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TORSIONAL BEHAVIOR OF RC BUILDING STRUCTURES UNDER EARTHQUAKE LOADING

Dr. Prahlad Prasad[1], Shekidi Mallesh[2]

1. Associate professor, Department of civil engineering, National Institute of Technology, Jamshedpur; Email: ppdnitjsr @gmail.com
2. P.G student, Structural Engineering National Institute of Technology, Jamshedpur Email:mallesh935@gmail.com

Abstract

Asymmetry of building in horizontal as well as in vertical planes is necessary evil. This may be also because of asymmetry in mass, stiffness and strength. Due to the asymmetry or irregularity in building plan, there may be chance of amplification of torsional effects in during varying earthquake ground motions. Thus, irregularity in plan i.e. stiffness of vertical members will cause torsional eccentricity i.e. centre of mass and centre of rigidity shift away from each other. This eccentricity will cause torsional moments under seismic forces and this may vary from floor to floor. In this study three models which are G+5, G+10, G+15 were considered for two different conditions. In first case the variation of torsional moments in columns with respect to height of building and variation of base shear in all seismic zones were studied. Critical positions of columns were identified. The reason behind the results given to columns is columns are more vulnerable to seismic loading. In second case the variation of storey torsional moments and additional shear developed by torsion were studied. The results were recorded to in both X,Y directions due to asymmetry of building models. The Indian standard code of practice IS-1893:2002 (Part I) guidelines and methodology were used to analyzed and designed building.

Keywords: Torsional effects, eccentricity, asymmetric building, centre of mass and centre of rigidity.

1. Introduction

Vulnerability of a building system is highly sensitive to torsion, arising due to horizontal and vertical irregularity. Damage in such situation initiates at the location of the structural weak planes present in the building systems. These weaknesses trigger further structural deterioration which leads to the structural collapse. The weakness of structure caused due to irregularity present in it. The structural irregularity can be broadly classified as plan and vertical irregularities. As per IS 1893:2002, Plan irregularities may be classified as torsion irregularity, re-entrant corners, diaphragm discontinuity, out-of-plane offsets and non-parallel systems. Vertical irregularities may be classified as stiffness irregularity (soft storey), mass irregularity, vertical geometric irregularity and discontinuity in capacity (weak storey).

The recent studies conducted by a number of researchers in the past few decades and investigations of the effects of past earthquakes have shown that the major cause of failure of building structure is torsional effect i.e. buildings with non coincident of the center of mass (CM) and the center of rigidity (CR). At each floor, it is possible to locate the centre of rigidity due to lateral stiffness and centre of mass. If the building is symmetric with respect to lateral stiffness and mass, there will no effect of torsion. But if they were away from each other definitely there will be effect of torsion in reinforced concrete buildings under seismic loading. The earthquake force acts through the centre of mass and is resisted by the building through its centre of rigidity. This leads to horizontal twisting of the building.

1.1 Need of Present Study

If we once observe a plan of recent buildings, by glance we can see the irregularity in plan. This may be because of irregular shape of site. Because of expensive land rates we cannot make symmetric plan from irregular shape of site. The maximum area will come under construction. The irregular plan buildings may also architecturally good. Because of asymmetry many problems occur to multi storey buildings under seismic loading, like torsion causes an increase in shear at the periphery of a building, and it also appears to have caused torsional failure in some columns [2]. Before design a building study of torsional effects and it's minimization is necessary. In the present study how the torsional moments are developing in columns and it's comparison with all seismic zones and variation of base shear has been studied. The reason behind the results given to columns is columns are more vulnerable to seismic loading.

The main objectives of present study are
1. To know the torsional behavior of irregular buildings under seismic loading.
2. Dynamic analysis of framed structures using Response Spectrum for zones II, III, IV and V.
3. Comparative dynamic analysis of irregular building by using SAP2000 in G+10 and G+15.

2. Literature review

In 1970's the seismic torsional effects on buildings conducted by D.G Elms [2] had given the torsional provisions of the New Zealand loading code. These provisions attempt to deal with the accidental eccentricity, torsional ground motion, and coupling between torsional and translational modes.

In 1990's Goel and Chopra also have studied the influence of the lateral and torsional frequencies. They proposed an analysis method which eliminates the need for explicit computation of the centre of rigidities and yet leads to results identical to those obtained by the approach which involves calculating the location of centre of rigidity.

In 2012 Bahador Bagheri, Ehsan Salimi Firoozabad, and Mohammadreza Yahyaei have studied the comparative Study of the static and dynamic analysis of multi-storey irregular building[3].

In 2015 Mohammed Rizwan Sultan, D. Gouse Peera have studied the dynamic analysis of multi-storey building for different shapes. The important objective of this study is to the behaviour of the structure in high seismic zone and also to evaluate Storey overturning moment, Storey Drift, Displacement, Design lateral forces. During this purpose they modeled a 15 storey-high building on four totally different shapes like Rectangular, L-shape, H-shape, and C-shape are used as a comparison.

3. Problem formulation

In this study there were three loads considered: dead (DL), live (LL), and earthquake (EQ) loads.
1. *Self-weight* of the structure consists of the weight of the columns, beams and slab of the structure.
2. *Dead load* of the structure consists of Wall load, Parapet wall load and floor finishes, according to (IS 875(Part1)).

A) Wall load: Weight unit of brick masonry * thickness of wall * height of the wall =
20 kN/m3 * 0.230m * 3m=13.8 kN/m.

B) Parapet wall: Weight unit of brick masonry * thickness of wall * height of the wall =
20 kN/m3 * 0.23m * 1m= 4.60 kN/m.

3. *Live load*: It consists of Floor load which is taken as 2Kk/m2 and Roof load as 1.5 kN/m2, according to (IS 875 (Part 2).
4. *Seismic Load*: The different seismic parameters are taken as follows, IS 1893(Part-1):2002.

- Seismic zone: Z (II=0.1, III=0.16, IV=0.24, V=0.36)
- Soil type: II.
- Importance factor: 1.
- Response reduction factor: 5.
- Damping: 5%.

4. Modelling

Here two models were considered. They are G+10, G+15. The plan is irregular as shown in figure1. The plan is same to both models. The area of the plan is 673 m^2. The earthquake date and structural data are given in table no 1 and table no 2 respectively.

Table 1: Earthquake Data

Earthquake Data	
ZONE	II,III,IV,V
Importance factor (I)	1
Response reduction factor (R)	5
Damping	5% for all models
Soil type	Medium

Table 2: Structural Data

Structural data	
Type of building	Residential
No of Models 2	(G+10,G+15)
Materials: Concrete	M25
Steel	Fe500
Floor height	3m
Ground Floor height	3m
Ground level at	1.5m from footing level
Live load	2 kN/m^2
Floor finishes	1 kN/m^2
Roof Treatment	1.5 kN/m^2
External wall	230 mm
Internal wall	115mm
Columns :G+10	Corner : 450mm x700mm External : 500mm x 700mm Internal : 600mm x 750mm
Columns :G+15	Corner : 450mm x750mm External : 600mm x 750mm Internal : 750mm x 900mm
All beams	380mm x 600mm
Slab thickness	125mm

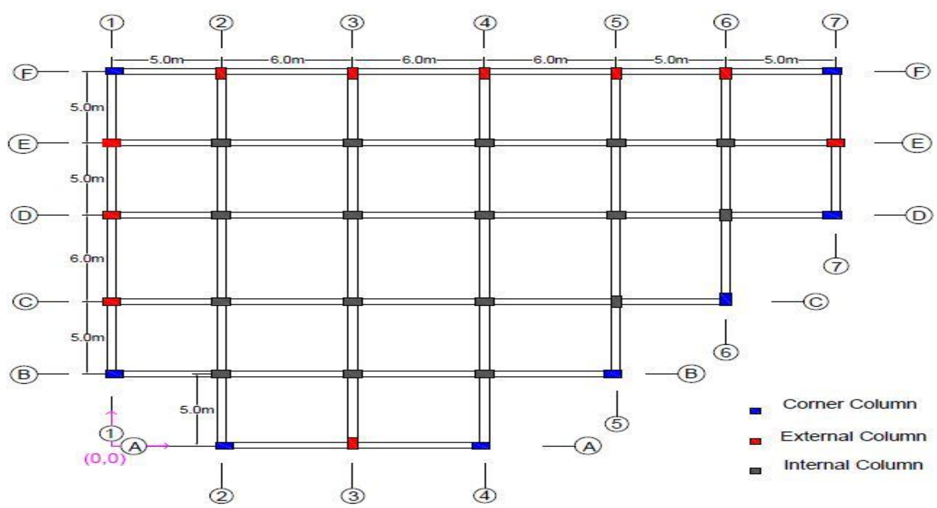


Figure1: Plan of building

5. Analysis and design

In the present study the gravity load analysis and lateral load analysis as per the seismic code IS 1893 (Part 1): 2002 are carried out for asymmetric buildings and buildings. The analysis is RSA. In the present study the gravity load analysis and lateral load analysis as per the seismic code IS 1893 (Part 1): 2002 are carried out for asymmetric buildings. The first model to analyses and design in SAP2000 was G+10 in zone V. The design base shear (V_B) was compared with a base shear ($\overline{V_B}$) calculated using a fundamental period. If V_B is less than $\overline{V_B}$, the factor $\frac{\overline{V_B}}{V_B}$ was used. If the members were failed, the cross sections of the members has been changed until all members passed. The final cross sections used in zone V model was used in remaining three zones model in order to get the results to different zones in all models. Likewise G+ 15 model has been analyzed and designed till all members passed. The response spectrum is shown in figure 2.

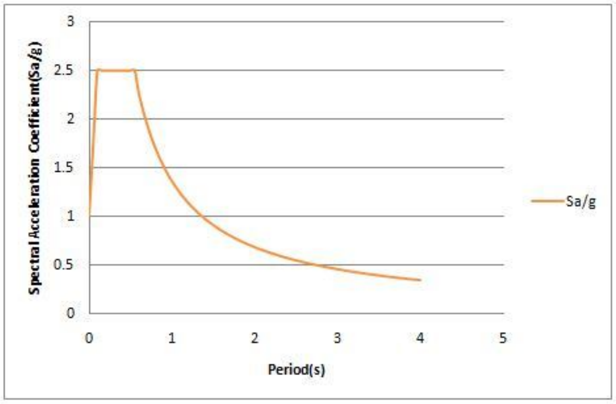


Figure 2: Response Spectra for medium soil and 5% damping

6. Results and disscussions

It includes all the analytical results of building elements. In this case the variation of torsional moments in columns with respect to height of building and variation of base shear in all seismic zones were drawn in graphs. The reason behind the results given to columns is columns are more vulnerable to seismic loading. The results given to both EQ X, EQ Y . All combinations were considered here. The critical combination is 1.5(DL+EQ). Almost all results were given to critical load combination. Some of the discussions are listed here.

- The results are given to a External column no E1 and internal column no. E4. Numbering of column are shown in figure 1.
- The torsional moments drawn in following graphs are plotted along the height of the building.
- The cross sections passed in zone V were used in other three zones.
- The results given to EQ X and EQ Y directions
- EQ X results are more compared to EQ Y results, because eccentricity in Y-direction more than eccentricity in X-direction (i.e. e_y=0.573m, e_x =0.14m), and dimension of building in y-direction is lesser than dimension of building in X-direction.
- The torsional moments at support condition (see figure 3) is lesser compared to top floor columns, because of soil interaction. Some moment may be released.
- The internal columns are getting more torsion compared to external columns.

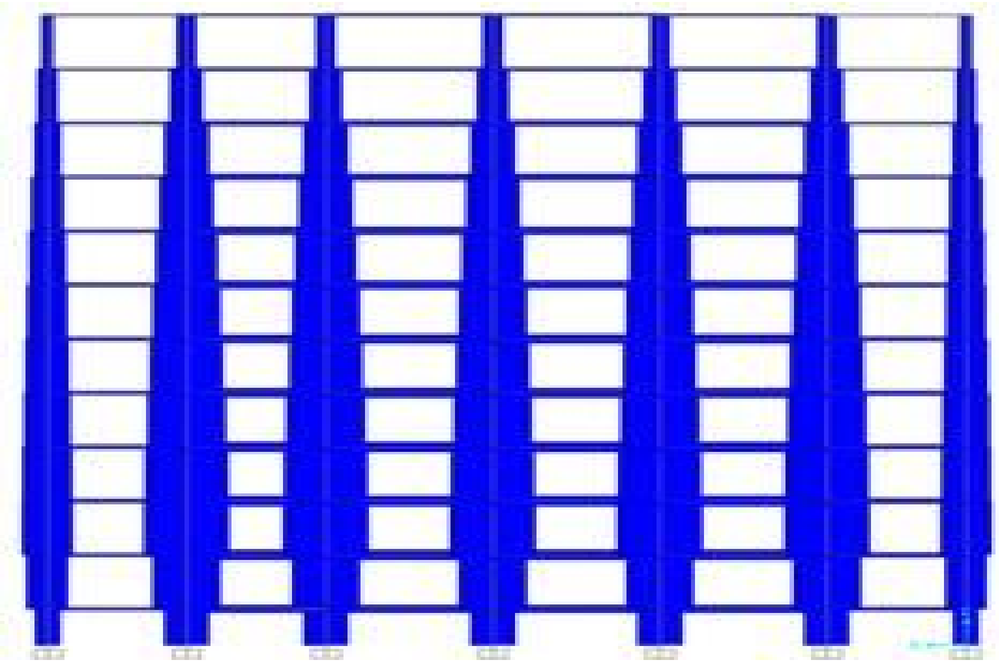
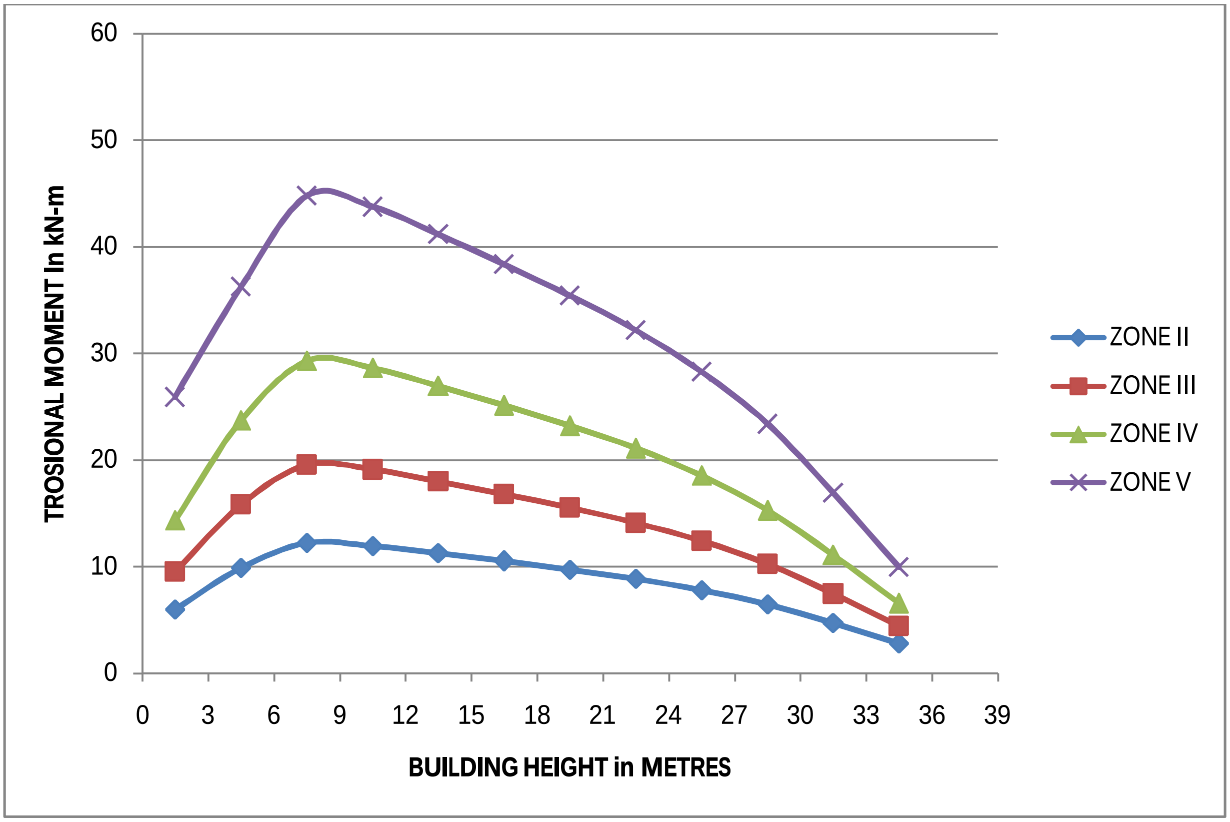


Figure 3 Model torsional diagram from SAP2000 for 1.5 (DL+EQ)

The results are tabulated below:

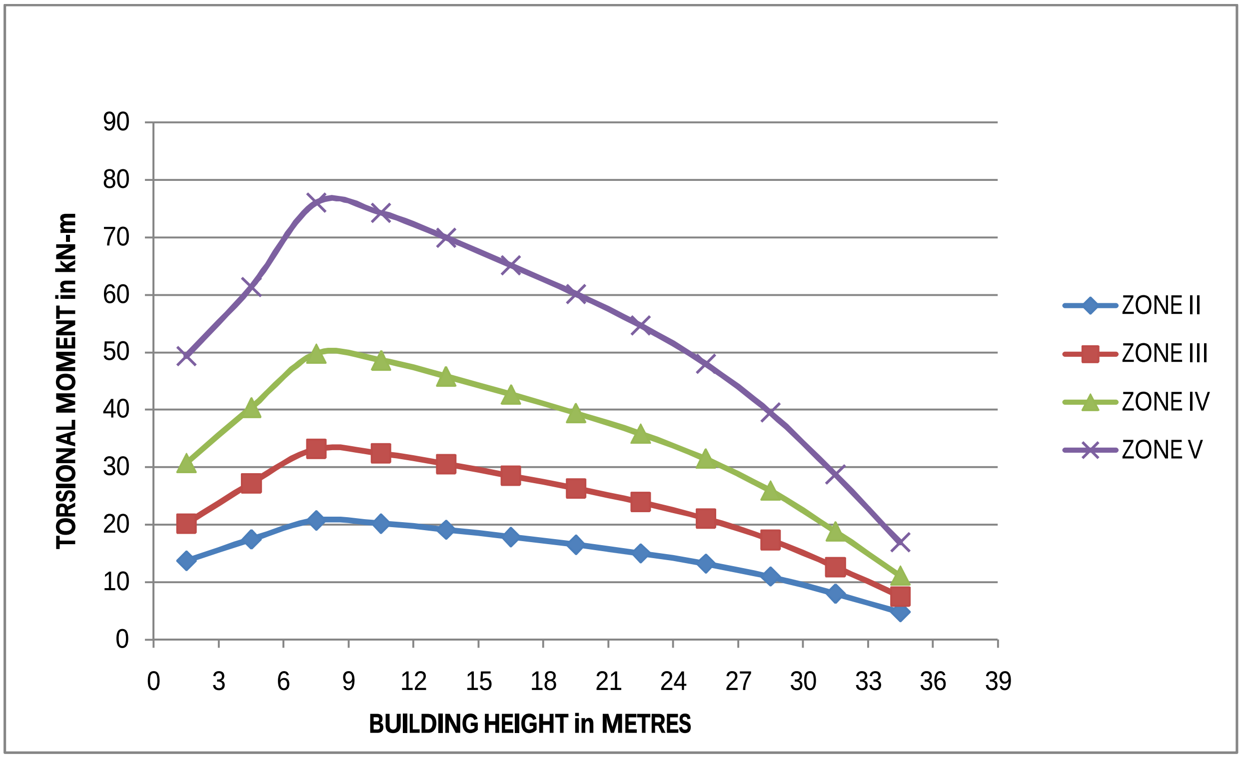
G+10 Building Model: Results to EQ in X-direction

i. Torsional moments External Column No: E1



Graph 1: Variation of torsional moments in external column

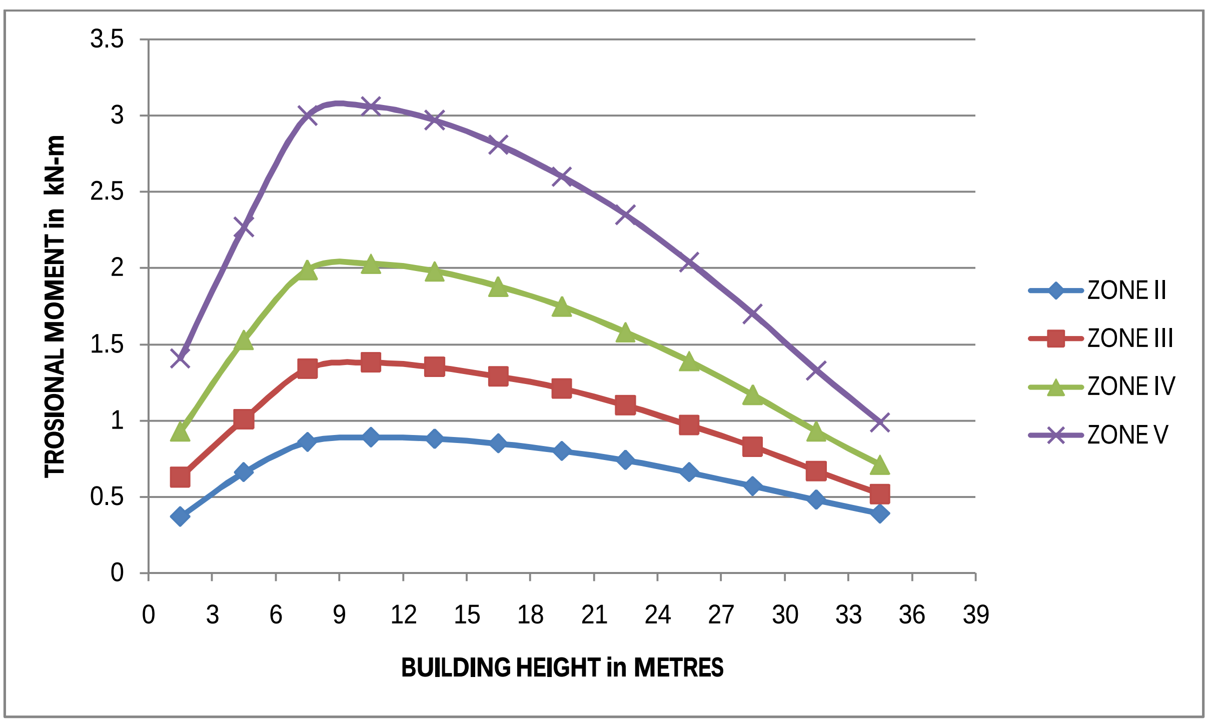
ii. Torsional moments Internal Column No: E4



Graph 2: Variation of torsional moments in internal column

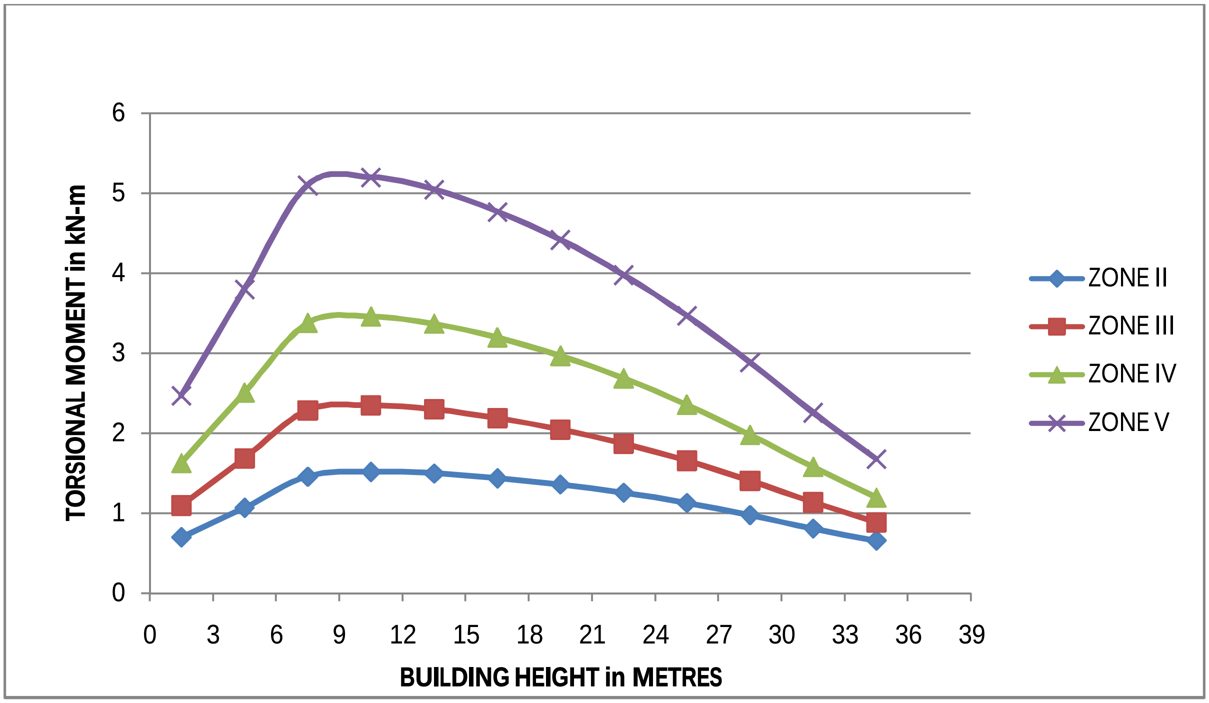
G+10 Building Model: Results to EQ in Y-direction

iii. Torsional moments External Column No: E1



Graph 3: Variation of torsional moments in external column

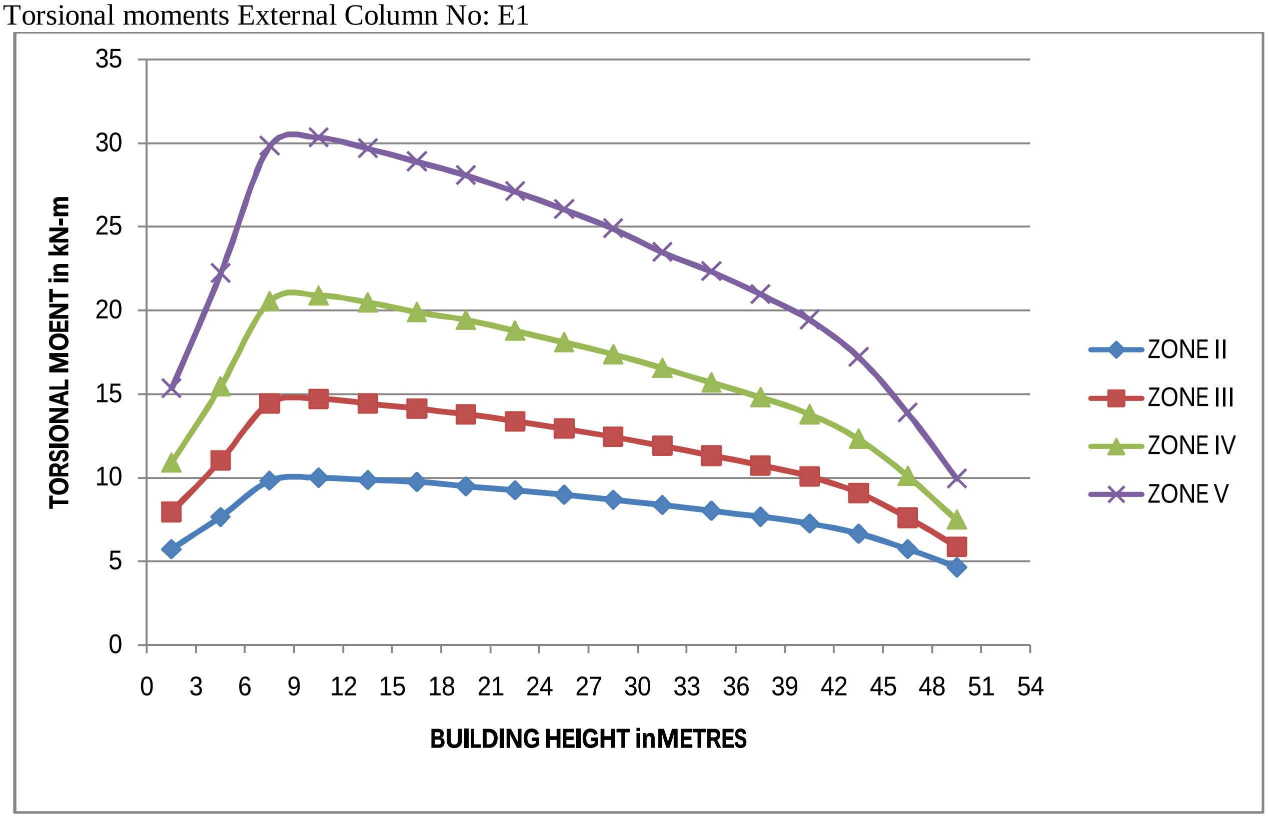
iv. Torsional moments Internal Column No: E4



Graph 4: Variation of torsional moments in internal column

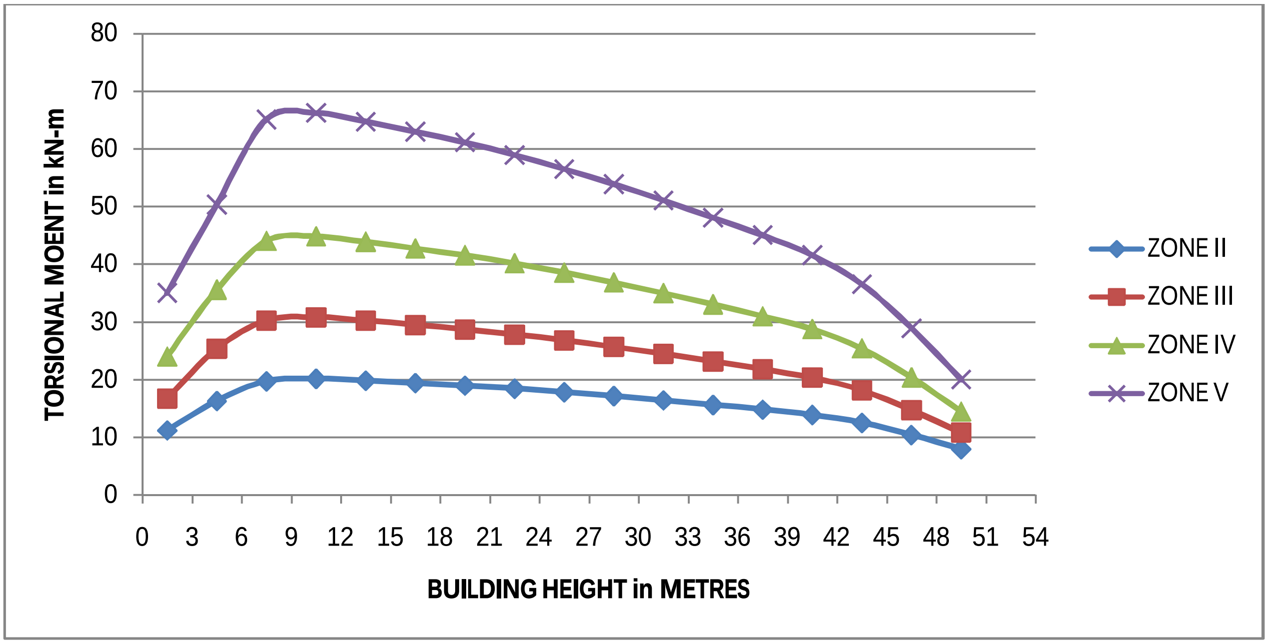
G+15 Building Model: Results to EQ in X-direction

v. Torsional moments External Column No: E1



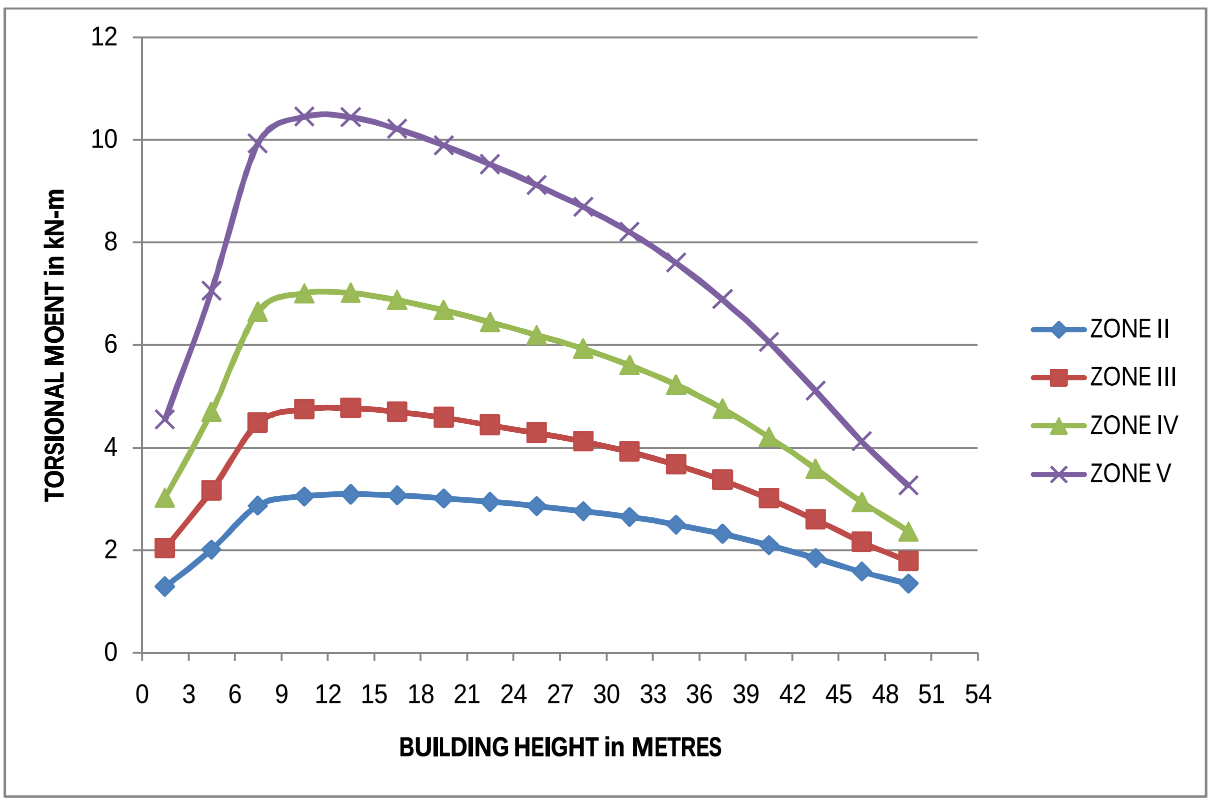
Graph 5: Variation of torsional moments in external column

vi. Torsional moments Internal Column No: E4



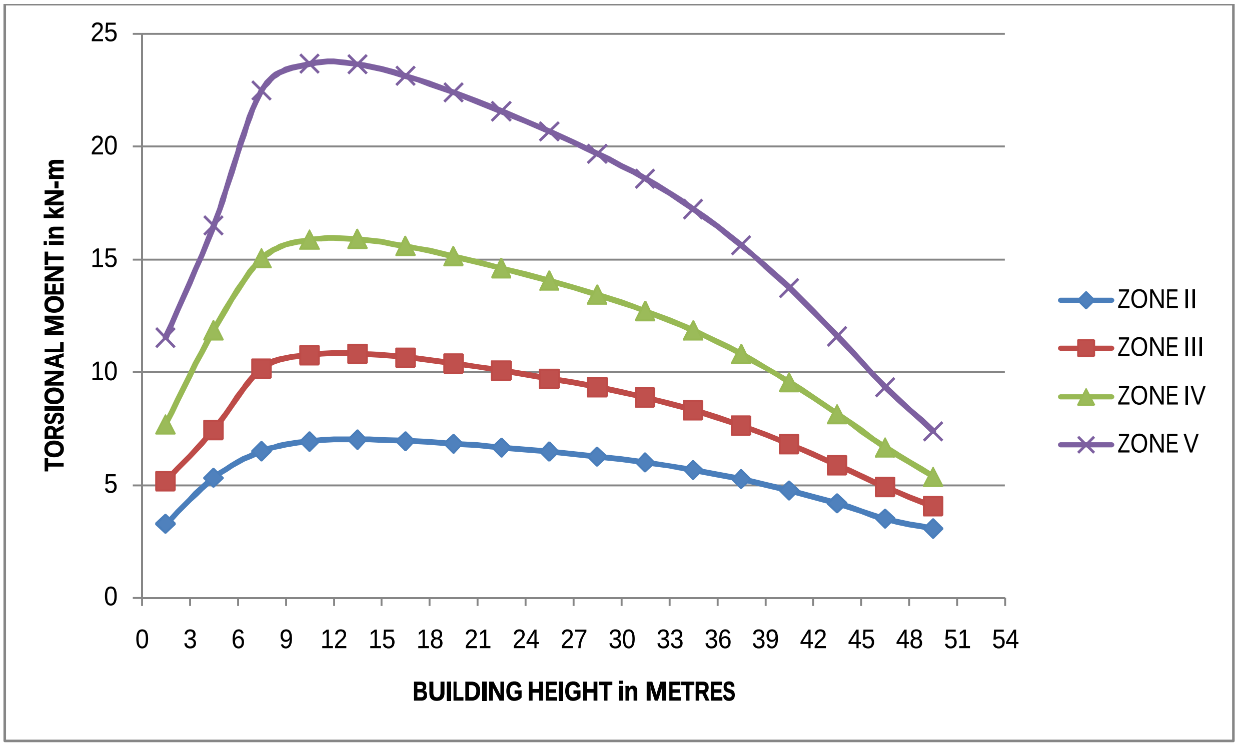
Graph 6: Variation of torsional moments in internal column

G+15 Building Model: Results to EQ in Y-direction
vii. Torsional moments External Column No: E1



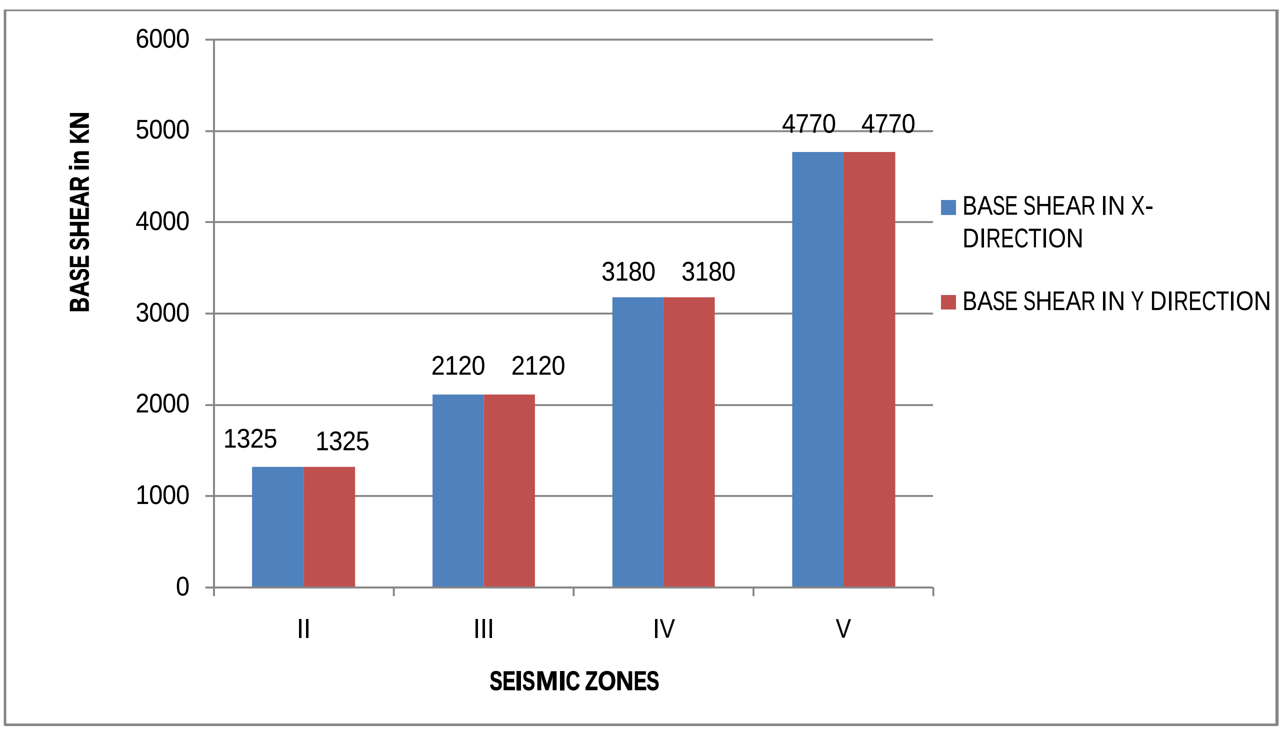
Graph 7: Variation of torsional moments in external column

viii. Torsional moments Internal Column No: E4



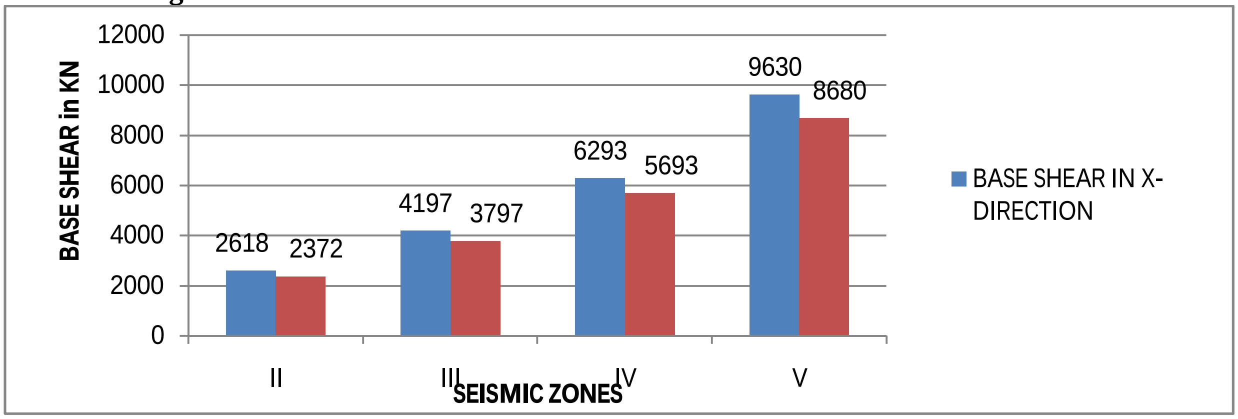
Graph 8: Variation of torsional moments in internal column

G+5 Building Model: Base shear variation



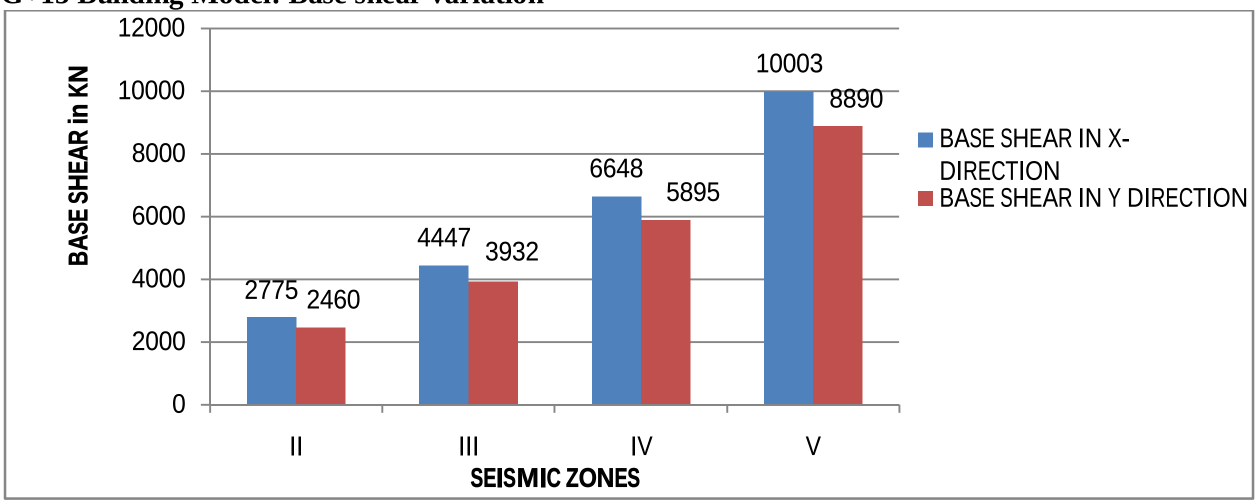
Graph 9: Variation base shear in G+5 Storey Building

G+10 Building Model: Base shear variation



Graph 10: Variation base shear in G+10 Storey Building

G+15 Building Model: Base shear variation



Graph 11: Variation base shear in G+15 Storey Building

7. Observations

The aim of the project was to investigate the torsional behaviour of a multi-storey asymmetric reinforced concrete building under seismic loading. The results compared in all seismic zones. On the basis of graphs no from 1 to 8 the following observations are listed here.

a. The percentage of variation of torsional moments with storey to storey in columns are:

Table 3: % of variation of torsional moments in G+10

G+10				
Column	% of variation with storey to storey			
	II	III	IV	V
Internal	5 to 40	5 to 40	5 to 40	5 to 40
External	5 to 40	5 to 40	5 to 40	5 to 40

Table 4: % of variation of torsional moments in G+15

G+15				
Column	% of variation with storey to storey			
	II	III	IV	V
Internal	5 to 25	5 to 25	5 to 25	5 to 25
External	5 to 20	5 to 20	5 to 25	5 to 25

b. The percentage of variation of torsional moments with zone to zone in columns are:

Table 5: % of variation of torsional moments in G+10

G+10			
Column	% of variation with zone to zone		
	II to III	III to IV	IV to V
Internal	60	50	52
External	60	50	52

Table 6: % of variation of torsional moments in G+15

G+15			
Column	% of variation with zone to zone		
	II to III	III to IV	IV to V
Internal	45	40	45
External	40	38	42

c. The % of variation of zone factor with zone II to III, III to IV and IV to V is 60, 50, 50 respectively. So the results shown in Table 7 shows % of base shear variation with zone to zone which was equal to zone factor variation. On the basis of graphs no from 9 to 11 the following results are tabulated.

Table 7 Variation of base shear with: zone to zone

G+5,G+10,G+15			
% of Base shear variation with zone to zone			
Zone	II to III	III to IV	IV to V
	60	50	50

8. Conclusions

- Variation of torsion effects in terms of moment have found to be increased for the internal columns with the increase of storey levels.
- The same inferences have been observed for external columns. Significant variations also are seen from internal to external columns.
- However, the increased of torsion moment for internal columns are found more than the external columns under varying earthquake loading, i.e. from zones II to V.
- The percentage of variation base shear with zone to zone is equal to zone factor variation in each model.
- The torsional moment at support condition in all models is lesser than the top floor, because of soil interaction condition.

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