



Seismic Analysis of Multistory Buildings: A Comprehensive Literature Review

Jeevan Singh Parmar¹; Rahul Sharma²

¹PG Research Scholar; ²Asst. Professor and Head

Department of Civil Engineering, Prashanti Institute of Technology and Science, Ujjain (M.P.)
India

Abstract

This review paper presents a comprehensive overview of recent advancements in the field of seismic analysis of buildings. It traces the evolution of analytical techniques from empirical methods to modern AI and BIM-integrated modeling. The study synthesizes findings from global research between 2020–2025, emphasizing retrofitting strategies, performance-based design, and soil-structure interaction. Despite extensive international progress, a significant research gap persists in the context of Indian buildings, particularly those situated in seismic zone III.

Keywords: Seismic analysis, Building retrofitting, Performance-based design, Soil-structure interaction, BIM integration.

1. Introduction

Seismic analysis forms a fundamental aspect of structural engineering, aimed at ensuring the safety and stability of buildings during earthquake events. The growing frequency and intensity of earthquakes worldwide have emphasized the need for a deeper understanding of structural behavior under dynamic loading. In India, where a significant portion of land area falls within moderate to high seismic zones, the assessment and design of earthquake-resistant structures have become a national priority. Seismic analysis helps engineers predict how buildings respond to ground motion, evaluate critical parameters such as base shear, storey drift, and displacement, and implement design strategies that minimize structural damage and loss of life.

Over the years, researchers across the globe have developed and refined various analytical methods such as the Equivalent Static Method, Response Spectrum Method, and Nonlinear Time History Analysis to evaluate seismic performance. Numerous studies have focused on improving retrofitting techniques, understanding soil–structure interaction, and enhancing the seismic



resilience of reinforced concrete buildings. However, despite global progress, limited literature exists focusing on Indian construction practices, especially for structures located in seismic zone III. Therefore, this review aims to consolidate and analyze recent research contributions in the field of seismic analysis of multistory buildings, highlighting emerging trends, key findings, and research gaps that can guide future studies toward region-specific solutions.

2. Contributions of researchers in the field of Seismic Analysis of Multistory Buildings

Following are the summaries of selected contributions of researchers in the field of seismic analysis of buildings.

Laguerre *et al.* (2025) conduct a numerical study addressing the seismic retrofit of Haitian reinforced concrete building frames, which underscores the pressing need for effective retrofitting solutions in regions with historic seismic vulnerabilities. The comparative analysis of various retrofitting techniques sheds light on their potential effectiveness in strengthening the structural integrity of buildings exposed to seismic forces (Laguerre *et al.*, 2025).

Dai *et al.* (2025) add to the understanding of seismic risks by focusing on the benefit-cost assessment of fiber-reinforced plastic (FRP) retrofitting schemes for corroded reinforced concrete (RC) frame structures. Their findings are crucial for building owners and policymakers, providing a quantitative framework for selecting appropriate retrofitting strategies based on economic feasibility and risk mitigation (Dai *et al.*, 2025).

Chiu *et al.* (2025) provided insights into the free surface response spectrum of building structures, emphasizing the importance of dynamic properties in seismic evaluations. The study illustrates how the characteristics of ground acceleration impact displacement requirements for buildings during seismic events. By focusing on dynamic analyses, the authors assert that the resulting evaluations significantly contribute to understanding a building's seismically resilient design (Chiu *et al.*, 2025). This aligns with the findings by Gallo *et al.* (2022), who investigated seismic resilience in the context of retrofit strategies for existing school buildings. Their work reviewed various methods for assessing seismic resilience and concluded that targeted retrofitting significantly enhances structural safety against seismic hazards, emphasizing the necessity of comprehensive evaluation frameworks for such interventions (Gallo *et al.*, 2022).



Verdugo and Dávila (2024) introduced an experimental numerical approach to examine the seismic response of tall buildings with basement levels. Their investigation utilized nonlinear finite element analysis coupled with results from centrifuge experiments, revealing that properly accounting for soil-structure interaction (SBSI) significantly alters seismic response parameters such as story drifts, shear forces, and natural frequencies, thereby contributing to more robust design strategies for basement-embedded structures (Verdugo & Dávila, 2024).

Thakur & Desai (2024) emphasized the necessity of earthquake analysis in nuclear reactor structures, illustrating how these analyses help predict force-deformation behavior. They pointed out that various analysis techniques can be employed depending on the complexity and uniqueness of the project, ranging from simple modeling for small buildings to sophisticated methods for complex infrastructure (Thakur & Desai, 2024). This research established a foundational perspective on integrating seismic considerations into the design of vital infrastructure.

Raman *et al.* (2024) conducted a parametric study on three-dimensional reinforced cement concrete (RCC) frame structures during earthquakes. Their findings highlighted critical parameters such as axial pressure and lateral forces, underscoring the inherent risks associated with inadequately designed multistory buildings. They reinforced the notion that comprehensive seismic analysis is essential for safety assurances in taller structures (Raman *et al.*, 2024). Additionally, they extended their research to investigate various soil conditions impacting the dynamics of multi-story buildings, further illustrating the intricate relationships between structural design and ground conditions under seismic stress (Raman *et al.*, 2024).

Pratama (2024) focused on non-linear static analysis in earthquake-resilient building design, employing the finite element method and the pushover method to evaluate the static performance of buildings like the Alton Apartment. Their work illustrated the effectiveness of these methodologies in the context of contemporary engineering challenges and adherence to seismic standards (Pratama, 2024).

Hassan *et al.* (2024) explored the vulnerability of multi-storied reinforced concrete buildings with re-entrant corners under seismic forces. Their finite element models elucidated critical



factors such as story drift and base shear, which are instrumental for understanding structural behavior in diverse seismic zones. This emphasis on geometry and vulnerability contributed significantly to the literature on irregular building designs (Hassan *et al.*, 2024).

Moreover, Wu & Wu (2024) examined the seismic response capabilities of significantly engineered prefabricated frame structures, developing methodologies to enhance collapse resistance in seismic zone classifications. Their analysis utilized incremental dynamic analysis to scrutinize vulnerabilities, reinforcing the importance of design adaptability in high-risk seismic environments (Wu & Wu, 2024).

Ahmadi & Jamkhaneh (2023) explore the seismic upgrading of existing steel buildings situated on soft soil by employing passive damping systems. Their research highlights the effectiveness of this method in mitigating seismic risks arising from soil-structure interaction and provides valuable insights into analytical simulations that can guide future retrofitting efforts in similar contexts (Ahmadi & Jamkhaneh, 2023).

Caruso *et al.* (2023) investigate decision-making approaches for optimal seismic and energy integrated retrofitting of existing buildings. They present multi-criteria decision-making (MCDM) methods that account for various factors including economic and environmental aspects, emphasizing the importance of evaluating both seismic vulnerability and energy efficiency when planning retrofitting strategies (Caruso *et al.*, 2023).

Mohammadgholibeyki *et al.* (2023) evaluate the feasibility of achieving functional recovery goals through the seismic retrofit of existing non-ductile RC buildings, particularly in California. This research is relevant as it addresses a significant number of at-risk buildings in seismic zones and ultimately aims to enhance overall community resilience by implementing retrofitting measures (Mohammadgholibeyki *et al.*, 2023).

Preciado (2023) examines the seismic floor acceleration and energy absorption of residential framed buildings using various retrofitting techniques combined with nonlinear dampers. The comparative analysis provides useful data on how different configurations can affect seismic performance, adding depth to existing knowledge about building design optimization for earthquake resistance (Preciado, 2023).



Scala *et al.* (2023) investigate seismic safety improvements via local strengthening in Italian pre-1970 residential RC buildings. Their work emphasizes the unique challenges associated with older construction techniques and the necessity for updated retrofitting approaches to ensure compliance with current seismic safety standards (Scala *et al.*, 2023).

Zhuang *et al.* (2024) address the impact of foundation stiffness changes on the dynamic characteristics of base-isolated structures, which are crucial when designing earthquake-resistant buildings. This research highlights the often-overlooked effects of soil-structure interaction and offers crucial insights for improving design protocols for base-isolated systems (Zhuang *et al.*, 2024).

Yasir *et al.* (2022) explored the integration of Building Information Modeling (BIM) within the seismic assessment of existing reinforced concrete structures. Their research highlighted that many traditional seismic analysis tools lack interoperability with current BIM methodologies, which limits the efficacy of seismic vulnerability assessments in buildings undergoing rehabilitation or changes in occupancy following seismic events. They propose a framework that incorporates BIM to enhance these assessments, ultimately improving the resilience of existing structures amid seismic threats (Yasir *et al.*, 2022).

Furthermore, Laissy (2022) analyzed the effects of different bracing systems and shear walls on the seismic response of reinforced concrete (RC) buildings located on sloped terrains. The findings indicate that exploiting appropriate shear wall configurations can substantially enhance the overall stability and minimize displacements in structures during seismic activities. This study complements the broader discourse on structural modifications aimed at improving seismic performance through innovative design approaches (Laissy, 2022).

Mahmoud *et al.* (2022) illustrated the structural response of high-rise RC buildings subjected to seismic loading, employing time-history analysis to reveal how building design directly correlates with resilience under earthquake conditions. Their research underscores the importance of considering multiple peak seismic sequences in evaluating structural vulnerabilities. This research finds utility in the ongoing development of sophisticated analytical tools to simulate various seismic impacts (Mahmoud *et al.*, 2022).



Moreover, Awayo (2022) developed seismic fragility curves for reinforced concrete buildings, investigating the role of masonry infill as a nonstructural element. The findings indicate that recognizing the interaction of infill with the surrounding frame is crucial for accurate seismic assessment and highlights the need for refined analytical models that better reflect real-world responses during seismic events (Awayo, 2022).

Çavdar (2021) investigated the seismic performance of high-rise buildings using both linear and non-linear evaluation methods. This study proposed a Nonadaptive Displacement-Based Pushover (NADP) procedure, which integrates conventional pushover analysis with invariant lateral load patterns to account for higher-mode effects. The findings highlighted that the NADP method allows for accurate predictions of seismic responses in such buildings, evidencing easier implementation compared to traditional methods (Çavdar, 2021).

Additionally, Dilmaç (2021) examined the seismic behavior of reinforced concrete (RC) buildings designed according to Turkish Building Seismic Code (TBSC) principles. The analysis involved assessing column and shear wall dimensions against the established code rules. The research demonstrated that the specified design parameters have the capability to ensure adequate seismic performance, thus supporting the development of earthquake-resilient structures in accordance with local regulations (Dilmaç, 2021).

Moreover, Mesutoğlu and Tok (2021) presented a numerical evaluation of various structural systems in multi-storey reinforced concrete buildings exposed to seismic movements. Through the use of advanced simulation tools like SAP2000, the study underscored the importance of performance-based designs that could utilize less material while achieving the same resistance to seismic activities. This work aligns with ongoing efforts to optimize resource use in construction while maintaining safety (Mesutoğlu & Tok, 2021).

In tandem with these studies, (Azeez & Alkhafaji, 2023) explored the integration of structural and envelope systems in earthquake-resistant designs, arguing for a holistic approach that combines both architectural and structural viewpoints. Their findings suggest a gap in collaborative efforts between structural and architectural engineers, which can lead to



inefficiencies in the design process, especially concerning earthquake resilience (Azeez & Alkhafaji, 2023).

Furthermore, the importance of retrofitting existing structures was underscored by (Huang *et al.*, 2024), who noted that many buildings may fail due to inadequate pre-existing designs in the context of seismic events. This underscores the necessity of updating and improving existing structures to better withstand seismic demands, which is critical in urban planning and disaster management (Huang *et al.*, 2024).

Askouni & Papagiannopoulos (2021) examined the seismic behavior of mixed reinforced concrete-steel buildings subjected to near-fault motions through non-linear time-history analyses. Their study revealed that these near-fault seismic motions are known for inducing substantial seismic demands, which can lead to significant interstorey drift ratios, thereby challenging the structural integrity of buildings designed according to contemporary seismic codes. The research emphasizes the need for specialized design considerations to cater to these unique seismic demands, which may exceed the typical performance expectations of common buildings (Askouni & Papagiannopoulos, 2021).

Proceeding in the similar manner, Hima & Castellano (2021) focused on the seismic isolation of buildings in Croatia, highlighting the effectiveness of isolation systems in reducing shear forces within the superstructure during seismic events. Their findings indicate that the implementation of seismic isolation significantly diminishes both interstorey drifts and structural damages, enhancing the safety and comfort of building occupants during earthquakes. The work underscores the practical benefits of seismic isolation in mitigating both structural damage and the psychological effects of seismic activities on inhabitants (Hima & Castellano, 2021).

Dimovska *et al.* (2021) conducted a vulnerability assessment of unreinforced masonry structures in Barcelona's Eixample District. This study employed a typological classification to evaluate the seismic performance of building categories through nonlinear static analysis. The research effectively illustrates how specific architectural typologies can influence seismic behavior and highlights the importance of model-based assessments in enhancing the resilience of historical and existing structures against seismic hazards (Dimovska *et al.*, 2021).



Achillopoulou & Stamataki (2021) advanced seismic analysis by investigating the seismic response of a transparent pavilion constructed of structural glass. Their study entailed detailed design considerations in seismic contexts, particularly regarding how the inherently brittle nature of structural glass impacts overall performance during earthquakes. The work presents a comprehensive analysis of the necessary design concepts and contextual applications within high-seismicity regions (Achillopoulou & Stamataki, 2021).

Baldassino *et al.* (2021) explored the shear behavior of floor diaphragms in light steel residential buildings. Their research highlighted the previously limited focus in the literature on diaphragm contributions to the overall seismic response, thus expanding understanding of lateral forces and building performance under seismic loading conditions. By emphasizing the diaphragm's role, the study encourages further investigation into materials science and structural engineering principles that govern seismic resilience in modern building designs (Baldassino *et al.*, 2021).

Gil-Oulbé *et al.* (2020) focused on the emerging concept of Performance-Based Seismic Design (PBSD). Their research emphasizes the shift from traditional Force-Based Design methodologies to PBSD, illustrating its utility in providing detailed insights into the performance levels of both structural and non-structural components under seismic loads. This innovative approach enhances the capability to evaluate buildings' resilience and overall seismic performance, facilitating better design practices for earthquake-resistant structures (Gil-oulbé *et al.*, 2020).

Huang *et al.* (2020) developed generalized algorithms to identify seismic ground excitations impacting building structures. Their study proposed a Kalman filter approach that adjusts for unknown inputs, effectively addressing the challenge of limited structural response measurements. This method allows for a more accurate prediction of building behavior during seismic events, contributing to improved structural analysis techniques and providing foundational knowledge necessary for effective seismic design (Huang *et al.*, 2020).

Moreover, Crowley *et al.* (2020) presented an exposure model aimed at improving European seismic risk assessment. Their research under the Horizon 2020 project SERA emphasized the importance of harmonized seismic risk models across Europe. This effort aims to standardize seismic risk assessments and enhance the understanding of vulnerabilities within the building



stock, ultimately guiding better policy and design codes for earthquake-prone regions (Crowley *et al.*, 2020).

Similarly, Wen-Liang *et al.* (2020) analyzed the impact of adjacent surface buildings on the seismic response of shallow buried subway structures. Their findings emphasized that building proximity and design significantly influence seismic wave propagation and the resultant forces in structures. This research underlines the necessity of considering nearby structures in seismic analysis to improve the resilience and safety of both surface and underground constructions (Wen-liang *et al.*, 2020).

3. Gaps in the Research and Objectives of Proposed Research

The following points represent the gaps in the research:

- a) There are very limited research papers which focus on seismic analysis of Indian buildings; and
- b) There are also very limited research papers found which were focused on buildings located in seismic zone – III.

The following points represent the objectives of the research work:

- a) Seismic analysis of a building in seismic zone- III;
- b) Validation and interpretation of results of seismic analysis.

4. Conclusion

This review paper presents a detailed assessment of existing research in the field of seismic analysis of multistory buildings. The studies reviewed highlight significant advancements in analytical and numerical methods, including finite element modeling, nonlinear static and dynamic analyses, and performance-based design approaches. Researchers have contributed valuable insights into retrofitting techniques, soil–structure interaction, and the behavior of reinforced concrete structures under various seismic conditions. Despite these global developments, the review identifies a clear gap in research focusing on Indian buildings, particularly those located in seismic zone III. Such regions demand region-specific studies that consider local soil characteristics, construction practices, and design codes.



References

- Achillopoulou, D., & Stamataki, N. (2021). *Seismic response of a transparent pavilion made of structural glass*. <https://doi.org/10.7712/120121.8817.19469>
- Ahmadi, M., & Jamkhaneh, M. (2023). Seismic upgrading of existing steel buildings built on soft soil using passive damping systems. *Buildings*, 13(7), 1587. <https://doi.org/10.3390/buildings13071587>
- Askouni, P., & Papagiannopoulos, G. (2021). Seismic behavior of a class of mixed reinforced concrete–steel buildings subjected to near-fault motions. *Infrastructures*, 6(12), 172. <https://doi.org/10.3390/infrastructures6120172>
- Awayo, D. (2022). Seismic fragility analysis of hollow concrete block-infilled reinforced concrete buildings. *International Research Journal of Innovations in Engineering and Technology*, 6(12), 52–59. <https://doi.org/10.47001/irjiet/2022.612008>
- Azeez, S., & Alkhafaji, M. (2023). Integration of structural and envelope systems in earthquake-resistant designs. *International Journal of Civil Engineering Research and Development*, 14(2), 112–121.
- Baldassino, N., Zandonini, R., & Zordan, M. (2021). Study of the shear behaviour of floor diaphragms in light-steel residential buildings. *Ce/Papers*, 4(2-4), 367–376. <https://doi.org/10.1002/cepa.1305>
- Caruso, M., Couto, R., Pinho, R., & Monteiro, R. (2023). Decision-making approaches for optimal seismic/energy-integrated retrofitting of existing buildings. *Frontiers in Built Environment*, 9, 1176515. <https://doi.org/10.3389/fbuil.2023.1176515>
- Çavdar, Ö. (2021). Seismic performance of a high-rise building by using linear and non-linear methods. <https://doi.org/10.21203/rs.3.rs-688918/v1>
- Chiu, C., Lin, Y., Zhuang, P., Zhang, X., Zhuo, B., & Zhang, L. (2025). Analysis of the free-surface response spectrum of building structures. *Ce/Papers*, 8(2), 1042–1055. <https://doi.org/10.1002/cepa.3194>
- Crowley, H., Despotaki, V., Rodrigues, D., Silva, V., Toma-Dănilă, D., Riga, E., ... & Gamba, P. (2020). Exposure model for European seismic risk assessment. *Earthquake Spectra*, 36(1 Suppl.), 252–273. <https://doi.org/10.1177/8755293020919429>
- Dai, K., Bi, K., Song, G., Jiang, Z., & Yu, X. (2025). Evaluating the seismic risk of FRP-retrofitting schemes for corroded RC frame structures based on benefit–cost assessment. *Earthquake Engineering and Resilience*, 4(1), 97–115. <https://doi.org/10.1002/eer2.70001>
- Dilmaç, H. (2021). A study on structural behaviour of RC buildings pre-designed according to TBSC design principles. *European Journal of Science and Technology*. <https://doi.org/10.31590/ejosat.988526>
- Dimovska, S., Saloustros, S., Pelà, L., & Roca, P. (2021). Seismic vulnerability assessment of representative building typologies from Barcelona’s Eixample district. <https://doi.org/10.23967/sahc.2021.239>
- Gallo, W., Clemett, N., Gabbianelli, G., O’Reilly, G., & Monteiro, R. (2022). Seismic resilience assessment in optimally integrated retrofitting of existing school buildings in Italy. *Buildings*, 12(6), 845. <https://doi.org/10.3390/buildings12060845>
- Gil-Oulbé, M., Al-Shaibani, F., & Lina, A. (2020). Performance-based seismic design for buildings. *Structural Mechanics of Engineering Constructions and Buildings*, 16(2), 161–166. <https://doi.org/10.22363/1815-5235-2020-16-2-161-166>



- Hassan, M., Chowdhury, S., & Shuvo, R. (2024). Seismic behavior of multi-storied RC buildings with re-entrant corners. *Jurnal Teknologi*, 86(2), 183–198. <https://doi.org/10.11113/jurnalteknologi.v86.20656>
- Hima, N., & Castellano, M. (2021). Seismic isolation of buildings in Croatia. <https://doi.org/10.5592/co/1crocee.2021.258>
- Huang, J., Rao, Y., Qiu, H., & Lei, Y. (2020). Generalized algorithms for identification of seismic ground excitations to building structures using generalized Kalman filtering. *Advances in Structural Engineering*, 23(10), 2163–2173. <https://doi.org/10.1177/1369433220906225>
- Huang, Y., Loh, C., Chou, C., & Chen, W. (2024). Long-term building safety assessment from a series of earthquake excitations. *Earthquake Engineering & Structural Dynamics*, 53(4), 1593–1611. <https://doi.org/10.1002/eqe.4084>
- Laguerre, M., Salehi, M., & DesRoches, R. (2025). A numerical study on the seismic retrofit of Haitian reinforced concrete building frames. *Earthquake Spectra*, 41(2), 1477–1505. <https://doi.org/10.1177/87552930241311975>
- Laissy, M. (2022). Effect of different types of bracing systems and shear walls on the seismic response of RC buildings resting on sloped terrain. *Civil Engineering Journal*, 8(9), 1958–1976. <https://doi.org/10.28991/cej-2022-08-09-014>
- Mahmoud, S., Saleem, M., Hasanain, A., El-Sokkary, H., Elsharawy, M., Genidy, M., & Abd-Elhamed, A. (2022). Structural response and damage evaluation of a typical high-rise RC building under earthquakes with single and multiple peaks. *Journal of Civil Engineering and Management*, 28(7), 509–522. <https://doi.org/10.3846/jcem.2022.16957>
- Mesutoğlu, M., & Tok, H. (2021). Numerical evaluation of the performance for different structural systems against seismic movements in multi-storey RC buildings. *Turkish Journal of Geosciences*, 2(1), 12–17. <https://doi.org/10.48053/turkgeo.800364>
- Mohammadgholibeyki, N., Echeverria, M., Safiey, A., Cook, D., Koliou, M., & Liel, A. (2023). Assessing the feasibility of achieving functional recovery goals through seismic retrofit of existing reinforced concrete buildings. *Earthquake Spectra*, 39(4), 2123–2151. <https://doi.org/10.1177/87552930231197669>
- Preciado, A. (2023). Seismic floor acceleration and energy-absorption comparison on residential framed buildings with typical retrofitting and combined with nonlinear dampers. <https://doi.org/10.21203/rs.3.rs-2670869/v1>
- Pratama, H. (2024). Analysis of non-linear static procedure based on FEMA 356 to evaluate structural performance in the Alton Apartment Building. *Jurnal Indonesia Sosial Teknologi*, 5(6), 2870–2885. <https://doi.org/10.59141/jist.v5i6.1138>
- Raman, R., Anjimon, S., Anandhi, R., Sheikh, A., Parmar, A., Sharma, N., ... & Adnan, M. (2024). Parametric study of three-dimensional RCC frame structures under earthquake conditions. *E3S Web of Conferences*, 507, 01030. <https://doi.org/10.1051/e3sconf/202450701030>
- Scala, S., Risi, M., Gaudio, C., & Verderame, G. (2023). Improvement of seismic safety by local strengthening in Italian pre-1970 residential RC buildings designed for gravity loads. <https://doi.org/10.7712/120123.10606.21273>
- Thakur, B., & Desai, A. (2024). Seismic performance of nuclear reactor structures through soil–structure interaction. *IOP Conference Series: Earth and Environmental Science*, 1326(1), 012039. <https://doi.org/10.1088/1755-1315/1326/1/012039>



- Verdugo, J., & Dávila, D. (2024). Seismic analysis of buildings with basements. *MATEC Web of Conferences*, 396, 03004. <https://doi.org/10.1051/mateconf/202439603004>
- Wen-Liang, H., Liu, T., Ge, Y., Wang, H., Zhong, L., & Jin, X. (2020). Influence of adjacent surface buildings on seismic response of shallow-buried subway station structures. *Journal of Vibroengineering*, 22(1), 111–119. <https://doi.org/10.21595/jve.2019.20502>
- Wu, Z., & Wu, W. (2024). Research on the collapse-resistance capacity of typical prefabricated frame structures in seismic zone 8. In *Proceedings of the International Conference on Civil Engineering Advances* (pp. 233–240). https://doi.org/10.2991/978-94-6463-449-5_23
- Yasir, M., Castro, L., Rodrigues, H., & Azenha, M. (2022). BIM-based seismic analysis of existing reinforced concrete buildings. In *Proceedings of the International Conference on Structural Engineering* (pp. 347–358). <https://doi.org/10.21814/uminho.ed.32.29>
- Zhuang, H., Chen, P., Liu, Y., & Xu, Y. (2024). Effect of the change of foundation stiffness on the dynamic characteristics of base-isolated structures. *Earthquake Engineering and Resilience*, 3(4), 680–696. <https://doi.org/10.1002/eer2.103>