International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Study and Analysis of Seismic Performance of RC Structures with Various Building Classes and Orientations

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Abstract-
In the framework of this project, an attempt was made to find out the influence of the shape, size and direction of the rectangular columns of the construction plan on the general stiffness and seismic response of the building suffering from the earthquake. A multistory RC building is modeled using ETABS software with different column shapes (square and rectangular), column sizes (different cross-sectional area at building height), and column orientations to determine the effect of each on the stiffness and seismic response of the building. . . The analytical results of each model were compared in terms of base movement, overburden displacement, layer deflection and time period.
***Keywords* –Moment resisting System, Lateral Loads, ETABS, Seismic response etc**

1. Introduction

All buildings, but notably tall buildings, are made to handle dynamic loads like earthquake and wind loads. In regions that are prone to earthquakes and quakes, wind loads are prioritised, and similarly in regions that are prone to cyclones. Wind is regarded as the major load in very tall structures. The analysis methodologies used to determine the wind and seismic forces operating on structures clearly differ from one another, according to the pertinent standards and specifications [1]. Building height and foundation type are significant considerations when assessing seismic strength as a zonal component. Basic characteristics including wind load, height, ground speed, terrain class, and numerous other elements like permeability are needed to estimate wind-induced forces. In addition to gravity, the structure is made to endure the effects of earthquake and wind forces. According to IS 1893 (Part 1), earthquake magnitudes are classified. Ratings for wind speed are based on IS 875 (Part 3): 1[1][2].

In the study and design of high-rise RCC buildings, lateral loads are a key factor. When analysing and developing tall building structures with lateral loads, stiffness is a top priority. A structural system known as a moment structure helps support the lateral loads of medium- and low-rise structures.

The combined axial shear bending effect of the beams and columns carries the lateral load. In order to prevent structural deformations, the columns must be stiffer than the beams based on the strong column and weak beam construction principle. The most significant variables that govern the overall rigidity of the building structure are the selection of the proper shape, size, and orientation of the pillars of a building (particularly a rectangular construction). Following these guidelines causes the structure to stiffen and deform when operating in the flexible mode under the effect of lateral loads.

2. Literature Review

This analysis of earlier investigations that have been written up in the literature is important. Technical writings published in journals and meeting minutes that are pertinent to comprehending the allocated scope of work and the present state of projects that have been implemented. Targets were established and analyses were conducted as a result of this comparative study of the effects of earthquakes on building construction. IS 1893 (Part 1), as well a significant earthquake code was added in 2002. Here are some key words and abbreviations: This standard deals with the assessment of the seismic load of various structures and the earthquake-resistant design of the building. Its basic provisions apply to buildings, high-rises, industrial and chimney-like structures, bridges, concrete and earth dams, embankments and retaining walls and other structures.

Dr. K. R. C. Reddy et. al. 2014 [1] It should be noted that wind loads are more critical than earthquake loads in most cases. Wind and earthquake loads increase with the height of the structure. Wind loads are more critical for tall structures than earthquake loads. Structures should be designed for loads applied independently in both directions due to critical wind or seismic forces. They estimate the wind load based on the design wind speed for that zone with a 20 percent variation. The resulting wind loads on the building were compared with seismic loads. Finally, wind loads are more critical than earthquake loads in most cases.

Dr. Suchita Hirde et. al. 2014 [2] It is observed that design parameters such as storey drift, storey displacement, storey deflection are calculated and compared to check wind force against seismic forces at different building heights. It can be seen that; Seismic zone V and wind zone VI are the strongest earthquake zones and wind zones according to IS codes. Therefore, 6 multi-story buildings in wind zone VI are analyzed and their performance is compared with buildings in seismic zone V of India to study wind force against 5 seismic forces. Y found that the effects of both seismic forces and wind forces on multistory buildings increase as the building height increases. Effect of earthquake forces compared with the effect of wind forces on performance of multistory buildings situated in seismic zone V and wind zone VI, earthquake is less effective than wind effect for tall buildings since tall buildings are more flexible and for short buildings earthquake is found to be more effective.

Kosta Talaganov et. al. 2004 [3] This study involves design of the structural system of such a unique symbol as is the Millennium cross, was a special professional challenge for the authors both as scientific applicative project and specific structural project. Therefore, all the activities realized within this study were aimed at making the Millennium Cross a long-lasting structure with a high level of static and dynamic stability. From the results performed it is noticed that the above two effects are predominant and crucial for structural safety evaluation. Due to the high seismicity of the region and the severe exposure of the structure to wind effects, there arose the need for consideration of these two types of effects upon the structure.

Azlan Adnan et. al. 2008 [4] From this study it can be noticed that the ESEA normally produced larger lateral load design forces than that from the SWA and EDRSA. The floor-to-floor drift indicator indicates that only non-structural parts of buildings can be affected. Earthquake static equivalent 6 is mainly checked by lateral loading followed by static wind loading and dynamic response spectrum analysis. They found that based on the shear response of the ESEA story, mid-rise buildings have potential failures at lower floors.

Baldev D. Prajapati et. al. 2012 [5] They discuss the analysis and design procedure adopted for the assessment of a symmetrical tower block (G 30) due to the effects of Wind and EQ. power A total of 21 different models are analyzed and designed, and it shows that the steel-concrete composite building is a better choice. These buildings have R.C.C. a steel and composite building whose shear wall is considered a lateral force-resisting system.

Several researchers have investigated the effect on reinforced concrete (RC) prefabricated industrial buildings, which have recently suffered excessive damage and significant direct and indirect damage, as many researchers have emphasized in their research.

Reinforced concrete (RC) industrial buildings revealed their vulnerability in recent earthquakes, highlighting structural and non-structural damage that is most related to insufficient transfer of horizontal forces, i.e., in the connections between elements. Several studies have been carried out in the evaluation of seismic vulnerability of RC structures, the background of which is mainly the need to protect the existing building stocks and human lives.

3. Research Methodology

Performance Based Design –

Performance-Based Seismic Design is a method for designing new buildings or seismic improvements to existing buildings with the specific goal of achieving specified performance goals in future earthquakes. The performance objectives are Operability (O), Immediate Occupancy (IO), Life Safety (LS), Collapse Prevention (CP) according to FEMA356, where in Figure 1, life safety is the main focus in reducing structural life safety hazards.

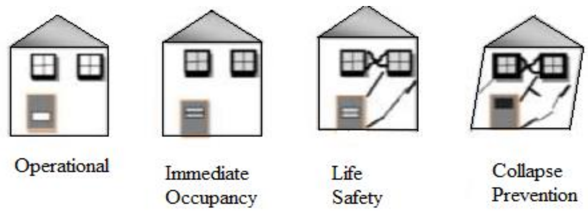

Figure 1. Performance levels

Performance By design, performance levels are described as displacement because damage correlates better with displacement than with forces. It is based on the idea that performance goals can be linked to the level of structural damage that can be associated with displacement and drift over time.

Figure 2 shows the typical process of design is to be followed.

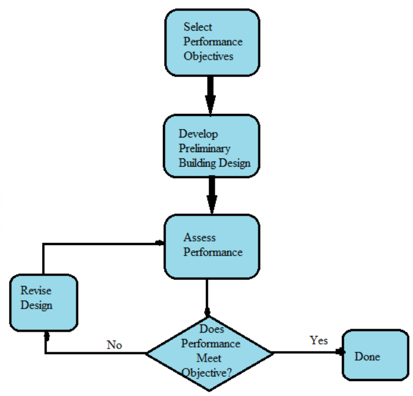

Figure 2. Flow chart of performance based design

SSI (Soil-Structure Interaction) is the effect of the free reaction of structures on the flexibility of the foundation soil. SSI can produce two different effects on the response of a structure, firstly, a change in the free field movement at the base of the structure and secondly, the introduction of deformation to the bearing soil due to the dynamic response of the structure. The former is called kinematic interaction, while the latter is called inertial interaction.

There are two ways to implement soil structure interaction. The first is the direct method, where the soil structure and foundation are represented as a continuum and modeled together using the finite element method. Ground motion is defined as free field motion and is applied to all boundaries. Another method is the substructure method, where the material properties of the soil are used to connect springs to show the stiffness at the soil-foundation interface. The general base structure method is suitable for complex structural idealizations where the land area is idealized as a semi-infinite continuum or element system. For places where essentially similar soils extend to a great depth without a rigid boundary, such as the soil-rock interface. The substructure method is computationally more efficient than the direct method because most of the disadvantages of the direct method can be eliminated by using the substructure method.

This middle floor construction report has been considered. First, the building and preliminary analysis are modeled using SAP2000 v19 and the design is done as per IS 56:2000. Performance analysis is then carried out by non-linear dynamic analysis and the building is designed according to the desired performance. In this study, the building is designed for Life Safety and DBE (Design Based Earthquake).

4. Orientation

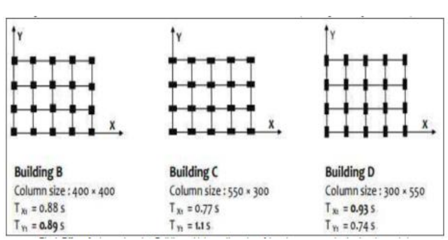

Figure 3. Orientation

Effect of column orientation: Buildings with larger dimension of the column cross section has less time period.

Various performance criteria were also taken into account to investigate the changes in orientation dependence of seismic structural response. orientation of columns and soft storey affect the seismic parameters such as deflection and time period. The study concludes that the soft storeys are to be provided in upper stories and combined effect of soft storey and column orientation by means of software aid to prevent failure of building during earthquakes.

5. Modeling And Analysis Of Buildings

- The analysis of G+14 storey building was carried out by using the ETABS software for buildings provided with moment resisting structural system situated in seismic zone V.
- Various seismic parameters such as base shear, top storey displacement, storey drift and time period were obtained.
- Building has lower stiffness and strength along Y direction due to less number of columns in its grids so the analysis of the building is carried out along y axis only. Below mentioned table 1 shows the various details of the building models.

Table 1 – Detail of the models

Model No	Model Code	Detail
1	M-1	Building with square columns
2	M-2	Building with rectangular columns(longer side of columns along X axes)
3	M-3	Building with rectangular columns(longer side of columns along X axes)
4	M-4	Building with varying column size from mid-building height
5	M-5	Building with varying column size for each five stories

Table 2 – Structural Data

Various details	
No of stories	G+14
Plan Shape	Rectangle
Plan Dimension	20m*30m
Typical floor height	3.5m for ground level and 3m for all above floors
Typical Column size	(600mm*600mm) for M-1 model
	(500mm*700mm) for M-2 and M-3 models
Column size for M-4 model	(500mm*700mm) from G.L to 7 storey
	(400mm*600mm) from 8 to 15 storey
Column size for M-5 model	(500mm*700mm) from G.L to 5 storey
	(400mm*600mm) from 6 to 10 storey
	(300mm*500mm) from 11 to 15 storey
Typical Beam size	300mm x 500mm
Slab thickness	130mm

Table 3 - Seismic Parameters

Type of analysis	Response Spectrum
Seismic zone	V
Soil type	Medium(II)
Response reduction factor (R)	5 for SMRF
Imp. factor (I)	1
Damping	for RCC , 2% for steel
Grade of concrete	M 25
Grade of steel	Fe 415
Live load	3 kN/ sq.m.
Floor finish	1.5 kN/sq.m.

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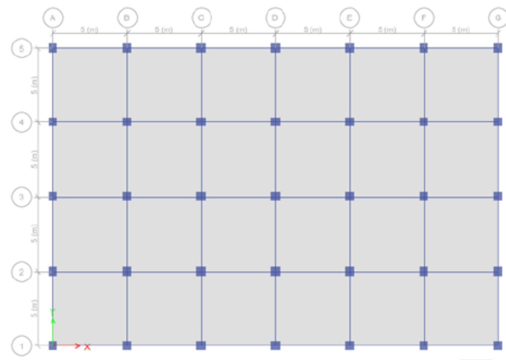
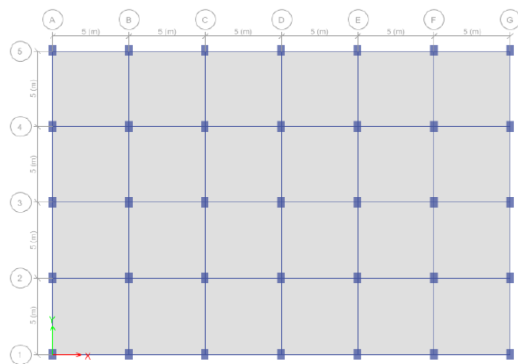
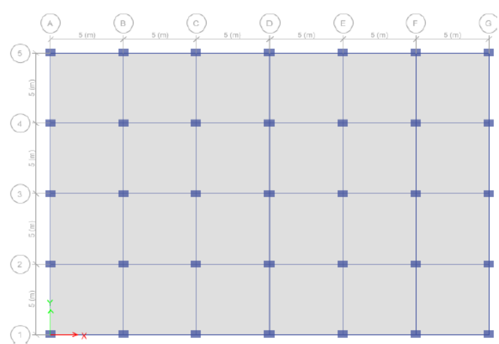
- **Plan of model M-1**



- **Plan of model M-2**



- **Plan of model M-3**



Data For Models
Modelling – We are using ETABS
Loading – Loading will be taken from

- As per IS-875 (Part 1) 2002 for dead load is 2KN/M2.
- As per IS-875 (Part 2) 2002 for live load is 4KN/M2.
- The earthquake parameter considered from Indian Standard code as per IS 1893: 2002 for analysis Some of Seismic Factor and data taken are mentioned in given below tables.

Earthquake different parameter used for analysis

	Values	Page No.	Table	Clauses
Importance Factor	1	18	7	6.4.2
Response Reduction Factor	3	23	8	6.4.2
Soil Type	II	16	2	6.4.2

Zone factor for different Seismic Zone as per Clause (6.4.2) in IS 1893 2002

Seismic Zone	Seismic Intensity	Zone Factor (Z)
II	Low	0.10
III	Moderate	0.16
IV	Severe	0.24
V	Very Severe	0.36

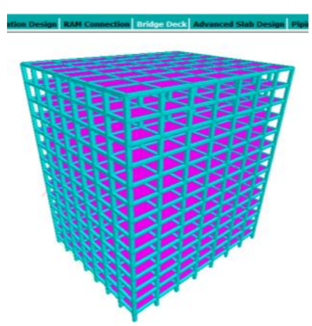
- Data Of Modelling

1. Type Of Structure Multi Story : Special Moment Resisting Frame : RCC
2. Zone : II, III, IV, V.
3. Layout Of Plan Dimension : 35x28 m
4. No. of Stories : 14
5. Total Height Of the Building : 41m
6. Floor Heights : 3m
7. Material : Concrete M30 & Steel Fe 415
8. Section Properties –

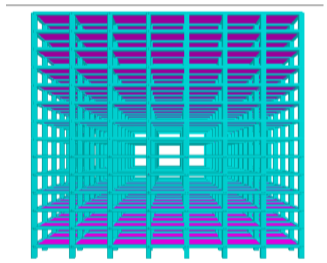
Beam 450 x 450 mm
Column 600 x 450 mm
Slab Thickness 200 mm

9. Seismic Analysis : Equivalent Static method as per IS 1893 – 2002.

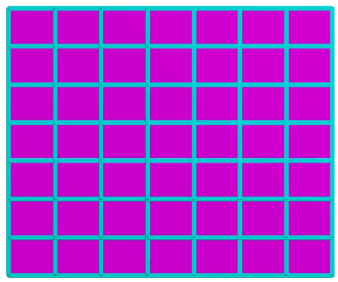
- **3-D model**



Isometric View

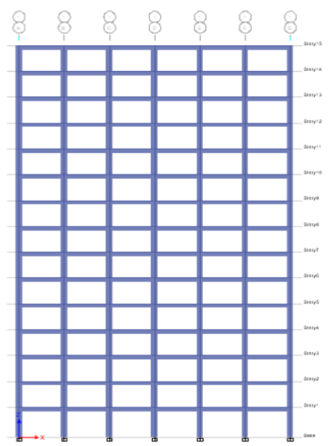


Front View

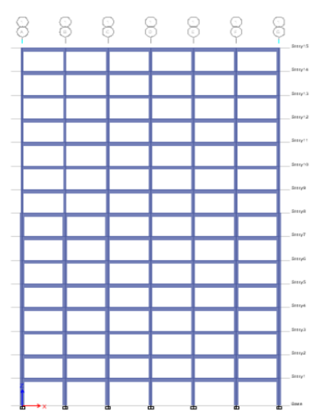


Top View

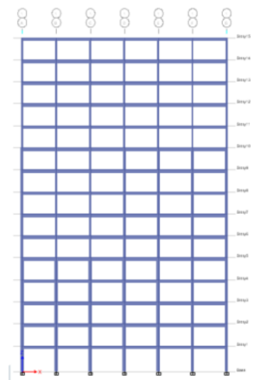
- **Elevation view of M-2**



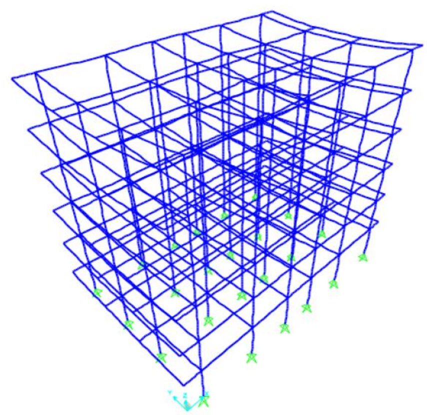
- **Elevation view of M-4**



- **Elevation view of M-5**



- **Load Analysis**



- **Summary of load analysis**

OutputCase	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN	GlobalMX KN-m	GlobalMY KN-m	GlobalMZ KN-m
DEAD	LinStatic	-5.185E-14	-2.043E-14	15102.407	109492.4537	-181228.889	7.816E-14
Live	LinStatic	-8.507E-15	-7.105E-15	10022.4	72662.4	-120268.8	8.527E-14
SIDL	LinStatic	-9.298E-15	-2.665E-14	7308	52983	-87696	-2.593E-13
Push X	LinStatic	-18.84	-5.64	2.33E-14	81.474	-271.876	68.91
Total Dead	Combination	-6.115E-14	-4.707E-14	22410.407	162475.4537	-268924.889	-1.812E-13
1.2/1.6	Combination	-8.699E-14	-6.786E-14	42928.329	311230.3844	-515139.95	-8.1E-14
Service Loa...	Combination	-6.965E-14	-5.418E-14	32432.807	235137.8537	-389193.69	-9.592E-14

Below tables and graphs show the program results for all building models considered

- ***For Base Shear capacity***

Table– Base Shear(kN) Comparison of all Models considered

Model	Base Shear(kN)	Difference(%)
M-1	3462.5	
M-2	3541.5	2.3
M-3	3313.8	-6.4
M-4	3492.4	5.4
M-5	3384.6	-3.1

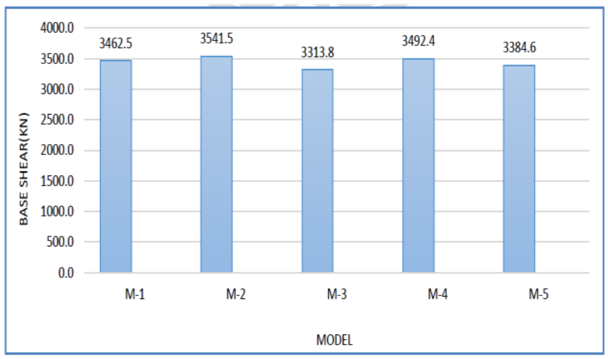


Chart 1. Base shear (kN) Comparison of various Models

- **For Lateral Displacement**

Table 5 – Lateral Displacement(mm) Comparison of all Models considered ,

Lateral Displacement(mm) along Y Direction		
Model	Displacement(mm)	Difference(%)
M-1	62.917	
M-2	60.75	-3.44
M-3	64.971	6.95
M-4	63.075	-2.92
M-5	66.106	4.81

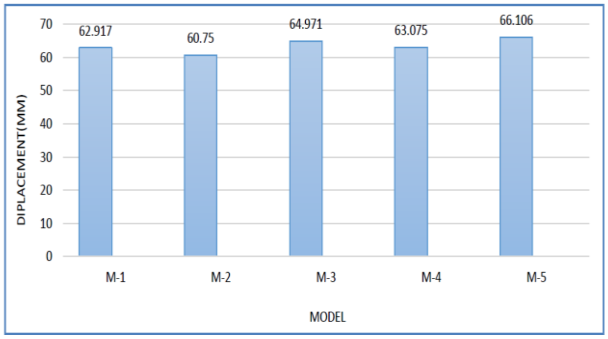


Chart 2. Displacement (mm) Comparison of All models considered

Table 5– Time Period(sec) Comparison of all Models considered

Fundamental time period(Ty) in Sec

Model	Time Period(Sec)	Difference(%)
M-1	2.23	
M-2	2.21	-0.99
M-3	2.41	8.22
M-4	2.34	5.03
M-5	2.45	9.88

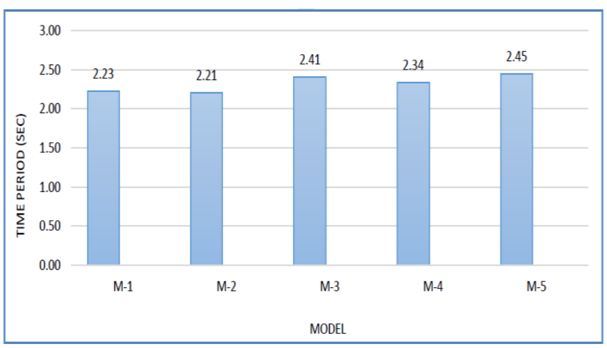


Chart 3. Fundamental Natural Period (sec) Comparison of All models considered

- **For Storey Drift**

Table 6 – Storey Drift Comparison of all Models considered,

No.Storey	Model/Storey Drift				
	M-1	M-2	M-3	M-4	M-5
15	0.0005	0.0006	0.0005	0.0006	0.0007
14	0.0008	0.0008	0.0008	0.0009	0.0010
13	0.0011	0.0011	0.0011	0.0012	0.0014
12	0.0013	0.0013	0.0013	0.0014	0.0017
11	0.0015	0.0015	0.0015	0.0016	0.0020
10	0.0017	0.0016	0.0017	0.0018	0.0018
9	0.0018	0.0018	0.0018	0.0019	0.0019
8	0.0019	0.0019	0.0019	0.0019	0.0020
7	0.0020	0.0020	0.0020	0.0019	0.0021
6	0.0020	0.0020	0.0021	0.0020	0.0021
5	0.0021	0.0021	0.0021	0.0020	0.0020
4	0.0021	0.0020	0.0021	0.0020	0.0020
3	0.0020	0.0020	0.0021	0.0020	0.0019
2	0.0018	0.0018	0.0020	0.0017	0.0017
1	0.0011	0.0010	0.0012	0.0010	0.0009
0	0	0	0	0	0

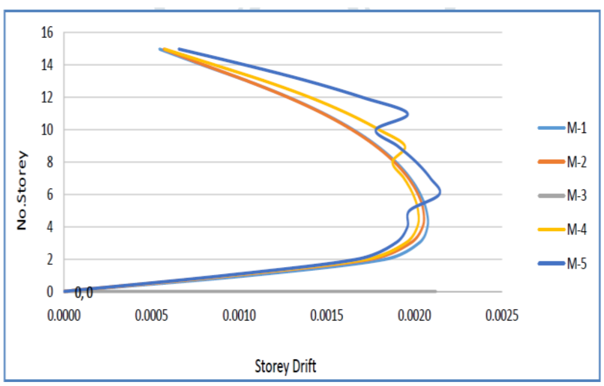


Chart 4. Inter-storey Drift Comparison of All models considered

6. Result & Discussion

Base shear capacity of the building along a specific direction increases with increase in stiffness. In current study the stiffness of building model M-2 is higher than M-1 and M-3 along Y direction so the base shear of M-2 model is more. Again the base shear result of building model M-4 and M-5 is less compared to M-1 and M-2 which are indicating that the change in column size across the building height reduces the base shear capacity of building. Model building M-3 has small column size along Y direction (500mm) which cause the stiffness to be reduced, hence the base shear capacity also reduces.

Like base shear, stiffness of the building has direct effect on lateral displacement of top storey of the building. Lateral displacement of building model M-2 is less compared to other models due to higher stiffness along y direction. By changing columns orientation (large column side) toward X direction, lateral displacement of building increases along Y direction which is indicated in displacement graph of model M-3. Also from displacement graph of model M-4 and M-5 it can be concluded that changing column size across building height is not effective from displacement point of view in low to mid-rise buildings.

As top storey displacement, same result we can get for time period of building models provided with different column size, orientation and shape. Fundamental time period of building model M-2 is less compared to other models which shows the effect of column orientation on stiffness of overall building and especially time period. Time period of building model M-3 is more compared to M-1 and M-2 building models due to weakness along y direction. The time period result of building models M-4 and M-5 are indicating that stiffness of building is reducing by reducing the column size across the building height.

Storey drift graphs of model M-4 and M-5 has a sudden jump at the points where size of the columns is changing. Storey drift of M-4 and M-5 models are less in lower stories due to higher stiffness and low building weight. The storey drift of model M-2 is following the smooth path and is less compared to building models M-1 and M-3.

7. Conclusion

[1] Rectangular column shape should be selected for buildings of rectangular plan with stronger column side along the grids with smaller dimension. This will increase the stiffness as well as strength of the building which in turn enhance base shear capacity, and overturning resistance of building. Reduction in lateral displacement and fundamental time period of the building will take place in weak direction of building when provided with larger column side.

[2] Increasing the column size increases both mass and stiffness of building model. When the percentage increase in mass as a result of increase in column size is smaller than the percentage increase in stiffness, the time period of the building reduces. Result of time period for building models M-4 and M-5 shows that the percentage reduction in stiffness is more than the percentage reduction in building mass with reducing the column size across the building height. For low to mid-rise buildings (up to 15 stories) changing column size has destructive effect on seismic performance of the building.

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