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Analysis of Vertical Irregular structures with and without Lateral force Resisting System

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Abstract - **In recent days Vertical Irregular buildings have been taking over conventional regular buildings. Vertical Irregular building gained importance due to its aesthetic and functional aspects. But the buildings with Vertical Irregularities are more vulnerable to lateral loads mainly seismic vibrations. In the present study, multi-storey building having different vertical irregularities such as Stiffness Irregularity, Mass Irregularity and Geometric Irregularity with and without Lateral Force resisting system have been analyzed using ETABS software for the parameters like storey displacement and storey shear. The main objective of the present study is to compare the seismic behavior of multi storey buildings having Vertical irregularity in seismic zone V with soil of type II (medium coursed). Dynamic response spectrum analysis was performed on the structure to get the seismic behavior. Then structures with these irregularities have been provided with bracings and dampers and the analysis was carried out again. Obtained results were compared with Vertical irregular bare structures.**

Keywords— Vertical Irregular building, seismic vibrations, Lateral Force Resisting System, Bracing, Dampers, Dynamic Response Spectrum analysis, Etabs.

I. INTRODUCTION

Buildings with unusual vertical alignments are a common occurrence in urban areas. Buildings typically develop irregular vertical shapes during the planning stage for both architectural and functional reasons. Buildings that depart in the vertical direction from standard geometric layouts or load distributions are said to exhibit vertical irregularity. The performance and safety of the structural system may be compromised by these abnormalities. Setbacks (geometric irregularities), changes in floor heights (stiffness irregularity), varied column arrangements, varying storey mass (mass irregularity), and other architectural characteristics that disrupt load distribution are some examples of the various sorts of vertical irregularities. The performance and safety of the structural system may be compromised by these abnormalities. One major worry is how these inconsistencies may affect the building's lateral stiffness and resistance to lateral forces such as wind and seismic loads. Lateral Force Resisting System (LFRS) and Damping System are being adapted to the structures to resist the deformation due to this type of lateral loading (mostly seismic load). The many lateral force resisting system (LFRS) types include moment frames, shear walls, and bracing systems. Research has predominantly focused on issues relating to vertical irregularities. This topic has been the subject of numerous deterministic investigations. The primary goal of the present investigation is to compare the performance of typical vertically uneven structures with and without lateral force resisting and damping systems (LFRS).

II. VERTICAL IRREGULAR STUCTURES

The configuration of a building's structures determines how it will behave. Examples of structural irregularity include a lack of symmetry or eccentricity between geometry, mass, stiffness, etc. In real design, irregularities are incorporated for both aesthetic and functional purposes. Variations in the distribution of mass, stiffness, and geometry along the height of the building are referred to as vertical irregularities. An irregular structure is a system having physical discontinuity.

A wide range of irregularities exist, including both vertical and horizontal irregularity. The irregularity in buildings is listed in section 7 of IS 1893(part1):2016. Both vertical irregularity and horizontal irregularity are categories for these types of irregularities. The phrase "vertical irregularity" refers to sudden variations in mass, stiffness, geometry, and strength that result in uneven force distributions or deformations throughout a building's height. Particularly during seismic events, these abnormalities may significantly affect the building's structural behavior and performance. Story displacement is the deflection of a single story relative to the base or ground level of the structure.

III. THE PRESENT STUDY

The focus of the present study is to carry out seismic analysis on Vertically Irregular structure with and without bracing and Dampers. Considering seismic effect from different types of Vertically Irregular Structures.

A. Methodology of the present study

In the present study seismic behavior of multistoried building with Vertical Irregularity is studied for various models. For the present study three Vertical Irregularities are been considered, they are a. Stiffness Irregularity, b. Mass Irregularity and c. Geometric Irregularity. Dynamic analysis for zone V is carried out. Dynamic response spectrum analysis includes Displacement in structures, Storey drift and Storey Shear. Modelling is carried out in ETABS software. Model for different Vertical Irregular Structures with & without Bracings and Dampers is made. Dynamic analysis is carried for each case and analyzed.

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B. Modeling and Analysis

In the present study, G+14 building is considered for various vertical irregularities. Fig. 1, 2&3 shows the typical 3-D view of the stiffness irregular structure with and without bracings and dampers respectively. Fig. 4, 5&6 shows 3-D view of mass irregular structure with and without bracing and dampers respectively and Fig. 7, 8&9 shows 3-D view of geometric irregular structures with and without bracing and dampers respectively.

1. STIFFNESS IRREGULAR STRUCTURE

Stiffness Irregularity is defined to exist when there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.

Stiffness Irregularity is been provided in the present structure at first and eighth storey where the floor to floor height has been considered as 4.5m and 6m respectively when compared to the typical floor height of 3m. The same has been followed in structures with bracing and dampers respectively.

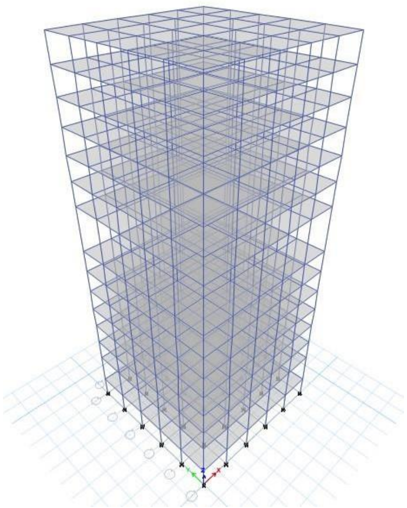

Fig. 1. 3D view of Stiffness Irregular Bare Structure

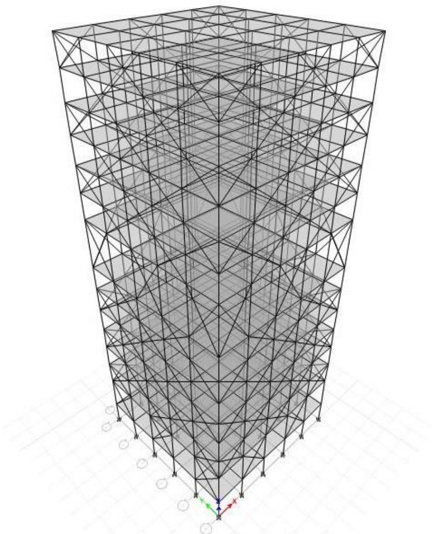

Fig. 2. 3D view of Stiffness Irregular Structure with Bracings

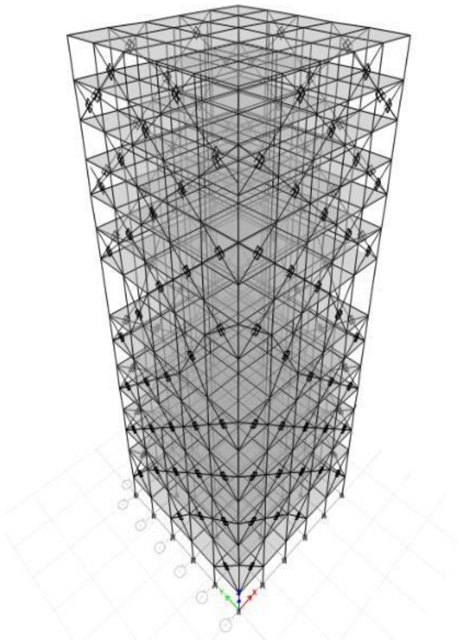

Fig. 3. 3D view of Stiffness Irregular Structure with Dampers

2. MASS IRREGULAR STRUCTURE

As per the code IS 1893 (2016), Mass irregularity is considered to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story.

Mass Irregularity is been provided in the present structure at the first floor where the slab thickness has been considered as 300mm when compared to the typical slab thickness of 150mm, which intern increases the Dead Load of the slab. The same has been followed in structures with bracing and dampers respectively.

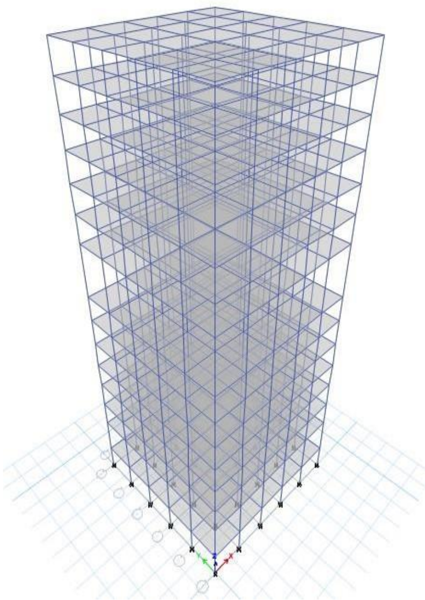

Fig. 4. 3D view of Mass Irregular Bare Structure

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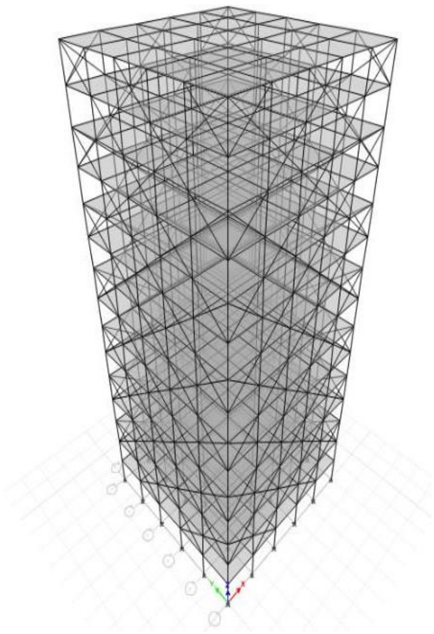

Fig. 5. 3D view of Mass Irregular Structure with Bracings

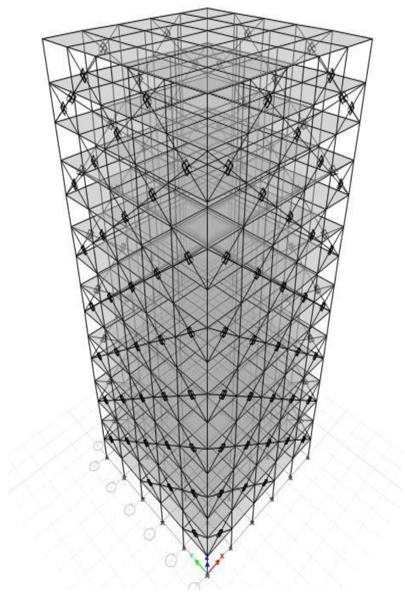

Fig. 6. 3D view of Mass Irregular Structure with Dampers

3. GEOMETRIC IRREGULAR STRUCTURE

As per the code IS 1893 (2016), Geometric irregularity is considered to exist where the horizontal dimension of the lateral force- resisting system in any story is more than 125% of that in an adjacent story.

Geometric Irregularity is been provided in the present structure where the vertical structural configuration changes at fifth storey and eleventh storey.
The same has been followed in structures with bracing and dampers respectively.

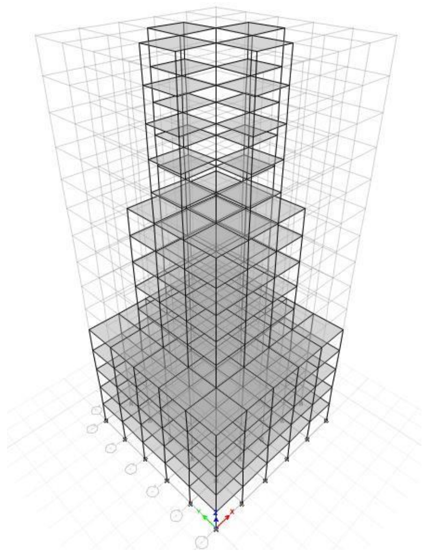

Fig. 7. 3D view of Geometric Irregular Bare Structure

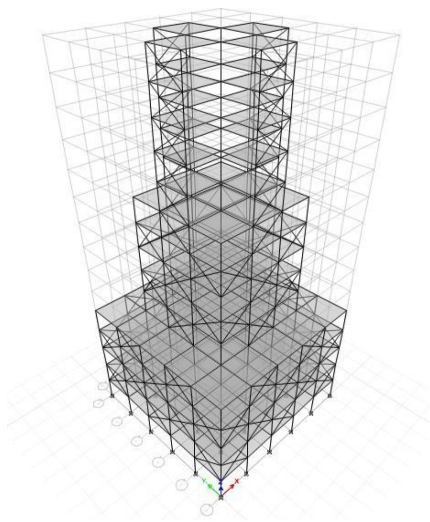

Fig. 8. 3D view of Geometric Irregular Braced Structure

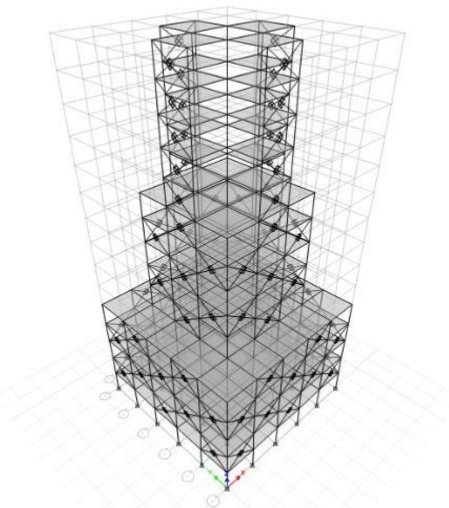

Fig. 9. 3D view of Geometric Irregular Braced Structure

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TABLE 1. STRUCTURAL PARAMETERS CONSIDERED IN ANALYSIS

Material and Geometry Data	
Dimension of structure	20m x 20m
Built up Area	400 m^2
Typical storey height	3m
No of storeys	G+14
Grade of concrete	M30
Grade of Steel	Fe500
Beam Size	300x450mm
Column Size	450x450mm
Slab Thickness	150 mm
Bracing Type	Cross Bracing ('X')
Damper Type	Fluid Viscous Damper

TABLE 2. LOAD PARAMETERS CONSIDERED IN ANALYSIS

Loading Data	
Live Load	3 kN/sqm
Finishing Load	1.5 kN/sqm
Seismic Zone	Zone 5
Zone factor (Z)	0.36
Soil Type	Type 2 (Medium coursed)
Importance Factor (I)	1.5
Response reduction Factor (R)	5
Type of structure	SMRF

The 3D view of the structures considered for the analysis are shown in Fig. 1-9 and the detailed structural parameters and loading data considered in the analysis of the structure are presented in Table 1 and Table 2 respectively.

IV. RESULTS AND DISCUSSION

The structures modeled using the above mentioned data are Vertically Irregular Structures with and without the bracings and the dampers and the results are analyzed. Each of the buildings is analyzed for seismic parameters like storey displacement, storey drift and storey shear. As the plan of the structure is symmetric in nature, the result data obtained in X and Y directions are almost same, hence the data is considered in X-direction only.

A. *Storey displacement*

Storey displacement is significant in seismic analysis when the structure is subjected to lateral load. Storey displacement is represented in Fig. 9, 10&11. From Fig it can be observed that storey displacement is more in stiffness irregular bare structure and minimum in Stiffness Irregular building with Dampers. From Fig. 9, 10&11 it can be observed that storey displacement is reduced when compared to structure with bracing and dampers installed respectively. Sudden fall in displacement is observed when Dampers are introduced to the structure. When the Dampers are located at the corners top displacement of the structure is lowest compared to bare structure and slightly higher with bracings.

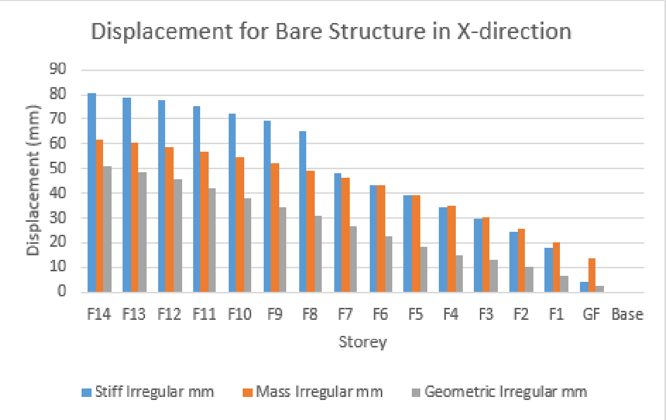

Fig. 10. Storey Displacement for Bare Structure

In the above chart it is clearly seen that in bare structure with stiffness irregularity provided, there is significant increase in the storey displacement at eighth storey and first storey respectively.

There is a considerable amount of decrease in storey displacement in structures provided with bracing and dampers being the least displaced. It can also be noted that there is also no drastic changes in the storey displacement at the location where the Mass irregularity is been provided and the storey displacement increases uniformly in Geometric irregular structure.

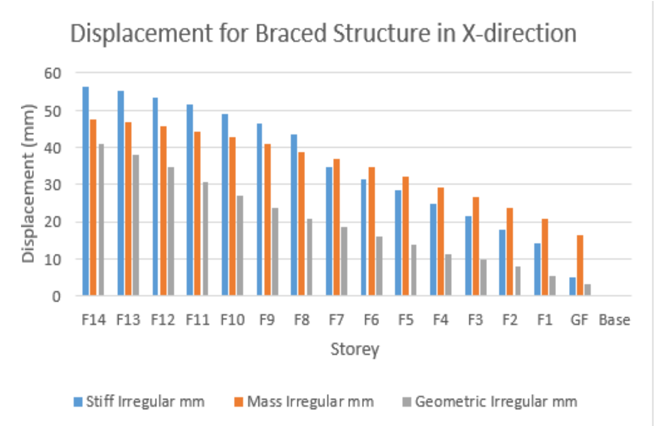

Fig. 11. Storey Displacement for Braced Structure

In the above picture it is clearly seen that in braced structure with stiffness irregularity provided, there is significant increase in the storey displacement at eighth storey and first storey respectively is reduced considerably

There is a substantial amount of decrease in storey displacement in structures provided with bracing and dampers being the least displaced. It can also be noted that there is also no drastic changes in the storey displacement at the location where the Mass irregularity is been provided and the storey displacement increases uniformly in Geometric irregular structure.

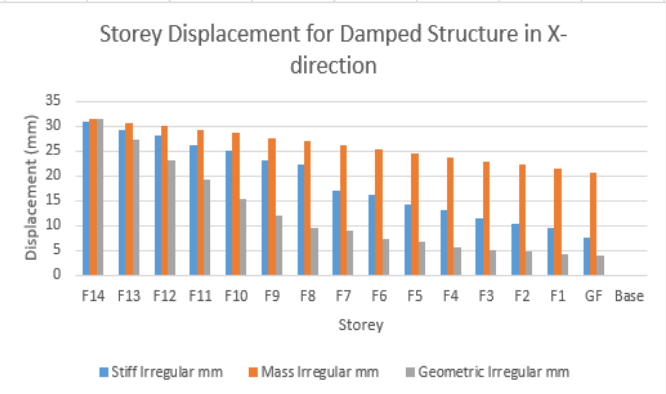

Fig. 12. Storey Displacement for Damped Structure

In the graph shown above it is clearly seen that in damped structure with stiffness irregularity provided, the significant increase in the storey displacement at eighth storey and first storey respectively is solved and follows the linear trend.

There is a significant amount of increase in storey displacement in Mass irregular structures provided with dampers. It can also be noted that there is also no drastic changes in the storey displacement at the location where the Mass irregularity is been provided and the storey displaces least in Geometric irregular structure when compared to other two irregularities.

B. *Storey Shear*

Seismic forces will create total reactive forces at column base in direction opposite to that of lateral load. Storey shear is represented in Fig.13, 14&15 for stiffness irregular, mass irregular and geometric irregular structures respectively. From the Fig shown it can be observed that Storey shear is maximum at ground floor and decreases in the above consecutive storeys. Shear is maximum in Stiffness Irregular structure and minimum in Geometric irregular building. The effect of shear increase with the addition of bracings to the structure and is maximum in case of damped structure

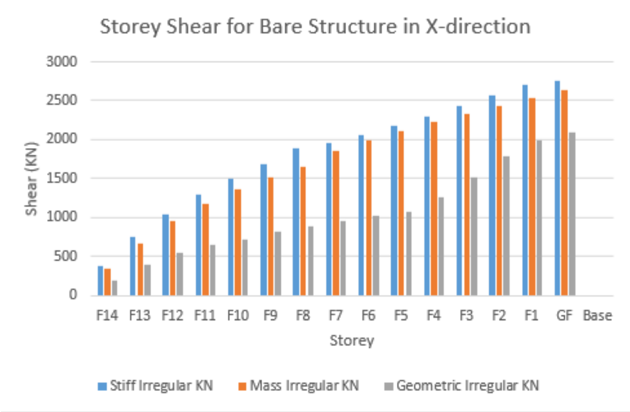

Fig. 13. Storey Shear for Bare Structure

In the above picture it is clearly seen that in bare structure with stiffness irregularity provided will have the maximum storey shear. The structure with Mass irregularity also shows the same trend as of the stiffness irregular structure, but Geometric irregular structures will be having the least storey shear. It can also be noted that there is also no drastic changes in the storey shear at the location where the irregularity are been provided and all three irregularity follows the linear trend.

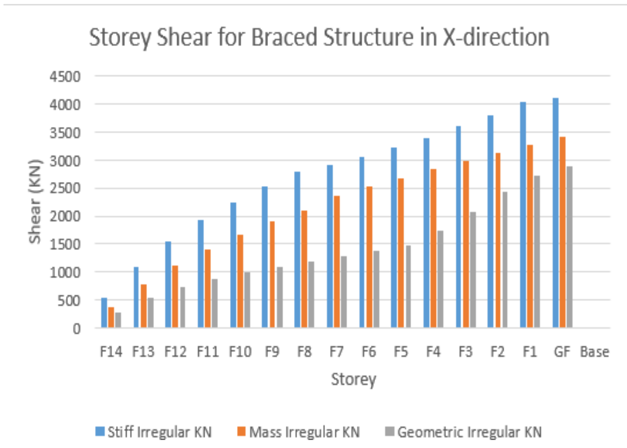

Fig. 14. Storey Shear for Braced Structure

In the above chart it is observed that in braced structure with stiffness irregularity provided will have the maximum storey shear. The structure with Mass irregularity will have lesser shear compared to stiffness irregular structure, but Geometric irregular structures will be having the least storey shear. It can also be noted that there is also no drastic changes in the storey shear at the location where the irregularity are been provided and all three irregularity follows the linear trend.

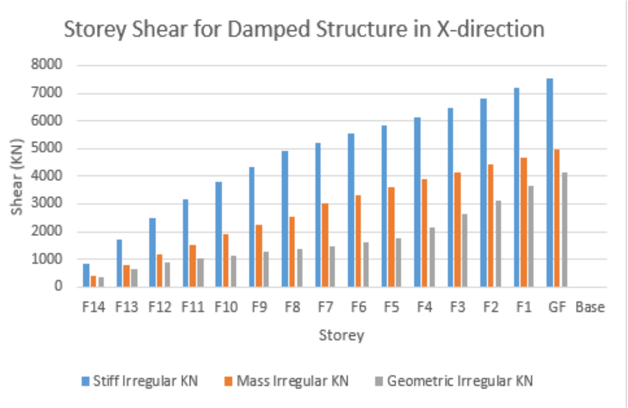

Fig. 15. Storey Shear for Damped Structure

In the above chart it is observed that in damped structure with stiffness irregularity provided will have the maximum storey shear. The structure with Mass irregularity Geometric irregular structures will be having the least storey shear comparatively. It can also be noted that there is also no drastic changes in the storey shear at the location where the irregularity are been provided and all three irregularity follows the linear trend.

DISCUSSION

Following inferences can be made from the comparison of storey displacement and storey shear of Vertical Irregular building with and without Bracings and dampers.

- Storey Displacement with respect to Stiffness Irregular building has shown significant variation in bare structure, while reduction of 33% and 68% has been observed in braced and damped structure.
- Storey Displacement with respect to Mass Irregularity has not shown any significant variation, while there is reduction of 25% and 55% has been observed in braced and damped structure.
- Storey Displacement with respect to Geometric Irregular building has not shown significant variation when compared with bare structure, while reduction of 31% and 69% has been observed in braced and damped structure.
- Storey Shear with respect to Stiffness Irregularity shows no significant variation in bare structure, while there is increase of 50% and 128% has been observed in braced and damped structure.
- Storey Shear with respect to Mass Irregularity shows no significant variation in bare structure, while there is increase of 30% and 88% has been observed in braced and damped structure.
- Storey Shear with respect to Geometric Irregularity shows no significant variation in bare structure, while there is increase of 39% and 97% has been observed in braced and damped structure.

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