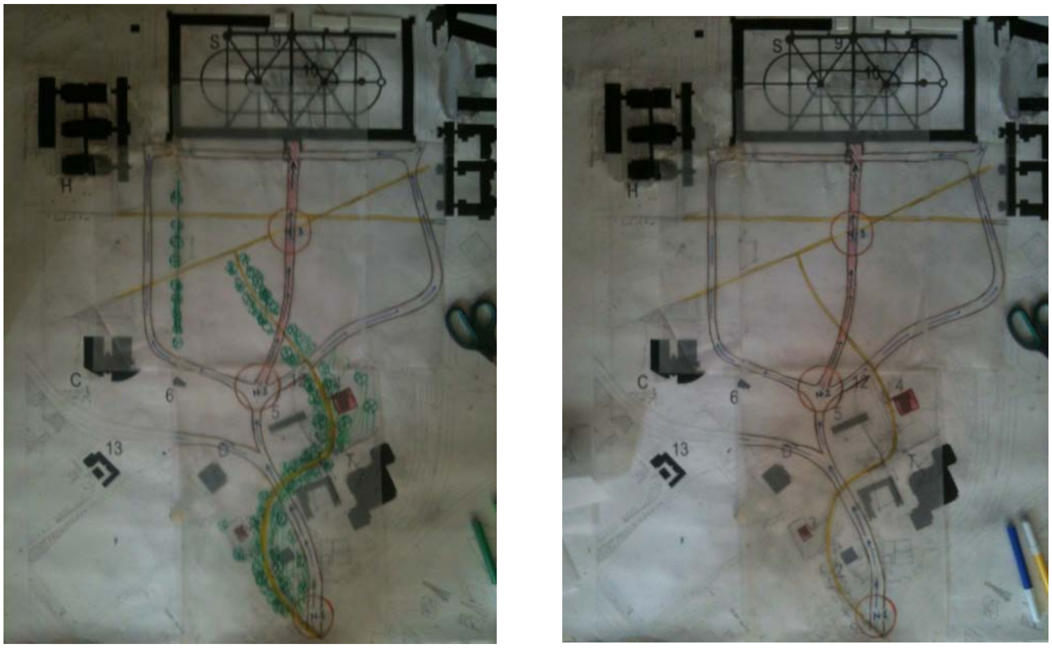


Figure 2.14- Preliminary draft showing the pathway and the car free zone

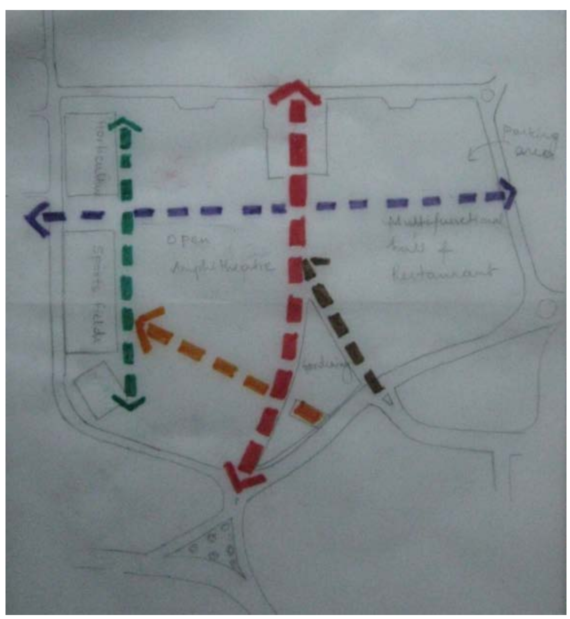


Figure 2.15- Preliminary draft showing the accessibility at project site

2.5 Master Plan

Figure2.16- Mater Plan

CHAPTER 3

ARCHITECTURAL DESIGN

3.1 Introduction

In this section we would like to present our concepts design and the process that we considered to cover the entire architectural design. The design is done following the competition brief and some additional design parts are also included while analyzing the function and potential of the site. Design principle was applied to attain the project aim and concepts. While discussing and studying the pros and cons we realized that our project site has a historical monument with a regular shape building having a courtyard and the other structure reflected the modern style. Before we could start our design, we reviewed a case study to understand the relationship of the building with landscape, and the interior with the natural surroundings.

3.2 Conceptual Approach and definition

The project is more of a landscape and architectural than urban detailing. But we have tried to address the issues on both aspects relating to architectural and urban. Our main concept is related to landscape concept which affects the shape and structure of the building to maximum extent.

The following is the functional area which is to be designed based on the architectural aspects:

1) Offices and other facilities:
    - Reception
    - Foyer
    - Offices
    - Conference hall
    - Exhibition hall
    - Bookstore
2) Auditorium space
    - Gallery
    - Cafeteria

- Hall
- Corridor

3) Restaurant Facility

- Cafeteria

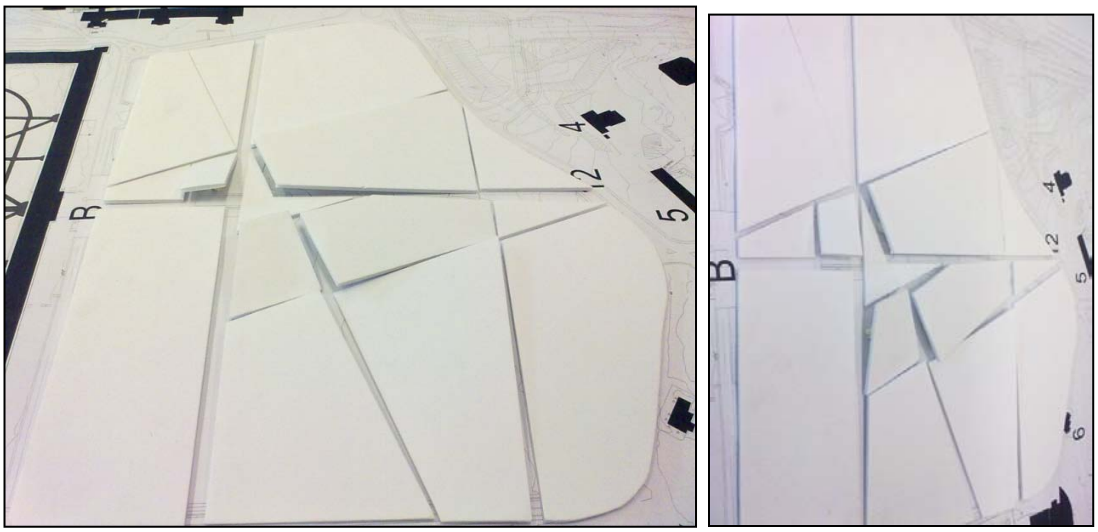


Figure 3.1- Model showing the preliminary stage of the Architectural design

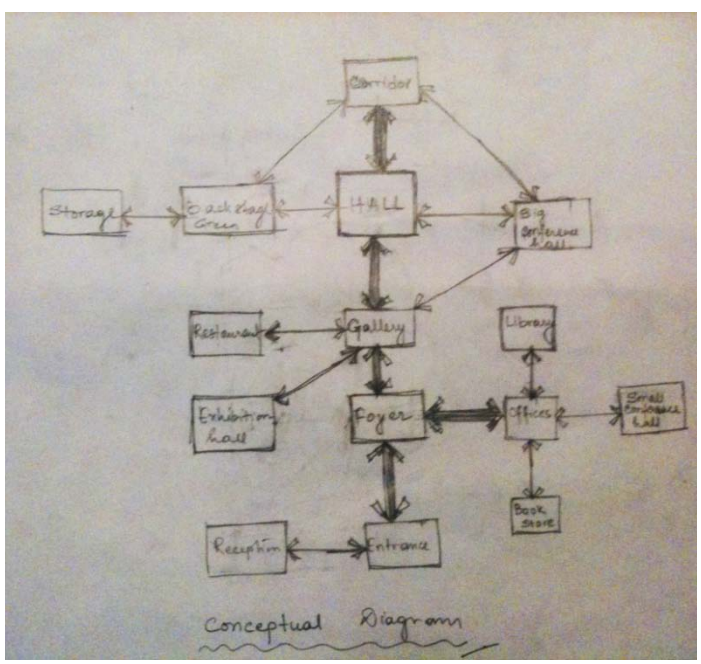


Figure 3.2- Conceptual diagram

3.3 Case Study of "Erl winter festival hall"

We started our architectural design process with a case study which is in Austria. In order to understand the relationship of the design with respect to the topography and forms we chose a case study close to our design concept.

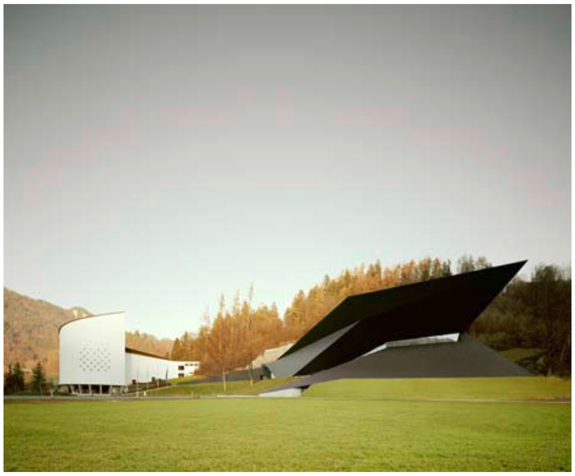



Figure 3.3-Winter festival hall in Austria

This angular black concert hall was designed by Delugan Meissl Associated Architects to contrast with the curved white playhouse. The new Festival Hall is a winter concert venue for the festival and its faceted shell spikes out from the landscape as a single monolithic volume. A staircase leads down to the building entrance, where visitors are directed through a clean white lobby into the timber-lined auditorium.

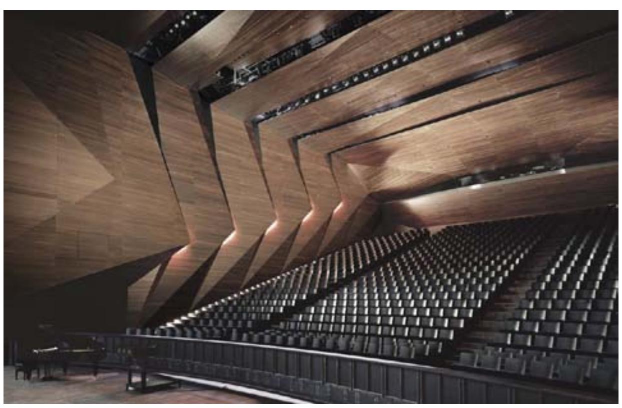



Figure 3.4- Internal Shot

The most interesting thing is the geometry of the Festival Hall developed from the topographical conditions, placing it in an adequate relationship with the existing Passionsspielhaus.

The building's form and positioning both relate to the impressive landscape setting defined by the rock formations in the back, and to the dynamic presence of its neighboring historical counterpart. This existing building and the new one are oriented towards one another. It complements and elevates their respective architectural articulation of the reference to the landscape by interacting visually with one another.

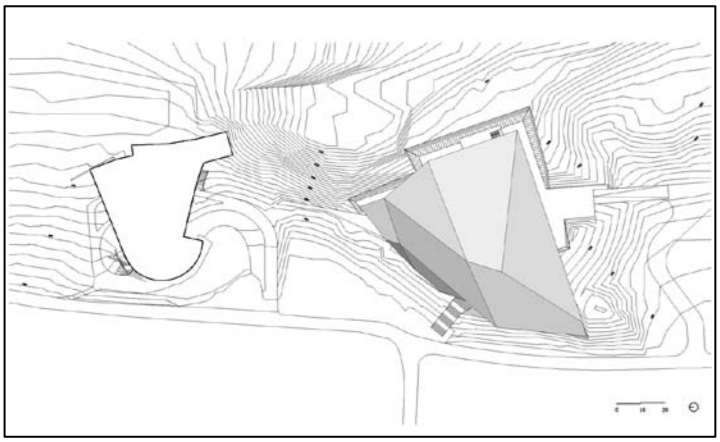


Figure 3.5- Roof plan

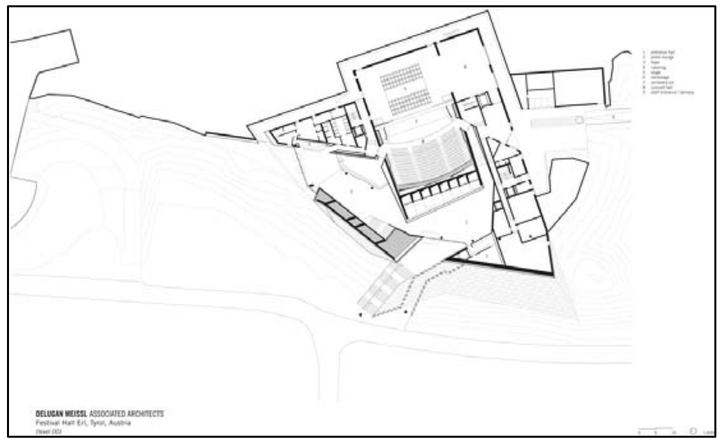


Figure 3.6- Ground floor plan

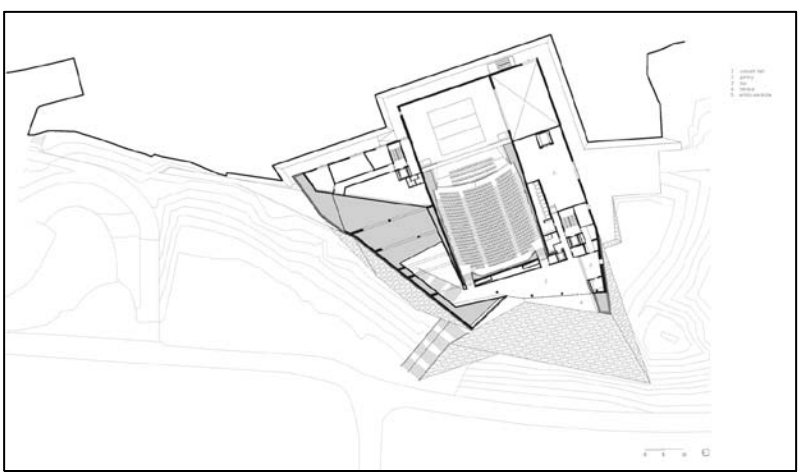


Figure 3.7- First floor plan

The new building increases existing qualities of the natural and architectural environment. Aside from the geometry, color also enhances the duality between old and new. While the white surface of the Passionsspielhaus stands out optically during the time of the summer festival, the changing of seasons brings upon a chromatic reversal of the ensemble. The configuration of the Festival Hall resembles a tectonic stratification. Its crevices and faults lying in between indicate the way into the building's interior. At nighttime the incisions and folds in the distinctive facade allow insight into the radiant foyer.

Access

The topographic imprint on the new building is consequently continued within its interior. The design idea is guided by two defining parameters: the interrelation between the interior and the surrounding natural space as well as the spatial configuration of a functional, internationally acclaimed concert hall. Flowing visual and functional spatial references define the architecture. Areas with diverse usage and geometry show the creative engagement with communication and calm, dynamism and concentration. The sequences of movement are subtly guided by the sensory experience of the rooms. The access staircase is integrated into the landscape thus guiding visitors into the building.

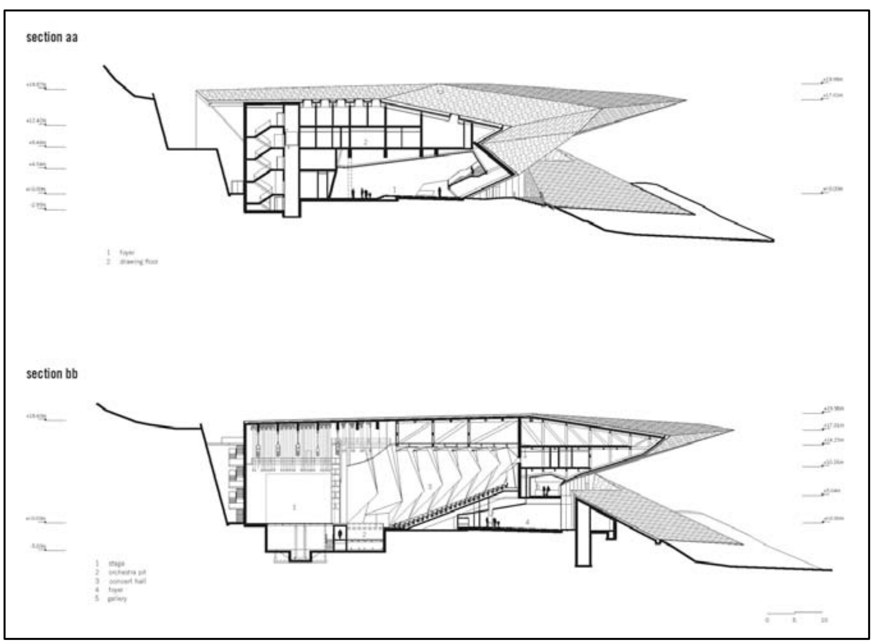


Figure 3.8- Sections

Functions

Cloakroom and reception desk are situated near the entrance. The foyer - an asymmetric construction volume - allows manifold views onto the surrounding nature as well as onto the neighboring Passionsspielhaus. A staircase running in the opposite direction leads onto the upper gallery where the impressive relationship between interior and exterior space can be experienced again through the ample west façade made of glass. This level also hosts the building's secondary functions. Orientation, room sequence and functional relations are integral parts of the architectural dramaturgy: ample communication areas, retracting and expanding circulation areas and varying room heights translate the building's tectonic geometry in a sensory manner. In a consequent and effective way, the approach to the concert hall is staged through a gentle surge of the entrance level. The respective levels of the foyer are connected with the concert hall through two entrances. The latter is situated in the centre of the building like a shell, its rear part being anchored in the rock. The transition from the foyer into the concert hall is accompanied by spatial and atmospheric change: dynamism, variability and asymmetry give way to maximum concentration, static calm and orthogonality.

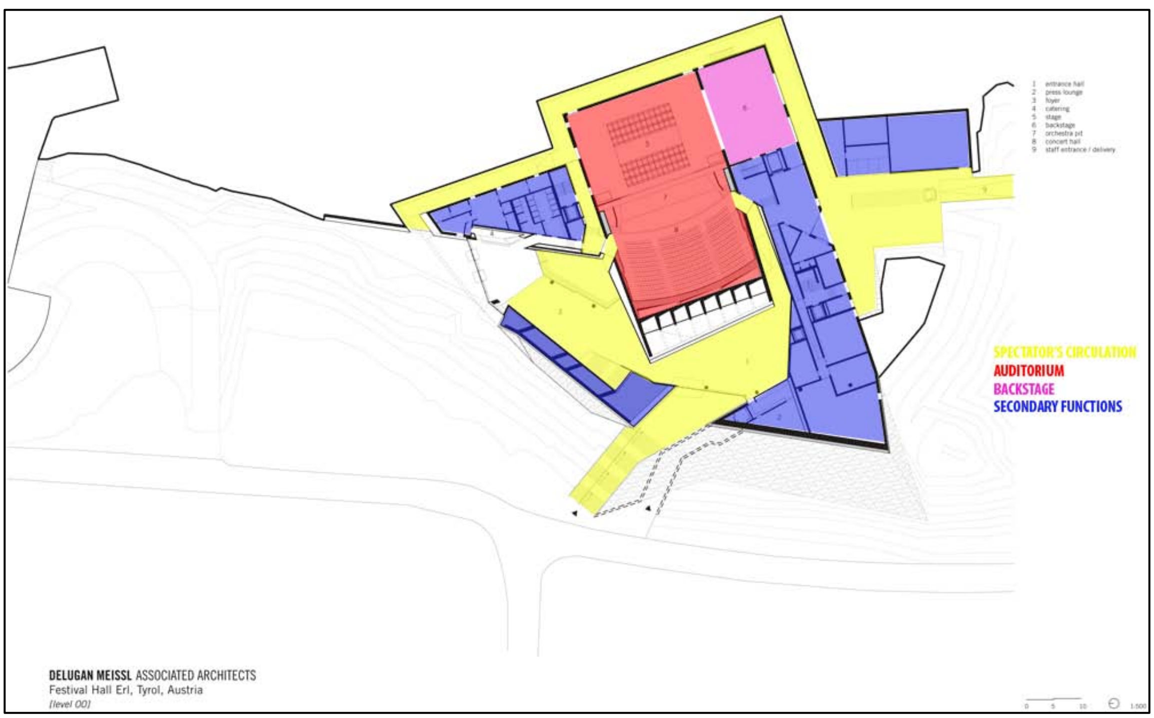


Figure 3.9- Showing functional layout in plan

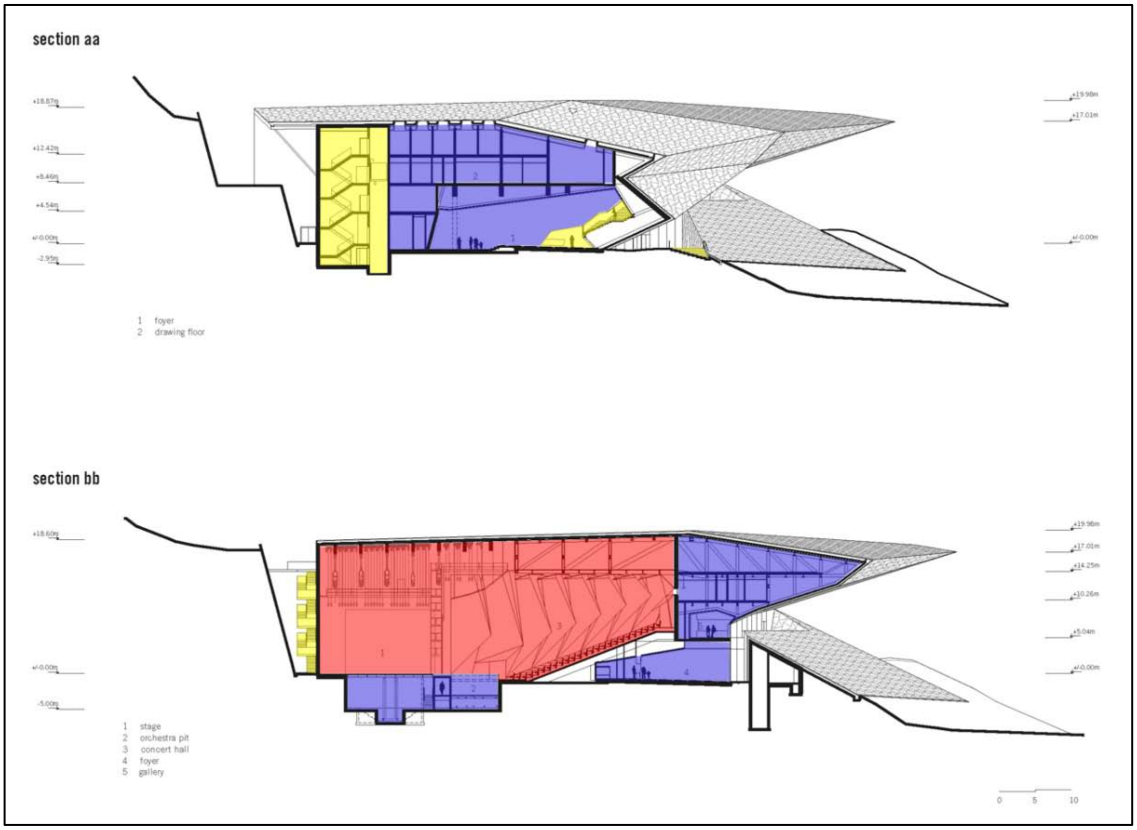


Figure 3.10- Showing functional Layout of Erl Hall in sections

Materials

The materials concept is equally defined by a sensorial perception of the respective usage areas. Differentiations in geometry and surfaces of room elements increase the sensorial experience of single function areas and facilitate orientation. The shine in the foyer during the winter's sunset increases the communicative character of this area of encounter. Following the metaphor of an exposed jewel, the concert hall is defined by a distinct change of materials: wood surfaces and subdued colors create a warm room composition of tense quiet thus directing the visitors' attention onto the performance to follow. Multiple technical equipments and the possibility to transform the hall allow a varied use which reaches far beyond the function of a classical concert and festival venue.

Conclusion

This case was studied as it have a close characteristic features with our project. The most interesting part is the unsymmetrical geometry and its approach to deal the complex landforms. The connectivity of different zone follows a distinct material composition, which makes it more impressive.

3.4 Architectural design goals and objectives

3.4.1 Typology

The geometrical form of the auditorium has an irregular and unsymmetrical dimension with respect to the historical barrack. The architectural form of the building is adopted as contemporary style such as, the main façade is totally glazed and it does not affect the other existing structures.

3.4.2 Identity

The auditorium is intended to be a strong cultural converging point which brings more leisurely and informal space exploring the possibility of other surrounding area. The building appearance best suited to fit in the context. The frontal elevation is mainly glazed façade which gives an extraordinary look facing towards the south east. The irregularity of the roofs flowing in two opposite direction is simple and elegant.

3.4.3 Articulation

After laying the internal articulation of the functions and circulation we kept in view all consideration regarding different functional requirements, simple approach is made to distinguish the length and width of complete structure in three different zones. The lobby is the center zone which forms the important diverging loop into the other parts of the building. The gallery is the buffer zone between the hall and the lobby which restricts the direct entry into the hall. The specific services that included the toilets, lifts, stairs are worked according to the typology of the building.

3.4.4 Sustainability

The key asset of sustainability is dealt to define and preserve the standards as far as possible for our design. In order to do so, we preferred to have green roof for the Auditorium, use of steel for integrating the structure as a whole. Orientation of the building has helped to avail the sunlight efficiently reducing the electricity consumption. Materials with low embodied energy used subsequently having lower thermal transmittance to minimize the adverse environmental impact on the surrounding areas. And also the use of photovoltaic solar panel on the green roof has benefited to produce renewable energy.

Figure 3.11- view showing the entrance

3.5 Architectural Drawings

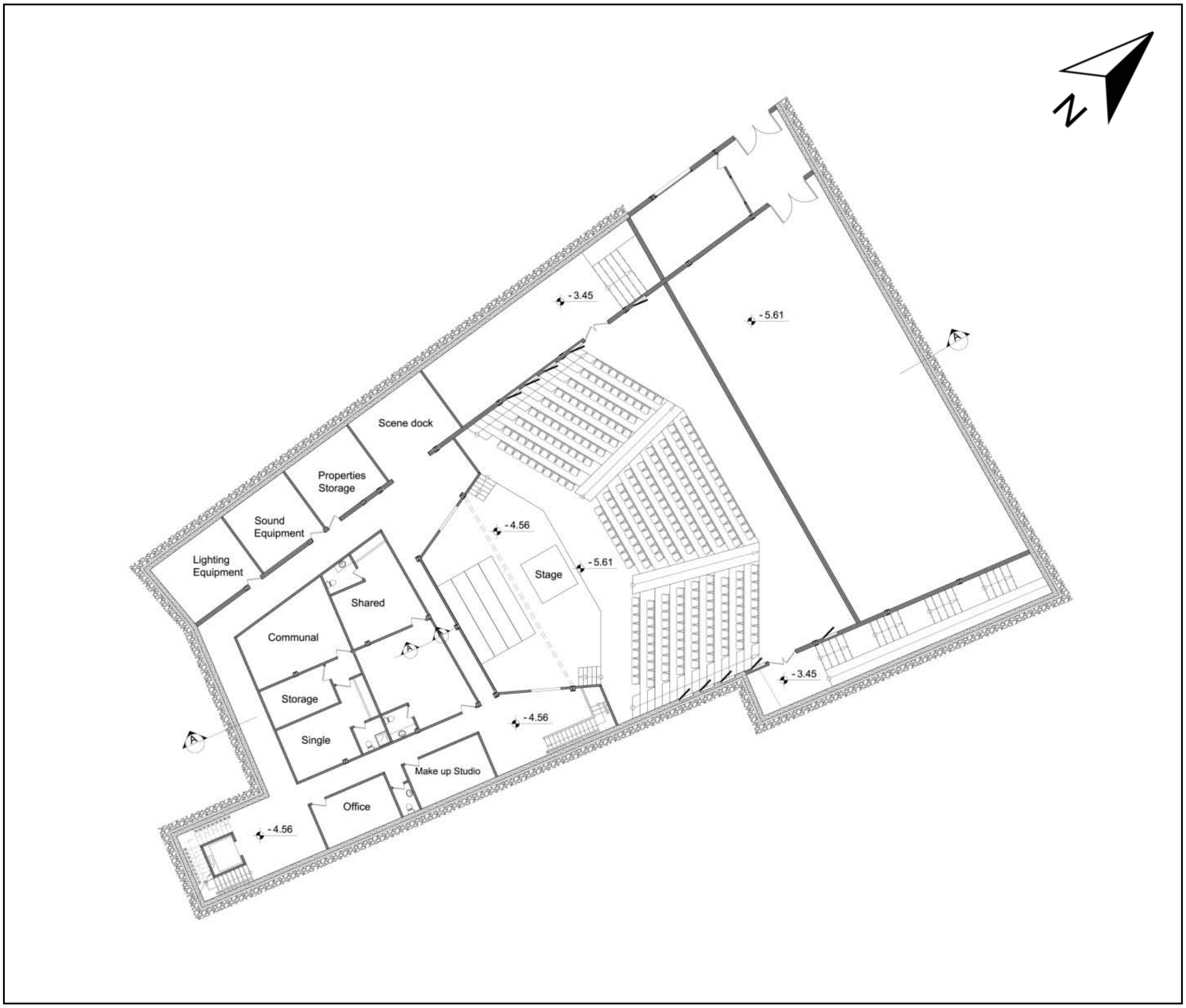


Figure 3.12- Basement Floor Plan

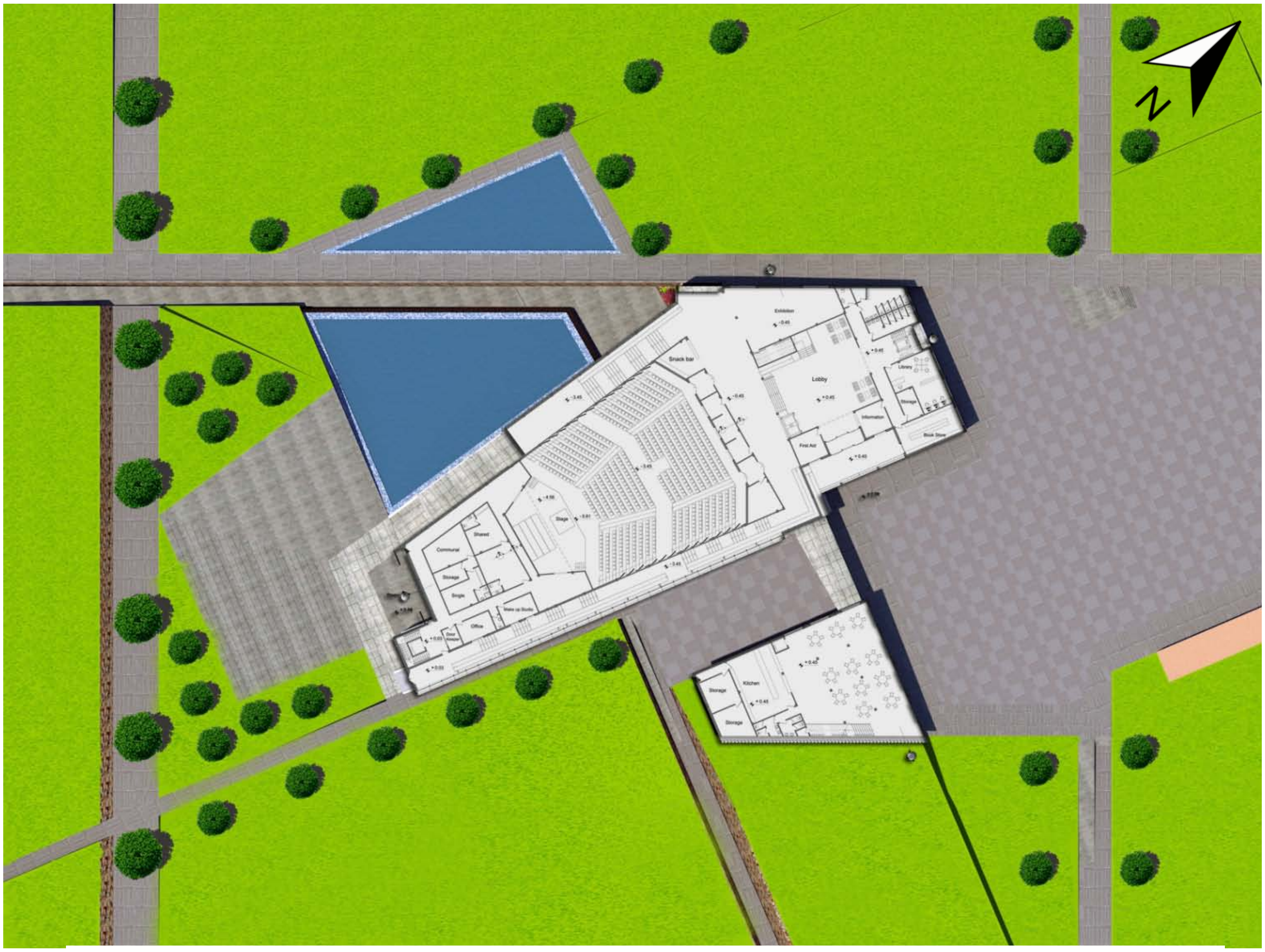


Figure 3.13- Ground Floor Plan

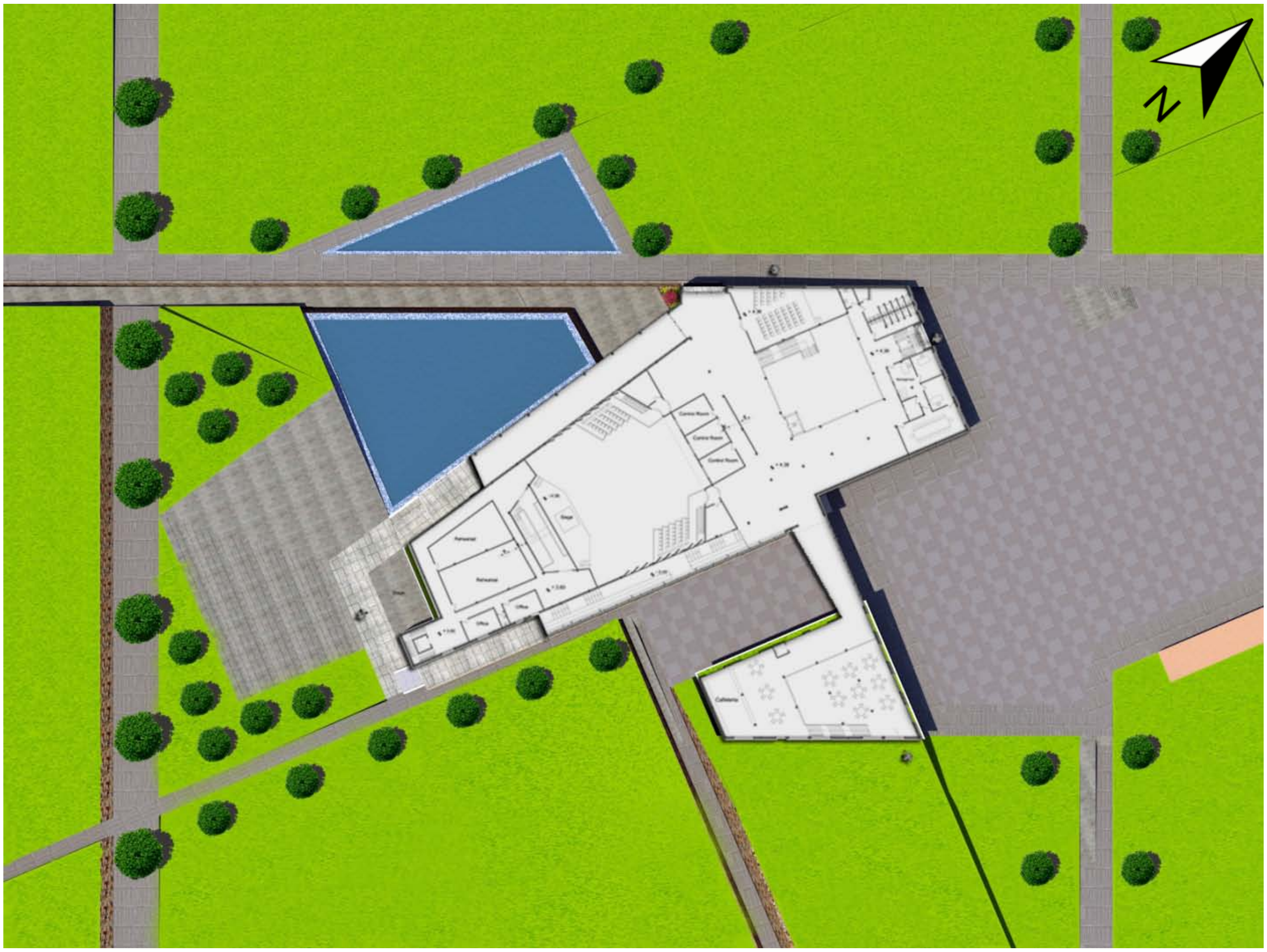


Figure3.14- First Floor Plan

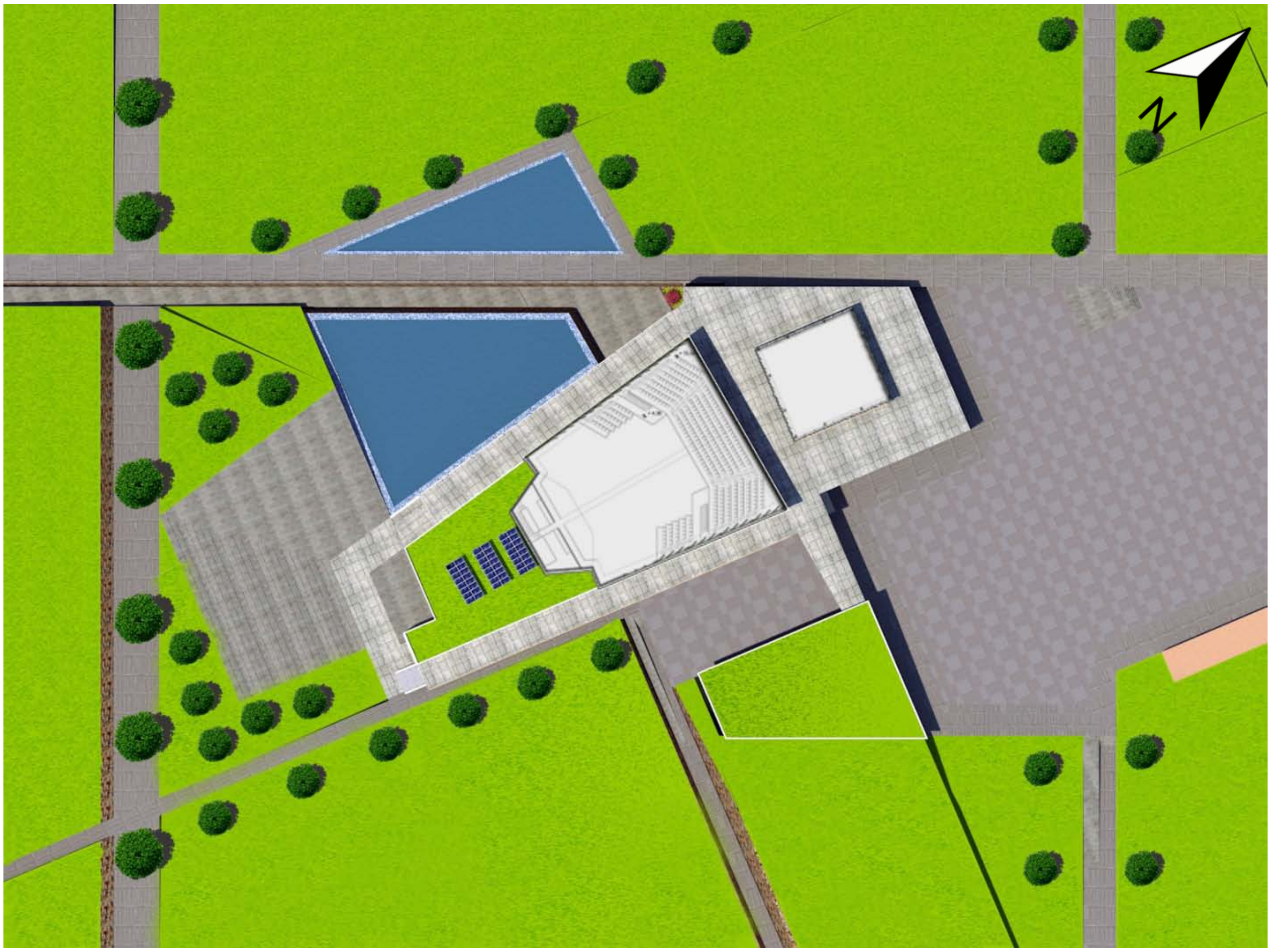


Figure 3.15- Second floor Plan

Figure 3.16- North east Elevation

Figure 3.17- South east Elevation

Figure 3.18- South west Elevation

Figure 3.19- North west Elevation

3.6 Functional Layouts

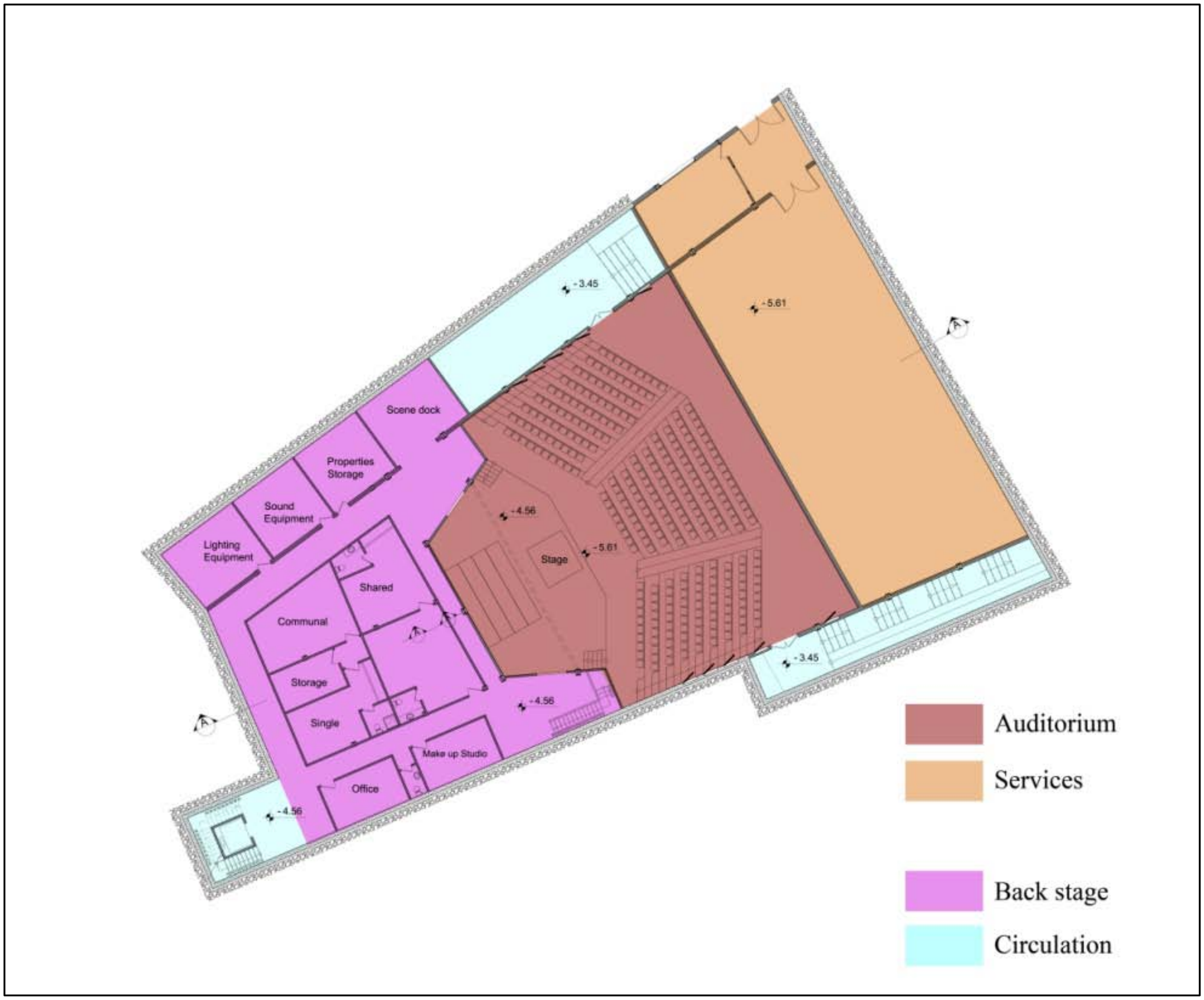


Figure 3.20- Basement floor functional layout

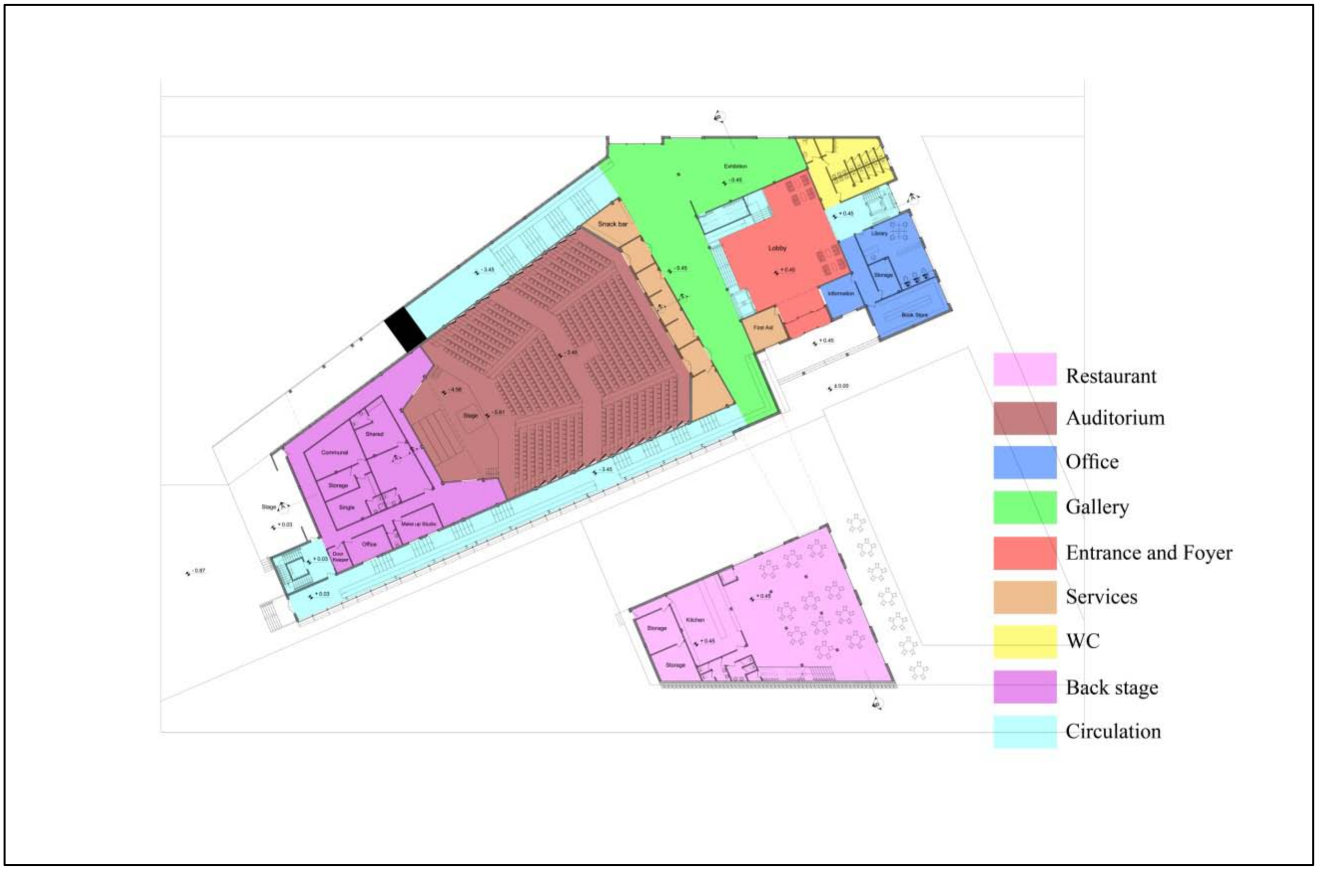


Figure 3.21- Ground floor functional layout

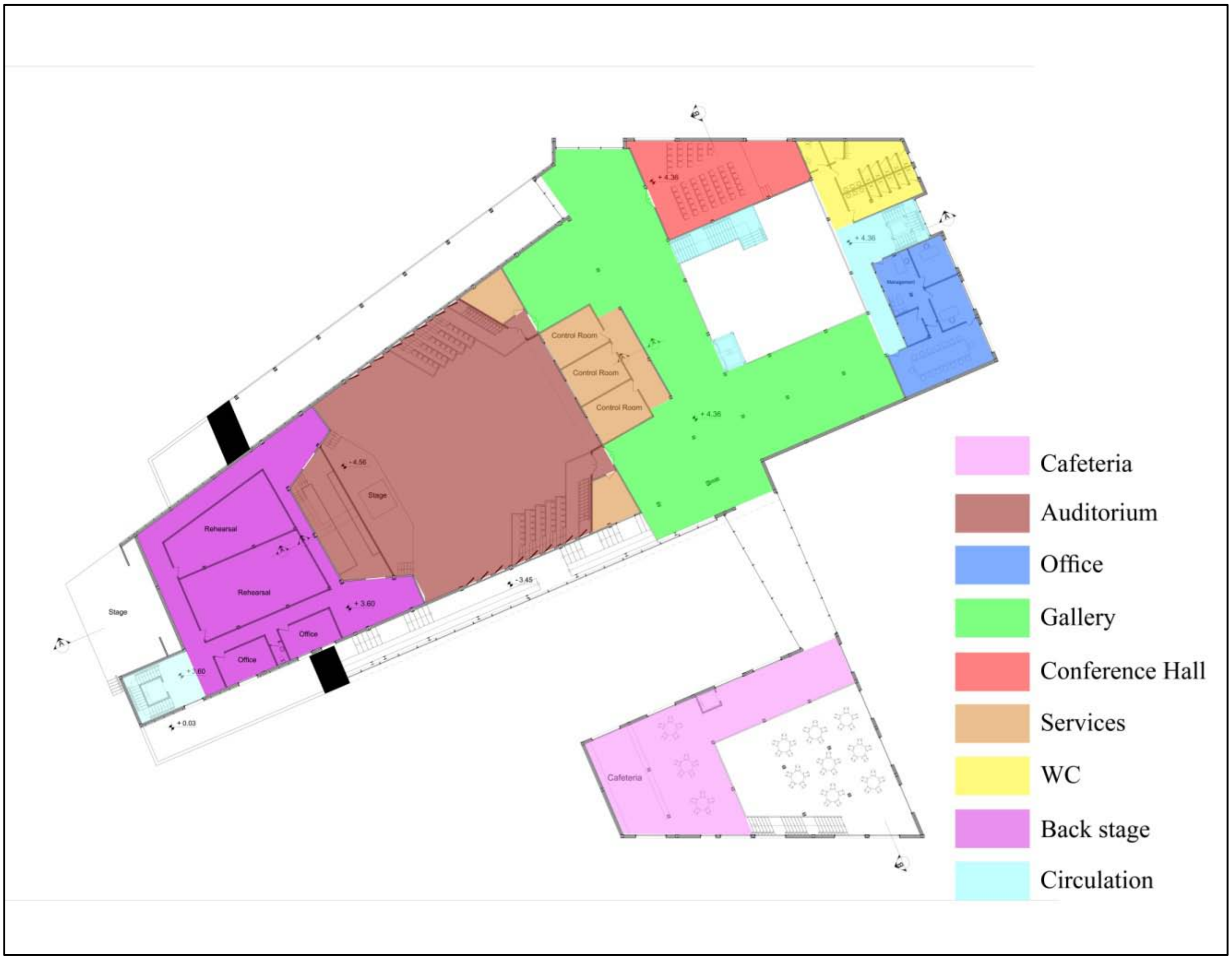


Figure 3.22- First floor functional layout

Figure 3.23-Second floor functional layout

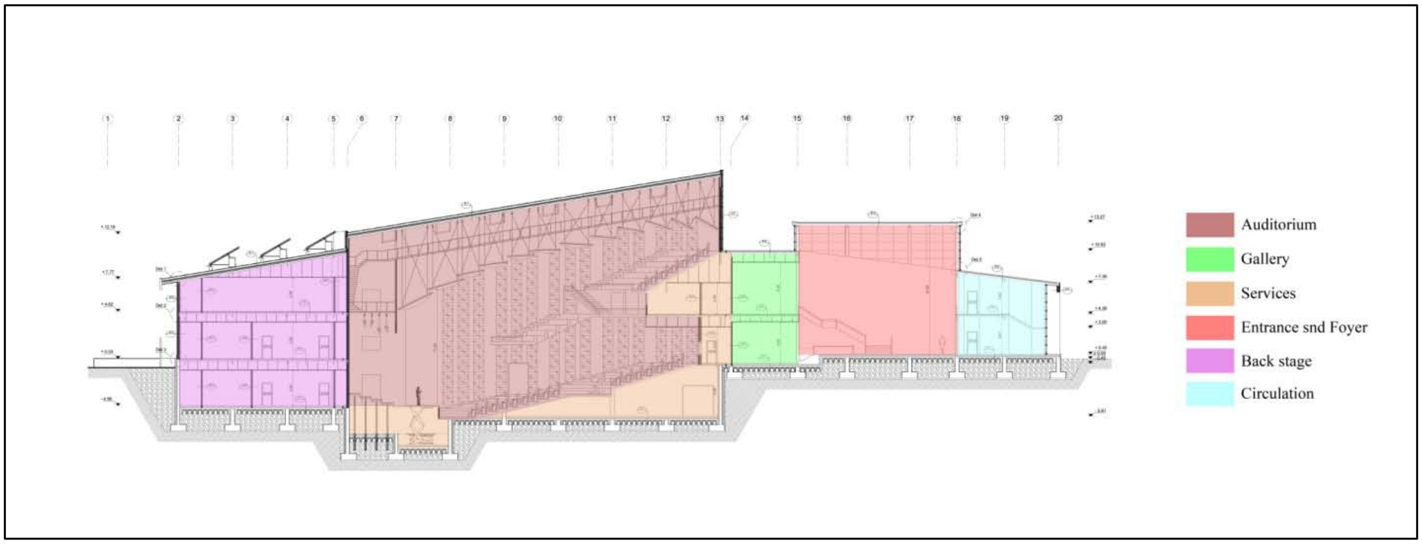


Figure 3.24- Section A-A Functional layout

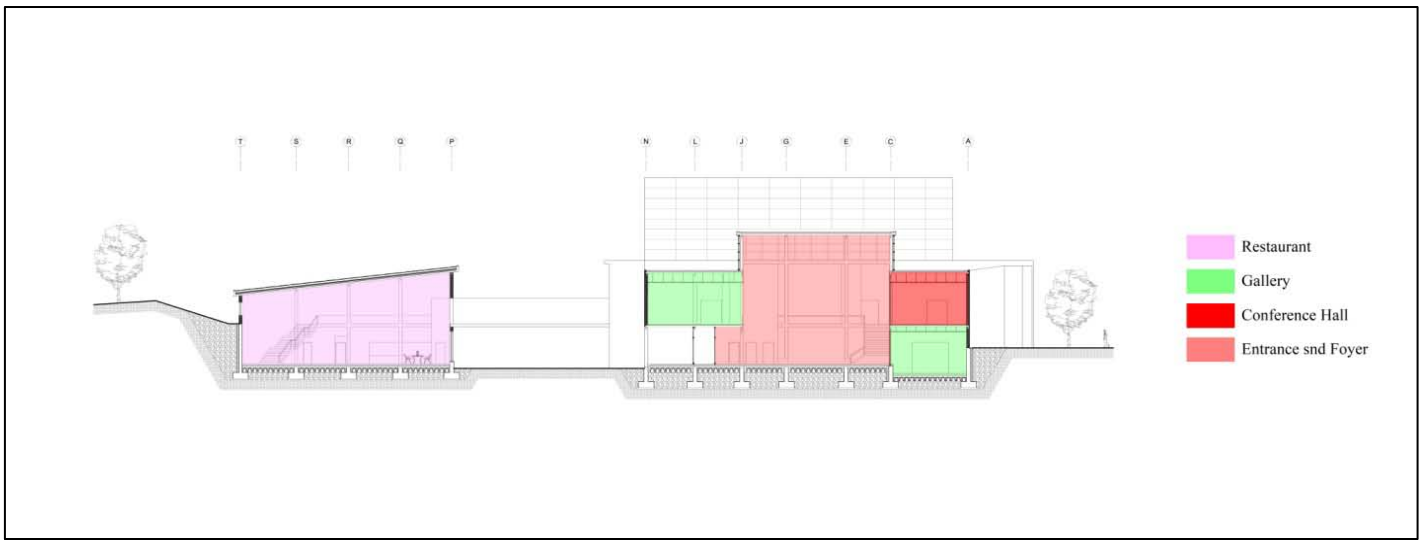


Figure 3.25- Section B-B Functional layout

Figure 3.26- Transition space between gallery and Restaurant

Figure 3.27- View from the open theatre

CHAPTER 4

STRUCTURAL DESIGN

4.1 Brief description of the structure

The building comprises of the following three parts: 1) The lobby 2) Concert hall 3) The offstage. The building parts are separated by an expansion joints. Steel columns and beams are mostly used for the superstructure. The foundation and basement walls are reinforced concrete.

4.2 Load calculation

The relevant loads actions are determined in accordance with the service life of the structure EN 1990 (3.2).

4.2.1 Permanent loads

It is the self weight of the structure and the non structural member such as exterior cladding, fixtures, ceiling etc. The project structure is at different functional use with difference in height from ground level, therefore to simplify the structural calculation it is divided into 3 parts. The following shows the loads are obtained for square meter:

Table 4.1- Dead Load Calculation for Entrance & Gallery Floors

Materials	Specific weight (kg/m^3)	Thickness (m)	Total weight of layer (kg/m^2)
Granite	2800.00	0.030	84.000
Cement Mortar	1900.00	0.030	57.000
Bitumen water proofing layer	1400.00	0.010	14.000
Expanded Polystyrene	30.00	0.050	1.500
Light weight concrete	1000.00	0.050	50.000
Plasterboard	14.00	0.015	0.210
Total weight			206.710

Table 4.2- Dead Load Calculation for Entrance Roof

Materials	Specific weight (kg/m3)	Thickness (m)	Total weight of layer (kg/m2)
Roof tiles		0.018	44
Expanded Polystyrene	30.000	0.050	1.5
Light weight concrete	1000.000	0.050	50
Plasterboard	14.000	0.020	0.28
Total weight			95.780

Table 4.3- Dead load for Backstage offices Floors

Materials	Specific weight (kg/m^3)	Thickness (m)	Total weight of layer (kg/m^2)
Hardwood	590	0.02	11.8
Cement screed	1900	0.05	95
Expanded Polystyrene	30.00	0.05	1.500
Light weight concrete	1000.00	0.05	50.000
Plasterboard	14.00	0.015	0.210
Total weight			158.510

Table 4.4- Dead Load Calculation for Green Roof

Materials	Specific weight (kg/m3)	Thickness (m)	Total weight of layer (kg/m2)
Cohesive Soil (clay & silt)	1600.00	0.15	240
Bitumen water proofing layer	1400.00	0.01	14
Expanded Polystyrene	30.00	0.05	1.5
Light weight concrete	1000.00	0.05	50
Plasterboard	14.00	0.02	0.21
Total weight			305.710

Table 4.5- Dead Load Calculation for Exterior Wall

Materials	Specific weight (kg/m3)	Thickness (m)	Total weight of layer (kg/m2)
Sinterflex tiles	2333.00	0.030	69.99
Cement mortar	1900.00	0.010	19.00
Cement board	1200.00	0.013	15.00
Mineral wool Insulation	40.00	0.200	8.00
Plaster Board 3 Nos	14.00	0.013	0.53
Total weight			112.52

Table 4.6-
Dead Load Calculation for Interior partition Wall for Entrance Office

Materials	Specific weight (kg/m3)	Thickness (m)	Total weight of layer (kg/m2)
Plaster Board 4 Nos	14.00	0.015	0.84
Mineral wool Insulation	40.00	0.200	8.00
Total weight			8.84

Assuming the net floor height = 3.993m , linear weight of the partition wall = 3.993 x 8.84 = 0.35 kN/m

4.2.2 Variable loads

It is a time dependent load, involves weight due to occupancy and maintenance, movable partitions, snow load, wind pressure (neglected because of the low range of wind velocities which does not have any threat to the structure). The subcategories are as follows:

Occupancy

According to EN 1991-1-1: 2001, Table 6.1 provides the category of occupancy. Depending on the condition of use the structure is has been divided into two parts, the Concert hall and Offices. The characteristic value of load based on the occupancy from Table 6.2:

i) Auditorium hall

- Floors (C2 category) q_k = 3.05 kN/m^2
- Roof (H category) q_k = 0.5 kN/m^2

ii) Offices

- Floors (C1 category) q_k = 2.0 kN/m^2
- Roof (H category) q_k = 0.5 kN/m^2

Total Load of the Building

Building Lobby Part - I

Table 4.7- Total Dead Load and Live load of Entrance & Gallery – I

	Permanent Load (kg/m2)	Variable Load (kg/m2)
Roof	95.78	50
Floor	206.71	250

Building Auditorium Hall – II

Table 4.8- Total Dead Load and Live load of
Auditorium Hall and Backstage – II

	Permanent Load (kg/m2)	Variable Load (kg/m2)
Roof	305.71	50.00
Floor	158.51	350.00

Movable partition

Therefore, the extra variable load as per EN 1991-1-1, the floor allows a lateral distribution of load which is to be added to the imposed load obtained from table 6.2. The defined uniform distributed load is dependent on the self weight of the partition wall:

- For movable partitions with self weight≤ 1.0 kN/m wall length: q_k = 0.5 kN/m^2
- For movable partitions with self weight≤ 2.0 kN/m wall length: q_k = 0.8 kN/m^2
- For movable partitions with self weight≤ 3.0 kN/m wall length: q_k = 1.2 kN/m^2

In this case total linear weight of the partition wall is less than 1 kN/m, therefore the corresponding uniform distributed load on floor is **0.5 kN/m^2**

4.2.3 Snow Load

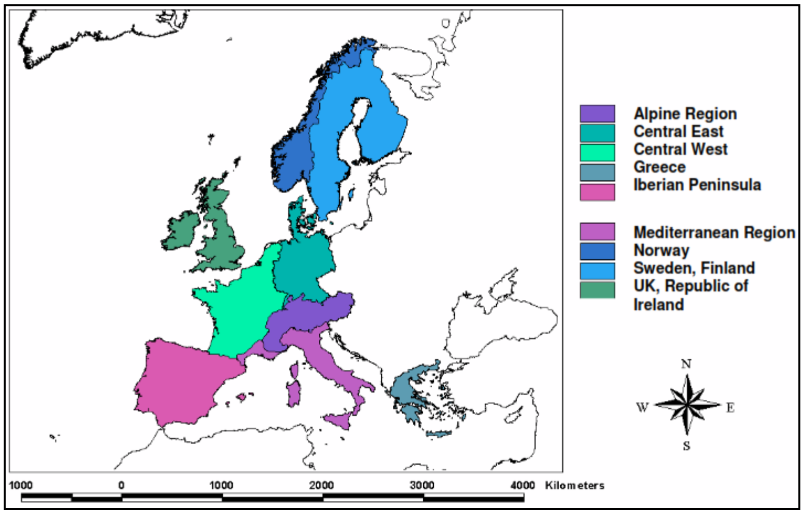


Figure 4.1- Europe climatic region

The following snow load calculation is based on climatic region close to Istanbul, Turkey for the sake of Eurocode. Snow loads on the roof are determined by the following standard equation:

$S = \mu_i * C_e * C_t * S_k$

μ_i - snow load shape co-efficient

C_e - exposure co-efficient

C_t – thermal co-efficient

S_k – characteristic value of snow load on the ground

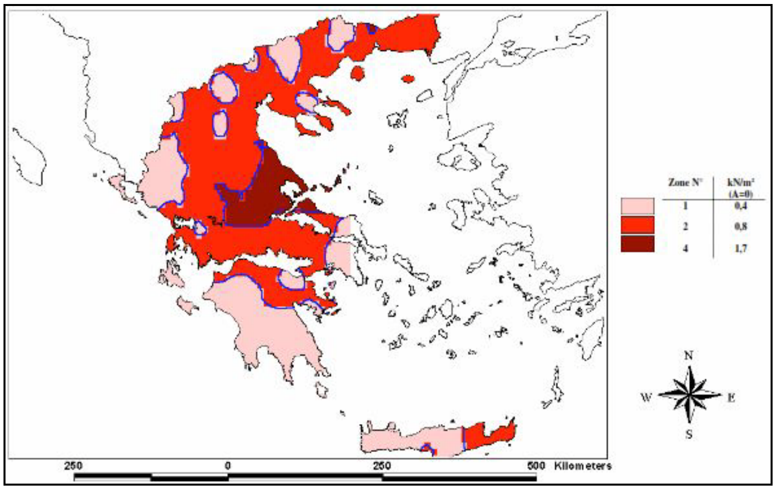


Figure 4.2- Snow load at sea level (Greece)

Ground Snow load:

$$S_k = (0.420Z - 0.030)\left[1 + \left(\frac{A}{917}\right)^2\right]$$

S_k is the characteristic snow load on the ground kN/m2

A is the site altitude above sea level (m)

Z is the zone number given on map

C_e value is considered to be 1.0 for normal topography, C_t is assumed to be 1.0 as the roof is well insulated. The shape of the roof is pitched $\alpha = 9^{\circ}$ and $\mu_i = 0.8$. S_k is calculated as 80 kg/m^2.

$S = \mu_i * C_e * C_t * S_k = 0.8*1*1*80 = 64$ kg/m^2. We assume total snow load on the roof top as 0.7 kN/m^2

4.2.4 Earthquake Load

Dynamic analysis is applicable for a building having height higher than 50 m which consists of Time history and Spectrum method.

For this project we use equivalent static force method. By using this method calculation for period of vibration for steel structures with moment resisting flexural frames in both direction of X and Y, the response of the structure is determined. Considering the soil type, importance factor of the structure, the type of the system and by having the weight of each story it is possible to determine the lateral forces for each level.

$T = 0.085H^{3/4}$

$S_e(T)$ - the elastic acceleration response spectrum

T - the vibration period of a linear single-degree-of-freedom system

a_g - the design ground acceleration on type A ground

T_B - the lower limit of the period of the constant spectral acceleration branch

T_C - the upper limit of the period of the constant spectral acceleration branch

T_D - the value defining the beginning of the constant displacement response range of the spectrum

S - the soil factor;

η - the damping correction factor. K = 1 for 5% viscous damping

$T = 0.085 * (16.7 \text{ m})^{3/4} = 0.70$ sec

According to EN 1998-1 the earthquake motion at the given point on the surface is represented by elastic ground acceleration response spectrum. The horizontal seismic action is described by two orthogonal components which are assumed independent.

Therefore, as per the classification of ground type we assume, **C** types ground condition. For horizontal component of seismic action, elastic response spectrum $S_e(T)$ is given as:

$$T_C \le T \le T_D : \; S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5\left[\frac{T_C}{T}\right]$$

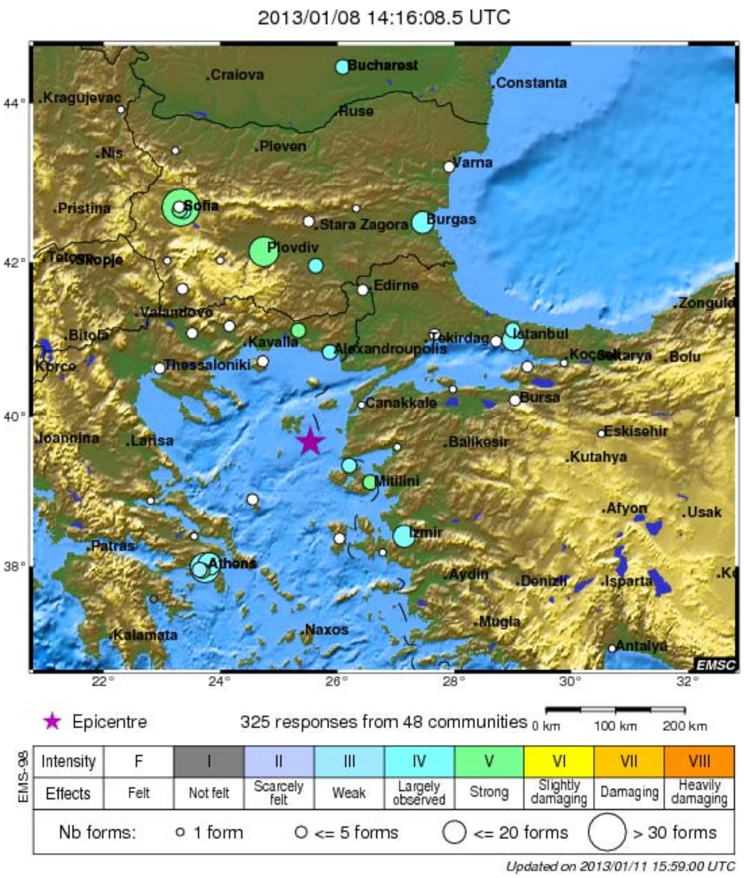


Figure 4.3- Scaling intensity and effect of earthquake

The most of the seismic hazard has the surface magnitude not greater than 5.5, so it is recommended Type-2 spectrum is adopted and the parameters values are given in Table 3.3 in *pg 25*.

Values of the parameters describing the recommended Type 2 elastic response spectra

Ground type	S	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,05	0,25	1,2
B	1,35	0,05	0,25	1,2
C	1,5	0,10	0,25	1,2
D	1,8	0,10	0,30	1,2
E	1,6	0,05	0,25	1,2

Table 4.9

$S = 1.5$, $T_B = 0.10$, $T_C = 0.25$, $T_D = 1.2$

$S_e(T) = 0.2*1.5*1*2.5\ (1.2/0.7) = 1.28\ m/s^2$

Since buildings are being favored by the same lateral resisting system in both directions, the distribution of seismic forces is equal for both directions.

Base Shear Force Calculation

The seismic base shear force (F_b) shall be determined using the following expression:

$F_b = S_e(T) * m * \lambda$

Whereas:

m - total mass of the building above the rigid basement

λ- the correction factor recommended value 0.85

Seismic base shear force F_b =	S_d (T)*m*λ

4.2.5 Load Combination

A steel structure can be designed in any of the following method:

- Elastic or Working stress method
- Plastic or Limit state method

In the working stress method, the worst combination of the load is ascertained and the members are proportioned on the basis of working stresses. In this design method service loads, elastic behavior, allowable stress are widely accepted and has been in practice.

The principle disadvantage of this method is that it fails to provide a uniform overload capacity for all the parts and types of structures. It does not take into account the non linear relationship between stress and strain and the ability of the structural members to resist load even after local yielding. It also does not consider the redistribution of forces and moments in statically indeterminate structures.

In Limit state design method has an improved design methodology which overcomes the drawbacks of the working stress method. This method expected to fulfils the performance of the structure to satisfy the intended purpose for which it is built. This is divided into two categories: 1) Ultimate limit state 2) Serviceability limit state.

Here, the structural analysis is carried out considering the most unfavorable condition. According to this method partial safety factor applied to the characteristic loads and combination of these loads includes factor that accounts the probability of occurrence for these action.

Ultimate limit state

$\sum_{j \geq 1} \gamma_{Gj} G_{kj} + \gamma_{Q1} Q_{k1} + \sum_{i \geq 1} \gamma_{Qi} \psi_{0i} Q_{ki}$

G_{kj} characteristic value of permanent action, and for unfavorable condition load factor γ_{Gj} = 1.35, and for favorable condition it is 1.0

Q_{k1} characteristic value for variable action, and for unfavorable condition load factor γ_{Q1} = 1.5, and for favorable condition it is zero.

Q_{ki} characteristic value for other variable action, and for unfavorable condition load factor γ_{Q1}= 1.5, and for favorable condition it is zero. ψ_{0i} = 0.7 from the table A1.1 of EN 1990

4.3 Design of steel structure

The structure was modeled with the help of SAP 2000 structural analysis software to determine the steel sections and forces. Loads were calculated based on the selected material specific weight and material thickness. According to the SAP 2000 modeling the selected beam and column sections for the lobby, restaurant and backstage is IPE 270, IPE240 for beams, HE 280M for the column and Tee section for roof truss. The structure is divided into 4 parts, and the selected calculation checks are done. Therefore, the design sections check was done to assure the safety as per the Eurocode norms.

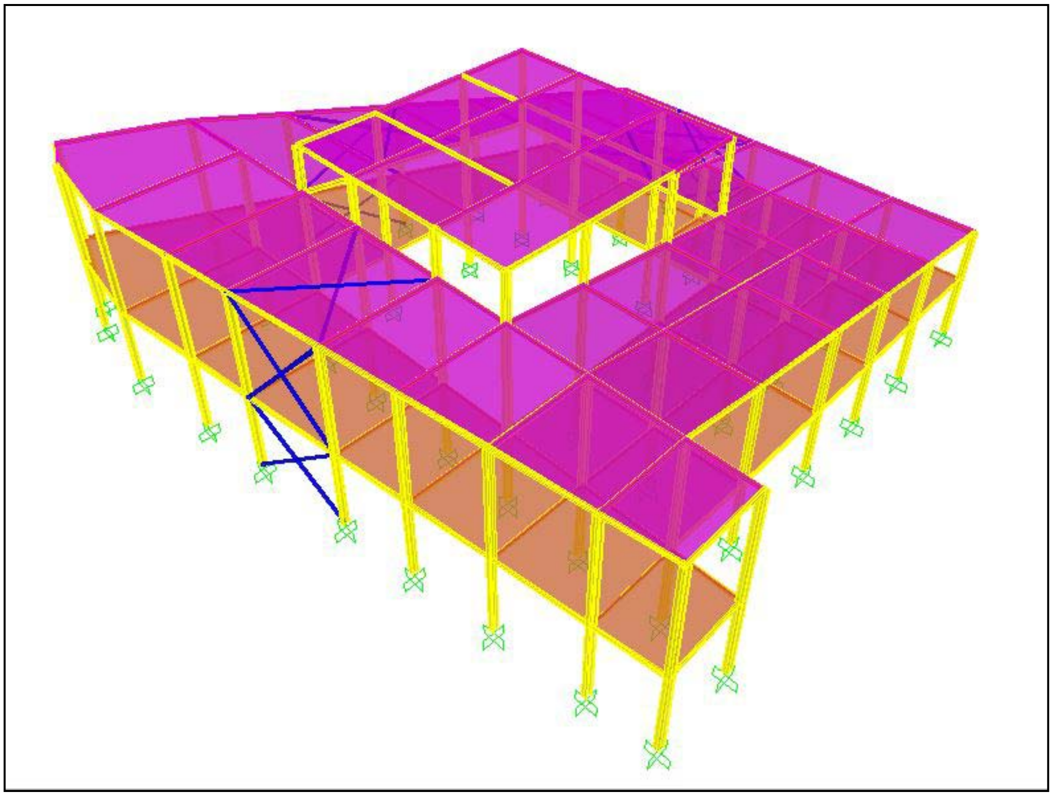


Figure 4.4- View of the Office structure

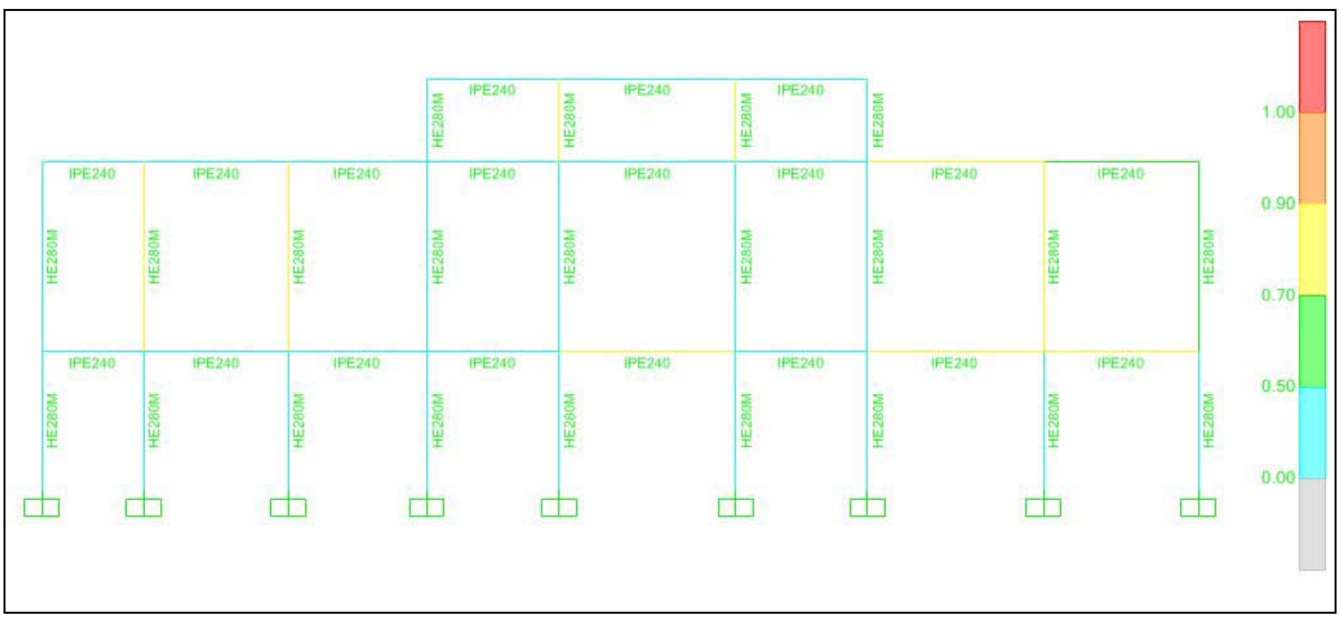


Figure 4.5- Steel section plan of Offices

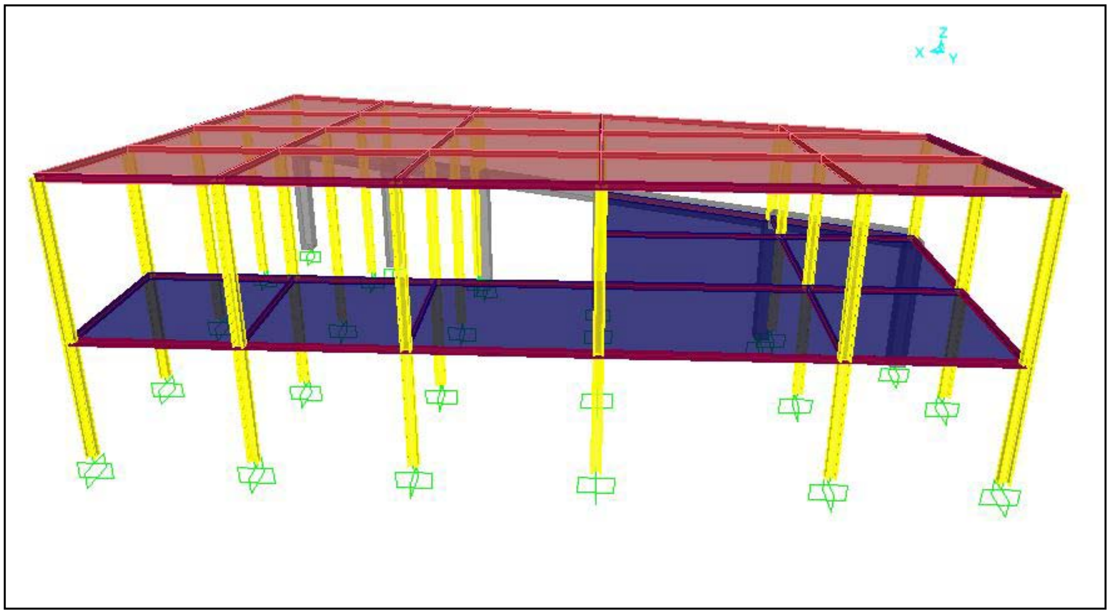


Figure 4.6- View of the restaurant structure

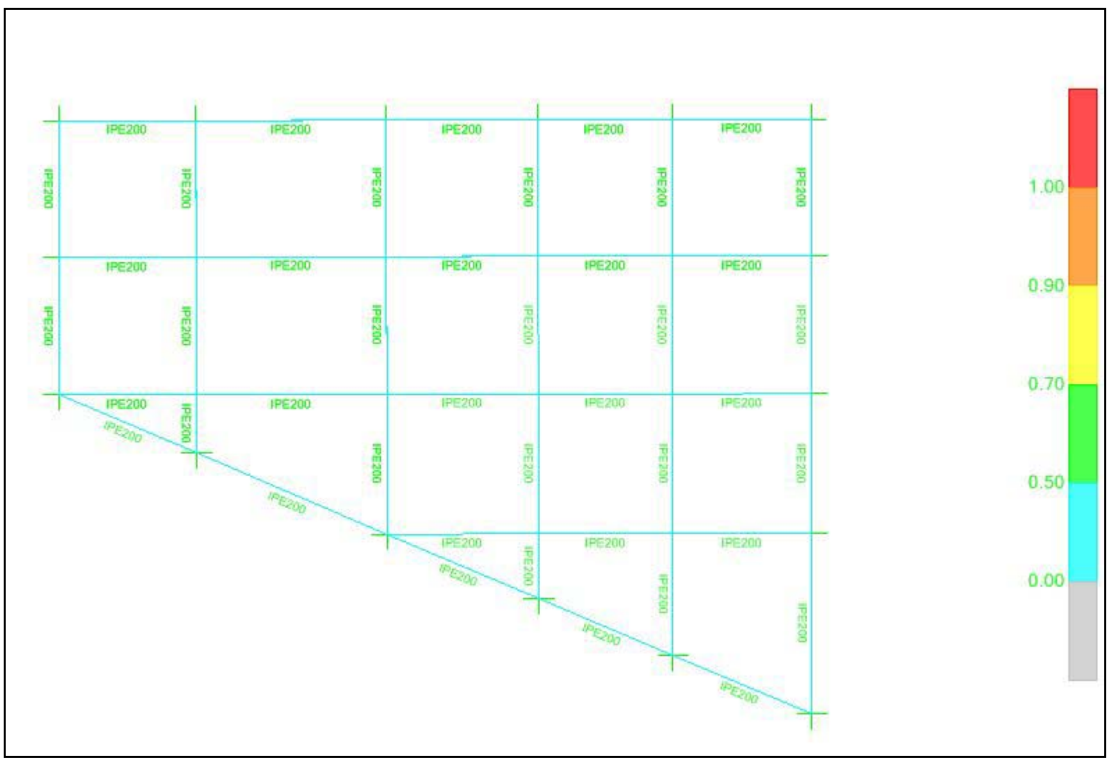


Figure 4.7- Steel section plan of Restaurant

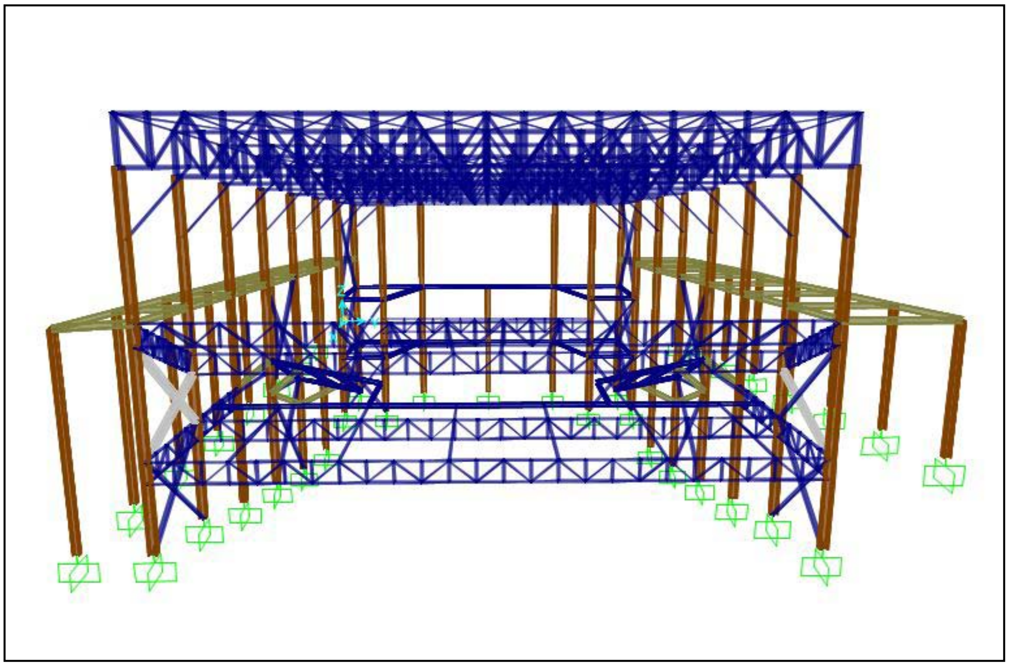


Figure 4.8- Steel section plan of Auditorium 1

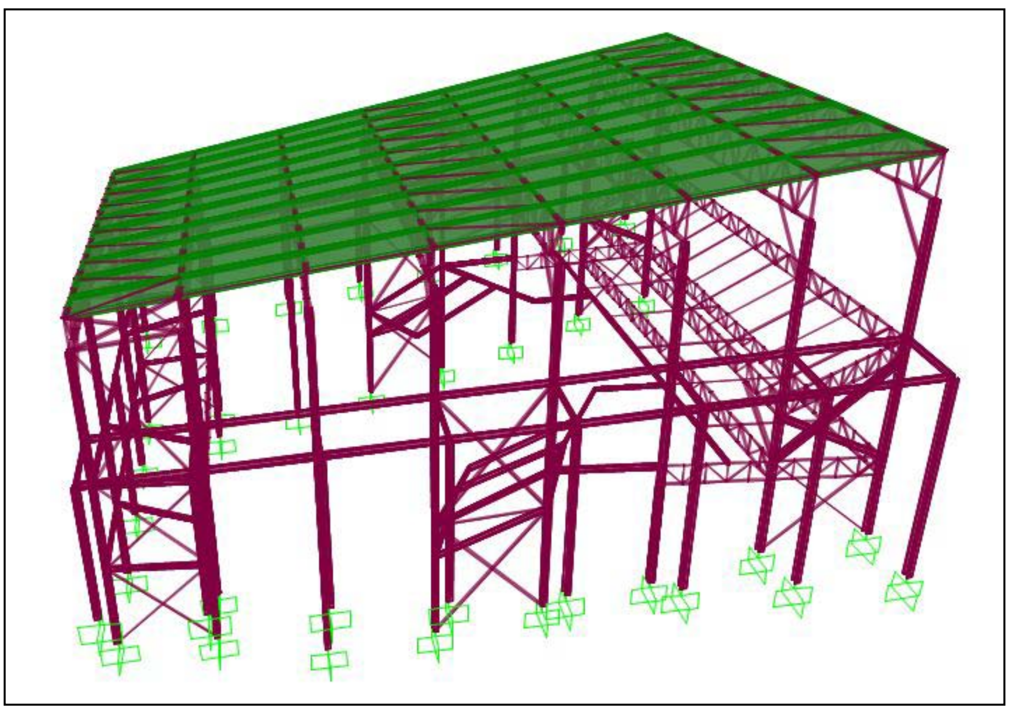


Figure 4.9- Steel section plan of Auditorium 2

4.3.1 Truss Geometry, Loading and Analysis

The truss is modeled and designed for the dead load, live load and snow load in SAP 2000.

Dead load of green roof: 3.05 kN/m^2

Live load: 0.5 kN/m^2

Snow load: 0.7 kN/m^2

It is assumed that the loads are applied as a uniformly distributed load on the top chords of the truss. The truss varies in height from 1.5m to 2.1m and is spaced as shown below.

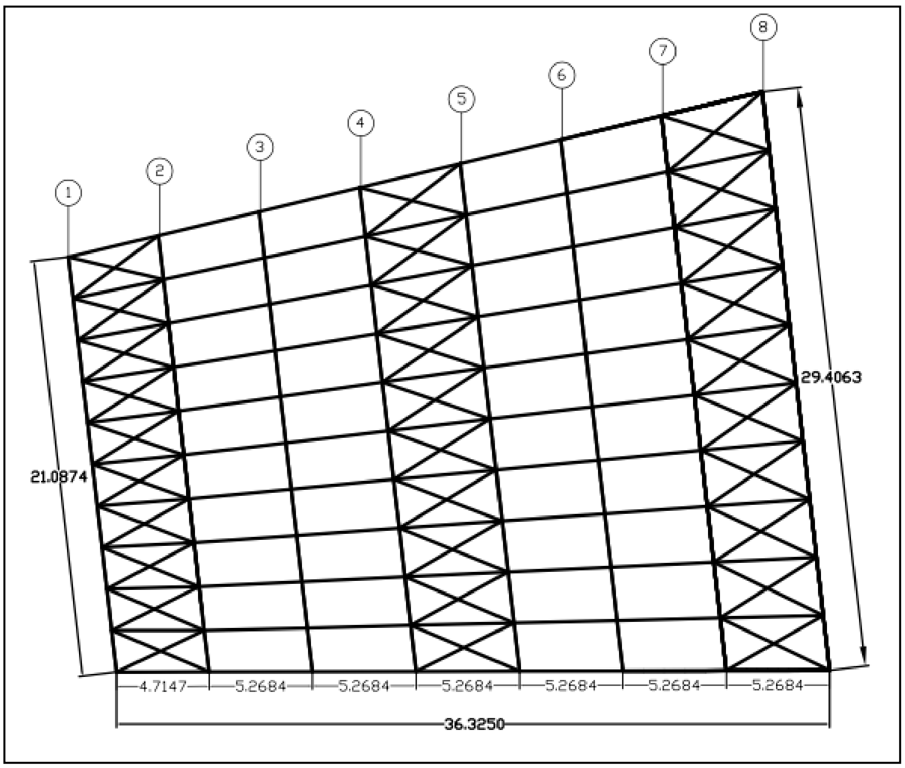


Figure 4.10- Layout plan of the roof truss

The design load is obtained taking into consideration partial factor of safety for unfavorable effect may be derived as follows:

Dead load of green roof: 3.05 x 1.35 = 4.11 kN/m^2

Live load: 0.5 x 1.5 = 0.75 kN/m^2

Snow load: 0.7 x 1.05 = 0.735 kN/m^2

The forces applied on each truss on top chord are calculated by multiplying with the center to center distance of the roof slab and is assigned to the frame as shown:

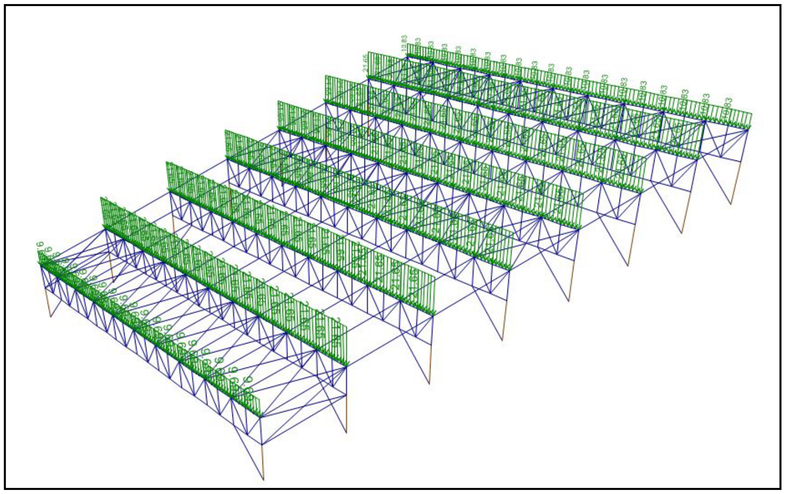


Figure 4.11- Load distribution on the roof truss

Design axial force compression = ***1772.4 kN***, We consider tee section of T-HE 320M

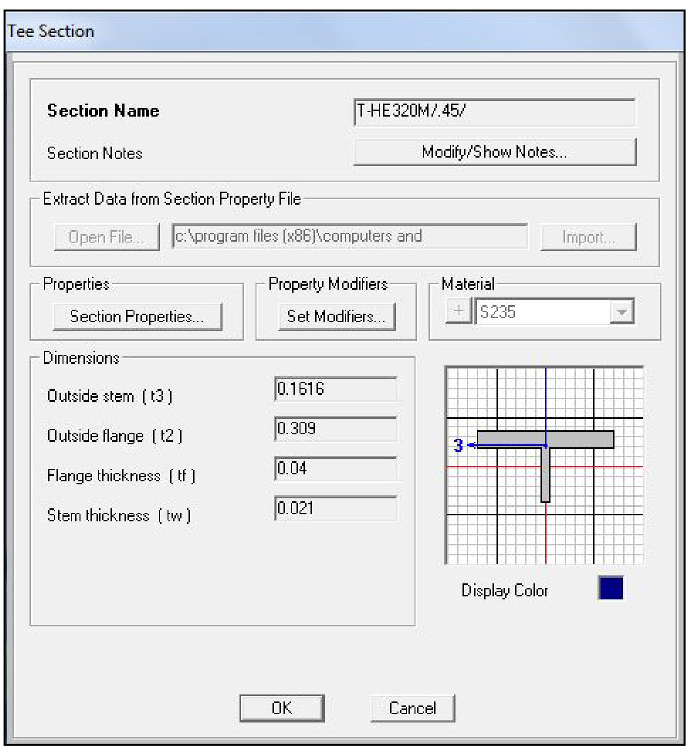


Figure 4.12- Dimensions of T- Section

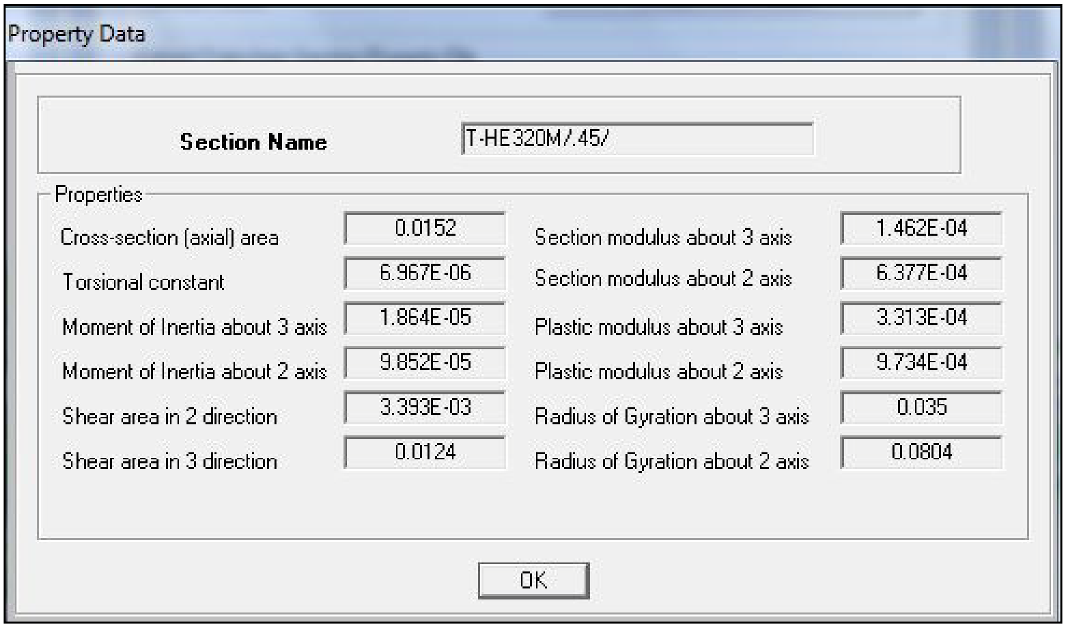


Figure 4.13- Properties of T- Section

Material Properties:

$t \leq 40$ mm

Yielding Stress: $f_y = 235$ MPa

Ultimate Tensile Stress: $(f_u) = 360\ N/mm^2$

Section classification:

$$\in = \sqrt{235/f_y} = 1,$$

$$\frac{c}{t} = \frac{\frac{308}{2}}{40} = 3.85$$

$10\ \varepsilon = 10 \times 1 = 10$

Therefore, the section satisfies the requirement for class 1 elements.

$$\frac{h}{t_w} = \frac{177.8}{21} = 8.46$$

The stem also satisfies class 1 requirement. **The same section is also used for the other diagonal, vertical truss members.**

The sections are checked for local as well as overall buckling. According to ***Eurocode 3, part 1-1 clause 5.4.4 and 5.5.1***

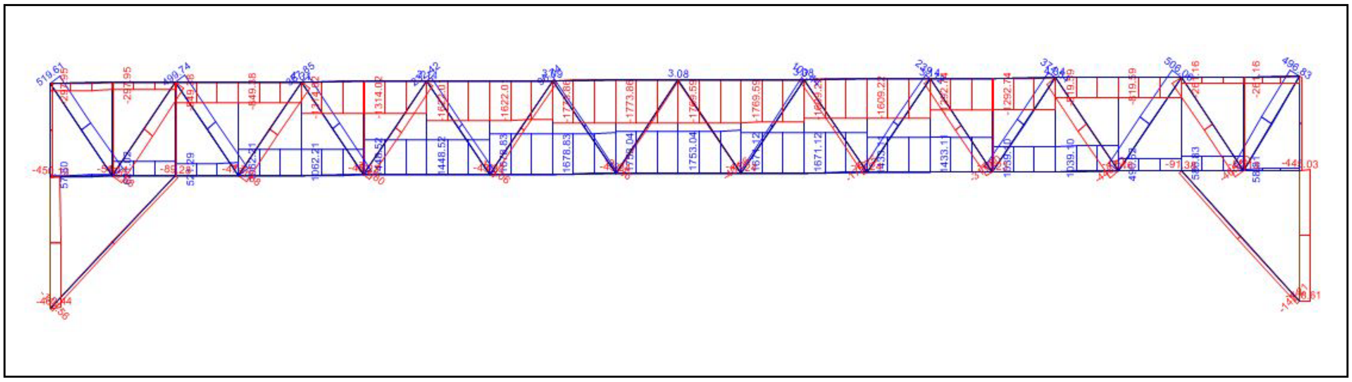


Figure 4.14- Axial force diagram

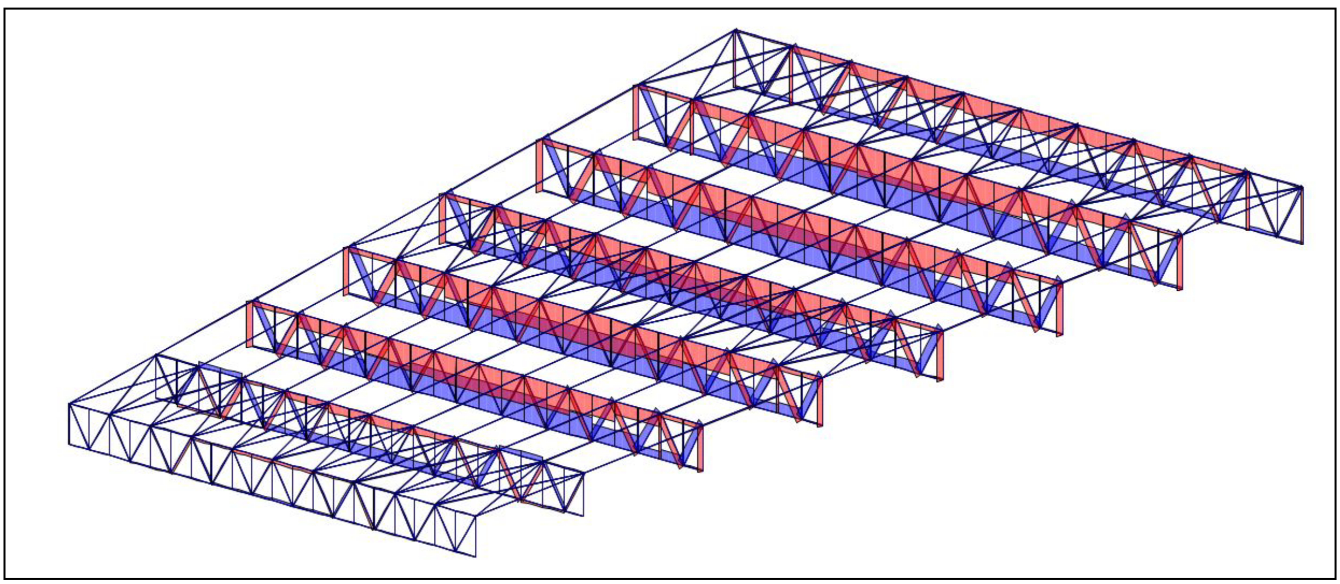


Figure 4.15- Axial force diagram for complete roof truss

For member in axial compression, design value of compressive force N_{Sd} at each cross section shall satisfy: $N_{Sd} \leq N_{C,\,Rd}$

Whereas: $N_{C,\ Rd}$ is the design compression resistance of the cross section. Partial safety factor for class 1 cross section $\gamma_{m0} = 1.0$

$$N_{C,\ Rd} = \frac{A.f_y}{\gamma_{m0}} = \frac{0.0152 \text{ x } 235 \text{ x } 10^3}{1.0} = \mathbf{3572\ kN}$$

N_{Sd} (1773.86 kN) $\leq$ $N_{C,\ Rd}$ (3572 kN)

Section in tension: The same section is used for the tension chord. ***N_{Sd} =1753 kN***

N_{Sd} =1753 kN $\leq$ $N_{C,\ Rd}$

Diagonal brace member

Design forces: maximum tension = 506.06 kN; maximum compression = 448.52 kN

N_{Sd} (506.06 kN) in tension $\leq$ $N_{C,\ Rd}$ (3572 kN)

N_{Sd} (448.52 kN) in compression $\leq$ $N_{C,\ Rd}$ (3572 kN)

Vertical brace member

Design forces: maximum tension = 3.14 kN; maximum compression = 48.24 kN

N_{Sd} (3.14 kN) in tension $\leq$ $N_{C,\ Rd}$ (3572 kN)

N_{Sd} (48.24 kN) in compression $\leq$ $N_{C,\ Rd}$ (3572 kN)

Hence, the check is satisfactory.

Buckling Resistance

The sections selected for the truss have same section for top, lower, diagonal and vertical elements and the check is done with respect to the maximum forces that are achieved by the member in compression and in tension:

For Top and bottom chord

The design buckling resistance of a compression member shall be taken as:

$$N_{b,Rd} = \chi\beta_A \frac{A.f_y}{\gamma_{m1}} = \frac{0.56x\ 1.0\ x\ 15.2\ x\ 235}{1.0} = 2000\ \boldsymbol{kN}$$

β_A = 1.0 for class 1 member.

X = reduction factor, but it should be less than 1

The section belongs to the C curve, so the reduction factor χ as calculated:

$$\chi = \frac{1}{\emptyset + (\emptyset^2 - \lambda_1{}^2)^{0.5}} = 0.56$$

N_{Sd} (1974 kN) in compression ≤ $N_{b,Rd}$ (2000 kN)

Diagonal brace member

Design forces: tension = 506.06 kN; maximum compression = 448.52 kN

N_{Sd} (448.52 kN) in compression ≤ $N_{C,Rd}$ (2000 kN)

Vertical brace member

Design forces: tension = 3.14 kN; maximum compression = 48.24 kN

N_{Sd} (48.24 kN) in compression ≤ $N_{C,Rd}$ (2000 kN)

Therefore, the above check for the selected members in tension and compression is satisfactory.

4.3.2 Design Check for Beam

From the steel table we select IPE 240 for the offices and backstage section and IPE 270 for the auditorium corridor section and balcony. Steel beams are designed on the basis of bending stress, according to *Eurocode 1993-1-1: 2004, clause 5.4.5*

IPE 240 beam section

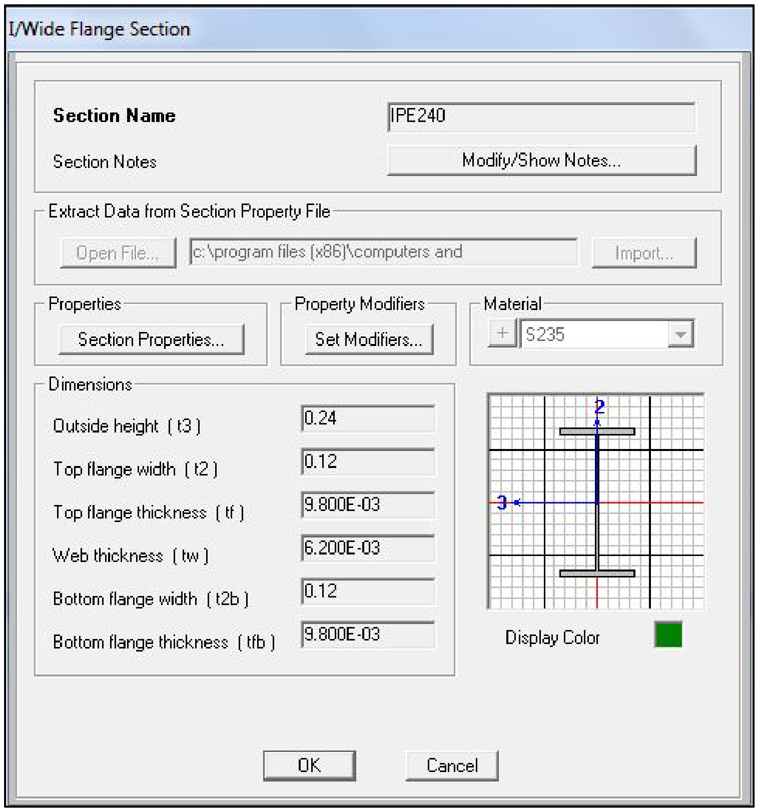


Figure 4.16- Dimensions of IPE 240 beam section

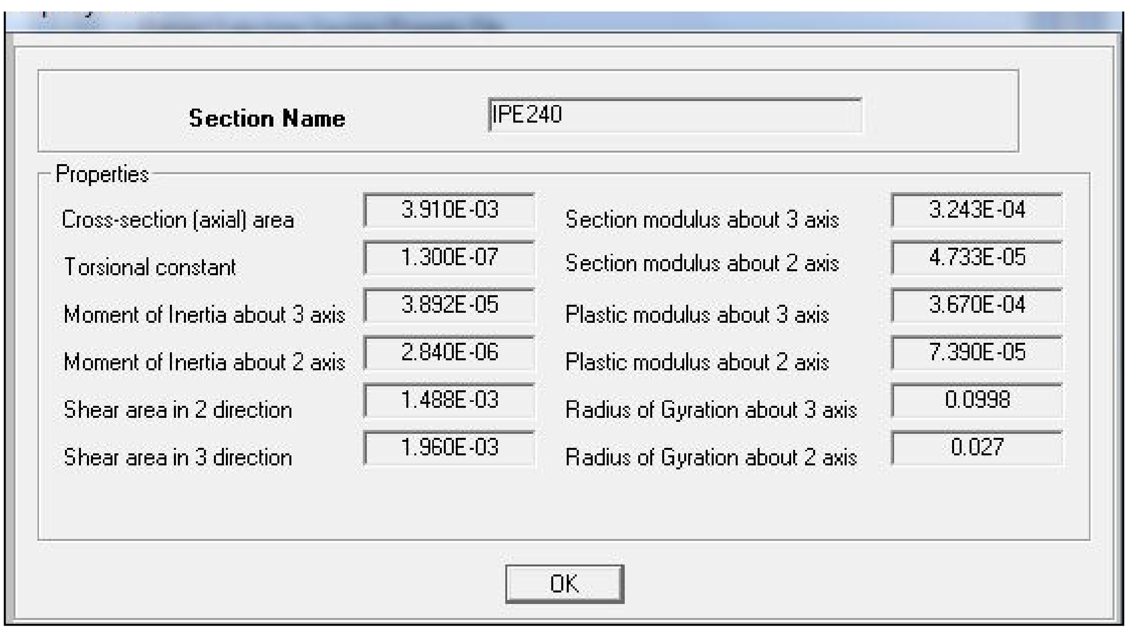


Figure 4.17- Section properties of IPE 240

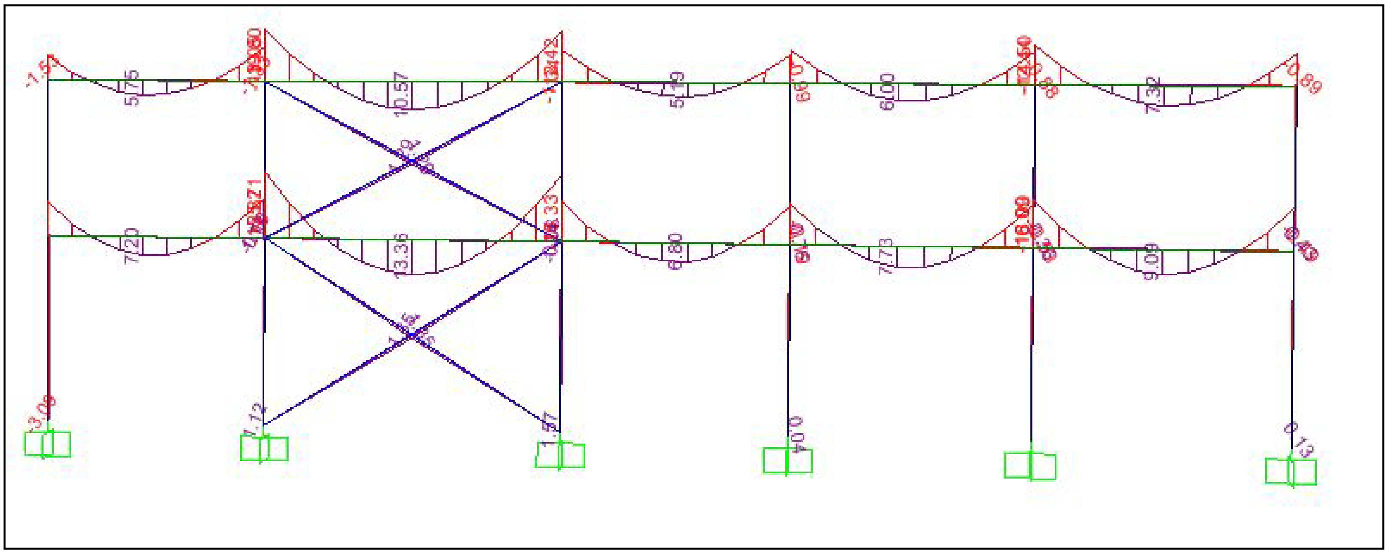


Figure 4.18- Bending moment diagram

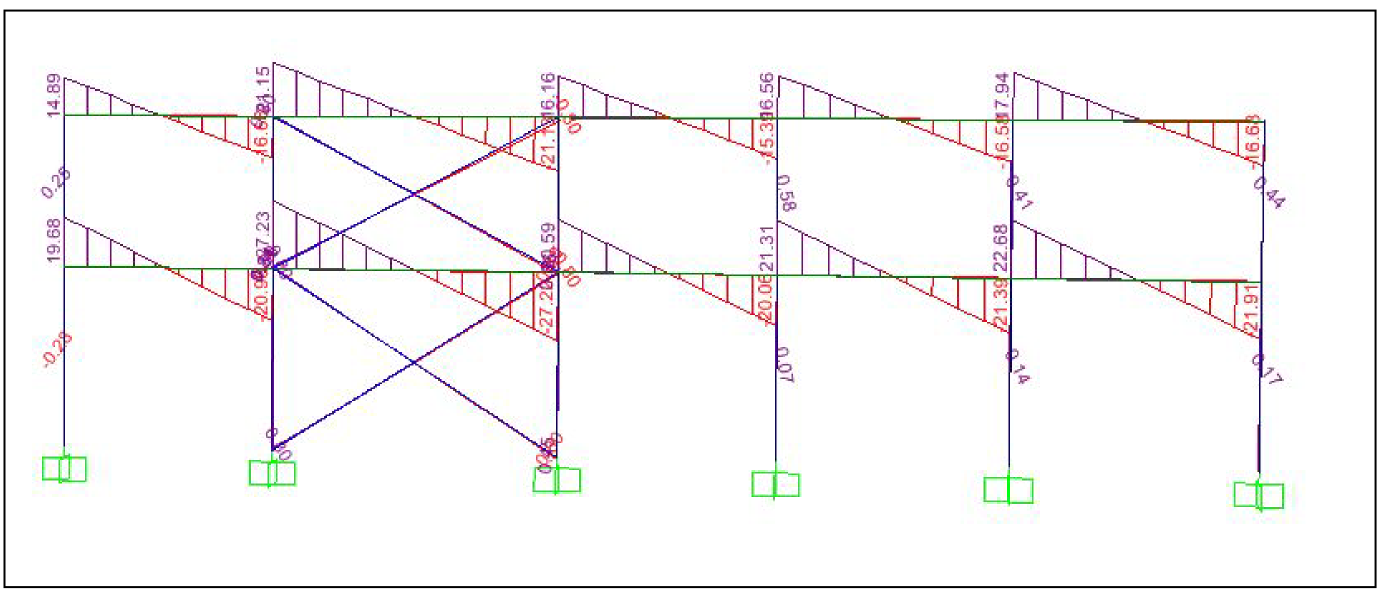


Figure 4.19- Shear force diagram

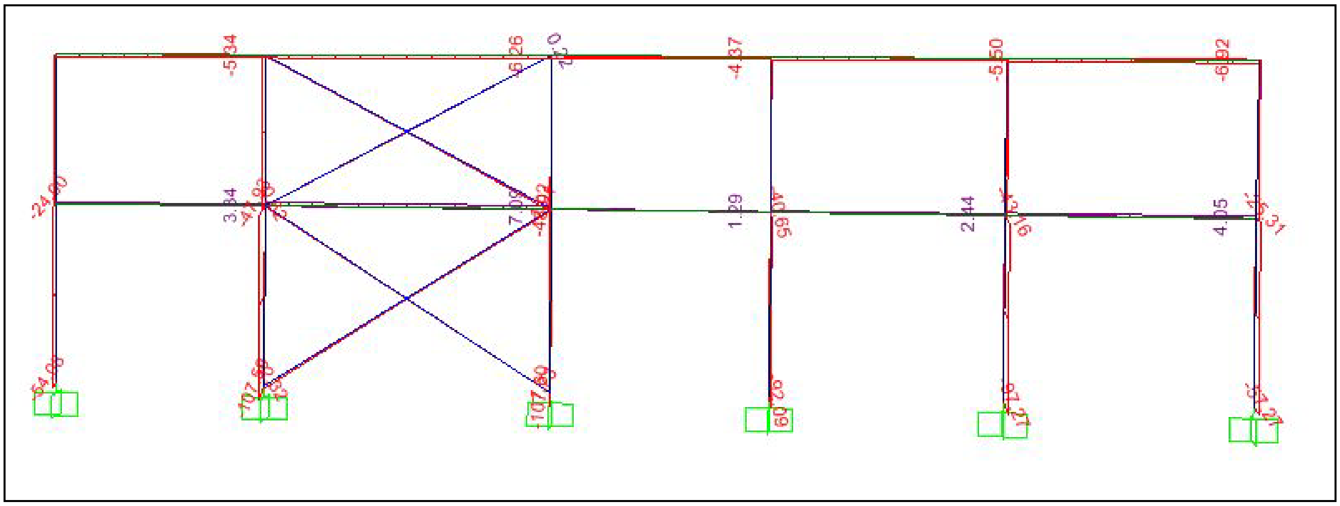


Figure 4.20- Axial force diagram

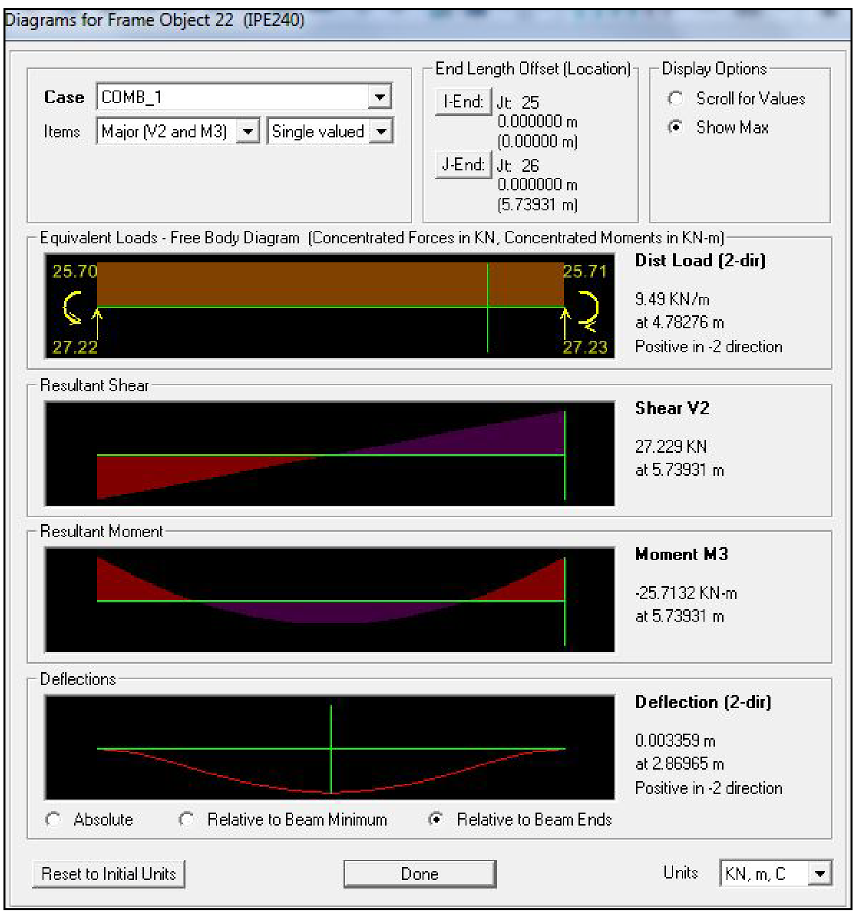


Figure 4.21- Details of the forces IPE 240

Section classification:

$\in = \sqrt{235/f_y} = \sqrt{235/235} = 1,$

$$\frac{c}{t} = \frac{\frac{120}{2}}{9.8} = 6.122$$

10 ε = 10 x 1 = 10, Hence, the section satisfies the requirement for class 1 elements.

In absence of shear force the design of bending moment shall satisfy the following:

$$\boldsymbol{M_{Ed} \leq M_{Rd}}$$

Whereas: M_{Rd} is the design moment resistance of the cross-section.

M_{ed} is the equivalent moment resistance of the cross-section.

Check for Bending in one axis

The design value of bending moment obtained from the analysis, $\mathbf{M_{Ed}}$ ***= 25.71 kN-m.***

Required section modulus:

$$W_{min} = \frac{M_{Ed}}{f_y} = \frac{25.71 \times 10^6}{235} = 1.075 \times 10^5 \text{ mm}^3$$

Therefore, we selected ***IPE 240*** which has section modulus of W = 3.24 x 10^5 mm^3

$$M_{c,Rd} = \frac{W_{pl} \cdot f_y}{\gamma_{m0}} = \frac{3.66 \times 10^5 \times 235}{1.0} \times 10^{-6} = \boldsymbol{86.01 kN.m}$$

$\boldsymbol{M_{Ed} \leq M_{Rd}}$ the check for bending is satisfactory.

Check for Shear force on web

The design values of shear force (V_{Ed}) at each cross section should satisfy the following criteria:

Maximum shear force ($\boldsymbol{V_{Ed}}$***) = 27.20 kN***

$$\boldsymbol{V_{Ed} \leq V_{pl,Rd}}$$

$V_{pl,Rd}$ is the design plastic shear resistance of the cross-section which is given as:

$$V_{pl,Rd} = \frac{A_v\left(f_y/\sqrt{3}\right).}{\gamma_{m0}} = \frac{1912.76(\frac{235}{\sqrt{3}}) \times 10^{-3}}{1.0} = 259.51 \text{ kN.m}$$

A_v is the shear area which may be taken as for I section:

$A_v = A - 2bt_f + (t_w + 2r)t_f = 3910 - 2352 + (6.2+30) \times 9.8 = 1912.76 \text{ mm}^2$

$\boldsymbol{V_{Ed} \leq V_{pl,Rd}}$ the check for bending is satisfactory.

We assume that the beam is fully restrained at both ends, so check for lateral torsion buckling is not required. Also shear buckling resistance for the beam is not required because section d/t_w is less than 69 ∈ for unstiffened web.

Additional checks as the section is on cleats

The beam is supported on a seating cleat, so the following check is done. The following check is done for 100 mm stiff bearing.

a) ***Design crushing resistance of the web $R_{y,Rd}$***

$$R_{y,Rd} = \frac{(s_s+s_y)t_w f_{yw}}{\gamma_{m1}}$$

$$S_y = 2t_f\left(\frac{b_f}{t_w}\right)^{0.5}\left(\frac{f_{yf}}{f_{yw}}\right)^{0.5}\left[1-\left(\frac{\sigma_{f,Ed}}{f_{yf}}\right)^2\right]^{0.5}$$

where S_s is the length of the stiff bearing

t_w is the thickness web

f_{yw} is the yield strength of the web

γ_{m1} is the material partial safety factor = 1.0

S_y is the length over which the effect takes place

At the support the stress in the beam flange is $\sigma_{f,Ed}$, zero, $f_{yf} = f_{yw}$ and the value is halved

$$S_y = 2t_f\left(\frac{b_f}{t_w}\right)^{0.5}\left(\frac{f_{yf}}{f_{yw}}\right)^{0.5}\left[1-\left(\frac{\sigma_{f,Ed}}{f_{yf}}\right)^2\right]^{0.5} = 2 \times \frac{9.8 \times \left(\frac{120}{6.2}\right)^{0.5}}{2} = 43.11\ mm$$

Therefore crushing resistance:

$$R_{y,Rd} = \frac{(100+43.11)\times 6.2 \times 235}{1\times 10^3} = 208.511\ kN$$

$\boldsymbol{V_{Ed}}$ ***(27.20 kN)*** $\leq$ $\mathbf{R_{y,Rd}}$, ***Hence, the check is satisfactory.***

b) Design crippling resistance of the web $R_{a,Rd}$

$$R_{y,Rd} = 0.5t_w^{\,2}(Ef_{yw})^{0.5}\left[\frac{\left(\frac{t_f}{t_w}\right)^{0.5} + 3\left(\frac{t_w}{t_f}\right)\left(\frac{s_s}{d}\right)}{\gamma_{m1}}\right]$$

$$= 0.5\times 6.2^2(210000\times 235)^{0.5}\left[\frac{\left(\frac{9.8}{6.2}\right)^{0.5} + 3\left(\frac{6.2}{9.8}\right)\left(\frac{100}{120}\right)}{1.0\times 10^3}\right] = 383.30\ kN$$

V_{Ed} ***(27.20 kN)*** $\leq$ $R_{y,Rd}$ **, *Hence, the check is satisfactory.***

Check for deflection of IPE 240 beam

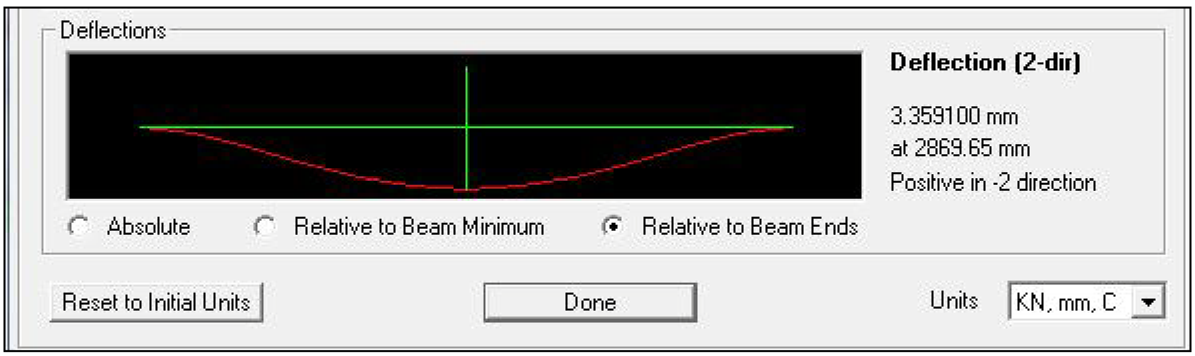


Figure 4.22- Deflection of beam

Maximum allowed deflection = L/250 = 5739 / 250 = ***22 mm ≥ 3.35 mm***

IPE 270 beam section

Material Properties:

Density: $\rho = 7697\ kg/m3$

Yielding Stress: $f_y = 235$ MPa

Ultimate Tensile Stress: $(f_u) = 360\ N/mm^2$

Elastic Modulus: E = 210 GPa

Poisson's Ratio: $\mu = 0.3$

Coefficient of Thermal Expansion: 1.17×10^{-5}

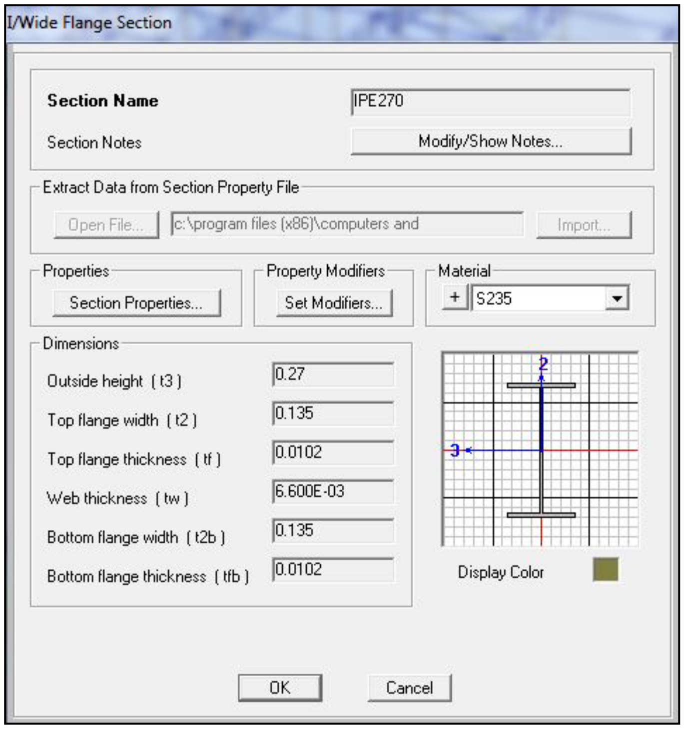


Figure 4.23- Dimensions of IPE 270 beam section

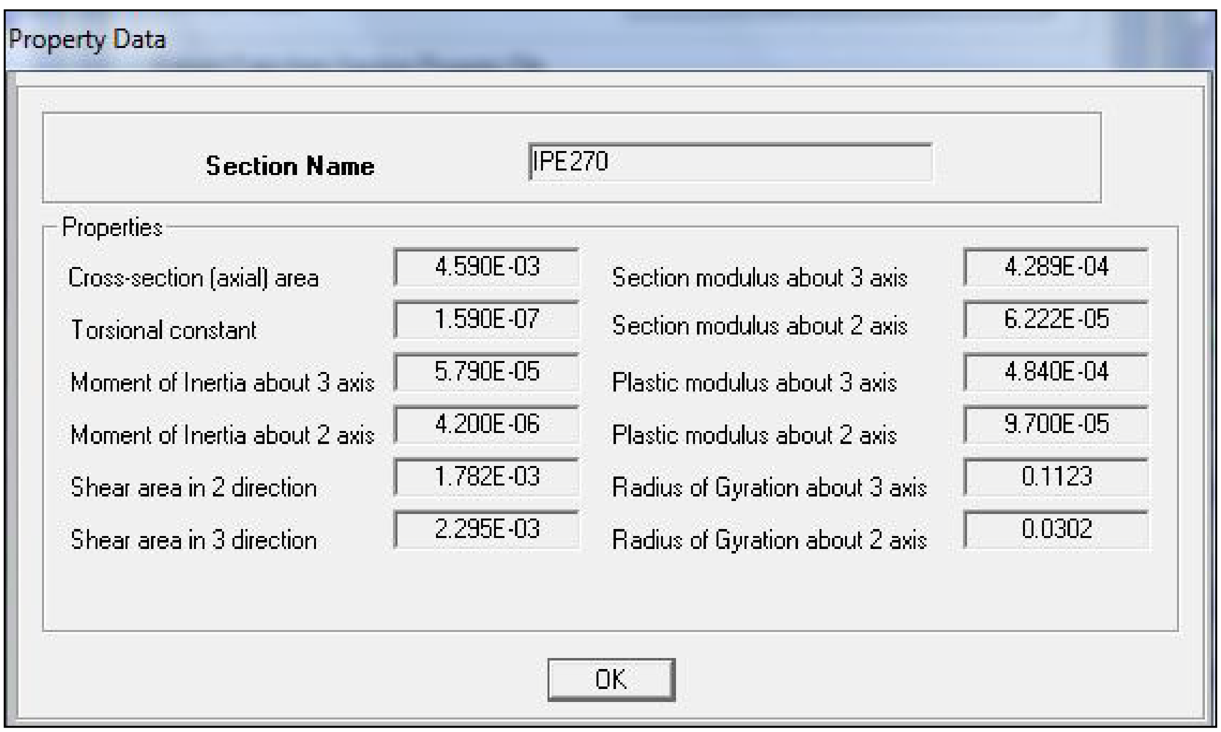


Figure 4.24- Section properties of IPE 270

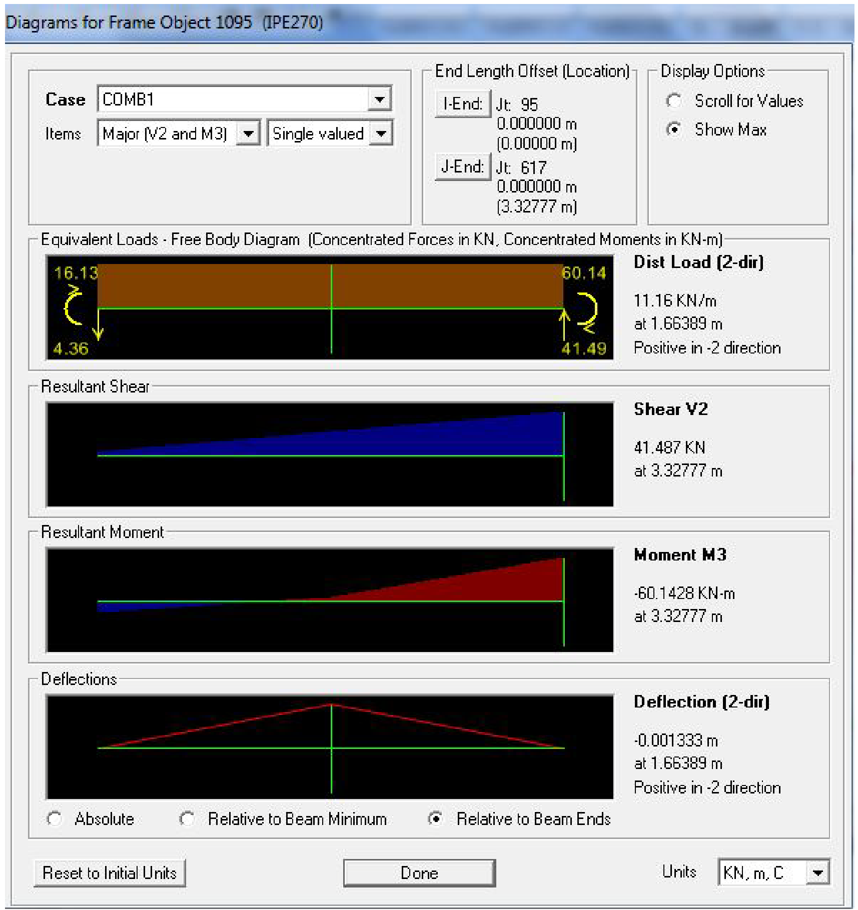


Figure 4.25- Details of the forces IPE 270

In absence of shear force the design of bending moment shall satisfy the following:

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

Whereas: M_{Rd} is the design moment resistance of the cross-section.

M_{Ed} is the equivalent moment resistance of the cross-section.

Check for Bending in one axis:

The maximum design value of bending moment is considered for calculation obtained from the SAP 2000 analysis, $\mathbf{M_{Ed}}$ = ***60.14 kN-m.***

Required section modulus:

$$W_{min} = \frac{M_{Ed}}{f_y} = \frac{60.14 \text{ x } 10^6}{235} = 2.55 \text{ x } 10^5 \text{ mm}^3$$

Therefore, we selected IPE 270 which has section modulus of $W = 4.29 \times 10^5\ mm^3$

Section classification:

$\epsilon = \sqrt{235/f_y} = \sqrt{235/235} = 1,$

$$\frac{c}{t} = \frac{\frac{135}{2}}{10.2} = 6.61$$

$10\ \varepsilon = 10 \times 1 = 10$, Hence, the section satisfies the requirement for class 1 elements.

For this type of cross section check for bending:

$$M_{c,\,Rd} = \frac{W_{pl} \cdot f_y}{\gamma_{m0}} = \frac{4.84 \times 10^5 \times 235}{1.0} \times 10^{-6} = \boldsymbol{113.74\ kN.m}$$

$M_{Ed} \leq M_{Rd}$ the check for bending is satisfactory.

Check for Shear force on web

The design values of shear force (V_{Ed}) at each cross section should satisfy the following criteria:

Maximum shear force (V_{Ed}) = ***41.48 kN***

$$\boldsymbol{V_{Ed} \leq V_{pl,\,Rd}}$$

$V_{pl,\,Rd}$ is the design plastic shear resistance of the cross-section which is given as:

$$V_{pl,\,Rd} = \frac{A_v\left(f_y/\sqrt{3}\right).}{\gamma_{m0}} = \frac{1462.68\left(\frac{235}{\sqrt{3}}\right) \times 10^{-3}}{1.0} = 198.45\ kN.m$$

A_v is the shear area which may be taken as for I section:

$A_v = A - 2bt_f + (t_w + 2r)t_f = 4590 - 2754 + (6.6+30) \times 10.2 = 1462.68\ mm^2$

$V_{Ed} \leq V_{pl,\,Rd}$ the check for bending is satisfactory.

We assume that the beam is fully restrained at both ends, so check for lateral torsion buckling is not required. Also shear buckling resistance for the beam is not required because section d/t_w is less than 69 ϵ for unstiffened web.

Additional checks as the section is on cleats

The beam is supported on a seating cleat, so the following check is done. The following check is done for 100 mm stiff bearing.

a) ***Design crushing resistance of the web $R_{y,Rd}$***

$$R_{y,Rd} = \frac{(s_s+s_y)t_w f_{yw}}{\gamma_{m1}}$$

$$S_y = 2t_f\left(\frac{b_f}{t_w}\right)^{0.5}\left(\frac{f_{yf}}{f_{yw}}\right)^{0.5}\left[1-\left(\frac{\sigma_{f,Ed}}{f_{yf}}\right)^2\right]^{0.5}$$

where S_s is the length of the stiff bearing

t_w is the thickness web

f_{yw} is the yield strength of the web

γ_{m1} is the material partial safety factor = 1.0

S_y is the length over which the effect takes place

At the support the stress in the beam flange is $\sigma_{f,Ed}$, zero, $f_{yf} = f_{yw}$ and the value is halved

$$S_y = 2t_f\left(\frac{b_f}{t_w}\right)^{0.5}\left(\frac{f_{yf}}{f_{yw}}\right)^{0.5}\left[1-\left(\frac{\sigma_{f,Ed}}{f_{yf}}\right)^2\right]^{0.5} = 2\times\frac{10.2\times\left(\frac{225}{6.6}\right)^{0.5}}{2} = 59.55\ mm$$

Therefore crushing resistance:

$$R_{y,Rd} = \frac{(100+59.55)\times 6.6\times 235}{1\times 10^3} = 247.462\ kN$$

V_{Ed} (41.48 kN) $\leq$ $R_{y,Rd}$, Hence, the check is satisfactory.

b) ***Design crippling resistance of the web $R_{a,Rd}$***

$$R_{y,Rd} = 0.5t_w^2(Ef_{yw})^{0.5}\left[\frac{\left(\frac{t_f}{t_w}\right)^{0.5}+3\left(\frac{t_w}{t_f}\right)\left(\frac{s_s}{d}\right)}{\gamma_{m1}}\right]$$

$$= 0.5\times 6.6^2(210000\times 235)^{0.5}\left[\frac{\left(\frac{10.2}{6.6}\right)^{0.5}+3\left(\frac{6.6}{10.2}\right)\left(\frac{100}{219.6}\right)}{1.0\times 10^3}\right] = 325.45\ kN$$

V_{Ed} (41.48 kN) $\leq$ $R_{y,Rd}$, Hence, the check is satisfactory.

Check for deflection of IPE 270 beam

Figure 4.26- Deflection of beam

Allowed maximum deflection = l / 250 = 3327/250 = 13.3 mm $\geq$ 1.33 mm

4.3.3 Design Check for Column

We Choose HE 280M for auditorium, offices and restaurant.

Material Properties:

Density: $\rho = 7697\ kg/m3$

Yielding Stress: $f_y = 235$ MPa

Ultimate Tensile Stress: $(f_u) = 360\ N/mm^2$

Elastic Modulus: E = 210 GPa

Poisson's Ratio: $\mu = 0.3$

Coefficient of Thermal Expansion: 1.17×10^{-5}

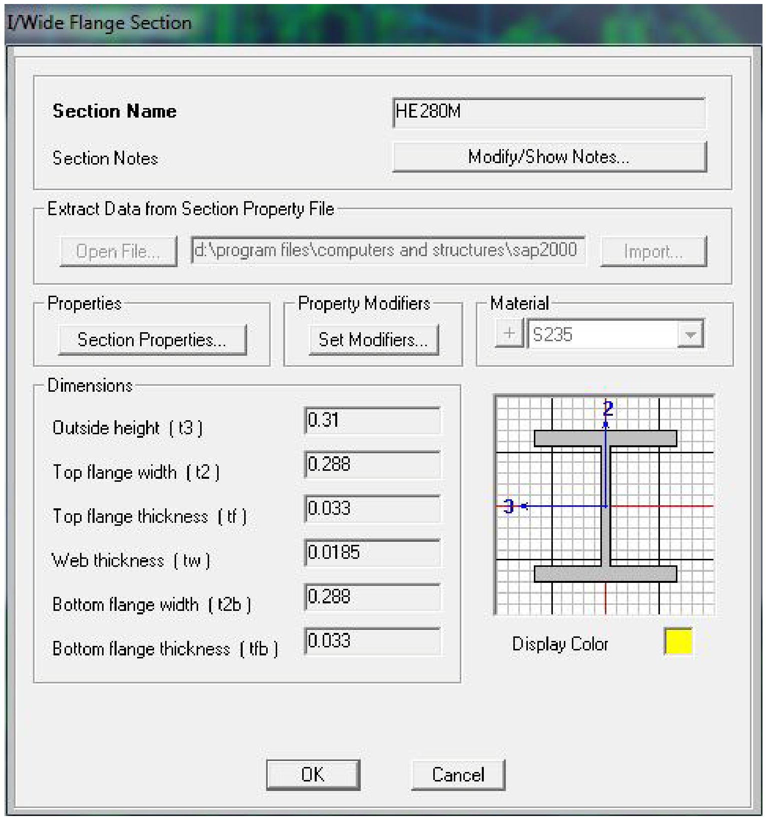


Figure 4.27- Dimensions of HE 280M Column section

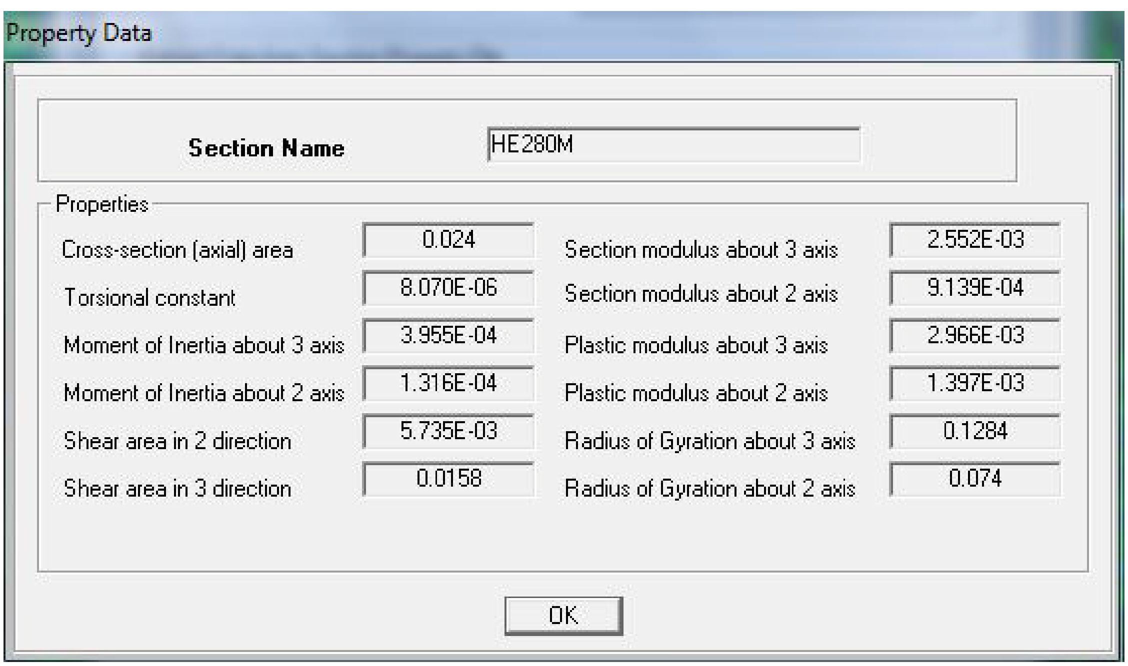


Figure 4.28- Section properties of HE 280M for column

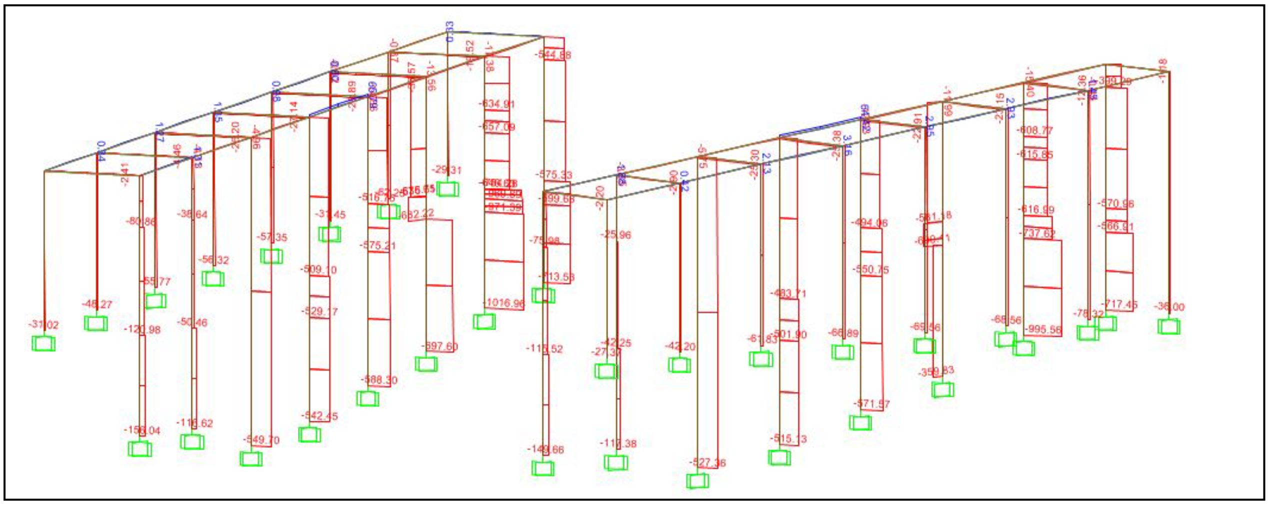


Figure 4.29- Axial force diagram for column at auditorium corridor

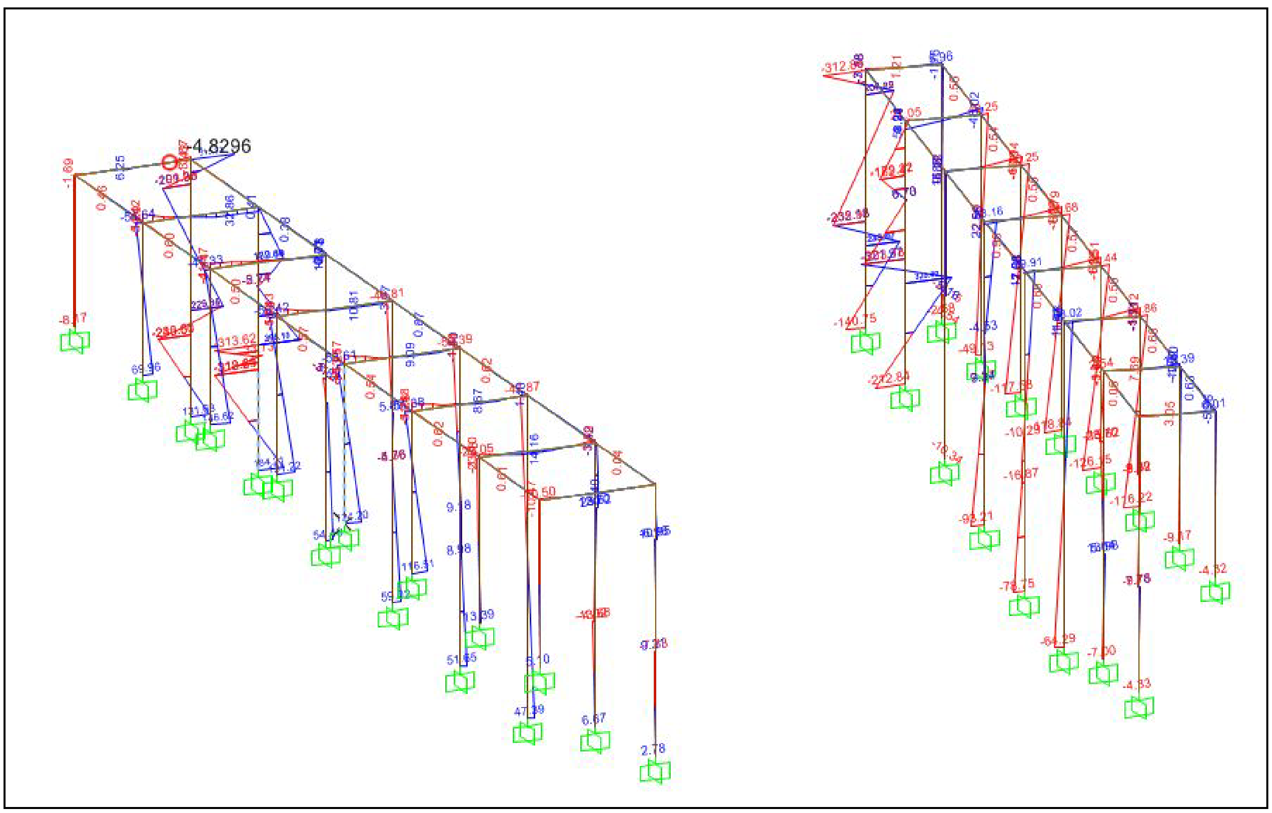


Figure 4.30- Bending moment diagram

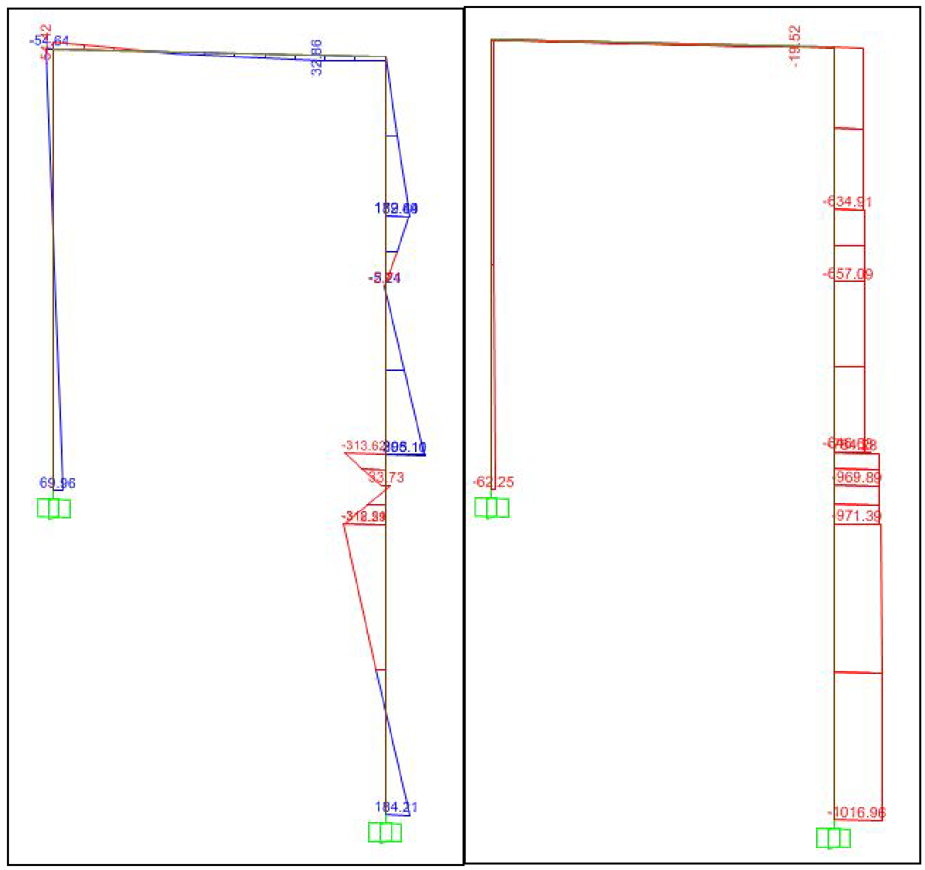


Figure 4.31- Maximum bending moment and axial force diagram of the section

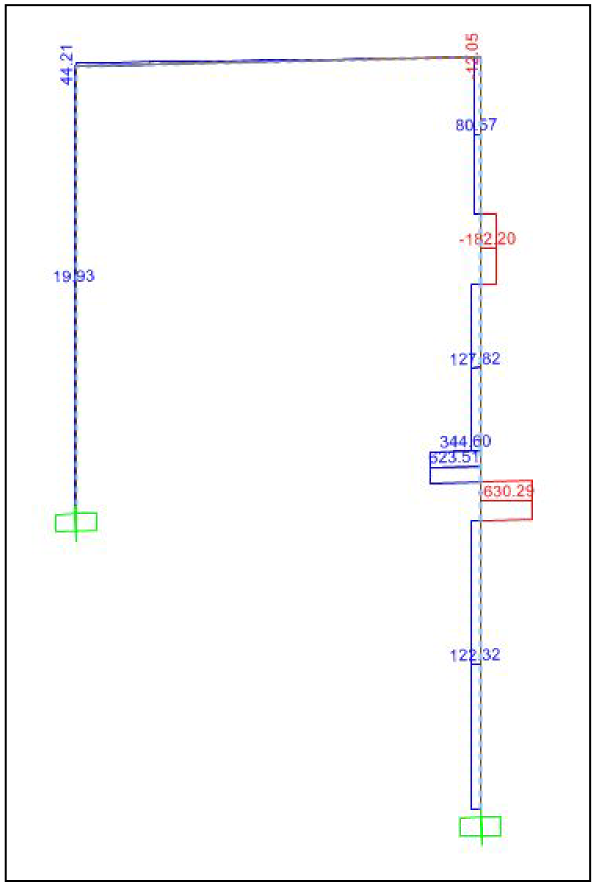


Figure 4.32- Shear force diagram

For HE 280M column check

Section classification:

$\in = \sqrt{235/f_y} = \sqrt{235/235} = 1,$

$$\frac{c}{t} = \frac{\frac{288}{2}}{33} = 4.36$$

10 ε = 10 x 1 = 10, Hence, the section satisfies the requirement for class 1 elements. Check is done for maximum stress attained by the section.

Resistance of the cross-section:

For member in axial compression, design value of compressive force N_{Sd} at each cross section shall satisfy: $N_{Sd} \leq N_{C,Rd}$

Whereas: $N_{C,Rd}$ is the design compression resistance of the cross section. Partial safety factor for class 1 cross section $\gamma_{m0} = 1.0$.

$$N_{C,Rd} = \frac{A.f_y}{\gamma_{m0}} = \frac{0.024 \times 235 \times 10^3}{1.0} = 5640\ kN$$

N_{Sd} (971.39 kN) $\leq$ $N_{C,Rd}$ (5640 kN), Hence, the check is satisfactory.

Check for Bending in one axis:

In absence of shear force the design of bending moment shall satisfy the following:

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

Whereas: M_{Rd} is the design moment resistance of the cross-section.

M_{Ed} is the equivalent moment resistance of the cross-section.

The design value of bending moment obtained from the analysis, **M_{Ed} = 398.*10 kN-m*.**

Required section modulus:

$$W_{min} = \frac{M_{Ed}}{f_y} = \frac{398.10 \times 10^6}{235} = 1.69 \times 10^6\ mm^3$$

Therefore, we selected HE 280M which has section modulus of W = $2.55 \times 10^6\ mm^3$

For this type of cross section check for bending:

$$M_{c,Rd} = \frac{W_{pl}.f_y}{\gamma_{m0}} = \frac{2.97 \times 10^6 \times 235}{1.0} \times 10^{-6} = 697.95\ kN.m$$

$M_{Ed} \leq M_{c,Rd}$ Hence, the check for bending is satisfactory.

Check for Buckling:

Design value of axial force N_{Sd} = 971.39 kN

Radius of gyration:

$$\rho = \sqrt{\frac{I_z}{A}} = \sqrt{\frac{1.32 \times 10^8}{2.40 \times 10^4}} = 74\ mm$$

Effective length: 0.5 x L = 0.5 x 8754 = 4377 mm

Slenderness ratio:

$$\lambda = \frac{L}{\rho} = \frac{4377}{74} = 59.14$$

Non dimensional slenderness:

$$\bar{\lambda} = \frac{\lambda}{\pi\sqrt{\frac{E}{f_y}}} = \frac{59.14}{\pi\sqrt{\frac{210000}{235}}} = 0.629$$

Assume the column section belongs to type C curve, from the graph. Then the reduction factor is $\chi = 0.79$.

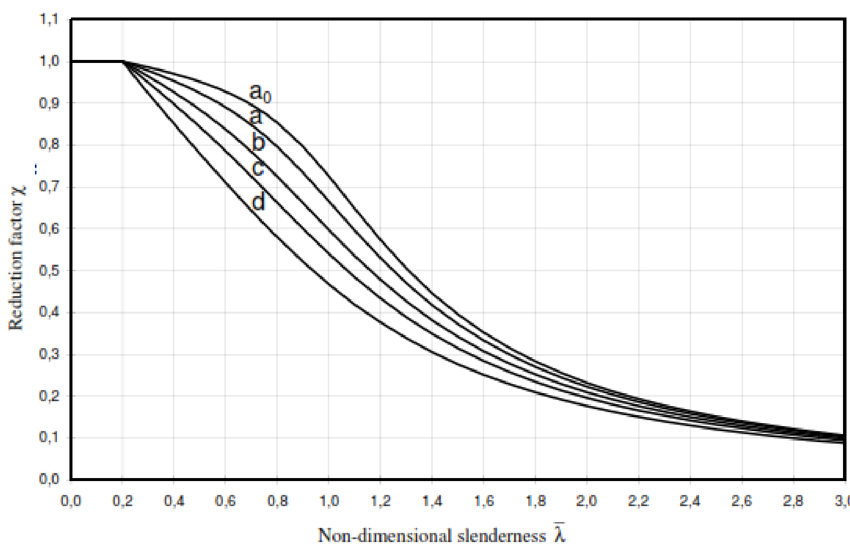


Figure 4.33- Buckling curve

The design buckling resistance of a compression member shall be taken as:

$$N_{b,\,Rd} = \chi\beta_A \frac{A.\,f_y}{\gamma_{m1}} = \frac{0.79\text{x } 1.0 \text{ x } 24000 \text{ x } 235}{1.0} = 4455.6 \; \boldsymbol{kN}$$

N_{Sd} (971.39 kN) $\leq$ $N_{b,\,Rd}$ (4455.6 kN) , Hence, the check is satisfactory.

4.3.4 Design of Column base plate foundation connection

Materials:

According to EN 1992-1-2 material properties and general rules has been taken into account for the structural calculation.

Concrete: Class of concrete C45/50

Characteristic compressive strength (f_{ck}) = 50 N/mm^2

Design compressive strength (f_{cd}) = (α_{cc} * f_{ck}) / γ_c = (0.85*50)/1.5 = 30 N/mm^2

Tensile strength (f_{ctm}) = 0.3* (f_{ck})^2/3= 6 N/mm^2

ε_2 = 0.002; ε_{cu} = 0.0035; α_{cc}= 0.85

Whereas: γ_c = partial factor of safety for concrete

Thickness of the column flange is 33 mm, so we selected 35 mm thickness base plate, 550 mm x 500mm. Therefore, the maximum potential effective bearing width of the plate is as follows.

$$C = t\left(\frac{f_y}{3 \times f_j \times \gamma_{m0}}\right)^{0.5} = 35\left(\frac{235}{3 \times 20.1 \times 1.0}\right)^{0.5} = 69.09 \text{ mm}$$

f_j = bearing strength = $\beta_j \times k_j \times f_{cd}$ = 0.67 × 1.0 × 30 = 20.1 N/mm^2

Effective area = 900 x 700 = 630000 mm^2

$$\text{Design bearing pressure} = \frac{107}{0.63} = 169.84 \text{ kN/m2}$$

Bearing strength (f_j) $>$ 169.84 kN/m2

Hence, it is satisfactory.

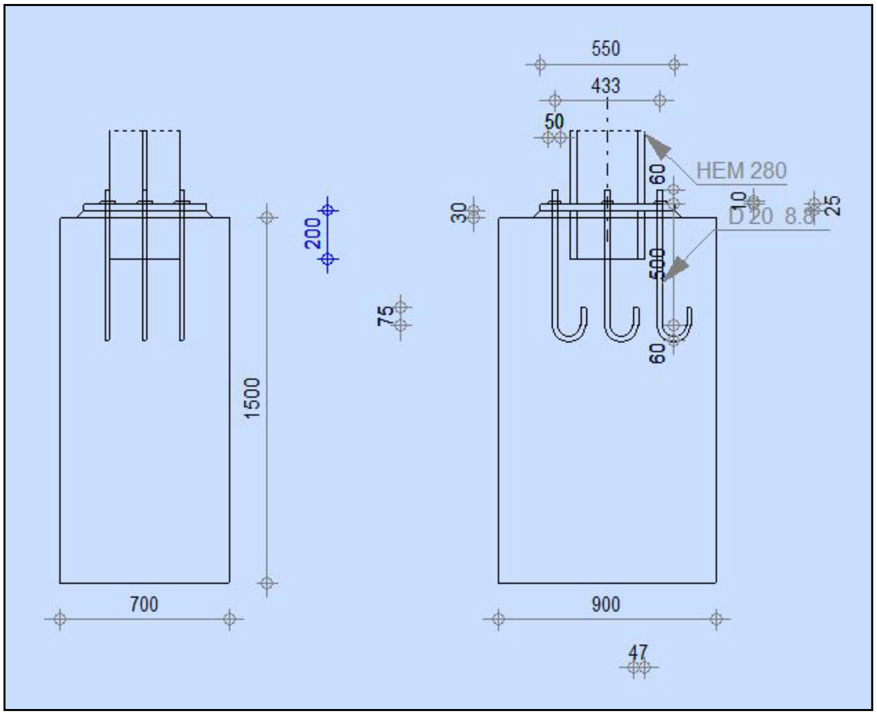


Figure 4.34- Section details of foundation connection

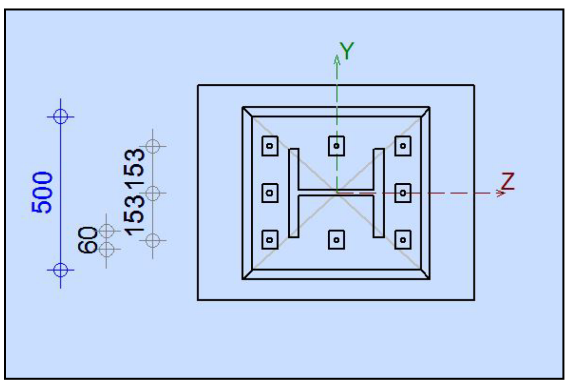


Figure 4.35- Details plan view of the Foundation connection

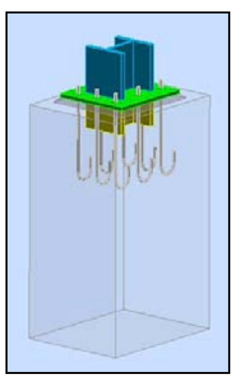


Figure 4.36- 3D view of the foundation connection

Shear resistance:

From the HE 280M column analysis we get the forces as follows:

N_{Sd} = **971.39 kN,** we assume that if the applied shear force is less than 20% of the axial load then, no necessary provision required for the transfer of shear load to base plate column foundation.

*$N_{Sd} = 0.2 \times 971.39 = 194.27$ kN $<$ V_{Sd} (**630** kN). Therefore, it is satisfactory.*

Welding of the column and base plate:

V_{Sd} **= 630** *kN,*

Design shear strength of weld: from Eurocode 3-1-1, clause 6.6.5.3

$$f_{y,wd} = \left(\frac{\frac{f_u}{\sqrt{3}}}{\beta \times \gamma_{mw}} \right) = \left(\frac{\frac{360}{\sqrt{3}}}{0.8 \times 1.25} \right) = 207.84 \text{ N/mm2}$$

8 mm fillet weld is used, throat thickness = 0.7 x 8 = 5.6 mm

Resistance of the weld per meter = $F_{w,Rd} = f_{w,d} \times a = 207.84 \times 5.6 = 1163.90\ N/mm2$,

4.3.5 Design Check of Beam to Column Connection

As per the Eurocode 3, clause 6, the bolted connection is designed for Category A. The design has been modeled with the help of Robot Structural analysis software. The following criteria should satisfy for bolted connection:

$$F_{v,Sd} \leq F_{v,Rd}$$

$$F_{v,Sd} \leq F_{b,Rd}$$

4.3.5.1 Beam connection to column flange

Material Properties:

Bolt grade: M16 grade 8.8

Yielding Stress: $f_y = 640$ MPa

Ultimate Tensile Stress: $(f_u) = 800\ N/mm^2$,

Plate height = 460 mm, plate width = 185 mm, thickness of the plate = 20 mm

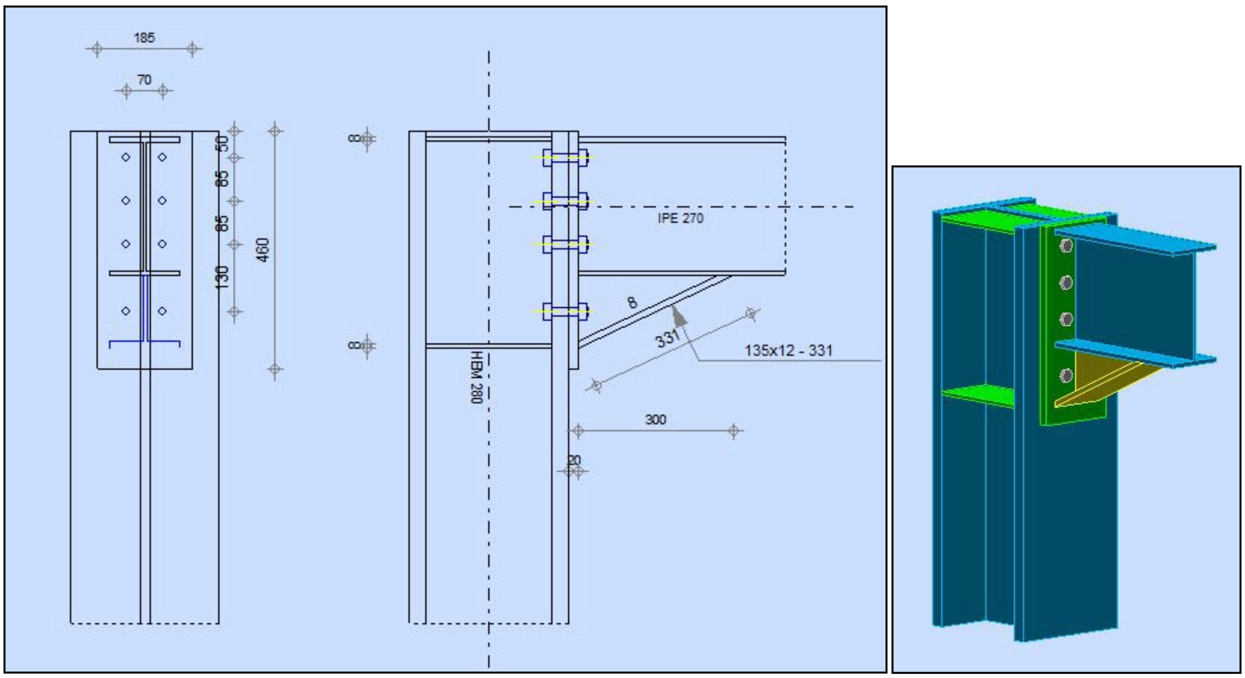


Figure 4.37- Detail scheme of connection beam to column flange

We are designing the IPE 270 beam connection to HE 280M. To show the sample calculation we chose a section at the auditorium corridor.

$\boldsymbol{V_{Sd} = 41.48\ kN}$

Design Shear force:

$$F_{v,\,Sd} = (F_v^{2} + F_m^{2})^{0.5} = (10.37^{2} + 4.90^{2})^{0.5} = 11.47\ \boldsymbol{kN}$$

F_v = Vertical shear component per beam web bolt = V_{Sd} / 4 = 41.48/4 = 10.37 kN

F_m = Horizontal shear component per beam web bolt :

$$F_m = \frac{V_{Sd} \times a}{Z} = \frac{6 \times V_{Sd} \times a}{n(n+1)p} = \frac{6 \times 41.48 \times 33.25}{4(4+1)85} = 4.90\ kN$$

Z elastic modulus of the bolt group:

$$Z = \frac{n(n+1)p}{6}$$

n is the number of bolts, p is the pitch

Resistance of bolt per shear plane:

$$F_{v,\,Rd} = \frac{0.6\,A.\,f_{ub}}{\gamma_{mb}} = \frac{0.6 \text{ x}156 \text{ x } 800}{1.25\text{x } 10^{3}}$$ = ***60.15 kN*** per shear plane

For double shear bolt resistance = 2 x 60.15 =***120.3 kN***

$F_{v,\,Sd}$ (11.47 kN) ≤ $F_{v,\,Rd}$ (120.3 kN) , Hence, the check is satisfactory

Shear rupture resistance from EN 1993-1-1, clause 6.5.2.2:

$$V_{eff,\,Rd} = \frac{A_{v,\,eff}\left(f_y/\sqrt{3}\right)}{\gamma_{m0}} = \frac{3329\ (\frac{235}{\sqrt{3}}) \times 10^{-3}}{1.0}$$ = 451.66 kN

A_b = Area of the beam section

$A_{v,\,eff}$ = Area of the effective shear area

V_{Sd} (41.48 kN) ≤ $V_{eff,\,Rd}$ (451.66 kN) , Hence, the check is satisfactory

Bearing resistance of bolts:

$$F_{b,\,Rd} = \frac{2.5 \times \alpha \times f_u \times d \times t}{\gamma_{mb}} = \frac{2.5 \times 1.0 \times 360 \times 20 \times 16}{1.25 \times 10^3} = 230.4 \text{ kN}$$

$F_{v,\,Sd}$ (41.48 kN) $\leq$ $F_{b,\,Rd}$ (230.4 kN) , Hence, the check is satisfactory

4.3.5.1 Beam connection to column web

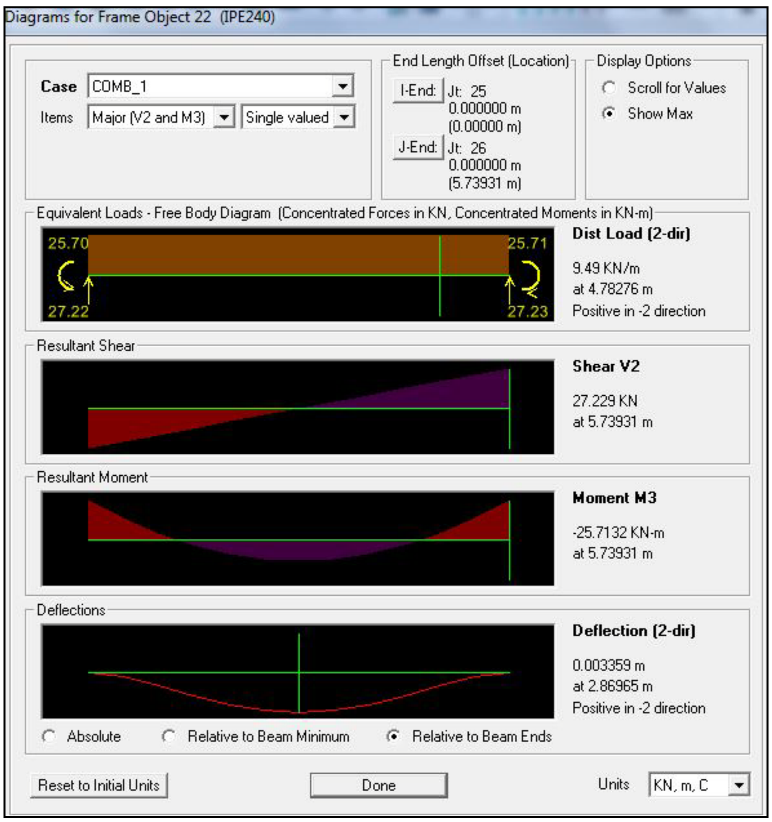


Figure 4.38- Details of the forces IPE 240

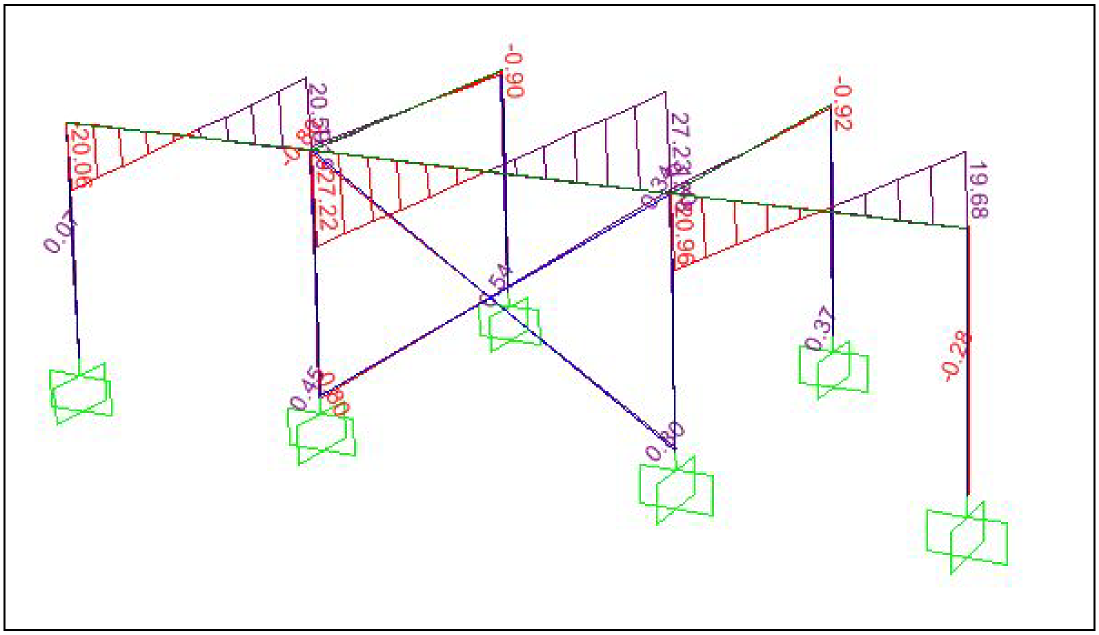


Figure 4.39- Shear force of the beam

Design Shear force:

V_{Sd} = 27.229 kN from the analysis.

$$F_{v,Sd} = (F_v^2 + F_m^2)^{0.5} = (13.61^2 + 29.48^2)^{0.5} = 32.47\ kN$$

F_v = Vertical shear component per beam web bolt = V_{Sd} / 4 = 27.229/2 = 13.61 kN

F_m = Horizontal shear component per beam web bolt :

$$F_m = \frac{V_{Sd} \times a}{Z} = \frac{6 \times V_{Sd} \times a}{n(n+1)p} = \frac{6 \times 27.22 \times 65}{2(2+1)60} = 29.48\ kN$$

Z elastic modulus of the bolt group:

$$Z = \frac{n(n+1)p}{6}$$

n is the number of bolts, p is the pitch

Resistance of bolt per shear plane:

$$F_{v,\,Rd} = \frac{0.6\,A.\,f_{ub}}{\gamma_{mb}} = \frac{0.6\ \text{x}156\ \text{x}\ 800}{1.25\text{x}\ 10^3} = \boldsymbol{60.15\ kN}\ \text{per shear plane}$$

For double shear bolt resistance = 2 x 60.15 =***120.3 kN***

$F_{v,\,Sd}$ (32.47 kN) ≤ $F_{v,\,Rd}$ (120.3 kN) , Hence, the check is satisfactory

Shear rupture resistance from EN 1993-1-1, clause 6.5.2.2:

$$V_{eff,\,Rd} = \frac{A_{v,\,eff}\left(f_y/\sqrt{3}\right)}{\gamma_{m0}} = \frac{2209\ (\frac{235}{\sqrt{3}}) \times 10^{-3}}{1.0} = 299\ \text{kN}$$

A_b = Area of the beam section

$A_{v,\,eff}$ = Area of the effective shear area

V_{Sd} (27.22 kN) ≤ $V_{eff,\,Rd}$ (299 kN) , Hence, the check is satisfactory

Bearing resistance of bolts:

$$F_{b,\,Rd} = \frac{2.5 \times \alpha \times f_u \times d \times t}{\gamma_{mb}} = \frac{2.5\ \text{x}1.0\ \text{x}\ 360 \times 20 \times 16}{1.25\text{x}\ 10^3} = 230.4\ \text{kN}$$

$F_{v,\,Sd}$ (27.22 kN) ≤ $F_{b,\,Rd}$ (230.4 kN) , Hence, the check is satisfactory

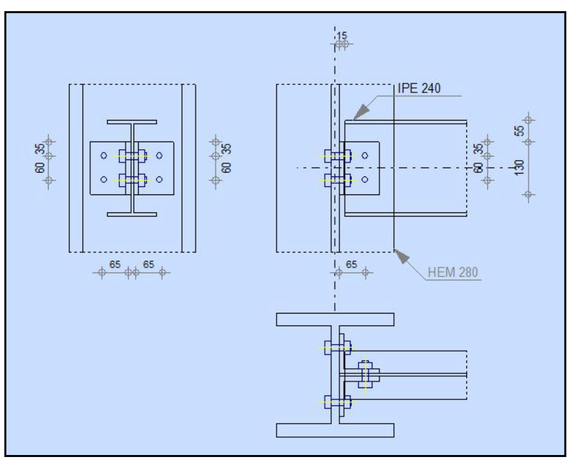


Figure 4.40- Connection details from Beam to column web

4.4 Structural Drawings

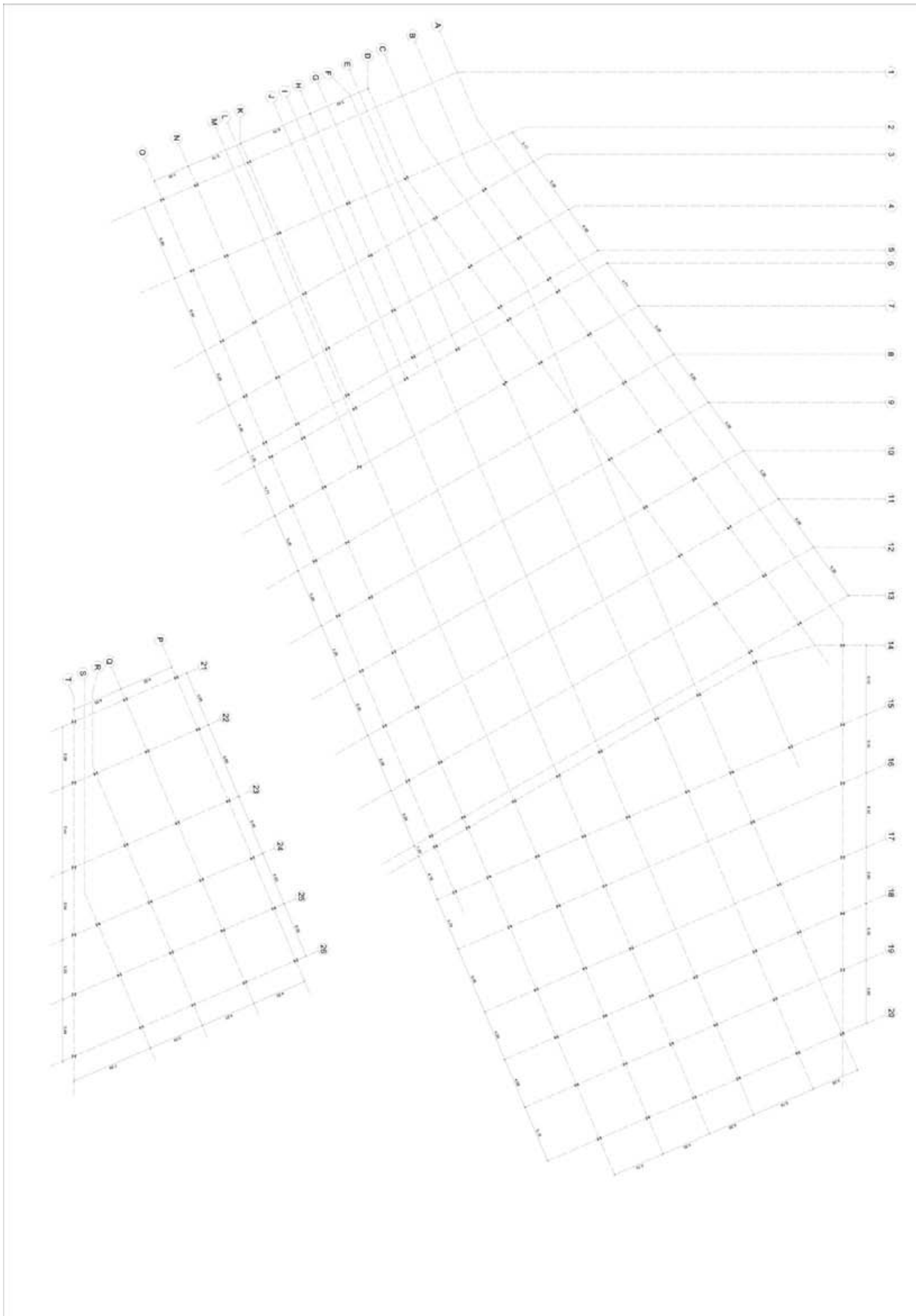


Figure 4.41- Columns Plan

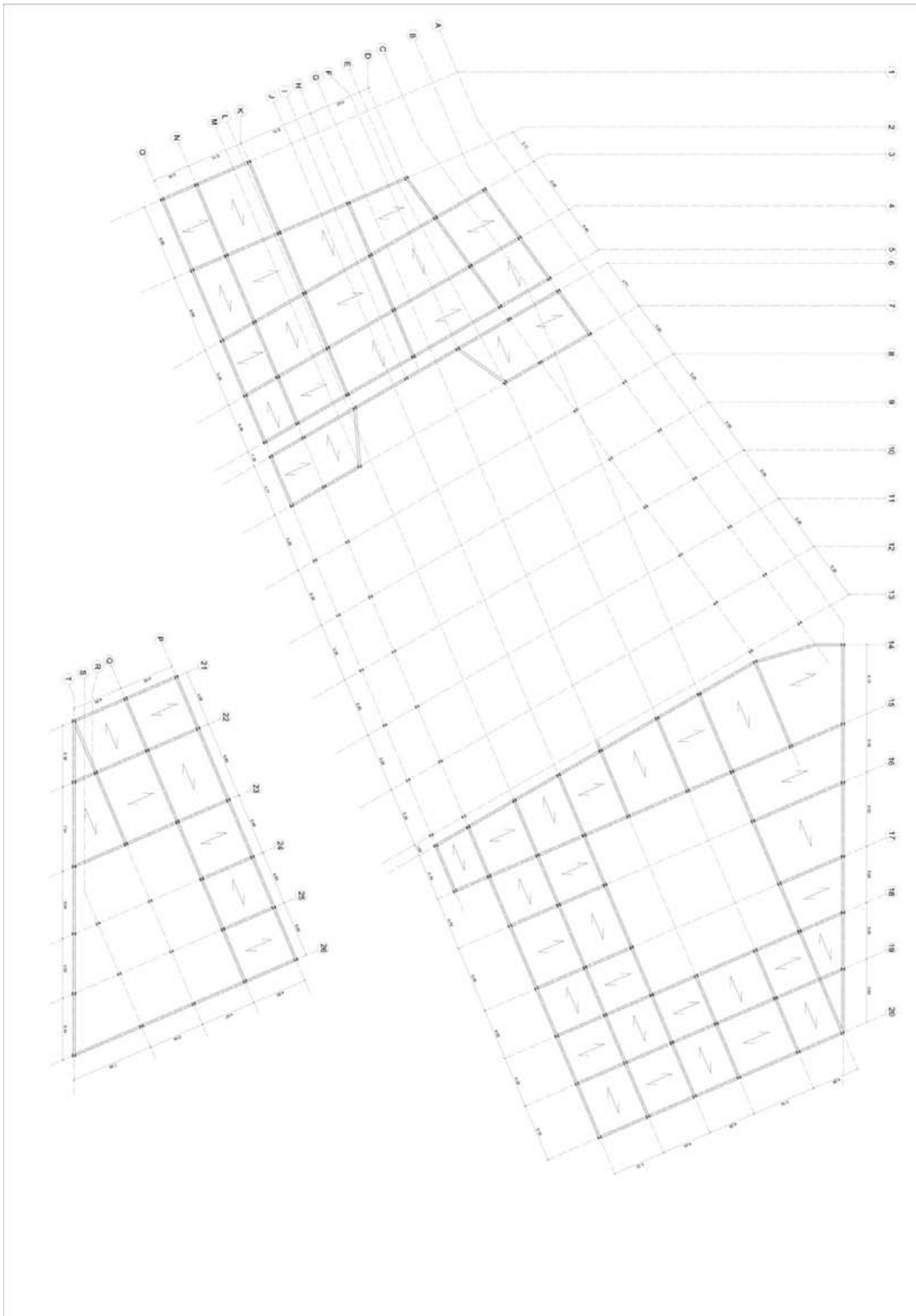


Figure 4.42- Structural Plan- Ground floor

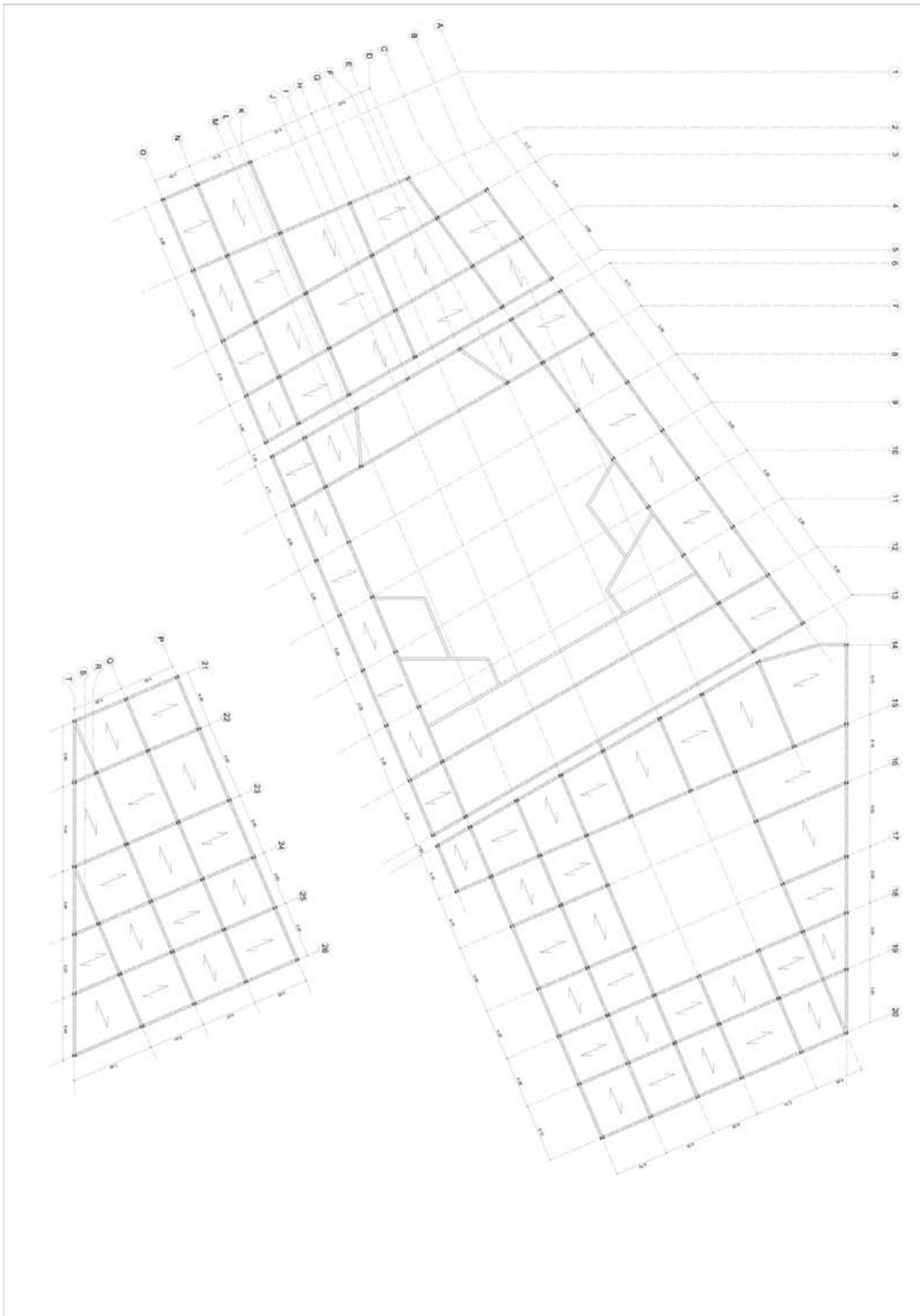


Figure 4.43- Structural Plan- First floor

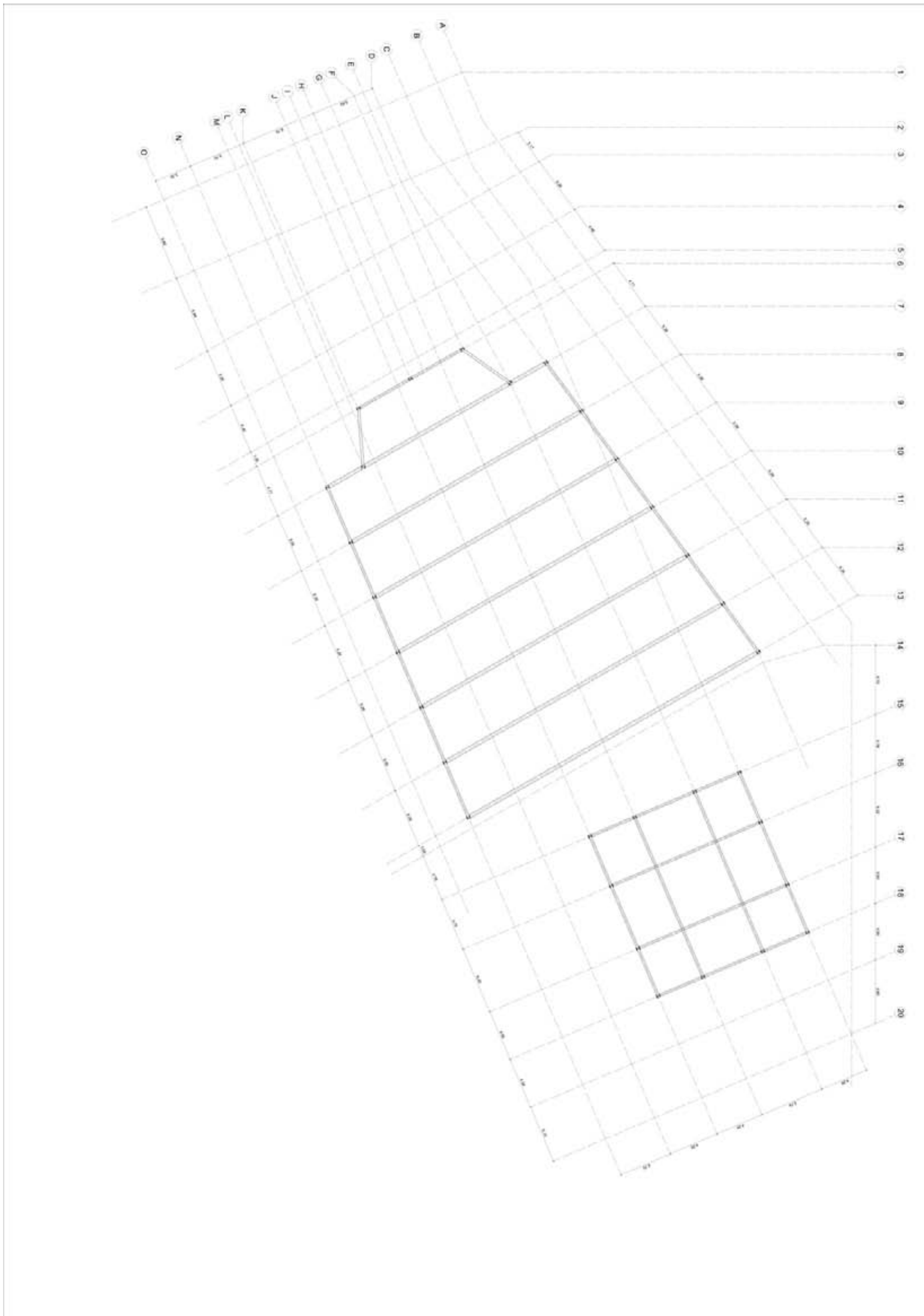


Figure 4.44- Structural Plan- Second floor

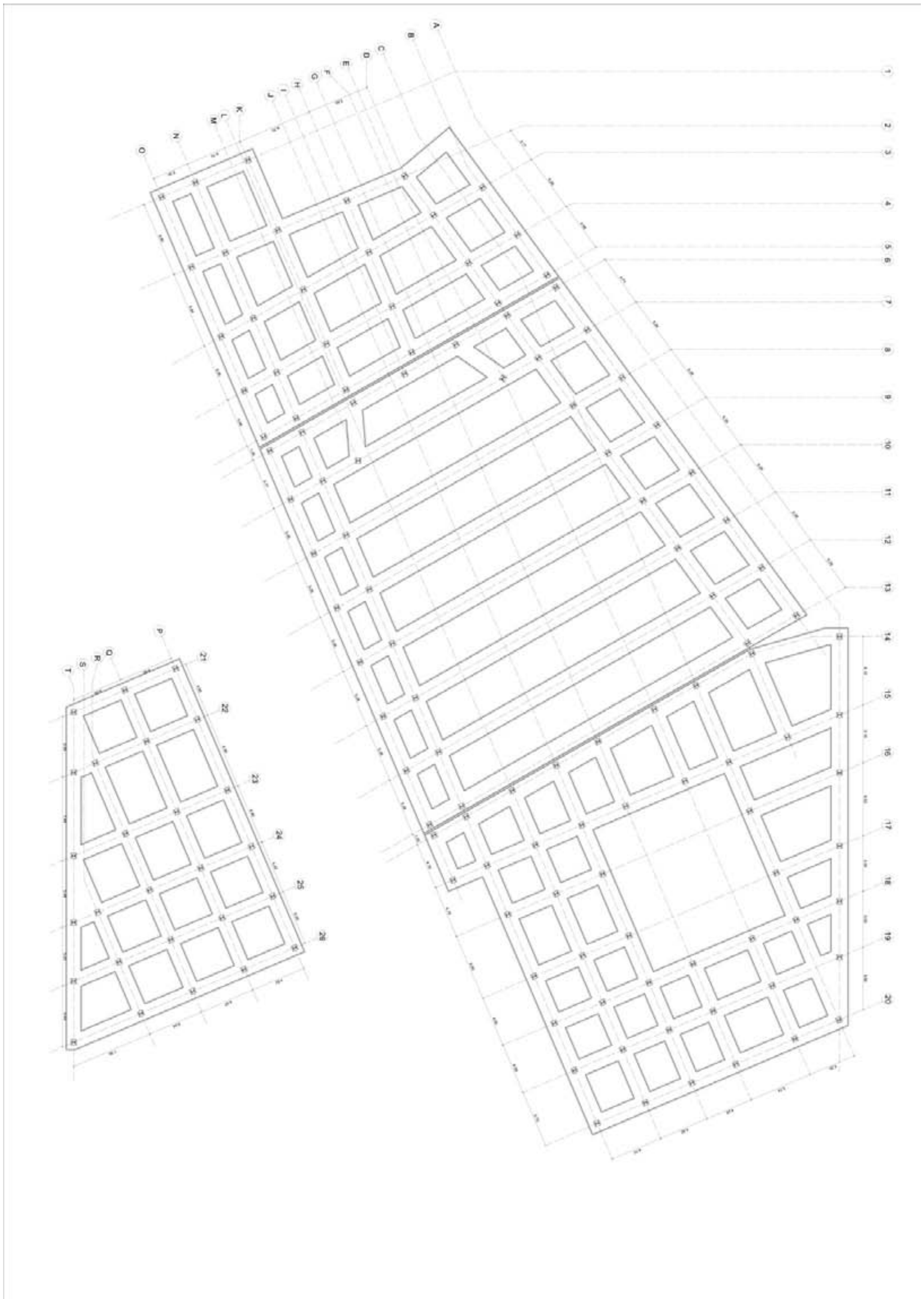


Figure 4.45- Foundation Plan

CHAPTER 5

TECHNOLOGICAL DESIGN

This chapter includes the technological aspects of our project building. With help of Ecotect analysis software we could analyze the area of interest such as solar exposure, lighting analysis, thermal analysis. We started by analyzing the climate and weather condition of Istanbul then calculated various parameters which are required for the further calculation and analysis.

5.1 Weather of Istanbul

Environmental conditions at different locations on Earth can vary quite significantly from freezing cold and snowing at the poles to blisteringly hot and dry in the deserts. Our project site Istanbul has a borderline humid subtropical climate and warm summer Mediterranean climate which is influenced by the oceanic climate. Summers are relatively dry, but rainfall is significant during that season. The graph shows the average temperature value range from 0ºC to 45ºC of Istanbul which is hot and humid. Here the plot is based on hourly temperature variation in week. The coded colors blue indicates temperature below 0ºC and yellow color to 45ºC. The maximum temperature recorded for Istanbul in 28th to 32nd week having an average of 35ºC. For further detail readings of temperature and analysis maximum and minimum temperature is also shown.

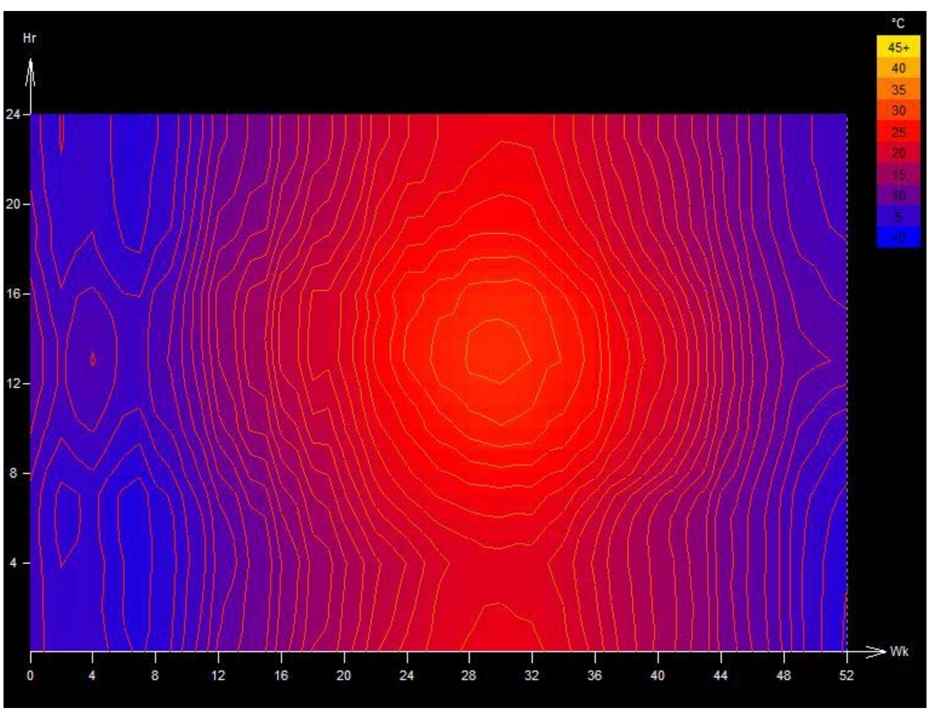


Figure 5.1- Weekly average temperature

The graph below shows that temperature in 16th week to 44th week that is from mid of April to October requires cooling. After 44th week to 52nd week and 0 until 16th week requires heating.

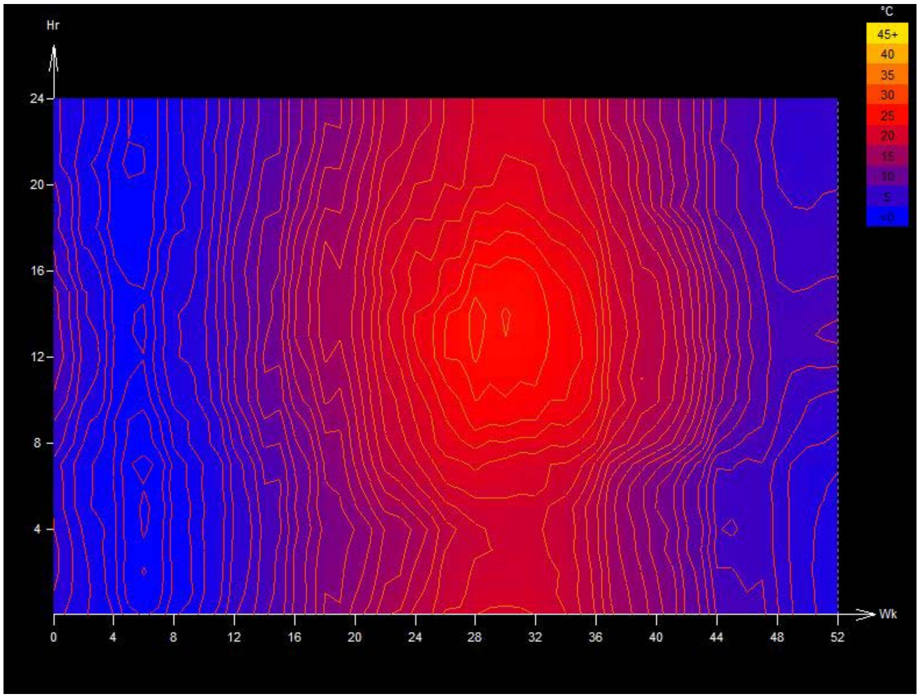


Figure 5.1- Weekly Minimum temperature

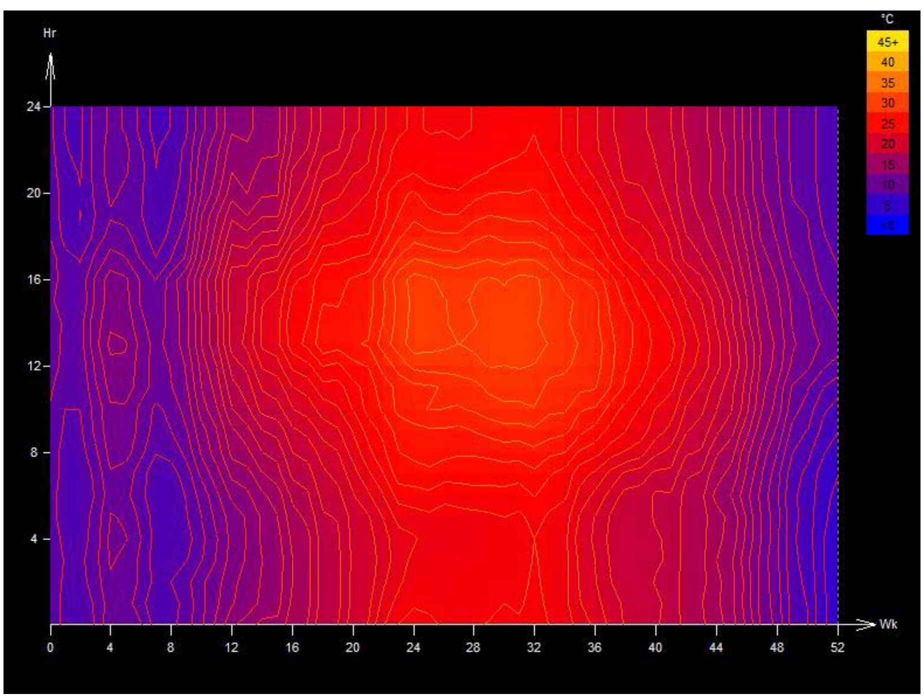


Figure 5.2- Weekly Maximum temperature

During winter it is cold, wet and often snowy. Snowfalls tend to be heavy, but the snow cover and temperatures below the freezing point rarely last more than a few days. Spring and autumn are mild, but are unpredictable and often wet, and can range from chilly to warm.

Istanbul has a persistently high humidity, which can exacerbate the moderate summer heat. The relative humidity of Istanbul is shown here in this coded graph. The Green color indicates 50% relative humidity from 11 hr to 16 hr which increases to 90% which is light greenish color. These readings and information helped us to figure out that maximum time humidity is present during morning and night time, which decrease during the peak hours of day time. This is mostly due to the fact that the site is near to the ocean.

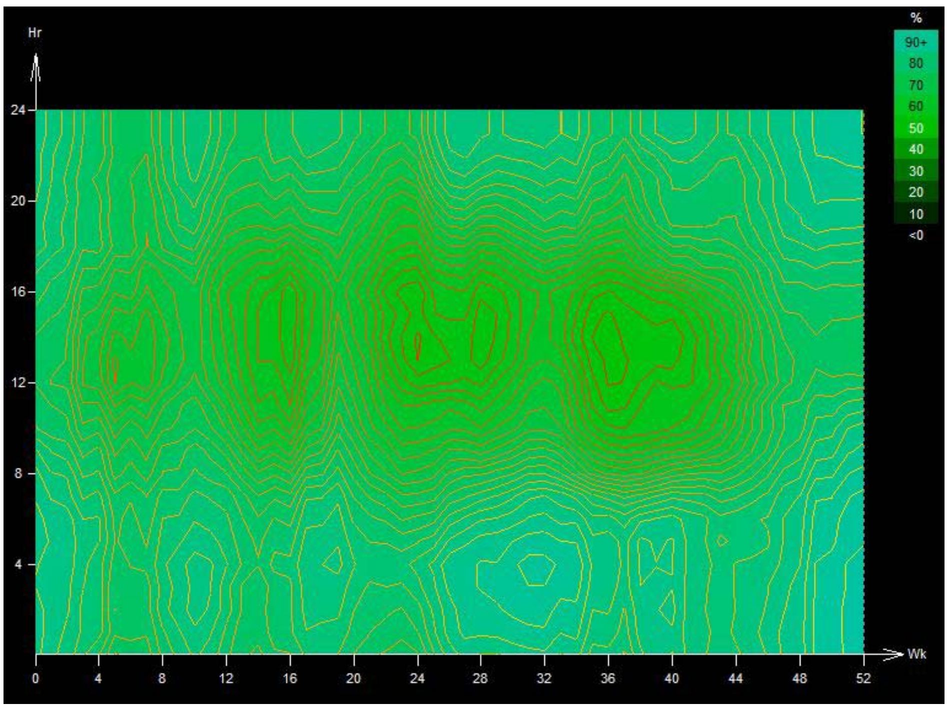


Figure 5.3- Weekly Relative Humidity

The graph below shows the direct solar radiation mostly available from 7 A.M to 17:00 P.M in 12th to 44th week, which is month of March to October, incident solar radiation value ranging from 400 – 900 W/m^2, other weeks has value range from 200 – 300 W/m^2. This gives us the opportunity to save energy and usage of photovoltaic solar panels for efficient power generation.

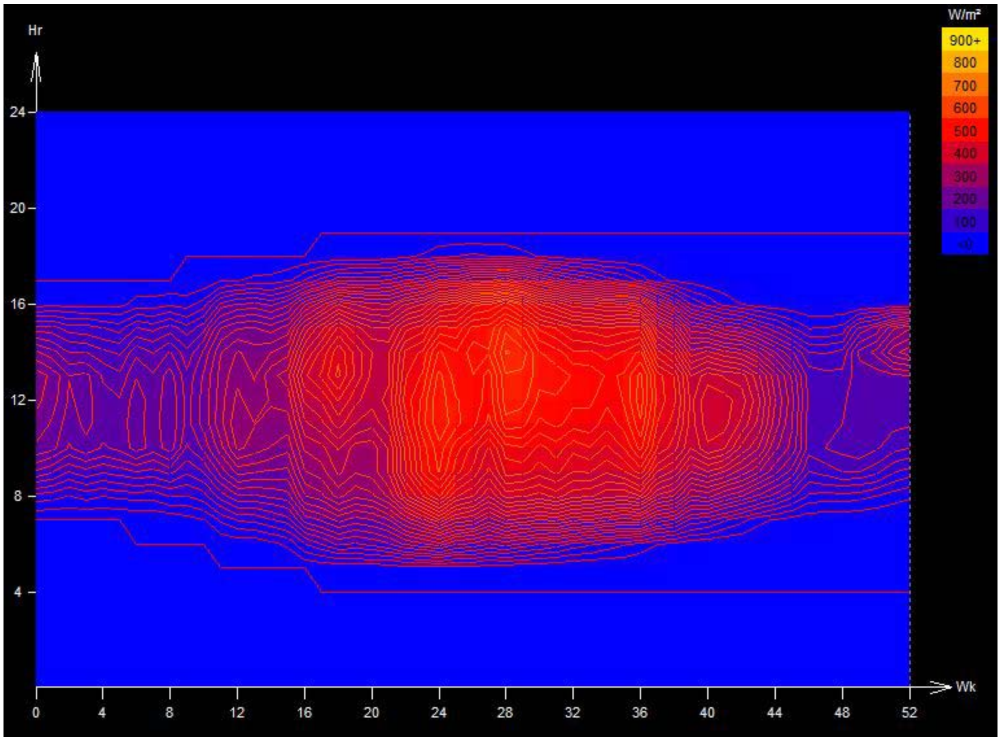


Figure 5.4- Weekly direct solar radiation

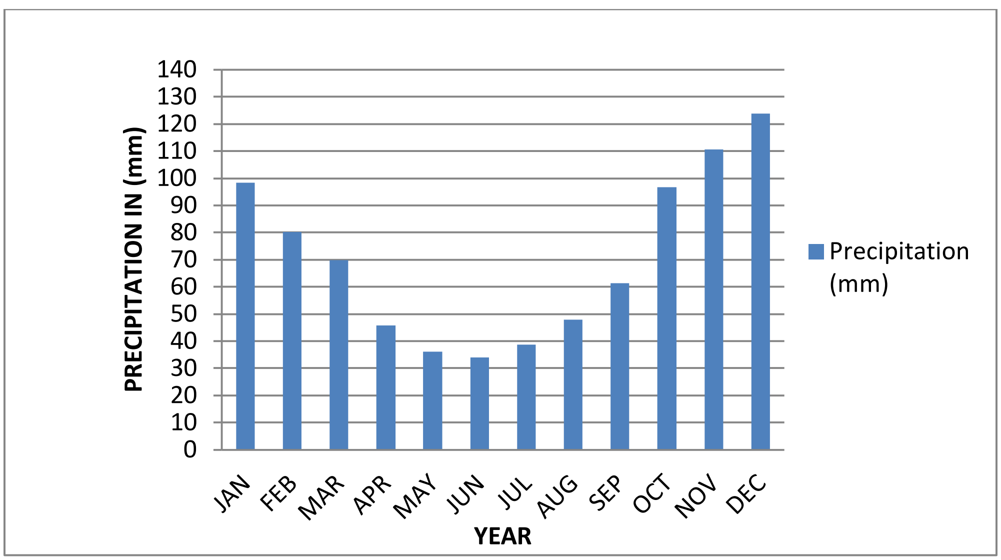


Figure 5.5- Precipitation in (mm) by months in a year

5.2 Sun Path Diagram and Orientation

The graphic projection shown below depicts the annual change of sun path within the sky vault projecting onto the horizontal plane of Earth. Successful day lighting design requires that the building occupant receive acceptable level of consistent quality illumination throughout the year. This analysis helped us to determine the favorable building orientation configuration in order maximize daylight access and limit the unwanted direct sunlight.

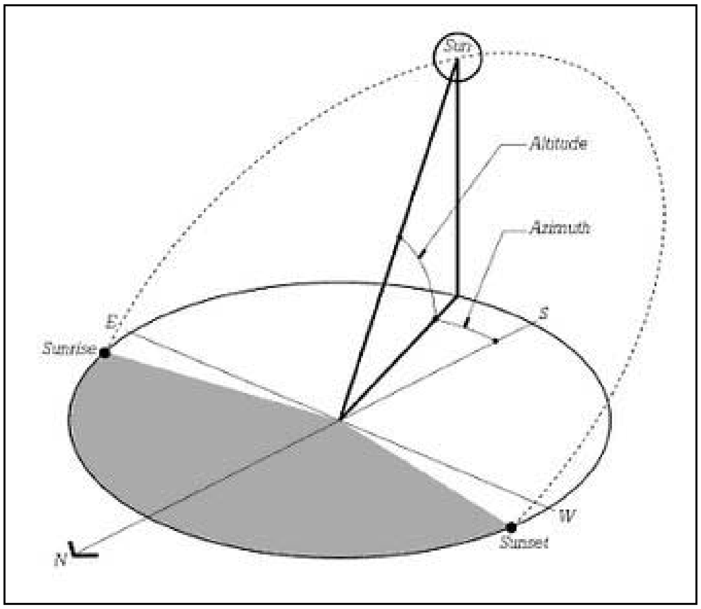


Figure 5.6- Showing a brief idea of the sun angles

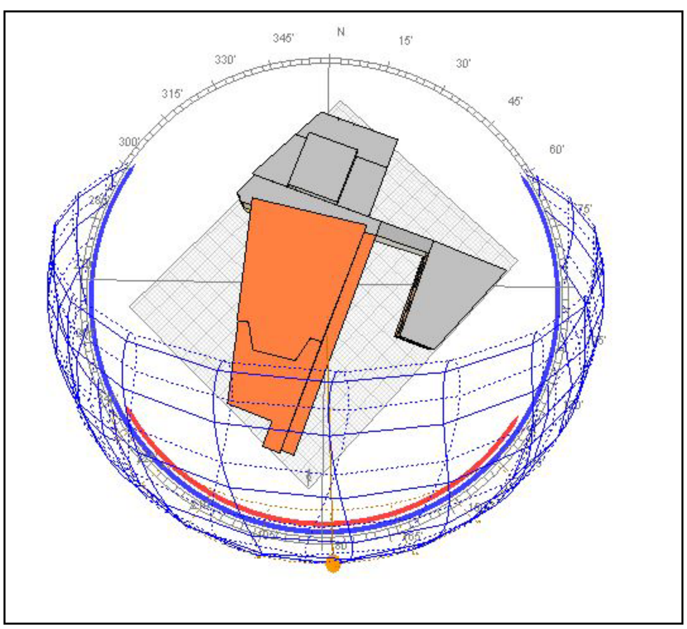


Figure 5.7- Projection of the Sun on the Site Building

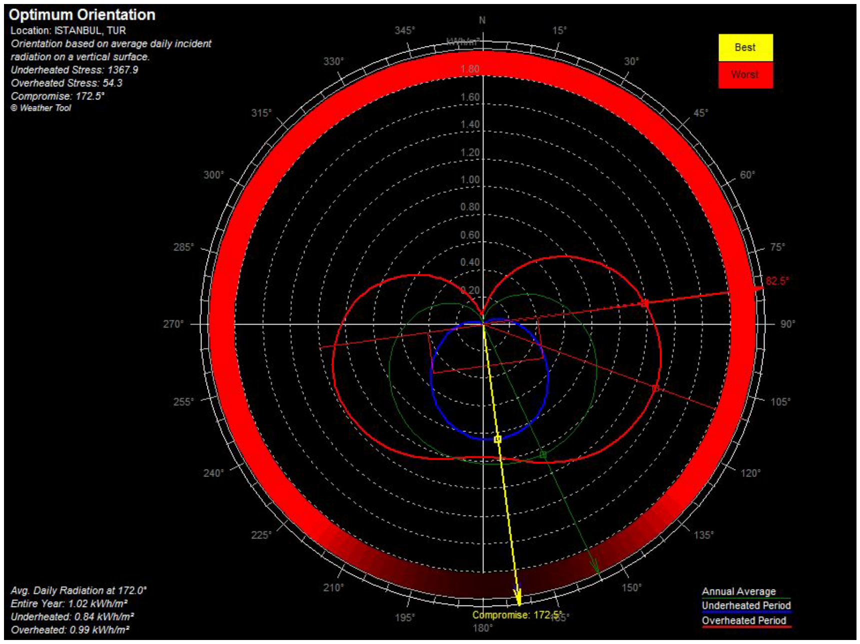


Figure 5.8- Optimum orientation angle based on solar radiation

The sun's position and the optimum orientation of building are obtained from weather tool in terms of latitude and azimuth. The optimum orientation of the building is based on the three hottest and three coldest months in a year which is considered to be one of the important aspects of building performance. The weather tool identifies 172.5º from the North to be the optimum orientation for our project building. In this case the project building is based on the landscape formation which is our main design concept. So, in order to best fit both the criteria of landscape concept and orientation of building for our design process we orient the building at an angle of 115º from the North clockwise.

5.3 Shadow Analysis

We designed the main façade of the auditorium corridor with fully glazed glass which receives the sunlight until 12:30 P.M. during summer and winter. So, shading device is used for obstructing the sunlight when it is not required during the day. It also helped us to understand how to create a high performance building. In this way we also analyzed the selected functional area.

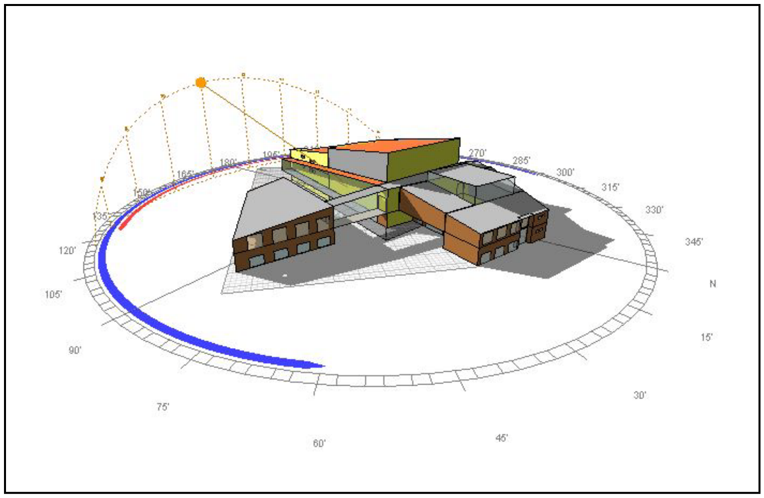


Figure 5.9- Daily Shadow formation at 12:00 P.M

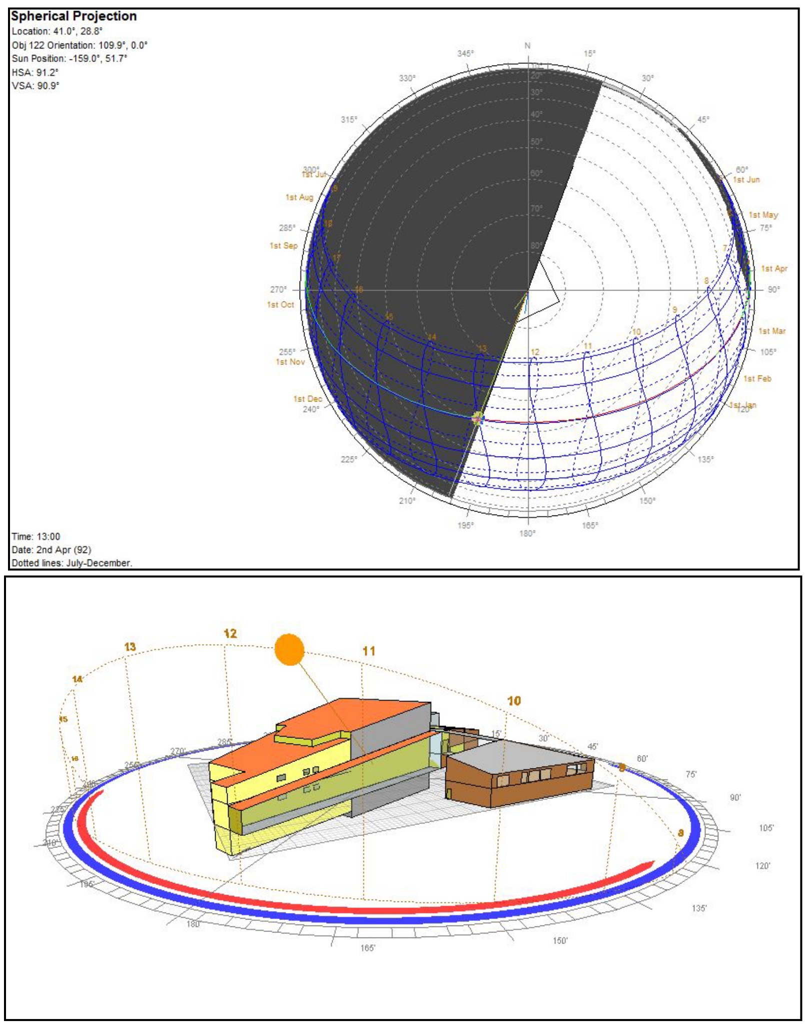


Figure 5.10- Hall Main glazed glass façade shadow analysis

The offices and library window facing North towards the main piazza has shadow from 10 A.M, this gives us a good indication of the level of light that is available for such functional use.

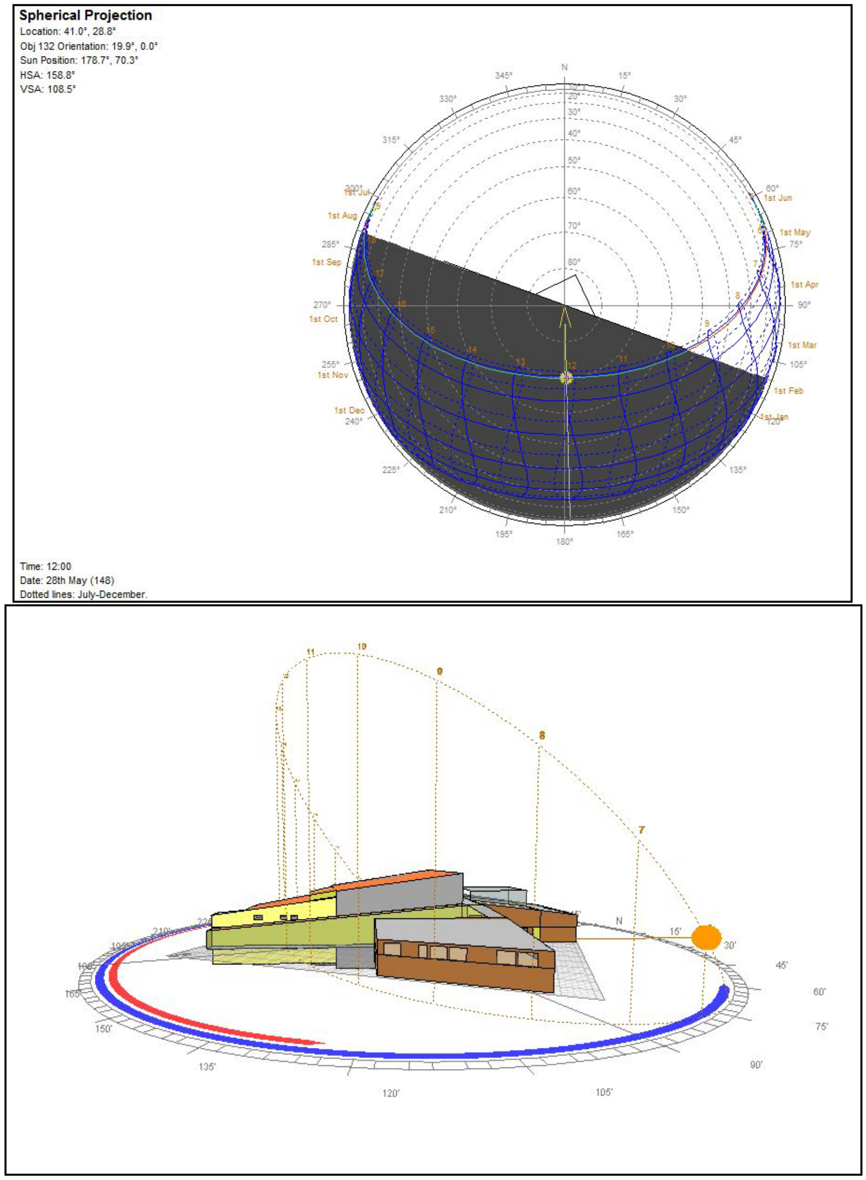


Figure 5.11- For offices and library shadow analysis

The conference hall and exhibition hall shows the same range of shadow. After 13:00 P.M there is full sunlight. For this section we planned to use artificial light for luminance. It depends on the type of exhibition and meeting to be held.

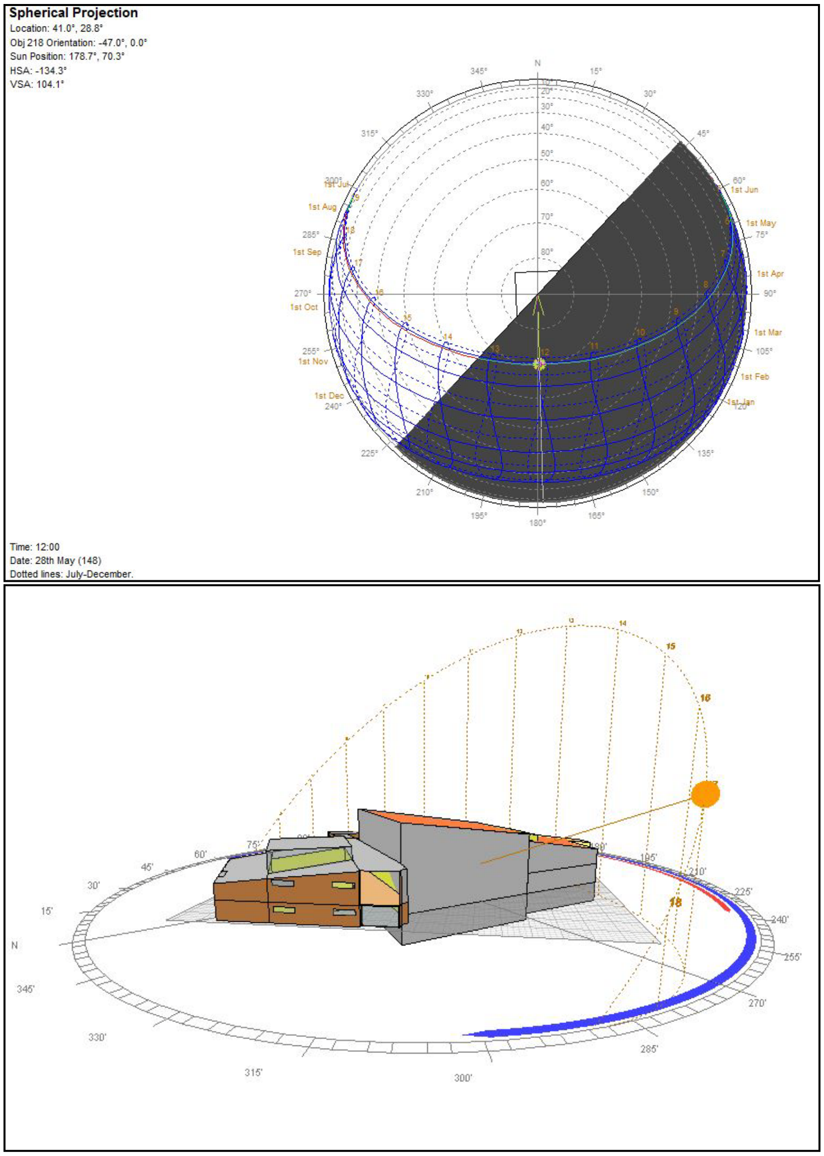


Figure 5.12- For conference and exhibition hall shadow analysis

5.4 Sky Luminance and Daylight Factor

Luminance levels deal with the actual amount of light incident on a surface and are therefore significantly affected by variations in the amount of light given off by the sky.

To deal with highly variable sky conditions, many building codes and design briefs use daylight factors as the design criteria instead of luminance on the working plane. Daylight factor (DF) is a numerical ratio used to describe the relationship between indoor and outdoor daylight luminance. It is the sum of three components: DF = SC + ERC + IRC, which is expressed in percentage.

Whereas:

SC light that directly comes from the sky normally referring to diffuse sky.

ERC externally reflected component, particularly in dense urban situation, owing to the closeness of the building

IRC internally reflected component, reflection from infinite possible surface.

In order to make sense of the daylight system performance, we analyzed the Auditorium and other functional space.

The table below provides the general recommendation for target daylight factor

SPACE	AVERAGE DF	MINIMUM DF
Commercial/Institutional		
Corridor	2	0.6
General Office	5	2
Classroom	5	2
Library	5	1.5
Gymnasium	5	3.5
Residential		
Dining Room/Studio	5	2.5
Kitchen	2	0.6
Living Room	1.5	0.5
Bedroom	1.0	0.3

Figure 5.13- Suggested day light factor criteria in percentage (overcast sky)

From the subjective perspective, the following user responses to day light factor have been suggested:

Day Light Factor	**Recommendation**
≤ 2%	A room seems gloomy. Electric lighting will be required for most of the day light hours.
2 % - 5%	A room is day lit, although supplementary electric lighting may be required.
≥ 5%	A room vigorously day lit, depending upon the task at hand, electric lightening may not be necessary during the daylight hours.

Table 5.1- Day light factor recommendation

With the help of Ecotect, we could get important information related to daylight level. For the office on ground floor the blue color is the lower range of 0.8% of day light in a room incrementing to 40.8%, the average daylight factor is 4.64%. For first floor the lower range is 0.8% of day light in a room incrementing to 80.8%, with an average of 5.47% respectively, this means that the office rooms are day lit and supplementary electric may not be required. Therefore, the location of space is used for library, book store, offices and the orientation of the window is facing close to North. For these rooms window blinds are used for shading.

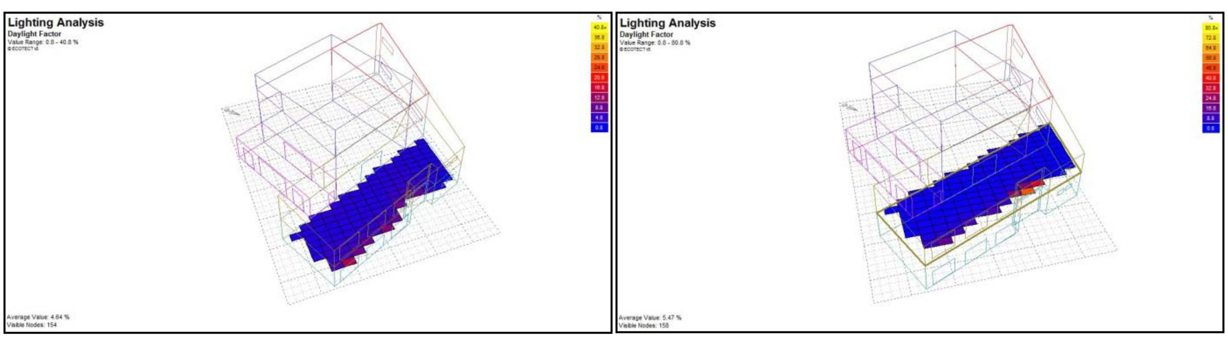


Figure 5.14- Daylight factor for ground floor and first floor office

Day light factor for the lobby area is a buffer zone. This space has an average day light of 20.49%. The room is vigorously lit by day light and is well suited for the desired activity. It has a shading device in the glazed upper window facing east.

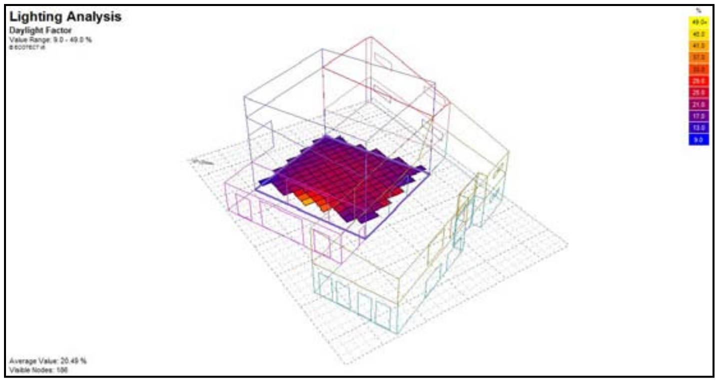


Figure 5.15- Daylight factor for Lobby

Exhibition Hall has an average day light factor of 2.45%. The orientation of the window is facing towards west. For this room supplementary electric lighting may be required depending on the type of exhibition and activity.

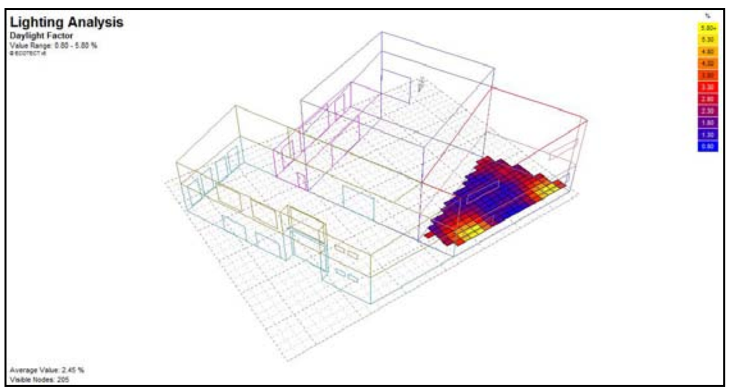


Figure 5.16- Daylight factor for exhibition hall

The restaurant is vigorously lit having an average day light of 20.54% on the ground floor and 86.91% at the first floor, receiving maximum sun light all through the time. Shading blinds has been used whenever necessary.

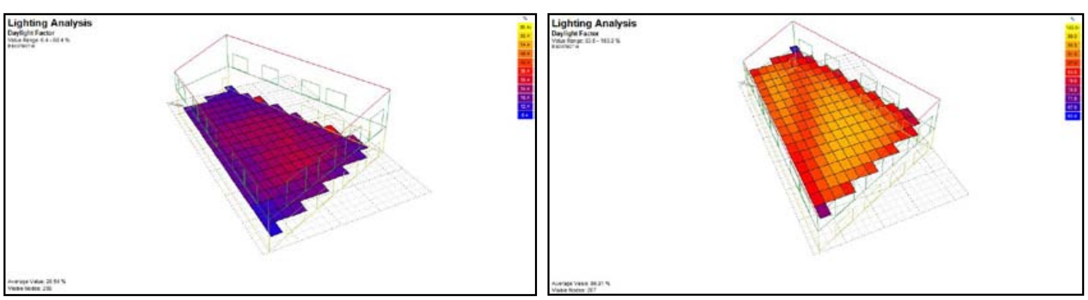


Figure 5.17- Daylight factor for 1st floor and 2nd floor restaurant

Photovoltaic Solar Electricity Generation:

It is immediately noted from the shape and orientation of the building that the auditorium hall roof best suits the installation of integrated PV panels. Building is facing closely towards the south which captures more solar radiation. This system is a renewable energy system, which provides the simplest, reliable and cost effective way to reduce carbon footprints. The following tables show the estimate of solar electricity generation obtained for our project site:

Nominal Power of the PV system: 1.0 kW (Crystalline silicon)

Estimated losses due to temperature and low irradiance: 13.2% (using local ambient temperature)

Estimated loss due to angular reflectance effects: 3.2%

Other losses cables and inverters: 14.0%

	Fixed system: inclination=9 deg., orientation=0 deg.			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	1.45	45.0	1.87	58.0
Feb	1.97	55.1	2.53	70.8
Mar	2.89	89.5	3.78	117
Apr	3.78	113	5.13	154
May	4.76	148	6.68	207
Jun	5.06	152	7.31	219
Jul	5.22	162	7.57	235
Aug	4.61	143	6.71	208
Sep	3.57	107	5.06	152
Oct	2.44	75.7	3.32	103
Nov	1.78	53.4	2.35	70.4
Dec	1.47	45.5	1.89	58.7
Year	3.26	99.1	4.53	138
Total for year		1190		1650

Table 5.2- Production of electricity per year from solar panel

Ed = Average daily electricity production from the given system = 3.26 kWh/m2

Em = Average monthly electricity production from the given system = 99.1 kWh/m2

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 module of the given system (kWh/m2)

The value has been estimated from the european commission interactive map of photovoltaic geographical information system.

5.5 Basic Acoustic for Auditorium

For every doubling of the distance sound decreases by 6.0 dB, the sound energy we receive in the auditorium space is due to reflection from ceiling surfaces. The geometrics of reflection of sound are same as light. Reflection from the finite surface depends on the size of the reflector and the wavelength of the sound. Hence, perfect reflection occurs at higher frequencies.

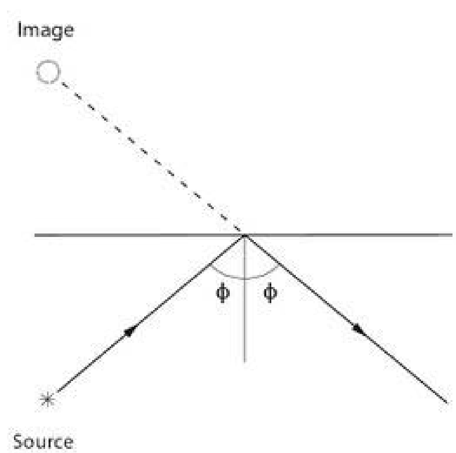


Figure 5.18- Geometry of reflection

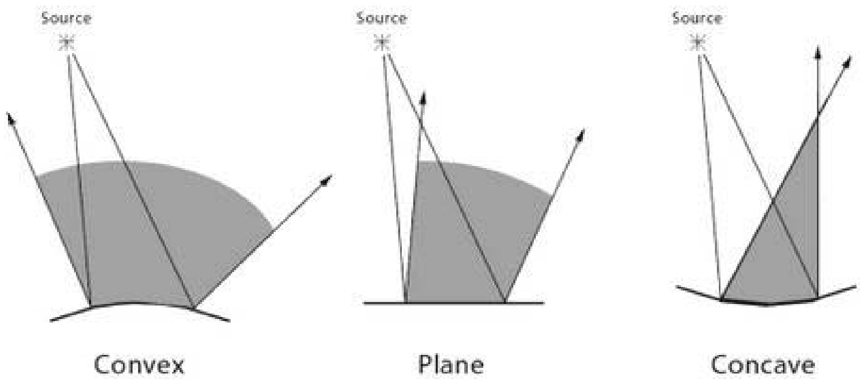


Figure 5.19- Reflection of Convex, Flat and Concave surface

We are using suspended convex type sound reflectors for the auditorium having 1000 seats which disperse sound at safe level than the flat surface which might produce undesirable effects and concave surface which focuses sound as an echo. The side walls are provided with sound panels made of 11cm thick wood which is a reflecting material.

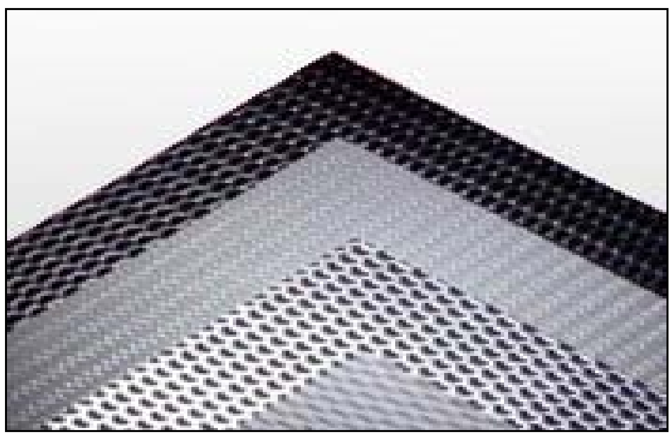


Figure 5.20- Perforated metal sheet

For controlling the reverberation time, the rear wall is provided with perforated aluminium metals sheets of hole diameter 3.0 mm and size 12x50cm. The floors of the hall are covered with carpets on the aisles only.

5.6 Heating and Cooling Loads

Before we could select heating and cooling system for the building, we made a rough draft of the simplified zoning of the building functional space to separately establish the controlled zone for thermal comfort to be achieved throughout the building. The building is modeled in Ecotect defining each area as different thermal zones. For weekdays and weekends it is assumed that the building opening hour is from 7 A.M to 11 P.M. In the element library material and thermal transmittance of the material is calculated. Then every wall, roofs and windows are assigned with the material defined material in the Ecotect model as shown. The detail result every zone is shown along with the graph.

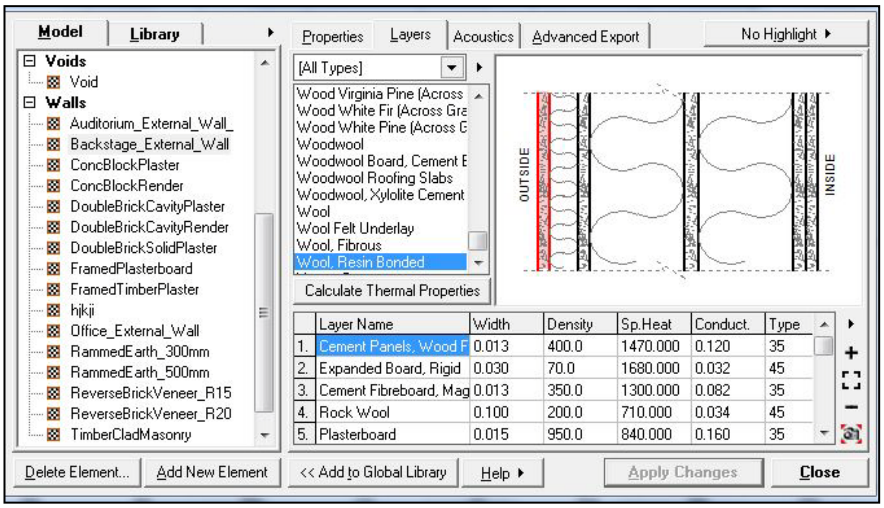


Figure 5.21- Element library defined in Ecotect

Zone Name	Floor (m2)	Surface (m2)	Exposed (m2)	Window (m2)	Volume (m3)	HVAC System	Temp. Range	Operation Hours
Entrance office_01	234.018	423.222	410.661	35.079	911.526	Air Conditioning	18.0-26.0	07-23/07-23
Entrance office_02	468.036	927.297	400.956	33.497	858.039	Air Conditioning	18.0-26.0	07-23/07-23
Reception office_01	140.343	235.543	142.689	11.6	273.564	Air Conditioning	18.0-26.0	07-23/07-23
Front Gallery_02	143.577	454.694	298.905	0	748.058	Air Conditioning	18.0-26.0	07-23/07-23
Exhibition hall	233.53	301.958	185.175	8	454.835	Air Conditioning	18.0-26.0	07-23/07-23
Lobby	218.601	654.392	437.148	0	2735.507	Air Conditioning	18.0-26.0	07-23/07-23
Gallery_1	489.822	561.537	299.104	23.826	953.701	Air Conditioning	18.0-26.0	07-23/07-23
Gallery_2	244.911	555.149	291.714	22.4	1484.21	Air Conditioning	18.0-26.0	07-23/07-23
Conference Hall	116.765	424.236	208.845	8	554.434	Air Conditioning	18.0-25.0	07-23/07-23
Backstage_00	771.784	1118.506	0	0	1763.57	Air Conditioning	18.0-26.0	07-23/07-23
Backstage_01	771.784	1118.506	342.671	3.081	1763.57	Air Conditioning	18.0-26.0	07-23/07-23
Backstage_02	385.892	1121.943	735.988	5	66.46	Air Conditioning	18.0-26.0	07-23/07-23
Restaurant_01	877.491	1226.382	787.488	19.8	1723.61	Mixed Mode	18.0-26.0	07-23/07-23
Restaurant_02	438.745	1232.145	774.484	98.689	136.912	Mixed Mode	18.0-26.0	07-23/07-23
Passage way	217.38	927.756	892.856	441.389	1503.988	Mixed Mode	18.0-26.0	07-23/07-23
Concert Hall_01	888.862	3288.661	1861.572	0	5660.471	Air Conditioning	18.0-26.0	07-23/07-23
Concert Hall_00	888.862	2525.438	0	0	5393.449	Air Conditioning	18.0-26.0	07-23/07-23
TOTAL	**7530.403**	**17097.365**	**8070.256**	**710.361**	**26985.904**			

Table 5.3- Thermal zoning summery of our project building

1) Auditorium:

Operation: Weekdays 07-23, Weekends 07-23.
Thermostat setting: 18.0 - 26.0 C
Max. Heating: 0.0 C - No Heating
Max. Cooling: 81963 W at 13:00 on 4th July
Floor Area: **888.862 m2**

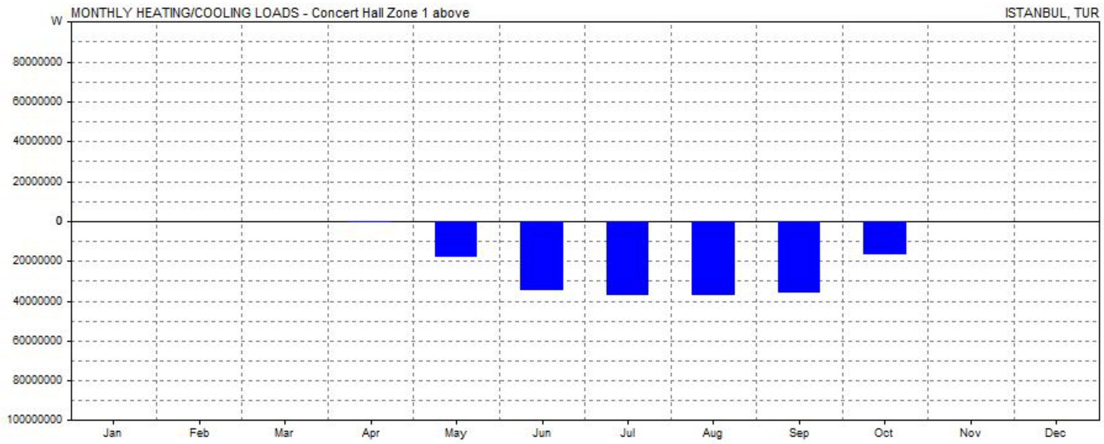


Figure 5.22- Monthly heating and cooling load of Auditorium Hall

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	0	0
Feb	0	0	0
Mar	0	0	0
Apr	0	447655	447655
May	0	17738888	17738888
Jun	0	34721696	34721696
Jul	0	37479920	37479920
Aug	0	37475676	37475676
Sep	0	35777312	35777312
Oct	0	16510909	16510909
Nov	0	0	0
Dec	0	0	0
TOTAL	**0**	**180152064**	**180152064**
PER M²	**0**	**202677**	**202677**

Table 5.4- Heating and cooling loads

From the above result it can be concluded that the hall requires maximum cooling in summer as well as in winter

2) Foyer

Operation: Weekdays 07-23, Weekends 07-23.
Thermostat setting: 18.0 - 26.0 C
Max. Heating: 27885 W at 16:00 on 18th February
Max. Cooling: 8810 W at 15:00 on 4th July
Floor Area: **218.601 m2**

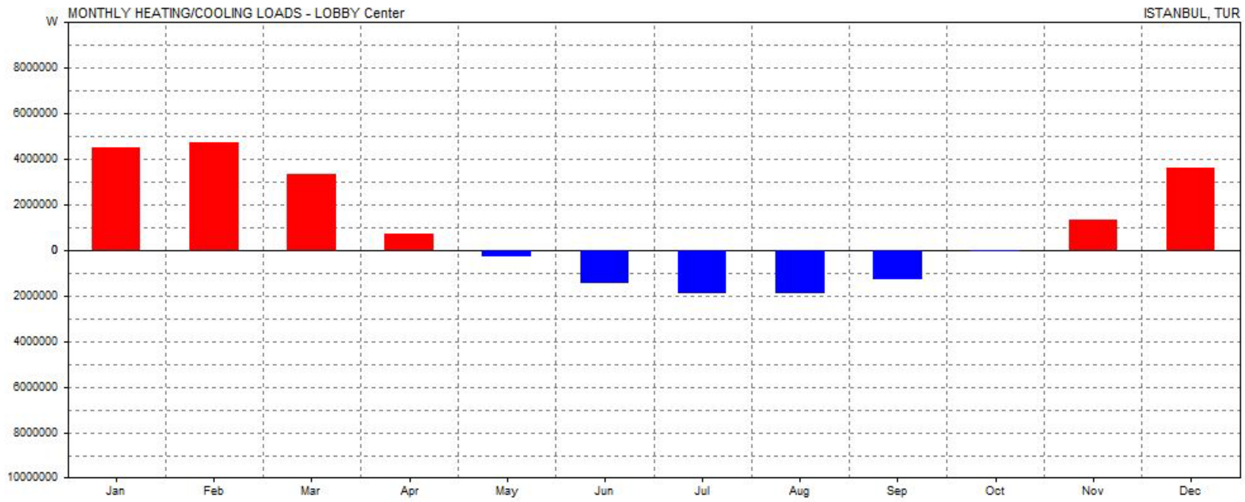


Figure 5.23- Monthly heating and cooling load of Foyer

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	4483704	0	4483704
Feb	4743798	0	4743798
Mar	3344684	0	3344684
Apr	727487	0	727487
May	23232	286826	310058
Jun	0	1442135	1442135
Jul	0	1888443	1888443
Aug	0	1887896	1887896
Sep	0	1273869	1273869
Oct	0	45507	45507
Nov	1317268	0	1317268
Dec	3626804	0	3626804
TOTAL	**18266976**	**6824677**	**25091652**
PER M²	**83563**	**31220**	**114783**

Table 5.5- Heating and cooling loads

The foyer needs heating and cooling load in winter. The table above gives the load requirement in a year.

3) Entrance Office 1st Floor

Operation: Weekdays 07-23, Weekends 07-23.
Thermostat setting: 18.0 - 26.0 C
Max. Heating: 5574 W at 16:00 on 18th February
Max. Cooling: 5264 W at 13:00 on 15th August
Floor Area: **234.018 m2**

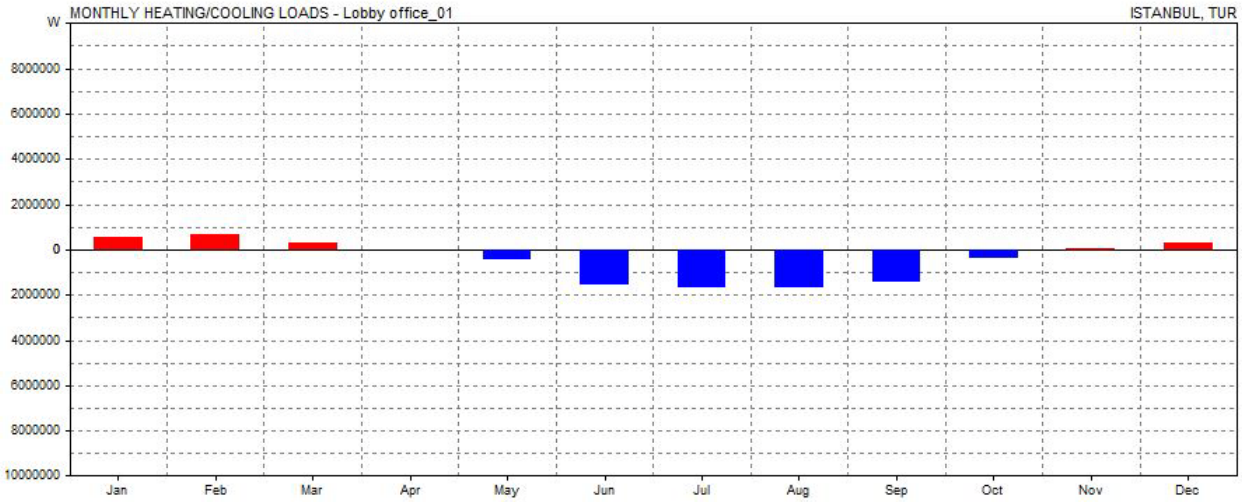


Figure 5.24- This shows that cooling load requirement is higher than heating load

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	541938	0	541938
Feb	690830	0	690830
Mar	290466	0	290466
Apr	17341	0	17341
May	0	440931	440931
Jun	0	1527263	1527263
Jul	0	1693806	1693806
Aug	0	1680439	1680439
Sep	0	1417138	1417138
Oct	0	369677	369677
Nov	52573	0	52573
Dec	306209	0	306209
TOTAL	**1899358**	**7129254**	**9028612**
PER M²	**8116**	**30465**	**38581**

Table 5.6- Heating and cooling loads

4) Conference Hall

Operation: Weekdays 07-23, Weekends 07-23.
Thermostat setting: 18.0 - 26.0 C
Max. Heating: 0.0 C - No Heating
Max. Cooling: 7020 W at 09:00 on 27th August
Floor Area: **116.765 m2**

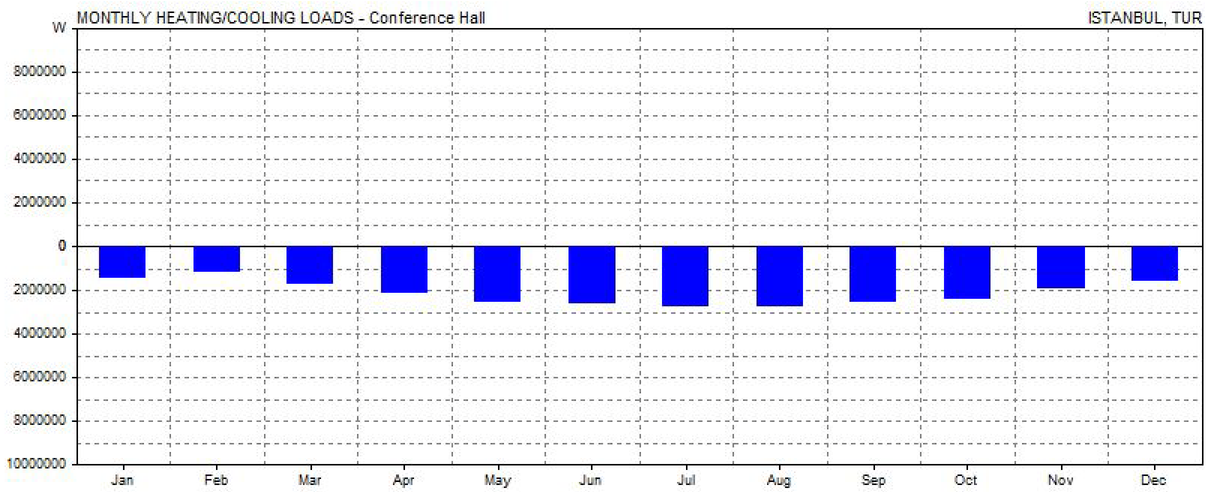


Figure 5.25- The conference hall has a high capacity to accommodate people so this also requires higher cooling load

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	1428333	1428333
Feb	0	1170803	1170803
Mar	0	1711502	1711502
Apr	0	2140724	2140724
May	0	2537158	2537158
Jun	0	2624894	2624894
Jul	0	2764117	2764117
Aug	0	2757657	2757657
Sep	0	2528405	2528405
Oct	0	2430922	2430922
Nov	0	1929112	1929112
Dec	0	1603335	1603335
TOTAL	**0**	**25626960**	**25626960**
PER M²	**0**	**219474**	**219474**

Table 5.7- Heating and cooling loads

5) Restaurant Ground Floor

Operation: Weekdays 07-23, Weekends 07-23.
Thermostat setting: 18.0 - 26.0 C
Max. Heating: 4885 W at 16:00 on 18th February
Max. Cooling: 10844 W at 13:00 on 4th July
Floor Area: **877.491 m2**

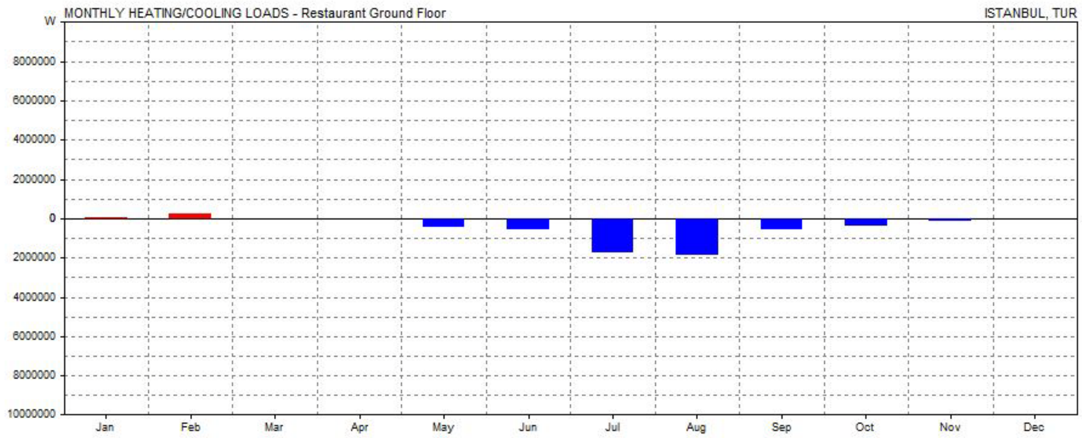


Figure 5.26- Cooling loads is higher in summers than heating loads in winter

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	62863	0	62863
Feb	251320	0	251320
Mar	15527	0	15527
Apr	0	0	0
May	0	428199	428199
Jun	0	591681	591681
Jul	0	1725450	1725450
Aug	0	1858780	1858780
Sep	0	538091	538091
Oct	0	398014	398014
Nov	0	141260	141260
Dec	1738	0	1738
TOTAL	**331448**	**5681475**	**6012923**
PER M²	**378**	**6475**	**6852**

Table 5.8- Heating and cooling loads

5.6.1 Material Thermal Transmittance (U Value)

It is the density of the heat transfer rate per temperature difference between the environmental temperatures in the absence of solar radiation in W/m^2K. Resistance to heat flow by a material depends on thickness, density, water content and temperature. Thermal resistance of homogeneous material is calculated by dividing its thickness by thermal conductivity. U-value is the reciprocal of thermal resistance.

$$Thermal\ resistance\ (R) = \frac{material\ thickness\ (t)\ m}{thermal\ conductivity(\lambda) W/mK}$$

U- value for Green Roof			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Cohesive loamy soil	0.780	0.150	0.192
Geo-textile filter	0.000	0.010	
Drainage layer	0.060	0.050	0.833
Root barrier	0.028	0.020	0.714
Polyfoam Slimline membrane	0.000	0.010	
Ecotherm (Polyisocyanurate	0.027	0.100	3.704
Polyethylene layer	0.410	0.010	0.024
Bitumen water proof	0.500	0.010	0.020
Concrete slab	0.750	0.130	0.173
U-Value			0.177

Table 5.9- U-value for green roof

U- value for Entrance Office & Gallery Roof			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Roof Tiles	0.8	0.018	0.023
Water proof	0.000	0.000	0.000
Cement Mortar	0.420	0.03	0.071
Ecotherm	0.027	0.100	3.704
Vapour barrier	0.330	0.002	0.006
Cement Screed	0.400	0.050	0.125
Concrete Slab	0.750	0.130	0.173
U-Value		0.312	0.244

Table 5.10- U-value for office and gallery roof

U- value for External Wall Auditorium Hall			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Sinterflex tiles	1.200	0.030	0.025
Epoxy Adhesive layer	0.350	0.005	0.014
Ecotherm	0.025	0.030	1.200
Aqua panel Cement board	0.350	0.013	0.036
Rock wool	0.038	0.100	2.632
Plasterboard	0.160	0.015	0.094
Air gap	0.250	0.020	0.120
Rock wool	0.038	0.100	2.632
Vapor barrier	0.33	0.002	0.006
Plasterboard	0.160	0.0125	0.078
U-Value		0.315	0.146

Table 5.11- U-value for External Auditorium walls

U- value for External Wall Office			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Hosowari tiles	0.840	0.020	0.024
Epoxy Adhesive layer	0.350	0.005	0.014
Ecotherm	0.025	0.030	1.200
Aqua panel Cement board	0.350	0.013	0.036
Rock wool	0.038	0.100	2.632
Plasterboard	0.160	0.015	0.094
Air gap	0.250	0.020	0.120
Rock wool	0.038	0.100	2.632
Vapor barrier	0.33	0.002	0.006
Plasterboard 2 nos	0.160	0.0125	0.156
U-Value		0.315	0.145

Table 5.12- U-value for External Office walls

U- value for External Wall Backstage			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Cement Board	0.350	0.013	0.036
Epoxy Adhesive layer	0.350	0.005	0.014
Ecotherm	0.025	0.030	1.200
Aqua panel Cement board	0.350	0.013	0.036
Rock wool	0.038	0.100	2.632
Plasterboard	0.160	0.015	0.094
Air gap	0.250	0.020	0.120
Rock wool	0.038	0.100	2.632
Vapor barrier	0.33	0.002	0.006
Plasterboard 2 nos	0.160	0.0125	0.156
U-Value		0.315	0.144

Table 5.13- U-value for External backstage walls

U- value for Ground Floor Entrance Office			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Granite	2.900	0.030	0.010
Cement mortar	0.720	0.050	0.069
Ecotherm	0.025	0.160	6.400
Polyethylene with vapour barrier	0.410	0.005	0.012
Basement concrete floor	1.900	0.100	0.053
Bitumen water proof	0.500	0.010	0.020
Concrete screed	0.750	0.050	0.067
Air gap (IGLU)	5.560	0.400	0.072
Plain concrete	0.050	0.050	1.000
U-Value		0.855	0.130

Table 5.14- U-value for Ground floor Entrance office

U- value for Basement Floor Backstage			
Materials	Thermal conductivity (W/mK)	Thickness (m)	Thermal Resistance (m^2K/W)
Hardwood	0.050	0.020	0.400
Epoxy Adhesive layer	0.195	0.003	0.015
Cement mortar	0.72	0.050	0.069
Ecotherm	0.025	0.160	6.400
Polyethylene with vapour barrier	0.410	0.005	0.012
Concrete Floor	1.900	0.100	0.053
Bitumen water proof	0.500	0.010	0.020
Concrete screed	0.750	0.050	0.067
Air gap (IGLU)	5.560	0.400	0.07
Plain concrete	0.050	0.050	1.000
U-Value		0.848	0.123

Table 5.15- U-value for basement floor backstage

5.7 Technological drawings

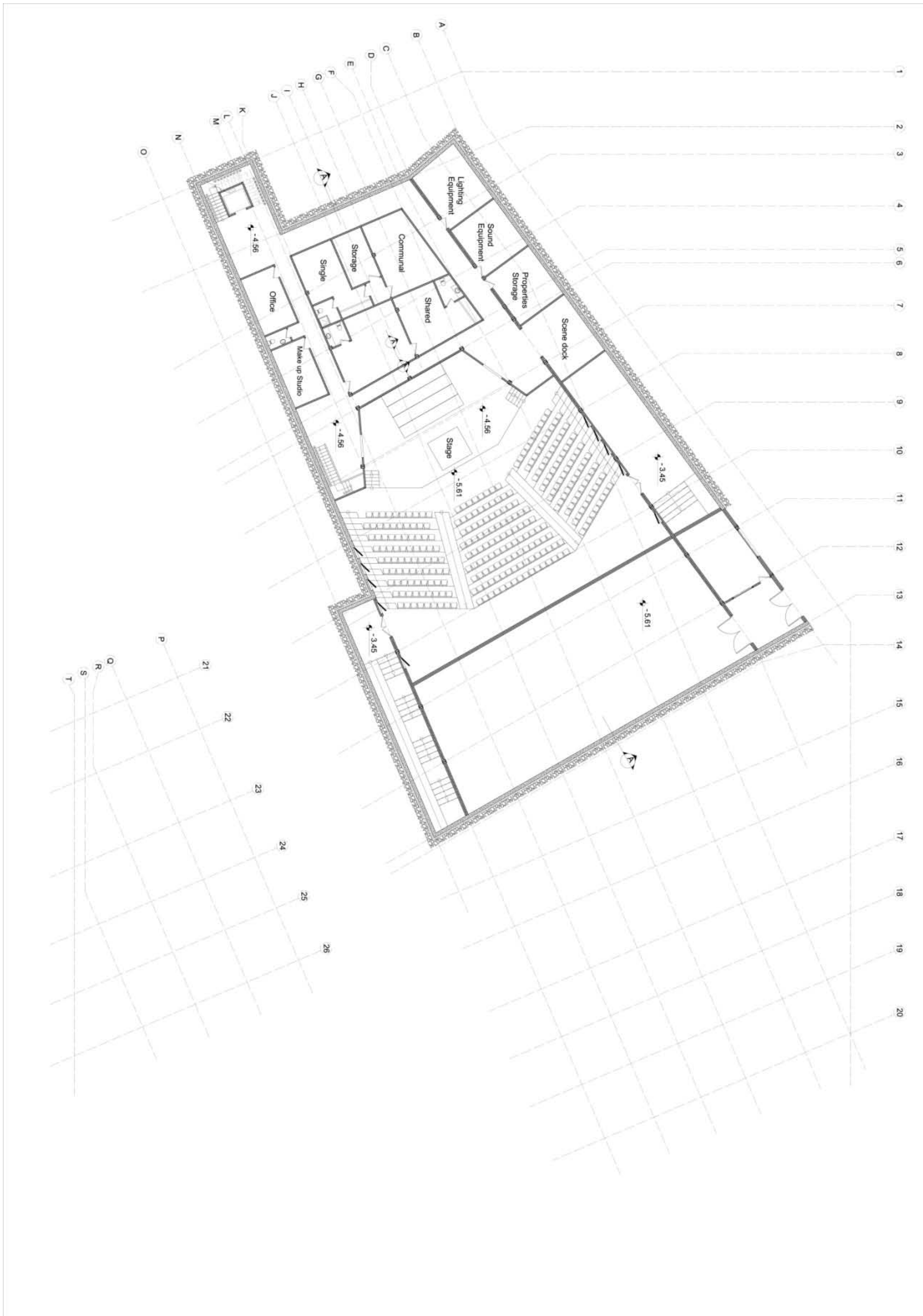


Figure 5.27- Basement Floor Plan

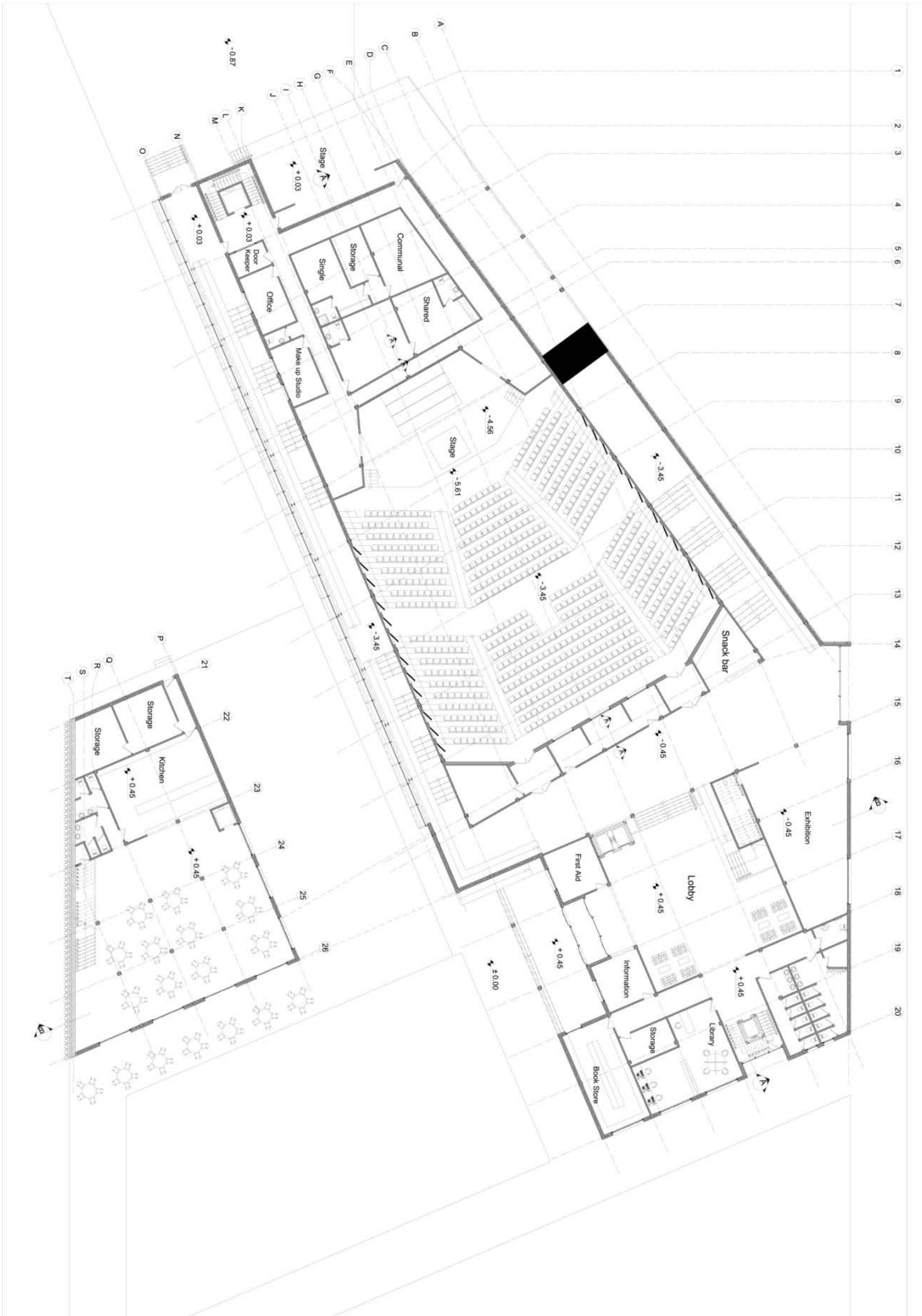


Figure 5.28- Ground floor plan

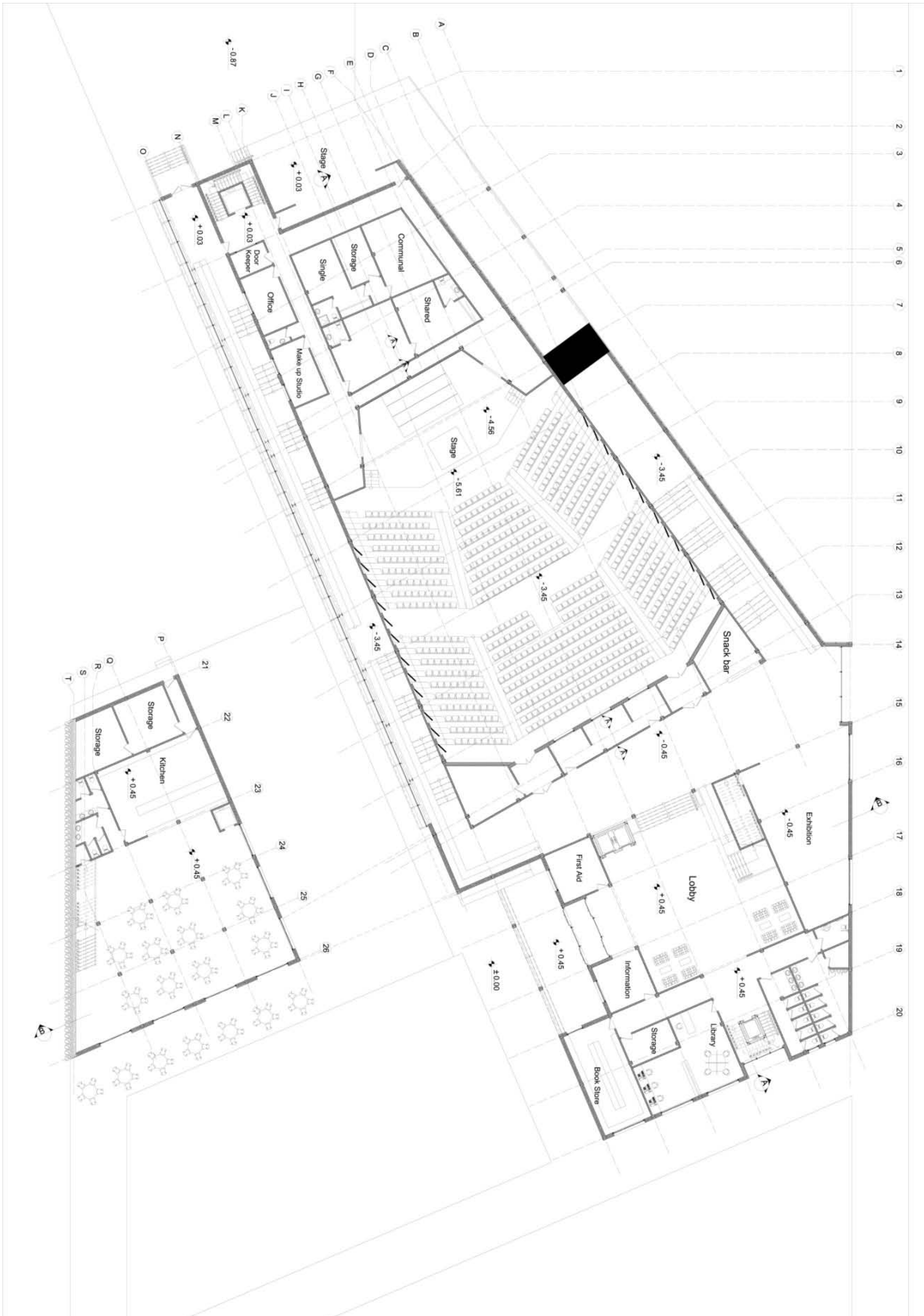


Figure 5.29- First floor plan

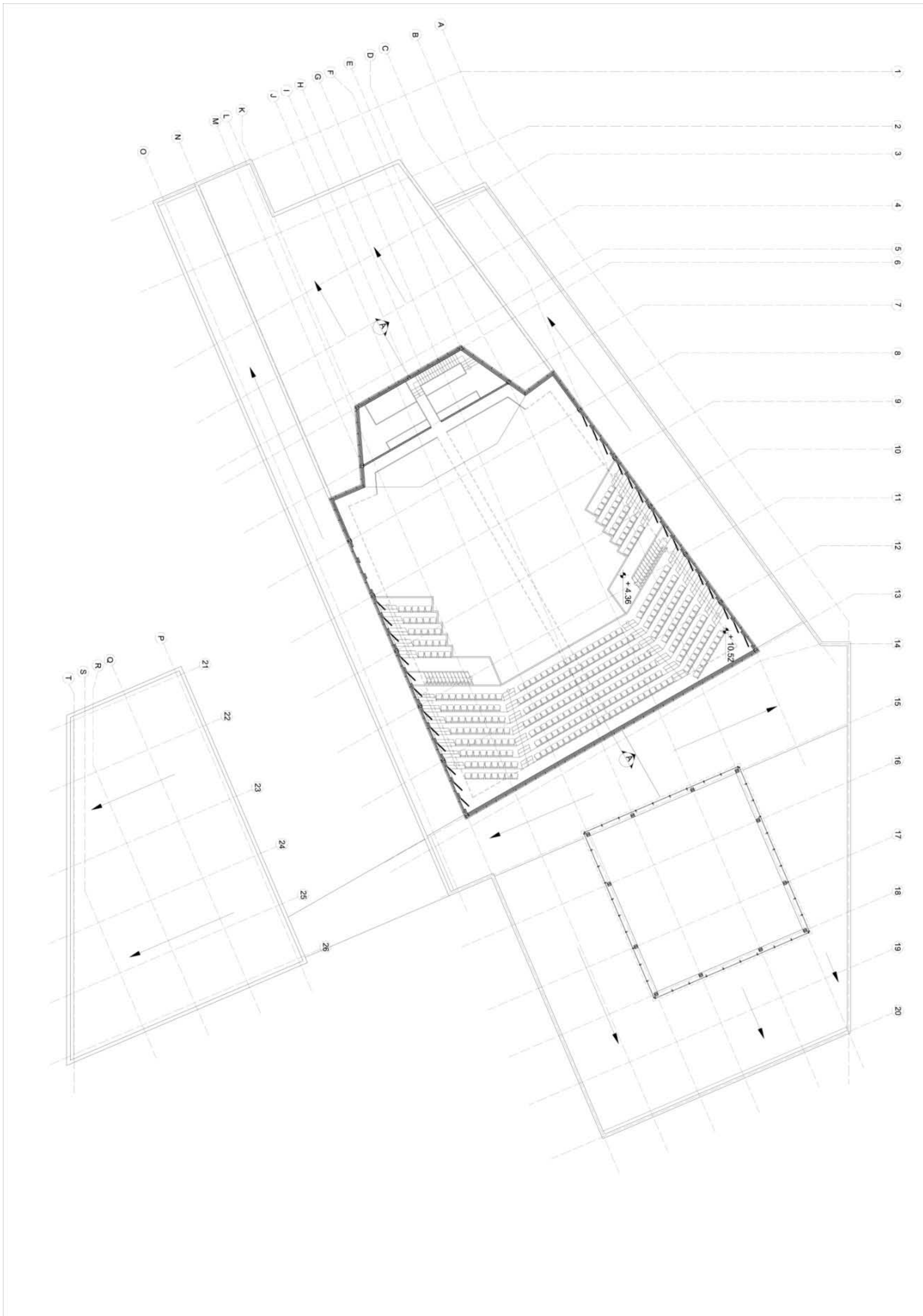
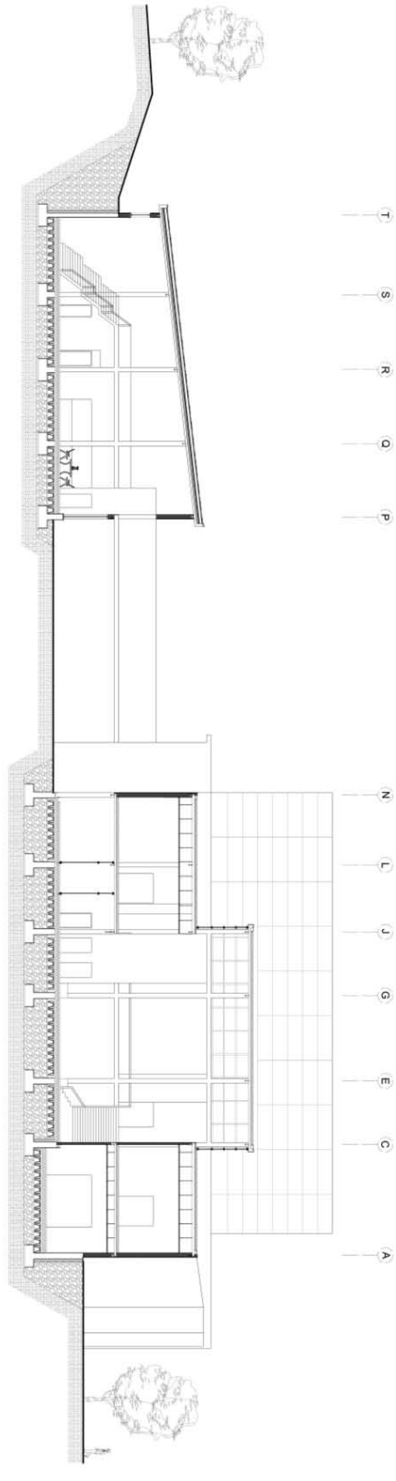


Figure 5.30- Second floor plan



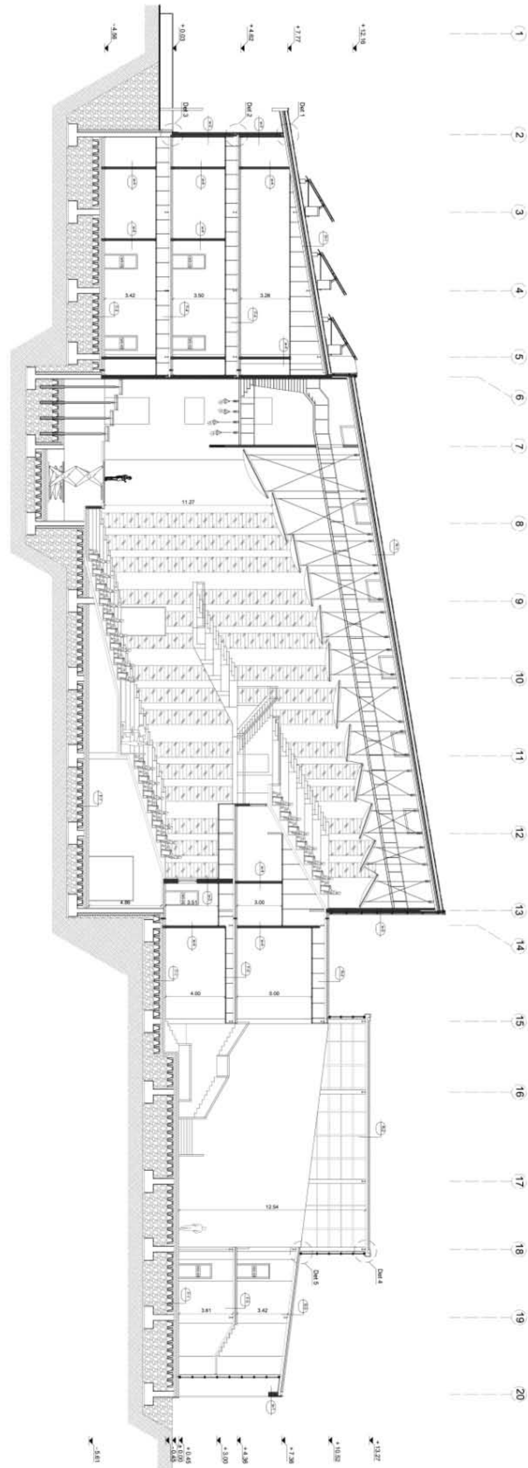


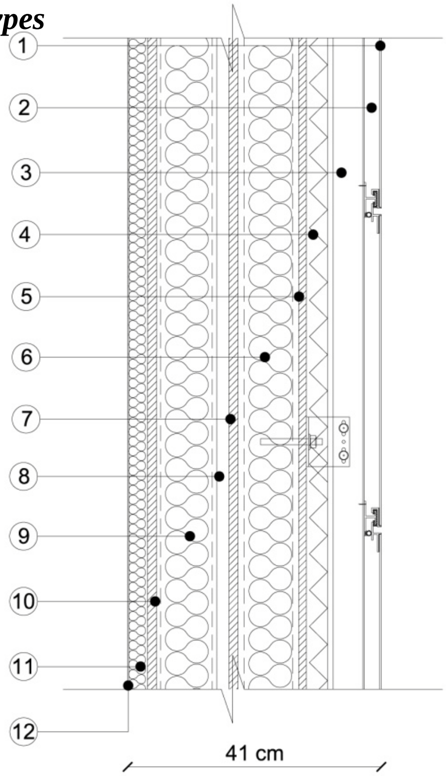
Figure 5.31- Section B-B

Figure 5.32- Section A-A

5.8 Technological Details

5.8.1 Wall types

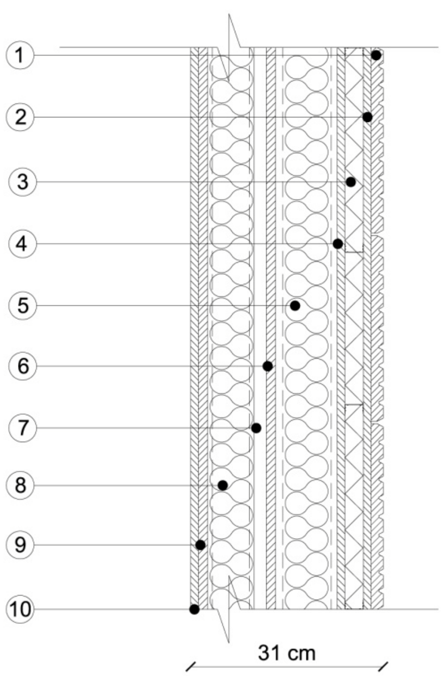
W-5: Wall with Sinterflex tile finish



1. Sinterflex tiles 0.3cm
2. Air gap 3cm
3. Aluminum T profile 5cm
4. Ecotherm insulation 3cm
5. Aqua panel cement board 1.25cm
6. Rock wool 10 cm
7. Plaster board 1.5cm
8. Air gap 2cm
9. Rock wool 10cm
10. Knauf board 1.5 cm
11. Compact rock wool 3cm
12. Metal sheet with holes 0.2cm

U Value: 0.144 m^2K/W

W-5: Wall with Hosowari tile finish

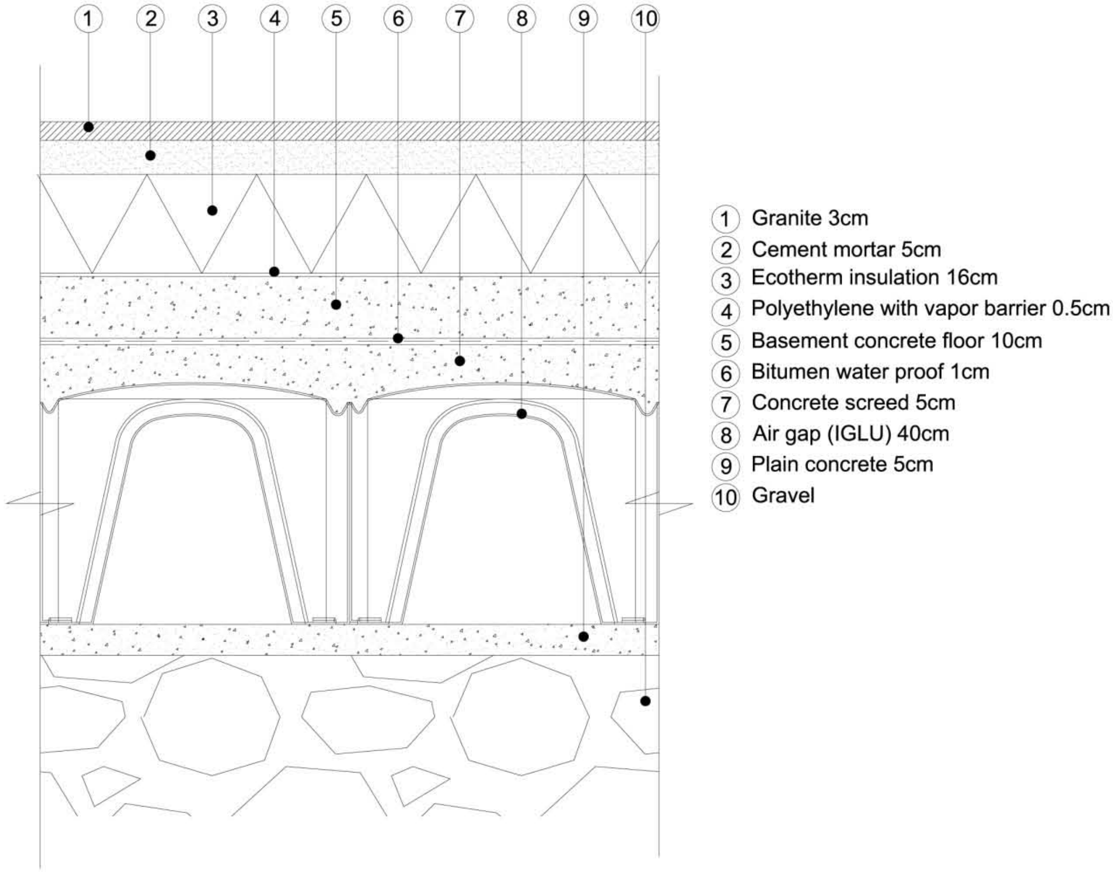


1. Hosowari tiles 2cm
2. Cement board 1.25cm
3. Ecotherm insulation 3cm
4. Aqua panel cement board 1.25cm
5. Rock wool 10 cm
6. Plaster board 1.5cm
7. Air gap 2cm
8. Rock wool 10cm
9. Knauf board 1.5 cm
10. Plaster board 1.25cm

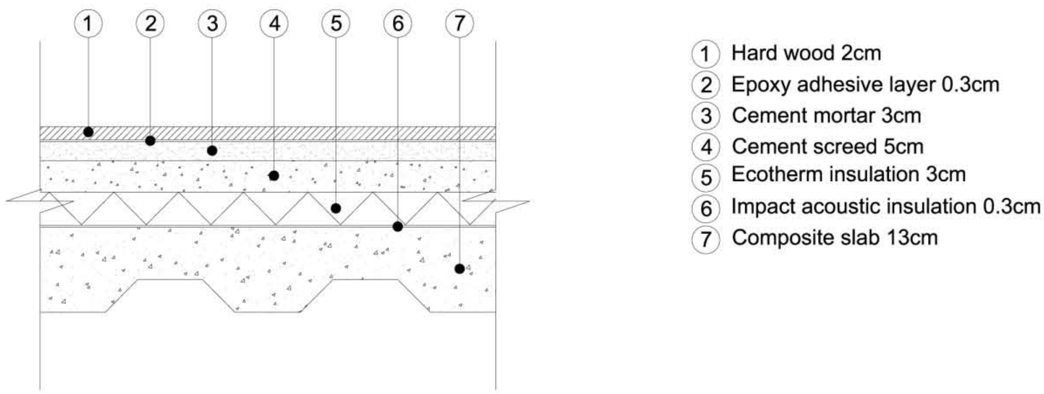
U Value: 0.144 m^2K/W

5.8.2 Floor types

F-1: Floor with granite finish

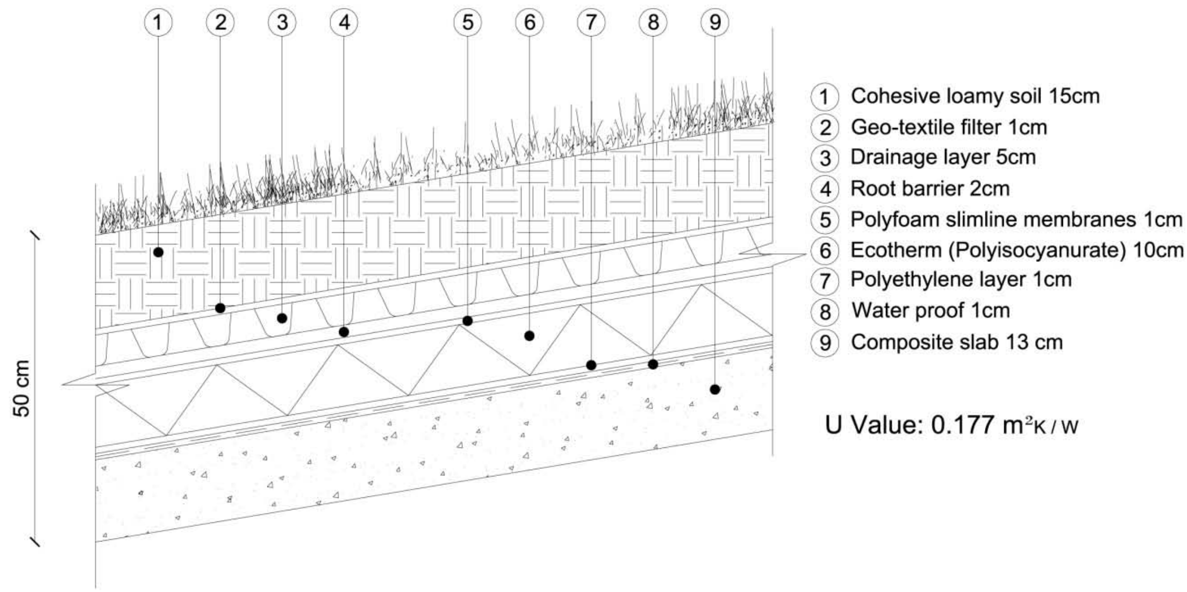


F-4: Floor with hard wood finish

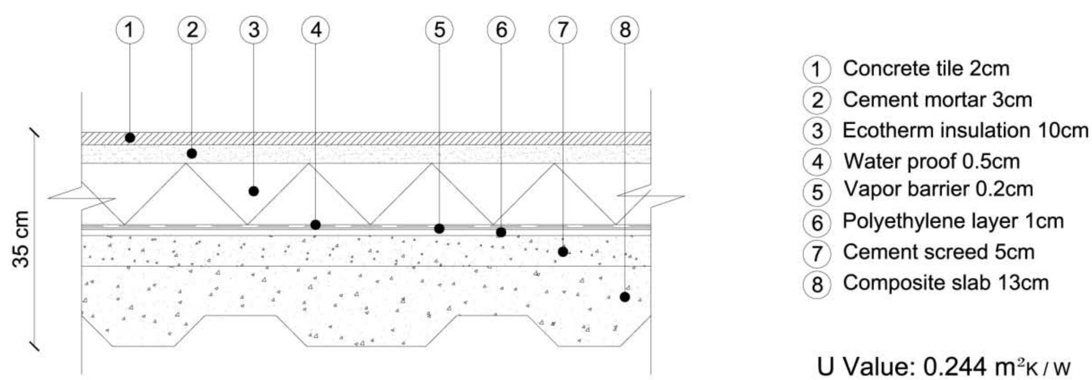


5.8.3 Roof types

R-1: Green roof

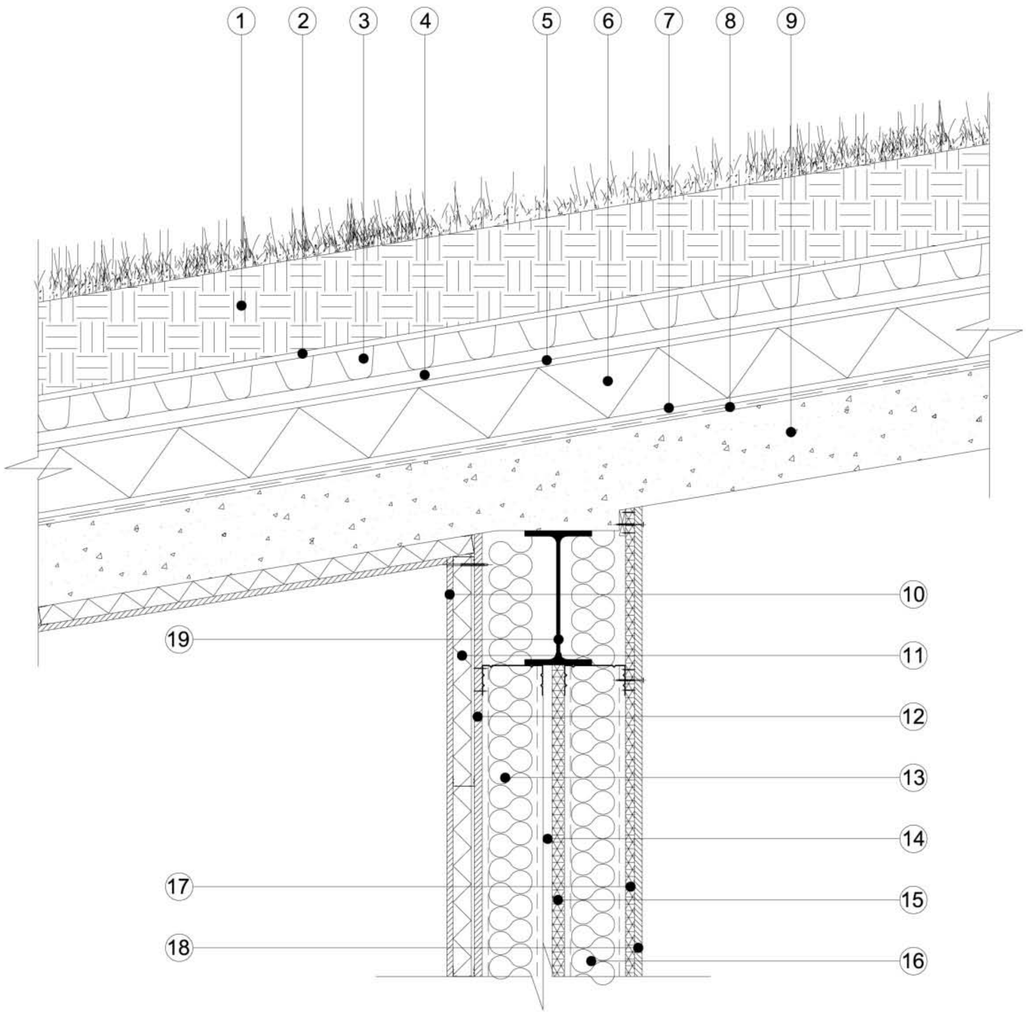


R-2: Flat roof



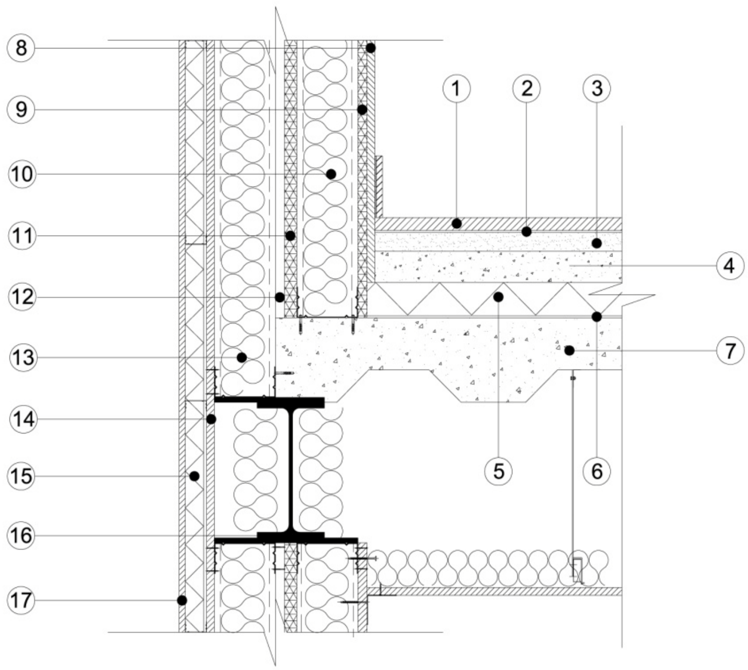
5.8.4 Connection Details

Detail 1



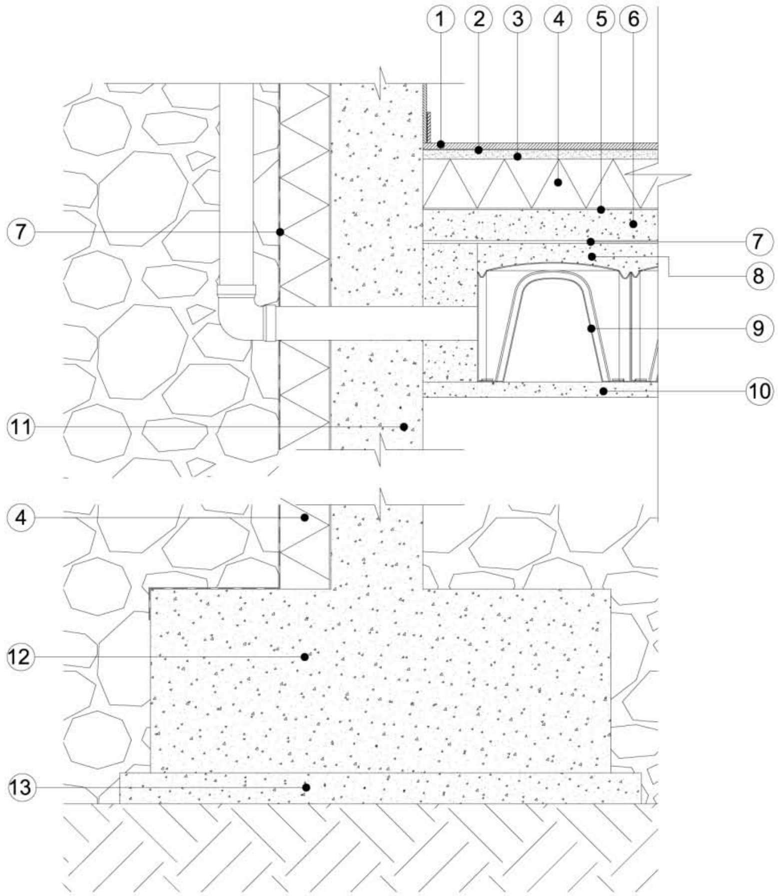
1. Cohesive loamy soil 15cm
2. Geo-textile filter 1cm
3. Drainage layer 5cm
4. Root barrier 2cm
5. Polyfoam slimline membranes 1cm
6. Ecotherm (Polyisocyanurate) 10cm
7. Polyethylene layer 1cm
8. Water proof 1cm
9. Composite slab 13 cm
10. Cement board with render 1.25cm
11. Ecotherm insulation 3cm
12. Aqua panel cement board 1.25cm
13. Rock wool 10 cm
14. Air gap 2cm
15. Plaster board 1.5cm
16. Rock wool 10cm
17. Knauf board 1.5 cm
18. Plaster board 1.25 cm
19. Steal beam IPE 200

Detail 2



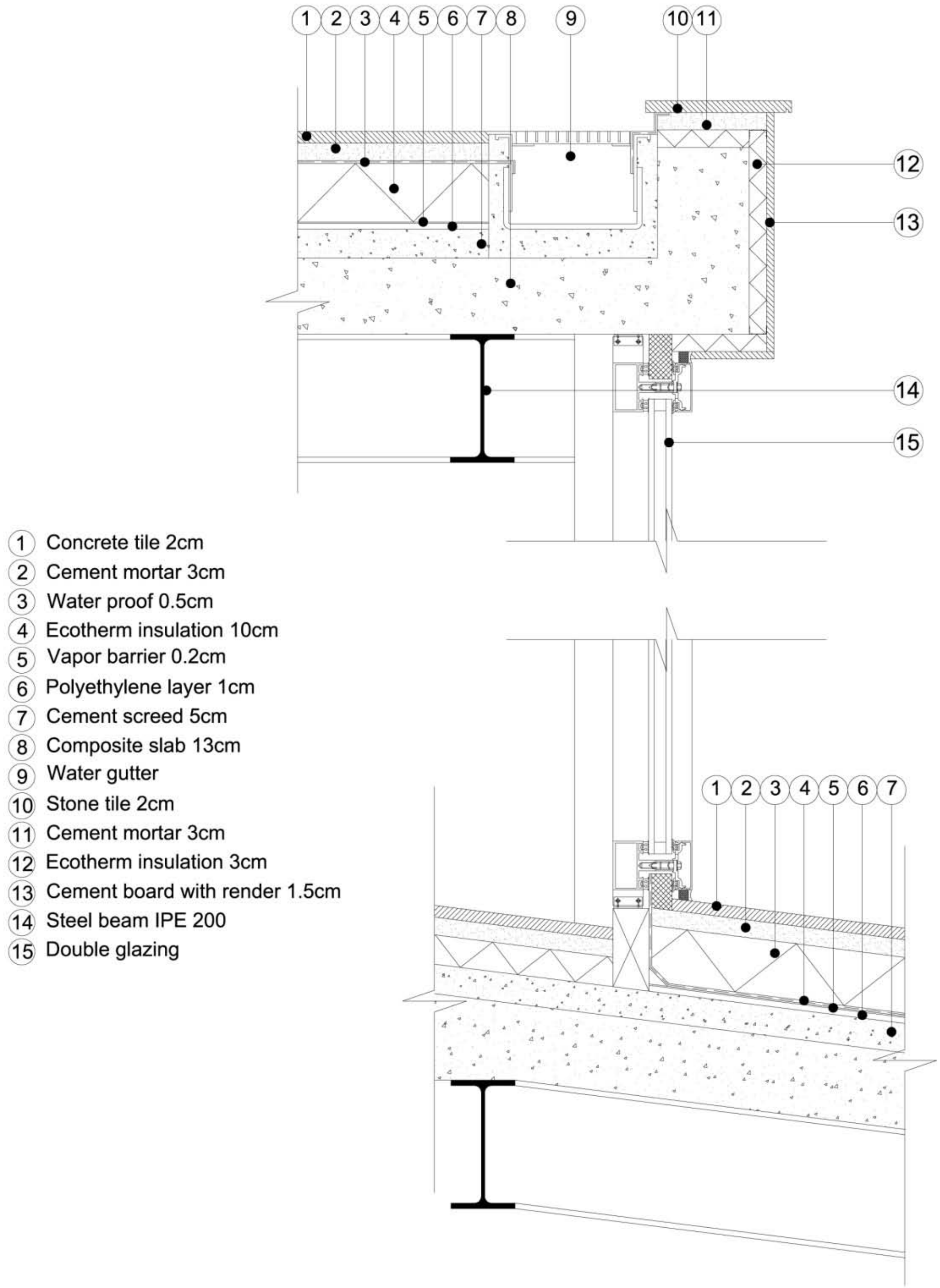
1. Hard wood 2cm
2. Epoxy adhesive layer 0.3cm
3. Cement mortar 3cm
4. Cement screed 5cm
5. Ecotherm insulation 3cm
6. Impact acoustic insulation 0.3cm
7. Composite slab 13cm
8. Plaster board 1.25 cm
9. Knauf board 1.5 cm
10. Rock wool 10 cm
11. Plaster board 1.5cm
12. Air gap 2cm
13. Rock wool 10cm
14. Aqua panel cement board 1.25cm
15. Ecotherm insulation 3cm
16. Steal beam IPE 200
17. Cement board with render 1.25cm

Detail 3



1. Hard wood 2cm
2. Epoxy adhesive layer 0.3cm
3. Cement mortar 3cm
4. Ecotherm insulation 16cm
5. Polyethylene with vapor barrier 0.5cm
6. Basement concrete floor 10cm
7. Bitumen water proof 1cm
8. Concrete screed 5cm
9. Air gap (IGLU) 40cm
10. Plain concrete 5cm
11. Concrete basement wall 30cm
12. Foundation concrete footing
13. Lean concrete 10cm

Detail 4


1 2 3 4 5 6 7 8 9 10 11
12
13
14
15
1 2 3 4 5 6 7
1 Concrete tile 2cm
2 Cement mortar 3cm
3 Water proof 0.5cm
4 Ecotherm insulation 10cm
5 Vapor barrier 0.2cm
6 Polyethylene layer 1cm
7 Cement screed 5cm
8 Composite slab 13cm
9 Water gutter
10 Stone tile 2cm
11 Cement mortar 3cm
12 Ecotherm insulation 3cm
13 Cement board with render 1.5cm
14 Steel beam IPE 200
15 Double glazing

Reference

1. *Building for the performing arts (a design and development guide) by Ian Appleton*
2. *Architectural Design in Steel, Author : Peter Trebilcock, Mark Lawson*
3. *The Green Studio Handbook: Environmental Strategies for Schematic Design By Alison G. Kwok, Walter T. 700 Grondzik*
4. *http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php*
5. *http://www.robur.com/technology/energy-class-a-buildings/energy-saving-buildings.html*
6. *http://www.soundproofcow.com/Acoustitone-Acoustic-Metal-Panels.html*
7. *http://www.knauf.lt/www/media/pdf_prie_produktu/neaiskus_20110228/aquapanel_sistemos_indoor_en.pdf*
8. *Reference map from www.emsc-csem.org*