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Asymmetrical Buildings Subjected to Seismic Forces: Torsional Behaviour

Mr. A. A. Kusanale[1], Mr. S. A. Patil[2], Mr. N. S. Patil[3], Mr. S. P. Patil[4]
[1,2,3,4] *Assistant Professor At Padmbhushan Vasantrao Dada Patil Institute of Technology, Budhgaon.4163054*

Abstract- **Recently earthquakes have shown that the irregular distribution of mass, stiffness and strengths may cause serious damage in structural systems. Due to several reasons structures acquire asymmetry hence Seismic demand in peripheral elements is enhanced. Torsional behaviour of asymmetric building is one of the most frequent causes of structural damage and failure during strong ground motions. A study on the influence of the torsional moment effects on the behaviour of structure is done by using Response spectrum method. Then a simplified nonlinear pushover analysis has been used to find structural descriptors required in seismic vulnerability assessment. Deformation demand for different story for low-medium rise framed building has been found by using software SAP2000.**

Index Terms **- Symmetric and Asymmetric plan, Earthquake, Torsion, Response spectrum, Pushover Analysis, Seismic Performance.**

I. INTRODUCTION

At present scenario many buildings are asymmetric in plan or in elevation based on the distribution of mass and stiffness along each storey throughout the height of the building. However an accurate evaluation of the seismic behavior of irregular buildings is quite difficult and a complicated problem Due to the variety of parameters and the choice of possible models for torsionally unbalanced systems, there is as yet no common agreement or any accurate procedure advised by researchers on common practice in order to evaluate the torsional effects. Seismic damage surveys and analyses conducted on modes of failure of building structures during past severe earthquakes concluded that most vulnerable building structures are those, which are asymmetric in nature. Asymmetric building structures are almost unavoidable in modern construction due to various types of functional and architectural requirements. Torsion in buildings during earthquake shaking may be caused from a variety of reasons, the most common of which are non-symmetric distributions of mass and stiffness Modern codes deal with torsion by placing restrictions on the design of buildings with irregular layouts and also through the introduction of an accidental eccentricity that must be considered in design. The lateral-torsional coupling due to eccentricity between centre of mass (CM) and centre of rigidity (CR) in asymmetric building structure generates torsional vibration even under purely translational ground shaking during seismic shaking of the structural systems, inertia force acts through the centre of mass while the resistive force acts through the centre of rigidity as shown in Fig.1

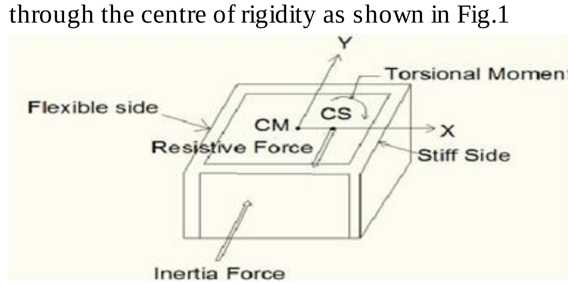

Figure 1. Generation of torsional moment in asymmetric structures

In order to design buildings in earthquake prone regions, seismic codes present different torsional provisions according to the seismicity of the region. Seismic provisions introduce design eccentricity to estimate the value of the torsion in buildings as accurately as possible. The dynamic eccentricity results from the irregular mass, resistance or stiffness distribution of the system, while the accidental eccentricity is expected to account for factors not explicitly considered, such as uncertain estimation of the mass, stiffness and rotational component, which is believed to play a highly important role.

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II METHODS OF SEISMIC ANALYSIS

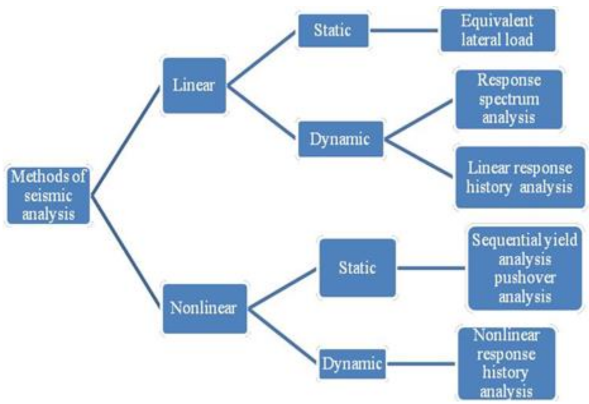

Figure 2. *Methods of seismic analysis*

Non-Linear Static Push-over Analysis

The pushover analysis of a structure is a static nonlinear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. On a building frame, plastic rotation is monitored, and lateral inelastic forces versus displacement response for the complete structure are analytically computed. This type of analysis enables weakness in the structure to be identified. The decision to retrofit can be taken in such studies. Two key elements of a performance based design procedure are demand and capacity. Demand is a representation of the earthquake ground motion. Capacity is a representation of the structures ability to resist the seismic demand. The performance is dependent on the manner that the capacity is able to handle the demand. In other words, the structure must have the capacity to resist the demands of the earthquake such that the performance of the structure is compatible with the objectives of the design. Once the capacity curve and demand displacement are defined, a performance check can be done. A performance check verifies that structural and nonstructural components are not damaged beyond the acceptable limit of the performance objective for the forces and displacements implied by the displacement demand. Non linear static pushover analysis was used to evaluate the seismic performance of the structures. The numerical analysis was done using SAP2000 and guidelines of ATC-40 and FEMA 356 were followed. The overall performance evaluation was done using capacity curves, storey displacements and ductility ratios. Plastic hinge hypothesis was used to capture the non linear behavior according to which plastic deformations are lumped on plastic hinges and rest of the system shows linear elastic behavior. The pushover or capacity curve represents the lateral displacements as the function of force applied to the structure. Location of hinges in various stages can be obtained from pushover curve as shown in Fig. 1. The range AB is elastic range, B to IO is the range of immediate occupancy, IO to LS is the range of life safety, and LS to CP is the range of collapse prevention [ATC-40]. If all the hinges are within the CP limit then the structure is said to be safe. However, depending upon the importance of structure the hinges after IO range may also need to be retrofitted.

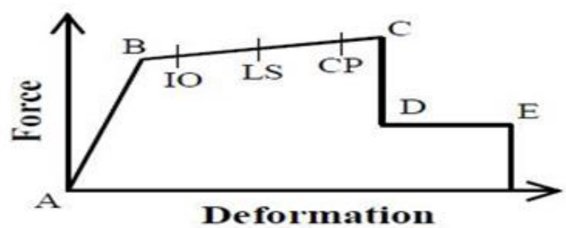

Figure 3. Different Stages of Plastic Hinge Formation.

III PROBLEM STATEMENT

Gravity load analysis and lateral load analysis as per the seismic code IS 1893 (Part 1): 2002 are carried out for three buildings one is symmetric and other two are asymmetric in plan for building height G+3 and G+6 and for comparison criteria is that numbers of columns are kept same for all three buildings and an effort is made to study the effect of seismic loads on them also determine torsional moments, base shear, displacement and time period by using response spectrum method and their capacity and demand is evaluated using nonlinear static pushover analysis guidelines given in FEMA-356 and ATC-40 by using software SAP2000.

Beam size –	0.30m x 0.45m
Column size –	0.30m x 0.45m
Thickness of slab –	150mm
Height of storied –	3m
Plinth height above GL –	2m
Unit weight of concrete –	25kN/m3
Live load on floor –	3kN/m3
Live load on roof –	2kN/m3
Grade of concrete –	M20
Grade of steel –	Fe415
Soil type –	Medium soil

Seismic zone –

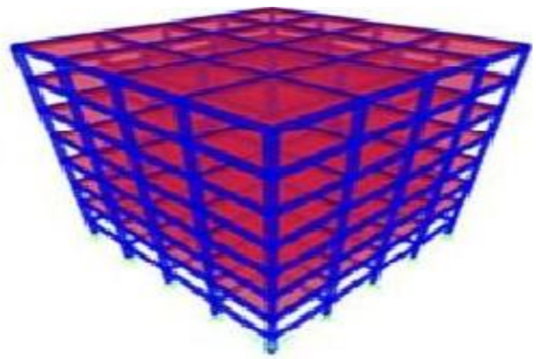

Figure 3(a). *Symmetric Building G+6*

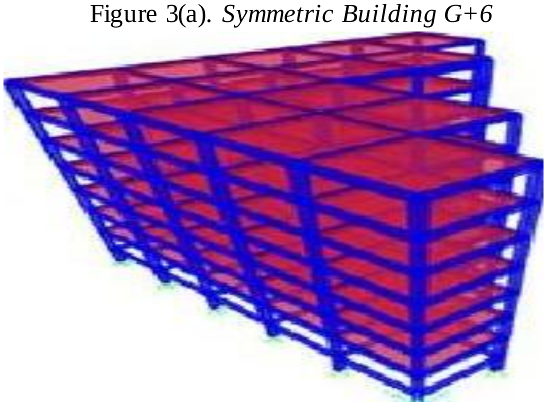

Figure 3(b). *L shape G+6.*

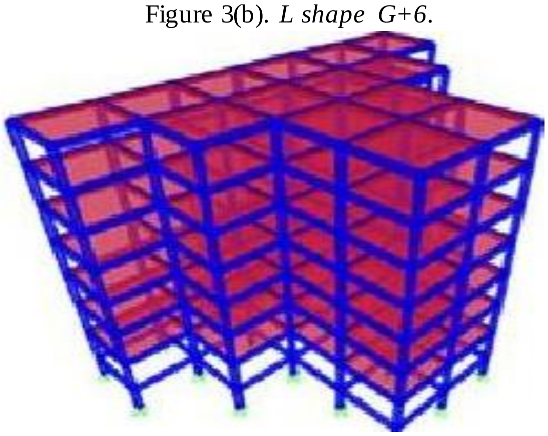

Figure 3(c). T *shape G+6*

IV RESULTS AND DISCUSSIONS

G+6 Storied building	Response spectrum method			
	Seismic weight (*kN*)	Time period (*sec*)	Base shear (*kN*)	Disp. (*mm*)
Symmetric	19796.87	1.48	548.5	11.88
L shape	17300.46	1.42	474.91	13.72
T shape	17300.46	1.45	488.64	12.52

Table 1. *Base shear and Time period*

	Torsional moment (*kN-mm*)			
	L shape		T shape	
	Column	Beam	Column	Beam
Story no 6	37.96	76.28	34.98	68.32
Story no 5	32.94	70.65	30.25	62.22
Story no 4	27.54	64.22	26.98	58.85
Story no 3	25.98	51.12	23.56	43.15
Story no 2	21.25	37.25	19.88	31.14
Story no 1	18.12	25.58	17.12	21.98

Table2. *Comparison of Torsional moments of column and beam*

G+6 Storied building	Design base shear (kN)	Performance point		Collapse Point	
		Base shear (kN)	Disp. (*mm*)	Base shear (kN)	Disp. (*mm*)
Symmetric	532.8	2319.47	60	3556.47	186.16
L shape	484.9	2177.3	68	3557.2	225.73
T shape	493.6	2224.5	68	3543.5	212.50

Table 3. *Performance and collapse point for different structures along x direction*

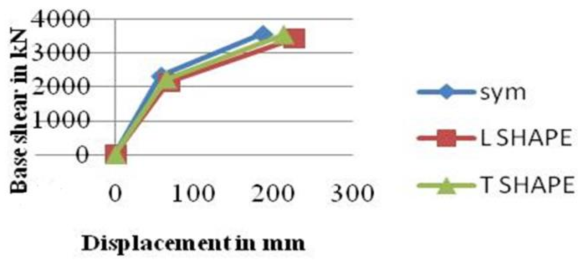

Figure 4. *Different Stages of Plastic Hinge Formation*

V. CONCLUSION

1. Time period and base shear calculation by using equivalent static method is approximately equal with response spectrum method in SAP.
2. While comparing the torsional moment (TM) in beam the result shows that for asymmetrical building the TM is more than symmetrical, therefore it is necessary to design the beam and column for torsional moment.
3. By using equivalent static method and response spectrum method in SAP it shows that, base shear and roof displacement for asymmetrical building is more than symmetrical building.
4. By using push over analysis performance of symmetrical building is better than asymmetrical building.
5. Formation of hinges in asymmetrical building is more and early than symmetrical building.

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