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STUDY OF TORSION IN BUILDING WITH HORIZONTAL AND VERTICAL IRREGULARITIES

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ABSTRACT: Irregularities are un-avoidable in construction of buildings; they constitute a large portion of the modern urban infrastructure. Many people are involved in constructing the building facilities, including owner, Engineer, contractor, architect and local authorities, contribute to the overall planning, and to its selection of building. This may lead to building structures with irregular distributions in their mass, stiffness and strength along the height of the building however the behavior of structures with these irregularities during earthquake has to be studied. And adequate precautions need to be taken. A detailed study of structural behavior of the buildings with irregularities is essential for design and behaviour in earthquake. The main objective of this study is to understand different irregularity and torsional response due to horizontal and vertical irregularity. In this study, it is intended to basically understand the behavior of the structure and hence structures with irregular shapes or plans have been considered. A set of eight different models are taken into account out of which the first model is with the regular structure, the second with both horizontal and vertical irregularities, three more models with horizontal irregularity and the remaining with vertical irregularity. Analysis is carried out using Equivalent static analysis and Response spectrum method. From the analysis it was observed that there is no torsion produced in the model one because of the symmetry in the building and the variation in the torsion is found in horizontal and vertical irregularities and the analysis is carried out for various factors like maximum displacement, maximum storey drift and base shear.

KEY WORDS: Torsion, Equivalent static analysis, Response spectrum method, Multi storey building, horizontal and vertical irregularities.

I. INTRODUCTION

If all the building elements are symmetrically arranged and earthquake ground motions would strike in the known directions it would be optimal. Due to lack of availability of land in big cities, architects usually go for the irregular building structures in order to make utilize maximum available land area and to provide proper light and ventilation in various building components. However, the structural irregularity is the result of a combination of both types that is horizontal and vertical. The horizontal irregularity may be classified on the bases of Asymmetrical plan shapes, Re-Entrant corners, Diaphragm discontinuity and irregular distribution of mass, strength, stiffness along plan etc., and the vertical irregularity may be classified on the bases of Mass, Strength, Stiffness and Setback. Due to one or more of such asymmetries, the structure's lateral resistance to the ground motion is usually torsionally unbalanced creating large displacement, drift and high force concentrations within the resisting elements which can cause severe damages and may lead to collapse of the structure.

CODE PROVISIONS IS1893 (part 1):2002

A structure is said to be irregular if the structure exceeds the limits as prescribed by different seismic design codes. The irregularity limits for both horizontal and vertical irregularities are described in Table.1

TYPE OF IRREGULARITY	IS 1893:2002
HORIZONTAL	
a) Re-entrant corners	Ri = 15%
b) Torsional irregularity	dmax = 1.2 davg
c) Diaphragm Discontinuity	Sd > 50% Od > 50%
VERTICAL	
a) Mass	Mi < 2 Ma
b) Stiffness	Si < 0.7Si+1 Or Si < 0.8 (Si+1 + Si+2 + Si+3)
c) Soft Storey	Si < 0.7Si+1 or Si < 0.8 (Si+1 + Si+2 + Si+3)
d) Weak Storey	Si < 0.8Si+1
e) Setback irregularity	SBi < 1.5 SBa

Table.1: code provisions

II. LITERATURE REVIEW

New Mark (1969), the first person to introduce the concept of accidental eccentricity which accounts for torsional vibration induced by the rotational excitation, in this paper it is concluded that the ratio of the accident eccentricity varies almost directly with the fundamental frequency of the vibration of the building. The building should be designed for high frequencies for large value of eccentricity rather than building with low frequency. Tso and Bozorgnia (1986), Irregular distributions of strength and stiffness are one of the major causes of failures during the earthquakes. Both of these irregularities are interdependent and to study the effect of these irregularities on seismic response, the researchers like Tso and Bozorgnia (1986) determined the inelastic seismic response of plan asymmetric building models with strength and stiffness eccentricity using curves proposed by Dempsey and Tso. Results of analytical study showed the effectiveness of the curves proposed by Tso and Dempsey except for torsionally stiff structures with low yield strength. Chandler et al. (1995) verified the torsional provisions prescribed by different codes of practice. For analytical study the authors considered two types of building models namely torsionally balanced (TB) and torsionally unbalanced (TU).The torsional unbalance in the building model was created by varying position of center of stiffness inducing stiffness eccentricity equal to 0.05b. The torsionally unbalanced building models were further divided into two types namely A1 and A2 having moderate and low torsional stiffness. Results of analytical studies showed the variation in seismic response in models A1 and A2 with flexible edge experiencing greater deformation as compared to the stiff edge. The stiff edge of building systems with small time period (T < 1 Sec) designed according to NZS 4203 and EC8:198924 experienced least additional ductility demand. However the additional ductility demand was found to be largest for building systems with T > 1 Sec. In case of TU systems designed according to EC 8 -1989 the ductility demand exceeded by 2.5 % as compared to the TB system.

Nehe P. Modakwar and Sangita S. Meshram, have tried to understand different irregularity and torsional response due to plan and vertical irregularity and to analyze cross shape and L shape building while earthquake forces and to calculate additional shear due to torsion in the columns. It was found that the Re-entrant corner columns are needed to be stiffened for shear force in the horizontal direction perpendicular to it as significant variation is seen in these forces. Significant variation in moments, especially for the higher floors about axis parallel to earthquake direction, care is needed in design of members near re-entrant corners. From the torsion point of view the re-entrant corner columns must be strengthen at lower floor levels and top two floor levels and from the analysis it is observed that behavior of torsion is same for all zones. Rajalakshmi K R & Harinarayanan S (2015): When buildings with irregularities are located in a high seismic zone, the structural engineer's role becomes more challenging. Therefore, the structural engineer needs to have a thorough understanding of the seismic response of irregular structures. This paper presents the details of the non-linear dynamic analysis performed on mass and stiffness irregular buildings. It is established that irregular buildings are subjected to large displacements compared to regular buildings and localized damages near the regions of irregularity. Special care needs to be taken while designing such buildings.

III. MODELLING

A 15-storeyed regular reinforced concrete moment resisting frame building model (A) is prepared in ETABS-2013 and preliminary dimensioning of structural members is tabulated in Table 2. The structure is designed as per the various load combinations as given in IS-456:2000. Analysis portion is done by Equivalent Static analysis and Response spectrum method.

TABLE 2: STRUCTURAL ELEMENT SIZES

STRUCTURAL ELEMENTS	SIZES(mm)	GRADE
BEAMS	600X200	M30
COLUMN		
1st floor to 5th floor	1200X300	M40
6th floor to 10th floor	1200X300	M35
11th floor to 15th floor	1200X300	M30
SLAB	200	M30

A set of eight different models are prepared for the analysis out of which the first model is symmetric, the plan of the building is as shown in the figure-1, and the second model is the combination of both vertical and horizontal irregularities. Three more models with horizontal irregularity and the remaining with vertical irregularity.

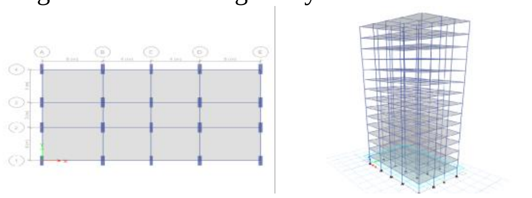

Figure-1: Model (A)

The second model (B) with both combinations of horizontal and vertical irregularities is as shown in figure-2

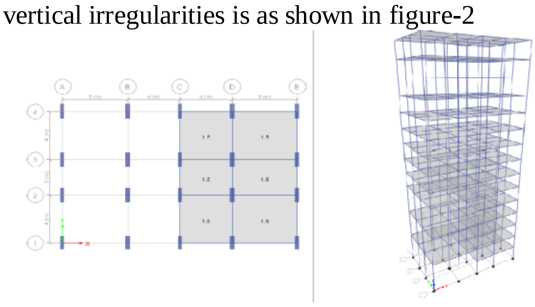

Figure-2: Model (B)

HORIZONTAL IRREGULARITY:

The next three models model (C), model (D) and model (E) are horizontally irregular structures. Model (C) as shown in figure-3 is made horizontally irregular by changing the live load and dead load for the half portion of the first two floors. The live load is changed from 3kN/m to 5kN/m and dead load from 1.5kN/m to 2kN/m.

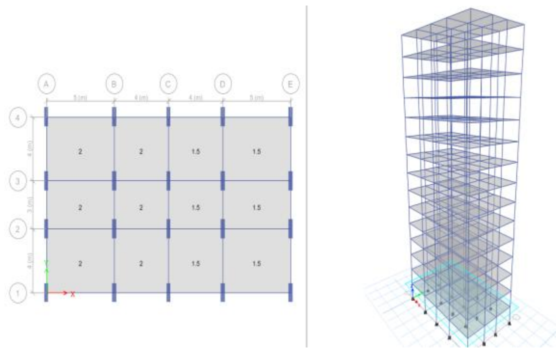

Figure-3: Model (C)

Similarly in the model (D) and the model (E), in model (D) the 7th and the 8th floor has been made changes and for the model (E) the 13th and 14th floor has been made changes.

VERTICAL IRREGULARITY: The next three models model (F), model (G) and model (H) are vertically irregular structures. Model (F) as shown in figure-4 is made vertically irregular structure by deleting the first floor completely, i.e., is to increase the column height and in model (G) the middle floor i.e., 8th floor is deleted and in model (H) the upper floor i.e., 14th floor has been deleted.

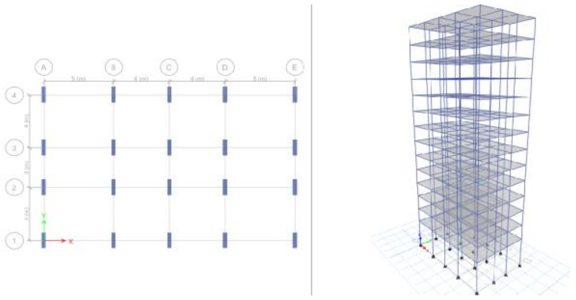

Figure-4 Model (F)

IV. RESULTS

Table 3: EQUIVALENT STATIC ANALYSIS

MODEL	MAX STOREY DISPLACEMENT	MAX STOREY DRIFT	BASE SHEAR
A	61.1355	0.001807	1832
B	62.722	0.001896	1615
C	61.2849	0.001812	1837
D	61.1857	0.001811	1835
E	61.2724	0.001808	1831
F	61.5902	0.003161	1730
G	67.1943	0.003213	1698
H	62.2871	0.001793	1836

Table 4: RESPONSE SPECTRUM METHOD

MODEL	MAX. STOREY DISPLACEMENT	MAX. STOREY DRIFT	BASE SHEAR
A	45.3214	0.001571	1653
B	48.281	0.001896	1095
C	45.3414	0.001572	1655
D	45.3753	0.001574	1655
E	45.4441	0.001572	1654
F	49.5689	0.003016	1616
G	47.3652	0.002382	1581
H	45.0878	0.001545	1624

COMPARISION OF STOREY DISPLACEMENT FOR EQUIVALENT STATIC ANALYSIS AND RESPONSE SPECTRUM METHOD

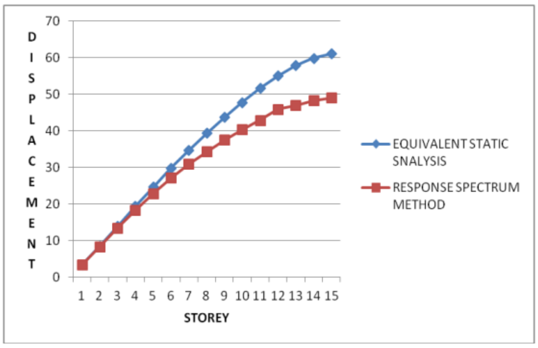

Figure 5: MODEL (A)

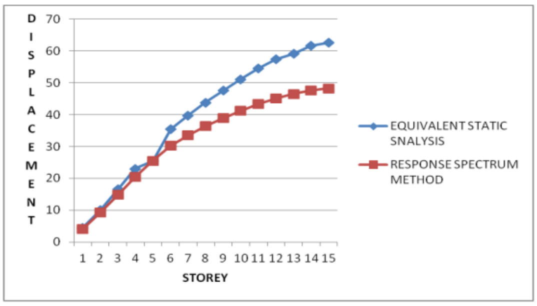

Figure 6: MODEL (B)

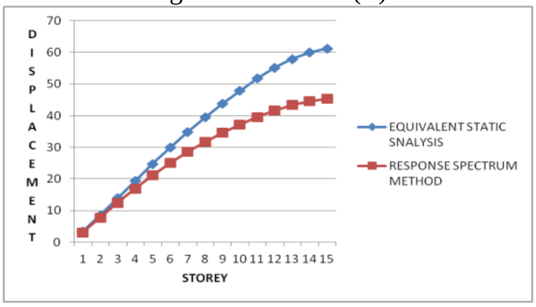

Figure 7: MODEL (C)

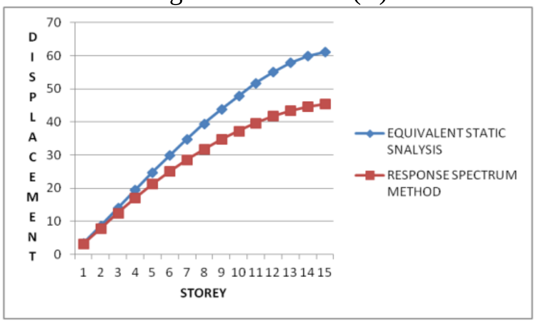

Figure 8: MODEL (D)

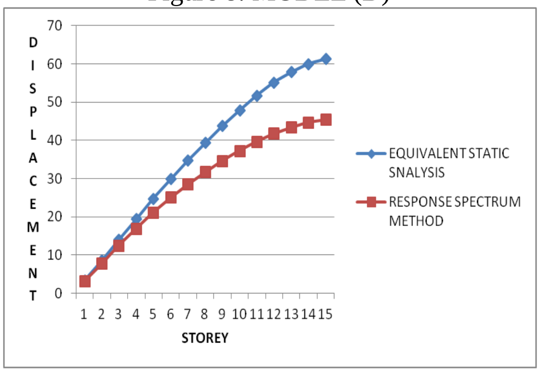

Figure 9: MODEL (E)

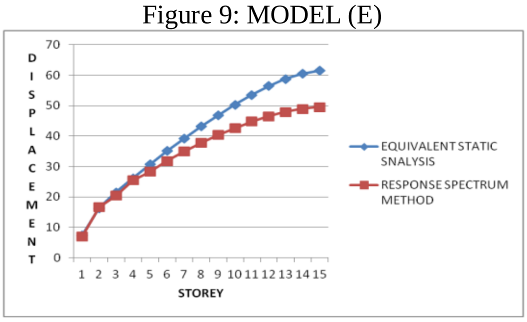

Figure 10: MODEL (F)

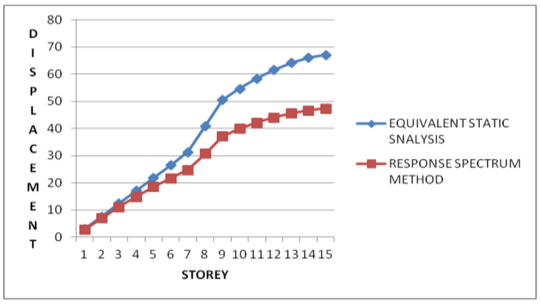

Figure 11: MODEL (G)

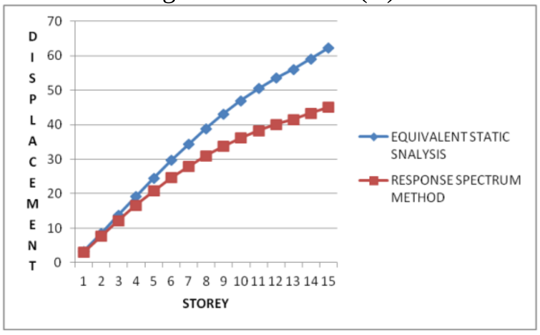

Figure 12: MODEL (H)

Chart representing the max Base Shear for different irregularities

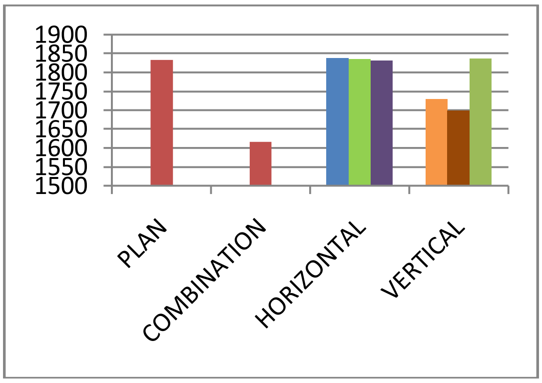

Figure 13: Equivalent static analysis

Chart representing the max Base shear for different irregularities

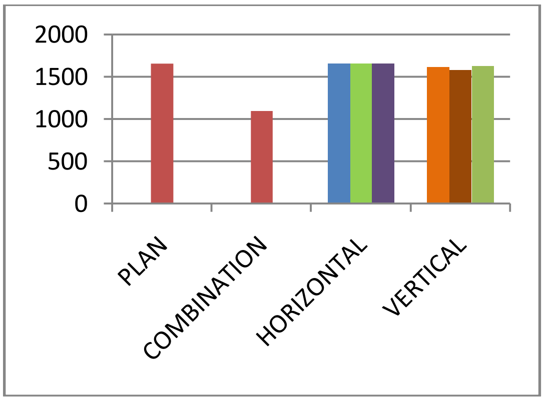

Figure 14: Response spectrum method

Table 5: TORSION CHART

MODEL	% OF TORSION
A	0.00
B	
1st floor	19.00
2nd floor	17.42
3rd floor	21.22
4th floor	19.34
5th floor	23.39
C	
1st floor	0.59
2nd floor	0.59
D	
7th floor	0.45
8th floor	0.45
E	
13th floor	0.45
14th floor	0.45
F	0.00
G	0.00
H	0.00

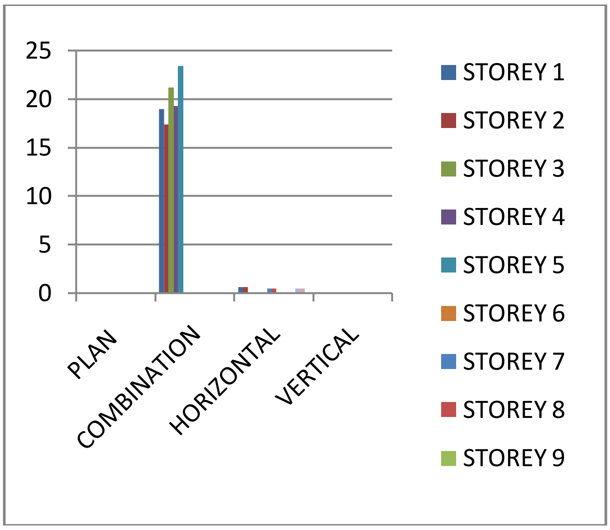

Figure 15

V. CONCLUSION

It is found that there is no much torsion produced in the model (A) due to the symmetry of the building but in model (B), large amount of torsion is produced due to asymmetry of the building. The torsion produced in this model is greater than the allowable torsion in the building hence the building is unsafe, the building element size should be increased or it should be redesigned. The model (C), model (D), and model (E) will also produce some amount of torsion but it is within the permissible limit hence it is safe. Base shear is very important parameter in earthquake resistant design of buildings. The result is based on equivalent static analysis and response spectrum analysis. It is found that the base shear for plan, combination, horizontal and vertical irregularity is less in response spectrum method when compared with Equivalent static analysis. It is observed from the analysis that there is large displacement in model (B) when compared to the other model in Equivalent static analysis and response spectrum method.

REFERENCES

[1] Nehe P. Modakwar,Sangita S. Meshram, Dinesh W. Gawatre,"Seismic Analysis Of Structures with Irregularities",IOSR Journal of Mechanical and Civil Engineering,Volume 3, Issue 2,March- April 2014 pp-63-66.
[2] Chandler, AM., Correnza, JC., Hutchinson, GL. (1994).Period-dependent effects in seismic torsional response of code systems Journal of Structural Engineeeering (ASCE) 120:12, 3418-3434.
[3] Tso, W.K. and Bozorgnia,Y. (1986)."Effective eccentricity for inelastic seismic response of buildings", Earthquake engineering and structural dynamics, Volume.14, No.3,pp.413-427.
[4] Sachin G. Maske, Dr. P. S.Pajgade,"Torsional Behaviour of Asymmetrical Buildings",International Journal of Modern Engineering Research, Vol.3, Issue.2, March-April. 2013 pp-1146-1149.
[5] Dr. S.K. Dubey et al., "seismic behaviour of asymmetric R.C. buildings" International Journal of Advanced Engineering Technology E-ISSN 0976-3945
[6] Structural elements on inelastic torsional response".Earthquake Engineering and Structural Dynamics, 28, 1071-1097.
[7] Al-Ali, A.A.K. and Krawinkler, H (1998). "Effects of Vertical Irregularities on Seismic Behavior of Building Structures", Report No. 130, 1998,The John A. Blume Earthquake Engineering Center, Department of Civil and Environmental Engineering, Stanford University, Stanford, U.S.A.
[8] IS 1893 (Part-1):2002,"Criteria for Earthquake Resistant Design Of Structures", General Provisions and Buildings

