Performance-Based Building Analysis of Different Shapes of Building By ETABS

Submitted By

Partho Protim Roy

(ID: - 201-47-381)

A Project and Thesis submitted in partial fulfillment of the requirements for the award of degree of

Bachelor of Science in Civil Engineering

Supervised by

Mr. Md Asaduzzaman Naeem

Lecturer

Department of Civil Engineering

Daffodil International University

DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

DAFFODIL INTERNATIONAL UNIVERSITY

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CERTIFICATION

This is to certify that this thesis entitled "Performance-Based Building Analysis of Different Shapes of Building by ETABS" is done by the following student under my direct supervision in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering. The work presentation was held on 20/11/2024.

Signature of the candidates

পার্থ প্রতীম রায়

Name: Partho Protim Roy

ID: 201-47-381

Countersigned

Md Asaduzzaman Naeem

Lecturer

Department of Civil Engineering

Daffodil International University.

The thesis entitled "Performance-Base building Analysis of Different Shapes of building by ETABS" submitted by Partho Protim Roy, ID No: 201-47-381, Session: Fall 2023 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering on 20/11/2024

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Torque Consulting Engineers

Dedicated to,

This thesis is dedicated to my beloved parents, whose unwavering love, support, and encouragement have been my guiding light throughout this journey.

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ACKNOWLEDGEMENT

I begin by expressing my sincere gratitude to God, the source of all knowledge and strength, for granting me the determination and resilience to complete this project. I extend my heartfelt thanks to **Md Asaduzzaman Naeem**, Lecturer of the Department of Civil Engineering, for his unwavering guidance and support as my thesis supervisor. His dedication, assistance, and direction have been instrumental in the successful completion of this thesis. I am deeply grateful for his invaluable advice and encouragement, which have significantly contributed to the fulfillment of this thesis. I also wish to acknowledge **Dr. Mohammad Hannan Mahmud Khan**, the head of the Department of Civil Engineering and assistant professor, for his constant assistance, motivation, and backing. My appreciation knows no bounds for my beloved family and friends. Their steadfast support, encouragement, and inspiration have been indispensable throughout my academic journey at this University.

ABSTRACT

Engineers are able to detect possible vulnerabilities in a structure and implement corrective steps to avoid collapse by examining the structure's reaction to a pushover load. By performing a pushover analysis can lessen the need for expensive retrofits or repairs by spotting possible issues early on. This Study presents the performance of building by pushover analysis in ETABS. By lowering the possibility of damage and enhancing general safety, pushover analysis can assist engineers in optimizing the structural performance of buildings. Pushover analysis results for Building are presented in this report in order to assess the building's behavior under monotonic lateral loads and to verify that it complies with ASCE7-05,FEMA 440, BNBC 2020,specifications.In this research all the building shapes (R,L,I,O) area was same. All value has collected and define in ETABS software for the result. The important term was calculated the maximum earthquake and design earthquake according to BNBC 2020.Also define the Response spectra was important. This response spectra value related to the maximum earthquake and design earthquake. In this thesis the maximum earthquake value has calculated according to the BNBC 2020.Those value helped to find the performance point of buildings. In ETABS there are an important tool called load case. For the result have been created the load case named pushover analysis as non-linear. For pushover analysis hinges have been defined for all beam and column member. Hinges gives us the information about the strong and weak member. The pushover points for all shapes (R, L, I, O) found After the the analysis. last capacity of the building is the best performance. FEMA 440 code helped to find the performance point of those building. Four different shapes building has been compared with each other and got the result. This thesis helps to find the performance of a building. The research also showed that the structure is highly sensitive to the position and magnitude of the seismic load, with the highest degree of non-linear behavior occurring at particular load combination.

CHAPTER ONE

INTRODUCTION

1.1 General

An earthquake occurs when energy is abruptly released in the Earth's crust, typically due to the movement of tectonic plates, volcanic activity, or the injection of fluids into the ground. Earthquake is a major problem for buildings buildings and bridges must be designed to withstand seismic forces and resist damage. Now a days without considering the earthquake is a very bad dissection for all civil engineers.

Now a day’s engineers are analysis with many methods to withstand seismic loads. Pushover is one of them. Pushover analysis a non-linear static analysis method is used to assess a structure's seismic response. Pushover analysis is used to assess a structure's seismic capacity, indicating its ability to endure inertial forces caused by an earthquake.

Pushover Analysis helps to quake estimation of capacity. Pushover analysis is helpful for feasibility studies, early design, or quick evaluation of already-existing buildings. It aids in locating crucial areas of the structure that are most susceptible to seismic stresses. Refitting or strengthening activities might be targeted with the help of this information. Pushover analysis is a useful tool for capturing nonlinear structural behavior, such as the impacts of geometric nonlinearity, material nonlinearity, and other nonlinear behavior types. Pushover analysis can be used for assessing a structure's seismic performance, including its capacity to withstand loads, absorb energy, and preserve structural integrity also it can be used to optimize the design of structures for seismic resistance in conjunction with optimization techniques.

Engineers can determine the structure's maximum capacity and assess whether it meets design requirements by analyzing the pushover curve. A progressive rise in the base shear force is applied in a simplified manner to mimic seismic loading until the structure collapses or reaches a predetermined limit state. When assessing the seismic performance of reinforced concrete (RCC) buildings, this methodology is especially helpful.

ETABS is used to determine the earthquake effect of a building. ETABS is a widely used software for static and dynamic analysis of buildings, bridges, and other structures. Pushover analysis is also done by this software. A thorough examination of the behavior of the structure under various load circumstances, including seismic loads, can be carried out by ETABS. This aids in precisely forecasting the structural response, which is necessary to guarantee the building's safety and integrity. engineers can create structures that are resistant to seismic stresses and deformations by using ETABS. To assist engineers in optimizing their designs for seismic performance, it offers a variety of tools and capabilities. Engineers can simulate the behavior of different building materials, such as concrete, steel, and masonry, using ETABS. This aids in simulating the structural reaction to seismic loads more precisely. In order to adhere to regional and federal building codes, the construction sector frequently uses ETABS.

A graph that displays the relationship between the building's base shear force (V) and roof displacement (Δ) is known as a pushover curve. (Santhosh.D 2014)

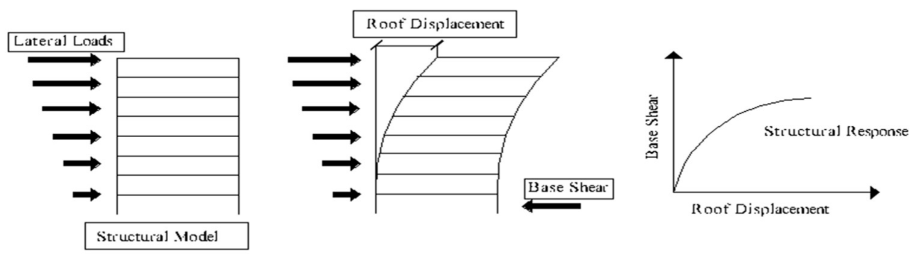


Fig. 1.1: Static approximation used in the pushover analysis (Santhosh.D 2014)

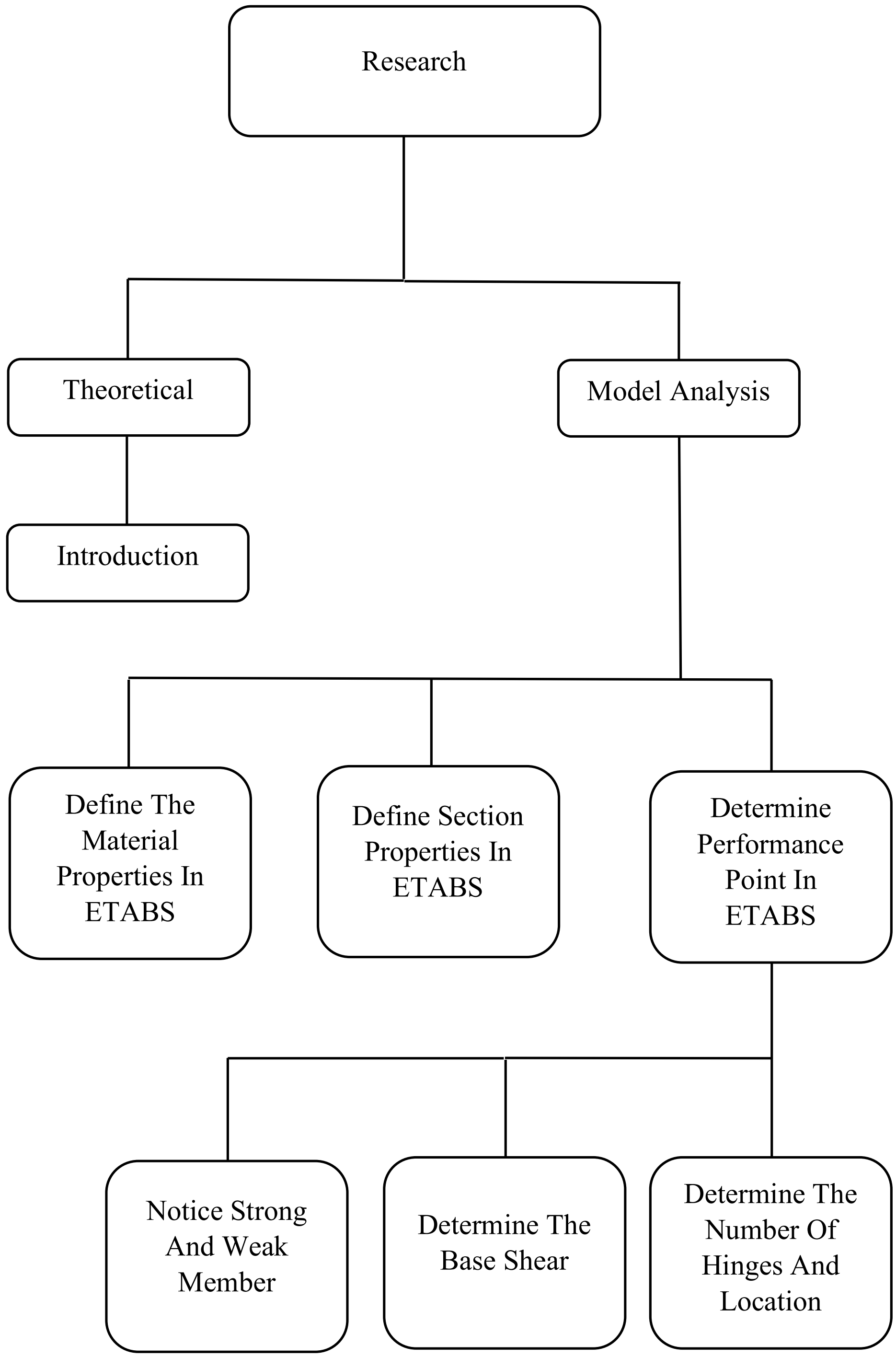
1.3 Objective of This Study

- To determine the performance point of the building.
- To Determine the capacity spectrum.
- Identify potential damage locations through hinges.
- To determine the stage of the building. (IO, LF, CP, Stage)
- To determine the performance of the beam and column for target displacement

1.4 Scope of study

This thesis focuses on the performance of the building. This thesis helps to find which building shapes provide the best performance. ETABS software was used for this thesis ETABS there are a load case where pushover load can be defined. Where buildings try to achieve target displacement. In this process, the performance point will be found and that will be the performance point of that building. In this thesis were defined hinges for all beam and column members in ETABS. Those hinges will show us the result of which member will fail. The pushover analysis helps to retrofit. Each building was compared with the result after getting the performance point. This research also shows us which members of those buildings are weak and strong.

1.5 Outline of This Research



CHAPTER TWO

LITERATURE REVIEW

2.1 About Pushover Analysis

The Pushover analysis is a non-linear static approach that increases the seismic load gradually until the structure reaches its full capacity, simulating the collapse of the structure. (Taghipour 2015)

Pushover analysis is a commonly employed method for evaluating the seismic performance of buildings. The technique is putting a structure under a lateral load usually an earthquake ground motion and assessing how it responds in terms of deformations, stresses, and damage. Determining a structure's ability to withstand earthquakes and the potential extent of damage during an occurrence are the main objectives of pushover analysis. The method has proven to be successful in forecasting the seismic performance of numerous types of structures, such as buildings, bridges, and dams, and it has been widely used in these kinds of projects. literature review aims to provide a comprehensive overview of the current state of pushover analysis in earthquake engineering. It will focus on recent advances in pushover analysis methods, including the use of advanced finite element models and statistical methods. The review will also discuss the limitations and challenges associated with pushover analysis and highlight areas for future research.

2.2 Hinges

Hinges are the locations on a structure where relatively high-intensity yielding and cracking are expected when the structure approaches its ultimate strength under cyclic loading (seismic loading). These locations exhibit substantial flexural displacement. Hinges help to get the strong and weak members of a building. (Eslami 2014)

The Design Earthquake: - The probabilistically specified design-based earthquake is the magnitude of ground shaking that has a 10% probability of being exceeded over 50 years (R M 2016).

The Maximum Earthquake:- The probabilistically specified design-based earthquake is the magnitude of ground shaking that has a 5% probability of being exceeded over 50 years (R M 2016).

2.3 Force-Deformation Behavior of Hinges

The force-deflection behavior of the hinge is defined by five points, labeled A, B, C, D, and E. These points are labeled Elastic state, below immediate occupancy, IO to LS, between life safety and collapse prevention, LS to CP, between collapse prevention and ultimate capacity, C to D, between C and residual strength, and D to E, between D and collapse >E – collapse (Santhosh.D 2014)

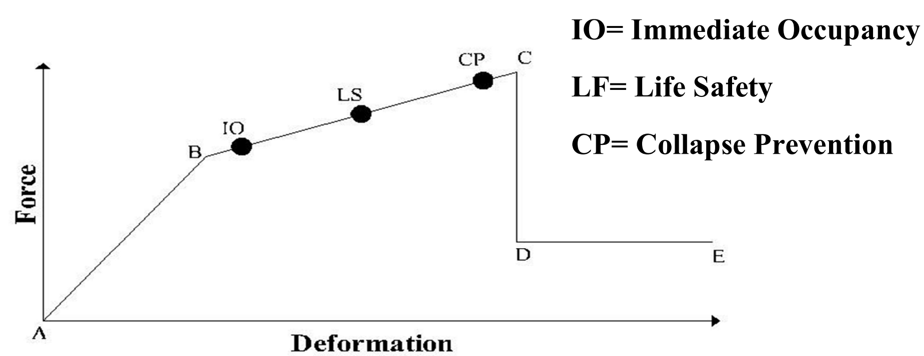


Fig. 2.0-1:Force Vs Deformation *(Santhosh.D 2014)*

Immediate Occupancy (IO): The structure is slightly Damaged but any repair could be done.

Life Safety (LF): Structure Damaged but reparable.

Collapse Prevention (CP): Do not collapse but the structure may be severely damaged. (Santhosh.D 2014)

2.4 Previous Researches

Several studies on Pushover Analysis on RCC buildings have been done recently, a few of these will be included in the following-

R.M. Faysal's research was the pushover analysis of a building located in Dhaka. It was found that the performance of the structure. Base share against displacements. Serviceability Earthquake, Design Earthquake, Maximum Earthquake calculated. The building he has used is located in Dhaka and the zone is 2 as BNBC 2006 and the soil profile type SC. This research analyzed a safe building. Here has used the pushover analysis for analysis of the building. After the analysis the building was safe. Because no hinges crossed the IO-LS and LS-CP ranges. That's why the building is safe. (R M 2016)

Santhosh. D's research was three different story buildings performance point and hinges locations in different stages. In the result, it was found the comparison of the maximum displacement of those buildings. That research uses a grate of concrete M20, Grade of steel Fe-415, This research uses FEMA-273, ATC-40, and FEMA-356.After the analysis the result of the pushover curve for all buildings. And found the maximum base shear for those three different-story buildings. It was found that five-story buildings carry higher base force and lower displacement. (Santhosh.D 2014)

This research pushover curve from four different high buildings and also calculated the performance point of those buildings. SAP2000 software has been used for Research 40, and FEMA356, and FEMA 440 were used for this research. Got the 3,6,9,12 story building pushover curve and got the performance point for ATC40, FEMA356, and FEMA440.The capacity spectrum method (ATC40) gives the lowest performance point. All the building's maximum story drift is <0.01 which can be categorized in IO according to ATC40 code. Overall building elements were at IO-LS level. The building was safe. (R.A 2014)

Ingale's research was the capacity curve from different zones according to the IS 1893 code. At the end of the analysis was found the comparison of story displacement from different zones and the design base earthquake and maximum earthquake. In this research G+5 storied reinforcement concrete frame building analysis. Zone 3,4,5 maximum considered earthquake and design-based earthquake. The total height of the building was 18m. Compare all the Capacity curves in zones 4,5,3 against maximum earthquake and design-based earthquake. In this research has shown the comparison of story displacement in zones 5,4,3 against maximum and design-based earthquakes. In this research result plastic hinges formed within the IO-LF level model followed the strong column and weak beam concept. (Ingale 2017)

Alashker's research analyzes the displacement of the different plans of the building with different aspect ratios. At the end of the analysis, the performance point and plastic hinges from different stages. In this research, there were four different eras of buildings used for pushover analysis. The area ratio of the first model was 1, the second building's area ratio was 1.5,2 and the last one was 4. The building with an area ratio of 1.5 shows the least base shear in the x-x and y-y directions. And other cases base shear increases with increases in the plan ratio. Increasing the area ratio has made the building more vulnerable in the Y direction. (Alashker 2015)

CHAPTER THREE

MODELING AND ANALYSIS

3.1 Introduction

For modeling use ETABS for this thesis for pushover analysis for four different shape buildings (R, L, I, O shapes). ETABS is the essential tool for the pushover analysis. Nonlinear static analysis. With this feature, users can model how structures might behave when lateral loads increase while accounting for phenomena like geometry and material nonlinearity. Various sophisticated material models, such as those for masonry, steel, and concrete, are available from ETABS and can be used to simulate the nonlinear behavior of structures under pushover loads. These material models can represent intricate phenomena including damage, yielding, and cracking.

3.2 Details of Modeling

This section provides an overview of the details and specifications included in the Structural model of all shapes. All the building areas were 3125 sq. Ft and the height is 70ft. The slab is considered to have a 5-inch thickness and slab material of 4000 psi for all shapes of buildings.

3.3 Material Property:

In this thesis, there uses concrete Compressive Strength (f'c) 4 ksi. Minimum Yield Stress (f'y) 60 ksi, Minimum tensile strength (Fu) of 90 ksi. A minimum tensile strength (Fu) of 90 ksi.

3.4 Section Properties:

Beam: A beam is a type of structural member that transfers loads from the supporting columns or walls to itself. It is usually horizontal or sloping. Beams, which can be composed of concrete, steel, or wood, are frequently used in building construction to provide the framework or skeleton of the structure. Here in this research have used for all building shapes were used beam cross-section size 12" X 14". In this thesis uses Beam cover to longitudinal rebar group centroid top bar 2.5" bottom bar 2.5" For all shapes.

Column: A column is a vertical structural component that gives a building or other structure stability and support. It is usually a vertical part that transfers weights from the floor or roof to the foundation. It is made to withstand compressive loads from the weight, the wind, and earthquakes. In this thesis uses for all building shapes were used column cross section size 12" X 15".

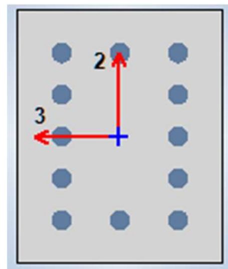


Fig. 3.1: Column (12"X 15")

longitudinal bar:

Clear cover to confinement bar 1.5".uses Number of the longitudinal bar along 3-dir face are 3. Several longitudinal bars along the 2-dir face are 5. longitudinal bar size #9 and the bar size is 1 in^2.

Confinement bar :

In this model uses confinement bar size #4 and an area of 0.2 in^2. The longitudinal Spacing of confinement bars (along 1 axis) is 6 in. Number of confinement bars in 3-dir. are 3.Several confine bars in 2-dir. are 3.

Slab:

Slab considered 5-inch thickness and slab material 4000 psi for all shapes building.

3.5 Mass Source

A mass source is a load that represents the mass of a structure or component. It is typically used to simulate the effects of gravity, seismic loads, and other dynamic forces on the structure. This thesis uses mass source as dead load with multiplier 1, Floor finish (FF) multiplied with 1, Partition Wall (PW) Maltiplier with 1, and live load (LL) Maltiplier considered with 0.25.

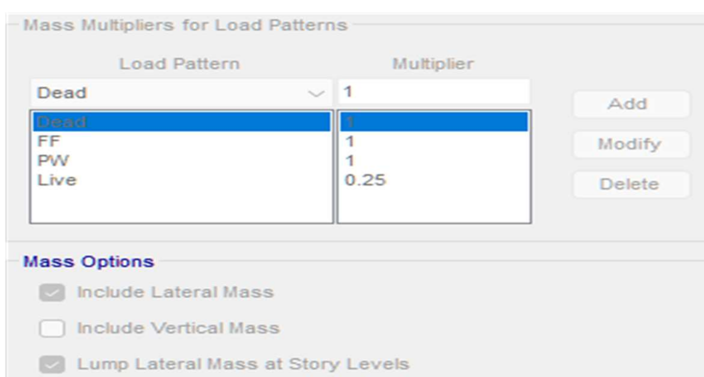


Fig. 3.2: Mass Source

3.6 Plan View & 3d View:

R Shape:

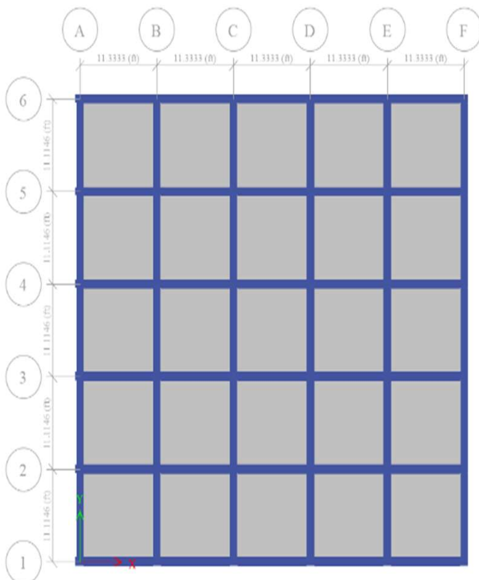


Fig. 3.3: R Shape Top View

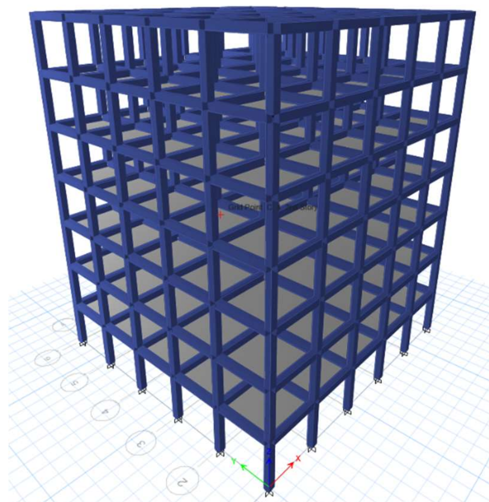


Fig. 3.4: R Shape 3D View

I Shape:

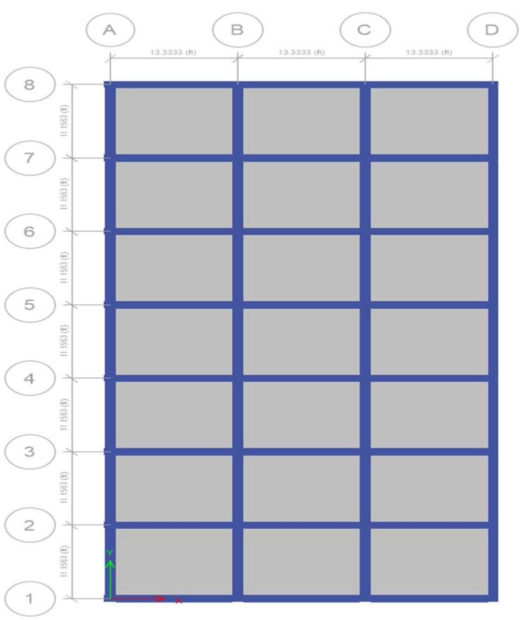


Fig. 3.5: I Shape Top View

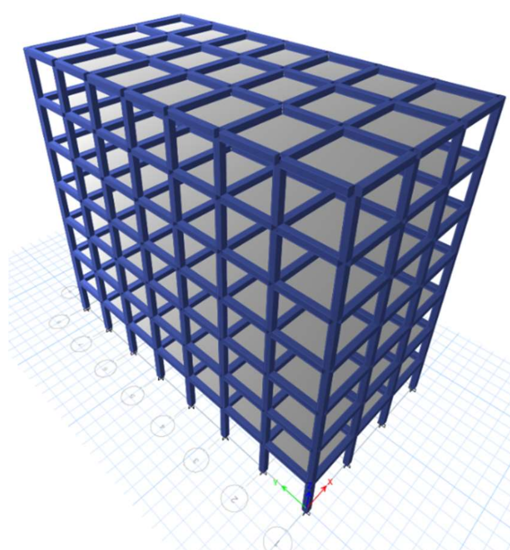


Fig. 3.6: I Shape 3D View

L Shape:

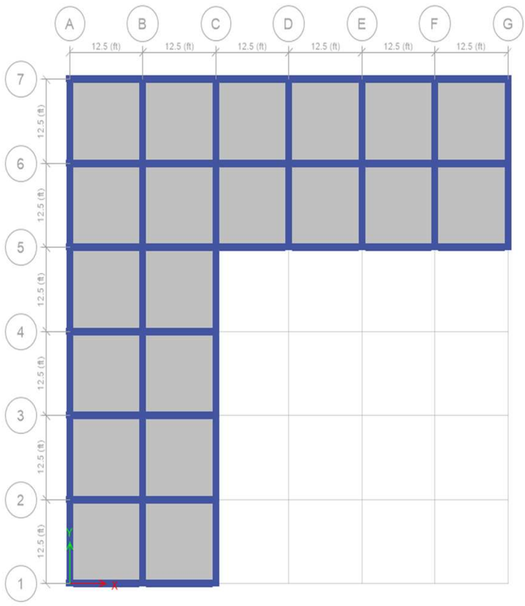


Fig. 3.7 :L Shape Top View

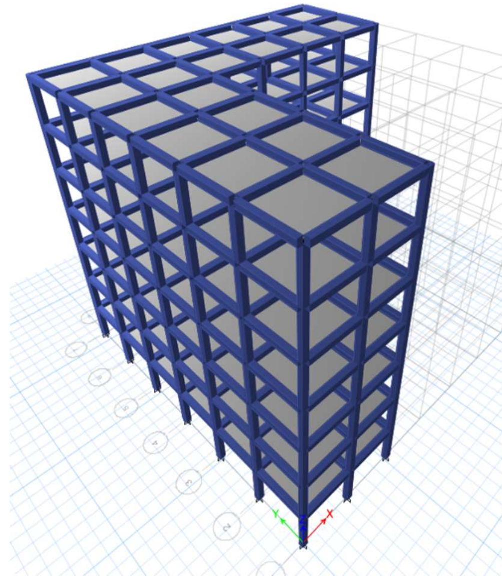


Fig. 3.8: L Shape 3D View

O Shape:

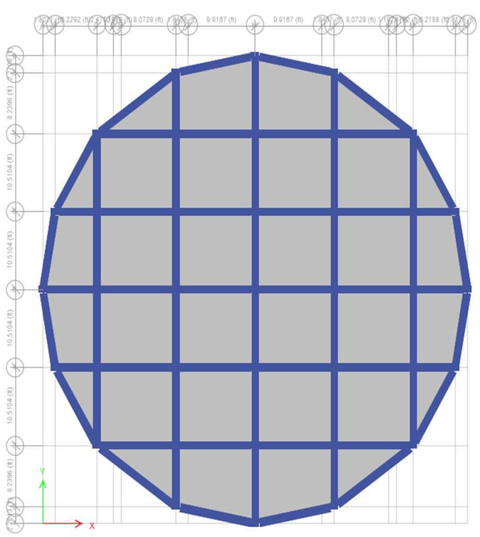


Fig. 3.9: O Shape Top View

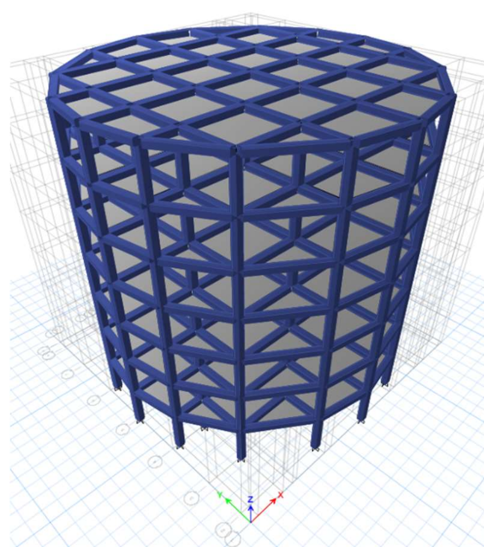


Fig. 3.10: O Shape 3D View

3.7 Load patterns

Assumed all the buildings located in DHAKA and the zone is 2 as BNBC 2020. (BNBC 2020)

Seismic zone coefficient (Z)	0.20
Site class	SC
Response Reduction Factor,(R)	8
Occupancy Importance (I)	1
Site Coefficient,(Fa)	1.15
Site Coefficient,(Fv)	1.725
Spectral Accel (Ss)	0.5
0.2 Sec spectral Accel (S1)	0.2

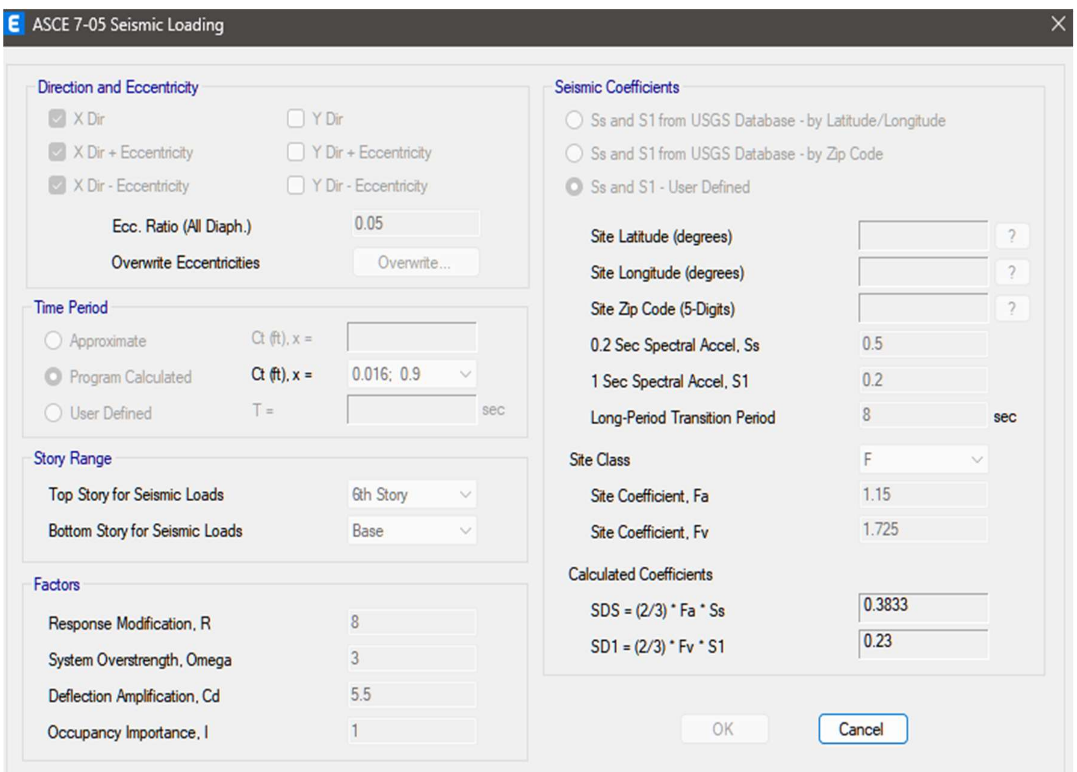


Fig. 3.11: Earthquake value From BNBC 2020

In this research here some load is applied for the result. Uses Dead Load (DL) calculated by the software, Live Load (LL) 42 psf as BNBC 2020, Floor Finish (FF) 22 psf and partition wall (PW) 40 psf. All the load is applied to all the building shapes.

Table 3.1: Vertical Load

Loads	lb/ft^2
Dead Load (DL)	Self-Calculated by Software
Live Load (LL)	42
Floor Finish (FF)	22
Partition Wall (PW)	40

3.8 Define Response Spectrum as ASCE 7-05 And BNBC 2020:

Design Earthquake Calculation:

0.2 Sec Spectral Accel S_s=0.5

1 Sec Spectral Accel S_1=0.2

Table 3.2: For Design Earthquake (BNBC 2020)

S_{ds}	S_{d1}
0.383	0.23

For Maximum Design Earthquake

0.2 Sec Spectral Accel (S_{ms})=0.575

1 Sec Spectral Accel S_{m1}=0.345

Table 3.3: For Maximum Design Earthquake (BNBC 2020)

S_{ms}	S_{m1}
0.575	0.345

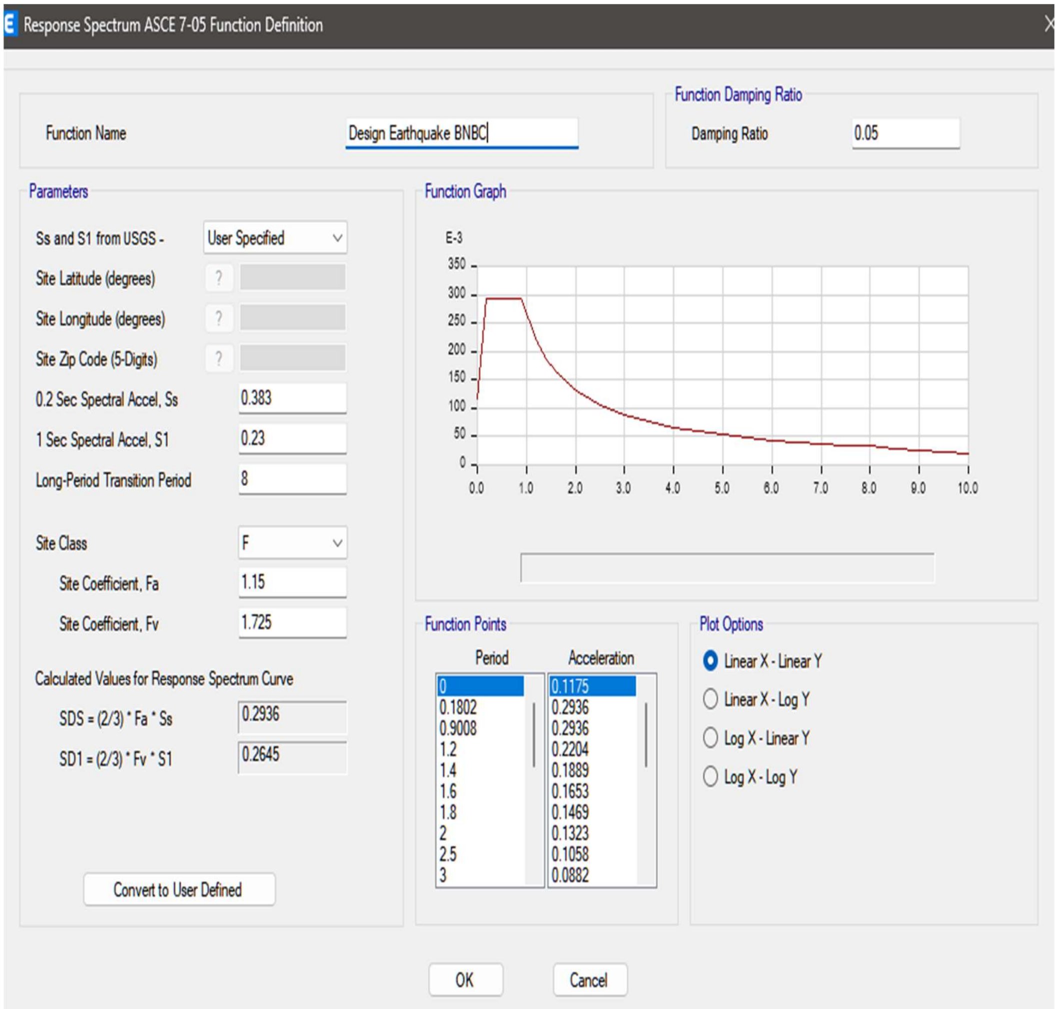


Fig. 3.12: Response Spectrum for earthquake

3.9 Assigned Hinge Properties

Once the frame components have been selected, select Assign > Frame/Line > Frame Nonlinear hinges to assign hinge attributes. In this study, default P-M2-M3 hinges were assigned to columns, while default M3 and case/combo hinges were assigned to beams. (R M 2016)

3.10 Define Load Case for Pushover Analysis

In this study were selected the defined option on ETABS then selected the load case created a new case named Push X then selected the load case as nonlinear static. Selected gravity load from load case that has been created before Push X load case created After selected the load case as nonlinear. Selected the direction of UX. P-Delta effect considered. Then the displacement control option and 20-inch target displacement has been considered.

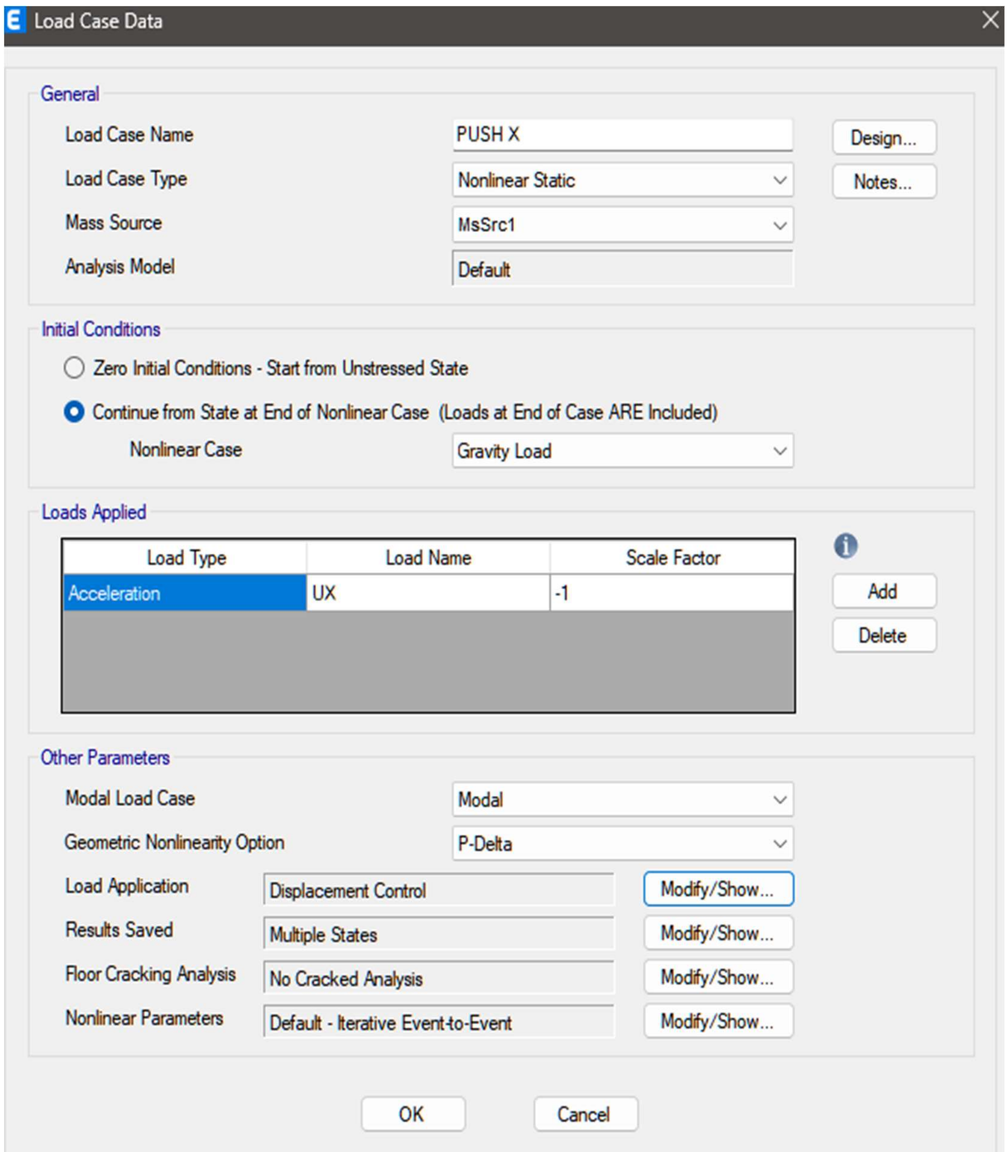


Fig. 3.13: Pushover Load Case

3.11 Gravity Load Case

The weight and distribution of gravity loads on a structure, including the weight of the building, its contents, and any additional external loads (such as wind, snow, etc.), are referred to as gravity load care. The objective is to precisely model the gravitational loads acting on the structure in a pushover analysis.

A gravity Load case has been created for the pushover analysis. Here the load case as nonlinear and the mass source is defined before. Here have been used Dead load scale factor 1, Live Load scale factor 0.25, Partition Wall scale factor 1, and floor finish scale factor 1.

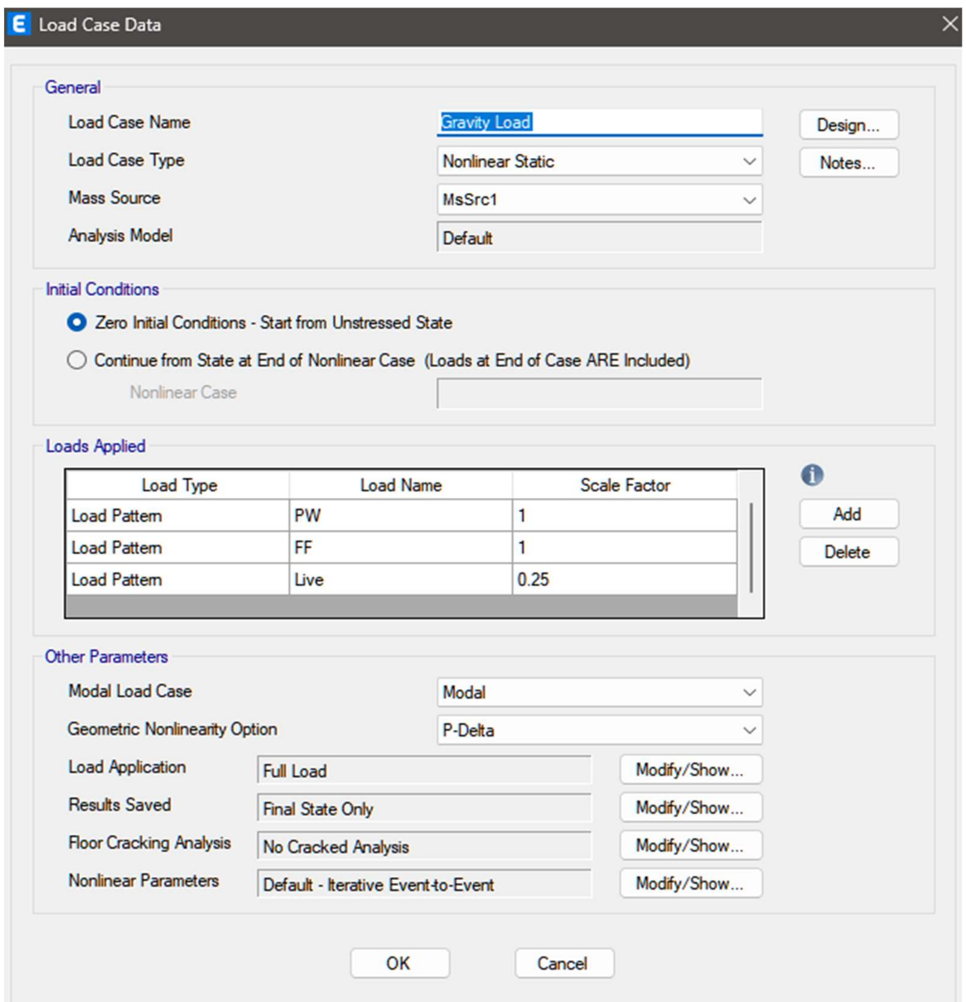


Fig. 3.14: P-Delta Load Case

3.12 Iterative P-Delta Load Case

P-Δ, also known as the "P-Δ effect" or "P-Delta buckling," refers to the phenomenon where the compressive force (P) in a column or a beam causes the structure to deflect (Δ) under its weight, leading to increased compressive force and further deflection. Here have used Dead Load scale factor 1, Floor finish scale factor 1, Live Load scale factor 0.25 partition wall scale factor 1.

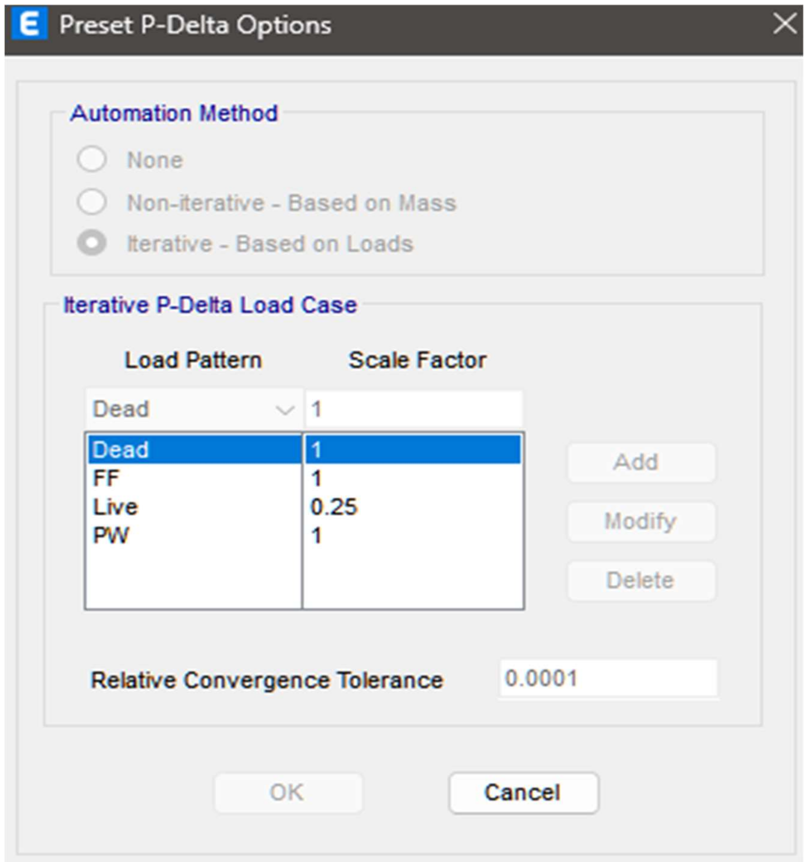


Fig. 3.15: P-Delta Load Case

3.13 Frame Assignment-Hinges

Assign Hinges in frame is most important things for pushover analysis. Hinges define so that the member can be called strong or weak. First click select adoption in ETABs then select the member and then select the frame and have selected hinges. Selected degree of freedom for column P-m2-m3 and for beam have been M3. Then selected the relative distance 0.1 and 0.9. Load case have selected as gravity load case. (R M 2016)

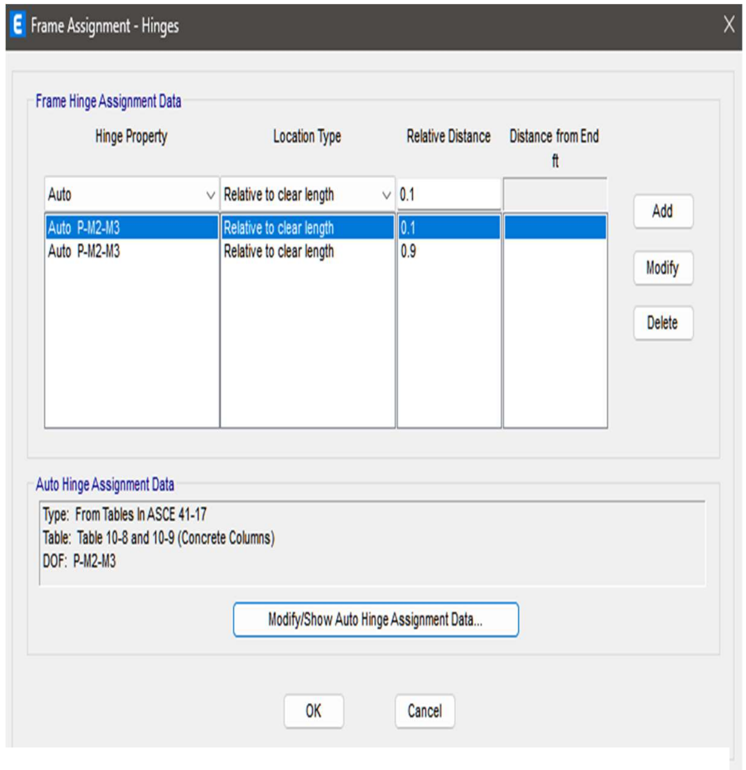


Fig. 3.16: Frame Assignment- Hinges

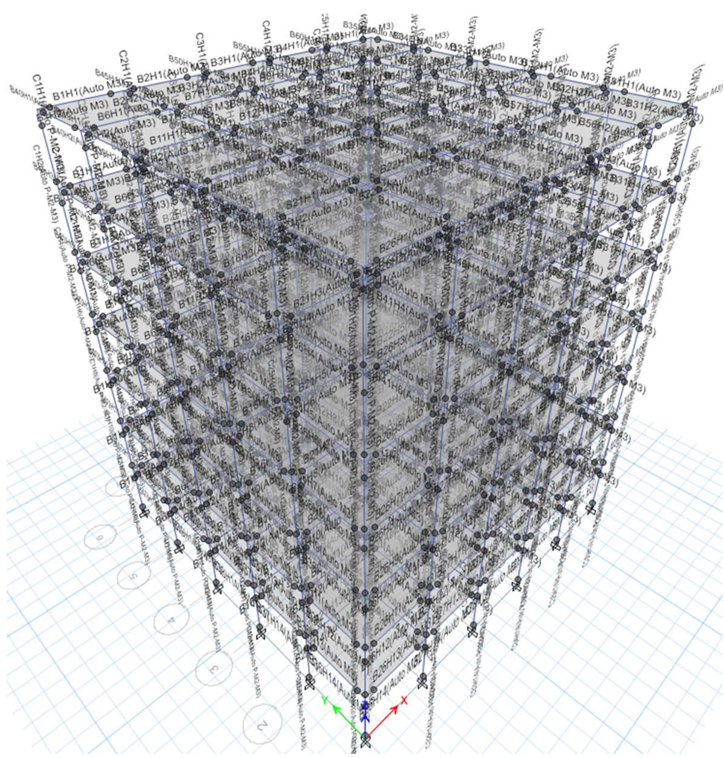


Fig. 3.17: After Assignment of Hinges

CHAPTER FOUR

Result And Discussion

4.1 Performance Point for R, L, I, O Shape Building:

Design Earthquake rectangular shape building performance point was 4.0445 in and the base shear was 1056.949 kips. For the Maximum design earthquake, the performance point was 5.290183 in and the base shear was 1200.905 kip. Design Earthquake for L shape building performance point was 3.226115 in and the base shear was 854.75 kips. Maximum design earthquake the performance point was 4.822316 in and the base shear was 1127.195kip. The design Earthquake for L shape building performance point was 3.380632 in and the base shear was 768.388 kips. Maximum design earthquake the performance point was 5.13112 in and the base shear was 1013.097 kip. The design Earthquake for the O shape building performance point was 3.274571 in and the base shear was 1005.473 kips. Maximum design earthquake the performance point was 4.6718 in and the base shear was 1232.601 kip. Here for the O shape building performance point of the building for design earthquake was 3.274571 in and the base shear was 1005.473 kips. That means the building gives the best performance at 3.27457 in displacement. The building displacement of 3.27457 inches can take a base shear of about 1005.473 kips. However, the R, I, and O shapes building did not perform well enough performance than the O shapes building.

Table 2.1: Pushover Point for Design Earthquake

Design Earthquake	Displacement (In)	Base Share (Kip)
R Shape	4.04455	1056.949
L Shape	3.226115	854.75
I shape	3.380632	768.388
O shape	3.274571	1005.473

Table 4.2: Pushover Point for Maximum Earthquake

Maximum Earthquake	Displacement (In)	Base Share (Kip)
R Shape	5.290183	1200.905
L Shape	4.822316	1127.195
I shape	5.13112	1013.097
O shape	4.6718	1232.601

Here the O-shaped building is 30% stronger than the I-shaped building,17%stronger than L shape building, and 5% stronger than the R-shaped building according to the base shear for the design earthquake. For maximum earthquake O-shaped building is 21% stronger than the I-shaped building, 9% stronger than the L-shaped building, and 2% stronger than the R-shaped building.

Here is the graph below For Design Earthquake:

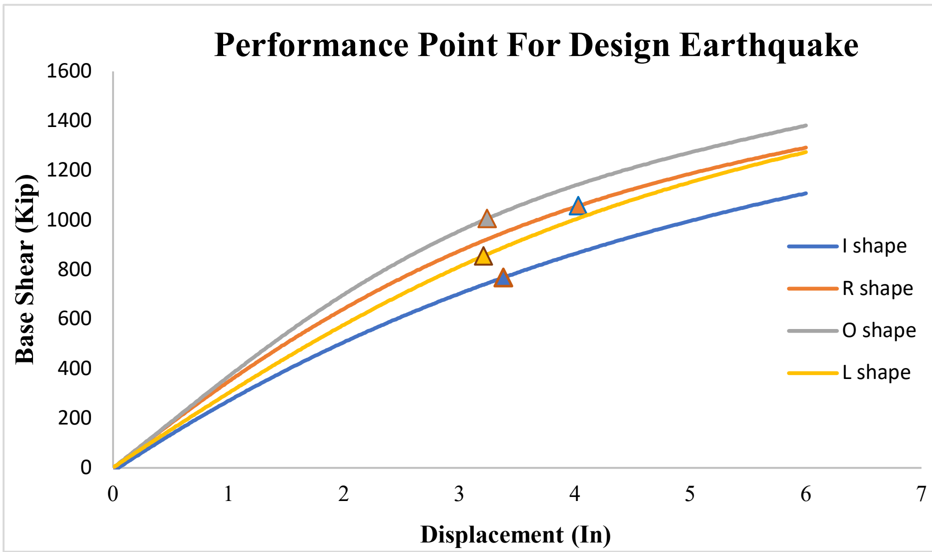


Fig. 4.1: Performance Point For Design Earthquake (FEMA 440 2005)

In this graph here all the shape's performance points are compared with each other. The blue line is for the I-shaped building, the red line is for the R-shaped building the brown line is for O shape. Let's see the performance point for the Maximum Earthquake for all buildings in a graph. Here is the graph below:

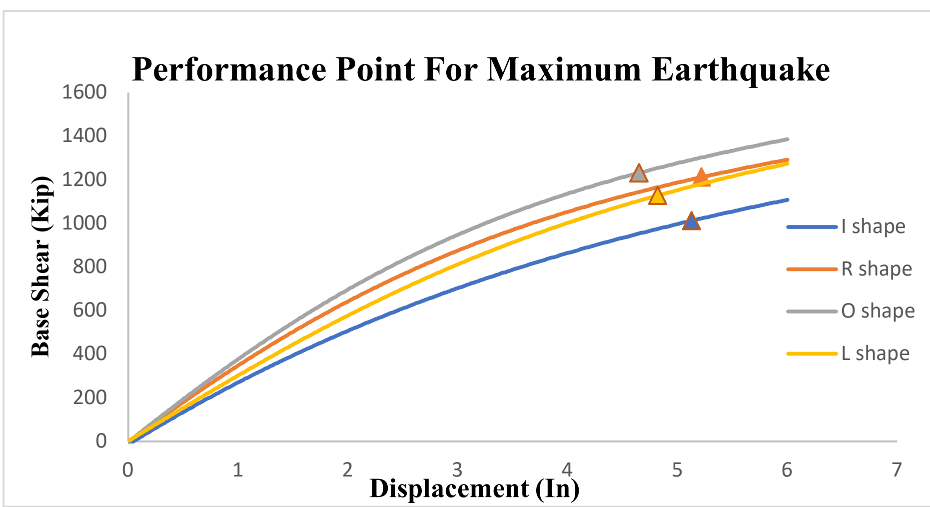


Fig. 4.2: Performance Point For Maximum Earthquake

Here for design earthquake, the O shape building gives 4% less displacement for performance points than the I shape building, 1% less displacement than the L shape, and 19% less displacement than the R shape building. For maximum earthquake O-shaped building gives 9% less displacement than an I-shaped building, 4% less displacement than L shape building, and 12% less displacement than an R-shaped building.

4.2 Monitored Displacement and Hinges Location

In this research, the hinge location was also calculated. For different Displacements, there were created different numbers of hinges. Hinges can give us the result of which buildings are safe or not. In this research there were used four types of shapes and have tried to get the result of which building would give the best performance. Here are all the building shapes and hinge locations below:

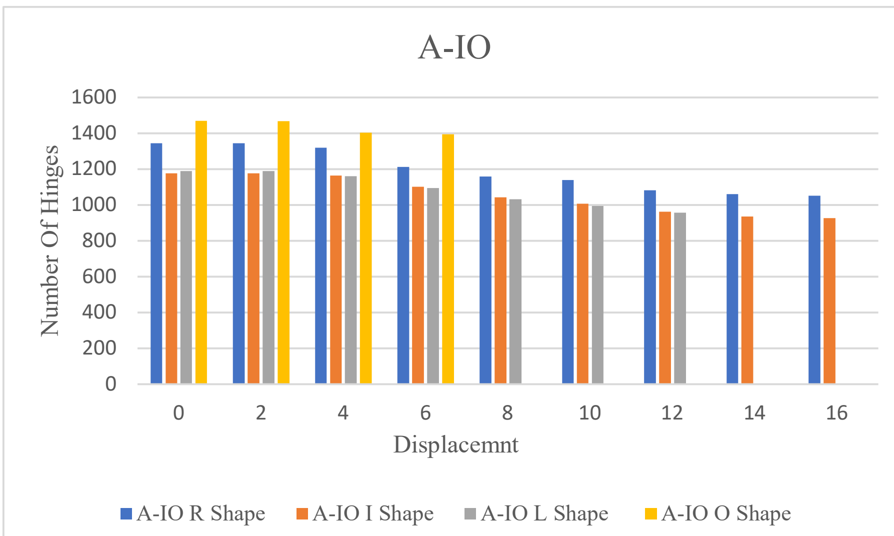


Fig. 4.3: Hinges At "A-IO" Level

In this graph, their maximum hinges were located at a 0-2-inch displacement location. The O-shaped building was created with the maximum number of hinges. At 4-inch displacement, the maximum number of hinges was created by an O-shaped building. The second highest was the R shape. Degreasing hinges with respect to the increasing displacement. At the displacement of 16 inches, there created a small number of hinges against zero to six-inch displacement. So, all the buildings Were safe.

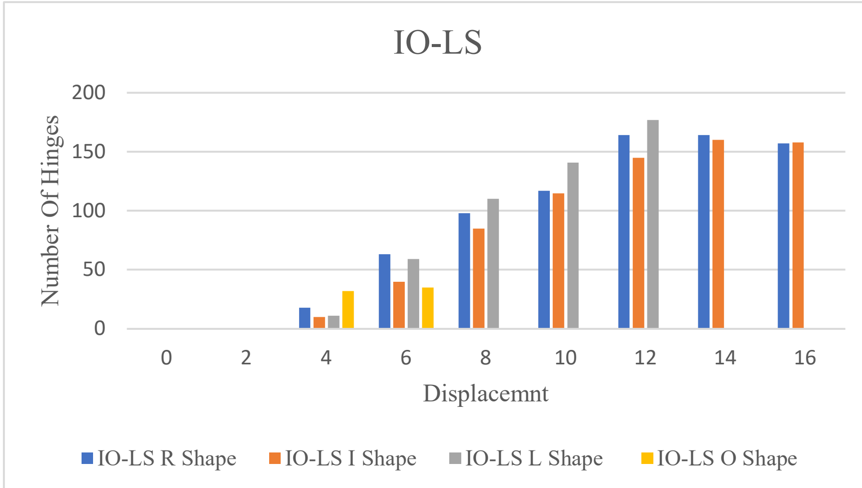


Fig. 4.4: Hinges at "IO-LS" Level

In this Graph, Their hinges were located at the IO-LS level. When the displacement was increasing the number of hinges was also increased with respect to displacement. In this graph, the highest number of hinges were located at the displacement of 10 inches. In this graph, the O-shaped building did not create the hinges so much. So, O shape building were giving the best performance than the other shapes.

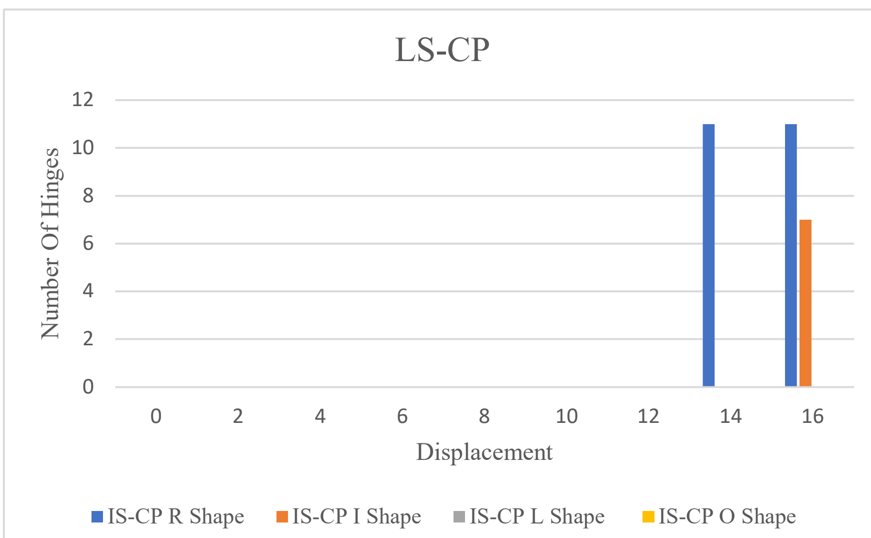


Fig. 4.5: Hinges At "LS-CP" Level

In this graph at the IS-CP level, there were some hinges for I shapes and R shapes buildings those buildings were at the life safety to collapse prevention so those buildings were a little weaker than the other building shapes. Here the O shape and L shape building did not create the hinges at the IS-CP level. So that those building shapes are stronger than the R shape and I shape building.

4.3 Hinges Location At A, B, C, D Point

For R Shape:

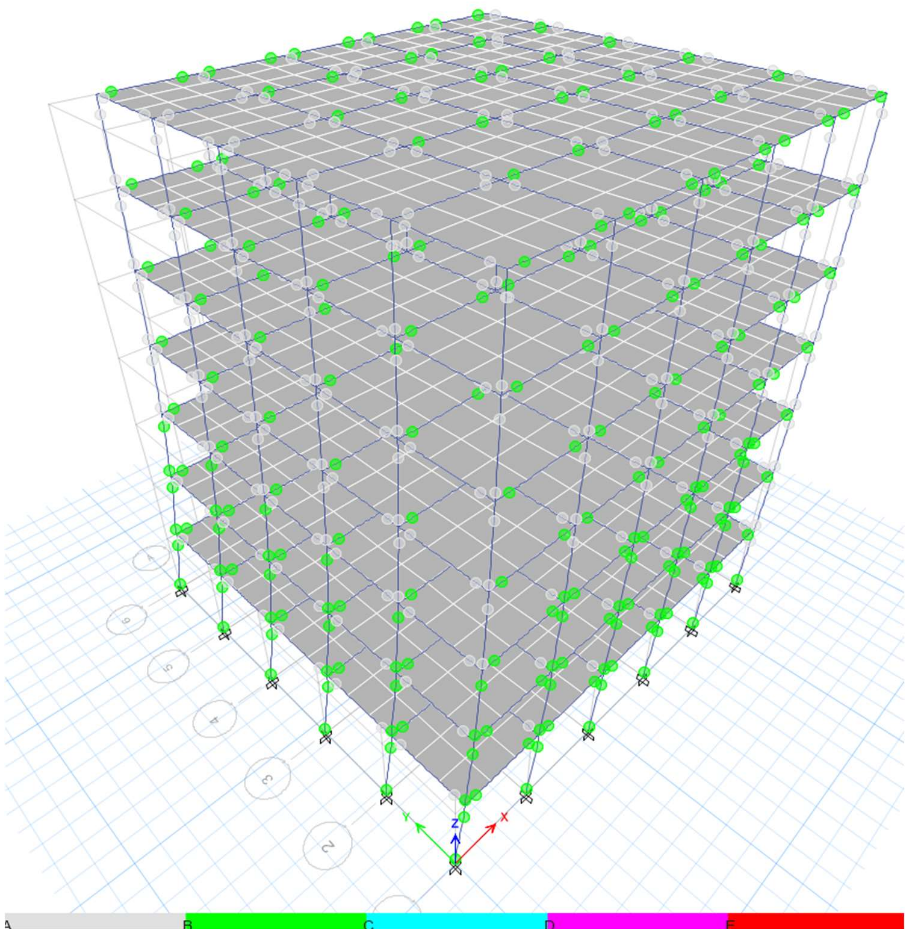


Fig. 4.6: Hinges location for R shape at A-B range

In this figure, the hinges were located A-C level. Maximum hinges located were at A-B level and the green color hinges were located at B-C level. So, all the beam and column members were safe.

Table 4.5: Hinges Location At A, B, C, D for R Shape

Monitored Dispel	Base Force	A-B	B-C	C-D	D-E	>E
in	kip					
0	0	1344	0	0	0	0
0.590792	208.345	1342	2	0	0	0
2.640582	792.873	942	402	0	0	0
3.700962	1017.24	816	528	0	0	0
5.806571	1260.584	722	622	0	0	0

For I Shape:

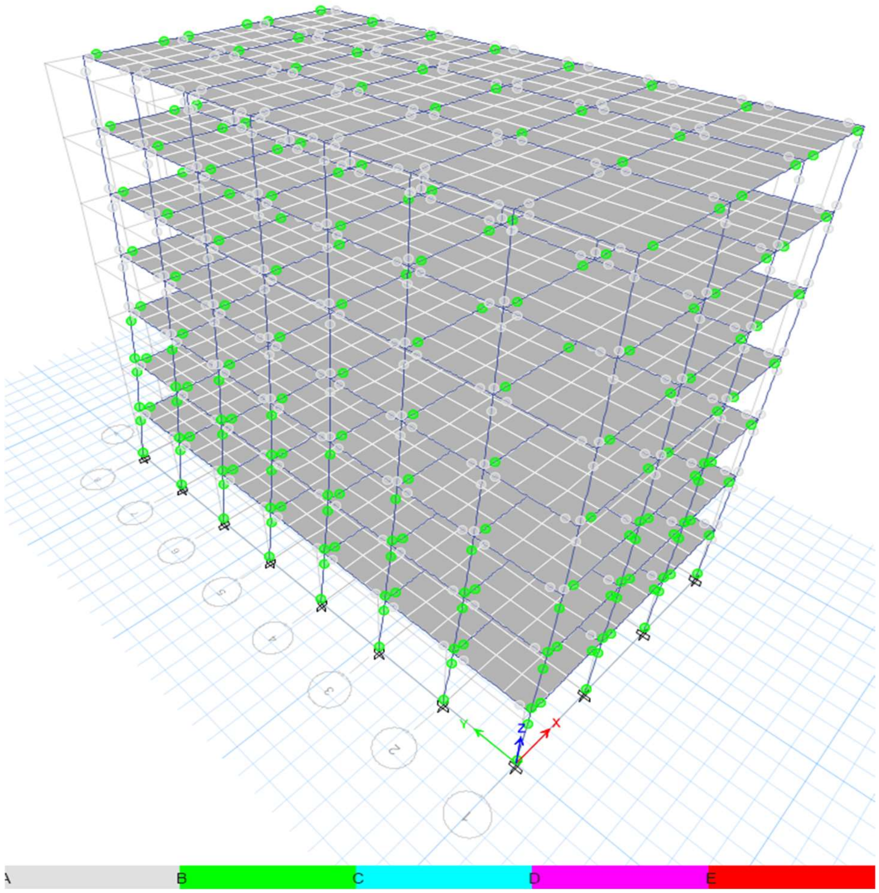


Fig. 4.7: Hinges location for I Shape at A-B range

For I shape all the hinges were located A-C level. The brown color is A-B level and the green color is B-C level. Here all the hinges Were located at A-C Levels. this shape of the building was safe.

Table 4.6: Hinges location At A, B, C, D for I Shape

Monitored Dispel	Base Force	A-B	B-C	C-D	D-E	>E
in	kip					
0	0	1176	0	0	0	0
1	260.156	1176	0	0	0	0
1.458478	379.432	1168	8	0	0	0
3.021321	706.566	878	298	0	0	0
4.819242	977.858	738	438	0	0	0
5.176434	1018.217	718	458	0	0	0

For L Shape:

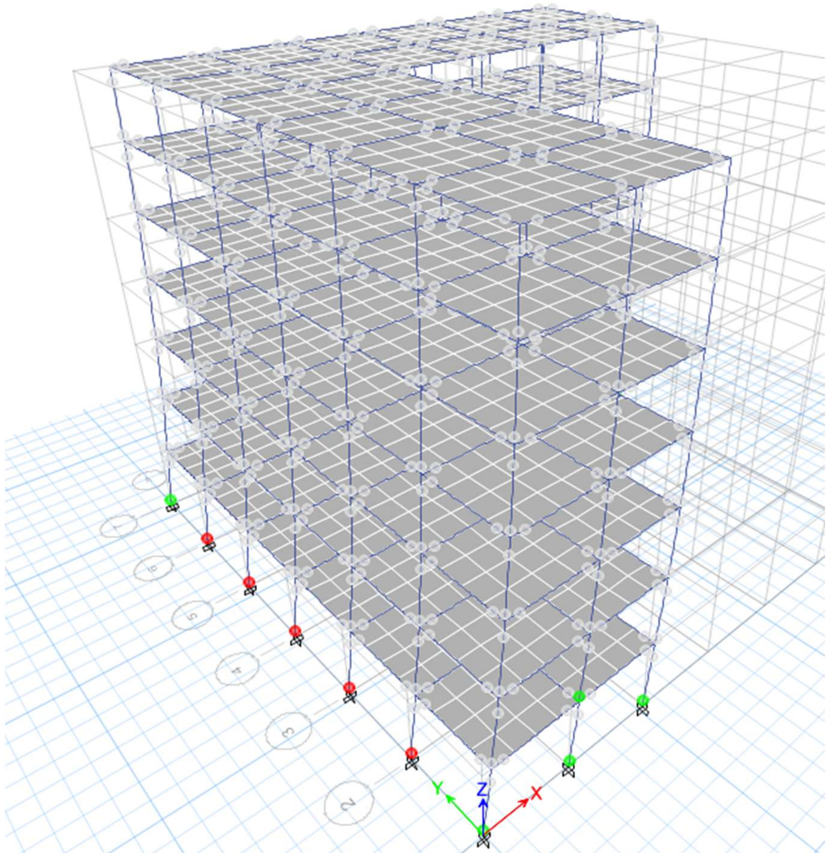


Fig.4.8: Hinges location for L shape at A-B range

For L shape all the hinges were located A-C level. The brown color is A-B level and the green color is B-C level. Here all the hinges Were located at A-C levels This shape of the building was safe.

Table 4.7: Hinges location at A,B,C,D for L shape

Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E
in	kip					
0	0	1190	0	0	0	0
1.129762	339.402	945	245	0	0	0
2.026372	583.573	871	319	0	0	0
2.959985	799.768	802	388	0	0	0
3.203765	851.153	789	401	0	0	0
3.853739	981.602	753	437	0	0	0
4.099038	1024.089	715	475	0	0	0
4.913615	1139.438	670	520	0	0	0
5.192236	1175.521	653	537	0	0	0

For O Shape:

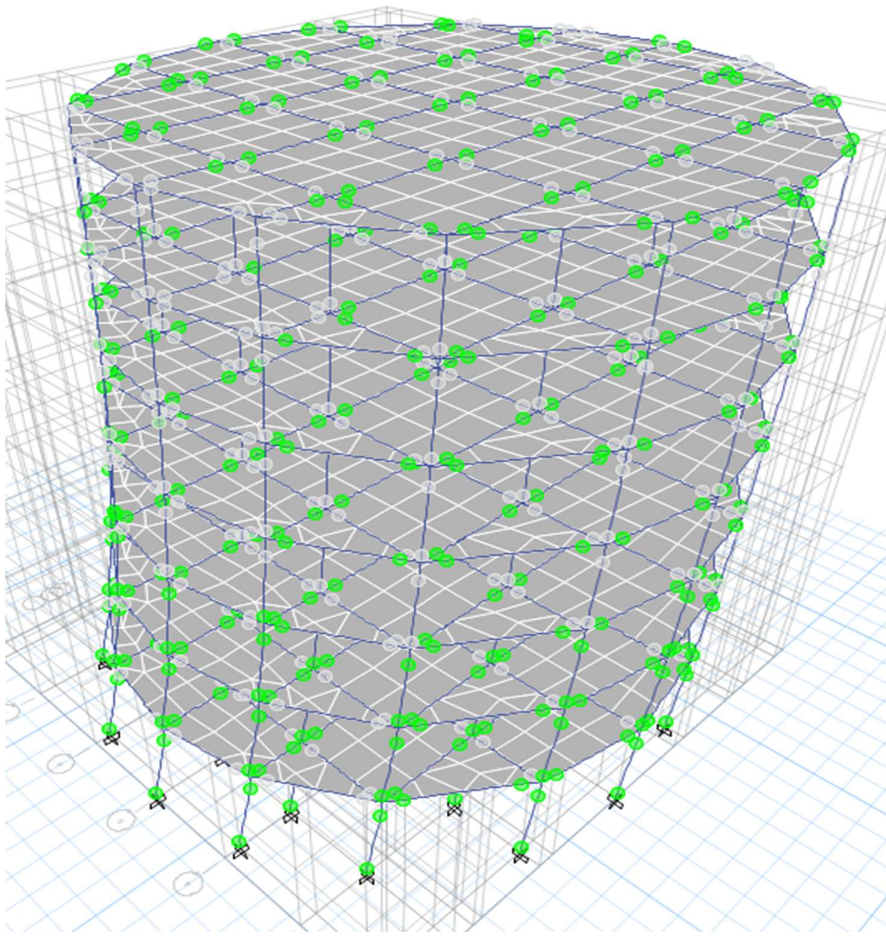


Fig. 4.9: Hinges location for O shape at A-B range

For O shape all the hinges were located A-C level. The brown color is A-B level and the green color is B-C level. Here all the hinges Were located at A-C levels this shape of the building was safe.

Table 4.8: Hinges Location At A,B,C,D For O Shape

Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E
in	kip					
0	0	1470	0	0	0	0
0.914387	337.412	1469	1	0	0	0
2.135641	738.854	1029	441	0	0	0
3.450853	1046.74	905	565	0	0	0
4.735783	1242.34	763	707	0	0	0

4.4 Story Drifts

In this research here the Story drift is exhibited in the bellow figure. Here the maximum story drifts were found for the R shape building the second maximum was I shape the third was L shape and the last was O shape building.

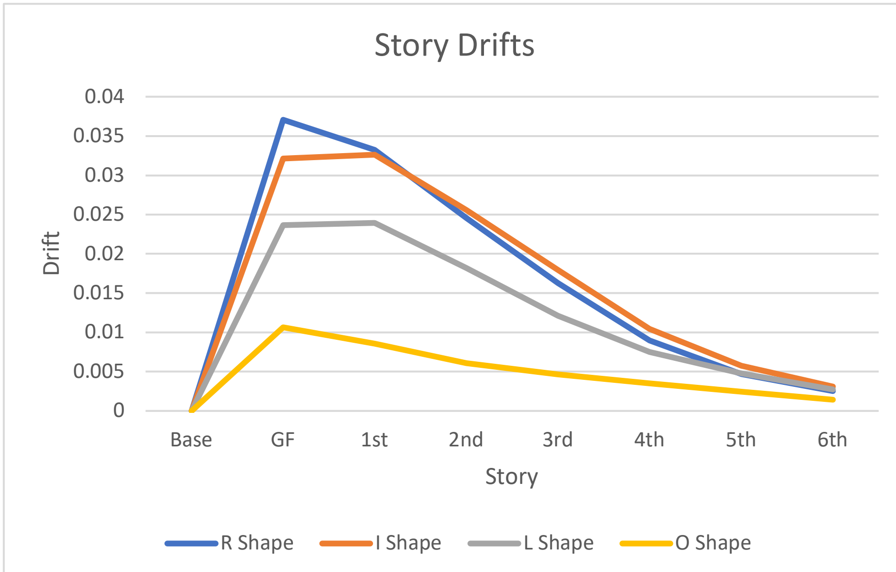


Fig. 4.10: Story Drifts

The Ground Floor of the O-shaped building has 28% less story drift than the R-shaped building, 33% less story drift than the I shape, and 45% less than the L-shaped building. So O shape building gives the best performance.

Table 4.9: Story Drifts

Height (Ft)	R Shape	I Shape	L Shape	O Shape
Base	0	0	0	0
GF	0.037063	0.03213	0.02365	0.01066
1st	0.033261	0.03263	0.02394	0.00854
2nd	0.024524	0.02558	0.01817	0.00609
3rd	0.016263	0.01792	0.01212	0.00464
4th	0.008965	0.01043	0.00752	0.00353
5th	0.004673	0.00573	0.00473	0.00245
6th	0.002508	0.00311	0.00269	0.00142

4.5 Spectral Displacement Vs Spectral Acceleration

For Design Earthwuak:

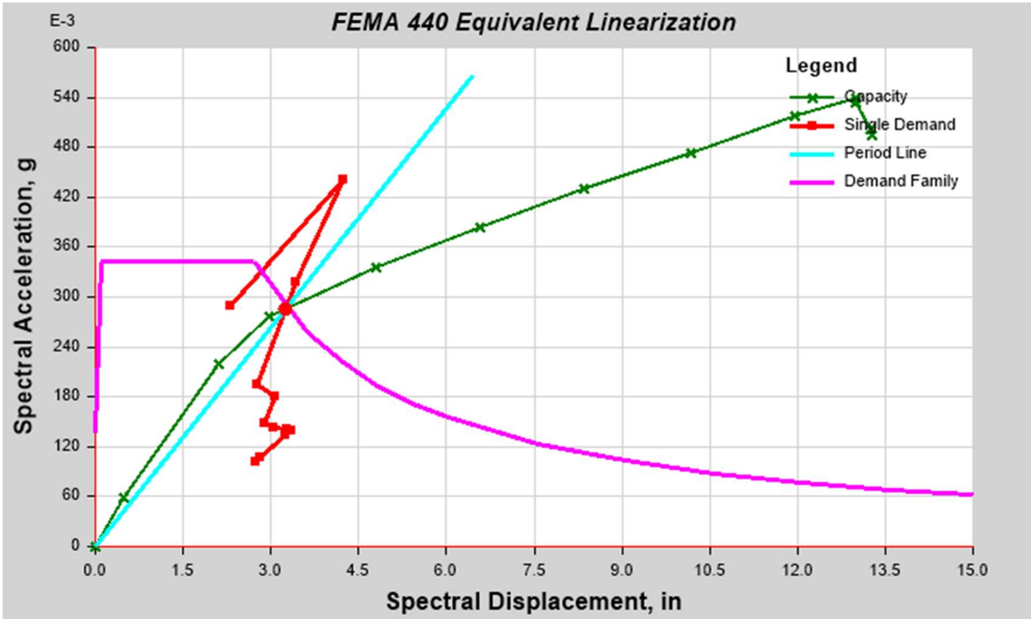


Fig. 4.11: Spectral Displacement Vs Spectral Acceleration for R Shape

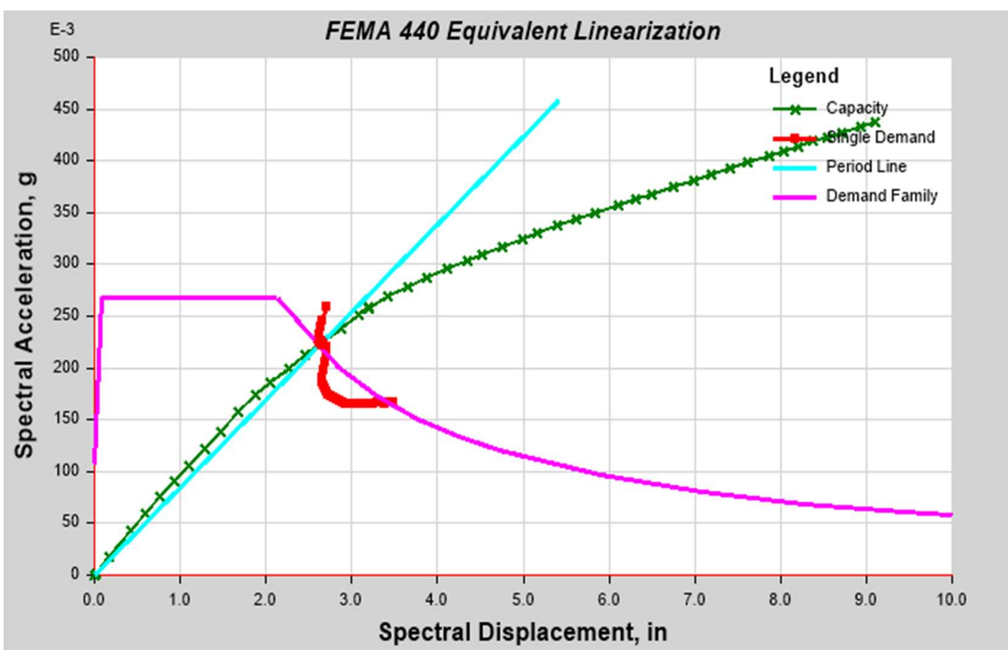


Fig. 4.12: Spectral Displacement Vs Spectral Acceleration for L Shape

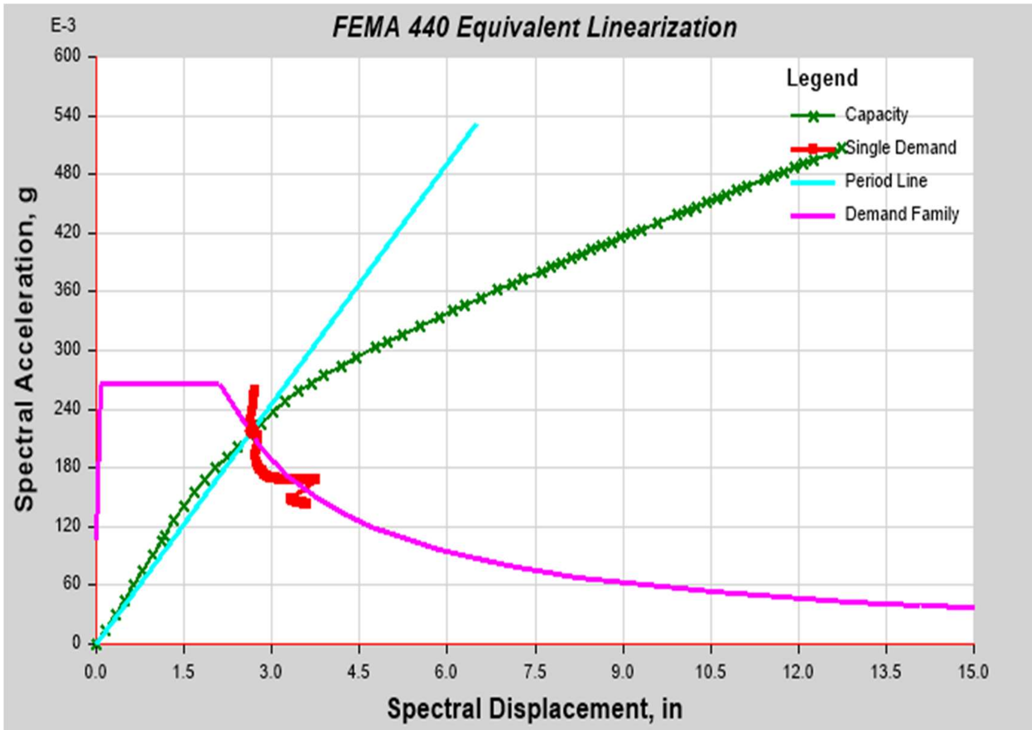


Fig. 4.13: Spectral Displacement Vs Spectral Acceleration for I Shape

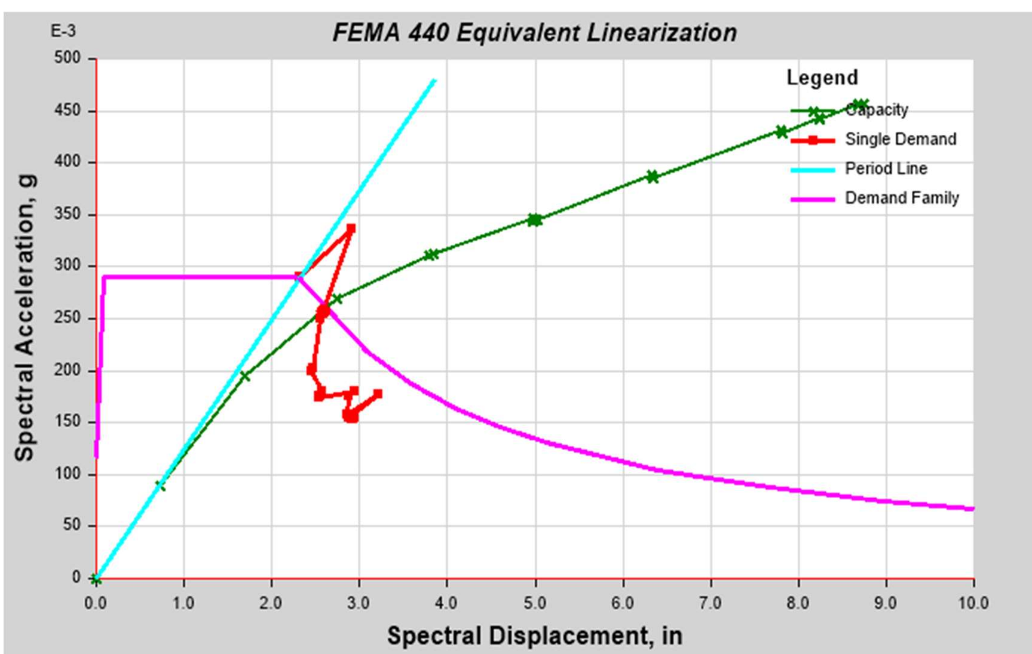


Fig. 4.14: Spectral Displacement Vs Spectral Acceleration for O Shape

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Pushover analysis can push a building to determine its performance. There were four types of buildings for pushover analysis. The analysis was performed using ETABS 21.0.0 software.

Notable findings obtained from this analysis are as follows:

- The value of S_{ds} and S_{d1} in table 2 and S_{ms} and S_{m1} in table 3 value helps to get the performance point.
- Based on the presented results of Table 4 in Chapter four, The performance point of O shape building was 3.274571 in displacement and the base shear was 1005.473 kip. This O-shaped building was more capable than the other three-shaped building. Because this O-shaped building gives more base shear respect to other three-shaped buildings. O-shaped buildings are 30% stronger than shaped buildings,17%stronger than L-shaped buildings, and 5% stronger than R-shaped buildings according to the base shear for the design earthquake. O shape building is 21% stronger than the I shape building, 9% stronger than the L shape building, and 2% stronger than the R shape building.
- Based on the presented results of Table 5, The performance point for maximum design earthquake has been exhibited. The O-shaped building capacity is much better than the other three-shaped buildings. O-shaped building gives 4% less displacement for performance points than the I-shaped building, 1% less displacement than the L-shape, and 19% less displacement than the R shape building. For maximum earthquake, an O-shaped building gives 9% less displacement than an I-shaped building, 4% less displacement than an L-shaped building, and 12% less displacement than an R-shaped building.
- This research helps to find out the strong and weak members. Tables 6,7,8 and 9 values show us the performance of the building level shape and L shape of building hinges located within the IO-LF range exhibited in Fig 4.3,4.4,4.5. This means O-shaped and L-shaped buildings are more secure than the other two-shaped buildings.
- All the Hinges were located at the A-C level at the performance point.

- O shape building has 28% less story drift than the R-shaped building, 33% less story drift than the I-shaped, and 45 % less than the L-shaped building. So O shape building gives the best performance.

5.2 RECOMMENDATION

This thesis focuses on the application of which shape building gives the best performance by pushover analysis using ETABS. Here are some recommendations for performance-based building analysis.

- Ensure that the ETABS model accurately represents the actual structure. Verify that material properties, cross-sectional dimensions, and connection details are correctly defined.
- Consider using multiple load patterns to evaluate different modes of response.
- Carefully selecting the load pattern, considering the structure's irregularities, and incorporating realistic material properties.
- Ensure the model accurately captures nonlinear behavior like yielding, plastic hinges, and cracking in critical structural elements.

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APPENDIX

Table 3: Spectral Response Acceleration Parameter S_S and S_1 for Different (BNBC 2020)

Parameters	Zone-1	Zone-2	Zone-3	Zone-4
S_S	0.3	0.5	0.7	0.9
S_1	0.12	0.2	0.28	0.36

Table 4: Site Coefficient Fa for Different Seismic Zone and Soil Type (BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.2	1.2	1.2	1.2
SC	1.15	1.15	1.15	1.15
SD	1.35	1.35	1.35	1.35
SE	1.4	1.4	1.4	1.4

Table 5: Site Coefficient Fv for Different Seismic Zone and Soil Type (BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.5	1.5	1.5	1.5
SC	1.725	1.725	1.725	1.725
SD	2.7	2.7	2.7	2.7
SE	1.75	1.75	1.75	1.75

Table 6: Spectral Response Acceleration Parameter Sds for Different Seismic (BNBC 2020)

SA	0.2	0.333	0.466	0.6
SB	0.24	0.4	0.56	0.72
SC	0.23	0.383	0.536	0.69
SD	0.27	0.45	0.63	0.81
SE	0.28	0.466	0.653	0.84

Table 7: Spectral Response Acceleration Parameter Sd1 for Different Seismic (BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	0.08	0.133	0.186	0.24
SB	0.12	0.2	0.28	0.36
SC	0.138	0.23	0.322	0.414
SD	0.216	0.36	0.504	0.648
SE	0.14	0.233	0.326	0.42

Table 8: Base Shear vs Monitored Displacement for R Shape

Step	**Monitored Displ**	**Base Force**	**A-B**	**B-C**	**C-D**	**D-E**	**>E**
	in	kip					
0	0	0	1344	0	0	0	0
1	0.590792	208.345	1342	2	0	0	0
2	2.640582	792.873	942	402	0	0	0
3	3.700962	1017.24	816	528	0	0	0
4	5.806571	1260.58	722	622	0	0	0
5	7.879775	1452.94	662	682	0	0	0
6	9.946629	1626.66	608	736	0	0	0
7	12.07085	1791.21	594	750	0	0	0
8	14.15757	1954.51	578	766	0	0	0
9	15.27404	2029.29	566	752	26	0	0

Table 9: Base Shear vs Monitored Displacement for L Shape

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E
	in	kip					
0	0	0	1190	0	0	0	0
1	0.01477	4.923	1173	17	0	0	0
2	0.21477	66.613	1173	17	0	0	0
3	0.515308	159.384	1169	21	0	0	0
4	0.716881	221.222	1134	56	0	0	0
5	0.924626	282.079	1016	174	0	0	0
6	1.129762	339.402	945	245	0	0	0
7	1.330714	394.674	905	285	0	0	0
8	1.555108	455.982	890	300	0	0	0
9	1.773977	515.589	879	311	0	0	0
10	2.026372	583.573	871	319	0	0	0
11	2.261206	644.632	847	343	0	0	0
12	2.463633	691.945	819	371	0	0	0
13	2.72762	749.889	811	379	0	0	0
14	2.959985	799.768	802	388	0	0	0
15	3.203765	851.153	789	401	0	0	0
16	3.459865	903.971	783	407	0	0	0
17	3.714103	955.728	768	422	0	0	0
18	3.853539	982.222	753	437	0	0	0
19	3.853739	981.602	753	437	0	0	0
20	4.099038	1024.089	715	475	0	0	0
21	4.377805	1065.535	703	487	0	0	0
22	4.640679	1102.838	693	497	0	0	0
23	4.913615	1139.438	670	520	0	0	0

Table 10: Base Shear vs Monitored Displacement for I Shape

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E
	in	kip					
0	0	0	1176	0	0	0	0
1	0.2	52.031	1176	0	0	0	0
2	0.4	104.062	1176	0	0	0	0
3	0.6	156.094	1176	0	0	0	0
4	0.8	208.125	1176	0	0	0	0
5	1	260.156	1176	0	0	0	0
6	1.2	312.187	1176	0	0	0	0
7	1.4	364.219	1176	0	0	0	0
8	1.458478	379.432	1168	8	0	0	0
9	1.674056	434.388	1098	78	0	0	0
10	1.896741	487.007	998	178	0	0	0
11	2.106554	533.486	953	223	0	0	0
12	2.326503	580.085	932	244	0	0	0
13	2.556217	624.203	886	290	0	0	0
14	2.789417	665.506	882	294	0	0	0
15	3.021321	706.566	878	298	0	0	0
16	3.267085	749.197	848	328	0	0	0
17	3.527054	793.137	838	338	0	0	0
18	3.775167	834.952	826	350	0	0	0
19	4.024961	876.4	794	382	0	0	0
20	4.302283	916.391	752	424	0	0	0
21	4.56822	948.302	746	430	0	0	0
22	4.819242	977.858	738	438	0	0	0

Table 11: Base Shear vs Monitored Displacement O Shape

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E
	in	kip					
0	0	0	1470	0	0	0	0
1	0.914387	337.412	1469	1	0	0	0
2	2.135641	738.854	1029	441	0	0	0
3	3.450853	1046.74	905	565	0	0	0
4	4.735783	1242.34	763	707	0	0	0
5	4.795578	1248.107	752	718	0	0	0
6	6.138467	1404.838	693	777	0	0	0
7	6.143467	1397.158	691	779	0	0	0
8	6.163846	1400.016	691	779	0	0	0
9	6.168846	1398.883	691	779	0	0	0