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Seismic Response of Vertically Irregular RC Frame with Stiffness Irregularity at Ground Floor

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Abstract

Structural engineer's greatest challenge in today's scenario is constructing seismic resistant structure. Uncertainties involved and behavior studies are vital for all civil engineering structures. 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 modeled as an 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 severer 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 (version 9.7) is used for modeling and analysis.

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

1. Introduction

In the past, several major earthquakes have exposed the shortcomings in buildings, which leads 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 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 2002), Seismic Response of Vertically Irregular Structures, seismic response of vertically irregular frames with pushover analysis (Chintanapakdee, Chopra, 2004) and evaluation of mass, strength and stiffness limits for regular buildings specified by UBC (Valmundsson and Nau, 1997), Seismic Response of RC Frame Buildings with Soft First Storeys (Arlekar Jaswant N, Jain Sudhir K. and Murty C.V.R, 1997) etc. In the present paper, response of a G+ 10-storeyed vertically irregular frame to lateral loads is 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) 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.

2. 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

3. Problem Formulation

The problem considered for the current study is taken in reference to IS 1893-part 1: 2002 and worked done by Valmundsson and Nau, 1997. This G+10 vertically irregular frame is considered with stiffness irregularity. Two frames including the base frame is referred. Two frames have been analyzed using equivalent static method of IS 1893-

part 1: 2002 assuming Preliminary data as Location of Structure in seismic zone V, with soil type medium soil , effective damping 5% and importance factor 1.5. Analysis has been carried out using ETABS V 9.7 program. Configuration of frames is as given below and typical layout is shown in Fig.1.

Frame-1: This is the base model frame of structure with geometrically vertical irregularities and having ten bays and G+10 storeys with 60mx60m, with a storey height of 3.5 m for ground floor and 3.0 m for remaining floor and the bay width of 5 m. The 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; M30, Fe415 materials are used. Depth of slab 150mm; Imposed load 5KN/m2; infill 230 mm thick, specific weight of infill and concrete are 20 KN/m3 and 30 KN/m3.

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.

Frame-2: This frame consists of increase in height of the column on ground floor introduced in Frame 1, and the building becomes irregular. 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 of 5 m.

The base model 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 data is same except of the following with respect to the base model.

Floor height : 5 m

The respective change is incorporated on the ground storey. In reference to this condition following structural & seismic data for modeling the plan, elevation & 3-D view of the base model is included.

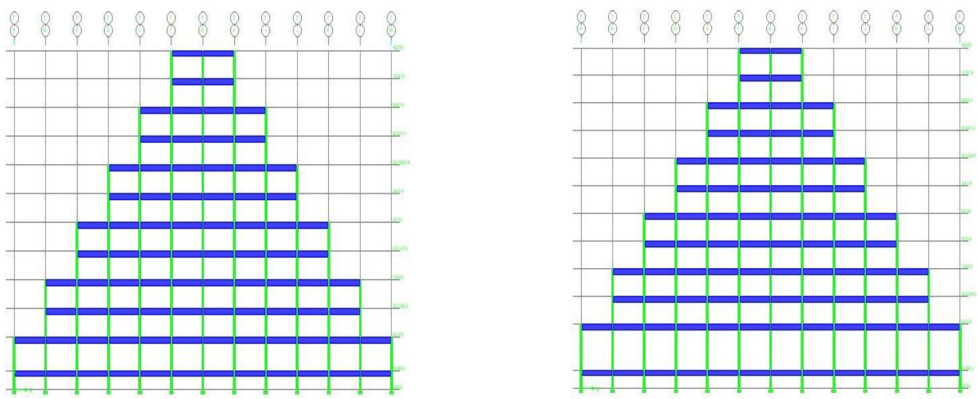


Fig 1: (a) Frame-1 Elevation (b) Frame-2 elevation

4. Analysis Results

Two frames have been analyzed 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-3 shows displacement of storeys of various frames in X-direction (horizontal) graphically presented in figure

It can be seen that from table-3 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. 4.

Table 3: Story Displacement (Ux) 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	0.03501	0.049515
THIRD	0.025377	0.039927
SECOND	0.01786	0.032342
FIRST	0.010113	0.024209
PLINTH	0.001783	0.002014
BASE	0	0

Table 4: Story Drift In X-direction (M)

STORY	FRAME-1	FRAME -2
ROOF	0.001162	0.001168
TENTH	0.00239	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	0.00238	0.004439
PLINTH	0.000892	0.001007

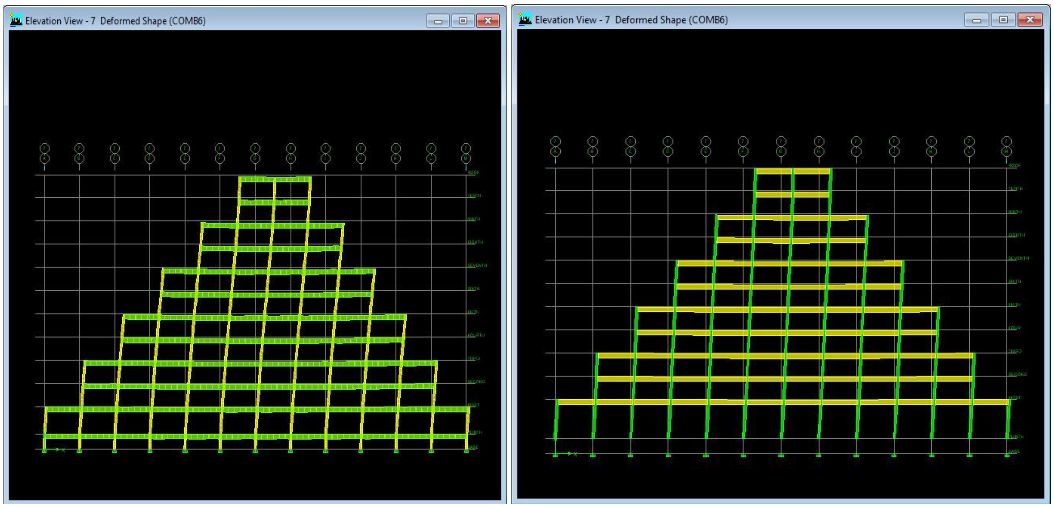


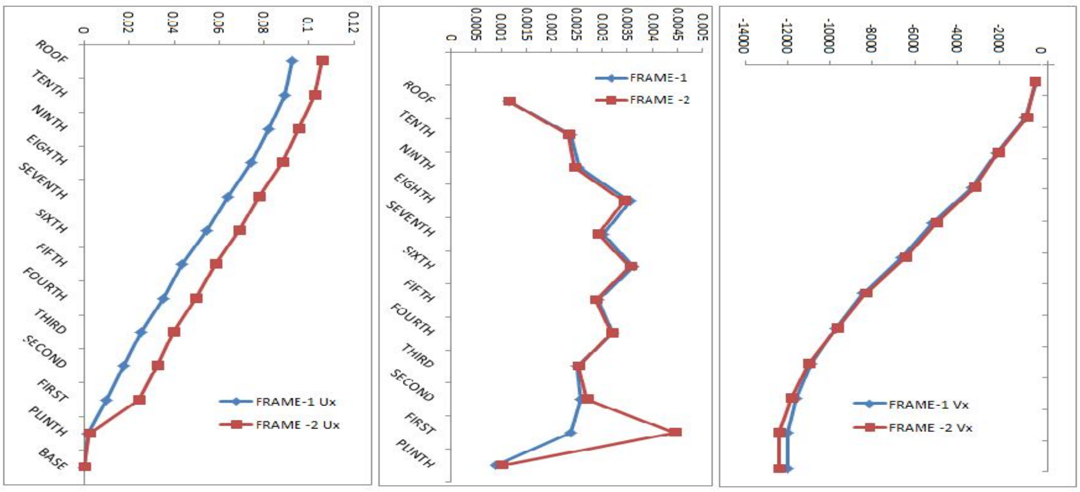
Figure 2: Deflected shapes of frames in their combination.

Storey-drifts for all the frames are tabulated Table-4 while graphically presented in Fig. 3(b). 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 part-1: 2002, are tabulated in Table-5 and represented in Fig. 3(c). Frame-2, being the slightly heaviest one, develops considerable amount of shear force in its storey's compare to Frames 1.

Table 5: 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	-2041.6
EIGHTH	-3283.75	-3165.3
SEVENTH	-5146.13	-4990.77
SIXTH	-6625.35	-6466.24
FIFTH	-8427.29	-8305.89
FOURTH	-9705.73	-9654.06
THIRD	-10908	-10984.7
SECOND	-11582.6	-11793.4
FIRST	-11981	-12374.2
PLINTH	-12016.6	-12417.7



Displacement (m) **b) Story Drift (m)** **c) Story Shear (KN)**

Figure 3: Response of various frames with irregularities.

5. Discussion and 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 analyzed to study their behavior when subjected to lateral loads. All the frames were analyzed with the same method as stated in IS 1893-part-1: 2002. 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-part-1: 2002 and IS- 456: 2000, and joints should be made ductile as per IS 13920:1993. Now a day, 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 behavior.

References

[1] Jack P. Moehle, A. M. ASCE (1984), “Seismic Response Of Vertically Irregular Structures”, ASCE Journal of Structural Engineering, Vol. 110, No. 9.

[2] Valmundsson and Nau. (1997),“Seismic response of buildings frames with vertical structural Irregularities”, ASCE Journal of Structural Engineering, Vol. 123, No. 1, 30-41.

[3] Arlekar Jaswant N, Jain Sudhir K. and Murty C.V.R, (1997), “Seismic Response of RC Frame Buildings with Soft First Storeys”. Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, New Delhi.

[4] Chintanapakdee and Chopra. (2004), “Seismic response of vertically irregular frames: response history and modal pushover analyses”, ASCE Journal of Structural Engineering, Vol. 130, No. 8, 1177-1185.

[5] Vinod K. Sadashiva, Gregory A. MacRae& Bruce L. Deam (2009), “Determination Of Structural Irregularity Limits – Mass Irregularity Example” Bulletin Of The New Zealand Society For Earthquake Engineering, Vol. 42, No. 4.

[6] Ravikumar C M, Babu Narayan K S, Sujith B V, Venkat Reddy D (2012) , “ Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings” Architecture Research 2012, 2(3): 20-26, Surathkal, India.

[7] C.V.R. Murty, “Earth quake tips ”, Indian Institute of Technology Kanpur, India.