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Seismic Analysis of Single Column Structure and Regular Structure: A Comparative Study

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ABSTRACT

Structural analysis is mainly used for finding out the behavior of a structure when subjected to some action. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. since all these loads are dynamic including the self-weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. Structural design of buildings for seismic loads is very important for structural safety during major ground motions. The recent earthquakes, in which many reinforced concrete structures have been severely damaged or collapsed, indicated the need for evaluating the seismic performance of buildings. In particular, the seismic rehabilitation of concrete structures in high seismicity areas is a matter of growing concern, so damage qualification of buildings must be identified and an acceptable level of safety must be determined. The aim of this project is to study the seismic behavior of G+ 8 RC regular structures and single column structure at ground storey using ETABS software. Maximum Storey Displacement in regular structure is 18.36 mm and 27.54 mm in zone IV and zone V respectively. While in single column structure, it is found to be 17.94 mm and 19.14 mm in zone IV and zone V respectively. It means that maximum storey displacement is increased in zone V as compared to zone IV. Whereas maximum storey displacement is increased in single column structure as compared to regular structure. By providing shear wall, storey displacement gets reduced. Maximum Storey Drift in regular structure is 0.000787 mm and 0.00118 mm in zone IV and zone V respectively. While in single column structure, it is found to be 0.000766 mm and 0.000818 mm in zone IV and zone V respectively. Results show that maximum storey drift is increased in zone V as compared to zone IV. Whereas maximum storey drift is increased in single column structure as compared to regular structure. The lower base shear is getting in regular structure and the higher base shear is getting in single column structure. Base shear in regular structure is 159.1529 kN and 238.7294 kN in zone IV and zone V respectively. Base shear in single column structure is 248.5192kN and 372.7789 kN in zone IV and zone V respectively. The joint of the single column structure holds to be weak under seismic loading. Necessarily requires the strengthening the joins of single column structure. Results show that maximum storey stiffness is increased by providing shear wall in single column structure. Single column structure offers best resistance to lateral loads. Maximum Storey Stiffness in regular structure is same for both zone IV and zone V as 1089102.20 kN/m along X direction and 781140.815 kN/m along Y direction. In single column structure, it is also same for both zone IV and zone V as 1258905.50 kN/m along X direction and 824590.56 kN/m along Y direction. Hence, it needs optimum design procedure to proceed for further studies and also for construction. In time period, there is no change in all single column structure and regular structure. It remains same 1.56 sec in both structures. The single column structure can be used for architectural purpose by giving the pleasing appearance to single support member, which increases the aesthetic appearance of the structure.

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KEYWORDS: *Earthquake Analysis, Static and Dynamic Loads, Seismic Coefficient Method, Storey Drift, Storey Stiffness, etc.*

INTRODUCTION

An earthquake is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to propel objects and people into the air, and wreak destruction across entire cities. The seismicity, or seismic activity, of an area is the frequency, type, and size of earthquakes experienced over a period of time. The word tremor is also used for non-earthquake seismic rumbling. At the Earth's surface, earthquakes manifest themselves by shaking and displacing or disrupting the ground. When the epicenter of a large earthquake is located offshore, the seabed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides and, occasionally, volcanic activity.

In its most general sense, the word earthquake is used to describe any seismic event whether natural or caused by humans that generate seismic waves. Earthquakes are caused mostly by rupture of geological faults but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. An earthquake's point of initial rupture is called its hypocenter or focus. The epicenter is the point at ground level directly above the hypocenter.

An earthquake is the sudden, rapid shaking or rolling of the Earth. Earthquakes happen when rocks break or slip along fault lines in the Earth's crust, releasing energy that causes the ground to move. An earthquake is a natural occurrence, like rain. Earthquakes affect almost every part of the Earth and like rain they can be either mild or catastrophic. Over the course of geological time, earthquakes, floods, and other natural events have helped to shape the surface of our planet. An earthquake may last only a few seconds, but the processes that cause earthquakes have operated within the earth for millions and millions of years. Until very recently, the cause of earthquakes was an unsolved mystery. It was the subject of fanciful folklore and equally fanciful learned speculation by peoples throughout the world.

Earthquakes today bring you the world's recent and latest earthquakes. Worldwide there are around 1400 earthquakes each day (500,000 each year). 275 of these can actually be felt. The largest earthquake ever recorded was a magnitude 9.5 (Mw) in Chile on May 22, 1960. The world's deadliest recorded earthquake occurred in 1556 in central China. It struck a region where most people lived in caves carved from soft rock. These dwellings collapsed during the earthquake, killing an estimated 830,000 people. More recent catastrophic earthquakes are the 2010 Haiti earthquake, the 2011 earthquake in Japan and the 2015 Nepal earthquake.

The following are the latest earthquake events:-

A. Feb. 24, 3:12 am Magnitude 4.4: 64 km northeast of Calama at a depth of 127.67 km.
B. Feb. 23, 9:37 pm Magnitude 4.4: 76 km west-northwest of La Ligua at a depth of 12.79 km.
C. Feb. 23, 10:01 am Magnitude 5.3: 61 km west-northwest of San Antonio de los Cobres, Argentina at a depth of 214.01 km.

Following table shows earthquakes from 2016-2022.

Table 1: Earthquakes from 2016-2023 in World [25]

Magnitude	2020	2021	2022	2023
8.0–9.9	0	3	3	0
7.0–7.9	9	15	25	14
6.0–6.9	112	131	165	60
5.0–5.9	1319	1949	2565	765
4.0–4.9	12,216	13793	14562	6621
Total	13654	15895	17390	7460

Up to June 2023, there are 7460 earthquakes were happened in world.

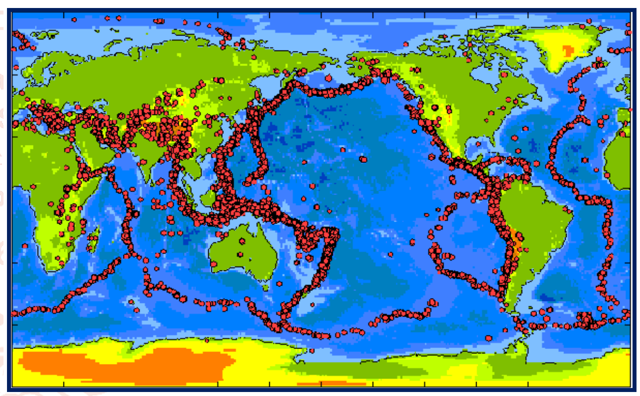


Fig. 1: Map Showing Total Earthquakes Occurred on Earth (Source: Earthquakes Today)

A. Need of Earthquake Study

When man landed on Moon back in 1969, the modern plate tectonic theory was just 6 years old. So you can imagine how much we lack in our understandings about the interior of earth. In fact, majority of what we apprehend about the internal structure of earth comes from studying the seismic waves (P and S waves) that an earthquake generates. That's how important studying earthquake is.

Earthquakes, as we know, are randomly distributed across time. Researches beat their brains out in order to find patterns of seismicity to predict earthquake but efforts have been in vain. Over the years, another group of researchers had been intrigued in studying certain precursory signals that precede earthquakes. Signals are subtle, often fleeting, and "unreliable" but time and again they have been reported. What if we figure out those signals to foretell an earthquake days or weeks in advance? Probably, thousands will live to see another day. The truth is, such studies, too, have often been greeted with skepticism. Yet, time to time this area of research has been rekindled by the scientific community because studying earthquake is the only way to counter the element of surprise that an earthquake brings with it.

Fig. 2: Building Collapse due to Earthquake (Source: Earthquake in Turkey) [26]

B. Seismic Analysis

Structural analysis is mainly used for finding out the behavior of a structure when subjected to some action. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. since all these loads are dynamic including the self-weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. Structural design of buildings for seismic loads is very important for structural safety during major ground motions. The recent earthquakes, in which many reinforced concrete structures have been severely damaged or collapsed, indicated the need for evaluating the Seismic performance buildings. In particular, the seismic rehabilitation of concrete structures in high seismicity areas is a matter of growing concern, so damage qualification of buildings must be identified and an acceptable level of safety must be determined.

Seismic analysis is the study of how earthquakes and other seismic events affect buildings, soils and the rocks of the Earth itself. As a field of study within structural engineering, seismic analysis is often used to study potential damage to buildings and other structures due to earthquakes. In geology, seismic analysis is used to study the interior of the Earth by analyzing the way seismic waves travel through the materials that make up the planet.

C. Methods of Seismic Analysis

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. In the past the buildings were designed just for gravity loads and seismic analysis is a recent development. It is a part of structural analysis and a part of structural design where earthquake is prevalent. [22]

There are different types of earthquake analysis methods. Some of them used in the project are:

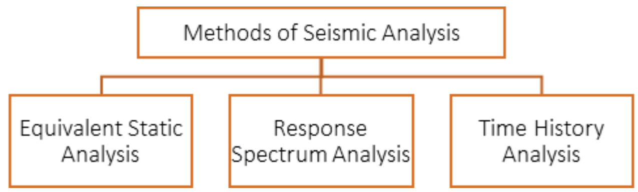


Fig. 3: Methods of Seismic Analysis

METHODOLOGY

A. Problem Statement

Sophisticated construction industry is rapidly increasing due to the developments and demands for population. The new idea is that a single column can be constructed. We can build a single column building. But the seismic performance should be studied to know whether these new construction techniques adaptable or not. Because, the performance of the high-rise, mid-rise and low-rise buildings will be different from each other for different angles under seismic loading. So it is very important to study the seismic performance for different types of building and also compare with the conventional method of construction. If it is replaceable for the normal constructions and with more advantages, it will be a revolutionary change in civil engineering world.

B. Aim of the STudy

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and adequate resistance to the effects of seismic and wind. Structure and structural elements shall normally be designed by Limit State Method. Account should be taken of accepted theories, experiment and experience and the need to design for durability. Design, including design for durability, construction and use in service should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, production, workmanship and also maintenance and use of structure in service.

C. Scope of the Study

The scope of this study is as follows:

a. RC building is considered.
b. Linear elastic analysis is to be done on the structures.
c. Column is modeled as fixed to the base.
d. Loading due to infill walls were taken into account.
e. Seismic coefficient analysis is done for obtained displacements.

D. Objectives of the Study

The reported work has aimed at the development and verification of a systematic methodology for process planning and optimization for most efficient method of analysis.

The objectives of this study are as follows:

a. To perform seismic analysis on G + 8 RC regular structure as per IS 1893 (Part 1): 2016 for zone IV and zone V,
b. To perform seismic analysis on G + 8 RC structure subjected to single column at ground storey as per IS 1893 (Part 1): 2016 for zone IV and Zone V,
c. To perform seismic analysis on G + 8 RC structure subjected to single column at ground storey as per IS 1893 (Part 1): 2016 for zone IV and Zone V,
d. To compare seismic analysis of single column structure and regular structure by different parameters like displacement, base shear, storey drift, storey stiffness and time period.

E. Methodology of the Study

The different phases of this project of work are shown in the following diagram. The figure simply describes the experimental strategy of this study step by step.

a. Review the existing literature on earthquake and seismic analysis methods,
b. Select type of structure for conducting comparative study,
c. Performing seismic analysis on G + 8 RC regular structure as per IS 1893 (Part 1): 2016 for zone IV and zone V,
d. Performing seismic analysis on G + 8 RC structure subjected to single column at ground storey as per IS 1893 (Part 1): 2016 for zone IV and Zone V,
e. Comparative seismic analysis of single column structure and regular structure by different parameters like displacement, base shear, storey drift, storey stiffness and time period.
f. Interpretation of results and conclusion.

F. Configuration of the Models

In the current study, buildings are modeled using the finite element software ETABS. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beams, columns, and slab. The non-structural elements that do not significantly influence the building behavior are not modeled. Modal analysis and seismic coefficient analysis are performed on models. It is proposed to study the effectiveness of G + 8 storied RC structure with single column structure and regular structure. The beam and column are modeled are two nodded line element with 6 DOF at each node. The slab is modeled using 4 noded area elements.

In present work, reinforced concrete G + 8 storied RC with single column structure and regular structure is taken which has situated in zone IV and Zone V, is taken for the study.

Details of models are shown below:

1. **Model 1:** G + 8 storied RC regular structure for Zone IV,
2. **Model 2:** G + 8 storied RC regular structure for Zone V,
3. **Model 3:** G + 8 storied RC structure with single column at ground storey for Zone IV,
4. **Model 4:** G + 8 storied RC structure with single column at ground storey for Zone V.

The structural data of all models are as follows:

Table 2: Structural Data for Model 1 to Model 4

Sr. No.	Description	Specifications
1	Type of Structure	G + 8 Storied RC Structure
2	Structure Type	Plan Regular Structure
3	Plan Dimensions	16 m X 16 m
4	Total Area	256 sq. m
5	Bay Width in Longitudinal Direction	4 m
6	Bay Width in Transverse Direction	4 m
7	No. of Bays in Longitudinal Direction	4 bays of 4 m length

8	No. of Bays in Transverse Direction	4 bays of 4 m length
9	Height of Building	28 m (G + 8 Storey)
10	Height of Each Storey	3 m
11	Plinth Height	1 m
12	Depth of Foundation	2 m
13	Size of Beams for Regular Structure	0.23 m X 0.60 m
14	Size of Beams for Single Column Structure	0.30 m X 0.80 m & 0.40 m X 1.00 m
15	Size of Columns for Regular Structure	C = 0.4 m X 0.4 m
16	Size of Columns for Single Column Structure	C = 0.3 m X 1.0 m C = 0.4 m X 1.2 m C = 2 m Diameter
17	Thickness of Slab	0.15 m
18	External Wall thickness	0.23 m
19	Internal Wall thickness	0.10 m
20	Height of Parapet Wall	1 m
21	Thickness of Shear Wall	0.23 m
22	Seismic Zone Factor (Z)	Zone IV and V
23	Soil Profile Type	SD
24	Importance Factor (I)	1.50
25	Response Reduction Factor (R)	5 (For SMRF)
26	Seismic Source Type	B
27	Damping Coefficient	1
28	Density of Concrete	25 kN/m^3
29	Concrete Grade	M 25
30	Grade of Steel	Fe 500
31	Unit Weight of Concrete	25 kN/m^3
32	Unit Weight of Steel	78.5 kN/ m^3
33	Density of Brick Masonry	20 kN/m^3
32	Zone Factor – For Zone IV	0.24
33	Zone Factor – For Zone V	0.36

1. Model 1 and Model 2: G + 8 Storied RC Regular Structure for Zone IV and Zone V

The structural model is as follows:

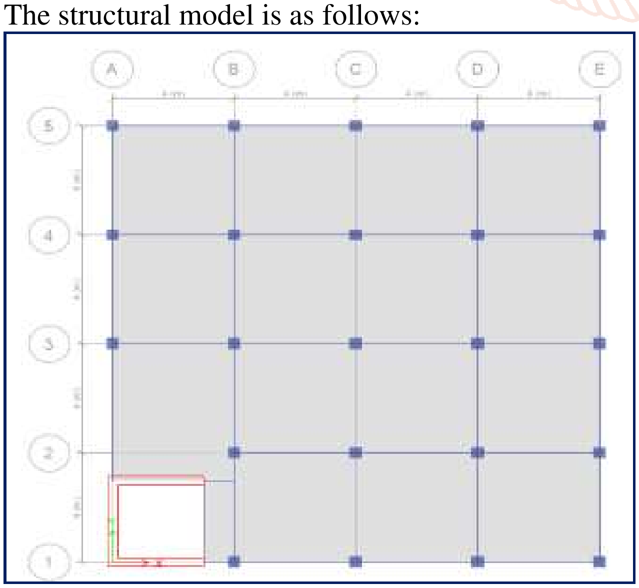


Fig. 4: Model 1 and Model 2: G + 8 Storied RC Regular Structure for Zone IV and Zone V

2. Model 3 and Model 4: G + 8 Storied RC Structure with Single Column at Ground Storey with Shear Wall for Zone IV and Zone V

The structural model is as follows:

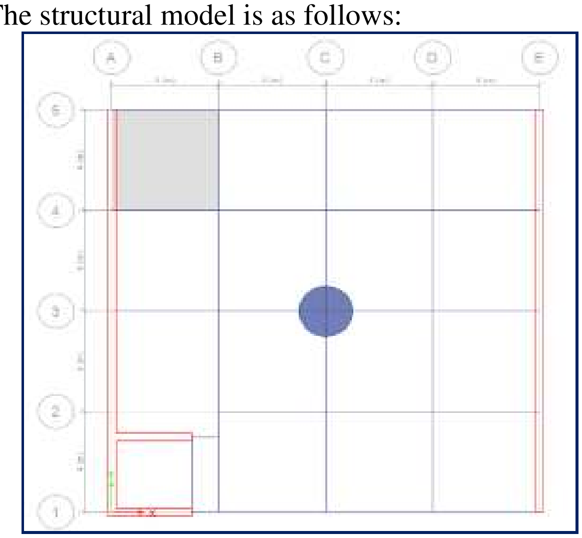


Fig. 5: Model 3 and Model 4: G + 8 Storied RC Structure with Single Column at Ground for Zone IV and Zone V

G. Modeling of the Structure in ETABS Softwre

The structural model of G + 8 storied RC structures are as follows:

1. **Model 1 and Model 2:** G + 8 storied RC regular structure for Zone IV and Zone V,

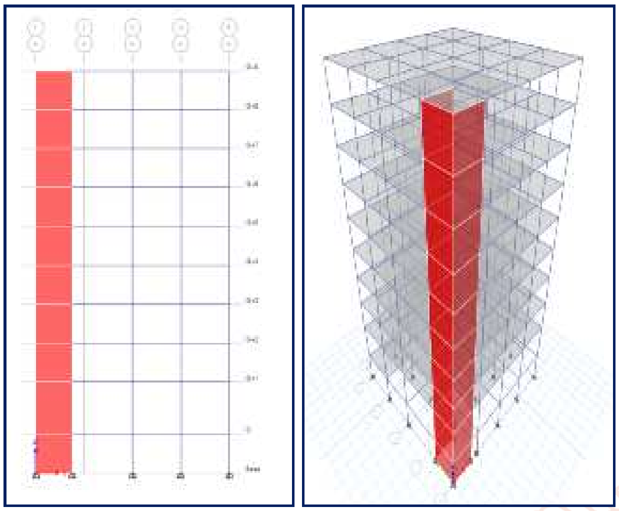


Fig. 7: Elevation and Rendered View of Model 1 Model 2: G + 8 storied RC Regular Structure for Zone IV and Zone V

2. **Model 3 and Model 4:** G + 8 storied RC structure with single column at ground storey with shear wall for Zone IV and Zone V,

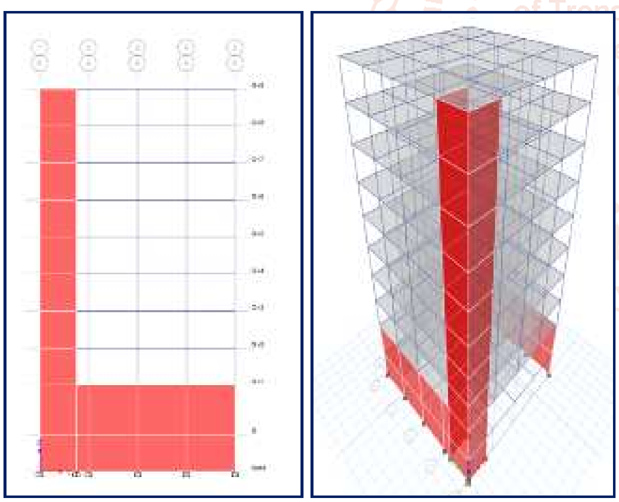


Fig. 8: Elevation and Rendered View of Model 3 and Model 4: G + 8 Storied RC Structure with Single Column at Ground Storey for Zone IV and Zone V

H. Loading on Models

Loads considered for analysis are as follows:

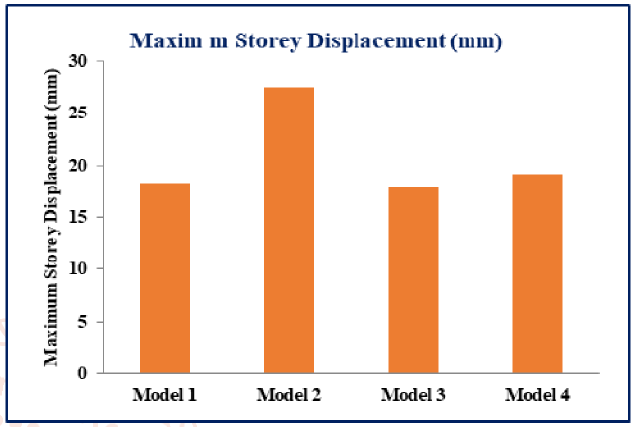
a. Dead Load (DL)
b. Live Load (LL)
c. Wind Load (WL)
d. Earthquake Load (EL)

RESULTS AND DISCUSSION

A. Analysis Results of Maximum Storey Displacement

Table 3: Analysis Results of Maximum Storey Displacement

Model No.	Direction	Value (mm)
Model 1	X and Y	18.36
Model 2	X and Y	27.54
Model 3	X and Y	17.94
Model 4	X and Y	19.14

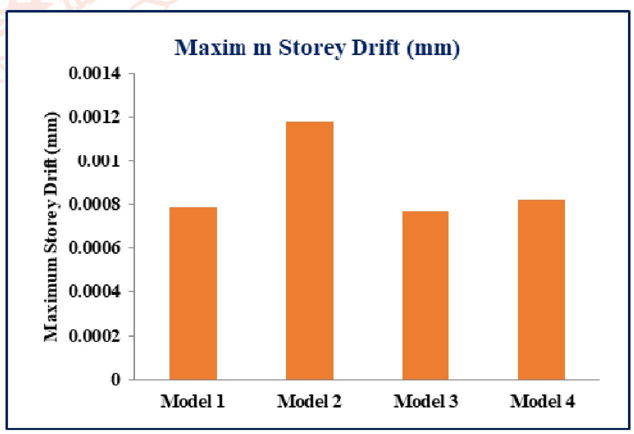


Graph 1: Comparative Analysis Results of Maximum Storey Displacement

B. Analysis Results of Maximum Storey Drift

Table 4: Analysis Results of Maximum Storey Drift

Model No.	Type	Direction	Value (mm)
Model 1	Max Drift X	X	0.000787
Model 2	Max Drift X	X	0.00118
Model 3	Max Drift Y	Y	0.000766
Model 4	Max Drift Y	Y	0.000818

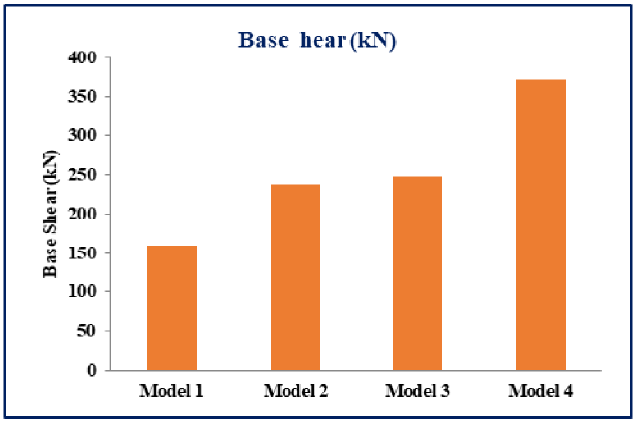


Graph 2: Comparative Analysis Results of Maximum Storey Drift

C. Analysis Results of Base Shear

Table 5: Analysis Results of Base Shear

Model No.	Direction	Value (kN)
Model 1	X and Y	159.1529
Model 2	X and Y	238.7294
Model 3	X and Y	248.5192
Model 4	X and Y	372.7789

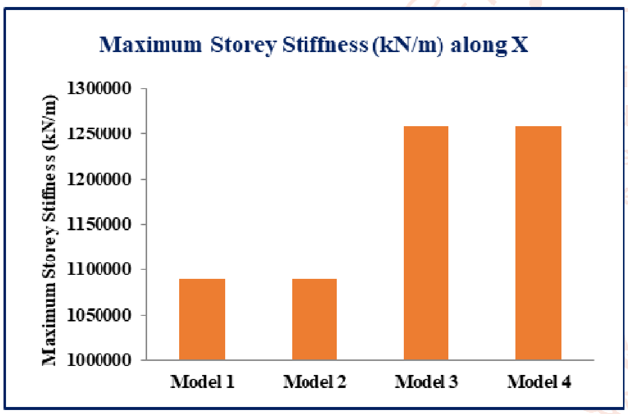


Graph 3: Comparative Analysis Results of Base Shear

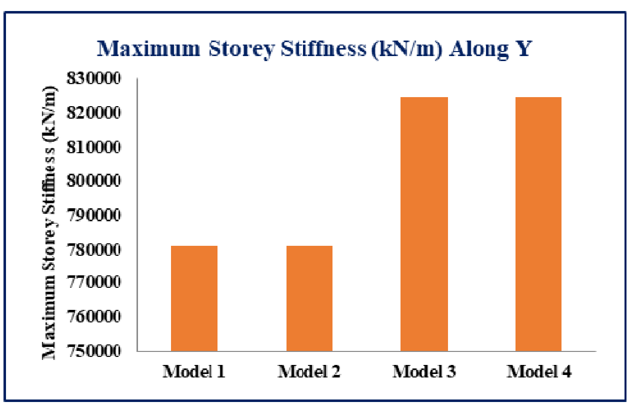
D. Analysis Results of Maximum Storey Displacement

Table 6: Analysis Results of Maximum Storey Stiffness

Model No.	Direction	Value (kN/m)
Model 1 and Model 2	X	1089102.20
	Y	781140.815
Model 3 and Model 4	X	1258905.50
	Y	824590.56



Graph 4: Comparative Analysis Results of Maximum Storey Stiffness along X Direction

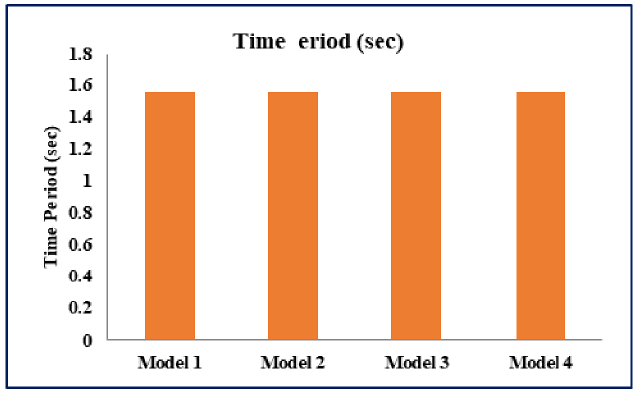


Graph 5: Comparative Analysis Results of Maximum Storey Stiffness along Y Direction

E. Analysis Results of Maximum Time Period

Table 7: Analysis Results of Time Period

Model No.	Direction	Value (sec)
Model 1	X and Y	1.56
Model 2	X and Y	1.56
Model 3	X and Y	1.56
Model 4	X and Y	1.56



Graph 5: Comparative Analysis Results of Time Period

CONCLUSION

It can be concluded that:

1. Maximum Storey Displacement in regular structure is 18.36 mm and 27.54 mm in zone IV and zone V respectively. While in single column structure, it is found to be 17.94 mm and 19.14 mm in zone IV and zone V respectively. It means that maximum storey displacement is increased in zone V as compared to zone IV. Whereas maximum storey displacement is increased in single column structure as compared to regular structure. By providing shear wall, storey displacement gets reduced.

2. Maximum Storey Drift in regular structure is 0.000787 mm and 0.00118 mm in zone IV and zone V respectively. While in single column structure, it is found to be 0.000766 mm and 0.000818 mm in zone IV and zone V respectively. Results show that maximum storey drift is increased in zone V as compared to zone IV. Whereas maximum storey drift is increased in single column structure as compared to regular structure.

3. The lower base shear is getting in regular structure and the higher base shear is getting in single column structure. Base shear in regular structure is 159.1529 kN and 238.7294 kN in zone IV and zone V respectively. Base shear in single column structure is 248.5192 kN and 372.7789 kN in zone IV and zone V respectively. The joint of the single column structure holds to be weak under seismic loading. Necessarily

requires the strengthening the joins of single column structure.

4. Results show that maximum storey stiffness is increased by providing shear wall in single column structure. Single column structure offers best resistance to lateral loads. Maximum Storey Stiffness in regular structure is same for both zone IV and zone V as 1089102.20 kN/m along X direction and 781140.815 kN/m along Y direction. In single column structure, it is also same for both zone IV and zone V as 1258905.50 kN/m along X direction and 824590.56 kN/m along Y direction. Hence, it needs optimum design procedure to proceed for further studies and also for construction.
5. In time period, there is no change in all single column structure and regular structure. It remains same 1.56 sec in both structures.
6. The single column structure can be used for architectural purpose by giving the pleasing appearance to single support member, which increases the aesthetic appearance of the structure.

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