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SEISMIC BEHAVIOUR OF BUILDINGS HAVING VERTICAL IRREGULARITIES

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***Abstract*— During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. The object of the present work is to compare the seismic behaviour of regular building frame with vertically irregular building frame at different positions. For this purpose four frames of multi-storey buildings are considered. To study the behaviour the response parameters selected are lateral displacement and storey drift. All the frames are assumed to be located in zone II, zone III, zone IV and zone V. For analysis STAAD.Pro software is used.**

Observation shows that for all the frames considered, drift values follow a similar path along storey height with maximum value lying somewhere near the thirteenth to fifteenth storey. From drift point of view, frame 1, 2 and 3 are within permissible limits in zone IV and zone V although at some storeys frame 2 and 3 exceeds marginally. But frame 4 in zone V exceeds permissible limits largely after tenth storey. In zone II and III all the frames are within permissible limit, hence there is no requirement of shear wall in these zones. And from displacement view point, only in zone II all the frames are within permissible limit. In zone III frame 1, 2 and 3 are in permissible limit but frame 4 requires shear wall to control the limit. In zone IV only frame 1 is within permissible limit, all other exceeds limits largely. And in zone V all the frames exceeds largely.

Present work provides a good source of information on the parameters lateral displacement and storey drift.

***Keywords*— Irregular Structures, Vertical Irregularity, Grid Slab, Seismic Forces, Lateral Displacement, Storey Drift.**

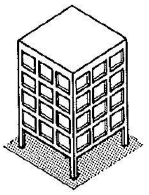
I. INTRODUCTION

Main structural damages occur when Dynamic Loads including both Earthquake and Wind loads are applied on a building. In these modern days, most of the structures are constructed with architectural significance and it is extremely impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under the action of dynamic loads. Therefore, wide research is required for achieving a great performance even with a poor configuration.

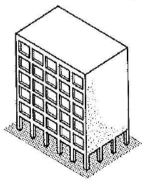
A building is supposed to be a regular when its configurations are nearly symmetrical about the axis and it is said to be the irregular when it lacks symmetry and discontinuity in the geometry, mass or elements which resists load.

At the time of an earthquake, structure starts to fail at the points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of the structure. The building structures having this type of discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the main reasons of failures of building structures during earthquakes. As an example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities on the seismic evaluation of structures becomes actually important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the regular building.

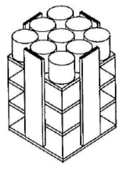
Irregular buildings make up a large portion of the urban infrastructure. The presence of irregularities can be due to architectural, functional, and economical constraints. The main objective of this research is to improve the understanding of the seismic behaviour of building structures with vertical irregularities. This is done by quantifying the effects of vertical irregularities in mass, stiffness, or strength on seismic demands.



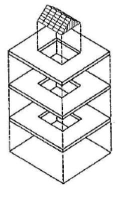
(1) "Soft" lower levels



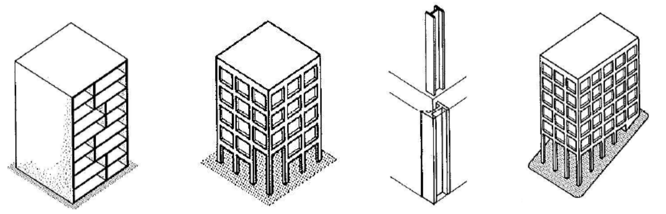
(2) Opening in Shear Walls



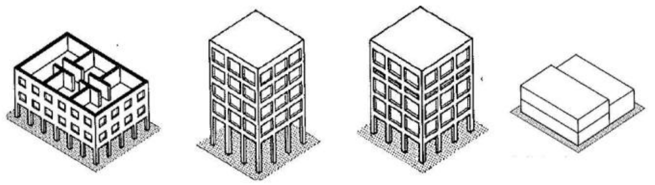
(3) Difference in floor mass



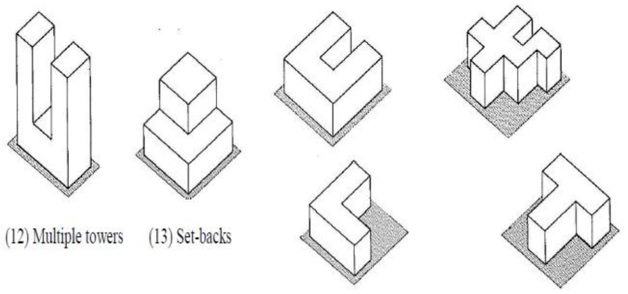
(4) Openings in diaphragms or difference in diaphragm systems



(5) Interruption of vertical-resisting elements (6) Interruption of beams (7) Abrupt changes in member sizes (8) Buildings on hillsides



(9) Different lateral force resisting systems in different storeys (10) A storey height being higher or lower than adjacent storey height (11) Split levels



(12) Multiple towers (13) Set-backs

(14) Buildings with different plan types (L, T, U etc. shapes)

Fig. 1 Types of irregularities

A. SEISMIC BEHAVIOR OF VERTICALLY IRREGULAR BUILDINGS-

Several studies have been conducted in the past explaining the behaviour of irregular structures. However, such studies have not been conducted particularly to quantify the variation in response related with a particular degree of irregularity so the authority of the irregularity limits, or the difference in response due to structures getting these limits, is not known.

At the time of an earthquake, structure starts to fail at the weakness points. This weakness is due to the discontinuity in mass, stiffness and geometry of the structure. The building structures having this type of discontinuity are termed as irregular building structures. Irregularity in structures contributes a huge portion of urban infrastructure. Vertical irregularities are one of the main reason of failures of building structures during earthquakes. As an example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities on the seismic evaluation of structures becomes actually important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the regular building.

Building structures are designed according to Design based earthquake, but the actual loads acting on the structure is far more than that of DBE. So, in higher seismic zones Ductility based design procedure is preferred as ductility of the structure which narrows the gap. The main objective in designing earthquake resistant structures is to ensure that the building has adequate ductility to withstand the earthquake loads, which will be subjected to during an earthquake.

II. PROBLEM FORMULATION & ANALYSIS

The objective of the present work is to compare the seismic performance of multi-storey buildings having vertical irregularity at different positions with that to regular buildings of similar properties. For this purpose four frames of multi-storey buildings are considered. For the comparison, parameters taken are lateral displacement and storey drift. All the four frames are analysed with and without shearwall for zone II, III, IV and V.

Details of the four frames are as follows:

Frame-I is a regular building of 20 stories having symmetrical plan configuration square in shape provided with 6 x 6 bays and is considered whose centre of mass coincides with centre of rigidity. Three other frames having 6 x 6 bays up to tenth floor and 2 x 2 bays from tenth floor to twentieth floor with unsymmetrical vertical configuration starting from tenth floor, placed at corner, at the center and at edge of the plan respectively are also considered. All these are twenty storied building frames with floor heights of 3.6m each and bay size of 4m x 4m. The total height of all the building frames is 72m.

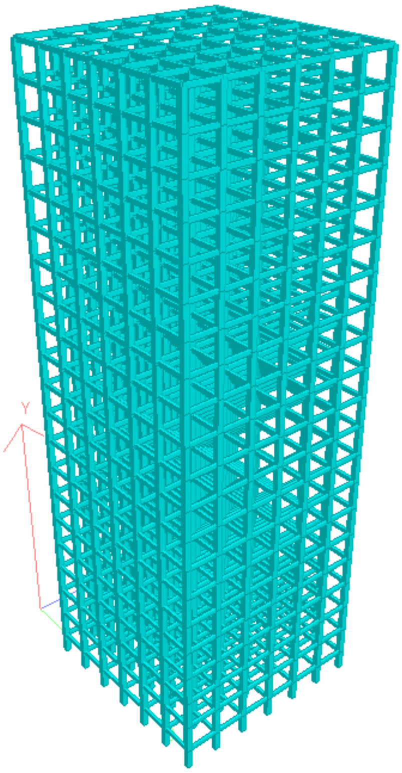


Fig. 2 Frame 1 without shearwall

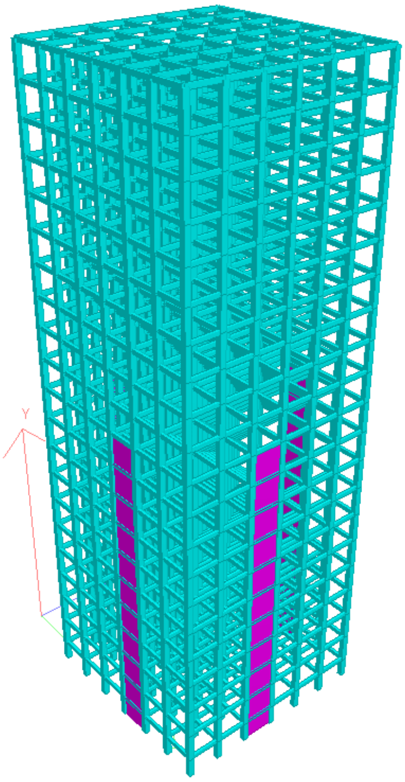


Fig. 3 Frame 1 with shearwall

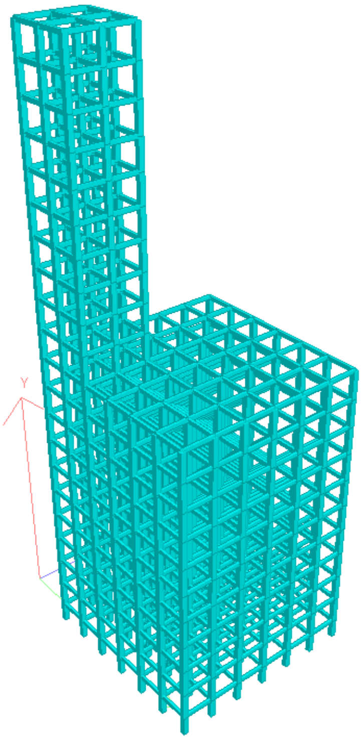


Fig. 4 Frame 2 without shearwall

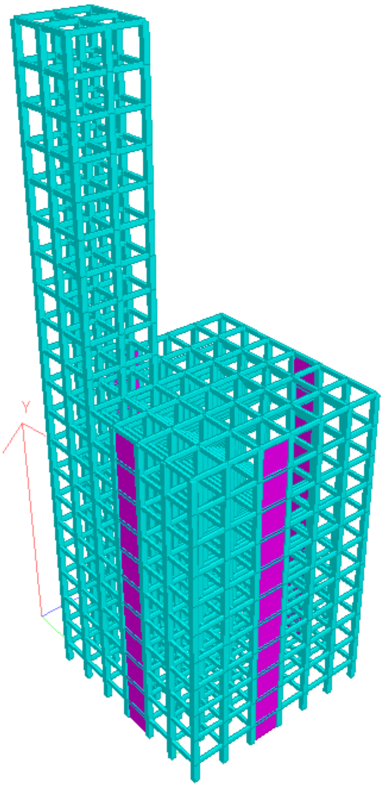


Fig. 5 Frame 2 with shearwall

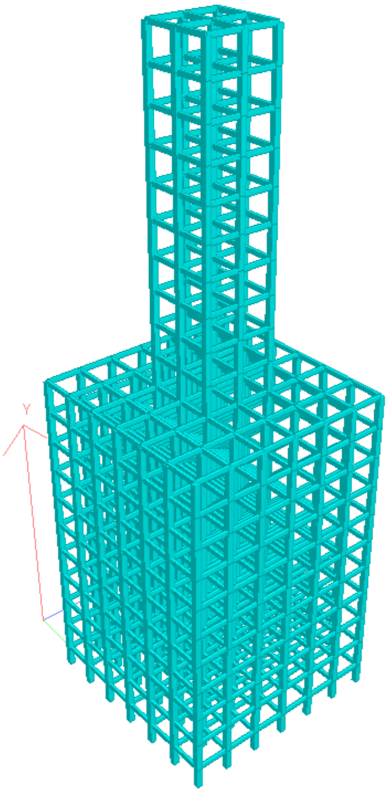


Fig. 6 Frame 3 without shearwall

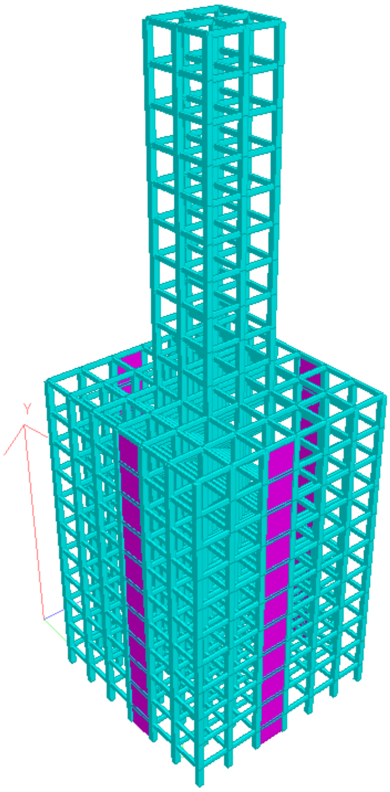


Fig. 7 Frame 3 with shearwall

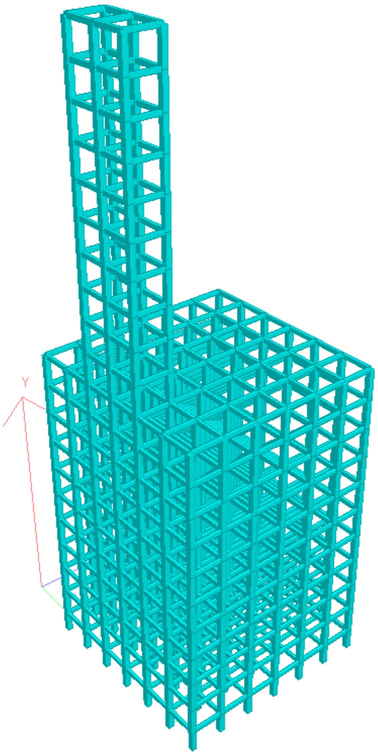


Fig. 8 Frame 4 without shearwall

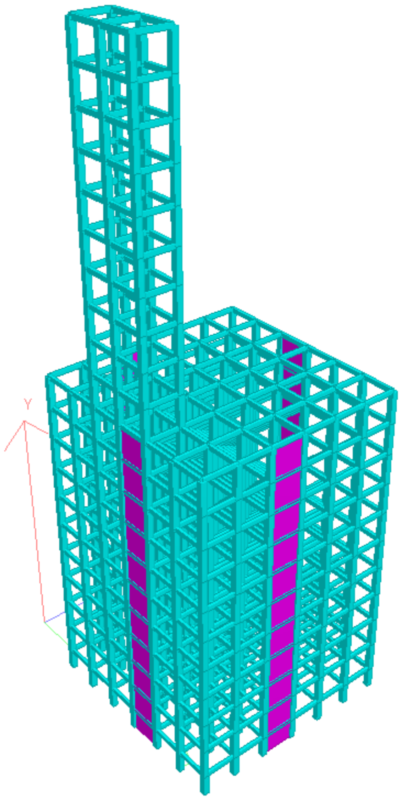


Fig. 9 Frame 4 with shearwall

Details of all the cases:

1. Storey height provided in all the cases is 3.6m.
2. Sizes of beams are taken as 300mm x 450mm in all the cases.
3. Sizes of columns are taken as 450mm x 450mm in all the cases.
4. Loadings considered are:

a). Dead Load- It is taken by software itself.
b). Live Load- 4 KN/m2 on all the floors.
c). Earthquake Load- As per IS 1893 (part-I):2002.

5. Load combinations considered are:

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

III. Results And Discussions

The study examines the seismic performance of multi-storey buildings having vertical irregularity at different positions. Four building frames are analysed for zone II, zone III, zone IV and zone V. To study the effectiveness of all these frames, the storey drift and lateral displacement are worked out and are presented here in detail.

Effect of parameters studied on storey drift:

1. According to IS:1893:2002 (part I), upper limit for storey drift with partial load factor 1.0 is 0.004 times of storey height. Here, for 3.6 m height and load factor of 1.5, though maximum drift will be 21.6 mm.
2. From the results it is observed that for all the frames considered drift values follow a similar path along storey height with maximum value lying somewhere near the thirteenth to fifteenth storey.
3. In zone II and III it is observed that for all the frames storey drift is safe under its permissible limit and hence there is no need to provide shear wall.
4. In zone IV it is observed that frame 1, 2 and 3 are safe and not exceeding maximum limit hence there is no need to provide shear wall. But frame 4 is exceeding limits in twelfth to sixteenth storeys by 0.4mm, 2.4mm, 1.4mm, 2.4mm and 0.4mm respectively in case of without shear wall and also in case of with shear

wall hence to make it safe shear wall should be provided throughout the building height.

5. In zone V in case of without shear wall and with shear wall it is observed that frame 1 regular building is well within permissible limits. Frame 2 exceeds drift at twelfth to fifteenth storey slightly by 1.4mm, 2.4mm, 1.4mm and 0.4mm. Frame 3 is well within permissible limit except thirteenth and fourteenth storey by 0.4mm which is ignorable. Frame 4 is safe only upto tenth storey and exceeds permissible values largely from eleventh to twentieth storey so in case of frame 4 shear wall should be provided throughout the building height.

Effect of parameters studied on lateral displacement:

1. As per IS:456:2000, upper limit for lateral displacement is H/500, where H is building height. Here for building height 72m maximum limit for displacement is 144mm.
2. In zone II it is obtained that all the frames are safe within permissible limit in the case of without shear wall so shear wall is not necessary to provide here.
3. In zone III it is observed that frame 1, 2 and 3 are safe within permissible limit hence there is no need to provide shear wall in these buildings. But in frame 4 it exceeds maximum permissible limit in 18th, 19th and 20th floors, so shear wall should be provided throughout the building height only in frame 4.
4. In zone IV it is observed that frame 1 regular building is safe in displacement. But frame 2, 3 and 4 irregular buildings exceeds maximum permissible limits of displacement. In which frame 4 exceeds largely by 101mm hence shear wall throughout the building height is to be provided in frame 2, 3 and 4 to reduce the displacements.
5. In zone V it is observed that all the four models exceeds largely to maximum permissible limits of displacement, therefore to reduce displacements shear wall must be provided throughout the building height.

IV. CONCLUSIONS

Within the scope of present work following conclusions are drawn:

1. For all the frames considered, drift values follow a similar path along storey height with maximum value lying somewhere near the thirteenth to fifteenth storey.
2. From drift point of view, frame 1, 2 and 3 are within permissible limits in zone IV and zone V although at some storeys frame 2 and 3 exceeds marginally. But frame 4 in zone V exceeds permissible limits largely after tenth storey. In zone II and III all the frames are within permissible limit, hence there is no requirement of shear wall in these zones.
3. From displacement view point, only in zone II all the frames are within permissible limit. In zone III frame 1, 2 and 3 are in permissible limit but frame 4 requires shear wall to control the limit. In zone IV only frame 1 is within permissible limit, all other exceeds limits largely. And in zone V all the frames exceeds largely.

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