International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

SEISMIC RESPONSE OF VERTICALLY IRREGULAR RC FRAME WITH STIFFNESS IRREGULARITY AT GROUND FLOOR

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ABSTRACT

In past, several major earthquakes have exposed the shortcomings in buildings, which had caused them to damage or collapse. It has been found that regular shaped buildings perform better during earthquake. The presence of vertical irregular frame subject to devastating earthquake is matter of concern. The present paper attempts to investigate the proportional distribution of lateral forces evolved through seismic action in each storey level due to changes in stiffness of frame on vertically irregular frame. As per the Bureau of Indian Standard (BIS) 1893:2002 (part1) provisions, a G+10 vertically irregular building is modelled as a simplified lump mass model for the analysis with stiffness irregularity at ground floor. To response parameters like story drift, story deflection and story shear of structure under seismic force under the linear static & dynamic analysis is studied. This analysis shows focuses on the base shear carrying capacity of a structure and performance level of structure under sever zone of India. The result remarks the conclusion that, a building structure with stiffness irregularity provides instability and attracts huge storey shear. A proportionate amount of stiffness is advantageous to control over the storey and base shear. The soft computing tool and commercial software CSI-ETABS is used for analysis.

Keywords:- Base Shear, I.S 1893:2002(Part1) Provisions, Storey Drift, Structural irregularities, Vertical irregularities.

I. INTRODUCTION

Recently and in past, several major earthquakes have exposed the shortcomings in buildings, which lead to damage or collapse. It has been found that regular shaped buildings perform better during earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. There must be a continuous path for these inertial forces to be carried from the ground to the building weight locations. A gap in

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

this transmission path results in failure of the structure at that location. There have been several studies on the irregularities, viz., (Jack P. Moehle, A. M. ASCE 1984) [1], Seismic Response of Vertically Irregular Structures, evaluation of mass, strength and stiffness limits for regular buildings specified by UBC (Valmundsson and Nau, 1997)[3], Seismic Response of RC Frame Buildings with Soft First Storeys (ArlekarJaswant N, Jain Sudhir K. and Murty C.V.R, 1997) [4] etc. In the present paper, response of a G+10-storeyed vertically irregular frame to lateral loads has studied for stiffness irregularity at ground floor in the elevation. These irregularities are introduced by changing the properties of the members of the storey under consideration maintaining aspect ratio for vertically irregular frame specified in I.S 1893:2002(part1) [9] guidelines. Stiffness irregularities include the height of the column increased on the ground floor which is applied on vertically irregular frame. Effects on storey-shear forces, storey drifts and deflection of beams is studied.

1.1 Structural Irregularities

There are various types of irregularities in the buildings depending upon their location and scope, but mainly, they are divided into two groups plan irregularities and vertical irregularities. In the Study, the vertical irregularities are considered which are described as follows.

Table 1: Types of Irregularity

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 Systems	Discontinuity in capacity-weak story

II. PROBLEM FORMULATION

With reference to IS 1893:2002 part-1[9] the vertical geometric irregular building model is considered for modelling purpose and on this irregular frame stiffness irregularity has been applied. This building model is G+10 storey building (35.5M) high is made of reinforced concrete (RC) Special moment resisting frame (SMRF). These two frames have been analysed using equivalent static method of IS 1893: 2002 (Part-1). Analysis has been carried out using commercial software ETABS program with following preliminary data. Location of structure in seismic zone V, with soil type is medium, zone factor is 0.36, effective damping 5% and importance factor is 1.

2.1 Frame-1

Frame-1 structure with geometrically vertical irregularities and having ten bays and G+10 storeys with 60m x 60m, with a storey height of 3.5 m for ground floor and 3.0 m for typical floor and the bay width of 5 m. The

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

basic specifications of the building are: Dimensions of the beam = 0.3 m × 0.6 m; Column size = 0.70 m × 0.30 m; Beam length = 5 m; M_{30}, Fe_{415} materials are used. Depth of slab 150 mm; Imposed load 5 kN/m^2; specific weight of infill is 20 kN/m^3, lateral stiffness of infill is not taken in the study and specific weight of concrete is 25 kN/m^3. The Frame-1 is as shown in Fig. 1.

Load combinations as per clause 6.3.1.2 of IS 1893:2002 (Part-1) are:

a) 1.5 (DL+ LL) b) 1.2 (DL + LL ± EQL) c) 1.5 (DL ± EQL) d) 0.9 DL ± 1.5 EQL.

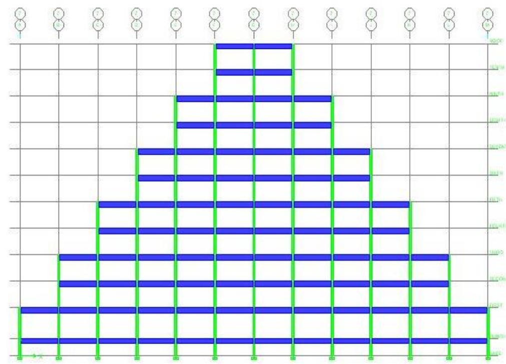

Fig 1: Frame-1 Elevation

2.2 Frame-2

Model-2 consists of increase in height of the column on ground floor which is introduced in Frame-1, the Frame-1 itself is a vertically irregular structure. It has 10 bays and ten storeys, with a ground storey height of 5 m and typical floor height 3.0 m the bay width is 5 m. The frame-1 having the shape irregular to know the effect of stiffness irregularity on the shape (vertical geometric) irregular building the excess height of column at ground floor as per the IS 1893:2002 (part-1). The structural and seismic forces are same with respect to the frame-1.

1. Floor height at GF : 5 m

The respective change is incorporated on the ground floor and as shown in Fig. 2.

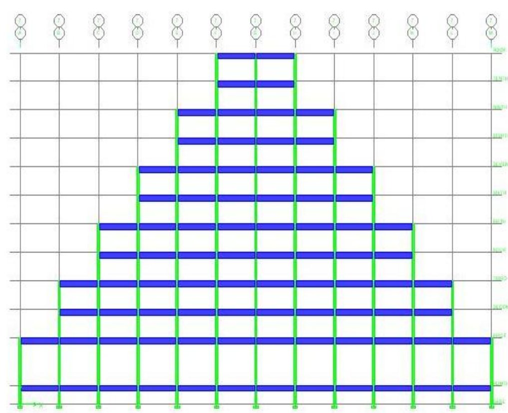

Fig 2: Frame-2 Elevation

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

III. ANALYSIS RESULTS

Two frames have been analysed and responses like lateral storey-displacements, storey drifts and base shears have been computed to study the effects of stiffness irregularity on the vertically irregular frame. The results are presented and discussed hereafter. Table-2 shows displacement of storeys of various frames in X-direction (horizontal) graphically presented in figure. It can be seen that from table-2, the frame-2 gets slightly displaced the more since the lateral stiffness with reference to frame-1 and the bottom two storeys is quite less than other storeys. Whereas its being minimum being in the base frame. Typical deflected shapes of two various frames in combinations is represented in Fig. 3.

Table 2: Story Disp. (Ux) In X-direction (M)

STORY	FRAME-1	FRAME -2
	Ux	Ux
ROOF	0.001162	0.001168
TENTH	0.002390	0.002331
NINTH	0.002554	0.002461
EIGHTH	0.003572	0.003447
SEVENTH	0.003021	0.002934
SIXTH	0.003641	0.003556
FIFTH	0.002927	0.002888
FOURTH	0.003211	0.003196
THIRD	0.002505	0.002528
SECOND	0.002582	0.002711
FIRST	0.002380	0.004439
PLINTH	0.000892	0.001007

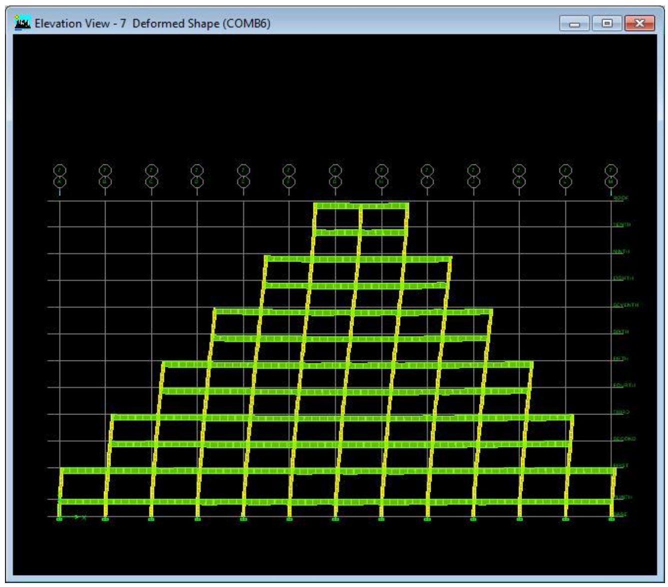

Fig. 3: Deflected shape of frame-1 in their combination

Table 3 shows the analysis result for Storey-drifts for two frames and graphically presented in Fig. 4. Frame-1 and frame-2 are seen to exhibit abrupt change in storey drifts at ground storey, which is slightly changed in respective storey.

The storey shears as given by ETABS using IS 1893: 2002 (part-1), are tabulated in table-4 and represented in fig. 5. Frame-2, being the slightly heaviest one, develops considerable amount of shear force in its storey's compare to frames-1.

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Table 3: Story Drift In X-direction (M)

STORY	FRAME-1	FRAME- 2
	Ux	Ux
ROOF	0.092815	0.105871
TENTH	0.089327	0.102367
NINTH	0.082156	0.095375
EIGHTH	0.074495	0.087991
SEVENTH	0.063778	0.077649
SIXTH	0.054715	0.068848
FIFTH	0.043792	0.058179
FOURTH	0.035010	0.049515
THIRD	0.025377	0.039927
SECOND	0.017860	0.032342
FIRST	0.010113	0.024209
PLINTH	0.001783	0.002014
BASE	0	0

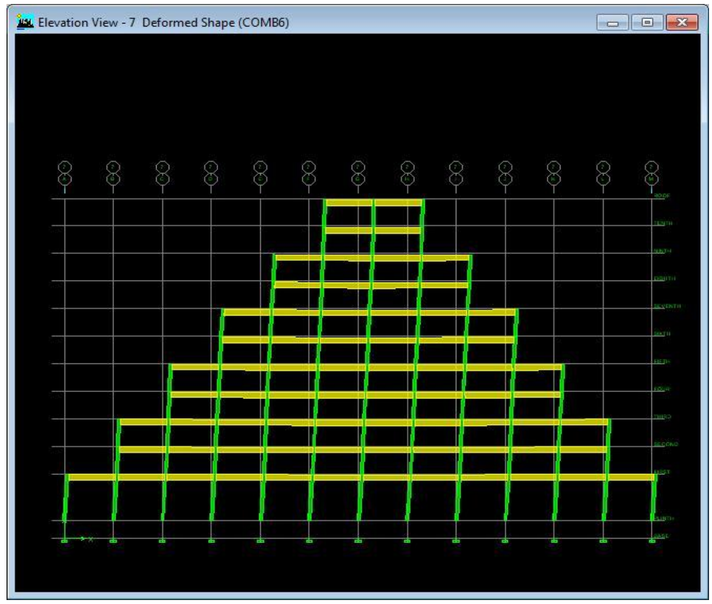

Fig. 4: Deflected shape of frame-2 in their combination

Table 4: Story Shear in X-direction (kN)

STORY	FRAME-1	FRAME-2
	Vx	Vx
ROOF	-279.809	-284.262
TENTH	-766.984	-746.045
NINTH	-2121.59	-2041.60
EIGHTH	-3283.75	-3165.30
SEVENTH	-5146.13	-4990.77
SIXTH	-6625.35	-6466.24
FIFTH	-8427.29	-8305.89
FOURTH	-9705.73	-9654.06
THIRD	-10908.0	-10984.7
SECOND	-11582.6	-11793.4
FIRST	-11981.0	-12374.2
PLINTH	-12016.6	-12417.7

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

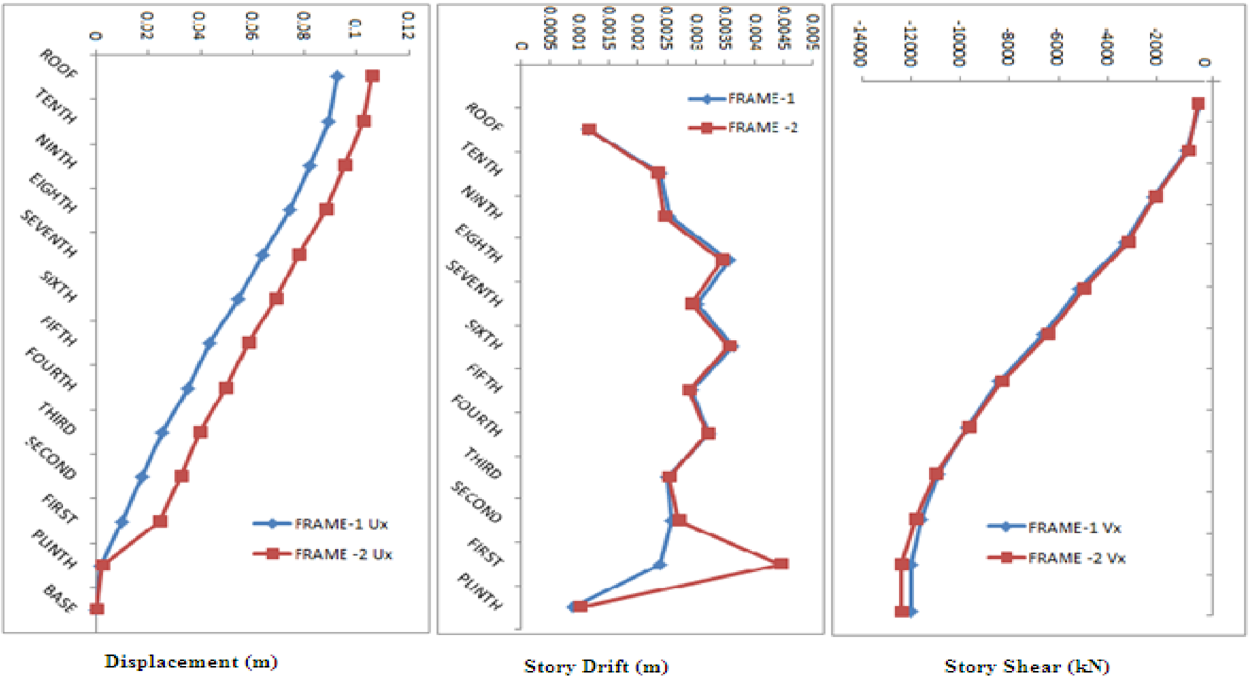

Fig 5 Response of two frames with ittegularities

IV. CONCLUSION

Considering the storey displacement, the frame with excess height of ground floor (frame-2) is the weakest than the (frame-1), as it suffers the considerable change in displacement in all the floors. As far as storey drift is concerned, frame-2 is weak than the frame-1, as the frame -2 having the suddenly extreme change at ground floor in story drift. Story shear is slightly more in frame-2. From this it is clear that the frame having stiffness irregularity on vertically irregular frame is susceptible to damage in earthquake prone zone.

In this paper, two frames having different irregularities but with same dimensions have been analysed to study their behaviour when subjected to lateral loads. All the frames were analysed with the same method as stated in IS 1893: 2002 (part-1). The frame-1 (vertically irregular) develops least storey drifts while the building with stiffness irregularity on vertically irregular building (frame-1) shows maximum storey drift on the respective storey levels. Hence, this is the most vulnerable to damages under this kind of loading and the same frame with excess height of story develops slightly more storey shears, which should be accounted for in design of columns suitably.

The analysis proves that vertically irregular structures are harmful and the effect of stiffness irregularity on the vertically irregular structure is also dangerous in seismic zone. Therefore, as far as possible irregularities in a building must be avoided. But, if irregularities have to be introduced for any reason, they must be designed properly following the conditions of IS 1893: 2002 (part-1) and IS- 456: 2000 [8], and joints should be made ductile as per IS 13920:1993. Now a days, complex shaped buildings are getting popular, but they carry a risk of sustaining damages during earthquakes. Therefore, such buildings should be designed properly taking care of their dynamic behaviour.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

IV. ACKNOWLEDGEMENTS

The authors wish to thank the management, principal, head of civil department and staff of Jawaharlal Nehru Engineering College and authorities of Dr. Babasaheb Ambedkar Marathwada University and Mr. Shaikh Aijaj for their support

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