Seismic Analysis of Multi-storied RCC Building with Soft-storey: A Critical review

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Abstract: **- It's the todays need to have a multi-storeyed building which can give a parking and other type of services like shops, marriage hall, commercial spaces etc. But these buildings with open ground and other floors at different levels are fundamentally vulnerable to breakdown due to earthquake. The main reason behind the collapse of this type of building consisting soft storey is drift created during earthquake. Thus this paper is to review its behaviour during earthquake and to establish detail concepts of building with soft-storey. According to past records soft-storey buildings have regularly shown bad performance during past earthquakes across the world for example during Kobe -1995, Chi-Chi Earthquakes -1999, Turkey -1999, Taiwan -1999, Bhuj-Gujrat earthquake -2001, Algeria -2003, and Nepal earthquake -2003. As we know that main cause of failure of soft-storey is sway mechanism during earthquake causing localized failure at the soft-storey level and ultimately resulting complete building failure. This is mostly due to the abrupt change in stiffness of a soft-storey with respect to upper stiffed storey. Thus the analysis of soft-storey is the todays need to control the failure particularly in higher seismic zone IV and V mostly Northern and Eastern part of India where Earthquake frequency is too much.**

Keywords: **- Soft-Storey, Inter storey drift, Storey Stiffness, Seismic, masonry infill.**

1. INTRODUCTION

Every weakness in buildings is the basic source of collapse during any earthquake. Reason behind the weakness in building is usually due to sudden changes in stiffness, strength or ductility, and the effects of these weaknesses are prominent by bad distribution of reactive masses.

So many structural damage suffered in several modern buildings during recent earthquakes demonstrates the significance of avoiding these abrupt changes in lateral strength and stiffness.

Many earthquake prone regions have building codes which specifically define a soft-storey building, and prohibit the construction of such buildings.

What is Soft-Storey? A soft-storey, basically known as a weak storey, is defined as in a building which has considerably less, stiffness or resistance, than the storeys above or below it.

Fig 1: Building with soft-storey

IS 1893 (2002) recommends a magnification factor of 2.5 to be applied on shear forces and bending moments in the columns of ground storey calculated for the bare frame under seismic loads. Soft-storey buildings are characterised as a storey which have lots of open space, for example, parking space are frequently soft storeys, or large retail spaces or floors with a lots of windows. This soft-storey creates a main weak point during earthquake, and meanwhile soft storeys are characteristically associated with parking garages and retail spaces, they are often on the lower storeys of a building, which means that when they collapse, they generally take the whole building down with them, causing serious structural damage which may results the structure totally unusable. Many earthquake prone regions have building codes which specifically define a soft-storey building, and prohibit the construction of such buildings. Buildings with soft-storey, the upper storey being stiffer as compare to lower one, undergo smaller inter-storey drifts. Though, in the soft storey the inter-storey drift is large. Though in the upper storeys, forces in the columns reduced efficiently due to the presence of soft-storey, the buildings with abrupt changes in storey stiffness have uneven horizontal force distribution throughout the height, which is likely to centrally persuade stress concentration.

2. Behaviour during Earthquake

As in Earthquake design the building is subjected to random and sudden motion of ground at its base, which induced a great inertia force in building, that in turn cause stress- this is displacement type loading. And soft-storey refers to the floor in building with significant lower stiffness than other floor, as in soft-storey building the floor is left empty of walls or lesser walls in comparison of upper floors. In regular building the non-structural members limits the ability of structural component to deform to horizontal force. During earthquake in regular building the earthquake shear distribute homogeneously in all floor, and deformation created is uniform, but when more flexible part of building support the rigid and massive structure upon it then bulk if energy is absorbed by that floor and rest of energy is distributed to other which in turn create a large relative deformation between two floors.

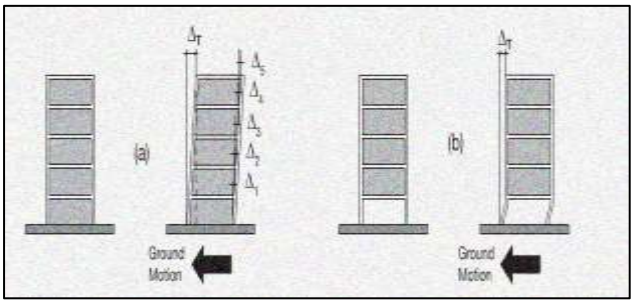

Fig 2. Showing distribution of earthquake shear in (a) regular building, (b) Soft-storey building

During earthquake in soft-storey building the portion above soft-storey moves as a single block while soft-storey floor moves in other direction with larger deformation due to less stiffness in comparison to above floor. For example: Consider the whole building as a reverse pendulum or a square block on 4 chops sticks and on a moving table.

Fig 3. Earthquake effected building due to soft-storey

3. Effect of masonry infill in RCC frame building

Today the design of Un-reinforced masonry is considered as accountant as it is assumed that they don't take any vertical or lateral load so declared as non -structural element in building. But this infill participates in load transfer during seismic effect on building and also interferes with lateral deformation in beam and column. Unreinforced masonry infill increases the lateral storey stiffness of a building. The distribution of lateral storey stiffness along the height in building effect the mode shape of building. The mode shape doesn't alter to much if the lateral storey stiffness remain same throughout in a building but it differ significantly when there is difference in stiffness between two storey. Consequently the mode shape of building effect due to presence of soft-storey.

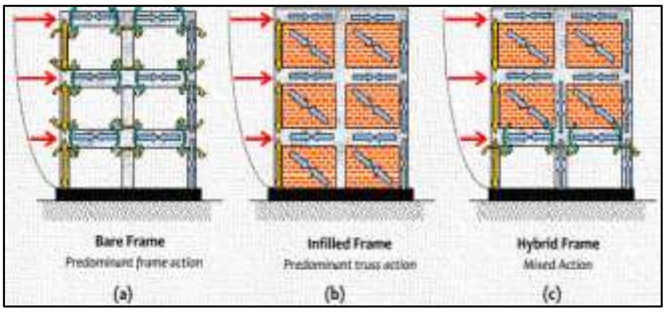

Fig 4. Lateral/horizontal force transfer mechanism (a) Bare frame, (b) Infilled frame, (c) Open storey

4. Deformation profile of building with soft-storey at different level

Taken two building A and B having soft-storey at different floor, and in wall infilled section the lateral load transfers takes according to compressive strut mechanism, this action general when diagonal struts are provided in frame. So stiffness deformity will cause unwarranted change in demands of structural elements.

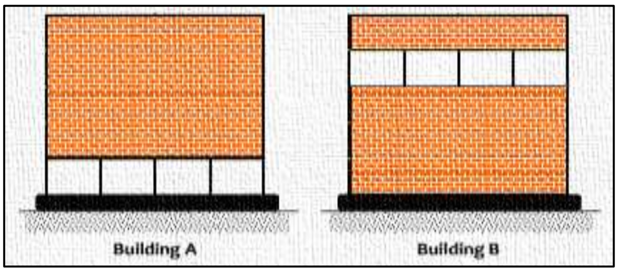

Fig 5. Showing soft-storey at different level

The lateral deformation profile will alter in different condition as in building A and building B.

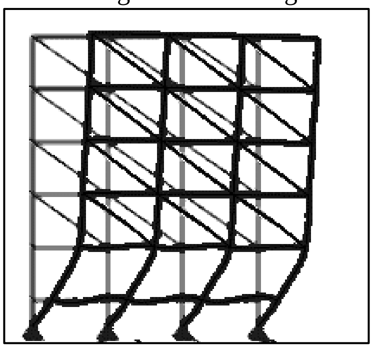

Fig 6: Lateral deformation profile in Building A

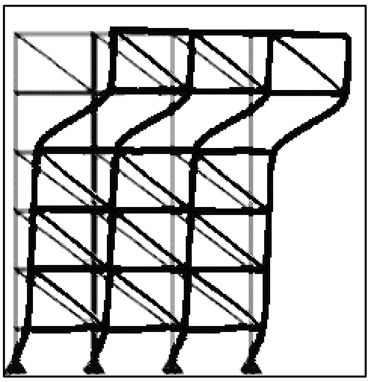

Fig 7: Lateral deformation profile in Building B

5. Drift Consideration

Storey drift is defined as the change in the lateral deformation between two consecutive floors. Basically storey drift have 3 primary effects on structure as it can affect structural member (beam, column), non-structural members (window, masonry walls etc.) or it can effect adjoin structure.

The intensity of drift is generally large when there is soft-storey present in that structure. Because due to consequently lesser stiffness of soft-storey level as compare to all floor above it.

Effect of drift on structural element- Structural element and joint are not the part of lateral load resisting system but needs to with stand the deflection and drifts. All design provision for moment resisting frame ensure that structure have ability to sustain inelastic rotation created during drift and deflection, but if proper is not taken it might cause premature failure and further is deformation is too large P-Δ effect can cause instability and result in complete failure.

Effect of drift on non-structural element- If non-structural element does not possess the lateral/horizontal load resisting system than adverse effect is likely.

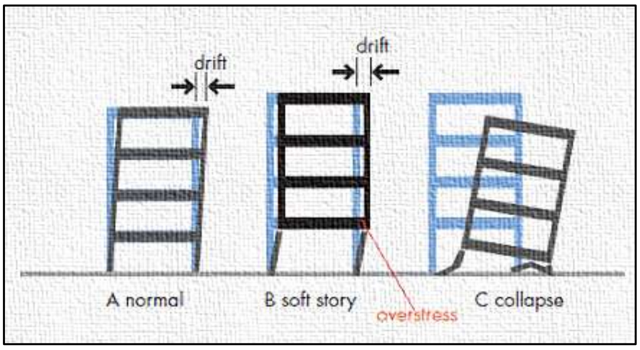

Fig 8 Failure mechanism of soft-storey building

Soft-storey are more flexible and less stiff and at any height they creates a problem, but as the total cumulative load is towards base of building it create a great discontinuity between soft-storey and other floor.

During earthquake the normal drift distribute equally among all the floor in normal building as shown in Fig 8(A), but due to soft-storey present at ground floor total drift intensity cumulate at second floor and this create overburden pressure Fig 8(B) at joints leading to distortion Fig 8(C).

If for soft-storey the local ductility demand are not fulfilled in design and the inter-storey drift are not limited a local failure and complete failure can happen due to high level of load deformation P-Δ effect.

6. Literature review

The paper given by **M.R. Amin et al** investigate the effect of multi-storey building with soft-storey using different symmetrical structure model with E-Tabs- 9.6.0 using provisions BNBC (1993).It is seen that, inter-storey drift ratio is increasing proportionately below the mid storey and maximum ratio was obtained where the soft storey is located. Thus it indicates that sudden drift control measures are to be adopted at this level.

Paper presented by **Manabu Yoshimura** studies seismic drift demand for RC buildings with weak first storeys. The seismic vulnerability of soft-storey also revealed in many past earthquakes like in 1995 Kobe and 1999 Chi-Chi earthquakes. To study the first storey drift Non-linear dynamic analysis were conducted. Major results which occupied are that strength of upper storey and balanced strength between floors will govern the first storey drift. It also concluded that first storey drift demand should be limited between 1%.

Paper given by **Neelima V. S. Patnala et al.** studied the structural capacity and to understand the seismic behaviour during some special cases in moment resisting frame using pushover analysis. Here it was observed that soft-storey building loses more stiffness when we compare it with building without soft-storey it is due to only sudden change in stiffness.

Another paper by **Dande P. S., Kodag P. B.** talks about by providing stiff column and adjacent infill we can increase the stiffness and strength of building with soft-storey. After analysis it results out that the displacement and force demands (i.e. BM &SF) in the first storey columns are very large for building with soft ground storey. So this demand should be reduced by providing enlarged column w.r.t to stiffed storey having ductile reinforcement.

Magdy Genidy et al. presented a paper, in this paper they used Egyptian code and studied the seismic response RCC building with soft-storey at different level. This analysis clearly providing us a fact about the masonry infill action in the soft storey building and also lead to the great sudden change it the storey drift. Investigation tells that due to soft-storey. The presence of soft storey at base or at any other level generally decreases the transmitted shear forces to the floors of the building models compared to masonry infill frame model.

Paper presented by **Haroon Rasheed Tamboli et al**. used equivalent lateral method to analyse the seismic effect on RCC framed building models having bare frame, infilled frame and open first storey frame. This analysis concluded that first storey has more storey drift as compare to upper storey and due to this collapse mostly occur. The infill wall increases the strength and stiffness of the structure, so emphases should be on to increase the stiffness without disturbing its utility.

7. Conclusion

After all this discussion on the related topic we can finally conclude that building with soft-storey is vulnerable during earthquake and can cause severe damage to life and property.

Due to the sudden change in the stiffness of the upper storey and the floor with soft-storey create a condition of irregularity. Since upper storey had infilled brick walls so their stiffness is about 4 times more than soft-storey floor.

The presence of soft storey at base or at any other level generally decreases the transmitted shear forces to the floors of the building models compared to masonry infill frame model. To safeguard the soft-storey different measure can be applied like providing Dampers, shear wall, stiffed column, and braces between columns to increase the stiffness in soft-storey.

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