Behaviour and Strengthening of Soft Storey Structure

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Summary

In the multi-storied buildings, generally upper floors are used for office or residential purpose and the ground floor is used for car parking or shops. The apartments in the upper floors generally have brick infill walls between the main frames. Thus, the upper stories are stiff and the inter-storey drifts in upper storeys are small. On the other hand, the ground storey is soft and weak and the storey-drift here is larger. The maximum shear occurs in the ground storey load-resting elements. Hence, the strength demand on the columns in the ground storey of the buildings is very high. The majority of this type of buildings had collapsed in the past earthquakes in many countries. Such type of failure can possibly be avoided if stiffness and strength of the ground soft storey are increased. The present study proposes various alternative ways and means to achieve these objectives by a) adding bracings made of concrete and steel; b) adding shear walls at the ground storey. A quantitative estimate is arrived at for various cases to provide guidelines for choosing a scheme or system. Proposed steel bracings may be used for retrofitting the existing buildings while the other schemes may be adopted for new construction.

Keywords: Infill brick, multi-storied building, soft storey, inter storey drift, time period, base shear, bracing and shear wall.

1. Introduction

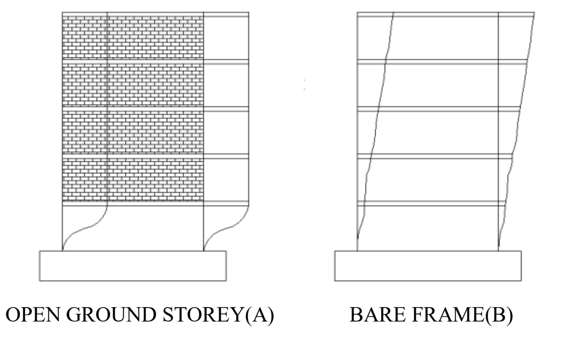

Fig.1: Deflected shape of multi-storeyed buildings with and without soft ground storey under seismic lateral force.

Generally, the multi-storied buildings containing residential apartments housed in the upper stories, have the garages or shops in the ground floor. The apartments in the upper floors generally have brick walls in the panels of outer frames. Such brick infill contributes considerably to the lateral stiffness through compressive strut action. The ground storey, however, generally does not have brick infill walls to attribute additional stiffness to the frames and hence the ground storey is more prone to failure than the upper stories and is very commonly known as “soft storey”. Fig. 1 shows the deflected shape of the building frame structure without the walls and also with the said walls.

The total seismic base shear as experienced by a building during an earthquake is dependent on the natural period of vibration of the building while the seismic force distribution along the height is dependent on the distribution of stiffness and mass. In buildings with soft first storey, the upper stories, being stiff, undergo smaller inter-storey drifts. However, the inter-storey drift in the soft first

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storey is large. This implies that the strength demands on the columns in the first storey of the buildings shoots up as the maximum shear occurs in the first storey.

Many earthquakes have observed failure of large number of buildings with open ground storey leading to high casualties. For instance, such experience has been repeated in Sumatra earthquake in 2004 and Bhuj earthquake in 2001 starting from San Fernando earthquake in 1971.

These observations demand practically viable strengthening measures through supplementing additional structural elements, which do not hamper the functional requirements. It has already been understood that addition of shear walls at the corners, additions of concrete or steel bracings of various forms may strengthen the open ground storey. However, some engineering guidelines are required to provide thorough information about the details of such additional elements versus the improvement of strength. Such a database may facilitate the designer to choose adequate additional

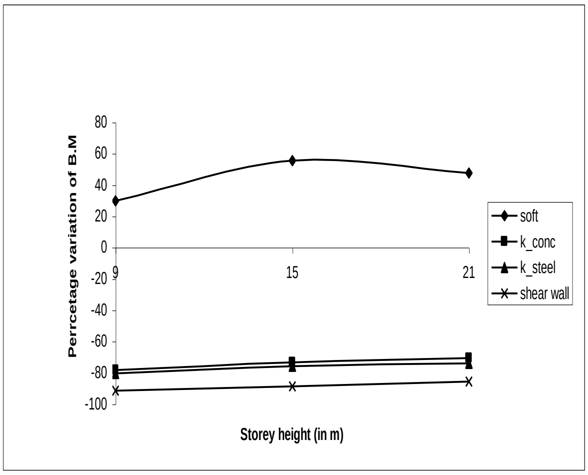

Fig. 2: Variation of bending moment at ground floor columns in different building frames, normalized by same in similar bare frame.

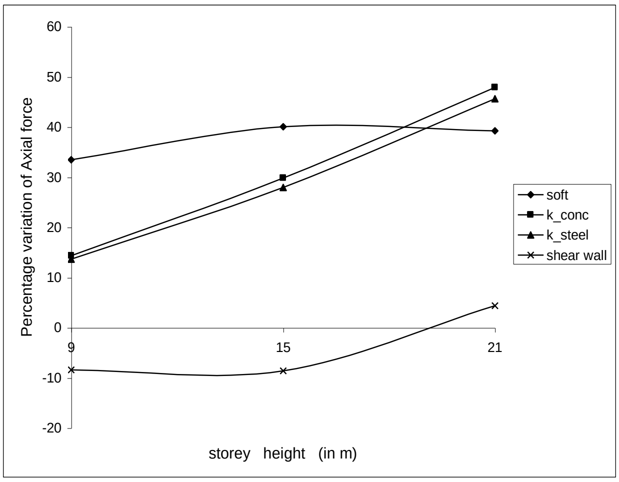

Fig. 3: Variation of axial force at ground floor columns in different building frames normalized by same in similar bare frame.

element to make up the lag in strength of ground storey of any particular structure. Present paper is an effort to achieve this end in the limited form.

In this backdrop, the present study attempts to examine the effectiveness of various additional structural elements, namely concrete and steel bracings and shear wall added to single storey portal and more realistic multi-storied frames to protect columns of soft ground storey. The other two bench mark conditions, namely, bare frame and frame with brick infill at upper stories (modelled through compression only diagonal struts) are also studied for facilitating the comparison. The change in base shear, lateral period, and the change in bending moment and axial force of columns of ground storey are primarily considered to see the change in overall behaviour and to note the efficacy of the additional structural elements in protecting the ground storey columns. The variation of bending moment in ground storey columns and the variation of axial forces in the same are presented in Fig.2 and Fig.3 respectively, as a function of storey heights reflecting the number of storeys of equal heights. The more detailed results are available in the full length paper in the form of soft copies. The study presented in the limited scope of the paper leads to following broad conclusions.

1) In a soft storey building, stiffened upper floors with brick infill lead to reduced period attracting more base shear. This may, in turn, causes an increased ground storey drift of 4 to 5 times that of other storey. This clearly indicates why ground storey bare columns are subjected to too much of bending moment, leading to the possibility of failure.

2) Addition of concrete or steel bracings and shear walls in single storey single bay portal frame or even more realistic multi-story frame reduces considerably the bending moment of columns leading to considerable reduction of percentage of reinforcement.

3) The curves exhibiting variation of bending moment, axial force and percentage of reinforcement may help designers to choose the effective element keeping in view of the functional requirement.

The study, thus, as a whole may be of help to practicing engineers to design adequately the multi-story buildings without hampering the functional requirements of ground storey of such structures.