# إهداء و شكر و تقدير

أهدي بحثي هذا بعد شكر الله عز وجل الذي اعانني على إنجازه

إلى من تتوه الكلمات في حضرتها،و تخجل الحروف من عظمتها من علمتني و عانت الصعاب لاصل الى هنا،

أمي الحبيبه

إلى من كلله الله بالهيبه و الوقار ، إلى من علمني العطاء بدون انتظار ، إلى من أحمل إسمه بكل افتخار ،

والدي الحبيب

إلى من وقف بجانبي في بحثي هذا و لم يتوانى لحظه عن تقديم المساعده و النصح استاذي الفاضل،

د . مهند الحج حسين

إلى الشموع اللتي تحترق من اجل إناره الطريق لنا ، أساتذتي الافاضل

إلى من شاركوني كل لحظه من لحظات دراستي ، و كانو بمثابه عائلتي الاوسع نطاقه ، زملائي وأصدقائي

إلى كل من علمني حرفاً ، و ساندني بأي وسيلةٍ كانت

إلى من أستقي من عشقها طهر الكلمات ، إليك يا فردوس الجنان ،إليك يا قدس العروبه ، إليك وطني الغالي فلسطين

أهدي بحثي هذا . . . . .

راجيا من الله عز و جل أن ينال القبول و النجاح

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**Abstract**

Among all countries of the world, Palestine is a historical country which is famous for its religions: and it is considered to be the birth of the three monotheistic religions, Islam, Christianity and Judaism, Thus Mosques, Churches and temples are significant for people, therefore our graduation project is to design an Environmental Friendly Mosque in Nablus to be the first Environmental Friendly Mosque in Palestine. The project presents an integrative design approach that involves structural, architectural, mechanical, electrical, environmental aspects.

In the structural design, the structures in the project will be analyzed and designed using computer software (SAP). An important attention will be given for this structural aspect to get the free column Mosque (zero column in the pray hall). This will play an important role for both architectural and environmental site in our project. The architectural design will focus on selecting the shape, and the form of the structures depending on the functionality and the environmental requirements. In mechanical and environmental design, HVAC, water, and sanitary systems in the project will be analyzed and designed. The electrical design will include designing power and lighting systems in the project.

All design and analysis details of the project will be documented in a report. In addition, the project will deliver shop drawings, which contain all design details and can be implemented in practice. At the end, this project will provide a unique, safe, and cost effective design of a mosque in Palestine.

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

After the migration of prophet Mohammed (PBUH), the first thing he ordered to do was establishing a mosque. That mosque was the start point for the establishment of Al-Madina Al-Monawwara which was the capital of the Islamic nation.

The mosque is considered to be the core of the architectural planning in the Islamic city and in every Islamic society because it is the basis of all Muslims activities. It is also the basis of Muslims architectural heritage through ages since no Islamic architectural building was before it.

The mosque is strongly connected with its surroundings which confirms the unity of the mosque with the architectural structure in its environment. This affected the planning and the design of the Islamic cities.

From the mosque a call is raised to invite people to pray five times a day where souls and hearts are gathered in one place towards Makkah as it is written in AL-Quran:

بسم الله الرحمن الرحيم

((في بيوت اذن الله ان ترفع و يذكر فيها اسمه يسبح له فيها بالغدو والاصال ، رجال لا تلهيهم تجارة ولا بيع عن ذكر الله واقام))

صدق الله العظيم

النور,(38)

## 1.2 Objective

1. Prepare and finalize the architectural design considering all other aspects of design.

2. Conduct an environmentally friendly structure as much as possible.

3. The design will include all aspects of design (structural, electrical, mechanical and environmental).

4. Solve most common problems in the existing mosques.

5. Design the mosque with zero column interior.

## 1.3 Methodology

The methodology adopted for this research is based principally on literature review, which focus on architectural, structural, lighting, and mechanical. The methodology also take into consideration some case studies like Al-Najah national university mosque, Mossab Ebnu Omair mosque. In addition the case studies environmental field measurements by visiting the site and collecting data.

# CHAPTER 2

# LITERATURE REVIWE

## 2.1 Architectural Design

### 2.1.1 Introduction

A mosque is a place of worship for followers of the Islamic faith. Muslims often refer to the mosque by its Arabic name, masjid. The Arabic word masjid means temple or place of worship and comes from the Arabic root sajada (root "s-j-d," meaning to bow or kneel) which means he worshipped in reference to the prostrations performed during Islamic prayers.

The primary purpose of the mosque is to serve as a place where Muslims can come together for prayer. Nevertheless, mosques are known around the world nowadays for their general importance to the Muslim community as well as their demonstration of Islamic architecture.

To achieve these purposes we designed a mosque with no internal columns. Unfortunately, the West Bank does not have many special mosques like that, so there will be a trend to design comprehensive mosques with suitable architectural, environmental and structural standards for this type of facilities.

### 2.1.2 Forms

There are many different styles depending on the era in which it was built, also depends on the civilization that existed. Show the table (2-1). [1]

**Table 2-1: Formes**

| Style | Description | Photo |
|---|---|---|
| 1-Hypostyle mosque | The most character of this style is the large number of internal columns shown in figure. |  |

| | | |
|---|---|---|
| 2-The Umayyad style | The Umayyad style is considered to be the first Islamic style. Umayyad's are the reason why Islamic architectural flourished. A good example is Masjid Al-Aqsa which is located in Palestine. |  |
| 3-Al-Abbasi Style | Is the style that came after the fall of the Umayyad's. This style in Islamic architecture prefer shoulders or beams over the columns in holding the arches, the most important legacy that this style has left us is the jamia mosque at Samarra. |  |
| 4-Fatimid Style | The most important highlight of mosques in this era is the care in their elevations, the most important element that they used is the two helmet minaret, and the dish under the dome. Examples of mosque in this era is Al-Azhar mosque. |  |

| | | |
|---|---|---|
| 5- Iranian style (Mughal) | The advantage of this model is that it is saturated with Chinese techniques that flooded Iran itself and its surrounding countries that were affected by these arts, Islamic architecture in the mosques has increased in its beauty and balance. |  |
| 6-Moroccan Style | Moroccan-style architecture with its horseshoe-shaped that sets on rounded column with decorative crown and simple ground base. |  |
| 7- Indian style | This style is famous for its lack of unity and cohesion because they used big areas and they didn't care much about the continuity of their building. The most famous mosque is Al-Jamee Al-Kabeer in India. |  |

| | | |
|---|---|---|
| 8- Ottoman style | The idea of mosques in this period were the halls with shoulders and small domes, light enters the mosque through windows beneath every dome. Examples of mosques in this period the Hagia Sophia mosque. |  |

### 2.1.3 Architectural Consideration for Mosque

**Space and Function [2]**

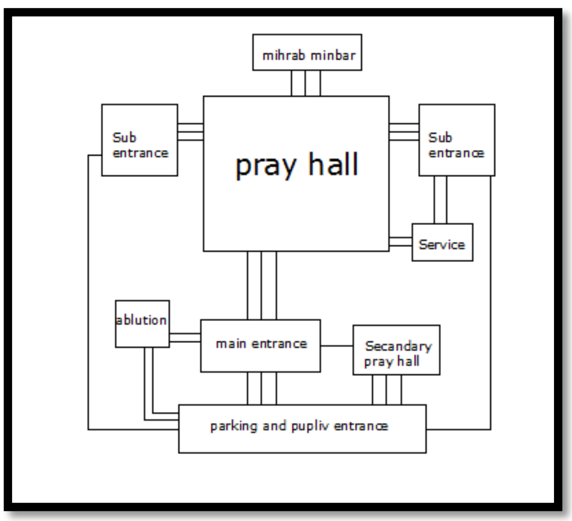



**Figure 2-1 : Spaces and function in mosque**

In Mosques, functionality is an important issue, because it provides comfort ability for prayers and gives psychological comfort see for more illustration in distribution pray hall.

**Pray halls:**

The pray hall must be wide enough and comfortable in order to respect its Functionality. The praying area should be directed towards the QEBLA direction, but other elements can be directed in a way taking in consideration that it doesn't destroy the image or the form of a mosque

**Spaces:**

- The first row in the pray hall is very important because of the great emolument; hence it should be large enough to hold as many prayers as we can.
- In the prayer area each person needs an area of 1.2m^2. 1.2*0.8 for each person.

**Service area:**

We have to consider that the entrance should be separated from the ablution area to avoid congestion and odors, mean while we must separate the men's entrance from the woman's.

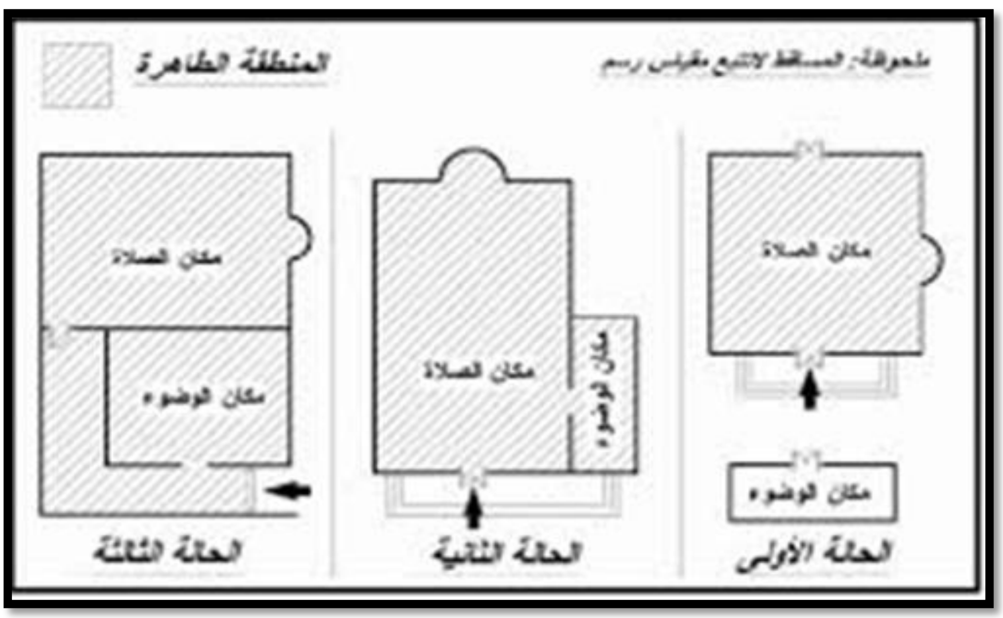



**Figure 2-2:The relationship between the place of prayer and ablution.**

We should consider that we should keep the mosque clean, so we must be careful when we design the bathrooms and the ablutions, we must consider that each 40 persons need one bath and 2 sinks.

**Elements: [3]**

The Islamic architecture has many elements that made many styles over the years which has distinguishes form it any other style. The Muslims used these styles in their buildings (Mosques, Schools, Markets, and Bathrooms).The Mosque contain the following elements:

1. Mosalla (place for prayer).
2. Member and Al- Mihrab (apse and platform).
3. The Mihrab (apse).
4. Ablutions.
5. The minaret.
6. Dome.
7. Windows and openings.
8. Shoe Rocks.

## 2.2 Environmental Consideration

### 2.2.1 Day light and fenestration

Light levels in mosques, are mostly related to the creation of an environment where the worshipper can fulfill his religious needs also is used to accentuate the building.

❖ **Consideration and strategies for design:-**

1- Optimize urban design and building orientation.

2-the perfect size form a glazing treatment.

3- Shading system.

### 2.2.2 Recommendation for Acoustics

1- Avoid columns inside prey hall will result in a better coverage of the direct sound throughout the audience area leads to improve clarity and intelligibility.

2- Avoid Parallel walls which cause the phenomena of Flutter Echoes. Flutter Echoes play a major rule in reducing the speech intelligibility inside a mosque.

3- Use interior surface of the dome from rough materials to avoid creep effect.

### 2.2.3 Recommendation for Thermal Comfort

1- Zoning is important for comfort control and energy saving specially in mosques with Friday.

2- Use Middle range of design temperature with small variation for summer and winter season because people when come to mosque are well dressed in addition to their presence is for short time there for 24C$^{O}$is good for summer and winter.

3- Relative humidity inside mosque (40-60) %.

4- Glazing area and distribution over mosque walls is an important issue, to balance the heat gain and loss in summer and winter ,U value of glazing should be kept to minimum Shading system also is necessary for summer to avoid excessive heat gain without affecting the daylight level.

## 2.3 Structural Design

### 2.3.1 Introduction

Structural design is an important issue in mosque design, since mosques are located in public and residential places; in addition to that mosques could be used as a shelter for people in case of disaster and during emergency response operations, so the mosque should remain functional and safe.

### 2.3.2 Structural Design Involve the Determination Of:

**a) Design requirements and goals:- [4]**

- Stability.
- Strength
- Serviceability
- Economy
- Atheistic

**b) Construction Materials: - [5]**

Wood, concrete, steel are common materials used but concrete is the most used material in construction of mosques because it endures very high temperatures from fire for a long time without loss of structural integrity also concrete requires no additional fireproofing treatments to meet stringent fire codes ,in addition to the availability of materials and skilled labor made concrete more economical, also concrete structures is energy efficient due to the mass of concrete structure which makes it a significant thermal reservoir with the ability to store large amounts of energy (example, it could work as a thermal mass) ,also R-value for exterior walls are greater so the energy losses due winter and summer season are smaller when comparing with steel structures.

**c) Structural elements**

1- Slabs.

2- Beams.

3- Columns.

4- Walls.

5- Footing.

**d) Loads: -**

The building structure will be subjected to loads that have been categorized as follows:

1. Dead Loads
2. Live Loads
3. Earthquake loads

**Seismic load depends, primarily, on:**

Anticipated earthquakes parameters at the site.

Geotechnical parameters of the site (Seismic site effect).

Structure's parameters.

**e) Load combination:**

Load combinations specified by ACI-02 are listed below:

- 1.4 D
- 1.2 D + 1.6 L
- 1.2 D + L
- 1.2 D + 0.8 W
- 1.2 D + 1.6 W + 1.0 L
- 1.2 D + 1.0 E + 1.0 L
- 0.9 D + 1.6 W
- 0.9 D + 1.0 E

- **Where ,**
- D is the dead load.
- L is the live load.
- E is the earthquake load and
- W is the wind load.

**f) Analysis and design**

In this stage internal forces are calculated to determine section dimension and reinforcement using software programs according to codes, specification, and design methods.

### 2.3.3 Long - spans Structural Systems

Long-span buildings create unobstructed, column with large free spans and spaces for a variety of functions. These include activities where visibility is important for large number of audiences, generally the systems are:-

- **Truss systems**

  Its consist of slender and long elements that are arranged in triangular fashion are used for roof support and bridges, loads on structure converts to compression and tension, Its used when the span of the structure is required to be large and its depth is not an important criterion for design, this system is economically feasible to cover spans ranging from 9 to 120 m. As shown in figure (2-3). [6]

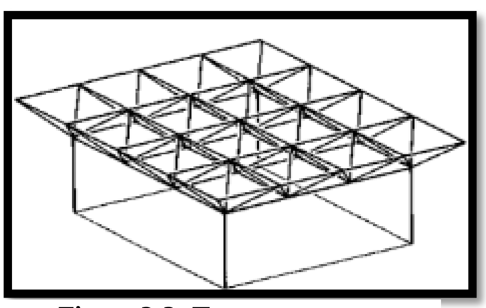


**Figure 2-3: Truss system**

- **Cable system**

Cables are usually flexible and carry their loads in tension, cables are commonly used to support bridges and building roofs, and has an advantage for span more than 45 m. As shown in figure (2-4). [6]

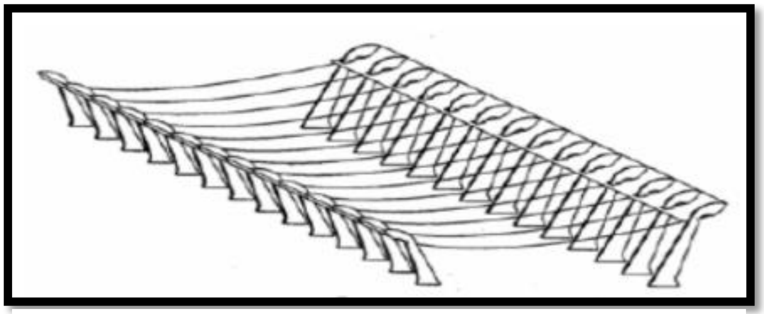


**Figure 2-4: Cable system**

- **Shells system**

Shells are curved surfaces in which the thickness is small when compared to the radius and other dimensions, the shell roofs are commonly used to cover clean spans with minimum intermediate supports, also permit to use extremely thin surfaces, and there are many forms of shells, shells system covers spans in general from 15m up to 200m depending on the form used and buckling failure, some types of shells are shown below.

✓ **Folded plates**

The folded plate roof is simple to form because it composed of flat surface, this roof is often employed for spans above 60m. As shown in figure (2-5). [5]

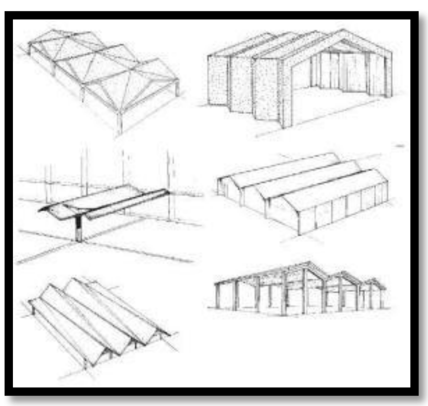


**Figure 2-5: Folded plate**

- ✓ **Cylindrical shell**

Shells which are obtained when one curve moves parallel to itself along another curve. As shown in figure (2-6).

**Figure 2-6: Cylindrical shell roof.**

- ✓ **Domed roofs**

Domed roofs are obtained when as plan cure is rotated about the axis of symmetry (shells of revolutions) tow common types are used.

1. Spherical
2. Conical dome

### 2.3.4 Seismic Design

**Background / Problem Statement - Seismicity of Palestine [7]**

The largest destructive recorded earthquake (Nablus Earthquake) occurred on 11 July 1927 north Jericho at the boundary between the Arabian and the Sinai plates and had a magnitude of about 6.3 (Richter scale).

Earthquake-resistant design of new structures and evaluating the seismic vulnerability of existing buildings take into account their response to site ground motions. Geophysical studies of seismic activity in Palestine, deep seismic sounding, pale seismic excavation, and instrumental earthquake studies of half a century demonstrate that damaging earthquakes occurred along the Dead Sea Rift/Transform fault. As shown in figure (2-7).

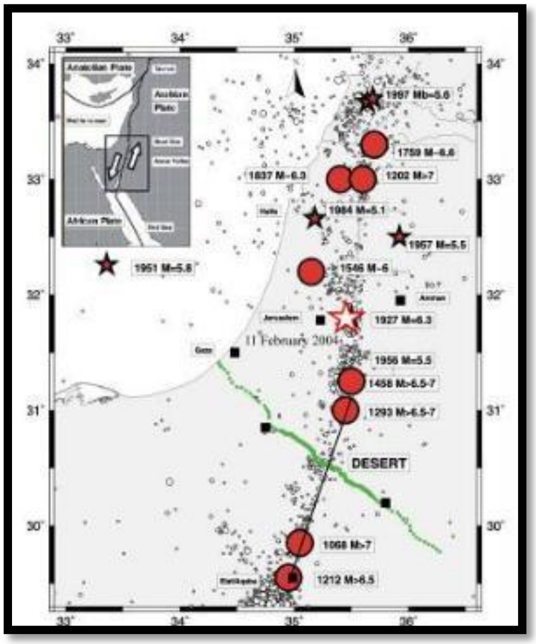
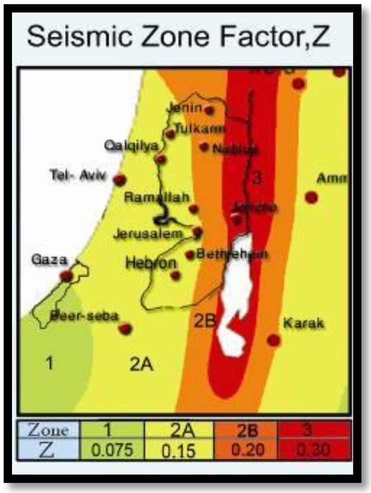



**Figure 2-7: Seismic activity in the Dead Sea Transform region; the map shows locations of historical earthquakes. Also shown is the most recent earthquake of 11 February 2004, ML 5.2.**

Referring to the seismic hazard maps of various levels of excellence probabilities and based on the PGA (Peak Ground Acceleration) values in Palestine (see figure 32). Nablus city is located within the seismic moderate zone, 2B seismic zones. The seismic zone factor (Z) on the rock for the zone 2B is equal to 0.20. According to the Uniform Building Code (UBC97), International Building Code (IBC), Jordanian Building Code 2005 and Arab Uniform Code 2006, it can be considered as moderate (or relative strong) seismic area. Show the figure (2-8).



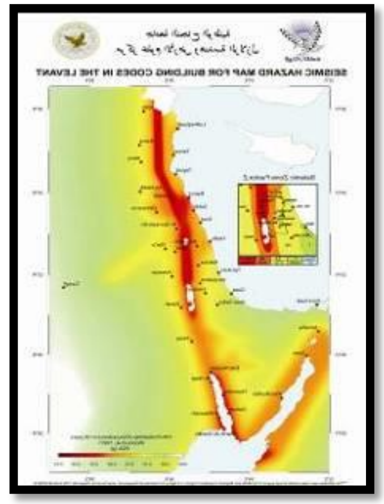



**Figure 2-8: Hazard Map and Seismic Zone Factor (Source ESSEU).**

**General Considerations**:

Economical earthquake-resistant design should aim at providing appropriate dynamic characteristics in structures so that acceptable response levels would result under the design earthquake. The structural properties which can be modified to achieve the desired results are the magnitude and distribution of stiffness and mass and the relative strengths of the structural members.

In some structures, such as cylinder free-standing towers (i.e. : minarets in mosques) or smoke stacks which depend for their stability on the stiffness of the single element making up the structure, or in nuclear containment buildings where a more-than usual conservatism in design is required, yielding of the principal elements in the structure cannot be tolerated. In such cases, the design needs to be based on an essentially elastic response to moderate-to-strong earthquakes, with the critical stresses limited to the range below yield.

In most buildings, particularly those consisting of frames and other multiply-redundant systems, however, economy is achieved by allowing yielding to take place in some members under moderate-to-strong earthquake motion.

The performance criteria implicit in most earthquake code provisions require that a structure be able to:-

1. Resist earthquakes of minor intensity without damage
2. Resist moderate earthquakes with negligible structural damage and some non-structural damage
3. Resist major catastrophic earthquakes without collapse; some structural and non-structural damage is expected.

The principal steps involved in the earthquake-resistant design of a typical concrete structure according to building code provisions are as follows:-

1- Determination of design earthquake forces

a. Calculation of base shear corresponding to computed or estimated fundamental period of vibration of the structure (a preliminary design of the structure is assumed here)

b. Distribution of the base shear over the height of the building.

2- Analysis of the structure under the (static) lateral earthquake forces calculated in step 1, as well as under gravity and wind loads, to obtain member design forces.

3- Designing members and joints for the critical combinations of gravity and lateral (wind or seismic) loads, and detailing them for ductile behaviour.

Depending on the building and the seismic zone or seismic performance or design category, the seismic forces may need to be applied in the direction that produces the most critical load effect. The requirement that orthogonal effects be considered in the proportioning of a structural element may be satisfied by designing the element for 100 percent of the prescribed seismic forces in one direction plus 30 percent of the prescribed forces in the perpendicular direction.

The combination requiring the greater component strength must be used for design.

The vertical component of the earthquake ground motion is included in the load combinations involving earthquake forces that are prescribed in the IBC. Special provisions are also required for structural elements that are susceptible to vertical earthquake forces (cantilever beams and slabs; pre-stressed members).

The capacity of a structure to deform in a ductile manner (i.e., to deform beyond the yield limit without significant loss of strength), allows such a structure to dissipate a major portion of the energy from an earthquake without collapse. Laboratory tests have demonstrated that cast-in-place and precast concrete members and their connections, designed and detailed by the present codes, do possess the necessary ductility to allow a structure to respond in elastically to earthquakes of major intensity without significant loss of strength.

## 2.4 Electrical Design

### 2.4.1 Introduction

Architectural acoustics may be defined as the design of spaces, structures, and mechanical/electrical systems to meet hearing needs. With proper design efforts, wanted sounds can be heard properly and unwanted sounds (noise) can be attenuated or masked to the point where they do not cause annoyance .

All acoustical situations have three common elements- a sound source, a sound transmission path or paths, and a receiver of the sound. Through design, a source can be made louder or quieter and a path can be made to transmit more or less sound .

### 2.4.2 Acoustics in the pray hall

The sound is very important in the mosque because people come to the mosque in order to her a clear sound, and it the main factor in the provision of any form speech (khtutba) / call the prayer so we must that provide the following

1) Loudness.

2) Quality.

3)Directivity.

4) Intelligibility.

Speech should be audible and with a high degree of sound quality within all areas of the mosque where the platform helps to access the audio for the top and half circular apse its shape gives voice back.

Sound is very important thing in mosque, but at the same time, Imam Voice may effect on the sound by enhancing interior echo, so cause noise to the prayers in the mosque Therefore, we must use filters to cancel sound from speakers that could provide feedback.

We must analyze the vocal system in the to avoid noise in the mosque and the voice of imam should reach for everybody in the mosque.

The location of loudspeakers shall be designed to provide optimum sound quality with consideration of the architecture.

### 2.4.3 Sound insulation

Sound insulation is a set of standards and procedures designed to provide adequate insulation to somewhere in order to reduce the annoying sounds resulting from different acoustic source. Figure (2-9).

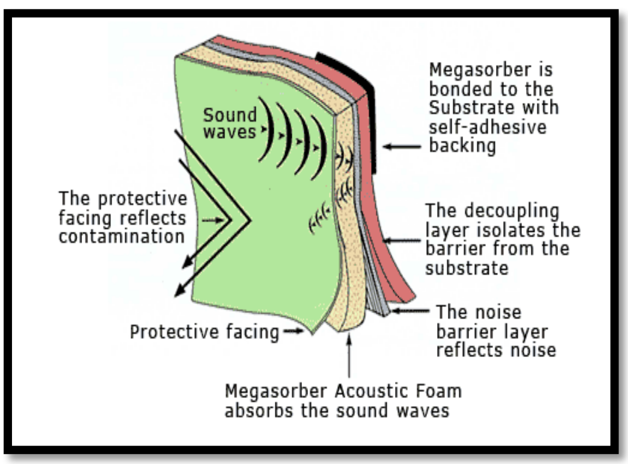



**Figure 2-9: Location of loudspeakers in mosque.**

### 2.4.4 Limitation for acoustical performance in the mosque

**Sound transmission ways** :

1- Air-borne transmission.

Where sound travels directly through the air vents like doors and windows, or through the vibration of the separation wall between the two places, where this vibration transferred the sound to direct air vacuum. Its initial energy is very small and it attenuates rapidly at boundaries. As shown in figure (2-10)

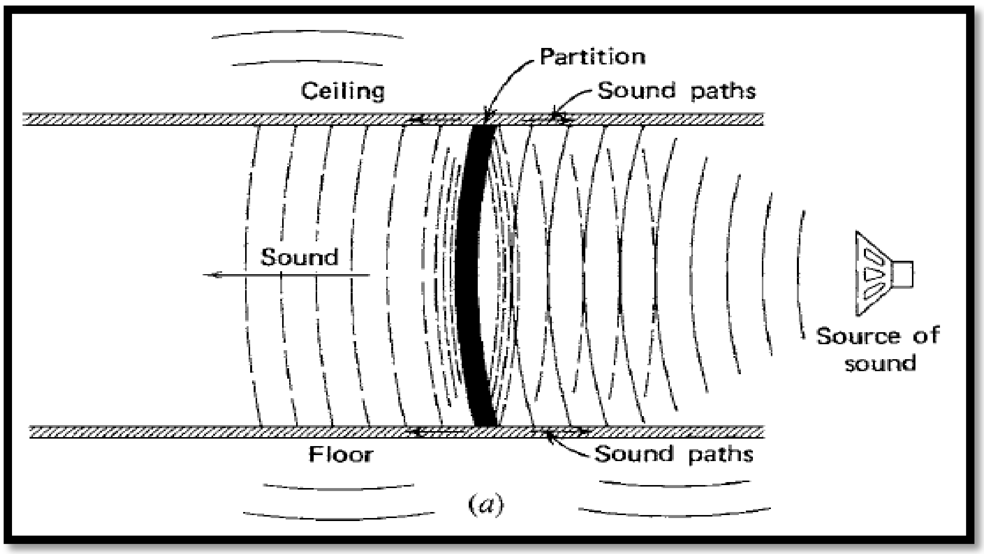



**Figure 2-10: Air borne transmission.**

**Table 2-2: the values of STC for material used in slabs or partition [8]**

| *Partition or Slab* | *Total Thickness* | *STC Value (approximate)* |
|---|---|---|
| Hollow concrete Block | 15 cm | 43-45 |
| Double Brick wall with plaster | 30 cm | 49-54 |
| Brick wall with Plaster | 13.5 cm | 42 |
| Concrete and Stone wall | 62 cm | 56 |
| Concrete wall with Plaster Both sides | 17.5 cm | 53 |
| Solid Concrete Block with plaster both sides | 40 cm | 63 |
| Gypsum wallboard with wooden studs | 12.5 cm | 37-39 |
| Fiber board, Plaster with wooden studs | 15 cm | 42 |
| Concrete Slab, with floor finishing | 16 cm | STC= 48-50<br>IIC= 47-49 |
| Reinforced concrete (12 cm ) with suspending ceiling | 25 cm | STC= 48<br>IIC= 47 |
| Reinforced concrete (12 cm ) with floating floor | 22 cm | STC= 51<br>IIC= 53 |
| Reinforced concrete with floor finishing | 30 cm | STC= 56-58<br>IIC= 52 |

## 2- Structure-borne transmission.

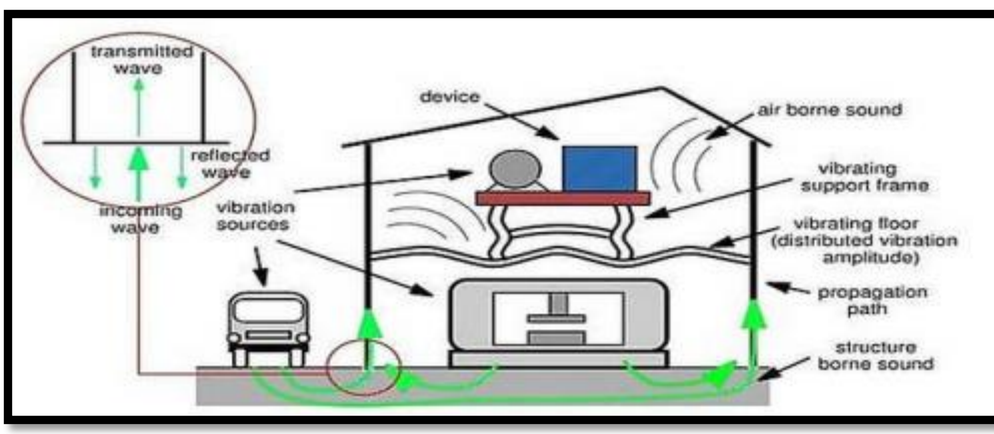



**Figure 2-11:Location of loudspeakers in mosque.**

We can reduce the sounds caused from vibration of machines by using one of the following methods:

1. Using suitable rubber by place it under machines.
2. Lifting machines over Jacks.
3. Put the machines or engines above rubber wheels surface.
4. Put machines or engines on surface and put springs under the surface.

### 2.4.5 Artificial Lighting

Lighting design as it applied to the built environment, also known as 'architectural lighting design', is both a science and an art. Lighting of structures must consider aesthetic elements as well as practical considerations of quantity of light required, occupants of the structure, energy efficiency and cost. For simple installations, hand-calculations based on tabular data can be used to provide an acceptable lighting design. More critical or optimized designs now routinely use mathematical modeling on a computer using software such as Ecotect which can allow an Architect to quickly undertake complex calculations to review the benefit of a particular design. [9].

**Lighting concept**

The light design for any building must be attention in type of the lamp, how much light is present (IL luminance), the quality of that light, daylight, and natural and artificial light. Show table (2-3).

**Table 2-3: Illumination values for mosque [10]**

| Annex | Minimum illumination (lux) | Maximum illumination (lux) |
|---|---|---|
| **Ceiling** | 220 | 300 |
| **Top part of walls** | 350 | 440 |
| **Columns** | 250 | 340 |
| **Tribune** | 450 | 550 |
| **Mehrab** | 350 | 420 |
| **Classrooms** | 460 | 540 |
| **Dish** | 65 | 100 |
| **Entrance to minaret** | 125 | 200 |
| **Exit door** | 85 | 180 |
| **Passages** | 125 | 200 |

Artificial light it is because an important issue in mosque especially that it could use more after sun set (at night).

## 2.5 Mechanical Design

### 2.5.1 Introduction

Generally, this chapter will talk about mechanical services in the mosque, which include air conditioning systems and ventilation, drainage system and water supply that used in the mosque. In addition, Climate control and comfort in mosque is a major design issue. Heating, ventilation and air conditioning (HVAC) system help to control the climate, and keep prayers comfortable by regulating the temperature and air flow. HVAC systems are also important to prayers health because a well regulated and maintained system will keep the mosque free from mold and other harmful organisms.

## 2.5.2 Sanitation design in mosque

**Drainage system**

The design of the sanitation fittings must be compatible with the structural element such as beams, columns and slabs.

Water drainage systems should be located at a suitable areas that don't effect on the structural side such that beams and columns.

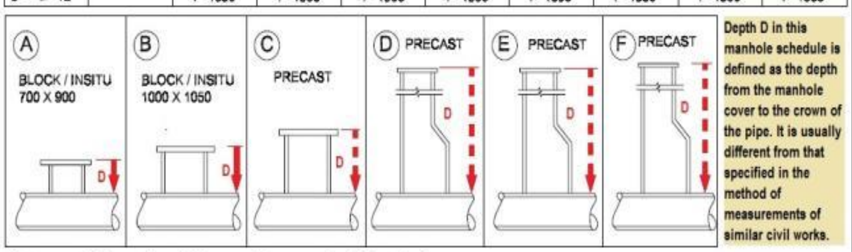
Surface water drainage collects the rainwater run-off from the roofs and paved areas and takes it away from the mosque for disposal to a sewer. The actual disposal method is dependent upon the policy of the responsible water authority.

**Access**

The actual method of providing access to drains is the construction of manholes, the size of manhole is dependent on the number of branches that are connected to it, and the depth from ground level to invert. As shown in table (2-4)

**Table 2-4: Manhol sizs [11]**

| DEPTH | PIPE DIAMETER | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| D | 225 | 300 | 375 | 450 | 525 | 600 | 675 | 750 | 900 |
| 0 → 1 | A 700 x 900 | A 700 x 900 | A 700 x 900 | A 700 x 900 | B 1000 x 1050 | B 1000 x 1050 | B 1000 x 1050 | B 1000 x 1050 | B 1000 x 1050 |
| 1 → 3 | C 900 | C 1050 | C 1050 | C 1050 | C 1200 | C 1200 | C 1350 | C 1350 | C 1500 |
| 3 → 5 | | D 1050 | D 1050 | D 1050 | D 1200 | D 1200 | D 1350 | D 1500 | D 1500 |
| 5 → 6 | | E 1050 | E 1050 | E 1050 | E 1200 | E 1200 | E 1350 | E 1500 | E 1500 |
| 6 → 12 | | F 1500 | F 1500 | F 1500 | F 1500 | F 1500 | F 1500 | F 1500 | F 1500 |




Determining the Dimensions of a Manhole

**Gutters**

Pitched roofs and dome are drained to eaves gutters or valley gutters depending on the type of roof that is to be drained.

Recommended size of gutter slopes draining roofs can be found in table (2-5).

**Table 2-5: Size of gutter slopes draining roofs [12]**

| Roof area | | | | | | | |
|---|---|---|---|---|---|---|---|
| Guttering diameter | | Slope of | | | | | |
| mm | Inches | 0.5% | | 1% | | 2% | |
| | | $m^2$ | $ft^2$ | $m^2$ | $ft^2$ | $m^2$ | $ft^2$ |
| 80 | 3 | 16 | 170 | 22 | 240 | 32 | 350 |
| 100 | 4 | 33 | 360 | 47 | 510 | 67 | 720 |
| 125 | 5 | 58 | 625 | 82 | 880 | 116 | 1250 |
| 150 | 6 | 89 | 960 | 126 | 1360 | 178 | 1920 |

**Vents**

Vents are used in the drainage system to admit air and discharge gases, soil and waste stacks are extended through roofs, and a system of air vents, largely paralleling the drainage system, is provided. As in the case of drainage stacks, the ventilating stacks extend through the roof or vent through the drainage stack. The functions of venting are often misunderstood. It is true that one important purpose is to ventilate the system by allowing air from the fresh-air inlet (or from the sewer, if there is no house trap or fresh-air inlet) to rise through the system and carry away offensive gases.

This provides some purification for the piping. However, several other purposes are served by the vent piping. The introduction of air near a fixture (and, in the case of circuit vents, at the branch soil line) breaks the possible siphonage of water out of a trap. [13]

### Sanitation of gray water and black water

In the buildings there must be separation between the gray and black water, and this indicate the loads of drainage system of the stacks, fittings, and traps used. Show figure (2-12) [13]

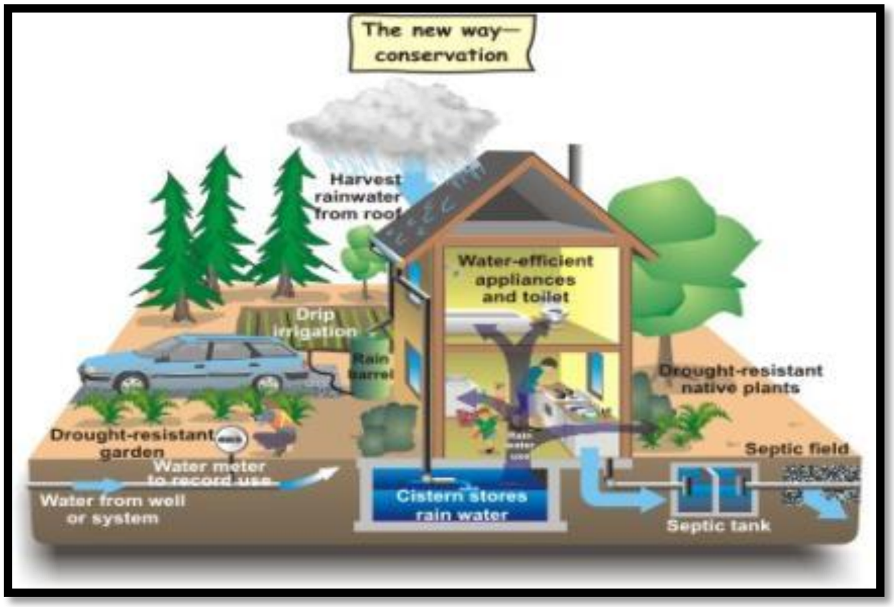



**Figure 2-12: water system**

### Water supply

Water supply in mosques is very important since water in mosques is used for , ablution ,cleaning ,personal hygiene ,landscaping and for protective reason in case of firefighting ,so a good water supply system should be used .

The first concern in the design of water supply system is to match the quality of the water to the task it performs, a good water supply system must have the following:

1- Good pressure.
2- Good water flow.
3- Good water quantity.
4- Good water quality.

**Water fixtures and conservation strategies [14]**

Building design and fixture choice can affect water and energy consumption over the life of the building.

1- Toilets and Urinals

- Waterless urinal.
- Dual-mode flush system.
- Urinal with on-demand sensors.

2- Use of grey water in flushing

Alternative sources of water can be used to flush toilets and urinals. In particular, water consumed in showers, wash basins, laundry operations, and storm water, after recycling is called grey water.

### 2.5.3 Heating, Ventilation and air conditioning.

Heat transferred by three ways, first conduction and it is primarily dependent upon surface temperature, second convection which is primarily dependent upon air temperature, air motion, humidity, thirdly radiation [15].

The term HVAC system refers to the three specialties of heating, ventilating, and Air-conditioning. Controls determine how HVAC systems run to achieve the design goals, comfort, and cost-effective operation.

**Ventilation**

Ventilation is the process of changing air in any space to provide high indoor air quality. It is used to remove unpleasant odors and excessive moisture, introduce outside air, to keep interior the mosque air circulating.

Ventilation is divided into two types: Natural Ventilation and Forced Ventilation.

### Natural ventilation.

Natural ventilation cooling has two variation: Cross ventilation Stack ventilation. Show figure (2-13)

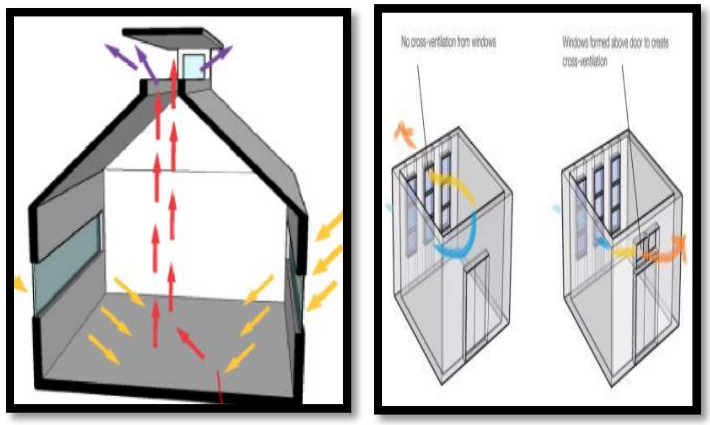



**Figure 2-13: Cross and Stack Ventilation**

### Forced ventilation (Fans).

Mechanical fan machine for producing air flow often for cooling.
Some basic design principles application to ventilation and air conditioning system:-

1-The air must be free from dust, odors and other impurities.
2- The air must be at temperature and relative humidity which will satisfy the design conditions for the space.
3-The air must contain sufficient fresh air.

**Table 2-6: Air supplay rates [15]**

| Air change rates/hour | Type of space |
|---|---|
| 6 | Bathrooms |
| 8-15 | Pray hall |
| 4 | Libraries |

**Heating**

Heating can be accomplished by heating the air within a space or by heating the occupants directly by radiation. There are many different types of heating systems, like radiant heat, under floor heat.

**Central heating system**

A central heating system provides warmth to the whole interior of a mosque from one point to all parts of the mosque.

In most systems, water is heated in a boiler and then circulated around the mosque to radiators ,Central heating provides consistent heat to a whole mosque, unlike other forms of heating which create hot and cold zones, because it takes moisture out of the air.

Radiator is not effective in the mosque because it requires many hours to gives heat to the mosque whole.

**Air- Condition**

The most used devices air conditioning system in mosques is air to air system (heat pump), because high efficiency, best air quantity and can be used for heating and cooling.

The function of an air conditioning system is to provide and maintain an artificial environment within the mosque enclosure.

## 2.6 Case Study

### 2.6.1 Global Case study (Shah Faisal mosque)

**Mosque definition**

The mosque is located in Pakistan, in the national capital city of Islamabad, the mosque covers an area of 5000 $m^2$, also Faisal Mosque has the third largest capacity of accommodating worshipers in its adjoining grounds after the Masjid al-Haram (Grand Mosque) of Mecca and the Al-Masjid al-Nabawi (Prophet's Mosque) in Medina. Show figures (2-14), (2-15). [16]

**Figure 2-14: Shah Faisal mosque**


**Figure 2-15: site plan Faisal mosque**

## Architectural aspects

### Form

The shape of the Faisal Mosque is an eight-sided concrete shell inspired by a desert Bedouin's tent and The Holy Kabbah in Mecca, four minarets are inspired by Turkish architecture. As shown in figure (2-16)

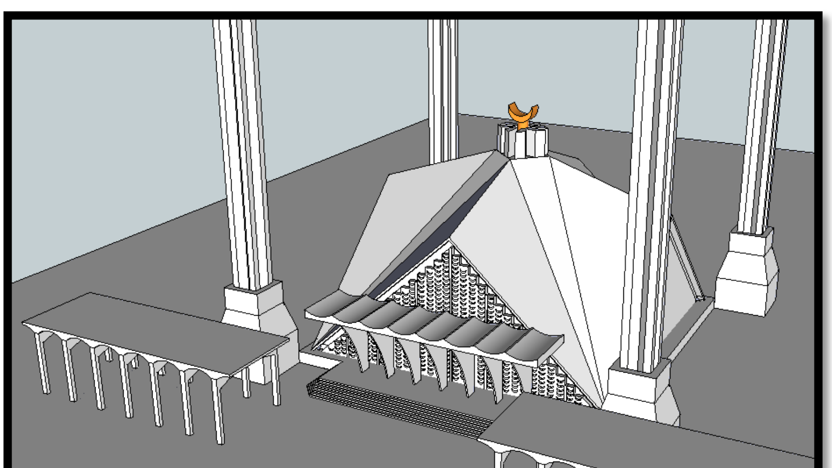


**Figure 2-16: general form for faisal mosque.**

**Architectural spaces of the mosque**

1. Pray hall for men .

   Accommodate 10,000 worshipers in its main prayer hall 24,000 in its porticoes, 40,000 in its courtyard, and another 200,000 in its adjoining grounds.As shown in figure (2-17).

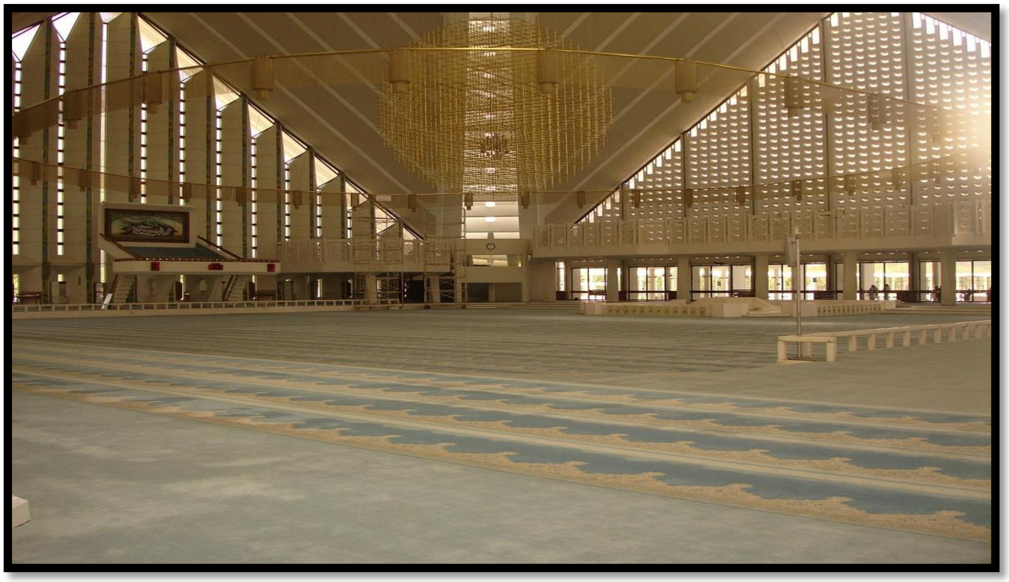


**Figure 2-17 : main pray hall for Faisal mosque.**

2. Pray hall for women .

3. Other spaces and facilities.
   Mosque houses, Library Lecture hall, Museum, Ablution, sanitary units for men and women and cafe.

**Environmental analysis**

Daylight is provided through the side walls , also from the opening in the ceiling, The north and south walls are designed with twenty raised vertical louvers in addition to horizontal louvers are extended from the roof , which gives good shading in summer season also provides visual comfort inside. Show the figure (2-18)

**Figure 2-18: fenestration and openings.**

## Structural system

The structural system used in the mosque is folded plates made of reinforced concrete, the roof has a height 132 feet above ground level, the roof shape is similar to the Gothic rib vaults in French method of the years 1140-1194, and the mosque is free column from inside, the minarets reaches up to 80 m. As shown in figure (2-19)

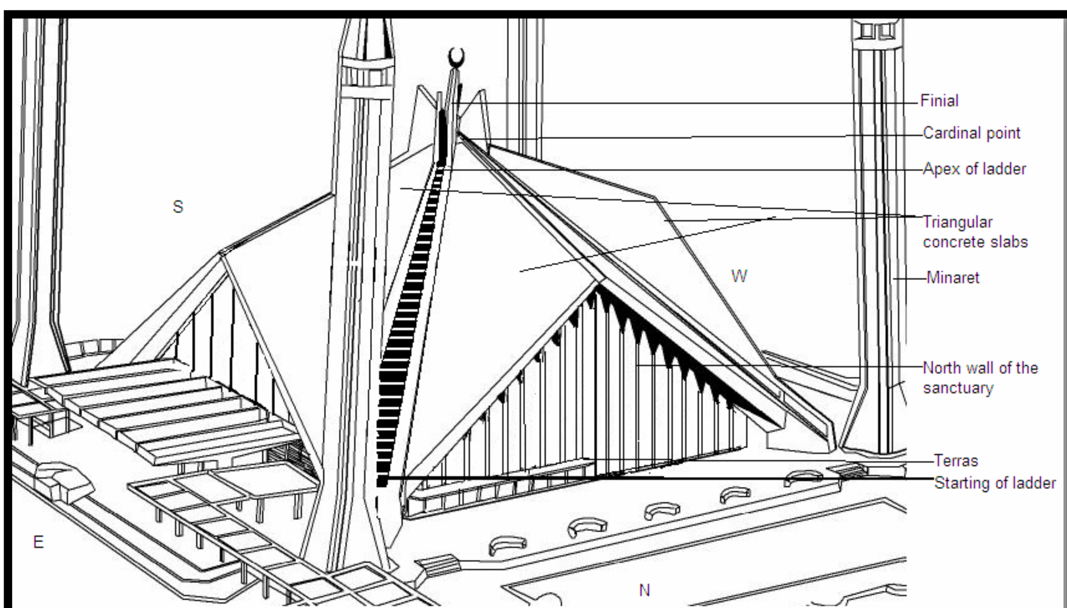



**Figure 2-19: structural elements and system in faisal mosque**

## 2.6.2 Local case study

Our second case study is Al Najah National University Mosque.

**Mosque Location**

The mosque is located in the west of Nablus city in Al- Najah National University campus.

**Mosque Description**

The mosque is in the north eastern of the university ,consist of three levels , first basement which has a prey hall for women ,second basement has a multipurpose hall with a library and cafeteria and the Ground Floor has a praying hall for men.

**Architecture Aspects**

**Form**

The mosque has a rectangular projection with three levels and is similar to hypostyle form. As shown in figure (2-20)


**Figure 2-20: Form of the Mosque.**

**Architectural spaces of the mosque**

1. Pray hall for men of area equal 600m$^2$.
2. Pray hall for women.
3. Ablution and sanitary units for men and women.
4. Library and multi purpose hall.
5. Parking for 30 cars.

**Architectural Elements of the mosque**

1. Entrances

   There are tow entrances for man and one Entrance for women, there is no relationship between the men and women entrances.
2. Dome
3. Mihrab
4. Minbar
5. Minaret

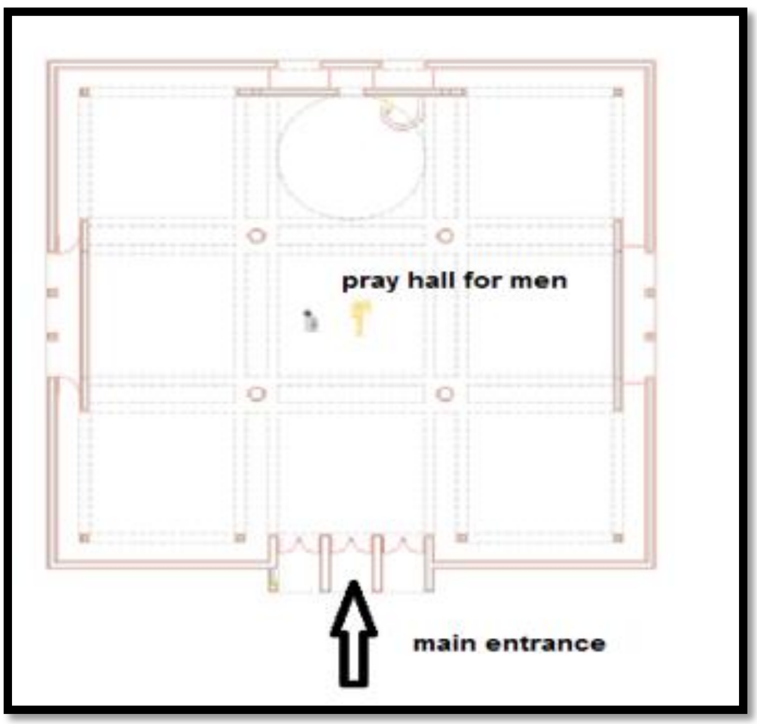



**Figure 2-21: Ground floor level.**


**Figure 2-22: First basement level**

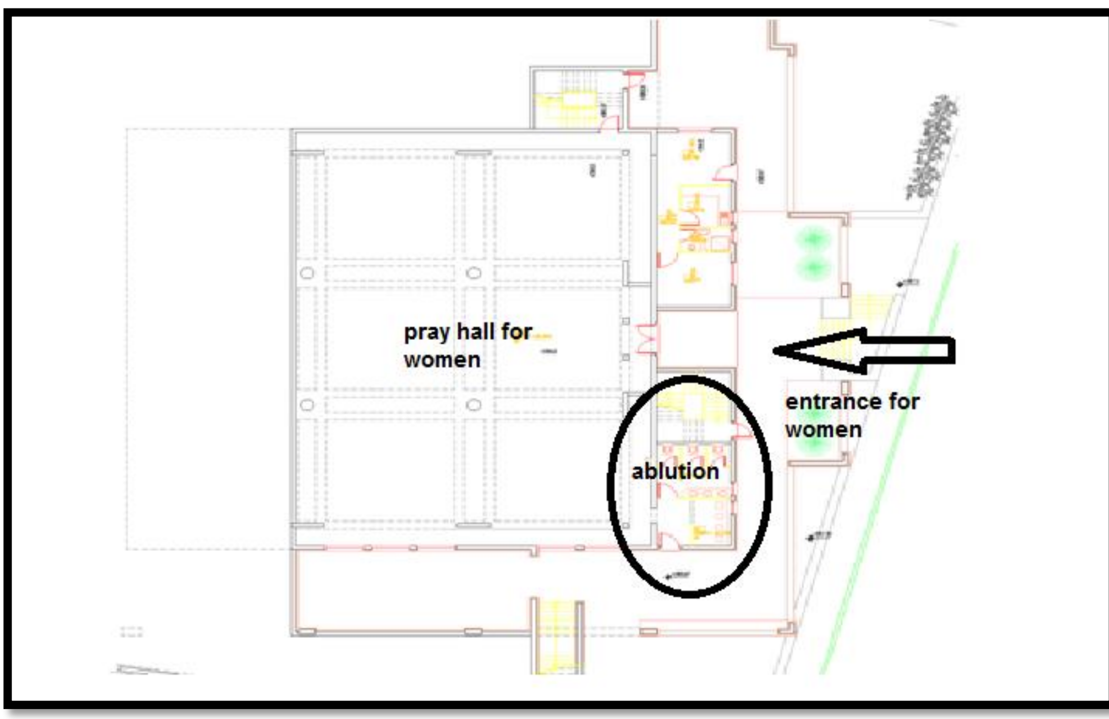



**Figure 2-23: second basement level**

## Environmental Analysis

### Daylight and sun movement

Daylight is provided through the side hidden windows in the eastern and western walls, also from the opening in the ceiling, limited view connection with the outdoor. Show figure (2-24)

**Figure 2-24: fenestration and openings**

### Wind direction

The prevailing wind direction in the most days of the year is south west and north west. We noticed that ventilation inside the pray hall is poor because there is not enough openings in the walls and the ceilings. Show the figure (2-25)

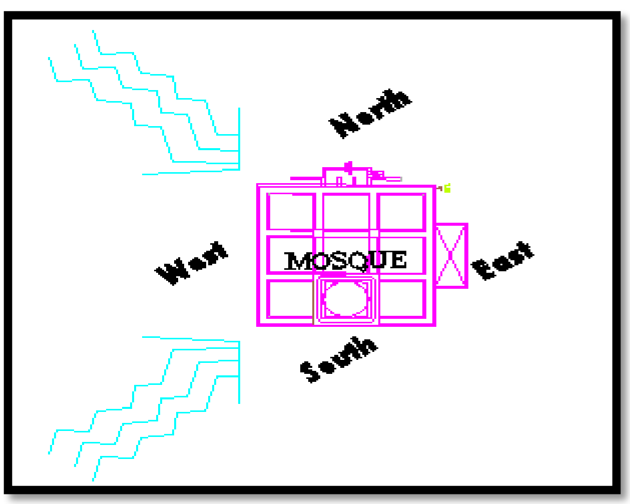



**Figure 2-25: Wind direction**

### Acoustics

The main noise source in the mosque is from stadium in the west and the main street in the north we noticed that reverberation time inside the pray hall was medium. As shown in figure (2-26)

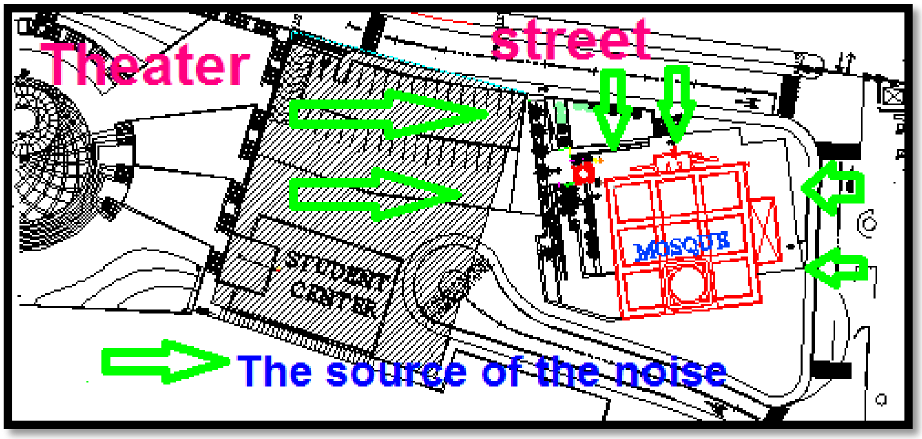



**Figure 2-26: Noise source**

### Thermal comfort

There is no side windows in the south elevation which can be used to heat the mosque in winter, also large thermal mass due to ceiling and walls can affect the inside thermal comfort by absorbing the heat in addition to, there is no thermal insulation.

### Structural Aspects

- The mosque has symmetrical shape and the minaret is isolated from the mosque this will improve the seismic resistance**.**
- Circular columns as used inside the pray hall, the distance between the columns equal 8m
- Shear wall system is used in construction of the minaret.

# CHAPTER 3

# ARCHETICTURAL DESIGN

## 3.1 Introduction

Architectural work is the first step in any construction project. The architectural design aims to provide creative and unique design. However, the best architectural design is the one that satisfies the client needs and requirements and at the same time does not conflict with other requirements.

The first step is selecting and analyzing the location of the project. The land proposed as a site for our project (Mosque) is situated on the cross roads of Tulkarm street and Tunis street. Three roads from three sides two main and secondary street surround it. The total area of the project site is 3580 $m^2$. As shown in figure (3-1) [17]


**Figure 3-1: Site**

## 3.2 Nablus city weather analysis:

Nablus ($35.263^o$ latitude and $32.214^o$ longitude) is situated in the fourth region according to climate data of Palestine; this region has a warm partially hydrated summer and a cold winter. The hottest months in Nablus are July and August with the average high 28.9 $^oC$. The coldest month is January with temperature 3.9$^oC$. Humidity rate of 60%, average rain fall about 75mm yearly. The prevailing winds is the west winds which is affected by the northern and the southern west winds.

**Wind average speed: [17]**

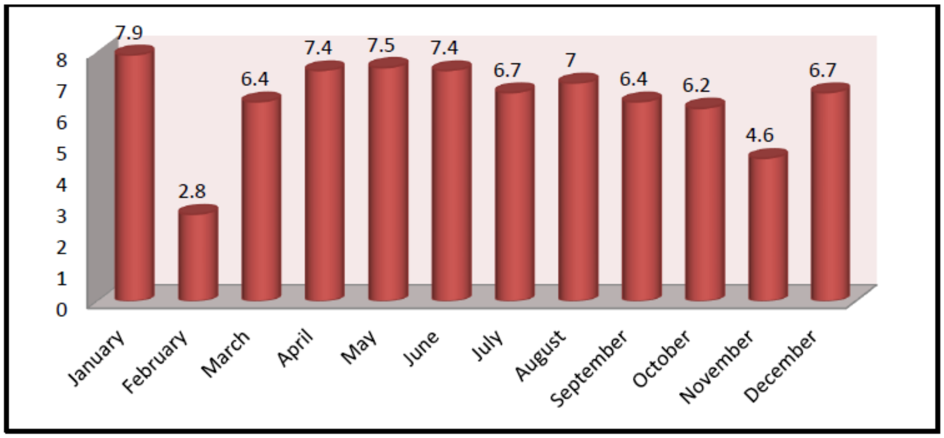



**Figure 3-2: Mean wind speed in Nablus by month**

**Relative humidity: [17]**

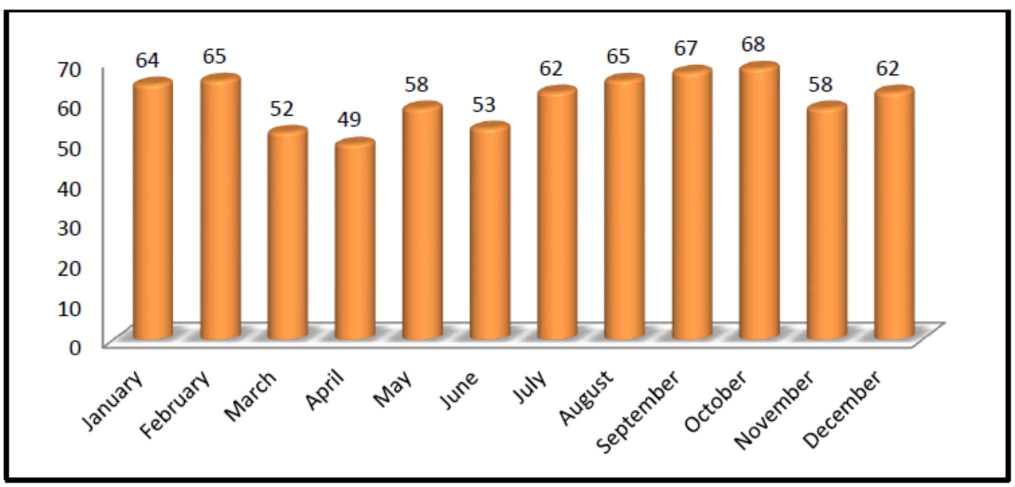



**Figure 3-3: Mean relative humidity in Nablus by month**

**Qibla direction:**

The qibla direction in Nablus city is about 202.5º from the north. As shown in figure (3-4).

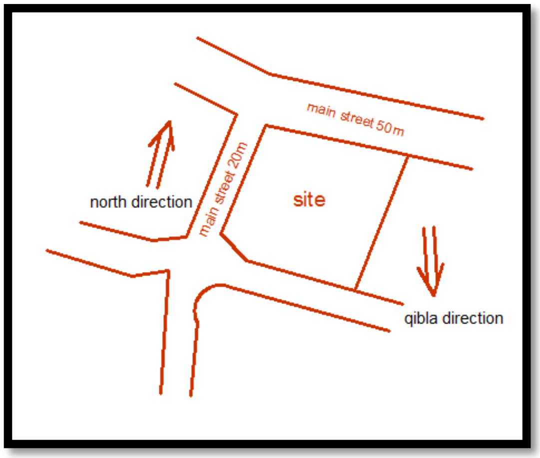



**Figure 3-4:Qibla direction.**

**Noise source:**

The noise mainly comes from quarries nearby from the west side, also the noise that comes from the street that surrounds the land. Therefore, the trees will be spread all round the circumference of the masjed lands with large leafs to help in reduction of the outdoor noise. , also insulation of masjed walls will be used in order to minimize it to the minimum limit without affecting the peaceful state of mind of worshipper when is performing his religious duties as shown in figure (3-5).

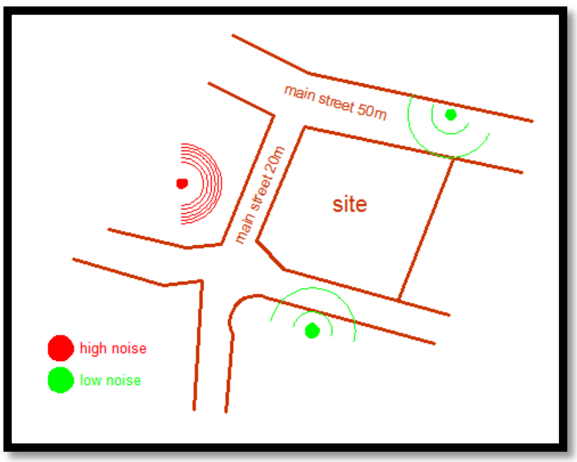



**Figure 3-5: Noise source.**

**Wind direction:**

The west and the southwest winds are the prevailing winds in this area with an annual average wind speed 100 Km/hr. With the help of wind and placing the ablution area in the correct place no bad smells will reach the masjed. Also, wind help in the natural ventilation by using large windows in the western side although there are stone crushers from this side. This problem is solved by planting trees between the mosque and the crushers. Another opposite windows on the eastern side as shown in figure (3-6).

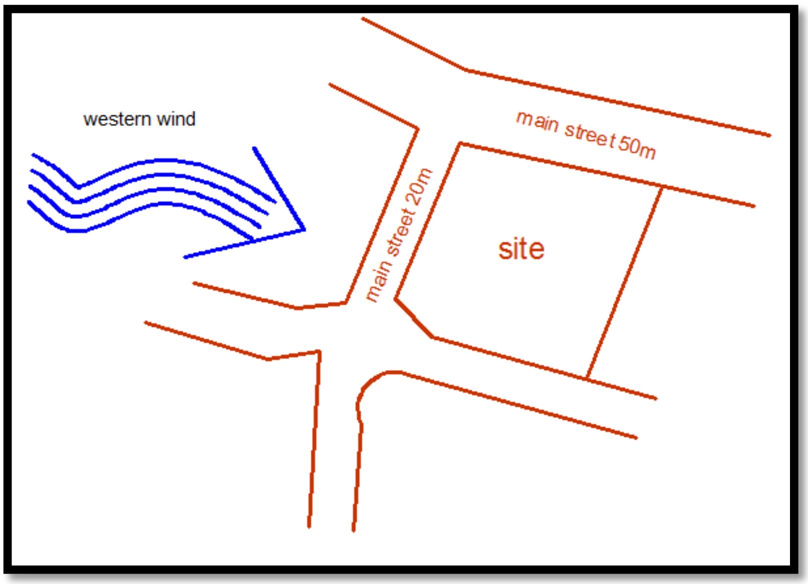



**Figure 3-6:wind direction**

**Overshadowing:**

High buildings do not surround the project site. So, the site is subjected to sunlight all day. This is an advantage point in the design. The sun revolves around the masjed land from south, this will consume in the process of heating and cooling the building by using Trombe wall in the southern wall of the masjed. Also placing windows will help in the natural lighting process.

## 3.3 Project Program

The project is to be a mosque as we discussed before, thus the program of execution the design of this project will depend on the areas and function used in the building. The previous collected data will help us to determine the required areas for the different functions that composing our building project.

The mosque will be designed for 400 worshippers; the area required for each space is shown in the table (3-1).

**Table 3-1: Estimated areas for mosque**

| Space | Area ($m^2$) |
|---|---|
| **Pray hall for men** | 400 |
| **Pray for women** | 75 |
| **parking** | 213 |
| **Imam room** | 9 |
| **Service room** | 9 |
| **ablution** | 60 |
| **toilet cubicle** | 30 |
| **washbasin** | 2 |
| **library** | 15-20 |
| **storage** | 20 |
| **Net area** | 938 |

In addition of the areas mentioned above there is 10% to 20% added areas for circulation and entrance.

The total estimated area for the building is about 1032$m^2$.

## 3.4 Design concept

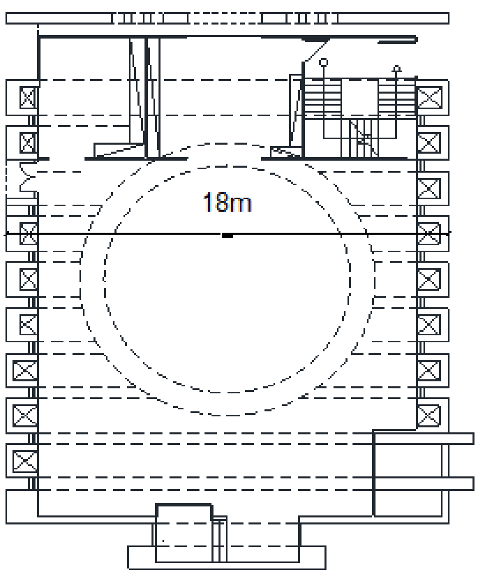
The concept of this project was to redesign a student project in 2nd years of Architectural department that helps to realize our main idea: zero interior columns and energy efficiency mosque.

## 3.5 Modification

In order to achieve the objective of our project, the following modification were done to the original design:

**Pray hall:**

1- The pray hall was expanded to accommodate 400 prayers. As shown in figure (3-7).



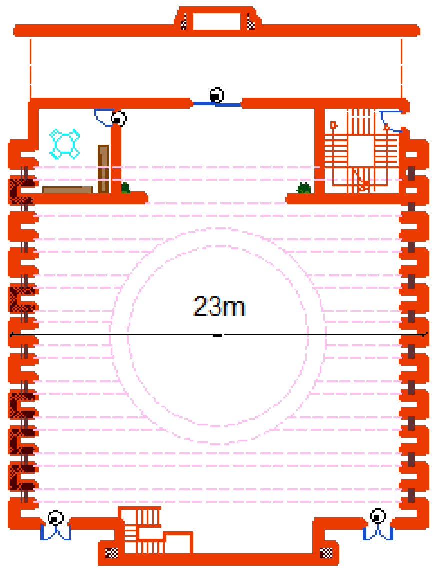




**Figure 3-7: Pray hal befor and after.**

2- The mosque structure is covered with Alcubond cladding as a lightweight material in addition to it gives good appearance and a modern style. The figure (3-9) shows.

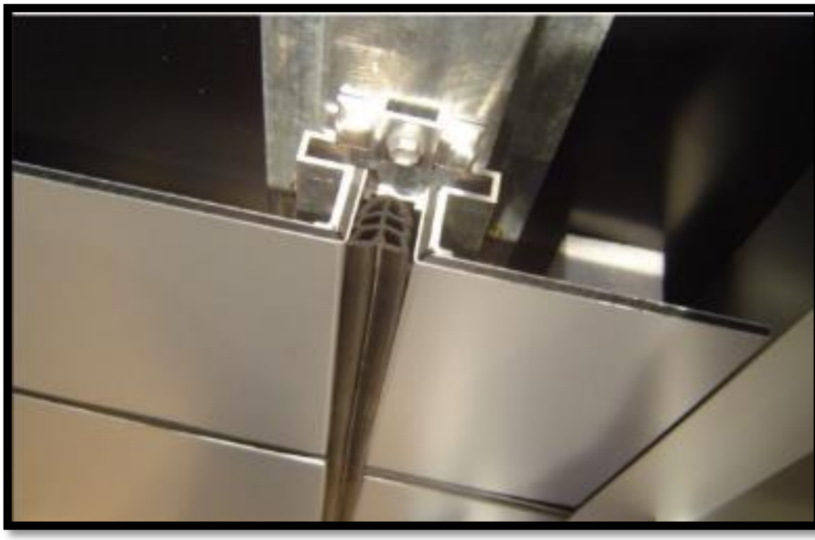


**Figure 3-8: Alcubond cladding.**

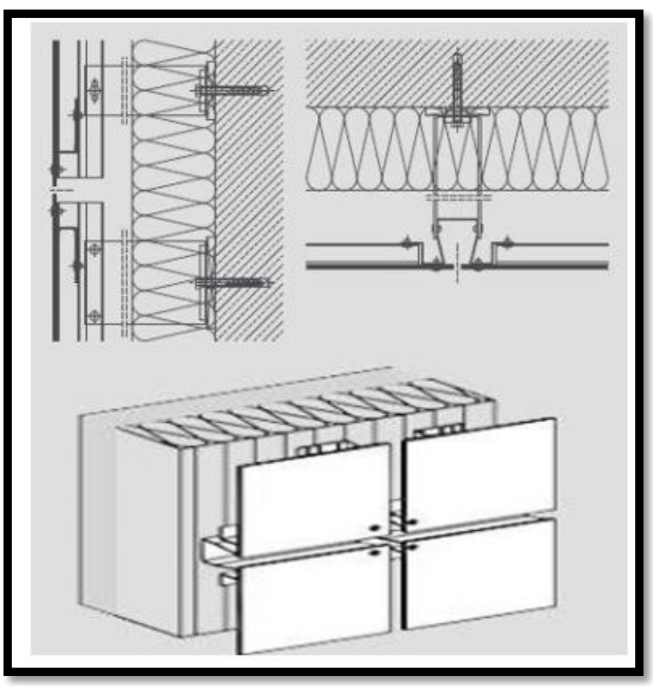


**Figure 3-9: Section for alcubond cladding**

3- The male prayers entrance was separated from the female one, as shown in the figure (3-11).

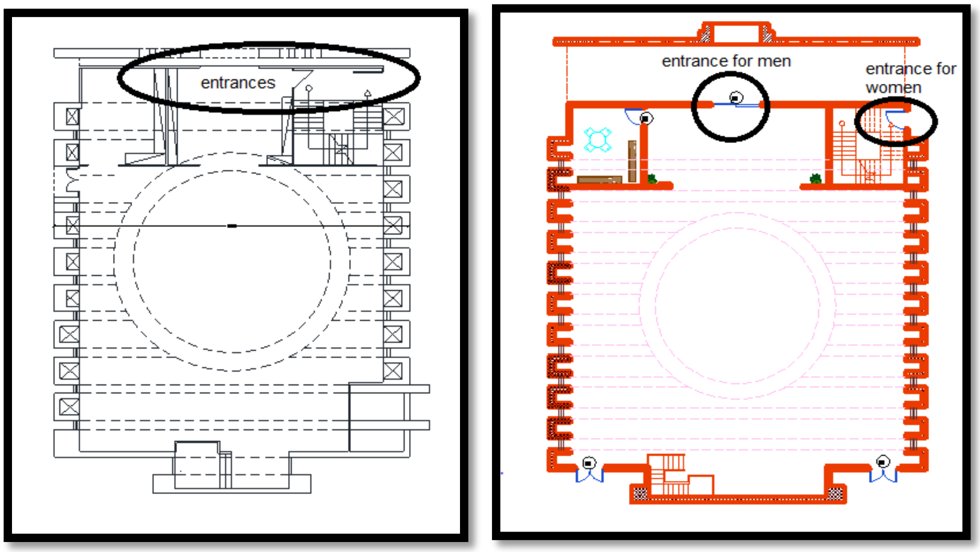



**Figure 3-10: Entances befor and after.**

4- The shelves of the prayers shoes where extended and their location was modified to be outside the mosque. This reduces the bad smell. Show the figure (3-12).

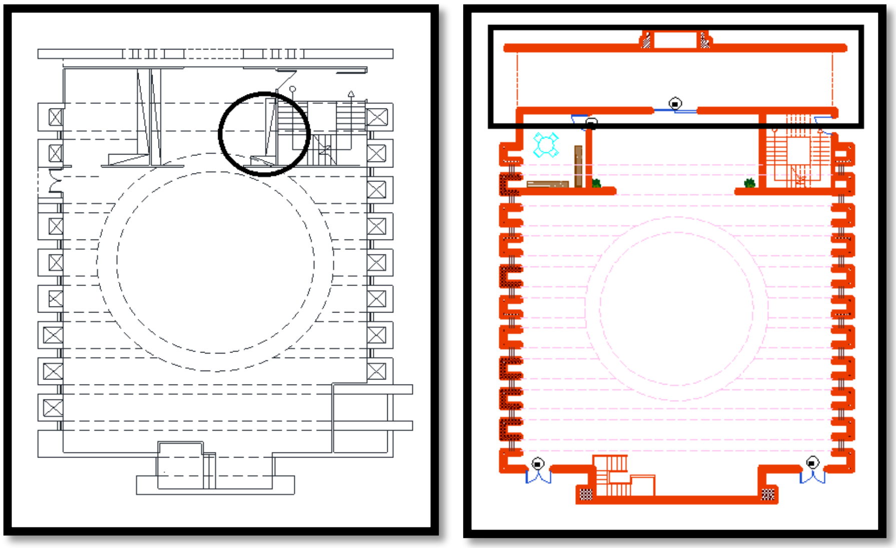


**Figure 3-11: Shelves of the prayers shoes befor and after extended.**

5- We have opened two emergency exist. As shown in figure (3-13).

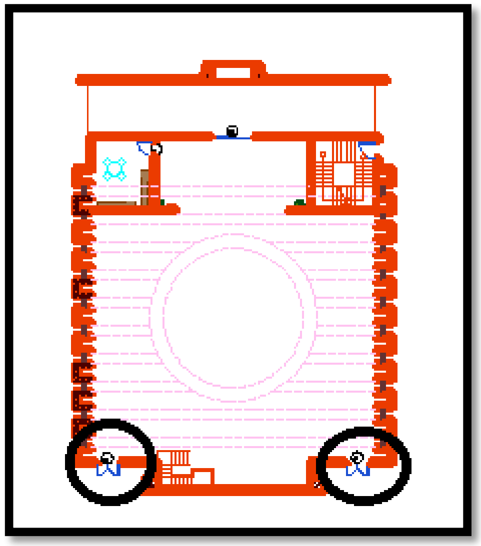


**Figure 3-12: Emergency exist**

**For the Minaret:**

1- The Minaret was separated from the rest of the mosque due to seismic issues. Show the figure (3-14).

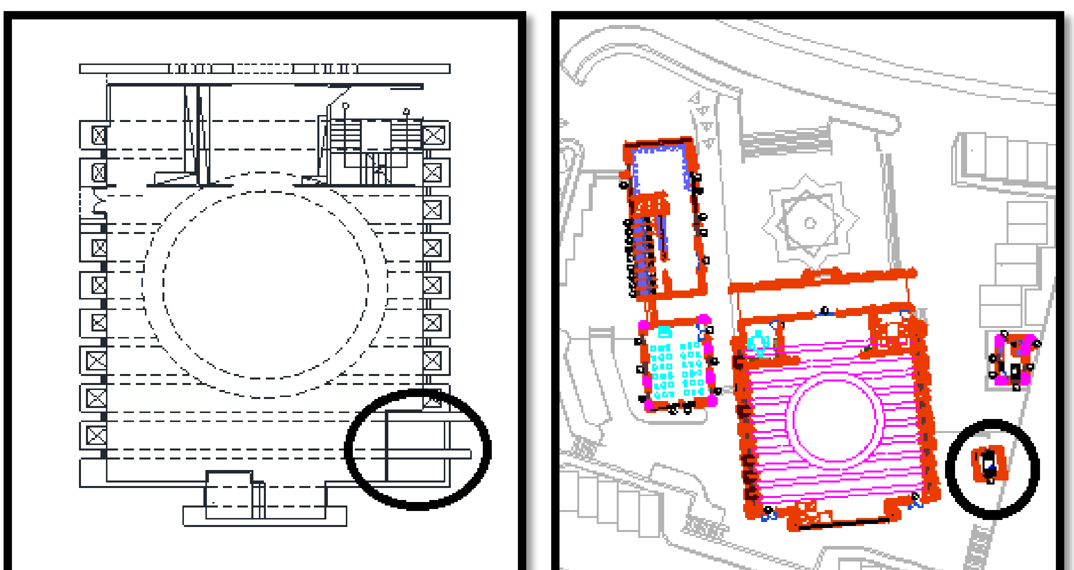


**Figure 3-13: Minaret befor and after separetion.**

2- The architectural design of the minaret is changed. Show the figure (3-15).

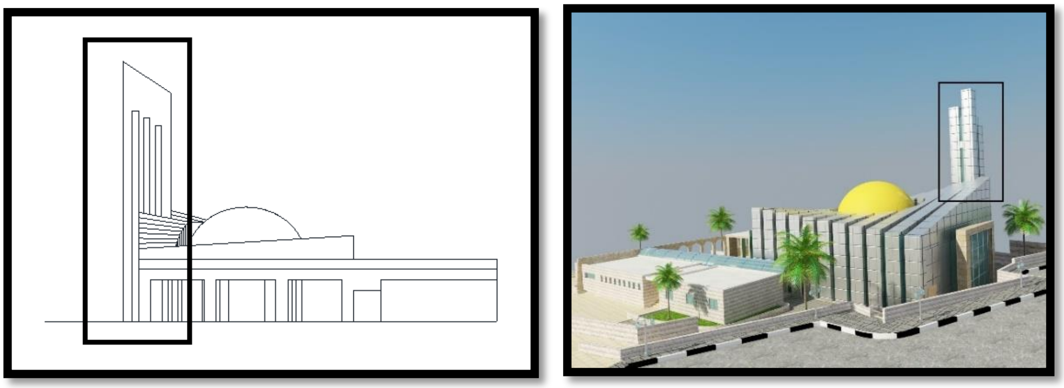


**Figure 3-14: Minaret befor and after redesign.**

**For the site**

1- The site was modified so that the total number of available parking lots is 35 vehicles.
2- The distribution of green areas and the location of the entrances were changed.
3- A ramp was added to service people with special needs. As shown in figure (4-16).

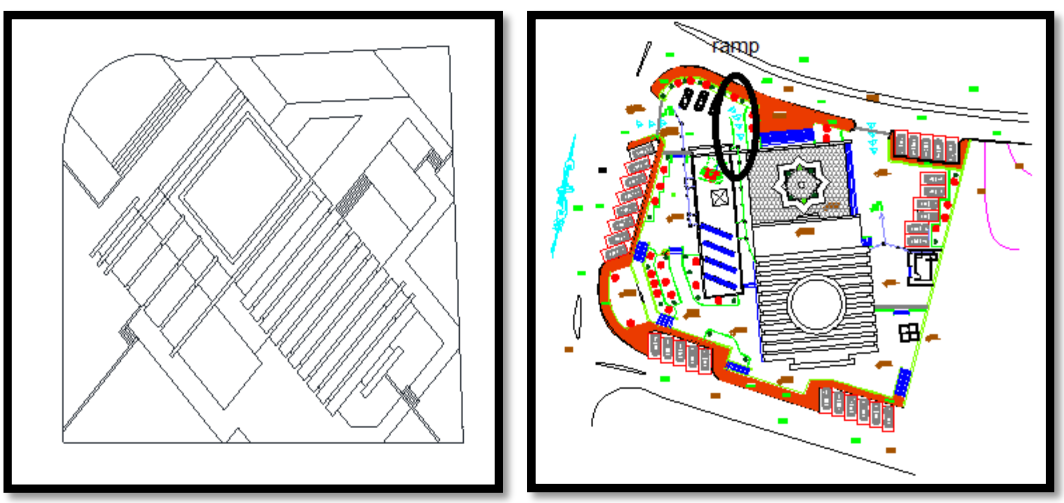



**Figure 3-15: site befor and after redesign**

**General modifications**

1- The location of the Multi-purpose hall was exchanged with ablution location. The Multi-purpose hall is now located in the south. The new location for the Multi-purpose hall gives an advantage of facing the south direction without any shading this will improve daylight levels and solar gains; the ablution is moved away from the mosque to keep good indoor air quality without bad smells (3-17).

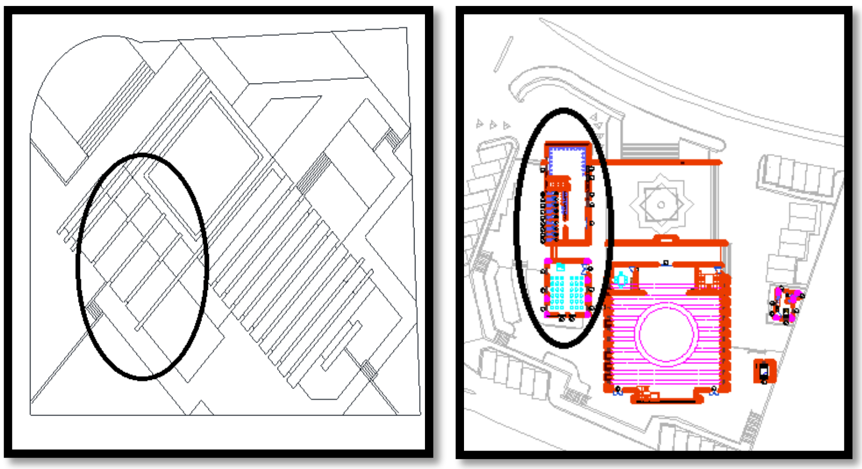


**Figure 3-16: location of the Multi-purpose and ablution before and after exchanged**

2- A special room for water tanks is constructed under the ablution. Show the figure (3-18).

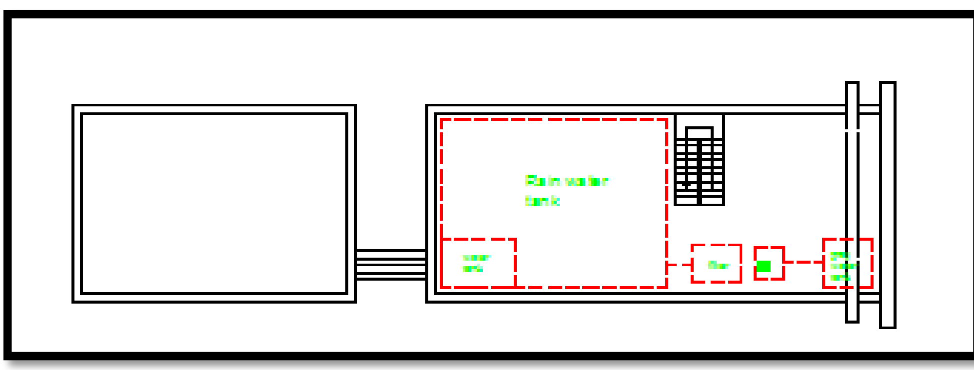



**Figure 3-17: room for water tanks**

# CHAPTER 4

# ENVIRONMENTAL

# DESIGN

## 4.1 Environmental Design

To check the environmental efficiency for the original design and the current design, two ECOTECT models were made to determine the optimum design and solutions for luminous of thermal comfort.

This part will illustrate the solar design by using ECOTECT program to give an indication of how much this mosque will be energy efficient in terms of daylight factor, heating and cooling demands.

ECOTECT is an industry leading building analysis program that allows designers to work easily in 3D and apply all the tools necessary for an energy efficient and sustainable future, as shown in the figure (4-1) below:

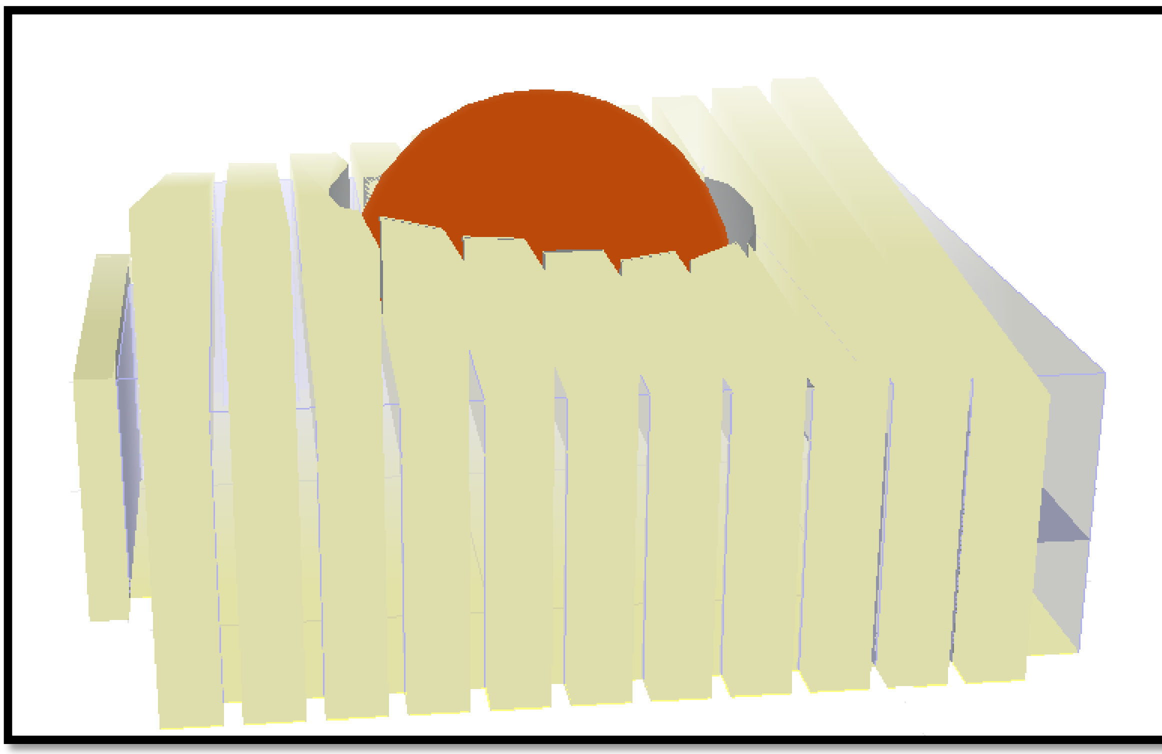


**Figure 4-1: Ecotect model for the current design**

## 4.2 Thermal analyses

Using thermal insulation is an important part of any construction project because it has a huge effect on power conservation, using effective material in thermal insulation in envelop as figures below. Materials will reduce amount of heat gained in summer and reduce the amount of heat lost in winter.

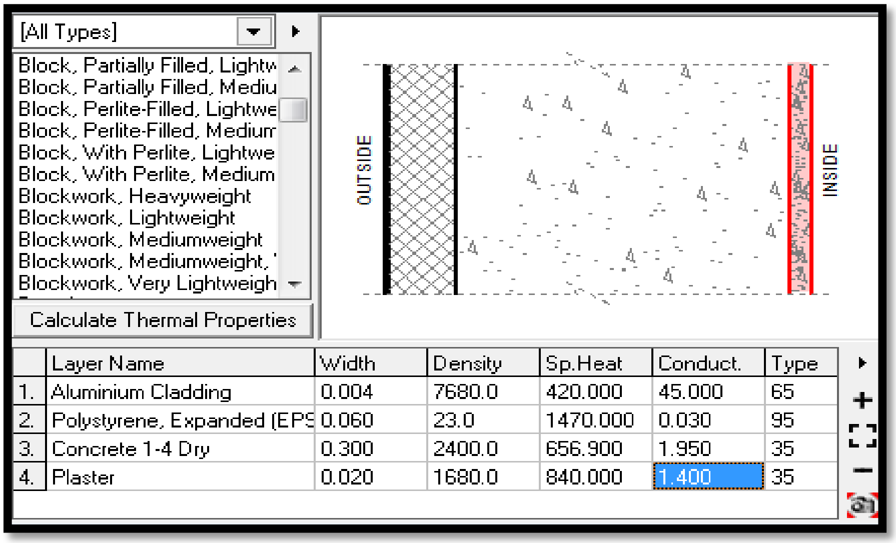



**Figure 4-2: layer of external wall with detail**

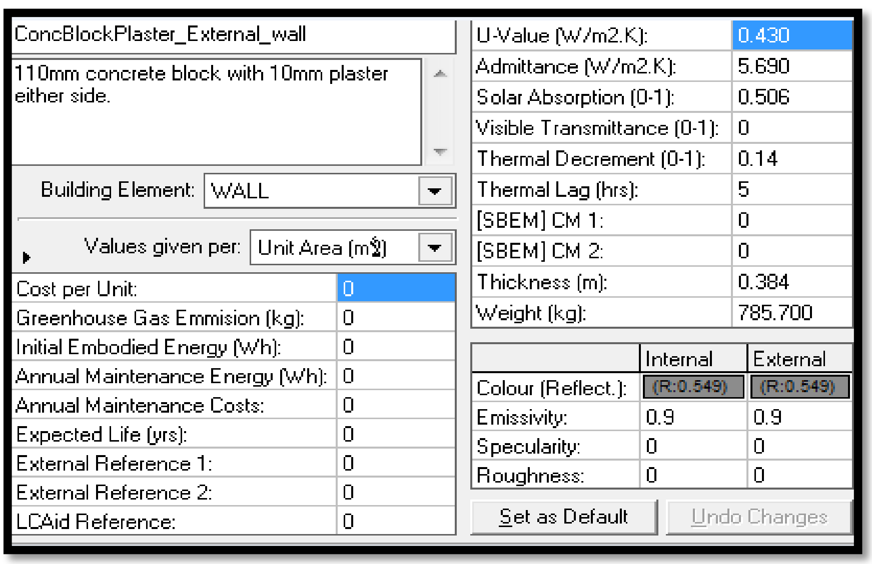



**Figure 4-3: layer of external wall with detail**

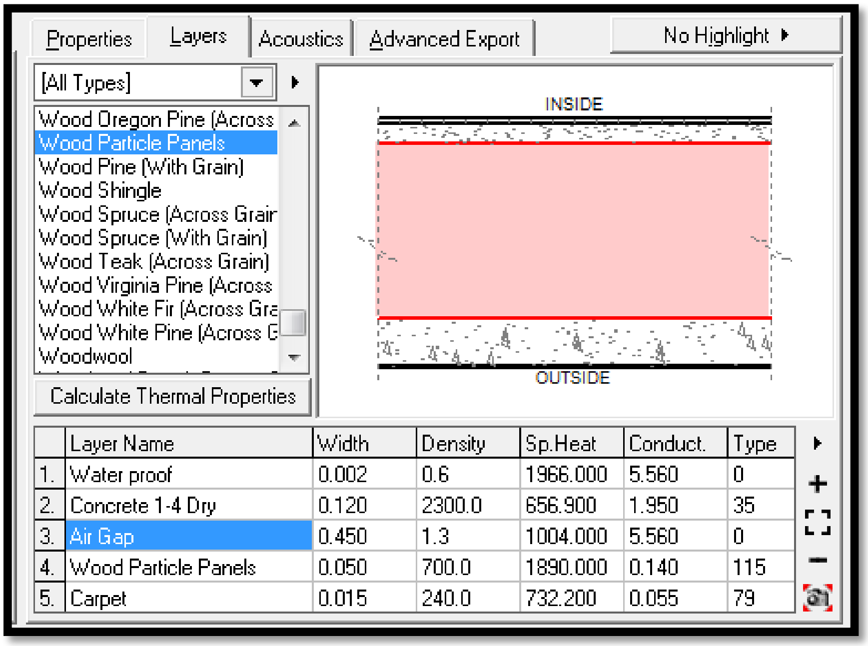



**Figure 4-4: layer of ground slab with detail**

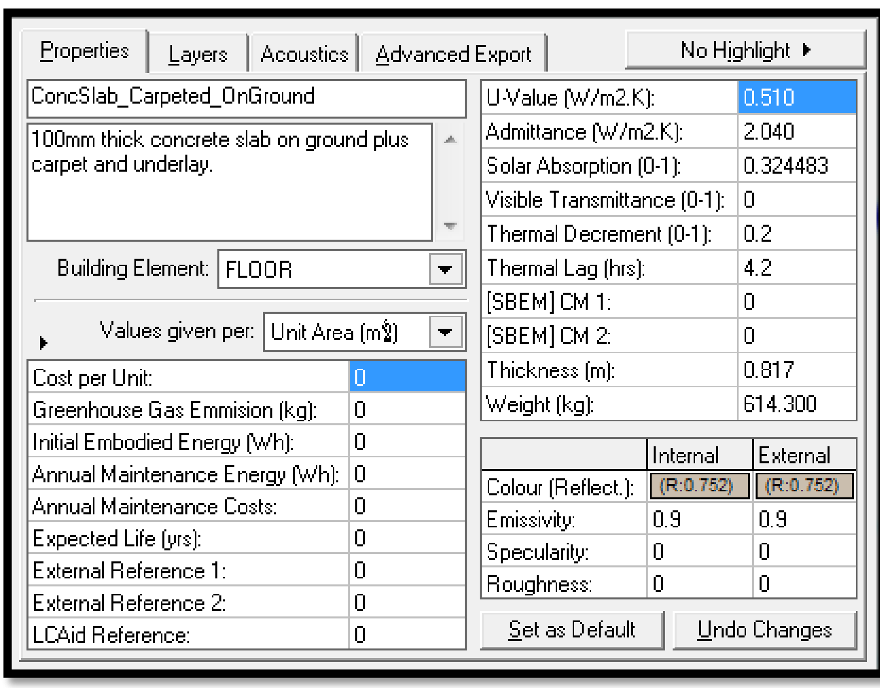



**Figure 4-5: U-value for ground slab.**

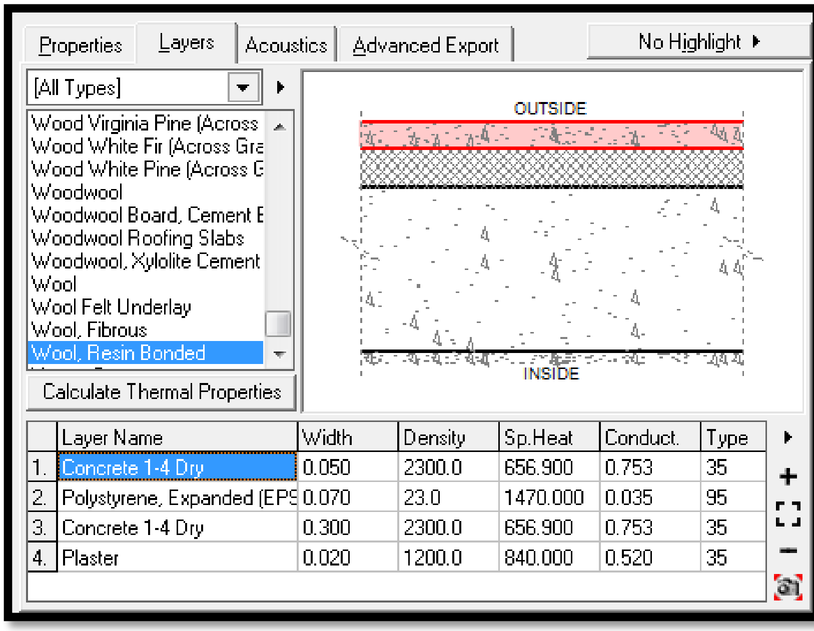



**Figure 4-6: layer of roof with detail**

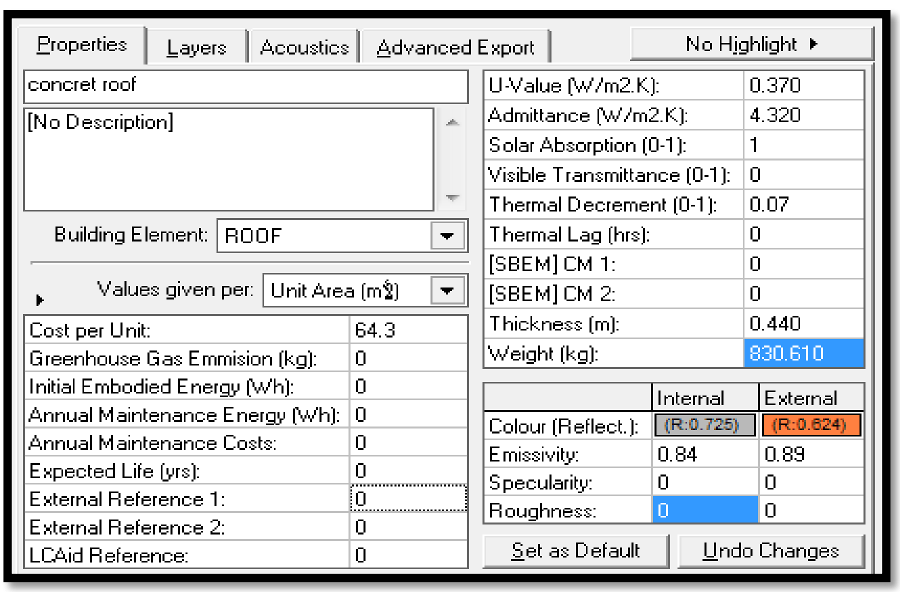



**Figure 4-7: U-Value for roof**

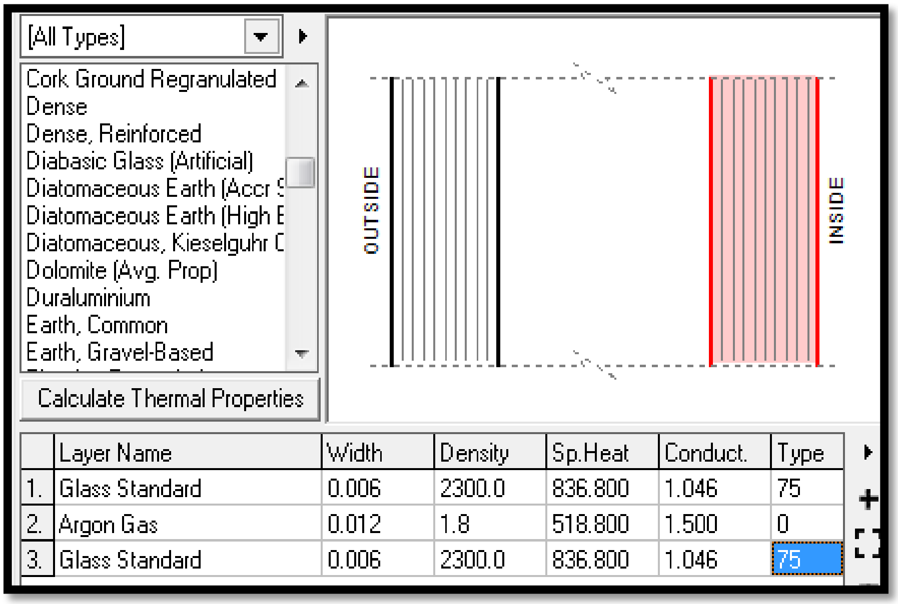



**Figure 4-8: layer of window with detail**

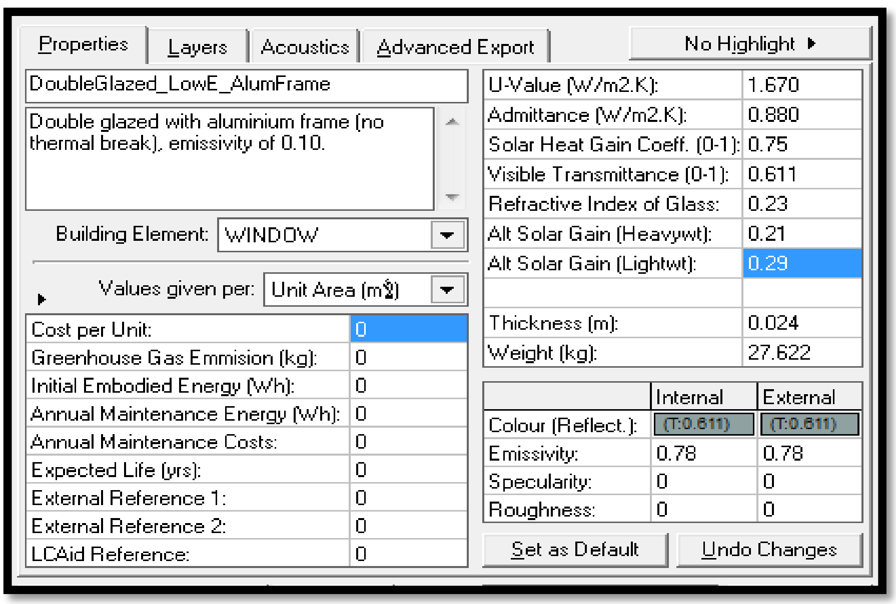



**Figure 4-9: U-Value of window**

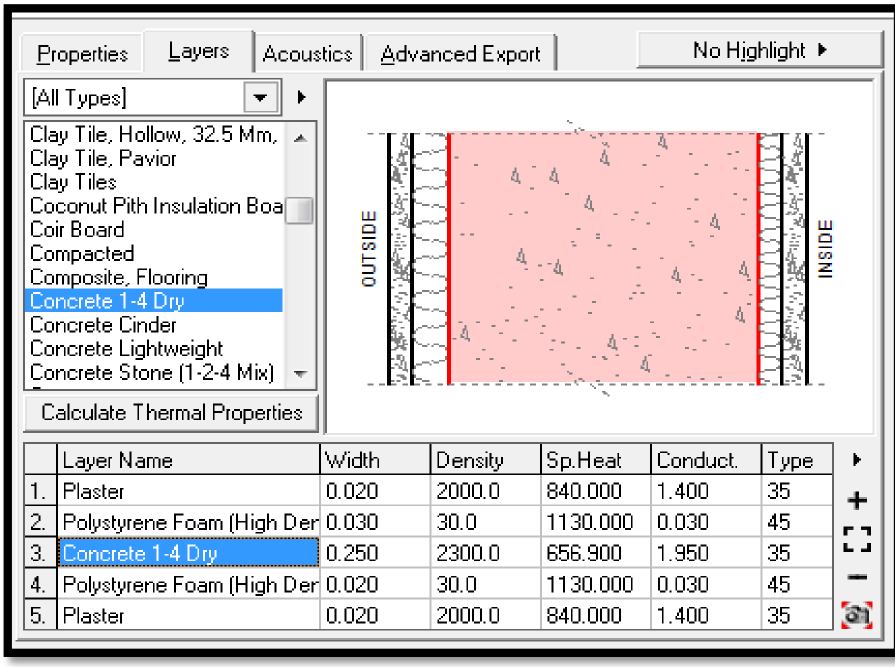



**Figure 4-10: layer of partitons with detail.**

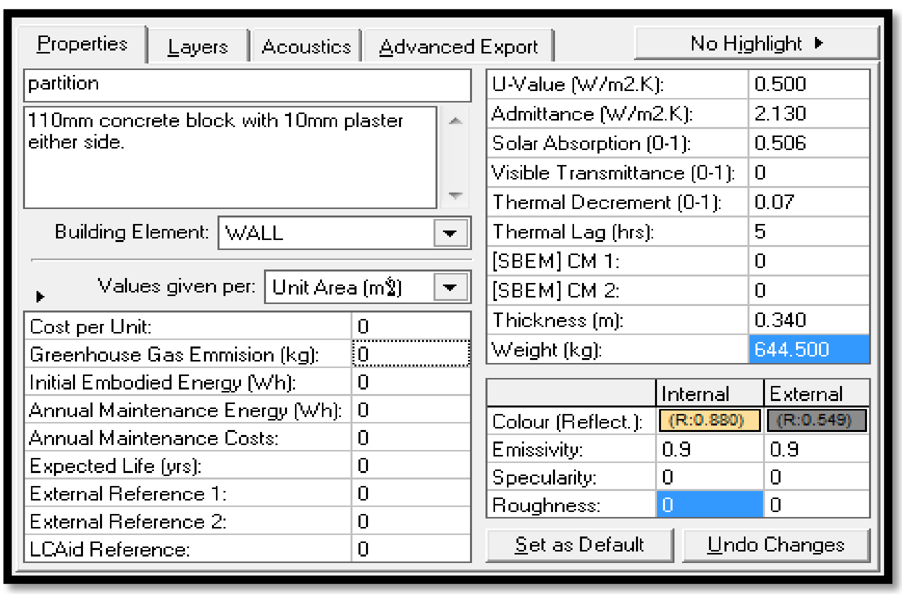



**Figure 4-11: U-Value for partitions.**

**Table 4-1:U-value used in Ecotect model.**

| Elements | U-value (w/m2.k) |
|---|---|
| External wall | 0.43 |
| Ground slab | 0.37 |
| Roof | 0.37 |
| Partition | 0.50 |
| Window | 1.17 |

As show in the following figures (4-12 & 4-13) general sittings of the pray hall zone in summer and winter.

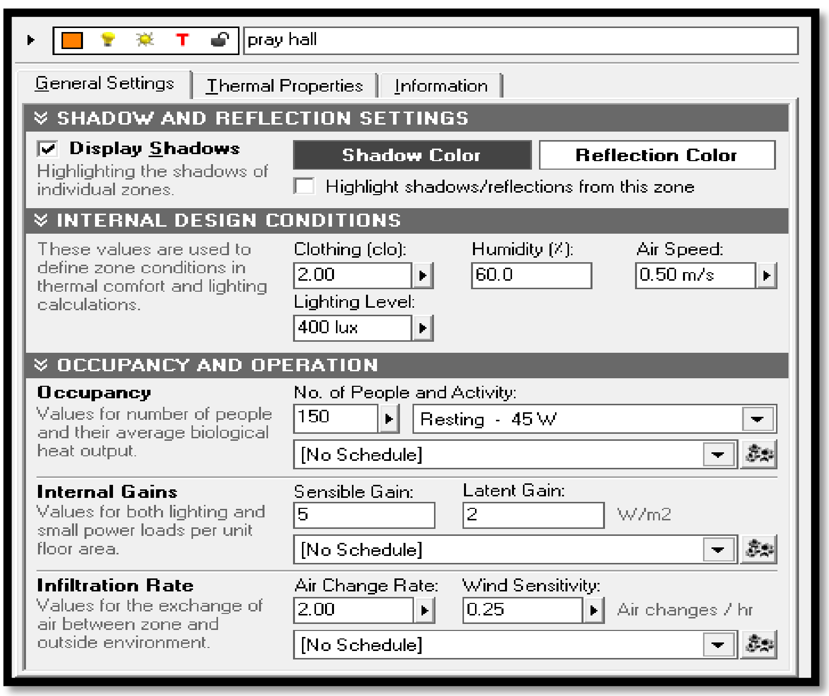



**Figure 4-12: General sitting of the pray hall zone in summer.**

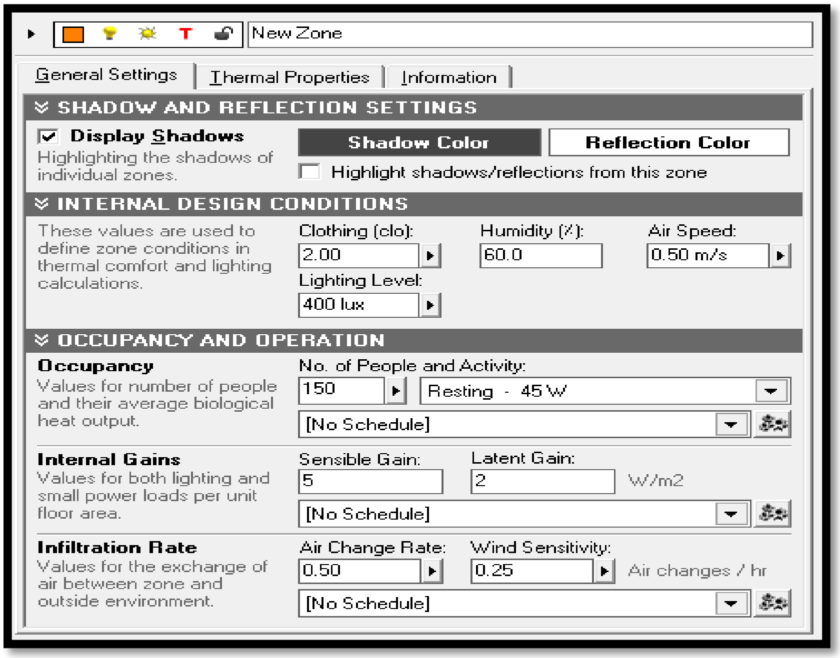



**Figure 4-13: General sitting of the pray hall zone in winter**

## 4.3 Ecotect results for the heating and cooling loads.

We use the heating and cooling load settings to obtain the cooling and heating values just to compare it with the energy efficient buildings according to ASHRAE code and the results are as shown in the figure(4-14) below.

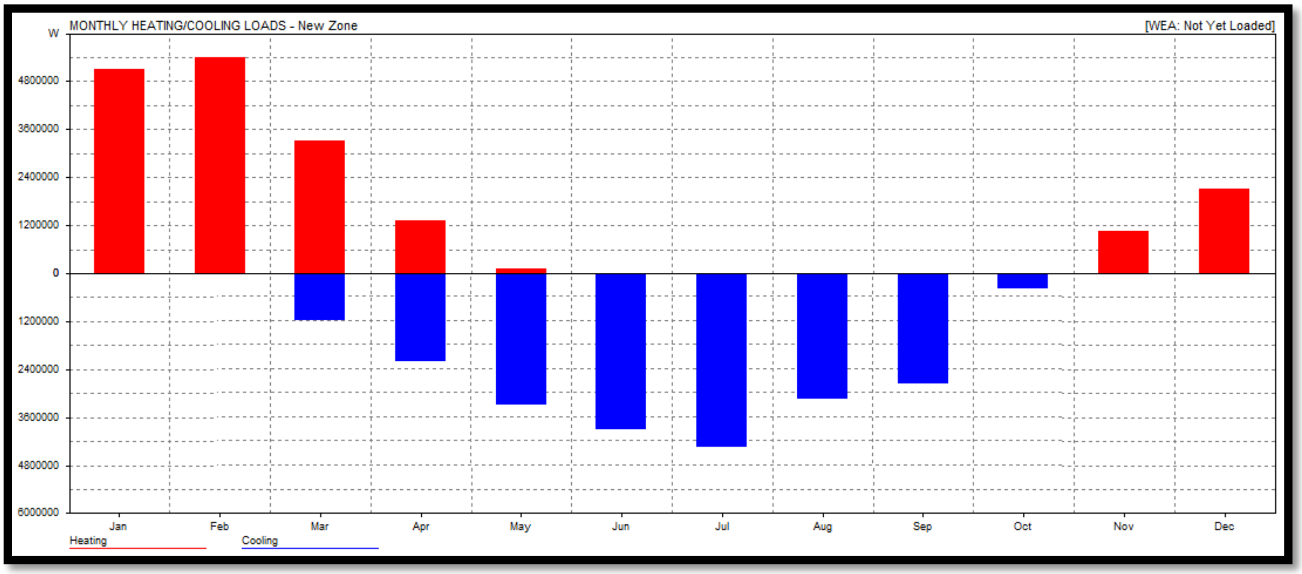



**Figure 4-14: monthly heating / cooling loads for the pray hall.**

Operation: Weekdays 12:00-21:00 , Weekends in summer

Operation: Weekdays 5:00-21:00 , Weekends in winter

Thermostat Settings: 18.0 - 24.0 C in summer

Thermostat Settings: 19.0 - 24.0 C in winter

**Table 4-2: heating and cooling consumption for all pray hall.**

| -------- MONTH | HEATING (Wh) | COOLING (Wh) | TOTAL (Wh) |
|---|---|---|---|
| ------------ | --------- | --------- | -------- |
| Jan | 5103702 | 0 | 5103702 |
| Feb | 5395804 | 0 | 5395804 |
| Mar | 3313187 | 0 | 3313187 |
| Apr | 1313465 | 794635 | 2108100 |
| May | 114929 | 2200991 | 2315920 |
| Jun | 0 | 1639865 | 1639865 |
| Jul | 0 | 3829481 | 3829481 |
| Aug | 0 | 5236511 | 5236511 |
| Sep | 0 | 1962702 | 1962702 |
| Oct | 0 | 1524377 | 1524377 |
| Nov | 1062857 | 0 | 1062857 |
| Dec | 2099710 | 0 | 2099710 |
| ------------ | ------------ | --------- | -------- |
| TOTAL | 18403654 | 17188562 | 35592216 |
| Total cost/year | ------------ | --------- | -------- |
| PER M² | 34742 | 32449 | 67191 |
| Floor Area: | 530 m2 | | |

- An environmental comparison between the original design and the current design is made.
- The current design was found to be more environmentally efficient or energy efficient.
- As mentioned in the previous section, the total of heating and cooling load in the original design in the pray hall area was about 105 Kw/$m^2$ annually and for our design was about 67 Kw/ $m^2$ annually.

The current design is more energy efficient because the values of heating and cooling loads have been reduced for the mosque almost to 64 % of the old design, this will reduce the energy consumption for the mosque.

## 4.4 Natural Day light analysis.

The following figures illustrate the natural lighting distribution in the presence of overhangs on southeast and northwest windows in each space of the mosque. It is expressed as daylight factor, figure (4-15) below shows the natural day light.

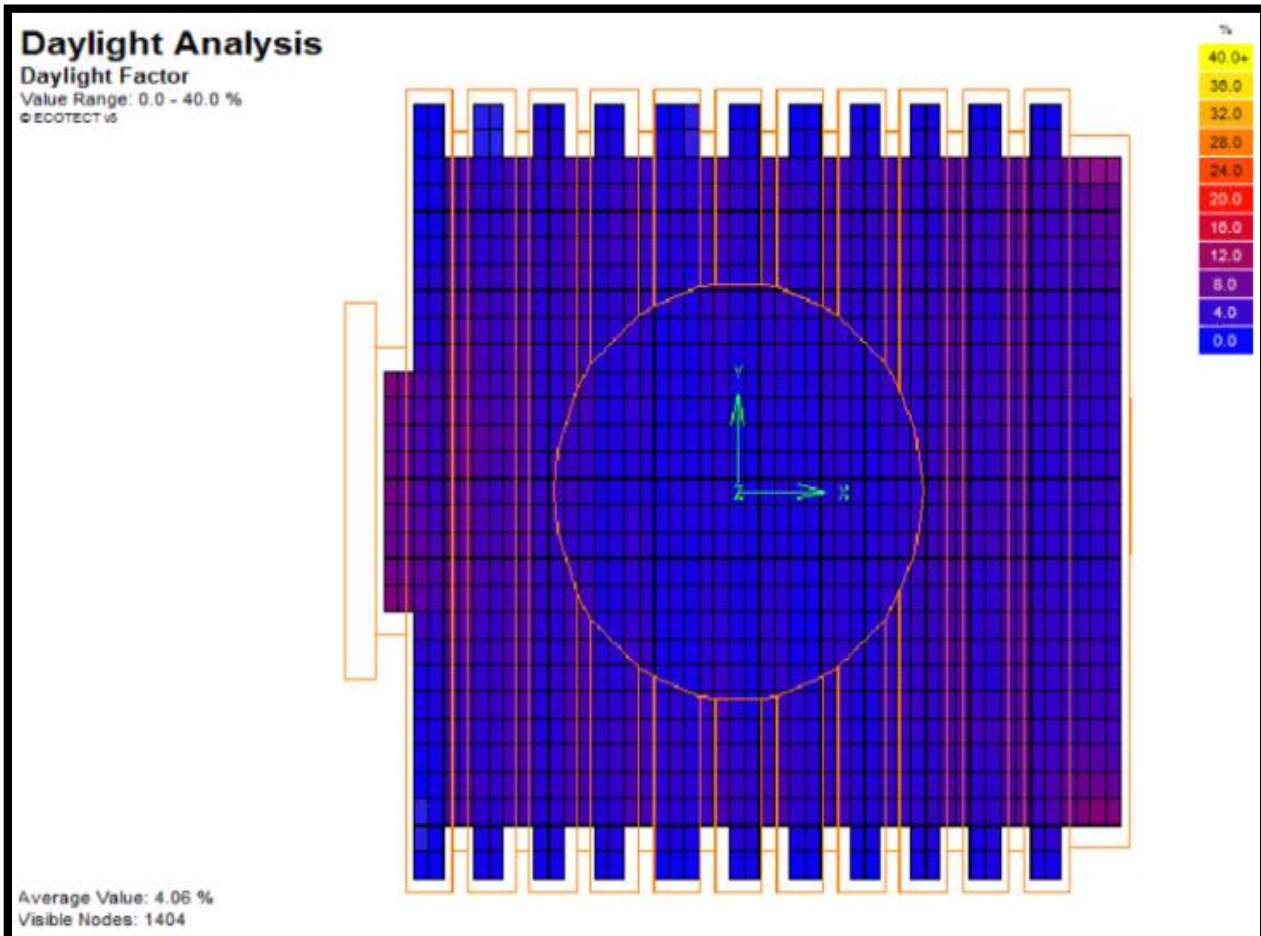



**Figure 4-15: daylight factor of the pray hall.**

From previous day lighting results, note that the day lighting levels for the pray hall are within the range (3%-5%) for day light factor. Also, the daylight distribution is approximately uniform.

## 4.5 Acoustical Analysis

The reverberation time $RT_{60}$ is define as the time required, in second, for the average second in a room to decrease by 60 dB after a source stops generating sound, as shown in figure (4-20) the statistical reverberation time for the pray hall.

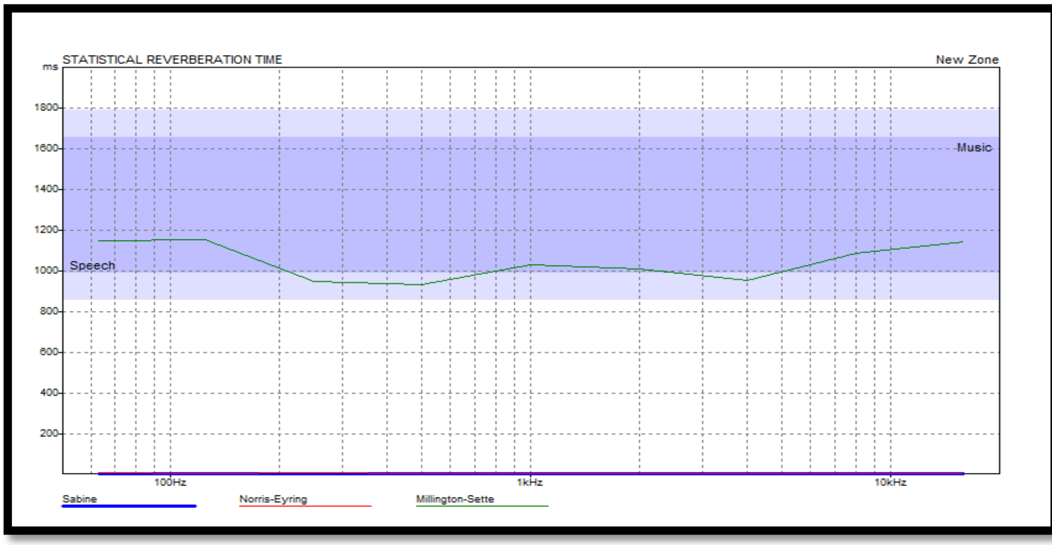



**Figure 4-16: reverberation time in the pray hall**

Surface Area: 2267 $m^2$

Occupancy: 120 (400 x 30%).

Optimum RT (500Hz - Speech): 0.99 s.

Optimum RT (500Hz - Music): 1.66 s.

Volume per Seat: 10.351 $m^3$.

Minimum (Speech): 5.001 $m^3$.

Minimum (Music): 8.908 $m^3$.

Most Suitable: Norris-Eyeing (Highly absorbent).

Selected: Sabine (Uniformly distributed).

Knowing that the optimum reverberation time for the mosque is 0.9- 1.2 second. We are interested in certain frequencies at which the speech occurs. These frequencies are 125 and 4000 Hz.

These values of $RT_{60}$ are achieved after adding ornamented glass in some of the internal frames, also adding ornamented glass well increase the reflectivity of the sound.

**Table 4-3: Reverberation time in the pray hall.**

| FREQ. | Total ABSPT. | MIL-SERT(60) |
|---|---|---|
| 63Hz | 757663.7 | 1.05 |
| 125Hz | 757668.8 | 1.05 |
| 250Hz | 757458.8 | 1.12 |
| 500Hz | 757479.7 | 1.1 |
| 1kHz | 757536 | 1.03 |
| 2kHz | 757494.3 | 1.01 |
| 4kHz | 757561.2 | 1.03 |
| 8kHz | 757560.6 | 1.09 |
| 16kHz | 757656.2 | 0.97 |

$As = 0.16V / RT60 = (0.16 * 3714) / 1.03 = 592\ m^2$.

$\alpha = As/Atotal = 592 / 2267 = 0.25$

$R = Atotal * \alpha / (1- \alpha) = 2267 * 0.26 / (1-0.26) = 801\ m^2$

$L_W$= 85 dB.

SPL at 4 m from the Member = $L_W+10 \log [(Q/(4л\ r^2))+(4/R)]$

SPL at 4 m from the Member = $85+10 \log [(2/(4л\ (4)^2))+(4/801)]$

$= 85+10 \log [(2/(4 *3.14 * 4^2))+(4/801)]$

$= 67$ dB.

**Noise level calculation:**

Area wall = 127.8 $m^2$

Area window = 42 $m^2$

**Table 4-4: STC for envelope walls.**

| Layer | STC |
|---|---|
| Solid concert with thickness = 30 cm | 56 |
| Add one side plaster | 2 |
| Polystyrene | 3 |
| Total | 61 |

STC for window = 32. [25]

Based on the filed measurement the obtained noise level on average equal 65 dB.

TLc = 10 Log (127.8/ 42*$10^{-4.2}$ + 85.8*$10^{-6.1}$) = 37 dB.

Thus, noise level inside the mosque equal 65 – 37 = 28 dB.

S / N (at 4 m) = 62.8 – 28 = 34.8 dB

% $AL_{cons}$ (at 4m ) = 9.2%

**Table 4-5:( %$AL_{cons}$ ) calculation.**

| **Distance (m)** | **SPL(dB)** | **S/N (dB)** | **AL%** |
|---|---|---|---|
| 4 | 67 | 39 | 9.2% |
| 12 | 62.8 | 34.8 | 9.2% |
| 20 | 62.2 | 34.2 | 9.2% |

The $AL_{cons}$ value calculated equal 9.2% ,so it is acceptable since the value is within the range (15-7)% . [25]

## 4.6 Solar system

**1. Trombe wall**

Trombe walls are used for heating , the trombe wall is located in the qibla direction of the mosque as shown in figure (1-16),(1-17) below.

It's designed in 21- January,

heat gain = insulation *(1-cc)*eff.*$A_{Glass}$ .

Insulation = 920 + 560 = 1480 BTU

Heat gain = $\frac{1480*0.24}{317} = 1.12\ \frac{kwh}{\mathrm{m2}\ .\ day}$.

Heat gain =1.12 * 40 = 45 kwh/day

Heat gain = $\frac{45*120}{530}\ = 10.2\ \mathrm{kw/m2}$.

**Figure 4-17: Elevation for trombe wall from inside.**

**Figure 4-18: Elevation for trombe wall from inside.**

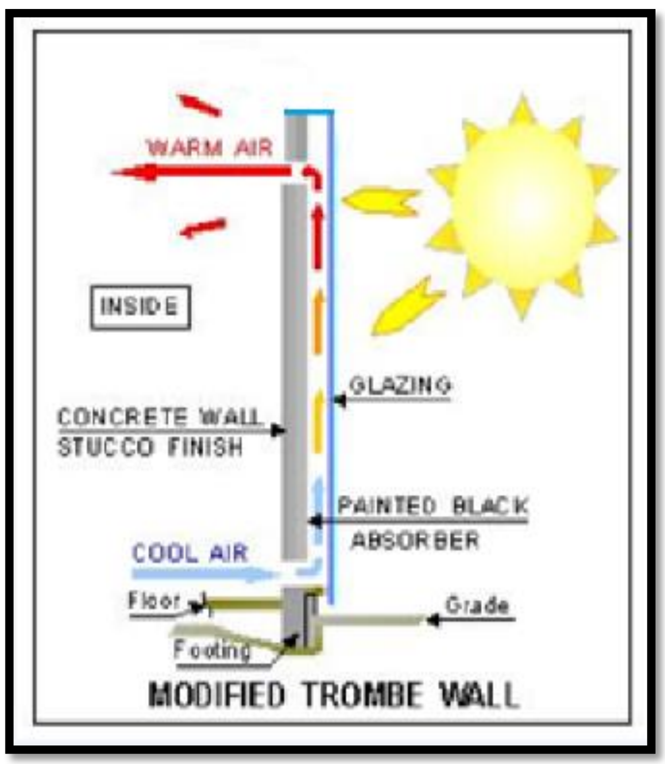



**Figure 4-19: section in thrombi wall**

## 2. Photovoltaic cells

Photovoltaic cells are used to convert solar energy to electrical energy, Photovoltaic cells are located roof the cultural center shown figures (1-19), (1-20) below we used in our project to reduce the electricity consumption in the mosque.

We use 28.8 $m^2$ of photovoltaic cells, every 100 cm2 give us 1.8 watt.

100 cm2 __________________ 1.8 watt

7200 cm2 _________________ 130 watt

Each module give us 130 watt, and the number of cells used equal 40, when each 40 cells gives 5.2 Kwp.

1 kwp _______________5.4 KW.H/day

5.2 kwp _______________28 KW.H/ day

So we have convert to KW.H/ M2: (28*365) /530 = 20 KW/M2.

The price of photovoltaic cells in the market 5750 $ / 5KwP.

Shown below figure (4-19) the photovoltaic cells distribution on the ceiling of the cultural center.

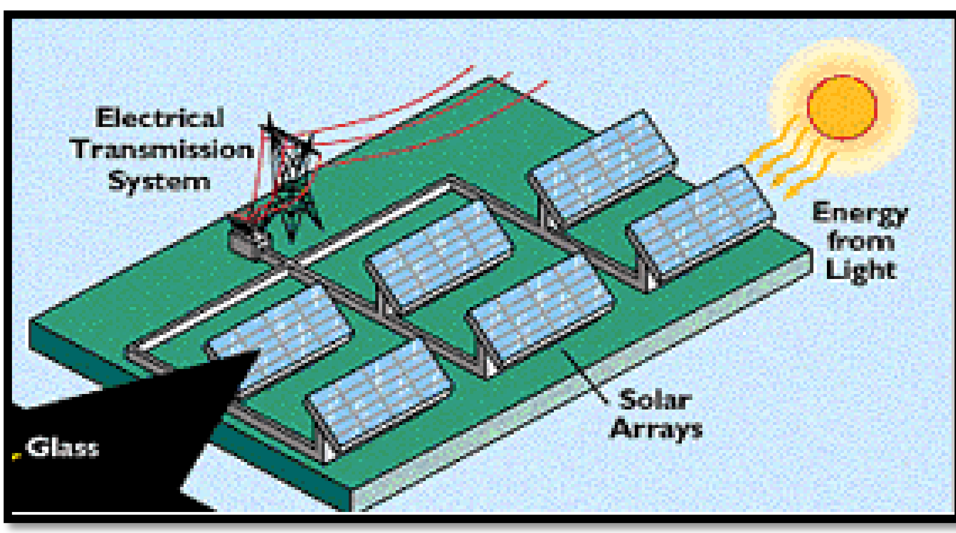



**Figure 4-20: distribution photovoltaic cells.**

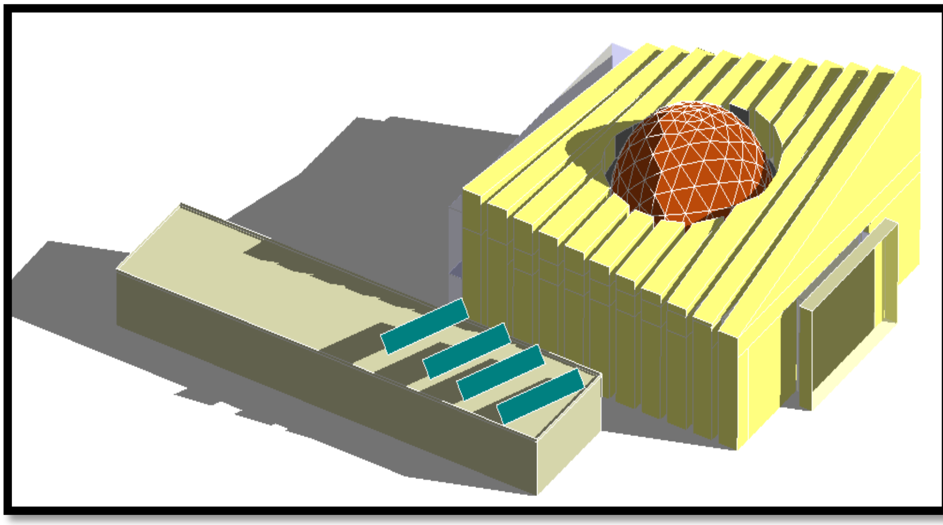


**Figure 4-21: directing photovoltaic cells.**

## Mosque energy consumption

After the work that we have done via Ecotect and considering the green building code, we came up with those results shown in the table below for the mosque.

**Table 4-6: Mosque energy consumptions**

| Devices | Consumption (KW/ $m^2$) |
|---|---|
| **Cooling** | 34.7 |
| **Heating** | 32.5 |
| **Lamps** | 10 |
| **Pump** | 0.5 |
| **Total** | 77.7 |

## Mosque energy gains

After installing the thrombi wall and photovoltaic cells we gained so much heat energy, and that reduced the heating load required.

**Table 4-7: Mosque enerdy gains**

| Types | Gain (KW/ $m^2$) |
|---|---|
| **Trombe wall** | 10.2 |
| **Photovoltaic cells** | 20 |
| **Total** | 30.2 |

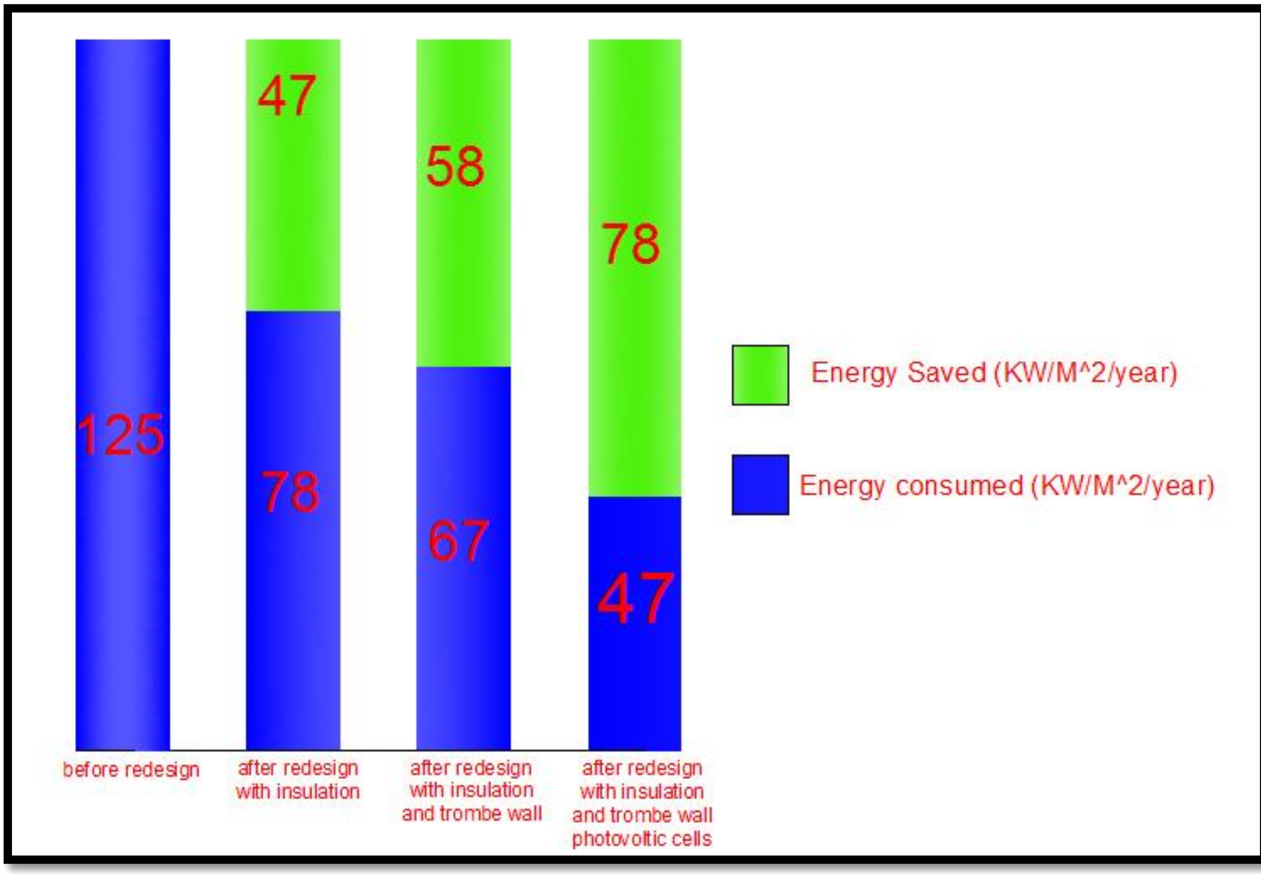



**Figure 4-22: Energy consumed in for the mosque**

# CHAPTER 5

# STRUCTURAL DESIGN

## 5.1 Introduction

**Site and Geology:**

The structure of the mosque will be built on sedimentary clay soil with 1 m rock fill and 0.5 m of compacted base course as a result the bearing capacity of soil will be 200 $KN/m^2$.

**Design codes:**

The structure will be designed for static and dynamic cases, the design will be done according to codes and standards such as:

- ACI -318-2011 for reinforced concrete structural design.
- UBC -97 for earthquake and wind load computations.
- Jordanian code for loads 2006.
- ASCE for load computations.

**Project description:**

The project has many spaces functions and elements, the structural part will include full design for the Mosque and the Minaret.

The figures (5-1), (5-2) bellow shows the SAP model for mosque and minaret

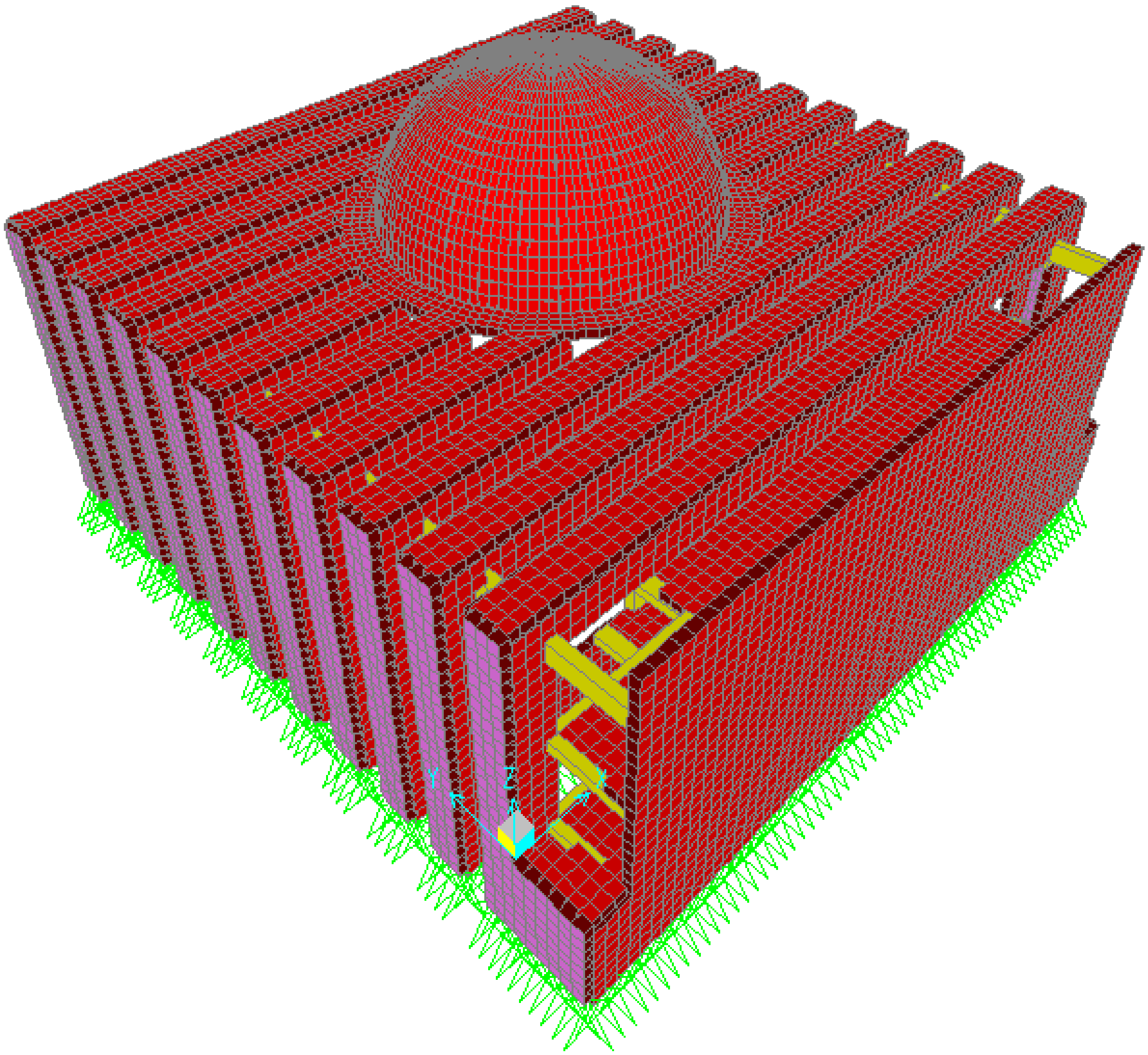


**Figure 5-1: 3D SAP model for the Mosque building.**

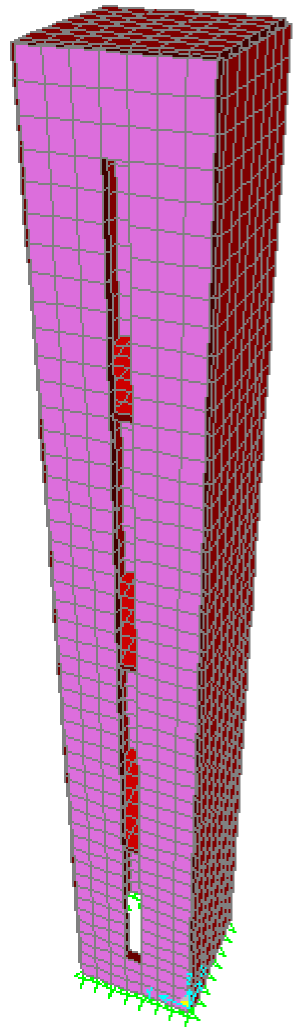


**Figure 5-2: 3D SAP model for the Minaret.**

**Materials:**

The materials used in construction will have the following characteristics:

1. Compressive strength of Concrete (fc`) = 24 MPa

The compressive strength is for standard cylinder crushed at 28 days.

2. Yielding strength of steel fy = 420 MPa

**Table 5-1: Material used and their density.**

| Material | Density ($KN/m^3$) |
|---|---|
| Reinforced Concrete | 25 |
| Polystyrene | 0.3 |
| Hollow Concrete block | 12 |
| Alcubond (Aluminum sheets) | 16 |
| Sand | 18 |
| Mortar | 23 |
| Course aggregate | 18 |
| Tiles (30 mm thick) | 26 |

**Concrete cover for reinforcement will be**:

- 5 cm for foundation with blinding.
- 4 cm for concrete columns.
- 3 cm for concrete slabs.
- 4 cm for concrete beams.

**Load and forces:**

1. **Dead load**

   Dead loads shall comprise of the own weights of structural elements while the superimposed dead loads are composed of weights of partition walls, fill, mortar, tiles and plastering. The weight of the (exterior) non-structural elements, Alcubond cladding and curtain walls are considered as superimposed dead loads.

2. **Live loads**

   According to ASCE 7-2005 based on type and use of space

3. **Snow loads**

   According to Jordanian code the snow load depends on the elevation above sea level

   For height ,$500 > h > 250m$, $q_s = \frac{h - 250}{800}$

4. **Wind load**

   Wind load is computed according UBC 97، it will be computed in design of minaret section

5. **Seismic load**

   Seismic load is computed according UBC 97، it will be computed in seismic design section

6. **Soil load**

   Will be computed in basement wall design section

**Table 5-2: Loads used for design**

| **Type of load** | **Load (KN/m$^2$)** |
|---|---|
| Super imposed | 4 for pray hall<br>Stairs (6 for flight and 4 for landing)<br>2 for the roof |
| live | 5 for the pray hall<br>5 for the stairs<br>1 for the roof |
| Snow | 0.5 |

**Load combinations**

According to ACI 318-2011 the main design combinations for ultimate strength design are summarized as follows:

The load combination according to ACI 318-2011:

1) Wu= 1.4D.L

2) Wu= 1.2D.L+ 1.6L.L + 0.5($L_r$ or S or R)

3) Wu= 1.2D.L +1.6($L_r$ or S or R) + (1.0L or 0.8W)

4) Wu= 1.2D.L+ 1.6W + 1.0L + 0.5($L_r$ or S or R)

5) Wu= 1.2D.L ± 1.0E + 1.0L + 0.2S

6) Wu= 0.9D.L ± (1.6W or 1.0E)

Where:

- D.L: Dead load

- L.L: live load

- E: Earthquake load

- S: Snow load

- W: Wind load

- $L_r$: Roof live load

- R: Rain load

**Program in use:-**

1. SAP2000: for structural analysis & design.
2. AutoCAD 2007: for all drawings.

## 5.2 Methodology

Based on building architectural, functional and environmental requirements, the following methodology was adopted:-

- Choosing the suitable structural configuration
- Choosing the structural system, the structural system used is the long span reinforced concrete frames.
- Computing the loads and forces on the structure: dead, super imposed, live, snow, wind and seismic loads.
- Preliminary design of structural elements, such as columns, beams, slabs, etc.
- Building sap model to analyze and design the structural system

## 5.3 Analysis and design:

In this section, sample of calculation for preliminary design and design of frame, dome, minaret , beam, slab, shear wall, footing, and stairs model and the SAP checks and results after putting the seismic shear force.

### 5.3.1 Preliminary design:

**For slab**

To determine the minimum thickness of slab, the deflection limit according to ACI 318-08 code for simply supported one way ribbed slab was used:

$$h = \frac{l_n}{16}$$

Where:

h = minimum thickness

$L_n$ = clear span length

h= 4.9 \ 16 = 0.3 m

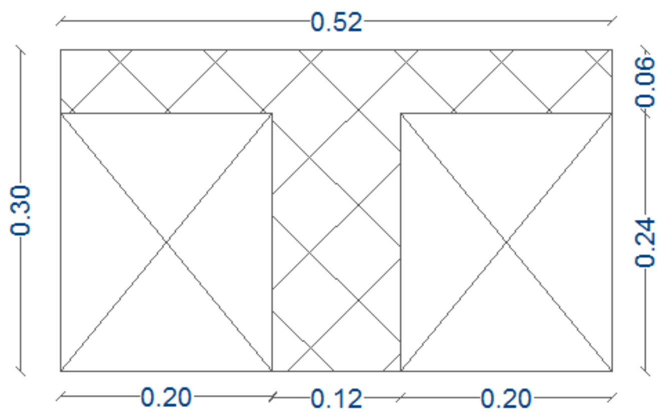



**Figure 5-3: Cross section in one way ribbed slab**

**For beams:**

To determine the minimum thickness, the deflection limit according to ACI 318-08 code was used

1. Rectangular

   For two end continuous span.

   $$h = \frac{l_n}{21}$$

   Where:

   h = minimum thickness

   $L_n$ = clear span length

   h= 7.65 \ 18.5 = 0.41$m$.

   Use beam 30X60 cm to increase strength and safety.

2. U- section

   Section dimension where established according to architectural and safety aspects since the beams is attached to glass

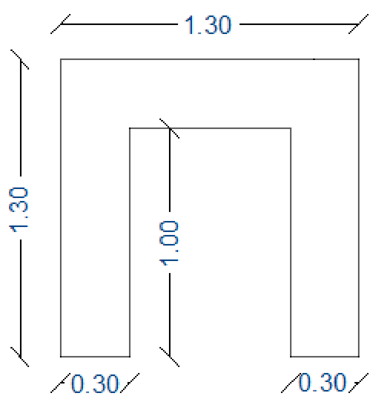



**Figure 5-4 : Cross section in U beam**

**For U- section columns**

Based on architectural and structural aspects the column dimensions will be used as U section.

The building is modeled as three dimensional structure using SAP 2000 program, beams and columns are modeled by frame elements (lines), whereas, shear walls ,dome, minaret and slabs are modeled by area (shells ) elements.

Note: - U section beams and columns are modeled by area (shells) to increase their accuracy.

**Table 5-3 : Modifier for sections used in Sap model.**

| Section type | Modifier | |
|---|---|---|
| **Rectangular Beams** | Torsional constant | 0.35 |
| | Moment of inertia about "2" axis | 0.35 |
| | Moment of inertia about "3" axis | 0.35 |
| **U section Beams** | f11 | 0.35 |
| **Rectangular Column** | Torsional constant | 0.35 |
| | Moment of inertia about "2" axis | 0.35 |
| | Moment of inertia about "3" axis | 0.35 |
| **U section Columns** | f22 | 0.35 |
| **Slab (30cm)** | m11 | 0.004 |
| **One way ribbed** | m22 | 0.25 |
| | m33 | 0.004 |
| **Shear wall** | m11 | 0.7 |
| | m22 | 0.7 |
| | m33 | 0.7 |

Where:

Bending m11 is: moment about the x-direction of section.

Bending m22 is: moment about the y-direction of section.

Bending m12 is: moment about the z-direction of section.

Torsional constant is: the moment of inertia about z axis.

Moment of inertia about “2” axis is: the moment of inertia about y axis.

Moment of inertia about “3” axis is: the moment of inertia about x axis.

To account for cracking, stiffness modifiers are used the model.

### 5.3.2 Model checks

To be confident that SAP model works properly and gives correct results, three checks on the model and the obtained results should be made. The checks are:

- Compatibility of structural elements in the model.
- Equilibrium.
- Internal stresses.

**1. Compatibility and deflection check:**

To make sure that all the structural elements are compatible with each other. This can be achieved and approved by noticing and analyzing the deformed shape animation of the model from SAP.

If compatibility is satisfied between structural elements, then the compatibility cracks will be avoided in reality.

The compatibility of the model was checked and it was found to be OK.

Figures (5-5) and (5-6) show the deformed shape of the model.

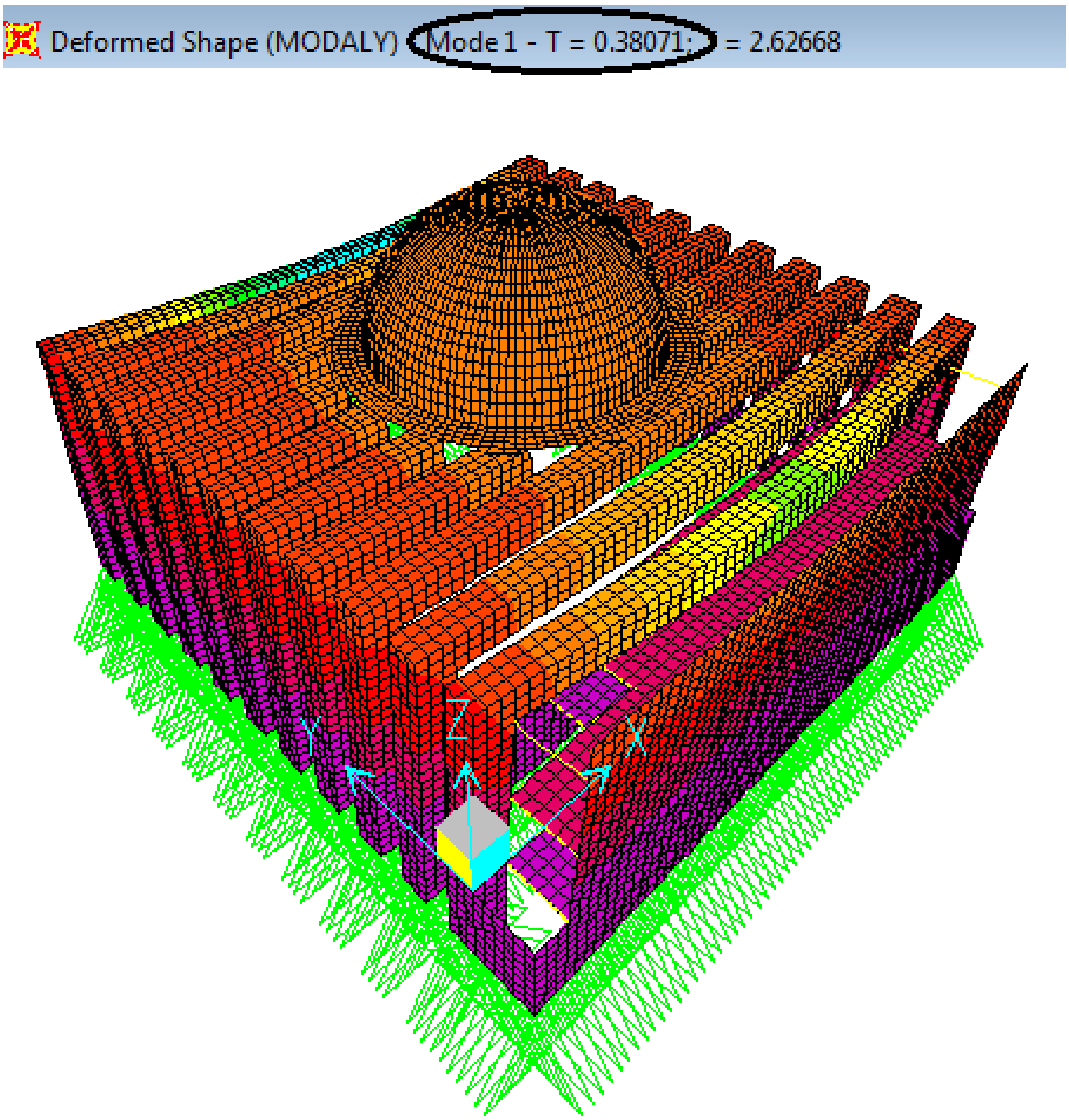



**Figure 5-5: Model compatibility and period.**

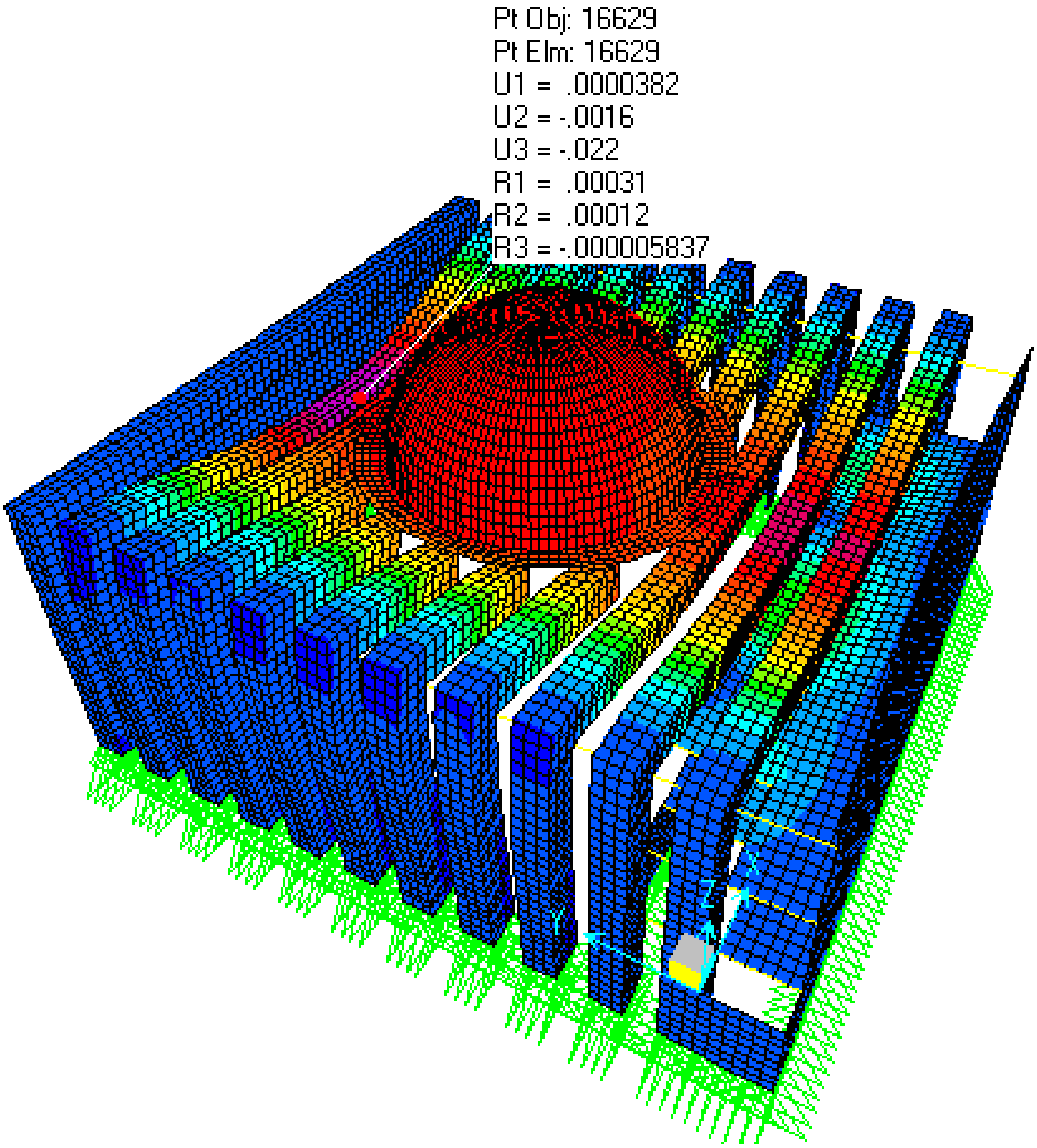



**Figure 5-6 : Deflected shape.**

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## 2. Equilibrium check:

For the static bodies, the summation of forces in any direction must be zero. Thus, for the model, the total reactions in columns must equal the total loads applied. However, because of the difference resulting from area modeling and weight computation, the allowable difference is less than 5%.

- Dead load , the table (5-4) below summarizes the hand calculations

**Table 5-4: Hand calculation for dead load.**

| Element | Name | Section (m) | Weight (KN) |
|---|---|---|---|
| **Beams** | B1 | 1.3X1.3 | 4974.7 |
| | B2 | 0.4X0.7 | 483 |
| | B3 | 0.3X0.6 | 320.4 |
| | B5 | 0.3X0.5 | 117.7 |
| | B6 | 0.3X0.3 | 46.8 |
| **Columns** | C1 | 1.3X1.3 | 4851 |
| | C2 | 0.4X0.7 | 36 |
| **Dome** | | R =5 d=0.15 | 588.75 |
| **Shear wall** | | Thickness =0.25 | 3714.7 |
| **Slab** | slab | Thickness =0.3 | 1442 |
| **Ring beam** | Ring | Thickness =0.3 | 295 |
| **Total weight =** | | | 16933.8 |

Thus, the total weight from manual calculation = 16933.8 KN However, the total weight from SAP = 16871 KN.

The percentage of difference = $\frac{\text{sap load}-\text{manual load}}{\text{sap load}} * 100\%$ = 0.37 % < 5% the check is OK.

- Live load

Manual total live load = 1117.46 KN.

SAP total live load = 1116 KN.

The percentage of difference = $\frac{\text{sap load}-\text{manual load}}{\text{sap load}} * 100\%$ = 0.13 % < 5 % the check is OK.

- Super imposed load

Manual total super imposed load = 753 KN.

SAP total super imposed load = 750 KN.

The percentage of difference = $\frac{\text{sap load}-\text{manual load}}{\text{sap load}} * 100\%$ = 0.4 % < 5 % the check is OK.

**3. Internal force**

The stresses will be checked for one frame as the rest of frames is similar to each other, in the calculation the second load combination will be used.

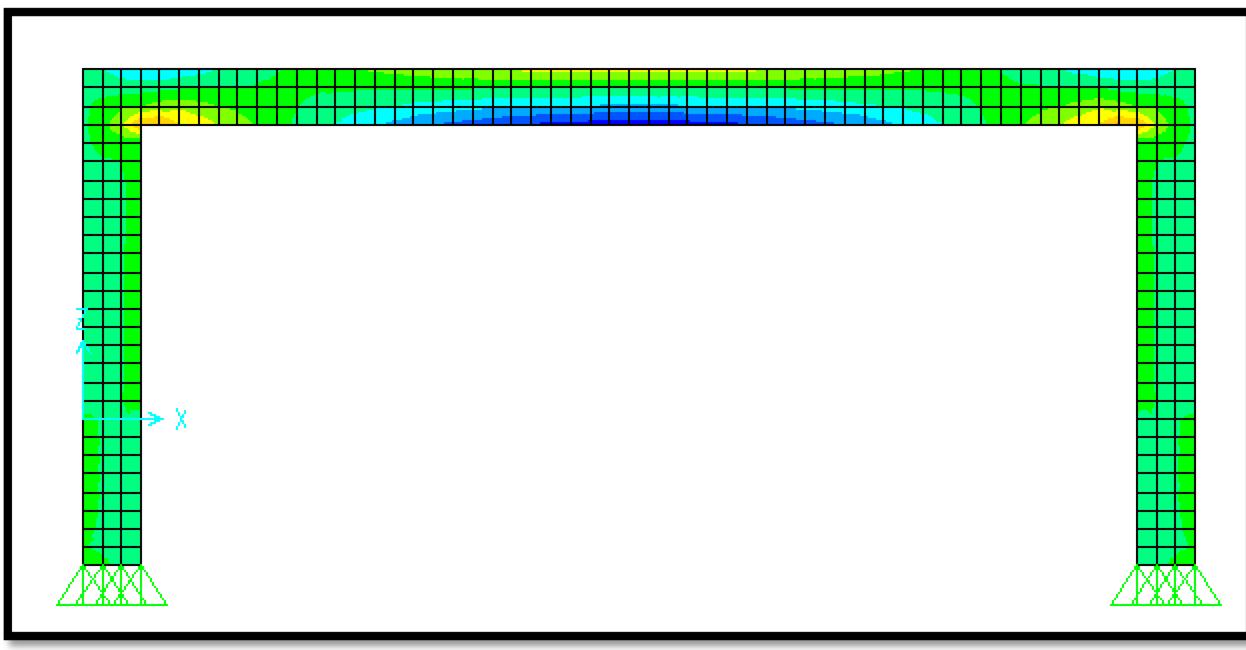



**Figure 5-7 : Frame.**

**For beam**

The beams were represented as area to increase the accuracy of the results , so SAP program gives internal stresses which should be close to stress calculated by hand .

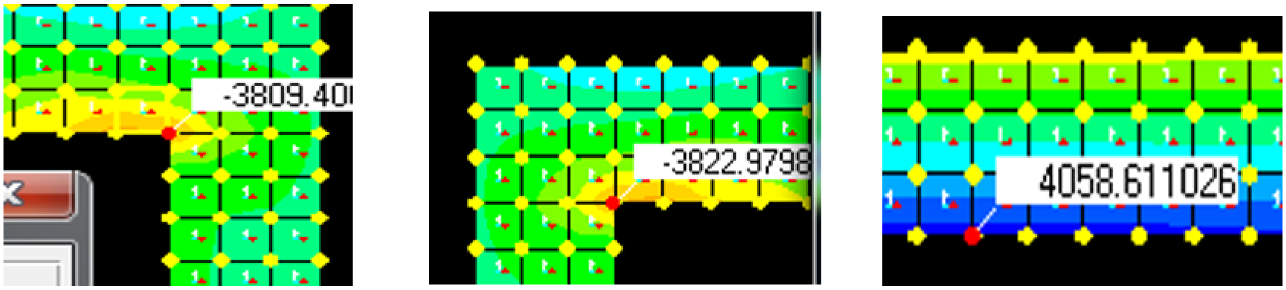



**Figure 5-8: Frame (right, left and middle) stresses.**

Stress from SAP:

$\sigma_{sap}$ = (middle) $\sigma + \frac{(\text{left } \sigma + \text{right } \sigma)}{2}$

$\sigma_{sap}$ = 8025 KN/m$^2$.

Stress by hand calculation:

$W_u$ = 31.41 KN/m.

Moment $= \frac{Wu*L^2}{8} = \frac{31.41*(20.4)^2}{8} = 1633.9$ KN. m

$\sigma_{hand} = \frac{M*C}{I} = \frac{1633.9*0.756}{0.1528I}$ = 8083 KN/m$^2$.

Difference (%) $= \frac{\text{sap stress} - \text{manualstress}}{\text{sap stress}} *100\ \% = \frac{8025-8083}{8025} = 0.71\%$

**For column**

Stress from SAP:

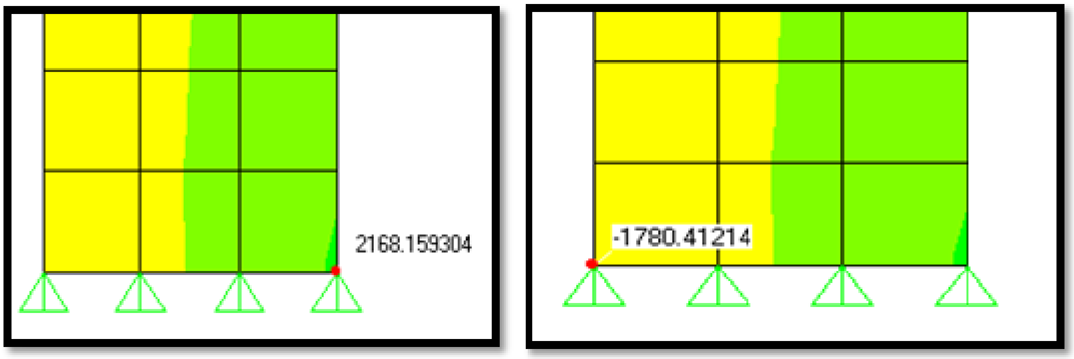



**Figure 5-9 : Tension and compression stress in column.**

Stress by hand calculation:

Pu from tributary area = 628.77 KN

σ (axial) = $\frac{Pu}{Area} = \frac{628.77}{0.99}$ = 6351.1 KN/m$^2$

by making 2d frame analysis the moment = 511.1 KN.m

$\sigma_{(max)} = \frac{Pu}{Area} + \frac{M*C}{I}$ = 6351.1 + $\frac{511.1*0.394}{0.1528}$ = 1952.1 KN/m$^2$ compression .

$\sigma_{(max)} = \frac{Pu}{Area} - \frac{M*C}{I}$ = 6351.1 + $\frac{511.1*0.756}{0.1528}$ = 1900 KN/m$^2$ tension .

Compression side difference (%) = $\frac{\text{sap stress} - \text{manualstress}}{\text{sap stress}} * 100$ % = $\frac{1780 - 1952.1}{1780}$ = 8.8%

Tension side difference (%) = $\frac{\text{sap stress} - \text{manualstress}}{\text{sap stress}} * 100$ % = $\frac{2168 - 1900}{2168}$ = 12.3%

From the above mentioned calculation there is an error of 12.3 % between hand calculation and sap result, this can be explained as the hand calculation is not accurate, moreover some of the stresses is transferred in other directions

### 5.3.3 Design for slab

The figures (5-10) and (5-11) shows the maximum negative and positive moment in the slab.

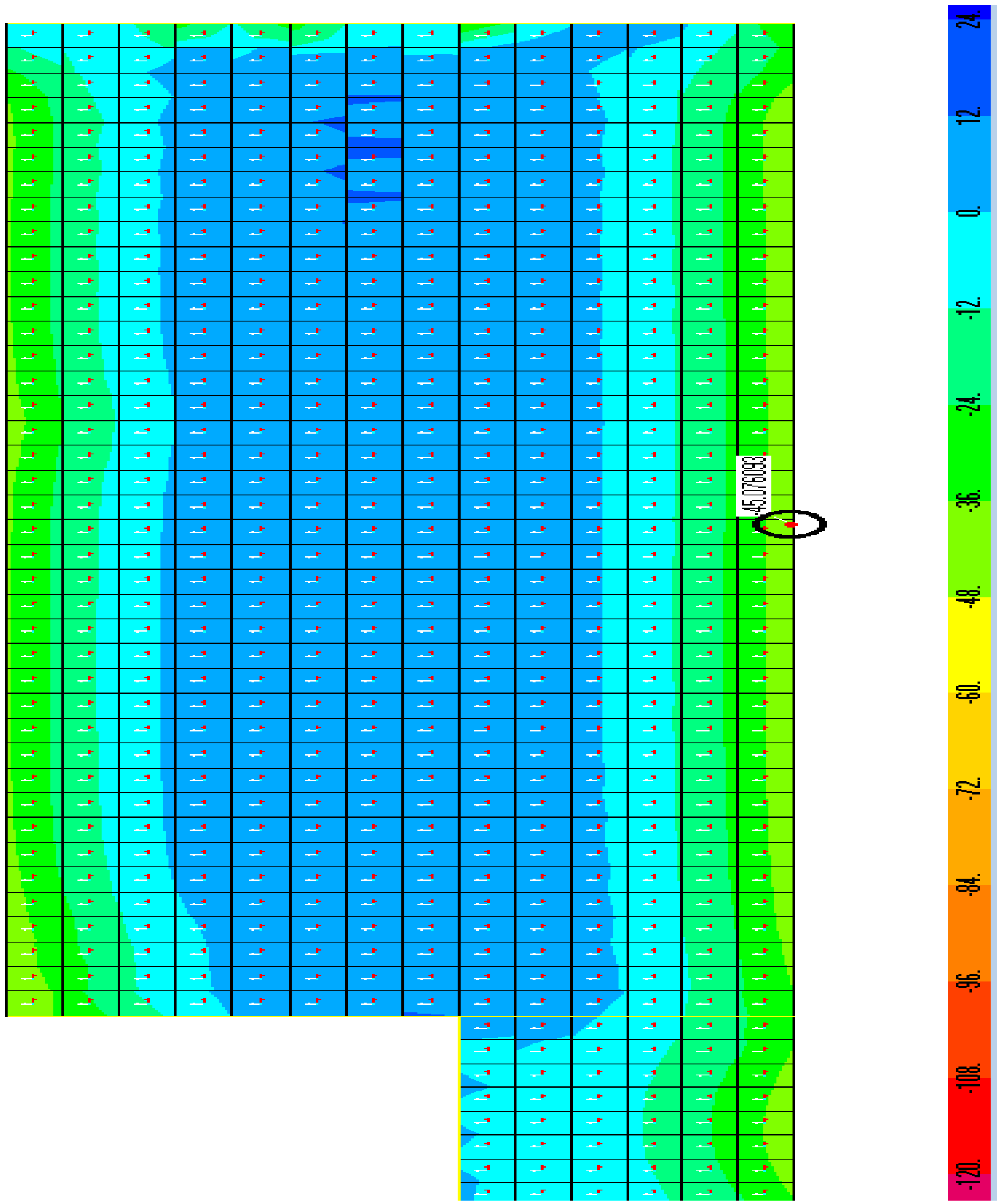



**Figure 5-10: Maximum negative moment in slab.**

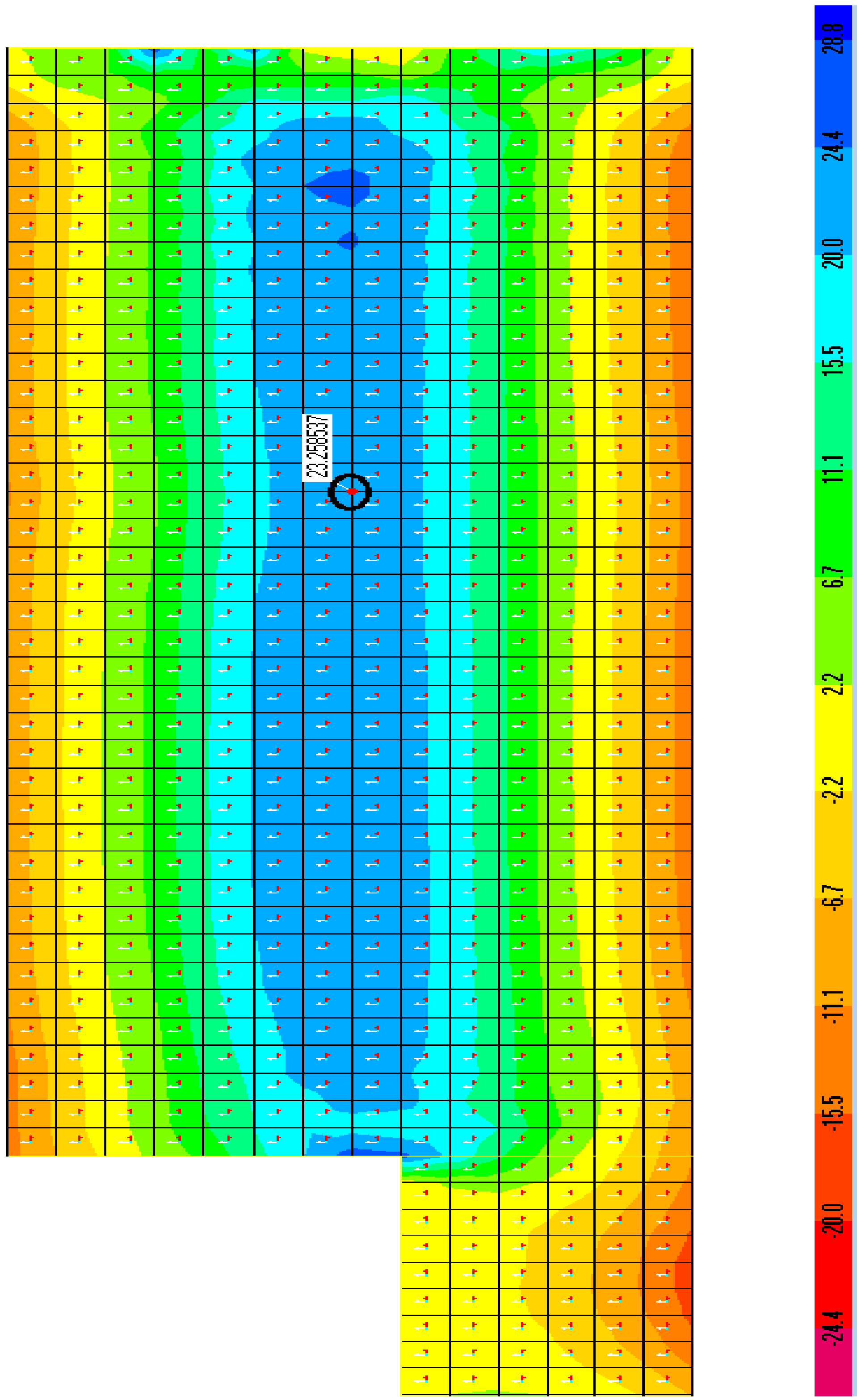



**Figure 5-11: maximum positive moment in slab.**

**For negative moment:**

Since the rib width = 0.52 m, the moment on each rib = 45 *0.52 = 23.4 KN.m / rib.

$$\rho = \frac{0.85 * f'c}{Fy} * \sqrt{1 - \frac{1-2.61\,Mu}{b * d^2 * f'c}} \;,$$

Where:

$M_u$ = 23.4 KN.m  $b_w$ = 120mm  d= 270mm  $f'c$ = 24 Mpa  $F_y$ = 420 MPa

$$\rho = \frac{0.85*28}{420} * 1 - \sqrt{1 - \frac{2.61*23.4*10^6}{120*270*270*24}} = 0.0072$$

$\rho_{min}$ in the slabs = $\frac{1.4}{Fy}$ = 0.0033 .

The steel ratio calculated is larger than the minimum ratio in the slabs, so the area of steel are calculated as follow:

$A_s = \rho * b * d$

Where:

ρ = 0.0072  b = $b_w$ = 120 mm  d = 270 mm.

$A_s$ = 0.0072*120*270 = 235 $mm^2$.

Use 12 mm diameter bars ----> area for one bar = 113 $mm^2$ .

Area of steel needed for the rib = $\frac{237}{113}$ = about 2 bars.

Use 2Ø12 mm top bars.

**For positive moment:**

By taking the maximum positive moment acting on the span which equals to about 23.3 KN.m/m since the rib width = 0.52 m , the moment on each rib = 23.3 *0.52 = 12.06 KN.m / rib .

$$\rho = \frac{0.85 * f'c}{Fy} * \sqrt{1 - \frac{1-2.61\,Mu}{b * d^2 * f'c}} \;,$$

Where:

$M_u$ = 12.06 KN.m  $b_w$ = 120mm  d= 270mm  $f'c$ = 24 Mpa  $F_y$ = 420 MPa

$$\rho = \frac{0.85*28}{420} * 1 - \sqrt{1 - \frac{2.61*8.5*10^\wedge 6}{120*270*270*24}} = 0.0015$$

$\rho_{min}$ in the slabs = $\frac{1.4}{Fy}$ = 0.0033 .

The steel ratio calculated is less than the minimum ratio in the slabs, (Use the minimum) so the area of steel are calculated as follow:

$A_s = \rho*b*d$

Where:

$\rho$ = 0.0033  b = $b_w$ = 120 mm  d = 270 mm.

$A_s$ = 0.0033*120*270 = 120 mm$^2$.

Use 10 mm diameter bars ----> area for one bar = 78.5 mm$^2$ .

Area of steel needed for the rib = $\frac{120}{78.5}$ = about 2 bars.

Use 2Ø10 mm bottom bars.

**Check the lab for shear:**

The maximum shear force acting on slab is shown in the figure (5-12) below:

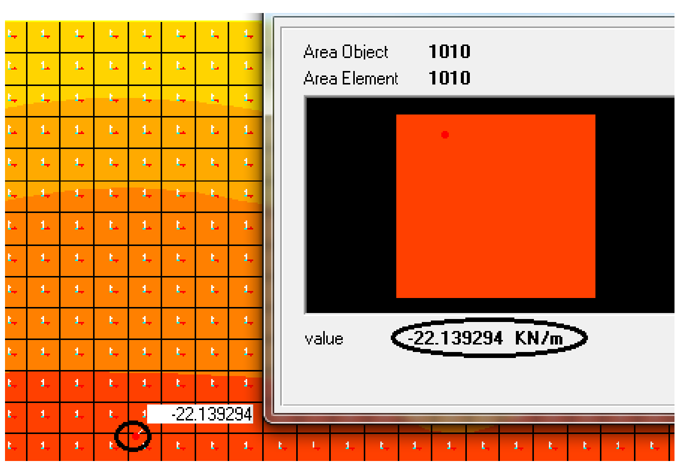



**Figure 5-12 : Maximum shear fore in slab.**

The ultimate shear force on one rib = 22.13*0.52 = 11.5 KN/rib.

$V_u$ = 2.13 KN, $V_c = 0.167 * \sqrt{f'c} * b * d = 0.167 * \sqrt{24} * 120 * 270 = 26.45$ KN.

$V_u /Ø$ = 11.5/ 0.75 = 15.34 KN < 26.45 KN

The slab thickness is suitable for resisting shear.

### 5.3.4 Beam design:

**1. Rectangular section**

The longitudinal reinforcement and shear reinforcement where obtained from sap as shown in the figures (5-13) and (5-14).

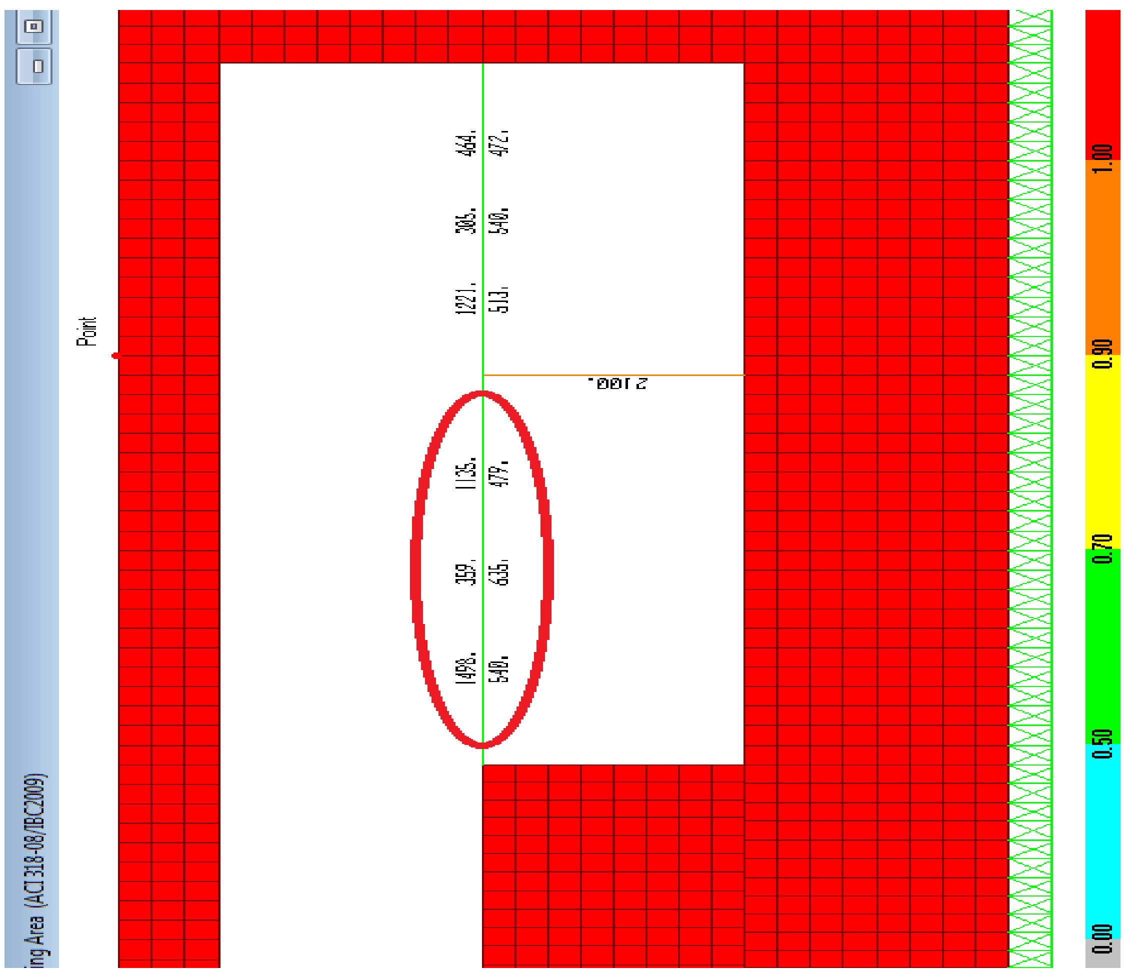
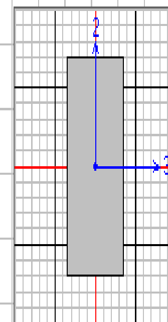



**Figure 5-13 : Longitudinal reinforcement for beam(4).**

ACI 318-08/IBC2009 BEAM SECTION DESIGN Type:Sway Intermediate Units: KN, mm, C (Summary)

| | | | | |
|---|---|---|---|---|
| Element | : 21 | D=600.000 | B=300.000 | bf=300.000 |
| Section ID | : beam 30 x60 | ds=0.000 | dct=60.000 | dcb=60.000 |
| Combo ID | : envelope | E=23.000 | fc=0.024 | Lt.Wt. Fac.=1.000 |
| Station Loc | : 135.000 | L=8000.000 | fy=0.414 | fys=0.414 |




| | |
|---|---|
| Phi(Bending): | 0.900 |
| Phi(Shear): | 0.750 |
| Phi(Seis Shear): | 0.600 |
| Phi(Torsion): | 0.750 |

Design Moments, M3

| Positive Moment | Negative Moment | Special +Moment | Special -Moment |
|---|---|---|---|
| 52150.513 | -267745.707 | 52150.513 | -52150.513 |

Flexural Reinforcement for Moment, M3

| | Required Rebar | +Moment Rebar | -Moment Rebar | Minimum Rebar |
|---|---|---|---|---|
| Top (+2 Axis) | 1466.296 | 0.000 | 1466.296 | 540.000 |
| Bottom (-2 Axis) | 351.657 | 263.743 | 0.000 | 351.657 |

Shear Reinforcement for Shear, V2

| Rebar Av/s | Shear Vu | Shear phi*Vc | Shear phi*Vs | Shear Vp |
|---|---|---|---|---|
| 0.250 | 52.166 | 98.849 | 41.886 | 48.974 |

Reinforcement for Torsion, T

| Rebar At/s | Rebar Al | Torsion Tu | Critical Phi*Tcr | Area Ao | Perimeter Ph |
|---|---|---|---|---|---|
| 1.449E-04 | 704.438 | 8.247 | 0.000 | 91709.229 | 1444.400 |

**Figure 5-14 : Shear reinforcement for beam(4).**

Longitudinal reinforcement:

The bars where computed based on the given area of steel from sap as show above after compering the result with the minimum area of steel for the beam section

1498 mm$^2$ → 4Ø25, 635 mm$^2$ →3Ø18, 1135mm2 → 3Ø25

As minimum = 600mm$^2$

Shear reinforcement:

Use 1Ø10 stirrup /10 cm c/c

2. **U section beam**

all the beams shown in fig (5-15) are modeled in SAP program as an area element to increase results accuracy , all U beams section have the same cross section dimension and they are classified in to two categories ( single span , cantilever) .

Taking the beam (2) shown in figure (5-15):

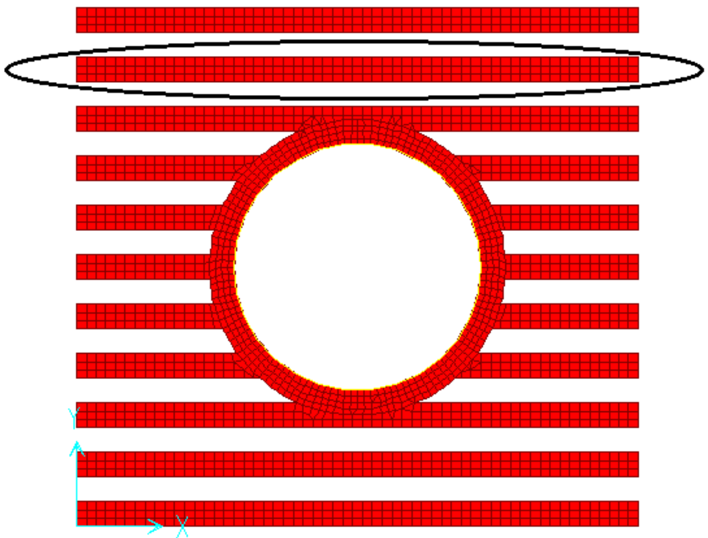



**Figure 5-15 : Beam 2.**

. The figure (5-16) below shows cross section in beam:

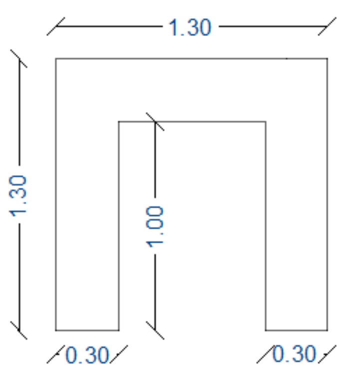



**Figure 5-16 : Cross section in beam 2.**

The final moment diagram from SAP software was as shown in figure (5-17) below:

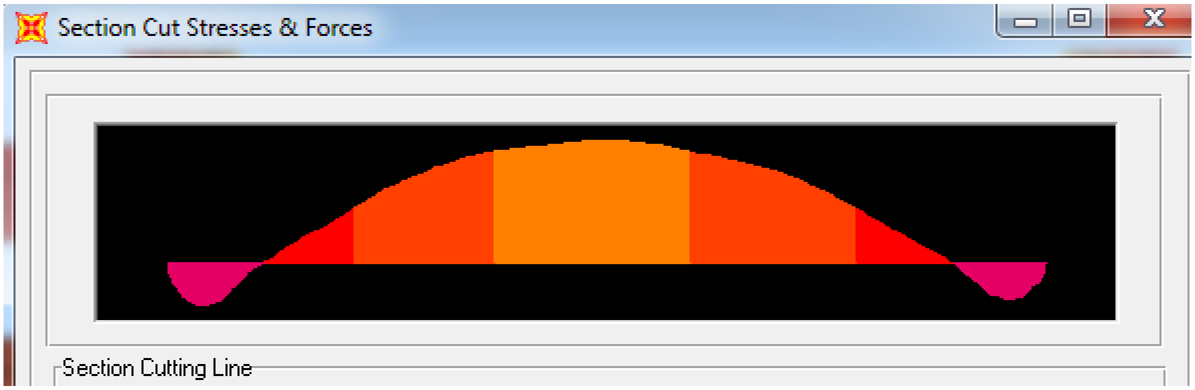



**Figure 5-17 : Moment diagram for beam 2.**

Note: The moment diagram shown above is not to scale since the section is done for the flange only and the rest of moment is distributed on web, to obtain the true value we should take the stress at a specific point and convert the stress to moment.

- Take the maximum ultimate negative stress as shown in fig (5-17)) acting on the beam ( 5700 KN/$m^2$) and design the beam according to this value of the stress by calculate the corresponding bending moment

$M_u$ max on the beam = $\frac{\sigma u\ (max) * I}{C}$

Where:

σu = maximum ultimate stress

I = Moment of inertia

C = Distance between centroid and a specific point on section

$M_u$ max on the beam = $\frac{5700 * 0.1528}{0.544} = 1601$ KN.m

**Check neutral axis:**

The U section was transformed to T equivalent section as shown in the figure (5-18) bellow:

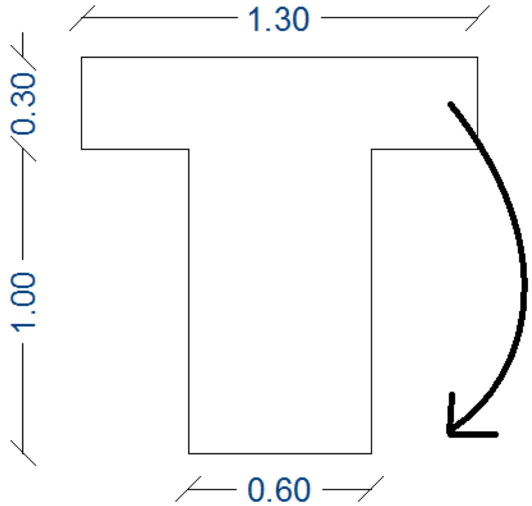



**Figure 5-18 : Equivalent T section for beam 2.**

Let the neutral axis (a) = tf = 1000 mm

Ø $M_n$* = 0.9 * $f'c$ * 0.85 * $b_f$ * $t_f$ * (d - $t_{f\,/}$ 2)

Where:

Ø $M_n$* = moment capacity.

fc′ = compressive strength of concrete.

d = effective depth.

Ø $M_n$*= 8151.8 KN.m

Mu < Ø $M_n$*, design same as rectangular

**<u>Note:</u>** take (h-d) = 60mm → d = 1240 mm.

The steel ratio according to ACI code ρ = $\frac{0.85*f'c}{Fy} * 1 - \sqrt{1 - \frac{2.61\,Mu}{b*d^2*f'c}}$ .

$M_u$= 1601 KN.m, f′c = 24 MPa, Fy = 420 MPa, b = 600 mm, d = 1240mm.

$$As = \frac{0.85*24}{420} * 1 - \sqrt{1 - \frac{2.61*1601}{600*1240*1240*24}} * bw *d = 3585 \text{ mm}^2$$

- $A_{s\,min}$ for T section = min of { max ((1.4/$F_y$) bw d) or (0.25 bw d fc′^0.5)/fy)) } or {0.25*$\sqrt{f'c}$ /$F_y$) }.

  $A_{s\,min}$ = 2480 $mm^2$

  $A_s > A_{s\,min}$, use $A_s$ = 3585 $mm^2$.

- take the maximum ultimate positive stress acting on the beam ( 6061 $KN/m^2$ )

  $M_u$ max on the beam = 1225 KN.m

  As = 2380 $mm^2$

**Calculating shear reinforcement in the beam:**

Shear analysis was done by SAP

Taking $V_u$ @ critical section (distance **d** from the face of support):

$V_u$ at critical section = 326 KN.

$V_u$/ Ø = 326 / 0.75 = 434.9 KN.

$V_c = 0.167 * \sqrt{f'c} * b * d = 0.167 * \sqrt{24} * 600 * 1240 = 607.4$ KN.

As we see $\frac{Vu}{Ø} > V_c/2$ , we need shear reinforcement.

$V_s$ = 260 KN.

$$Av / s = \frac{Vs}{Fy*d} = \frac{260*10^3}{420*1240} = 0.5 \text{ mm}^2/\text{mm}$$

Use three stirrup Ø 10 because of execution and geometry reasons

s1 = 15 cm, s2 = 25 cm

$$s_1 = Min\begin{Bmatrix} d/4 \\ 8d_b \\ 24d_s \\ 300\text{ mm} \end{Bmatrix}$$

$s_2 = d/2$

**Detailing:**

- for <u>negative</u> moment

  $As = 3585\ mm^2$

  If we try to use steel bars (Ø = 18 $_{mm}$), the bar area = 254 $mm^2$ .

  Number of bars needed = 3585 / 254.3 = 15Ø18 $_{mm}$

- for <u>positive</u> moment

  $As = 2512\ mm^2$

  If we try to use steel bars (Ø = 20 $_{mm}$), the bar area = 314 $mm^2$.

  Number of bars needed = 2512 / 314 = 8Ø20 mm

### 5.3.5 Column design:

The longitudinal rebar percentage for column (2) is shown in the figure (5-19)

A = ρ * b * d

Where:

A = area of steel.

ρ = rebar percentage.

b = width of the section

d = depth of section.

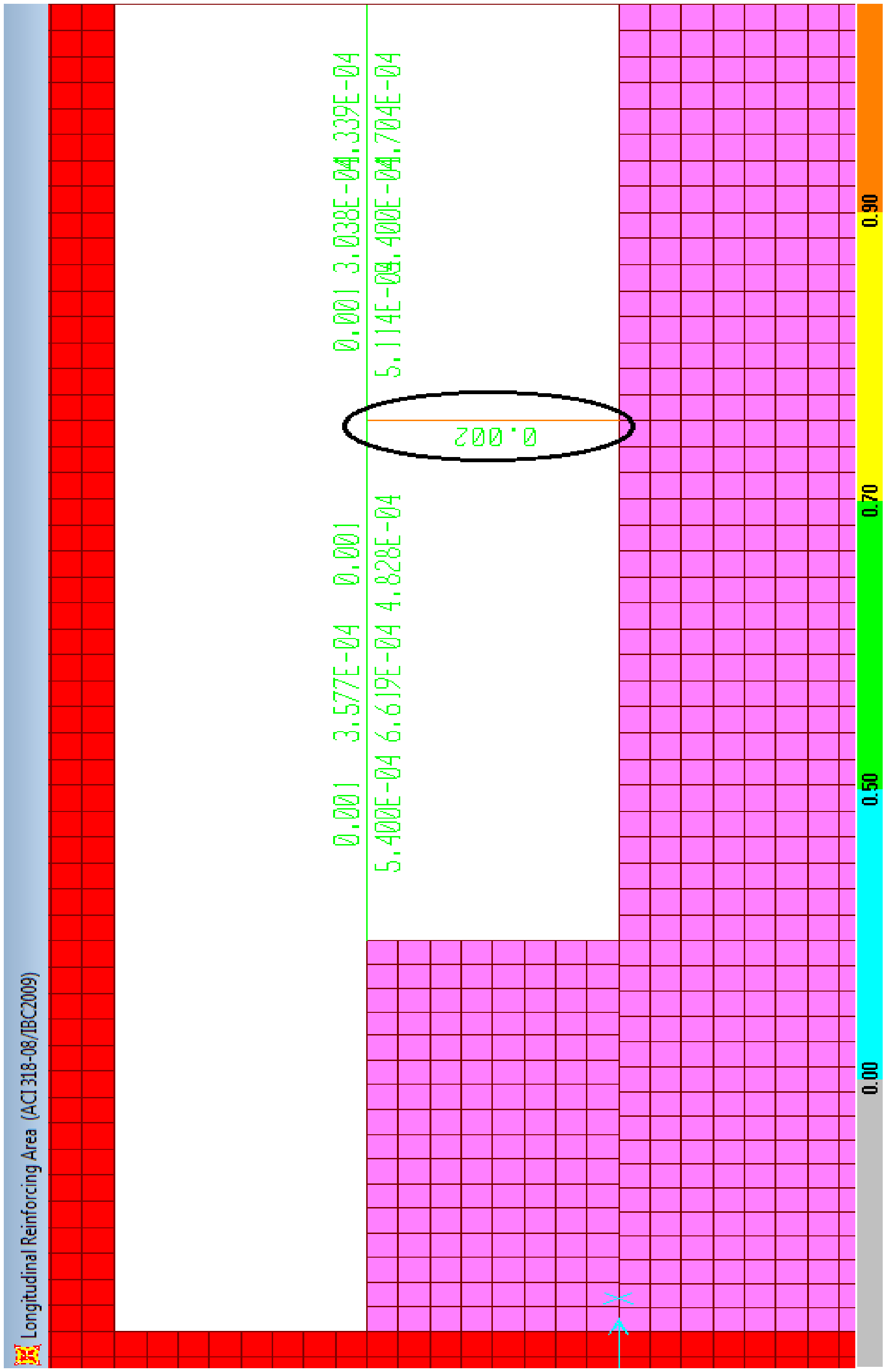



**Figure 5-19 : Rebar percentage for column (2).**

$As = 0.02*300*700 = 4200\ mm^2$

**Note:** ACI318-08 requires the spacing between longitudinal bars in column should not exceed 150 mm.

Assume we want to use (Ø 20) mm bars.

Area for each Bar = 314mm$^2$.

4200/314 = 14 bars,

Use 14Ø 20 mm.

**Spacing between stirrups in the column as ACI-318 requires:**

$$s_0 = Min\begin{Bmatrix} \text{least column dimension/2} \\ 8d_b \\ 24d_s \\ 300\text{ mm} \end{Bmatrix}$$

$$s_1 = Min\begin{Bmatrix} \text{least column dimension} \\ 16d_b \\ 48d_s \end{Bmatrix}$$

$l_d$ = development length of the steel reinforcement in tension

$$l_0 = Max\begin{Bmatrix} \text{clear height of column/6} \\ \text{maximum column dimension} \\ 450\text{ mm} \end{Bmatrix}$$

As shown in the figure (5-20) below:

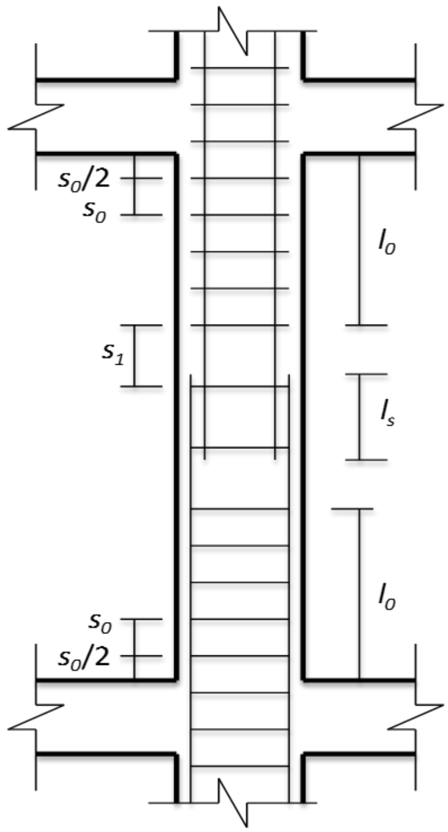



**Figure 5-20 : Stirrup details for column.**

### 5.3.6 Seismic design:

In order to perform the analysis and the design the following parameters will be used based on UBC-97 design code.

- Peak ground acceleration (PGA): since the building is located in Nablus city, from PGA map Z = 0.2

- Soil profile: the expected soil profile for the site is ($S_D$).

- Importance factor (I) : I = 1.25

- Seismic coefficient ( $C_v$) : $C_v$ = 0.4

- Seismic coefficient ( $C_a$) : $C_a$ = 0.28

- Structural system coefficient (R):

The system will be designed as sway intermediate, so Structural system coefficient (R) = 5.5 in the x-direction, but in the y- direction the value is reduced to (R) = 4.5 because there are shear walls in this direction.

**Period:**

The interval of time between successive occurrences of the same state in an oscillatory.

The period from sap program should be close enough to the period calculated by hand.

**Period calculations:**

Period by hand:

$$T_{(building)} = C_T*(hn)^{\left(\frac{3}{4}\right)}$$

Where:

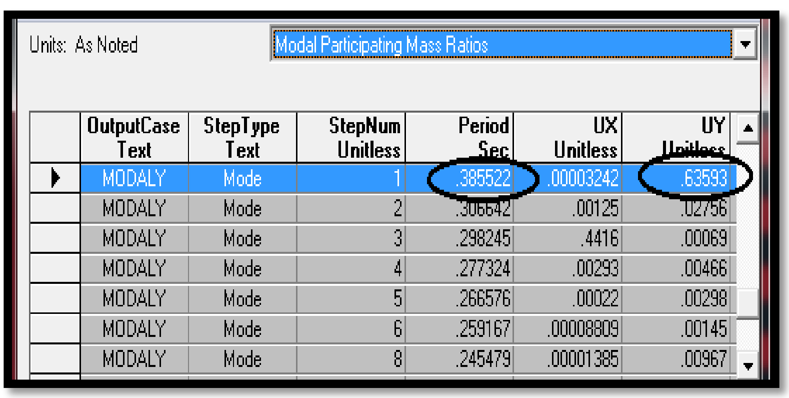
$C_T = 0.0488.$

$h_n =$ height of the building in meters.

$$\text{So, } T_{(building)} = 0.0488*(15.3)^{\left(\frac{3}{4}\right)} = 0.377 \text{ sec}$$

Period from sap:

The period was selected for the highest modal participation ratio as shown in figure (5-21).


Units: As Noted    Modal Participating Mass Ratios

| OutputCase Text | StepType Text | StepNum Unitless | Period Sec | UX Unitless | UY Unitless |
|---|---|---|---|---|---|
| MODALY | Mode | 1 | .385522 | .00003242 | .63593 |
| MODALY | Mode | 2 | .306642 | .00125 | .02756 |
| MODALY | Mode | 3 | .298245 | .4416 | .00069 |
| MODALY | Mode | 4 | .277324 | .00293 | .00466 |
| MODALY | Mode | 5 | .266576 | .00022 | .00298 |
| MODALY | Mode | 6 | .259167 | .00008809 | .00145 |
| MODALY | Mode | 8 | .245479 | .00001385 | .00967 |

**Figure 5-21 : Mass participation ratio and period.**

As a result, the manual calculation is close to SAP results.

**Seismic force**

The structure will be subjected to earthquake force so, in this part we will calculate this forces in different ways and compare them.

**Manually by equivalent static method:**

$V = C_s * W$

V = Base shear.

$C_s$ = seismic coefficient.

W = weight of the building

**Base shear in x-direction:**

$V_x = \frac{Cv*I}{Rx*T} * w = \frac{0.4*1.25}{4.5*0.377} * 18178 = 5357.5$ KN.

$V_{max} = \frac{2.5*Ca*I}{Rx} * w = \frac{2.5*0.28*1.25}{4.5} * 18178 = 3534.6$ KN.

$V_x = V_{max} = 3534.6$ KN.

**Base shear in y-direction:**

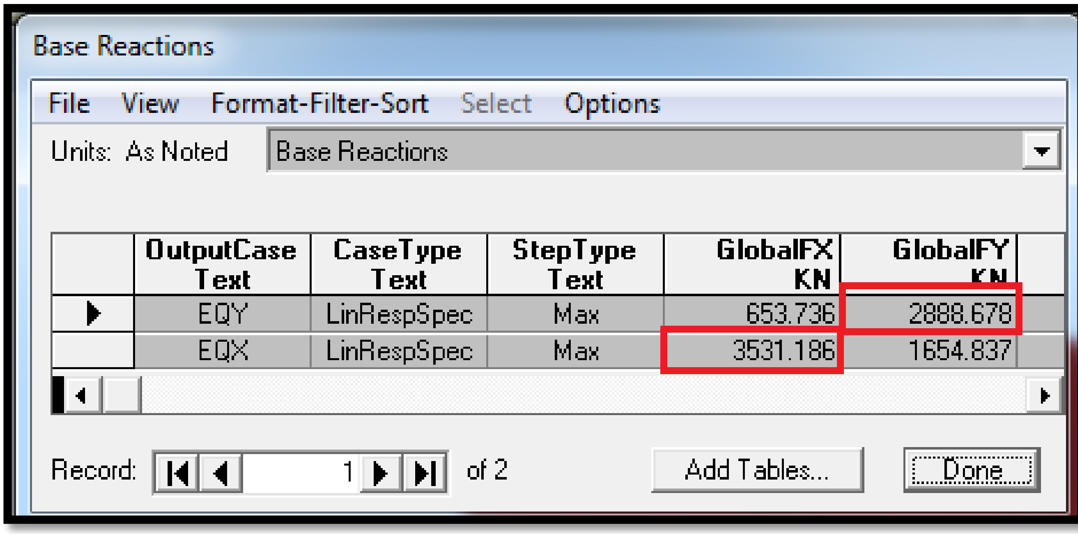
$V_y = \frac{Cv*I}{Ry*T} * w = \frac{0.4*1.25}{5.5*0.377} * 18178 = 4383.4$ KN.

$V_{max} = \frac{2.5*Ca*I}{Ry} * w = \frac{2.5*0.28*1.25}{5.5} * 18178 = 2891.9$ KN.

$V_y = V_{max} = 2891.9$ KN.

**By sap program:**

The figure (5-22) below shows the base shear force obtained from SAP.


Base Reactions

File View Format-Filter-Sort Select Options

Units: As Noted | Base Reactions

| | OutputCase Text | CaseType Text | StepType Text | GlobalFX KN | GlobalFY KN |
|---|---|---|---|---|---|
| ▶ | EQY | LinRespSpec | Max | 653.736 | 2888.678 |
| | EQX | LinRespSpec | Max | 3531.186 | 1654.837 |

Record: 1 of 2 Add Tables... Done

**Figure 5-22 : Base shear reactions.**

The results obtained from hand calculation and sap program are very close to each other.

### 5.3.7 Design of shear wall

From sap2000 program

$V_u$ = 906 KN, $M_u$ = 6130 KN.m, $N_u$ = 4576 KN, H = 10.15 m, B = 22.7 m.

b (thickness) = 0.25 m, fc′ = 24 MPa.

Check:

The dominant force in the shear wall is shear force since H/B<2, (10.15/22.7 = 0.47) <2

$ØV_c = 0.167 * 0.75 * 0.8 * \sqrt{24} * 250 * 22700 = 2780$ KN, ØVc > Vu → Safe

**For boundary:**

Boundary zone = 4*b = 4*0.25 = 1 m.

$\rho = 1\ \%$ , $As = \rho*b*h = 0.01 * 250*1000 = 2500\ mm^2$

Use 14Ø16.

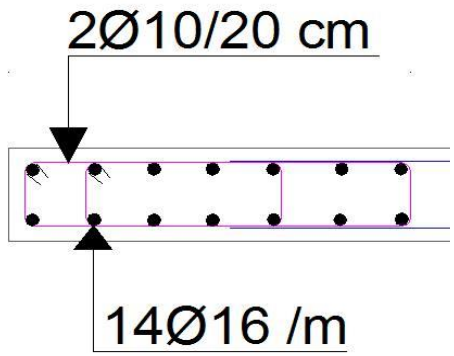



**Figure 5-23: Boundary reinforcement.**

**For vertical:**

$\rho = 0.3\ \%$

$As = \rho*b*h = 0.003*250*1000 = 750\ mm^2$

Use 4Ø12 / m for each layer

**For horizontal:**

$\rho = 0.25\ \%$

$As = \rho*b*h = 0.0025*250*1000 = 625\ mm^2$

Use 4Ø12 / m for each layer

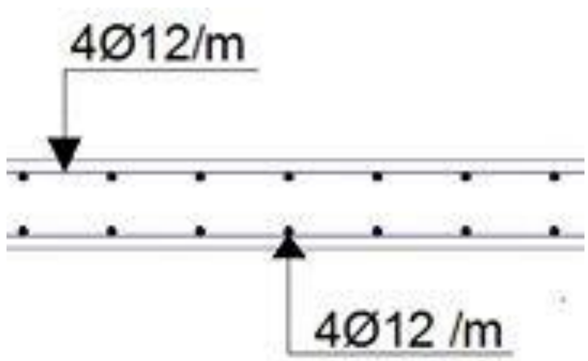



**Figure 5-24 : Web reinfrocement**

### 5.3.8 Design of Stairs:

Staircases provide means of movement from one floor to another in a structure. Staircases consist of a number of steps with landings at suitable intervals to provide comfort and safety for the users.

The stair case is simply supported by beams and shear wall as shown sap model figure (5-23):

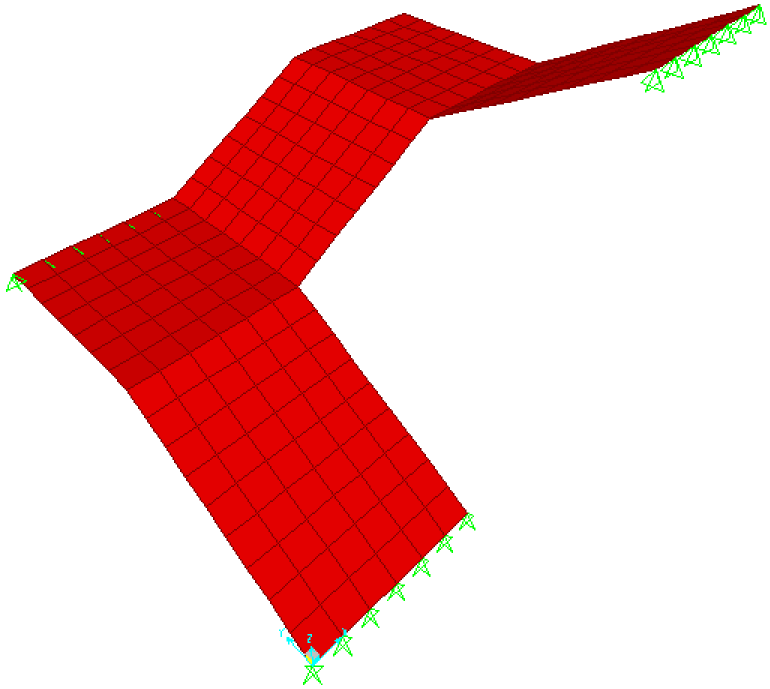


**Figure 5-25 : Stairs 3D model.**

### 5.3.9 Design of Dome

The Dome is modeled on Sap program as figure (5-24) shows:

Dimensions:

- The diameter of the dome = 10m.

- The maximum height of the dome = 5 m.

- Thickness of dome = 0.12 m

  Loads:

- Super imposed load = 0.5 KN / $m^2$.

- Live load = 1 KN/$m^2$.

- Snow load = 0.5 KN/$m^2$.

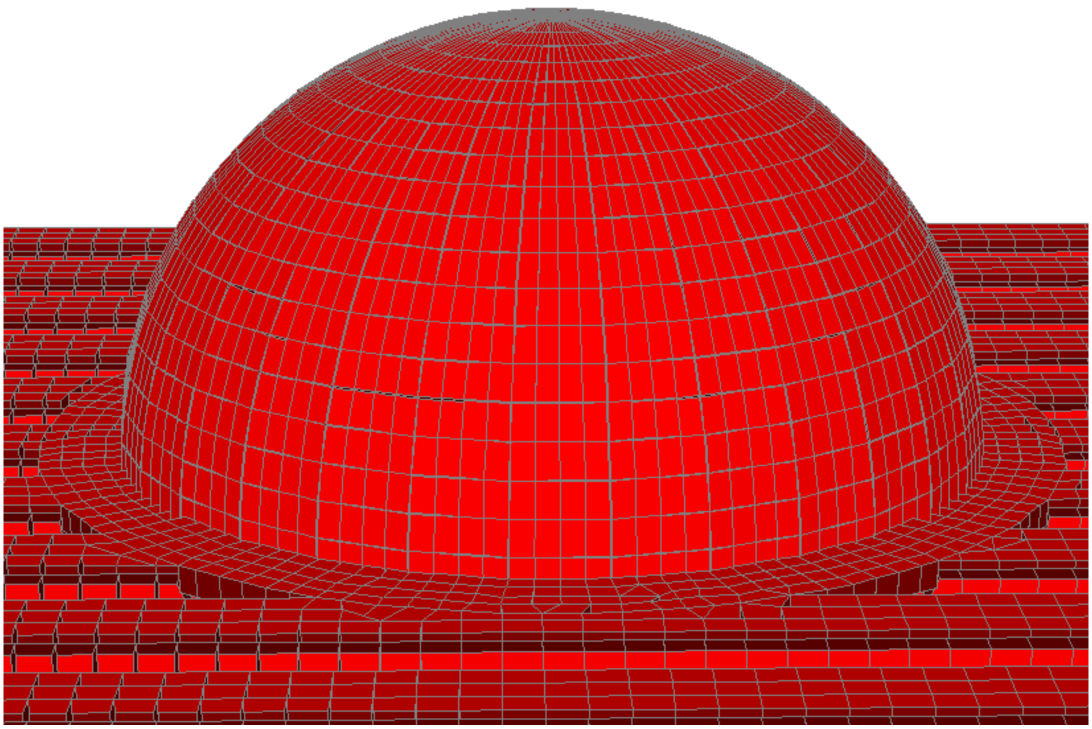


**Figure 5-26 : 3D Sap model for Dome.**

Dead load and seismic force are computed by SAP program based on geometry concrete density and response spectrum analysis.

Design:

The dome is designed based on the internal forces obtained from Sap program.

- **Vertical reinforcement calculation**

The dome is subjected to compression and tension forces in the direction of meridian, thus the design will be as follow

**For tension force:**

The figure (5-25) bellow shows tension force in the meridian direction (f 22):

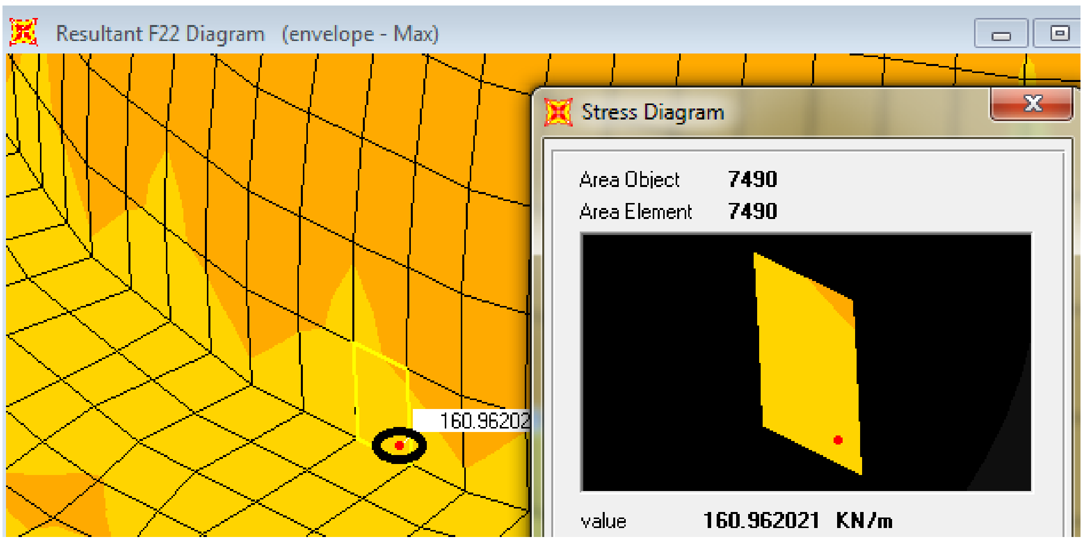



**Figure 5-27 : Tension force in the meridian direction (f 22).**

As = $\frac{f22}{0.9 * fy} = \frac{161*10^3}{0.9*420}$ = 425.9 $mm^2$

Where:

As = area of steel.

F22 = force in the meridian direction.

$fy$ = yielding of steel bars.

**For compression force:**

The figure (1-26) bellow shows compression force in the meridian direction (f 22):

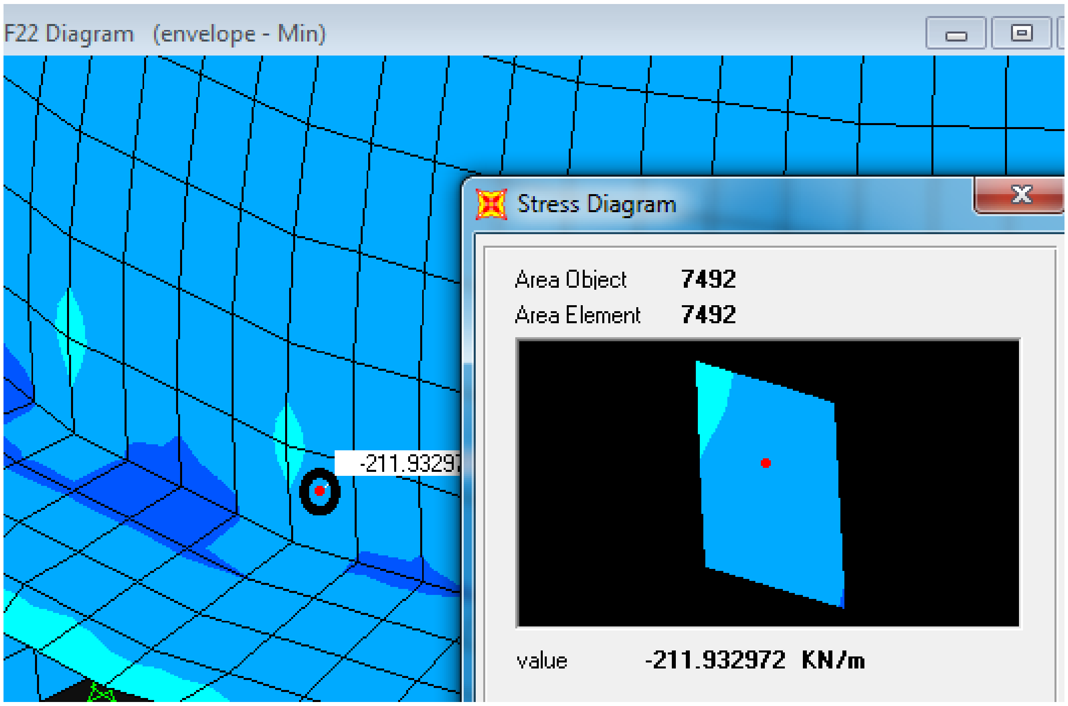



**Figure 5-28 : Compression force in the meridian direction (f 22).**

$\sigma = \frac{f22}{h} = \frac{213}{0.12} =$ 1775 KN/m$^2$ = 1.77 MPa < 0.3 fc′ = 7.2 MPa.

Where:

σ = axial stress.

F22 = force in the meridian direction.

h= section thickness.

As min = 0.002 * b * h = 0.002 * 1000 * 120 = 240 mm$^2$.

As min < As for tension, As = As for tension.

Use 6Ø10/m.

**-Horizontal reinforcement calculation.**

The dome is subjected to compression and tension forces in the direction of Hoop, thus the design will be as follow:

**For tension force:**

The figure (5-27) bellow shows tension force in the meridian direction (f 11):

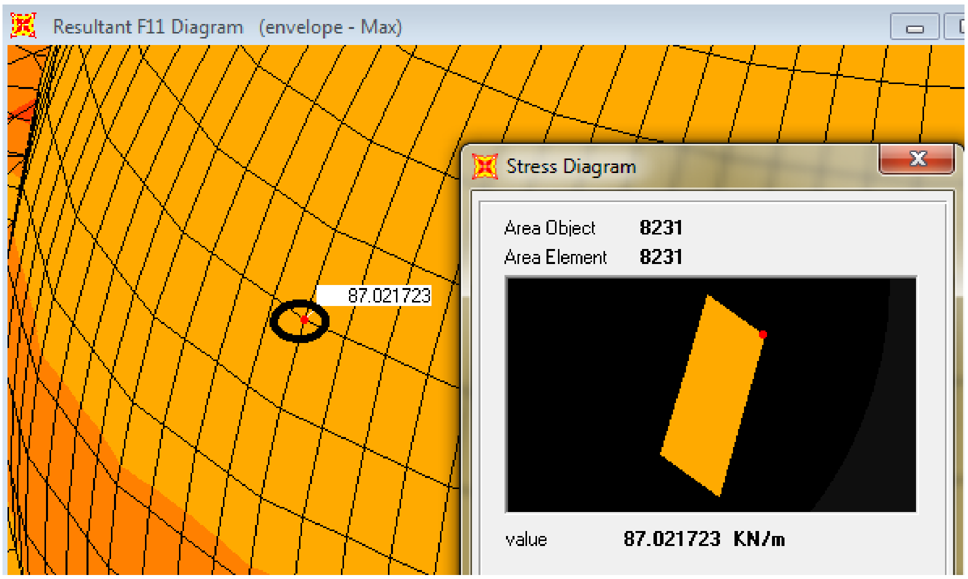



**Figure 5-29 : Tension force in the Hoop direction (f11).**

As = $\frac{f11}{0.9*fy}$ = $\frac{87*10^3}{0.9*420}$ = 230 $mm^2$

Where:

σ = axial stress.

F11 = force in the Hoop direction.

h= section thickness.

**For compression force:**

The figure (5-28) bellow shows compression force in the meridian direction (f11):

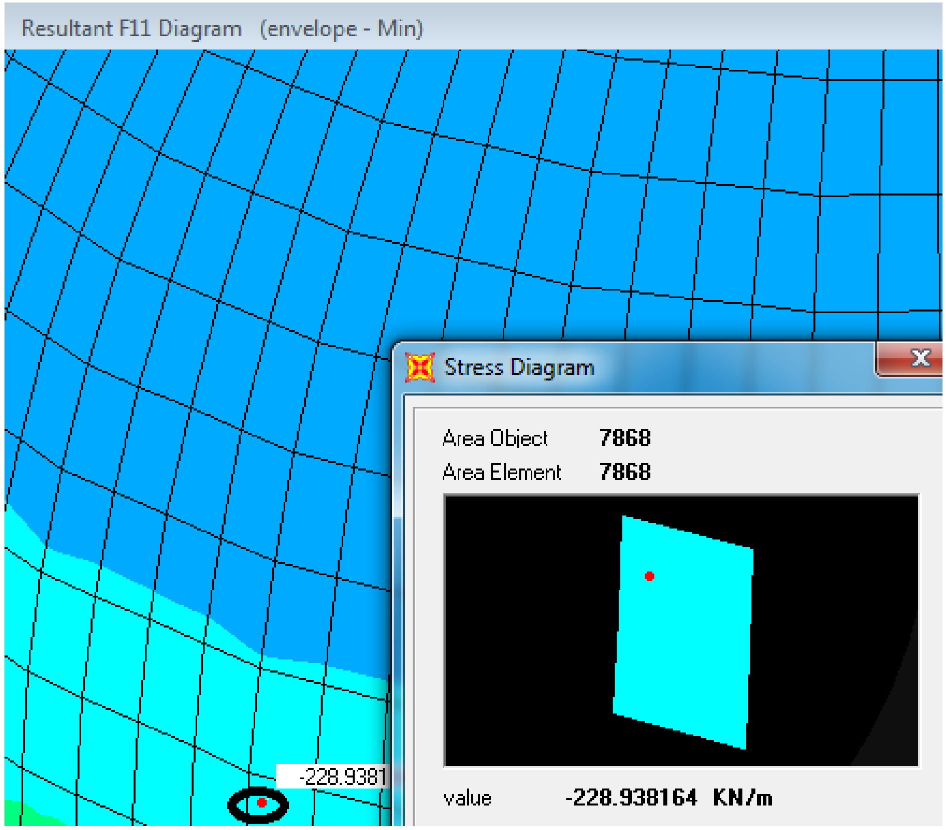



**Figure 5-30 : Compression force in the Hoop direction (f11).**

$\sigma = \dfrac{f11}{h} = \dfrac{228}{0.12} = 1900\ KN/m^2 = 1.9\ MPa < 0.3\ fc' = 7.2\ MPa.$

As min = 0.002*b*h = 0.0025*1000*120 = 300 $mm^2$.

As min > As for tension, As = As min.

Use 4Ø10/m.

**Dome reinforcement details:**

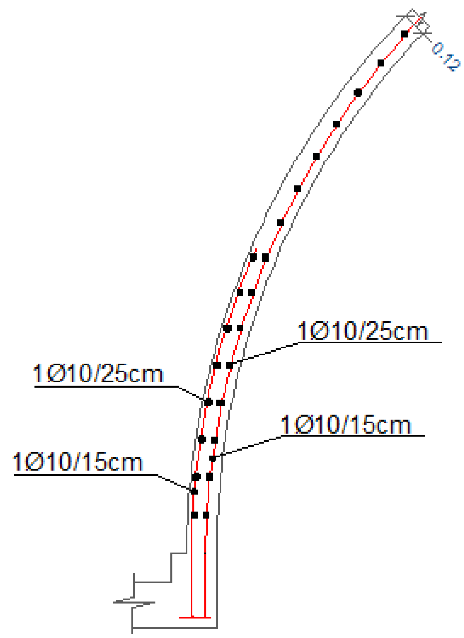



**Figure 5-31: Dome details.**

### 5.3.10 Footing design

**Wall footing:**

Base reaction from Sap model was determined due to service loads in order to calculate preliminary dimensions for the footings and analyze the footings to determine the final dimensions (length, width, thickness) and required area of steel in both directions, the figures (5-30), (5-31) shows wall footing plan and section.

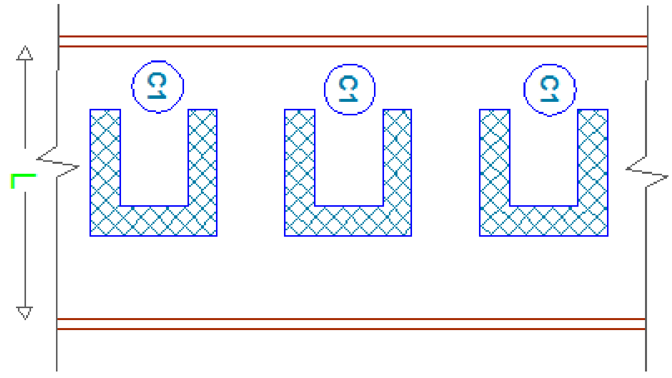



**Figure 5-32: Wall footing plan.**

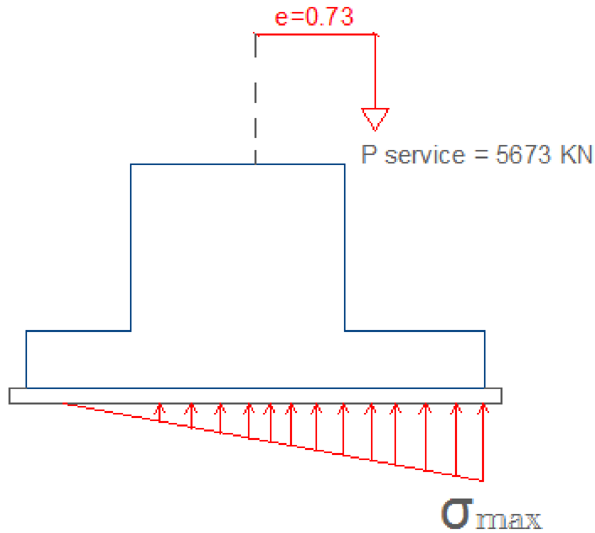



**Figure 5-33: Wall footing section**

**<u>Footing area:</u>**

Assume L = 2.8 m

$Q_{(allowable)}$ = 200 KN/m$^2$

$P_{(service)}$ = 5733.3 KN

$M_{(service)}$ = 4185 KN

Note: service loads is multiplied by 1.1 to account for footing and backfill weights.

$e = \frac{M\ (service)}{P\ (service)} = \frac{5733.3}{4185}$ = 0.73,   L/6= 0.46

For one column $P_{(service)}$ = 5733.3/11= 512 KN

e > L/6, so σ (max) = $\frac{2*p\ service}{1.5*l(l-e*2)} = \frac{2*512}{1.5*2.8(2.8-0.73*2)} =$ 182 < q allowable = 200 KN/m2

Section dimension is ok.

**Thickness:**

The footing should be thick enough to resist the loads without any type of failure which include wide beam shear failure and punching shear failure.

**Wide beam shear check:**

Pu = (1.4 *P $_{(service)}$) = 1.4*512 = 717 KN

σ (max) = 254 KN/M2

$V_u$ = σ max (x-d)

Where:

$V_u$ = Ultimate shear force.

σ (max) = maximum ultimate stress under the footing .

x = clear length for footing cantilever.

D = effective depth.

Ø $V_c$ = Concrete shear capacity

$V_u$ = 254*(0.86-0.d)

Ø $V_c$ = 0.75*0.167 * $\sqrt{f'c}$ * b * d = 0.167 * $\sqrt{24}$ * 1000 * d

Ø $V_c$ = Vu, solve for unknown d

d = 250 mm, use h = 350 mm

**Reinforcement:**

For short direction:

$\sigma_u$ = 254 KN/m$^2$

$M_u = \frac{\sigma u * X^2}{2}$ = 93.9 KN.m/m.

Where:

$M_u$ = Ultimate moment.

$\sigma_u$ = Ultimate stress .

x = clear length for footing cantilever.

$$\rho = \frac{0.85*24}{420} * 1 - \sqrt{1 - \frac{2.61*93.9*10^6}{1000*290*290*24}} = 0.00317$$

As per meter = ρ * b* d = 0.00317*1000*290 = 920 $mm^2$.

$As_{(minimum)}$ = 0.0018 * b* h = 0.0018*1000*350 = 630 $mm^2$, $A_{s\ min} < A_s$, use $A_s$

Use 6Ø14 mm / m.

For long direction:

As = $As_{(shrinkage)}$

$As_{(shrinkage)}$ = 0.0018*b*h

$As_{(shrinkage)}$ = 0.0018 *1000*2800 = 1764 $mm^2$

Use 6Ø12 mm / m.

Where:

$As_{(shrinkage)}$ = area of steel for shrinkage

b = footing width

h = footing height

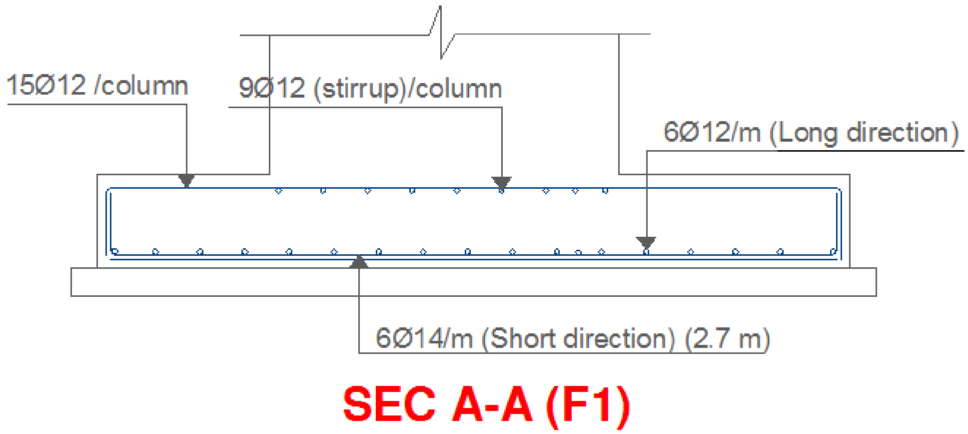



**Figure 5-34: Wall footing details.**

### 5.3.11 Design of Tie Beams

Tie beams can be used to transfer the column loads to foundations in some structural systems. Here, tie beams are used to support the slab on grade since large spans are used without interior column in addition to the bearing capacity of soil is relatively small, as a result tie beams will be used to prevent ground slab from settlement.

Tie beam dimension will be 500mm deep with 300 mm width.

After analysis and design by SAP2000, all beams have $\rho < \rho_{min}$

Thus, all ground beams were reinforced with minimum steel.

$\rho_{min} = 1.4 / Fy = 0.0033$

b = 300mm, h = 500 mm

As = 0.0033 * 300 * 440 = 435.6 mm

Use 4 Ø14 for positive moment

Use 4Ø14 for negative moment

**Shear reinforcement:**

For Av/s = 0.025

S = Av/ (Av/S) = 1.57/0.025 = 62 cm

Use 1 Ø 10mm/25 cm.

### 5.3.12 Design of Minaret:

**Analysis and design**

The strategy of the design is to calculate wind and earthquake load respectively and decide about the load combination which will be used in analysis and design procedure by using sap program, the figure (5-33) below shows 3D model for minaret:

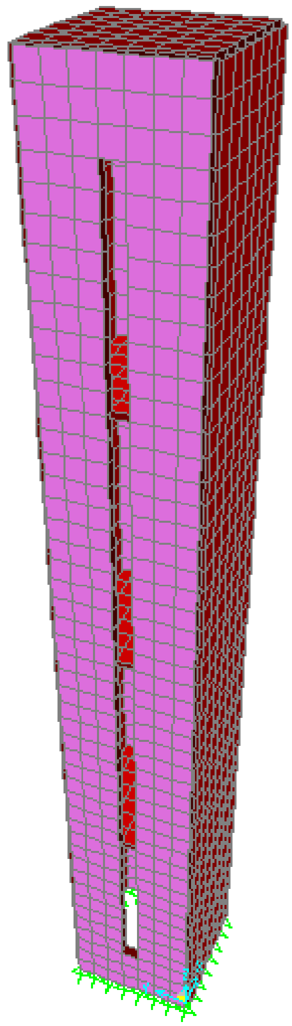


**Figure 5-35 : Minaret 3D model.**

**Calculation of the base from lateral forces:**

1. **Base shear from the wind load according to UBC-97 code**

$P = C_e * C_q * q_s * I_w$

Where:

$P$ = wind pressure.

$C_e$ = taken from table depending on zone exposure and height of building.

$C_q$ = pressure coefficient.

$Q_s$ = wind stagnation pressure.

$I_w$ = importance factor.

Note that the height of minaret is 24 m and the exposure is C

$P = 1.3 * 0.8 * 1 * 1.25 = 1, 3\ KN/m^2$

Base shear = pressure * area exposed to wind

Base shear = 109.2 KN

2. **Base shear from earthquake load according to UBC97**

- Peak ground acceleration (PGA): since the project is located Nablus city (PGA) = 0.2 According to (PGA) map for Palestine.
- Soil profile: the expected soil profile for the site is ($S_D$).
- Importance factor (I): I = 1.25
- Seismic coefficient ($C_v$): $C_{v\,=}$ 0.4
- Seismic coefficient ($C_a$): $C_{a\,=}$ 0.28
- Structural system coefficient (R): R= 3.5

**Period calculations:**

Period by hand:

$T_{(building)} = C_T * (hn)^{(\frac{3}{4})}$

So, $T_{(building)} = 0.0488 * (24)^{(\frac{3}{4})} = 0.53$ sec.

Period from sap as shown in figure (5-34) below:

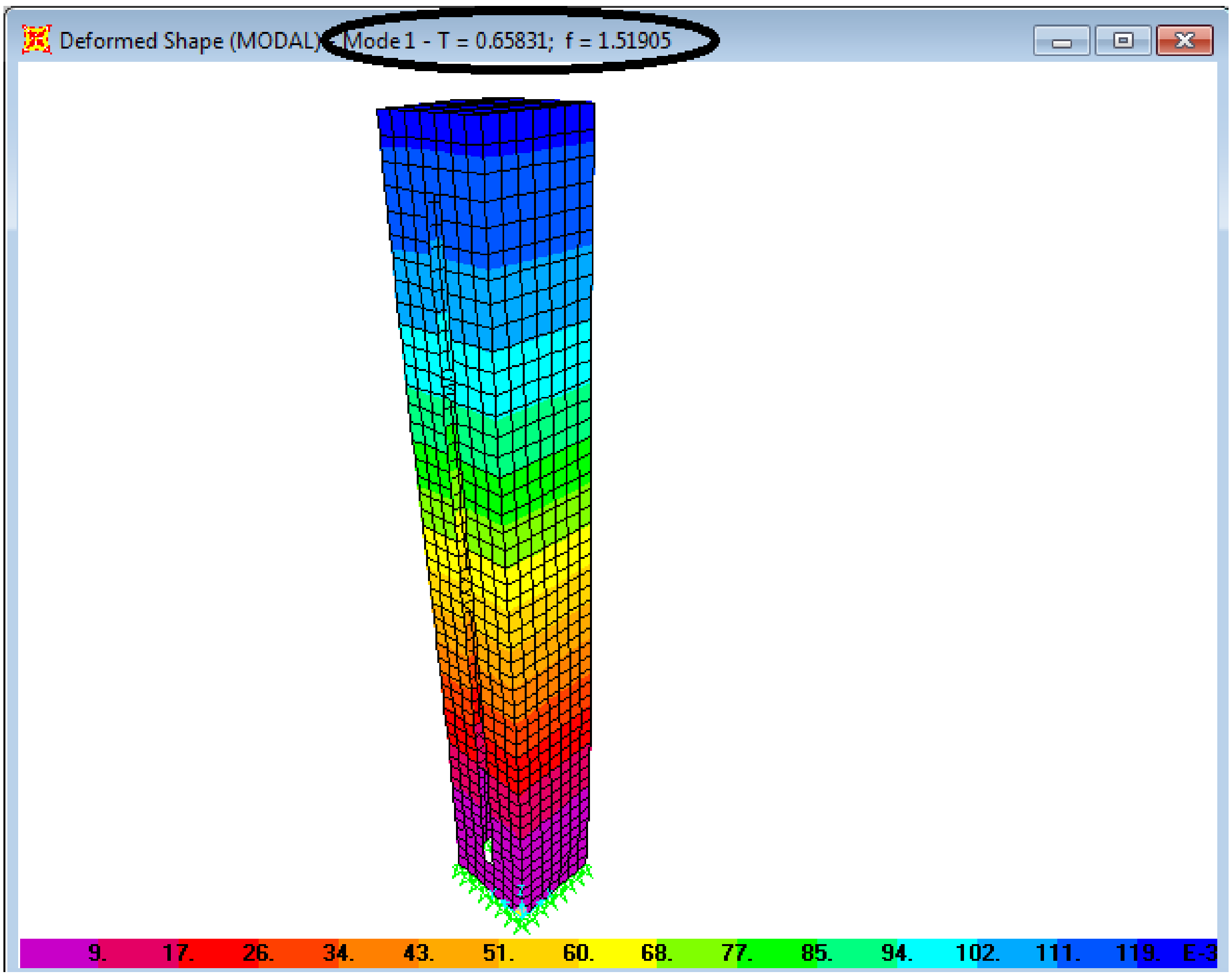



**Figure 5-36 : Minaret 3D model period.**

**Seismic force**

The structure will be subjected to earthquake force so, in this part we will calculate this forces in different ways and compare them.

**Manually by equivalent static method:**

V = Cs *W

V = Base shear.

Cs = seismic coefficient.

W = weight of the building

Base shear:

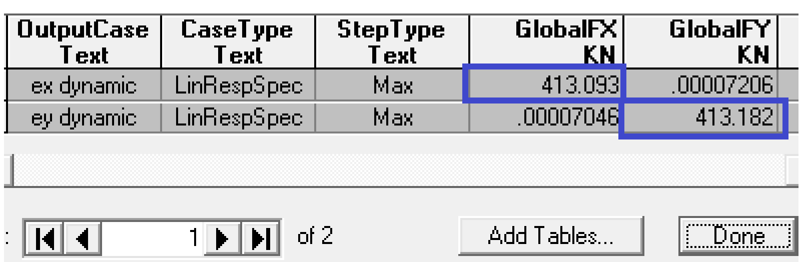
$V = \frac{Cv*I}{Rx*T} * w = \frac{0.4*1.25}{3.6*0.529} * 2128 = 446.9$ KN.

$V_{max} = \frac{2.5*Ca*I}{Rx} * w = \frac{2.5*0.28*1.25}{3.6} * 2128 = 413.7$ KN.

$V = V_{max} = 413.7$ KN.

**By sap program:**

The figure (5-35) below shows the base shear force obtained from sap.



| OutputCase Text | CaseType Text | StepType Text | GlobalFX KN | GlobalFY KN |
|---|---|---|---|---|
| ex dynamic | LinRespSpec | Max | 413.093 | .00007206 |
| ey dynamic | LinRespSpec | Max | .00007046 | 413.182 |



**Figure 5-37 : Minaret base shear reactions**

The results obtained from hand calculation and sap program are very close to each other.

By comparing the results (wind base shear = 109.2 KN and quake base shear = 413KN) the quake force will be used in analysis and design procedure.

**Section design:**

**<u>Note:</u>**

Ultimate compression strength for concrete = 0.3 fc′ = 7.2 MPa

Ultimate compression strength for concrete = $\frac{1}{3} * \sqrt{fc'}$ = 1.63 MPa

Vertical reinforcement calculation:

The ultimate maximum compression stress where calculated by sap program as shown in fig (5-36),

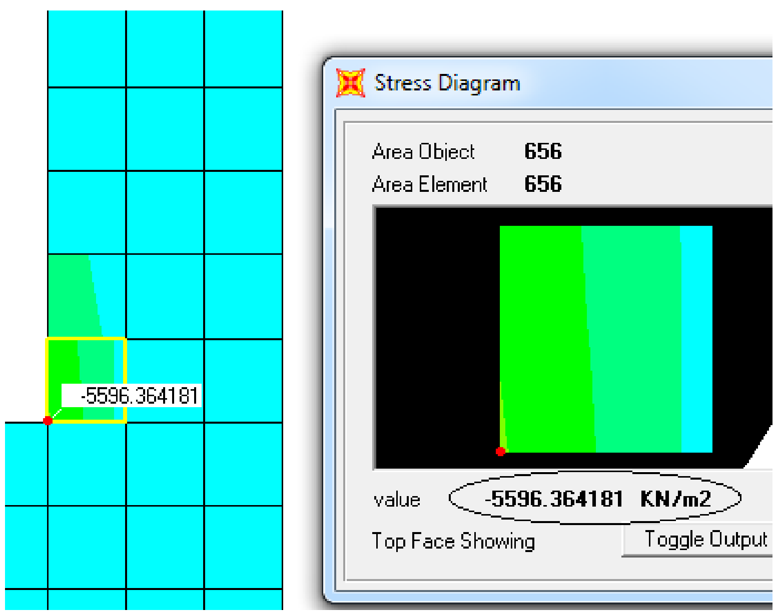



**Figure 5-38 : Maximum compression stress for Minaret.**

Check compression stress:

5.596 MPa < 7.2 MPa → section dimension OK.

The maximum ultimate Tension stress where calculated by sap program as shown in fig (5-28).

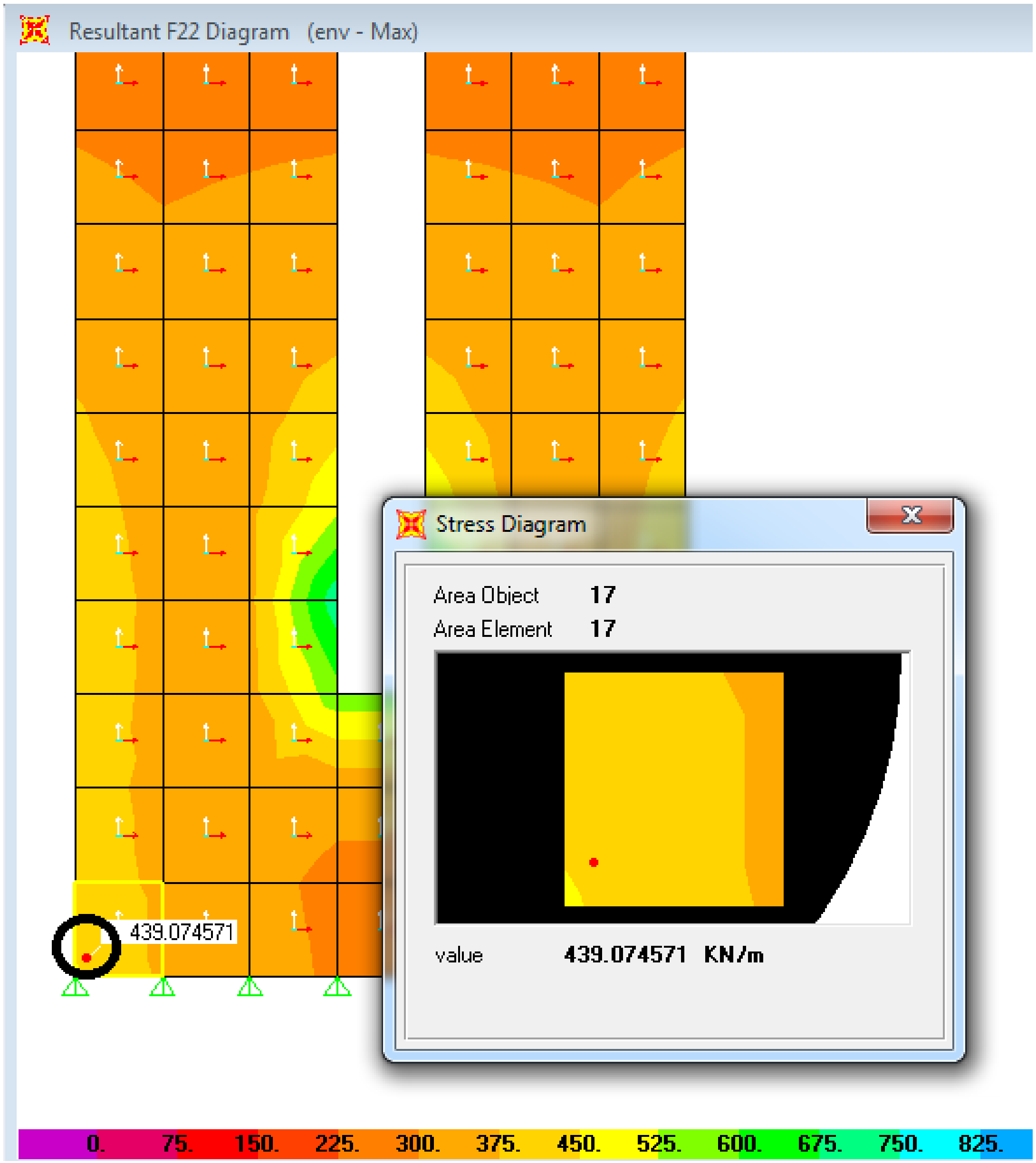



**Figure 5-39 : Maximum tension stress for Minaret.**

Check tension stress:

1.92 MPa > 1.63 MPa

Tension stress is greater than the allowable

$$A_s = \frac{\sigma}{fy*0.9}$$

Where:

As = area of steel.

σ = stress

$fy$ = yielding stress for steel.

As = $\frac{440*10^3}{420*o.9} =$ 1164 $mm^2$

Assume we want to use (Ø 14) mm bars.

Area for each Bar = 153 $mm^2$.

1164/153 = 8 bars

Section thickness is 25 cm so bars should be distributed on two layers

Use 4 Ø14 mm/ layer.

**Horizontal reinforcement:**

Taking Vu @ critical section (distance d from the face of support):

$V_u$ at critical section = 413 KN.

$V_u$/ Ø = 413 / 0.75 = 266.6 KN.

$V_c$ = 0.167 * $\sqrt{f'c}$ * b * d = 0.167 * $\sqrt{24}$ * 3500 * 1750 = 5000 KN.

$A_s$ we see $\frac{Vu}{Ø}$ < $V_c$ . So minimum horizontal steel will be provided

$A_s$ = 0.0025*b*h = 0.0025*250*1000= 625 $mm^2$

$A_s$ for one layer = AS/2 = 312.5 $mm^2$

Use 4 Ø 12 /m for each layer.

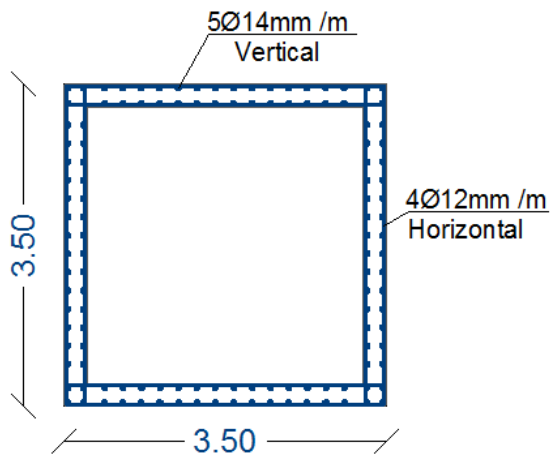



**Figure 5-40 : Reinforcement details for minaret.**

**Check over turning:**

The footing should be design to resist over turning due to lateral forces, for minaret case the lateral forces are due to earthquake so the factor of safety against overturning is 1.5

**The over turning moment:**

Over turning moment= (earthquake base shear) *((2/3)*height of minaret)

Over turning moment = 413*(2/3)*24 = 6619.2 KN

**Resisting moment:**

Assume footing dimension equals (6.5x 6.5 x1) m, ɣ soil = 18 KN/$m^3$ , soil height over footing=3.5 m

Resisting moment = soil load + dead load

Resisting moment = 14214 KN

Factor of safety against overturning = $\frac{\text{Resisting moment}}{\text{Over tuning moment}} = \frac{14214}{6619.2} = 2.14$

2.14 > 1.5 OK.

**Check allowable deflection:**

The maximum elastic deflection from sap is shown in fig (5-30)

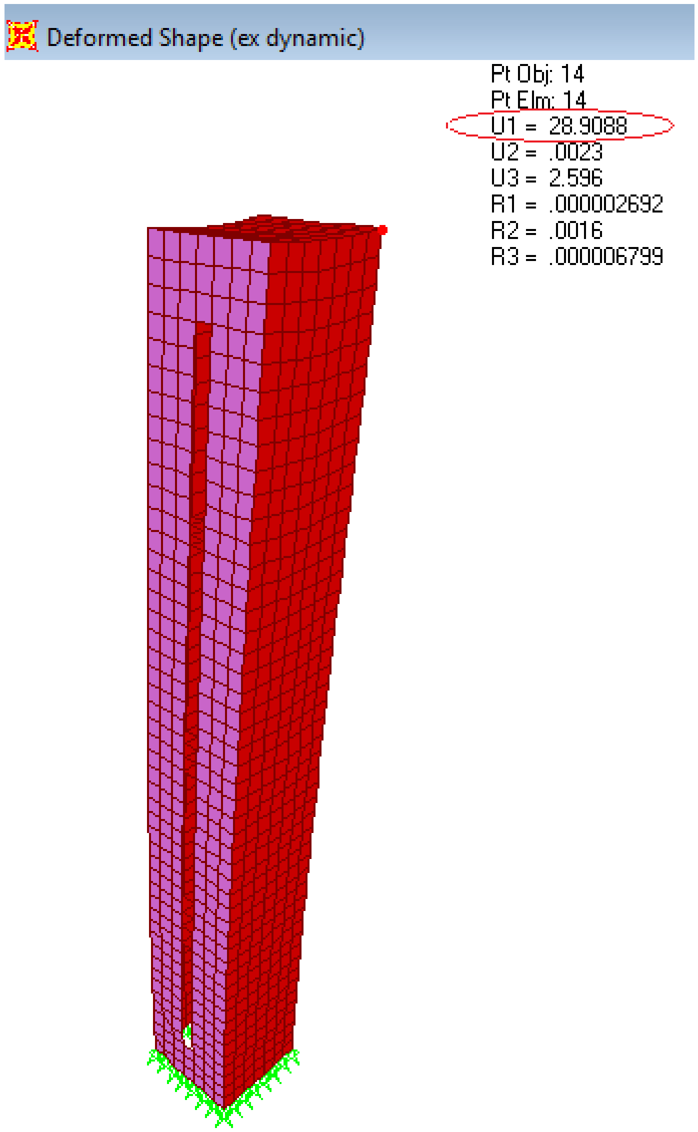



**Figure 5-41 : Maximum elastic lateral deflection.**

To obtain the maximum plastic deflection the elastic deflection should be multiplied by amplification factor (Cd), the factor depends on structural system coefficient (R)

From UBC-97, R table.

$C_d = 2$, for R =3.6

Maximum deflection = Cd * elastic deflection = 2*28.9 = 57.8 mm

Maximum allowable deflection = 0.0025 * H → for buildings with period less the 0.7 sec

Maximum allowable deflection = 0.0025*24 = 57.6 mm < 57.8

It could be consider acceptable since values are relatively close

**Minaret Footing design:**

Base reaction from Sap model was determined due to service loads in order to calculate preliminary dimensions for the footings and analyze the footings to determine the final dimensions (length, width, thickness) and required area of steel in both directions.

Footing area:

Assume footing area 6.5 x 6.5 x 0.8 m

$P_{Dead\ (service)} = 4738$ KN

$M_{(service)} = 6619.2$ KN

$e = \frac{M\ (service)}{P\ Dead\ (service)} = \frac{6619.2}{4738} = 1.39$, L/6= 1.08

$e > L/6$, so $\sigma_{(max)} = \frac{2 * p\ service}{1.5 * l(l - e*2)} = \frac{2*4738}{1.5*6.5(6.5-1.39*2)} = 260 < 4/3$ q allowable = 266

Section dimension is ok.

Thickness:

The footing should be thick enough to resist the loads without any type of failure which include wide beam shear failure and punching shear failure.

1. **Wide beam shear check**

$M_u = 6619$ KN.

$P_u$ = (1.4 * Dead load) = 1.4 * 4738 = 6725.6 KN

$\sigma_{(max)}$ = 304.4 KN/M2

$V_u = \sigma_{max}$ (L-d)

Where:

$V_u$ = Ultimate shear force.

$\sigma_{(max)}$ = maximum ultimate stress under the footing .

L = footing clear cantilever length.

d = effective depth.

Ø $V_c$ = Concrete shear capacity

Vu = 304.4*(1.5-0.72) = 237.4 KN

Ø $V_c = 0.75 * 0.167 * \sqrt{f'c} * b * d = 0.167 * \sqrt{24} * 1000 * 920 = 563.3$ KN.

Ø $V_c$ > Vu, The footing thickness is suitable for resisting wide beam shear.

2. **Punshing shear check**

Ø $V_{c\,(punshing)}$ = 14885 KN

$Vu^*_{(punshing)}$ = 5977 KN.

Ø $V_{c\,(punshing)} > Vu^*_{(punshing)}$, The footing is suitable for wide beam shear resisting shear

**Reinforcement:**

The reinforcement in both direction are the same since L=B

$\sigma_u$ = 304.4 KN.

$M_u = \frac{\sigma u * X2}{2}$ = 342.45 KN.m/m.

$$\rho = \frac{0.85*24}{420} * 1 - \sqrt{1 - \frac{2.61*342.45}{1000*720*720*24}} = 0.0017$$

$A_s$ per meter = $\rho$ * b* d = 0.0017*1000*720 = 1270 $mm^2$.

$A_{s\ min}$ = 0.0018 * b* h = 0.0018*1000*800 = 1440 $mm^2$, As min > As, use $As_{min}$

Use 8Ø16 mm / m for each direction

The detailing as shown in the figure (5-40) below:

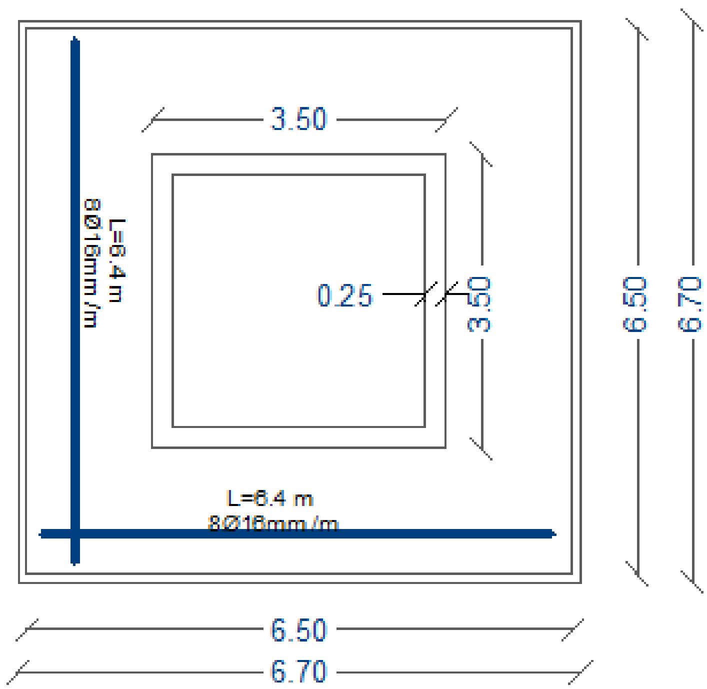



**Figure 5-42 : Reinforcement details for minaret footing.**

# CHAPTER 6

# ELECTRICAL LIGHTING

## 6.1 Electric lighting design.

The main aims of artificial lighting (as for day lighting) are:

Functional – so tasks can be carried out:

- Accurately.
- Comfortably.
- Safely.

**Table 6-1: Lighting requirments for mosque. [10**

| Annex | Minimum illumination(Lux) | Maximum illumination(Lux) |
|---|---|---|
| **Pray hall** | 350 | 400 |
| **Minber** | 450 | 550 |
| **Mihrab** | 350 | 420 |
| **Exit door** | 85 | 180 |
| **Passages** | 125 | 200 |

**Uniformity**

In order to avoid problems of fatigue and to generate a feeling of wellbeing in an interior it is important to create a uniform distribution of luminance. This involves maintaining a certain uniformity of illuminance at the work plane, expressed as the ratio of minimum to mean illuminance. For the ambient lighting in the pray hall interiors, it should be minimum (0.6).

**The Recommended reflectance in mosque is:**

Using surfaces with a high reflectance will help with even light distribution. Suitable levels are:

- Walls not less than 0.6.
- Ceilings not less than 0.7.
- Floor coverings with as high a reflectance as possible.

After calculating the daylight factor in the pray hall, the daylight is almost the same as the desired lux inside the pray hall (400 lux).

Therefore, we are choosing the suitable lamps and luminaries for the pray hall and for the library area.

**Pray hall.**

Height of Room: 6 m.

Total Luminous Flux: 240000 lm.

Total Load: 4800W.

Maintenance factor: 0.80.

Suspended height: 0.300 m.

u0=0.68.

Average [lx]: 400

Efficacy = 72.

The figures (6.1), (6-2) show the luminaries and the lamps are used for the pray hall.

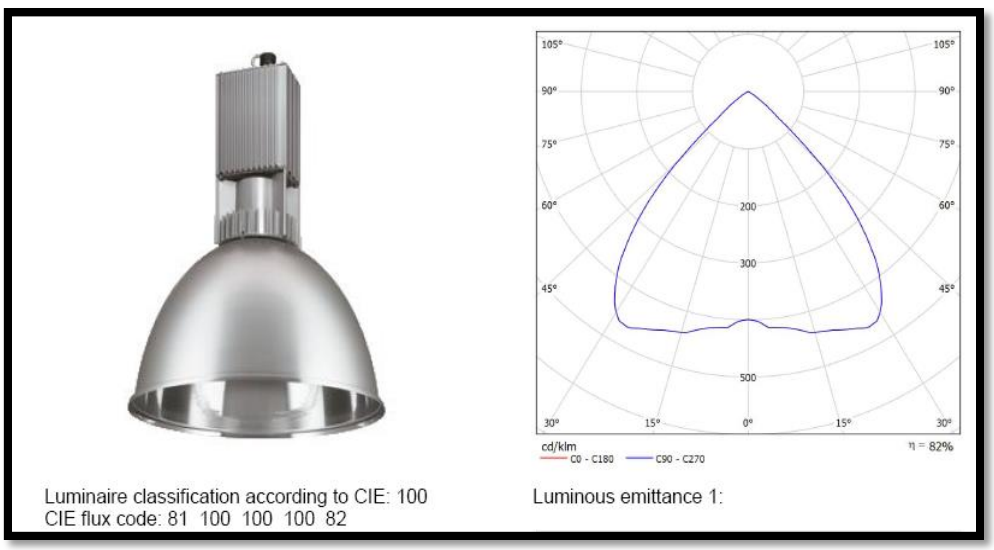



**Figure 6-1:The luminaries and the lamps are used for the pray hall.**

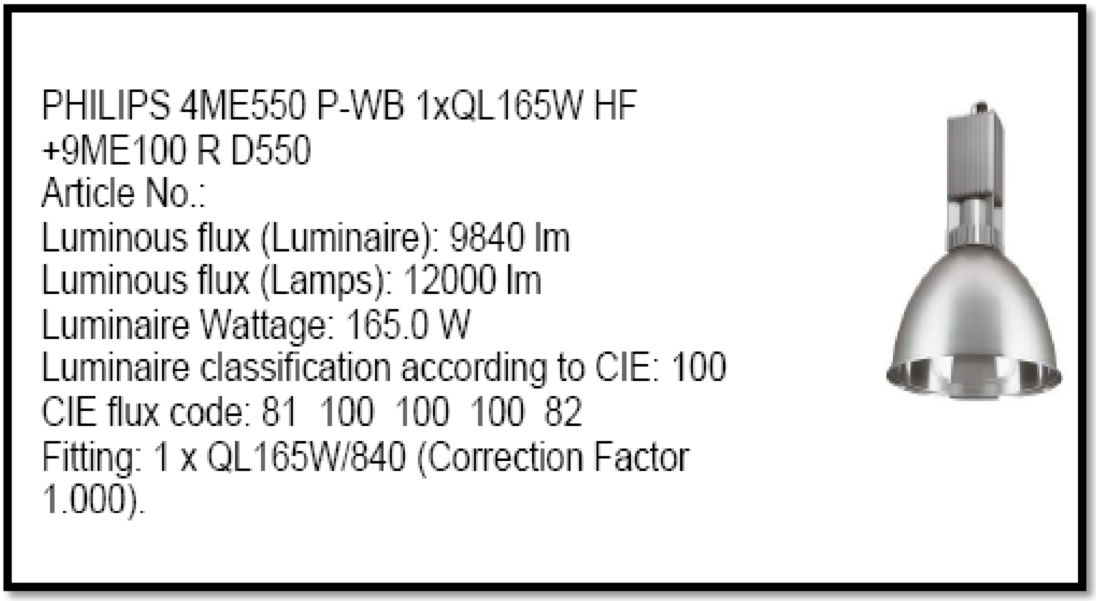



**Figure 6-2: The type lamps are used for the pray hall**

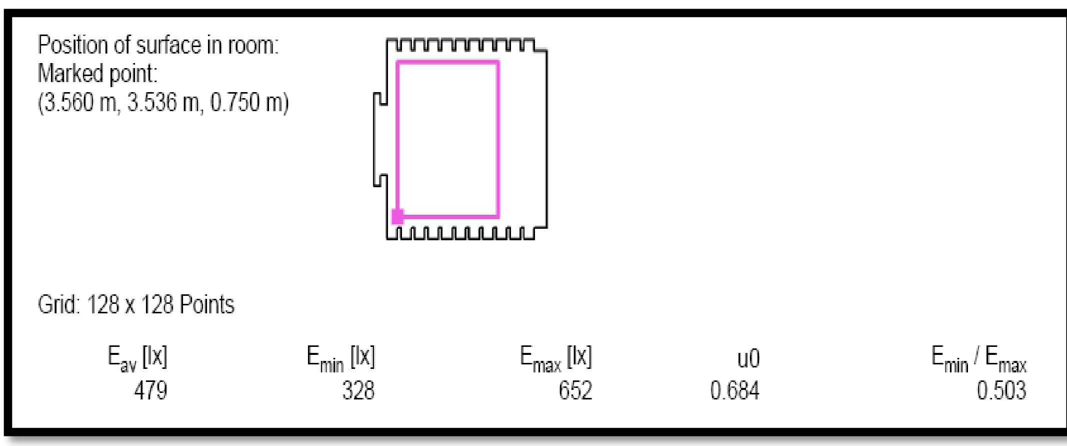



**Figure 6-3: Uniformity-value in the pray hall.**

The figure (6-4) show Isolines for pray hall.

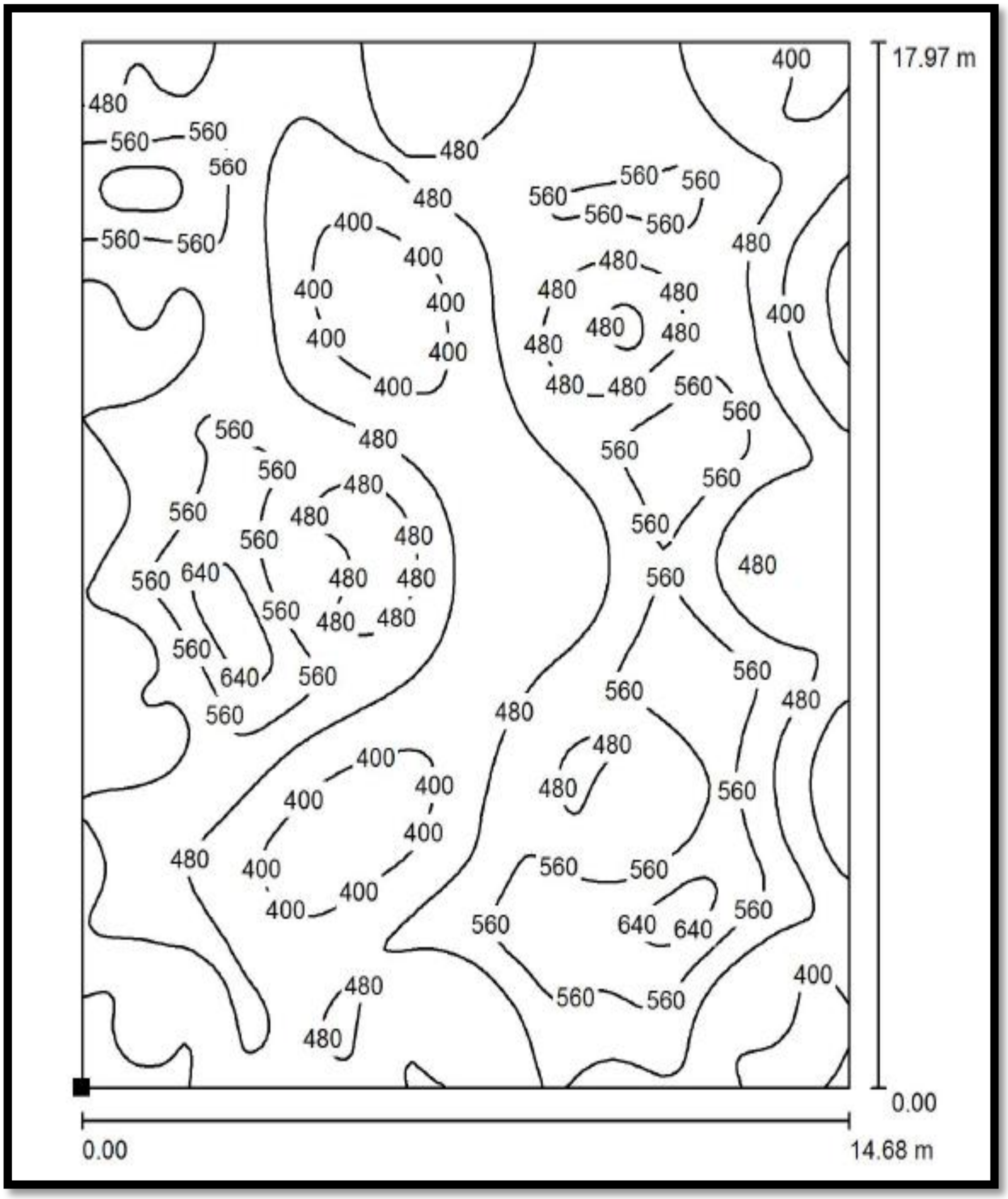



**Figure 6-4: Isolines.**

The figure (6-5) Show interior views for the mosque.

**Figure 6-5: Interior view for the mosque.**

The figure (6-6) Show pray hall lighting unit's distribution by DIALUX program.

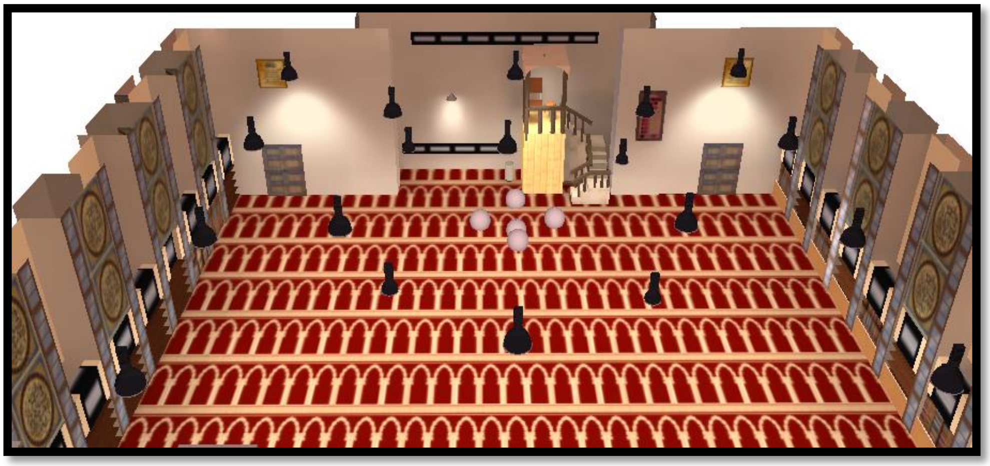


**Figure 6-6: Pray hall lighting unit's distribution by DIALUX program**

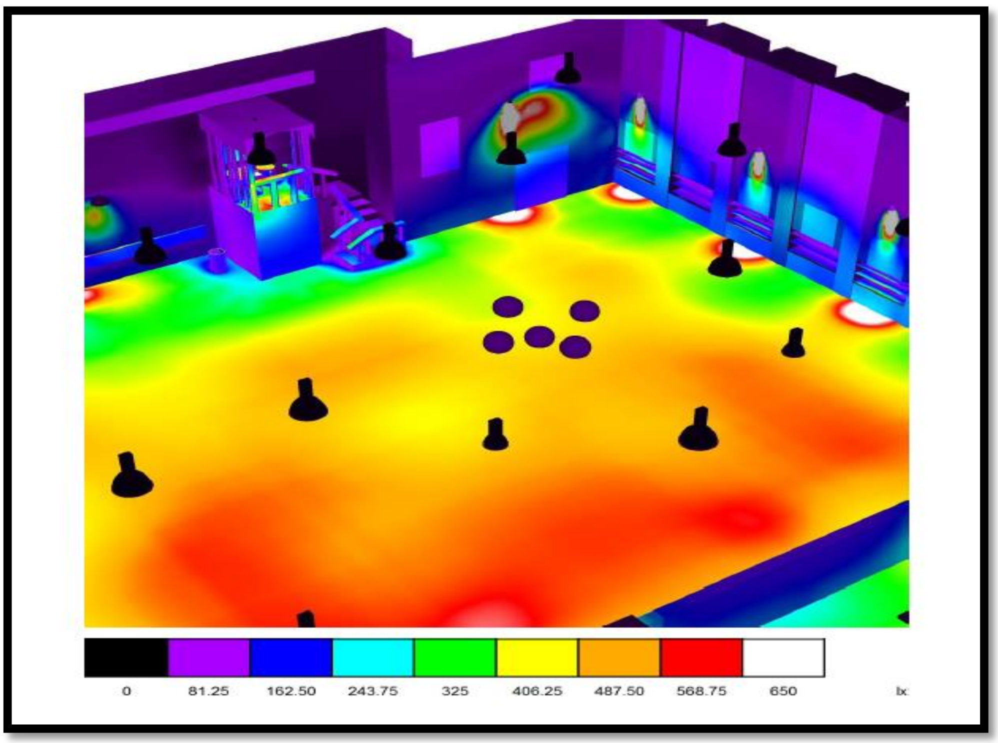



**Figure 6-7: False color displayfor the pray hall.**

The figure (6-8) show the grayscale and value glare for the pray hall by DIALUX program.

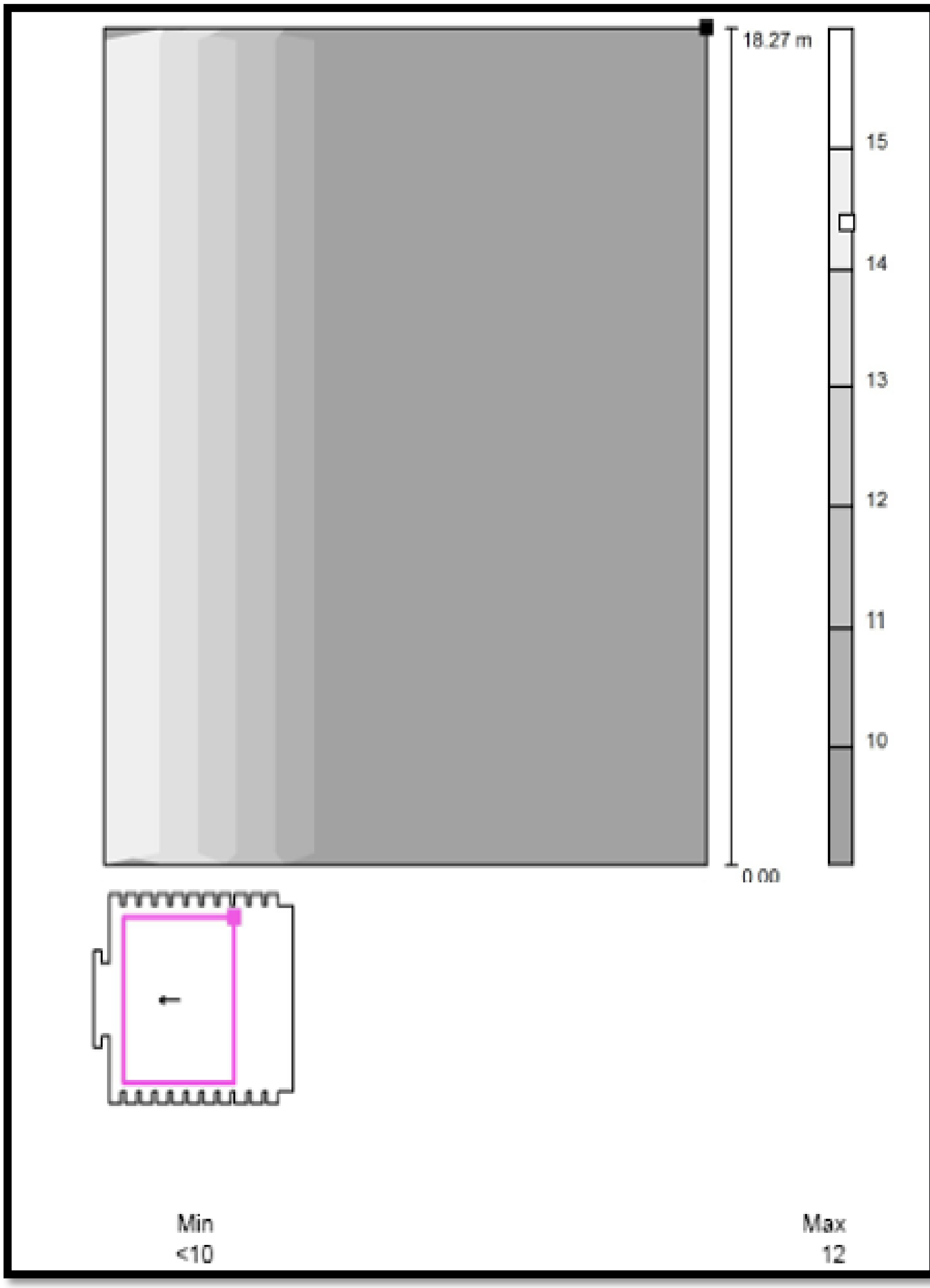



**Figure 6-8: The grayscale and value glare for the pray hall by DIALUX program.**

**Library**

Height of Room: 3.000 m.

Total Luminous Flux: 18000 lm.

Maintenance factor: 0.80.

Suspended height: 0.00 m.

u0=0.72.

Average [lx]: 400.

Efficacy = 80.

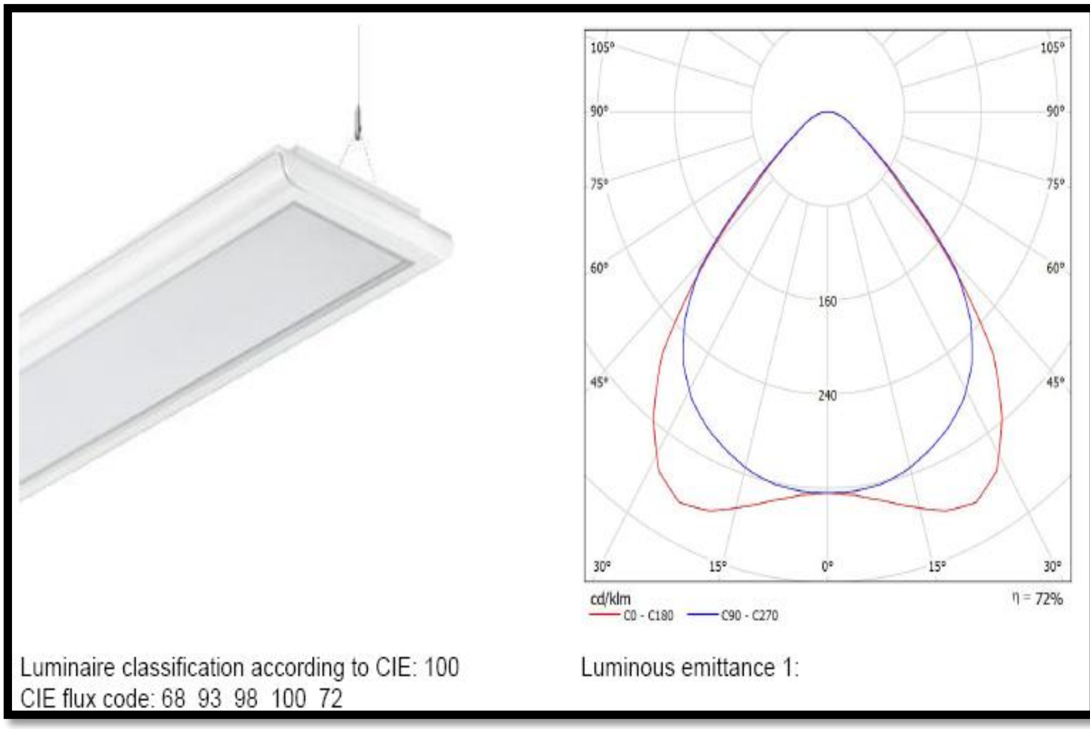



**Figure 6-9: The grayscale and value glare for the pray hall by DIALUX program.**

PHILIPS BPS460 W33L124 1xLED48/840 AC-MLO
Article No.:
Luminous flux (Luminaire): 3600 lm
Luminous flux (Lamps): 3600 lm
Luminaire Wattage: 42.0 W
Luminaire classification according to CIE: 100
CIE flux code: 71 94 99 100 100
Fitting: 1 x LED48/840/- (Correction Factor 1.000).

**Figure 6-10: luminaries are used for the library and woman pray hall**

**Figure 6-11: Distribution lighting for library by DIALUX program.**

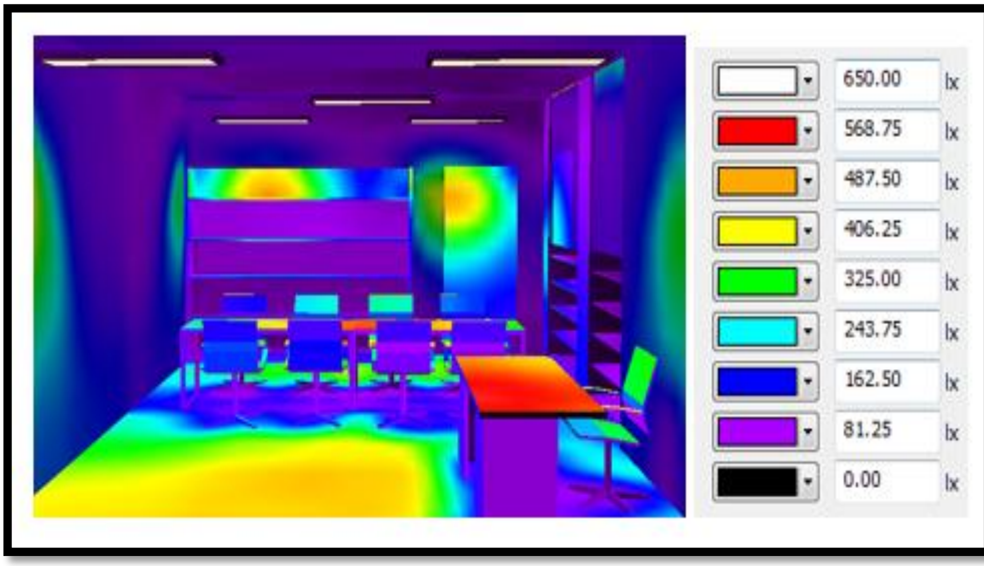



**Figure 6-12: False color display for library**

Zumtobel 60510021 SCON-S 500 1/23W TCG-SE CR [STD]
Article No.: 60510021
Luminous flux (Luminaire): 658 lm
Luminous flux (Lamps): 1060 lm
Luminaire Wattage: 21.0 W
Luminaire classification according to CIE: 92
CIE flux code: 54 92 98 92 62
Fitting: 1 x TCG-SE 18W (Correction Factor 1.000).

PHILIPS ST640T 1xLED16S/830 MB ACT
Article No.:
Luminous flux (Luminaire): 1750 lm
Luminous flux (Lamps): 1750 lm
Luminaire Wattage: 21.5 W
Luminaire classification according to CIE: 100
CIE flux code: 98 100 100 100 100
Fitting: 1 x LED16S/830/- (Correction Factor 1.000).

**Figure 6-13: The lamps are used for the pray hall.**

## 6.2 Electrical load calculation.

**Circuit breaker lighting.**

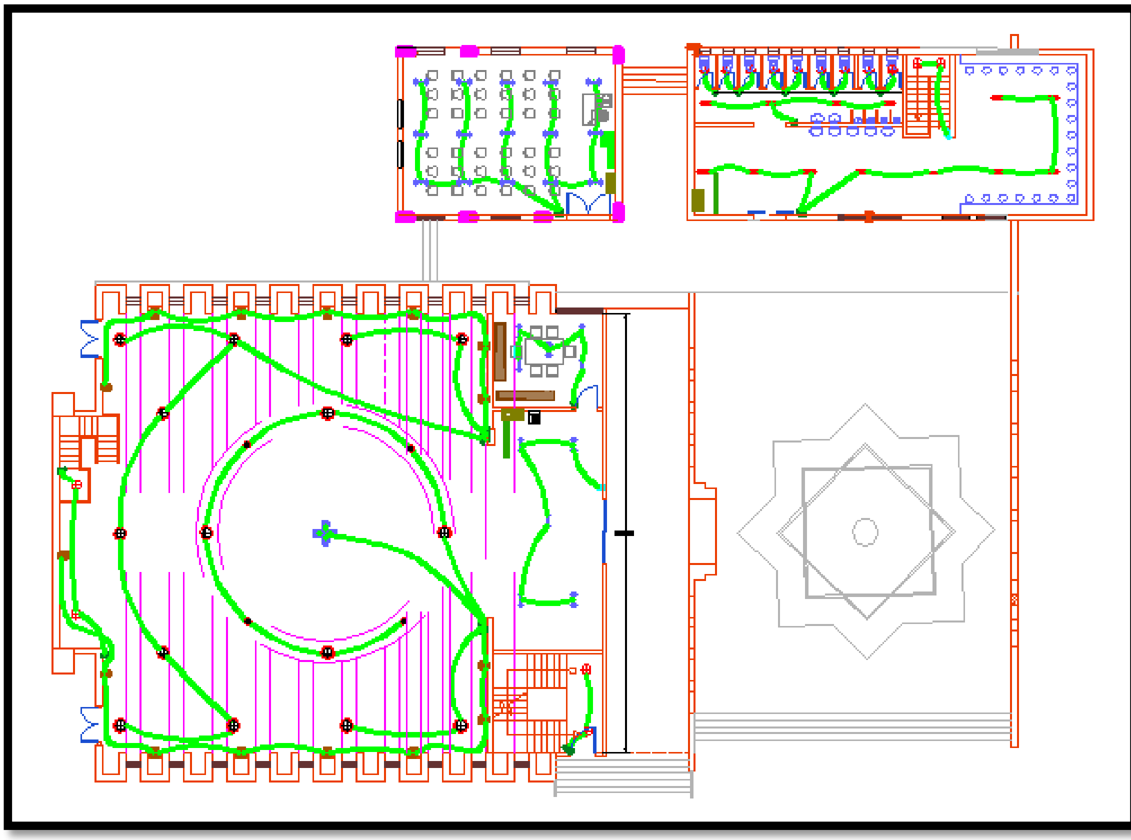


**Figure 6-14: mosque lighting unit's distribution.**

N=number of circuit breaker.

D.F=diversity factor= 0.8.

S.F=safety factor= 1.2.

Current value of the lighting circuit value =10AMP.

Electrical voltage =220.

Every 50m2 needs 1 Circuit breaker.

**Circuit breaker socket.**

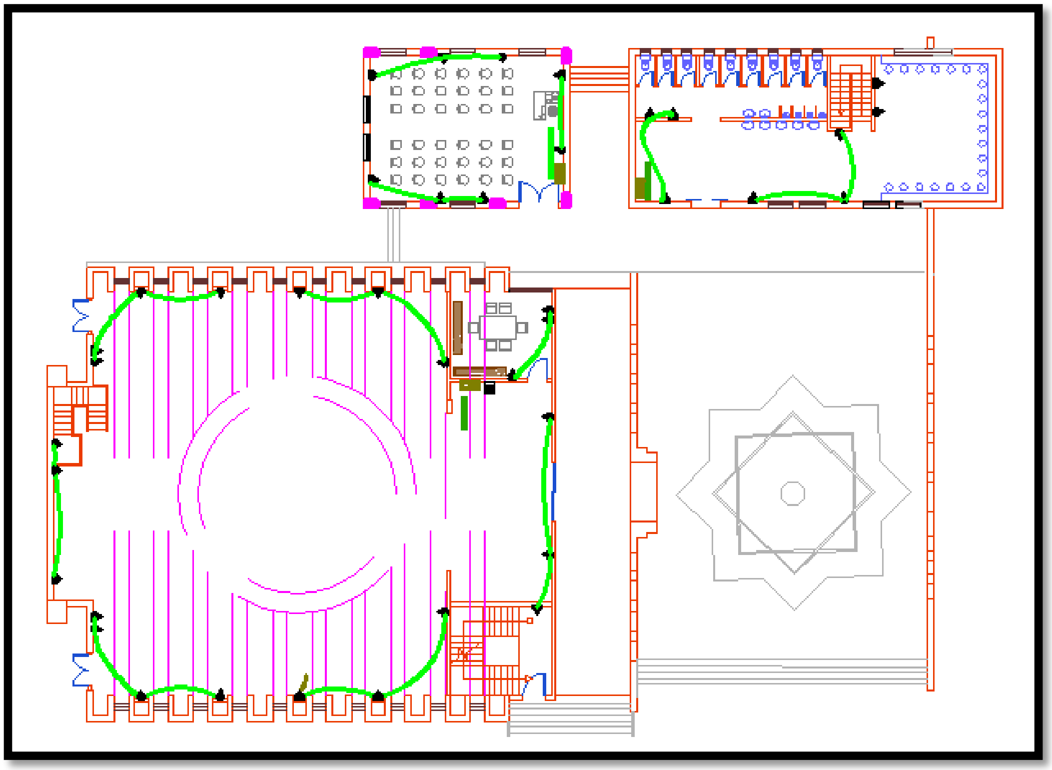


**Figure 6-15: Socket distribution.**

Diversity factor= 0.3.

Safety factor=1.5.

16AMP=current value of the lighting circuit value.

For 3-5 sockets we need one circuit breaker.

Table 6-2: Number circuit breaker in the mosque.

| Space Name | Number of for Circuit breaker lighting | Number of for Circuit breaker lighting |
|---|---|---|
| **Pray hall** | 9 | 6 |
| **Library** | 2 | 1 |
| **Woman pray hall** | 2 | 2 |
| **Cultural center** | 2 | 2 |
| **ablution** | 2 | 4 |
| **basement** | 2 | 2 |

Table 6-3: Mosque Lighting Loads.

| Space Name | Number of Luminaries | Luminaire load(W) | Total Load(W) |
|---|---|---|---|
| **Pray hall** | 165 | 19 | 3135 |
| | 5 | 42 | 210 |
| **Library** | 5 | 42 | 210 |
| **Woman pray hall** | 10 | 42 | 450 |
| **Cultural center** | 15 | 42 | 630 |
| **ablution** | 13 | 42 | 224 |
| | 9 | 24 | 216 |
| **basement** | 11 | 24 | 264 |
| | 11 | 24 | 264 |
| **Total** | | | 5603 |

$P_{\text{actual for Lighting}} = (P_{\text{lighting}} * D.F_{\text{ Lighting}}) / P.F$

$= (5603*0.80)/1 = 4482.4$ watt

**Table 6-4: Mosque Lighting Loads.**

| Space Name | Number of normal loads | Number of special loads | Total Load(Amp) |
|---|---|---|---|
| **Pray hall** | 3 | **3** | 18 |
| **Library** | 2 | **1** | 4 |
| **Woman pray hall** | 2 | **1** | **4** |
| **Cultural center** | 2 | **1** | **4** |
| **ablution** | 2 | **5** | **4** |
| **basement** | 2 | **1** | **4** |
| **Total** | | **12** | **38** |

Number of normal loads= 38………….. They give 76 A

Number of special loads= 38………….. They give 120 A

$I_{circuit\ breaker}$ = {Plight $*D_{Flight}$ + $P_{socket}*DF_{socke}$t + $P_{special}$ $*DF_{special}$}*{SF/3}

= {((5603/220)* 0.8) + (76*0.15) + (120*0.5)}*{1.2/3}= 31 A

= 31A

$I_{cable}$ = SF* $I_{circuit\ breaker}$ = 1.2*30.7 = 36.85 A.......... use 37 A

**Table 6-5: Circuit breaker ampere and wire sections**

| uses | Current(Amp) | uses | Area(mm2) |
|---|---|---|---|
| **Lighting breaker** | 10 | Lighting | 1.5 |
| **Power breaker** | 16 | Power | 2.5 |
| **Main breaker** | 37 | Main | 6 |

# CHAPTER 7

# MECHANICAL DESIGN

## 7.1 Water supply system:

In our project, large amount of water is needed when people come to the mosque to pray. The supply system for water was taken from Nablus Municipality to the mosque, gray water tank and rain water tank.

## 7.2 Water system design:

The sizes for the pipes used in the design:

**Table 7-1: Pipes used in desgin**

| Pipe size | Function |
|---|---|
| **2(inch)** | For the sinks |
| **4(inch)** | Black and gray water drainage |
| | Stacks |
| | Branch for toilet |
| **6(inch)** | For the manholes |

The mosque will be designed for 400 worshippers and each one of them consumes 10 liters on average each time.

Table 7-2: Consumed water in our project.

| Pray time | No. of prayers | Consumed in ablution | Total consumed water in ablution | No. of prayers | Consumed in W.C | Total consumed water in W.C. |
|---|---|---|---|---|---|---|
| **Fajr** | 10 | 10 | 100 | 5 | 15 | 75 |
| **Douhr** | 50 | 10 | 500 | 25 | 15 | 375 |
| **Asr** | 50 | 10 | 500 | 25 | 15 | 375 |
| **Maghreb** | 30 | 10 | 300 | 15 | 15 | 225 |
| **Isha** | 30 | 10 | 300 | 15 | 15 | 225 |
| **total consumed water in ablution /day** | | | 1700 | | | 1275 |
| | Total consumed water in the mosque equals to 2975 lt par day | | | | | |

For water storage, we constructed a chamber under the ground and put all water tanks in it. Show figure (7-2).

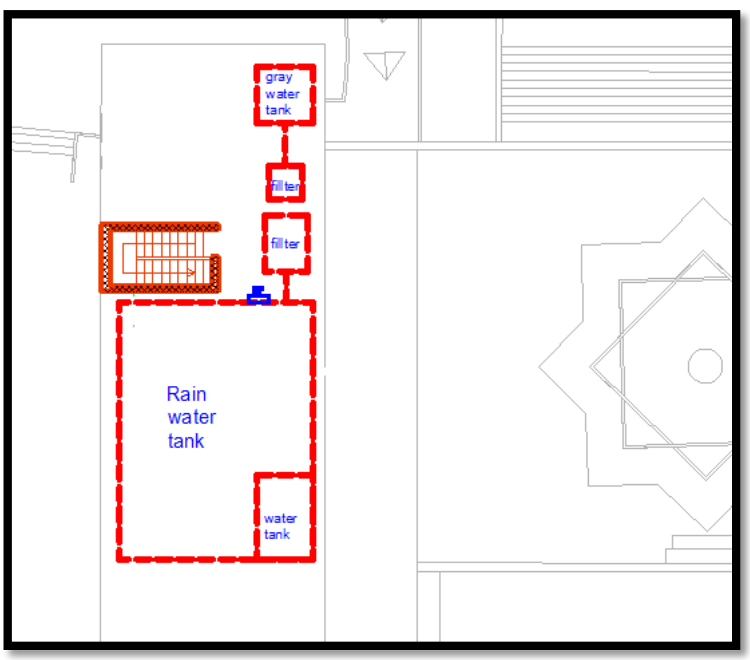



**Figure 7-1: Chamber.**

a) Gray water tank

In the chamber, there is a tank for grey water that collects water from men ablution.

**Table 7-3: Gray water tank calculation**

| Average grey water from men ablution/ day (LITER) | Storage period (day) | Total stored water in the storage period | Factor of safety | Required grey water tank volume ( LITER) | Grey water tank dimensions (m) | Designed water tank volume (LITER) |
|---|---|---|---|---|---|---|
| **1700** | 3 | 5100 | 1.5 | 7650 | 1.6X1.6X3 | 7680 |

The grey water will be used for W.C., irrigation and cleaning.

b) Water tank

**Table 7-4: Water tank calculation**

| Total consumed water per day (LITER) | Storage period (DAY) | Total stored water in the storage period ( LITER) | Factor of safety | Total volume of required water tank (LITER) |
|---|---|---|---|---|
| **3000** | 3 | 9000 | 1.5 | 13500 |

c) Rain water tank

The rainwater could be collected from all the structures and the ground of the site but the volume of the rainwater tank would be extremely large. Therefore, the rainwater tank is designed to collect the rainwater from part of the surface of the mosque, the ablution and the multipurpose room. The remained surface discharge water into direct manholes.

**Table 7-5:Rainwater tank calculation**

| average rain precipitation in Nablus (mm) | Total area that discharge in the rain water tank ($m^2$) | Total required volume to store rain water (Liter) |
|---|---|---|
| **540** | 400 | 216000 |

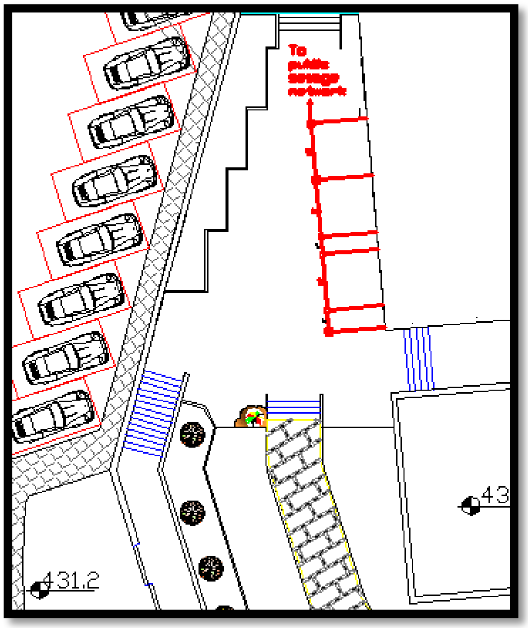
The water tank that was calculated previously will be a part of the rainwater tank.

**Table 7-6: Rain water and water tank calculation**

| Required volume of the rain water tank (LITER) | Required volume of the water tank (LITER) | Total required volume (LITER) | Water tank dimensions (M) | Volume of the designed water tank (LITER) |
|---|---|---|---|---|
| **216000** | 13500 | 229500 | 9.2X8.4X3 | 2318400 |

**Black water**:

Black water direct to the manholes. As shown in figure (7-4).



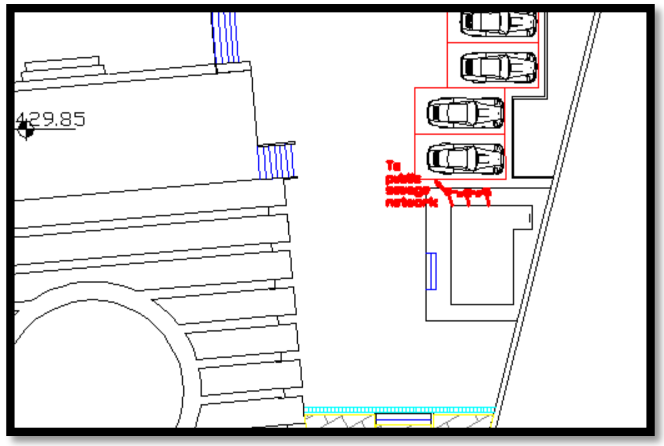



**Figure 7-2: drainage of black water**

## 7.3 HVAC system

The HVAC system has been designed for the pray hall area. The heating and cooling were taken from the ECOTECT model and the duct system was designed based on these values.

An AutoCAD model was made for the duct system to illustrate the relation between the supplies duct and the return duct and their relation with the air handling unit and the chiller.

As mentioned in the environmental section, the total heating and cooling loads was found to be 67 Kw/m2 annually. The maximum load that the duct system shall be designed for, as following.

**In summer**

Operation: week days (12-21), weekends 12-21.

Maximum Cooling: 123800 w at 13:00 on 15$^{th}$ august.

Thermostat setting: 18.0-24.0 $^{o}$C.

**In winter**

Operation: week days (5-21), weekends 12-21.

Thermostat setting: 19.0 -24.0 $^{o}$C

Maximum Heating: 39455 w at 12:00 on 21$^{th}$ January.

The duct system design was based on the heating load in the 15th of August at 13:00.

From this value (124 Kw), the mass flow rate will be

$Q = m\ \rho\ \Delta T$

Where:

Q = total heating or cooling load in Kw.

M = mass flow rate.

P = air density = 1.25

$\Delta$T = temperature difference between the inside of the mosque and outside the mosque 15 $^{o}$C.

By substituting these values in the equation above, these results will be obtained.

The mass flow rate is = 6614 L/s.

In the current design, the pray hall area is divided into two parts and use one chiller for each part. Therefore, the value for one chiller is 3307 L/s.

The method used in calculating pipe diameter is balanced pressure drop method, the longest run is ABCDEFGHI, the duct length and distribution is dependent on diffuser throw and pray hall dimension.

To get value of throw at least 10m for each diffuser take dimension (30*61) cm and number of diffuser = 8.

**Table 7-7: The recommended velocities for the duct system.**

| description | Public buildings |
|---|---|
| **Outside air** | 2.5 |
| **Heating coils** | 2.5 |
| **Cooling coils** | 2.5 |
| **Fan suction** | 4 |
| **Fan outlet** | 6.5-10 |
| **Main duct** | 5-6.5 |
| **Branch duct** | 3-4.5 |
| **Branch riser** | 3-3.5 |

The dimensions for the main duct in the pray hall area can be computed using the values obtained from the table and the equation above.

From table (7-7) the recommended velocity for the main duct in the warehouse is (V) = 6m/s.

For each chiller:

$M_{.}$ = 3307 L/s.

Using table (10-5) (HEATING AND AIR CONDITIONING).[15]

$\Delta p/L$ = 0.45 Pa/m.

The diameter for the main duct is =840mm.

The equivalent dimensions for the main duct is = 1400 X 350 mm.

The size of the diffusers used in the pray hall area is = 300 X610 mm.

The flow rate for each diffuser is = 410 L/s.

The dimensions for the whole duct system are shown in the AUTOCAD drawings with details.

Show below table the volumetric flow rates and diamete for all duct.

**Table 7-8: The volumetric flow rates and diamete for all duct**

| Duct section | V M3/s | d m | Δp/EL PA /m | V m/s |
|---|---|---|---|---|
| A1 | 3.3 | 0.84 | 0.45 | 6 |
| A2 | 2.89 | 0.8 | 0.45 | 5.8 |
| A3 | 2.48 | 0.75 | 0.45 | 5.7 |
| A4 | 2.07 | 0.68 | 0.45 | 5.5 |
| A5 | 1.66 | 0.63 | 0.45 | 5.1 |
| A6 | 1.25 | 0.57 | 0.45 | 4.7 |
| A7 | 0.84 | 0.48 | 0.45 | 4.5 |
| A8 | 0.41 | 0.38 | 0.45 | 4.3 |
| B1 | 0.41 | 0.32 | 1.05 | 5.2 |
| B2 | 0.41 | 0.34 | 0.75 | 4.5 |
| B3 | 0.41 | 0.37 | 0.55 | 3.8 |
| B4 | 0.41 | 0.41 | 0.3 | 3.2 |
| B5 | 0.41 | 0.45 | 0.26 | 2.8 |
| B6 | 0.41 | 0.46 | 0.24 | 2.7 |
| B7 | 0.41 | 0.48 | 0.22 | 2.3 |

The figure (7-3) below duct system distribution in the pray hall.

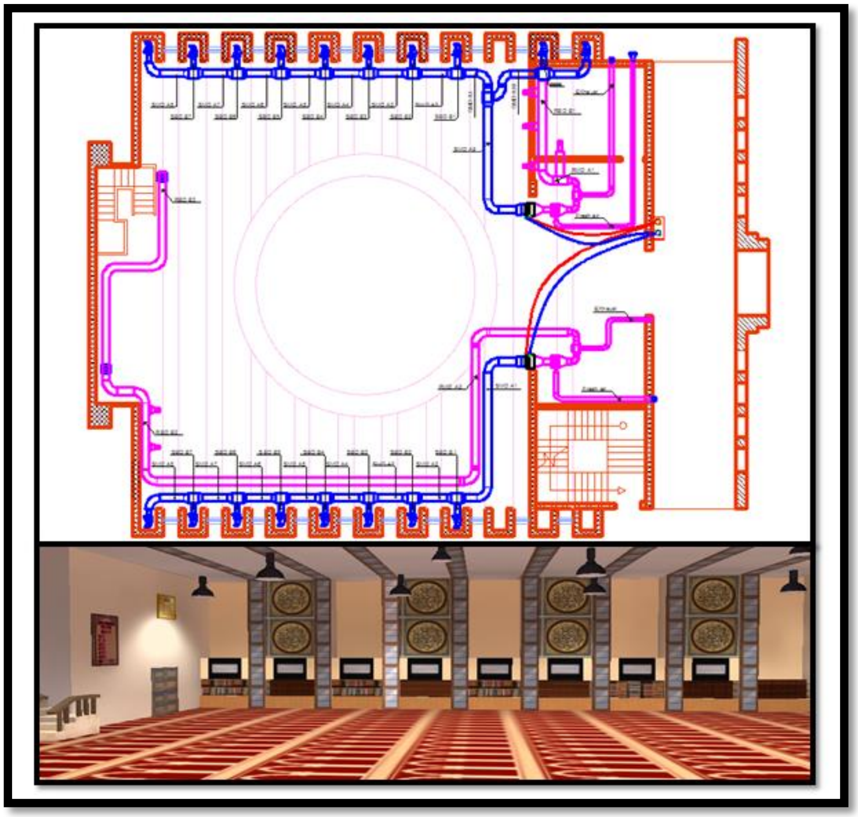


**Figure 7-3: duct system distribution**

## 7.4 Raised Floor

The most challenging problem we faced was installing the HVAC ducts and electrical installation, so after thinking we thought that raised floor system is the best solution.

We used the raised floor system in the pray hall only because it is the most efficient solution for installing the HVAC ducts in terms of money and maintenance.

The working load of this system is at least 2kN. Table (7-9) shows different type of raised floor system.

**Table 7-9: Load class for raised floor system**

| LOAD CLASS | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Ultimate load | > 4 kN | > 6 kN | > 8 kN | > 9 kN | > 10 kN | > 12 kN |
| Working load | > 2 kN | > 3 kN | > 4 kN | > 4.5 kN | > 5 kN | > 6 kN |

The free space between the concrete and the raised floor can vary according to need from 10 to 100 centimeters, and even more.

**Figure 7-4 : installing HVAV under raised floor**

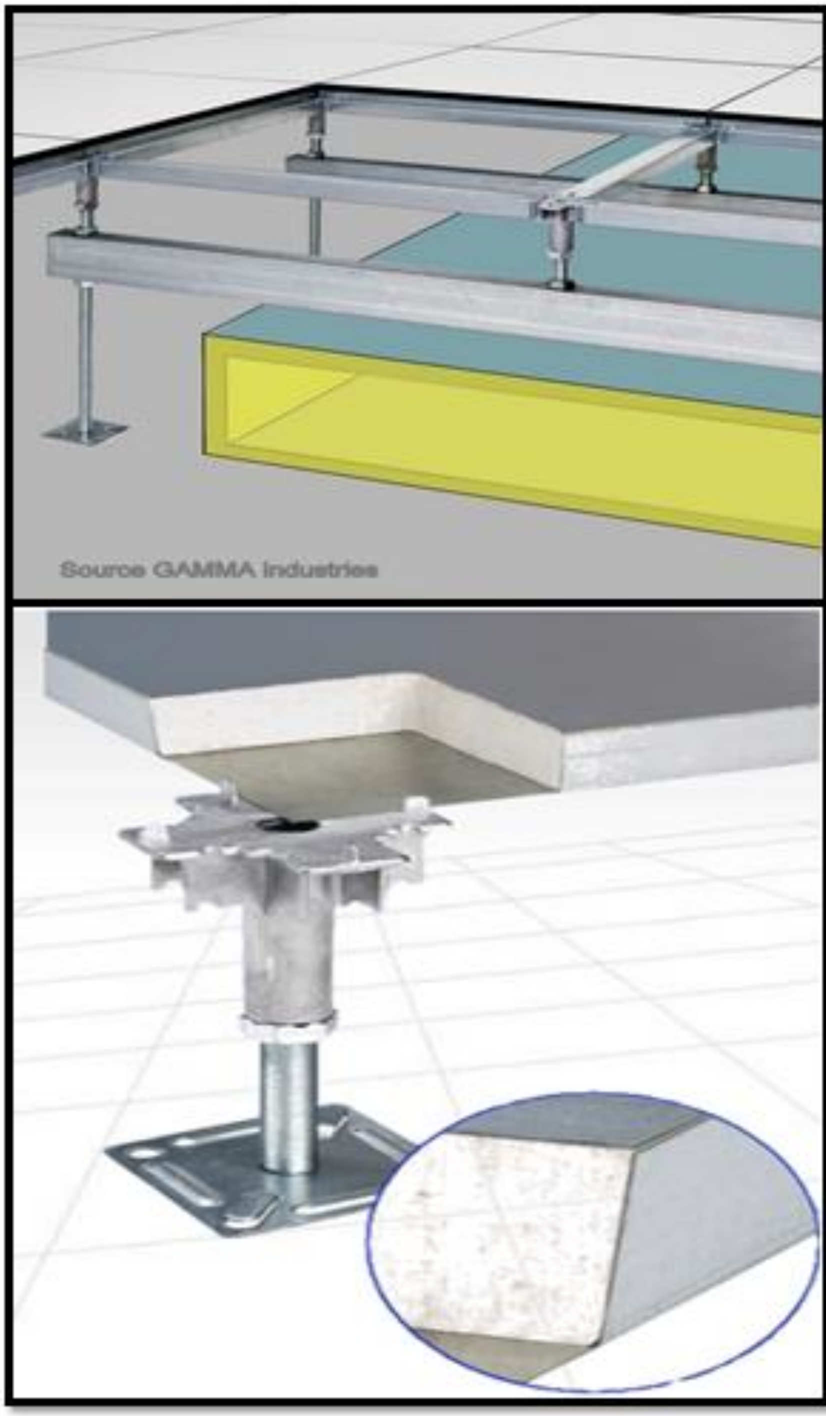



**Figure 7-5: Section in raised flloor**

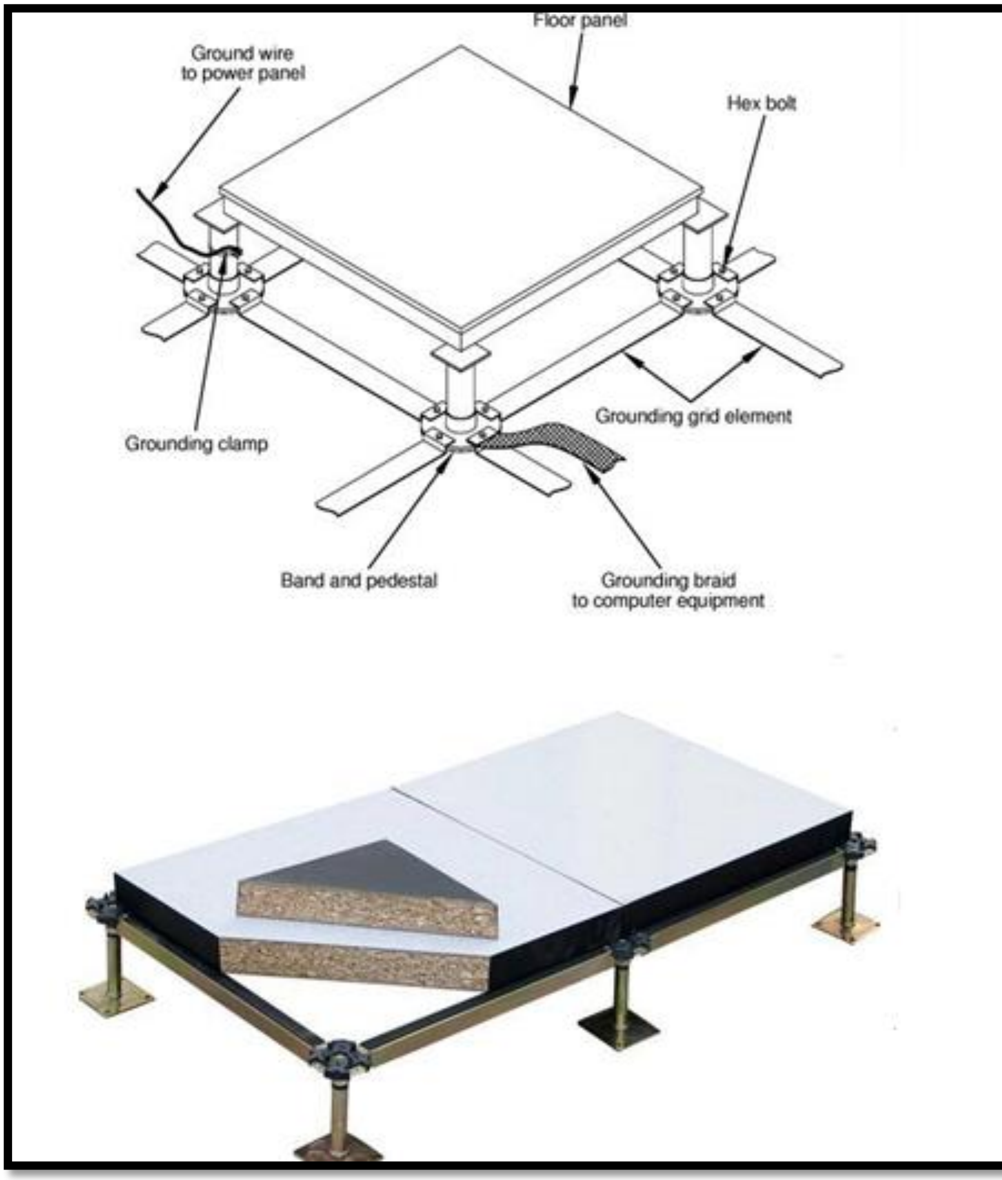



**Figure 7-6: Componant of raised floor system.**

## 7.5 Fire protection system

Fire protection system is a necessity in every structural since the hazard of a fire is possible in every minute and unexpected. In a place like a Masjid the most sensitive area is the prayer halls because of the carpet on the floor and the wood used in decoration inside, fire hose cabinet also fire extinguisher are established plus smoke detector and alarm system in case.

**Figure 7-7: Fire hose cabinate.**

# CHAPTER 8

# QUANTITITIES

# SURVAYING

| Work | Unit | Quantity | Cost (NIS) | | |
|---|---|---|---|---|---|
| Earth works | | | | | |
| Excavation | $M^3$ | 2178 | 65340 | | |
| Backfilling | $M^3$ | 1462 | 30000 | | |
| External works | - | - | 371000 | | |
| Total cost = 466340 | | | | | |
| concrete works | | | Material | Labor | total |
| plain Concrete (B300) | $M^3$ | 69.7 | 22304 | 6970 | 29274 |
| Footing Concrete (B300) | $M^3$ | 64.3 | 20576 | 9860 | 30436 |
| U-beams Concrete | $M^3$ | 243 | 78016 | 52200 | 130216 |
| Ring beam | $M^3$ | 18.3 | 5856 | 7880 | 13736 |
| Beams | $M^3$ | 21.19 | 6780 | 6400 | 13180 |
| Concrete for slabs | $M^3$ | 32 | 10240 | 8000 | 18240 |
| Concrete for columns | $M^3$ | 262 | 83840 | 26400 | 110240 |
| concrete for shear wall | $M^3$ | 64.7 | 20704 | 3560 | 24264 |
| Total cost = 369586 | | | | | |
| Steel work | | | | | |
| Steel for footing | Ton | 9.6 | 28800 | | |
| Steel for All beams | Ton | 16.32 | 48960 | | |
| Steel for ground slab | Ton | 3.6 | 10800 | | |
| Steel for ground slab | Ton | 13.1 | 39300 | | |
| steel for columns | Ton | 18 | 5400 | | |
| Steel for shear wall | Ton | 5.55 | 16650 | | |
| Total cost = 149910 | | | | | |
| Finishing | | | | | |
| Plastering | $M^2$ | 1234 | 24680 | | |
| Painting | $M^2$ | 1234 | 12340 | | |
| Tiling | $M^2$ | 198 | 19800 | | |
| Skirting | M | 82 | 900 | | |
| Doors | - | - | 13700 | | |
| Glasses | $M^2$ | 257 | 91700 | | |
| roof floor screed | $M^2$ | 600 | 36400 | | |
| Alcubond | $M^2$ | 1456 | 728000 | | |
| Raised floor | $M^2$ | 510 | 151000 | | |
| Total cost = 1078520 | | | | | |

| | | | |
|---|---|---|---|
| Block | | | |
| Ribs | No | 1260 | 3780 |
| Internal walls | No | 450 | 1800 |
| Total cost = 5570 | | | |
| Electrical work | | | |
| Electrical installation and equipment | - | - | 27700 |
| Total cost = 27700 | | | |
| Mechanical work | | | |
| mechanical installation and equipment | - | - | 20500 |
| HVAC system | - | - | 79500 |
| pumps | - | - | 3300 |
| Total cost = 103300 | | | |
| Other elements | | | |
| Dome | $M^2$ | 52.3 | 20900 |
| stairs | No | 40 | 7200 |
| Total cost = 28100 | | | |
| Additional cost | | | |
| Men ablution | | | |
| concrete | $M^3$ | 209.9 | 172000 |
| Block (10*20*40) | $M^2$ | 274 | 13700 |
| rib | No. | 1650 | 4950 |
| blaster | $M^2$ | 623 | 12460 |
| paint | $M^2$ | 623 | 6230 |
| stones | $M^2$ | 215 | 75750 |
| doors | - | - | 10600 |
| glasses | $M^2$ | 8.4 | 3780 |
| tile | $M^2$ | 100 | 15200 |
| Electrical | - | - | 10700 |
| Mechanical | - | - | 42950 |
| Multi-purpose hall | | | |
| concrete | $M^3$ | 25.7 | 21000 |
| Block (10*20*40) | $M^2$ | 147.2 | 7360 |
| rib | No. | 485 | 1455 |
| blaster | $M^2$ | 377 | 7540 |
| paint | $M^2$ | 377 | 3770 |

| | | | |
|---|---|---|---|
| stones | $M^2$ | 148 | 52875 |
| doors | - | - | 2500 |
| glasses | $M^2$ | 15.6 | 7020 |
| tile | $M^2$ | 75 | 7500 |
| Electrical | - | - | 4000 |
| mechanical | - | - | 1500 |
| Imam room | | | |
| concrete | $M^3$ | 8 | 6560 |
| Block (10*20*40) | $M^2$ | 81.3 | 4065 |
| Block (20*20*40) | No. | 785 | 2355 |
| rib | No. | 132 | 369 |
| blaster | $M^2$ | 70 | 1400 |
| paint | $M^2$ | 70 | 700 |
| stones | $M^2$ | 76 | 26725 |
| doors | - | - | 3400 |
| glasses | $M^2$ | 4.5 | 2025 |
| tile | $M^2$ | 19 | 1900 |
| Electrical | - | - | 1600 |
| Mechanical | - | - | 8600 |
| Minaret | | | |
| concrete | M | 24 | 84000 |
| plaster | $M^2$ | 315 | 6300 |
| paint | $M^2$ | 315 | 3150 |
| alcubond | $M^2$ | 320 | 160000 |
| glasses | M | 42 | 10500 |
| doors | - | - | 2500 |
| Electrical | - | - | 3500 |
| Total cost = 814489 | | | |
| | | | |
| Total cost of the project = 2925615 | | | |
| Total cost / $m^2$ = 2535.2 | | | |

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