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Effect of Mass and Stiffness of Vertically Irregular RC Structure

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Abstract - *Irregular buildings form a large portion of the modern urban infrastructure. In the past, several major earthquakes have exposed the shortcomings in buildings, which had caused them to damage or collapse. This paper is an attempt to evaluate the seismic response of vertically irregular building frames by considering mass and stiffness irregularities of the models with shear wall and compare the results with the bare frame. These irregularities can be avoided by providing shear wall in center of building. In the present paper, response of a G+ 10-storeyed vertically irregular frame to lateral loads is studied by IS-1893-part 1.The soft computing tool and commercial software CSI-ETABS (version 16.20) is used for modeling and analysis. Effects on base shear forces, maximum storey drifts and maximum storey deflection of beams is studied. The buildings has been modelled with a floor area of (25m x 25m) with 5 bays of 5m span along both the directions. Storey height being 3m.*

Key Words: Irregular building, Mass and Stiffness Irregularities, Base shear forces, Maximum storey drifts, Maximum storey displacement.

1. INTRODUCTION

In the past years, 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 earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. There must be a steady 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. The structures having these discontinuities are known as Irregular structures. This may lead to irregular distributions in their mass, stiffness along the height of building. When such buildings are located in a high seismic zone, the structural engineer's role becomes more challenging. Hence, the structural engineer needs to have thorough understanding of the seismic response of irregular structures.

1.1 Structural Irregularities

Vertically irregularities are divided into two groups—plan irregularities and vertical irregularities.

Vertically Irregularities are of five types:

1. Stiffness Irregularity –

   a) Soft Storey - A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storey' s above.

   b) Extreme Soft Storey - An extreme soft storey is one in which the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three storey' s above.

2. Mass Irregularity – Mass irregularity exists when the weight of any storey is more than 200% of that of its adjacent storey.

3. Vertical Geometric Irregularity – When the horizontal dimension of the lateral force resisting system is more than 150% of that in its adjacent storey.

4. In – Plane Discontinuity in Vertical Elements Resisting Lateral Force.

5. Discontinuity in capacity – The storey lateral strength is less than 80% of above storey.

1.2 Objectives

To obtain the performances of different stiffness irregularity in multi storey buildings located in severe earthquake zone IV of India, and also identify the most vulnerable building among them.

1. To obtain the response of bare frame with no irregularity.

2. Seismic response with stiffness irregularity.

   a) To obtain the maximum Displacement.
   b) To obtain the maximum Drift.
   c) To obtain the maximum Storey Shear.
   d) Effect of Shear Wall on the structure.

Analysis has been carried out by using CSI-ETABS 2016 (Extended 3D Analysis of Building System) program.

1.3 Scope of the Study

1. Only Reinforced Concrete buildings are considered.
2. Only vertical irregularity in Structure was studied.
3. Linear elastic analysis was done on the structures.
4. Column was modeled as fixed to the base.

5. The contribution on infill wall to the stiffness was not considered.
6. Loading due to infill wall was not taken into account.
7. The effect of soil structure interaction is ignored

2. METHODOLOGY

The problem considered for the current study is taken from IS 1893-part 1 : 2002 this 10-storey building frame is considered with two different irregularities as mass and stiffness irregularities are taken from IS-1893-part 1: 2002 thus, we have six frames including the bare frames. These six frames have been analyzed using Response Spectrum method of IS-1893-part 1: 2002 while assuming seismic zone IV, and importance factor 1.5 considering the PLAN of vertical irregular building frames to analysis the MASS and STIFFNESS IRREGULARITES to evaluate the seismic response of these irregularities can be reduced by using SHEAR WALL the shear zones in India. Analysis has been carried out using CSI-ETABS (extended 3d analysis of building system) program.

Model -1 for bare frame (conventional structure)

This is the basic and the regular structure of the building with no irregularities and having 5 bays and 10 storey's, with a storey height of 3m and the bay width of 5m.

Model – 2 for Mass Irregularity at top storey.

This frames carries heavier loading on the top storey, e.g, in the top storey swimming pool has been introduced hence making the top storey heavy, and the building becomes irregular. It has five bays and 10 storey's, with a storey height of 3m and the bay width of 5m.

Model – 3 for Mass Irregularity at 4th and 8th storeys.

This frames carries heavier loading on 4th and 8th storey. It has five bays and 10 storey's with a storey height of 3m and the bay width of 5m.

Model – 4 for Stiffness Irregularity frames having 1st and 2nd storey's soft.

Frame having 1st and 2nd storey's soft. No floor slab has been provided which makes these storey's less stiff, i.e; softer.

Model – 5 for Stiffness Irregularity opening at middle 3 bays at middle two storey's.

Frame opening at middle 3 bays at middle two storey's. No floor slab has been provided at these frame opening which makes these storey's less stiff.

Model – 6 varying column size at bottom two Storey's.

The frame section of column sizes varies at bottom two storeys by 400*400mm and rest of storey's by column size of 600*600mm.

3. STRUCTURAL MODELLING

Building of symmetric plan dimensions of 25m x 25m, bay spacing of 5m along each direction and story height of 3m is being selected. All building structures are modeled and analyzed using CSI ETABS 2016 software. Total six different building geometries, one regular and five vertical irregular is considered in the present study. Figure given below presents the plan and elevation of all six different structural models with and without shear walls. The regular frame is designated as RF. Vertical irregular frames are named as VI1, VI2, VI3, VI4 and VI5 as shown in the figure below.

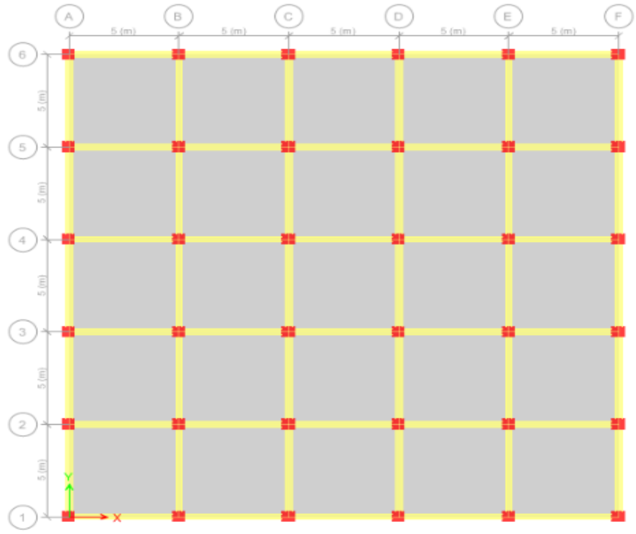
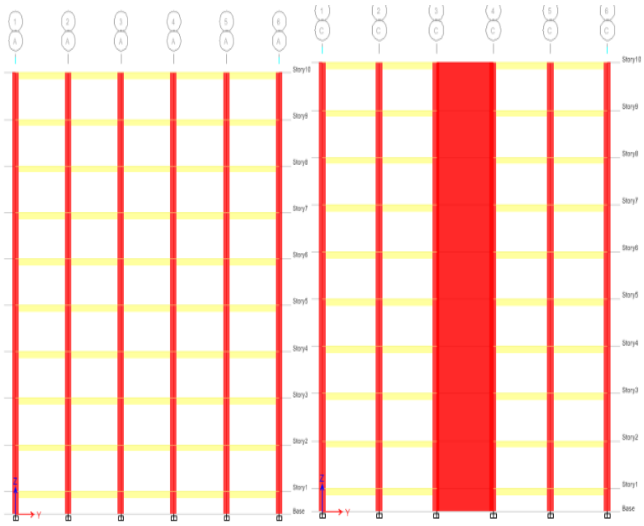
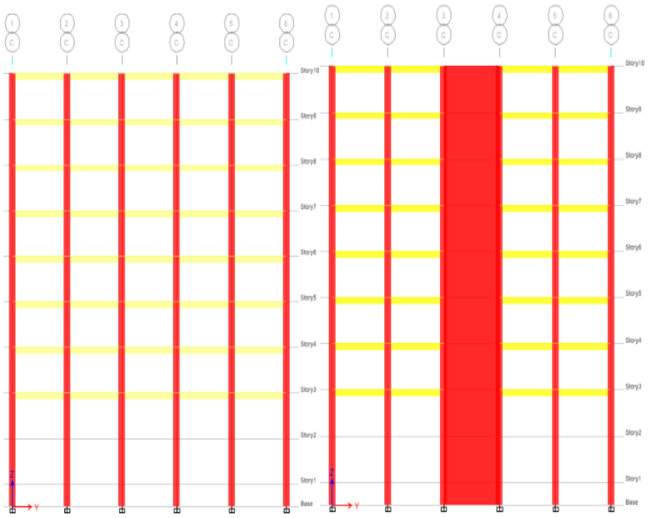


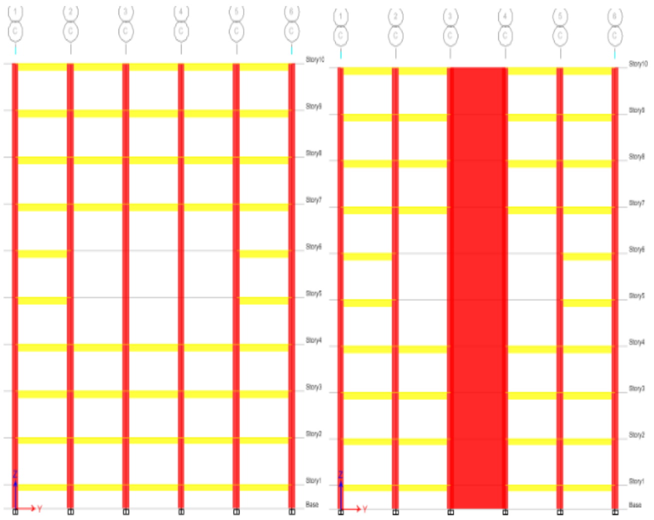
Figure 1: Typical plan of building model



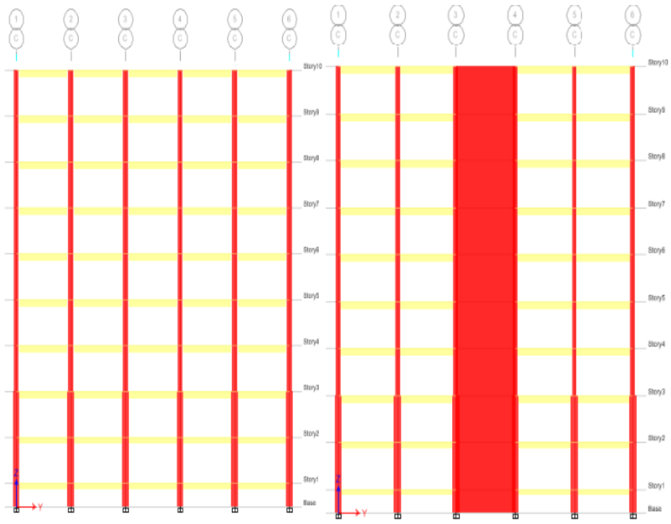
RF, VI1 AND VI2



VI3



VI4



VI5

Figure-2 Configuration of different building models

The method used in this study is response spectrum analysis. Seismic load corresponding to seismic zone IV of IS 1893:2002 are considered for the analysis.

The properties of material and geometric properties are shown below.

Table-1: Material Properties

a) Properties of concrete	
Grade of concrete	M25
Elastic Modulus, E_c	25000MPa
Poisson's Ratio	0.2
Density of concrete	25KN/m³
b) Properties of reinforcement steel	
Grade of steel	Fe500
Modulus of elasticity, E_s	20000Mpa
Poisson's Ratio	0.3

a) Dimensions of Structural Elements

Beam size: 300mm * 450mm

Column dimensions: 600mm * 600mm

Slab thickness: 125mm

Storey height: 3m

Shear wall thickness: 250mm

b) Seismic parameters

Zone: IV

Importance factor: 1

Response Reduction Factor: 5

Type of soil: Medium

Type of structure: Special Moment Resisting Frame

c) Loads on structure

Live load on roof and floor: 3KN/m^3

Swimming pool load 18KN/m^3

4. RESULTS AND DISCUSSION

Results of all the different types of models with and without shear wall using response spectrum analysis for reinforced concrete structures are obtained and mentioned here.

a) Model-1 Comparison of Bare Frame without Irregularity (conventional structure) with and without shear wall.

Chart-1: Max storey displacement with and without shear wall.

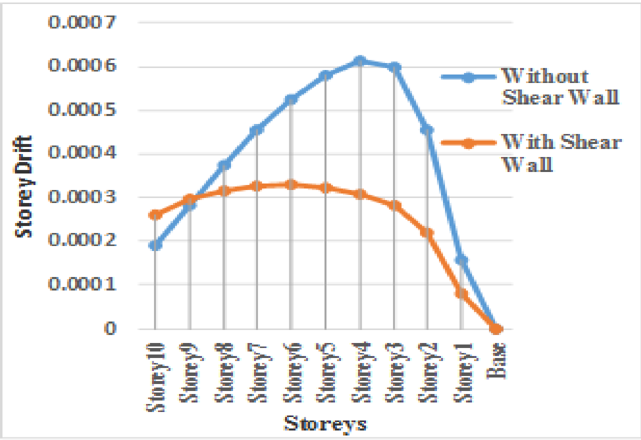


Chart-2: Max storey Drift with and without shear wall.

b) Model-2 Comparison of Mass Irregularity at top storey with and without shear wall.

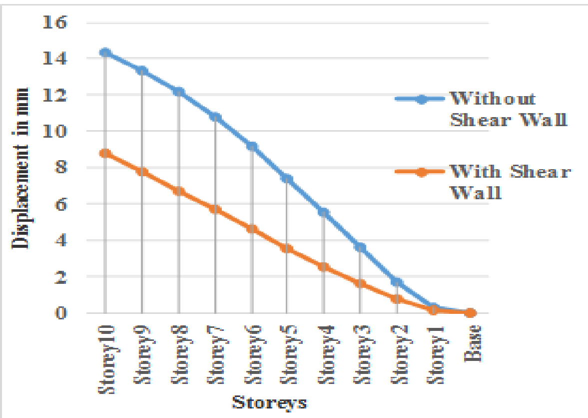


Chart-3: Max storey displacement with and without shear wall.

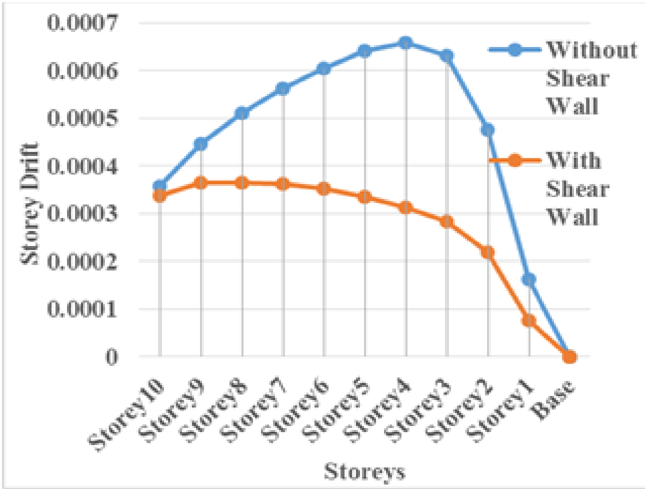


Chart-4: Max storey Drift with and without shear wall.

c) Model-3 Comparison of Mass Irregularity at 4th and 8th storey with and without Shear Wall.

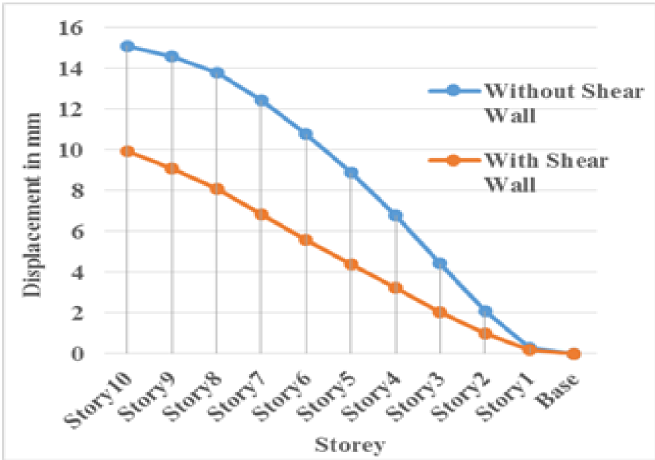


Chart-5: Max storey displacement with and without shear wall.

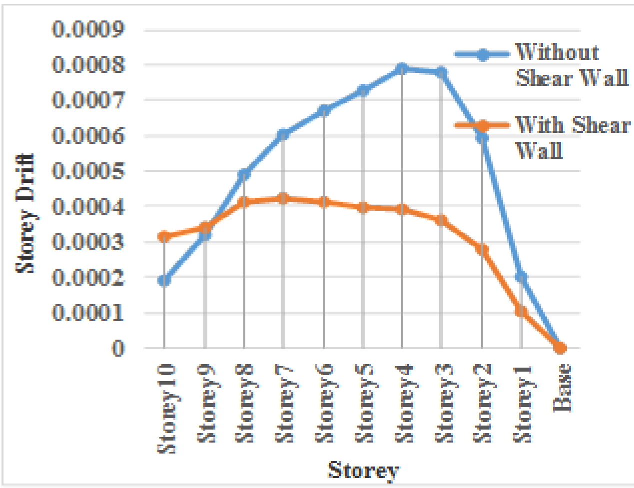


Chart-6: Max storey Drift with and without shear wall.

d) Model-4 Comparison of Stiffness Irregularity Soft storey 7.5m at bottom with and without shear wall.

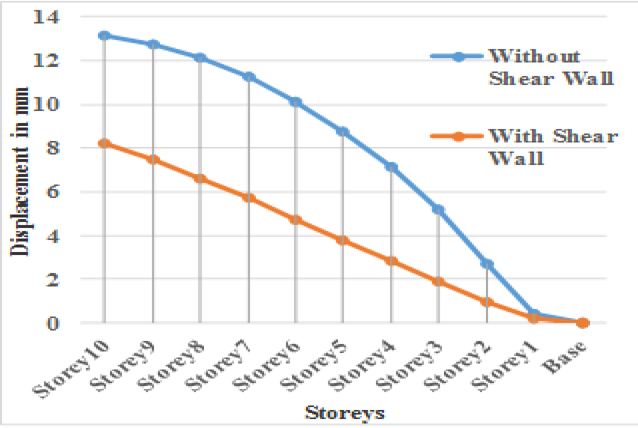


Chart-7: Max storey displacement with and without shear wall

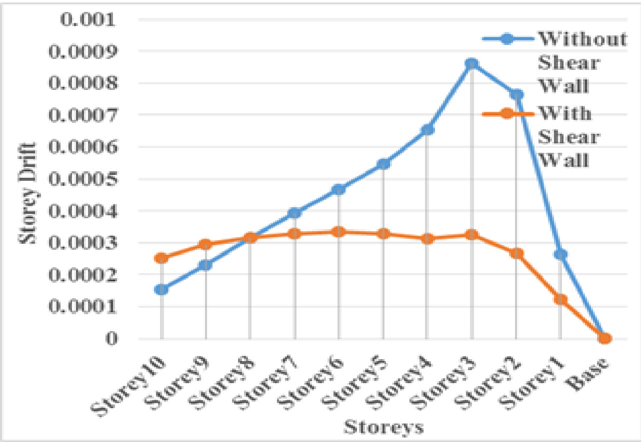


Chart-8: Max storey Drift with and without shear wall.

e) Comparison of Stiffness Irregularity opening at middle 3 bays at middle two storey with and without shear wall.

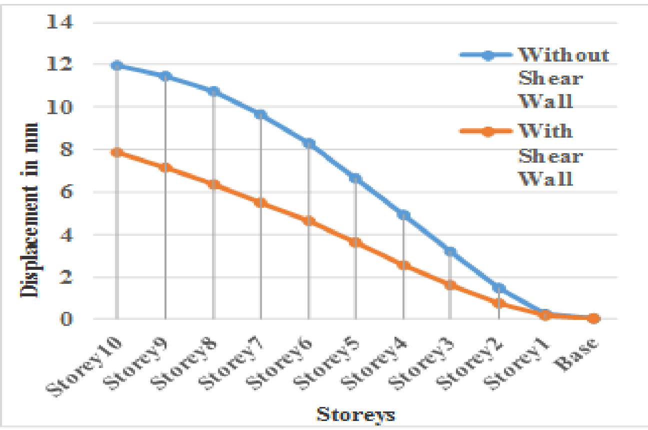


Chart-9: Max storey displacement with and without shear wall

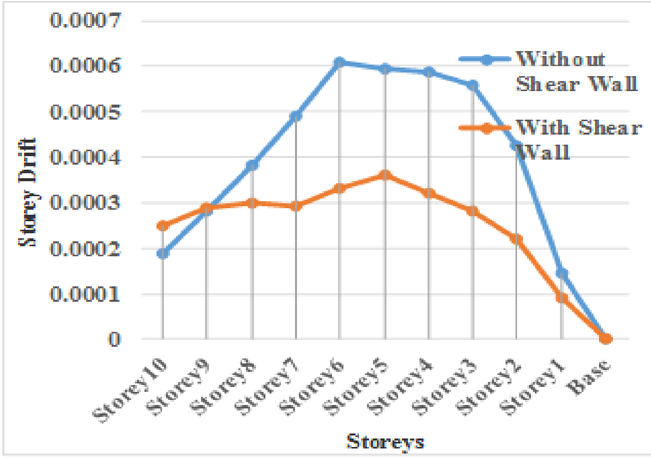


Chart-10: Max storey Drift with and without shear wall.

f) Comparison of Varying Column size at bottom two storey's with and without shear wall

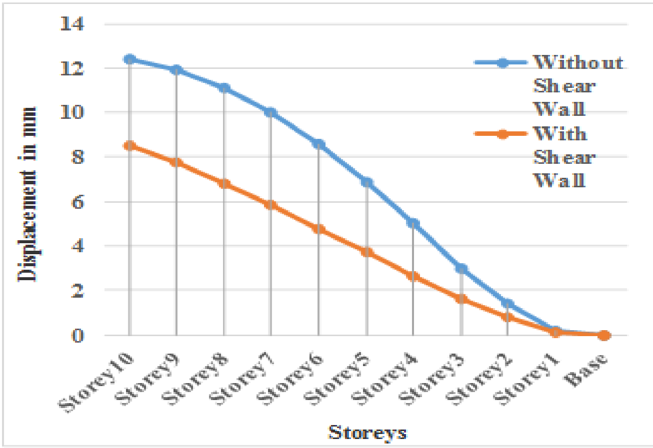


Chart-11: Max storey displacement with and without shear wall

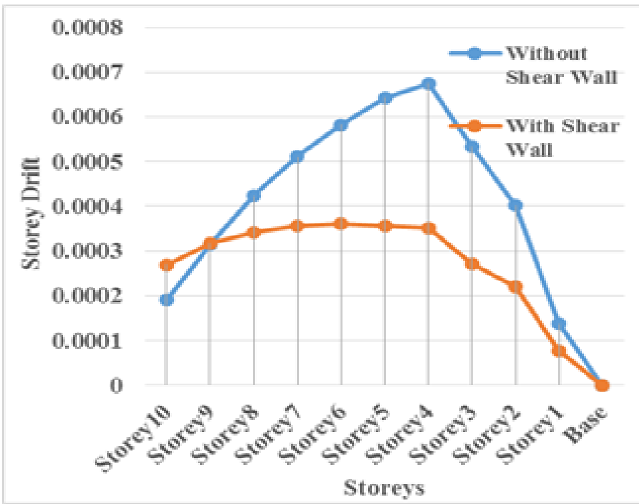


Chart-12: Max storey Drift with and without shear wall.

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