IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

A STUDY ON RC FRAME BUILDING HAVING SOFT STORY AT INTERMEDIATE LEVEL

[1]Ovais Bin Dawood, [2]Mohd Kashif Khan, [3]Devendra Singh, [4]Mohd Mohsin Khan, [5]Tabarej Alam

[1]Student of MTech (Structural Engineering), [2]Associate Professor, [3]Student of MTech (Structural Engineering),
[4]Student of MTech (Structural Engineering), [5]Student of MTech (Structural Engineering)
Department of Civil Engineering
Integral University, Lucknow, Uttar Pradesh-India

Abstract: This dissertation involves the study of the behavior of soft story located at intermediate level in high rise building under seismic loading. Unfortunately, open first floors are an inescapable aspect of many urban multistory structures in India nowadays. The main reason for adopting this is to make room for parking or reception lobbies in the first story. The goal of the current analytical study is to determine how certain parameters affect a structure with soft story behavior. The aspect of difference in performance of a building with a soft story under seismic forces is described in this thesis, specifically for different places of the soft story along the height of the building structure. This thesis examines a twelve-story moment-resisting RC-framed building for zone V. The fourteen models of the twelve-story RC-framed building are prepared. Bare frame model, infill & other twelve versions of infill frame are studied, each with one Soft Story (one story at a time from bottom to top, by removing the masonry infill in that Story). The computer program ETABs is used for modelling the whole building. The analytical findings are discussed in terms of base shear, lateral displacement, lateral forces and maximum bending moment.

Index Terms **- Soft story, ETABS, High Rise, Seismic Analysis.**

I. Introduction

The term earthquake refers to any seismic event that generates seismic waves, whether natural or caused by people. Earthquakes are primarily triggered by the rupture of geological faults, although they can also be caused by other events such as volcanic activity, landslides, mine explosions, and nuclear testing. Many structures have been damaged as a result of soft-story system failures in recent earthquakes. The seismic design requirements for buildings do not offer suitable criteria for forecasting the actual displacement of such structures. Open first floors in multistory structures (Soft story) are known to perform badly during significant earthquake shaking. When masonry infill walls interact with their surrounding frames, the structure's lateral stiffness and load bearing capability is considerably increased. The substantial damage or collapse of multiple soft-story buildings following recent earthquakes has inspired a concentrated research effort into linear and nonlinear analytical techniques to examining the behavior and capacity of such structures. Buildings with soft stories are susceptible to the phenomena known as soft story collapse, which occurs after earthquakes of moderate intensity. A disproportionate share of the building's total side-to-side drift was concentrated on that floor because it was inadequately braced level and so less resistant to lateral seismic motion than other levels.

II. Literature Review

1) ***Das and Murthy*** (2002) [1] determined that when infill walls are present in a building, they often reduce the damage sustained by the RC framed elements of a completely infilled frame during earthquake shaking. Lower story columns, beams, and infill walls are more prone to damage than higher story columns, beams, and infill walls.
2) According to ***Davis and Menon*** (2004) [2], the use of masonry infill panels dramatically affects the structural load distribution in a soft first story structure. In the presence of masonry infill on the upper level of the structure, the total storey shear force increases as the stiffness of the building increases. Furthermore, the bending moments in the ground floor columns rise (more than double), and the mode of failure is soft storey (creation of hinges in ground floor columns).
3) ***Asokan*** (2000) [3] investigated how the presence of masonry infill walls in building frames affects the lateral stiffness and strength of the structure. This study presented a plastic hinge model for an infill wall to be employed in a nonlinear performance-based analysis of a structure, concluding that the ultimate load (UL) technique, along with the proposed hinge property, gives a superior estimate of the building's inelastic drift.
4) ***Hashmi and Madan*** (2008) [4] carried a non-linear time history and pushover analysis of soft first story structures. The study's conclusions show that the MF suggested by IS 1893(2002) for these kinds of constructions is enough for preventing collapse. The inelastic behaviour of building structures may be assessed using two widely used methods, both of which are based on nonlinear static pushover analysis. The capacity spectrum technique, often known as ATC-40, is one of the most used methods for valuing buildings [5]. It was made by Freeman [6]. In this method, the structural capacity curve is calculated and then contrasted with the demand spectrum. A performance point that lies on the capacity spectrum and the efficiency

spectrum must be determined in order to assess the system's performance.

5) Using invariant narrative forces proportionate to the deflected form of the structure was suggested by ***Fajfar and Fischinger*** [7]. Eberhard and Sozen [8] provided load patterns based on mode shapes generated from secant stiffness at each load step in relation to this topic. In a related work, Park and Eom [9] suggested a novel design approach utilizing secant rigidity. It is claimed that the new approach more accurately and immediately estimates the inelastic strength and deformation requirements. In their study, they emphasized that only energy dissipation inside the structure can avoid the soft-story, and that the only way to maximize it is by distributing the plastic hinges throughout the building height.
6) A technique to ascertain the higher mode effects in tall structures was researched by ***Moghaddam*** [10]. Buildings that employ elastic mode forms as load patterns go through a variety of pushover analyses.
7) A multimodal technique was proposed by ***Sasaki***, ***Freeman***, and ***Paret*** [11] to forecast high mode effects.
   The suggested method is reportedly effective in foreseeing high mode effects, however it is unable to offer precise seismic response of such structures. Contrary to the aforementioned methods
8) Pushover analysis was developed by ***Chopra*** and ***Goel*** [12] and given the term Modal Pushover Analysis (MPA). Comparing the outcomes of this method under different loads. The MPA is more accurate than all pushover analysis methods in estimating floor displacements, story drifts, plastic hinge rotations, and plastic hinge locations, as the other pushover methods underestimate the story drift demands and result in significant errors in plastic hinge rotations, according to patterns. Additionally, it was noted that the MPA results and the results of the time history analysis were comparable.
9) The accuracy of the MPA process is assessed in a different study by ***Chintanapakdee*** and ***Chopra*** [13], and it was shown that the MPA results had a strong association with nonlinear research, In that work, the seismic demand of inelastic systems is likewise estimated using the MPA approach, with the seismic demand being characterized by an elastic design spectrum. The accuracy of the modal pushover analysis method for distorted frames was examined by the same authors [14].
10) In their investigation of a modified MPA technique in which a variant load pattern is produced from the mode shape of a yielding point, ***Attard and Fafitis*** [16] note that, following iteration on the suggested strategy usually always yields findings that match the parameters discovered by time history analysis.
11) The significance of higher mode effects in pushover analysis is examined in another work by ***Chopra and Goel*** [17]. The higher mode pushover curves are discovered to produce plastic hinge mechanisms that are undetectable by the FEMA-356 effective first mode load pattern or other force distributions. On the other hand, it is claimed that in a typical building without a soft and/or weak storey, these processes do not emerge during ground motion. In same work, it is also demonstrated that reversals in a higher mode pushover curve happen after the development of a mechanism if the resulting force above the bottom of the mechanism moves the roof in the opposite direction from where it did before the mechanism was formed. Only pushover analysis for higher modes can result in reversals; pushover analyses for the first mode or other FEMA-273 [18] force distributions cannot. When a narrative is soft or weak, it is claimed that the story's drift requirements are enhanced in the changed and nearby stories and dropped in the other stories. On the other hand, a tough and/or compelling narrative reduces the need for drift in the modified and additionally, it is said that although the roof displacement is often unaffected by vertical irregularity, it differs dramatically for frames with irregularities in stiffness and strength in their bottom half. The height-wise distribution of floor displacements is significantly impacted by irregularity in the base level or lower floors.
12) In order to account for higher mode effects and fix the FEMA-356 procedure's flaws, ***Gupta and Kunnath*** [19] studied the FEMA-356 processes and proposed the Adaptive Pushover Procedure (APM). It is stated that APM is more accurate at assessing seismic demands than the FEMA 356 technique is at accurately evaluating ductility needs.
13) ***Jan T.S.*** [20] introduced Upper Bound Pushover Analysis process, a novel type of pushover analysis process that takes higher mode effects into account. It is begun that the triangular load patterns and MPA procedure are better than the proposed method in predicting seismic demands in low rise structures, but these procedures underestimate the responses in high and mid-rise structures, for which the proposed method makes reasonable predictions. It is also said that their proposed strategy overestimates demand in upper stories while underestimating demand in lower ones.
14) ***Kalkan and Kunnath*** [21] concentrated on the prediction of seismic demands on buildings and contrasted the findings of time history analysis with various nonlinear pushover static loadings. It is claimed that the FEMA-356 approach and the Upper-Bound Pushover Procedure provide poorer more accurate projections of demand. when stories are higher However, higher as mode I the is method inelastic substantial is observed and contribution to MPA be of higher procedure misleading modes leads in They concluded that the Adaptive Modal Combination Procedure, which incorporates the capacity spectrum, modal combination, and adaptive loading patterns, is the optimum way for anticipating the seismic demands of a building construction.
15) The local component needs of FEMA-356 are addressed in another research by ***Kalkan and Kunnath*** [22]. The pushover methods are characterized as force-based processes that give vital information on probable collapse mechanisms and the vulnerability for soft narrative. It is also mentioned that, for structures that respond predominantly to the first mode, nonlinear static techniques may be a valid choice to predict inelastic demands but rising structures. In addition to the above-mentioned research on nonlinear static pushover techniques, investigations on diverse load patterns have also been conducted.
16) ***Mwafy and EInashai*** [23] explored the usefulness and accuracy of inelastic static pushover analysis in forecasting the seismic response of reinforced concrete buildings. It is suggested that if the load pattern is correctly set, the model may simulate the inelastic response of low and mid-rise structures. It is advised to utilize additional load patterns in high-rise structures due to the difficulty in projecting greater mode impacts. Furthermore, in that investigation, the uniform load pattern is proven to be quite cautious in predicting earthquake demands.
17) ***Krawinkler and Seneviratna*** [24] outlined the fundamental elements upon which the pushover analysis might be built. They also evaluated the accuracy of pushover forecasts and established the situations under which the pushover will give sufficient information. They also discovered the cases in which misleading pushover forecasts are insufficient, rigorous pushover analysis may give insight into structural factors that govern performance during strong earthquakes. It is also said that pushover analysis will yield better results for constructions when the predominant mode of vibration is the fundamental mode. Weaknesses such as narrative mechanisms, excessive deformation demands, strength irregularities, and overloads on columns and connections that may have gone undetected in an elastic analysis will be identified.

18) ***Moghaddam and Hajirasouliha*** [25] explored the pushover analysis's capability for estimating the seismic deformation demands of concentrically braced steel frames. It is said that the findings of a pushover study are extremely sensitive to the applied load pattern, and such analyses often yield erroneous demands.
19) ***Inel et al.*** [26] investigated several load patterns employed in pushover analysis. The project also included a soft-story covering for structures. Simplified inelastic approaches were discovered to yield extremely good predictions of peak displacement response for both regular and weak-story structures. It is also said that when many modes are included, the findings of inter-story drift and story shear are often improved. The results also suggested that simplifications in the first mode lateral load pattern may be easily implemented with a minor loss of accuracy.
20) ***Korkmaz and Sar*** [27] used pushover and nonlinear dynamic time history analysis to assess the performance of the frame constructions under varied load patterns. According to this paper, for high-rise frame structures, first yielding and shear failure of the columns occurs at larger story displacements, and uniform distribution always gives the higher base shear-weight ratio when compared to other load distributions for the corresponding story displacement. It is also discovered that nonlinear static pushover analysis results do not match with nonlinear dynamic time history analysis results, particularly for long period high-rise frame structures. It was also mentioned that the findings of the pushover analyses for uniform load distribution estimate maximal seismic demands during the given earthquakes more accurately than the other load distributions.
21) ***Kömür and Elmas*** [28] used nonlinear pushover studies with multiple multimodal processes and inverted triangle loadings to assess reinforced concrete frame systems constructed to current Turkish Codes. It was discovered that the pushover curves of the multimodal process and inverted triangle loading are almost identical, as are the collapse limits. As a result of this, the multimodal technique has been proven to be ineffective in the evaluation of such building structures.
22) ***Oguz*** [29] tested the pushover analysis approach with different load patterns and methods. It was discovered that for low and mid-rise structures, the variance in the outcomes of all modal load patterns and triangular load patterns is insignificant. It is also said that triangle load patterns predict displacements and inter-story drift ratios in low and mid-rise structures when compared to MPA and Elastic Mode load patterns. None of the load patterns first can capture the precise demands and hinge positions acquired from time history analysis in the studies, but the accuracy of the findings may be fair based on the load patterns for low and mid-rise buildings. The accuracy of high-rise structures has been observed to be declining.
23) ***Bayülke et al***. [30] used a non-linear pushover analysis approach to calculate lateral force in earthquake-damaged and undamaged reinforced concrete structures. For the analytically obtained R factors, compare the limit lateral forces with the lateral load level calculated from elastic acceleration spectrums. It is concluded that buildings with symmetric shear walls in plan do not lose their lateral stiffness' in a dangerous way after the limit lateral force level, and it is added that the formation of the collapse mechanism is found to be very quick and progressive for buildings without shear walls.
24) ***Polat et al.*** [31] offered a case study on the use of linear analysis in traditional retrofitting. The linear analytic approach of evaluating seismic demands and cost needs is proven to be irrational, and the use of more realistic analysis methods is strongly suggested in such circumstances.

III. Conclusion

In view of the results obtained by the analysis of the considered building structures, following primary conclusions on the prediction of the nonlinear behavior of the models are obtained:

- The presence of soft story at the lower levels of the building structure especially at the first story level is most undesirable, as it attracts larger story force with greater story drift in comparison to fully infill frame.
- In comparison to the stiffness contribution of the top story, the masonry infill's contribution to stiffness in the lower stories—particularly the first story—is quite significant.
- Depending on the structure's story height, preparations are made for the design of soft story.
- Buildings with soft floors and bare frames are nearly equally stiff.
- Analysis shows that brittle collapse occurs in soft story buildings at relatively modest base shear and displacement through a ground story mechanism.
- The amplification factor for the impacts of seismic activity on the vertical structural components of soft story has to be reduced; the factor given depends on the story height, i.e., whether the soft story is in the lower section or higher portion.
- The structural performance of a completely infill frame is not greatly impacted by the presence of a soft story at the top level. While the bottom level's soft story has a significant impact on the structural performance.
- All building constructions are susceptible to earthquake damage, particularly those with soft story and just lateral load-resisting systems made of frames.
- The easiest way to solve this issue could be to arrange symmetrical shear walls to stiffen up the system that resists lateral loads.
- Designing the columns and beams of the soft stories in accordance with extremely high seismic demands by utilizing an amplification factor just for these stories is another approach for improving the stiffness of the lateral force resisting system.

IV. Acknowledgment

Without mentioning the people who made it possible, whose continual direction and support crowned my work with success, the happiness and exhilaration on the successful completion of any endeavor would be incomplete.
I would also like to take this opportunity to express my heartfelt gratitude to Mr. Rajiv Banerjee, Associate Professor Associate Professor in the Department of Civil Engineering at Integral University in Lucknow, who served as my dissertation advisor and gave me invaluable advice throughout the entire process as well as at key points.
I would like to thank Dr. Syed Aqeel Ahmad, Professor and Head of the Civil Engineering Department of Integral University in Lucknow, for his assistance, insightful comments, and provision of the lab resources needed for the project work.

I also want to thank the entire Civil Engineering Department at Integral University in Lucknow for providing the project with the right environment and support.

REFERENCES

[1] Murty, C. V. R. (2002) Performance of reinforced concrete frame buildings during 2001 Bhuj earthquake. Proceedings of the 7" Us National Conference on Earthquake Engineering. Boston. USA. Paper no. 745

[2] P. R. Davis (2009) Earthquake Resistant Design of Open Ground Story RC Framed Buildings. Ph.D. Thesis, Indian Institute of Technology Madras, Chennai

[3] A. Asokan, (2006) Modeling of Masonry Infill Walls for Nonlinear Static Analysis of Buildings under Seismic Loads. M. S. Thesis, Indian Institute of Technology Madras, Chennai.

[4] Hashmi, A. K. and A. Madan (2008) Damage forecast for masonry infilled.

[5] Applied Technology Council, ATC 40, Seismic Evaluation and Retrofit of Concrete Buildings, Volume 1-2, California, 1996.

[6] Freeman S.A., Mahaney J.A., Paret T.F. and Kehoe B.E., The Capacity Spectrum Method for Evaluating Structural Response during the Loma Prieta Earthquake, National Earthquake Conference, Central U.S. Earthquake Consortium, Tennesse, (501-510), 1993

[7] Fajfar, P. and Fischinger M., Nonlinear Seismic Analysis of R/C Buildings: Implications of a Case Study, European Earthquake Engineering, Vol.1, (31-43), 1987.

[8] Eberhard M.0. and Sözen M.A., Behavior-Based Method to Determine Design Shear in Earthquake Resistant Walls, Journal of the Structural Division, American Society of Civil Engineers, New York, Vol.119, No.2, (619-640), 1993.

[9] Park H. and Eom T, Direct Inelastic Earthquake Design Using Secant Stiffness, ANCER Networking of Young Earthquake Engineering Researchers and Professionals, Hawaii, 2004.

[10] Moghaddam A.S., A Pushover Procedure for Tall Buildings, 12th European Conference On Earthquake Engineering, 2002

[11] Sasaki F., Freeman S. and Paret T., Multi-Mode Pushover Procedure-A Method to Identify the Effect of Higher Modes in a Pushover Analysis Proc, 6th U.S. National Conference on Earthquake Engineering, Seattle, 1998

[12] Chopra A. and Goel R.K., Modal Pushover Analysis Procedure to Estimate Seismic Demands for Buildings: Theory and Preliminary Evaluation, The National Science Foundation: U.S-Japan Cooperative Research in Urban Earthquake Disaster Mitigation, CMS-9812531.2001

[13] Chintanapakdee C. and Chopra A.K., Evaluation of Modal Pushover Analysis Using Generic Frames, Earthquake Engineering and Structural Dynamics, Vol. 32, (417-442), 2003

[14] Chintanapakdee C. and Chopra A., Evaluation of The Modal Pushover Analysis Procedure Using Vertically Regular and Irregular Generic Frames, A Report on Research Conducted under Grant No. CMS-9812531 from the National Science Foundation, 2003.

[15] Federal Emergency Management Agency, FEMA 356, Prestandard and Commentary for the Rehabilitation of Buildings, 2000.

[16] Attard T. and Fafitis A, Modeling of Higher-Mode Effects Using an OptimalMulti-Modal Pushover Analysis, Earthquake Resistant Engineering Structures V, 2005.

[17] Chopra A. and Goel R.K., Role of Higher-"Mode" Pushover Analyses in Seismic Analysis of Buildings, Earthquake Spectra, Vol.21 No.4, (1027-1041), 2005

[18] Federal Emergency Management Agency, FEMA-273, NEHRP Guidelines For the Seismic Rehabilitation of Buildings, 1997

[19] Gupta B. and Kunnath K., Adaptive Spectra Based Pushover Procedure for Seismic Evaluation of Structures, Earthquake Spectra Vol.16, No.2, 2000

[20] Jan T.S., Liu M.W. and Kao Y.C. An Upper-Bound Pushover Analysis Procedure for Estimating the Seismic Demands of High-Rise Buildings, Engineering Structures 26 (117-128), 2004

[21] Kalkan E. and Kunnath S., Assessment of Current Nonlinear Static Procedures for Seismic Evaluation of Buildings, Engineering Structures, Vo1.29, (305-316), 2007.

[22] Kunnath K. and Kalkan E., Evaluation of Seismic Deformation Demands Using Nonlinear Procedures in Multistory Steel and Concrete Moment Frames, ISET Journal of Earthquake Technology Paper No. 445, Vol. 41, No.1, 2004.

[23] Mwafy A.M. and Elnashai A.S., Static Pushover versus Dynamic Analysis of R/C Buildings, Engineering Structures, Vol. 23, 407-424, 2001

[24] Krawinkler H. and Seneviratna K., Pros and Cons of a Pushover Analysis of Seismic Performance Evaluation, Engineering Structures, Vol.20, (452-464), 1998.

[25] Moghaddam A.S., and Hajirasouliha L An investigation on the accuracy of Pushover analysis for estimating the seismic deformation of braced steel Frames, Journal of constructional Steel Research 62 (343-351), 2006

[26] Inel M., Tjhin and Aschheim M., The Significance of Lateral Load Pattern in Pushover Analysis, Sth National Conference on Earthquake Engineering, AE-009, Turkey, 2003

[27] Korkmaz A., Sarı A. and Akbas B., An Evaluation of Pushover Analysis for Various Load Distributions, 5th National Conference on Earthquake Engineering, AE-017, Turkey, 2003.

[28] Kömür. M.A. and Elmas M., The Inelastic Static Analysis of Reinforced Concrete Plane Frame Systems wvith Different Lateral Load Shapes, 5'h National Conference on Earthquake Engineering, ATE-021, Turkey, 2003

[29] Oguz S., Evaluation of Pushover Analysis Procedures for Frame Structures, Master of Science Thesis, METU, 2005.

[30] Bayülke N., Kuran F, Dogan A., Kocaman C., Memis H. and Soyal L., Nonlinear Pushover Analysis of Reinforced Concrete Structures and Comparison with Earthquake Damage, 5th National Conference on Earthquake Engineering, AT-108, Turkey, 2003

[31] Polat Z., Kirçil M.S. and Hancioglu B. Performance Evaluation of a Conventionally Retrofitted Building by Nonlinear Static Analysis, 5''h National Conference on Earthquake Engineering, AT-087, Turkey, 2003.