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POLO REGINONALE DI LECCO

MASTER OF SCIENCE IN ARCHITECTURAL ENGINEERING

CUKUROVA MUNICIPALITY HALL & CULTURAL CENTER

MASTER THESIS OF:
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Abstract

A municipality hall is usually recognized as a public office building, which people go to when they have administrative business to get done. While accommodating a significant number of staff, municipality halls also welcome many visitors on daily basis. Thinking over the past experiences in a municipality hall, most people usually try to get out from the building as fast as they can or they try to solve their issues in once so that they don't need to come over again. This is usually due to the bureaucratic procedures that the people face while they are in the building which may seem as a waste of time. Sometimes the problem is the location of the building or even the lack of way finding signs that transforms a simple rectangular shaped building into a maze. Whatever the reason is, a municipality hall is usually evaluated based on the criteria that how much time one spends in the building. While keeping in mind that even a perfect design cannot change the speed or complexity of bureaucratic procedures, what we try to seek in this academic study is to change the impression of the term, municipality hall.

The design proposal for Cukurova Municipality Hall seeks to change the quality of experience within the building using the urban park where the site is located in. Even though that the "quality of experience" is based on many different items, some of them being administrative issues (procedures, staff, etc.), the design proposal challenges to improve the quality of experience by interdisciplinary studies.

Adana, the city that the project is located in, has been gone through a rapid growth in the second half of the last century. As the many other cities in Turkey, this growth was uncontrolled in many ways. Although that the issues such as FAR, height of the building, land setbacks are meant to be strictly regulated by the governmental bodies, the regulations have changed periodically each time the ruling power of the city & country has changed. This has led to an uncontrolled growth of the city, converting Adana, once known as a "land of cotton" into a pile of concrete. The design proposal aims to set a model for the new developments in Cukurova, Adana and also other administrative buildings in Turkey. Using the sustainable green concept which is not well known in the region and strongly relating it with the landscape are seen as the key elements of the design.

Chapter One - Introduction

1.1 Introduction

This academic study is based on the "Cukurova Municipality Hall & Cultural Center Architectural Design Competition" which is promoted by Cukurova Municipality of Adana, Turkey and was held in the fall of 2011. This national-level competition has aimed to find the best architectural solution for the new municipality building and encouraged the participants to enrich their designs by conceptual engineering studies. The competition has been finalized at the end of 2011 and the winners of the competition have been announced by the municipality officers. Neglecting the competition deadlines, the process of design has been expanded and modified in a more academical approach during this research, following the constraints and guidelines determined by the competition brief and expanding it with the necessity of careful design of the urban park in which the building complex is located. The process has been divided into consequent stages of design such as urban design, architectural design, structural design and technological design & building service design which will be introduced in the following chapters.

1.2 Competition Brief

1.2.1 Location

The project site is located in the Cukurova district of Adana which is a city in the southern part of Turkey. The site's location has a crucial importance since its vicinity to important roads that connect the city center to the airport and the northern rural part of the city to the city center. The site, in the existing situation, is covered with various types of trees and functions as a public park.

Figure 1.1 – Project site

1.2.2 Objectives

The primary objective of the competition is to design a new municipality hall and a cultural center on the project site that would satisfy the needs of the municipality in a modern, technological and sustainable approach. Municipality hall being one of the most important public spaces within the city, the brief strictly highlights the importance of public use and accessibility of the building and the site. The project site, itself, is a part of a huge urban park, thus the relationship of the urban park and the project site has a crucial importance. The urban park, today, is green space which has various types of trees, pedestrian paths and benches. An important goal is to define and propose new activities to this public space in the urban scale.

The new design is asked to be strongly connected with the surrounding landscape, thus the challenge is not to design only a building, but an urban park that would act as a recreation center which satisfies the needs of the residents. Also the new design is seen as a new triggering point that would bring a new set of activities to the area and more importantly increase the value of the close vicinity. Cukurova, a currently developing district, has empty plots owned by the government which today serve as parks and gardens for the residents of Cukurova, but these plots have no specific functions and they are only spaces that the residents pass through within the daily life. The competition brief asks the contestants to re-evaluate these spots within the urban park and its surroundings, so that these spaces can be used frequently by the residents for recreational uses.

Sustainability is the utmost important challenge defined in the brief, a goal that should be reached at the urban and the architectonic scale. The brief points out the importance of the pedestrian accessibility to the building through the urban park and minimizes the usage of private transportation to encourage the maximum usage of public transportation to reach sustainability at the urban scale. Creating pedestrian paths between the different types of public transportation networks and the urban park is one of the most important goals of the urban design.

Chapter Two - Urban Design

2.1 Urban Context

2.1.1 Adana

Adana, the fifth most populous city in Turkey with 2 million inhabitants, is located at the southern part of Turkey and also being at the northeastern edge of the Mediterranean, where it serves as the gateway to the Cukurova plain. The city is situated on the River Seyhan, 30 km inland from the Mediterranean Sea, in south-central Anatolia.

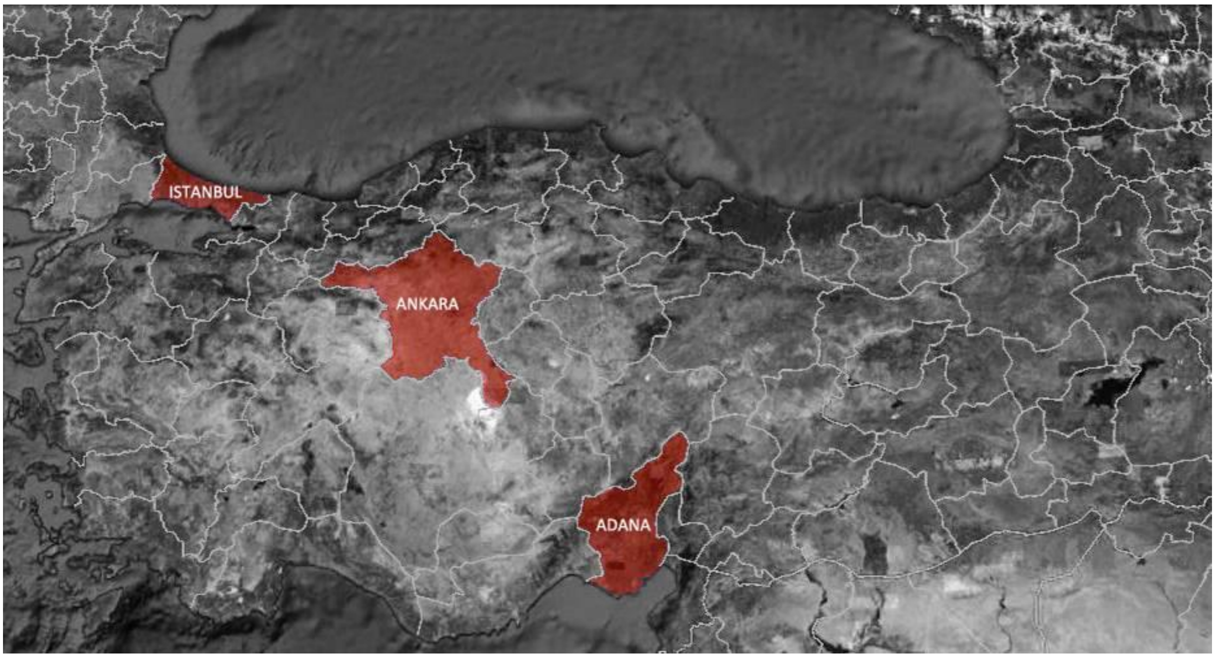


Figure 2.1 – Map of Turkey

The city is nestled in the most fertile area of the country, thanks to the life giving waters of the River Seyhan which feeds it. The origins of the name Adana stretches all the way back to mythology. Legends say that Adana was founded by Adanus himself, the son of the God of Weather, Kronus.

The city is surrounded by; Kayseri on the north, Osmaniye on the east, Kahramanmaras on the northeast, Hatay on the southeast, Niğde on the northwest, Mersin on the west and Mediterranean Sea on the south (See Fig 2.2). The city has 160 km long shores on the Mediterranean Sea.

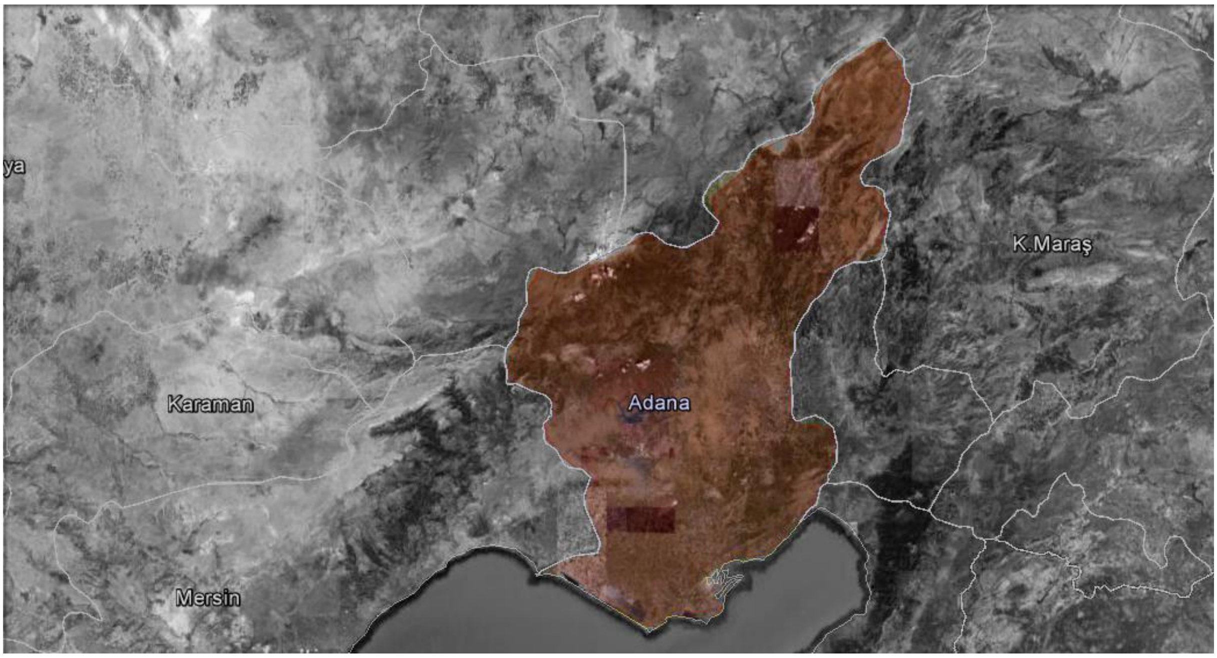


Figure 2.2 – Adana & its surrounding

2.1.2 History of Adana

The history of the Tepebag tumulus in the middle of Adana dates to the Neolithic Period, 6000 B.C., and the time of the first human settlements. It is considered to be the oldest city of the Cukurova region. A place called Adana is mentioned by name in a Sumerian epic, the Epic of Gilgamesh, but the geography of this work is too imprecise to identify its location.
According to the Hittite inscription of Kava, found in Hattusa (Boğazkale), Kizzuwatna was the first kingdom that ruled Adana, under the protection of the Hittites by 1335 BC. At that time, the name of the city was Uru Adaniyya, and the inhabitants were called Danuna. Beginning with the collapse of the Hittite Empire, c. 1191-1189 BC, invasions from the west caused a number of small kingdoms to take control of the plain, as follows: Kue Assyrians, 9th century BC; Persians, 6th century BC; Alexander the Great in 333 BC; Seleucids; the pirates of Cilicia; Roman statesman Pompey the Great; and the Armenian Kingdom of Cilicia (Cilician Kingdom).

The history of Adana is intrinsically linked to the history of Tarsus; they often seem to be the same city, moving as the neighbouring Seyhan River changed its position. Their respective names also changed over the course of the centuries. Adana was of relatively minor importance during the Roman's influential period, while nearby Tarsus was the metropolis of the area. During the era of Pompey, the city was used as a prison for the pirates of Cilicia. For several centuries thereafter, it was a waystation on a Roman military road leading to the East. After the permanent split of the Roman Empire in 395 AD, the area became a part of the Byzantine Empire, and was probably developed during the time of Julian the Apostate. With the construction of large bridges, roads, government buildings, irrigation and plantation, Adana and Cilicia became the most developed and important trade centers of the region. Ayas (today Yumurtalık), and Kozan (formerly Sis) were the other major urban and administrative centers in the area, especially during the period of the Cilicians.

In the mid 7th century, the city was captured by the Arabs. According to an Arab historian of that era, the name of the city was derived from Ezene, the prophet Yazene's grandson.
The Byzantines recaptured Adana in 964. After the victory of Alp Arslan at the Battle of Manzikert in 1071, the Seljuq Turks overran much of the Byzantine Empire. They had reached and captured Adana sometime before 1071 and continued to hold the place until Tancred, a leader of the First Crusade, captured the city in 1097.
In 1132, it was captured by the forces of the Armenian Kingdom of Cilicia, under its king, Leo I. It was taken by Byzantine forces in 1137, but the Armenians regained it around 1170. In 1268, there was a terrible earthquake which destroyed much of the city. Adana was rebuilt and remained a part of the Kingdom of Cilician Armenia until 1359, when the city was ceded by Constantine III to the Mamluk Sultan of Egypt in return for obtaining a peace treaty. The Mamluks' capture of the city allowed many Turkish families to settle in it. The Ramadanids family, one of the Oghuz families brought by the Mamluks, ruled Adana until the Ottomans captured the city.

From the end of the Renaissance to the modern era (1517–1918), the Ottoman Empire ruled the area. In the 1830s, in order to secure Egypt's independence from the Ottoman Empire, the army of Muhammad Ali Pasha, the governor of Ottoman Egypt and Sudan, invaded Syria on two occasions, and reached the Adana plain. The soldiers of Muhammad Ali Pasha destroyed Adana Castle and the Walls, a major hit to city's history. The subsequent peace treaty secured Egypt's independence, but (at the insistence of Great Britain, Austria, Russia and Prussia) required the evacuation of all Egyptian forces from Syria, and its return to Ottoman sovereignty. In the aftermath, Adana was established as a province in its own right.

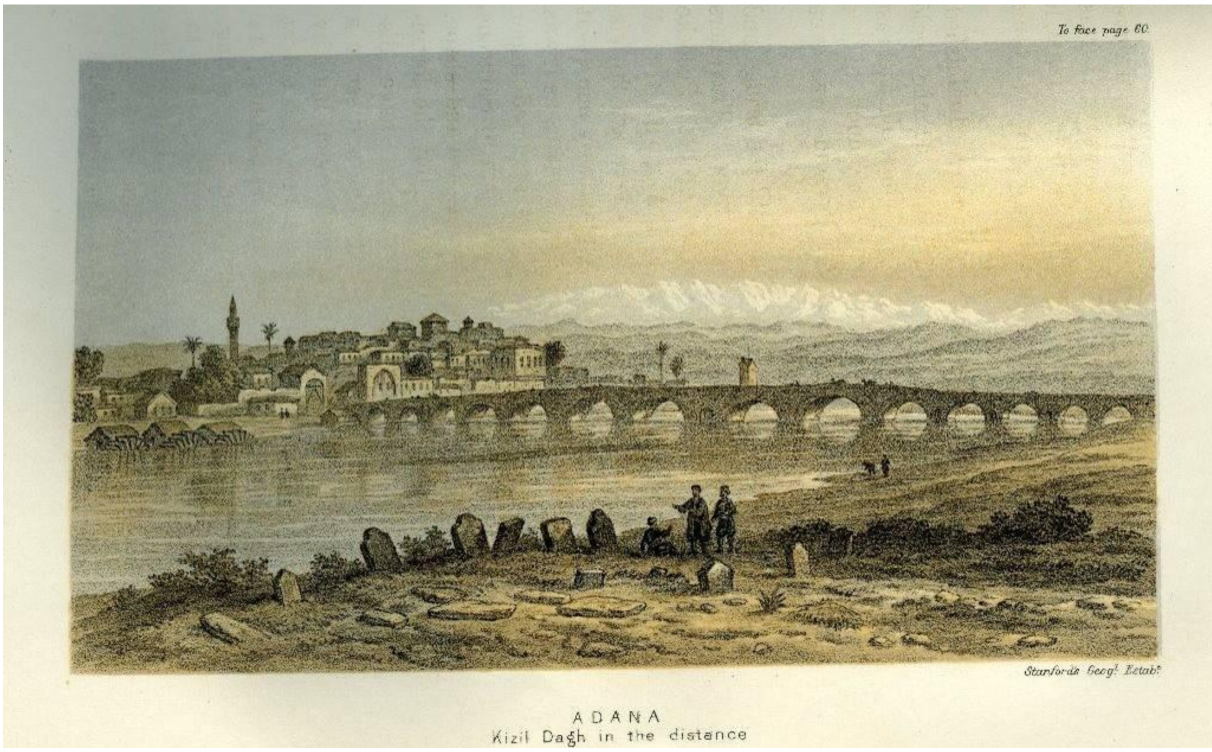


Figure 2.3 – Adana, 1879

After World War I, the Ottoman government surrendered control of the city to French troops, and the four battalions of the French Armenian Legion were sent to occupy Adana and oversee the repatriation of Armenian refugees. The French forces were, however, spread too thinly in the region and, as they came under withering attacks by Muslim elements both opposed and loyal to Mustafa Kemal Pasha, eventually reversed their policies in the region. The Armenian Legion was gradually disbanded, the repatriation was halted, and the French ultimately abandoned all pretensions to Cilicia, which they had originally hoped to attach to their mandate over Syria. On October 20, 1921, the Treaty of Ankara was signed between France and the Turkish Grand National Assembly. Based on the terms of the agreement, France recognized the end of the Cilicia War, and French troops together with the remaining Armenian volunteers withdrew from the city on January 5, 1922. Adana became a city of the Republic of Turkey, established in 1923.

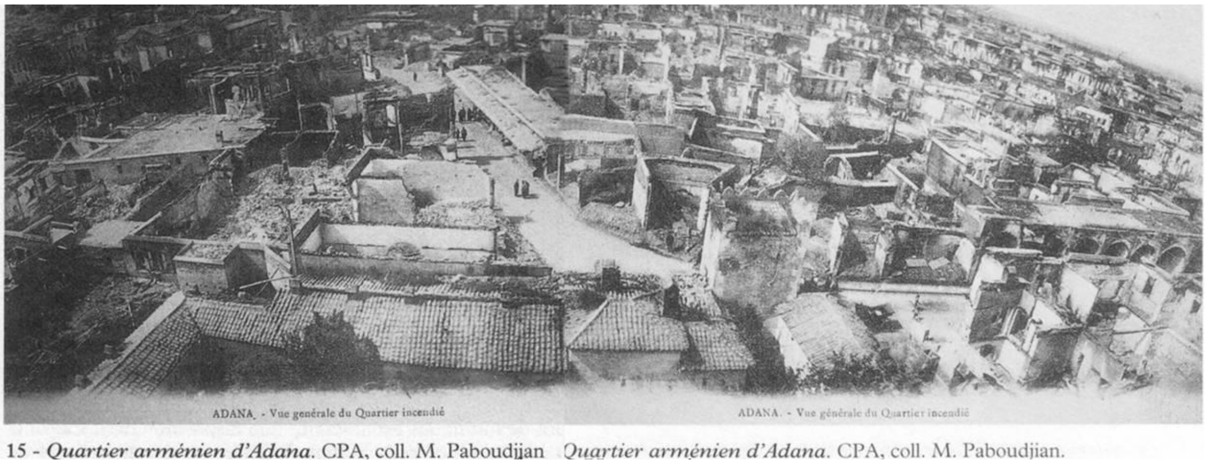


Figure 2.4 – Adana, 1909

The development of the city of Adana started with the rehabilitation of swamps surrounding the city into agricultural land in the second half of the nineteenth century. The production of cotton and the establishment of factories which process cotton into industrial and textile goods enabled the city to become one of the major cities of Turkey in the second half of the twentieth century.

Figure 2.5 – Adana, 2007

2.1.3 Geography: Cukurova Plain & Adana

Cukurova Plain, historically known as Cilicia, is a geographic, economic and cultural region in south-central Turkey, covering the provinces of Mersin, Adana, Osmaniye and Hatay.
With a population of almost 5.7 million, it is one of the largest population concentrations in Turkey.

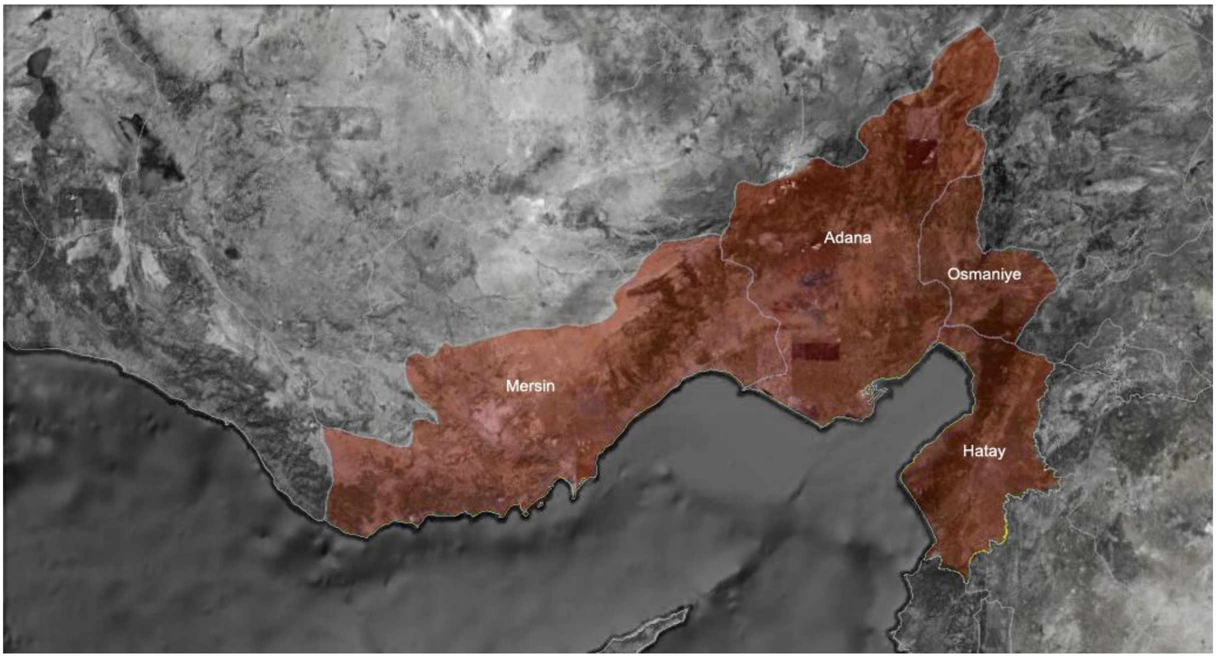


Figure 2.6 – Cukurova Plain

Most of the Cukurova region is a large stretch of flat, fertile land which is among the most agriculturally productive areas of the world. Throughout history, Cukurova was a gateway from Europe to the Middle East and, being the shortest access point to the Mediterranean from the northern Middle East and Central Asia, it is a transportation hub, with its two major seaports and oil terminal.

Cukurova Plain covers 27% of the lands of Adana. Cukurova plain on the territories of Adana city, is divided into smaller plains. Ceyhan Plain, being the largest plain, is spread over 205,000 hectares of land.

The city located in the two banks of the Seyhan River is between the 35°-38° north latitude and 34°-36° east longitude. The province of Adana has an area of 14,125 km², making it the 14^{th} largest city of Turkey. Meanwhile the city of Adana has 2700 km² or area, 5390 km² of lands is reserved for agricultural purposes which are approximately 38% of the total area, highlighting the crucial importance of the economical support of agriculture to the city.

Adana lies 23 meters (75 ft) above sea level and surrounded by mountains that are up to 3500 meters. River Seyhan (560 km long) and River Ceyhan (509 km long) run through the city.

Figure 2.7 – Scale Comparison between Adana and Milano

Considering the large elevation difference between the city and the surrounding mountains the city is suitable for dam constructions. Within the city there are four dams that are built for producing electricity, avoiding flood of Seyhan & Ceyhan Rivers and irrigation purposes.

The north of Adana is surrounded by the Seyhan reservoir, which was built in 1957. The lake is used to produce electricity, and to provide the irrigation water to the lower part of Cukurova plain, agricultural production area located in the south part of the city. Two irrigation canals in the city flow to the plain passing through the city center from east to west. Also there is another canal for irrigating the Yuregir plain to the southeast of the city.

Figure 2.8 – Seyhan Reservoir

2.1.4 Climate of Adana

Adana has a typical Mediterranean climate. Winters are mild and wet and summers are hot and dry. The highest recorded temperature was on 8 July 1978 with 44.0 °C. The lowest recorded temperature was –6.4 °C.

Extreme Maximum, Minimum and Average Temperatures Measured in Long Period (°C)

ADANA	January	February	March	April	May	June	July	August	September	October	November	December
Maximum Temp.	26.5	25.0	32.0	37.5	40.6	41.3	44.0	43.8	43.2	39.4	33.3	30.8
Minimum Temp.	-4.2	-6.4	-3.6	-1.3	5.6	13.7	16.8	16.8	10.9	4.8	-1.0	-3.5
Average Temp.	9.6	10.5	13.6	17.6	21.8	25.7	28.2	28.5	26.1	21.6	15.3	10.9

Measured in Long Period

Max. Precipitation	19.01.1977	**125.5** kg/m^2	**Max. Wind**	13.02.2011	**126.4** km/hour	**Max. Snow Height**	21.01.1972	**1.0** cm

Figure 2.9 – Extreme Climate Facts of Adana

Adana receives on average 612 mm of precipitation annually or 51 mm each month. On balance there are 56 days annually on which greater than 0.1 mm of precipitation or 4.7 days on an average month. The month with the driest weather is July when on balance 4 mm (0.2 in) of rain, sleet, hail or snow falls across 0 days. The month with the wettest weather is January when on balance 111 mm of precipitation across 9 days. Mean relative humidity for an average year is recorded as 57.3% and on a monthly basis it ranges from 49% in October to 61% in June.

There is an average range of hours of sunshine in Adana of between 4.8 hours per day in December and 12.0 hours per day in July. On balance there are 3076 sunshine hours annually and approximately 8.4 sunlight hours for each day

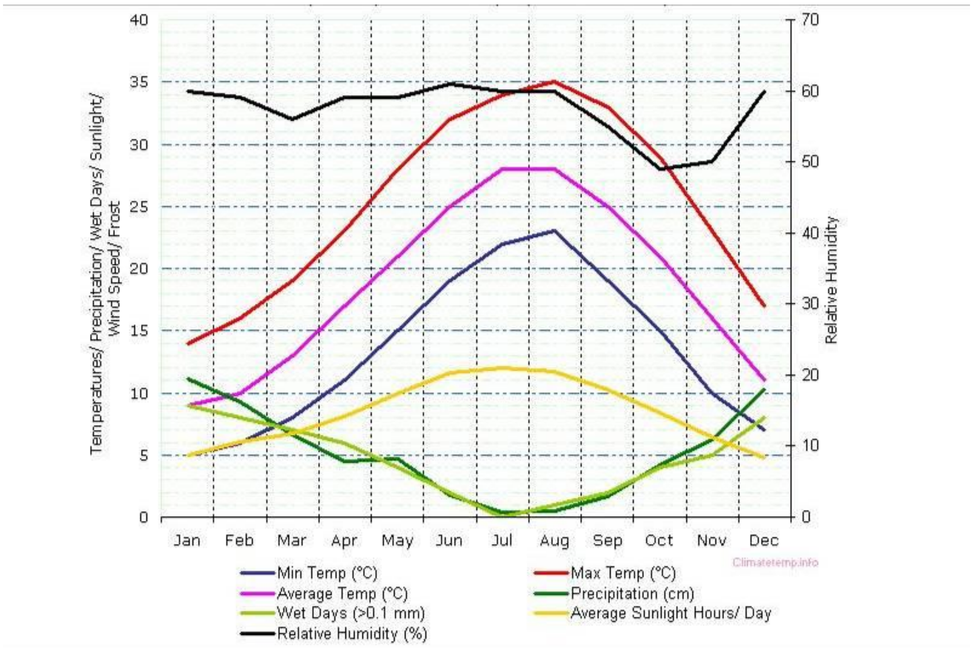


Figure 2.10 – Climate Graph of Adana

2.1.5 Demographics of Adana

Adana has a population of 2.108.805 people making it the fifth most populous city in Turkey. The density of population is 152 people/km² within the borders of the province which is almost twice as much as the density of population of Turkey (98 people/ km²). 1.617.284 people live in the metropolitan area which has a total area of 2700 km², making the population density 598 people/km².

Like the rest of Turkey, Adana has a very young population. 67% of the population is between the ages 0-29. In Adana, the number of male and female citizens is almost the same.

The growth rate of population in Adana is parallel with the growth rate of population of Turkey as seen in Table 2.1. Although the population growth continues with a descending rate, the estimated population of Adana for 2015 is 2,388,682, for 2020 is 2,560,036 and for 2025 is 2,718,056.

YEAR	TURKEY	ADANA
1960	2,853	3,421
1965	2,463	2,742
1970	2,519	3,615
1975	2,501	3,608
1980	2,065	2,997
1985	2,488	2,286
1990-2000	1,834	1,771
2010	1,350	1,124

Table 2.1 – Annual growth rate of population (%)

Although the statistics show that the population is steadily increasing in Adana, the decrease in the growth rate is related to the migration. As seen in Table 2.2, Adana has a positive migration rate until mid-90s. Starting from 1995, the number of people moving to Adana has been less than the number of people moving from Adana. Analyses showed that people who move to Adana are coming from neighboring cities and the eastern cities where the employment opportunities are scarce. The people who are moving from Adana tend to move to bigger cities such as İstanbul, Ankara and İzmir.

MIGRATION RATE OF ADANA				
PERIODS	MIGRATION TO ADANA	MIGRATION FROM ADANA	NET MIGRATION	NET MIGRATION RATE (%)
1975 – 1980	74.119	73.300	819	0,70
1980 – 1985	99.672	75.843	23.829	16,40
1985 – 1990	124.479	97.545	26.934	15,80
1995 – 2000	92.684	133.181	-40.497	-23,9
2011	53.096	57.402	- 4.306	- 2.06

Table 2.2 – Net migration rate (%)

2.1.6 Socio-Economic Aspects of Adana

Adana is one of the first industrialized cities, as well as one of the economically developed cities of Turkey. A mid-size trading city until mid 1800's, the city has seen attraction from European traders after the major cotton supplier, USA, turmoil with Civil War. Cukurova farmers exported agricultural products for the first time and thus started building capital. By the turn of the century, factories almost all processing cotton, began to operate in the region.

Beside cotton, which is the utmost important product of the region, wheat, corn, soy bean, barley, grapes and citrus fruits are produced in great quantities. Farmers of Adana produce half of the corn and soy bean in Turkey. 34% of Turkey's peanut and 29% of Turkey's orange is harvested in Adana.

Until 1970s, 49% of the population was living in the rural parts of Adana, showing the importance of the agriculture and livestock in the city economy. Starting from the early 60s, rapid growth of industrialization caused people to leave their villages and move to the city. Results of the census made on 2008 showed that 87% of the population of Adana lives in the city whilst the average of Turkey is 75%.

Year	**Nr. Of People Working in the Industry Field**
1964	15832
1974	34285
1988	41669
2007	86121

Table 2.3 – Nr. Of People Working in the Industry Field by Years

With the construction of Seyhan Dam and improvements in agricultural techniques, there was an explosive growth in agricultural production during 1950s. Large-scale industries were built along D-400 state road and Karatas road. Service industry, especially banking, also developed during this period.

Rapid growth of the economy continued until mid 1980's, then extensive neo-liberal policies to centralize the country's economy caused almost all Adana-based companies to move their headquarters to Istanbul. The decline in cotton planting in the region, raised the raw material cost for the manufacturing, thus city has seen a wave of plant closures starting from mid 1990s.

Identity crisis of the young professionals fleeing the city at the times of heightened illusions, further contributed to make Adana the top city of Turkey in brain drain. In 2010, unemployment in the city reached a record high of %19.1. After 20 years of stagnation, the economy of Adana is picking up recently with investments in the tourism and service industry, wholesale and retail sectors and the city is re-shaping as a regional center.
Adana was named among the 25 European Regions of the Future for 2006/2007 by Foreign Direct Investment magazine.

2.1.7 Development of the City

Adana, a city which is 8000 years old, has expanded its borders throughout eras. After the foundation of Turkish Republic, Adana became an important actor in an uprising newly-found country. With its suitability to agriculture and the important routes that the city is located on, the city rapidly developed.

In the first years of the Republic, foreign engineers, architects, doctors and scientists were invited to Turkey to participate to planting the seeds of a new modern country. Hermann Jansen, architect and urban designer, was invited to participate to the urban design studies of the cities such as Ankara, the capital of Turkey, İzmit, Adana, Mersin and Gaziantep.
Hermann Jansen started planning the development of Adana as of 1932. He proposed 3 different master plans between 1935 and 1937 considering only, the west part of River Seyhan, Seyhan district of Adana. He defined the public spaces, town hall, railway station and every other important space that would make up the new Adana with his sketches.

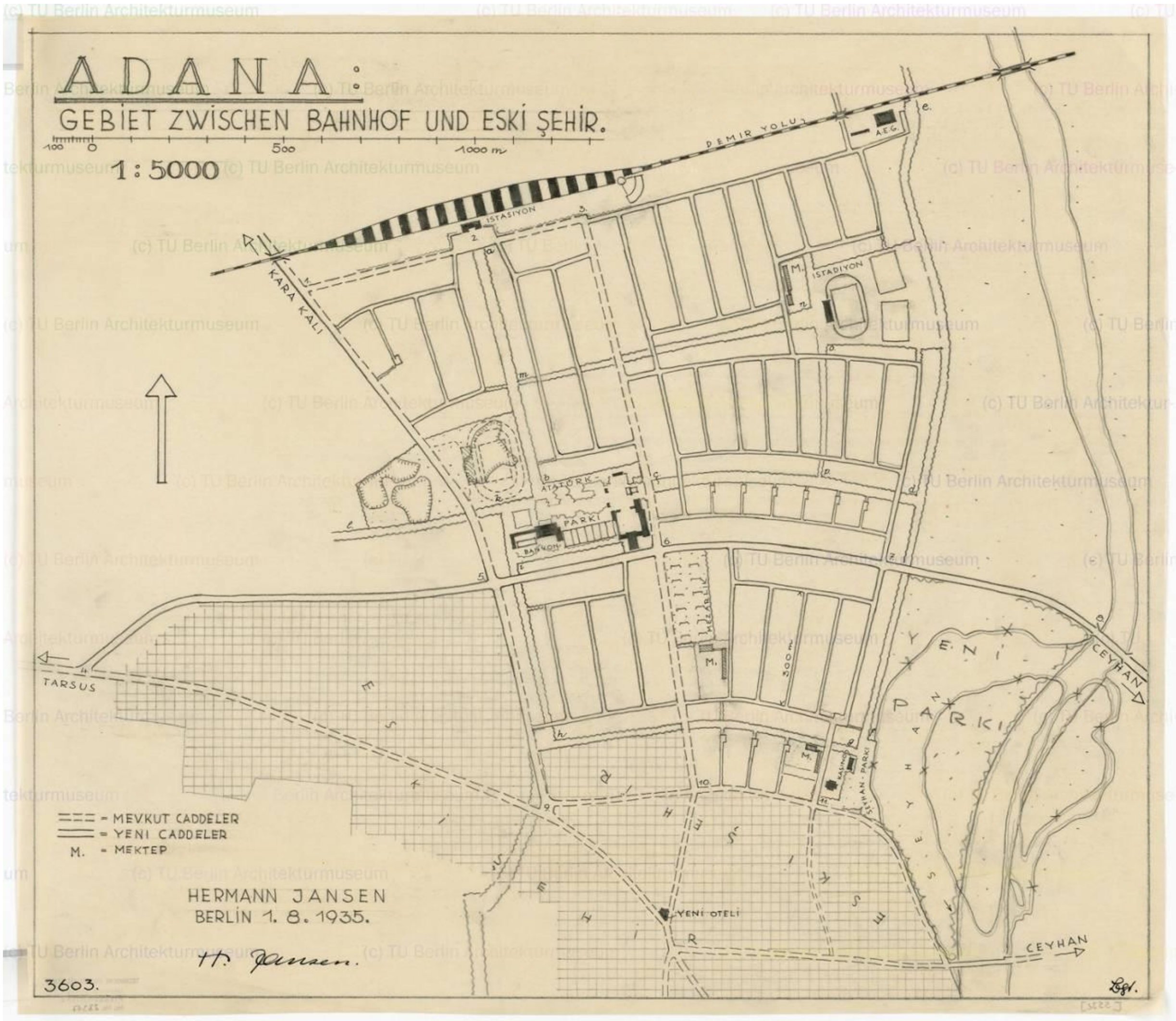


Figure 2.11 – Planning Of The Area Between Train Station And The Old City, Adana
By Hermann Jansen, 1935

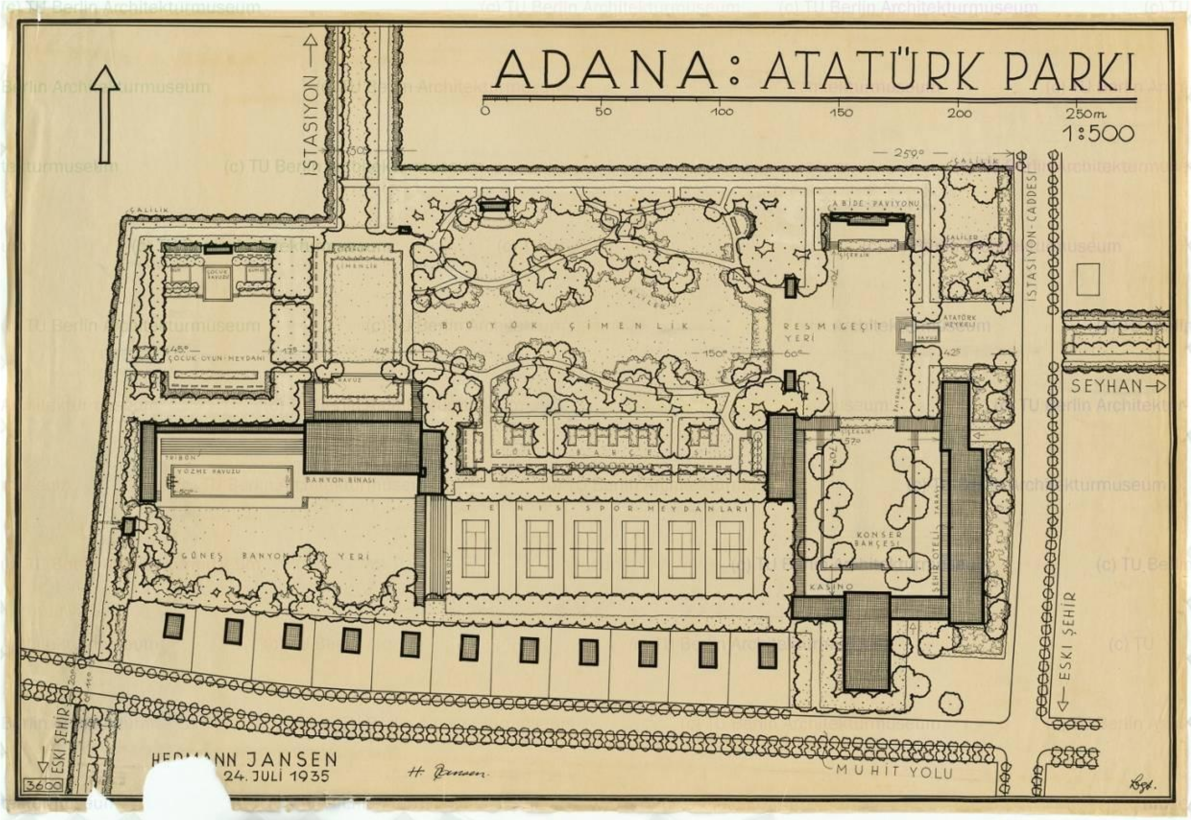


Figure 2.12 – Plan of Ataturk Park, Adana by Hermann Jansen, 1935

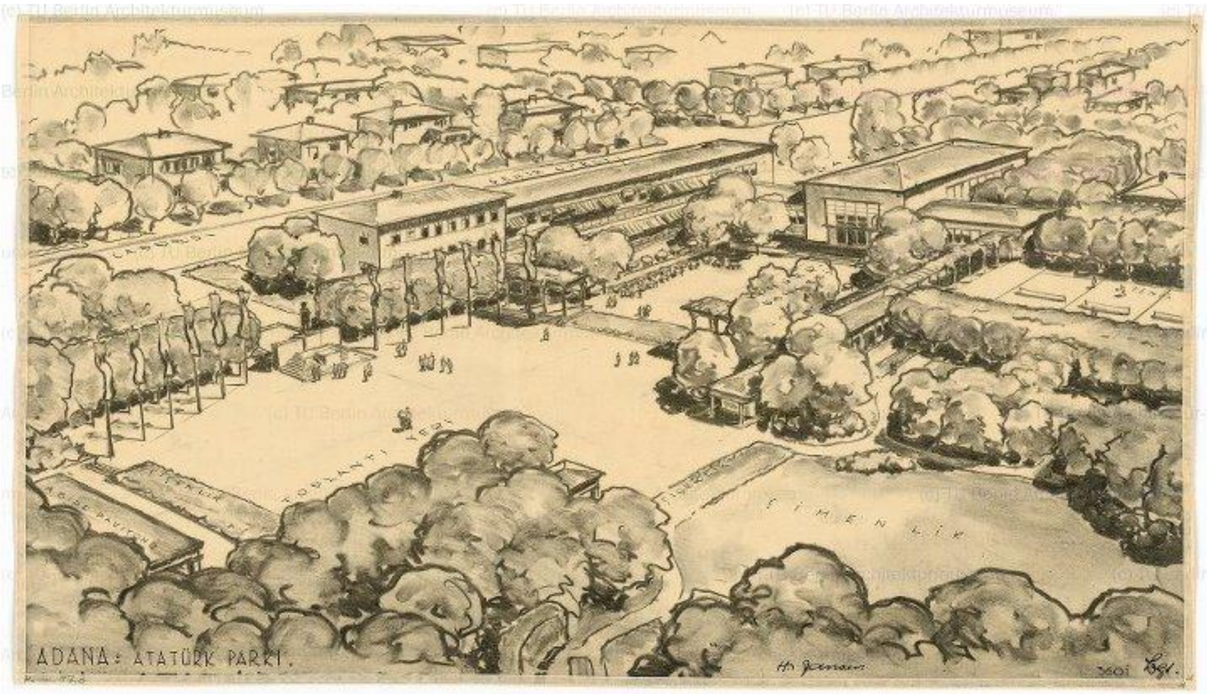


Figure 2.13 – Perspective of Ataturk Park, Adana by Hermann Jansen, 1935

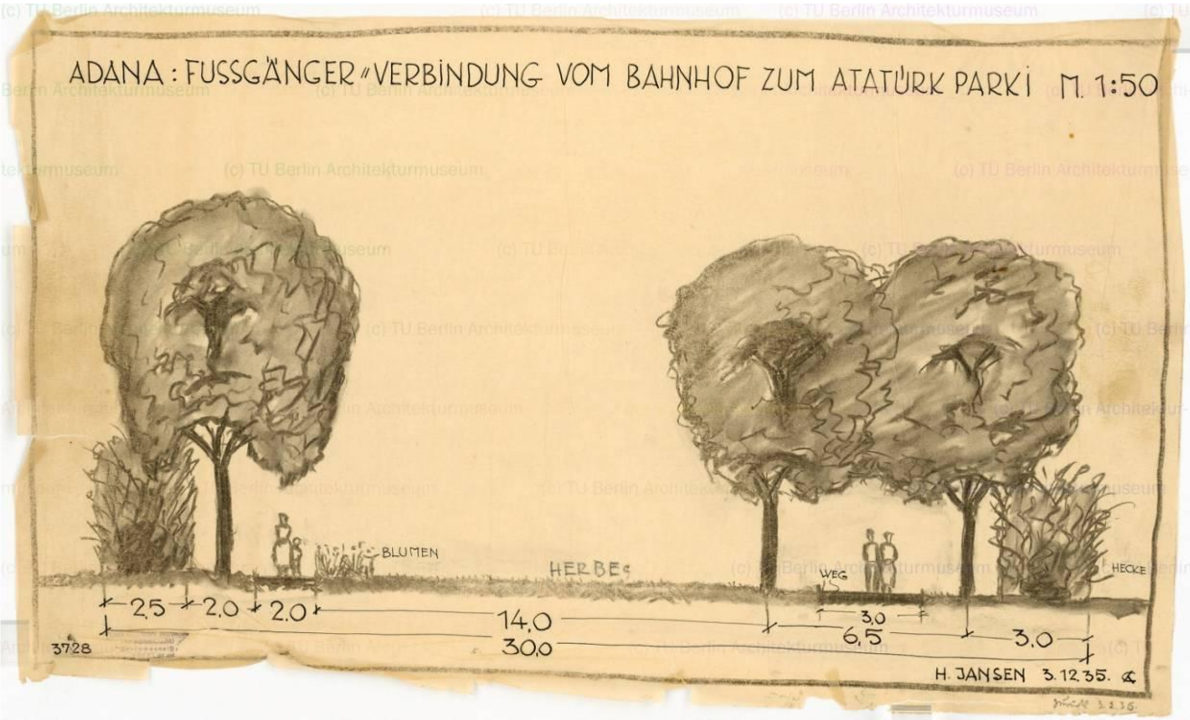


Figure 2.14 – Section from Ataturk Park, Adana by Hermann Jansen, 1935

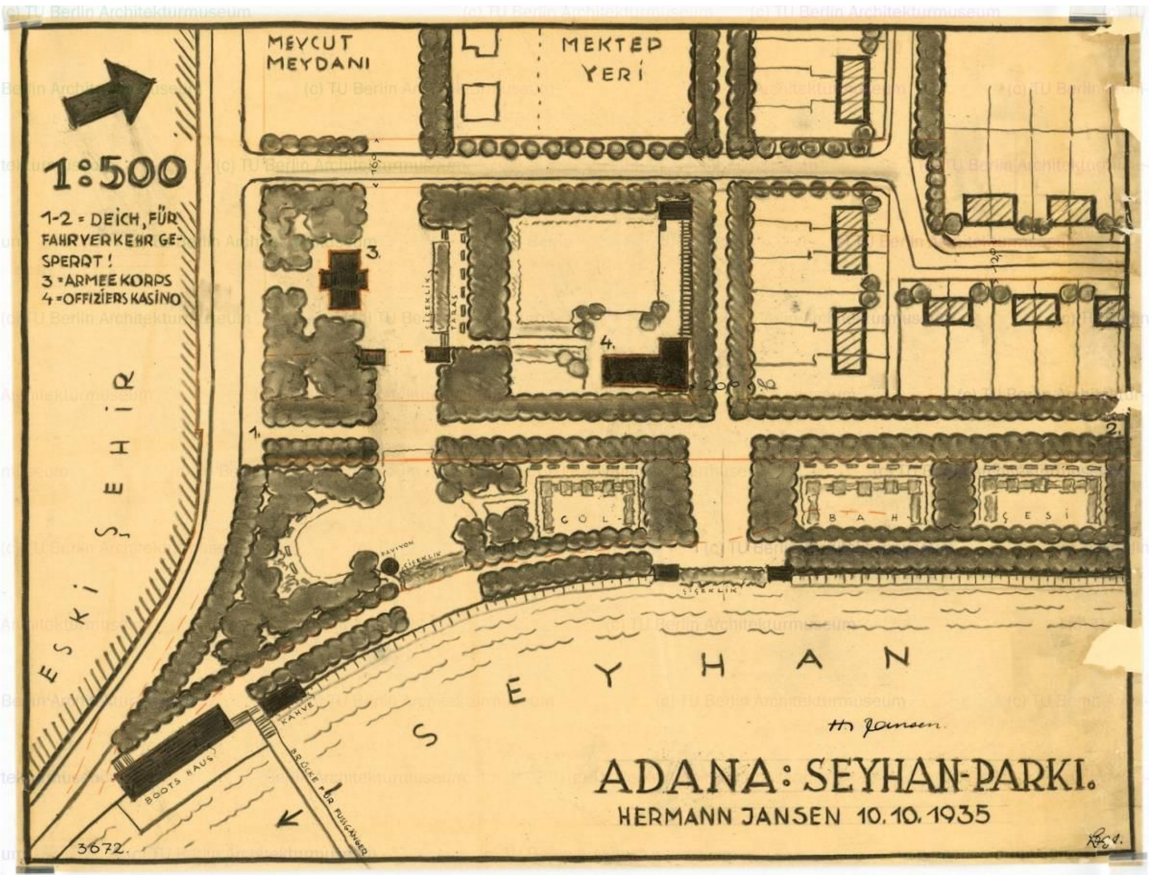


Figure 2.15 – Plan of Seyhan Park, Adana by Hermann Jansen, 1935

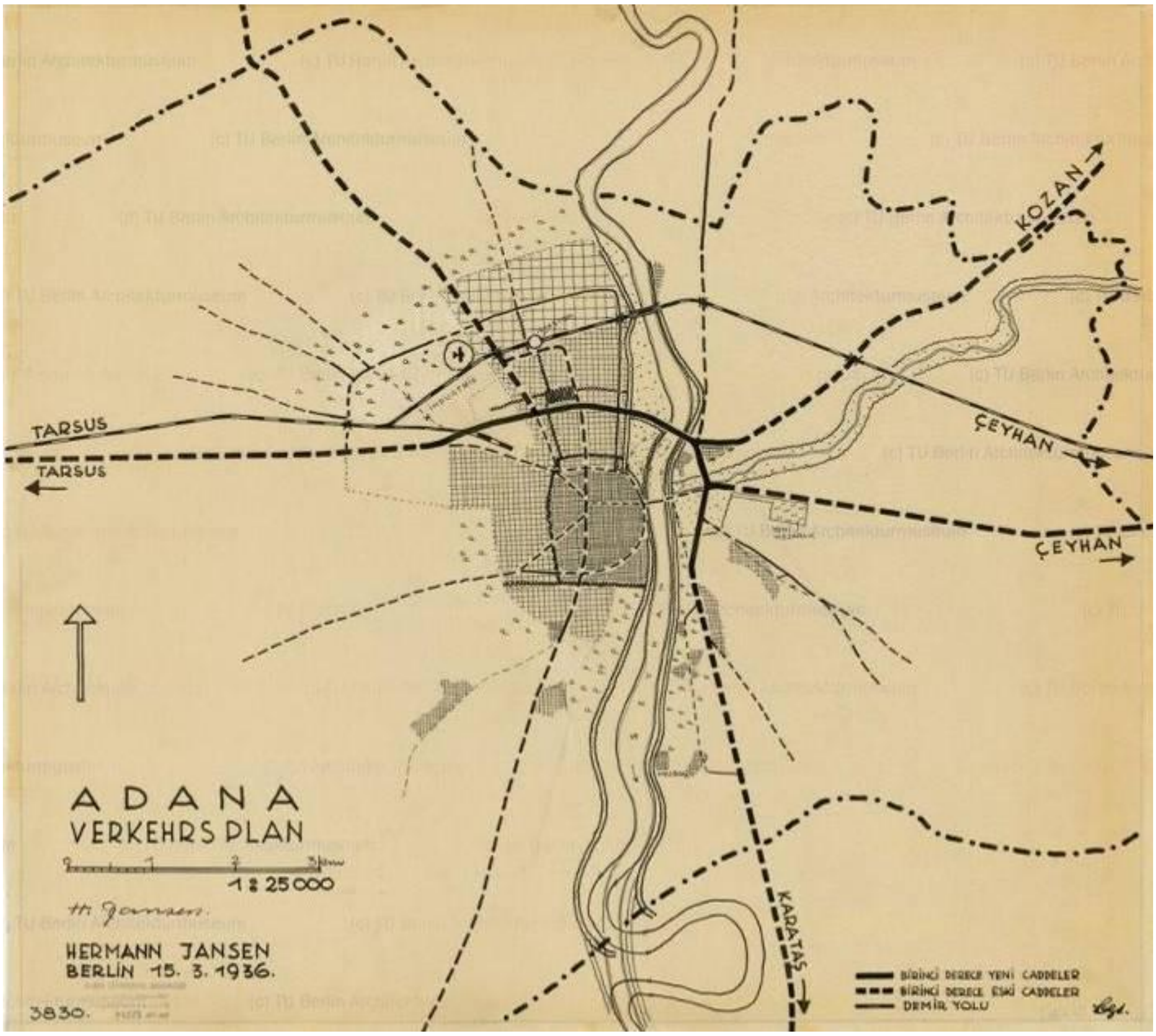


Figure 2.16 – First Master Plan of Adana by Hermann Jansen, 1936

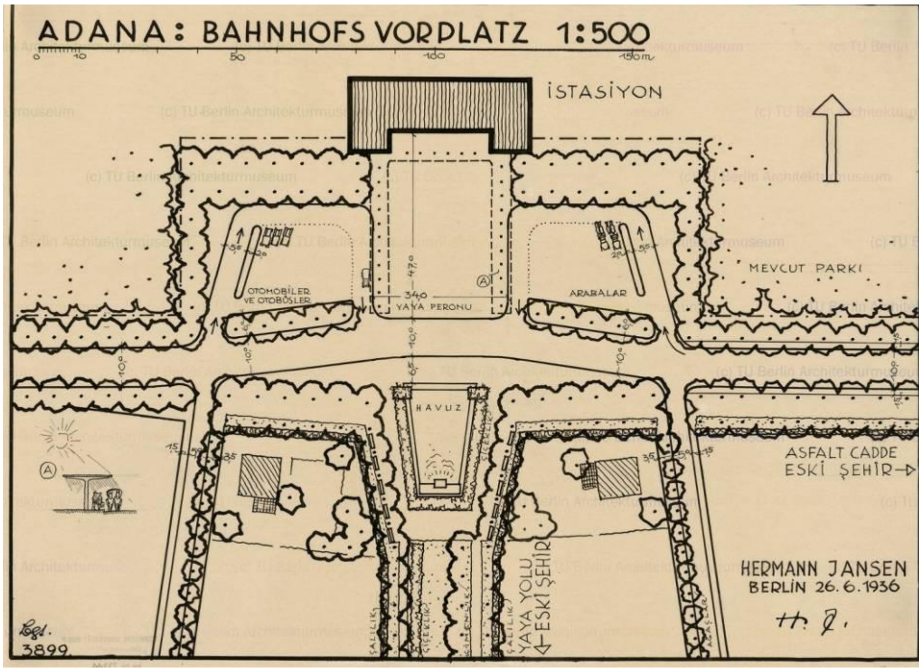


Figure 2.17 – Plan of the Railway Station, Adana by Hermann Jansen, 1936

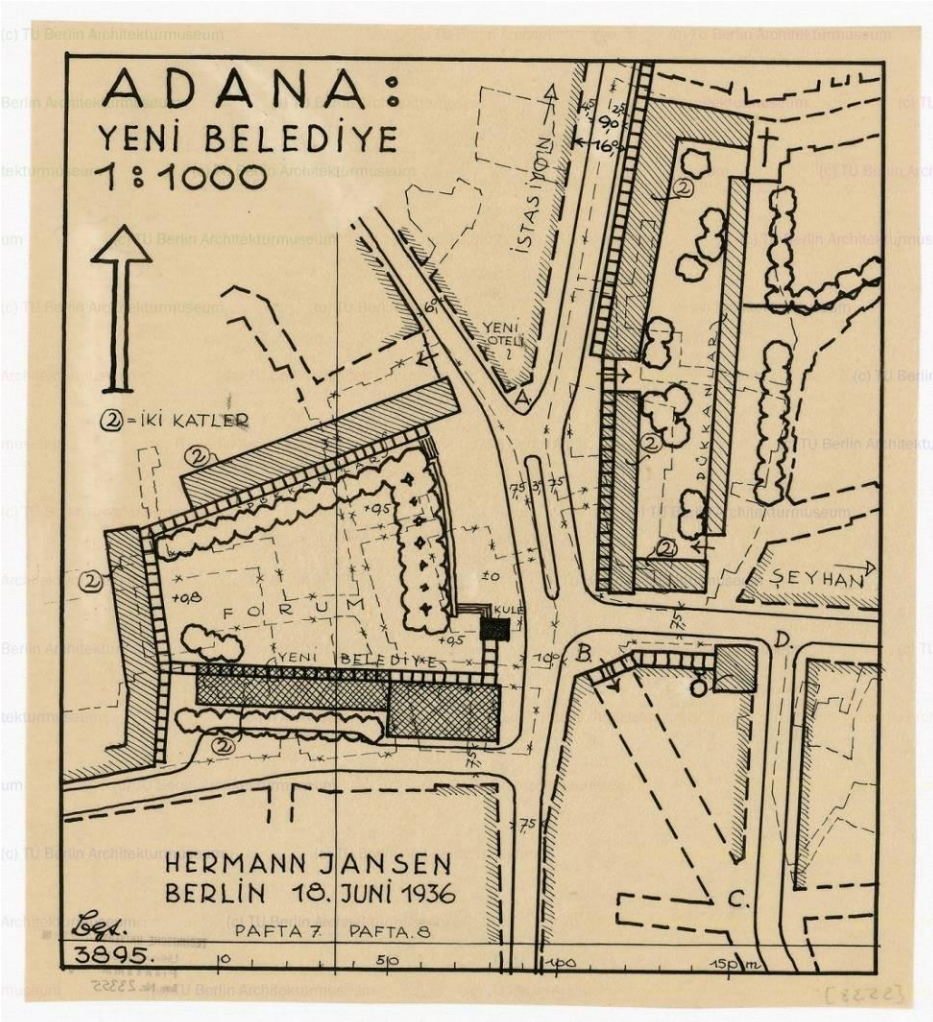


Figure 2.18 – Plan of the New Town Hall, Adana by Hermann Jansen, 1936

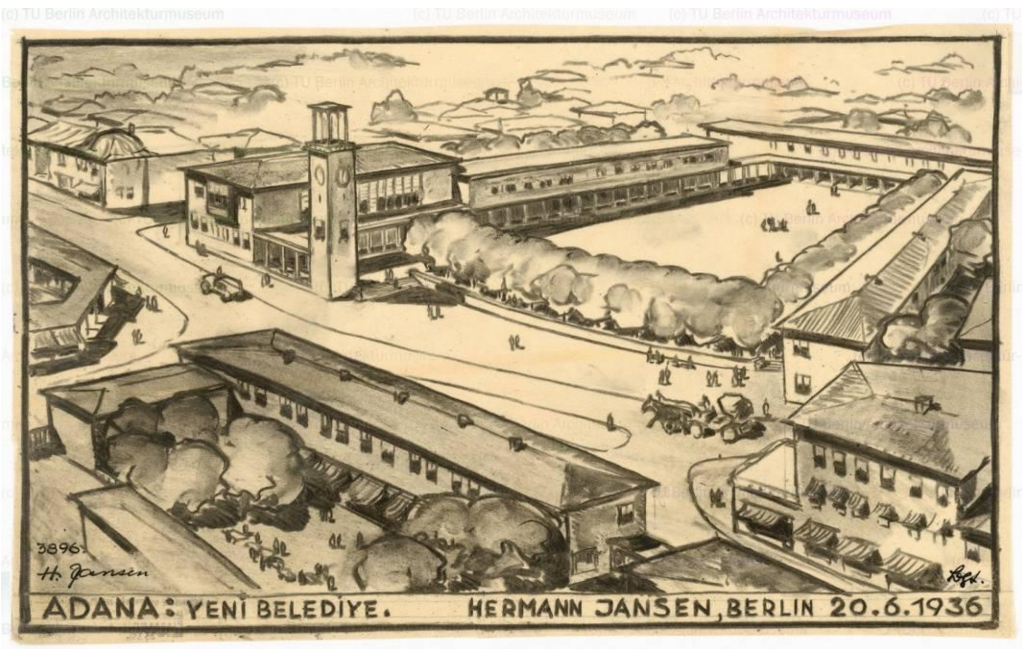


Figure 2.19 – Perspective from the New Town Hall, Adana by Hermann Jansen, 1936

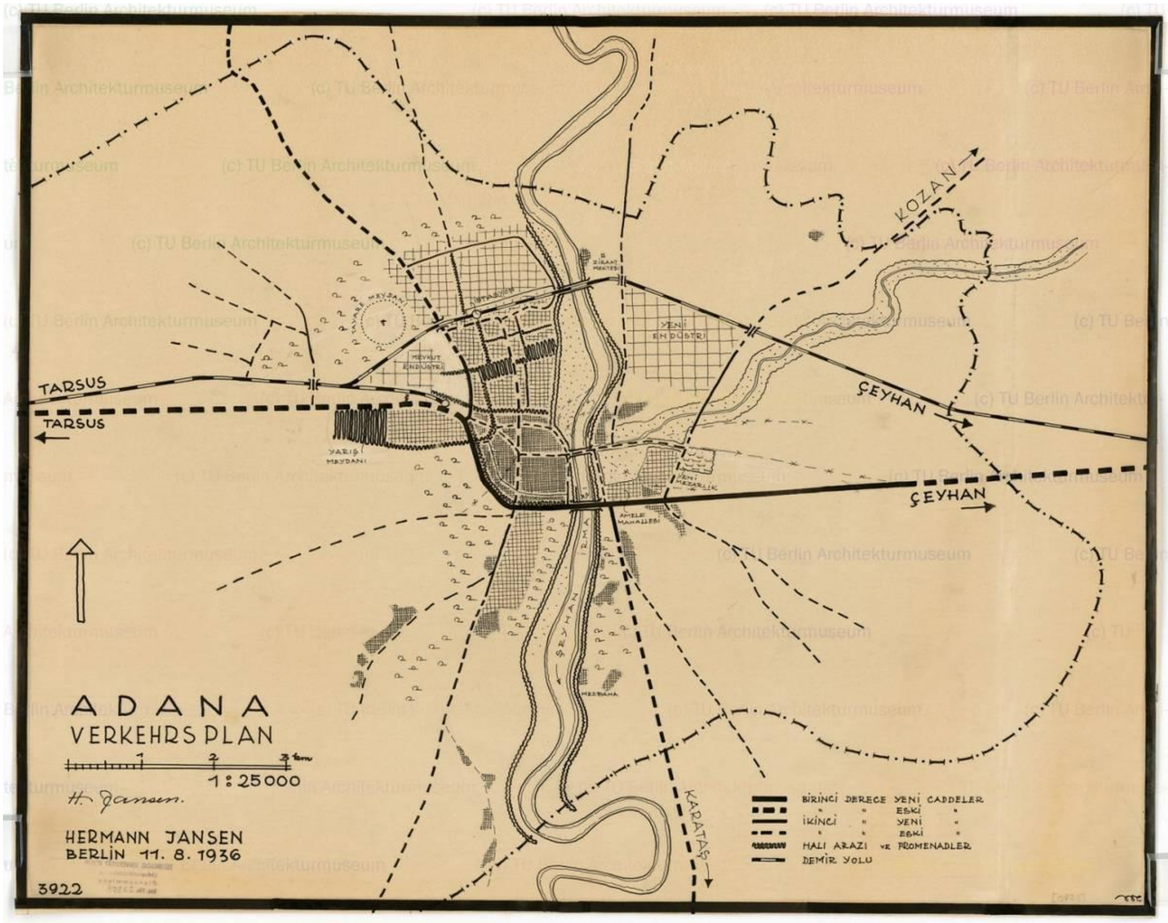


Figure 2.20 – Second Master Plan of Adana by Hermann Jansen, 1936

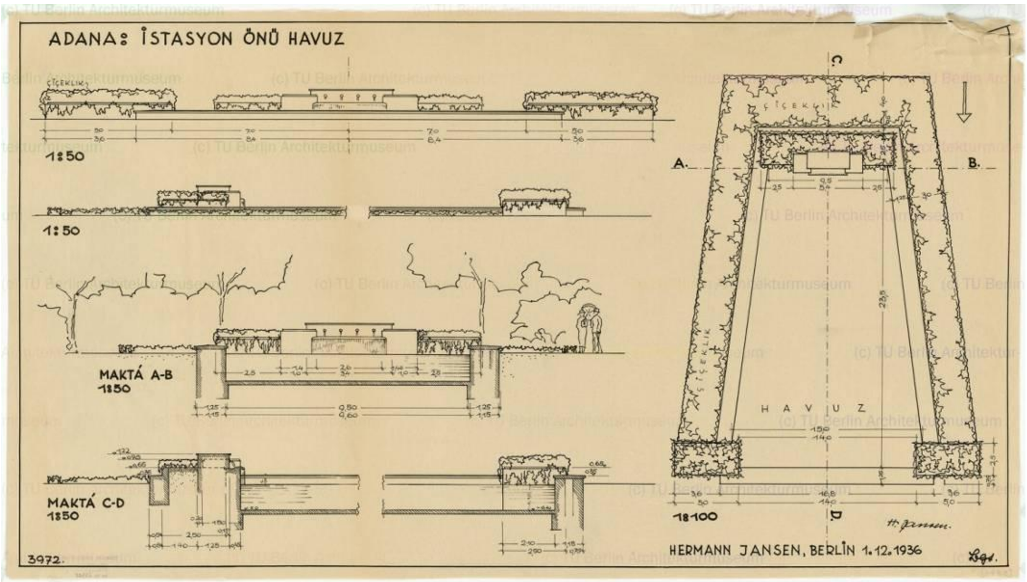


Figure 2.21 – Drawings of the Pool in front of the Railway Station, Adana
by Hermann Jansen, 1936

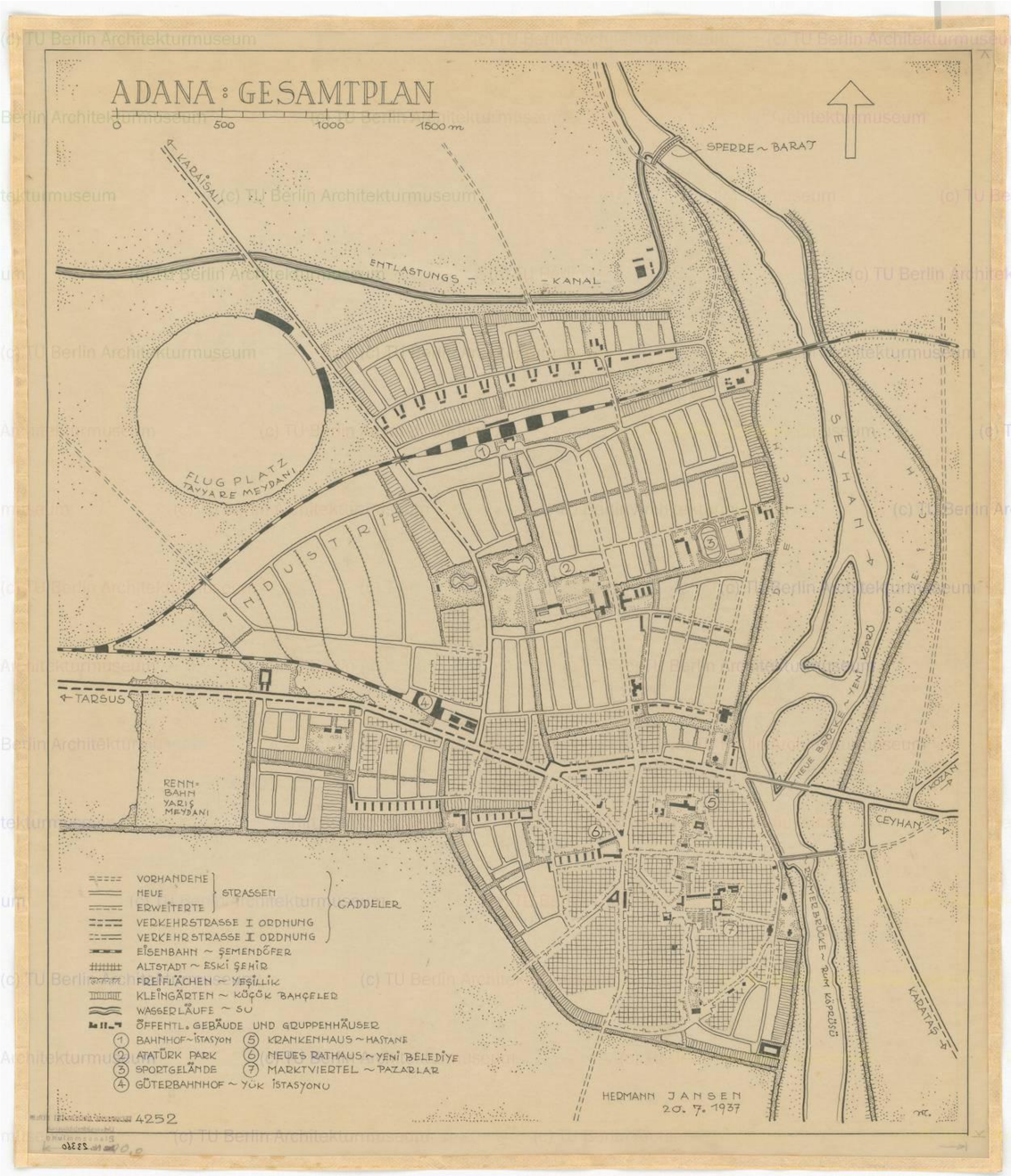


Figure 2.22 – Third Master Plan of Adana by Hermann Jansen, 1937

Figure 2.23 – Comparison between the Axis of the Previous Master Plan (on the right) and the New Master Plan (on the left) of Adana by Hermann Jansen, 1937

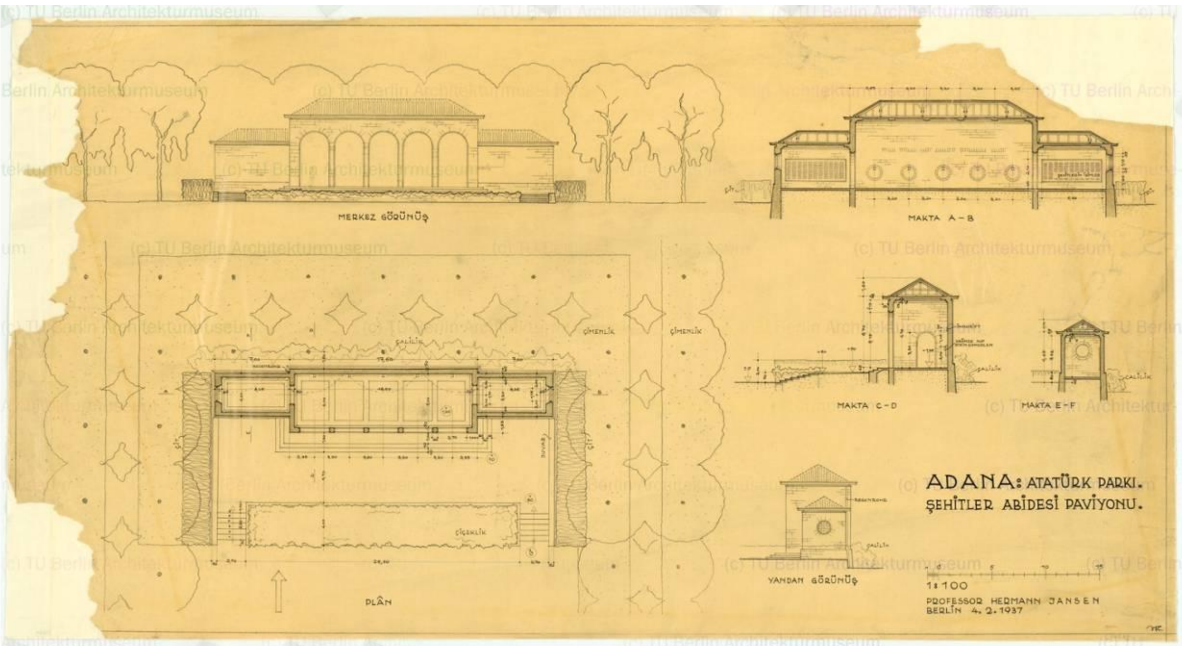


Figure 2.24 – Sketches of the Pavilion located in Ataturk Park, Adana by Hermann Jansen, 1937

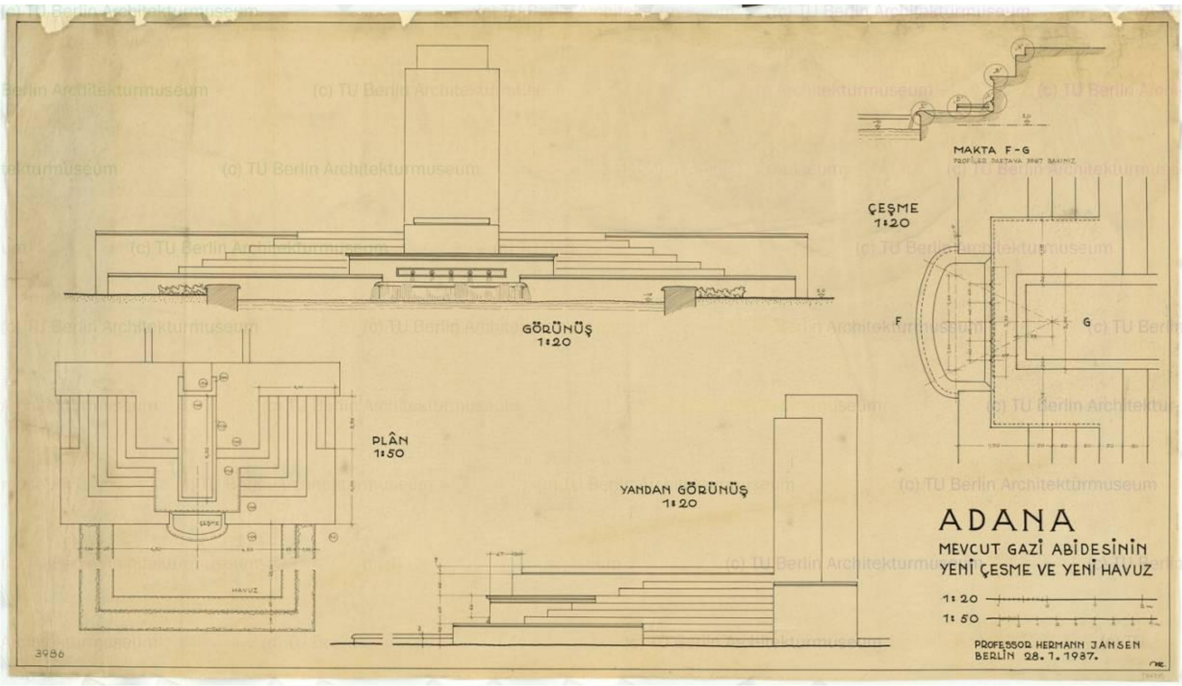


Figure 2.25 – Sketches of a fountain, Adana by Hermann Jansen, 1937

Figure 2.26 – Final Master Plan of Adana by Hermann Jansen, 1940

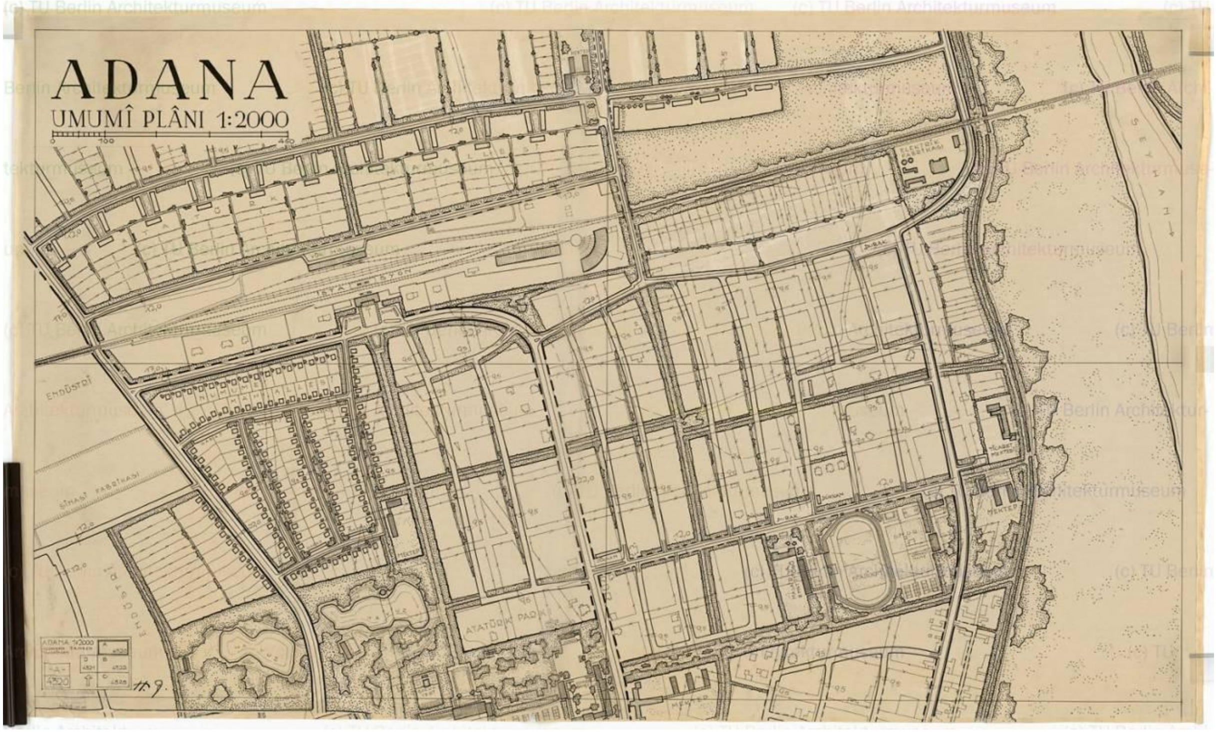


Figure 2.27 – Final Master Plan, Northwest of Adana by Hermann Jansen, 1940

Figure 2.28 – Final Master Plan, West of Adana by Hermann Jansen, 1940

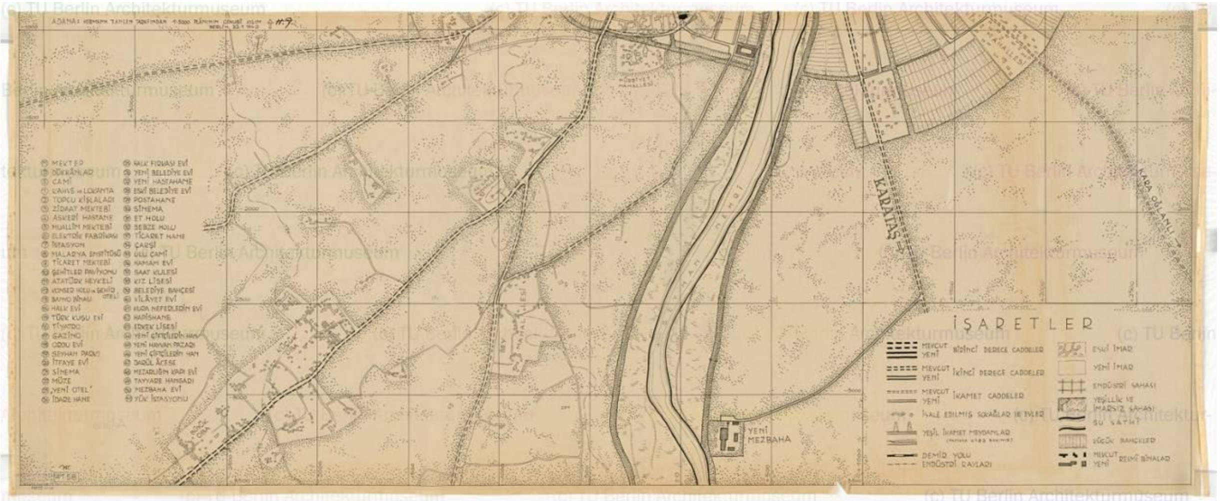


Figure 2.29 – Final Master Plan, South of Adana by Hermann Jansen, 1940

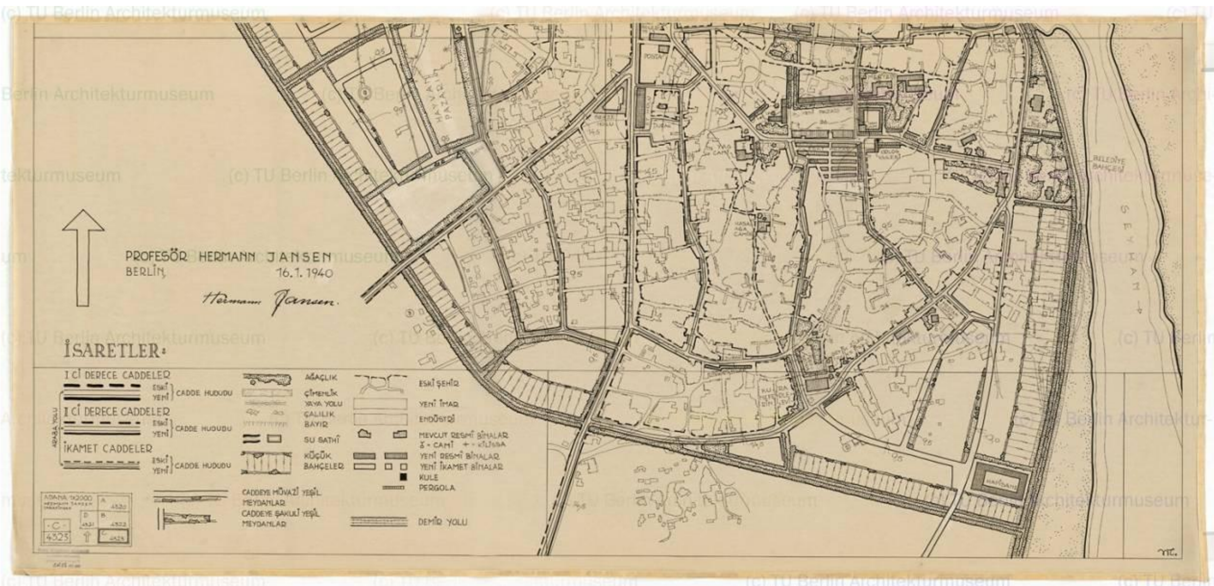


Figure 2.30 – Final Master Plan, Southwest of Adana by Hermann Jansen, 1940

Jansen prepared the final master plan including Yüregir district resulting of a city settlement on the both sides of River Seyhan in 1940. Jansen preserved the old city and proposed to develop the city to every direction except south, as southern part of the city was a rich agricultural land. In his master plan Jansen, proposes the Seyhan district, west side of the river banks, to be developed as a commercial and cultural area, meanwhile preserving the historical tissue of the city. He proposed new boulevards on the north-south direction whilst preserving the existing structures and preventing any future traffic may occur from the new railway station. He designed the housing projects as they would benefit from the wind and sun in maximum ways.

Figure 2.31 – Zoning of Adana by Hermann Jansen, 1940

In the early 40s Adana had been through a rapid modification according to the master plan of Jansen, and preserved as he foresaw until 1980s. In the early 80s, the duty of city planning was given to municipalities from the central administrative board. Thus, it became harder to keep the essentials of Jansen's project with rapidly increasing population in the city center because of the socioeconomic reasons explained in the previous sections.

Today, Adana has become a city with a population over 2,000,000, and a population density in the urban part of the city nearly 600 people/km². After the construction of the Seyhan reservoir in 1957, the city expanded to south and west directions.

Figure 2.32 – Adana City Center

Since 2008, Adana has 5 metropolitan districts; Seyhan, Yüregir, Cukurova, Sarıcam and Karaisalı. Seyhan and Yüregir districts are fully within the metropolitan city limits whereas, Cukurova, Sarıcam and Karaisalı districts have rural areas outside the metropolitan city. The city center is within the borders of three metropolitan districts: Seyhan, Çukurova and Yüreğir.

District	# of Neighborhoods	Urban Population	# of Villages	Rural Population	Total Population
Cukurova	16	267.453	11	3.891	271.344
Seyhan	99	752.308	-	-	752.308
Sarıcam	28	86.727	34	20.655	107.382
Yuregir	99	411.299	-	-	411.299
Karaisalı	11	7.328	17	4166	11.594
TOTAL	**315**	**1.525.115**	**62**	**28.762**	**1.553.827**

Table 2.4 – Distribution of Population among the Metropolitan Districts

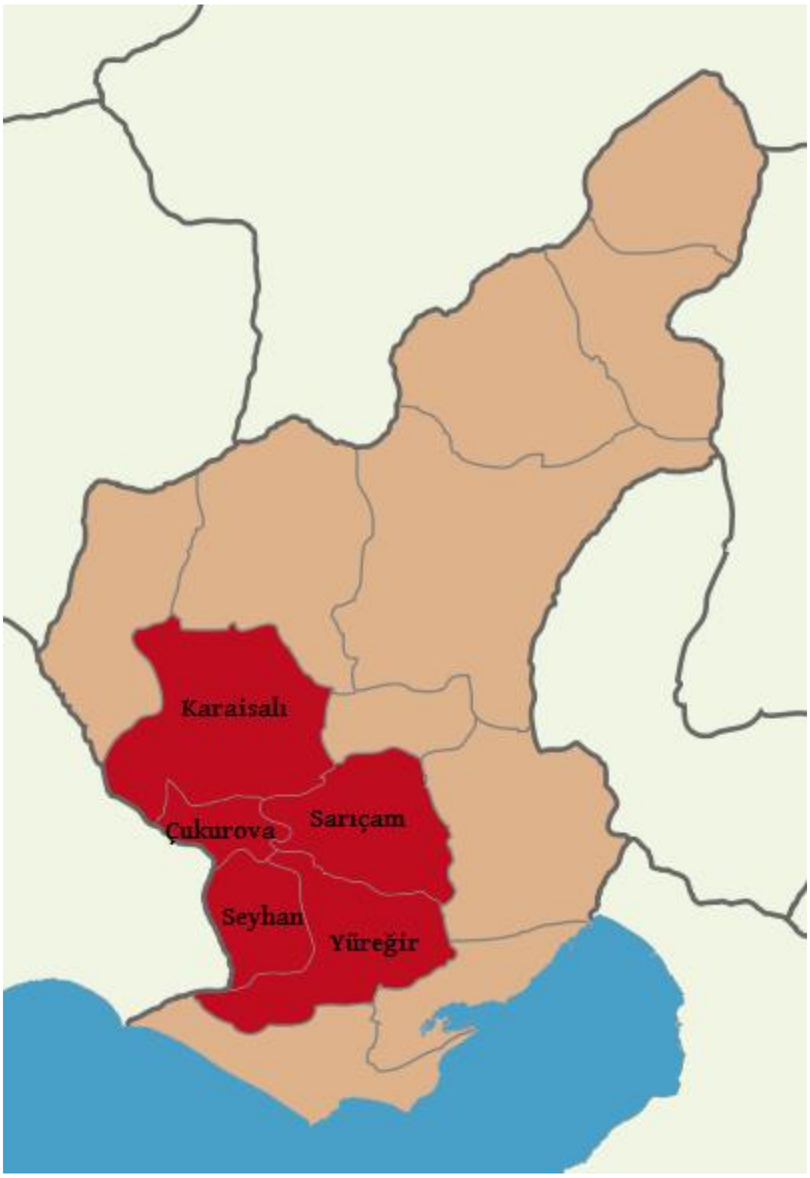


Figure 2.33 – Metropolitan Districts of Adana

From the five metropolitan districts Seyhan and Yuregir were the two districts planned by Jansen. Today they are the most populous districts of Adana. Seyhan's north of D-400, is economically the most developed part of the city. Along D-400, hotels, cultural centers, commercial and public buildings line up. Old town, located south of D-400, is the market place where traditional and modern shops serve the residents. South of the old town is a low-income residential area. Yuregir district, located east of the river, consists mainly of low-income residential areas and large scale industries. With the construction of new bridges on the river and the extension of metro line to the district, Yuregir became increasingly important. An extensive urban redevelopment plan is under effect in the district which will convert the neighborhoods of Sinanpasa, Yavuzlar, Koprulu and Kısla into modern residential areas. District of Sarıcam lies north and east of Yuregir, consisting of former municipalities that are amalgamated to the City of Adana in 2008. Some of the large institutions of the city are in Sarıcam: Cukurova University, Incirlik Air Base and the Organized Industrial Region.

Karaisalı is a small district outside the urban area, lying north of the Seyhan Reservoir. The district is largely rural, includes large recreational areas along the Seyhan river and cottage country at the high lands to the north.

2.1.8 Cukurova District

The reason behind the introduction of Cukurova district in this section is because the project site is located within this district. The district, taking its name from Cukurova plain, is a modern residential district that lies north of the Seyhan district and west of the Seyhan Reservoir. The district was planned in mid 1980s to direct the urban sprawl to low-fertile 3,000 hectare land north of the city. Named as New Adana, the project consisted of 200,000 homes including villas along the lake shore and high-rise apartment buildings along the newly opened wide boulevards of Turgut Özal, Süleyman Demirel and Kenan Evren.

Figure 2.34 – Panaoramic View of Cukurova District from Turgut Özal Boulevard

Cukurova has total of 16 neighborhoods, 12 of them in the urban area, 4 are outside the urban area. The neighborhoods outside the urban area are the former villages and the municipalities that annexed to the city of Adana as city borders are expanded in 2008.As the city borders expanded the municipalities and villages in the new limits of the city are annexed to the city. Neighborhoods of the former municipalities and former villages then became part of the Cukurova district as neighborhoods.

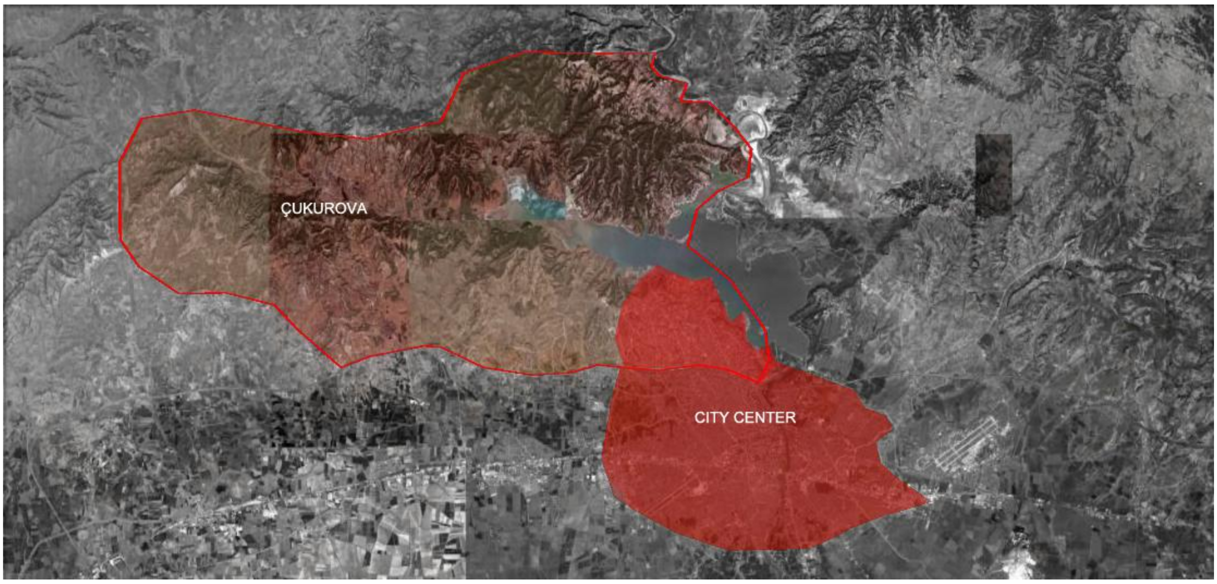


Figure 2.35 – Intersection of the City Center & Cukurova District

As seen in Figure 2.34, the urban part of Cukurova district is in the intersection between the district and the city center. Most of the remaining area is the rural part of the district.

Considering that over 265.000 people living in the intersection area and only 4000 people living in the remaining part of the district, there is a conflict in the population distribution among the district. This conflict has caused a high-density region in the intersection area as the high-rise residential blocks can be seen in Figure 2.33.

2.2 Urban Design

2.2.1 Location of the Site

The site determined by the competition brief is situated within the intersection of Cukurova District and City Centre.

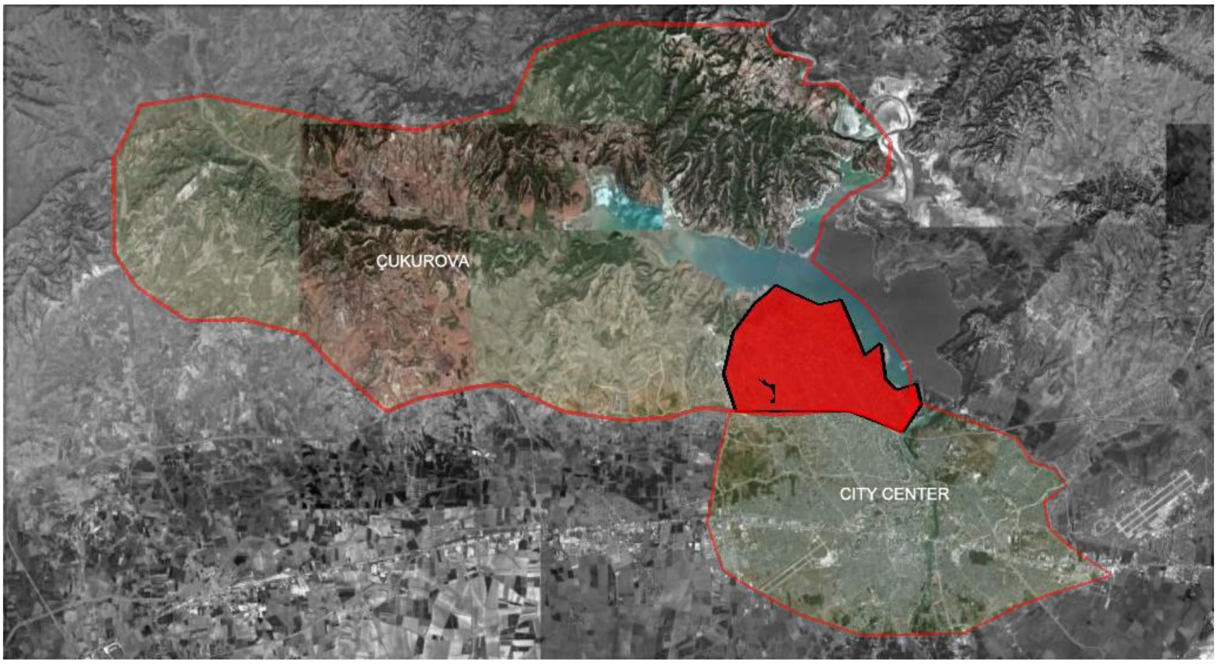


Figure 2.36 – The Intersection & The Site

The site's location has a crucial importance since its vicinity to important roads that connect the city center to the airport and the northern rural part of the city to the city center. The site, in the existing situation, is covered with various types of trees and functions as a public park. The area shaded in black in Figure 2.36 is the area assigned for the urban park which also includes the site where Cukurova Municipality Hall & Cultural Center shall be designed. The relationship between the urban park and the project site can be seen in Figure 2.37.

Figure 2.37 – The Intersection & The Site

Figure 2.38 – Urban Park (outlined in black) vs. the Project Site (shaded in red)

Figure 2.39 – Photo of the Project Site

Figure 2.40 – Existing condition of the Project Site

2.2.2 Scale Comparison

In Figure 2.40 the footprints of the project site, Comune di Milano, and Piazza Del Duomo have been shown respectively. The project site is approximately 13,000 m² and located in the urban park which has an approximate area of 85,000 m².

Figure 2.41a – Project Site (Eye alt. 880m)

Figure 2.41b – Comune di Milano (Eye alt. 880m)

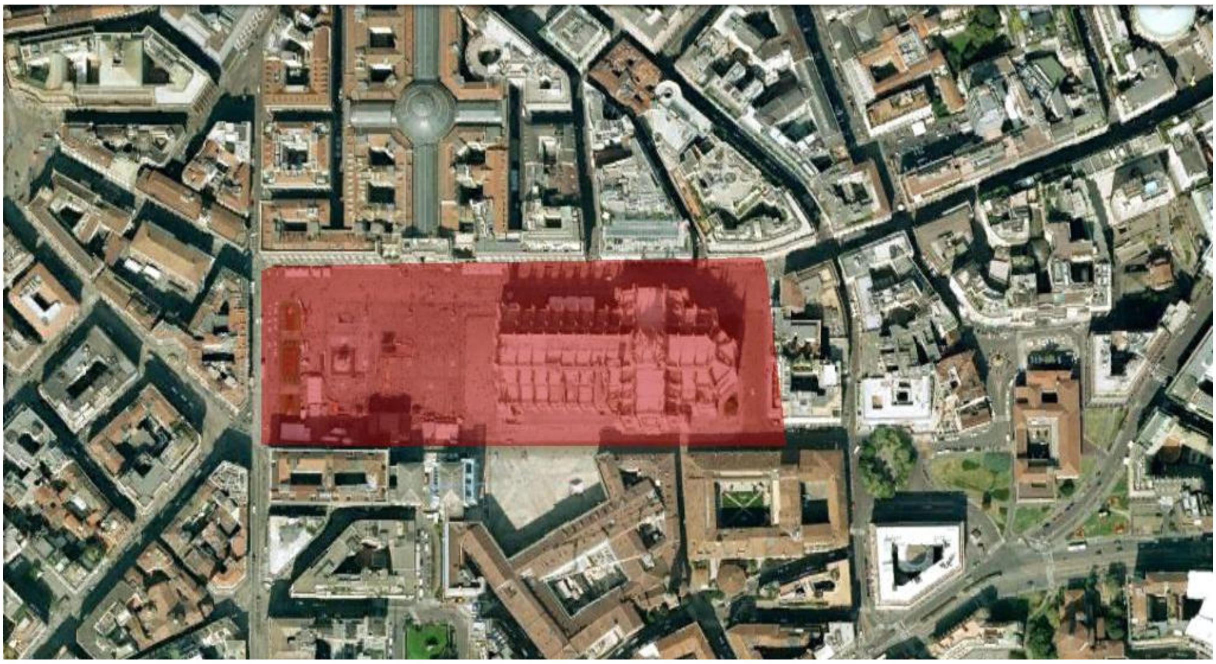


Figure 2.41c – Piazza del Duomo (Eye alt. 880m)

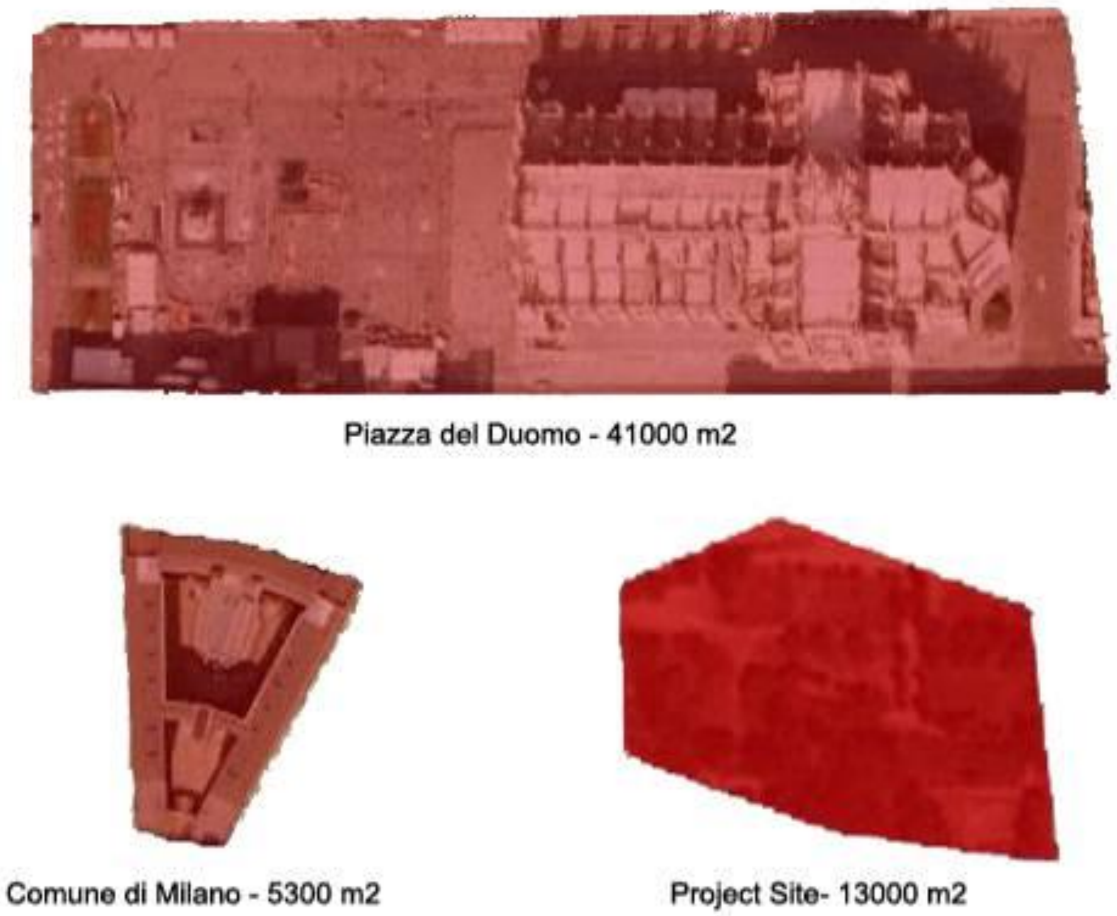
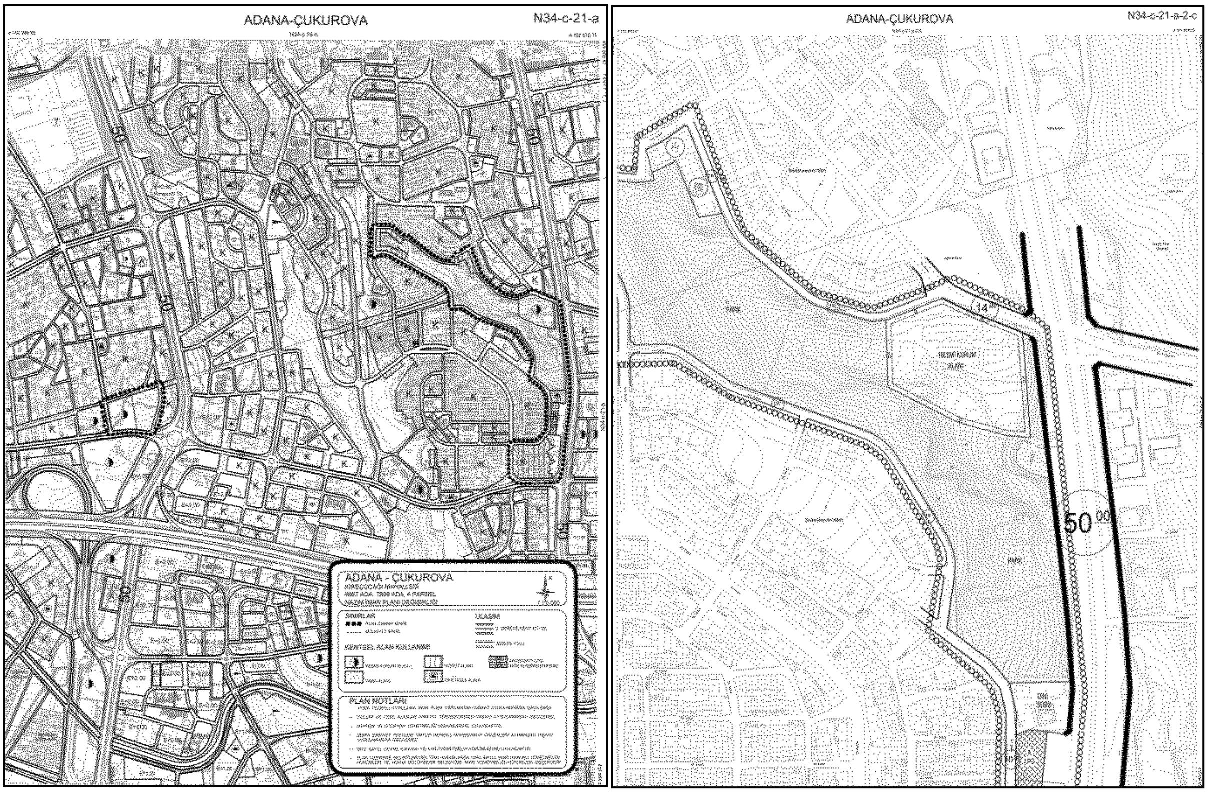


Figure 2.42 – Comparison between Piazza del Duomo, Comune di Milano and the project site

2.2.3 Determining the Area of Intervention: Two Different Urban Scales

Two different urban scales have been determined by the competition brief and the contestants have been asked to determine problems and propose solutions for each urban scale. The first scale is 1/5000 scaled map, as shown in Figure 2.42a, determining the area intervention as the urban park and most of Yuzuncu Yıl District which is the most developed district of Cukurova. The second scale is 1/1000 scaled map, as shown in Figure 2.42b, focusing the area of intervention as the urban park. In accordance with the competition brief, the urban analyses and interventions will be presented in respect to these scales determined by the competition brief.



2.2.4 Urban Mobility

2.2.4.1 Main Road Network

Figure 2.43 – Main Road Network

2.2.4.2 Bus Route

Figure 2.44 – Public Transportation Network – Bus Route

2.2.4.3 Subway Route

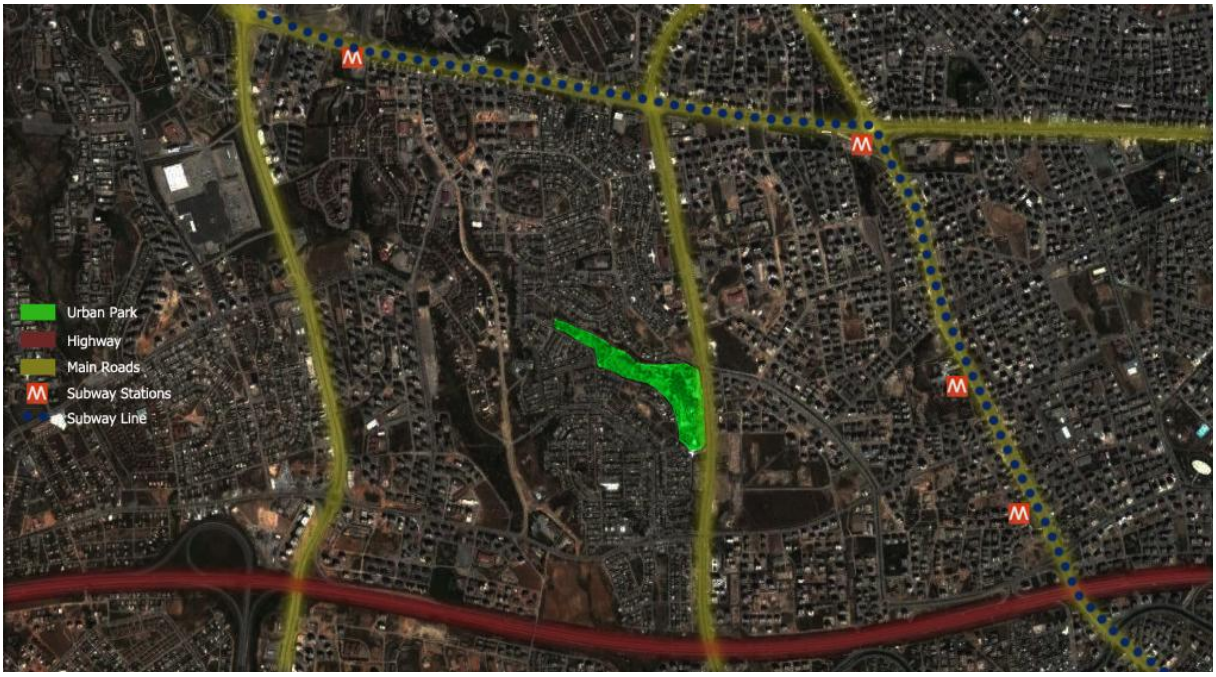


Figure 2.45 – Public Transportation Network – Subway Route

As seen with green colored areas on the maps, the urban park occupies a considerable space in the district. Although the main access to the site is with vehicular transportation, the road network is well connected and there are enough bus lines from the edges of the park. Besides the metro station is located in a walkable distance. In the close vicinity of the site pedestrian and bicycle traffic is considered to be the main transportation. This decision has been made through the urban analysis part of the study resulting the importance of neighborhood concept.

2.2.5 Land Use

Figure 2.46 – Residential Units

Figure 2.47 – Service Areas

Figure 2.48 – Market Places

Figure 2.49 – Green Areas

2.2.6 Vehicular Traffic

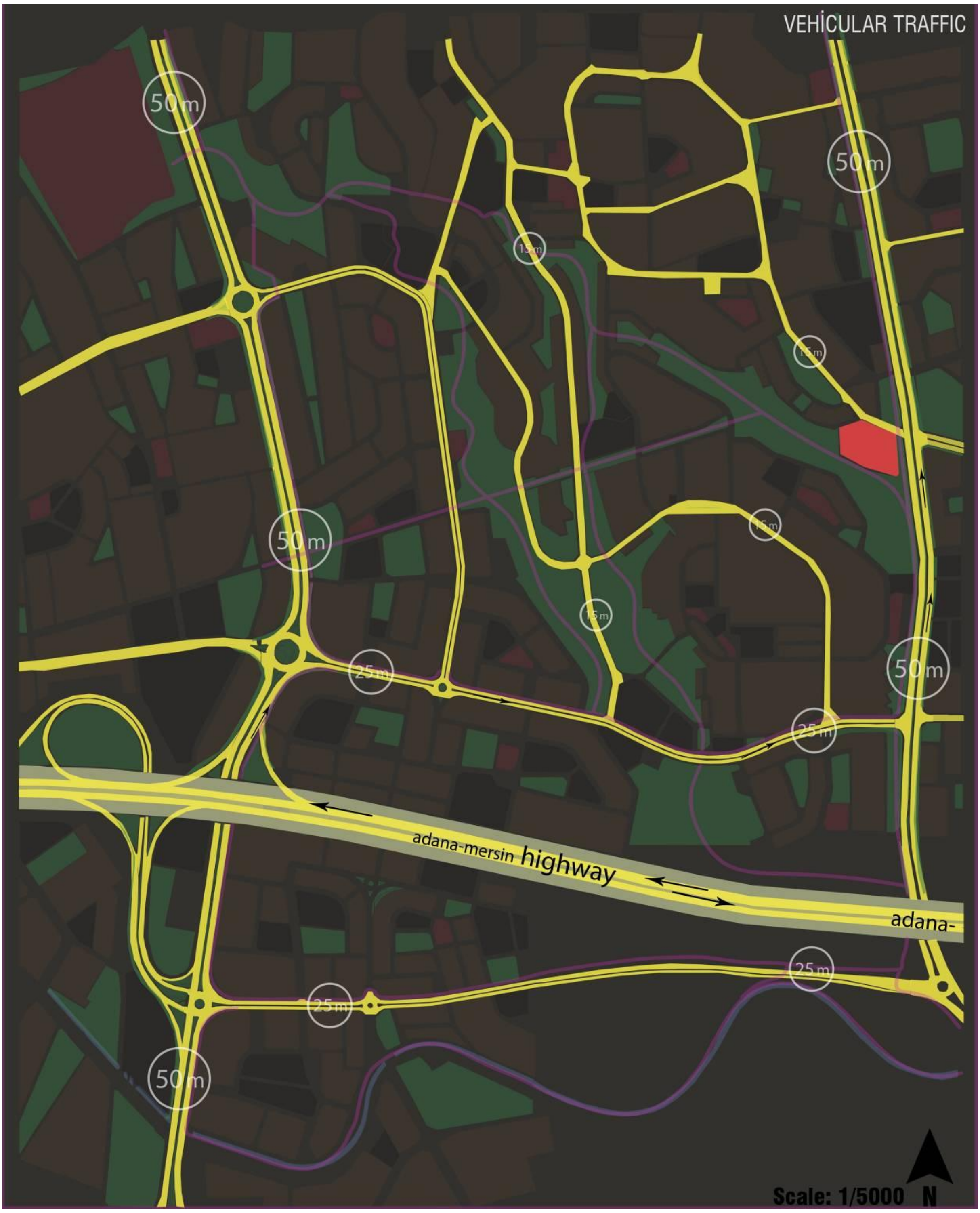


Figure 2.50 – Vehicular Road Hierarchy

2.2.7 Occupancy & Vacancy

Figure 2.51 – Occupancy vs. Vacancy

2.2.8 Private vs. Public Spaces

Figure 2.52 – Private vs. Public Spaces

2.2.9 Green Areas Gradation

Figure 2.53 – Green Areas Gradation

2.2.9 SWOT Analysis

STRENGTHS

Adana and Çukurova:

- Adana's strategic location in Mediterranean Region.
- Adana being the 5th populous city in Turkey.
- Strong economy and production.
- Cukurova Plain as a gateway from Europe to the Middle East.
- Çukurova Region among the most agriculturally productive areas of the world.

Site:

- Presence of green areas.
- Presence of newly developed mobility infrastructure.
- Presence of service areas, such as schools, hospitals etc.
- Well connected to the city center by public transportation.
- Closeness to airport.
- Presence of a considerable number of traditional market places.

WEAKNESSES

Adana and Çukurova:

- Ranked 16th city in Turkey in socio economic development index.
- No Specific Urban Pattern especially in Çukurova.
- High temperature values especially in summer.
-

Site:

- Lack of connection between green areas.
- Lack of recreational activities.
- No promotion of bicycle usage, lacking of bike routes.
- Lack of biodiversity.

OPPORTUNITIES

Adana and Çukurova:

- Adana's economic power and population.
- Adana being rich in water resources.
- Çukurova's historically rural life style.

Site:

- Urban and Architectural Competition.
- Being inside an urban park.
- Presence of vacant sites owned by the government.
- Presence of wide boulevards.
- Variety of slope.
- Existing spaces for possible development.

<u>THREATS</u>

Adana and Çukurova:

- Fast urbanization.
- High rise building trend.
- Car dependency.

Site:

- Presence of wide boulevards.
- High slope differences within the site.
- Separation between the south and north of the district due to highway.

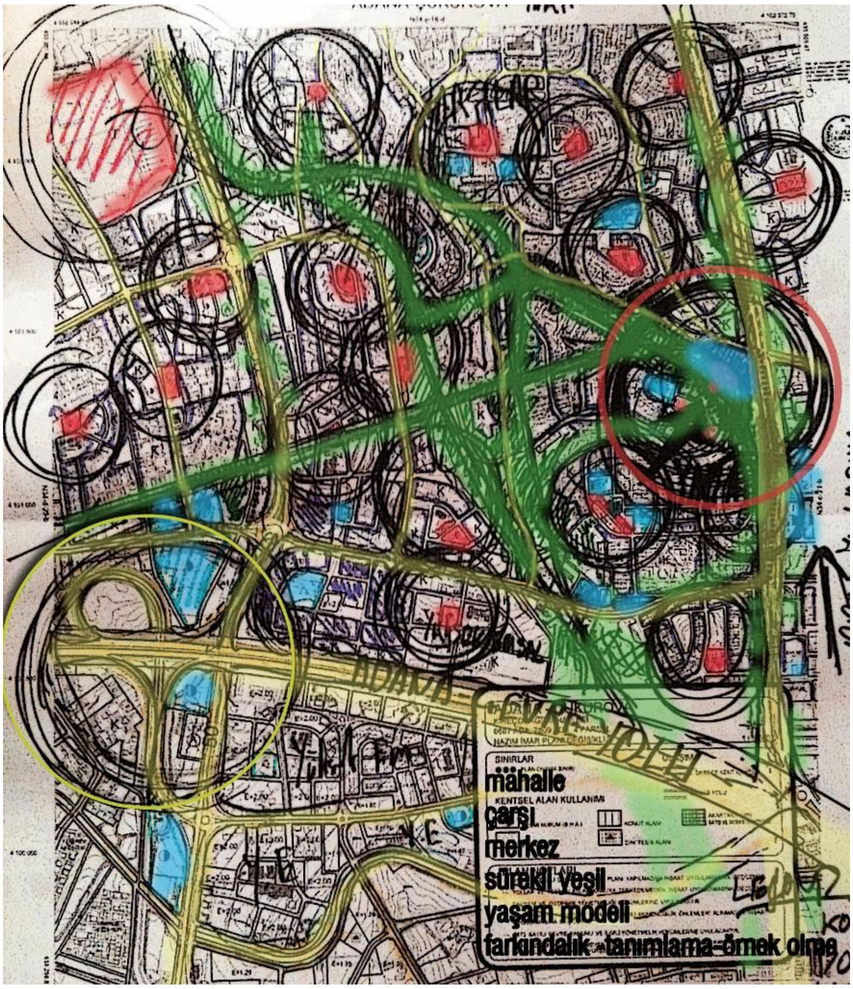


Figure 2.54 – 1/5000 scale SWOT sketch

2.2.10 1/5000 Scale Master Plan Design & Green Network Concept

The highway passing through the south of the district creates a great diversion between the south and the north. The highway connects the city center to the airport also a connection between Adana and neighboring cities. Although it creates a physical barrier between the south and the north, it's the main artery to feed the district as it's the main way from the city center to the area. The highway, itself creates a fast center and traffic distribution points. On the other hand the north of the highway is a typical Turkish district, consisting of small neighborhoods each can be identified by their own marketplaces, service areas and green areas. Hypothetically, when a circle with a radius of 500 meters is drawn from the marketplaces shown in Figure 2.53, neighborhoods can be identified within the district. From the Figure 2.53, it can be easily seen that how these neighborhoods are well integrated with each other and the opportunity to connect in means of pedestrian movement through green areas is obvious.

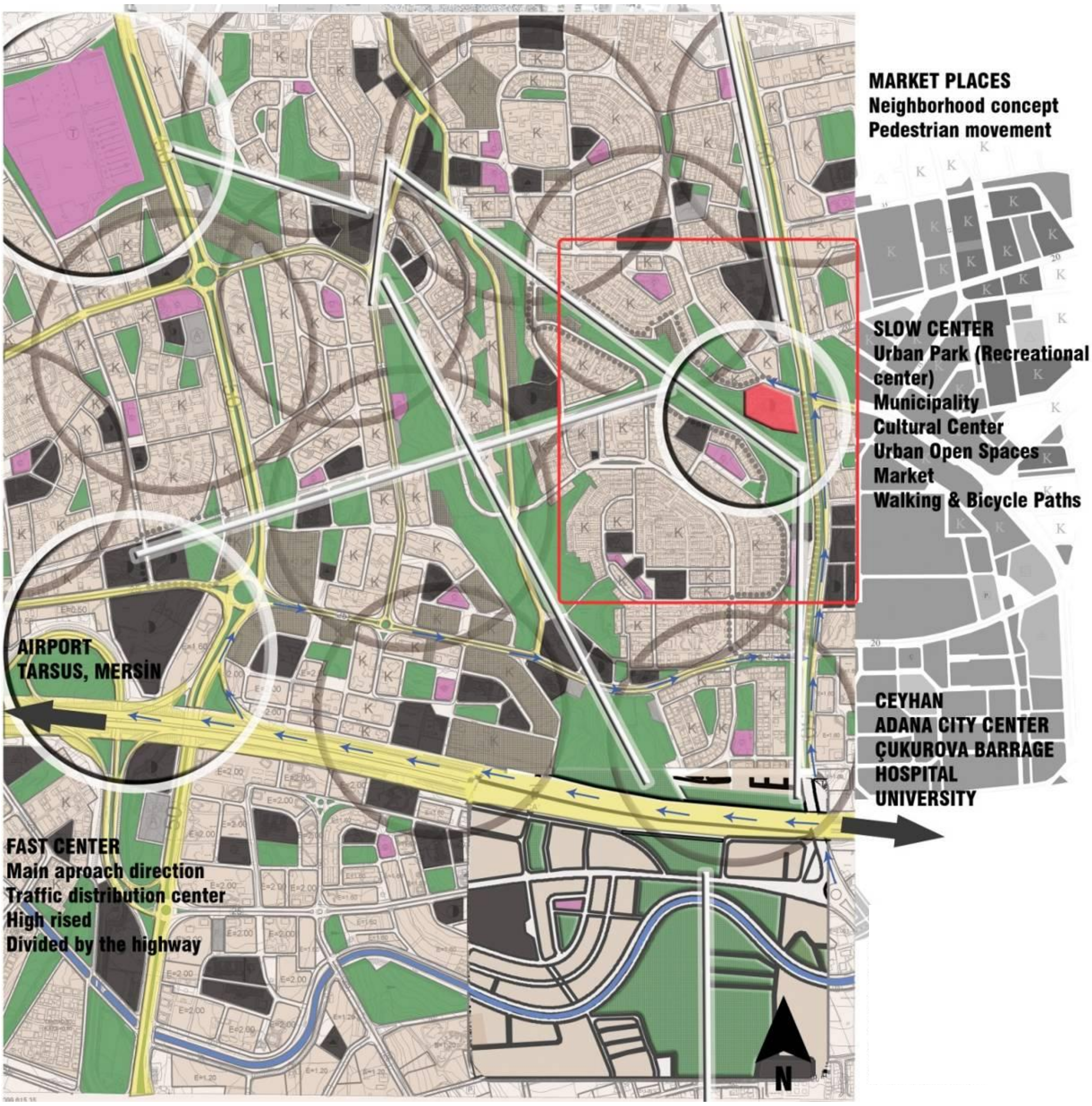


Figure 2.55 – Urban Synthesis Map

Green Network, shown in Figure 2.54, is a 7.2 km continuous urban connection formed by pedestrian and bicycle roads. It connects the green areas to the urban services and market places using the green also as shading element. So with the proposed green network the neighborhoods shown in the Figure 2.53 are connected through green areas. In order to achieve this continuous path some interventions have been made mainly in the vacant public areas. The green network reaches from the highway to the commercial center on the Northwest. Centralized in the Urban Park, it connects the neighborhoods and services with pedestrian movement & bicycle paths.

Figure 2.56 – Green Network

Master Plan proposal for 1/5000 scale is shown in Figure 2.55. Green network, introduced in the previous pages, connects the market places and service areas through green areas within the district. The design proposal determines the point of focus of the green network as the Urban Park as the new design proposal for new Municipality Hall and Culture Center will be located there. So therefore, the following urban studies will focus on the Urban Park on a larger scale.

Figure 2.57 – Master Plan 1/5000

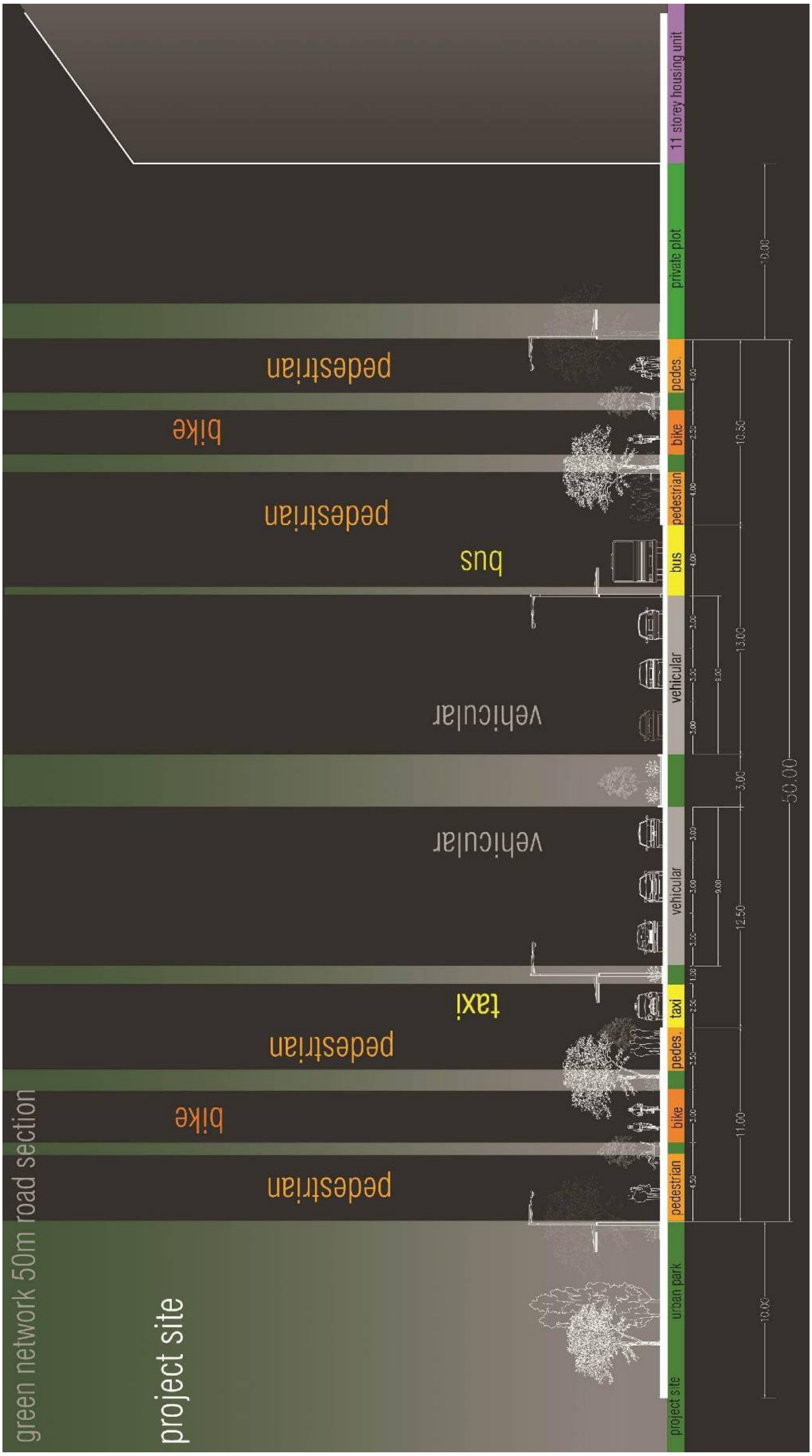


Figure 2.58 – Typical Green Network & 50m Road Section

2.2.11 Land Use

Figure 2.59 – 1/1000 scale land use plan

2.2.12 Occupancy vs. Vacancy (1/1000 Scale)

Figure 2.60 – 1/1000 Nolli Analysis

2.2.13 Building Heights (1/1000 Scale)

Figure 2.61 – Building Heights

2.2.14 Topography (1/1000 Scale)

Figure 2.62 – Slope Analysis

2.2.15 Master Plan (1/1000 Scale)

Figure 2.63 – Synthesis 1/1000

The master plan study is based on the urban park and the relation of the building with the park. It is designed to be the welcoming and collecting point of the study area. The green network's arms meet within the building forming the hills in the landscape and connect the users to the heart of the park. The neighborhood's urban pattern is currently under new

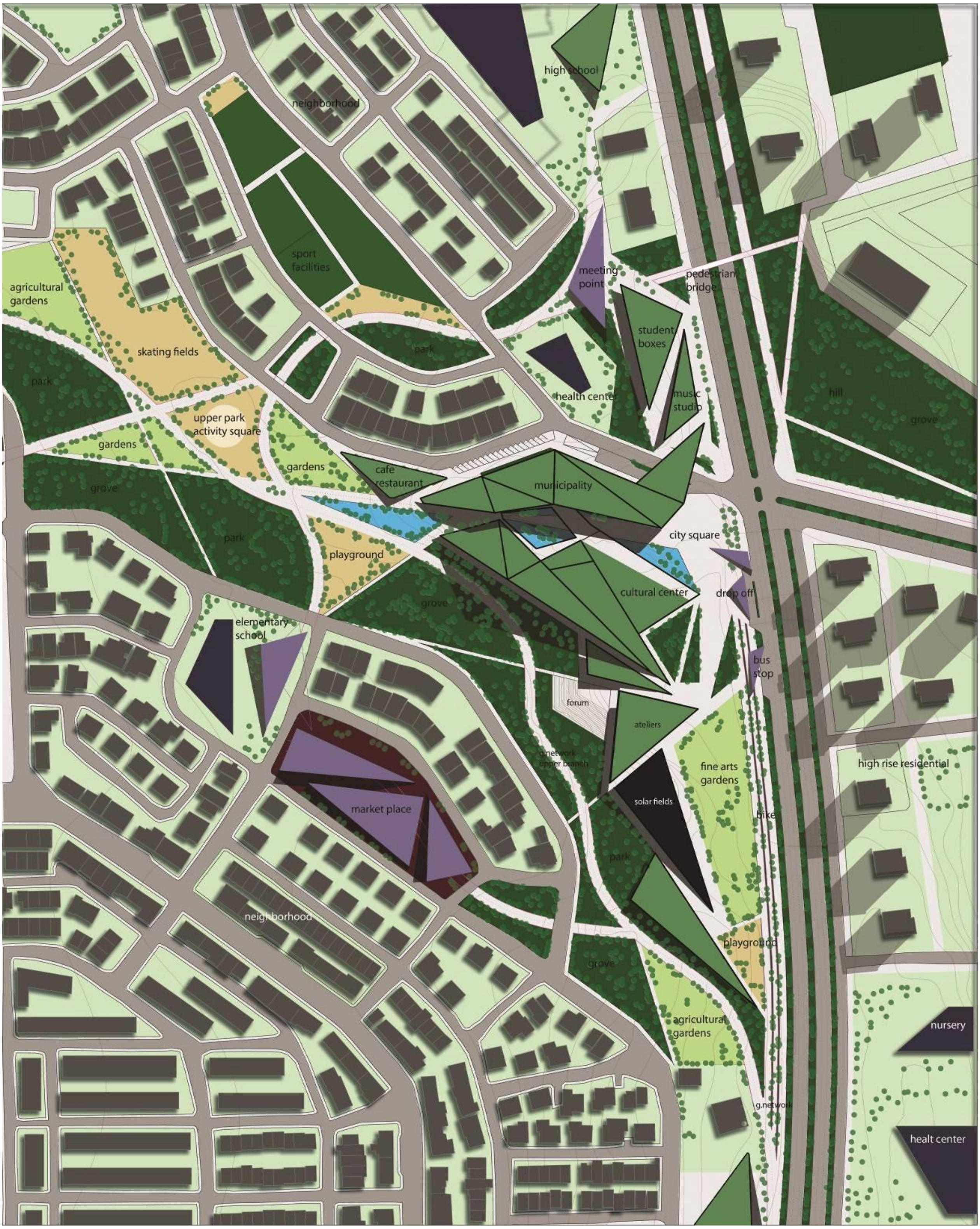


Figure 2.64 – Master Plan 1/1000

development and the new municipality building to be constructed is considered to be the architectural and urban pioneer building concept of the district. One part of the upper branch of the network cross the market place and the elementary school and reconnects to the park next to the playground. The other part of the upper branch is a green road, grooves on the sides, for pedestrian and bicycle traffic.

Figure 2.65 –Building Complex 1/1000

The triangular tectonic like build up area encloses the facilities to be used in the park other than the municipality building and social center. Together they form the shaped landscape of the site which is "the meeting arms". The slope is one of the main challenge in terms of connection between levels and building heights as well as visual harmony in the park. The design is held carefully to limit the building height in human scale.

Figure 2.66 – Building & Facilities nearby 1/1000

Urban facilities near the building site are also seen to be part of the urban design. The triangular concept continues in shading elements of the market place, meeting point, drop off area and the bus stop. Besides new designs of the high school, elementary school, nursery and the health centers are to be the first examples of the green concept for public buildings in the district. Municipality and the Social center is predicted to change the building concept of the neighborhood.

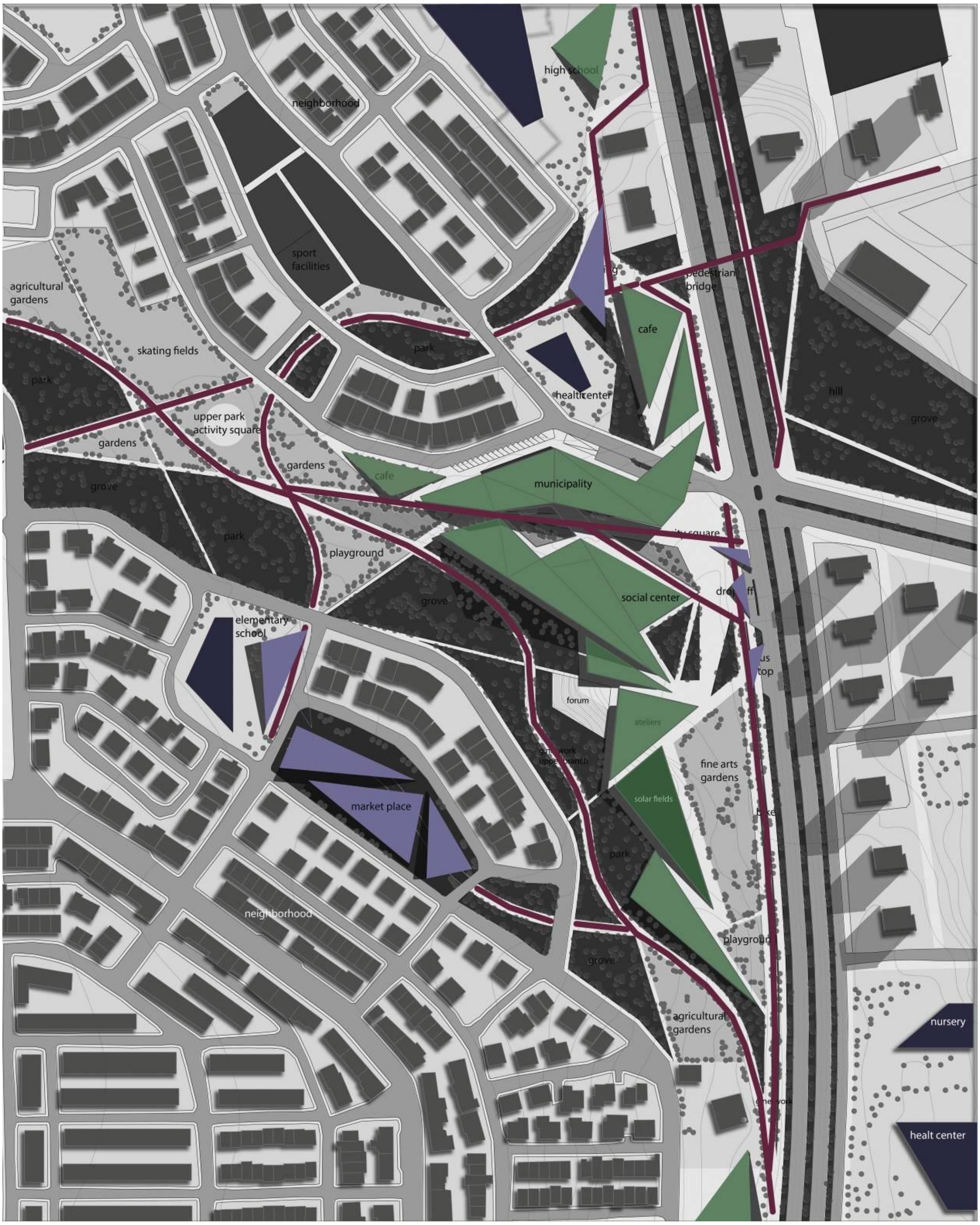


Figure 2.67 – Building & Facilities nearby & Green Network 1/1000

As seen in Figure 2.67 all the facilities are directly connected to each through the green network. The existence of traditional market places put forward the habit of walking in the neighborhood. The new design of the park allows users to reach every important urban space by walk providing them an enjoyable journey through various functions along the road. Bicycle usage is promoted by ensuring the bikeways reaching the attraction points.

Figure 2.64 – Master Plan 1/1000(upper park)

From the city square the green roof of the social center and the ramp from the entrance box lead people to the upper park. The park welcomes visitors with water element, cafeteria and restaurant on one side, and playground on the other. The restaurant is faced to the water and gardens. The activity square is design to be an interactive space where people can decide how it’s going to be use within periods and it is also seen as the ceremony place of the municipality. Historically, gardens are beloved elements of the Turkish green areas therefore it is also used in Çukurova district park. In addition, agricultural gardens are introduced in public areas where people can cultivate together not separately in their own plot. The upper park square is the junction and distribution point to various complementary functions strongly related to each other. On the north east side sport field meeting point, high school, student boxes and the health center, on south playground and park’s grass area. On North West, beside the grass area an important function is introduced which is the skating fields.

Nowadays Adana became one of the important freestyle BMX centers in Turkey. These cyclists are also known to be booming Rap Bands. Considering the new trend in the city the project put forwards skating fields and a music recording and practicing studio to the area.

Another important concept is the forum space which became a need in urban parks with the will of the people in many cities of Turkey after May 2013 Gezi Park events. The accelerated spread of forums in country leaded us to design the forum space with service space and workshops within the triangular green elements.

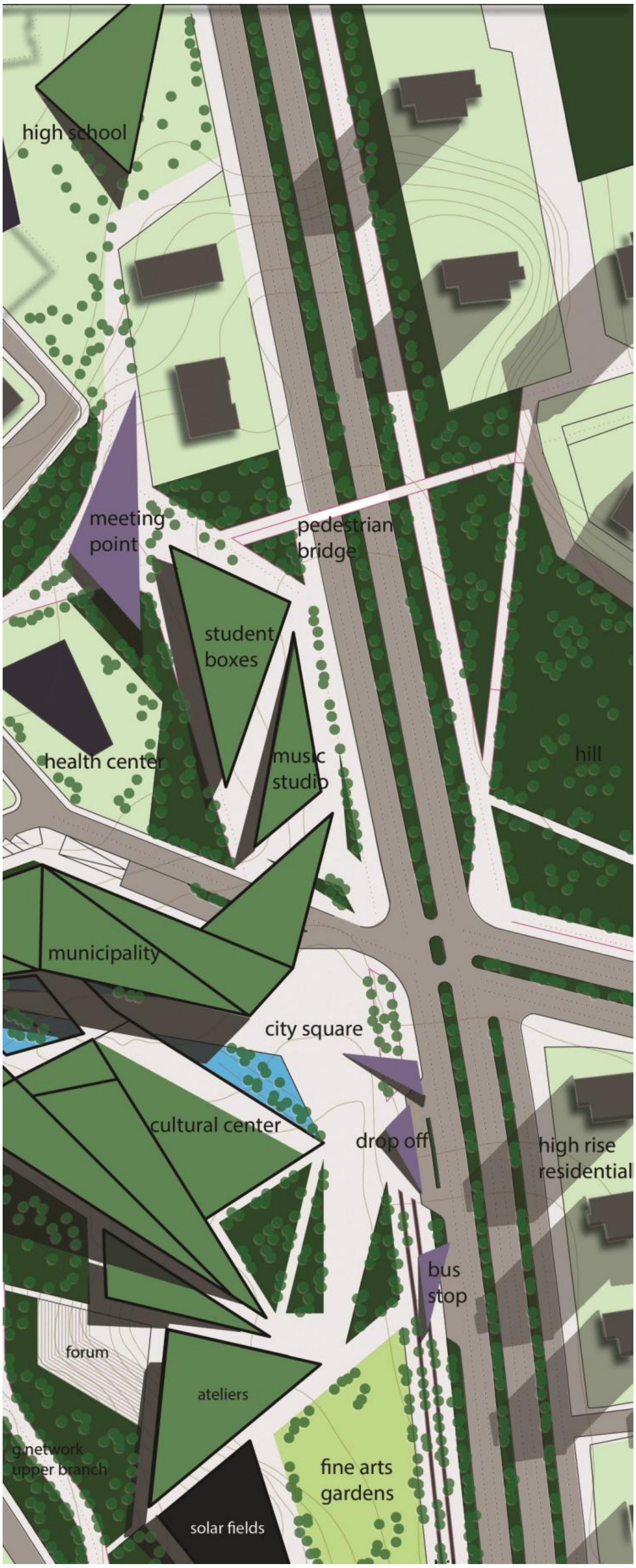


Figure 2.64 – Master Plan 1/1000(road side)

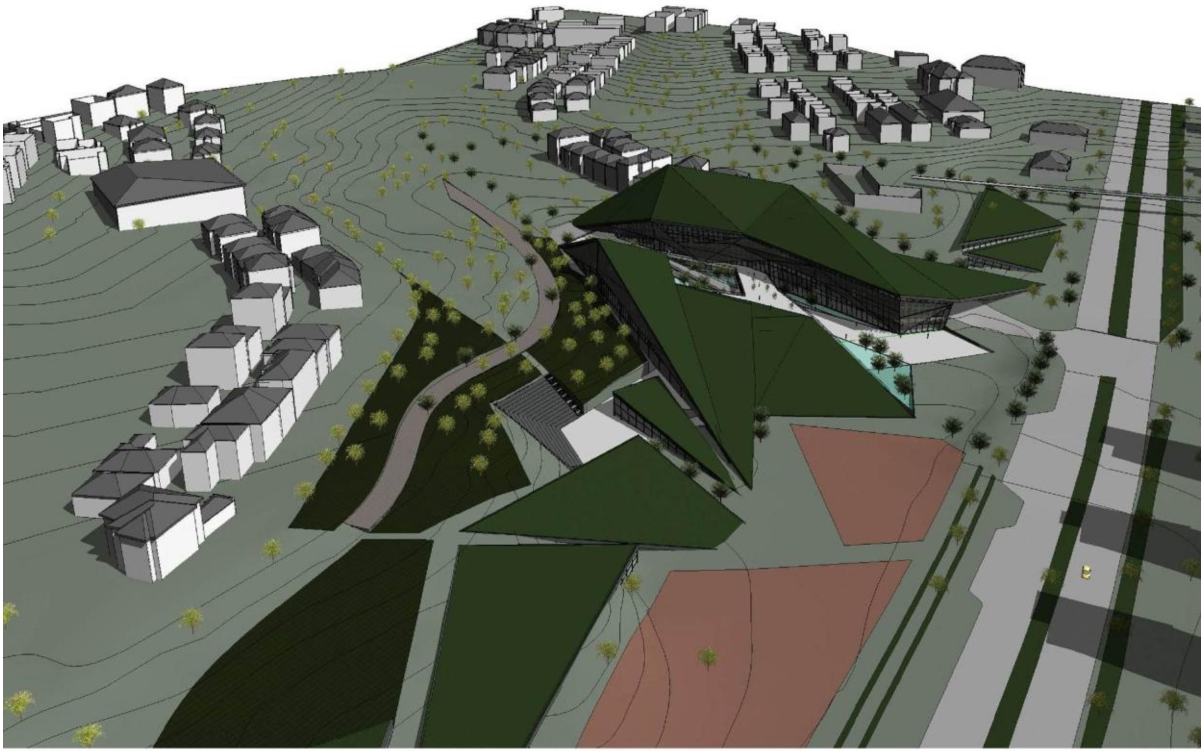


Figure 2.68 – Aerial View South

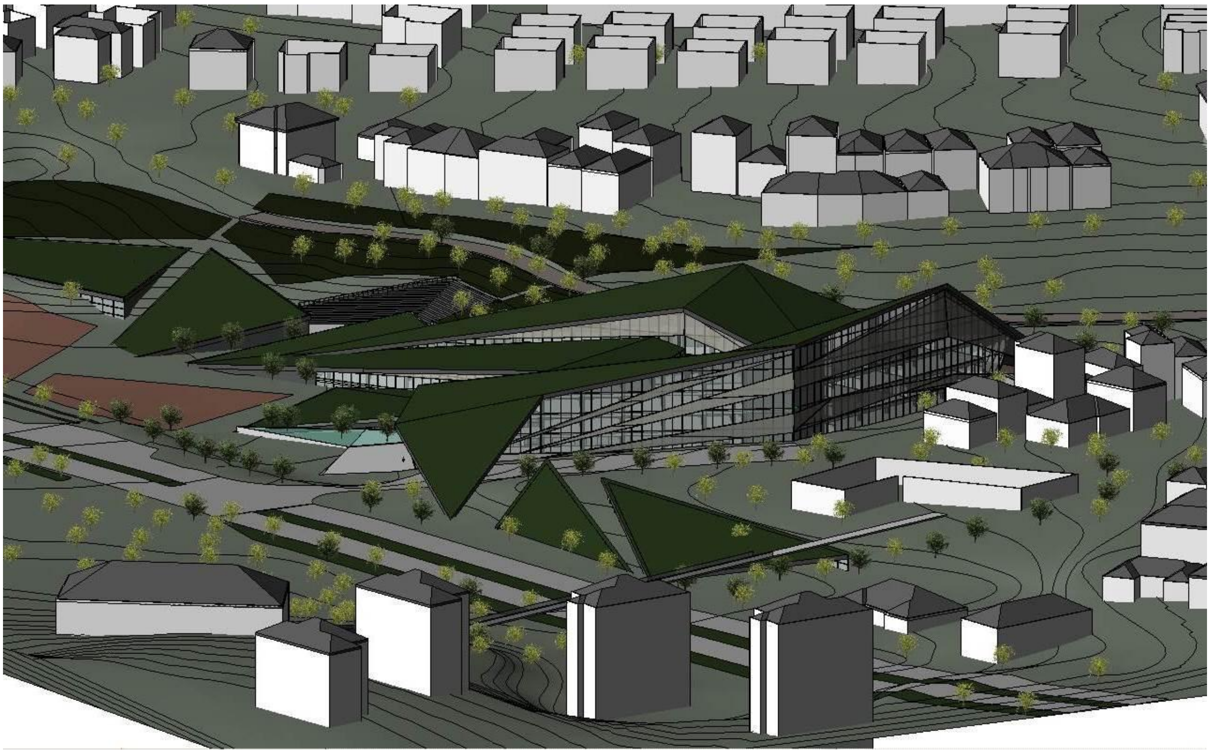


Figure 2.69 – Aerial View North

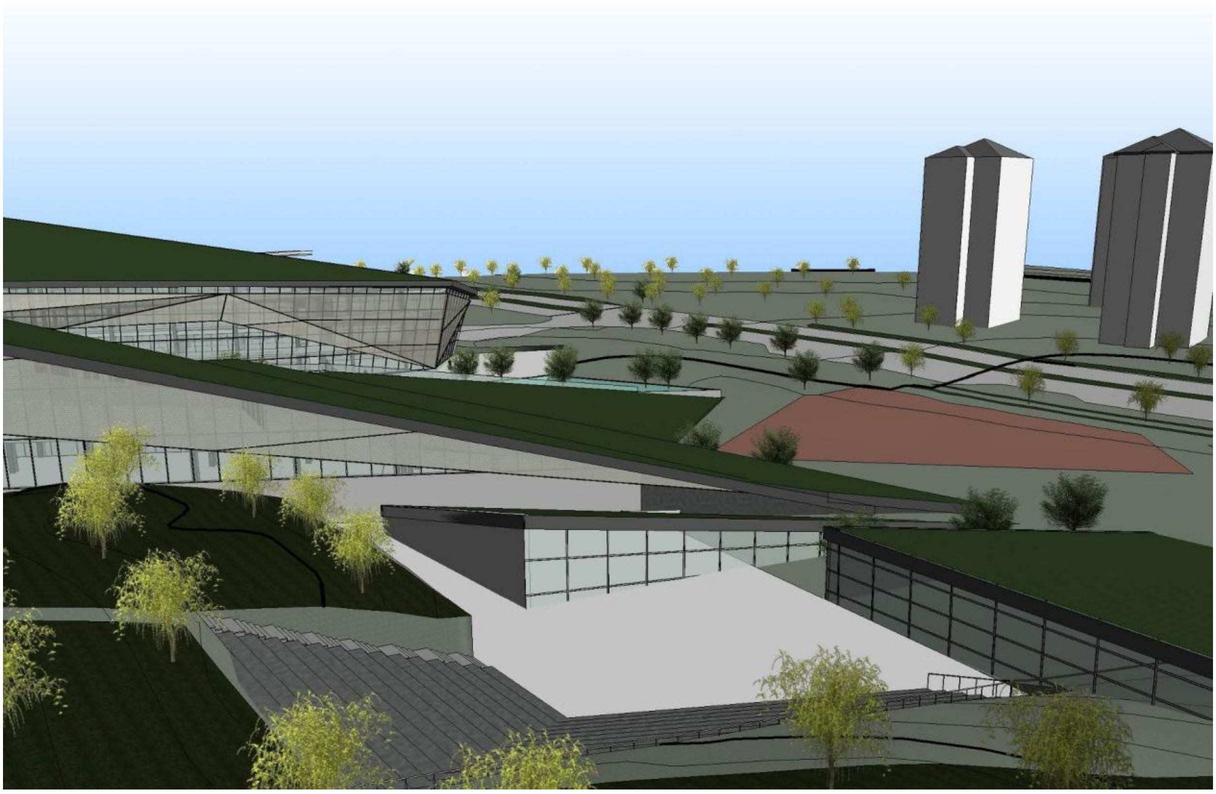


Figure 2.70 – Forum Square and its Facilities

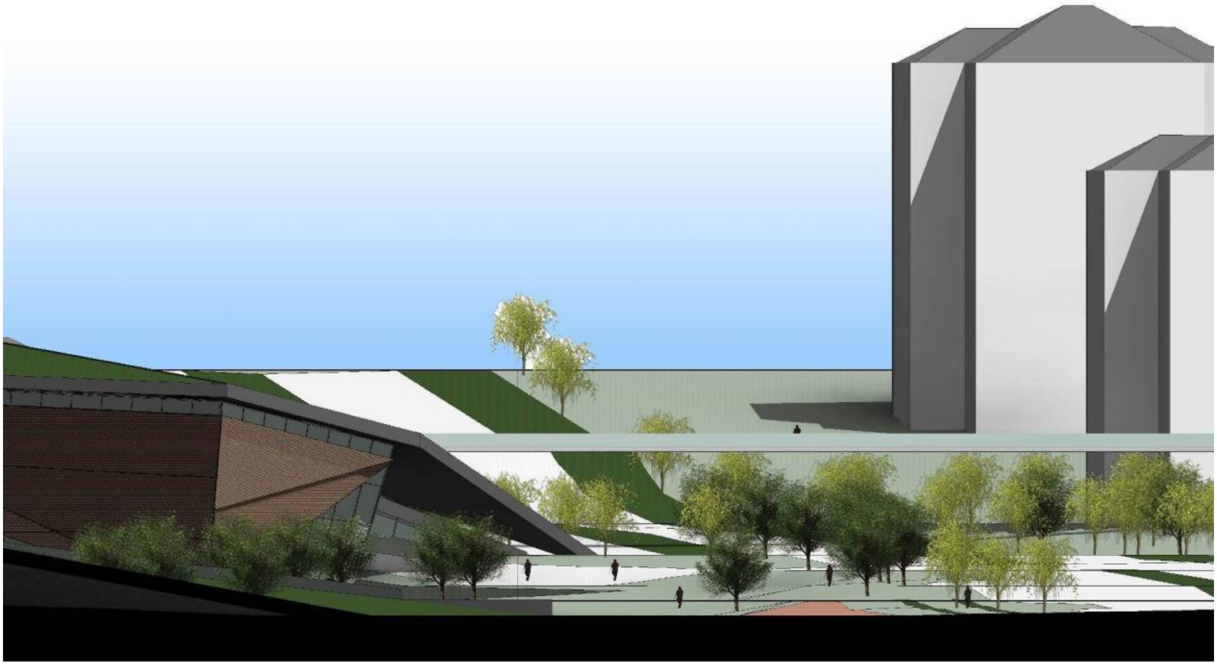


Figure 2.71 – Pedestrian Bridge and the building

Chapter Three - Architectural Design

3.1 Design Parameters

3.1.1 Objectives

The objective of the competition is to design a new municipality hall and a cultural center on the project site that would satisfy the needs of the municipality in a modern, technological and sustainable approach. Municipality hall being one of the most important public spaces within the city, the brief strictly highlights the importance of public use and accessibility of the building and the project site.

The new design is asked to be strongly connected with the surrounding landscape, thus the challenge is not to design only a building, but an urban park that would act as a recreation center which satisfies the needs of the residents. Also the new design is seen as a new triggering point that would bring a new set of activities to the area and more importantly increase the value of the close vicinity. In other words, it's been aimed that the new design is to be not an administrative building, but a meeting point for the residents of Cukurova.

The building, being the public space itself, should act as an extension of the urban park especially on the ground floor level. Along the modern concept of city management, the municipality hall should be a space that the public can easily access to. Accessibility of the building by public transportation and walking has the priority when compared to private transportation. Also the brief requires an easy flow of horizontal & vertical circulation within the building, since that it is a public space and it will host the local residents within the day.

Transparency is one of the keywords defined in the competition brief. In the modern concept of city management visual accessibility of the building is as much as important as the physical accessibility. The transparency of the envelope of the building lets the residents to observe the activities within the building which makes them confident about that the municipality is working for a better city, which they live in.

Sustainability is the utmost important challenge defined in the brief, a goal that should be reached at the urban and the architectonic scale. The brief points out the importance of the pedestrian accessibility to the building through the urban park and minimizes the private transportation to encourage the maximum usage of public transportation to reach sustainability at the urban scale. Adana, being one of the hottest cities in Turkey, has a hot climate that underlines the needs of energy efficiency of the building.

3.1.2 Requirements of the Competition Brief

The building has two primary functions: Municipality Hall and the Cultural Center. The Municipality Hall is mainly an office building with supporting functions such as cafeteria, exhibition halls and information centers. Cultural Center, on the other hand, is the place where the wedding ceremonies are performed, conferences and seminars are held. When not used for the stated events, the cultural center shall be used as a movie theatre.

3.1.2.1 Municipality Hall

The area breakdown of the Municipality Hall shall be as defined below;

1. Entrance Area...Area to be defined by the contestants

2. Management Offices
    - 2.1 Mayor's Chair..184 m²
    - 2.2 Executive Asistant..188 m²
    - 2.3 Deputy Mayors...96x4=384 m²
    - 2.4 Consultants...72x3=216 m²
    - 2.5 Master of Ceremonies...100 m²
    - 2.6 Inspectors...62x3=186 m²

3. Municipal Council
    - 3.1 Meeting Room...250 m²
    - 3.2 Chair's Office...36 m²
    - 3.3 Secretary's Room..16 m²
    - 3.4 Press Room..48 m²
    - 3.5 Group Meeting Rooms..52x3=156 m²

4. Municipal Committee...96 m²

5. Departments
    - 5.1 Press and Public Relations..160 m²
    - 5.2 Legal Affairs...176 m²
    - 5.3 Municipal Police...232 m²
    - 5.4 License and Supervision..120 m²
    - 5.5 Civil Defence Expert..40 m²
    - 5.6 Editorship..144 m²
    - 5.7 Information Technologies...152 m²
    - 5.8 Environmental Protection & Development...148 m²
    - 5.9 Social and Administrative Affairs..224 m²
    - 5.10 Financial Services (Administrative Section)...168 m²
    - 5.11 Financial Services (Cashier Offices)...316 m²
    - 5.12 Real Estate & Expropriation..280 m²
    - 5.13 Survey and Projects...500 m²
    - 5.14 Marriage Registry ....40 m²
    - 5.15 Supporting Services...144 m²
    - 5.16 Construction Affairs...148 m²
    - 5.17 Parks Gardens and Green Fields...24 m²
    - 5.18 Strategic Planning...100 m²
    - 5.19 Human Resources...144 m²
    - 5.20 Cleaning Services...24 m²

5.21 Transportation...68 m²
5.22 Department of Technical Works...296 m²
5.23 Cultural and Social Affairs..152 m²
5.22 Supervisory Board..60 m²

6. Facilities
6.1 Switch Board...60 m²
6.2 Archive...1000 m²
6.3 Storage...100 m²
6.4 M&E Plant Rooms..516 m²

Total Area of Premises...7,394 m²
Circulation Area & Wcs (60%)...4,436 m²
Municipality Hall Total Area..**11,830 m²**

3.1.2.2 Cultural Center

Cultural center shall be able to accommodate 500 people and shall be suitable for different events such as wedding ceremonies, conferences and seminars.

Auditorium (500 people)...1,400 m²
Circulation Area & Wcs (60%)...1,400 m²
Cultural Center Total Area...**2,800 m²**

3.1.2.3 Underground Car Park & Shelter

Car Park..**750 m²**
Shelter..**750 m²**

3.1.2.4 Total Construction Area

Municipality Hall Total Area..**11,830 m²**
Cultural Center Total Area...**2,800 m²**
Car Park..**750 m²**
Shelter..**750 m²**

TOTAL CONSTRUCTION AREA:..**16,130 m²**

3.1.3 Municipality Organization Chart

Like many other administrative bodies, municipality hall has a well-defined organization scheme. There are four major departments each managed by a deputy mayor. The organization chart determines the units that work in conjunction, thus they shall be close to each other physically in order to work in most efficient way. The organization chart for Cukurova Municipality Hall was defined by the competition brief an can be seen in Figure 3.1.

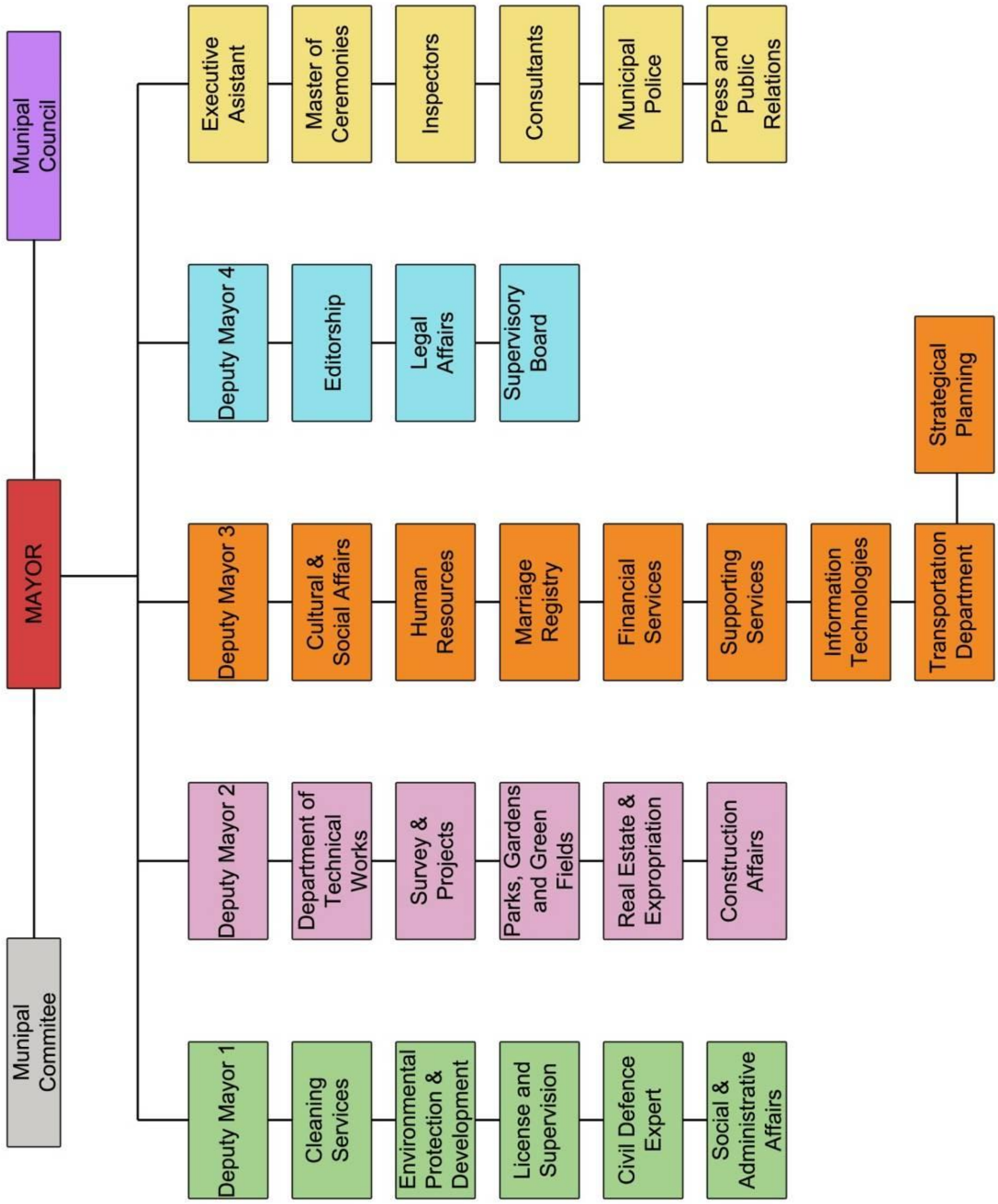


Figure 3.1 – Municipality Organization Chart

3.2 Design Concept

3.2.1 Urban Park vs. The Building

A municipality hall is usually recognized as an administrative office building, which people go to when they need to get something done. While accommodating a significant number of staff, municipality halls also welcome many visitors on daily basis. Thinking over the past experiences in a municipality hall, most people usually try to get out from the building as fast as they can or they try to solve their issues in once so that they don't need to come over again. This is usually due to the bureaucratic procedures that the people face while they are in the building which may seem as a waste of time. Sometimes the problem is the location of the building or even the lack of way finding signs that transforms a simple rectangular shaped building into a maze. Whatever the reason is, a municipality hall is usually evaluated based on the criteria that how much time one spends in the building. While keeping in mind that even a perfect design cannot change the speed or complexity of bureaucratic procedures, what we try to seek in this academic study is to change the impression of the term, municipality hall.

The design proposal for Cukurova Municipality Hall seeks to change the quality of experience within the building. Even though that the "quality of experience" is based on many different items, some of them being administrative issues (procedures, staff, etc.), the design proposal challenges to improve the quality of experience by interdisciplinary studies.

The first issue that is considered during the concept design studies is the activities that take place. Since the experiences are the results of activities that take place, this issue has a great importance. As explained in Chapter 3.1.2, the building has an intense program which sets the basic needs of the building. Without the cultural center, the building becomes only an office building which is in use within weekdays and work hours. So other than this sharply defined time period, the building wouldn't be used. Also the intense development in internet usage reduces the needs to go to the municipality hall while one can handle his issues on his computer or even on his smart phone. Rapid growth of the technology shows us that the significance of administrative buildings will dilute in the coming years as well. This challenge can be overcome by implementing new activities into the building & its surrounding, so that the people do not only go to this building when they have to. The most challenging task that our design proposal faces is to create such an environment that the residents of Cukurova would see the building as a place to spend time, not as a place that wastes their time. Since the building program and the construction area is defined within the competition brief does not foresee the required space for other activities that may take place within the building, the usage of open and semi-open areas becomes significantly important. Thus the urban park, which is explained in the first section, carries the utmost importance within the design concept of the building.

Figure 3.2 – Green Network & the Building Complex

The interaction between the urban park and the building, is to be maintained within the open & semi-open spaces, which aims to unite the building and the urban park and merge into each other so that the urban park can feed the municipality hall while the municipality hall can support the urban park. So the design concept of the municipality hall & the cultural center is not defined by the parameters within the building site, but the urban park.

3.2.2 Design Studies

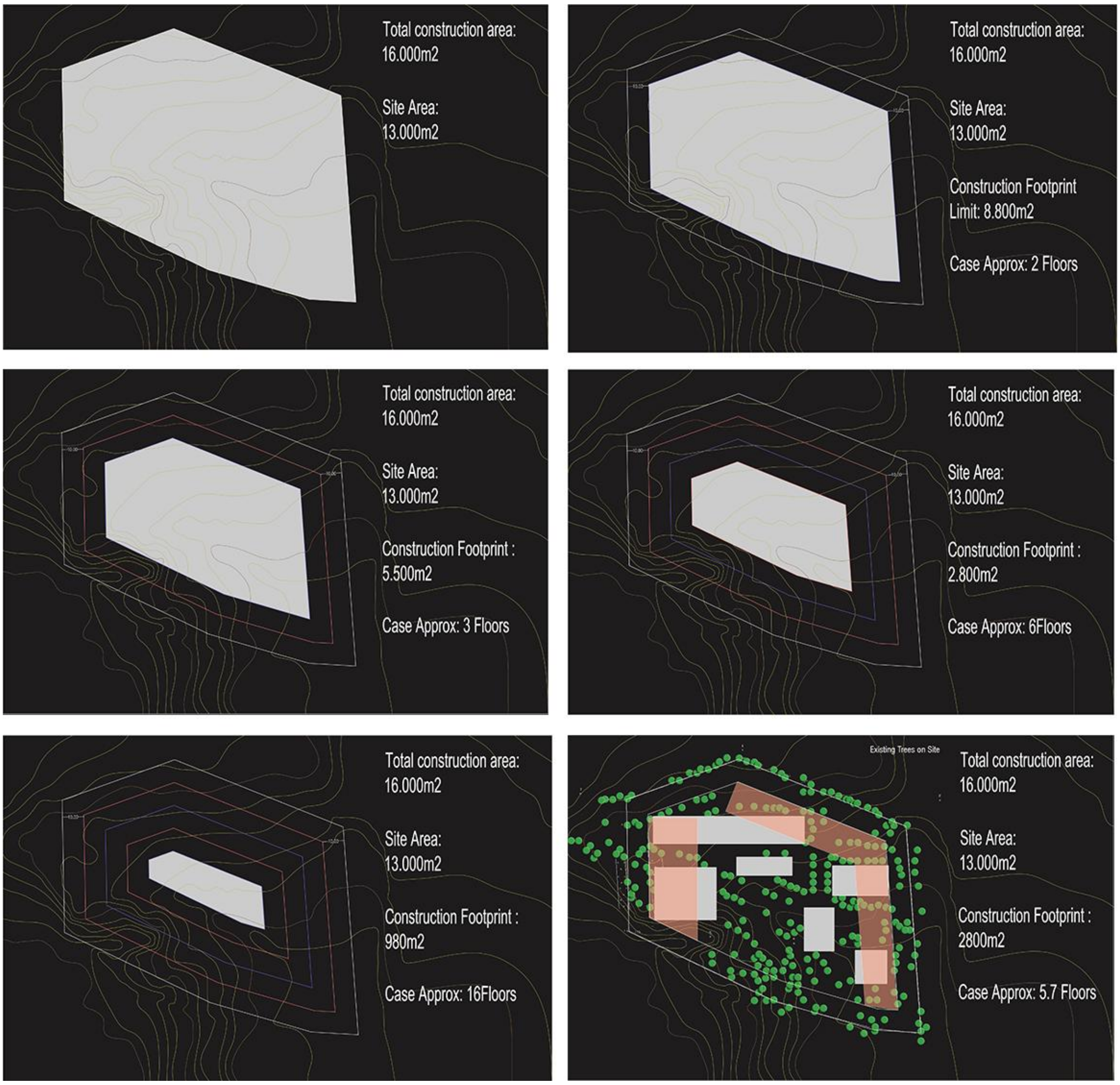


Figure 3.3 – Footprint studies

The site area is 16.000m2 and the program given by the municipality is 13.000 m2. So one of the first studies was to control the footprint area to satisfy the program. Determining the footprint is also seen as the research for daily life style. The restrictions of the program and the floor area ratio is studied in Figure 3.3.

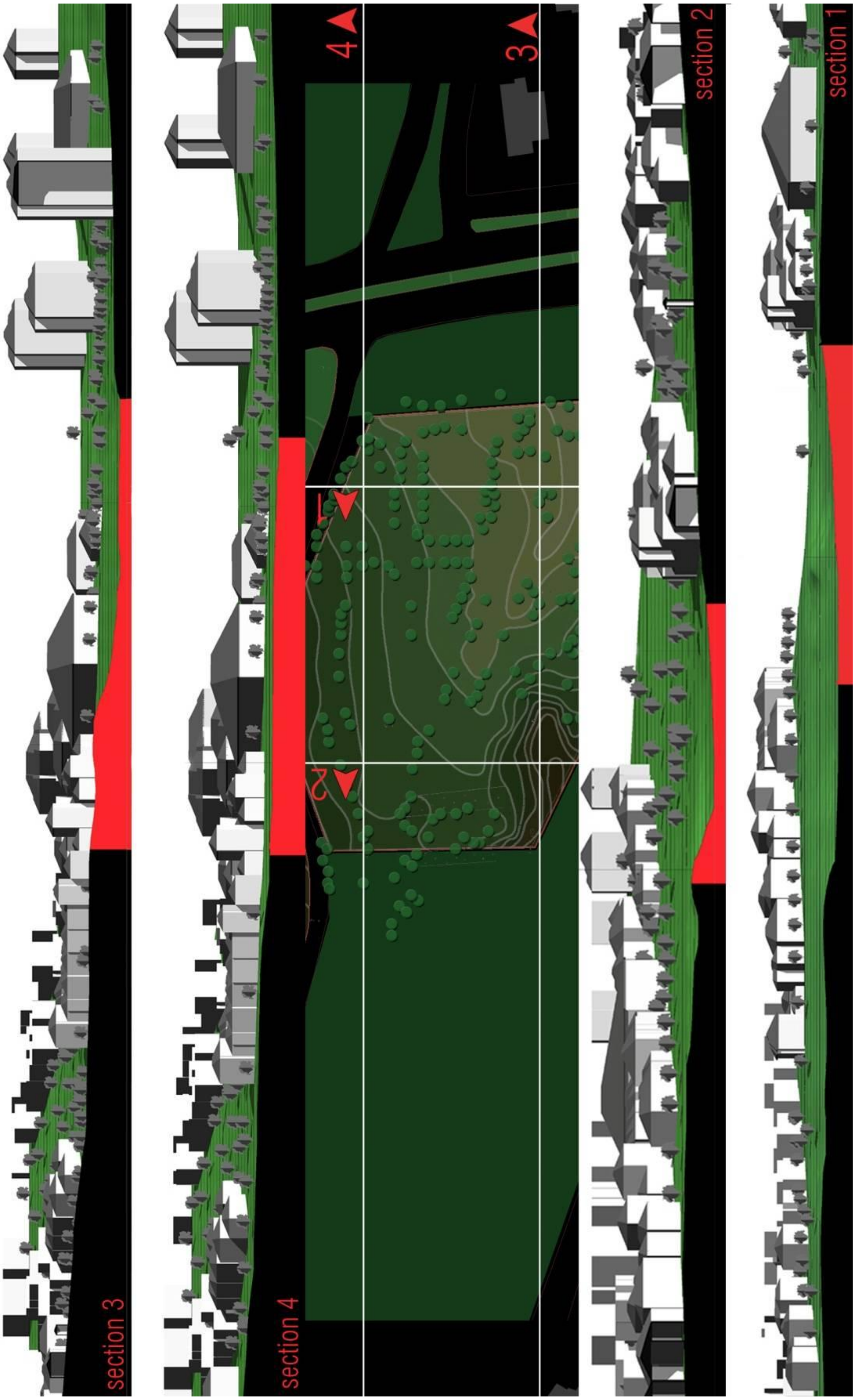


Figure 3.4 – Site Section and slope studies

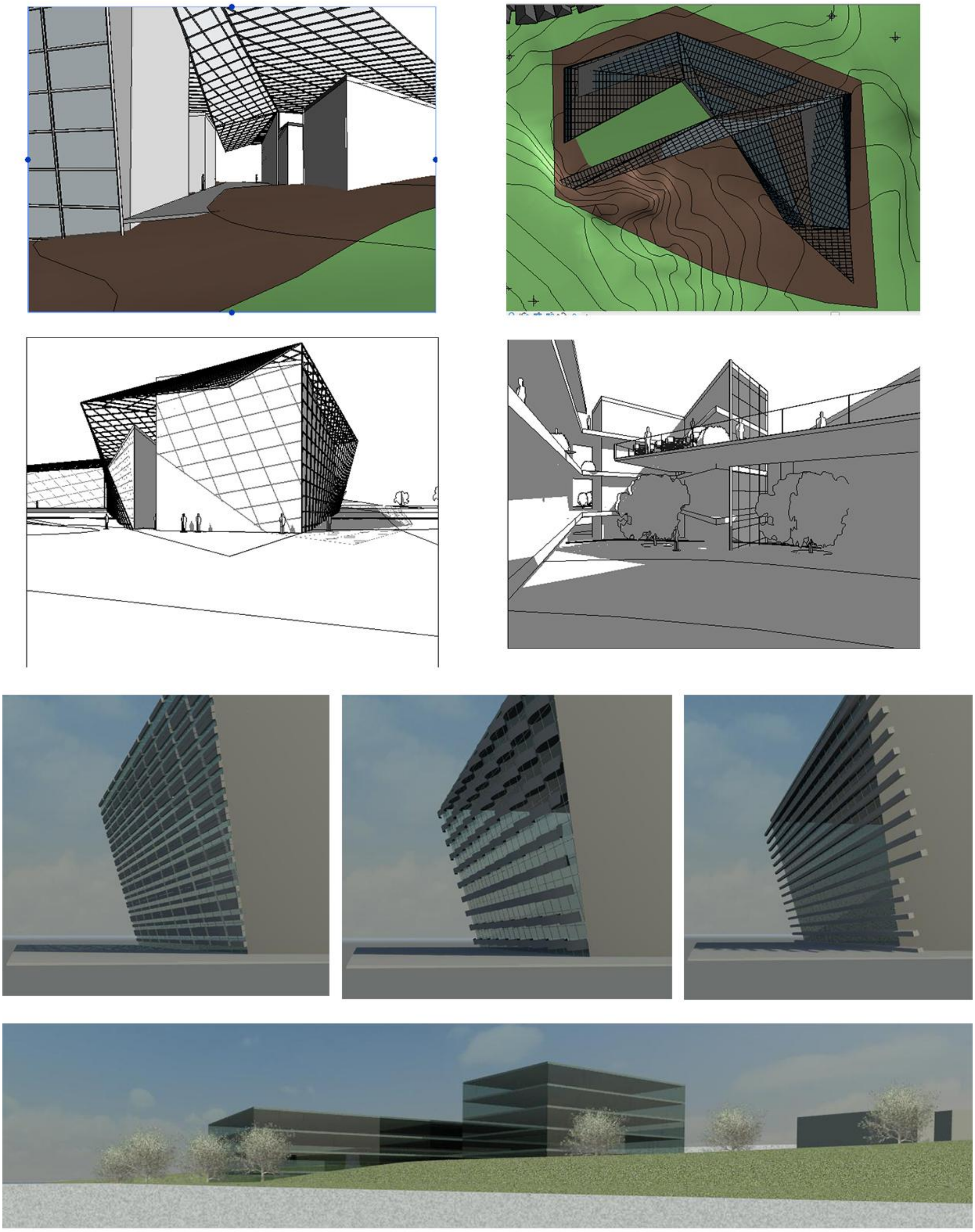


Figure 3.5 – Space, shading and façade studies

Figure 3.6 – Model Studies

In order to achieve the architectural solution for the building following the concepts of meeting arms, harmony and being united with the park is held by model studies. Considering the sharp movements of the land and strict program series of model have been made to find the desired design. After finding the form in model, the design is drowned in 3d computer model which helped us to define clearly the boundaries of architectural elements like roofs, floors and facades. Meanwhile the façade design studies is held especially with shading elements. There were two main challenges; one was the protection from strong effects of the sun due to climate and second was the continuity of the form in façade.

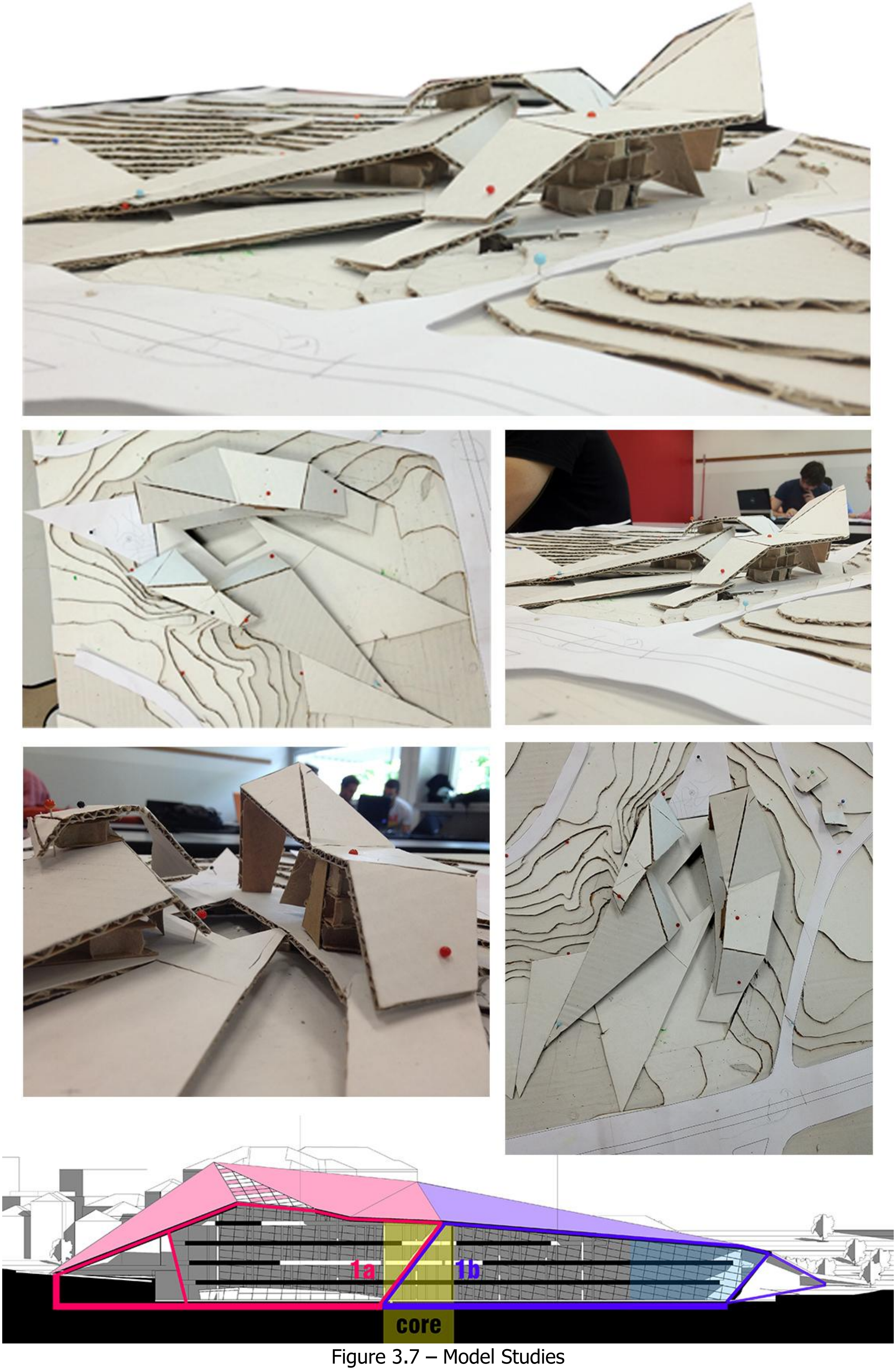


Figure 3.7 – Model Studies

3.2.3 Metamorphosis of the Topography: The Building

The design of the building is triggered by the triangular tectonic-like plates of the urban park. The location of the building site is at the center of the urban park, where the two arms of the park comes from north and south and meets at the building site and elongates to the west. The site is the point where these two arms reach to each other which metaphorically expresses the gathering point of Cukurova residents. These arms of the urban park are created by triangular tectonic-like plates. At the clash point, these plates go through a metamorphosis and shape the building.

The metamorphosis of the topography creates the green roofs, on some of these green roofs pedestrians can walk. The municipality hall is an important public space but the usual perception of the community is that a municipality hall is a building which has certain restrictions and people that are not related shouldn't be there. So in order to change that impression the concept design proposes a building that the people can get into physical interaction, not only a building that the people can only see or enter. The selection of the accessible roofs is based on the function underneath, which gives the parameter of roof inclination. The green roofs emerged from the ground act shells and accommodate the required functions underneath.

Transparency of a public space or an office building is an important issue in modern architecture. The transparency of a building allows people to see the activities inside which creates the sense of trust. This issue has been one of the most challenging tasks to overcome due to the hot local climate. In order to achieve such a transparency with energy efficiency, the buildings have transparent façades on the south and north while all the façades are opaque on west & sides. In order to avoid solar heat gains as much as possible a solar shading element is designed and integrated with the façade, being more intense on the south façade.

Sustainability as briefly introduced above is a major issue to be covered in the design. Due to the hot local climate avoiding heat gains is the most important challenge. The design proposal seeks the balance between avoiding solar radiation and allowing maximum natural lighting & ventilation. The perforated metal shade element is designed such that the natural light is entered into the building without over heating the building. The design approach seeks to use local materials with low environmental impact, and easy to maintain, that are durable & reliable which will be introduced in the coming chapters.

3.2.4 Approaching to The Building

3.2.4.1 Site Plan

Mainly the site is approached from two directions which are the Eastern city square and Western upper park square. Main entrance is from the road side , directly connected to city square, bus stop, drop off point, taxi stop and lower green network.

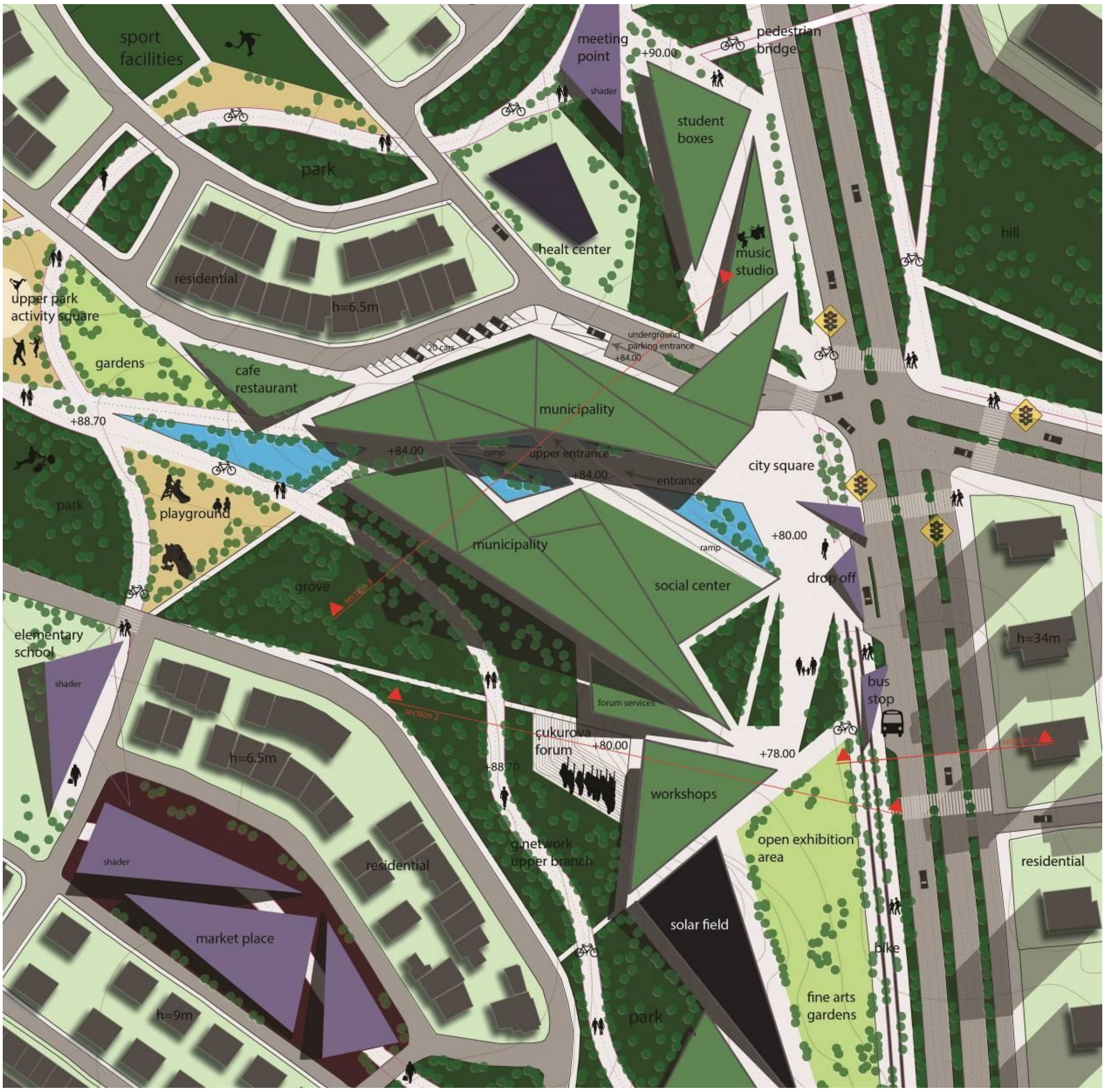


Figure 3.8 – Site Plan

The diagonal entrance axis from the city square reaches the entrance box of the building complex where visitors are distributed into three masses. The western part of the axis which is coming from the upper park square along the restaurant and water element arrives to the building's courtyard and the entrance box with a ramp. Along the road side permanent and temporary fine arts gardens and open exhibition areas welcomes the visitors to the social heart of the district where forum and its facilities located with the social center. One of the tectonic triangles is used for solar panels to produce energy for the complex. The roof of the social center is designed to be the ramp to go to the second level entrance of the municipality and to the upper park forming the upper courtyard. On the north side of the building music studio and student boxes lead the visitors to the meeting point and high school. This area, student square, is directly connected to sport fields and pedestrian bridge crossing the 50m width road. The 50m road section is modified in Site Section 1 (figure3.9) Site Section 2 and 3 show the relations of various functions within the park in figure 3.10.

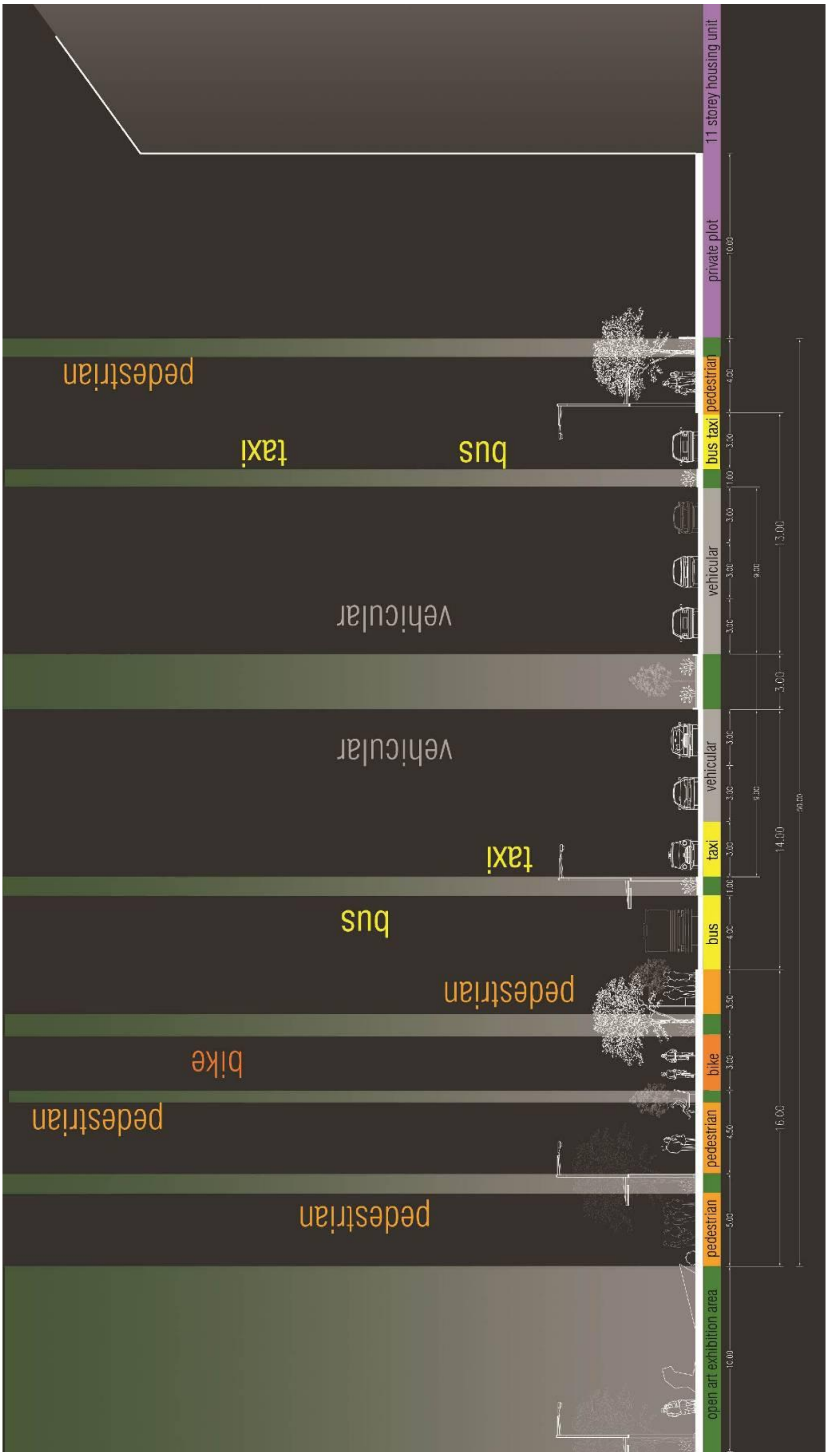


Figure 3.9 – Site Section 1

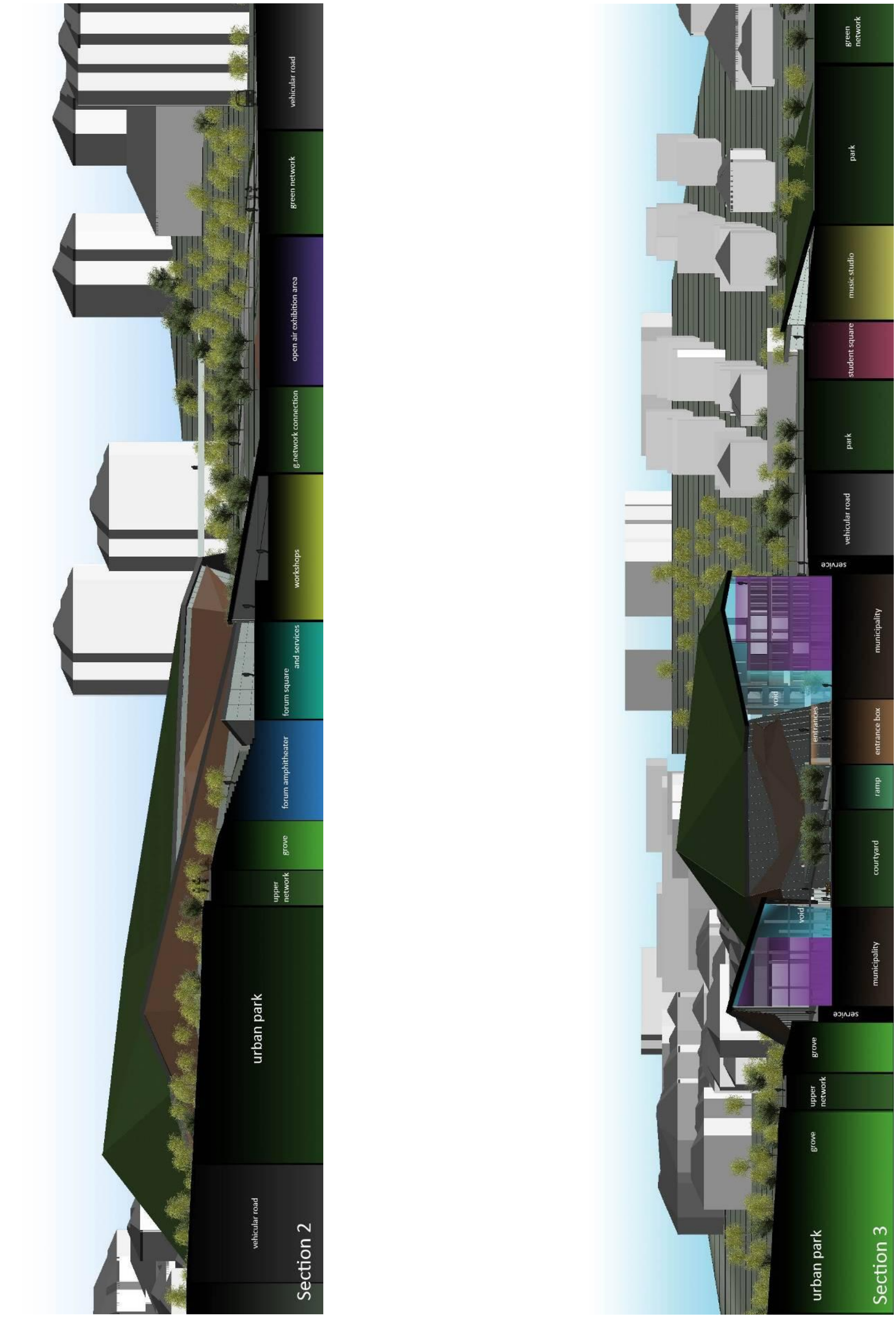


Figure 3.10 – Site Section 2 & 3

3.2.4.2 Accessibility

Figure 3.11 – Accessibility 1 - Vehicular and pedestrian traffic

Figure 3.12 – Accessibility 2 - From street to park

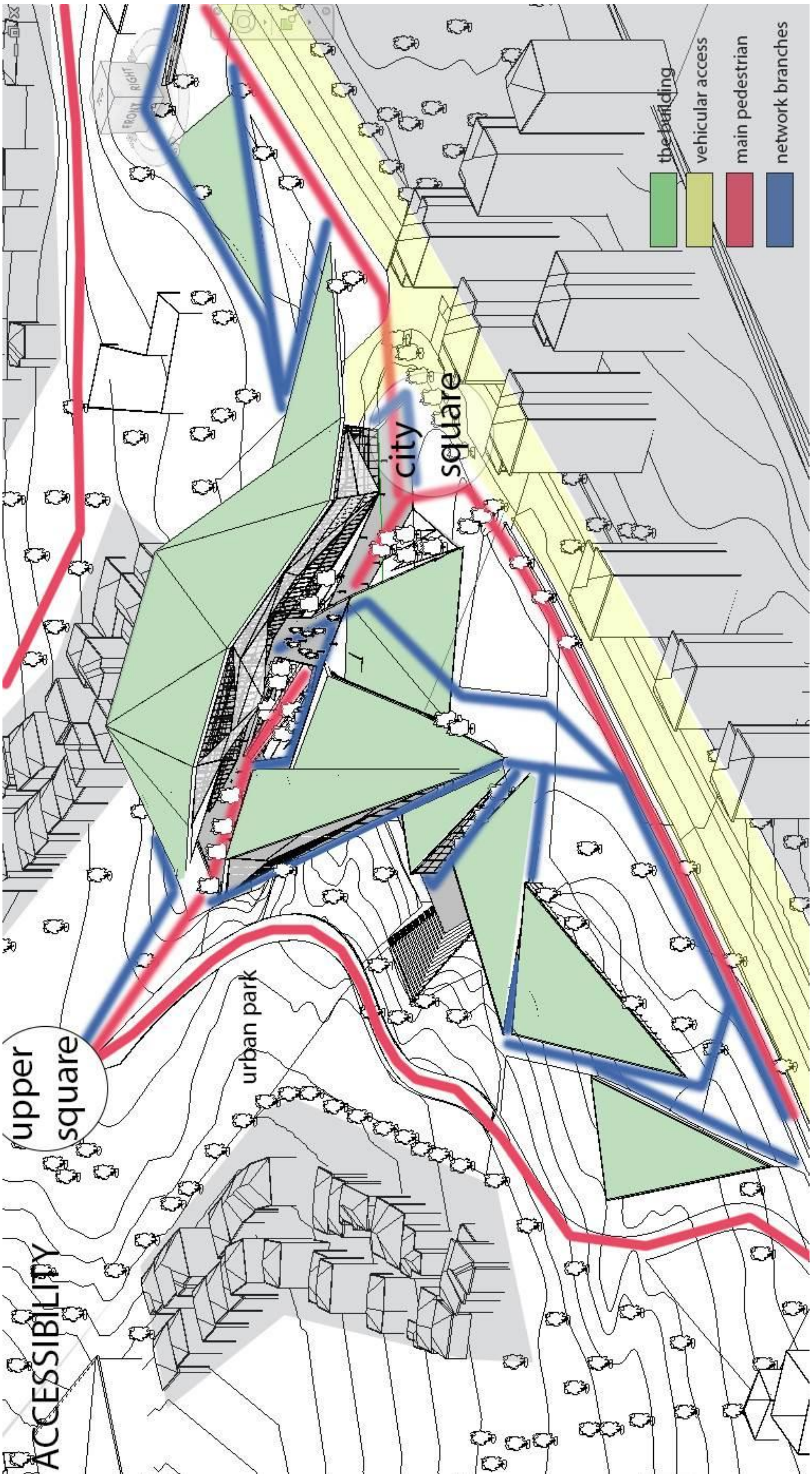


Figure 3.13 – Accessibility 3 - Pedestrian dominance and connection

3.2.4.3 Entrances

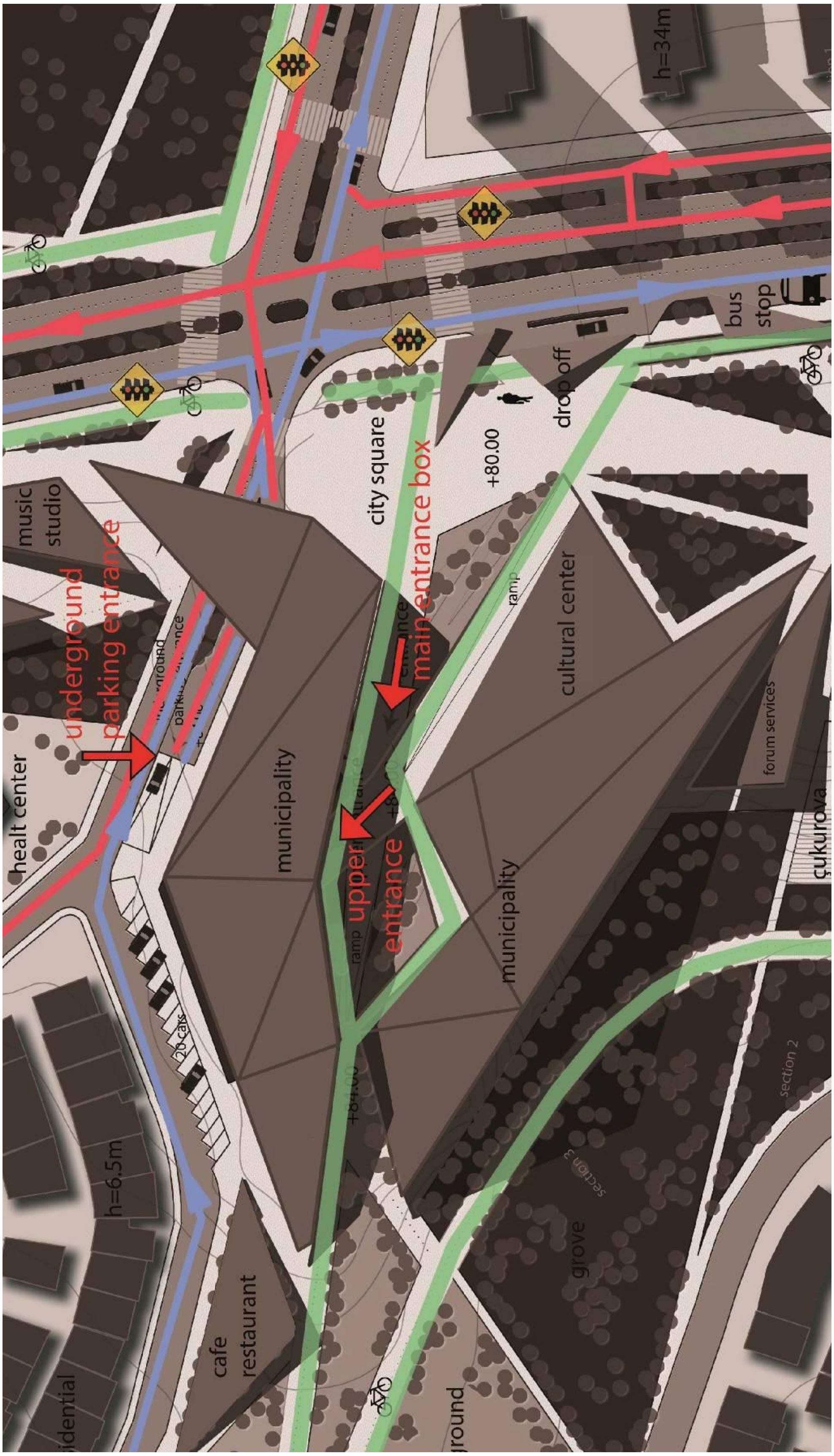


Figure 3.14 – Entrances

3.3 The Building

3.3.1 Volume

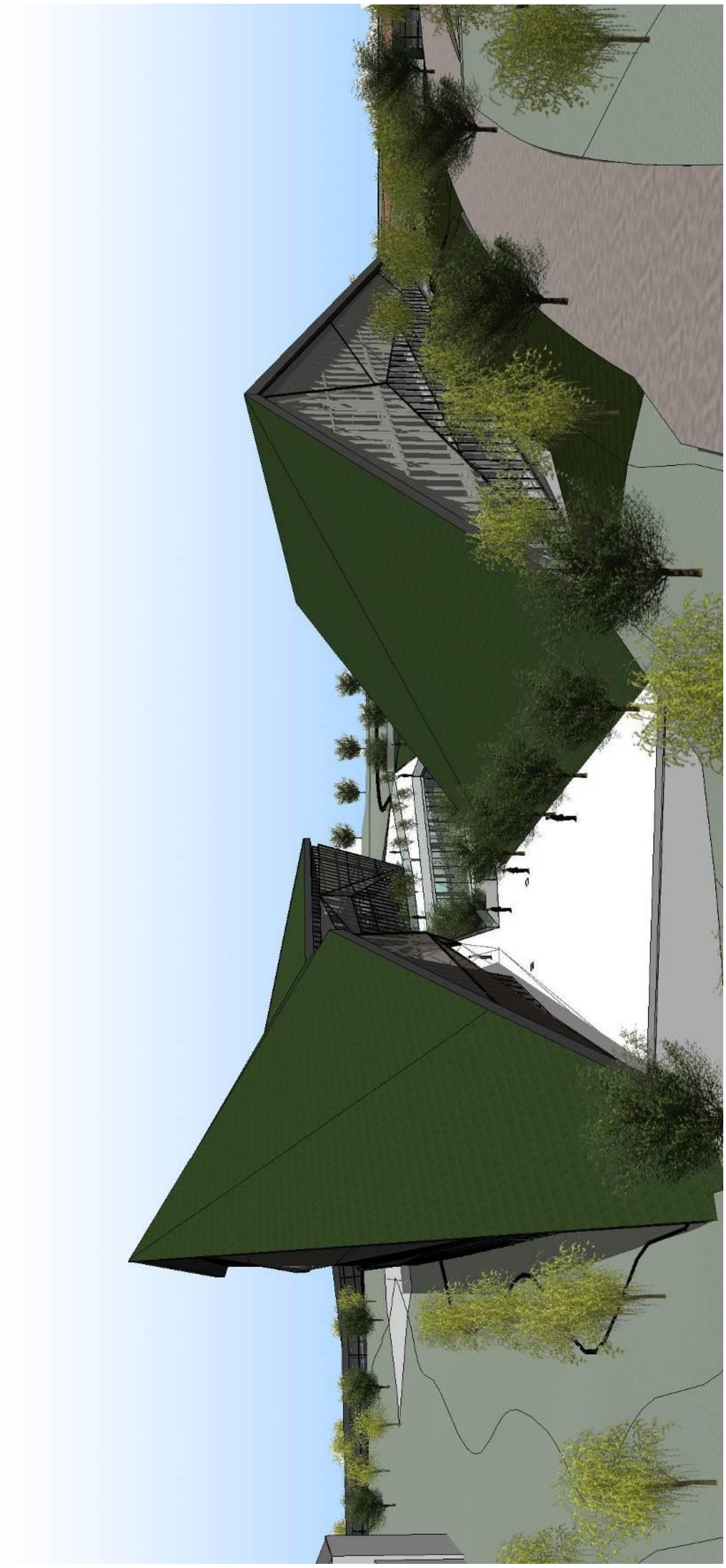


Figure 3.15 – Escalating from the park

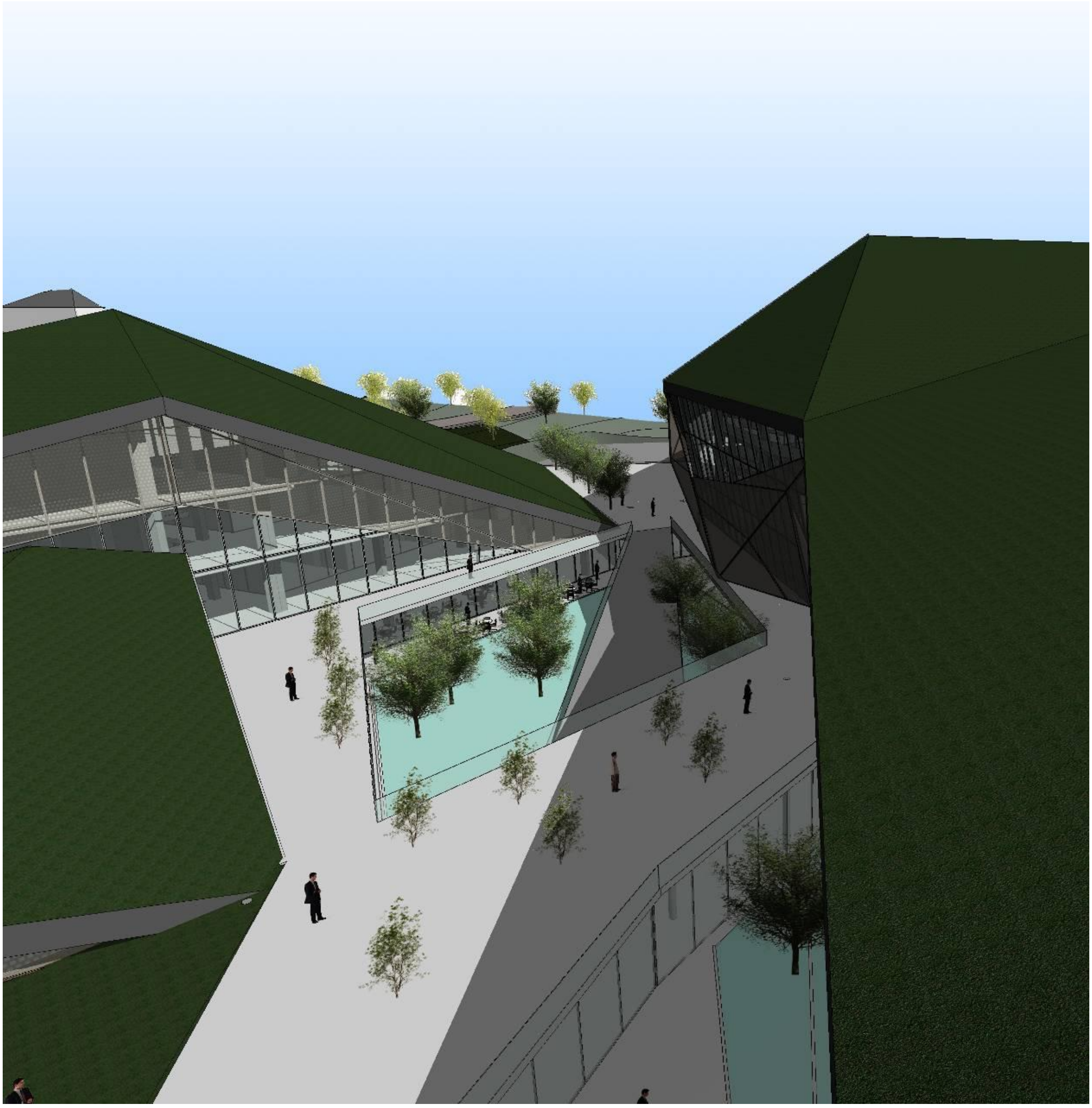


Figure 3.16 – Common ground use of the volumes

The volume rises up from the ground as pieces of land forming the buildup hills of the park. The essential characteristics of the volume are based from the human perspective. Considering the loaded program in a small plot, the masses are divided in parts in order not to create a huge single building. The connection of two levels is smoothly handled with the ramp which goes down to the entrance box and the walkable roof of the cultural center. On the higher level, entrances create the urban scale balcony and continuity. With the balcony two ground levels have been composed increasing the interaction between levels. The maximum height of the building is limited with five floors in the northern mass, three floors on the south.

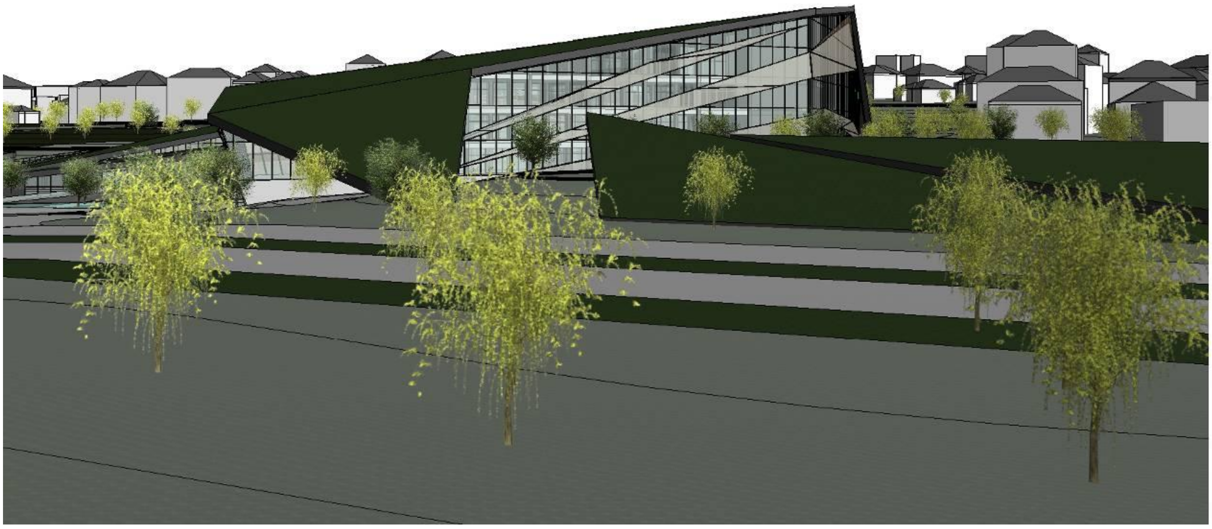
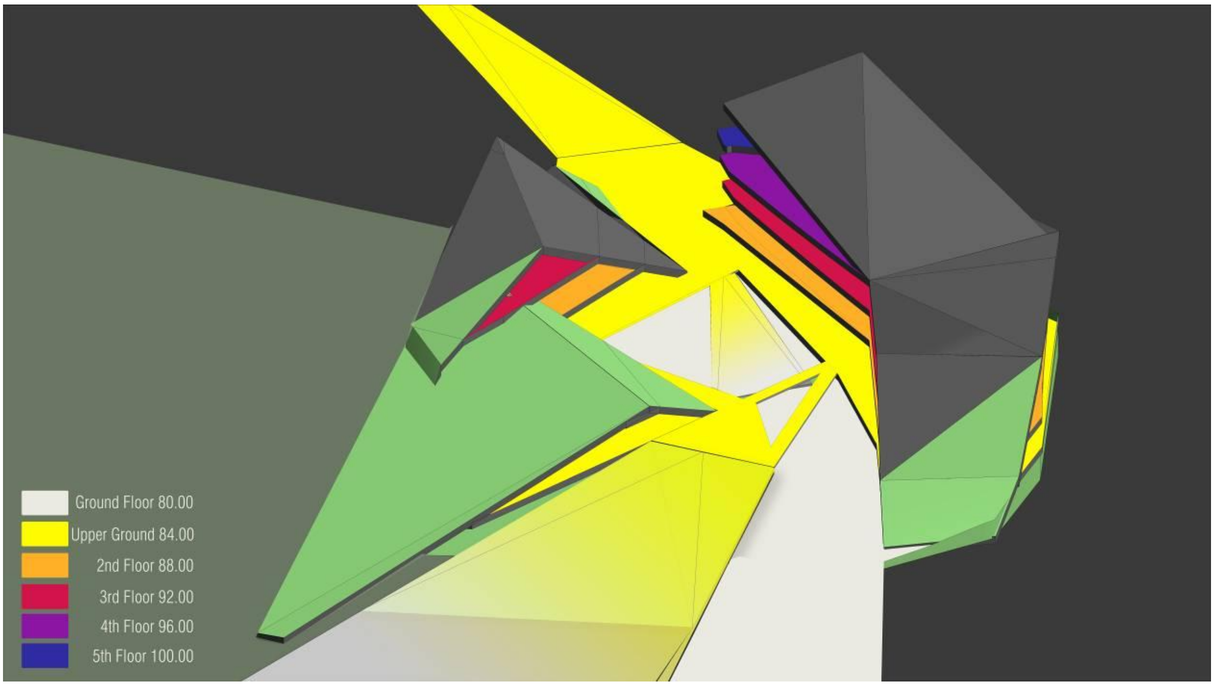


Figure 3.17 – Raising volumes from the north



The northern part of the plot is included to the design in order to completely relate the building to the site. Two volumes introduce the rising of the buildup land which are used for the park functions and a third one is connected to the roof of the building. The northern façade is used for office spaces which is also the only façade of the building perpendicular to the ground. The upper ground level (+84.00) is where the main functions are placed and is the biggest common ground for users.

3.3.2 Circulation

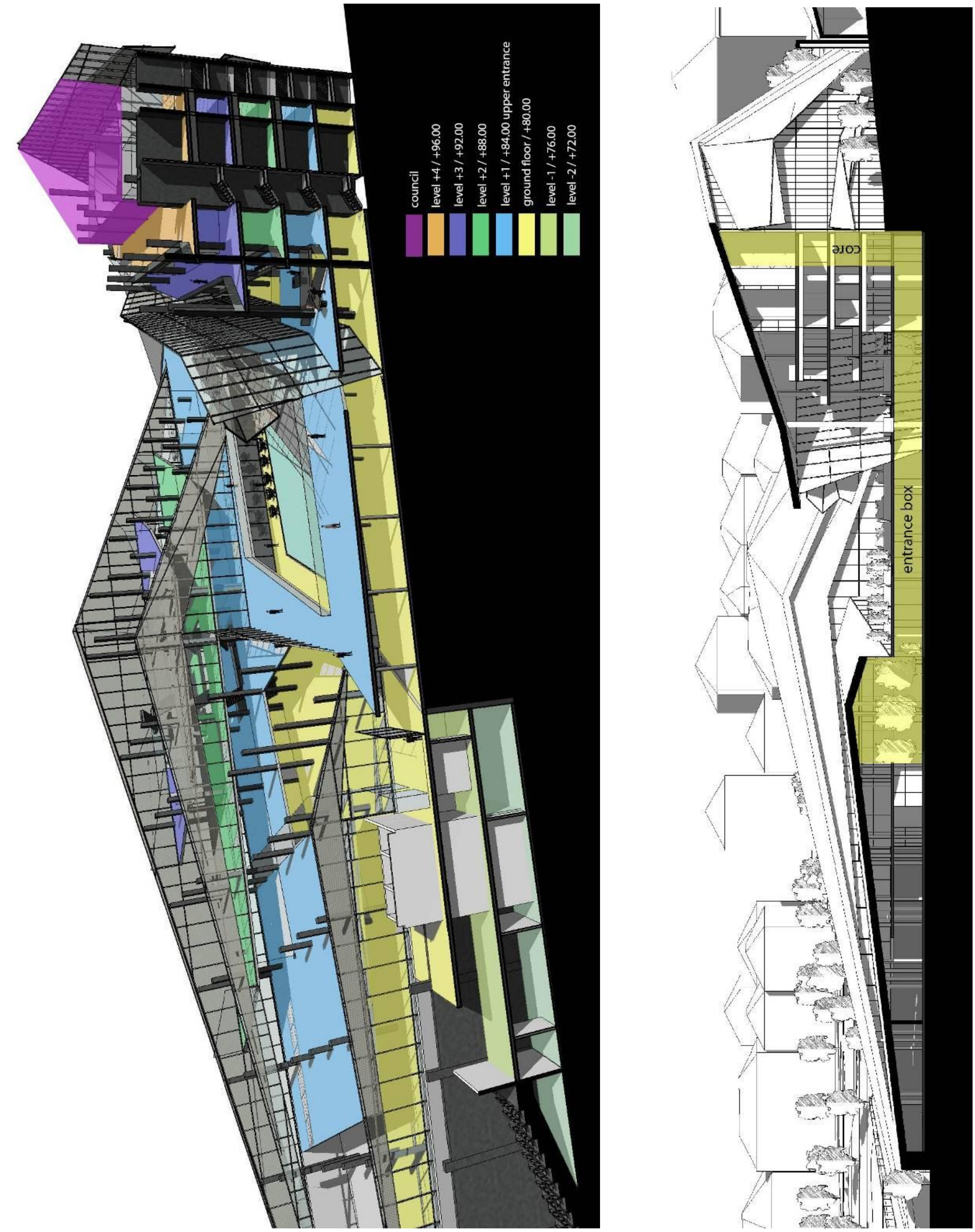


Figure 3.18 – Circulation Schemes

3.3.3 Distribution of Functions

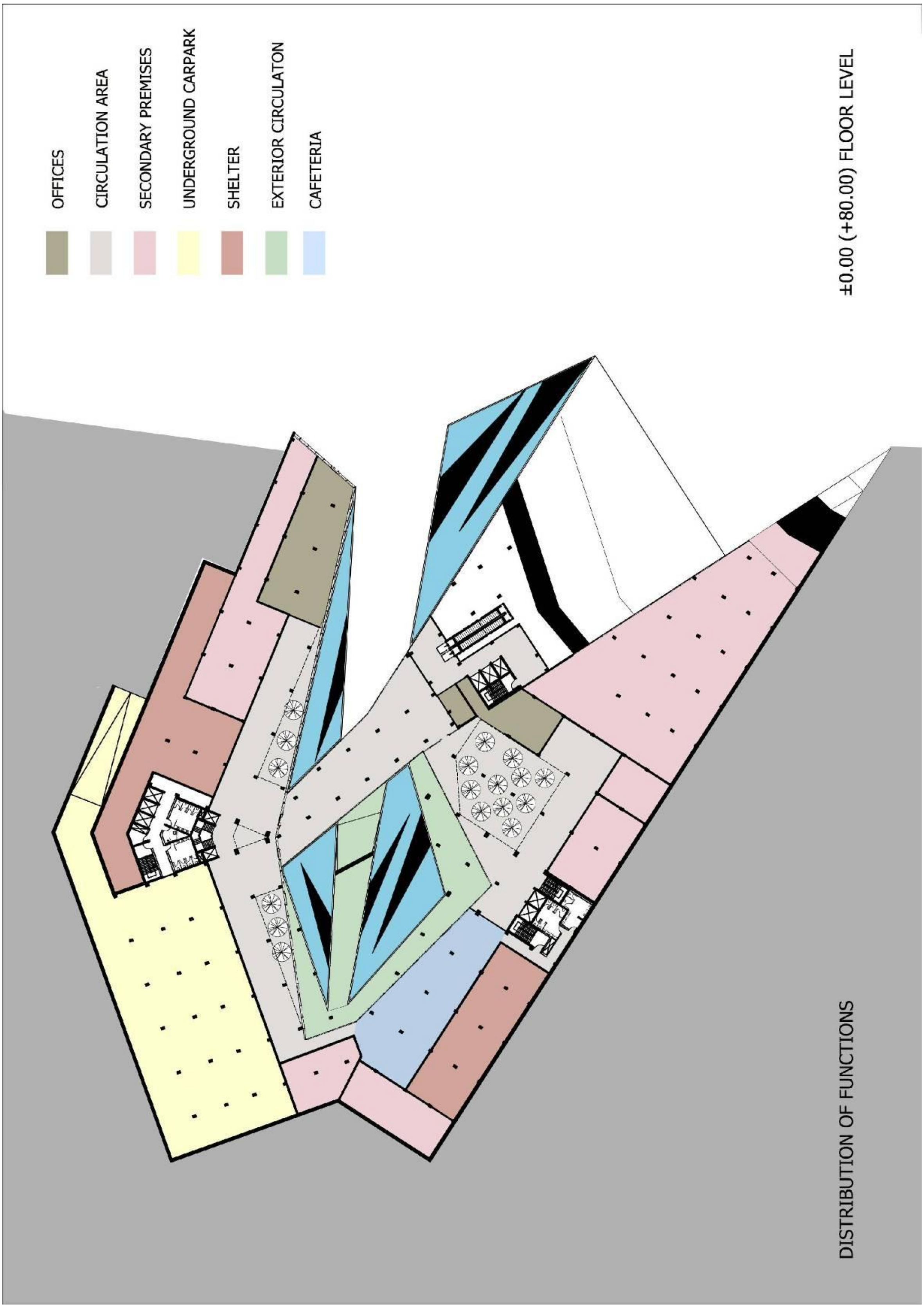


Figure 3.19 – Function Distribution Scheme Ground Floor

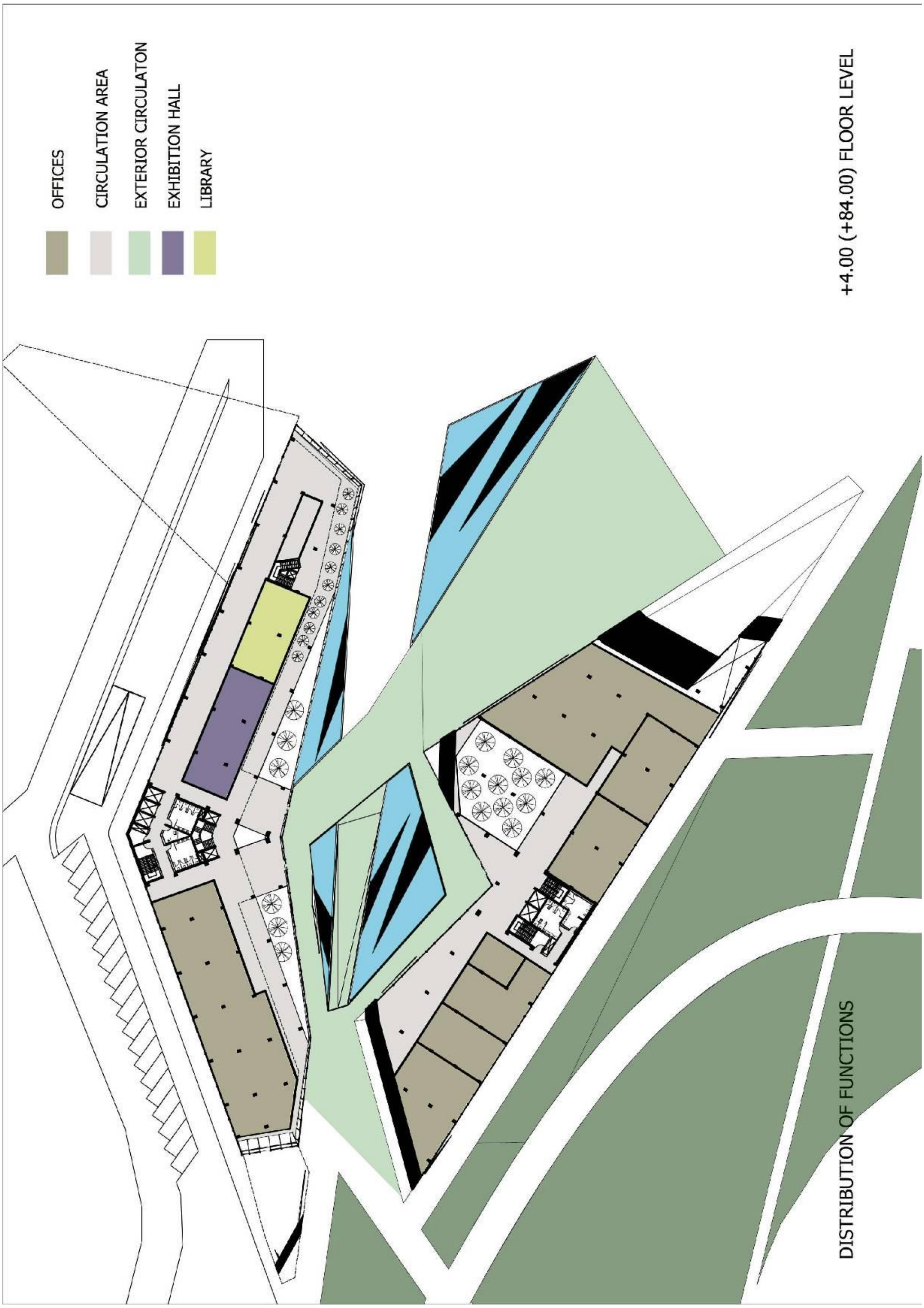


Figure 3.20 – Function Distribution Scheme Level 1 (2nd Ground Floor)

Figure 3.21 – Function Distribution Scheme Level 2

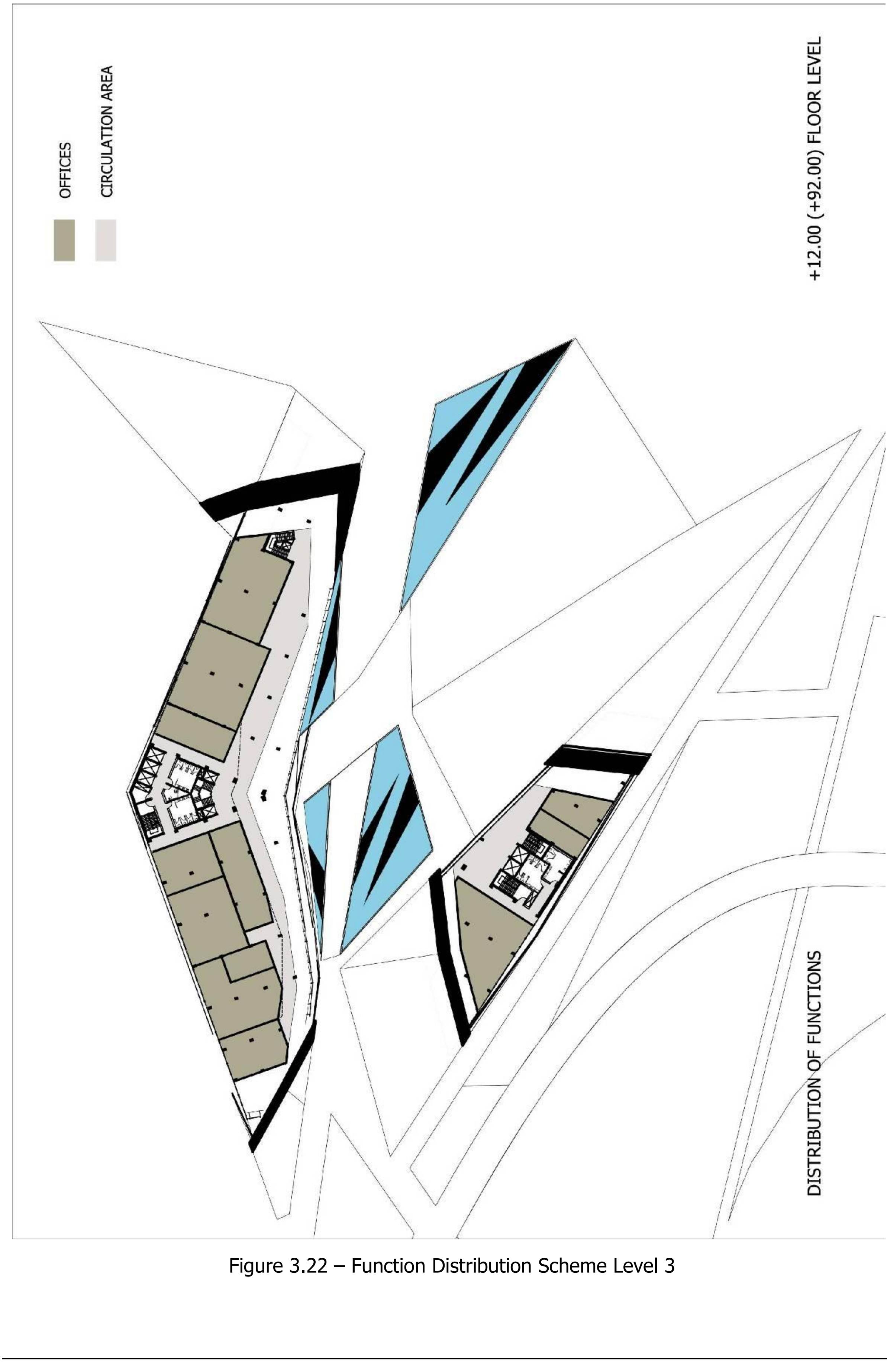


Figure 3.22 – Function Distribution Scheme Level 3

Figure 3.23 – Function Distribution Scheme Level 4

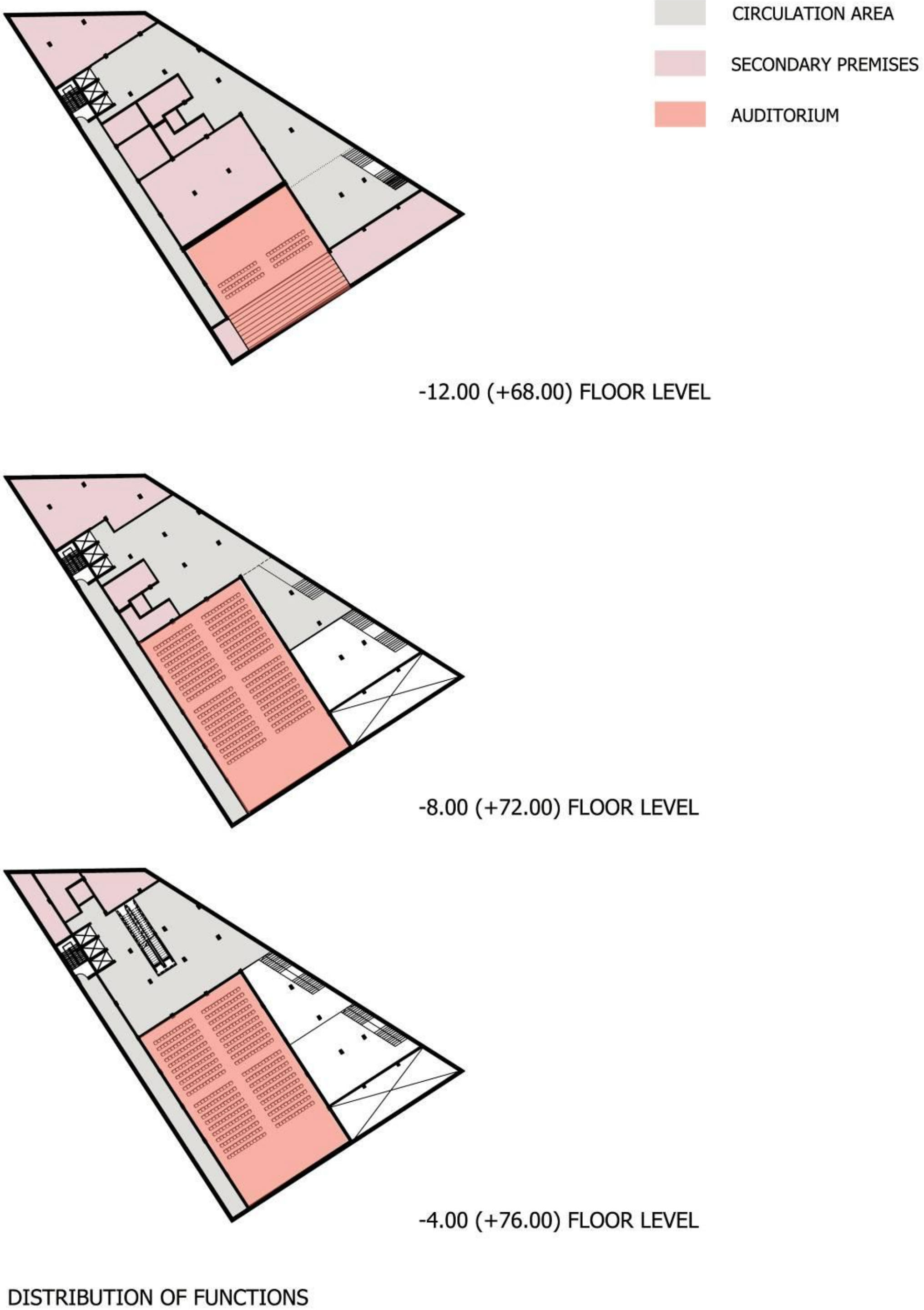


Figure 3.24 – Function Distribution Scheme Cultural Center

3.3.4 Distribution of Offices

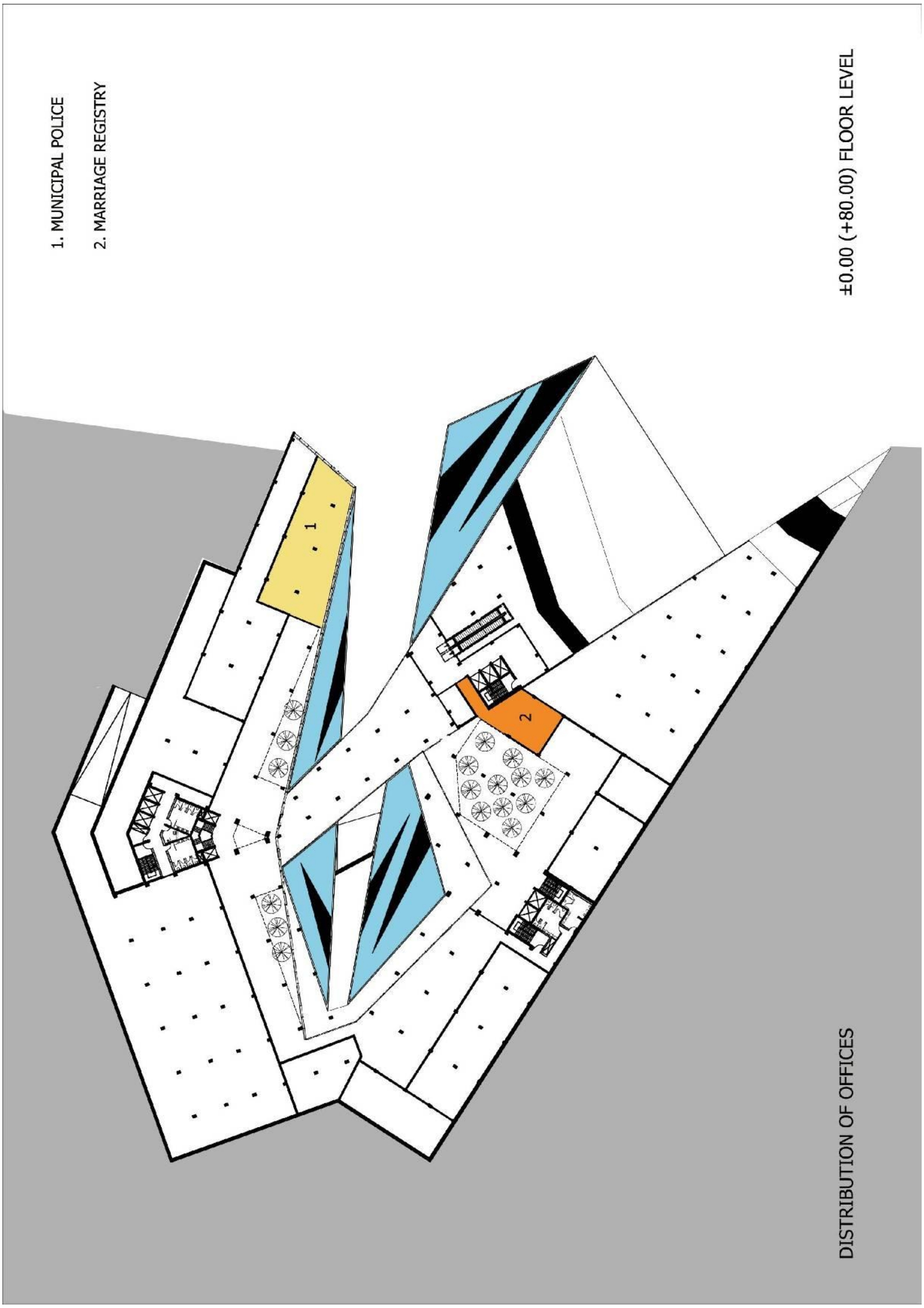


Figure 3.25 –Office Distribution Scheme Ground Floor

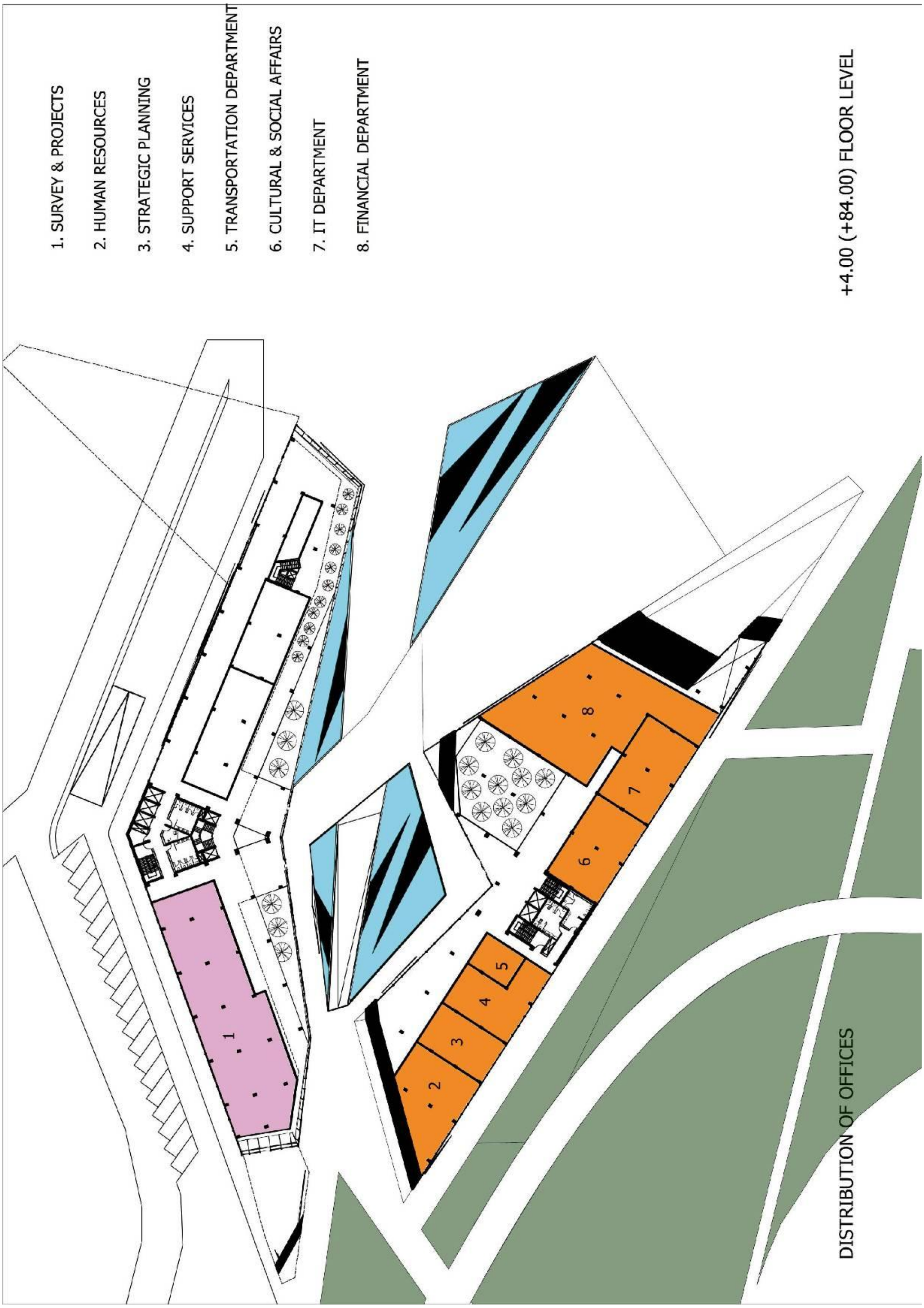


Figure 3.26 – Office Distribution Scheme Level 1 (2nd Ground Floor)

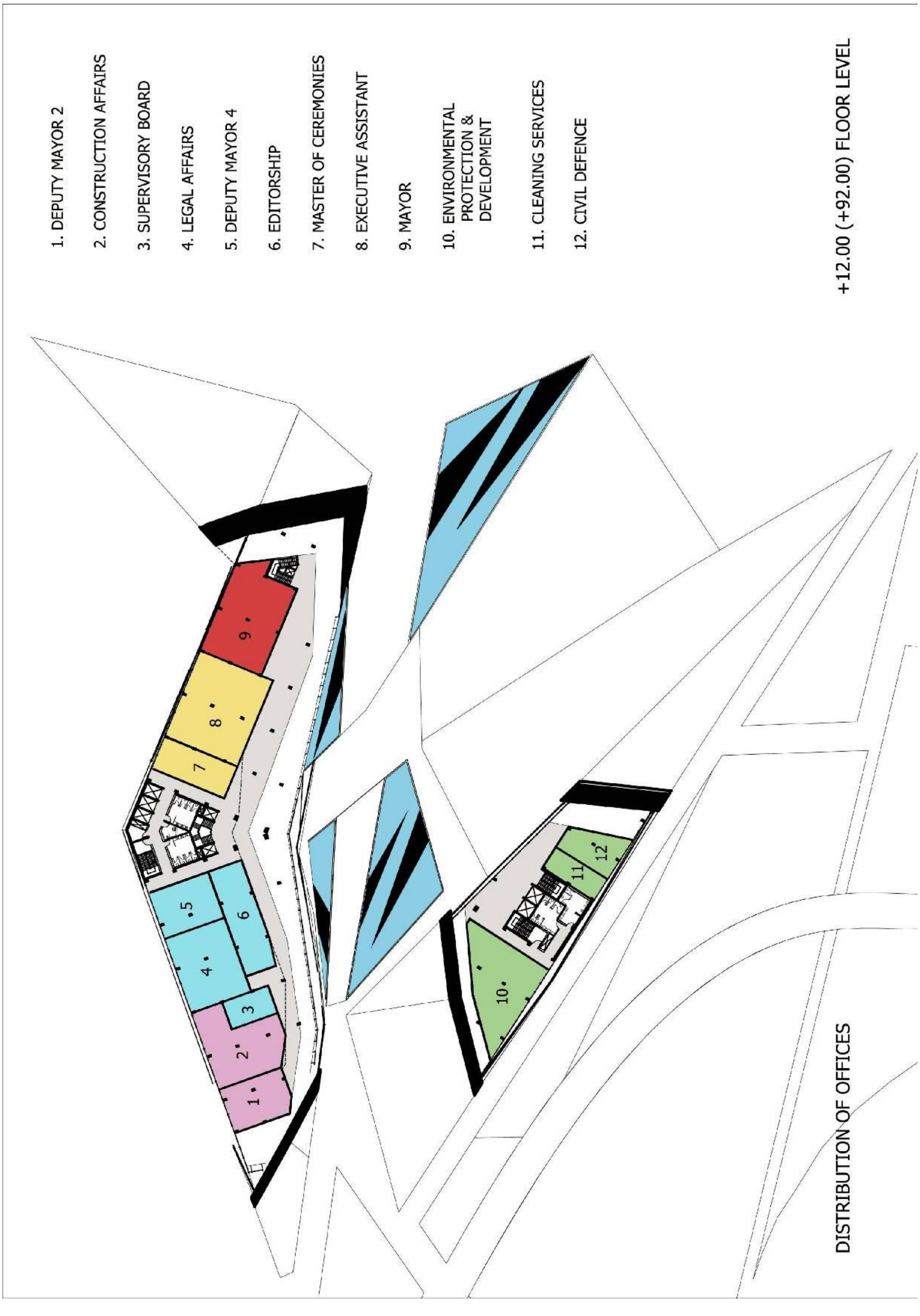


Figure 3.27 – Office Distribution Scheme Level 2

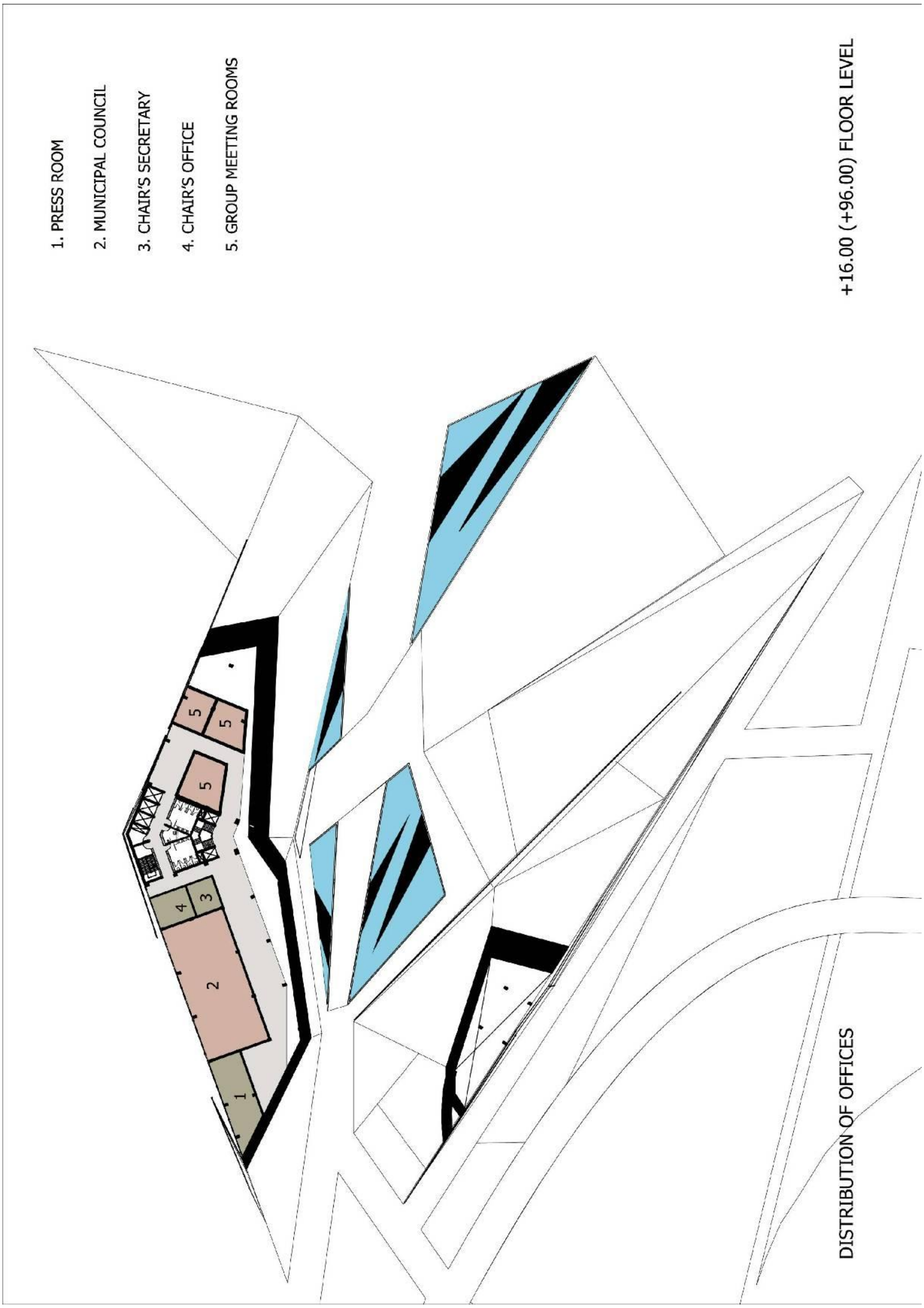
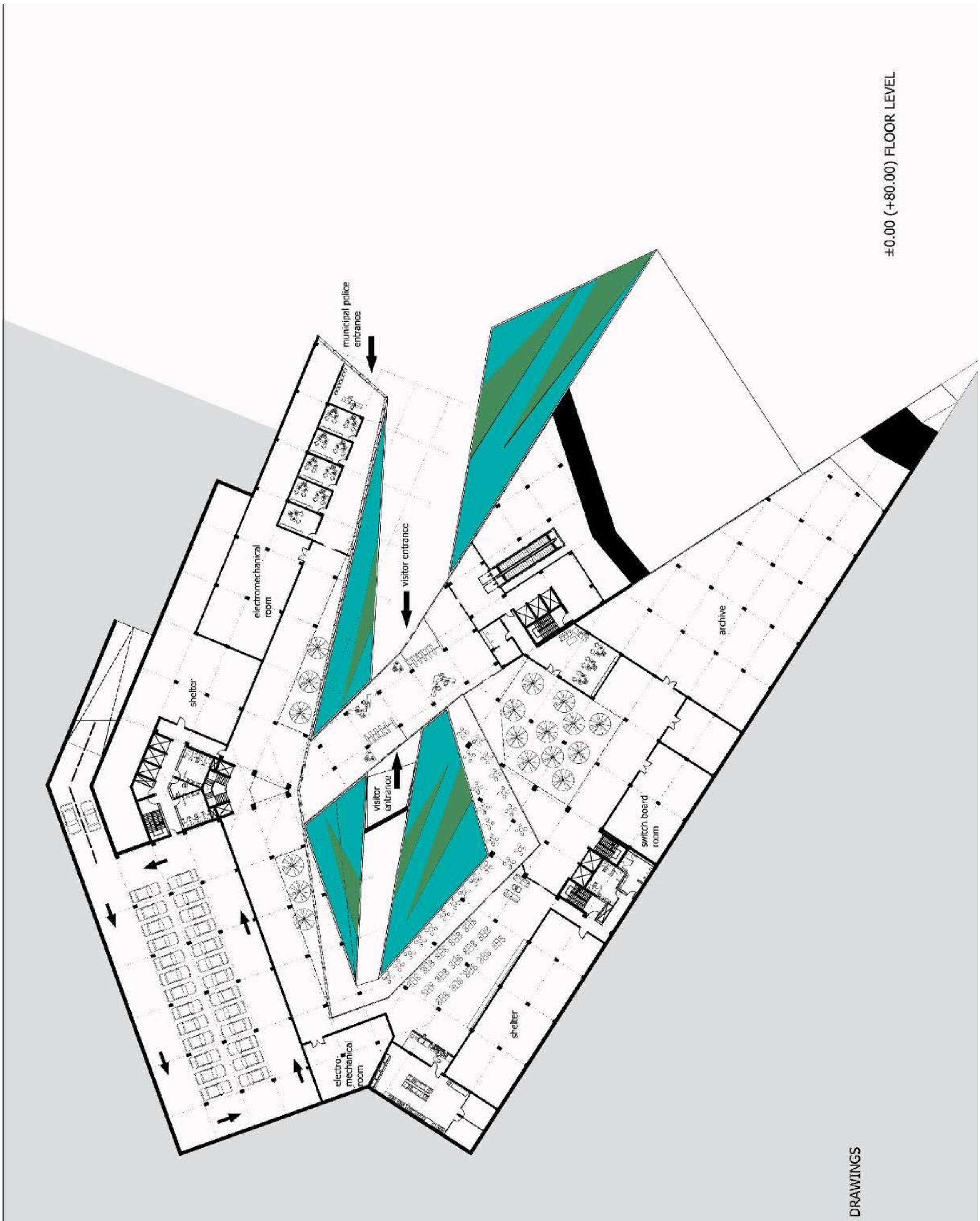


Figure 3.28 – Office Distribution Scheme Level 3

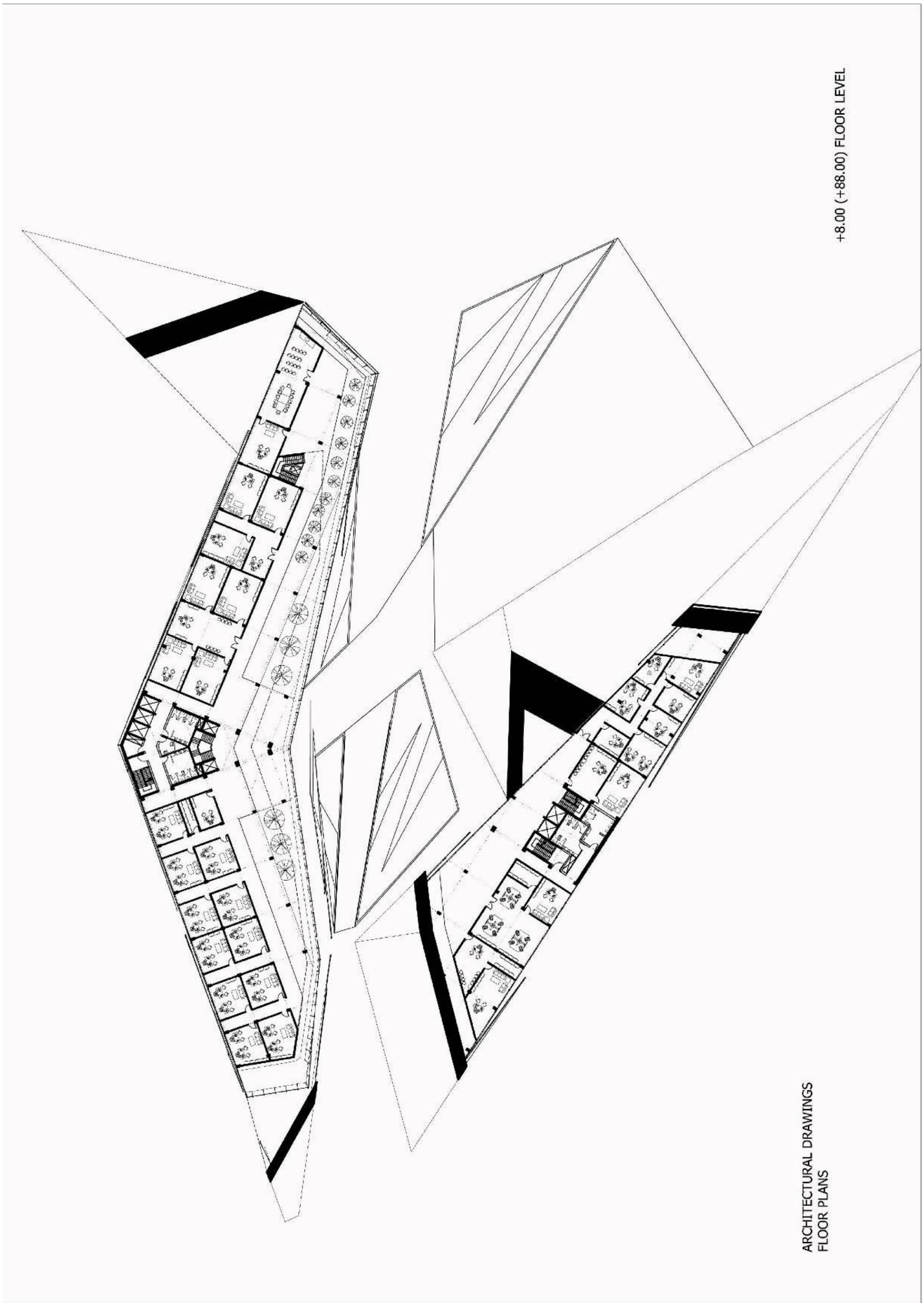
3.4 Architectural Drawings

3.4.1 Plans

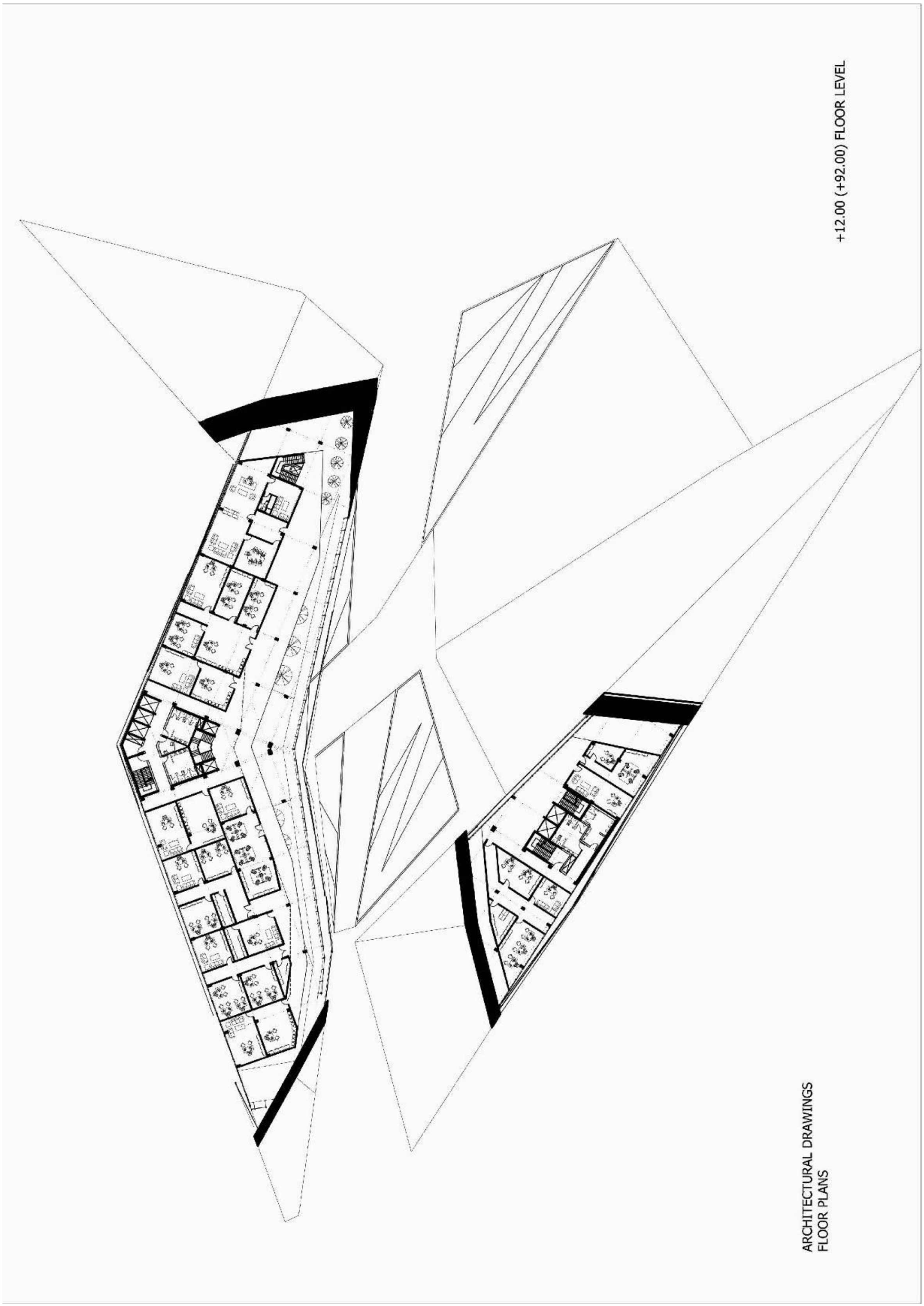


Drawing 3.1 – Ground Level Plan

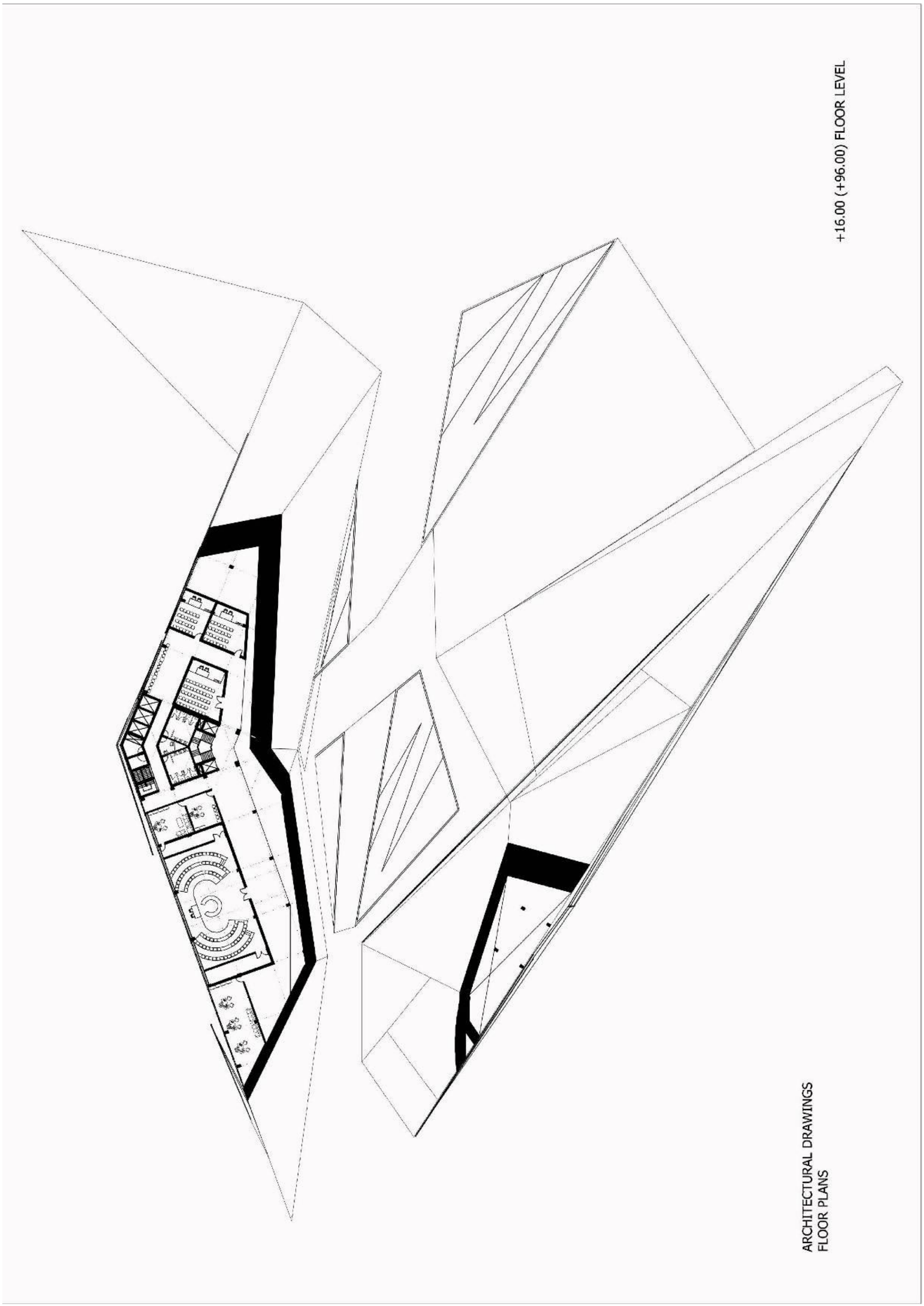
Drawing 3.2 – First Floor Plan (2nd ground level)



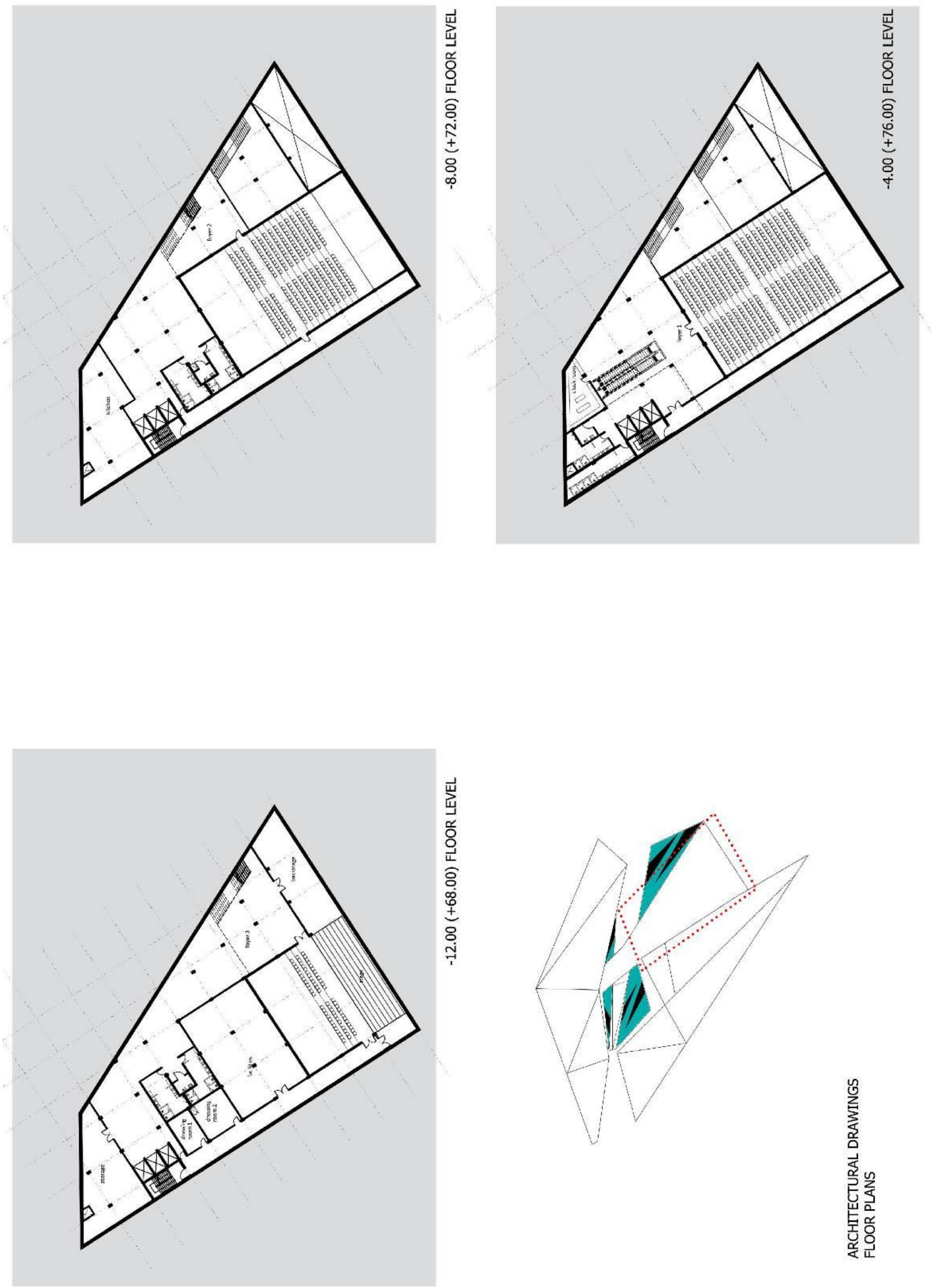
Drawing 3.3 – Second Floor Plan



Drawing 3.4 – Third Floor Plan



Drawing 3.5 – Fourth Floor Plan



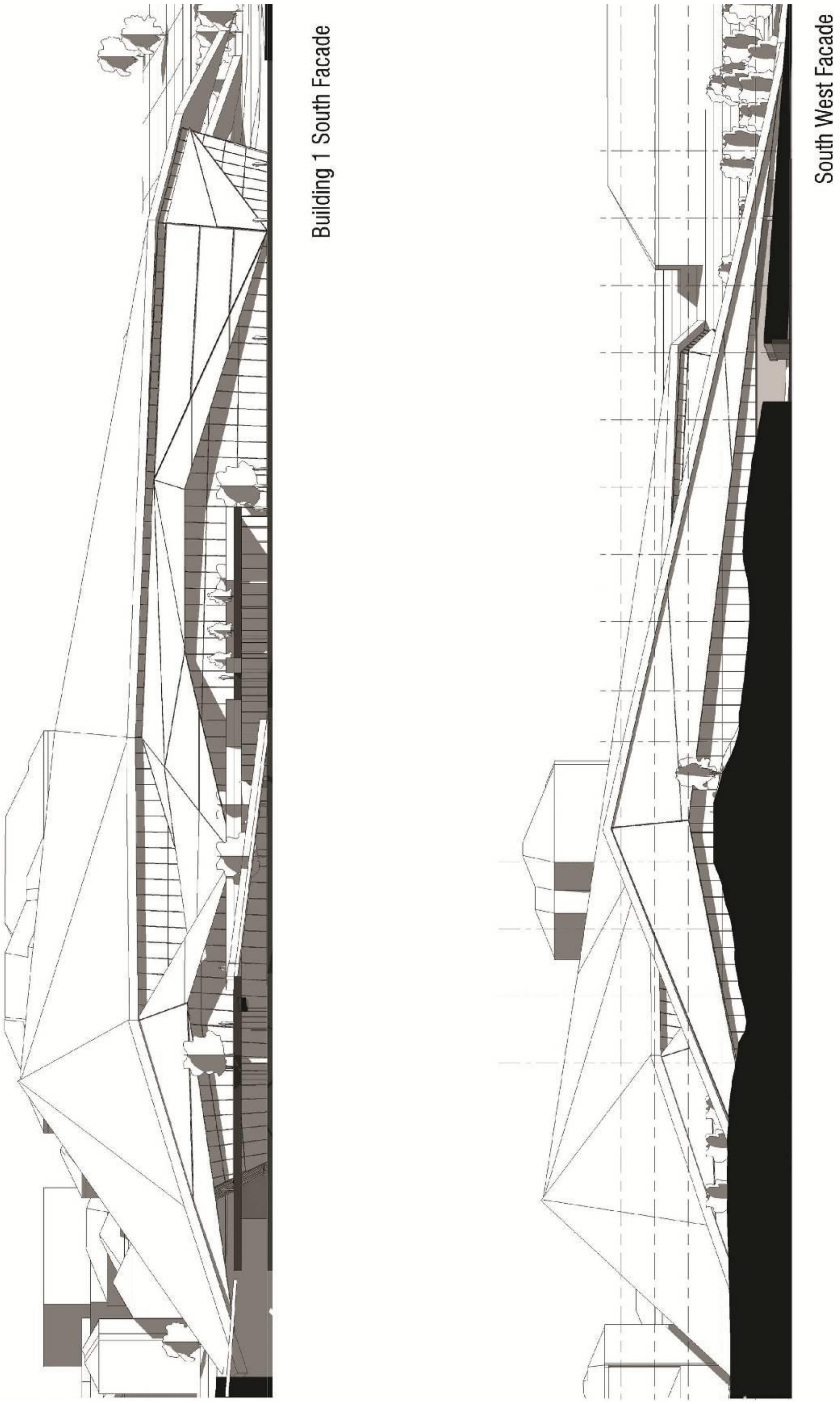
Drawing 3.6 – Cultural Center Floor Plans

3.4.2 Sections

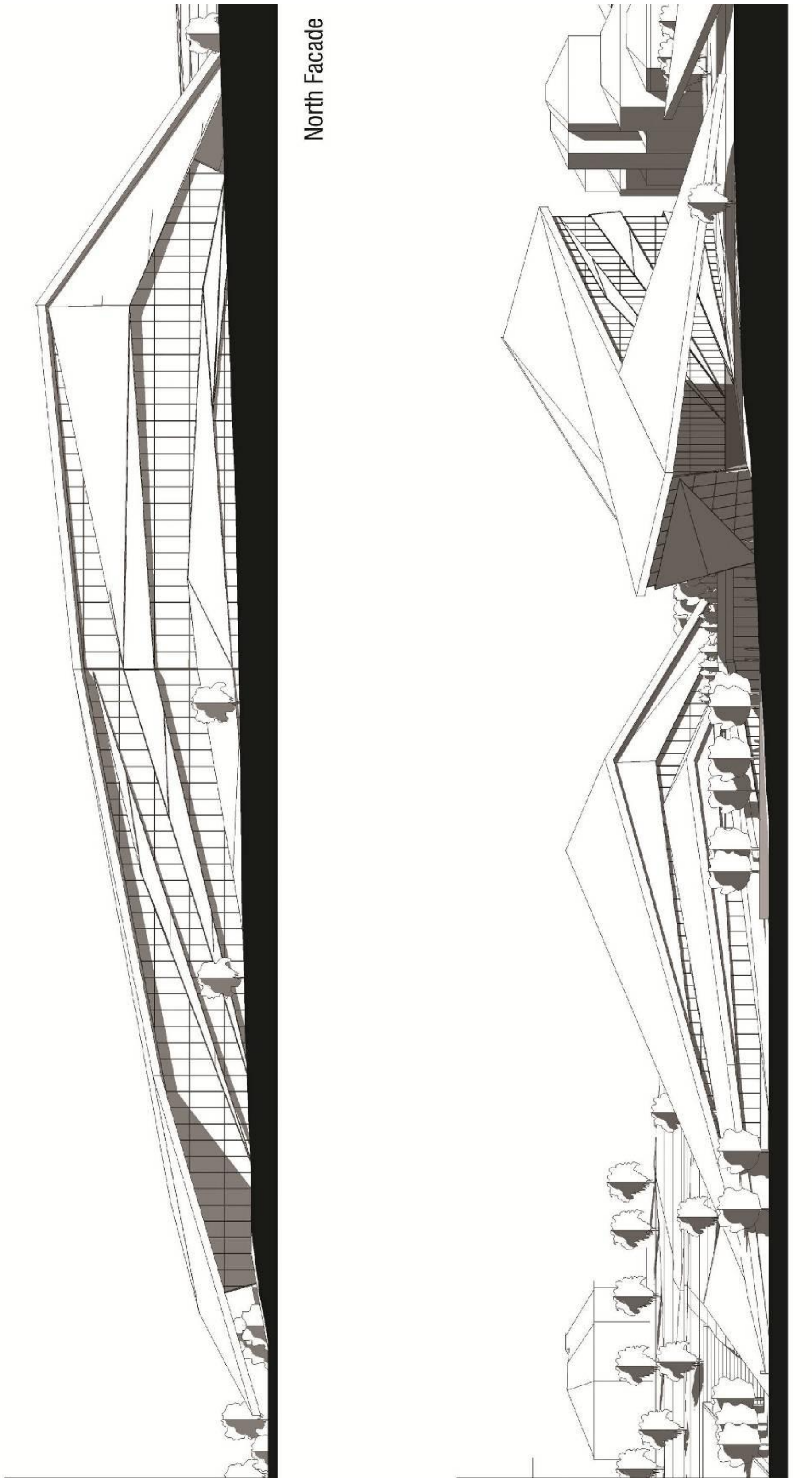
Drawing 3.7 – Section 1-1’

Drawing 3.8 – Sections 2-2′ & 3-3′

3.4.3 Elevations



Drawing 3.9 –South & South West Elevations



Drawing 3.10 –North & East Elevations

3.5 Renders

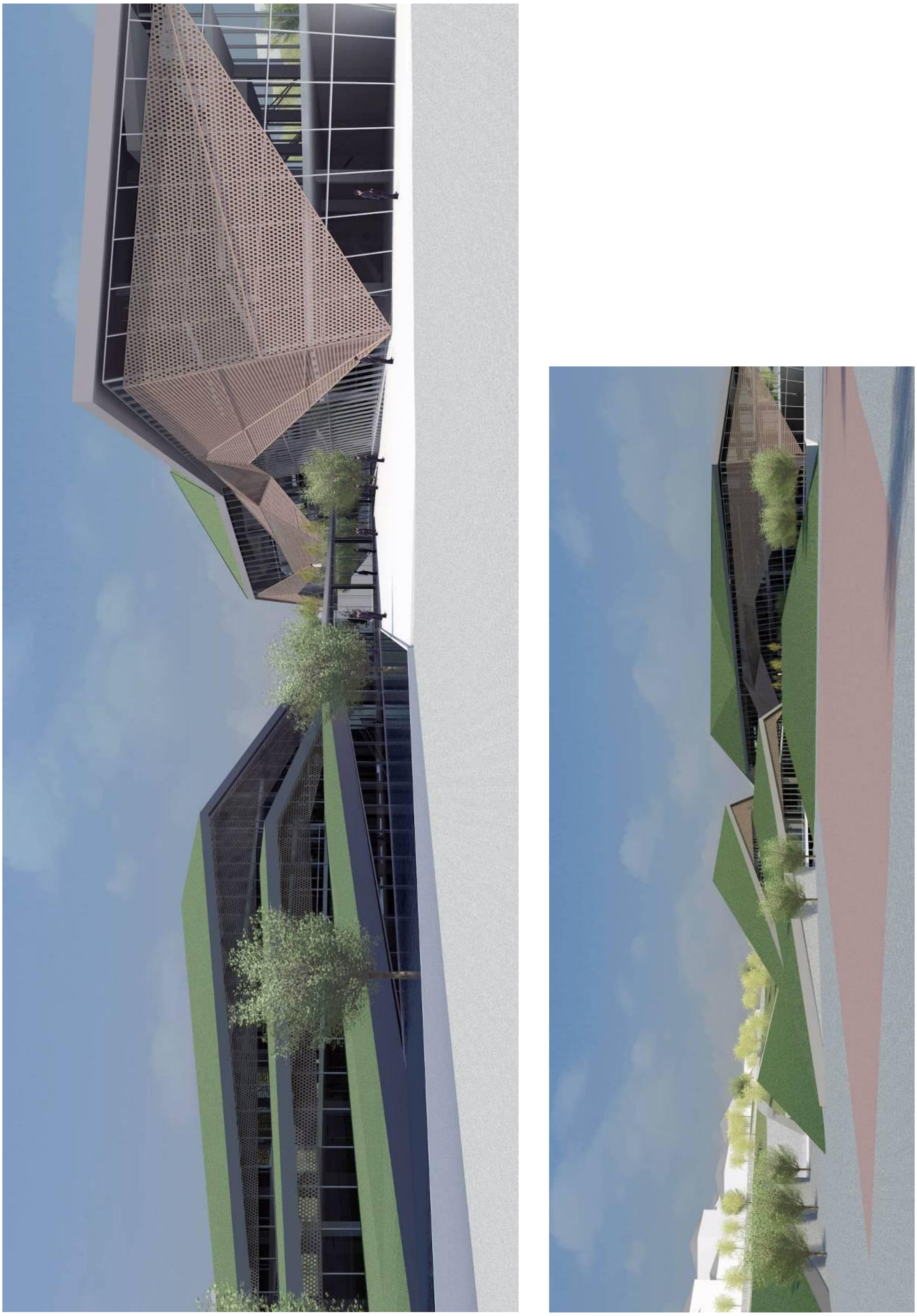


Figure 3.29 – Exterior Renders

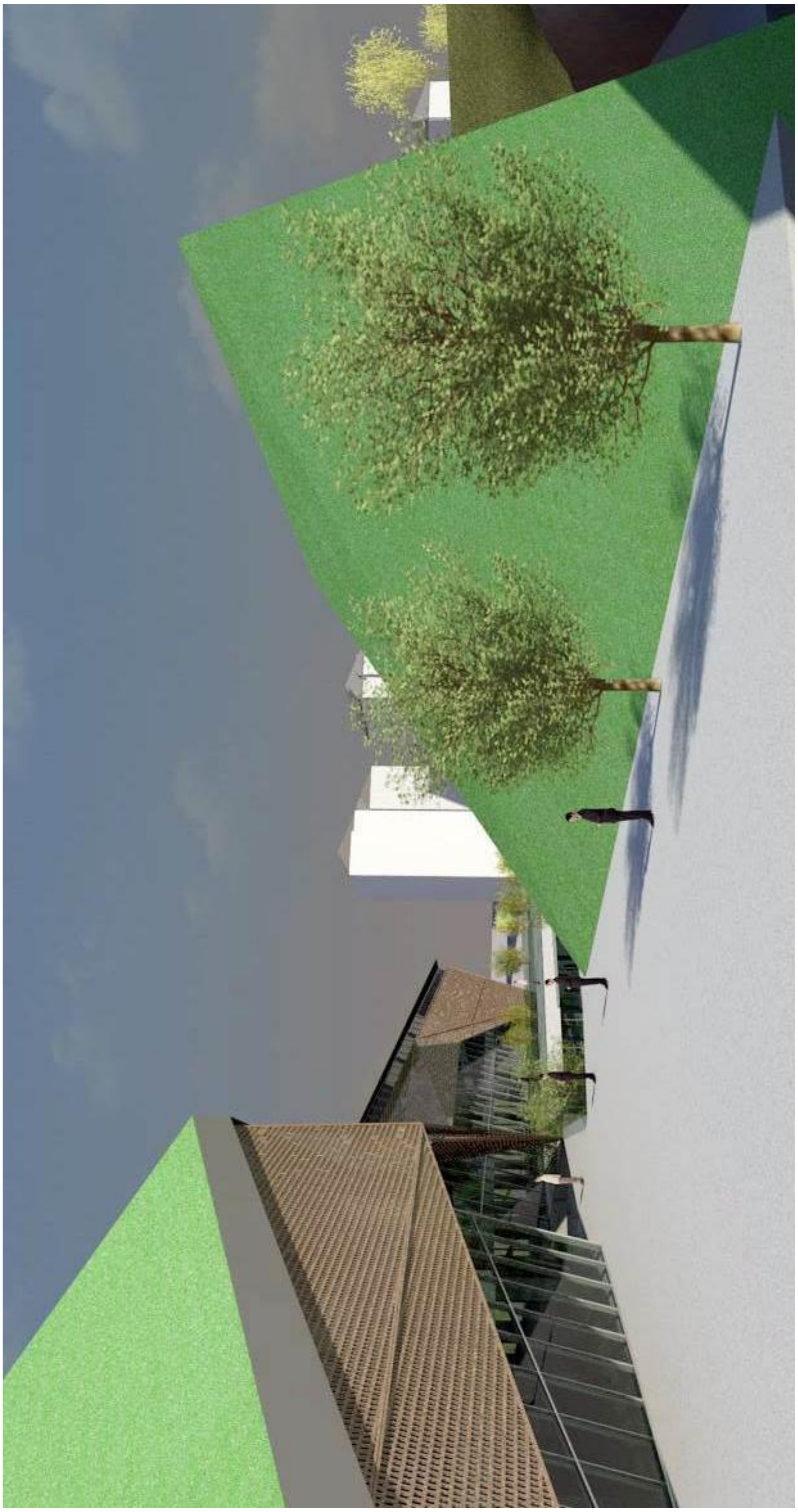


Figure 3.30 – Exterior Render

Figure 3.31 – Exterior Render

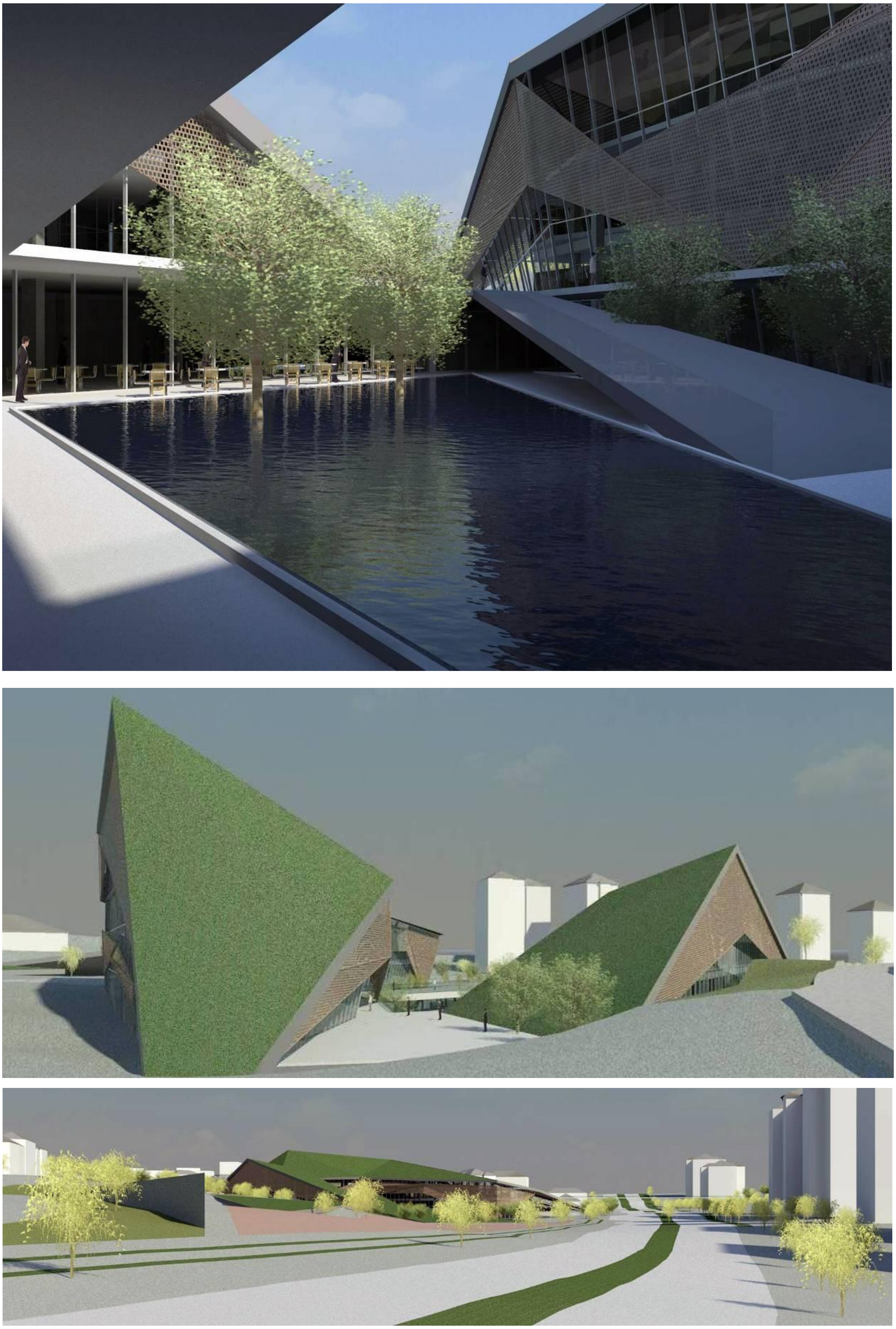


Figure 3.32 – Exterior Renders

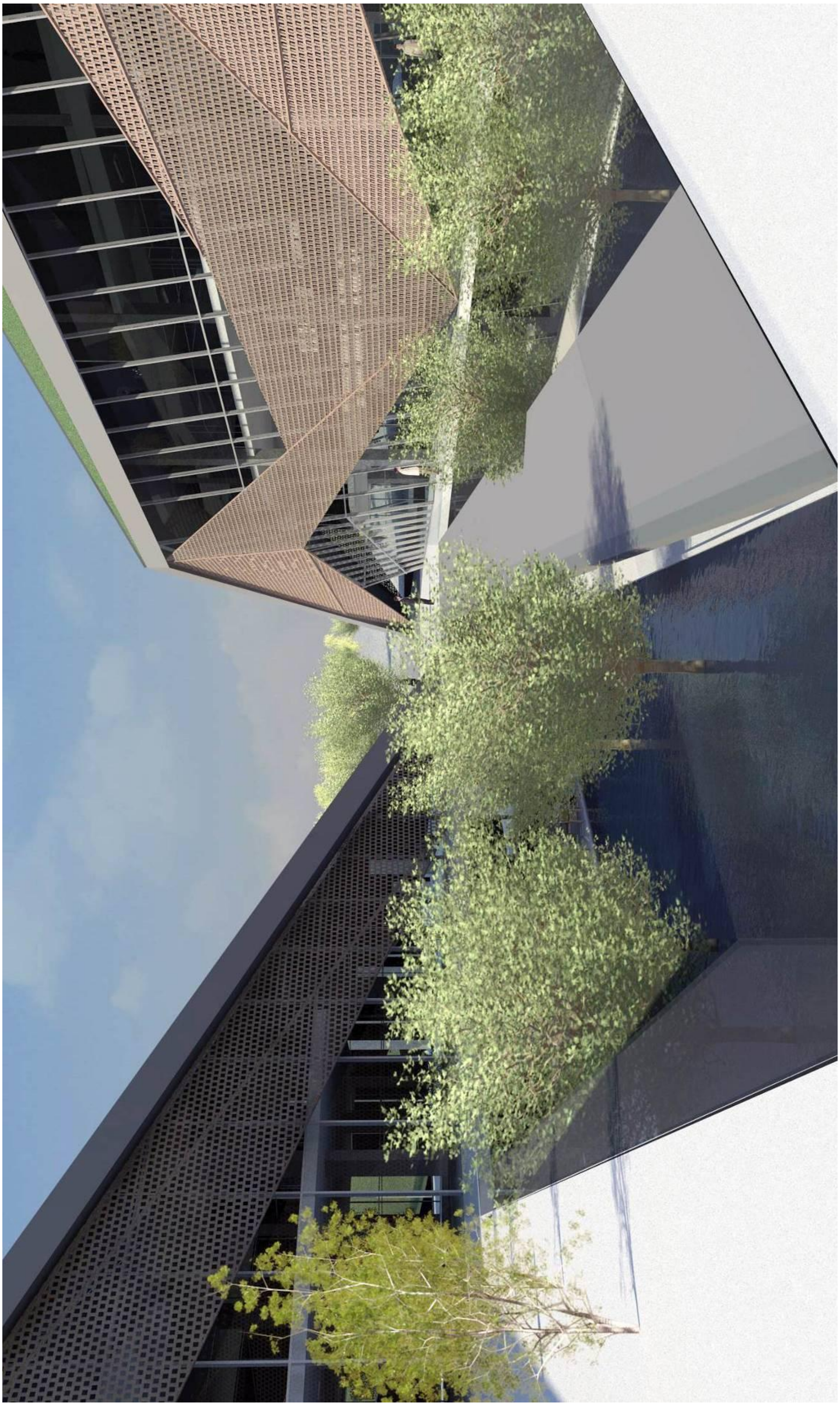


Figure 3.33 – Exterior Render

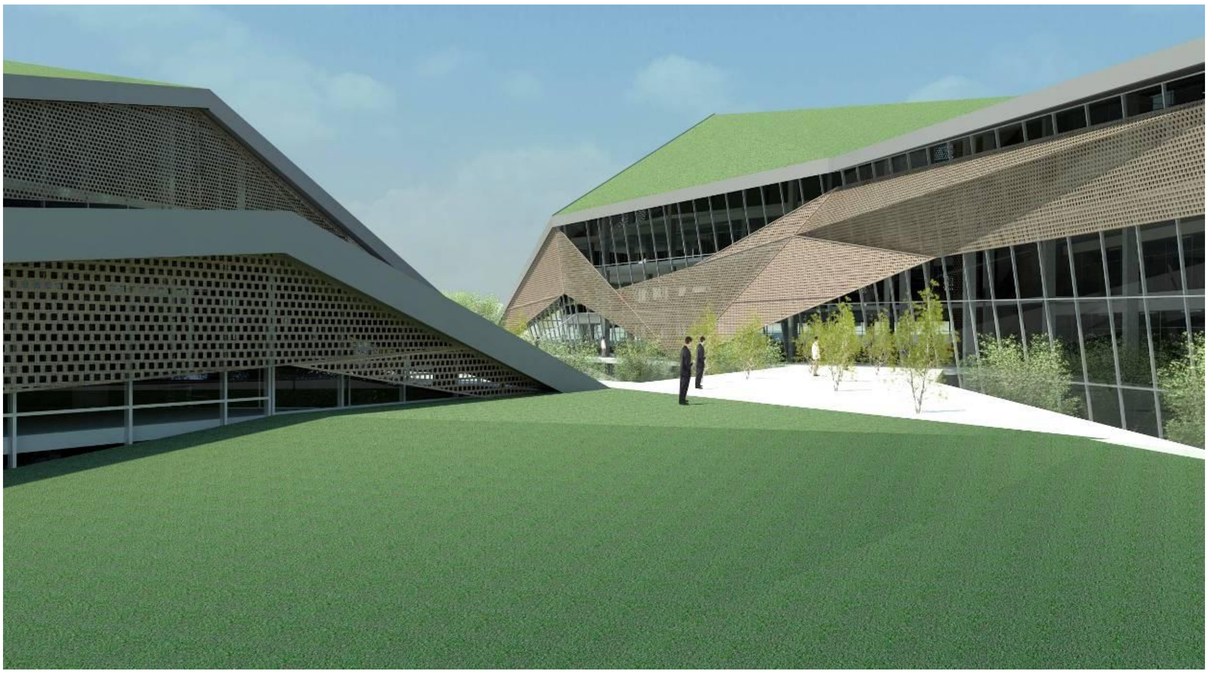


Figure 3.34 – Exterior Render

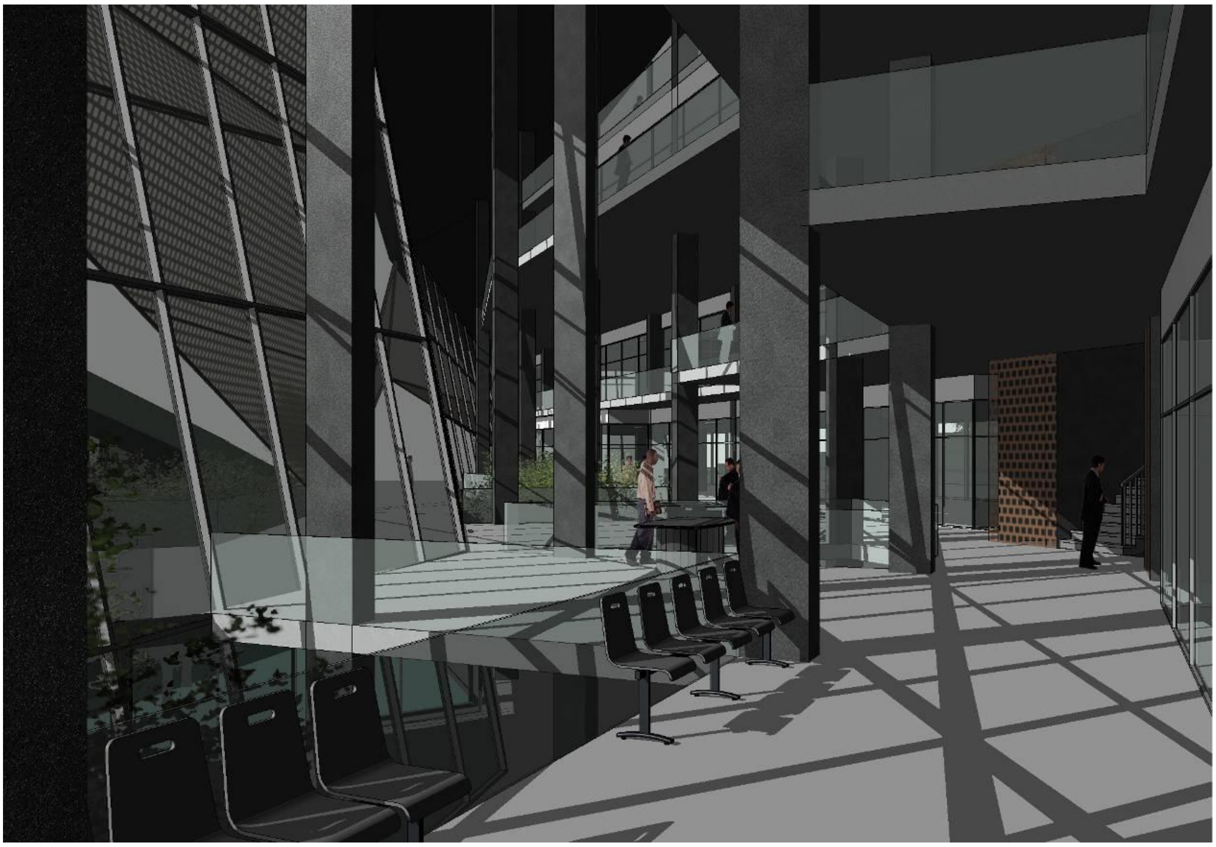
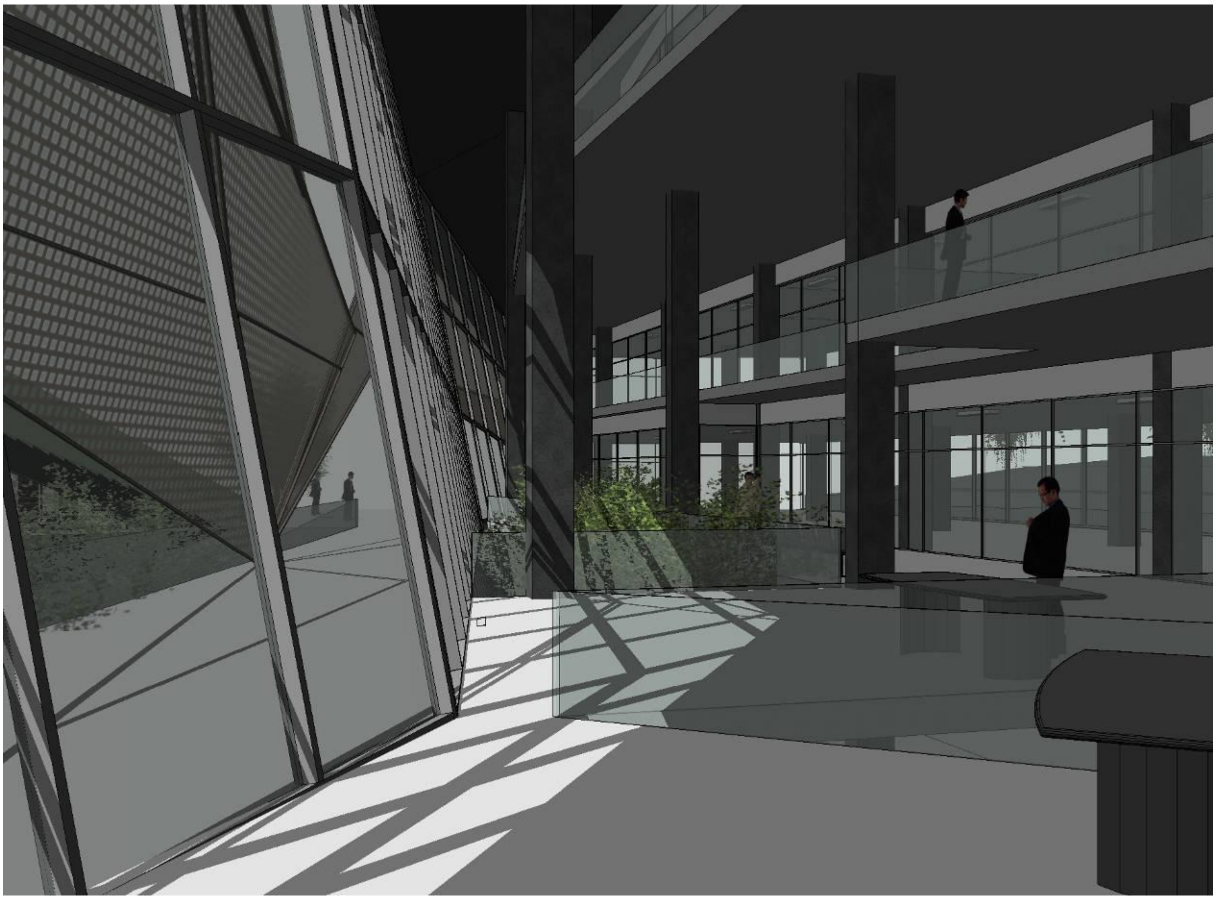


Figure 3.35 – Interior Render



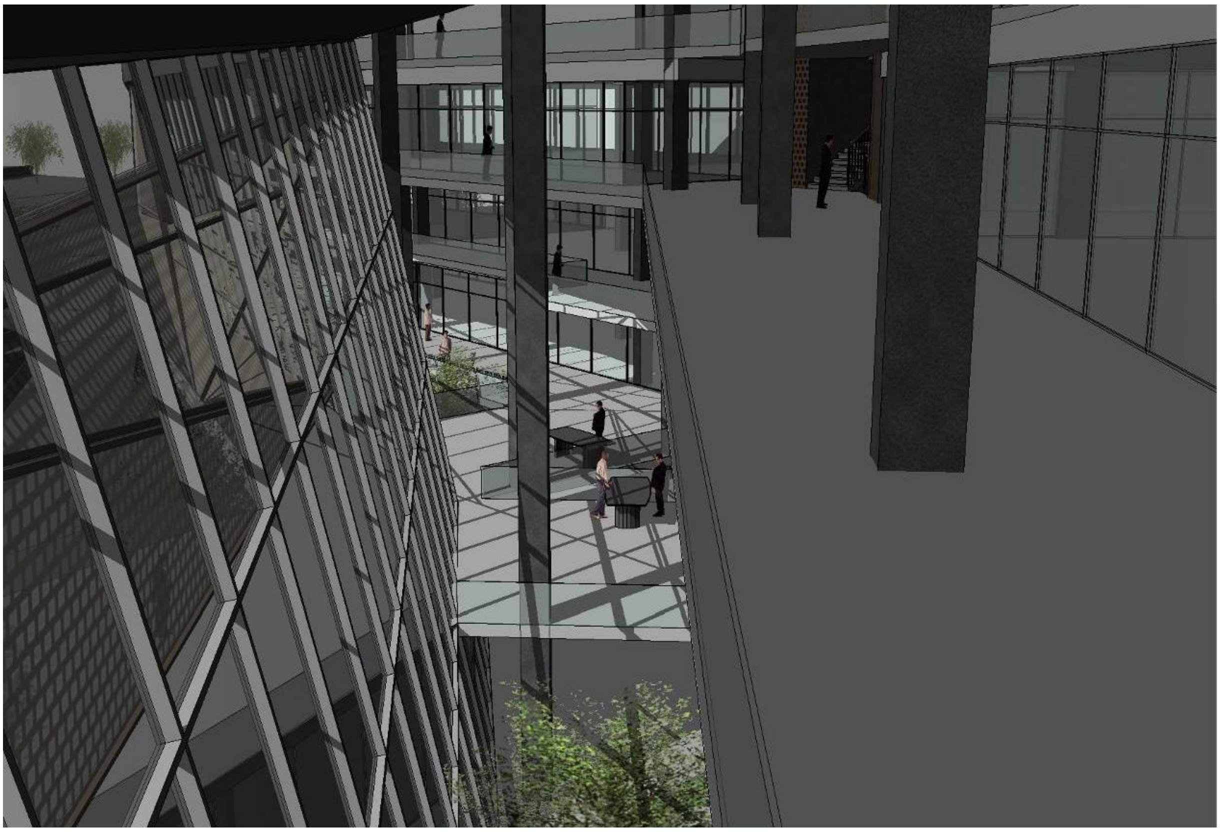


Figure 3.36 – Interior Renders

Chapter Four - Technological Design

4.1 Concept Design

As explained in details in the first section, Adana has been gone through a rapid growth in the second half of the last century. As the many other cities in Turkey, this growth was uncontrolled in many ways. Although that the issues such as FAR, height of the building, land setbacks are meant to be strictly regulated by the governmental bodies, the regulations have changed periodically each time the ruling power of the city & country has changed. This has led to an uncontrolled growth of the city, converting Adana, once known as a "land of cotton" into a pile of concrete. This issue has been covered in the first section of this academic study. In this section, a bigger problem is to be discussed a problem that none of the rulers of the city has considered until 5 – 10 years ago. As the city kept its rapid growth, its energy consumption has increased accordingly. More than 25% of the electricity consumed in the city is consumed by the residential buildings. A photo from the Cukurova below is quite self-explanatory.

Figure 4.1 – Photo from Cukuruova District

As it can be seen from Figure 4.1, the so-called modern high-rise buildings, which are located just near to our site, do not have any environmental concerns in means of passive housing. All of them have identical four-sided façades with flat roofs. Our design proposal aims to set a model for the Adana's development in the coming years in means of sustainability and usage of renewable energy sources.

Architecture shall be in close relationship with climatic context. It is not possible to create buildings and spaces without considering the climatic conditions. Specially for a sustainable design, where the impact on environment is required to be kept insignificant, understanding the climate of the project area constitutes a crucial step at the very beginning of our design process.

The energy demand of buildings, such as heating, cooling and lighting, can be supplied from various sources; however, energy efficient design concept suggests the use of renewable energy sources instead of non-renewable ones. In the developing countries, the usage of renewable energy sources is not feasible as it is in the developed countries, thus optimizing energy requirements of the building has a crucial importance.

Hence our vision is to exert a conscious effort in the design of a climate responsive, user friendly and energy efficient building that satisfies user needs. We have chosen some latest technologies and materials which can give more strength and meaning to our project. But, achieving these energy demands cannot just be reduced to isolated solutions such as rain water collection or photovoltaic installations on the roof. Rather, the building must be understood as a complex gestalt a total energy concept that makes the best possible use of locally available natural resources such as solar energy. We should thereby understand that passive and active measures counterpart one another in the pursuit to conserve energy.

From the viewpoint of human comfort and energy use, the climatic condition of a place can be divided broadly into negative and positive effects. In general, the aim of climate-conscious architecture is to provide protection from the negative factors and take advantage of the positive ones in order to meet the comfort requirements of the people and secure economical level energy consumption. A year-round analysis is required. Buildings have to perform appropriately in summer, winter and intermediate seasons. The latter are often characterized by great day-to-day variability, demanding flexibility of operation. To allow the architect to analyze the climate at a particular site, the climatic factors need to express quantitatively. The key factors are the position of the sun, the amount if solar energy, the air temperature, long wave radiation and wind condition. Humidity, best assessed as the water-vapor pressure, is also an important factor in hot weather.

4.2 Environment & Physics

4.2.1 Basic Geographical Information

Located in the southern Turkey, Adana shows the typical Mediterranean climate characteristics with mild winter seasons and hot & arid summer seasons. The city receives rain primarily during winter with extreme summer aridity that may exist for up to 5 months.

Figure 4.2 – Turkey Map

Latitude: +37.0 (37°00'00"N) **Longitude**: +35.32 (35°19'12"E)
Continent: Asia **Altitude**: ~20 m

- The average temperature in Adana, Turkey is 19.1 °C .
- The average temperature in the hottest month, August, is 34.5 °C.
- The average temperature in the coldest month, January, is 5.5 °C.

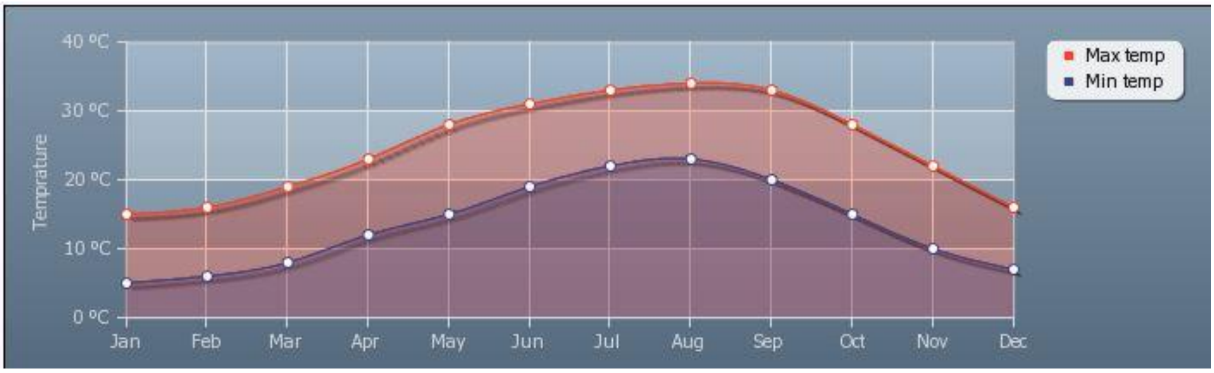


Figure 4.3 – Average minimum and maximum temperature over the year

- Adana receives an average of 690 mm of precipitation annually.
- On balance there are 77.3 days annually on which greater than 0.1 mm of precipitation (rain, sleet, or hail) occurs.
- The month with the driest weather is July & August when on balance 123.9 mm of rainfall (precipitation) occurs.
- The month with the wettest weather is January & December when on balance 141 mm of rainfall (precipitation) occurs.
- There is an average range of hours of sunshine in Izmir of between 4.65 hours per day in January and 11 hours per day in July.
- On balance there are 2717.7 sunshine hours annually and approximately 7.45 sunlight hours for each day.

Figure 4.4 – Average monthly hours of sunshine over the year

4.2.2 Temperature

Figure 4.5 shows a color coded graph of the average temperature of Adana on a weekly basis. The blue color indicates temperatures below 0° C as the color becomes purple the temperature increases up to 15° C. Reddish and orange colors indicate temperature values above 25° C. In the Y axis the hours of the day are given.

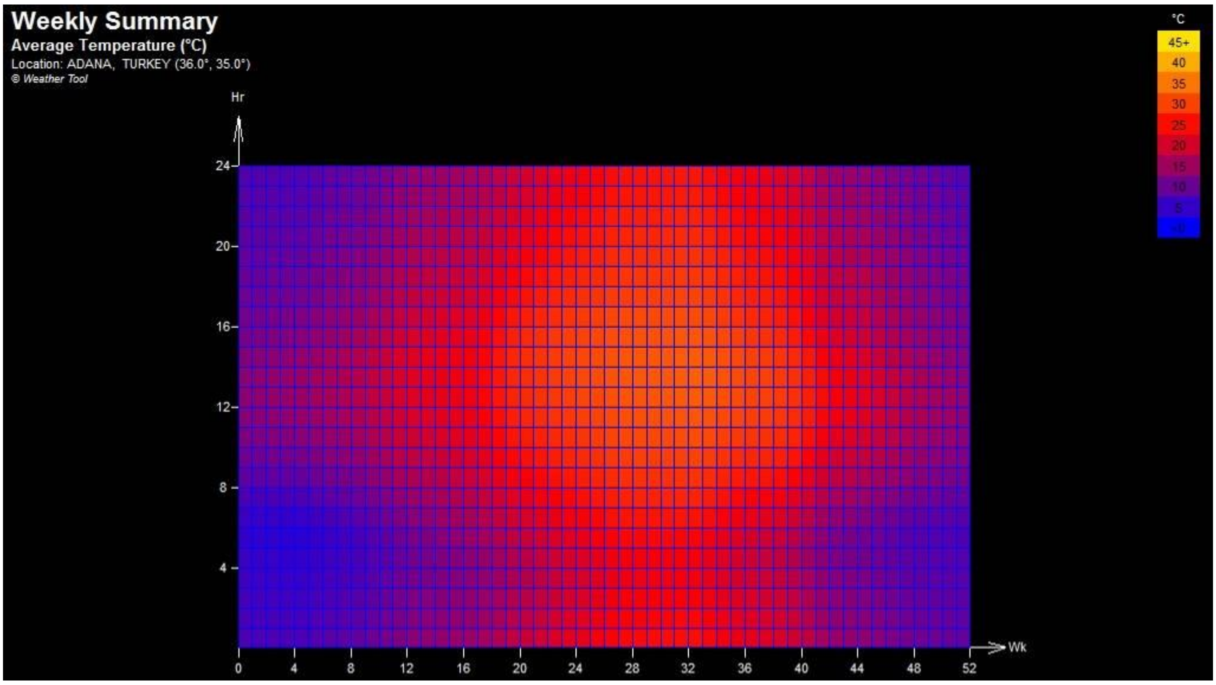


Figure 4.5 – Average Temperature – Weekly Summary

Figure 4.6 shows a color coded graph of the maximum temperature of Adana on a weekly basis. Average temperatures in Adana, does not exceed 35°C and the highest average values are recorded between 24th and 32nd week. Considering that the municipality hall will be open during the day time from Figure 4.6 we understand that reducing cooling loads during the summer time is an important challenge to overcome.

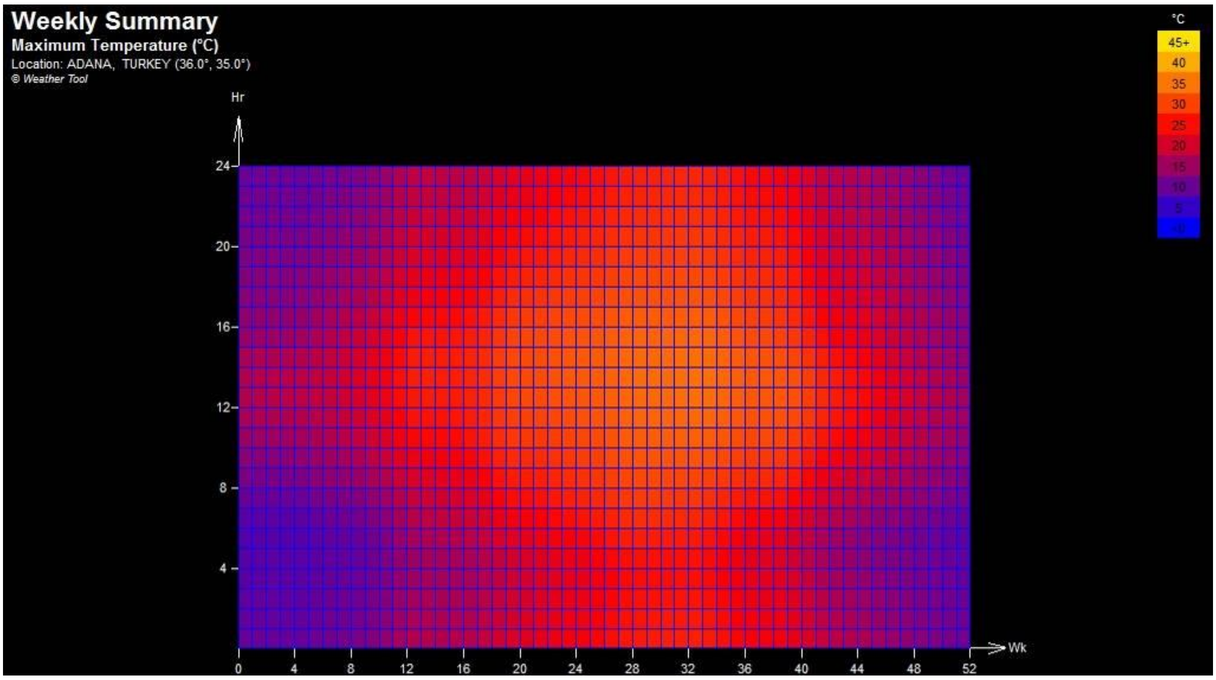


Figure 4.6 – Maximum Temperature – Weekly Summary

During the work hours, from Figure 4.7 we can see that the minimum temperature will be faced in the first 8 weeks of the year which will range between 0-10°C, which shows us the heating loads of our building will not be very high.

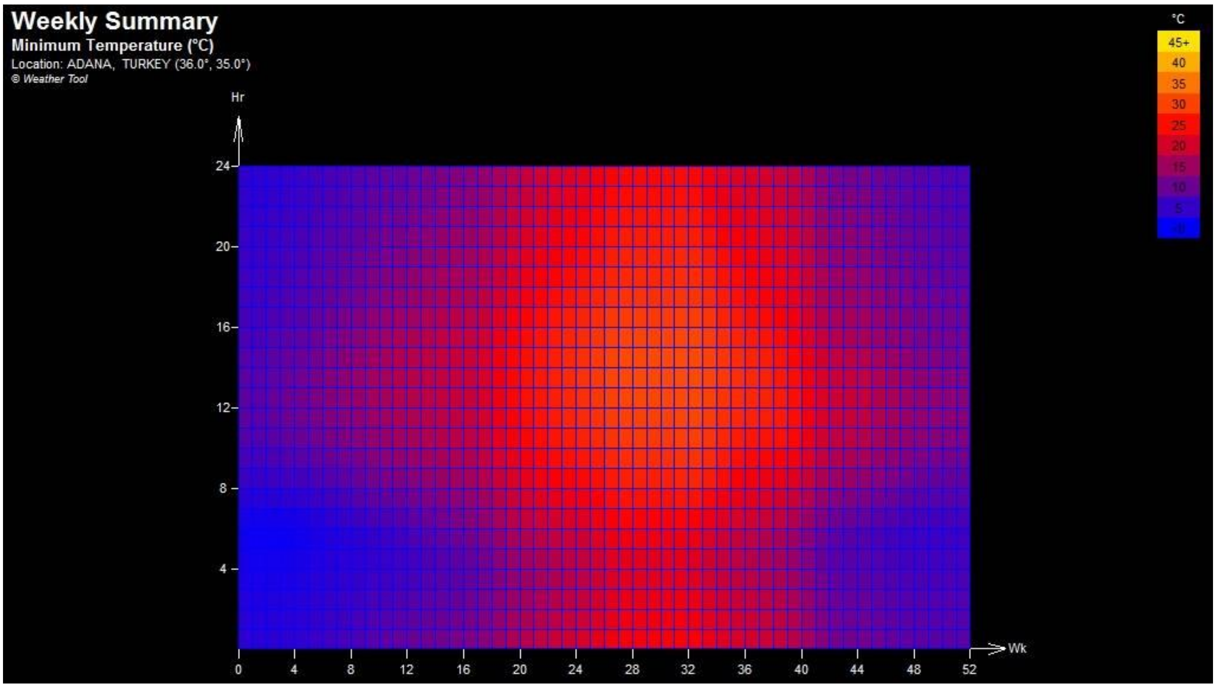


Figure 4.7 – Minimum Temperature – Weekly Summary

4.2.3 Wind

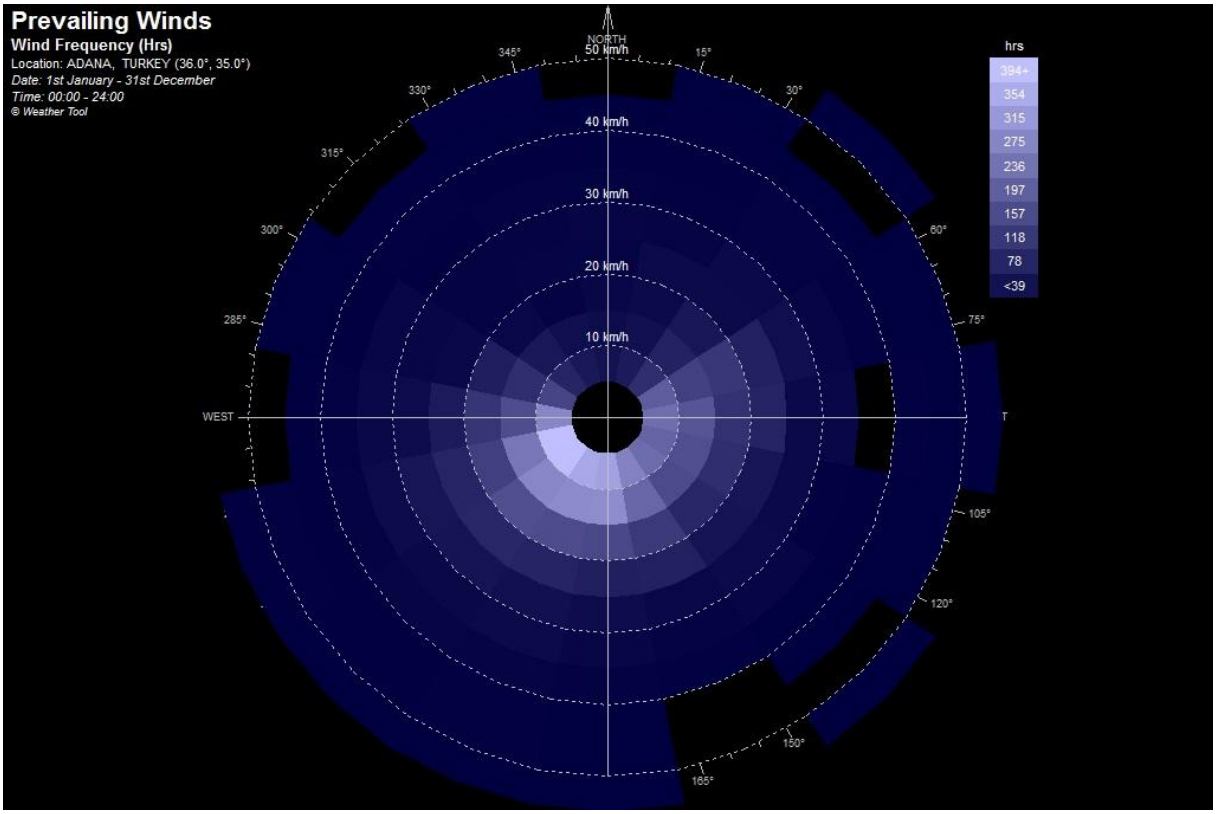


Figure 4.8 – Wind Analysis

In Figure 4.8, the colored segments plot the frequency of wind speed and direction for the selected period, with the brighter colours representing the greatest number of hours. 10km/h on the SOUTH WEST are the most frequent winds that our building will be faced throughout the year.

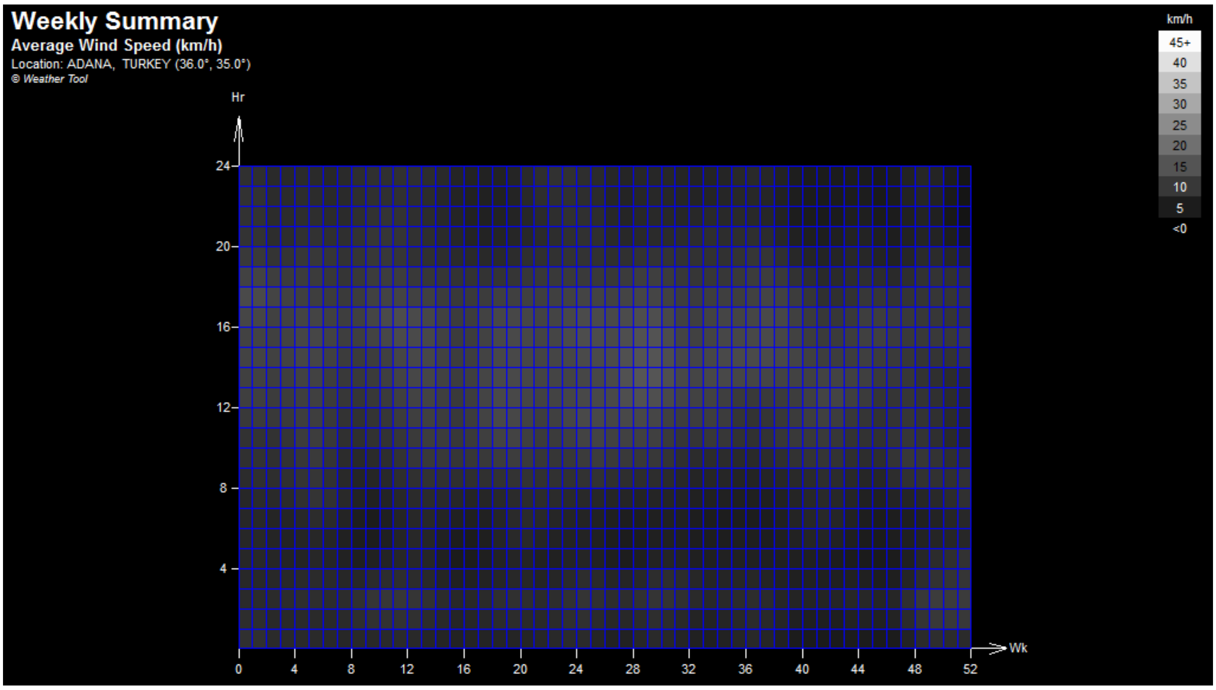


Figure 4.9 – Average Wind Speed

Figure 4.9 indicates the average wind speed on a weekly basis. Y-axis of the graph indicates the day hours, while x-axis represents the week of the year. From Figure 4.7, we can see that the wind speed increases between 10.00 am – 17.00 pm. This data shows us the opportunity of natural ventilation within the building.

4.2.4 Precipitation

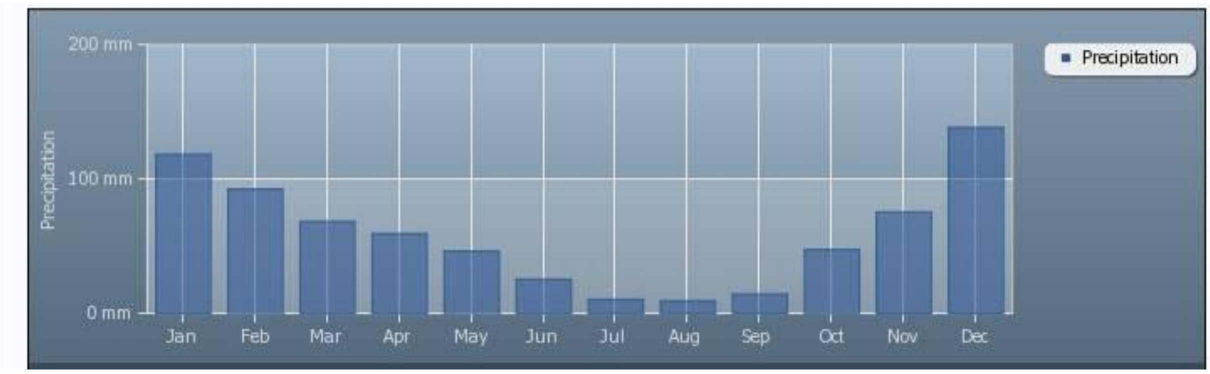


Figure 4.10 – Average monthly precipitation over the year

Figure 4.10 indicates the average monthly precipitation throughout the year. As it can be seen from the graph, between October and May the city receives precipitation in form of rain. So within these months rain water storage system can be used in order to supply water to the building.

4.2.5 Relative Humidity

Relative humidity is a measure of the amount of moisture in the air relative to the total amount of moisture the air can hold. Compared to summer, when the moisture content of the air (relative humidity) is an important factor of body discomfort, air moisture has a lesser effect on the human body during outdoor winter activities. But it is a big factor for winter indoor comfort because it has a direct bearing on health and energy consumption.

The colder the outdoor temperature, the more heat must be added indoors for body comfort. However, the heat that is added will cause a drying effect and lower the indoor relative humidity, unless an indoor moisture source is present.

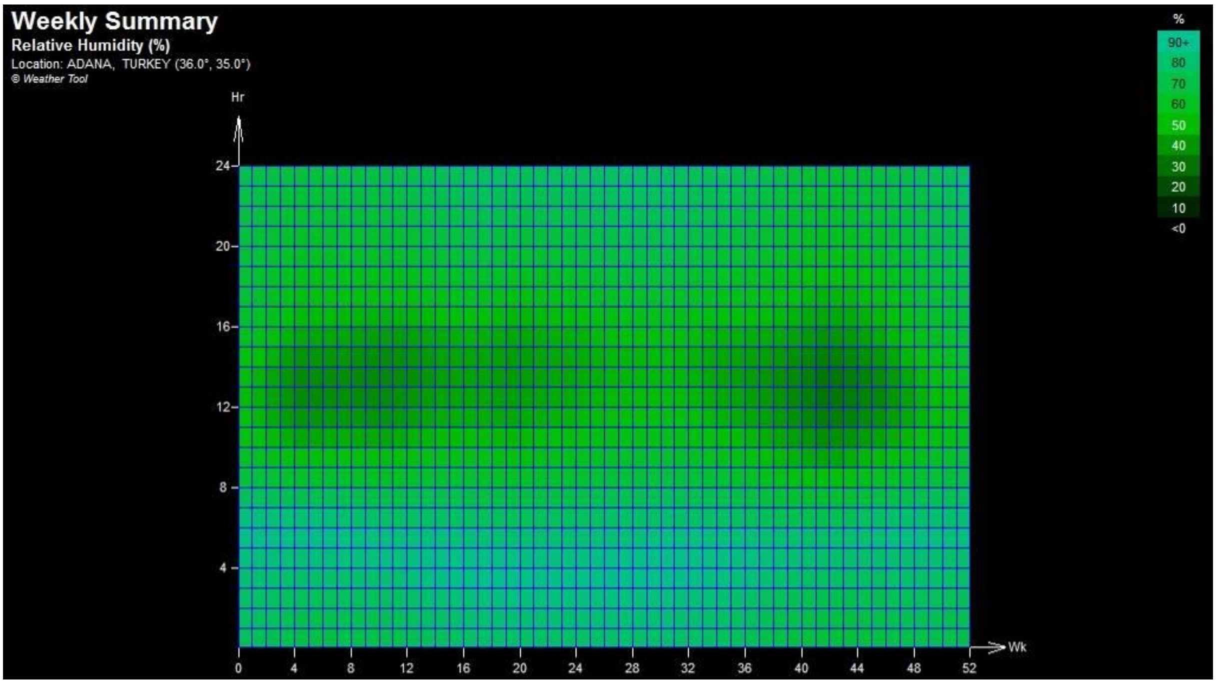


Figure 4.11 – Relative humidity

Figure 4.11 shows a color coded graph of the relative humidity in Adana on a weekly basis. The darkest green color shows the lowest relative humidity of 30%, between weeks 40-44.

From Figure 4.12 we can see the relative humidity ratio throughout the year on a weekly basis. Most of the year, the relative humidity ratio is between 40-80%.

Looking at Figure 4.13 Average Hourly Relative Humidity diagram, the relative humidity in Adana tends to decrease between day time (between 08.00 am- 16.00 pm), while it reaches above 80% after midnight. During day time, relative humidity drops until 40% which gives us the opportunity to employ a evaporative cooling into our design.

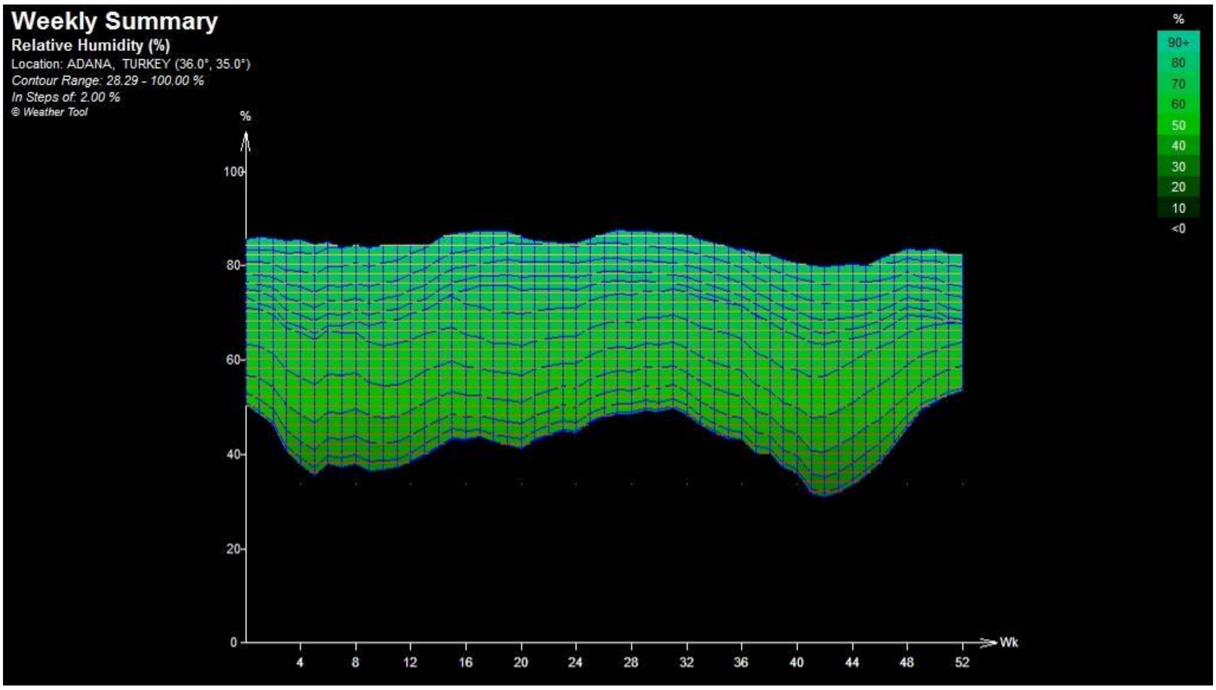


Figure 4.12 – Relative humidity (%/Wk)

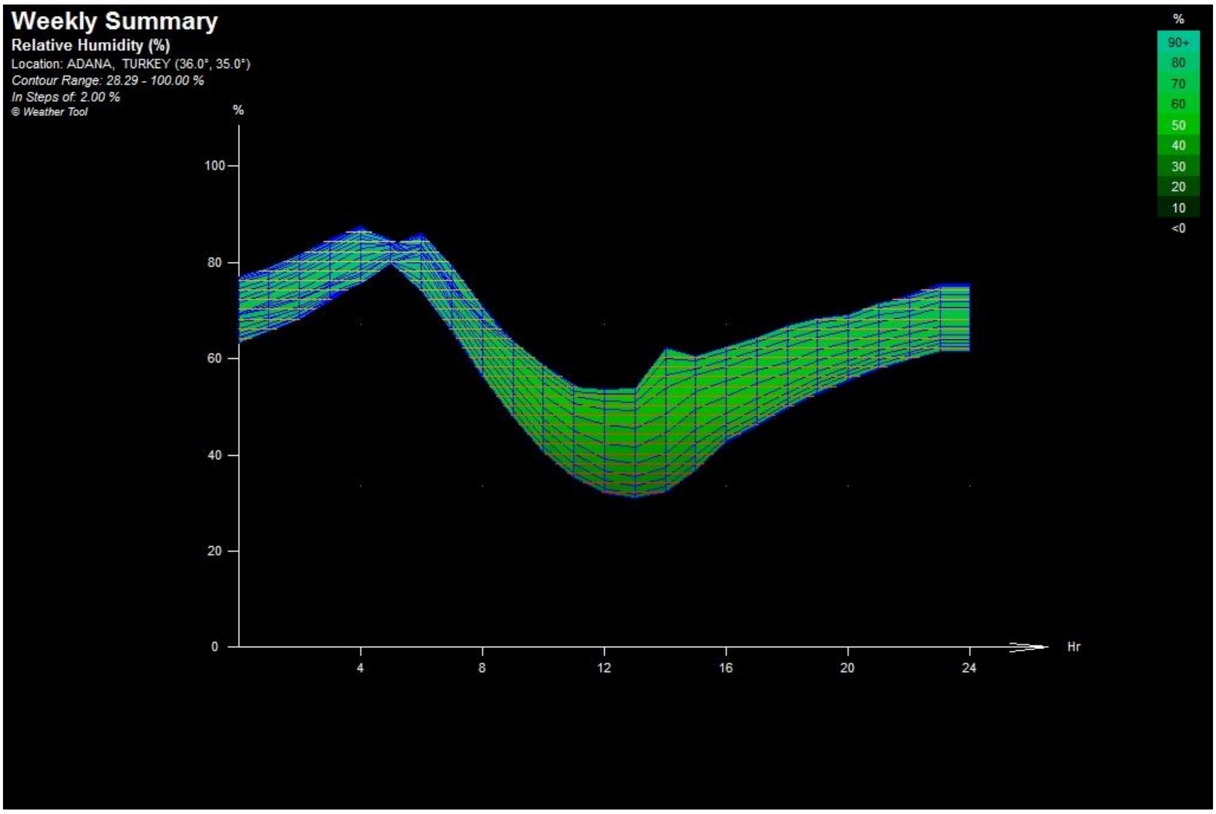


Figure 4.13 – Relative humidity (%/Hr)

4.2.6 Direct Solar Radiation

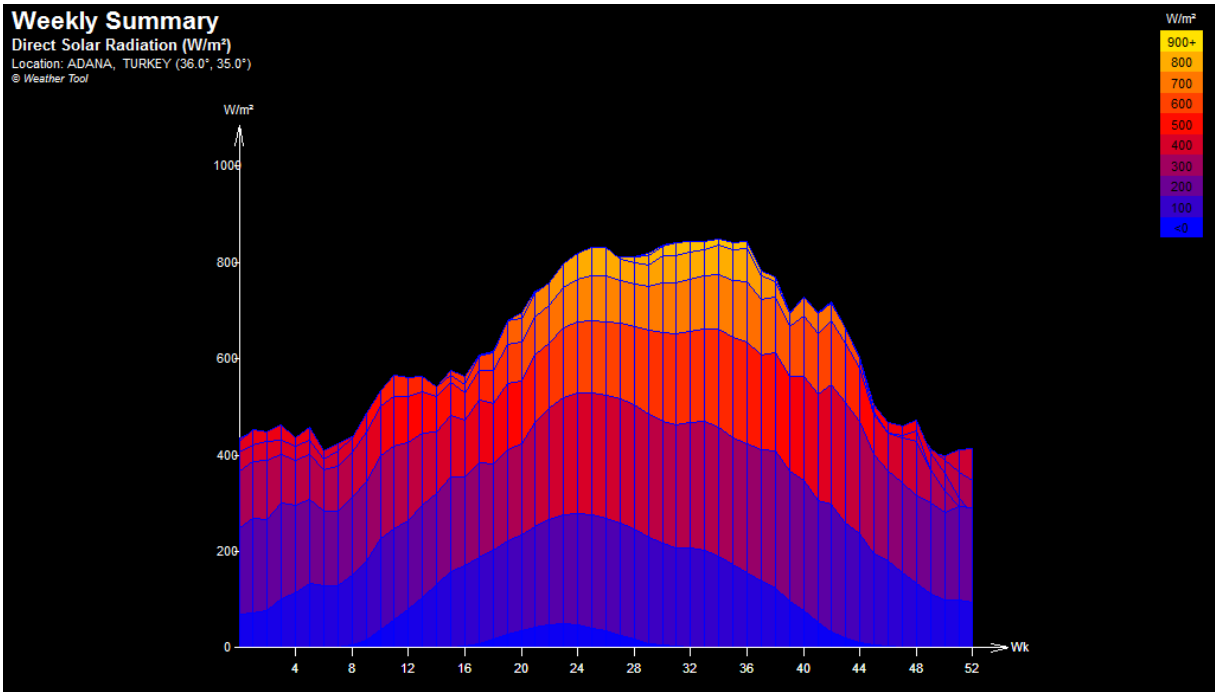


Figure 4.14 – Direct Solar Radiation

Figure 4.14 shows the direct solar radiation Adana receives on a weekly basis.
The highest direct solar radiation in Adana is between week 28 and 38 where it receives around 800- 850W/m² direct solar radiation from 9am to 5pm.

This data gives the valid information for the designing of the shading system and the energy required to be generated by PV panels.

In the following pages, the weather data is summarized based on the summer (Figure 4.15) and winter (Figure 4.16) peaks that occur on the 14th of August and 8th of February respectively.

In the Figure 4.15 & 4.16, basically show the maximum, minimum and average monthly temperatures in Adana. In addition to that the dotted green line shows the relative humidity while the solid green area shows the comfort zones for the particular months.

The graphs on the bottom right hand corner show the daily details for the summer peak, 14th of August and for the winter peak, 8th of February. The figures also tell us that the between December and March, the building is required to be heated. While, between June, and September the building is required to be cooled if we are to attain comfort conditions.

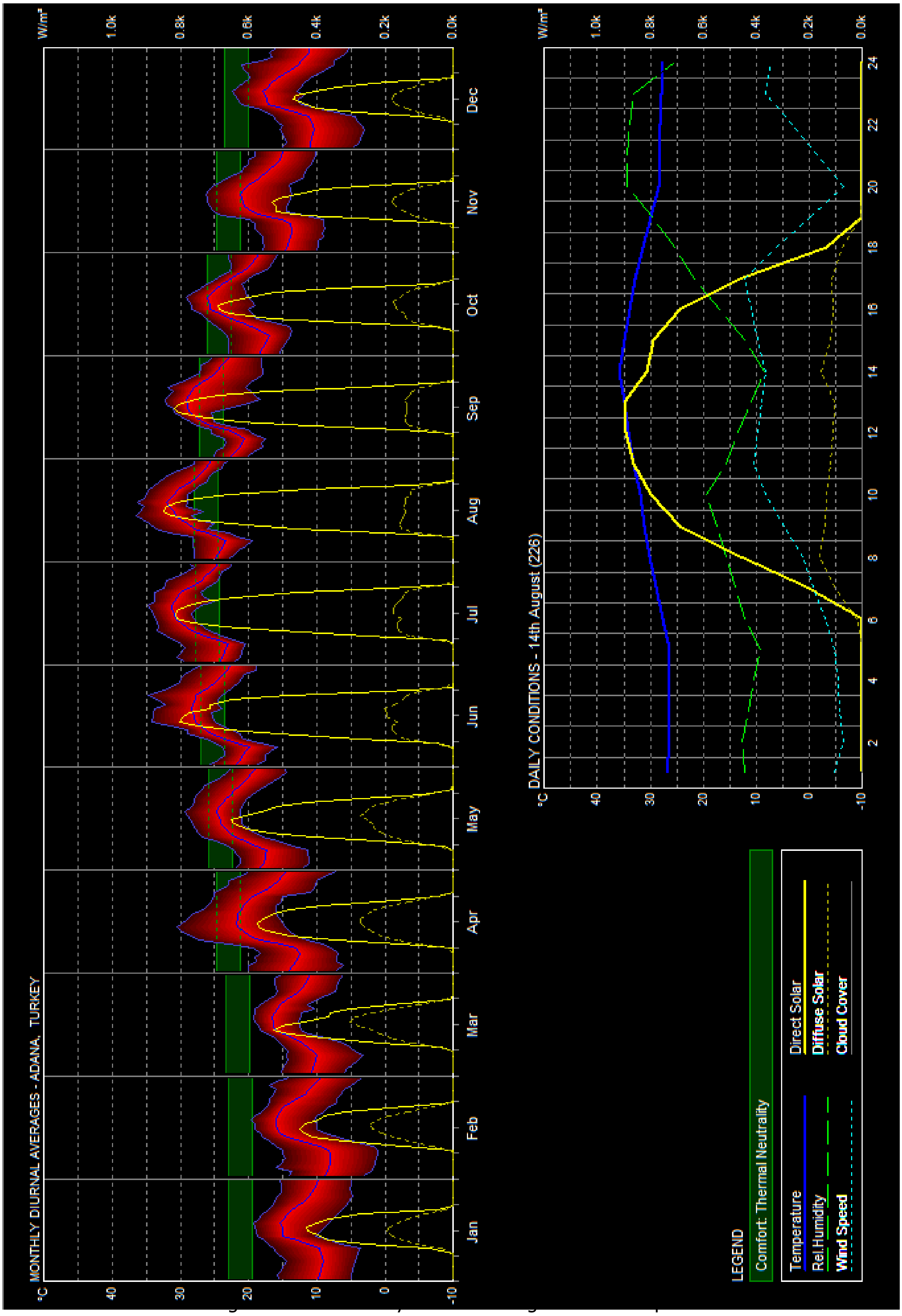


Figure 4.15 – Monthly diurnal averages - summer peak

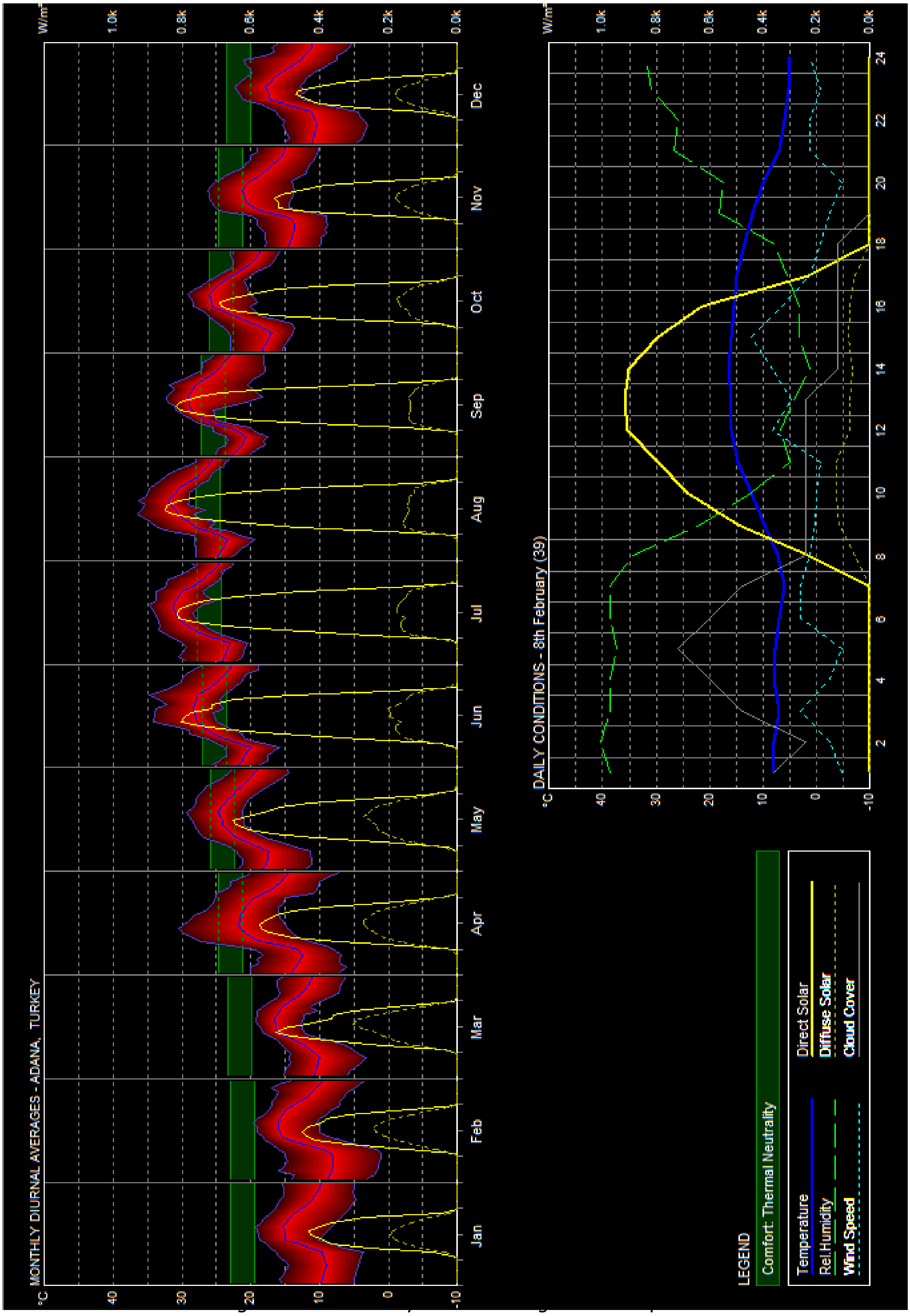


Figure 4.16 – Monthly diurnal averages - winter peak

4.2.7 Psychometric Chart

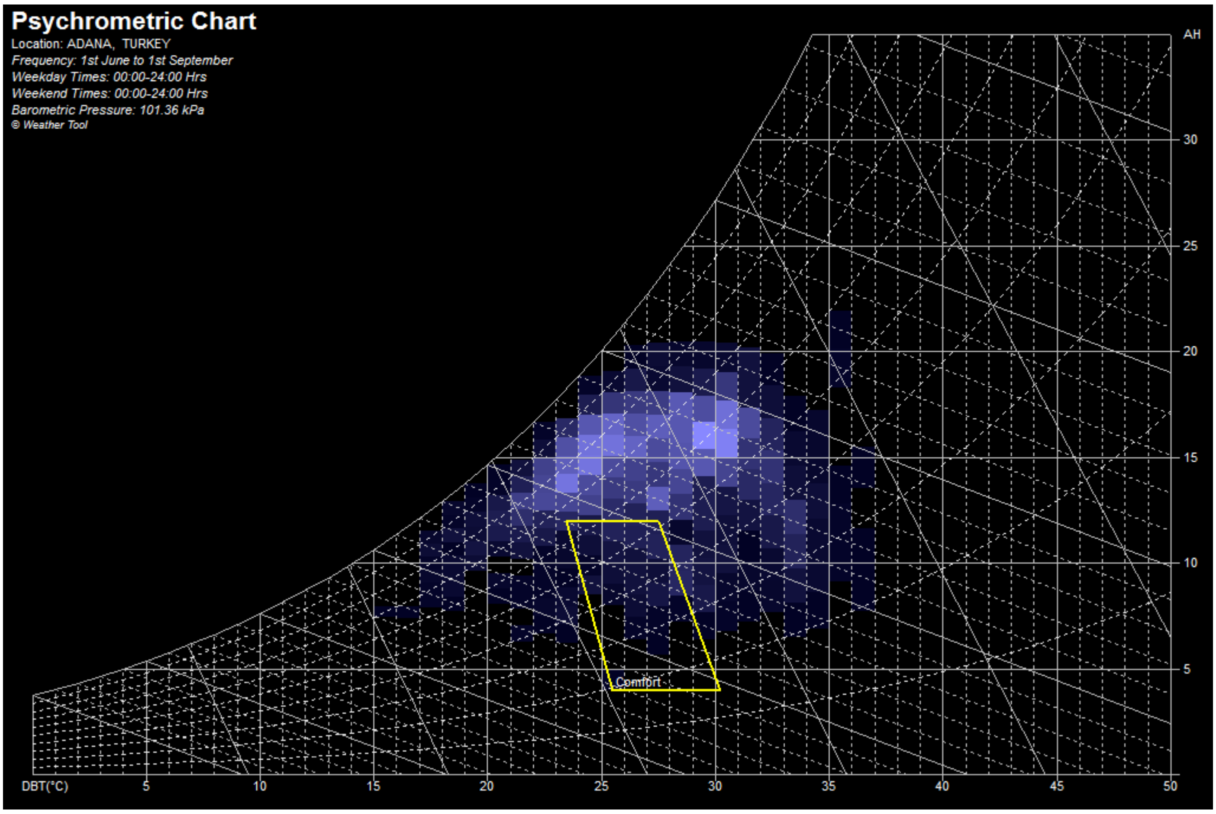


Figure 4.17 – Psychometric Chart – Adana, Summer Period

The figures 4.17 and 4.18 show us where the comfort zone lies for sedentary activity zones in Adana for summer and winter respectively.

From the summer comfort zone it is clear that the cumulative frequency of the temperature remains between 20 and 25 ° C and the relative humidity also remains inside the comfort band with 50 to 60 % for the most days of the summer. This indicates summer cooling in our site with dehumidification during the days is required.

Again, from the winter comfort zone it is easily understood that the cumulative frequency for temperature falls short of the comfort zone. The relative humidity on the other hand stays at a comfortable level of 50% to 60%. Therefore, in the winter, we conclude, that we are required to heat the incoming air while probably also humidifying it since when air is heated without humidification the relative humidity decreases. If the relative humidity of the heated air drops below comfort levels we shall humidify it in hopes of attaining comfort. However, if we choose to heat the morning air, with considerably high relative humidity and low in temperature, we lower the relative humidity while increasing the temperature of incoming air.

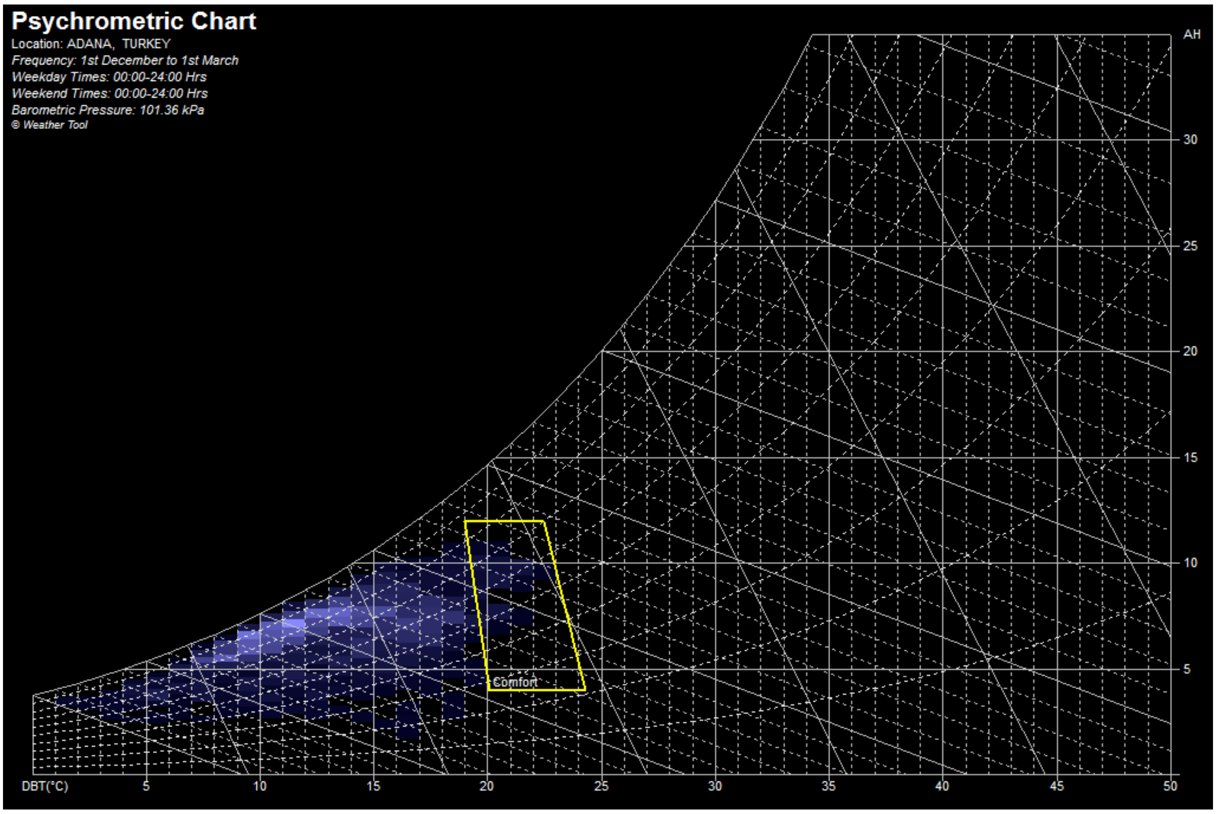
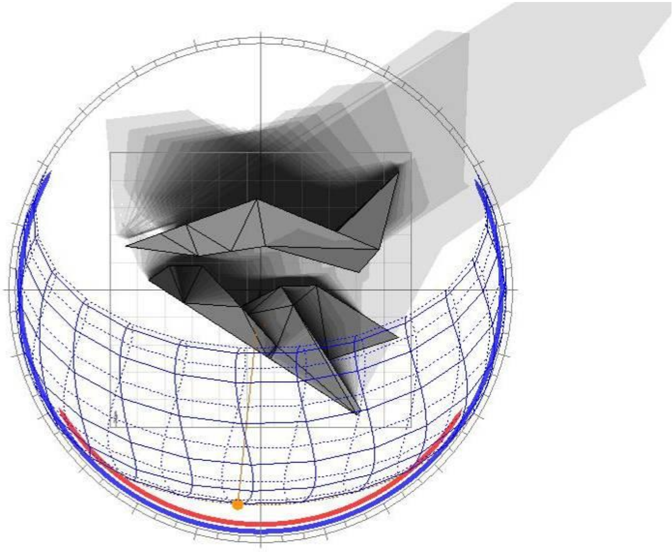


Figure 4.18 – Psychometric Chart – Adana, Winter Period

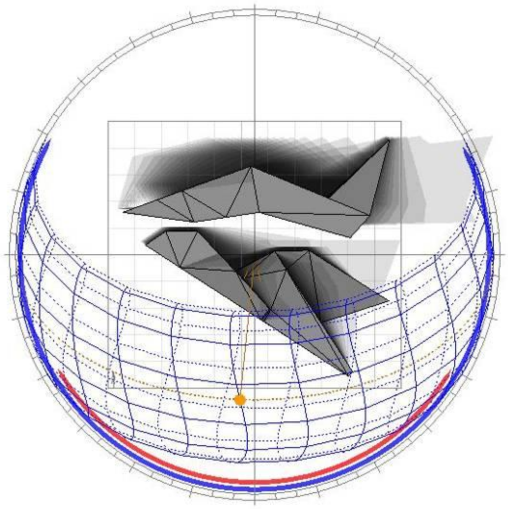
4.2.8 Sun Path Diagram

Sun path refers to the apparent significant seasonal-and hourly positional changes of the sun (and length of daylight) as the Earth rotates, and orbits around the sun. The relative position of the sun is a major factor in the heat gain of buildings and in the performance of solar energy systems. Accurate location-specific knowledge of sun path and climatic conditions is essential for economic decisions about solar collector area, orientation, landscaping, summer shading, and the cost-effective use of solar trackers.

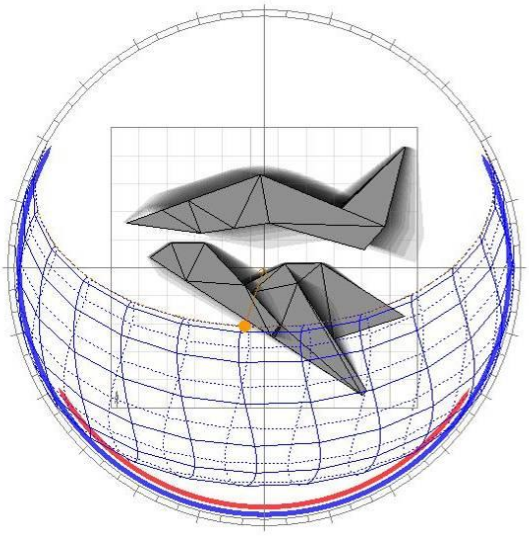
For Cukurova Municipality Hall & Cultural Center, the shape, the position, and the internal distribution, was decided considering the architectural concepts and the sun path together. It was decided to accommodate the atrium and the internal gardens towards the Southern side of the building, in order to get natural illumination, positive incident solar radiation, and to have the perception of the "democratic valley". There are two types of offices according to the layout. First one is the one that faces towards the atrium at the south and the second type is the one facing north façade. This was established in order to avoid negative effect of solar radiation.



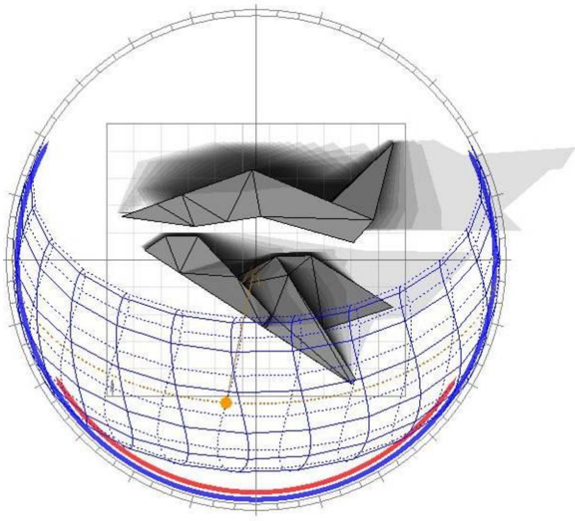
21st of December



21st of March



21st of July



21st of December

Figure 4.19 – Sun Path Diagrams

4.3 Daylight Analysis

The use of natural light has always been treated with care in building design, as to provide better quality lighting and living conditions inside an environment, and to reduce the need for the artificial light in terms of quantity and time, cutting the electric power consumption as a direct consequence.

As the function of the building is office space we will calculate the lighting levels for surfaces at 60 cm as work desk height. Since the glazing for the offices are oriented towards the north, it is very favorable use of natural light. External and internal shaders help with potential glare problems while they keep the daylight levels at a satisfactory rate.

The daylight factor is used to calculate illuminance levels at each point on the analyzed surface at any time of day for any day of the year.

The average values for daylight factor for residential use are:

- <2% – Not adequately lit – artificial lighting will be required.
- 2% to 5% – Adequately lit but artificial lighting may be in use for part of the time.
- >6% – Well lit – artificial lighting generally not required except at dawn and dusk – but glare and solar gain may cause problems

Input conditions for daylight factor:

- Average window cleanliness – 0.9 transmittance reduction factor
- CIE overcast sky distribution model at 8500 lux illuminance
- Analyzed surface height 60 cm for working area in office space

Ground floor offices

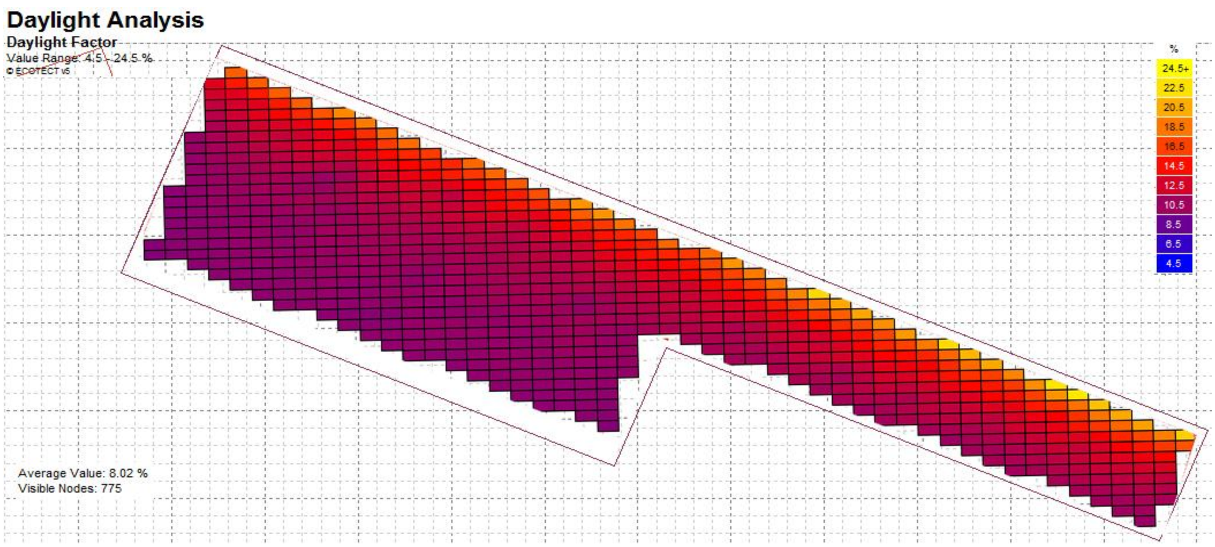


Figure 4.20a – Ground Floor Daylight Analysis – West Wing

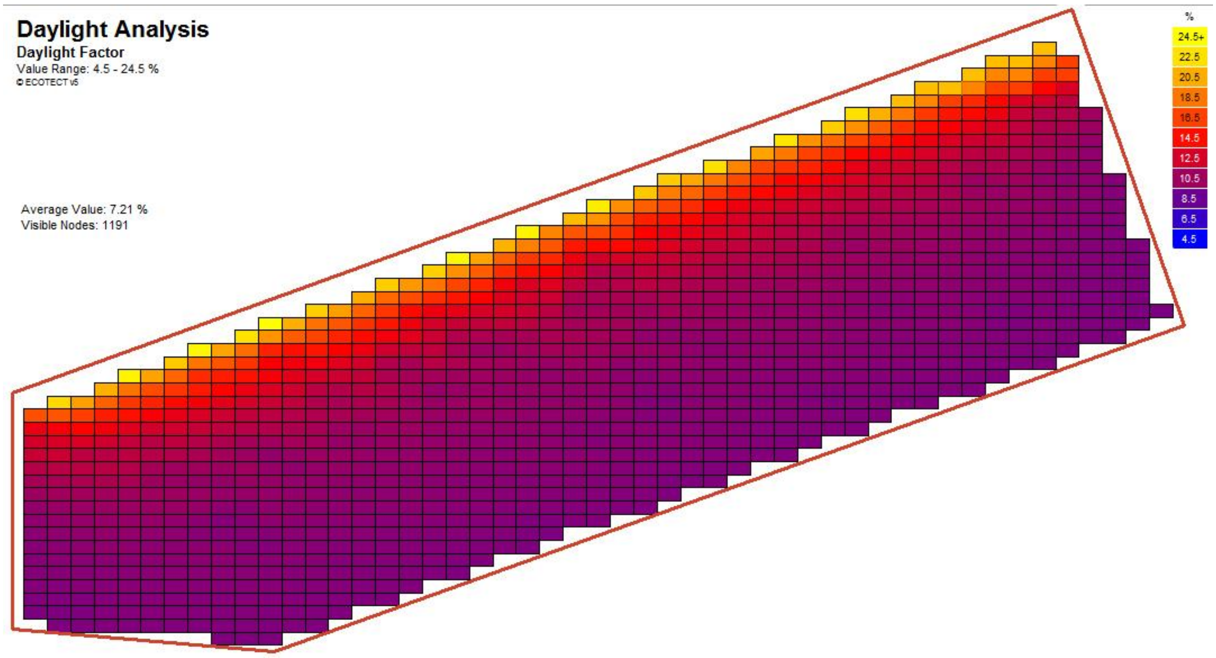


Figure 4.20b – Ground Floor Daylight Analysis – East Wing

Value range for ground floor offices is from 4.5 to 24.5% and the average value is 8.02% and 7.21%, so we can conclude that the natural light levels are quite high, even the minimum values are within the range for adequately lit. However there are possibilities of glare problems, and therefore adjustable internal shading is placed to help with these issues. Also the external shading devices made of perforated metal sheets are letting the light in, while keeping glare out. Furthermore, as mentioned above, the orientation of the glazing is north side, so there would be no direct sunlight during office hours, which is a plus for the visual comfort.

First floor offices

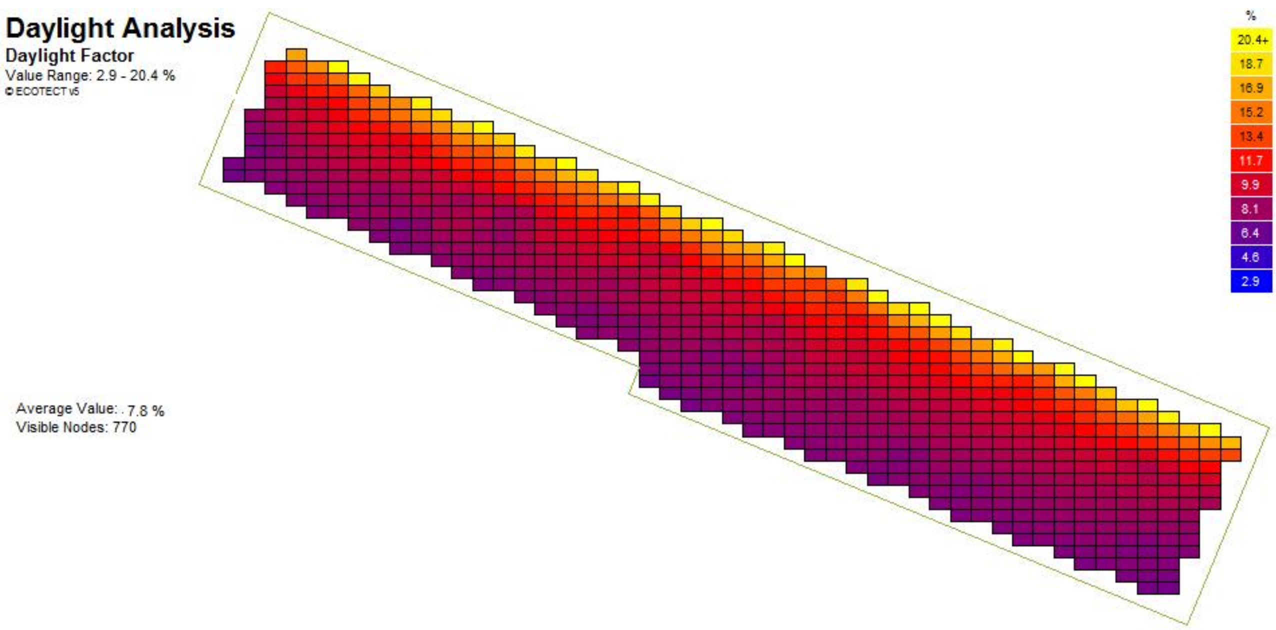


Figure 4.21a – First Floor Daylight Analysis – West Wing

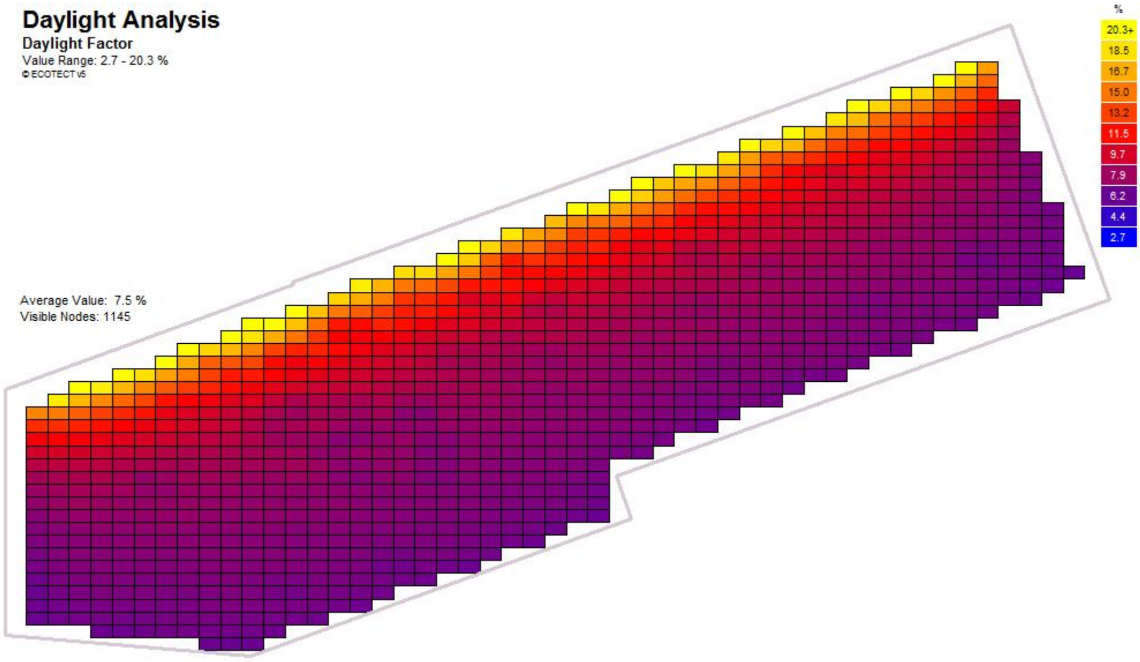


Figure 4.21b – First Floor Daylight Analysis – East Wing

At first floor level offices we see almost the same results, with value range from 2.9-20.4% and 2.7-20.3% and the average at 7.8% and 7.5%, we see that also these offices are well lit spaces, with concerns being possible glare problems. Continuous perforated metal shading devices on the exterior of the north façade partly cover also offices at this floor level, while the interior blinds are placed covering the whole glazing area to deal with these issues.

Second floor offices

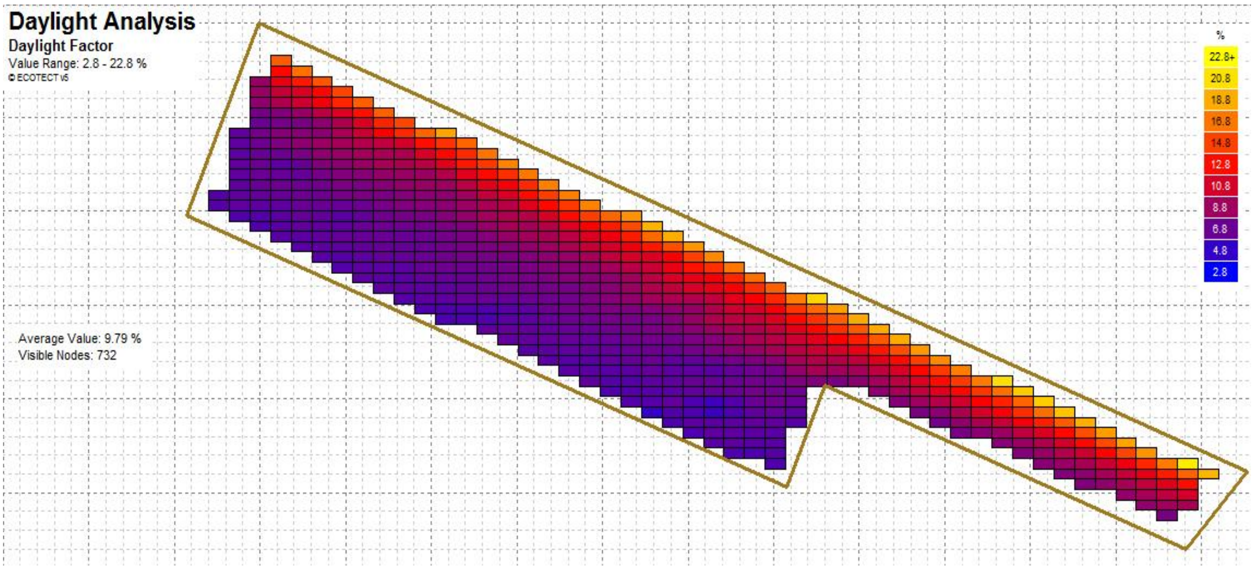


Figure 4.22a – Second Floor Daylight Analysis – West Wing

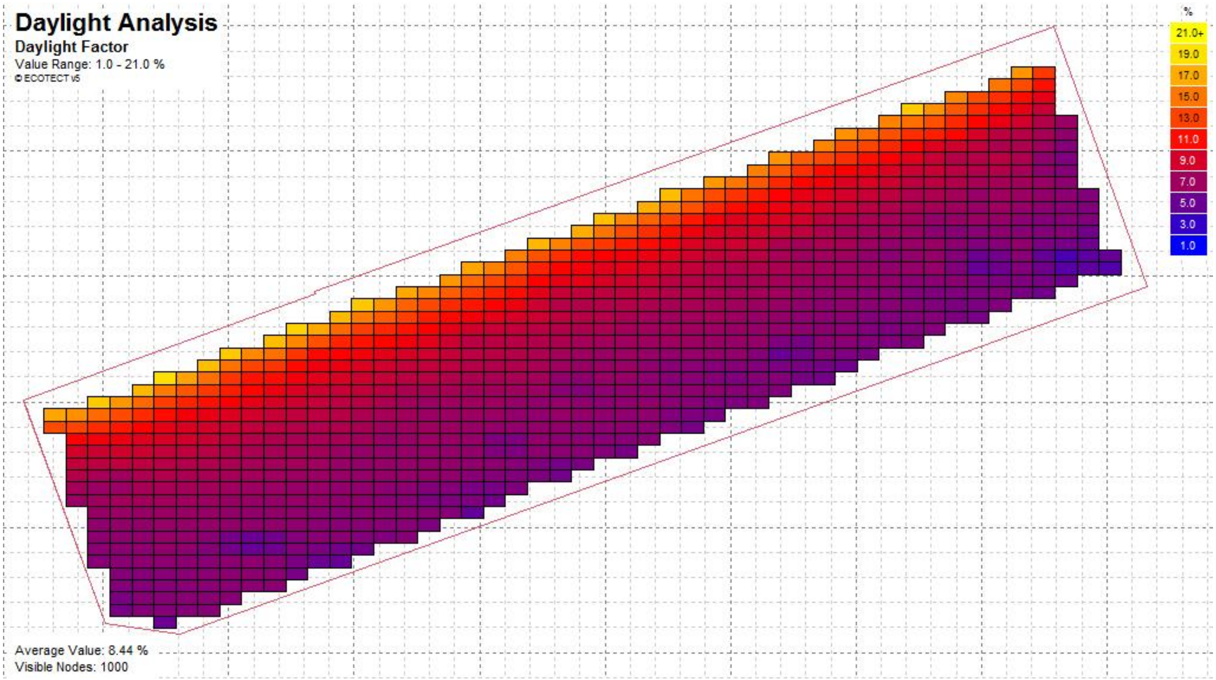


Figure 4.22b – Second Floor Daylight Analysis – East Wing

Daylight factor value range at second floor level is 1-21% and 2.8-22.8%, and the average 8.44% and 9.79%. As previously concluded for higher average level, with minimum slightly below adequately lit limits, the internal shading devices together with exterior shaders will help neutralize the glare effects.

Third floor offices

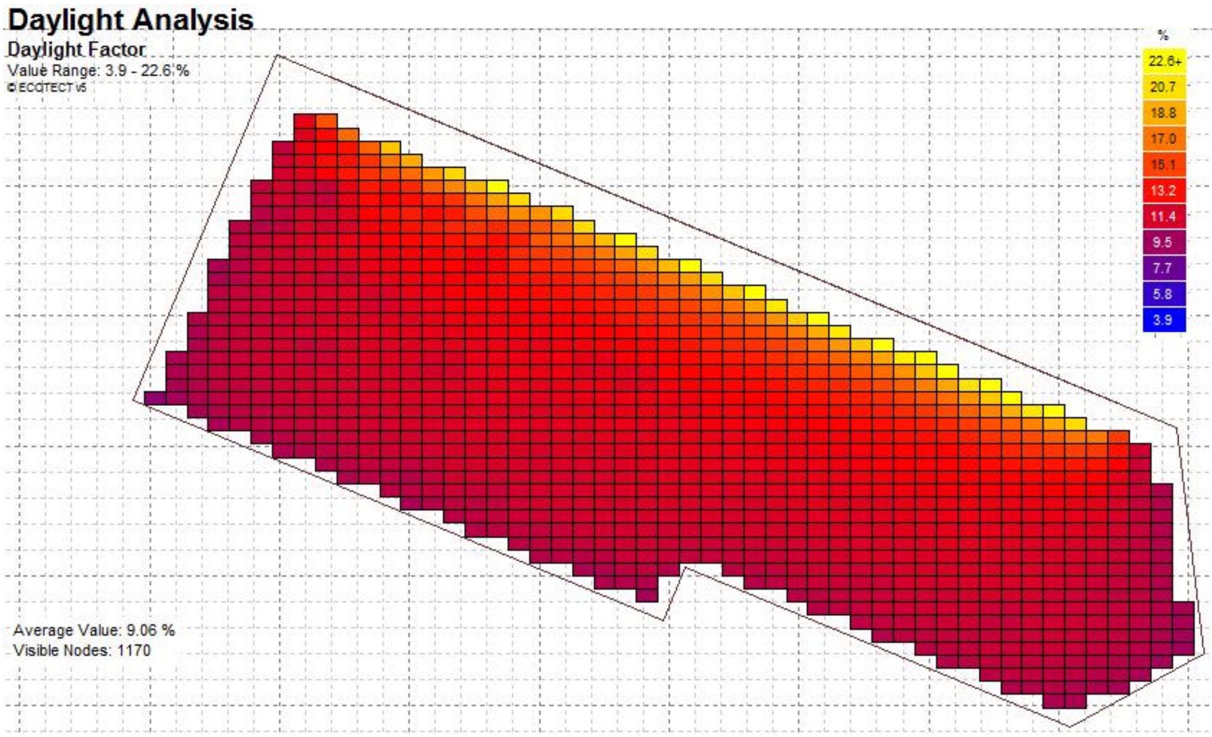


Figure 4.23a – Third Floor Daylight Analysis – West Wing

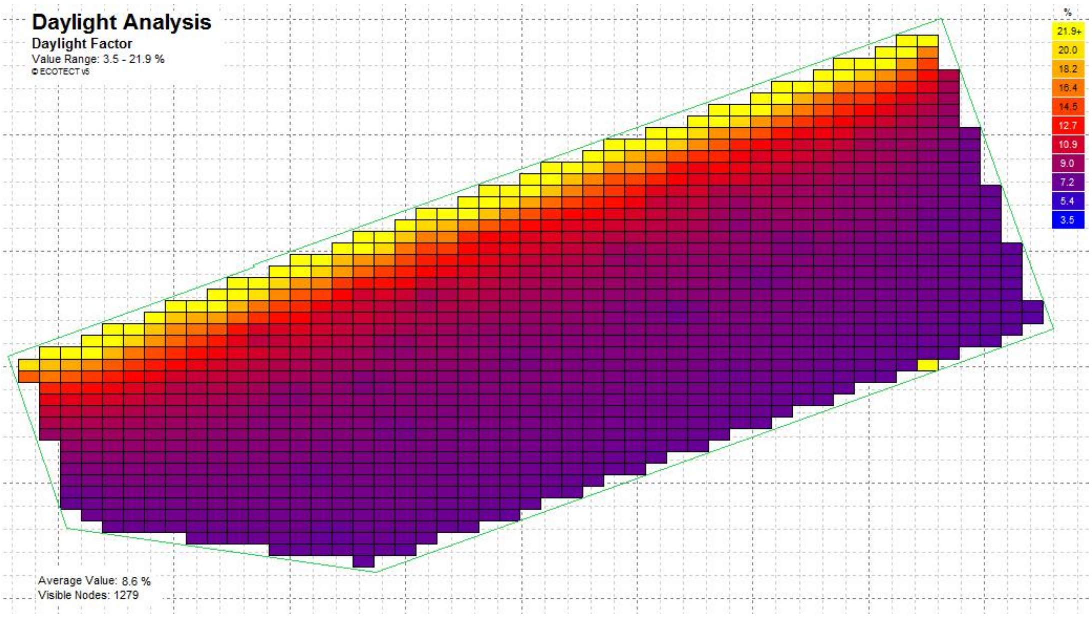


Figure 4.23b – Third Floor Daylight Analysis–East Wing

Daylight factor value range at third floor level is 3.9-22.6% and 3.5-21.9%, and the average 9.06% and 8.6%. As previously concluded for higher average level, with minimum within adequately lit limits, the internal shading devices together with exterior shaders will help neutralize the glare effects.

Fourth floor offices

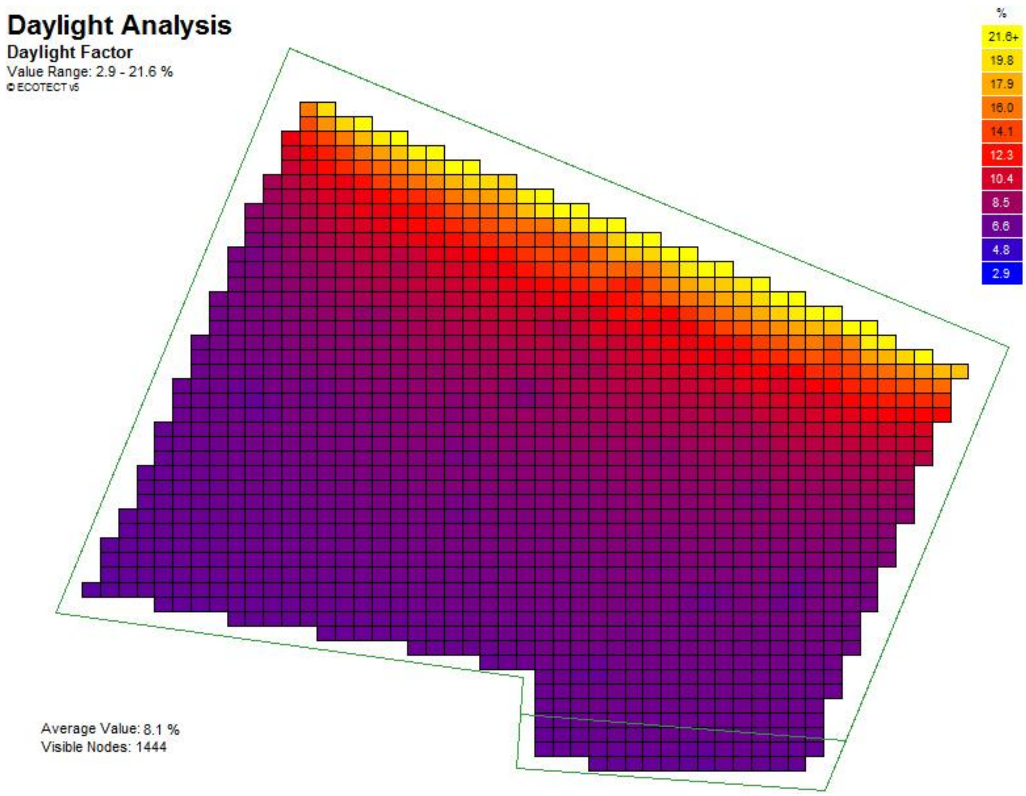


Figure 4.24a – Fourth Floor Daylight Analysis – West Wing

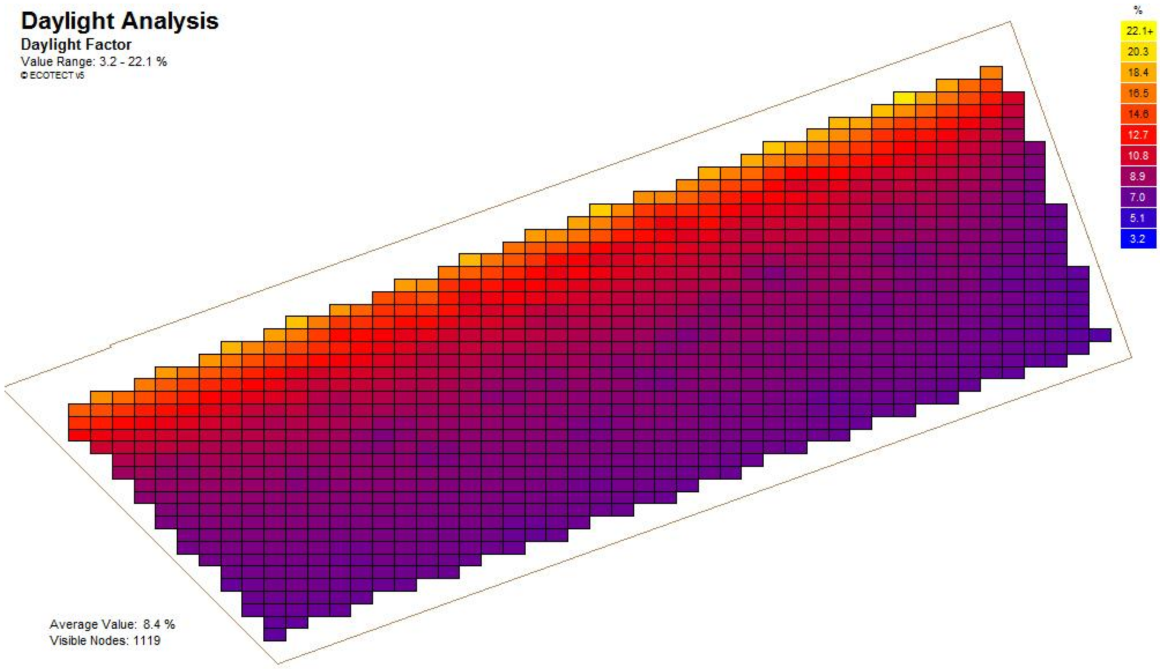


Figure 4.24b – Fourth Floor Daylight Analysis – West Wing

Daylight factor value range at fourth floor level is 2.9-21.6% and 3.2-22.1%, and the average 8.4% and 8.1%. As previously concluded for higher average level, with minimum within adequately lit limits, the internal shading devices together with exterior shaders will help neutralize the glare effects.

4.4 Heating & Cooling Loads / Thermal Analysis

Building is a man-made shelter to provide for quality space to spend certain amount of time in pleasant surroundings. Thermal comfort of the occupied space is an important factor and special care is dedicated to achieving thermal performance and comfort whilst keeping the energy consumption low. The building envelope is the interaction place between the outdoor and indoor environment, and its components and their arrangement is the most influential factor in the thermal performance of the whole system and its energy consumption.

Objective

The objective of a building design is to provide a quality environment to the users. The approach is to obtain knowledge about the behavior of all factors influencing thermal performance, and having also analyzed the comfort conditions for the given environment, we can optimize the parameters to achieve the desired goal. Depending on priorities, building and operating costs, or thermal loads or thermal discomfort, or energy consumption can be minimized.

Output

Heating and cooling loads are the amount of energy which a space needs to be added in or removed from in order to achieve the desired levels of thermal comfort and air quality, either by mechanical or natural systems, or both. Once the loads are known, understood and analyzed, one can begin to design and size these systems according to the results. The values obtained from the thermal analysis will be a guideline to choosing the equipment, sizing ducts to provide conditioned air to spaces and size the HVAC system.

Simulation

Ecotect software has been used to evaluate the thermal properties such as annual heating and cooling loads of the project building. The Mixed mode system is used to apply the heating and cooling loads to the environment, since it is the system which combines the air-conditioning with the natural ventilation, while the HVAC shuts the supply down whenever the outside conditions meet the design conditions.

Material Input

In Ecotect software we can assign the properties of the layers and components to our model by adding U-value and layers. In order to insert the necessary information we have calculated the thermal conductivities of the building envelope, intermediate floors and partition walls. Below the thermal conductivities of the indicated elements are shown:

Green roof					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Upward flux hi=0,1 ; he=0,04
	Outside				
	External surface			0,17	
	Roof Vegetation				
1	Intensive substrate	0,15	0,6	0,25	
2	Filter membrane				
3	Drainage layer	0,08	0,2	0,40	
4	Water insulation membrane	0,08	0,170	0,47	
5	Vapour barrier				
6	XPS rigid thermal insulation	0,08	0,03	2,67	
7	Concrete slab	0,2	1,7	0,12	
8	Air gap	0,6			
9	Mineral wool	0,05	0,035	1,43	
10	Plasterboard suspended ceiling	0,015	0,16	0,09	
	Internal surface			0,04	
	Inside				
	Total	1,255	2,895	5,6372	
			U-value (w/m²k)	0,18	

Table 4.1 – Thermal Conductivity Calculation for Green Roof

Basement Floor					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Downward flux hi=0,17 ; he=0,04
	Inside				
	Internal surface			0,17	
1	Epoxy floor finish				
2	Self levelling screed layer	0,05	1,7	0,03	
3	XPS rigid thermal insulation	0,1	0,03	3,33	
4	Separation sheet polyethylene				
5	Reinforced concrete	0,12	1,7	0,07	
6	Igloo	0,5	0,4	1,25	
7	Reinforced concrete	0,12	1,7	0,07	
8	Gravel	0,4	1,5	0,27	
	External surface			0,04	
	Total	1,29	7,03	5,2306	
			U-value (w/m²k)	0,19	

Table 4.2 – Thermal Conductivity Calculation for Basement Floor

Intermediate Floor					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Resistance R (m².k/W)	Upward flux hi=0,1 ; he=0,04
	Inside				
	Internal surface			0,135	
1	Natural stone tile	0,015	2	0,01	
2	Woodcore panel	0,03	0,1	0,30	
3	Air gap	0,105			
4	Concrete slab	0,15	1,7	0,09	
5	Air gap	0,51			
6	Mineral wool	0,05	0,035	1,43	
	Internal surface			0,135	
	Inside				
	Total	0,86	3,835	2,0943	
			U-value (w/m²k)	0,48	

Table 4.3 – Thermal Conductivity Calculation for Indermediate Floor

Partition Wall W1					
Layer	Material	Thickness s (m)	Thermal conductivity λ(W/m.k)	Ressistance R (m².k/W)	Vertical flux hi=0,13 ; he=0,04
	Inside				
	Internal surface			0,13	
1	Gypsum board	0,0125	0,16	0,08	
2	Gypsum board	0,0125	0,16	0,08	
3	Mineral wool	0,04	0,035	1,14	
4	Service gap				
5	Mineral wool	0,04	0,035	1,14	
6	Gypsum board	0,0125	0,16	0,08	
7	Gypsum board	0,0125	0,16	0,08	
	External surface			0,04	
	Outside				
	Total	0,13	0,71	2,7682	
			U-value (w/m²k)	0,36	

Table 4.4 – Thermal Conductivity Calculation for Partition Wall

In addition to the above calculations we have acquired the thermal conductivity of the façade directly from the application provided by a manufacturer:

Glazing from external to internal:

Pane 1

8 mm Float Glass ExtraClear SunGuard SNX 60/28

Spacer 1 - 16 mm

10% Air
90% Argon

Pane 2

6 mm Float Glass ExtraClear
0,76 mm PVB Clear
6 mm Float Glass ExtraClear

Results

Visible light (EN 410 - 2011)

transmittance [%]	τ_v =	58,4
reflectance external [%]	ρ_v =	12,2
reflectance internal [%]	ρ_v =	14,1
general colour rendering index [%]	R_a =	91,8

Thermal properties (EN 673 - 2011)

U-value [W/(m²K)]	U_g =	1,0
slope α = 90°		

Solar energy (EN 410 - 2011)

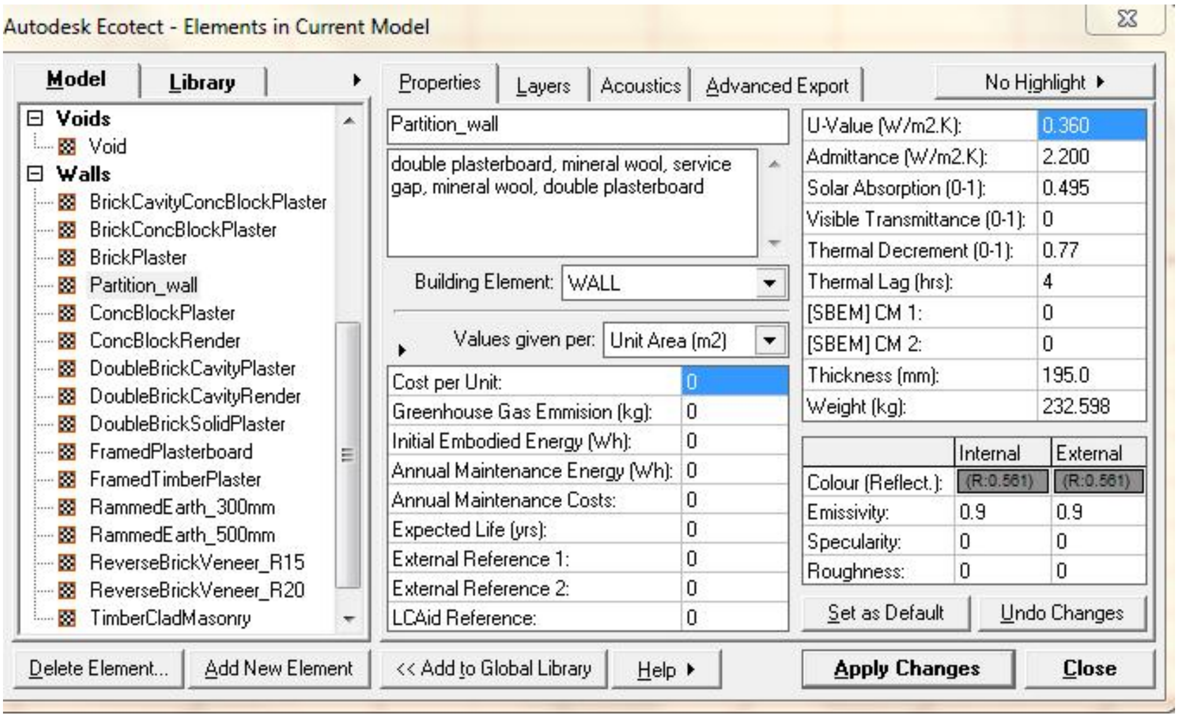
solar factor [%]	g =	27,8
shading coefficient [g/0.87]	sc =	0,32
direct transmittance [%]	τ_e =	24,6
direct reflectance external [%]	ρ_e =	38,1
direct reflectance internal [%]	ρ_e =	30,6
direct absorption [%]	a =	37,3
UV transmittance [%]	τ_{uv} =	0,1
secondary internal heat transfer factor [%]	q_i =	3,2

Other data

estimated sound reduction index [dB]	R_w =	NPD
(EN 717-1)	C =	NPD
	C_{tr} =	NPD

Figure 4.25 – Thermal Conductivity Calculation for Glazed Curtain Wall

This is a sample of the material editing interface from Ecotect:



The U-values and layers for all the envelope components are as previously analyzed.

Energy Class

Once the loads are assessed, we can assign an energy class to the building to evaluate its performance with respect to the annual energy consumption. The energy classes according to international standards are:

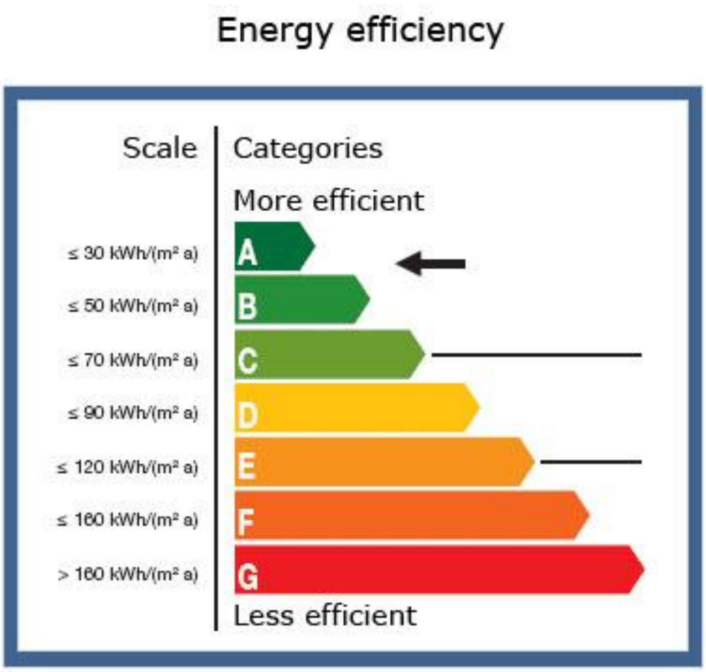


Figure 4.26 – Energy Class Rankings

All visible thermal zones

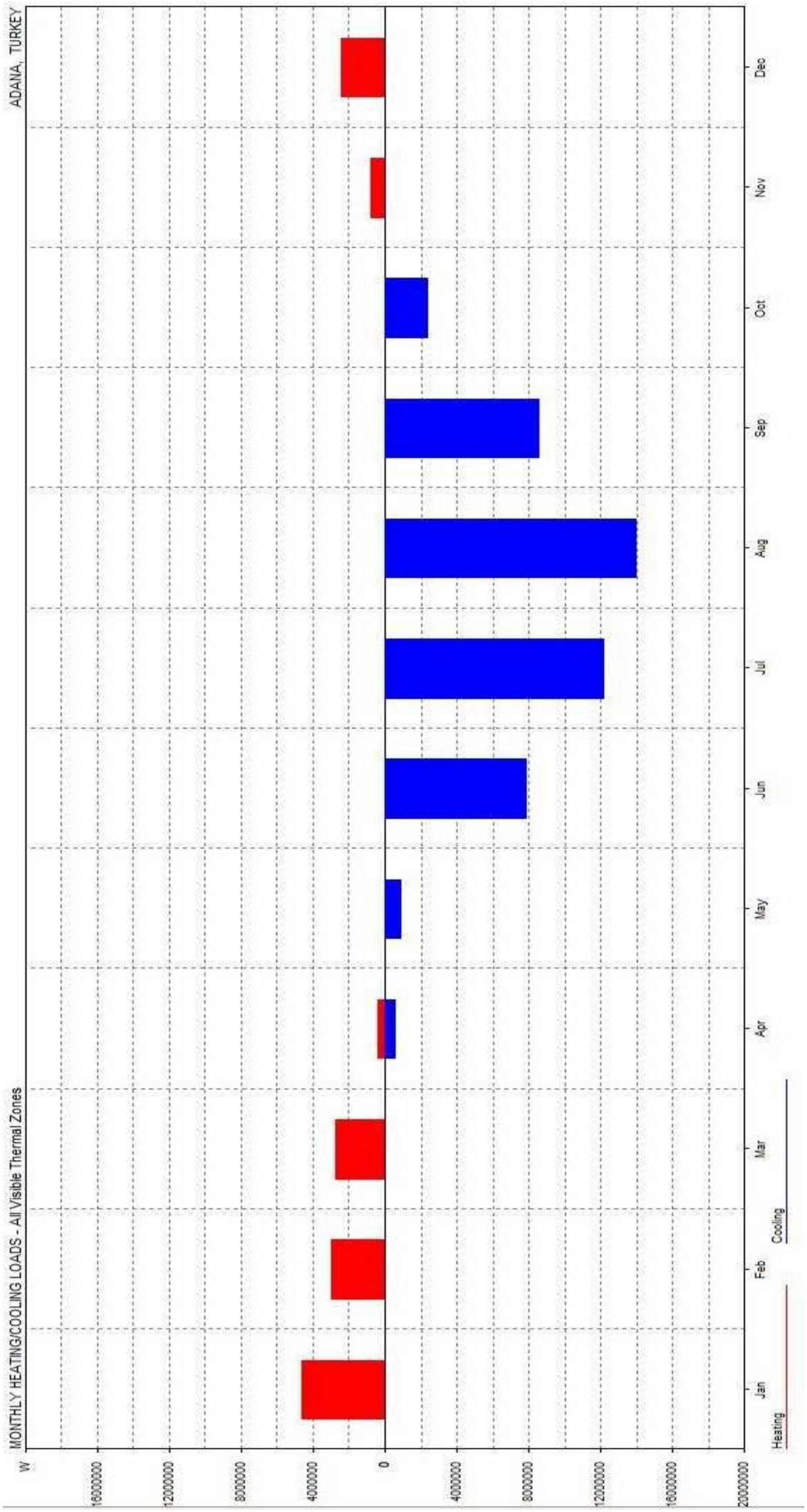


Figure 4.27 – Total Annual Heating And Cooling Demands

The calculations show the graphical reproduction of total annual heating and cooling demands for the entire office building. Only the actual office space and meeting rooms is considered, as only they are heated, while the atrium acts as a non-heated buffer space towards the south oriented façade which is completely glazed. The north façade is also glazed but the solar heat gains are less than on the opposite side, hence the choice of such orientation of offices. We can notice from the graph that heating load is much less than the cooling loads, which is expected due to the location of the project (Adana, Turkey), and also to the large glazing areas. However, the building still achieves quite satisfactory energy efficiency standards.

Numerical data

MONTHLY HEATING/COOLING LOADS - All Visible Thermal Zones - Comfort: Zonal Bands
Max Heating: 84565 W at 17:00 on 16th January
Max Cooling: 120528 W at 13:00 on 15th August

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	4582942	0	4582942
Feb	2970216	0	2970216
Mar	2722186	0	2722186
Apr	384961	597063	982024
May	609	958895	959504
Jun	0	7920280	7920280
Jul	0	12218123	12218123
Aug	0	14010144	14010144
Sep	0	8573869	8573869
Oct	0	2443750	2443750
Nov	756284	0	756284
Dec	2394274	0	2394274
TOTAL	13811473	46722120	60533592
PER M²	8296	28064	36360
Floor Area:	1664.823 m2		

Table 4.5 – Monthly Heating And Cooling Demands

Notices:

For the whole office building the total energy demand is 36.36 kWh/m^{2}year, which corresponds to the B energy class building according to the international energy certification. As we can notice the heating demand is slightly high, which is due in great length to large glazing areas, increasing immensely the solar heat gains. The result is given for all visible thermal zones, that is for all the office space within the building.

4.5 Building Service Systems

4.5.1 Heating & Cooling

4.5.1.1 Zoned Air-Conditioning System

Choosing the air-conditioning system of the building is as much as important as designing the passive solar systems of the building. The air-conditioning system considered so far provides a single source of air with uniform temperature to the entire space, controlled by one space thermostat and one space humidistat.

However, in many buildings there are a variety of spaces with different users and varying thermal loads. These varying loads may be due to different inside uses of the spaces, or due to changes in cooling loads because the sun shines into some spaces and not others. Thus our simple system, which supplies a single source of heating or cooling, must be modified to provide independent, variable cooling or heating to each space. Since our building accommodates different types of spaces we have divided it into zones in means of air-conditioning; such as atriums, offices, performance hall, foyer & back of house areas

There are four types of zoned air conditioning systems: all-air systems, air-and-water systems, all-water systems and unitary, refrigeration-based systems. Within these four systems we have chosen all-air systems for our design. The advantages of this system are;

- Maintenance is performed in unoccupied areas, since major equipment is centrally located.
- No drain piping or power wiring or compressors are located in occupied areas.
- Systems can include options such as air-side economizer, heat recovery, winter humidification, and large outside air volumes where required.
- Good choice where close zone temperature and humidity control is required.
- Simple seasonal changeover
- Simultaneous cooling and heating in various zones.

All-air systems fall into two general categories - constant volume and variable air volume (VAV). Constant air volume systems accomplish cooling and heating by varying the supply air temperature and keeping the air volume constant. VAV systems keep the air temperature constant and vary the air supply volume. VAV systems are easy to control, are energy efficient, and allow fairly good room control. We have chosen VAV systems since they are more efficient and more suitable for our building.

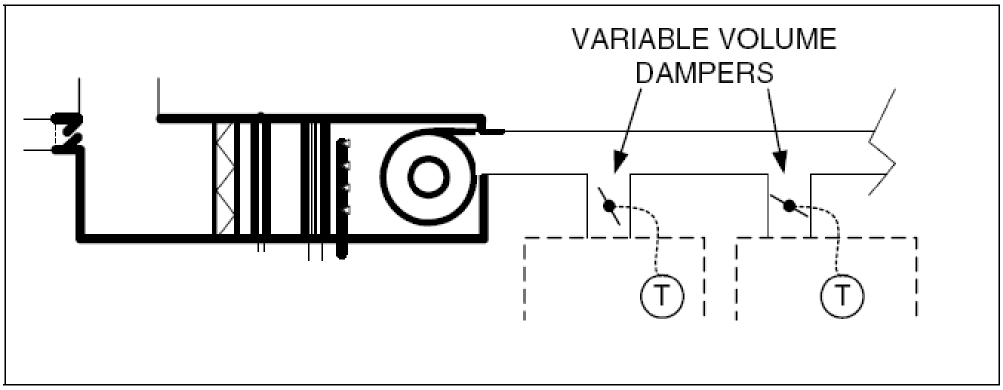


Figure 4.28 – Variable Air Volume System

A geothermal forced-air system is similar to a conventional furnace forced-air system except a geothermal heat pump provides the heat rather than a furnace using gas, electricity, or fuel oil. The geothermal heat pump utilizes ductwork to distribute heat to the building in the winter and cool air in the summer.

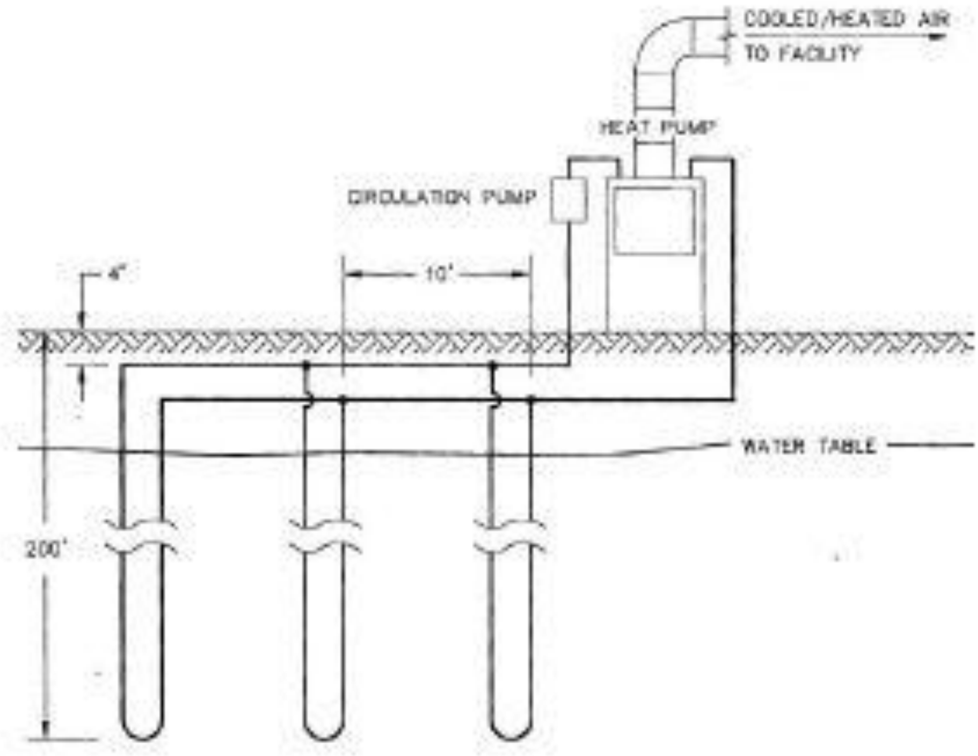


Figure 4.29 – Closed loop ground coupled heat pump system connection with the all-air HVAC system

4.5.1.2 Natural Ventilation

Natural ventilation is the process of supplying and removing air through an indoor space by natural means, meaning without the use of a fan or other mechanical system. It uses outdoor air flow caused by pressure differences between the building and its surrounding to provide ventilation and space cooling.

The use of natural ventilation is definitely an advantage with the raising concerns regarding the cost and environmental impact of energy use. Not only does natural ventilation provide ventilation (outdoor air) to ensure safe healthy and comfortable conditions for building occupants without the use of fans, it also provides free cooling without the use of mechanical systems. When carefully designed, natural ventilation can reduce building construction costs and operation costs and reduce the energy consumption for air-conditioning and circulating fans.

There are basically two types of natural ventilation that can be employed in a building: wind driven ventilation and stack ventilation. Both of which are caused by naturally occurring pressure differences. Stack ventilation is where air is driven through the building by vertical pressure differences developed by thermal buoyancy. The warm air inside the building is less dense than cooler air outside, and thus will try to escape from openings high up in the building envelope; cooler denser air will enter openings lower down. The process will continue if the air entering the building is continuously heated, typically by casual or solar gains. The atrium, shown in the figure below, creates a good environment for natural ventilation. And the section of the mass gives us to opportunity to use stack ventilation.

Figure 4.30 – Partial Section of the Building

The problem is; stack effect ventilation is an especially effective strategy in winter, when indoor/outdoor temperature difference is at a maximum. Stack effect ventilation will not work in summer (wind or humidity drivers would be preferred) because it requires that the indoors be warmer than outdoors, an undesirable situation in summer. But keeping the atrium sealed air-tight turn this space into a green-house, especially during the weekends, without the air-conditioning system running in the offices, the atrium space become hotter than outdoor air temperature. During weekdays, with the air-conditioning running in the offices, the conduction and infiltration leakages into the atrium space reduces its daily peak operative temperature but not enough to keep it at comfortable level.

The best solution is to ventilate the atrium with open bottom & top with a temperature control system. Open the ground floor and rooftop for natural ventilation whenever, the air temperature of the indoor atrium space is higher than the outdoor air temperature. Close the natural ventilation whenever, the outdoor air temperature is higher than the indoor atrium space air temperature. This will allows colder outdoor air to cool the atrium space down when the time is right and when the outdoor air is hot, keep the atrium space air-tight to prevent it from heating up the space.

Due to the captured cooling that was conducted and infiltrated from the offices to the atrium space, the peak operative temperature of the ground floor atrium space is lower than the peak outdoor air temperature. In short, this strategy provides the best combination of comfort and energy reduction scenario. Unfortunately, we are still unable to achieve comfort condition at all time for the atrium space, thus we'll use geothermal heat pump whenever the natural ventilation fails to achieve comfort level.

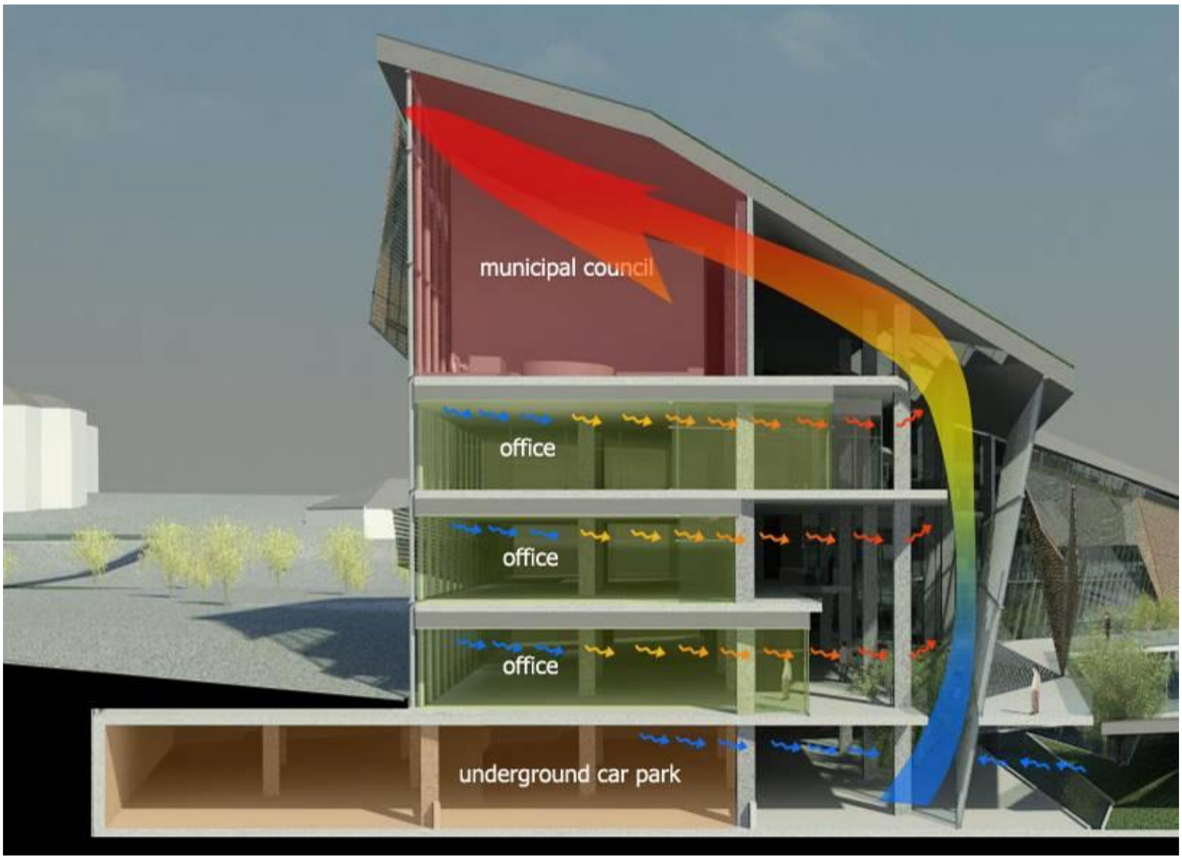


Figure 4.31 – Natural Ventilation Scheme

4.5.1.3 Geothermal Heat Pump

The shallow ground or the upper 3 meters of the Earth, maintains a nearly constant temperature between 10° and 16°C. Like a cave, this ground temperature is warmer than the air above it in the winter and cooler than the air in the summer. Geothermal heat pumps take advantage of this resource to heat and cool buildings.

Geothermal heat pump systems consist of basically three parts: the ground heat exchanger, the heat pump unit, and the air delivery system (ductwork). The heat exchanger is basically a system of pipes called a loop, which is buried in the shallow ground near the building. A fluid (usually water or a mixture of water and antifreeze) circulates through the pipes to absorb or relinquish heat within the ground.

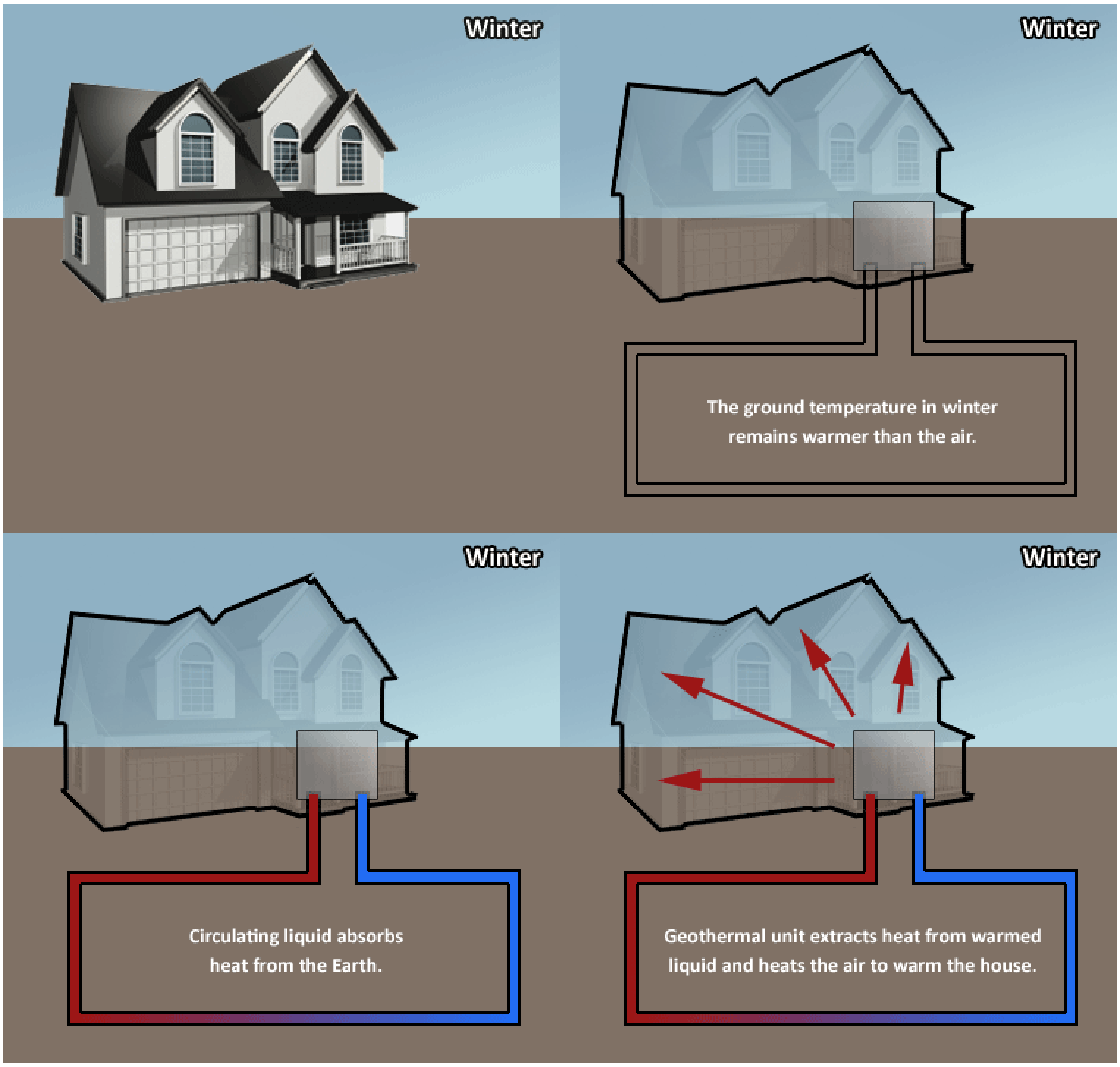


Figure 4.32 – Geothermal Heat Pump – Winter Scheme

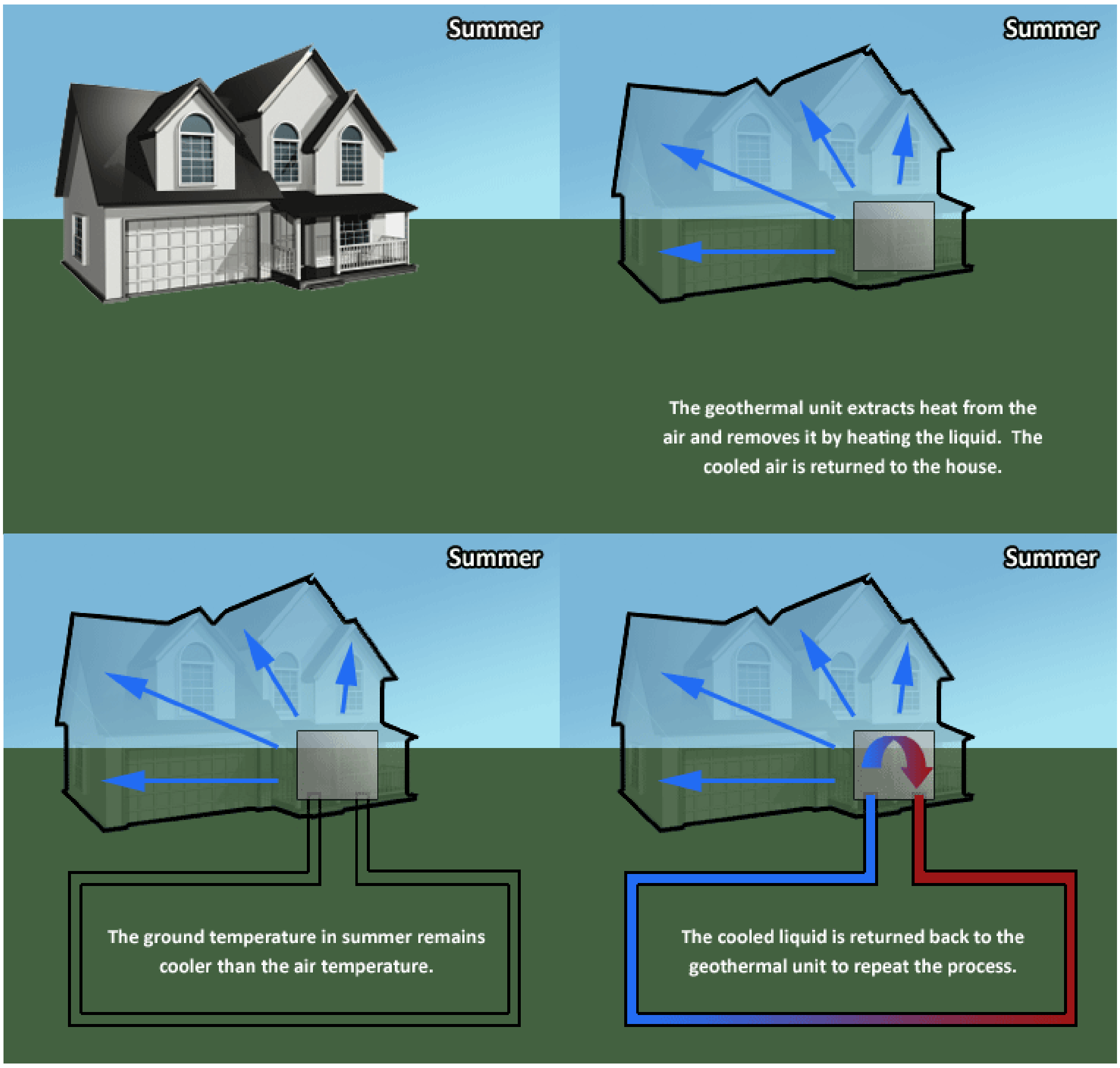


Figure 4.33 – Geothermal Heat Pump – Summer Scheme

In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer can also be used to heat water, providing a free source of hot water.

The net thermal efficiency of a heat pump should take into account the efficiency of electricity generation and transmission, typically about 40%. Since a heat pump takes heat from the ground, the total heat energy output to the building is greater than the electricity input. This results in thermal efficiencies greater than 100%, up to around 150%.

Geothermal heat pumps use much less energy than conventional heating systems, since they draw heat from the ground. They are also more efficient when cooling the building. Not only does this save energy and money, it reduces air pollution.

Ground-source heat pumps are characterized by high capital costs and low operational costs compared to other HVAC systems. Their overall economic benefit depends primarily on the relative costs of electricity and fuels, which are highly variable over time. Based on recent

prices, ground-source heat pumps currently have lower operational costs than any other conventional heating source almost everywhere in the world. In general, a savings of anywhere from 20% to 70% annually on utilities can be achieved by switching from an ordinary system to a ground-source system.
The U.S. Environmental Protection Agency (EPA) has called ground-source heat pumps the most energy-efficient, environmentally clean, and cost-effective space conditioning systems available. Heat pumps offer significant emission reductions potential, particularly where they are used for both heating and cooling and where the electricity is produced from renewable resources.
Ground-source heat pumps have unsurpassed thermal efficiencies and produce zero emissions locally, but their electricity supply almost always includes components with high greenhouse gas emissions. Their environmental impact therefore depends on the characteristics of the electricity supply. Therefore, we propose to supply the required electricity from PV panels which will be introduced in details in the coming chapters.

4.5.2 Space Air Diffusion

A ventilating system is intended to introduce air to or remove air from a space, to move air without changing its temperature. With potentially high amount of different contaminants present in indoor air, ventilating systems may be used to improve indoor air quality or to improve thermal comfort. Obviously identifying indoor air quality (IAQ) problems and developing solutions is extremely important in system design therefore it is necessary that we integrate ventilation systems in our building. In fact the ventilation system used not only removes air borne pollutants from the interior but also provide a thermally comfortable indoor environment by cooling the internal space.

In the previous chapter we have expressed our intention to condition the supply air by geothermal heat exchangers. In this chapter, how the supply air will be diffused into a room will be discussed. As discussed in the previous chapters, the cooling is a more important issue than heating due to the local climate characteristics; we have chosen mixing diffusion which is more efficient in cooling scenario.

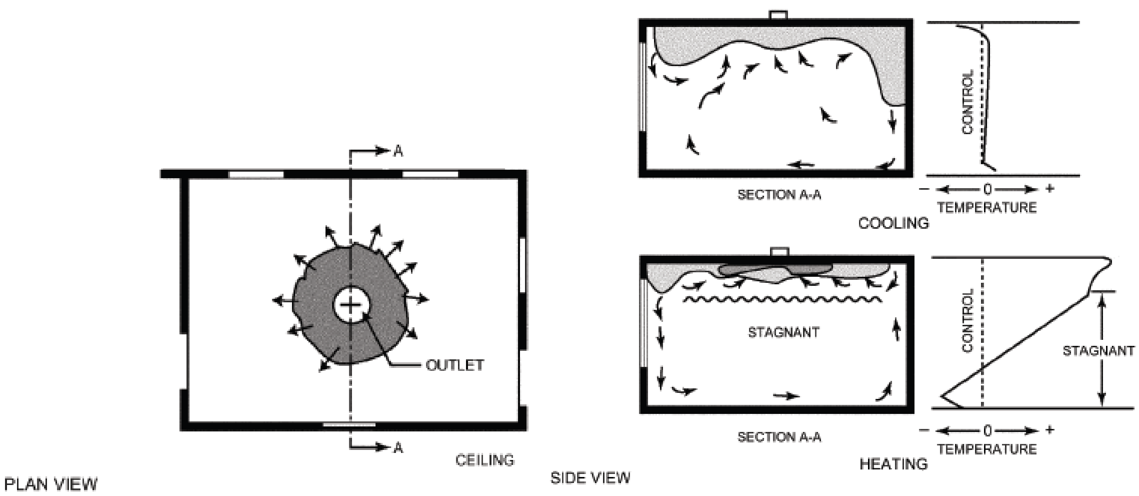


Figure 4.34 – Space Air Diffusion System

As seen in the figure above, the outlets will be mounted in the ceiling which will discharge the air horizontally. Due to the Coanda effect the horizontally projected cool air stream will drop to the floor while there may be a stagnant air zone during the heating scenario.

4.5.3 Water Conservation Strategies

Modern water use concepts for buildings aim on saving natural resources ensuring minimum emissions like carbon dioxide and wastewater. Beside the ecological benefits, economic but also additional benefits arise: using the internal water cycle as a visible design element and improving the climate within the building at the same time. In contrast to easily accountable benefits like reduced freshwater consumption the former are more difficult to account for.

Large office buildings can consume between 15,000 to 50,000 kL of fresh potable water per annum. In buildings without cooling towers, up to 75% of this water may be used for toilet and urinal flushing, evenly split between the two.

The advent of waterless urinal technology eliminates the need to flush down a small amount of urine with five to ten liters of perfectly good drinking water. Using the latest low flush toilets can cut toilet water consumption by 30 to 50%. It increases the proportion of water consumed by taps considerably, even if all taps are flow restricted.

In this changed water balance, 40% of the total water supply to an office building may be used in taps and showers, zero for urinals and 50% for toilet flushing with 10% for the rest.
In new buildings, it is feasible to collect water from hand basins and showers in a separate waste stack. This water is only lowly contaminated. It can easily be treated to the required standards for reuse in toilet flushing.

Grey water can supply up to 60% of toilet flushing needs. The rest can be made up from rainwater. Since there is an intrinsic link between toilet water use and greywater production from hand washing after toilet use, only a small buffer storage is required. It ensures compliance with most authority's stipulations to not store gray water for more than 24 hours. Linking gray water production and gray water reuse in such an obvious fashion, coupled with rainwater harvesting and latest low flow or no flow water conserving technologies, can reduce water consumption from office buildings by over 80%.

In order to accomplish a sustainable design reduction of water consumption is a great challenge to overcome. Water scarcity is a rising problem of the world and water used in buildings are one of the main reasons behind it. In line with our mission of setting a model for sustainable architecture in Adana, our design seeks different ways of water conservation. In our design we propose to use three water conservation strategies:

- Water saving measures: Low flush toilets and dry urinals
- Rainwater harvesting: Roof collection and outdoor storage in an open canal
- Gray water treatment: In-door CW treatment

4.5.3.1 Multi-Source Harvesting System: Gray Water & Rain Water

The objective for any water harvesting system is to make it as efficient as possible in replacing the greatest amount of potable municipal water with non-potable water collected on the property. Often that can be accomplished by using water from one source – like rooftop rainwater. But the more efficient system is to collect water from multiple on-site sources such as rainwater and gray water from showers and sinks. Those same systems can support multiple uses on-site like toilet flushing and above ground irrigation

Rainwater is a notoriously inconsistent source for harvesting, depending on variable rain events day to day and week to week. In drier seasons, total average supply is often insufficient to meet the demand for non-potable water, preventing a single-source rainwater harvesting system from meeting a building’s water needs. And although grey water harvesting provides a more consistent supply of water than rainwater alone, in office buildings production of grey water is not constant. In this case, the best way to meet a building’s total non-potable water demand is to combine multiple water sources to maximize efficiency and thereby minimize the building’s impact on water resources and the environment.

The ideal system would be able to meet the demand for water using untreated rainwater or gray water, but there is need to address a potential health risk posed by these water sources. The risk from rainwater is low, on the whole, where as gray water requires a higher treatment level. However, once raw gray water is properly filtered and sanitized it technically is no longer “gray water” and becomes a new standard of “on-site treated non-potable water” just as rainwater and storm water do when they are properly treated. We can then combine the treated water from multiple sources and use the “on-site treated non-potable water” for many applications.

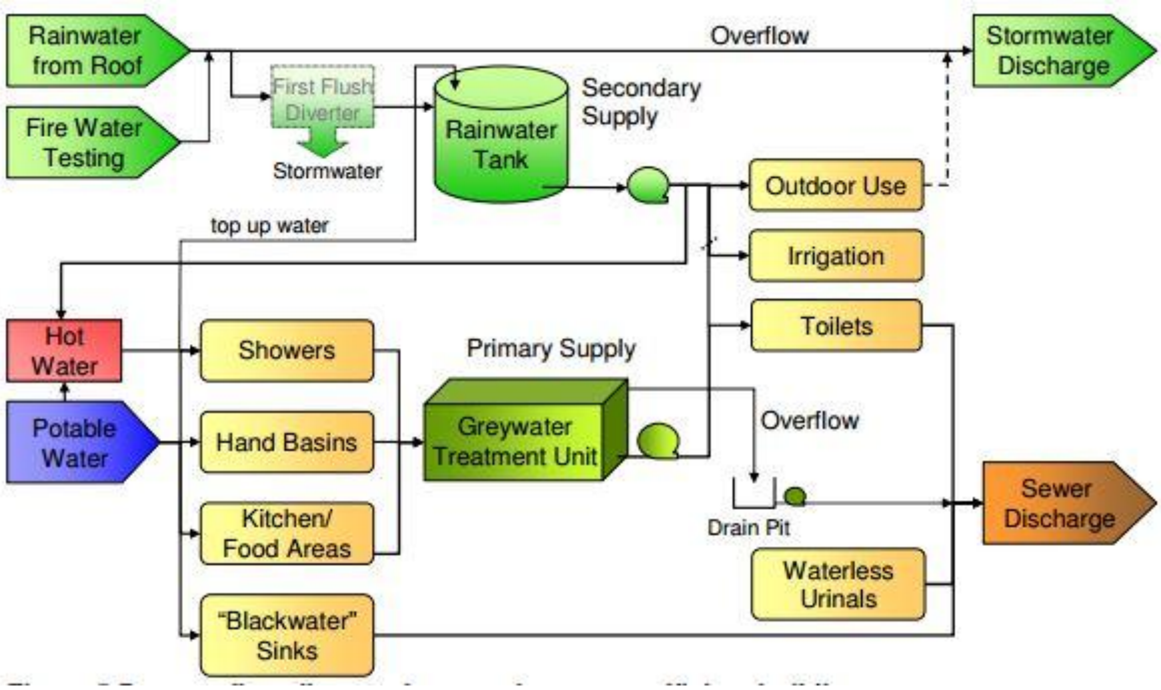


Figure 4.35 – Multi-Source Harvesting System

We have proposed two design solutions for rain water harvesting. First of them is green roofs. As introduced in the previous chapters, the complex has green roofs. Other than aesthetics green roofs offer many advantages. Green roofs reduce total rain water runoff volume and peak flows, improve building insulation properties and extend the expected life of the roof's base material. The green roofs allow for more consistent capture and provision of harvested rainwater which gives the opportunity to reduce potable water consumption.

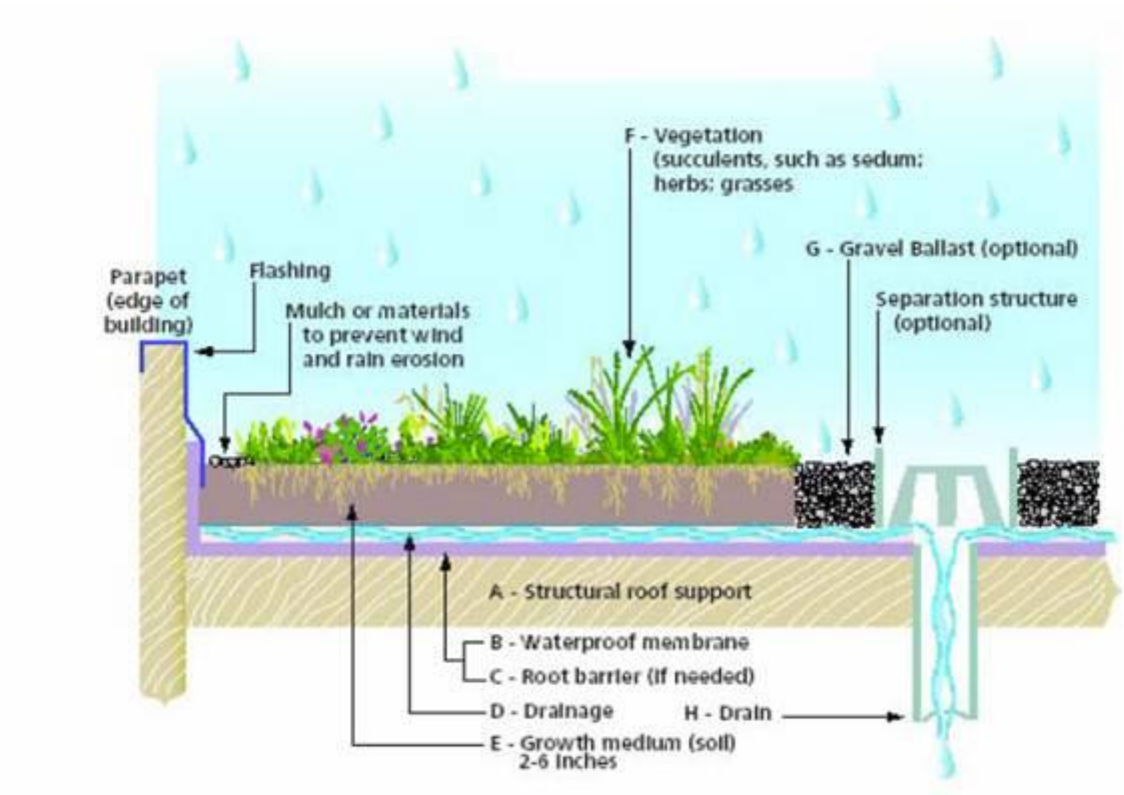


Figure 4.36 – Green Roof Drainage System

The second design feature in our project for harvesting rain water is the rainwater canal. The water features in our project act as an outdoor open canal. In the rainy seasons, when the water level exceeds the canal height, the excessive water will be filtered and sent to rain water storage tank.

Figure 4.37 – Rainwater Storage Canal

4.5.3.2 Water Efficient Sanitary Appliances & Fittings

Even though our design proposes to use grey water as a water conservation strategy, the installation of high efficient toilets into the building is a major support to reducing water consumption. In order to reduce water conservation we have chosen several water & energy efficient sanitary appliances & fittings.

Waterless urinals eliminate the need for flushing after usage. A waterless urinal cartridge that is made out of non-stick, non-porous material and designed to work like a funnel in installed in the urinal. Urine passes through the waterless system where the sealant forms a barrier between it and the restroom space. The sealant is less dense than water allowing urine to pass through and flow into the drain. The waterless urinal cartridge then collects uric sediment translating into an odor-free restroom, clean pipes and zero water waste. The cartridge also features an O ring, which provides an airtight barrier between the cartridge and the urinal itself. The only maintenance required is routine cleaning of the fixture and an easy change of the cartridge, two to four times per year (depending on the use). Roughly 5% of the world’s fresh water is used to carry away urine. A waterless urinal can save up to 151.000 liters of fresh water per year. A water free urinal also reduces sewerage costs due to the fact that no supply water piping is required.

Waterless urinals is an effective way to reduce water consumption, but its range of usage is limited, so the conservation. Thus we have chosen a high efficient toilet system which reduces the water consumption. Instead of dual flush toilets we have chosen a double-cyclone flushing system (a patented product by TOTO). The system to harness the power of water and gravity to create a more powerful 1.28 GPF flush that maximizes cleaning action. Using two nozzles (instead of rim holes), water can be used more efficiently for a better rim and bowl wash, while directing more water to the siphon, for a more powerful flush. This system's main advantages are:

- Hole-free rim design means less trapped dirt and bacteria. and that means less cleaning.
- The dual-nozzle water propulsion system allows more water to be directed to the siphon.

In the figure below (left) the main principle of the mechanism is briefly explained.

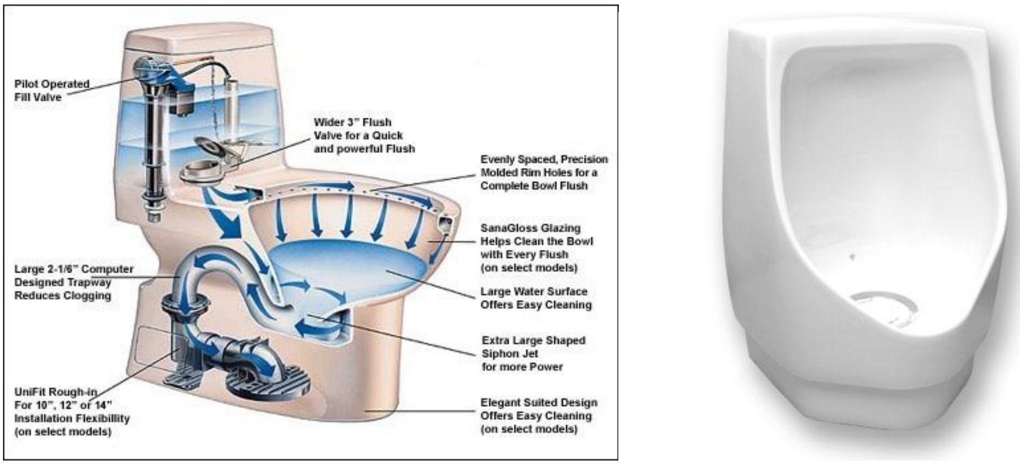


Figure 4.38 – High Efficiency Toilet Systems

In addition to the high toilet systems, we have chosen self-sustaining faucets. This item features both water & energy conservation. It requires no electricity or routine disposable battery replacement.

The turbine, powered by water, creates an electrical current that is stored in rechargeable cells that power the Smart Sensor System of either the faucet or valve. The system replenishes its charge with as few as five uses a day and is optimized at a mere 10 uses per day.

Figure 4.39 – Self Sustaining Faucets

4.5.4 Lighting

Lighting in an office environment has crucial importance. Office lighting systems are a dominant user of electrical energy and a source of internal heat that often needs to be removed from the space. Modern energy-efficient lamps, luminaires (fittings) and controls can often reduce energy consumption by up to 50%. Specifying a well-controlled, high quality, energy-efficient lighting system that can take advantage of available natural light can provide an effective and comfortable working environment for occupants.

Reducing artificial lighting requirement of the building is the first goal of the design, but due to the hot local climate, this issue has been considered in most effective way. The first step to allow natural lighting without the effects of the solar radiation was the orientation of the building itself. We have maximized north and south façade exposure for daylight harvesting to reduce lighting electrical loads while using shading element to reduce cooling loads caused by solar gain on south façades. Also the shading element designed is made of perforated metal which does not block the southern sunlight totally. The shading element covers most of the south façade for avoiding solar gains. The shading element is installed on the north façade in strips just for aesthetics. As it can be seen from the below figure the atriums face to south where there is also a huge natural ventilation opportunity. The offices face either to the north façade or atriums. Also the office spaces lay in north & south direction.

Figure 4.40 – Building Section

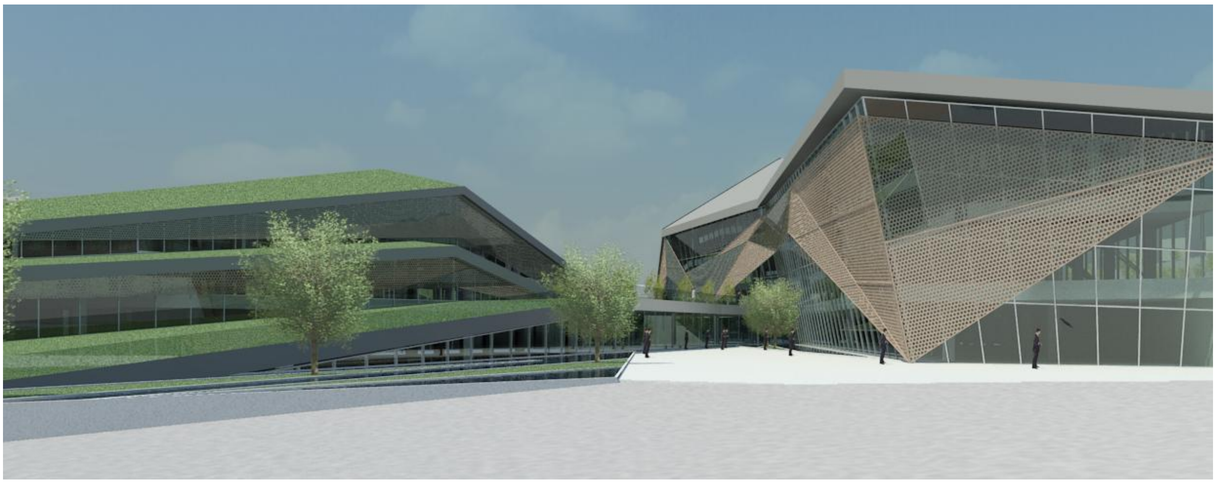


Figure 4.41 – Perforated Metal Shading Element

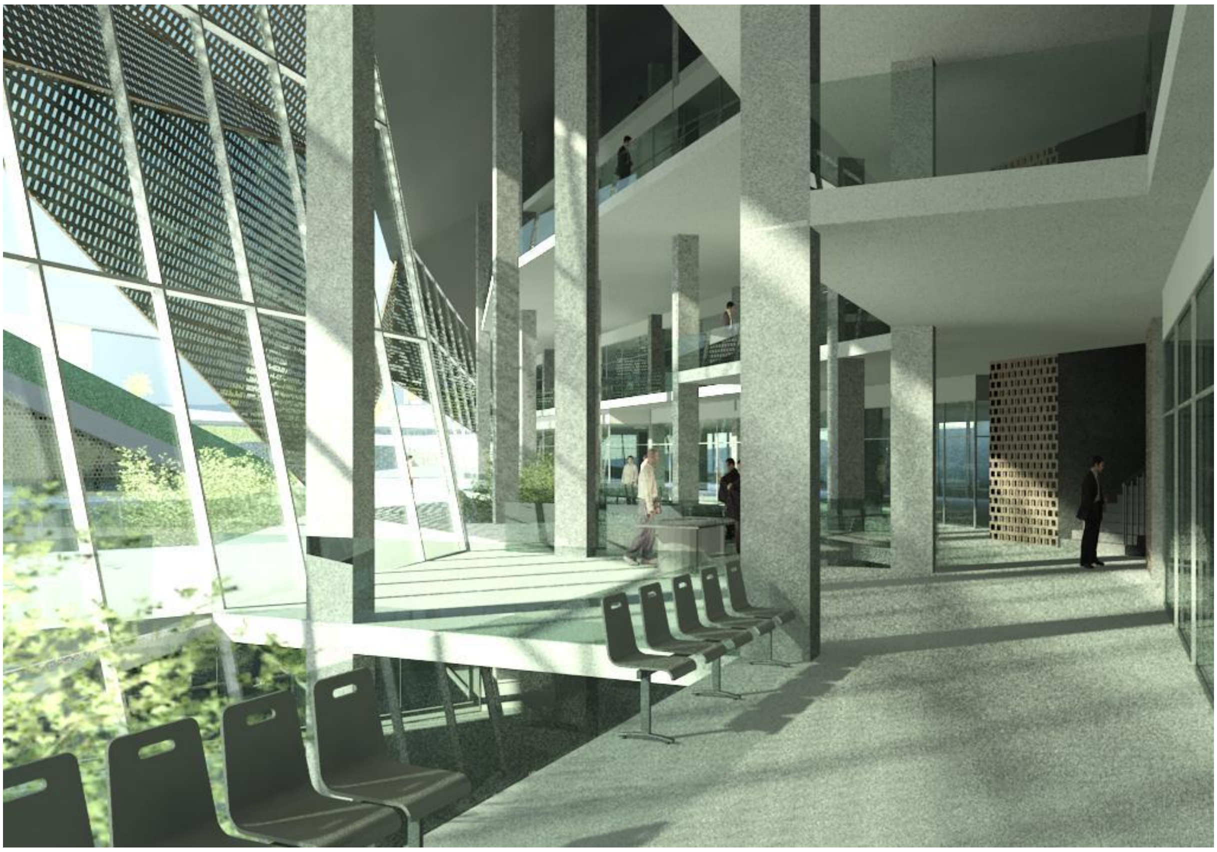


Figure 4.42 – Interior Render from the Atrium

Besides the orientation of the offices, office layout plays an important role in allowing natural light and reducing artificial lighting. With the glass partitions between the office spaces the natural light can glide into spaces that are not adjacent to the façade. Also open office layouts give opportunity to reduce artificial lighting as well. Thus we have designed open offices as much as the project brief has allowed as shown in the figure below.

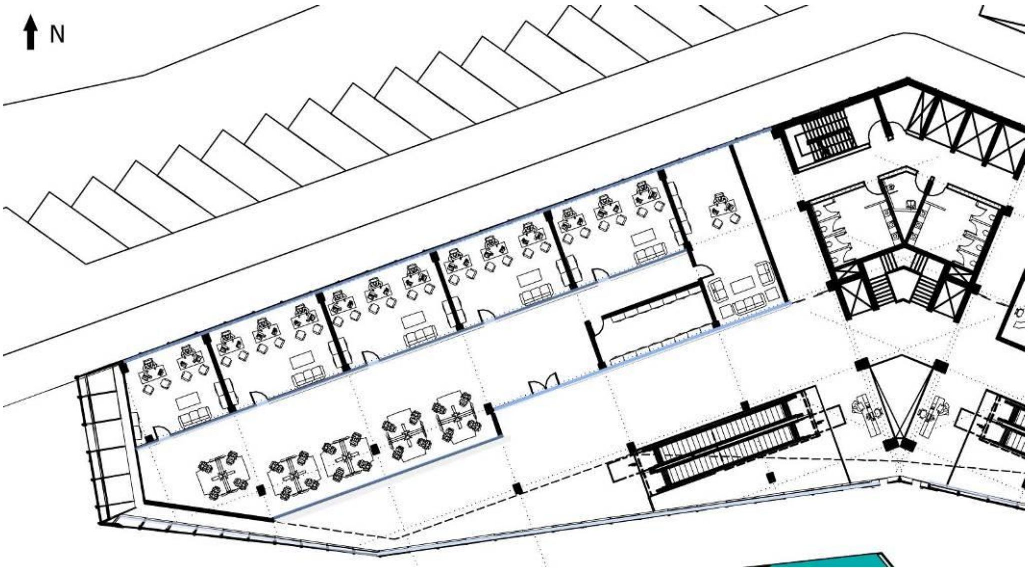


Figure 4.43 – Typical Office Layout

In the above paragraphs the methods for maximizing the natural light within the spaces without negative effects of solar radiation is discussed. Even that the natural light is maximized, artificial lighting is necessary in order to achieve comfortable working ambience. Thus energy efficiency in artificial lighting is considered as well. In an office environment, there needs to be ambience lighting instead of task/spot lighting. The most suitable way to achieve that is to use discharge lamps instead of incandescent or led lighting. Discharge lamps comprise two components – the light itself, and a ballast that controls the flow of electric current through the light. Fluorescent tubes are the most efficient form of fluorescent light. Modern triphosphor lamps are much more efficient than the older halophosphor types. The latest T5 tubes produce about 5 to 6 times as much light output for the same energy input as an incandescent lamp. They can last 15,000 hours or more. T5 tubes also use energy efficient electronic ballasts rather than magnetic ballasts. So in the office space lighting we propose to use T5 fluorescent tubes.

4.6 Electricity Production - Solar Energy

The electricity from photovoltaic cells can be used for a wide range of applications from power supplies for small consumer products to large power stations feeding electricity into the grid. We applied such electricity generation system after analyzing the production capacity by PVGIS (Photovoltaic Geographical Information System) located in a field within the urban park. The system will be directly connected to the city grid. The main purpose of using this system is not only to supply sufficient electricity to the building, but also supplying electricity to the city as well.

<u>Input for the PVGIS:</u>

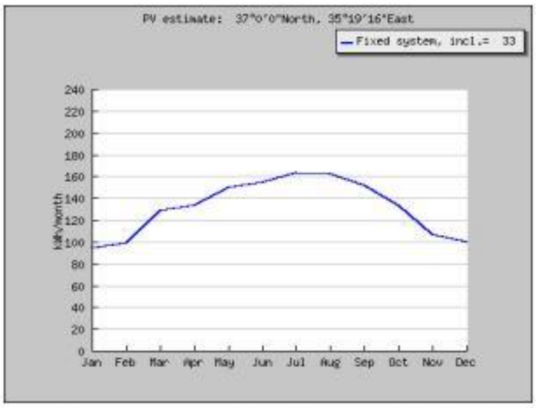
Adana, Turkey
Location: 37°0'0" North, 35°19'16" East, Elevation: 34 m a.s.l.,
Solar radiation database used: PVGIS-CMSAF
Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 11.6% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.6%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 25.9%

<u>Output from the PVGIS:</u>

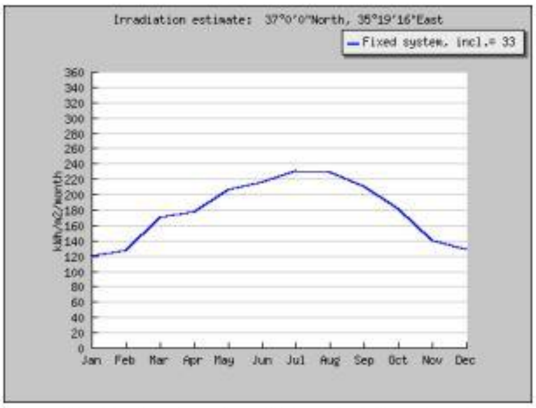
	Fixed system: inclination=33 deg., orientation=0 deg. (Optimum at given orientation)			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	3.04	94.2	3.87	120
Feb	3.52	98.6	4.54	127
Mar	4.15	129	5.48	170
Apr	4.44	133	5.91	177
May	4.83	150	6.66	207
Jun	5.14	154	7.22	217
Jul	5.27	163	7.41	230
Aug	5.23	162	7.38	229
Sep	5.04	151	7.01	210
Oct	4.31	134	5.87	182
Nov	3.56	107	4.65	140
Dec	3.23	100	4.12	128
Year	4.32	131	5.85	178
Total for year		1580		2130

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

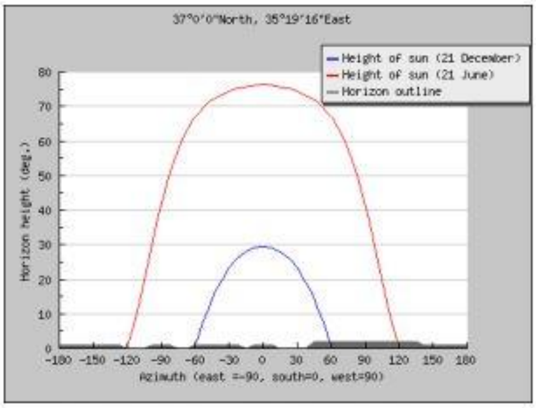
Figure 4.44 – Solar Electricity Generation



Monthly energy output from fixed-angle PV system



Monthly in-plane irradiation for fixed angle



Outline of horizon with sun path for winter and summer solstice

Figure 4.45 – Graphical Output from PVGIS

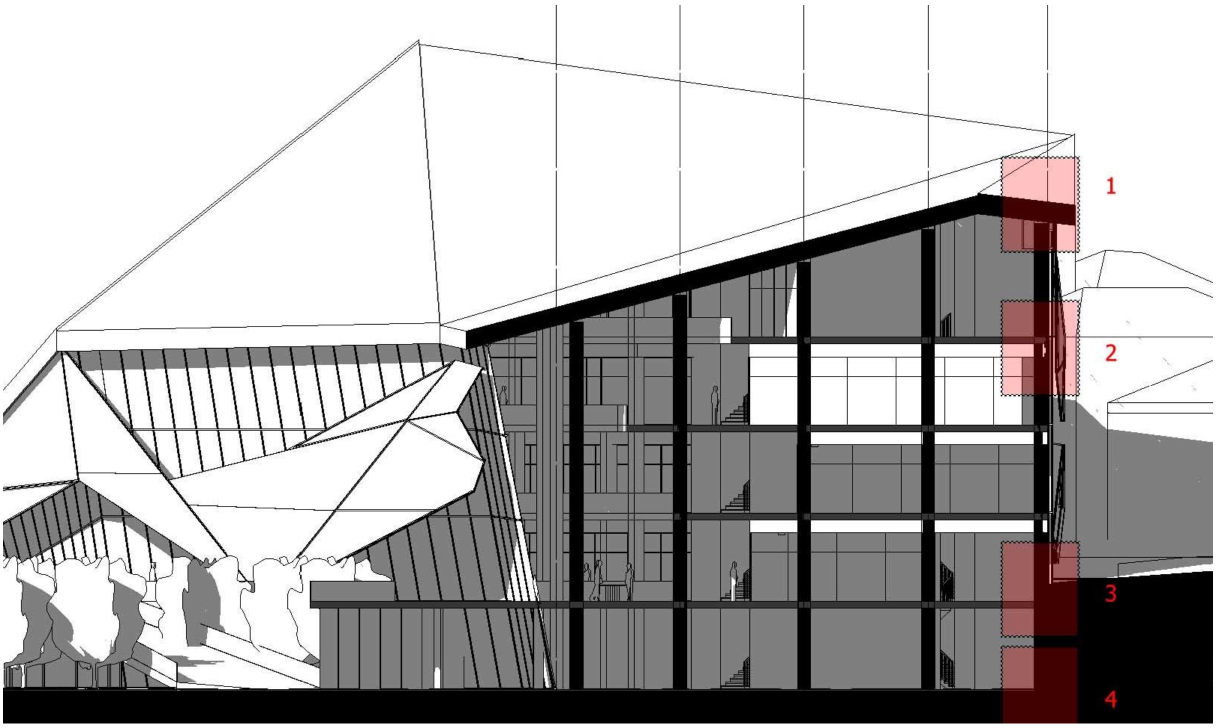
As it can be seen from the Figure 4.44 average monthly electricity production from the 33° inclined fixed system with 1kWp peak PV power is 1580 kWh (Em). Assuming that the 1kWp system is approximately 10 m² of PV area, the electricity generated by 1 m² PV panel in year is 1896 kWh/m²-year. The area of the plot that the PV panels will be located allows 1250 m² of PV panel installation, which gives us the opportunity to generate 2.370.000 kWh-year. We have analyzed a municipality building which has very similar electricity consumption strategies and construction area (app. 20.000m²). The mentioned municipality hall in Eskisehir, Turkey consumes 960.000 kWh-year. By integrating the PV panels to the city grid, we will supply more electricity to the city than the electricity the building would use itself.

Our intention is not to be limited with the mentioned PV panels, but to use solar street lights in order to light up the urban park. Since the urban park itself is almost as big as a neighborhood we don't want to consume all the electricity generated by the PV panels to be used for the urban park.

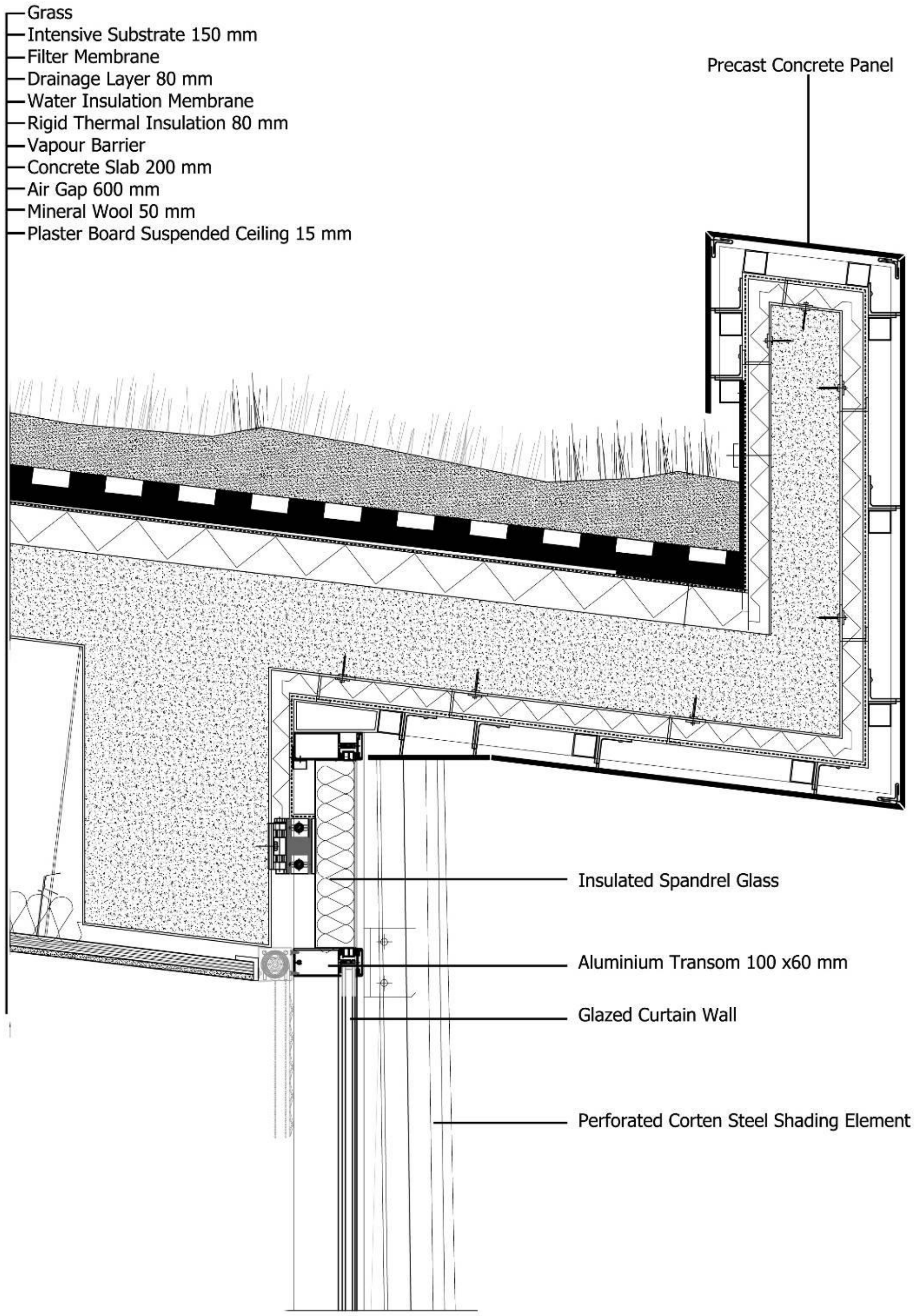
The solar street lights comprise of the photovoltaic cells, which absorb the solar energy during daytime. The photovoltaic cells convert solar energy into electrical energy, which is stored in the battery. At the night time the lamp starts automatically and it consumes the electricity already stored in the battery. During the day time the battery gets recharged and the process keeps on repeating every day.

Figure 4.46 – Proposed Solar Lighting System for the Urban Park

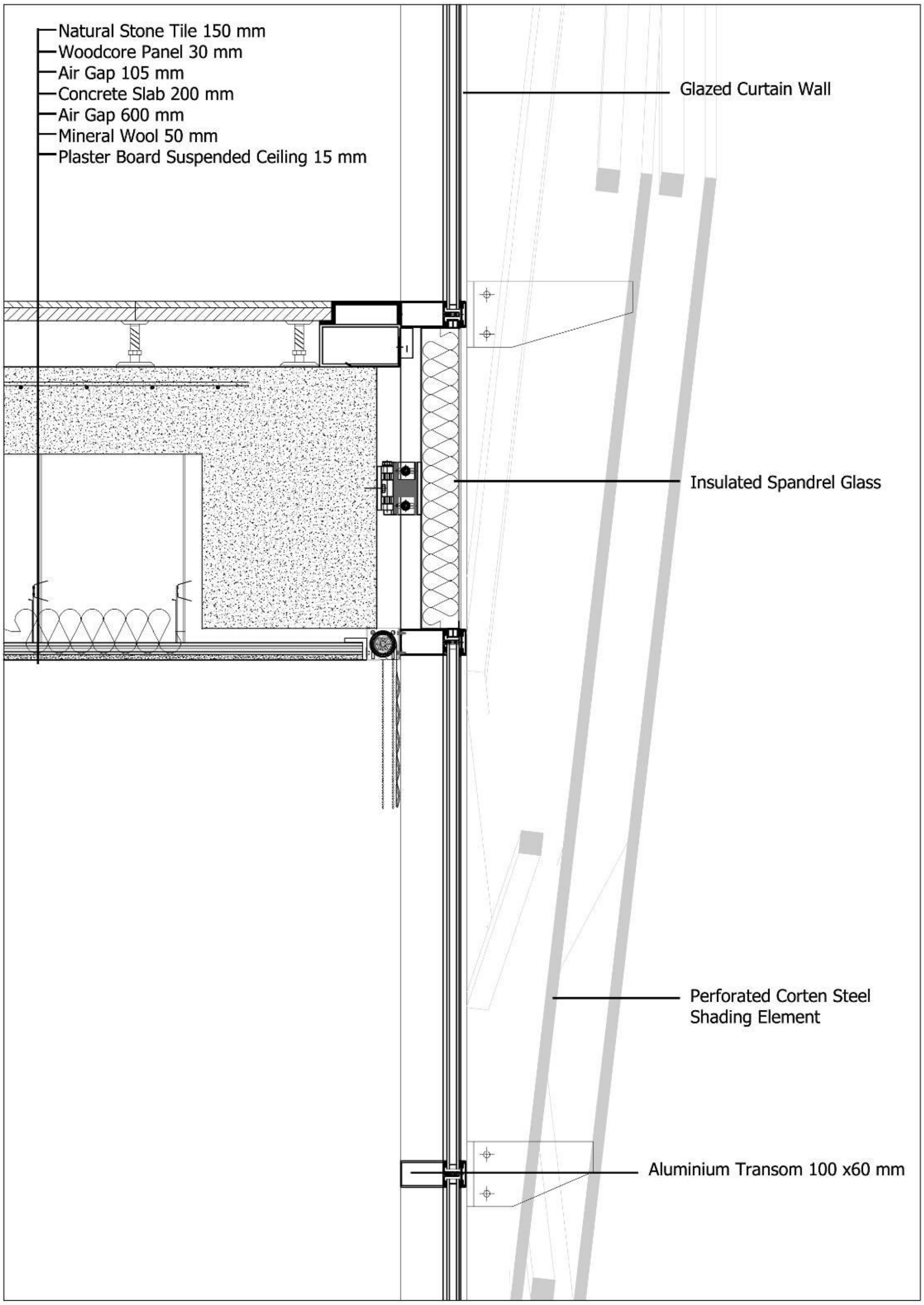
4.7 Details



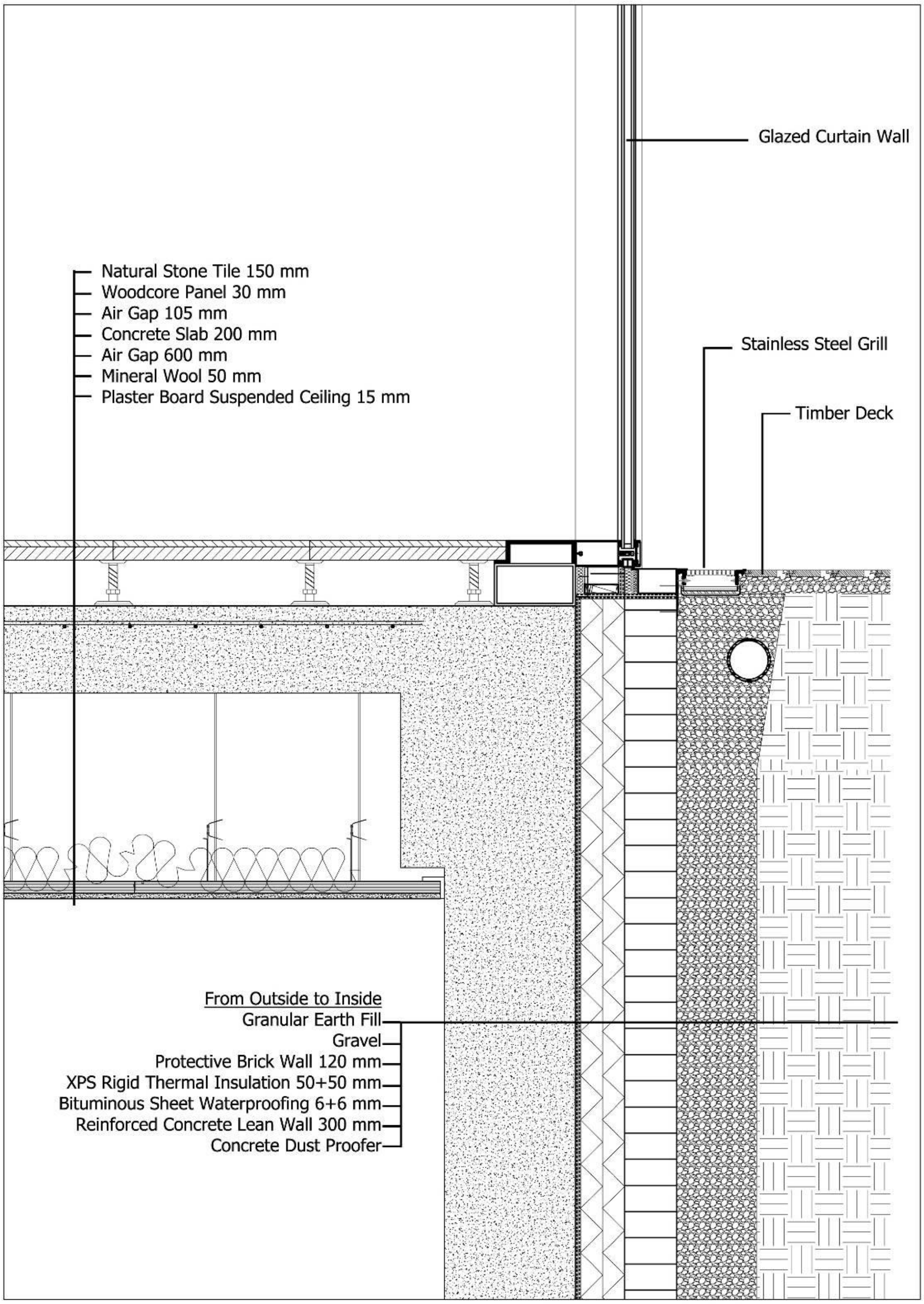
Drawing 4.1 – Key Section



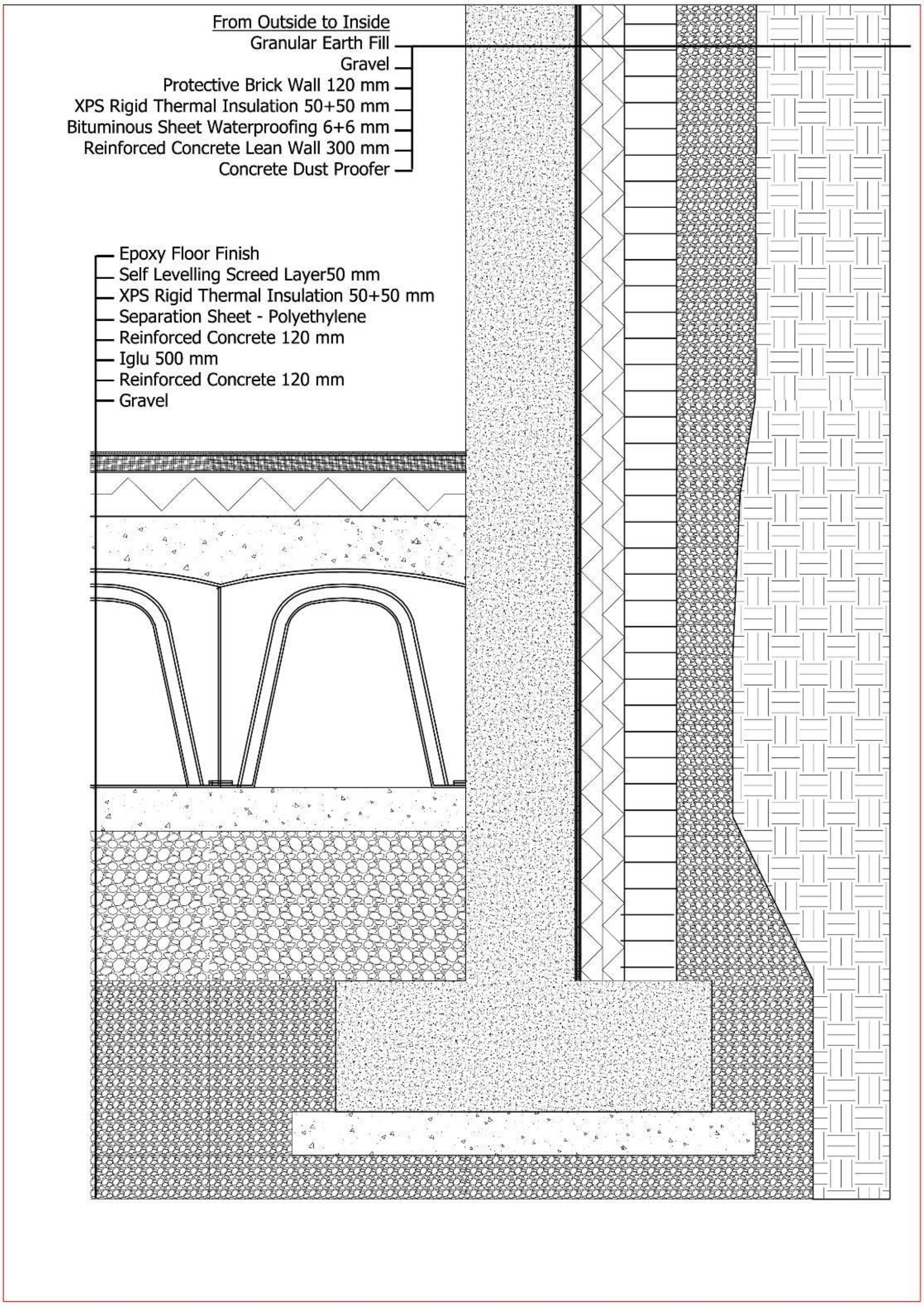
Drawing 4.2 – Roof Detail (1)



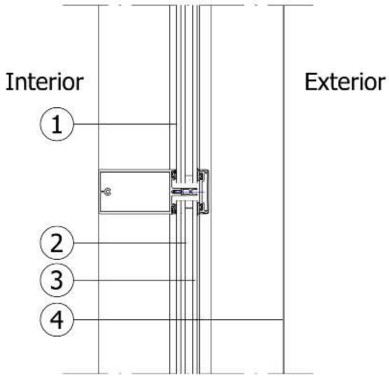
Drawing 4.3 – Intermediate Floor Detail (2)



Drawing 4.4 – Ground Floor Detail (3)

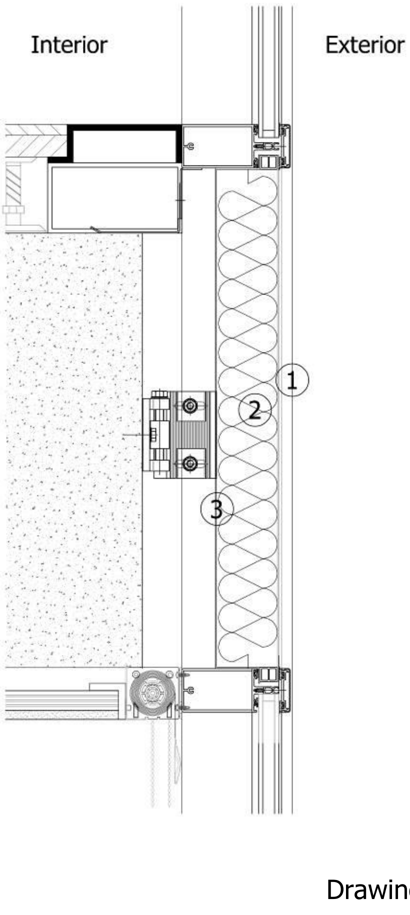


Drawing 4.5 – Basement Floor Detail (4)



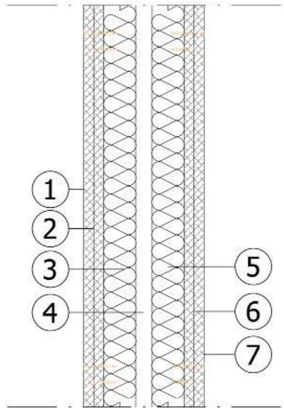
1	Inner Pane - Laminated Clear Glass	6+0.76+6 mm
2	Spacer/gas - %10 air, %90 argon	16 mm
3	Outer Pane - Clear Glass - Coating on Inner Face	8 mm
4	Perforated Corten-Steel Shading Element	2 mm

Drawing 4.6 – Glazed Curtain Wall Detail



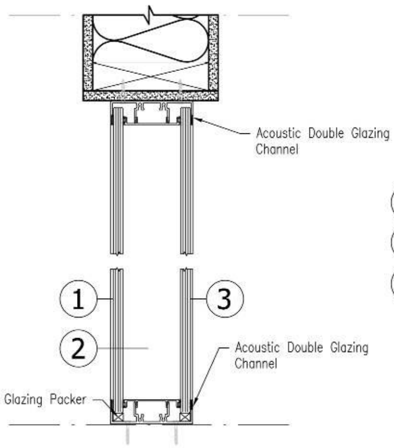
1	Monolithic toughened glass with enameled ceramic paint	10 mm
2	Mineral Wool	80 mm
3	Galvanised steel back panel	2 mm

Drawing 4.7 – Insulated Glass Spandrel Detail



1	Acrylic bonded water based paint	
2	Double gypsum board	25 mm
3	Mineral Wall	40 mm
4	Air gap	10 mm
5	Mineral Wall	40 mm
6	Double gypsum board	25 mm
7	Acrylic bonded water based paint	

Drawing 4.8 – Opaque Office Partition Wall



1	Laminated Tempered Glass (Interior)	12 mm
2	Air Gap	76 mm
3	Clear Tempered Glass	12 mm

Drawing 4.9 – Transparent Office Partition Wall

Chapter Five - Structural analysis and design

5.1. Introduction

"Structural design can be defined as a mixture of art and science, combining the engineer's feeling for the behavior of a structure with a sound knowledge of the principles of statics, dynamics, mechanics of materials, and a structural analysis, to produce a safe economical structure that will serve its intended purpose." (Salmon and Johnson 1990)

The first step was to define the structural system and materials. After a thorough analysis of different structural systems and the building's characteristics, the traditional reinforced concrete frame structure was chosen to be most convenient due to the following advantages:

1. Strength: the main advantage of reinforce concrete is its strength.
2. Safety: Better resistance to fire, earthquake, accidental actions on a structure if correctly designed and detailed.
3. Economy: lower price in the interested region
4. Durability: long service life with low maintenance cost
5. Insulation: high degree of thermal and sound insulation.
6. Ease and Versatility: the reinforced cast in place concrete is fairly easy to work with and any shape.

As a primary design code for reinforced concrete structures following were used

- Eurocode 0: EN 1990:Basis of structural design
- Eurocode 1: EN 1991: (Eurocode 1) Actions on structures
- Eurocode 2:EN 1992: (Eurocode 2) Design of concrete structures
- Eurocode 2:EN 1998: (Eurocode 8) Design of structures for earthquake resistance

The latest edition of this codes is dated 2004 and is the main reference of this design. Moreover, Turkish design codes for used for calculation of loads on the structure such as snow, wind and seismic.

5.2 Structural analysis

5.2.1 Building description

The municipality hall and cultural center consists of two separate buildings and a central part that connects them. In present thesis work only one building will be modeled, analyzed and designed.

As a foundation for the building a mat foundation was chosen to transfer vertical and overturning moments to soil, this type of foundation has several advantages over separate shallow footings such as uniform settlement, good distribution of stresses on soil, good seismic resistance. Depending on the geological and geotechnical site tests a piled slab is a possible solution.

The frame system consists of columns, beam, two-way slab and nuclear cores by stair and elevators shafts, all casted on site.

5.2.2. Loads analysis

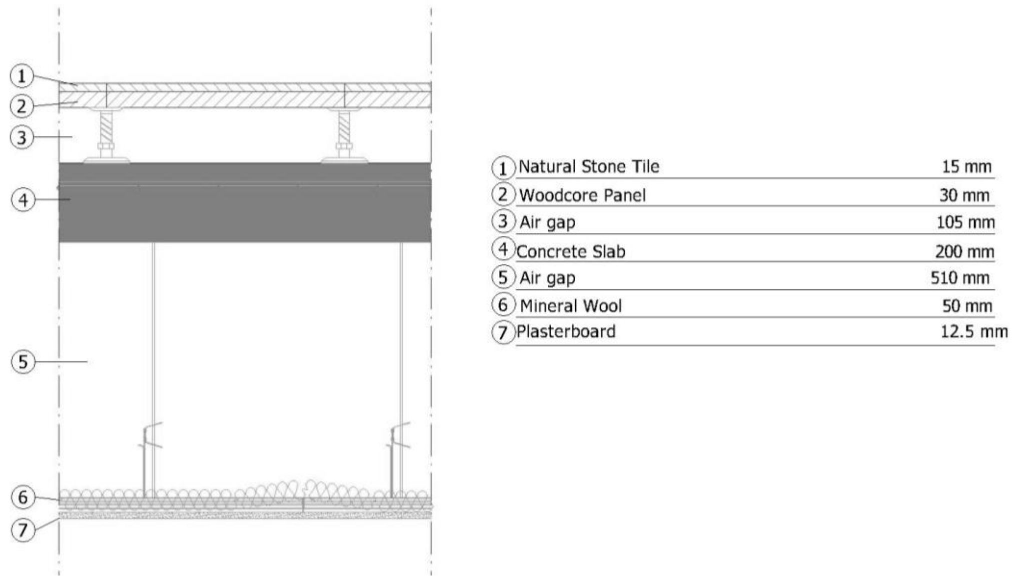
Eurocode classifies actions on the buildings as permanent and variable loads and gives some design guidelines on calculations of characteristic values. Afterwards the combinations of actions shall be calculated for verifications of various limit states. Nonetheless Eurocode provides partial factors for each applicable combination of actions; it is engineers' responsibility to identify the most critical load cases for each combination.

- Permanent actions, are any actions that are presented on the structure permanently during whole service life of it, these include:
  Self-weight of structural elements (G_1)
  Self-weight of all non-structural elements such as exterior cladding, permanent partitions and fixtures, ceilings and static machinery(G_2)
  Soil weight pressure (G_3)
  Hydrostatic pressure of groundwater if present
  Expected differential settlements and deformations loads.
- Variable vertical actions include loads coming from people, snow; and horizontal variable actions such as wind (Q_1, Q_2, Q_3, $Q_{i,}$).
- Seismic: ground acceleration, spectral response.
- Combinations

5.2.2.1. Permanent loads

The self-weight of the load bearing elements is calculated directly by the software code using the geometry in the model and the characteristics of the materials.

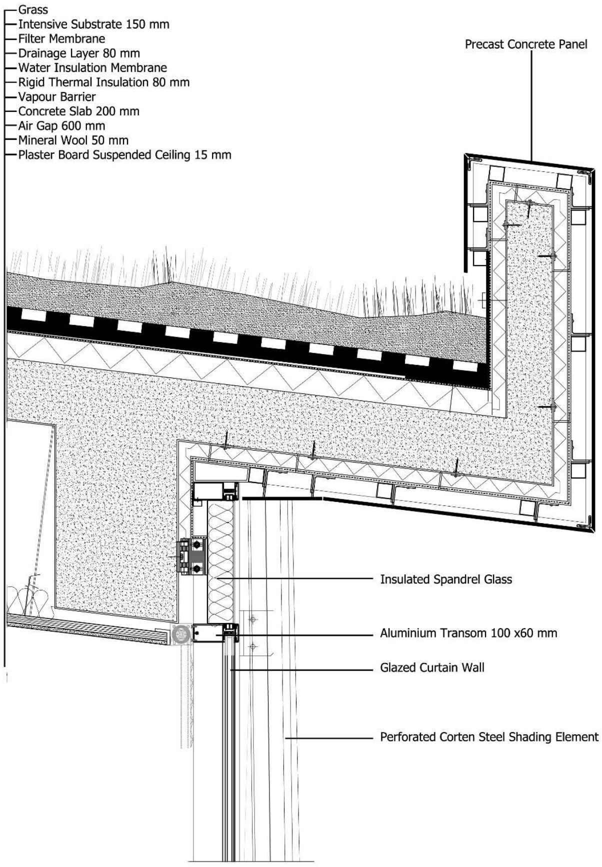
The self-weight of the non-structural elements and soil is introduced in the model manually using distributed and concentrated loads which are then transformed into masses for the seismic analysis.



Drawing 5.1. Floor layers for permanent loads.

Load name	Load (kN/m2)
Suspended ceiling package	0.4
Elevated floor package	0.5
Mechanical systems	3.0
Total:	3.9

Moreover, the roof is covered with layer of grass and intensive substrate. For safety purposes it was considered that the layer is water saturated with density, ρ=1800kg/m3.



Drawing 5.2. Roof layers for permanent loads

Load name	Load (kN/m2)
Suspended ceiling package	0.4
Insulation package+drainage layer	0.5
Intensive substrate and grass	3.0
Mechanical systems	3.0
Total:	6.9

5.2.2.2. Variable loads

IMPOSED LOADS OCCUPANCY (Q_1)

Imposed loads on buildings are those arising from occupancy. These loads include:

- normal use by persons;
- furniture and moveable objects (e.g. moveable partitions, storage, the contents of
- containers);
- vehicles;
- anticipating rare events, such as concentrations of persons or of furniture, or the moving or stacking of objects which may occur during reorganization or redecoration.

For the determination of the imposed loads, floor and roof areas in buildings should be sub-divided into categories according to their use. The categories are shown in the table below.

Category	Specific Use	Example
A	Areas for domestic and residential activities	Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets.
B	Office areas	
C	Areas where people may congregate (with the exception of areas defined under category A, B, and D[1])	**C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions. **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3**: Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts. **C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages. **C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms.
D	Shopping areas	**D1**: Areas in general retail shops **D2**: Areas in department stores

Table 5.1. Categories of use [TS EN 1991-1-1]

Table below shows imposed variable loads according to TS EN 1991-1-1 that depend on the function of a building or area of a building.

Categories of loaded areas	q_k [kN/m^2]	Q_k [kN]
Category A		
- **Floors**	1,5 to2,0	2,0 to 3,0
- **Stairs**	2,0 to4,0	2,0 to 4,0
- **Balconies**	2,5 to 4,0	2,0 to 3,0
Category B	2,0 to 3,0	1,5 to 4,5
Category C		
- C1	2,0 to 3,0	3,0 to 4,0
- C2	3,0 to 4,0	2,5 to 7,0 (4,0)
- C3	3,0 to 5,0	4,0 to 7,0
- C4	4,5 to 5,0	3,5 to 7,0
- C5	5,0 to 7,5	3,5 to 4,5
category D		
- D1	4,0 to 5,0	3,5 to 7,0 (4,0)
- D2	4,0 to 5,0	3,5 to 7,0

Figure 5.1 Imposed loads on floors, balconies and stairs in buildings [TS EN 1991-1-1]

In the building in interest there are mainly areas with use of B category, however there are some zone with C category, in particular C2 and C3. As a conservative measure loads for C3 category were used for both C categories, 5kN/m^2.

5.2.2.3. Roof Loads

Roofs shall be categorised according to their accessibility into three categories as shown in Table 5.2.

Categories of loaded area	Specific Use
H	Roofs not accessible except for normal maintenance and repair.
I	Roofs accessible with occupancy according to categories A to D
K	Roofs accessible for special services, such as helicopter landing areas

Table 5.2 - Categorization of roofs [TS EN 1991-1-1]

The roof has no function and it is accessible only for normal maintenance and repair. Therefore, the value of action on the roof is q_k = 0.5 kN/m^2

5.2.2.4. Snow load

According to TS EN 1991-1-3 there are different factors that define design snow load on a roof. These include:

- shape of the roof
- its thermal properties
- the roughness of its surface
- the amount of heat generated under the roof
- the proximity of nearby buildings
- the local meteorological climate

Snow load acting on a roof for the persistent design situation is defined by Eurocodes with the following formula:

$$s = \mu_i C_e C_t s_k$$

where

μ_i is the snow load shape coefficient (see Section 5.3 and Annex B)

s_k is the characteristic value of snow load on tile ground

C_t is the thermal coefficient which is equal to 1 in our case

C_e is the exposure coefficient

Topography	C_e
Windswept [a]	0,8
Normal [b]	1,0
Sheltered [c]	1,2

[a] *Windswept topography*: flat unobstructed areas exposed on all sides without, or little shelter afforded by terrain, higher construction works or trees.

[b] *Normal topography*: areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees.

[c] *Sheltered topography*: areas in which the construction work being considered is considerably lower than the surrounding terrain or surrounded by high trees and/or surrounded by higher construction works.

The standard gives recommended values of C_e for different topographies which are shown in the table above. In our case the exposure coefficient is equal to 1.

The standard gives a map for finding the characteristic value of snow load on tile ground which is shown below. Adana is in zone I and because it lies 23 m above sea level, the characteristic snow load ,s_k, is 0.75kN/m^2.

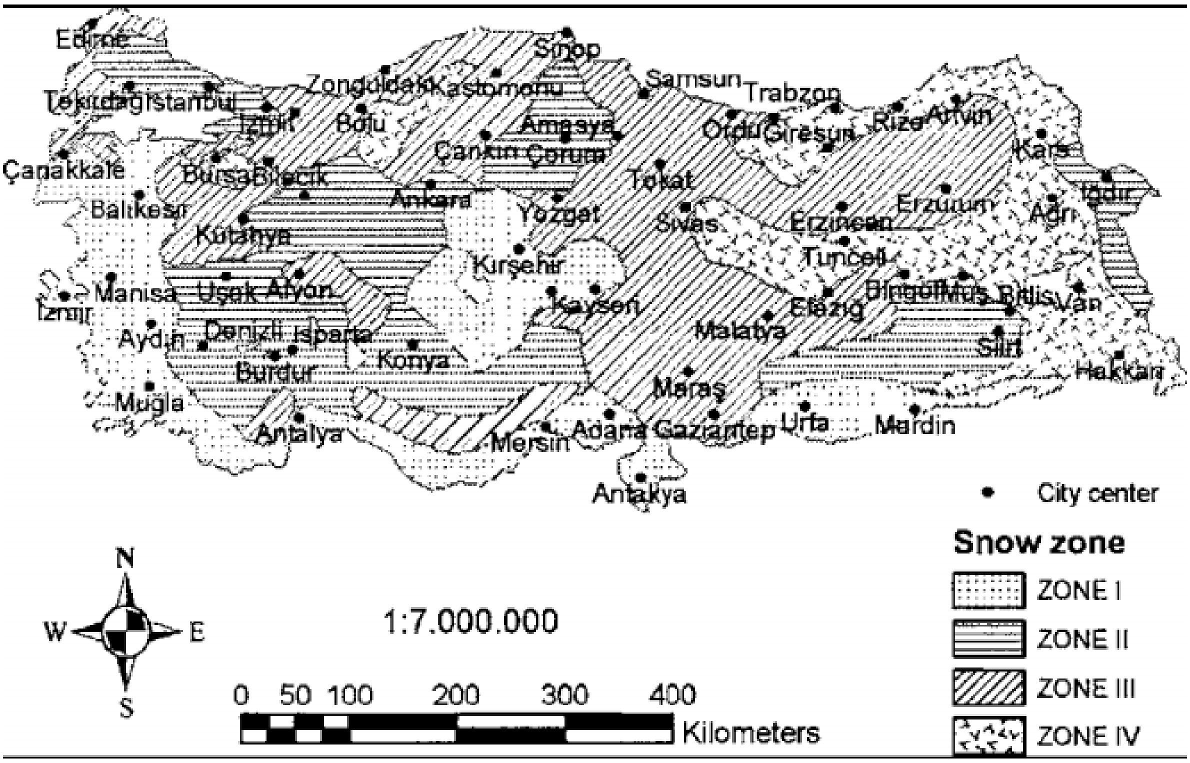


Figure 5.2. Map of snow zone of Turkey according to TS EN 1991-1-3

Elevation of the location (m)	Zones			
	I	II	III	IV
≤200	0.75	0.75	0.75	0.75
300	0.75	0.75	0.75	0.80
400	0.75	0.75	0.75	0.80
500	0.75	0.75	0.75	0.85
600	0.75	0.75	0.80	0.90
700	0.75	0.75	0.85	0.95
800	0.80	0.85	1.25	1.40
900	0.80	0.95	1.30	1.50
1000	0.80	1.05	1.35	1.60
>1000 and <1500	a	a	a	a
>1500	b	b	b	b

a The values corresponding to 1000 m are increased by 10%.
b The values corresponding to 1000 m are increased by 15%.

Figure 5.3. Design Ground Snow Load (sk) Values according to TS EN 1991-1-3 [2] (kN/m2)

The structure in interest has monopitch roof, thus snow load shape coefficient for this case is shown in figure below.

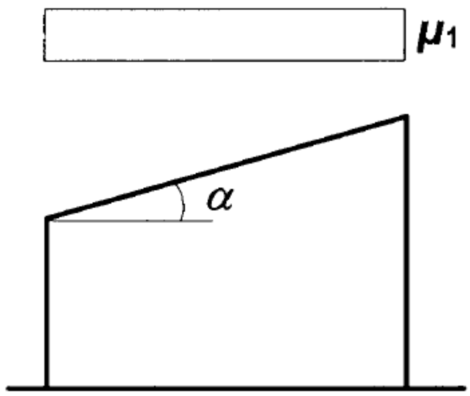


Figure 5.4. Snow load shape coefficient – monopitch roof

The values are reported in the table below.

Angle of pitch of roof α	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1	0,8	0.8(60 - α)/30	0,0
μ_2	0,8 + 0,8 α/30	1,6	--

Table 5.3. Snow load shape coefficients

As the structure has varying slope from 10 to 32°. Therefore, to simplify one coefficient is used for different cases.

Thus, the snow load is

s=0.8*1*1*0.75= 0.6 kN/m^2

5.2.2.5. Wind loads

The wind actions calculated using EN 1991-1-4 are characteristic values (See EN 1990,4.1.2). They are determined from the basic values of wind velocity or the velocity pressure. In accordance with EN 1990 4.1.2 the basic values are characteristic values having annual probabilities of exceedence of 0,02, which is equivalent to a mean return period of 50 years. The effect of the wind on the structure (i.e. the response of the structure), depends on the size, shape and dynamic properties of the structure. The response of structures should be calculated according to Section 5 from the peak velocity pressure, q_p, at the reference height in the undisturbed wind field, the force and pressure coefficients and the structural factor c_sc_d (see Section 6). q_p depends on the wind climate, the terrain roughness and orography, and the reference height. q_p is equal to the mean velocity pressure plus a contribution from short-term pressure fluctuations.

The wind action is represented in the model by a simplified set of pressures or forces whose effects are equivalent to the extreme effects of the turbulent wind.

The mean wind velocity v_m should be determined from the basic wind velocity v_b which depends on the wind climate and the height variation of the wind determined from the terrain roughness and orography. The basic wind velocity is given by the following formula,

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

where:

$v_{b,0}$ is the fundamental value of the basic wind velocity.

c_{dir} is the directional factor; in this case the recommended value 1 is used.

c_{season} is the season factor; in this case the recommended value 1 is used.

The mean wind velocity v_m\{z) at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity, v_b, and should be determined using formula below.

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

where:

$c_r(z)$ is the roughness factor

$c_o(z)$ is the orography factor, taken as 1.0

$$q_p(z) = \left[1 + 7 \cdot I_v(z)\right] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

where:

$c_e(z)$ is the exposure factor

q_b is the basic velocity pressure $q_b = \tfrac{1}{2} \cdot \rho \cdot v_b^2$

Values z_{min} and z_0 are dependent on the terrain category and parameters. The category IV was chosen.

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

Table 5.4. Terrain categories and terrain parameters

v_b	28	m/s	
q_b	490	N/m^2	
Terrain cat.	IV		
z_0	1	m	
z_{min}	10	m	
z_1	22	m	
z_{max}	200	m	
$z_{0,II}$	0.05	m	
k_r	0.23		
σ_v	6.56		
$c_r(z)$	$v_m(z)$	Iv	**$q_p(z)$ [N/m^2]**
0.54	15.11	0.43	**576.32**
0.72	20.28	0.32	**839.24**

After the peak velocity pressures were found for different heights, the pressures on the external surfaces of the building are found by multiplying pressure coefficients.

$$w_e = q_p(z_e) \cdot c_{pe}$$

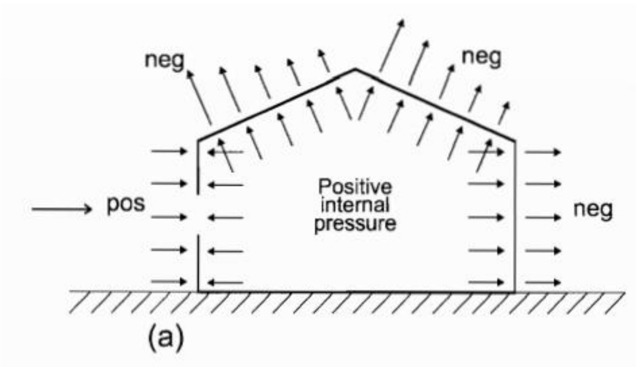


Figure 5.5. Pressure on surfaces

5.2.2.6. Seismic loads

Turkey is an highly active seismically area as it lies in complex tectonic zone. Main part of the country lies on the Anatolian plate which confines with Eurasian Plate in the north , African plate in the south and Arabian plate in the southwest. There are two major strike-slip fault zones, the North Anatolian Fault and East Anatolian Fault.

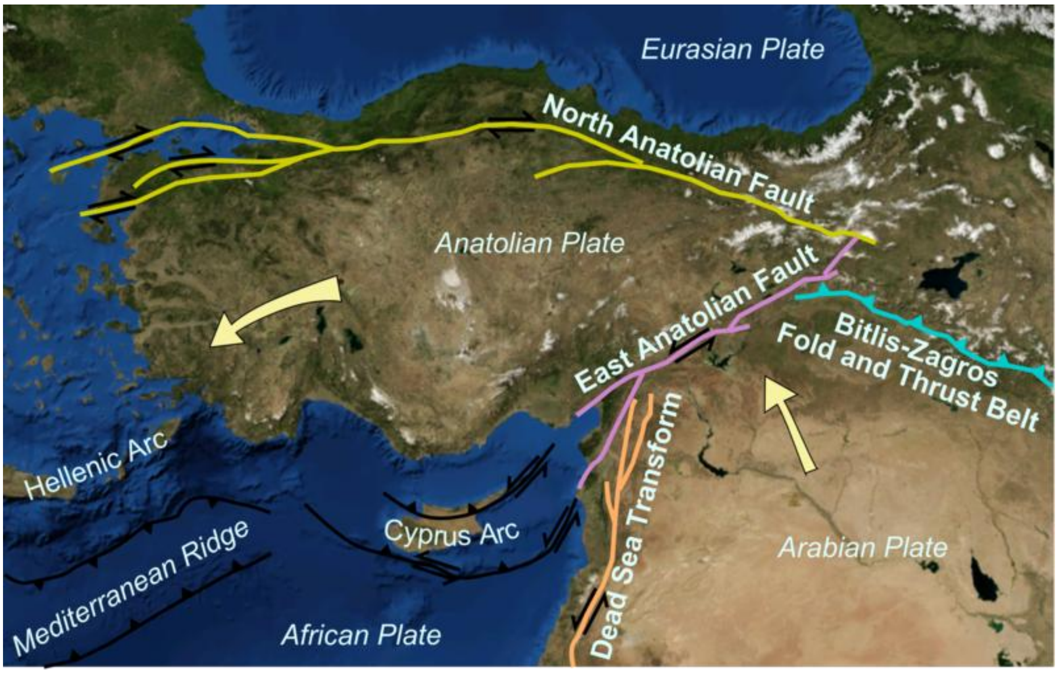


Figure 5.6. Map of plate boundaries affecting Turkey

The recent major earthquake in Adana region was in 1998 with a magnitude 6.2 Mw according to US Geological Survey. The event was about 30 km southeast of Adana and killed 145 people and left 1,500 people wounded and many thousands homeless. The main reason for such a high number of casualties and damage was inadequate seismic design of buildings.

Therefore, it is the first priority to correctly identify seismic loads on the structures for the correct seismic design.

Since Turkish national annex for EN 1998-1 is not prepared, the national seismic standard "Specifications for structures to be built in disaster areas" to identify design seismic loads on the structure.

The specification uses the response spectrum method for the seismic structural analysis.

The method requires the determination of a response spectrum from measured seismic activity. This data is then reduced into a spectrum of seismic action versus T natural frequency. The seismic action could be displacement, velocity, or acceleration, although the typical value used is acceleration. Detailed information from the structural model was coupled with the corresponding spectral values for each specific mode of vibration. The independent results are then combined using an appropriate technique to determine the response of the overall structure.

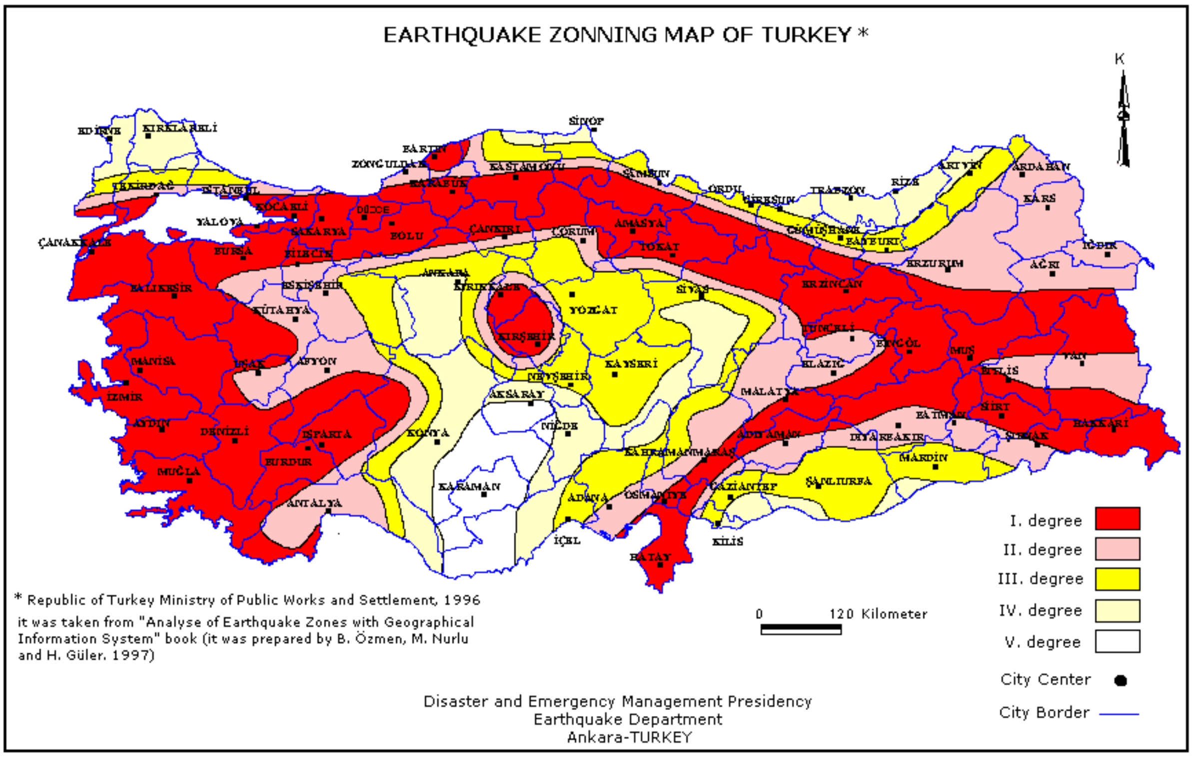


Figure 5.7. Earthquake zones map

"Specifications for structures to be built in the disaster areas" refers to this map for the calculation of acceleration values that will affect the construction.

Earthquake zones of Turkey classified as fallow due to expected acceleration values

- 1^{st} degree earthquake zone: more than 0.4g
- 2^{nd} degree earthquake zone: between 0.3g and 0.4g
- 3^{rd} degree earthquake zone: between 0.2g - 0.3g
- 4^{th} degree earthquake zone: between 0.2g - 0.1g
- 5^{th} degree earthquake zone: less than 0.1g

Adana corresponds to 2^{nd} degree seismic zone with acceleration values between 0.3g to 0.4g.

The Spectral Acceleration Coefficient, A (T), which shall be considered as the basis for the determination of seismic loads is given by equation below.

$$A(T) = A_o \, I \, S(T)$$

where:

A_o =0.3 is the effective ground acceleration coefficient for 2^{nd} seismic zone.

I = 1.4 is the building importance factor for intensively and long-term occupied buildings and buildings preserving valuable goods

S(T) is the spectrum coefficient which is determined by equations below

$$S(T) = 1 + 1.5\,\frac{T}{T_A} \qquad (0 \le T \le T_A)$$
$$S(T) = 2.5 \qquad (T_A < T \le T_B)$$
$$S(T) = 2.5\left(\frac{T_B}{T}\right)^{0.8} \qquad (T_B < T)$$

Spectrum characteristic periods, T_A and T_B , appearing in Equation (2.2) are specified in table 2.4, depending on local site classes defined in Table 6.2.

Local Site Class according to Table 6.2	T_A *(second)*	T_B *(second)*
Z1	0.10	0.30
Z2	0.15	0.40
Z3	0.15	0.60
Z4	0.20	0.90

Table 5.5. Spectrum characteristic periods (TA, TB)

Soil Group	*Description of Soil Group*	*Standard Penetration* (N/30)	*Relative Density* (%)	*Unconfined. Compressive Strength* (kPa)	*Drift Wave Velocity* (m / s)
(A)	**1.** Massive volcanic rocks, unweathered sound metamorphic rocks, stiff cemented sedimentary rocks **2.** Very dense sand, gravel... **3.** Hard clay and silty clay…	— > 50 > 32	— 85 – 100 —	> 1000 — > 400	> 1000 > 700 > 700
(B)	**1.** Soft volcanic rocks such as tuff and agglomerate, weathered cemented sedimentary rocks with planes of discontinuity…… **2.** Dense sand, gravel......... **3.** Very stiff clay, silty clay…	— 30 – 50 16 – 32	— 65 – 85 —	500 – 1000 — 200 – 400	700 – 1000 400 – 700 300 – 700
(C)	**1.** Highly weathered soft metamorphic rocks and cemented sedimentary rocks with planes of discontinuity **2.** Medium dense sand and gravel......…………………… **3.** Stiff clay and silty clay.....	— 10 – 30 8 – 16	— 35 – 65 —	< 500 — 100 – 200	400 – 700 200 – 400 200 – 300
(D)	**1.** Soft, deep alluvial layers with high ground water level **2.** Loose sand...................….. **3.** Soft clay and silty clay…..	— < 10 < 8	— < 35 —	— — < 100	< 200 < 200 < 200

Table 5.6 Soil groups

Local Site Class	*Soil Group according to Table 6.1 and Topmost Soil Layer Thickness* (h_1)
Z1	Group (**A**) soils Group (**B**) soils with $h_1 \leq 15$ m
Z2	Group (**B**) soils with $h_1 > 15$ m Group (**C**) soils with $h_1 \leq 15$ m
Z3	Group (**C**) soils with 15 m $< h_1 \leq 50$ m Group (**D**) soils with $h_1 \leq 10$ m
Z4	Group (**C**) soils with $h_1 > 50$ m Group (**D**) soils with $h_1 > 10$ m

Table 5.7 Local site classes

Since the soil characteristics are missing, Z2 local site class was assumed for calculations.

Elastic Spectral Acceleration, S_{ae} (T) which is the ordinate of Elastic Acceleration Spectrum defined for 5 % damped rate is derived by multiplying Spectral Acceleration Coefficient with gravity,g.

$$S_{ae}(T) = A(T)\,g$$

The resulting elastic spectral acceleration is shown in the graph below.

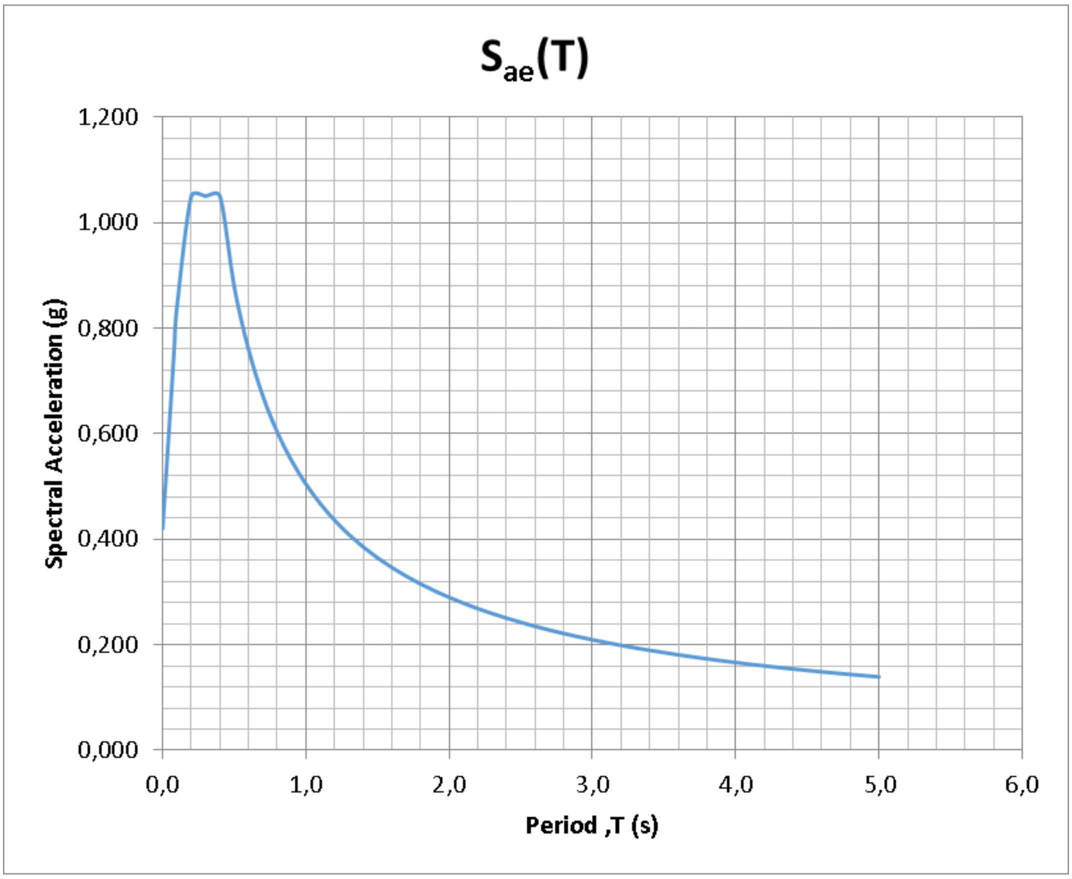


Figure 5.8 Elastic spectral acceleration, S_{ae}(T)

BUILDING STRUCTURAL SYSTEM	*Systems of Nominal Ductility Level*	*Systems of High Ductility Level*
(1) CAST-IN-SITE REINFORCED CONCRETE BUILDINGS		
(**1.1**) Buildings in which seismic loads are fully resisted by frames..........	4	8
(**1.2**) Buildings in which seismic loads are fully resisted by coupled structural walls..........	4	7
(**1.3**) Buildings in which seismic loads are fully resisted by solid structural walls..........	4	6
(**1.4**) Buildings in which seismic loads are jointly resisted by frames and solid and / or coupled structural walls..........	4	7

Table 5.8 Structural system behaviour factors for cast in place RC buildings (R)

For the design using mode superposition method a reduced acceleration spectrum ordinate is taken into account in any n'th vibration mode and it is determined by

$$S_{aR}(T_n) = \frac{S_{ae}(T_n)}{R_a(T_n)}$$

where

$$R_a(T) = 1.5 + (R - 1.5)\,\frac{T}{T_A} \qquad (0 \le T \le T_A)$$

$$R_a(T) = R \qquad (T_A < T)$$

The structural system of the building is a mixed one, where seismic loads are jointly resisted by frames and walls and the high ductility level is chosen, which gives R=7 from the table above.

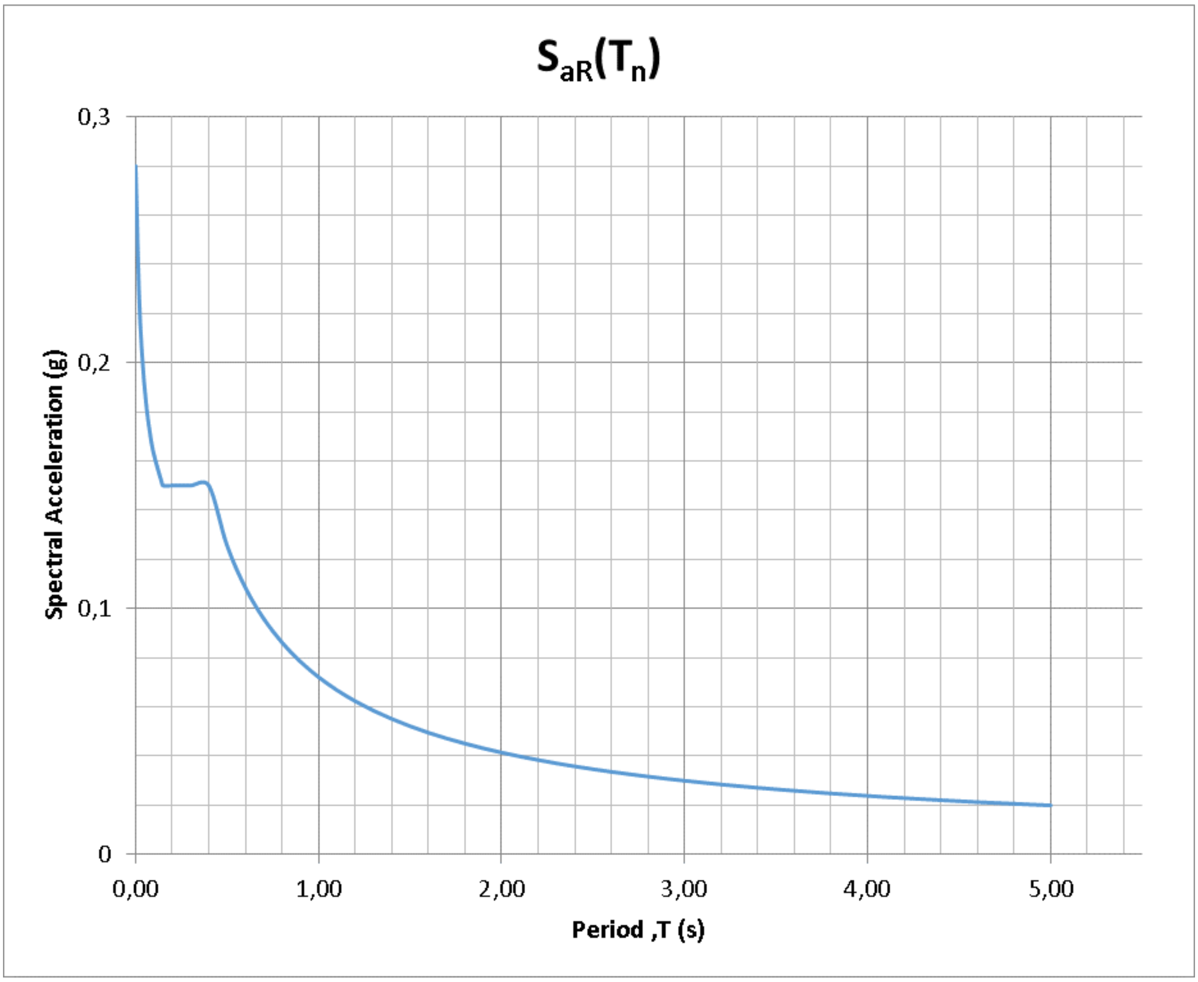


Figure 5.9 Design response spectrum

5.2.2.7. Load combinations

Eurocode is based on the concept of the limit states together with the partial factor method. It defines two different types of limit states, ultimate limit state and serviceability limit state. The partial factor method the variables such as actions, resistances are given design values through the use of partial factors and reduction coefficients.

The ultimate limit state verifications, where safety is of first priority, should be done for the following states.

- EQU. Loss of static equilibrium of the structure or any part of it.
- STR. Internal failure or excessive deformation of the structure, its members
- GEO. Failure or excessive deformation of the ground.
- FAT. Fatigue failure of the structure or its members.

In this work only STR verification is performed and reported. The main condition of STR ultimate limit state is as follows:

$$E_d \leq R_d$$

where E_d is the design value of the effect of actions

R_d is the design value of the corresponding resistance

Moreover, Eurocode EN 1990 gives two alternative methods to find the effects of actions using different combinations. For the simplicity the first method is chosen which considers one combination as in figure below.

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}\text{ "+" }\gamma_P P\text{ "+" }\gamma_{Q,1}\,Q_{k,1}\text{ "+" }\sum_{i>1}\gamma_{Q,i}\psi_{0,i}\,Q_{k,i}$$

In this combination expression the effects are governed by one variable action while other variable actions are reduced with appropriate combination factor, ψ. All actions are multiplied by their safety factor , γ, to obtain design values.

The serviceability state limit concerns with the functioning of the building, the comfort of people and the appearance.

For the serviceability limit states verification, three combinations should be taken into account for different limiting design criteria.

- The characteristic (rare) combination is used mainly for verification of permanent and irreversible damage.

$$\sum_{j\geq 1}G_{k,j}\text{ "+" }P_k\text{ "+" }Q_{k,1}\text{ "+" }\sum_{i>1}\psi_{0,i}Q_{k,i}$$

- The frequent combination is used mainly for verification of temporary local damage, deformations.

$$\sum_{j\geq 1}G_{k,j}\text{ "+" }P\text{ "+" }\psi_{1,1}Q_{k,1}\text{ "+" }\sum_{i>1}\psi_{2,i}Q_{k,i}$$

- The quasi-permanent combination is used mainly for verification of long term effects.

$$\sum_{j\geq 1}G_{k,j}\text{ "+" }P\text{ "+" }\sum_{i\geq 1}\psi_{2,i}Q_{k,i}$$

Partial Factor	Permanent action, $\gamma_G = 1.35$
	Variable action, $\gamma_Q = 1.5$
Combination factor	Office areas, $\psi_0 = 0.7$
	Roofs, $\psi_0 = 0.7$
	Snow loads (at lower altitudes), $\psi_0 = 0.5$
	Wind loads, $\psi_0 = 0.5$

Figure 5.10 Partial factors and combination factors for load combinations

5.2.3. Modeling and analysis

For the structural analysis MIDAS Gen was used to model and to design the structure. Midas Gen is a general-purpose structural analysis and optimal design system. The intuitive user Interface, contemporary computer graphics and powerful solver are some of the highlights of Midas Gen. The user-oriented input/output features and a wide range of analysis capabilities enable to readily perform structural analysis and design for even complex and large structures. Midas Gen utilizes the latest multi-frontal solver and analysis algorithms, which instantly generate accurate and practical analysis results. In addition, Midas Gen provides design capabilities using various international standards producing optimal design solutions.

- **Model description**

The analysis and verification of the safety of the structural elements occurs with the methods of structural analysis of buildings. The structural analysis is conducted with the displacement method for the assessment of stress deformation state induced by static loads. The seismic structural analysis is conducted with the method of modal analysis and response spectrum in terms of acceleration for the evaluation of the stress deformation state induced by dynamic loads imposed on the building by an earthquake.

The structural analysis is performed with the finite element method. The above stated method is based on the schematization of the structure in elements connected only in correspondence with a predetermined number of points called nodes. The nodes are defined by the three Cartesian coordinates in a global reference system. The unknowns of the problem (in the context of the displacement method) are the displacement components of the nodes referring to the global reference system (translations along X, Y, Z, rotations around X, Y, Z). The solution of the problem is achieved with a system of linear algebraic equations whose terms are made known by the loads acting on the structure suitably concentrated at the nodes:

K * u = F where K = stiffness matrix
u = vector nodal displacements
F = vector nodal forces

From the displacements obtained and with solving the system the stresses on each element are then deducted, generally referring to a local system of an element.

The reference system used is constituted by a right-handed XYZ Cartesian system of coordinates. It was assumed the Z axis as being vertical and oriented upwards.

The elements used for the modeling of the static scheme of the structure are the following:

TRUSS element type (rod-D2)
BEAM element type (beam-D2)
Element type PLATE (plate-shell-D3)
Element type STIFFNESS (stiffness matrix)
Element type FLOOR (macro element consists of several membranes)

- **Materials**

For the main structural model elements (columns, beams, slabs, walls) were assigned with reinforced concrete of class C35/45, having following characteristics:

f_{ck}=45Mpa	characteristic cylinder compression strength
γ_c=1.5	partial safety factor for concrete

$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c$=30MPa design compression strength
ε_c=0.002
ε_{c3}=0.00175
ε_{cu}=0.0035
E_{CM}=34GPa

For preliminary design the following stress-strain relation was used

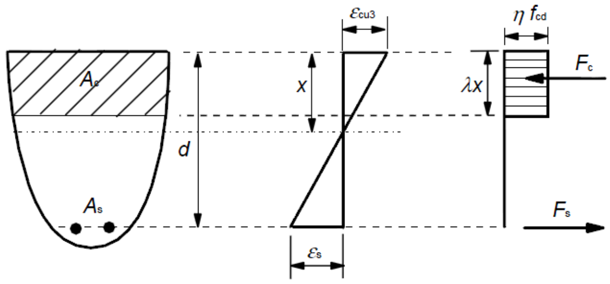


Figure 5.11 Simplified rectangular stress distribution

with λ=0.8 and η=1

For the detailed final design of cross-sections, the following stress-strain relationship was used.

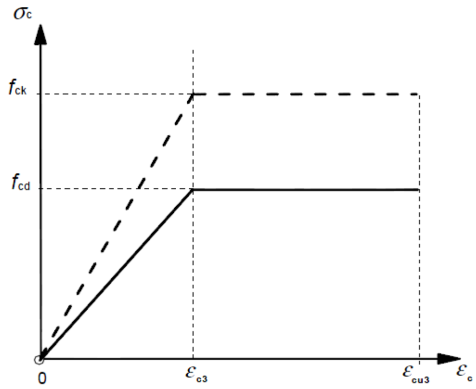


Figure 5.12 Bilinear stress-strain relation

As for the reinforcement B450C class was used.
f_{yk} =450Mpa characteristic steel yield strength
γ_s=1.15 partial safety factor for steel
$f_{yd} = f_{yk} / \gamma_s$=391MPa design yield strength
Es=200GPa Elastic Modulus

As for the structural steel S235JR class was used.
f_{yk} =235Mpa steel yield strength
f_{uk}=360MPa tensile strength
Es=200GPa Elastic Modulus

- **Structural Model**

In the following section the geometry, boundary conditions of the structural model are shown.

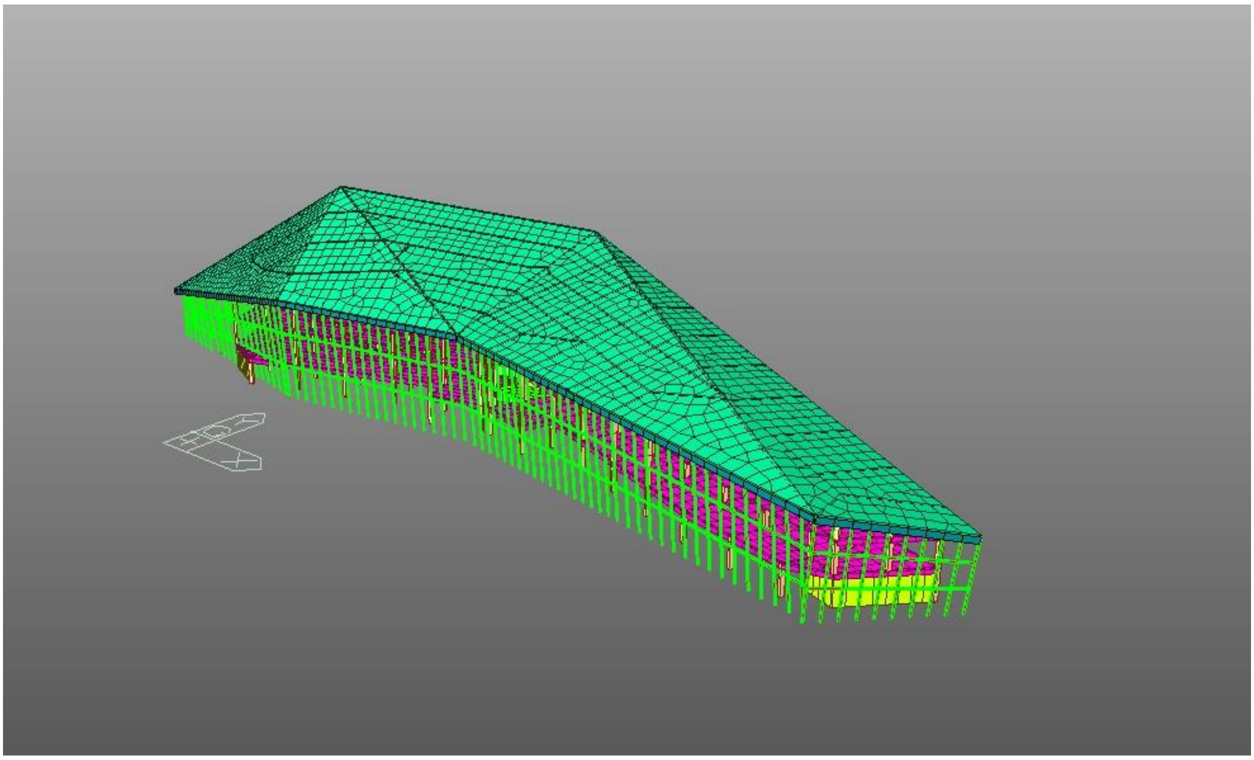


Figure 5.13 - 3D Front view

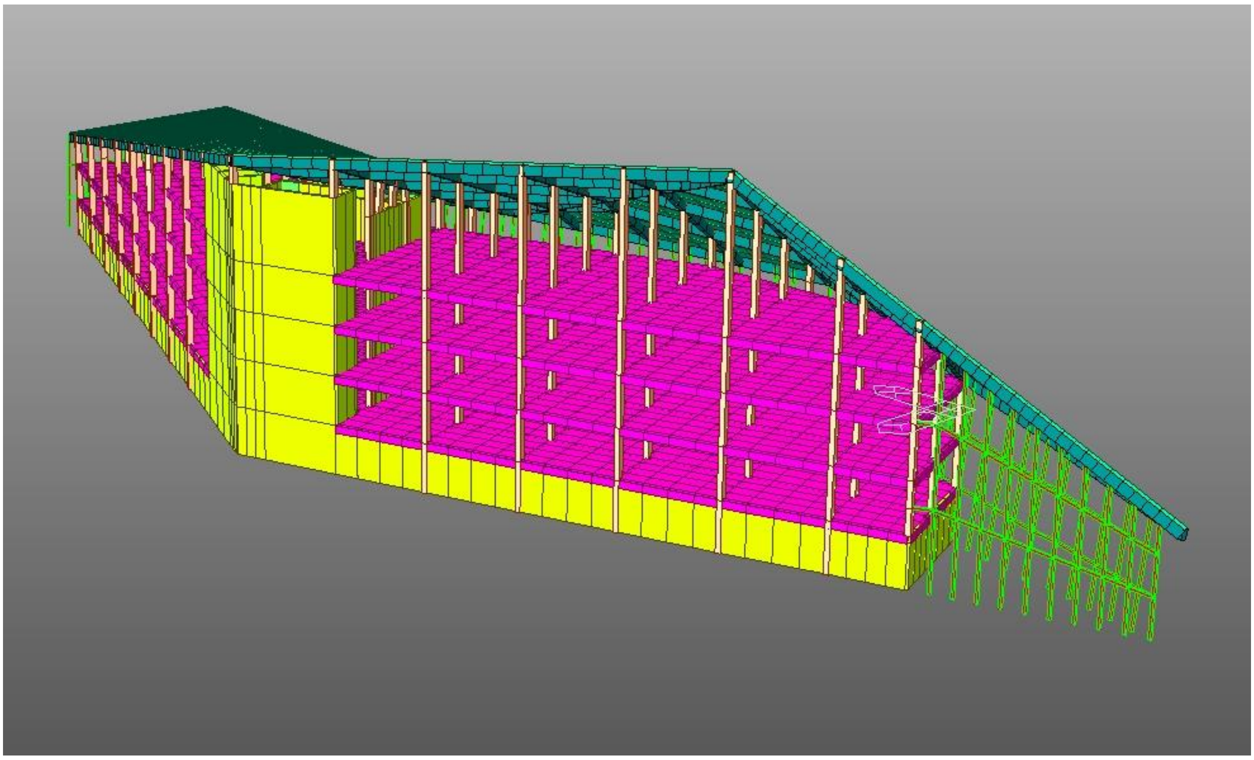


Figure 5.14 3D Back view

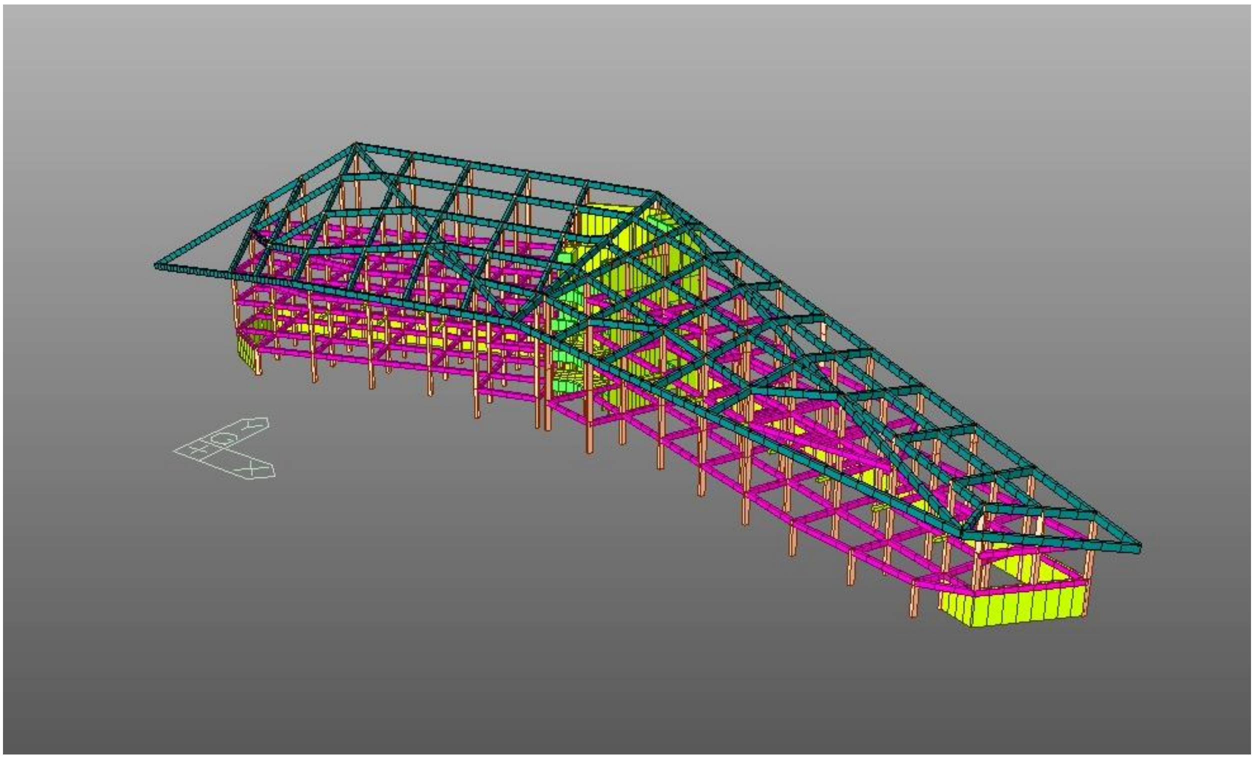


Figure 5.15 Frame and walls

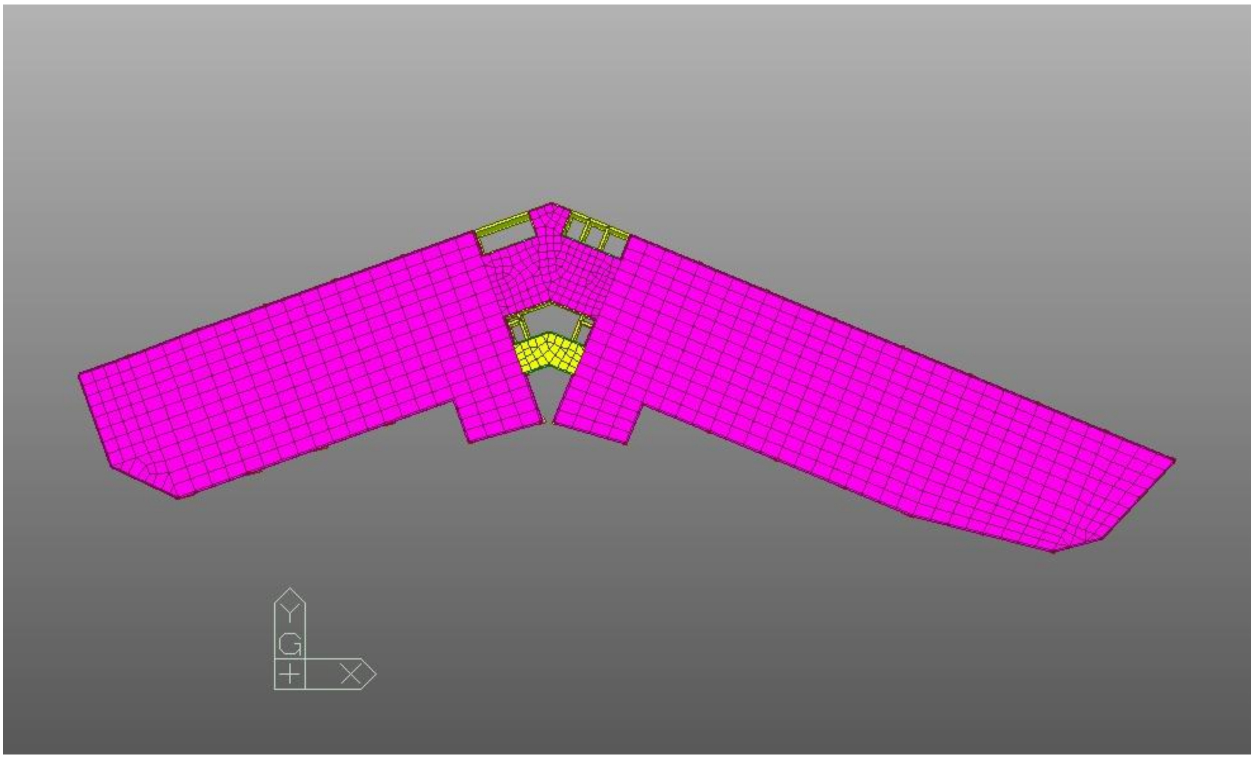


Figure 5.16 Plan +4 Level

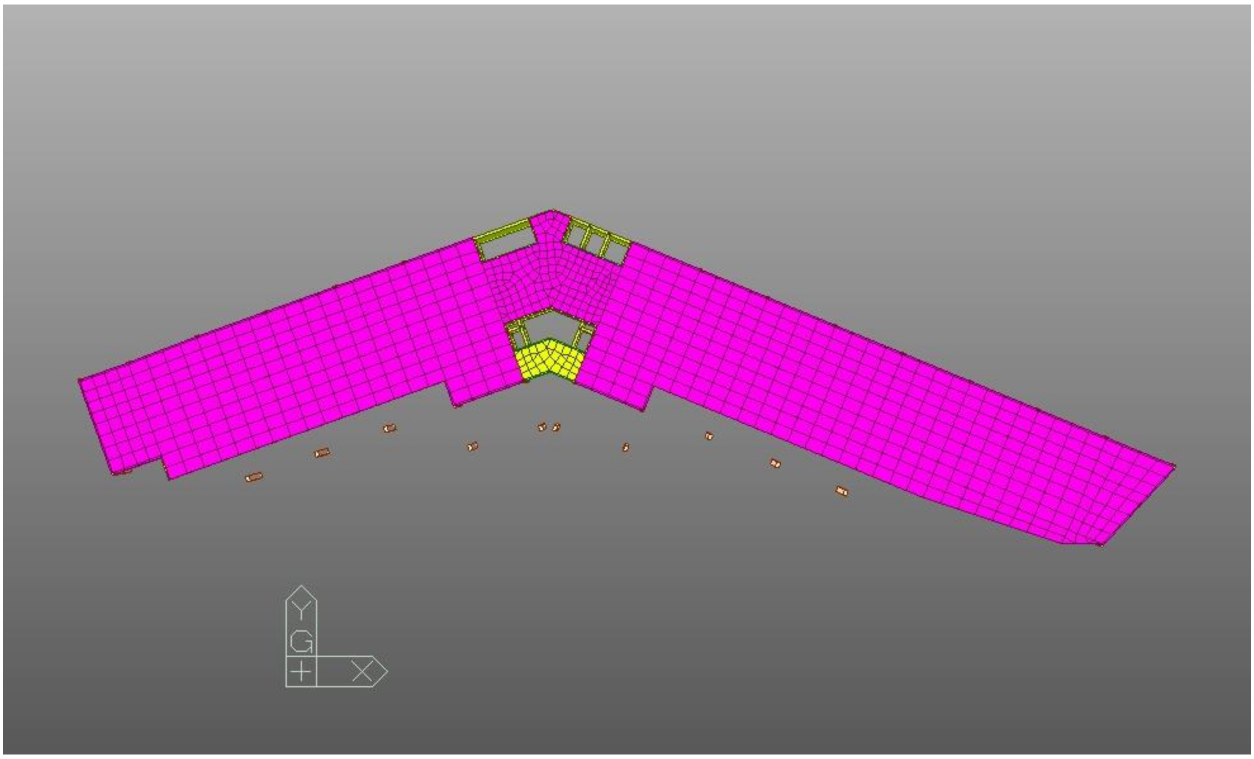


Figure 5.17 Plan +8 Level

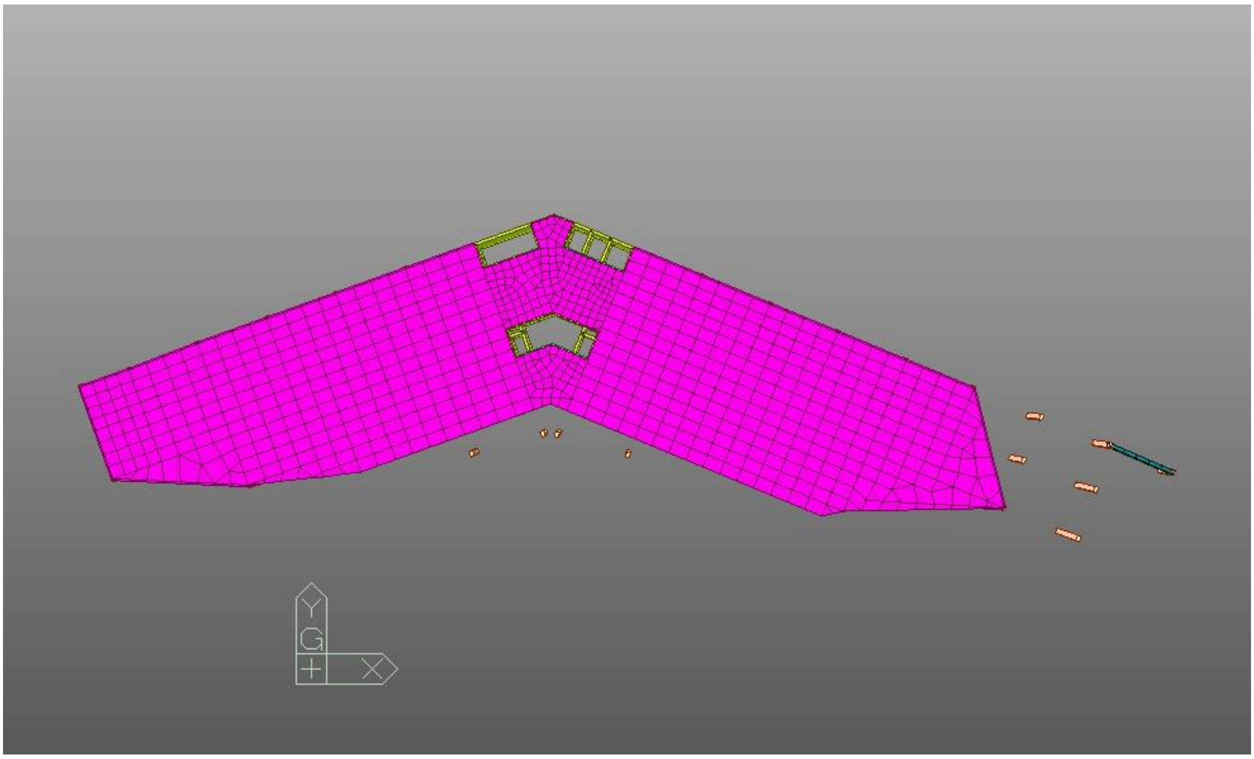


Figure 5.18 Plan +12 Level

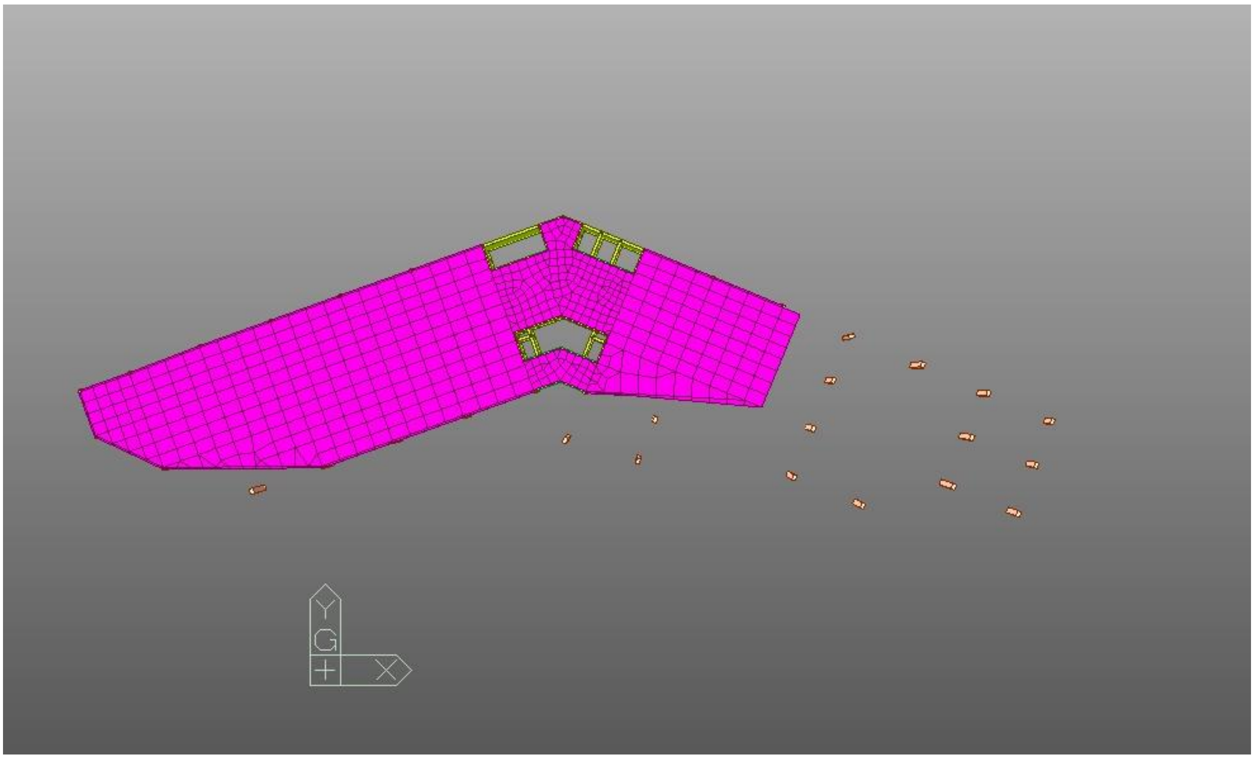


Figure 5.19 Plan +16 Level

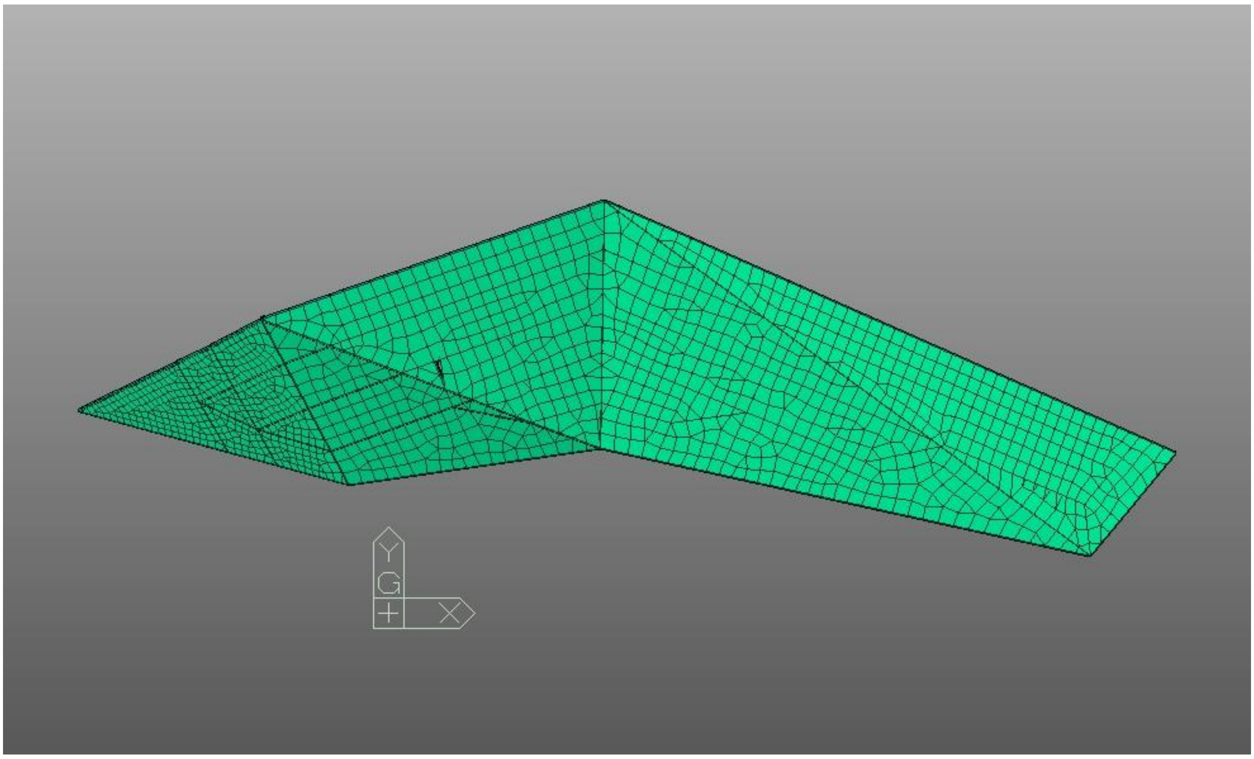


Figure 5.20 Plan of the roof

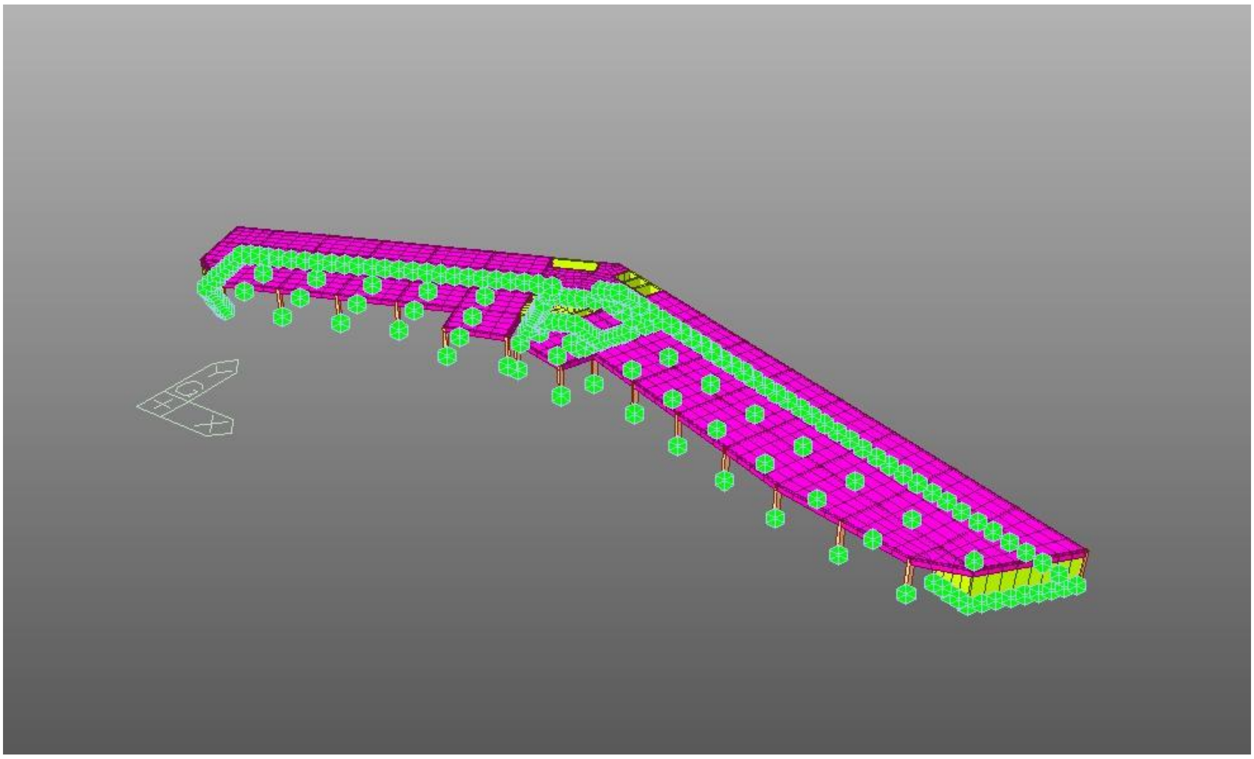


Figure 5.21 Boundary conditions

- **Results**

The results of the analysis are shown below.

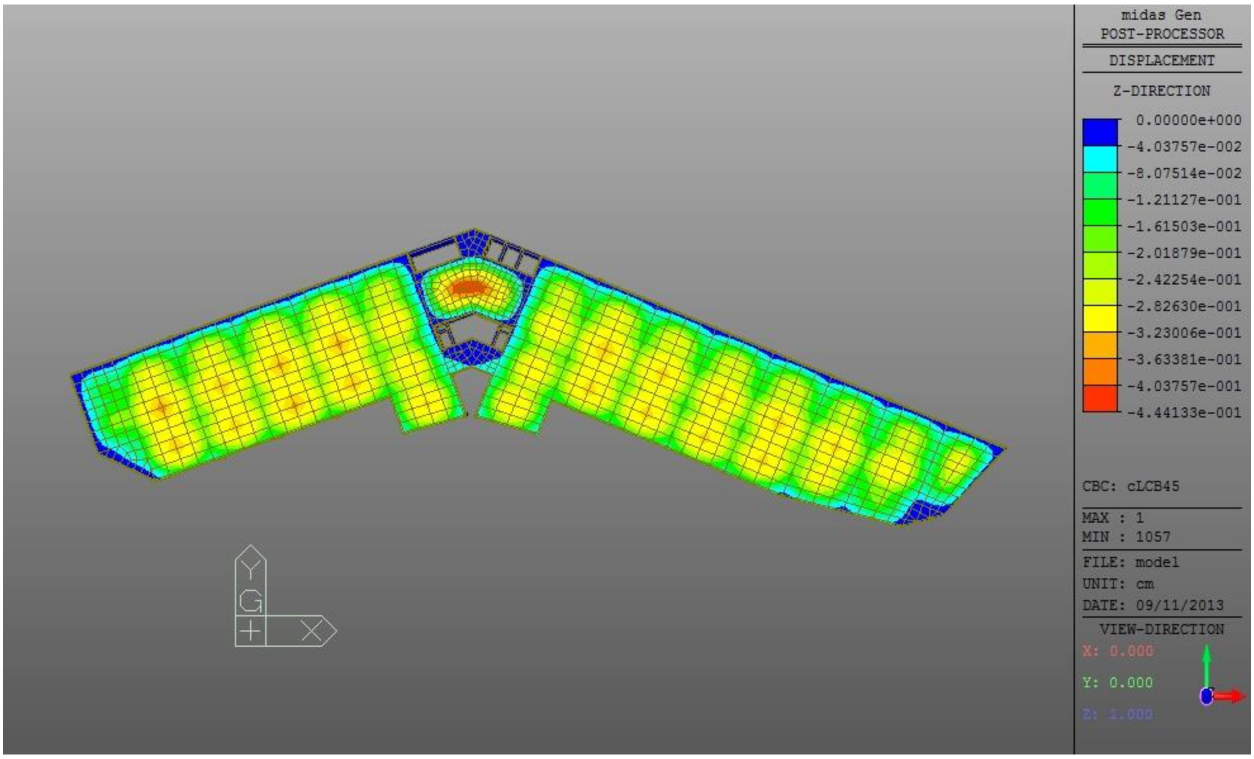


Figure 5.22 Deformations of the slab at level +4

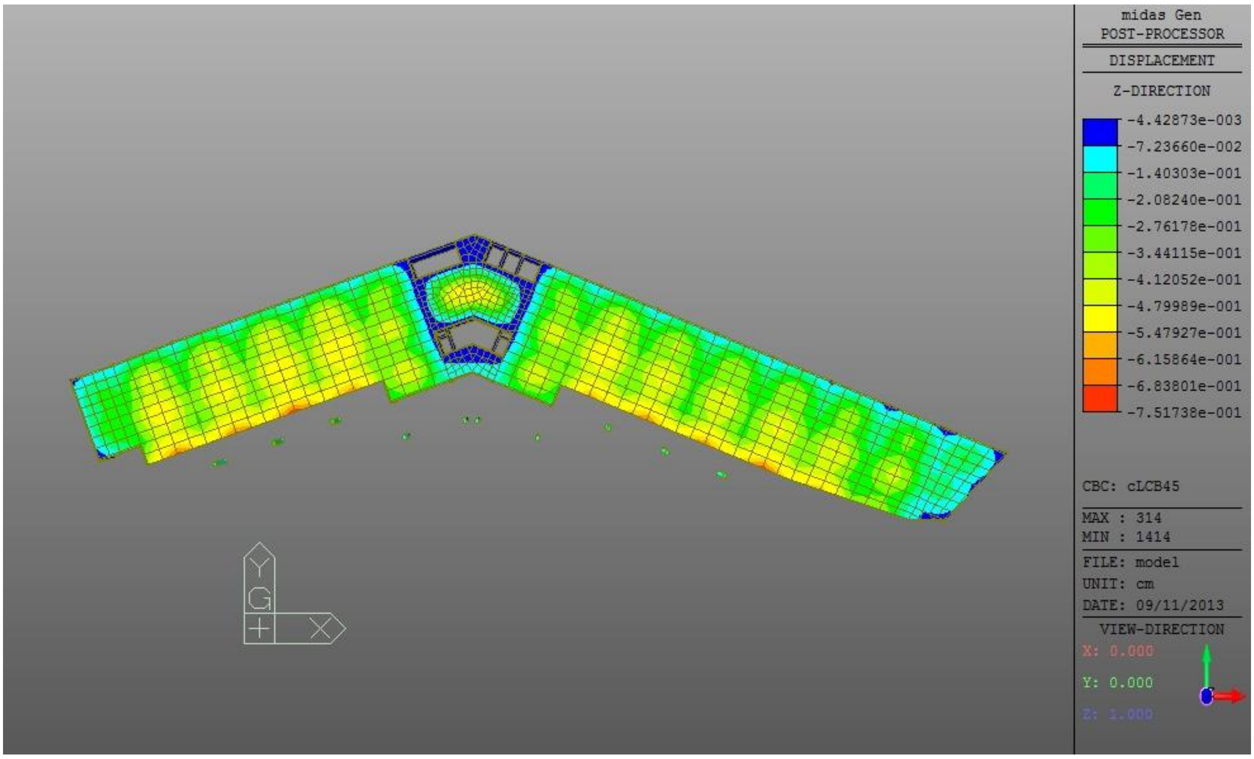


Figure 5.23 Deformations of the slab at level +8

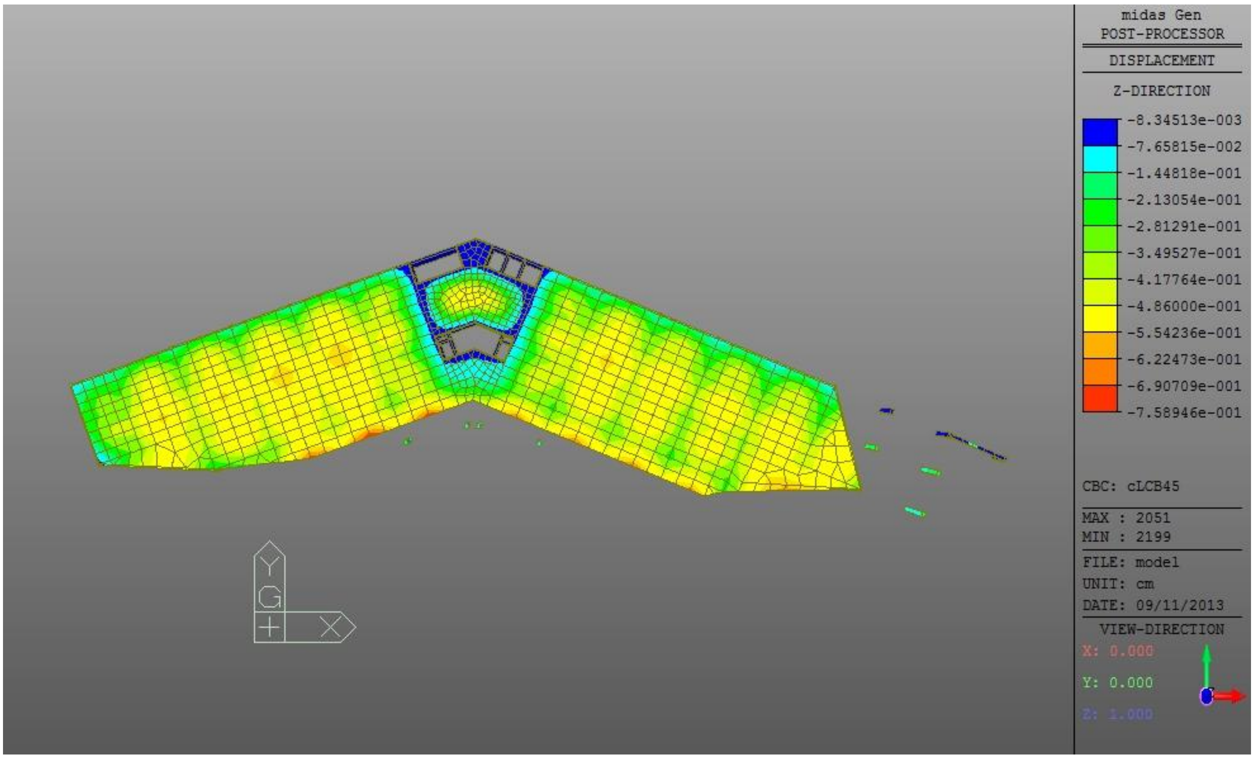


Figure 5.24 Deformations of the slab at level +12

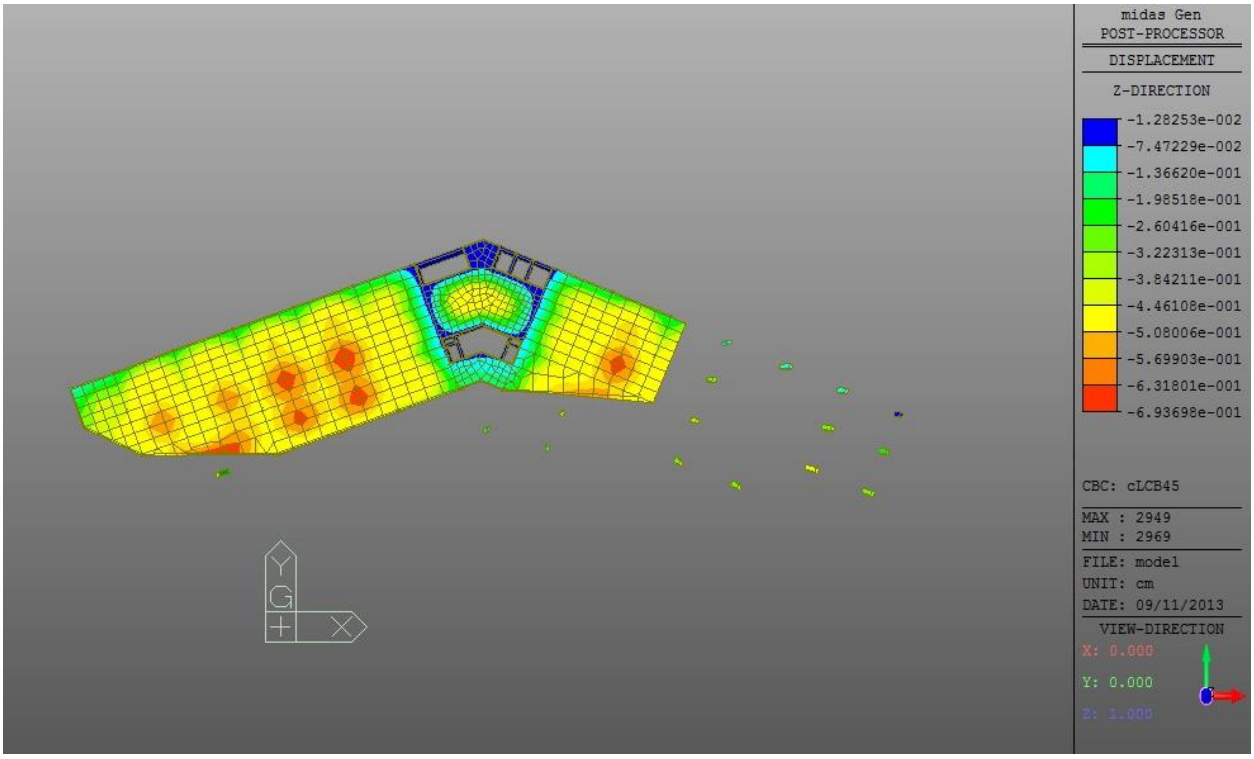


Figure 5.25 Deformations of the slab at level +16

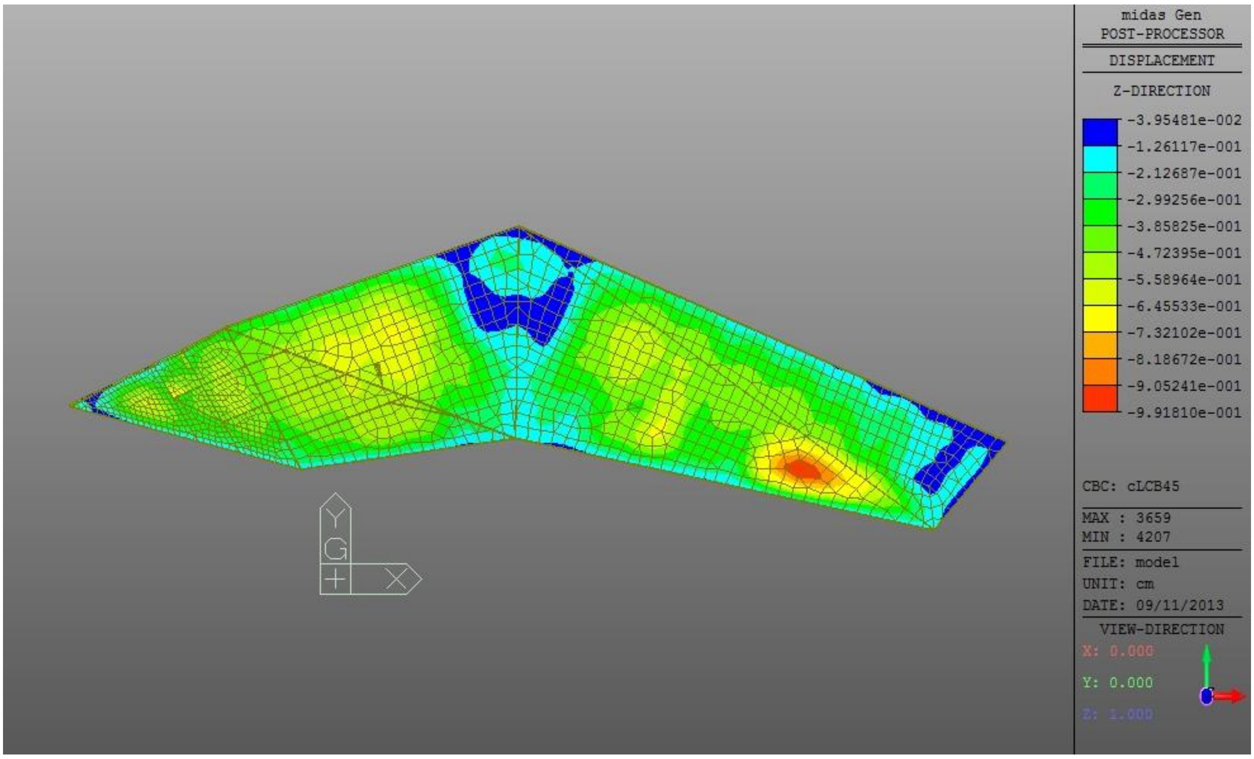


Figure 5.26 Deformations of the roof slab

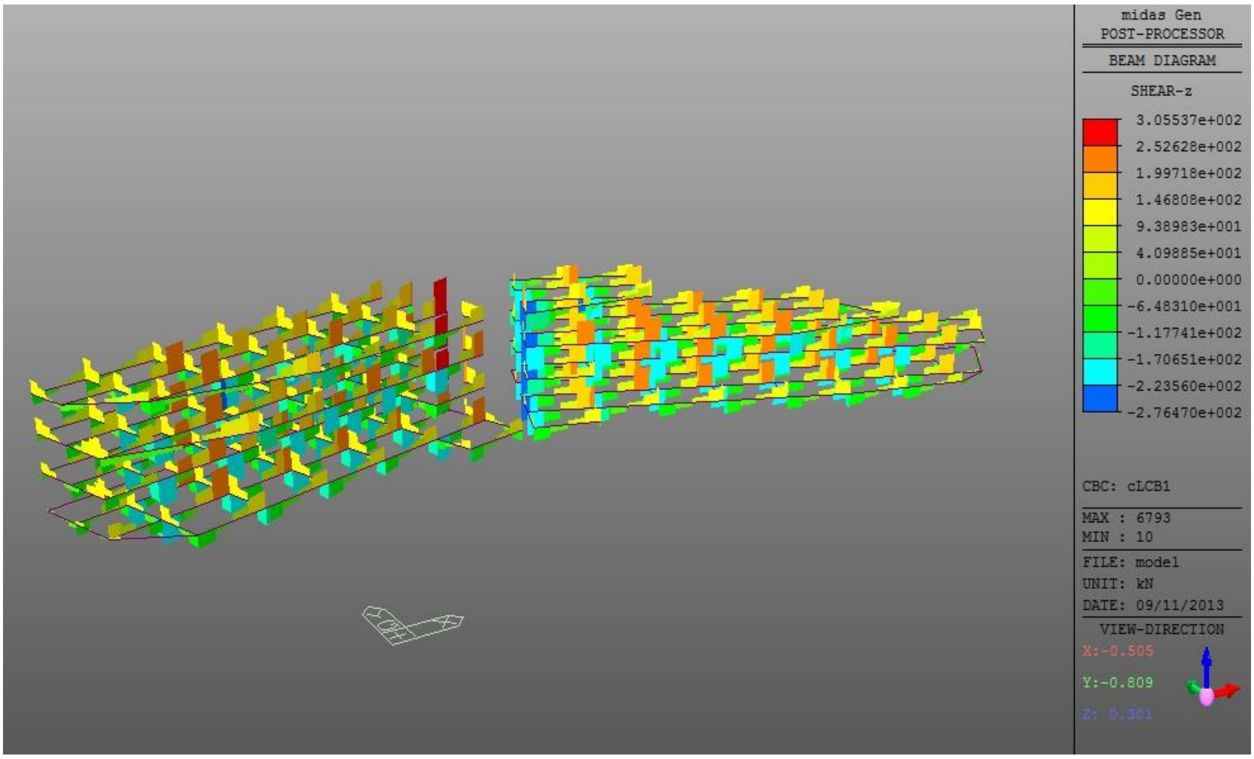


Figure 5.27 Shear on beams for Ultimate limit state

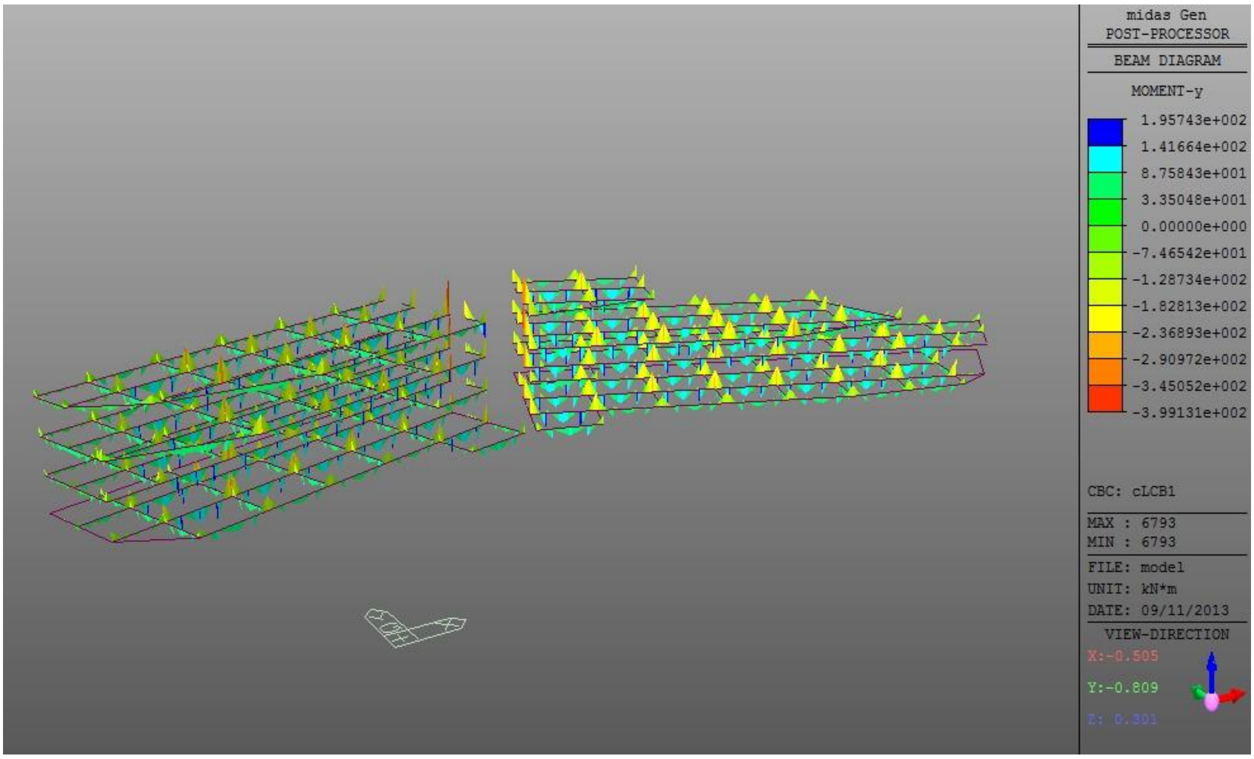


Figure 5.28 Moment diagram of beams for Ultimate limit state

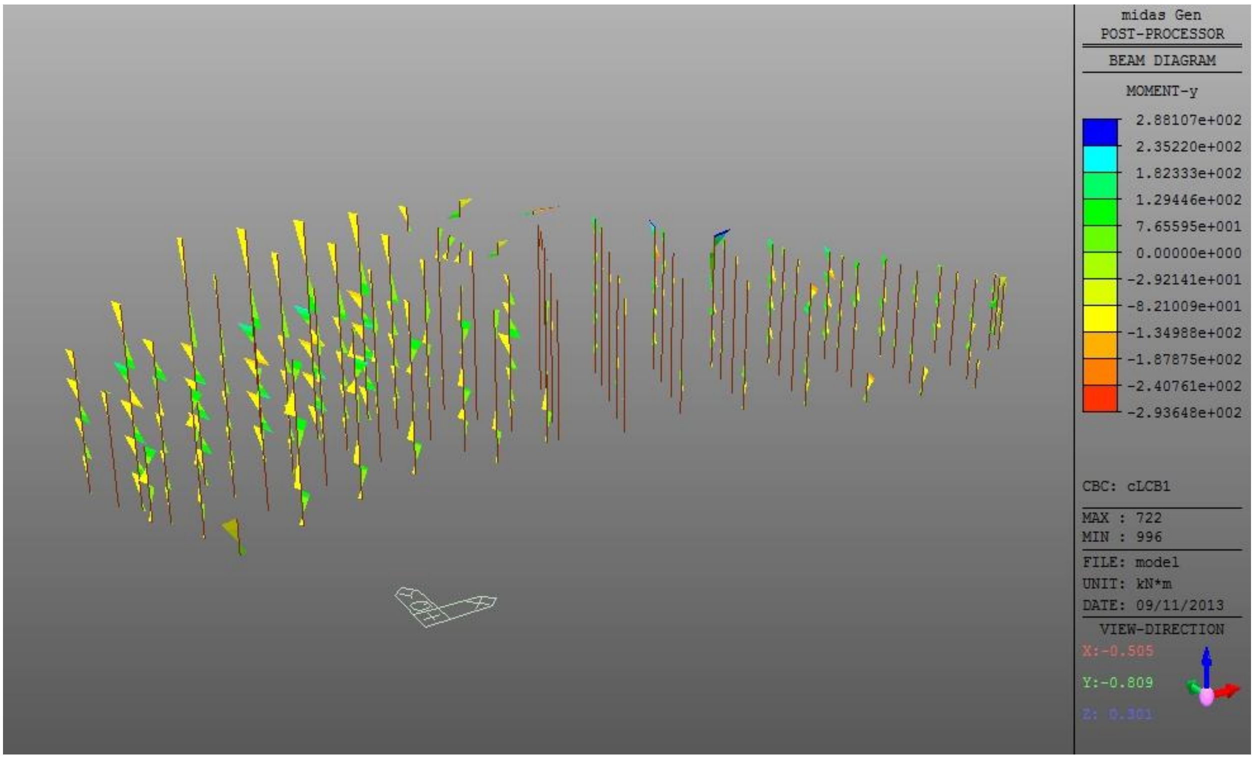


Figure 5.29 Column moments My for Ultimate limit state

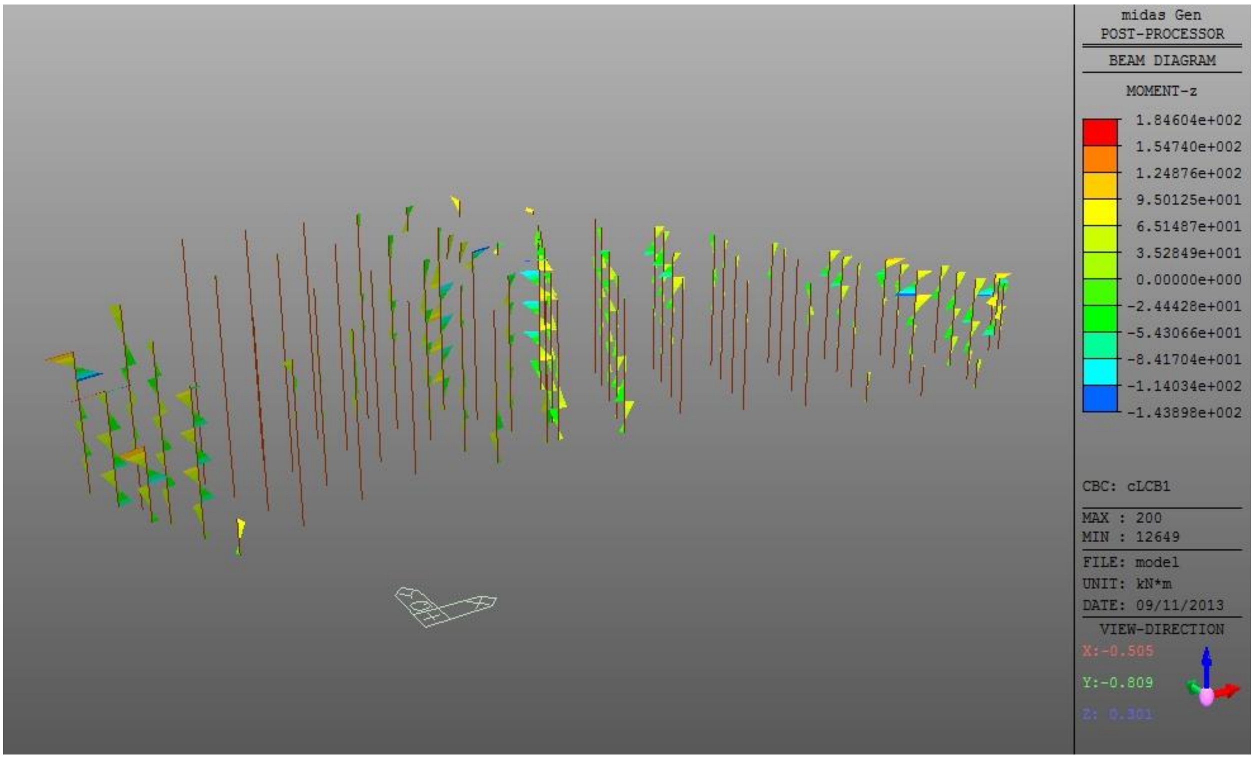


Figure 5.30 Column moments Mz for Ultimate limit state

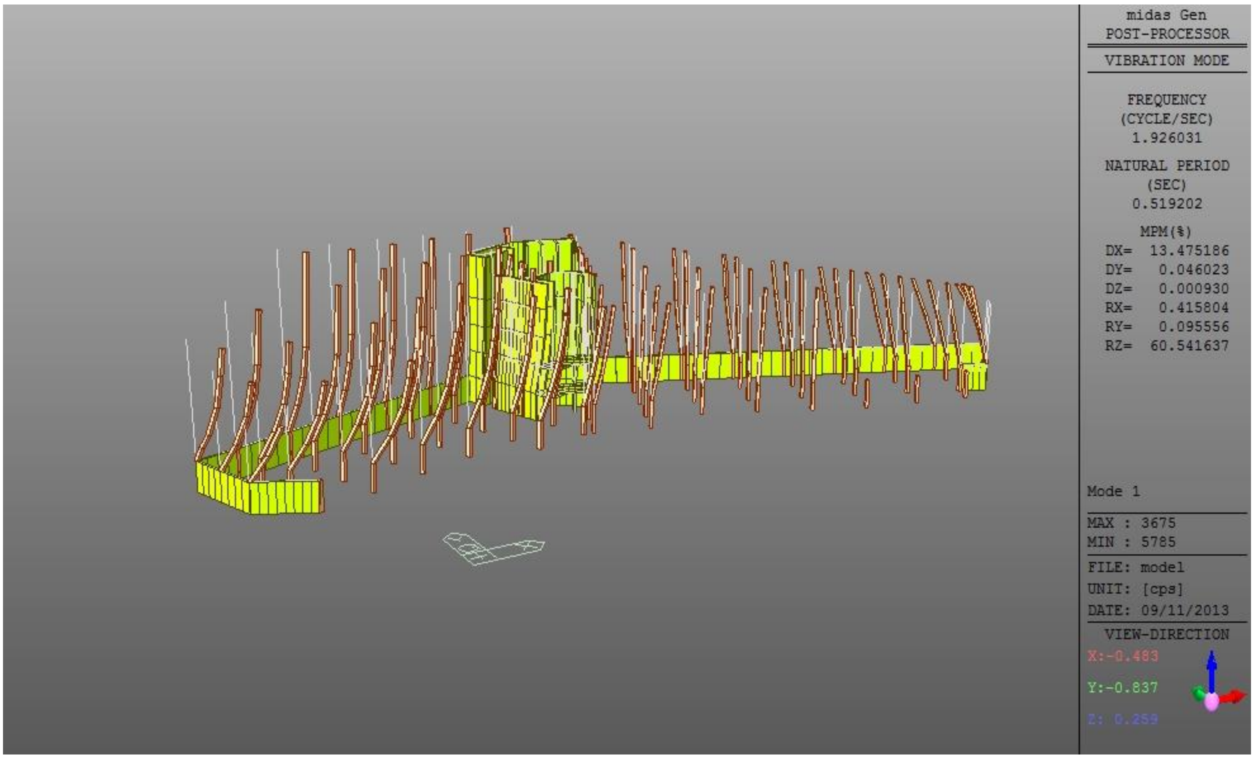


Figure 5.31 First mode of vibration

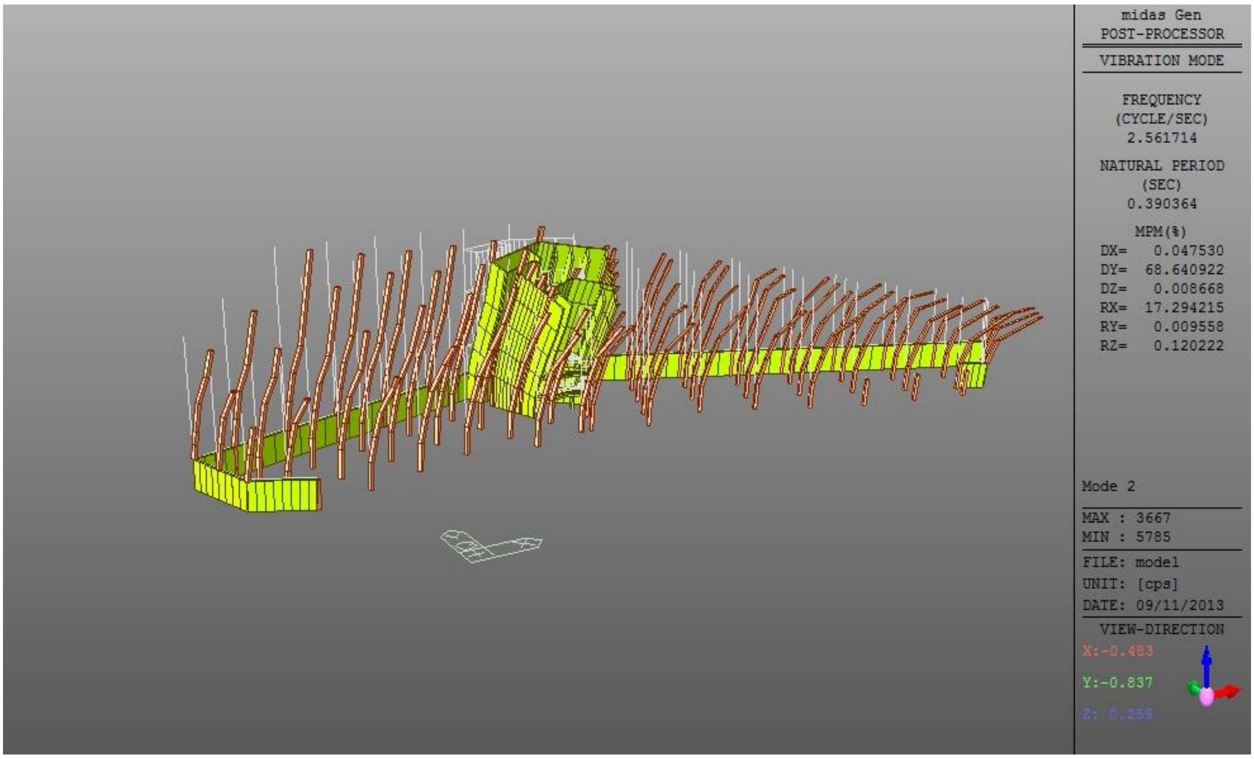


Figure 5.32 Second mode of vibration

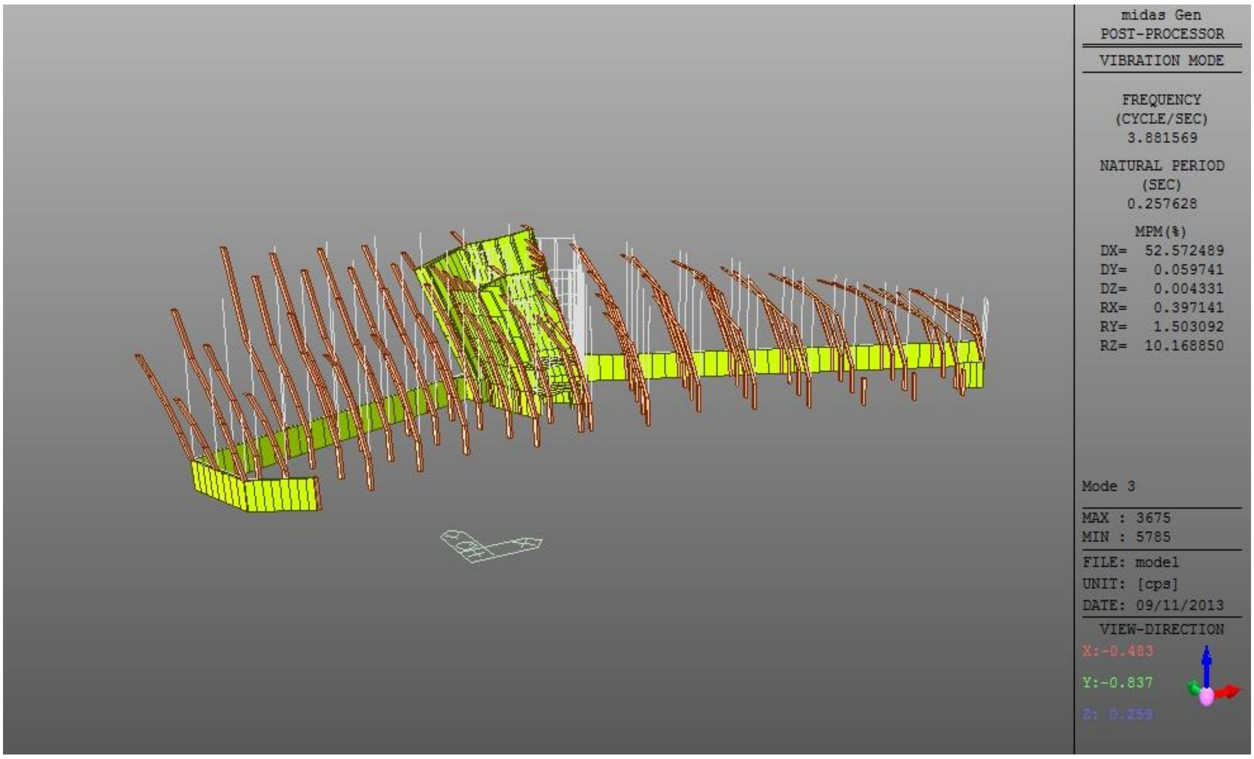


Figure 5.33 Third mode of vibration

EIGENVALUE ANALYSIS

Mode No	Frequency (rad/sec)	Frequency (cycle/sec)	Period (sec)	Tolerance
1	12.1338	1.9311	0.5178	0.0000e+000
2	16.3319	2.5993	0.3847	0.0000e+000
3	24.8149	3.9494	0.2532	0.0000e+000
4	28.4715	4.5314	0.2207	0.0000e+000
5	40.0698	6.3773	0.1568	0.0000e+000
6	43.9683	6.9978	0.1429	0.0000e+000
7	57.1735	9.0994	0.1099	0.0000e+000
8	66.7126	10.6176	0.0942	0.0000e+000
9	116.7120	18.5753	0.0538	0.0000e+000
10	125.3943	19.9571	0.0501	0.0000e+000

MODAL PARTICIPATION MASSES PRINTOUT

Mode No	TRAN-X MASS(%)	TRAN-X SUM(%)	TRAN-Y MASS(%)	TRAN-Y SUM(%)	TRAN-Z MASS(%)	TRAN-Z SUM(%)	ROTN-X MASS(%)	ROTN-X SUM(%)	ROTN-Y MASS(%)	ROTN-Y SUM(%)	ROTN-Z MASS(%)	ROTN-Z SUM(%)
1	13.5699	13.5699	0.0518	0.0518	0.0009	0.0009	0.3968	0.3968	0.0969	0.0969	60.4936	60.4936
2	0.0553	13.6251	69.0283	69.0801	0.0087	0.0096	17.0179	17.4147	0.0100	0.1069	0.1332	60.6268
3	53.4112	67.0363	0.0765	69.1566	0.0028	0.0124	0.3728	17.7875	1.4801	1.5869	10.5568	71.1837
4	0.0232	67.0595	0.0074	69.1641	0.0167	0.0291	0.0055	17.7931	0.0151	1.6021	0.0684	71.2521
5	0.4965	67.5561	0.5266	69.6906	0.2138	0.2429	0.0611	17.8541	0.0633	1.6653	0.1403	71.3924
6	0.2247	67.7807	0.2281	69.9188	0.2637	0.5066	0.0530	17.9071	0.3115	1.9769	1.5355	72.9279
7	0.7955	68.5762	12.2377	82.1564	0.0249	0.5315	6.9496	24.8568	0.0684	2.0452	0.0243	72.9522
8	8.1571	76.7333	1.8389	83.9953	0.0609	0.5924	0.3075	25.1643	0.0746	2.1198	0.4373	73.3895
9	6.1012	82.8345	8.5885	92.5838	0.4915	1.0839	0.1475	25.3118	0.6724	2.7922	0.0131	73.4026
10	9.9900	92.8246	4.4808	97.0646	0.1128	1.1967	0.4482	25.7599	0.3419	3.1341	1.3624	74.7651

Figure 5.34 Modal analysis results

5.2.4. Design and verifications

- **Beams design**

As for Eurocode capacity design first the beams should be designed before columns.

Below ultimate limit state design and verifications are represented.

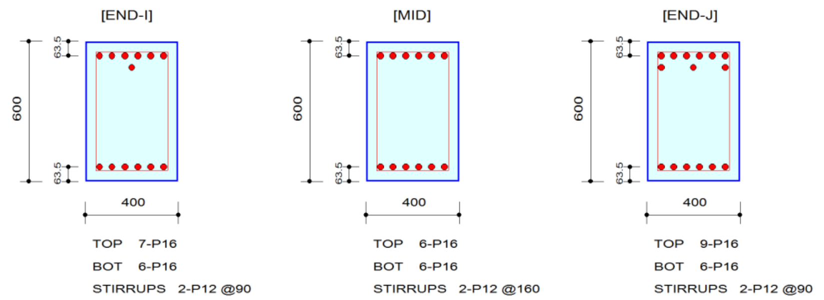
midas Gen **RC Beam Strength Checking Result**

MIDAS	Company		Project Title	
	Author		File Name	C:\...\midas\model.str.final.mgb

1. Design Information

Design Code	Eurocode2:04	Unit System	kN, mm
Material Data	fck = 0.045, fyk = 0.45, fyw = 0.45 kN/mm^2		
Section Property	60*40 (No : 2)	Beam Span	8000 mm

2. Section Diagram



3. Bending Moment Capacity

	END-I	MID	END-J
(-) Load Combination No.	10	8	8
Moment (M_Ed)	250228.72	85592.54	337523.80
Strength (M_Rd)	279028.73	245017.08	348304.61
Check Ratio (M_Ed/M_Rd)	0.8968	0.3493	0.9690
Neutral Axis (x/d)	0.1147	0.1077	0.1299
(+) Load Combination No.	10	6	8
Moment (M_Ed)	125114.36	194032.29	192544.92
Strength (M_Rd)	245944.75	245017.08	248083.42
Check Ratio (M_Ed/M_Rd)	0.5087	0.7919	0.7761
Neutral Axis (x/d)	0.1150	0.1077	0.1260
Using Rebar Top (As_top)	1407.4200	1206.3600	1809.5400
Using Rebar Bot (As_bot)	1206.3600	1206.3600	1206.3600

4. Shear Capacity

	END-I	MID	END-J
Load Combination No.	5	12	4
Factored Shear Force (V_Ed)	126.72	120.95	137.49
Shear Strength by Conc.(V_Rdc)	127.50	121.75	137.67
Shear Strength by Rebar.(V_Rds)	469.69	267.12	462.78
Using Shear Reinf. (Asw)	2513.3333	1413.7500	2513.3333
Using Stirrups Spacing	2-P12 @90	2-P12 @160	2-P12 @90
Shear Ratio by Conc	0.9939	0.9934	0.9987
Shear Ratio by (V_Rds ; V_Rdmax)	0.2698	0.4528	0.2971
Check Ratio	0.9939	0.9934	0.9987

Figure 5.35 RC Beam Strength Checking Result

- **Slab design**

Slab design is based on Wood-Armer's moments is performed and required reinforcement in two directions is represented.

The method Wood-Armer, in the proposed simplified formula in EC2 .A.2.8., is a procedure that provides for the allocation of a portion of m_{xy} torque in both directions x and y. Sometimes the design requirements force the designer to choose an reinforcement oriented differently from the classic grid horizontally and vertically. Applying Wood-Armer to general procedure turn the moment the main m_{xx}, m_{yy} and m_{xy} in the ultimate moments for design, that is, new stress values which take into account orientation of any reinforcement.

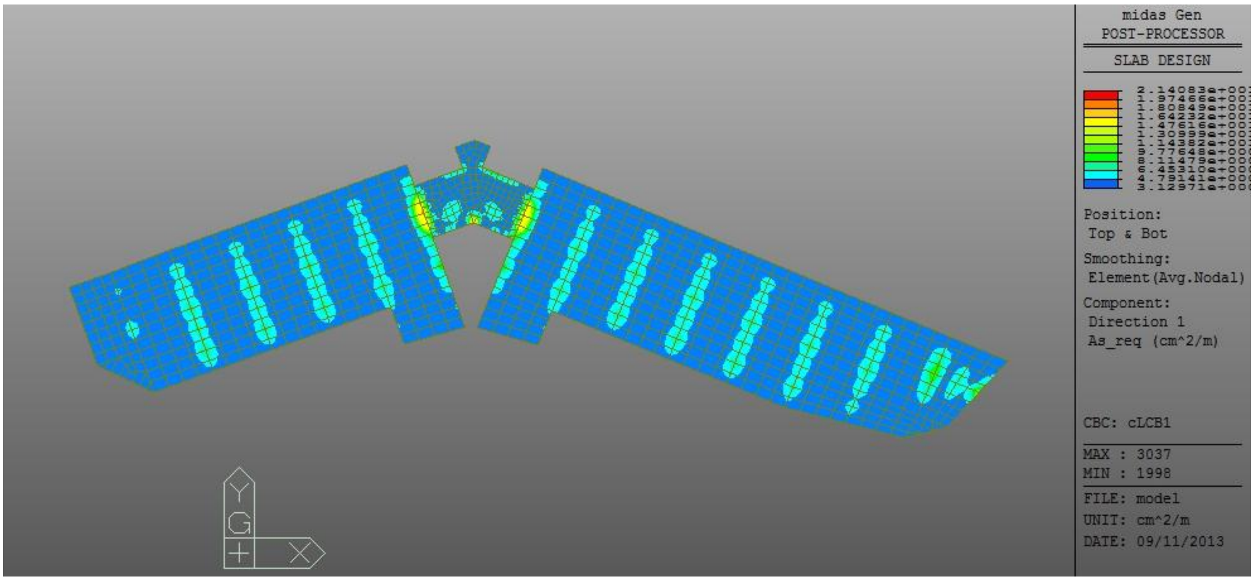


Figure 5.36 Required reinforcement in first direction

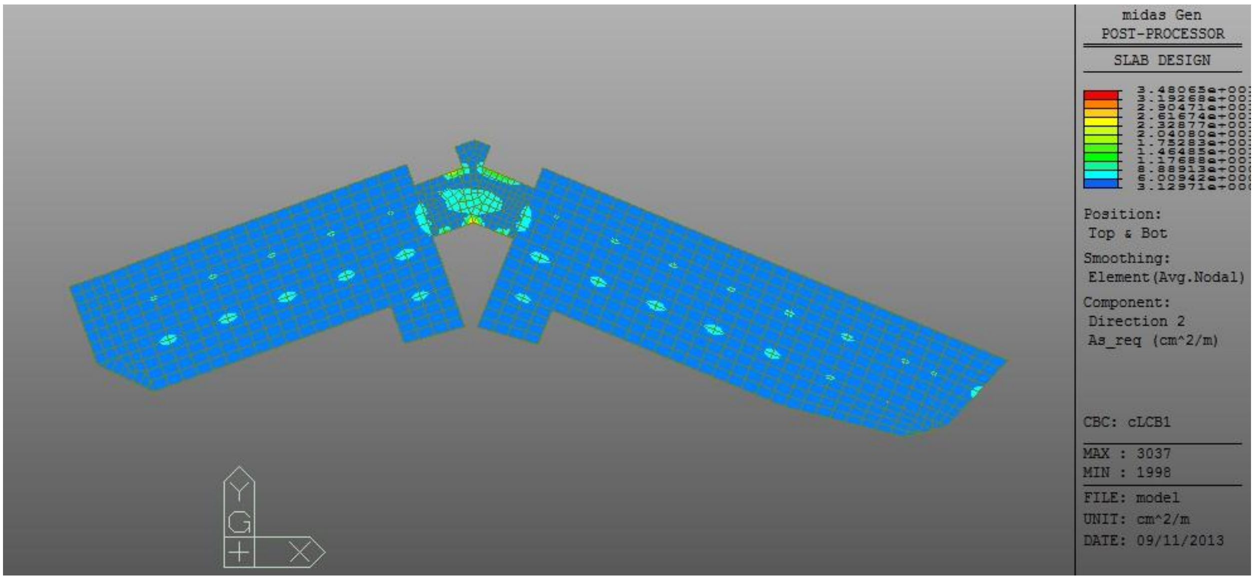


Figure 5.37 Required reinforcement in second direction

Slab shear check is performed including punching shear verifications as can be seen in the figure below the slab is verified as ratio of Ved/Vrd is less than 1.

$$v_{Ed} = \beta \frac{V_{Ed}}{u_i d}$$

$$v_{Rd,c} = C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} + k_1 \sigma_{cp} \geq (v_{min} + k_1 \sigma_{cp})$$

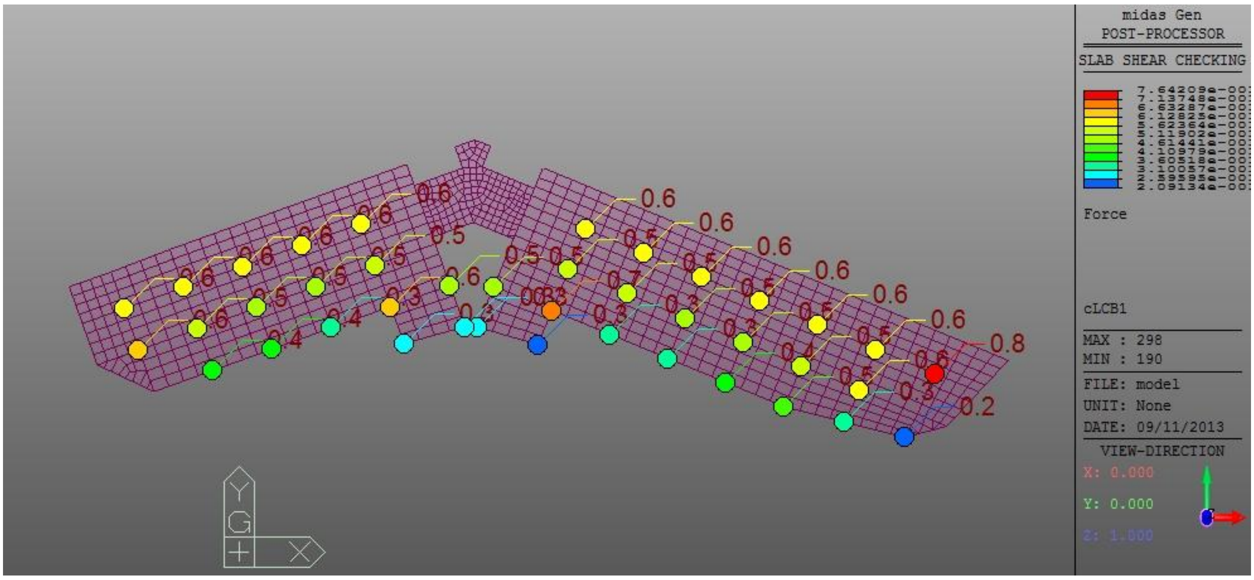


Figure 5.38 Punching shear verifications

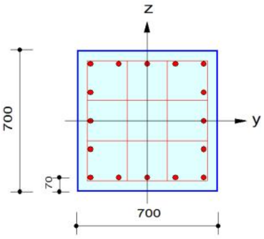
- **Columns design**
  First design to Eurocode 2 is performed for the ultimate limits state for static cases and then it is checked to Eurocode 8 and ductility requirements.

midas Gen **RC Column Design Result**

MIDAS	Company		Project Title	
	Author		File Name	C:\...\midas\model.str.final.mgb

1. Design Condition

Design Code	Eurocode2:04	UNIT SYSTEM kN, mm
Member Number	333 (PM), 238 (Shear)	
Material Data	fck = 0.045, fyk = 0.45, fyw = 0.45 kN/mm^2	
Column Height	4000 mm	
Section Property	pil.60*40 (No : 1)	
Rebar Pattern	: 16 - 5 - P20	Ast = 5026.56 mm^2 (Rhost = 0.010)



2. Applied Loads

Load Combination 13 AT (I) Point

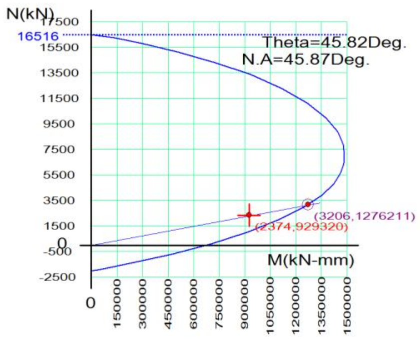
N_Ed = 2373.71 kN M_Edy = 647095 kN-mm M_Edz = 667011 kN-mm

M_Ed = SQRT(M_Edy^2+ M_Edz^2) = 929320 kN-mm

3. Axial Forces and Moments Capacity Check

Concentric Max. Axial Load	N_Rdmax	= 16516.1 kN	
Axial Load Ratio	N_Ed/N_Rd	= 2373.71 / 3205.86	= 0.740 < 1.000 .... O.K
Normalized Axial Load Ratio	Nu_d / 0.55	= 0.161 / 0.550	= 0.294 < 1.000 .... O.K
Moment Ratio	M_Ed/M_Rd	= 929320 / 1276211	= 0.728 < 1.000 .... O.K
	M_Edy/M_Rdy	= 647095 / 889473	= 0.728 < 1.000 .... O.K
	M_Edz/M_Rdz	= 667011 / 915179	= 0.729 < 1.000 .... O.K

4. M-N Interaction Diagram



N_Rd(kN)	M_Rd(kN-mm)
16516.12	0.00
15820.33	294188.19
14349.49	721594.28
12313.00	1119831.97
10032.52	1378956.25
7885.62	1480313.82
6642.77	1488977.23
5634.71	1463853.06
3930.82	1354547.47
1992.81	1098852.53
133.53	703531.22
-1375.32	238779.19
-1966.91	0.00

5. Shear Force Capacity Check

Applied Shear Strength	V_Ed	= 7.39799 kN (Load Combination 9)
Shear Ratio by Conc	V_Ed/V_Rdc	= 7.39799 / 640.890 = 0.012
Shear Ratio by (V_Rds ; V_Rdmax)	V_Ed/V_Rds	= 7.39799 / 836.448 = 0.009
Shear Ratio	V_Ed/V_Rd	= 0.012 < 1.000 .... O.K
		(Asw-H_req = 7540.00000 mm^2/m, 4-P12 @60)
Joint Shear Ratio	Vjhd/Vjs	= 1407.04 / 1415.13 = 0.994 < 1.000 .... O.K
		(Ash = 1771.89704 mm^2, 4-4 P12)

Figure 5.39 RC Column Design Result

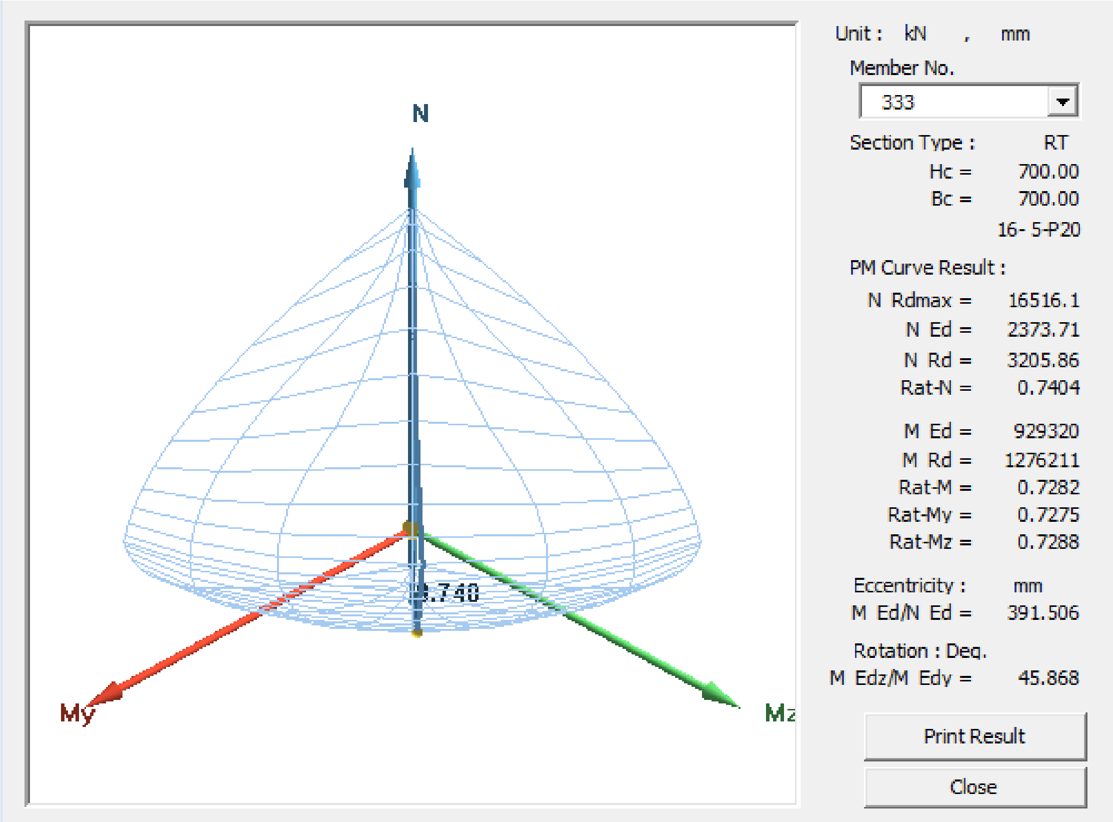


Figure 5.40 3d M-N interaction curve

- **Serviceability limit state verifications**

Following requirements were imposed for the serviceability limit states:

Class : XC3

Stress Parameters:

k1=0.6 k2=0.45 k3=0.8 k4=1

Crack control for quasi permanent combination w_{lim}=0.3mm

For the deflection control under quasi permanent combination L/250 limit was used.

- **Slabs**

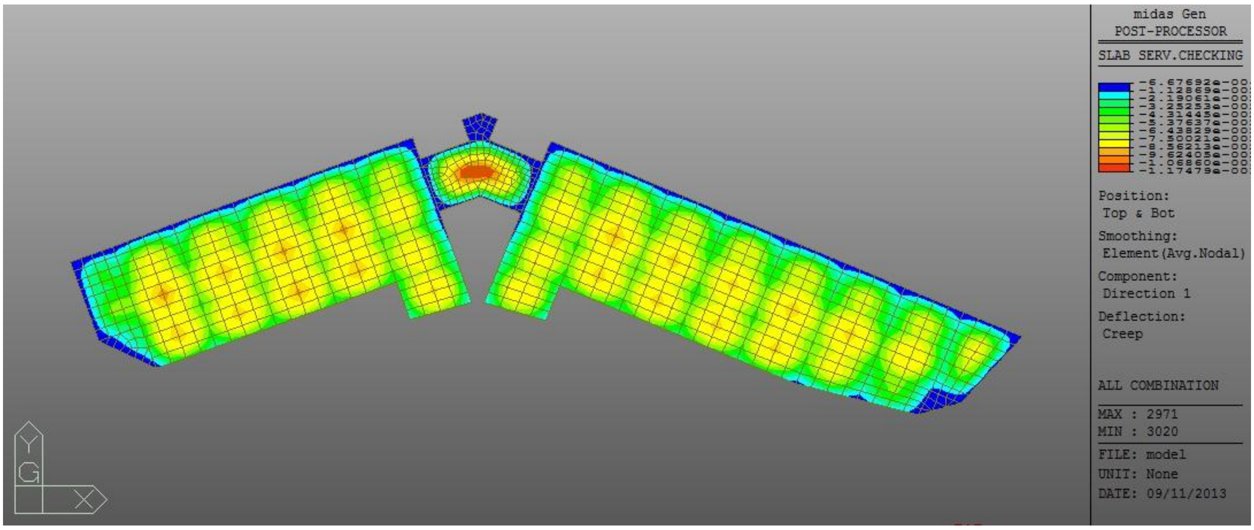


Figure 5.41 Deflection checks

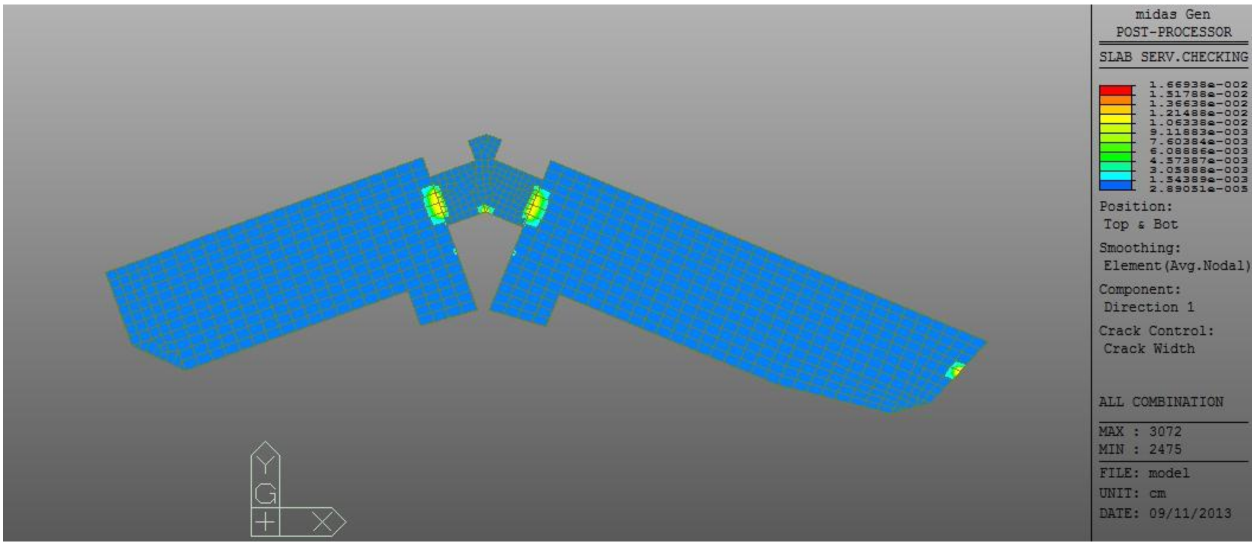


Figure 5.42 Crack width check

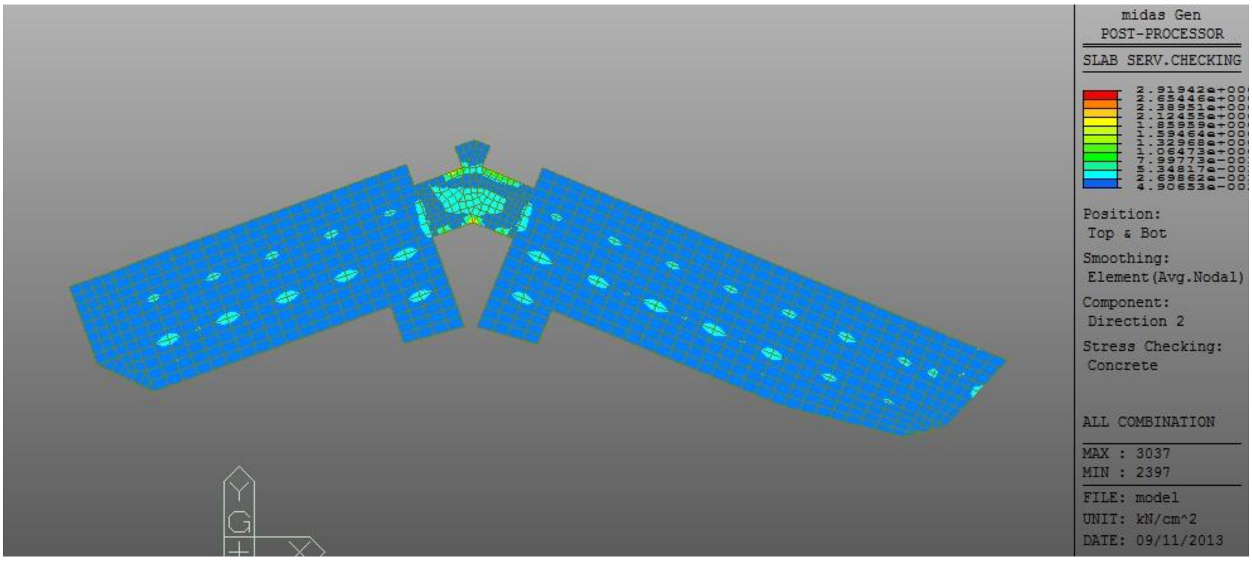


Figure 5.43 Stresses checks

- **Beams**

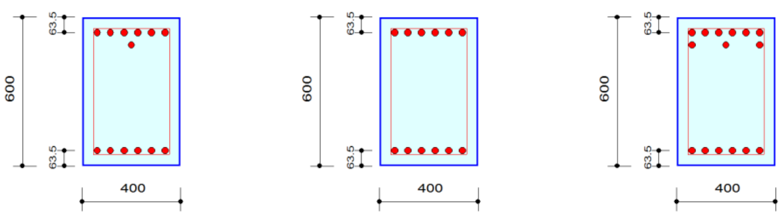
midas Gen **RC Beam Serviceability Checking Result**

MIDAS	Company		Project Title	
	Author		File Name	C:\...\midas\model.str.final.mgb

1. Design Information

Design Code	Eurocode2:04	Unit System	kN, mm
Material Data	fck = 0.045, fyk = 0.45, fyw = 0.45 kN/mm^2		
Section Property	60*40 (No : 2)	Beam Span	8000 mm

2. Section Diagram



[END-I]	[MID]	[END-J]
TOP 7-P16	TOP 6-P16	TOP 9-P16
BOT 6-P16	BOT 6-P16	BOT 6-P16
STIRRUPS 2-P12 @90	STIRRUPS 2-P12 @160	STIRRUPS 2-P12 @90

3. Stress Check

	END-I		MID		END-J	
	Concrete	Rebar	Concrete	Rebar	Concrete	Rebar
(-) Load Combination No.	56	56	52	52	52	52
Stress(s)	0.00	0.03	0.00	0.02	0.01	0.29
Allowable Stress(sa)	0.00	0.36	0.00	0.36	0.03	0.36
Stress Ratio(s/sa)	0.9975	0.0890	0.5731	0.0525	0.5071	0.8015
(+) Load Combination No.	64	64	50	50	47	47
Stress(s)	0.00	0.00	0.00	0.03	0.00	0.03
Allowable Stress(sa)	0.00	0.00	0.00	0.36	0.00	0.36
Stress Ratio(s/sa)	*****	*****	0.9972	0.0914	0.9997	0.0919

4. Crack Control

	END-I	MID	END-J
(-) Load Combination No.	64	64	64
Crack Width(w)	0.23	0.02	0.26
Allowable Crack Width(wa)	0.30	0.30	0.30
Check Ratio(w/wa)	0.7789	0.0524	0.8634
(+) Load Combination No.	64	64	64
Crack Width(w)	0.00	0.19	0.20
Allowable Crack Width(wa)	0.00	0.30	0.30
Check Ratio(w/wa)	*****	0.6487	0.6539

5. Deflection Control

L/250 = 31.999997 > 1.1486 (LCB:49, POS:4000.0mm from END-I)............................ O.K

Figure 5.44 RC Beam Serviceability Checking Result

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