# Prevention Measures for Soft Storey Building

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*Abstract*— Reinforced concrete (RC) frame buildings are very common in the world. In such types of structure for functional requirements of parking space under the buildings no masonry in fill are provided resulting a construction with stilts. Wall buildings with vertically irregular configurations have been severely damaged or collapsed due to a story mechanism during severe earthquakes. This paper presents a criterion to prevent such failures. A story-safety factor is defined to represent the relative reserve strength against a story mechanism of the structure. The validity of this factor was examined by conducting dynamic response analyses of various analytical models of 7- and 11-story wall structures with an irregularity at the first story using two real earthquake records with long and short vibration periods and their numerous generated motions. The results show that the story-safety factor well controlled the failure mechanism of the structures. When the story-safety factor was larger than the corresponding dynamic shear magnification factor proposed by Paulay and Priestley [11] minus unity, a story mechanism of the structures did not occur in all cases. Practical procedure of using the story-safety factor for preventing a story mechanism at irregular stories is also presented.

***Key words:*** Storey Building, Reinforced concrete (RC)

## I. Introduction

During the 1994 Northridge and 1995 Kobe earthquakes, many wall buildings with irregular configurations were severely damaged or collapsed. In such buildings, the irregularity is often located at the first story in the form of discontinuous wall panels due to the functional requirements. As a consequence, this may lead to a significant reduction in stiffness and strength and initiate an undesirable collapse mechanism at the first story of the buildings, while the other stories behave elastically. Figure 1 illustrates the undesirable and desirable failure mechanisms of an irregular wall building. The severity of the collapse will increase with the number of stories, because the plastic energy accumulated at the weak story of the building increases. Thus, control of the collapse mechanism in irregular wall buildings under earthquake excitation is needed especially in high-rise buildings. There have been numerous experimental and analytical studies investigating the seismic performance of buildings with vertical irregular configurations. Moehle and Alarcon [1] have concluded that the inelastic analysis methods have advantages over the elastic analysis methods in anticipating the effects of the structural discontinuities, which is also discussed by Hidalgo et al. [2]. Kabeyasawa et al. [3] further note that neglecting shear transfer of slab due to the formulation of an overall collapse mechanism underestimates the base shear of wall-frame systems with a soft first story. In addition, Chopra [4] shows that the story ductility demands on multistory buildings with weak and soft stories vary depending on the relative yield strengths. Recent studies by Al-Ali and Krawinkler [5], Dooley and Bracci [6], and Lu [7] demonstrate that the effect of stiffness on the seismic response is much smaller than that of strength. Such an effect is negligible on the estimation of the seismic response when the building responds primarily in the fundamental mode as discussed by Miranda [8]. More recently, Das and Nau [9] suggest that the use of the equivalent lateral force procedure is not necessarily restricted for certain types of vertically irregular buildings, such as with a taller or heavier story. The FEMA document [10] includes various rules related to the discontinuities of story strength, which is defined as the total strength of all seismic-resisting elements sharing the story shear. For example, the seismic design categories E and F in the document prohibit a weak story in which the story strength is less than 80 percent of that in the story above. However, there may still be lacking a criterion applicable to the evaluation of the collapse mechanism, particularly in vertically irregular wall buildings.

## II. Design Approaches

Open ground story building is inherently poor systems with sudden drop in stiffness and strength in the ground story. In the current design practice, stiff masonry walls are neglected and only bare frames are considered in design calculations. Thus, the inverted pendulum effect is not captured in design.

## III. Safeguard Against Failure

The failure can be avoided following two considerations in structural proportioning:

### A. To avoid soft story

*B. When soft storey cannot be avoided, providing special design provision in designing such structure*

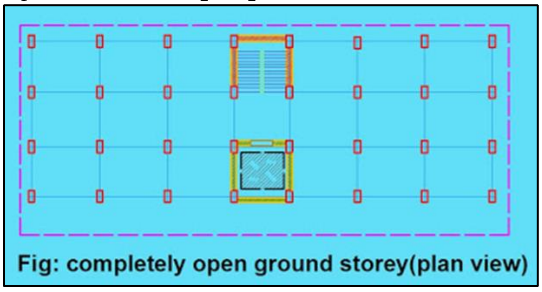
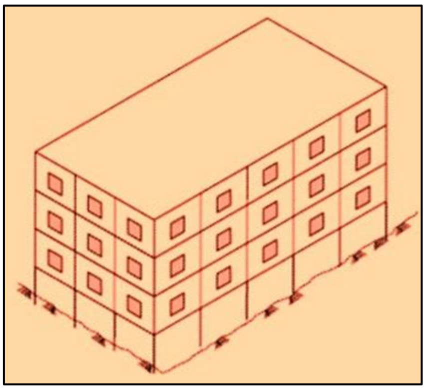


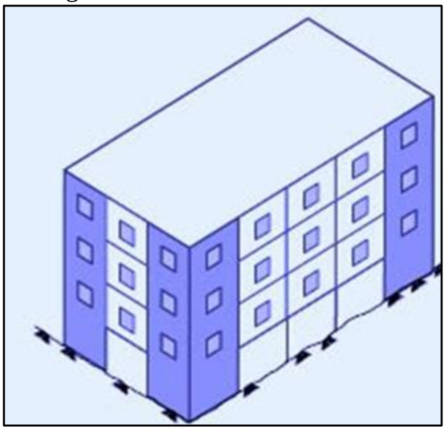
Fig: completely open ground storey(plan view)

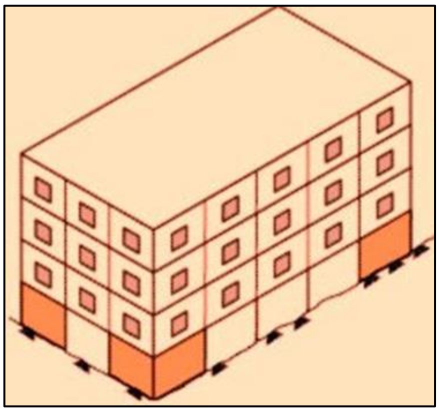


## IV. HOW TO AVOID SOFT STOREY

Architects and structural designers can use the following conceptual design strategies to avoid undesirable performance of open ground storey buildings in earthquake:

1) Provide some shear walls at the open ground story level : this should be possible even when the open ground story is being provided to offer car parking
2) Select an alternative structural system (e.g., RC shear walls) to provide earthquake resistance: when the number of panels in the ground storey level that can be filled with masonry walls is insufficient to offer adequate lateral stiffness and resistance in the ground storey level, a ductile frame in not an adequate choice. In such cases an alternative system, like a RC shear wall, is required to provide earthquake resistance. Some remedial measures to counter the bad performance are shown in fig:





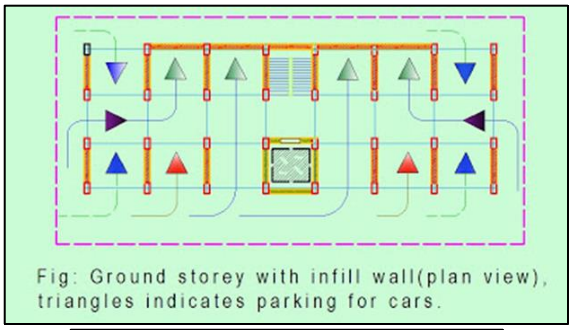
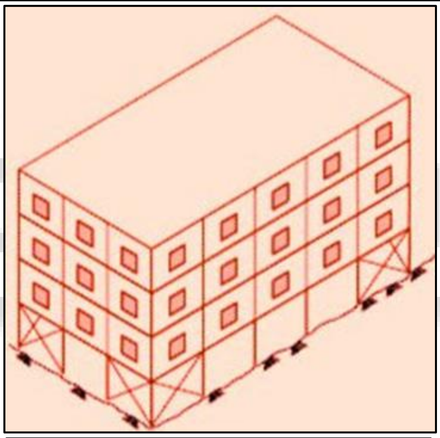
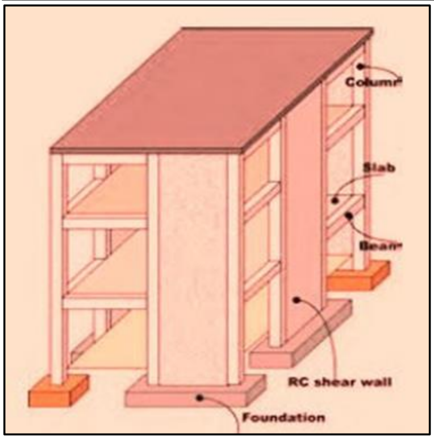


Fig: Ground storey with infill wall(plan view), triangles indicates parking for cars.






## V. SPECIAL DESIGN PROVISION

To safeguard the soft first storey from damage and collapse code provides two alternative design approaches:

1) The dynamic analysis of the building is to be carried out which should include the strength and stiffness effects of infills as well as the inelastic deformations under the

design earthquake force disregarding the reduction factor R.

2) The building is analyzed as a bare frame neglecting the effect of infills and, the dynamic forces so determined in columns and beams of the soft (stilt) storey are to be designed for 2.5 times the storey shear and moments: or the shear walls are introduced in the stilt storey in both directions of the building which should be designed for 1.5 times the calculated storey shear forces.

## VI. CONCLUSIONS

This paper has verified the validity of the story-safety factor used for preventing a story mechanism of vertically irregular wall buildings by conducting dynamic response analyses of various analytical models with an irregularity at the first stories for two real earthquake records with long and short vibration periods and their numerous generated motions with various intensity levels. From this study, the following can be concluded:

1) The story-safety factor defined in Eq. (1) represents the relative reserve strength for each story of a building against a story mechanism. As the story-safety factor of a story increased, the probability of a story mechanism at that story decreased.
2) The required story-safety factor for preventing a story mechanism at an irregular story varied even if the response spectra were similar. This implies that the likelihood of a story mechanism to future seismic events cannot be evaluated based only on the results of a static analysis.
3) The required story-safety factor tended to increase with the seismic intensity and number of stories of the structure. When the story-safety factor was larger than the corresponding dynamic shear magnification factor proposed by Paulay and Priestley [11] minus unity, a story mechanism did not occur in all cases. The effects of the flexural hinge location and geometrical irregularity on the required story-safety factor were minor.

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