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PUSHOVER ANALYSIS OF HIGH RISE RCC BUILDING WITH VERTICAL IRREGULARITIES

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Abstract — *The seismic behavior of multi-storied building frame during an earthquake motion depends upon the distribution of strength, mass and stiffness in both horizontal and vertical planes. The structural damage of the building frame is occurs due to the discontinuity in the stiffness mass and strength between the adjacent stories. The common type of discontinuity is vertical geometric irregularity which is due to the irregular building configuration in vertical plane. So there is need to study the seismic response of building frames under different structural irregularities. Pushover analysis is one of the analysis method which is adopted for the present study. Present study aims towards doing Nonlinear Static Pushover Analysis of G +20 high rise RCC residential building. This work shows that the comparison seismic performance and behavior of building frame with and without vertical irregularity in terms of parameter like story shear, storey displacement, and storey drift. Also comparison of seismic response of the structure in terms of base shear and displacement along with the location of the plastic hinges at the performance point of all the models are considered. All building frames are analyzed by using design and analysis software ETABS and design as per IS 456:2000 and IS 1893:2002.*

Keywords- *pushover analysis, type of irregularity, story drift, base shear, lateral displacement.*

I. INTRODUCTION

Over the past decades and more it has been recognized that damage control must become a more explicit design consideration which can be achieved only by introducing some kind of nonlinear analysis into the seismic design methodology. Following this pushover analysis has been developed during past decades and more and has become the preferred method of analysis for performance-based seismic design, PBSD and evaluation purposes. It is the method by which the ultimate strength and the limit state can be effectively investigated after yielding, which has been researched and applied in practice for earthquake engineering and seismic design. The failure in the multistorey building due to seismic loading generally initiates at the location where there is a weakness in the building. This weakness causes deterioration of the building which results in structural collapse. This weakness mostly occurs due to the presence of irregularities in stiffness, strength and mass in a building. These irregularities are classified into two forms namely plan irregularity and vertical irregularity. As per IS 1893:2002 (part I) vertical irregularities are classified as follows:

1) Stiffness irregularity:

a) Soft storey: A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above

b) Extreme soft storey: A 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.

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.

3) Vertical geometric irregularity: Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

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: A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

II. OBJECTIVE OF STUDY

The main objective of the study is to evaluate the performance of G+20 RCC Building structure with and without vertical irregularities using pushover analysis. Different regular and vertical irregular structures are considered in this study. The pushover analysis is carried out for all the structures and they are compared. The specific objectives are as given below:

- To Analyze high-rise RCC building by using ETABS software
- To study three irregularities in structures namely Mass irregularity, Stiffness irregularity and Combine irregularity.
- Comparative Study of Structural Parameters like Base Shear, Storey Drift and Story Displacement of RCC Building.
- To calculate the design lateral forces on regular and irregular buildings using pushover analysis and to compare the results of different structures.

III. STRUCTURAL MODELLING, METHODOLOGY AND ANALYSIS OF FRAMES

A RCC frame with G+9 storey of dimension, has been taken for seismic analysis. Four building models with different types of irregularities are considered for comparison:

- **Regular Building.**
- **Regular Building with Stiffness Irregularity.**

The structure is same as that of regular structure but the ground storey has a height of 4.5 m.
Stiffness of each column= $12EI/L^3$
Therefore,
Stiffness of ground floor/stiffness of other floors=
$(3.5/4.5)^3$ =0.47<0.7
Hence as per IS 1893 part 1 the structure is stiffness irregular.
Stiffness Irregularity is provide in the G.F and 10th floor.

- **Regular Building with Mass Irregularity.**

The structure is modeled as same as that of regular structure except the loading due to heavy mass is provide in the 5^{th} and 15^{th} floor.

- **Regular Building with Combine Irregularity.**

The structure is same as that of regular structure but it is combination of stiffness and mass irregularity.
Stiffness Irregularity is provide in the G.F and 10^{th} floor.
Mass irregularity is provide in the 5^{th} and 15^{th} floor.
Stiffness, mass and combine irregularity 3D models are created for all the considered building structures and material properties, frame sections, load cases are defined and assigned. Gravity analysis and linear static analysis is carried out as per IS 456-2000 and IS 1893-2002.For beams default hinge (PM3) is assigned and for columns default hinges of axial force and bending moment (PM2-M3) is assigned. Hinges are assigned both for end beams and columns. Two static pushover cases are defined. Initially gravity load is applied to the structure and then lateral load along longitudinal direction is applied to the structure and pushover analysis is carried out using ETABS software.

➢ ***Description of the building:-***

The data of modeled building is as follows:
Number of storey-G+20
Floor height - 3m
Type of building – Residential
Soil strata – Medium

➢ ***Material Properties***

Grade of concrete - M25
Grade of steel - Fe 415
Density of concrete – 25kN/m3
Density of brick – 20kN/m3

➢ ***Member Properties***

Thickness of slab - 150mm
Beam size –230 mm x 4500 mm, 300mm x 450mm
Column size: For 1^{st} to 6^{th} floor - 300mm x 750mm,
For 7^{th} to 13^{th} floor - 300mm x 600mm,
For 14^{th} to 21^{th} floor - 300mm x 530mm
External wall thickness - 230mm
Internal wall thickness - 125mm

➢ ***Load Intensities***

Floor finish – 1.5KN/m^2

Live load – 2KN/m^2

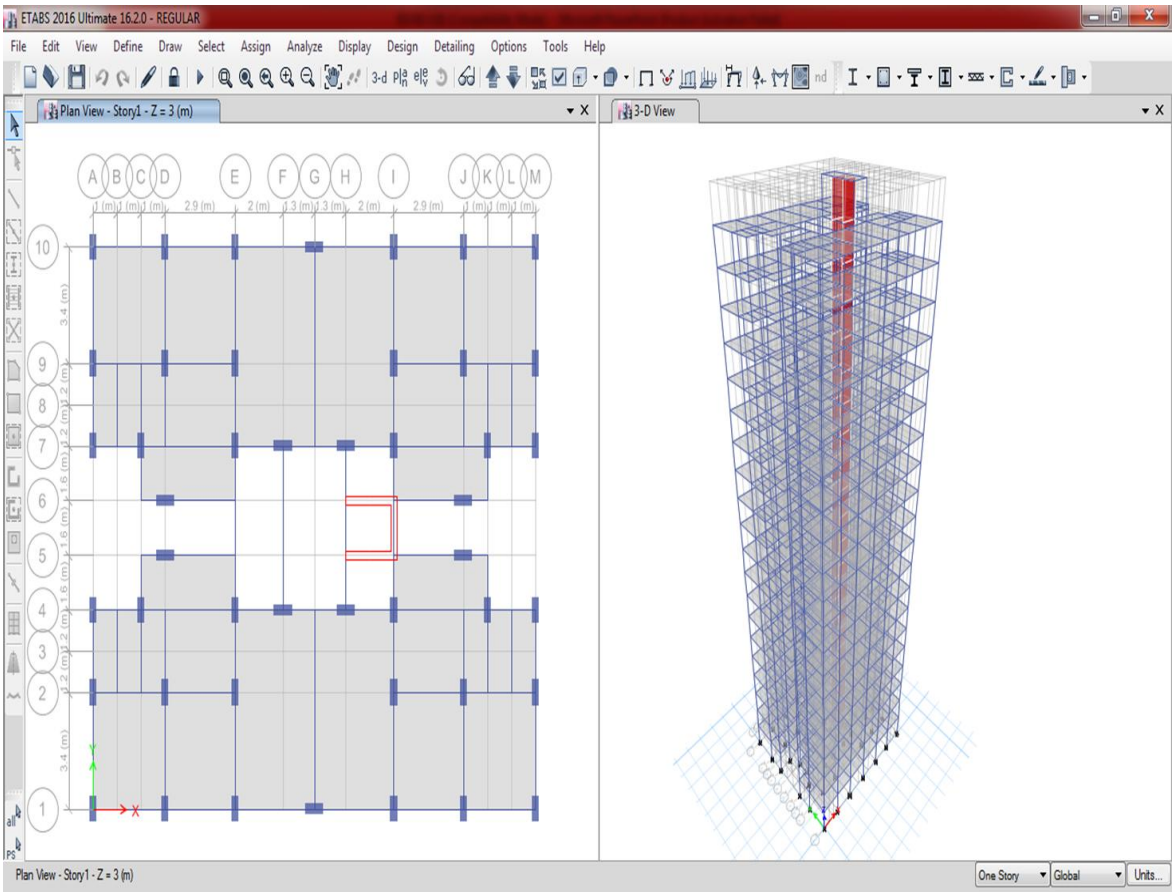

Figure 1: Model-1 - PLAN OF REGULAR RC BUILDING

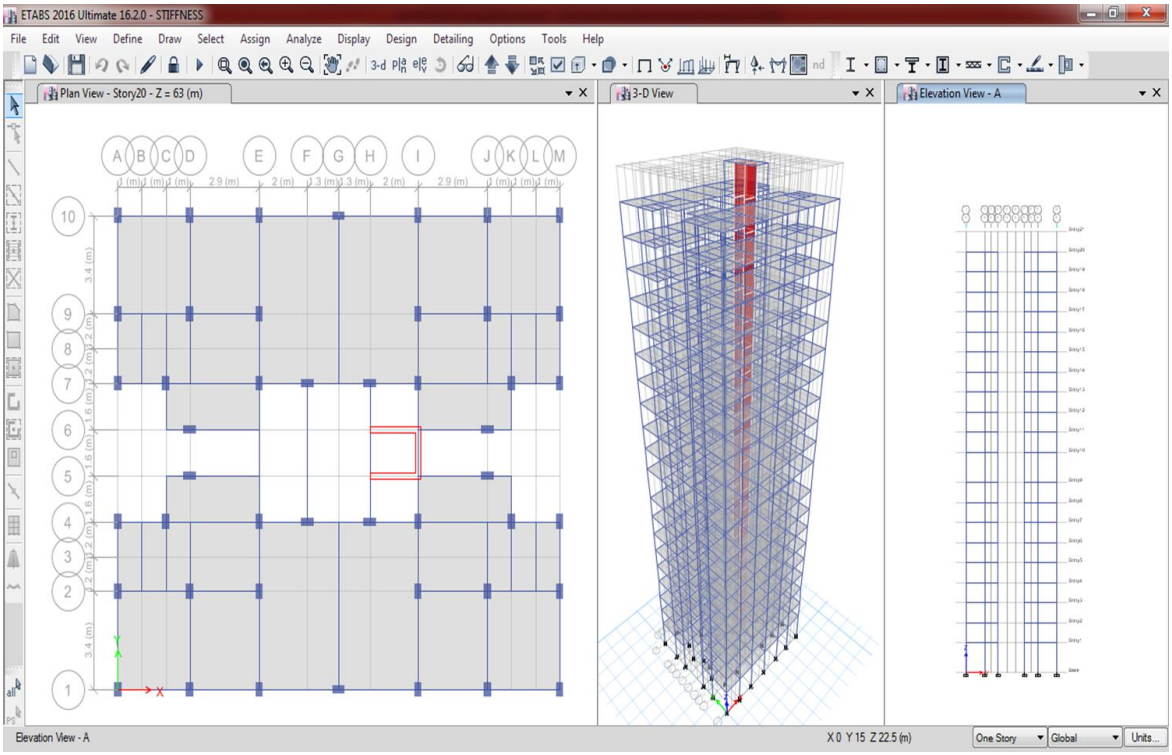

Figure 2: Model-2 - PLAN OF STIFFNESS IRREGULARITY BUILDING

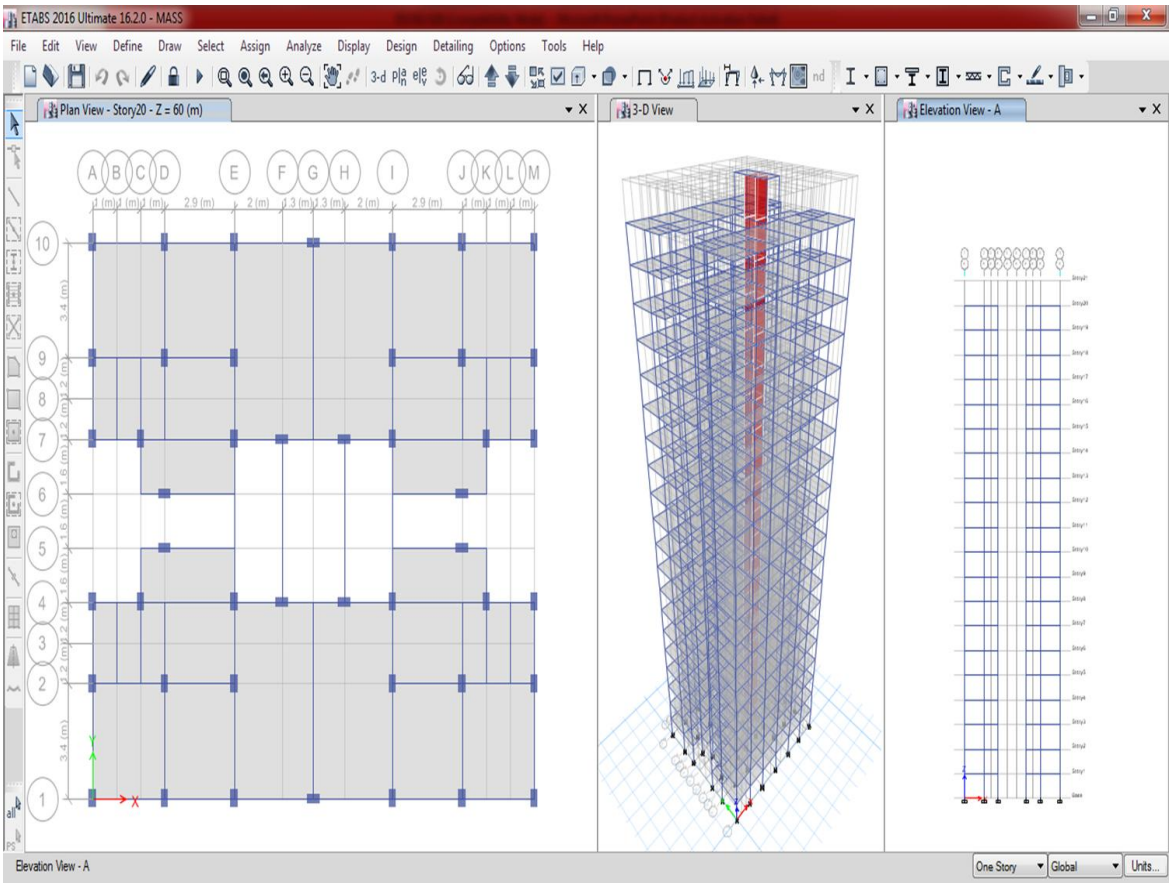

Figure 3: Model-3 PLAN OF MASS IRREGULARITY BUILDING

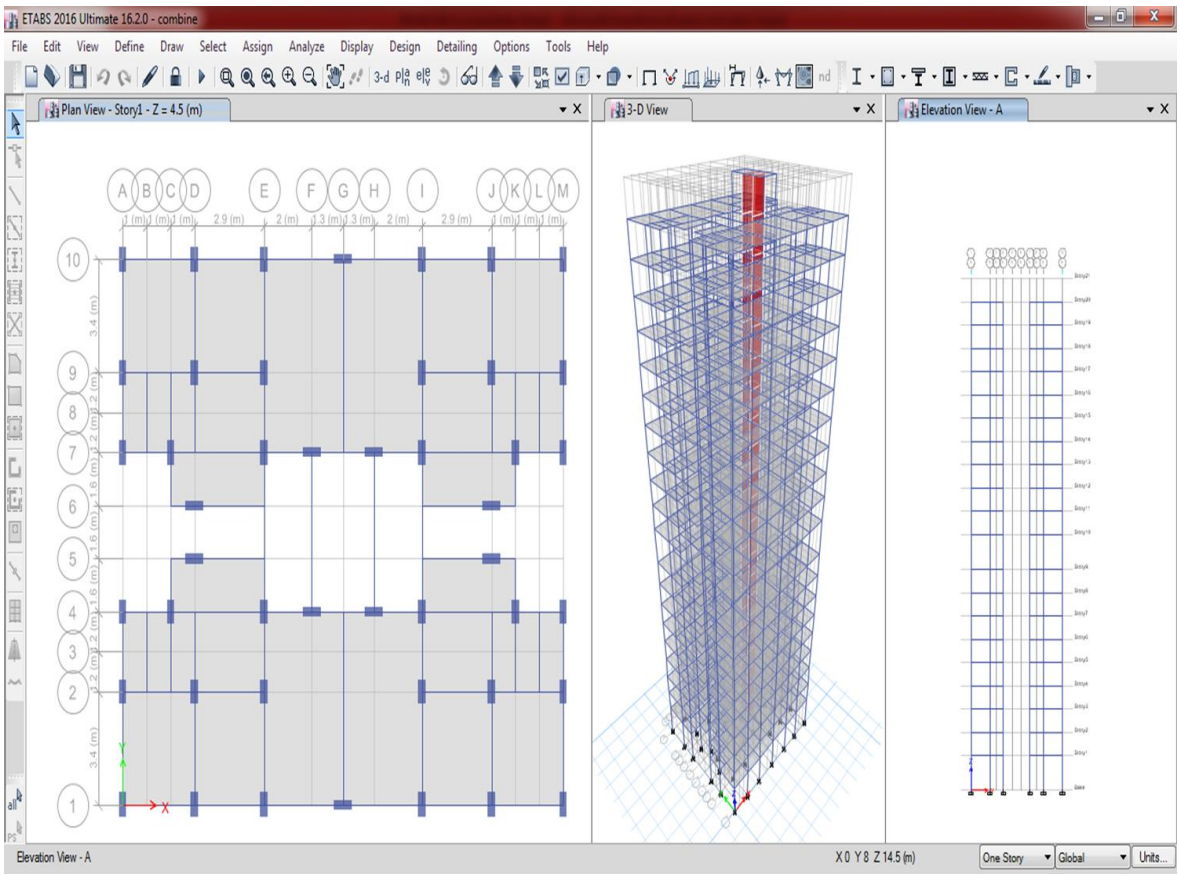

Figure 4: Model-4 - PLAN OF COMBINE IRREGULARITY BUILDING

IV. RESULTS AND DISCUSSIONS

After completing modeling and analysis work, now it is a time to discuss about the result. Here, results are obtained for Pushover Analysis. This is a comparative study, so parameters like story displacement, story shear, storey drift and base shear are compared for Regular and Vertical Irregular Building. Analysis of G+20 storied building, with and without vertical irregularity is done using E-tabs. From the analysis results obtained, building with and without irregularities are compared. The comparison of these results to find effect of vertical irregularity is given below.

8.1 RESULTS FOR COMPARISON OF SEISMIC PERFORMANCE IN TERMS OF PARAMETER STOREY DISPLACEMENT, STOREY DRIFT AND STOREY SHEAR:

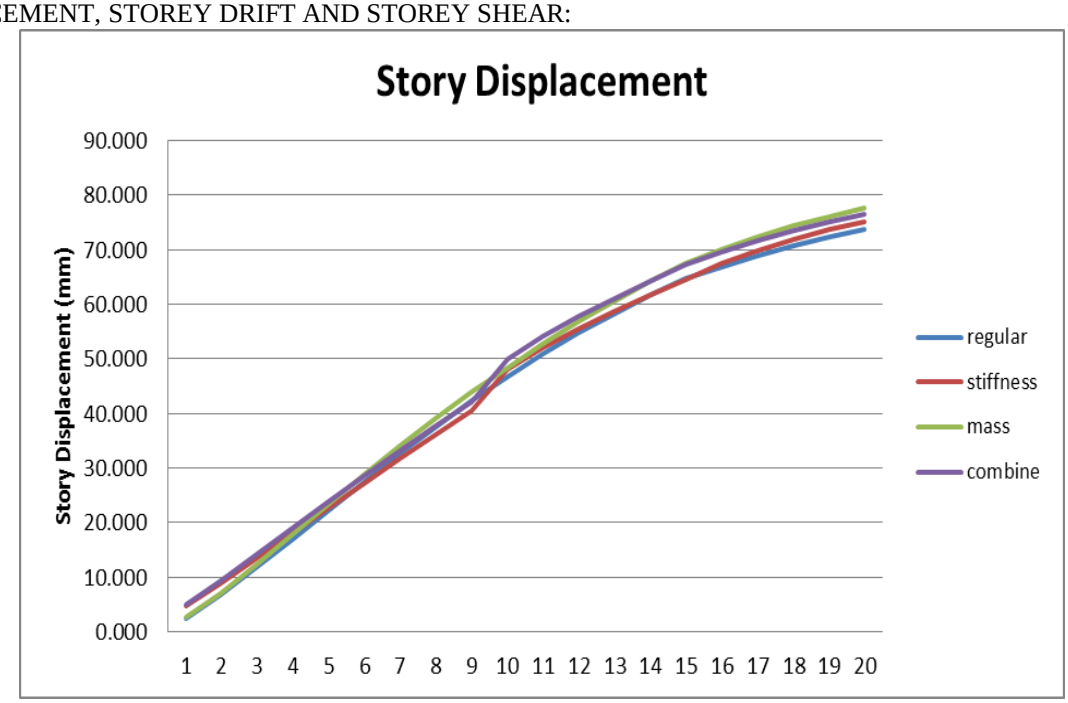

Figure 5 : Story Displacement in X-direction

In case of building with vertical irregularity, the maximum storey displacement is occurs compare to without irregularity. Here maximum story displacement occurs in Mass Irregular Structure and minimum story displacement occurs in Regular Irregular Structure.

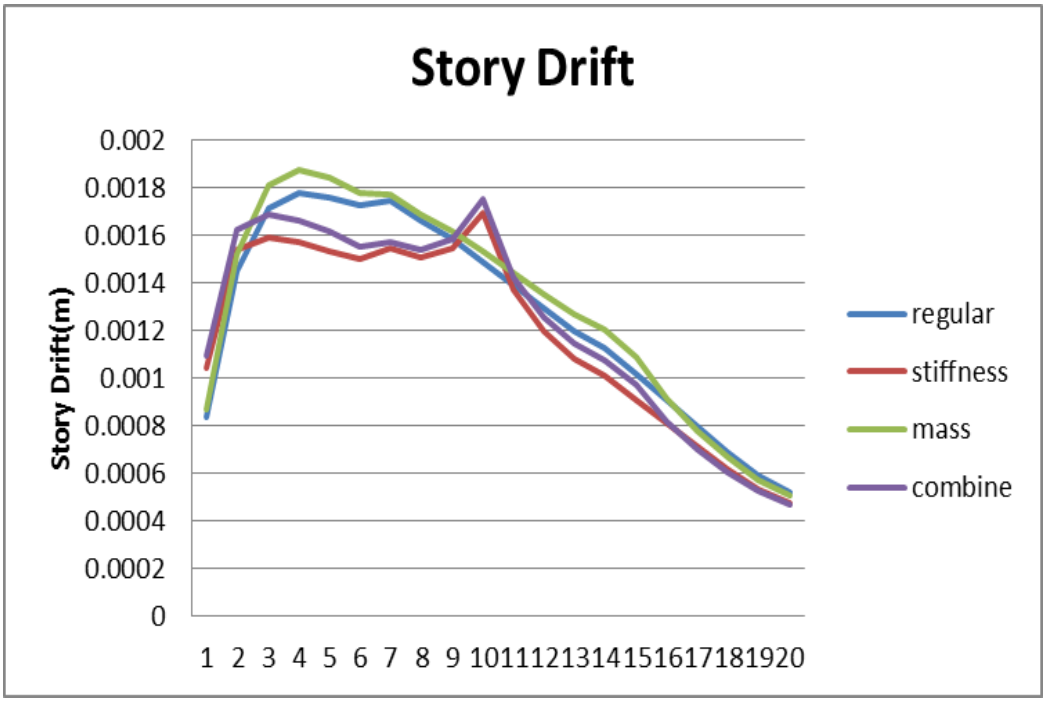

Figure 6: Story Drift in X-direction

Due to the discontinuity in stiffness, strength and mass, there is increase in storey drift for irregular structure. For all building models maximum storey drift occurs for mass irregularity. This occurs due to irregularity of structure. A structure having irregularity gives higher storey drift.

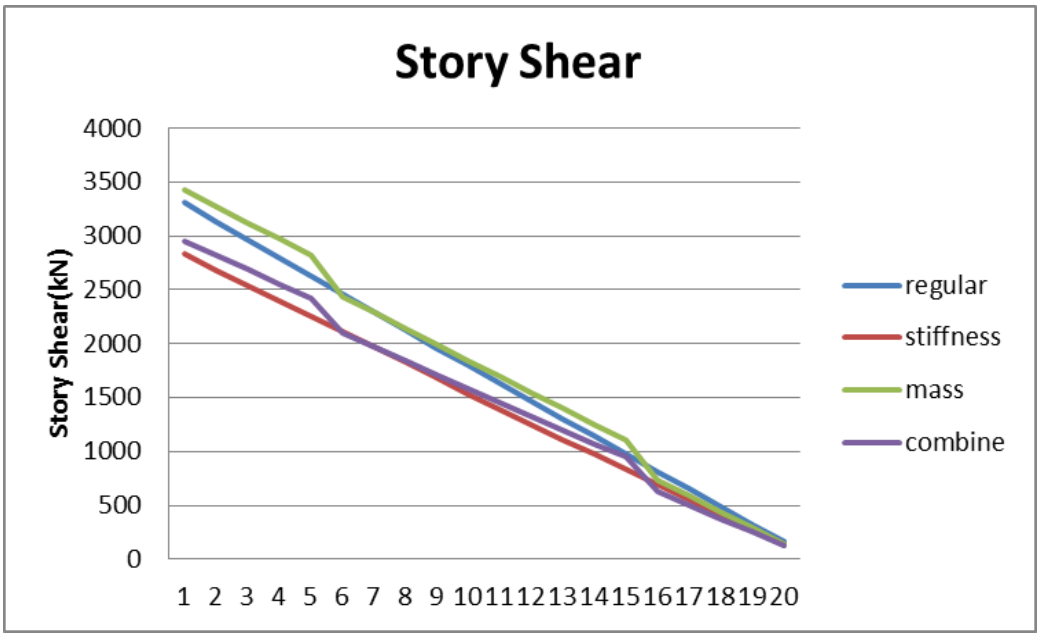

Figure 7: Storey Shear in X-direction

After comparing the building performance, it is seen that there is increase in storey shear for irregular structure as compared to the Regular Structure. For all building models maximum storey shear occurs for Mass irregularity.

8.2 RESULTS FOR PUSHOVER ANALYSIS:

Table 1: Performance point of base force and Displacement in X Direction

S. NO	MODEL	BASE FORCE(kN)	DISPLACEMENT(m)
		Push X	Push X
1	Regular Structure	3320.54	0.031
2	Stiffness Irregularity	2853.91	0.034
3	Mass Irregularity	3440.32	0.036
4	Combined Irregularity	2970.93	0.031

Table 2: Performance point of base force and Displacement in Y Direction

S. NO	MODEL	BASE FORCE(kN)	DISPLACEMENT(m)
		Push X	Push X
1	Regular Structure	4095.88	0.048
2	Stiffness Irregularity	3690.84	0.046
3	Mass Irregularity	3911.61	0.043
4	Combined Irregularity	4647.68	0.050

From the pushover analysis, The Base Force and Displacement is more in the structure having mass irregularity when compared to other models because of heavy mass is provided in mass irregularity building in X Direction and Combine irregularity in Y Direction.

V. CONCLUSIONS

From the analysis results, it has been concluded as follows:

- The building with vertical irregularity undergoes maximum storey displacement as compared to the building without vertical irregularity. The maximum storey displacement is occurred for Combine irregularity building.
- Due to provision of vertical irregularity there is increase in storey drift and it is optimum for Mass Irregularity building.

PUSHOVER ANALYSIS:-

- The Base Force is more in the structure having mass irregularity when compared to other models because of heavy mass is provided in mass irregularity building along X Direction.
- The Base Force is more in the structure having Combine irregularity when compared to other models along Y Direction.
- The structure having Mass irregular Building produces more displacement than other structures in X Direction.
- The structure having Combine irregular Building produces more displacement than other structures in Y Direction.
- From the above observations, it is concluded that the Regular building has more lateral load carrying capacity as compared to the building with vertical irregularity
- The analysis proves that irregularities are harmful for the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution around the building.
- Therefore, as far as possible irregularities in a building must be avoided. But, if Irregularities have to be introduce for any reason, they must be designed properly.

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