Dynamic Analysis of Steel Framed Building with Soft Story

Pranita Anand kate[1], Dr. Amol Pote[2],
[1]*P.G. Student, G H Raisoni College Of Engineering and Management, Pune, India*
[2]*Associate Professor, Dept. of Civil Engineering, G H Raisoni College Of Engineering and Management, Pune, India*

***Abstract*— This research paper aims to investigate the dynamic behavior of steel-framed buildings with a soft story under different types of bracing systems. The vulnerability of buildings with soft stories to lateral loads, such as earthquakes, has been well-documented. The effectiveness of different bracing systems in mitigating the structural vulnerabilities associated with soft stories is a critical aspect of earthquake-resistant design. In this study, a comprehensive analysis is conducted using advanced computational tools to assess the performance of various bracing systems in enhancing the seismic resilience of steel-framed buildings with soft stories. In this paper we have analyzed G+5 steel framed building with soft story at various locations using ETABS software and effect of different bracing systems like X bracing, v bracing, k bracing has been compared. The research findings provide valuable insights into selecting optimal bracing strategies for such structures.**

***Index Terms*— Soft Storey, IS1893 2016, Bracing, weak story, response spectrum analysis, earthquake-resistant design, bracing systems.**

I. INTRODUCTION

Steel-framed buildings with soft stories are susceptible to significant damage during seismic events due to their uneven distribution of stiffness and lateral load resistance. Soft stories are typically characterized by one or more floors with reduced stiffness, often used for parking or commercial spaces. The objective of this study is to evaluate the effectiveness of different bracing systems in enhancing the seismic performance of steel-framed buildings with soft stories.

1.1 Types of Bracing

X bracing: Cross-bracing (or X-bracing) uses two diagonal members crossing each other. These only need to be resistant to tension, one brace at a time acting to resist sideways forces, depending on the direction of loading. As a result, steel cables can also be used for cross-bracing.

K-bracing: K-braces connect to the columns at mid-height. This frame has more flexibility for the provision of openings in the facade and results in the least bending in floor beams. K-bracing is generally discouraged in seismic regions because of the potential for column failure if the compression brace buckles.

V-bracing: Two diagonal members forming a V-shape extend downwards from the top two corners of a horizontal member and meet at a centre point on the lower horizontal member (left-hand diagram). Inverted V-bracing (right-hand diagram, also known as chevron bracing) involves the two members meeting at a centre point on the upper horizontal member.

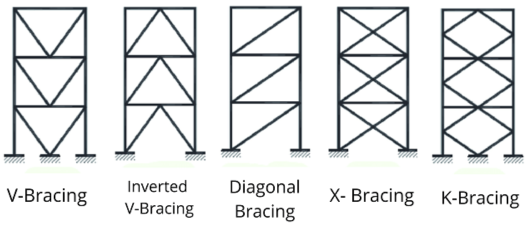


Figure. 1 Different bracing system

1.2 Soft Storey Failure

Due to the limited horizontal space and high cost, multi-story structures in metropolitan areas must have an open, taller first floor for parking automobiles and/or retail shopping, a sizable space for a conference room, or a banking hall. The first level has less strength and stiffness than the upper stories, which are reinforced by brick infill walls, as a result of this practical requirement. In multi-story buildings, this aspect of building construction causes weak or soft-storey issues. Extreme deflections caused by the first story's increased flexibility in turn cause a concentration of forces at the connections to the second storey and cause significant plastic deformation. Additionally, the soft columns disperse the majority of the energy generated by the earthquake. The soft tales are turned into a mechanism in this phase by the formation of plastic hinges at the ends of the columns. The collapse is inevitable in such circumstances. Soft stories should therefore receive special attention in both analysis and design. According to the survey, the damages are primarily caused by the collapse and buckling of columns, especially in areas where parking spaces are not adequately protected. On the contrary, where the parking places are sufficiently covered, the damage is significantly reduced. It is understood that a number of other unfavorable factors, including torsion, excessive mass on upper levels, P-effects, and a lack of ductility in the bottom storey, combine to cause this form of failure. Some of the examples of soft stores are shown in the illustration. Technically and practically speaking, the soft-storey concept is superior than traditional structure. First, as in a base-isolated structure, there is a decrease in spectral acceleration and base shear caused by an increase in the structure's natural period of vibration. But this force reduction comes at a cost—increased structural displacement and inter-storey drift, which has a substantial P-effect and jeopardizes the integrity of the structure. Second, there are instances when a taller first floor is required for parking spaces, retail stores, large meeting rooms, or banking halls. Due to this practical necessity, the first story’s columns are less rigid than those in the stiff upper-floor rooms, which are typically built with masonry infill walls. Figure 1.1 depicts a soft tale failure in the normal sense.

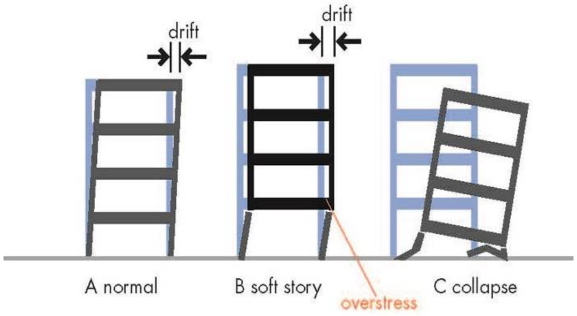


Figure 2. Soft story failure

II. RELATED WORK

Vyshnavi Pesaralanka et al. (2023) investigated the effect of a soft story and its location on the seismic behaviour of a supporting building and NSCs. The lowest (ground), middle, and top story levels of the hypothetical building models were supposed to contain the soft story. To analyse structural behaviour, story displacements and inter-story drift ratios were examined. To comprehend the behaviour of NSCs, the floor response spectra and the amplification effects of NSCs on the floor acceleration responses were investigated. According to the analysis's findings, the bottom soft story has a significant vertical stiffness irregularity, and its location has a significant impact on the floor response spectra. At the soft-story level, it was discovered that the floor acceleration reaction was amplified more. This study found that the component's acceleration is amplified most noticeably in middle soft-story buildings. The code-based formulation's linear assumption may cause peak floor response demands to be underestimated or exaggerated, it was discovered after peak floor response demands and the code-based formulation were compared. [1]

George C. Manos et al. (2022) Due to the existence of masonry infills in the upper floors, multi-story, old reinforced concrete (RC) structures with a "soft story" on the ground floor experience significant damage to the soft story during earthquakes. They briefly examined certain aspects of the relationship between brick infill and RC frames. To avoid such soft-story inadequacies, it consists of RC infills that are put inside the ground floor frames' bays and paired with RC jacketing of the surrounding frame. The effects of such a refit were investigated through the measured behaviour of single-story, one-bay frames built to 1/3 scale and exposed to horizontal stresses of the cyclic seismic variety. It was established that this retrofit increases stiffness, strength, and plastic energy consumption significantly for the better. It was also shown how crucial it is to have strong steel connectors connecting this RC infill to the surrounding frame. Additional design goals were set with the intention of preventing early failure of the RC infill panel and/or fracture of the steel links and safeguarding the surrounding RC frame from unintended local damage in order to accomplish these desired beneficial effects on such sensitive buildings. A numerical methodology that was proven to be capable of reasonably predicting these crucial response mechanisms and was validated using the resulting experimental results can now be used for design purposes. [2]

Florin Pavel and Gabriel Carale (2019) completed a seismic evaluation for a Bucharest, Romania-typical low-code, high-rise, soft-storey reinforced concrete (RC) building. After the earthquake in 1977, the majority of these structures were not retrofitted, were not well-maintained, and were impacted by two more earthquakes in the Vrancea region in 1986 and 1990. The seismic assessment of these buildings is therefore a pressing issue given that many people in Bucharest still live there. As a result, a fragility study is carried out first using the outcomes of standard pushover analyses as well as incremental dynamic analyses. Additionally, a thorough sectional investigation of the ground-floor vertical structural parts' seismic resilience is also carried out, highlighting the brittle seismic behaviour of several RC vertical structural elements. The analyses also revealed that the construction has more transverse strength, but its longitudinal displacement capability is only approximately half as great. Last but not least, data gathered after the 1977 Vrancea earthquake supports the observation that the mean annual collapse probabilities calculated using the ground motions for a Monte-Carlo simulated earthquake catalogue for the Vrancea intermediate-depth seismic source have the same order of magnitude on both principal directions of the structure. [3]

J.M. Jara et al. (2019) aimed to evaluate the seismic vulnerability of typical soft-story structures, analyse the seismic damages seen during the visual inspection of the affected area, and propose retrofit alternatives including braces and energy dissipation systems to increase the seismic capacity of existing buildings. According to the findings, elastoplastic and viscous dampers are good substitutes for reducing the seismic vulnerability of existing low-rise, soft-story buildings. The pairing of braces in one bay and elastoplastic dissipaters in the other proved to be a workable retrofit choice when the structures' number of floors rose. This study investigated several seismic retrofit techniques for existing soft-story structures. Based on data on structures in Mexico City that were harmed by the earthquake that occurred on September 19, 2017, the buildings were chosen. The predicted seismic behaviour of four-, six-, and eight-story buildings was evaluated using accelerograms from seismic sensors nearby the locations of building collapses. As potential retrofit methods, the usage of braces, metallic energy dissipaters of elastoplastic behaviour, and viscous dampers was taken into consideration. Three original buildings were also examined for comparison's sake. These structures had no retrofit systems installed. The findings of the nonlinear studies performed after the investigation of the earthquake damages lead to the following conclusions: Soft-story structures made up more over half of the destroyed buildings. The majority of the 2 to 8 story buildings that sustained damage in Mexico City were situated in areas with soft ground. Models that weren't adapted were created in accordance with the regulations that applied in Mexico in the 1970s and 1980s. The damages that were seen following the earthquake's occurrence were justified by the results of the drift ratio and rotation demands in the first story columns. Braces can be added as a way to lessen the consequences of quakes in the future. Base-shear standards, however, would necessitate altering already-built foundations, which is never a simple structural operation to carry out. [4]

Pravesh Gairola and Sangeeta Dhyani (2019) examined the seismic response of soft-storey buildings under earthquake stress using various models (Bare frame, Infill frame, Bracing Frame, and shear wall frame). It has been found that using different models rather than only soft storeys improves the structure's resistance behaviour. They came to the conclusion that all constructions have a lateral load that is zero at the bottom and maximum at the top storey based on the results of applying the analogous static approach. The first level was found to have the highest storey shear force, while in every case, the top storey had the lowest storey shear force. The bare frame building has a significant displacement when compared to the rest. It shown that bare frame buildings in seismically active areas could likewise exhibit larger displacement than the remainder of the building. [5]

Objectives of investigation:

1. To evaluate the response of braced and un-braced structure subjected to seismic loads with and without soft story.
2. To compare the displacement, storey drift, time period, overturning moment and for different types of bracing systems with and without soft story.
3. To identify the best possible location of story for steel frames building.

4. To identify the suitable bracing system for resisting the seismic load efficiently.

III. METHODOLOGY

- To develop a G+5 storey steel framed building with soft s tory art different levels on ETABS for dynamic seismic analysis.

- The model is retrofitted with various steel bracing systems on periphery columns storey wise and analyze for seismic forces.

- To analyze the model for K bracing, X bracing and 'V' type bracing and compare with an unbraced frame.

- The main parameters in this study to compare the seismic analysis of buildings are lateral displacement, storey drift, time period, and over turning moment.

- Comparative study of all steel bracings and finding best suitable bracing for steel framed building with soft story at various levels.

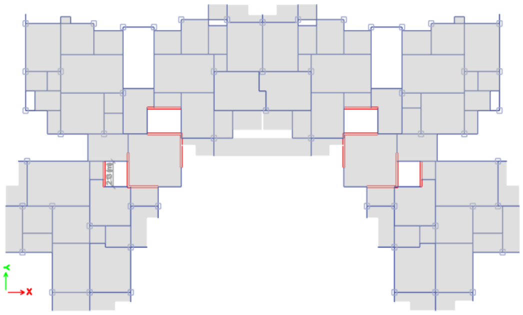
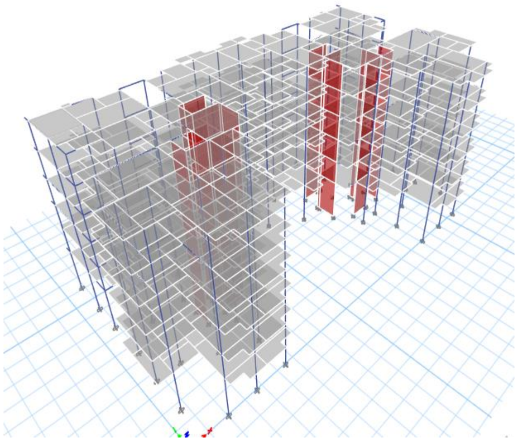


Figure 3: Plan of building considered in ETABS



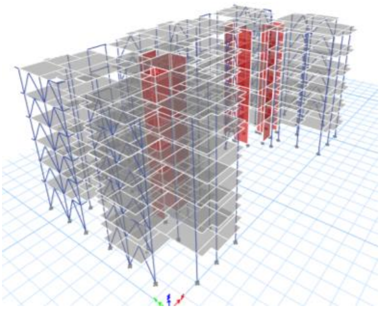


Figure 4: 3D view of building with (a) without bracing (b) with V bracing

IV. RESULTS AND DISCUSSIONS

All models are first analysed by equivalent static analysis to calculate the base shear of all models, then response spectrum analysis is performed. After equating the base shear for static and dynamic analysis by dynamic scaling following results are extracted to compare the seismic performance of the building:

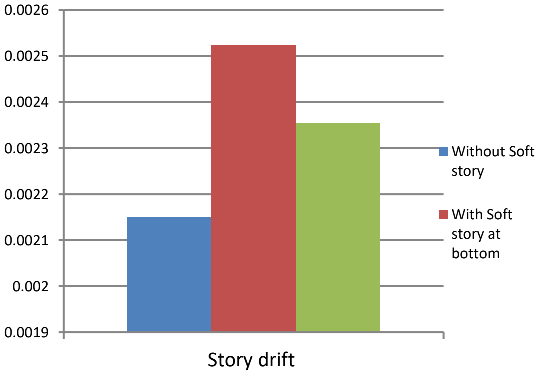


Figure 5: Variation of Story drift for un-brace system

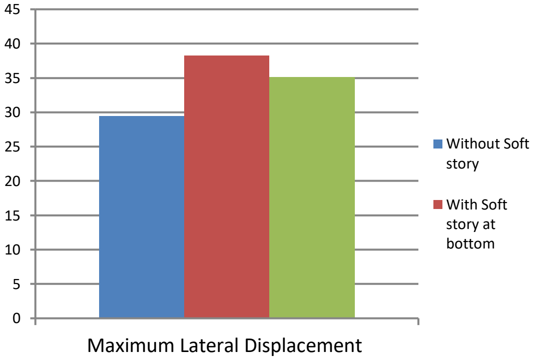


Figure 6: Variation of Maximum lateral displacement for un-brace system

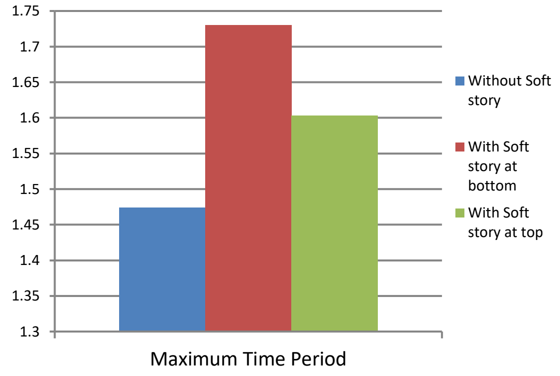


Figure 7: Variation of Maximum time period for un-brace system

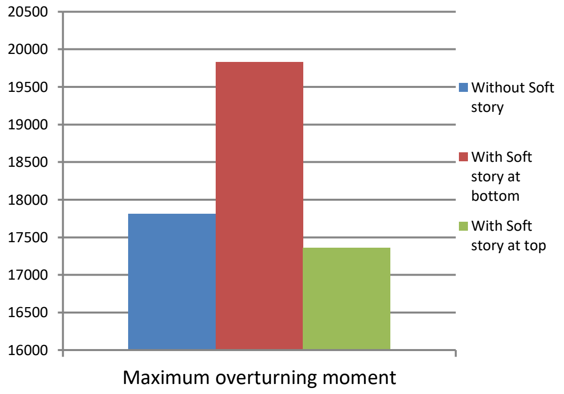


Figure 8 Variation of overturning moment for un-brace system

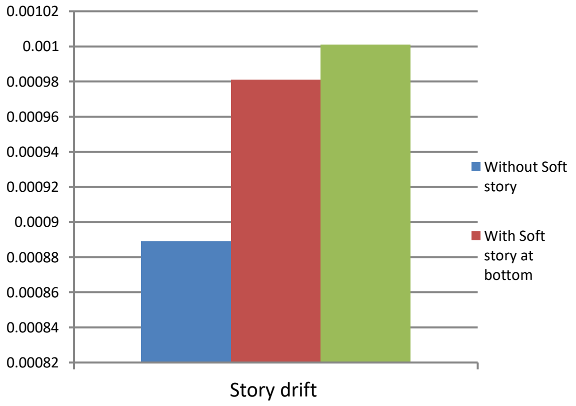


Figure 9: Variation of Story drift for X bracing system

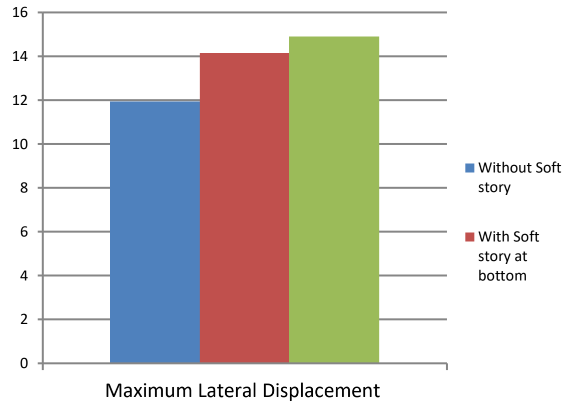


Figure 10: Variation of Maximum lateral displacement for X bracing system

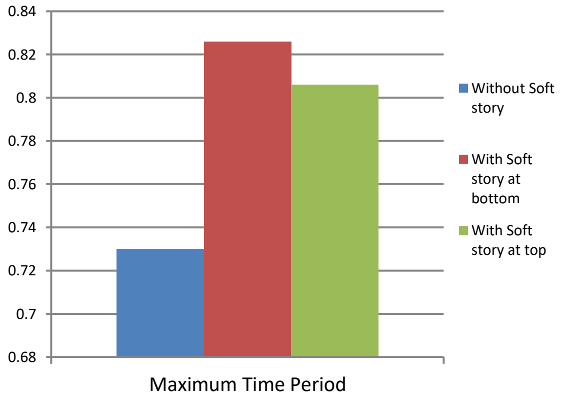


Figure 11: Variation of Maximum time period for X bracing system

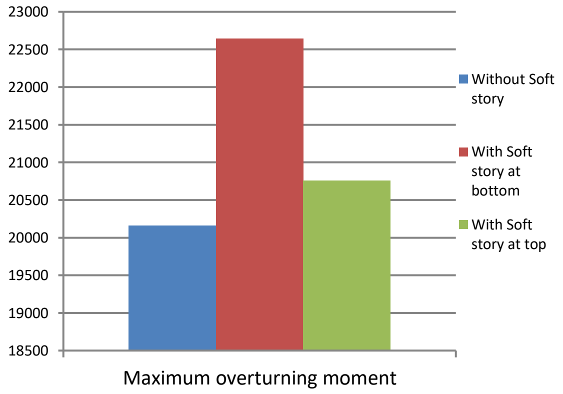


Figure 12 Variation of overturning moment for X bracing system

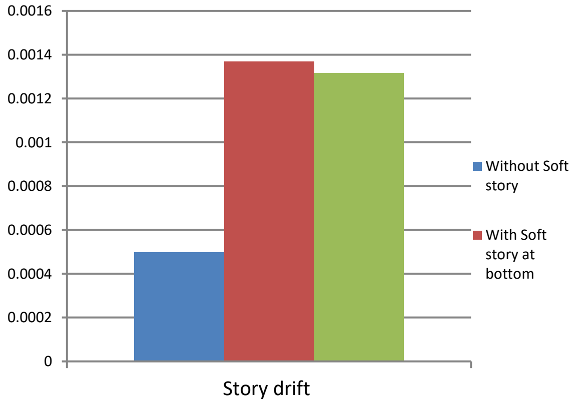


Figure 13: Variation of Story drift for V bracing system

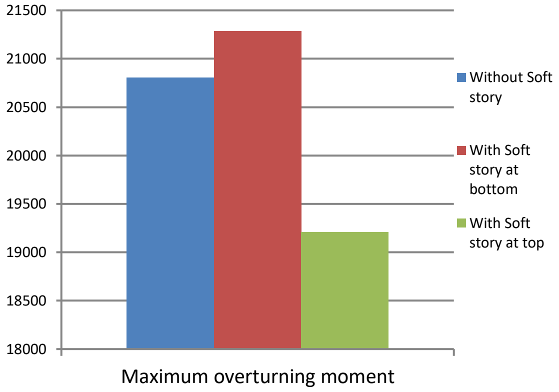


Figure 16 Variation of overturning moment for V bracing system

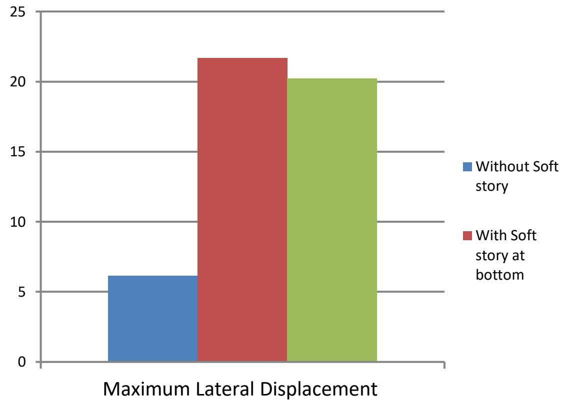


Figure 14: Variation of Maximum lateral displacement for V bracing system

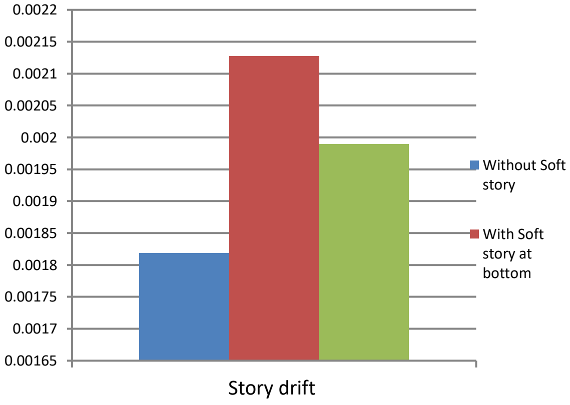


Figure 17: Variation of Story drift for K bracing system

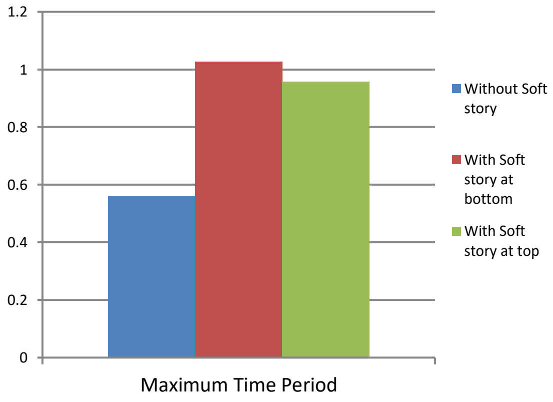


Fig. 15: Variation of Maximum time period for V bracing system

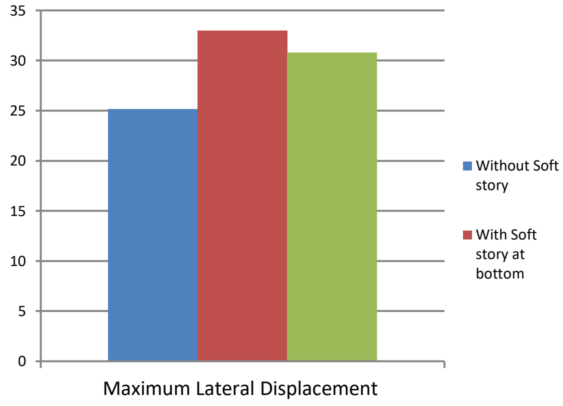


Figure 18: Variation of Maximum lateral displacement for K bracing system

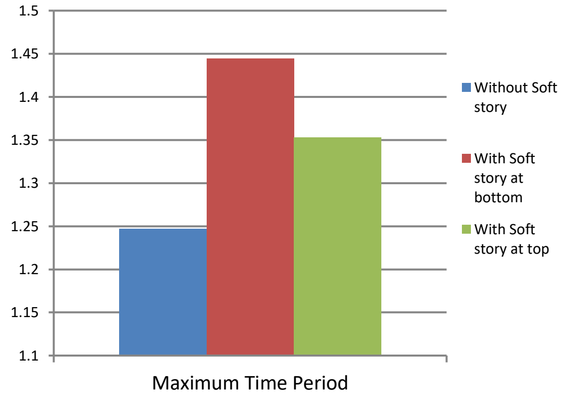


Figure 19: Variation of Maximum time period for K bracing system

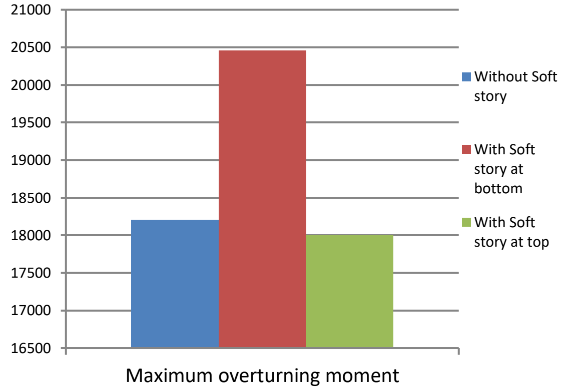


Figure 20 Variation of overturning moment

for K bracing system

V. CONCLUSIONS

There is a substantial reduction in the maximum story drift of the building with the use of bracing systems, which is maximum for X bracing with around 75% reduction. The time period of the building is also considerably reduced with the use of bracing systems; around 50% reduction was seen with the use of X bracing. The reduction in lateral displacement is also similar. There is no significant change in the overturning moment of the building due to the addition of the bracing system, which is around 3–4%. So we can conclude that the use of bracing systems in steel-framed buildings improves the seismic performance of the building significantly. Also, we can conclude that X bracing performs better as compared to other bracing systems. Also, from the results, we can see that the seismic performance of the building is affected by the addition of soft stories, and soft stories at the bottom are more vulnerable to seismic activity as compared to soft stories at the top.

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