WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Seismic Damage Assessment of Irregular RC Buildings with Re-Entrant Corner Plan Irregularities Using Drift-Based Criteria Through Nonlinear Dynamic Analysis: A Review

***Gaurav Chaturvedi*[1], *Prof. Hussain Hararwala*[2]**

[1]M. Tech. Scholar,[2]Asst. Professor

[1,2]Department of Civil engineering, Mahakal Institute of Technology and Management,Ujjain, India

A B S T R A C T

The damaging effects of the earthquake on the RC structures are volatile; it can be more disastrous in irregular shapes. Irregularity can be vertical as well as horizontal; The Configuration irregularities present significant challenges in the seismic design of building structures. One notable form of such irregularity is the presence of re-entrant corners, which often lead to stress concentrations and increased seismic vulnerability. Various studies and research are performed in this field. A structure is classified as irregular when there is a significant variation in the distribution of mass, stiffness, or both across its geometry. In contrast, regular structures exhibit uniformity in these parameters, resulting in more predictable and favorable seismic performance. Irregular configurations, however, tend to exhibit complex and often undesirable seismic responses due to asymmetries and discontinuities, making their dynamic behavior more difficult to anticipate and assess accurately. The main objective of this study is to propose and develop a drift-based index to estimate damage to RC buildings with plan irregularities. For this purpose, first, a time-history analysis is performed on several RC buildings with different types of re-entrant corners.

Keywords: Irregularity, RC Structures, Seismic damage analysis, Drift- based index

1. Introduction-

Earthquake is a mostly insane but unpredictable phenomenon of nature, but it adversely to the civil structure. Sometime it develops the reciprocal effect in the bending and the sway beams. In the metropolitan the largest construction is re-entrant type, most of the educational buildings construction like school and college are in irregular shape, L & C shape buildings are most susceptible for the tension cracks & collapse during the earthquake [1]. There are many factors on which the behavior of buildings depends at the time of earth quakes like strength, ductility of structure, shape of buildings. Buildings are in regular shape is much safer than the irregular shape [2].A plan discontinuity typically arises when a building's structural configuration includes a projection exceeding 15% of the total plan dimension in a given direction. One common manifestation of such discontinuity is the presence of re-entrant corners—an irregularity frequently observed in modern multi-story buildings, primarily driven by architectural preferences and aesthetic considerations [3]. The overall plan geometry plays a critical role in determining a structure's seismic resilience. Observations from past strong earthquakes have revealed that buildings with such irregular configurations tend to suffer significant structural damage, underscoring their poor performance under seismic excitation.The possibility of detriment of structure is more in unequal shape RC structures. Buildings are unsafe in the zone where the lateral load due to seismic is more due to lateral forces the fault-finding effect may be produce due to structural Irregularities, the structural irregularities having different types plan irregularities and vertical irregularities, torsion irregularities and re-entrant corners, are also the part of plan irregularities. Software likes Etabs, SAP2000 are used for model making and assessment purpose.IS 1893 (Part 1): 2016 play a most important role in this. This research aims to develop quantitative drift-based relationships for assessing structural damage in reinforced concrete (RC) frame buildings subjected to seismic loading. Utilizing nonlinear dynamic analysis, the study systematically evaluates damage induced by inter-story drift. Special emphasis is placed on irregular configurations, particularly those with re-entrant corner geometries, by incorporating irregularity indices into the formulation of drift-based damage functions. The resulting framework enhances the accuracy of seismic vulnerability assessments for geometrically irregular RC structures.

* *Corresponding author.* Tel.: +0-000-000-0000 ; fax: +0-000-000-0000.
E-mail address: author@institute.xxx

2. Objectives of The Study-

To conduct a detailed seismic performance evaluation of reinforced concrete (RC) framed buildings exhibiting plan irregularities, specifically re-entrant corners, under multiple earthquake ground motion records. The study focuses on plan irregularity due to re-entrant corners, with seven distinct earthquake time histories selected to capture a range of seismic intensities and frequency content. To perform nonlinear regression analysis on analytically derived response data, aiming to formulate a drift-based damage index equation that quantitatively estimates structural damage in RC buildings with plan irregularities.

3. Literature Review-

(Habibi & Asadi, 2017) In the presented study, two damage functions based on drift were formulated for the estimation of damage in SRCMRFs (Steel Reinforced Concrete Moment Resisting Frames). To achieve this goal, various forms Numerous asymmetrical vertical frames were created following the guidelines of the standard 2800-3rd as well as the ninth Iranian national building code. To stablish a robust foundation for the development of the proposed methodology, non-linear dynamic analyses was executed on all frame types, using a set of ten distinct earthquake records. The outcomes of these analyse was subsequently utilized to perform a nonlinear regression analysis using multiple variables. This analysis aimed to derive two effective functions, encompassing a power equation and a quadratic polynomial equation. These functions were formulated in terms of overarching drift, fundamental period, and irregularity indices of the structures. The results of this process demonstrated that both of the proposed functions had the capability to reasonably accurately predict the extent of damage in SRCMRFs.[4]

(Danesi et al., 2023) The fragility of historically significant buildings and the considerable damages brought on by earthquakes have been highlighted by recent seismic disasters. In order to remedy this, a research study evaluated several damage indices from the literature to see how well they rated structural and non-structural damage. The evaluation contained 48 actual seismic accelerations that were characterized by elements including soil conditions, magnitude, and distance from the epicentre, and it was carried out using synthetic data from a 2D reinforced concrete frame designed with Open Sees. The study took into account both local and global damage indices with the goal of identifying those suited for post-earthquake evaluations utilizing minimum equipment, such as accelerometers, for real- time damage assessment.[5]

(Chauhan & Parikh, 2023) The study investigated the problem of evaluating building damage with conventional techniques. It established a new stiffness-based damage index that took pushover analysis's tendency to accumulate lateral loads and displacements into account. A non-accumulative energy-based damage index was also created. These techniques were tested on a variety of structures with varying features, demonstrating their potential for swiftly predicting damage in low- to medium-rise structures with uneven vertical surfaces. Although both strategies worked, their levels of performance varied. Overall, the research showed how user-friendly and accurate they were, making them essential tools for structural designers who employ pushover analysis to estimate global damage in irregular buildings.[6]

(M. Mazloom, N. Fallah 2023) This paper presented a new stiffness-based damage index with simple formulation by performing pushover analysis on existing concrete models and applying the results. Using the capacity curve obtained from the pushover analysis output, this index can provide a quantitative estimate of the amount of damage to the entire structure. To validate the results, damage estimation was also performed using several reliable models such as the Park-Ang model and then compared with the proposed index results. Finally, the implemented reform proposals led to an improvement in the performance of the proposed index, resulting in excellent accuracy due to the simple computational process compared to the complex implementation of the park & Ang index.[7]

(Mohebi et al., 2019) The study introduced a novel damage index based on the relationship between the maximum inter-story drift ratio and the spectral acceleration at the first-mode period of a structure. This index ranged from 0 at the yield point to 1 at the collapse point and was computed using incremental dynamic analysis. Various steel models were used as examples to demonstrate its performance and compare it to existing damage indices. Unlike others, this new index was not affected by successive hardening and instantaneous softening and consistently increased with higher ground motion intensity. However, its correlation with comparative indices decreased with longer periods, more floors, and structural inconsistencies.[8]

(Haque et al., 2021) The researchers investigated the understanding and prediction of the behaviour of buildings, which was a prime engineering interest for improving the seismic design of building systems, especially for buildings with planar irregularities. In this study, a detailed numerical investigation was carried out to enhance the understanding of the seismic responses of buildings with planar irregularities. Four common and widely observed irregular shapes, namely C, L, I, and T shapes, were considered. Two ground excitations with different ranges of dominant frequencies were utilized to excite the irregular buildings. Both modal and time history analyses were carried out, and important dynamic features such as modal characteristics, base shear, roof displacement, roof acceleration, and band drift of the irregular buildings were predicted. Various irregularity parameters in terms of the planar geometry of the buildings were defined to identify the most appropriate parameter for representing the seismic responses of the irregular buildings. It was found that among the various irregularity parameters defined, the overall aspect ratio, i.e., the L/B ratio of buildings, was highly correlated with the seismic responses of the buildings. However, the seismic responses of the irregular buildings varied significantly from each other depending on the nature of the earthquake and planar irregularity. It was also found that I and T shapes buildings had the highest seismic responses among the considered buildings.[9]

(Ankon, 2020) The researcher investigated one of the major challenges of constructing any high-rise building for civil engineers, which was making it earthquake-resistant. This resistance largely depended on the building's shape and structural system. A comparative study was conducted in this paper about the seismic behaviour and response of buildings that had a regular plan and plan irregularity (re-entrant corners). The five building models considered in this study were 15 stories each, had the same area, and were of identical weight. Among the five building models, two had a regular plan (square, rectangle), and the other three building models had plan irregularity (re-entrant corners). All of them were modelled using the ETABS 2015 program for Dhaka, Bangladesh (seismic zone 2). Static loads, wind loads, and seismic loads were considered for each model, and dynamic response under the Bangladesh National Building Code (BNBC) 2006 response spectrum was meticulously analysed. A comparison for story displacement, base shear, story drift, and time period was established and explored for dynamic response spectrum among the models. The results showed that buildings with irregularity had a greater value of time period, drift, and displacement and were thereby more susceptible to damage during an earthquake or disaster.[10]

(Naveen et al., 2019) This study investigated the impact of structural irregularities on multi- storey buildings during strong earthquakes. Irregular configurations, common in seismic zones, posed significant risks. The research considered various irregularities in both plan and elevation on a nine-storey regular frame, creating 54 different configurations. Seismic loads were applied, and it was found that irregularities had a substantial influence on seismic response. Stiffness irregularity had the most significant impact among single irregularities, while configurations with mass, stiffness, and vertical geometric irregularities exhibited the highest response in combinations. These findings provided valuable insights for designing irregular structures without compromising their performance.[11]

(Nader Amarloo, Ali R. Emami 2018) the study proposes a new approach to address these challenges by presenting a 3-dimensional perspective for drift, ductility and damage indices.4-, 8- and 12-storey reinforced concrete moment-frame structures with a typical L- shaped plan are employed in multi-direction pushover and nonlinear response history analyses, using 60 record component pairs of near-field and far-field earthquakes. Based on nonlinear regression analysis, derived for the critical responses polarized on non-principal directions at each storey level. A substantial increase (20%-to-60%) in the responses is observed; it depends on seismic orientation scheme, vertical distribution and planar direction of interest, and response definition.[12]

(Ercan Işık, Mesut Özdemir, İbrahim Baran Karaşin 2018) This study examined the state of irregularity by the A3 plan in the Turkish Building Earthquake Regulation of 2016. Four different A3-type irregularity cases were considered. The five steel structures were compared by obtaining pushover curves for both the X and Y directions. The Canada Seismic Screening Method was used in the study. Both in the rapid assessment method and from the pushover curves, the study also allows a comparison among the earthquake performances of the structures using the rapid assessment method. If one has to construct such structures, the defence mechanism of the structure should be strengthened by taking various measures.[13]

(J. Cici Jennifer Raj and M. Vinod Kumar 2021) In this study, scrap tire rubber pads (STRP) made from used automobile tires were assessed as seismic shock absorbers, showing their effectiveness in low-rise buildings even in high seismic risk areas and their affordability for developing nations. The research analysed four-story regular buildings and irregularly shaped structures (H shape, square core type, and plus type) using SAP 2000 software and Nonlinear Modal Time History Analysis. STRPs were designed following UBC-97 principles for Indian conditions, ensuring compatibility with IS:1893–2016 standards for various soil conditions. The analysis revealed that regular-shaped buildings exhibited superior dynamic behaviour when utilizing STRPs as base isolators compared to irregularly shaped structures, particularly in terms of base shear and acceleration reduction, although the energy absorption capacity varied among building types.[14]

(Anurag Sharma, R. K. Tripathi, Govardhan Bhat 2021) This paper investigates the DDBD methodology for G + 3 storied RC buildings, having different structural configurations by varying bays in the longitudinal and transverse directions, but having the same total plan area. The selected case-study RC buildings are analysed via non-linear time history analysis considering seismicity of zone-V of Indian regions. A suite of different spectrum compatible ground motions is used. The seismic behaviour has been analysed in terms of base-shear ratio, ductility demand, displacement profiles and drift ratios. The results illustrate that the DDBD procedure proves to be useful in designing RC buildings situated in seismic regions of India and are competent enough to withstand lateral forces due to seismic excitations.[15]

4. Conclusion-

The reviewed literature underscores the heightened seismic vulnerability of reinforced concrete (RC) buildings with re-entrant corner plan irregularities, primarily due to stress concentrations, torsional effects, and uneven lateral force distribution. Numerous studies have demonstrated that such irregular configurations exhibit amplified inter-storey drifts and localized damage under seismic excitation, often leading to premature structural failure.Drift-based damage indices have emerged as a reliable metric for quantifying seismic damage, offering a direct correlation between structural deformation and performance degradation. Nonlinear dynamic analysis, employed across various investigations, has proven effective in capturing the complex response of irregular RC frames, especially under real earthquake ground motions.Despite advancements, existing seismic design codes often fall short in addressing the nuanced behavior of irregular structures. The literature advocates for enhanced modeling techniques, incorporation of irregularity indices, and development of empirical damage functions tailored to plan irregularities. Collectively, these insights pave the way for more resilient design strategies and informed retrofitting practices for irregular RC buildings in seismic-prone regions.

References

1. Divyashree, M. and Siddappa, G., 2014. Seismic behavior of RC buildings with re-entrant corners and strengthening. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 3, pp.63-69.
2. Dhanyashree, A.S., Akash, R., Ashok, M., Premsai, S.R. and Bhavyashree, B.N., 2019. To Study the Effect of Re-entrant Corner RC Framed Building under Seismic
3. Farhan, M.A. and Bommisetty, J., 2019. Seismic analysis of multistoried RCC buildings regular and irregular in plan. International Journal of Engineering Research & Technology (IJERT), 8(11).
4. . Habibi, A. and Asadi, K., 2017. Development of drift-based damage index for reinforced concrete moment resisting frames with setback. International Journal of Civil Engineering, 15(4), pp.487-498.
5. Danesi, L., Castelli, S., Bosio, M., Rota, L., Marini, A., Riva, P. and Belleri, A., 2023. Damage identification after seismic events through damage indexes. Procedia Structural Integrity, 44, pp.838-845.

6. CHAUHAN, H.M. and Parikh, K.B., 2023. Damage estimation of low to medium rise reinforced concrete buildings considering vertical irregularity. Journal of Materials and Engineering Structures «JMES», 10(1), pp.51-68.
7. Mazloom, M. and Fallah, N., 2023. Seismic Vulnerability Assessment of Existing RC Moment Frames using a New Stiffness Based Damage Index. International Journal of Engineering, Transactions B: Applications, 36(5), pp.1000-11.
8. Mohebi, B., 2019. A new damage index for steel MRFs based on incremental dynamic analysis. Journal of Constructional Steel Research, 156, pp.137-154.
9. Haque, M.N., Zisan, M.B., Kibria, M.G. and Dey, A.K., 2021. Influence of planar irregularities on seismic responses of RC building. Asian Journal of Civil Engineering, 22(5), pp.995-1009
10. Ankon, S.B., 2020. A comparative study of behavior of multi-storied regular and irregular buildings under static and dynamic loading. Open Journal of Civil Engineering, 10(04), p.337.
11. Abraham, N.M. and SD, A.K., 2019. Analysis of irregular structures under earthquake loads. Procedia Structural Integrity, 14, pp.806-819.
12. Amarloo, N. and Emami, A.R., 2019. A 3-dimensional perspective for inter-storey drift, ductility and damage distributions in plan-irregular RC buildings considering seismic orientation effect. Bulletin of Earthquake Engineering, 17(6), pp.3447-3474.
13. Işık, E., Özdemir, M. and Karaşin, İ.B., 2018. Performance analysis of steel structures with A3 irregularities. International Journal of Steel Structures, 18(3), pp.1083-1094.
14. Cici Jennifer Raj, J. and Vinod Kumar, M., 2022. Nonlinear Modal Time History Analysis on RC framed buildings with scrap tyre as the base isolator for Past Indian earthquakes. Journal of Building Pathology and Rehabilitation, 7(1), p.24.
15. Sharma, A., Tripathi, R.K. and Bhat, G., 2021. Applicability of DDBD approach on low-rise RC buildings situated in Indian seismic regions. Architecture, Structures and Construction, 1(2), pp.193-205.

.