STUDY OF VERTICAL IRREGULARITY IN MULTI-STOREY BUILDING FRAMES UNDER SEISMIC FORCES

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Abstract
The behaviour of a multi-storey framed building during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. Combined stiffness and strength irregularity have the largest effect among all the irregularities . In the present study a comparative study of regular frame and vertically irregular frame is done in SAP2000. Also the variation in performance of frame in terms of maximum displacement is done with combined strength and stiffness irregularity in each floor. An expression is formulated in this study to predict the occurrence of minimum of maximum displacement, which forms the location to place an unavoidable vertical irregularity.

Keywords: **Combined strength and stiffness irregularity, Pushover analysis, SAP 2000.**

I. INTRODUCTION

To perform well in earthquake, buildings should possess simple and regular configuration, adequate lateral strength , stiffness and ductility. Buildings having simple regular geometry and uniformly distributed mass and stiffness in plan and elevation, suffer less damage than buildings with irregular configuration. All buildings are irregular in some sense. Some have been initially designed so. Others have become so by accident, for example due to inconsistencies or even errors during the construction process, while many have been rendered irregular during their lifetime because of damage, rehabilitation or change of use. Vertical irregularities in buildings are imposed by city regulations and structural designers have to assess their effects on the earthquake response.

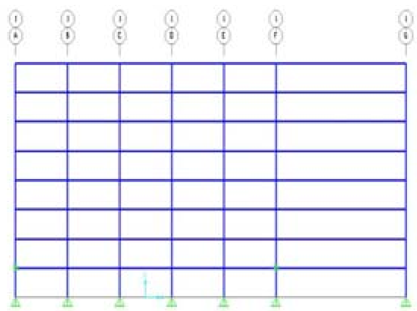
Four types of irregularities have been examined by several researchers including stiffness, strength, combined stiffness–strength and mass irregularities. From that Combined stiffness and strength irregularity have the largest effect among the irregularities considered. Strength comes second while mass and stiffness are the least influential [3].

II. ANALYSED STRUCTURE

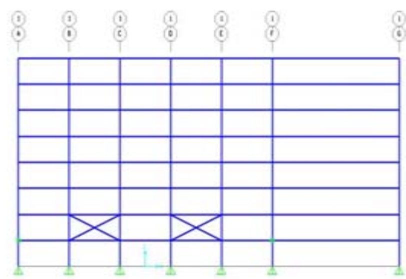
The 3-, 9- and 20-story structures used for this benchmark study were designed by Brandow & Johnston Associates for the SAC Phase II Steel Project. Although not actually constructed, these structures meet seismic code and represent typical low-, medium- and high-rise buildings designed for the Los Angeles, California region. These buildings were chosen because they also serve as benchmark structures for the SAC studies and, thus, will provide a wider basis for the comparison of results[15].

In order to introduce combined strength and stiffness irregularity along the height of the building a bracing system of special concentrically braced frames(SCBF) is selected. In SCBFs, X-braces were placed in two central bays. Circular hollow sections were used in both configurations for the braces; their strength is equalto 248 MPa . In SCBFs, sections with diameters (d) of 400mm and wall thickness (tw) of 20mm were used [8]. Providing these braces throughout the height of the building creates the building regular in vertical direction again. To study the effect of combined strength and stiffness irregularity along the height, the bracing system is provided in each floor separately.

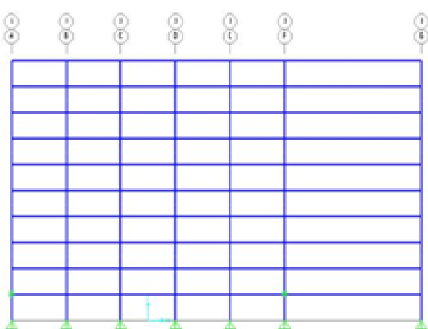
Modeling of the structures were done in the software sap2000. A total of 52 structures were modeled in sap2000. For each 7,9 ,12 and 20 storey buildings, one case of regular and 7, 9, 12 and 20cases of irregular structures were formed respectively. Figure 1 shows the typical figures of regular and irregular building with irregularity in ground storey which were modeled in sap2000. These structures were analysed by pushover analysis method. The non-linear static procedure or pushover analysis is now used by the structural engineering profession as a standard tool for estimating seismic demands for buildings. Pushover analysis is a static nonlinear procedure in which the magnitude of the lateral load is increased monotonically maintaining a predefined distribution pattern along the height of the building



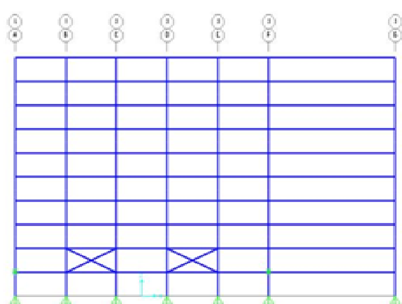
(a) Regular 7 storey building



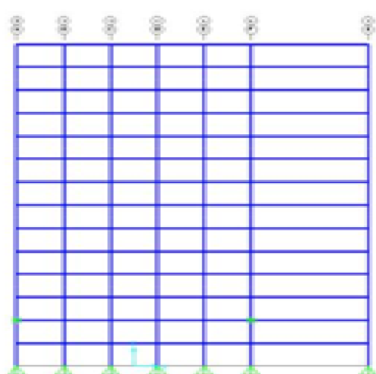
(b) Irregular 7 storey building



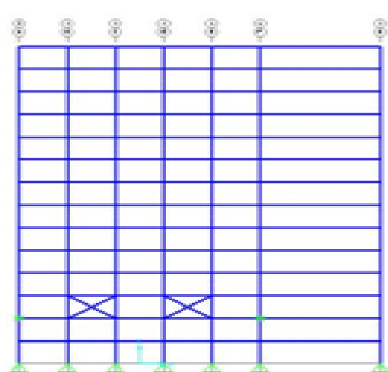
(c) Regular 9 storey building



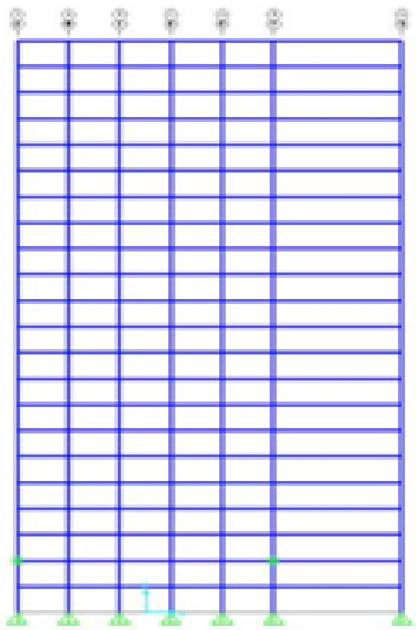
(d) Irregular 9 storey building



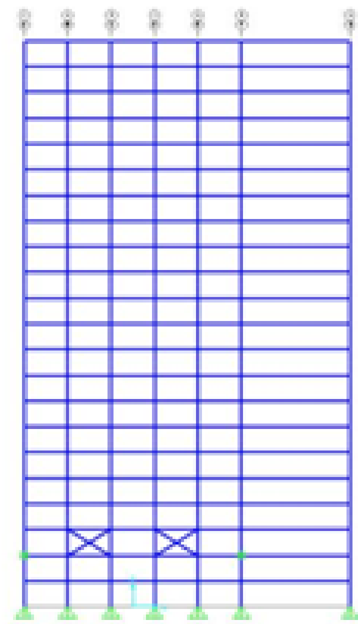
(e) Regular 12 storey building



(f) Irregular 12 storey building



(g) Regular 20 storey building

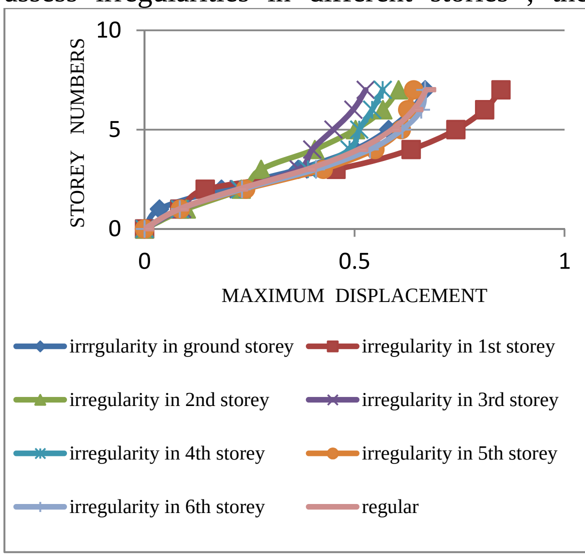


(h) Irregular 20 storey building

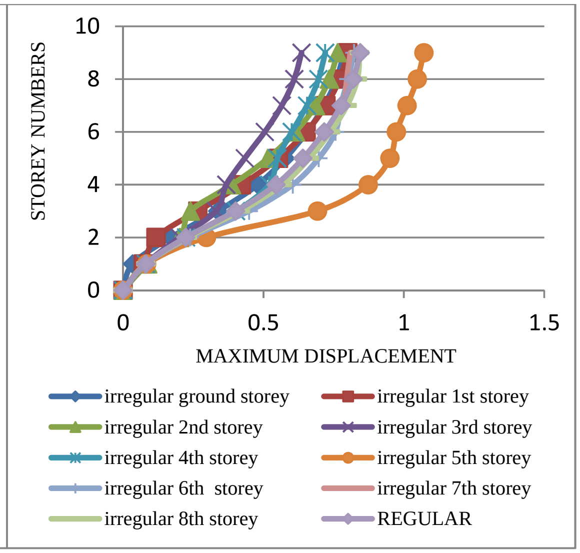
Fig.1 Typical 7 storey, 9 storey, 12 storey, and 20 storey regular and irregular frames modeled in sap2000

III.RESULTS

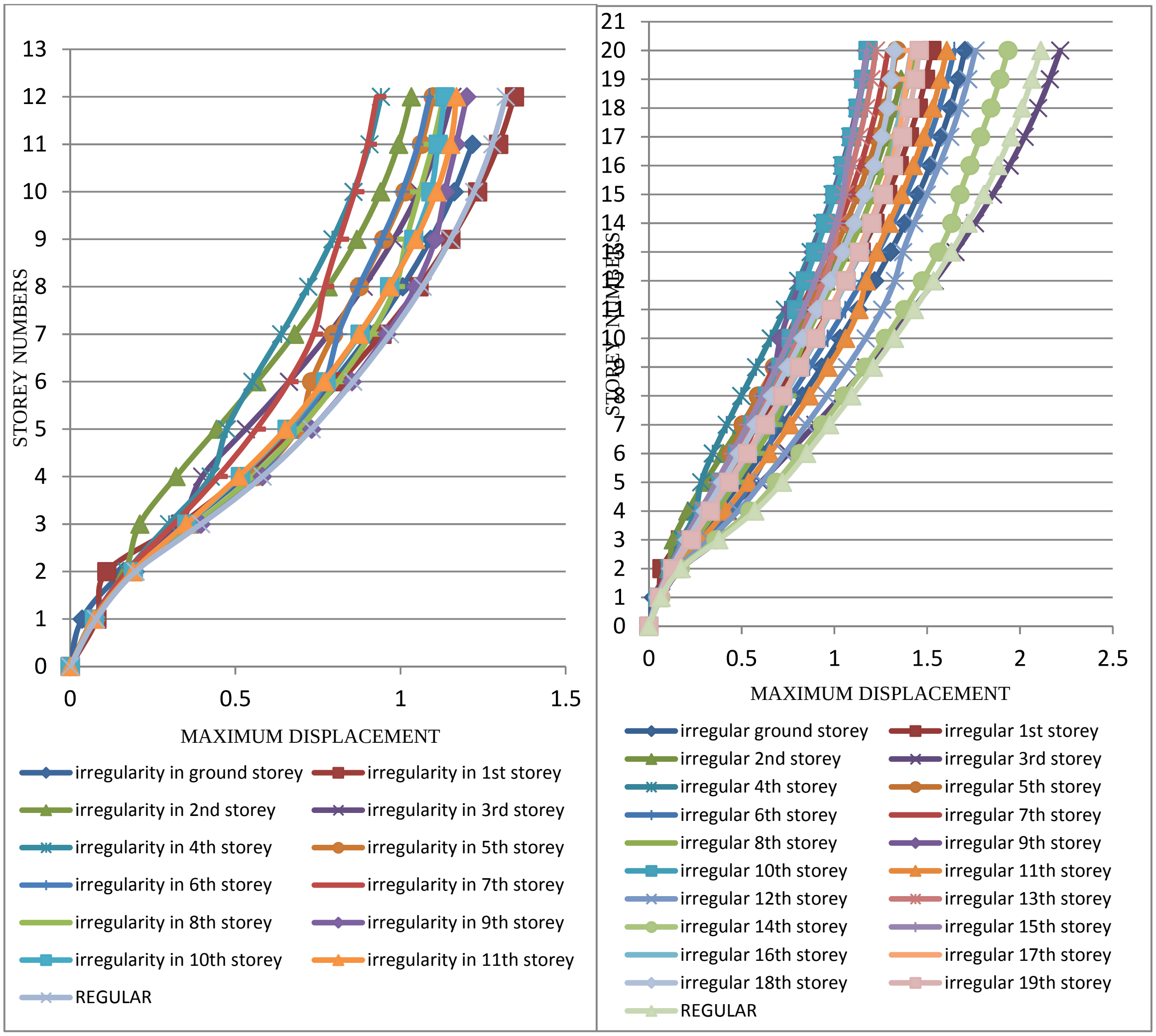
The variation of 'maximum displacement' pattern produced while placing the irregularity in different floors are obtained. In order to assess irregularities in different stories , the variations of displacements along the height of the buildings using the specified methods of analyses are obtained and compared with one another.



(a) Maximum displacement of 7 storey building



(b) Maximum displacement of 9 storey building



(c) Maximum displacement of 12 storey building (d) Maximum displacement of 20 storey building

Fig.2 Maximum displacements of 7,9,12,20 storey buildings with irregularity in different positions

Here the variations of maximum displacement along the height of the building produced by irregularity at different positions of all the 52 structures are shown in fig 2. From this the minimum of maximum displacement can be taken as a factor of concern. By considering the position of irregularity that produce minimum of maximum displacement we can decide the position for placement of unavoidable irregularity.

IV. ANALYZING RESULTS

Considering the different results of displacements obtained by placing irregularity in different levels, the pattern of displacement increment in each floor shows a variation at the position of irregularity. Here the roof displacement at the position of is irregularity is less. As the type of irregularity considered is improved combined strength and stiffness irregularity this variation is obvious. For each height level of building the minimum of maximum displacement is considered. The results obtained are shown in table 1. From this pattern variation of minimum of maximum displacement is found.

Table 1:Percentage height for positioning of irregularity according to displacement

Number of stories	Percentile height for positioning of unavoidable irregularity
7	42%
9	44%
12	58%
20	75%

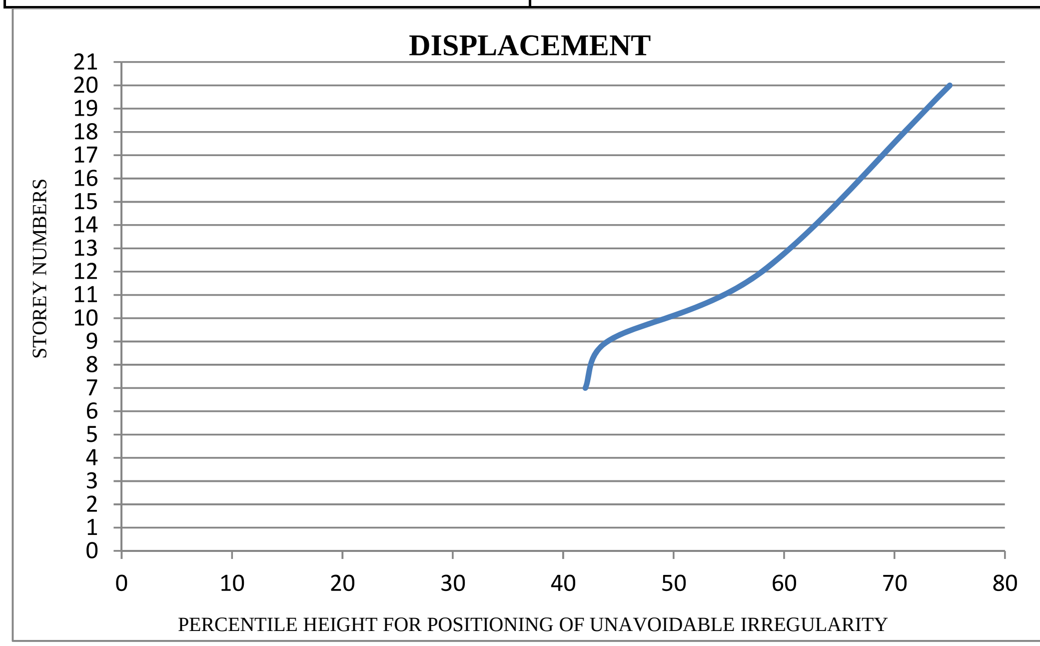


Fig.3Percentage height for positioning of irregularity according to displacement

For the typical curve obtained for placing of unavoidable irregularity an equation is also formed by regression analysis.

Percentile height for positioning of unavoidable irregularity $= e^{\frac{\text{story number}+70.28}{2.07}}$

V CONCLUSION

In this study 52 structures were analysed as regular and irregular structure. It includes 7storey, 9 storey 12 storey and 20 storey structures. The irregularity considered is vertical irregularity, and the type of irregularity is combined strength and stiffness irregularity. Maximum displacement occurred in all these cases were studied. Minimum of maximum displacement can be considered as a factor governing the response when the lateral forces are acting. Unavoidable irregularity can be placed at the position occurring minimum of maximum displacement and this position is found using regression analysis.

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