

A Study on Effect of Eccentricity in RC Frame Structures

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ABSTRACT: Structural Engineers often encounter buildings which exhibit some degree of plan asymmetry. Structure with non-coincident centre of mass (CM) and centre of rigidity (CR) are referred to as torsionally unbalanced structure or asymmetric structures. As the distance between mass centre (CM) and rigidity centre (CR) increases in the structures, the structures become more and more asymmetric. The response of plan-asymmetric structures is highly complex when compared to that of symmetric structures as torsion induces under seismic excitation which leads to bi-directional response of the structure. From seismic point of view, torsion is a critical factor which leads to major damage in plan-asymmetric structure. Keeping this in view, seismic induced torsional effect on RC frame structures having irregular distribution of mass are dealt in the present study. In the present study, seismic analysis has been performed for G+4, G+8 and G+11 storey RC frame structures by equivalent lateral force method as well as response spectrum method for three different seismic zones(III, IV V) founded on soil type III as per the IS 1893(part 1):2002 specifications. The analysis has been performed using ETABS 2015 software package. The study concludes that the different centres of buildings like centre of mass and centre of rigidity have great impact on seismic response of the building system as torsion generated depends upon the position of centre of mass and centre of rigidity. As the eccentricity ratio increases torsional moment also increases. The analysis proves that irregularities are dangerous for the structures and it is important to have regular structures and uniform load distribution around the building as far as possible. But, if irregularities have to be introduced for any reason, they must be designed properly.

KEYWORDS: Centre of mass, Centre of rigidity, Eccentricity ratio, Equivalent lateral force method, Response spectrum method, ETABS 2015.

I. INTRODUCTION

When the irregular structures are subjected to seismic excitation, torsion induces in the structures because of eccentricity between the mass centre and stiffness centre. Other than this, torsion induces because of the accidental eccentricity, which is considered to account for the inevitable uncertainties in the building.

Torsion irregularity in the structure can be represented by,

- Eccentricity ratio, (I.e. the ratio of eccentricity between the mass centre and rigidity centre to the building dimension in the direction of eccentricity) and
- $\frac{\Delta_{max}}{\Delta_{avg}}$, (i.e. the ratio of maximum storey drift and average storey drift, at a particular storey)

Eccentricity ratio is non-dimensional parameter, which depends on the distribution of mass and stiffness in the building, it also depends on the building configuration but it is independent of the method of analysis chosen. Code suggests the provision of accidental eccentricity (e_a) in terms of this eccentricity ratio i.e. $e_a = 0.05b$, where 'b' is the building dimension perpendicular to the seismic force considered.

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“ $\Delta_{max}/\Delta_{avg}$ ” Depends on the distribution of mass, stiffness and also the method of analysis chosen. According to the code, in a structure at any storey, if this ratio exceeds 1.2, then it is said to be irregular structure.

II. RELATED WORK

1. Lohit Kumar et al (2016) did the study on seismic response of tall buildings under the influence of torsion. Study was performed by equivalent lateral force method for all zones and for all soil types for various irregularities such as diaphragm irregularity, mass irregularity, Non parallel offset irregularities for 10, 15 ,20 storey buildings. The results in the form of torsion moment, fundamental natural time period and base shear are compared for different irregularities and analysis was done with ETABS 9.2 software. They concluded that torsional moments, fundamental period and base shear increases with the increase in the height of a regular building. The effect of variation in the torsional moments are high in a 10 and 15 storeys in seismic zone II founded on soil type III and zone III founded on soil type I respectively. The effect of torsional moment is high in 10 and 20 stories building in all seismic zones and soil types.
2. **Castillo et al** (2001) studied torsional response of ductile structures indicating the need for improvement in current seismic design provisions. This is because most standard deal with the torsion problems were based on the concept of elastic response. These provisions may be satisfactory at the serviceability limit state but are generally irrelevant for ductile structures. This paper evaluates the rotation of asymmetric structures and its effect on the displacement ductility demand using a displacement approach based on as realistic element modelling. It is illustrated, how the mass rotation inertia plays an important role in the response of asymmetric structures. It is showed how strength eccentricity and distribution of mass affect the rotation of the system. It is suggested that the strength distribution to element of a reduction of the system rotation and allow the structure to be modelled as an equivalent single degree of freedom system. Thus the system displacement ductility capacity becomes a simple function of the displacement ductility of the critical element.

III. METHODOLOGY

The software used in this research is ETABS 2015. Equivalent lateral force method of analysis and response spectrum method of analysis have been adopted to study the effect of Eccentricity in RC frame structure having irregular distribution of mass as per IS 1893 (part 1):2002 codal provision. For this study, four types of models, each having 5, 9 and 12 storey is considered. Each type of buildings models has different eccentricity. In the buildings stiffness distribution is regular, however the mass distribution is irregular along Y-axis.

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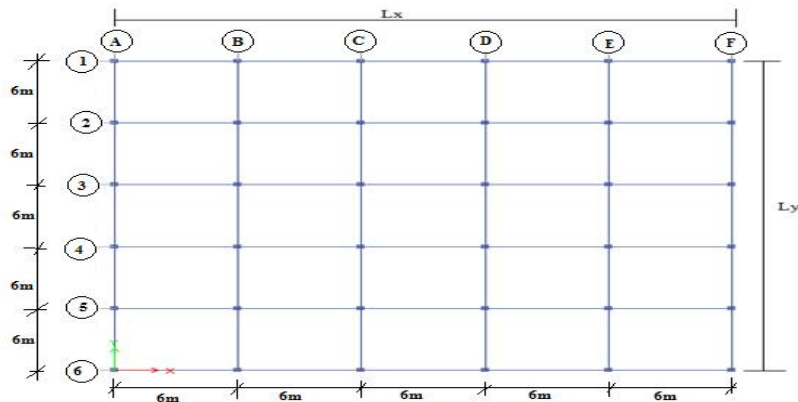


Fig.1: Typical model of the building considered in the present study

Fig.1 shows the typical plan considered in the present study, for analysis purpose only single frame are considered (Fig 2 (a)).

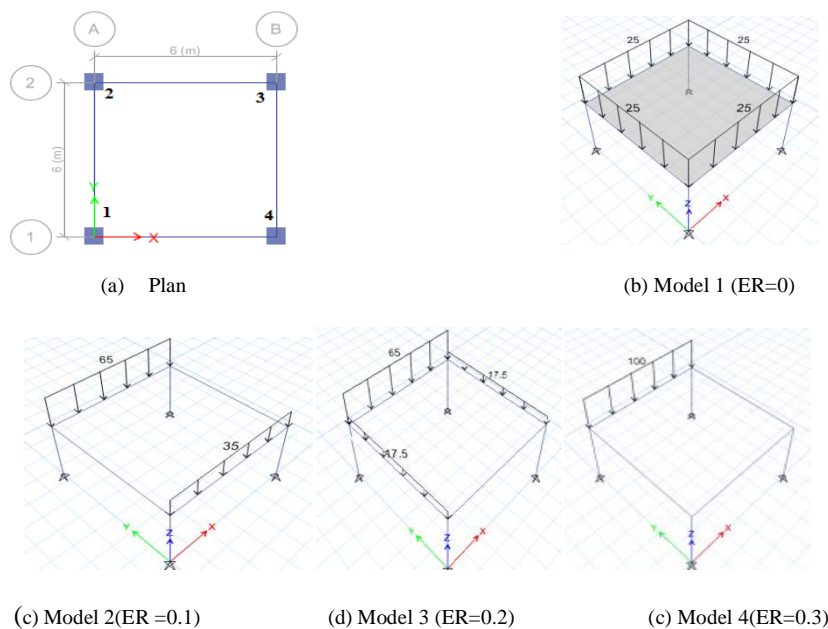


Fig.2: Typical loading pattern in kN/m^2 for 1 storey buildings considered in the present study

Fig.2 shows the typical loading pattern for 1 storey frame, in the same way the loading are considered for G+4, G+8 and G+11 storey frames. The floor slab is assumed to be in-plan rigid. The overall mass and stiffness is kept constant in all models in each type of building. However the mass distribution in plan is made such a way that the eccentricity ratio in Y-direction is 0.0, 0.1, 0.2 and 0.3 for models 1, 2, 3 and 4 respectively.

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IV. ANALYSIS

In this project, equivalent static force method and response spectrum method are adopted and the analysis is carried out using ETABS 2015 software as per the IS 1893 (part 1):2002. The structure was modelled in ETABS-2015 by considering the parameters shown in table 1. Fig.3 shows the typical 3D model of the frames considered in the present study.

Table.1: parameters considered in the present study.

Structural type	Ordinary moment resisting frame
No. Of storey	G+4, G+8, G+11
Typical storey height	3.5m
Type of building use	Public cum office
Foundation type	Isolated footing
Seismic zone	III, IV and V
Soil type	III
Material properties types	
Grade of concrete	M ₂₀ , M ₂₅
Grade of steel	Fe 415
Young's modulus of concrete, E _c	25x10 ⁶ kN/m ²
Poisson's ratio of reinforced concrete	0.2
Density of reinforced concrete	25kN/m ³
Member properties	
Thickness of slab	0.150 m
Beam size	0.230x0.600 m
Column size(G+4)	0.400x0.400 m
Column size (G+8)	0.650x0.650 m
Column size (G+11)	0.750x0.750 m
Dead load intensities	
Roof finish	2.0 kN/m ²
Floor finish	1.0 kN/m ²
Partition wall load	1.0 kN/m ²
Live load intensities	
Roof	1.5 kN/m ²
Floor	3.0 kN/m ²
Percentage of earthquake LL considered on slab as per clause 7.3.1 and 7.3.2 of IS 1893 (part 1):2002	25%

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Earthquake forces are considered along X and Y direction. Variation of centre of mass, centre of rigidity and response of the structure like fundamental natural period as well as the maximum torsional moment at column - 2 (Fig.2 (a)) in different seismic zones(III, IV and V) founded on soil type III for G+4, G+8 and G+11 are dealt in the present study. Fig.3 shows the typical 3D models of G+4, G+8 and G+11 storey RC frames. Difference between seismic response evolution, through equivalent lateral force method and response spectrum method are clarified through graphs.

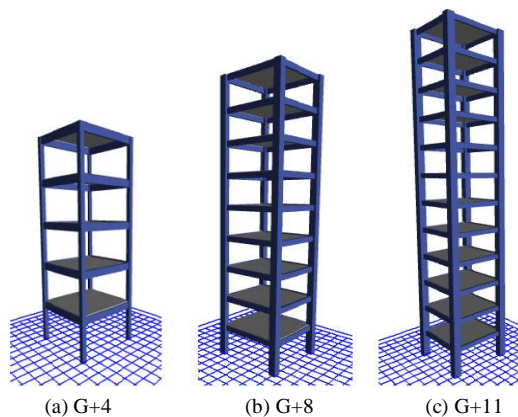


Fig.3 Typical 3D model of the frames considered in the present study

V. RESULTS AND DISCUSSION

The following section discusses the results obtained after the analysis of the frames by both equivalent static force method as well as response spectrum method.

Table.2: variation of fundamental period in mass asymmetric buildings

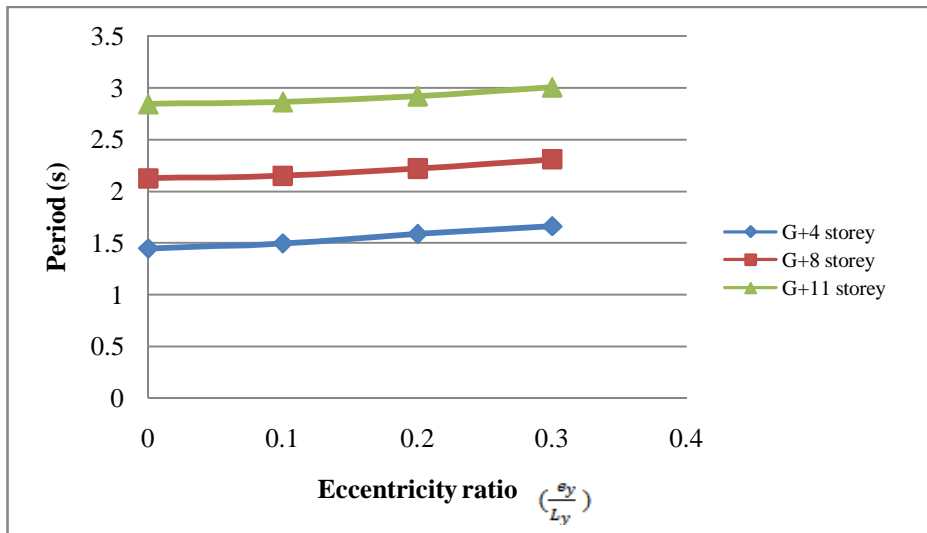
Total No. of storey	Model No.	Eccentricity Ratio	Centre of mass(CM)	Centre of rigidity(CR)	Period in seconds		
			(X, Y)	(X, Y)	ETABS		IS 1893 (Empirical) $(T_a=0.075h^{0.75})$
			(m)	(m)	Along X	Along Y	
G+4	1	0	(3,3)	(3,3)	1.45	1.45	0.642
	2	0.1	(3,3.6)		1.498	1.45	
	3	0.2	(3,4.2)		1.588	1.45	
	4	0.3	(3,4.8)		1.663	1.45	
G+8	1	0	(3,3)	(3,3)	2.126	2.126	0.997
	2	0.1	(3,3.6)		2.15	2.126	
	3	0.2	(3,4.2)		2.219	2.126	
	4	0.3	(3,4.8)		2.308	2.126	
G+11	1	0	(3,3)	(3,3)	2.846	2.846	1.237
	2	0.1	(3,3.6)		2.864	2.846	
	3	0.2	(3,4.2)		2.922	2.846	
	4	0.3	(3,4.8)		3.007	2.846	

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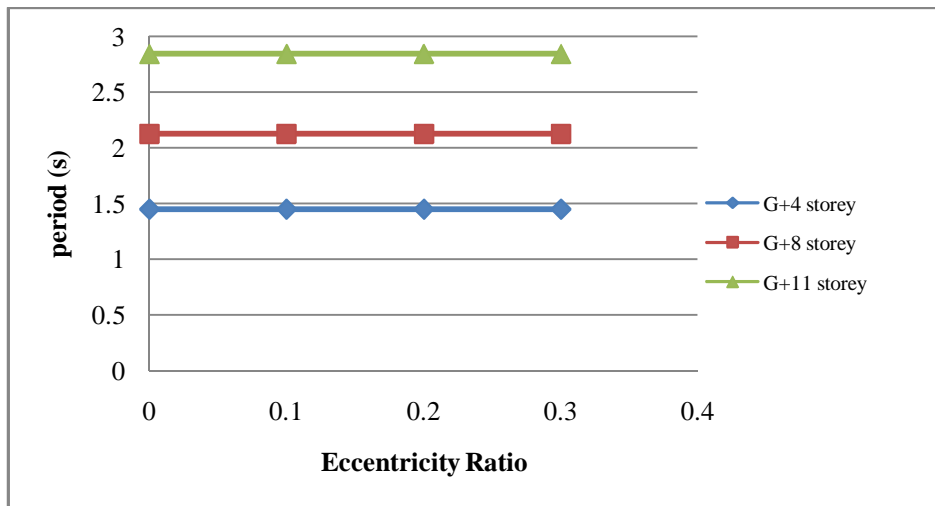
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Chat 1: Variation of maximum fundamental period along X-direction with eccentricity ratio



Chat 2: variation of maximum fundamental period along Y-direction with eccentricity ratio

Chat 1 and chat 2 shows the variation of fundamental period along X and Y respectively. The codal empirical equation for the determination of fundamental period of the structure does not have any provisions to incorporate the effect of structural irregularity. However, from the present study it can be observed that as the structural irregularity increases the period of the structure also increase in a linear manner. In the model having eccentricity ratio of 0.3 and the total number of storeys 5, 9 and 12, the increase in period along the X-axis is about 15%, 9% and 6% respectively, compared to the models having zero eccentricity ratio. In all the cases, period of the structure determined using codal empirical expression lag behind that of the dynamic analysis.

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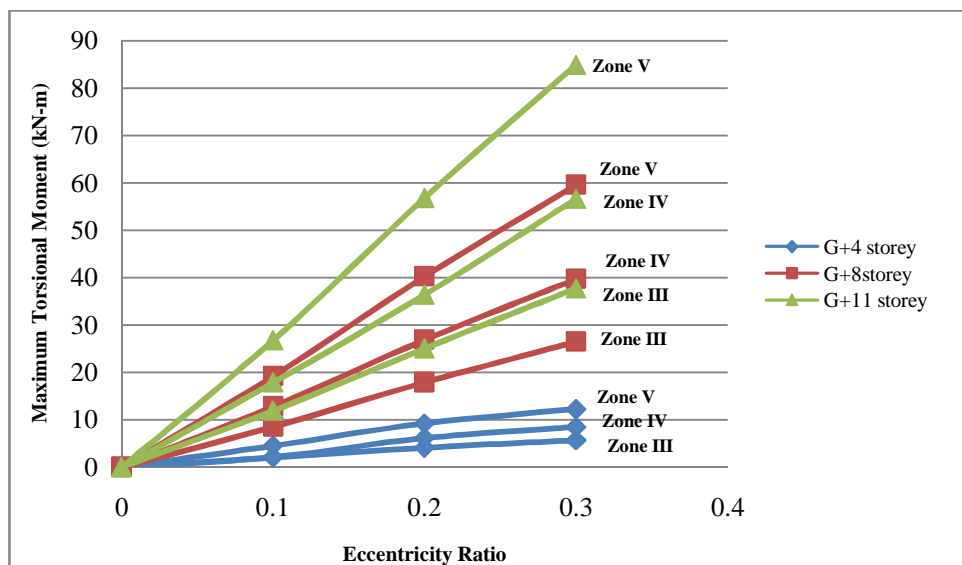
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Table.3: variation of maximum torsional moment at column- 2 in mass asymmetric buildings for Soil type III

Total No. of storeys	Eccentricity Ratio $(\frac{e_y}{L_y})$	Maximum Torsional Moment in kN-m					
		ZONE III		ZONE IV		ZONE V	
		ELF -X	RSM - X	ELF - X	RSM -X	ELF -X	RSM -X
G+4	0	0	0	0	0	0	0
	0.1	1.993	8.267	2.089	9.247	4.485	18.599
	0.2	4.074	11.031	6.11	16.409	9.166	24.82
	0.3	5.626	11.312	8.439	16.968	12.195	25.462
G+8	0	0	0	0	0	0	0
	0.1	8.533	20.948	12.799	31.422	19.199	47.133
	0.2	17.908	36.955	26.862	55.432	40.293	83.148
	0.3	26.489	44.198	39.733	66.297	59.599	99.305
G+11	0	0	0	0	0	0	0
	0.1	11.891	22.246	17.837	33.369	26.755	50.053
	0.2	25.021	42.802	36.407	64.203	56.802	96.305
	0.3	37.745	55.359	56.617	83.039	84.926	124.559

* Y=0

Chat 3 and 4 sows the variation of maximum torsional moment at column 2 in static and dynamic method of analysis respectively with eccentricity ratio. It can see that as eccentricity ratio increases maximum torsional moment also increase.



Chat 3: Variation of maximum torsional moment at column-2 in equivalent static force method

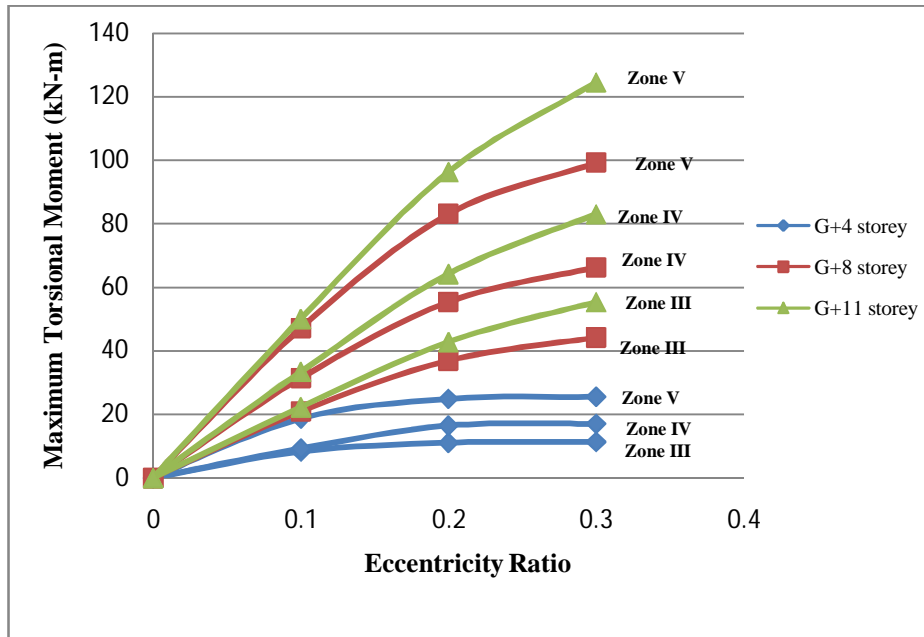


Chart 4: Variation of maximum torsional moment at column-2 in response spectrum method

The torsional moment along Y-axis is zero as the mass distribution along Y-axis is regular (*Y=0).

The value of maximum torsional moment at column 2 in static analysis is less compared to response spectrum method. For irregular structures static analysis alone is not sufficient and it necessary to provide dynamic analysis.

VI. CONCLUSION

It has been observed that the different centre of buildings like centre of rigidity and centre of mass have a great impact on seismic response of the building system as torsion generated depends upon the position of centre of mass and centre of rigidity of the structures. As the eccentricity ratio increases maximum torsional moment also increases. The study concludes that, it is important to have regular as well as uniform load distribution around the building, therefore as far as possible irregularities must be avoided in the buildings. But, if irregularities have to be introduced for any reason, they must be designed properly.

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