Graduation Project report II

An-Najah National University
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Twisted offices tower

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Dedication

Dedicate a graduation project for those who have given me what they can to get me to this place, Those I will not be able to give them their right whatever I presented to them.

May God prolong age mom and dad to see fruit picking has come after a long wait, and your words will remain guided me as stars for today and tomorrow and forever

الإهداء

(قل إعملوا فسيرى الله عملكم ورسوله والمؤمنون)
صدق الله العظيم

إلى من كلله الله بالهيبة والوقار، إلى من علمني العطاء بدون انتظار، إلى
من أحمل أسمه بكل افتخار ... والدي العزيز

إلى معنى الحب وإلى معنى الحنان والتفاني ، إلى
بسمة الحياة وسر الوجود
إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي
أمي الحبيبة...
.إلى من يحملون في عيونهم ذكريات طفولتي وشبابي .. اخوتي واخواتي .
إلى عنوان الإبداع .. لك كل معاني المديح بعدد قصائد الشعراء ... المهندس مؤيد سلهب

.إلى كل من أشعل شمعة في دروب عملنا .. إلى من وقف على المنابر
وأعطى من حصيلة فكره لينير دربنا .. دكاترة قسمي

إلى الأخوة اللائي لم تلدهم أمي .. إلى من تحلو بالإخاء وتميزوا بالوفاء والعطاء إلى من
.معهم سعدت ، وبرفقتهم في دروب الحياة الحلوة والحزينة سرت ... الزملاء والزميلات

إلى من هم اكرم منا مكانة ..شهداء فلسطين

إلى من ضحوا بحريتهم من أ جل حرية غيرهم .. اسرانا البواسل

نهدي هذا العمل

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Symbol	Description/Definition
M	Meter
hp	Horse Power
Min	Minutes
m/s	Meter per second
U	Thermal Conductivity of Materials
F.U	Fixture Unit
D.F.U	Drainage Fixture Unit
CAD	Computer Aided Design
HVAC	Heating, Ventilating, and Air Conditioning
PVC	Polyvinyl Chloride
W.C.	Water Closet
RT	Reverberation Time
STC	Sound Transmission Class
IIC	Impact Insulation Class
E	Luminance
lux	Luminance Level
C^0	Celsius
mm	Millimeter
cm	Centimeter
%	Percentage
f'c	Concrete compressive strength
Fy	Yielding steel strength
N	Number of lighting unit in the first floor.
Em	Lighting intensity in the unit area measured with LUX
A	The area of space.
n:	Number of lamps in each lighting unit.
FL	Total light flux given by the lamp.
Km	Maintenance factor, depend on the type of area.
Ku	Utilizing factor, this is related to the room factor Kr.
L	The length of the room in meter
W	The width of the room in meter.
Hm	The distance between the lamp and the work surface in meter.
CLTD	Cooling load temperature difference.
LM	Latitude correction factor.
K	Adjustment factor.
Vo	Volumetric flow rate (m^3/sec)

Abstract

Recently the number of offices in local and international companies has increased, so there is a need to provide separate buildings for these offices to accommodate the large number of them, and also to help customers access easily to these offices In addition, non-traditional buildings design has been the focus of world attention. Because it will be a key factor that puts the world's cities on the tourist map or a map of developed countries, therefore, our project is a twisted tower for offices.

In our project we will working on exploiting all possible resources in order to reduce the cost of construction and operation, that is to say that the building will be designed thermally and will be eco friendly. The designs' aim is to create an environment that is both quiet and suitable for offices and the nature of their work. The vertical construction of the building creates a lot of obstacles during the process of designing .One of these obstacles is the concentration of the sun on the large areas of glass in the building and it's location, another reason is the force of the wind against the building ,and also the power of earthquakes that surrounds it, under those circumstances we will design the building so that it will overcome these challenges and we will make sure that every problem has a solution.

Thus, this project will go through two phases. First one , researchers which should be conducted on previous projects, and analyzing some case studies to eliminate any possible mistakes which may appear during design phase by conducting SWOT analysis. During this phase field searching for international twisted towers in Arabian and European countries is very important to find out the problems that appear within design.

Secondly, design phase will start based on the data gained from the first stage. In this phase different aspects should be considered to be designed such as Architectural and Environmental aspects, Structural aspects, Mechanical aspects, and Electrical aspects. There's many software that will be used in design phase for Architectural and Environmental aspects, such as AutoCAD that used to draw 2D plans, Revite used to set 3D model, Dialux & Ecotect used for lighting and acoustics design, and for Structural aspects SAP & E-Taps program will be use.

This project has been done internationality before, but no similar applications available in Palestine.

Chapter 1 :

Introduction

1.1. Statement of the problem

the main aim of this project foucuses on how to design an energy-efficient office building in Nablus . and have twisted shape
This research project contributes to understand the office building towers that are usually designed in a wrong way in our country, thus we are trying to solve these problems as much as possible

1.2. Objectives of the work

The main objective of this project is to provide an integrative design twisted offices tower in Palestine.

1.3. Scope of the work

* Architectural design: in the architectural design the structure will be design based on functionality and the environmental requirements

* Structural design: In the structural design, the structures in the project will be analyzed and designed using computer software. The analysis will include dynamic analysis,3- D model of the structure, and soil structure interaction.

* Mechanical and environmental design. HVAC, water, and sanitary systems in the project will be analyzed and designed.

*Electrical design will include designing power and lightening systems in the project

*Public safety design includes designing the emergency exits. alarm system and fire protection system

1.4. Significance or importance

the number of offices in local and international companies has increased, so there is a need to provide separate buildings for these offices to accommodate the large number of them, and also to help customers access easily to these offices.
In addition, non-traditional buildings design has been the focus of world attention. Because it will be a key factor that puts the world's cities on the tourist map or a map of developed countries, therefore, our project is a twisted tower for offices.
The project contributes to employ many employees and reduce the unemployment rate , in order to improve the economy .

1.5. Organization of the report

Our project is organized as follows:
chapter 2 : Literature Review, chapter 3 : architectural design , chapter 4 : environmental design , chapter 5: mechanical design , chapter 6 : electrical design , chapter 7 : structural design , chapter 8 : electrical design , chapter 9 : Quantity Survey and Cost

1.6. Standard /codes

1.6.1. Constrains:

In redesigning the twisted tower we made case study of kayan tower in Dubai and we have faced many problems.
* In Palestine there is no twisted tower so we made case study of kayan tower.
* Kayan tower located in Dubai so its difficulty to visit it and collect enough information about it.
* The lack of study cases and information about kayan tower in internet.
* We could not get the special plans tower entity to take advantage of them.

1.6.2. Codes and requirements:

Offices specifications and requirements:
1. The required temperature 22-25 c.
2. The required relative humidity in the area is 60%.
3. The internal area should be ventilated.

- ACI -318-08 for reinforced concrete structural design.
- UBC -97 for earthquake load computations
- ASCE for load computations.
- ASHRAE American Society of Heating, Refrigeration& Air Conditioning Engineers.
- ASME American Society of Mechanical Engineers
- NFPA National Fire Protection Association.
- NPC National Plumbing Code.
- SMACNA Sheet Metal and Air Conditioning Contractors National Association.
- NFPA Codes:

The following NFPA list of codes may be used for the systems:
1. NFPA 13 Standard for the Installation of Sprinkler Systems 2007 Edition
2. NFPA 14 Standard for the Installation of Standpipe and Hose Systems 2007 Edition
3. NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems 2004 Edition.
4. UL Underwriters Laboratories.
5. FM (factory Mutual).

Compliance Construction Codes
The construction of the mechanical works shall be in accordance with international codes and

regulations as listed below, and accepted by the local Authorities:

- ASHRAE American Society of Heating, Refrigeration & Air Conditioning Engineers
- ASME American Society of Mechanical Engineers
- NFPA National Fire Protection Association
- NPC National Plumbing Code
- SMACNA Sheet Metal and Air Conditioning Contractors National Association

1.6.3. Earlier coarse work :

There are many courses that have been used to perform the analysis and the design progress such as:

- Concrete 1, 2 and 3 to design wall , footing , slab .
- Steel structure design to design any steel structure in our project
- Designing buildings using AUTOCAD and revit .
- . • Solar system design.
- H-VAC system design.
- Lighting system design

Chapter 2 :

Literature Review

2.1. Architectural design

2.1.1. Introduction :

Architecture is defined as the art and science of designing buildings and structures. A wider definition would include within this scope the design of any built environment, structure or object, from town planning, urban design, and landscape architecture to furniture and objects. It could also be defined as the manipulation of shapes, forms, space and light to change our environment. A very famous definition of architecture is the one made by French architect Le Corbuiser: "Architecture is the masterly, correct, and magnificent play of forms under the light “

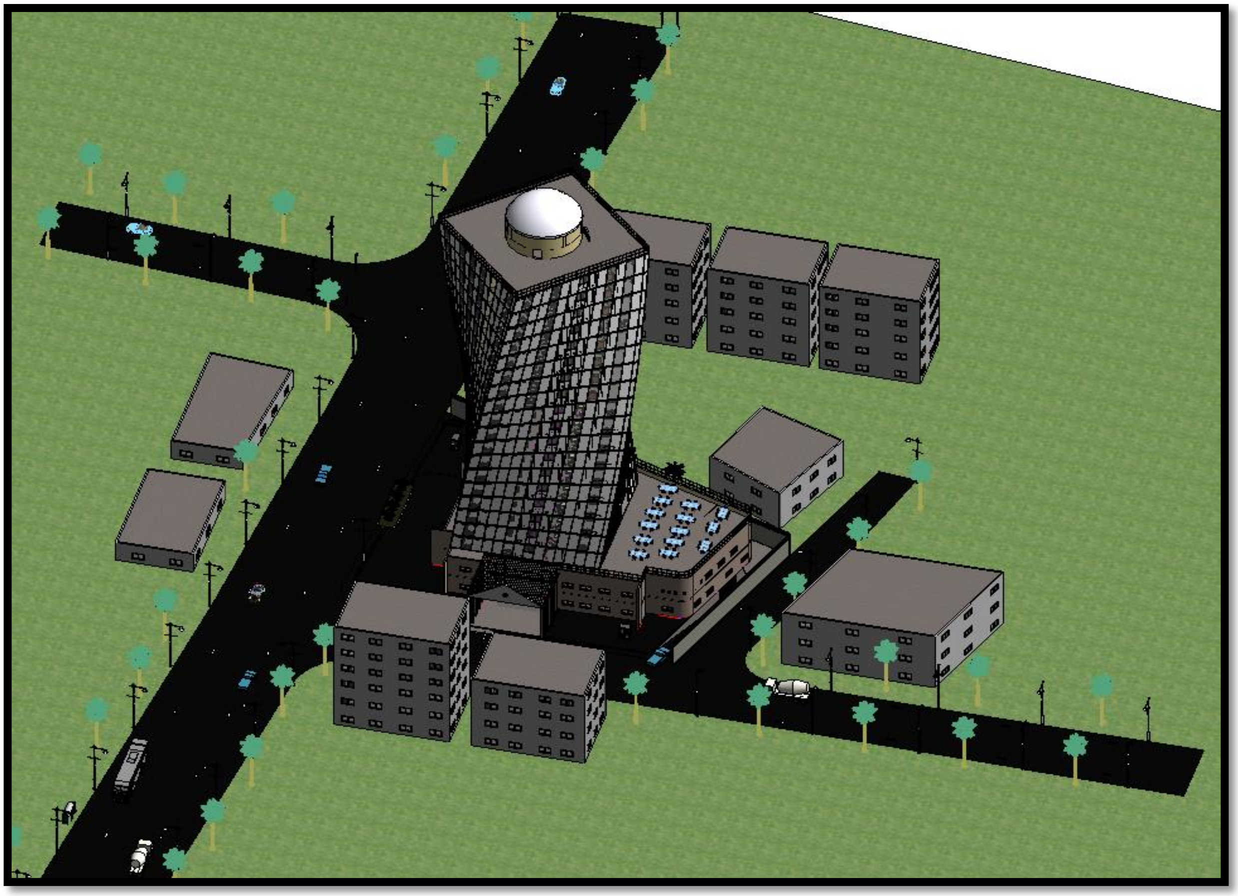


Figure 1 : 3D view of the tower .

2.1.2. Spaces :

Offices spaces :

a- open office .

b- closed office .

Meeting and conferences room.

Corridors and circulation.

W.C’s - (water closet/toilet).

Cafeteria .

branch of banks .

Sport hall (gym) .

Parking .

The table below show the area required for spaces

Table 1 : the area required for spaces [1]

space	Required area (m^2)
Private office	**8-10**
Open office	**12-15**
Circulation space	**1-1.50 /employee**
Bank	**5-10**
Cafeteria	**5**
garage	**37.5**
Gym	**4**

2.2. Environmental design

Environmental design is very important aspect to improve the efficiency of building. Environmental design is the process of addressing surrounding environmental parameters when devising plans and that will be analyzed according to these factors.

2.2.1. Climate and Passive Solar :

Passive solar design means heating, lighting and cooling the building using the sun's heat and light. This will slash the energy use, reducing energy bills and greenhouse gas emissions, while making the building more comfortable.

The key principles of passive solar design are orientation, insulation, shading and air flow. The basic goal is to exclude sunlight during summer, so the building stays cool, and allowing it to warm the building in winter.

Passive solar designs are simple. This simplicity means greater reliability, lower costs, and longer system lifetimes.

2.2.2. Sun path diagram:

Sun path diagrams are sun's path across the sky. They are used to easily and quickly representations on a flat surface to determine the location of the sun at any time of the day and at any time of the year. Each latitude has its own sun path diagrams.

The horizon is represented as the outer circle, with you in its center. The concentric circles represent the angle of the sun above the horizon, that is, its height in the sky. The radial lines represent its angle relative to due south

The paths of the sun on the 21st day of each month are the elliptical curves. Roman numerals label the curves for the appropriate months. For example, curve III (March) is the same as curve IX (September). The vertical curves represent the time of day. Morning is on the right (east) side of the diagrams and afternoon on the left (west).

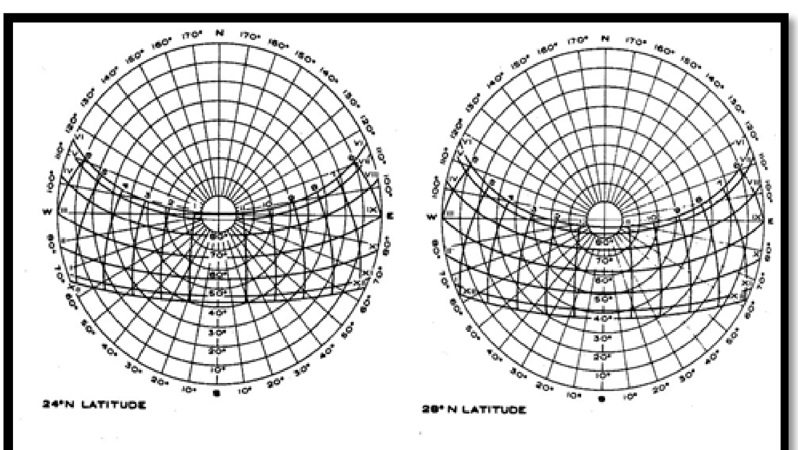


Figure 2 : sun path diagram [2]

2.2.3. Building Orientation:

The direction of the building's faces is the starting point of passive solar design. Orientation of the building generally is the sitting of building with respect to solar access. Although any building will have different orientations for its different sides, by maximizing southern exposure, for example, one can take optimal advantage of the sun for daylight and passive solar heating, .This will result in lower cooling costs by minimizing western exposures, where it is most difficult to provide shade from the sun. The building orientation can have an impact on heating, lighting and cooling costs.

Surrounding buildings and trees from south faced affect the solar design that require shading in the summer but in the winter affects for heating gain. In another side, the wide streets do positive effect against thin street because the heating gain depends on maximum glazing in the south.

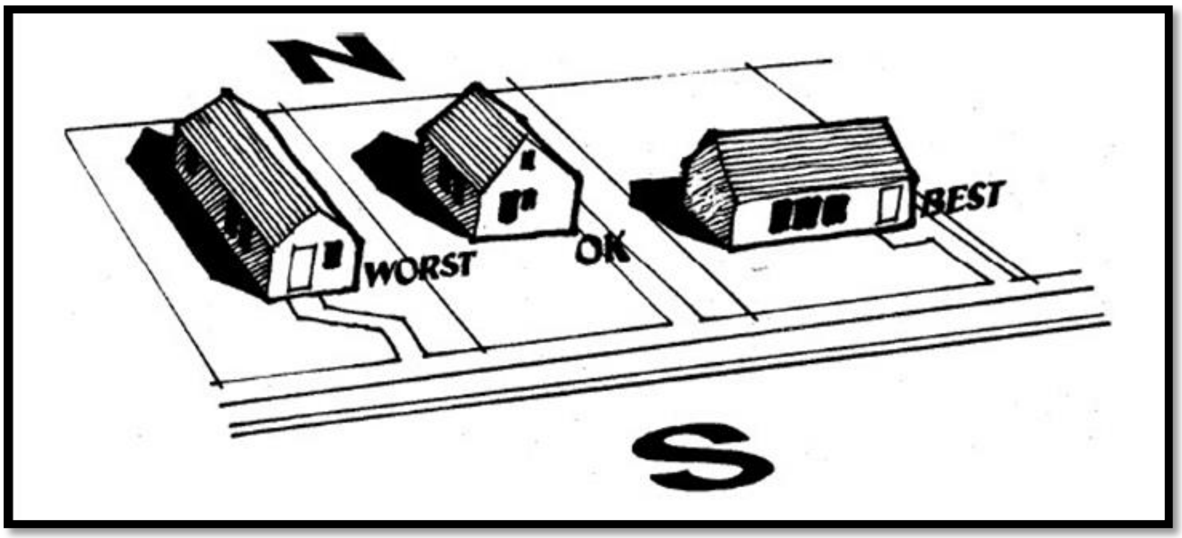


Figure 3 : direction of facing south

2.2.4. Acoustics :

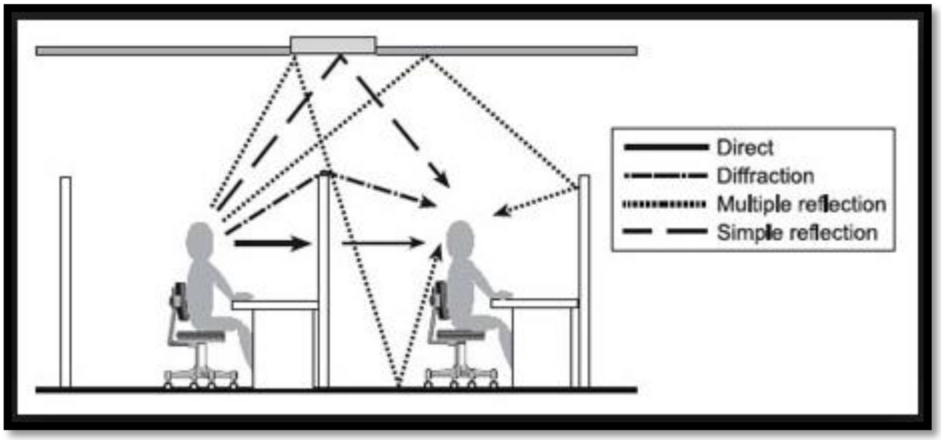


Figure 4 : spread of sound

Introduction:

Proper acoustical design is vitally important to the functionality of a given space. Interior space has a multitude of uses and applications .that mean there's a lot of sources of sound. acoustic design is the science of controlling noise in buildings and minimize transmission of noise from one spaces to another , the good design for acoustic preserves the privacy of offices, maintain human health ,increase productivity for employees and prevent the annoyance between employees.
From physically point, sound define as physical waves, or as a mechanical vibration that transmit by a medium. Sound travels at different speeds, depending on the medium, for example in air, at sea level, sound velocity is 344 m/s. Since sound travels not only in air but also through parts of a structure, it is of interest to know the speed of sound in other media

Reverberation time (RT60): is defined as the time required, in seconds, for the average sound in a room to decrease by 60 dB after a source stops generating sound.

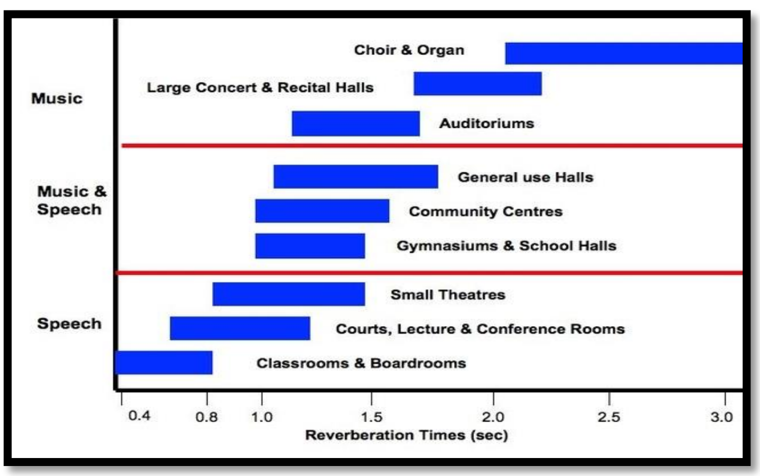


Figure 5 : Reverberation time recommendation for many spaces [3]

Noise level :

Table 2 : acceptable noise level [4]

Managements offices	40
Gymnasium	50
Restaurant	45
Meeting room (seats >=20)	30
Convention room (seats>50)	25

Sound Transmission Class (STC): rates a partition's resistance to airborne sound transfer at the speech frequencies (125-4000 Hz). The higher the number, the better the isolation.

2.2.5.natural lighting (Daylight) :

the natural lighting mean use the daylight to illuminate interior spaces naturally .The daylight make the vision more comfort ,Healthy , Reduce dependency on electric energy (energy efficiency), Reduce operating costs and Reduce emissions.

Daylight :

is the controlled admission of natural light into a space through windows to reduce or eliminate electric lighting and it's diffuse natural light from the sky.

Daylight design:

is not so much how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects.
In other words, it involves more than just adding windows and skylights to a space. It is the careful balancing of heat gain and loss, glare control, and variations in daylight availability.

Daylight factor:

Daylight factor (DF) is defined as the ratio of the actual illuminance at a point in a room (lux) and the illuminance available from an identical unobstructed sky.

DF = (Eint / Eext) * 100%
Where,
Eint = inside illuminance at a fixed point.
Eext = outside horizontal illuminance under an overcast (CIE sky) or uniform sky.

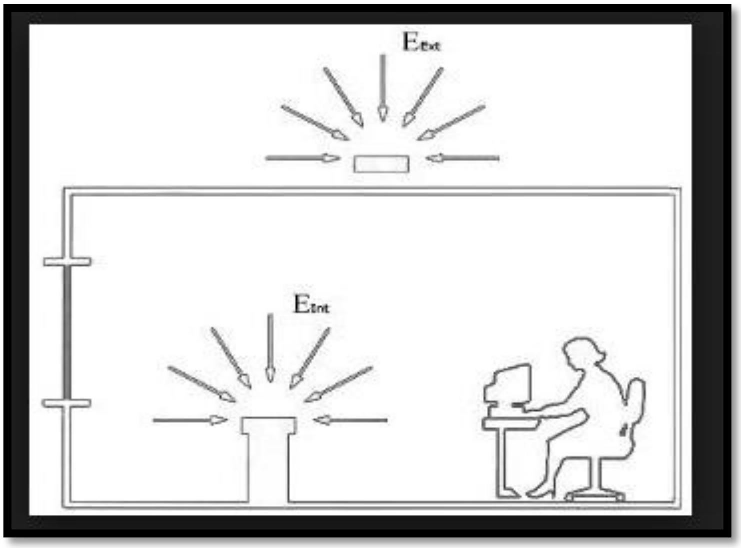


Figure 6 : inside and outside illuminance

Daylight Factore in a building depends on the sum of three components

1. Sky component or direct component (SC): The direct illuminance if the sky is visible from the considered point
2. Externally reflected component (ERC): The illuminance due to the reflections on the outside environment .
3. Internally reflected components (IRC): The illuminance due to the reflections on the inside surfaces .

Daylight factor = SC + ERC + IRC

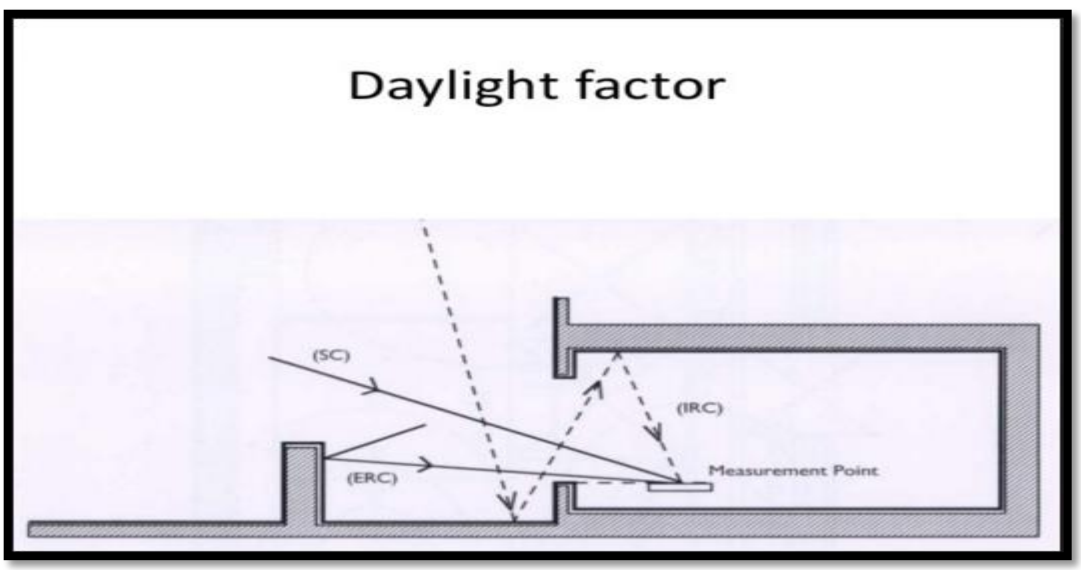


Figure 7 : components of daylight Factor

The table below show the description of view in the workplace according to the percentage of daylight factor

Table 3 : description of view in the workplace according to the percentage of daylight factor [5]

Zone	DF (Southen Europe	DF (Northern Europe	Daylight contribution
Bright	> 3%	>6%	Very large (Solar shading probably indispensable)
Average-bright	1.5 – 3%	3-6%	Good. Bright. Solar shading required
Average – dark	0.5 – 1.5 %	1-3%	Fair
Dark	0.1 – 0.5 %	0.2-1%	Poor for work (artificial light required most of the time) Can be acceptable for some circulations
Very Dark	<0.05 %	< 0.1%	No Daylight / Artificial light required all day

* With a DF < 2%, a room will seem gloomy. Electric lighting will be required for most of the daylight hours.
* With 2% < DF < 5%, supplementary electric lighting may be needed.
* With DF > 5%, Depending upon the task at hand, electric lighting may not be necessary during daylight hours.

2.2.6.Ventilation:

Ventilating is the process of replacing air in any space to provide high indoor air quality. Ventilation is used to remove unpleasant smells and excessive moisture, introduce outside air, to keep interior building air circulating, and to prevent stagnation of the interior air.
Ventilation includes both the exchange of an air to the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. Methods for ventilating a building may be divided into mechanical (forced) and natural types. And table 3.6 shows the minimum outside air requirements for ventilation.

Table 4 : Minimum outside air requirements for ventilation

Application	Max. accup./100m^2	L/s/person	L/s/m^2
Office space	7	10	**2.5-10**
Reception areas	60	8	**3.5-7.5**
Conference rooms	50	10	-----------
Public restrooms	**100**	**25**	-----------

Air quality:

Air quality is an important aspect of the indoor environment that is often neglected in naturally ventilated buildings. It may also conflict with other strategies for energy efficiency.
Reduction of infiltration is an important strategy to improve IAQ and reduce energy consumption. This however has the effect of reducing natural ventilation, which allows the build-up of indoor air contaminants.

Air velocity:

Air movement increases both convection and evaporation, which in turn increases heat loss from the body. The comfort temperature is highly dependent on air velocity, particularly if light clothing is worn. Control of air movement with fans is an important opportunity to give individuals control over their climatic environment. Using air movement to control comfort is a delicate balance since too high an air velocity (or too large a temperature).

2.3. Structural design

2.3.1. Introduction

the way in which the parts of a system or object are arranged or organized, or a system arranged in this way .
in the structural design first of all we should select the material used ,the next step is to select structural system , third point is to compute loads such as dead load , live load ,wind load ,seismic… etc., Stage before the final is modeling and analysis ,means how to convert the structural type to model ,and the final step is design , in this step we calculate internal forces to get dimensions, reinforcement needed .. etc ,. Design code must be taken into consideration .

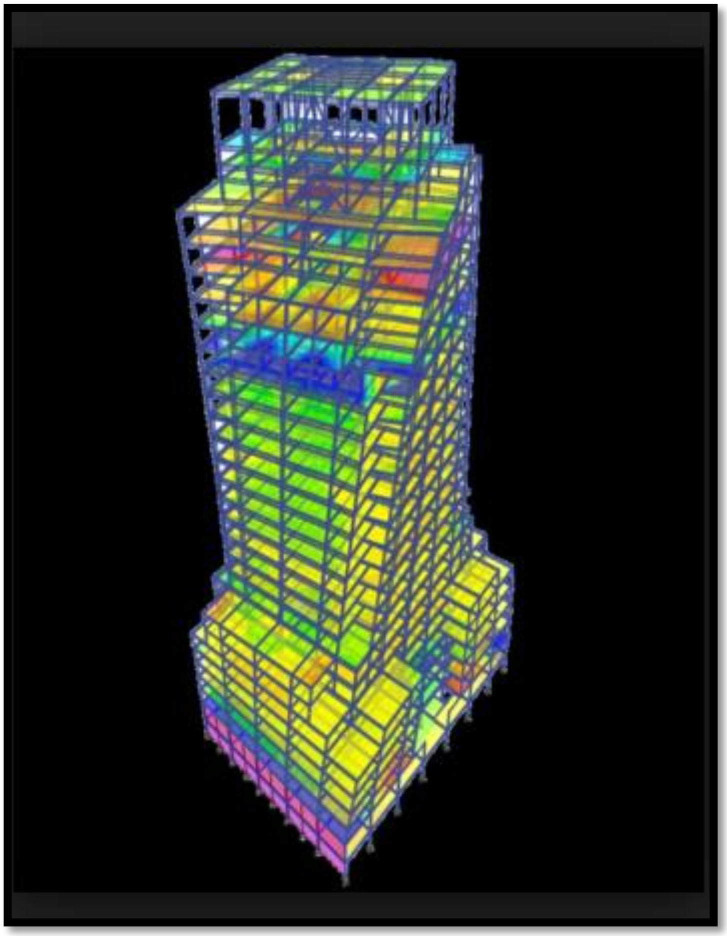


Figure 8 : 3D model structural

2.3.2. Objectives of structural design :

The main objectives of structural design is to assure the following:

1. Safety: It has been the prime and one of the most important requirements to design a safe and stable structure. The structure shall be designed that it will not collapse in such a way during its expected life duration.
2. Serviceability: The performance is rated by the fitness of the structure to maintain deflection, deformation, and cracking and vibration effects within the acceptable limits.

3. Durability: The structure shall resist effectively environmental actions during exposure conditions such as rain, wetting and drying or freezing, climatic variations in temperature and humidity.

4. Economy: The design shall be economical. The economy shall be of material by optimum utilization of its strength. Also, the economy of cost includes cost of construction as well as cost of maintenance and repairs.

5. Appearance, feasibility and acceptability: The structure has to be designed that the proposed solution is feasible and acceptable and provide a pleasing appearance without affecting economy.

2.3.3. Main Structural materials:

- Concrete construction:

Figure 10 : concrete construction

- Steel structure:

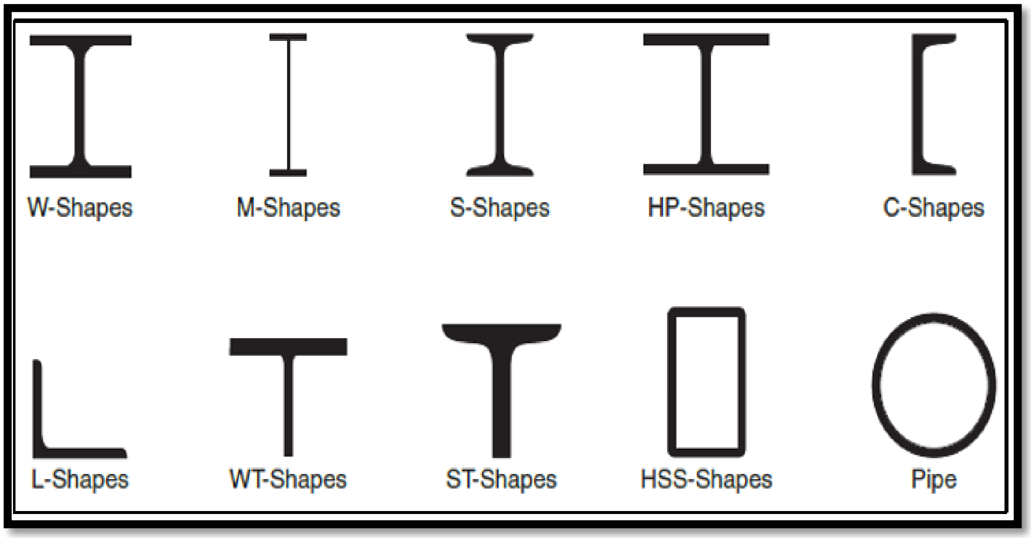


Figure 11 : Steel structure shape

2.3.4. Structural Elements of Buildings:

1. Foundations.
2. Slabs .
3. Columns.
4. Beams .
5. Walls.

1- Foundation:

Foundation is The structure that carry the building and transmits the lord of the building to the soil, and it's the main function to re-distribute loads on the ground ,also it constructed under the ground.

Foundations are constructed according to the following stages:

- **Site Preparation:**

we have to remove or clean the site from the trees and their roots ,rock , jungle and any other obstacles. then The whole area will be roughly leveled ,if there's any holes in the site will filled. and then relocating any existing infra structures such as cables or pipelines .Finally bench marks must be established at a suitable point in the construction site and laying out the centers for each foundation base (footing base).

- **Excavations:**

Excavation for each footing base according to the design level and shape of the foundation base

Footing Construction:

after we excavation the foundation according to the design level we constructed the foundation base on layers as shown in figure.

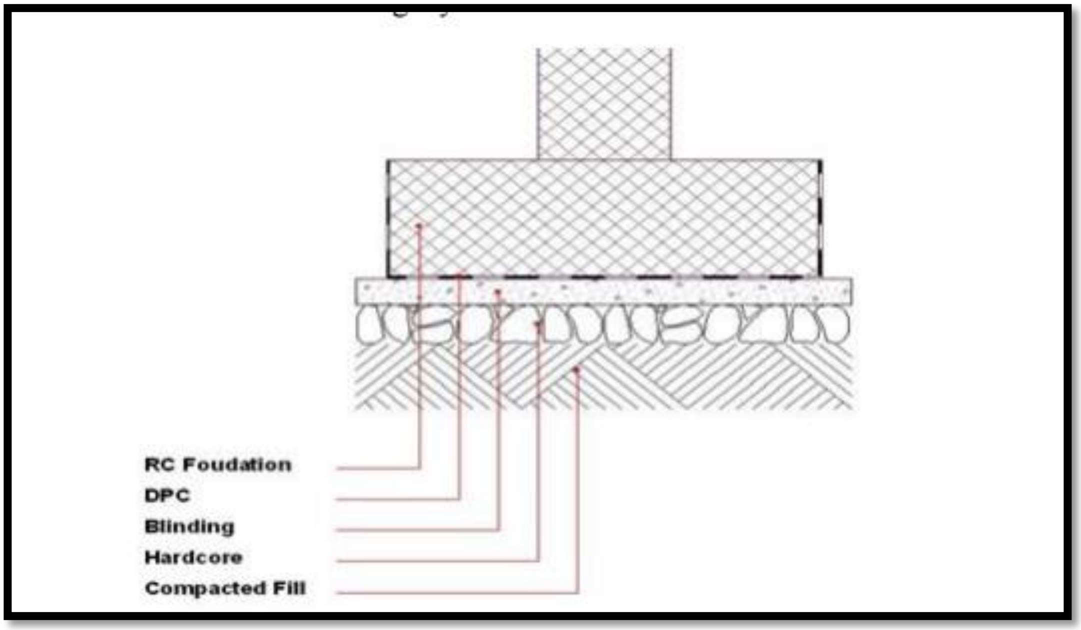


Figure 12 : foundation layers

Types of foundation systems:

1. Single Footings: is the kind of foundation when sufficient amount of good soil at is kept around a column at shallow depth.
2. Raft Footings: are used when the quality of soil is not strong.
3. Combined Footings.
4. Strap Footings.
5. Pile Footings: are used when the load to be supported is large and the necessary firm soil is not available in that region.

And these types are in figure

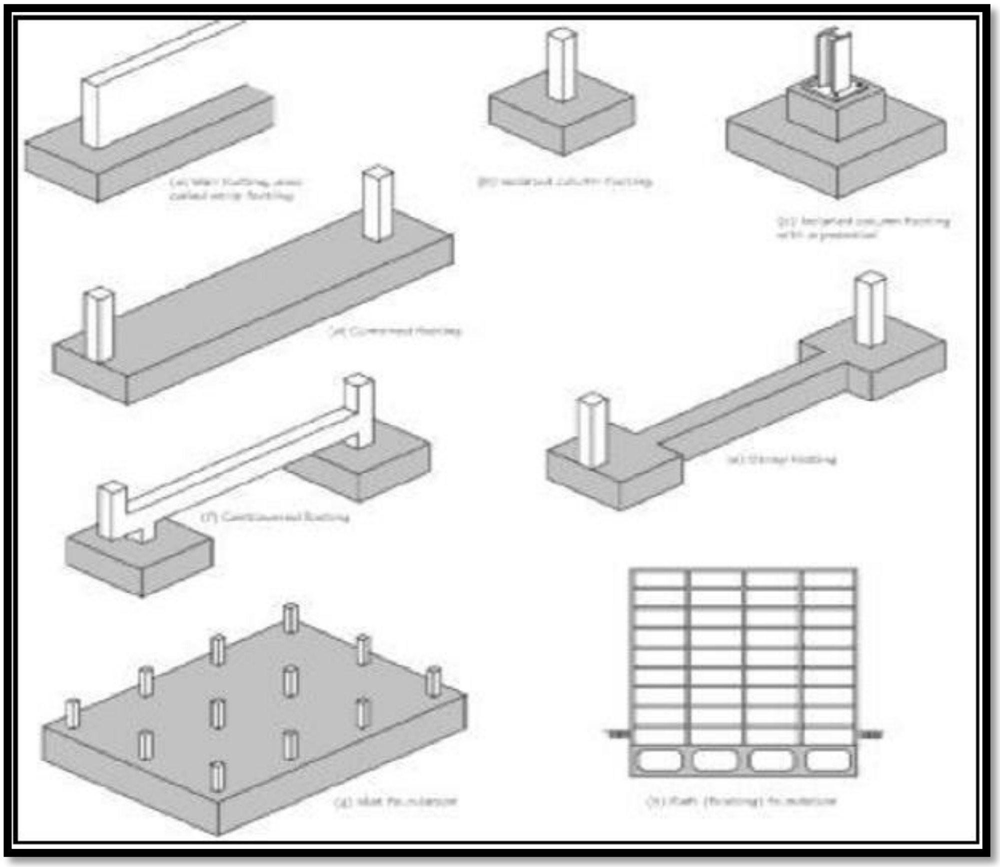


Figure 13 : Types of foundation systems

2- Slabs :

A concrete slab is a common structural element use in modern buildings, which the thickness considers a small compared to its own length and width. The Horizontal slabs of steel reinforced concrete thick typically lay between 100 and 500 millimeters, are most often used to construct floors and ceilings and roof construction, while the thinner slabs are also used for exterior paving.According to the way the loads are transferred to supporting beams and column, slabs are classified into two types one way and two ways. One way slab IF ly/lx > 2, Two way slab IF ly/lx < 2

Where;

Long direction = ly ,Short direction = lx

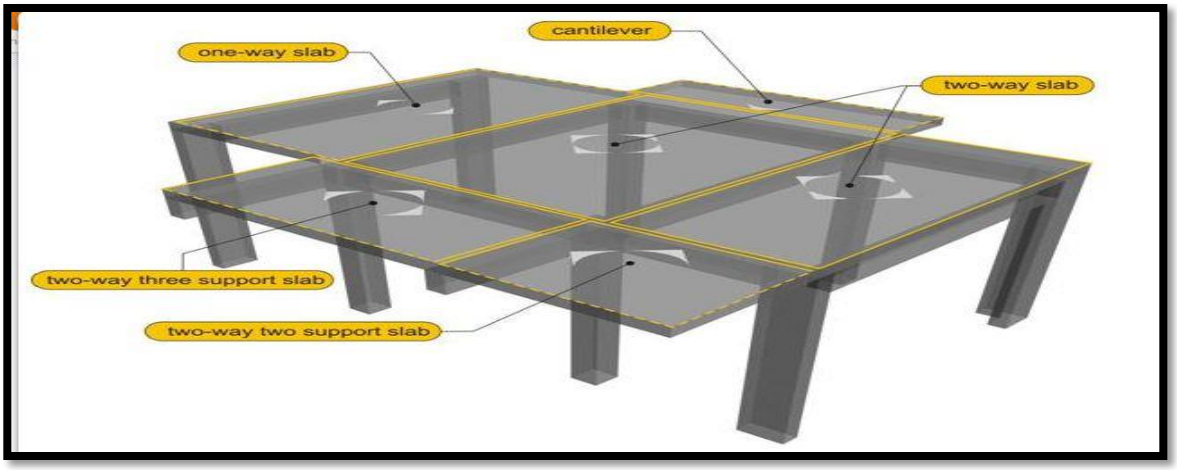


Figure 14 : type of slab according to reinforcement direction

Structural system for reinforcement concrete slab:

- One way reinforced solid slab
- Two way reinforced solid slab
- One way ribbed slab
- Tow way ribbed slab
- Waffle slabs

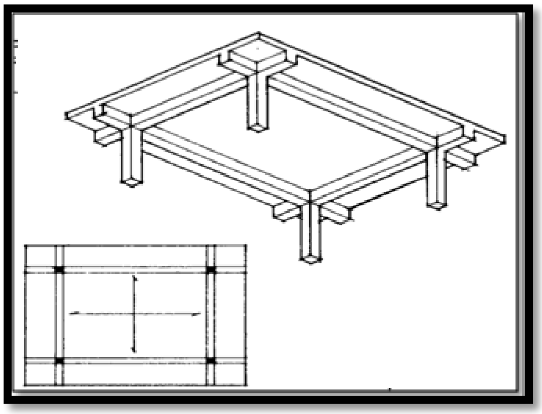


Figure 15 : One way solid slab

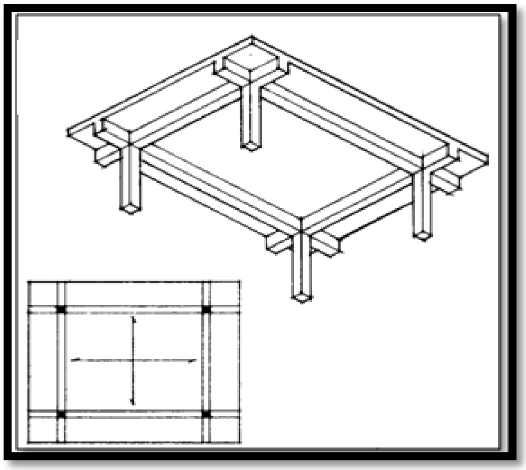


Figure 16 : Tow way solid slab

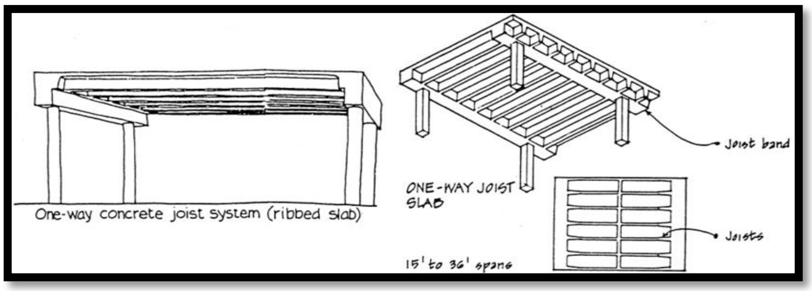


Figure 17 : One way ribbed slab

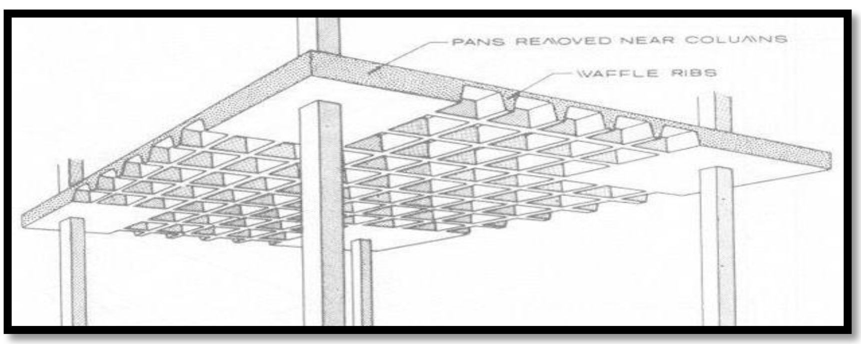


Figure 18 : Waffle slabs

3- Columns :

A reinforced concrete column is considering from main & initial parts of structure, it's usually design to carry compressive loads and resist lateral forces also, use to support the beams and arches and used to transmit the load to the foundation . For design purposes, the columns are separated into two categories, short columns and slender columns.

Short columns:

the column is said to be short column when the height of the column is small compared with the cross-sectional area ,the failure of this type occurs as a result of crushing of material .

Slender columns:

the column is said to be long column when the height of the column is large compared with the cross- sectional area ,the failure of this type occurs as a result of buckling .

the reinforcement of column consist longitudinal bars for axial force and bending ,ties or spiral for lateral load .

4- Beams:

A beam is a structural element that capable withstanding load primarily by resisting bending, This bending force induced in beam as a result of the external loads, own weight, spans of slab, and external reactions to these loads is called a bending moment .beam also carry horizontal load from wind or earthquake the lingual reinforcement in beam used to resist bending moment and stirrups used to resist shear force .

Classification of beams based on supports :

- Simply supported - a beam supported on the ends which are free to rotate and have no moment resistance.
- Fixed - a beam supported on both ends and restrained from rotation.
- Over hanging - a simple beam extending beyond its support on one end.
- Double overhanging - a simple beam with both ends extending beyond its supports on both ends.
- Continuous - a beam extending over more than two supports.
- Cantilever - a projecting beam fixed only at one end

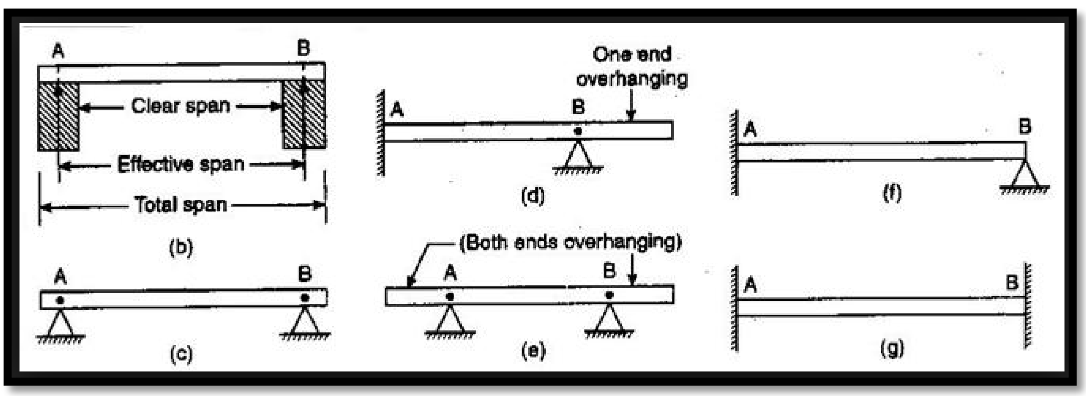


Figure 19 : type of beams

5- Walls :
Walls are defined as the boundaries on the outside and the inside of the building ,there are many type of wall such as :
External wall:
this type of wall used to separate between outside spaces and inside spaces, also protect the occupant from the external impact such as ,rain ,temperature ,wind and snow...etc . to achieve comfort for occupant . also it may be a bearing wall .

- **Partition walls:**

It's used to separate between the internal spaces ,in the most cases it's not bearing wall .

- **Shear walls:**

Shear walls are vertical elements of the horizontal force resisting system. like wind load and earthquake load.

- **Curtain walls:**

Curtain walls used for architectural needs such decoration (good view), usually it's not bearing wall . Also it may used in a specific building sides to purpose of solar design (used in green building).
Retaining walls :
Retaining walls are structures designed to restrain soil to unnatural slopes. They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes.

2.3.5. Loads

Structural loads or actions are forces, deformation, or accelerations applied to a structure or its components .Loads cause stresses, deformations, and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis. Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled.

Type of loads

- **Dead load:**

The dead load are static loads that constant over the time ,including the weight of the structure itself, and immovable fixtures such as walls, plasterboard or carpet. Roof is also a dead load. The dead load may be a tension or compression forces .Dead loads are also known as Permanent loads.

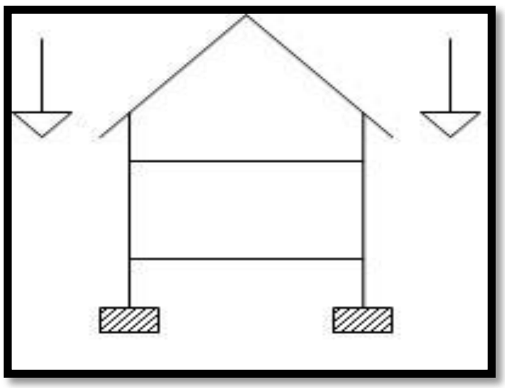


Figure 20 : Dead Load

- **Live load:**

These Live load not a constant over time ,it's moving loads or nonpermanent forces , loads within buildings caused by the weight of people furniture , Since it is not possible to measure these loads, aprobabilistic approach is used depending on codes dynamic loads may involve considerations such as impact, momentum, vibration, slosh dynamics of fluids…etc.

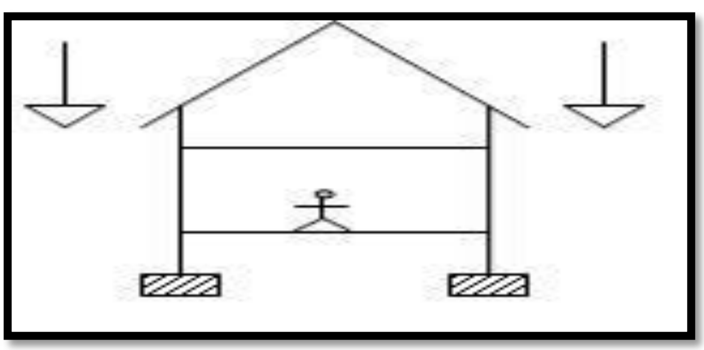


Figure 21 :live Load

- **Environmental loads**

These are loads that act as a result of weather, topography and other natural phenomena.

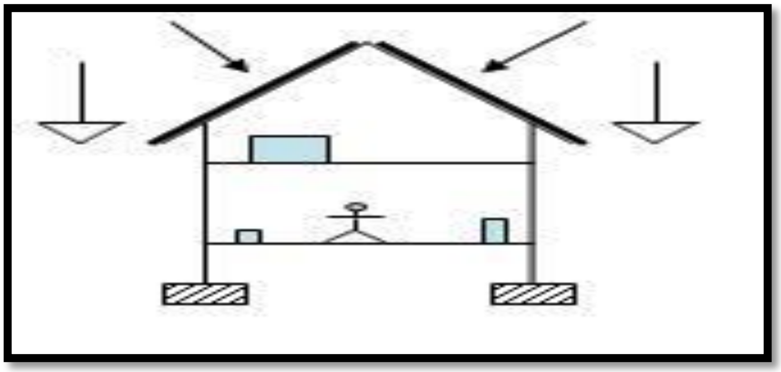


Figure 22 : Environmental loads

- **Environmental load types :**

1- Wind loads
2- Loads from fluids or floods
3- Seismic loads
4- Temperature changes leading to thermal expansion cause thermal loads
5- Lateral pressure of soil, ground water or bulk materials
6- Dust loads
7- Snow, rain and ice loads

2.4. Electrical Design :

2.4.1. Artificial lighting:[6]

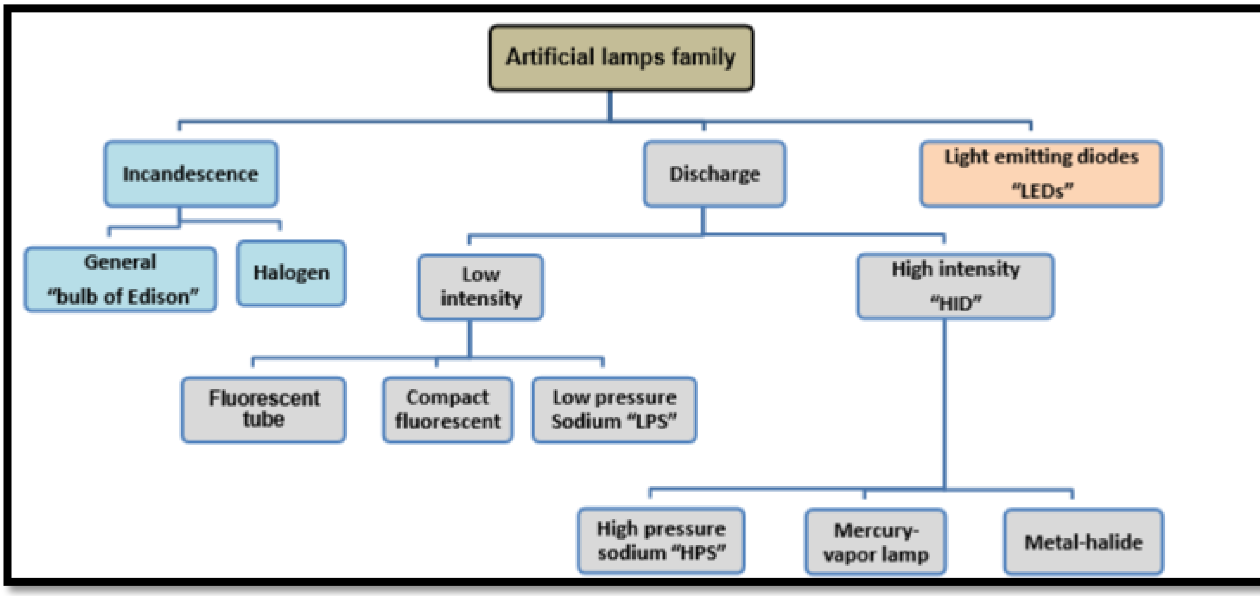


Figure 23 : Types of lamps

Parameters of lamp selection:

*Luminous Flux [lm]
* Lamp Efficacies "K" [lm/W]
* Luminance [cd/m2] / Brilliance
* Correlated Color temperature "CCT" [Kelvin]
* Color rendering index (CRI) or (Ra)
* Spectrum: A spectral power distribution (SPD)
* Dimensions
* Response times
* Service life (hours)
*Direction
* Cost
* auxiliary devices: Control gear, ballast, starter etc
* Durability

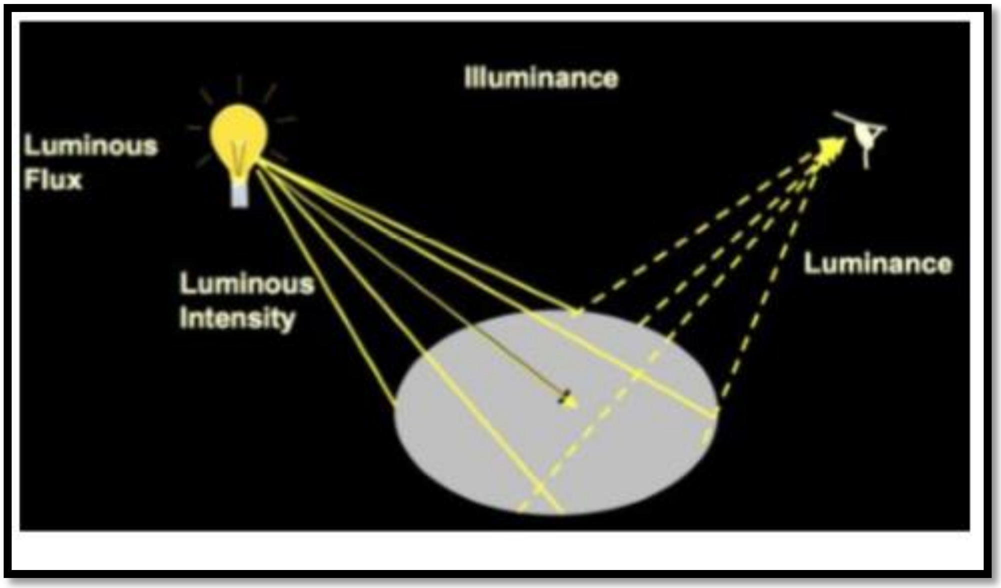


Figure 24 : Luminous Flux

Luminous Flux [lm] Φ= K*P

Where;

K : is a relationship between light output and electrical input (lumens/watt)

P: power for lamp (Watt)

Luminous Intensity (I):

Luminous intensity is the luminous flux emitted from a source within a certain solid angle.

$$I = \frac{\Delta\phi}{\Delta\Omega} = \frac{\Delta\phi . d^2}{\Delta A}$$

$$\Delta\Omega = {\Delta A}/{d^2}$$

I :[W/sr] vs. [lm/sr] or Candela [Cd]

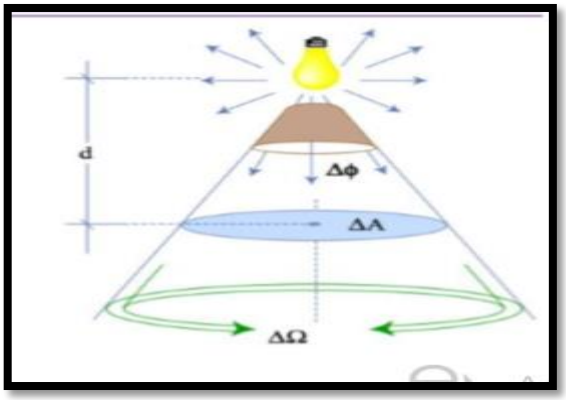


Figure 25 : Luminous Intensity

Illuminance (E):

is a measure of photometric flux per unit area, or visible flux density.measured in [W/m2] vs [lm/m2] or lux [lx].

$$E_{\perp} = \frac{\Delta\phi}{\Delta A}$$

Where;

Φ :is flux in lm.

A: is the area of the surface receiving the light in m^2.

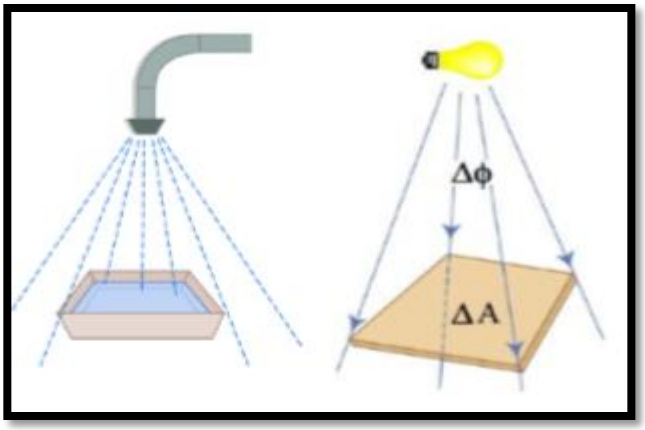


Figure 26 : Illuminance

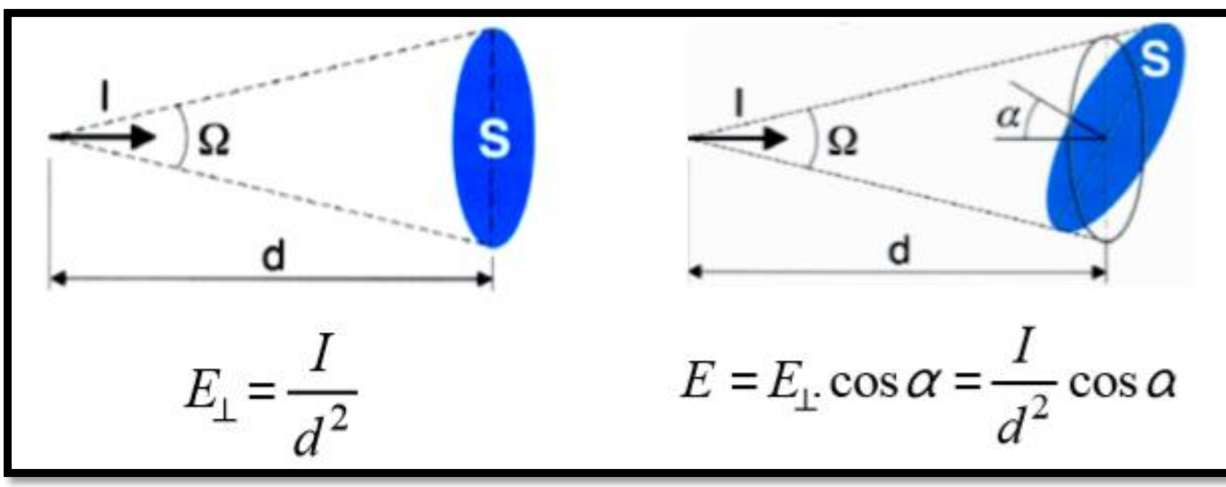


Figure 27 : Illuminance according to the Luminous Intensity

The table below show the required E according to the nature of task

Table 5 : required E according to the nature of task [7]

Category of Visual Task	Required E (lux)[a]	
	RF = 50%	RF = 10%
Casual	62–125	300–625
Ordinary	125–625	625–3,125
Moderate	625–1,250	3,125–6,250
Difficult	1,250–2,500	6,250–12,500
Severe	>2,500	>12,500

Luminance (L):

is flux emitted by apparent surface in a given direction. Measured in [W/m2.sr] vs. [lm/m2.sr] or [Cd/m2].

$$L = I / A_{apparent}$$

$$= I / A \cos \alpha$$

The table below show the required luminance according to the nature of task

Table 6 : required luminance according to the nature of task [8]

Category of Visual Task	Required Luminance (cd/m^2)
Causal	10–20
Ordinary	20–100
Moderate	100–200
Difficult	200–400
Severe	Above 400

Correlated Color temperature (CCT) [Kelvin]:

It defines whether the light from the lamps look 'warm' or 'cool'.

Lamps with a warm appearance having a CCT of 2700-3000K are generally considered appropriate in a domestic setting. Lamps of 4000K and above are considered 'cool' and are more appropriate for office and some retail applications.

The table below show the CCT for some source of lighting

Table 7 : the CCT for some source of lighting [9]

Type of light	Color temperature (k)
Candles	1900-2500
Tungsten filament lamps	2700-3200
Fluorescent lamps	2700-6500
High pressure Sodium	2000-2500
Metal halide	3000-5600
High pressure mercury	3400-4000
Moonlight	4100
Sunlight	5000-5800
Daylight (sun + clear sky)	5800-6500
Overcast sky	6000-6900

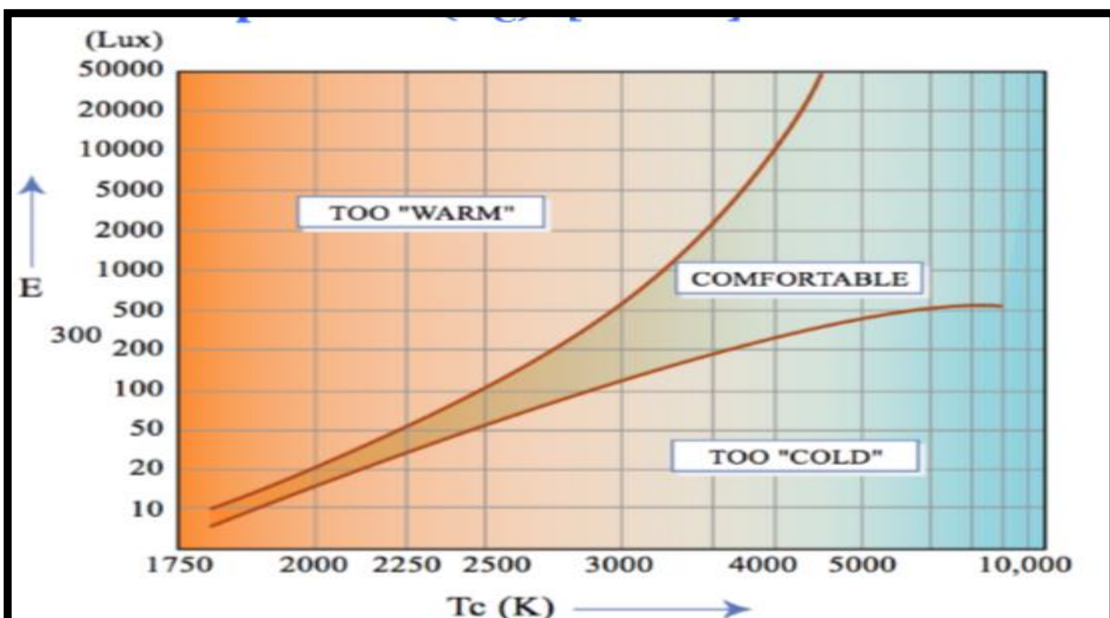


Figure 28 : Diagram of KRUITHOFF [10]

Color rendering index (CRI) or (Ra):

It is the ability of a light source to show surface colors as they should be.

Table 8 : CRI value [11]

CRI	Description
90-100	Excellent
80-90	Good
60-80	Acceptable
<60	Poor

Function/application	CRI
Street lighting	> 60
Office & residential lighting	> 80
Shops & supermarkets	> 90

Luminaires :

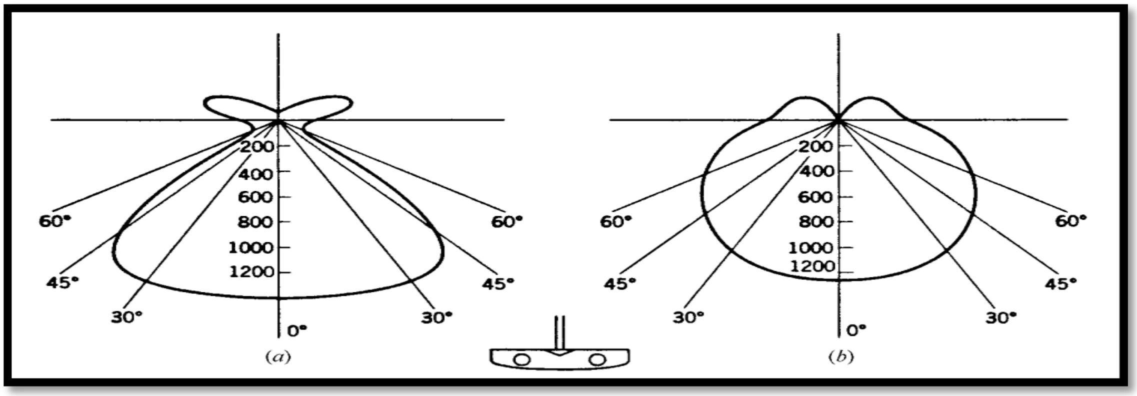


Figure 29 : Luminaire distribution

The type of luminaires include Direct, Indirect, Direct-Indirect and Asymmetrical

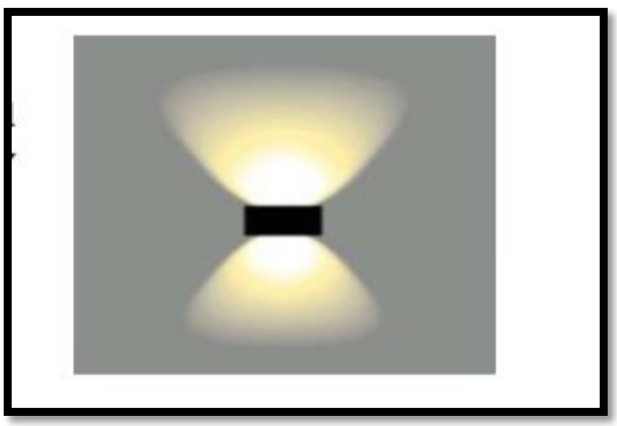


Figure 30 : Direct-Indirect luminaire

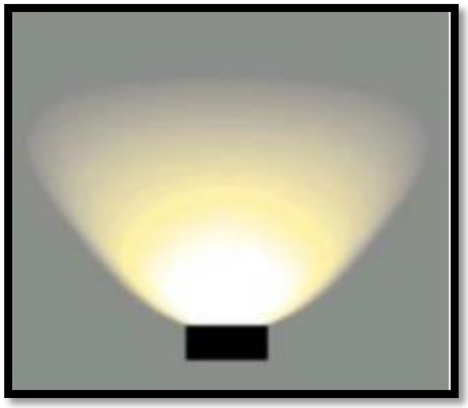


Figure 31 : Indirect luminaire

Luminaire efficiency :

It is the percentage of lamp lumens produced that actually exit the fixture.

Generally, the most efficient fixtures have the poorest visual comfort.

The component of luminaire mostly include , Reflectors, Louvers , Lenses (Diffuser) and Distribution (classes). this components affects on the amount of illuminance,which produce from the lamps.

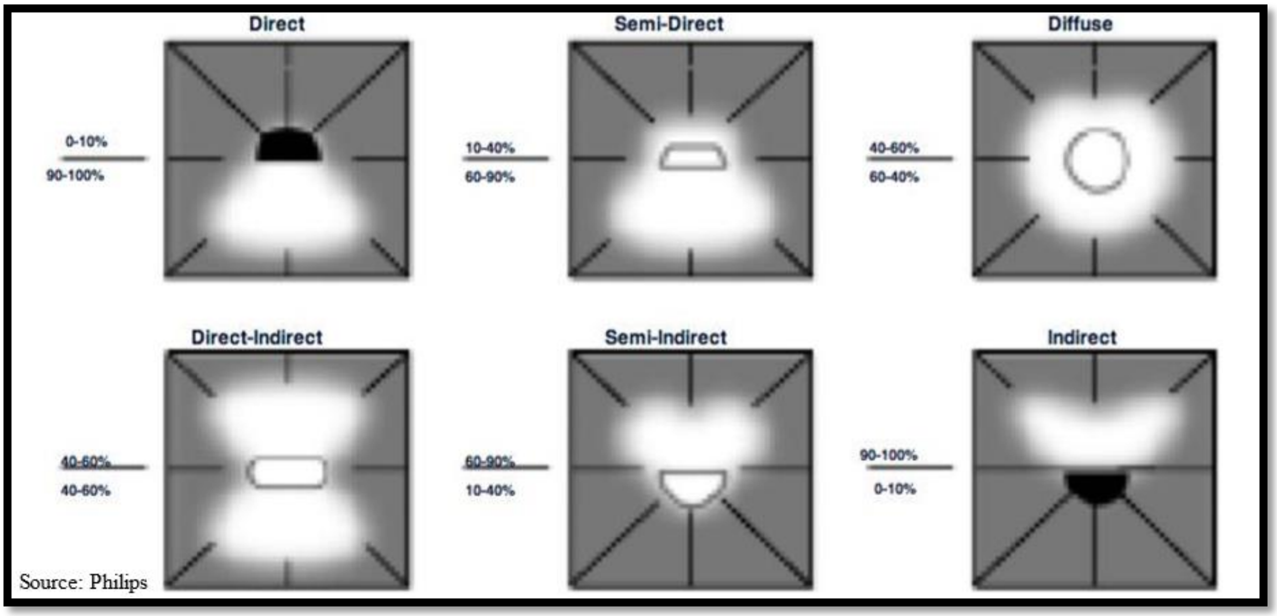


Figure 32 : light distribution produced by luminaires

Glare:

Glare is a visual impression created by the presence of illuminated area in the field of view. It can cause tiredness, errors and injuries.

Figure show that glare occurs when glare sources in the field of view which cause sensation of irritation in the eye.

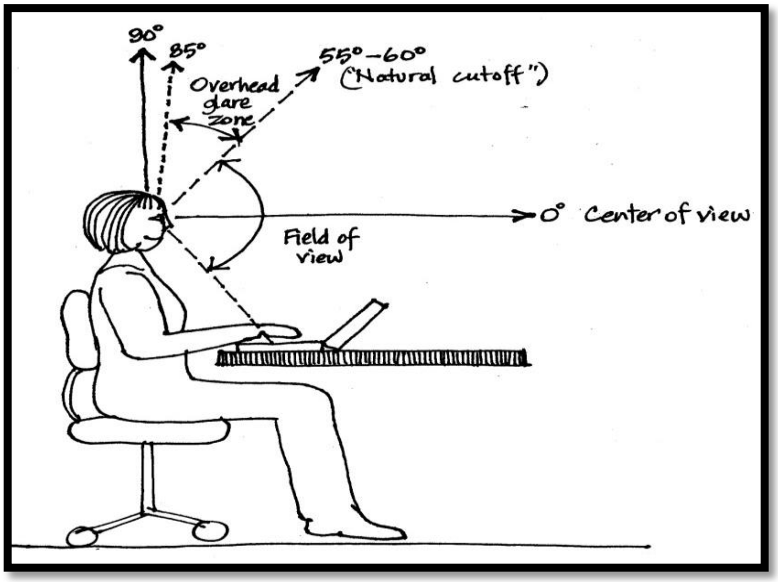


Figure 33 : angles of eye vision [12]

The table below show the recommended limiting glare index and the glare index rating

Table 9 : recommended limiting glare index and the glare index rating [13]

UGR ratings.

Zone	Region	UGR
Discomfort Zone	Intolerable (not suited for work lighting)	>28
	Just intolerable	28
	Uncomfortable	25
	Just Uncomfortable	22
Comfort Zone	Acceptable	19
	Just acceptable	16
	Noticeable	13
	Just Perceptible (no glare)	10

Recommended limiting glare indices.

Working area	Maximum allowed UGR
Drawing rooms	16
Offices	19
Industrial work, fine	22
Industrial work, medium	25
Industrial work, coarse	28

The table below show the recommended illuminance for workplace and facilities.

Table 10 : recommended illuminance for workplace and facilities [14]

Task position or area	Optimum average illumination in lux	Notes
General offices	500	
Computer work stations	500	Local lighting may be required for reading a document
Drawing work stations	750	Local lighting is appropriate
Other areas, e.g. file storage and reception, telephone operators	300	

Areas common to most buildings	Lux (lm/m^2)
Entrance hall, lobby, waiting room	200
Enquiry desk	500
Corridor, passageway, stairs	100
Atria	50-200
Changing room, cloakroom, lavatory	100
Rest room	150
Canteen, cafeteria, dining room	200
Kitchen	300
Gymnasium	500

2.4.2. Sockets :

AC power sockets are devices that allow electrically operated equipment to be connected to the primary alternating current (AC) power supply in a building. Electrical sockets differ in voltage and current rating, shape, size and type of connectors.

Demand factor and Diversity factor

Demand factor and diversity factor are necessary values used in the electrical design process. Demand factor is defined as the fractional amount of the maximum demand of a system relative to the total connected load on the system and it is always less than one. On the other hand, diversity factor is defined as the ratio between the sum of individual maximum demand and the maximum demand on power station. Diversity factor for different circuit functions are listed in the table3.11.

Table 11 : Diversity factor for different circuit function [15]

Circuit Functions	Diversity Factor
Lighting	**0.9**
Heating and air conditioning	**0.8**
Sockets – outlets	**0.7**

2.5. Mechanical Design :

2.5.1. Introduction :

Mechanical issue of various kinds is one of the most important determinants of the design of these buildings, Therefore, the architect (designer) should be on the lookout appropriate requirements necessary for this business, and capable of understanding with the mechanical engineer at the design of mechanical installations without conflict with the rest of the disciplines involved, So we must choose the most appropriate system for the convenience of people inside the building, It is the most important things that must be considered from the mechanical point of view, natural ventilation, the degree of surface air temperature and direction of movement, relative humidity, water supply, plumbing, heat transfer

2.5.2. HVAC Systems :

Hvac systems in general include two system , Central and Local Systems ,central generally include centralized equipment ,such as ,(chillers ,boilers ,cooling towers ,and maybe air handling units),and local systems contain window air conditioners ,packaged heat pumps ,and water-cooled packaged units without central source equipment, in general the central system needs large spaces other than the local system which is need less spaces for equipment

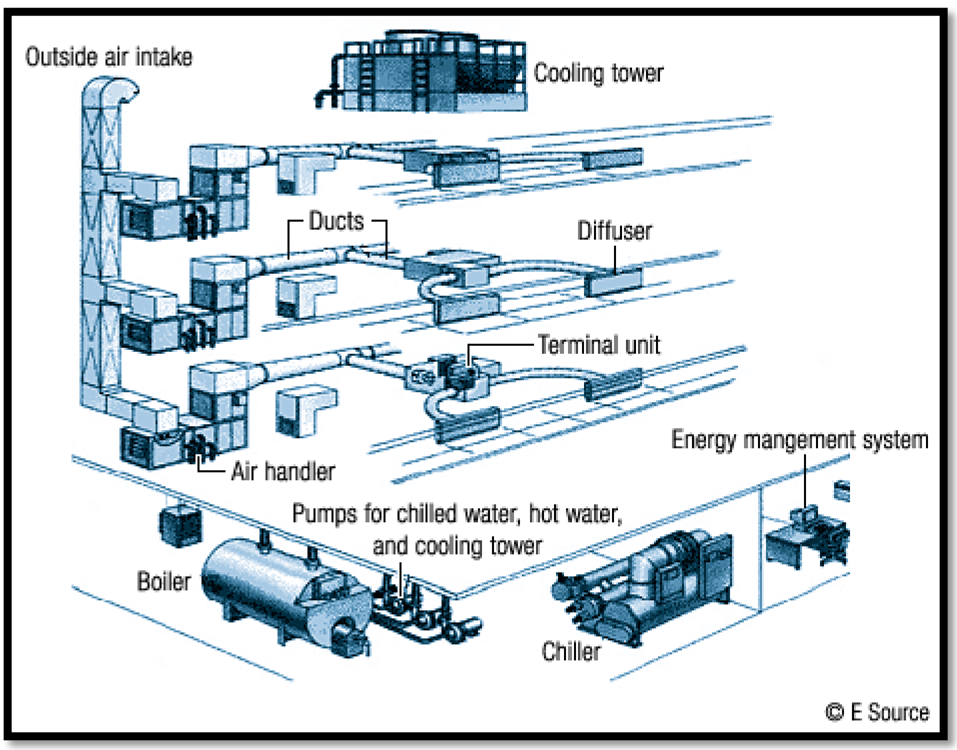


Figure 34 : centralized components for central systems [16]

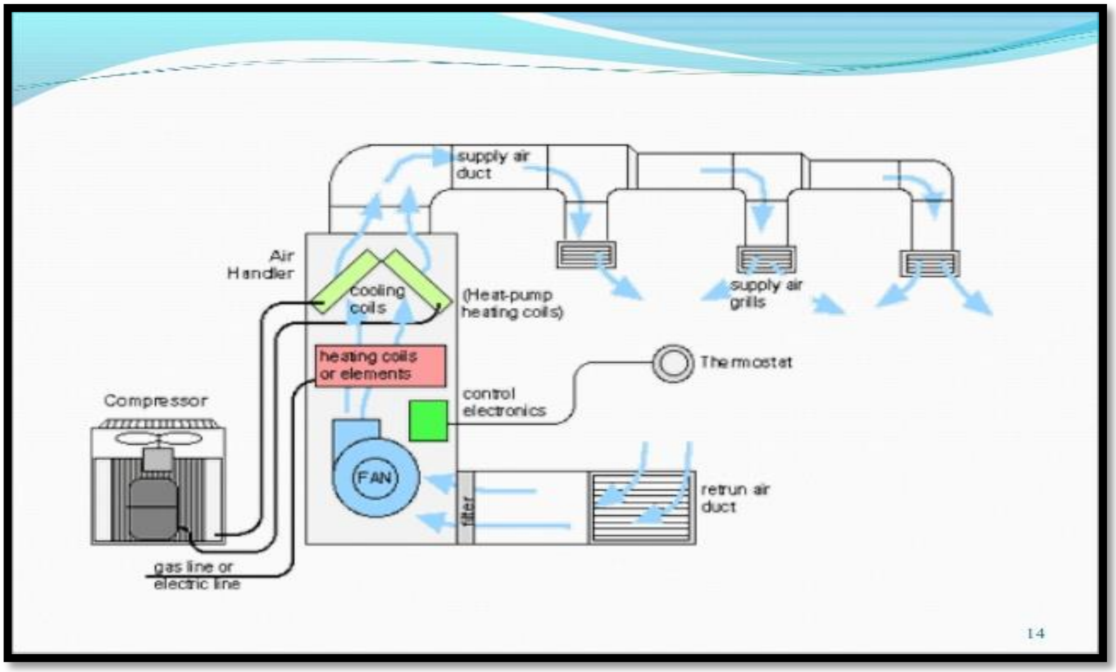


Figure 35 : components of local Hvac systems

2.5.3. Elevators :

Elevators are devices that move people and goods vertically within a dedicated shaft that connects the floors of a building

Vertical transportation such as elevators and escalators Is important things to be taken into considerations during the design phase to make the service and transportation for passengers more efficient and effective. The decision that must be very important and must be taken into consideration is to select the best and safest system for the vertical transportation equipment.

“More than any other element of construction, elevators are governed by strict codes.

The last resource in the United States is the American Society of Mechanical Engineers’ ANSI/ASME Standard A17.1, Safety for elevators and escalators, the latest version of which should be in every architect’s and engineer’s working library. The code has legal force in most parts of the United States. Two related code standards should be noted. ANSI/ASME Standard A17.3 covers existing elevators and escalators, and Standard A17.4 covers emergency evacuation of passengers from elevators”. (Michael and Donald 2004)

There are many types of elevators. Hydraulic elevators they are used for low rise applications(buildings)and residential buildings(2-8 stories) because it’s simple and low speed . The other type is roped elevators are lifted by ropes and They are used for mid and high-rise applications and have much higher travel speeds than hydraulic elevators.

The size of elevators ,speed and it’s capacity depends on several factors, including building type(Residential, Commercial buildings ,offices ….etc)and the amount of passengers or People that the elevator will transports them in the unit of time .

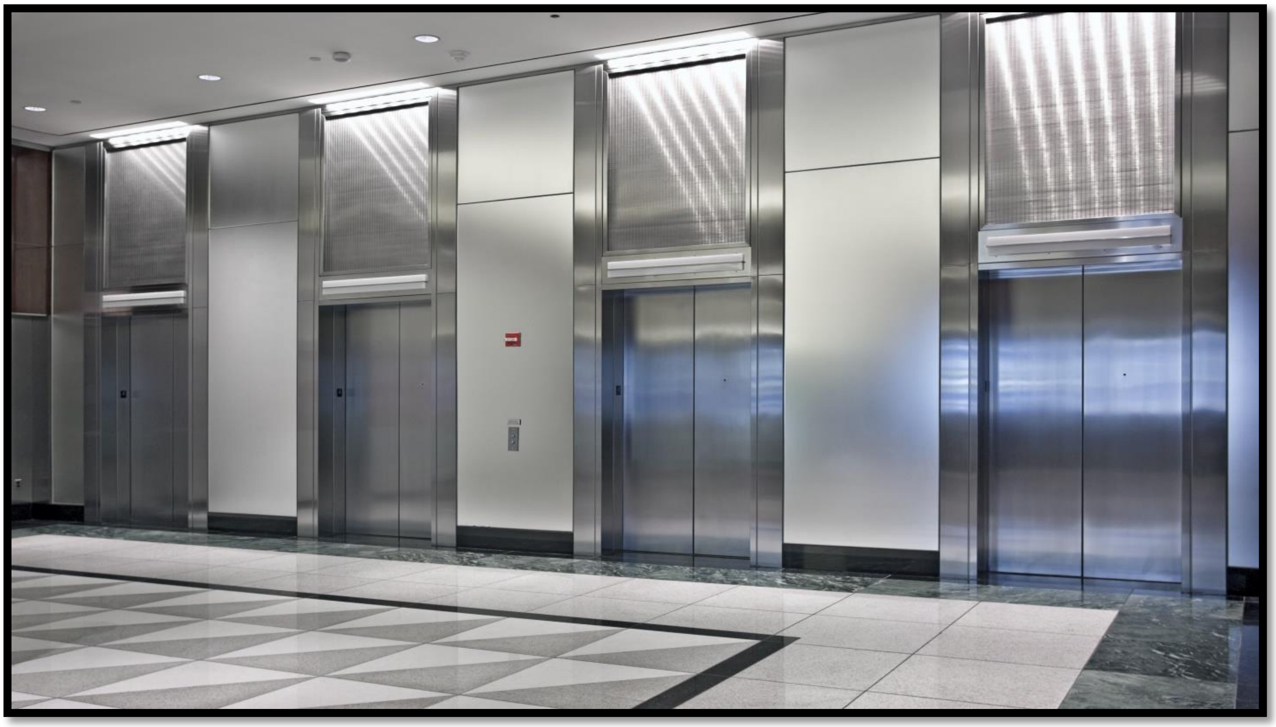


Figure 36 : picture of elevator

Important definitions:

Average lobby time or average lobby waiting time: The average time spent by a passengers between arriving in the lobby and leaving the lobby in a car. This is a key selection criterion(Mechanical and Electrical Equipment for Buildings, Grondzik, et al. 2010)

Handling capacity (HC): The maximum number of passengers that can be handled in a time given period—usually 5 minutes .Thus the term 5-minutes handling capacity when expressed as a percentage 0f the building's population ,it's called percent handling capacity (PHC) . This is a key selection criterion (Mechanical and Electrical Equipment for Buildings, Grondzik , et al. 2010)

Interval (I) or lobby dispatch time: average time between departure of cars from lobby.

Registration time: Is the Waiting time at an upper floor after a call is registered.

Round-trip time (RT): The average time required for a car to make a round trip with some stop. This time include number of upper floor stops in one direction

Travel time or average trip time (AVTRP): The average time spent by passengers from the moment they arrive in the lobby to the moment they leave the car at an upper floor. This is a key selection criterion.

Zone: A group of floors in a building that is considered as a unit with respect to elevator service. It may consist of a physical entity—a group of upper floors above and below which are blind shafts—or it may be a product of the elevator group control sys- tem, changing with system needs.

Car passenger capacity (p): passengers per car.
All of these definitions must be taken into considerations to reach a good level of comfortable range
And to estimate the approximate number of needed elevators.
The following tables obtained from the codes show some factores to evaluate the number of elevators needed and their capacity and speed for the buildings according its type

2.5.4. Sanitation system :

Water Drainage system : should be in place which does not affect on the structural Components such as beams ,and columns . This separate system of pipe used to carry the foul water , surface water ,car park ..etc , to disposal or Getting benefit of them .

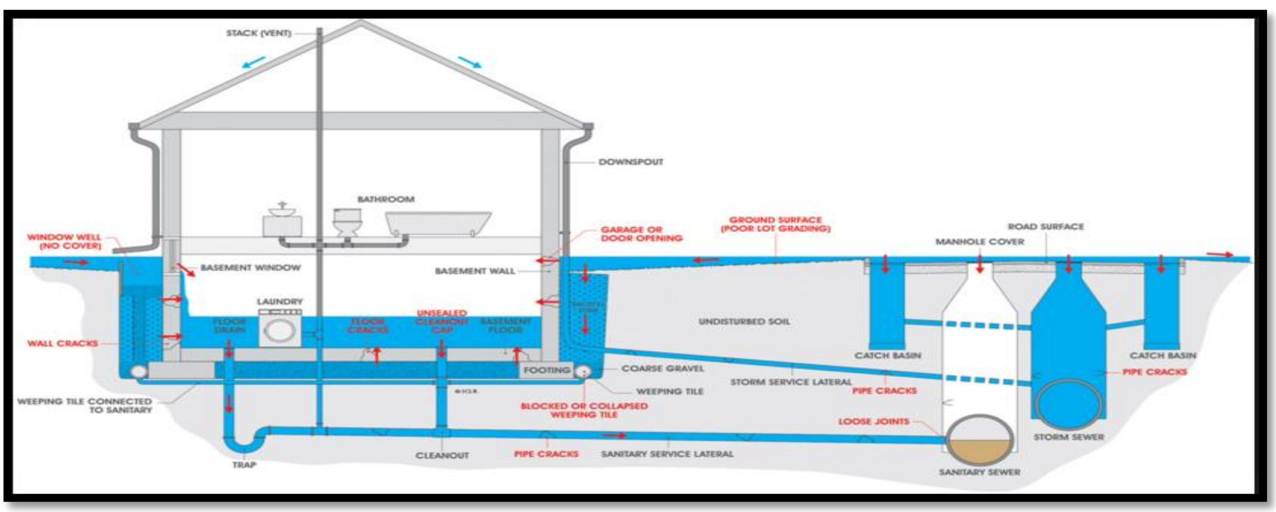


Figure 37 : Water Drainage system

Drainage of gray water and black water:

Grey water is wastewater generated from domestic activities such as laundry, dishwashing, and bathing, which can be recycled on-site for uses such as landscape irrigation and constructed wetlands. Grey water differs from water from the toilets which is designated sewage or black water to indicate it contains human waste.

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.

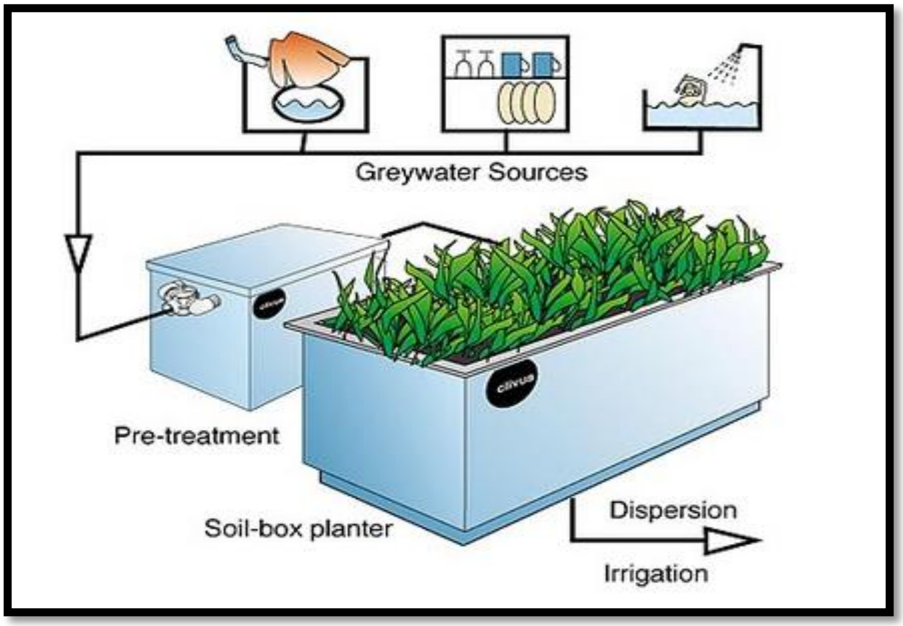


Figure 38 : sources of Grey water

Water supply system :

"Buildings require an adequate supply of clean water for drinking, cooking, washing, industrial processes, and agriculture. This requires a system that has three basic components: a source of water; a means to purify the water, if necessary ;and a way to distribute the water to points of use inside buildings." The needed demand weight of water depend on the number of fixture units in the building.

To get the suitable pressure and the required flow the diameter of pipe should be suitable to achieve that. the table below shows the demand weight of fixture in fixture units .

Table 12 : demand weight of fixture in fixture units(NBS Report BMS79 water –distribution for building [17]

Table 10.10 *Demand Weights of Fixtures in Fixture Units*[a]

Fixture or Group[b]	*Occupancy*	*Type of Supply Control*	*Weight in Fixture Units*[c]
Water closet	Public	Flush valve	10
Water closet	Public	Flush tank	5
Pedestal urinal	Public	Flush valve	10
Stall or wall urinal	Public	Flush valve	5
Stall or wall urinal	Public	Flush tank	3
Lavatory	Public	Faucet	2
Bathtub	Public	Faucet	4
Shower head	Public	Mixing valve	4
Service sink	Office, etc.	Faucet	3
Kitchen sink	Hotel or restaurant	Faucet	4
Water closet	Private	Flush valve	6
Water closet	Private	Flush tank	3
Lavatory	Private	Faucet	1
Bathtub	Private	Faucet	2
Shower head	Private	Mixing valve	2
Bathroom group	Private	Flush valve for closet	8
Bathroom group	Private	Flush tank for closet	6
Separate shower	Private	Mixing valve	2
Kitchen sink	Private	Faucet	2
Laundry trays (1–3)	Private	Faucet	3
Combination fixture	Private	Faucet	3

[a] From NBS Report BMS79 *Water-Distributing Systems for Buildings*

The figure below show the relation between the number of fixture units and the required demand.

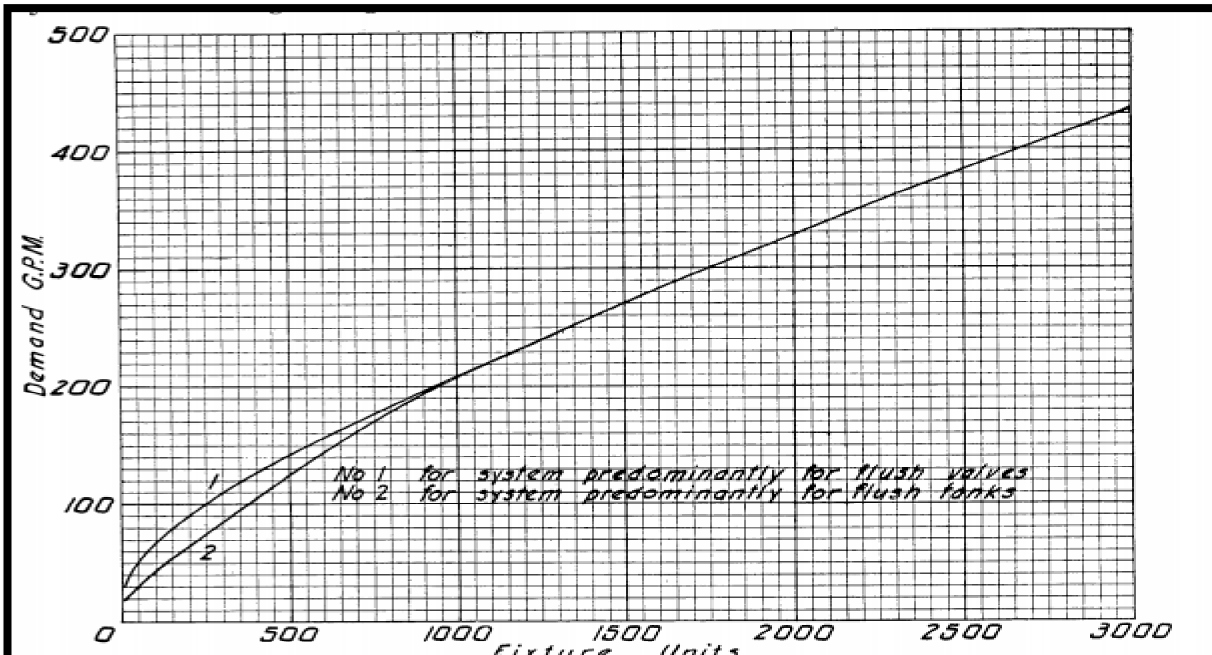


FIGURE 7.—*Estimate curves for demand load.*

Figure 39 : relation between the number of fixture units and the required demand(NBS Report BMS79 water –distribution for building [18]

Table 13 : flow needed for plumping fixture(uniform plumbing code) [19]

Fixture	Occupancy	Type of Supply Control	Load Values in WSFU		
			Cold	Hot	Total
Bathroom group	Private	Flush tank	2.7	1.5	3.6
Bathroom group	Private	Flush valve	6	3	8
Bathtub	Private	Faucet	1	1	1.4
Bathtub	Public	Faucet	3	3	4
Bidet	Private	Faucet	1.5	1.5	2
Combination fixture	Private	Faucet	2.25	2.25	3
Dishwashing machine	Private	Automatic		1.4	1.4
Drinking fountain	Offices, etc.	⅜ in. (9.5 mm) valve	0.25		0.25
Kitchen sink	Private	Faucet	1	1	1.4
Kitchen sink	Hotel, restaurant	Faucet	3	3	4
Laundry trays (1 to 3)	Private	Faucet	1	1	1.4
Lavatory	Private	Faucet	0.5	0.5	0.7
Lavatory	Public	Faucet	1.5	1.5	2
Service sink	Offices, etc.	Faucet	2.25	2.25	3
Shower head	Public	Mixing valve	3	3	4
Shower head	Private	Mixing valve	1	1	1.4
Urinal	Public	1 in. (25 mm) flush valve	10		10
Urinal	Public	¾ in. (19 mm) flush valve	5		5
Urinal	Public	Flush tank	3		3
Washing machine, 8 lb (3.6 kg)	Private	Automatic	1	1	1.4
Washing machine, 8 lb (3.6 kg)	Public	Automatic	2.25	2.25	3
Washing machine, 15 lb (6.8 kg)	Public	Automatic	3	3	4
Water closet	Private	Flush valve	6		6
Water closet	Private	Flush tank	2.2		2.2
Water closet	Public	Flush valve	10		10
Water closet	Public	Flush tank	5		5
Water closet	Public or private	Flushometer tank	2		2

2.6. Safety System :

2.6.1. Introduction

The design of the buildings became associated with Providing factors of safety inside the building against accident,such as fires.so the fire detection , Suppression and notification System shoud be available in the building design. the behavior of fire depend on some factors,some of it depend on the building content,and the others depend on the building design.

$$\text{a- Building Content}\begin{cases} 1 - Naturalofthefuel\ . \\ 2 - Amountoffuel\ . \\ 3 - Arrangmentoffuel. \end{cases}$$

$$\text{b- Building Design}\begin{cases} 1 - Sizeandshapeoftheroomcotainingthefire \\ 2 - Sizeandshapeofthe\ window. \\ 3 - Thermalinsulationofwallsandceiling. \end{cases}$$

2.6.2. The safety systems component :

- Fire Doors: fire doors are installed to minimize the spread of fire, including the passage of smoke through a building. Fire doors has to be made from nonflammable material. Also, it has small window to enable people see from both side and opens to the stair ay by long bar lock.
- Fire extinguishers
- Standpipes and hose stations.
- Automatic sprinkler systems
- Fire Suppression System
- Smoke detector
- Heat detector and Flame detector .

Figure 40 : safety systems component

2.7. Case study [20]

Introduction :

known as Infinity Tower prior to its inauguration, is a 306 meters (1,004 ft), 73 story skyscraper in Dubai, United Arab Emirates , the tower has become world's tallest high rise building with a twist of 90 degrees. (wikipedia).
It has been designed carefully each floor, so going by 1.2 degrees on the floor which preceded, constituting spiral movement unique and wonderful in the world of architecture.
3.1.2.Location :
This residential tower is located in a beautiful location near the Dubai Marina and includes 495 luxury apartments.

Analysis:

Table14 : Analysis for kayan tower

Official Name	Cayan Tower
Location	**Dubai | United Arab Emirates**
Function	**Residential**
Construction	**2006 - 2013**
Architectural Height	**306,4 m**
Floors Above Ground	**73**
Floors Belove Ground	**5**
Number of Apartments	**495**
Number of Parking Spaces	**623**
number of Elevators	**7**
Top Speed of Elevators	**28.8 km/h (8m/s)**
Gross Floor Area	**111 000 m^2**
Construction Cost	**US $ 207 million**

DESIGN IDEA &   GOALS:

- Cayan Tower is the tallest twisted tower in the world.

- Each floor of Cayan Tower has exactly same contours and is rotated by 1.2 degrees to achieve the full 90°spiral creating the shape of a helix.

- Unique spiral shape of Cayan Tower reflects the ever-changing shapes of the deserts, winds, and seas that surround it.

- The shape of the tower is a variation on Turning Torso in Malmö, Sweden, which also twists exactly 90.

- The design team presents 3 options; a) 60deg rotation; b) 90deg rotation; c) 90deg rotation with glazing pushed 20 cm from exterior face of the columns from original 12 cm for maximizing sellable area to the client. Based on the clients comments, last one was picked.

TOP VIEW & ELEVATIONS

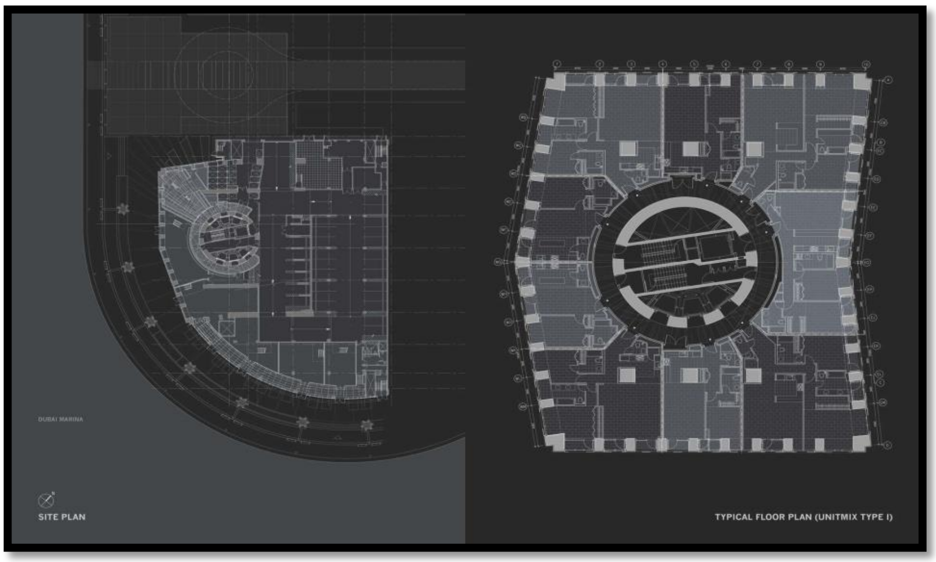


Figure 41 : top view for kayan tower

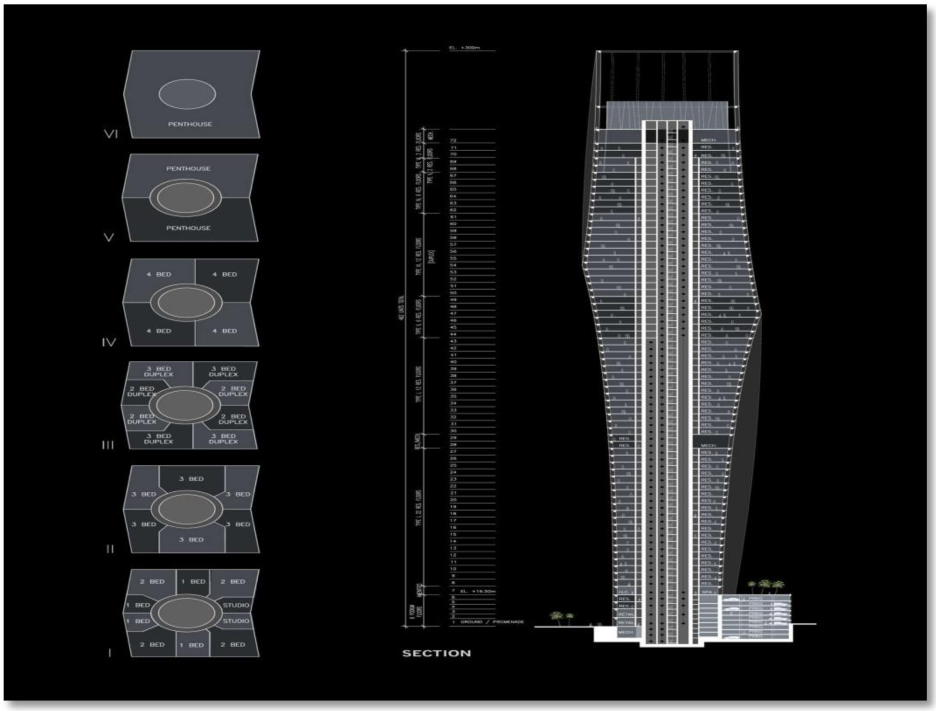


Figure 42 : elevation of kayan tower

BUILDING FUNCTIONS:

- Cayan Tower has six podium floors in which there are tower lobby,car parks, retails and public cafes.
- There are two mechanical floor in Cayan Tower and they are located on 28th and 72nd floors. Both mechanical floor are in two story-height.

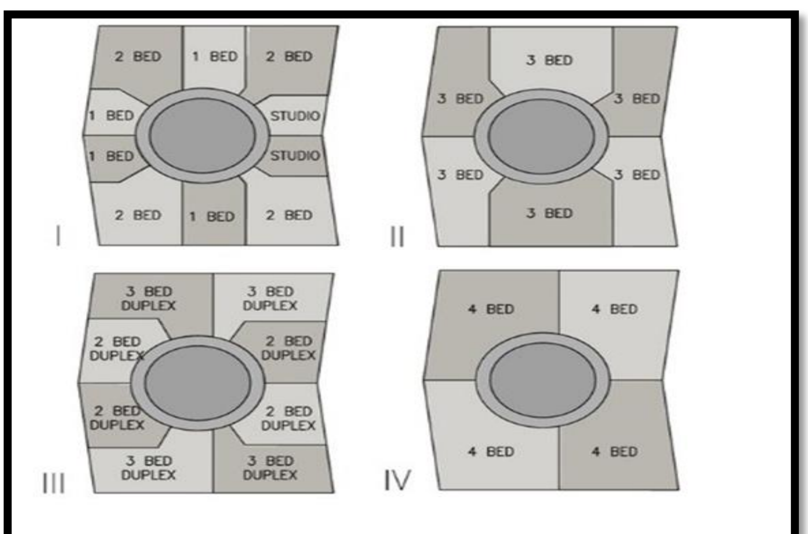


Figure 43 : Residential plan layouts in kayan tower

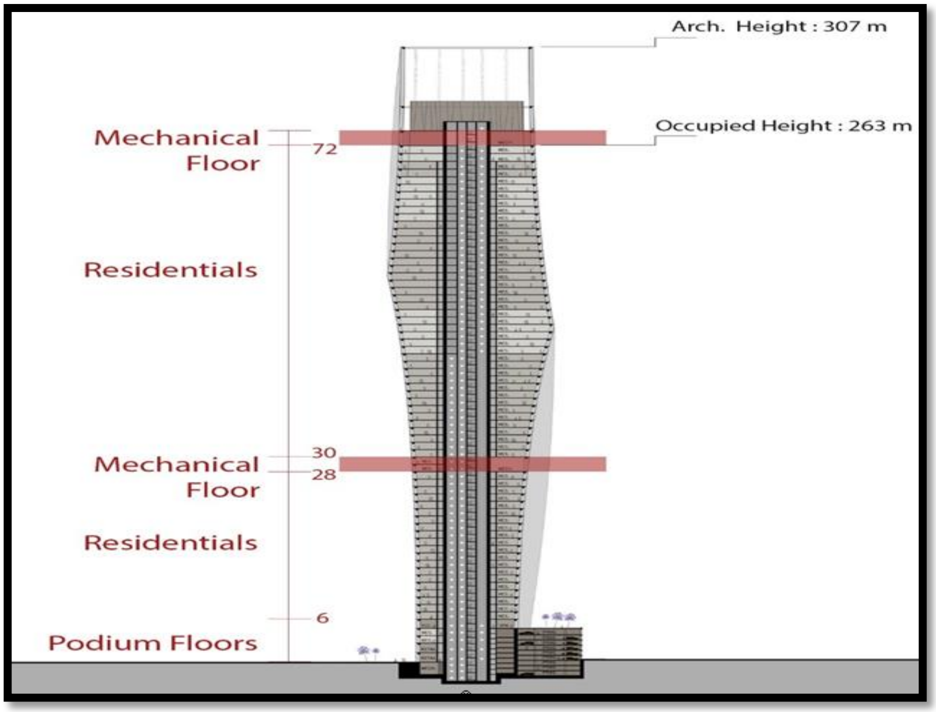


Figure 44 : functional diagram for kayan tower

STRUCTURAL SYSTEM

- The design philosophy for the Tower is based upon the exterior form of the building as a direct expression of the structural framework.

- The lateral load resisting system for the Tower consists of a combination of a reinforced concrete moment-resisting perimeter tube frame and a circular central core wall, connected at each level by the two-way spanning reinforced concrete flat plate slabs acting as diaphragms. Perimeter columns are also connected to each other with spandrel beams.

- Floor to floor height of each identical structural floor is 3.7 meters.

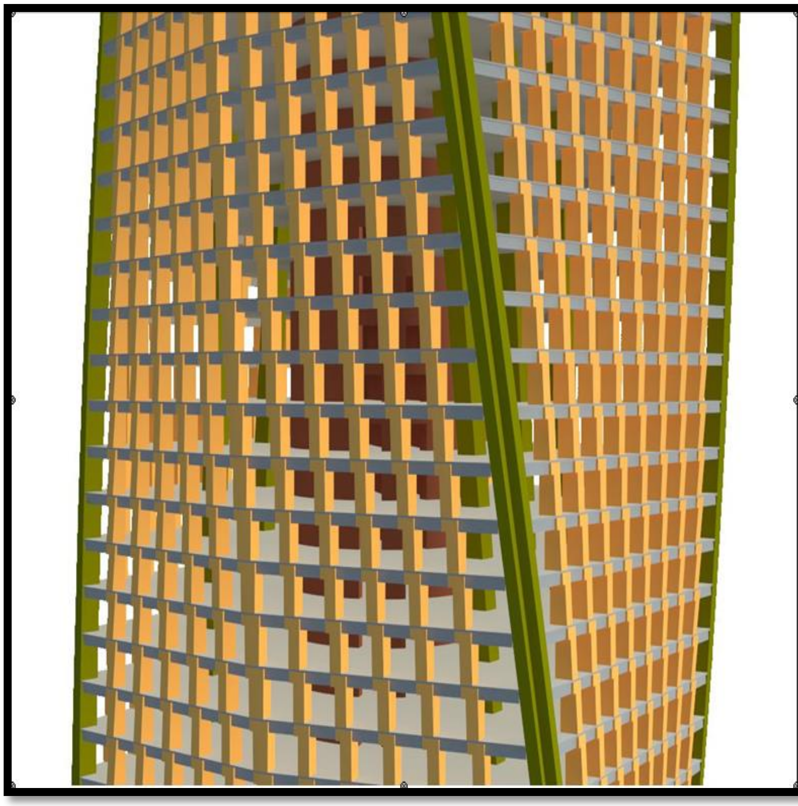


Figure 45 : structural model for kayan tower

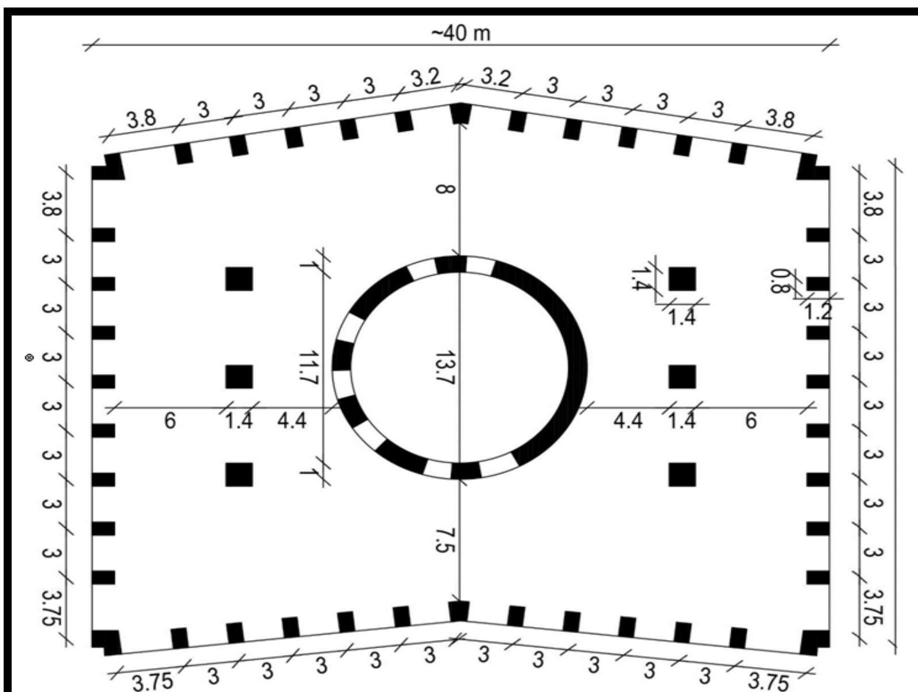


Figure 46 : structural plan of kayan tower

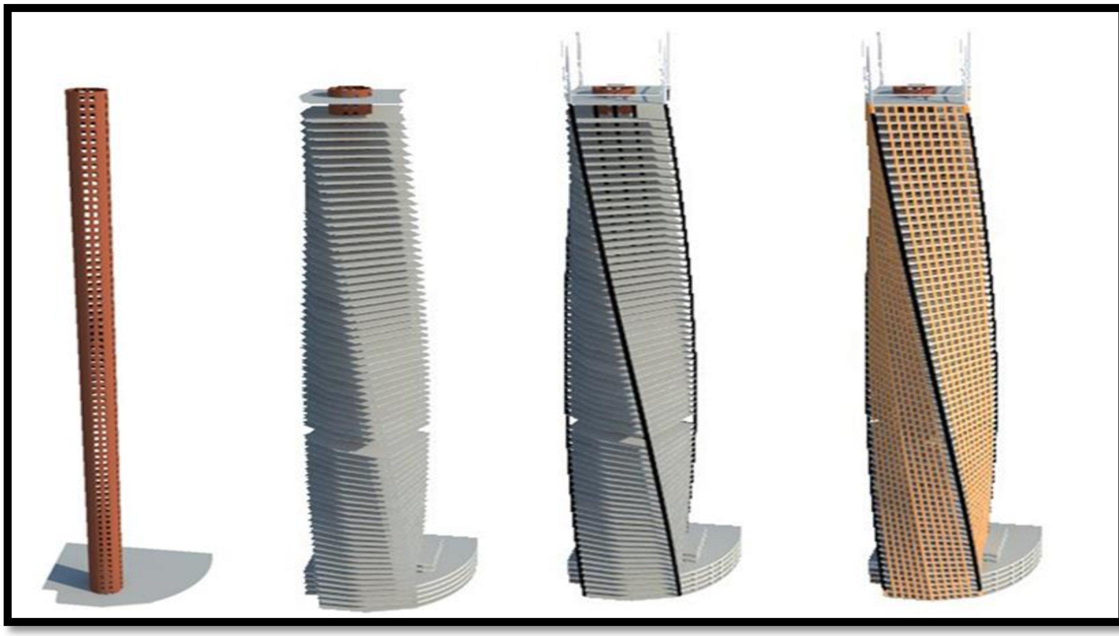


Figure 47 : Kayan tower

- A series of options are studied for the perimeter frame in order to create the unique twisting geometry of the Tower. For its distinct advantages, from the standpoint of 'architectural efficiency, structural performance and ease of construction', stacking the columns in a step-wise manner at each level, where each column slopes in one directin , and is offset over the column below is applied as the perimeter columns system.

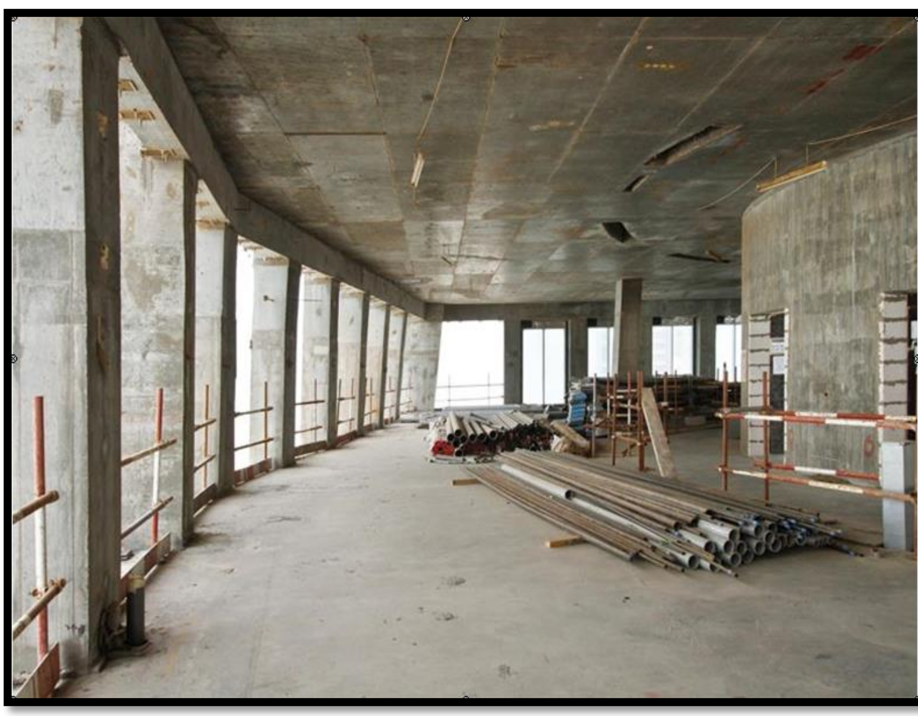


Figure 48 : Construction work in kayan tower

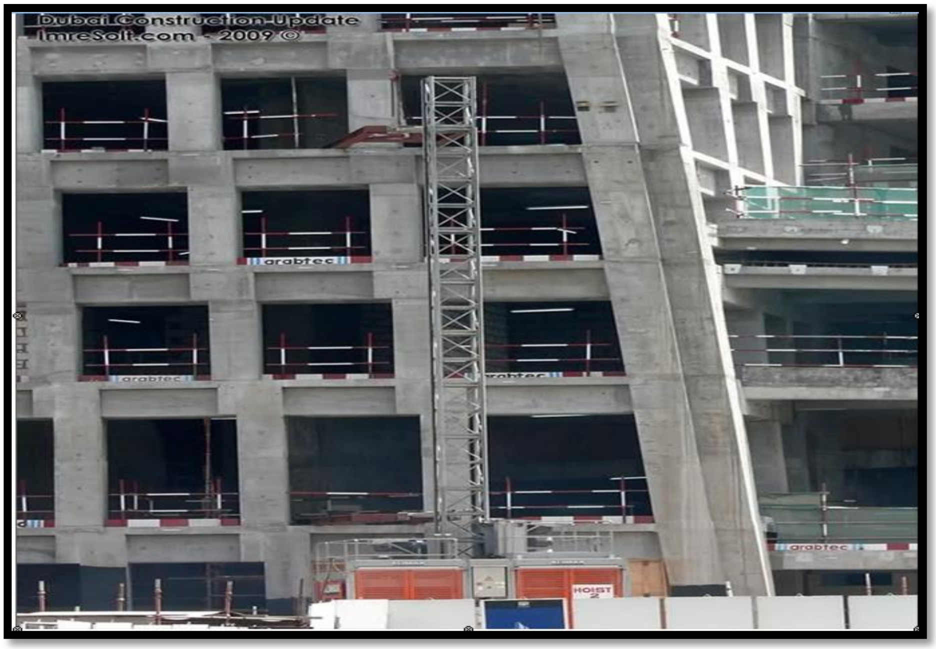


Figure 49 : Construction work in kayan tower

- As the perimeter columns ascend from story to story, they lean in or out, in a direction perpendicular to the slab edge. At every level, the columns make a small step to the side, shifting in position along the spandrel beams so that as the building twists, each column maintains a consistent position at each floor relative to the tower envelop The corner columns and the six (6) interior columns follow a different rule, twisting as they ascend.

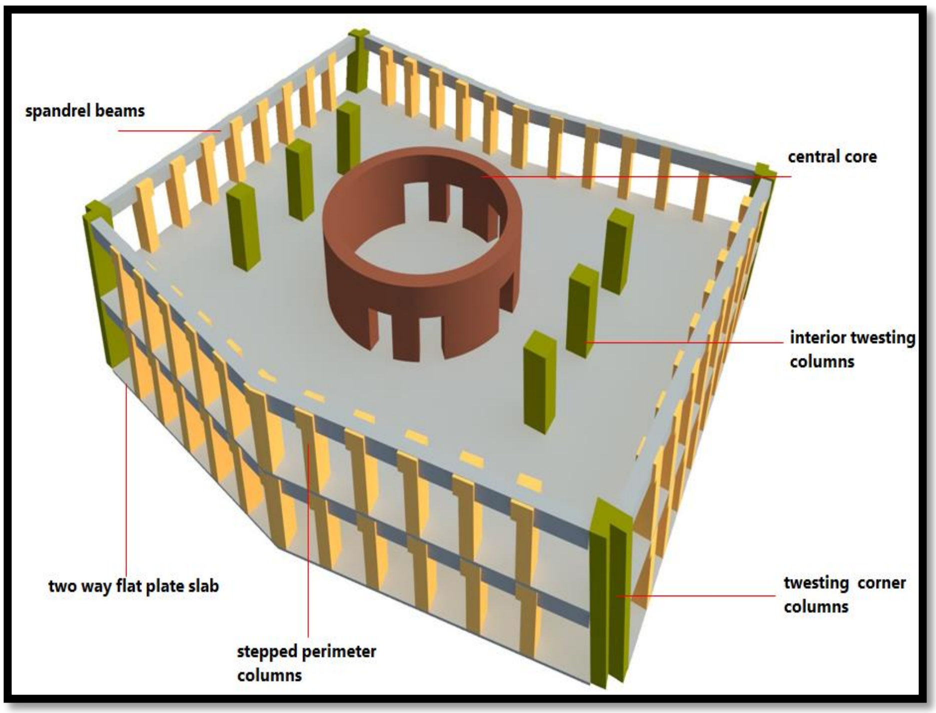


Figure 50 : structural orthogonal drawing of kayan tower

- The structural system offers significant construction simplification by permitting a high level of repetition in the formwork, which directly impacts the construction cycle time. Also, this system leads to residential floor layouts which are repetitive at each level despite the twisting nature of the building form.

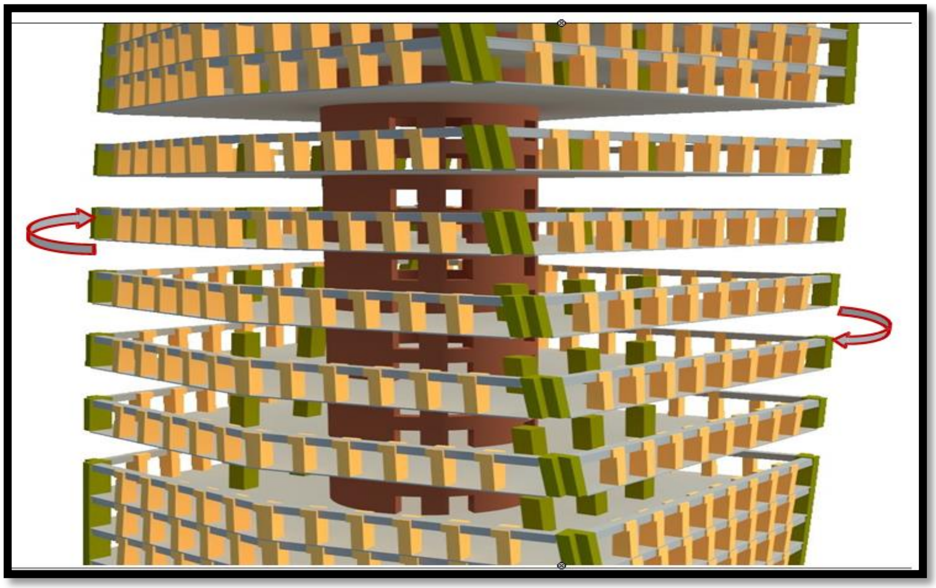


Figure 51 : floor twist of kayan tower

WIND design

- Due to the Tower's significant height and unique shape, detailed wind tunnel testing was performedin order to understand the wind forces acting on the building
- A series of 1:400 scale model tests were performed in order to determine the design wind loads for the structure as well as peak pressures for the designof the cladding.
- Pedestrian wind studies were also performed to ensure a comfortable wind environment for those spaces designated for outdoor use, and foradjacent public thoroughfares, respecting air, and sun rights of the surrounding.

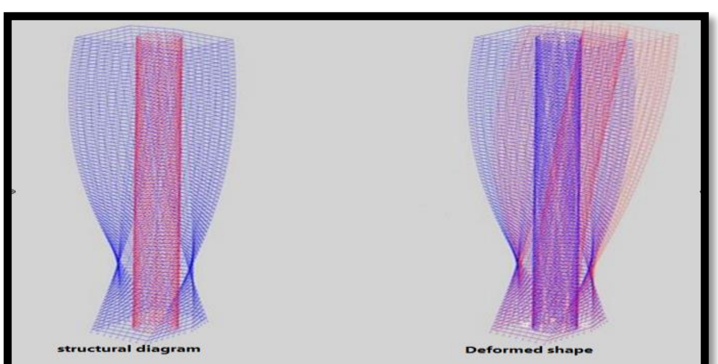


Figure 52 : deformed shape due to wind load

- For the twisting Cayan Tower, the variation in the building silhouette over its height creates a constantly changing frontal wind sail dimension as the building ascends, acting to disorganize the wind forces which are generated

- This disorganization of the wind forces, and therefore a reduced correlation of the Tower's wind response over its height, results in reduced lateral motion and thus reduced effective wind forces acting upon the building. Morever, corners are also designated as notched to contribute buildings performance against the wind forces.

- When compared to a similar building taken as a straight extrusion with height (no twist), it is estimated that the twisting form of the Cayan Tower reduced the structure's across-wind excitation by some 25% or more.

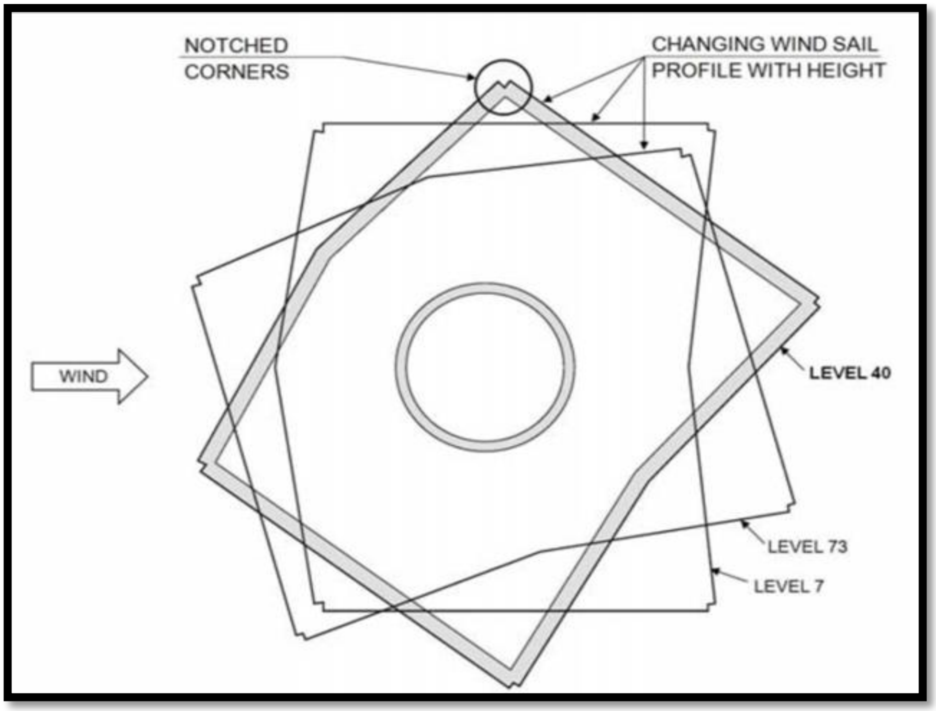


Figure 53 : The effect of wind load

Mep design :

In Cayan Tower, major mechanical risers are located in the circular central core, which allows a straight vertical path through the Tower.

The balance of the building's mechanical, electrical and plumbing systems is located within a deep demising wall between the central circulation corridor and the residential units. This zone is specifically located and designed to create a minimally obtrusive vertical path for the building services to access all residential units as they rotate about the central core as the building ascends.

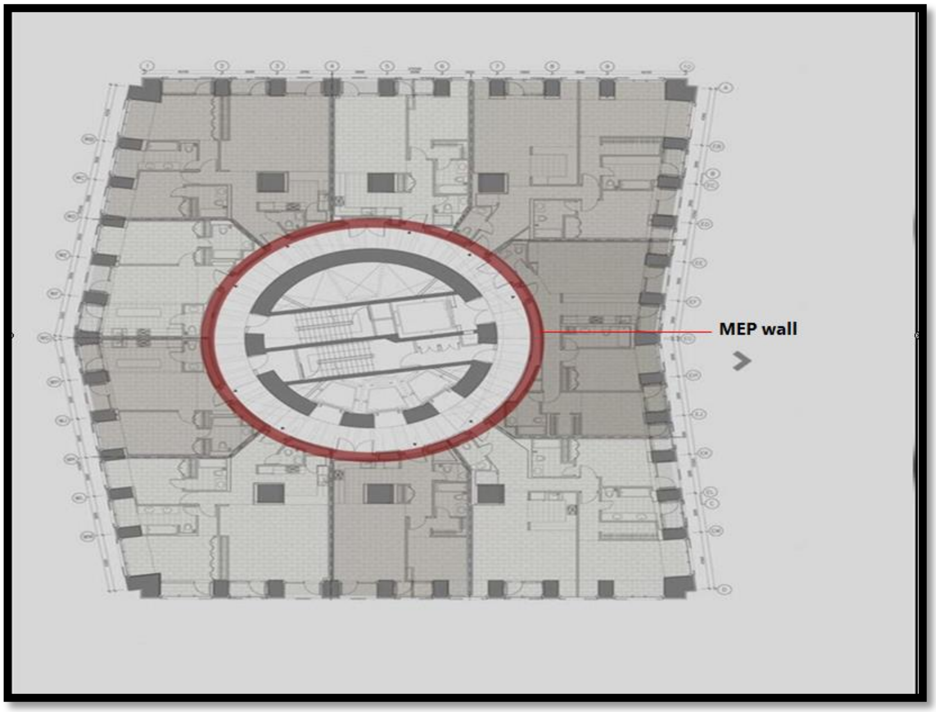


Figure 54 : MEP plan in kayan tower

Faced design :

- The winding shape of Cayan Tower reveals a structure that helps protect its interior from the sun.
- Yet, in order to protect the building from the intense desert heat and to provide additional shade, reinforced concrete structure on the exterior is fully clad in metal (titanium) panels and screens.
- Balconies of the residents are covered with sun blinds which are again made out of titanium panels in order to control the sunlight.

Chapter 3 :

Project Design

3.1. Architectural design

3.1.1 Introduction

work is the first step in any construction work, since the architectural design aims to provide creative and unique design. However, the creative architectural design may be incompatible with Environmental, Structural and Seismic design. So the best architectural design that satisfy the client's needs and requirements and at the same time does not conflict Environmental, Structural and Seismic design. In our project we tried to make a creative architectural design as much as we can. The tower consists of 18 offices floors , two podium floors , and three parking floors located in nablus city .

3.1.2 Site Properties

3.2.2.1 Location:

Figure 55 : nablus location

Nablus is a Palestinian city in west bank, approximately 69 kilometers north of Jerusalem, with a population of 321000 person. The area of the city is 28.6 km^2, and it is about 550 meters above sea level.

3.2.2.2 Climate

The climate in nablus is the Mediterranean climate. In winter, the town is subject to the harsh rainy south-western winds and sometimes to the dry but cold north-eastern winds . The hottest months in Nablus are July and August with the average high being 28.9 °C. The coldest month is January with temperatures usually at 3.9 °C. Rain generally falls between October and May, with annual precipitation rates being approximately 589 mm.

Relative humidity and Winds the overall annual average up to (61%). And the northwesterly winds considered the prevailing wind directions in Nablus , with an overall annual average wind speed of 10 km / hr. which equal 2.78 m/s.

3.2.2.3. Site of the project

-Tunis street , beside Forum businessmen Nablus . Our project is located in Nablus

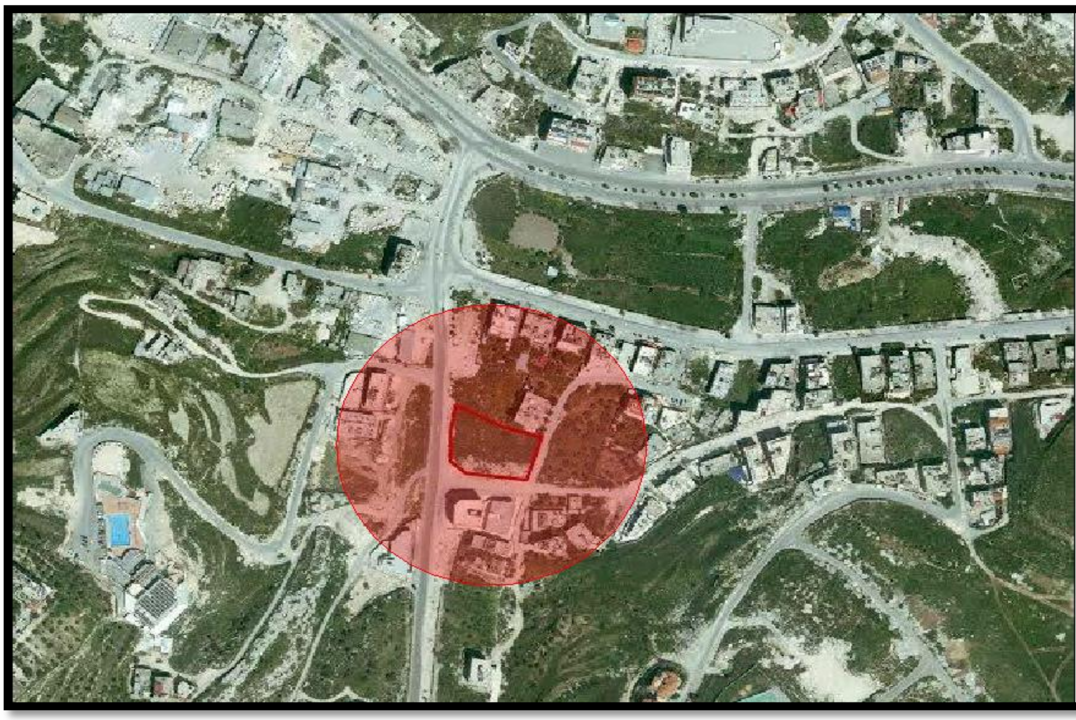


Figure 56 : site of the tower

3.1.3. Site analysis

3.1.3.1. Introduction

Site analysis is the study of the properties of different access to the general perception about the pros, cons and the possibilities that can be invested and design limitations imposed on this design. The site analysis includes two main elements. The first one related to the physical elements and the second one related to the non-material elements.

1. Physical elements include:

a) Natural elements: include natural elements with regard to climate (the movement of the sun, prevailing winds, temperature, humidity, rain). In addition to that natural resources (such as topography, the nature of the soil, water and plants available).

b) Unnatural elements: Include the boundaries of the site, buildings, bridges and roads on the site and walkways, and water and electricity networks connecting to the site as well as the empty spaces in addition to the nature of the road and lighting Furniture and other.

2. Non-material elements: Unusual items material: involves the study of neighboring uses, permitted and favorite uses (depending on the nature of the project to be done on-site), communication patterns (how to access the site), the economic returns to the land, the locations of nearby services, and modes of transport available.
3.

3.1.3.2. Location advantage

1. Relatively quit region and far from the noise of the city.
2. Relatively low slop help us in design.
3. good view from all direction.
4. No surrounding high building that prevent sun and wind.

3.1.3.3. Environmental analysis of the site

The orientation of the site plays a very important role in sitting of the building. This would give a good idea as to how the building should be oriented, when the wind direction and sun path combined, also the view is very important restriction for the orientation.

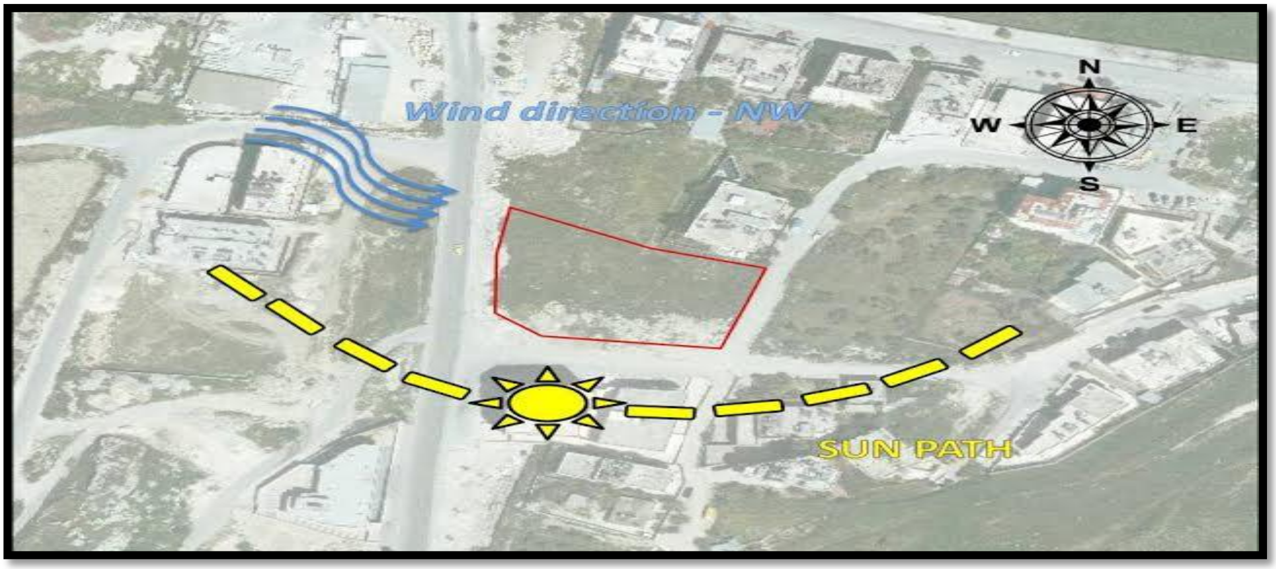


Figure 57 : wind direction and sun path

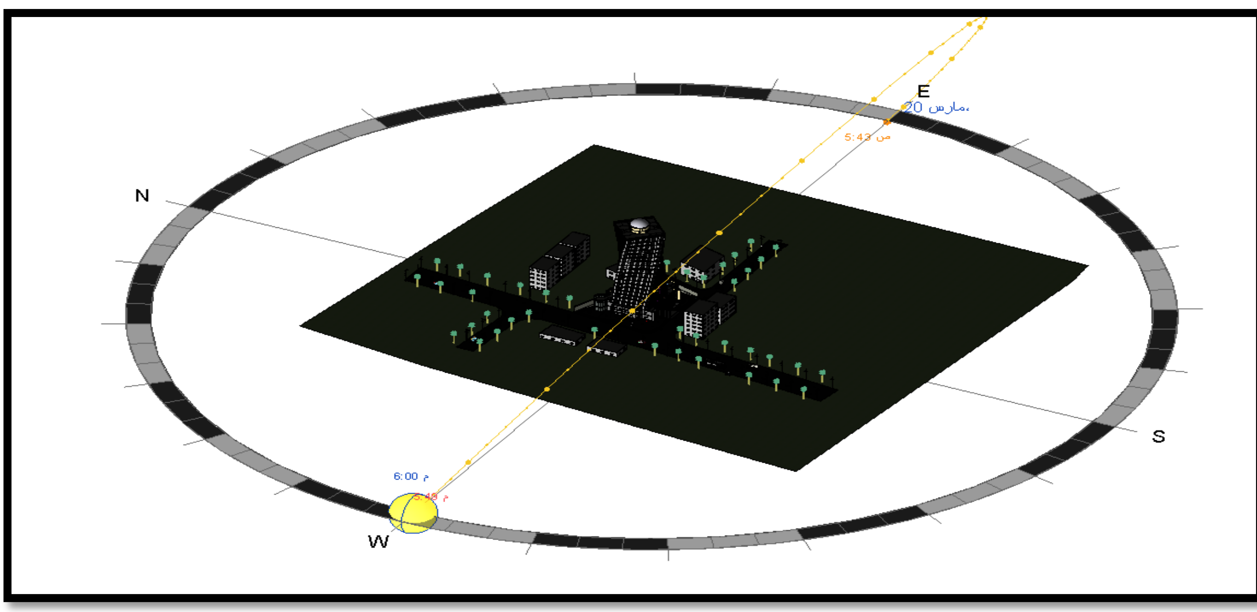


Figure 58 : sun path in the project

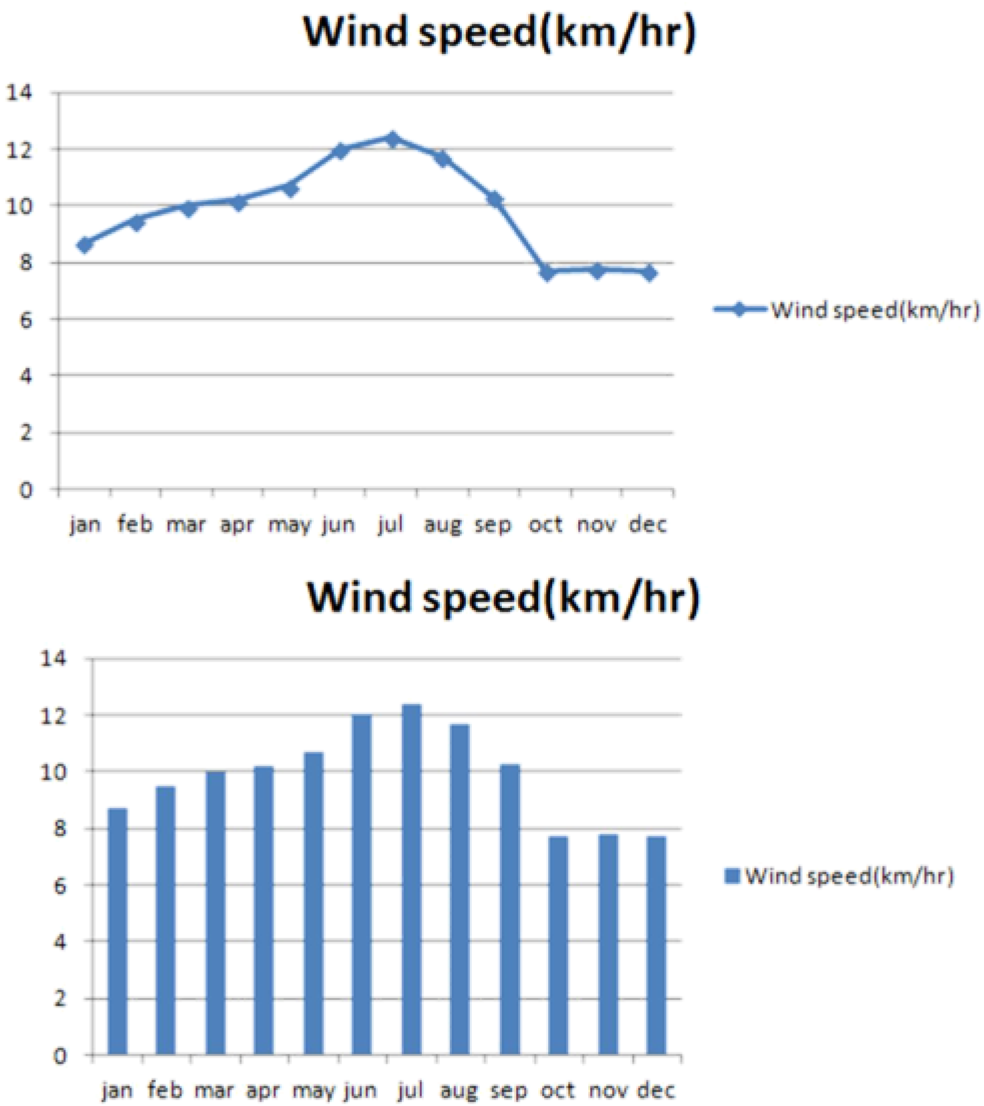


Figure 59 : wind speed in project site (PCB)

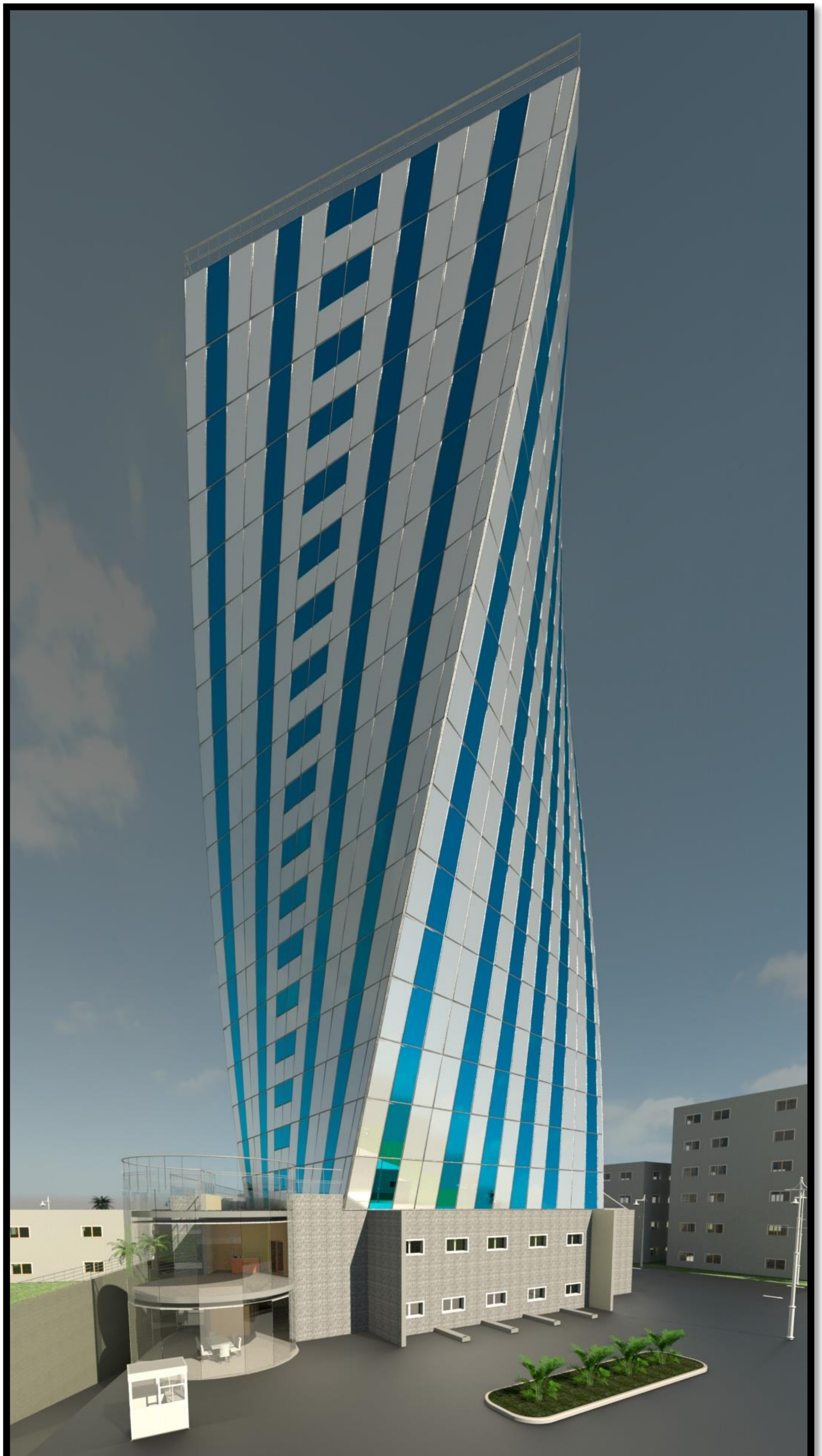
3.1.4. Methodology

This project which is twested offices tower have been design from zero point , taking in consideration a good external shape with suitable distribution of its components to achieve comfort phase for the customers, at the same time it must to avoid conflict between architectural with structural, environmental, mechanical aspects.

The total area designed in this project is about 20000 m^2, distributed on 18 offices floors , two podium floors , and three parking floors . During design it take in consideration to avoid match between staffs or worker with customers so that there's a separated elevator for them, also special corridors and WC's.

Figure 60 : south elevation of tower

Figure 61 : 3D view for tower



3.1.4.1. The project consist:

1- Basement 1 Floor (3m height):

which have capacity for 70 cars and its own entrance, total area of the floor = 2039 m^2

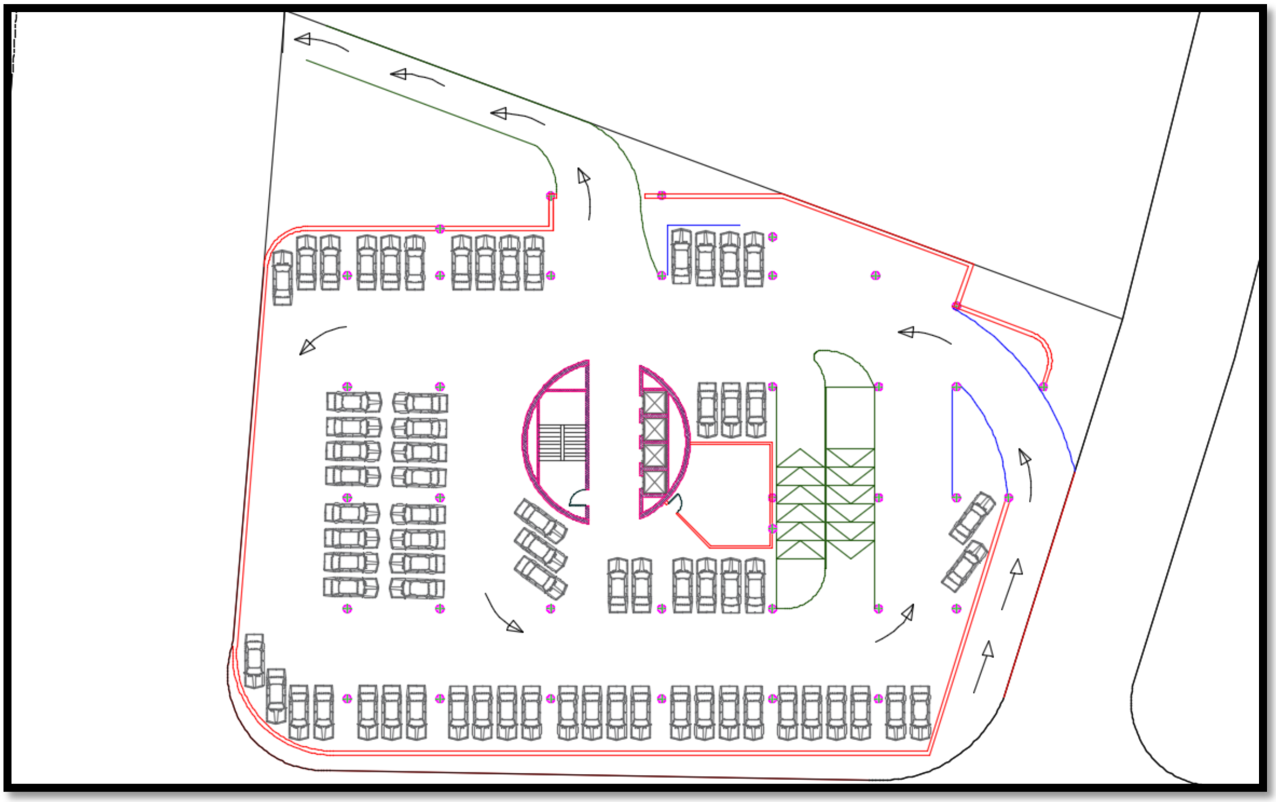


Figure 62 : basement 1 plan

2- Basement 2, 3 Floor (3m height):

which have capacity for 70 cars and its own entrance, total area of the floor = 2039 m^2 .

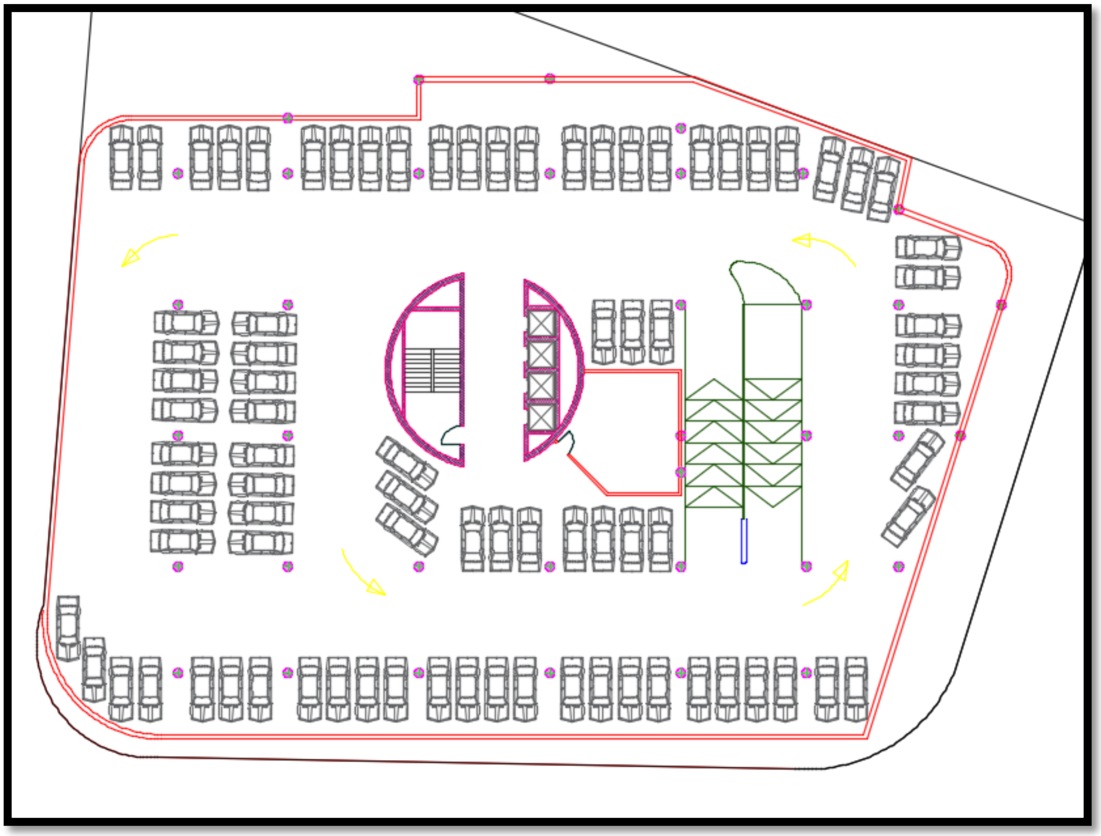


Figure 63 : basement 2,3 plan

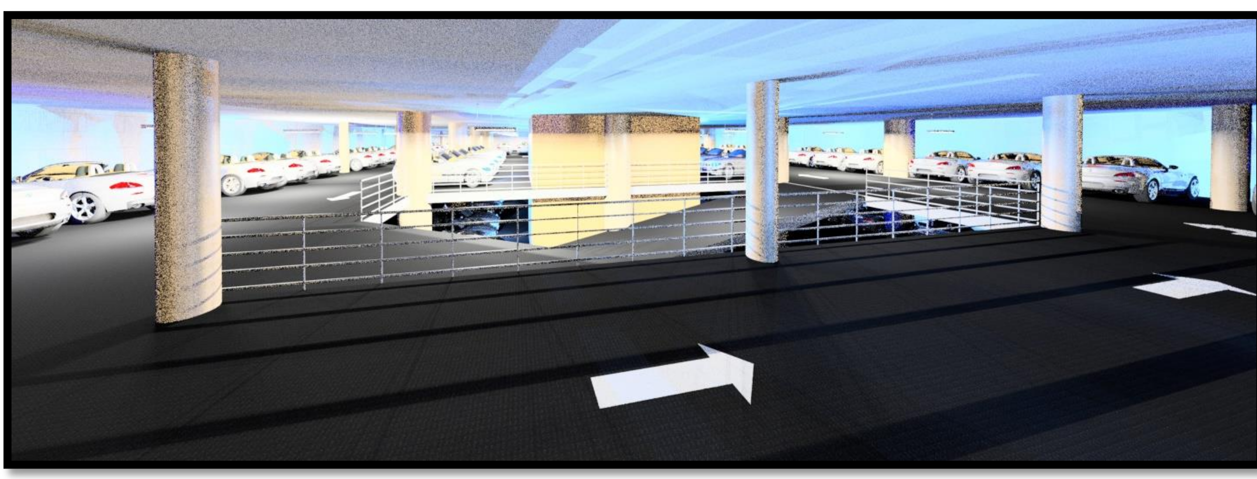


Figure 64 : picture of parking in tower

3- podium 1 (4 m height) :

Podium 1 include the following areas :

Table 15 : areas in podium 1

Contain	Area (m^2)	Notic
Bank	145	Main room
shops (10)	207	about 20 m for each
hole	489	For horizontal movement between shops
Super market	170	-----------
Security room	39	--------
Story	33	For super market
space for story and coridoor for meeting room	66	For bank Documents
Meeting room	54	in bank
Bath room (4)	20	in bank
administration	20	For bank administrator
Core	113	Contain stair and elevators

Total area is 1361 m^2

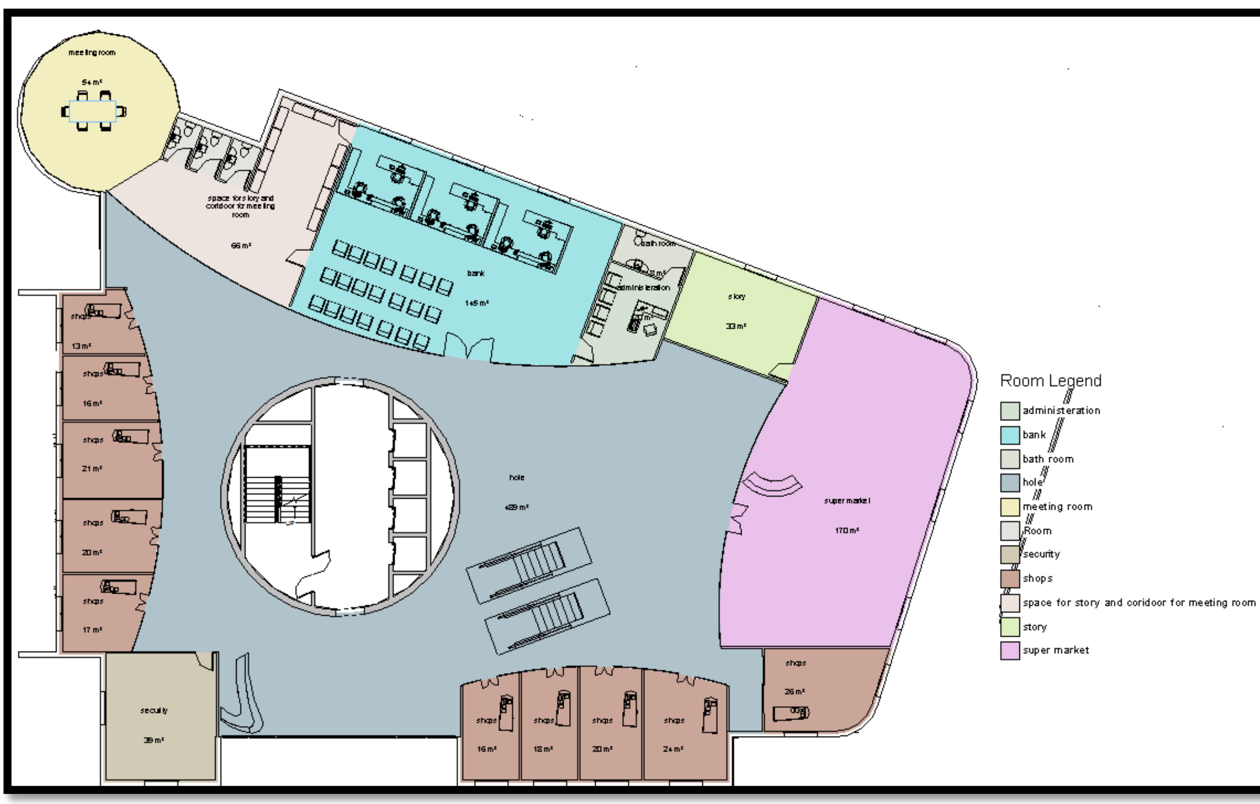


Figure 65 : podium 1 plan

Figure 66 : picture of bank in podium 1

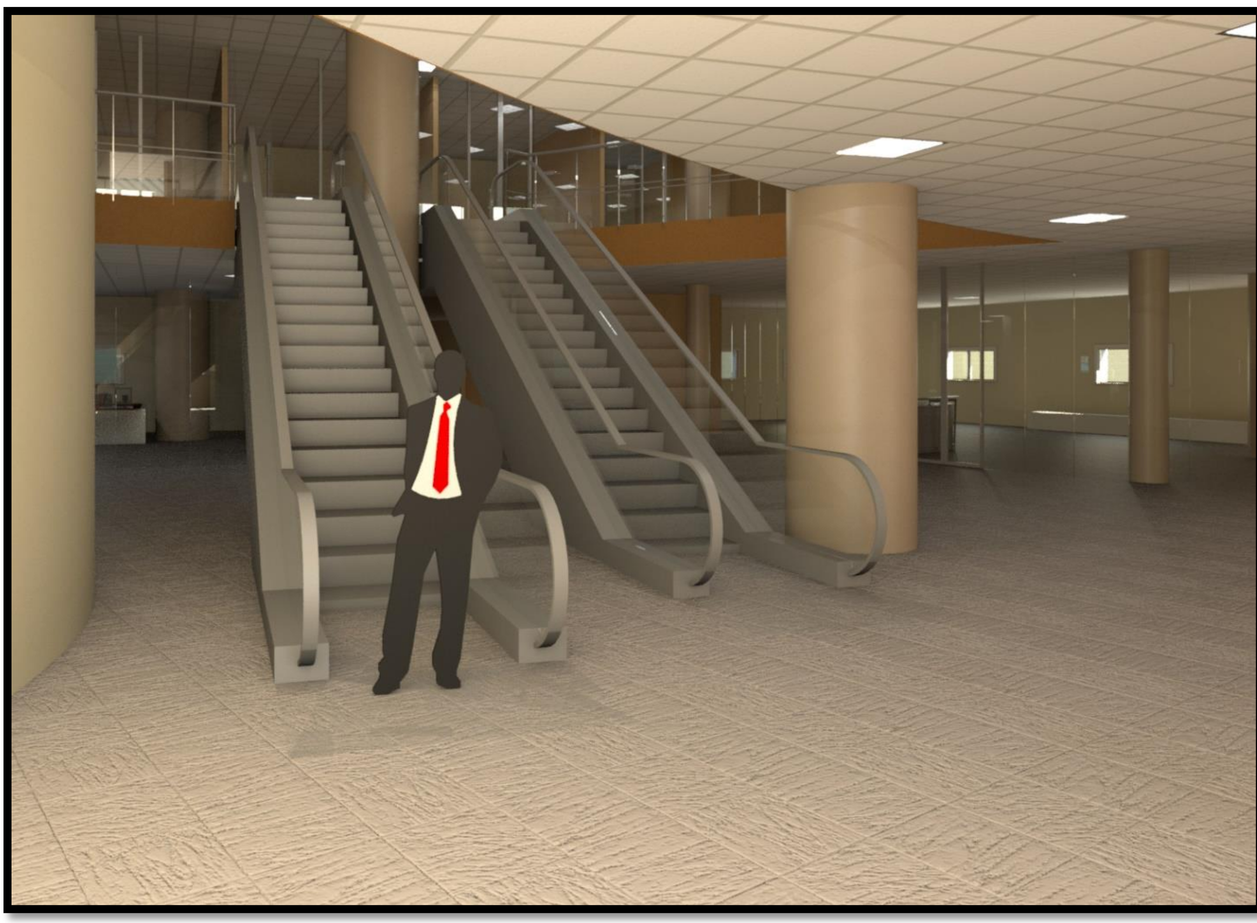


Figure 67 : picture of scalator in podium 1

4- podium 2 (4 m height) :

Podium 2 include the following areas :

Table 16 : areas in podium 2

Room	Area (m^2)	Notic
Cafeteria	106	Main hall
Kitchen	10	In cafeteria
Wastage	9	In cafeteria
Wash	14	In cafeteria
Story	6	In cafeteria
Shops (18)	500	
Path room	28	Public Wc
Hall	545	For horizontal movement between shops
Core	113	Contain stair and elevators

Total area is 1361 M^2

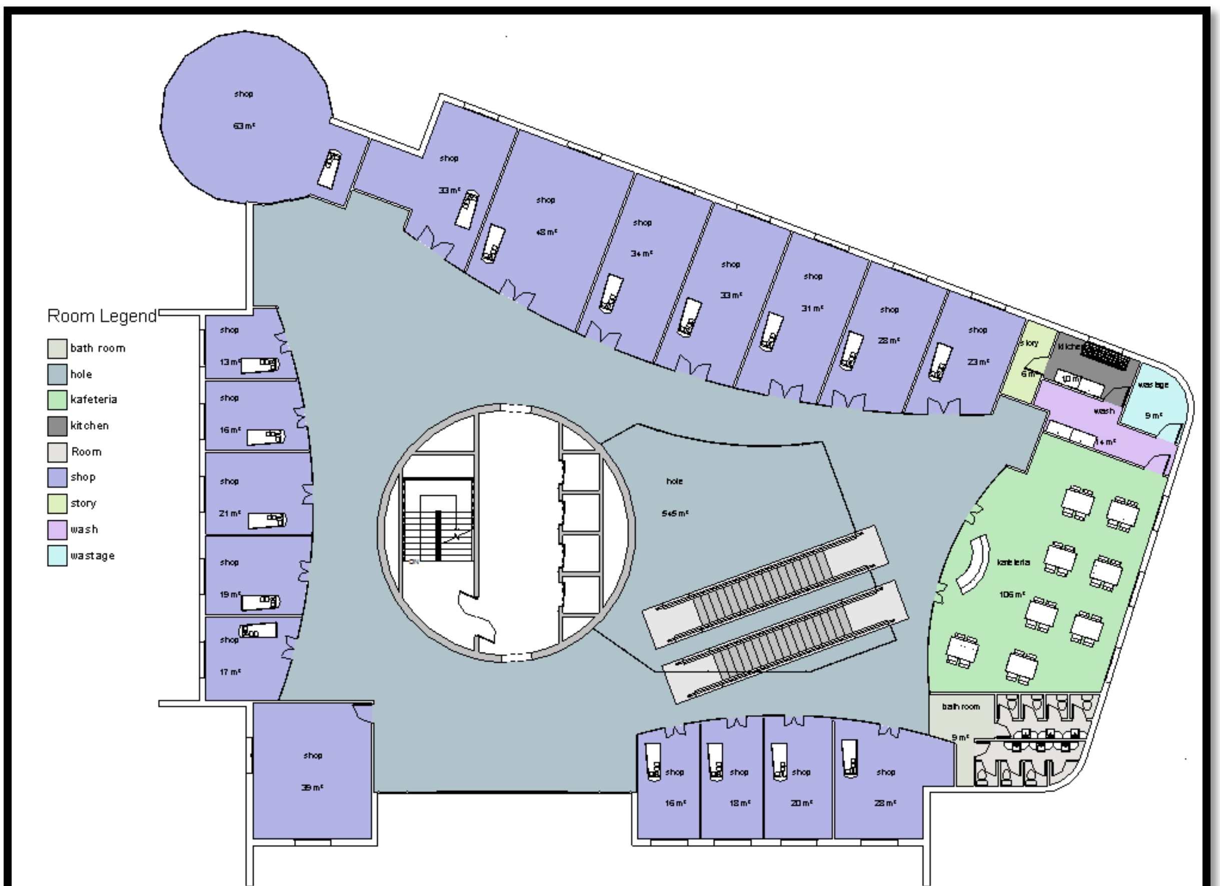


Figure 68 : podium 2 plan

Figure 69 : picture of cafeteria in podium2

5- floor 1 (3m height) :

Floor 1 include the following areas :

Table 17 : areas in floor 1

Room	Area (m^2)	Notic
Cafeteria	170	Main hall
Kitchen	30	In cafeteria
Story	33	In cafeteria
Inter space (2)	10	----------
Stuff room (2)	96	In office
Administration (2)	49	In office
waiting (2)	103	In office
Path room (4)	16	-------
Core	113	Contain stair and elevators
enter (2)	10	

Total space is 630 m^2

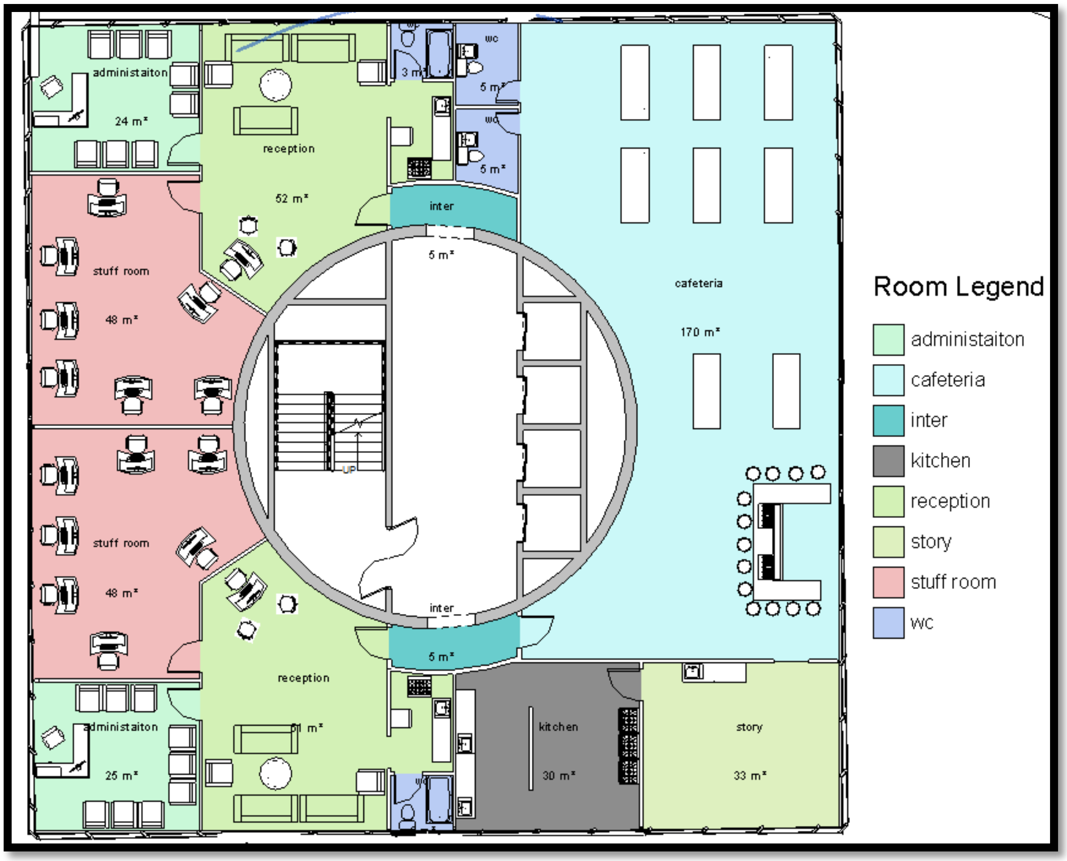


Figure 70 : floor 1 plan

Figure 71 : picture of carridor in floor 1

6- floor 2 (3m height) :

Floor 2,3,4,5,6,7,8,9,and 10 are same

Floor 2 include the following areas :

Table 18 : areas in floor 2

Room	Area (m^2)	Notic
Stuff room (4)	192	In office
Administration (4)	100	In office
waiting (4)	192	In office
Path room (4)	12	-------
Core	113	Contain stair and elevators
enter (2)	10	

Total space is 630 m^2

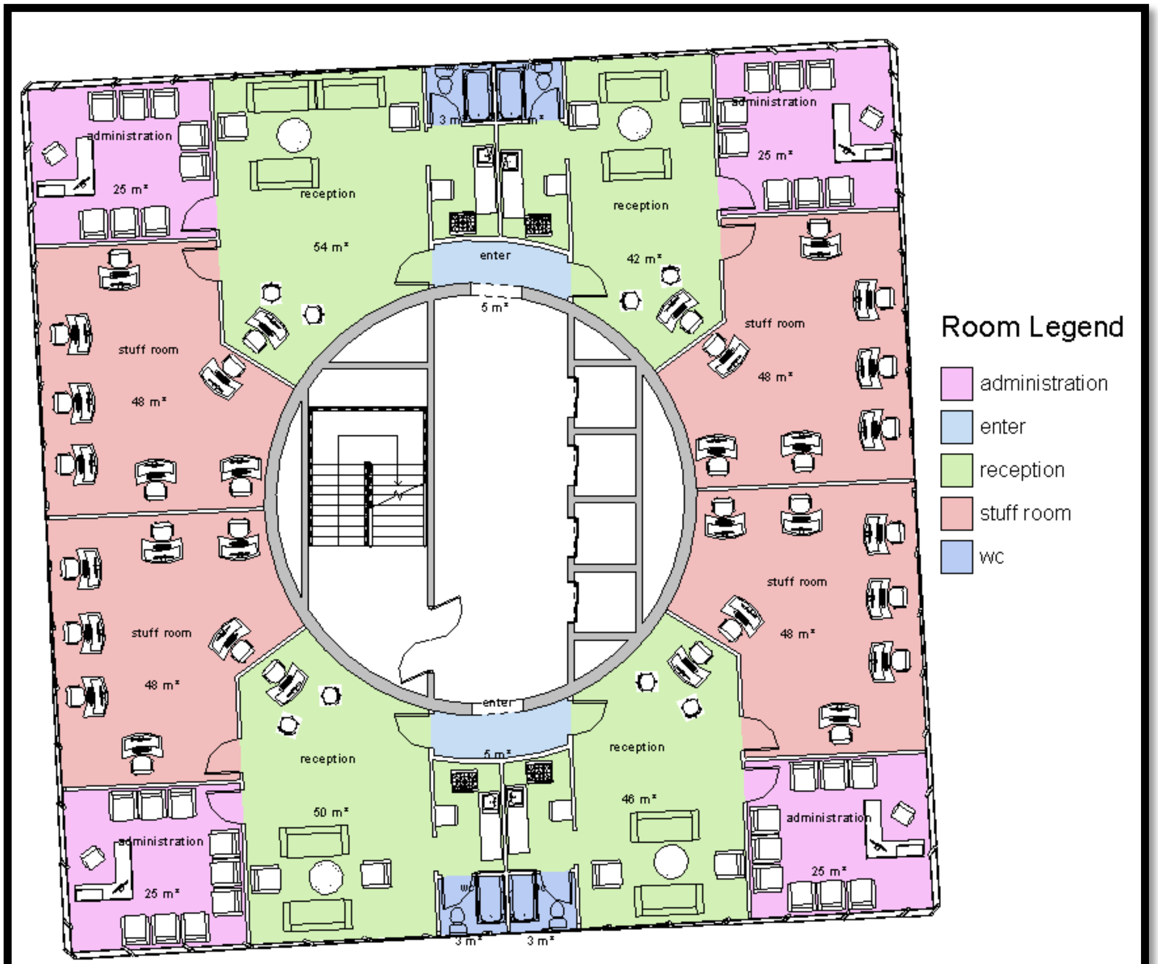


Figure 72 : floor 2 plan

Figure 73 : picture of waiting room

Figure 74 : picture of manager room

7- floor 11 (3m height) :

Floor 11,12,13,14,16,17, and 18 are same
Floor 11 include the following areas :

Table 19 : areas in floor 11

Room	Area (m^2)	Notic
Stuff room (2)	226	In office
Administration (2)	46	In office
waiting (2)	108	In office
Path room (2)	32	In office
Story (2)	62	In office
Core	113	Contain stair and elevators
enter (2)	10	

Total space is 630 m^2

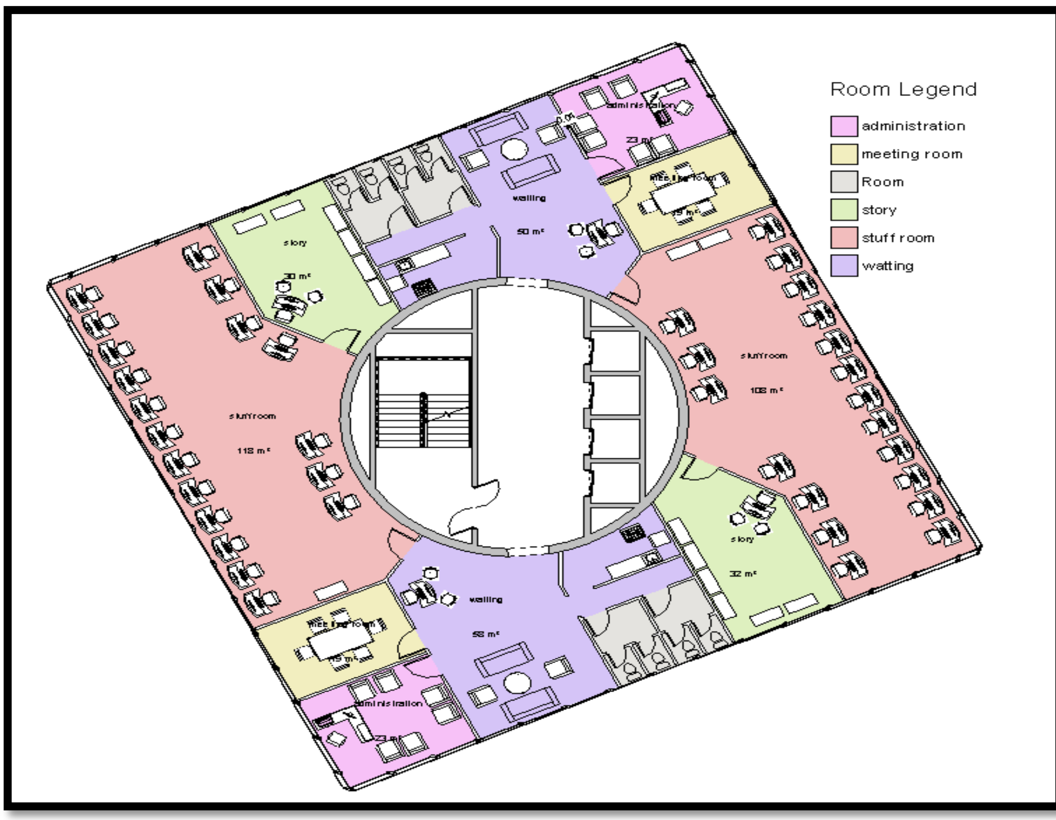


Figure 75 : floor 11 plan

Figure 76 : picture of stuff room

Figure 77 : picture of gym in floor 15

3.2.Environmental design

3.2.1.Introductin

The Environmental Design is very important issue in design the building for human to feeling comfort during the work and minimize the amount of heating and cooling load ,and the most important issue is heating design , cooling design , insulation , thermal mass , day light factor , and simulation .

and to achieve the required level of thermal design there are some factors affect it like thermal conductivity for materials (U factor), orientation of building, length of wall facing south, location of building

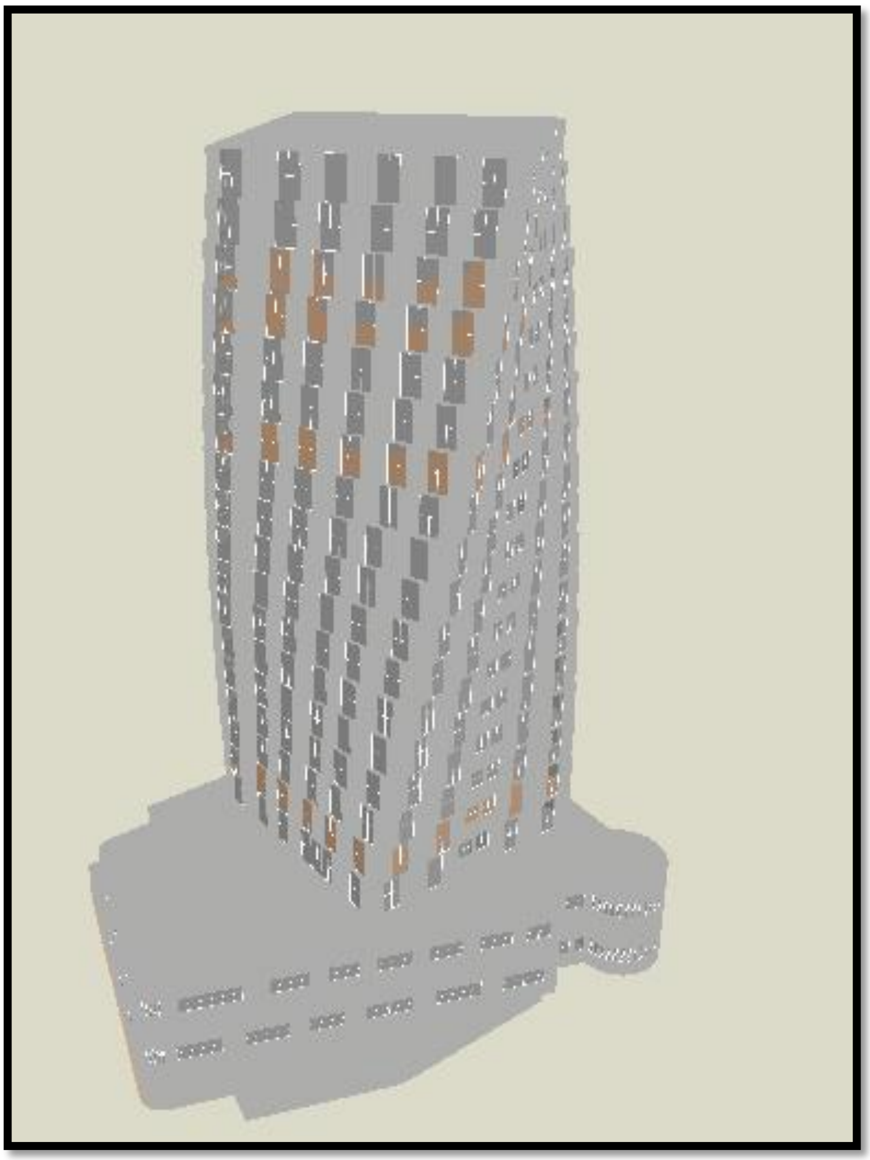


Figure 78 : 3D model from Design Builder

3.2.2. Heating design

1- U value for external walls = 0.346

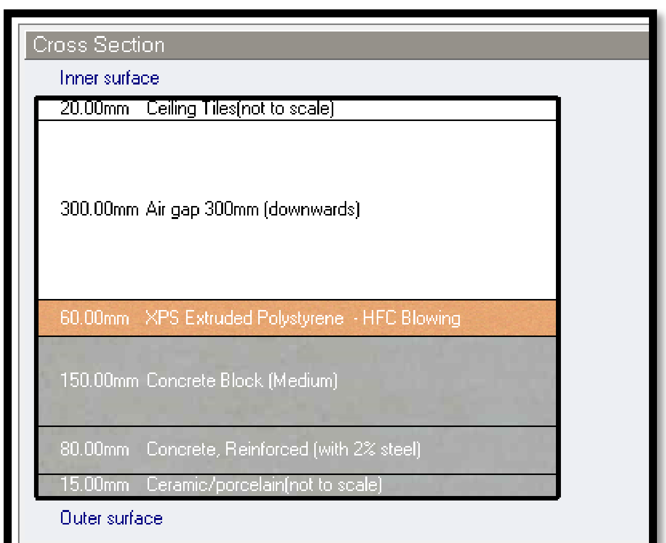
As shown in the figures below the type of materials and U value for the wall

U-Value surface to surface (W/m2-K)	0.368
R-Value (m2-K/W)	2.887
U-Value (W/m2-K)	**0.346**

Figure 79 : U value for external walls

2- U value for slab = 0.354

As shown in the figures below the type of materials and U value for the slab



U-Value surface to surface (W/m2-K)	0.382
R-Value (m2-K/W)	2.828
U-Value (W/m2-K)	**0.354**

Figure 80 : U value for slab

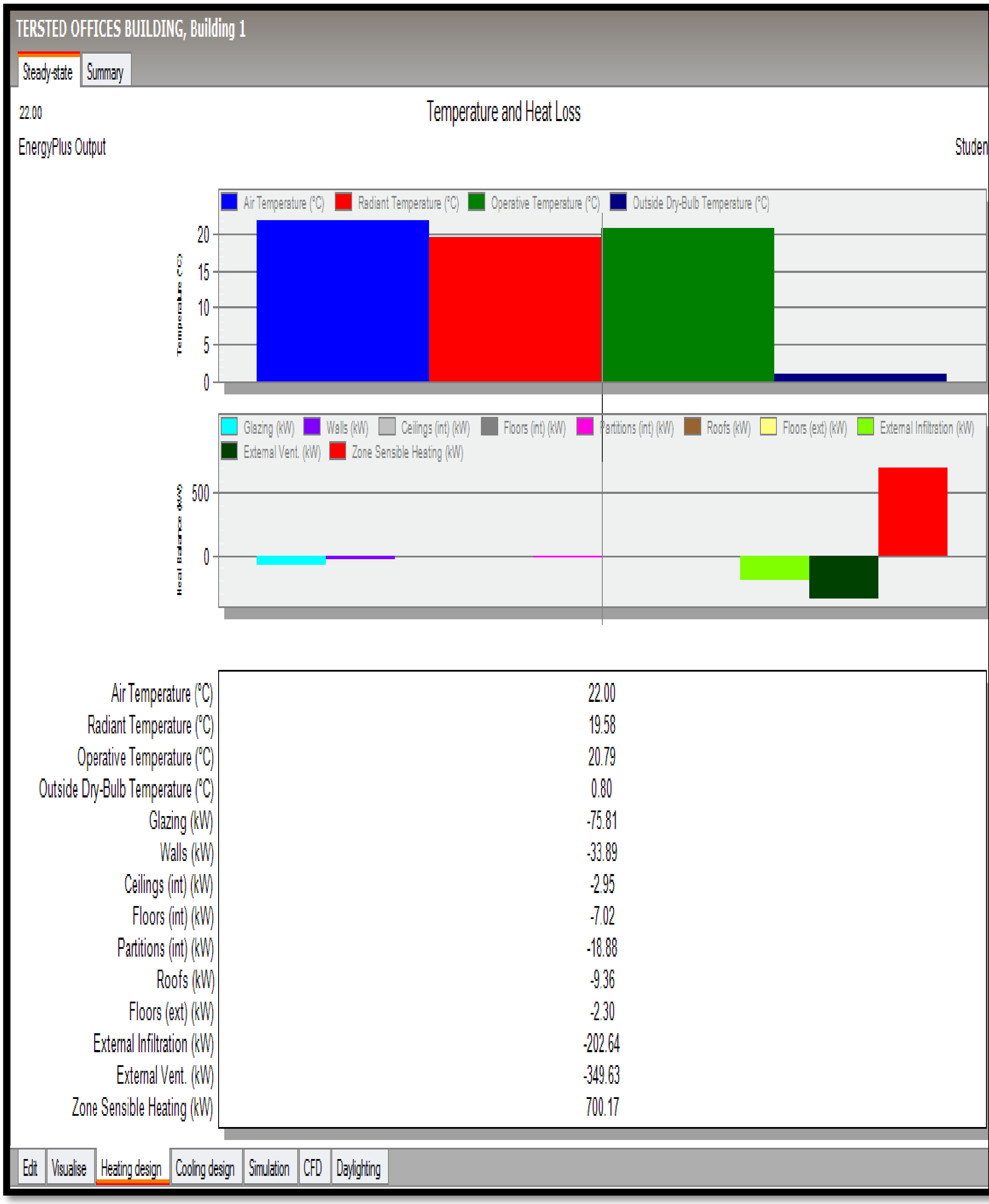


Figure 81 : Heating loads for building

total heating load capacities of the original building is 500 kW

as show in the figures below a results for the same office plan but with deferent floor :

second floor

Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)	Design Capacity (W/m2)
second floor Total Design Heating Capacity = 27.230 (kW)				
maneger office 3	20.77	1.21	**1.39**	60.1631
staff room 3	21.09	2.59	**2.98**	55.6095
staff room 4	20.89	1.61	**1.85**	52.3120
maneger office 4	20.85	1.74	**2.00**	68.6190
reception 4	21.16	1.91	**2.20**	61.8471
bath 4	11.46	0.00	**0.00**	0.0000
kitchen 4	13.97	0.00	**0.00**	0.0000
circulation	21.19	0.47	**0.54**	71.2468
reception 2	21.16	2.12	**2.44**	61.3026
kitchen 2	13.97	0.00	**0.00**	0.0000
bath 2	11.45	0.00	**0.00**	0.0000
maneger office 2	20.85	1.58	**1.81**	62.7092
staff room 2	21.07	2.16	**2.48**	62.5885
Zone 29	9.82	0.00	**0.00**	0.0000
Zone 22	8.02	0.00	**0.00**	0.0000
reception 3	21.16	1.72	**1.98**	61.5668
maneger office	20.76	1.50	**1.72**	74.9387
reception	21.15	1.81	**2.08**	55.4449
kitchen	13.98	0.00	**0.00**	0.0000
kitchen 3	13.98	0.00	**0.00**	0.0000
staff room	21.08	2.79	**3.20**	67.6191
circulation	21.26	0.48	**0.56**	54.1554
bath	11.50	0.00	**0.00**	0.0000
bath 3	11.49	0.00	**0.00**	0.0000
Zone 23	10.68	0.00	**0.00**	0.0000
Zone 24	10.10	0.00	**0.00**	0.0000

Figure 82 : heating design results for second floor

Floor 11

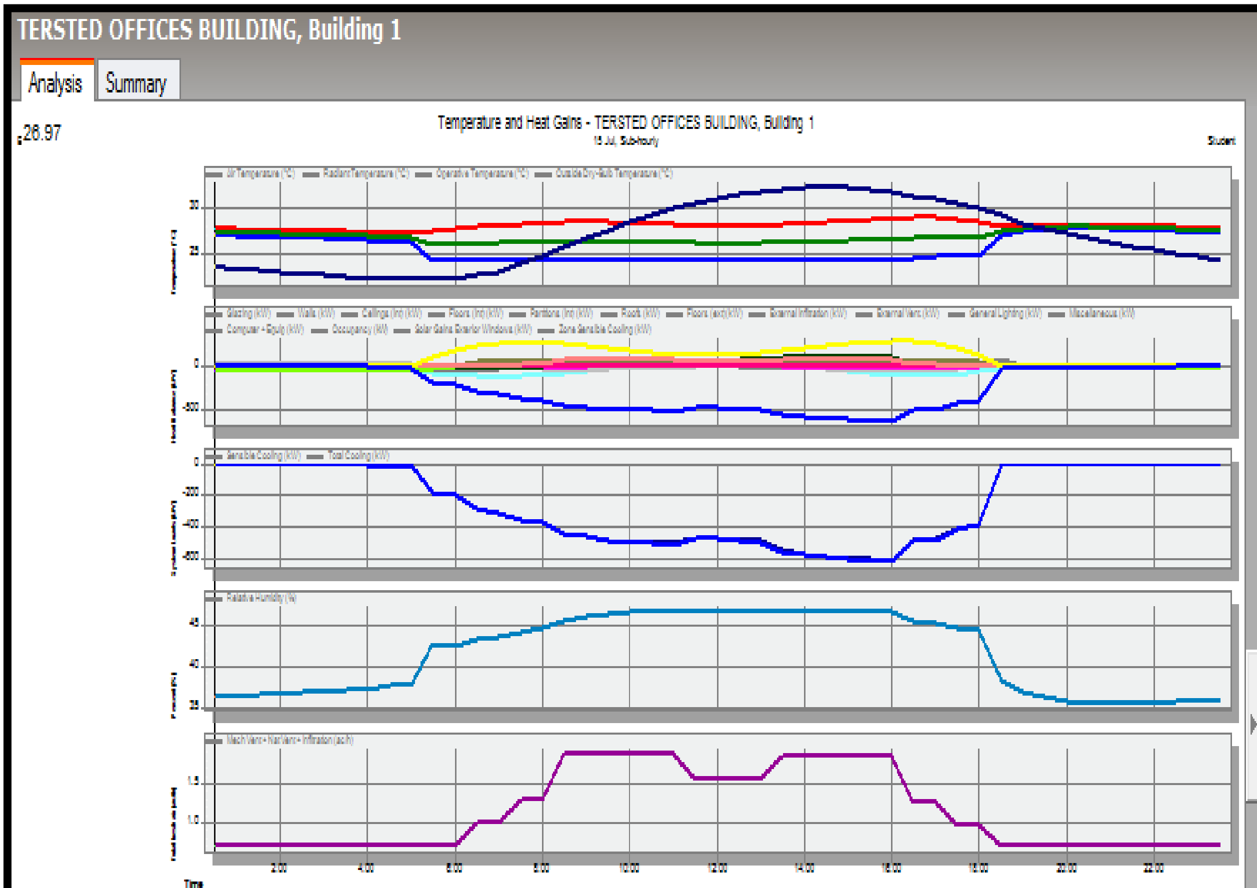
Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)	Design Capacity (W/m2)
floor 11 Total Design Heating Capacity = 31.110 (kW)				
maneger office 2	20.72	1.60	**1.84**	79.3237
staffroom 2	21.06	2.72	**3.13**	62.5210
staff room	21.03	2.54	**2.92**	78.7576
maneger office	20.80	1.77	**2.04**	69.9006
maneger office 3	20.72	1.64	**1.89**	82.3625
reception 3	21.09	2.08	**2.39**	65.9558
bath 3	10.11	0.00	**0.00**	0.0000
bath 2	10.11	0.00	**0.00**	0.0000
reception 2	21.09	1.78	**2.05**	63.7103
reception	21.13	2.30	**2.64**	71.3717
bath1	10.04	0.00	**0.00**	0.0000
kitchen	12.58	0.00	**0.00**	0.0000
circu	21.01	0.57	**0.66**	76.2369
reception 4	21.11	2.24	**2.57**	62.6051
kitchen 4	12.58	0.00	**0.00**	0.0000
bath 4	10.05	0.00	**0.00**	0.0000
maneger office 4	20.80	1.54	**1.77**	61.1881
staffroom 4	21.04	2.57	**2.96**	75.1772
Zone 23	9.53	0.00	**0.00**	0.0000
Zone 24	7.58	0.00	**0.00**	0.0000
Zone 26	8.35	0.00	**0.00**	0.0000
Zone 27	8.02	0.00	**0.00**	0.0000
Zone 20	10.49	0.00	**0.00**	0.0000
staffroom 3	21.05	3.11	**3.58**	74.5659
kitchen 3	12.60	0.00	**0.00**	0.0000
kitchen 2	12.60	0.00	**0.00**	0.0000
circulation	21.03	0.58	**0.67**	75.7563

Figure 83 : heating design results for floor 11

3.2.3. Cooling design

Cooling Analysis for the building

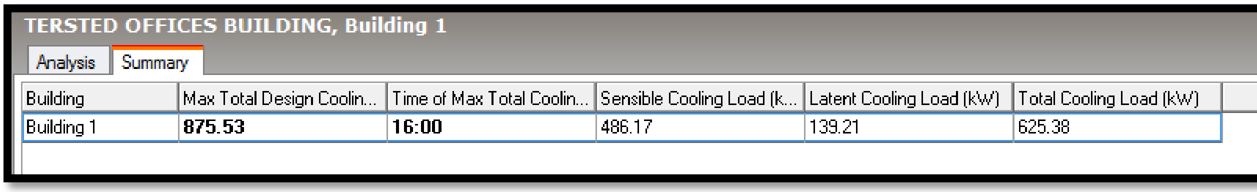
From figure solar gain from external window is the maximum gain in this building



Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	26.71	26.44	24.28	24.11	24.13	24.15	24.17	24.17	24.75	27.69	27.46
Radiant Temperature (°C)	27.52	27.32	27.67	28.30	28.33	27.94	28.27	28.85	28.50	28.01	27.92
Operative Temperature (°C)	27.12	26.88	25.98	26.21	26.23	26.05	26.22	26.51	26.62	27.85	27.69
Outside Dry-Bulb Temperature (°C)	22.83	22.21	22.21	24.70	28.45	31.05	32.40	31.78	29.90	27.20	25.33
Glazing (kW)	-26.35	-27.50	-92.75	-90.39	1.01	42.25	-6.34	-85.48	-50.20	-14.66	-20.22
Walls (kW)	3.84	0.26	-3.63	-7.58	9.05	17.10	10.33	14.46	35.07	15.44	12.30
Ceilings (int) (kW)	31.00	37.63	16.11	-28.98	-21.31	5.15	-20.53	-46.66	-1.99	7.24	12.33
Floors (int) (kW)	8.70	8.65	-14.43	-17.16	14.32	13.71	-22.65	-25.34	39.07	-1.06	3.84
Partitions (int) (kW)	5.81	7.30	6.99	-3.89	2.34	7.30	-3.15	-6.68	1.32	-4.79	-0.52
Roofs (kW)	3.49	3.24	1.29	-0.30	1.28	1.89	-0.41	-0.54	3.94	2.35	3.19
Floors (ext) (kW)	0.96	0.90	0.34	0.07	0.77	0.76	-0.44	-0.42	1.76	0.52	0.78
External Infiltration (kW)	-35.47	-38.67	-20.73	3.01	34.93	56.64	67.67	62.41	41.14	-5.69	-19.85
External Vent. (kW)	0.00	0.00	0.00	2.72	60.56	73.54	117.16	108.14	18.51	0.00	0.00
General Lighting (kW)	0.00	0.00	0.00	2.17	1.37	1.86	2.28	2.80	5.10	0.72	0.72
Miscellaneous (kW)	0.02	0.02	0.02	0.33	0.33	0.33	0.33	0.33	0.03	0.02	0.02
Computer + Equip (kW)	2.76	2.76	2.76	54.90	55.25	55.25	55.25	55.25	50.31	3.60	3.60
Occupancy (kW)	0.00	0.00	0.00	44.40	86.33	65.40	86.05	85.45	20.29	1.28	0.64
Solar Gains Exterior Windows (kW)	0.00	0.00	194.01	278.57	199.49	137.43	218.19	294.52	136.91	0.00	0.00
Zone Sensible Cooling (kW)	0.00	0.00	-200.68	-376.13	-496.35	-475.71	-571.46	-616.65	-382.48	-4.56	-3.71
Sensible Cooling (kW)	0.00	0.00	-200.55	-376.13	-496.35	-475.71	-571.46	-616.65	-382.48	-4.56	-3.71
Total Cooling (kW)	0.00	0.00	-200.55	-376.14	-500.68	-480.86	-579.42	-625.38	-382.60	-4.58	-3.79
Relative Humidity (%)	36.77	37.31	42.45	44.62	46.58	46.59	46.68	46.64	44.40	36.03	35.74
Mech Vent + Nat Vent + Infiltration (ac/h)	0.71	0.71	0.71	1.30	1.88	1.57	1.86	1.86	0.98	0.70	0.70

Figure 84 : Cooling analysis for building

total heating load capacities of the original building is 875 kW as shown below



TERSTED OFFICES BUILDING, Building 1

Analysis | Summary

Building	Max Total Design Coolin...	Time of Max Total Coolin...	Sensible Cooling Load (k...	Latent Cooling Load (kW)	Total Cooling Load (kW)
Building 1	**875.53**	**16:00**	486.17	139.21	625.38

Figure 85 : total heating load capacities of the original building

After heating and cooling design, the HVAC capacity for design HVAC system is explained in mechanical chapter and The total energy consumed by building in HVAC equals 875.53 KW

3.2.4. Simulation

Thermal Simulation for building :

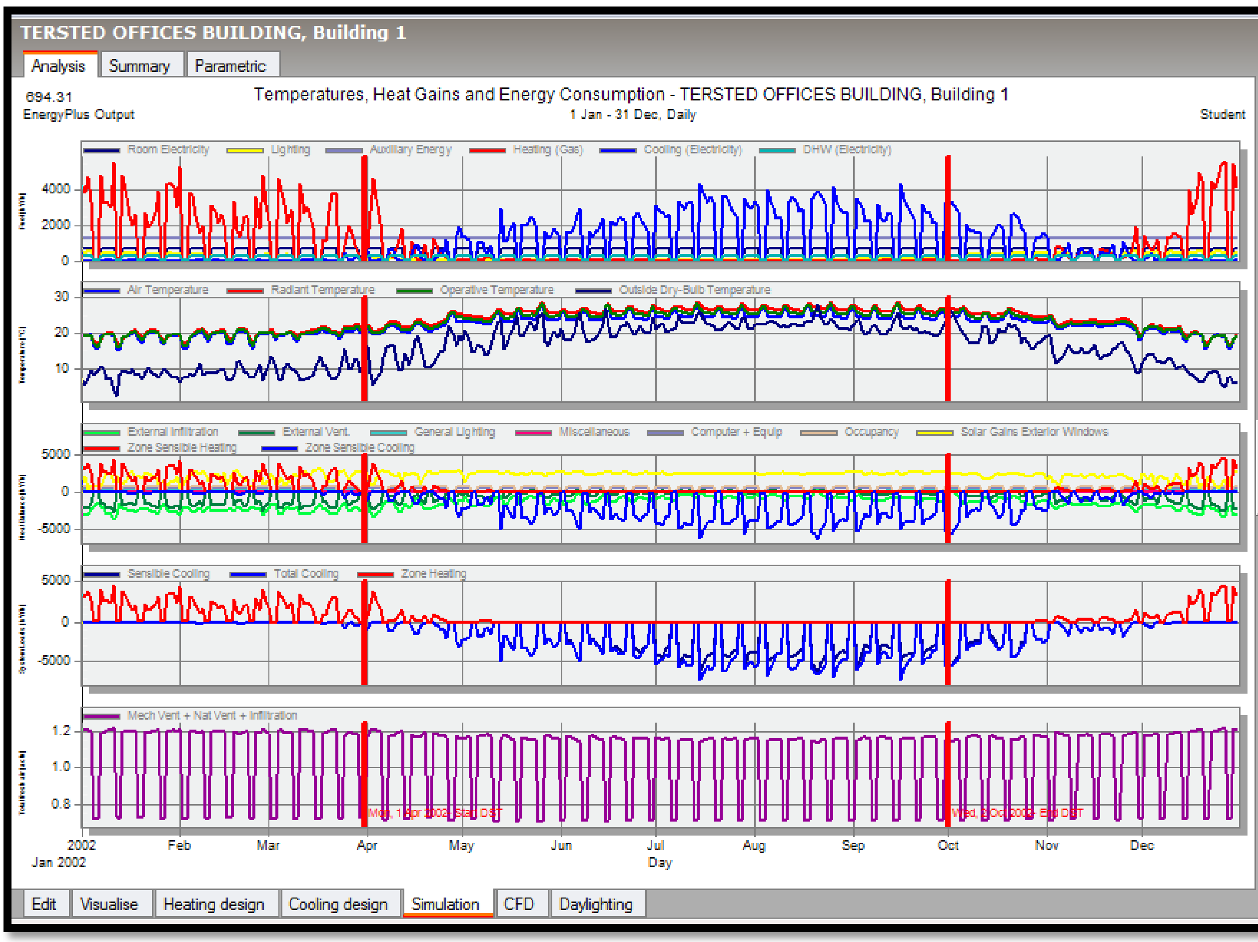


Figure 86 : Simulation comfort results as a graph for building

TERSTED OFFICES BUILDING, Building 1

Analysis | Summary | Parametric

Temperatures, Heat Gains and Energy Consumption - TERSTED OFFICES BUILDING, Building 1

1 Jan - 31 Dec, Daily

EnergyPlus Output

Day										
Room Electricity (kWh)	80.02	694.31	694.31	80.02	694.31	694.31	694.31	80.02	694.31	694.31
Lighting (kWh)	4.77	364.86	149.06	2.96	23.64	22.45	46.81	3.61	423.82	464.68
Auxiliary Energy (kWh)	1291.97	1291.97	1291.97	1291.97	1291.97	1291.97	1291.97	1291.97	1291.97	1291.97
Heating (Gas) (kWh)	71.87	2122.58	187.04	0.04	8.20	0.00	0.00	0.00	7.74	258.56
Cooling (Electricity) (kWh)	0.00	0.00	606.22	22.75	2375.16	3239.46	3521.53	22.46	1787.72	691.39
DHW (Electricity) (kWh)	76.13	310.62	310.62	76.13	310.62	310.62	310.62	76.13	310.62	310.62
Air Temperature (°C)	16.18	20.21	22.50	26.43	24.08	24.79	25.11	26.89	23.66	22.58
Radiant Temperature (°C)	17.77	20.53	23.70	27.02	25.97	27.14	27.82	27.76	25.79	24.11
Operative Temperature (°C)	16.98	20.37	23.10	26.73	25.02	25.97	26.46	27.32	24.72	23.34
Outside Dry-Bulb Temperature (°C)	7.28	11.58	16.93	23.65	22.53	22.58	23.69	21.97	17.42	15.35
External Infiltration (kWh)	-2013.79	-1928.78	-1216.19	-602.35	-392.18	-504.02	-343.81	-1042.15	-1364.10	-1583.31
External Vent. (kWh)	0.00	-1334.80	-597.30	0.00	357.89	112.18	415.16	0.00	-585.80	-873.66
General Lighting (kWh)	4.77	364.86	149.06	2.96	23.64	22.45	46.81	3.61	423.82	464.68
Miscellaneous (kWh)	0.40	3.26	3.26	0.40	3.26	3.26	3.26	0.40	3.26	3.26
Computer + Equip (kWh)	79.63	691.05	691.05	79.63	691.05	691.05	691.05	79.63	691.05	691.05
Occupancy (kWh)	13.23	884.21	803.54	11.83	783.59	781.92	781.67	11.82	787.66	802.06
Solar Gains Exterior Windows (kWh)	948.86	1464.86	2310.07	2873.66	2704.29	2628.44	2657.04	2874.70	2483.50	2262.51
Zone Sensible Heating (kWh)	59.65	1761.74	155.24	0.04	6.80	0.00	0.00	0.00	6.42	214.60
Zone Sensible Cooling (kWh)	0.00	0.00	-1012.45	-37.99	-3679.46	-4112.10	-5326.80	-32.30	-2308.71	-1102.09
Sensible Cooling (kWh)	0.00	0.00	-1012.38	-37.99	-3679.27	-4115.00	-5331.03	-32.30	-2308.73	-1101.98
Total Cooling (kWh)	0.00	0.00	-1012.38	-37.99	-3966.51	-5409.90	-5880.95	-37.51	-2985.50	-1154.63
Zone Heating (kWh)	59.65	1761.74	155.24	0.04	6.80	0.00	0.00	0.00	6.42	214.60
Mech Vent + Nat Vent + Infiltration (ac/h)	0.72	1.19	1.17	0.71	1.15	1.16	1.15	0.71	1.17	1.18

Figure 87 : Simulation comfort results as a table for building

Total energy intensity used in the building :

Analysis | Summary | Parametric

Utility Use Per Conditioned Floor Area

	Electricity Intensity [kWh/m2]	Natural Gas Intensity [kWh/m2]	Additional Fuel Intensity [kWh/m2]	District Cooling Intensity [kWh/m2]	District Heating Intensity [kWh/m2]	Water Intensity [m3/m2]
Lighting	5.74	0.00	0.00	0.00	0.00	0.00
HVAC	0.00	0.00	0.00	55.09	29.77	0.11
Other	17.64	0.00	0.00	0.00	0.00	0.00
Total	23.37	0.00	0.00	55.09	29.77	0.11

Utility Use Per Total Floor Area

	Electricity Intensity [kWh/m2]	Natural Gas Intensity [kWh/m2]	Additional Fuel Intensity [kWh/m2]	District Cooling Intensity [kWh/m2]	District Heating Intensity [kWh/m2]	Water Intensity [m3/m2]
Lighting	3.42	0.00	0.00	0.00	0.00	0.00
HVAC	0.00	0.00	0.00	32.85	17.75	0.07
Other	10.52	0.00	0.00	0.00	0.00	0.00
Total	13.94	0.00	0.00	32.85	17.75	0.07

Figure 88 : Total energy intensity used in the building

3.2.5. Day lighting

In this building which has a different function spaces; need a special daylight level and daylight factor according to the activities in the space.

By using a computer program such as design builder Analysis, these values have been taken.

We analyze natural daylight for these spaces:

- first floor
- floor 12

First floor :

The day light factor for this first floor = 3.457 which is in rang (2-6)

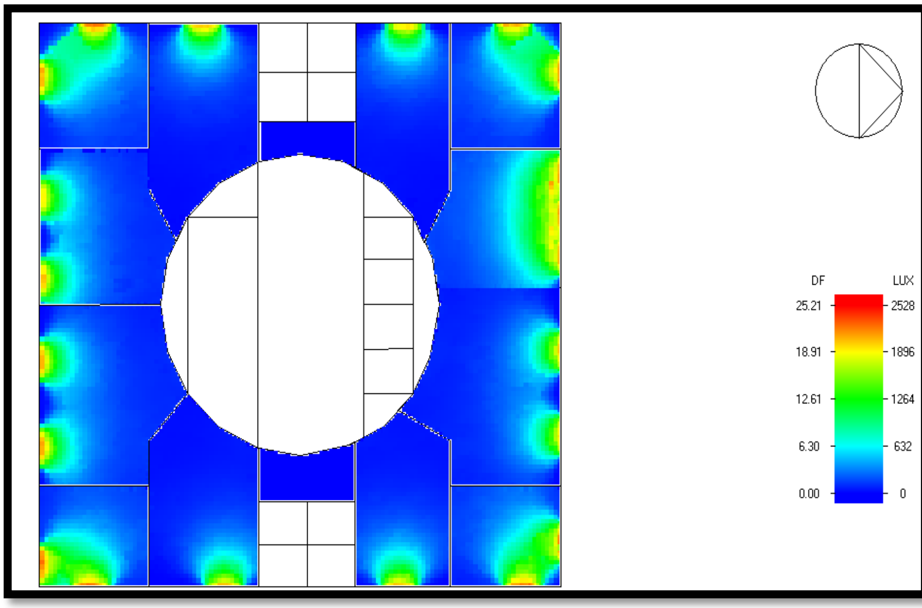


Figure 89 : day light distribution in floor 1

TERSTED OFFICES BUILDING, Building 1, second floor

Illuminance

Zone	Block	Floor Area (m2)	Floor Area above ...	Floor Area above ...	Average Daylight ...
maneger office 3	second floor	21.930	16.320	74.419	5.747
staff room 3	second floor	51.370	20.480	39.868	2.731
staff room 4	second floor	33.720	28.270	83.837	6.254
maneger office 4	second floor	27.540	17.270	62.709	4.805
reception 4	second floor	33.820	9.380	27.735	2.021
circulation	second floor	6.670	0.000	0.000	0.000
reception 2	second floor	38.180	9.220	24.149	1.949
maneger office 2	second floor	27.540	19.260	69.935	5.070
staff room 2	second floor	38.100	20.800	54.593	3.643
reception 3	second floor	30.200	10.200	33.775	2.451
maneger office	second floor	21.930	17.260	78.705	5.791
reception	second floor	35.970	8.940	24.854	1.955
staff room	second floor	45.600	22.720	49.825	3.420
circulation	second floor	9.150	0.000	0.000	0.000
Total		**421.720**	**200.120**	**47.453**	**3.457**

Figure 90 : summary of day light factor in floor 1

Floor 12 :

The day light factor for this first floor = 3.647 which is in rang (2-6)

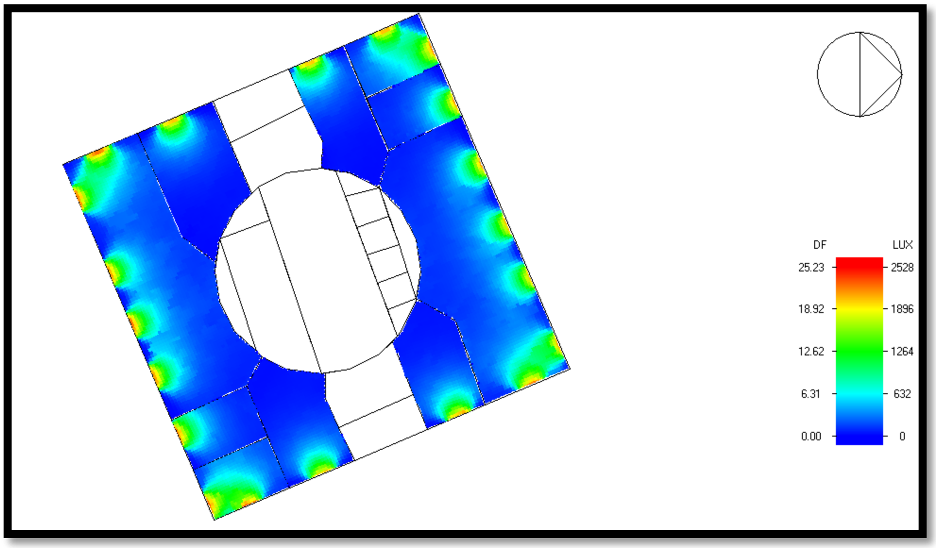


Figure 91 : day light distribution in floor 12

TERSTED OFFICES BUILDING, Building 1, floor 12

Illuminance

Zone	Block	Floor Area (m2)	Floor Area above ...	Floor Area above ...	Average Daylight ...
staffroom	floor 12	102.860	60.310	58.633	3.740
office room 4	floor 12	17.930	8.560	47.741	3.602
office room 3	floor 12	17.850	16.270	91.148	7.058
office room	floor 12	17.340	16.090	92.791	7.117
reception	floor 12	31.440	10.410	33.111	2.296
store room 2	floor 12	27.180	10.740	39.514	2.738
reception 2	floor 12	29.570	9.040	30.572	2.310
officeroom 2	floor 12	17.520	9.000	51.370	3.802
staffroom 2	floor 12	99.020	62.200	62.816	4.033
store room	floor 12	39.180	10.360	26.442	2.014
Total		**399.890**	**212.980**	**53.260**	**3.647**

Figure 92 : summary of day light factor in floor 12

3.2.6 Acoustical Analysis

In the final design, we want to evaluate the acoustical behavior of this building. This includes two main aspects: Sound Transmission through walls and partitions and Reverberation Time (RT60) in offices , bank , gym , and Cafeteria.

3.2.6.1. Sound Transmission Class (STC) :

According to the manufacturer specifications of the 10 cm Dense hollow block with both side plaster in our project has a STC value = 52 dB. This is a good value for partitions and external walls for office buildings as show in figure 82 . And STC and IIC for floor equals 56 dB and 51 dB, respectively.

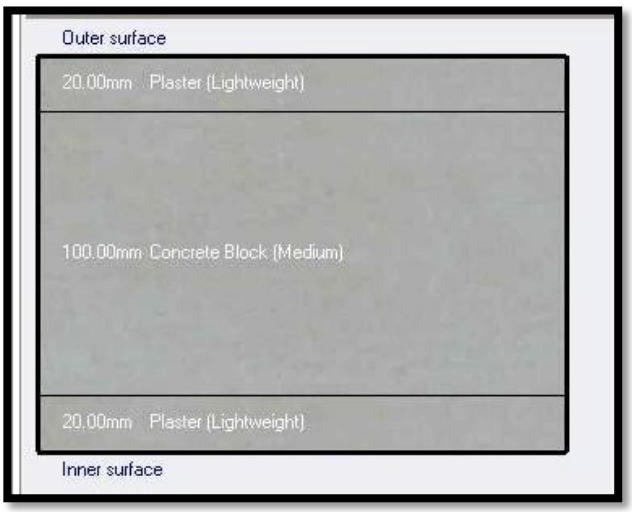


Figure 93 : section in internal wall

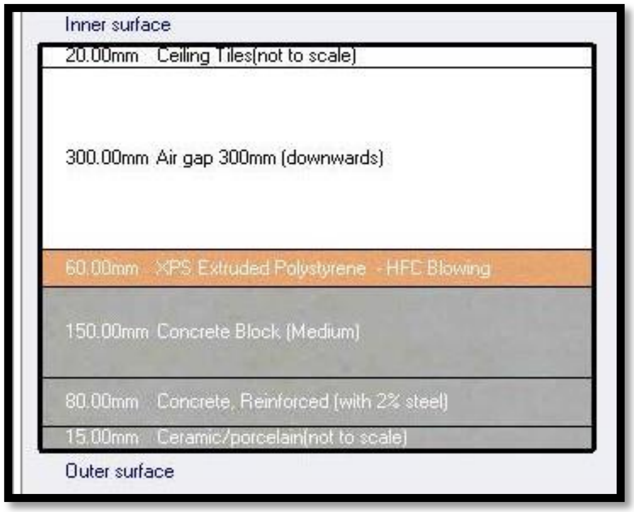


Figure 94 : section in ceilling

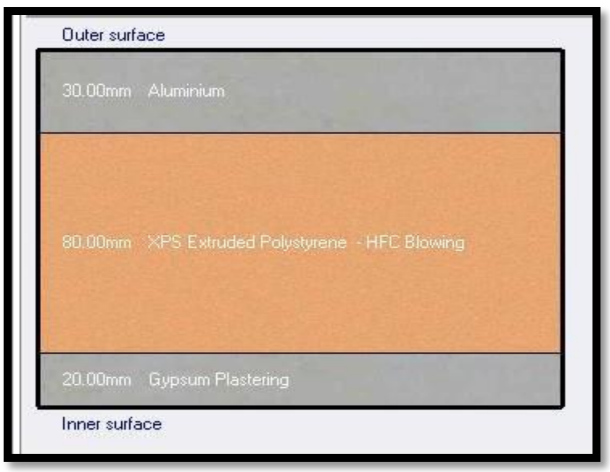


Figure 95 : section in external wall

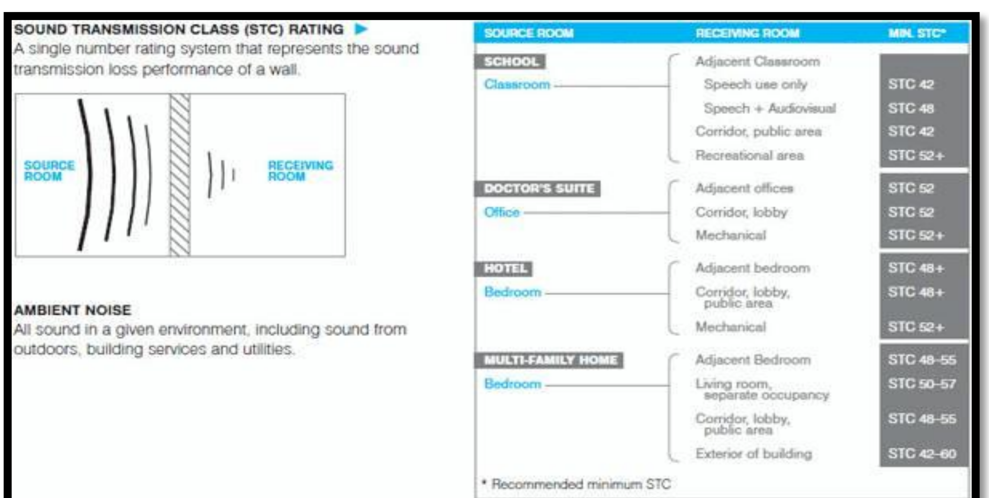


Figure 96 : recommended minimum STC

3.2.6.2. Reverberation Time (RT60)

The recommended value for RT60 in :

1- offices ranges between 0.60 to 1.20 second.
2- Gym ranges between 1.0 to 1.50 second .
3- Bank ranges between 0.4 to 0.8 second .
4- Stuff room (open office) ranges between 0.8 to 1.20 second .

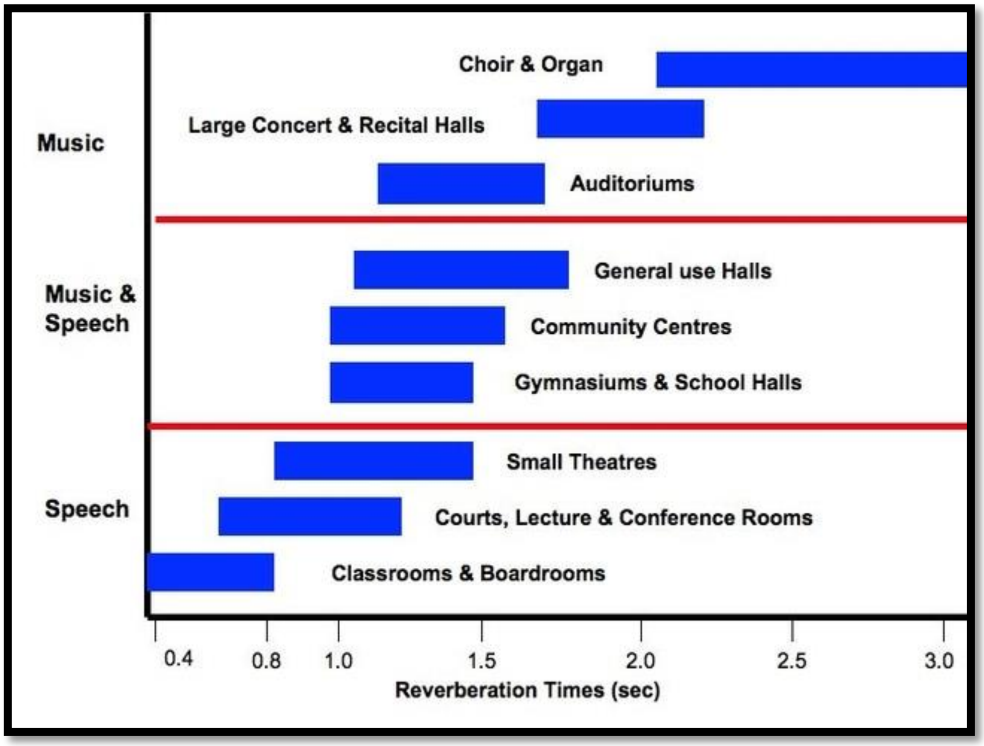


Figure 97 : recommended RT60 for many space

Internal Space	Reverberation Time (T_{mf}) - Seconds
Private Office	0.6 – 0.8
Open Plan Office	0.8 – 1.2

Figure 98 : recommended RT60 for office [21]

Calculate RT60 :

- **Case 1 (bank in podium 1)**

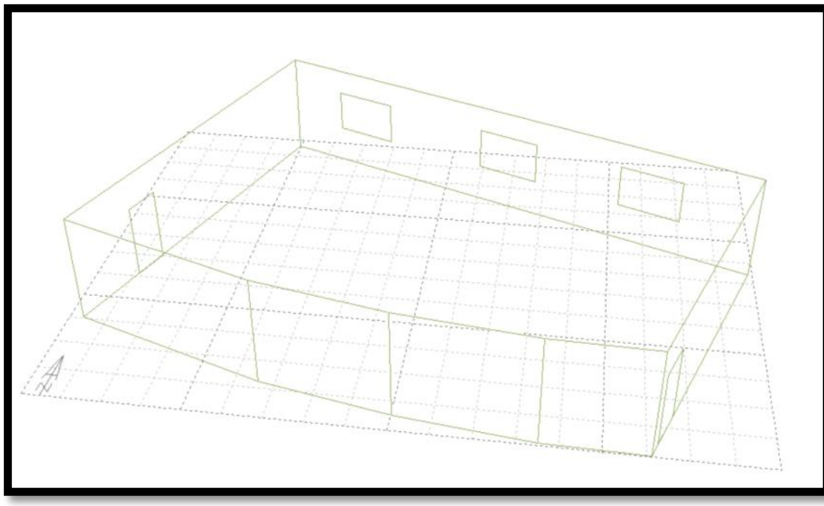
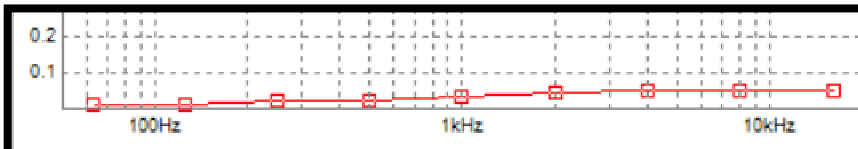


Figure 99 : 3D Model of bank from ecotect

ABSORPTION COEFFICIENTS :

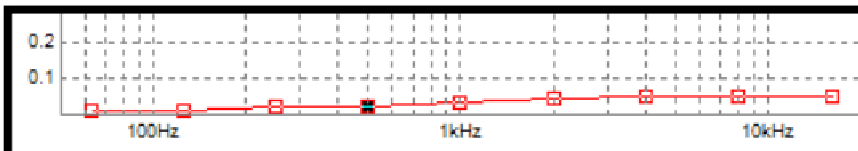
1- External walls (aluminum – isolation – gypsum board)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 100 : Absorption coefficient for external walls (bank)

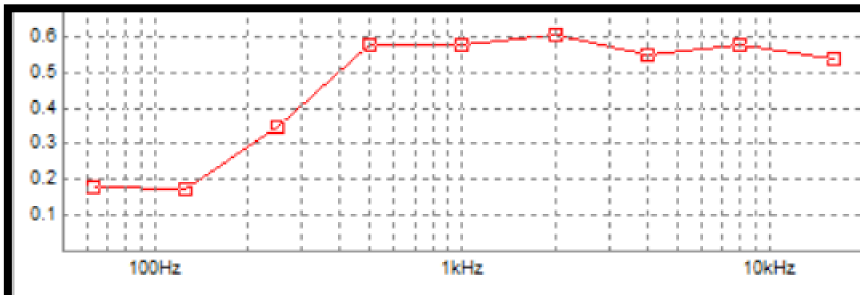
2- internal walls (100 mm hollow block with both plaster side)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 101 : Absorption coefficient for internal walls (bank)

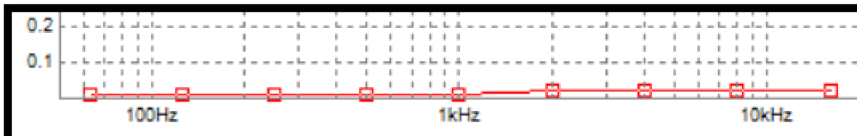
3- ceiling (suspended ceiling tiles)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.18	0.17	0.35	0.58	0.58	0.61	0.55	0.58	0.54

Figure 102 : Absorption coefficient for ceiling (bank)

4- Floor (glazed tile)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

Figure 103 : Absorption coefficient for floor (bank)

The RT60 in bank is in standard range (0.40-0.8) sec. See figure and table below :

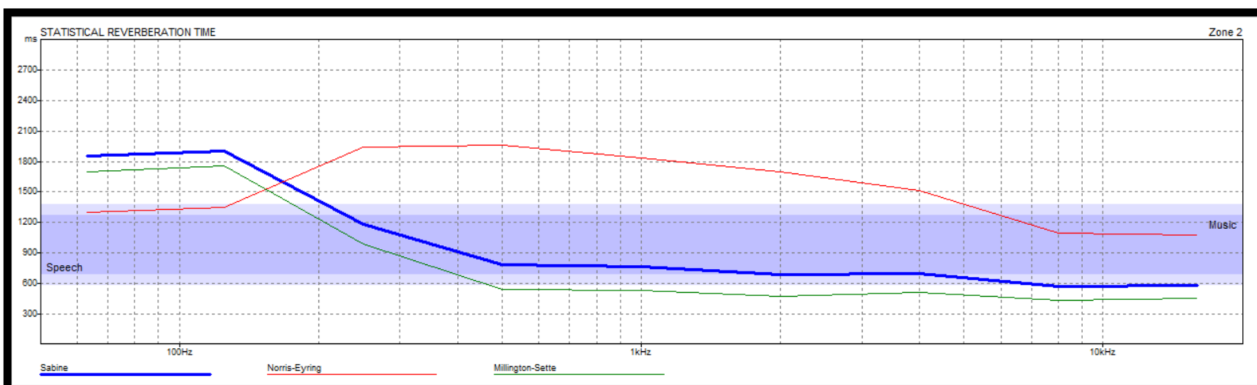


Figure 104 : Reverberation Time in the bank

Table 20 : summary results of RT60 in bank

Volume: 441.350 m3
Surface Area: 433.568 m2
Occupancy: 10 (20 x 50%)
Optimum RT (500Hz - Speech): 0.69 s
Optimum RT (500Hz - Music): 1.27 s

Volume per Seat: 22.068 m3
Minimum (Speech): 4.202 m3
Minimum (Music): 8.032 m3

Most Suitable: Millington-Sette (Widely varying)
Selected: Millington-Sette (Widely varying)

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	36.695	1.87	1.31	1.72
125Hz:	35.148	1.91	1.35	1.77
250Hz:	56.192	1.20	1.99	1.00
500Hz:	87.644	0.79	2.01	0.54
1kHz:	88.557	0.77	1.86	0.53
2kHz:	94.577	0.69	1.73	0.47
4kHz:	86.920	0.70	1.53	0.52
8kHz:	91.142	0.57	1.10	0.43
16kHz:	85.414	0.58	1.08	0.46

Case 2 (cafeteria in floor 1) :

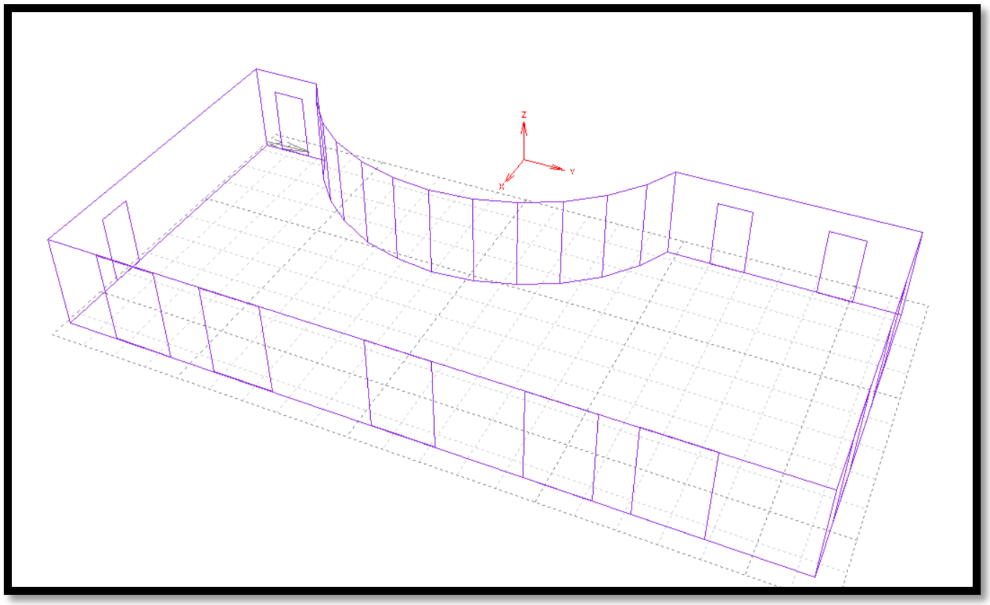
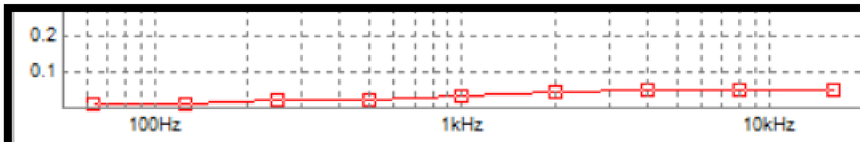


Figure 105 : 3D Model of cafeteria from ecotect

ABSORPTION COEFFICIENTS :

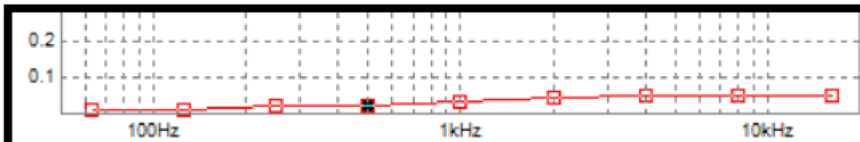
1- External walls (aluminum – isolation – gypsum board)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 106 : Absorption coefficient for external walls (cafeteria)

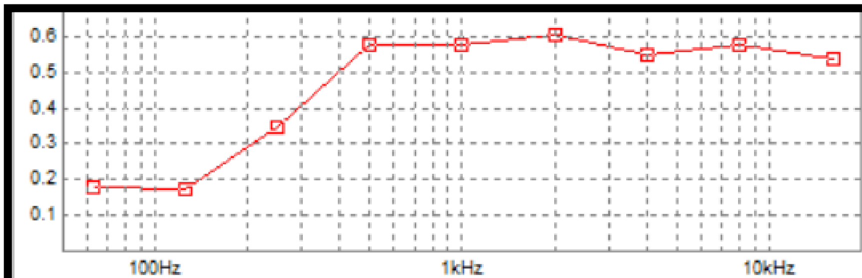
2- internal walls (100 mm hollow block with both plaster side)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 107 : Absorption coefficient for internal walls (cafeteria)

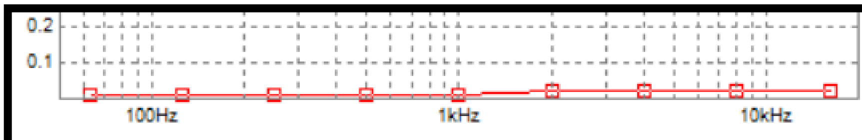
3- ceiling (suspended ceiling tiles)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.18	0.17	0.35	0.58	0.58	0.61	0.55	0.58	0.54

Figure 108 : Absorption coefficient for ceiling (cafeteria)

4- Floor (glazed tile)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

Figure 109 : Absorption coefficient for floor (cafeteria)

The RT60 in cafeteria is in standard range (0.70 - 1.3) sec. See figure and table below

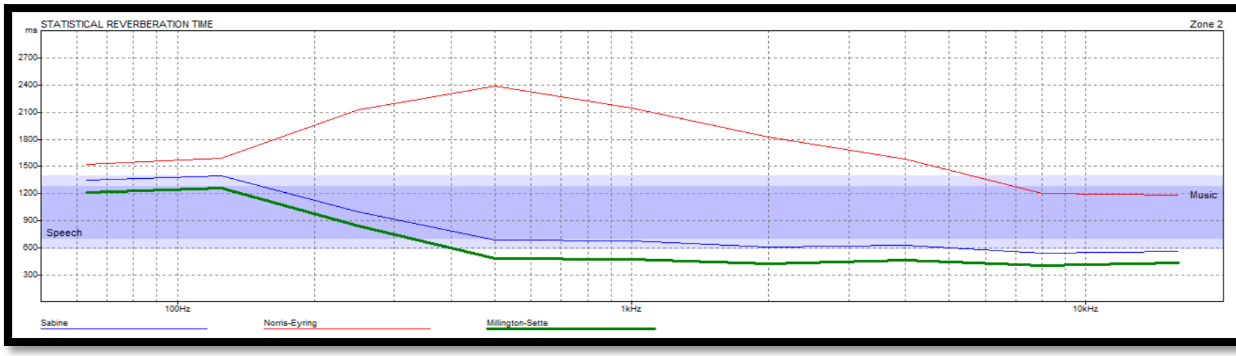


Figure 110 : Reverberation Time incafeteria

Table 21 : summary results of RT60 in cafeteria

Volume: 468.060 m3
Surface Area: 510.350 m2
Occupancy: 24 (30 x 80%)
Optimum RT (500Hz - Speech): 0.70 s
Optimum RT (500Hz - Music): 1.28 s

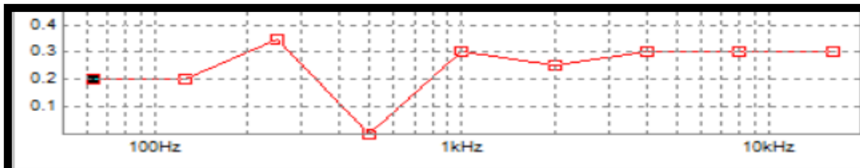
Volume per Seat: 15.602 m3
Minimum (Speech): 4.289 m3
Minimum (Music): 8.151 m3

Most Suitable: Millington-Sette (Widely varying)
Selected: Millington-Sette (Widely varying)

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	53.588	1.35	1.53	1.22
125Hz:	51.664	1.39	1.60	1.26
250Hz:	69.552	1.00	2.13	0.84
500Hz:	104.498	0.69	2.39	0.48
1kHz:	104.837	0.68	2.15	0.47
2kHz:	113.424	0.61	1.83	0.42
4kHz:	105.138	0.63	1.58	0.47
8kHz:	110.070	0.54	1.21	0.40
16kHz:	103.299	0.56	1.18	0.43

Most result < .7 so we need to improve RT_{60}

So we used ceiling (Plywood 12mm thick perforated 5mm diameter holes 6200 m2 11% open area with 60mm deep air space behind) instead of ceiling (suspended ceiling tiles) with Absorption coefficient :



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.20	0.20	0.35	0..55	0.30	0.25	0.30	0.30	0.30

Figure 111 : Absorption coefficient for ceiling (cafeteria) NEW [22]

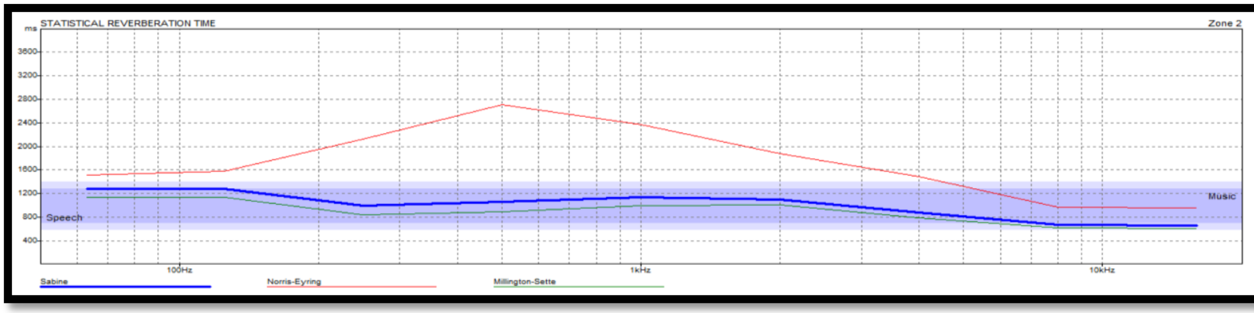


Figure 112 : Reverberation Time in the cafeteria after improve RT60

Table 22 : summary results of RT60 in cafeteria after improve RT60

Volume: 468.060 m3
Surface Area: 510.350 m2
Occupancy: 15 (30 x 50%)
Optimum RT (500Hz - Speech): 0.70 s
Optimum RT (500Hz - Music): 1.28 s

Volume per Seat: 15.602 m3
Minimum (Speech): 4.289 m3
Minimum (Music): 8.151 m3

Most Suitable: Sabine (Uniformly distributed)
Selected: Sabine (Uniformly distributed)

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	56.931	1.29	1.54	1.15
125Hz:	56.679	1.29	1.60	1.15
250Hz:	69.552	1.02	2.24	0.86
500Hz:	66.045	1.08	2.87	0.90
1kHz:	58.024	1.16	2.47	1.01
2kHz:	53.237	1.12	1.94	1.02
4kHz:	63.342	0.89	1.50	0.80
8kHz:	63.258	0.67	0.98	0.62
16kHz:	63.174	0.66	0.96	0.61

Case 3 (open offices) :

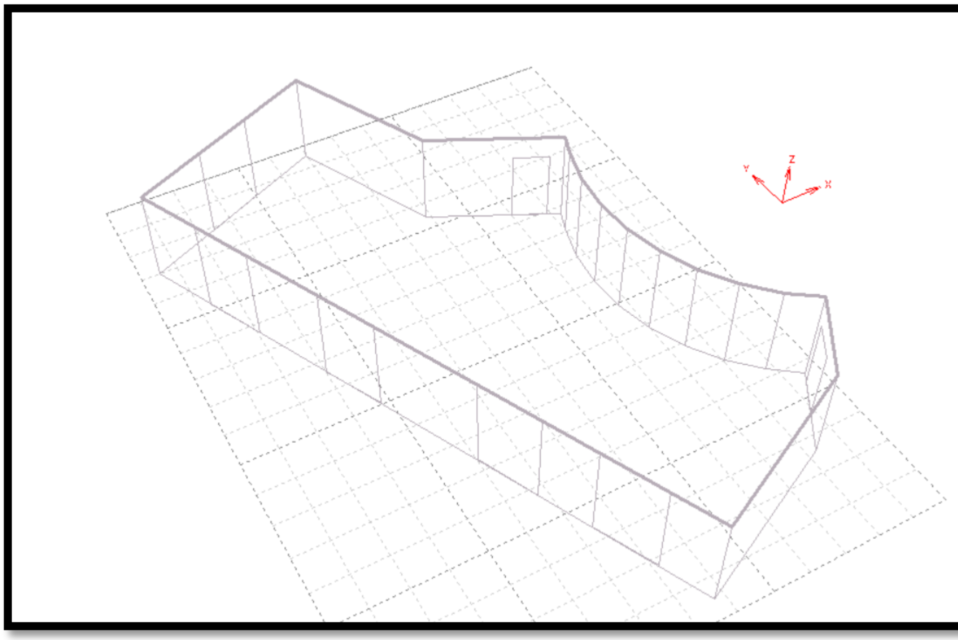
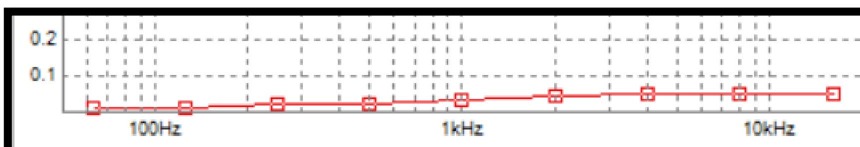


Figure 113 : 3D Model of offices from ecotect

ABSORPTION COEFFICIENTS :

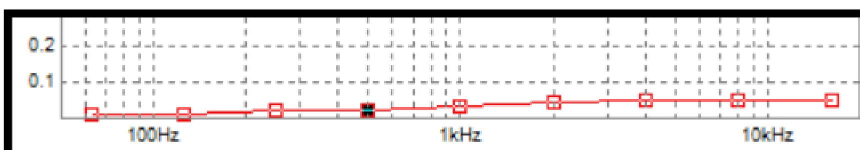
1- External walls (aluminum – isolation – gypsum board)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 114 : Absorption coefficient for external walls (open office)

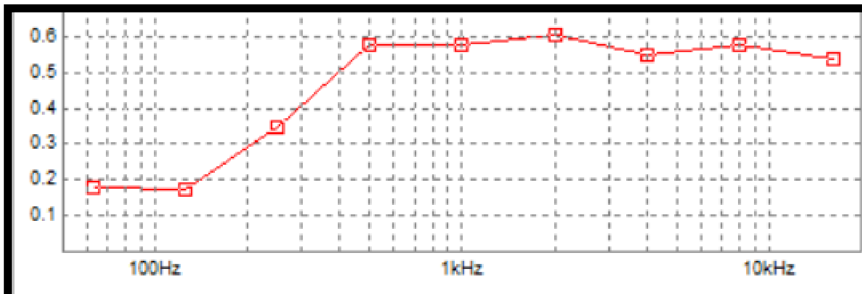
2- internal walls (100 mm hollow block with both plaster side)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 115 : Absorption coefficient for internal walls (open office)

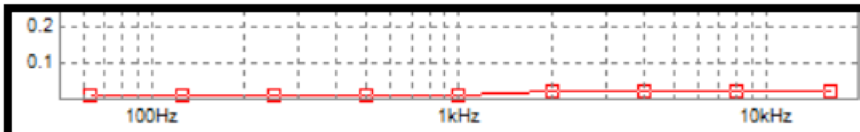
3- ceiling (suspended ceiling tiles)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.18	0.17	0.35	0.58	0.58	0.61	0.55	0.58	0.54

Figure 116 : Absorption coefficient for ceiling (open office)

4- Floor (glazed tile)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

Figure 117 : Absorption coefficient for floor (open office)

The RT60 in open offices is in standard range (0.80 - 1.2) sec. See figure and table

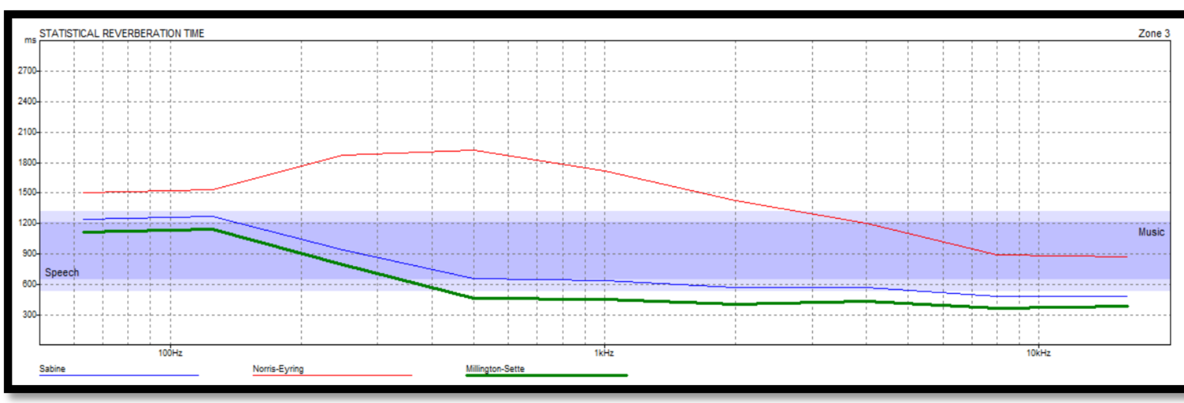


Figure 118 : Reverberation Time in the open office

Table 23 : summary results of RT60 in open office

Volume: 314.330 m3
Surface Area: 356.990 m2
Occupancy: 20 (20 x 100%)
Optimum RT (500Hz - Speech): 0.65 s
Optimum RT (500Hz - Music): 1.21 s

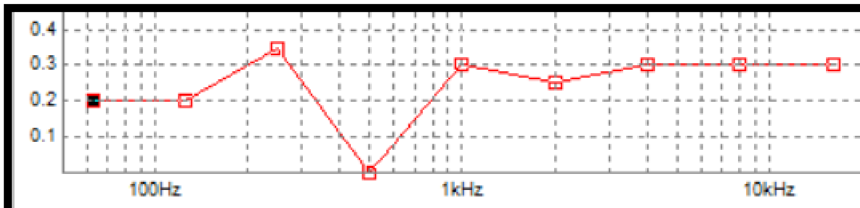
Volume per Seat: 15.716 m3
Minimum (Speech): 4.202 m3
Minimum (Music): 8.032 m3

Most Suitable: Millington-Sette (Widely varying)
Selected: Millington-Sette (Widely varying)

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	37.841	1.24	1.50	1.12
125Hz:	36.603	1.27	1.53	1.15
250Hz:	47.122	0.94	1.87	0.80
500Hz:	70.052	0.66	1.92	0.46
1kHz:	70.305	0.64	1.72	0.46
2kHz:	76.330	0.57	1.42	0.40
4kHz:	71.070	0.57	1.21	0.44
8kHz:	74.367	0.48	0.90	0.37
16kHz:	69.873	0.49	0.87	0.39

Most result < < .8 so we need to improve RT_{60}

So we used ceiling (Plywood 12mm thick perforated 5mm diameter holes 6200 m2 11% open area with 60mm deep air space behind) instead of ceiling (suspended ceiling tiles) with Absorption coefficient:



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.20	0.20	0.35	0..55	0.30	0.25	0.30	0.30	0.30

Figure 119 : Absorption coefficient for ceiling (open office) NEW

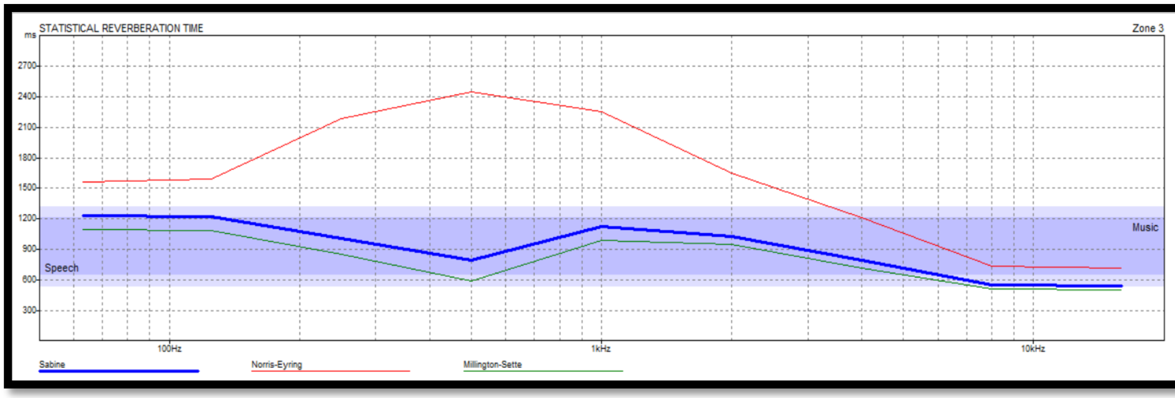


Figure 120 : Reverberation Time in the open offices after improve Rt60

Table 24 : summary results of RT60 in open office after the improve

Volume: 314.330 m3
Surface Area: 356.990 m2
Occupancy: 20 (20 x 100%)
Optimum RT (500Hz - Speech): 0.65 s
Optimum RT (500Hz - Music): 1.21 s

Volume per Seat: 15.716 m3
Minimum (Speech): 4.202 m3
Minimum (Music): 8.032 m3

Most Suitable: Sabine (Uniformly distributed)
Selected: Sabine (Uniformly distributed)

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	40.067	1.18	1.49	1.06
125Hz:	39.941	1.17	1.51	1.05
250Hz:	47.122	0.94	1.87	0.80
500Hz:	57.810	0.78	2.05	0.61
1kHz:	39.144	1.03	1.90	0.91
2kHz:	36.266	0.96	1.47	0.88
4kHz:	43.247	0.76	1.14	0.69
8kHz:	43.205	0.55	0.73	0.52
16kHz:	43.163	0.54	0.72	0.51

Case 4 (gym in floor 15) :

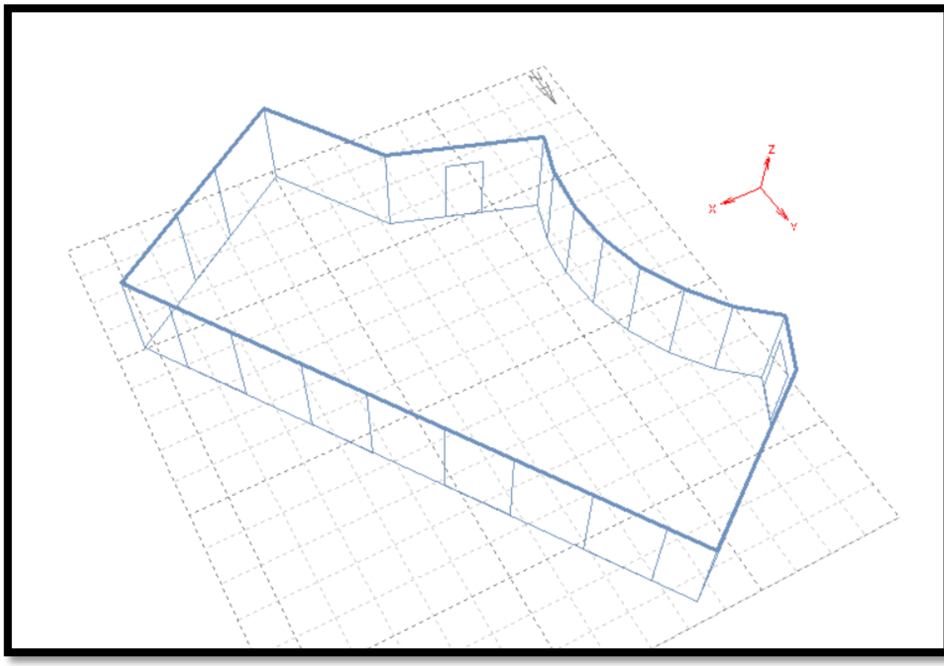
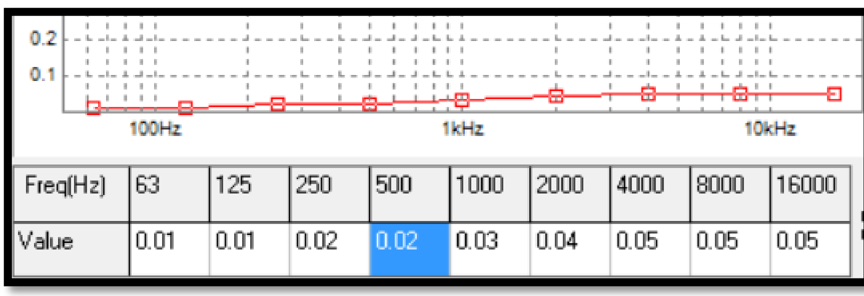


Figure 121 : 3D Model of gym from ecotect

ABSORPTION COEFFICIENTS :

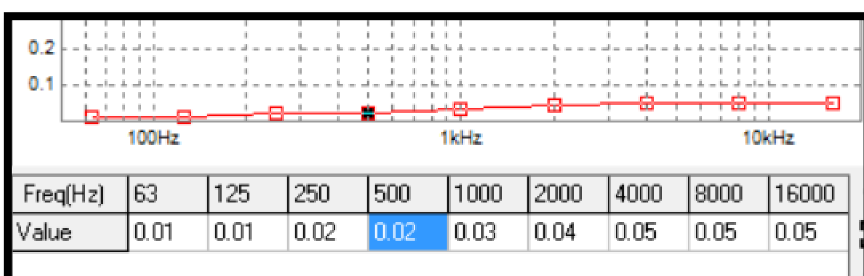
1- External walls (aluminum – isolation – gypsum board)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 122 : Absorption coefficient for external walls (gym)

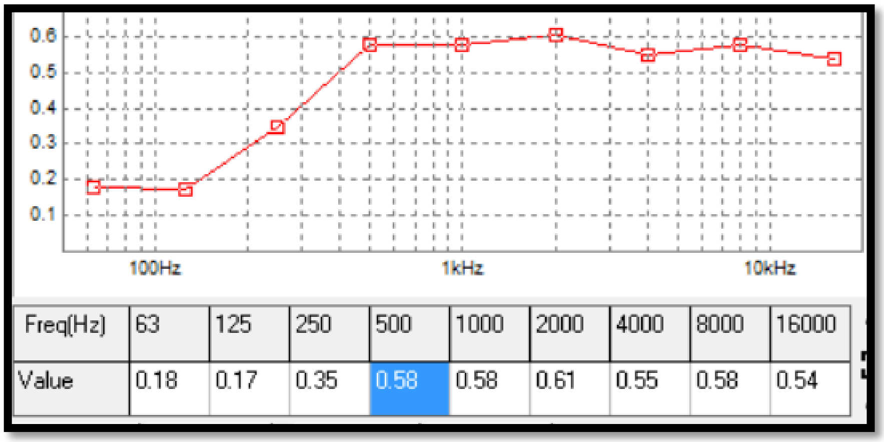
2- internal walls (100 mm hollow block with both plaster side)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05

Figure 123 : Absorption coefficient for internal walls (gym)

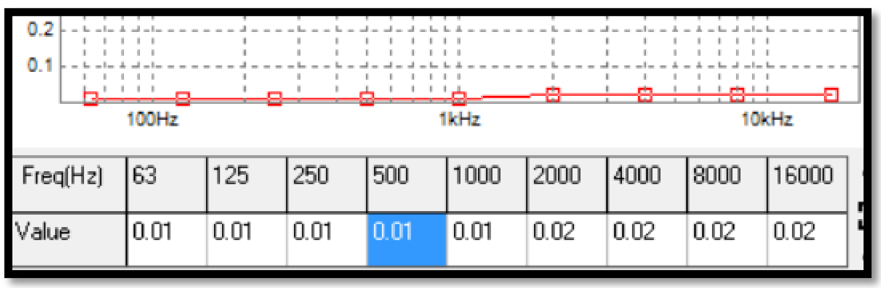
3- ceiling (suspended ceiling tiles)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.18	0.17	0.35	0.58	0.58	0.61	0.55	0.58	0.54

Figure 124 : Absorption coefficient for ceiling (gym)

4- Floor (glazed tile)



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

Figure 125 : Absorption coefficient for floor(gym)

The RT60 in gym is in standard range (1.0 - 1.5) sec. See figure and table below

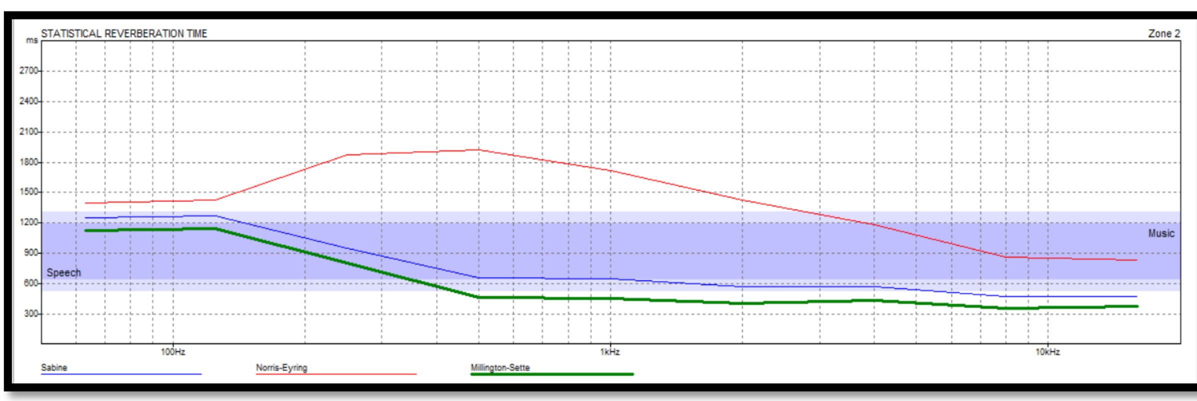


Figure 126 : Reverberation Time in the gym

Table 25 : summary results of RT60 in gym

Volume: 292.200 m3
Surface Area: 335.825 m2
Occupancy: 13 (25 x 50%)
Optimum RT (500Hz - Speech): 0.64 s
Optimum RT (500Hz - Music): 1.20 s

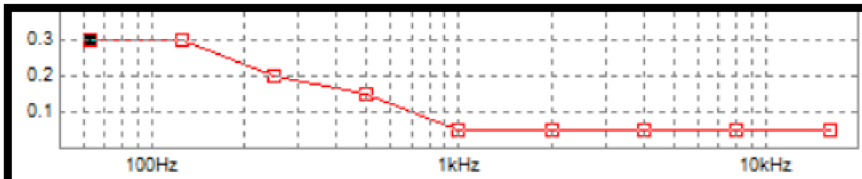
Volume per Seat: 11.688 m3
Minimum (Speech): 4.250 m3
Minimum (Music): 8.097 m3

Most Suitable: Millington-Sette (Widely varying)
Selected: Millington-Sette (Widely varying)

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	35.583	1.25	1.40	1.12
125Hz:	34.407	1.27	1.43	1.15
250Hz:	44.416	0.95	1.87	0.81
500Hz:	66.082	0.66	1.93	0.46
1kHz:	66.319	0.64	1.72	0.46
2kHz:	71.937	0.57	1.43	0.40
4kHz:	66.930	0.57	1.19	0.43
8kHz:	70.039	0.47	0.86	0.36
16kHz:	65.796	0.48	0.84	0.38

Most result < < 1 so we need to improve RT_{60}

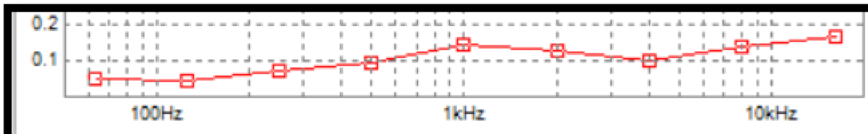
So we used ceiling (Plasterboard 10mm thick backed with 25mm thick bitumen) instead of ceiling (suspended ceiling tiles) with Absorption coefficient :



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.30	0.30	0.20	.15	0.05	0.05	0.05	0.05	0.05

Figure 127 : Absorption coefficient for ceiling (gym) NEW

And we used Floor (ConcSlab_Timber_OnGround) instead of Floor (glazed tile) with Absorption coefficient :



Freq(Hz)	63	125	250	500	1000	2000	4000	8000	16000
Value	0.05	0.04	0.07	0.09	0.14	0.12	0.10	0.14	0.17

Figure 128 : Absorption coefficient for floor (gym) NEW

Now the result OK as shown below :

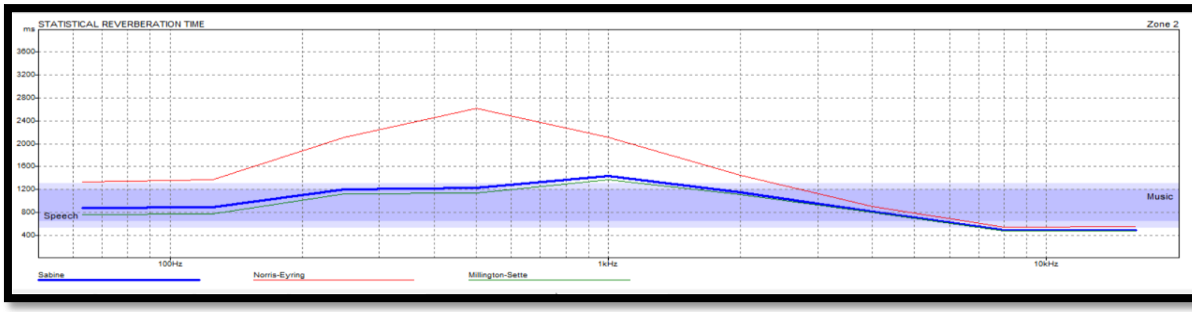


Figure 129 : Reverberation Time in the gym after the improve

Table 26 : summary results of RT60 in gym after the improve

```
Volume:  292.200 m3
Surface Area:  335.825 m2
Occupancy:  13  (25 x 50%)
Optimum RT (500Hz - Speech):  0.64 s
Optimum RT (500Hz - Music):  1.20 s

Volume per Seat:  11.688 m3
Minimum (Speech):  4.250 m3
Minimum (Music):  8.097 m3

Most Suitable:  Sabine (Uniformly distributed)
Selected:  Sabine (Uniformly distributed)
```

FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	52.389	0.88	1.33	0.76
125Hz:	51.575	0.89	1.37	0.77
250Hz:	35.236	1.21	2.11	1.12
500Hz:	34.813	1.23	2.62	1.14
1kHz:	24.719	1.44	2.11	1.38
2kHz:	24.099	1.14	1.44	1.11
4kHz:	22.952	0.82	0.91	0.80
8kHz:	26.976	0.48	0.54	0.48
16kHz:	29.830	0.49	0.56	0.48

3.2.6.3. Noise control [23]

to address speech privacy and noise control issues we used (sound masking system) see figer

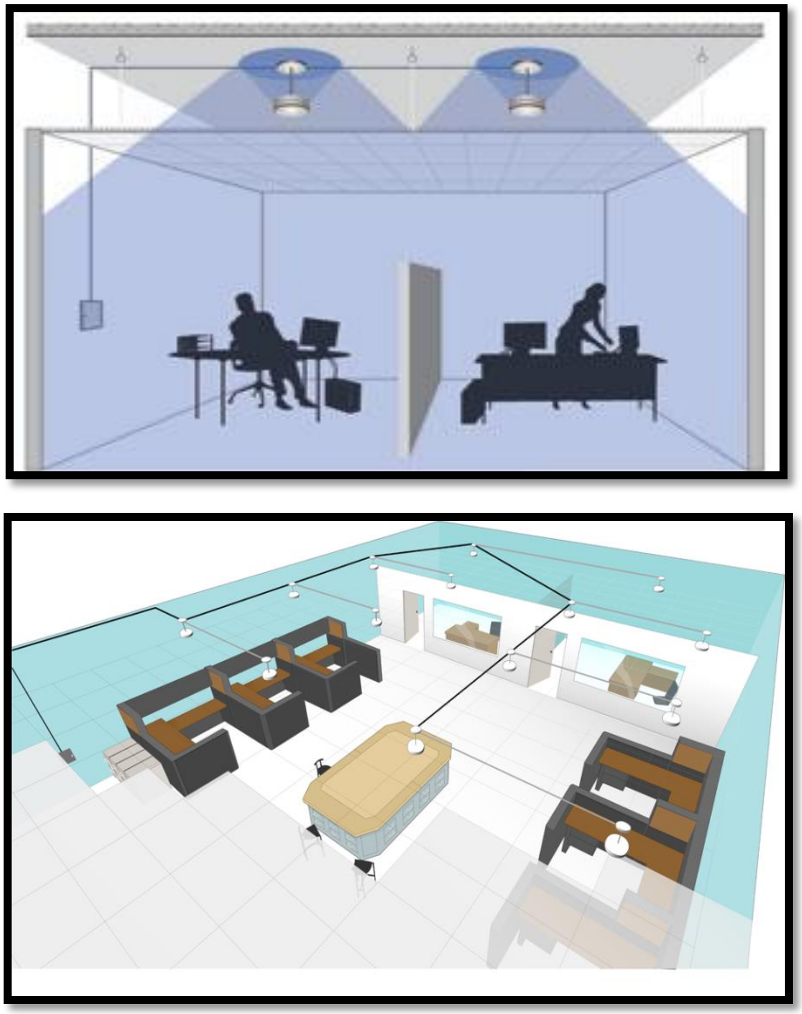


Figure 130 : Sound masking system

A sound masking system basically consists of a series of loudspeakers installed in a grid-like pattern in the ceiling, as well as a method of controlling their zoning and output. The loudspeakers distribute a background sound, raising the facility's ambient level in a controlled fashion.

The premise behind this solution is simple: any noises that are below the new background level created by the masking sound are covered up and the impact of those still above it is lessened because the degree of change between baseline and peak volumes is smaller. Similarly, conversations are either entirely masked or their intelligibility is reduced, improving occupants' privacy and decreasing the number of disruptions to their concentration .

The Sound Masking System is easily installed in new or occupied facilities of any size , and System that we used called (LogiSon) and consists of :

1- Control panel :

The Network Control Panel (NCP-2) can be wall-mounted within a room or closet. It provides the functionality of numerous rack-mounted components, reducing the costs, energy and space needed for equipment.

Specifications

Control Performance	Network initialization, masking, paging, timer, keypad settings, zoning, paging/music inputs, system monitoring and diagnostics
Masking Performance	
Volume	35 to 85 dBA in 0.5 dBA steps + mute
Equalization (w/ PC)	1/3-octave, 23 bands, 63 to 10,000 Hz
Preset Contours	50 preset options; ustomization of each band
Paging Performance	
Audio Inputs	3, any combination of auxiliary, telephone and microphone
Zone Configuration	Zone 1, 2, 3 or none; unlimited zones with Page Director Software
Volume	35 to 85 dBA @ 1 m in 0.5 dBA steps + mute
Equalization (w/ PC)	1/1-octave, 8 bands
Preset Contours	50 preset options; customization of each band
Timer Performance	
Zone Number	Up to 9
Zone Size	Unrestricted
Schedule	Unique schedules for each day
Volume Changes Per Day	Up to 9
Volume Increments	0.5 dBA steps
Rate of Change	0 to 9 minutes per increment
Exception Schedules	Up to 30 days, 3user defined schedules
Delayed Start Feature	Yes
Ramp Up Feature	Up to 15 days, user defined schedule in 0.5 or 1dBA steps
Daylight Savings Adjustment	Yes
Components per Panel	
Max. # of Componenets	125 per panel
Max. # of Loudspeakers	375 per panel
Network Type	
Upstream from Panel Input	Open; protected with 128-bit AES encryption
Downstream from Panel	Closed; standard RS-485

Connections	
Power Input	3-pin, screw terminal
Network Ouput	6-pin
Ethernet Connections	10 Base-TRJ-45
Audio Inputs	3-pin, screw termainal x3
Priority Page	2-pin, screw terminal
Power	
Input	30 Vdc
Output	30 Vdc
Consumption	Maximum 12 W
Ground	Earth Ground
Relay Outputs	2-pin, screw terminal x2
Battery	
Size	1/2 AA
Voltage	3.6 V
Life Expectancy	10 years
Physical Specifications	
Dimensions (WxHxD)	28 x 23 x7.6cm; 11 x9 x3inches
Enclosure	Steel with powdercoat finish
Color	Charcoal grey
Weight	2 kg; 5 lbs
Keypad	20-key membrane panel
Display	4 x 20 backlit LCD
Mounting	4 keyhole mounting positions
Security	
Physical	Key-lock enclosure
Electronic	Password required to access settings; 2 levels
Warranty	5 years; see *LogiSon® Product Warranty* for details
Certifications	Meets UL, FCC and CE standards; RoHS compliant

Figure 131 : Control panel specifications

2- Hubs :

Primary Hubs are connected to the Network Control Panel in series and each one is automatically assigned a unique operating address during system start up. The panel uses these addresses to communicate with the hubs, allowing the administrator to program the zoning and output variables for individual loudspeakers.

Specifications

Masking Performance	
Sound Generation	Digital Signal Processor (DSP), truly random (nondeterministic)
Volume	35 to 85 dBA in 0.5 dBA steps + mute
Equalization (w/PC)	1/3-octave, 23 bands, 63 to 10,000 Hz
Preset Contours	50 preset options; customization of each band
Paging Performance	
Zone Configuration	Zone 1, 2, 3 or none
Volume	35 to 85 dBA @ 1 m in 0.5 dBA steps + mute
Equalization (w/PC)	1/1-octave, 8 bands
Preset Contours	50 options
Timer Performance	Zoning and events set using Network Control Panel or Acoustic Network Manager Software
Components per Hub	
Number of SNH-1	0 to 2
Number of Loudspeakers	1 to 3
Connections	
Network Input	6-pin
Network Output	6-pin
SNH Output	2-pin x2
Loudspeaker Assembly Output	2-pin
Power Input (PNH-2P)	2-pin
Accessory Input (PNH-2A)	6-pin
Cabling	
PNH to PNH	CA6 series cable
PNH to SNH	CA2 series cable
Power	
Input	40 Vdc
Consumption	3.6 W at typical settings; 6.4 W at maximum settings

Power	
Input	40 Vdc
Consumption	3.6 W at typical settings; 6.4 W at maximum settings

Integrated Amplifier	5 Watts
Physical Specifications	
Dimensions (W x H)	13.0 cm x 4.5 cm; 5.1 inches x 1.75 inches
Enclosure	Plenum-rated resin
Colour	Off-white or charcoal grey; custom colors available * White available for use with LA-1OP (not plenum rated)
Weight	0.2 kg; 0.4 lb
Mounting	Flexible mounting options; see installation manual
Security	
Physical	No physical controls
Electronic	Monitored of communication, power and loudspeakers
Warranty	5 years; see LogiSon® Product Warranty for details
Certifications	Meets UL, FCC and CE standards and is approved for use in air-handling plenums; RoHS compliant

Figure 132 : Hub specifications

3- Loudspeaker :

A loudspeaker is suspended from a hub and used to broadcast masking, paging and/or music. The LA-1 model is very flexible and used throughout most LogiSon Sound Masking System installations. The custom clip allows the length of chain to be adjusted without tools. Slack cable retracts into the enclosure, ensuring tidy installation. The full-range driver provides output exceeding the typical masking spectrum of 100 to 5,000 Hz, including the lower frequencies needed for comfort.

Specifications	
Audio Performance	
Masking Output	87 dBA maximum
Paging Output	87 dBA maximum
Driver Specifications	
Frequency Range	90 to 10,500 Hz
Dimension	10.1 cm; 4 inches
Power Handling	25 W (RMS)
Sensitivity	88.6 dBA @ 1W / 1m
Magnet Structure	510 g; 18 oz
Impedance	16 ohms
Connections	
Loudspeaker Input	2-pin
Cabling	
Loudspeaker to Hub	Integrated cable assembly
Physical Specifications	
Dimensions (W x H)	16.5 x 9.0 cm; 6.5 x 3.5 inches
Enclosure	Plenum-rated resin
Color	Off-white or charcoal grey; custom colors available
Weight	0.95 kg; 1.9 lbs
Mounting	
Method	Suspend from hub or from deck
Chain Length	61 cm; 24 inches
Chain Adjustment	Tool-free clip
Loudspeaker Orientation	Upwards; tool-free reversibility to downwards if necessary
Cable Management	Slack retracts into enclosure
Warranty	5 years; see LogiSon® Product Warranty for details
Certifications	LA-1 and LA-1CM meet UL, FCC and CE standards and are approved for use in air-handling plenums; LA-1OP meets UL, FCC and CE standards; all are RoHS compliant

Figure 133 : loudspeaker specifications

4- Audio Input Modules :

Audio Input Modules are used to connect paging and/or music sources to the Network Control Panel. They offer analog to digital conversion and automatically adjust for input sensitivity. Each panel accepts any combination of three inputs: Auxiliary (AIM-2A), Microphone (AIM-2M) and Telephone (AIM-2T).

Specifications

Auxiliary	
Input Impedance	100 kohm
Input Level	10 V maximum
Input Sensitivity	300 mV for maximum output
Gain	Maximum 20 dB, adjustable in thirty two 1 dB steps
Frequency Response	20 to 10,000 Hz
Microphone	
Input Impedance	600 ohm
Input Level	30 mV maximum
Input Sensitivity	1 mV for maximum output
Gain	Maximum 70 dB, adjustable in thirty two 1 dB steps
Frequency Response	20 to 10,000 Hz
Telephone	
Input Impedance	600 ohm
Input Level	10 V maximum
Input Sensitivity	300 mV for maximum output
Gain	Maximum 20 dB, adjustable in thirty two 1 dB steps
Frequency Response	20 to 10,000 Hz
Warranty	5 years; see LogiSon® Product Warranty for details
Certifications	Meets UL, FCC and CE standards; RoHS compliant

Figure 134 : Audio Input Modules specifications

5- Cable :

A single line of plenum-rated, low-voltage cable connects the components, carrying power, control and audio signals across the LogiSon Sound Masking System.

Specifications

Physical Specifications

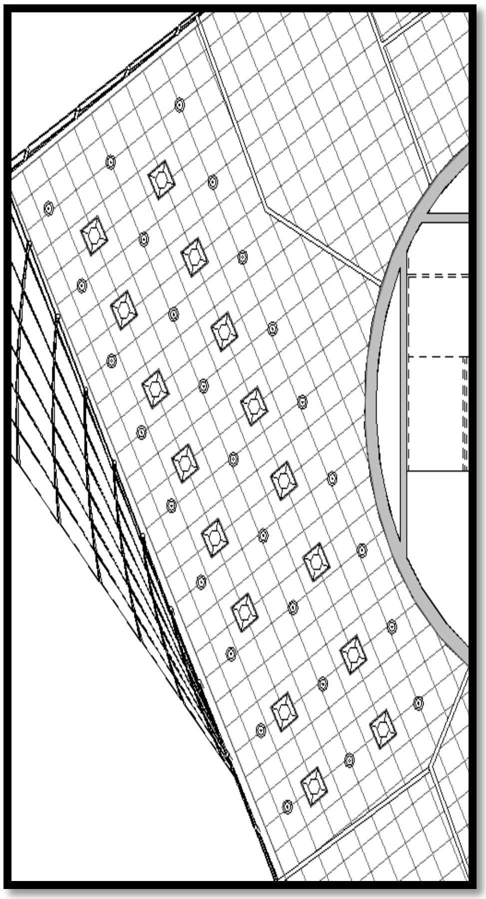
Lengths	CA2-5 5 ft; 1.5 m CA2-18 18 ft; 5.5 m CA2-25 25 ft; 7.6 m CA2-50 50 ft; 15.2 m CA6-5 5 ft; 1.5 m CA6-18 18 ft; 5.5 m CA6-25 25 ft; 7.6 m CA6-50 50 ft; 15.2 m CA6-100 100 ft; 30.4 m
Connectors	2- and 6-pin over-molded micro-connectors featuring orientation guides and positive-lock mechanism
Gauge	20 AWG
Material	Copper stranded
Color	White or charcoal grey
Warranty	5 years; see LogiSon® Product Warranty for details
Certifications	Meets UL, FCC and CE standards and is approved for use in air-handling plenums; RoHS compliant

Figure 135 : cable specifications

6- Power:

The LogiSon Sound Masking System’s energy consumption is very low: less than that of a typical light bulb for an area of 13,500 ft2.

Distribution of system units on plan :



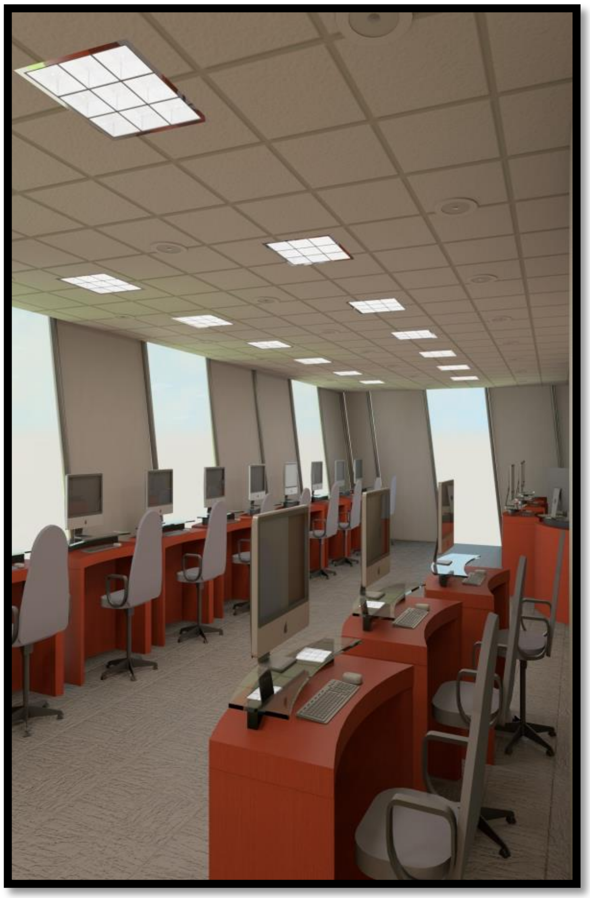


Figure 136 : Distribution masking sound system units in open office

3.3.structural design

3.3.1. Introduction

In this chapter, the structural elements were designed by studying the loads and stresses that these elements are subjected to. loads are divide to static loads such as gravity loads(O.W,SID,live ..etc) and dynamic loads such as earthquakes. This design expected to protect the building from failure under loads to improve the safety needs for human.
Etabs 2015 software program was used to analysis the frames in the building. SAP2000v16 was used to analysis and design the concrete water tank and safe v14.2 software program was used to analysis and design the foundation.

3.3.1.1. Structural system

concrete frame system was used in the project , because the ratio between the long span and short span less than one the two way ribbed slab system was used in the project It is usually used to minimize the dead load of the slab by using special hollow blocks .

3.3.1.2. Material properties

The materials used consist the following properties:

Concrete:

- Compressive strength of concrete (f'c): it is the compressive strength of test cube of cylinder measured after 28 days.

f'c(beam and slab,isolated footing) = 28 MPa (B350) ,

f'c (column ,shear wall and Foundation)= 48 MPa (B600)

- Modulus of elasticity: it equals 4700$\sqrt{f'c}$ = 24870MPa.
- Modulus of elasticity: it equals 4700$\sqrt{f'c}$ = 32562MPa.

Steel:

- Steel bars: yielding strength (Fy) = 420 MPa.

Soil : the soil in the site has the following properties:

- Allowable bearing capacity (q) = 300 KN/m2
- The friction angle (Ø) = 30o

3.3.1.3. Loads

Loads that effect on structures can be divided into three board categories: dead load, live loads, lateral loads.

- Dead loads (D.L):- Own weight: the loads due to the own weight of the structure, which will remain constant during the life of the building.

- Super Imposed dead load (SID):-it is considered as dead load it result from the own weight of the backfill, the tile and mortar.

- Live Load (L.L):- The expected load that the structure will carry it, such as the people, machines, and all movable loads expected during the life of the structure.

- Lateral loads consider earthquake load.

Sample calculation for SID loads on the slab

Filling: γfilling = 17 KN/m3, thickness = 6 cm
Weight = 17 * 0.06 = 1.00 KN/m2
Mortar: γmortar = 22 KN/m3 ,thickness = 3 cm
Weight = 22 * 0.03 = 0.66 KN/m2
Tile: γtile = 20 KN/m3, thickness = 2 cm
Weight = 20 * 0.02 = 0.40 KN/m2
the weight of the partition = 0.94 KN/m2

- SID = 3.00 KN/m2

SID (on slab) = 3KN/m2
SID (offices floors parameter)= 3 KN/m2
SID (commercial floors parameter) = 23KN/m2
Live load for offices = 3 KN/m2, and for stores, parking,commercial floor and stairs = 5 KN/m2

3.3.1.4. Load Combinations

The following are the load combinations and factors of safety in design from ACI 318-08:

Ultimate combination

1) Wu= 1.4D.L.
2) Wu= 1.2D.L+ 1.6L.L + 0.5(Lr or S or R).
3) Wu= 1.2D.L +1.6(Lr or S or R) + (1.0L or 0.8W).
4) Wu= 1.2D.L+ 1.6W + 1.0L + 0.5(Lr 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 :
DL:dead load , L: live load , E: Earthquake Load
S: Snow Load, W: Wind load, Lr: Roof live Load, R: Rain load.

Service combination

$$D \quad (12\text{-}7)$$

$$D + L + (L_r \text{ or } S) \quad (12\text{-}8)$$

$$D + \left(W \text{ or } \frac{E}{1.4}\right) \quad (12\text{-}9)$$

$$0.9D \pm \frac{E}{1.4} \quad (12\text{-}10)$$

$$D + 0.75\left[L + (L_r \text{ or } S) + \left(W \text{ or } \frac{E}{1.4}\right)\right] \quad (12\text{-}11)$$

3.3.2. Preliminary design

3.3.2.1. Beams and Columns

we assumed dimensions for beam and column after analysis the dimensions was ok

Depth and width :

in the project we have one type of beams, wich is drop beam.

The selection of the depth of dropped beams made to meet the deflection requirements according to the ACI318 code requirements .

the appropriate dimensions have be to chosen to satisfy the safety criteria. As preliminary dimensioning, 70*60cm and are going to be used, column 1,2* 1.2 and 0.5*0.5.

3.3.2.2. Shear wall

The thickness of shear wall equal 40 cm .

3.3.2.3. slab

According to ACI Code 9.5.3 specifies a minimum slab thickness – for two way slab- to control deflection.

For $\alpha fm \geq 2$.

$$\frac{\ln(0.8 + \frac{fy}{1400})}{36 + 9B} = \text{h(min}$$

*Assume (columns is D = 1.2 m , beams width is 70 cm) .

$$B = \frac{long..clear..span}{short..clear..span} = \frac{8.3-1.2}{8-1.2} = 1.04$$

$$h(min) = \frac{7.1\times1.1}{36+9\times1.04} = 17cm$$, Try h = 20 cm ($Ig_{(solid)} = 366*10^6$ mm^4) .

Try ribbed section with block (40 * 20 * 24) :

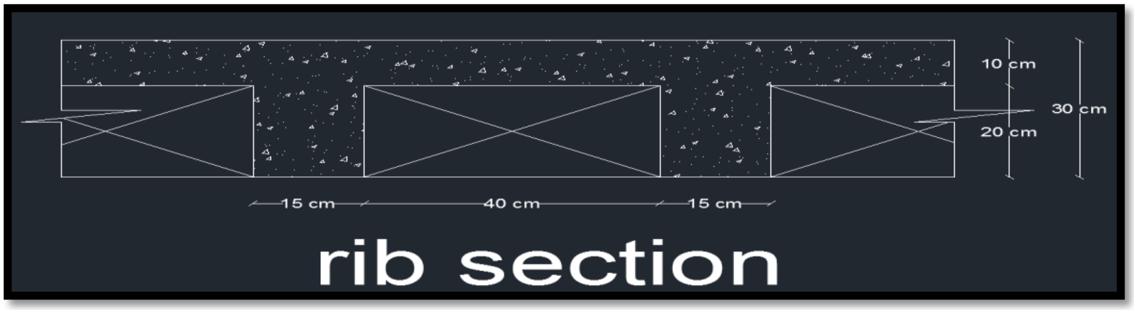


Figure 137 : rib section

The section dimensions for the ribbed slab are shown in figure.

According to ACI code:

bw= 150 mm $\geq$ 100mm

h = 300 mm $\leq$ 3.5 bw=3.5X150=525 mm.

S = 400 mm $\leq$ 750mm.

hf = 100mm $\geq$ 50mm.

$\geq$S/12=400/12=33.33 mm.

➔ Rib dimensions are **OK**

$Ig_{(rib)} = 582*10^6$ mm^4 >> $Ig_{(solid)} = 366*10^6$ mm^4 ok

we must check section for shear :

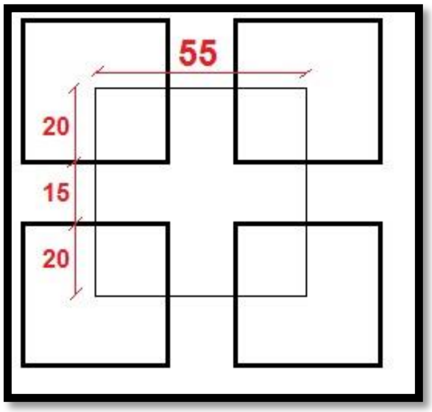


Figure 138 : plane of two way slab

slab own weight :

W_o = {(**0.55*0.55*0.3) - (0.2*0.2*0.2*4) }*25 + {4*0.2*0.2*0.2}*12**
W_o = 1.852KN/two way rib unit
W_o = 1.852/(0.55*0.55) = 6.12KN/m^2

Wu = 1.2 WD + 1.6 WL = 1.2 (6.12 + 3) + 1.6 (5) = 18.94 KN/m^2
$Wu*_{(\text{ distributed load on rib})}$ = 18.94* 0.55 = 10.41 KN / m.rib

Check shear

$$\mathbf{V_{u,d}} = Wu^* \{ \frac{Ln}{2} - d \}$$

$$= 10.41\{ \frac{5.8}{2} - 0.26 \}$$

$$\mathbf{= 27.4\ KN}$$

$$\mathbf{\text{Ø}V_c} = \frac{\text{Ø}}{6}\sqrt{28}\ {}^{*}b_w d^{*}1.1$$

$$\mathbf{= 28.4\ KN > V_{u,d}}$$ **(good)**

<u>Check αfm:</u>

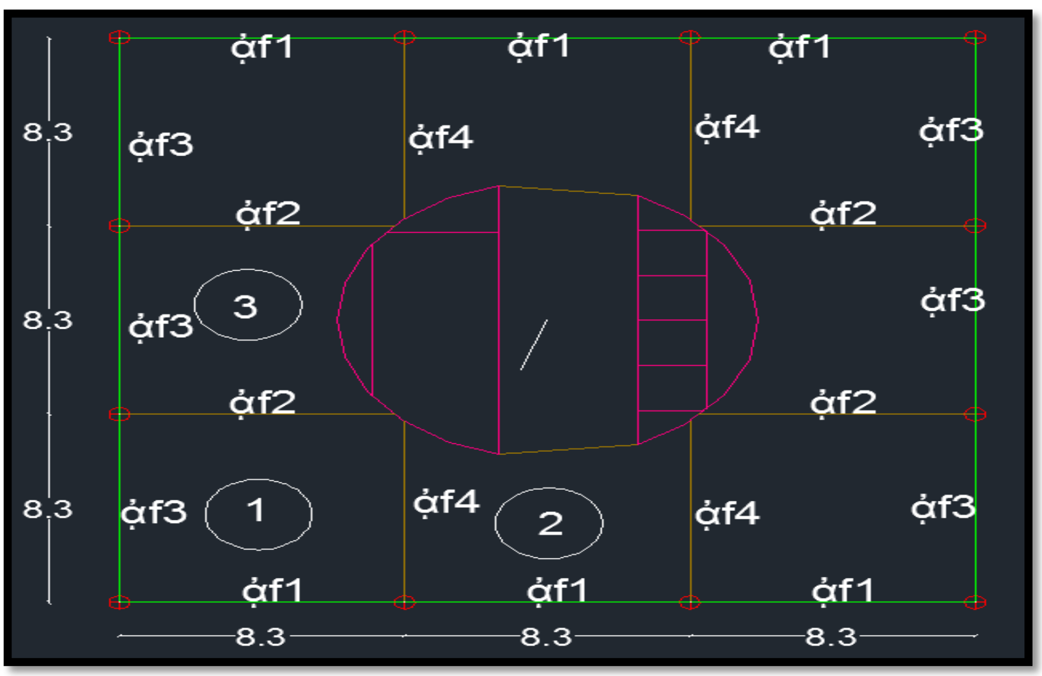


Figure 139 : Plane for check alpha

. $\alpha f1 = Ib / Is = \frac{1.26*10^{10}}{\frac{1*4150*233^3}{12}} = 2.88$

. $\alpha f2 = Ib / Is = \frac{1.26*10^{10}}{\frac{1*8300*233^3}{12}} = 1.44$

. $\alpha f3 = Ib / Is = \frac{1.26*10^{10}}{\frac{1*4150*233^3}{12}} = 2.88$

. $\alpha f4 = Ib / Is = \frac{1.26*10^{10}}{\frac{1*8300*233^3}{12}} = 1.44$

αfm= (αf1 + αf2+ αf3+ αf4) / 4

$\boldsymbol{\alpha fm_1}$= (αf1 + αf2+ αf5+ αf6) / 4 =2.16

$\boldsymbol{\alpha fm_2}$= (αf1 + αf2+ αf6+ αf6) / 4 =1.92

$\boldsymbol{\alpha fm_3}$= (αf2 + αf3+ αf5+ αf6) / 4 =1.92

least value of αfm = 1.92 .

0.2 < $\boldsymbol{\alpha fm_4}$ <2 → use

$$\boldsymbol{h}_{min} = \frac{l_n\left(0.8 + \frac{f_y}{\mathbf{1400}}\right)}{\mathbf{36 + 5}\beta\mathbf{(Afm-.2)}}$$

$$= \frac{8.3-1.2}{8.3-1.2} = 1 \ \ \text{B}$$

$\boldsymbol{h}_{min} =$ 18cm so … use h = 30 cm

$Ig_{(solid)} = \frac{b*h^3}{12} = \frac{550*180^3}{12} = 267*10^6 mm^4$

$Ig_{(rib)} = 570*10^6\ mm^4 >> Ig_{(solid)} = 267*10^6\ mm^4$ ok

3.3.3. Analysis and Verification

3.3.3.1. 3D ETABS Model

The building is modeled as 3D structure using ETABS program, columns and beams are modeled in Etabs as frame elements (lines), while, shear wall and slabs are modeled as area elements (shells).

There are many steps that must be followed on Etabs to reach the final design such as:

1. Define the unit: "kN, m, C" was usedin the model .

2. Draw grid lines, the spacing between these lines was taken from AutoCAD architectural drawings.

3. Define materials, frame sections, and area sections.

4. Define load pattern and load cases.

5. Draw the model.

For defining materials, the material used for the slabs, beams,columns and shear walls is concrete B600 (48 MPa) For each section, modifiers shall be defined. Figures shows the modifiers for slab, beam and column.

Slab Modifier

Type	Membrane f11 direction	Membrane f22 direction	Membrane f12 direction	Bending m11 Direction	Bending m22 Direction	Bending m12 Direction
Slab Modifier	1	1	1	0.25	0.25	0.25

Shear v13 direction	Shear V23 direction	Mass	Weight
1	1	1	1

Beam Modifier

Type	Cross section Axial area	Shear Area in 2 direction	Shear Area in 2 direction	Torsional constant	Moment of inertia about 2 axis	Moment of inertia about 2 axis	Mass	Weight
Beam Modifier	1	1	1	0.001	0.35	0.35	1	1

Column Modifier

Type	Cross section Axial area	Shear Area in 2 direction	Shear Area in 2 direction	Torsional constant	Moment of inertia about 2 axis	Moment of inertia about 2 axis	Mass	Weight
Column Modifier	1	1	1	0.001	0.7	0.7	1	1

Shear wall Modifier

Type	Membrane f11 direction	Membrane f22 direction	Membrane f12 direction	Bending m11 Direction	Bending m22 Direction	Bending m12 Direction
Shear wall Modifier	1	1	1	0.7	0.7	0.7

Shear v13 direction	Shear V23 direction	Mass	Weight
1	1	1	1

➢ After drawing the modal and defining sections property , loads shall be inserted in the modal .

3.3.3.2. Modal Verification

- **Compatibility Check:**

we make this check to insure that all the structural elements are compatible with each other which main the all elements of structure are connected with other . This can be achieved and improved by noticing and analyzing the deformed shape animation of the structure model from Etabs. By start animation for the modal and display the deformed shape we notice that all the structural elements are compatible with each other's. The value of factor (T =1.7 s) is within the acceptable range which mean that our structure is OK .

The following figure explain the compatibility check

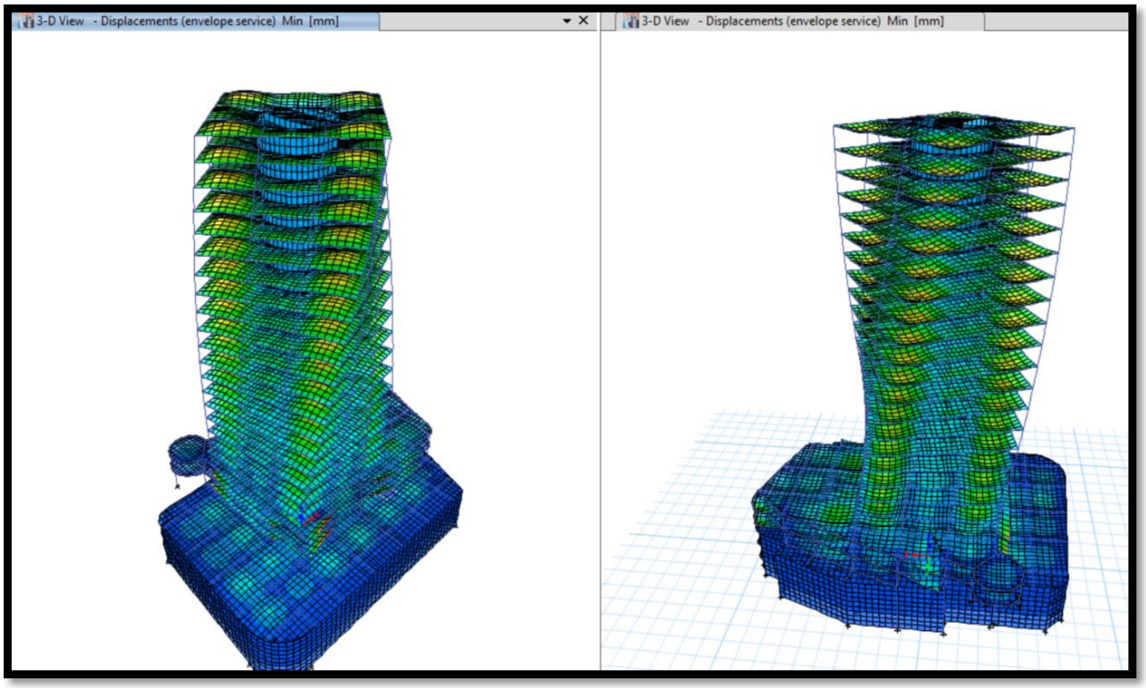


Figure 140 : compatibility check

- **Equilibrium check:**

It's the second main check in this check we compare between the ETABS results that concerning with the dead ,live and SID load of the building with manual calculation with accepted percentage error less or equal than 5%, in this check we insure that the load put on the modal is correct.

Equilibrium from live load:-

Total area of the building = 19603.2m2.

- Manual solution for building :

Total live load = {(live load/m2) * (Area)}

- By using excel sheets

G	F	E	D	C	B	A	
	live load	live		Area	floor		4
	10605.75	5		2121.15	1		5
	10605.75	5		2121.15	2		6
	10853.09	5		2170.618	3		7
	6681.932	5		1336.386	4		8
	5968.136	5		1193.627	5		9
	1683.201	3		561.067	6		10
	1683.201	3		561.067	7		11
	1683.201	3		561.067	8		12
	1683.201	3		561.067	9		13
	1683.201	3		561.067	10		14
	1683.201	3		561.067	11		15
	1683.201	3		561.067	12		16
	1683.201	3		561.067	13		17
	1683.201	3		561.067	14		18
	1683.201	3		561.067	15		19
	1683.201	3		561.067	16		20
	1683.201	3		561.067	17		21
	1683.201	3		561.067	18		22
	1683.201	3		561.067	19		23
	1683.201	3		561.067	20		24
	1683.201	3		561.067	21		25
	1683.201	3		561.067	22		26
	1683.201	3		561.067	23		27
	1683.201	3		561.067	24		28
	76695.48			19603.2			29
							30
							31

Figure 141 : total live load by hand

- Total Live load by hand = 76695.48 KN
- Total Live load from Etabs = 76516.55 KN

Load Case/Combo	FX kN	FY kN	FZ kN
Dead	-0.0246	0.0942	280594.5238
Live	0.0099	0.017	76516.556
SID	0.0073	0.0199	72471.9021

Figure 142 : Total live load from ETABS

✓ % Error = $\frac{76695.48-76516.55}{76695.48} * 100\% = 0.233\% < 5\%$ **Check is OK**

Equilibrium from SID :-

Total area of the building = 19603.2m2.

- Manual solution for building :

Total SID load = {(live load/m2) * (Area)}+(parameter * SID/m)

- By using excel sheets

R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B
SID tot			P*SID	SID	prameter	floor				A total * 3				SID	Area	floor
14122.68			0	0	0	1								3	2121.15	1
			0	0	0	2				58809.614				3	2121.15	2
			0	0	0	3								3	2170.618	3
			3927.94	23	170.78	4								3	1336.386	4
			3927.94	23	170.78	5								3	1193.627	5
			301.2	3	100.4	6								3	561.067	6
			301.2	3	100.4	7								3	561.067	7
			301.2	3	100.4	8								3	561.067	8
			301.2	3	100.4	9								3	561.067	9
			301.2	3	100.4	10								3	561.067	10
			301.2	3	100.4	11								3	561.067	11
			301.2	3	100.4	12				total for two				3	561.067	12
			301.2	3	100.4	13				72932.294				3	561.067	13
			301.2	3	100.4	14								3	561.067	14
			301.2	3	100.4	15								3	561.067	15
			301.2	3	100.4	16								3	561.067	16
			301.2	3	100.4	17								3	561.067	17
			301.2	3	100.4	18								3	561.067	18
			301.2	3	100.4	19								3	561.067	19
			301.2	3	100.4	20								3	561.067	20
			301.2	3	100.4	21								3	561.067	21
			301.2	3	100.4	22								3	561.067	22
			301.2	3	100.4	23								3	561.067	23
			301.2	3	100.4	24								3	561.067	24
			544	17	32	ramp									19603.2	

Figure 143 : total SID load by hand

- Total SID load by hand = 72932.29 KN
- Total SID load from Etabs = 72471.9 KN

Load Case/Combo	FX kN	FY kN	FZ kN
Dead	-0.0246	0.0942	280594.5238
Live	0.0099	0.017	76516.556
SID	0.0073	0.0199	72471.9021

Figure 144 : Total SID load from ETABS

✓ % Error = $\frac{72932.29-72471.9}{72932.29} * 100\% = 0.63\% < 5\%$ **Check is OK**

Equilibrium from dead load:-

Manual solution for all building :

	by hand:		16
			17
type	floor	dead	18
O.W slab	6 to 19	65241.2	19
O.W slab	4	7304.9	20
O.W slab	5	8178.6	21
O.W slab	1	13284	22
O.W slab	2+3	12981.4	23
main beam	24	1041	24
main beam	23	1041.78	25
main beam	22	1045.45	26
main beam	21	1046.21	27
main beam	20	1045.73	28
main beam	19	1044.47	29
main beam	18	1037.57	30
main beam	17	1038.35	31
main beam	16	1037.57	32
main beam	15	1040.51	33
main beam	14	1039.91	34
main beam	13	1039.19	35
main beam	12	1038.89	36
main beam	11	1039.25	37
main beam	10	1038.29	38
main beam	9	1039.91	39
main beam	8	1039.61	40
main beam	7	1039	41
main beam	6	1039	42
main beam	5	2450	43
secondary beam	5	427.2	44
main and secondary	4	2889.46	45
main beam	1+2+3	9399.72	46
shear wall	1to 3	19635	47
core shear	1 to 24	80525.7	48

G1 D500	parking	1236.37	49
G2 D1200	parking	3560.76	50
G3 D500	commercial	583.8	51
G4 D1200	commercial	2373.8	52
G5 D1200	offices	1186.92	53
G6 D 1200	offices	7293.66	54
G7 D 1200	offices	14435.52	55
			56
		272759.7	57
			58
			59

Figure 145 : Hand calculation for the daed load

Total weight from manual calculation = 272759.7 kN

➢ Total weight from Etab = 280594.5 kN.

	Load Case/Combo	FX kN	FY kN	FZ kN
▶	Dead	-0.0246	0.0942	280594.5238
	Live	0.0099	0.017	76516.556

Figure 146 : Total dead load from Etabs

✓ % Error = $\frac{280594.5-272759.7}{280594.5} * 100\% = 2.79\ \% < 5\%$ **Check is OK**

Internal forces check (Stress – Strain Relationship) :

This check shows comparisons between internal forces results(moment ,axial,shear...etc)from ETABS analysis and hand result.

- **Axial check for columns:**

This check was carried out for five columns have been selected randomly, the table below show comparison between the Etabs result and hand result.

Table 27 : percent of error in column axial force

Column	Manual result(KN)	Etab result (KN)	% Error
Column (floor 24)(corner)	502.26	510.59	1.63 <10 ok
Column (floor 24)(edge)	756.85	705	6.85 <10 ok
Column (floor 11)(corner)	7031.64	7161	1.8 <10 ok
Column (floor 11)(edge)	10595.9	9715.6	9 <10 ok
Column (floor 1)(interior)	19164.4	20074.2	4.5 <10 ok

Sample calculation:

- **Manual : Column (floor 11)(corner)**

load on the column:

-live = (17.5*3) = 52.5 KN

- SID = (17.5*3) = 52.5 KN

- Dead load from slab = (17.5* 6.12) = 107.1KN

- weight of beam = (4.18*0.7*0.6*25*2) = 87.78 KN

- weight of column = (3.58*3.14*0.6^2*25) = 101.17 KN

Ultimate load on the column:

Pu(hand) = 1.2(52.5+107.1+87.78+101.17) +1.6(52.5)= 502.26*14 = 7031.64 KN

Pu (Etab) = 7161 KN

✓ % Error = $\frac{7161-7031.64}{7161} * 100\% = 1.8\ \% < 10\%$ **Check is OK**

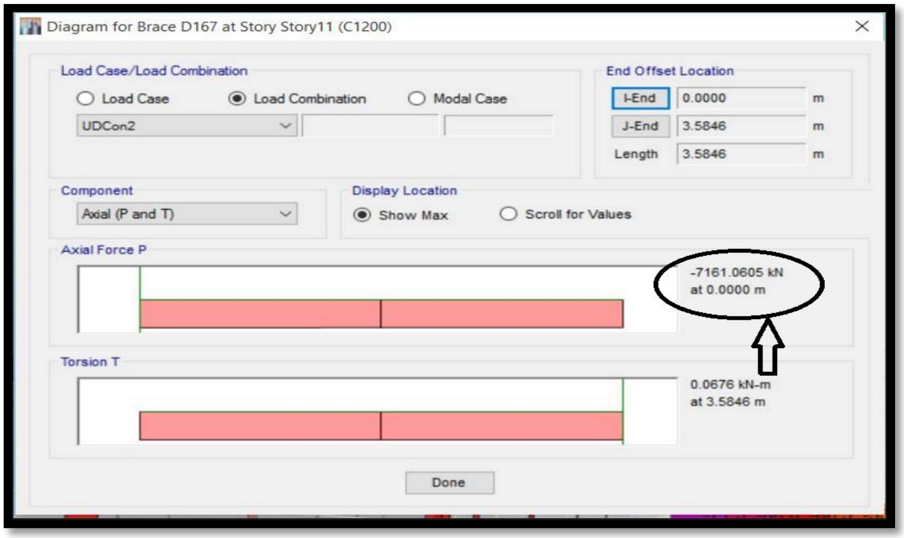


Figure 147 : column axial forces from ETAB

- **Check For beams :**

This check shows comparisons between internal forces results(moment) from ETABS analysis and hand result . This check was carried out for four beam have been selected randomly, the table below show comparison between the Etabs result and hand result.

Table 28 : percent of error in the result

Beam	Location	Manual Moment	Etab Moment	% Error
Beam	Floor 24	397.5	400.72	0.8 < 10 ok
Beam	Floor 4	706.96	640.36	9.4 < 10 ok
Beam	Floor 2	477.6	433.5	9.2 < 10 ok
Beam	Floor 6	642.36	616.4	4 < 10 ok

Sample calculation:

- **Manual :beam (floor 4)**

load on the beam :

- Trebutary Area = 32 m^2
-live = (32*5) = 160 KN
- SID = (32*3) = 96 KN
- Dead load from slab = (32* 6.12) = 195.84 KN
- weight of beam = (8*0.7*0.6*25*) = 84 KN

Ultimate load on the beam :

Pu(hand) = 1.2(96+84+195.84) +1.6(160)= 707 KN

Wu = Pu/L = 707/8 = 88.37 KN/m

Mu(hand) = $\frac{Wu*L^2}{8} = \frac{88.37*8^2}{8} = 706.96\ KN.m$

Mu (Etab) = $\left(\frac{M1+M2}{2}\right) + M3 = \frac{373.53+314.2}{2} + 296.5 = 640.36\ KN.m$

✓ % Error = $\frac{706.9-640.36}{706.9} * 100\% = 9.4\ \% < 10\%$ **Check is OK**

Figure 148 : Ultimate moments from ETABS

- **Check For slabs:**

This check was carried out for three slab have been selected randomly, the table below show comparison between the Etabs result and hand result.

Table 29 : percent of error in check rib result

Slab	Location	Manual Moment KN.m/rib	Etab Moment KN.m/rib	% Error
Slab 1	Floor 24	62.45	43.67	30
Slab 2	Floor 5	69.8	48.6	30
Slab 3	Floor 4	62.45	48.73	22

✓ Sample calculation:

Manual:

Dead load =3.36 KN/rib.

Super imposed = 1.65 KN/rib .

Live load = 1.65 KN/rib.

Length of rib = 7.6 m.

The ultimate load on the rib = 1.2(3.36+1.65) + 1.6*1.65 = 8.65 KN/rib.

Mu(hand) = $\frac{Wu*L^2}{8} = \frac{8.65*7.6^2}{8} = \mathbf{62.45}\ \boldsymbol{KN}$**/m.rib**

From **Etab**:

M1 = 18.7 KN.m/m.

M3 = 48.2 KN.m/m.

M2 = 44.1 KN.m/m.

Mu (Etab) = $\left(\frac{M1+M2}{2}\right) + M3 = \frac{18.7+44.1}{2} + 48.2 = 79.4 KN.m/m$ = 43.67 KN/m.rib

✓ % Error = $\frac{62.45-43.67}{62.45} * 100\% = 30\ \%$

- Note : the result of hand more than the result from Etab because the load transfer in the opposite direction .

3.3.3. Dynamic Analysis (Response spectrum analysis):

using Response spectrum analysis on the building perform the dynamic analysis , UBC97 design code was used in these stage .

3.3.3.1. Dynamic data input

- The following parameters are required to perform the dynamic analysis:
  - 1. Importance factor: I =1 .
  - 2. Peak Ground Acceleration (PGA): the value of (Z) = Rock acceleration/g, since the

3.3.3.2.Earthquake data input

- building is located in Nablus city according to Palestine seismic map Zone is 2B with Z= 0.2 .
- Soil profiles in the project (SD) & the soil stiff.
- Seismic coefficient (Cv) = 0.4.
- Seismic coefficient (Ca) = 0.28.
- The structural system to be designed is assumed to be Sway Intermediate.
- Response modification factor (R) = 5.5 .

3.3.3.3. Dynamic check

- **Check Dynamic Analysis Results (Response spectrum analysis):**

  In order to make the results correct, the base shear from response spectrum function have to be made close to the base shear from the equivalent static method (manual).

- **Period:**

We have to calculate the period manually and compare it with Etabs results.

Calculate the period for the building (**Manually**):

T=$Ct * hn^{3/4}$

Where:

- Ct = 0.0488 When unit in m , for the building that classified as **others building** in UPC97

- hn= Total height of the building = 84 m.

Tb=$0.0488 * 84^{3/4}$ = 1.354 second .

T (allowable) = 1.4 * Tb = 1.4 * 1.354 = 1.895 second

- **The period from Etabs in y and x direction :**

Ty = 1.7 second < 1.895 second (OK)
Tx = 1.57 second < 1.895 second (OK)

Modal Participating Mass Ratios | Modal Participating Mass Ratios

1 من ٢٠ Reload Apply

	Case	Mode	Period sec	UX	UY
▸	Modal	1	1.7	0.0096	0.4659
	Modal	2	1.573	0.465	0.0098

Figure 149 : period from ETab in X and Y direction

- **Manual Base shear (V) :**

Weight of the building(W) = dead load+ SID load+ 0.25 live load
W = 280594 + 72472 +(0.25*76516.5) = 372195.1 KN

$$\text{Base shear (V)} = Min \begin{cases} \dfrac{2.5*Ca*I*w}{R} \\ \dfrac{Cv*I*w}{RT} \end{cases} = Min \begin{cases} \dfrac{2.5*0.28*1*372195.1}{5.5} \\ \dfrac{0.4*1*372195.1}{5.5*1.354} \end{cases}$$

$$\text{Base shear (V)} = Min \begin{cases} 47370.3 \\ 19991.7 \end{cases} = 19991.7 \text{ KN}$$

	Load Case/Combo	FX kN	FY kN	FZ kN
▸	Dead	-0.0355	0.0043	280593.9722
	Live	-0.0127	0.0014	76516.4619
	SID	-0.0157	0.0018	72471.803

Figure 150 : load cases used for calculating base shear (V)

- **Base shear from ETABS (V) :**

	Load Case/Combo	FX kN	FY kN	FZ kN
▸	Dead	-0.0355	0.0043	280593.9722
	Live	-0.0127	0.0014	76516.4619
	SID	-0.0157	0.0018	72471.803
	EQx Max	20631.4372	6630.4953	[illegible]
	EQy Max	6561.0485	20392.48	[illegible]

Figure 151 : Base shear From ETABS

In X-direction :

EQx (ETAB)max = 20631.4 KN > 19991.7 KN **OK** .
EQy (ETAB) = 6630.49 KN > 0.3 * 19991.7 KN **OK** .

In Y-direction :

EQx (ETAB) = 6561 KN > 0.3 * 19991.7 KN **OK** .
EQy (ETAB)max = 20392.48 KN > 19991.7 KN **OK** .

check for Modal participating Mass ratio :

Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	UZ	Sum UX	Sum UY	Sum UZ
Modal	23	0.064	0.0298	0.0224	0	0.9115	0.9291	0
Modal	24	0.062	0.0097	0.0061	0	0.9212	0.9352	0
Modal	25	0.059	0.0003	0.0013	0	0.9215	0.9365	0
Modal	26	0.059	4.398E-06	0.0004	0	0.9215	0.9369	0

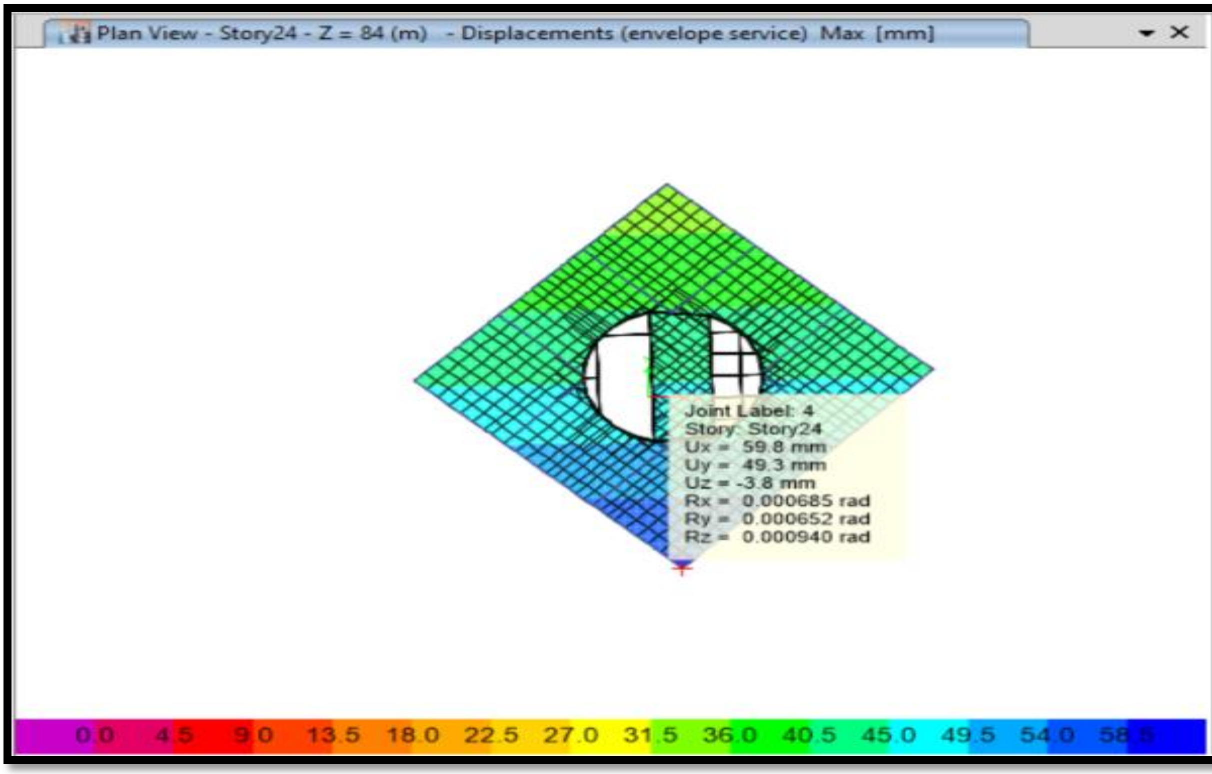
Figure 152 : result of Modal participating Mass ratio

The check for Modal participating Mass ratio is larger than 90% in X, Y direction after 23 mode , **so The model is ok.**

- **Drift check :**

In X-direction :

The result below show the displacement for the last floor which is the critical floor.



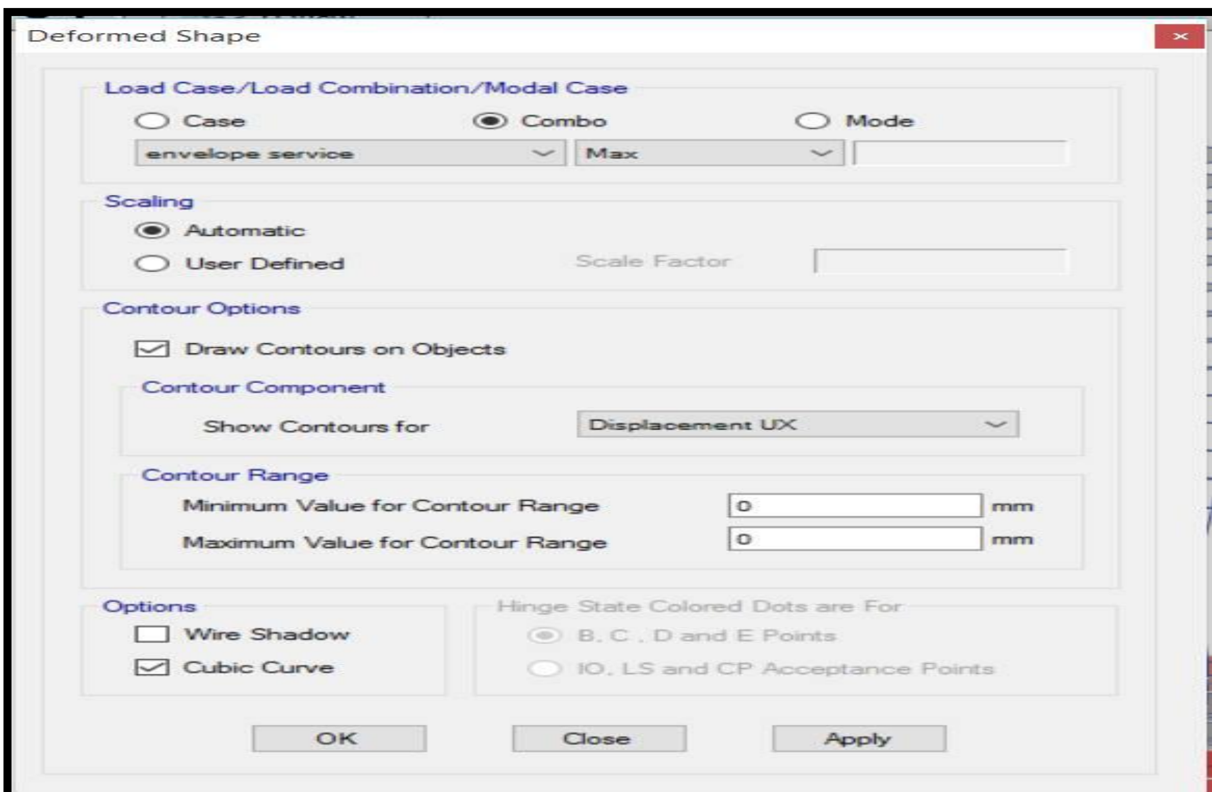


Figure 153 : displacement(top) for the last floor in X- direction

avg displacement (Top) in x- direction = $\frac{59.8+54+49.4+44.5}{4} = 51.9\ mm$

avg displacement (bottom) in x- direction = $\frac{57.4+51.3+46.6+41.6}{4} = 49.2\ mm$

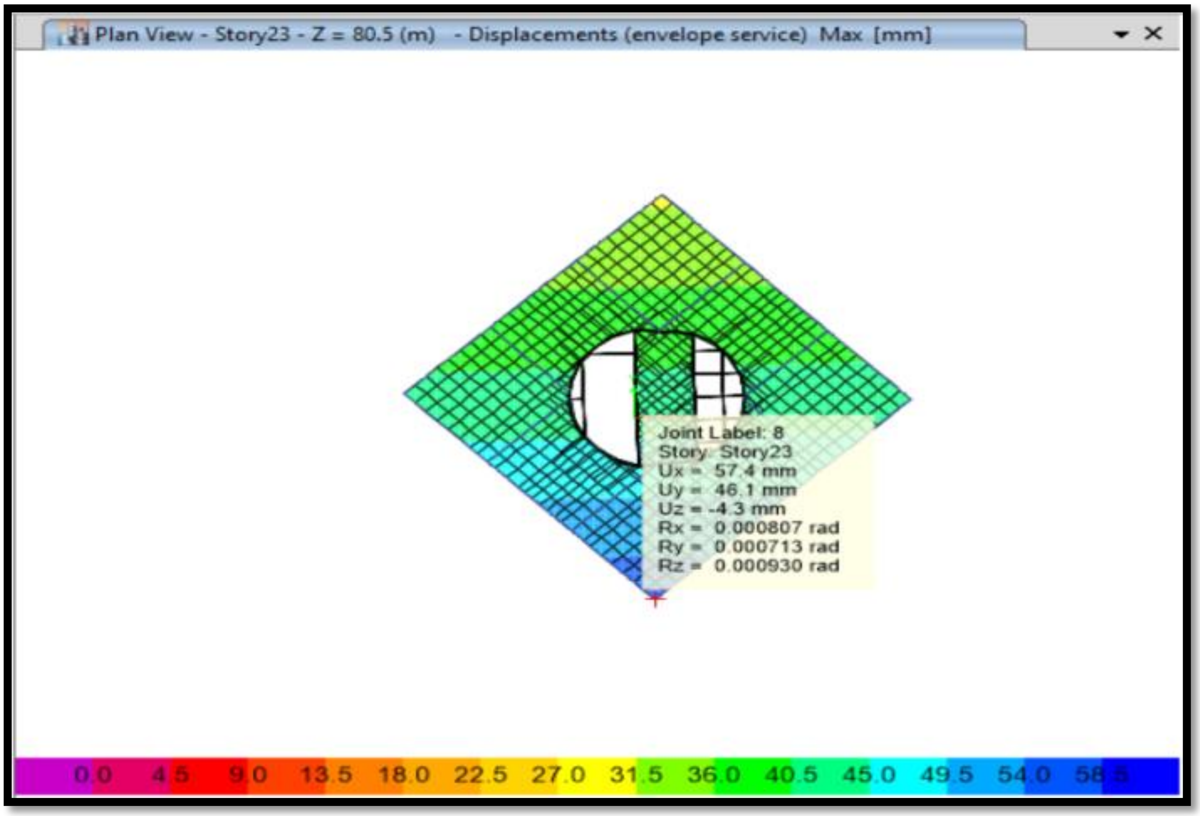


Figure 154 : displacement(bottom) for the last floor in X- direction

The differenace in displacement (Δx) = 51.9 − 49.2 = 2.7 mm

ΔM= 0.7*R*Δx = 0.7* 5.5 * 2.7 = 10.4 mm

Since T> 0.7

Drift allowable = 2% * H = 2% * 3500 = 70 mm > 10.7 **OK**

Where :

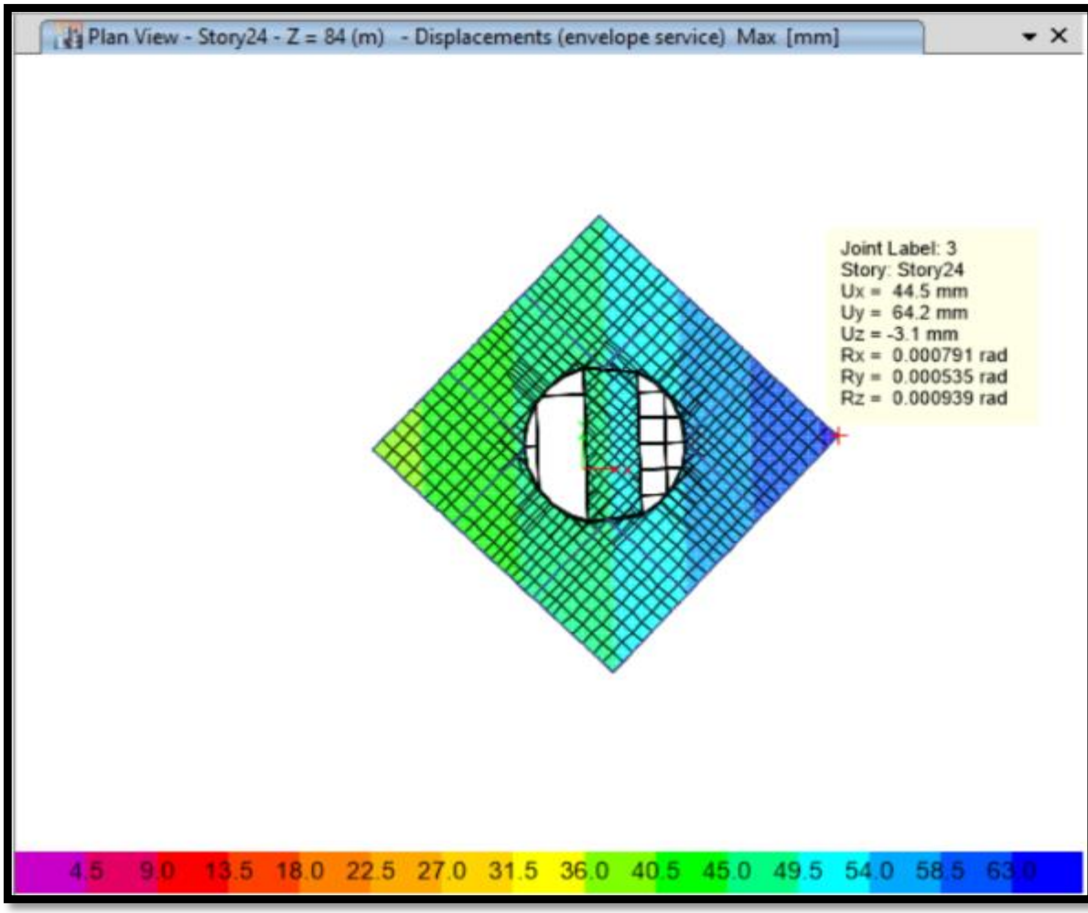
H: height of floor .

Δx: displacement in x .

R: response modification factor.

In Y-direction :

The result below show the displacement for the last floor which is the critical floor.



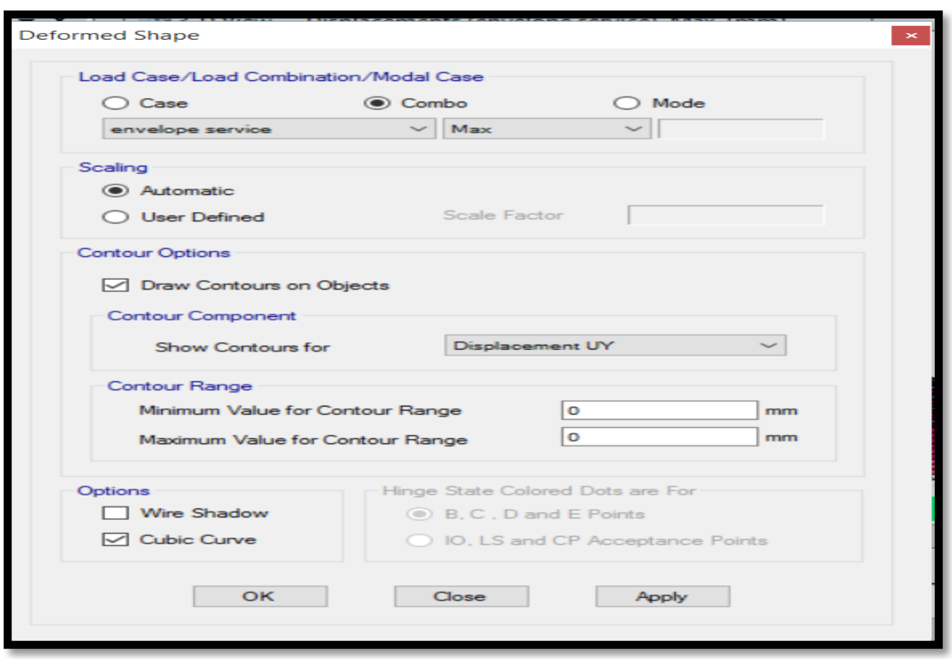


Figure 155 : displacement(top) for the last floor in Y- direction

avg displacement (Top) in y- direction = $\frac{64.2+59.1+54.1+49.3}{4} = 55.92\ mm$

avg displacement (bottom) in y- direction = $\frac{61.4+56.5+51.8+47.1}{4} = 54.2\ mm$

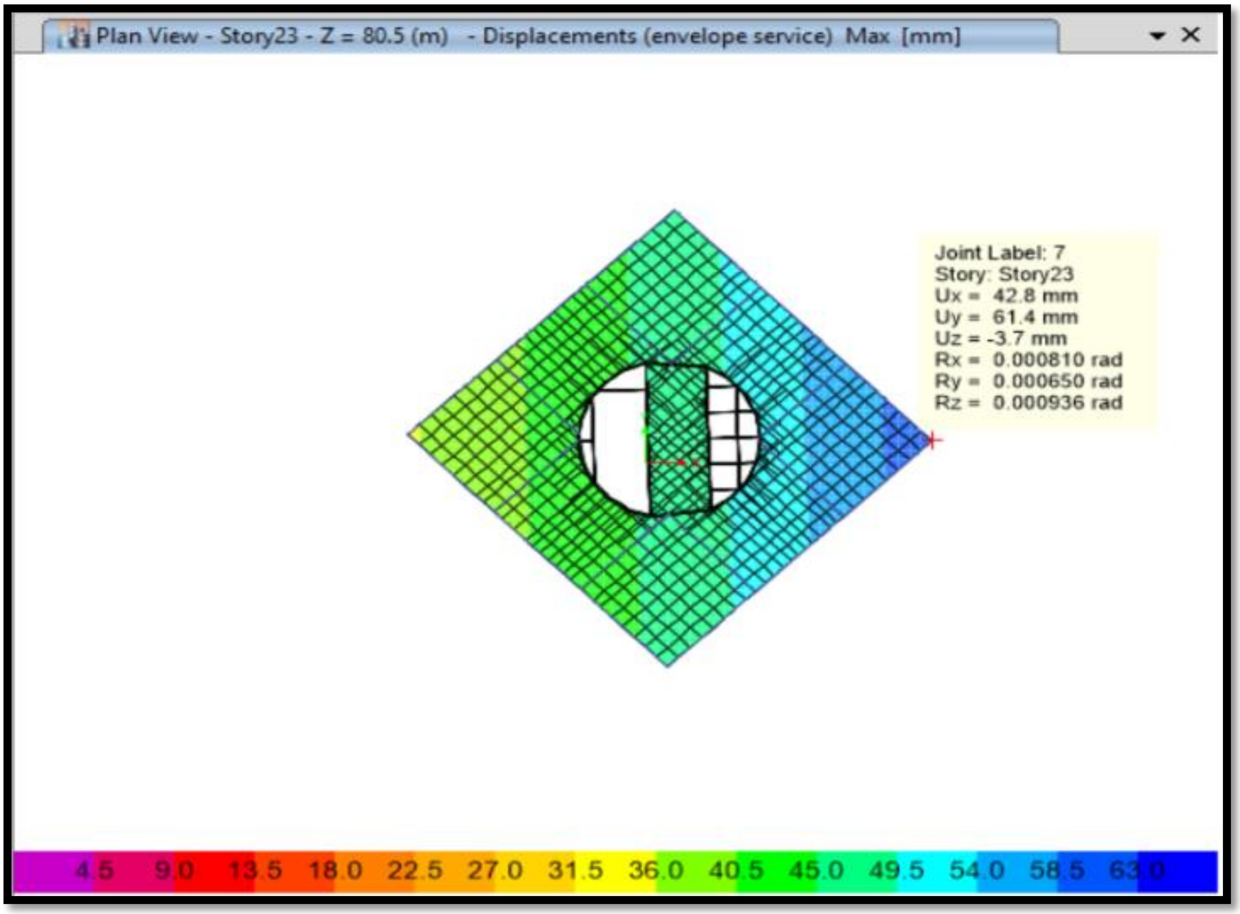


Figure 156 : displacement(bottom) for the last floor in Y- direction

The differenace in displacement (Δy) = $55.92 - 54.2$ = 1.72 mm

dM= 0.7*R*Δy = 0.7* 5.5 * 1.72 = 6.62 mm

Since T> 0.7

Drift allowable = 2% * H = 2% * 3500 = 70 mm > 6.62 **OK**

Where :

H: height of floor .

Δy: displacement in y .

R: response modification factor

- **Deflection check for slab :**

The result below show the displacement for the last slab floor which is the critical floor.

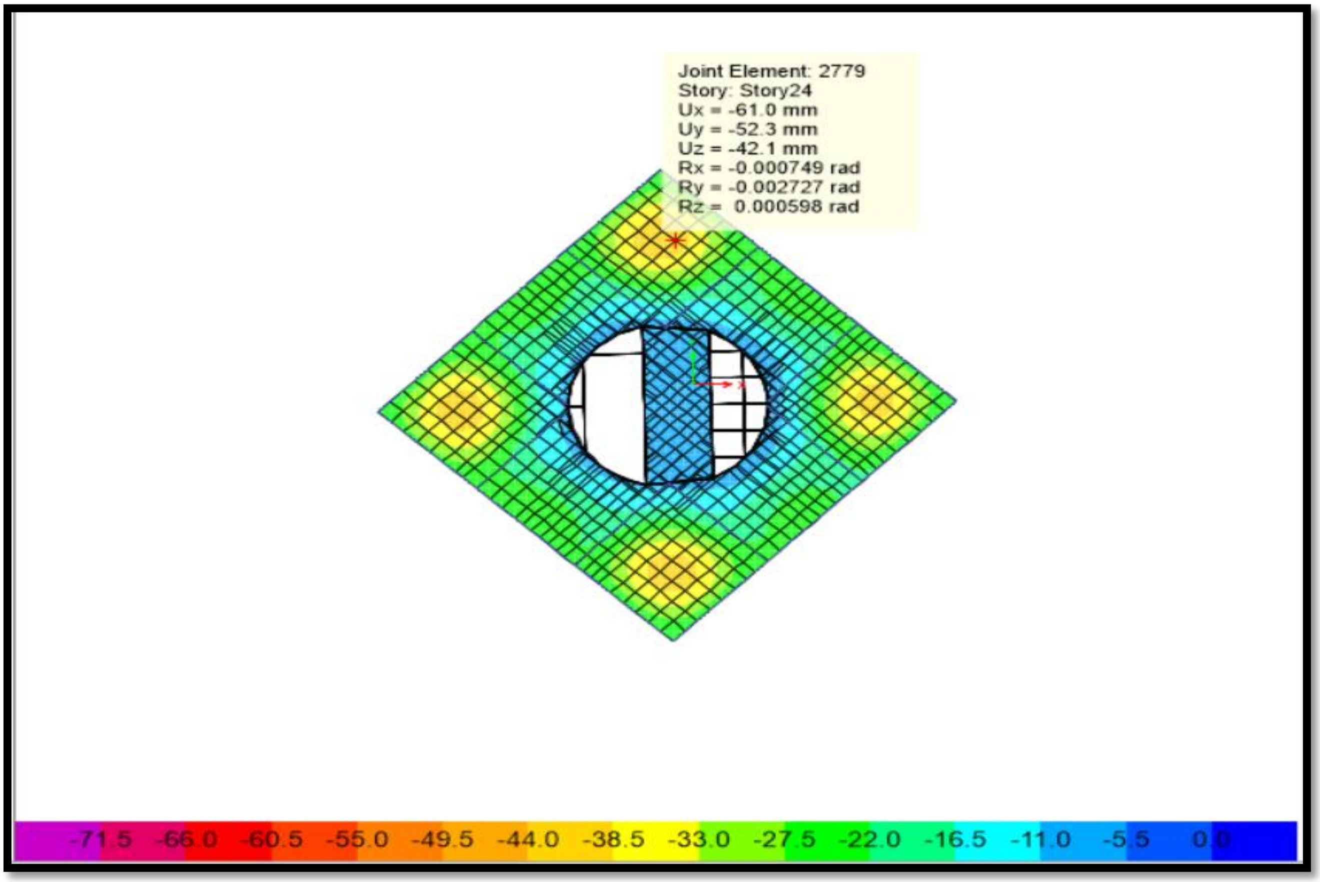


Figure 157 : displacement in mid span for the last slab floor

Deflection = $\Delta z3 - \left(\frac{\Delta z1+\Delta z2}{2}\right) = 42.1 - \frac{24.3+27.1}{2} = 16.4\ mm$

Deflection allowable = $\frac{L}{240} = \frac{8000}{240} = 33.3\ mm > 16.4\ \ \boldsymbol{OK}$

Where :

-$\Delta z1$: displacement in end span .

-$\Delta z2$: displacement in opposite end span.

-$\Delta z3$: displacement in mid span .

3.3.4. Design

3.3.4.1.Slab design

Check shear for slab: to insure that the thickness of slab is sufficient to resist the shear force and the slab doesn't need for shear reinforcement.

The figures below show which floors have the critical shear forces in the structure .

- **In direction 1-1 (V13)**

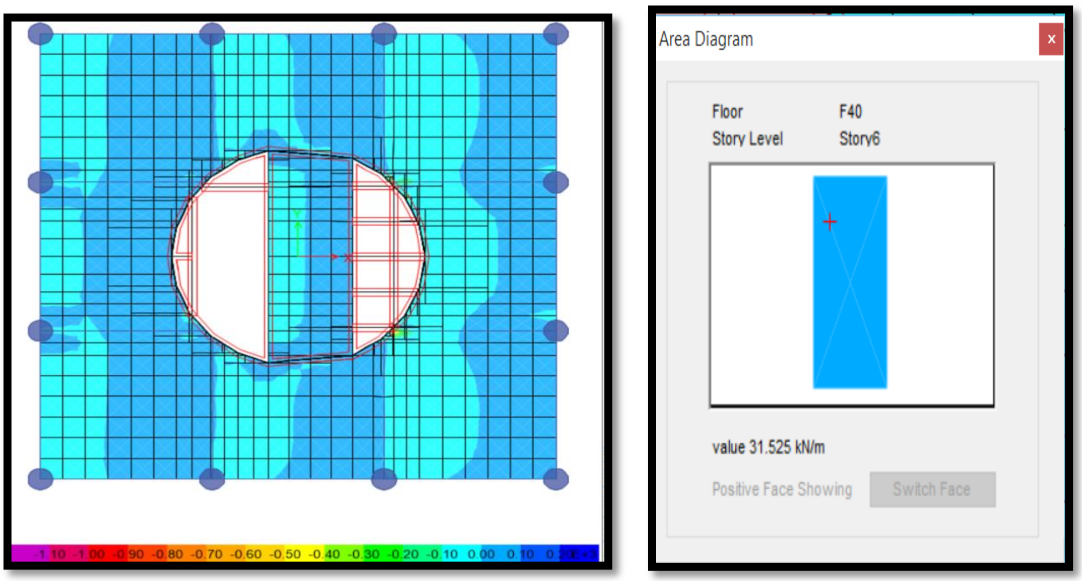
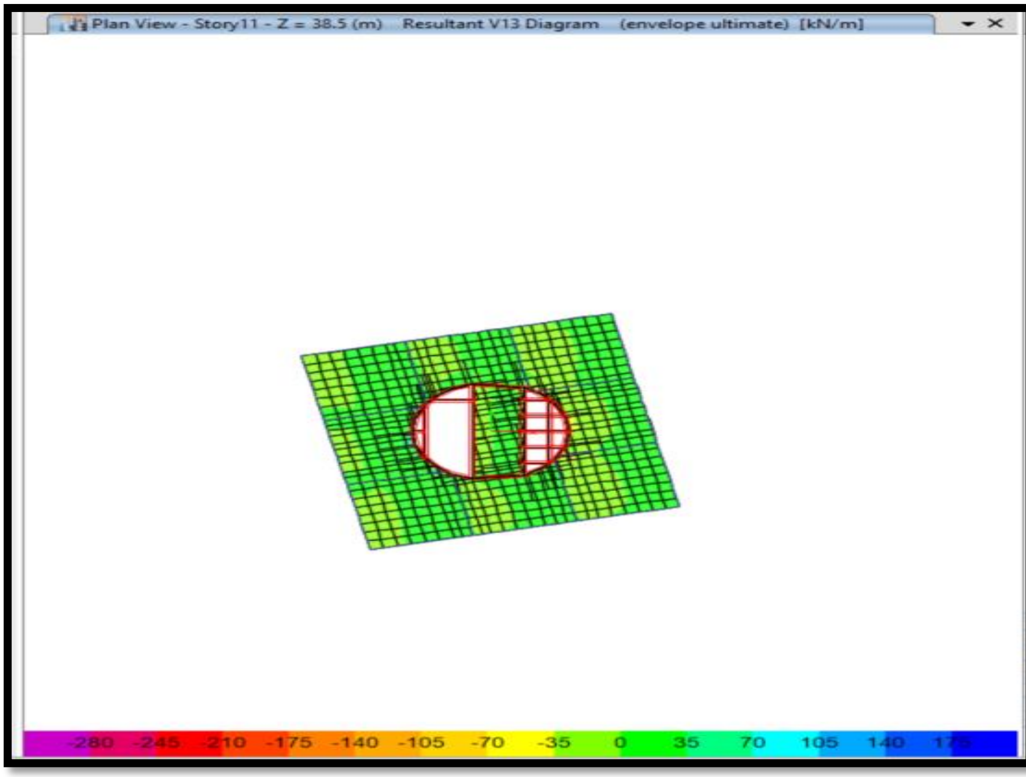


Figure 158 : Max shear force (V13) in floor 1



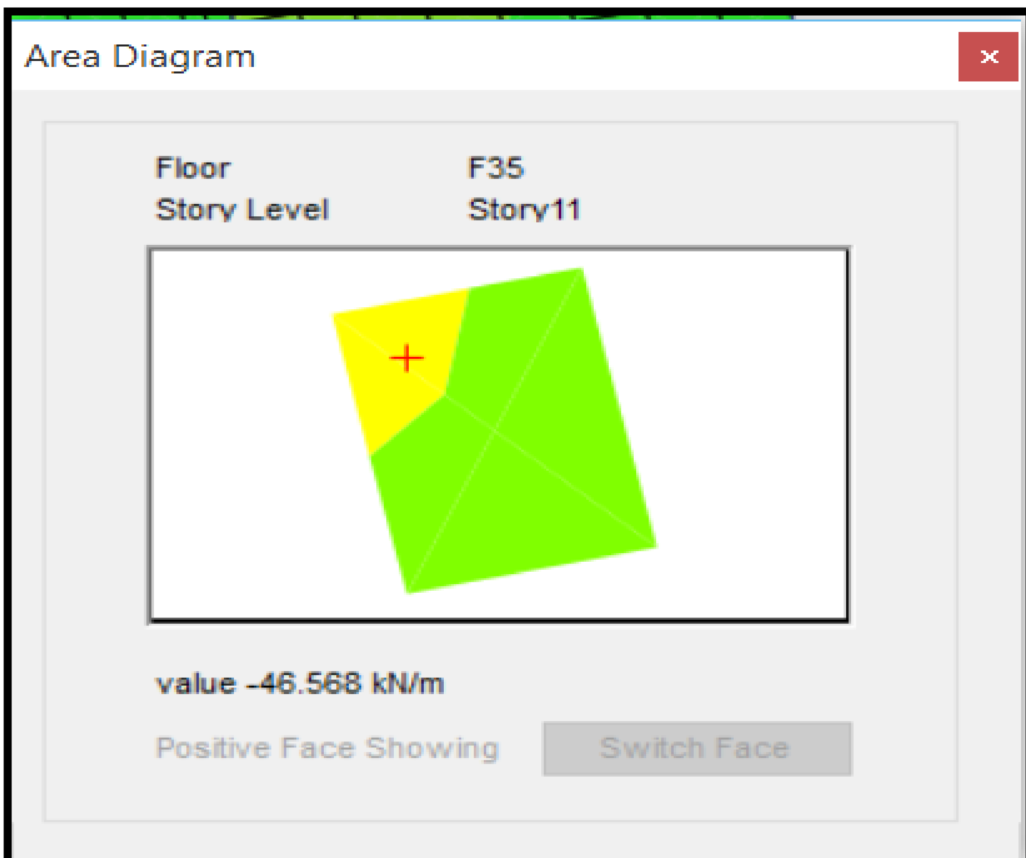


Figure 159 : Max shear force (V13) in floor

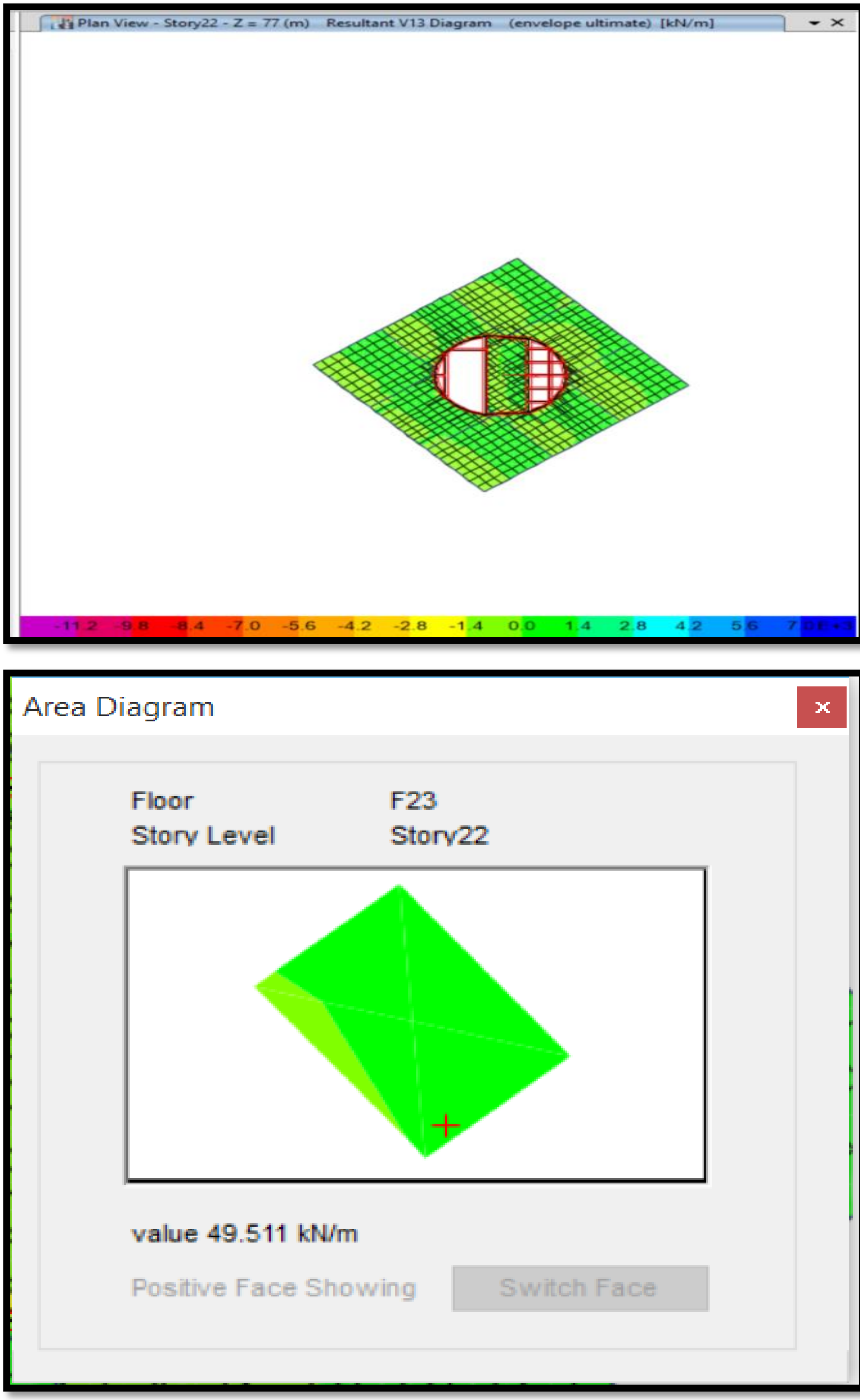


Figure 160 : Max shear force (V13) in floor 17

- **The maximum shear force(critical):**

Vu at d 49 kN/ m.
Vu at d = 49*0.55 = 26.9 kN/ m.rib

$\text{ØVc} = \text{Ø} * \frac{1}{6} * \sqrt{\text{fc}'} * \text{bw} * \text{d}$

$ØV_c$ = $\frac{0.75}{6}\sqrt{28}$ *****150*260*1.1 **= 28.4 KN/m.rib**

Vu ≤ ØVc   **Check ok …no need for shear reinforcement.**

- **Design for flexural reinforcement:**

flexural reinforcement for Slab was done through assuming that there is a minimum reinforcement in the rib which is:

As min = 0,0033 * bw * d = 0.0033*150* 260 = 129 mm^2 Use (2Ø10 mm/rib)

As (2Ø10 mm) = 157 mm^2

- ✓ This area of steel can carry Moment which is :

ØMn= 0.9 * As * Fy *(d-$\frac{As*\text{Fy}}{1.7*fc*bw}$) *$10^{-6}$

ØMn= 0.9 * 157* 420 *(260-$\frac{157*420}{1.7*28*150}$) *$10^{-6}$ = 14,88 KN.m/rib = 27KN.m/m

- **bottom reinforcement:**

✓ By showing the slab moment that lies between (-27, 27), it’s clear that most of the slab areas need a minimum bottom reinforcement of 2Ø10 mm/rib.

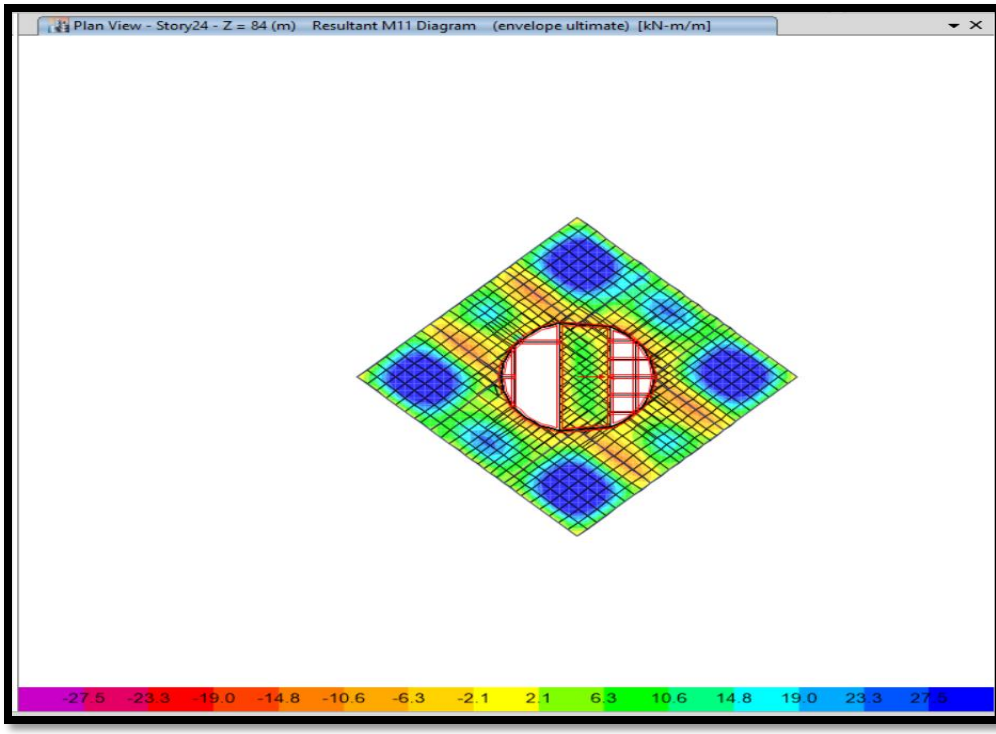


Figure 161 : Ultimate moment on the slab (-27- 27KN.m/m)

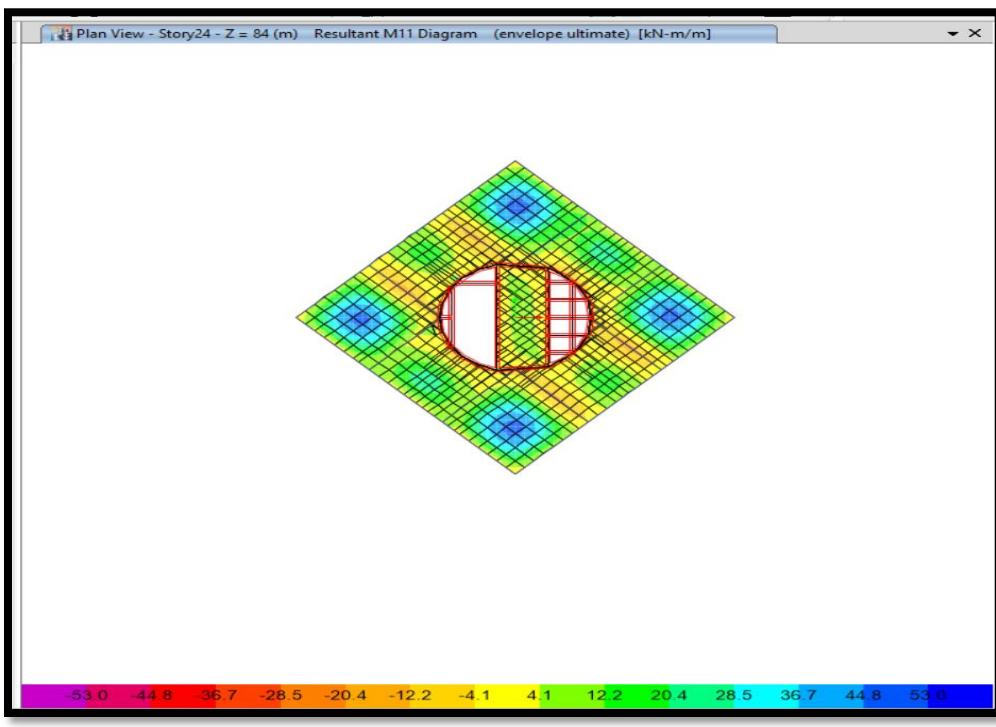


Figure 162 : Ultimate moment on the slab (-53- 53 KN.m/m)

➢ All other areas that is not lies in the range (-27, 27), have a moment less than 53 KN.m/m, which need a reinforcement of 2Ø14 mm/rib.

➢ **top reinforcement:**

the same for bottom reinforcement.

✓ By showing the slab moment that lies between (-27, 27), it's clear that most of the slab areas need a minimum bottom reinforcement of 2Ø10 mm/rib.

➢ All other areas that is not lies in the range (-27, 27), have a moment less than 53 KN.m/m, which need a reinforcement of 2Ø14 mm/rib.

➢ **Shrinkage steel:**

As = 0.0018* b* h= 0.0018*1000*100 = 180 mm2/m

Use (1Ø8mm)/25cm in both direction.

➢ **Diaghragms steel (Tension steel)** :

the avg tensile force equal = 35 KN/m

AS = T/0.9*Fy = 35*1*1000 / 0.9*420 = 92 mm2

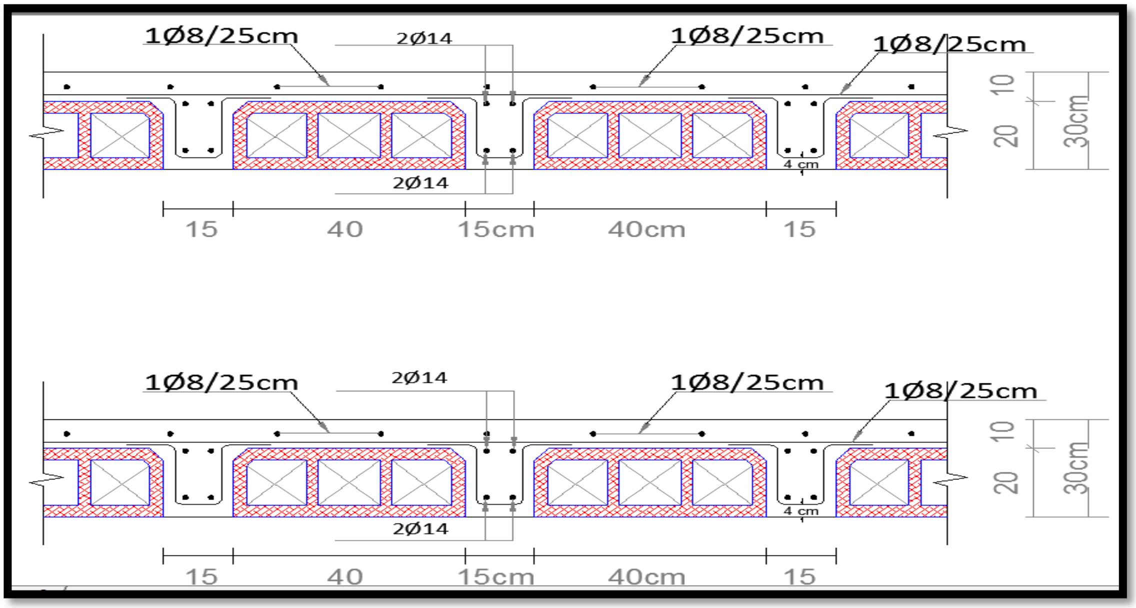


Figure 163 : Slab Reinforcement

➢ **In direction 2-2 (V23)**

Check of shear :

The same of direction 1-1 .

Reinforcement :

The same of direction 1-1 .

3.3.4.2.beam design

the figure's below show The longitudinal reinforcement and shear reinforcement for floor 24 were obtained from ETABS.

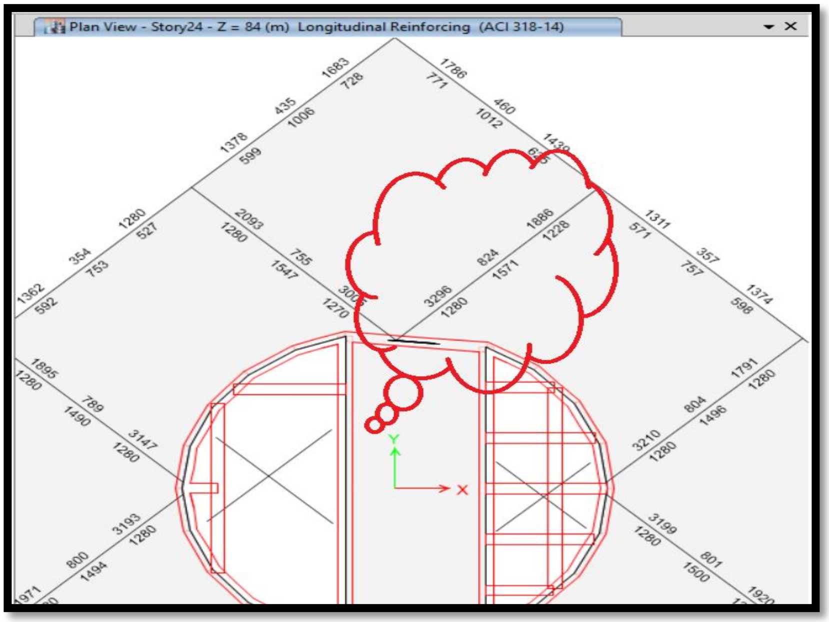


Figure 164 : Beam longitudinal reinforcement (floor 19)

Beam Element Details (Summary)

Level	Element	Section ID	Combo ID	Station Loc	Length (mm)	LLRF	Type
Story24	B468	B 700 *600	UDCon3	0	8418.1	0.781	Sway Intermediate

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
600	700	600	0	60	60

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
24870	27.58	1	413.69	413.69

Design Code Parameters

Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}
0.9	0.65	0.75	0.75	0.6	0.85

Design Moment and Flexural Reinforcement for Moment, M_{u3}

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm²	+Moment Rebar mm²	Minimum Rebar mm²	Required Rebar mm²
Top (+2 Axis)	-725.8026		3296	0	1280	3296
Bottom (-2 Axis)		241.9342	0	1040	1280	1280

Shear Force and Reinforcement for Shear, V_{u2}

Shear V_{u2} kN	Shear ΦV_c kN	Shear ΦV_s kN	Shear V_p kN	Rebar A_v/S mm²/m
359.0112	251.1722	107.839	120.8952	543.08

Torsion Force and Torsion Reinforcement for Torsion, T_u

Φ*T_u kN-m	Tth kN-m	Tcr kN-m	Area A_o cm²	Perimeter, p_h mm	Rebar A_t/s mm²/m	Rebar A_l mm²
1.0607	25.2957	101.1827	2654.8	2244.4	0	0

Figure 165 : Beam shear reinforcement.

From the result of reinforcement above

Flextural reinforcement

Top steel use (7 Ø 25 mm)

Bottom steel (7 Ø16)

Shear reinforcement

Use 1 Ø10 / 250 mm

NOTE: See attached AUTOCAD sheets that shows more details for beams .

3.3.4.3.column design

Design of column have been done according to Etabs results, the longitudinal rebar percentage (1%)

The longitudinal rebar percentage for column → dimension (D1200)

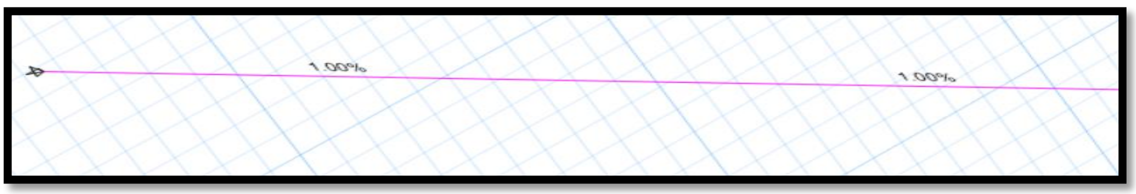


Figure 166 : rebar percentage for column

Using As = ρ * Ag

Where:

As = area of steel.

ρ = rebar percentage.

Ag = area gross for section

- ✓ As = 0.01*3.148* 600^2= 11304 mm2.

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

Assume we want to use (Ø 25 mm) bars.

Area for each Bar = 491mm2.

11304/491= 23 bars . >>> Use 23 Ø 25 mm.

Stirrups reinforcement :

Vu ≤ ØVc

Use (1Ø 10 mm)/250 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

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

Figure 167 : Spacing between stirrups in column

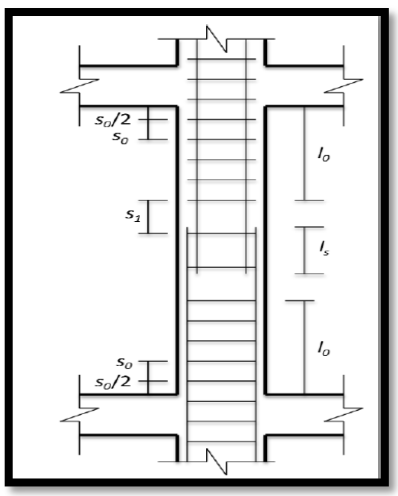


Figure 168 : stirrups detailing in column

NOTE: See attached AUTOCAD sheets that shows more details for columns.

3.3.4.4. Shear wall design

In the project there are more than shear wall

The outer shear wall

For the outer shear wall which the **thikness** is **0.4 m** and the **length** is ***187m*** .

And it rotate around all building.

✓ The outer shear wall is exsposed to latral force by soil :

Where :

H : height of wall = 1.5 m

K : Coefficient of lateral earth pressure = 0.333

γs: soil coefficient = 18 KN/m^3.

: Internal friction angle = 30

q: pressure = γs * H * K

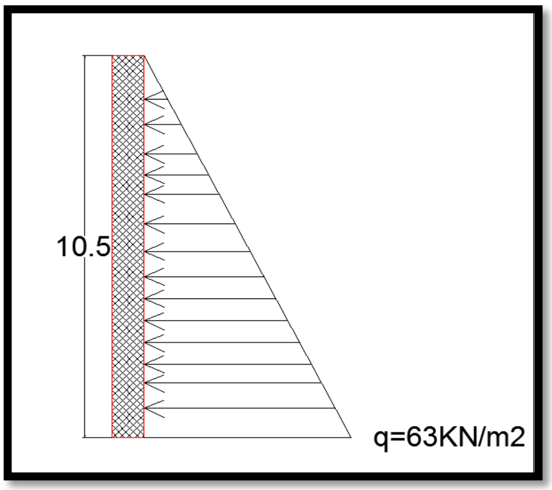


Figure 169 : Soil pressure

➢ from Etabs we get:

the result for the shear wall shown in figure below

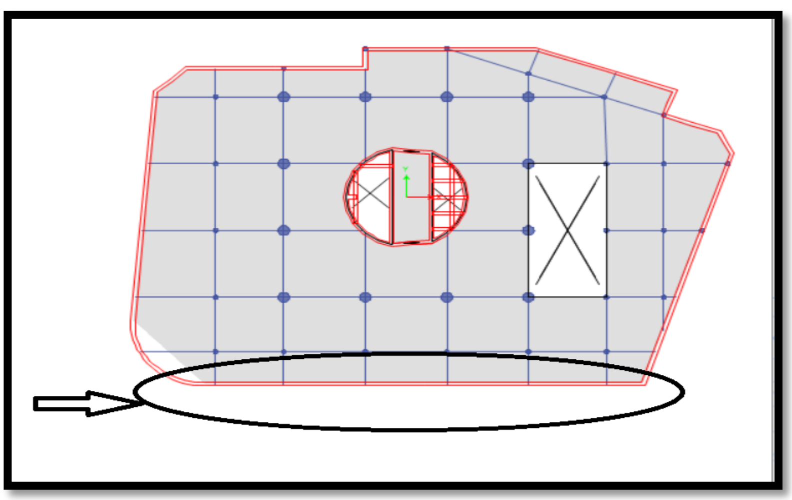


Figure 170 : plan shear wall

Result from Etabs

ETABS 2015 Shear Wall Design

ACI 318-14 Pier Design

Pier Details

Story ID	Pier ID	Centroid X (mm)	Centroid Y (mm)	Length (mm)	Thickness (mm)	LLRF
Story1	p1	1862.9	-23435.8	44929.8	400	0.457

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
32562.55	48	1	413.69	413.69

Design Code Parameters

Φ_T	Φ_C	Φ_V	Φ_V (Seismic)	IP_{MAX}	IP_{MIN}	P_{MAX}
0.9	0.65	0.75	0.6	0.04	0.0025	0.8

Pier Leg Location, Length and Thickness

Station Location	ID	Left X_1 mm	Left Y_1 mm	Right X_2 mm	Right Y_2 mm	Length mm	Thickness mm
Top	Leg 1	-20602	-23435.8	24327.8	-23435.8	44929.8	400
Bottom	Leg 1	-20602	-23435.8	24327.8	-23435.8	44929.8	400

Flexural Design for P_u, M_{u2} and M_{u3}

Station Location	Required Rebar Area (mm²)	Required Reinf Ratio	Current Reinf Ratio	Flexural Combo	P_u kN	M_{u2} kN-m	M_{u3} kN-m	Pier A_g mm²
Top	73518	0.0041	0.0023	envelope ultimate	3799.2805	4644.4333	-23992.7196	17971916
Bottom	44930	0.0025	0.0023	envelope ultimate	12822.0274	-3.1173	-51852.5383	17971916

Shear Design

Station Location	ID	Rebar mm²/m	Shear Combo	P_u kN	M_u kN-m	V_u kN	ΦV_c kN	ΦV_n kN
Top	Leg 1	1000	envelope ultimate	3799.2805	17474.2546	8413.7084	21040.9223	32193.0039
Bottom	Leg 1	1000	envelope ultimate	4811.4752	31803.0119	8008.6781	21192.7515	32344.8331

Boundary Element Check (Part 1 of 2)

Station Location	ID	Edge Length (mm)	Governing Combo	P_u kN	M_u kN-m	Stress Comp MPa	Stress Limit MPa
Top–Left	Leg 1	0	envelope ultimate	9826.1956	-23992.7196	0.73	9.6
Top–Right	Leg 1	0	envelope ultimate	9826.1956	17474.2546	0.68	9.6
Bottom–Left	Leg 1	0	envelope ultimate	12822.0274	-51852.5383	1.1	9.6
Bottom–Right	Leg 1	0	envelope ultimate	12822.0274	31803.0119	0.95	9.6

Boundary Element Check (Part 2 of 2)

C Depth mm	C Limit mm
Not Required	Not Required
Not Required	Not Required
Not Required	Not Required
Not Required	Not Required

Figure 171 : Result from Etabs for shear wall design

Reinforcement

Vertical reinforcement
As= 73518/45=1633 mm^2/m **(use 6Ø14 / m)** in both face .
Horizontal reinforcement
As = 1000 mm^2/m (**(use 1Ø12 / 200 mm)** in both face .

NOTE: See attached AUTOCAD sheets that shows detail of shear wall wich optained from Etab detail .

3.3.4.5. Stair Design design

Stairs are a continuous substructure which are used for moving from one floor to another in a structure, types of supporting required for stair different such as shear wall and beams.
the figure below show the type of supports used in the stairs which is shear wall from all side.

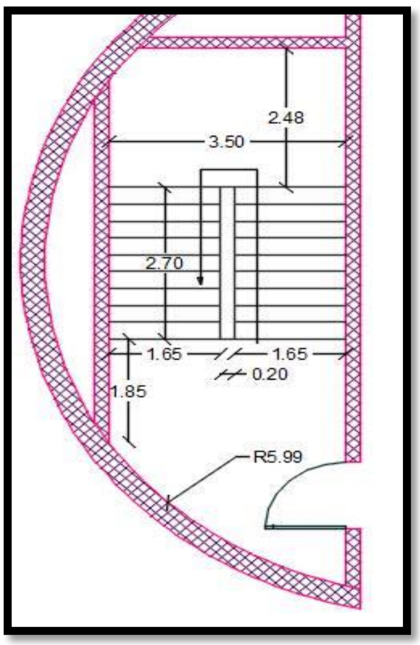


Figure 172 : Stair plan.

ETABS software program was used to design the stair in the structure . assumed The thickness of slab in the stair equals 15cm as solid slab (as shown in figure below).

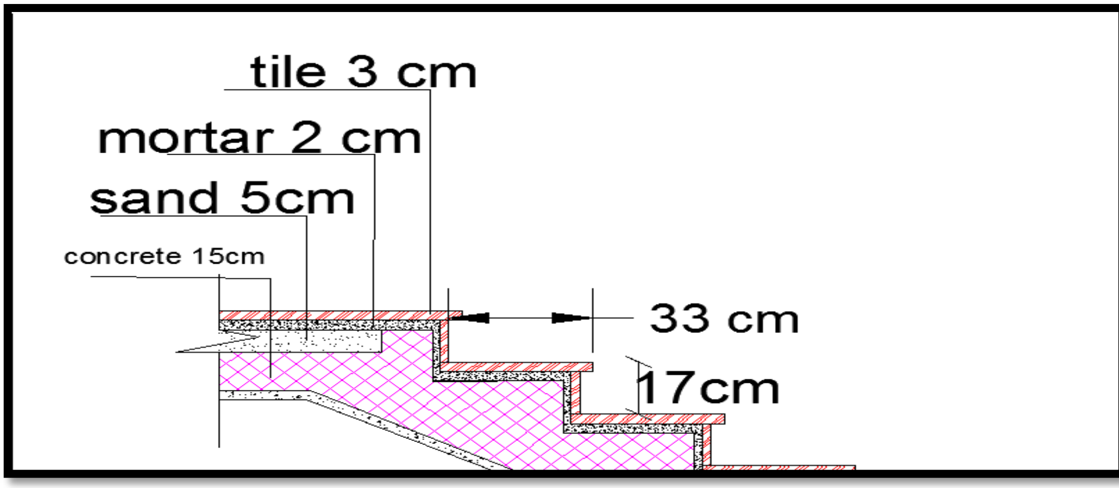


Figure 173 : Section in stair which shows the details of components stair.

Load on the stairs :

Dead load = super imposed load + own weight = 5 + 25*0.15 = 9.75 ≅ 10 KN/m2

Live load = 5 KN/m2

3D model :

the 3D model of staire was done by using ETABS software program. the elevation of staires was 3.5 m in height The steps and data that were inserted to make this model (as shown in figure below) were as following:

- Define the unit and draw the stair on ETABS
- Define materials (Concrete B350 - Fy = 420MPa).
- Define load patterns and load combinations.

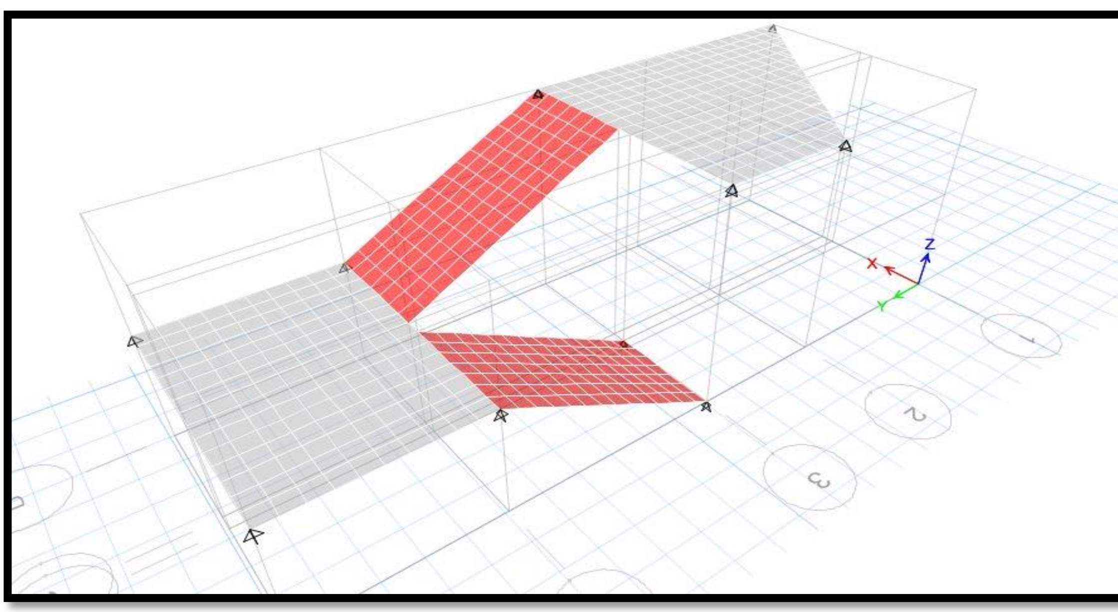


Figure 174 : 3D stair model in ETABS.

Check's model

There are some checks should be made in order to be insure that ETABS model gives correct results. These checks include :

1. Compatibility check .
2. Equilibrium check.
3. Stress- strain check .
4. Deflection check.

1. Compatibility:

we make this check to insure that all the structural elements are compatible with each other which main the all elements of structure are connected with other . This can be achieved and improved by noticing and analyzing the deformed shape animation of the structure model from Etabs. By start animation for the modal and display the deformed shape we notice that all the structural elements are compatible with each other's.

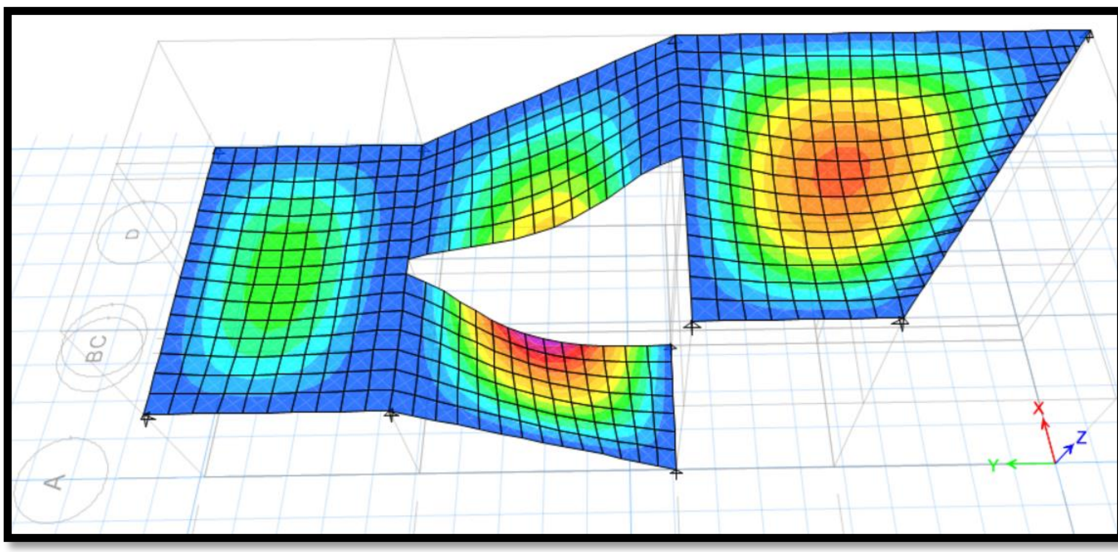


Figure 175 : The deformed shape of stair.

2. Equilibrium check:

Area stair = 31.24 m^2

Table below show the Difference between manual weight calculation and ETABS results

Table 30 : Difference between manual weight calculation and ETABS results

Load type	Hand results (KN)	ETAB results (KN)	Differences %
Dead load	312.4	312.4	0 < 5 OK
Live load	156.2	156.2	0 < 5 OK

	Load Case/Combo	FX kN	FY kN	FZ kN
▸	Dead	0	0	312.3627
	Live	0	0	156.1813

Figure 176 : ETABS results for weight.

3. Stress - Strain relationship:

Mu(hand) = $\frac{\boldsymbol{Wu*L^2}}{\boldsymbol{8}} = \frac{20*2.7^2}{8} = 18.2\ KN.m/m$

Mu (Etab) = $\left(\frac{M1+M2}{2}\right) + M3 = \frac{13.4+8.3}{2} + 3.5 = 14.35KN.m/m$

%error = (18.2-14.35)/18.2 = 21 % (accepted)

4. Deflection check:

Max Deflection = $\Delta z3 - \left(\frac{\Delta z1+\Delta z2}{2}\right) = 1.2 - \frac{0.0001+0}{2} = 1.2mm$

Deflection allowable = $\frac{L}{240} = \frac{3200}{240} = 13.4\ mm > 1.2\ mm \quad \boldsymbol{OK}$

Where :

-Δz1: displacement in end span .

-Δz2: displacement in opposite end span.

-Δz3: displacement in mid span .

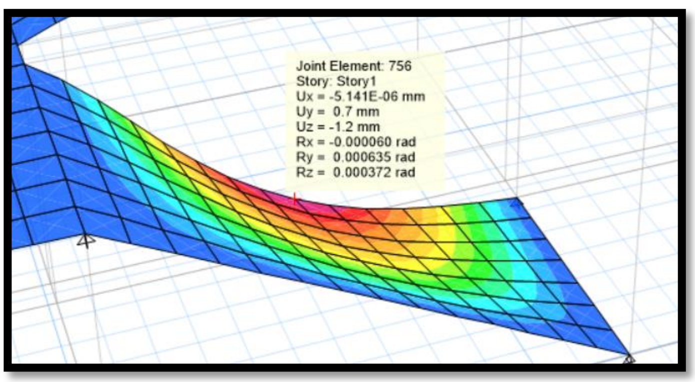


Figure 177 : max deflection in stairs

Steel Reinforcement for stairs :

Asmin = As-shrinkage = 0.0018*bw*h

= 0.0018 * 1000 * 150 = 270 mm2 **(use 5 Ø10 mm/m,** As= $392.5mm^2$ **)**

✓ This area of steel can carry Moment which is :

ØMn= 0.9 * As * Fy *(d-$\frac{As*Fy}{1.7*fc*bw}$) *10^{-6}

ØMn= 0.9 * 392.5* 420 *(120-$\frac{392.5*420}{1.7*28*1000}$) *$10^{-6}$ = 17.3 KN.m/m

✓ By showing the slab moment that lies between (-17.3, 17.3), it’s clear that all of the slab stairs areas need a minimum reinforcement of 5 Ø10 mm/m.

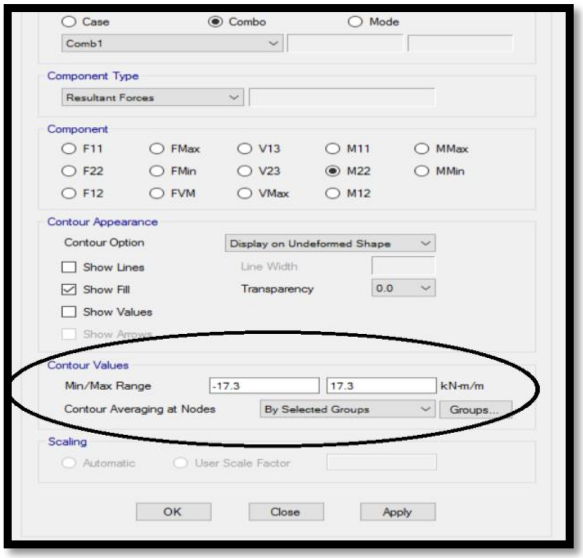


Figure 178 : The expected min. and max. moment values in the stairs.

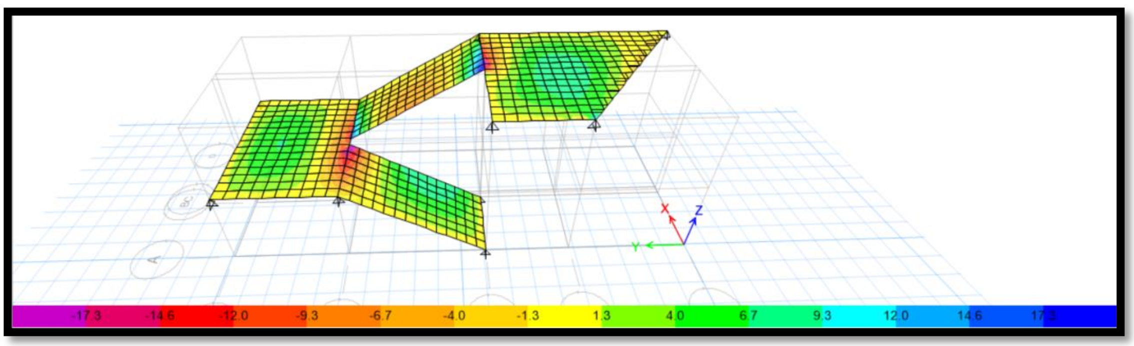


Figure 179 : The moment values in the stair from ETAB(M22).

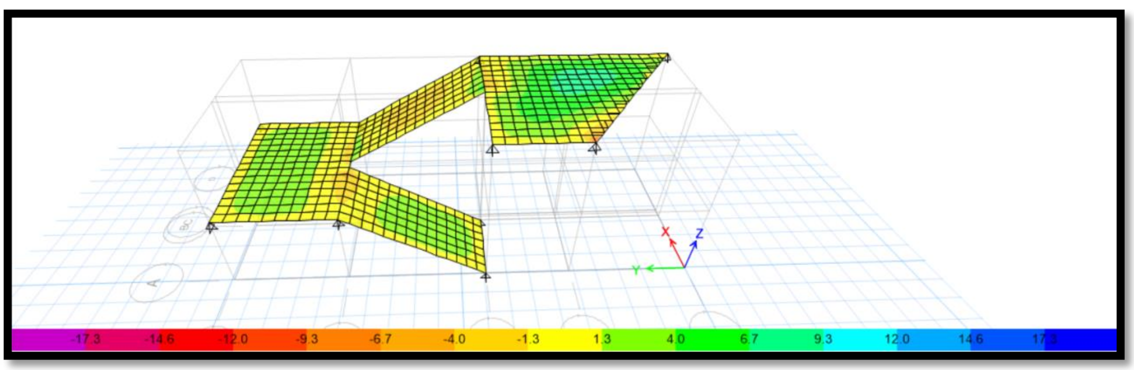


Figure 180 : The moment values in the stair from ETAB(M11).

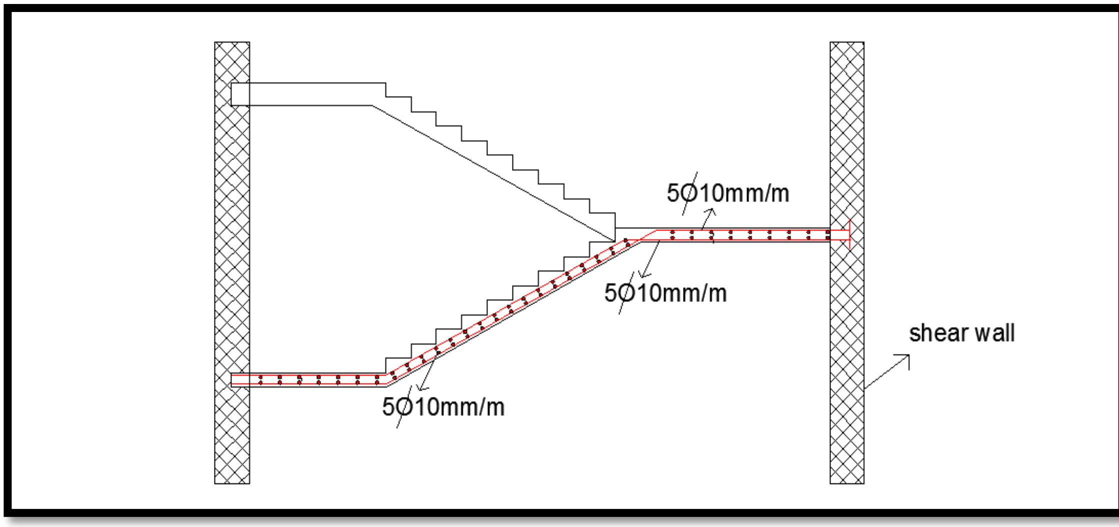


Figure 181 : Stair details

- **The maximum shear force**

Vu ≤ ØVc **Check ok …no need for shear reinforcement.**

NOTE: See attached AUTOCAD sheets that shows detail of stairs .

3.3.4.6. ramp design

design of external ramp

Reinforcement:

As shrinkage = 0.0018 *1000*200 = 360 mm2

Use 4 Ø12 / m , 1Ø12mm /25 cm in both sides and in two layers

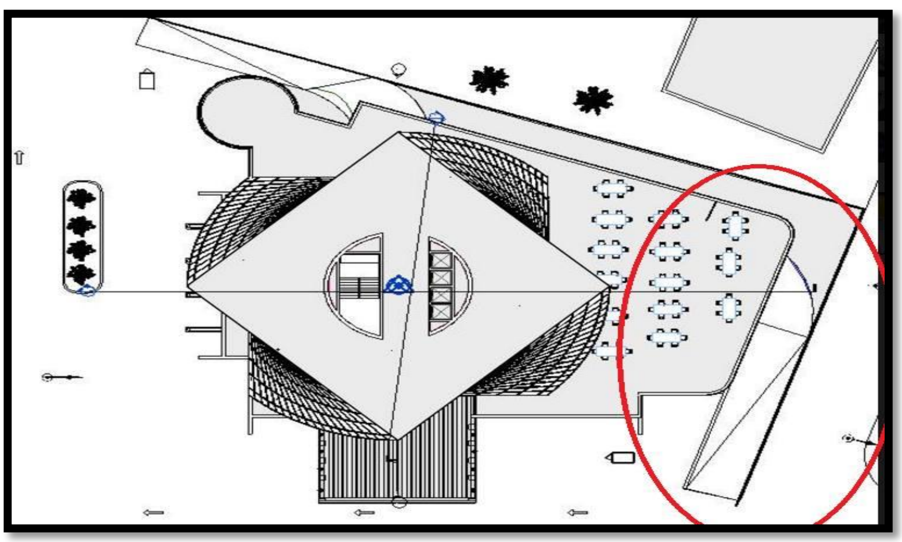


Figure 182 : Ramp plan

NOTE: See attached AUTOCAD sheets that shows detail of external ramp.

Internal ramp design :

ramp are a continuous substructure which are used for moving from one floor to another in a structure, types of supporting required for stair different such as slab and beams and columns. the figure below show the type of supports used in the ramp which is beam and columns.

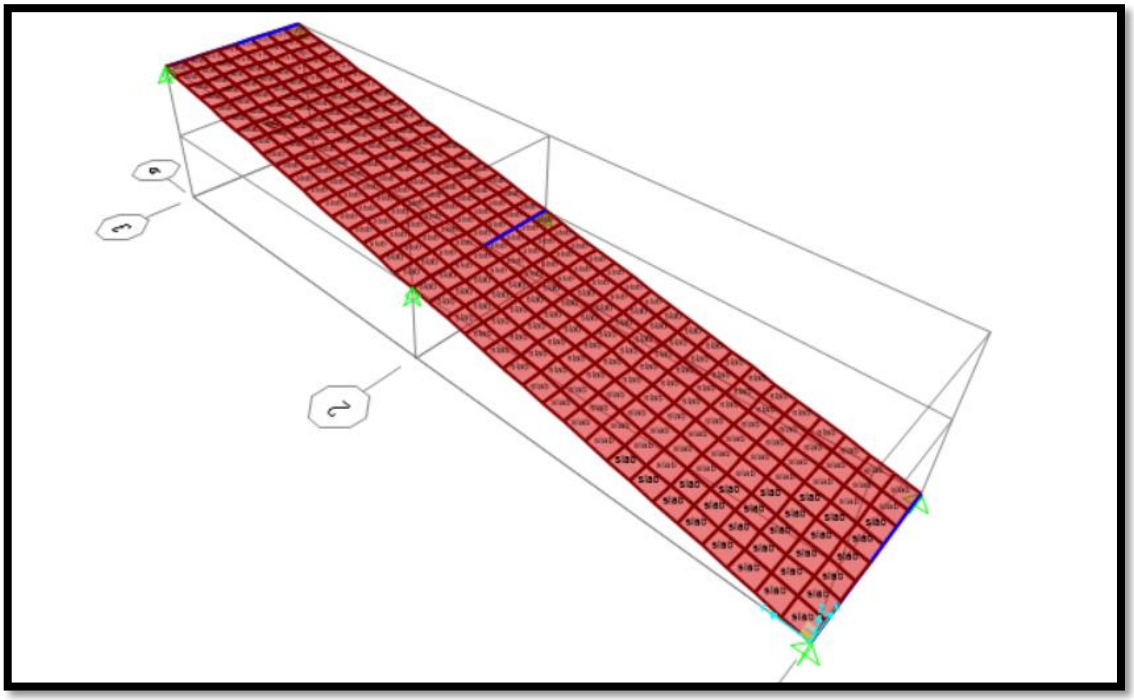


Figure 183 : support of ramp .

Sap software program was used to design the ramp in the structure . assumed The thickness of slab in the ramp equals 30 cm as solid slab

Load on the stairs :

Dead load = super imposed load + own weight = 5 + 25*0.3 = 12.5KN/m2

Live load = 5 KN/m2

3D model :

the 3D model of ramp was done by using sapv.16.0 software program. the elevation of ramp was 3.5 m in height The steps and data that were inserted to make this model (as shown in figure below) were as following:

- Define the unit and draw the ramp on sap
- Define materials (Concrete B350 - Fy = 420MPa).
- Define load patterns and load combinations.

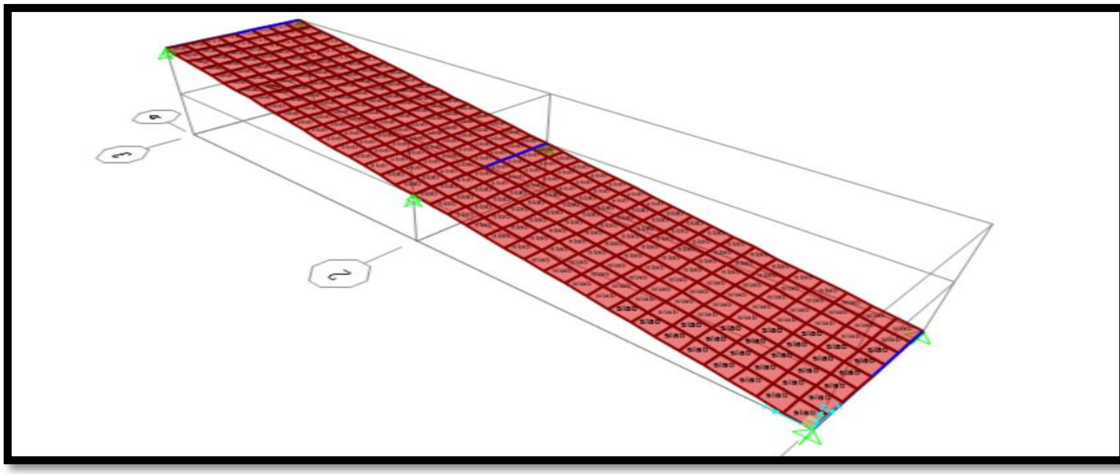


Figure 184 : 3D ramp model in sap.

Check's model

There are some checks should be made in order to be insure that sap model gives correct results. These checks include :

1. Compatibility check .
2. Equilibrium check.
3. Stress- strain check .
4. Deflection check.

1. Compatibility:

we make this check to insure that all the structural elements are compatible with each other which main the all elements of structure are connected with other . This can be achieved and improved by noticing and analyzing the deformed shape animation of the structure model from sab. By start animation for the modal and display the deformed shape we notice that all the structural elements are compatible with each other's.

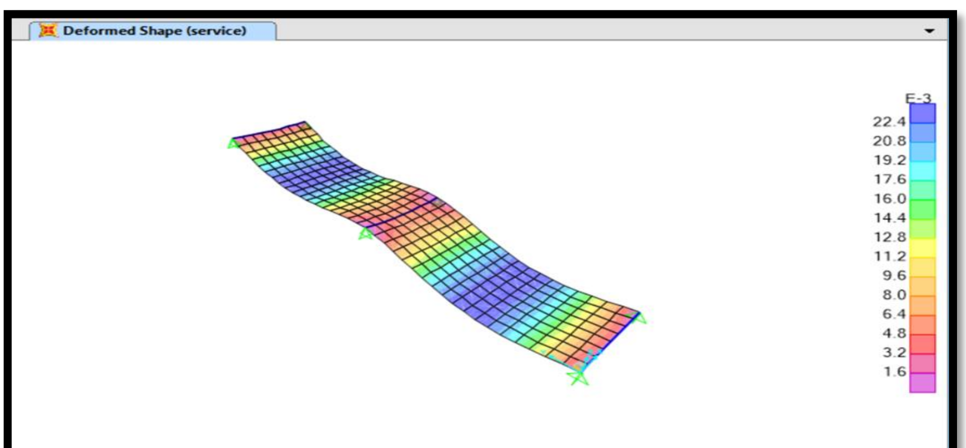


Figure 185 : The deformed shape of ramp.

2. Equilibrium check:

Area ramp = 63.5 m^2

Table below show the Difference between manual weight calculation and ETABS results

Table 31 : Difference between manual weight calculation and sap results

Load type	Hand results (KN)	Sap results (KN)	Differences %
Dead load	794	794	0 < 5 OK
Live load	317.5	317.5	0 < 5 OK

	OutputCase Text	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN
▶	DEAD	LinStatic	000000001381	000000001102	793.683
	live	LinStatic	2.065E-13	000000004353	317.473

Figure 186 : sap results for weight

3. Stress - Strain relationship:

Mu(hand) = $\frac{\boldsymbol{Wu*L^2}}{\mathbf{8}} = \frac{23*8.4^2}{8} = 203\ KN.m/m$

Mu (Etab) = ((M1+M2)/2)+M3=(206+0.8)/2+120=223KN.m/m

%error = (223-203)/223 = 9 <10 % (accepted)

4. Deflection check:

Max Deflection = Δz3-((Δz1+Δz2)/2)=0.02 mm

Deflection allowable = L/240= 8500/(240)=35mm>0,02mm OK

Where :

-Δz1: displacement in end span .

-Δz2: displacement in opposite end span.

-Δz3: displacement in mid span .

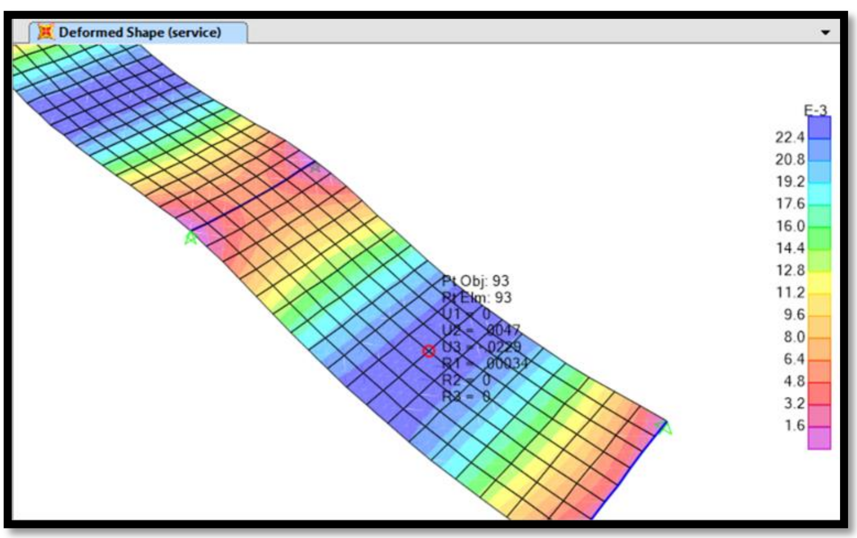


Figure 187 : max deflection in ramp

Steel Reinforcement for stairs :

Asmin = As-shrinkage = 0.0018*bw*h

= 0.0018 * 1000 * 300 = 540 mm2 **(use 5 Ø12 mm/m,** As= $565mm^2$ **)**

✓ This area of steel can carry Moment which is :

$ØMn= 0.9 * As * Fy *(d-\frac{As*Fy}{1.7*fc*bw}) *10^{-6}$

$ØMn= 0.9 * 565* 420 *(270-\frac{565*420}{1.7*28*1000}) *10^{-6}$ = 56.5 KN.m/m

✓ By showing the slab moment(**M11**) that lies between (-75, 75), it's clear that all of the slab ramp areas need a minimum reinforcement of **5 Ø14** mm/m.

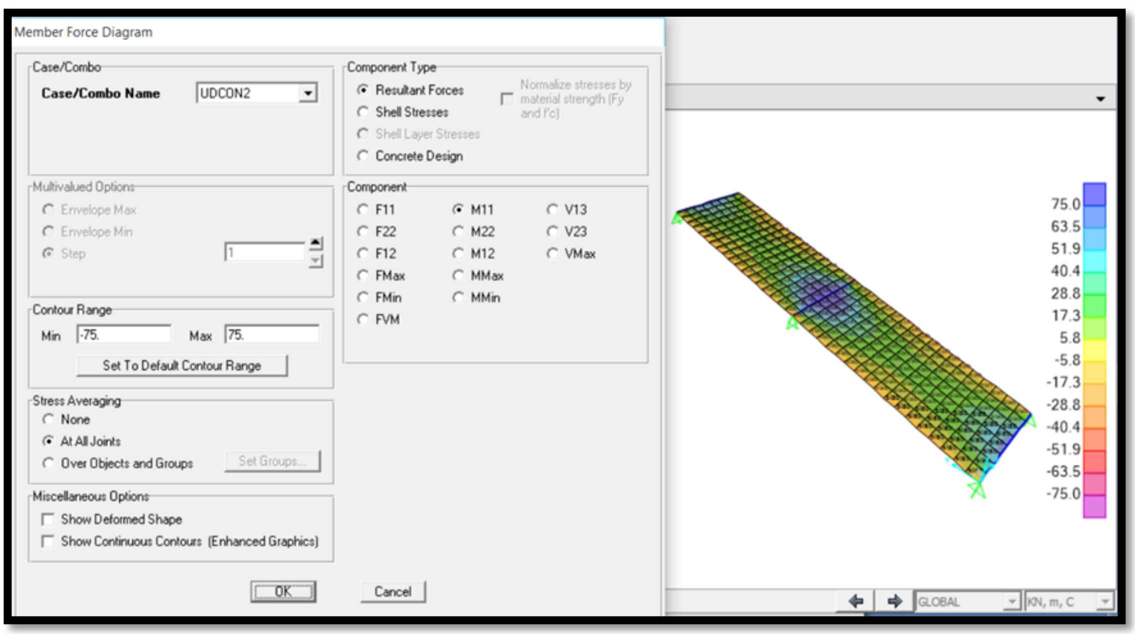


Figure 188 : The expected min. and max. moment values in the ramp and The moment values(M11).

✓ By showing the slab moment(**M22**) that lies between (-215, 215), it's clear that all of the slab ramp areas located in the rang .

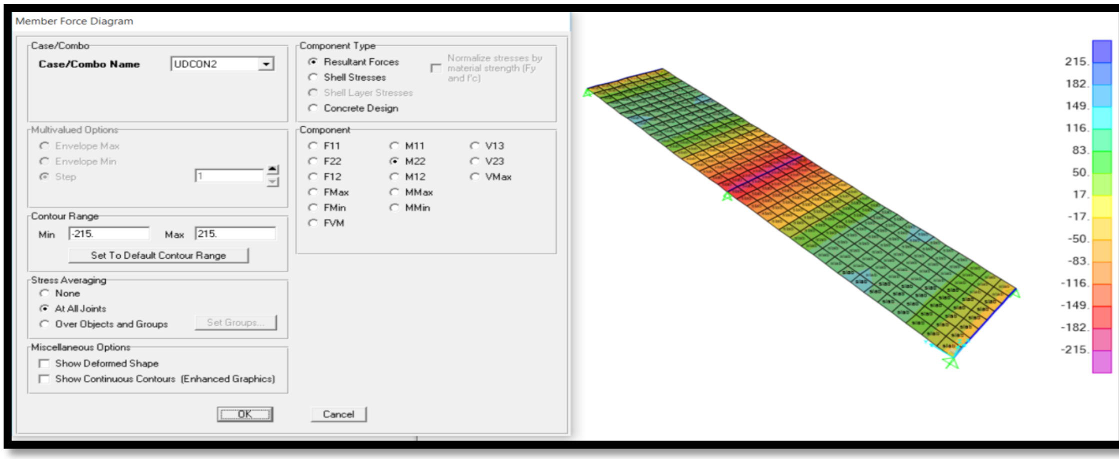


Figure 189 : The expected min. and max. moment values in the ramp and The moment values(M22).

So >> $M_{u=215\ KN.m/m}$, d = 260 mm , b=1000mm

$\rho = \frac{0.85 f'c}{f_y}\left(1-\sqrt{1-\frac{2.61 M_u}{b d^2 f'c}}\right)$, $A_s = \rho * b * d$, ρ=0.0043.

$A_s = 0.0043 * 1000 * 270 = 1164\ mm2/m$

Use 5 Ø18 mm/m.

➢ **The maximum shear force(critical):**

Vu at d 125 kN/ m.

$\emptyset Vc = \emptyset * \frac{1}{6} * \sqrt{fc'} * bw * d$

$\boldsymbol{\emptyset V_c} = \frac{0.75}{6}\sqrt{28}$ *1000*270 = **178 KN/m**

Vu ≤ ØVc **Check ok …no need for shear reinforcement.**

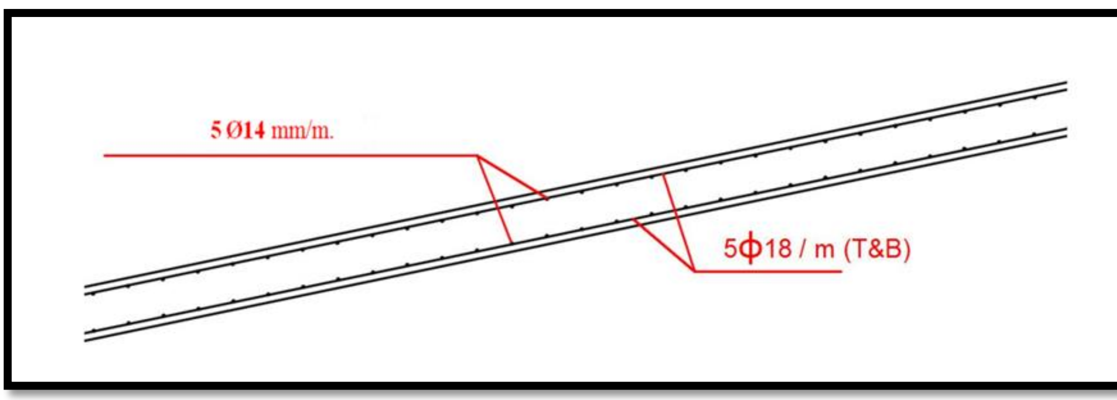


Figure 190 : reinforcement of ramp

NOTE: See attached AUTOCAD sheets that shows detail of ramp .

3.3.4.7. Water Tank design

In this project, there are one Square concrete water tanks located in the top of building ,These tanks must be designed to resist the earthquake loads. Therefore, the ACI 350.3-06 code was used to calculate these earthquake loads and then SAP2000v16.0.0 software program was used to design this tank. the tank has 8*8 m dimensions, and 2.5m height.

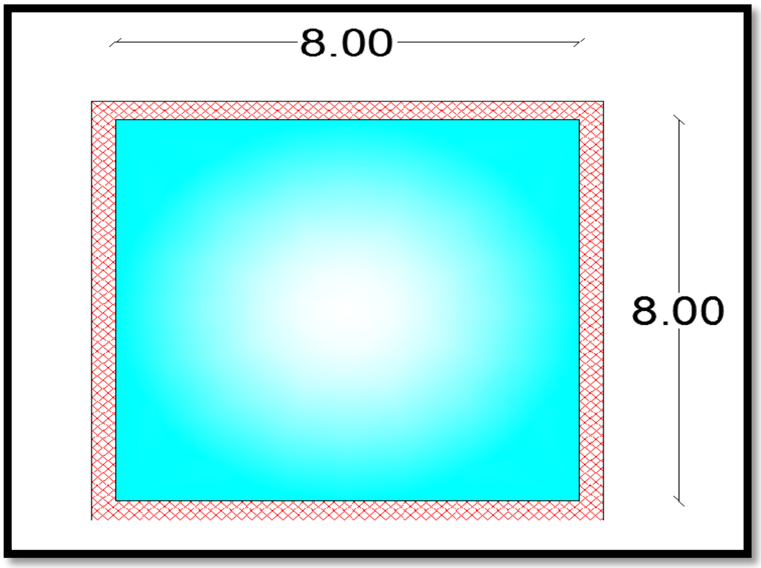


Figure 191 : plan of water tank

load Calculations

Before starting the calculations, there are some values had to be determine. These values were summarized in the table shown below

Table 32 : required values to design water tank

Description	Symbol	Value	Unit
Wall height	Hw	2.5	m
Water height	HL	2.2	m
Wall length	L	8	m
Weight of one wall	Ww	200	KN
Weight of water	WL	1408	KN
Earthquake spectral response accelerations at short period	Ss	0.5	m/sec2
Earthquake spectral response accelerations at 1 sec period	S1	0.25	m/sec2
Soil classification	---	D	---

Short-period site coefficient (at 0.2 s-period)	Fa	1.4	---
Long-period site coefficient (at 1.0 s-period)	Fv	1.9	---
The design spectral response acceleration at short periods	SDS	0.46	m/sec2
The design spectral response acceleration at a 1 sec period	SD1	0.31	m/sec2
Importance Factor	I	1.25	---
Response modification factor for the convective component of the accelerating liquid	Rc	1	---
Response modification factor for the impulsive component of the accelerating liquid	Ri	2	---
Seismic weight of water	γw	10	KN/m3

- **Pressure from water:**

Pressure = γw * HL = 10*2.2 = 22 KN/m2 (as shown in figure below)

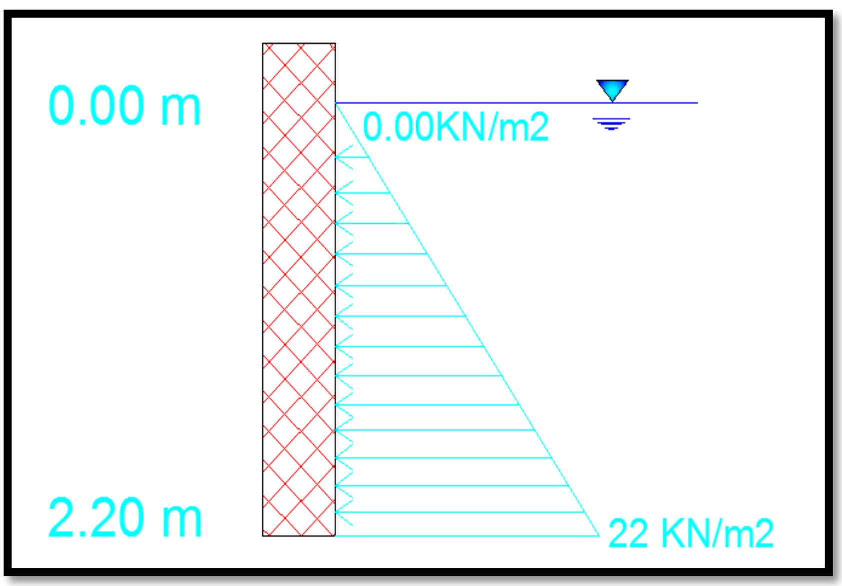


Figure 192 : Pressure from water on the wall tank

➢ Pressure from water (earthquake):

By using ACI 350.3-06 code as a reference to calculate the convictive, impulsive, wall, and vertical pressure from earthquake we find the result as the following:

WL =1408 KN , $\frac{L}{HL} = \frac{8}{2.2} = 3.6$

hc: height above the base of the wall to the center of gravity of the convective lateral force for the case excluding base pressure (m).

hi : height above the base of the wall to the center of gravity of the impulsive lateral force for the case including base pressure(m) , were obtained from figure shown below .

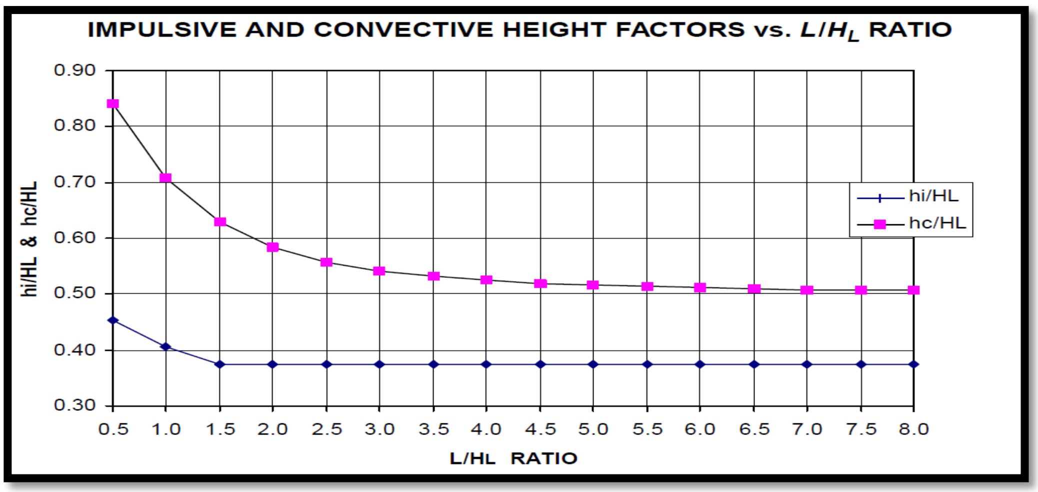


Figure 193 : impulsive and convection height factors

$\frac{hi}{HL} = 0.38$ ⟶ hi = 0,84 m

$\frac{hc}{HL} = 0{,}54$ ⟶ hc = 1.2 m

Wc: equivalent weight of the convective component of the stored liquid (kN).
Wi : equivalent weight of the impulsive component of the stored liquid (KN) .

Wi & Wc obtaind from the figure shown below .

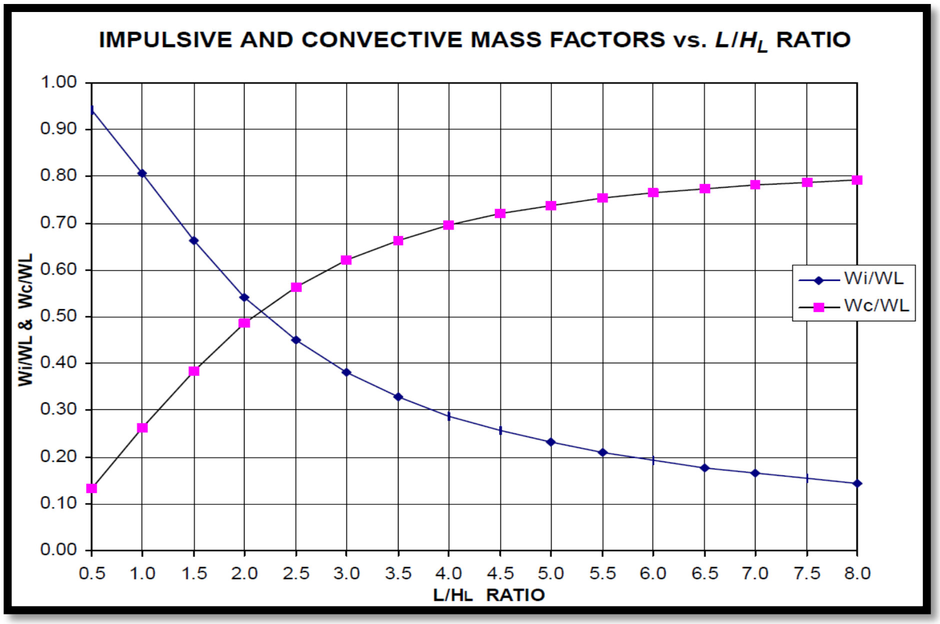


Figure 194 : impulsive and convection mass factors

$\frac{\text{Wi}}{\text{WL}} = \mathbf{0.31}$ ⟶ Wi = 436.5 KN

$\frac{\text{Wc}}{\text{WL}} = \mathbf{0.67}$ ⟶ Wc = 943.4 KN

And then,we find the Seismic response coefficients (**Ci, Cc**):

Ci = SDs = 0.46

$\text{Ts} = \frac{SD1}{SDs} = \frac{0.31}{0.46} = 0.67$

$\text{Tc} = \frac{2\pi}{\lambda}\sqrt{\text{L}} = 2$

$\text{Cc} = \frac{1.5*SD1}{Tc} = \frac{1.5*0.31}{2} = 0.23 < 1.5\ SDs = 0.69$

Cc = 0,23

- Then we find dynamic lateral forces as follow :

Pw(KN) = lateral inertia force of the accelerating wall with Ww .

$\text{Pw} = Ci * I * (\frac{\varepsilon*\text{Ww}}{Ri})$

Pc(KN) = total lateral convective force associated withWc , $\text{Pc} = Cc * I * (\frac{\text{Wc}}{Rc})$

Pi(KN) = total lateral impulsive force associated with Wi .

$\text{Pi} = Ci * I * (\frac{\text{Wi}}{Ri})$

- Pw = 30.5 KN ,Pc = 271 KN ,Pi = 125.5 KN

Pv(KN) : unit equivalent hydrodynamic pressure due to the effect of vertical acceleration.

Pv= ü qh

qh = γw * HL = 10*2.2 = 22 KN/m2

ü = $Ct * I * \frac{b}{Ri} \geq 0.2\ SDs$

Ct = 0.4 SDs = 0.4 * 0.46 = 0.184

ü = $0.184 * 1.25 * \frac{2/3}{2} < 0.2\ SDs$

use ü = 0.2 SDs = 0.2 *0.46 = 0.92

Pv= 0.092*22= 2.02 KN/m2

The figure below summarizes the dynamic lateral forces .

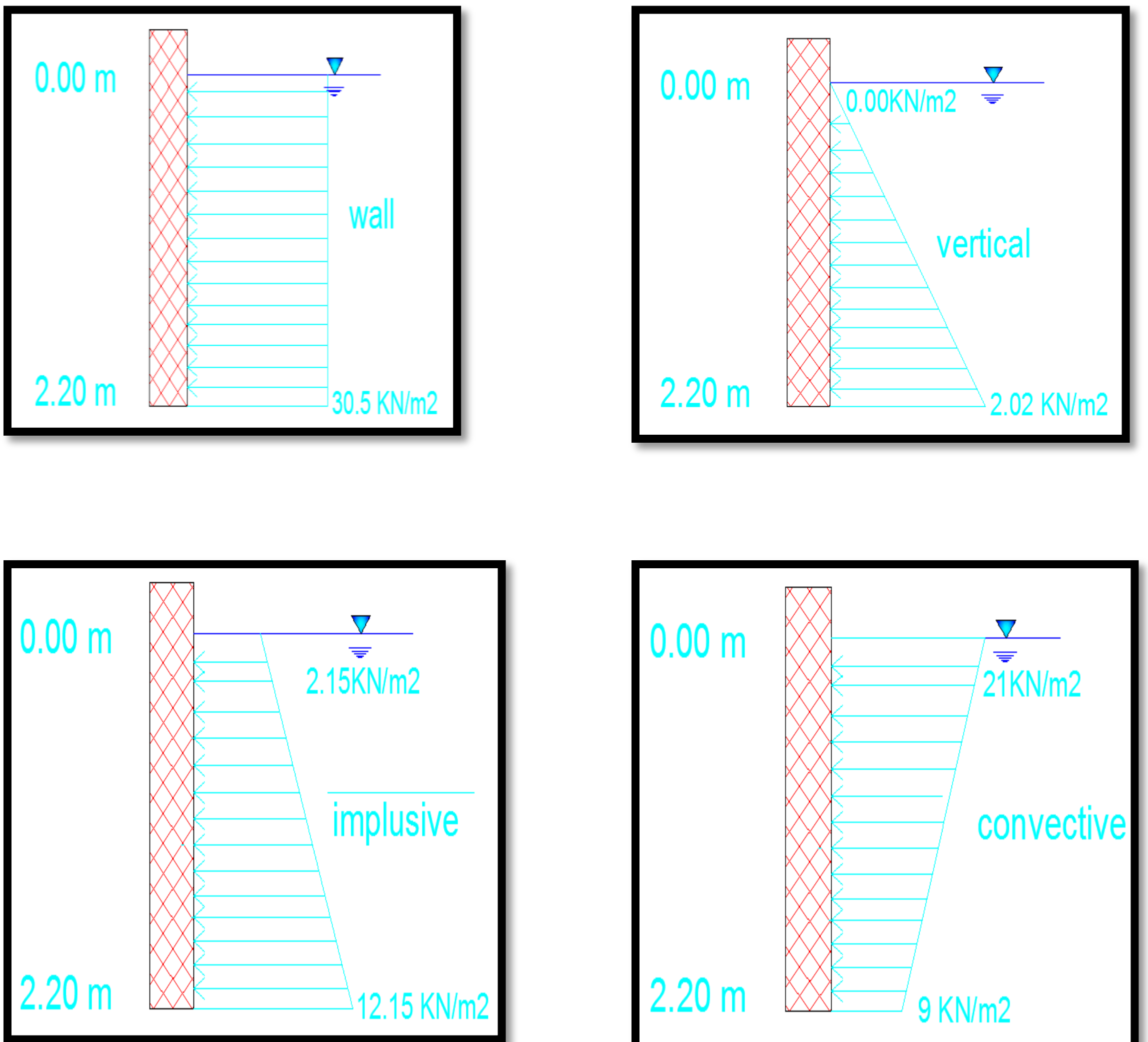


Figure 195 : The dynamic lateral forces

Then we find the resultant of these lateral forces

V1 = $\sqrt{(Pi + Pw)^2 + Pc^2\ + Pv^2}$ = $\sqrt{(2.15 + 30.5)^2 + 21^2 + 0}$ = 39 KN/m2

V2 = $\sqrt{(Pi + Pw)^2 + Pc^2\ + Pv^2}$ = $\sqrt{(12.15 + 30.5)^2 + 9^2 + 2.02^2}$ = 43.6 KN/m2

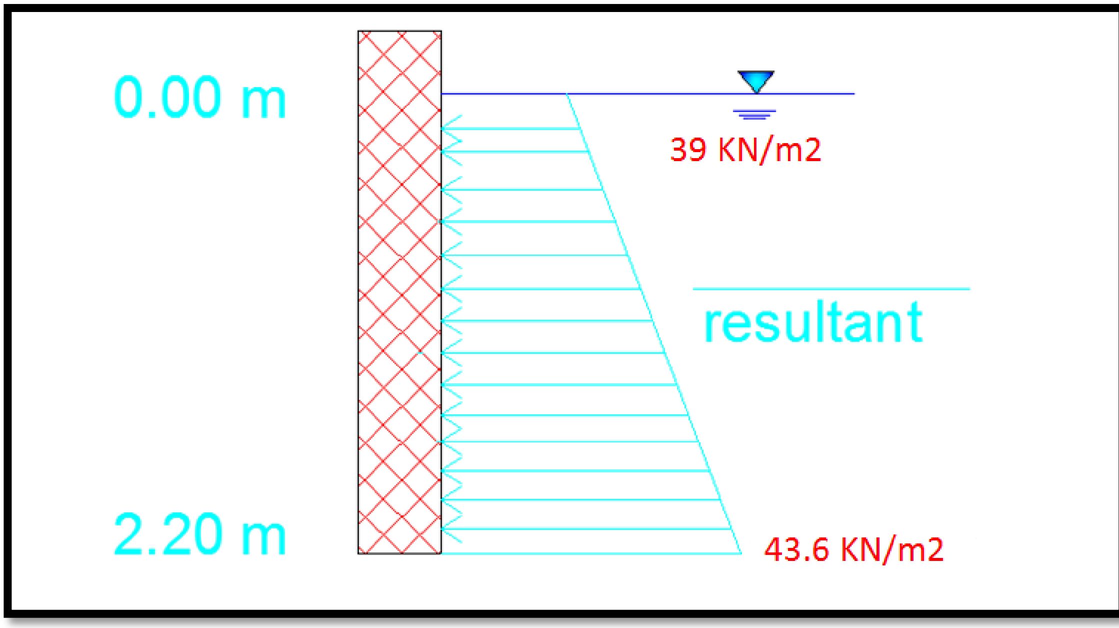


Figure 196 : The resultant stresses of the dynamic lateral forces

Analysis and Check's model

the 3D model of water tank was done by using SAP2000 v.16 software program. with 2.2m water height, 2.5 m wall height, and 8*8m dimensions. The steps and data that were inserted to make this model (as shown in figurebelow) were as following:

- Define the unit, define materials (concrete B600), and area section (wall = 40cm and basement = 40cm thickness).
- Define load patterns and load combinations.

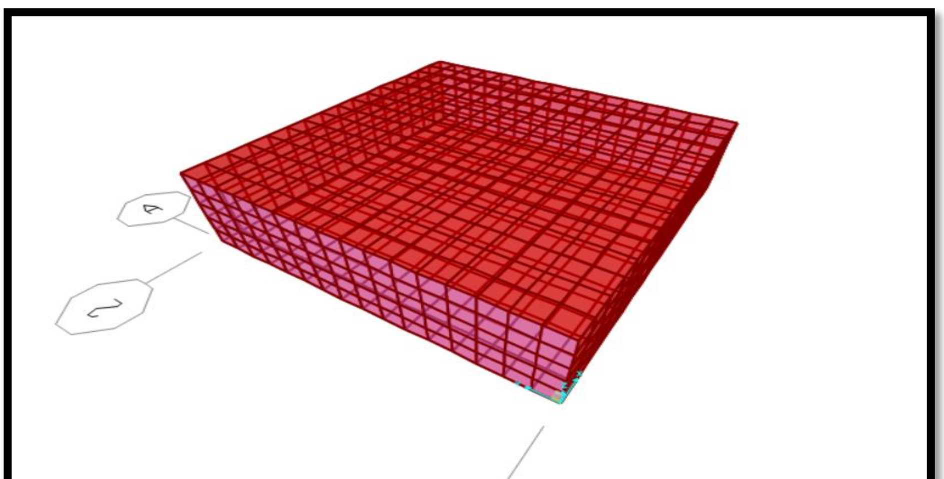


Figure 197 : 3D model of water tank

Check's model

There are some checks should be made in order to be insure that ETABS model gives correct results. These checks include :

1. Compatibility check .
2. Deflection check.
3. Stress- strain relationship.

Compatibility:

we make this check to insure that all the structural elements are compatible with each other which main the all elements of structure are connected with other . This can be achieved and improved by noticing and analyzing the deformed shape animation of the structure model from sap . By start animation for the modal and display the deformed shape we notice that all the structural elements are compatible with each other's.

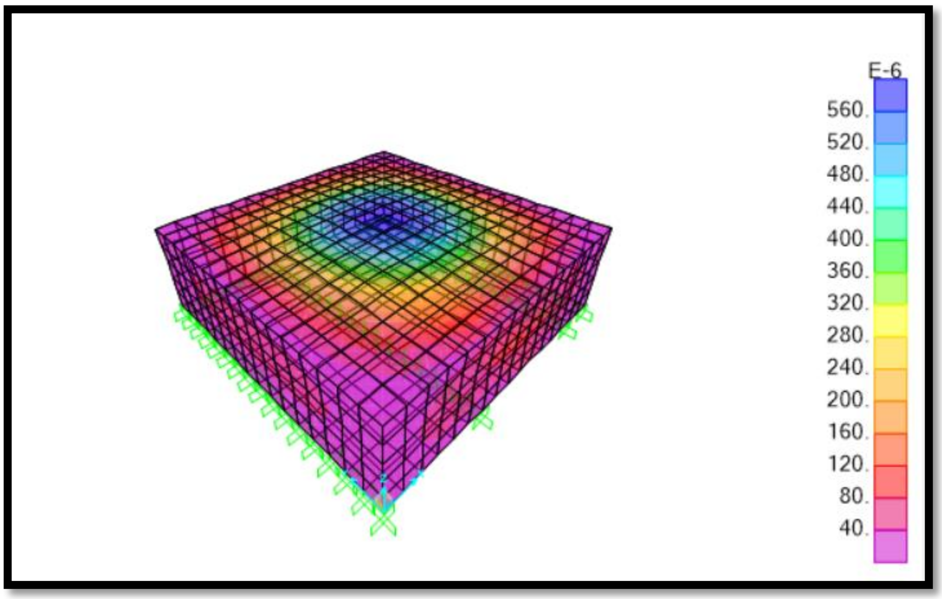


Figure 198 : The deformed shape of water tank .

Deflection check:

Max Deflection in top $= \Delta z3 - \left(\frac{\Delta z1+\Delta z2}{2}\right) = 0.006$

Deflection allowable $= 10\ mm > 0.006\ mm \quad \boldsymbol{OK}$

Where :

-Δz1: displacement in end span .

-Δz2: displacement in opposite end span.

-Δz3: displacement in mid span .

Max Deflection in base $= \Delta z3 - \left(\frac{\Delta z1+\Delta z2}{2}\right) = 0.0001\ mm$

Deflection allowable $= 10\ mm > 0.0001\ mm \quad \boldsymbol{OK}$

Where :

-Δz1: displacement in end span .

-Δz2: displacement in opposite end span.

-Δz3: displacement in mid span .

Max Deflection in wall $= \Delta z2 - \Delta z1 = 0.0002\ mm < 10mm\ ok$

All values of deflection in wall and base and roof less than 10 mm

Check walls thickness for shear:

$$\emptyset Vc = 0.75 * \frac{1}{6} * \sqrt{48} * \frac{1000}{1000} * 320 = 277\ \text{KN/m}$$

Vu (from sap) = 68 KN/m < 277 OK

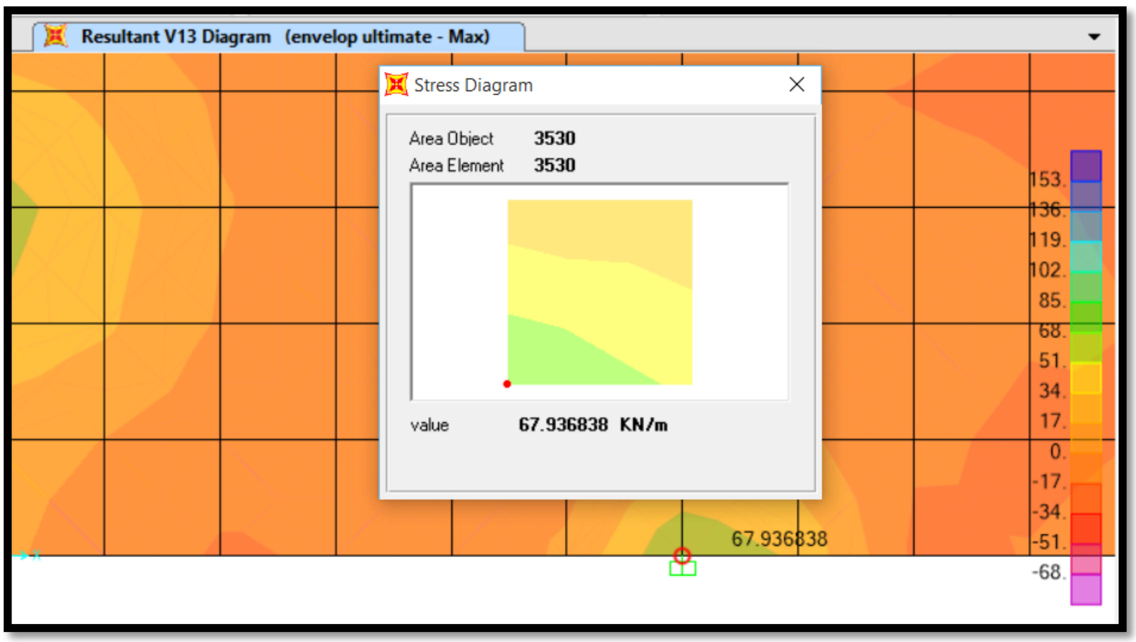


Figure 199 : shear force in wall

Stress – Strain relationship:

From PCA table

At $\frac{b}{2} = 4$, At $\frac{b}{2} = 3$

Mu= 9.2 KN.m , Mu= 9.2 KN.m

At $\frac{b}{2} = 3.2$

Mu= 9.2 KN.m

MSAP = 9.02KN.m

Difference = 1.95 % < 10%

Stress-Strain check was satisfied

*** Steel Reinforcement**

M11 max = 31 KN.m/m (as shown in figurebelow)

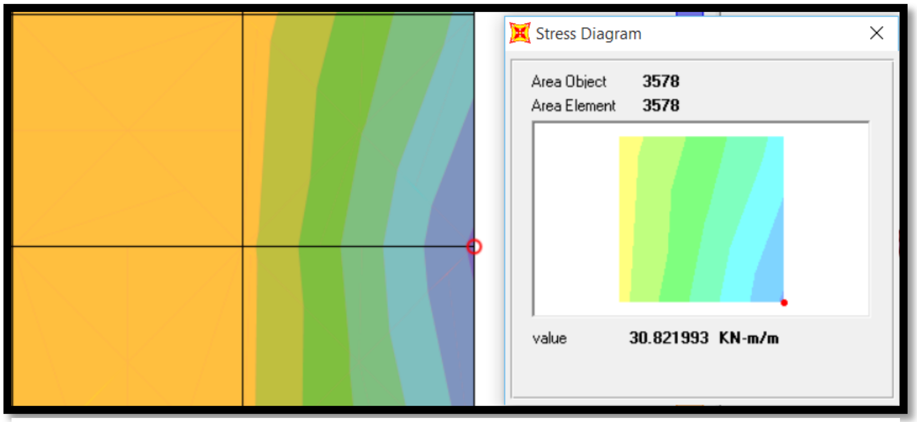


Figure 200 : stress diagram M_{11}

Mudesign = 1.06 Sd Mu

H = 0.4 m $\longrightarrow$ Fs max = 210 mpa

Sd $= \frac{\emptyset * Fy}{\gamma \text{ fsmax}} = \frac{0.9 * 420}{1.4 * 210}$

Sd = 1.3

Mudesign = 1.06 *1.3*31 = 42.7 KN.m / m

$\rho = \frac{0.85 f'c}{f_y}(1 - \sqrt{1 - \frac{2.61 M_u}{bd^2 f'c}})$, $A_s = \rho * b *$d , ρ=0, 0011

As = 0.0011*1000*320 = 352 mm2

As horizantal. min = ρmin * b * h = 0.005 * 1000 * 400 = 2000 mm2/m

Use **14 Ø 14** mm/m (in two layers)

In Vertical direction:

M22 max = 107 KN.m/m (as shown in figure below)

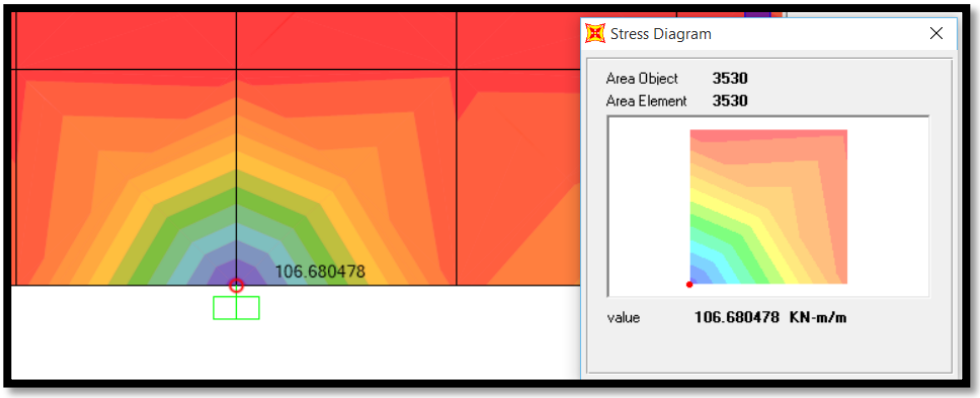


Figure 201 : stress diagram M22

Mudesign = 1.06 *1.3*107 = 147 KN.m / m

$\rho = \frac{0.85f'c}{f_y}(1 - \sqrt{1 - \frac{2.61M_u}{bd^2f'c}})$, $A_s = \rho * b$ *d , ρ=0, 00386

As = 0.00386*1000*320 = 1235.2 mm2

As vertical min = ρmin * b * h = 0.005 * 1000 * 400 = 2000 mm2/m

Use **14 Ø 14** mm/m (in two layers) .

For basement and roof use As min(felxture steel) = 0.0018 * 1000 * 400 = 720 mm2

Use (5 Ø 14/m)

Diaghragms steel (Tension steel) :

the avg tensile force equal = 115 KN/m

AS = T/0.9*Fy = 115*1*1000 / 0.9*420 = 304 mm2 (use 2**Ø 14/m**)

We add (2**Ø 14/m**) for horizontal steel and for roof and base.

The reinforcement become as follow :

Wall horizontal steel Use **16 Ø 14** mm/m (in two layers).

Roof and base steel use **8 Ø 14** mm/m (in two layers and both direction).

Wall vertical steel Use **14 Ø 14** mm/m (in two layers) .

NOTE: See attached AUTOCAD sheets that shows detail of water tank.

3.3.4.8. single footing for columns design

footing for column :

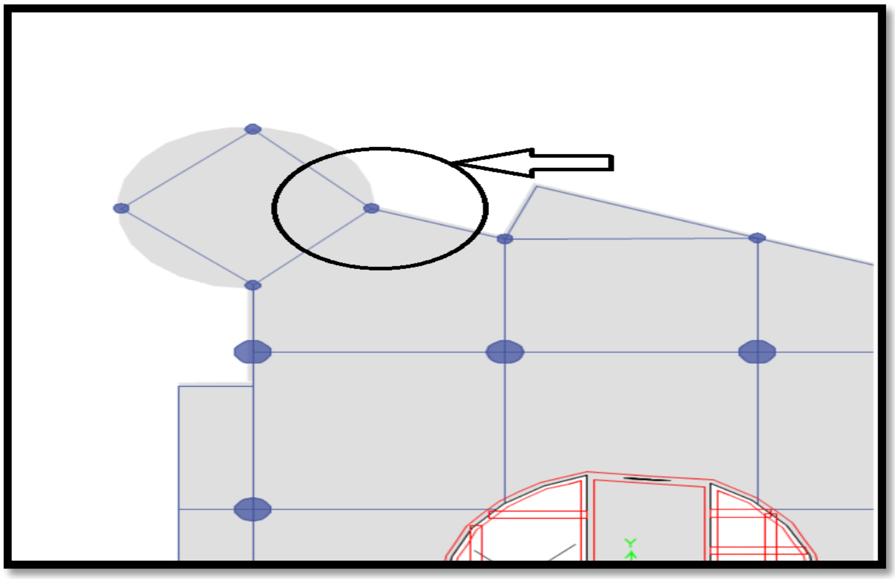


Figure 202 : location of column

q_{all}=300 KN/m^2

The axial load(service) =955 KN (from sap)

The axial load(ultimate)=1227 KN(from sap)

Dimensions :

∂_{max} =(P/B*L)= 300

Guess B to find L , so B = √(P/ q_{all})

B=√(955/300)=1.78m use B=1.8m

∂_{max} =(955/1.8*L)= 300>> L=1.76 use L=1.8m

$\partial_{max=}$ (955/1.8*1.8) =295< 300 (ok)

Thickness :

P_u= 1.2 * P_D + 1.6* P_L =1227 KN (from ETAB)

$\partial_{u,}$ = (Pu/B*L)= 1227/1.8*1.8 = 379 KN/m2

Assume the punching failure will occure first

Guess thickness acoording to punching d= 10√P_u d in mm , P in KN

.d= 10√1227 =350mm use d = 360mm

h= d + cover = 360+90= 450mm

check punching:

$\emptyset v_{cp} = \emptyset\ min\{\begin{matrix} 1/3 \\ 1/6(1+2/Bc \end{matrix}\}\lambda\sqrt{f'c}b_0 d$ Bc =البعد الاصغر /البعد الاطول للعمود

$\emptyset v_{cp}$ = .75*1/3*1*$\sqrt{28}$* (4270)*360 /1000 = 2034 KN

$V_{up} = P_u$ – (stress *area p) = 1227 -(379*1.45) = 650 KN

$\emptyset v_{cp} > V_{up\ (OK)}$

Wide beam shear :

$\emptyset v_c = \emptyset \left\{\frac{1}{6}\right\} \lambda\sqrt{f'c} * bw * d =$ .75*1/6 * $\sqrt{28}$ * 1000*360 /1000= 238 KN

$V_u = \partial_{u*}$ (L-d) = 379(0.75-0.36) =148 KN

$V_u < \emptyset v_c$ (ok)

Reinforcement :

Longitudinal direction : (along B)

M_u (along B) =(∂_u * L^2) /2 = 379*.0.75*0.75 /2 = 107KN.m /m

$M_{u=107\ KN.m/m}$, d = 360 mm , b=1000mm

$\rho = \frac{0.85f'c}{f_y}(1-\sqrt{1-\frac{2.61M_u}{bd^2f'c}})$, $A_s = \rho * b$ *d , ρ=0.00218,

$A_s = 0.00222 * 1000 * 360 = 800\ mm2/m$

Asmin = $\rho * b$ *h = 0.0018*1000*450 = 810 mm2/m >As (use As=810 mm2/m)

Total Longitudinal steel = A_s * L =810*1.8= 1458 mm2 (13ø12)

Transverse direction: (along L)

M_u (along B) =(∂_u * L^2) /2 = 379*.0.75*0.75 /2 = 107KN.m /m

$M_{u=107\ KN.m/m}$, d = 360 mm , b=1000mm

$\rho = \frac{0.85f'c}{f_y}(1-\sqrt{1-\frac{2.61M_u}{bd^2f'c}})$, $A_s = \rho * b$ *d

ρ=0.00218,

$A_s = 0.00222 * 1000 * 360 = 800\ mm2/m$

Asmin = $\rho * b$ *h = 0.0018*1000*450 = 810 mm2/m >As (use As=810 mm2/m)

Total Longitudinal steel = A_s * L =810*1.8= 1458 mm2 (13ø12)

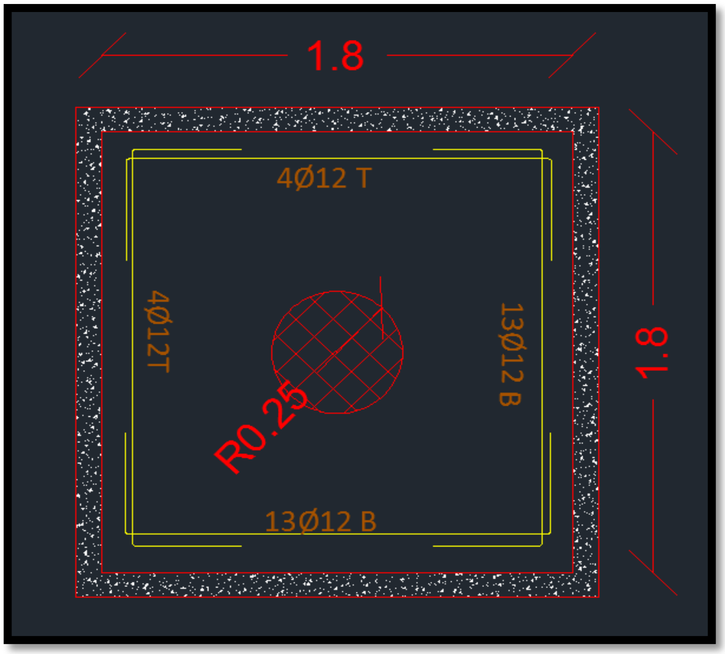


Figure 203 : reinforcement of footing

Ld bottom bar = 50db = 0.6m
Available length > Ld No need hooked.

Design single footing for column :

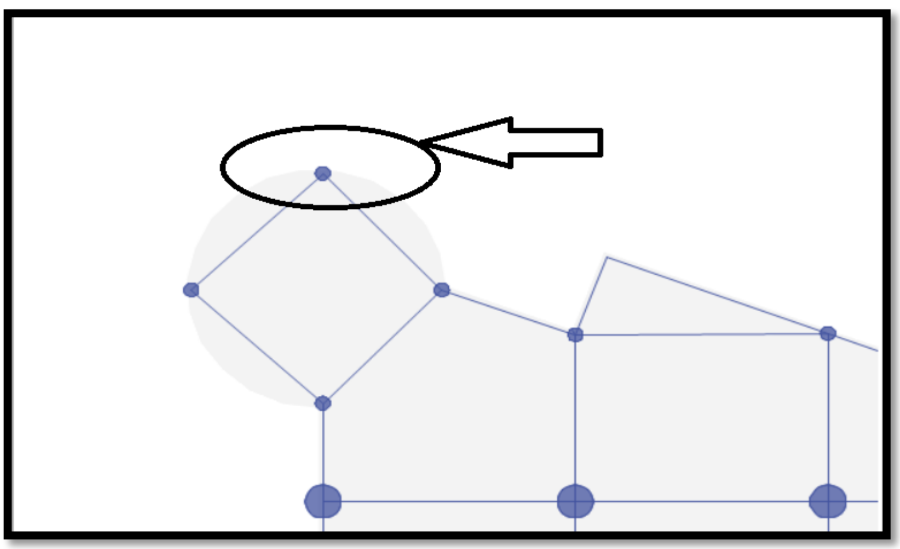


Figure 204 : location of column

q_{all}=300 KN/m^2
The axial load(service) =765 KN (from sap)
The axial load(ultimate)=1025 KN(from sap)

Dimensions :

∂_{max} =(P/B*L)= 300

Guess B to find L , so B = √(P/ q_{all})

B=√(765/300)=1.59 use B=1.6m

∂_{max} =(765/1.6*L)= 300>> L=1.59 use L=1.6m

$\partial_{max=}$ (765/1.6*1.6) =299< 300 (ok)

Thickness :

P_u= 1.2 * P_D + 1.6* P_L =1227 KN (from ETAB)

$\partial_{u,}$ = (Pu/B*L)= 1025/1.6*1.6 = 400 KN/m2

Assume the punching failure will occure first

Guess thickness acoording to punching d= 10√P_u d in mm , P in KN

.d= 10√1025 =320mm use d = 360 mm

h= d + cover = 360+90= 450mm

check punching

$\emptyset v_{cp} = \emptyset\ min\left\{ \begin{matrix} 1/3 \\ 1/6(1+2/Bc \end{matrix} \right\} \lambda\sqrt{f'c}b_0 d$ Bc =البعد الاطول للعمود/ البعد الاصغر

$\emptyset v_{cp}$ = .75*1/3*1*√28* (4270)*360 /1000 = 2034 KN

V_{up} = P_u – (stress *area p) = 1025 -(400*1.45) = 445 KN

$\emptyset v_{cp}$ > $V_{up\ (OK)}$

Wide beam shear :

$\emptyset v_c = \emptyset \left\{ \frac{1}{6} \right\} \lambda\sqrt{f'c} * bw * d =$ .75*1/6 * $\sqrt{28}$ * 1000*360 /1000= 238 KN

V_u = ∂_{u*} (L-d) = 400(0.55-0.36) =76 KN

V_u < $\emptyset v_c$ (ok)

Reinforcement :

Longitudinal direction : (along B)

M_u (along B) =(∂_u * L^2) /2 = 400*.0.55*0.55 /2 = 60.5KN.m /m

$M_{u=\ 60.5\ KN.m/m}$, d = 360 mm , b=1000mm

$\rho = \frac{0.85f'c}{f_y}(1-\sqrt{1-\frac{2.61M_u}{bd^2f'c}})$, $A_s = \rho * b *$d , ρ=0.00124,

$A_s = 0.00124 * 1000 * 360 = 449\ mm2/m$

Asmin = $\rho * b *$h = 0.0018*1000*450 = 810 mm2/m >As (use As=810 mm2/m)

Total Longitudinal steel = A_s * L =810*1.6= 1296 mm2 (12ø12)

Transverse direction: (along L)

M_u (along B) =(∂_u * L^2) /2 = 400*.0.55*0.55 /2 = 60.5KN.m /m

$M_{u=\ 60.5\ KN.m/m}$, d = 360 mm , b=1000mm

$\rho = \frac{0.85f'c}{f_y}(1 - \sqrt{1 - \frac{2.61M_u}{bd^2 f'c}})$, $A_s = \rho * b$ *d , ρ=0.00124,

$A_s = 0.00124 * 1000 * 360 = 449\ mm2/m$

Asmin = $\rho * b$ *h = 0.0018*1000*450 = 810 mm2/m >As (use As=810 mm2/m)

Total Longitudinal steel = A_s * L =810*1.6= 1296 mm2 (12ø12)

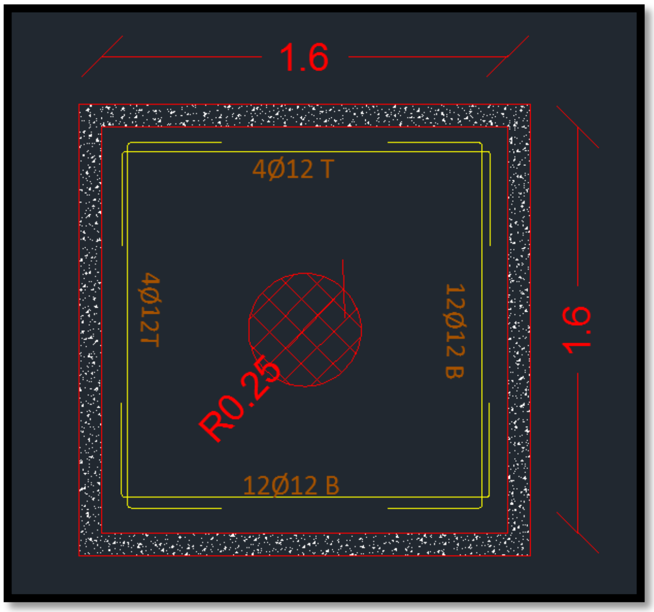


Figure 205 : reinforcement of footing

Ld bottom bar = 50db = 0.6m

Available length < Ld need hooked.

Design single footing for column :

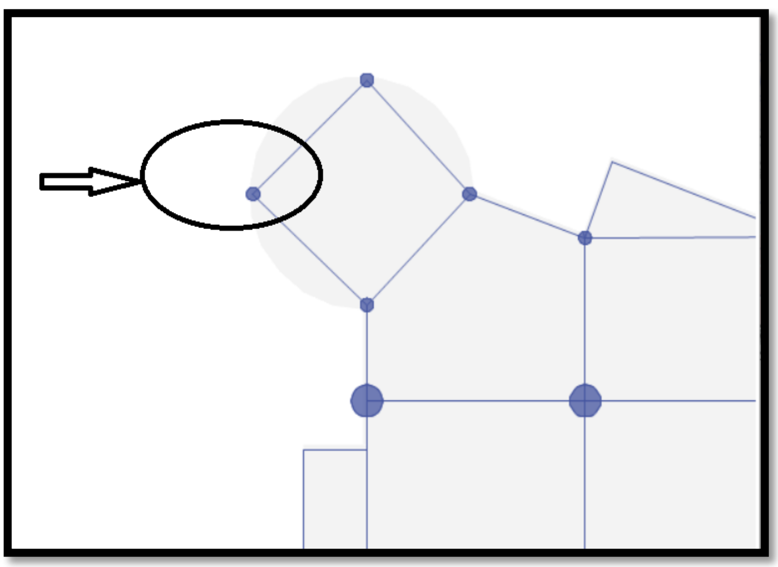


Figure 206 : location of column

q_{all}=300 KN/m^2
The axial load(service) =765 KN (from sap)
The axial load(ultimate)=1025 KN(from sap)

Dimensions :
∂_{max} =(P/B*L)= 300
Guess B to find L , so B = √(P/ q_{all})
B=√(765/300)=1.59 use B=1.6m
∂_{max} =(765/1.6*L)= 300>> L=1.59 use L=1.6m
$\partial_{max=}$ (765/1.6*1.6) =299< 300 (ok)

Thickness :
P_u= 1.2 * P_D + 1.6* P_L =1227 KN (from ETAB)
$\partial_{u,}$ = (Pu/B*L)= 1025/1.6*1.6 = 400 KN/m2
Assume the punching failure will occure first
Guess thickness acoording to punching d= 10√P_u d in mm , P in KN
.d= 10√1025 =320mm use d = 360 mm
h= d + cover = 360+90= 450mm

check punching

$$\emptyset v_{cp} = \emptyset\, min\{\begin{matrix} 1/3 \\ 1/6(1+2/Bc \end{matrix}\}\lambda\sqrt{f'c}\, b_0 d$$ Bc =البعد الاصغر /البعد الاطول للعمود

$\emptyset v_{cp}$ = .75*1/3*1*$\sqrt{28}$* (4270)*360 /1000 = 2034 KN
V_{up} = P_u – (stress *area p) = 1025 -(400*1.45) = 445 KN
$\emptyset v_{cp}$ > V_{up} (OK)
Wide beam shear :
$\emptyset v_c = \emptyset \left\{\frac{1}{6}\right\} \lambda\sqrt{f'c} * bw * d =$ .75*1/6 * $\sqrt{28}$ * 1000*360 /1000= 238 KN
V_u = ∂_{u*} (L-d) = 400(0.55-0.36) =76 KN
V_u < $\emptyset v_c$ (ok)

Reinforcement :
Longitudinal direction : (along B)
M_u (along B) =(∂_u * L^2) /2 = 400*.0.55*0.55 /2 = 60.5KN.m /m
$M_{u= 60.5\ KN.m/m}$, d = 360 mm , b=1000mm
$\rho = \frac{0.85f'c}{fy}(1-\sqrt{1-\frac{2.61M_u}{bd^2 f'c}})$, $A_s = \rho * b$ *d , ρ=0.00124,
$A_s = 0.00124 * 1000 * 360 = 449\ mm2/m$
Asmin = $\rho * b$ *h = 0.0018*1000*450 = 810 mm2/m >As (use As=810 mm2/m)
Total Longitudinal steel = A_s * L =810*1.6= 1296 mm2 (12ø12)

Transverse direction: (along L)

M_u (along B) =(∂_u * L^2) /2 = 400*.0.55*0.55 /2 = 60.5KN.m /m

$M_{u= 60.5\ KN.m/m}$, $_d$ = 360 mm , b=1000mm

$\rho = \frac{0.85f'c}{f_y}(1 - \sqrt{1 - \frac{2.61M_u}{bd^2f'c}})$, $A_s = \rho * b *$d , ρ=0.00124,

$A_s = 0.00124 * 1000 * 360 = 449\ mm2/m$

Asmin = $\rho * b *$h = 0.0018*1000*450 = 810 mm2/m >As (use As=810 mm2/m)

Total Longitudinal steel = A_s * L =810*1.6= 1296 mm2 (12ø12)

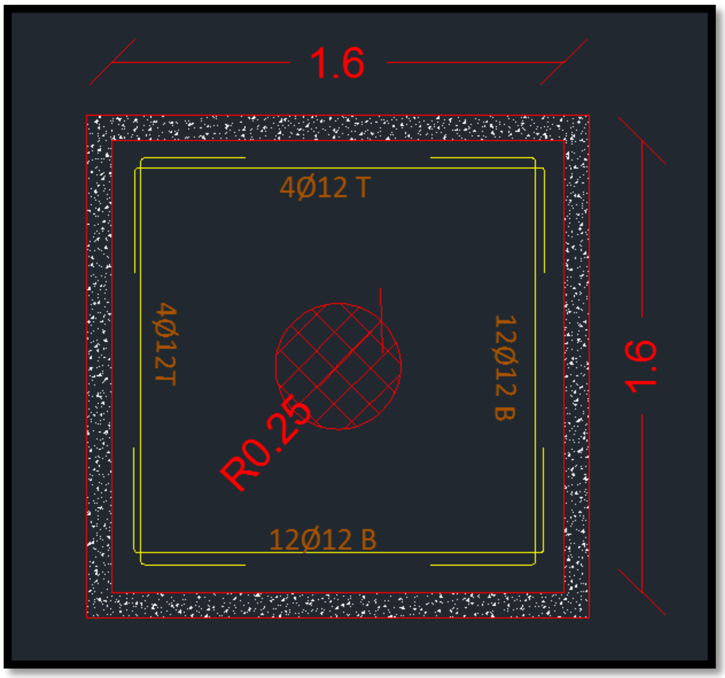


Figure 207 : reinforcement of footing

Ld bottom bar = 50db = 0.6m

Available length < Ld need hooked.

NOTE: See attached AUTOCAD sheets that shows detail of footing .

3.3.4.9. Mat Footing design

In this project, mat foundation was used because the bearing capacity is low and the project consist from 23 floors . Etab 2015 software program was used to design the mat foundation .

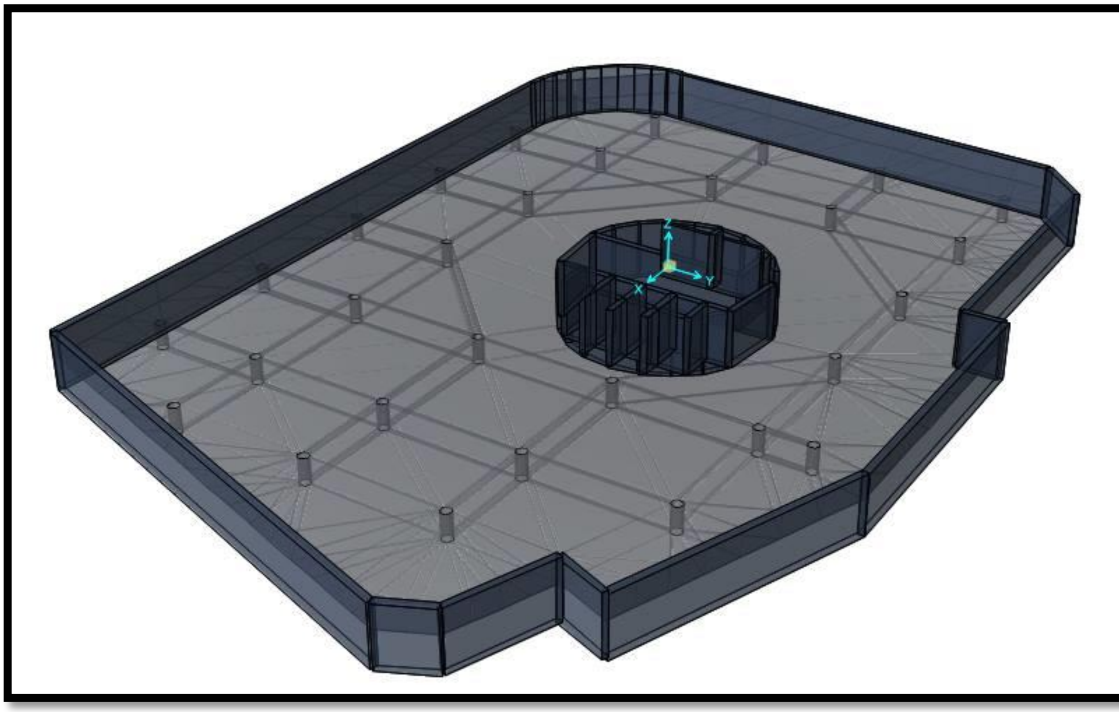


Figure 208 : Mat footing in safe program .

First of all , we assume the thickness of mat 1700 mm. Therefore, the deflection, punching, and wide beam shear must be checked to insure the modal and thickness is ok .

- **Defelction check**

The max deflection allowable in footing = $\frac{q\text{all}}{\text{spring force}} = \frac{\mathbf{300}}{\mathbf{30000}}$ = 10 mm

Max Deflection(ETAB's) = 11.6 mm

The figure below show the maximum deflection in mat from ETAB'S program = 11.6 mm

Δallowable < ΔETABs not OK but we accept that

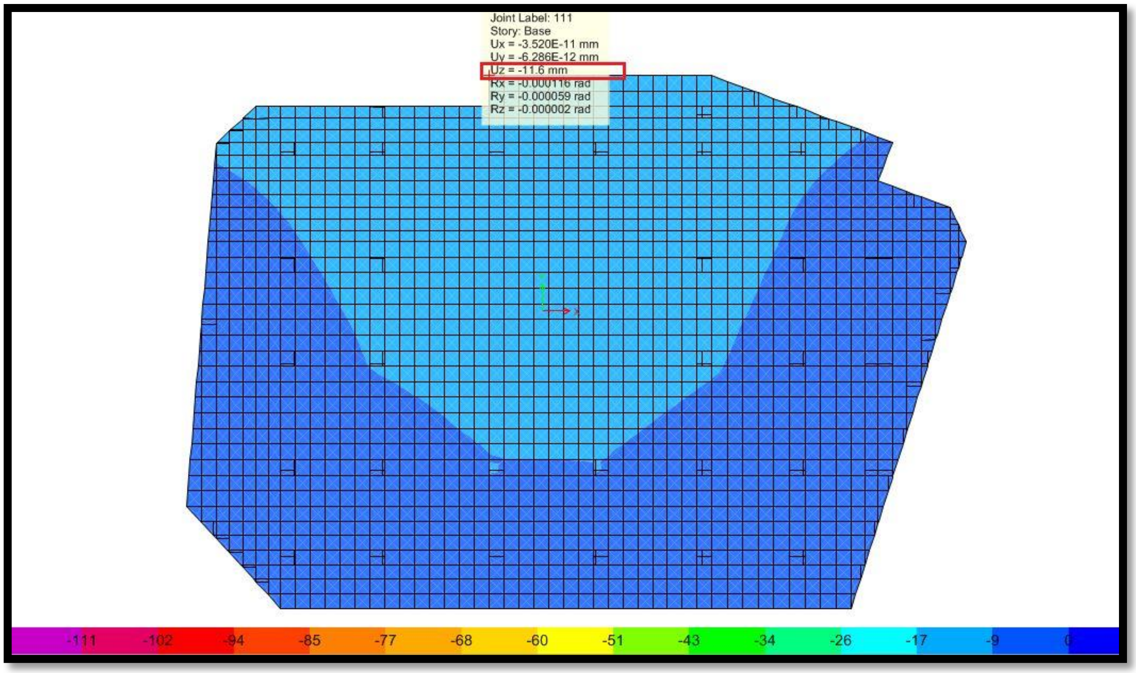


Figure 209 : MAX deflection and deflection shape in mat footing from ETABs.

- **Check Punching Shear :**

σu = qall = 300 KN/m2

Center column(critical):

Vu = Pu - σu A = 21464 – 300 (6.15)
= 19617.6 KN

$\emptyset$ Vc = $\frac{0.75}{3*1000}\sqrt{48}$ bo d = $\frac{0.75}{3000}\sqrt{48}$ (8792) * 1600
$\emptyset$ Vc = 24365 KN
$\emptyset$ Vc > Vu OK

- **Wide Beam Shear:**

$\emptyset v_c = \emptyset \left\{\frac{1}{6}\right\} \lambda\sqrt{f'c} * bw * d =$ .75*1/6 * $\sqrt{48}$ * 1000*1600 /1000= 1385.6 KN/m

$Vu\Big|_{d}$ max = 1270 KN/m   as shown in the figure belolow.

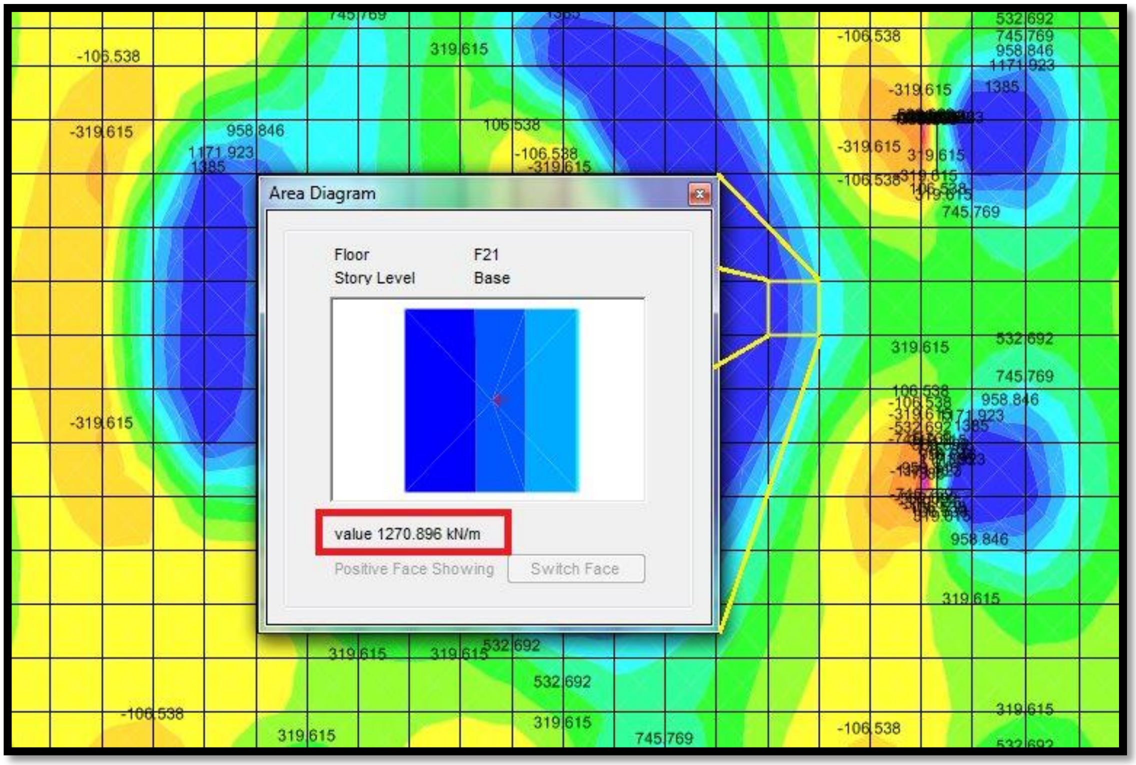


Figure 210 : max shear in matt foundation

- **Reinforcement steel:**

First, 8 Ø 25 mm/m was used. Then:

$$. a = \frac{As*Fy}{0.85*fc*bw} = \frac{3925*420}{0.85*48*1000} = 40.4 \text{ mm}$$

$$ØMn. \text{ min,max} = 0.9 * As * Fy *(d-\frac{a}{2}) *10^{-6} = 0.9 * 3925 *420 *(1600-\frac{40}{2}) *10^{-6}$$

ØMn. min,max = 2344 KN.m /m

From figure shown below , 8 Ø 25 mm/m was enough to resist the moment 1-1 accept in blue regions And from next figure shown below , 8 Ø 25 mm/m was enough to resist the moment 2-2 accept in blue regions.

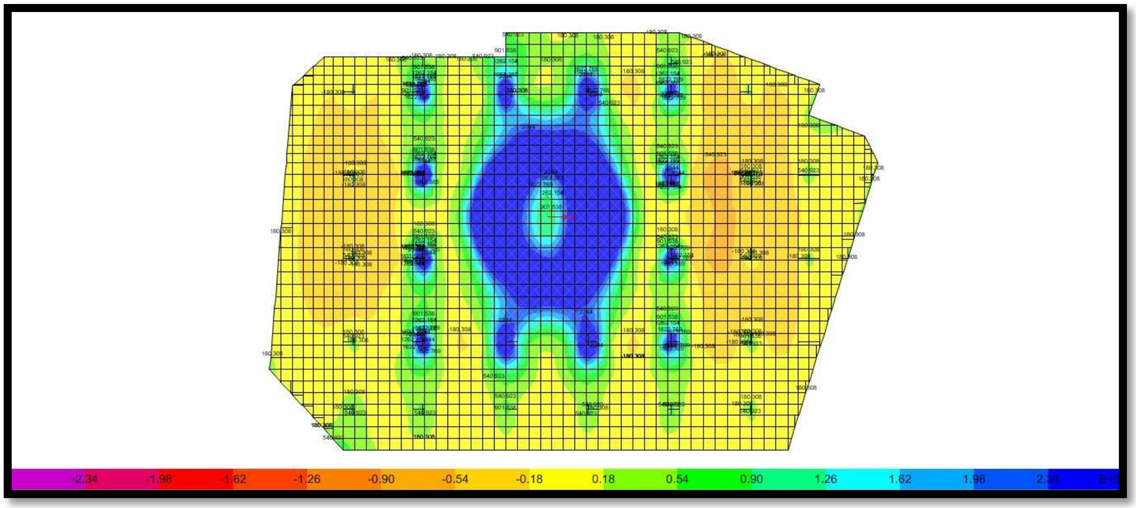


Figure 211 : The moment 1-1 values in mat from ETABs (when 8 Ø 25 mm/m was used).

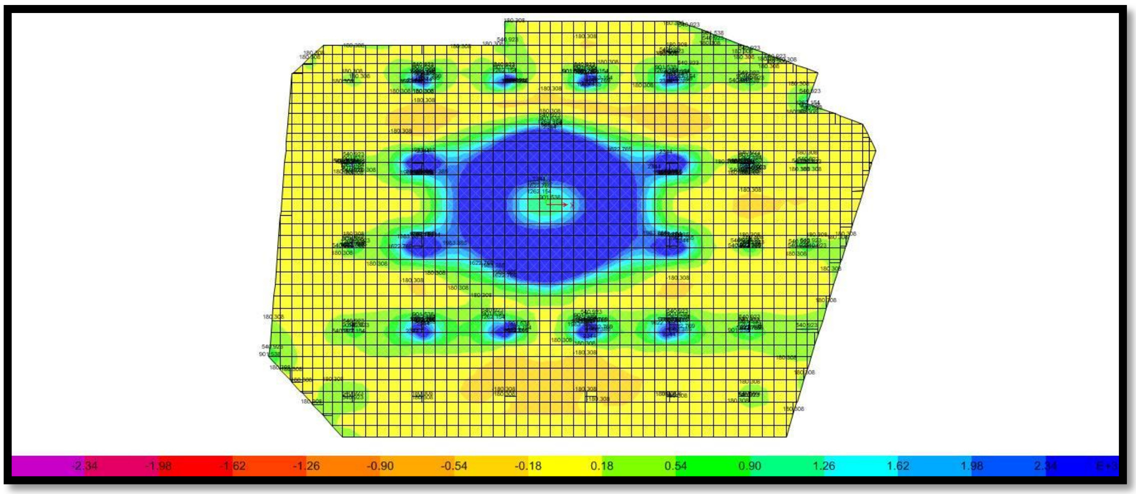


Figure 212 : The moment 2-2 values in mat from ETABs (when 8 Ø 25 mm/m was used).

In these(blue regions), the enlarge area of steel were needed. Therefore,
16 Ø 32 mm/m was used. Then:

. $a = \frac{As*Fy}{0.85*fc*bw} = \frac{12861*420}{0.85*48*1000} = 132$ mm

$ØMn.\ min,max = 0.9 * As * Fy *(d-\frac{a}{2}) *10^{-6} = 0.9 * 12861*420 *(1600-\frac{132}{2}) *10^{-6}$

ØMn. min,max = 7457 KN.m /m

From figure shown below these regions are in moment range(-7457,7457). Therefore,
16 Ø 32 mm/m was used.

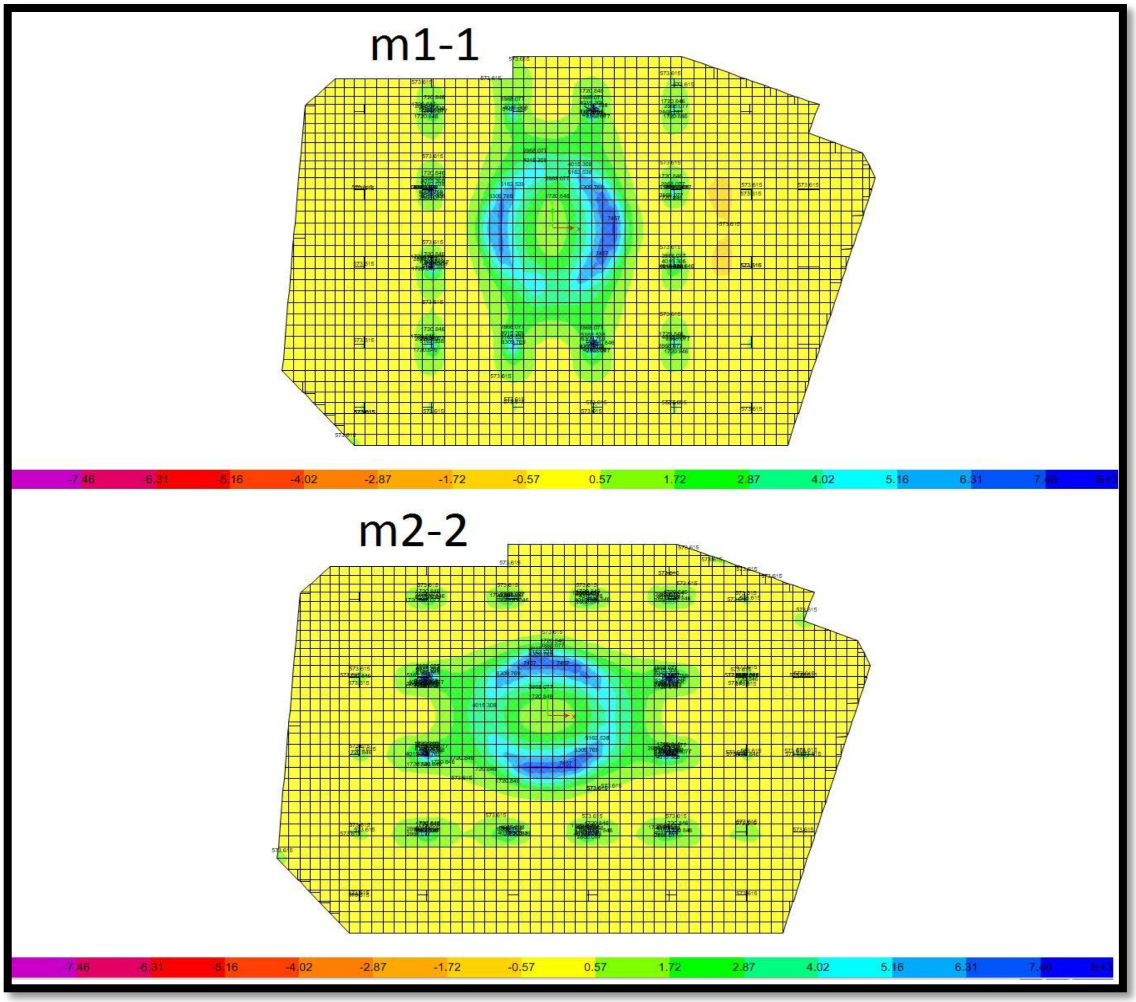


Figure 213 : The moment 2-2and 1-1 values in mat from ETABs (when 16 Ø 32 mm/m was used).

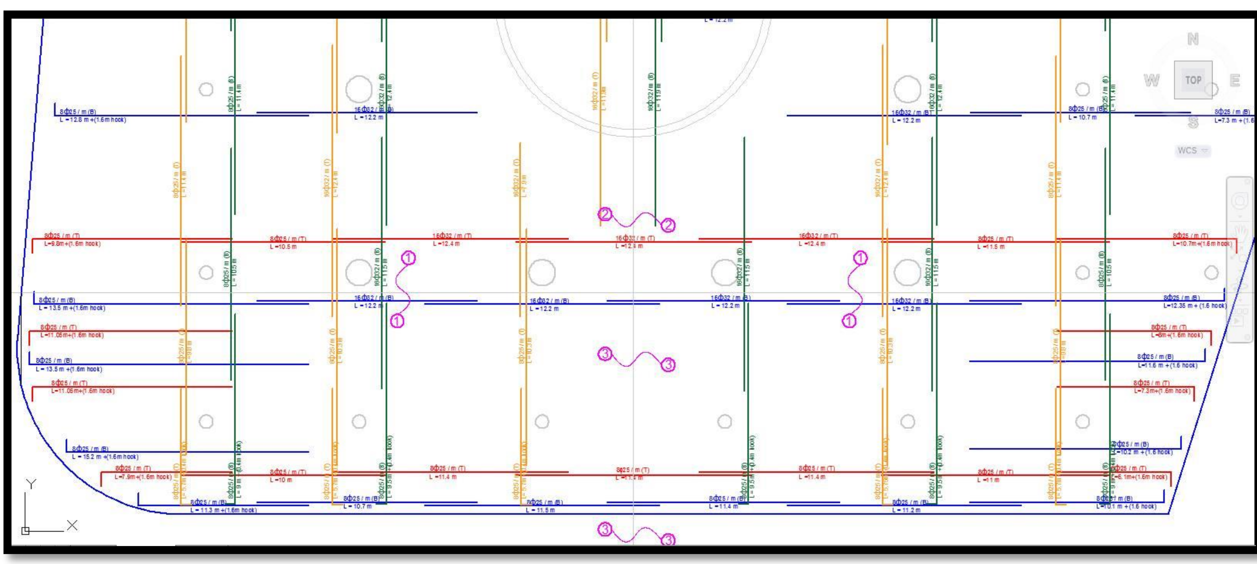


Figure 214 : reinforcement of mat foundation

3.4.Mechanical design
3.4.1. Introduction

Mechanical systems involve any building service using machines. They include water supply and drainage system. heating and air-conditioning systems (HVAC), vertical transportation (elevators and escalators), fire protection .

3.4.2.Water Supply Design

Offices building require an adequate supply water for bathrooms, kitchen,
Laundry room, fire resistance ...etc . Which require well-design of piping system to have suitable pressure at the point of use inside the offices to achieve required flow. These convenience and sanitation objectives result in prescribed pressures that must be maintained at the various fixtures to ensure the proper flow rates.

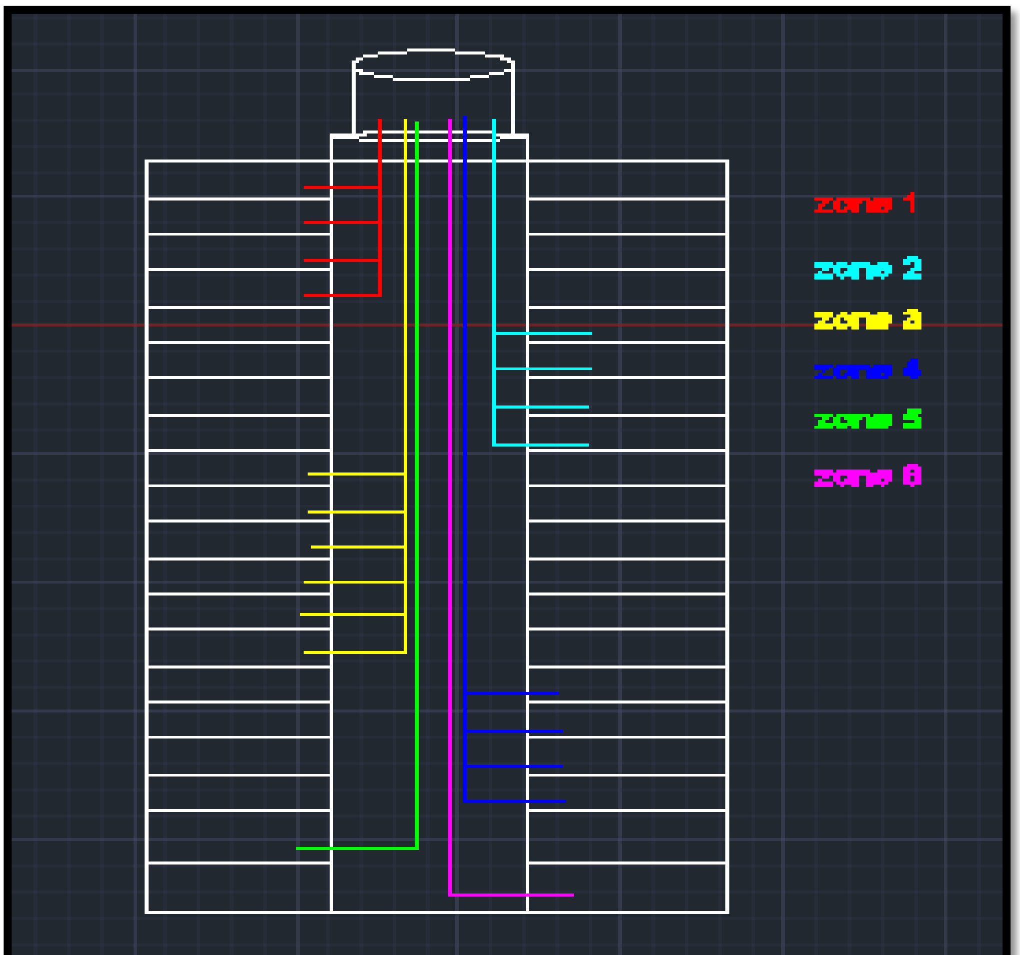


Figure 215 : zones for Water Supply Design

Design for zone 1 which include floors (15,16,17,18) :

Table 33 : Total fixture unite in zone 1

Type	Weight of fu's	number of fu's in floor	Number of floor	Total fu's
Lavatory	2	8	4	64
Kitchen sink	2	2	4	16
Water closet (flush tank)	5	8	4	160
				240

- ✓ Total fixture unite in this floors = 240 FU`s.
- ✓ FU`s (vertical line) = 240 Fu's.
- ✓ FU`s (horizontal line) = 60 Fu's.

- The worst case which have the max. Pressure that is shower =12 psi

- ✓ FU`s (branch line) = 5 Fu's.

- **Water Demand** : (depending on # of FU`s)

- Vertical line = 100 gpm.
- Horizontal line = 55 gpm.
- Branch line = 5 gpm.

- ✓ Length of vertical line = 52 ft
- ✓ Length of branch line = 23 ft

- **Approximately equivalent length** of :

- Vertical line (metal pipe) = 52 * 1.5 = 78 `
- Horizontal line (PVC pipe) = 36* 1.2 ≈ 44`
- Branch line (PVC pipe) = 23 * 1.2 ≈28`

➤ Available pressure = h * 0.433.

= (52) *0.43 = 22.5 psi.

- Critical fixture unite pressure (shower) = 12psi.
- ✓ Available pressure to lose by fitting = 22.5 - 12 = 10.5 psi

For vertical pipe

100 gpm

Length = 78 ft

Table 34 : pressure loss in vertical pipe

Pipe diameter	5`	4`	3.5`	3`	2.5`
Loss/100	0.15	0.45	0.9	2	4.5
Loss/78	0.117	0.35	0.7	1.56	3.51

For horizontal pipe
55 gpm
Length = 44 ft

Table 35 : pressure loss in horizantal pipe

Pipe diameter	4`	3.5`	3`	2.5`	2`
Loss/100	0.17	0.33	0.8	1.7	5.5
Loss/44	0.075	0.145	0.352	0.748	2.42

For branch pipe
5 gpm
Length =28 ft

Table 36 : pressure loss in branch pipe (zone 1)

Pipe diameter	1.5`	1.25`	1`	0.75`	0.5`
Loss/100	0.2	0.5	1.4	6	40
Loss/28	0.056	0.14	0.392	1.68	8.5

Best choice :

Table 37 : best choise of pipes

Type	Diameter	loss
Vertical	2.5`	3.51
Horizontal	2`	2.42
Branch	0.75`	1.68
Total losses		7.61

• available pressure to lose by fitting = 10.5 psi > 7.61 psi →ok

We have to reduce the pressure by using globe valve before collection by 3 psi

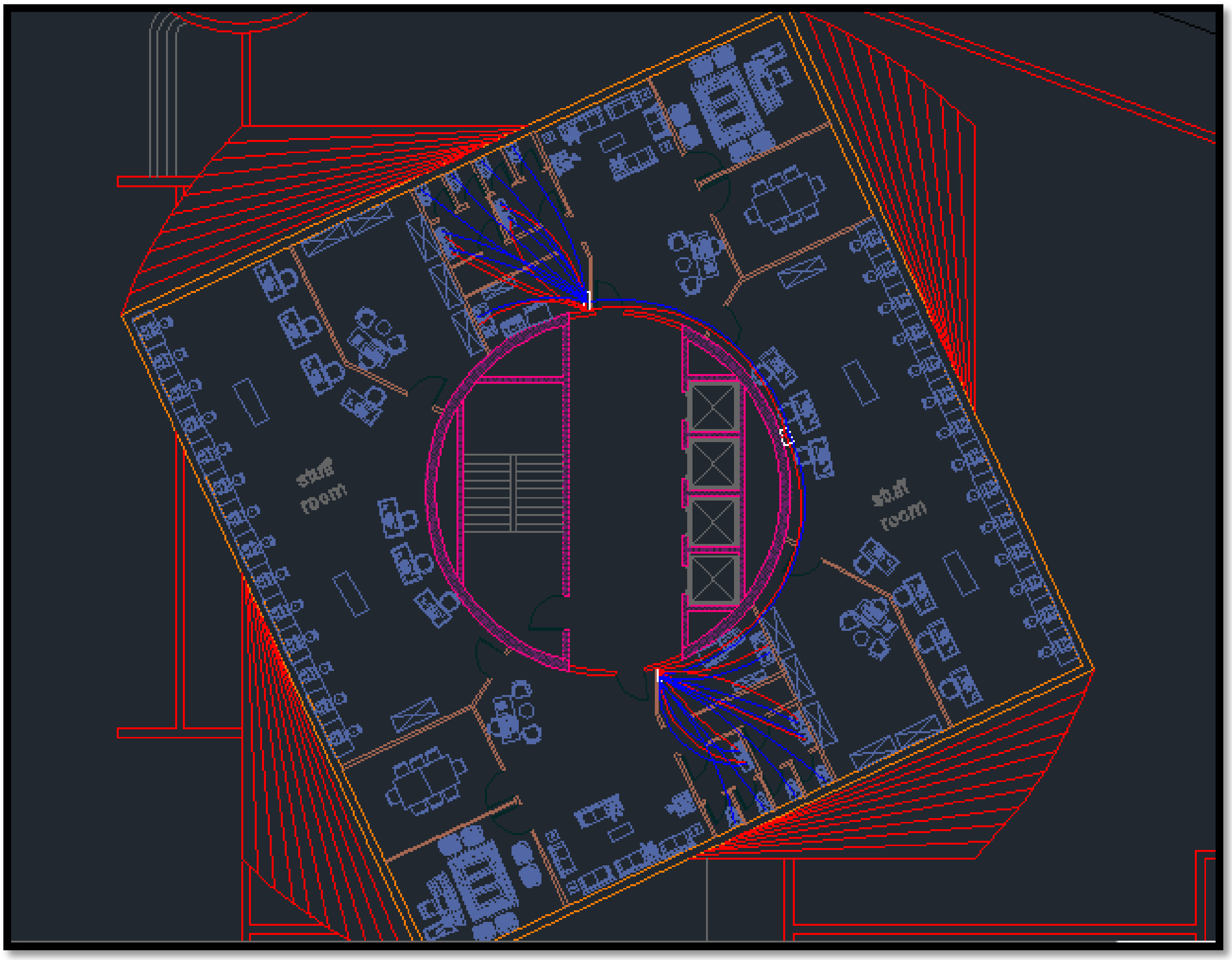


Figure 216 : mechanical plan for zone 1

Design for zone 2 which include floors (11/12/13/14)

Table 38 : Total fixture unite in zone 2

Type	Weight of fu's	number of fu's in floor	Number of floor	Total fu's
Lavatory	2	8	4	64
Kitchen sink	2	2	4	16
Water closet (flush tank)	5	8	4	160
				240

- ✓ Total fixture unite in this floors = 240 FU`s.
- ✓ FU`s (vertical line) = 240 Fu's.
- ✓ FU`s (horizontal line) = 60 Fu's.

- The worst case which have the max. Pressure that is water closet =10 psi

- ✓ FU`s (branch line) = 5 Fu's.

- **Water Demand** : (depending on # of FU`s)

- Vertical line = 100 gpm.
- Horizontal line = 55 gpm.
- Branch line = 5 gpm.

- ✓ Length of vertical line = 98 ft
- ✓ Length of branch line = 23 ft

- **Approximately equivalent length** of :

- Vertical line (metal pipe) = 98 * 1.5 = 147 `
- Horizontal line (PVC pipe) = 36* 1.2 ≈ 44`
- Branch line (PVC pipe) = 23 * 1.2 ≈28`

- ⅄ Available pressure = h * 0.433.

  = (98) *0.43 = 42.4 psi.

- Critical fixture unite pressure (water closet) = 10psi.
- ✓ Available pressure to lose by fitting = 42.4 - 10 = 32.4 psi

For vertical pipe
100 gpm
Length = 147 ft

Table 39 : pressure loss in vertical pipe

Pipe diameter	5`	4`	3.5`	3`	2.5`
Loss/100	0.15	0.45	0.9	2	4.5
Loss/147	0.22	0.66	1.32	2.94	6.615

For horizontal pipe
55 gpm
Length = 44 ft

Table 40 : pressure loss in horizantal pipe

Pipe diameter	4`	3.5`	3`	2.5`	2`
Loss/100	0.17	0.33	0.8	1.7	5.5
Loss/44	0.075	0.145	0.352	0.748	2.42

For branch pipe
5 gpm
Length =28 ft

Table 41 : pressure loss in branch pipe

Pipe diameter	1.5`	1.25`	1`	0.75`	0.5`
Loss/100	0.2	0.5	1.4	6	40
Loss/28	0.056	0.14	0.392	1.68	11.2

Best choice

Table 42 : best choice of pipe in zone 2

Type	Diameter	loss
Vertical	3	1.56
Horizontal	2`	2.42
Branch	0.75`	11.2
Total losses		15.18

● available pressure to lose by fitting = 32.4 psi > 15.18 psi →ok

We have to reduce the pressure by using globe valve before collection by 17 psi

Design for zone 3 which include floors (5/6/7/8/9/10)

Table 43 : Total fixture unite in zone 3 floors

Type	Weight of fu’s	number of fu’s in floor	Number of floor	Total fu’s
Lavatory	2	4	6	48
Kitchen sink	2	4	6	48
Water closet (flush tank)	5	4	6	120
				216

- ✓ Total fixture unite in this floors = 216 FU`s.
- ✓ FU`s (vertical line) = 216 Fu’s.
- ✓ FU`s (horizontal line) = 36 Fu’s.

- The worst case which have the max. Pressure that is water closet =10 psi

- ✓ FU`s (branch line) = 5 Fu’s.

- **Water Demand** : (depending on # of FU`s)

- Vertical line = 95 gpm.
- Horizontal line = 45 gpm.
- Branch line = 5 gpm.
- ✓ Length of vertical line = 167 ft
- ✓ Length of branch line = 48 ft

- **Approximately equivalent length** of :

- Vertical line (metal pipe) = 167 * 1.5 = 251 `
- Horizontal line (PVC pipe) = 36* 1.2 ≈ 44`
- Branch line (PVC pipe) = 23 * 1.2 ≈28`
- ⅄ Available pressure = h * 0.433.

  = (167) *0.43 = 72.3 psi.

- Critical fixture unite pressure (water closet) = 10psi.
- ✓ Available pressure to lose by fitting = 72.3 - 10 = 62.3 psi

For vertical pipe
95 gpm
Length = 251 ft

Table 44 : pressure loss in vertical pipe (zone 3)

Pipe diameter	5`	4`	3.5`	3`	2.5`
Loss/100	0.13	0.41	0.8	1.8	4.2
Loss/251	0.33	1.03	2	4.5	10.54

For horizontal pipe
45 gpm
Length = 44 ft

Table 45 : pressure loss in horizantal pipe (zone 3)

Pipe diameter	3.5`	3`	2.5`	2`	1.5`
Loss/100	0.17	0.4	1	3	12
Loss/44	0.062	0.176	0.44	1.32	5.28

For branch pipe
5 gpm
Length =28 ft

Table 46 : pressure loss in bravch pipe (zone 3)

Pipe diameter	1.5`	1.25`	1`	0.75`	0.5`
Loss/100	0.2	0.5	1.4	6	40
Loss/28	0.056	.14	0.392	1.68	11.2

Best choice

Table 47 : best choice of pipe in zone 3

Type	Diameter	loss
Vertical	2.5`	10.54
Horizontal	1.5`	5.25
Branch	0.5`	11.2
Total losses		27

• available pressure to lose by fitting = 62.3 psi > 27 psi →ok

We have to reduce the pressure by using globe valve before collection by 36 psi

Design for zone 4 which include floors (1/2/3/4)

Table 48 : Total fixture unite in zone 4 floors

Type	Weight of fu's	number of fu's in floor	Number of floor	Total fu's
Lavatory	2	4	4	32
Kitchen sink	2	4	4	32
Water closet (flush tank)	5	4	4	80
				144

✓ Total fixture unite in this floors = 144 FU`s.
✓ FU`s (vertical line) = 144 Fu's.
✓ FU`s (horizontal line) = 36 Fu's.
- The worst case which have the max. Pressure that is water closet =10 psi

✓ FU`s (branch line) = 5 Fu's.

▪ **Water Demand** : (depending on # of FU`s)
- Vertical line = 80 gpm.
- Horizontal line = 45 gpm.
- Branch line = 5 gpm.
✓ Length of vertical line = 213 ft
✓ Length of branch line = 23 ft
▪ **Approximately equivalent length** of :
- Vertical line (metal pipe) = 213 * 1.5 = 320 `
- Horizontal line (PVC pipe) = 36* 1.2 ≈ 44`
- Branch line (PVC pipe) = 23 * 1.2 ≈58`
⅄ Available pressure = h * 0.433.
= (213) *0.43 = 92.3 psi.
▪ Critical fixture unite pressure (water closet) = 10psi.
✓ Available pressure to lose by fitting = 92.3 - 10 = 82.3 psi

For vertical pipe
80 gpm
Length = 320 ft

Table 49 : pressure loss in vertical pipe (zone 4)

Pipe diameter	5`	4`	3.5`	3`	2.5`	2`
Loss/100	0.11	0.3	0.6	1.3	3	9
Loss/320	0.352	0.96	1.92	4.16	9.6	28.8

For horizontal pipe
45 gpm
Length = 44 ft

Table 50 : pressure loss in horizontal pipe (zone 4)

Pipe diameter	3.5`	3`	2.5`	2`	1.5`
Loss/100	0.17	0.4	1	3	12
Loss/44	0.075	0.176	0.44	1.32	5.28

For branch pipe
5 gpm
Length =28 ft

Table 51 : pressure loss in branch pipe (zone 4)

Pipe diameter	1.5`	1.25`	1`	0.75`	0.5`
Loss/100	0.2	0.5	1.4	6	40
Loss/28	0.056	0.14	0.392	1.68	11.2

Best choice

Table 52 : best choice of pipe in zone 4

Type	Diameter	loss
Vertical	2`	28.8
Horizontal	1.5`	5.28
Branch	0.5`	11.2
Total losses		45.28

• available pressure to lose by fitting = 82.3 psi > 45.28 psi →ok

We have to reduce the pressure by using globe valve before collection by 37 psi

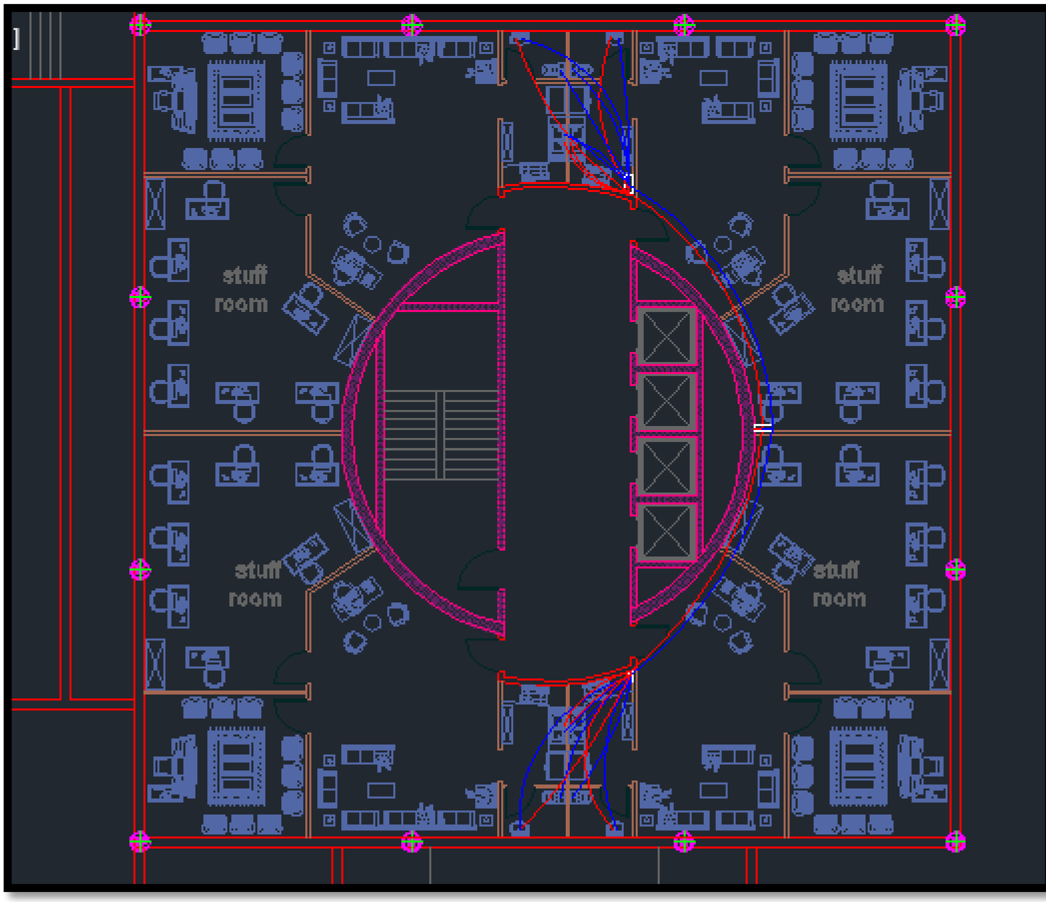


Figure 217 : mechanical plan for floor 1

Design for zone 5 which include floor (podium 2)

Table 53 : Total fixture unite in podium 2 floor

Type	Weight of fu's	number of fu's in floor	Number of floor	Total fu's
Lavatory	2	8	1	16
Kitchen sink	2	4	1	8
Water closet (flush tank)	5	8	1	40
				64

- ✓ Total fixture unite in this floor = 64 FU`s.
- ✓ FU`s (vertical line) = 64 Fu’s.
- ✓ FU`s (horizontal line) = 64 Fu’s.

- The worst case which have the max. Pressure that is water closet =10 psi

- ✓ FU`s (branch line) = 5 Fu’s.

- **Water Demand** : (depending on # of FU`s)

- Vertical line =54 gpm.
- Horizontal line = 54 gpm.
- Branch line = 5 gpm.

- ✓ Length of vertical line = 230 ft
- ✓ Length of branch line = 17 ft

- **Approximately equivalent length** of :

- Vertical line (metal pipe) = 230 * 1.5 = 345 `
- Horizontal line (PVC pipe) = 58* 1.2 ≈ 70`
- Branch line (PVC pipe) = 17 * 1.2 ≈21`

⅄ Available pressure = h * 0.433.

= (230) *0.43 = 99.6 psi.

- Critical fixture unite pressure (water closet) = 10psi.
- ✓ Available pressure to lose by fitting = 99.6 - 10 = 89.6 psi

For vertical pipe

54 gpm

Length = 320 ft

Table 54 : pressure loss in vertical pipe (podium 2)

Pipe diameter	4`	3.5`	3`	2.5`	2`
Loss/100	0.13	0.25	0.6	1.5	4.5
Loss/345	0.45	0.86	2.07	5.18	15.5

For horizontal pipe
54 gpm
Length = 70 ft

Table 55 : pressure loss in horizontal pipe (podium 2)

Pipe diameter	**4`**	**3.5`**	**3`**	**2.5`**	**2`**
Loss/100	0.13	0.25	0.6	1.5	4.5
Loss/70	0.091	0.175	0.42	1.05	3.15

For branch pipe
5 gpm
Length =21 ft

Table 56 : pressure loss in branch pipe (podium 2)

Pipe diameter	**1.5`**	**1.25`**	**1`**	**0.75`**	**0.5`**
Loss/100	0.2	0.5	1.4	6	40
Loss/21	0.042	0.105	0.294	1.26	8.4

Best choice

Table 57 : best choice of pipe in podium 2

Type	**Diameter**	**loss**
Vertical	2`	15.5
Horizontal	2`	3.15
Branch	0.5`	8.4
Total losses		27.05

- available pressure to lose by fitting = 89.6 psi > 27.05 psi →ok

We have to reduce the pressure by using globe valve before collection by 63 psi

Design for zone 6 which include floors (podium 1)

Table 58 : Total fixture unite in podium 1 floor

Type	Weight of fu's	number of fu's in floor	Number of floor	Total fu's
Lavatory	2	2	1	4
Kitchen sink	2	1	1	2
Water closet (flush tank)	5	2	1	10
				16

- ✓ Total fixture unite in this floor = 16 FU`s.
- ✓ FU`s (vertical line) = 16 Fu's.
- ✓ FU`s (horizontal line) = 16 Fu's.

- The worst case which have the max. Pressure that is water closet =10 psi

- ✓ FU`s (branch line) = 5 Fu's.

- **Water Demand** : (depending on # of FU`s)

- Vertical line =32 gpm.
- Horizontal line = 32 gpm.
- Branch line = 5 gpm.

- ✓ Length of vertical line = 247 ft
- ✓ Length of branch line = 12 ft

- **Approximately equivalent length** of :

- Vertical line (metal pipe) = 247 * 1.5 = 371 `
- Horizontal line (PVC pipe) = 41* 1.2 ≈ 50`
- Branch line (PVC pipe) = 12 * 1.2 ≈15`

➤ Available pressure = h * 0.433.

= (247) *0.43 = 107 psi.

- Critical fixture unite pressure (water closet) = 10psi.
- ✓ Available pressure to lose by fitting = 107 - 10 = 97 psi

For vertical pipe
32 gpm
Length = 371 ft

Table 59 : pressure loss in vertical pipe (podium 1)

Pipe diameter	3`	2.5`	2`	1.5`	1.25`
Loss/100	0.23	0.51	1.7	6.5	16
Loss/371	0.85	1.89	6.3	24.1	59.36

For horizontal pipe
32 gpm
Length = 50 ft

Table 60 : pressure loss in horizontal pipe (podium 1)

Pipe diameter	3`	2.5`	2`	1.5`	1.25`
Loss/100	0.23	0.51	1.7	6.5	16
Loss/50	0.115	0.255	0.85	3.25	8

For branch pipe
5 gpm
Length =15 ft

Table 61 : pressure loss in branch pipe (podium 1)

Pipe diameter	1.5`	1.25`	1`	0.75`	0.5`
Loss/100	0.2	0.5	1.4	6	40
Loss/15	0.03	0.075	0.21	0.9	6

Best choice

Table 62 : best choice of pipe in podium 1

Type	Diameter	loss
Vertical	1.25`	59.36
Horizontal	1.25`	8
Branch	0.5`	6
Total losses		73.4

• available pressure to lose by fitting = 97 psi > 73.4 psi →ok
We have to reduce the pressure by using globe valve before collection by 24 psi

3.4.3. Water Drainage Design

The water piping system for drainage design depends on the natural flow and diameter of pipe. during the design phase the following steps will be used .

1- Determine drainage fixture unit value (dfu) for each unit

PART A. BY TYPE OF FIXTURE			
Fixture(s)	Drainage Fixture Units (dfu)	*Minimum Trap Size* in.	*Minimum Trap Size* mm[a]
Automatic clothes washers: Commercial[b]	3	2	51
Residential	2	2	51
Bathroom group: Water closet (1.6 gpf [6 Lpf]), lavatory, and bathtub or shower; with or without a bidet and emergency floor drain	5	—	—
Bathroom group: Water closet (>1.6 gpf [6 Lpf]), lavatory, and bathtub or shower; with or without a bidet and emergency floor drain	6	—	—
Bathtub[c] (with or without overhead shower or whirlpool	2	1½	38
Bidet	1	1¼	32
Combination sink and tray	2	1½	38
Dental lavatory	1	1¼	32
Dental unit or cuspidor	1	1¼	32
Dishwashing machine[d], domestic	2	1½	38
Drinking fountain	0.5	1¼	32
Emergency floor drain	0	2	51
Floor drains	2	2	51
Kitchen sink, domestic	2	1½	38
Kitchen sink, domestic, with food waste grinder and/or dishwasher	2	1½	38
Laundry tray (1 or 2 compartments)	2	1½	38
Lavatory	1	1¼	32
Shower	2	1½	38
Service sink	2	1½	38
Sink	2	1½	38
Urinal	4	[e]	
Urinal, 1 gal (3.8 L) per flush or less	2[f]	[e]	
Urinal, nonwater supplied	0.5	[e]	
Wash sink (circular or multiple) each set of faucets	2	1½	38
Water closet, flushometer tank, public or private	4[f]	[e]	
Water closet, private (1.6 gpf [6 Lpf])	3[f]	[e]	
Water closet, private (>1.6 gpf [6 Lpf])	4[f]	[e]	
Water closet, public (1.6 gpf [6 Lpf])	4[f]	[e]	
Water closet, public (flushing >1.6 gpf [6 Lpf])	6[f]	[e]	

Figure 218 : Drainage fixture units (DFU's) [24]

2- Diameter of pipe and slop:

Diameter of Pipe			Maximum Total Number of dfu Allowable		
			Stacks[b]		
in.	mm[c]	Horizontal Branch	One Branch Interval	Three Branch Intervals or Less	Greater than Three Branch Intervals
1½	38	3	2	4	8
2	51	6	6	10	24
2½	64	12	9	20	42
3	76	20	20	48	72
4	102	160	90	240	500
5	127	360	200	540	1100
6	152	620	350	960	1900
8	203	1400	600	2200	3600
10	254	2500	1000	3800	5600
12	305	3900	1500	6000	8400
15	381	7000	d	d	d

Figure 219 : Horizontal fixture branches and stacks [25]

the slope of 4" equals 1% and for 2" equals 2%.

3- Make vent to avoid water siphonage

Diameter of Soil or Waste Stack in. (mm)[b]	Total Fixture Units Being Vented (dfu)	Maximum Developed Length[a] of Vent, Feet (m)[b]									
		Diameter of Vent, In. (mm)[b]									
		1¼ (32)	1½ (38)	2 (51)	2½ (64)	3 (76)	4 (102)	5 (127)	6 (152)	8 (203)	10 (254)
1¼ (32)	2	30 (9.1)									
1½ (38)	8	50 (15.2)	150 (45.7)								
1½ (38)	10	30 (9.1)	100 (30.5)								
2 (51)	12	30 (9.1)	75 (22.9)	200 (61.0)							
2 (51)	20	26 (7.9)	50 (15.2)	150 (45.7)							
21/2 (64)	42		30 (9.1)	100 (30.5)							
3 (76)	10		42 (12.8)	150 (45.7)	360 (109.7)	1040 (317)					
3 (76)	21		32 (9.8)	110 (33.5)	270 (82.3)	810 (246.9)					
3 (76)	53		27 (8.2)	94 (28.7)	230 (70.1)	680 (207.3)					
3 (76)	102		25 (7.6)	86 (26.6)	210 (64.0)	620 (189.0)					
4 (102)	43			35 (10.7)	85 (25.9)	250 (76.2)	980 (298.7)				
4 (102)	140			27 (8.2)	65 (19.8)	200 (61.0)	750 (228.6)				
4 (102)	320			23 (7.0)	55 (16.8)	170 (51.8)	640 (195.0)				
4 (102)	540			21 (6.4)	50 (15.2)	150 (45.7)	580 (176.8)				
5 (127)	190				28 (8.5)	82 (25.0)	320 (97.5)	990 (301.8)			
5 (127)	490				21 (6.4)	63 (19.2)	250 (76.2)	760 (231.6)			
5 (127)	940				18 (5.5)	53 (16.2)	210 (64.0)	670 (204.2)			
5 (127)	1400				16 (4.9)	49 (14.9)	190 (57.9)	590 (179.8)			
6 (152)	500					33 (10.1)	130 (39.6)	400 (121.9)	1000 (304.8)		
6 (152)	1100					26 (7.9)	100 (30.5)	310 (94.5)	780 (237.7)		

Figure 220 : Size and length of vent [26]

4- Put clean out at the end of each branch which is used for maintenance

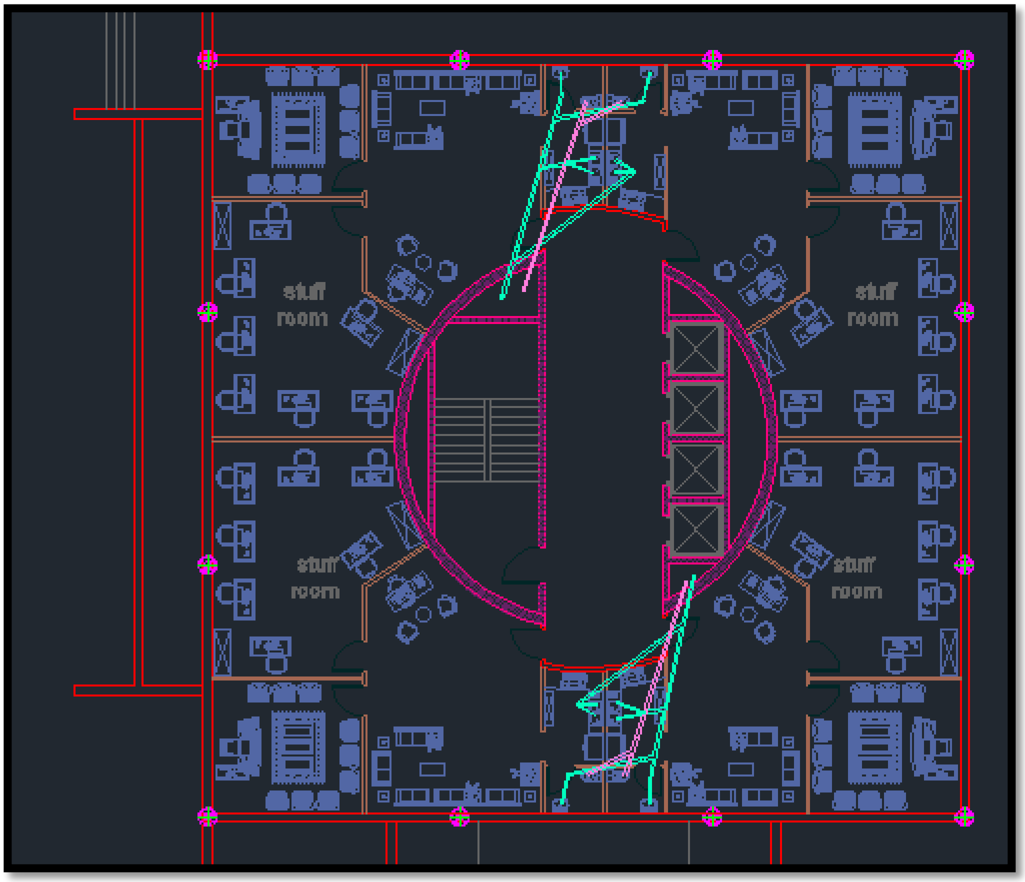


Figure 221 : plan of Water Drainage system in floor 1

Drainage Calculations:

- Each W.C represents 4Dfu.
- Each Lavatory Represent 1 Dfu.
- Each kitchen sinks Represent 2 Dfu.
- Max. total Dfu of stakes is less than 240 Dfu so use main sakes 4" .

Use ventilation stakes 4" .

- The sewers for lavatory which reach to the main drainage = 2"
- The sewers for kitchen sink which reach to the main drainage =2"
- The sewers for W.C which reach to the main drainage = 4" .

3.4.4. HVAC system

The primary function of all air-conditioning systems is to provide thermal comfort for building occupants. There are a wide range of air conditioning systems available, starting from the basic window-fitted units to the small split systems, to the medium scale package units, to the large chilled water systems, and currently to the variable refrigerant flow (VRF) systems.

Variable Refrigerant Flow System

Variable refrigerant flow (VRF) is an air conditioning system configuration where there is one outdoor condensing unit and multiple indoor units. The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to the multiple evaporators (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit. The arrangement provides an individualized comfort control, and simultaneous heating and cooling in different zones.

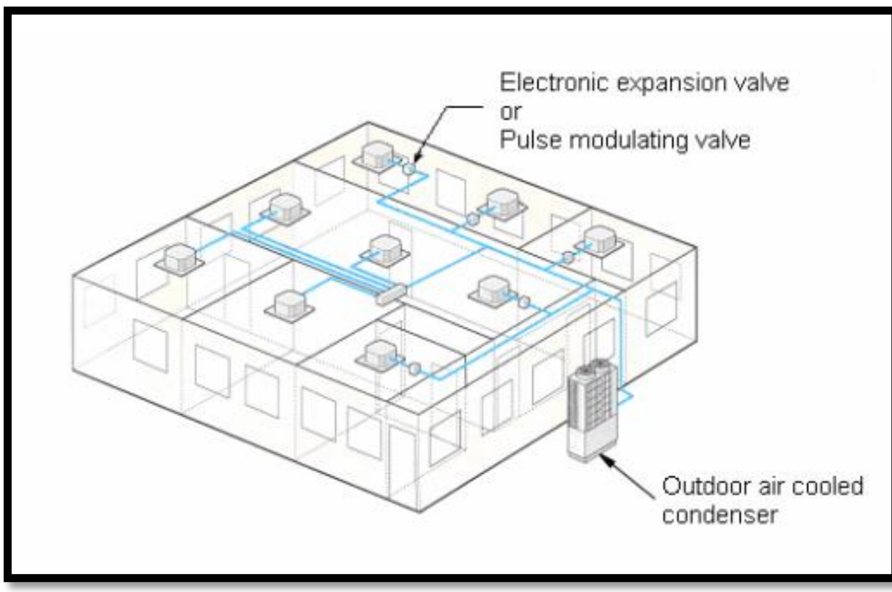


Figure 222 : VRF System with multiple indoor evaporate units

Refrigerant piping runs of more than 200 ft are possible, and outdoor units are available in sizes up to 240,000 Btu/ h (60478.98 kW).

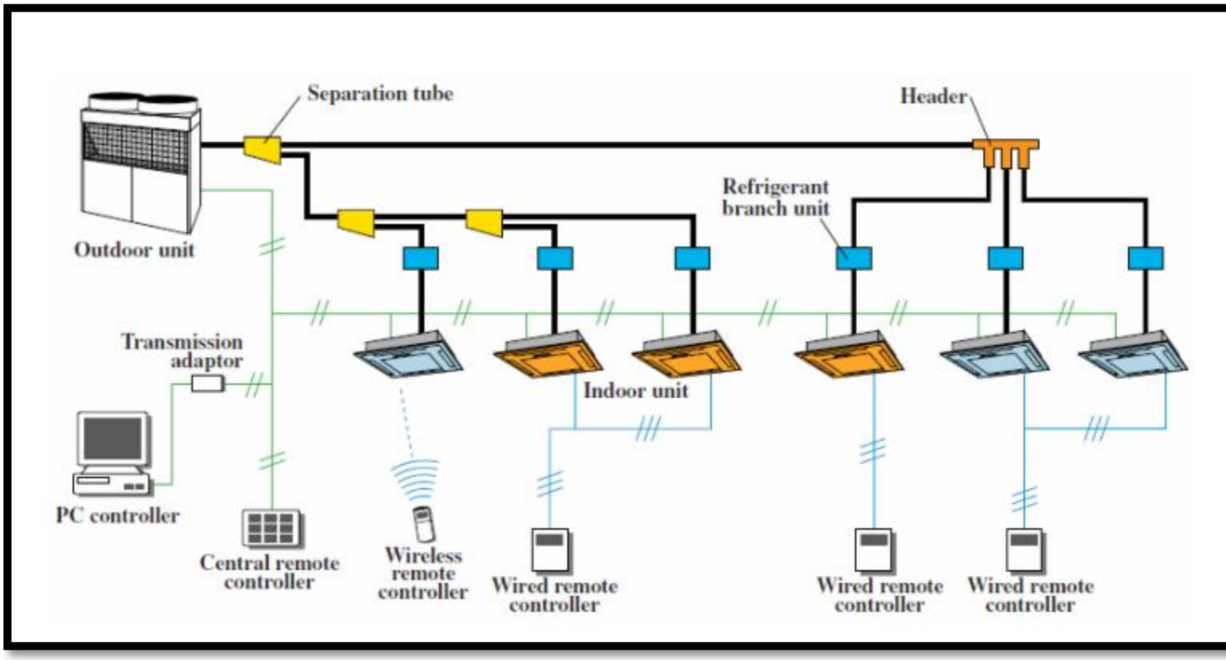


Figure 223 : A schematic VRF arrangement

A separation tube has 2 branches whereas a header has more than 2 branches. Either of the separation tube or header, or both, can be used for branches. However, the separation tube is never provided after the header because of balancing issues.

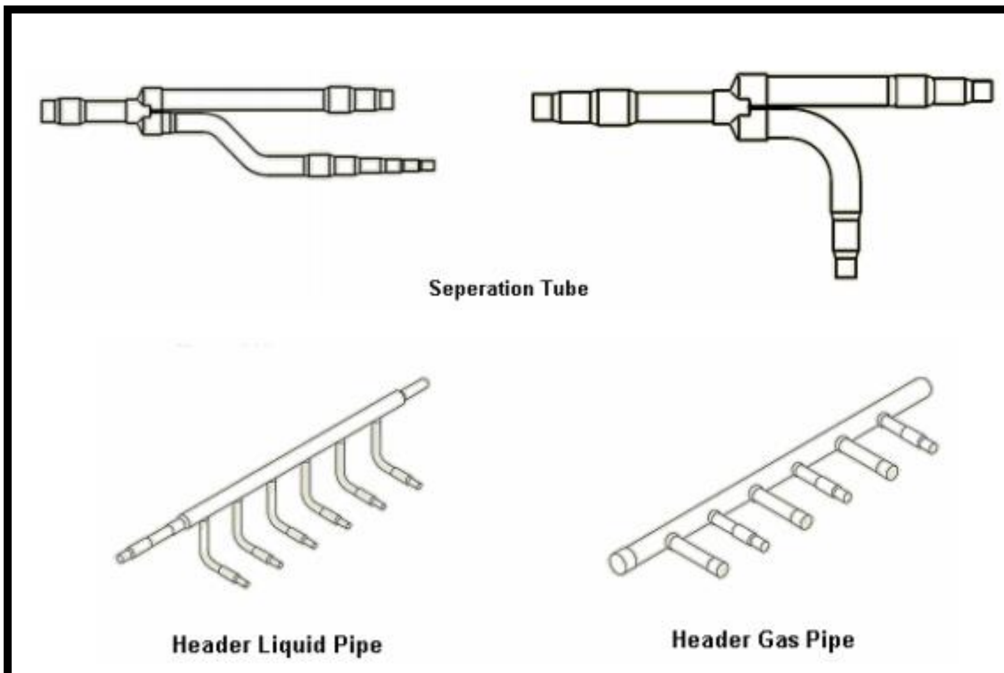
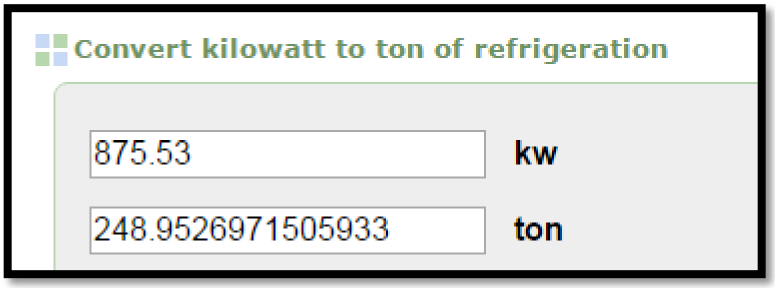


Figure 224 : Separation and header tubes

Selection units

This section talks about selection of outdoor and indoor units of VRF system, depending on the "Samsung VRF catalogue",
Outdoor and indoor units are selected according to the thermal load of the building.



Outdoor unit

It was chosen 7 outdoor units with capacity of individual is 249 Ton (**AM432FXVAJR/AA**)
Each outdoor unit = 36 ton

Indoor unit

In this project there are two types of indoor units selected, which are split and cassette units. The split unit is used for manager room , and the cassette units are used for staff room ,circulation , shops , cafeteria , and mall .
The figure below shows the two types of selected units:

Figure 225 : Spilt and cassette indoor units

The selected indoor units for the building are listed in the tables below:

Table 63 : Indoor units for (podium1) floor

Room Name	Cooling Load (Kw)	Flow rate (m^3/sec)	Indoor Unit Type	Indoor Unit Name	Number of indoor unit	Dimension (Mm)
mall	20.44	.53	Cassette	AM009FNNDCH/AA	8	575 x 250 x 575
Office store	2.44	.13	Cassette	AM009FNNDCH/AA	1	575 x 250 x 575
Open office	10.88	.6	Cassette	AM009FNNDCH/AA	4	575 x 250 x 575
Circulation	5.36	.327	Cassette	AM009FNNDCH/AA	2	575 x 250 x 575
Shop 11	5.05	.277	Cassette	AM009FNNDCH/AA	2	575 x 250 x 575
Shop 1	3.41	.187	Cassette	AM009FN4DCH/AA	2	575 x 250 x 575
Shop 7	1.49	.085	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 8	1.78	.097	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 9	1.78	.098	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 10	2.02	.107	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Circulation	21.49	1.3	Cassette	AM009FNNDCH/AA	8	575 x 250 x 575
Circulation	2.58	.158	Cassette	AM009FNNDCH/AA	1	575 x 250 x 575
Manage office	2.53	.144	Split	AM009FNTDCH/AA	1	825 x 285 x 189
Shop 2	1.21	.066	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 3	1.17	.063	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 5	1.79	.096	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 6	1.19	.065	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Shop 4	1.32	.032	Split	AM007FNTDCH/AA	1	825 x 285 x 189

Table 64 : Indoor units for floor 12

Room Name	Cooling Load (Kw)	Indoor Unit Type	Indoor Unit Name	Number of indoor unit	Dimension (Mm)
staff room	7.52	Cassette	AM009FNNDCH/AA	3	575 x 250 x 575
Office room 4	1.67	Split	AM007FNTDCH/AA	1	825 x 285 x 189
Office room 3	3.32	Split	AM012FNTDCH/AA	1	825 x 285 x 189
Office room	2.80	Split	AM009FNTDCH/AA	1	825 x 285 x 189
Reception	2.97	Cassette	AM012FNNDCH/AA	1	575 x 250 x 575
Store room 2	2.67	Cassette	AM012FNNDCH/AA	1	575 x 250 x 575
Reception 2	3.39	Cassette	AM012FNNDCH/AA	1	575 x 250 x 575
Office room 2	1.49	Split	AM007FNTDCH/AA	1	825 x 285 x 189
staff room	7.46	Cassette	AM009FNNDCH/AA	3	575 x 250 x 575
Store room	3.48	Cassette	AM012FNNDCH/AA	1	575 x 250 x 575

3.4.5. Safety Design:

3.4.5.1. Introduction:

The first aim of safety engineering is to control and reduce risk to acceptable levels. Risk is the combination of the probability of a failure event, and the severity resulting from the failure.

In our project Fire protection design include: sprinklers, smoke detector, fire extinguishers , and fire alarm

3.4.5.2. Sprinklers

Figure 226 : Sprinklers

In our project we use sprinkler can cover 12 m^2 as maximum protection area and the maximum distance between two sprinklers is 4.6m.

Table 65 : The type of the hazard and the area covered by one sprinkler

Type of hazard	Low	Moderate	High
Area	$20m^2$	$12m^2$	9m2

Table 66 : The type of the hazard and the maximum distance between two sprinklers

Type of hazard	Low	Moderate	High
Max .distance	4.6m	4.6m	3.7m

*** Sample Calculation:**

the staff room was taken to make a sample of calculation for the distribution of sprinklers.
→Area of staff room = 102 m2.
→Number of sprinkler = 102 / 12 = 8.5 use 9 sprinkler.

3.4.5.3. smoke detector :

It gives an indication about the location of smoke in the building

Figure 227 : smoke detector

3.4.5.4. fire extinguishers

Portable extinguishers are designed to control or extinguish small fires. They are placed through the building to be ready when someone finds a fire. and there is many type of fire extinguishers As shown below

Figure 228 : fire extinguishers

3.4.5.5.Fire alarm :

It gives an indication about the location of the fire alarm bottom as pictures below:

Figure 229 : Fire alarm

3.4.5.6. Safety signs

1- Exits &Exit signs:

Exit signs should be visible from any place in the corridor. Those that are not near an exit door will have an arrow showing the direction to the nearest exit.

Figure 230 : Exit signs

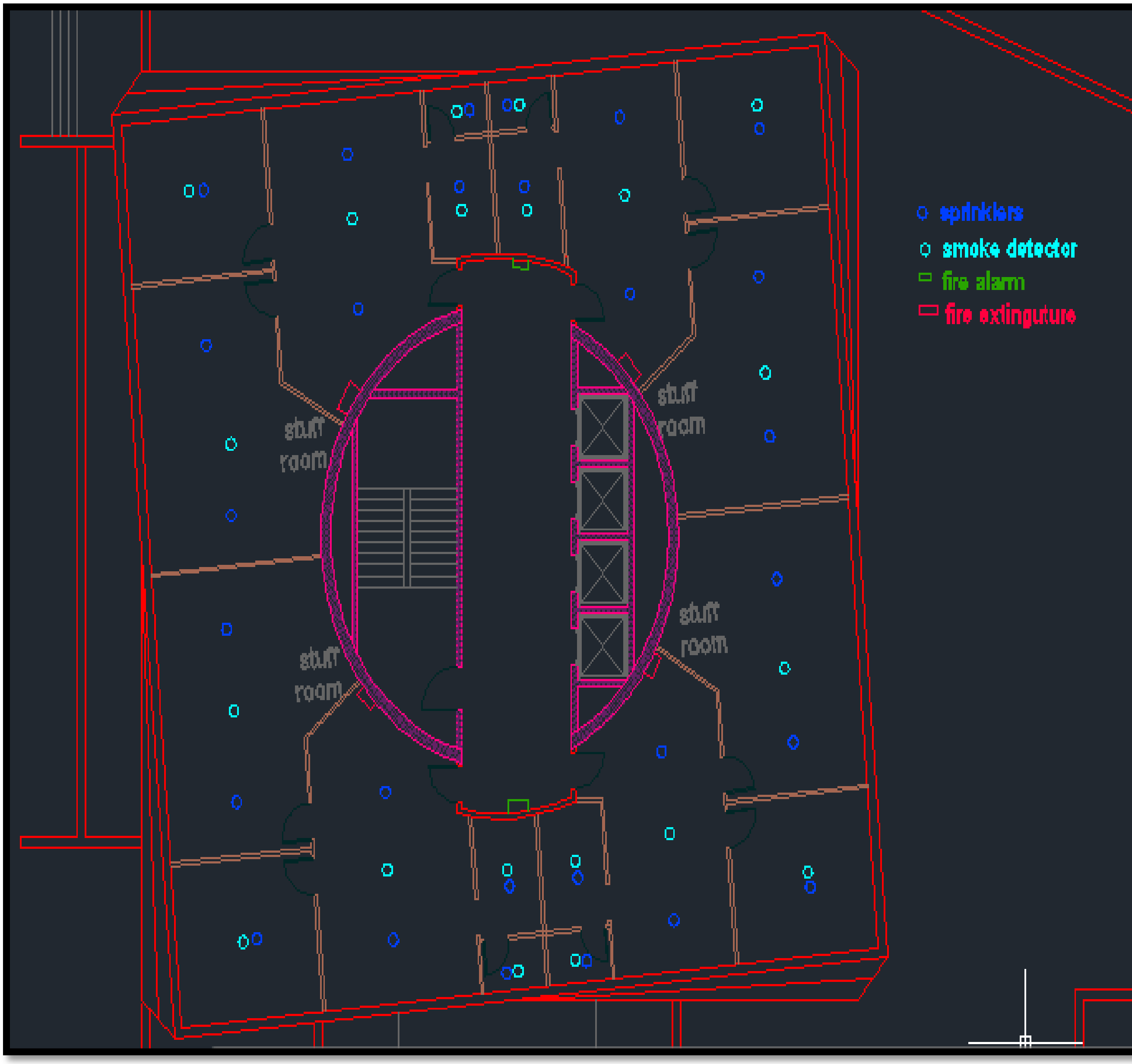


Figure 231 : distribution of safty system on plan floor

3.4.6. Elevators

An elevator is a mean of vertical transportation equipment that efficiently moves people or goods between floors of a building. The provision of elevators in multistory buildings (above 3 stories) is a requirement by the Jordanian Engineers Association in Palestine.
The following steps can be used to calculate the number of elevators need in the building:

1. **The Population in the building:**

P = 10-12 m2/person
Area of the building = 615*19 = 11685m2
Max population = 11685/12 = 973.75

2. **Percent Handling Capacities:**

The min. PHC = (14-16) %
∴ HC = 973.75 * 16 % = 155.8 person/ 5 minutes
Rise = 4.6 * 19 = 87.4 m
Speed = 800 fpm

The possible types of elevators in the building
will be(2500 lb/800fpm , 3000 lb/800 fpm , 3500 lb/800 fpm)

Table 67 : number of Elevators needed in tower

	2500 lb / 800 fpm	3000 lb / 800 fpm	3500 lb / 800 fpm
Car Passenger Capacity (P)	13	16	19
Round-trip time (RT)	112	125	136
Handling Capacity (H.C.)	300*13/112 = 34.8	300*16/125 = 38.4	300*19/136 = 41.9
Number of elevators (n)	155.8/34.8 = 4.5	155.8/38.4 = 4.05	155.8/41.9 = 3.7
User number of elevator (N)	4	4	3
Checks:			
Percent Handling Capacity (PHC)	4*34.8/973.75 = 14.2	4*38.4/973.75 = 15.7	3*41.9/973.75 = 12.9
Elevator Intervals (I)	112/4 = 28	125/4 = 31.25	136/3 = 45.3

four elevators from type (2500 Ib, 800 fpm) are suitable to the building

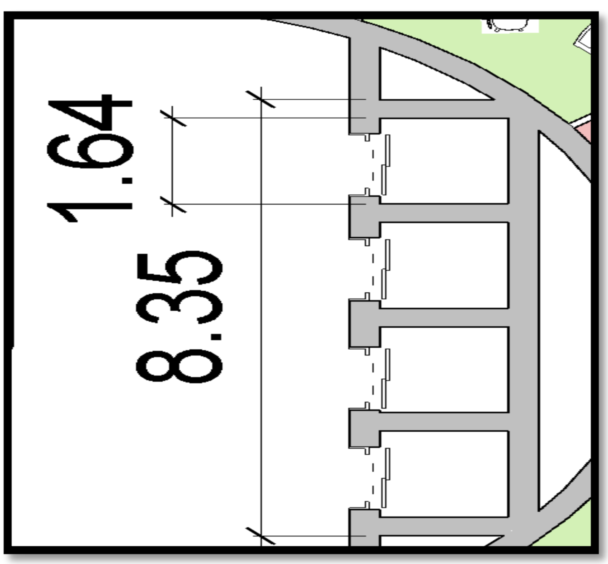


Figure 232 : plan of elevators

3.5.Electrical Design

3.5.1. Introduction

Vision is the most important of all the five senses – and the one were on most heavily at work. So correct workplace lighting is matter of particular importance. As numerous scientific studies have shown, close links exist between the quality of lighting on the one hand and productivity, motivation and well-being on the other .In the modern working world, however, we need more than just the right amount of light for workplace tasks. We need a succession of stimulating and relaxing situations throughout the day .So creating different lighting scenes in rooms with different functions(workrooms, meeting rooms, recreation/regeneration zones)helps boost motivation and promote a sense of well-being .So the natural lighting and artificial lighting are integrated to increase occupant comfort.

In order to get the best artificial lighting arrangement, DIALux evo. software was used for analysis and calculations. Different spaces where analyzed the following aspects were considered:

1. Illuminance (E): is a luminous flux per unit area and measured in lux (lx).
2. Glare index (or unified glare rating-UGR): is a visual impression created by the presence of illuminated area in the field of view.
3. Uniformity(U): is the ratio between the minimum illuminance and the average illuminance in the space. And it equals (0.6-1).

Table 68 : recommended Illuminance [24]

Task position or area	Optimum average illumination in lux	Notes
General offices	500	
Computer work stations	500	Local lighting may be required for reading a document
Drawing work stations	750	Local lighting is appropriate
Other areas, e.g. file storage and reception, telephone operators	300	

Areas common to most buildings	Lux (lm/m²)
Entrance hall, lobby, waiting room	200
Enquiry desk	500
Corridor, passageway, stairs	100
Atria	50-200
Changing room, cloakroom, lavatory	100
Rest room	150
Canteen, cafeteria, dining room	200
Kitchen	300

3.5.2. DIALux evo. Design

Many spaces in the building were taken and designed in DIALux4.12 software. These spaces are in first, fifth, and seventh floor.

- **Type of luminaires [25] :**

There are five types of luminaires used in this project as shown in figure

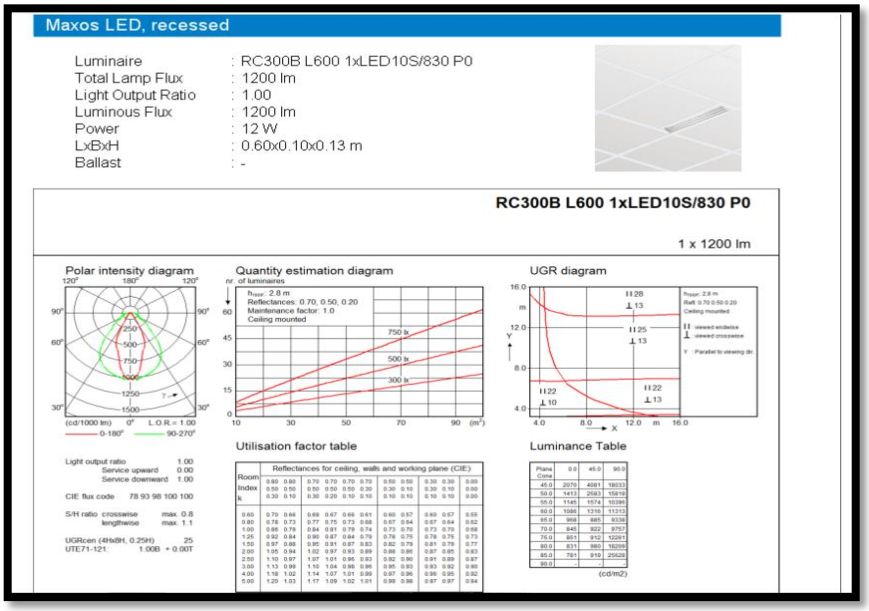


Figure 233 : luminaire 1 specification

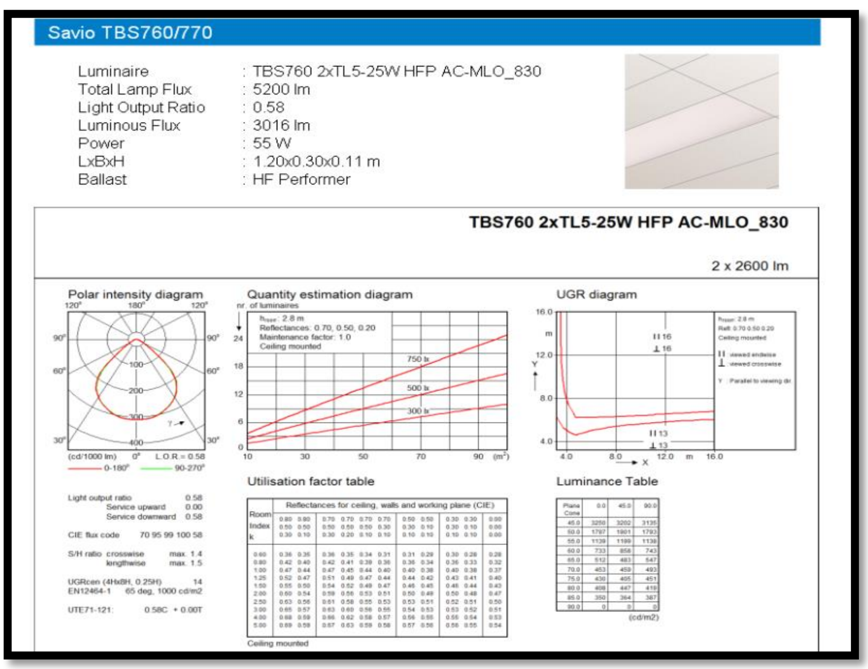


Figure 234 : luminaire 2 specification

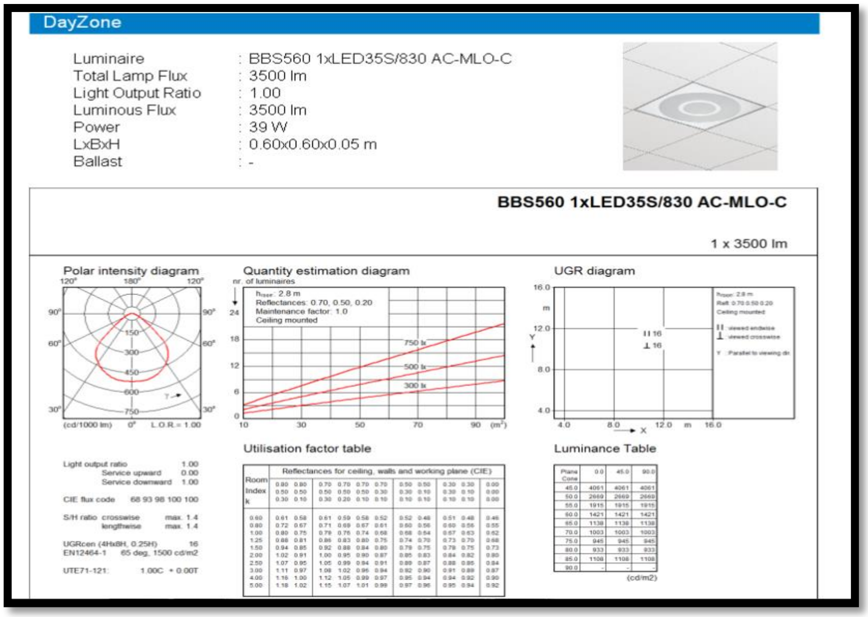
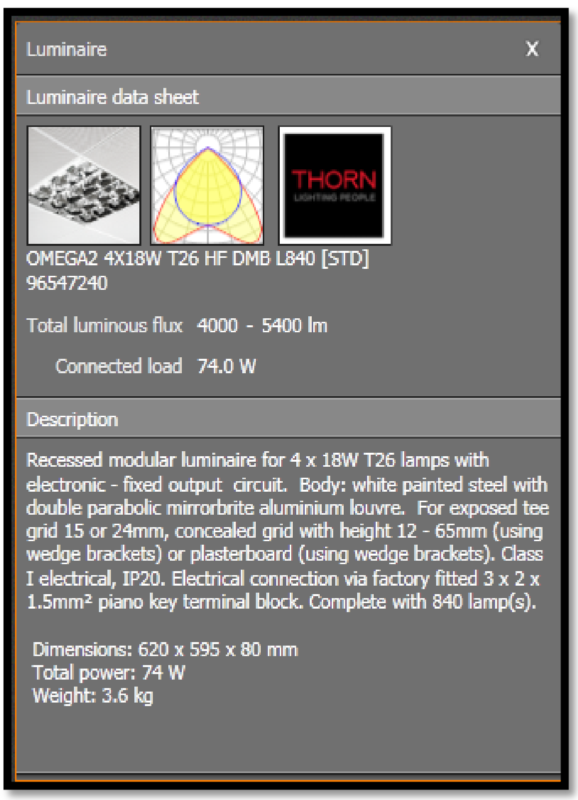


Figure 235 : luminaire 3 specification



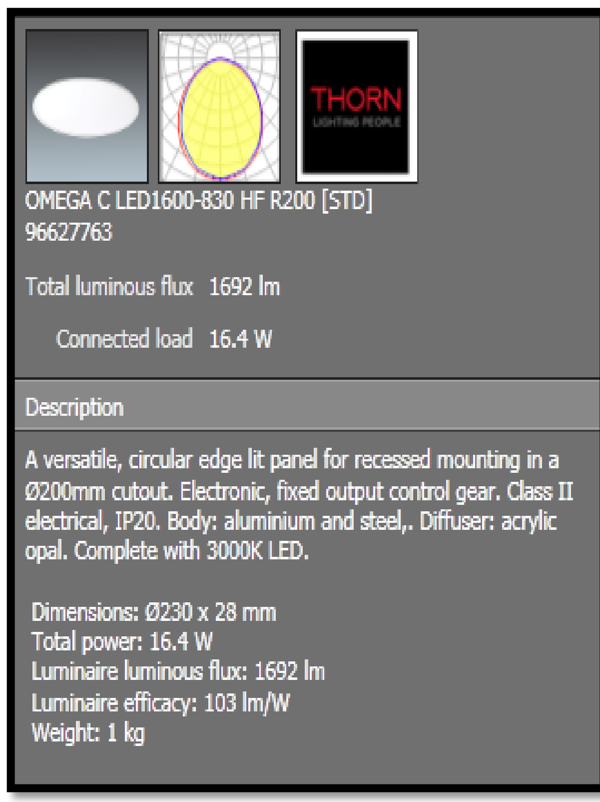
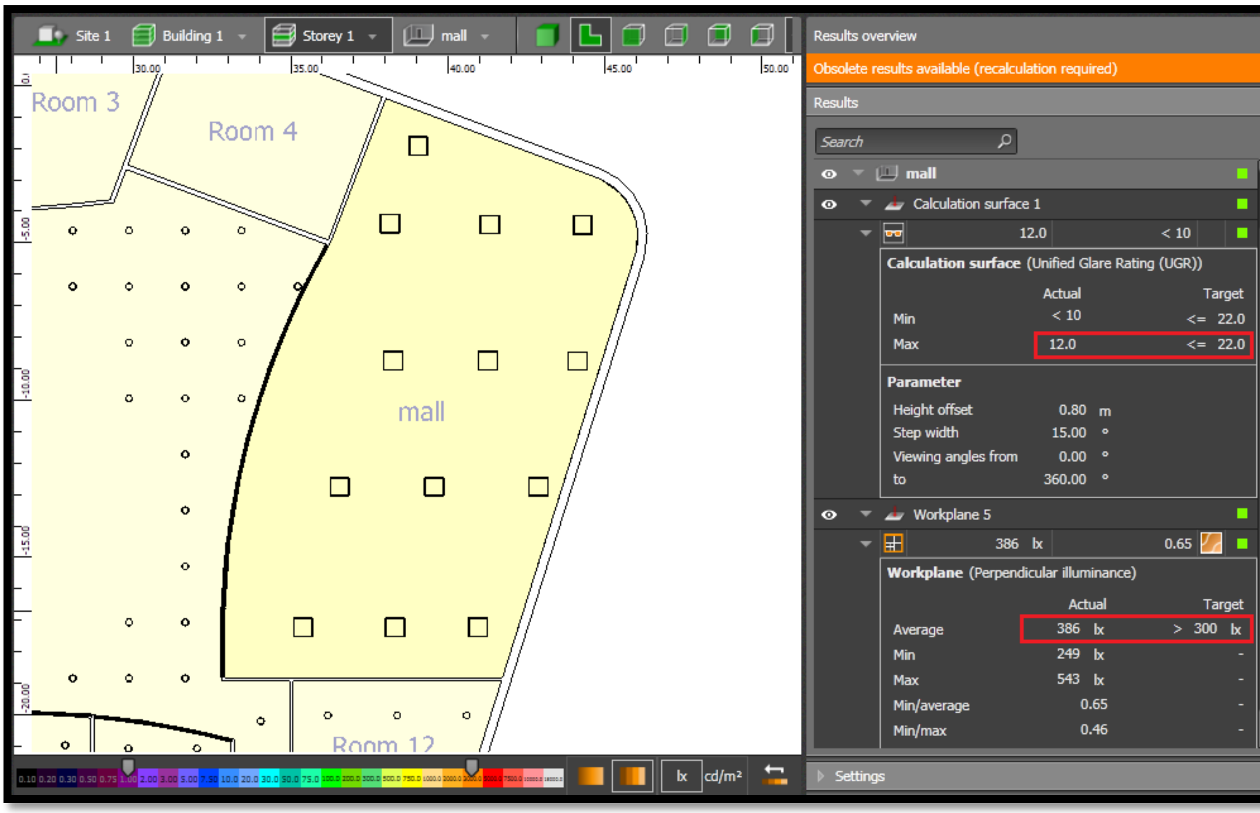


Figure 236 : luminaire 4 ,5 specification

Spaces and result :

1- Mall (podium 1)

In **podium 1** floor, the mall was selected to calculate and distribute the lighting in it and it was considered as general space . This space has 166 m^2 area. The luminaire was a surface type (4*18w T26 HF DMB L840 (STD). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:



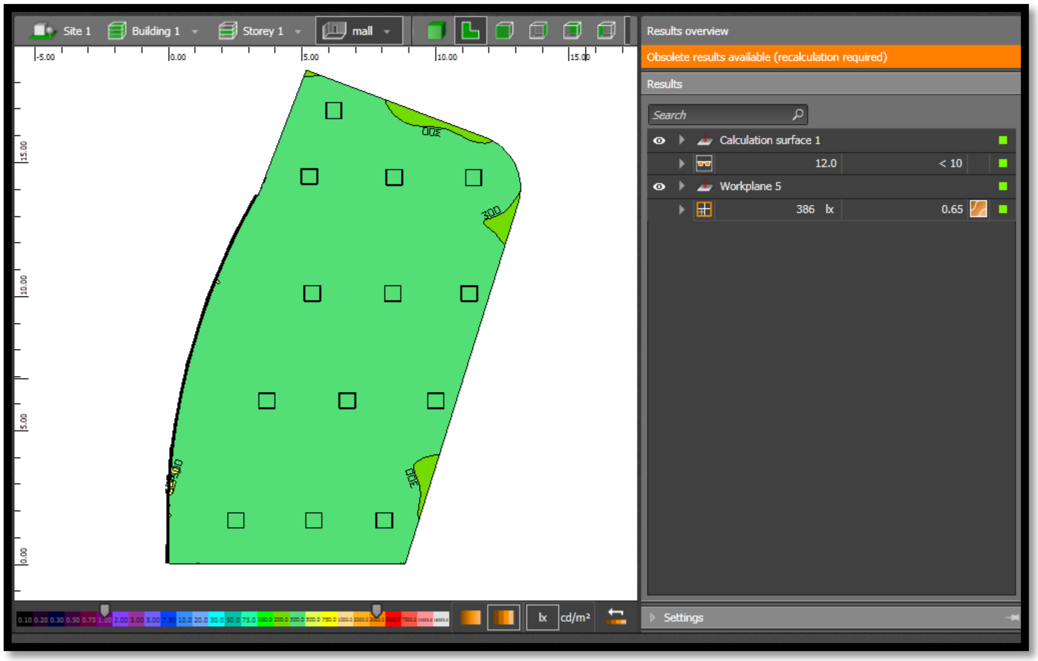


Figure 237 : illuminance in mall

The average illuminance in the room (386 lux) which larger than the recommended value (300 lux) as mentioned before in table 63. The uniformity in the mall (0.65) which was between (0.6-1.00). That means the uniformity in the mall very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the mall (12) which is less than the recommended value (22) .

The figure below shows the 3D-modal to the mall and the distribution of luminaires in it.

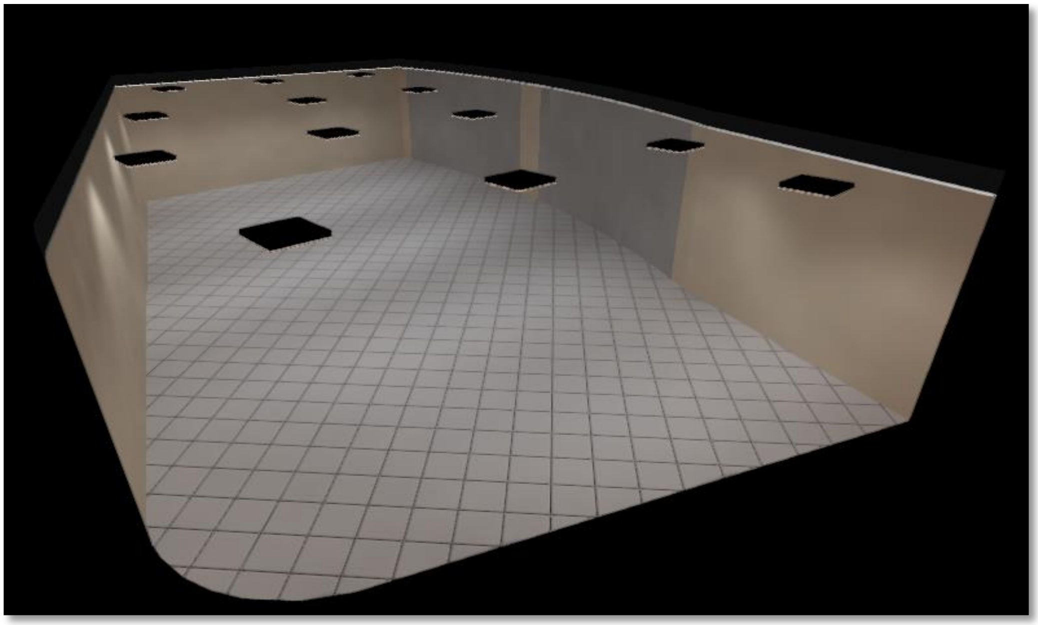


Figure 238 : 3D-modal to the mall and the distribution of luminaires in it

2- Hole space (podium 2)

In **podium 2** floor, the hole space selected to calculate and distribute the lighting in it and it considered as general space . This space has 539 m^2 area. The luminaire was a surface type (OMEGA C LED 1600-830 HF R200 (STD)). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

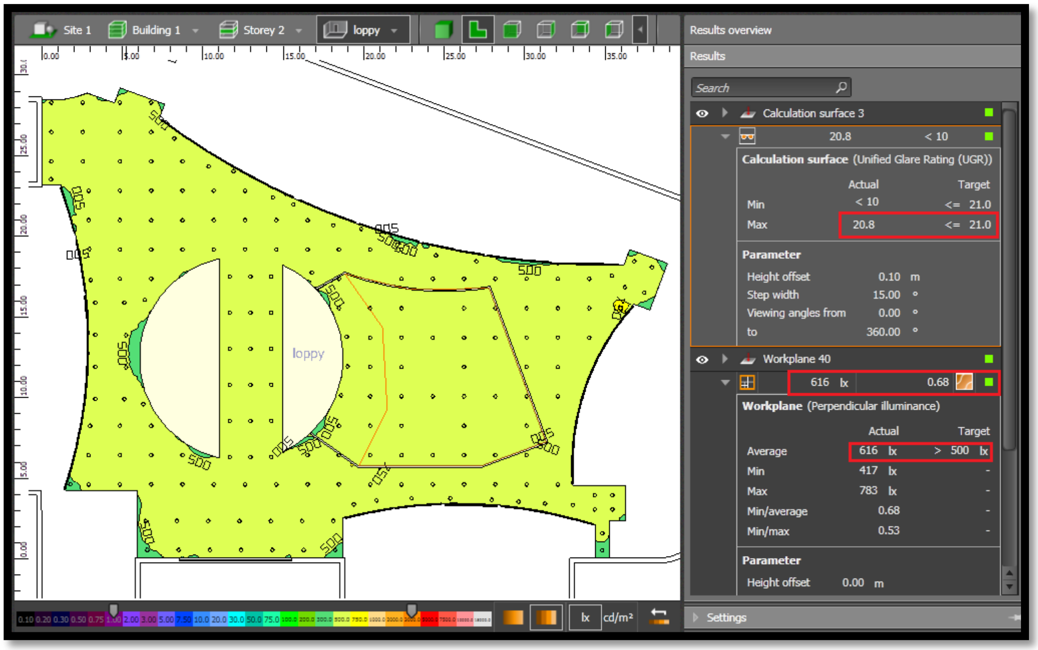


Figure 239 : illuminance in hole space (podium 2)

The average illuminance in the room (616 lux) which larger than the recommended value (500 lux) as mentioned before in table 63 . The uniformity in the HOLE (0.68) which was between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the hole (20.8) which is less than the recommended value (21) .

The figure below shows the 3D-modal to the mall and the distribution of luminaires in it.

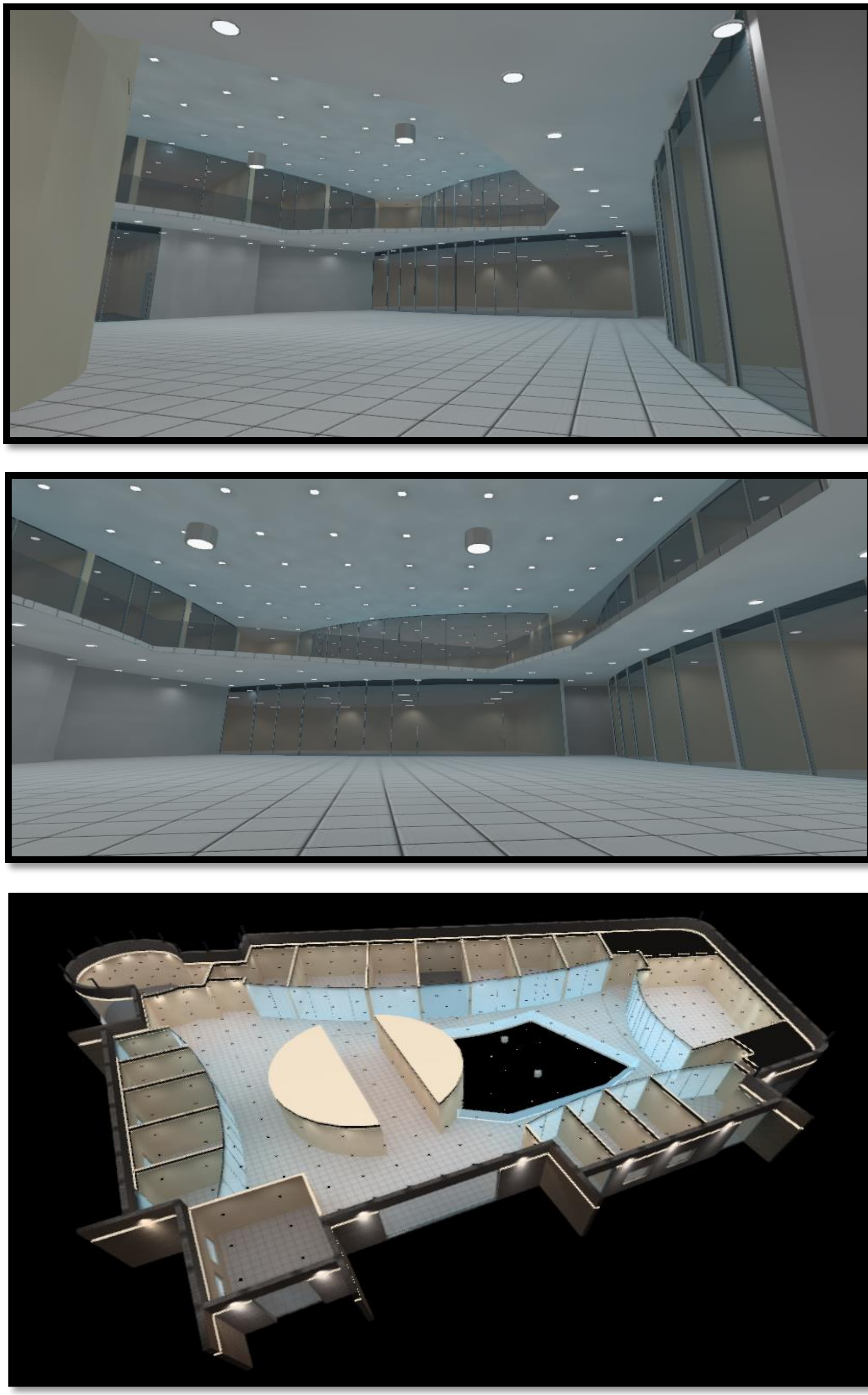


Figure 240 : 3D-modal to the mall and the distribution of luminaires in it

3- Manager room (1-18 floor)

In **1-18 floor**, the manager room selected to calculate and distribute the lighting in it and it considered as office space . This space has 25 m^2 area. The luminaire was a surface type (TBS760 2*TL5-25WHPF AC-MLO-830). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

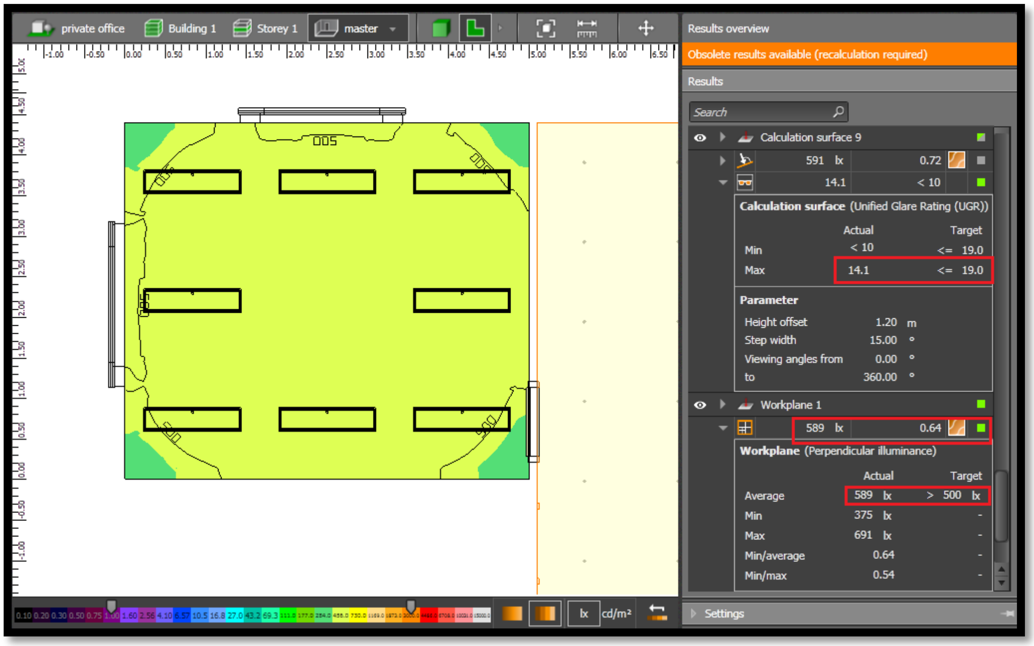


Figure 241 : illuminance in manager room

The average illuminance in the room (589 lux) which larger than the recommended value (500 lux) as mentioned before in table 63. The uniformity in the manager room (0.64) which was between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the manager room (14.1) which is less than the recommended value (19) .

The figure below shows the 3D-modal to the manager room and the distribution of luminaires in it.

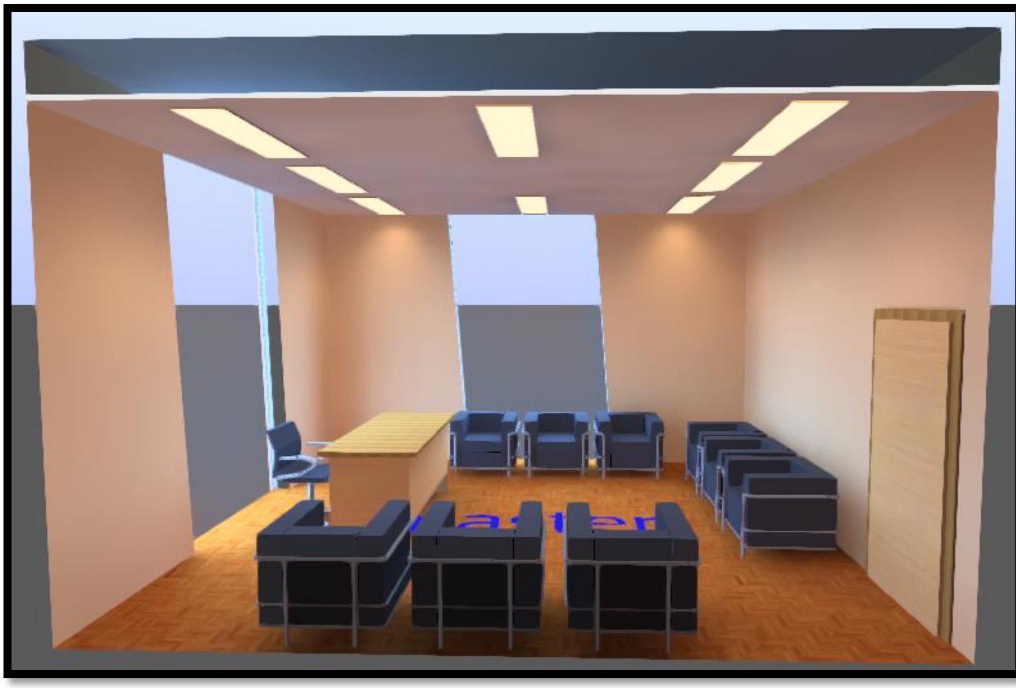


Figure 242 : 3D-modal to the manager room and the distribution of luminaires in it

4- Waiting room (1-18 floor)

In **1-18** floor, the waiting room selected to calculate and distribute the lighting in it and it considered as office space . This space has 45.6 m^2 area. The luminaire was a surface type (TBS760 2*TL5-25WHPF AC-MLO-830). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

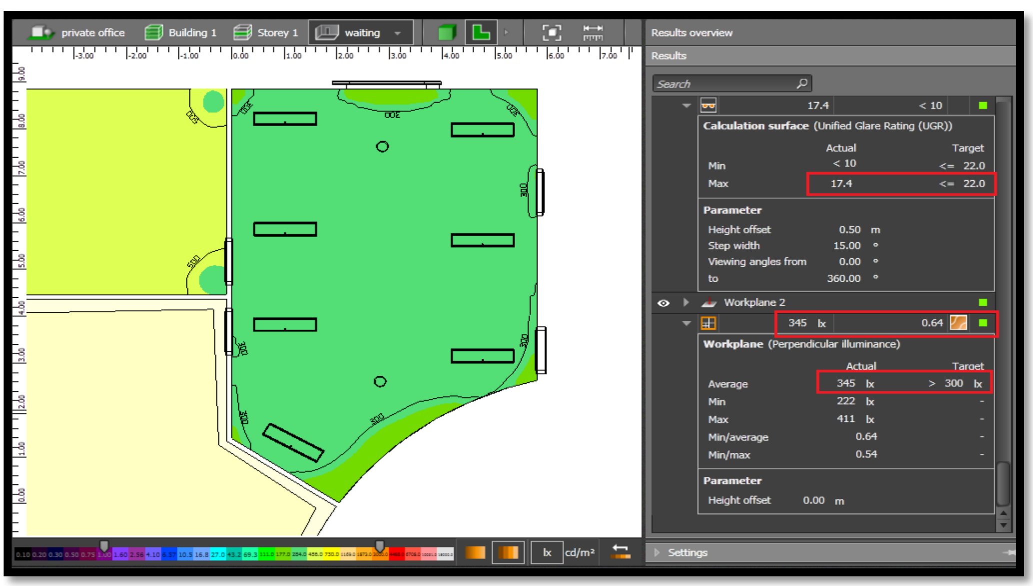


Figure 243 : illuminance in waitting room

The average illuminance in the room (345 lux) which larger than the recommended value (300 lux) as mentioned before in table 63. The uniformity in the waiting room (0.64) which was between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, glare index shall be calculated to insure that there are no problems. The maximum glare index in the waiting room (17.4) which is less than the recommended value (22) .

The figure below shows the 3D-modal to the waiting and the distribution of luminaires in it.

Figure 244 : 3D-modal to the waiting room and the distribution of luminaires in it

5- Open office – stuff room - (1-10 floor)

In **1-10 floor**, the **stuff room** selected to calculate and distribute the lighting in it and it considered as office space . This space has 48 m^2 area. The luminaire was a surface type (BBS560 1*LED35S/830 AC-MLO-C). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

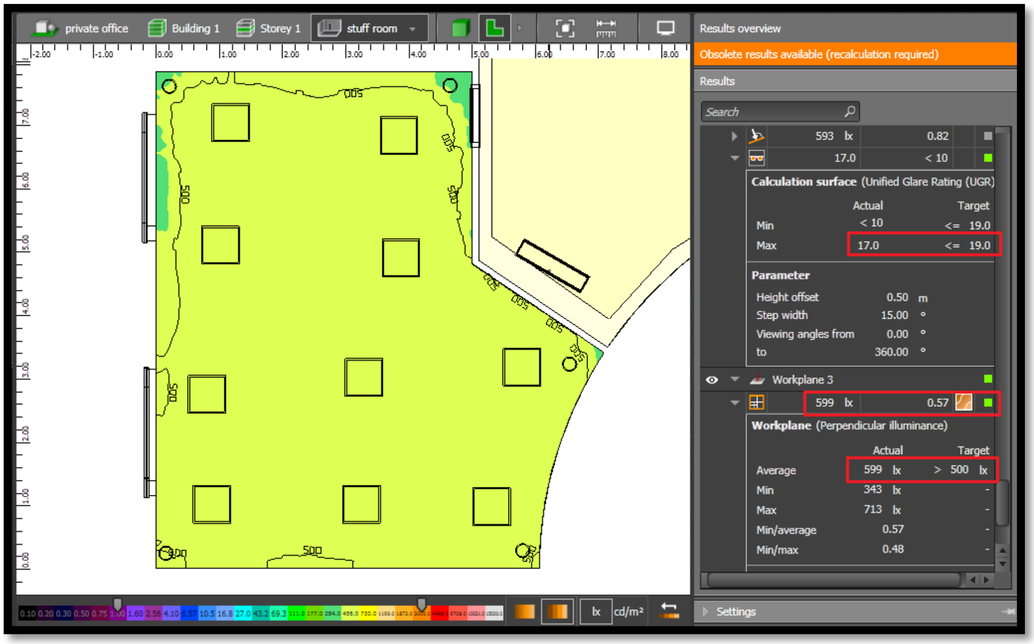


Figure 245 : illuminance in stuff room

The average illuminance in the room (599 lux) which larger than the recommended value (500 lux) as mentioned before in table 63. The uniformity in the **stuff room** (0.57) which was nearly 0.6 between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the **stuff room** (17) which is less than the recommended value (19) .

The figure below shows the 3D-modal to the stuff room and the distribution of luminaires in it.

Figure 246 : 3D-modal to the stuff room and the distribution of luminaires in it.

6- corridor (1-18 floor)

In **1-18** floor, the **corridor** selected to calculate and distribute the lighting in it and it considered as general corridor space . This space has 44 m^2 area. The luminaire was a surface type (OMEGA C LED 1600-830 HF R200 (STD)). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

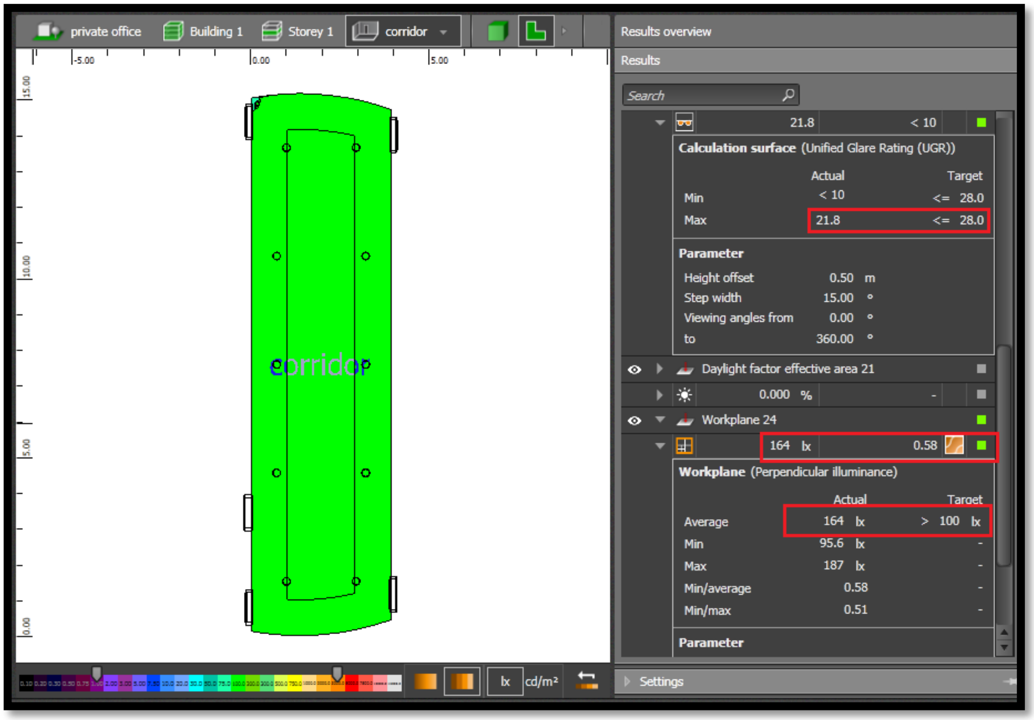


Figure 247 : illuminance in corridor

The average illuminance in the **corridor** (164 lux) which larger than the recommended value (100 lux) as mentioned before in table 63. The uniformity in the **corridor** (0.58) which was nearly 0.6 between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the **corridor** (21.8) which is less than the recommended value (28) .

The figure below shows the 3D-modal to the corridor and the distribution of luminaires in it.

Figure 248 : 3D-modal to the corridor and the distribution of luminaires in it.

7- kitchen (1-10 floor)

In **1-10 floor**, the **kitchen** selected to calculate and distribute the lighting in it and it considered as cutting food space . This space has 6.4 m^2 area. The luminaire was a surface type (OMEGA C LED 1600-830 HF R200 (STD). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

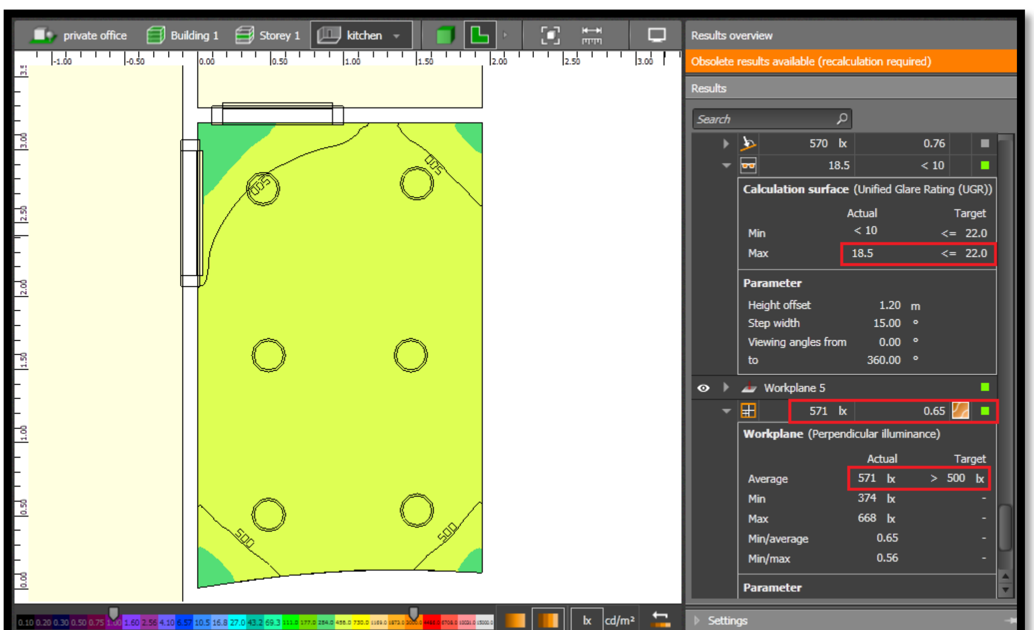


Figure 249 : illuminance in kitchen

The average illuminance in the **kitchen** (571 lux) which larger than the recommended value (500 lux) as mentioned before in table 63. The uniformity in the **kitchen** (0.65) which was between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the **kitchen** (18.5) which is less than the recommended value (22) .

The figure below shows the 3D-modal to the kitchen and the distribution of luminaires in it.

Figure 250 : 3D-modal to the kitchen and the distribution of luminaires in it.

8- bathroom (1-10 floor)

In **1-10 floor**, the **bathroom** selected to calculate and distribute the lighting in it and it considered as toilet & bathroom space . This space has 6.4 m^2 area. The luminaire was a surface type (RC300B L600 1*LED10S/380 P0). After the build the model in the DIALux evo. program, the results of the distribution of luminaries and the illuminance in room were shown in figure below:

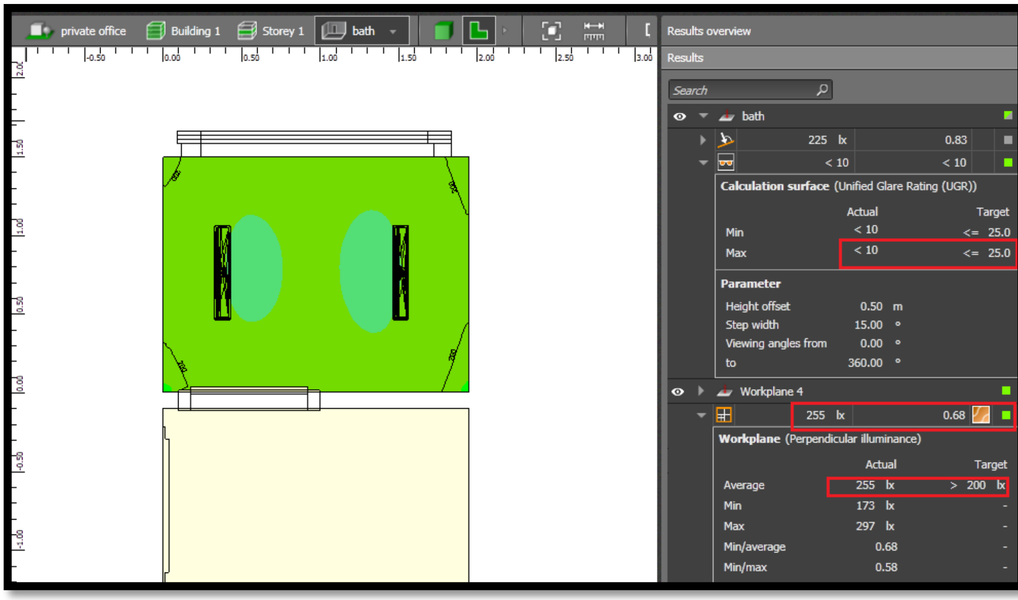


Figure 251 : illuminance in bath room

The average illuminance in the **bathroom** (255 lux) which larger than the recommended value (200 lux) as mentioned before in table 63 . The uniformity in the **bathroom** (0.68) which was between (0.6-1.00). That means the uniformity in the hole very good and acceptable. On the other hand, the glare index shall be calculated to insure that there are no problems. The maximum glare index in the **bathroom** (less than 10) which is less than the recommended value (25) .

The figure below shows the 3D-modal to the bath room and the distribution of luminaires in it.

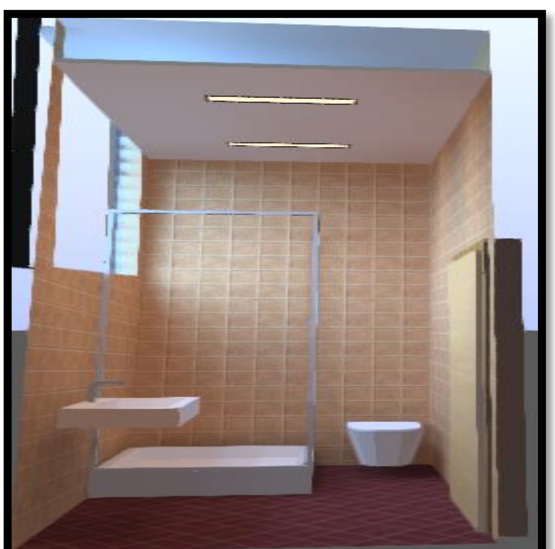


Figure 252 : 3D-modal to the bath room and the distribution of luminaires in it.

The figures below show (3d model) for external lighting of the podium and site plan :

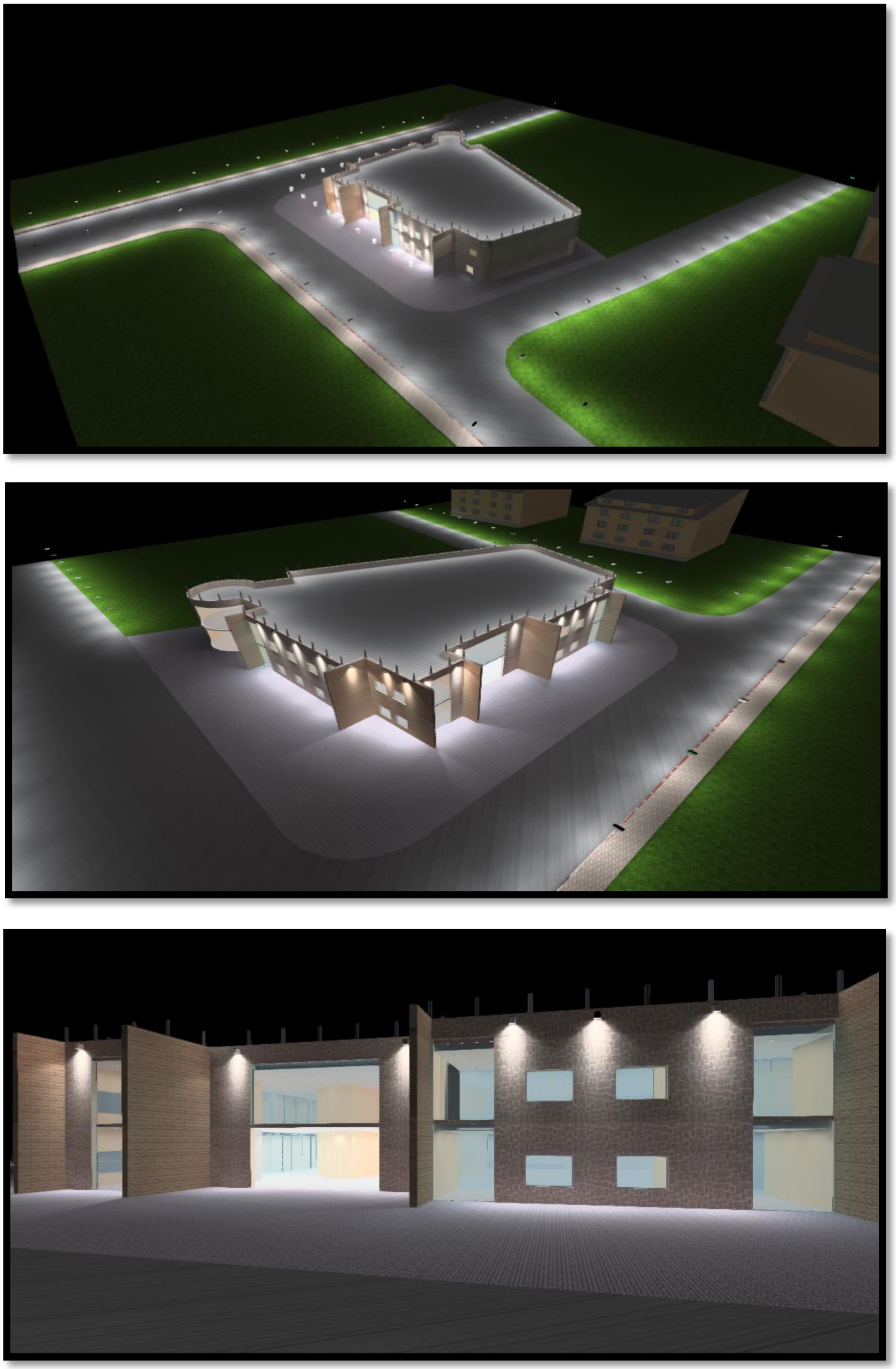


Figure 253 : (3d model) for external lighting of the podium and site plan

Manual Design

After using DIALux software, the luminaires were distributed on other space in the building . And then, total consumption power in the building were calculated.

Table 69 : total consumption power in podium 1

podium 1							
Space	Em (lux)	Luminaire type	FI (lum)	n (unit)	N (unit)	Watt/unit	Watt
mall	300	4*18w T26 HF DMB L840 (STD)	4000-5400	4	13	74	962
Shops	500	C LED1600-830 HF R200	1692	1	15	16.4	246
TOTAL 1208							

Table 70 : total consumption power in podium 2

Podium 2							
Space	Em (lux)	Luminaire type	FI (lum)	n (unit)	N (unit)	Watt/unit	Watt
Cafeteria	300	4*18w T26 HF DMB L840 (STD)	4000-5400	4	15	74	1110
Shops	500	C LED1600-830 HF R200	1692	1	18	16.4	296
TOTAL 1406							

Table 71 : total consumption power in 1st floor

1st floor							
Space	Em (lux)	Luminaire type	FI (lum)	n (unit)	N (unit)	Watt/unit	Watt
Bathroom	200	RC300B L600 1*LED10S/380 P0	1200	1	12	12	144
Kitchen	500	C LED1600-830 HF R200	1692	1	24	16.4	394
Corridor	100	C LED1600-830 HF R200	1692	1	8	16.4	132
Manager room	500	TBS760 2*TL5-25WHPF AC-MLO-830	3016	2	36	55	1980
Waiting room	300	TBS760 2*TL5-25WHPF AC-MLO-830	3016	2	28	55	1540
Stuff room	500	BBS560 1*LED35S/830 AC-MLO-C	3500	1	52	39	2028
TOTAL 6218 watt							

The floors from (2-10) as the same as 1st floor = 9*6218 = 55962 watt

Table 72 : total consumption power in floor 11

Floor 11							
Space	Em (lux)	Luminaire type	FI (lum)	n (unit)	N (unit)	Watt/unit	Watt
Bathroom	200	RC300B L600 1*LED10S/380 P0	1200	1	6	12	72
Kitchen	500	C LED1600-830 HF R200	1692	1	12	16.4	197
Corridor	100	C LED1600-830 HF R200	1692	1	8	16.4	132
Manager room	500	TBS760 2*TL5-25WHPF AC-MLO-830	3016	2	36	55	1980
Waiting room	300	TBS760 2*TL5-25WHPF AC-MLO-830	3016	2	14	55	770
Stuff room	500	BBS560 1*LED35S/830 AC-MLO-C	3500	1	26	39	1014
TOTA 4165 watt							

The floors from (11-18) as the same as floor 11 =7*4165 = 29155 watt

Total power in the building = 1208 + 1406 +62180 + 33320 = 98114 watt = 99 KW

3.5.3. Sockets design

The sockets arrangement :

Table 73 : sockets arrangement in podium 1

floor	Type of area	# socket	Socket current	# special socket	Special socket current	Total current	Voltage	DF	Watt
Podium 1	mall	10	2	3	10	30	220	0.2	962
	Shops	45	2	0	0	90	220	0.2	246
# of Circuit Breaker =15 C.B									

Table 74 : sockets arrangement in podium 2

floor	Type of area	# socket	Socket current	# special socket	Special socket current	Total current	Voltage	DF	Watt
Podium 2	Cafeteria	15	2	5	10	50	220	0.2	1110
	Shops	54	2	0	0	108	220	0.2	296
# of Circuit Breaker = 15 C.B									

Table 75 : sockets arrangement in 1st floor

floor	Type of area	# socket	Socket current	# special socket	Special socket current	Total current	Voltage	DF	Watt
1st floor	Bathroom	4	2	0	0	8	220	0.2	144
	Kitchen	20	2	4	10	40	220	0.2	394
	Corridor	4	2	0	0	8	220	0.2	132
	Manager room	12	2	0	0	24	220	0.2	1980
	Waiting room	8	2	0	0	16	220	0.2	1540
	Stuff room	80	2	0	0	160	220	0.2	2028
# of Circuit Breaker = 10 C.B									

# of circuit breaker for each floor from (2-10) = 10 C.B

Table 76 : sockets arrangement in floor 11

floor	Type of area	# socket	Socket current	# special socket	Special socket current	Total current	Voltage	DF	Watt
Floor 11	Bathroom	2	2	0	0	4	220	0.2	72
	Kitchen	10	2	2	10	20	220	0.2	197
	Corridor	4	2	0	0	8	220	0.2	132
	Manager room	24	2	0	0	48	220	0.2	1980
	Waiting room	8	2	0	0	16	220	0.2	770
	Stuff room	40	2	0	0	80	220	0.2	1014
# of Circuit Breaker = 10 C.B									

# of circuit breaker for each floor from (11-18) = 10 C.B

3.5.4. Circuit breakers (C. B.)

After the calculations of power and lighting design, the circuit breaker must be designed.
A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow.
Two types are used:

1- 1 -10 amp circuit breaker for lighting.
2- 2- 16 amp circuit breaker for outlets.

Calculation of circuit breakers for lighting in each floor

Circuit breakers = $total\ lighting*DF*SF/\ voltage*current\ for\ lighting$
Where DF for lighting= 0.8, SF=1.2

- Sample calculation for podium 2 floor :

#CB= (6218*0.8*1.2)/(220*10) = 2.7 = 3 C.B

Table 77 : # Circuit breakers

Floor	#C.B.
Podium 1	1
Podium 2	1
(1-10) each floor	3
(11-18)	2

To determine the cross sectional area of the circuit breaker the following equation should be applied:

I = {(I Lighting * Diversity Factor) + (I socket * Diversity Factor) + (I special load* Diversity Factor)}* 1.15
Where: I= Total current.
D.F. of lighting = 0.8
D.F. of socket = 0.2
D.F. of special load = 1

Sample calculation for the second floor :

I= (6218/220)*0.8) + (216*0.2) + (40*1) = 105.8

Where 3 phase have been used
Then, 105.8 /3= 35.3
from below table the cross section of the CB = 10 mm².

I cable=1.15 I_{CB}
1.15*35.3=40.5 from the below table the cross sectional area

(Burned and enclosed in conducting) equals 16 mm².

Table 78 : summary of Electrical design

Area	**Electric item**			
	Circuit beaker	Cable	Lighting	Socket
Podium 1	4 mm^2	4 mm^2	1.5 mm^2	2.5 mm^2
Podium 2	4 mm^2	4 mm^2	1.5 mm^2	2.5 mm^2
(1-10)	10 mm^2	16 mm^2	1.5 mm^2	2.5 mm^2
(11-18)	6 mm^2	10 mm^2	1.5 mm^2	2.5 mm^2

conductor	Burned and enclosed in conducting trunk مدفون		Clipped direct to the surface and unclosed (معلق في الهواء)	
Nominal cross sectional area (mm2)	Single phase Current rating (Amp)	Three phase Current rating (Amp)	Single phase Current rating (Amp)	Three phase Current rating (Amp)
1.0	11	9	13	12
1.5	13	11	16	15
2.5	18	16	23	20
4.0	24	22	30	27
6.0	31	28	38	34
10	42	39	51	46
16	56	50	68	61
25	73	66	89	80
35	90	80	109	98

3.6.Quantities surveying & cost

3.6.1. Introduction

In this part of the project, the overall cost of each type of building was estimated. And the operation of them cost was also estimated. The table below show the The price of materials

Table79 : The price of materials

Material	Price
Concrete	**310 NIS/m^3**
Steel (bars and stirrups)	**2800 NIS/ton**
Block (10cm)+ Plaster	**56NIS/m^2**
Block (20cm) (use in slab)	**2.6 NIS/unit**
Traditional stone wall	**220-250 NIS/m^2**
Sand	**100 NIS/m^3**

3.6.2. cost and quantity for Excavation work

Type	Unite	Quantity	cost/m3 (include labore) (NIS)	Total cost (NIS)
leveling	m3	2380	**25**	**59500**
Excavation	m3	30000	**35**	**1050000**
Base coarse	m3	123	**90**	**11070**
∑				**1120570**

3.6.3.Construction Cost

3.6.3.1.Footing

type	Quantity	Unit	Cost /unit	Total cost	
Concrete	4185.7	m^3	380	1590566	
Blinding	250	m^3	310	77500	
Steel	764	Ton	2800	2139200	
$\sum$				3807266	

3.6.3.2.Columns and Shear Walls

type	Quantity	Unit	Cost /unit	Total cost	
Columns concrete	1150	m^3	380	437000	
Shear wall concrete	3670	m^3	380	1394600	
Columns steel (bars, stirrups)	111	Ton	3000	333000	
Shear wall steel (bars,stirrups)	762	Ton	3000	2286000	
$\sum$				4450600	

3.6.3.3.Slab and Beams

type	Quantity	Unit	Cost /unit	Total cost	
Beam concrete	2361	m^3	310	731600	
Slab concrete	4500	m^3	310	1395000	
beam steel (bars, stirrups)	114	Ton	3000	342000	
Slab steel (bars,stirrups,shrinkage)	702	Ton	3000	2106000	
Σ				4574600	

3.6.4.cost and quantity for Finishes work

type	Quantity	Unit	Cost /unit	Total cost	
Tiles	14690	m^2	90	1322100	
glass	3060	m^2	200	612000	
Block 10 cm+plaster	7945	m^2	57	452865	
Block 20 cm	133895	Number	3	401685	
Sand	927	m^3	130	120510	
Stone	5350	m(length)	55	294250	
Ceiling	14690	m^2	80	1175200	
External wall (aluminum,isoulation,gypsum)	3850	m^2	300	1155000	
Σ				5533610	

Total cost for all building = 19486646 NIS

Cost /m2 = 868 NIS

3.7. Conclusions and summary

In this project, an office building built downtown Nablus have been selected built downtown Nablus for design. This building has 25 floors with concrete structure and Alaminum panels façade. The main purpose is to build twest office tower .

3.7.1. Architectural

In Architectural design we designed 25 floors with areas of about 20000 m^2 include :

1- As main function : offices , open and close
2- Bank
3- Cafeteria
4- Gym

The building has twist shape .

3.7.2. structural

In this project we used concrete and steel as main material in design , the type of steel has f_y = 420 Mpa and the type of concrete we used is B600 for columns and mat foundation and type B300 for other .
We designed :

1- Slabs.
2- Beams .
3- Columns.
4- Ramps.
5- Water tank .
6- Stairs .

3.7.3. Hvac system

In this project we used (VRF) system After calculate the cooling , heating , and simulation for tower as shown in design chapter .

3.7.4. acoustics and lighting

- In lighting design we used 5 types of *luminaires after calculate the daylight in the tower* .

- In acoustics design we calculate STC and we compare values with recommendation STC , and we calculate RT_{60}

- For noise control in office space we used (masking sound system) .

3.7.5. Quantities surveying & cost

After finish design phase we calculate nearly total cost for building (**19486646 NIS)**
And for M^2 (870 NIS)

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Appendix A

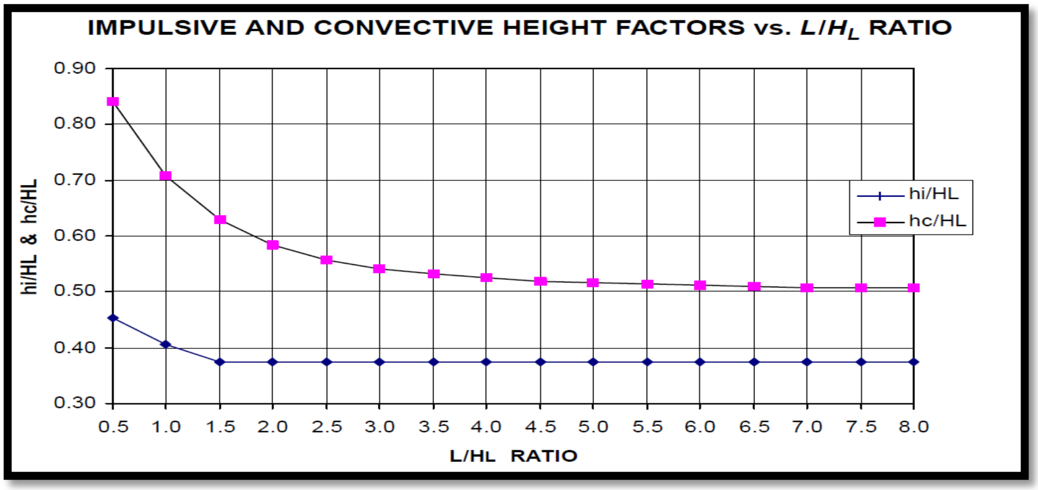

Figure A.1 : impulsive and convection height factors

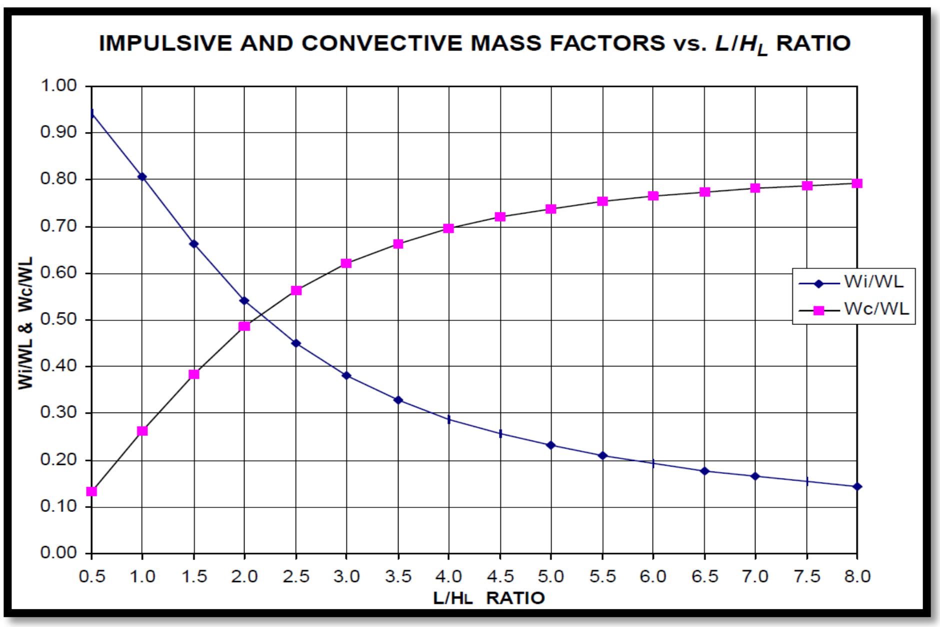

Figure A.2 : impulsive and convection mass factors

Appendix B

B.1. Water Drainage

PART A. BY TYPE OF FIXTURE			
Fixture(s)	**Drainage Fixture Units (dfu)**	***Minimum Trap Size***	
		in.	**mm[a]**
Automatic clothes washers: Commercial[b]	3	2	51
Residential	2	2	51
Bathroom group: Water closet (1.6 gpf [6 Lpf]), lavatory, and bathtub or shower; with or without a bidet and emergency floor drain	5	—	—
Bathroom group: Water closet (>1.6 gpf [6 Lpf]), lavatory, and bathtub or shower; with or without a bidet and emergency floor drain	6	—	—
Bathtub[c] (with or without overhead shower or whirlpool	2	1½	38
Bidet	1	1¼	32
Combination sink and tray	2	1½	38
Dental lavatory	1	1¼	32
Dental unit or cuspidor	1	1¼	32
Dishwashing machine[d], domestic	2	1½	38
Drinking fountain	0.5	1¼	32
Emergency floor drain	0	2	51
Floor drains	2	2	51
Kitchen sink, domestic	2	1½	38
Kitchen sink, domestic, with food waste grinder and/or dishwasher	2	1½	38
Laundry tray (1 or 2 compartments)	2	1½	38
Lavatory	1	1¼	32
Shower	2	1½	38
Service sink	2	1½	38
Sink	2	1½	38
Urinal	4	[e]	
Urinal, 1 gal (3.8 L) per flush or less	2[f]	[e]	
Urinal, nonwater supplied	0.5	[e]	
Wash sink (circular or multiple) each set of faucets	2	1½	38
Water closet, flushometer tank, public or private	4[f]	[e]	
Water closet, private (1.6 gpf [6 Lpf])	3[f]	[e]	
Water closet, private (>1.6 gpf [6 Lpf])	4[f]	[e]	
Water closet, public (1.6 gpf [6 Lpf])	4[f]	[e]	
Water closet, public (flushing >1.6 gpf [6 Lpf])	6[f]	[e]	

Figure B.1 : Drainage fixture units (DFU's) [24]

Diameter of Pipe			Maximum Total Number of dfu Allowable		
			Stacks[b]		
in.	mm[c]	Horizontal Branch	One Branch Interval	Three Branch Intervals or Less	Greater than Three Branch Intervals
1½	38	3	2	4	8
2	51	6	6	10	24
2½	64	12	9	20	42
3	76	20	20	48	72
4	102	160	90	240	500
5	127	360	200	540	1100
6	152	620	350	960	1900
8	203	1400	600	2200	3600
10	254	2500	1000	3800	5600
12	305	3900	1500	6000	8400
15	381	7000	d	d	d

Figure B.2 : Horizontal fixture branches and stacks [25]

Diameter of Soil or Waste Stack in. (mm)[b]	Total Fixture Units Being Vented (dfu)	Maximum Developed Length[a] of Vent, Feet (m)[b]									
		Diameter of Vent, In. (mm)[b]									
		1¼ (32)	1½ (38)	2 (51)	2½ (64)	3 (76)	4 (102)	5 (127)	6 (152)	8 (203)	10 (254)
1¼ (32)	2	30 (9.1)									
1½ (38)	8	50 (15.2)	150 (45.7)								
1½ (38)	10	30 (9.1)	100 (30.5)								
2 (51)	12	30 (9.1)	75 (22.9)	200 (61.0)							
2 (51)	20	26 (7.9)	50 (15.2)	150 (45.7)							
21/2 (64)	42		30 (9.1)	100 (30.5)							
3 (76)	10		42 (12.8)	150 (45.7)	360 (109.7)	1040 (317)					
3 (76)	21		32 (9.8)	110 (33.5)	270 (82.3)	810 (246.9)					
3 (76)	53		27 (8.2)	94 (28.7)	230 (70.1)	680 (207.3)					
3 (76)	102		25 (7.6)	86 (26.6)	210 (64.0)	620 (189.0)					
4 (102)	43			35 (10.7)	85 (25.9)	250 (76.2)	980 (298.7)				
4 (102)	140			27 (8.2)	65 (19.8)	200 (61.0)	750 (228.6)				
4 (102)	320			23 (7.0)	55 (16.8)	170 (51.8)	640 (195.0)				
4 (102)	540			21 (6.4)	50 (15.2)	150 (45.7)	580 (176.8)				
5 (127)	190				28 (8.5)	82 (25.0)	320 (97.5)	990 (301.8)			
5 (127)	490				21 (6.4)	63 (19.2)	250 (76.2)	760 (231.6)			
5 (127)	940				18 (5.5)	53 (16.2)	210 (64.0)	670 (204.2)			
5 (127)	1400				16 (4.9)	49 (14.9)	190 (57.9)	590 (179.8)			
6 (152)	500					33 (10.1)	130 (39.6)	400 (121.9)	1000 (304.8)		
6 (152)	1100					26 (7.9)	100 (30.5)	310 (94.5)	780 (237.7)		

Figure B.3 : Size and length of vent [26]

B.3. Elevators

Table B.2: Population of Typical Buildings for Estimating Elevator and Escalator Requirements

Building Type	Net Area
OFFICE BUILDINGS	FT2 PER PERSON (M2/PERSON)
Diversified (multiple tenancy)	
Normal	110–130 (10–12)[a]
Prestige	150–250 (14–23)
Single tenancy	
Normal	90–110 (8–10)
Prestige	130–200 (12–19)
HOTELS	PERSONS PER SLEEPING ROOM
Normal use	1.3
Conventions	1.9
HOSPITALS	VISITORS AND STAFF PER BED[b]
General private	3
General public (large wards)	3–4
APARTMENT HOUSES	PERSONS PER BEDROOM
High-rental housing	1.5
Moderate-rental housing	2.0
Low-cost housing	2.5–3.0

Table B.3: Elevators Equipment Recommendations

	Car Capacity[a]		*Rise*		*Minimum[a] Car Speed*	
Building Type	**lb**	**kg**	**ft**	**m**	**fpm**	**m/s**
Office building	2500 3000 3500	1250 1250 1600	0–125 126–225 226–275 276–375 Above 375	0–40 41–70 71–85 86–115 >115	350–400 500–600 700 800 1000	2.0 2.5 3.15 4.0 5.0
Hotel	2500 3000	1250 1250	As above		As above	
Hospital	3500 4000	1600 2000	0–60 61–100 101–125 126–175 176–250 >250	0–20 21–30 31–40 41–55 56–75 >75	150 200–250 250–300 350–400 500–600 700	0.63 1.0 1.6 2.0 3.15 4.0
Apartments	2000 2500	1000 1250	0–75 76–125 126–200 >200	0–25 26–40 41–60 >60	100 200 250–300 350–400	0.63 1.0 1.6 2.0
Stores	3500 4000 5000	1600 2000 2500	0–100 101–150 151–200 >200	0–30 31–45 46–60 >60	200 250–300 350–400 500	1.0 1.6 2.0 2.5

Facility	Percent of Population to Be Carried in 5 Minutes
OFFICE BUILDINGS	
Center city	12–14
Investment	11.5–13
Single-purpose	14–16
RESIDENTIAL	
Prestige	5–7
Other	6–8[a]
Dormitories	10–11
Hotels—first quality	12–15
Hotels—second quality	10–12

Table B. 4: Recommended Elevator Intervals and Related [a] Lobby Waiting Time:

Facility Type	Interval (sec)	Waiting Time[a] (sec)
OFFICE BUILDINGS		
Excellent service	15–24	9–14
Good service	25–29	15–17
Fair service	30–39	18–23
Poor service	40–49	24–29
Unacceptable service	50+	30+
RESIDENTIAL		
Prestige apartments	50–70	30–42
Middle-income apartments	60–80	36–48
Low-income apartments	80–120	48–72
Dormitories	60–80	36–48
Hotels—first quality	30–50	18–30
Hotels—second quality	50–70	30–42

[a]Based on the relationship: waiting time = 0.6 × interval.

Table B. 5: Car Passenger Capacity (P)

Elevator Capacity lb (kg)	Maximum Passenger Capacity	Normal Passenger[a] Load per Trip
2000 (907)	12	10
2500 (1134)	17	13
3000 (1361)	20	16
3500 (1588)	23	19
4000 (1814)	28	22

B.4. Water supply

Table C. 6: Water Supply Fixtures Units (WSFU):

Fixture	Occupancy	Type of Supply Control	Load Values in WSFU		
			Cold	Hot	Total
Bathroom group	Private	Flush tank	2.7	1.5	3.6
Bathroom group	Private	Flush valve	6	3	8
Bathtub	Private	Faucet	1	1	1.4
Bathtub	Public	Faucet	3	3	4
Bidet	Private	Faucet	1.5	1.5	2
Combination fixture	Private	Faucet	2.25	2.25	3
Dishwashing machine	Private	Automatic		1.4	1.4
Drinking fountain	Offices, etc.	⅜ in. (9.5 mm) valve	0.25		0.25
Kitchen sink	Private	Faucet	1	1	1.4
Kitchen sink	Hotel, restaurant	Faucet	3	3	4
Laundry trays (1 to 3)	Private	Faucet	1	1	1.4
Lavatory	Private	Faucet	0.5	0.5	0.7
Lavatory	Public	Faucet	1.5	1.5	2
Service sink	Offices, etc.	Faucet	2.25	2.25	3
Shower head	Public	Mixing valve	3	3	4
Shower head	Private	Mixing valve	1	1	1.4
Urinal	Public	1 in. (25 mm) flush valve	10		10
Urinal	Public	¾ in. (19 mm) flush valve	5		5
Urinal	Public	Flush tank	3		3
Washing machine, 8 lb (3.6 kg)	Private	Automatic	1	1	1.4
Washing machine, 8 lb (3.6 kg)	Public	Automatic	2.25	2.25	3
Washing machine, 15 lb (6.8 kg)	Public	Automatic	3	3	4
Water closet	Private	Flush valve	6		6
Water closet	Private	Flush tank	2.2		2.2
Water closet	Public	Flush valve	10		10
Water closet	Public	Flush tank	5		5
Water closet	Public or private	Flushometer tank	2		2

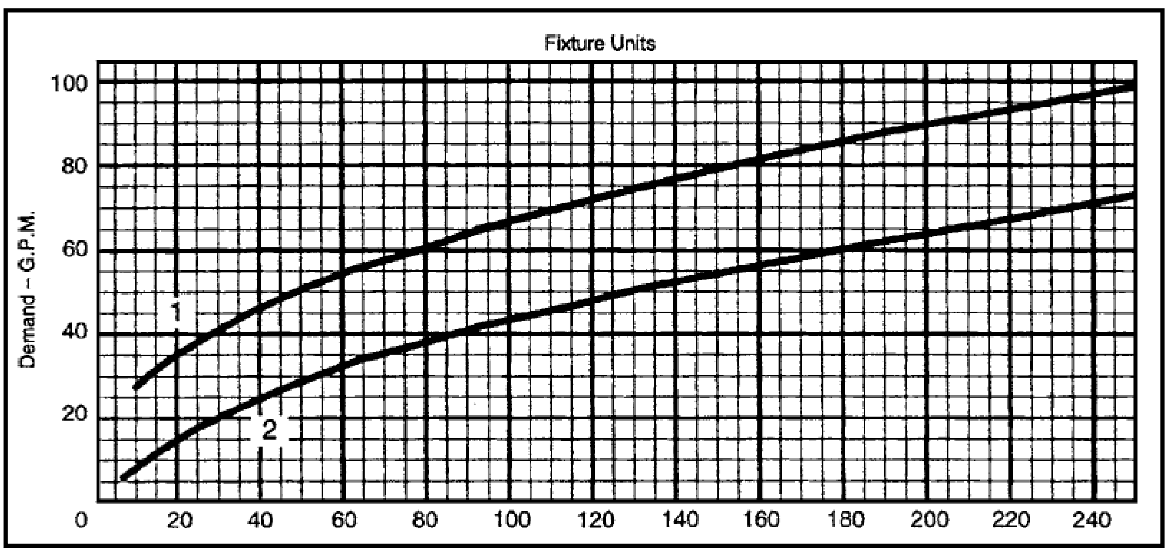

Figure B.5: Estimate curves for flow based upon total water supply fixture units, curve 1is for a system with predominantly flush valves; curve 2 is for a system with predominantly flush tanks

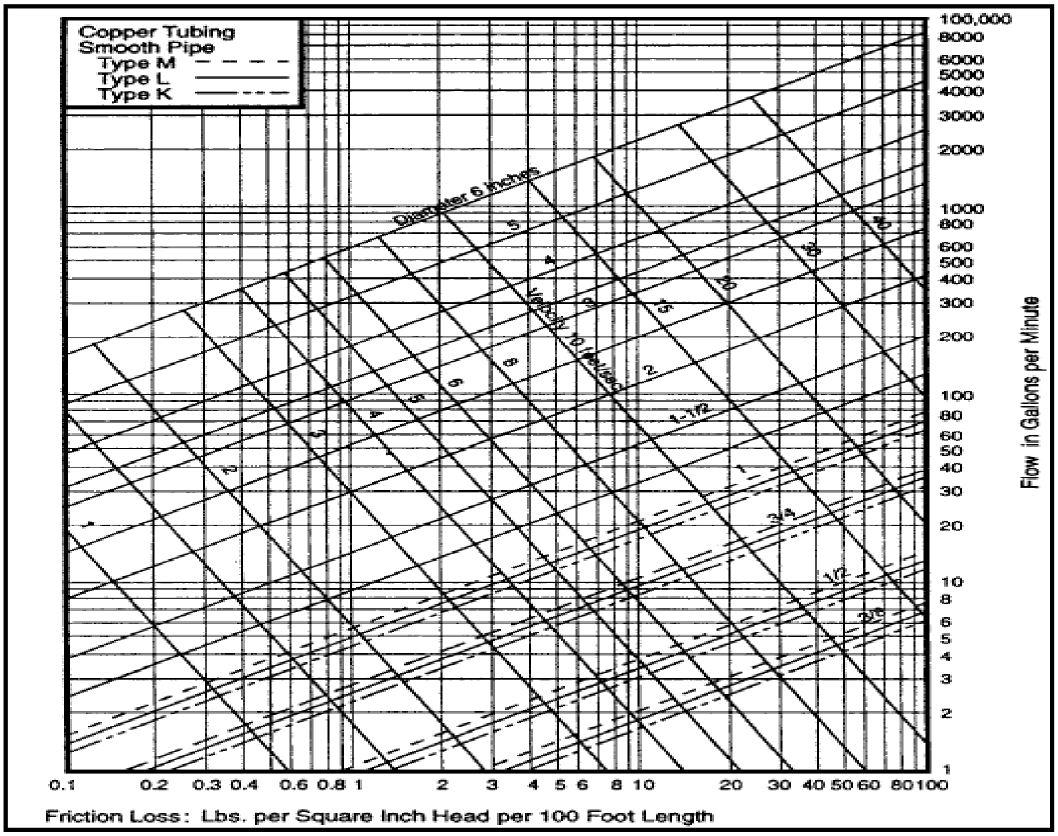

Figure B.6: Friction loss chart for smooth pipe. Velocity is shown to assist in noise control efforts: above 10 fps (3 m/s), moving water can be clearly heard within pipes.

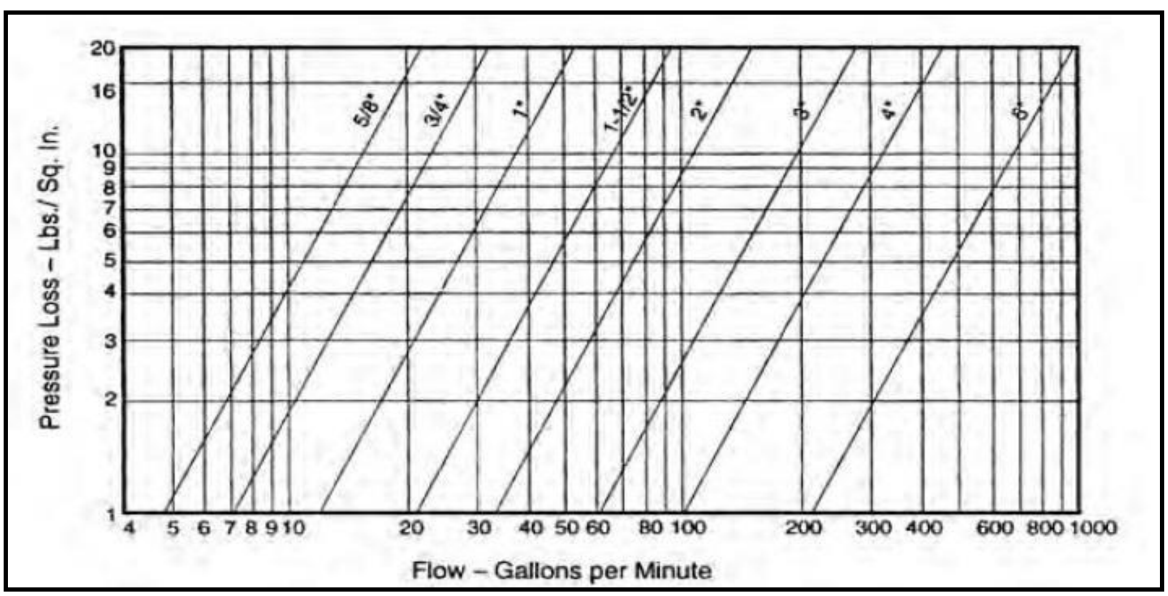

Figure B.7: Pressure losses in disk-type water meters.