SEISMIC ANALYSIS AND COMPARISON OF VARIOUS BUILDING PARAMETERS FOR DIFFERENT ZONES ACCORDING TO BNBC 2020

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Section: 15B
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DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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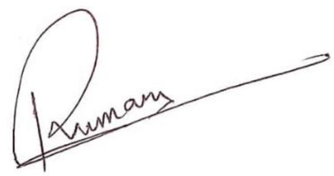
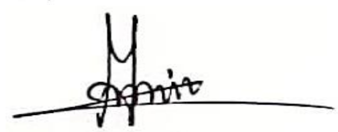
Ruman Molla	**BCE1803015069**	
Md Monir Hossen	**BCE1803015085**	
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Dedicated

to

"Our Respectful Teachers

And Parents"

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ABBREVIATION

LSA= Linear Static Analysis.

RSA= Response Spectrum Analysis.

LVDT= Linear Variable Differential Transformer.

ETABS= Extended Three-Dimensional Analysis of Building System.

BNBC= Bangladesh National Building Code.

UBC= Uniform Building Code.

ACI= American Concrete Institute.

DTHA= Dynamic Time History Analysis.

ABSTRACT

This thesis shows the effects of seismic load analysis of different zones of Bangladesh which states in BNBC 2020. We perform Linear Static Analysis and Response Spectrum Analysis by ETABS version 16.2.1. We performed those analyses to understand the earthquake effect in Bangladesh as there is a huge vulnerability to earthquake effect. This thesis covers both the analysis and comparison of result for all the four zones in Bangladesh.

The storey displacement from the result were comparable with each other. The higher zone co-efficient seems to be responsible for a higher storey displacement. Though we take a 4 storied residential building for analysis but RSA results are not a satisfactory level where the LSA results are some beyond the limit, and some are not. Other building parameters are in satisfactory level such as Column P-M-M ratio is less than 1. As the LSA results are not such devastating like RSA, so there should be some addition for reducing the storey displacement in RSA result for each zone as like shear wall. Therefore, more analysis should be done for better result.

Doing numerical evaluation helps us understand seismic behavior for small frame structures. It can also provide results and decisions about unique moment-resisting frame structures. But there should be done some practical or project work to establish a better performance of this thesis.

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CHAPTER 1
INTRODUCTION

1.1 Background Theory

Seismology is the study of the passage of *elastic waves* through the earth. Earthquake seismology is the best tool to study the interior of the earth. When an earthquake or explosion occurs, part of the energy released as elastic waves that are transmitted through the earth.

Earthquake

Most earthquakes are caused by the sudden release of built-up stress along faults, fractures in the Earth's crust where large blocks of crustal rock move against one another. Earthquakes are one of the most powerful natural forces that can disrupt our daily lives. Few natural phenomena can wreak as much havoc as earthquakes. Over the centuries they have been responsible for millions of deaths and an incalculable amount of damage to property.

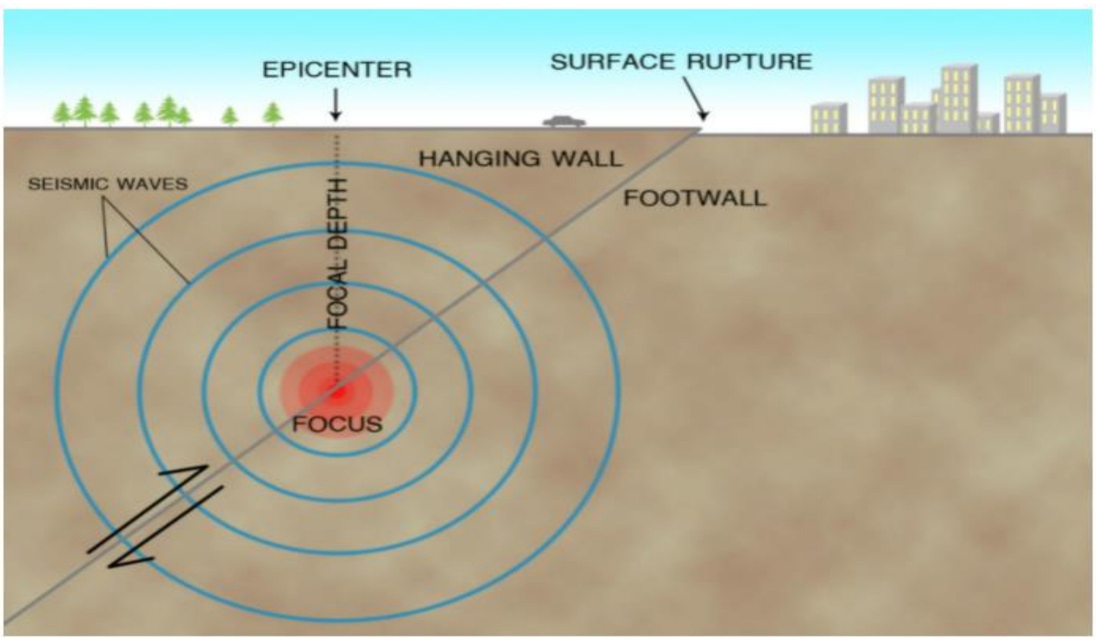


Fig. 1.1: Focus, Epicenter, Fault Line and Seismic Waves [20]

Seismic Wave

There are two different types wave produced by an earthquake**:** Body waves and Surface waves.

Body Waves

Body waves are seismic waves that travel through the body of the earth. Body waves are reflected and transmitted at interfaces where seismic velocity and/or density change, and they obey *Snell's law*.

The two different types of Body Waves are:

P-Waves

These waves are also called longitudinal waves or compressional waves due to particle compression during their transport. These waves involve compression and rarefaction of the material as the wave passes through is but not rotation. P-wave is transmitted by particle movement back and forth along the direction of propagation of the wave. The most correct description of P-waves is it is a dilatational or irrotational waves. P-waves have the greatest speed and appears first on seismograms.

S-Waves

Also known as transverse waves, because particle motions are transverse to the direction of movement of the wave front, or perpendicular to the ray. These waves involve shearing and rotation of the material as the wave passes through it, but not volume change. S-waves have speeds less than P-waves, and appear on seismograms after P-waves.

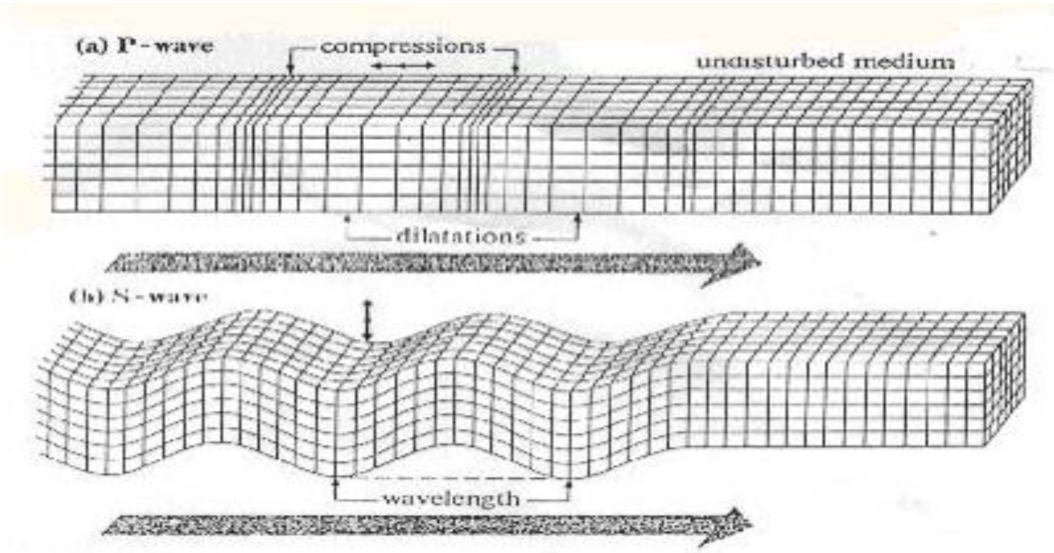


Fig 1.2: Body Wave (Both P & S wave) [16]

Surface Waves

Surface waves are seismic waves that are guided along the surface of the Earth and the layers near the surface. These waves do not penetrate the deep interior of the earth, and are normally generated by shallow earthquakes (nuclear explosions do not generate these surface waves). Surface waves are larger in amplitude and longer in duration than body waves. These waves arrive at seismograph after the arrival of P- and S-waves because of their slower velocities.

The two different surface waves are:

Rayleigh waves

Descriptively called "ground roll" in exploration seismology. The particle motion of this wave is confined to a vertical plane containing the direction of propagation and retrogrades elliptically. The particle displacements are the greatest at the surface and decrease exponentially downward. Rayleigh waves show dispersion, and its velocity is not constant but varies with wavelength. This wave is similar to how ocean waves propagate.

Love waves

Travel by a transverse motion of particles that is parallel to the ground surface. This wave is somewhat similar to S-waves. Love wave cannot exist in a uniform solid, and can only occur when there is a general increase of S- wave velocity with depth. Their existence is another proof of the Earths vertical inhomogeneity. The particle motion is transverse and horizontal. Generally, love wave velocities are greater than Rayleigh waves, so love waves arrive before Rayleigh waves on seismograph.

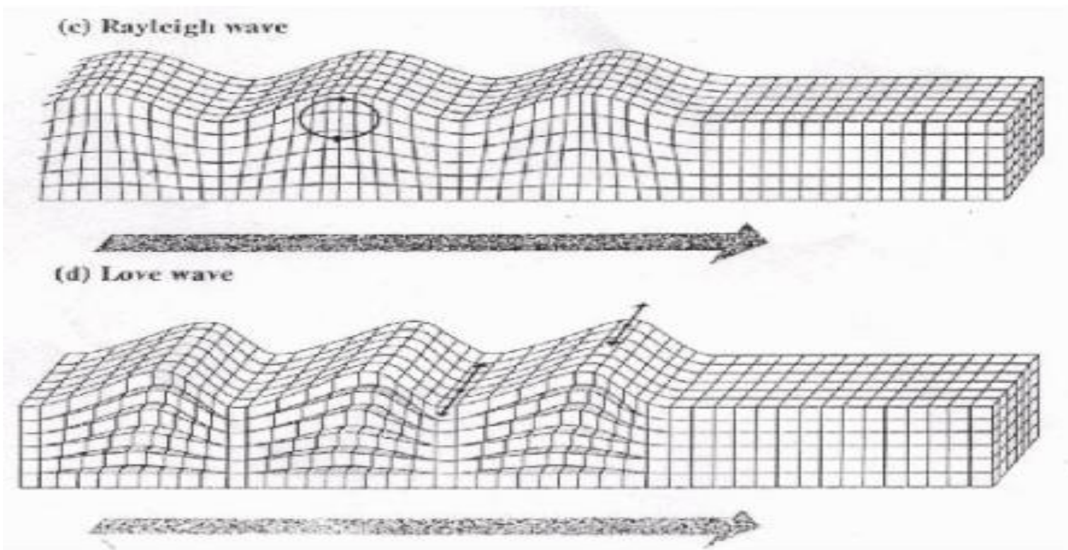


Fig 1.3: Surface Wave (Both Rayleigh & Love wave) [17]

1.2 Earthquake in Bangladesh

During the last 150 years, seven major earthquakes (with M > 7.0) have affected the zone that is now within the geographical borders of Bangladesh; some also had epicenters within Bangladesh. The earthquakes and their effects are described in Table 1.1.

Table 1.1: List of major Earthquakes affecting Bangladesh [15]

Date	Name of Earthquake	Epicenter	Magnitude (Richter)	Epicentral distance from Dhaka (km)
10th Jan, 1869	Cachar Earthquake	Cachar (east of Sylhet)	7.5	250
14th July, 1885	Bengal Earthquake	Manikganj	7.0	170
12th June, 1897	Great Indian Earthquake	Assam (north of Mymensingh)	8.7	230
8th July, 1918	Srimongal Earthquake	Srimongal	7.6	150
2nd July, 1930	Dhubri Earthquake	Dhubri (east of Rangpur)	7.1	250
15th Jan, 1934	Bihar-Nepal Earthquake	India-Nepal border	8.3	510
15th Aug, 1950	Assam Earthquake	Assam	8.5	780

Fig 1.4: New mega-thrust fault-line [18]

Fig 1.4 shows the fault-line around Sylhet-Comilla-Chattogram which is apprehended to cause catastrophic earthquake in the future, possibly causing major damage all over Bangladesh.

But the major fault line shows in the Fig 1.5 which is responsible for the major earthquakes around Bangladesh.

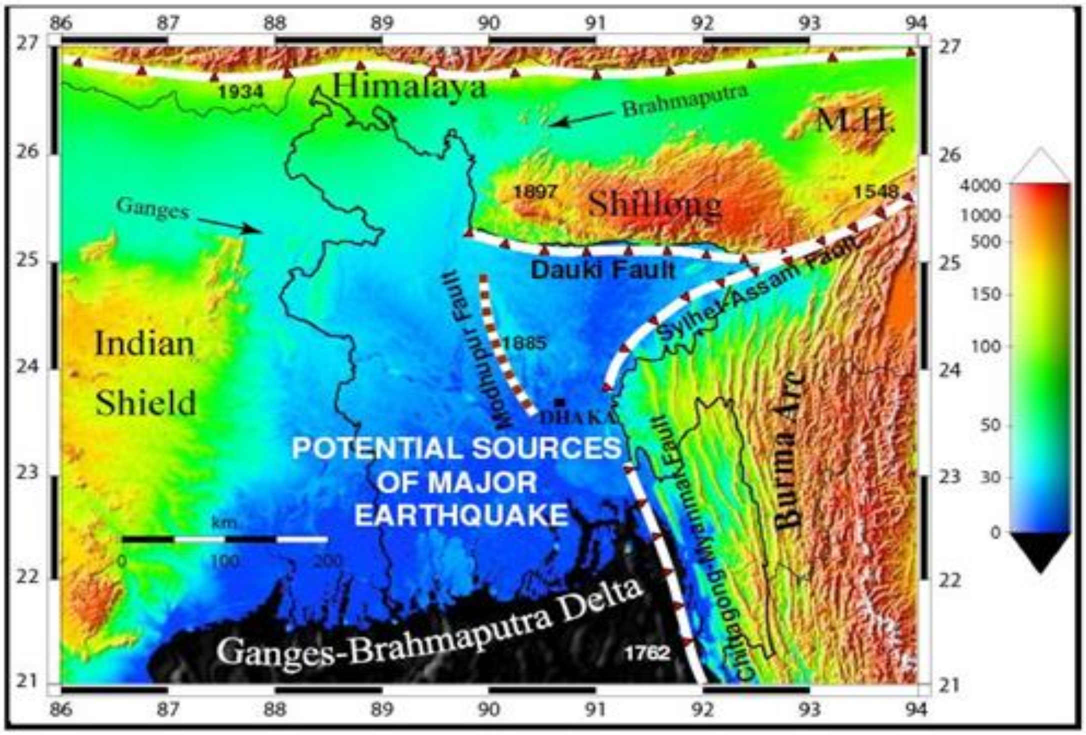


Fig 1.5: Major Fault-lines around Bangladesh [19]

For these major criteria of updating earthquake knowledge, there should be necessary steps while structural members are constructed by the study of earthquake with seismic data. So, this thesis has been taken for such analysis and comparison of the result in various earthquake zone in Bangladesh.

1.3 Objective

The main objective of this thesis is to perform numerical analysis of a residential building for each of the zone which are described in BNBC 2020. Here we analyzed Equivalent Static Analysis and Response Spectrum Analysis of the taken model of building. We also compared the risk factors of the numerical result values in different zones and evaluated the numerical results using ETABS version 16.2.1.

1.4 Thesis Layout

The thesis has been organized in five chapters. Following is the content layout.

Chapter 1: Contains background theory and the basic concepts of seismology and earthquake, earthquake history in Bangladesh, major fault lines, the objective of the work and the thesis layout.

Chapter 2: Includes the Literature Review of some of the previously done thesis works on this field.

Chapter 3: Presents theoretical background and the numerical analysis method of the thesis description about the software ETABS.

Chapter 5: Describes the results and discussion about it.

Chapter 6: Contains the conclusions of the study as well as recommendations for future study and work.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this chapter we will discuss about some literature review of previous works in this field. Numerous researches have been performed and going on worldwide for better understanding of the seismic behavior of the ground motion or earthquake. Outstanding works have been published in journals and presented in conferences. The knowledge gained and the methodology adopted is important for gradual increase of sense of new researchers. The chapter includes a brief discussion of some of the relevant works.

2.2 International and National works

Mohd Abdul Aqib Farhan and Jagadeesh Bommisetty (2019) **"Seismic Analysis of Multistoried RCC Buildings Regular and Irregular in Plan." [8]**

This paper focuses on the study of seismic response of buildings having regular and irregular plan in configurations. FEM modelling and analysis was carried out using ETABS software. Response spectrum Analysis is carried out for seismic zones. Linear Static Dynamic Analysis has been performed to understand the performance characteristics of the irregular structures in comparison with regular RC structures.

Here the study is carried out for the behavior of G+14, G+19, G+6 and building with different shapes in all zones which is Regular-shape, T-shape, C-shape and I-shape. The general software ETABS has been used for the modeling.

It can be observed that the T shaped building structure has the maximum storey displacement whereas the C shaped building has the minimum storey displacement for G+6, G+9, G+14 structures in all zones. Regular building has the highest base shear values whereas the T shaped building has the least values of base shear when compared with other C shaped and I shaped for G+6.G+9. G+14 building structures. T shaped building has the highest storey drift values whereas the C shaped building has the least values of storey drift when compared with other regular shaped and I shaped for G+ 6, G+9, G+14 building structures.

Md. Ashikur Rahman & Md. Ariful Islam (2018) **“Strengthening and Retrofitting of Flat Slab Frame in Earthquake” [9]**

This thesis presents performance of RC flat plate in seismic ground motion. Ductile reinforcement and drop panel were used to improve the performance of flat plate. Analyses were performed both numerically and experimentally.

Objective of this thesis work was to find a way of reduce the vulnerability of flat plate in dynamic loading by gaining strength with using ductile reinforcement. Four specimens were used to perform the tests.

Numerical models are developed using ETABS v16.0.2 for analysis of the frame structure. In laboratory, displacements were measured by using LVDT sensor to obtain time history graph. The numerical and the experimental values matched reasonably well.

Three types of structural models are used in this work. A two-storied model is used to verify the performance of LVDT sensor. Then the slabs are subjected to static moment for punching shear failure.

After performing the test, for model-1 the load vs. deflection curve showed that normal slab taking more deflection and it is for loading the slabs in wrong direction. Though the ultimate load capacity can be compared but the numerical analysis seemed much different from the experimental data.

Deflection can be endured by using drop panel and displacement increases as the load increase. But a specific increase of load-displacement decreases as the frequency of earthquake waves the displacement reaches peak.

In this work drop panel is used for external strengthening. Slab with ductile reinforcement can take more load than normal slab and the increase of load capacity is 60 percent. Its results also said that if slab is well strengthened in shear by proper means, then the punching shear failure can be avoided.

A frame structure is also analyzed numerically by ETABS to simulate tilt table test. The result shows that the horizontal component of force acted on the slab due to inclination is almost equal to pushing force to cause the same deflection. Therefore, the methodology of tilting structure has potential to be simply form of experimental pushover analysis, omitting the need of a reaction wall. Inclination of 15-25 degree provides better data.

Anand, N., Mightraj, C. and Prince Arulraj, G., 2010, “**Seismic Behaviour of RCC Shear Wall Under Different Soil Conditions” [10]**

From the analysis they tried to find-out most of the designers do not consider the soil structure interaction and its subsequent effect on structures during an earthquake and the effect on ground so that the designer should be considered earthquake load calculation using ETABS software. One to fifteen storied building with and without shear wall analyzed and the result are compared in various aspects. Up to three storied the base shear value were same for the all-other type of soil. Above three stories, the base shear values increases when the soil type changes from hard to medium and medium to soft.

The percentage of decrease varies from 0 to 26.5% and the 0 to 18.5% if soil type medium to hard. The lateral displacement value increases when the type of soil changes from hard to medium and medium to soft for all the building frames. The percentage of decrease in lateral displacement for all the building frames varies from 0 to 26.5% when the type of soil changes for medium to hard and 0 to 18.7% when the type of soil changes from soft to medium. The axial force and moment in the column increase when the type of soil changes from hard to medium and medium to soft. Since the base shear, axial force, column moment and lateral displacements increase as the soil type changes, soil structure interaction must be suitably considered while designing frames for seismic forces.

ANKALKHOPE, Y., GHALE, V., HARMALKAR, P., GIRI, M. and MHASKE, N., 2021. “**Wind and Seismic Analysis of Building Using ETABS” [11]**

In seismic and wind analysis of building by using ETABS and design of multi storey building by using ETABS software for analysis seismic load and wind load. They analyzed G+11 storey Building and considering seismic analysis after G+5. As per their analysis rectangular and circular column for economic structure.

They find out the parameters like bending moments, shear force, base reaction, storey stiffness, storey shear, overturning moment, storey displacement, storey drift etc. of all storey of building discuss the results coming from the Linear Static Analysis method and Linear Dynamic Analysis (Response Spectrum Analysis) Method.

1) Analysis was done by using ETABS software and successfully verified manually as per IS 456-2000.

2) ETABS is the perfect useful software for this project which reduce the time for analysis and design.

Coelho, E., Candeias, P., Anamateros, G., Zaharia, R., Taucer, F. & Pinto, A. V. (2004) **"Assessment of the Seismic Behavior of RC Flat Slab Building Structure" [12]**

This research paper highlights an experimental program of seismic behavior of flat slab structure. It is performed based on Portuguese design code. Tests were performed considering 475 yrp and 2000 yrp.

475 yrp results (Fig. 2.1) showed flexural cracks in primary and secondary column strip (CS) but no cracks were identified in the mid span. During the second test for 2000 yrp the structure was damaged heavily (Fig. 2.2).

Test had to be stopped at a point of 2.05 seconds of the accelerogram. Due to displacement, negative moments developed on the exterior slab-column connections of columns P1 and P3. Some flexural crack also occurred for positive moment around columns P2 and P4. Very thin flexural crack was observed above and below the slab.

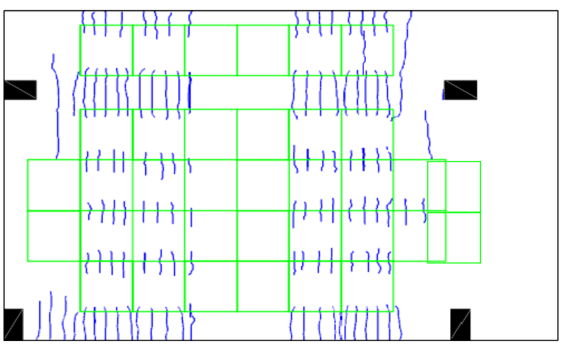


Fig. 2.1: Crack points for 475 yrp

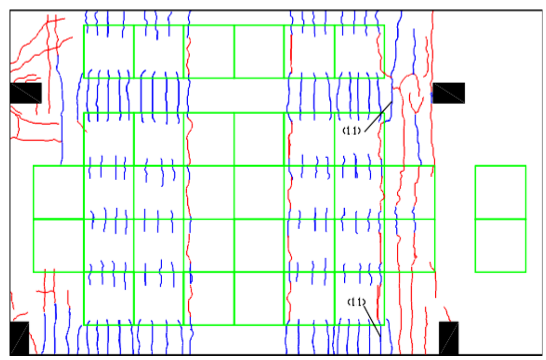


Fig. 2.2: Crack points for 2000 yrp

After performing the tests, it was observed that important flexural and torsion crack around the exterior slab-column connection. It is advised that this structure demands combination with other stiffer structural system like shear walls.

Md. Lutfar Rahman Rana & Md. Amran Hossain (2017) **"Behavior of Flat Plate with Ductile Reinforcement" [13]**

Brittle failure of RC flat plate in punching shear, particularly due to seismic vibration, is the main focus of this thesis. They used ductile reinforcement in the flat plate and compare with non-ductile specimens both numerically and experimentally. Numerical model was analyzed using ETABS 16.0.2 and experiments were done in lab with 12 RC flat slabs made with and without ductile shear reinforcements. Among them six were made without shear reinforcement and others were made with ductile shear reinforcements. Concrete mix ratio was 1:2:4. Six concrete cylinders also made to test compressive strength of concrete,

Tests were performed for vertical load to obtain load vs. deflection graphs. Load was applied gradually and mid punching started 40-50 KN and shorter direction column were Punching 50-55 KN approximately.

Results from experiments are quite similar to the results from numerical analysis using ETABS and more load were needed for punching of shorter direction column and mid column punched before shorter direction column punching.

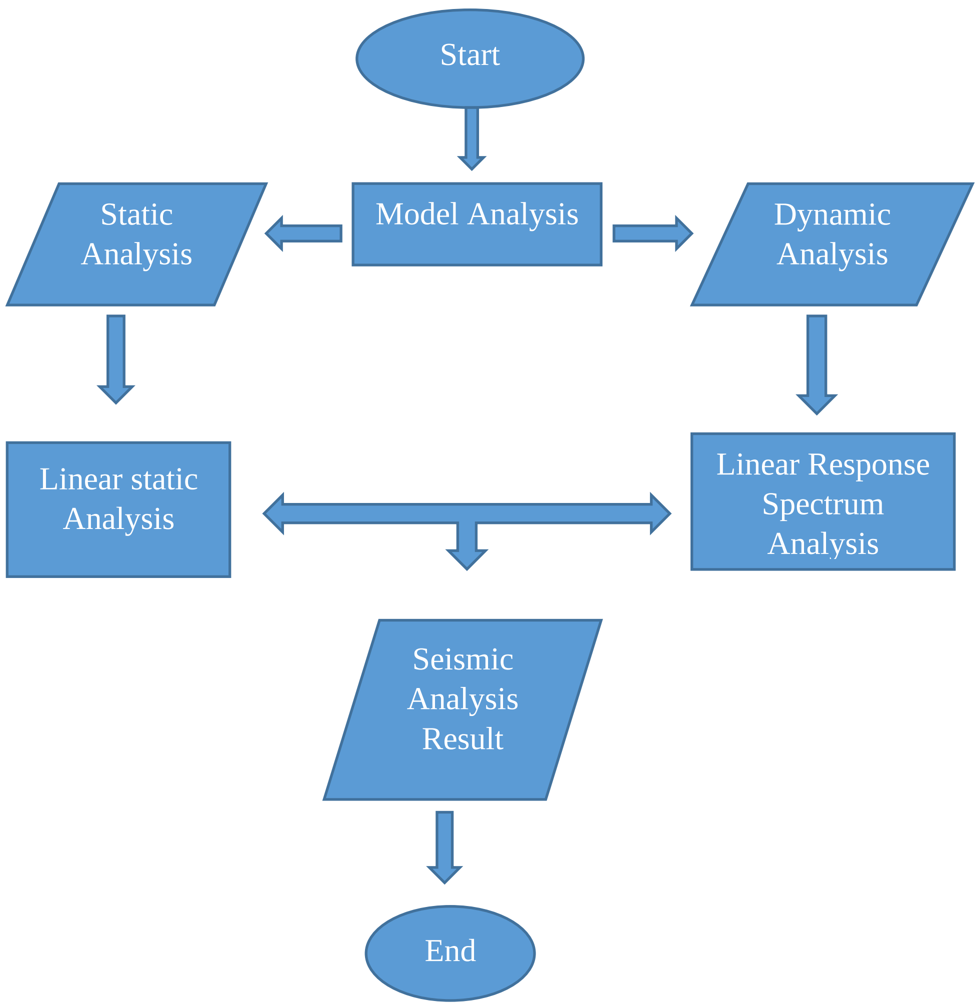
2.3 Summary

After reviewing some thesis and journal papers we can extract some points for our next movement of the thesis. In this chapter we study broadly about seismic analysis of some structures with and without shear wall, flat plate design & plan irregularity. Now we can proceed in next chapter with the theoretical and numerical work of our suggested 4 storied residential building.

CHAPTER 3
DESIGN OF RC BUILDING

3.1 Introduction

During the preliminary design stage of a structure, a structure's probable external forces are estimated and the size of structure's members and interconnections are determined based on this estimated load. Many types of structural analyses have been developed to estimate all the possible behavior of structure. Some of them are very complicated also. In this chapter the methods of analysis are discussed and the process of analysis is also described. Here the methodology *flow chart* is given below-



3.2 Static Analysis:

Static analysis allows the designer to determine the reaction force of the whole mechanical system as well as inter connection forces transmit to other individual joints. Static analysis is of two types

1. Linear Analysis
2. Pushover analysis (nonlinear analysis)

3.2.1 Linear Static Analysis

A linear static analysis is an analysis where a linear relation holds between applied forces and displacements. In practice, this is applicable to structural problems where stresses remain in the linear elastic range of the used material (Fig. 3.1).

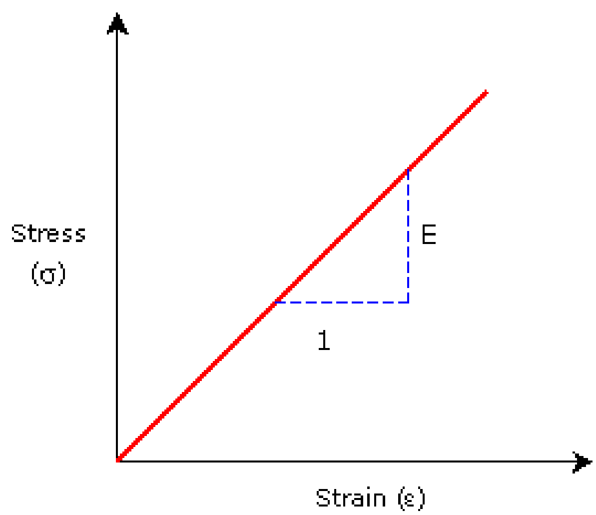


Fig 3.1: Stress vs Strain curve

3.2.2 Steps of Linear Analysis by ETABS

Assigning Material Properties

Concrete Property

Define > Material property > Concrete >Modify/show property > Modify/show property Design Data

> $f_c' = 3000\ lb/in^2$

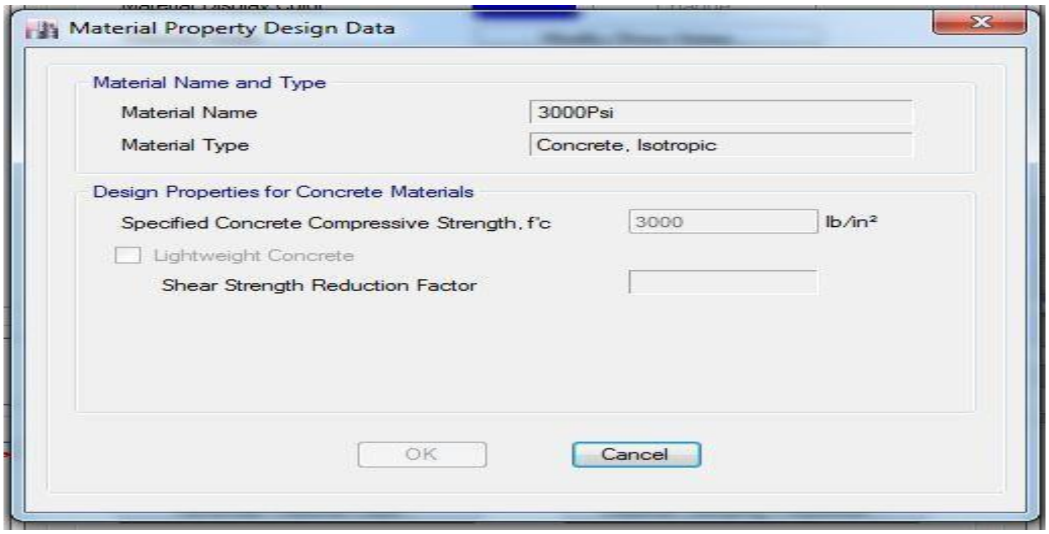


Fig. 3.2: Material Property Design Data (Concrete)

Assign Steel Property

Define > Material property >Steel>Modify/show property > Modify/show property Design Data > fc'

= 60000 lb/in^2

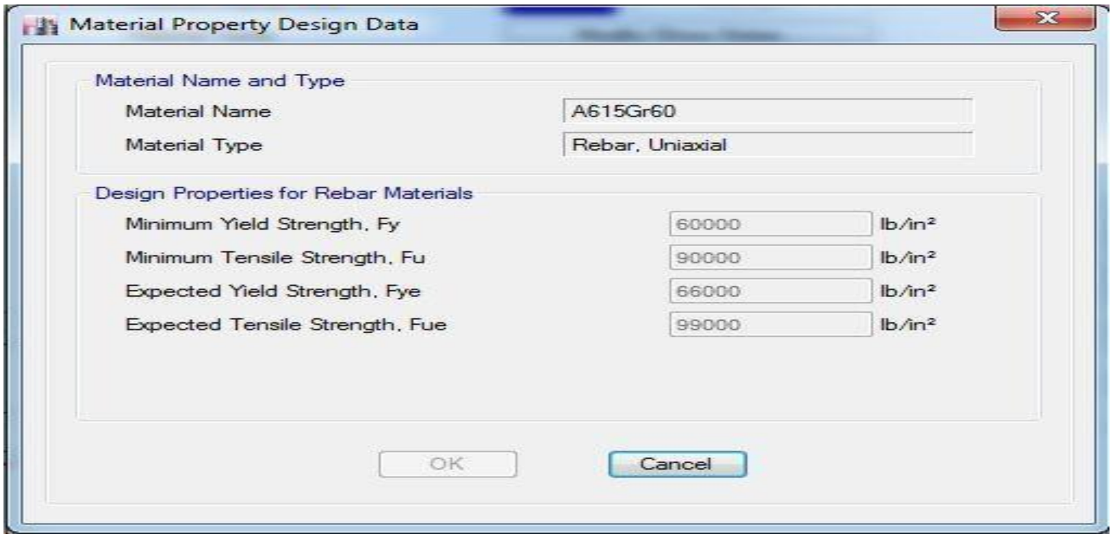


Fig. 3.3: Material Property Design Data (STEEL)

Assign Section Properties

Define > Section property > Frame Sections>Add New property >Rectangular Section

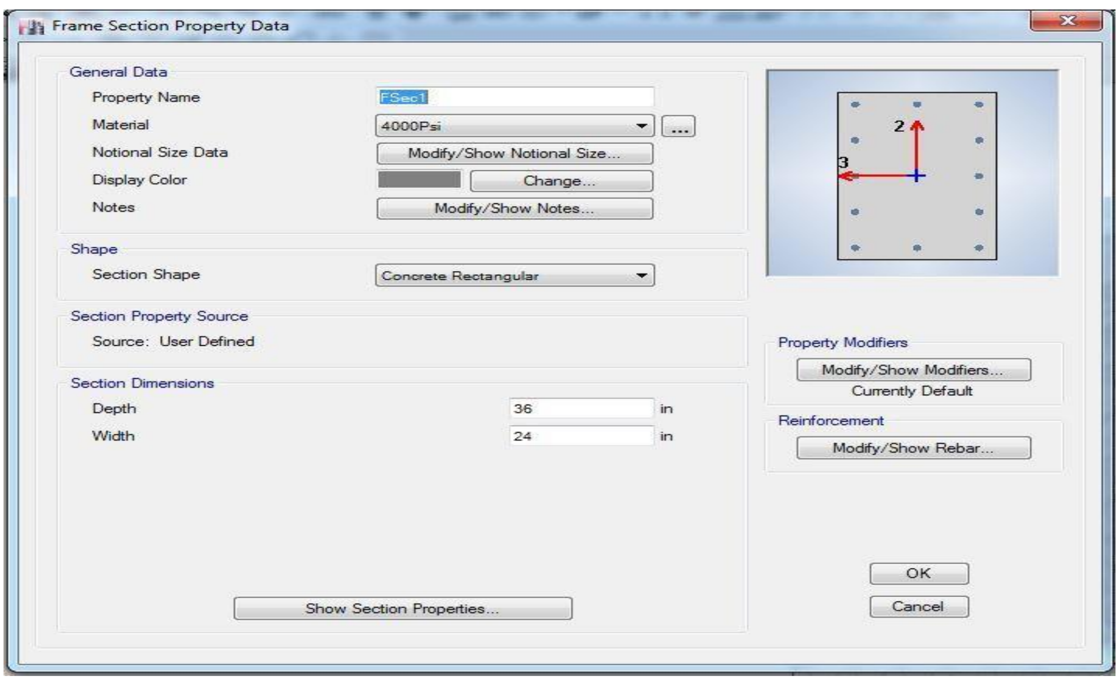


Fig. 3.4: Create Frame Section

Define > Selection property > Slab Sections>Add New property

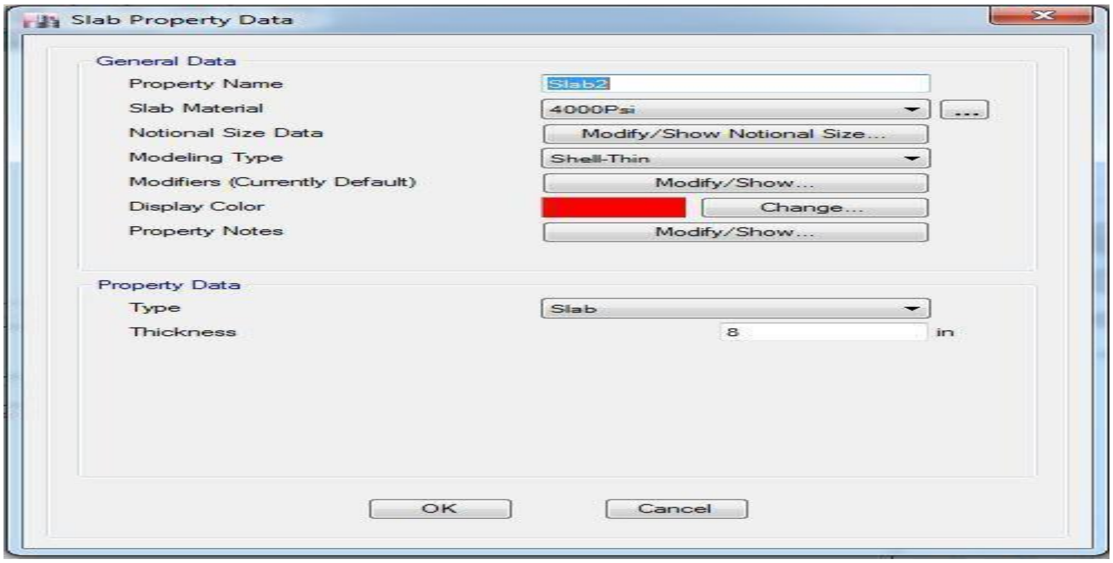


Fig 3.5: Create slab section

Load Patterns for Linear Static Analysis

Define > Load Patterns > Add New Load > EX as follow UBC 94 and modify

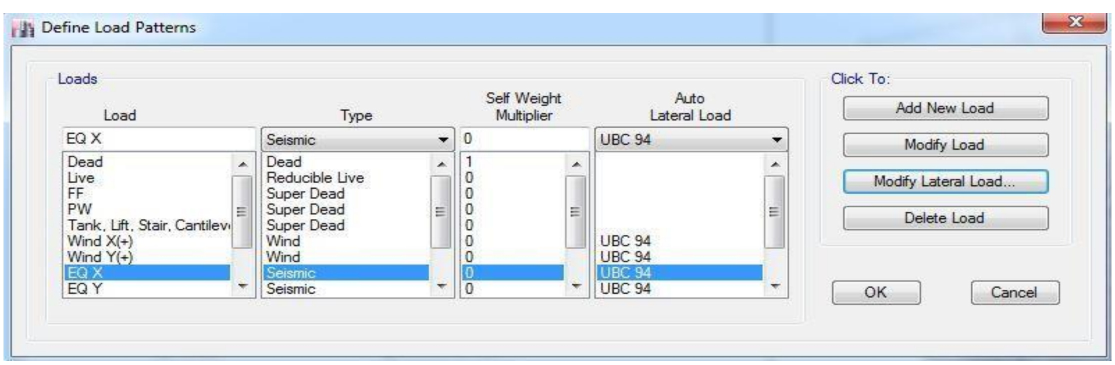


Fig. 3.6: Load Pattern Assign

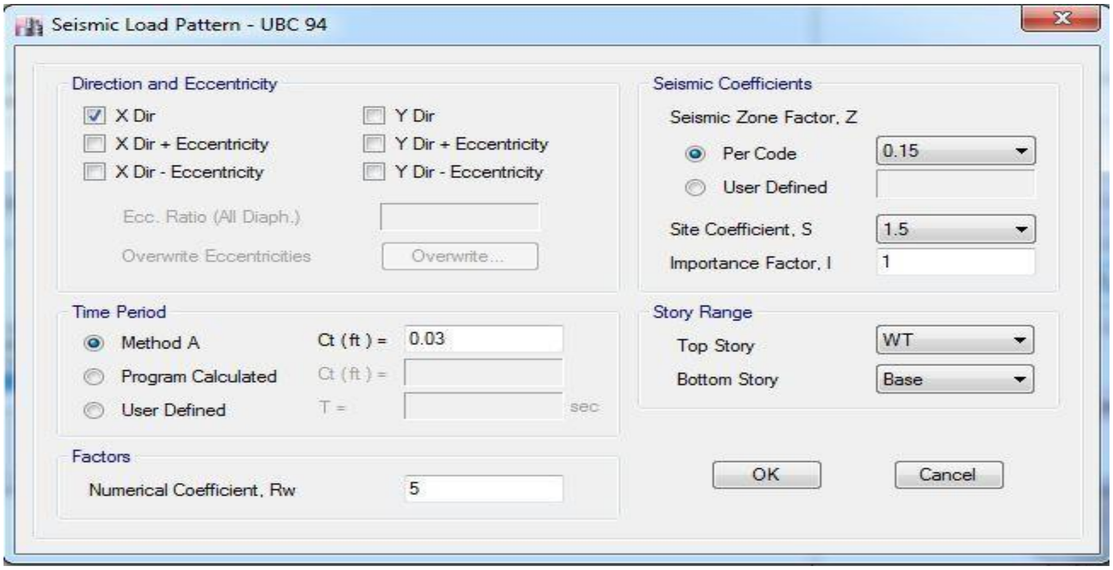


Fig. 3.7: Earthquake Load assigns

Define > Mass Source > Add New Mass Source

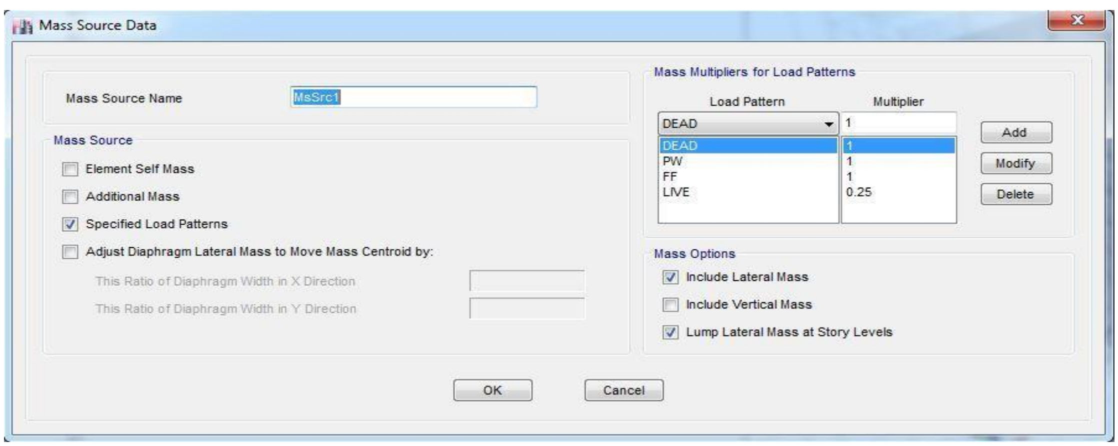


Fig. 3.8: Create Mass Source

3.3 Dynamic Response Spectrum Analysis:

Response Spectrum Analysis is a dynamic statistical analysis method which determines contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure. This analysis provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity or displacement as a function of structural period for a given time history and level of damping. It is practical to envelope response spectra such that a smooth curve represents the peak response for each realization of structural period.

This method is useful for design decision-making because it relates structural type-selection to dynamic performance. Structures of shorter period experience greater acceleration, whereas those of longer period experience greater displacement. Structural performance objectives should be taken into account during preliminary design and response-spectrum analysis. To estimate the structural response to short, nondeterministic, transient Dynamic Response Spectrum Analysis is used. Examples of such events are earthquakes and shocks.

Dynamic Response Spectrum Analysis is also two types.

1. Linear Response Spectrum Analysis
2. Nonlinear Response Spectrum Analysis

3.3.1 Linear Response Spectrum Analysis

Response spectrum analysis is recognized as a reliable and practical method for dynamic analysis of structures subjected to earthquake excitation**.**

3.3.2 Steps for Linear Response Spectrum Analysis (RSA)

Define Function

Define > Functions > Response spectrum > add new Function

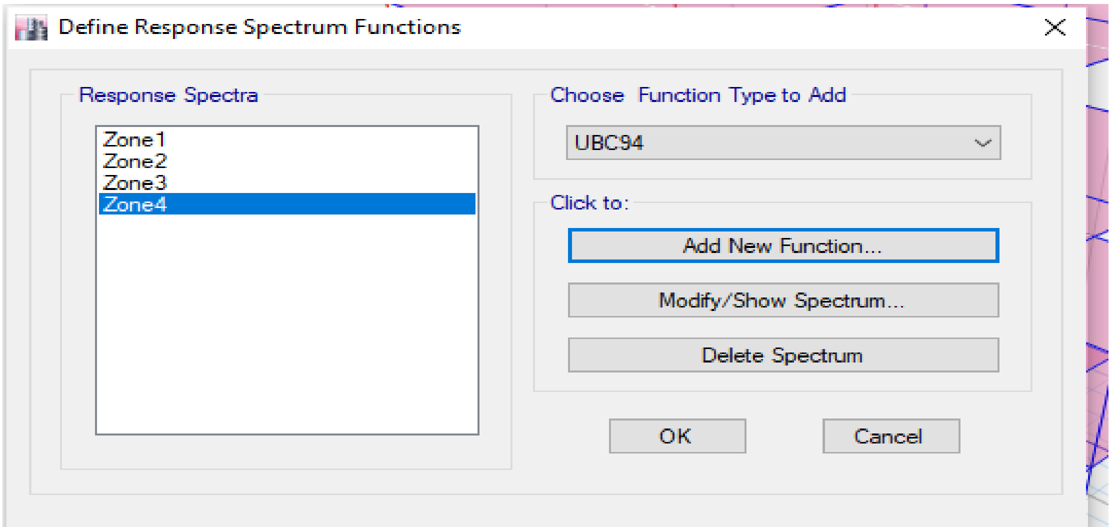


Fig 3.9: Define RSA Functions

Modify Function with Zone Co-efficient (BNBC Zone 1-4)

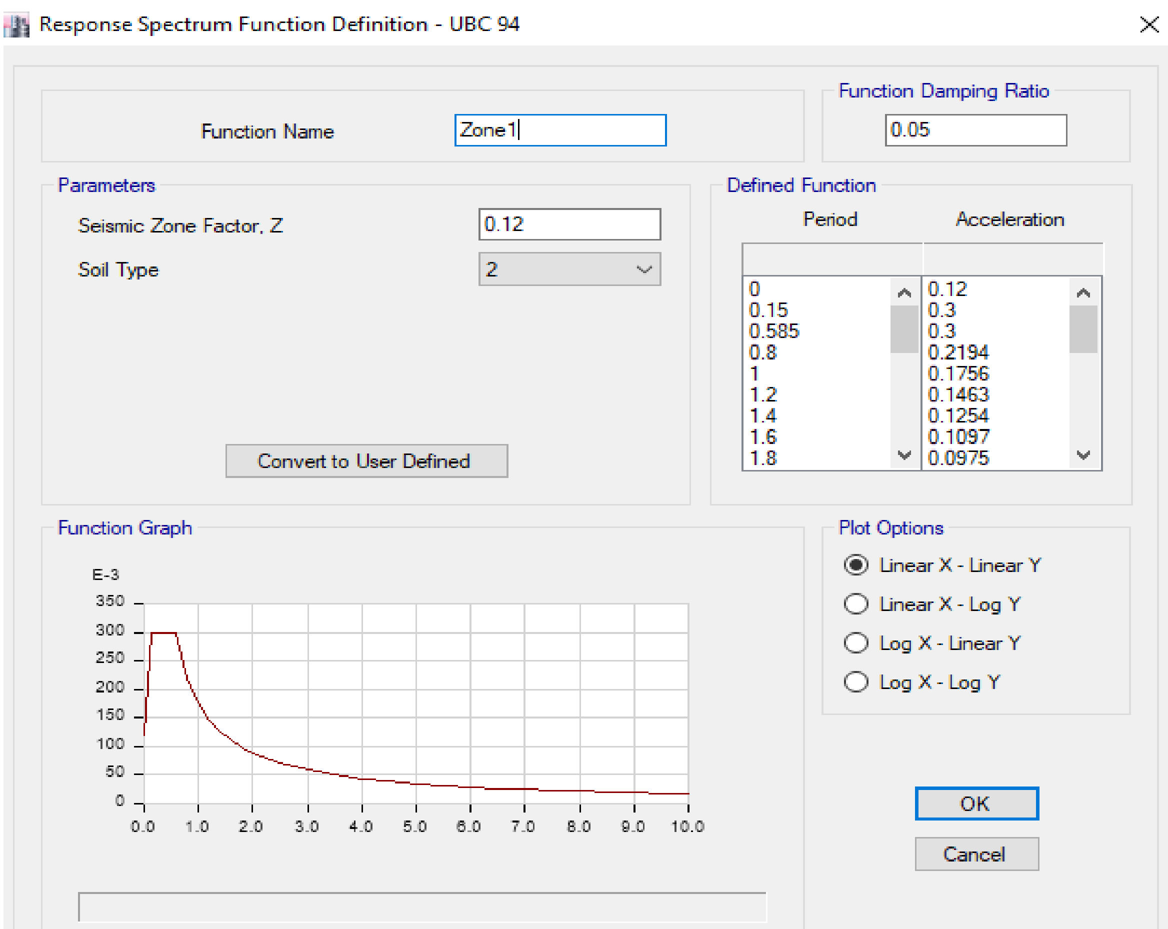


Fig 3.10: Modify RSA function

Define > P-Delta Options

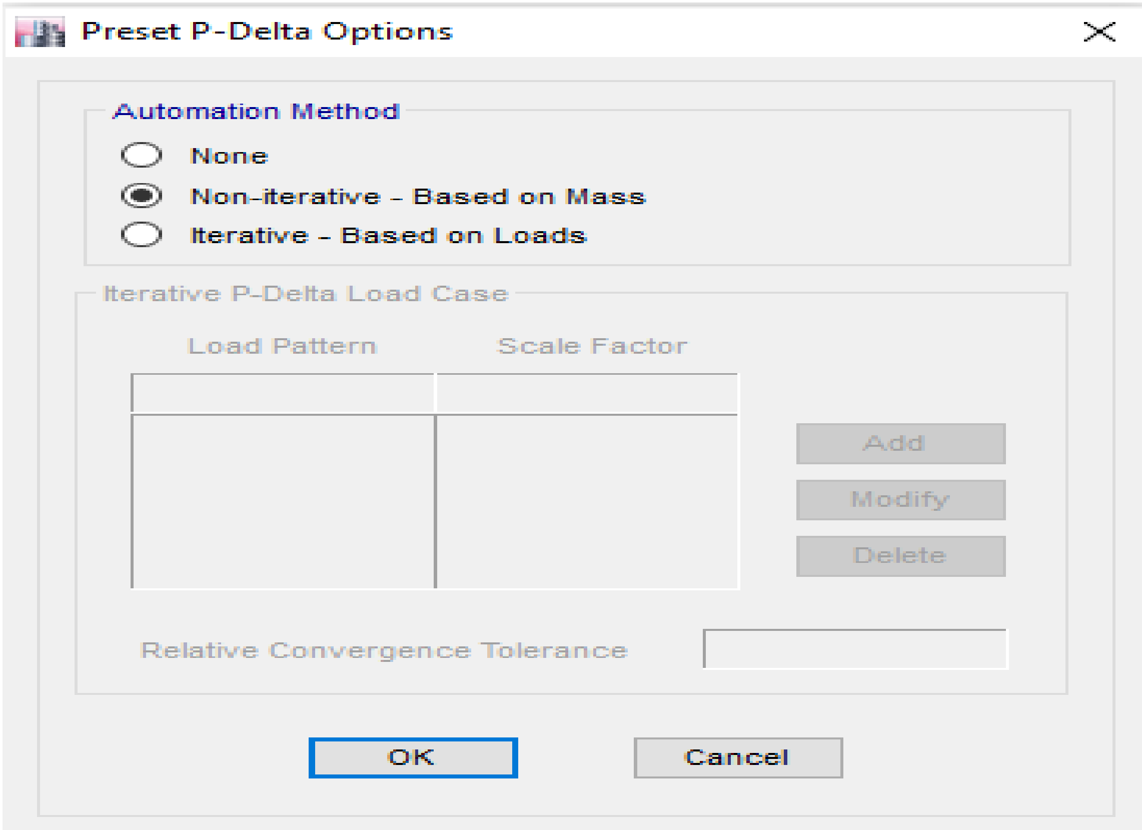


Fig 3.11: P-Delta Options

Define > Load case> Add new > RSA data

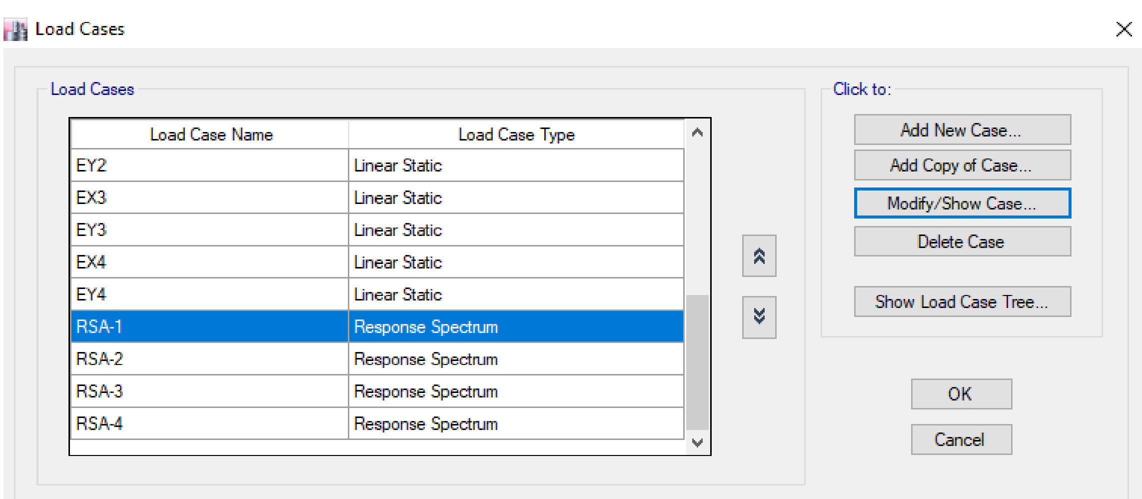


Fig 3.12: Define RSA load case

Modify RSA Load case data

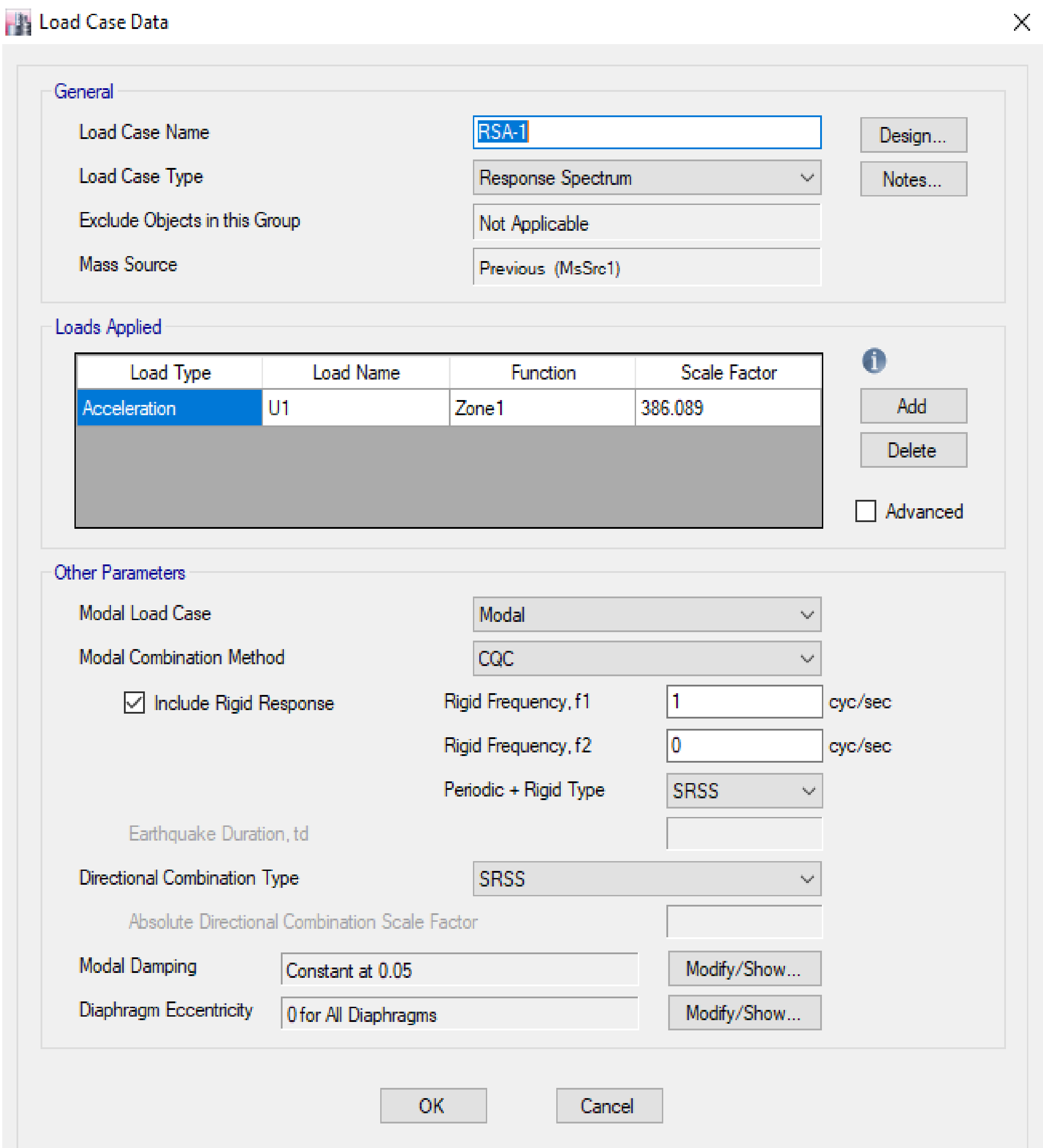


Fig 3.13: Modify RSA Load case data

Define > Modal Case data

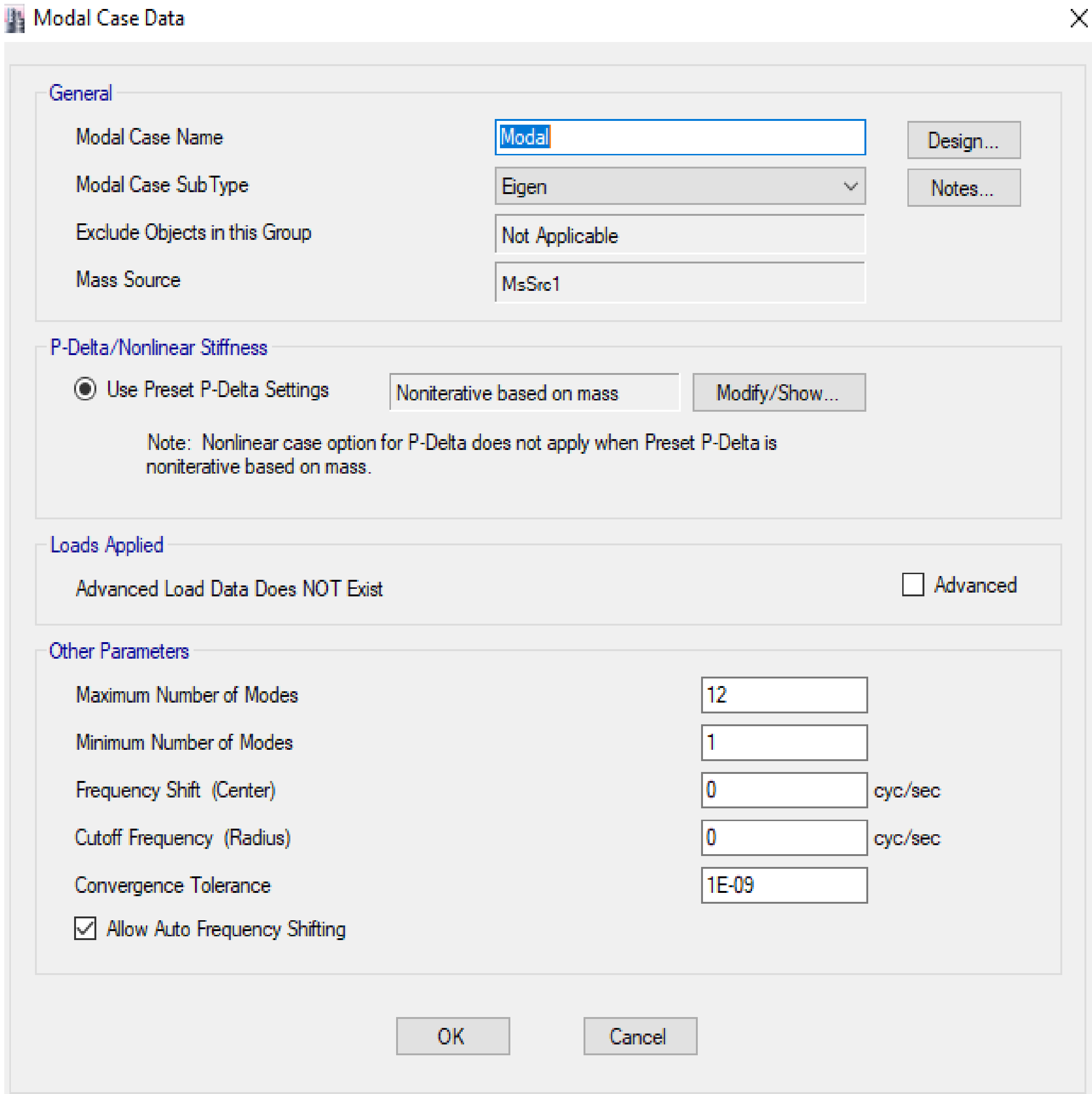


Fig 3.14: Modal Case data

Check Code

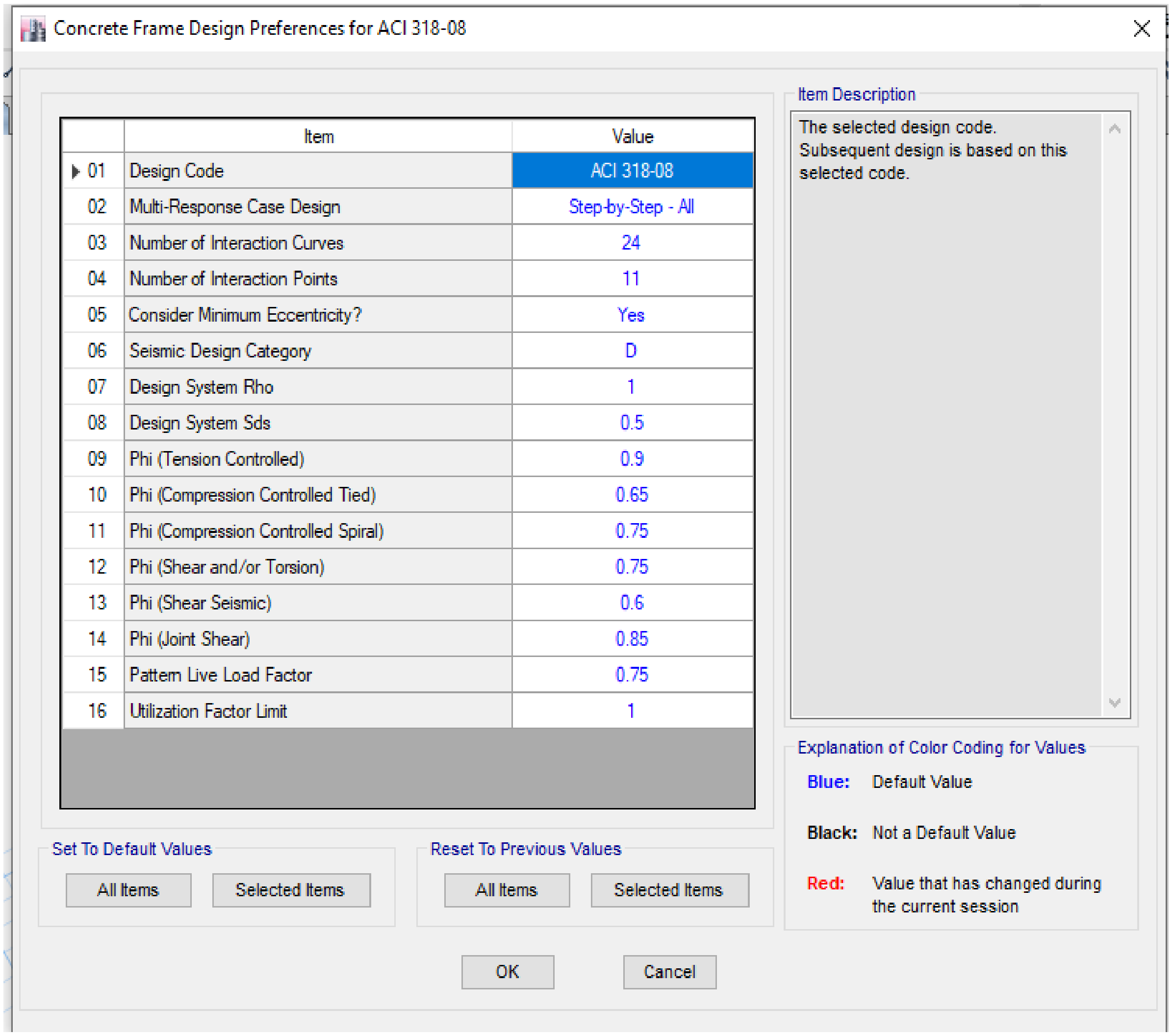


Fig 3.15: Check Code

Check Framing Category

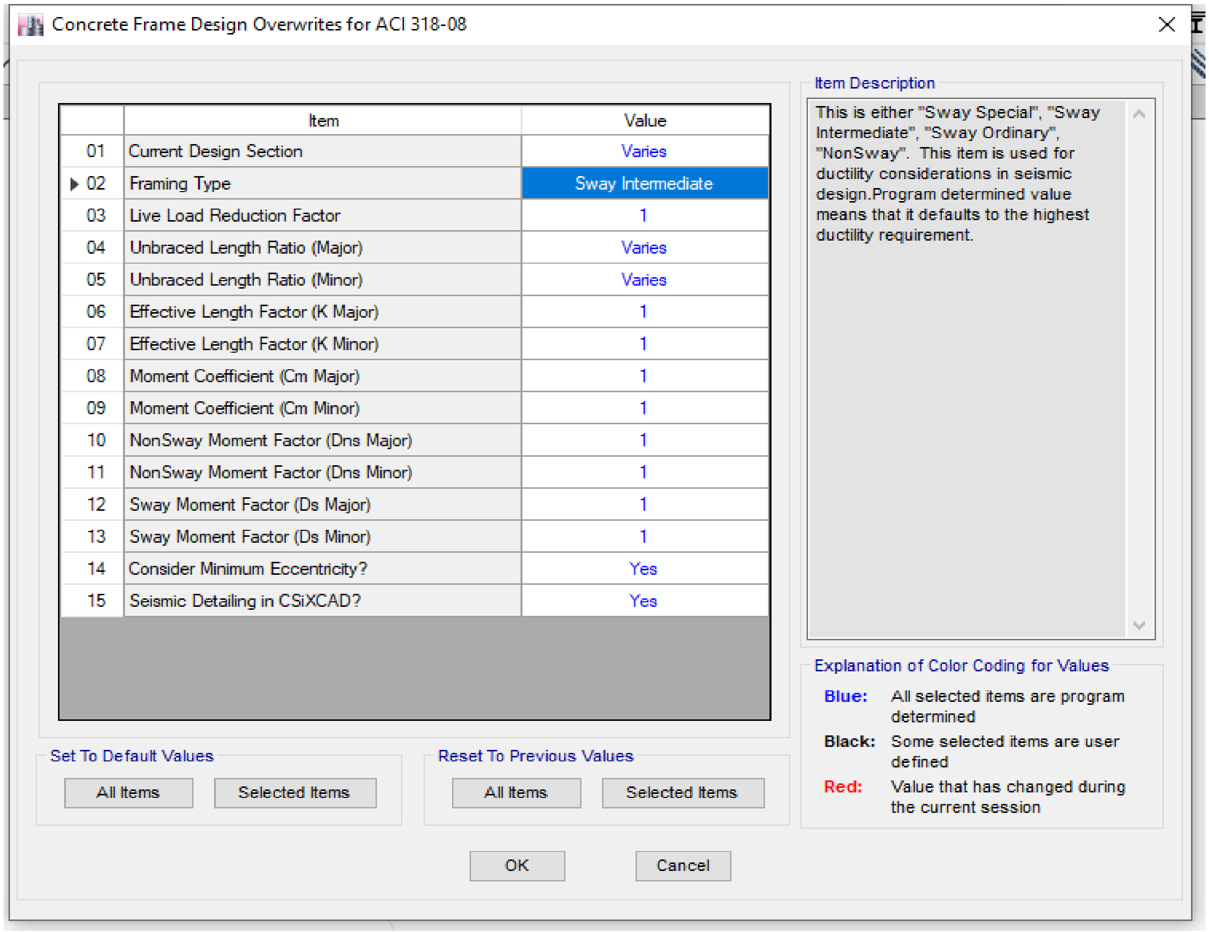


Fig 3.16: Check Frame

Frame Auto mesh

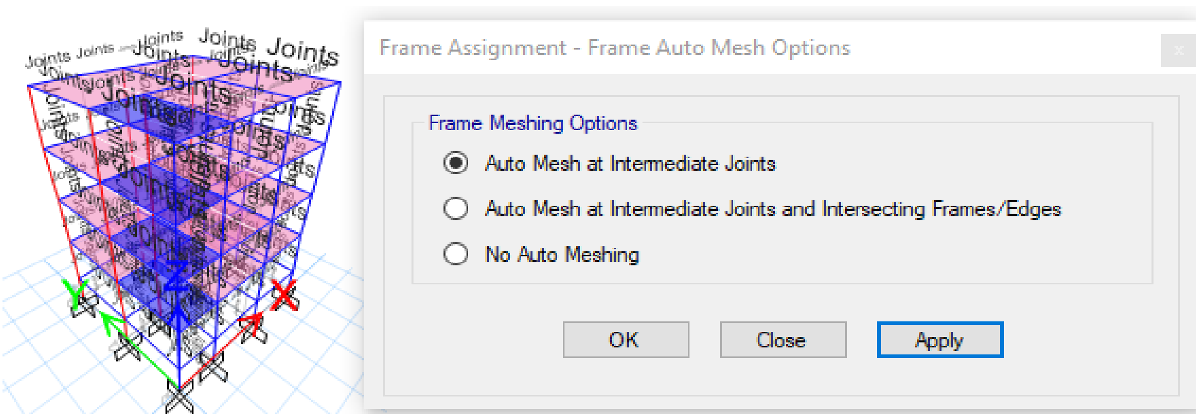


Fig 3.17: Frame Auto mesh

Frame Object Mesh

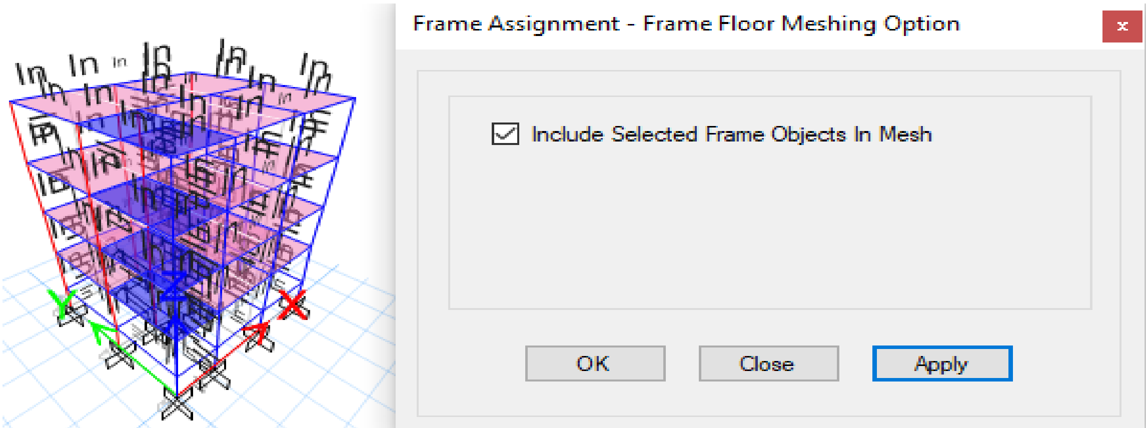


Fig 3.18: Frame Object Mesh

Floor Auto mesh

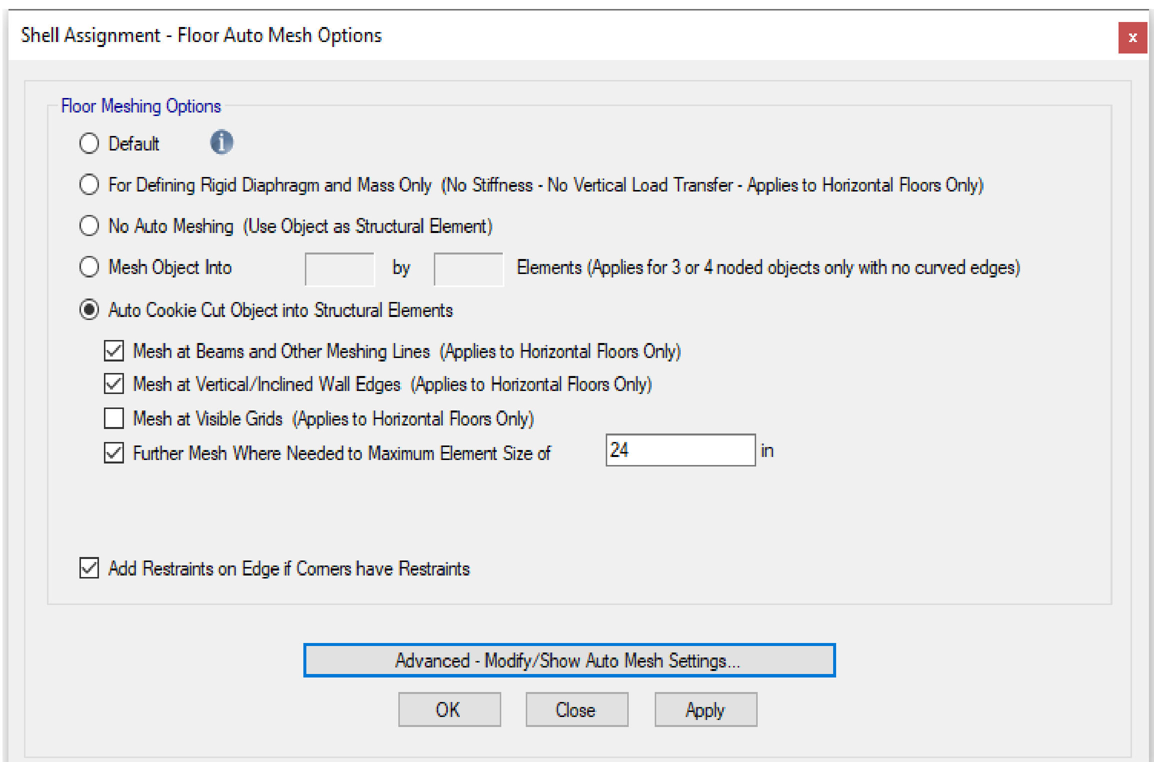


Fig 3.19: Floor Auto Mesh

Check Model

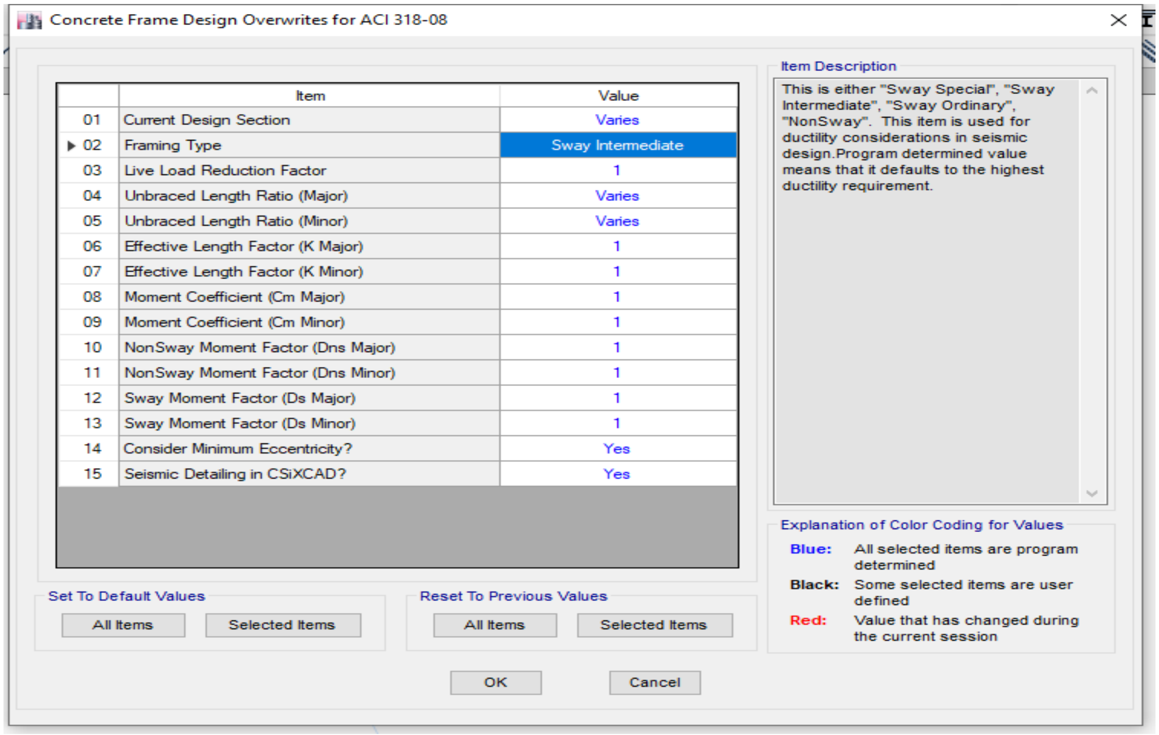


Fig 3.20: Check Model

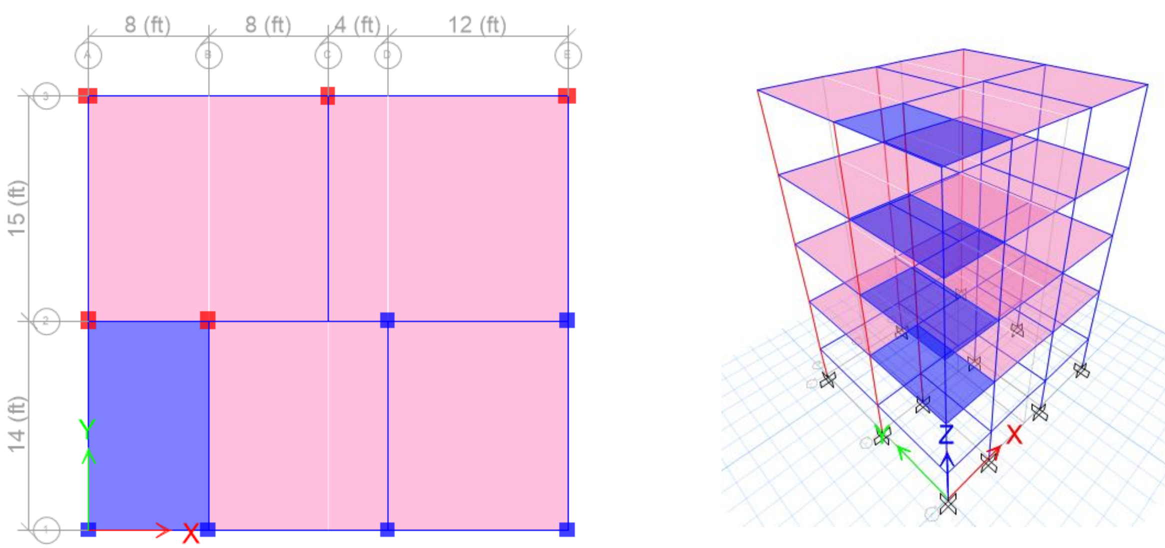


Fig 3.21: Plan & 3D view of the building

After that run for analysis.

3.4 Summary

In this chapter we perform numerical procedure for modelling and analyzing the taken building structure for the thesis. We use all the parameters as per BNBC and ACI guideline. We use ETABS 16.2.1 software for structural analysis procedure. As follows we will get and discuss the result of the thesis.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

This chapter contains the results of numerical analysis by ETABS which is described in Chapter 3. ETABS (Extended Three-Dimensional Analysis of Building System) can be used for static and dynamic analysis result of any building structure.

The main purpose of this analysis is to get software result of Base reactions, Moments and storey displacement of the structure.

4.2 Method of Analysis

ETABS can analyze a structure in various way and give highest safest result of the structure. In this thesis we use the version of ETABS 16.2.1. We perform Linear Static Analysis and Linear Response Spectrum Analysis in this thesis.

4.3 Design Loads

4.3.1 Vertical Loads

The applying vertical loads are

1. Dead load = ETABS self-calculated
2. Floor finish load = 20 psf
3. Partition wall load = 35 psf
4. Live load = 50 psf
5. Stair case load = 84 psf
6. Rooftop live load = 30 psf

4.3.2 Load Combination

List of Load Combination Used-

- 1.4D
- 1.2D+1.6L + 0.5Lr
- 1.2D + 1.6Lr + L
- 1.2D + 1.6Lr + 0.8W
- 1.2D + 1.6W + L + 0.5Lr
- 1.2D + E + L
- 0.9D + 1.6W

- 0.9D + E

4.3.3 Design Codes

BNBC 2020, UBC 94, ACI 318-08.

4.4 Material Properties

Compressive strength of concrete, fc'= 3500 psi

Tensile strength of steel, fy= 60 ksi

4.5 Results from ETABS Analysis

In this thesis we perform Linear Static Analysis and Linear Response Spectrum analysis to fulfill our work. And from the analysis we got the results shown below-

Column P-M-M ratio

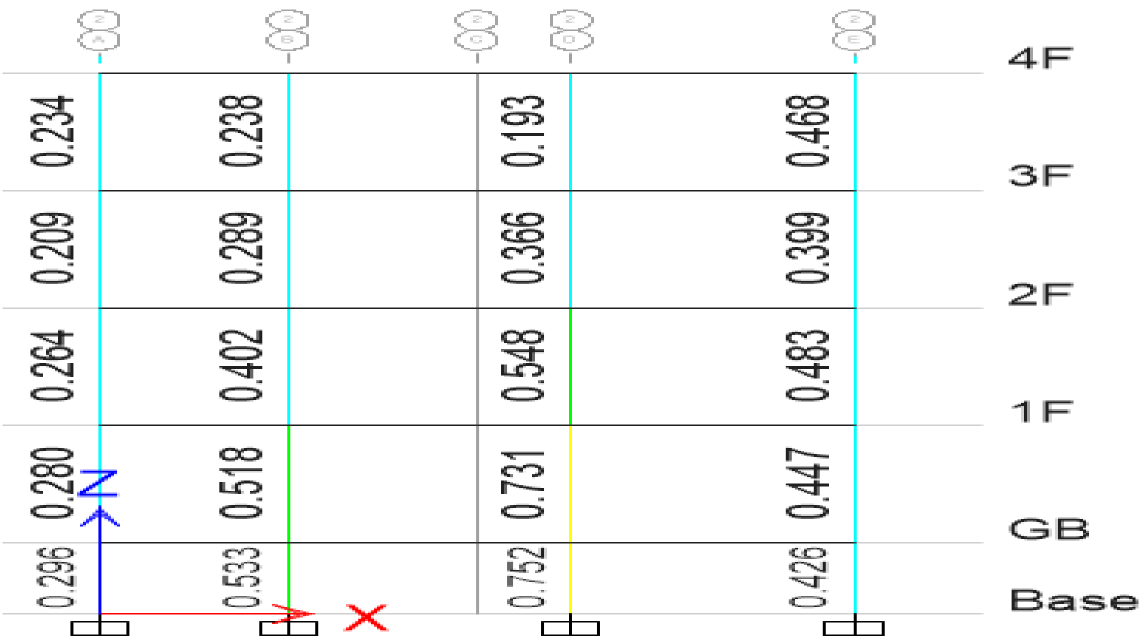


Fig 4.1: Column P-M-M ratio

Figure 4.1 Column P-M-M ratio, it's explored that the ratio of the sum of the axial force demand vs capacity, whereas the result is less than 1.0 so, satisfactory.

4.5.1 Force Diagram

Axial Force

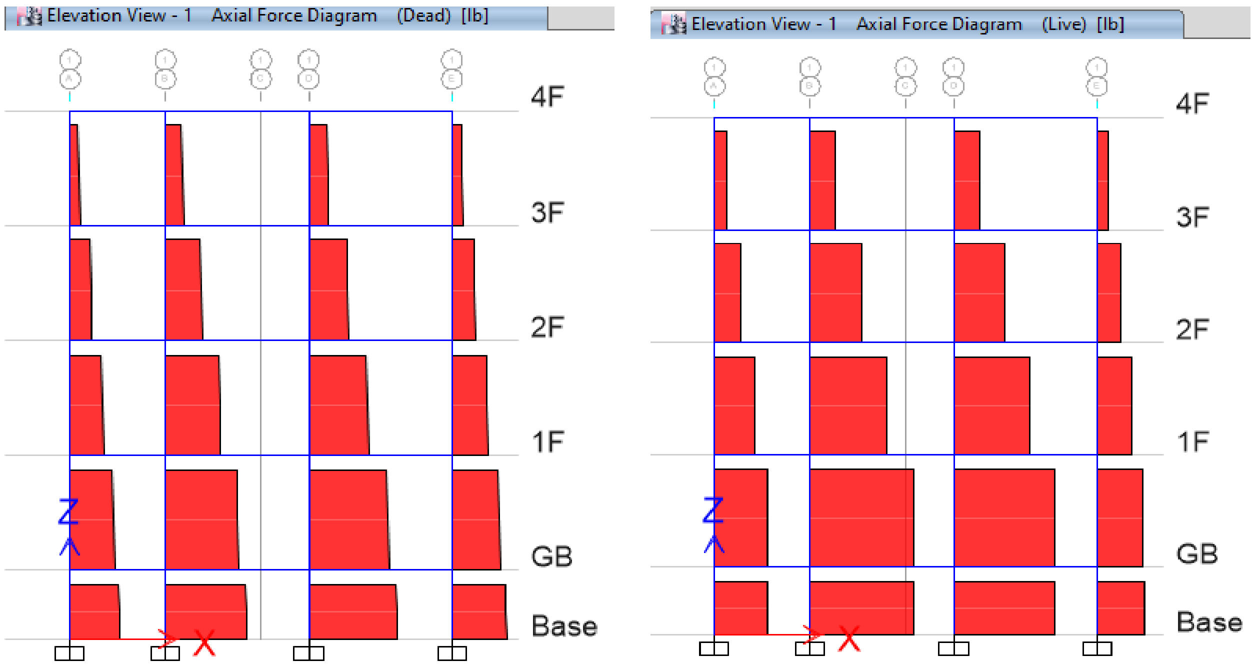


Fig 4.2 (a-b): Axial Force Diagram (Both Dead & Live load)

Shear Force

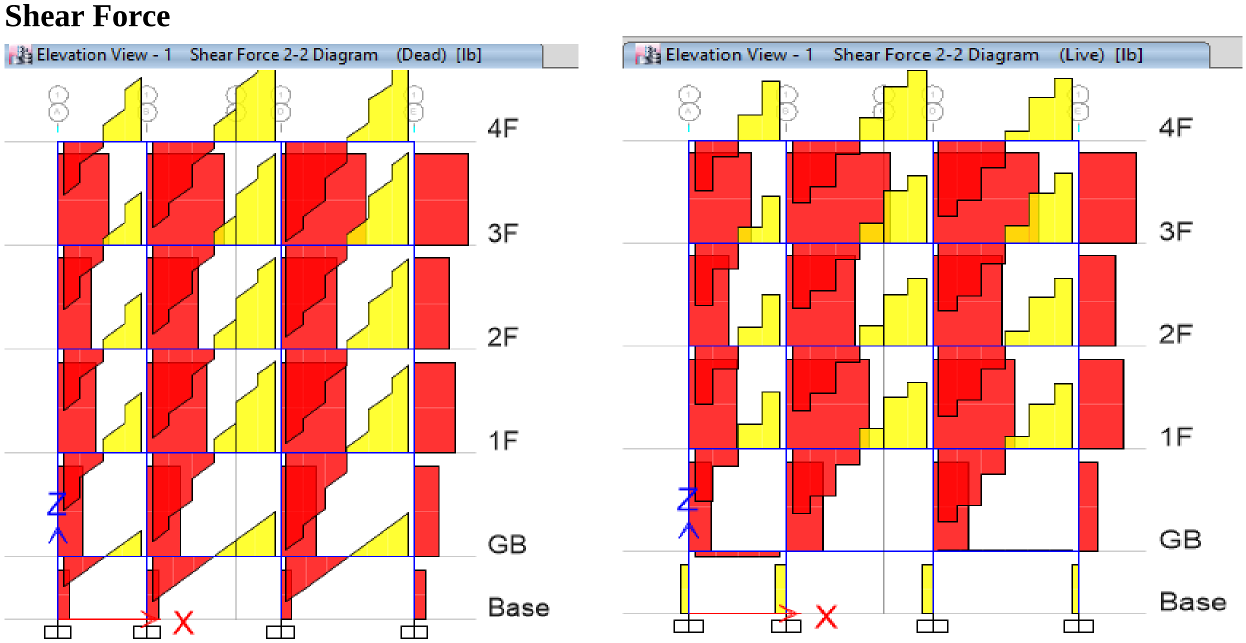


Fig 4.3 (a-b): Shear Force Diagram (Both Dead & Live load)

Moment

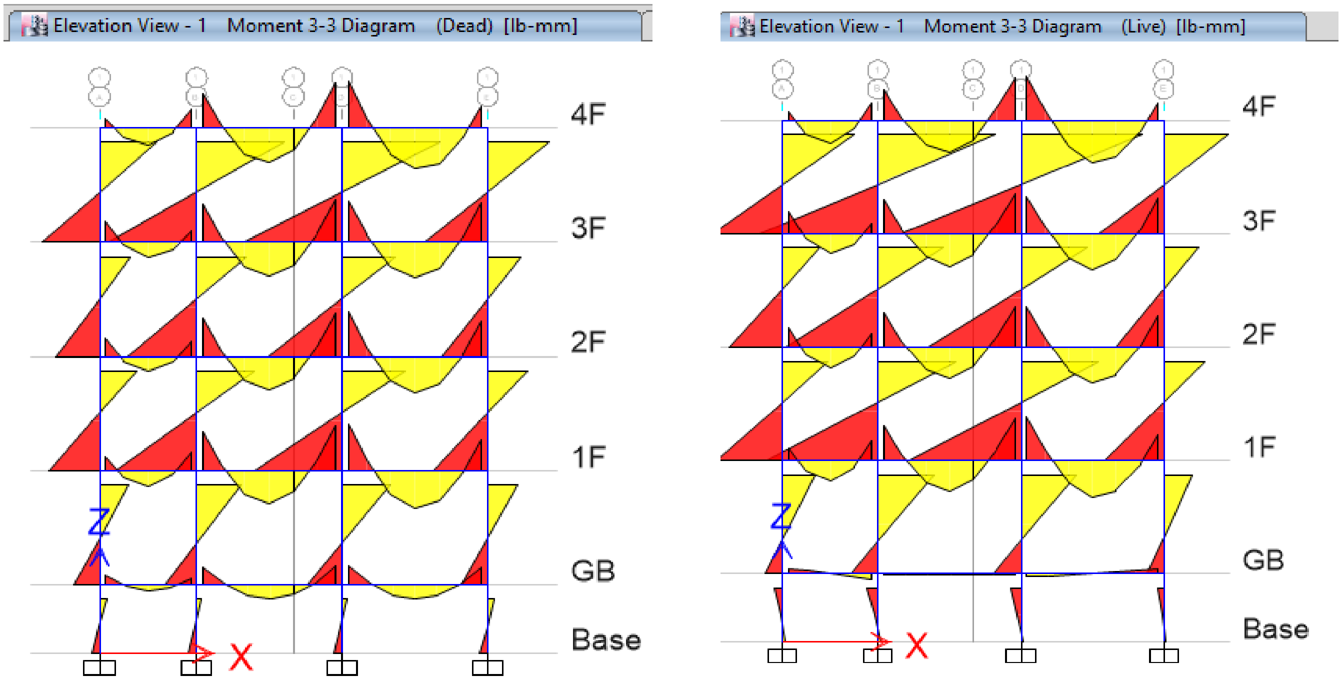


Fig 4.4 (a-b): Bending Moment Diagram (Both Dead & Live load)

Base Reaction for vertical load

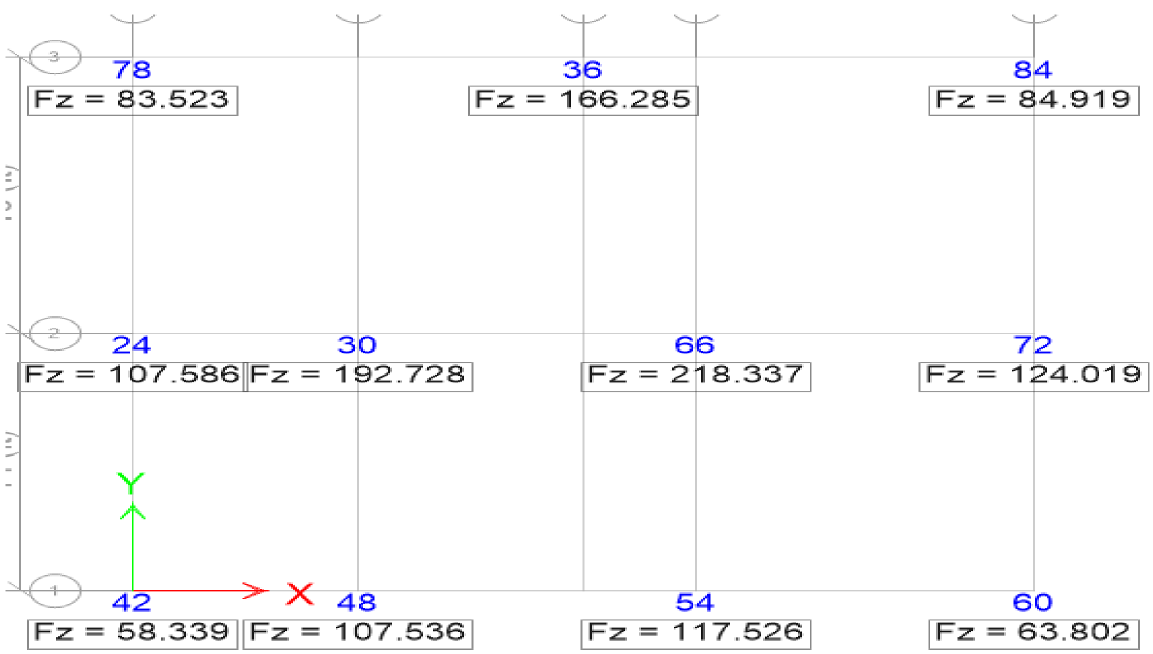


Fig 4.5: Base Reaction

4.5.2 Seismic Analysis Results

Base Reaction for Seismic Load

Table 4.1: Base Reaction

Load Case/Combo	FX kip	FY kip	FZ kip	MX kip-ft	MY kip-ft	MZ kip-ft
EX1	-23.132	0	0	0	-812.6588	328.2561
EY1	0	-23.132	0	812.6588	0	-360.8709
EX2	-38.554	0	0	0	-1354.4313	547.0935
EY2	0	-38.554	0	1354.4313	0	-601.4516
EX3	-53.976	0	0	0	-1896.2038	765.931
EY3	0	-53.976	0	1896.2038	0	-842.0322
EX4	-72.912	0	0	0	-2557.7996	1034.6403
EY4	0	-72.912	0	2557.7996	0	-1137.4345
RSA-1 Max	100.16	7.547	0	254.2574	3360.3239	1589.3472
RSA-2 Max	166.934	12.578	0	423.762	5600.5339	2648.9092
RSA-3 Max	233.707	17.609	0	593.2667	7840.7475	3708.4729
RSA-4 Max	300.481	22.64	0	762.7715	10080.9611	4768.0366

Table 4.1 provides the base reaction for seismic analysis of different zones. Where we found reaction in X & Y direction and also found the moment reaction in X, Y & Z axis.

Table 4.2 - Centers of Mass and Rigidity

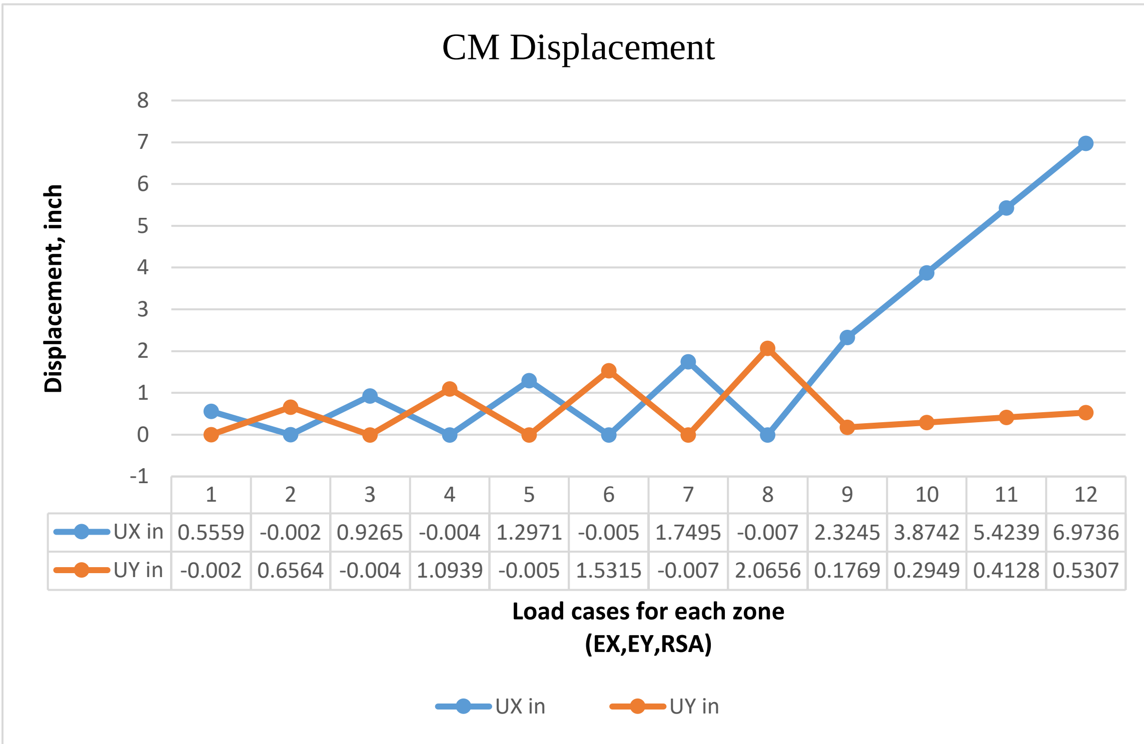
Storey	Diaphragm	Mass X lb-s²/ft	Mass Y lb-s²/ft	XCM ft	YCM ft	Cumulative X lb-s²/ft	Cumulative Y lb-s²/ft	XCCM ft	YCCM ft	XCR ft	YCR ft
4F	D1	5210.96	5210.96	15.6255	14.1985	5210.96	5210.96	15.6255	14.1985	14.4221	12.4337
3F	D1	5496.51	5496.51	15.5856	14.1893	10707.47	10707.47	15.605	14.1938	14.3922	12.5876
2F	D1	5496.51	5496.51	15.5856	14.1893	16203.99	16203.99	15.5984	14.1922	14.3552	12.7926
1F	D1	5496.51	5496.51	15.5856	14.1893	21700.5	21700.5	15.5952	14.1915	14.3023	13.2867

Table 4.2 shows the centers of mass and centers of rigidity for each floor with necessary value and calculation from software evaluation.

Table 4.3: Diaphragm Centre of Mass Displacement

Story	Diaphragm	Load Case/Combo	UX in	UY in	RZ rad	Point	X ft	Y ft	Z ft
4F	D1	EX1	0.555913	-0.002352	-0.000279	17	15.6255	14.1985	46
4F	D1	EY1	-0.002288	0.656356	0.00019	17	15.6255	14.1985	46
4F	D1	EX2	0.926521	-0.003921	-0.000465	17	15.6255	14.1985	46
4F	D1	EY2	-0.003813	1.093927	0.000317	17	15.6255	14.1985	46
4F	D1	EX3	1.297129	-0.005489	-0.000651	17	15.6255	14.1985	46
4F	D1	EY3	-0.005338	1.531498	0.000444	17	15.6255	14.1985	46
4F	D1	EX4	1.749497	-0.007403	-0.000878	17	15.6255	14.1985	46
4F	D1	EY4	-0.007199	2.065632	0.000599	17	15.6255	14.1985	46
4F	D1	RSA-1 Max	2.324544	0.176912	0.003501	17	15.6255	14.1985	46
4F	D1	RSA-2 Max	3.874236	0.294853	0.005834	17	15.6255	14.1985	46
4F	D1	RSA-3 Max	5.42393	0.412794	0.008168	17	15.6255	14.1985	46
4F	D1	RSA-4 Max	6.973624	0.530735	0.010502	17	15.6255	14.1985	46
3F	D1	EX1	0.479984	-0.001942	-0.000233	18	15.5856	14.1893	36
3F	D1	EY1	-0.001988	0.566729	0.000166	18	15.5856	14.1893	36
3F	D1	EX2	0.799974	-0.003236	-0.000388	18	15.5856	14.1893	36
3F	D1	EY2	-0.003314	0.944548	0.000277	18	15.5856	14.1893	36
3F	D1	EX3	1.119963	-0.00453	-0.000543	18	15.5856	14.1893	36
3F	D1	EY3	-0.004639	1.322367	0.000387	18	15.5856	14.1893	36
3F	D1	EX4	1.511411	-0.006113	-0.000733	18	15.5856	14.1893	36
3F	D1	EY4	-0.006259	1.784531	0.000523	18	15.5856	14.1893	36
3F	D1	RSA-1 Max	2.032139	0.155151	0.003043	18	15.5856	14.1893	36
3F	D1	RSA-2 Max	3.386895	0.258585	0.005072	18	15.5856	14.1893	36
3F	D1	RSA-3 Max	4.741654	0.362019	0.007101	18	15.5856	14.1893	36
3F	D1	RSA-4 Max	6.096412	0.465454	0.00913	18	15.5856	14.1893	36
2F	D1	EX1	0.357489	-0.001422	-0.000165	19	15.5856	14.1893	26
2F	D1	EY1	-0.001451	0.421582	0.000125	19	15.5856	14.1893	26
2F	D1	EX2	0.595814	-0.00237	-0.000275	19	15.5856	14.1893	26
2F	D1	EY2	-0.002419	0.702637	0.000208	19	15.5856	14.1893	26
2F	D1	EX3	0.83414	-0.003319	-0.000385	19	15.5856	14.1893	26
2F	D1	EY3	-0.003386	0.983691	0.000292	19	15.5856	14.1893	26
2F	D1	EX4	1.126214	-0.00448	-0.00052	19	15.5856	14.1893	26
2F	D1	EY4	-0.004571	1.328098	0.000394	19	15.5856	14.1893	26
2F	D1	RSA-1 Max	1.5347	0.116868	0.002272	19	15.5856	14.1893	26
2F	D1	RSA-2 Max	2.557831	0.194779	0.003787	19	15.5856	14.1893	26
2F	D1	RSA-3 Max	3.580964	0.272691	0.005302	19	15.5856	14.1893	26
2F	D1	RSA-4 Max	4.604097	0.350603	0.006817	19	15.5856	14.1893	26
1F	D1	EX1	0.201317	-0.000634	-8.1E-05	20	15.5856	14.1893	16
1F	D1	EY1	-0.00069	0.236435	7.1E-05	20	15.5856	14.1893	16
1F	D1	EX2	0.335529	-0.001056	-0.000136	20	15.5856	14.1893	16
1F	D1	EY2	-0.00115	0.394058	0.000118	20	15.5856	14.1893	16
1F	D1	EX3	0.469741	-0.001479	-0.00019	20	15.5856	14.1893	16
1F	D1	EY3	-0.001609	0.551681	0.000165	20	15.5856	14.1893	16
1F	D1	EX4	0.634404	-0.001997	-0.000256	20	15.5856	14.1893	16
1F	D1	EY4	-0.002173	0.745048	0.000223	20	15.5856	14.1893	16
1F	D1	RSA-1 Max	0.873909	0.066604	0.001253	20	15.5856	14.1893	16
1F	D1	RSA-2 Max	1.456513	0.111007	0.002089	20	15.5856	14.1893	16
1F	D1	RSA-3 Max	2.039118	0.15541	0.002924	20	15.5856	14.1893	16
1F	D1	RSA-4 Max	2.621724	0.199813	0.00376	20	15.5856	14.1893	16

Table 4.3 explain Diaphragm Centre of Mass Displacement in all 4 seismic zone of BNBC-20. Where Load cases Indicates as (EX1, EY1 & RSA-1 for Zone-1), (EX2, EY2 & RSA-2 for Zone-2), (EX3, EY3 & RSA-3 for Zone-3) and, (EX4, EY4 & RSA-4 for Zone-4)



	1	2	3	4	5	6	7	8	9	10	11	12
UX in	0.5559	-0.002	0.9265	-0.004	1.2971	-0.005	1.7495	-0.007	2.3245	3.8742	5.4239	6.9736
UY in	-0.002	0.6564	-0.004	1.0939	-0.005	1.5315	-0.007	2.0656	0.1769	0.2949	0.4128	0.5307

Figure 4.6: CM Displacement Graph

Fig 4.6 shows the variation (UX & UY) of CM Displacement among all the zones. Where X axis indicates the displacement in inch and Y axis indicates the value of load cases for each zone.

Table 4.4: Max/Avg storey Displacement

Story	Load Case/Combo	Direction	Maximum in	Average in	Ratio
4F	EX1	X	0.605484	0.556922	1.087
3F	EX1	X	0.521343	0.480852	1.084
2F	EX1	X	0.386816	0.358104	1.08
1F	EX1	X	0.215775	0.201621	1.07
4F	EY1	Y	0.693735	0.657211	1.056
3F	EY1	Y	0.599435	0.567554	1.056
2F	EY1	Y	0.446207	0.422204	1.057
1F	EY1	Y	0.250369	0.236786	1.057
4F	EX2	X	1.009139	0.928204	1.087
3F	EX2	X	0.868906	0.80142	1.084
2F	EX2	X	0.644693	0.59684	1.08
1F	EX2	X	0.359625	0.336035	1.07
4F	EY2	Y	1.156226	1.095352	1.056
3F	EY2	Y	0.999059	0.945924	1.056
2F	EY2	Y	0.743678	0.703673	1.057
1F	EY2	Y	0.417282	0.394644	1.057
4F	EX3	X	1.412795	1.299485	1.087
3F	EX3	X	1.216468	1.121988	1.084
2F	EX3	X	0.902571	0.835576	1.08
1F	EX3	X	0.503475	0.470448	1.07
4F	EY3	Y	1.618716	1.533493	1.056
3F	EY3	Y	1.398683	1.324294	1.056
2F	EY3	Y	1.04115	0.985142	1.057
1F	EY3	Y	0.584195	0.552502	1.057
4F	EX4	X	1.905485	1.752674	1.087
3F	EX4	X	1.64161	1.514143	1.084
2F	EX4	X	1.218576	1.128152	1.08
1F	EX4	X	0.679948	0.63536	1.07
4F	EY4	Y	2.183255	2.068323	1.056
3F	EY4	Y	1.88752	1.787131	1.056
2F	EY4	Y	1.405676	1.330057	1.057
1F	EY4	Y	0.78896	0.746157	1.057
4F	RSA-1 Max	X	2.807347	2.372347	1.183
4F	RSA-1 Max	Y	0.766636	0.467779	1.639
3F	RSA-1 Max	X	2.448286	2.074458	1.18
3F	RSA-1 Max	Y	0.666253	0.40687	1.638
2F	RSA-1 Max	X	1.841854	1.56661	1.176
2F	RSA-1 Max	Y	0.497579	0.304394	1.635
1F	RSA-1 Max	X	1.038788	0.891769	1.165
1F	RSA-1 Max	Y	0.275591	0.169553	1.625
4F	RSA-2 Max	X	4.678907	3.953907	1.183
4F	RSA-2 Max	Y	1.277725	0.779631	1.639
3F	RSA-2 Max	X	4.080472	3.457427	1.18

Story	Load Case/Combo	Direction	Maximum in	Average in	Ratio
3F	RSA-2 Max	Y	1.110421	0.678117	1.638
2F	RSA-2 Max	X	3.069753	2.611015	1.176
2F	RSA-2 Max	Y	0.829298	0.507324	1.635
1F	RSA-2 Max	X	1.731311	1.48628	1.165
1F	RSA-2 Max	Y	0.459318	0.282589	1.625
4F	RSA-3 Max	X	6.55047	5.53547	1.183
4F	RSA-3 Max	Y	1.788815	1.091483	1.639
3F	RSA-3 Max	X	5.712661	4.840397	1.18
3F	RSA-3 Max	Y	1.554589	0.949363	1.638
2F	RSA-3 Max	X	4.297655	3.65542	1.176
2F	RSA-3 Max	Y	1.161017	0.710253	1.635
1F	RSA-3 Max	X	2.423835	2.080791	1.165
1F	RSA-3 Max	Y	0.643045	0.395624	1.625
4F	RSA-4 Max	X	8.422033	7.117033	1.183
4F	RSA-4 Max	Y	2.299904	1.403336	1.639
3F	RSA-4 Max	X	7.34485	6.223368	1.18
3F	RSA-4 Max	Y	1.998757	1.22061	1.638
2F	RSA-4 Max	X	5.525556	4.699826	1.176
2F	RSA-4 Max	Y	1.492736	0.913182	1.635
1F	RSA-4 Max	X	3.11636	2.675303	1.165
1F	RSA-4 Max	Y	0.826773	0.50866	1.625

Table 4.4 explain the max/avg. story displacement for different load cases in different zones. It appears that the maximum value of displacement founded in top floor (4^{th}).

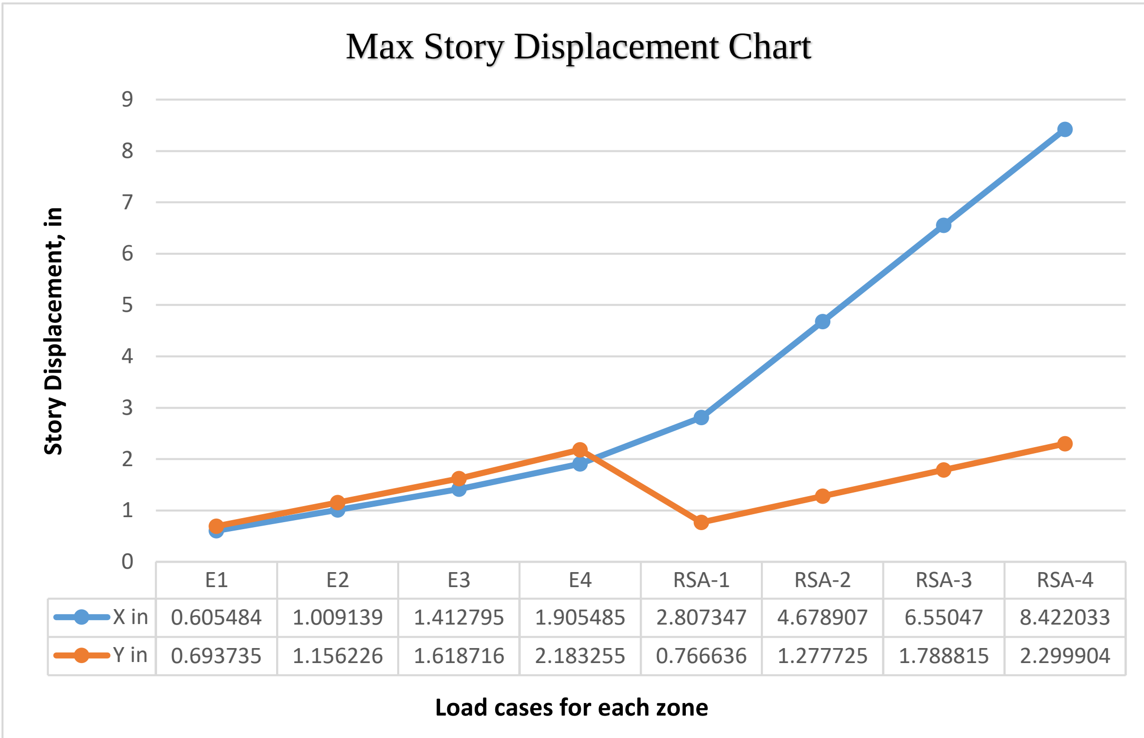


Figure 4.7: Max storey Displacement Graph

Fig 4.7 shows the story displacement variation for different load cases in different zones. Where X axis indicates story displacement in inch and Y axis indicates different Load cases of different zones.

Table 4.5: Storey Drift

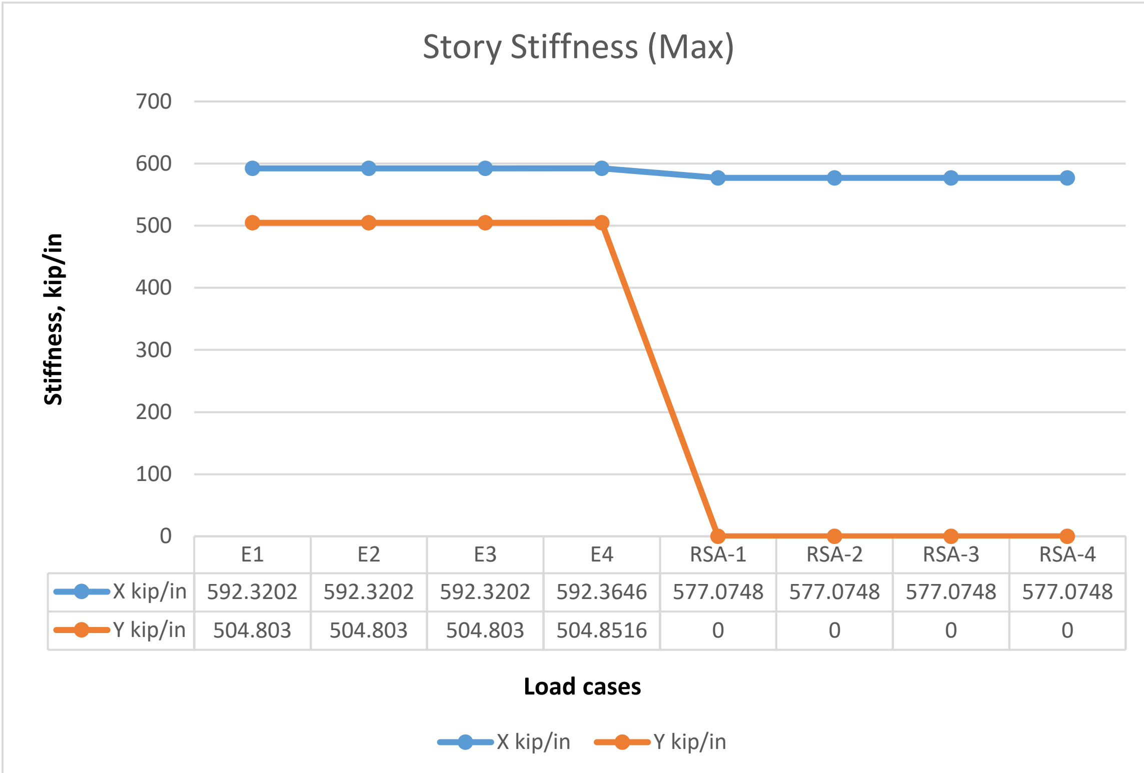
Story	Load Case/Combo	Direction	Drift	Label	X ft	Y ft	Z ft
4F	EX1	X	0.000701	7	32	29	46
4F	EY1	Y	0.000786	7	32	29	46
4F	EX2	X	0.001169	7	32	29	46
4F	EY2	Y	0.00131	7	32	29	46
4F	EX3	X	0.001636	7	32	29	46
4F	EY3	Y	0.001834	7	32	29	46
4F	EX4	X	0.002199	7	32	29	46
4F	EY4	Y	0.002464	7	32	29	46
4F	RSA-1 Max	X	0.003184	7	32	29	46
4F	RSA-1 Max	Y	0.000866	8	0	29	46
4F	RSA-2 Max	X	0.005307	7	32	29	46
4F	RSA-2 Max	Y	0.001444	8	0	29	46
4F	RSA-3 Max	X	0.00743	7	32	29	46
4F	RSA-3 Max	Y	0.002022	8	0	29	46
4F	RSA-4 Max	X	0.009552	7	32	29	46
4F	RSA-4 Max	Y	0.002599	8	0	29	46
3F	EX1	X	0.001121	7	32	29	36
3F	EY1	Y	0.001277	7	32	29	36
3F	EX2	X	0.001868	7	32	29	36
3F	EY2	Y	0.002128	7	32	29	36
3F	EX3	X	0.002616	7	32	29	36
3F	EY3	Y	0.002979	7	32	29	36
3F	EX4	X	0.003525	7	32	29	36
3F	EY4	Y	0.004015	7	32	29	36
3F	RSA-1 Max	X	0.005202	7	32	29	36
3F	RSA-1 Max	Y	0.001426	5	0	0	36
3F	RSA-2 Max	X	0.008669	7	32	29	36
3F	RSA-2 Max	Y	0.002377	9	0	14	36
3F	RSA-3 Max	X	0.012137	7	32	29	36
3F	RSA-3 Max	Y	0.003328	5	0	0	36
3F	RSA-4 Max	X	0.015605	7	32	29	36
3F	RSA-4 Max	Y	0.004279	5	0	0	36
2F	EX1	X	0.001425	7	32	29	26
2F	EY1	Y	0.001632	7	32	29	26
2F	EX2	X	0.002376	7	32	29	26
2F	EY2	Y	0.00272	7	32	29	26
2F	EX3	X	0.003326	7	32	29	26
2F	EY3	Y	0.003808	7	32	29	26
2F	EX4	X	0.004489	7	32	29	26
2F	EY4	Y	0.005139	7	32	29	26
2F	RSA-1 Max	X	0.006738	7	32	29	26
2F	RSA-1 Max	Y	0.001856	8	0	29	26
2F	RSA-2 Max	X	0.01123	7	32	29	26

Story	Load Case/Combo	Direction	Drift	Label	X ft	Y ft	Z ft
2F	RSA-2 Max	Y	0.003094	8	0	29	26
2F	RSA-3 Max	X	0.015722	7	32	29	26
2F	RSA-3 Max	Y	0.004331	8	0	29	26
2F	RSA-4 Max	X	0.020214	7	32	29	26
2F	RSA-4 Max	Y	0.005569	8	0	29	26
1F	EX1	X	0.001439	7	32	29	16
1F	EY1	Y	0.001668	2	32	0	16
1F	EX2	X	0.002398	7	32	29	16
1F	EY2	Y	0.00278	2	32	0	16
1F	EX3	X	0.003358	7	32	29	16
1F	EY3	Y	0.003892	2	32	0	16
1F	EX4	X	0.004535	7	32	29	16
1F	EY4	Y	0.005256	2	32	0	16
1F	RSA-1 Max	X	0.006921	7	32	29	16
1F	RSA-1 Max	Y	0.001832	8	0	29	16
1F	RSA-2 Max	X	0.011534	7	32	29	16
1F	RSA-2 Max	Y	0.003053	8	0	29	16
1F	RSA-3 Max	X	0.016148	7	32	29	16
1F	RSA-3 Max	Y	0.004275	8	0	29	16
1F	RSA-4 Max	X	0.020762	7	32	29	16
1F	RSA-4 Max	Y	0.005496	8	0	29	16
GB	EX1	X	0.000598	11	16	29	6
GB	EY1	Y	0.000697	7	32	29	6
GB	EX2	X	0.000997	11	16	29	6
GB	EY2	Y	0.001162	7	32	29	6
GB	EX3	X	0.001396	11	16	29	6
GB	EY3	Y	0.001627	7	32	29	6
GB	EX4	X	0.001886	11	16	29	6
GB	EY4	Y	0.002197	7	32	29	6
GB	RSA-1 Max	X	0.002896	11	16	29	6
GB	RSA-1 Max	Y	0.000777	5	0	0	6
GB	RSA-2 Max	X	0.004826	11	16	29	6
GB	RSA-2 Max	Y	0.001294	5	0	0	6
GB	RSA-3 Max	X	0.006756	11	16	29	6
GB	RSA-3 Max	Y	0.001812	5	0	0	6
GB	RSA-4 Max	X	0.008687	11	16	29	6
GB	RSA-4 Max	Y	0.00233	5	0	0	6

Table 4.6: Storey Stiffness

Story	Load Case	Shear X kip	Drift X in	Stiffness X kip/in	Shear Y kip	Drift Y in	Stiffness Y kip/in
4F	EX1	9.259	0.07607	121.7102	0.001	0.00496	0
3F	EX1	15.802	0.122748	128.7319	0.002	0.007355	0
2F	EX1	20.588	0.156483	131.566	0.002	0.009237	0
1F	EX1	23.594	0.161248	146.3208	0.003	0.007215	0
GB	EX1	23.913	0.040372	592.3202	0.003	0.001642	0
4F	EY1	0.001	0.0024	0	9.289	0.089657	103.6065
3F	EY1	0.002	0.004137	0	15.868	0.145351	109.1678
2F	EY1	0.002	0.005523	0	20.69	0.185417	111.5873
1F	EY1	0.003	0.005535	0	23.729	0.189128	125.4639
GB	EY1	0.003	0.00137	0	24.053	0.047648	504.803
4F	EX2	15.431	0.126784	121.7102	0.001	0.008267	0
3F	EX2	26.336	0.20458	128.7319	0.003	0.012258	0
2F	EX2	34.313	0.260805	131.566	0.004	0.015394	0
1F	EX2	39.323	0.268747	146.3208	0.005	0.012025	0
GB	EX2	39.855	0.067287	592.3202	0.005	0.002736	0
4F	EY2	0.001	0.004	0	15.482	0.149428	103.6065
3F	EY2	0.003	0.006894	0	26.446	0.242251	109.1678
2F	EY2	0.004	0.009205	0	34.484	0.309029	111.5873
1F	EY2	0.005	0.009226	0	39.548	0.315213	125.4639
GB	EY2	0.005	0.002283	0	40.088	0.079414	504.803
4F	EX3	21.603	0.177497	121.7102	0.002	0.011574	0
3F	EX3	36.87	0.286412	128.7319	0.004	0.017161	0
2F	EX3	48.038	0.365127	131.566	0.005	0.021552	0
1F	EX3	55.053	0.376246	146.3208	0.007	0.016835	0
GB	EX3	55.797	0.094201	592.3202	0.007	0.003831	0
4F	EY3	0.002	0.0056	0	21.674	0.209199	103.6065
3F	EY3	0.004	0.009652	0	37.024	0.339152	109.1678
2F	EY3	0.005	0.012886	0	48.277	0.43264	111.5873
1F	EY3	0.007	0.012916	0	55.367	0.441298	125.4639
GB	EY3	0.007	0.003196	0	56.124	0.111179	504.803
4F	EX4	28.978	0.238531	121.4837	0.002	0.015577	0
3F	EX4	49.692	0.385991	128.74	0.005	0.023129	0
2F	EX4	64.845	0.492792	131.5864	0.007	0.029082	0
1F	EX4	74.361	0.508121	146.3445	0.009	0.022729	0
GB	EX4	75.371	0.127237	592.3646	0.009	0.005173	0
4F	EY4	0.002	0.007519	0	29.074	0.281191	103.3945
3F	EY4	0.005	0.013006	0	49.9	0.457075	109.1732
2F	EY4	0.007	0.017392	0	65.167	0.5839	111.6064
1F	EY4	0.009	0.017443	0	74.785	0.595958	125.4868
GB	EY4	0.01	0.004317	0	75.811	0.150165	504.8516
4F	RSA-1	37.896	0.318758	118.886	2.777	0.063341	0
3F	RSA-1	66.315	0.524296	126.4839	4.987	0.104259	0
2F	RSA-1	87.446	0.680108	128.576	6.601	0.135376	0

Story	Load Case	Shear X kip	Drift X in	Stiffness X kip/in	Shear Y kip	Drift Y in	Stiffness Y kip/in
1F	RSA-1	102.375	0.712606	143.6635	7.715	0.134978	0
GB	RSA-1	103.449	0.179264	577.0748	7.794	0.034526	0
4F	RSA-2	63.16	0.531262	118.886	4.629	0.105567	0
3F	RSA-2	110.525	0.873826	126.4839	8.312	0.173766	0
2F	RSA-2	145.742	1.133512	128.576	11.002	0.225626	0
1F	RSA-2	170.626	1.187675	143.6635	12.859	0.224963	0
GB	RSA-2	172.415	0.298773	577.0748	12.99	0.057543	0
4F	RSA-3	88.423	0.743767	118.886	6.48	0.147794	0
3F	RSA-3	154.735	1.223357	126.4839	11.637	0.243272	0
2F	RSA-3	204.039	1.586916	128.576	15.403	0.315876	0
1F	RSA-3	238.876	1.662745	143.6635	18.003	0.314948	0
GB	RSA-3	241.38	0.418283	577.0748	18.186	0.08056	0
4F	RSA-4	113.687	0.956272	118.886	8.331	0.190021	0
3F	RSA-4	198.945	1.572888	126.4839	14.962	0.312778	0
2F	RSA-4	262.336	2.040321	128.576	19.803	0.406126	0
1F	RSA-4	307.126	2.137815	143.6635	23.146	0.404933	0
GB	RSA-4	310.346	0.537792	577.0748	23.382	0.103577	0



	E1	E2	E3	E4	RSA-1	RSA-2	RSA-3	RSA-4
X kip/in	592.3202	592.3202	592.3202	592.3646	577.0748	577.0748	577.0748	577.0748
Y kip/in	504.803	504.803	504.803	504.8516	0	0	0	0

Figure 4.8: Storey Stiffness Graph

Table 4.7: Diaphragm Acceleration

Storey	Diaphragm	Load Case/Combo	UX in/sec²	UY in/sec²	UZ in/sec²	RX rad/sec²	RY rad/sec²	RZ rad/sec²
4F	D1	RSA-1 Max	101.899	32.379	4.67	0.063	0.39	0.15
4F	D1	RSA-2 Max	169.831	53.964	7.784	0.106	0.65	0.251
4F	D1	RSA-3 Max	237.764	75.55	10.897	0.148	0.91	0.351
4F	D1	RSA-4 Max	305.696	97.136	14.011	0.19	1.171	0.451
3F	D1	RSA-1 Max	81.082	26.749	3.7	0.083	0.384	0.125
3F	D1	RSA-2 Max	135.137	44.581	6.166	0.138	0.64	0.208
3F	D1	RSA-3 Max	189.191	62.413	8.633	0.193	0.897	0.291
3F	D1	RSA-4 Max	243.246	80.246	11.099	0.249	1.153	0.375
2F	D1	RSA-1 Max	73.444	22.287	2.878	0.066	0.337	0.103
2F	D1	RSA-2 Max	122.407	37.145	4.797	0.11	0.562	0.172
2F	D1	RSA-3 Max	171.369	52.003	6.716	0.154	0.787	0.241
2F	D1	RSA-4 Max	220.332	66.861	8.635	0.198	1.011	0.31
1F	D1	RSA-1 Max	61.389	15.273	2.313	0.069	0.267	0.07
1F	D1	RSA-2 Max	102.315	25.456	3.854	0.115	0.444	0.117
1F	D1	RSA-3 Max	143.241	35.638	5.396	0.16	0.622	0.163
1F	D1	RSA-4 Max	184.167	45.82	6.938	0.206	0.8	0.21

Modal Result

Table 4.8: Modal Periods and Frequencies

Case	Mode	Period sec	Frequency cyc/sec	Circular Frequency rad/sec	Eigenvalue rad^2/sec^2
Modal	1	1.201	0.833	5.2331	27.3858
Modal	2	1.111	0.9	5.6571	32.0026
Modal	3	0.875	1.143	7.1834	51.6015
Modal	4	0.365	2.738	17.2044	295.9914
Modal	5	0.343	2.915	18.313	335.3642
Modal	6	0.274	3.654	22.9573	527.0365
Modal	7	0.194	5.142	32.3064	1043.7022
Modal	8	0.187	5.336	33.5266	1124.0362
Modal	9	0.15	6.656	41.8238	1749.2263
Modal	10	0.128	7.783	48.9027	2391.473
Modal	11	0.127	7.871	49.4531	2445.6066
Modal	12	0.101	9.945	62.4892	3904.9011

Table 4.9: Modal Direction Factors

Case	Mode	Period sec	UX	UY	UZ	RZ
Modal	1	1.201	0.005	0.982	0	0.013
Modal	2	1.111	0.952	0.009	0	0.039
Modal	3	0.875	0.043	0.01	0	0.948
Modal	4	0.365	0.006	0.976	0	0.018
Modal	5	0.343	0.97	0.009	0	0.02
Modal	6	0.274	0.024	0.015	0	0.961
Modal	7	0.194	0.002	0.97	0	0.028
Modal	8	0.187	0.995	0.003	0	0.002
Modal	9	0.15	0.003	0.027	0	0.97
Modal	10	0.128	0.38	0.576	0	0.044
Modal	11	0.127	0.612	0.384	0	0.004
Modal	12	0.101	0.007	0.041	0	0.952

Table 4.8 & 4.9 explains the modal results of the building. Modal analysis is the study of the dynamic properties of systems in the frequency domain. It provides us frequencies, circular frequencies, eigenvalues and also the modal direction factors in X, Y & Z axis respectively.

4.6 Discussion of Results

After performing Linear Static Analysis and Linear Response Spectrum analysis and after study the results we can say that-

- Storey displacement of different Zone co-efficient shows different displacement results which state that higher co-efficient can makes higher value of displacement.
- As the floor displacement limits consider by H/400= 1.38 inch but we get a maximum displacement result from Linear Static Analysis is 2.18 inch.
- Response Spectrum Analysis of BNBC Zone-4 for displacement carries a vulnerable result than the other Zones.
- Column P-M-M ratio are beyond satisfied limit.
- Retrofitting like shear wall can be an effective procedure for reducing the storey displacement.
- More numerical works should be done for better analysis result.

4.7 Summary

In this chapter we study the result of the software analysis and comment through the result. We will discuss about the thesis future works and necessary steps for developing good quality work and result for seismic analysis and behavior.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Introduction

Numerical analysis of a 4-storey residential building was developed in the previous chapter using ETABS 16.2.1, while chapter 4 presented the numerical results and relevant discussion.

This chapter includes the conclusions of the work done and recommendations for possible future research on this topic.

5.2 Conclusion from this work

A 4-storey ongoing construction building plan has taken for analysis. The building is monitored with working progress and numerically analyzed by ETABS.

ETABS is stand for Extended Three-Dimensional Analysis of Building System. We developed our building structure in ETABS software for analysis. Our aim was to get the result of seismic analysis for different BNBC zone. As the BNBC2020 has 4 different zone co-efficient value so we define 4 different load cases for each zone.

We also developed Response Spectrum Analysis with 5% damping ratio for each of the zone separately. However, for getting seismic result we need both the Equivalent static method and Response Spectrum analysis method. Our aim was to get the reaction from this approaching result.

The following conclusions are found from this work

As we analyze the structure for all 4 zones of BNBC 2020, the results are not same for every zone. It is varying from zone to zone. So, we mentioned some comments for it-

Storey Displacement

- For BNBC 2020 Zone 1 & 2, the storey displacement results did not exceed the limits value which is 0.60 inch for zone 1 and 0.69 inch for zone 2.
- Storey displacement results of Zone 3 & 4 did not satisfy the limits value (1.38inch) which is 1.61inch for zone 3 and 2.18inch for zone 4.
- Results from Response Spectrum Analysis did not satisfy the maximum limit and it showed more devastating results.

Other Static Analysis

- For vertical load carrying, columns capacity is far good from required value.
- Force diagrams were behaved proportionally in the linear static analysis results.
- Base reaction for lower zone co-efficient was low and high for higher zone co-efficient. Response spectrum analysis showed a same statistic value like linear results.
- The maximum centre of mass displacement was found in Zone-4 for response spectrum analysis in X axis which is 6.97 inch.
- Storey stiffness are found to be greater in linear analysis than the response spectrum in X axis which 592.32 kip/in. For all other zones, this value is the same in linear condition.

Dynamic Analysis

Dynamic Time History Analysis would be more accurate analysis instead of commonly used Linear Static analysis. After performing DTHA, the results may change a lot and it should be wise to use EL Centro Factored data while doing the Time History Analysis.

5.3 Future Recommendation

As the Numerical results are not a perfect match with Linear Static Analysis and Linear Response Spectrum Analysis, further analysis and work should be done with Shear wall as follows-

- Static Pushover Analysis (non-linear)
- Non-Linear Response Spectrum Analysis.
- Linear Time History Analysis.
- Non-Linear Time History Analysis.

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