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Review Article

SEISMIC PERFORMANCE OF RC FRAME STILT BUILDINGS – A REVIEW

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ABSTRACT
In countries like India, the masonry infill walls are quite popular in Reinforced concrete (RC) frames. In general practice, the masonry infill walls are treated as non-structural element for the design and analysis of frames. In order to calculate the load over structure, contribution of their mass is considered and their structural parameters such as lateral strength, stiffness and ductility are generally ignored in practice. Such kind of approaches may results in unsafe design. The performance of such structures during severe earthquakes has proved to be superior when compared to their corresponding bare frames. The response of RC frames due to the effect of masonry infill panel when subjected to seismic action is widely recognized. Infill walls resist the lateral loads but due the openings in the infill walls, the resistance may reduce up to some extent. It is necessary to consider the effect of masonry infill walls for the seismic assessment of moment resisting RC frames. It has been well understood that the infill walls play significant role in increasing the lateral stiffness of RC framed structure. This paper intends to highlight the need of knowledge on the behaviour of different RC frames such as stilt, infill, etc. and their composite action. It also summarizes the findings till date done by various researchers on the behavior of RC frames under lateral loads.

Keywords: *Stilt Building, Infill Walls, Lateral Strength and Stiffness, Ductility*

INTRODUCTION
Due to the increase in population especially in the developing countries like India, need of space plays a very vital role in day-to-day life. This need of space leads to the small size of plots and high cost of land. In order to counteract these difficulties, ground storey area is provided as parking in the different multi-storey buildings. The upper storey in such buildings consists of infill walls while the ground storey area does not constitute any partition wall between them. Such buildings are generally known as “soft storey buildings” or “buildings on stilts” or “stilt building” or “open ground storey buildings” (Murty, 2004).
The concept of stilt building has taken its place in the urban environment due to the fact that it fulfills the requirement of parking facility in the ground storey of the given building. The cost of construction of these stilt building is quite lower than that of other types of buildings. In the past earthquakes, surveys of buildings failed show that these types of structures are found to be the most vulnerable. It is considered that the collapse mechanism of these types of buildings is predominantly due to the fact that the formation of soft-storey behavior in the ground storey takes place.
The rapid decrease in mass and lateral stiffness in the ground storey leads to the creation of higher stresses in the columns of ground storey during seismic loading. During the conventional design practices, the stiffness contributions of infill walls present in upper storeys of stilt framed buildings are ignored (commonly known as bare frame analysis). Design based on such kind of analyses, results in under-estimation of the shear forces and bending moments in the columns of ground storey, and hence, it can also be said that this ignorance of infill wall stiffness may be one of the primary reasons that leads to the failures observed in the stilt frames.
During an earthquake shaking, if the occurrence of abnormal inter-story drifts between adjacent storeys takes place, there is an unequal distribution of lateral forces along the height of the structure takes place. This situation leads the lateral forces to concentrate on the respective storey having large amount of displacement(s). In addition, if the inter-storey drifts are not limited, a local failure mechanism or, even, a storey failure mechanism may take place, which may results in the collapse of the structure. It may be

formed due to the high level of load deformation (P-Δ) effects. Figure1 shows the collapse mechanism of a stilt building structure under both seismic and gravity loads (Setia *et al.*, 2012).

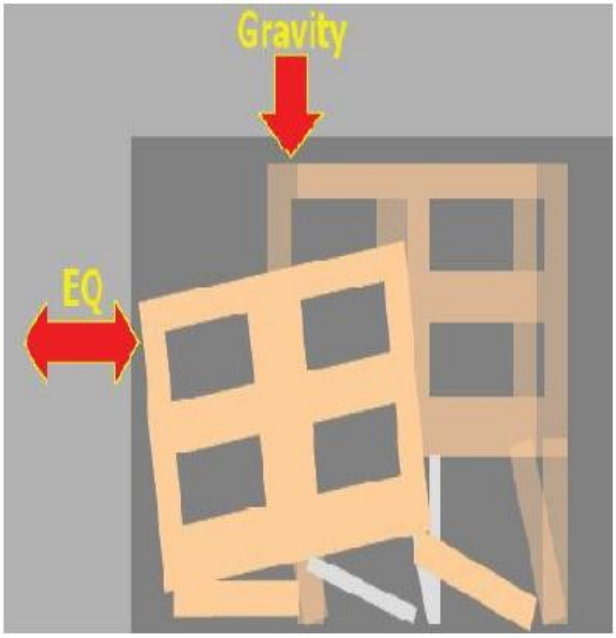

Figure 1: Collapse Mechanism of Structure Having Soft Storey (Setia *et al.*, 2012)

Performance of Stilt Buildings during the Past Earthquakes

Stilt buildings have consistently shown poor performance during past earthquakes across the world (1971 San Fernando, 1994 Northridge, 1995 Kobe, 1997 Jabalpur, 1998 Adena-Ceyhan, 1999 Kocaeli, 1999 Taiwan, 2001 Bhuj, 2003 Algeria, 2009 Padang and 2011 Sikkim); a significant number of them have collapsed. Major damage to many reinforced concrete and steel buildings in the 1995 Kobe earthquake, and to critical hospital facilities in the 1971 San Fernando earthquake, were attributed to the open ground storey. Alarming amount of damage to the buildings with open basements for parking has been reported during the 1994 Northridge earthquake (Arlekar *et al.*, 1997; Murty, 2004). Performance of buildings with open ground storey in some of the past earthquakes is discussed in the following.

1997 Jabalpur (India) Earthquake

The Jabalpur earthquake of 1997 for the first time illustrated the seismic vulnerability of the Indian buildings with soft storey. This earthquake, the first one in urban vicinity in India, provided an opportunity to assess the performance of engineered buildings in the country during ground shaking. The damage incurred by Himgiri and Ajanta apartments in the city is the good examples of the inherent seismic risk to buildings with soft storey. Himgiri apartment was an RC frame building with open ground storey on one side for parking, and brick infill walls on the other side. The infill portion of the building in the ground storey was meant for shops. All the upper storeys had brick infill walls. The ground storey columns in the parking area were badly damaged including spalling of concrete cover, snapping of lateral ties, buckling of longitudinal reinforcement bars and crushing of core concrete. The columns on the other side had much lesser level of damage. There was only nominal damage in upper storeys consisting of cracks in the infill walls. This is clear case of columns damaged because of soft ground storey.

The Ajanta apartment buildings were a set of almost identical four-storey RC frame building located side-by-side. In each of these buildings, there were two apartments in each storey, except in the ground storey. One building had two apartments in the upper Storeys, but only one apartment in the ground storey. The open space on the other side was meant for parking, and hence, had no infill walls. Whereas, only nominal damages were reported in the building with two apartments in the ground storey, the ground

storey columns on the open side in other buildings were badly damaged. The damage consisted of buckling of longitudinal bars, snapping of ties, spalling of cover, and crushing of core concrete. Another 3-storey C-shaped RC frame building (Youth Hostel building) suffered extensive damage to the columns in the stilt storey in the form of severe X-type cracking. Here also, the upper two storeys had brick infilled walls. This made the upper storeys very stiff as compared to the stilt storey. There was no damage to the columns in the storeys above. The soft ground storey at the stilt level is clearly the primary reason for such a severe damage (Arlekar *et al.*, 1997).

1998 Adana-Ceyhan (Turkey) Earthquake

During the 1998 Adana-Ceyhan (Turkey) earthquake, the most catastrophic failure was due to discontinuity of vertical elements of the lateral load resisting system. It is common in Turkey to construct multi-storey buildings with the ground storey being left open for parking to storage. In some cases, such areas are enclosed by glass partitioning windows to be used as showrooms. Such relatively flexible Storeys are subjected to higher stresses under which they may fail with the upper storeys usually moving as a unit. The almost vertical collapse of the buildings without considerable lateral movement indicated a very low shear and vertical load carrying capacity of the ground storey. Another unique example of the soft storey effect was observed in a 6-storey building of similar type but have partially soft storey; the portion of the building having infill in ground storey experienced no damage while the portion with openings resulted in the soft storey formation and collapsed. In the near proximity, other similar types of buildings with reasonably symmetric geometry and without significant variation in stiffness and strength in plan and in elevation performed well, with only nominal damage, usually in the form of the cracking of brick infill walls (Adalier *et al.*, 2001).

1999 Kocaeli (Turkey) Earthquake

In the 1999 Kocaeli (Turkey) Earthquake, a large number of multi-storey RC framed buildings with masonry infills collapsed. Typically, a storey mechanism was formed in the bottom storey or in the bottom storey or in the bottom two storeys. In some cases, the obvious reason was soft storey effect due to absence of infill walls in the bottom storey. In many cases, however, a soft storey mechanism was observed in structures with a uniform vertical distribution of infills after the fall out of the infills in the bottom two storeys (Figure 2). In Figure 3, two similar buildings, located within the same complex of the buildings, are shown after the earthquake. In one building (Figure 3 (a)], which did not collapse, a concentration of damage in the bottom two storeys can be clearly seen. The other building collapsed due to complete failure of the bottom two storeys, as shown in Figure 3 (b) (Dolsek, 2001).

Figure 2: Soft Storey Mechanism Formed after the Fall Out of Infill in the Bottom Two Storeys (Dolsek *et al.*, 2001)

(a) Concentration of Damage in Bottom 2-Storeys

(b) Collapse in Bottom 2- Storeys

Figure 3: Multi-Storey RC Frame with Masonry Infill near Golcuk (Dolsek *et al.*, 2001)

2001 Bhuj (India) Earthquake

Most of the residential apartment buildings in affected areas had weak RC frames; masonry infills played a crucial role in the survival of many buildings by providing lateral strength and stiffness. A completely filled RC frame with uniform strength and stiffness sustained almost uniform damage along the height. A four storey uniformly filled building in Gandhidham had suffered minor cracking at frame infill interface. While its symmetric half, which had open ground storey to facilitate parking, completely collapsed along their stair tower in the middle, the site in the foreground was leveled flat after clearing the debris (Murty *et al.*, 2002).

A large number of stilt buildings in Ahmadabad, Bhuj, Gandhidham, and other towns suffered severe damage or catastrophic collapse. Almost all of the buildings that collapsed in Ahmadabad were having open ground storey configuration. In many other buildings that did not collapse, the damage was confined to the open ground storey columns with only nominal frame infill separation in upper storeys. Many buildings were neither designed for seismic load nor detailed for ductile behavior. Hence, ground columns suffered brittle shear failure (Murty *et al.*, 2002).

2003 Bingol (Turkey) Earthquake

Most of the damage witnessed in the earthquake was due to the soft storey effect, whereby the absence of masonry infills, in order to provide extra space for commercial enterprises at ground floor, proved detrimental. Generally, the larger the ground floor outlet and the smaller the area of the infills, the heavier was the damage observed. Furthermore, the buildings with ground storey height significantly higher than the typical storey height, suffered more damage. This was manifested generally in the brittle behavior of columns, affected by diagonal shear cracks in them. The apartment building that lies on the gentle sloping ground, at the bottom of a steep hill, suffered a weak storey collapse in the ground floor, where the three shops were operating. The underlying basement was undamaged whilst the overlying typical Storeys had infill damage (Ellul *et al.*, 2003).

2009 Padang (Indonesia) Earthquake

The 2009 Padang (Indonesia) Earthquake is one of the severe earthquakes in Indonesia which lead the catastrophic damage to the engineered structures. The structurally deficient buildings were found to be quite weak, as they were either constructed in a very poor manner, or of weak materials. The major causes behind the damage were short column effects, inferior vertical configurations and a lack of ductile detailing. In spite of all the above reasons, soft storey failure (Figure 4) was found to be the most prevalent failure mode in multi-storey buildings. Most of the damaged buildings consisted soft storey at

the base as they were having an open ground floor and were comparatively stiffer on upper storeys because of infill walls. In other words, the buildings having infill walls evenly distributed horizontally as well as vertically performed well. In certain cases, after the failure of RC columns, the brick walls provided the gravity support system and saved the buildings. In Figure 5 (left) a small building is shown whose front was supported on a retaining wall and the back was on slender stilts. Although this small building survived, it suffered torsion between the wall and building (Figure 5 (right)).

Figure 4: Damage to Soft Storey in Residential Building (Bothara *et al.*, 2010)

Figure 5: Building on Stilts (Arrow Shows the Direction of Gravity) (Bothara *et al.*, 2010)

2015 Kathmandu Valley (Nepal) Earthquake

During the 2015 Kathmandu valley (Nepal) Earthquake, the RC framed buildings having masonry walls as infills performed very well. The diagonal cracks on brick infills walls and plaster was observed to be the most common damage. As the stiffness of infills was not taken into considerations during designing, the lateral loads were transferred to the infills, leading to the damage (Figure 6). The Most significant damage was observed due to the poor-construction and soft-storey phenomenon in which the ground storey was relatively weaker and flexible than the upper Storeys of the building. In the Kathmandu valley, most of the RC framed buildings were appeared to have soft storey with very lesser number of infill walls for stores, parking or other commercial purposes. These soft Storeys lead to the reduction of stiffness of

the ground Storeys when compared with the upper Storeys with more infill walls. The soft ground storey is clearly the primary reason for such damage (Surana *et al.*, 2015).

Figure 6: Soft Storey Failure on RC Frame Structure in Kathmandu (Surana *et al.*, 2015)

Previous Studies on Stilt Buildings

For the sake of brevity henceforth in this document, buildings with no infills, with infills in all the Storeys of the frame and those with infills only in upper storeys will be referred as "bare", "infill", and "stilt" frame, respectively. A large number of experimental and analytical researches have been carried out to understand the effect of infill on seismic behavior of RC buildings. However, research work exclusively on stilt building is limited.

Linear analysis of a four-storey building with 4.4 m ground storey height and 3.2 m height in upper storeys having symmetrical plan was performed in ETABS (Arlekar *et al.*, 1997). The stiffness irregularity in the stilt building model was the evident from the fact that the ground storey stiffness was only 5% of the first storey stiffness. However, in bare and infill frames buildings, ground storey stiffness was about 50% of the first storey stiffness. The lateral deformation profile of bare and infill buildings were smooth, while that of stilt had abrupt slope change at first floor level, i.e., most of the total displacement was contributed by the ground storey. The fundamental natural period of the bare, stilt and infill frames in transverse direction was 0.64 s, 0.43 s, and 0.18 s respectively, while it was 0.42 s as per codal formula. Bending moments and shear forces reduced significantly due to presence of infill in upper Storeys of stilt frame and all Storeys of infill frame. The bending moment and shear force demands were severely higher for ground storey columns in case of the stilt building.

A study was conducted to evaluate the effect of vertical structural irregularity on seismic performance of 5, 10, and 20 storey plane frames (Valmundsson *et al.*, 1997). The frames were designed for moderate seismic zones according to the UBC requirements. The frames were designed and detailed for ductility levels for 2, 6, 10. The ductility demand in the ground storey increases noticeably as the strength and stiffness of that storey reduced. For a design ductility of 2 and a 30% decrease in strength and stiffness of the ground storey, the increase in the ground storey ductility demand was 80% for 5-storey structures, 130% for 10-storey structures, and more than 200% for 20-storey structures. The increase in ductility demand is generally less for a design ductility of 6 and 10.

The over-strength and ductility were investigated for three-bay RC plane frames of 3, 6, and 10 storeys using non-linear pushover analysis (Balendra *et al.*, 1999). These frames were designed to resist gravity loads, wind loads, and a notional horizontal load in accordance with the British code BS 8110. The study showed that the over-strength decreases for bare frame analysis as the number of storeys increases. The ductility of bare frame was found to be slightly more than 2.0 in all frames (3, 6 and 10-storey). Infill was modeled as bi-diagonal struts. The struts width was as per Mainstone formula and stress-strain curve for concrete masonry given by Priestly and Elder were adopted. The infill walls have increased the lateral strengths of 3, 6 and 10 storey frames to 12.5, 14.5 and 15.4 percent of seismic gravity loads from 11.3,

8.3, and 4.9 percent respectively. The ductility factors for 3, 6, and 10-storey stilt frame are 1.89, 1.47 and 1.01. This shows that ductility of stilt frames are lesser than that of bare frames.

A four-storey RC frame structure were selected as a test example to represent a contemporary earthquake resistant building (Dolsek, 2001). Storey height was 3.5m in the ground storey and 3.0m in upper three storeys. The bare frame structure was designed according to Eurocode 8, as a high ductility class structures. It was designed for 0.3g peak ground acceleration, which results in a base shear coefficient of 0.15. The lateral strength of bare frame is about 30-35% of its total weight. Pushover analysis shows a global beam-hinge mechanism formation over the bottom three storeys. In the uniformly infilled structure, both stiffness and strength were much higher. However, with increasing deformation, the infills failed, and base shear decreased. A hinge mechanism was formed in the ground storey at a relatively large deformation, similar to the deformation of bare frame. In the bare frame, damage was limited and more or less uniformly distributed. The presence of infill changed the response of the structure significantly. In the case of the stilt frame, a concentration of drift was observed in the ground storey. In the uniformly distributed infill frame, both storey drift and roof displacement was much reduced. The test led to the complete destruction of infills in the lower two Storeys, severe damage of infill in second storey and almost no damage in top storey.

A six storey three bay framed structure with no infill i.e., bare frame (BFR) and infill other than bottom storey i.e., stilt frame (PIF) were designed to satisfy the seismic requirements for ductility class "Medium" in accordance with EC8 (EC8-1994 which is changed now significantly), with design peak ground acceleration (PGA) of 0.3g (Lu, 2002). EC8 adopts the concept of behavior factor q, to factor down the elastic spectrum for determination of the seismic design lateral load. The value of the q factor is determined according to the ductility class chosen, taking into account the structure type and irregularities involved. Specific detailing requirements are stipulated to satisfy the respective ductility demand. In the case of stilt frame, the contribution of the infill is not considered in the final strength design seismic load. A general countermeasure in detailing with all vertical irregularities, as explicitly prescribed in EC8 is a reduction of design q factor (thus, an increase in the design base shear). The reduction co-efficient is taken as a function of regularity index, which is defined as the ratio of the minimum storey-shear overstrength factor to average. The storey shear overstrength factor is calculated as the ratio of available Storey-shear strength (taking into the account all vertical members including infills in the storey) and design storey shear force. A minimum regularity index of 0.55 is imposed. In fact, it was the minimum requirement that actually governed the proportioning of the open ground storey columns in frame PIF and as a result, its ground storey column size was larger than that of frame BFR. The final design q factors were 3.5 for BFR and 2.4 for PIF. The proportioning of structural members was carried out following capacity design procedures for a weak-beam, strong column design and to avoid premature shear failure. For the experiment, the reduced scale (1:5.5) models were constructed and tested under the same scheme of simulated earthquakes on an earthquake simulator. Frame BFR exhibited uniformly distributed cracking patterns. The severe damage at the fifth storey is attributed to the abrupt reduction (over 20%) of the column cross-section size and subsequently intensified higher mode whipping effects. Its response remained stable, however, cracking widened substantially, indicating extensive yielding, while spalling of concrete occurred in the lower Storeys. In frame PIF, the enlarged ground storey columns appeared to be effective in preventing what would usually be anticipated a soft storey mechanism. Instead, the cracking spread into the beam column members as well as masonry walls throughout the frame.

A five-storey building with 3.0 m typical storey height having symmetrical plan was designed for zone V as per Indian seismic codes (Kanitkar *et al.*, 2004). The stilt building was designed as per the code provision of 2.5 times and the bare and the stilit, both frames were detailed as per ductile detailing code IS:13920-1993. The inelastic analysis of the bare and stilt buildings were performed. The bare frame exhibited good hysteric behavior with almost no decrease in lateral capacity even at high displacement levels. While the stilt frame lateral capacity decreased in successive cycles. Its initial stiffness and lateral strength was much higher than that of bare frame. The rapid drop in lateral strength could be attributed to the fact that the inelastic deformation was confined to open storey columns. In the bare frame, the

inelastically propagated into the upper Storeys due to redistribution of load within the structure. This did not happened in the stilt frame and consequently, lateral strength decreased in successive cycles. The lateral strength of bare and stilt frame were approximately equal to $1.0\,V_B$ ($V_B$is design base shear) and $2.4V_B$, respectively. Although, a scale factor of 2.5 is specified for moments and shear in the open ground storey members, the current provisions do not account for increase in column axial forces, which could compromise flexural capacity.

In order to study the frame behavior and steel requirements of the columns with and without brick masonry infill, a finite element investigation was performed (Muyeed-Ul-Azam, 2005). The various loads and different load combinations were considered during the finite element analysis of the building. It was observed that frames with infill exhibits quite smaller deflections and deformations as compared to the frames without infill. It was also observed that there is considerable difference in the requirements of steel in the exterior columns and significant difference in requirements of steel in the corner column while there is no difference in steel requirements of interior column. This indicates considering stiffness of the infill may not result in an economy in the design of multi-storey buildings if the number of interior columns is significantly greater compared to the number of exterior and corner columns. An appreciable reduction in lateral deflection takes place in the infilled frame as compared to the frame without infill.

The effect of partial masonry infills on the seismic behavior of low, medium and high rise buildings was addressed (Taher *et al.*, 2008). The system under consideration was assumed to a homogenized continuum for RC members having the unilateral diagonal struts for each bay. These bays generally behave as compression members by undergoing compressive stresses. In this study, the effect of number of bays, numbers of storeys, infill proportions along with their locations was also considered. The most simple equivalent frame system with reduced degrees of freedom is proposed for handling multi-storey multi-bay infilled frames.

A significant analytical research was carried on four models namely, bare frame, soft first Storey model, soft first storey having infill walls at particular locations in first storey and soft first Storey having stiffer columns (Munde *et al.*, 2012). These models were analyzed under the heads of Equivalent Static Analysis and response Spectrum Analysis using the ETABS software as analyzing platform. It was observed that for model I, the Storey stiffness of first Storey was found to be about 42.16% of above Storey stiffness. The stiffness of first Storey for model II was approximately 12% of the Storey stiffness. For model III, the first Storey stiffness was increased to about 37% of the above storey stiffness. In case of model IV, the use of stiffer columns raised the stiffness to 60.77% in longitudinal direction. It was concluded that the strength and drift demand in first Storey column is very large in soft storey buildings. The use of stiffer column may be done for the sake of diminishing the lateral drift demand on first storey columns.

In order to study the influence of horizontal loading on RC frame with brick masonry infill wall, a 12 Storey (G+11) building frame was considered (Dande *et al.*, 2013). This building frames was initially analyzed as bare frame and then, in the form of stilt frame with different stiffness conditions along the height of the building. The building frame was analyzed using SAP2000 Non-linear software. For the analysis and design of tall buildings, the deflection is considered to be the most prominent parameter. Therefore, it was observed that the bare frame models fundamental time period was more than the prescribed by the code and hence, this model may not be appropriate for the analysis. However, if infill wall is introduced in the bare frame, the fundamental time period reduces. In addition to this, behavior building frame when designed as bare frame was quite flexible causing horizontal shear distribution across floors. While in case of building frame when designed as infill frame, the total inertia of all the upper Storeys leads to the significant increase in lateral shear force at base. It was also observed that the presence of infills in upper Storeys provides much stiffness than the open ground Storey. Therefore, the movement of upper Storeys was observed in the form of single block and most of the lateral displacement occurred in the soft ground Storey itself. Such kind of buildings swung back and forth like inverted pendulums during earthquake shaking and the columns in soft ground Storey exhibited severely stressed.

The equivalent static response of a G+10 reinforced concrete frame building with bottom Storey as soft Storey was analyzed using STAAD. Pro V8i (Nagare *et al.*, 2015). This building frame was analyzed in

the form of 9 models having variations in thickness of infill walls along the different directions. The analysis was completely done for zone III as per IS:1893-2002. It was concluded that for earthquake in X-direction, all the bare frames exhibited less base shear as compared to their respective models by a factor of 1.3 while for earthquake in Z-direction, all the bare frames exhibited less base shear as compared to their respective models by a factor of 1.33.

The decrease in displacement for the model having higher thickness of outer infill wall as compared to bare frame model was by a factor of 3.9 along X-direction while for Z-direction, this factor was about 4.58. Moreover, the axial forces for all the models were almost equal. In addition to this, when the earthquake is in the X-direction, the bending moment along Y-direction decreased by a factor of 1.6 for the models having higher thickness of outer infill walls as compared to bare frame and the bending moment along Y-direction decreased by a factor of 1.26 for the models having higher thickness of outer infill walls as compared to bare frame. However, when the earthquake is in Z-direction, the decrease in bending moment took place by a factor of 5.36.

An analytical study was conducted on soft Storey building frame model G+9 when designed as soft Storey frame as model IFSS, soft Storey frame with the provision of shear walls as model IFSW and soft Storey frame with steel bracing as model IFCB for seismic zone III on ETABS software (ArunKumar *et al.*, 2016). The soil type was assumed to be medium and the design of the frame was strictly based upon IS:456-2000. It was concluded that the base shear capacity of model IFSW exhibited was quite higher as compared to the other respective models. The base shear of model IFSW was 39.8% and 30.6% more than model IFSS and model IFCB respectively. The displacement of model IFSW was about 40% and 150% more than that of model IFSS and IFCB respectively. It was also concluded that the Inter-Storey drift of IFSS was comparatively much higher than the codal provision. The inter-storey drift for model IFSW is about 200% and 10.5% lesser than the IFSS and IFCB respectively. Storey force of IFSW is 3% and 89% more than the Storey force of IFCB and IFSS respectively. Hence, it was observed that the building with shear walls maximum Storey force than the other respective systems. Due to the provision of shear walls, the Storey ability of the soft Storey building was observed to be increased by 3.89 times than that of infilled frame with soft storey. The model with shear wall at the bottom storey has higher amount of moment when compared with the other systems irrespective of the number of Storeys in the building models.

Conclusion

The lessons from the performance of stilt buildings during past earthquakes indicate that partially infilled frame structures i.e. stilt frames are highly vulnerable towards the ground motions and if there is any method identified for modeling of such structures, the seismic hazard to the structures would be reduced significantly. It is also observed from the previous research studies that infills walls tend to increase the lateral strength of structures. However, the contribution of partial infill walls towards the structural stability must be identified properly so that during the analysis of real structures, the composite action of the frame and infill walls would be realized.

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