Australian Journal of Basic and Applied Sciences, 7(13) November 2013, Pages: 16-23

AENSI Journals
Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Influence of Torsional Irregularities of RC Buildings in High Seismic Zone

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ARTICLE INFO

Article history:
Received 12 October 2013
Received in revised form 14 November 2013
Accepted 15 November 2013
Available online 15 December 2013

Keywords:
Seismic behavior, Irregularity, Torsional, Response Spectrum, Re-entrant Corner, High Seismic Zone

ABSTRACT

Since the earthquakes are the most unpredictable and devastating of all natural disasters, it is very essential to identify the behavior of buildings, especially their torsional behavior during an earthquake. The proposed study made an attempt to realise the seismic response of the structures, for various location of shear walls on RC building having re-entrant corners during a devastating earthquake (high seismic zone). In this study a five storey-high building on six different location of shear walls was observed. The guidelines and the methodology of the Indian standard of practice IS 1893 (Part I) : 2002 is used to analyse the structures. The present work also considered the accidental torsion of both negative and positive X and Y directions. The results proved that the structures are more vulnerable when they are more irregular, and also the eccentricities between center of mass and center of resistance are more significant to the torsional behavior of structures during an earthquake.

To Cite This Article: Amin Alavi, Prof. P.Srinivasa Rao, Influence of Torsional Irregularities of RC Buildings in High Seismic Zone. ***Aust. J. Basic & Appl. Sci.****, 7(13): 16-23, 2013*

INTRODUCTION

Past earthquakes damages have proved that, structural irregularities to wit plan irregularity role play quite considerably (Costa, Anibal G., Carlos S. Oliveira and Ricardo T. Duarte. 1988). Hence, in order to identify the behavior of the structures especially torsional behaviour during an earthquake and to withstand the earthquake disaster force on plan irregularities, this type of irregularity was observed. This irregularity are considered as per the Indian standard code IS 1893 (Part I): 2002. This paper develops a linear model for plane moment resisting frames connected to shear walls without any setback and sudden interruption by rigid diaphragm and applied it to a five storey building with six different shear walls location. All the buildings were analysed by ETABS software of version 9.7.

In this case, the design engineers can save many lives and engineering properties as much as possible. In order to quantity the effect of frequent minor earthquakes as well as major earthquakes and also the performance level of the structures there are as many as 100 guidelines and standard codes all over the world. So that, it is very important to choose one of the guidelines from all to design the structures for even strong earthquakes.

In case, the structure designers and architects must work together in all over design procedure to avoid undesirable characteristics and they must choose the favourable features and the best building geometrical configurations (Banginwar, Rucha S., M. R. Vyawahare and P. O. Modani. 2012). When a building located in a high seismic zone, the structural engineer's role becomes more challenging. Therefore, the designers and architects need to understanding of the behavior and seismic response of plan irregular as best as vertical irregular buildings completely (Dubey, S K and Sangamnerkar. 2011).

Generally, we receive two types of structures, irregular configuration and asymmetrical building. In case of irregular configuration overall there are two types of irregularity such as plan and elevation. 0 shows the different kinds of irregularities in plan and elevation (IS 1893(Part 1): 2002). In case of asymmetric building basically, there are two kinds of symmetries, geometrical and structural. The geometrical symmetry is nothing by geometrical irregularity whereas the structural asymmetric means that, the center of rigidity (C.R) of the building does not coincide with its center of mass (C.M). The eccentricity between the center of rigidity and mass produce torsion and stress concentration (Banginwar, Rucha S., M. R. Vyawahare and P. O. Modani. 2012). This torsion just occurs because of unequally loaded. If there is torsion, the building will rotate about its center of rigidity, due to the torsional moment about the center of structural resistance (Duggal, S.K. 2011). Thus, the designers prefer to use symmetrical forms rather than asymetrical ones.

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0 shows how torsional effects develop in a building and 0 displays that the implication of torsion irregularity.

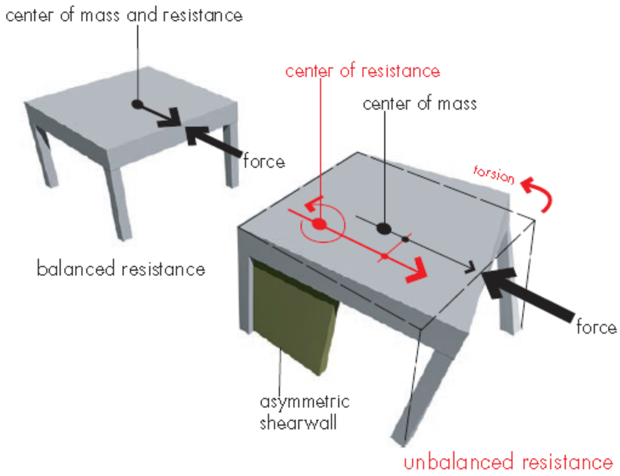
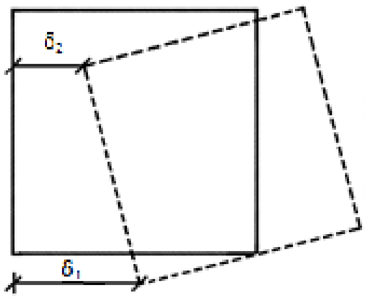


Fig. 1: How Torsional Effects Develop in A Building (courtesy: FEMA 454).

δ_{AVE} = Storey Drift $(\delta_1 + \delta_2)/2$.



IF $\delta_1 > 1.2\ \delta_{AVE}$
Torsional Irregularity

Fig. 2: The Implication of Torsion Irregularity.

The aim of the study:

To identify the maximum lateral top storey displacements, storey drifts of plan irregularity with accidental torsion and also to obtain the most vulnerable building among them.

Scope of the study:

The proposed work attempts to evaluate the maximum lateral top displacement and storey drift of plan irregular reinforced concrete building by the use of various analytical approaches (linear and nonlinear). The building irregularity involves plan irregularity i.e, re-entrant corners. It was examined in terms of base shear, lateral top displacement, storey drift and so on by the help of IS-1893 (part I): 2002. The whole models were analysed by ETABS software 9.7 version.

Table 1: Types of Irregularities [IS 1893].

Plan irregularity	Vertical irregularity
Torsion irregularity	Stiffness irregularity
Re-entrant corners	Mass irregularity
Diaphragm discontinuity	Vertical geometric irregularity
Out of plane offsets	In plane discontinuity in vertical elements resisting lateral force
Non parallel system	Discontinuity in capacity –weak storey

Methodology:

Illustrative examples:

The plan consists of 6x5 beys of equal length of 4m. All the buildings considered are dual system of ductile shear wall with special reinforced concrete moment resisting frame (SMRF) of 5 storey high with six different location of shear walls. The building is assumed as commercial complex. A regular location of shear wall served as a comparison.

0 shows the overall structural and earthquake data and 0 represents an isometric view of the proposed building.

Table 2: Structural and Earthquake Data.

Type of building	Commercial
No. of storey	5
Storey height	3.6 m
Slab thickness	15.0cm
Shear wall thickness	30.0cm
Grade of concrete	M-25.0
Grade of steel	Fe-415.0
Concrete density	25.0 KN/m^3
Zone	v (0.36)
Importance factor	1.0
Response reduction factor	4
Type of soil	Medium (2)
Damping ratio	5.0%

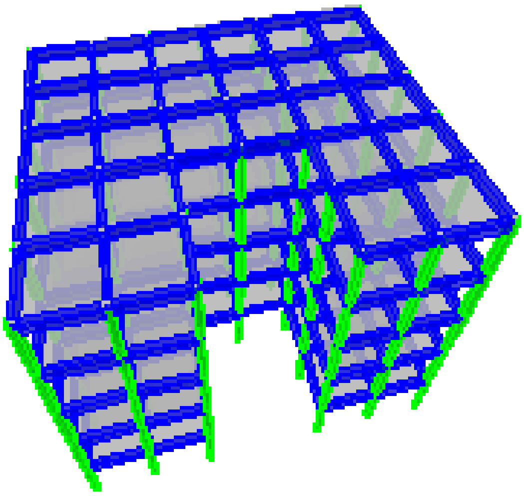


Fig. 3: Isometric View of the Proposed Building.

The buildings are represented as shown as below.

- M_1:the first model is a re-entrant corner in U shape and four shear walls which has 41.6% eccentricity in X and 35.5% in Y direction.
- M_2: the second model is a re-entrantcorner in U shape and four shear walls which has 33.33% eccentricity in X and 25.5% in Y direction.
- M_3: the third model is a re-entrantcorner in U shape and four shear walls which has 25.0% eccentricity in X and 15.5% in Y direction.
- M_4: the fourth model is a re-entrantcorner in U shape and four shear walls which has 16.67% eccentricity in X and 5.5% in Y direction.
- M_5: the fifth model is a re-entrantcorner in U shape and four shear walls which has 8.33% eccentricity in X and -4.5% in Y direction.
- M_6: the sixth model is a re-entrantcorner in U shape and four shear walls which has 0.0% eccentricity in X and -4.5% in Y direction.

0 Represents building models.

Analysis methods:

Earthquake analysis methods are generally classified as two types, static analysis and dynamic analysis. In these, both methods are subsequently categorized as linear and nonlinear.

In addition, the linear static analysis also called as equivalent static analysis method which can be used for regular structure with limited heigh. And the non linear analysis method known as pushover analysis. the linear dynamic analysis is divided by two several kinds, response spectrum method (RSM) and elastic time history method. Eventually, the non linear dynamic analysis or inelastic time historey method.

In this paper, the buildings have been analysed by two different kinds of analysis methods such as static linear analysis which is also known as equivalent static and linear dynamic method i.e. Response spectrum method.

Equivalent static method:

Equivalent static method of analysis is a linear static procedure, in which the response of the building is assumed as linear elastic manner. The analysis is carried out as per IS-1893 (part I): 2002.

Response spectrum method:

Since the response spectrum method is one of the linear dynamic methods, it is very suitable when the structural loads are small.

The response spectrum method plays an important role in practical analysis of multistory buildings for earthquake motions. The maximum response of the building is estimated directly from the elastic or inelastic design spectrum characterizing the design earthquake for the site and considering the performance criteria for the building (A.K., Chopra and Cruz E. F. 1986 and Jaiswal, Dr. O. R. 2000).

Most of the standard building code characteristic for earthquake motions are the basis on simplifications of the response spectrum method, so this method is extremely significant in the design procedure and also to select the best model for the proposed building.

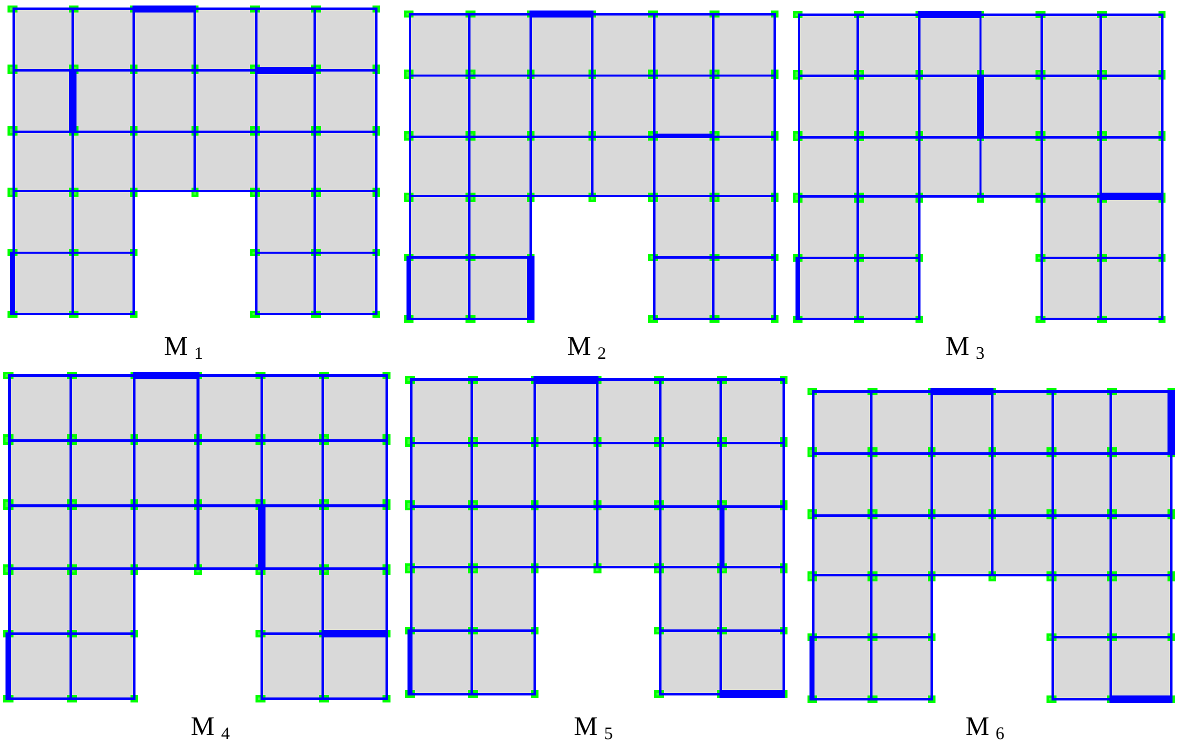


Fig. 4: Building Models.

RESULTS AND DISCUSSION

Fundamental natural periods and vibration modes:

The fundamental natural periods and vibration modes have been considered to identify the dynamic properties of the building analysed. 0 represents the first, second and third modes of vibration of six different location of shear walls. The first mode of M_1 displays that all floors have been rotated. This rotate is the same as M_2, whereas M_4, M_5 and M_6 moved toward the Y - direction. The second mode shows all models of building moved along the X - direction, whereas M_1, M_2 and M_3 moved along the Y - direction too.

In the third mode every building rotated. Among of them M_1 rotated in the opposite direction of its first mode. Like M_1, M_5 and M_6 twisted in a similar direction, whereas M_2 and M_3 twisted in the different direction.

0 shows the fundamental natural period of vibration of the first, second and the third mode.

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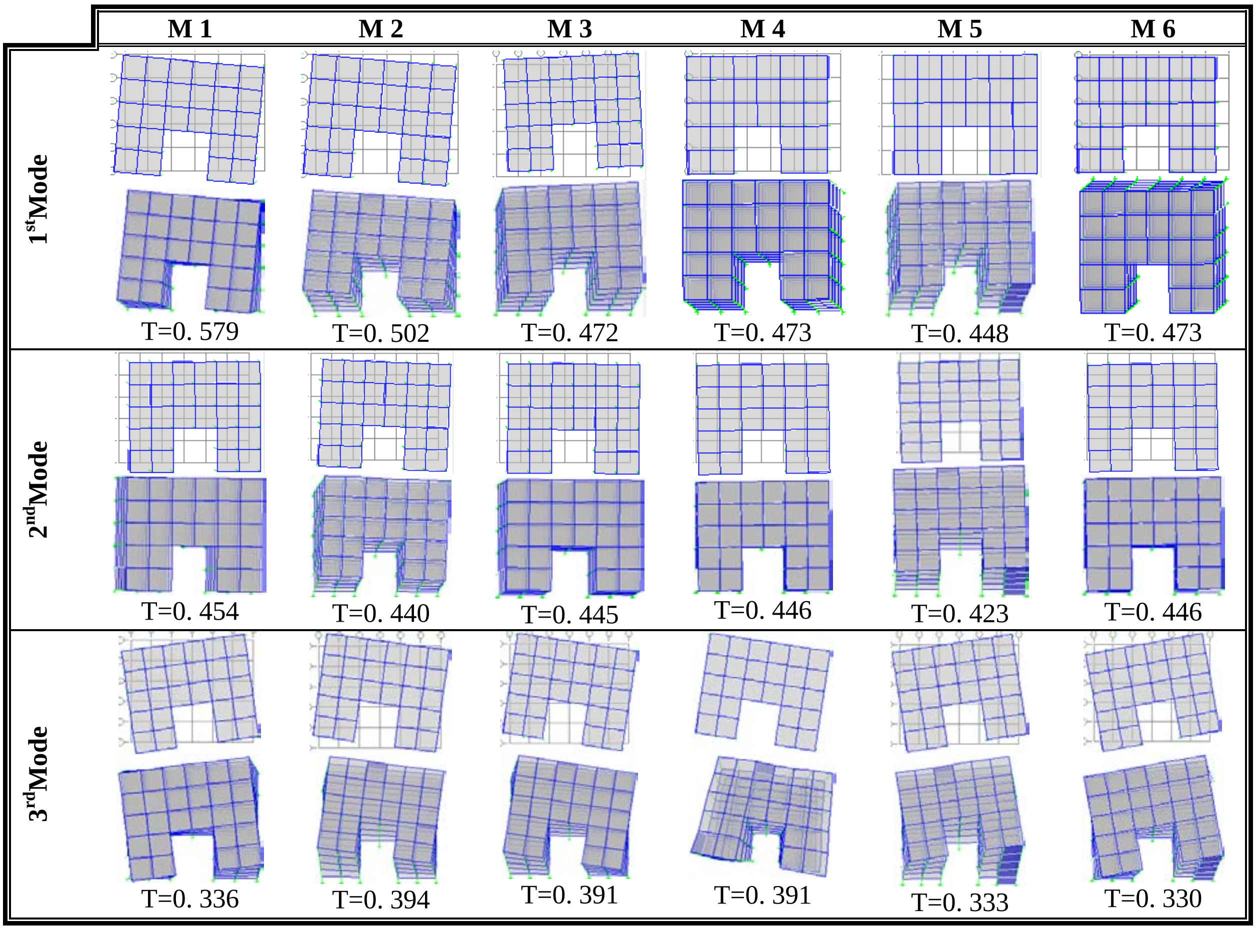

Fig. 5: Fundamental Natural Periods and Vibration Modes.

Response spectrum analysis:

0 contains the maximum top storey displacement towards X – Y and Z - directions, and 0 displays the maximum storey drift in both X and Y - directions.

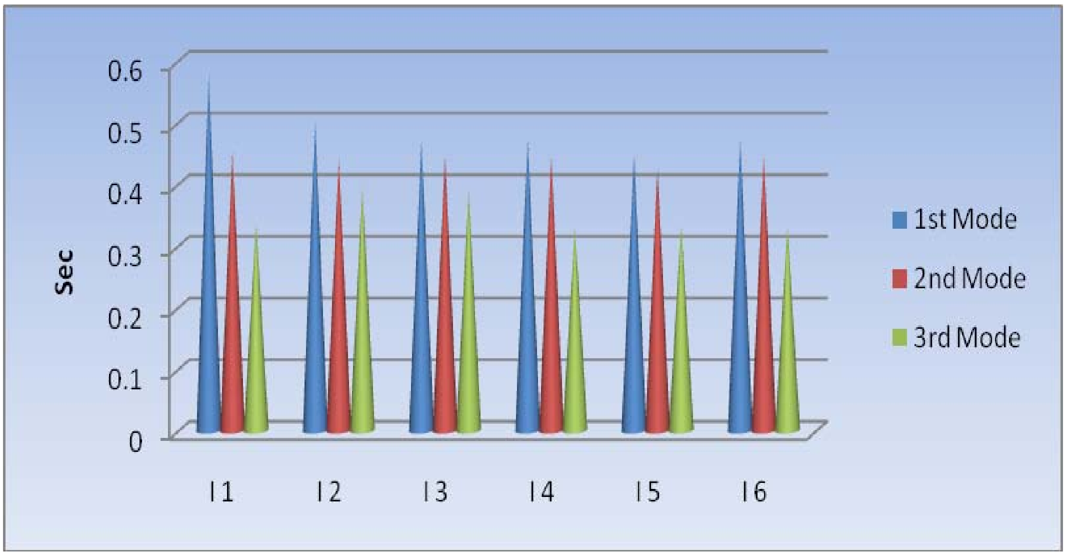

Fig. 6: Fundamental Natural Period of Vibration in Sec.

The results have proved that the displacements in Y - direction is much more than X -direction for M_1 and M_2 which means when the building is asymmetric about one direction there is more displacement about its direction. As the 0 and 0 imply in M_3 the displacement in Y - direction is just slightly higher than X - direction. Also it can be seen that the M_4, M_5 and M_6 have the similar displacement in both X and Y - directions, which the eccentricity is less than 20% of dimensions of the building. These results have demonstrated behavior of torsional irregularities.

The displacements in Z - direction don't depend on irregularity, in other words, the plan irregularity has no effects on the Z - direction. As the 0 implies the Z - displacements have just slightly different from each other.

0 displays the comparison of base shear for building models in both X and Y directions.

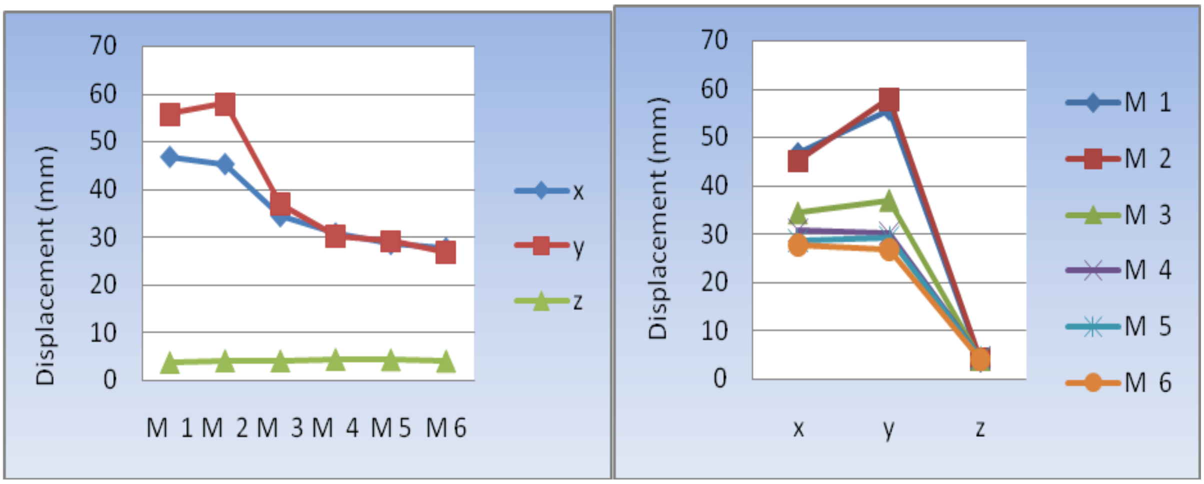

Fig. 7: Maximum Lateral Top Displacement.

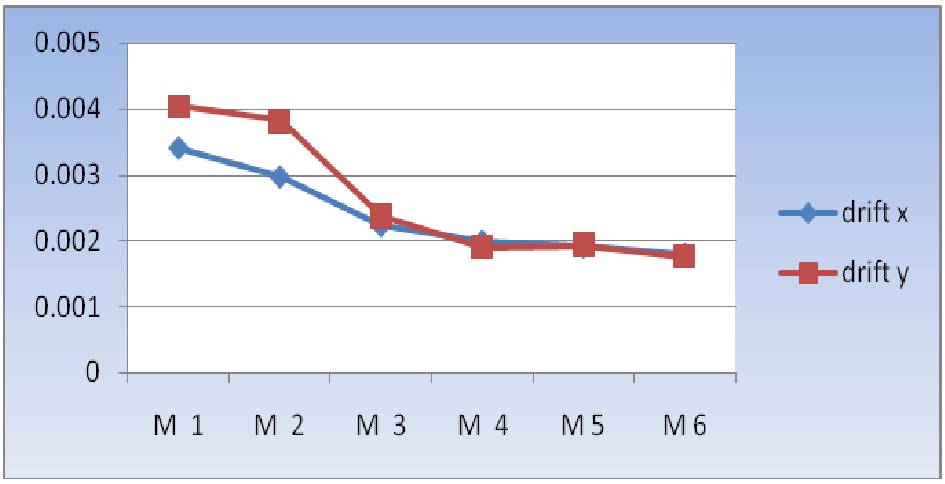

Fig. 8: Maximum Storey Drift.

Table 3: Maximum Lateral Top Displacement And Storey Drift.

	M 1	M 2	M 3	M 4	M 5	M 6
X	46.72	45.21	34.36	30.73	28.54	27.62
Y	55.74	57.97	36.96	30.15	29.13	26.74
Z	3.75	4.11	4.07	4.39	4.31	4.04
Drift X	0.003	0.003	0.002	0.002	0.002	0.002
Drift Y	0.004	0.004	0.002	0.002	0.002	0.002

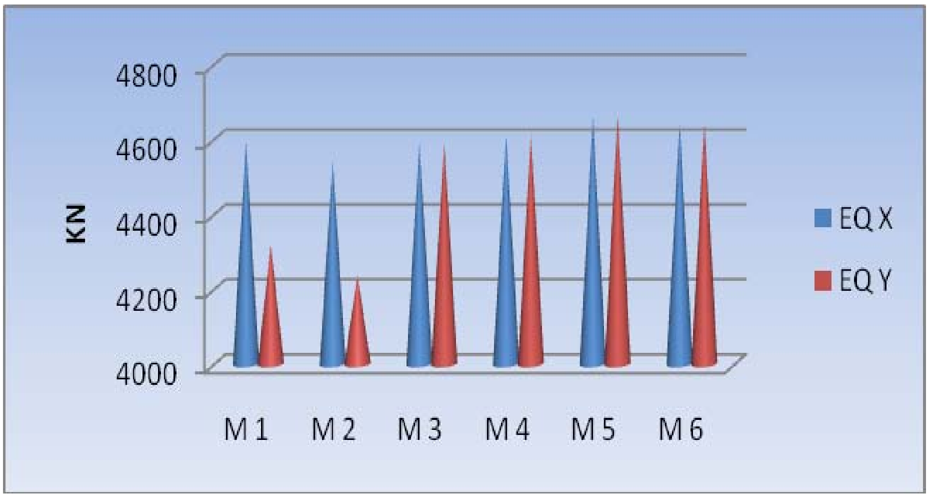

Fig. 9: Comparison of Base Shear for Both X and Y Direction.

Conclusions:

In this paper, the torsional response of plan asymmetric RC building structures for predicting the seismic responses were investigated. The linear dynamic response of plan asymmetric with different eccentricities were initially compared, in order to evaluate the effects of the torsional response.

- ✓ The results evidenced that the model one with 41.6% in X and 35.5% eccentricity in Y direction has the maximum storey drift which is 0.004 in the Y direction. So we can conclude that the structures are more vulnerable when they are more irregular.
- ✓ The linear analysis have been proved the significant information for torsional behavior of plan or/and mass asymmetric structure.
- ✓ The eccentricities between center of mass and center of resistance various are more significant to the torsional behavior of structures during an earthquake.
- ✓ When the eccentricity between center of mass and center of rigidity is less than 20% of its dimensions, the displacement is less in both X and Y directions than the ones have more eccentricity. This proved the torsion irregularity which mentioned in the code. In other words if the eccentricity between center of mass and center of resistance of the building is less than 20% of its dimension, we can ignore the torsional irregularity.

Since torsion is the most critical factor leading to major damage or complete collapse of buildings therefore, it is very essential that irregular buildings should be carefully analyse for torsion and the designer should avoid these types of structures as much as possible.

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