Momentum Int. J. Civ. Eng, Vol 2, No 1, January 2026
e-ISSN: 3090-6571

Comparative Seismic Analysis of Fixed and Isolated Base RC Bare Frames with Plan Irregularity under Equivalent Static Loads

Crimsan Singh Negi[1*], Dhiraj Pant[2]
[1]School of Engineering, Far Western University, Nepal, negicrimsan@gmail.com
[2]School of Engineering, Far Western University, Nepal pantdhiraj08@gmail.com
[*]Corresponding author, e-mail: negicrimsan@gmail.com

Abstract— This study presents a comparative evaluation of the seismic response of mid-rise (G+4) reinforced concrete (RC) bare frame structures featuring plan irregularities, specifically L, I, and T-shaped configurations under fixed base and base-isolated conditions. These irregularities, typical in public buildings, lead to asymmetrical mass and stiffness distributions, affecting seismic performance. Six models were developed and analyzed using the Equivalent Static Method (ESM), with key parameters including base shear, storey drift, top-storey displacement, and fundamental time period. The results show that base isolation using rubber bearings effectively reduces base shear by 15-18%, although it increases overall system flexibility. Isolated models exhibited 44-45% higher top-storey displacements and 108-115% greater storey drifts compared to fixed-base counterparts. The fundamental time period also increased by approximately 40%, indicating enhanced energy dissipation and reduced structural stiffness. Among the plan configurations, I-shaped models experienced the highest base shear, while T-shaped structures performed best in terms of seismic efficiency. Despite excluding masonry infill and soil-structure interaction, the findings highlight the potential of base isolation to significantly enhance the seismic resilience of irregular RC buildings. The study recommends integrating base isolation in the design of geometrically irregular public buildings, particularly in high seismic zones, to improve safety and performance under earthquake loading.

***Keywords**: Plan irregularities, ESM, Rubber isolators, RC bare frames, Seismic resilience.*

1. Introduction

Reinforced concrete (RC) moment-resisting frames are among the most commonly used structural systems in building construction due to their cost-effectiveness, durability, and ability to withstand both gravity and lateral loads [1], [2], [3]. Their widespread application in residential, commercial, and public infrastructure stems from their structural efficiency and adaptability to various architectural layouts [4], [5], [6]. However, when these frames incorporate plan irregularities—such as L, T, I, or U-shaped configurations—their seismic performance becomes significantly more complex and potentially vulnerable [7], [8], [9], [10]. Such irregularities disrupt the uniform distribution of mass and stiffness, leading to torsional imbalances, localized stress concentrations, and an overall reduction in earthquake resistance [11], [12], [13]. In high-seismic regions like Nepal, where earthquakes pose a moderate to severe threat (as classified in NBC 105:2020) [14], the design of irregular RC structures demands meticulous attention to ensure safety and resilience [9], [15]. These irregularities disrupt the natural load path, causing torsional moments, differential displacements, and increased storey drifts under seismic

Received: 4 July 2025, Revised: 7 January 2026, Accepted for publication: 14 January 2026
https://doi.org/10.64123/mijce.v2.i1.3

excitation [12], [13], [15], [16]. Unlike regular rectangular buildings, which distribute seismic forces uniformly, irregular structures experience twisting (torsion) due to the eccentricity between the center of mass and the center of rigidity. This phenomenon amplifies damage in certain structural elements, particularly at re-entrant corners or abrupt geometric discontinuities [17], [18], [19]. Consequently, buildings with plan irregularities often exhibit higher vulnerability to collapse during strong earthquakes unless properly addressed in design [15], [20], [21], [22].

To enhance the earthquake resistance of irregular structures, engineers employ various techniques, including base isolation systems, which decouple the building from ground motion using elastomeric or sliding bearings to reduce seismic forces [23], [24], [25] . Tuned Mass Dampers (TMDs) and energy dissipation devices (e.g., viscous dampers, buckling-restrained braces) are integrated to absorb and dissipate seismic energy, minimizing structural damage [15], [26], [27], [28], [29]. Shear walls and bracing systems are strategically placed to improve torsional stiffness and redistribute lateral forces more evenly. Seismic retrofitting of existing irregular buildings often involves adding steel frames, fiber-reinforced polymers (FRP), or concrete jacketing to strengthen weak elements [28], [30], [31], [32]. Additionally, advanced structural analysis methods, such as nonlinear dynamic analysis, help optimize designs by accounting for irregular geometry and material behavior under seismic loads [33], [34]. These methods collectively improve performance by mitigating torsional effects, reducing displacements, and preventing collapse during earthquakes [35], [36], [37], [38]. Base isolation is an advanced seismic protection technique that decouples a structure from ground motion by introducing flexible bearings at the foundation level, significantly reducing earthquake-induced forces [39]. These isolators, typically made of layered rubber and steel (laminated rubber bearings) or sliding mechanisms, absorb and dissipate seismic energy, preventing it from fully transferring to the superstructure [40]. By elongating the building's natural period, base isolation shifts its response away from the dominant frequencies of earthquake shaking, thereby minimizing resonance effects. Base isolation is particularly beneficial for critical infrastructure, irregularly shaped buildings prone to torsional effects, and structures in high-seismic zones, offering a cost-effective solution for both new constructions and retrofits [41].

Existing studies have extensively investigated the seismic behavior of regular reinforced concrete (RC) structures with base isolation, demonstrating its effectiveness in reducing base shear and improving energy dissipation [39], [42]. However, research on irregular-plan buildings—particularly L, T, and I-shaped configurations—remains limited, despite their prevalence in urban architecture and heightened vulnerability to torsional forces during earthquakes. Prior work has highlighted challenges such as uneven mass distribution and stress concentrations in irregular frames but lacks comprehensive comparisons of isolation efficacy across different geometric layouts under simplified analysis methods. This study addresses these gaps by employing the Equivalent Static Method (ESM)—a practical approach for regions with limited computational resources—to systematically evaluate the seismic performance of bare RC frames (excluding infill walls) with plan irregularities under both fixed-base and base-isolated conditions. The Equivalent Static Method (ESM), though simplified, remains an accepted and practical approach for seismic analysis of regular and irregular buildings, especially when nonlinear dynamic methods are not feasible [43]. This study applies ESM to evaluate and compare the seismic performance of plan irregular RC bare frames with fixed base and isolated base conditions, focusing on displacements, base shear, storey drifts and time period. By doing so, it aims to provide meaningful insight into the applicability and benefits of base isolation for irregular buildings under simplified seismic loading assumptions.

2. Method

The research focused on assessing the seismic behavior of plan irregular reinforced concrete (RC) buildings under both fixed base and base-isolated scenarios using the Equivalent Static Method (ESM). Three distinct geometrically irregular shapes—L-shaped, I-shaped, and T-shaped—were modeled as ground plus four (G+4) structures with consistent material properties, floor heights of 3.5 meters, and bay dimensions of 5 meters by 4 meters. Important structural components consisted of columns measuring 400 mm by 400 mm, beams of 300 mm by 300 mm, and slabs that are 150 mm thick. Two different base conditions were examined: fixed base (FB) and base-isolated (BI) utilizing rubber isolators with a linear stiffness of 800 kN/m and a vertical stiffness of $15*10^6$ kN/m. The results derived from the ESM—base shear, storey drift, top displacement, and time period—were analyzed to evaluate the effectiveness of the isolation. The analysis incorporated both gravity and seismic loads to assess the structural behavior. Gravity loads comprised exterior wall loads (16.1 kN/m), interior wall loads (8.75 kN/m), parapet loads (3 kN/m), and live loads (5 kN/m^2). For the seismic evaluation, the parameters adhered to Nepal's NBC 105:2020 code, utilizing an equivalent static load of 0.936 kN/m^2. Crucial seismic factors consisted of a zone factor (Z) of 0.30 for areas with moderate-to-high seismic activity, an importance factor (I) of 1.5 designated for public structures, a response reduction factor (R) of 5 for reinforced concrete moment frames, and a damping ratio of 5%. The structures were examined on stiff soil (Type D). These loading conditions and parameters facilitated a comparison between fixed-base and isolated systems against standardized seismic demands [40], [42], [44].

Table 1. Section properties

S.N.	Description	Dimensions
1	No. of Floors	G+4
2	Height of each floor	3.5 m
3	Size of the bay considered	5 m* 4 m
4	Size of the column	400 mm *400 mm
5	Size of the beams	300 mm *300 mm
6	Thickness of the slabs	150 mm
7	Thickness of outer wall	230 mm
8	Thickness of partition wall	150 mm
9	Height of parapet wall	1.2 m
10	Thickness of parapet wall	150 mm

Table 2. Base isolator link properties

S. N.	Name of the Property	Value
1	Linear Effective Stiffness U2	800 kN/m
2	Non-linear Effective Stiffness U2&U3	250 kN/m
3	Linear Effective Stiffness U3	$15*10^6$ kN/m

Table 3. Material Properties

S.N.	Description	Size
1	Grade of concrete	M25
2	Grade of steel	Fe415
3	Density of concrete	25 kN/m^3
4	Density of bricks	20 kN/m^3

Table 4. Seismic factors

S. N.	Description	Value
1	Importance factor (I)	1.5
2	Response reduction factor (R)	5
3	Zone factor (Z)	0.30
4	Soil type	D (Stiff soil)
5	Damping	5 %
6	EQ load applied	0.936 kN/m2

Table 5. Loading details

S. N.	Description	Values
1	Wall load on exterior walls	16.1 kN/m

S. N.	Description	Values
2	Wall load on interior walls	8.75kN/m
3	Parapet wall load	3 kN/m
4	Live load	1.5 kN/m2

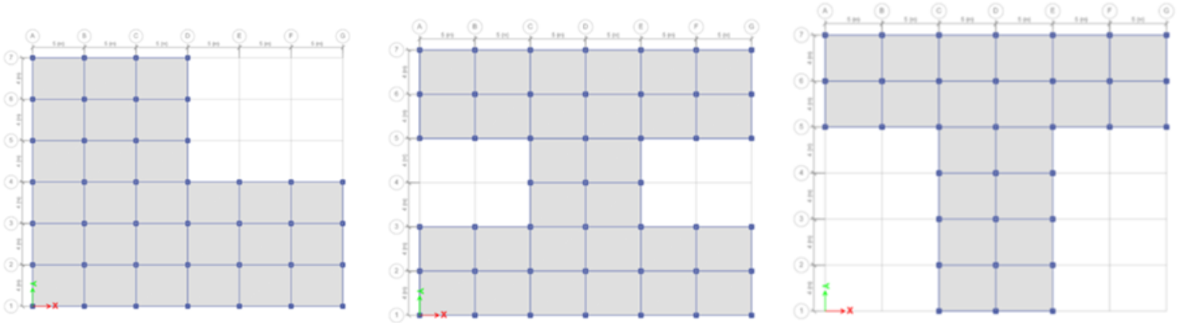

Figure 1. Plan Views of L, I & T-Shaped Building Models

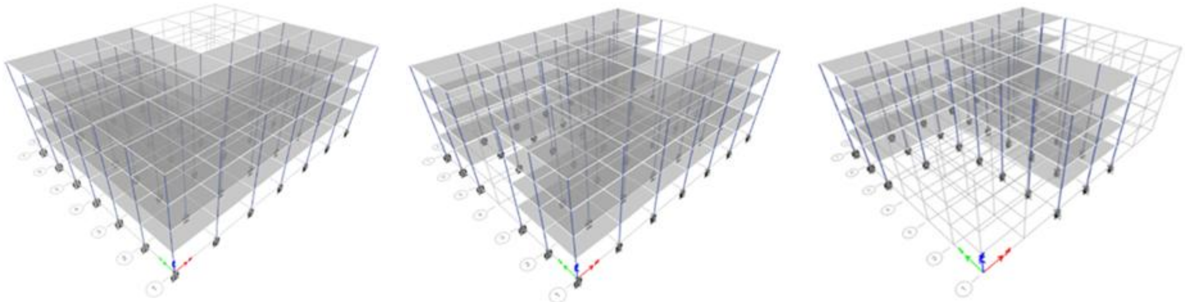

Figure 2. Isometric Views of L, I & T-Shaped Building Models

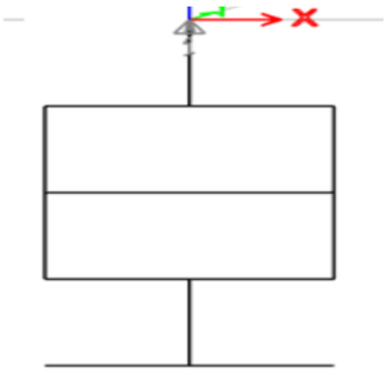

Figure 3. Rubber Base Isolator

3. Result and Discussion

3.1. Base Shear

Base shear represents the total lateral earthquake force acting at a structure's foundation level, serving as a critical measure of seismic demand [11]. This force develops when ground motions induce inertial forces throughout the building, with its magnitude depending on the structure's mass, stiffness, height, and seismic zone characteristics [45]. Excessive base shear can lead to structural damage or collapse, making its reduction a key objective in earthquake-resistant design. The study's comparative analysis reveals significant variations across different building configurations: fixed-base models exhibited the highest base shear values (4454 kN for L-shaped, 4711 kN for I-shaped, and 3401 kN for T-shaped), demonstrating how geometric irregularities amplify seismic forces. Notably, base isolation consistently reduced these demands by 15-18% across all configurations (3748 kN for L-shaped, 3954 kN for I-shaped, and 2777 kN for T-shaped) as shown in the figure 4. The I-shaped building showed the greatest seismic vulnerability with the highest base shear in both fixed and isolated conditions, while the T-shaped configuration demonstrated the most favorable performance. These findings underscore how both structural geometry and isolation systems fundamentally influence a building's seismic force distribution, with base isolation proving particularly effective for irregular structures in high-risk zones [25].

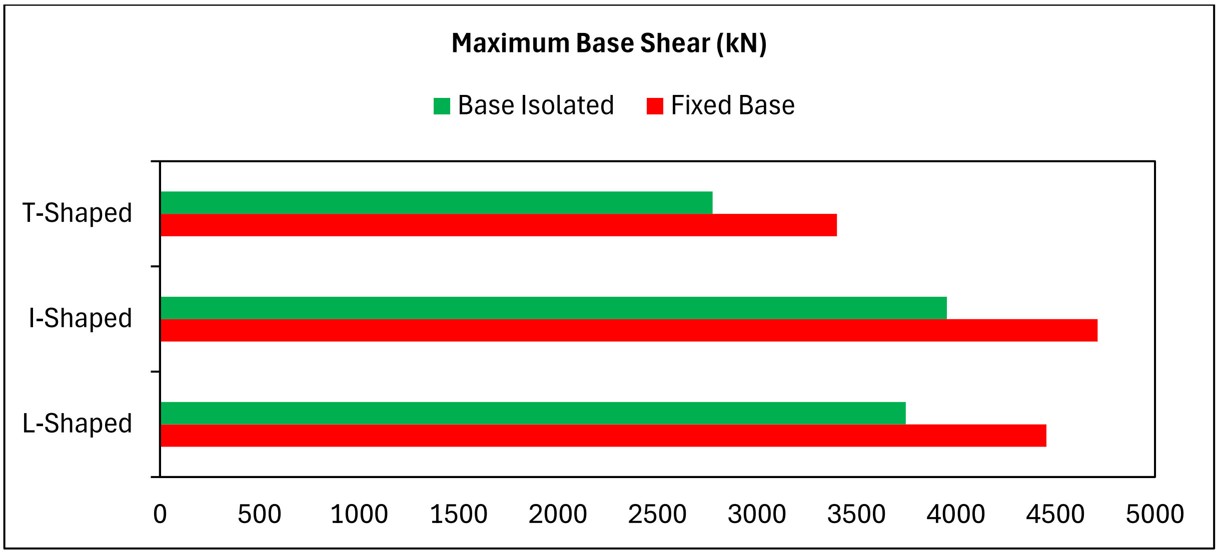

Figure 4. Base Shear Comparison

3.2. Maximum Story Drift

Maximum story displacement measures the peak lateral movement of any floor level relative to the ground, serving as a crucial indicator of a building's seismic performance [10], [46]. Excessive displacements can lead to structural damage and non-structural component failures, making this parameter vital for earthquake-resistant design. The study's results reveal distinct patterns: fixed-base models showed relatively consistent displacements across configurations (0.0061 for L-shaped, 0.0059 for I-shaped, and 0.0060 for T-shaped), while base-isolated models exhibited 44-45% greater displacements (0.0131 for L-shaped, 0.0125 for I-shaped, and 0.0124 for T-shaped). Notably, the isolation system shifted the location of maximum displacement from the second story in fixed-base buildings to the first story in isolated structures. This increased flexibility, while potentially concerning for serviceability, demonstrates the isolation system's effectiveness in redistributing seismic energy. The T-shaped configuration again showed the best performance with the lowest displacements in both conditions, reinforcing the influence of geometric regularity on seismic response. These displacement characteristics provide critical insights for designing isolation systems that balance safety with acceptable deformation limits.

3.3. Maximum Top Story Displacement

Maximum story drift, defined as the greatest relative lateral displacement between adjacent floors during seismic loading, serves as a critical parameter for assessing structural integrity and potential damage [10]. This measure directly relates to building safety, as excessive interstorey drift can lead to non-structural damage, structural yielding, and even collapse. The comparative analysis reveals significant differences between fixed-base and base-isolated systems as represented by the figure 5 below: fixed-base models demonstrated drift values of 64.7mm (L-shaped), 62.4mm (I-shaped), and 63.5mm (T-shaped), while base-isolated counterparts showed substantially higher drifts of 93.9mm (L-shaped), 90.0mm (I-shaped), and 91.7mm (T-shaped) - representing a 108-115% increase. This dramatic rise in drift values for isolated structures, while potentially concerning for serviceability limits, reflects the intentional flexibility of the isolation system that effectively reduces floor accelerations and base shear. The consistent pattern across all configurations (with I-shaped buildings showing the highest drift sensitivity and T-shaped the lowest) underscores how base isolation fundamentally alters structural response characteristics. These findings emphasize the need for careful consideration of drift limits when implementing base isolation systems, particularly for irregular structures where torsional effects may exacerbate localized drift demands.

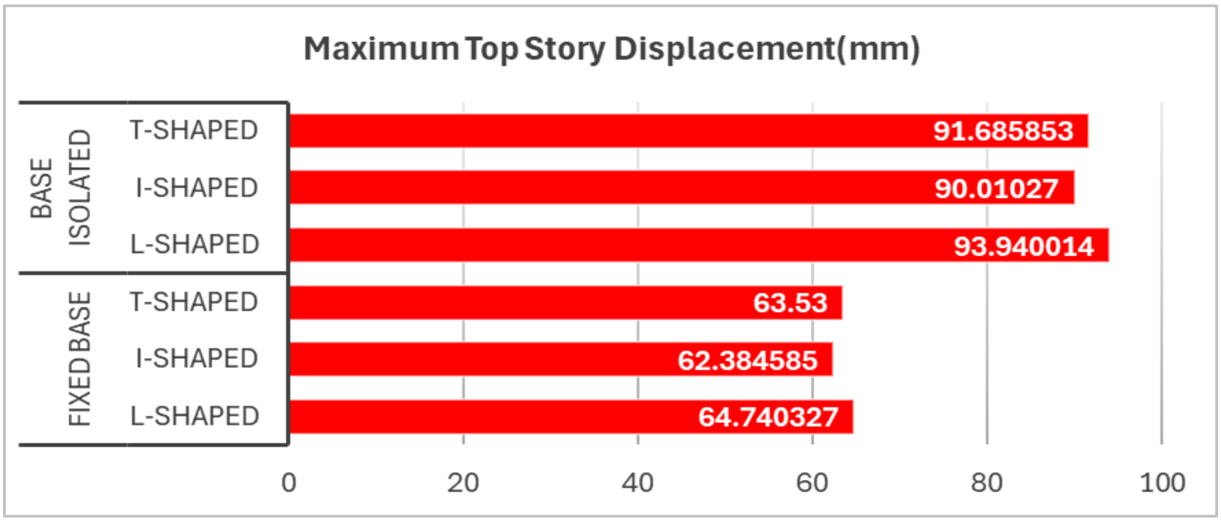

Figure 5. Maximum Top Storey Displacement

3.4. Time Period and Frequency

The time period and natural frequency are fundamental dynamic properties used to assess and compare the seismic response of different structural models under varying base conditions [10], [18]. A longer time period corresponds to a lower natural frequency, indicating greater structural flexibility. Figure 6 below presents the time periods (in seconds) and their corresponding frequencies (in Hz) for all 6 models analyzed clearly demonstrating that models with base isolation exhibit higher time periods and thus lower frequencies compared to those with fixed bases, highlighting the effectiveness of isolation in reducing dynamic stiffness and enhancing seismic performance.

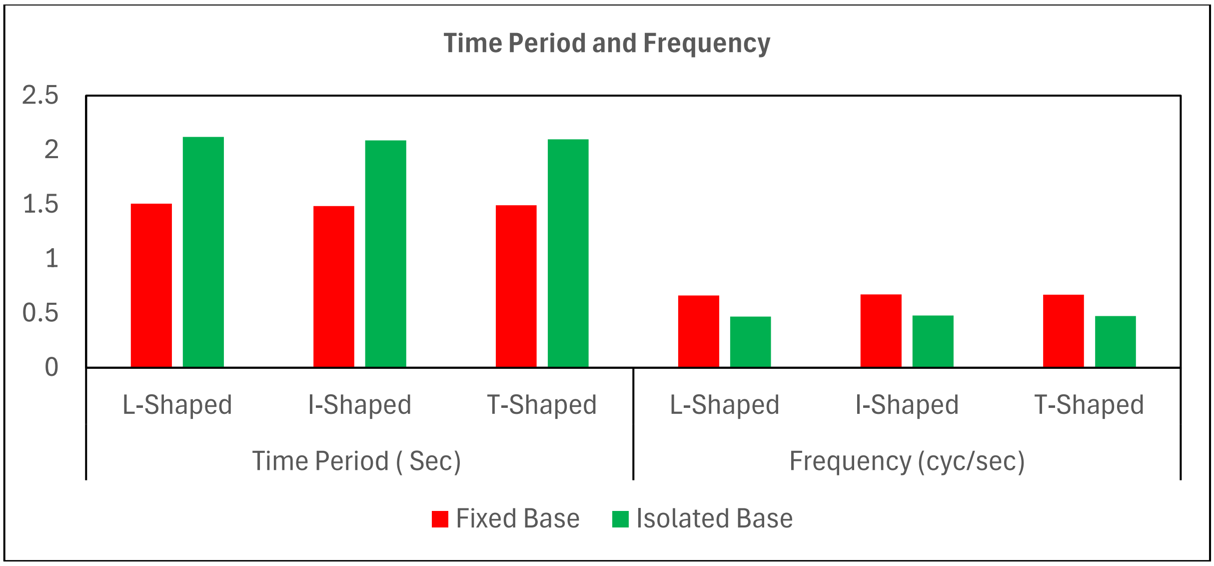

Figure 6: Time period and natural frequencies

4. Conclusion

The study demonstrates that base isolation significantly enhances the seismic performance of irregular RC buildings, offering both advantages and design considerations. Key findings reveal that rubber isolators effectively reduce seismic demand, decreasing base shear by 15–18% across all irregular configurations (L, T, and I-shaped) by decoupling the superstructure from ground motions. However, this reduction comes with trade-offs: isolated structures exhibit greater flexibility, with 44–45% higher top-story displacements and 108–115% increased inter-story drifts compared to fixed-base systems. The extended fundamental time period (approximately 1.4 times longer) confirms improved energy dissipation but requires careful consideration of displacement limits in design.

Configuration significantly influences seismic response, with I-shaped buildings experiencing the highest base shear demands, while T-shaped structures demonstrate superior performance. These results highlight the critical role of geometric regularity in seismic resilience.

While the study validates base isolation as an effective strategy for irregular buildings, certain limitations—such as excluded masonry infill effects and soil-structure interaction—suggest the need for more comprehensive modeling in future research. Nevertheless, the findings strongly support adopting base isolation for critical infrastructure in high-risk seismic regions like Nepal, where it can substantially improve structural safety without compromising architectural functionality. The research provides valuable benchmarks for engineers designing irregular buildings in earthquake-prone areas, emphasizing that proper isolation system design must balance force reduction with controlled displacement management.

References

[1] A. Massumi, “Experimental Study on Behavior of RC Frames Strengthened by Steel Bracings (Under Lateral Loads). M.Sc. Thesis, Structural Eng., Tarbiat Modares University, Tehran, Iran.,” 1997.

[2] D. Gautam and H. Chaulagain, “Structural performance and associated lessons to be learned from world earthquakes in Nepal after 25 April 2015 (MW 7.8) Gorkha earthquake,” Eng Fail Anal, vol. 68, pp. 222–243, 2016, doi: 10.1016/j.engfailanal.2016.06.002.

[3] H. Chaulagain, H. Rodrigues, E. Spacone, and H. Varum, “Seismic response of current RC buildings in Kathmandu valley,” Structural Engineering and Mechanics, vol. 53, no. 4, pp. 791–818, 2015, doi: 10.12989/sem.2015.53.4.791.

[4] B. J. Mary, “Machine Learning for Sustainable Architectural Design,” 2025. [Online]. Available: https://www.researchgate.net/publication/387668574

[5] S. Al-Safi, I. A. Alameri, R. A. M. Badhib, and M. Kuleib, “Evaluation of performance-based earthquake engineering in Yemen,” Challenge Journal of Structural Mechanics, vol. 6, 2020, doi: 10.20528/cjsmec.2020.01.002.

[6] Specification for structural steel buildings. Chicago: American Institute of Steel Construction (AISC), 2016.

[7] R. Bhasker and A. Menon, “Characterization of ground motion intensity for the seismic fragility assessment of plan-irregular RC buildings,” Structures, vol. 27, no. August, pp. 1763–1776, 2020, doi: 10.1016/j.istruc.2020.08.019.

[8] R. G. Herrera and C. G. Soberón, “Influence of Plan Irregularity of Buildings,” Proceedings of 14th World Conference on Earthquake Engineering, no. 1982, 2008.

[9] A. T. Jereen, S. Anand, and B. M. Issac, “Seismic evaluation of buildings with plan irregularity,” in Applied Mechanics and Materials, Trans Tech Publ, 2017, pp. 225–230.

[10] B. K. Bohara, K. H. Ganaie, and P. Saha, “Effect of position of steel bracing in L-shape reinforced concrete buildings under lateral loading,” Research on Engineering Structures and Materials, vol. 8, no. 1, pp. 155–177, 2022, doi: 10.17515/resm2021.295st0519.

[11] B. Khanal and H. Chaulagain, “Seismic elastic performance of L-shaped building frames through plan irregularities,” Structures, vol. 27, no. January, pp. 22–36, 2020, doi: 10.1016/j.istruc.2020.05.017.

[12] M. M. M. Ahmed, S. E. Abdel Raheem, M. M. Ahmed, and A. G. A. Abdel Shafy, “Irregularity Effects on the Seismic Performance of L-Shaped Multi-Story Buildings,” JES. Journal of Engineering Sciences, vol. 44, no. 5, pp. 513–536, 2016, doi: 10.21608/jesaun.2016.111440.

[13] S. E. Abdel Raheem, M. M. M. Ahmed, M. M. Ahmed, and A. G. A. Abdel-shafy, “Evaluation of plan configuration irregularity effects on seismic response demands of L-shaped MRF buildings,” Bulletin of Earthquake Engineering, vol. 16, no. 9, pp. 3845–3869, 2018, doi: 10.1007/s10518-018-0319-7.

[14] NBC 105: 2077, “SEISMIC DESIGN OF BUILDINGS IN NEPAL.”

[15] B. K. Bohara, D. B. Kunwar, and B. Kunwar, “Torsional Irregularity Control in Irregular Plan RC Buildings through Optimized Shear Wall Placement: A Parametric Study,” Momentum International Journal of Civil Engineering (MIJCE), vol. 1, no. 2, pp. 32–43, Jul. 2025, doi: 10.64123/mijce.v1.i2.1.

[16] M. Haque, “Seismic Performance Analysis of RCC Multi-Storied Buildings with Plan Irregularity,” American Journal of Civil Engineering, vol. 4, no. 3, p. 68, 2016, doi: 10.11648/j.ajce.20160403.11.

[17] B. K. Bohara, “Study of Common Construction Practices and Structural Defects in RC Buildings in Darchula District Far-Western Nepal,” Far Western Review, vol. 1, no. 2, pp. 117–137, Dec. 2023, doi: 10.3126/fwr.v1i2.62137.

[18] B. K. Bohara, “Seismic Response of Hill Side Step-back RC Framed Buildings with Shear Wall and Bracing System,” International Journal of Structural and Construction Engineering, vol. 15, no. 4, pp. 204–210, 2021.

[19] Birendra Kumar Bohara, “Nonlinear Behavior of Moment Resisting Reinforced Concrete with Steel Braced Frame under Lateral Loading,” Mtech in Sharda University, 2021.

[20] S. Paudel, T. Ii. M. Ilham Maulana, and H. Prayuda, “Seismic Vulnerability Assessment of Regular and Vertically Irregular Residential Buildings in Nepal,” Journal of the Civil Engineering Forum, pp. 199–208, Apr. 2024, doi: 10.22146/jcef.10316.

[21] S. Monish and S. Karuna, “A study on seismic performance of high rise irregular RC framed buildings,” International Journal of Research in Engineering and Technology (IJRET), vol. 4, no. 5, pp. 340–346, 2015.

[22] G. Özmen, S. Pala, G. Gülay, and E. Orakdöğen, “Effect of structural irregularities to earthquake analysis of multi-story structures,” Turkey Earthquake Foundation, Technical Report, pp. 27–28, 1998.

[23] S. Rehni, Masrilayanti, K. Ruddy, A. A. Luthfi, and S. Sourkan, “Seismic vulnerability analysis of irregular and regular structures using fragility curve,” in E3S Web of Conferences, EDP Sciences, Jan. 2025. doi: 10.1051/e3sconf/202560412005.

[24] L. A. Flores and R. M. Delgadillo, “The Evaluation of the Seismic Performance of Unsymmetric-Plan Tall Buildings Using Modal Spectral Time History and Multi-Mode Pushover Analysis †,” Engineering Proceedings, vol. 83, no. 1, 2025, doi: 10.3390/engproc2025083006.

[25] Y. W. Abduljaleel, A. S. Ali, F. Usman, A. Syamsir, and B. M. Albaker, “Evaluation the Seismic Behavior of Irregular Moment Resisting Steel Frame with Combination System of Base Isolator and Friction Damper,” Annales de Chimie: Science des Materiaux, vol. 49, no. 2, pp. 121–132, Apr. 2025, doi: 10.18280/acsm.490202.

[26] B. K. Bohara, K. H. Ganaie, and P. Saha, “Seismic Analysis of Retrofitting of RC Regular Frame with V-Braced Frame,” Journal of Engineering Technology and Planning, vol. 2, no. 1, pp. 55–63, 2021, doi: 10.3126/joetp.v2i1.39229.

[27] K. H. Ganaie, B. K. Bohara, and P. Saha, “EFFECTS OF INVERTED V BRACING IN FOUR-STORY IRREGULAR RC,” International Research Journal of Modernization in Engineering Technology and Science, vol. 03, no. 04, pp. 2346–2351, 2021, [Online]. Available: www.irjmets.com

[28] B. K. Bohara, N. M. Joshi, and S. Jagari, “Impact of inadequate column performance and repair techniques on the seismic performance of RC buildings,” Discover Civil Engineering, vol. 2, no. 1, p. 94, May 2025, doi: 10.1007/s44290-025-00253-5.

[29] B. K. Bohara, “Steel Brace Connection with Reinforced Concrete Frame Structure: A Review,” Momentum International Journal of Civil Engineering (MIJCE), vol. 1, no. 2, pp. 72–82, Jul. 2025, doi: 10.64123/mijce.v1.i2.5.

[30] B. K. Bohara, “Ductility, R, and Overstrength Factors for V Braced Reinforced Concrete Buildings,” International Journal of Structural and Construction Engineering, vol. 16, no. 3, pp. 101–105, 2022.

[31] V. Semko and D. Prokhorenko, "Effect of bracing systems on overall stability and deformability of cold-formed steel roofing structures," in Design, fabrication and economy of metal structures, K. Jármai and J. Farkas, Eds., Berlin: Springer, 2013. doi: 10.1007/978-3-642-36691-8_35.

[32] L. Zeng, W. Zhang, and Y. Ding, "Representative strain-based fatigue and fracture evaluation of I-shaped steel bracing members using the fiber model," J Constr Steel Res, vol. 160, 2019, doi: 10.1016/j.jcsr.2019.05.051.

[33] P. Fajfar, H.Krawinkler., Nonlinear Seismic Analysis and. 2005.

[34] R. Sharma, A. K. Dwivedi, V. Rani, and B. Rc, "Seismic Evaluation of Step-Back Building and Regular Building by Using Nonlinear Static and Nonlinear Dynamic Analysis," in IOP Conference Series: Earth and Environmental Science, Institute of Physics, 2024. doi: 10.1088/1755-1315/1326/1/012040.

[35] T. P. Prajwal, I. A. Parvez, and K. Kamath, "Nonlinear Analysis of Irregular Buildings Considering the Direction of Seismic Waves," Mater Today Proc, vol. 4, no. 9, pp. 9828–9832, 2017, doi: 10.1016/j.matpr.2017.06.275.

[36] C. Kolay, A. Prashant, and S. K. Jain, "Nonlinear dynamic analysis and seismic coefficient for abutments and retaining walls," Earthquake Spectra, vol. 29, 2013.

[37] Fema, "Improvement of Nonlinear Static Seismic Analysis Procedures FEMA 440 FEMA nehrp," 2005.

[38] F. Nateghi-A and A. Rezaei-Tabrizi, "Nonlinear dynamic response of tall buildings considering structure-soil-structure effects," Structural Design of Tall and Special Buildings, vol. 22, 2013.

[39] R. C. Bush, A. I. Shirkol, and J. S. Sruthi, "Comparative Analysis of Base Isolation and Fixed Base Irregular Structures," in Lecture Notes in Civil Engineering, Springer Science and Business Media Deutschland GmbH, 2023, pp. 501–515. doi: 10.1007/978-981-99-1608-5_36.

[40] K. K. Prakash, J. Mahalakshmi, and D. Rathod, "Response of Soil and Structure to Base Isolation: A State-of-the-Art-Review," Indian Geotechnical Journal, 2025, doi: 10.1007/s40098-025-01196-5.

[41] "Cardone, D., Dolce, M. and Palermo, G. Force based Vs. Direct displacement based design of buildings with seismic isolation. The 14th World Conference on Earthquake Engineering. Beijing, China, pp. 12–17 (2008)."

[42] E. Ozer and M. Inel, "The effect of single and combined use of base isolator and fluid viscous damper on seismic performance in a conventional RC building with torsional irregularity," Journal of Building Engineering, vol. 101, p. 111898, 2025, doi: https://doi.org/10.1016/j.jobe.2025.111898.

[43] W. Al Agha and N. Umamaheswari, "Analytical study of irregular reinforced concrete building with shear wall and dual Framed-Shear wall system by using Equivalent Static and Response Spectrum Method," Mater Today Proc, vol. 43, pp. 2232–2241, 2020, doi: 10.1016/j.matpr.2020.12.525.

[44] L. Ruifeng, L. Liping, L. Haiming, and L. Yingmin, "Seismic response and design of base-isolated hillside stilted structures," Journal of Building Engineering, vol. 103, p. 112217, 2025, doi: https://doi.org/10.1016/j.jobe.2025.112217.

[45] A. Das and D. Bandyopadhyay, "Study on seismic base shear and deformation of regular and irregular buildings using different properties of fluid viscous dampers," Structures, vol. 76, p. 108925, 2025, doi: https://doi.org/10.1016/j.istruc.2025.108925.

[46] B. K. Bohara and P. Saha, "Nonlinear behaviour of reinforced concrete moment resisting frame with steel brace," Research on Engineering Structures and Materials, no. June, 2022, doi: 10.17515/resm2022.383st0404.