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Seismic Response of Different Irregularities on Low Rise to High Rise Structures

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Abstract
This paper presented the concept of irregularity. Damage occurred during an earthquake, in a structure generally due to plan geometry, mass and stiffness discontinuity. Such structures are known as irregular structures. These weaknesses trigger further structural Deterioration. Irregularity arises difficulties in designing and construction of structure. It is important to have simpler and regular shapes of frames as well as uniform load distribution around the building because irregularities are harmful for the structures. Therefore, as far as possible irregularities in a building are to be avoided.
Keywords: *Response spectrum method, ETAB, IS 1893:2016, Plan irregularity, stiffness irregularity.*

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I. INTRODUCTION

The behavior of a building during an earthquake depends on several factors such as stiffness, lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry, uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But nowadays thirst and demand of the new generation engineers are planning towards an irregular configuration for better aesthetic perspective. Hence earthquake engineering has developed the key issues in understanding the role of different types of building configurations. When a building is subjected to seismic forces, it is being opposed by horizontal inertia forces which are generated from the building.

1.1.1 Scope of the Study

1. Only RC buildings are considered.
2. Linear elastic analysis was done on the structures.
3. Column was modeled as fixed to the base.
4. The contribution of infill wall to the stiffness was not considered. Loading due to infill wall was taken into account.
5. The effect of soil structure interaction is ignored.

1.1.2 Methodology

1. Review of existing literatures by different researchers.
2. 2. Selection of types of structures.
3. 3. Modelling of the selected structures.
4. 4. Performing dynamic analysis on selected building models and comparison of the analysis results.
5. Ductility based design of the buildings as per the analysis results

II. PROBLEM STATEMENT

Six storey (G+5), Eleven storey (G+10) and Sixteen storey (G+15) reinforced concrete frame buildings have been considered & analyzed with the help of ETAB software by using Response spectrum method as per IS 1893 2016 code procedures and detailed as per IS 13920:2016 recommendations.. Following properties are considered for buildings.
Analysis Property Data
a) Material used was M40 Grade Concrete.
b) Yield stress fy = 500 N/mm2
c) Compressive Cube Strength of Concrete = 25 N/mm2

d) Poisson's ratio = 0.15
e) Analysis was done using ETABS Software 9.7
Building Details
a) Type of frame: Special RC moment resisting frame fixed at the base
b) Number of storey: G+5, G+10, G+15
c) Ground Floor height: 3m
d) Floor height: 3.0 m
e) Depth of Slab: 120 mm
f) Size of beam: (250 × 800) mm
g) Size of column: (400 × 900) mm
h) Spacing between frames : (i) 6 m in X & Y direction (General),
(ii) 30 m × 24 m in X & Y direction
i) Live load on floor: 2 kN/m2
j) Floor finish: 1.0 kN/m2
m) Thickness of wall: 230 mm
o) Density of concrete: 25 kN/m3
p) Density of masonry wall: 19 kN/m3
Depth of foundation from ground level = 1.5 m
Seismic Data
a) Type of soil: Medium
b) Seismic zone: IV
c) Importance factor: 1.2
d) Reduction factor: 5
e) Response spectra: As per IS 1893(Part-1):2016
s) Damping of structure: 5 percent

III. MODELING

The main aim of the model is to study the change in building responses (mainly deflection and storey drift) due to various irregularities as peer IS 1893:2002 and IS 1893:2016. The building is analyzed in 6 stages as follows,

1. Regular structure: It is simple structure and is configured as per the problem statement as stated in 2. All the loads and details are same as mentioned conforming to IS 1893. It is a simple structure analyzed for earthquake resistant conforming to the Indian design standard codes.
2. Structure with plan irregularity: It is the modification over the first model. Plan irregularity is introduced by removing size 18m x 12 m from middle side of plan as per the Indian Standard code specifications.

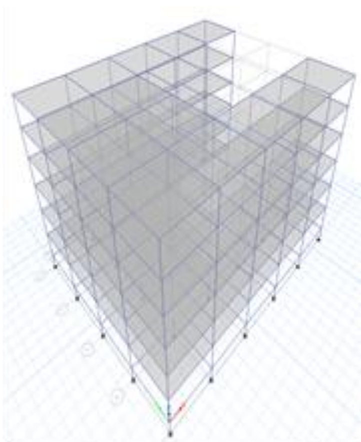

Figure1: Isometric view of Structure with plan irregularity

3. Structure with vertical irregularity: It is the modification over the first model. Vertical irregularity is introduced by removing top two stories in G+5 building, top five stories in G+10 building and five stories after every each span from half of total plan dimensions in G+15 building as per the Indian Standard code specifications.

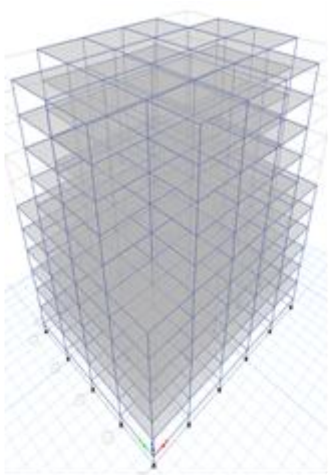

Figure 2: Isometric view of Structure with vertical irregularity

4. Structure with stiffness irregularity: It is the modification over the first model. Stiffness irregularity is introduced by removing beams at fourth slab level in G+5 building, seventh slab level in G+10 building and seventh and thirteenth slab level as per the Indian Standard code specifications.

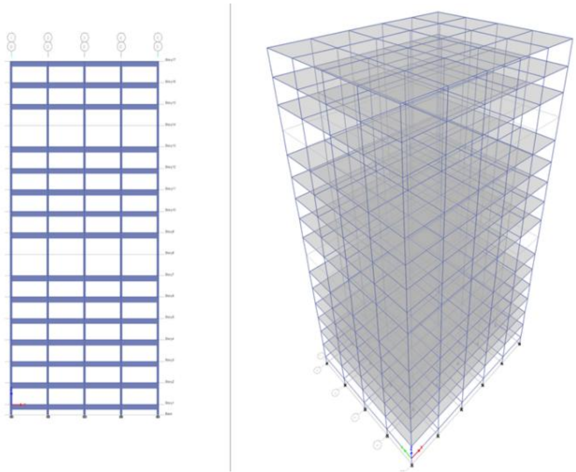

Figure 3: Elevation & isometric view of Structure with stiffness irregularity

5. Structure with mass irregularity: It is the modification over the first model. Mass irregularity is introduced by adding extra 5kN/m² load at fourth slab level in G+5 building, at seventh slab level in G+10 building and ninth and fifteenth slab level as per the Indian Standard code specifications.

6. Structure with strength irregularity: It is the modification over the first model. Weak storey irregularity is introduced by removing six columns at ninth storey in G +5 building, fifth and tenth storey in G+10 building, fifth and eleventh storey in each row as per the Indian Standard code specifications.

IV. RESULTS AND DISCUSSIONS

Figure 4 shows graph of maximum base shear in X direction. In low rise (G+5) building base shear is maximum for structure with vertical irregularity and lowest for structure with plan irregularity. In midrise (G+10) building base shear is maximum for structure with mass irregularity and lowest for structure with plan irregularity. In highrise (G+15) building base shear is maximum for structure with mass irregularity and lowest for structure with vertical irregularity.

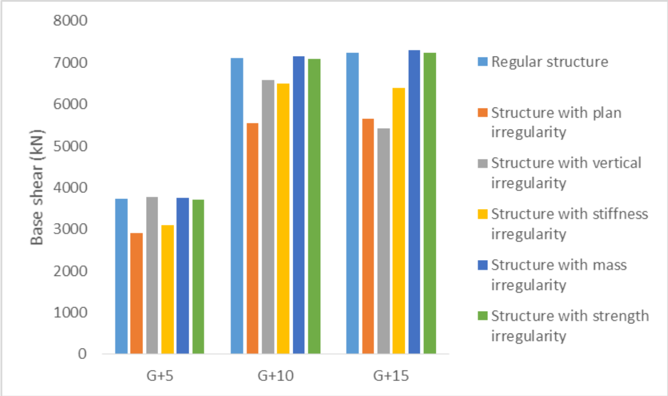

Figure 4: Base shear (kN)

Figure 5 shows graph of maximum lateral displacement in X direction. It shows that lateral displacement is highest for structure with stiffness irregularity in G+5, G+10 and G+15storied building. And lateral displacement is lowest for structure with plan irregularity in G+5 and G+10 storied building. But it is minimum for structure with vertical irregularity in G+15 storied building. So lateral displacement in building fluctuate with respect to plan and vertical irregularity as number of storey changed.

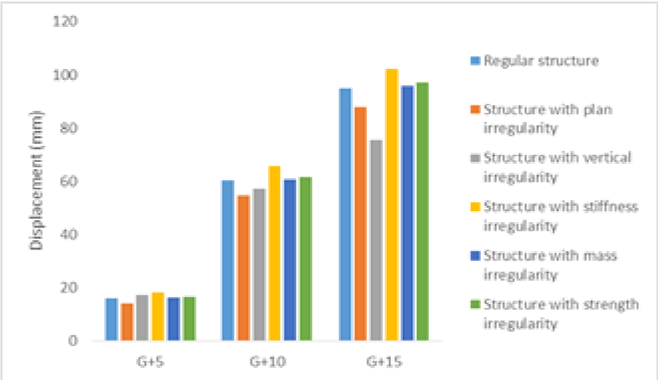

Figure 5: Maximum Lateral Displacement (mm) in X-direction

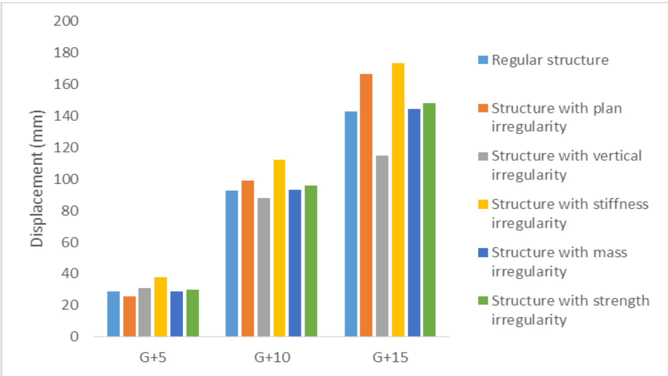

Figure 6: Maximum Lateral Displacement (mm) in Y-direction

Figure 6 shows graph of maximum lateral displacement in Y direction. It shows that lateral displacement is highest for structure with stiffness irregularity in G+5, G+10 and G+15storied building. And lateral displacement is lowest for structure with plan irregularity in G+5 storied building. But it is minimum for structure with vertical irregularity in G+10 and G+15 storied building. So lateral displacement in building fluctuate with respect to plan and vertical irregularity as number of storey changed.

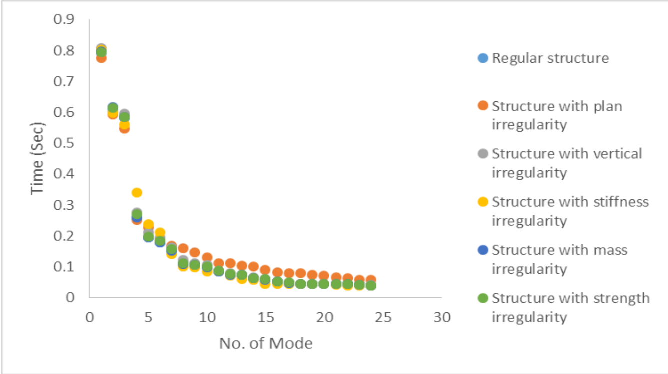

Figure 7: Modal periods (sec) (G+5) storied building

Figure 7 shows graph of modal periods for G+5 storied building with different irregularities. It shows that modal period for structure with vertical irregularity is maximum in all modes.

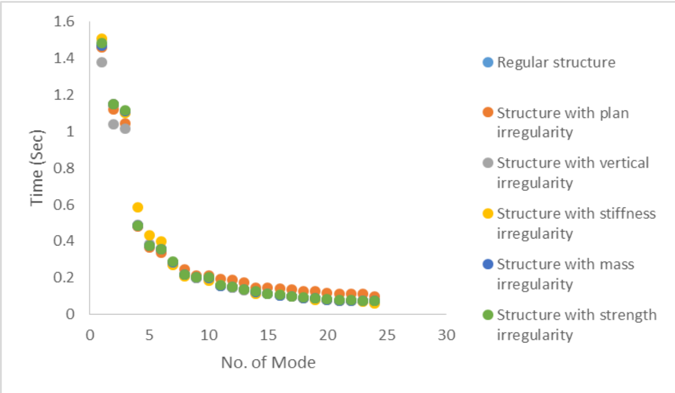

Figure 8: Modal periods (sec) (G+10) storied building

Figure 8 shows graph of modal periods for G+10 storied building with different irregularities. It shows that modal period for structure with stiffness irregularity is maximum in all modes.

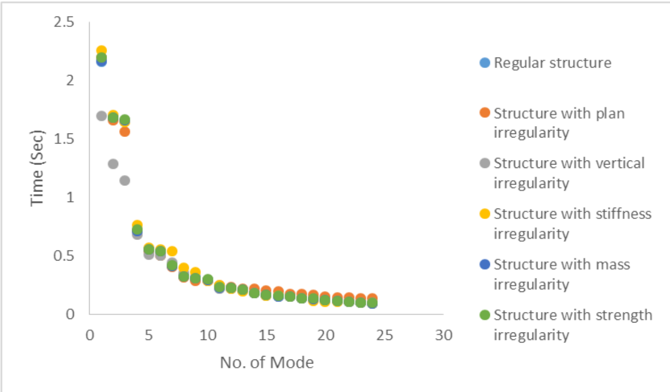

Figure 9: Modal periods (sec) (G+15) storied building

Figure 9 shows graph of modal periods for G+15 storied building with different irregularities. It shows that modal period for structure with stiffness irregularity is maximum in all modes.

V. CONCLUSION

1. In X direction, Lateral force or storey shear at each consecutive storey level for mass irregularity is more as compared to other types of irregularity. Vertical irregularity has least lateral force on consecutive story's as compared to other types of irregularity. Approximately on an average 15% lateral force or storey shear is decreased or increased between all studied types of irregularities.

2. In Y direction, Lateral force or storey shear at each consecutive storey level for regular structure is more as compared to other types of irregularity. Vertical irregularity has least lateral force on consecutive story's as compared to other types of irregularity. Approximately on an average 15% lateral force or storey shear is decreased or increased between all studied types of irregularities.
3. Storey shear and base shear in both the directions i.e. along X-direction and along Z-direction are increased by nearly same amount i.e. approximately 15% when using IS 1893:2016.
4. In X direction, nodal displacement for stiffness irregularity is more as compared to other types of irregularity. Vertical irregularity has least nodal displacement as compared to other types of irregularity. Approximately on an average 25% nodal displacement is decreased or increased between all studied types of irregularities.
5. In Y direction, nodal displacement for stiffness irregularity is more as compared to other types of irregularity. Vertical irregularity has least nodal displacement as compared to other types of irregularity. Approximately on an average 25% nodal displacement is decreased or increased between all studied types of irregularities.
6. Modal time period for stiffness irregularity is more as compared to other types of irregularity. Vertical irregularity has least time period as compared to other types of irregularity

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