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# Analysis of Vertically Regular and Irregular Buildings Subjected to Seismic Load using Pushover Analysis

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*Abstract*—**Earthquakes are the most dangerous natural hazards that cause great loss of life and livelihood. Most of the losses are due to the building collapses or damages, therefore it is very important to design the structure in accordance with codal specification. Most of the physical phenomena that we see every day are nonlinear and therefore we cannot neglect this kind of phenomenon. Therefore pushover analysis helps us to understand nonlinear behavior of structure under gravity loads and monotonically increase in the lateral load. In the present study pushover analysis method is adopted according to IS 1893 (part 1):2002 specifications and analysis has been performed using ETABS version 15.2.2.**

***Keywords— Lateral displacement, Vertical Irregularity, Stifness Irregularity, Storey Shear, Pushover Analysis, ETABS 2015 (V 15.2.2)***

## I. INTRODUCTION

Irregularly shaped architectural innovation is challenges faced by structural engineers nowadays, as in the urban areas the available space for the construction of building is limited.
So this leads to the height wise changes in buildings, the variable height is termed as Irregular Structures. Vertical Irregularities such as Stiffness Irregular, Mass Irregular and Geometry of the structure weakens the structure. Vertical Irregularities are one of the major reasons for the failure of structure during earthquake.

As per IS 1893 (Part 1): 2002, Vertical Irregular buildings are mainly classified in to two categories, viz. Plan Irregularity and Vertical Irregularity.

Plan Irregularity may be because of Plan Geometric Irregularity, Diaphragm Irregularity, Setbacks, Torsional Irregularity, and Non parallel system. Vertical Irregularity may be because of Stiffness Irregularity, Mass irregularity, In-Plane discontinuity, Vertically Geometric Irregularity, Discontinuity in capacity. Vertical Irregularities are mainly of five types-

1) a) Stiffness Irregularity — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above

*b) Stiffness Irregularity* — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.

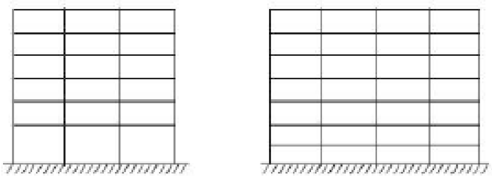

Fig. 1. Stiffness Irregularities

2) *Mass Irregularity*-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

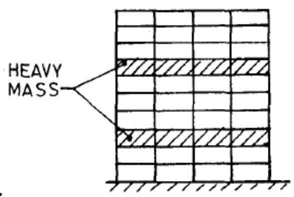


Fig. 2. Mass Irregularity

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 05, May-2018

3) *Vertical Geometric Irregularity*- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

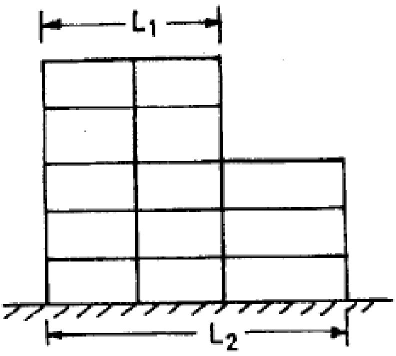


Fig. 3. Vertical Geometric Irregularity

4) *In-Plane Discontinuity in Vertical Elements Resisting Lateral Force*-An in-plane offset of the lateral force resisting elements greater than the length of those elements.

5) *Discontinuity in Capacity* - Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

## II. MODELING USING ETABS

The building is columns spaced at 5m from center to center. Floor to floor height of 3.2m is kept for stiffness regular building and for stiffness irregular building the first storey height is varied as 4.5m, and volume of all building kept same that is 3.2m.The shape of the building is regular model (Box).

Loads are assigned to the models based on IS 875 (part 2):1897. Loads are applied to the models. Hinges are assigned to the models at a distance of 5% and 95% length of beams and columns. Later, the defined diaphragm is assigned. Finally Pushover analysis is carried out to the models by applying the seismic loads in push X and push Y directions.

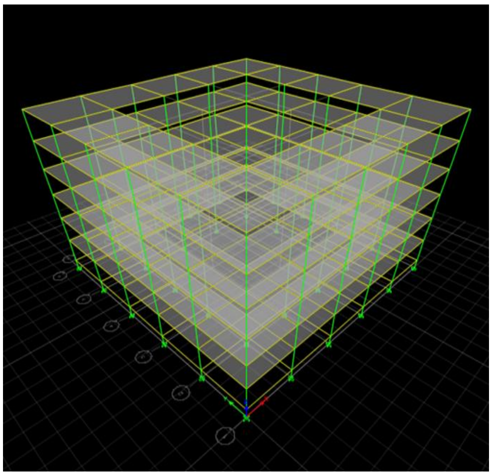

Fig. 4. 3D view of stiffness regular building

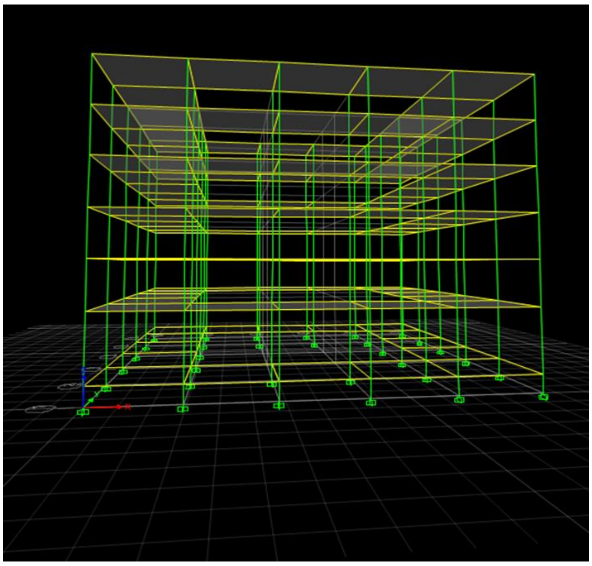

Fig. 5. 3D view of Stiffness Irregular building

## III. METHODOLOGY

The software used in the present study is ETABS-2015 and the method of seismic analysis used is Non-linear Static Analysis also known as Pushover Analysis. The models used for present study include buildings with stiffness regularity and stiffness irregularity. The shape of the model considered is a box shaped model. Both stiffness regularity and stiffness irregularity models consist of each (G+5).

The dimension of the columns being fixed at 230mm x 600mm and that of the beams at 230mm x 450mm for stiffness regularity and stiffness irregularity models as shown in table 1. Also both the stiffness regularity and stiffness irregular models have been analysed for rigid and semi rigid in membrane also, rigid and semi rigid in shell. In this study the results are considered at End of the projection and Re – entrant corner as shown in fig 5.

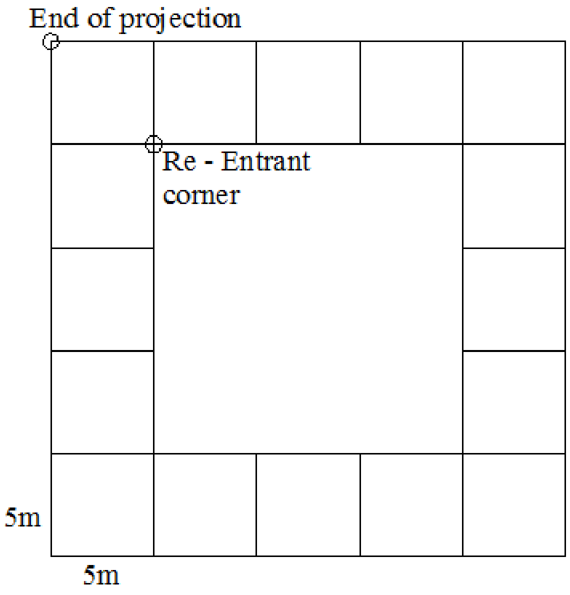


Fig. 6. End of projection and Re-Entrant corner

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 05, May-2018

TABLE I: PARAMETERS CONSIDERED IN THIS STUDY

| | | |
|---|---|---|
| 1 | Structure Type | Ordinary Moment Resisting Frame |
| 2 | No. of Storey | G+5 |
| 3 | Typical Storey Height | 3.2m |
| Material Properties | | |
| 1 | Grade of Concrete | M20 |
| 2 | Grade of Steel | Fe-500 |
| 3 | Density of Concrete | 25kN/m3 |
| Member Properties | | |
| 1 | Slab Thickness | 0.15m |
| 2 | Beam size | 0.23mX0.45m |
| 3 | Column size | 0.23mX0.6m |
| Loads considered | | |
| 1 | Live Load | 3.5 kN/$m^2$ |
| 2 | Reduced Live Load | 2.5kN/$m^2$ |
| 3 | Floor Finish | 1kN/$m^2$ |

## IV. RESULTS AND OBSERVATIONS

In the present study, Storey shear and Lateral displacement of vertically regular and irregular structures are identified. Significance and effects of different parameters are studied in detail. Seismic analysis is carried as per IS 1893 (part1): 2002 guidelines. Pushover analysis is adopted and analysis is carried out using ETABS 2015 v 15.2.2 software package.
The variation of storey shear with respect to number of storey for stiffness regular and stiffness irregular building is shown in Fig. 7. to Fig. 10. It can be observed that the storey shear goes on increasing from top storey towards the support.

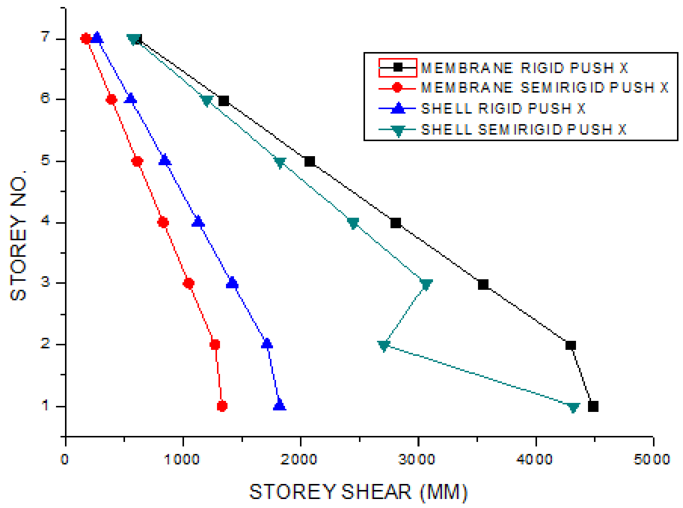


Fig. 7.Variation of storey shear along PUSH X for Stiffness Irregular building.

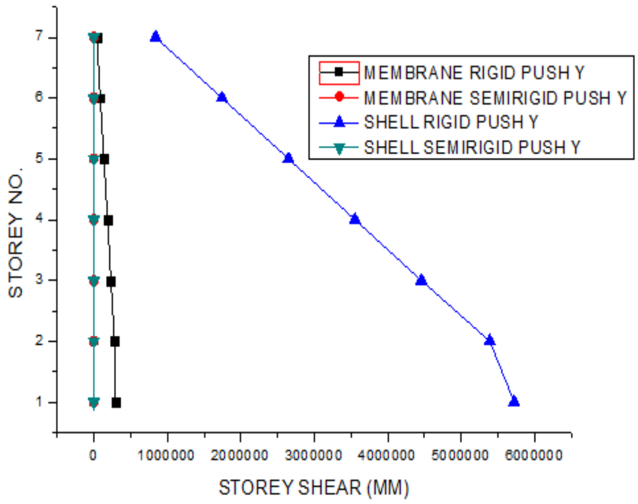


Fig. 8.Variation of storey shear along PUSH Y Stiffness Irregular building.

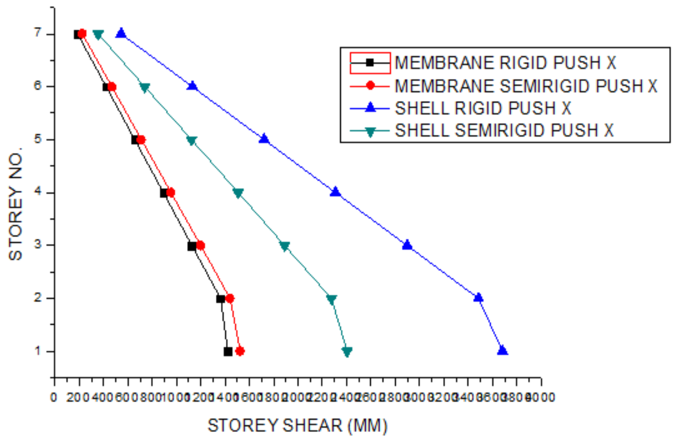


Fig. 9.Variation of storey shear along PUSH X for Stiffness regular building.

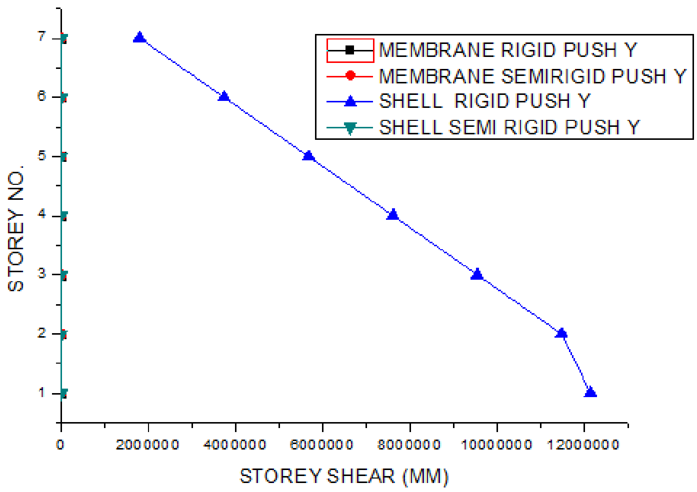


Fig.10.Variation of storey shear along PUSH Y for Stiffness regular building

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The variation of lateral displacement with respect to number of storey for stiffness regular and stiffness irregular building is shown in Fig. 11. to Fig. 18. It can be observed that the lateral displacement goes on increasing as the height of the building increases.

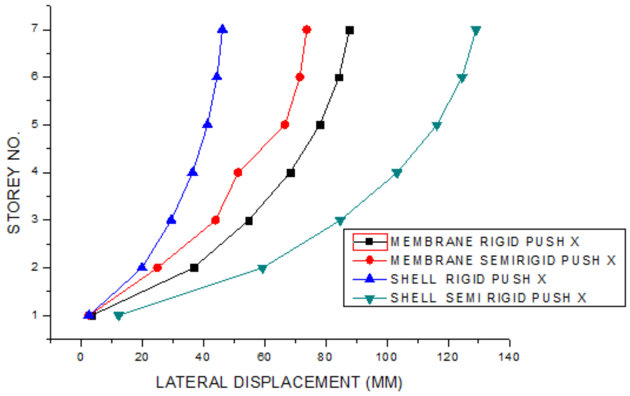


Fig. 11. Variation of Lateral displacement along PUSH X for Stiffness Irregular at Re-entrant corner.

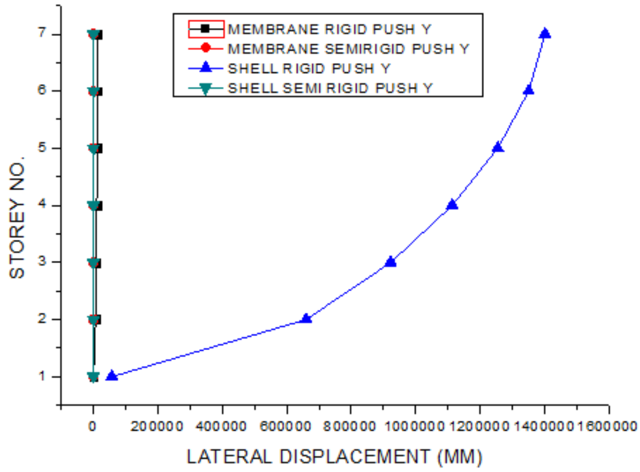


Fig. 12. Variation of Lateral displacement along PUSH Y for Stiffness Irregular at Re-entrant corner.

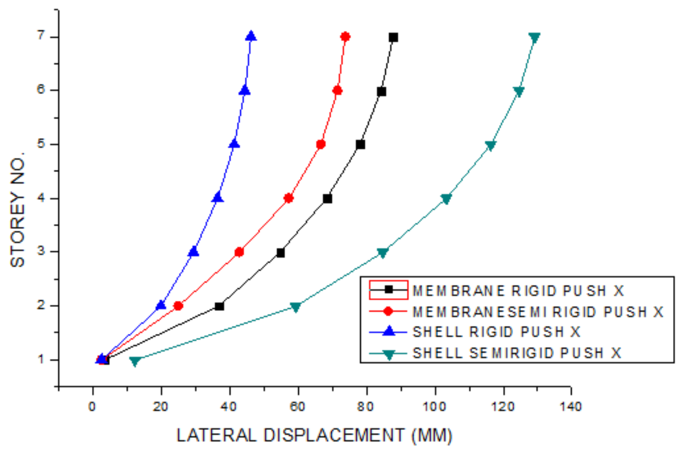


Fig. 13. Variation of Lateral displacement along PUSH X for Stiffness Irregular at End of projection

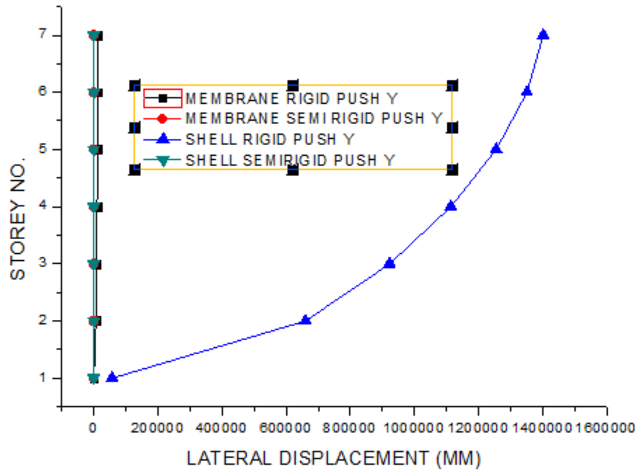


Fig. 14. Variation of Lateral displacement along PUSH Y Stiffness Irregular at End of projection

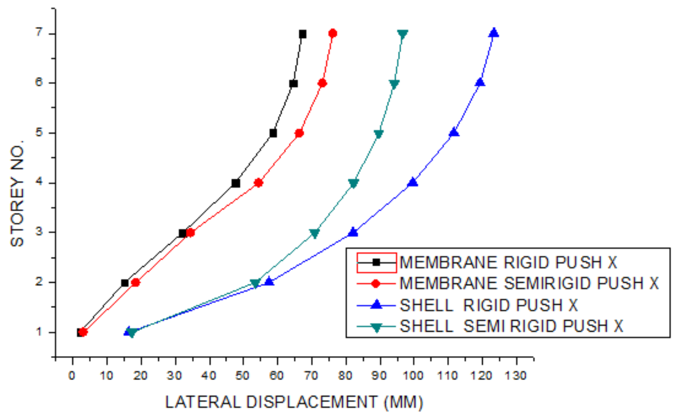


Fig. 15.Variation of Lateral displacement along PUSH X Y for Stiffness regular at Re-entrant corner.

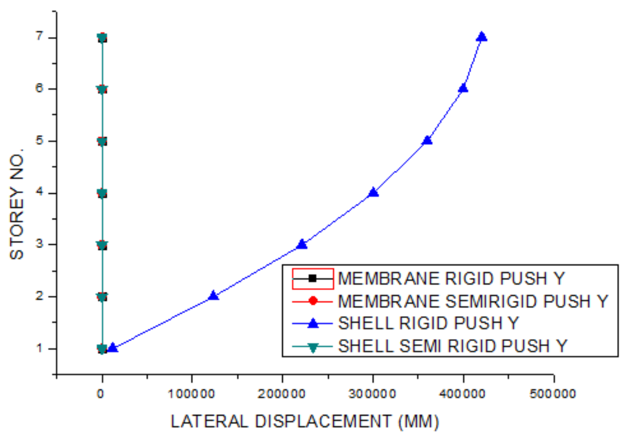


Fig. 16. Variation of Lateral displacement along PUSH Y for Stiffness regular at Re-entrant corner.

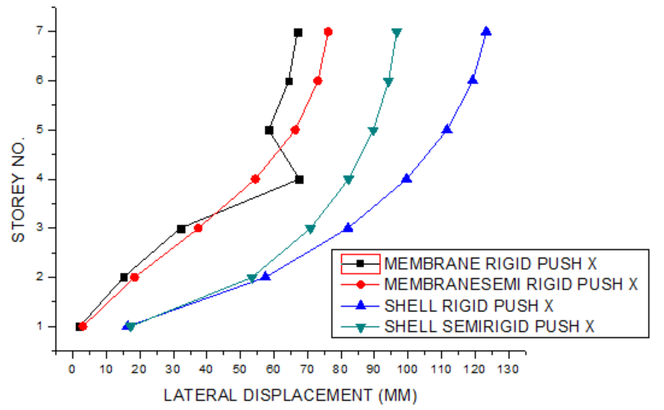


Fig.17. Variation of Lateral displacement along PUSH X for Stiffness regular at End of projection.

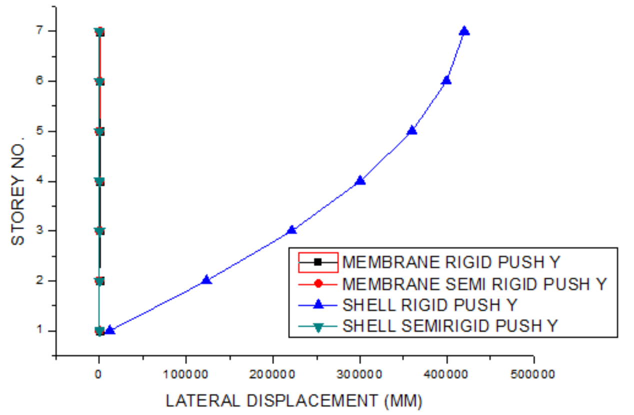


Fig. 18.Variation of Lateral displacement along PUSH Y for Stiffness regular at End of projection.

## V. CONCLUSIONS

As of urbanization, the world is facing a lot of scarcity of land, which has lead to the vertical development in the field of Civil Engineering. In order to meet the demand of people, the buildings are constructed in a more irregular way. So in the present study, it can be seen that, the membrane with semi-rigid diaphragm and shell with semi-rigid diaphragm are performing better in the seismic area when compared to membrane rigid diaphragm and shell rigid diaphragm. Also, it can be seen that the storey shear goes on increases with the decrease in height of the building. Similarly, the lateral displacement increases as the height of the building increases.

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