Seismic Analysis of Buildings Symmetric & Asymmetric in Plan

B K Raghuprasad[1], Vinay S[2], Amarnath.K[3]
[1]Professor (retired) Indian Institute Of Science, Dept. of Civil Engineering, Bengaluru, Karanataka, India.
[2]Student M.Tech structural engineering, The Oxford College of Engineering, Bengaluru, , Karanataka, India
[3]Professor & HOD of civil engineering department, The Oxford College of Engineering, Bengaluru, , Karanataka, India

Abstract

Structural asymmetry can be a major reason for the poor performance of buildings under severe seismic loading, Asymmetry contributes significantly for translational-torsional coupling in the seismic response which can lead to increased lateral deflections, increased member forces and ultimately collapse. In this paper the inelastic seismic behaviour of symmetric and asymmetric single & multi-storied buildings are studied. The effects of torsion on buildings are investigated. There is an increase in shear in columns and the rotation of columns need some special attention. Although seismic response of building asymmetric in the plan has been studied in the past in great detail, the contribution of the torsional resistance of the individual columns in total torsional response is not well understood. In order to study that, in the present work a single storey structure (asymmetric plan) with three degrees of freedom is modelled in two ways, viz. Once with column replaced by springs and next with columns modelled is they are. In the latter case the torsional rotation of individual columns can be obtained while in the former case, it is not possible. Considerable difference between the two responses is observed.
Further a 11 storey building with eccentricity same on all the floors (uniform eccentricity) and the other with eccentricity varying over the floors have been subjected to EL-Centro 1940 N-S component ground motion input and the responses like spectral displacement, spectral acceleration, spectral velocity are obtained is there considerable difference between the two.

Keywords — *Symmetric & Asymmetric buildings, spring model, base shear, time history, spectral acceleration, spectral displacement, spectral velocity*

I. INTRODUCTION

The torsional effects that are sometimes difficult to assess due to a lack of symmetry in plan, and can be very adverse. The preferred method of minimizing torsional effects is to select floor plans that are symmetric in the floor plan. Complex plan buildings should be divided by seismic separation joints, introduced between rectangular blocks. The buildings behaviours during earthquakes will be satisfactory only if all measures are taken to provide a favourable mechanism of failure. A special account must be taken so that torsional effects do not preclude or endanger the global ductile behaviour of the structure. Buildings with an asymmetric distribution of strength and stiffness in plan undergo coupled torsional and lateral motions during earthquakes. Because of torsion, the seismic demands of asymmetric buildings increase above those required by just translational deformation. It is well-known that the larger the eccentricity between the centre of mass and the centre of stiffness, the larger is the torsional effects. An important aspect of the inelastic behaviour of asymmetric structures is the considerations of the degree of control over inelastic twist. One of the design aims should be to restrain the system against unrestricted inelastic twist. Torsional vibrations cause significant additional displacements and forces in the lateral load resisting elements. However, the design of the majority of buildings relies on inelastic response, where torsional motion leads to additional ductility demands. Hence, the relevance of current code recommendations, based on elastic torsional response, is open to question. More importantly torsional resistance offered by the individual columns is quite significant and must be quantified.

A numerical study has been reported on a single storey building having 6 columns and rigid diaphragm [1] Time history investigation and incremental dynamic analysis have been performed. Ceballos et al. [3] Examined parametric 3D models of one-storey RC structures with in-plan asymmetry in two directions and elastic behaviour. Nonlinear seismic response of building asymmetric plan is reported. [6] Torsion caused by asymmetry results in increasing base shear. [13] Some columns carry more torsional moments and need to be taken care of in design. The columns of peripheral frames need to be taken care of in design with some modifications.

II. DETAILS OF MODEL AND ANALYSIS

A single storey frame with 150mm thickness of slab resting on four numbers of beams 300 x 300mm cross section of span 4m and 300 x 300mm four numbers of columns is considered for the analysis. In the above model we change the sizes of two columns to 400 x 400mm to make it asymmetric in plan. The above frame has been modelled in two ways,

- COLUMNS REPLACED BY SPRINGS
- COLUMNS MODELLED AS THEY ARE

The format is called the spring model and the latter is called the column model. In the spring model the stiffness of the spring is taken a 12EI/H3. Eleven storey symmetric building model contains nine columns 300x300 mm size and span 4 m, beam size 300 x 300 mm and slab 150mm. In 11 storey asymmetric building model the plan is same as a 11 storey

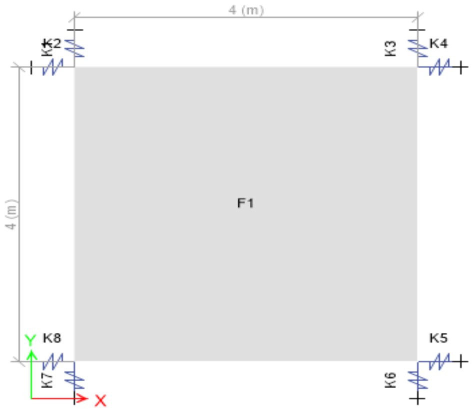

Fig. 1 Single Storey Building Symmetric in Plan with Symmetric Spring on Columns, (Spring Model)

symmetric building model, the beam and slab sizes, is same, only one side column sizes are varying for different floor levels bottom 4 floors column size 600 x 600mm, next 4 floors 500 x 500 mm, remaining 400 x 400 mm. Figs 1 to 3 show the all models.

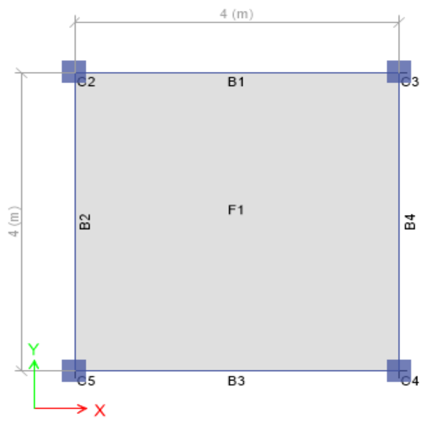

Fig. 2 Single Storey Building Symmetric in Plan with Column Modelled as they are

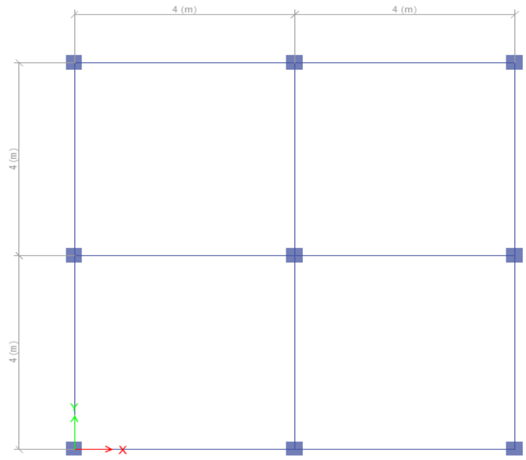

Fig. 3 11 Storey Building with the Same Eccentricity at Each Floor Level. That is Eccentricity Uniform, (uniform Eccentricity Tall Building).

III. RESULT AND DISCUSSION

A. Free vibration Analyses

Natural frequencies and mode shapes have been obtained for all the types of frames. The frequencies and periods are shown in below table been obtained for all the types of frames.

TABLE I : MODAL PERIODS AND FREQUENCIES OF SINGLE STOREY SPRING MODEL

Mode	Symmetric spring model		Asymmetric spring model	
	Period	Frequency	Period	Frequency
	Sec	cyc/sec	Sec	cyc/sec
I	0.109398	9.1409	0.095394	10.483
II	0.109398	9.1409	0.077252	12.945
III	0.109398	9.1409	0.075875	13.18

TABLE III : MODAL PERIODS AND FREQUENCIES OF SINGLE STOREY COLUMN MODEL

Mode	Symmetric column model		Asymmetric column model	
	Period	Frequency	Period	Frequency
	sec	cyc/sec	sec	cyc/sec
I	0.145798	6.8588	0.129471	7.7237
II	0.145798	6.8588	0.119219	8.3879
III	0.134942	7.4106	0.102046	9.7995

TABLE IV : MODAL PERIODS AND FREQUENCIES OF 11 STOREY BUILDING

Mode	Symmetric column model		Asymmetric column model	
	Period	Frequency	Period	Frequency
	sec	cyc/sec	sec	cyc/sec
I	2.061709	0.48503	1.753041	0.57044
II	2.032500	0.492	1.740951	0.5744

III	1.667369	0.59975	1.305998	0.7657
IV	0.673251	1.4853	0.567522	1.762
V	0.664471	1.505	0.56463	1.7711
VI	0.549523	1.8198	0.439858	2.2735
VII	0.385166	2.5963	0.32025	3.1226
VIII	0.382744	2.6127	0.309688	3.2291
IX	0.321925	3.1063	0.247071	4.0474
X	0.271631	3.6815	0.215792	4.6341
XI	0.264881	3.7753	0.203014	4.9258
XII	0.232614	4.299	0.16207	6.1702

B. Time History

The models are subjected to EL-Centro 1940 N-S component earthquake ground motion. . In this present work El centro data is used to conduct a time history analysis using

SAP 2000 to get the response of structure (Symmetric and asymmetric buildings). The response history plots are taken for comparison of Symmetric and asymmetric buildings.

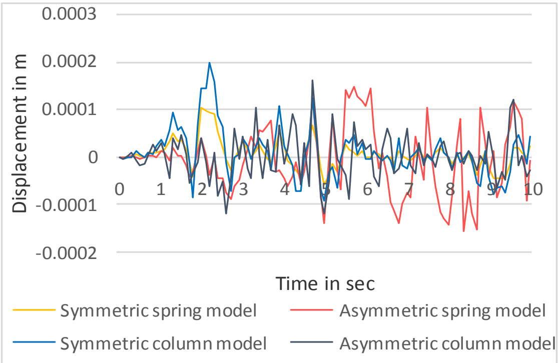

Fig 4 Response History for El-Centro N-S component 1940 of Single Storey Building Models

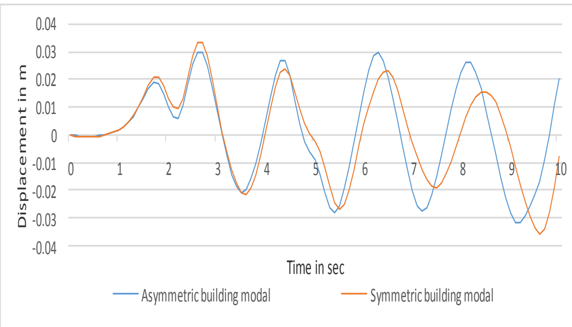

Fig 5 Response History for El-Centro N-S Component 1940 of 11 Storey Building Models

C. Spectral Displacement and Spectral Acceleration

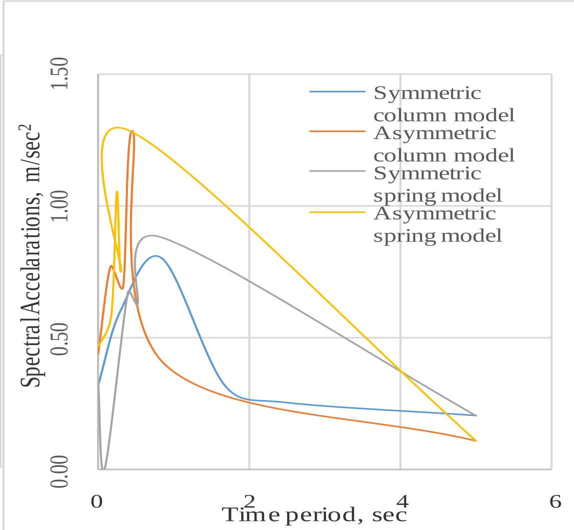

Fig 6 Spectral Displacement vs Time Period of Single

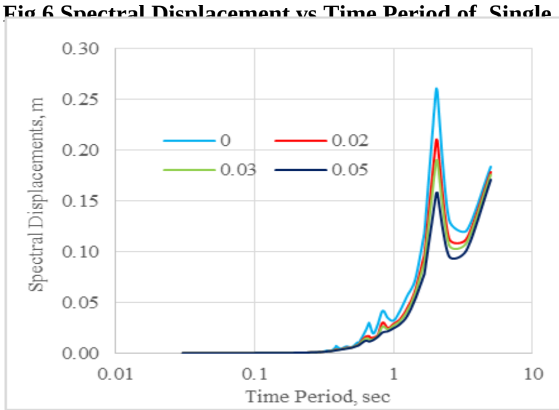

Fig 7 Spectral Acceleration vs Time Period of Single

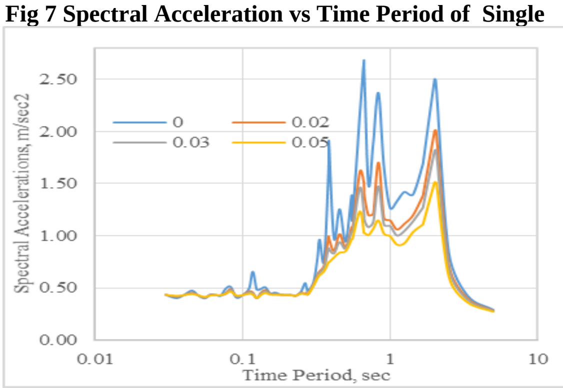

Fig 8 Spectral Displacement vs Time Period of 11 Storey Symmetric Building Model at Top Floor Joint for Different Damping Ratio

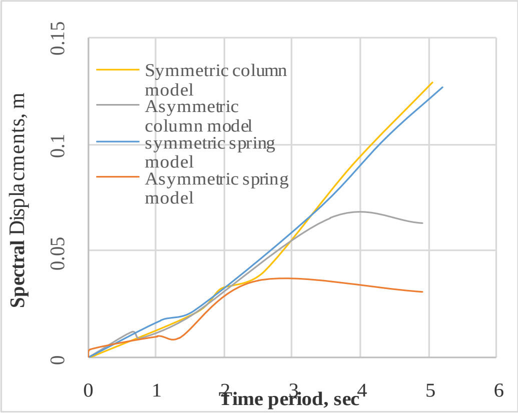

Fig 9 Spectral Displacement vs Time Period of 11 Storey Asymmetric Building Model at Top Floor Joint for Different Damping Ratio

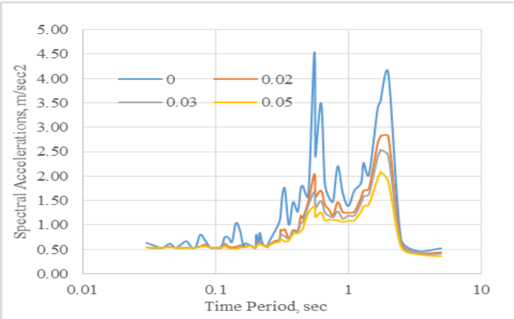

Fig 10 Spectral Acceleration vs Time Period of 11 Storey Symmetric Building Model at Top Floor Joint for Different Damping Ratio

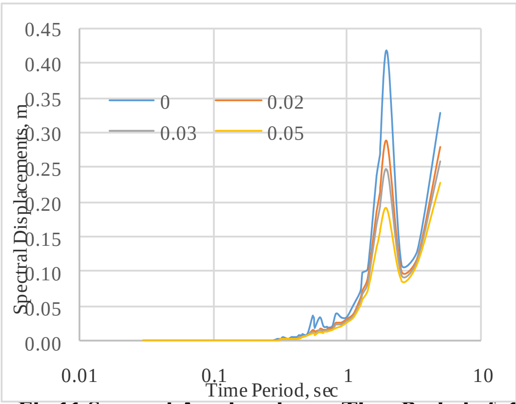

Fig 11 Spectral Acceleration vs Time Period of 11 Storey Asymmetric Building Model at Top Floor Joint for Different Damping Ratio

Table Iv: Maximum Values Of Displacement

Type of model	Time in sec	Max value of displacement in m
Symmetric Spring model	2.00	1.02E-04
Asymmetric Spring model	5.70	1.48E-04
Symmetric column model	2.20	1.98E-04
Asymmetric column model	4.70	1.61E-04
11 Story symmetric building	2.70	3.37E-02
11 Story asymmetric building	2.60	2.903E-02

TABLE V: BASE SHEAR

Type of model	Base shear in kN
Symmetric Spring model	7.105
Asymmetric Spring model	6.076
Symmetric column model	10.046
Asymmetric column model	10.528
11 Story symmetric building	159.355
11 Story asymmetric building	194.267

It can be observed from tables 1 to 3 that the natural frequencies have increased when eccentricity is introduced or in another words, the natural frequencies of an asymmetric structure are more than those of a symmetric structure. The natural frequencies of a column model are less than those of a spring model, because the columns where as they are make it more flexible. When springs are included to represent columns the stiffness of the spring is taken as 12EI/h3 which is that of a column restrained against rotation at both the ends. Therefore obviously overestimates the stiffness.

The time histories of the response are shown in fig 4 & 5. The maximum values are picked from the time history and are shown in table 6. It can be observed that the response of the asymmetric spring model is more compared to that of the symmetric model. However the response of the symmetric column model is more compared to that of the asymmetric column model.

IV. CONCLUSIONS

The natural frequencies of an asymmetric spring model are greater than those of symmetric spring model while the rotations about the vertical axis through the mass centre of an asymmetric model are lesser than those of symmetric model.

Maximum displacement of asymmetric column model due to an earthquake ground motion (eccentricity 17%) is greater than that of symmetric column model.

Similarly, maximum displacement of an asymmetric spring model due to an earthquake is greater than that of symmetric spring model.

The base shear of an asymmetric 11 story building (eccentricity 11%) is larger than that of a symmetrical 11 story building.

REFERENCES

[1] Lucchini Andrea, Monti Giorgio and Kunnath Sashi. “Non linear response of two way asymmetrical single storey building under bi-axial excitation.” Journal of structural engineering, ASCE (January, 2011), 137(1), pp. 34-40

[2] Julio J HERNÁNDEZ, Oscar A LÓPEZ, “Influence of Bidirectional Seismic Motion on the Response of

Asymmetric Building" by 12 World Conference on Earthquake Engineering, 2000, 1813, pp. 1-8

[3] Dorde Ladinovic, "Nonlinear seismic analysis of asymmetric in plan building" by FACTA UNIVERSITATIS: Architecture and Civil Engineering Vol. 6, No 1, pp. 25 – 35, 2008,

[4] Raúl González Herrera1, Consuelo Gómez Soberón, "Influence of Plan Irregularities of Buildings" by 14th World Conference on Earthquake Engineering, 2008,

[5] Andrea Lucchini, Giorgio Monti, Enrico Spacone, "Asymmetric-Plan Building: Irregularity Levels and Nonlinear Seismic Response" by E.Cosenza (ed), Eurocode 8 Perspectives from the Italian Standpoint Workshop, pg 109-117, Doppiavoce, Napoli, Italy, 2000

[6] N. Özhendekci, Z. Polat, "Torsional Irregularity of Buildings" by 14 World Conference on Earthquake Engineering, 2008,

[7] Rucha S. Banginwar, M. R. Vyawahare, P. O. Modani, "Effect of Plan Configurations on the Seismic Behaviour of the Structure by Response Spectrum Method" by International Journal of Engineering Research and Applications(IJERA), May-June 2012, 2(3), pp. 1439-1443

[8] Christos A. Zeris, Stephen A. Mahin, "Behaviour of Reinforced Concrete Structures Subjected to Biaxial Excitation" by Journal of Structural Engineering (ASCE), Sept 1991, 117(9), pp. 2657-2673

[9] Christos A. Zeris, Stephen A. Mahin, "Behaviour of Reinforced Concrete Beam-Columns under Uniaxial Excitation" by Journal of Structural Engineering (ASCE), April 1998, 114(4), pp. 804-820

[10] H. P. Hong, "Torsional Responses under Bi-Directional Seismic Excitations: Effects of Instantaneous Load Eccentricities" by Journal of Structural Engineering (ASCE), March 2012,

[11] Juan C. De La Llera, Anil K. Chopra, "Estimation of Accidental Torsion Effects for Seismic Design of Buildings" by Journal of Structural Engineering (ASCE), Jan 1995, 121(1), pp. 102-114

[12] Czeslaw Bajer, "Time Integration Methods – Still Questions" by Theoretical Foundations of Civil Engineering, Warsaw, 2002, pp.45-54

[13] S. J. Patil, "Seismic Response of Asymmetric Buildings" by International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol. 2 Issue 4 July 2013, pp. 365-369

[14] Dj. Z. Ladjinovic and R. J. Folic, "Seismic analysis of asymmetric in plan buildings", The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[15] Raghu Prasad B K and Saibaba S, "Influence of shape in plan of building on the inelastic earthquake response", Proceeding of 8th European conference on earthquake engineering, Libson, Portugal, pp 17-24, September 7-12,1986.

[16] Raghu Prasad B K and Jagadish K S, "Inelastic torsional response of a single storey framed structure", Journal of engineering mechanics, ASCE, vol.115, number 08, pp 1782-1797, August 1989.

[17] M. Shahrouzi and A.A. Rahemi "Improved seismic design of structural frames by optimization of equivalent lateral load pattern", International Journal of Civil Engineering, Vol. 12, No. 2, pp 256-267, Transaction A: Civil Engineering, June 2014.