**POLITECNICO DI MILANO**
SCHOOL OF ARCHITECTURE URBAN
PLANNING CONSTRUCTION ENGINEERING
POLO TERRITORIALE DI LECCO

**MASTER OF SCIENCE DEGREE IN ARCHITECTURAL ENGINEERING**

**MASTER'S THESIS**

# Giza Sustainable Science City

**RELATORE**
Prof. Gabriele Masera

**MASTER THESIS OF**
Heba Ahmed Mohamed Youssef
Noha Sobhi Mohammed Ali Hossam

**APRIL 2018**

# AKNOWLEDGMENT

We would like to express our gratitude to our thesis supervisor Prof. **Gabriele Masera** for his useful comments, remarks and engagement throughout the learning process of this master thesis. Furthermore, we would like to thank Prof. **Massimo Tadi**, Prof. **Roberto Francieri** and Prof. **Marta Maria Sesana** for their guidance and support in our reviews. Thank you also to the **Politecnico di Milano** teaching staff who taught us and provided their precious information and time.

Also, we would like to thank the participants in our survey, who have willingly shared their precious time during the process of interviewing. we would like to thank our loved ones who have supported us throughout the entire process, both by keeping us harmonious and helping us putting pieces together. we will be grateful forever. We wanted also to dedicate special thanks to our friends (Ahmed El sheikh, Matthew Davey, and Zeinab Mahmoud Morsi) for giving us a hand.

Heba
For my second father Mohamed Ezz El-arab god bless his soul, Moustafa Ezz El-arab my beloved life partner, my parents Hemat and Ahemed, Saad, Sohaila and my lovely aunt Mona, words are not enough to thank you. I know you spent lots of days and nights praying for me, each of you did support me in a very special way that I really appreciate. Thank you for standing by me.

Noha
Firstly, thanks a lot to my Lord for all his blessing to me. I would like to thank my mum- you are my soul, my father, my Egyptian family, my lovely husband, my English family, my grandmother Zeinab -I know that you are watching me from paradise and all my friends who supported me.

## Abstract

This project is investigating the impact on architecture of a new kind of buildings involving embedded sensing technology as it moves from scientific, engineering, defense, and industrial contexts to the wider personal, social and urban contexts. It aims to find a relation between people, objects, and physical spaces to enable new kinds of social exchange and offer new and unexpected views of our communities. The project is developing principles that are vital for the future of Egypt. Ultimately, this kind of project in Egypt will yield fundamental participating, sharing, and interpretation of physical life. The science city will play a significant role that has usually demonstrated how design tools can approach different disciplines and let the building of our contexts evolve to a better future. Being part of a new established city, this thesis has focused to propose a new architectural typology in 6th of October city. The design development passed through an integrated process to explore the various opportunities for implementation where the master plan considered the urban transformation of Egypt. Imposing an interacting architecture product that follow the brief requirements, in parallel it was complying with different areas of technology, energy efficiency and structural design.

*As an architect, you design for the present with an awareness of the past for a future which is essentially unknown.* – **Norman Foster**


After a certain high level of technical skill is achieved, science and art tend to coalesce in esthetics, plasticity, and form. The greatest scientists are always artists as well. – Albert Einstein

# 0. CONTENTS

# 0. CONTENTS

# 1. INTRODUCTION



# 2. ANALYSIS PHASE

# 3. GOALS AND PRINCIPLES



# 4. DESIGN PROCESS

## 5. TECHNICAL DESIGN PHASE



## 6. REFERENCES 

# 1. INTRODUCTION

1.1. THE CHALLENGES OF THE SCIENCE CITY
1.2. THE PHILOSOPHY OF THE SCIENCE CITY
1.3. THE PROPOSED DEVELOPMENT
1.4. VISION
1.5. OBJECTIVES
1.6. EGYPT
1.7. SUSTAINABILITY APPROACH
1.8. SUSTAINABILITY IN EGYPT
1.9. RENEWABLE ENERGY IN EGYPT

# CHAPTER 1 | INTRODUCTION

## 1.1. THE CHALLENGES OF THE SCIENCE CITY

The Bibliotheca Alexandria, the new library of Alexandria, aspires to implement landmark honoring the enterprise of science. Considering this mission, the library of Alexandria has endorsed a science city project by organizing an open, one stage international architectural competition for the comprehensive master plan and conceptual design. The new **Science City** complex, will be built on the western edge of Cairo, in the heart of 6$^{th}$ of October City. This new complex to be constructed on the prime land, calls for inspiring new comprehensive master plan and conceptual design; that will ultimately create the first 21$^{st}$ century science museum, learning, research facility in **Egypt.**

## 1.2. THE PHILOSPHY OF THE SCIENCE CITY

The design of science city will create set of buildings and spaces that must be inspiring on the outside and motivating and exciting on the inside to visitors and employees alike. It must express a particular vision of the search for knowledge and the pursuit of science.

Humans interact with one another and with nature. They explore the limitless universe and the inner self and the subtlety and complexity of these explorations and social relations from the web of life. Such explorations result in expression that we have come to call **Art or Science**.

Science is driven by curiosity about the natural world and the inner self. It is empirical, rational and logical. Technology is the utilitarian application of science. It may precede science, as it did when people used tools and levers without understanding the scientific principles that underline them. More recently, technological development kept pace with scientific research. “Research and Development”, has engineered progress throughout 20$^{th}$ century.

The science city celebrates scientific enterprise with its exhilarating and unending journey of discovery and promotes the “culture of science”. It is a place where we honor the past, celebrate the present and invert the future. It helps our greater society, as well as its national and foreign visitors, gain insights into and an appreciation of the scientific culture, which is more than a widespread knowledge of scientific facts and figures. Scientific culture embraces the acquisition of a skeptical outlook and promotes evidence-based regulation of human social activities and interactions.

The scientific method is central to the enterprise of science. Without is there can be no real “Research and Development”, no technology. It is a necessity, not a luxury. Younger generations must become producers of knowledge, not just consumers benefit of science and technology. You must allow the scientists of tomorrow to make their contributions to a better future for all.

In thinking about how to design the buildings that will constitute **science city,** the designer should reflect on the evolving nature of science. The classical definitions of natural sciences include the following:

- Physical sciences: Physics and -chemistry
- Life sciences: Biology (Zoology and Botany)
- Earth science: Geology, Observation and Meteorology

These classical definitions that have functioned separately for a good part of the last two centuries have been challenged in the last half century. Increasingly, discoveries have resulted in overlapping scientific domains: Biochemistry, paleontology and molecular genetics, to name but a few. Furthermore, we rely increasingly on process and system views, rather than isolated events or "snapshots". For example, photosynthesis is now seen as a drawing on the different scientific disciplines in different ways. Thus,

- Light: the energy source (physics)
- Photosynthesis: the food production process (chemistry)
- For plants: (biology)

Energy, biochemical pathways, cell biology and plant physiology all contribute to enhance our understanding of nature. The domains have blurred: we see mathematics as the basis of music. We study brain to understand mind. Neurology and psychiatry are seen to be different ways of looking at that most fundamental part of ourselves: computational linguistics and literary criticism seek greater understanding of language, its uses and the messages that it carries.
The pace of changes is rapid. Thus, the science city must be built in stages in order to allow it the flexibility to absorb changes in museology or exhibition format, to update interactive learning facilities, and to remain open to new possibilities from building to building during the execution of the campus.

## 1.3. THE PROPOSED DEVELOPMENT

The Bibliotheca Alexandrina is launching an international competition for architects and planners to design the Science City **(SC)**. The project aims to foster scientific culture and knowledge to the public. Through its architecture and program, the Science City will connect past achievements with present advancement, while guiding future development.
Egypt has been a world leader in scientific achievements. At the dawn of civilization, Egypt laid the foundation of scientific knowledge and scientific thinking. Scholarship and literacy, a system of writing, classification and practical knowledge were at the heart of remarkable Egyptian achievements in all fields of knowledge.
Early Egyptians observed the stars and contributed to the development of astronomy, thus ultimately paving the way for the exploration of outer space. They used their knowledge of the stars to navigate and explore the seas preceding future ages of exploration. Their knowledge of chemistry, medicine, geology, mining, metallurgy, plants, animals, and architecture was essential for later achievements. Above all, it is their contributions to mathematics and geometry that provided the basis for later advances in the physical sciences.

## 1.4. VISION

The vision is to establish a national central institute with international standards that can illuminate the world of scientific knowledge and technology. The SC will be comprehensive in its content, demonstrating unity among the sciences. The SC will not only be connected to educational and cultural facilities within the 6th of

October City, but also to other local, national, regional and worldwide organizations facilities. These include universities, educational facilities, scientific research centers, libraries, and media production centers. This connection to major scientific and research centers worldwide will enable the SC to simultaneously act as an eye and a vehicle, linking our society to the latest achievements in the fields of science and technology.

## 1.5. OBJECTIVES

The main strategic objectives of the SC are:

- Disseminate scientific knowledge and scientific thinking among the public.
- Promote science for development
- Support science education and research

Science City should address various aspects in society by ensuring that science-related projects and findings are presented to the public in an exciting and entertaining manner, with thoughtful simplification that conveys the key principles of scientific investigations as well as their importance from human welfare and development.

It is vital to promote science for development. The demands for scientific research in a developing country must be driven by a desire to contribute creation of jobs, to put scientific ideas to use, and to utilize local human and natural resources for the maximum economic benefit without sacrificing environmental safety and social well-being.

The potential to explore where Egypt can make an impact and increase its export of scientific goods is one of the main objectives of the science city. By helping in creating the proper climate for inventors and by fostering the spirit of discovery, and emphasizing the importance of curiosity-driven research, the public and students will be able to venture into new areas that can directly benefit society.

## 1.6. EGYPT

### 1.6.1. GEOGRAPHY

Egypt lies primarily between latitudes 22° and 32°N, and longitudes 25°and 35°E. At 1,001,450 square kilometers (386,660 sq mi). It is the world's 30th-largest country. Due to the extreme aridity of Egypt's climate, population centers are concentrated along the narrow **Nile Valley** and **Delta**, meaning that about 99% of the population uses about 5.5% of the total land area.98% of Egyptians live on 3% of the territory.

Apart from the Nile Valley, the majority of Egypt's landscape is desert, with a few scattered oases. Without the Nile River, all of Egypt would be desert. Only about an inch (2.5 centimeters) of rain falls throughout Egypt each year. But each summer, the river rises because of rains at its source far to the south in Ethiopia. Floods cover the river's valleys, leaving sediments needed for trees, plants, and crops to grow.

Egypt is often divided into two sections: Upper Egypt in the south and Lower Egypt in the north. The sections are named this way because the Nile flows from south to north. The river empties into the Mediterranean Sea.

Southern Egypt's landscape contains low mountains and desert. Northern Egypt has wide valleys near the Nile and desert to the east and west. North of Cairo, the capital, is the sprawling, triangular Nile River Delta. This fertile land is completely covered with farms.

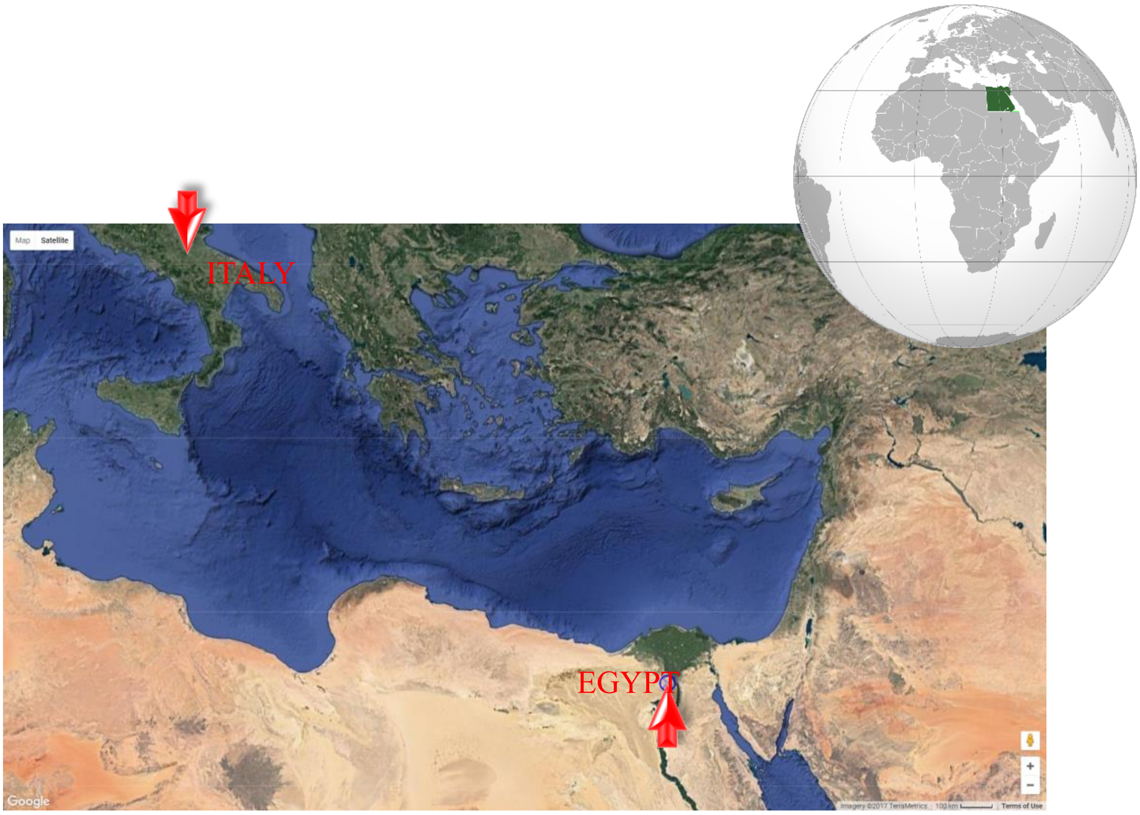




**Fig. 1.1** location of Egypt and 6th of October city

### 1.6.2. PEOPLE AND CULTURE

Egypt is the most populous country in the Arab world and the third most populous country in Africa, behind Nigeria and Ethiopia. Egypt's rapid population growth – 46% between 1994 and 2014 – stresses limited natural resources, jobs, housing, sanitation, education, and health care.

Although the country's total fertility rate fell from roughly 5.5 children per woman in 1980 to just over 3 in the late 1990s, largely as a result of state-sponsored family planning programs, the population growth rate dropped more modestly because of decreased mortality rates and longer life expectancies. During the last decade, Egypt's total fertility rate decline stalled for several years and then reversed, reaching 3.6 in 2011, and has plateaued the last few years. Population pressure, poverty, high unemployment, and the fragmentation of inherited land holdings have historically motivated Egyptians, primarily young men, to migrate internally from rural and smaller urban areas in the Nile Delta region and the poorer rural south to Cairo, Alexandria, and other urban centers in the north, while a much smaller number migrated to the Red Sea and Sinai areas.


**Fig. 1.2** graph showing the population growth in Egypt from 2008 to 2016

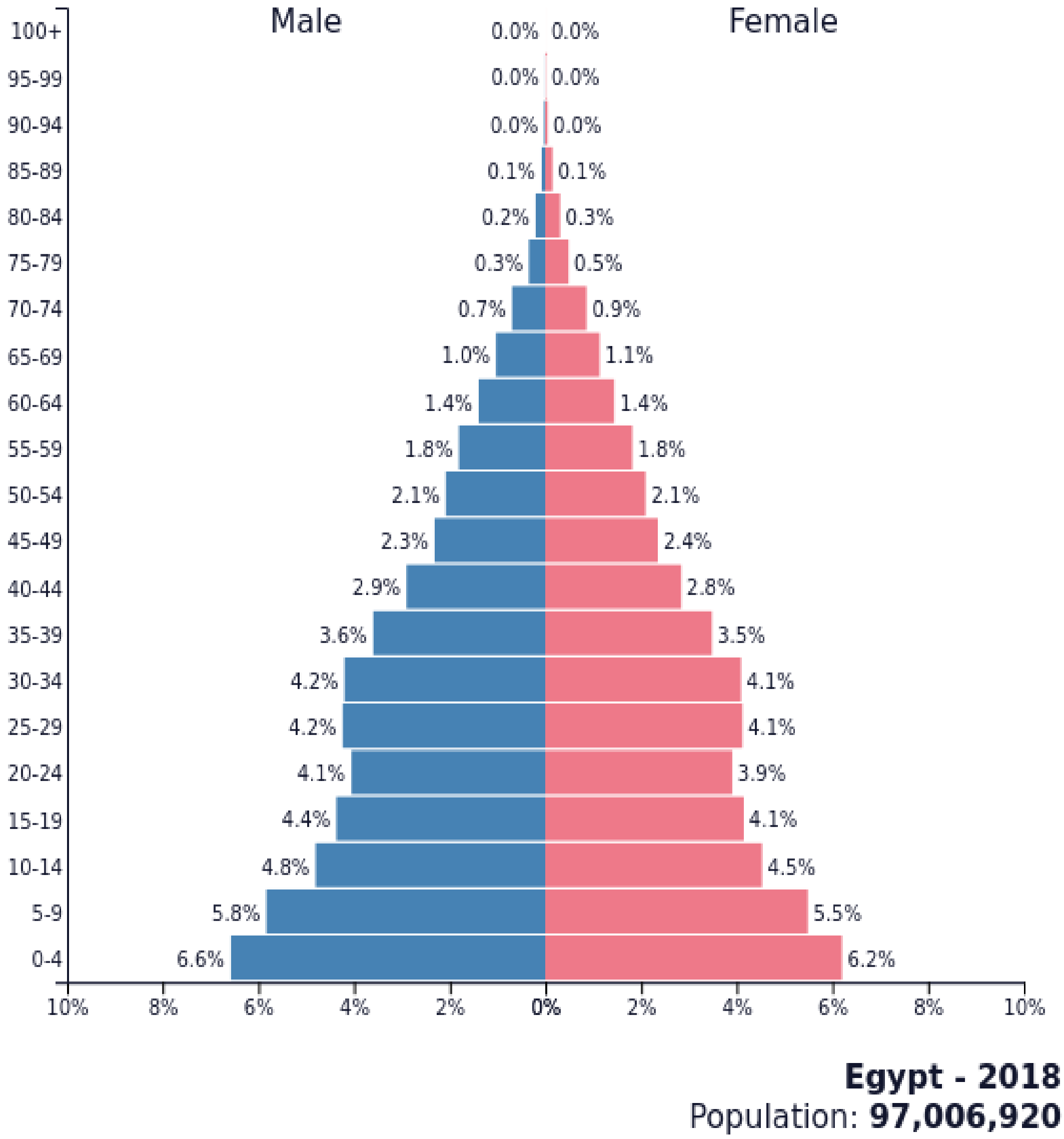



**Fig. 1.3** Graph showing population in Egypt 2018, analyzed in male and female giving an estimated age ranges for both

### 1.6.3. TOWARDS THE REVILATILAZTION OF NEW TOWNS IN EGYPT

Egypt adapted many experiments by establishment of new towns and urban settlements in the desert areas. These experiments aim to achieve developmental strategic aspects in the fields of urbanization, environmental, economic, and social. However, there is severe limitation in the achievement of the requirement rates either in the demographic growth rates, or in the economic growth rates, or in the urban development rates. Therefore, it should be evaluated either from the theoretical aspect or the executive one.

The history and growth of new towns are reviewed; challenges as well as achievements are identified. The establishment of new towns in the desert is of the most important experience which aims to develop desert regions in Egypt. In order to investigate this experience, it should firstly study the historical evolution of new town experience and track the establishment of new towns and communities in the Egyptian desert. It is also essential to monitor the most significant problems associated with planning processes, especially in Sixth of October new Town as one of the largest new towns in order to stand on the potential proposals that may support and promote the achievement of urban development goals in the Sixth of October and other new towns.


**Fig. 1.4** Map of Egypt showing the new towns in each generation

Over the last three decades there have been numerous criticisms of new towns from various quarters fig.4.3. One significant criticism is that new towns are too expensive for average citizens. This is attributed to the high cost of housing units, the poorly developed shopping sector and the need for adequate, affordable, and efficient public transportation systems. Also, the level of services (schools, health services, and entertainment facilities) is considered less than adequate. For most critics, the answer to these criticisms is, simply, that the government must provide more housing, cheaper and improved transport, and better services and public facilities.

However, the concept of the new towns itself has rarely been questioned. Solutions to the problems are typically simply more governmental investments, more private sector and public private partnership applications, better coordination, and "integrated" approaches. In effect, the new towns have been created with spatial supply-driven policies and wholesale land distribution attitudes which, in spite of the best of intentions, simply do not begin to fit with or stimulate the urban processes and markets that have dominated the dynamics of urbanization in Egypt and which to continue to replicate them in existing agglomerations.

### 1.6.4. EGYPTIAN ART AND ARCHITECTURE

The ancient architectural monuments, sculptures, paintings, and decorative crafts produced mainly during the dynastic periods of the first three millennia BCE in the Nile valley regions of Egypt and Nubia. The course of art in Egypt paralleled to a large extent the country's political history, but it depended as well on the entrenched belief in the permanence of the natural, divinely ordained order. Artistic achievement in both architecture and representational art aimed at the preservation of forms and conventions that were held to reflect the perfection of the world at the primordial moment of creation and to embody the correct relationship between humankind, the king, and the pantheon of the gods. For this reason, Egyptian art appears outwardly resistant to development and the exercise of individual artistic judgment, but Egyptian artisans of every historical period found different solutions for the conceptual challenges posed to them.

Geographical factors were predominant in forming the particular character of Egyptian art. By providing Egypt with the most predictable agricultural system in the ancient world, the Nile afforded a stability of life in which arts and crafts readily flourished. Equally, the deserts and the sea, which protected Egypt on all sides, contributed to this stability by discouraging serious invasion for almost 2,000 years. The desert hills were rich in minerals and fine stones, ready to be exploited by artists and craftsmen. Only good wood was lacking, and the need for it led the Egyptians to undertake foreign expeditions to Lebanon, to Somalia, and, through intermediaries, to tropical Africa. In general, the search for useful and precious materials determined the direction of foreign policy and the establishment of trade routes and led ultimately to the enrichment of Egyptian material culture

### 1.6.5. CONTEMPORARY ARCHITECTURE IN EGYPT

The Egyptian architecture lacks the character and identity that distinguishes it and flounder in the design of its buildings, and the diversity of materials used and components without determinants, because their vocabulary and composition and concepts are taken from different styles and whims, which created the ordeal of building and planning these cities. It also emphasizes the fact that the building of existing cities is characterized by poor design of spaces, lack of consideration of social needs such as privacy, absence of important functional spaces, separation between design and use, separation from society, Physical properties are at the expense of use, as are the repetition and similarity of architectural works to save money, and the dissonance of works with the surrounding environment and hence the lack of comfort within that architecture.

Another study showed that the process of designing and shaping the facades of buildings in this style depends on personal emotions and individual sensations, which led to the loss of the general character and character of the modern Egyptian city architecture. This is evident in the strange carnival that is noticed in the formation, all this only reflects the individualism and indifference and chaos of architectural formations, which led to the loss and loss of the general character of the Egyptian city.

Briefly, this dominant style of architecture in the modern Egyptian city has lost its identity fig. 4.6 and character because it has been linked to Western laws and concepts that are alien to society fig. 4.4 and which have succeeded in setting a general policy for Egyptian architecture and finally changing the architectural thought made it difficult to change the situation which inevitably led to an architecture lacking identity Do not reflect the values and customs of the population associated with the teachings and values derived from Islamic law.

**Fig. 1.5** Residential building showing contemporary architecture in Egypt

**Fig. 1.6** Random morphology of Egypt

**Fig. 1.7** Architectural identity of Egypt

**Fig. 1.8** Islamic architectural in Egypt

## 1.7. SUSTAINABILITY APPROACH

### 1.7.1. WHAT IS SUSTAINABILITY AND WHY IS IT IMPORTANT?

There is no universally agreed definition on what sustainability means. There are many different views on what it is and how it can be achieved. The idea of sustainability stems from the concept of sustainable development which became common language at the World's first Earth Summit in Rio in 1992.

The original definition of sustainable development is usually considered to be:

"*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." **Bruntland Report for the World Commission on Environment and Development (1992)**

Since then, there have been many variations and extensions on this basic definition. Many argue that sustainability has been hijacked and twisted to suit government and business that really want to continue with business as usual.

The quotes below will provide some ideas on what constitutes sustainable development and sustainability.

"*A process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations*" **The World Commission on Environment and Development**

"*Sustainable development is a dynamic process which enables people to realize their potential and improve their quality of life in ways which simultaneously protect and enhance the earth's life support systems*" **(Forum for the Future)**

"*In essence, sustainable development is about five key principles: quality of life; fairness and equity; participation and partnership; care for our environment and respect for ecological constraints - recognizing there are 'environmental limits'; and thought for the future and the precautionary principle*". **(From Making London Work by Forum for the Future's Sustainable Wealth London project)**

Sustainability is important for a very simple, very straightforward reason: we cannot maintain our quality of life as human beings, the diversity of life on Earth, or Earth's ecosystems unless we embrace it. There are indications from all quarters and from the smallest to the largest scale that sustainability is something we must address. We will run out of fossil fuels. Thousands if not millions of animal species will become extinct. We will run out of lumber. We will damage the atmosphere beyond

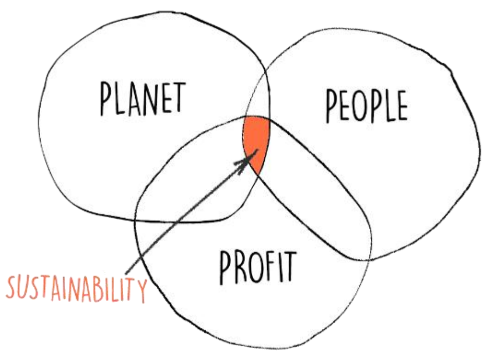



**Fig. 1.9** Sustainability pillars

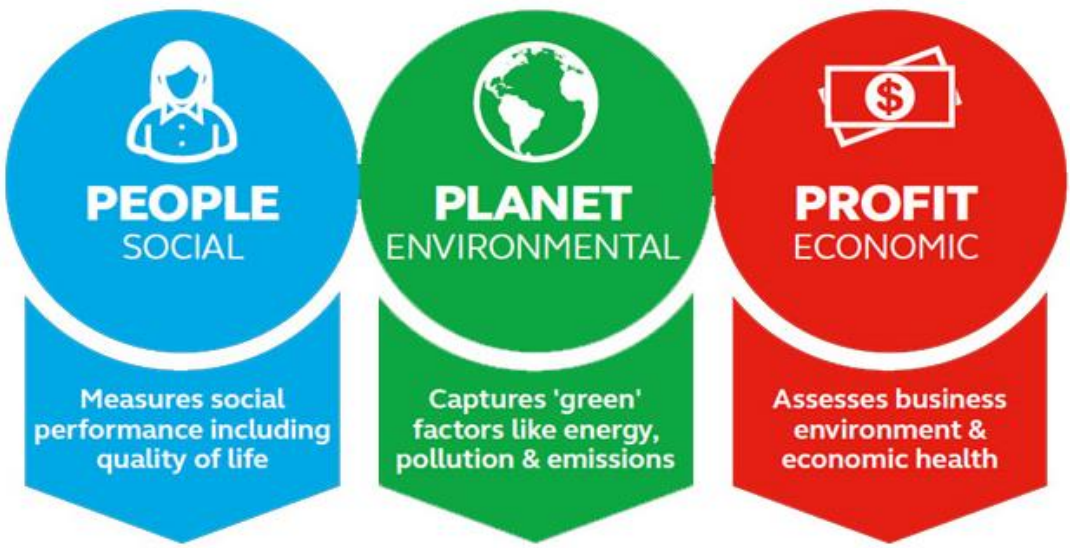
repair… If we don't change. And the root of that change lies in understanding and striving for sustainability—in our own homes, in our communities, in our ecosystems, and around the world.

### 1.7.2. THE THREE PILLARS OF SUSTAINABILITY

In 2005, the World Summit on Social Development identified three core areas that contribute to the philosophy and social science of sustainable development. These "pillars" in many national standards and certification schemes, form the backbone of tackling the core areas that the world now faces. We must consider the future then, in making our decisions about the present.

- **Economic Development**
  This is the issue that proves the most problematic as most people disagree on political ideology what is and is not economically sound, and how it will affect businesses and by extension, jobs and employability. It is also about providing incentives for businesses and other organizations to adhere to sustainability guidelines beyond their normal legislative requirements. Also, to encourage and foster incentives for the average person to do their bit where and when they can; one person can rarely achieve much, but taken as a group, effects in some areas are cumulative. The supply and demand market is consumerist in nature and modern life requires a lot of resources every single day; for the sake of the environment, getting what we consume under control is the paramount issue. Economic development is about giving people what they want without compromising quality of life, especially in the developing world, and reducing the financial burden and "red tape" of doing the right thing.
- **Social Development**
  There are many facets to this pillar. Most importantly is awareness of and legislation protection of the health of people from pollution and other harmful activities of business and other organizations. In North America, Europe and the rest of the developed world, there are strong checks and programmes of legislation in place to ensure that people's health and wellness is strongly protected. It is also about maintaining access to basic resources without compromising the quality of life. The biggest hot topic for many people right now is sustainable housing and how we can better build the homes we live in from sustainable material. The final element is education - encouraging people to participate in environmental sustainability and teaching them about the effects of environmental protection as well as warning of the dangers if we cannot achieve our goals.
- **Environmental Protection**
  We all know what we need to do to protect the environment, whether that is recycling, reducing our power consumption by switching electronic devices off rather than using standby, by walking short journeys instead of taking the bus. Businesses are regulated to prevent pollution and to keep their own carbon emissions low. There are incentives to installing renewable power sources in our homes and businesses. Environmental protection is the third pillar and to many, the primary concern of the future of humanity. It defines how we should study and protect ecosystems, air quality, integrity and sustainability of our resources and focusing on the elements that place stress on the environment. It also concerns how technology will drive our greener future; developing technology and biotechnology is key to this sustainability, and protecting the

environment of the future from potential damage that technological advances could potentially bring.




### THE PEOPLE SUB INDEX

Rates health (life expectancy and obesity), education (literacy and universities), Income inequality, work-life Balance, the dependency Ratio, crime, housing and Life costs. These indicators Can be broadly thought of as capturing "quality of life".

### THE PLANET SUB INDEX

Ranks cities on energy consumption and renewable energy share, green spaces within cities, recycling and composting rates, green-house gas emission, natural catastrophe risk green space, drinking water, sanitation and air pollution. These indicators can be broadly thought of as capturing "green factors".

### THE PROFIT SUB INDEX

Examines performance from a business perspective, combining measures of transport infrastructure (rail, air and traffic congestion), ease of doing business, tourism, GDP per capita, the city's importance in global economic networks, connectivity in terms of mobile and broadband access and employment rates. These indicators can be broadly thought of as capturing "economic health".

## 1.8. SUSTAIABILITY IN EGYPT

### 1.8.1. ENERGY, DEVELOPMENT, AND GREEN HOUSE GAS EMISSIONS

"Greenhouse gases are not a primary concern for our own environmental well-being", and the cities of Egypt share a small portion in global greenhouse gas emissions. Such a claim ignores the fact that Egypt's total emissions from energy use have grown 8 times since 1971, with its per capita emissions growing 4 times during the same period, according to International Energy Agency statistics. Egypt's share of global emissions has also risen substantially over the past few years, growing from 0.4% in 1998 to 0.63% in 2007, according to the World Resources Institute.

Egypt's recent demographic and economic growth patterns make it a near certainty that its energy use and emissions will continue to grow rapidly if there is no change in course. In fact, the United Nations Development Programme forecasts that, based on current trends, energy demand in Egypt will increase threefold by 2030. Conservation measures are thus required, not only to reduce emissions, but also to avert potential energy shortages that may hinder economic development.

Steering Egypt's much-needed development in a more sustainable direction is not only the right thing to do for the environment, but is also an economic necessity. Moreover, Egypt's environmental well-being is facing grave challenges as a result of global warming. The most conservative estimates of global sea-level rises project that 34% of the Nile Delta will be flooded, displacing approximately 7 million people and causing substantial economic damage due to the loss of the fertile soils, according to the Arab Environment Climate Change report. Surely, this threat posed by excessive carbon emissions must concern Egyptians as much as they concern everyone else, if not more.

### 1.8.2. TRADITIONAL COLLECTION OR WASTE MANAGEMENT

Restoring and developing the system of garbage collectors and sorters–or zabaleen–is environmentally friendly and sustainable. Egypt's garbage collectors are often praised for sorting and exporting non-organic waste for reuse by foreign industries, and for reusing organic matter as compost and fodder for their livestock. However, the suggestion that the garbage collectors can be a solution for Egypt's waste problems appears unrealistic due to scale limitations. There are natural limits to how much waste the zabaleen can handle with their modest carts, how many pigs they can raise, and how large the waste-infested unsanitary urban dwellings they reside in can grow.

These limits are already evident in the zabaleen's limited share of waste collection, which is no more than a third of Cairo's garbage. The uncollected garbage in the streets of Cairo is a reminder that Egypt's current waste management policy is not viable, but this does not imply that the zabaleen are the future solution for waste management in Egypt. Alternative proposals that incorporate valuable components of the zabaleen's work, such as manual sorting and composting, together with modern technologies, can perhaps provide a workable and more sustainable solution.

### 1.8.3. INFRASTRUCTURE UPGRADE

In order to cope with future demand, a systematic expansion and reinforcement of the electricity infrastructure and generation facilities is crucial and can be achieved through increased Governmental commitment to infrastructure investment. It is estimated that to meet the increased demand, an average annual expansion in generation, transmission and distribution capacity of 2000-3000 MW is required – approximately 10% of the installed capacity. Although average transmission losses in the National Unified Power System declined from 6.56% in 1998/1999 to 3.8% in 2007/2008, additional infrastructure upgrade work is also required to improve the efficiency of the transmission and distribution networks and to reduce losses within them.

Egypt needs to invest in various sectors including energy generation and other utilities. At least half of this investment is likely to come through Public-Private Partnerships (PPPs), which involve private firms in the funding, construction, maintenance and management of new or overhauled infrastructure. However, it should be noted that while building enough power plants to satisfy every possible supply and demand scenario is one possible solution to meeting growing energy demand, the economic cost and environmental impact (e.g. resultant emissions) of adopting this approach would be tremendous.

### 1.8.4. INCREASING THE EFFICIENCY OF THE BUILDING STOCK

The buildings sector in Egypt is responsible for 26% of the total overall energy consumption. However, the sector accounts for 60% of the total electricity consumption and around 70% of resultant $CO_2$ emissions in 2006. Due to Egypt's growing population, its high rate of rural electrification, its increasing use of electrical appliances, and its urban "heat island effect", the residential sector has become the main consumer of electricity in the country. Statistics show that the electricity consumption of building appliances in residential, public, and government buildings accounts for approximately 50% of total electricity consumption.

The most effective approach to improving energy efficiency in the building sector is reducing buildings' energy demand through the improvement of fabric efficiency (e.g. using insulation) which can achieve a 40% reduction, and the installation of efficient equipment, appliances and lighting, which can achieve a 30% and 10% reduction respectively.

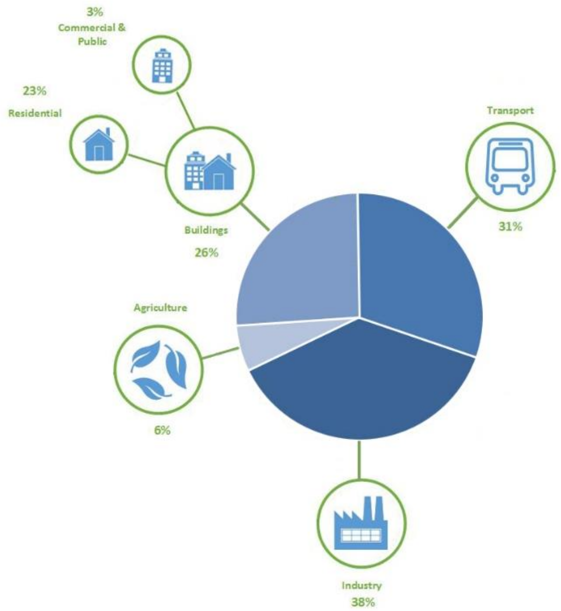



**Fig. 1.10** Energy consumption distributior

An economic analysis of energy efficient strategies in buildings suggests that the introduction of efficient lighting was both easy to roll out, economically attractive, and had a short payback period (i.e. are usually profitable for the end user). Energy efficient appliances had a much longer payback period compared to other countries due to the highly subsidized electricity tariffs. Thermal retrofitting of existing buildings and the construction of new efficient buildings were unprofitable for the end user and are unlikely to develop on the basis of spontaneous market mechanisms due to the high initial investment cost of energy efficiency measures, compared to the financial capacity of the consumer.

To encourage the uptake of these measures it is important that a wide scale national program is developed and implemented. While some efforts have been made to promote and increase the energy efficiency of buildings through regional projects, programs and initiatives, this has been hampered by limited coordination of efforts and accumulation of gained experience. In addition, such factors as the lack of adequate enforcement of building codes and appliance energy labelling program requirements hinder successful implementation.

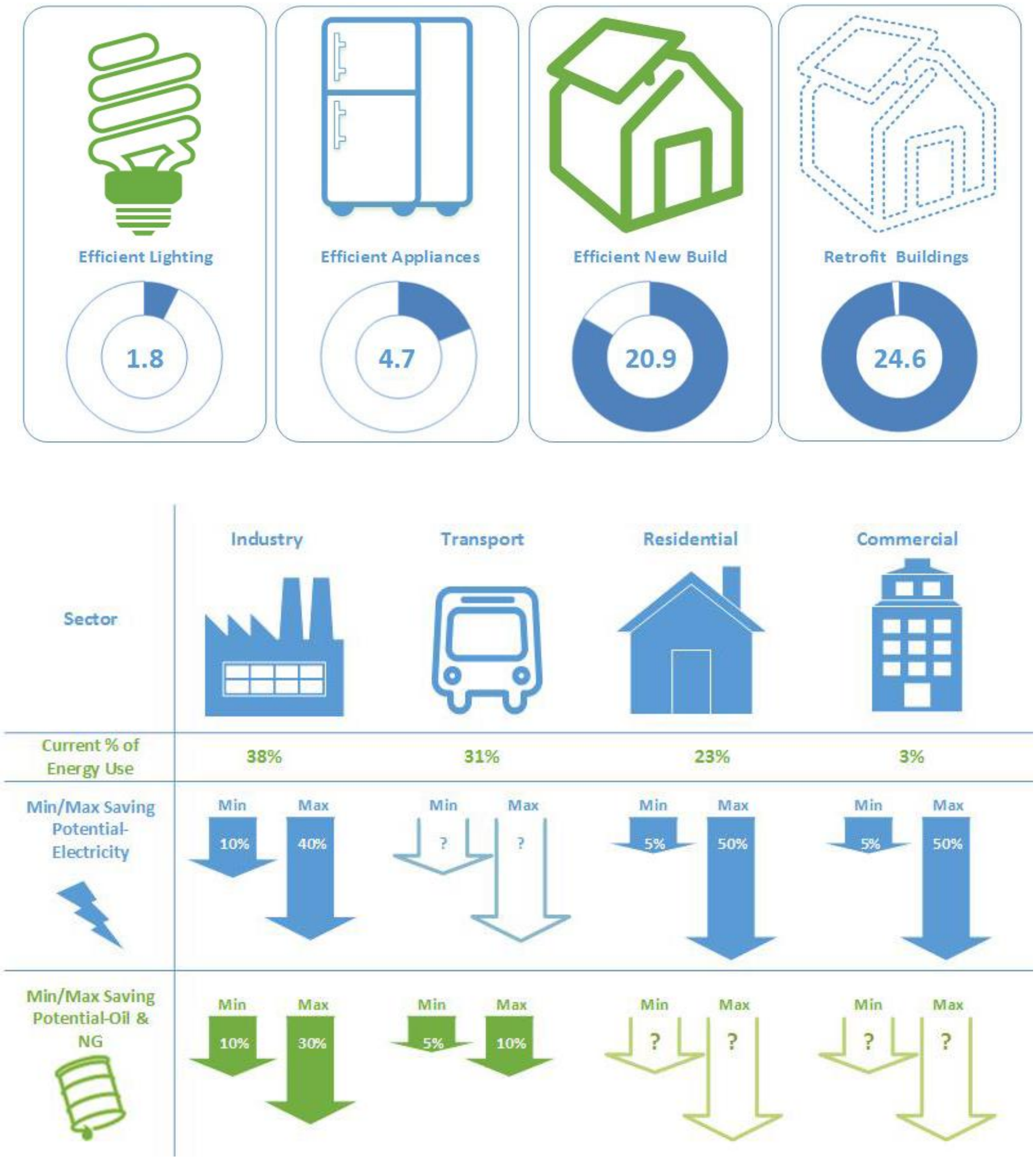



**Fig. 1.11** Energy use in different building sectors

The current situation of public buildings in Cairo and its relation with sustainability:
By studying the current situation of public buildings in Cairo there's an indication of the absence of some sustainability aspects, as follows:

| | sustainable elements | The headquarters of the Bank for Development and Agricultural Credit (xiv)  | Children's Cancer Hospital 57357 (xv)  |
|---|---|---|---|
| Systems | Presence of Intelligent systems | Doesn't exist | exist |
| Water | Water management reduction & recycling | Doesn't exist | Using waste and water management systems |
| Outer environment | Minimizing negative impact on the surrounding environment | Don't do that | exist |
| Energy | Integration of intelligent systems to reduce energy consumption | Doesn't exist | exist |
| | Building Energy Management System (BEMS) | Doesn't exist | exist |
| | Efficient use of energy | Doesn't exist | exist |
| | Installing geothermal heating & cooling systems | Doesn't exist | Doesn't exist |
| | Double skin facades | double glazing | Doesn't exist |
| | Automated louvers | Doesn't exist | Doesn't exist |
| | Facades sensors to response to outer environment | Doesn't exist | Doesn't exist |
| | Controlling natural & artificial lighting | Doesn't exist | natural day lighting by using glazing facades |
| | Automatic daylight control | Doesn't exist | Doesn't exist |
| | Integration of lighting control systems through (BMS) | Doesn't exist | Doesn't exist |
| | Energy-saving lamps and Led lighting | Using compact fluorescent lamps | Using compact fluorescent lamps |
| | Installing energy-efficient ventilation systems | Doesn't exist | Doesn't exist |
| | Innovated design to reduce energy | Doesn't exist | Doesn't exist |
| | Encouragement natural ventilation systems | Doesn't exist | Doesn't exist |
| | Responsiveness to the environmental changes | Doesn't exist | Doesn't exist |
| Renewable energy | Installing renewable energy tools like photovoltaic panels (BIPV), wind turbines, and solar heaters. | Doesn't exist | Doesn't exist |
| Materials | smart materials | Doesn't exist | Doesn't exist |
| | The use of environment -friendly material | Doesn't exist | Few exist in facades and flooring |
| Recycling | Recycling materials | Doesn't exist | Sandstone |
| Indoor quality | Indoor air quality systems | HVAC systems | HVAC systems & Air purification system |
| | Indoor thermal quality systems | exist | exist |
| | Indoor acoustic quality systems | Doesn't exist | Few exist |
| pollution | Reduction pollution&Co2 emission | Doesn't exist | Few exist |
| Architectural treatments | Compatibility with climate &usage of treatments to deal with climate | Few exist | Medium exist |

**Fig. 1.12** Table shows the current situation of public buildings in Cairo and its relation with sustainability

The best practice examples in Egypt:
HSBC bank Egypt Global Service Center, is one of the best practice examples in Egypt, it has the first golden LEED certificate project in Egypt.

| **HSBC Bank Egypt Global Service Centre:** |  *Figure (5) shows HSBC Bank Egypt Global Service Centre.* |
|---|---|
| Location | Giza, Egypt's Smart Village. |
| Gross square feet | 210,000 sq ft. |
| Space Type Use | Offices (17% of activities) . |
| Description of the building | - A four storey building Ground floor and three typical floors (3000 sq ms each) and two underground parking floors (4500 sq ms each).<br>- The 3000 sq.m semicircular plan responds to an important corner plot in Smart Village with a sweeping fully glazed north facade and a mostly solid south service and gateway facade. An offset Atrium brings daylight from clerestory windows to the deep zones and break out areas. |
| Gold rating is the result of a range of green features including | -Energy consumption cost saving by 9%.<br>-Chilled water consumption cost saving by 39%.<br>-Domestic water consumption cost saving by 47%.<br>-84% of construction waste diverted from landfill. (xvii) |
| Water efficiency | - 50% reduction in potable landscape water use.<br>- 20% reduction in baseline indoor water use. |
| Energy and Atmosphere | - 28% improvement on baseline building performance rating.<br>- The building uses smart technologies to help monitor and control energy use throughout the building. Meters will record electrical use and a centralized control system will determine usage trends and help building managers increase the efficiency of the building systems. |
| Indoor environmental quality | 90% of occupied space has quality views. |
| Dust control | The building used an erosion and sedimentation control plan to improve dust control. Airborne dust was kept to a minimum by keeping sand piles covered and moistened with non-potable water. |

**Fig. 1.13** Table shows the best practice example in Egypt for sustainability

## 1.9. RENEWABLE ENRGY IN EGYPT

Securing energy resources to meet the national demand both on the short and long terms, are considered vital elements for sustainable development. Securing such energy resources can be achieved through the diversification of generation capacity and the creation of a well-balanced energy system comprising various power generation technologies with suitable capacity. This enables the advantages of each to be maximized, allows prices to remain reasonably stable, and ensures the sustainability of supply. While Egypt depends on oil and natural gas to meet the increasing demand on primary energy, renewable energy represents an important option for changing its energy mix.

- **hydropower**

  Renewable energy (mainly hydropower) currently accounts for a fraction (approximately 10%) of Egypt's electricity generation. Under existing plans, Egypt hopes to produce up to 20 % of its electricity from renewable energy by 2020 while also developing a nuclear power program.

  However, since the capacity for additional hydropower is limited due to the development of all major sites, it is important to diversify generation through the increased incorporation of other renewable resources such as wind and solar which have been identified as having the most significant potential at national scale.

- **Wind Energy**

  In 2006-2007 the installed wind power in Egypt represented a mere 1.1 % of the total installed capacity and generated only 0.3 % of total electrical energy. However future plans supported by such programs as the World Bank Clean Technology Fund aim to increase this to approximately 12% by 2020 through increased installations in key regions such as the Suez Gulf, 7 Beni Suef ,Menia. and El-Kharga Oasis.

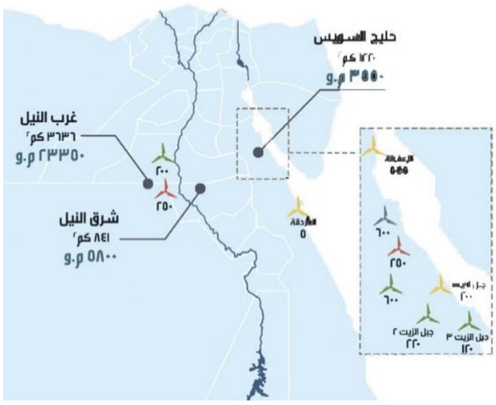



**Fig. 1.14** Wind energy fields in Egypt

  Egypt enjoys excellent wind along the Suez Gulf with an average wind speed of 10.5 m/sec, and Egypt is just one of 38 countries in the world with a published National Wind Atlas.

  Since 2001, a series of large-scale wind farms have been established, with total capacity of 550 MW, in cooperation with Germany (KFW), Denmark (DANIDA), Spain, and Japan (JICA). Implementation of the Spanish project in Jebel El Ziet took place in 2013 which clarifies the huge increase in Egypt imports for renewables that year, which were mainly wind generators imported from Spain.

  In 2014 the implementation of a JICA wind project started with expectations to raise imports by USD 200 million. Another 540 MW project is under construction at Gulf of Suez, a 580 MW project is in financing also at the Gulf of Suez and a feasibility study is under way for a 200 MW project at West Nile. Recently, the GOE allocated an area of about 7,845 square kilometers in the Gulf of Suez region and the Nile Banks for NREA to implement additional wind energy projects.

- **SOLAR ENERGY**

  Egypt's Solar Atlas states that Egypt is considered a "sun belt" country with 2,000 to 3,000 kWh/m²/year of direct solar radiation. The sun shines 9-11 hours a day from North to South in Egypt, with few cloudy days.

  The first Solar Thermal Power Plant at Kuraymat was built in 2011. It has a total installed capacity of 140 MW, with solar share of 20 MW based on parabolic-trough technology integrated with a combined-cycle power plant using natural gas. The power plant is financed from the Global Environmental Facility (GEF) and the Japan Bank for International Development. A 10 MW power plant has been operating in Siwa since March 2015, and the remaining plants are expected to be implemented and operated consequentially in 2016. Egypt is also considering financing options to conduct feasibility studies for the following projects: Solar-thermal power plant using CSP technology for both electricity generation and water desalination. Solar-thermal power plant for industrial purposes. Designing a technical-financial mechanism to promote the use of solar water heaters in Egypt's residential sector. Local manufacturing of renewable energy equipment.

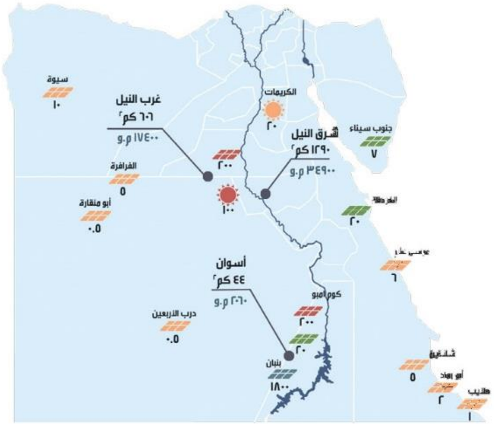



**Fig. 1.15** Solar energy fields in Egypt

# 2. ANALYSIS PHASE

2.1. OVERVIEW OF 6$^{TH}$ OF OCTOBER CITY
2.2. URBAN LAYERS
2.3. SWOT ANALYSIS

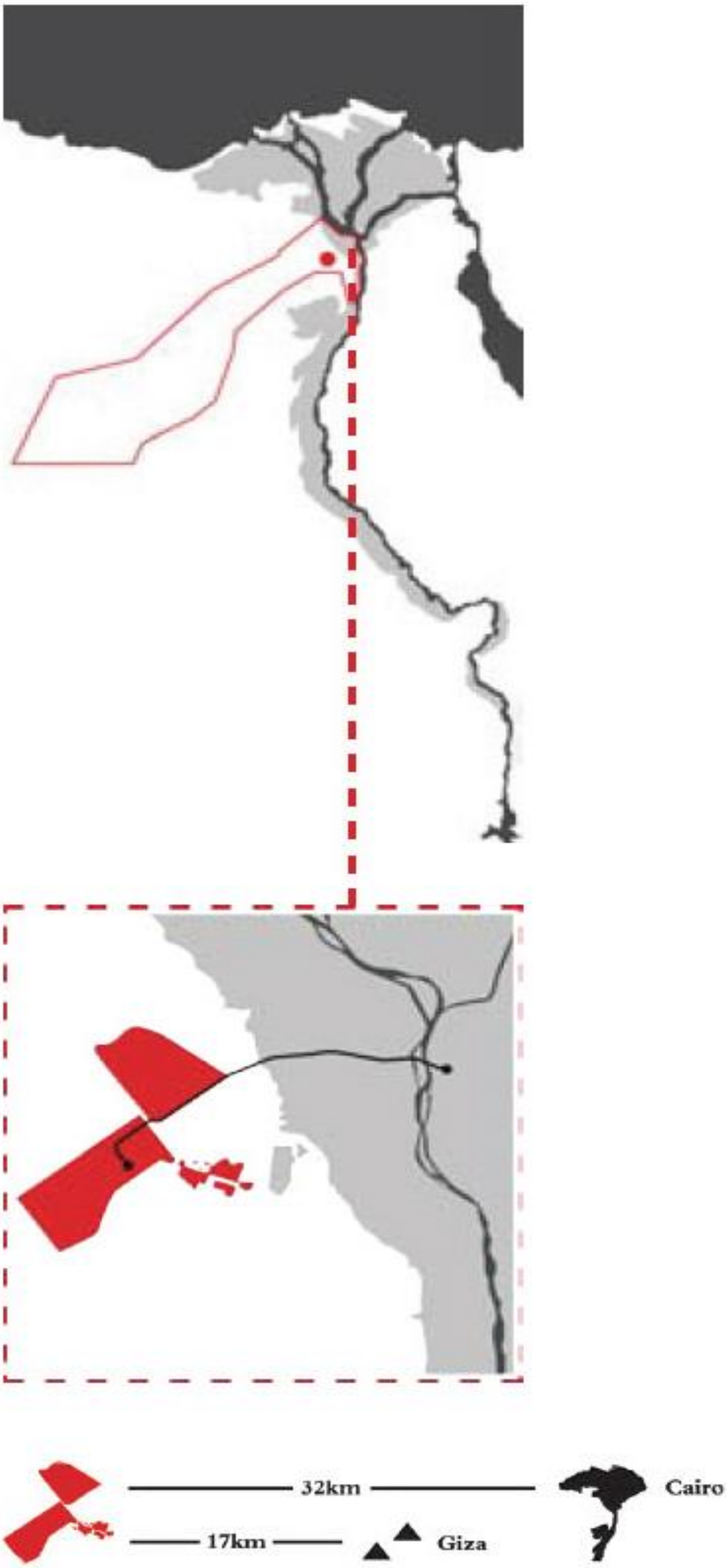



**Fig. 2.1** Distance between 6th of October city and Giza and Cairo

## 2.1. OVERVIEW OF 6TH OF OCTOBER CITY

6th of October is a city in Giza Governorate, a satellite town and part of the urban area of Cairo, Egypt, 32 km (20 miles) outside the city. It has a population ranging between some 185,000 in the city to an estimated 500,000 inhabitants in the wider area. 6th of October is a new city in the desert.
The settlement was established in 1979 by the 504th presidential decree of Egyptian president Anwar El Sadat. It is 17 km from the great pyramids of Giza and 32 km from downtown Cairo. The city has a total area of 119.2 thousand acres and, eventually, is expected to have 6 million inhabitants, although there are many unoccupied or incomplete buildings.
It was announced as the capital of the 6th of October Governorate in April 2008. Following the governorate's dissolution in April 2011, in the wake of the Egyptian revolution, it was reincorporated into the Giza Governorate, to which it had originally belonged.
The city's name commemorates the commencement of the October War on 6 October 1973, the same date chosen as Egypt's Armed Forces Day. It has one of the largest industrial zones in Egypt on which the entire city is established. The industrial zone provides jobs for employees within the city as well as from other parts of Giza. It is accompanied by a banking sector that groups branch of all banks in Egypt in an area that is close to the industrial area to serve the needs of the industry and residents.

### 2.1.1. URBAN DEVELOPMENT OF 6TH OF OCTOBER CITY

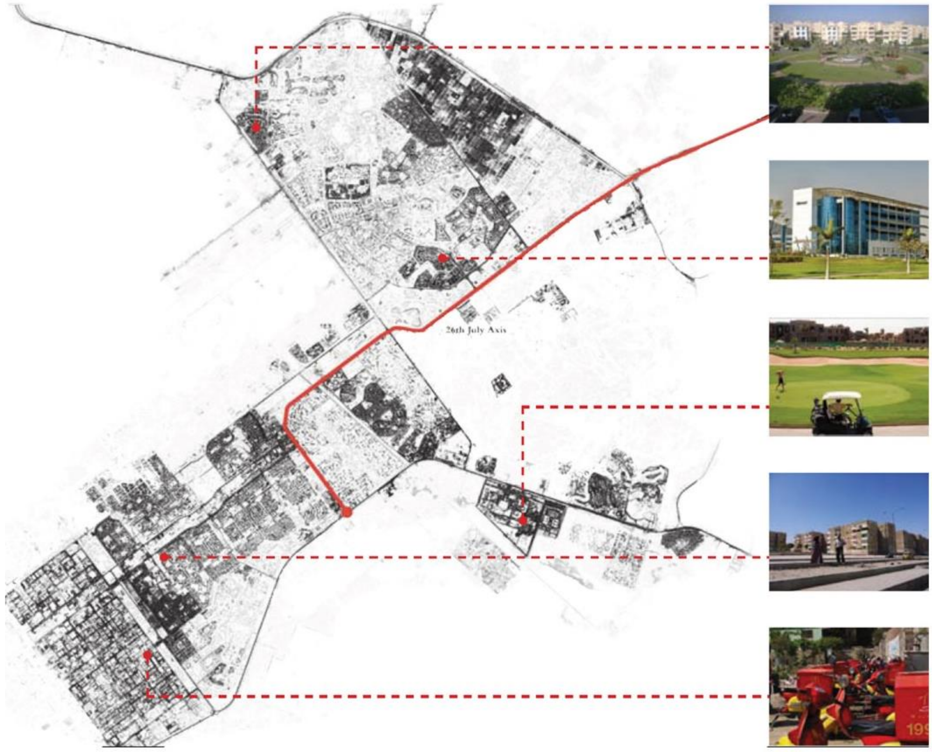



**Fig. 2.2** Morphology of 6th of October city and different building typologies

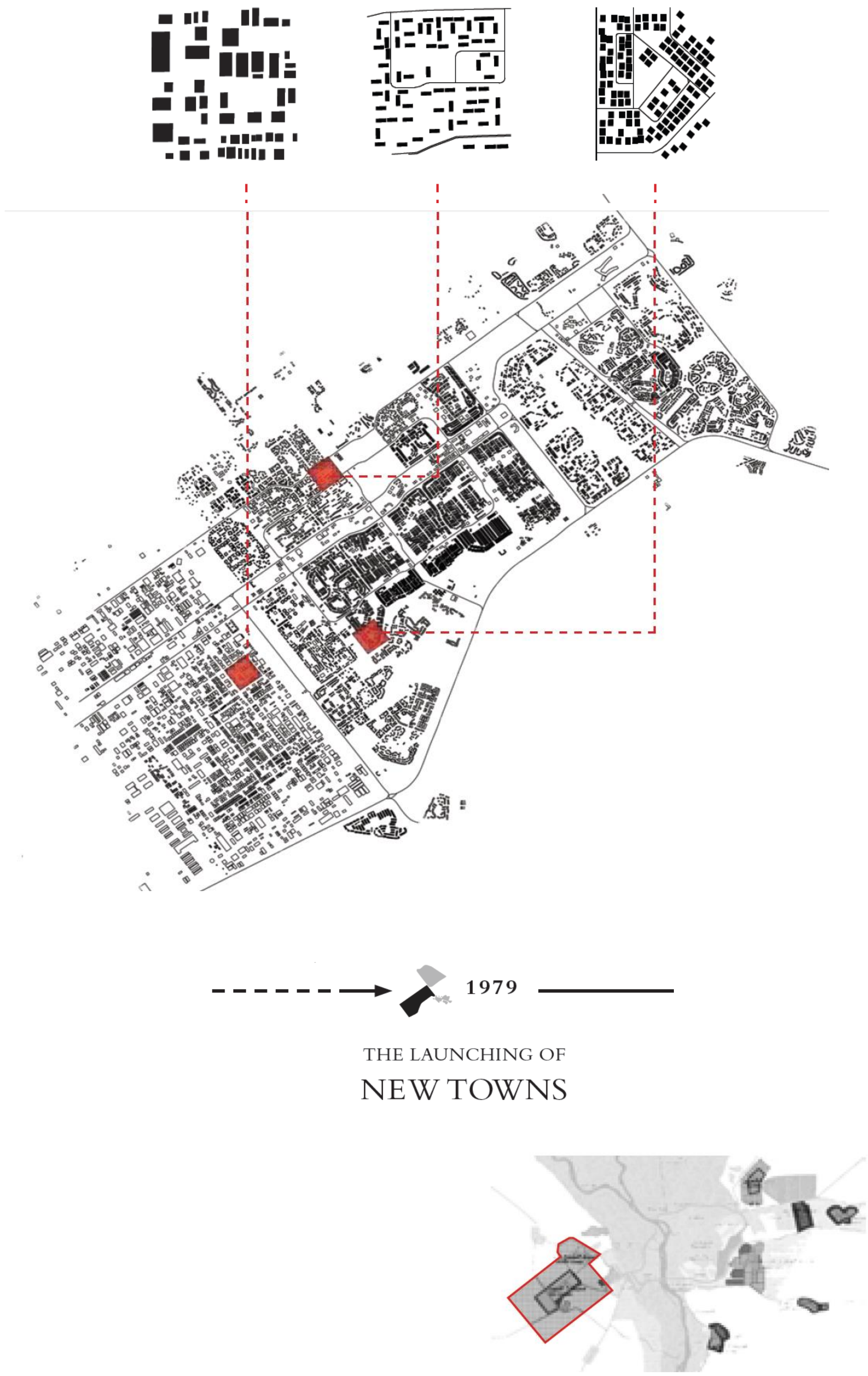
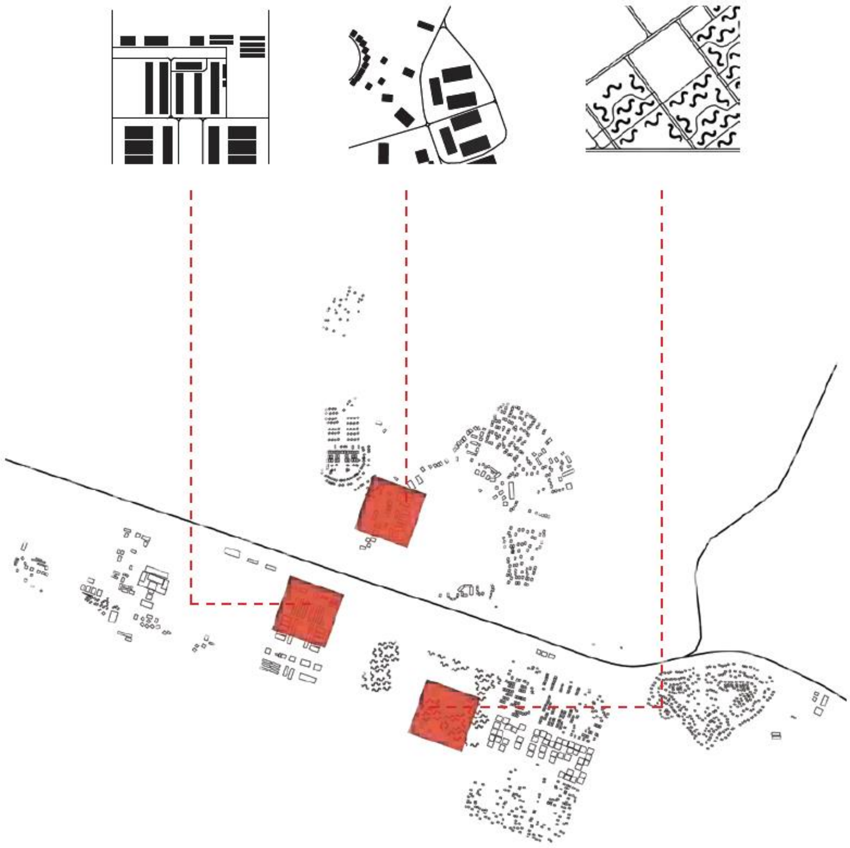



**Fig. 2.3** Morphology of 6th of October city in 1979



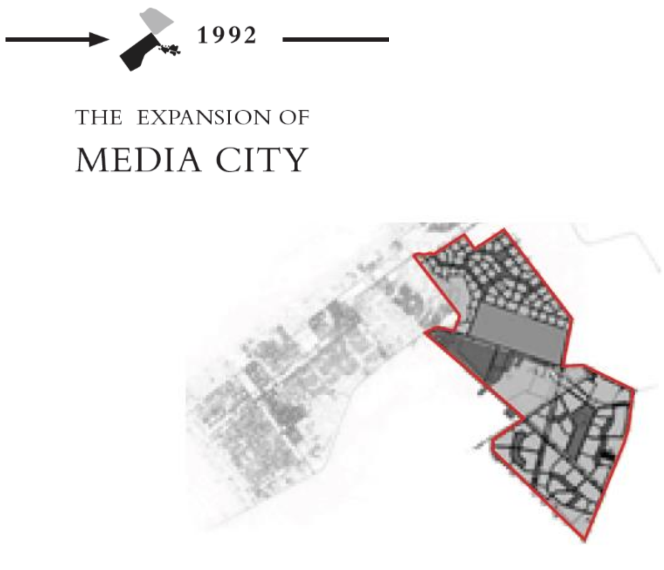



**Fig. 2.4** City expansion in 1992

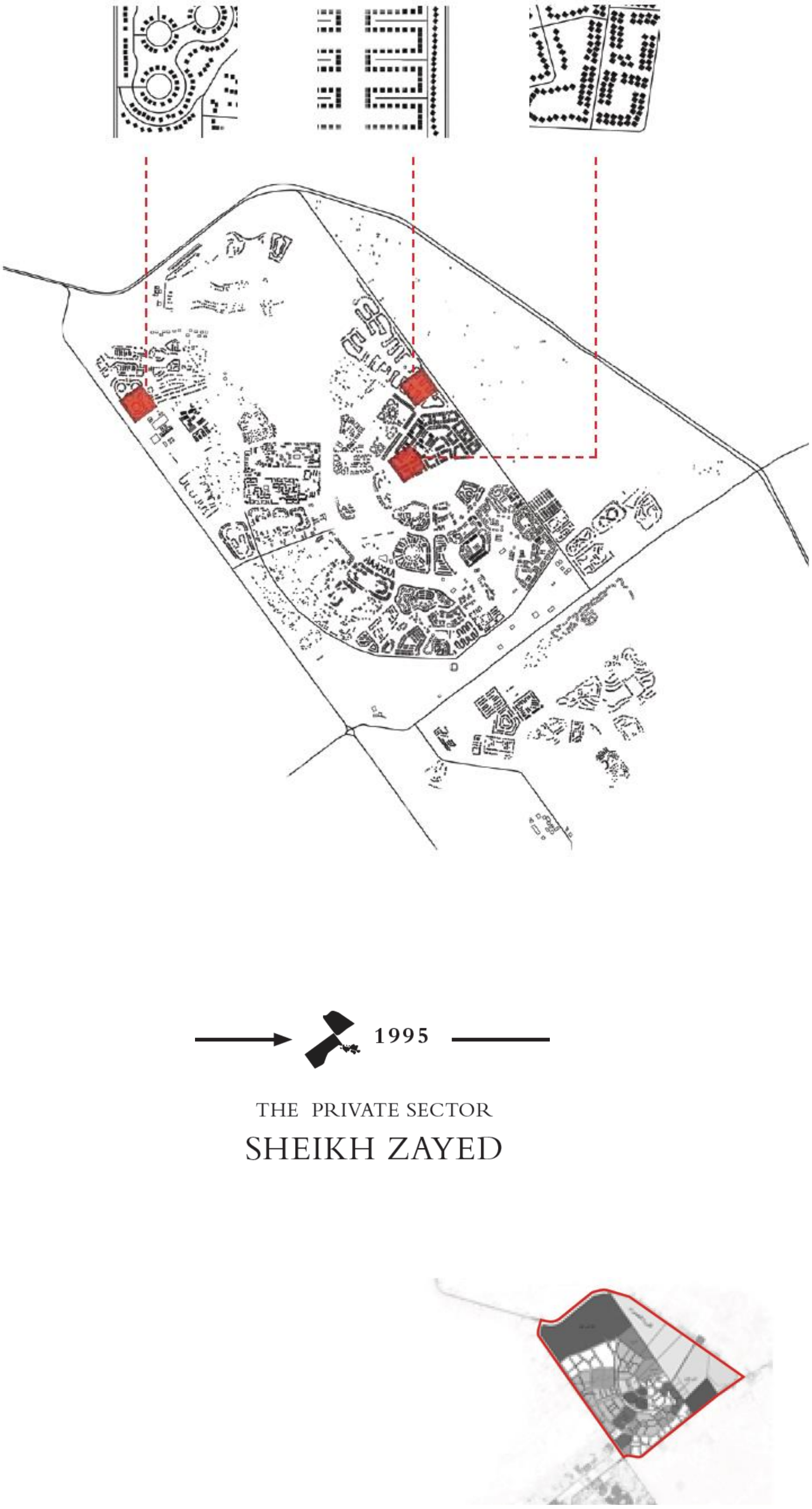



**Fig. 2.5** Expansion of 6th of October city in 1995

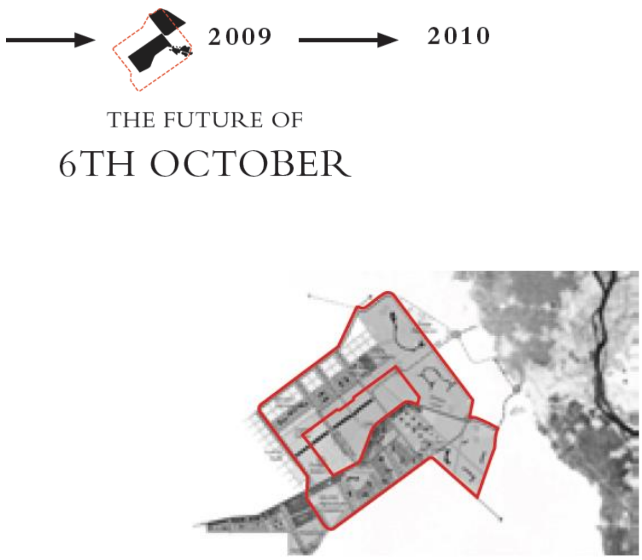



**Fig. 2.6** Expansion of 6th of October city in 2009


**Fig. 2.7** Undeveloped areas in 6th of October city


**Fig. 2.8** Gated communities in 6th of October city

### 2.1.2. UNFULFILLED PROMISE AND CONTINUED CRITICISMS

Despite the tremendous scale of investments, both public and private, plus the city's huge governmental land resource and strategic location within Greater Cairo, 6th of October has refused to meet its promise. This section provides the analysis and critical opinions toward new town policy and practice in one of the largest new towns, in order to investigate its development issues and obstacles. The following paragraphs summarize the main weaknesses.

- **No logical sequencing of development**
  Lands in the original core of 6th of October were all rapidly allocated in the 1980s. There was no attempt to stage the development. In the same way, "Build-out proved very slow and irregular, and in instead of trying to densify and restructure the core areas, in the early 1990s vast new areas were begun to be deigned" (in particular the "tourist zone" directly east of the core city with an area of 1400 hectares) which were parceled for individual plots and for tourism projects (mostly residential compounds)". Lands in these areas were allocated in a wholesale fashion without any staging and this has resulted in a more irregular development with the odd successful project intermixed with massive empty spaces and stalled subdivisions. In this context, it was argued that to develop any city, even a new one, it is essential to be developed progressively out from its core. As development occurs, immediate fringe sites gain in value and, if well planned, a rolling program of radiating land marketing will both maximize financial returns and promote dense and logical development. Such a logic has, unfortunately, been totally lacking in strategies to develop 6th of October.
- **Wasteful land allocations which remain dormant**
  6th of October, like all new towns, is characterized by empty lots, stalled construction, huge empty concessions, and skeletal subdivisions. Thousands and thousands of hectares of land in 6th of October have been allocated for projects and sold to individuals and investors. In the early years, land prices were purely nominal, although recently land prices have been set to recover (at least partially) infrastructure costs are sold through closed-envelope auctions.
  In parallel, large parcels in 6th of October have been (and continue to be) allocated at no cost for government and public sector uses. Most of these lands have been used for the construction of public housing estates. Once built, these neighborhoods at least give the appearance of being fully developed, but vacancies are very high.
- **Extremely poor take-up on individual plot subdivisions**
  Large blocks of Sixth of October have been designed as residential subdivisions with individual plots in the 300–500 m2 range for multi-story structures and large land for open spaces and public services. These were and continue to be distributed under an application system where plots are allocated by lots if demand exceeds supply. In the same way, the different types of residential land development, these subdivisions have proven to be the most disappointing, at least in build-out and occupancy terms".
  Even the earlier subdivisions, which date back more than 25 years, are still sparsely settled, and the more recent ones are largely an assembly of empty lots.

Districts Two, Three, and Four

Total area: 580 hectares
Started: 1985
35% built on and completed (but occupancy low)
35% under construction or stalled
30% remain empty
Date: June 2012

District One

Total area: 182 hectares
Started: 1990
20% built on and completed (but occupancy practically nil)
30% under construction or stalled
50% remain empty
Date: June 2012

Tourist Area

Total area: 576 hectares
Started: 1995
10% built on and completed (but occupancy practically nil)
15% of plots under construction
75% remain empty
Date: June 2012

**Fig. 2.9** 6th of October city morphology in 2012

- **Lacking public transport and poor accessibility**

  Poor public transport services have for years been identified as one of the obstacles to the development of 6th of October. At some 35 km from central Cairo, rapid and affordable public transport is needed for the city to become fully linked to the metropolitan area. Although the 26th July Street Extension was built in 1999 specifically to improve the 6th of October's road links to Cairo, and even though private minibuses now serve the city on a regular basis, inter-city public transit remains a problem. Better means of public transport within and around Sixth of October is needed. Even if transport services to the city are vastly improved, it remains problematic how passengers are to reach their ultimate destinations. The problem is one of distance, as the following illustrate:

  - The distance between the present boundaries of 6th of October measures 20km in an east–west direction and 23 km in a north–south direction.
  - The commercial spine of the core city is itself 7 km in length.
  - From the eastern part of the tourist area to the beginning of the commercial spine is 5 km in length.
  - From recent public housing to the commercial spine varies from 2 to 5 km in distance.
  - From the furthest factory location in the industrial area to the nearest point on the central spine is 6 km.

  Such huge distances within 6th of October would not be problematic if everyone could rely on the private car. Certainly, those who live in the residential compounds will own vehicles, but the same cannot be assumed for those of more modest incomes.

## 2.2. URBAN LAYERS

### 2.2.1 URBAN CONTEXT OF THE PROJECT

The selected site is located in Giza governate within the boundaries of the 6th of October city approximately 38km from Cairo. The 6th of October city was founded as a result of president Sadat's open-door policy post 1973, to create new centers for human settlement and economic activity outside of the existing urban center. The 6th of October city is established within the greater Cairo master plan.

It can be accessed from several routes; Cairo- Alexandria desert road, ring road, Al fayom- Al wahat road. Using the 26th of July axis, it takes 20 minutes from Al mohandeseen neighborhood to reach the SC site. Organized public transportation does not yet reliably connect the city with the greater Cairo region, people depend on private cars, corporate private buses, and commercial private sector mini-buses. Although somewhat hazardous, these mini-buses are the most efficient means of communal transportation for the moment.

To the northeast, adjacent to the site, is a new compound under the construction named High Land. To the northwest is vacant land planned to house another residential compound. To the southwest, across an internal road, is as electric power plant facing the site. Between the Al wahat-Al fayom road and the internal road is vacant land planned to be a buffer zone servicing the highway.

The city consists of 12 neighborhoods hosting different housing categories and elite residential compounds, several universities (e.g. Modern science and Art University, the 6th of October university, Misr university for science and technology and Ahram Canadian university), high institutes, the media and production city, dream land recreational park hotels and restaurants, supermarkets and mega stores, among a growing number of projects aimed at enhancing the lifestyle of Cairo residents. In addition, its industrial area is becoming one of the most important industrial zones in Egypt.

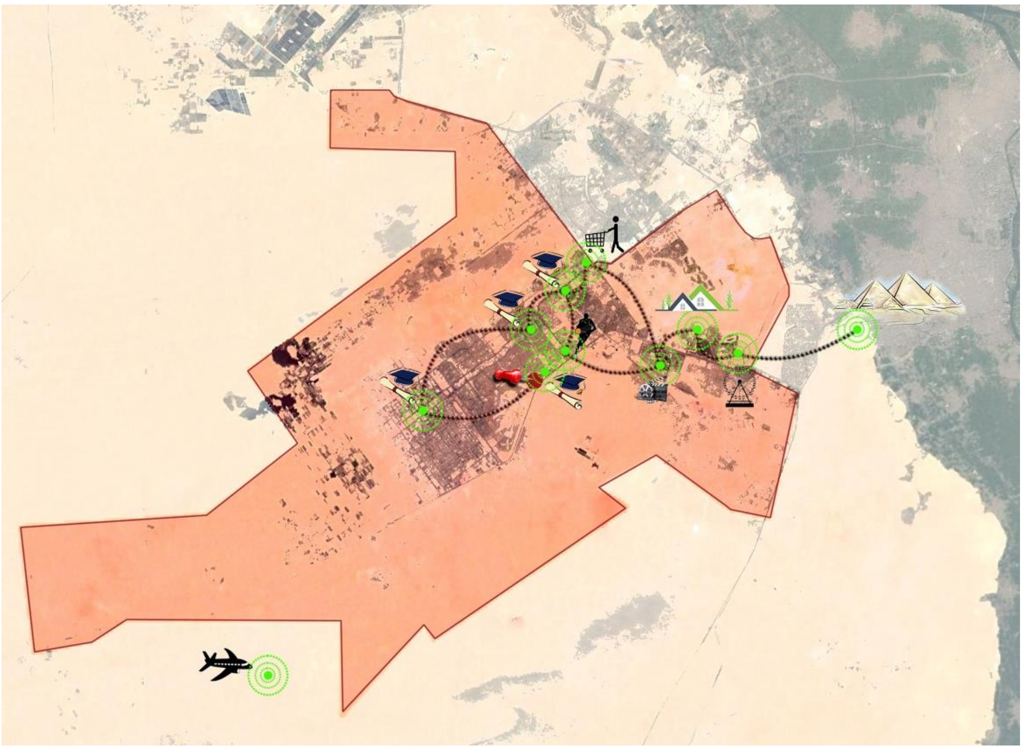


**Fig. 2.10** Important spots around the project's location

### 2.2.2. CURRENT MORPHOLOGY

The negative effects of speed development seen through the particular urbanization of 6th of October city. As the current plan resulted from a lot of development that reflects different periods in decision making and influenced by the desired goals of each period, which results in more fragmented ways of life and segregation. The newly built projects fail to create a proper environment related to articulation. However, articulation means adaptation to consuming patterns, which are strategically determined and controlled by the authorities.

As shown in the current plan of the city. There is a non-homogenous pattern mixed between different urban typologies. Areas with high dense buildings of 5-6 floors and very narrow corridors in between. A medium dense area with buildings of 3-4 floors and proper street width. The last study area is a mixture between scattered residential buildings of 1-2 floors and huge factories with irregular distribution of streets and corridors.

A higher urban building density and relatively low porosity level, seem to offer a plausible explanation for its higher air pollution level, despite the low vehicle density and relatively better climatic conditions. However, the high air pollutant concentration in few areas thus should be explained by some other factor than porosity/building density, like if the area is open or semi open or close. Mixed patterns fig. 2.12 in findings of this study demand further investigation.

The mean building height of an urban fabric would create a high building canopy this could have impacted on higher mixing height of airflow. As the vertical plane created by building height together with narrower street widths could create more vortices and thus decrease airflow within an urban street canyon. In addition, threshold in relationship between mean building height and street level air pollution is also important finding.

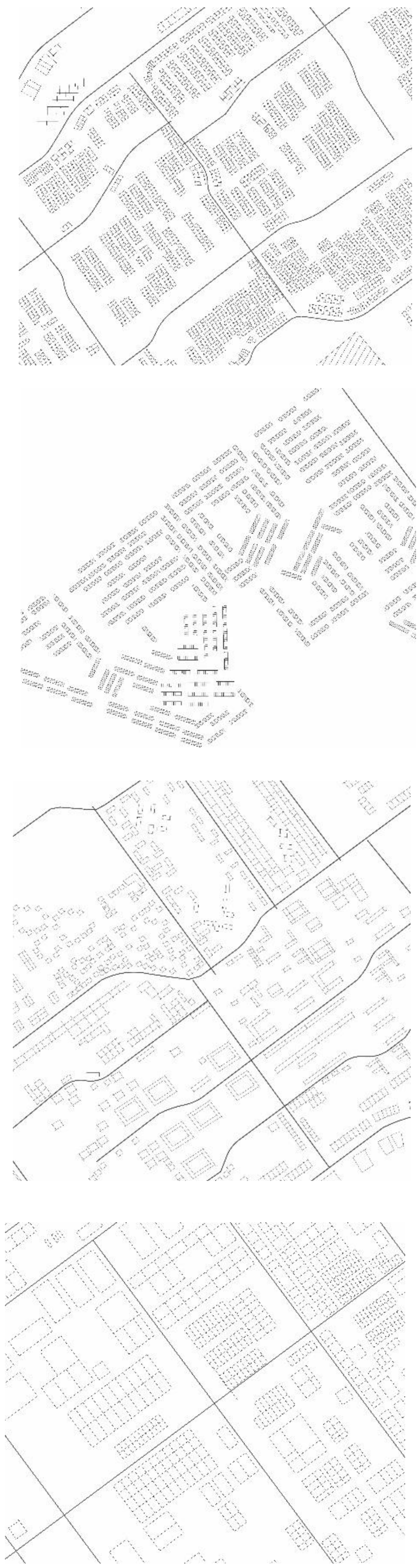


**Fig. 2.11** Different urban texture

**Fig. 2.12** Current morphology of 6th of October city


Gamma Internationa

### 2.2.3. FUNCTIONS

It is divided into three areas, an industrial area, governmental apartment buildings, and finally private villas and apartment blocks. The residential area is around 22.3 thousand acres and is divided into three districts, low/medium priced housing, above medium-priced housing, and luxury priced housing. Each residential district consists of around nine neighborhoods, which are expected to have a population between 5,000 to 10,000 inhabitants. The new residential districts are designed as self-contained cities within the city integrating all needed services. In addition to small mosques within each neighborhood there will be the possibility to build cultural and religious institutions along main roads and at their junctions.

The industrial area has many mechanic shops that deal with electricity and cars. 6th of October's industrial sector has a total area of 8,000 acres. It also has a number of companies and factories that work in/produce/manufacture plastics, paper, weaving, metals and machines, chemical and pharmaceutical, and building materials.

The number of schools, universities, and companies is increasing in the City. However, social services, such as schools, will be integrated within residential districts. Schools are distributed in each neighborhood according to current standards of catchment areas and radii. There are also a number of malls which include Dandy Mall, Hyper1, Diamond Mall, and ZamZam Mall. The main commercial centers will focus on junctions of the main roads, where it is furthermore planned to integrate leisure areas, such as pocket parks. There are also several functioning public and private hospitals.


**Fig. 2.13** Different functions in 6th of October city

### 2.2.4. GREEN AREAS

Most areas are extensive landscape areas fig. 2.14, which means desert-like vegetation and reduced investments into maintenance, certain areas are developed as intensive landscape areas with continuous cultivation. These intensive landscape areas fig. 2.16 include leisure facilities, such as sports clubs, or agricultural uses. Thus, public as well as private sports clubs of larger scale are located at certain junctions of the extensive green corridors serving adjacent city districts.

**Fig. 2.14** Extensive landscape

There is a green belt divided into five major parts, adjacent to main and subsidiary roads where public utilities like water, electricity and irrigation facilities were provided to encourage land buyers to transform desert land into green areas. According to the green belt's construction code, buildings were supposed to account for only three per cent of the total area and each acre (4200 meters) was to have a residence no bigger than l20 square meters. But the green areas are so small compared to the built ones. Although, landscape is well designed in the private sectors of hospitals, universities, clubs and residential compounds of 6th of October city.

**Fig. 2.15** Urban landscape

**Fig. 2.16** Intensive landscape

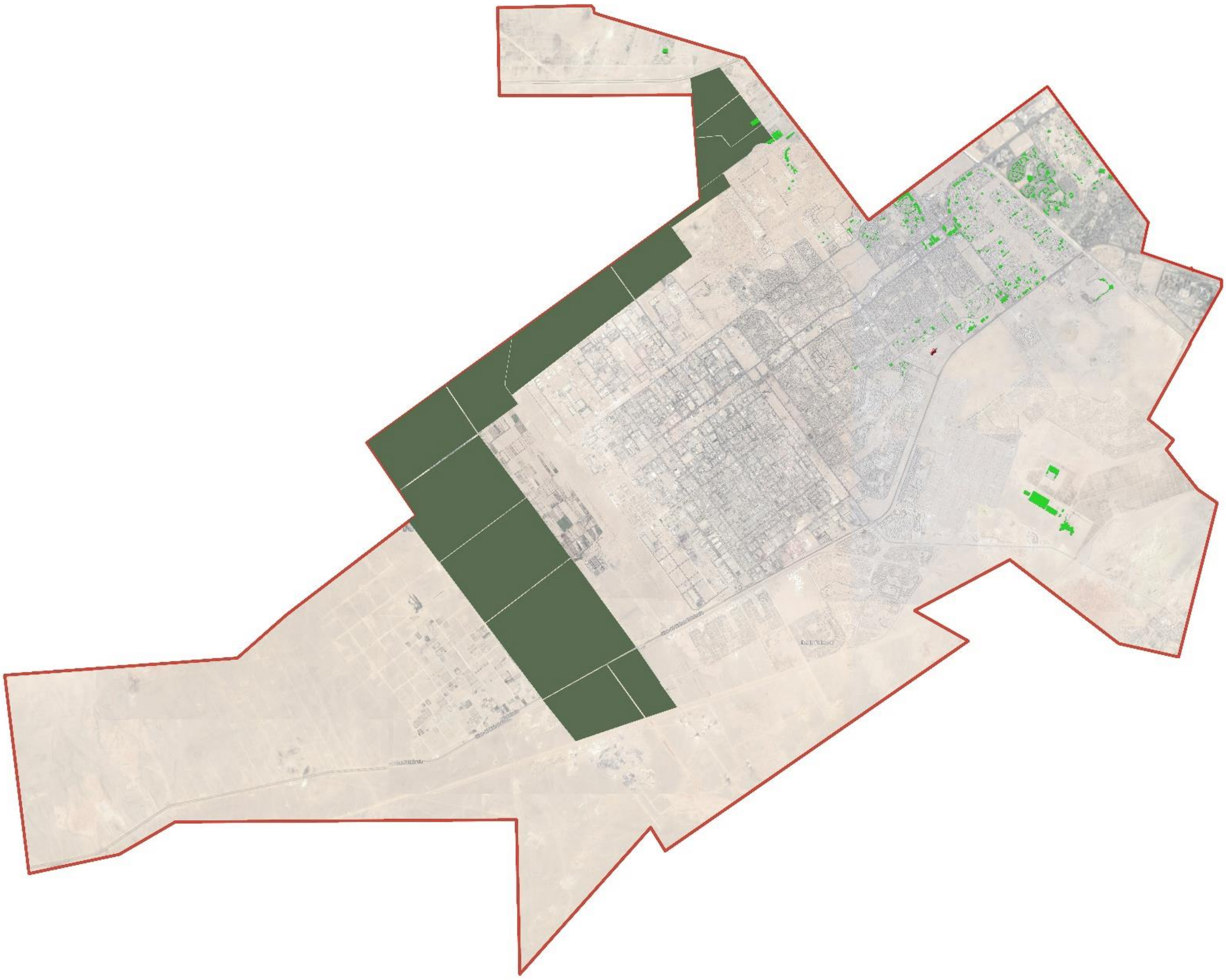


**Fig. 2.17** Green areas distribution

### 2.2.5. TRANSPORTATION AND MOBILITY NETWORK

Roads and communication:

- Length of finished networks 1146.5 km
- 13 bridges are under constructions
- Length of finished communication networks 2040 km
- Length of under construction road networks 1787 km
- Length of under construction communication networks 10 km

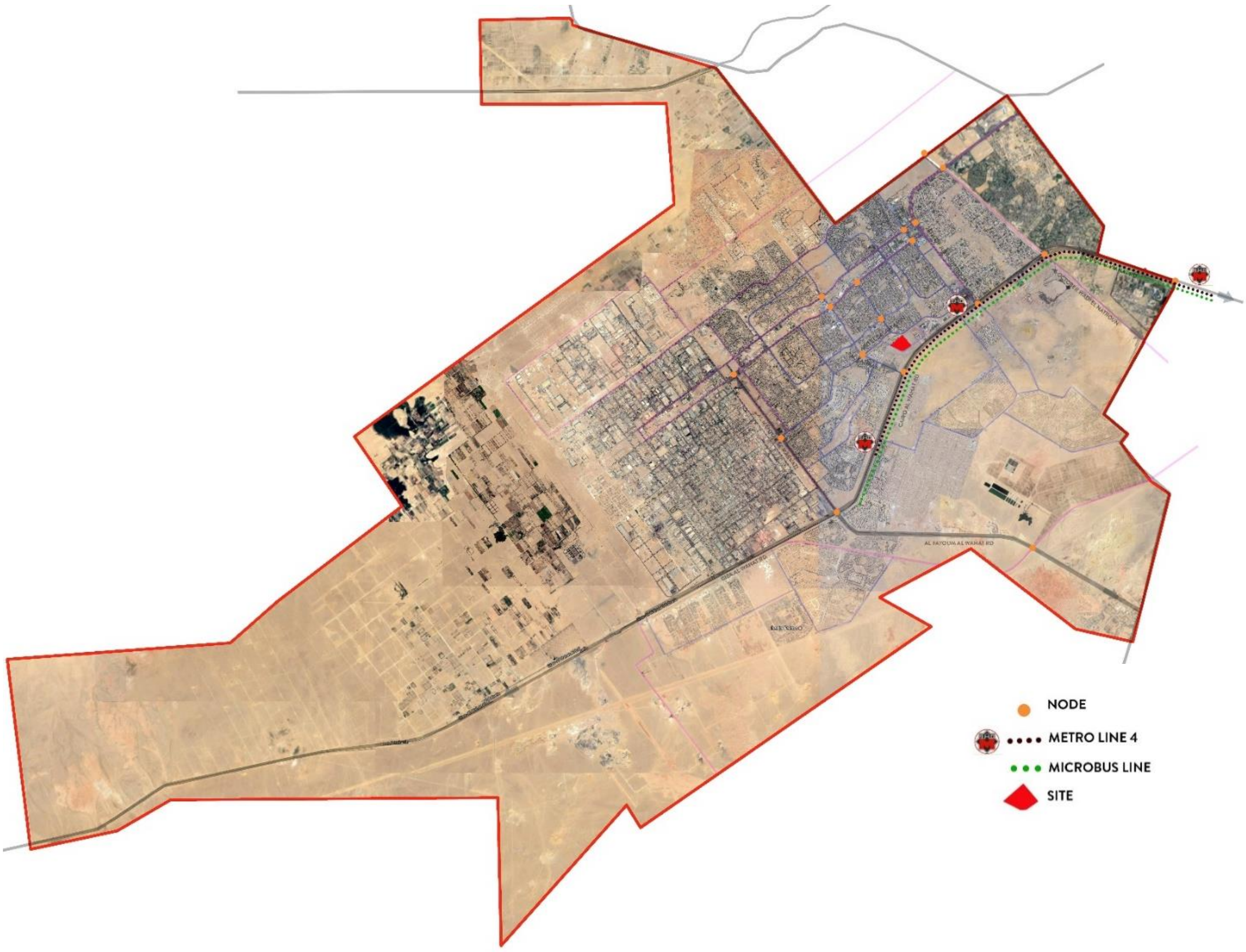



**Fig. 2.18** Transportation and mobility map

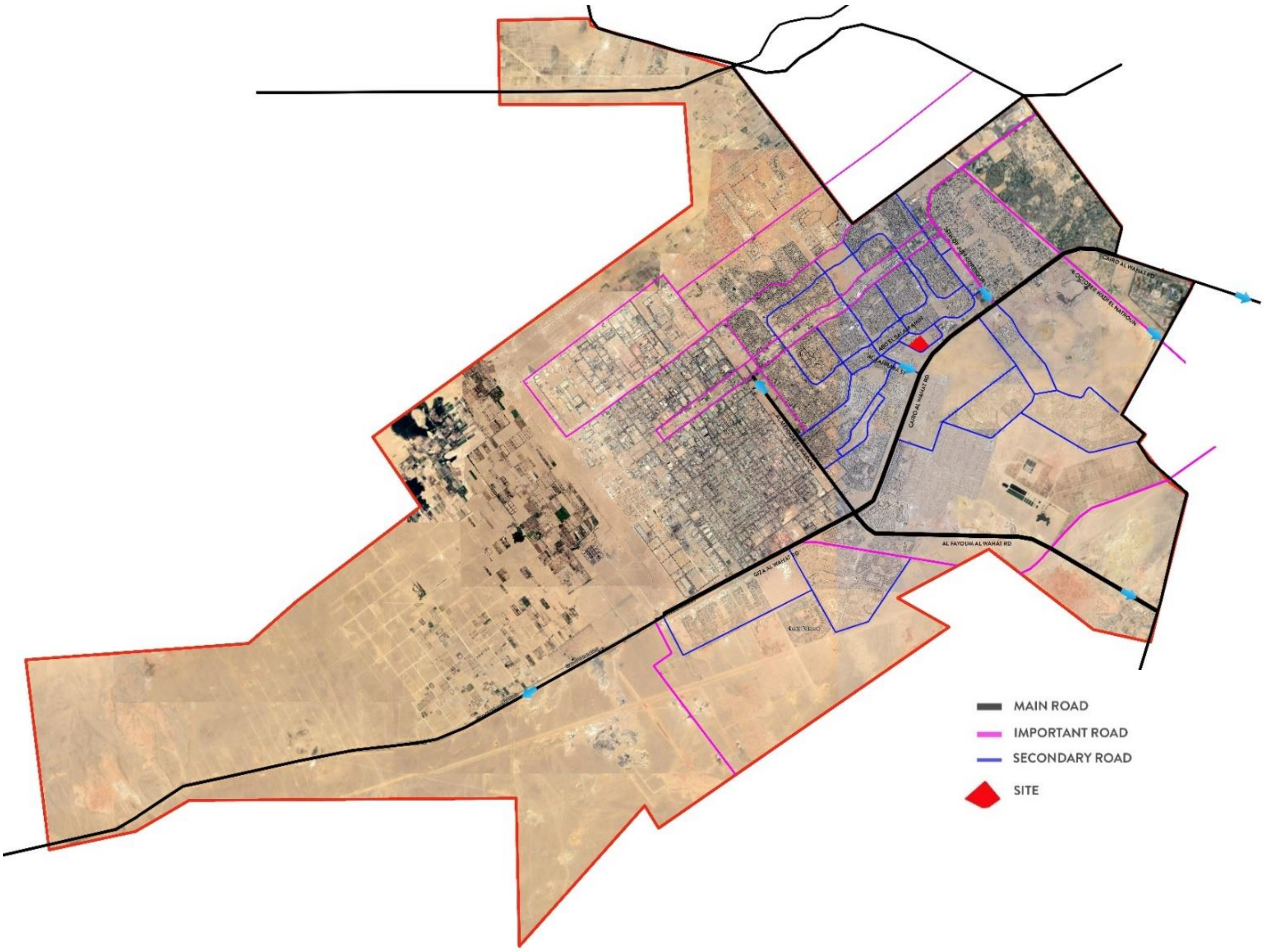



**Fig. 2.19** Street networks

The "High quality Bus" Pilot Project is one of the Sustainable Transport Project (STP) pilots that aim to reduce the growth of the energy consumption and the related greenhouse gas emissions of the transport sector in Egypt.
The Pilot is to provide 7 new public bus lines to serve as an attractive public transport alternative to the private car, encouraging a modal shift to such environmentally friendly and energy saving mode for daily travel. The new public bus lines will connect the cities of Sixth of October and Sheikh Zayed with the Metro Station at Cairo University, Giza Governorate.
The bus services should start at the beginning of (2018), connecting most parts of the cities of 6 October city and Sheikh Zayed.
In order to achieve the objective of attracting private car users to shift to the bus, the high-quality buses will be managed according to the latest smart operating systems, applied or the first time in Egypt. The 7 bus lines should offer high quality service

- **7 new public bus lines**

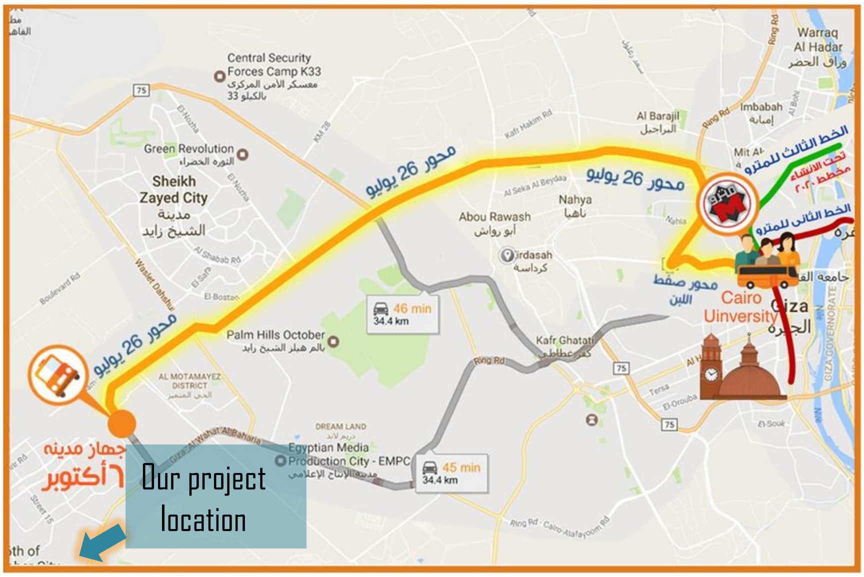



Fig. 2.20 Direct bus line from Cairo university metro station to 6th of October city

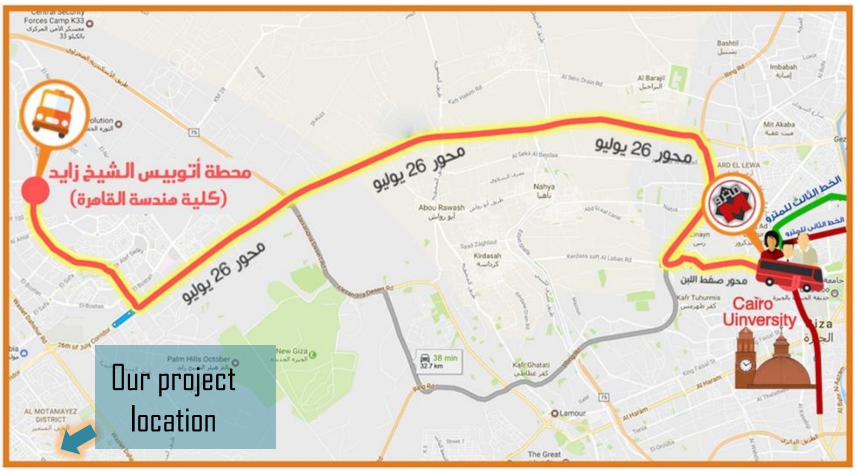



Fig. 2.21 Direct bus line from Cairo university metro station to sheikh Zayed city

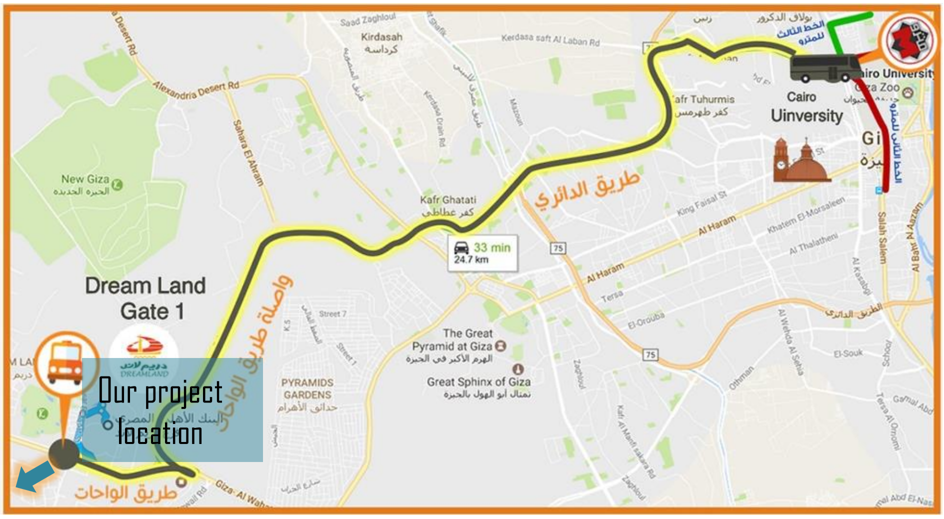



**Fig. 2.22** Direct bus line from Cairo university metro station to dream land


**Fig. 2.23** Direct bus line from Cairo university metro station to Arab mall


**Fig. 2.24** Direct bus line from Cairo university metro station to hyper mall 1

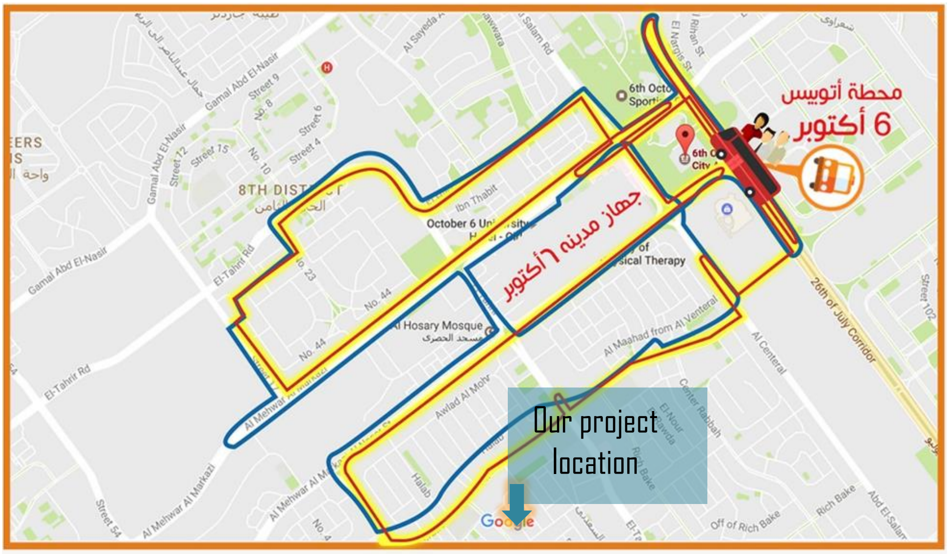



**Fig. 2.25** Internal lines in 6th of October city


**Fig. 2.26** Extended bus lines from El Shaeikh Zayed city

- **Metro line 4**

  The project calls for the construction of metro line 4 in Cairo, Egypt. Phase 1 metro line will run from El-Malek El-Saleh Station (Interchange with Line 1) to the October-Oasis Highway Station with a total length of 18 km, passing through Giza Railway Station (Interchange with Line 2). The project also includes the plan to connect the end of Line 4 to the suburbs of 6 October mainly through executing The October 6th Tram system (The O6T) which will be by using a Tram-train system supplied with the Alstom Regio-Citadis trams. For the rolling stock, the project will require eight train sets, with each featuring 23 cars.

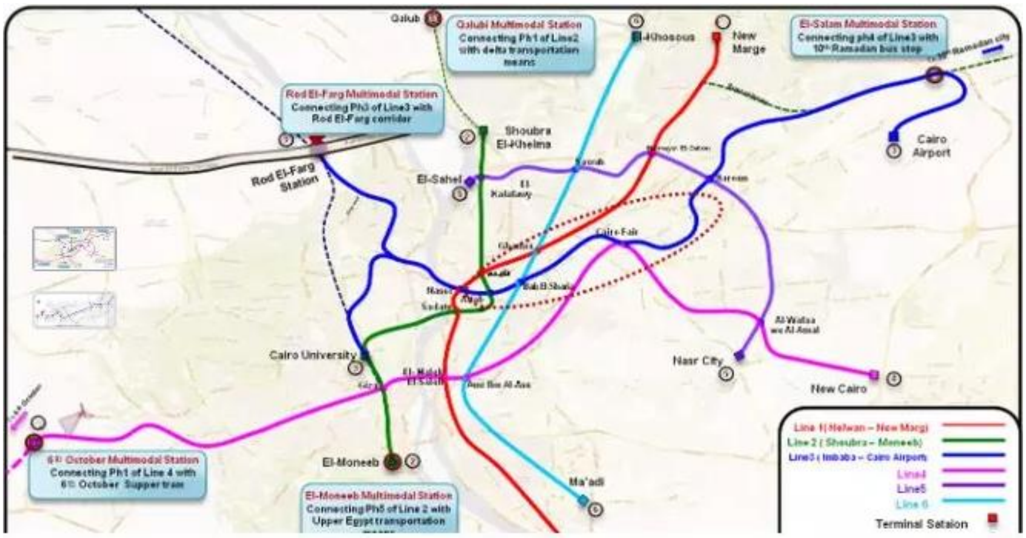



**Fig. 2.27** Metro lines around the city

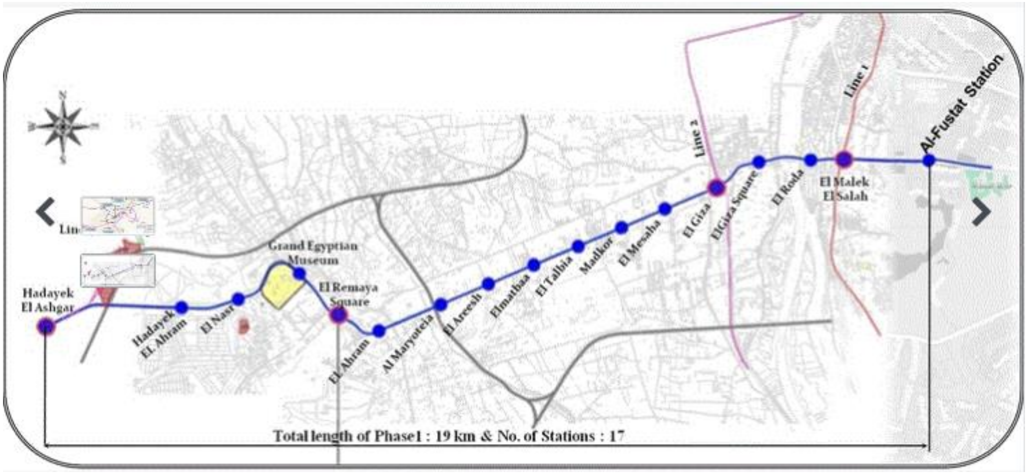



**Fig. 2.28** Metro line 4

- **Micro bus lines in 6th October city**


**Fig. 2.29** Micro-bus lines

### 2.2.6. UTILITIES AND INFRASTRUCTURE SECTOR

- **The city is supplied by drinking water:**
  - A purification plant with a capacity of 268 thousand m³/day
  - Water line from Shaikh Zayed station diameter 1500 mm and 280,280 m³/day
  - The first phase new purification plant, the outlet, cranes and conveyor lines with a capacity of 400 thousand m³/day (of which 100 thousand m³/day for Faisal and Haram)
  - Length of finished networks: 1887.7 km
  - Water networks of different countries are being carried out with a length of 782.5 km
  - The work of the second phase with a capacity of 400,000 m³/day is running

- **Sewage:**
  - A 3D mechanical processing plant was implemented west of 6th of October city with a capacity 150 thousand m³/day
  - An oxidation pool with a capacity of 15 thousand m³/day was implemented
  - A new treatment station with a capacity of 100 thousand m³/day (south of the city) was constructed to accommodate the city's drainage
  - Sewage networks with different diameters have been implemented at a length of 1545.5 km
  - The second phase of the western treatment plant is being implemented with a capacity of 150 thousand m³/day
  - The implementation sewage networks with different diameters with length 624.5 km

- **Electricity:**
  - 3 transformer stations with the capacity of 640 M.F.A has been finished
  - 2 stations with the capacity of 400 M.F.A are being implemented.
  - A mobile station in El Fardos has been implemented: 40 MVA
  - In addition to feeding from El sheikh Zayed stations with a capacity of 200 MVA
  - Electricity networks finished by 12695 km/L
  - Under construction 170 km/L

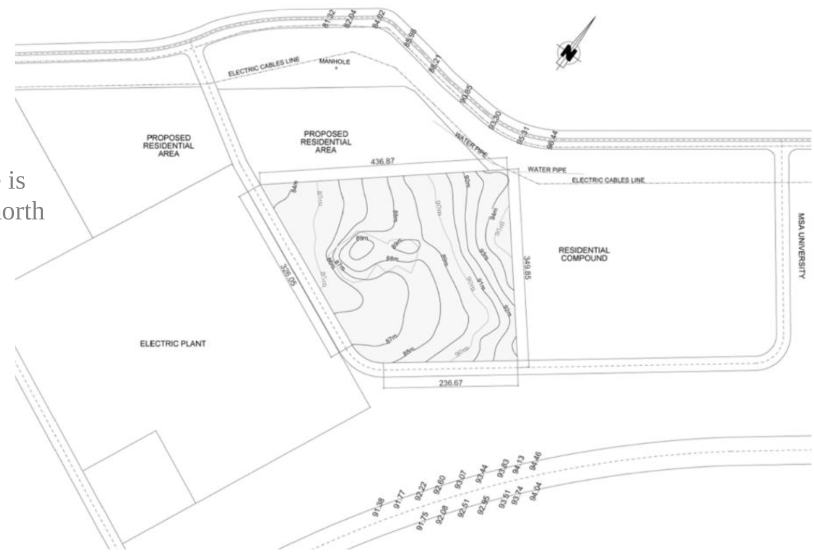



**Fig. 2.30** Infrastructure is located mostly in the north the site

## 2.3. SWOT ANALYSIS FOR THE LOCAL SCALE

| | STRENGTHS | WEAKNESSES | OPPORTUNITIES | THREATS |
|---|---|---|---|---|
| **FUNCTIONS MAP** | | | • There is an Electric plant at the south of the plot area<br>• The industrial area to the west of the land can be used to support some functions<br>• The existence of the pyramids to the east of the land by 17 km.<br>• The existence of the important educational universities around our area<br>• (Al ahram university, Misr university, October university and Modern sciences and arts university, these will support our science city function).<br>• The existence of entertainment and culture buildings around our area) Egypt media production, dream land, mall El Arab, Wadi Degla club and Dream park) | • Most of the surrounded residential units are not occupied<br>• The industrial area to the west of the land is a source of pollution<br>• The cemetery at the east west direction impede any development<br>• Surrounding by desert area from east and south side |

| | | | | |
|---|---|---|---|---|
| | | | • 6th October airport is at the west side of the land | |
| **MORPHOLOGY** | • The contour of the plot area (around 10 differences in levels from east to west). | • Arid climate conditions and in summer the temp. can reach 45 Celsius degree. | • all the height of all surrounding buildings is max 5 floors. | • lake of public landscape areas surrounding<br>• Lake of green area in the surrounding<br>• Reduction of biodiversity |
| **TRAFFIC AND MOBILITY STREET PATTERN** | • Good access to our plot area from main surrounding streets. | | • Existence of main street at south direction (Cairo El Wahat road) which is main connection to Cairo city. | • No public transportation to our area, only private microbus service<br>• Streets quality around our area are in a bad condition |

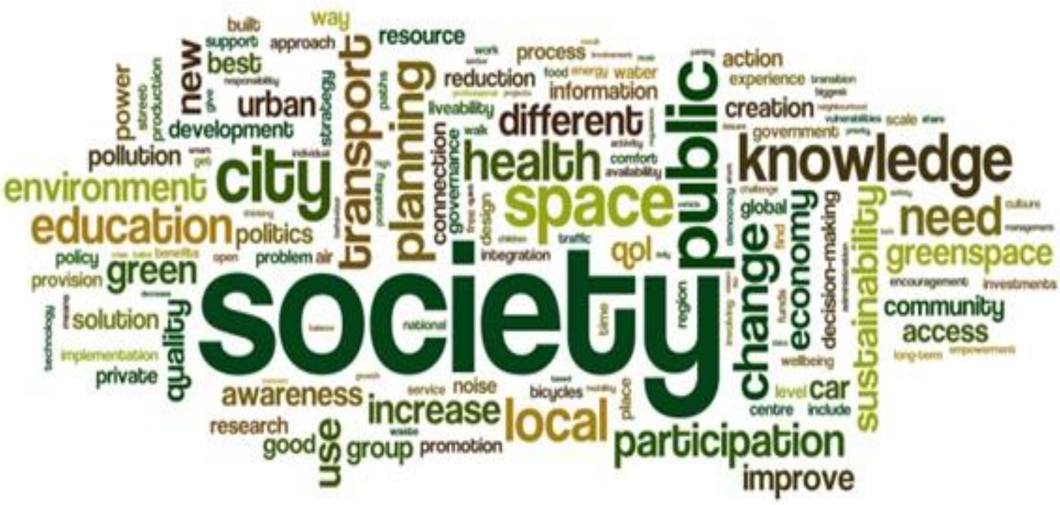
# 3. GOALS AND PRINCIPLES

3.1. VISION
3.2. GOALS AND ACTIONS
3.3. SCIENCE CITY PROGRAMME AND REQUIREMENTS
3.4. PLANNING AND DESIGN CONSIDERATIONS
3.5. APPLIED SUSTAINABLE PASSIVE STRATEGIES
3.6. STUDY CASES

## 3.1. VISION

The aim is to inspire curiosity, discovery, and learning about science and technology through
outstanding exhibitions, collections, and educational activities.
Having made these analyses and pointed out the results through the SWOT analysis we decided to focus on one vision: "*Create a natural environment where people can share and enjoy time and knowledge*." Indeed, the most important elements of the analysis that caught our attention was the presence in a new city of many student and worker flows during the day that imply the possibility for them to be involved in the daytime and the night time of the area. Moreover, we are looking to guaranty a unique sensation in the area for them as well as for the tourists and the feeling as if as they had been in their own natural environment or "landscape". From this vision, we deduce three goals, which are listed in the following table:

- Make the area a place livable and attractive not only for tourists but also for the local population, workers and students passing through the site. That means that the project has to be designed also for the people which live in this area every day.
- Social requalification of the site, making the area livable also during the night.
- design a project in favor of every dimension of sustainability.



## 3.2. GOALS AND ACTIONS

| Goals | STRATEGIES | ACTIONS |
|---|---|---|
| Make the area a place livable and attractive not only for tourists but also for the local population, workers and students passing through the site. | • Creation of gathering and social point free of car traffic.<br>• Create a natural environment and livable during all the year.<br>• Extension of the internal functions of the building in the external part. | • Creation of external temporary exposition zone.<br>• Distributions of green areas with lazy spaces and games area directly connected with the exhibitions.<br>• Bike sharing point into the site<br>• Positioning of eye-catching landmark<br>• Requalification of the pedestrian paths in order to guaranty them a good visibility and good connection between the site and surroundings.<br>• Create a multi diversity of plants and make a pleasant landscape |
| Social requalification of the site making the area livable also during the night | • Organization of events during the night hours.<br>• Decrease the sense of insecurity given by the darkness of the site.<br>• Take advantage of the existing infrastructures and buildings and foresee the future. | • Open air shows.<br>• Open the auditorium during the night hours.<br>• Creation of facilities like bars and restaurants in order to encourage the people to live in the area.<br>• While designing the landscape consider a public area that can be a part of outer dimensions |
| Sustainable project | • Turn the passage of pedestrian flows into energy.<br>• Turn the railway from grey to green.<br>• Minimize short- term and long-term costs. | • Use renewable energy like solar energy for the artificial lightning and the public facilities requiring electric supply.<br>• Mitigate the heat island effect.<br>• Choose low maintenance furniture, materials and construction solutions.<br>• Use of regional materials.<br>• Use local plants and desert vegetation. |

## 3.3. SCIENCE CITY PROGRAMME AND REQUIREMENTS

Having arrived at the 21st century, the world is on the verge of great scientific advancement. Science City will be the vehicle with which Egypt can join the fast-advancing world of science, bring Egyptians closer to the world around them and engage Egyptian scholars in an active dialogue with the future. Egypt, with its long-standing civilization and scientific achievements that once dazzled the world, is worthy of a new lighthouse of scientific knowledge not only to reclaim Egypt's role as a leading nation, but also to guide young Egyptians in a world open to all kinds of messages. It will also serve to create the climate conducive to further scientific advances, demonstrating links between science, technology and industry. Egypt has successfully re-established the **Bibliotheca Alexandrina (BA)** and started the construction of a **Grand Egyptian Museum** to showcase Egypt's ancient past. The **Science City (SC)** will become the third jewel in this triangle crowning the achievements of a new era that celebrates the past with an eye to the future, balancing literature, science and the arts.

### 3.3.1. PROJECT LOCATION

- Site area: net area 124,994.8 m². The maximum built-up area is 37,498.44 m² not to exceed 30% of the total area.
- The estimated required floor area is 85,000 m2 (+/- 10%).
- Expected visitors per year 1 to 1.5 million person.
- Expected numbers of employees: around 450 employees.
- Purpose: to create a Science Center including Interactive Science Exhibitions, Collections Museum, Research & Development Facilities, Workshops and Conference Center.
- The outdoor space, exhibition area and Science Park shall not be added to the total built-up area and is at some to 88,200 m2 (+/- 10%).

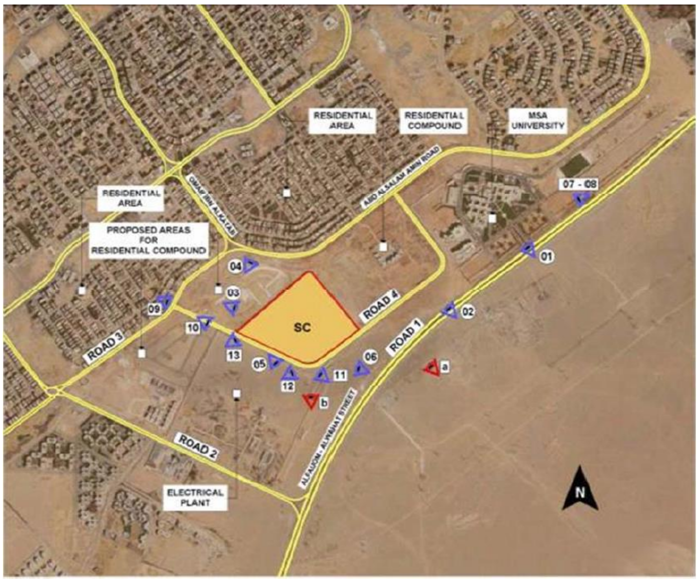



**Fig. 3.1** Project location intermediate scale

### 3.3.2. COMPONENTS OF THE PROJECT

An architectural design provides the spatial layout for exhibiting scientific themes and ideas. The building could serve as an educational instrument as it exhibits building sciences. Similar to other first-class international science cities, the science city accommodates services and functions that are related to science projects, scientific research, communication, exhibit maintenance and production, recreation, and support for technical installations.

### 3.3.3. REQUIRED MAIN COMPONENTS OF THE PROJECT

The science city programme consists of eight main components that accommodate all of its functions. The 8 components shall be phased into 3 campuses & central cores of services. These components are as shown in the following list:

- Exhibition halls
- Conference center
- Planetarium
- Science park
- Research center
- Observatory tower (project's landmark)
- Administration
- Technical services


**Fig. 3.2** Exhibition

**A- Exhibition halls**

Orientation and information hall
Collection exhibitions
Interactive exhibition
Temporary Exhibition
High Definition Theatre

**B- Conference Center**

Auditorium
Two Lecture Halls
One Multi-Purpose Hall
Four Meeting Rooms

**Fig. 3.3** Planetarium

**C- Planetarium**

**D- Science Park**

The park is a thematic recreational outdoor space, expressing Egypt's diverse landscape and natural life.

**E- Research center**

**Fig. 3.4** laboratories

**F- Observation Tower**

The observatory Tower will provide facilities for astronomy and the observation. It will also act as a Landmark for the project.

**Fig. 3.5** Observatory tower

**G- Administration**

SC Head Department
Finance and legal Department
Information and Public Relations
Personnel and Recruiting
ICT Department
Finance Management and Fund Raising
Engineering and Maintenance

**H- Technical services**

Inventory
Workshops
Complementary Ser ices
Technical Plants an Security

### 3.3.4. DEFINITIONS OF FUNCTIONS

**A- Exhibition halls:**

- **Orientation and information hall**

  The hall should be in the science city's core; easily accessed from the entrance and directly

  connected to all the exhibitions, HD theater, conference facilities, public services and amenities. It will introduce the visitor to the world of science, scientific culture and research. Exhibits in this hall should reflect unity within the sciences, and must allow for periodic changes to the master exhibits. The hall will accommodate as well as visitors' services as; conferences; exhibitions, events and cafes.
- **Collections Exhibitions**

  The Collections Exhibitions will host the permanent collections which will develop incrementally. Each group of the collections will tell its own story, or as part of didactic, thematic or contextual displays. These objects are frequently replaced and they are of major assets for the science city and part of human scientific culture. The environment standards must be considered within this exhibition so as to preserve the exhibits in good conditions. The exhibition area will contain information nodes which allow visitors to navigate through the eight main collections sections data base.
- **Interactive Exhibition**

  The interactive exhibition thematic spaces and galleries should allow for reasonable flexibility in order to periodically update the exhibits as scientific discoveries and theories develop. Interactive exhibits will need special installations: power, water supply, water drainage, data, etc.

  The general exhibit concept for each theme should consider the following: historic development of ideas, Egyptian examples, applications in daily life, inspiring scientific figures and their major contributions in the past and present, industrial applications to science, social influences, and future visions.

  The Interactive exhibition should include the children's world, which is a place for children to learn, share, experience and create. Whether they come with family or a class, children can experience the scientific approach through games. The hands-on exhibits teach children how to formulate hypotheses and make deductions by themselves. The Children's World will be hosting the activities for children aging from 3 up to 6 years old.
- **Temporary Exhibition**

  The temporary exhibition is intended to host travelling exhibitions, commercial applications to science, and technological innovations. It should be designed to accommodate flexible exhibitions where flexibility of space and installation are the key factors of the success of this function.
- **High Definition Theater (HD Theater)**

  The high definition theater gives viewers the ultimate large screen experience with projections of stunning documentary movies. It will be educational and entertaining for all age groups. It will be equipped with state-of-the-art projection equipment.

**B- Conference center:**

Special events, scientific and ICT conferences will take place in the Science City auditorium.

Supporting facilities will consist of 2 lecture rooms, one multipurpose hall and 4 meeting rooms. These spaces should be equipped with advanced technological equipment which will allow for overseas conferences that establish international networks.

**C- Planetarium:**

the planetarium plays a central role in shows that cover diverse scientific themes with a special emphasis on astronomy. It will provide both live and multimedia shows every day and will receive an average of 150 to 200 visitors per show.

**D- Science Park (Outdoor spaces):**

The main objectives of the science park landscape are: to provide education through recreational interactive activities, and to revitalize the landscape nature. The exhibits will be an extension of the science city indoor interactive exhibits. It should display different elements of natural Egyptian landscapes. The exhibits should portray aspects pertaining to fauna and flora, hydrology, geology, and energy using hard and soft landscape.

**E- Research center:**

The research center will host a range of collections which conform with the collection acquisition policy of the science city. While the shared facilities will comprise, the public interface reception digital archive, library, shared laboratory, meeting rooms, administration and scientist’s offices and lounge. All labs will be adequately fully equipped with computer stations to help in processing data and cataloguing it.

All departments will accommodate curators who will be responsible for identifying specimens, plan and oversee the arrangement, cataloging and exhibition collections. They also maintain collections with technicians and conservators. They acquire and preserve important documents and other valuable items for permanent storage or display. They also identify, acquire, describe, catalogue, and analyze, special collections for the benefit of the researchers and the public.

All departments will comprise a storage area which should allow the collections to grow. Design should consider state-of-the-art preservation method; therefore, maintaining environmental standards is a must. Climate control, air movement and outdoor air, air cleanliness, light levels, materials, macroclimates, pest control and movements (visitors, objects and machines) are main environmental factors that need to be considered.

**F- Observatory Tower (Landmark of the SC.):**

The observatory tower will provide facilities for the astronomy and the observation. It is the landmark; characterized by an observation tower. the observation tower shall mark the zone of the 6th of October with a special nature overlooking the pyramids. The observatory tower upper floors consist of an observatory and services and open deck or view area.

**G- Administration:**

The administration is the brain of the Science City. The administration will work as one large central administration associated by small satellite administration units located within different components of the Science City for facility management

The main departments are the following;


- **The Science City Head Department**
- **Finance and legal Department**
- **Information and Public Relation Department**
- **Personnel and Recruiting Department**
- **ICT (Information and Communication Technology) Department**
  The department will host the Science City main server. It will be responsible for updating the science city digital library. These updates will accompany the occasional changes in the interactive exhibits. The department will also prepare for the advertising concerning the conferences, scientific workshops. etc. it will be maintaining and upgrading the computer terminal which the visitors uses to navigate through the science city digital library.
- **Finance Management and Fund Raising**
  This department studies the long and short-term strategies of the exhibitions, and systematically analyzes and establishes plans regarding finance, administration, exhibitions and their facilities.
- **Engineering**
  This department plans exhibition themes, ideas and design relevant drawings, models, lighting and exhibition display, and to manage and supervise their productions.

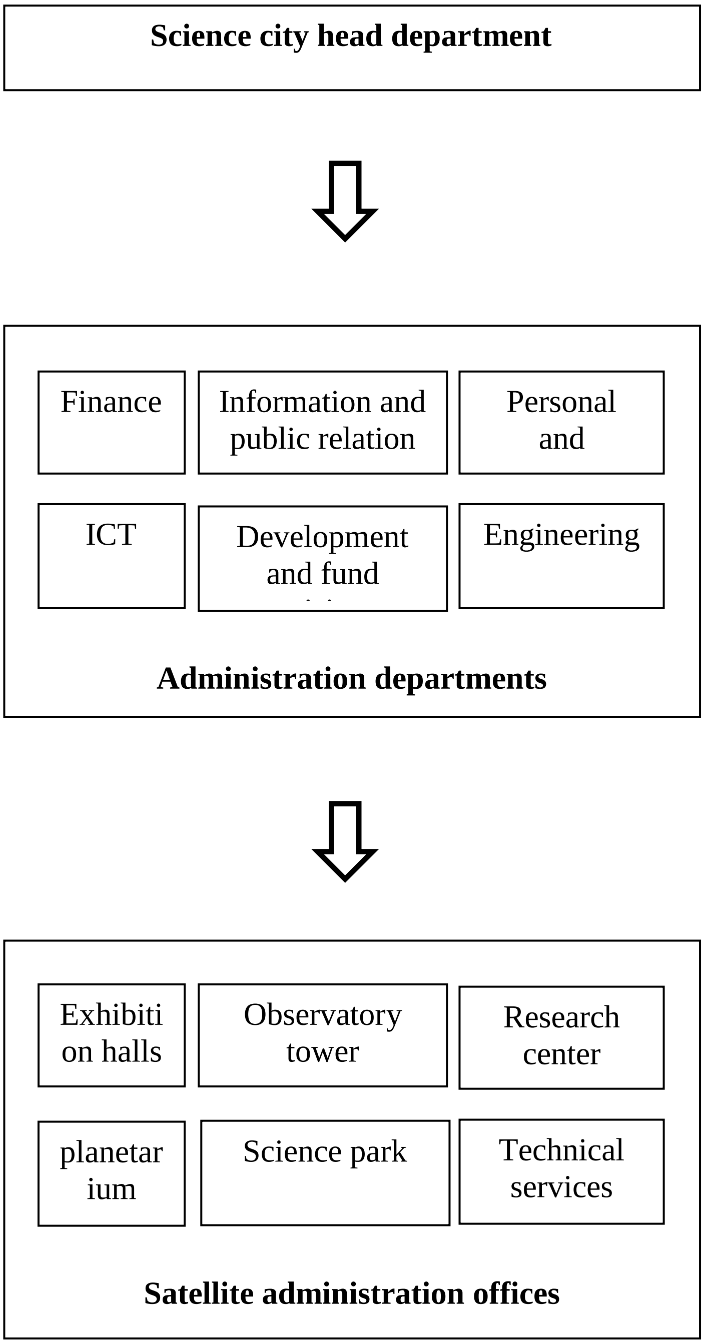



**Fig. 3.6** Administration organization offices

**H- Technical services**

The Services section is the backbone of the whole science city complex. It contains the following departments:

- **Inventory**
  This will include all kinds of storage such as; stationary, exhibit storage, workshop storage…etc.
- **Workshops**
  The science city will be equipped with workshops that will allow for the installation and maintenance of exhibits. The workshops may organize educational public visits to the science city's backstage
- **Complementary Services**
  These services include a common loading and unloading bay and dock for receiving exhibits for the exhibitions, collections specimens and material for workshops. They also should include, security, crating services, worker's services and offices managing the services operations. Designing these services should consider the following:
  - All rooms to have unobstructed access with no steps, ramps, or turns, to research center storages, Interactive exhibition area and workshops.
  - Direct uninterrupted flow of works
  - All areas must be restricted to authorized staff during operational hours only.
- **Technical Plant and Security**
  The space will accommodate the main technical equipment access doors that will associate the technical systems, and for the security, fire and safety control and management. The most technologically advanced mechanical systems available at construction time should be considered in the design.

## 3.4. PLANNING AND DESIGN CONSIDERATIONS

### 3.4.1. PLANNING CRITERIA

The planning and architectural design should take into account a number of the following complex considerations:

- It should be a campus of several buildings in which implementation can proceed one integrated building at a time, each building being usable for the public as soon as it is completed, but conceived in such a way that the entire complex, when completed, produces an effect where the whole is more than the sum of its parts.
- The complex should become a landmark for the 6th of October City and for the rebirth of science in 21st century Egypt.
- The buildings themselves should be "green & smart buildings" and demonstrate how environmental concerns can be an integral part of the design and an add-on to a conventional building.

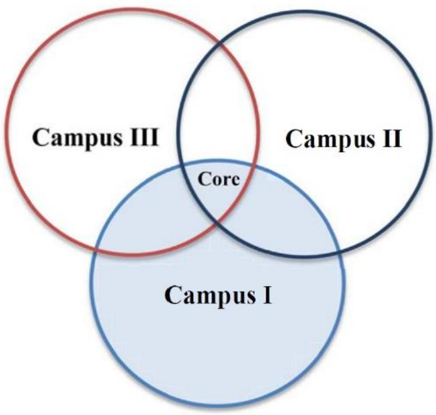



**Fig. 3.7** Planning criteria

- The buildings should be flexible in their internal use, adaptable to the new and rapidly evolving technologies, such as interactive displays and virtual and real learning environments, and should facilitate interaction between the public and the staff. The facility should cater to all age groups.
- At each stage of implementation, the buildings and plan should be linked in an inviting and dramatic way facilitating functionality (e.g. parking and service facilities) and enticing visitors to use covered pedestrian walkways to explore the landscaping. Such walkways maybe reduced or changed as more building are implemented and the complex grows.

**Fig. 3.8** Building core

- Access and circulation design guidelines
  - Maximum safety and efficiency.
  - Security control requirements.
  - Identifications of different functional categories.
  - Optimization of infrastructure works.
  - Possibility of future expansion.
  - Handicapped and special needs circulation fulfilment.
- Each phase shall consist of integrated elements selected from the architectural facilities list of the programme.
- The challenge **i**s to analyze the list of project programme needs and select the integrated elements in each phase. This could compose the three campuses, and the central core of services.

### 3.4.2. MUSEOLOGY THEME

The main themes in the exhibition areas will be governed and guided by certain concepts follows;

- **Collections Exhibitions**

  The Collections Exhibitions will include, but will not be limited to; Geology, Natural History, Plants, Animals, Paleontology and Anthr**o**pology. Other collections might be added depending on availability and need.
- **Interactive exhibitions**

  The interactive exhibition hall is the hands-on science facility of the project. It should include interactive exhibits and exhibitions covering different fields of science. The interactive exhibition should encompass three mesological layers and stratus; Themes, disciplines and age group. These layers will overlap and/or intersect giving maximum flexibility in organizing the exhibition tours. Concepts and topics under each layer are demonstrated in an interactive manner and will be changed frequently.

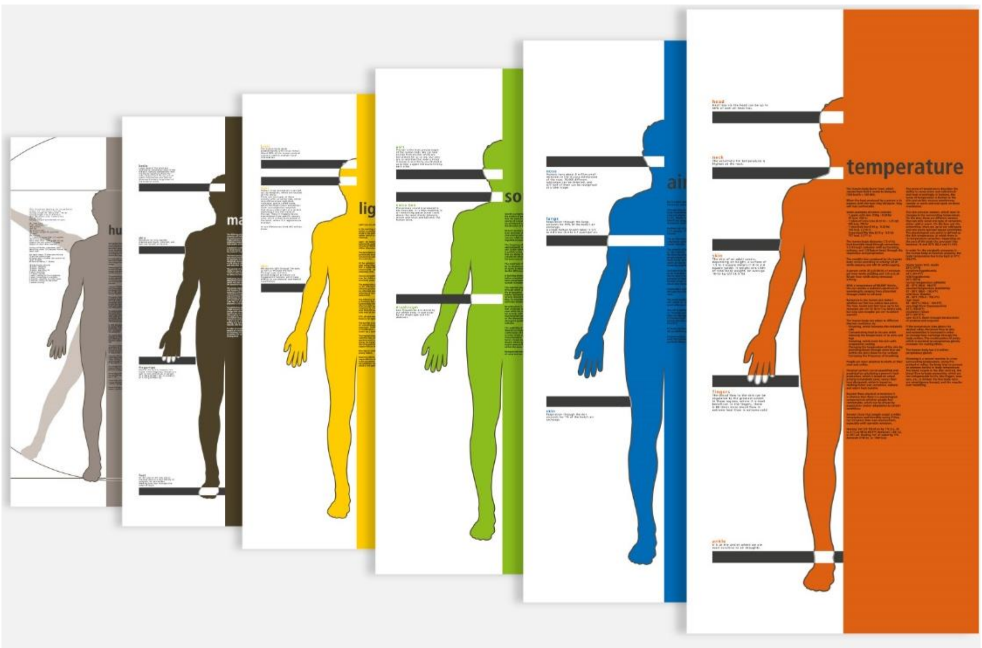
  The Museology design should be subtle enough to allow visitors to reflect with their internal personal knowledge, their environment and universe without direct facing with the intricate complexities of any particular field of science.

- **Human Body**

  An example of a theme that should be tackled in the Interactive Exhibition hall is the Human Body. The design should reflect the interdisciplinary and integrative nature of the theme.

  This part of the interactive exhibition should be mainly concerned with taking the visitor into an intriguing trip into the human body. The five senses, the structure and function of the DNA and the mystery of the genes and the hereditary system are some of the sections that must be covered under this broad theme.

  - Interactive exhibits covering these sections would take the young visitor into a walk- through trip into a model of the human ear to experience its mechanical function and a trip on a large model of the human tongue to see where the taste buds are located. Youth and adults may be exposed to another level of information about the structure of the DNA, with a model of the double helix present as an exhibit. The history of the discovery of the DNA by Watson and Crick can be presented on a poster or an interactive screen.
  - Each section should provide different levels of information for different age groups. This could be done through various interactive exhibits, models as well as animated short movies presented on plasma screens together with educational poster and banners.
  - The interior design and museology of any area should reflect the general scientific theme addressed in any particular area should be in harmony with the items in display.




- **Science park**

  Exhibits in the landscape should introduce the visitors to how science and technology should be in harmony with nature and environment. They should be designed with nature and technology as two ends of the spectrum of human experience. The park should be a landscape for discovery and imagination. It should be a microcosm portraying potentials of nature and ingenuity of humankind.

Elements of nature should include; life, air, water. Egyptian interpretations should be included in the park layout and features. And Egyptian landscape aspects should be expressed like; flat plain (delta), river valley (Nile), sloping land, desert and urban area.
Concepts of the science park are, natural elements, manmade elements, Egyptian interpretations and Egyptian landscape aspects. These would overlap in layers in an interactive way so that the visitor can experience one natural theme.

### 3.4.3. MUSEOLOGY DESIGN ASPECTS

The mesological design should consider the interdisciplinary spirit of today's sciences. It should portray the following among other ideas that the competitor might suggest;

- **History of science**
  Since science is based on historical accumulation and development of knowledge, a historical component should be included in each theme. This allows the visitor to appreciate how very complex scientific achievements are based on simple beginnings. Basic Elements from Egyptian culture should be used, so the visitor will gain an appreciation of how science developed step by step. For example, the rotating wheel (Saqqyia) is showing the development from a simple technique to the turbine.

**Fig. 3.9** Saqqia

- **Science Theoretical Aspects**
  Theories should be displayed in an attractive interactive fashion. An understanding of the main theoretical principles of a field is essential for active participation in the scientific endeavors.
- **Science, Technology and Industry**
  Exhibits should explore how scientific discoveries are translated into technological applications and how such applications may then be the basis for industrial developments.
- **Science and Society**
  It is essential to highlight how scientific discoveries and new technologies influence and change societies. Current examples include the impact of television and mobile phones on social relations.


**Fig. 3.10** Interactive exhibition

- **Future of Science**
  The exhibits in the science city should consider future possibilities of science and engage the visitors in visioning of science and technology. The future of science is rich in possibilities ranging from Nano-technologies to cloning.
- **Exploration and Discovery (Interactive Exhibits)**
  Exhibits should be designed to encourage exploration and discovery. Exhibition should be "interactive "engaging the visitor in experimentation and discovery by themselves.
- **Visitors Paths**
  The arrangement of the interactive exhibition according to the themes, disciplines, and age group, portrays the dynamism inherent in science and discovery. Circulation should allow for different combinations of visit paths and easy access to special areas and exits. Visitors paths should encourage visits to research and activities.

## 3.5. APPLIED SUSTAINABLE PASSIVE STRATEGIES

In this section, different criteria of passive strategies had been studied. Passive strategies application started from the preliminary conceptual idea of the project. Starting from the design approach ending with implementation of technical systems to provide the lowest possible cooling load that reduces the building's energy consumption.

### 3.5.1. PASSIVE DESIGN APPROACH

A 'passive' design approach is most cost effective when it comes to reducing the energy consumption of buildings. the design level, from urban planning to architectural design, is the start for cost effective energy efficient buildings. A good design can even reduce the investment cost of a building, when considering compactness, efficient lay-outs and orientation.
Once a building is designed with an optimal energy demand, the 'active systems' such as heating, cooling and lighting equipment can be added for indoor thermal comfort.
The passive design approach consists of different climate responsive strategies, to avoid heat transfer through the building envelope:

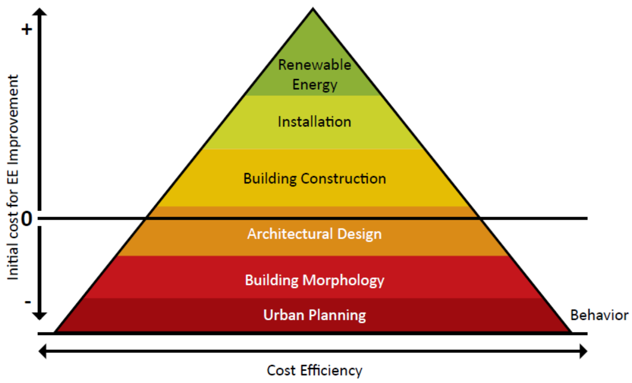



**Fig. 3.11** Strategy for cost effective energy efficient buildings

- **Orientation:** reduce solar radiation on the building envelope.
- **Thermal zoning:** allocate functions related to time of use and solar gain.
- **Building form and typology:** reduce the solar radiation on the building envelope and optimize daylight access.
- **Building envelope design**: provide the minimum required daylight access, together with a minimal heat gain and maximal external reflection.
- **Ventilation:** use airflow to release heat and humidity.

- **Materials selection:** to reduce heat transfer to the indoor space.
- **Landscaping:** provide shade on the building, reducing the heat gain, and to create pleasant outdoor space.

Climate responsive strategies reduce the energy demand of a building based on basic physics, climate and thermal comfort. The energy demand indicates the energy needed to obtain a comfortable indoor climate and depends on the climate condition and building design. The energy consumption is the energy needed to meet the energy demand.


**Fig. 3.12** Architectural development of the climate responsive design process

In the past traditional, vernacular, buildings in the middle east north Africa region were designed and built according to passive design approach as there was no electric equipment to control the indoor climate.

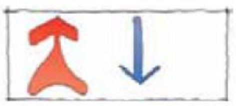
In modern buildings these concepts can be applied as well. This does not mean that the building looks like a traditional building. On the contrary, contemporary building design can be very well 'traditional' in their energy concept without noticing it at first sight.

**Fig. 3.13** Traditional and vernacular buildings

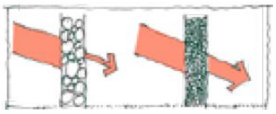
### 3.5.1.1. BASIC PHYSICS

The energy efficiency Building Guidelines present climate responsive strategies for architectural design and building envelope construction using the basic principles of physics:

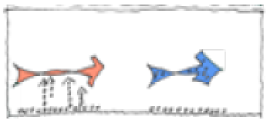
- **Warm and cold airflow**
  Warm air rises because it is lighter and lower in density than cool air. Cold air moves downward and replaces the warm air.



- **Lightweight and dense materials**
  Air reduces energy transfer. When a material contains a lot of air bubbles, it is more resistant to thermal energy heat flow.



- **Evaporation: dry and humid air**
  Water evaporation requires energy. When dry air absorbs water vapor, the ambient temperature lowers and humidity rises.



### 3.5.1.2. CLIMATE

A climate responsive strategy is based on the specific climate characteristics. Climate data needed to determine the strategy to reduce the major specific energy demand of the building, (cooling, heating or lighting):

- Sun angles (α - 0)
- Temperature (T - 0C)
- Solar radiation (horizontal and diffuse) – (kWh/m2)
- Relative humidity (RH - %)
- Wind speed and direction (m/s)
- Precipitation (mm/year).

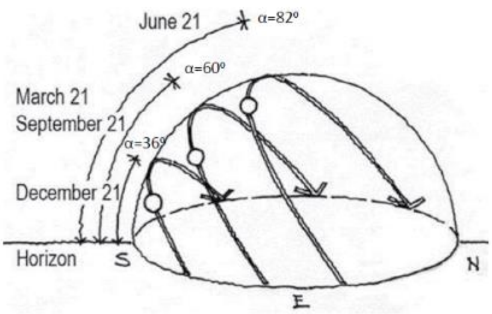
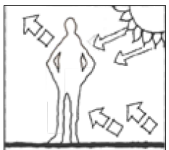



**Fig. 3.14** Sun angles in summer and winter

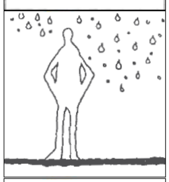
### 3.5.1.3. THERMAL COMFORT

Thermal comfort is an individual perception. It indicates the balance between the energy produced, received and lost by the human body. Factors influencing this state of physical thermal wellbeing are: activity level, age, clothing, culture and human acclimatization. The following modes of energy transfer, which can be influenced by building design, affect the feeling of thermal comfort as well.

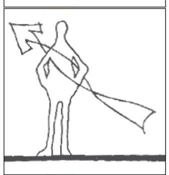
- **Radiation:** emission of thermal energy



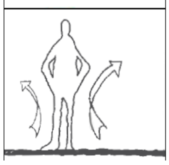
- **Evaporation:** phase change from liquid to gas.



- **Conduction:** energy transfer between particles in a substance.



- **Convection:** energy transfer between a solid surface and the adjacent liquid or gas that is in motion.



Thermal comfort is a personal perception. However, there is a general range or comfort zone in which 80% of the people feel comfortable. In dry hot climate use evaporation for additional cooling
and indoor climate comfort.

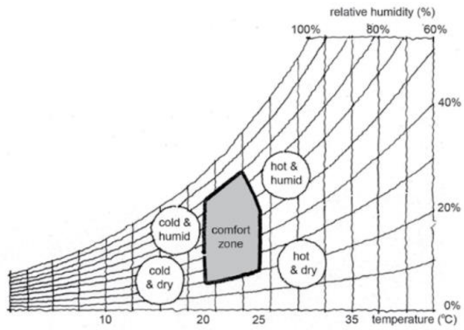



**Fig. 3.15** Range for indoor climate comfort

### 3.5.2. ORIENTATION

The building orientation towards natural elements such as wind and sun influences energy consumption. The wind orientation is important to increase natural ventilation, as this can reduce the energy demand for cooling. The natural ventilation needs to make use of the prevailing wind direction; therefore, it is important to include options for air inlet on the side of the prevailing wind. Solar heat gain of a building depends on the sun orientation.
Reduction of solar heat gain is the key strategy for warm and hot climates. Solar heat that does not enter the building does not need to be cooled, thus a reduction of the cooling load. On the north and south side, the solar radiation is lower than on the east and west side. Therefore, the preferred building orientation is along the east-west axis. This means that the largest elevation surfaces face north and south. On the north side, there is hardly any exposure towards the sun, which results in a minimum heat gain from solar radiation. On the south side where the sun is at its highest angle, it is easy to limit solar heat gain with shading elements for the windows and the façade. Since the largest solar intensities are on the east and west sides, the heat gain is reduced when the smaller facades are on the east and west sides.

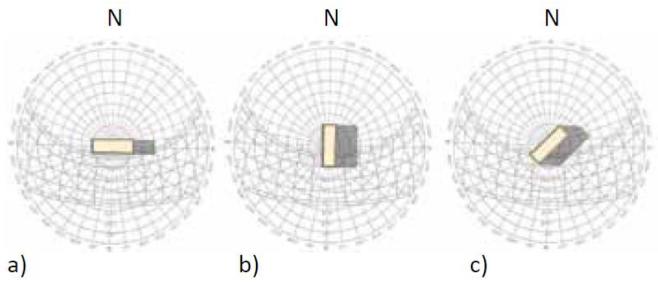



**Fig. 3.16** Orientation on the east-west axis reduces (a) cooling load

### 3.5.3. THERMAL ZONING

building layout. The location of the building functions should relate to the solar radiation and the users' occupancy patterns. The spaces are positioned in relation to the time of use, and as required, the need to gain or to be protected from solar radiation. This strategy can be used for the floor plan layout, and the building section.
**"Full time building"** are used day and night, which is represented in the research center, as researchers will be occupying the building in the full working time or maybe more, are located in the cool zone of the complex.

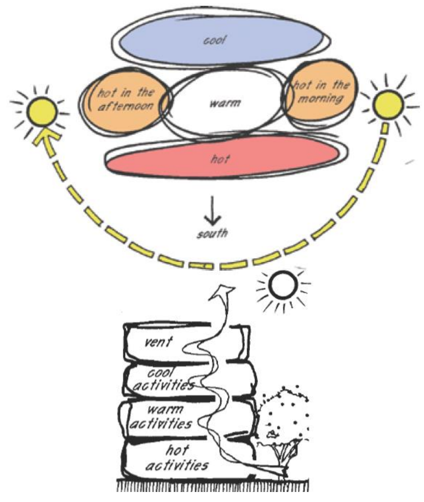
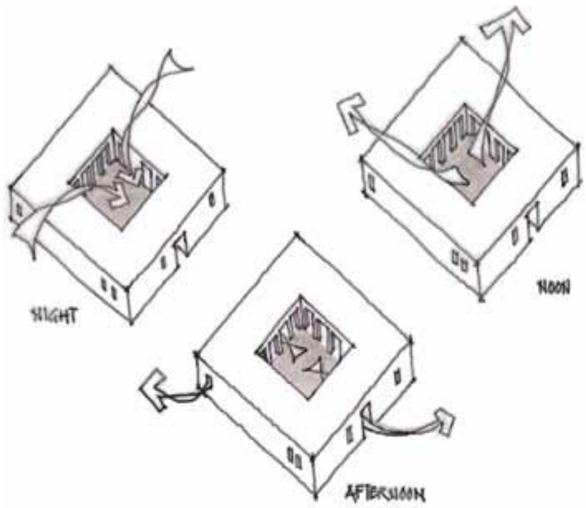



**Fig. 3.17** Thermal zoning in floor plan and section

**"Part time buildings"** are usually occupied for a part of the day, such as offices and exhibitions. Functions with a short terms use, such as meeting rooms or spaces with low occupancy by people, such as storage rooms, can be placed on the hot side of the building. So, exhibition and administration areas are positioned in the first and second campus where occupants will not be in the same zone for the full working hours.

### 3.5.4 BUILDING FORM AND TYPOLOGY

Different examples of building mass configurations can support daylight access, while limiting direct solar radiation Parallel blocks, oriented along the east west axis, offer also shaded outdoor space. The courtyard building offers the possibility to make use of daylight without solar heat gain. At night the cool night air descends into the courtyard. Sun heats up the air in the courtyard which creates an upward draft during the day. In the late afternoon the air rises up, supporting the natural ventilation in the building. At night the courtyard cools down again.




### 3.5.5. Building Envelope Design

The challenge for the building envelope is to design it in such a way that there is an optimal balance between sufficient day light in the building, and a minimal heat transfer through the envelope. The transparent parts of the envelope, such as windows or doors, can transfer heat around five times faster than the closed, or opaque, part of the envelope. This means for a warm/hot climate that the size of the windows and doors has an effect on the cooling load. The larger the openings the more likely it is to have a higher cooling load.

When designing daylight access (window openings, skylights, etc.) the following needs to be considered:

- **Strategic positioning of windows and envelope openings;** where lighting is needed.
- **Visual comfort;** avoid excessive contrast and glare.
- **Avoid direct sunlight access;** small windows in thick walls could be efficient, and openings oriented to the courtyard are a good solution.
- **Shading elements or screens;** provide diffused light and reducing heat gain such as the traditional Mashrabiya.

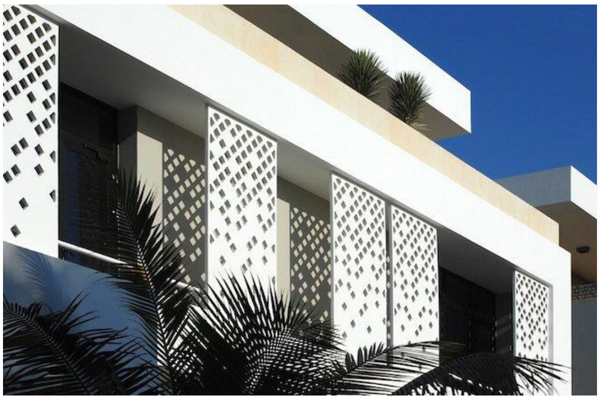


**Fig. 3.18** Modern Mashrabia screen

### 3.5.6. NATURAL VENTILATION

This strategy uses both wind and temperature differences to cool by ventilation. Ventilation can release heat, and thus reduce the cooling load. A natural air flow contributes to indoor climate comfort. In addition, it improves the indoor air quality, however, dust infiltration should be prevented.

Passive cooling systems rely on natural heat-sinks to remove heat from the building. They derive cooling directly from evaporation, convection, and radiation without using any intermediate electrical devices. All passive cooling strategies rely on daily changes in temperature and relative humidity. The applicability of each system depends on the climatic conditions. This section briefly describes the various passive techniques that aim heat loss from the building by convection, radiation and evaporation.

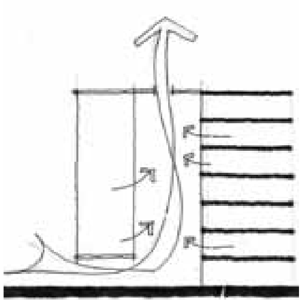


**Fig. 3.19** Natural ventilation

#### 3.5.6.1 THE WIND CATCHER

In this system, wind catchers guide outside air over water-filled tubes, inducing evaporation and causing a significant drop in temperature before the air enters the interior. Such wind catchers become primary elements of the architectural form also. That system named as **evaporative cooling**.

In dry, arid climates, the installation and operating cost of an evaporative cooler can be much lower than that of refrigerated air conditioning, often by 80% or so. However, evaporative cooling and vapor-

**Fig. 3.20** Wind catcher

compression air conditioning are sometimes used in combination to yield optimal cooling results. Some evaporative coolers may also serve as humidifiers in the heating season.

**Principles of Operation:**

- Small water droplets are sprayed directly into air
- Droplets evaporate in the air
- Air is cooled and humidified within the occupied area.

In arid climates like Egypt, the scarcity of water makes water consumption a concern in cooling system design. By harvesting rain water and treated grey water in this system will reduce the scarcity of water.

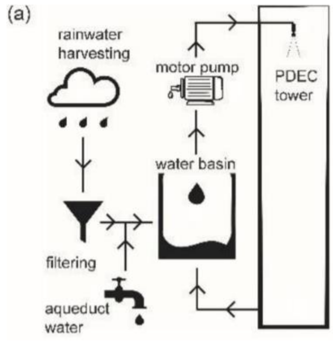



**Fig. 3.21** A scheme of the designed PDEC system

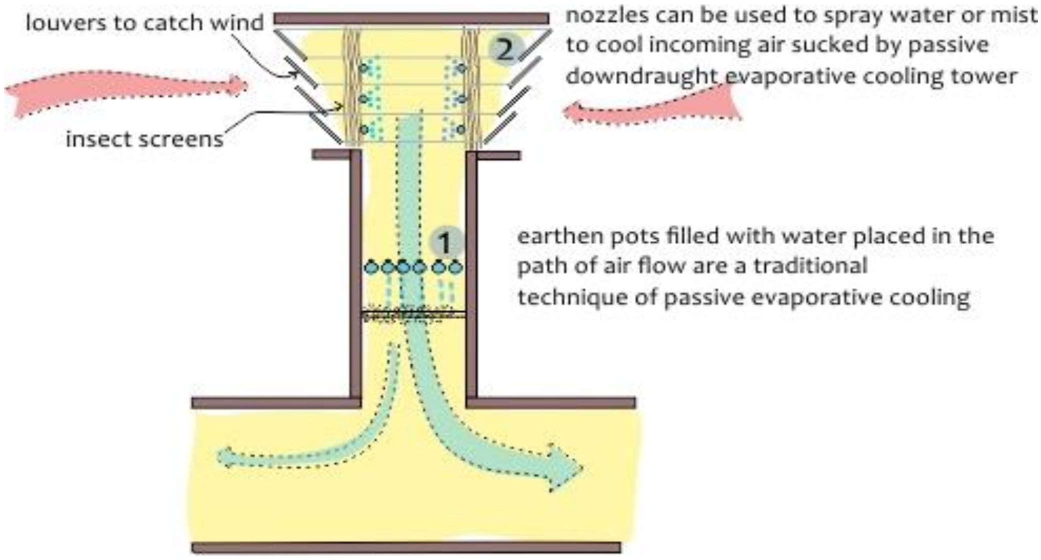



**Fig. 3.22** A scheme of evaporative cooling

### 3.5.6.2 VENTILATED FAÇADE

Ventilated facade is a complex system that works by combining various physical and technical principles. This system is composed of the following layers:

- Perimeter constructed wall with insulation
- An air gap for ventilation
- A structure to support the outside wall covering
- The outside wall covering

It is resulted in a number of benefits that are hard to get with a tradition wall covering system:

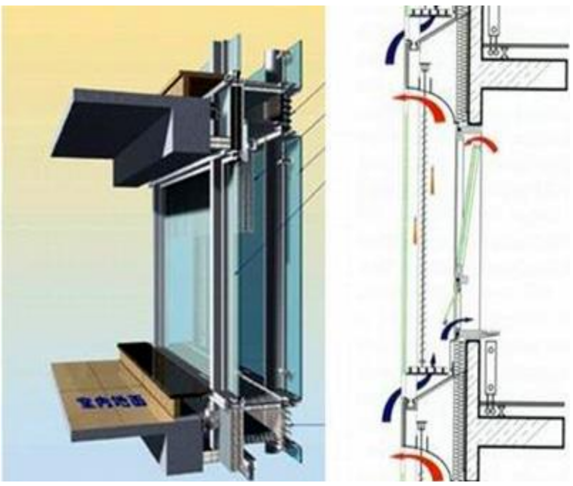


**Fig. 3.23** A scheme of ventilated facade

- **Elimination of condensation**
  When two environments, separated by a wall, have a different temperature and relative humidity, vapor tends to migrate towards the face of the wall facing the environment with the lowest actual pressure. Condensation will form if the actual pressure decreases more rapidly than the saturation pressure during this migration following the lowering of the temperature. The curves of the effective- and saturation pressure will never cross if the insulation is fitted on the outside of the wall and so condensation will never form. The internal humidity eliminated through the higher breathing perimeter walls is also rapidly removed by natural ventilation before it has the chance to settle on the outside face or wall covering.
- **Thermal insulation of structures and supporting walls**
  Their improved performance in terms of thermal insulation (less heat bridging, damping and phase shift of the thermal wave and reduction in the thermal loads on the surface) significantly cuts strain and stress and enhances the performance and durability of the building's structures and supporting walls.
- **Elimination of thermal bridging**
  A modern building is typified by the discontinuity of the shapes and materials used in its construction, leading to heat bridging. In turn this leads to an uneven distribution of the temperature with a negative impact on the climate inside and promoting the formation of condensation and mold. A continuous layer of external insulation protects it in a more uniform way and the outdoor facing blocks the sun's rays: together, they lower its thermal instability and improve the building's energy performance.
- **Ease of maintenance**
  Although the external face is made using hardwearing materials with exceptional technical specifications, the substructure has a modular design so that each individual plate can be replaced immediately should it be damaged.

### 3.5.6.3. WASTEWATER RECYCLING

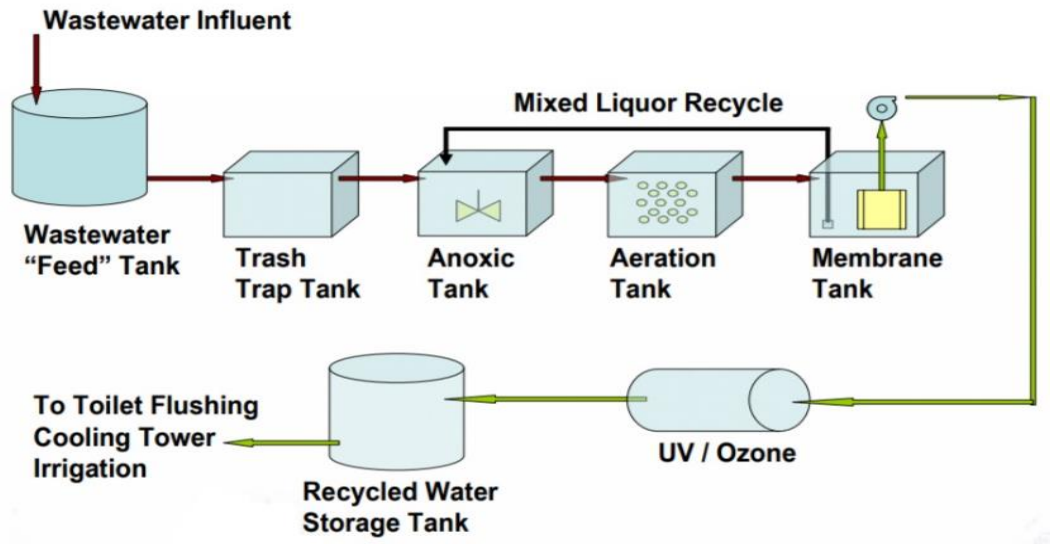



**Fig. 3.24** A scheme of water recycling

Although sources of fresh water are finite, they are part of a naturally-replenishing system. The problem – the water tends to be used up faster than it can be replenished. The solution – use water more efficiently. Part of that is using less water through a variety of means, including more efficient irrigation systems, ocean friendly gardens that don't require much water and water-conserving appliances and shower heads. But an equally important part of the solution is reusing (and reusing, and reusing…) the water we have. Much of the water ("graywater") that goes down the drains from showers and sinks in buildings is suitable to be used locally for irrigation purposes. The rest ("black" water) can be used for irrigation after going through a conventional primary/secondary sewage treatment process, typically followed by filtration and disinfection. This treated wastewater is often referred to as reclaimed water and can be used to irrigate parks, cemeteries and other landscaping. And 100% recycling is possible.
The science city is capturing, treating and reuse of water onsite.

Reuse Applications:

- Toilet Flushing
- Wind catchers Make-Up Water
- Landscape Irrigation

## 3.6. STUDY CASES

### 3.6.1 NATURAL SCIENCE MUSEUM MUSE-TRENTO

The Renzo Piano-designed project puts Trento on the international map. Far more than a science museum, this is a bold statement of intent. The region realizes that investment in culture reaps rewards. The results go beyond a cutting-edge museum and the regeneration of an old industrial district. The museum sits at the heart of a new urban park, residential and entertainment zone that will reshape the city.
The project also reconnects the city with its mountainous landscape. Shifting views of Monte Bondone will tempt visitors to explore the Dolomite peaks. it is deeply rooted in the Dolomites, presenting glaciers and extreme Alpine experiences as part of its remit. With its jagged, futuristic forms, even the design of the building seems like a tribute to the surrounding mountains. But Muse aspires to be much more than a museum. As a bold research center, MUSE also harbors lofty planetary ambitions, exploring everything from the birth of the solar system to Alpine eco-systems, sustainability and global warming. It's more concrete aim is to reposition Trento as a dynamic cultural and scientific center on the world stage.

The exhibitions favor a hands-on approach to science, at once educational but engaging. According to Renzo Piano, culture is a springboard for relaunching Italy's economic recovery and MUSE, a museum for the third millennium, can perform the same role for the local economy. The museum's messages are inextricably bound up with Alpine heritage, broader environmental issues and sustainable development. Although the museum presents the natural world through the prism of science, this is science applied to ethical, social and global issues. The museum explores the relationship between nature, science and society and also considers the impact of science on everyday life.

The Natural Sciences Museum, MUSE is designed as a center of scientific culture, projected particularly towards ethical and social issues and current controversies such as ecology and
sustainable development. Composed of 6 floors (4 light and 2 basements), the verticality of the building designed by Renzo Piano winds around the themes of diversity of natural environments, offering visitors a real journey through the various ecosystems and habitat change and their associated biodiversity.

Great attention has been paid to the architectural idea in the development of structures and facades of the work, such as immediate presentation of the museum visitors. The facades and roofs were made by Stahlbau Pichler aluminum profiles customized for the project and produced by Metra. The building almost entirely of glass (21.000 sqm) is constituted by a succession of spaces and volumes, solids and voids.

The project is characterized by a remarkable geometric complexity due to 4 main volumes (Block Offices, Lobby, Museum area and Serra), at their intersections and mortgage-plots.

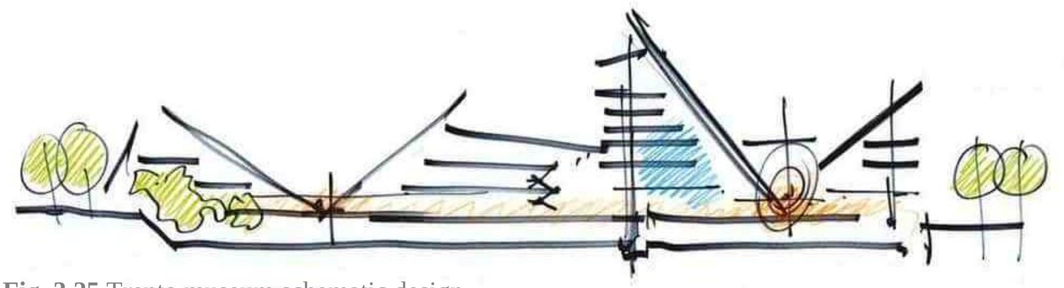
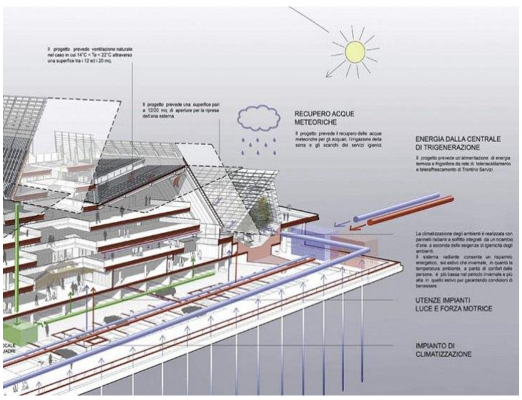


**Fig. 3.25** Trento museum schematic design



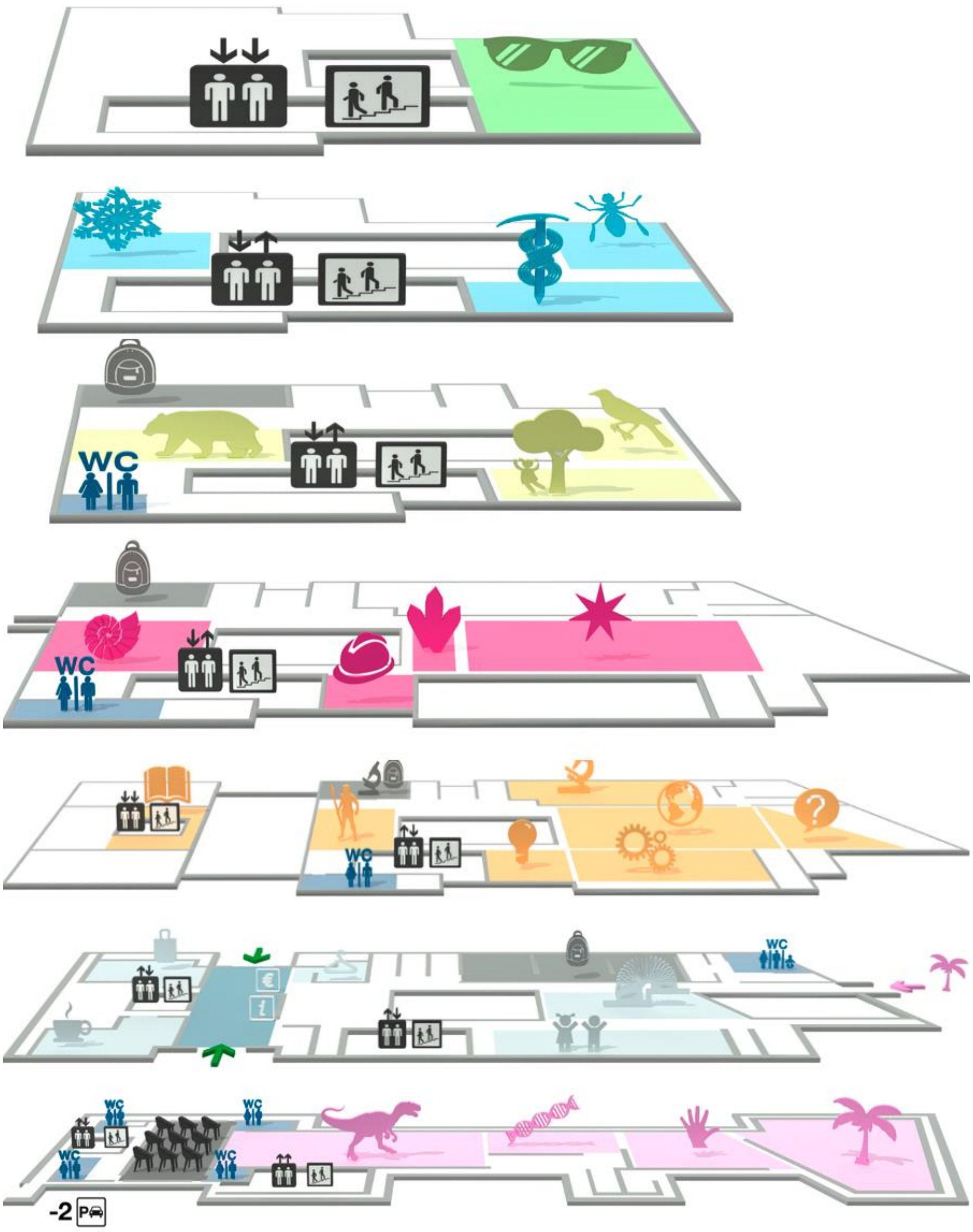



**Fig. 3.26** Trento museum function distribution in all floors


**Fig. 3.27** Trento museum ground floor

### 3.6.2. CALIFORNIA SCIENCE ACADEMY

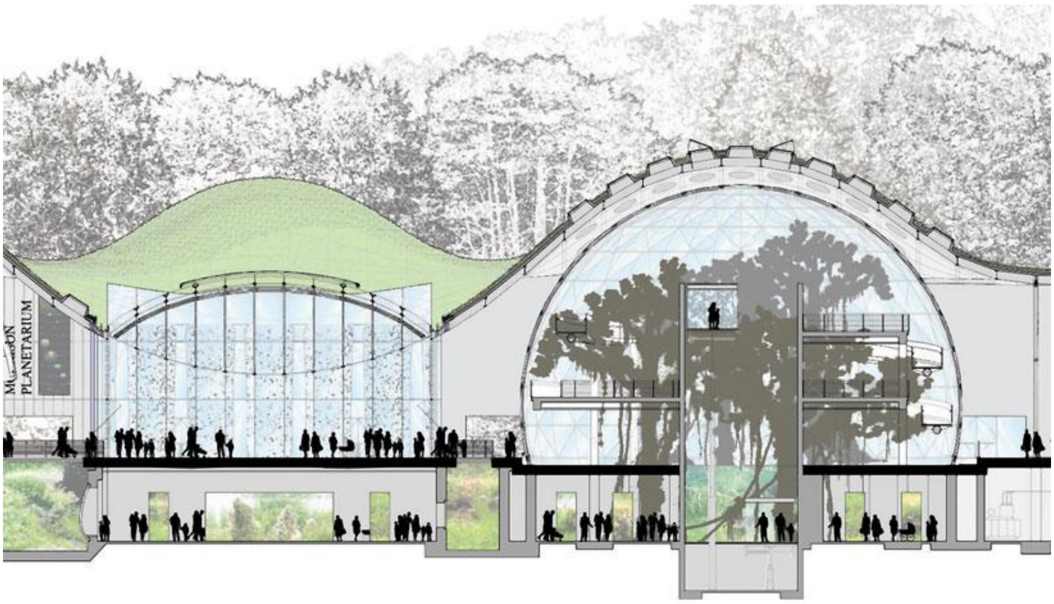
Located in San Francisco's Golden Gate Park, the California Academy of Sciences is touted as the "world's greenest museum" for its ambitious sustainable design. Completed in 2008, the academy's 400,000- square foot LEED-platinum green building replaces an outdated, earth-quake damaged complex of buildings that served as the academy's home since 1916.

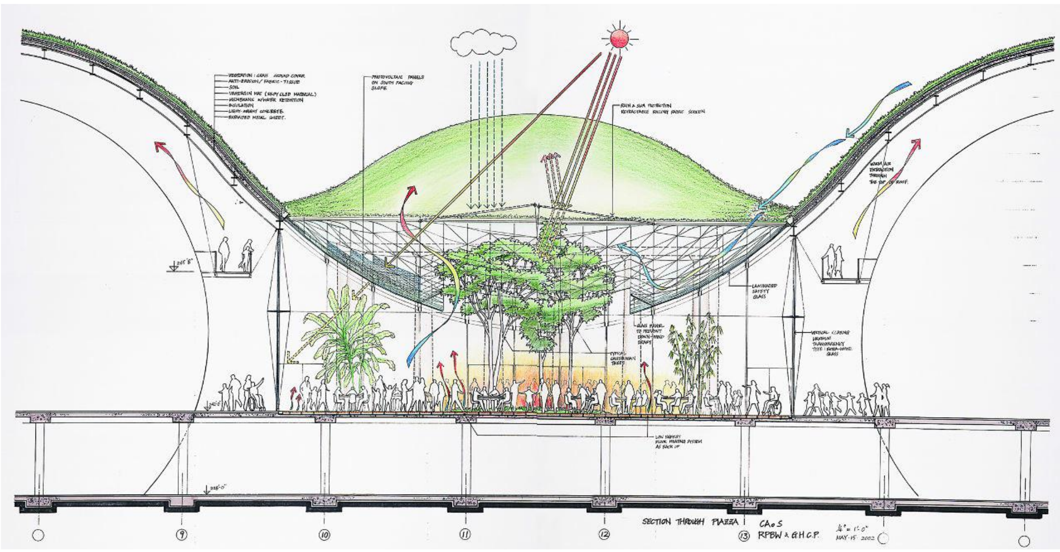
The design of the new building seeks to reinforce the Academy's goals to "explore, explain and protect the natural world." Landscape architecture played a crucial role in realizing the design team's concept of "lifting up a piece of the park and putting a building under it." The bold new building includes a 2.5- acre living roof, which spans the museum's three main wings – the Steinhart Aquarium, the Morrison Planetarium, and the Kimball Natural History Museum. By combining the academy's different functions under one roof, the new building reduces the facility's physical footprint by approximately 1.5 acres.

A smaller footprint means fewer materials were needed to complete construction and less energy is needed to heat and cool the building. In addition, the reclaimed real estate is used for new gardens that accommodate gatherings, receptions, and outdoor dining. In order to teach visitors about local plants and wildlife, the exhibit highlights the numerous environmental and economic benefits of the green roof. The plants and soil composition absorb and filter rain water, helping to reduce runoff by more than 90 percent. Less runoff means smaller storm drains can be installed, saving the project cost and materials.

Visitors can learn about how the green roof makes the building more energy efficient. A six-inch layer of soil and plants insulates the building interior, lowering interior temperatures by an average of 10 degrees during the summer. Skylights add to the building's energy efficiency, allowing natural light to filter to rooms below.

**Fig. 3.28** California science academy section


PLANETARIUM


SECTION THROUGH PLAZA

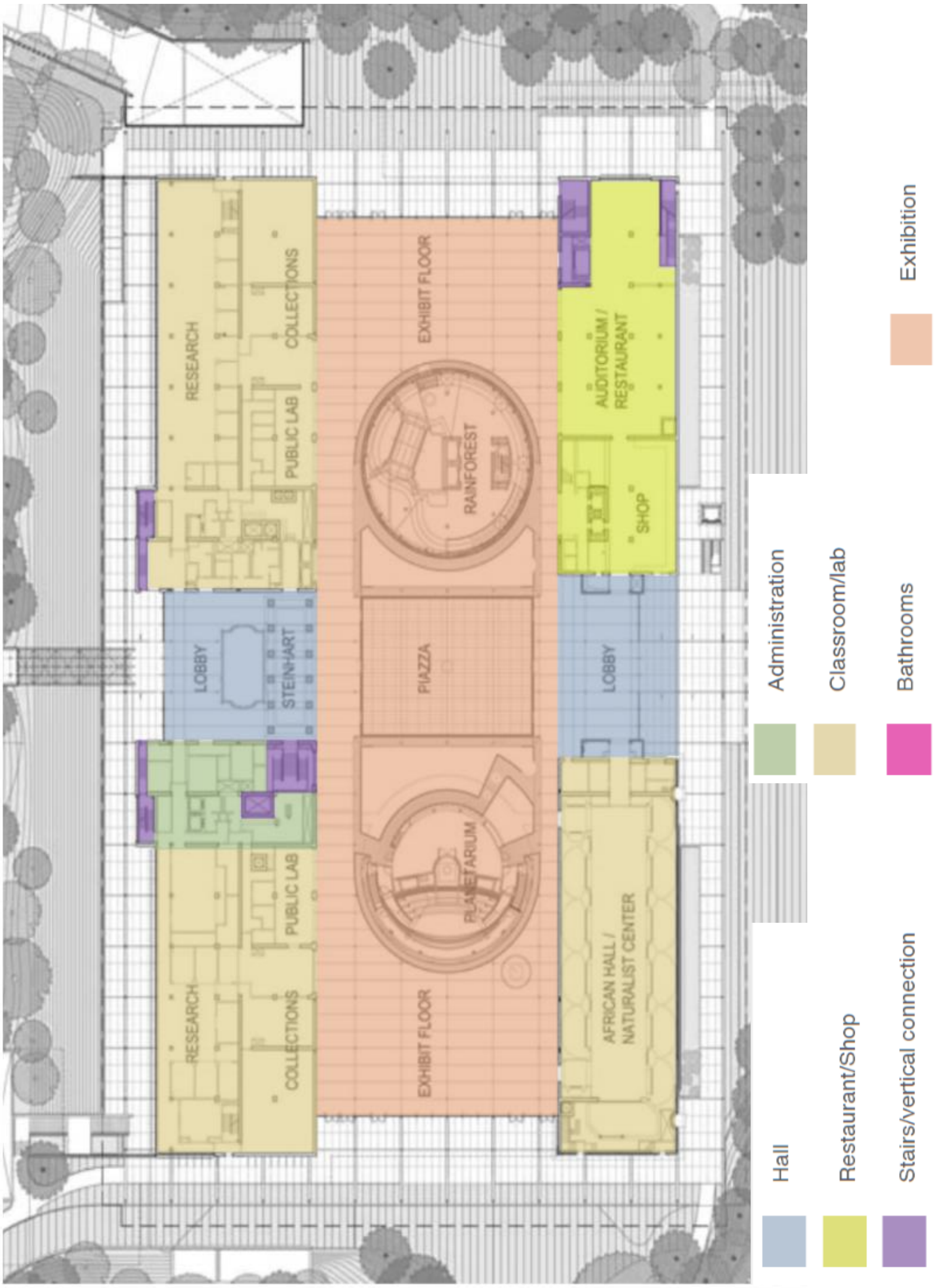



**Fig. 3.29** California science academy ground floor

### 3.6.3. GRAND EGYPTIAN MUSEUM

Designed to provide an Egyptology center of excellence for the next 100 years, the Grand Egyptian Museum will occupy a prestigious site near the pyramids of Giza. Following an international architectural competition, Arup is working on the design of the museum as part of a joint venture.

One of the most striking features of the new museum will be a translucent stone wall, 800m long. Separate from the building, the wall will rise to 40m in places, allowing visitors to explore the sheltered space behind. Illuminated by the dramatic lighting schemes of the main building, the wall will add night-time drama to the desert landscape.

Unlike any other museum in Egypt, the GEM will have its own state-of-the-art conservation center. Energy efficient electrical drives will ensure the HVAC system is able to maintain an optimal environment in which to preserve the museum's valuable historical monuments and treasures. Other parts of the project include the main energy center, conference center, museum building, food and beverage halls, children's entertainment areas and a ticketing building.

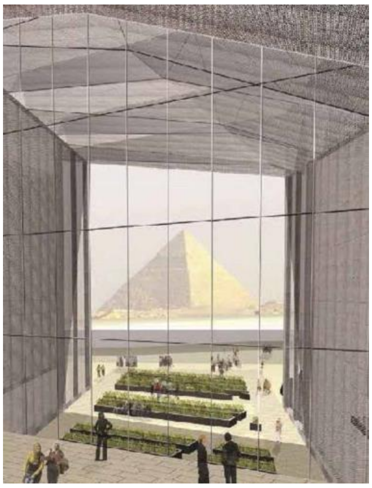
The site's main building will house the museum and a conference center, connected by a large shaded courtyard. As well as exhibition space, there will be an 800-seat auditorium. Nearby auxiliary and support buildings will house a restaurant, ticketing facilities and other services. On a separate part of the site, the conservation and energy center will house special laboratories for cleaning, cataloguing and restoring artefacts.

Areas of soft landscaping will provide outdoor leisure areas with internal circulation and access roads winding between them. The site area is 50 hectares. The building is characterized by 800 m long translucent stone wall. The building includes a huge piece of art (121 tons statue of Ramses).

The translucent stone wall will sit 10m from the main building, propped back to the building structure at mid-height and at roof-level. Elsewhere on site, it will be necessary to construct large retaining walls in order to achieve the architect's vision. The largest of these, the Menjaurus Wall, will be 500m and will reach a height of 35m in places.

The majority of the conservation and energy building will be underground so as not to detract from the landscape and to aid security and preservation. The highly controlled environment will link to the lower levels of the museum building via a 220m long underground tunnel. This enables artefacts to be transported securely, as well as housing services and offering a dedicated escape route via the 'middle' tunnel.

**Fig. 3.30** Egyptian Grande museum main facade



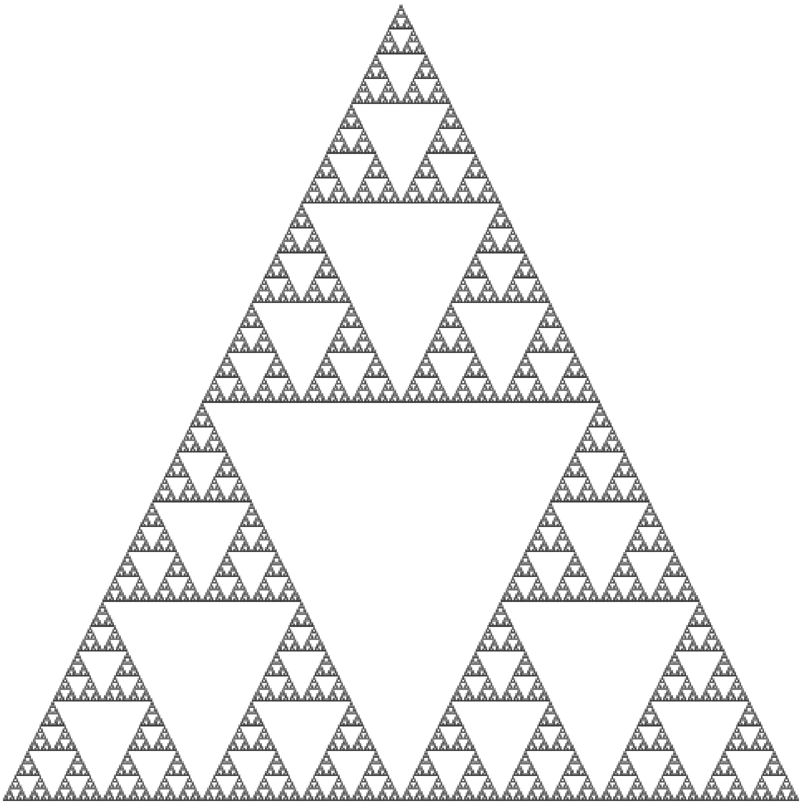
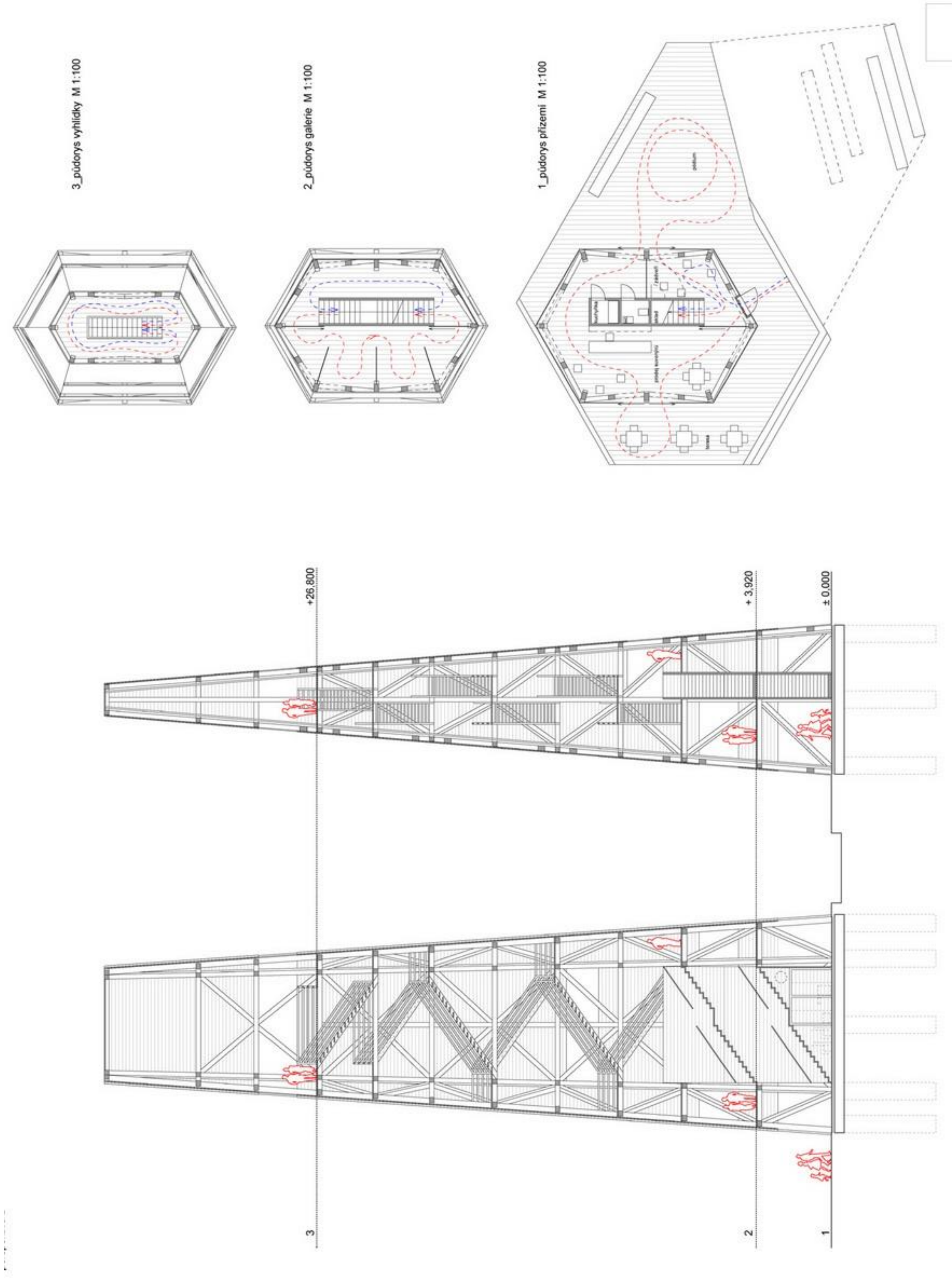
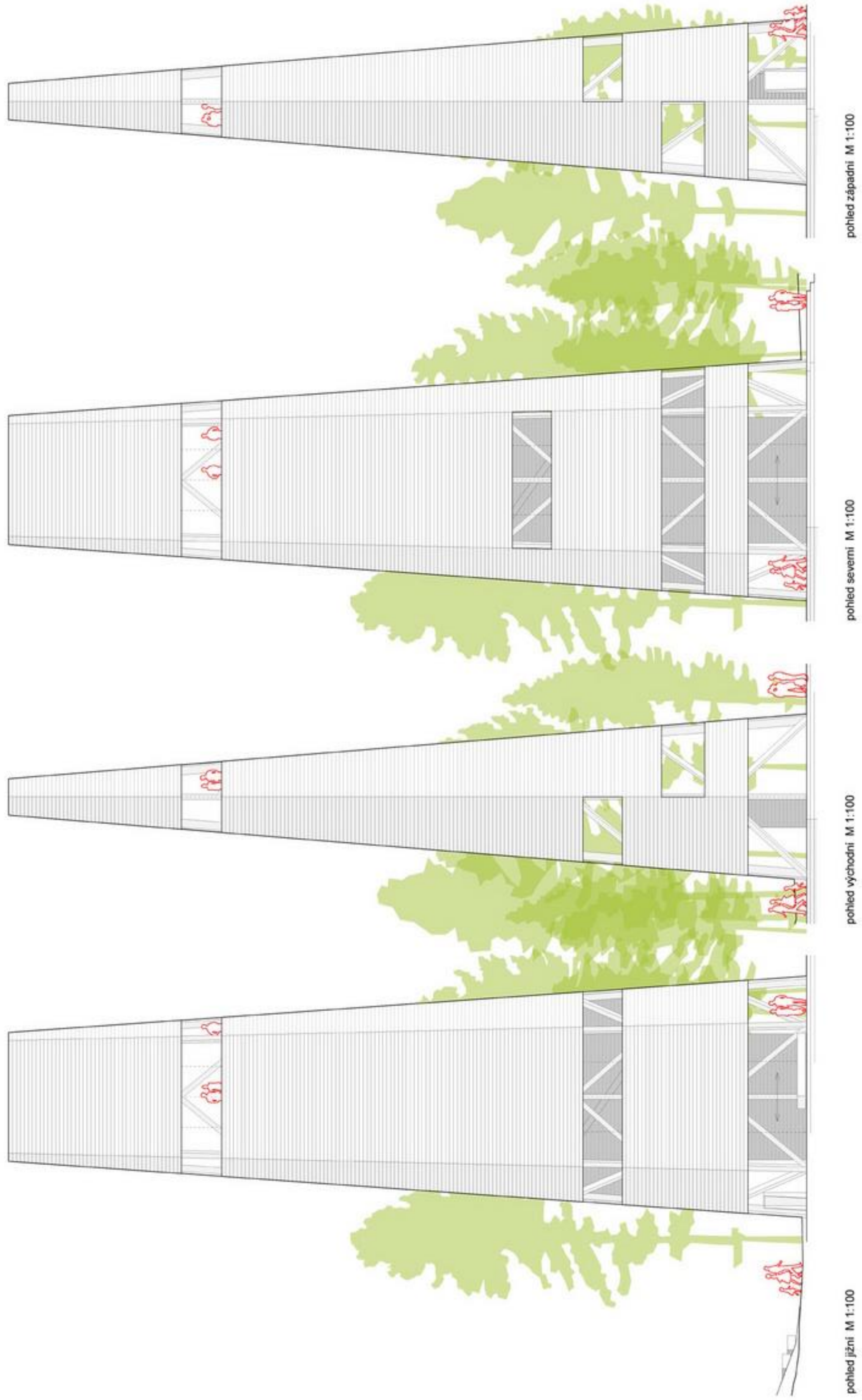


**Fig. 3.31** Egyptian Grande museum main façade pattern, science city skin design was inspired by the same pattern

### 3.6.4. OBSERVATION TOWER HÝLAČKA

hýlačka was always a popular spot for tourists. in addition, it used to be a place where people could meet and enjoy various types of entertainment – from amateur theatre to small exhibitions.
the atmosphere of the place and the iconic and unique shape of the original observation tower hýlačka led to respect this structure in many aspects – a logical outcome was a wooden framework built on a hexagonal basis and orientation of the main viewpoints towards the historical center of tábor. the design of the new observation tower is a kind of translation of the original tower into the modern architectonic language while the essence and fundamental values remain unchanged.
There are two hiking routes leading to the object, a zoo was built in the area and there is a playground and a sport area in the adjacent forest park. the goal was to embed the observation tower into this mosaic in a way that it would stand out only visually -it is considered as a traditional element of větrovy the concept thus deals not only with the tower itself but also with its surroundings. It was recommended to use the neighboring grass area as a place where to put benches, picnic tables and wooden playground elements. The observation tower would become a traditional spot for tourists for traditional sightseeing destination, offering more than just a view of the countryside.


3_půdorys vyhlídky M 1:100
2_půdorys galerie M 1:100
1_půdorys přízemí M 1:100
+26,800
+ 3,920
± 0,000
3
2
1


pohled západní M 1:100
pohled severní M 1:100
pohled východní M 1:100
pohled jižní M 1:100

# 4. DESIGN PROCESS

4.1. URBAN DESIGN
4.2. ARCHITECTURE DESIGN OF CAMPUS (2)
4.3. ARCHITECTURE DESIGN OF THE OBSERVATION TOWER
4.4. RENDERS

## 4.1. URBAN DESIGN

Landscaping is an important element in altering the micro-climate of a place. Proper landscaping reduced direct sun from striking and heating up building surfaces. It is the best way to provide a buffer for heat, sun, noise, traffic, and airflow or for diverting airflow or exchanging heat in a solar-passive design. Additionally, the shade created by trees, reduces air temperature of the micro climate around the building through vapor-transpiration.

The master plan for the project's area is a continuous development based on the municipality goals and actual recommendations which is looking for transforming the area to an integral part of the city and act as a cultural bridge that connects different users.

The main aspect was to approach the masterplan through two main piazzas, one is collecting the visitors from the highway and main roads, and the other one is working as a hinge that connects the science city with the surrounding residential neighborhoods and connects it with the nearby university MSA by three spines.

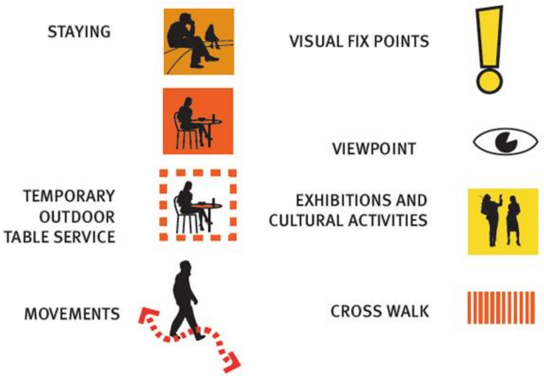



**Fig. 4.1** Urban design tools

However, improving street quality around the science city site is a necessity. Streets need to be paved and furnished to enhance the accessibility to the site. In order to give a high quality to the project and its master plan, the first decisions have to come from the surroundings as shown in fig. 4.3

In addition, maintaining a vibrant district through providing livable areas including (outdoor seating, temporary outdoor elements, exhibitions and cultural activities). All of these landscape features fig. 4.1 can be done through adjusting and designing adequate routes, sidewalks, viewpoints and movements.

As a representation of the identity of the Nile of Egypt, simple shallow water channels fig. 4.2 have been used in the site taking into account the solar intensity constraint, so water can evaporate easily. Water is a good modifier of micro-climate. It takes up large amount of heat in evaporation and causes significant cooling.

Water has a moderating effect on the air temperature of the micro climate. It possesses a very high thermal storage capacity much higher than the building materials like brick, concrete, stone. During the day the air is hotter over the land and rises, drawing cooler air in from the water mass resulting in land breezes. During the night, as the land mass cools more quickly, the airflow will be reversed. Water evaporation has a cooling effect on the surroundings.

**Fig. 4.2** Shallow water channel

### 4.1.1. URBAN CONTEXT

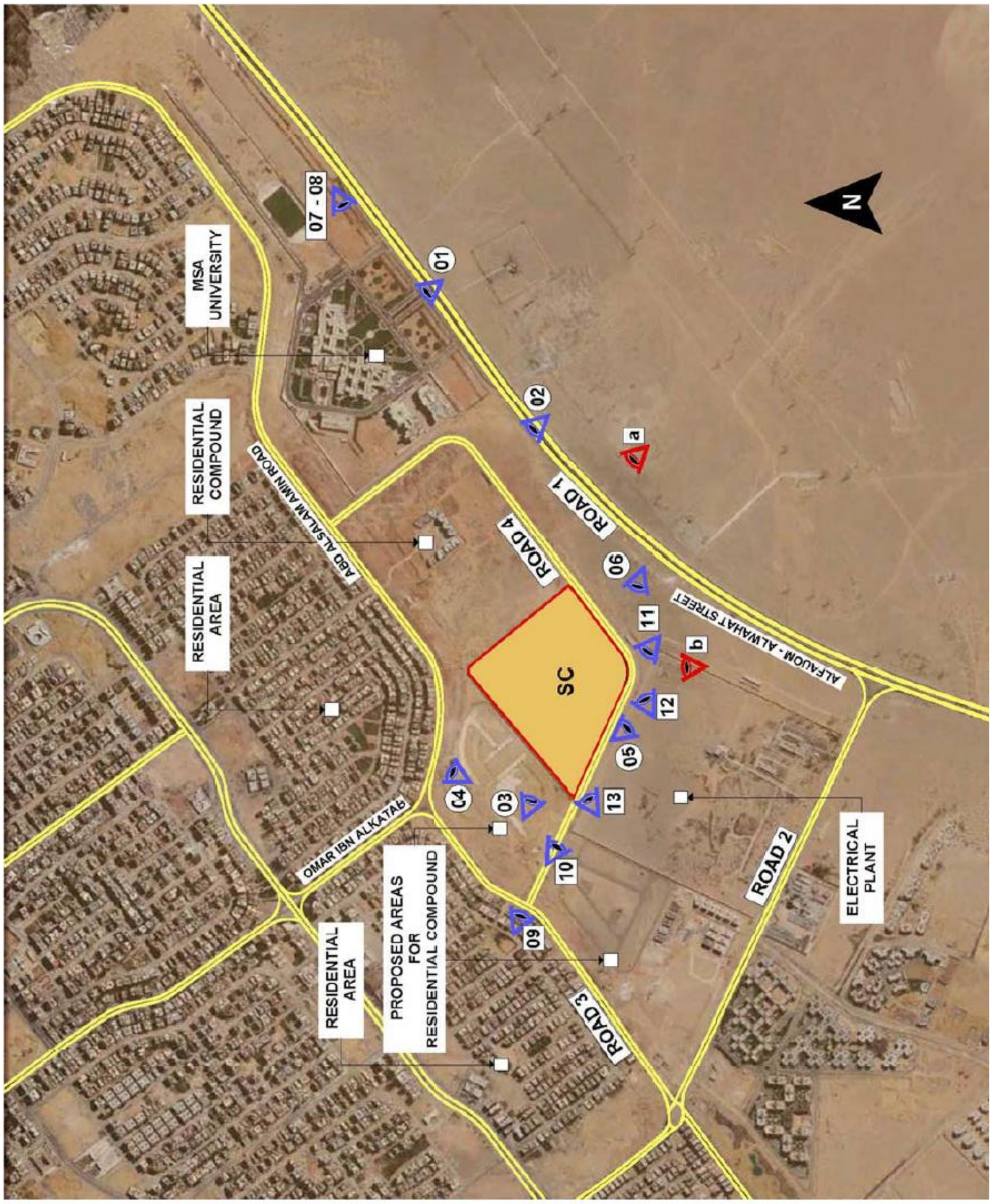



**Fig. 4.3** Science city site and its surroundings

**(a)** Site panorama view
North West direction

**(b)** Site panorama view
North direction


**(01)** Modern science and Art university MSA

**(02)** Highland park compound

**(03)** Vacant land Northwest of the site

**(04)** Residential area at the Northwest in proximity to the site

**(05)** Electrical plant area

**(06)** Electrical plant facing the site

**(07)** Al Wahat Al fauom Road

**(08)** Al Wahat Al fauom Road

**(09)** Internal Road #4

**(10)** Internal Road #4

**(11)** Internal Road #4

**(11)** Internal Road #4

## 4.1.2. SITE ANALYSIS


**Fig. 4.4** Site analysis diagram

### 4.1.3. MASTER PLAN


**Fig. 4.5** Master plan 1:1000

**Fig. 4.6** Master plan and surrounded neighborhood

### 4.1.4. SITE VEGETATION


**Fig. 4.7** Used hard and soft scape

| Code | Image | Botanical name | Dimensions |
|---|---|---|---|
| SY-RO |  | SYAGRUSS ROMANZIFIANA | spread: 3-4m<br>trunk height: 4-5 m<br>trunk diameter: 2" |
| YU-AL |  | YUCCA ALOIFOLIA | spread: 1.5 m<br>height:2m |
| CI-SI |  | CITRUSS SINENSIS | trunk height: 4m<br>spread: 3-4 m |
| MA-GR |  | MAGNOLIA GRANDIFLORA | trunk diameter: 3 "<br>height: 2.5 - 3.5 m,<br>spread: 3-4 m |

**Fig. 4.8** Used vegetation in the site

## 4.2. ARCHITECTURE DESIGN OF CAMPUS (2)

### 4.2.1. FUNCTIONAL REQUIREMENTS

Due to the complexity of the science city design program, the study of the eight components of the science city:

- Exhibition halls
- Conference center
- Planetarium
- Science park
- Research center
- Observatory tower (landmark of the project)
- Administration
- Technical services

We pointed out the best connections between the different elements of the project as the following functional diagrams.
Since it is a science city project, the orientation and information hall is the main component where from the visitors can know how to discover the science city, once entering in the hall of each of the three campuses, you can choose where you go in the exhibitions area, in the conference zone, in the auditorium, in the research or in the workshops area.
In the following functional programs, it is pointed out how the different functions are connected with each other and with the orientation and exhibitions hall.

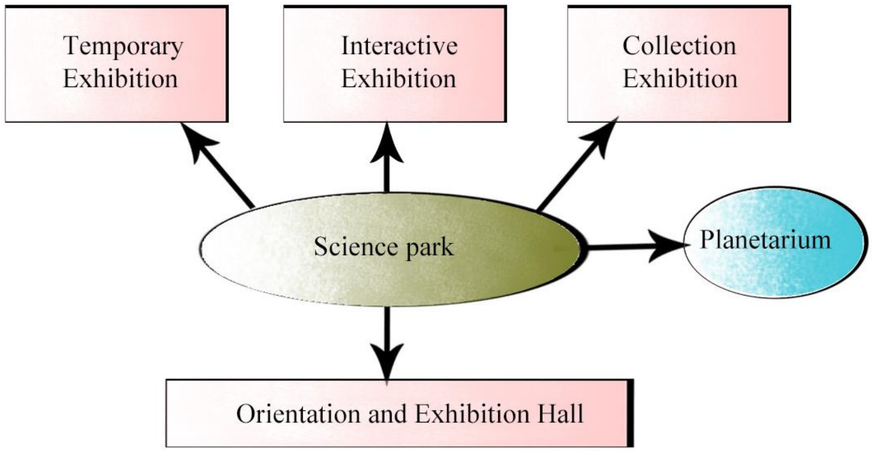



**Fig. 4.9** Science and exhibition hall

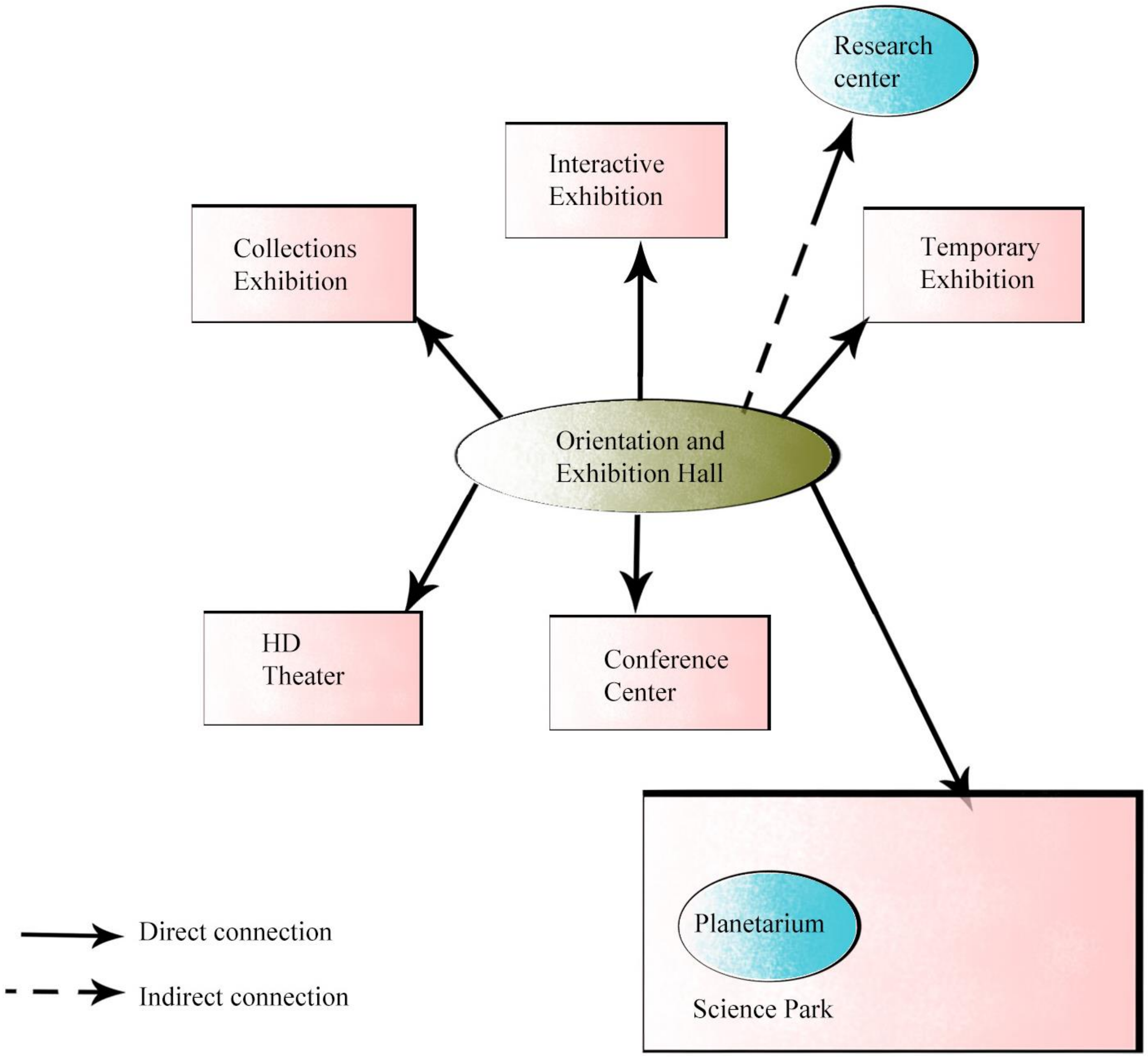



**Fig. 4.10** Orientation and information hall spatial relation diagram

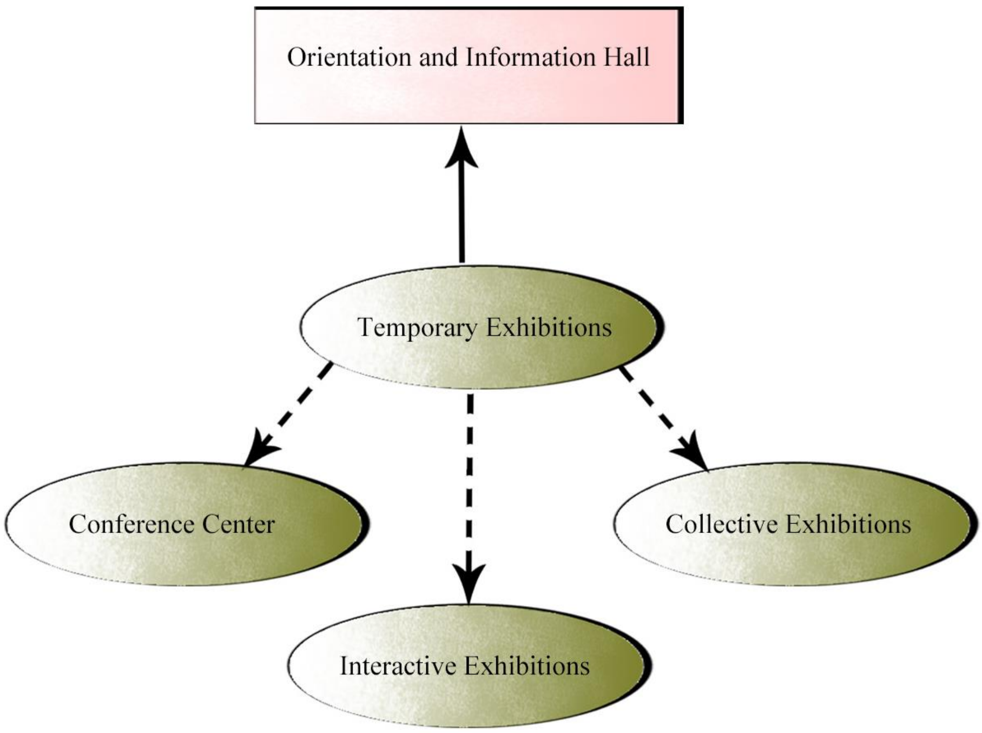



**Fig. 4.11** Temporary spatial relation diagram

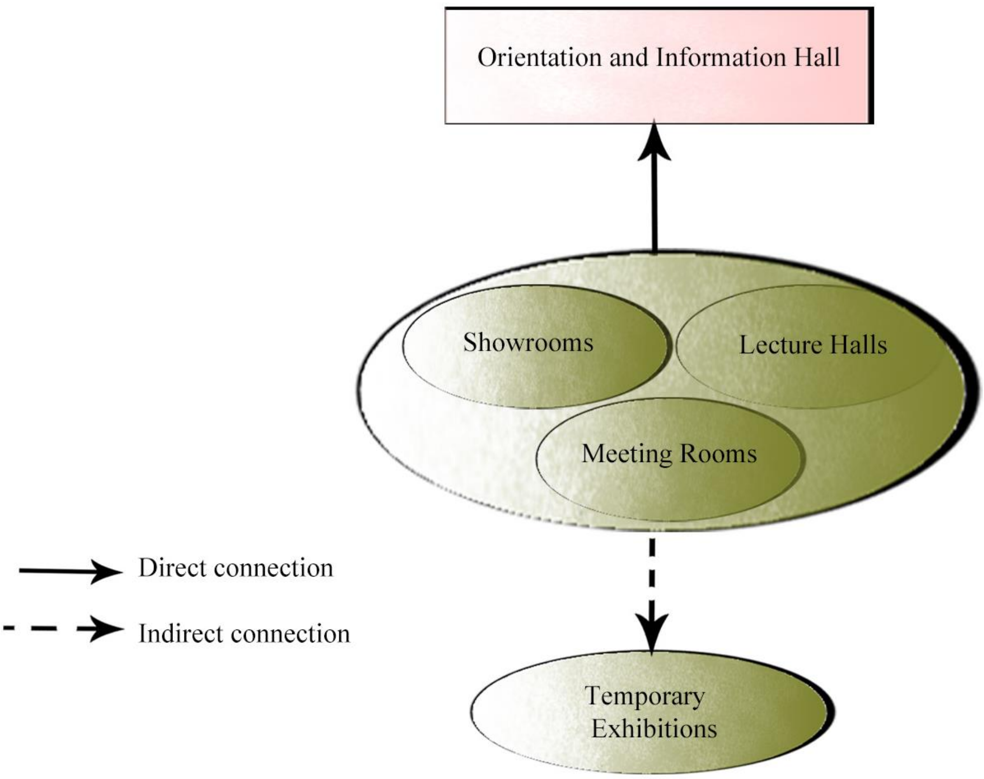



**Fig. 4.12** Conference facilities spatial relation diagram

### 4.2.2. BUBBLE DIAGRAM

After studying the eight components of the science city and each function of each component, the following bubble diagram shows all the functions proposed, as well as connections in between them. This will be important input for further development of the volume of the science city complex.

The diagram divides the functions into:

- Main components
- Sub-components
- Sub- facilities

And divides the connections between them to:

- Direct main connections
- Direct secondary connection
- Indirect connections

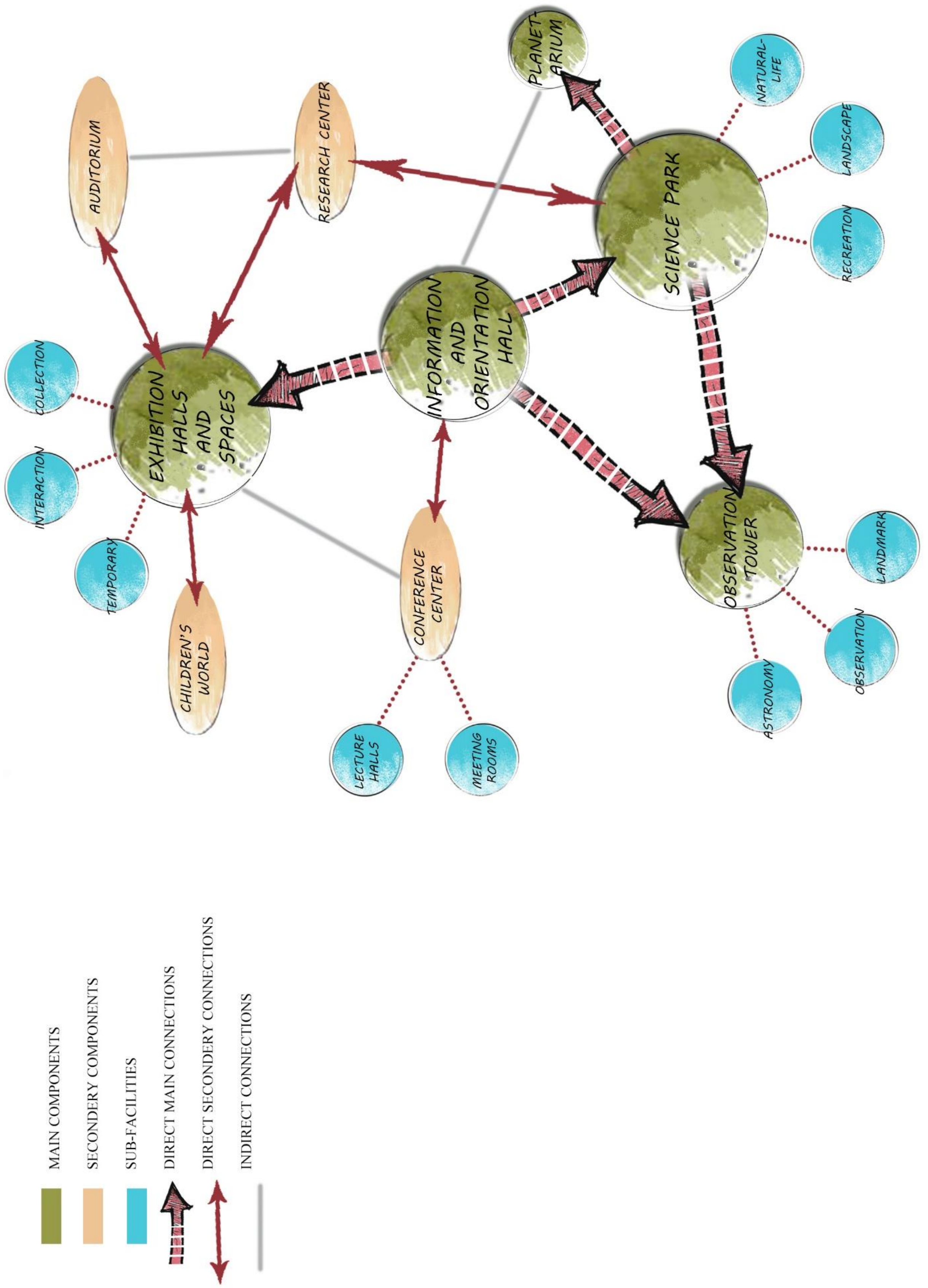
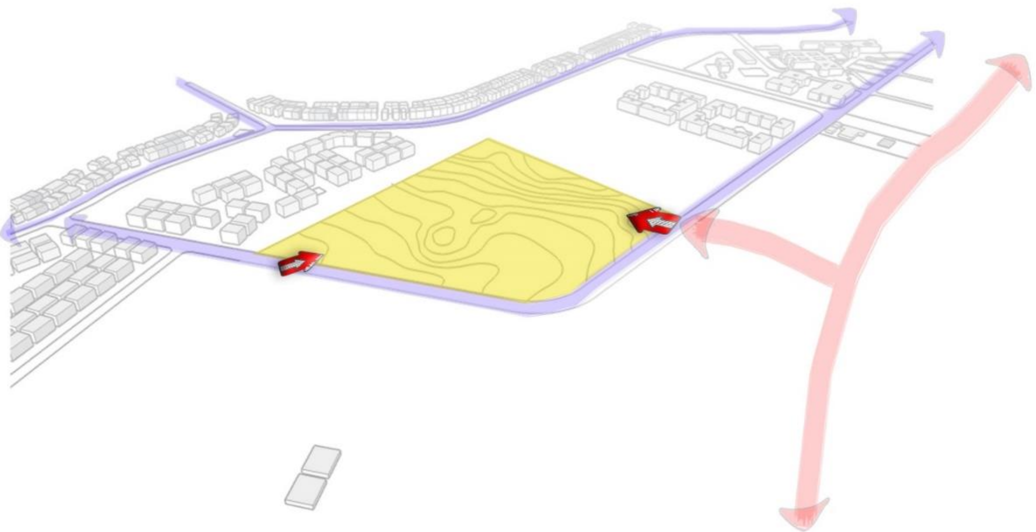



**Fig. 4.13** Bubble diagram

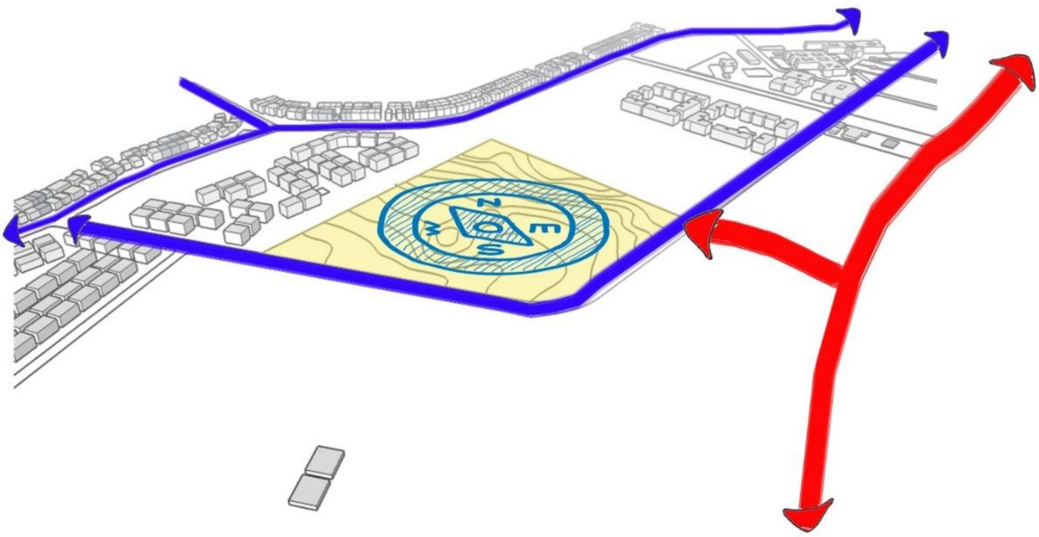
### 4.2.3. VOLUME DIAGRAMS

- In the design phase of the science city, it has been considered to combine the science complex together with their immediate surroundings.
  It was important to connect the complex with the surrounding residential compounds.
  And connect the complex to the main educational spots in the site (MSA university) to be an educational spot for the students.
  The site is easily accessible from the surrounding roads and after studying the hierarchy of the surrounding roads, it has been indicated the main and secondary entrances for the project.

**(1)**

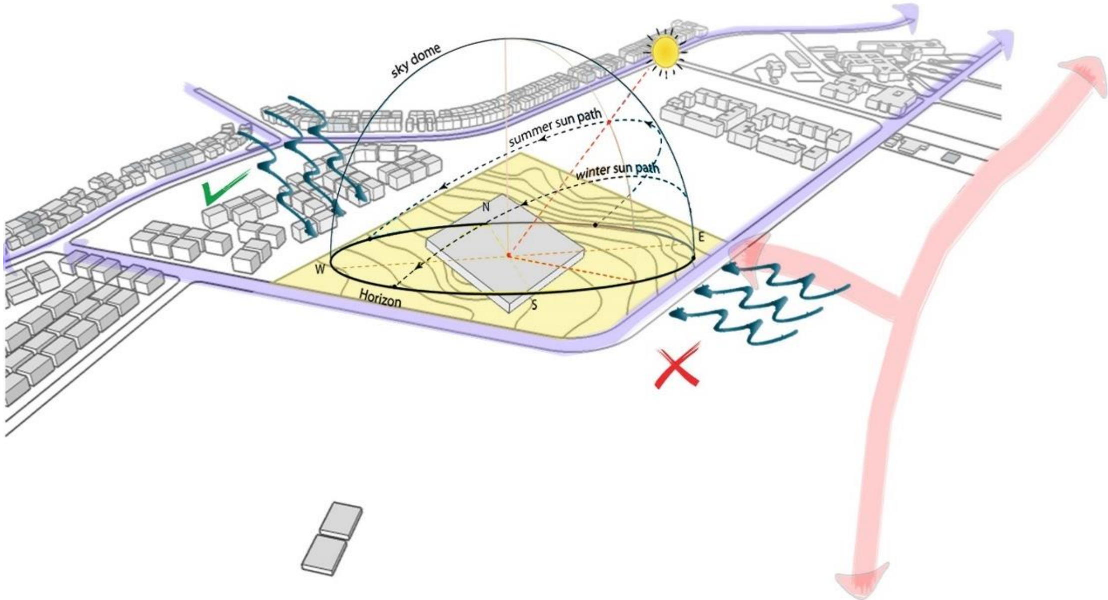


**(2)**



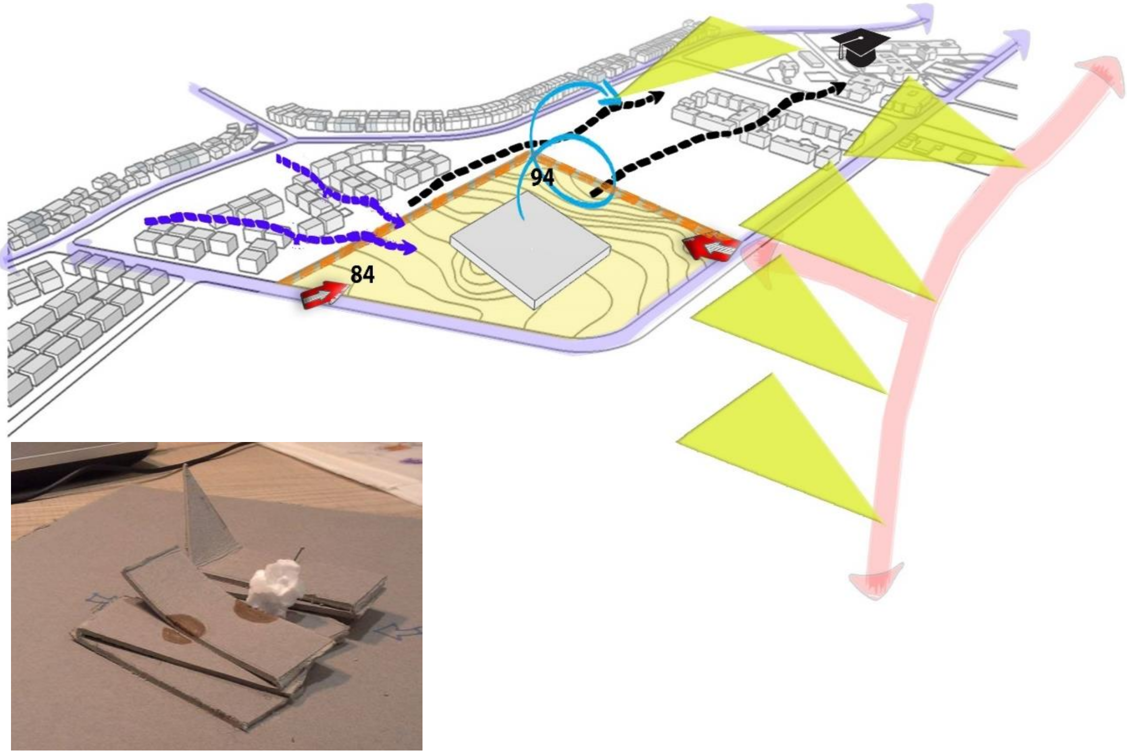
- The sun path, the wind directions have been studied in the design phase to enable us to take good sustainable decisions in designing the science city.

**(3)**




- The observation tower should be designed to be a landmark of the science complex and shall mark the zone of the 6th of October city so that it should be the highest point of the project.

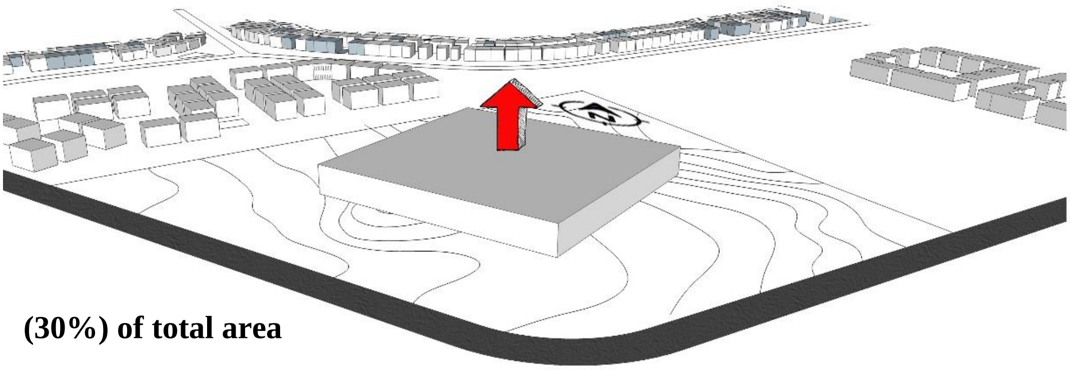
**(4)**




- According to the design program, the maximum built-up area is 37,498.44 $m^2$ not to exceed 30% of the total area.

(According to the 6th of October City Council regulations and permitted 3 floors heights).

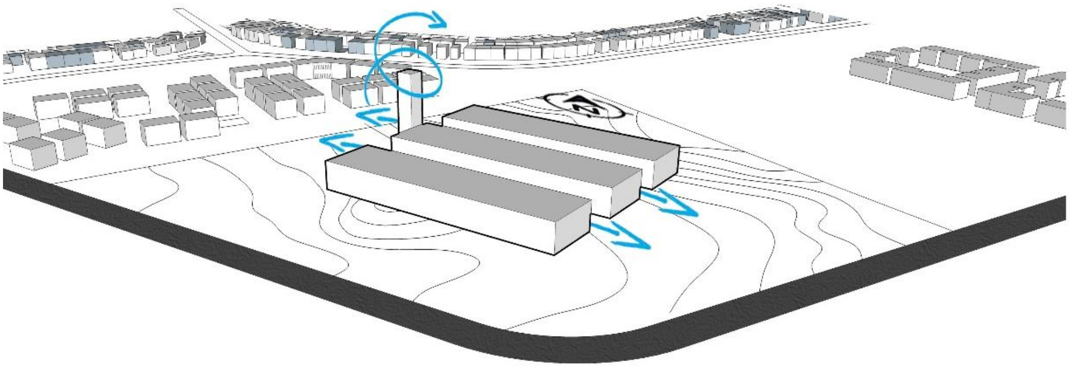
**(5)**



**(30%) of total area**

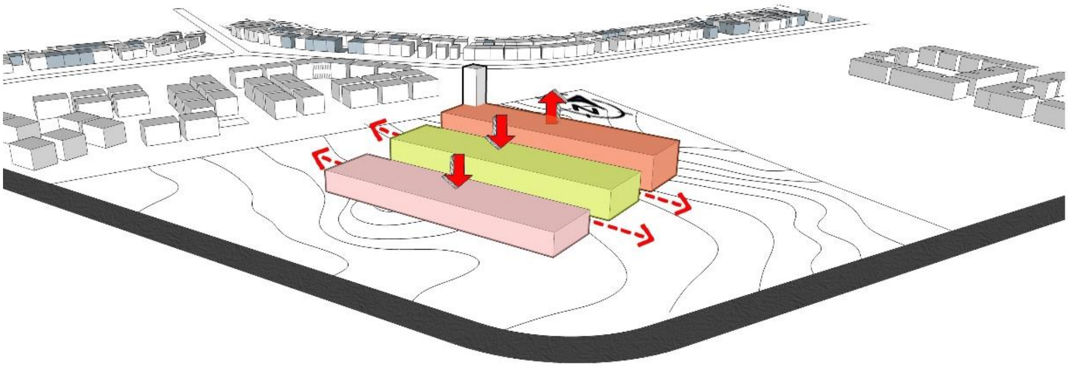
- The program divisions providing open spaces in between the three campuses of the science city interconnected with the surrounding science park and the context

**(6)**



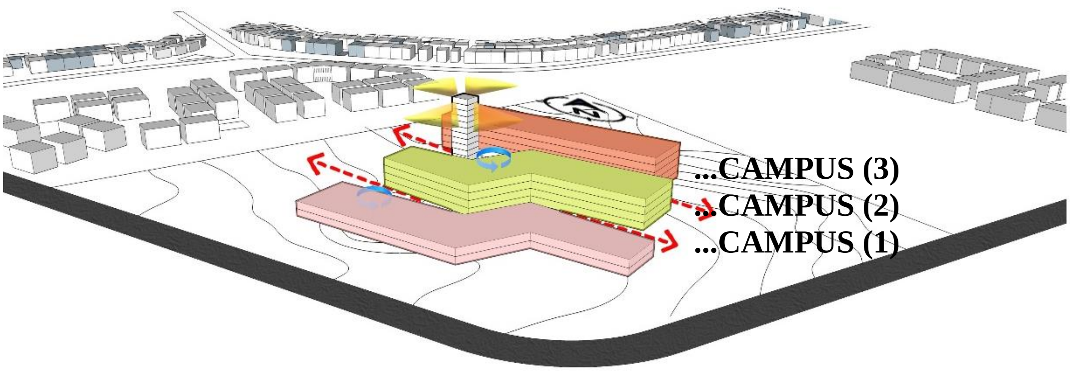
- A stepped relation has been created between the three campuses as the first campus consists of two floors, the second campus is consisting of four floors and the third campus consists of five floors, these were affected by the gentle slope of the site as there is a difference of 10 m from the south to north of the site.

**(7)**



- Campus (1) at the south direction and Campus (2) located in the middle have been rotated to provide more open spaces that could be used by different users, in addition a gateway has been implemented at the west side of the site to provide a main piazza of the project and has been highlighted with the observation tower in the middle of the piazza surrounded by hard scape elements to force the interaction of the visitors

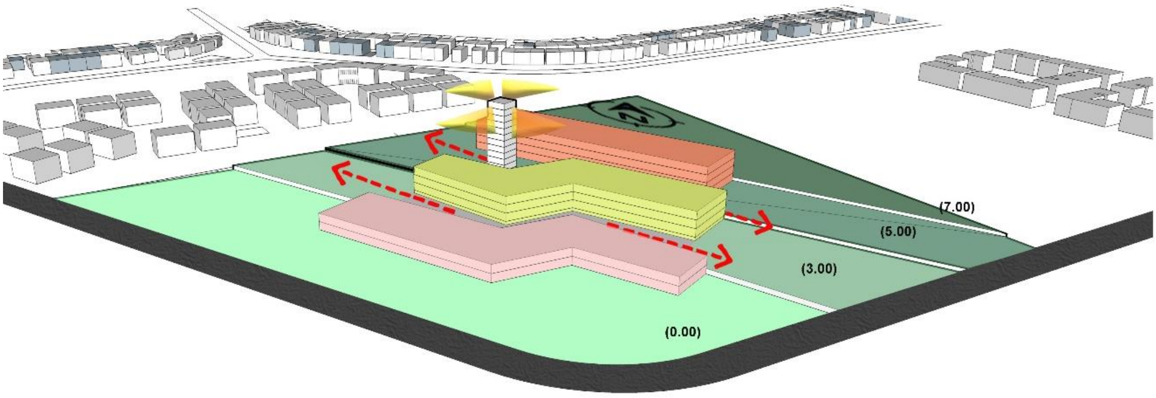
**(8)**




- During the volume development the solar path according to the building orientation has been taken into account to maintain the maximum amount of natural lighting to the research and workshops spaces and facilities keeping in consideration the amount of sun exposure to avoid any kind of glare that may affect the research and workshops. Because of this, they are located in the north direction at campus (3).
- The three campuses are surrounded by the science park in four levels (0.00 m, 3.00m, 5.00m and 7.00m) using the topography of the site as there is a difference of 10 m from site south to north directions

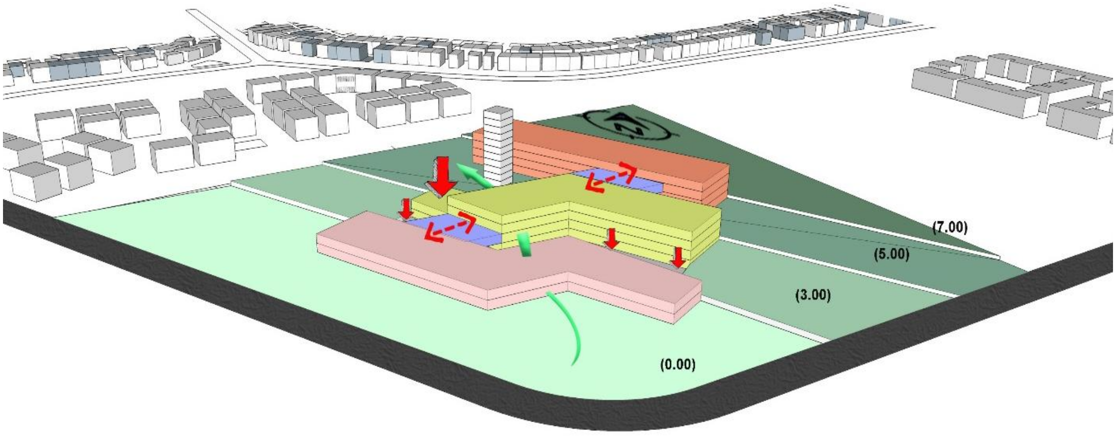
- The volume composition and solid-void relation have been developed in accordance with the wind flow direction to give the possibility of natural ventilation.

**(9)**




- Around the campuses' boundaries, it was important to provide a clear relation between the indoor spaces and the extended science park around them, so that a green spine has been created to connect the project parts together and create a smooth harmony of moving from landscape to hardscape, that's why a number of wooden decks have been designed surrounding the observation tower.
  The relation between the three campuses was defined through the landscape design on the ground level (+5m), however it was important to develop a secondary relation between the three campuses, that's why the bridges have been implemented between the three masses

**(10)**



- Some wind catchers have been implemented in the design to be a sustainable passive strategy for the project.

**(11)**

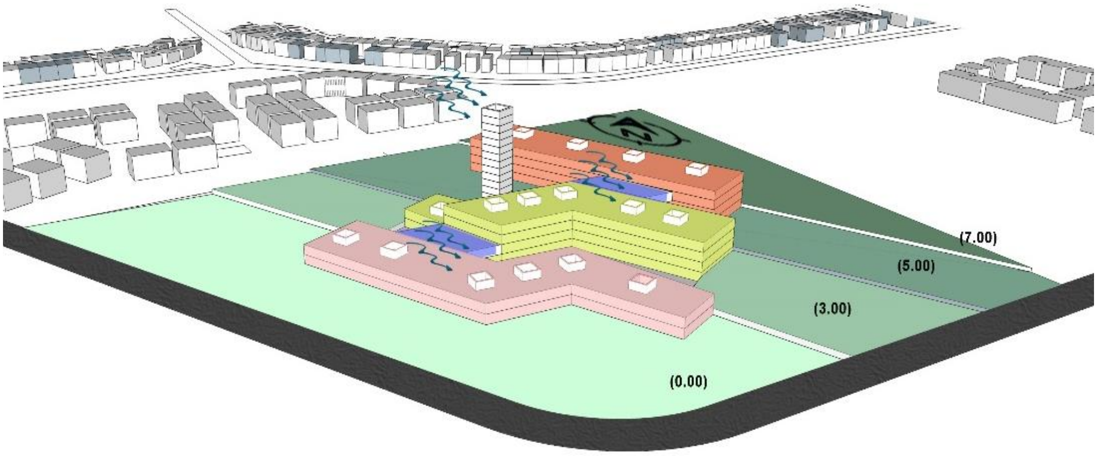



**Fig. 4.14** Volume diagrams

### 4.2.4. SCHEMATIC DESIGN

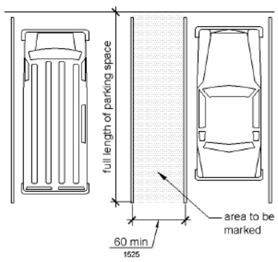
**Campus (2) is** considered the most vital campus occupied by mixed functions in the science city as it is a central building between the other two campuses and is considered the south wall of the central piazza. It includes the main functions in the science city like (exhibitions, planetarium, administrations, information center) and it is connected with the two other campuses by links from south and north directions, this is why it has been chosen for studying.
In the schematic design phase, the eight components of the science city have been organized together into the campuses as shown in the following diagrams to create a harmony relationship between the building, the site and the context.
Some codes (Egyptian and international) have been used for helping us how we can design for example the garage and how to make our project suitable for disabled people.

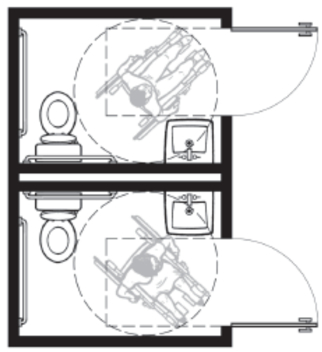
- **The Egyptian garage code.**

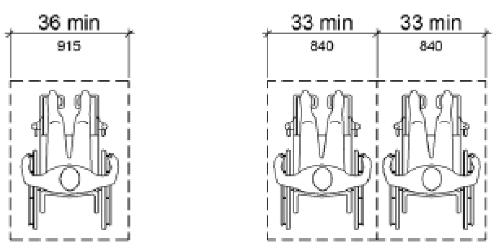
Two garage entrances from levels +6m and +3m to basement level (±0.00) have been created, the slope of the ramp is 1:7 according to the code

- **ADA standard**

It helps in understanding disabled people’s needs in the project






(a)
single space

(b)
two spaces

Basement floor plan ± 0.00 (level 1)      1-1000

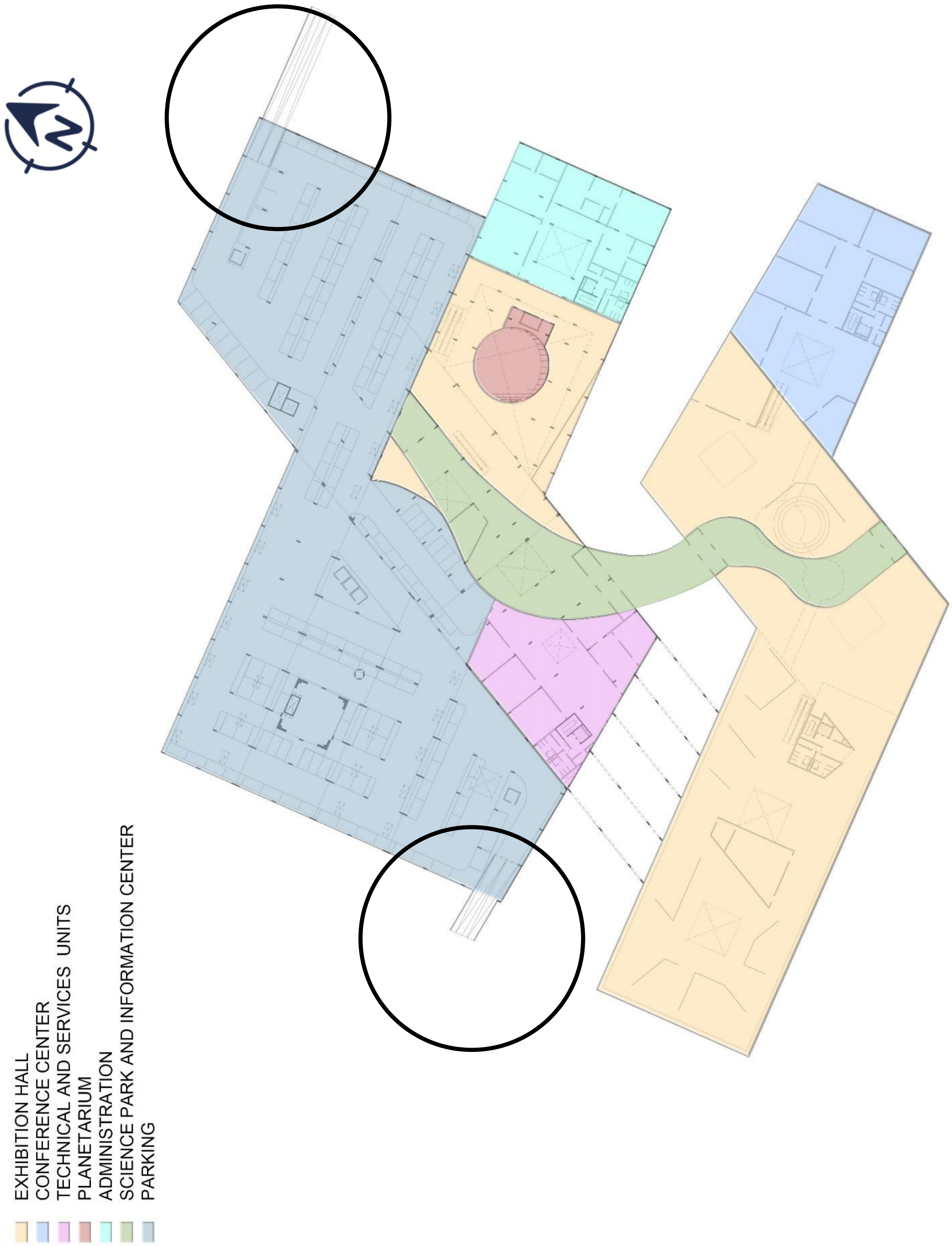



**Fig. 4.15** Functions distribution level 1

Ground floor plan + 5.00 (level 2)     1-1000

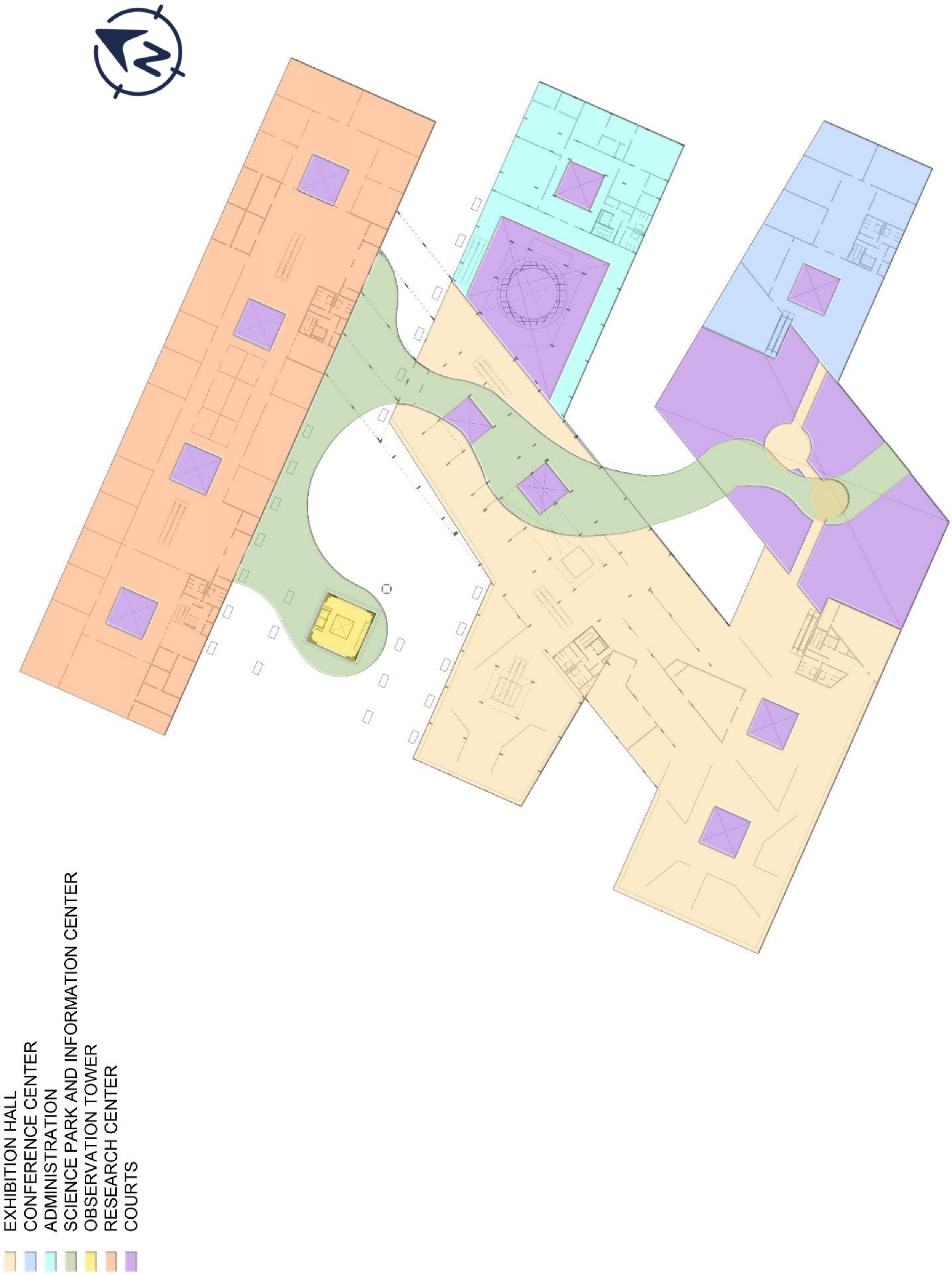



**Fig. 4.16** Functions distribution level 2

First floor plan + 10.00 (level 3) 1-1000

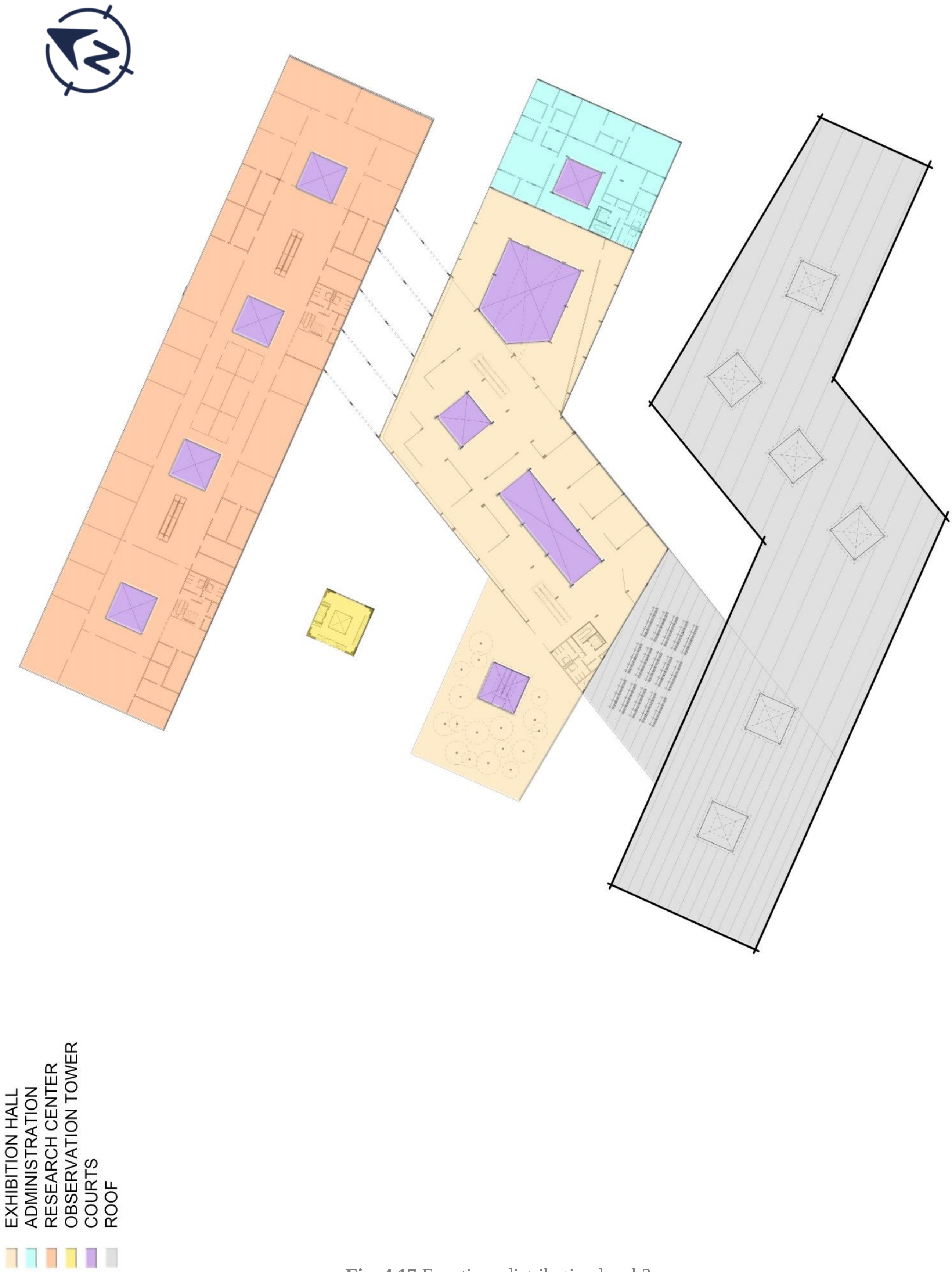



**Fig. 4.17** Functions distribution level 3

Second floor plan + 15.00 (level 4) 1-1000

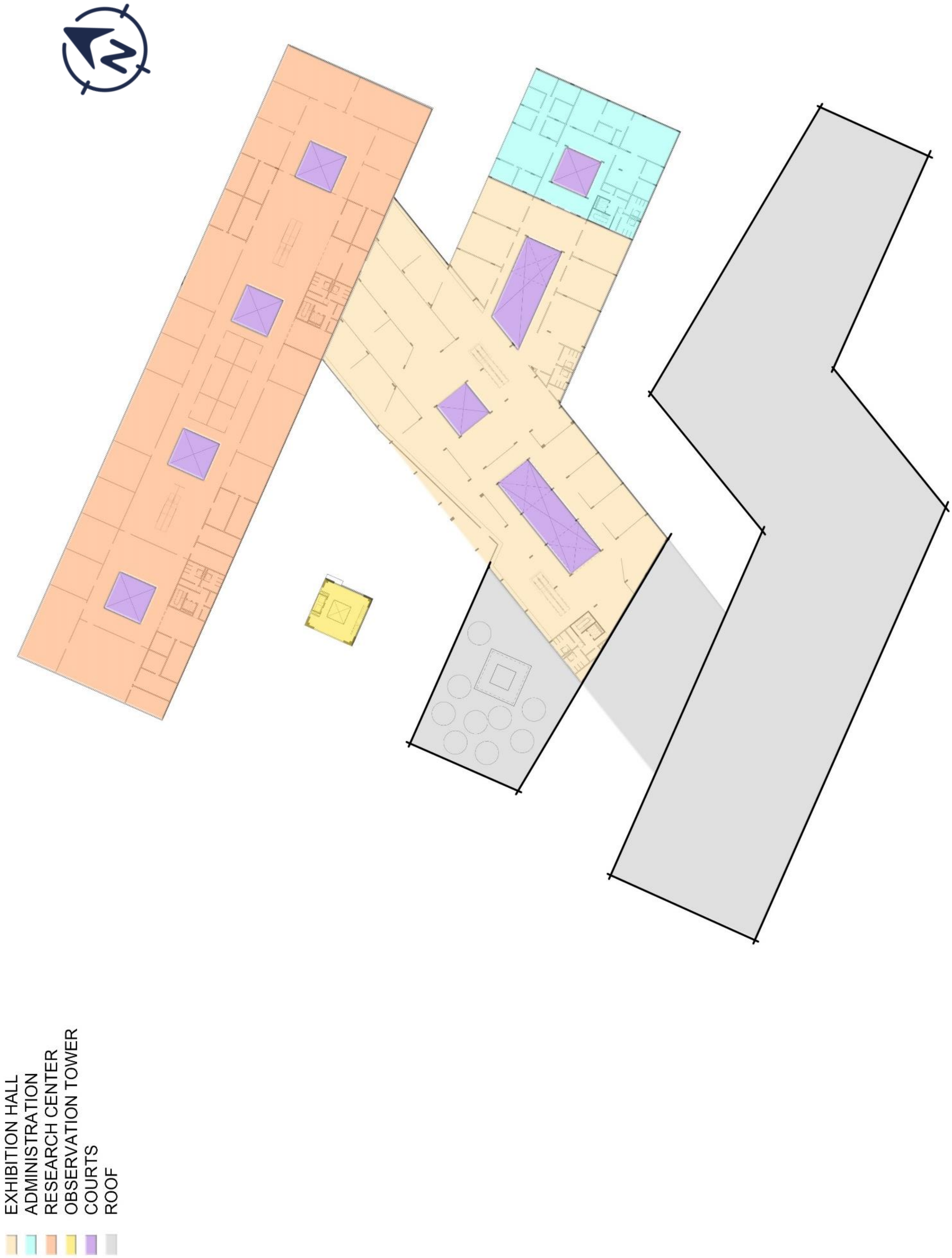



**Fig. 4.18** Functions distribution level 4

Roof floor plan + 20.00 (level 5)      1-1000

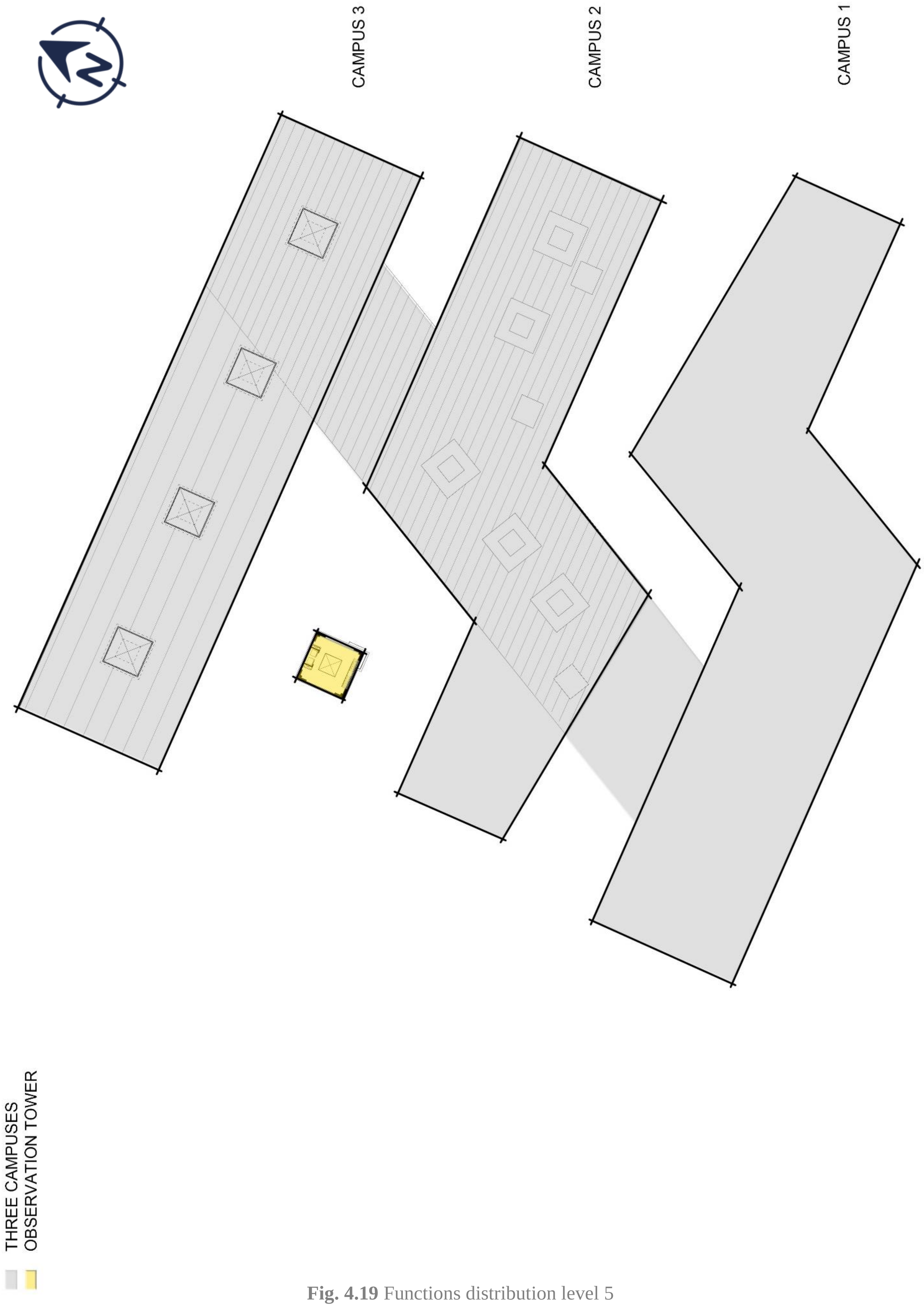



**Fig. 4.19** Functions distribution level 5

## 4.2.5. HORIZONTAL CIRCULATION

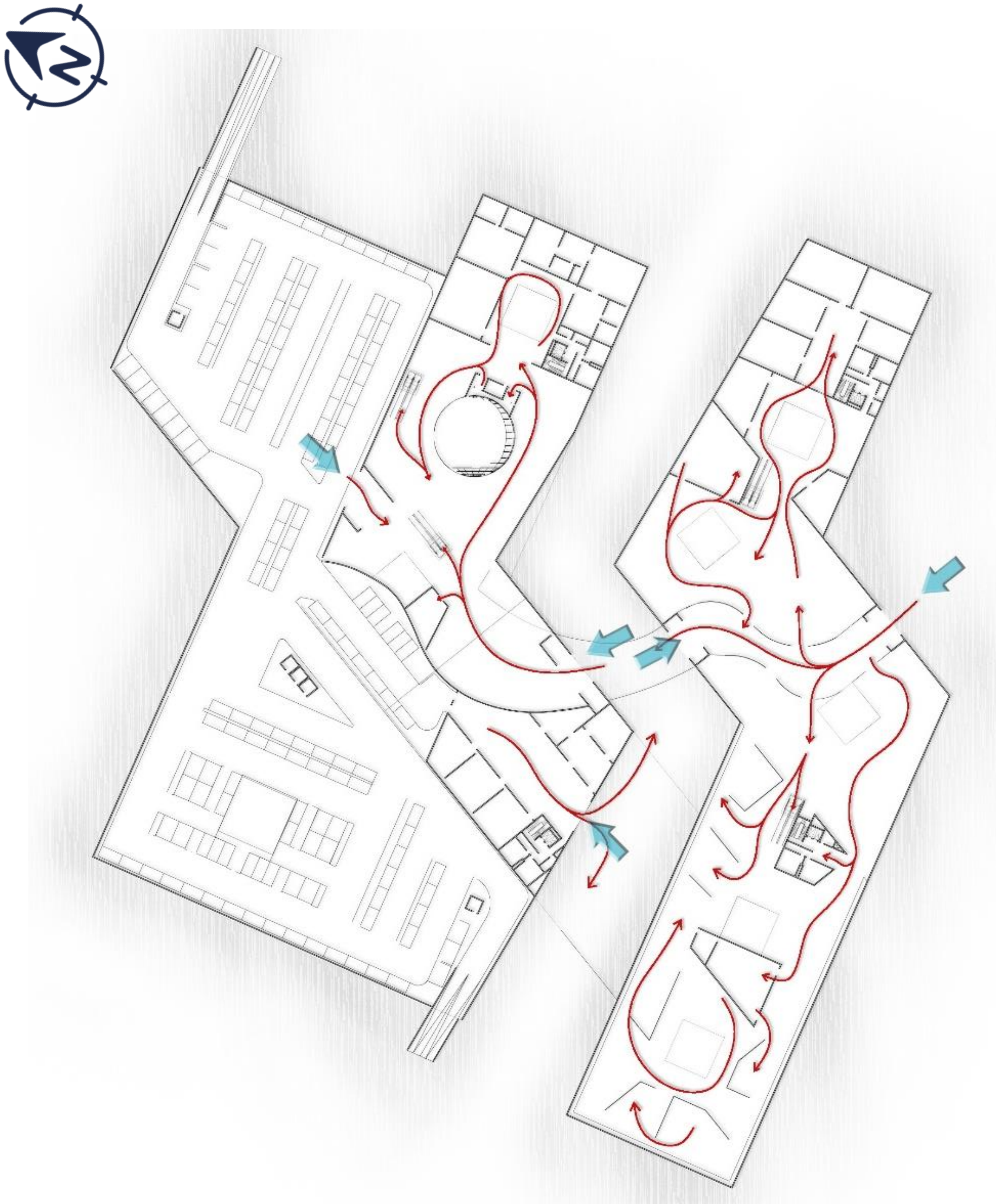


**Fig. 4.20** Horizontal circulation level 1

**Fig. 4.21** Horizontal circulation level 2

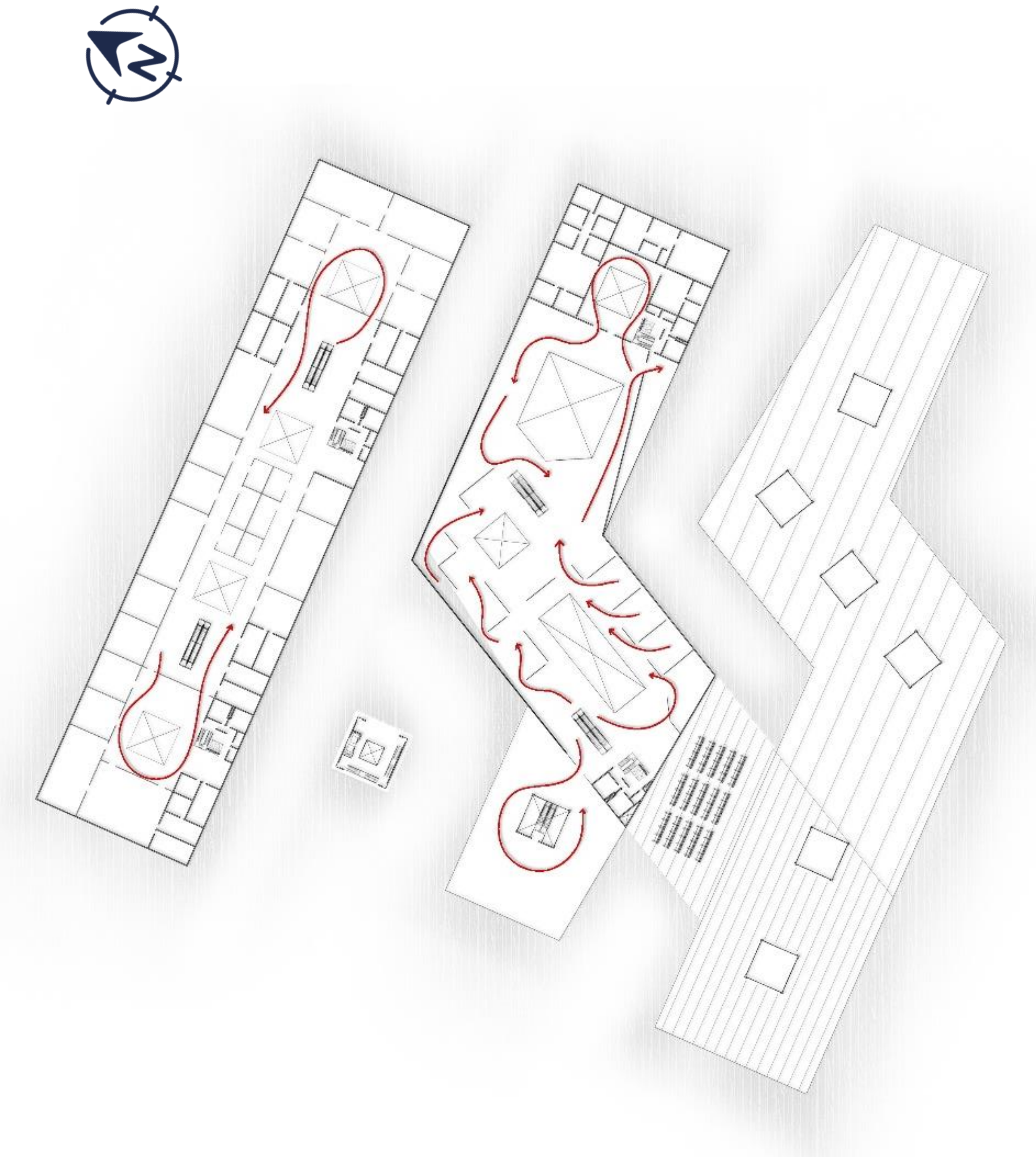


**Fig. 4.22** Horizontal circulation level 3

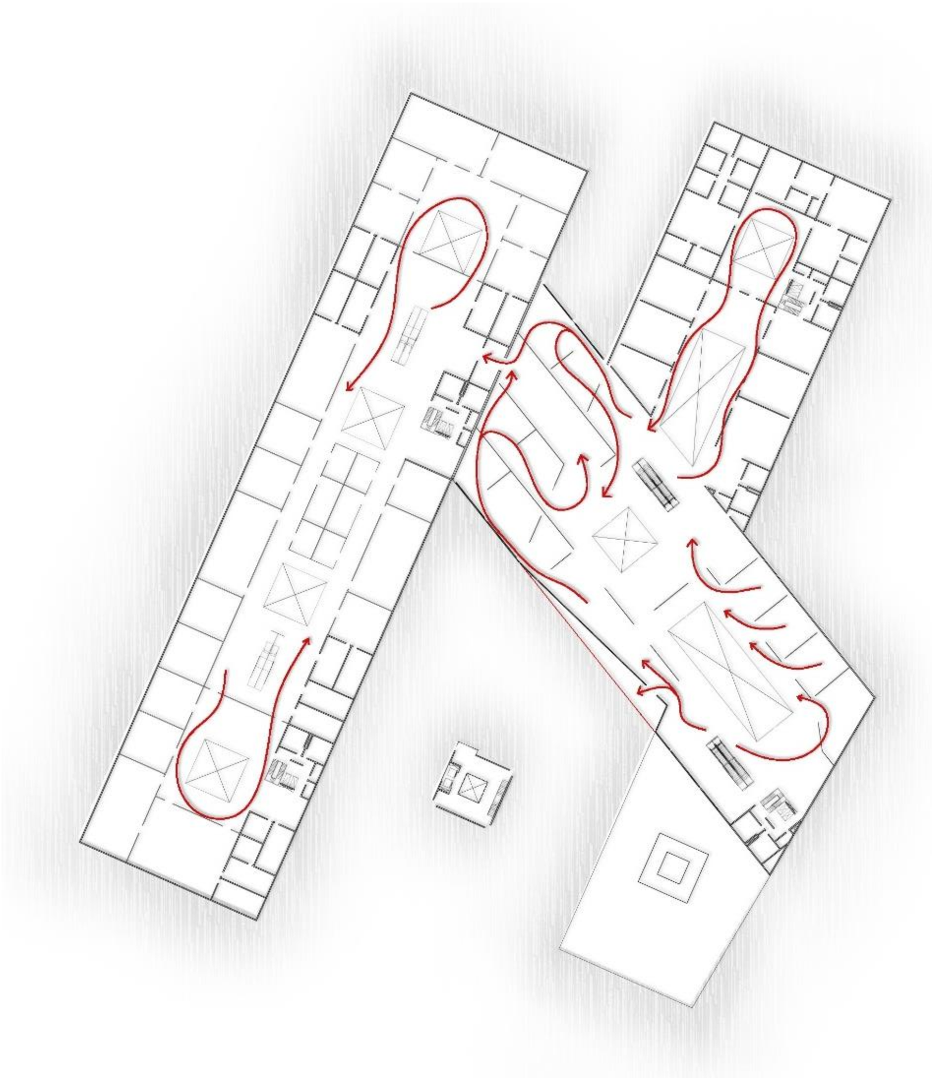


**Fig. 4.23** Horizontal circulation level 4

### 4.2.6. VERTICAL CIRCULATION

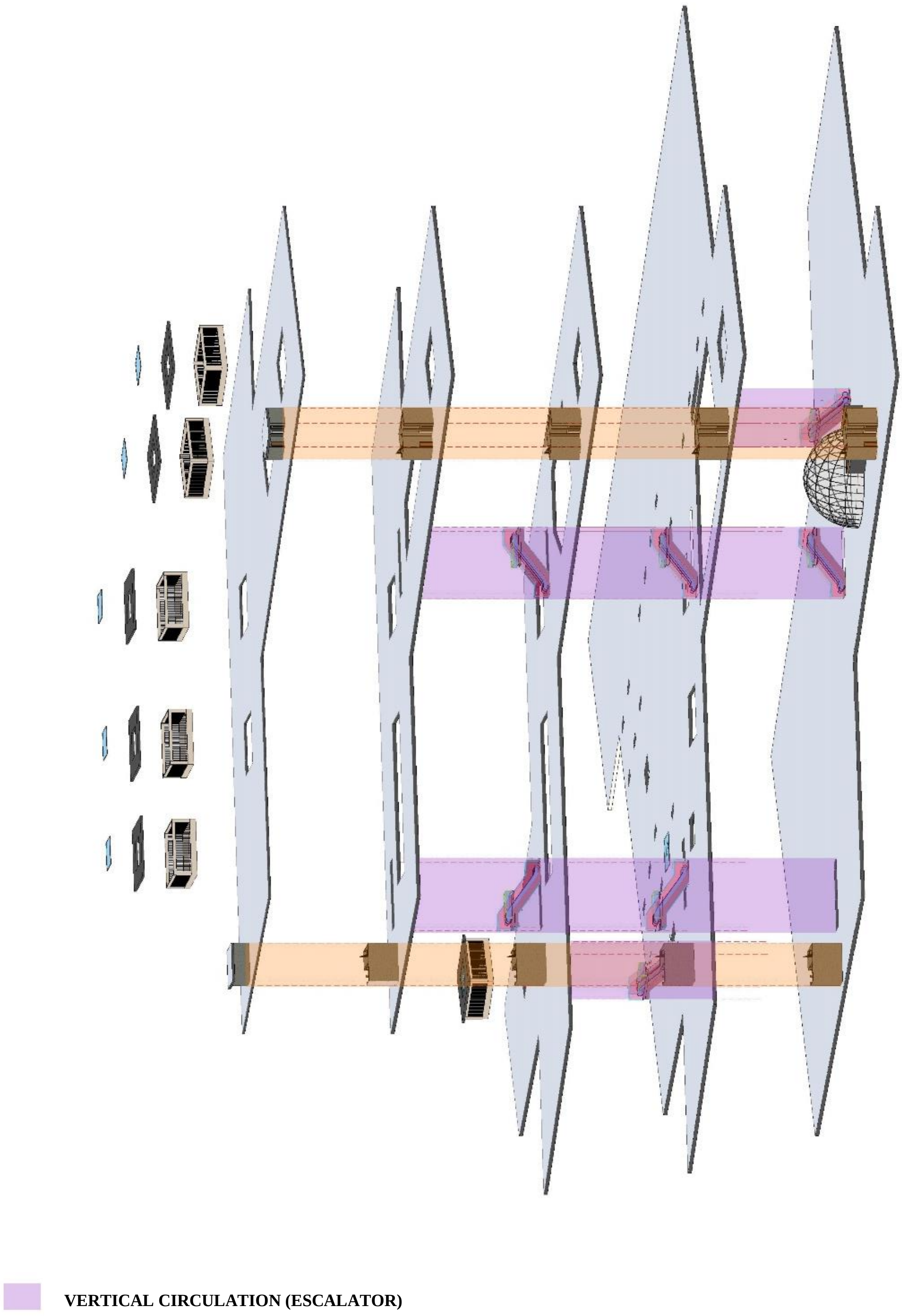


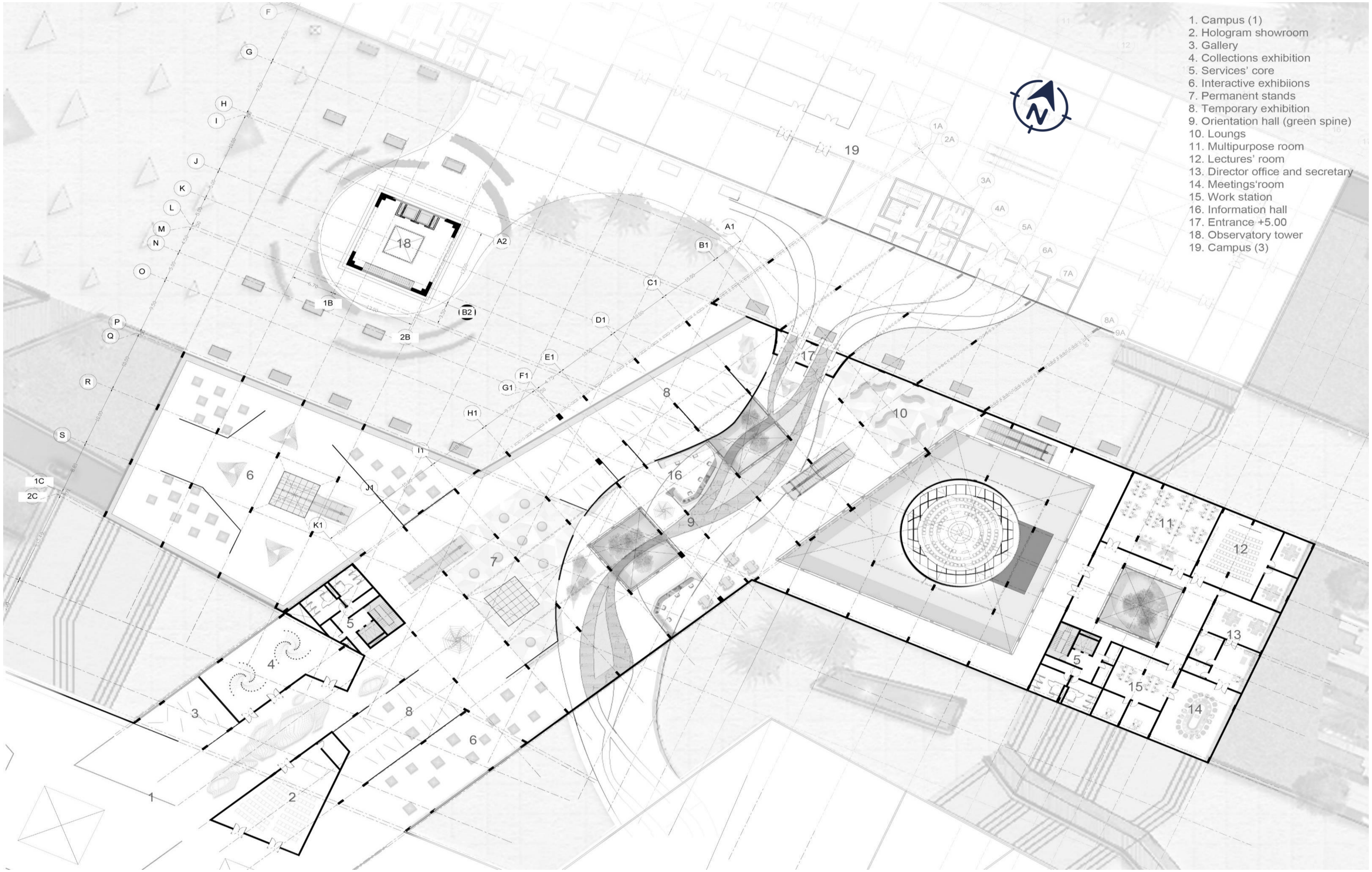

**Fig. 4.24** Vertical circulation scheme

## 4.2.7. ARCHITECTURE PLANS

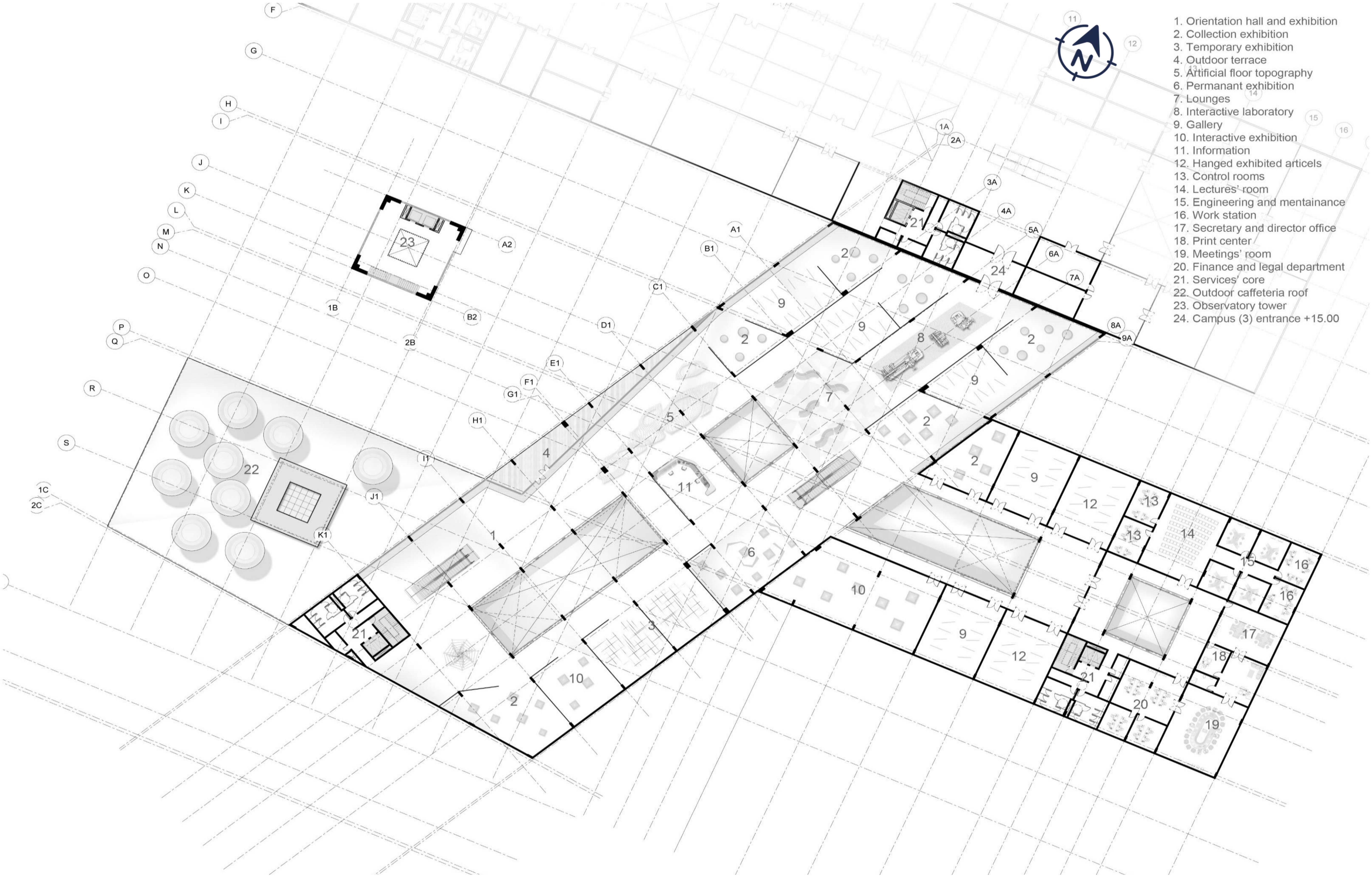
Basement floor plan ± 0.00 (level 1) - Scale 1-500

1. Mechanical services
2. Electrical services
3. Control room
4. Complementary services
5. Technical services
6. Security room
7. High defination theater
8. Building entrance +_ 0.00
9. Planetarium
10. Control system
11. Workshop
12. Work station
13. Director office and secretary
14. Meetings' room
15. Work station
16. Services' core
17. Parking
18. Lounges
19. Observatory tower core
20. Collection exhibition
21. cafeteria
22. Information hall and temporary exhibition
23. Service entrance +_ 0.00

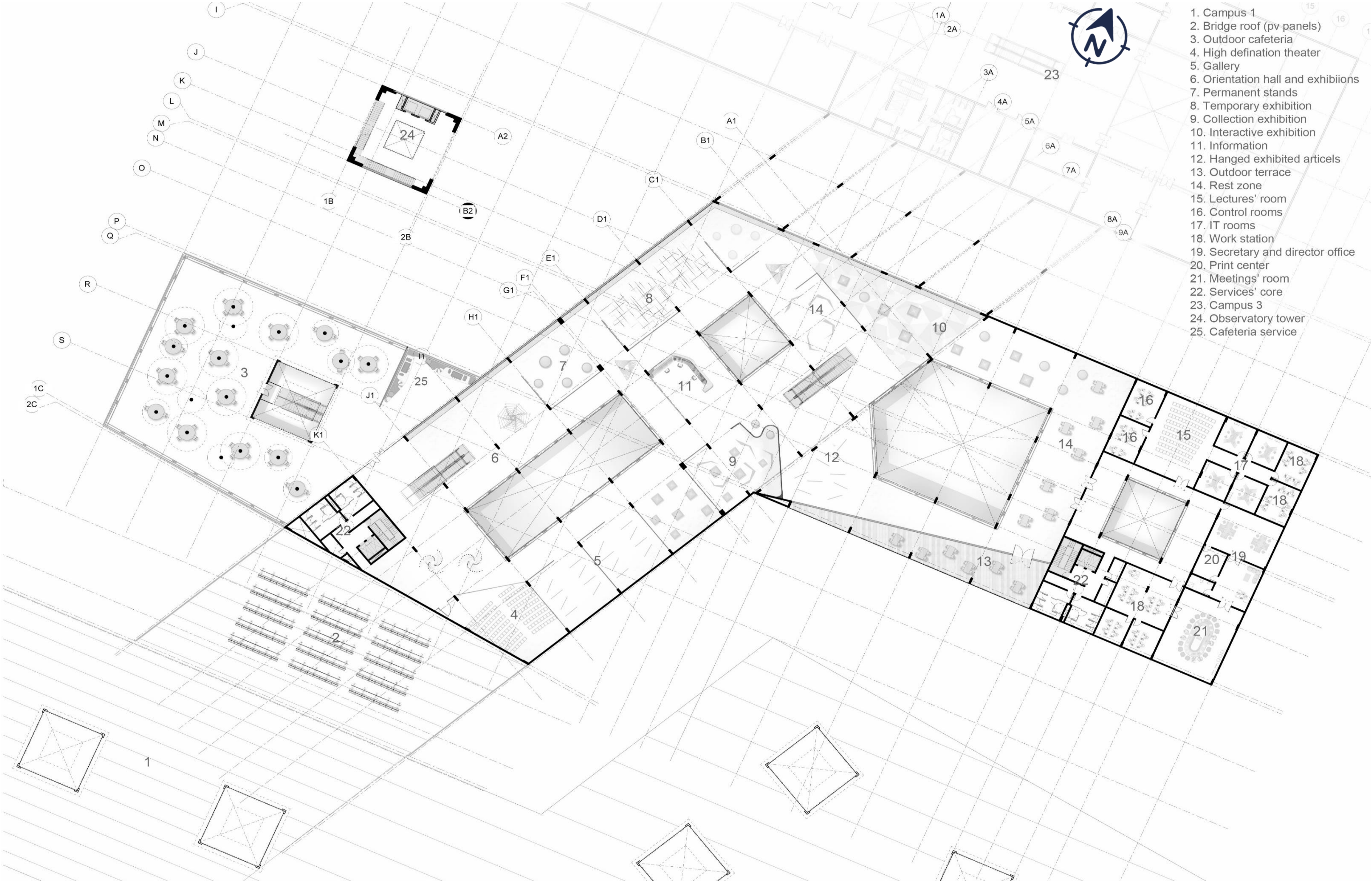
Ground floor plan + 5.00 (level 2) - Scale 1-500



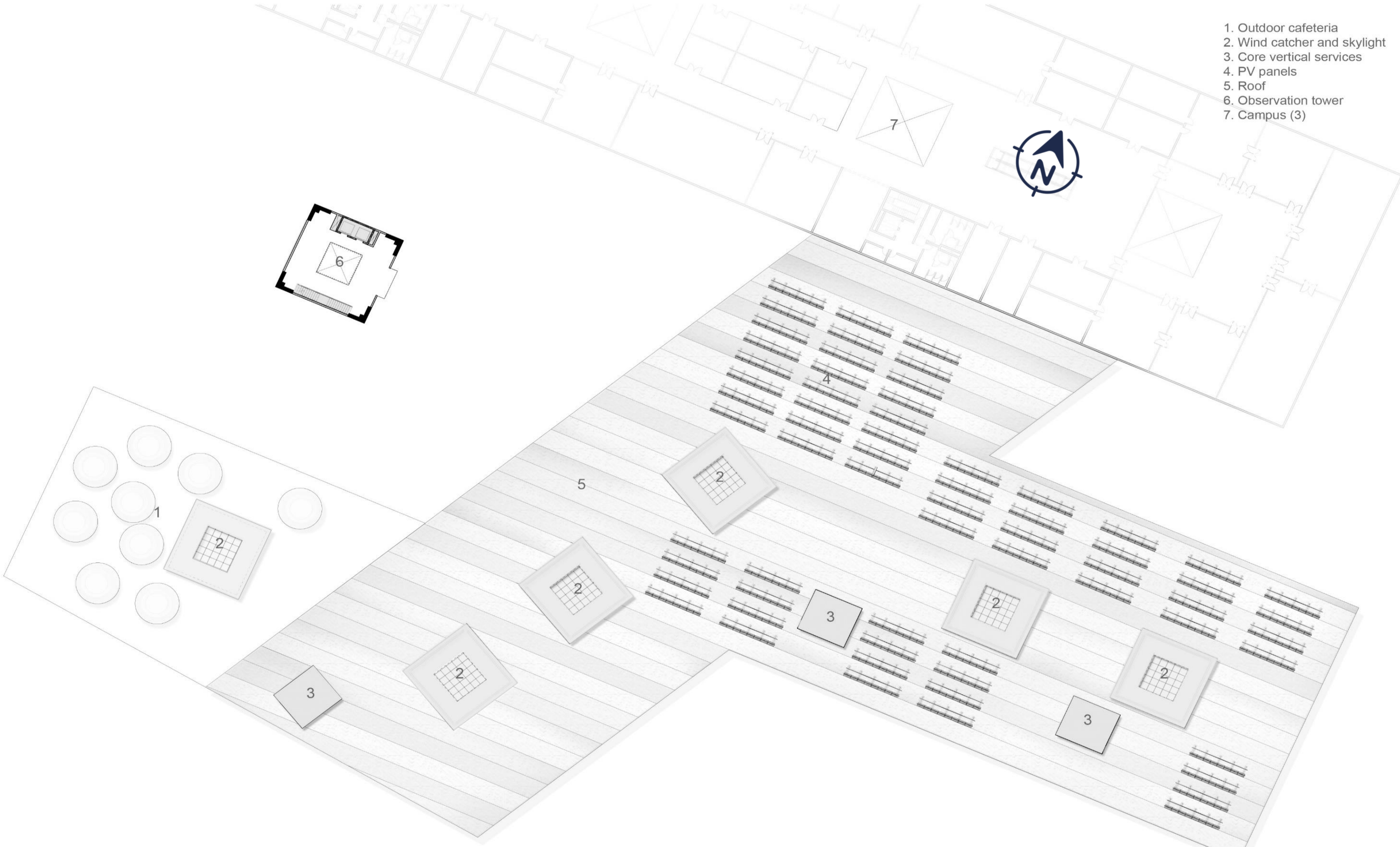
First floor plan + 10.00 (level 3) - scale 1-500



Second floor plan + 15.00 (level 4) - Scale 1-500



Third floor plan + 20.00 (level 5) - Scale 1-500



## 4.2.8. ELEVATIONS

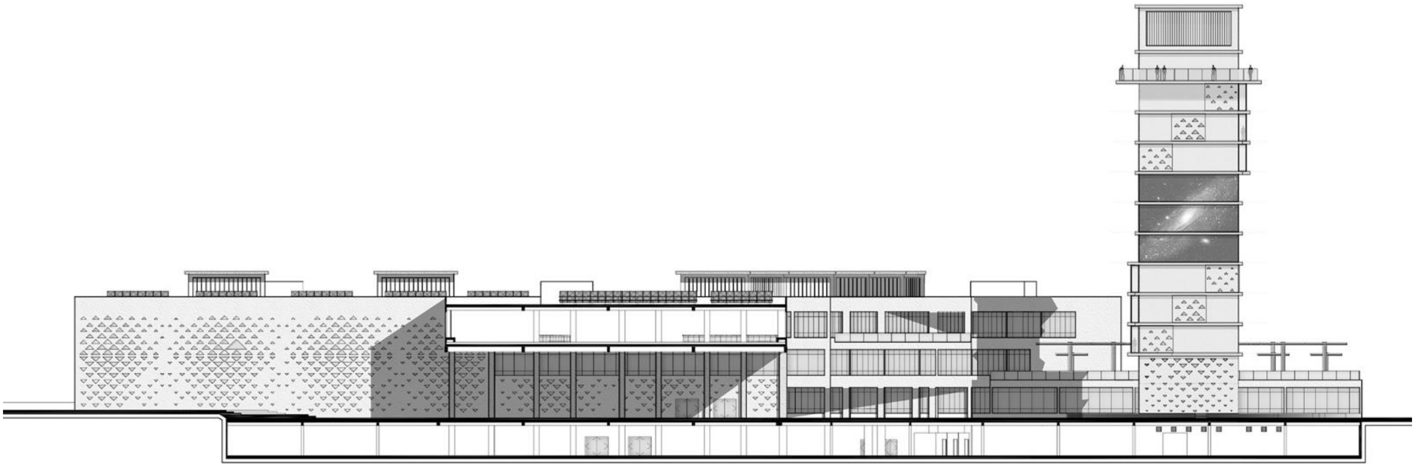


**Fig. 4.25** North elevation 1-1000

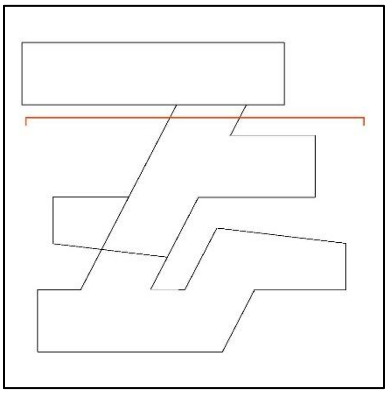



**Fig. 4.26** North elevation 1-500 part 1

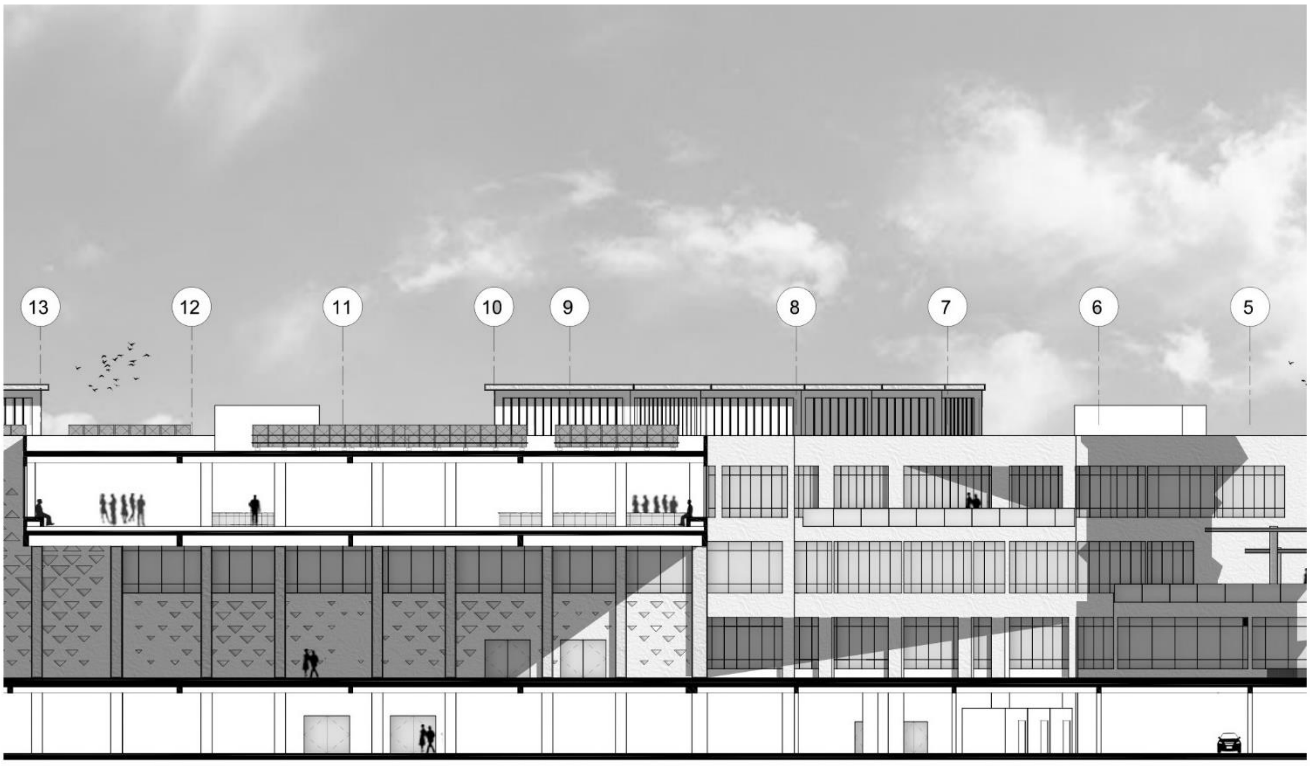



**Fig. 4.27** North elevation 1-500 part 2

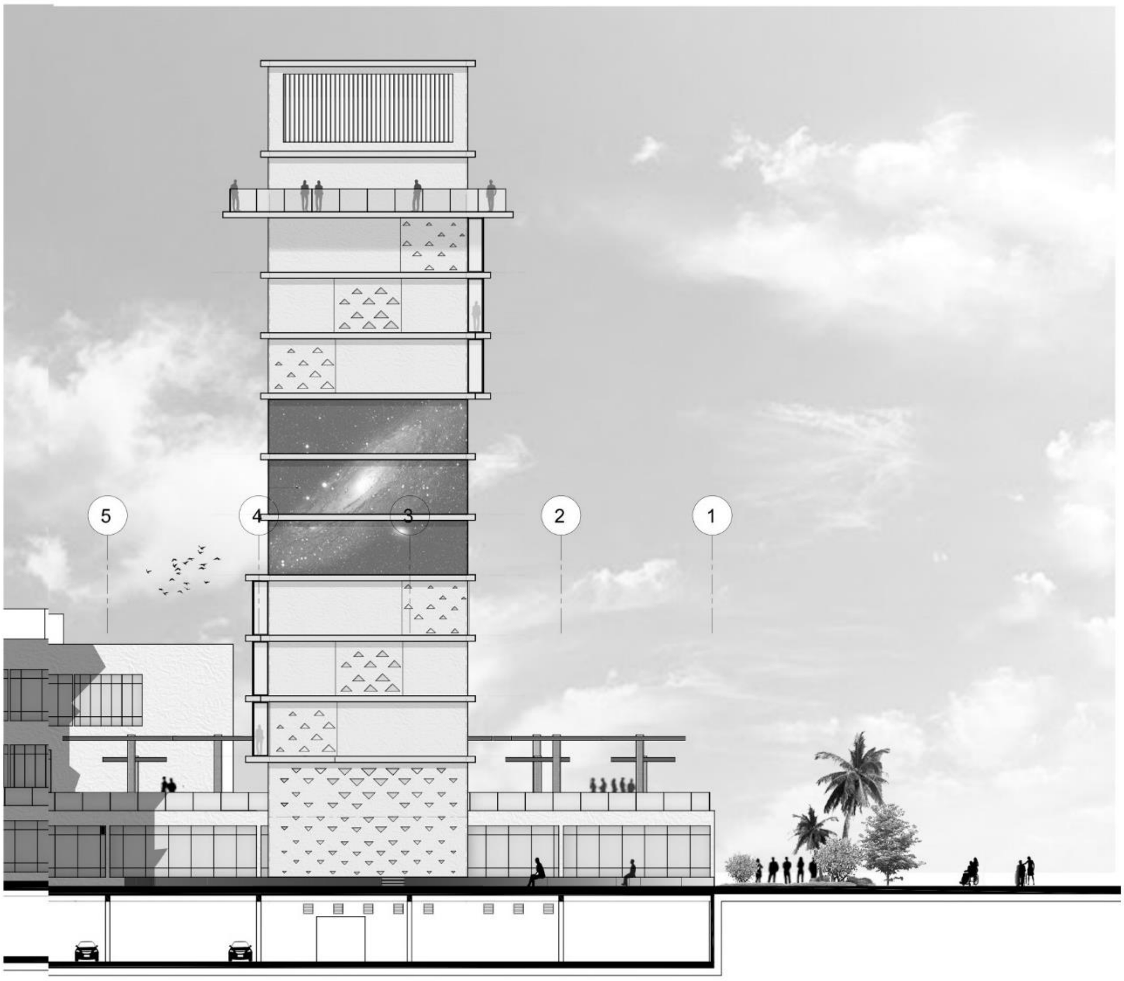



**Fig. 4.28** North elevation 1-500 part 3

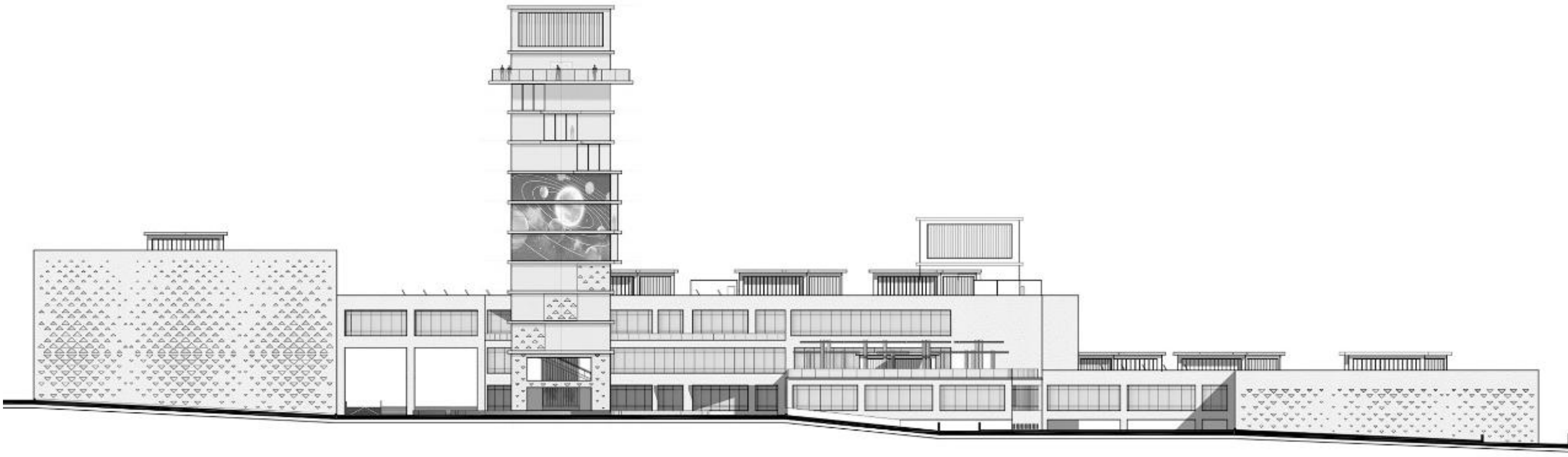


**Fig. 4.29** West elevation 1-1000

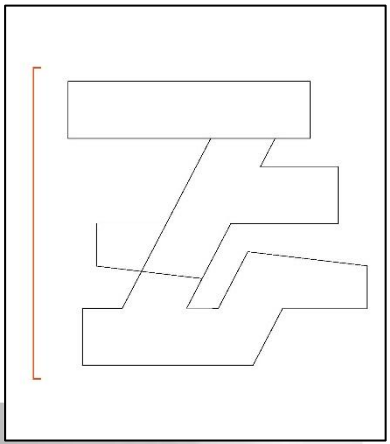



**Fig. 4.30** West elevation 1-500 part 1


**Fig. 4.31** West elevation 1-500 part 2

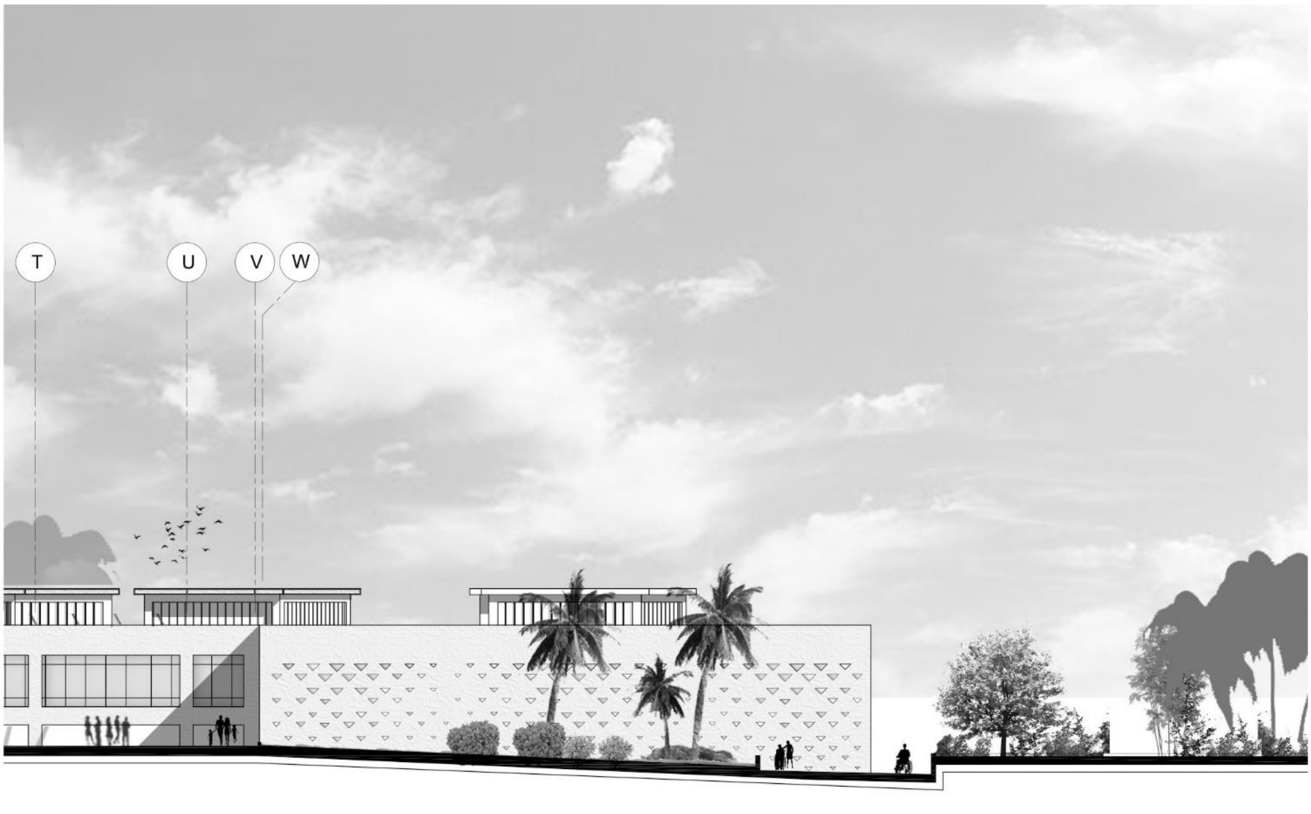
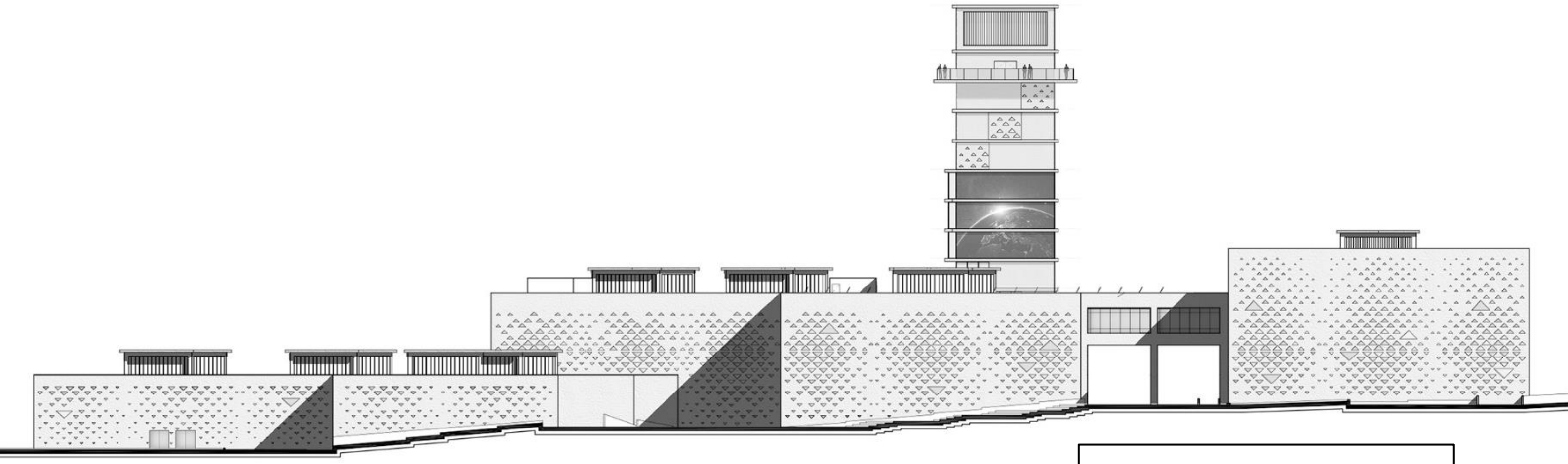



**Fig. 4.32** West elevation 1-500 part 3



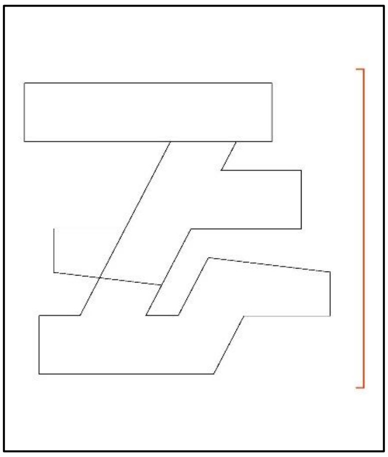


**Fig. 4.33** East elevation 1-1000


**Fig. 4.34** East elevation 1-500 part 1

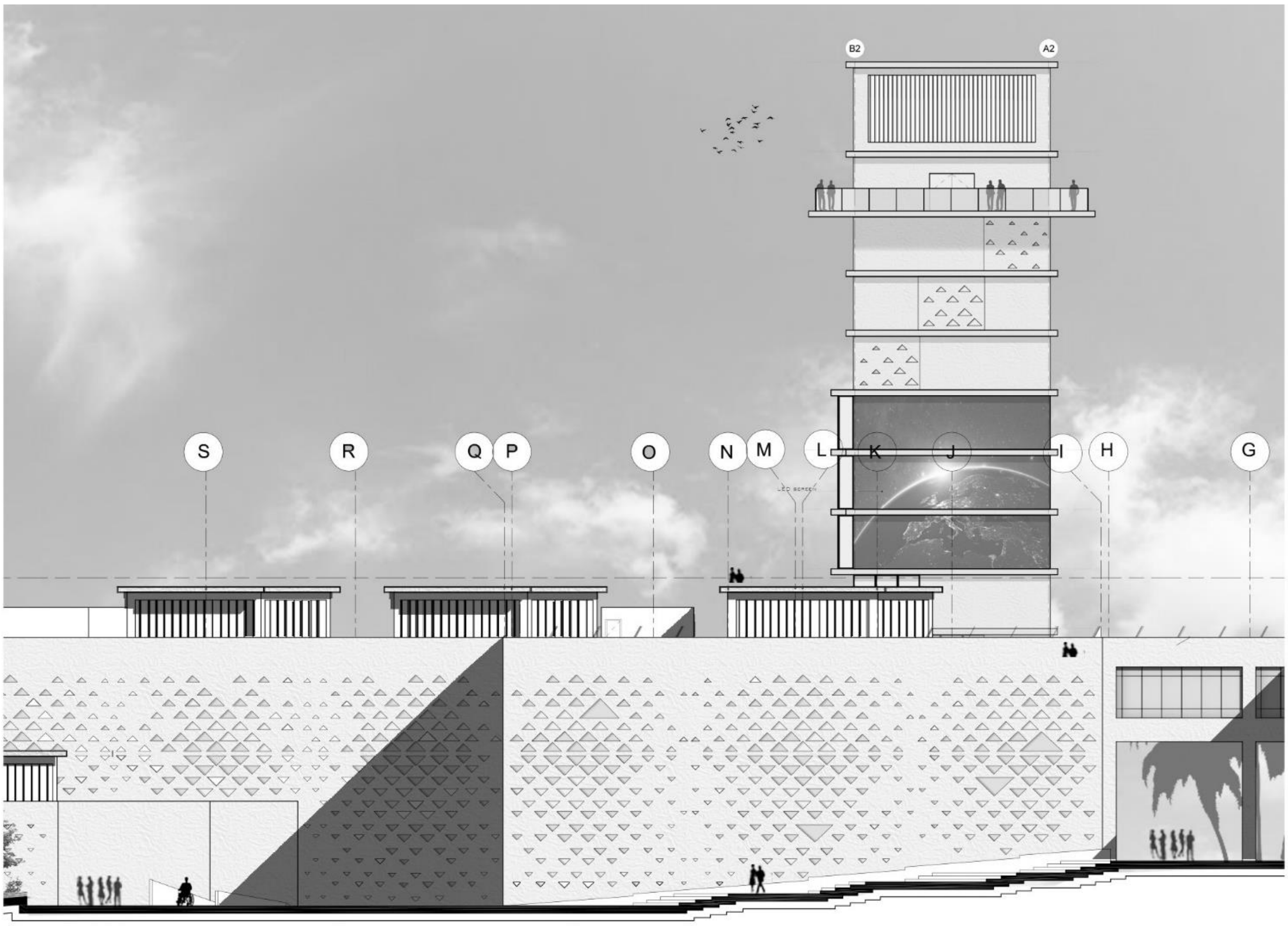



**Fig. 4.35** East elevation 1-500 part 2


**Fig. 4.36** East elevation 1-500 part 3

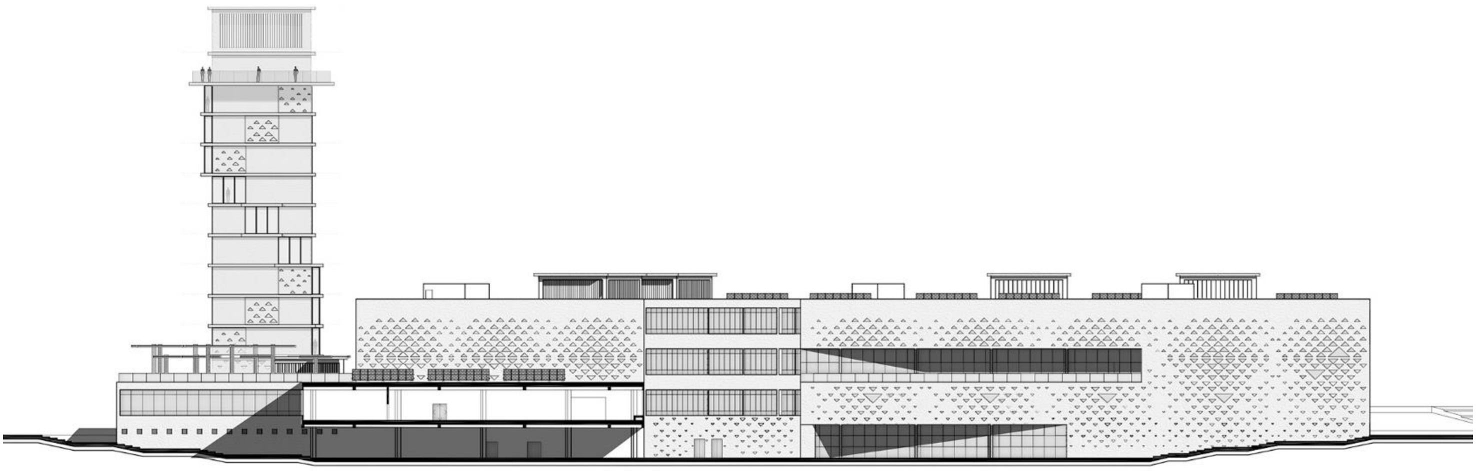
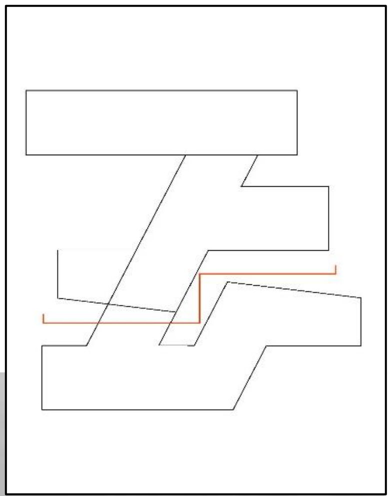


**Fig. 4.37** South elevation 1-1000



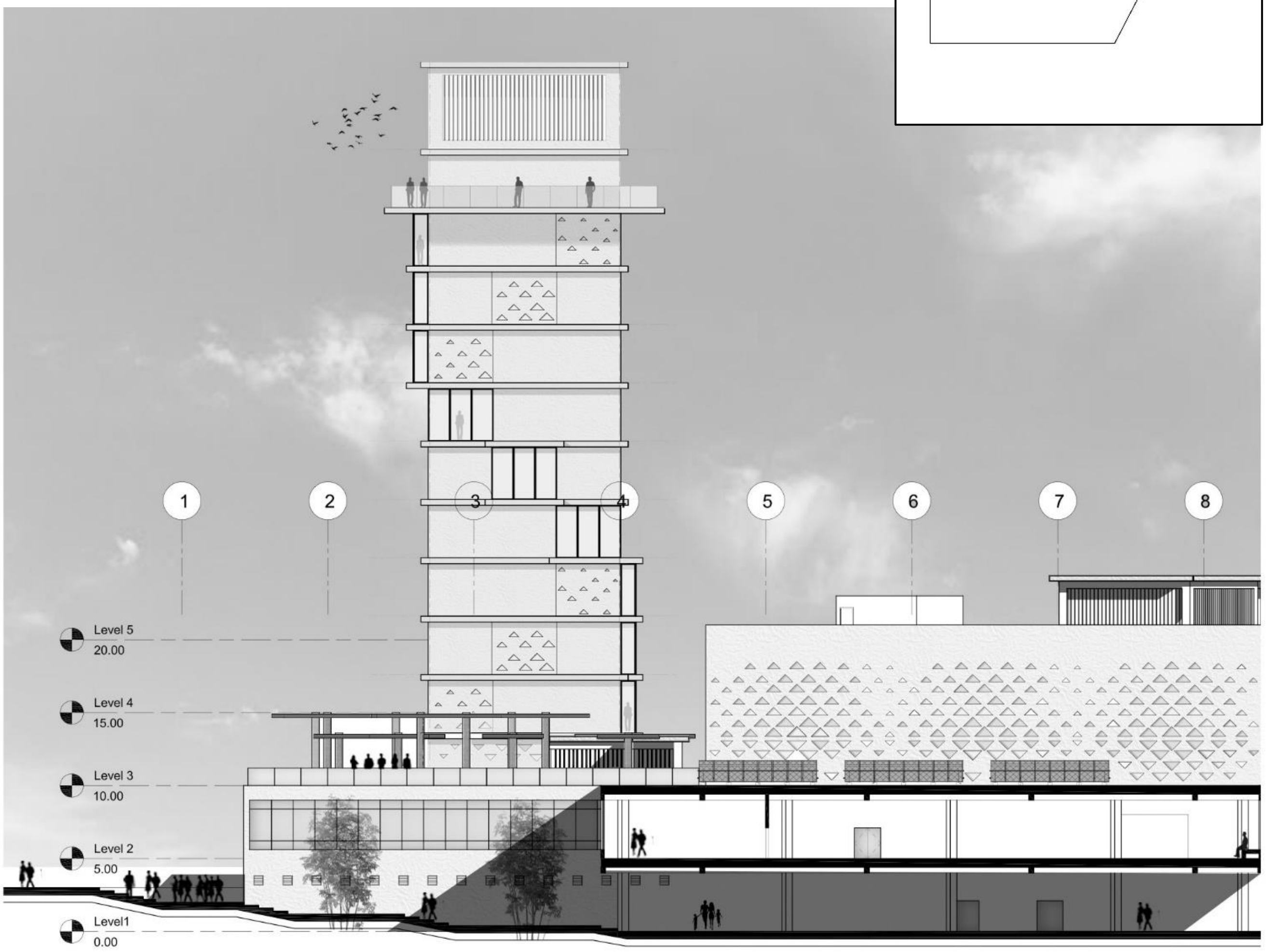



**Fig. 4.38** South elevation 1-500 part 1

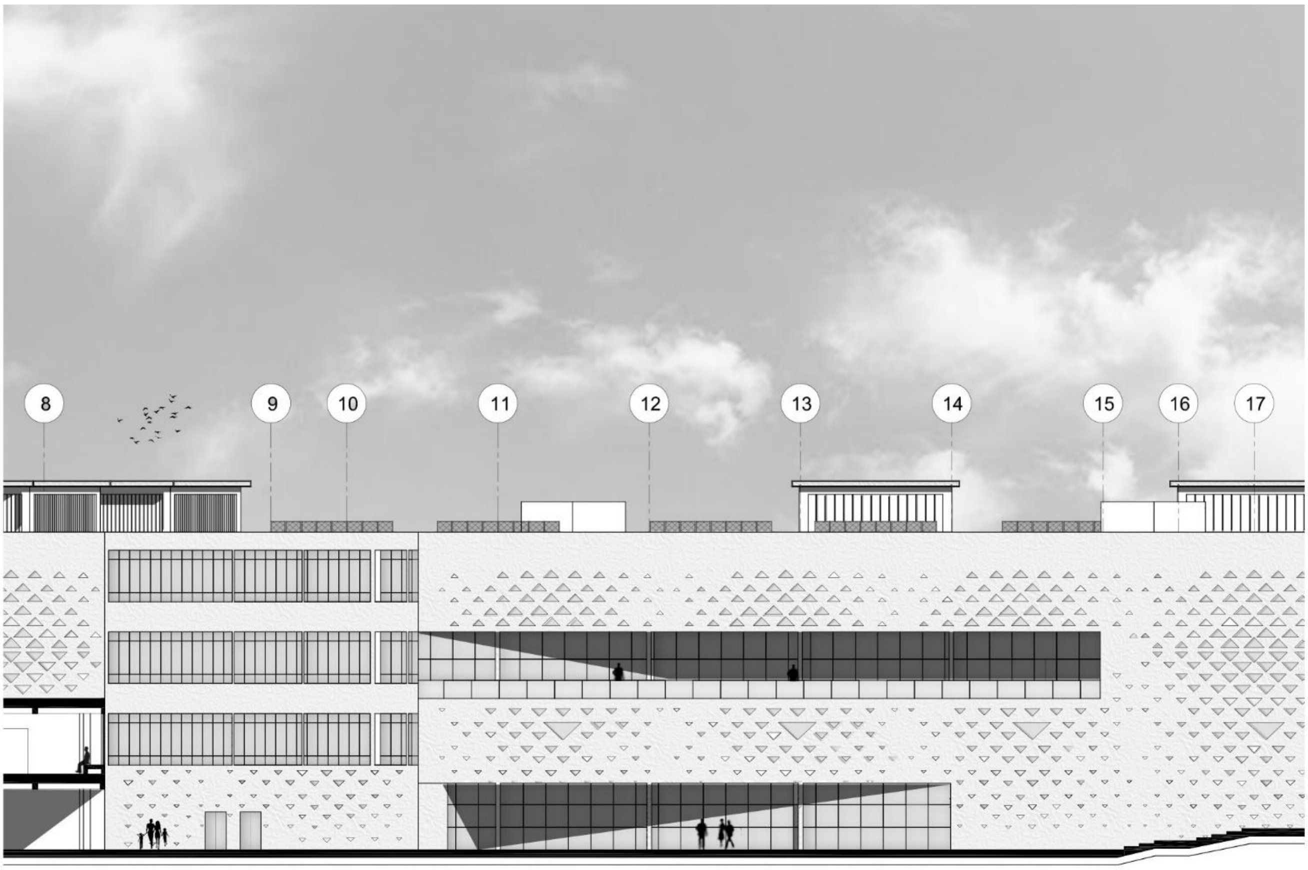



**Fig. 4.39** South elevation 1-500 part 2

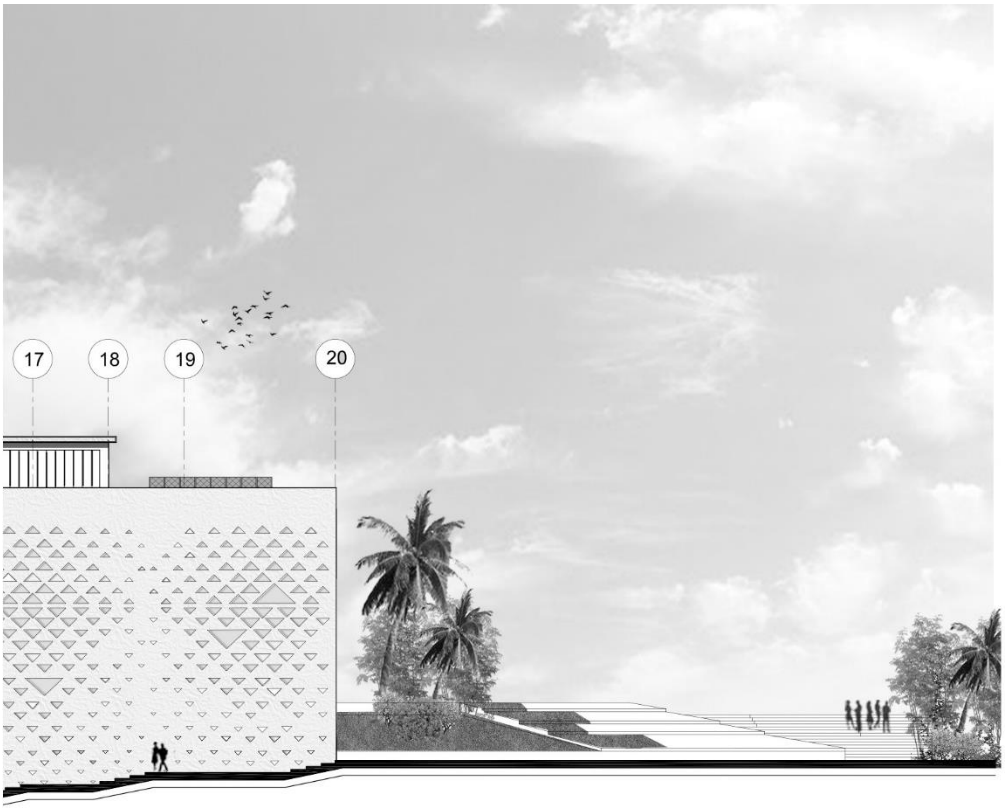



**Fig. 4.40** South elevation 1-500 part 3

## 4.2.9. SECTIONS

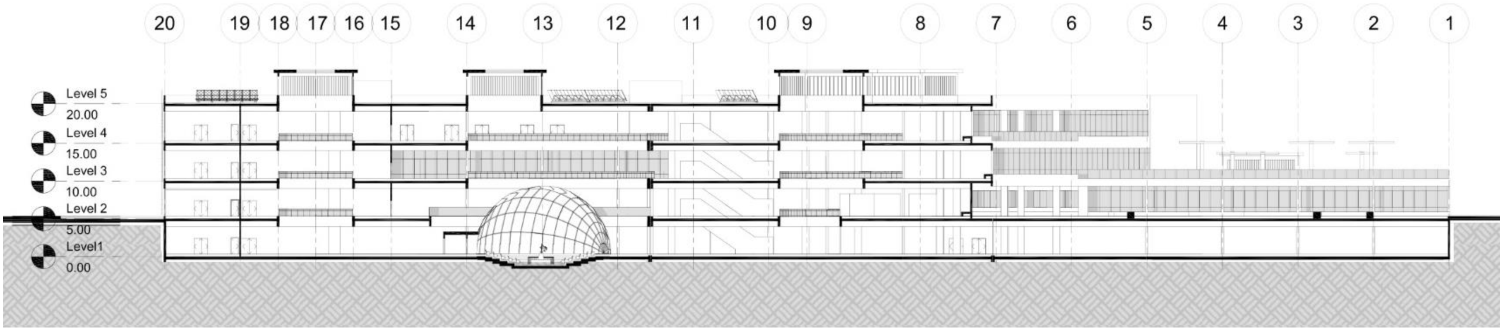
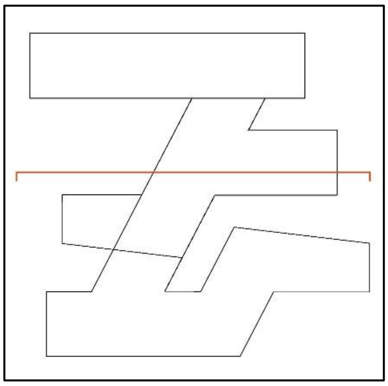



**Fig. 4.41** Section A-A 1-1000



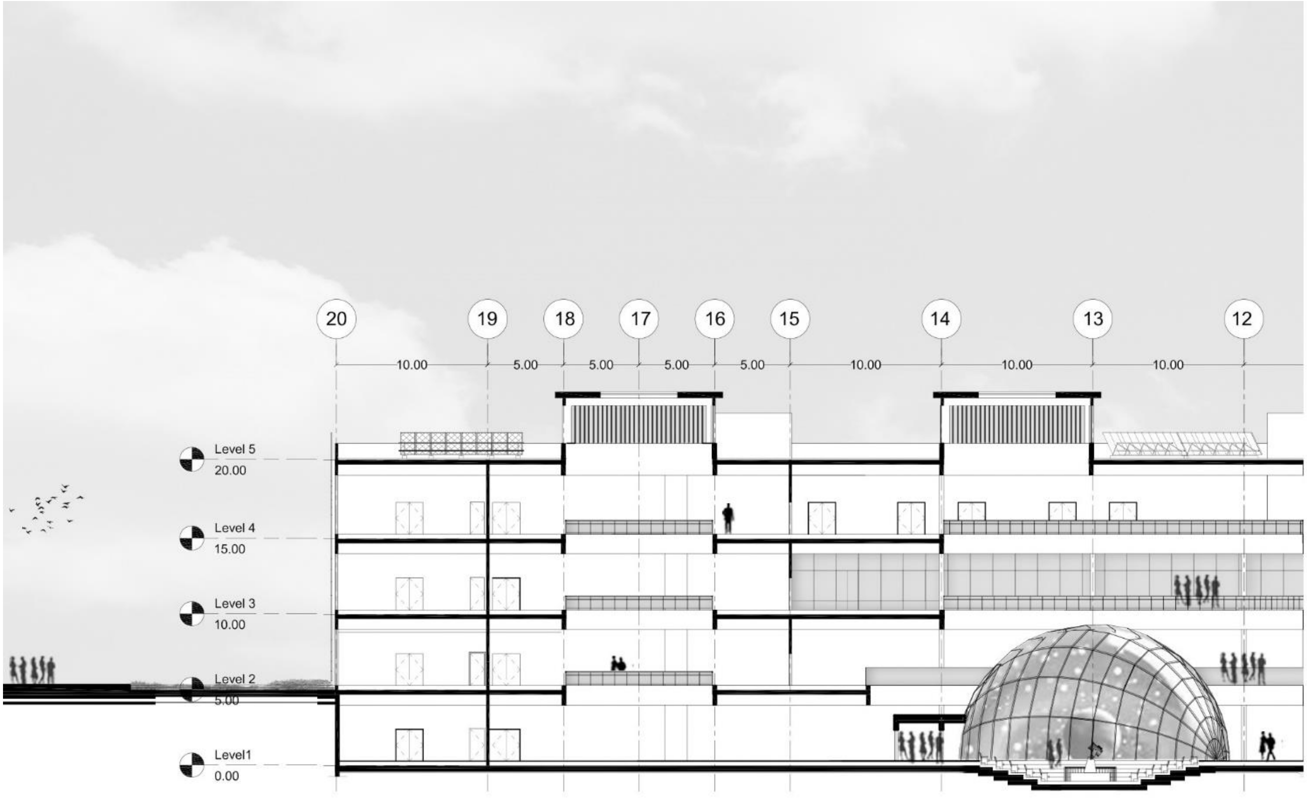



**Fig. 4.42** Section A-A 1-500 part 1

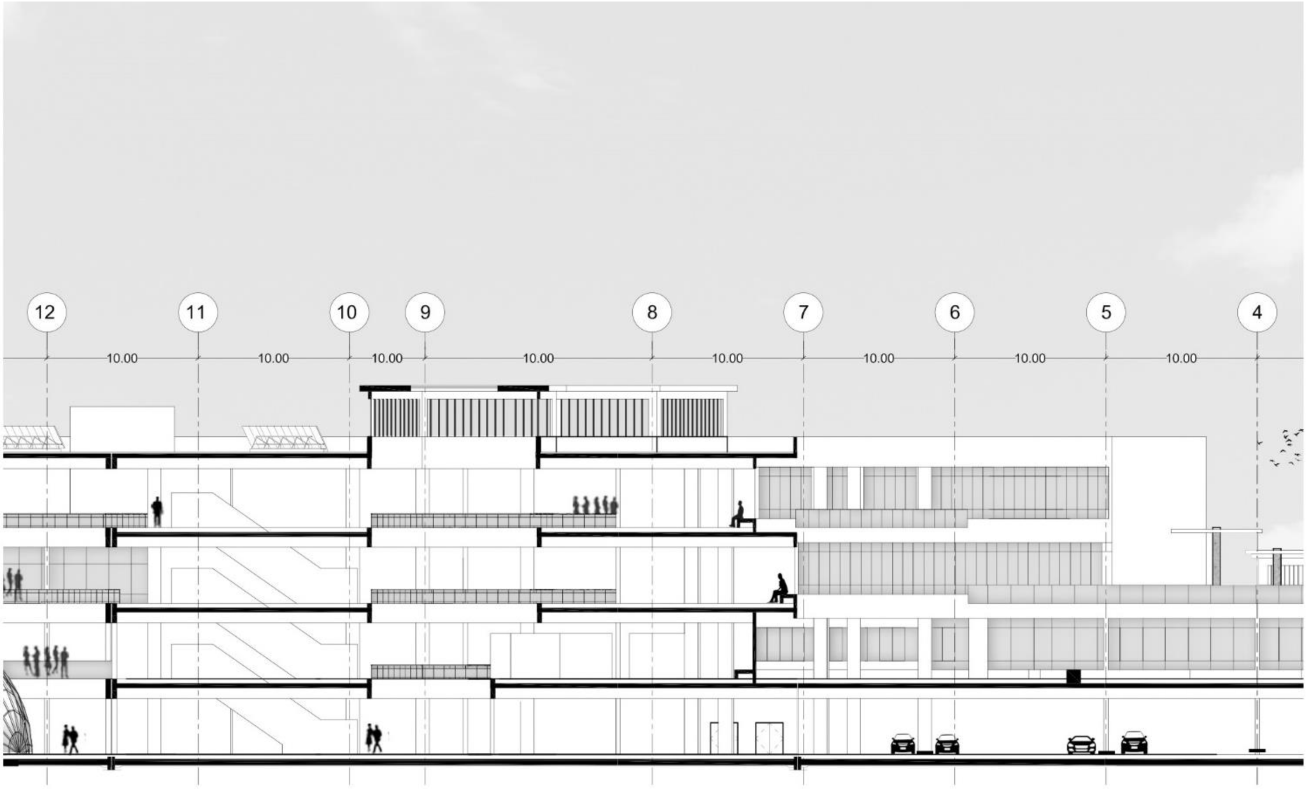



**Fig. 4.43** Section A-A 1-500 part 2

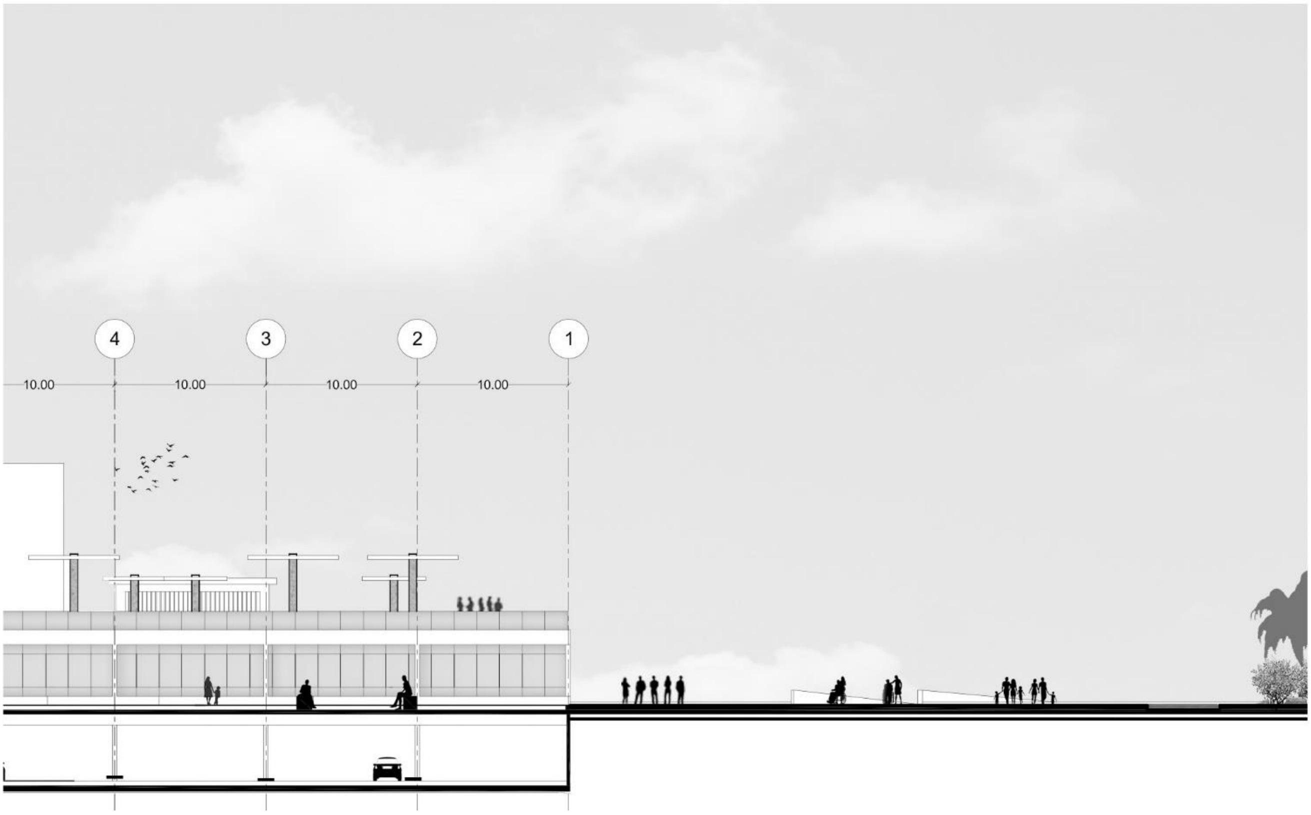
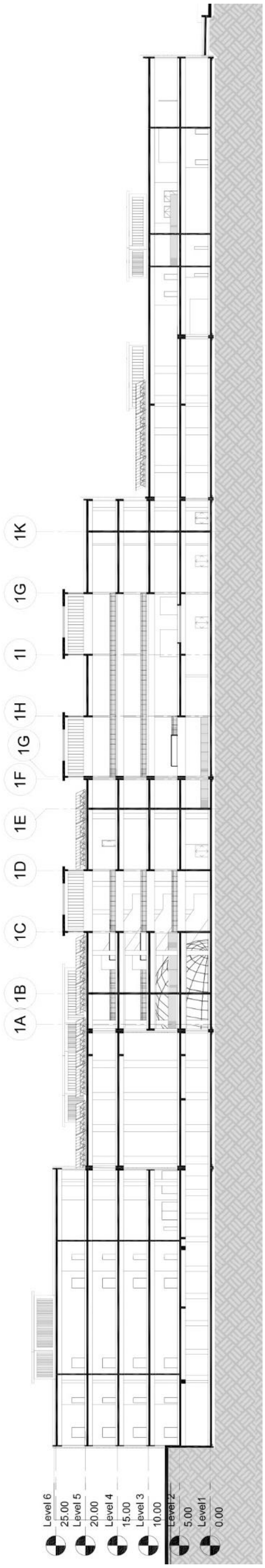



**Fig. 4.44** Section A-A 1-500 part 3



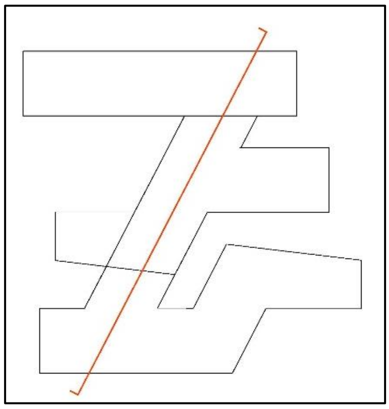



**Fig. 4.45** Section B-B  1-1000


**Fig. 4.46** Section B-B 1-500 part 1

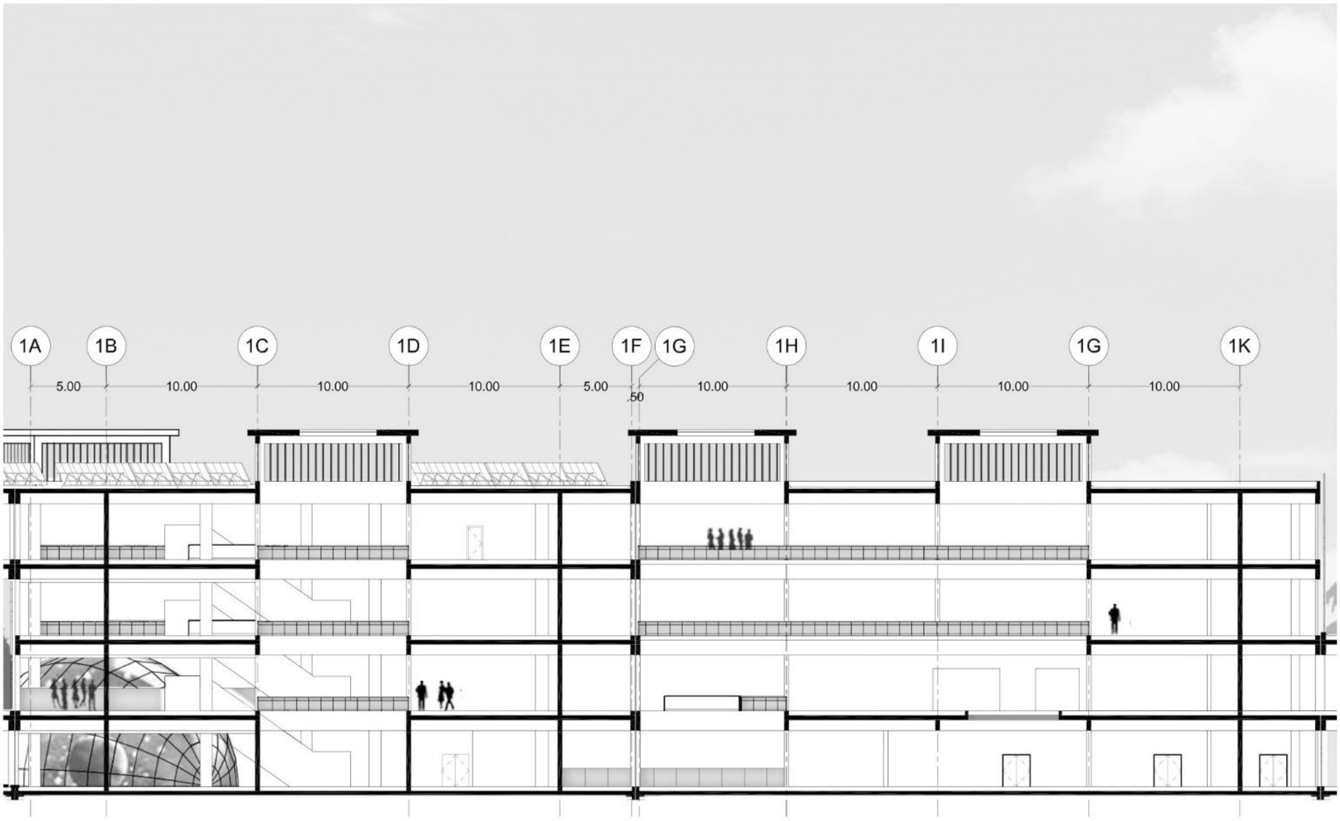



**Fig. 4.47** Section B-B 1-500 part 2

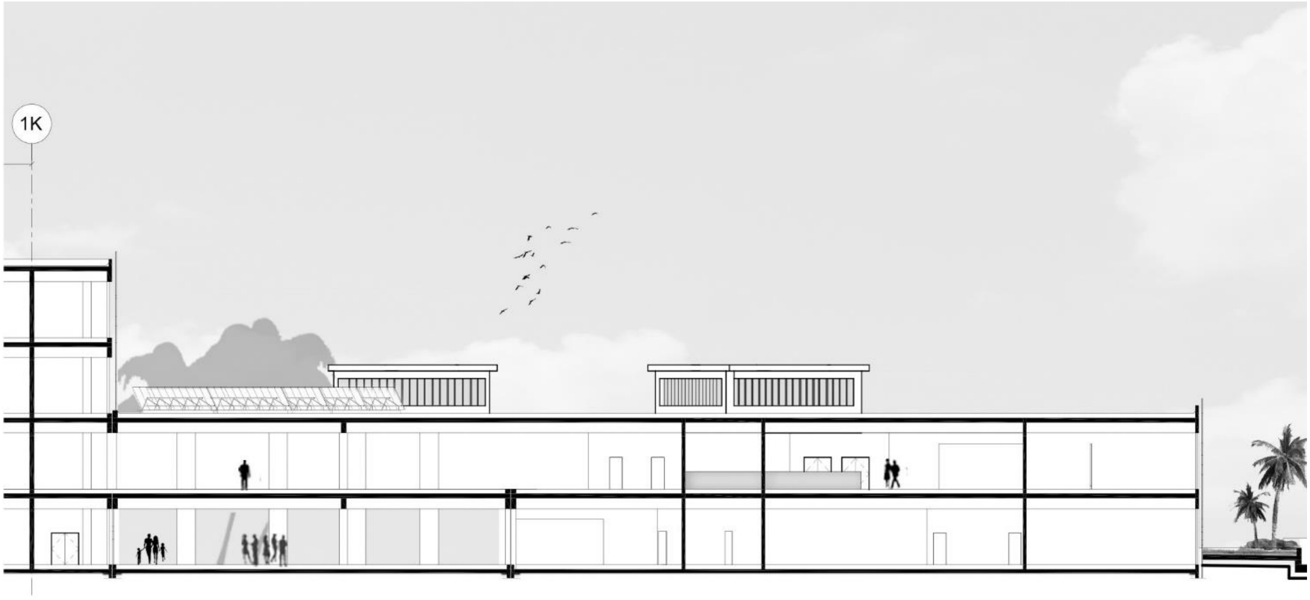
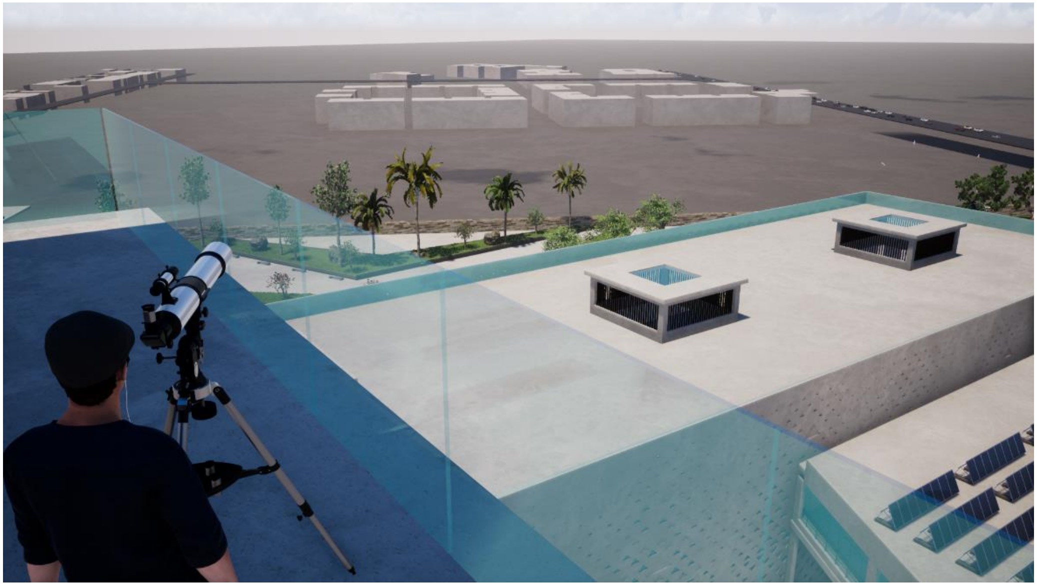



**Fig. 4.48** Section B-B 1-500 part 3

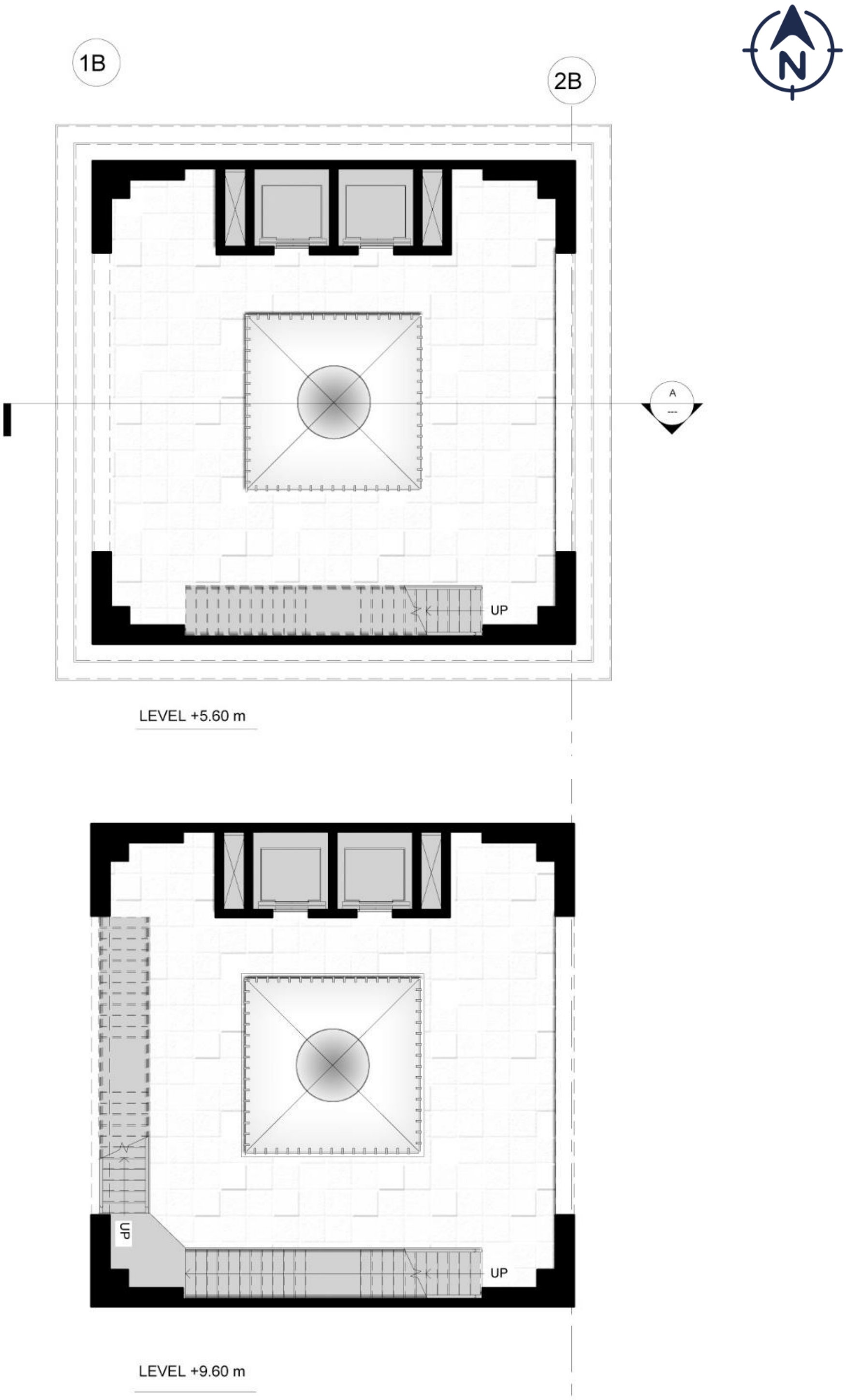
## 4.2. ARCHITECTURE DESIGN OF THE OBSERVATION TOWER

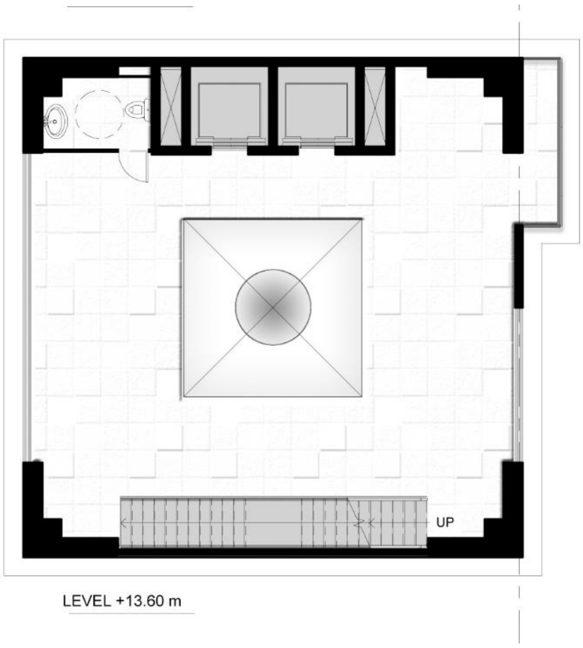
The observatory tower will provide facilities for the astronomy and observation. It is the landmark; characterized by an observation tower. The observation tower will provide the zone of the 6th of October with a landmark overlooking the pyramids. The observatory tower upper floors consist of an observatory and services and open deck or viewing area.

The observation tower consists of 13 floors with height 53 m, a square core is located in the center of the typical floor plan creating a path of fresh air to the piazza around the tower, thanks to the wind chimney above the tower. In the last floor, there is an open terrace with a big telescope enabling the visitor to discover the surroundings.

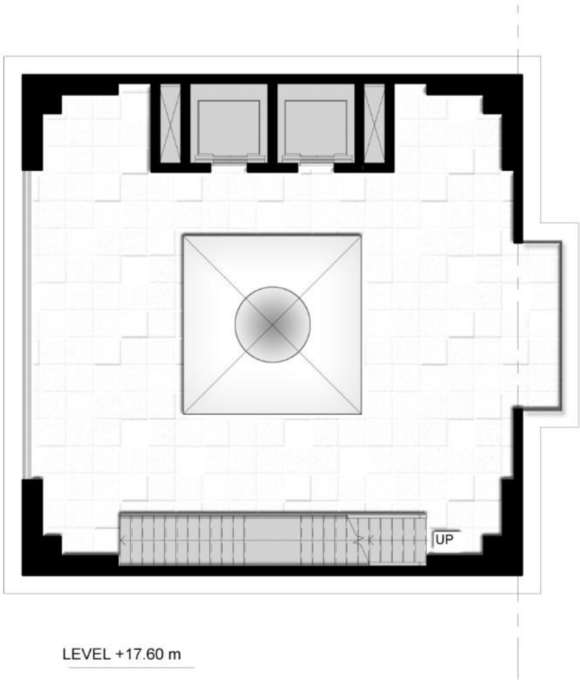


### 4.2.1. ARCHITECTURE PLANS






LEVEL +13.60 m




LEVEL +17.60 m

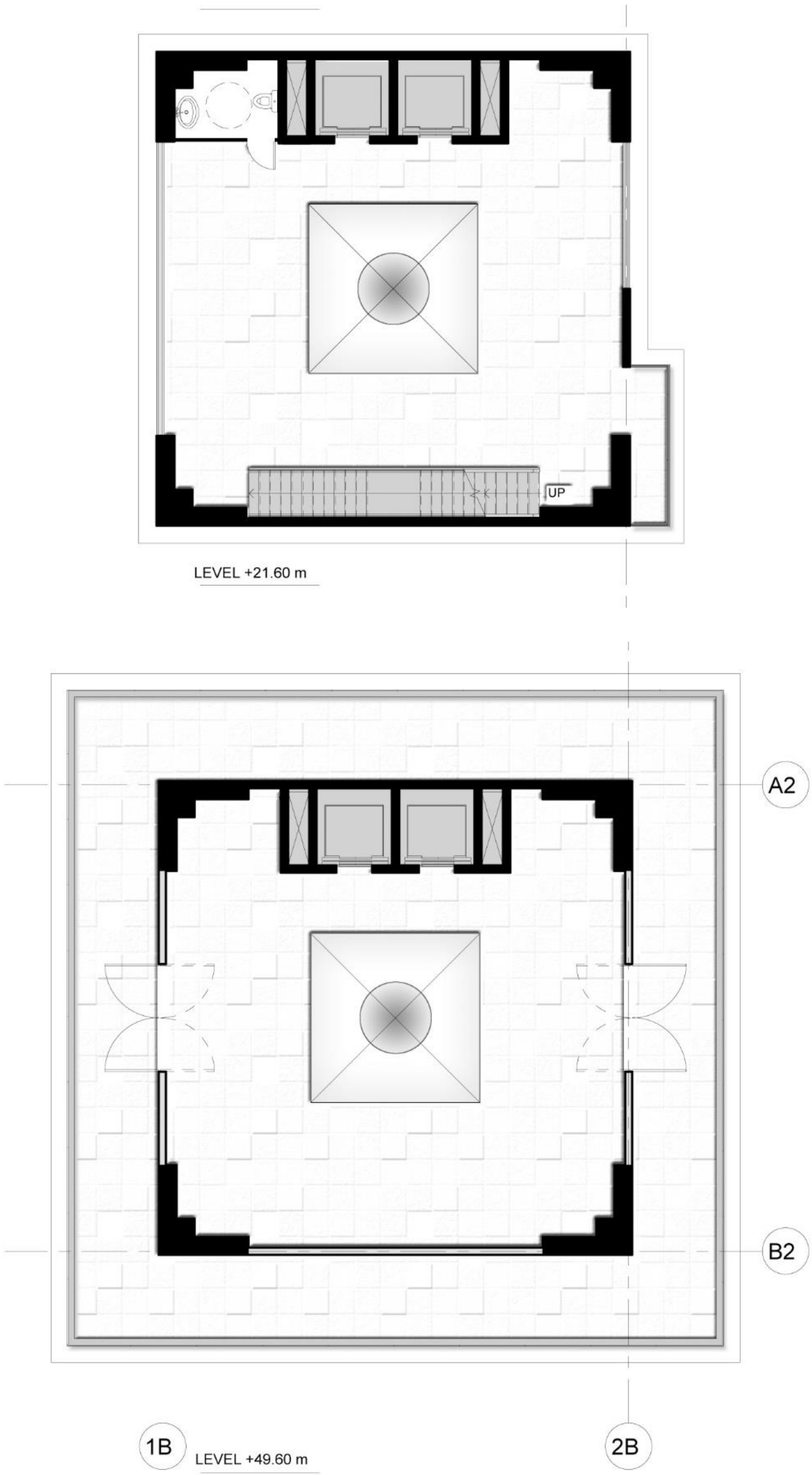



**Fig. 4.49** Observatory tower plans 1-200

### 4.3.2. ELEVATIONS

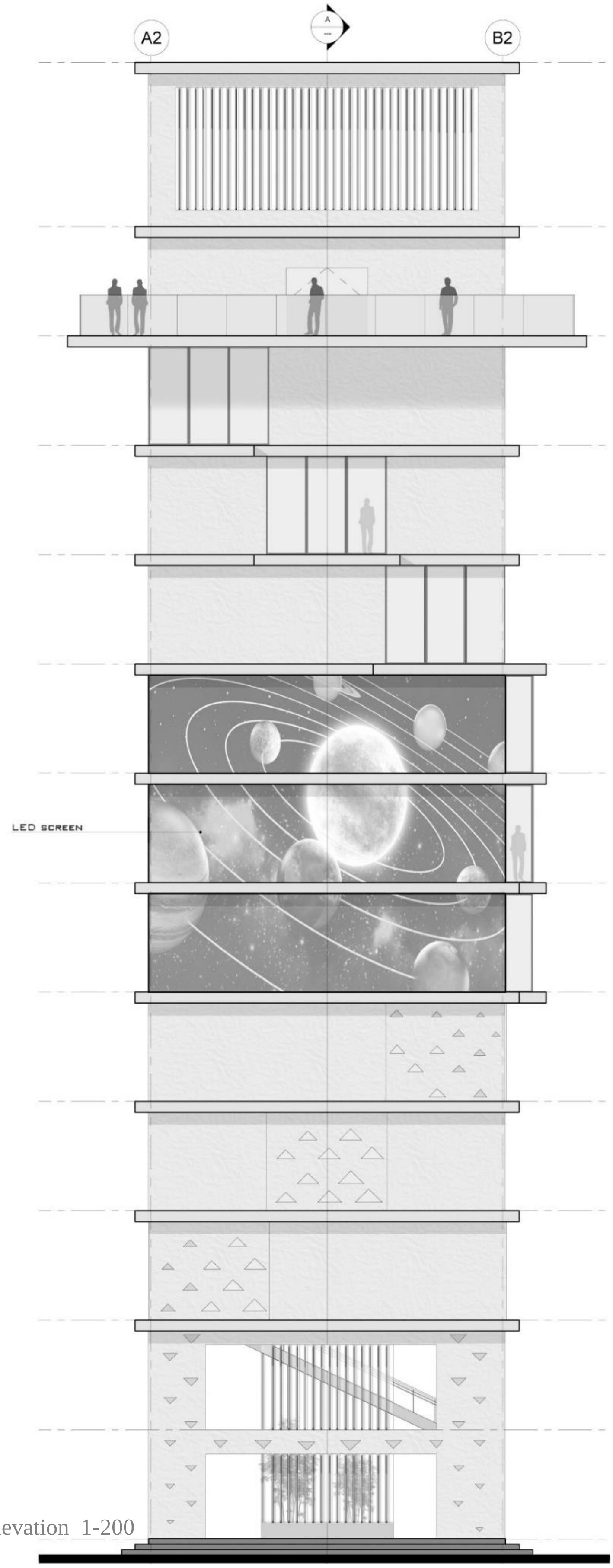



**Fig. 4.50** West elevation 1-200

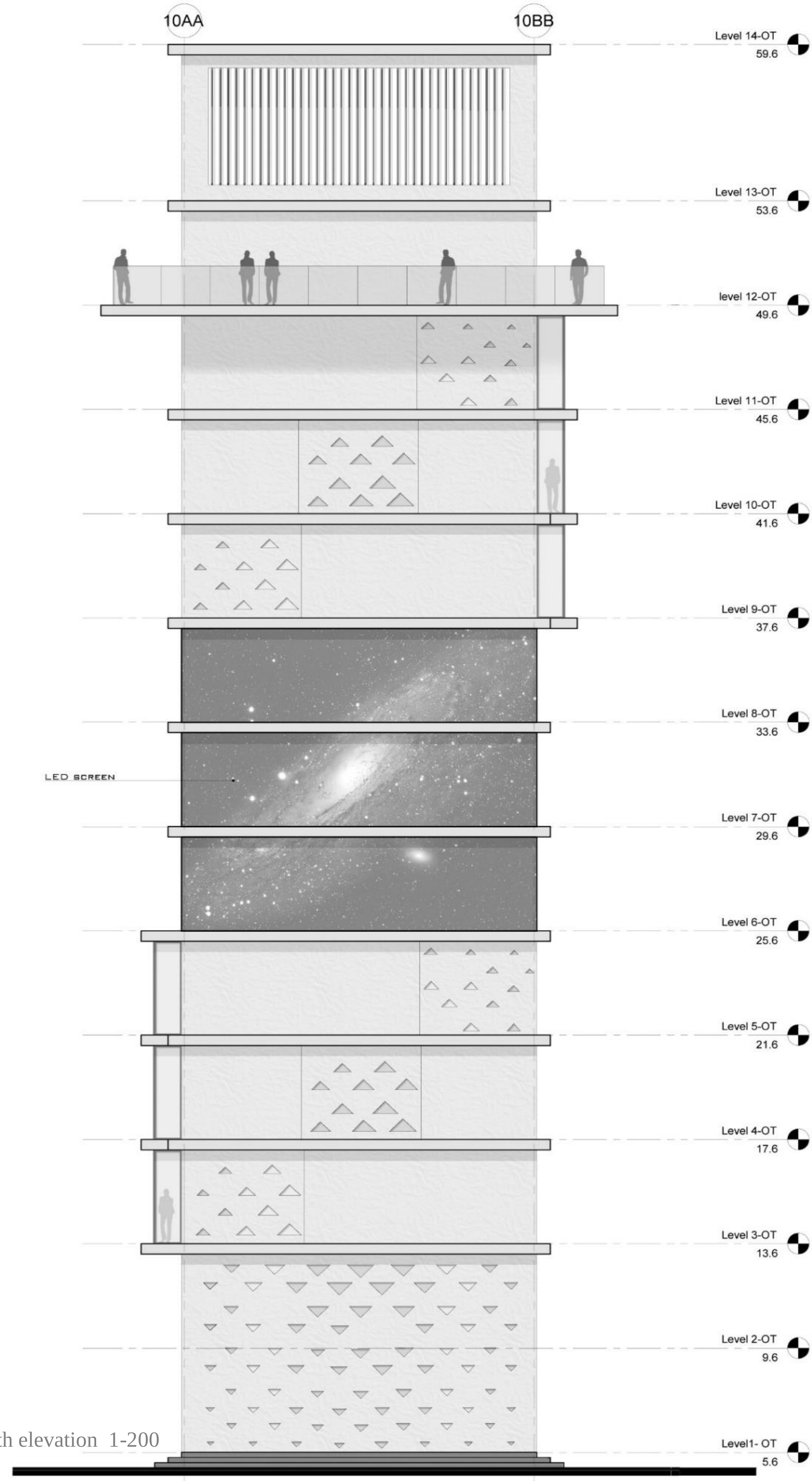



**Fig. 4.51** North elevation 1-200

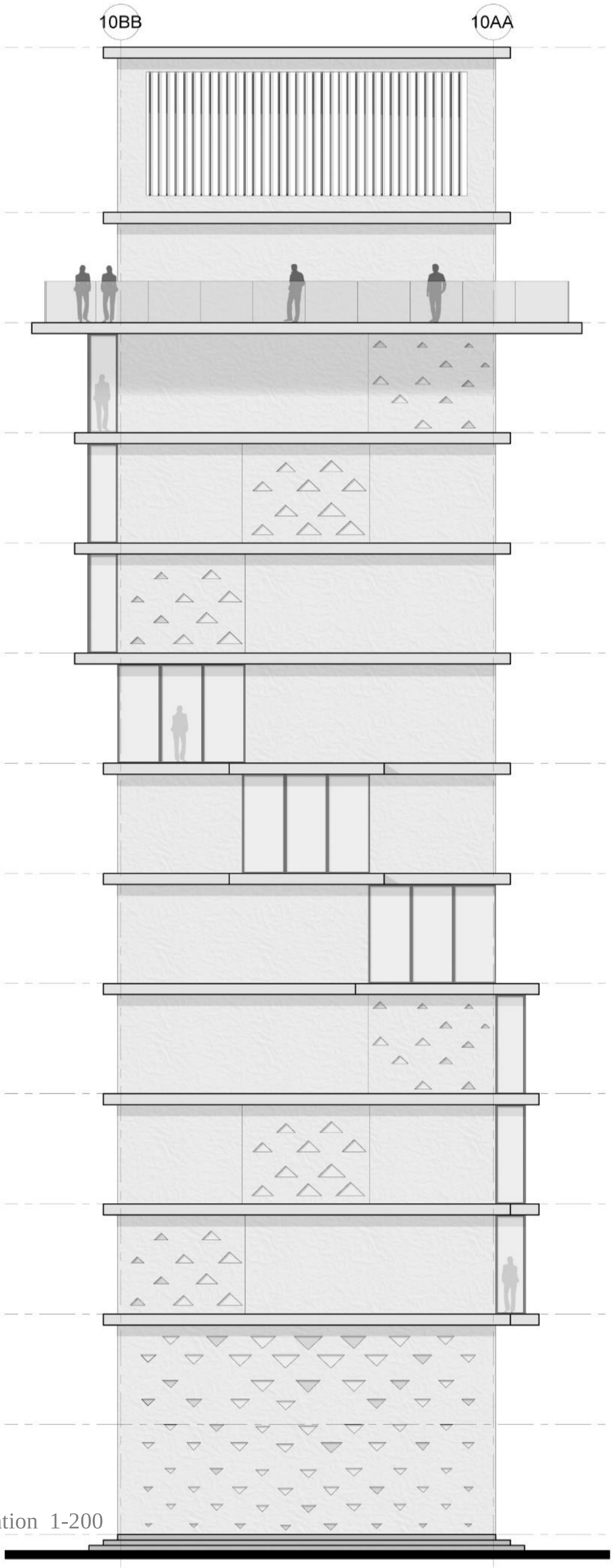



**Fig. 4.52** South elevation 1-200

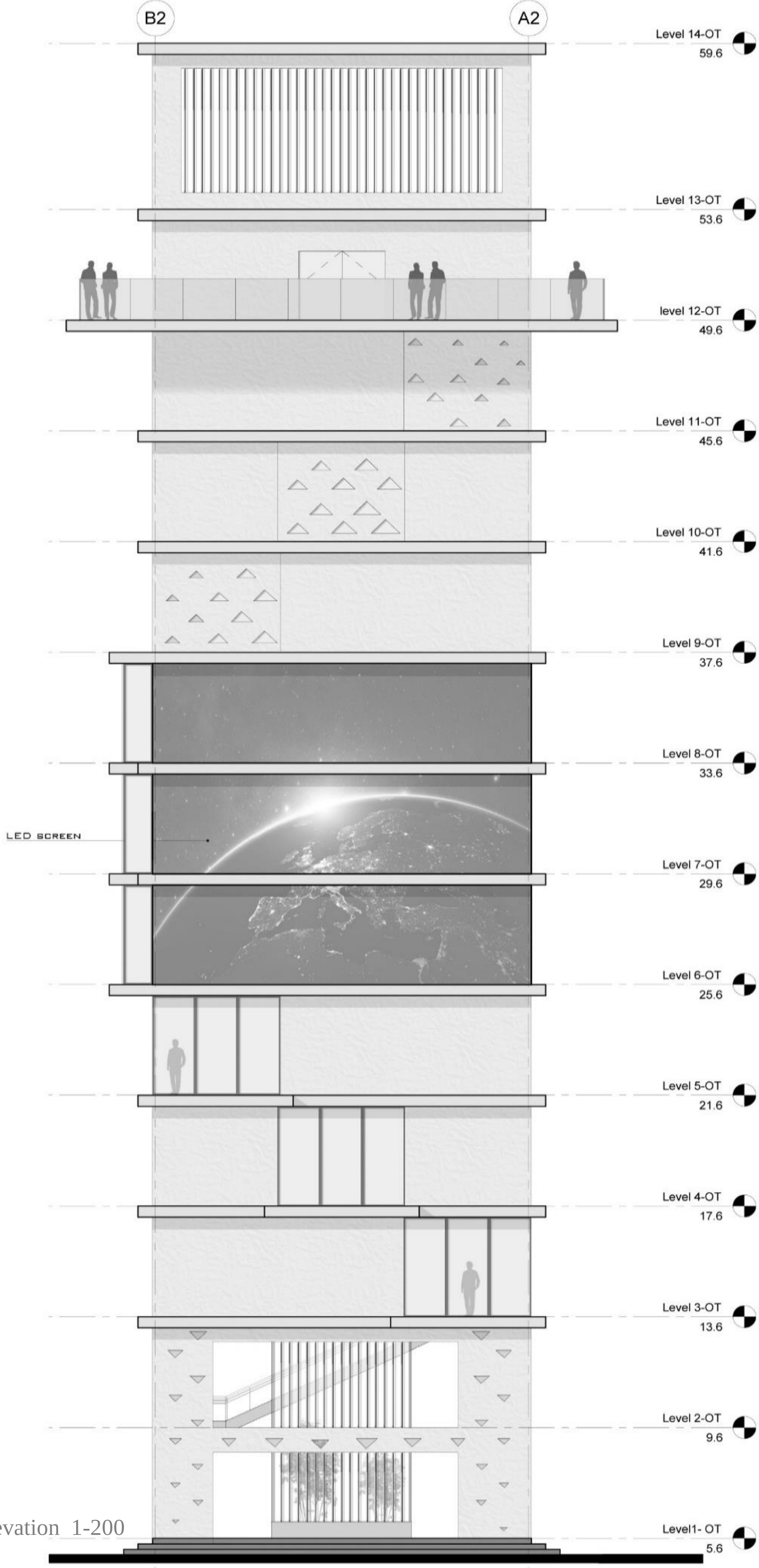



**Fig. 4.53** East elevation 1-200

### 4.3.3. SECTION A-A

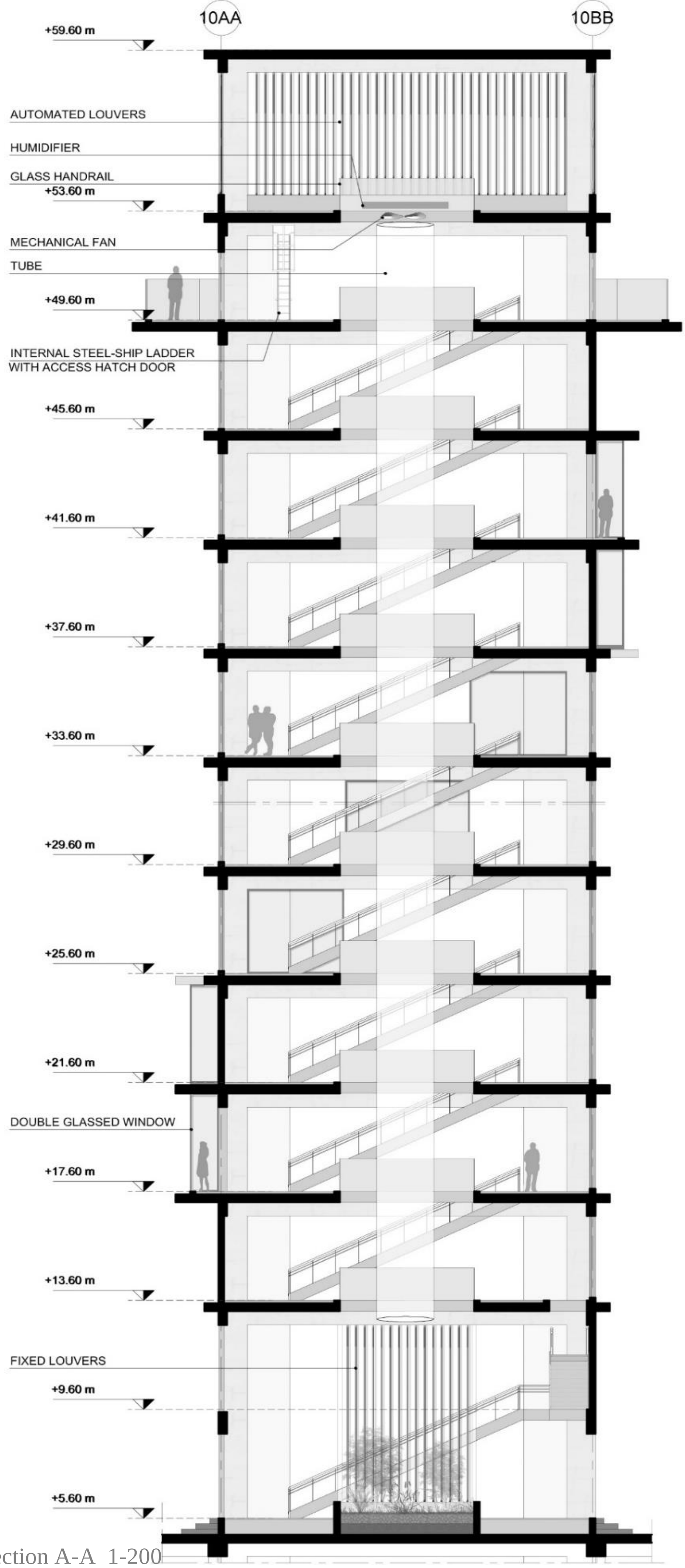
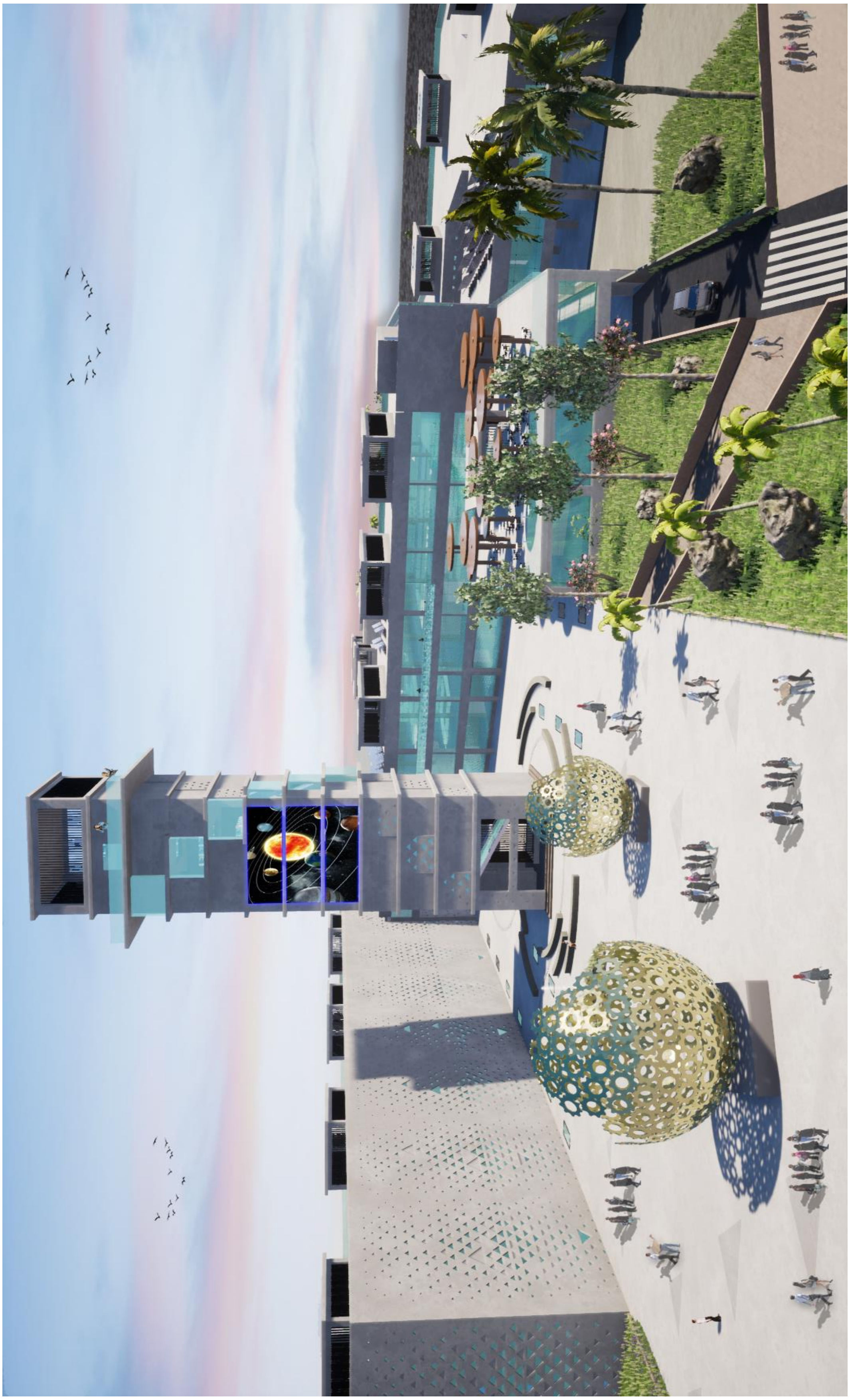
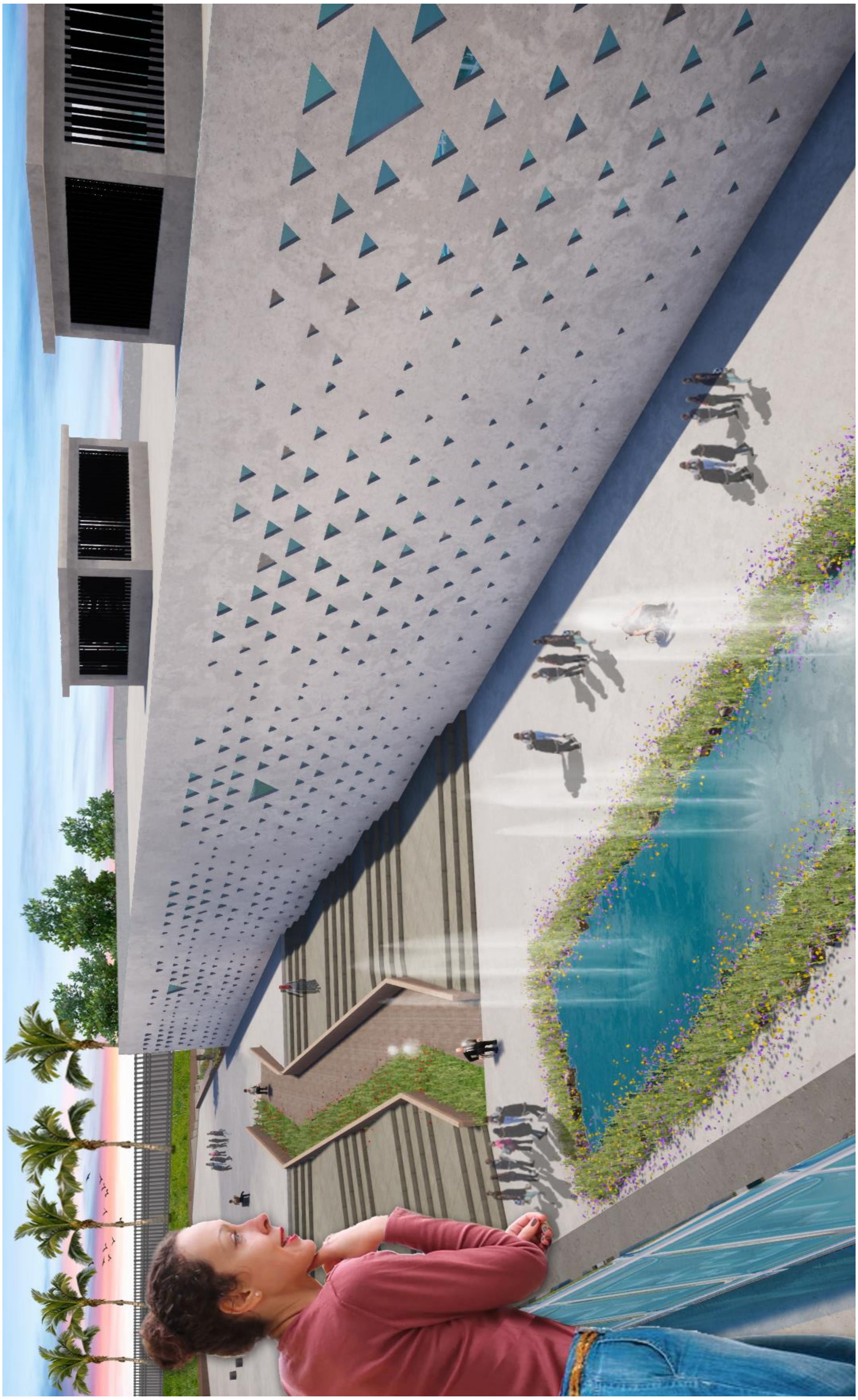
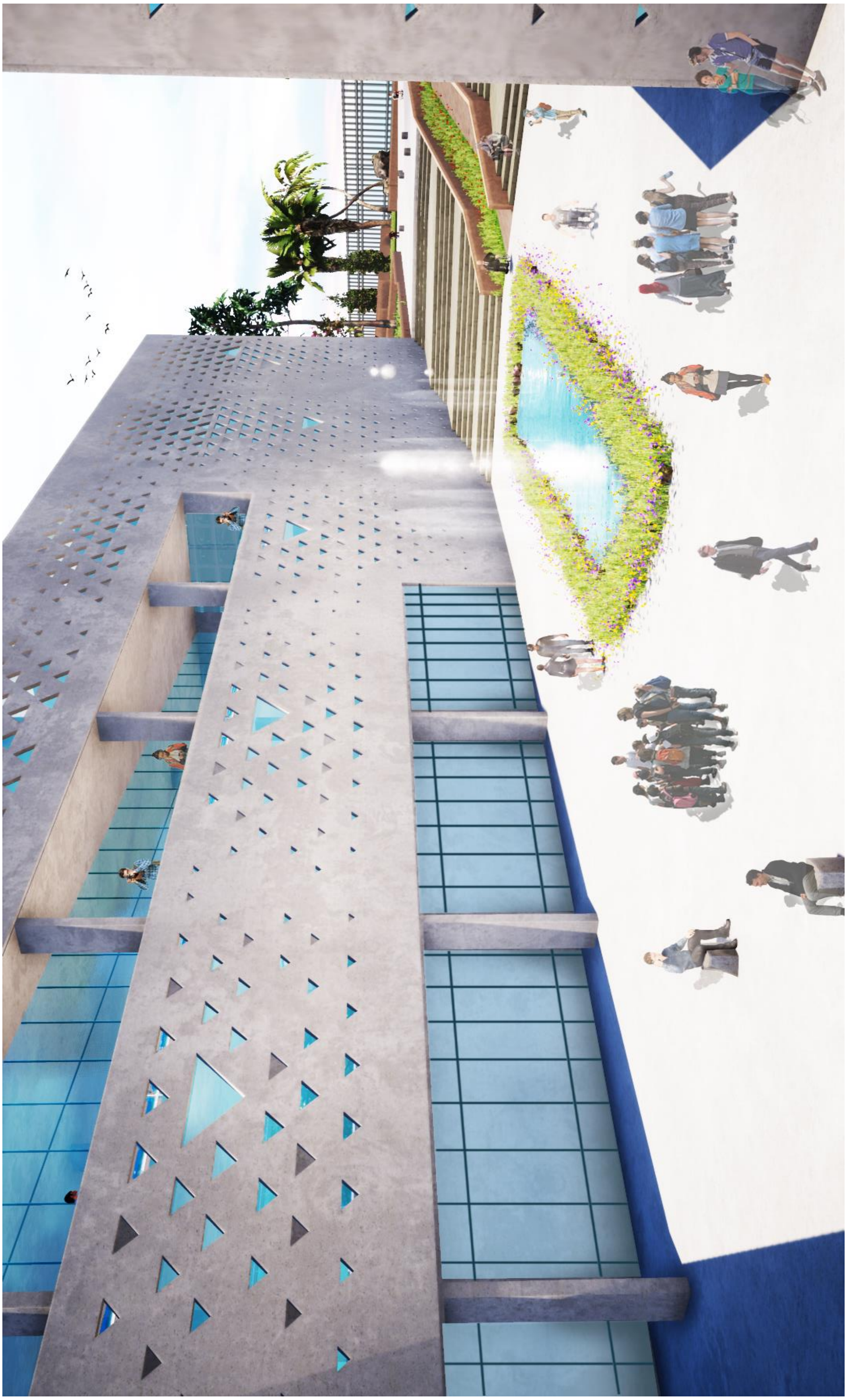


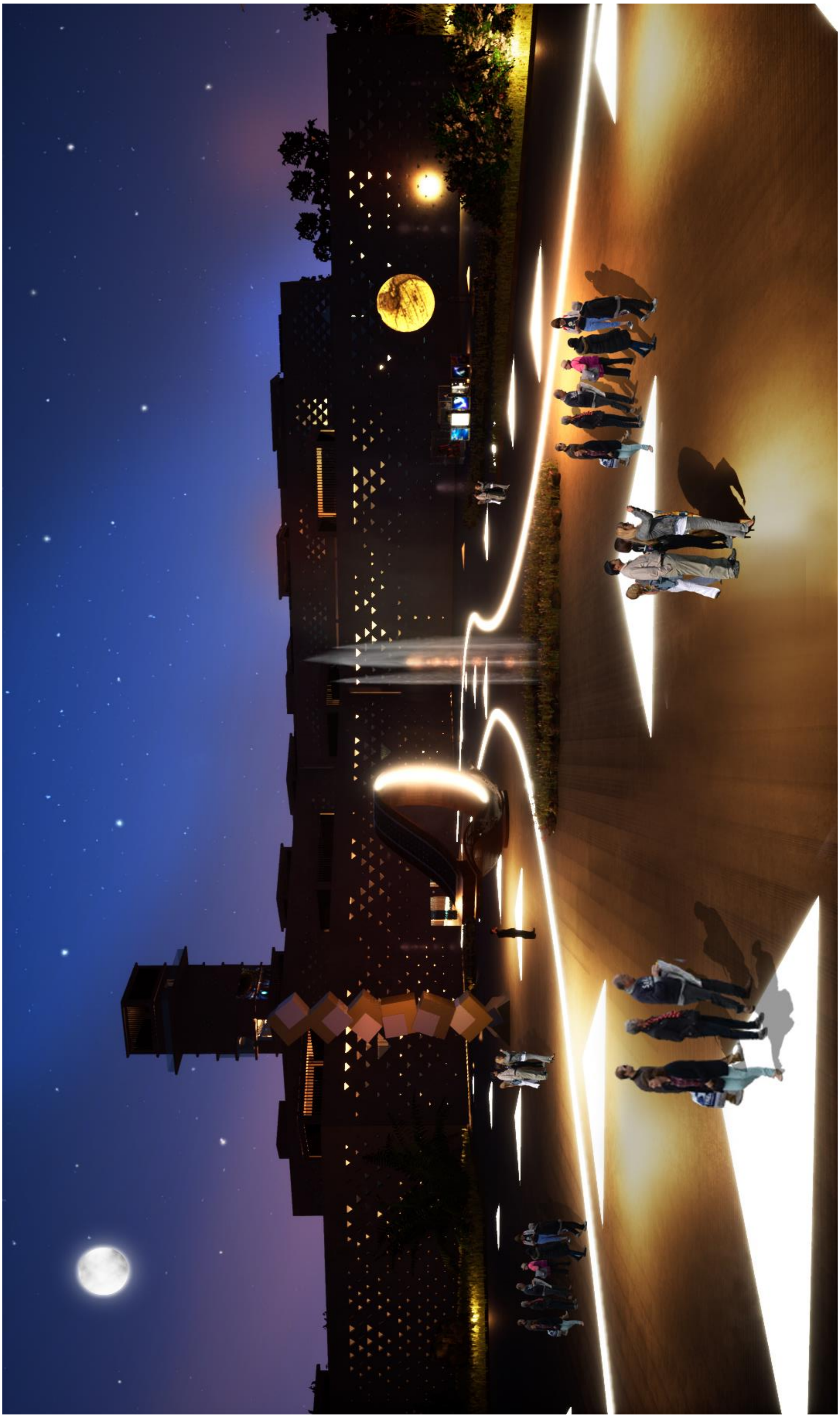

**Fig. 4.54** Section A-A 1-200

## 4.2. RENDERS









# 5. <u>TECHNICAL DESIGN PHASE</u>

5.1. SUSTAINABLE BBUILDING TECHNOLOGIES
5.2. ENVIRONMENTAL SECTIONS
5.3. ACTIVE STATEGIES
5.4. BUILDING TECHNOLOGICAL DETAILS
5.5. BUILDIMNG ELEMENTS LAYERS
5.6. STRUCTURAL DESIGN

# 5.1. SUSTINABLE BUILING TECHNOLOGY

## 5.1.1. CLIMATE ANALYSIS

Based on the provided climate data showed in this work, some specific elements were studied in depth to evaluate the possible contribution to the internal conditions of the building in order to reach the maximum possible comfort with the minimum energy consumption. Elements such as: dry bulb temperature (Tab), wind velocity, relative humidity of the air (RH) and Total solar radiation; which could easily contribute to implement passive or to improve active strategies.

The first element to analyze was the air temperature of the area. The design can be done using the maximum, the minimum or the average values, it depends on the designer choice. In this work, the methodology used was to work with the averages but taking into account the peak values (maximum and minimum) in a way that they can be handled in case of occurrence. From the next graphs, it is possible to observe that the city in fact is moderate and rainy in winter, and hot and dry in summer (the monthly dry bulb average temperature in the peak summer -June, July, August- can reach 36 degrees Celsius, but in the peak winter -December, January, February- the average dry bulb temperature does not fall below 10 degrees). However, the peak (maximum and minimum) values are the ones which could cause discomfort to the users.

The Egyptian standards state that the indoor air temperature in adequate conditions should fall into a range which varies between 21 and 27 Celsius degrees. It is also possible to conclude that implementing a heat recovery system coupled with natural ventilation could cover the building's cooling and heating needs. Although, as the climate nature in Egypt is so hot in summer and moderate in winter, so the need of cooling systems or ventilation strategies are essential in the cooling season, but the power used for heating is more or less negligible with comparison to the power which is needed for cooling in summer.

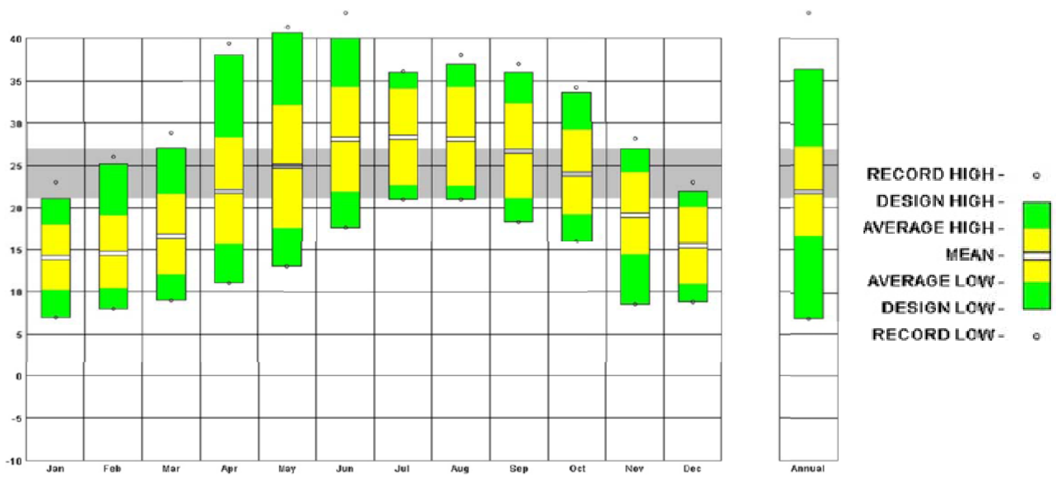



**Fig. 5.1** average air temperature

The Sun is the ultimate energy provider. The development of the renewable energy market is, to a large extent, based on that fact. Most of the green technologies currently are operating harvest solar energy, directly or indirectly. Direct solar energy source consists of solar rays reaching the atmosphere. They can be collected by two different technologies: solar photovoltaics (also known as solar PV) and solar thermal systems.

Solar PV is based on the photovoltaic effect, by which a photon (the basic unit of light) impacting a surface made of a special material generates the release of an electron. Solar thermal, on the other hand, uses sunlight to heat a fluid (depending on the particular application, it can be water or other fluid).

The graph indicates sunshine hours per day in 6th of October city range from 7.00 for every day in December to 11:8 each day in July. The longest day of the year is 13:56 long and the shortest day is 10:03 long. There is an average of 3451 hours of sunlight per year (of a possible 4383) with an average of 9:26 of sunlight per day. It is sunny 78.7% of daylight hours. The remaining 21.3% of daylight hours are likely cloudy or with shade, haze or low sun intensity. At midday, the sun is on average 60.2° above the horizon in the city.

As a conclusion, sunshine from the architectural point of view can be useful for exploiting in day lighting inside the building.

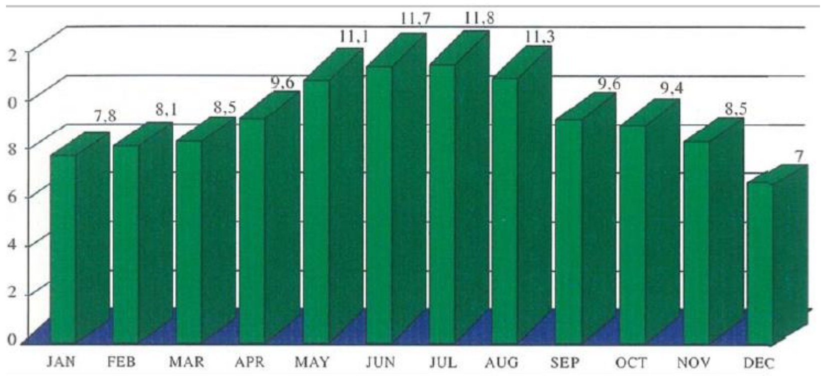



**Fig. 5.2** Average hours sunshine per day

Considering the solar energy, it can be absorbed and converted to electricity used to feed our science city with electricity or even to provide our building with hot water. But the negative aspect of sun is that, thermal energy will be transferred to the indoor and will heat up the zones, only if it's not treated well by using proper thermal insulation or massive envelope to reduce heat transfer or slow down the process to use the transferred heat during the night instead of the day time.

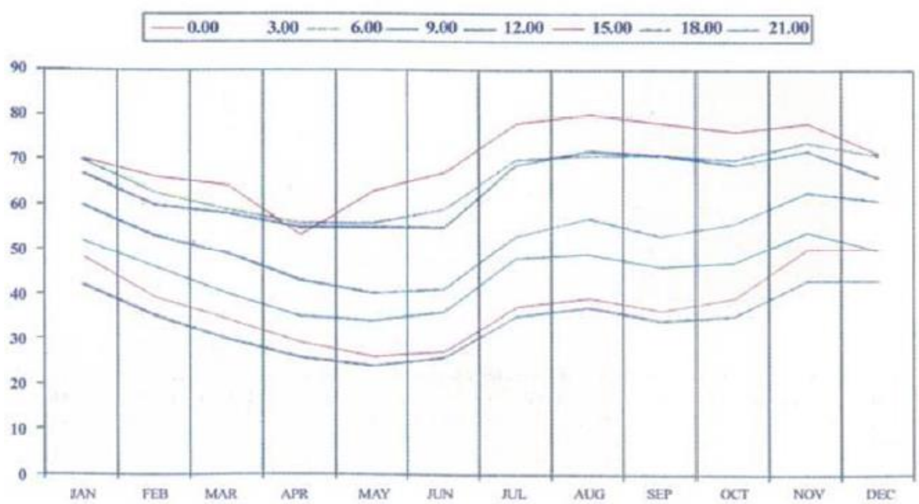



**Fig. 5.3** Relative humidity (%)

Wind conditions are presented as wind rose showing the existing wind patterns in terms of frequency and direction. 6th of October city's climate is very similar to Giza and Cairo, owing to its proximity to them. Every year, sometime from March to May, in intervals of two to three days approximately four times throughout this two-month duration, an extremely hot, dry and dusty wind blows from the south or the southwest. This wind is called khamasīn. When the flow of dry air continuously blows over vast desert regions, it picks up fine sand and dust particles and finally results in a dusty wind which is generally felt in the periphery of the desert. When this wind blows over Egypt, it causes high temperatures to soar temporarily at dangerous levels, usually over 45 °C (113 °F), the relative humidity levels to drop under 5%. The khamasīn causes sudden, early heat waves and the absolute highest temperature records in Egypt.

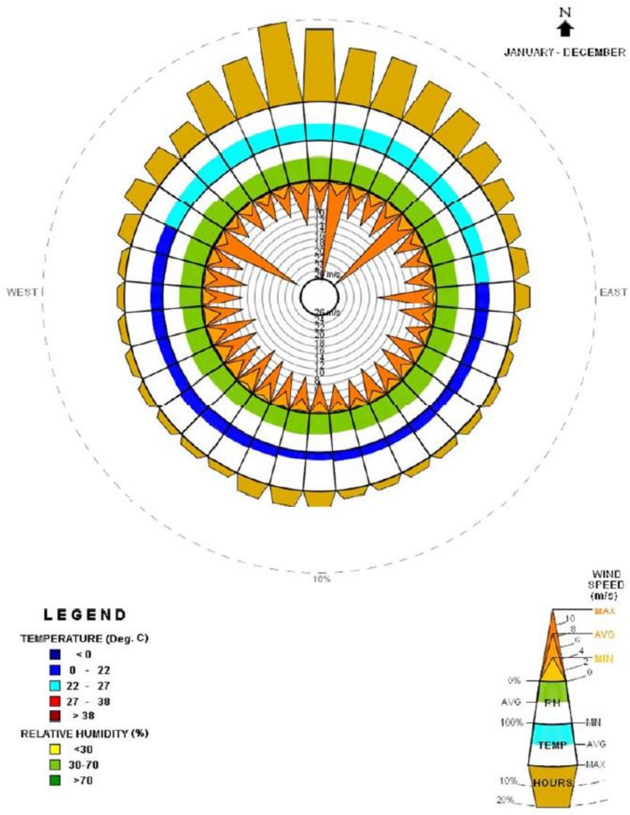
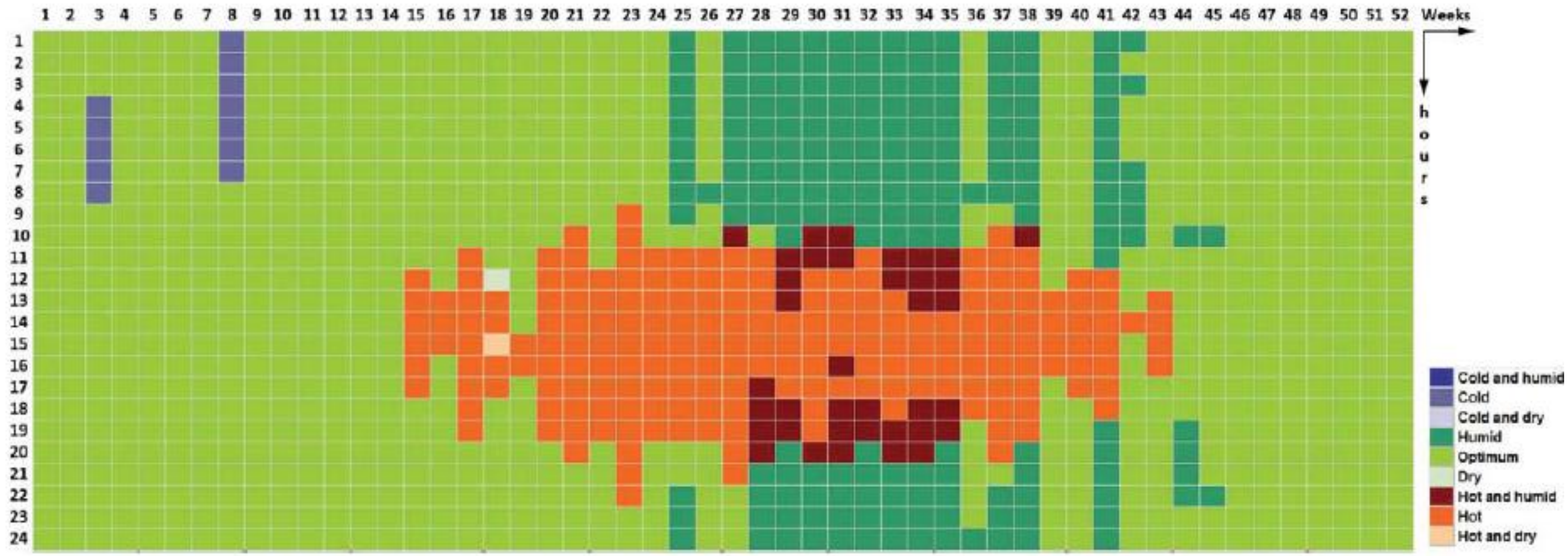



**Fig. 5.4** Wind rose


**Fig. 5.5** Average rain fall




). Heat map of the climate in Cairo showing temperature limitations during the central hours of summer and humidity limitations during the night-time.

Cold and humid: 0%
Cold: 1%
Cold and dry: 0%
Humid: 16%
Optimum (Climatic Potential for Natural Ventilation): 61%
Dry: 2%
Hot and humid: 5%
Hot: 14%
Hot and dry: 1%
In Cairo, weeks from 15 to 43 are too hot during the day, and it is too humid at night-time between weeks 25 and 42. But the climate is optimal for natural ventilation between weeks 1 and 14 and between weeks 46 and 52.

**Fig. 5.6** Heat map of the climate of Cairo

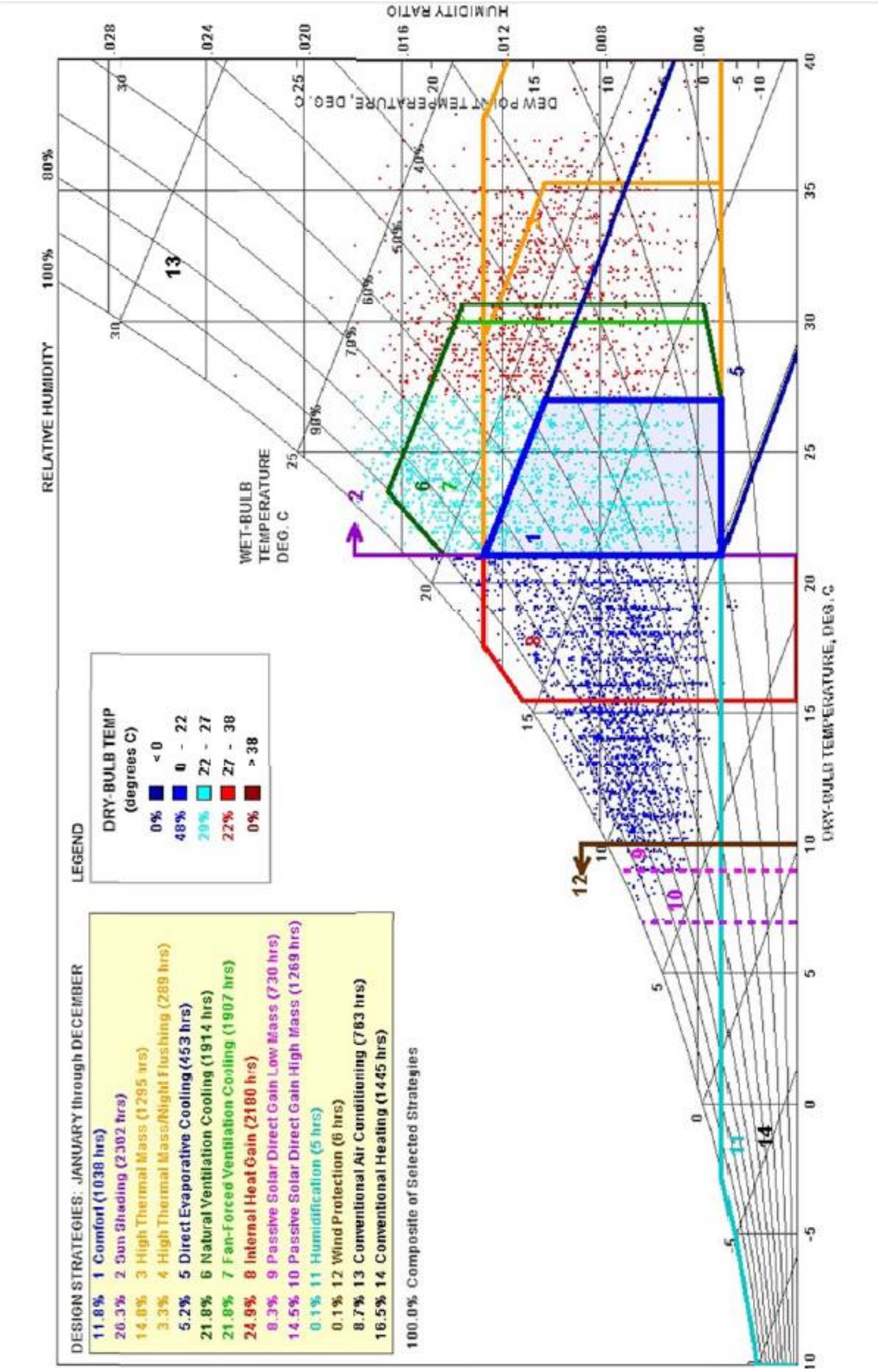



**Fig. 5.7** Psychometric chart showing temperature ranges in Egypt and comfort zone according to standards

### 5.1.2. GENERAL BUILDING ENERGY MODELLING

Given the fact that the design process of the project took into account the sustainable part in parallel with the development of the urban and architectural design, in this section of the work is shown how the energy performance of the building had been changing due to the decisions taken for the realization of the final product.

The analysis was done to the main target of sustainable project, and then was developed in a more detailed procedure which can be found in the following section of this chapter. Starting from the analysis of the shape factor, passing through the daylight analysis and finishing with the energy consumption analysis of the building complex.

Starting with the already defined ASHRAE 90.1-2013 baseline as shown in fig 5.8, surfaces of the model were defined as fixed and operable Glazing, Floor, Exterior/Interior wall and Roof. The model was analyzed initially with the SEFAIRA Plug-In installed in Google Sketch Up from which the results are also shown in this work. The tool is able to obtain general values before realizing a deep analysis on the building conditions, this are shown in an easy reading presentation which are included in this work. The fact that the tool tells the designer than the project's energy consumption is mainly dominated by the equipment gives an idea that the cooling and heating needs are not as big as expected, and they could be lowered into a point in which the plant systems are not as big as they were foreseen on the space required during the internal space organization.

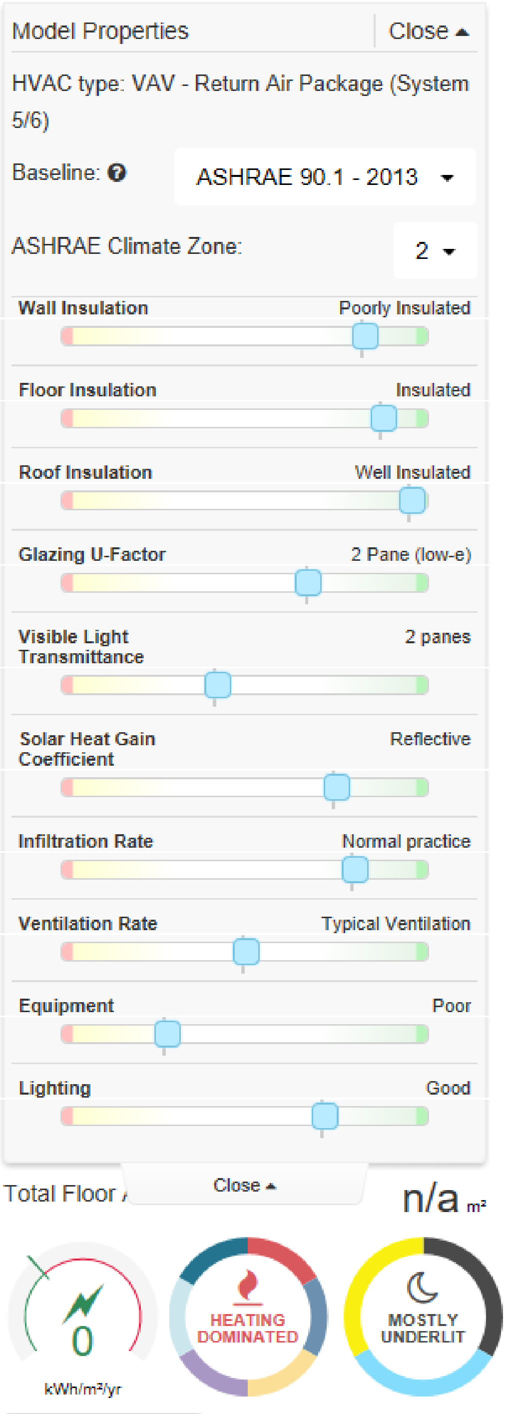



**Fig. 5.8** ASHREA 90.1-2013 baseline

To proceed was necessary to check which were the elements generating more advantageous or disadvantageous to keep as there were (This doesn't make sense), which ones should be approached in order to diminish the energy consumption. For this case, the lighting (to be checked by daylight analysis), equipment (defined by Egyptian standards for the building typology) and the Fresh air (provided by natural ventilation) were the 3 main aspects to control to have a big impact. The equipment can't be assessed directly by passive or active strategies, it depends on the devices used, its efficiency and the occupancy. For the lighting, it would be hard to improve it because it will require a meticulous study to obtain a more effective glazing distribution to increase the spaces that do not required artificial lighting.

So, in this case the fresh air is the most likely element to attack in order to get better results, this to the ambient temperature which according to climate analysis previously shown in this project gives values that range approximately between 10 and 36 degrees Celsius during the whole year, becoming a great heat sink useful for winter but unfavorable for summer. So, the ventilation rate can be increased by assuring a sufficient air tightness of the building avoiding air leaks. But not only ensuring a good air tightness would be useful, its beneficial contribution could be developing the building envelope to enhance the building performance through decreasing internal heat gains, as well as air, implementing other strategies to ensure indoor air quality.

One can note that the solar gains coming through the glazing are generating a significant overheating compared to the ones helping to reduce the heating needs, that means that the glazing would require shading or to be reduced in order to decrease its contribution to the cooling loads. Probably the shading has to be such that during summer it will be able to block the direct solar radiation but is able to let it pass during winter when it is more needed.

The glazing conduction also represents an important element generating gains for heating, but solving this issue would require decreasing its thermal conduction by having higher resistance provided by the glass sheet and with distances between each pane and this involves a great economical inversion to obtain a lower U-value.

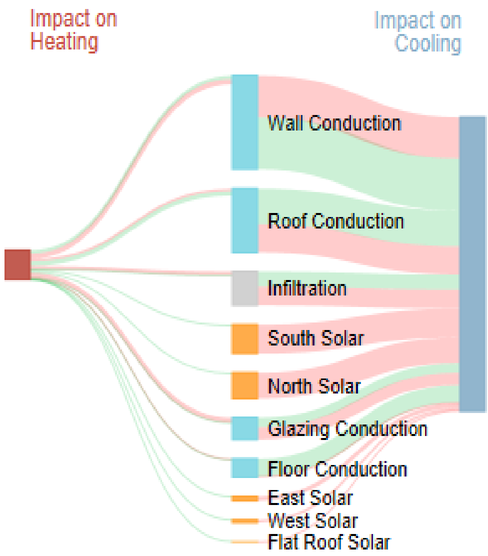



**Fig. 5.9** Impact on heating and cooling

**SAFAIRA BASELINE CONCEPT**

**Wall u value:** 0.59 w/m²k
**Floor u value:** 0.32 w/m²k
**Roof u value:** 0.18 w/m²k
**Glazing u value:** 1.99 w/m²k
**Visible light transmittance:** 0.42
**SHGC:** 0.4
**Infiltration rate:** 7.2 m³/m²h
**Ventilation rate:** 15 L/sec. person
**Equipment:** 25 w/m²
**Lighting:** 10 w/m²

- **Orientation analysis**

A correctly orientated building can save a lot of money in no longer requiring heating and cooling costs expenditure - in effect the building itself maintains a comfortable environment for you with little additional costs. This is especially relevant with rising fuels bills and the increasing costs of electricity. By simply building this way, a house can reduce its heating and cooling costs by 85%!

Along with massing, orientation is one of the most important steps in providing a building with passive thermal and visual comfort. Orientation was decided together with massing early in the design process, as neither can be truly optimized without the other. As with massing for visual comfort, the science city is oriented east-west rather. This orientation allows consistently harness daylight and control glare along the long faces of the building. It also minimizes glare from the rising or setting sun.

Considering east-west orientation is resulted in greater amount of incident radiation in winter than that in summer. In addition, glazing orientation is as important as the mass orientation, so that we designed the science city to have most of the glazing facing the north and less and controlled glazing facing the south, taking into account also the type of activity that is happening behind so where it's needed to provide large amounts of natural light and where it's better not to have natural light.

The graph shows that the suggested orientation which at zero degree is the best. From the energy point of view, with addition to the site limitation.

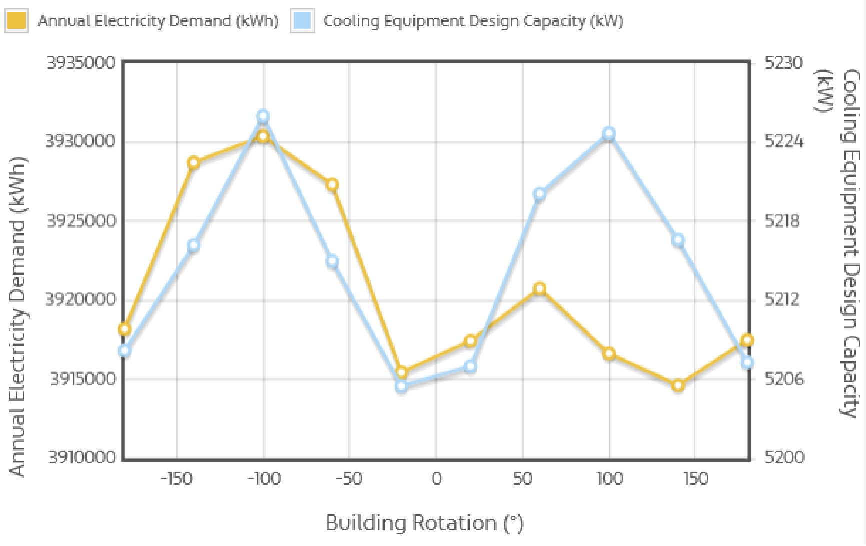



**Fig. 5.10** Building orientation graph

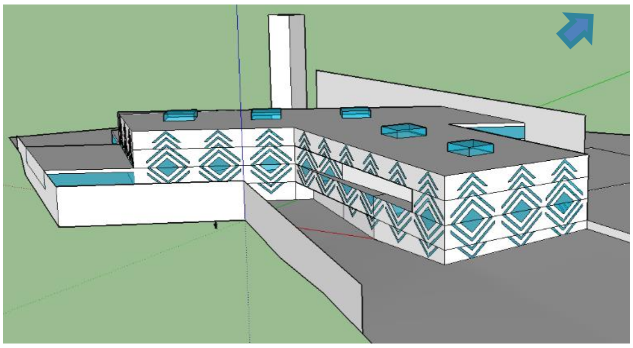


**Fig. 5.11** Sefaira building model

- **shape analysis**

From the literature and from the experience on previous designed projects, the shape factor is a good initial indicator of the energy performance of the building .By giving a first idea of the compactness of the shape, due to the fact that it tells the designer how small or how big is the amount of area is which is transmitting the **heat out or into the building in relation with the volume of air which would be contained,** the lower the value of this transmittance area the lower is the heat transmission, encouraging lower heat gains and losses.
The shape limitation was a result of the project program to have 3 campuses to be built in 3 phases, also to be flexible allowing any future modifications. Due to different possibilities, we developed the lower energy consumption design, although the differences were not so big, but it will be huge considering the whole area.

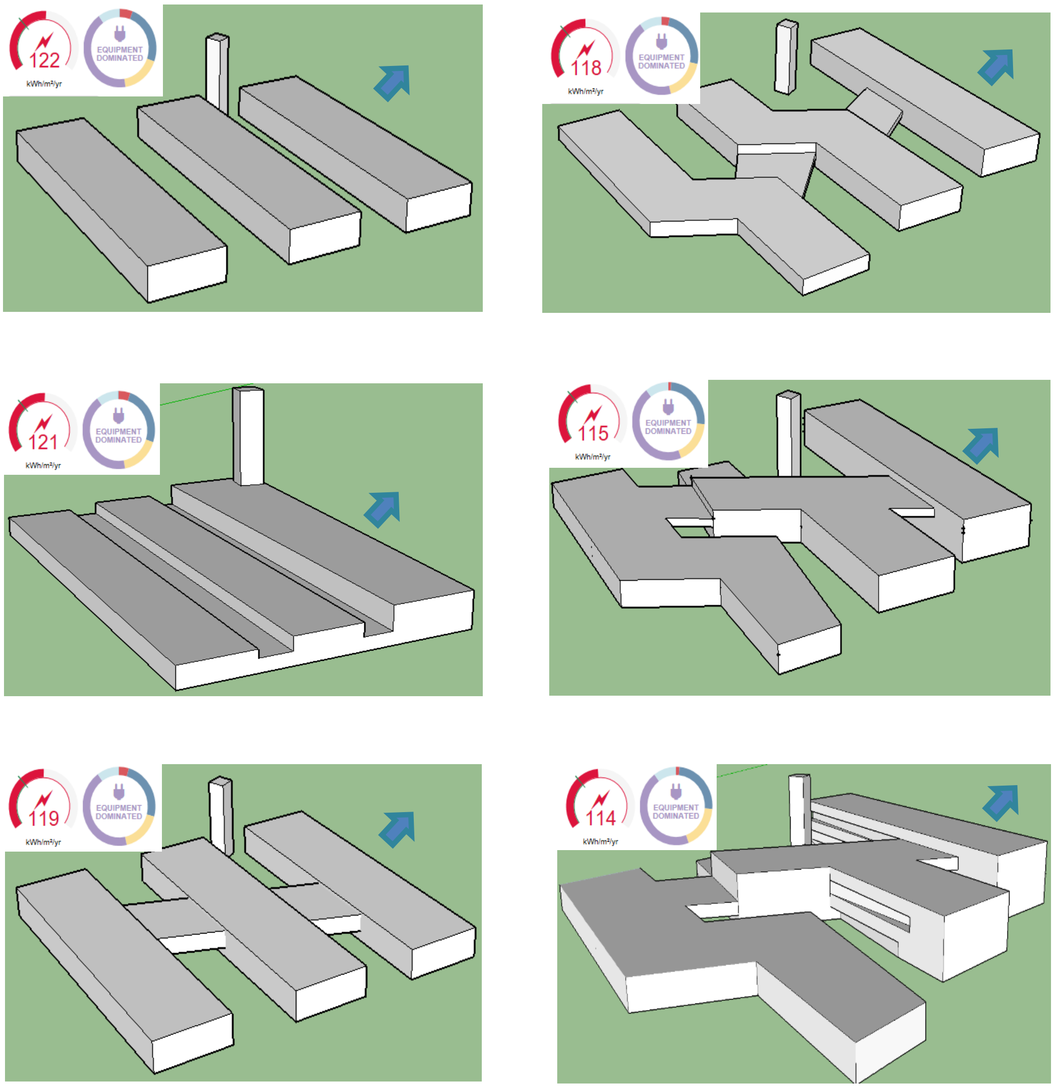



**Fig. 5.12** Shape analysis

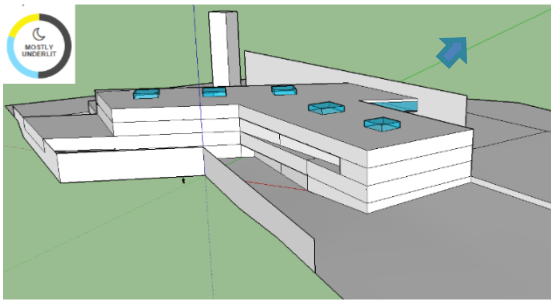
- **Daylight analysis**

Starting from here analysis is focused on the middle mass as it is characterized by different activities inside, also it is the most interesting as its linking the other two masses together. After the orientation and building shape according to the previous analysis were decided, we moved to the daylight analysis. Firstly, the overall well and over lit analysis have been checked, then each floor of the building separately was analyzed.

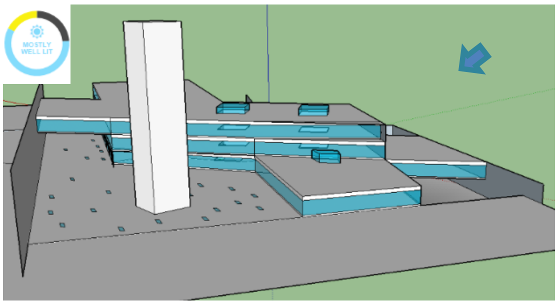
Different possibilities have been tried with different percentage of glazing in each façade, considering mostly the south and north facades, taking in account that they are the longitudinal facades, and the west and east facades areas are small in comparison to the north and south ones.

The mass is composed of 3 active floors with a basement half imbedded underground. Each floor is 5 meters high. The function in the western wing is mainly exhibitions, and in the eastern wing is part exhibition, part administration and auditorium. The mass is not affected by any external shades as the surrounding buildings are so far and a low height, so the only shading around our mass is the two other external campuses of the Science City complex.

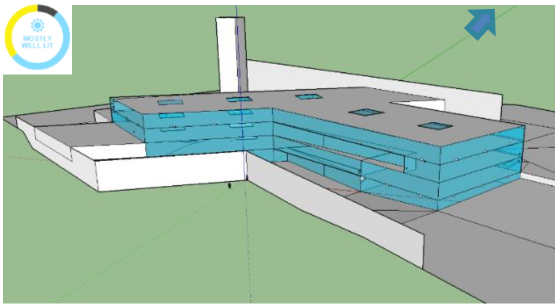
**total area:**
for all floors 35,321m²
**option 1:**
the south façade is fully solid and the north one is 60% glazed, with skylights
**conclusion:**
need to reduce the dark zones



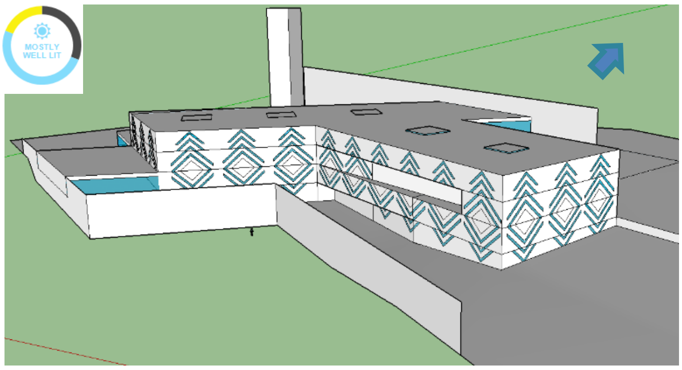

**total area:**
for all floors 35,321m²
**option 2:**
the north and west façades are fully glazed and the south one is solid
**conclusion:**
well-lit increased but still need to reduce the dark zones



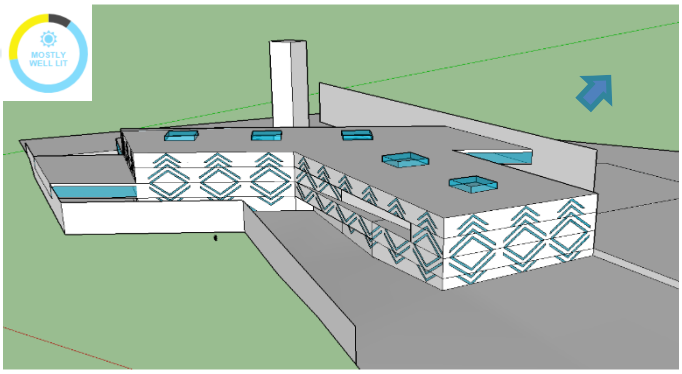
**total area:**
for all floors 35,321m²
**option 3:**
the south and east façades are fully glazed and the north one is 60% glazed, with flat skylights
**conclusion:**
better than option 1 and 2, but over lit increased a lot



**total area:**
for all floors 35,321m²
**option 4:**
the south façade is controlled glazed and the north one is 70% glazed
**conclusion:**
well-lit increased but the over lit need to be reduced




**total area:**
for all floors 35,321m²
**option 5:**
the south façade controlled glazed and the north one is 70% glazed, with skylights
**conclusion:**
well-lit increased and over lit and dark zones decreased.




**total area:**
for all floors 35,321m²
**option 5:**
increasing the amount of controlled glazing in the south façade and the north one is 70% glazed, with skylights
**conclusion:**
the optimum option as well-lit increased and dark zones decreased.

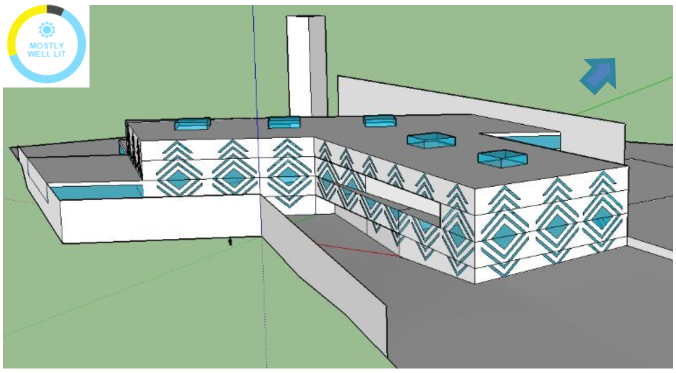



**Fig. 5.13** Daylight analysis

According to the glazing analysis we developed more option 5, trying to control more the amount of over lit. taking into account that by using Sefaira as an energy simulation tool, glazing application on facades has been simplified using a simple model. But in the real model the glazing design is more complicated, so a balanced amount of glazing had been used approximated to that model to have similar results. Moving to the next step to analyze daylighting for each floor separately. The skylights are elevated 4 meters height to integrate automated louvers in the lateral sides for the sake of natural ventilation, so the glazed area involved in the horizontal surface and the lateral surfaces are working as wind catchers.

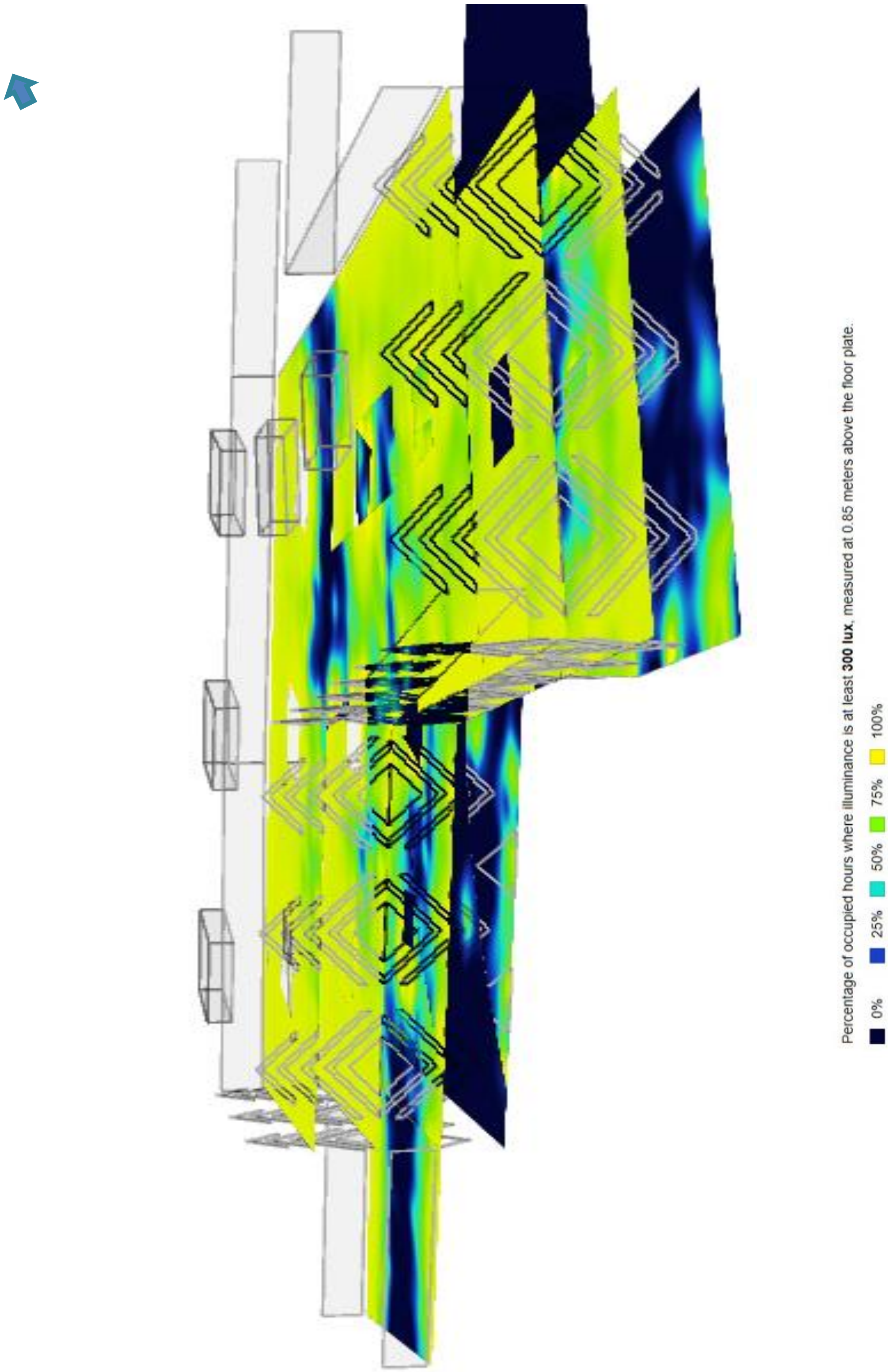



**Fig. 5.14** Daylight analysis for the whole building (mass 2)

Second floor

First floor

Ground floor

Basement

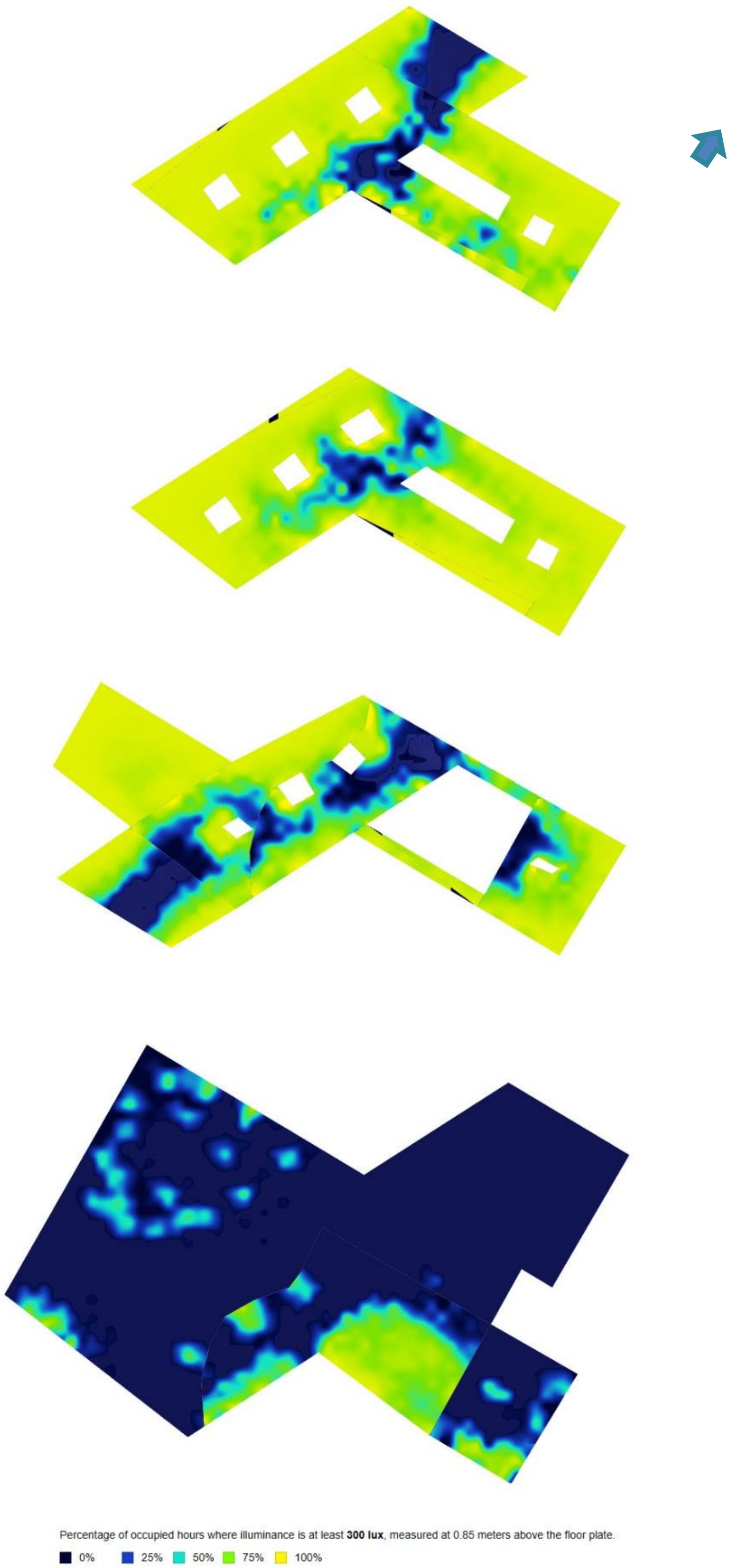



**Fig. 5.15** Daylight analysis for each floor (mass 2)

- **Single strategy application effects**

After the masses and orientation study and considering the climatic analysis, applying the concept and architecture consideration an integrated design proposal was reached, and this section will show the analysis and evaluation of the proposal starting from the baseline concept and the impact of using this baseline. For this part of analysis, the web app of SEFAIRA analysis application was used and response curves was produced to reach a proper baseline for our design. In the Web Application of SEFAIRA the model was described in more detail. This is that the energy resources, occupation, building typology, wall assembly type, roof type and core structure type can be defined to give the tool more information which is necessary to narrow the uncertainties that could be giving the wrong results.
The main two points were always analyzed are the cooling load and annual electricity demand and how to decrease them. By designing our own baseline, we define U values of the envelope of the project. SEFAIRA web application allows us to integrate some building strategies (for example; natural ventilation, PV panels and shading system) to study how it will affect our energy system. For these strategies we define working schedules or insert some data to be useful for more accurate results.

**Strategy 1: HVAC systems**

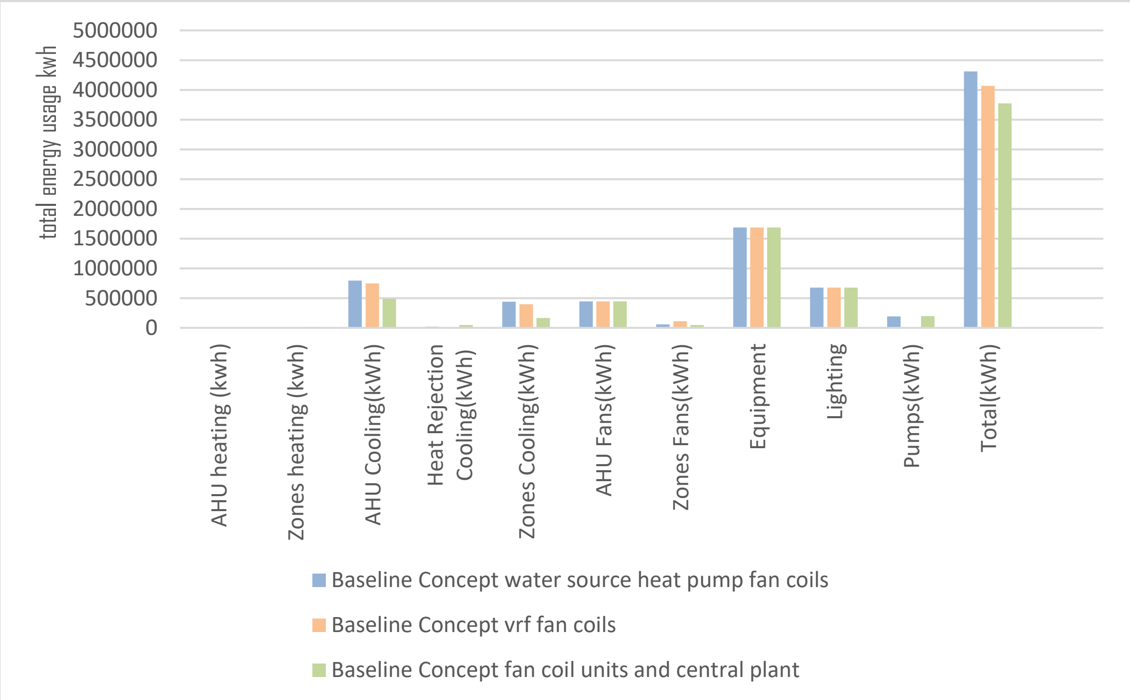



**Fig. 5.16** Different HVAC systems and total energy usage per year (kwh)

Total energy usage per year kWh has been compared by applying different HVAC systems in our building. The result shows the influence of each system on different building loads (heating, cooling, equipment and pumps). As shown here the total energy usage for the fan coil units and central plant -keeping the same baseline concept-, is the best result giving the lowest total energy usage. It's also obvious here that heating loads are null.

**Strategy 2: natural ventilation**

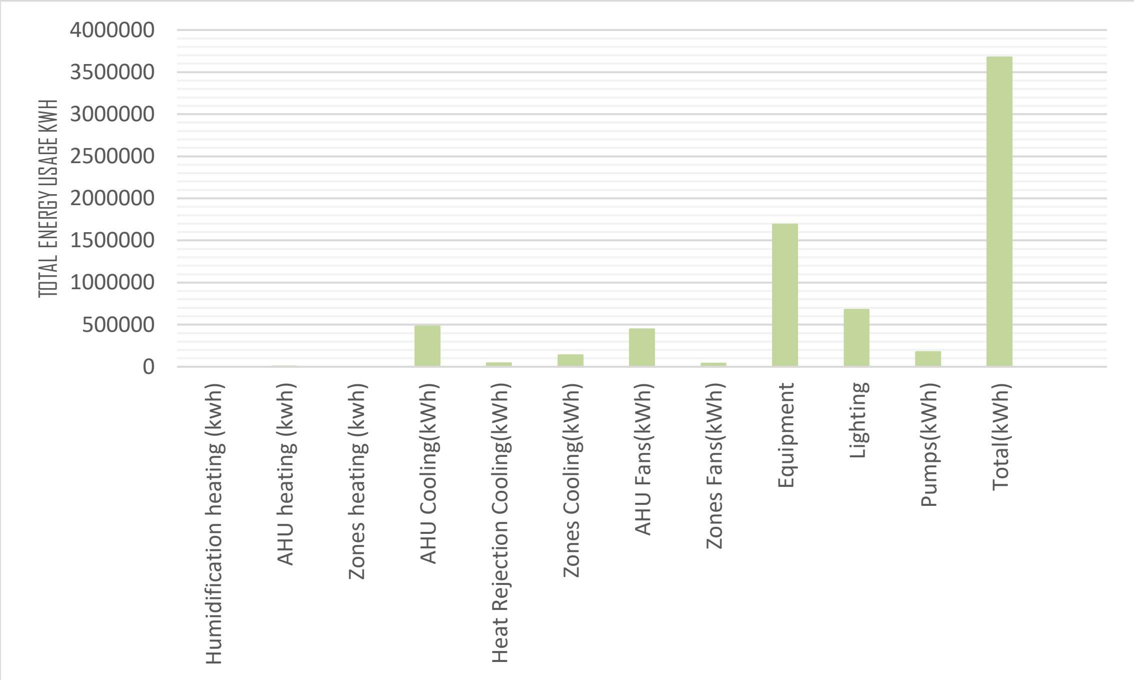



**Fig. 5.17** Effect of combination of strategy 1 and 2 on total energy usage per year (kwh)

There are many ways in which buildings can utilize natural ventilation to provide an acceptable level of thermal comfort. Orientation is an important factor in allowing cross ventilation by providing access to predominant wind directions. innovative solutions such as wind towers can allow natural ventilation like we implemented in the observation tower.

Natural ventilation was implemented in mass 2 using facade operable glazing, also by using automated louvers in wind catchers. The ventilation outside air rate per person is 15 L/s. person defined for the building typology. The HVAC system is considered to be natural ventilation and cooling. It's working during the working hours schedule as was considered that all openings are closed if the building is unoccupied and if the weather condition is windy outside.

The working schedule of HVAC system starting from 10am till 7pm. The building is working 6 days per week. The design temperature setpoints is the range of thermal comfort temperatures that mentioned before (21 degrees Celsius to 25 degrees Celsius). And setback temperatures from 12 degrees Celsius to 28 degrees Celsius.

### Strategy 3: building envelope

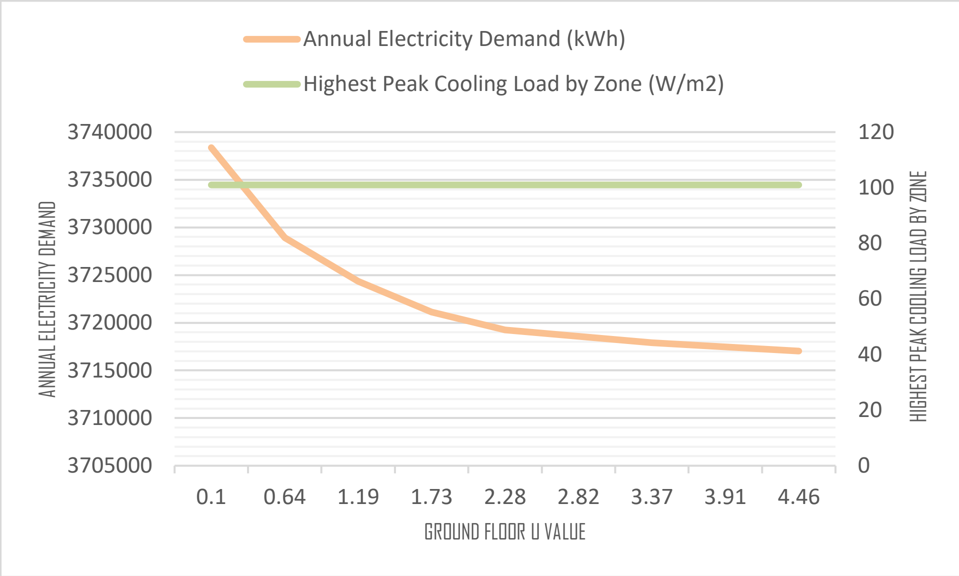



**Fig. 5.18** Effect of ground floor U-value on annual electricity demand (kwh)

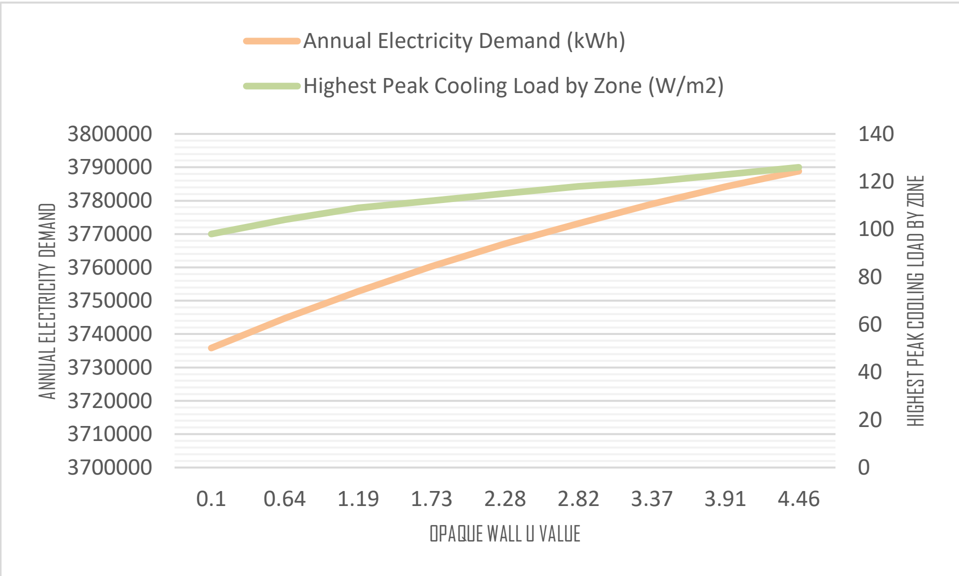



**Fig. 5.19** Effect of opaque wall U-value on annual electricity demand (kwh)

Check the effect of different u values changing in ground floor. U value doesn't affect the highest peak cooling load by zone, it is constant for all u values at 101 w/m². For the annual electricity demand, starting from 0.1 w/m²k u value till 2.82 w/m²k dropped dramatically from 3737000 kWh to 3719000 kWh respectively, then it is decreased slightly in a linear relation with the u value. According to this analysis, the u value of the ground floor was fixed to be 2.8 w/m².
For the second graph, the opaque wall u value was checked. It's giving the same relation for both parameters, they increase while increasing u value, it's obvious from the graph that the slope of annual electricity demand is much higher than the slope of highest peak cooling load by zone. According to this result, for the opaque wall u value to be 0.1 w/m²k was selected.

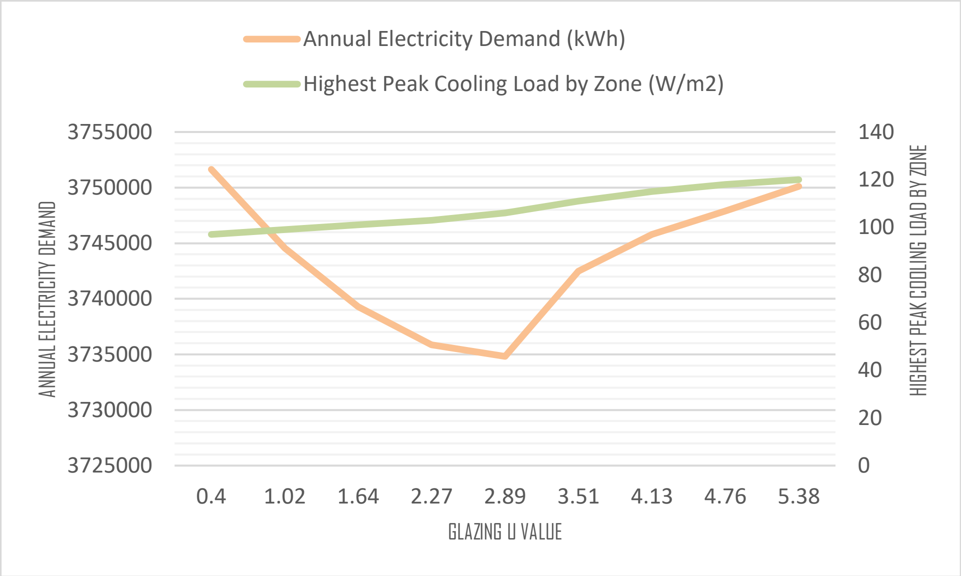



**Fig. 5.20** Effect of glazing U-value on annual electricity demand (kwh)

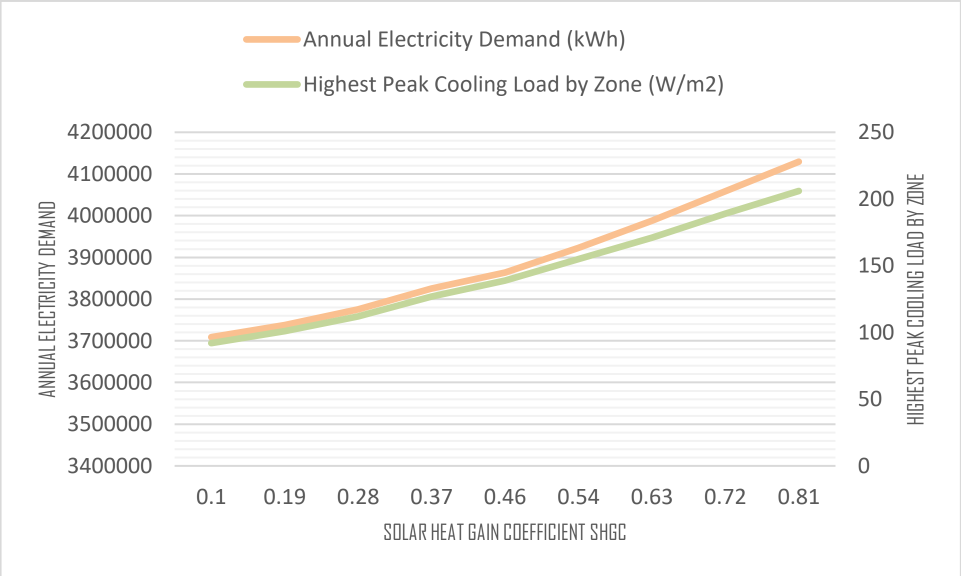



**Fig. 5.21** SHGC and annual electricity demand (kwh)

Glazing U values and SHGC factors were vital parameters that affect the cooling load and energy demand. In the glazing u value graph, it is shown that the annual energy demand decreased till 2.8 w/m²k then it is increased, but for the cooling load the u value change does not affect a lot. SHGC has a directly proportional relationship with both parameters.

A U value of 2.8 w/m²k was chosen, this value was suitable for the project in terms of energy consumption and architecture point of view. The glazing is operable or fixed. It is composed of Double insulated glazing 24 mm with argon filling with distance 3 cm. The operable glazing is used in natural ventilation which is a passive strategy that was used to decrease cooling loads. The skylight glazing is established in the roof for a better performance of daylighting inside mass 2.

**N.B: FENESTRATION SHGC**

The solar heat gain coefficient (SHGC) for fenestration indicates how much solar gain enters the space. The proposal would reduce SHGC requirements in hot climate zones, which will result in reduced heat gain and less energy used for space cooling. Peak cooling and cooling equipment sizes may also be reduced. Add fenestration shading as an option to reduce SHGC.

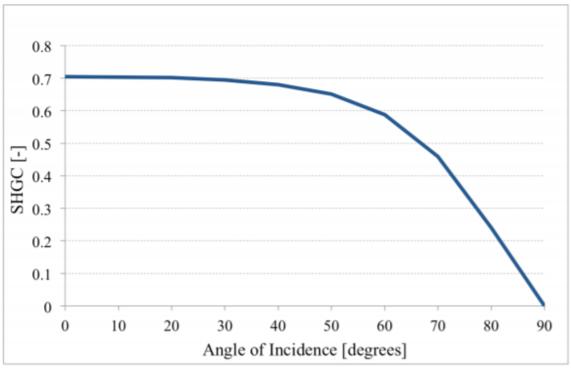



**Fig. 5.22** Solar heat gain coefficient for a clear double glazing as a function of angle of incidence under NFRC slandered conditions with

SHGC is not only specified for each façade or fenestration orientations but it should be calculated for each hour of the year taking into account the specific solar angle, diffuse and direct intensity, outside temperature and wind speed conditions, orientation, shading and building geometry.

Whole building annual energy simulation tools like SEFAIRA cannot calculate the SHGC of a window. This is due to the fact that the solar energy transmitted through a window (direct and diffuse radiation and the inward flowing fraction of the absorbed energy) depends on dynamic simulation, but SEFAIRA tool is based on generic static analysis.

- **Vertical fenestration**

**North**

This is the most desirable direction for even, day-long light. It's a safe direction to have windows protected from overheating concerns. So, we select SHGC for north glazing 0.2

**South**

South is important direction for reducing heating in our project. By decreasing south-facing window area and Solar Heat Gain Coefficients SHGC, we reduce heating. So, we design the south façade to be mostly solid (by applying prefabricated panels to the external surface of the façade with glazing behind). As its protected we are not worried about having higher SHGC 0.25

**East & West**

East and west windows are worse than the south direction as shown in fig. 23 as east and west glazing collects almost 3 times the solar of the south window radiation. In both facades, shaded glazing with (SHGC 0.25) and unshaded glazing (SHGC 0.2) areas have been selected.

- **Horizontal fenestration**

In Egypt, the highest solar radiation in summer reaches 1000 W/m² with an angel of 83°. The sun radiation inclination is almost vertical, so it was necessary to decrease as much as possible the SHGC that's why we selected the horizontal glazing SHGC 0.15.
A horizontal window receives 4 to 5 times more solar radiation than south window on June 21.

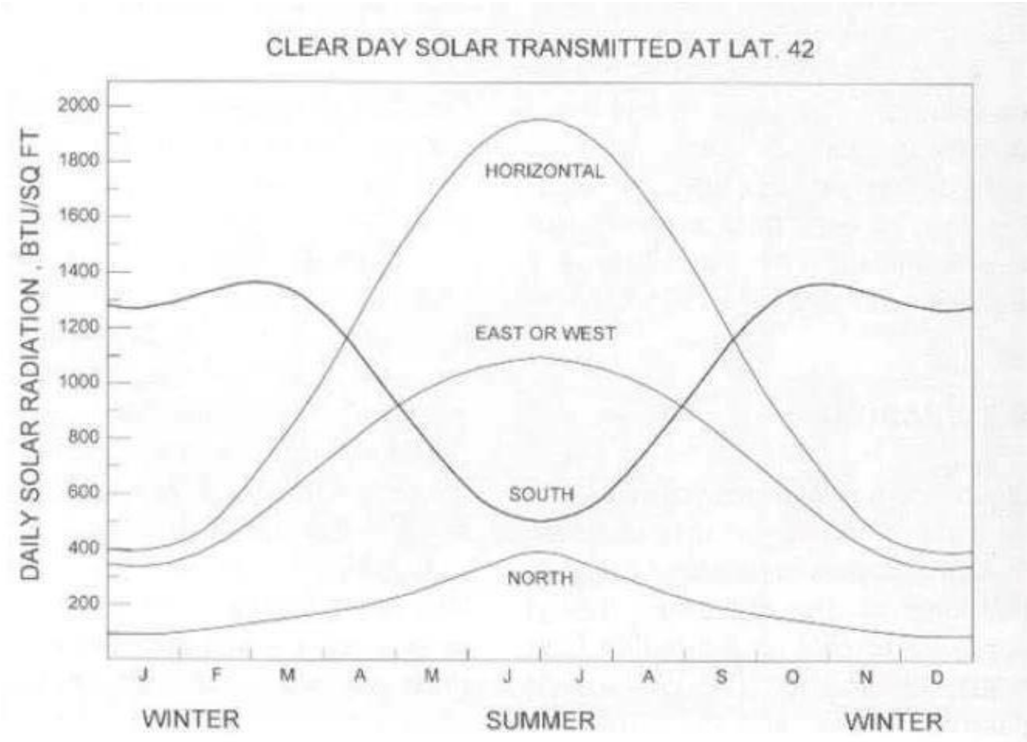



**Fig. 5.23** Solar Radiation received on different façades and roof

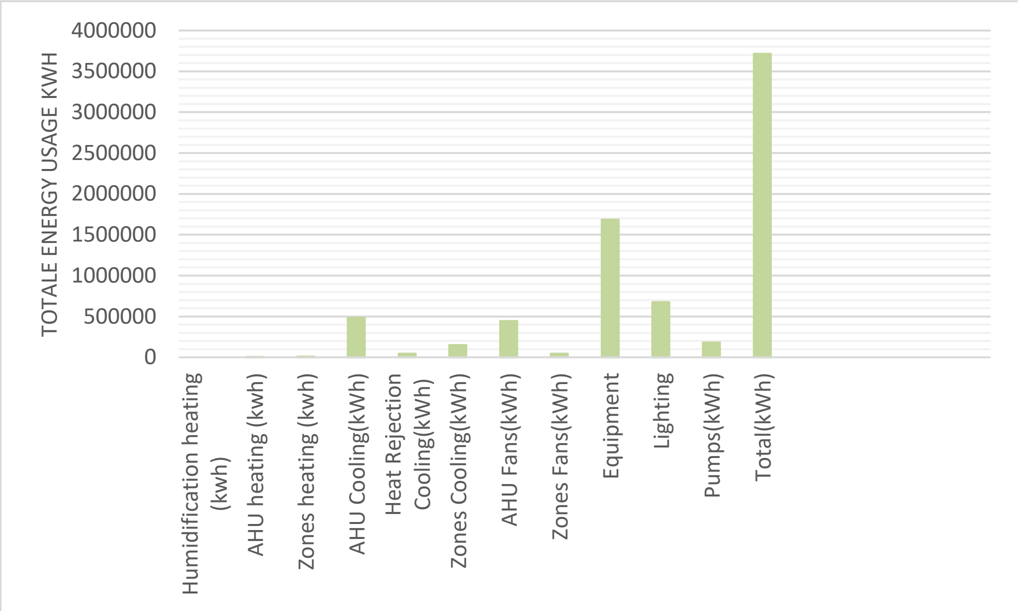



**Fig. 5.24** The impact of the new envelope settings

The graph shows the impact of the new envelope settings applied in our building on the different building services and loads. The equipment load is the highest load but it's out of our control as its defined by the Egyptian standards, so we have to implement other strategies to improve the building performance through decreasing the cooling loads (482224 kWh) and artificial lighting by using LED lights instead of the normal ones also it can be managed to work automatically depending in the established working hours schedule.

**DEFINED ENVELOPE**

**Wall u value:** 0.1 W/m²k
**Floor u value:** 2.8 W/m²k
**Roof u value:** 0.1 W/m²k
**Façade glazing u value:** 2.8 W/m²k
**Roof glazing u value:** 2.4 W/m²k
**Visible light transmittance:** 0.67
**Infiltration rate:** 2 m³/m²h
**Ventilation rate:** 15 L/sec. person
**Equipment:** 25 W/m²
**Lighting:** 10 W/m²
**SHGC:** varies from 0.15 to 0.25 depending on orientation

**Strategy 4: shading**

Applying internal venation shading to control basis SHGC.

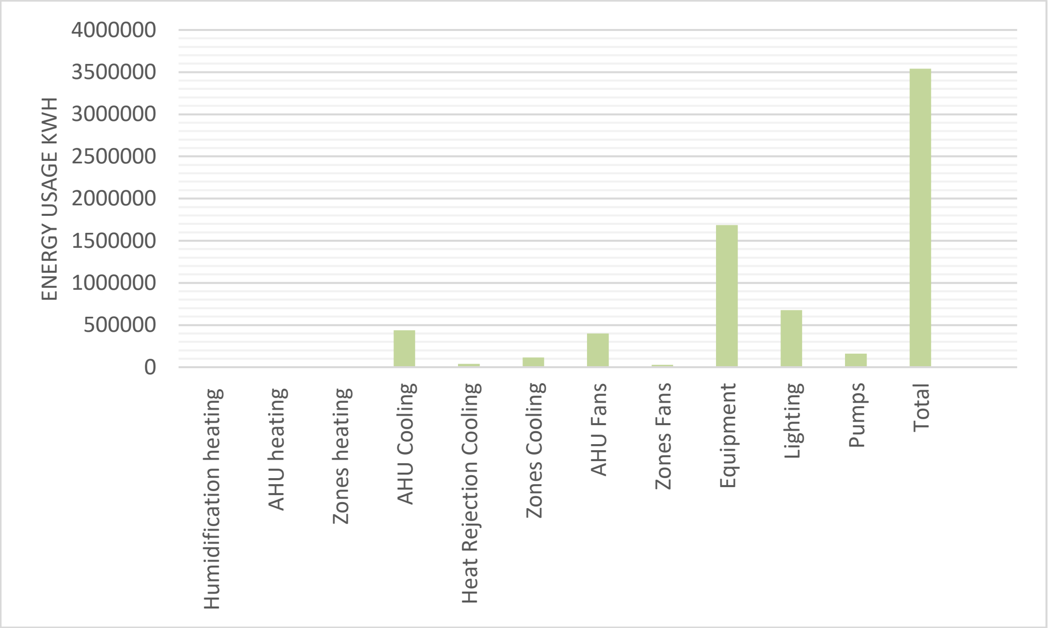



**Fig. 5.25** The impact of shading on energy usage (kwh)

**Strategy 5: PV panels**

The performance of PV modules depends on the temperature and on the solar irradiance- the power per unit area received from the Sun in the form of electromagnetic radiation in the wavelength range of the measuring instrument, but the exact dependence varies between different types of PV modules. Due to the low voltage of an individual solar cell (typically 0.5V), several cells are wired in series in the manufacture of a "laminate". The laminate is assembled into a protective weatherproof enclosure, thus making a photovoltaic module or solar panel. Modules may then be strung together into a photovoltaic array. The electricity generated can be either stored, used directly or fed into a large electricity grid powered by central generation plants or combined with one or many domestic electricity generators to feed into a small grid. Depending on the type of application, the rest of the system consists of different components. To estimate the energy produced from the PV panels we used an online application called **photovoltaic geothermal information system**. depending on interactive maps. We inserted some data about the location of our project and information about the panel specifications to give an accurate estimated energy produced.

Some definitions to help in understanding the PV estimation analysis

- **Peak power:**
  This is the power that the manufacturer declares that the PV array can produce under standard test conditions, which are a constant 1000W of solar irradiation per square meter in the plane of the array, at an array temperature of 25° C.
- **Estimated system losses**
  The estimated system losses are all the losses in the system, which cause the power actually
  delivered to the electricity grid to be lower than the power produced by the PV modules. There are several causes for this loss, such as losses in cables, power inverters, dirt on the modules and so on. We have given a default value of 14%.
- **Mounting position**
  For fixed (non-tracking) systems the way the modules are mounted will have an influence on the temperature of the module, which in turn affects the efficiency. Experiments have shown that if the movement of air behind the modules is restricted, the modules can get considerably hotter (up to 15° C at 1000W/$m^2$ of sunlight).
  We chose: free-standing, means that the modules are mounted on a rack with air flowing freely behind the modules.
- **Inclination angle**
  This is the angle of the PV modules from the horizontal plane, for a fixed (non-tracking) mounting
- **Tracking options**
  The previous options assume that the modules are mounted in a fixed position at a given slope and orientation. However, there are systems that can move the PV modules to allow them to track the movement of the sun. In this way, we can increase the amount of sunlight arriving at the PV modules. This movement can be made in several different ways like vertical axis, inclined axis and two axis tracking.

## PV ESTIMATION

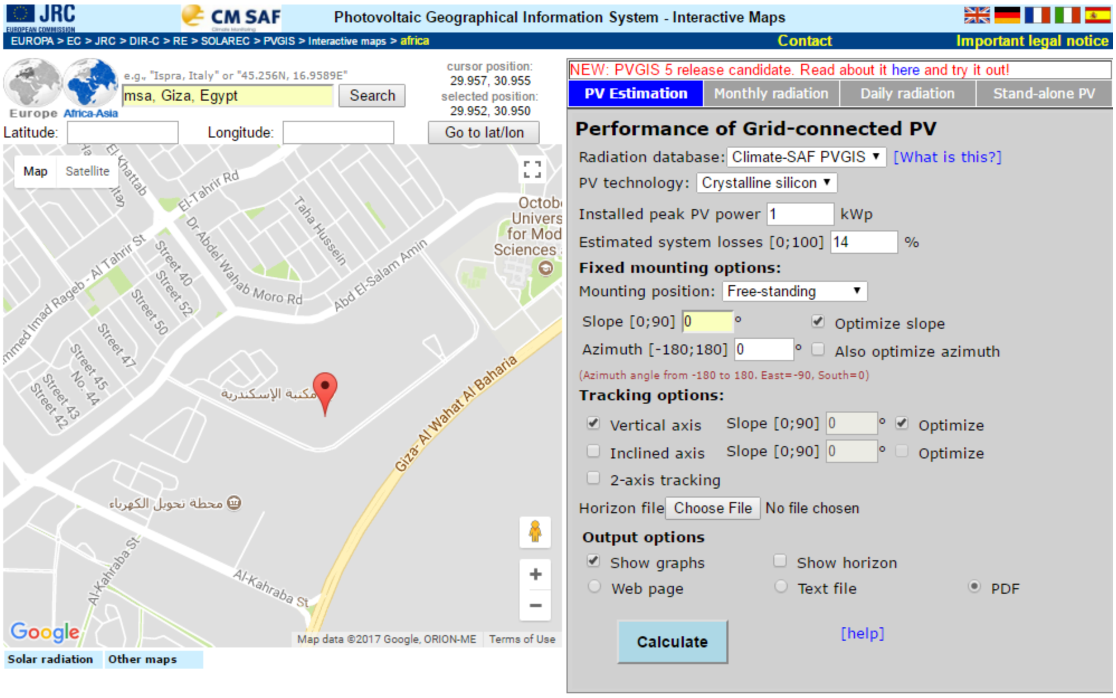



**Fig. 5.26** PV estimation analysis

PVGIS estimates of solar electricity generation
**Location:** 29°57'6" North, 30°56'58" East, Elevation: 189 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:** 12.4% (using local ambient temperature)
**Estimated loss due to angular reflectance effects:** 2.5%
**Other losses (cables, inverter etc.):** 14.0%
**Combined PV system losses:** 26.6%
**$E_d$:** Average daily electricity production from the given system(kWh)
**$E_m$:** Average monthly electricity production from the given system (kWh)
**$H_d$:** Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m$^2$)
**$H_m$:** Average sum of global irradiation per square meter received by the modules of the given system (kWh/m$^2$)

| **Fixed system: inclination=28°, orientation=0°** | | | | |
|---|---|---|---|---|
| **Month** | **$E_d$** | **$E_m$** | **$H_d$** | **$H_m$** |
| Jan | 3.93 | 122 | 5.09 | 158 |
| Feb | 4.36 | 122 | 5.71 | 160 |
| Mar | 5.33 | 165 | 7.15 | 222 |
| Apr | 5.06 | 152 | 6.95 | 209 |
| May | 5.07 | 157 | 7.08 | 220 |
| Jun | 5.16 | 155 | 7.31 | 219 |
| Jul | 5.18 | 161 | 7.33 | 227 |
| Aug | 5.19 | 161 | 7.36 | 228 |
| Sep | 5.10 | 153 | 7.14 | 214 |
| Oct | 4.84 | 150 | 6.63 | 206 |
| Nov | 4.20 | 126 | 5.55 | 166 |
| Dec | 3.83 | 119 | 4.95 | 153 |
| **Yearly average** | **4.77** | **145** | **6.52** | **198** |
| **Total for year** | | **1740** | | **2380** |

**Fig. 5.27** Average electricity production

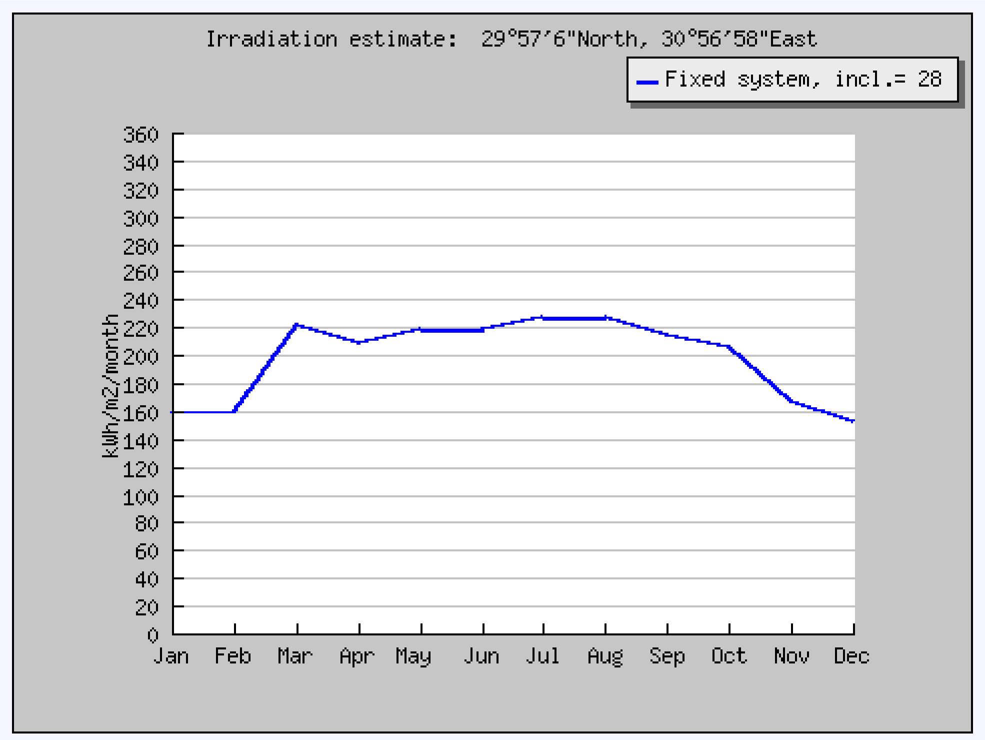



**Fig. 5.28** Solar irradiance received from the sun by using Fixed PV panels

The graph shows that the fixed PV panels with inclination 28 degree is giving maximum performance in between April and October. Referring to the climatic analysis part in our previous studies in these months we have design high temp ranges from 38 degrees Celsius to 35 degrees Celsius respectively during the year.

## MONTHLY GLOBAL IRRADIATION DATA

Some definitions to help in understanding the Monthly radiation analysis:
**Horizontal irradiation:**
This value is the monthly/yearly average of the sum of the solar radiation energy that hits one square meter in a horizontal plane in one day. This is measured in $Wh/m^2/day$
**Optimal inclination angle**
The optimal inclination angle is the angle you should use to receive the maximum amount of solar energy on a flat plate facing south (such as a solar power panel)
**Ratio of diffuse to global radiation**
A large fraction of the radiation arriving at the ground does not come directly from the sun but as a result of scattering from the air (the blue sky) clouds and haze. This is known as diffuse radiation. This number gives the fraction of the total radiation arriving at the ground which is due to diffuse radiation.

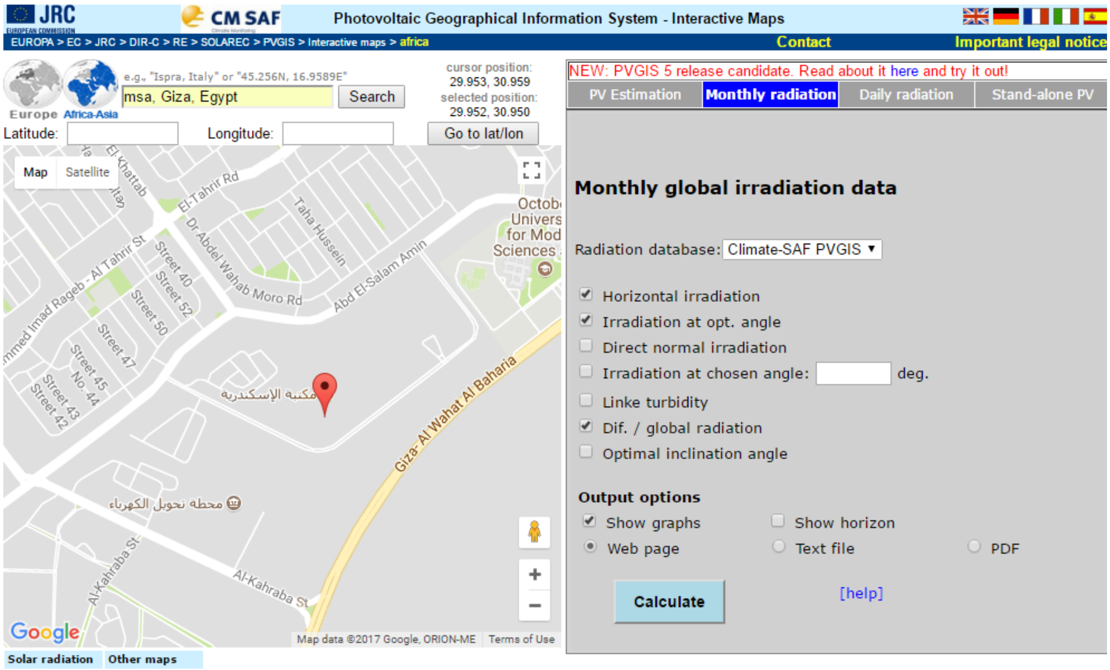



Fig. 5.29 Monthly radiation analysis

PVGIS Estimates of long-term monthly averages
**Location:** 29°57'6" North, 30°56'58" East, Elevation: 189 m a.s.l.
**Solar radiation database used:** PVGIS-CMSAF
**Optimal inclination angle:** 28 degrees
**Annual irradiation deficit due to shadowing (horizontal):** 0.0 %
**$H_h$:** Irradiation on horizontal plane ($Wh/m^2/day$)
**$H_{opt}$:** Irradiation on optimally inclined plane ($Wh/m^2/day$)
**D/G:** Ratio of diffuse to global irradiation (-)

| Month | $H_h$ | $H_{opt}$ | D/G |
|---|---|---|---|
| Jan | 3570 | 5090 | 0.39 |
| Feb | 4430 | 5710 | 0.37 |
| Mar | 6210 | 7150 | 0.37 |
| Apr | 6780 | 6950 | 0.35 |
| May | 7540 | 7080 | 0.32 |
| Jun | 8190 | 7310 | 0.27 |
| Jul | 8000 | 7330 | 0.28 |
| Aug | 7430 | 7360 | 0.29 |
| Sep | 6450 | 7140 | 0.31 |
| Oct | 5310 | 6630 | 0.33 |
| Nov | 3990 | 5550 | 0.36 |
| Dec | 3360 | 4950 | 0.38 |
| **Year** | 5950 | 6520 | 0.32 |

Fig. 5.30 Monthly irradiation schedule

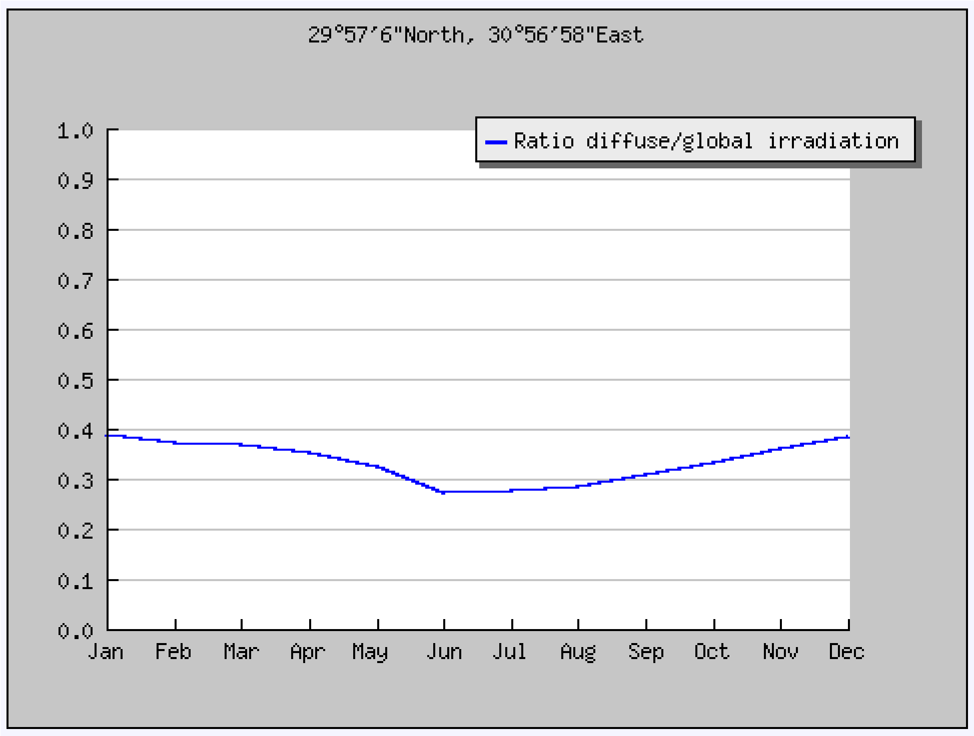



**Fig. 5.31** Ratio of diffuse to global irradiation

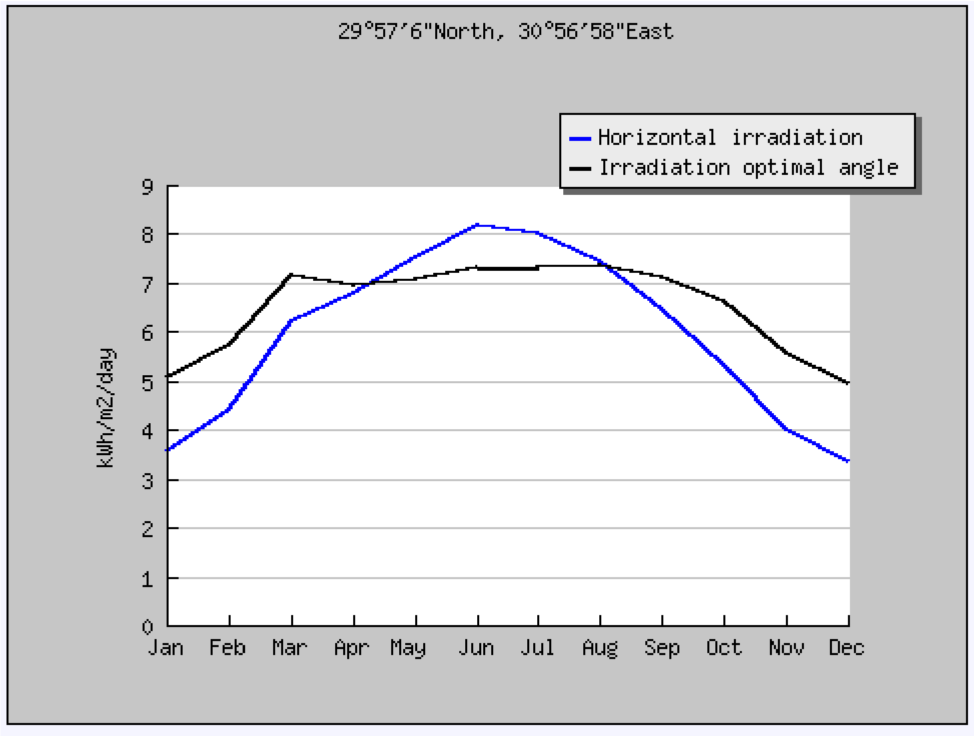



**Fig. 5.32** Irradiation on horizontal and optimally inclined plane

## PV PANEL SPECIFICATIONS

ON GRID SYSTEMS – FOR ALL LOADS is the proper system which was chosen for the energy generated from the PV panels system.
It is Self-Consumption but with Battery Backup system when electricity cuts out only.

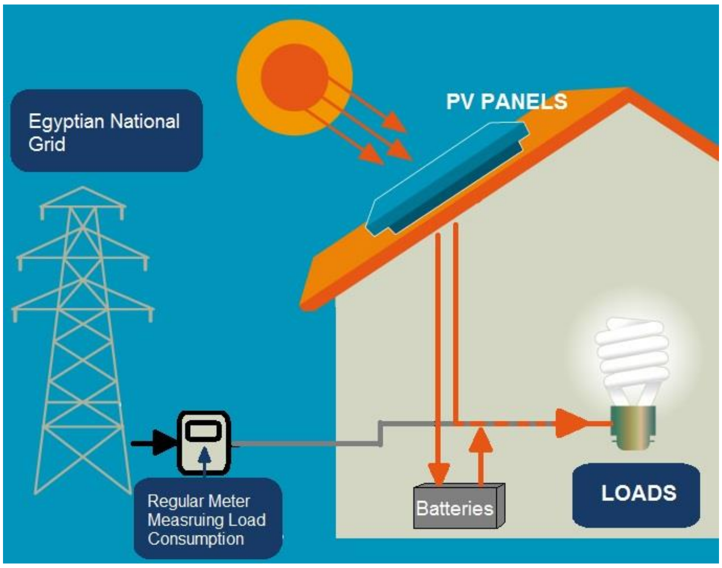



**Fig. 5.33** On grid system diagram

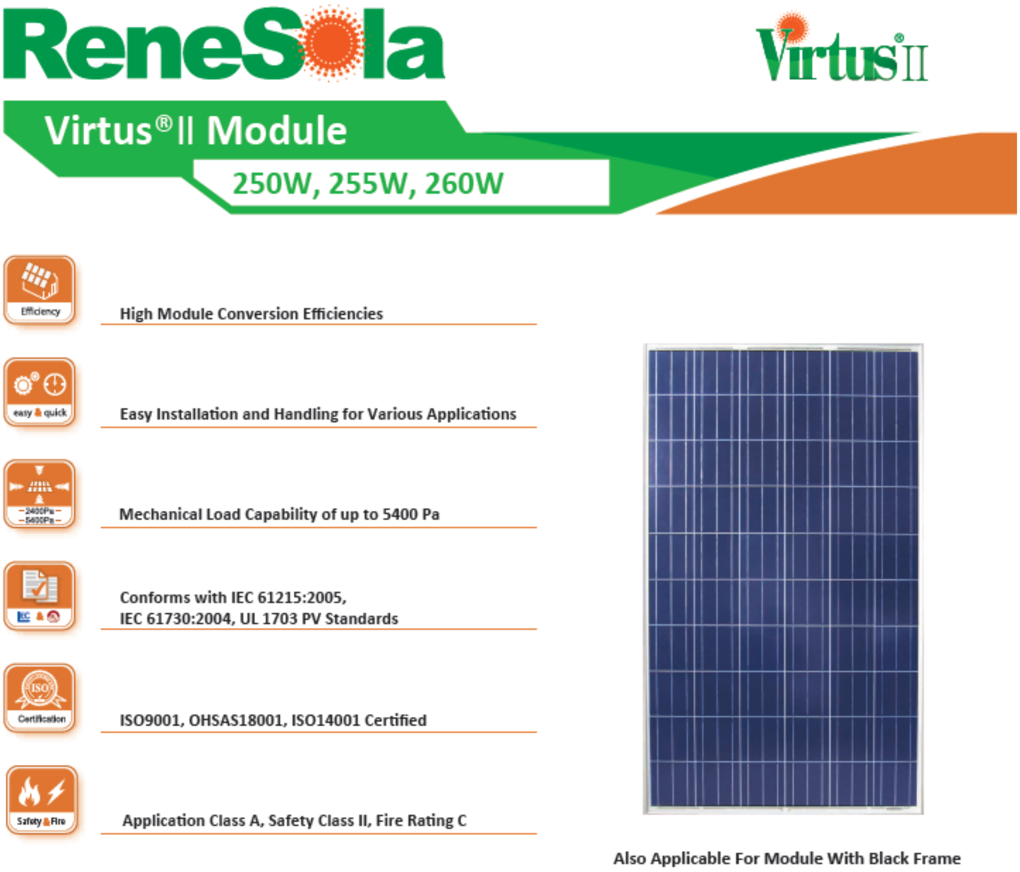


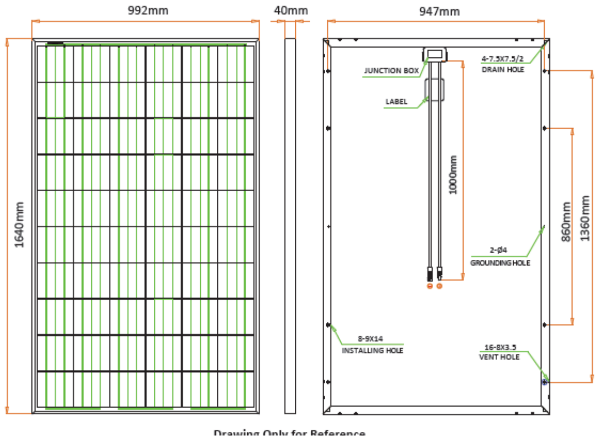

**Fig. 5.34** Selection PV -panel

# ReneSola

## Virtus®II Module

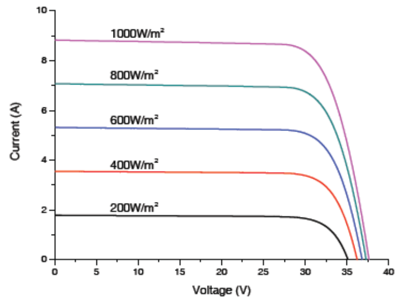
### 250W, 255W, 260W

### Dimensions




Drawing Only for Reference

### I-V Curves




### Varied Irradiation Efficiencies

| Irradiance | 200W/m² | 400W/m² | 600W/m² | 800W/m² | 1000W/m² |
|---|---|---|---|---|---|
| Efficiency | 15.8% | 16.2% | 16.2% | 16.1% | 16.0% |

| Electrical Characteristics STC | JC250M-24/Bb | JC255M-24/Bb | JC260M-24/Bb |
|---|---|---|---|
| Maximum Power (Pmax) | 250 W | 255 W | 260 W |
| Power Tolerance | 0 ~ +5W | 0 ~ +5W | 0 ~ +5W |
| Module Efficiency | 15.4% | 15.7% | 16.0% |
| Maximum Power Current (Imp) | 8.31 A | 8.39 A | 8.53 A |
| Maximum Power Voltage (Vmp) | 30.1 V | 30.4 V | 30.5 V |
| Short Circuit Current (Isc) | 8.83 A | 8.86 A | 8.95 A |
| Open Circuit Voltage (Voc) | 37.4 V | 37.5 V | 37.6 V |

Values at Standard Test Conditions STC (AM1.5, Irradiance 1000W/m², Cell Temperature 25°C)

| Electrical Characteristics NOCT | JC250M-24/Bb | JC255M-24/Bb | JC260M-24/Bb |
|---|---|---|---|
| Maximum Power (Pmax) | 185 W | 189 W | 193 W |
| Maximum Power Current (Imp) | 6.57 A | 6.63 A | 6.74 A |
| Maximum Power Voltage (Vmp) | 28.2 V | 28.5 V | 28.6 V |
| Short Circuit Current (Isc) | 7.12 A | 7.20 A | 7.27 A |
| Open Circuit Voltage (Voc) | 35.0 V | 35.1 V | 35.2 V |

Values at Normal Operating Cell Temperature, Irradiance of 800 W/m², AM 1.5, ambient temperature 20°C, wind speed 1 m/s

### Mechanical Characteristics

| | |
|---|---|
| Cell Type | Virtus II (Polycrystalline) 156 x156 mm, 60 (6x10) pcs in series |
| Glass | High Transmission, Low Iron, Tempered Glass |
| Frame | Anodized Aluminum Alloy |
| Junction Box | IP65/IP67 Rated, With Bypass Diodes |
| Dimension | *1640 x 992 x 40 mm |
| Output Cable | 4 mm² (EU)/12 AWG (US), 1000 mm |
| Weight | 19 kg |
| Installation Hole Location | See Drawing Above |

### Characteristics

| | |
|---|---|
| Temperature Coefficient of Voc | -0.30%/°C |
| Temperature Coefficient of Isc | 0.04%/°C |
| Temperature Coefficient of Pmax | -0.40%/°C |
| Nominal Operating Cell Temperature (NOCT) | 45°C±2°C |

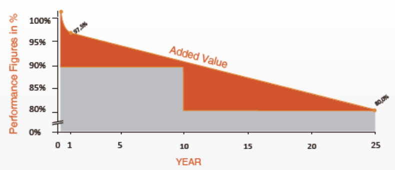
### Packing Information

| Container | 20' GP | 40' GP | 40' HQ |
|---|---|---|---|
| Pallets per Container | 12 | 28 | 28 |
| Pieces per Container | 300 | 700 | 770 |

### Maximum Ratings

| | |
|---|---|
| Operating Temperature | -40°C ~ +85°C |
| Maximum System Voltage | 1000VDC (EU) / 600VDC (US) |
| Maximum Series Fuse Tating | 20A (EU) / 20A (US) |

Guarantee




10-year material & workmanship

25-year linear power output

PV CYCLE

Fig. 5.35 Technical specifications for selected PV panel

## FINAL DECISIONS ABOUT PV PANELS

**Area of one panel:** 1.65 $m^2$

**One module includes 8 panels of PV,**
**area of module:** 1.65 x 8 = 13.2 $m^2$

**We implement 80 PV panels module,**
**total area:** 13.2 x 80 = 1,056 $m^2$

**Average energy production in one month per 1 $m^2$:** 145 kWh

**Average annual energy production per 1 $m^2$:** 1740 kWh

**Annual energy production:** 1740 x 1,056 = 1,837,440 kWh/year (52 kWh/$m^2$. year)

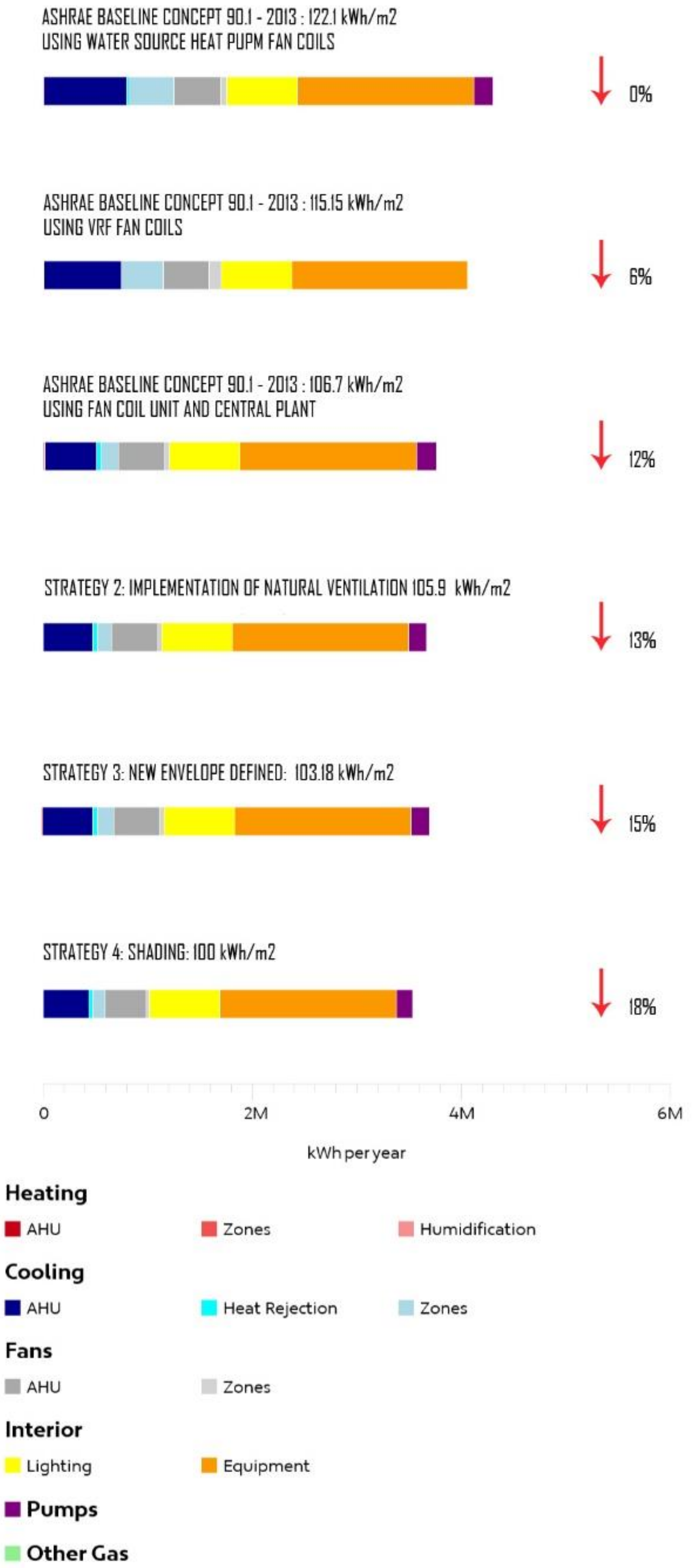



**Fig. 5.36** Final energy results

**Final energy result after mixing the 5 strategies:**

The first applied strategy in SEFAIRA web application is the selection of HVAC system, then we integrate it in the natural ventilation. The new envelope strategy is combination of the natural ventilation with the new envelop settings. Finally, we applied the shading strategy that made an obvious difference in energy consumption.

This result from SEFAIRA web application does not include the implementation of PV panels. After the implementation of PV panels, we need to subtract the production of PV panels from the total energy usage of our building, as we mentioned before we will use all the produced energy in onsite.

The annual net energy usage is:
3,539,785 - 1,837,440 = 1,704,768 kWh/year (48 kWh/m². year) ↓40%

The annual net electricity demand is:
2,975,157 – 1,837,440 = 1,137,717 kWh/year (32kWh/m². year)

## 5.2. ENVIRONMENTAL SECTIONS

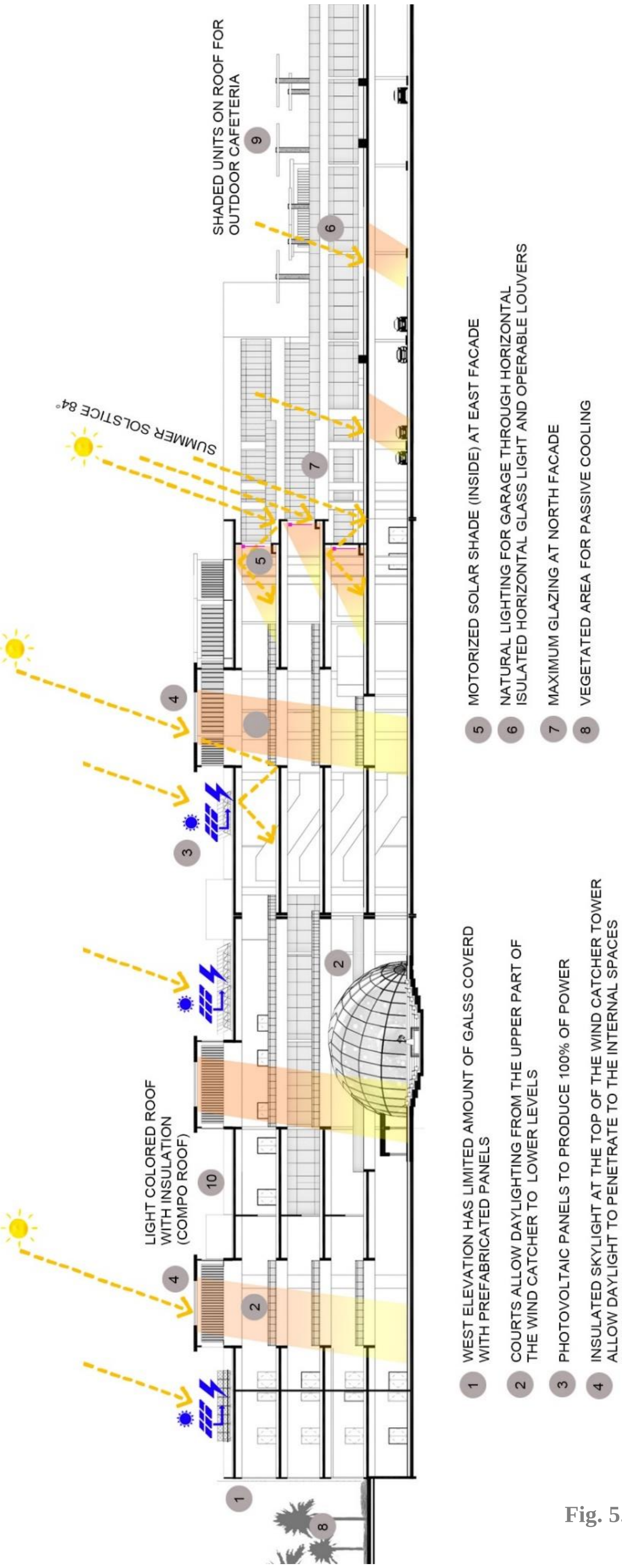



**Fig. 5.39** Natural lighting – summer

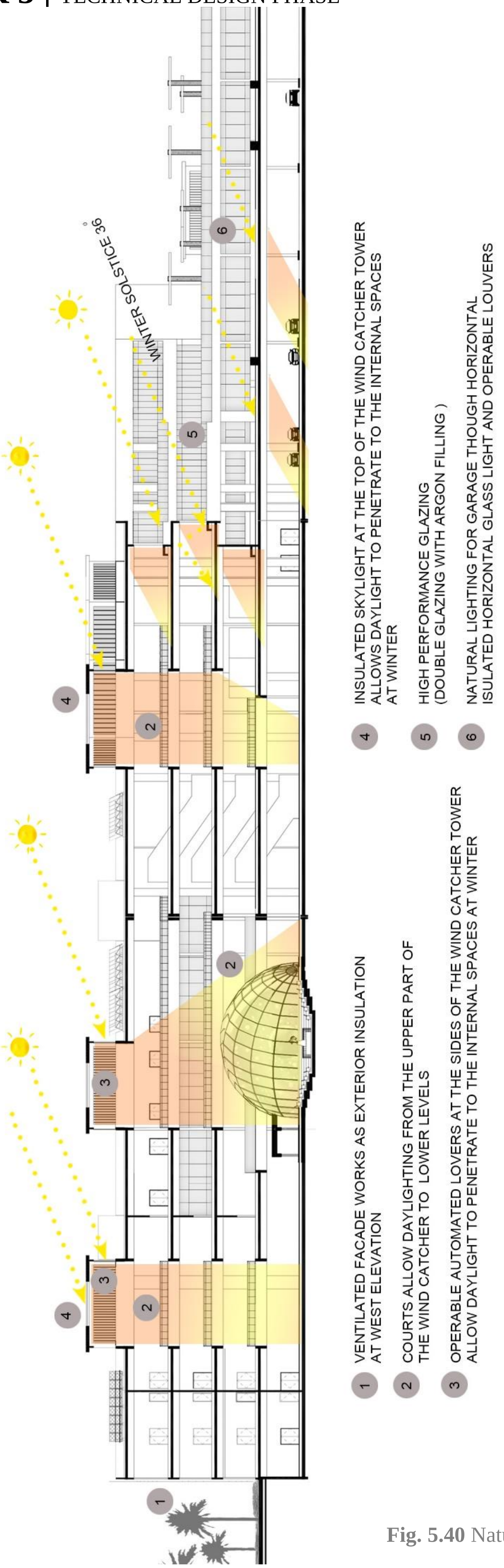



**Fig. 5.40** Natural lighting – winter

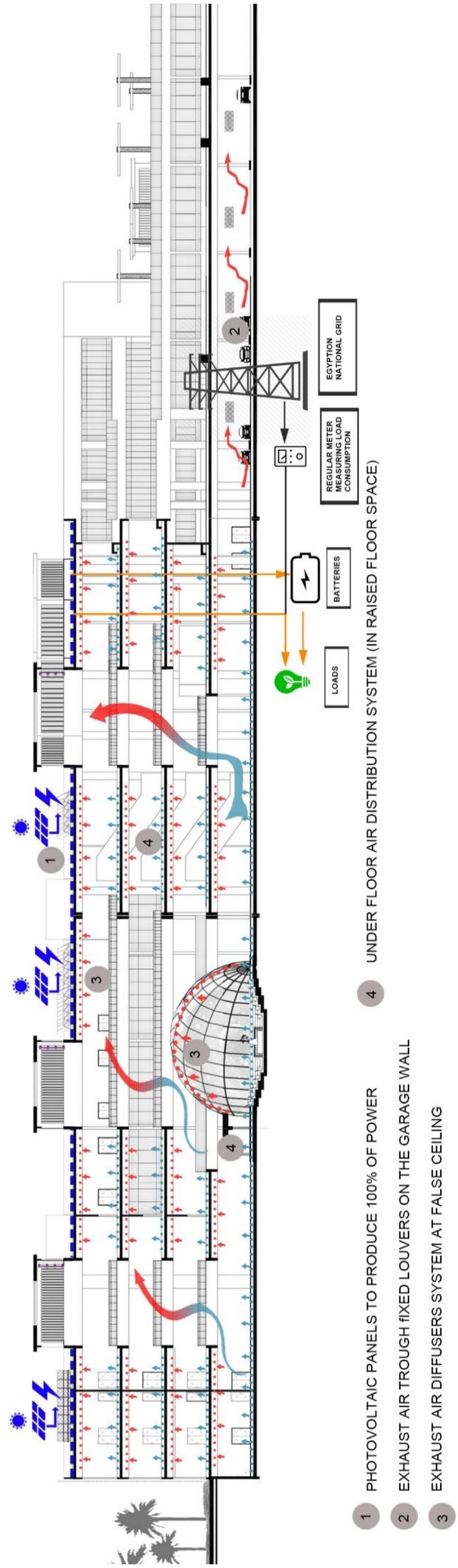



**Fig. 5.41** Mechanical ventilation

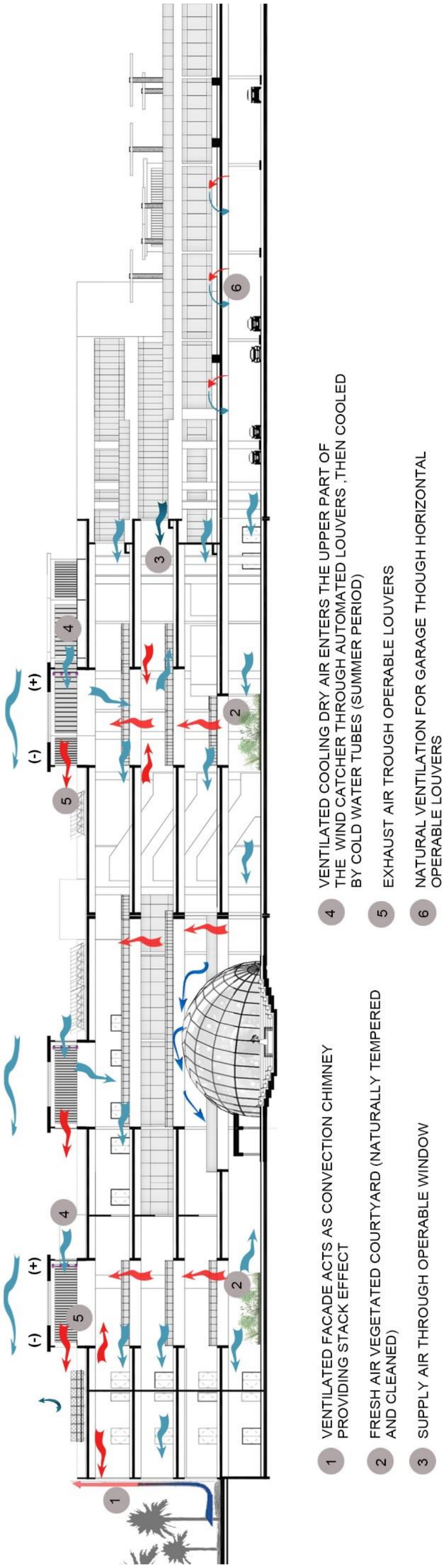



**Fig. 5.42** Natural ventilation

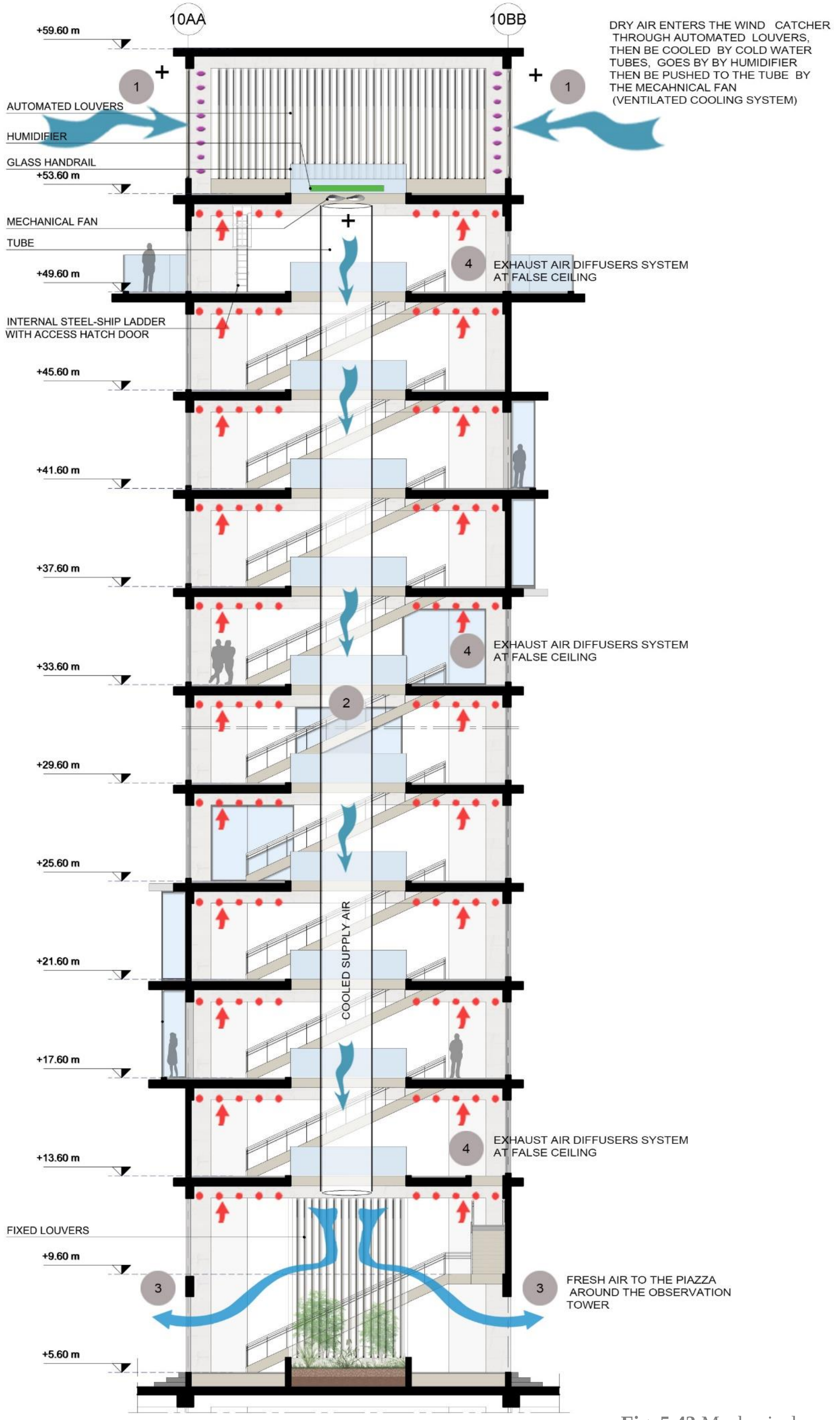



**Fig. 5.43** Mechanical ventilation in observation tower

## 5.3. ACTIVE STRATEGIES

Passive strategies are an important issue in order to reduce the loads for heating and cooling and improve the internal comfort of the building, but they are not enough to guarantee a certain level of comfort, therefore the introduction of an active system becomes necessary.
In order achieve the standard of green building or nearly zero energy building a right balance between passive and active strategies should be established.

In this section, the active strategies which we have used in our project will be introduced:

- PV PANELS
- UFAD SYSTEM RELY ON RAISED FLOOR

Then we will introduce some technical properties of some materials which have been used in the ceiling and the ventilated façade and how these materials will help to achieve the thermal comfort of the building.

### 5.3.1. PV panels

The solar energy is a renewable and green source of energy because it does not emit pollutants during the energy production process.
Thanks to the arid climate of Egypt and the sunny weather, Solar Photovoltaic (PV) devices have been used in our flat roof to generate clean electricity which will be used in the building.
Photovoltaic means light and electricity. These cells collect the sun’s energy and convert it into electricity.
These solar cells are made of materials that show photovoltaic effect, when the sun rays strike the Photovoltaic cell.

**Fig. 5.44** Solar panels on flat roof

### 5.3.2. UFAD SYSTEM RELY ON A RAISED FLOOR

A raised floor system has been used in the floor system in our project. A raised floor system is an elevated floor structure built on top of a base floor. This creates a space for infrastructure such as electrical and mechanical systems. Access points can then be built into the floor that allow for maintenance.

A raised floor system is used to deliver ventilation and cooling to the space.

**The components of the raised access floor**

**1. Coverings surfaces**
**Factory glued:**
High pressure laminate
Vinyl
Rubber
Linoleum
Real wood
Ceramic
Natural Stones

**Loose-lay coverings:**
Vinyl
Rubber
Ceramic

**2. Panels cores**
W: chipboard core
FF: calcium sulphate core
GW: encapsulated panel with chipboard/calcium sulphate core

**3. Bottom surfaces**
Aluminum - High pressure laminate - Steel sheet

**4. ABS side edges**

**5. Acoustic pedestal head gasket**

**6. Acoustic stringers gasket**

**7. Steel stringers**
Galvanized steel open or closed section

**8. Steel Pedestal**
Galvanized steel head and base plate


**Fig. 5.45** Raised floor system

UFAD system uses the underfloor plenum formed by installation of a raised floor, the plenum is about 30 cm above the structural concrete slab. Special designed floor diffusers are used as the supply outlets. The most common UFAD configuration consists of a central handling unit delivering air through a pressurized plenum and into the space through floor diffusers

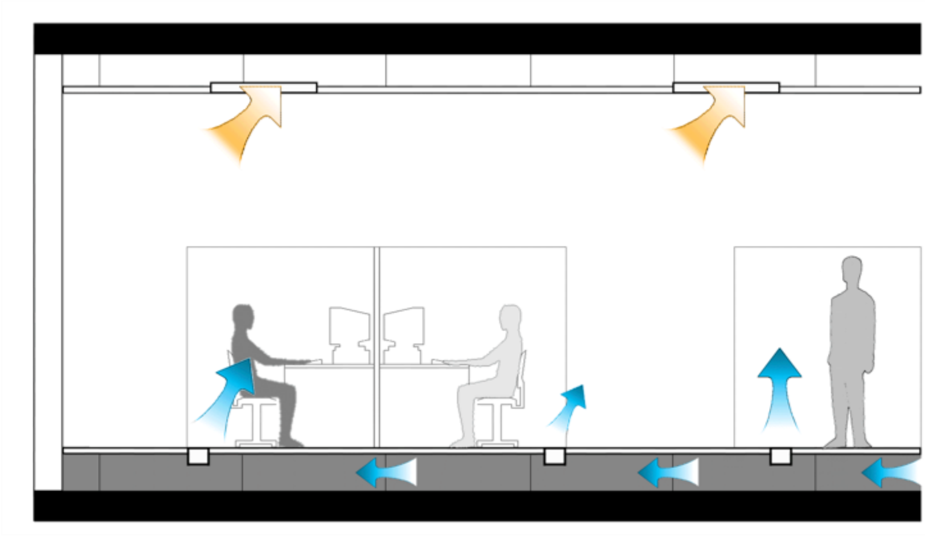


**Fig. 5.46** Diagram of air movement in an underfloor air distribution

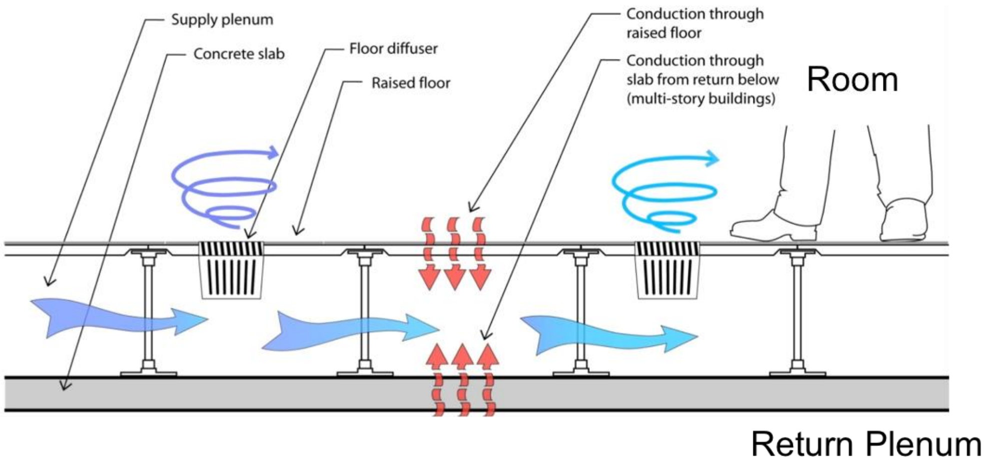



**Fig. 5.47** Heat transfer pathways in UFAD system

### 5.3.3. TECHNICAL PROPERTIES OF BUILDING'S ELEMENTS

- **Combo roof**

Combo roof system is applied in the roof of our building, Combo Roof system is a comprehensive system comprising of waterproofing, thermal insulation and finishing for the roof. This unique system is a technically advanced fast curing. This system provides a manufacturer's Guarantee of 25 years against any leakage. The uniqueness of this system is that the manufacturer and the applicator is the same.

**Benefits of Combo Roof System**

- Joint free insulation & waterproofing with 25 years manufacturers guarantee.
- Load bearing capacity up to 2½ tons per sq.mtr.
- Single submittal & approval for the entire system.
- Roof tiles not required.
- Fully mechanized time saving installation procedures.
- Ability & capacity to undertake fast track projects.
- Easy repair & maintenance.
- Multilayer waterproofing.
- Lower electricity consumption due to better insulation.
- Thermal shock resistant roof.

**(1) SITE PREPERATION**

**(2) PANELING AND SCREED LYING**

**(3) PU APPLICATION**

**(4) ANGLE FILLETS AND JOINT TREATMENTS**

(5) UV PROTECTION COATING

(6) FLOOD TESTING THE ROOF

(7) FINISHING

**Fig. 5.48 Combo Roof Application Procedures**

- **Polymer concrete panels for ventilated façade**

A ventilated façade system has been used in our building for its effect in the achievement of the energy efficiency for the building. The ventilated facade is a coating system of the building walls which leaves a ventilated chamber between the coating and the insulation.

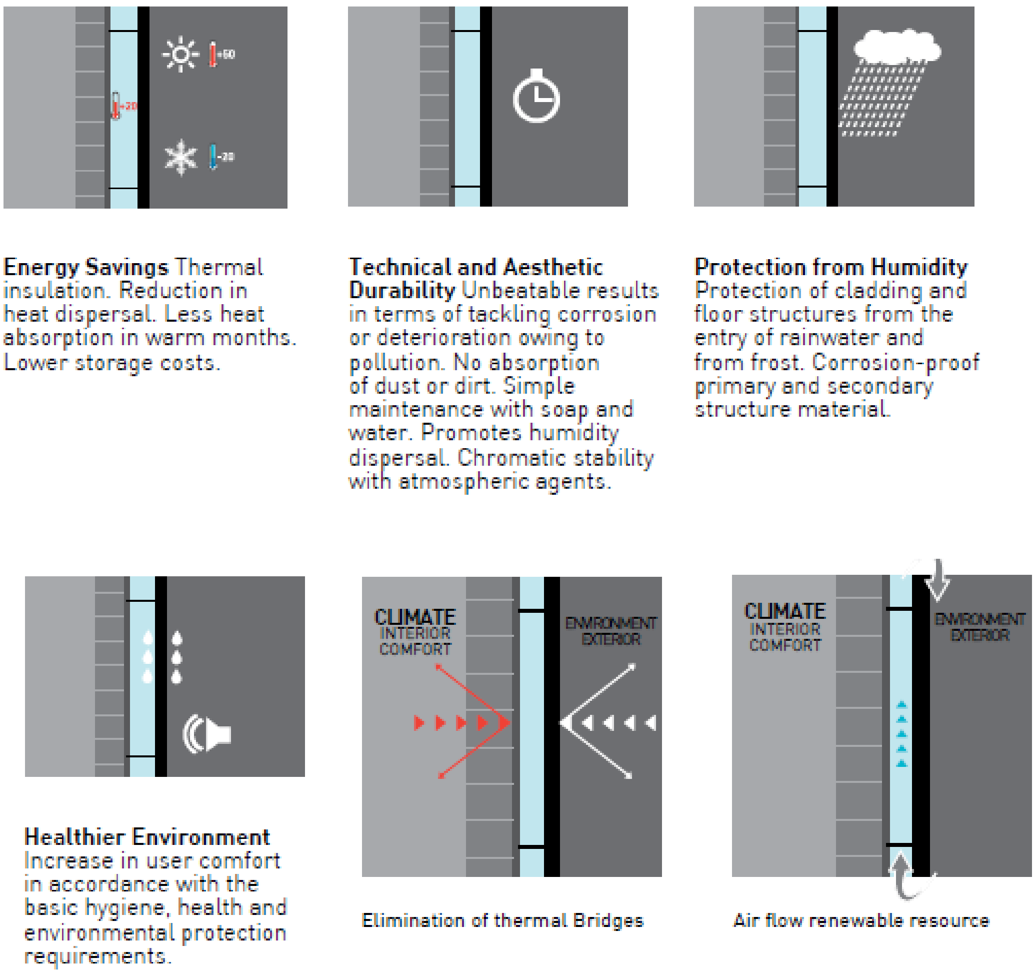



Fig. 5.49 Advantages of the ventilated facade

**Polymer concrete panels** have been used in the ventilated façade of the building because of its sustainable properties and how they will achieve an effective ventilated façade.

Fig. 5.50 Polymer concrete panel

**Properties of the panel**

- Concealed and visible fixing
- Non-porous product
- Very light panel
- High resistance under traction
- High shock resistance
- Zero water absorption
- Easy post - graffiti treatment
- High resistance under compression
- High color durability
- Resistant to industrial environments
- No heavy metals in their composition
- Long-lasting
- Highly resistant to chemicals
- Ease of maintenance

- **False ceiling boards**

Two several types of false ceiling panels have been used in the project depending on the location

- Aqua panel cement board for outdoor
- Dry wall board for indoor

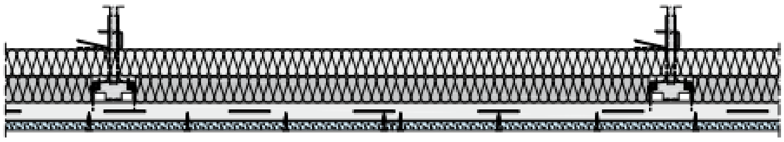
**Aqua panel cement board** provides a solid, dry base that can withstand the extreme weathering effects. It is an ideal substrate for directly applied render finishes and can be used for exterior ceilings. It is a proof building material, water resistance and low weight. Additionally, it has good strength, so that it has been used for the outdoor false ceiling.

Fig. 5.51 Aqua panel board

There are some other benefits:

- 100% water-resistant
- No deterioration, swelling or loss of stability
- Resistant to moisture, weathering, mold, and mildew
- Freeze-thaw cycle proven
- Stable and durable Portland cement construction
- Board can be curved
- Safe and hygienic material
- Non-combustible
- Strong, robust, and highly impact-resistant

**Dry wall board** (gypsum board or plaster board) is a fire-resistant and sound insulated material, so it has been used for indoor spaces.



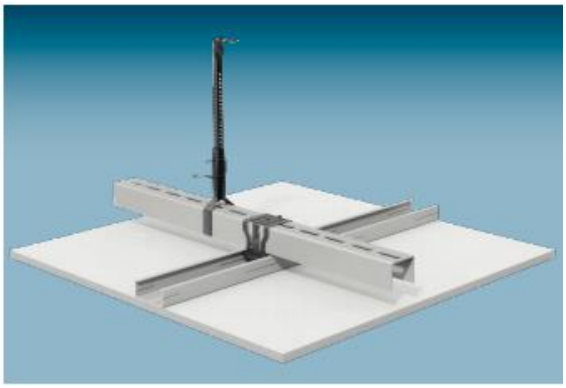


**Fig. 5.52 Dry wall board**

**There are some other benefits:**

- Ease of installation
- Fire resistance
- Sound insulation
- Durability
- Economy
- Versatility
- Storage and Handling
- Jobsite Preparations
- Tools
- Application Sequence
- Cutting and Fitting Procedures
- Single-Ply and Multi-Ply Application
- Control joints

## 5.4. BUILDING TECHNOLOGY DETAILES (BLOW-UPS)

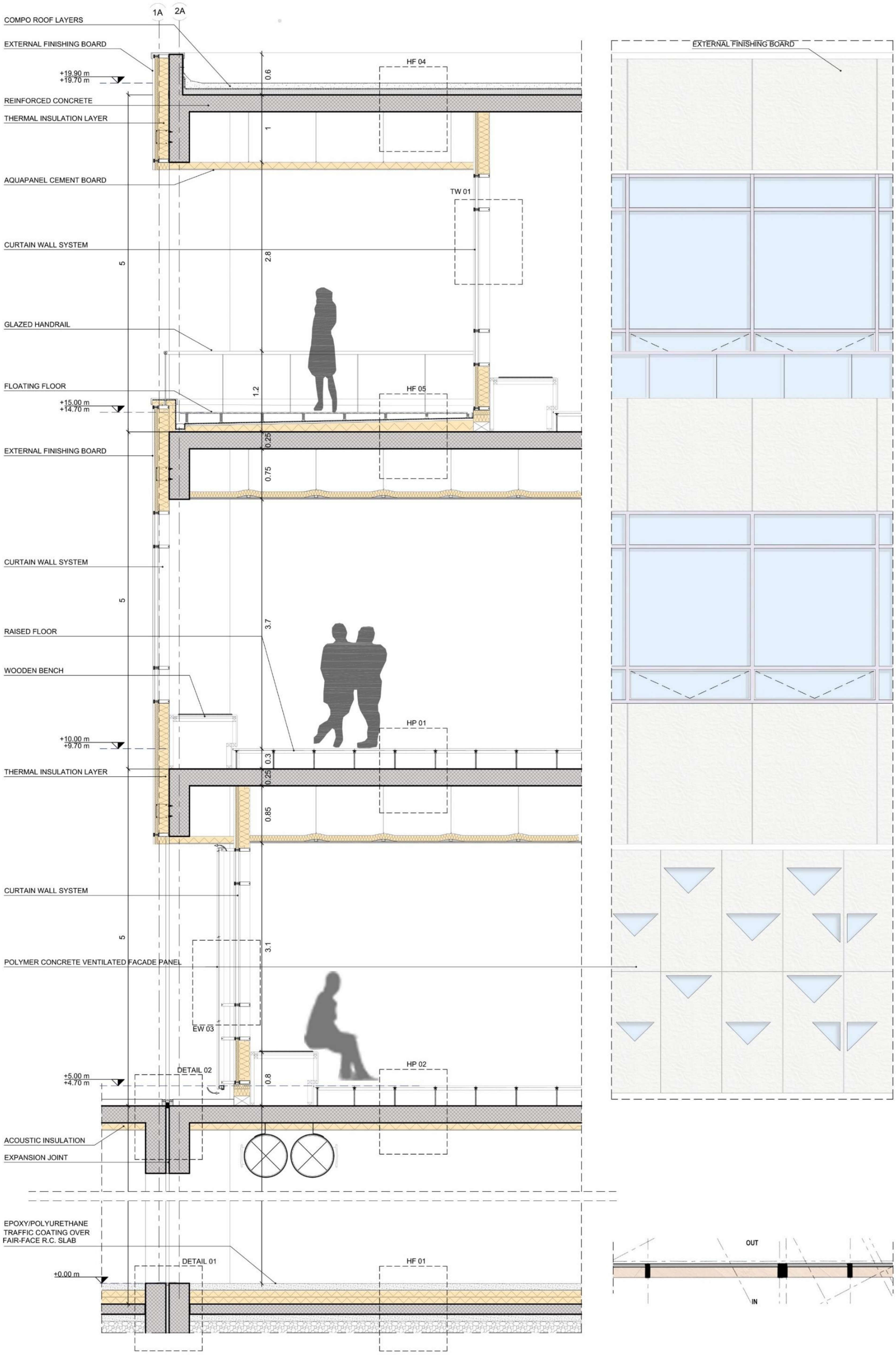



Fig. 5.53 Blowup 1 - Scale 1-50

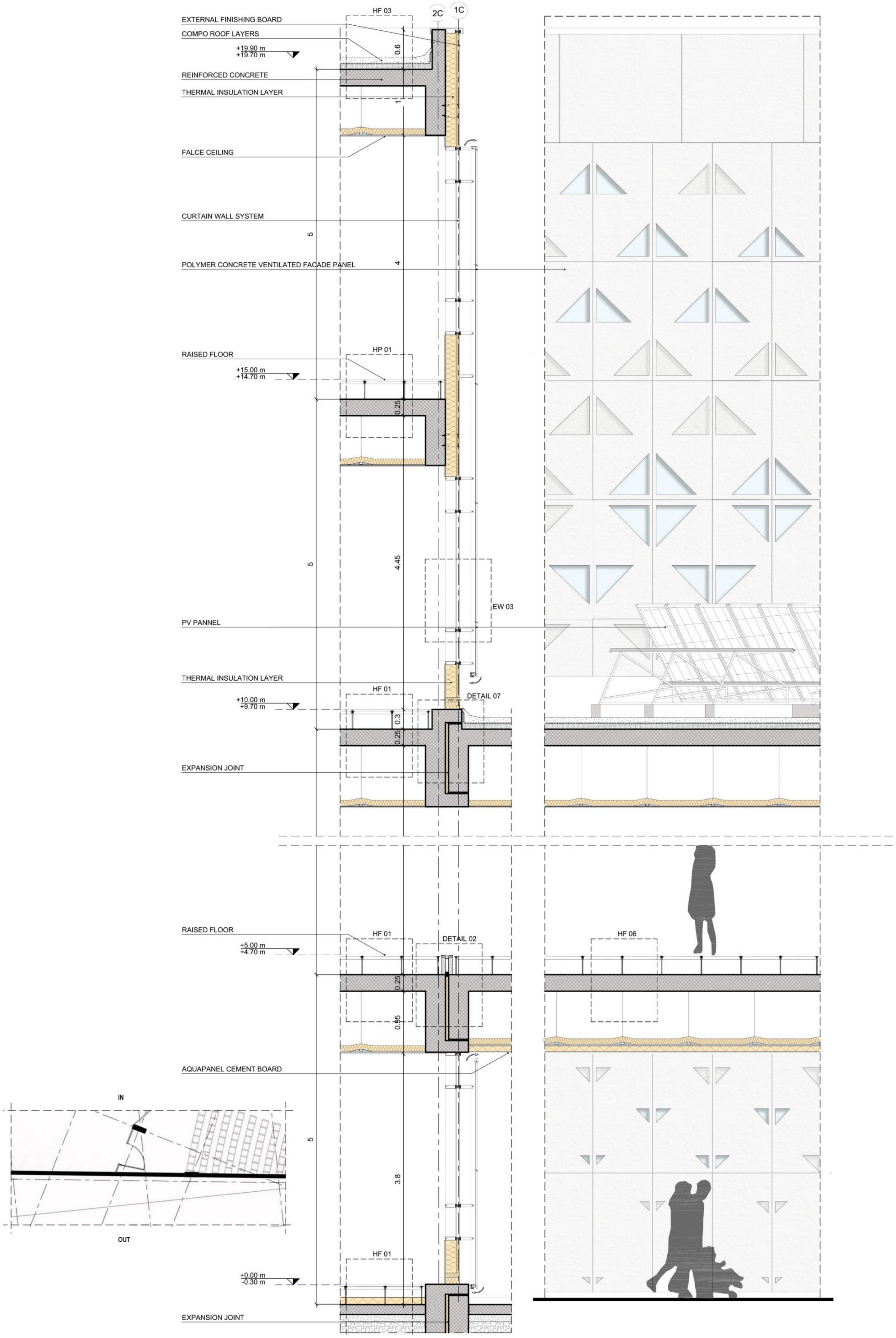
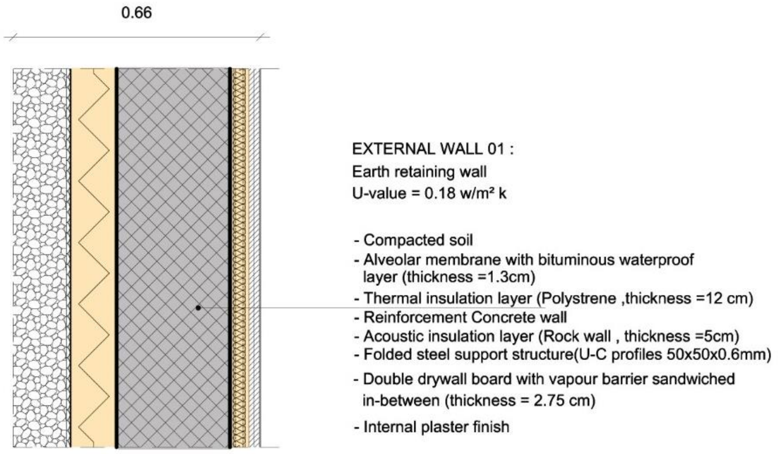



**Fig. 5.54** Blow up 2 - Scale 1-50

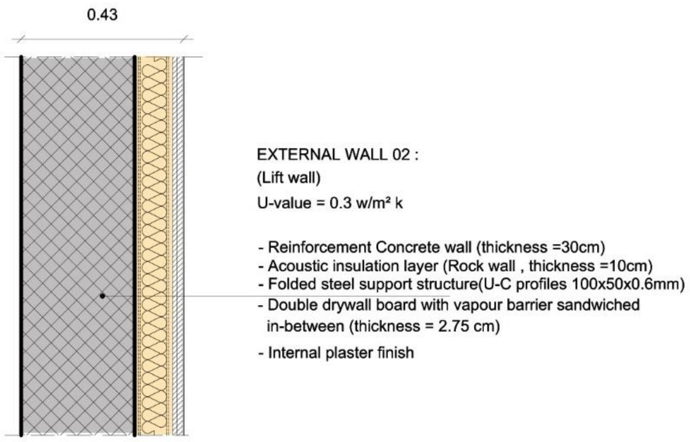
# 5.5. BUILDING ELEMENTS LAYERING

NODES & BUILDING LAYERING

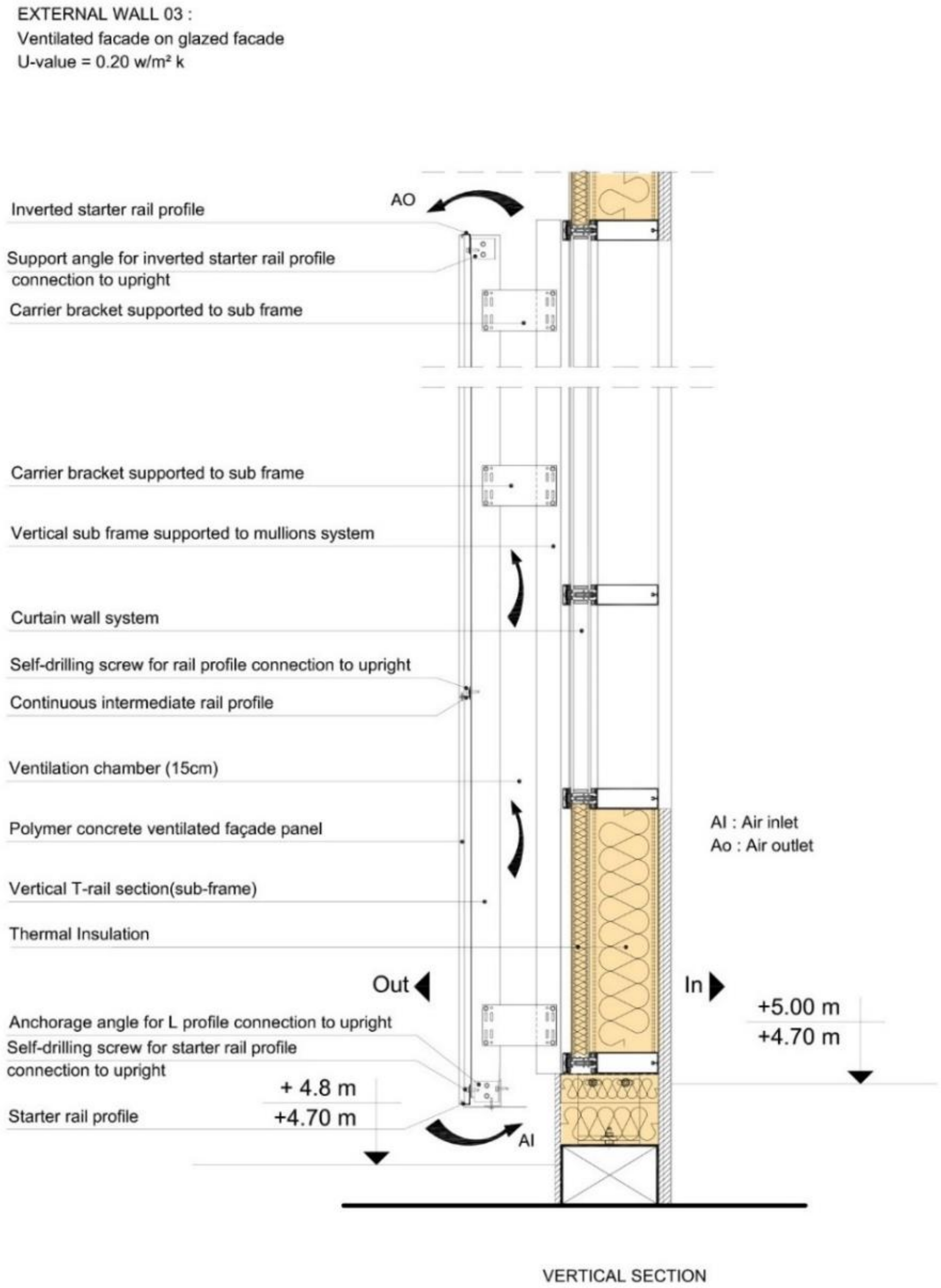
## 5.5.1. EXTERNAL WALLS




VERTICAL SECTION




VERTICAL SECTION


EXTERNAL WALL 03 :
Ventilated facade on glazed facade
U-value = 0.20 w/m² k
AO
Inverted starter rail profile
Support angle for inverted starter rail profile connection to upright
Carrier bracket supported to sub frame
Carrier bracket supported to sub frame
Vertical sub frame supported to mullions system
Curtain wall system
Self-drilling screw for rail profile connection to upright
Continuous intermediate rail profile
Ventilation chamber (15cm)
Polymer concrete ventilated façade panel
Vertical T-rail section(sub-frame)
Thermal Insulation
AI : Air inlet
Ao : Air outlet
Out
In
+5.00 m
+4.70 m
Anchorage angle for L profile connection to upright
Self-drilling screw for starter rail profile connection to upright
+ 4.8 m
+4.70 m
Starter rail profile
AI
VERTICAL SECTION

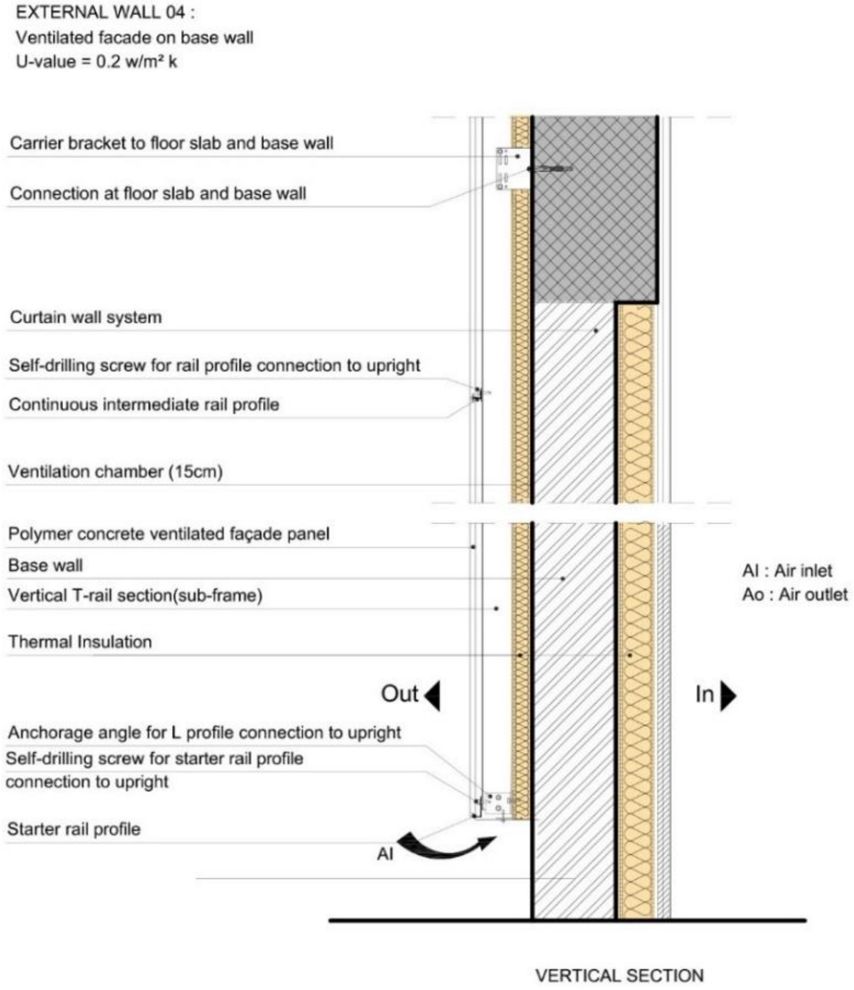
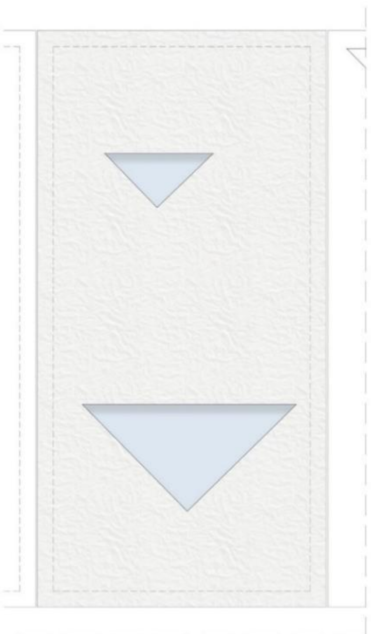
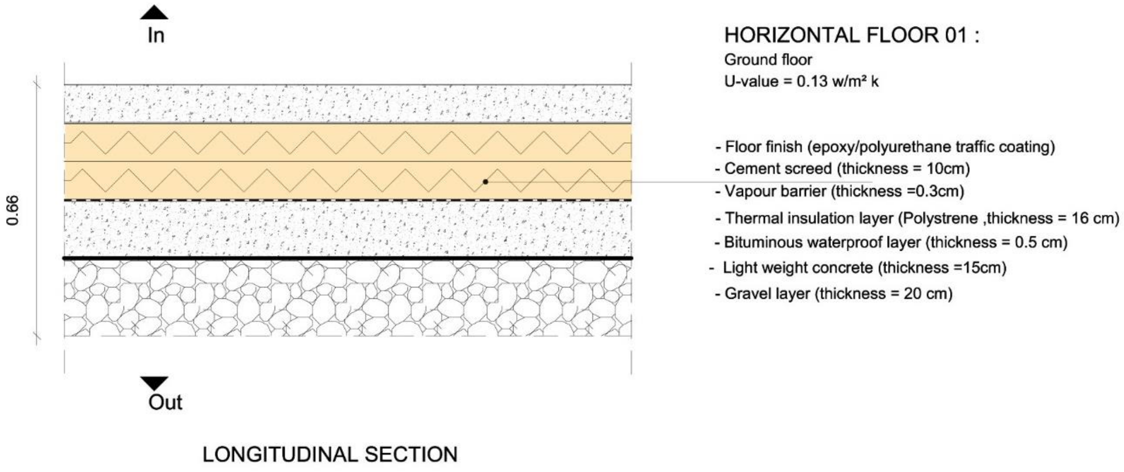



**Fig. 5.55** External wall layering & Polymer concrete panel – Scale 1-20



### 5.5.2. HORIZONTAL FLOORS



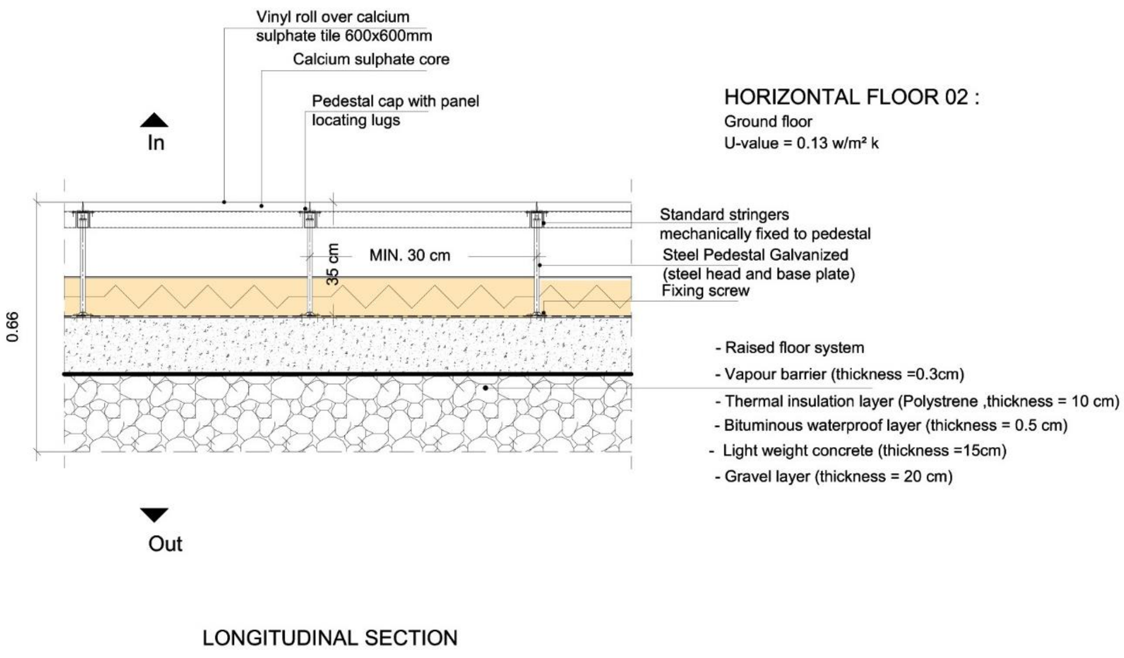
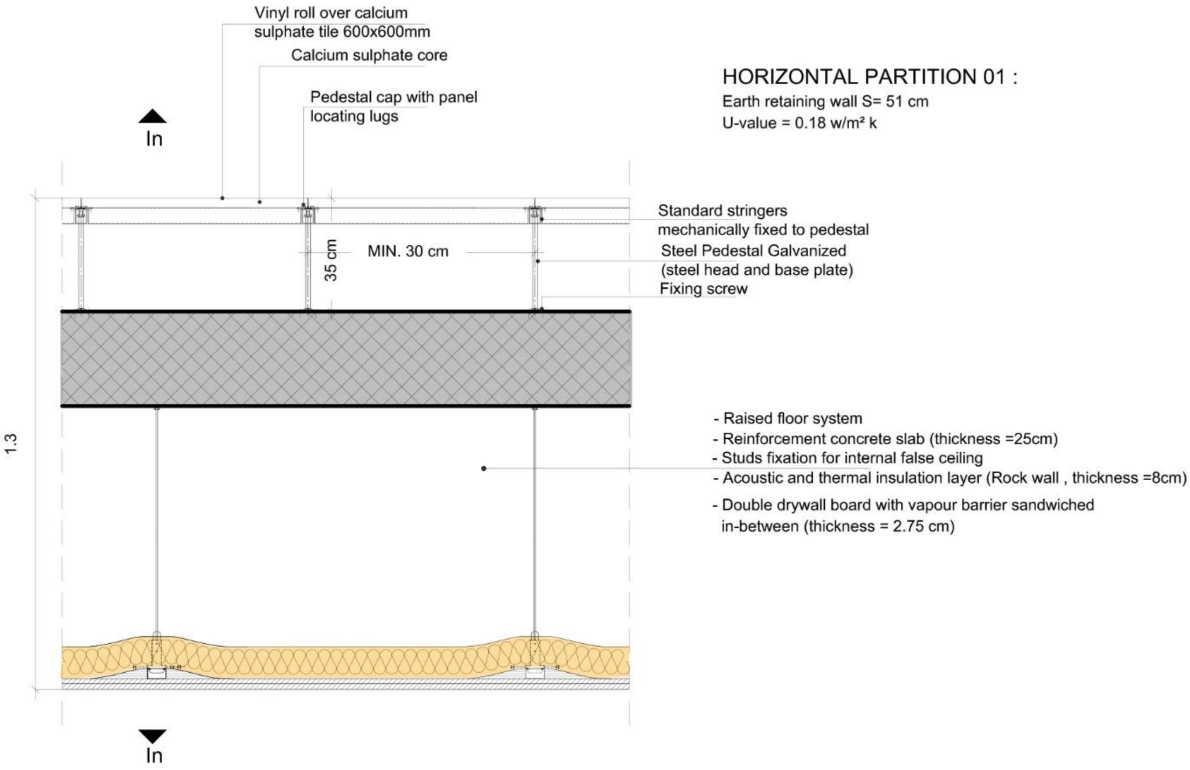
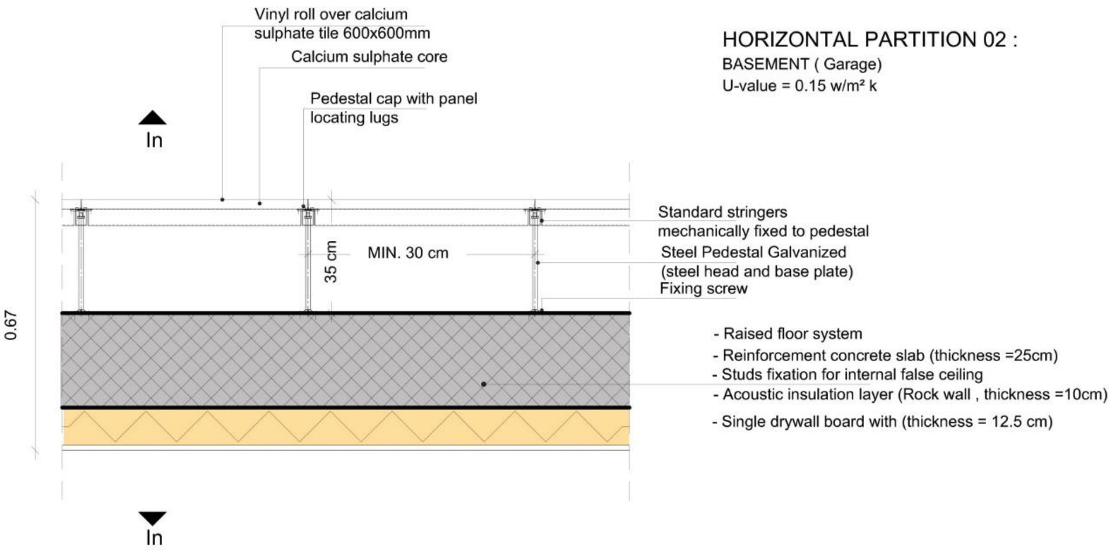




**Fig. 5.56** Horizontal floor layering – Scale 1-20

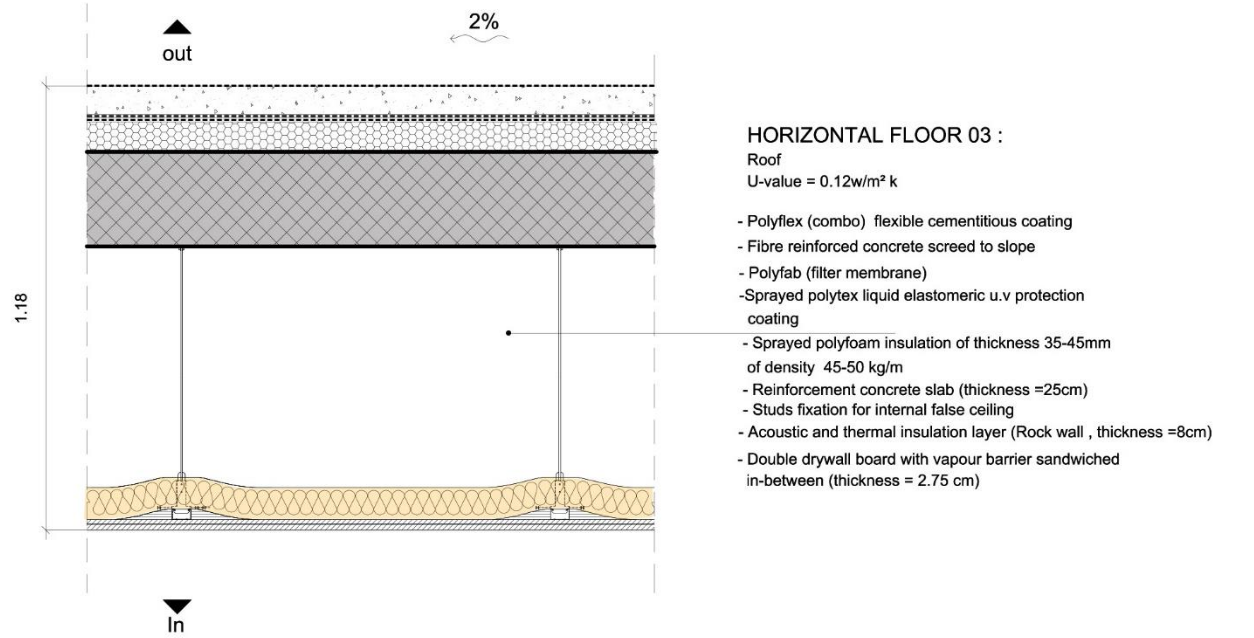
### 5.5.3. HORIZONTAL PARTITIONS



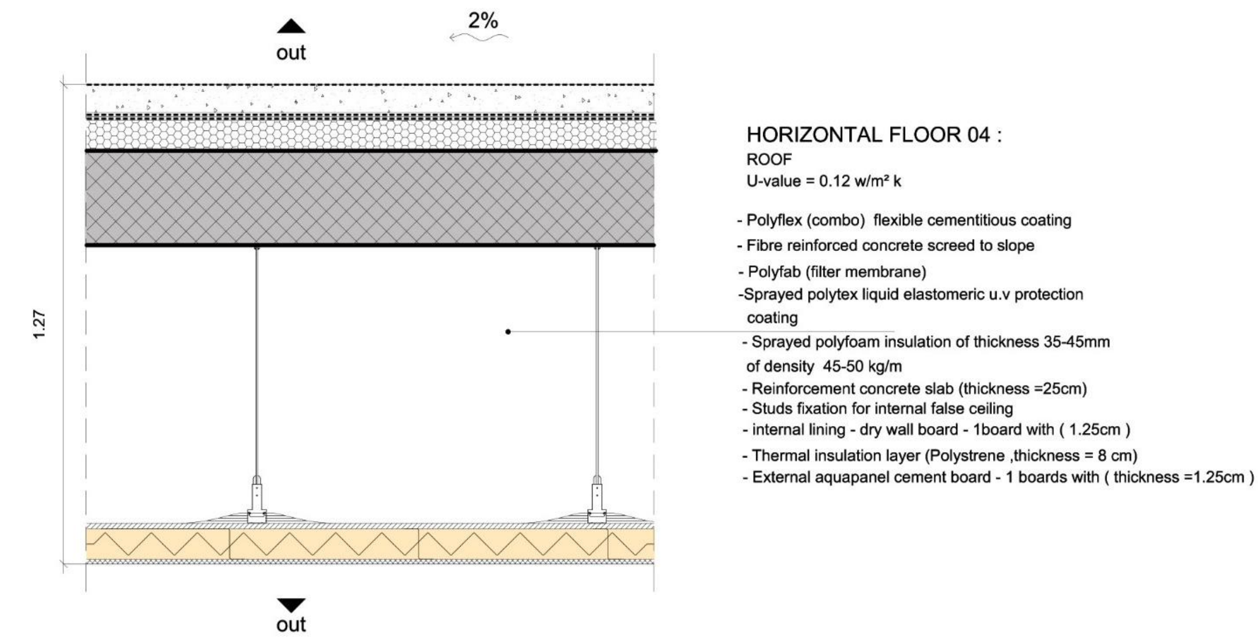

LONGITUDINAL SECTION



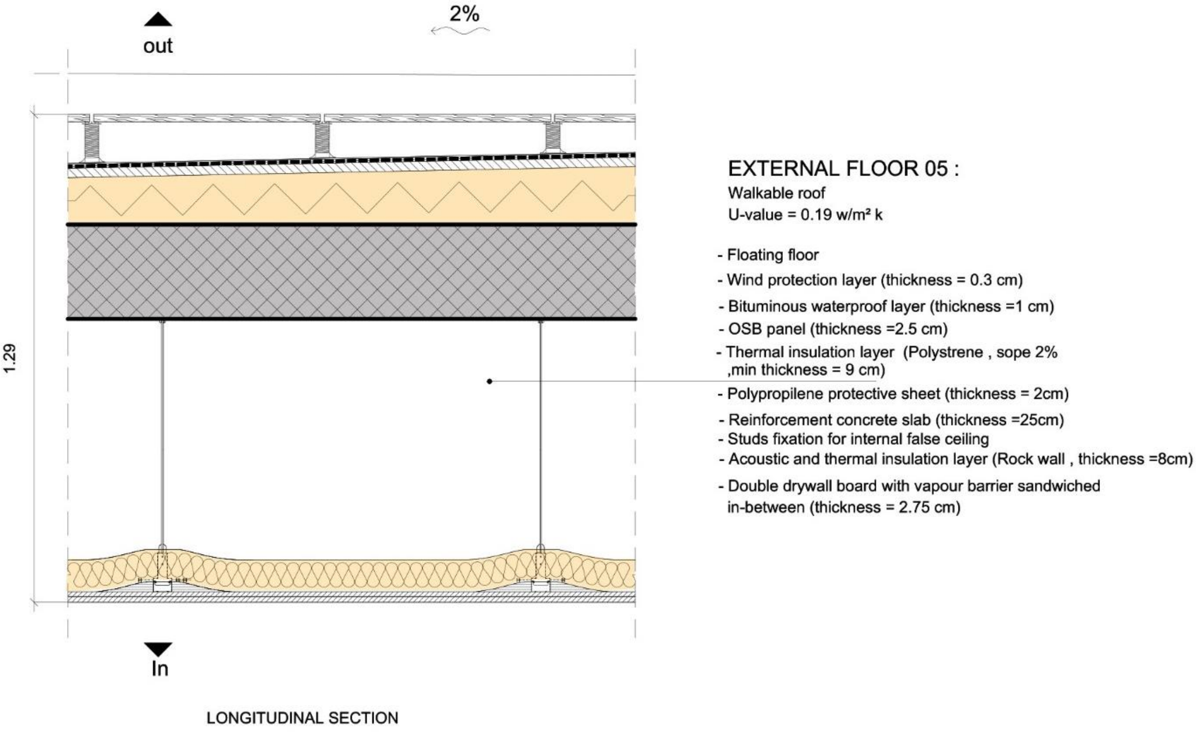

LONGITUDINAL SECTION




LONGITUDINAL SECTION




LONGITUDINAL SECTION



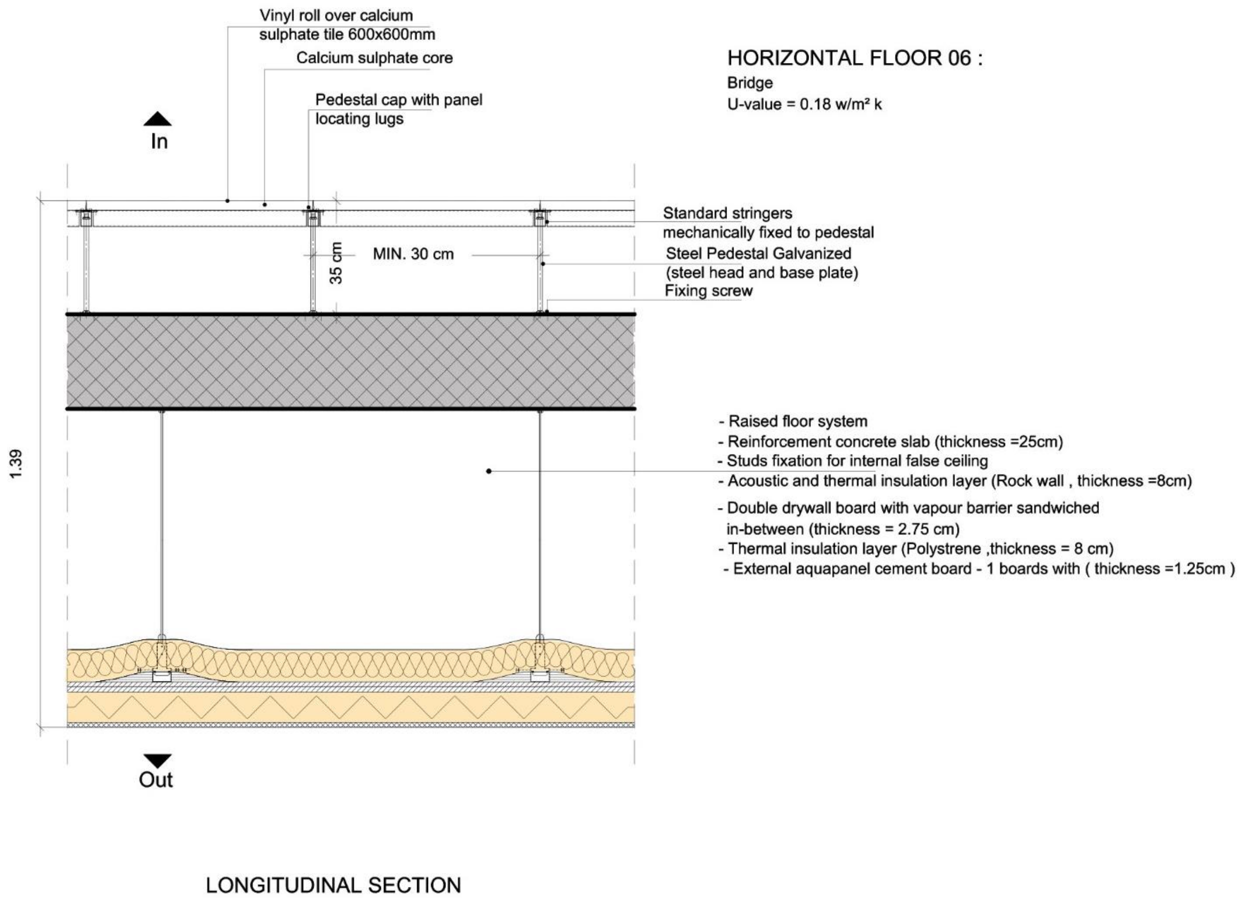
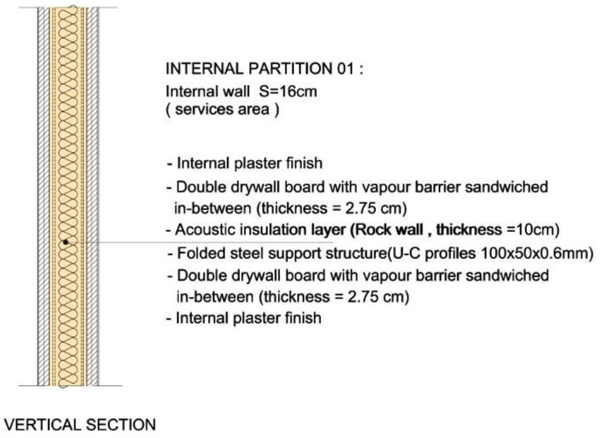
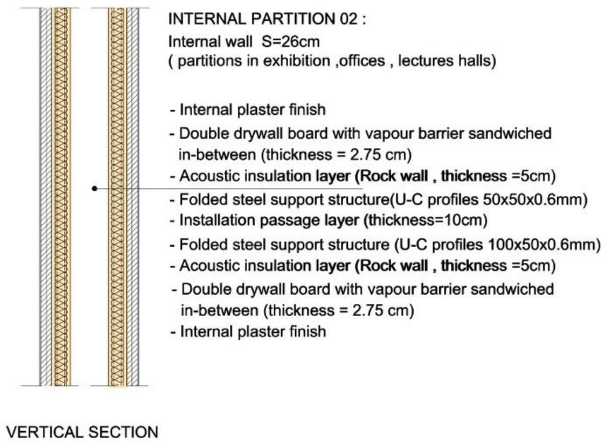




**Fig. 5.57** Horizontal Partitions layering – Scale 1-20

## 5.5.4. INTERNAL PARTITIONS AND TRANSPARENT ELEMENTS



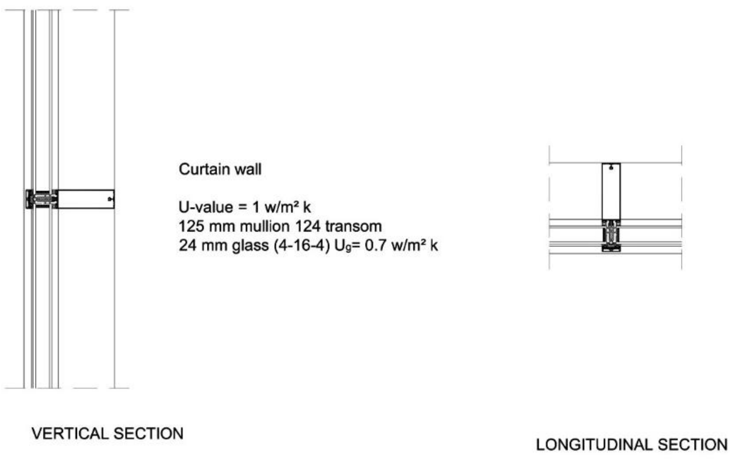
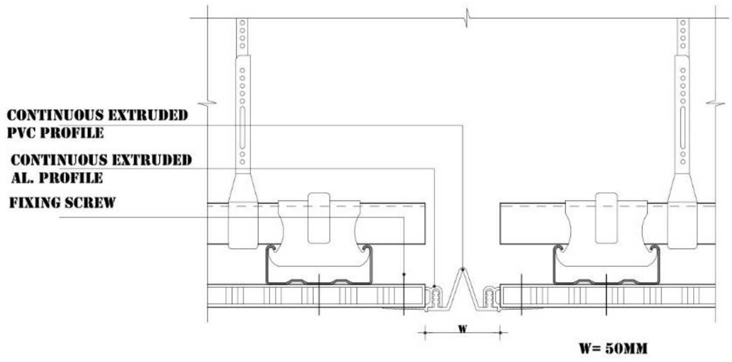



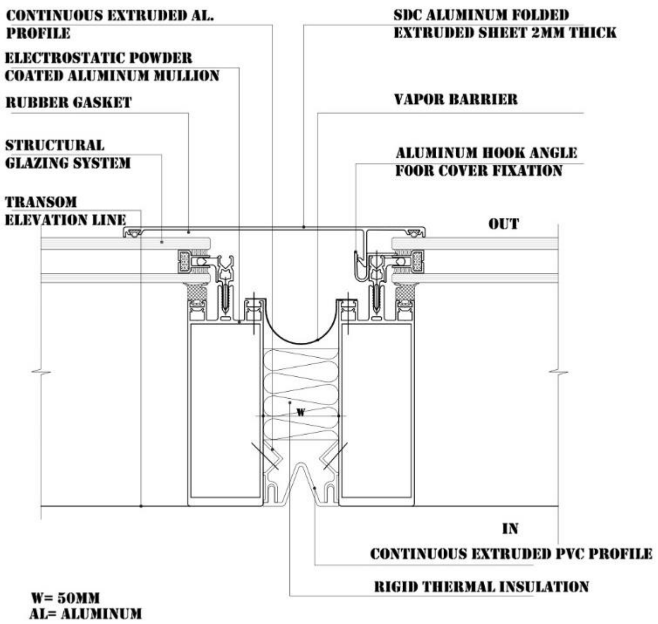

**Fig. 5.58** Internal Partitions and transparent elements layering – Scale 1-20

### 5.5.5. TYPICAL DETAILS



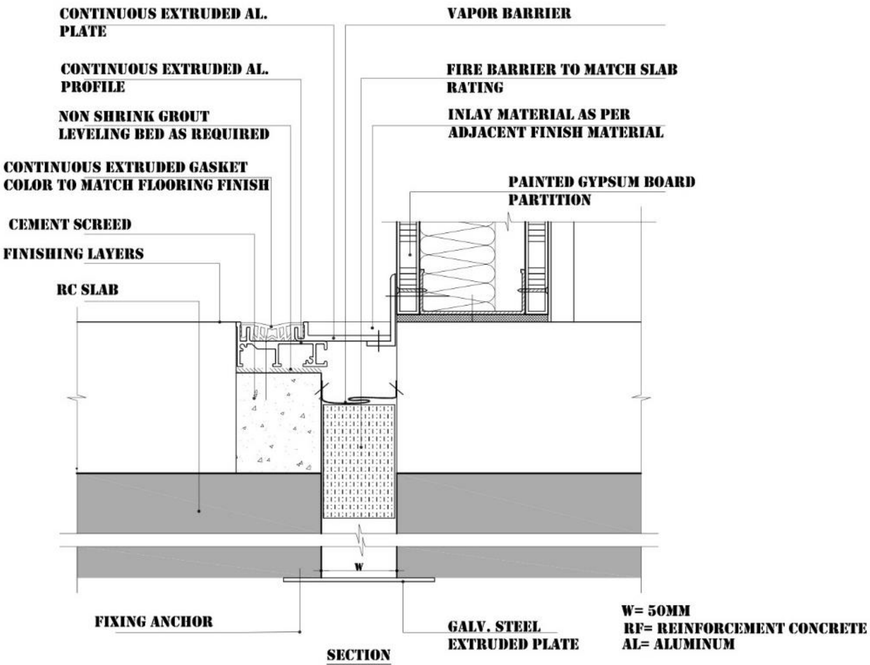

SECTION

DETAIL 04 : EXPANSION JOINT- FALSE CEILING



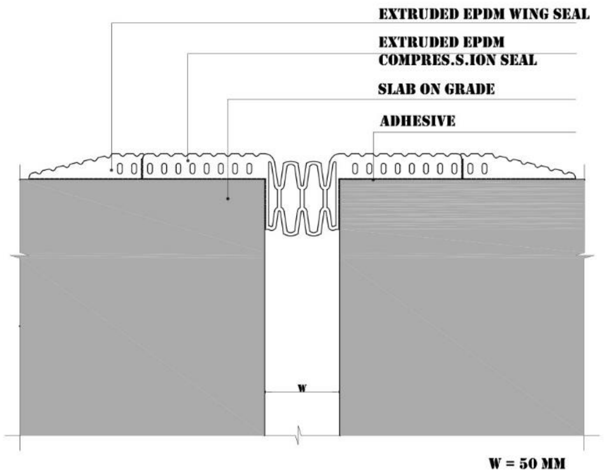

PLAN

DETAIL 05 : EXPANSION JOINT AT STRUCTURAL GLAZING SYSTEM (CURTAIN WALL )



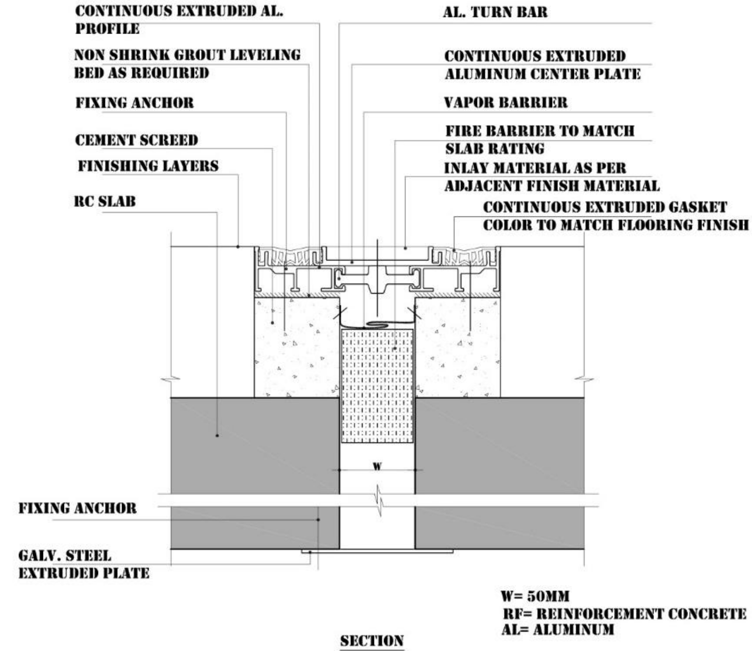

SECTION

DETAIL 06 : EXPANSION JOINT- PARTITION TO FLOOR

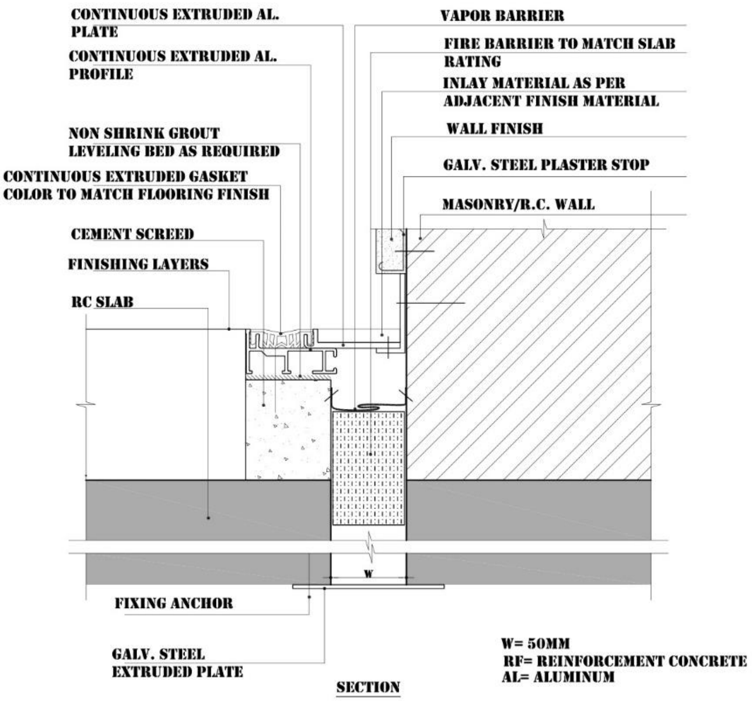



SECTION

DETAIL 01 : EXPANSION JOINT- FLLOR TO FLOOR - HEAVY DUTY(PARKING FLOOR)

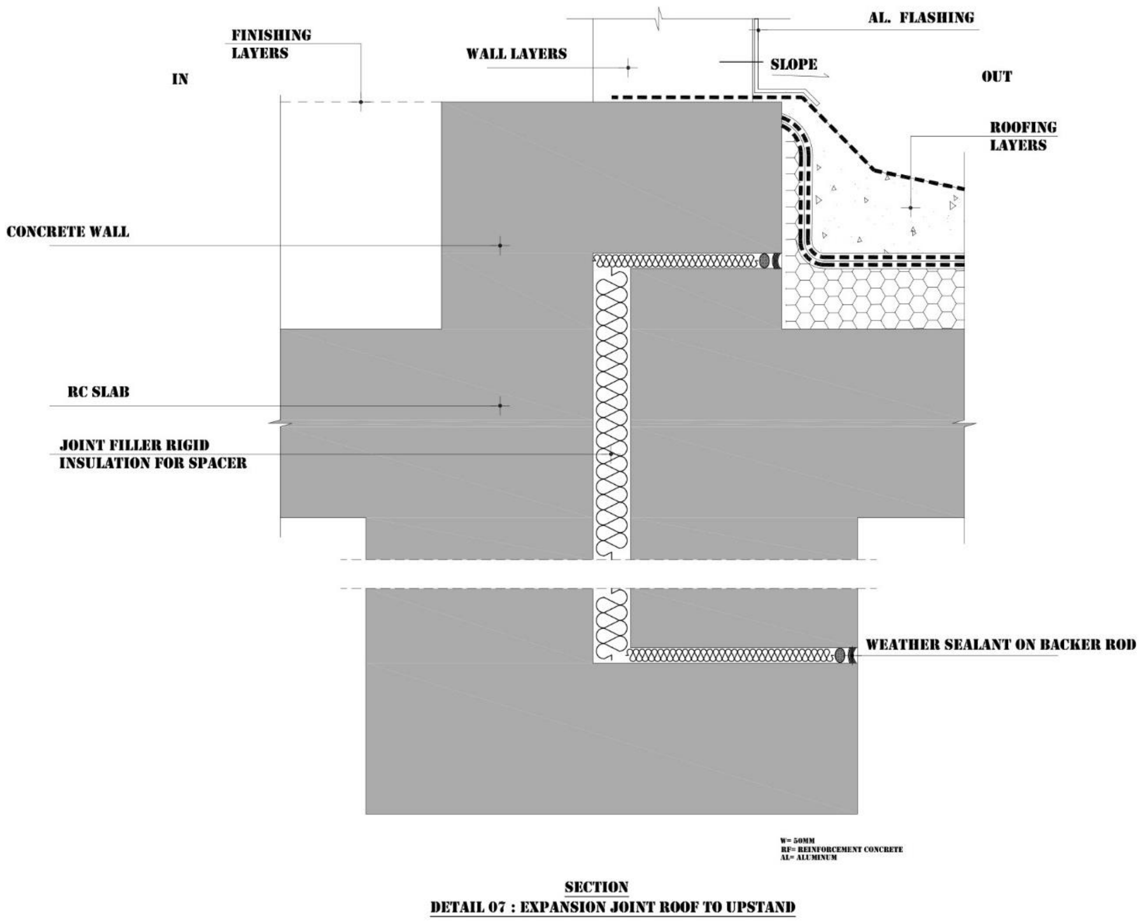



DETAIL 02 :EXPANSION JOINT- FLOOR TO FLOOR




DETAIL 03 :EXPANSION JOINT- WALL TO FLOOR

**Fig. 5.59** Typical details – Scale 1-5



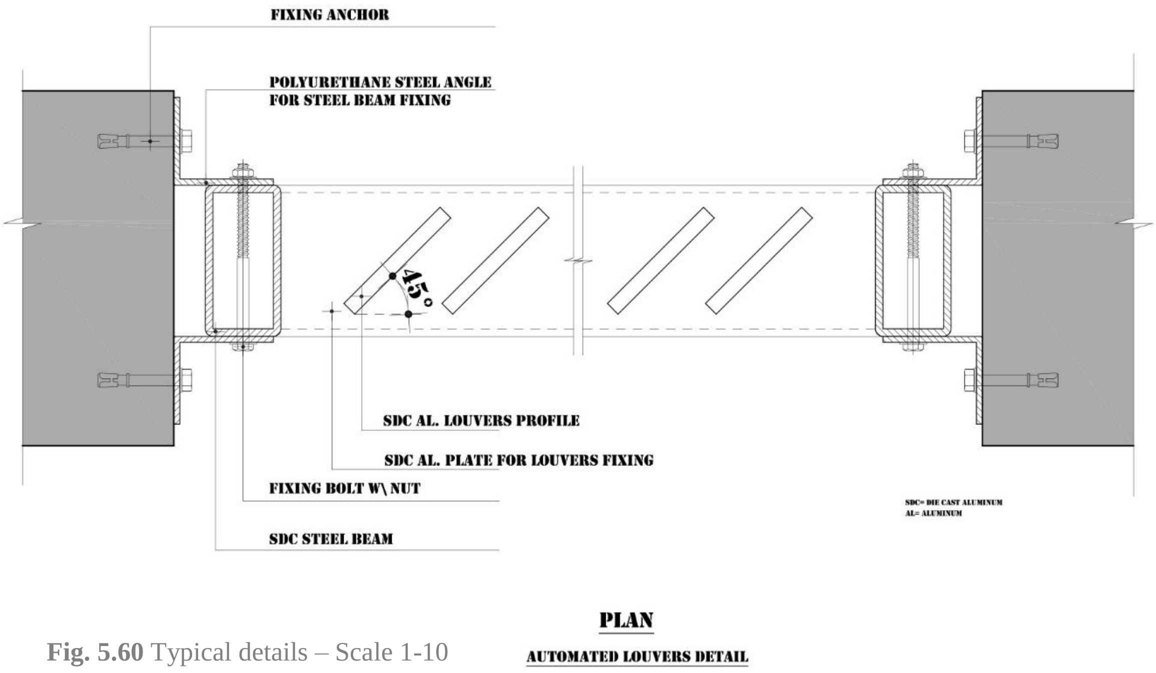




**Fig. 5.60** Typical details – Scale 1-10

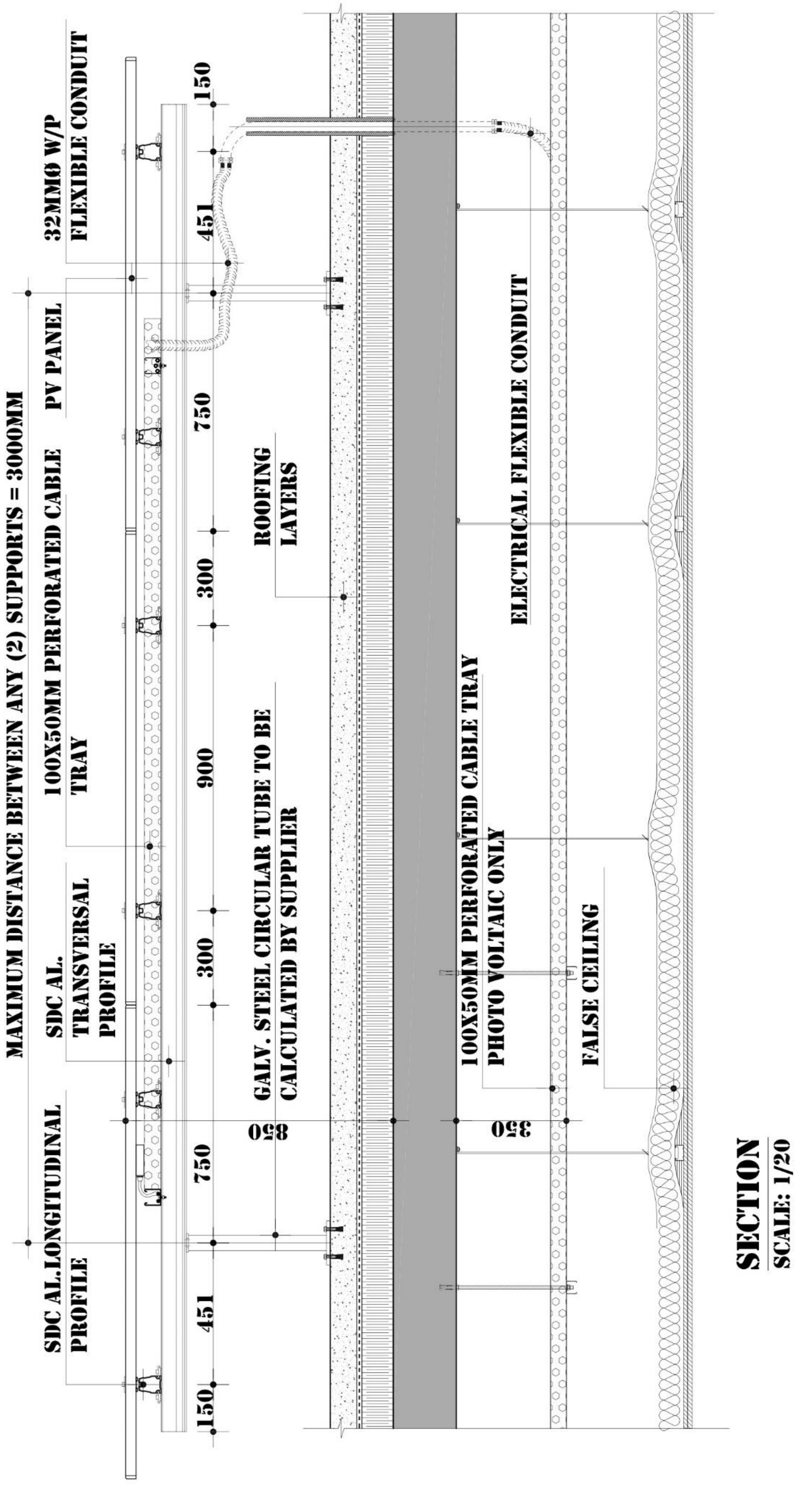



**Fig. 5.61** Typical details – Scale 1-20

## 5.6. STRUCTURAL DESIGN

### 5.6.1. BUILDING DESCRIPTION

In this section is shown the Structural Design of the different elements which compose the system proposed to withstand all the loads comprised by the use and composition of the building. It is important to mention that in this section the central building (The one dedicated mainly for Exhibitions, administration and auditorium zone) is the main focus of the analysis and is foreseen that the results obtained here could be used as a starting point in the other two buildings. Horizontal loads were not included in the calculations but were considered for the element placement, such as shear walls and retaining walls.

This section of the work concerns the design of reinforced concrete as main structure system of our project. As reinforcement concrete system is the mostly used system in buildings construction in Egypt rather than steel construction.

The designed elements are slabs, beams, columns, foundations. The Building is composed by 3 stores in elevation and 1 underground level with total area 35321 m², the common grid of the building is 10mX10m, the height of all the floors is 5 m. From the beginning the building was thought to be as regular as possible in terms of the grid, this ease the placing of columns and beams, also the elements become like one another with some few exceptions.

Solid slab system has been used in the structure design, it consists of reinforced concrete floor (slab), horizontal elements (beams) and vertical elements (columns) connected by rigid joints. The solid slab system is a customized, efficient, economical, loosely reinforced, and is widely used in diverse types of constructions, the typical floor slab is a two-way slab with beams. Two-way slabs are slabs that are supported on four sides. In two-way slabs, the load will be carried in both directions, thus main reinforcement is provided in both directions. The slabs are considered as spanning two-way when the longer to shorter span length is less than a ratio of two. A two-way slab with beams is a type of economical flooring system, often used as it costs less than flat plates or flat slabs.

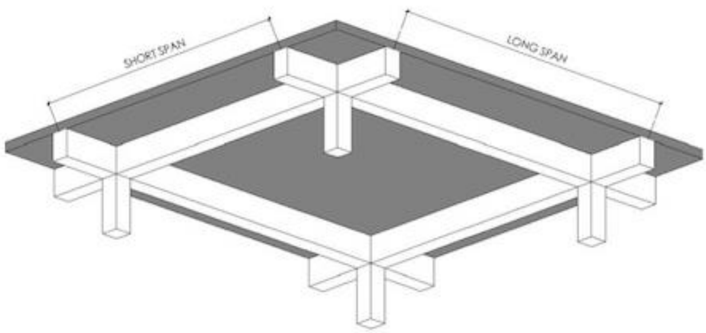



**Fig. 5.62** Two -way solid slab

The Slab is supported by 4 reinforced concrete beams (or 3 depending on the part which is being analyzed); The beams are supported by concrete columns; a retaining wall system is assigned to under ground floor to support the lateral earth loads. There are 2 stiff cores made by R/C walls, both of them serve for the purpose of stiffening the structure, support the stairs and the elevators. Furthermore, a perimeter shear wall would provide enough resistance to support the horizontal forces acting on the building, an expansion joints system (5 cm) should be applied in our building according to the Egyptian code, that is related to its large span. Also, a settlement joints system is applied (5 cm) between the tower (13 floors) and the entire building (1 basement floor) because of the different of levels.

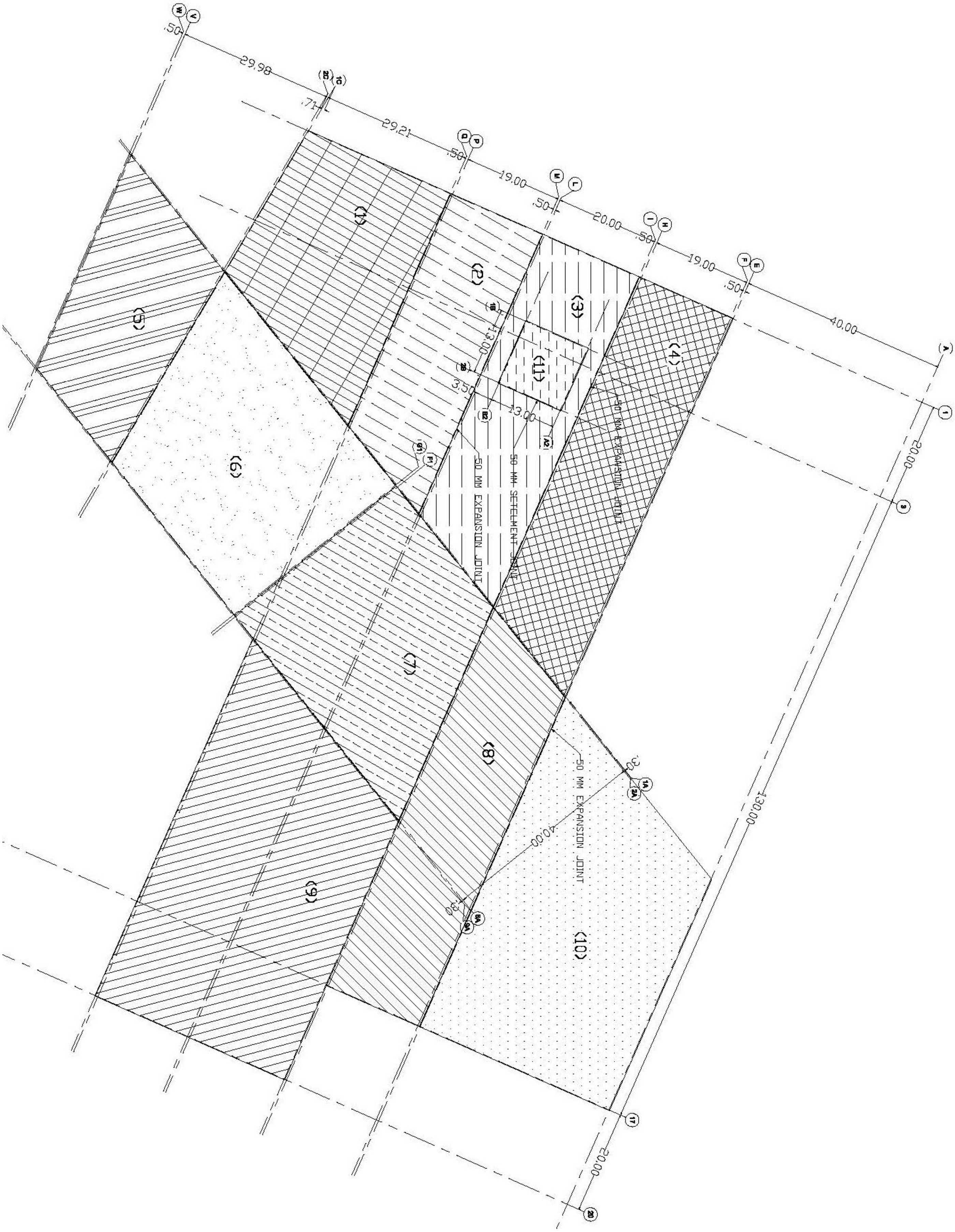



**Fig. 5.63** Expansion joints in the slabs

According to the normative, the design working lifecycle of the building will be considered as 50 years, Category 5 (Table2.1 – EN 1990). In the design the normative used was:

- EN 1990: Eurocode. Basis of structural design.
- Design and construction of concrete structures EGYPTIAN CODE (ECP 203- 2007)
- EN 1991: Eurocode 1. Actions on structures.
- EN 1992: Eurocode 2. Design of concrete structures.
- EN 1993: Eurocode 3. Design of steel structures.
- EN 1997: Eurocode 7. Geotechnical design.

- The observation tower consists of 13 typical floor slabs, the slab is a two-way solid reinforced concrete slab, is supported by 4 reinforced concrete beams; The beams are supported by four L-shape columns at the four corners of the observation tower to resist the lateral loads at the square corners of the tower, the grid of the tower is a square 13mX13m, the typical height is 4 m.
  There is 1 stiff core made by R/C walls around the elevators on the northside of the tower.
  The structure of the observation tower is not analyzed in this section, but the structural concept of the design is based on the analysis of the studied building.

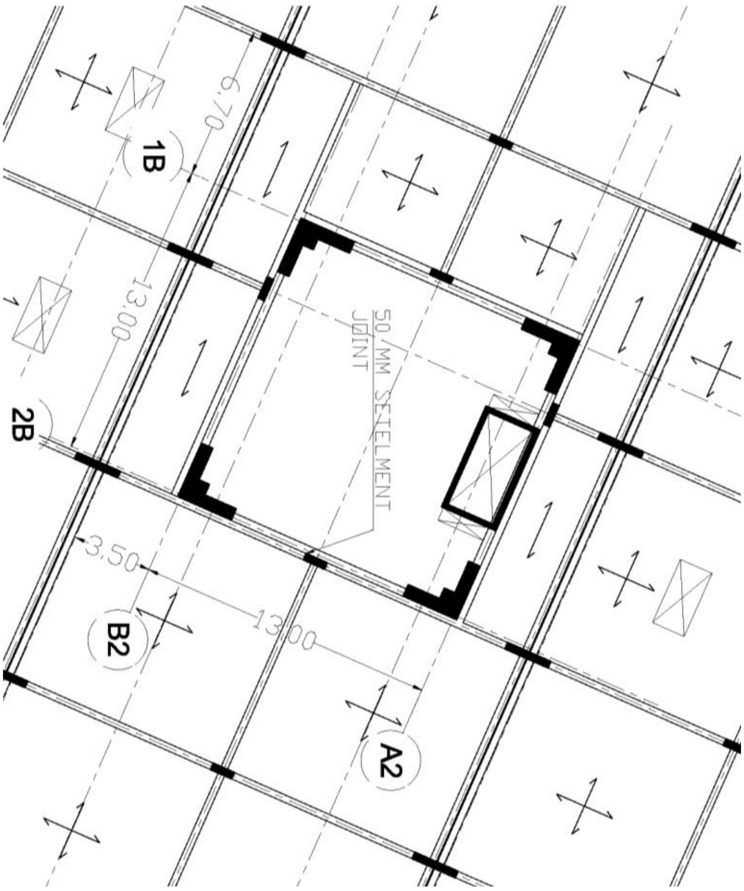



**Fig. 5.64** partial plan for the Structure of the observation tower at level (1)

### 5.6.2. MATERIALS

It is important to mention the materials' properties which affect the design. Therefore, contribution from both reinforced concrete and steel are expected

- **Concrete**

Selecting a concrete class C30/37 (structural class S4), and using the reference values mentioned in Eurocode 2, it was possible to obtain the principal properties of the concrete for the design:

Concrete Characteristic cubic compressive strength: Rck = 37 MPa Using the relation between the cubic compressive strength and the cylinder compressive strength we can obtain:

**Fck =** 0.83·Rck
**Fck =** 0.83· (37)
**Fck =** 30.71 MPa

For the design compressive strength of concrete, we will consider different values, one for serviceability limit state ($\alpha cc=1$) and another for ultimate limit state ($\alpha cc=0.85$):

**Fcd =** αcc·F_ck/**γc, γc =** 1.5
**FcdSLS =** (1) · (30.71)/ (1.5)
**FcdSLS =** 20.47 MPa

**FcdULS =** (0.85) · (30.71)/ (1.5)
**FcdULS =** 17.4 MPa

**The 'αcc' was taken from the code. For the allowable compressive stress:**
**σc,adm =** k1·Fck , **k1**=0.6
**σc,adm =** (0.6)·(30.71)
**σc,adm =** 18.43 MPa

**For the medium tensile strength:**
**Fctm =** 0.3(Fck)^ (2/3)
**Fctm =** 0.3(30.71) ^ (2/3)
**Fctm =** 2.94 MPa

**For the characteristic tensile strength:**
**Fctk,0.05 =** 0.7·Fctm
**Fctk,0.05 =** 0.7 · (2.94)
**Fctk,0.05 =** 2.06 MPa

**Design tensile strength:**
**Fctd =** αct·Fctk/γc
**Fctd =** (1) · (2.06)/ (1.5)
**Fctd =** 1.37 MPa

**Secant modulus of elasticity:**
**Ecm =** 22·(Fcm/10) ^0.3
**Fcm =** Fck+8

**Ecm =** 22· ((30.71+8)/10) ^0.3
**Ecm =** 33.02 MPa

**For the modulus of elasticity:**
**Ec =** 9500· (Fck)^ (1/3)
**Ec =** 9500· (30.71) ^ (1/3)
**Ec =** 29.75 GPa

- **Steel**

By using Steel characteristic yielding strength: Fyk = 440 MPa

**Design yield strength:**
Fsd= Fyk/γs, γs = 1.15
Fsd = (440)/ (1.15) = 382.61 MPa

**Admissible stress:**
**σs,adm =** k3·Fyk , **k3 =** 0.8
**σs,adm =** (0.8)·(440) = 352 MPa

**Modulus of elasticity for that particular steel:**
**Es =** 210 GPa

- **Design of the composite R/C Slab**

In this work only, the design for the typical floor slab of the second building will be presented.

**Loads calculations**

**Permanent load: G =** 4.91 kN/m^2
**Variable load: Q =** 4.9 kN/m^2 (Reference Eurocode)

### 5.6.3. STRUCTURAL DESIGN ANALYSIS

- **Structural design program**

Sap models were used to design and check the safety of the reinforcement concrete elements (slabs, columns and beams) for a study module of 10x10m in the structure building design according to the previous calculations.
SAP2000 is general-purpose civil-engineering software ideal for the analysis and design of any type of structural system. Basic and advanced systems, ranging from 2D to 3D, of simple geometry to complex, may be modeled, analyzed, designed, and optimized using a practical and intuitive object-based modeling environment that simplifies and streamlines the engineering process.

- **Numerical model**

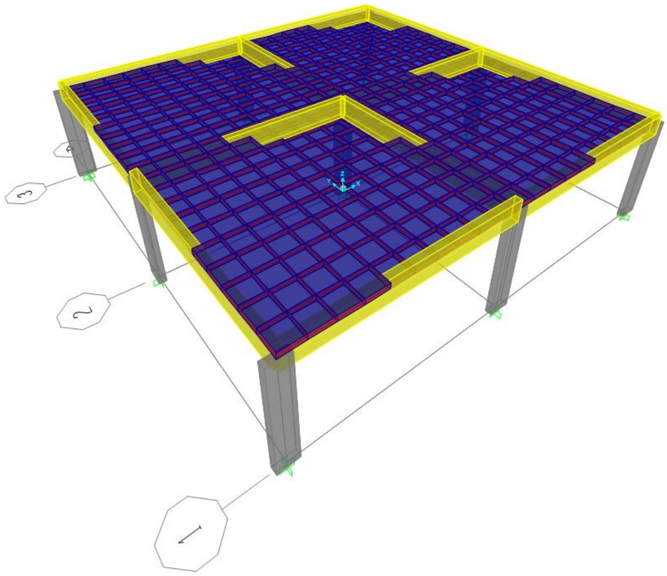


**Fig. 5.65** Module 10m X10m

- **Concrete Dimensions**

Sap 2000 checked the concrete dimensions of the beams, columns and analyzes the required safety solid slab thickness

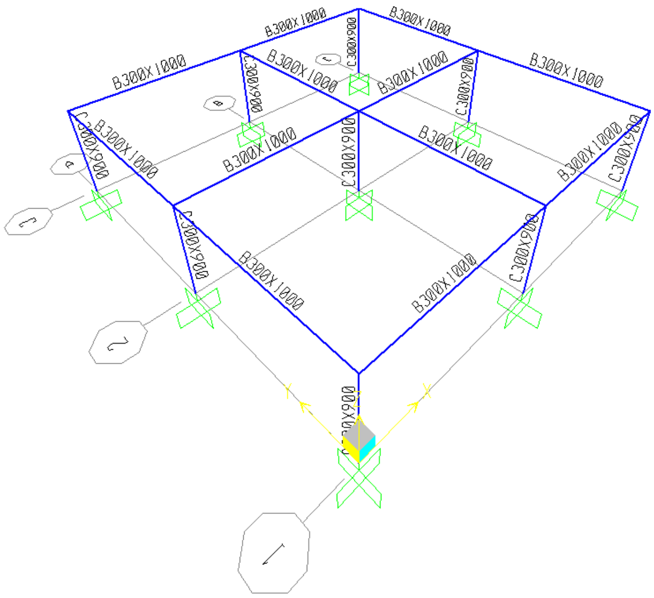



**Fig. 5.66** Concrete dimensions

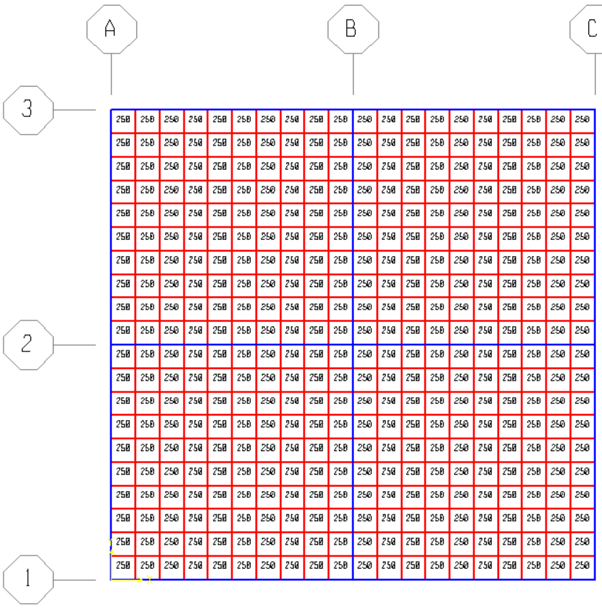



**Fig. 5.67** Slab thickness =250mm

- **Applied Loads:**

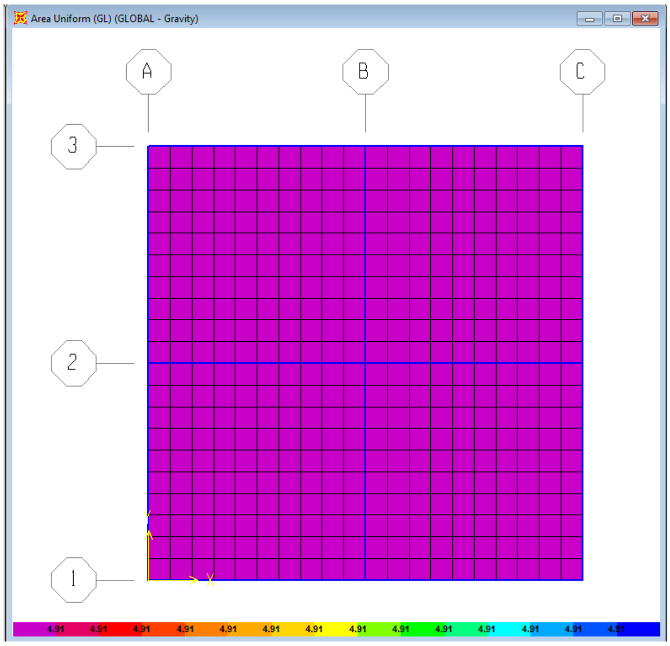



**Fig. 5.68** Permanent loads

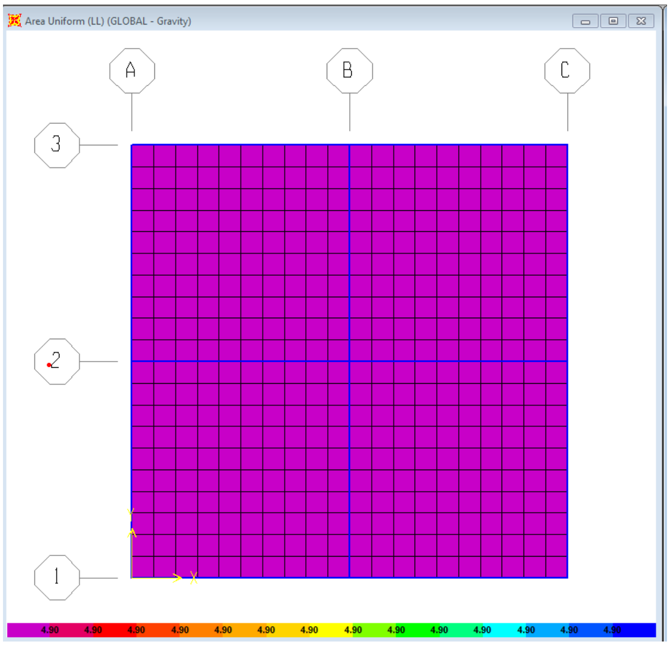



Fig. 5.69 variable loads

- **Output results**

Deformed shape (SLS) on the slab was analyzed bySAP2000

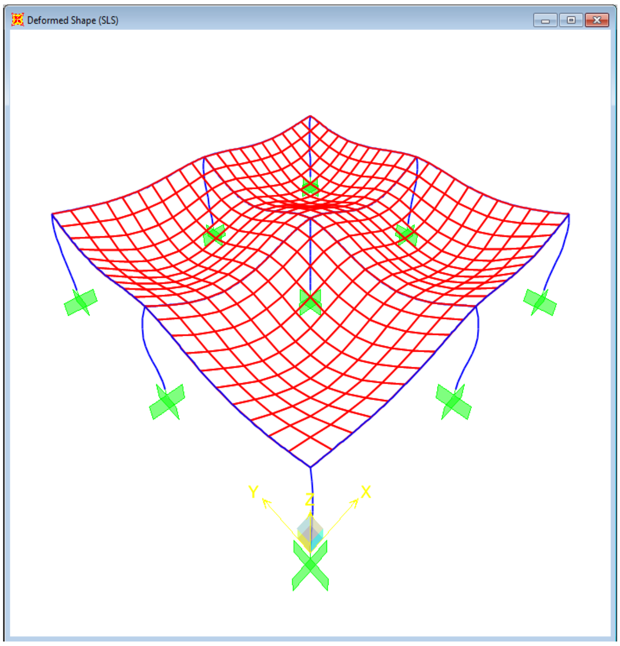



Fig. 5.70 SLS on the slab

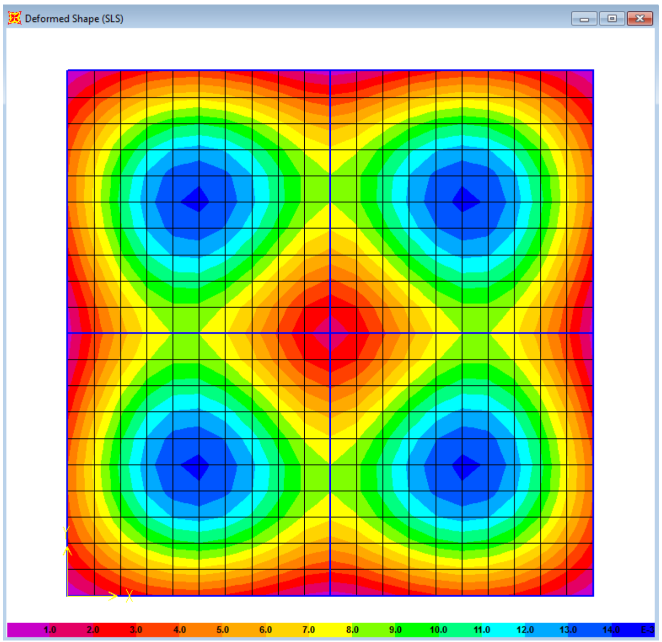



**Fig. 5.71** SLS on the slab

- **Straining actions (ENVELOPE)**

**A- Straining actions (ENVELOPE) for slabs:**
The moment distribution diagram for the slab is analyzed in X &Y directions (M11, M22).

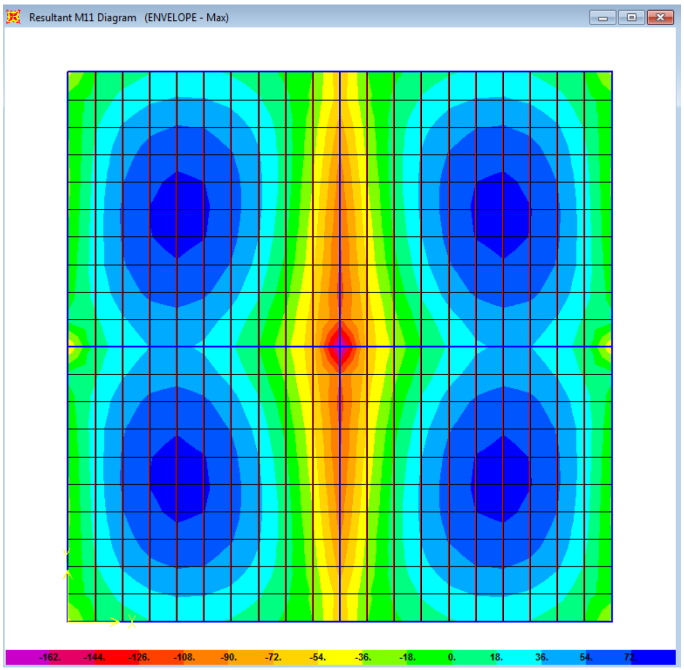



**Fig. 5.72** M11 diagram

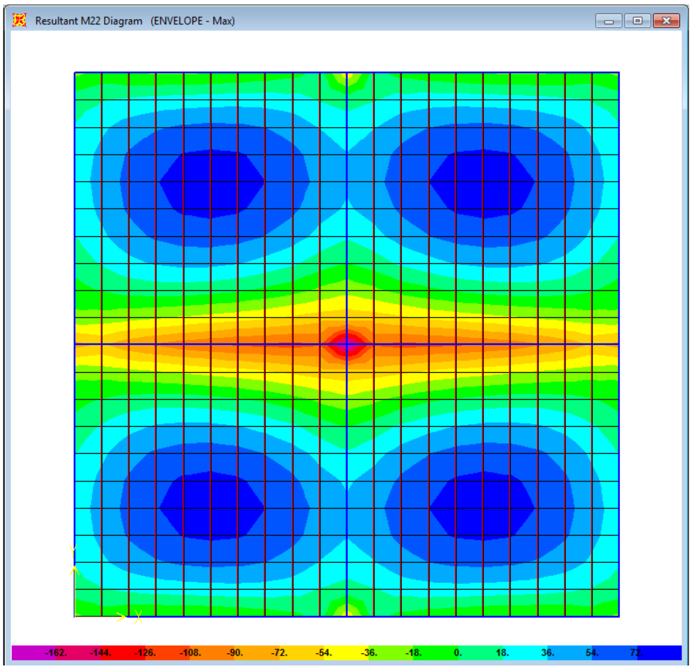



**Fig. 5.73** M22 diagram

**B- Straining actions (ENVELOPE) for beams:**

Straining actions for beams, bending moment diagram and shear force diagram are analyzed by SAP2000

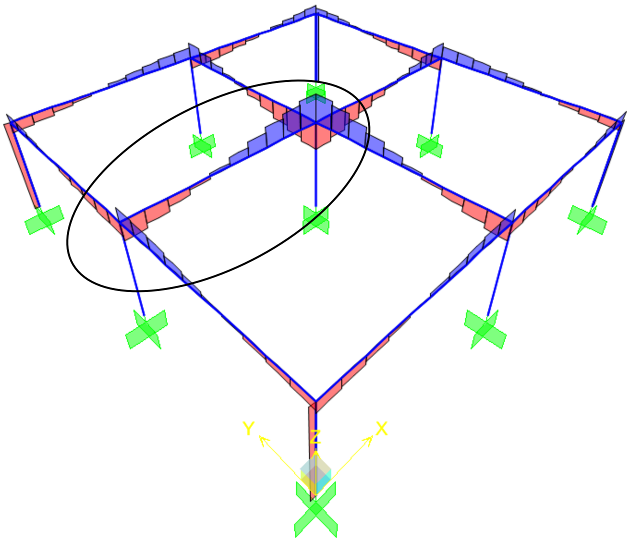



**Fig. 5.74** Shear force diagram

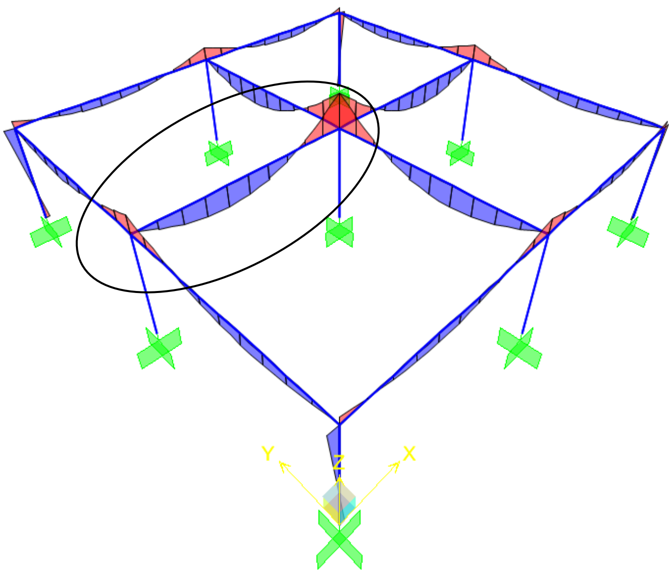
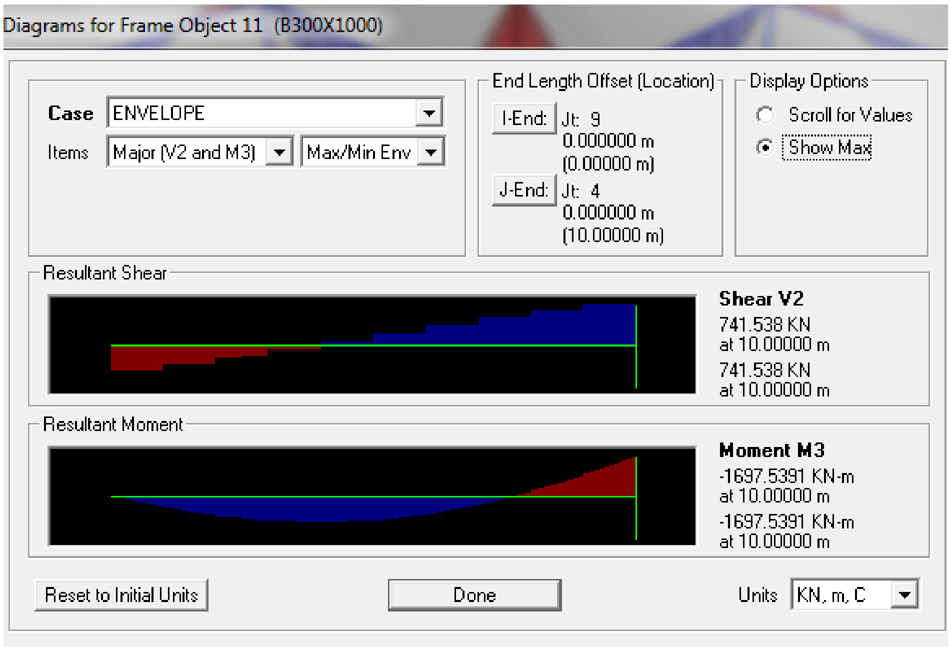


**Fig. 5.75** Bending moment diagram

Checking the shear force and the bending moment on section of the middle beam (as shown in figure no. 74 &75) and checking the Axial force in the middle column.

- **BM and SF in the middle beam**



### C- Straining actions (ENVELOPE) for columns:

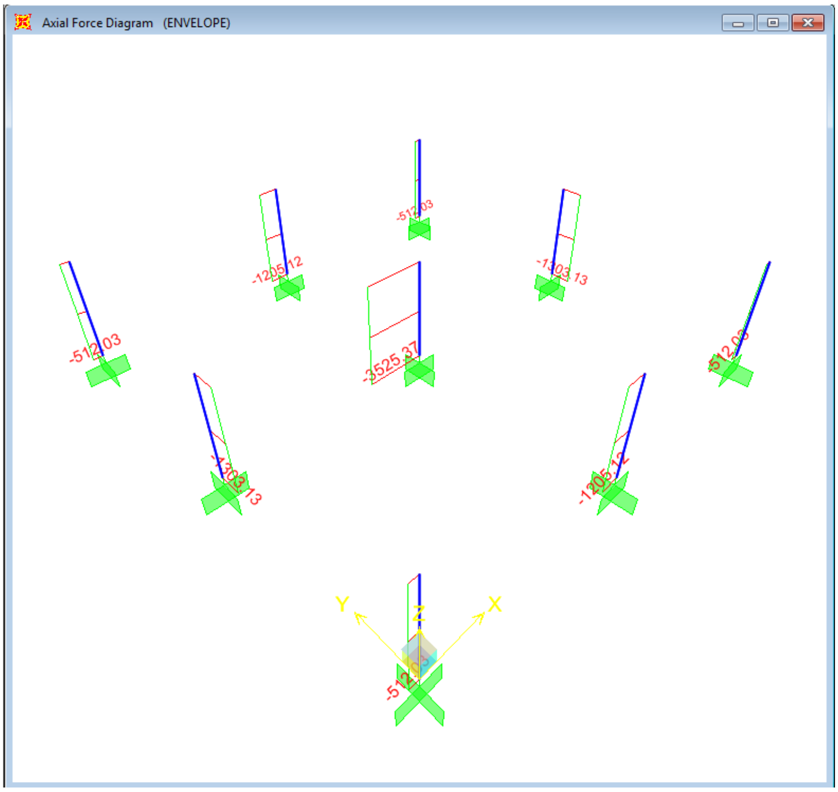
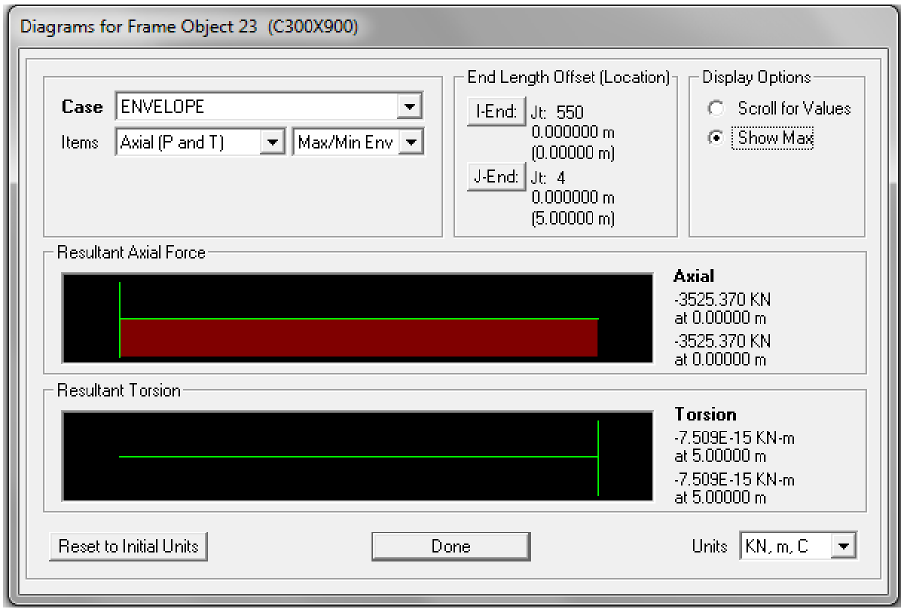



Fig. 5.76 Axial Force (KN)

- Checking the Axial force in the middle column:



- **Design and check according to Eurocode 2004**

**A- Columns Design**

(Figure no. 77) shows that all the design of columns is safe and shows the column interaction ratio which is the ratio between the actual stress of the column and the max. stress of it and from this ratio, the reinforcement steel at column can be calculated as the following:

**Longitudinal rebar:** 14T20

**Stirrups RFT:** 3T10@150

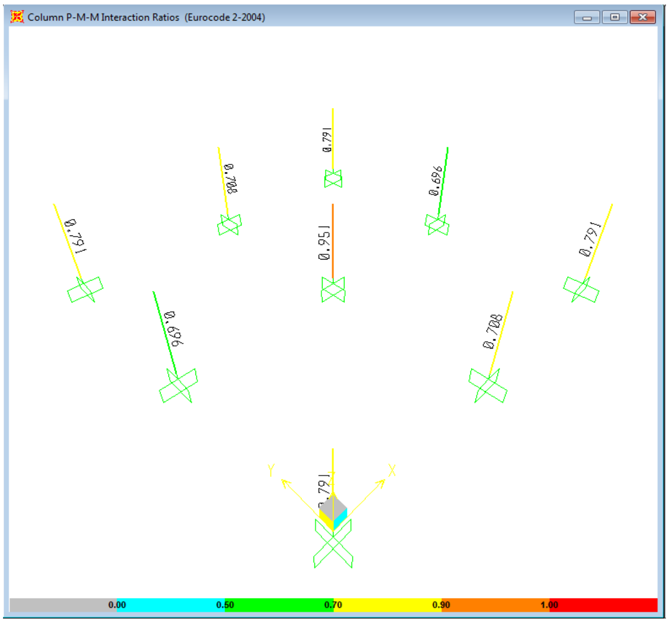



**Fig. 5.77** The design of columns

**B- Beams Design**

- Beams longitudinal reinforcement (Cm2):

Fig. 5.78 shows the longitudinal reinforcing area (As) steel of the beams and by knowing the area of the steel bar, the reinforcement steel design can be calculated. For instance: AØ16 =2.01cm2 & AØ22 = 3.79cm2

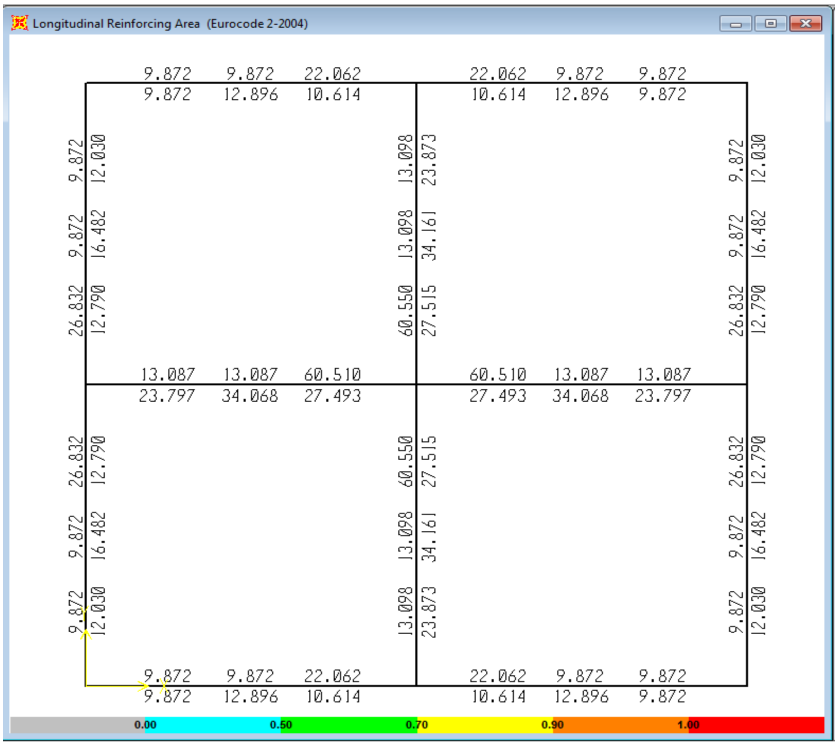



**Fig. 5.78** the longitudinal reinforcing area **(As)**

- Beams Shear reinforcement (cm2\m):

(Figure no. 79) shows the shear reinforcing area per unit length for the shear reinforcement (stirrups).

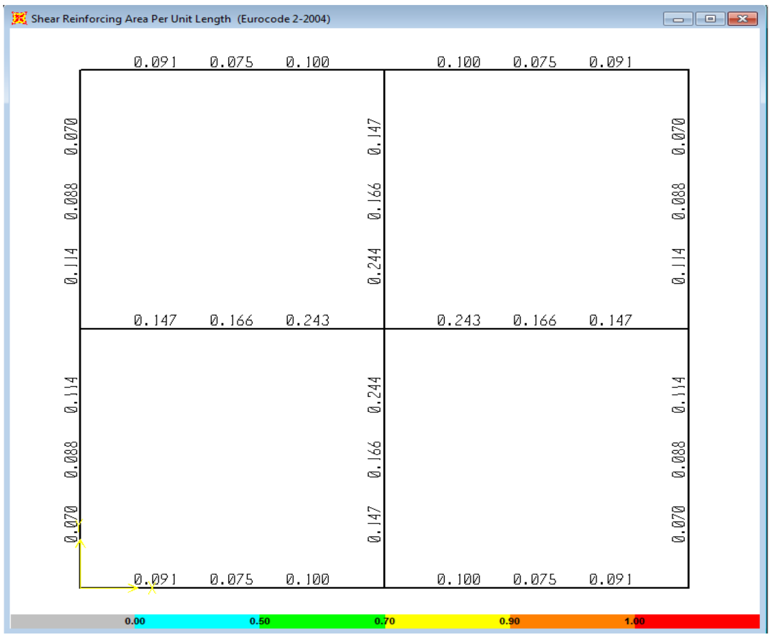



**Fig. 5.79** the shear reinforcing for stirrups

## Area of Steel Bars in $cm^2$ (used in Egypt)

| Φ | Weight | Cross sectional area ($cm^2$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | kg/m' | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 6 | 0.222 | 0.28 | 0.57 | 0.85 | 1.13 | 1.41 | 1.70 | 1.98 | 2.26 | 2.54 | 2.83 | 3.11 | 3.39 |
| 8 | 0.395 | 0.50 | 1.01 | 1.51 | 2.01 | 2.51 | 3.02 | 3.52 | 4.02 | 4.52 | 5.03 | 5.53 | 6.03 |
| 10 | 0.617 | 0.79 | 1.57 | 2.36 | 3.14 | 3.93 | 4.71 | 5.50 | 6.28 | 7.07 | 7.85 | 8.64 | 9.42 |
| 12 | 0.888 | 1.13 | 2.26 | 3.39 | 4.52 | 5.65 | 6.79 | 7.92 | 9.05 | 10.18 | 11.31 | 12.44 | 13.57 |
| 14 | 1.208 | 1.54 | 3.08 | 4.62 | 6.16 | 7.70 | 9.24 | 10.78 | 12.32 | 13.85 | 15.39 | 16.93 | 18.47 |
| 16 | 1.578 | 2.01 | 4.02 | 6.03 | 8.04 | 10.05 | 12.06 | 14.07 | 16.08 | 18.10 | 20.11 | 22.12 | 24.13 |
| 18 | 1.998 | 2.54 | 5.09 | 7.63 | 10.18 | 12.72 | 15.27 | 17.81 | 20.36 | 22.90 | 25.45 | 27.99 | 30.54 |
| 20 | 2.466 | 3.14 | 6.28 | 9.42 | 12.57 | 15.71 | 18.85 | 21.99 | 25.13 | 28.27 | 31.42 | 34.56 | 37.70 |
| 22 | 2.984 | 3.80 | 7.60 | 11.40 | 15.21 | 19.01 | 22.81 | 26.61 | 30.41 | 34.21 | 38.01 | 41.81 | 45.62 |
| 25 | 3.853 | 4.91 | 9.82 | 14.73 | 19.63 | 24.54 | 29.45 | 34.36 | 39.27 | 44.18 | 49.09 | 54.00 | 58.90 |
| 28 | 4.834 | 6.16 | 12.32 | 18.47 | 24.63 | 30.79 | 36.95 | 43.10 | 49.26 | 55.42 | 61.58 | 67.73 | 73.89 |
| 32 | 6.313 | 8.04 | 16.08 | 24.13 | 32.17 | 40.21 | 48.25 | 56.30 | 64.34 | 72.38 | 80.42 | 88.47 | 96.51 |
| 38 | 8.903 | 11.34 | 22.68 | 34.02 | 45.36 | 56.71 | 68.05 | 79.39 | 90.73 | 102.1 | 113.4 | 124.8 | 136.1 |

**Fig. 5.80** Table of used steel bars in Egypt

### C- Slab Design

- Slab reinforcement in X&Y direction:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Floor | | | | | | Date: | March 2018 | | |
| Subject | | | S 250 mm | | | Sheet No.: | 1 | | |
| *Dimensions and reinforcement* | | | | | | *Materials* | | | |
| Thickness of section (t) | | | = | 25 | Cm | | | | |
| Breadth of Section (b) | | | = | 100 | Cm | Steel Yield Stress ($f_Y$) | = | 4400 | Kg/Cm$^2$ |
| concrete clear cover (dc) | | | = | 3.5 | Cm | Concrete Cube Strength ($f_{CU}$) | = | 370 | Kg/Cm$^2$ |
| Depth of Section (d) | | | = | 21.5 | Cm | | | | |
| Min reinforcement | | | = | 3.23 | cm2/m` | | $\mu_{min}$ = | 0.150% | |
| Max reinforcement | | | = | 30.40 | cm2/m` | | $\mu_{max}$ = | 1.414% | |
| | | | | | | | $\mu_{def}$ = | 1.261% | |
| *Main reinforcement* | | | | | | | | | |
| Top mesh/m` | 10 | $\phi$ 12 | As = | 11.30 | cm2/m` | $\mu_b$ | = | 2.110% | |
| | | | $\mu$ = | 0.53% | | $\mu_{max}$ Top | = | 1.414% | Safe |
| Bottom mesh /m` | 10 | $\phi$ 12 | As = | 11.30 | cm2/m` | $\mu_{min}$ Top | = | 0.150% | Safe |
| | | | $\mu$ = | 0.53% | | $\mu_{max}$ Bott. | = | 1.414% | Safe |
| a = 2.62 cm | | | | | | $\mu_{min}$ Bott. | = | 0.150% | Safe |
| Ultimate Moment ($M_U$) | | | = | 8.7328 | m. t | Bottom | | | |
| a = 2.62 cm | | | | | | | | | |
| Ultimate Moment ($M_U$) | | | = | 8.7328 | m. t | top | | | |

### 5.6.4. DESIGN OF FOUNDATIONS

According to the soil report (from the project brief).

- the allowable net bearing capacity for the soil on top of soil replacement should not be exceed than 150 kpa (1.5 kg/cm3) and at locations where soil replacement is not required, the allowable net bearing capacity for natural soil at foundation level should not be exceed than 500 kpa (5 kg/cm3)
- Soil replacement is required to a depth (1 m ) below the designed foundation level
- Bulk density for soil = 2.1 ton/m3
- The Egyptian code for Geotechnical design was used for designing the foundation and depending on the values which have been obtained previously, the following excel sheet has been created to analyze the foundation dimensions

γ soil = 2.1 ton/m3
γ Rc = 2.5 ton/m3
γPc = 2.5 ton/m3
Net bearing capacity = 15 ton/m2
Gross bearing = 15+(0.4X2.2) +(0.7X2.5) +(1.5x2.1) = 20.78 ton/m2

| FOOTING: Isolated Footings | | DATE | 4-Mar-2018 |
|---|---|---|---|
| Subject | FOOTING NO. F1 | | |
| | | input | |
| ***Input Data*** | | | |
| fcu (Kg./$cm^2$) | 370 | | |
| fy (Kg./$cm^2$) | 4400 | | |
| Working Axial Load (ton) | 260 | | |
| Thikness of p.c (m) | 0.4 | | |
| Gross Bearing capacity (ton/$m^2$) | 20 | | |
| Column breadth (Cy) (m) [ Short Side] | 0.30 | | |
| Column length (Cx) (m) [ Long Side ] | 0.90 | | |
| ***Plain Concrete*** | | Lx' suggested (m) | 4.32 |
| Plain concrete area | 16.055 | Lx chosen(>or<Lx') | 4.35 |
| Gross working vertical load = | 321.1 | Ly` (m) | 3.69 |
| Plain concrete arm | 0.4 | Ly chosen(m) >Ly` | 3.70 |
| Working Gross bearing stress (ton/m2) | 19.9503 | ok | |
| ***Reinforced Concrete*** | | | |
| Working Axial Load (ton) = | 260 | | |
| Thickness of reinforced concrete t (m) | 0.7 | | |
| Depth of reinforced concrete d (m) | 0.63 | | |
| Breadth of Rc (Bx) (m) | 3.55 | | |
| Length of Rc (By) (m) | 2.9 | | |
| Ultimate Axial Load (ton) | 382.2 | | |
| Ultimate bearing stress (ton/$m^2$) | 37.12482 | | |
| Ultimate bearing strength (ton/$m^2$) | 1652.667 | Safe Bearing | |
| ***Punching Shear*** | | | |
| permiemter (m) | 4.92 | | |
| Ultimate punching shear (ton) | 329.3751 | | |
| Ultimate punching stress due to N (ton/$m^2$) | 106.2637 | | |
| Ult. punching strength (ton/$m^2$) | | | |
| q1 (t/m2) | 282.9725 | | |
| q2 (t/m2) | 130.7859 | | |
| q3 (t/m2) | 156.9431 | | |
| $q_{cup}$ (ton/$m^2$) | 130.7859 | Safe Punching | |
| ***One-Way Shear*** | | | |
| Ultimate Shearing force Qy (ton) | 129.8162 | | |
| Ultimate shear stress quy (ton/m2) | 58.04436 | | |
| Ultimate Shearing force Qx (ton) | 108.7386 | | |
| Ultimate shear stress qux (ton/m2) | 59.51757 | | |
| Max ultimate shear stress qu (ton/m2) | 59.51757 | | |
| Ult. shear strength qcu (ton/m2) | 79.46488 | Safe Shear | |
| ***Flexural Strength and Reinforcement*** | | | |
| Depth in the main direction (m) | 0.63 | | |
| Depth in the secondary direction (m) | 0.61 | | |
| Mu about x (ton.m)/m | 31.37047 | | |
| d | 0.63 | | |
| Ru | 79.03873 | | |
| $\mu_{min(6/fy)}$ | 0.001364 | | |
| $\mu_{min(1.3M)}$ | 0.002752 | | |
| $\mu_{min}$ | 0.0015 | | |
| $\mu$ | 0.002117 | RFT.In the Y-direction Is the lower steel | |
| Asy ($cm^2$) | 13.34 | | |
| $\mu_{max}$ | 0.01414 | OK | |
| Mu about y (ton.m)/m | 32.58863 | | |
| d | 0.61 | | |
| Ru | 87.5803 | | |
| $\mu_{min(6/fy)}$ | 0.001364 | | |
| $\mu_{min(1.3M)}$ | 0.003058 | | |
| $\mu_{min}$ | 0.0015 | | |
| $\mu$ | 0.002353 | | |
| Asx ($cm^2$) | 14.3513 | | |
| $\mu_{max}$ | 0.01414 | OK | |

| | | P.C. DIMENSIONS | | | R.C. DIMENSIONS | | |
|---|---|---|---|---|---|---|---|
| | | Thick. | Long Dir. | Short Dir. | | Long Dir. | Short Dir. |
| Bar diameter in long dir. mm | 16 | | Lx | Ly | Thick. | Bx | By |
| Bar diameter in short dir. mm | 16 | 0.4 | 4.35 | 3.70 | 0.7 | 3.55 | 2.9 |
| | | | | | As / m | 8 ϕ 16 | 7 ϕ 16 |

### 5.6.5 Structural ceiling drawings

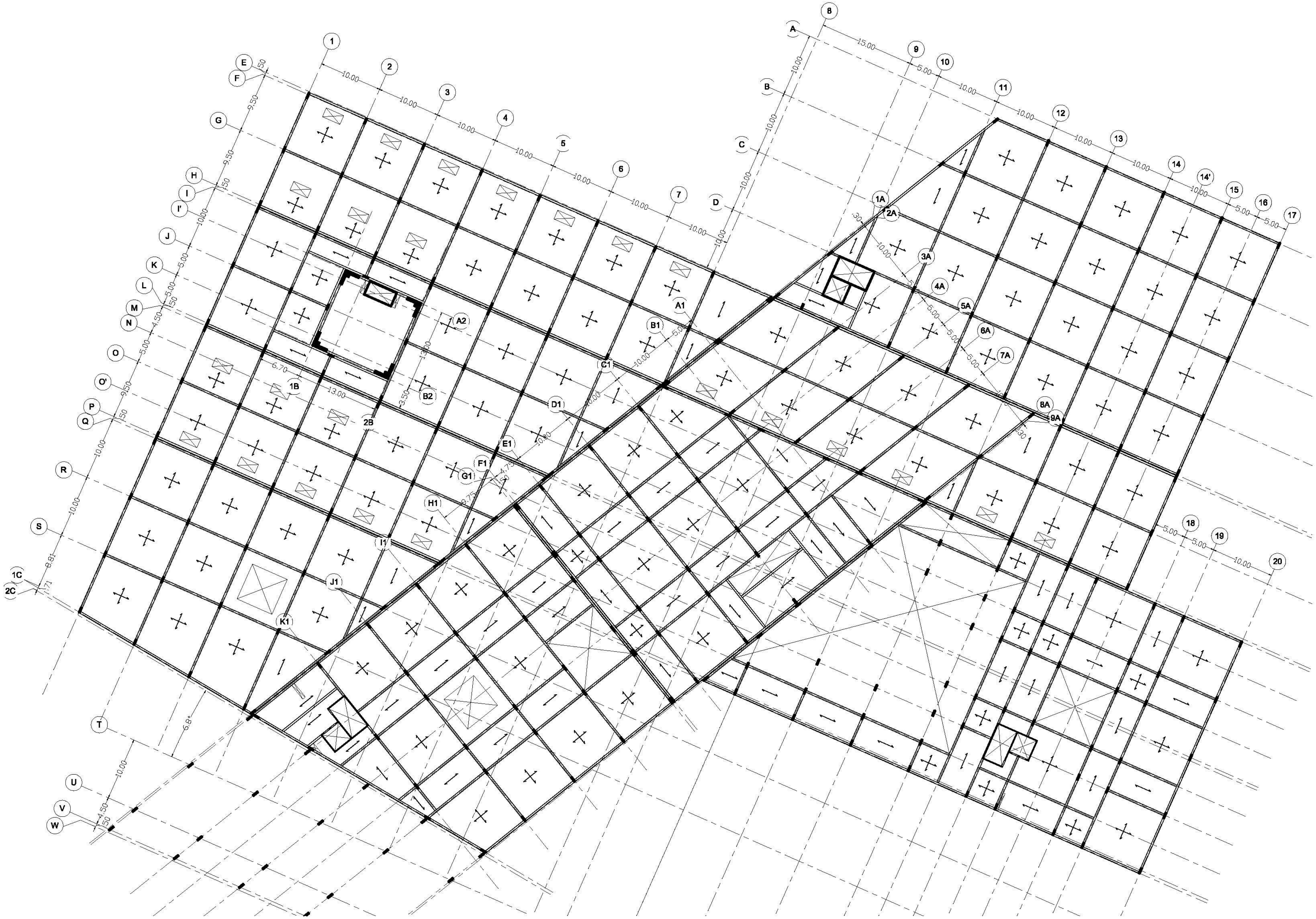


**Fig.5.81** Structural ceiling of level 1 **Scale 1-500**

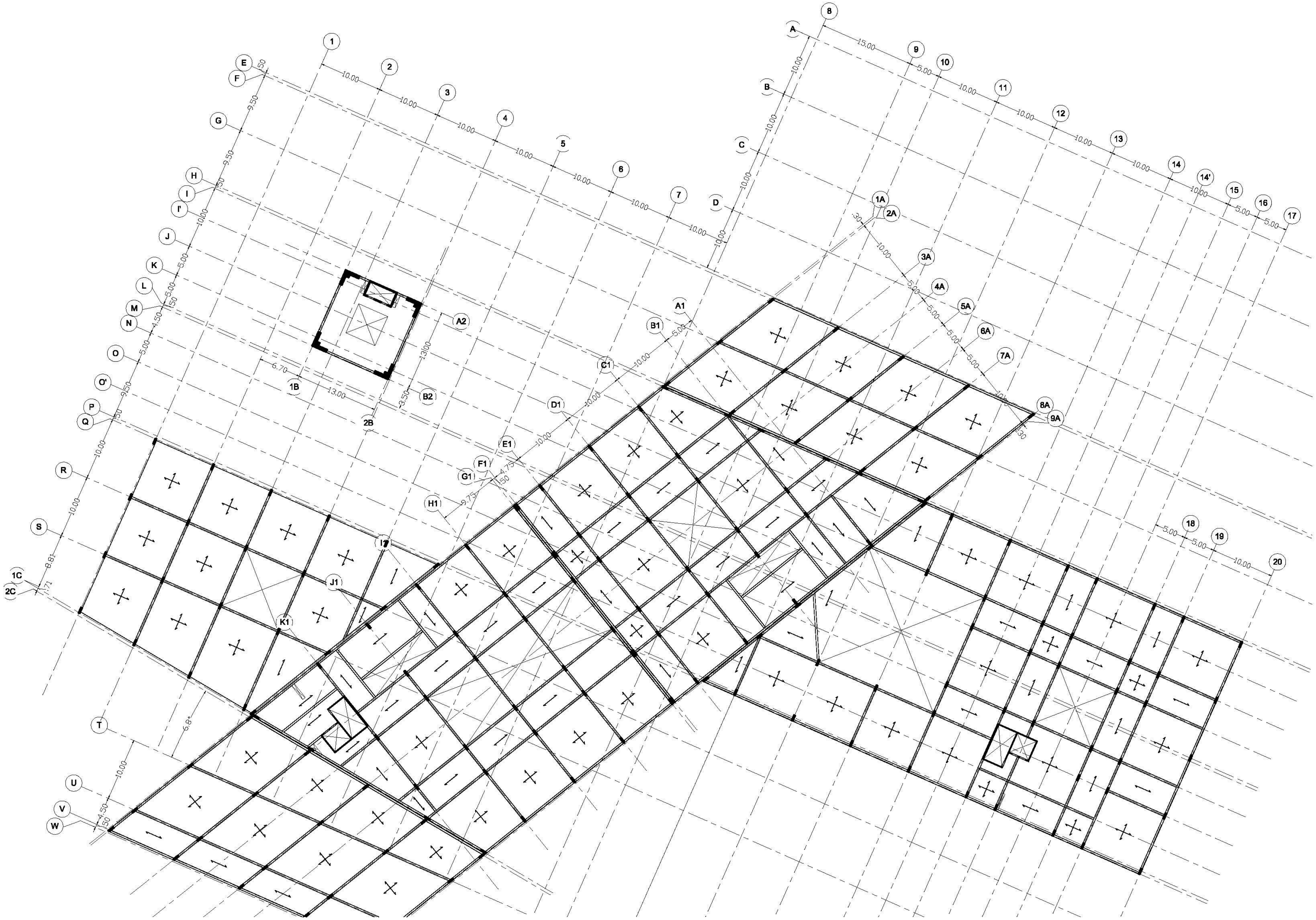



**Fig. 5.82** Structural ceiling of level 2
**Scale 1-500**

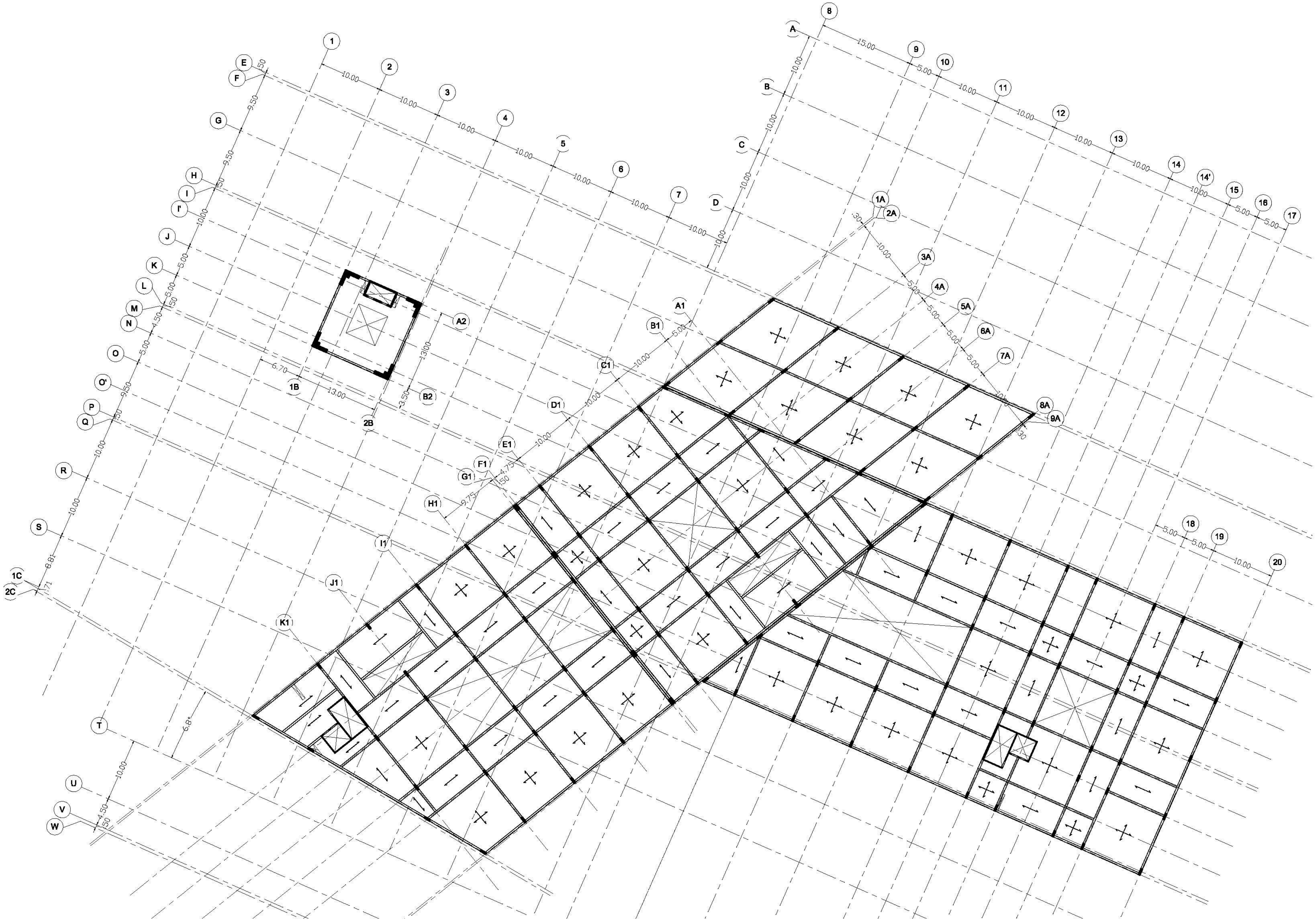



**Fig. 5.83** Structural ceiling of level 3
**Scale 1-500**

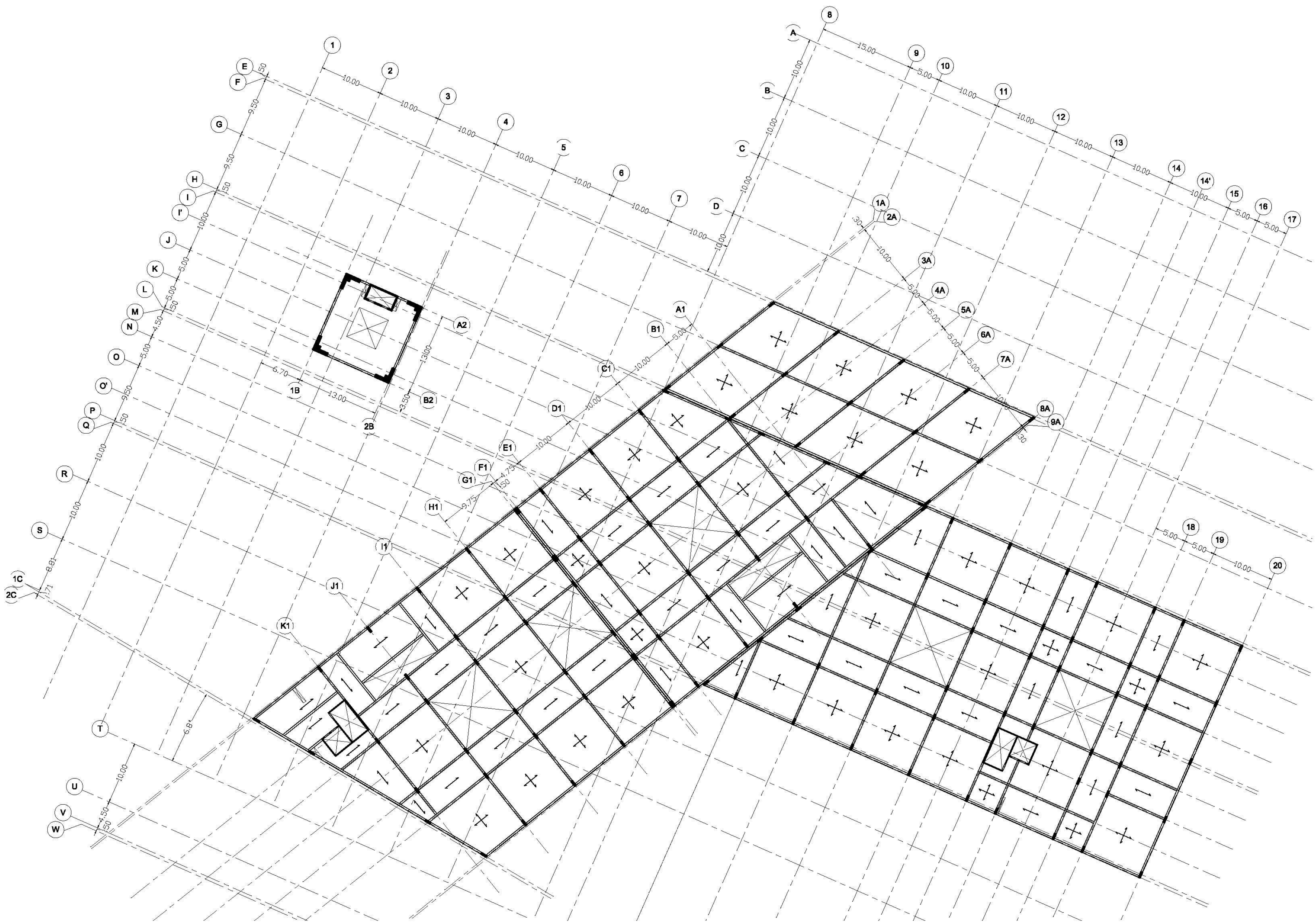


**Fig. 5.84** Structural ceiling of level 4
**Scale 1-500**

## 5.6.6. TYPICAL STRUCTURAL DETAILS

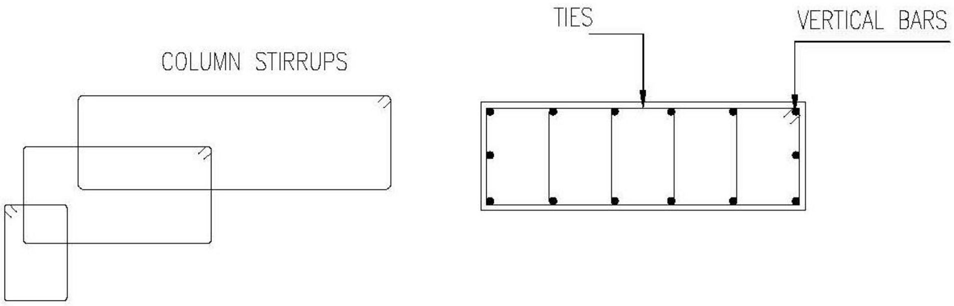
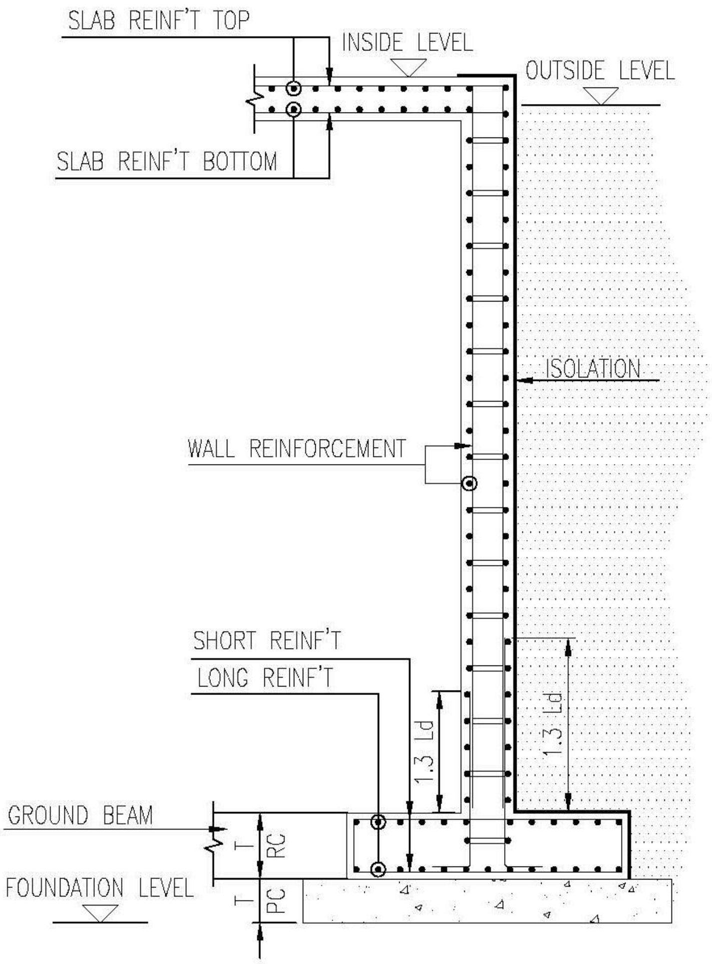



**Fig.0.0.** Typical Column Section
**NTS**




LD: Lap Splice

**Fig. 5.85** Typical retaining wall
**NTS**

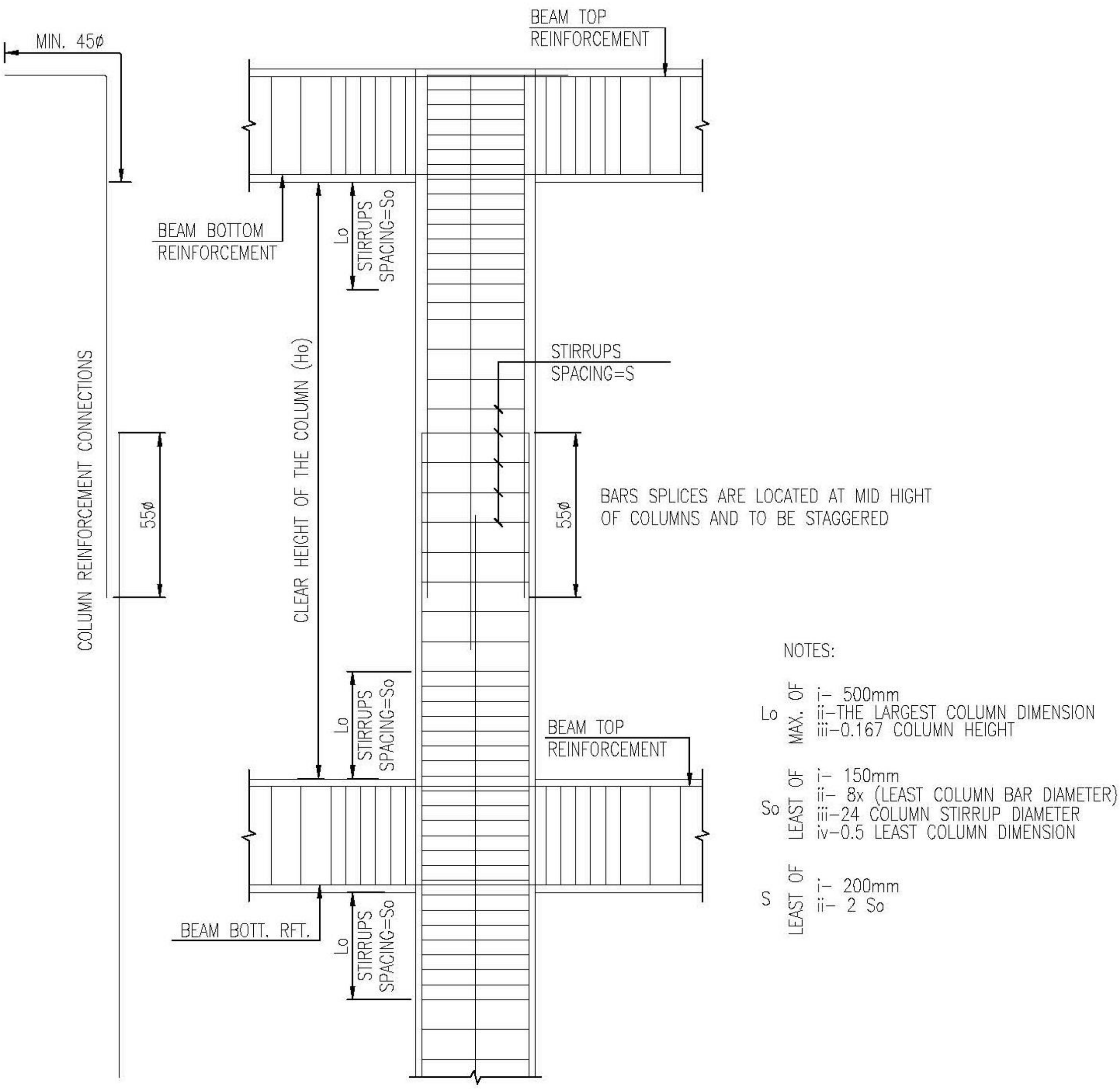



**Fig. 5.86** Typical detail for column reinforcement connections
**NTS**

Lap Splice is when two pieces of reinforcing bar are overlapped to create a continuous line of rebar and depends on

- Concrete strength
- Diameter of reinforcement steel
- Force load

-

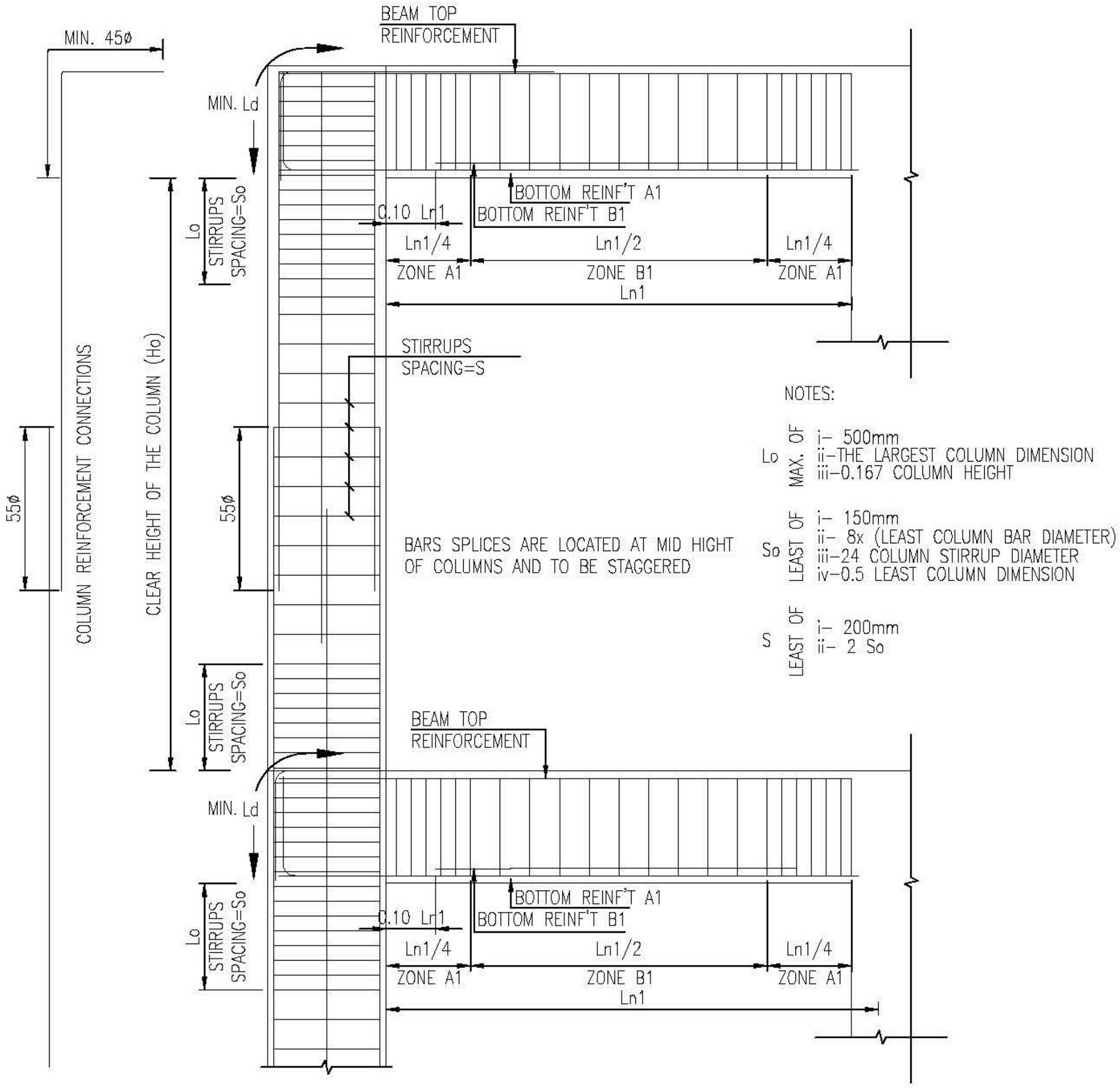



**Fig. 5.87** Typical detail for end beam column reinforcement connections - **NTS**

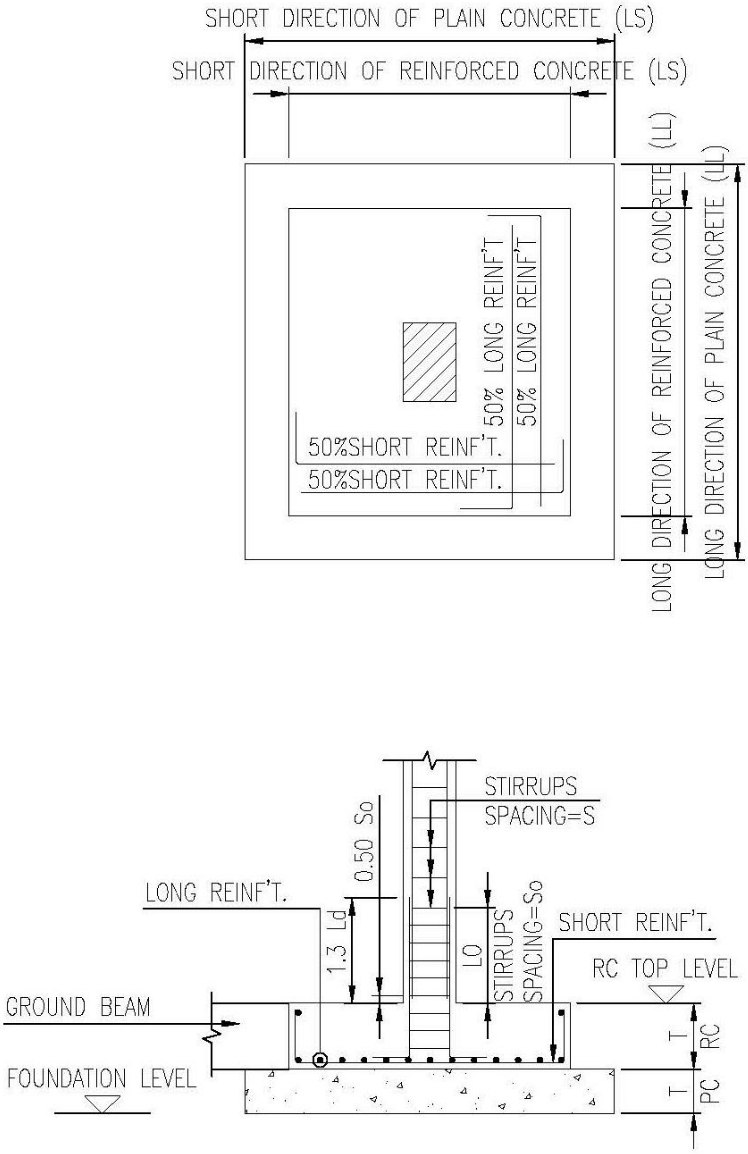



**Fig. 5.88** Typical isolated footing
**NTS**

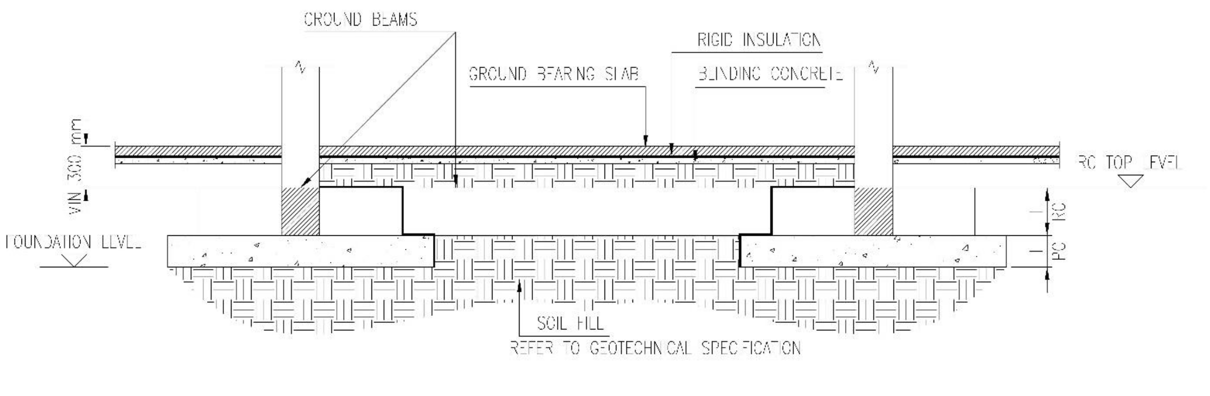
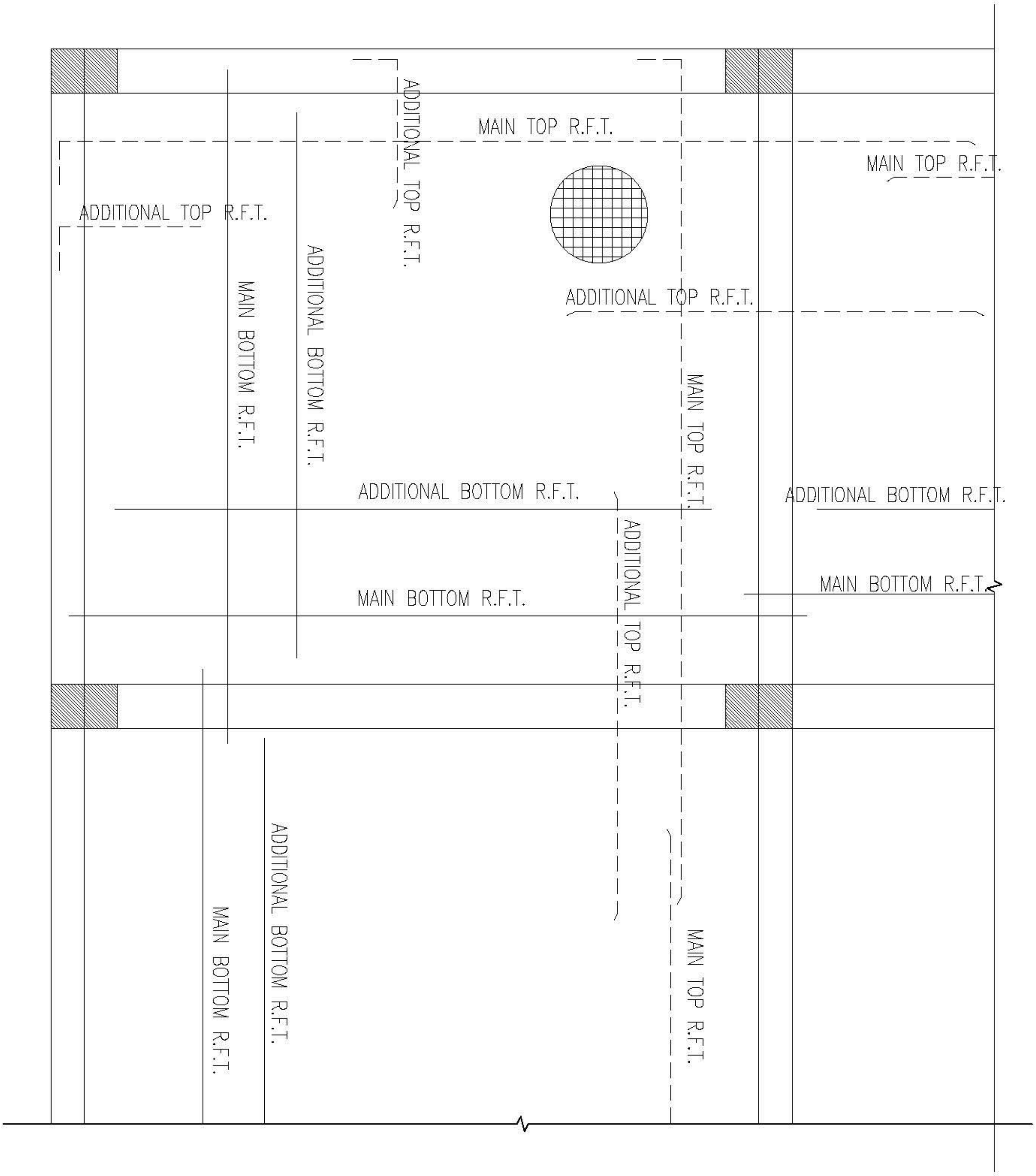



**Fig. 5.89** Typical ground slab to footing connections
**NTS**




R.F.T: Reinforcement

**Fig. 5.90** Typical detail for slabs
**NTS**

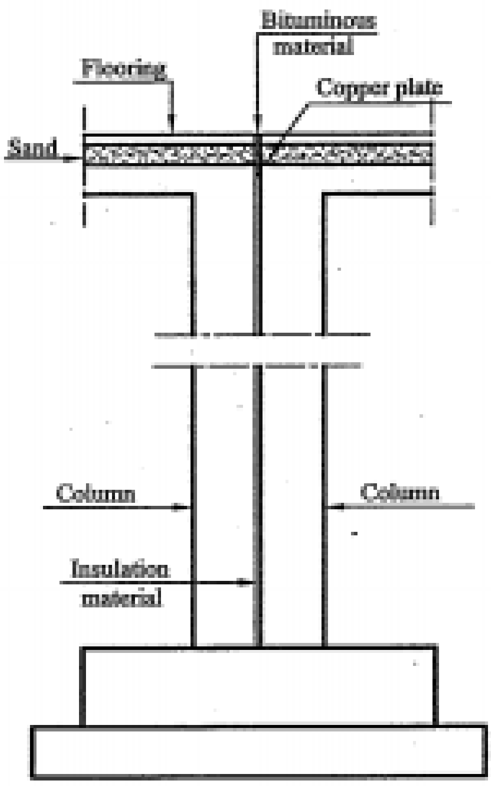



**Fig. 5.91** Expansion joint detail
Two columns and the same footing
**NTS**

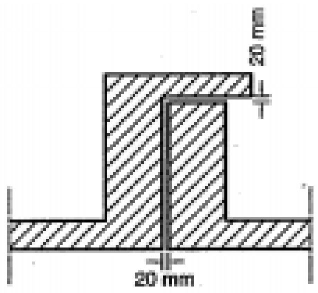



**Fig. 5.92** expansion joints detail at the roof
**NTS**

# 6. REFERENCES

- EN 1990. Eurocode: Basis of structural design
- EN 1991-1-1. Eurocode 1: Actions on structures: General actions – Densities, self-weight, imposed loads for buildings.
- EN 1992-1-1. Eurocode 2: Design of concrete structures: General rules and rules for buildings.
- EN 1993-1-1. Eurocode 3: Design of steel structures: General rules and rules for buildings.
- EN 1994-1-1. Eurocode 4: Design of steel and composite structures: General rules and rules for bridges.
- EN 1997-1. Eurocode 7: Geotechnical design – Part 1: General rules.
- http://mw2015.museumsandtheweb.com/paper/enhancing-visitor-experience-and-fostering-museum-popularity-through-deep-insights-in-the-placement-of-exhibits-by-new-techniques-in-visitor-flow-visualization-in-space-and-time/
- http://www.world-housing.net/wp-content/uploads/2011/06/RC-Frame_Yakut.pdf
- https://www.marazzigroup.com/media/filer_public/ba/15/ba15dd60-1a78-4259-b903-158757831a20/marazzi_facciateventilate-vantaggi.pdf
- http://pubs.rsc.org/en/content/articlehtml/2012/ra/c2ra20340e
- https://www.arup.com/projects/grand-egyptian-museum#project-anchor
- http://curvelandscape.com/newsletter/june2014/Curve%20Newsletter.pdf
- http://www.newcities.gov.eg/english/New_Communities/October/default.aspx
- http://www.globalfootprints.org/sustainability
- http://www.epa.gov/sustainability/basicinfo.htm
- https://www.academia.edu/9294719/Urban_Sustainability_in_Theory_and_Practice_Circles_of_Sustainability_2015_
- http://degrowth.org/wp-content/uploads/2011/05/Lorek_Sustainable-consumption.pdf
- http://www.sd-commission.org.uk/pages/what-is-sustainable-development.html
- http://epa.gov/ncer/rfa/forms/sustainability_primer_v7.pdf
- http://cmsdata.iucn.org/downloads/iucn_future_of_sustanability.pdf
- http://www.sustainabilityconsortium.org/wp-content/themes/sustainability/assets/pdf/whitepapers/Social_Sustainability_Assessment.pdf
- https://sustainabledevelopment.un.org/content/documents/4538pressowg13.pdf
- https://sustainabledevelopment.un.org/focussdgs.html
- http://cpor.org/ce/Diamond%282005%29CollapseHowSocietiesChooseFailureSuccess.pdf
- http://www.pnas.org/content/106/8/2483.full.pdf+html
- http://assets.panda.org/downloads/living_planet_report_2008.pdf
- http://www.histecon.magd.cam.ac.uk/historysust/files/Big_Here_and_Long_Now-presentation.pdf
- http://www.rainforest-alliance.org/work/agriculture
- http://www.unesco.org/new/en/unesco/about-us/who-we-are/introducing-unesco/
- http://cmsdata.iucn.org/downloads/iucn_future_of_sustanability.pdf

- https://architizer.com/projects/california-academy-of-sciences/#.UPaaWonjmXQ
- https://www.wbdg.org/resources/natural-ventilation
- http://europe.breezair.com/natural-air-conditioning-the-use-of-evaporative-cooling-in-ancient-arabic-architecture/
- http://egyptera.org/Downloads/taka%20gdida/renewable%20Energy.pdf
- https://www.export.gov/article?id=Egypt-Renewable-Energy
- http://www.masdar.ae/assets/downloads/content/264/masdar_clean_energy_factsheet-final-jan_8,_2017.pdf
- https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/ashrae_62_table_6.1_-_minimum_ventilation_rates.pdf
- https://www.ventaxia.com/sites/default/files/Ventilation%20Design%20Guidelines%202.pdf
- https://www.energycodes.gov/sites/default/files/becu/lighting07.pdf
- https://www.engineeringtoolbox.com/number-persons-buildings-d_118.html
- http://waset.org/publications/9997500/an-analysis-of-thermal-comfort-for-indoor-environment-of-the-new-assiut-housing-in-egypt
- http://www.newcities.gov.eg/know_cities/October/default.aspx
- http://www.naturalbuildingblog.com/additional-passive-cooling-strategies-for-hot-climates/
- http://design490.org/hot-arid-climate-building-design-considerations/
- https://simplicable.com/new/raised-floor
- https:// www.topfloor.it
- https://www.steelconstruction.info/File:How_thermal_mass_works.png
- https://en.wikipedia.org/wiki/Underfloor_air_distribution
- http://www.roof-care.com/roofing-solutions/combo-roof/
- http://www.greentech-wp.com/combo-roof/
- https://www.archdaily.com/catalog/us/search/category/construction-materials-facade-systems-enclosures-double-skin- facades-panels-prefabricated-assemblies
- https://www.designboom.com/tag/observatory-architecture-and-design/
- http://www.solargcc.com/egypt-solar/
- https://www.archweb.it/dwg/Particolari_costruttivi/pareti_ventilate/Soluzioni_di_facciata/soluzioni_facciata_isolamento.html
- https://www.limitless.uk.com/portfolio/
- http://engineeringfeed.com/ventilation-catcher-analyses
- http://www.aquapanel.co/products-solutions/exterior-walls-facades/products/aquapanel-cement-board-outdoor/
- http://design490.org/hot-arid-climate-building-design-considerations/
- http://www.newcities.gov.eg/know_cities/October/default.aspx

POLITECNICO
MILANO 1863