Evaluation of Axial forces in Diagonal Strut modelled as Infill in plan asymmetric Building

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***Abstract* - At present scenario many buildings are asymmetric in plan and/or in elevation based on the distribution of mass and stiffness along each storey throughout the height of the building. Most recent earthquakes have shown that the irregular distribution of mass, stiffness and strengths may cause serious damage in structural systems. This research quantifies the performance of the torsionally balanced and torsionally unbalanced buildings also called as symmetric and asymmetric buildings by subjecting to Response Spectrum Analysis. The buildings have un-symmetrical distribution of mass in storeys. In this paper the effort is made to study the effect of eccentricity between Centre of mass (CM) and Centre of stiffness (CR) on Axial forces in Strut. Four building models are considered for study,G+4 & G+8 which are constructed on medium soil in seismic zone V of India (as per IS: 1893-2002[9]), Two symmetric and Two asymmetric in mass distribution. Infills were modeled using equivalent strut approach. Response Spectrum analysis is performed. It is concluded that the axial forces in Asymmetric building increased as compared to that of symmetric building showing that more forces get gets transfer to infill as Asymmetricity increases.**

***Index Terms* - Infill, Asymmetry, Diagonal Strut, SAP 2000**

I. INTRODUCTION

Earthquakes are one of the most devastating natural hazards that cause great loss of life and livelihood. Most recent earthquakes have shown that the irregular distribution of mass, stiffness and strengths may cause serious damage in structural systems, such buildings undergo torsional motions. An ideal multi-storey building designed to resist lateral loads due to earthquake would consist of only symmetric distribution of mass and Stiffness in plan at every storey and a uniform distribution along height of the building. Such a building would respond only laterally and is considered as torsionally balanced (TB) building. But it is very difficult to achieve such a condition because of restrictions such as architectural requirement and functional needs. The structures whose performances were evaluated in this study, are designed with the provisions from IS: 1893-2002. Equivalent static force method of determining earthquake force is limited to the structures having height of less Than 40 meters. Hence this study deals with medium rise buildings (G+4 & G+8). The purpose of paper is to evaluate changes in axial forces in diagonal strut modelled as infill due to asymmetry.

II. LITERATURE REVIEW

Dhiman Basu and Sudhir K. Jain[3] In this paper, the definition of centre of rigidity for rigid floor Diaphragm buildings has been extended to unsymmetrical buildings with flexible floors. A superposition-based Analysis procedure is proposed to implement code-specified torsional provisions for buildings with flexible floor Diaphragms. The procedure suggested considers amplification of static eccentricity as well as accidental Eccentricity. The proposed approach is applicable to orthogonal as well as non-orthogonal unsymmetrical Buildings and accounts for all possible definitions of centre of rigidity. Analysis results of a sample building clearly show the significance of considering the torsion provisions of design codes for asymmetric flexible Diaphragm buildings. It is seen that treating the diaphragms of such buildings as rigid for torsional analysis may Cause considerable error. The example also illustrates that the contribution of accidental torsion as well as the Torsional amplification terms can be quite significant.

Humar et al [7] [2003] showed that eccentricities between the centres of rigidity and centres of mass in a building cause torsional motion during an earthquake. Seismic torsion leads to increased displacement at the Seismic Performance Evaluation of Rc-Framed Buildings - An Approach To Torsionally extremes of the building and may cause distress in the lateral load-resisting elements located at the edges, particularly in buildings that are torsionally flexible. For an equivalent static load method of design against torsion, the 1995 National Building Code of Canada specifies values of the eccentricity of points through which the inertia forces of an earthquake should be applied. In general, the code requirements are quite conservative. They do not place any restriction on the torsional flexibility, however. New proposals for 2005 edition of the code which simplify the design eccentricity expressions and remove some of the unnecessary conservatism are described. The new proposals will require that a dynamic analysis method of design be used when the torsional flexibility of the building is large. Results of analytical studies, which show that the new proposals would lead to satisfactory designs.

R. Shahrin & T.R. Hossain [15] has overviewed the performance of bare, full infilled and soft ground storey buildings which is situated in Dhaka city. The building models have been designed according to BNBC (2006) and their performance based seismic investigation is assessed by pushover analysis. The performance of the buildings is assessed as per the procedure prescribed in ATC 40 and FEMA 273. For different loading conditions resembling the practical solutions of Dhaka city, the performances of these structures are analysed with the help of capacity curve, capacity spectrum, deflection, drift and seismic performance level. For the bare frame structure they kept regular throughout its height and bay length to concentrate on the effects caused by the distribution of infill. The structure is six storeys high with a storey height of 3 meters. In order to investigate the effect of infill distribution they have considered 3 geometrical cases: The first case comprises a fully infilled structure resembling the regular structures representing a regular distribution of stiffness throughout the height. Second case examined the effects of omitting infills from ground floor only, such as with infamous soft ground storey configuration. On the other hand third case specifically dealt with the consequences of omitting the infills of the third floor of the building and observed the influences on structural performances. It has been concluded that the performance of an infilled frame is found to be much better than a bare frame structure and also the consideration of effect of infill leads to significant change in the capacity.

A. Kadid and A. Boumrkik[12] an experimental pushover analysis was carried out with an objective to evaluate the performance of framed buildings under future expected earthquakes. To achieve this objective,
Three framed buildings with 5, 8 and 12 stories respectively were analysed. The results obtained in this paper shows that properly designed frames will perform well under seismic codes.

III. MODELLING AND ANALYSIS

In the present study lateral load analysis as per the seismic code IS: 1893-2002 is carried out for Symmetric and asymmetric buildings and an effort is made to study the effect of seismic loads. The plan layout of the reinforced concrete ordinary moment resisting frame building of Five and nine storied Building without and with consideration of stiffness of walls is as shown in Fig. 1 and 2, with open ground storey and Unreinforced masonry infill walls in the upper storey are chosen. The bottom storey height is kept 3.1m and a Height of 3.1m is kept for all the other storeys, bay dimensions in both x and y directions are kept as 4m and 4m respectively. Modulus of Elasticity of Infill if 2255 N/mm^2 . The building is deliberately kept symmetric in both the orthogonal directions in plan to avoid Torsional response under pure lateral forces for symmetric buildings and for asymmetric buildings the plan of the Building is kept symmetric but one side edge columns are made stiffer than all other columns. This makes the Structure torsionally unbalanced i.e. Asymmetric. The elevations of the different building models considered are shown in Fig.4. The masonry infill is modelled as equivalent diagonal strut in the upper storey. The equation for Calculation of equivalent diagonal strut width is considered from Kasim Armagon et al[11] paper.

The width is given by

$$W_{ef} = 0.175\,(\lambda_h \mathrm{H})^{-0.4}\ \sqrt{H^2 + L^2}$$

where

$$\lambda_h = \sqrt[4]{\frac{E_i t \sin 2\theta}{4 E_c I_c H_i}}$$

H and L are the height and length of the frame, Ec, and Ei are the elastic moduli of the column and of The infill panel, t is the thickness of the infill panel, q is the angle defining diagonal strut, Ic is the modulus of Inertia of the column and Hi is the height of the infill panel. Concrete frame elements are classified as beam and column elements. Columns and beams are modelled using three dimensional frame elements. Slabs are modelled as rigid diaphragms. The beam column Joints are assumed to be rigid.
The following four distinct building models are used in the study.
Model I: The building is G+8 symmetric in plan and also in distribution of storey stiffness & mass, both in plan and along height. Building has no walls in the first storey and brick masonry walls in the upper storeys. Two forms of this model are studied, one in which the stiffness of walls is ignored and the other in which stiffness of infill walls is considered Ref. Fig. 1.
Model II: The building is G+8 similar to the building in Model I in both plan and elevation, but mass Eccentricity is introduced by increasing the mass on left side to7.65 kN/m^2. This introduces a static eccentricity of 20.04%. This model is also studied by considering the stiffness of in fill walls.
Model III: The building is G+4 symmetric in plan and also in distribution of storey stiffness & mass, both in plan and along height. Building has no walls in the first storey and brick masonry walls in the upper storeys. Two forms of this model are studied, one in which the stiffness of walls is ignored and the other in which stiffness of infill walls is considered. Irrespective of whether the stiffness of infill walls is ignored or considered, the mass of the infill walls is always considered .Ref. Fig. 2.
Model IV: The building is G+4 similar to the building in Model I in both plan and elevation, but mass Eccentricity is introduced by increasing the mass on left side to7.65 kN/m^2. This introduces a static eccentricity of 20.04%. This model is also studied by considering the stiffness of in fill walls.

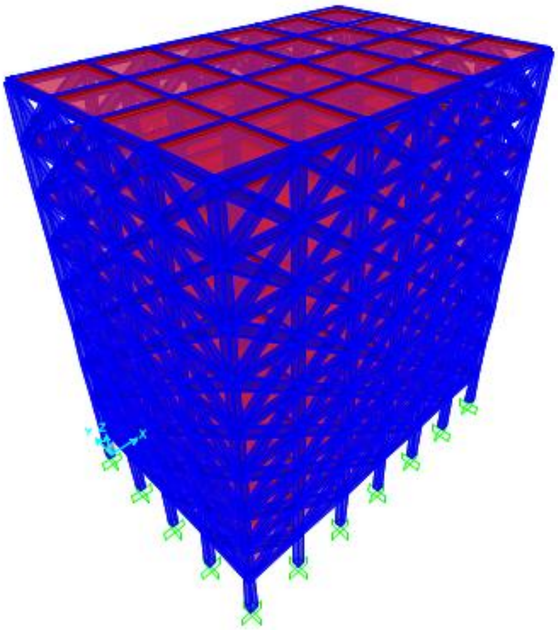

Fig.1 : G+8 Building with Infill

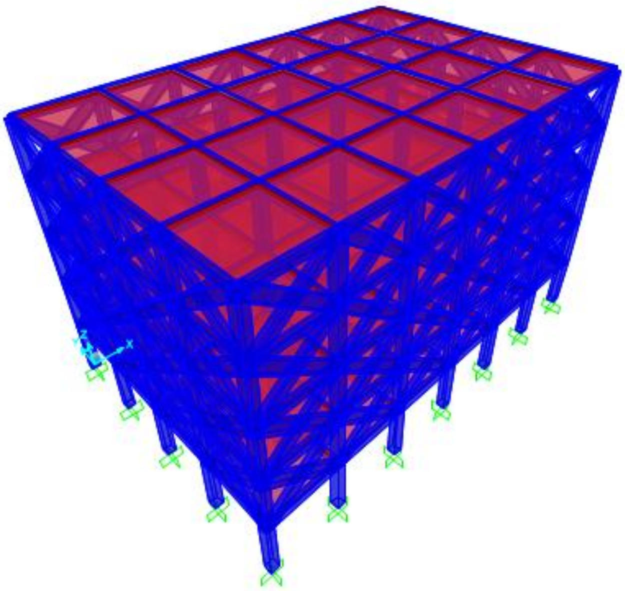

Fig.2 : G+4 Building with Infill

IV. TABLES

TABLE I: Axial Forces in Diagonal Strut in G+8 Building

Sr. No.	Storey	Symmetric (kN)	Asymmetric(kN)
1	1st	131.47	143.68
2	2nd	104.47	113.97
3	3rd	92.25	101.81
4	4th	80.47	88.12
5	5th	66.78	73.56
6	6th	50.56	56.82
7	7th	32.65	37.75
9	8th	12.45	19.72

TABLE II: Axial Forces in Diagonal Strut in G+4 Building

Sr No.	Storey	Symmetric (kN)	Asymmetric(kN)
1	1st	131.47	143.68
2	2nd	104.47	113.97
3	3rd	92.25	101.81
4	4th	80.47	88.12

TABLE III: Base Shear of G+8 Building

Sr No.	Model	Base Shear (kN)
1	Symmetric	3216
2	Asymmetric	3132

TABLE IV: Base Shear of G+4 Building

Sr No.	Model	Base Shear (kN)
1	Symmetric	2864
2	Asymmetric	2760

V. CONCLUSION

It is concluded from the study that as asymmetry in building increases the forces taken by infill also increases.
Base Shear Got Decreased by 4% with increase in Asymmetry of the Building.

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