Seismic analysis of multi-story building having different structural systems using ETABS

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ABSTRACT

This project presents the analysis of a multi-story building based on an architectural project. The scope of this work is to create a structure with minimize the cost with ensuring the safety of the building when facing external loads such as (Dead load, Live load, and Seismic load). The purposed study object has an regular geometry in plan, with an implantation area of approximately 680 m_2 the building has an elevation of 37.8 m from the ground level, The structure has been designed using ETABS Software.

Main purpose is to use two different structural systems and checking safety for both systems with some seismic criteria.

CHAPTER ONE INTRODUCTION

1.1 Background

The first principles of any structural design are safe and economic, cost , quality , serviceability, And we are as designer engineers should achieve these goals very nicely especially in seismic regions which is difficult but we say not Impossible .

1.2 Multi-story building

The development of the high-rise building has followed the growth of the city closely. For civil Engineers multi story building refers as a tall building which can be affect highly by lateral forces, such as wind or seismic loads , and they have direct relation with structural design of the building.

Using a reinforced concrete in the weak tensile zone of the concrete especially , is very common and the goal is to maintain ductility for the structural members .

1.3 Structural members

Every multi-story building generally have two types of structural elements , horizontal such as slabs and beams , verticals such as columns and Shear walls, and we have foundation which is directly Supported by the soil to distribute the loads tranferred by elements above .

1.4 Earthquake

Generaly it is sudden shaking of earth surface caused by transferring of the seismic waves in the rocks below the earth surface, and this energy will be transmit through foundation to the building , analyzing and estimating this forces and deformation, will be major criteria because highly affect the structure.

1.5 Seismic design

When we talk about designing a building or a structure to resist earthquake, that mean the building must dissipate the energy that comes from movement of below earth particles , at this point we can say ductility of beams and columns is major and very effective point because suddenly that loads come to the building , so the members should be ductile enough to deform at limit without high damage , and this taking advantage by using sufficient amount of steel in members . first that energy transmit to the building through foundation as a loads and transfered to all floors , therefore each floor diaphragm should be stiff enough to transfer loads to vertical members like columns and shear walls , so in multi-story buildings the floors in addition to resist gravity loads , must design to act as diaphragms .

1.6 Structural systems for resisting lateral loads

Choosing the frame type will directly affect safety and cost of the project so the structural engineer desecion will be critical and effective.

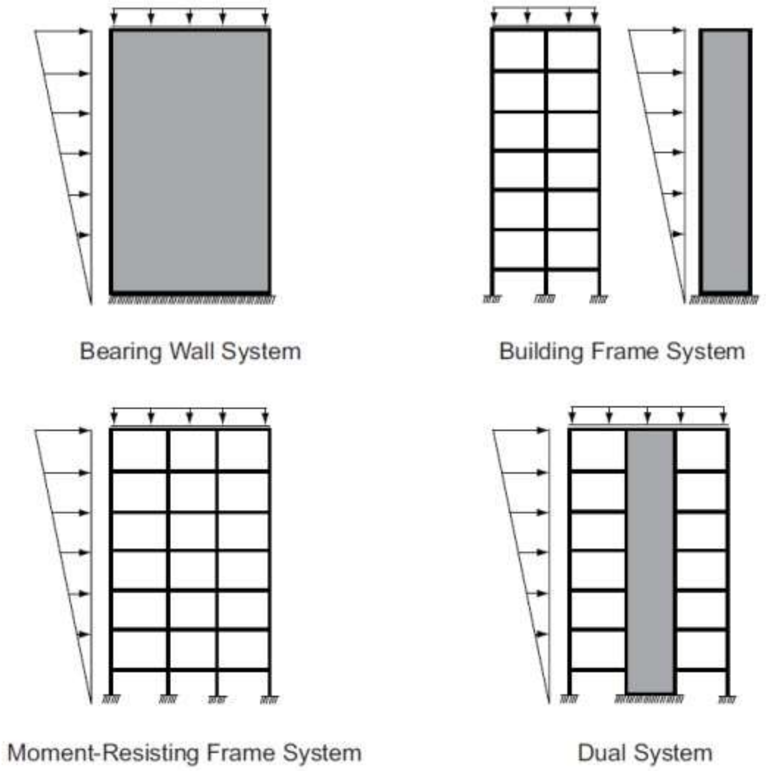

Figure 1.1 : Earthquake-Resisting Structural Systems of Reinforced Concrete

we have four Earthquake resistant systems which we can use it in the buildings

- Bearing wall system : the structural walls provides vertical support for the building vertical forces and some resistance to the lateral forces, this type commenly used in residential houses and low rise commercial buildings.
- Moment resisting frame : In this system lateral stiffness will be provided by columns only and there is no need to use shear walls.

- Building frame or shear wall frames : lateral forces will be resist by shear walls only.
- Dual system : both columns and shear walls will be design for resisting lateral loads.

in our research we analyze 10 story building with two different systems which are building frame and dual system , after analyzing we can evaluate the results between this systems.

1.7 ETABS Software

In present times, there are several methods to analyzing and design buildings so we can choose a structural software like ETABS which is simple to use and has a very interactive user interface which allows to model the frame and input load values , dimensions and material properties . FEA is computerized method which is use for solving mathematical problems and models in 2 dimensions and 3 dimensions , and engineers with selecting etabs they use this method for analyzing structural models , to maintain more accurate results .

1.8 Objectives of the study

To understand how the buildings act at time of incoming seismic waves , how the loads distribute between structural elements , how the results will change if you have different structural systems and how to use a 3D software for modeling a structure and analyzing it.

CHAPTER TWO LITERATURE REVIEW

2.1 General Review

For analyzing any buildings due to lateral loads, or we can say to estimate the amount of loads that apply laterally to structural members we need to choose methods and codes, the seismic codes are set of formulas for resistant design of earthquake , by the time these codes are changed and Improved with investigating and researches continously, however always the objective is to design buildings safely and economy .

2.2 Assessment previous research

In this section we talk about a research carried with name (Seismic analysis of structure with varying height & soil condition) , in this case they have different types of soil strata which lead to different moition of ground when the structure subject to Earthquakes, and change in alteration that transfer from ground to the building floors with variation in floors (G + 8 , G + 16 , G + 24) .

2.2.1 Geometry of the building

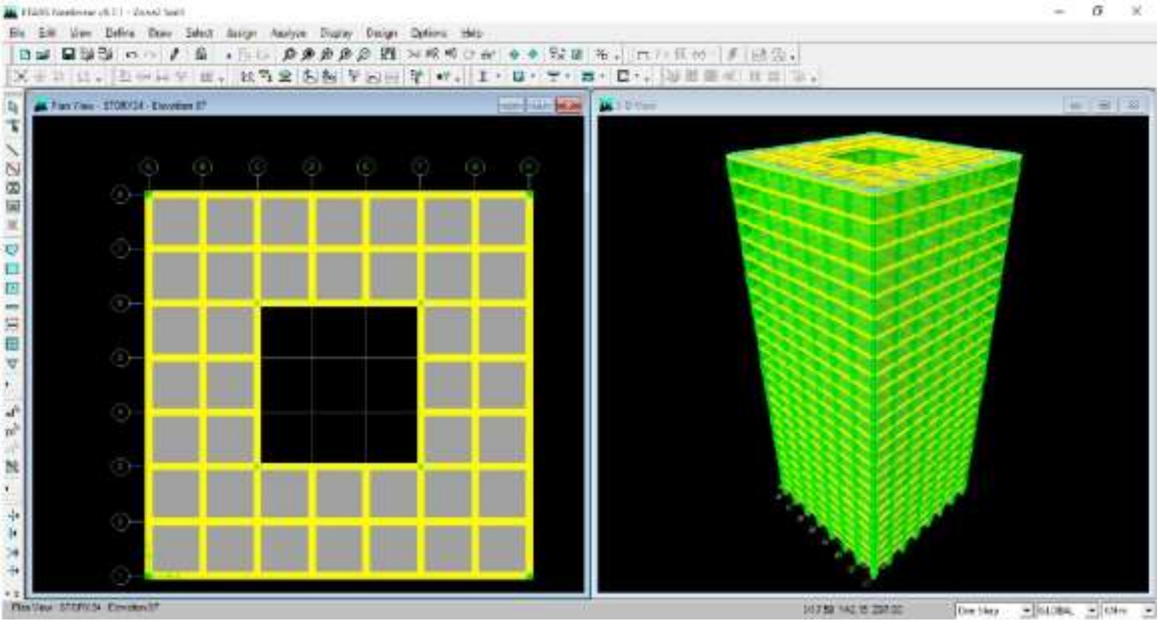

Figure 2.1 : Plan and 3D of the building

From the figure we can see the structural elements which is slabs , beams , columns and foundation . the structural system (moment resisting frame) used in this model which is all lateral loads should be resisting by columns so we expect larger size of columns compare to (dual system) which is a percentage of lateral loads resist by shear walls .

2.2.2 Parameters used in the model

Table 2.1 : parameters used for analyzing the structure

	Specification	Detail
1	Zones	II,III,IV,V
2	Types of soil	Hard , Medium , soft
3	Thickness of slab	15 cm
4	Imposed load	4 kN/m2
5	Finishing load	1 kN/m2
6	Size of bottom columns G+8	1.00 x 1.00 m
7	Size of columns 8 to 16 story	.80 x .80 m
8	Size of columns 16 to 24 story	.60 x .60 m
9	Materials	Fc=40Mpa Fy=415Mpa
10	Importance factor	1
11	Response reduction factor	5
12	Seismic analysis	Equivalent static load method IS 1893 (part1):2002

In Indian standards the seismic zones distribute to four zones (Zone II , Zone III , Zone IV , Zone V) and according to these zones you can find the rist category and Response reduction factor which affect the base shear

they used gravity and lateral load combinations with normal dead and live load , and equivalent static lateral load method that we can use in case we have a symmetric and regular building , or we should use dynamic analysis which is more complex .

2.2.3 Analyzing the results

Table 2.2 : Base shear for G+8 Story

Zone	Rocky soil	Medium soil	Soft soil
II	670.688	912.625	1120.26
III	1073.10	1460.20	1792.42
IV	1609.65	2190.30	2688.63
V	2414.48	3285.45	4032.95

For the 8 story building clearly we can see increasing base shear with decreasing the foundation soil and moving to active seismic zones , for example at zone II and rocky soil they have minimum base shear , and this load distribute to all stories which is in this case the floors and vertical members apply on them smaller lateral force magnitude compare to soft soil and zone V, so we can say buildings in non-active seismic zones and on the hard soils needs less concrete sections and amount of steel so it's more economical. Table 2.3: Base shear for G+24 story

Zone	Rocky soil	Medium soil	Soft soil
II	1868.87	2541.65	3101.55
III	2971.56	4041.32	4962.51
IV	4457.54	6061.96	7443.74
V	6685.99	9092.99	11164.63

From the equation of base shear we notice it relations directly proportional with the weight of the building so for the 24 story building increased base shear compare to 8 story.

$$\boldsymbol{V} = \frac{\boldsymbol{C\,v\;I}}{\boldsymbol{R\,T}}\boldsymbol{W}$$

CHAPTER THREE METHODOLOGY

3.1 GENERAL

Methods of modeling and applying the seismic loads are important in order to understand the seismic behavior of the structures . This project is carried out by using finite element method with ETABS software .

3.2 DESCTIPTION AND MODEL OF THE BUILDING

A ten-storey building with penthouse as shown in figures 3.1 to 3..3

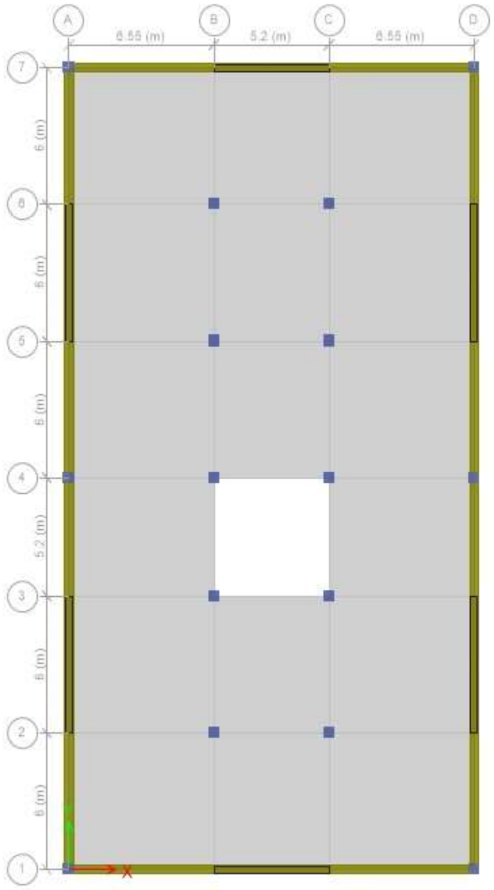

Figure 3.1 : Structural plan of the building

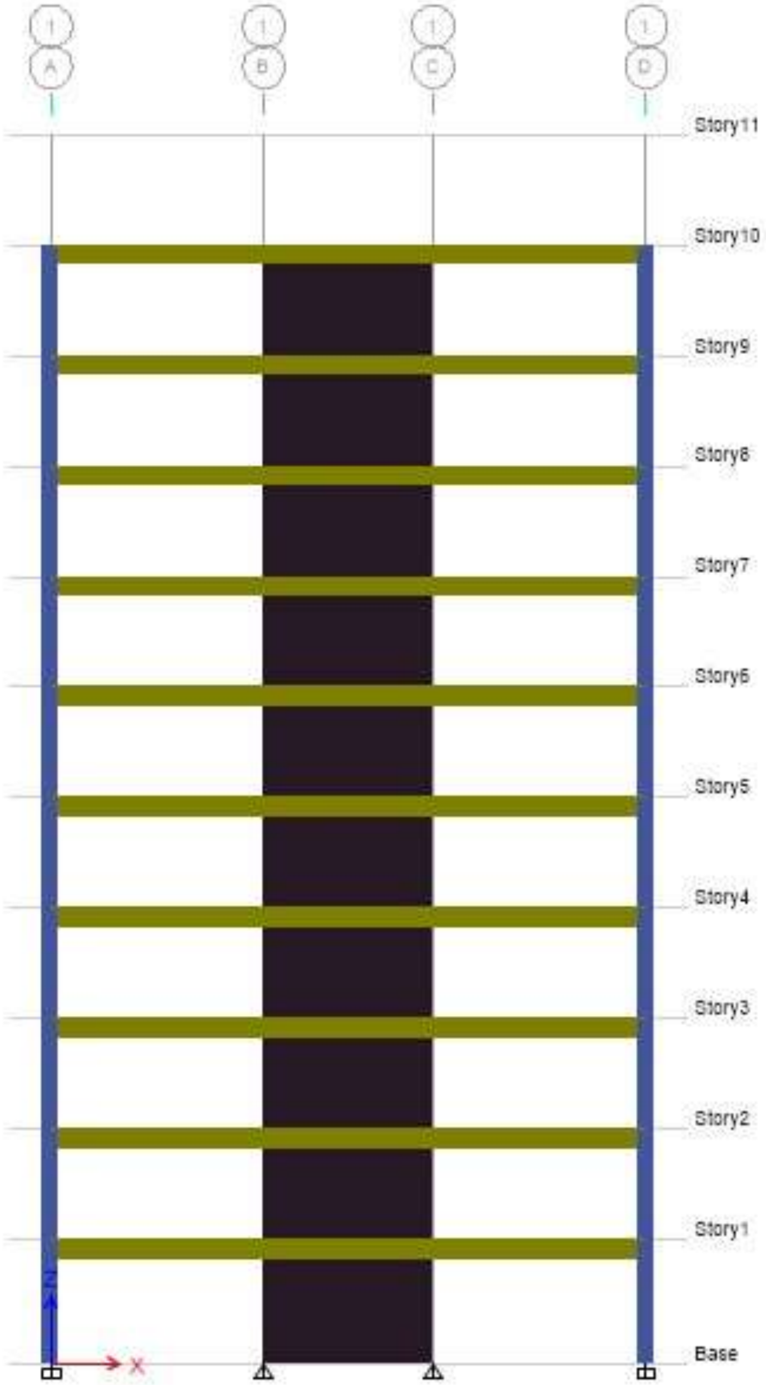

Figure 3.2 : Structural side elevation of the building

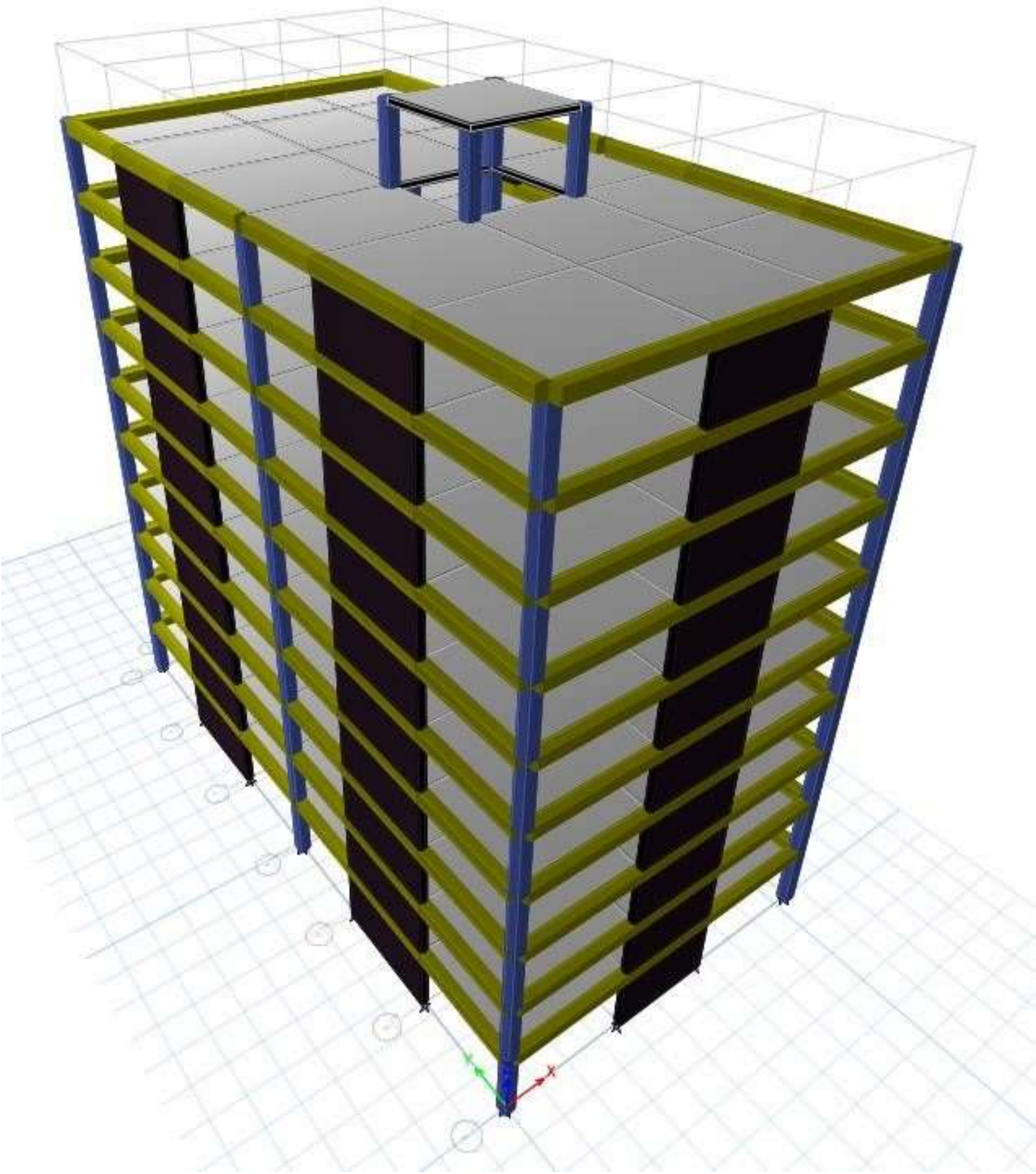

Figure 3.3 : Three-dimensional view of the building and structural members

The building is composed of Flat slab 20cm thickness . Frame elements used for columns & beams , and shell element used for slabs and shear walls .
The overall plan of the building is rectangle with dimensions 35.80 m x 18.90 m as shown in figure 3.1

Height of the building is 37.8 m , and story height for each floor is 3.4 m expect first floor

3.8 m .

3.3 Structural Systems

Choosing structural system for resisting both gravity and lateral loads is very important because directly affect the safety and economy of the structural design , the path of gravity loads usually from slabs to beams (if solid slab) next to columns and then to foundation . For lateral loads if we talk about seismic , lateral movement of earth during earthquakes result the force we call base shear , generally it depends on the weight of the structure and seismic coefficients . This Horizontal force will distribute to center of rigity of each storey slab , The above definition is valid when slab is modelled as a rigid diaphragm . the stories lateral force will be greater with increasing height of the story as shown in figure 3.4 The loads will transfer from slabs to beams then to vertical members (columns and shear walls) . with building frame system all lateral loads will resist by shear walls , and columns only resist gravity loads . if the columns and shear walls both resist gravity and lateral loads then the structural system will be dual system .

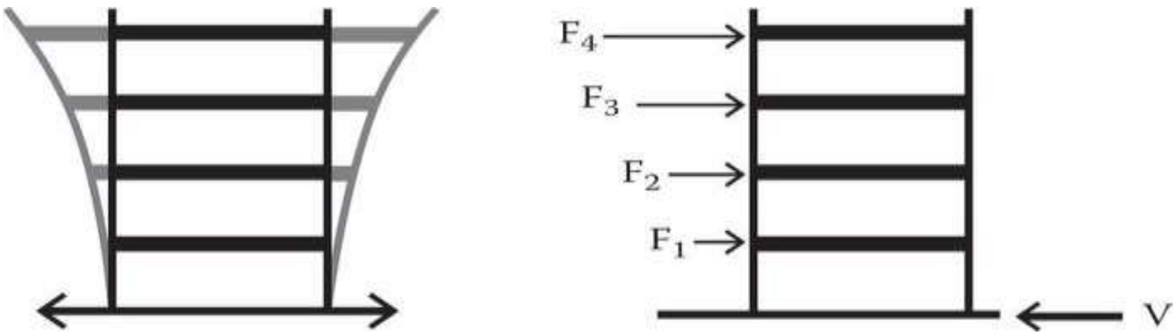

Figure 3.4 : Base shear and lateral load on the structure

3.4 ETABS ANALYSIS

3.4.1 Concrete Properties

Table 3.1 : Concrete properties

Compressive strength	25 MPa
Weight density	24 kN/m3
Modulus of Elasticity	23500 MPa
Mass density	2447.319 kg/m^3

3.4.2 Steel reinforcement Properties

Table 3.2 : Steel reinforcement properties

Yield strength	420 MPa
Ultimate strength	525 MPa
Expected yield strength	462 MPa
Expected Tensile Strength	577.5 MPa
Min. Unit-weight	7800 kN/m^3

3.4.3 Concrete cover for structural members

Table 3.3 : Concrete cover

Structural members	Cover mm
Beam	**40**
Column	**40**
Slab	**15**
Shear wall	**40**

3.4.4 Assign frames as continuous moment release

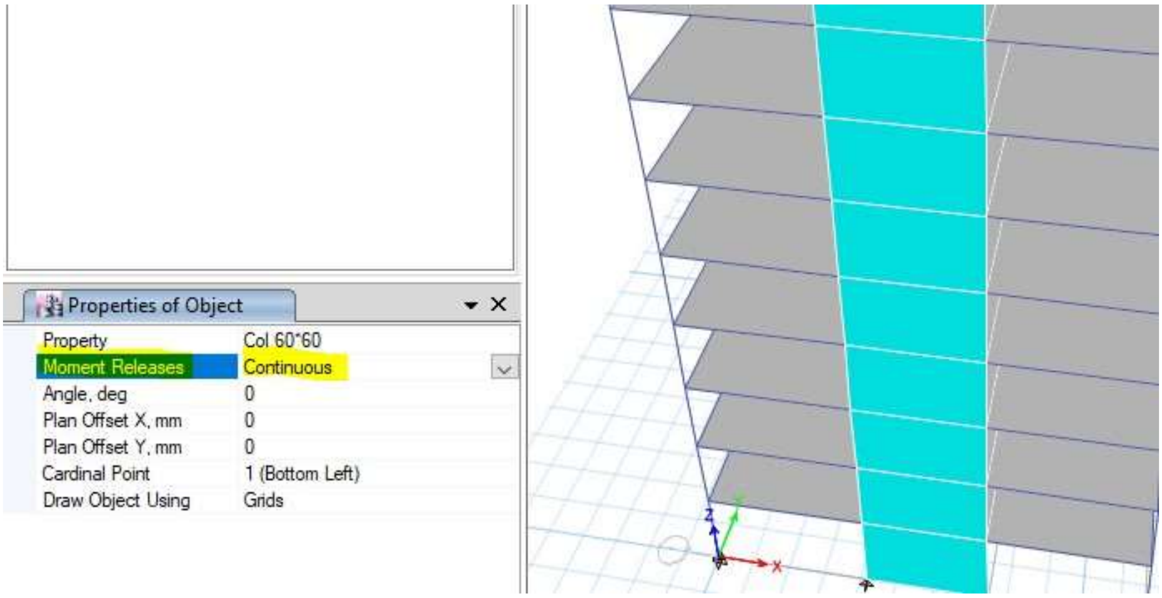

Figure 3.5 : Continous moment releases

A Continuous end represents, in reality, a condition where the connection is:

1. designed to transfer moment from one member to the next, and,
2. Is relatively not free to rotate.

3.4.5 Assign Slabs as shell

When we use etabs we recognize that we have 3 options for slab and wall elements , they are shell & membrane and plate , choosing one of them will have effect on the our results. If slab assigned as membrane then it will not resist bending moment because it doesn’t have out-of-plane stiffness . If slab assigned as plate section it has out-of-plane stiffness and resist bending moment but can’t resist horizontal loads because it doesn’t have inplane stiffiness . And finally we can assign slabs as shell which have full in-plane and out-of-plane stiffness , a percent of bending on the slab directly transfer to columns so we have larger slab thickness and lesser bending moment on beams and we need to mesh the slabs to get more accurate results.

CHAPTER FOUR CONCLUSION AND RECOMMENDATION

The following main conclusion can be drawn :

1-Maximum drift of stories for dual system higher than building frame system .

2-Story displacement due to earthquake load lesser in building frame system compare to dual system .

3-Lateral load applied to stories in building frame model higher than dual system and therefore we say base shear in the building frame is higher .

4-The difference between center of mass and rigidity in dual system is higher than building frame system .

RECOMMENDATION

Flat Slabs are considered suitable for most of the construction and need special considerations during implementation in terms of formwork, safety, formwork removal, and concrete casting. Formwork should be designed by specialist engineering team to avoid any difficulties and maintaining safety environment

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