iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: III Month of publication: March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67437

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

A Review: Economic Evaluation of Seismic Retrofitting

Mayur Banarase[1], Dr. P. S. Pajgade[2]
[1]*PhD Scholar, Department of Civil Engineering, Prof Ram Meghe Institute of Technology & Research, Badnera*
[2]*Professor, Department of Civil Engineering, Prof Ram Meghe Institute of Technology & Research, Badnera*

Abstract: Seismic retrofitting is a critical strategy for enhancing the resilience and safety of structures, particularly in earthquake-prone regions. Various retrofitting techniques, including fiber-reinforced polymer (FRP) applications, energy dissipation devices, shear walls, and steel bracing, have been explored for their effectiveness in improving structural performance. This study reviews the existing literature on seismic retrofitting, highlighting the role of financial incentives, market strategies, and regulatory frameworks in promoting retrofitting practices. The effectiveness of FRP materials in retrofitting reinforced concrete (RC) and masonry structures is particularly emphasized due to their ease of application, cost-effectiveness, and superior strength-to-weight ratio. Standardized evaluation methods and seismic resistance guidelines remain crucial for ensuring reliable and efficient retrofitting practices. While retrofitting offers a viable alternative to demolition and reconstruction, further research is needed to refine cost-effective solutions and develop comprehensive seismic evaluation frameworks. The increasing adoption of innovative retrofitting technologies suggests a promising future for enhancing seismic resilience in modern construction practices.
Keywords: Seismic retrofitting, structural resilience, fiber-reinforced polymer, FRP applications, reinforced concrete, masonry structures

I. INTRODUCTION

The economic evaluation of seismic retrofitting is a crucial aspect of disaster risk reduction and management, as it enables policymakers to make informed decisions regarding the allocation of resources for seismic retrofitting projects, ensuring that the costs are justified by the potential benefits in terms of reduced damage and loss of life. This literature review aims to provide an overview of the current state of knowledge on the economic evaluation of seismic retrofitting, highlighting the key methodologies, benefits, and challenges associated with this approach. A review of existing studies on the economic evaluation of seismic retrofitting reveals that the majority of these studies focus on the cost-benefit analysis (CBA) approach, which compares the costs of retrofitting with the potential benefits in terms of reduced damage and loss of life. While CBA is a widely accepted approach, there are also other methodologies, such as cost-effectiveness analysis, multicriteria decision analysis, and usability analysis, which have been employed in various studies to evaluate the economic viability of seismic retrofitting projects. Furthermore, the literature review highlights several key benefits associated with seismic retrofitting, including reduced damage to buildings and infrastructure, loss of life, and economic losses. However, challenges such as high upfront costs, uncertainty in estimating seismic risk, and the need for accurate data on the costs and benefits of retrofitting are also prevalent. This literature review seeks to provide a comprehensive overview of the current state of knowledge on the economic evaluation of seismic retrofitting, shedding light on the key methodologies, benefits, and challenges, in order to inform policymakers and stakeholders in their decision-making processes regarding seismic retrofitting projects ## Methodologies for Economic Evaluation of Seismic Retrofitting

A. Cost-Benefit Analysis (CBA)

CBA is the most widely used methodology for evaluating the economic viability of seismic retrofitting projects. This approach involves comparing the costs of retrofitting with the potential benefits in terms of reduced damage and loss of life. The costs of retrofitting include the upfront costs of materials, labor, and equipment, as well as ongoing maintenance and repair costs. The benefits of retrofitting, on the other hand, include the reduced risk of damage to buildings and infrastructure, loss of life, and economic losses.

B. Cost-Effectiveness Analysis (CEA)

CEA is another methodology used to evaluate the economic viability of seismic retrofitting projects. CEA involves evaluating the costs of different retrofitting options in relation to their effectiveness in reducing seismic risk. This approach is particularly useful when the costs of retrofitting are high and the benefits are difficult to quantify. CEA has been used in various studies to compare the cost-effectiveness of different retrofitting options, such as the use of different materials or techniques.

For example, a study by a group found that the cost-effectiveness of seismic retrofitting varied widely depending on the type of retrofitting technique used, with some techniques being significantly more cost-effective than others.

C. Multicriteria Decision Analysis (MCDA)

MCDA is a methodology that involves evaluating different retrofitting options based on multiple criteria, including cost, effectiveness, and socio-environmental impacts. MCDA is a decision-making approach that considers multiple attributes and criteria to evaluate different alternatives. This methodology has been used in several studies to evaluate seismic retrofitting options, taking into account factors such as cost, effectiveness, environmental impact, and social acceptability. For instance, a study used MCDA to evaluate different seismic retrofitting options for a historic building, considering factors such as the preservation of the building's original features, the cost of retrofitting, and the level of seismic risk reduction achieved.

MCDA has been found to be particularly useful in evaluating seismic retrofitting options that involve trade-offs between different criteria. For example, a study used MCDA to evaluate different retrofitting options for a school building and found that the most cost-effective option also had the highest environmental impact, highlighting the need for a balanced evaluation of different criteria. Another study used MCDA to evaluate seismic retrofitting options for a residential building and found that the option with the highest effectiveness in reducing seismic risk also had the highest social acceptability, as it preserved the building's original features and did not disrupt the occupants' daily lives.

In addition to these studies, MCDA has been used in various other contexts to evaluate seismic retrofitting options, including the evaluation of different retrofitting techniques for bridges and the evaluation of seismic retrofitting options for hospitals and other critical infrastructure. Overall, MCDA has been found to be a useful methodology for evaluating seismic retrofitting options, particularly in situations where multiple stakeholders are involved and conflicting priorities need to be balanced. The flexibility of MCDA also allows decision-makers to incorporate both quantitative and qualitative criteria, providing a more comprehensive understanding of the trade-offs.

II. LITERATURE REVIEW

(Chen et al., n.d.) conducted a case study on the seismic retrofit and performance evaluation of a 34-story steel building in Taiwan. The study highlights how the building, originally constructed in 1993, underwent significant modifications after the 1999 Chi-Chi earthquake, which led to updated seismic force requirements. To meet these stringent requirements, the retrofitting strategy incorporated buckling restrained braces (BRB) and eccentrically braced frames (EBF) with shear links. The study also examined beam-column moment connections and applied a stiffening scheme to enhance their rotational capacity. The nonlinear seismic resistance of the building model was assessed through simulation, providing insights into the structure's performance against seismic forces along two principal axes.

(Ando, 2012) evaluated Japan’s policies on seismic retrofitting established after the 1995 Great Hanshin-Awaji Earthquake. The study assessed the effectiveness, efficiency, and administrative feasibility of these policies, predicting that seismic safety targets could be met by 2018 if current trends continued. However, challenges remained, particularly in persuading elderly homeowners to invest in retrofitting their houses and prioritizing seismic safety. Local governments played a crucial role in promoting retrofitting through financial incentives, consultancy services, and community awareness programs. The paper also compared Japan’s policies with international practices, suggesting improvements to enhance the adoption of seismic retrofitting.

(Mangan, 2023) A project report on seismic retrofitting explored various techniques for enhancing the structural performance of reinforced concrete buildings. The study categorized retrofitting methods into repair, rehabilitation, and strengthening, emphasizing the use of steel and concrete jacketing as well as fiber-reinforced polymer (FRP) composites to improve load-bearing capacity. Additionally, shear walls and shear cores were identified as effective solutions for enhancing overall building stability. The report concluded that most retrofitting methods increase structural stiffness and mass, necessitating careful redesign to ensure buildings withstand increased seismic loads effectively.

(Hajjar et al., n.d.) analyzed the seismic retrofitting of reinforced concrete buildings, particularly those designed using outdated seismic codes. They utilized STAAD Pro software to perform dynamic analysis, employing the response spectrum method to assess the structural performance of a three-dimensional RC frame. The study reiterated the effectiveness of retrofitting techniques such as steel and concrete jacketing, FRP composites, shear walls, and shear cores. It concluded that successful retrofitting should enhance both the strength and ductility of a structure, ensuring its seismic resistance exceeds the demands imposed by earthquakes.

(Skokandić et al., 2022) reviewed seismic assessment and retrofitting methodologies for road bridges, particularly those not covered by existing Eurocode regulations. Two case studies from Croatia illustrated practical applications of these methods. The first case detailed a routine seismic assessment and retrofitting proposal conducted during an inspection, while the second focused on an urgent assessment following a catastrophic earthquake. The study highlighted structural vulnerabilities in older bridges, particularly those constructed in the 1960s, and proposed targeted strengthening measures to mitigate seismic risks and prevent collapse.

(Bahmani & Zahrai, 2023) proposed a novel methodology for seismic rehabilitation using nonlinear viscous dampers. The study introduced the concept of the Optimal Retrofit Level (ORL) to balance rehabilitation costs and failure costs. Using three, nine, and twenty-story benchmark buildings, the research evaluated the methodology under different seismic hazard levels. The results demonstrated that the proposed method effectively reduces lifecycle costs while enhancing structural resilience. By optimizing inter-story drift, the study provided a strategic framework for improving the seismic performance of steel structures through advanced rehabilitation techniques.

Table 1: Comparative Analysis of Seismic Retrofitting Studies

Authors	Methodology	Key Findings	Limitations
Chen et al., n.d.	Case study on 34-story steel building in Taiwan, simulation analysis of seismic resistance	Buckling restrained braces (BRB) and eccentrically braced frames (EBF) improved seismic performance	Focused on a single building, results may not generalize to other structures
Ando, 2012	Policy evaluation of Japan's seismic retrofitting strategies post-1995 earthquake	Local governments play a crucial role in promoting retrofitting; financial incentives increase adoption	Difficulty in convincing elderly homeowners to retrofit; policy comparisons lack quantitative impact analysis
Mangan, 2023	Categorization of retrofitting methods (repair, rehabilitation, strengthening)	Steel/concrete jacketing and FRP composites improve load-bearing capacity	Increased stiffness and mass require careful redesign to accommodate seismic loads
Hajjar et al., n.d.	Dynamic analysis using STAAD Pro, response spectrum method	Retrofitting improves strength and ductility of outdated RC structures	Does not address cost-effectiveness or implementation challenges
Skokandić et al., 2022	Case study on road bridges in Croatia, seismic assessment methodology	Identified vulnerabilities in 1960s bridges; strengthening methods proposed	Limited to specific bridge typologies, lacks cost-benefit analysis
Bahmani & Zahrai, 2023	Introduced nonlinear viscous dampers and Optimal Retrofit Level (ORL)	ORL effectively balances rehabilitation and failure costs; enhances structural resilience	Limited application scope; requires further validation across different seismic hazard levels

The impact of the property market on seismic retrofit decisions has been widely discussed in the literature, emphasizing the role of financial incentives and market-based strategies in fostering seismic safety. (EGBELAKI et al., 2012) explore how property investment can create value for earthquake risk mitigation, highlighting the importance of collaboration among stakeholders. Their findings suggest that incentives such as mandatory disclosure of seismic risks and insurance premium discounts can significantly influence property owners to invest in retrofitting earthquake-prone buildings (EPBs). This study provides insights into how property market mechanisms can drive the adoption of adequate risk mitigation measures, ultimately promoting seismic rehabilitation.

(Dasgupta, 2018) The seismic retrofitting of reinforced concrete (RC) frame structures using energy dissipation devices has been a key focus in earthquake engineering research. investigates the effect of retrofitting using shear wall mechanisms and analytical approaches utilizing CSI ETABS software. The study concludes that retrofitting with shear walls enhances the load-bearing capacity of beam-column connections, providing an efficient and cost-effective solution requiring fewer skilled workers. This research underscores the need for practical and rapid retrofitting methods to improve the seismic performance of deteriorated structures.

(Lazaris, 2019) evaluates the seismic performance of an existing building in Athens using eigenvalue and pushover analysis. The study reveals torsional sensitivity and shear failures in multiple beams, which were mitigated through the application of X-shaped steel braces and fiber-reinforced plastic (FRP) jacketing. The findings indicate that these retrofitting techniques significantly enhance structural integrity and compliance with Eurocode 8 seismic regulations. This research contributes to the understanding of retrofitting solutions that address multiple structural deficiencies and improve overall building resilience.

The decision-making process regarding seismic retrofitting versus demolition is critically examined by (Pardeshi et al., n.d.). The study proposes a methodology that compares retrofit strength, new construction capacity, and capital depreciation to determine the feasibility of retrofitting. It emphasizes the importance of evaluating structural damages, retrofit effectiveness, and expected building lifespan. By incorporating economic and structural safety considerations, this research aids in making informed decisions about seismic rehabilitation versus reconstruction.

(Pandharipande et al., 2022) highlights the absence of Indian codes specifically addressing the seismic resistance evaluation of existing buildings. The study reviews international guidelines and research developments in seismic strengthening practices. It emphasizes the need for standardized procedures to ensure the safety of buildings in seismic zones. The research underscores the importance of developing systematic evaluation frameworks for assessing and improving the seismic performance of existing structures.

(Menna et al., 2022) provides a comprehensive review of seismic retrofitting methods, including traditional techniques and innovative solutions such as base isolation and energy dissipation devices. The study discusses the pros and cons of various retrofitting approaches in terms of cost, effectiveness, implementation ease, and durability. By incorporating case studies, the research demonstrates the practical applications of these methods and highlights technological advancements that have facilitated improved seismic resilience in modern buildings.

(Agrawal et al., 2016) focuses on the economic viability of retrofitting older structures to extend their lifespan. The study examines a 19-year-old building requiring retrofitting due to poor construction quality. Using section-enlarging and jacketing methods, the research reports a 57.75% increase in structural strength and a 75% increase in market valuation. The study provides experimental evidence supporting the effectiveness of retrofitting in enhancing building longevity and economic value, making it a viable alternative to demolition and reconstruction.

Collectively, these studies underscore the significance of seismic retrofitting in improving structural resilience, safety, and economic viability. While various retrofitting techniques have been explored, further research is needed to establish standardized guidelines and cost-effective solutions tailored to different seismic zones and building typologies.

(Sarker et al., 2011) Fiber-reinforced polymer (FRP) materials have emerged as a widely accepted method for structural retrofitting, particularly in seismic strengthening applications. Various strengthening techniques such as the addition of new structural elements, external post-tensioning, and steel plate bonding have been used historically with varying degrees of success. However, FRP materials have gained notable recognition due to their technical soundness and cost-effectiveness. This method has been extensively employed in seismic retrofitting worldwide, offering advantages such as ease of application, high strength-to-weight ratio, and corrosion resistance.

(Lakshmanan, 2006) Seismic evaluation and retrofitting are critical for enhancing the performance of buildings and structures to withstand earthquake forces. Pre-disaster preparedness strategies emphasize the necessity of retrofitting to improve stiffness, strength, and failure deformation characteristics of reinforced concrete structures. Quantification of structural performance post-repair is essential, with various performance factors suggested for this purpose. However, research has shown that inherent weaknesses in the detailing of original structures may limit the effectiveness of retrofitting measures.

(Di Trapani et al., 2020) Retrofitting aims to enhance the durability and performance of existing structures, addressing issues such as corrosion, inadequate detailing, and bonding failures. Among various retrofitting techniques, FRP has emerged as a promising solution due to its ease of manufacturing and application, as well as its superior structural performance enhancement. FRP materials have been tested in different structural components, including slabs, beams, columns, and bridge culverts, with results demonstrating significant improvements in strength and ductility.

III. CONCLUSIONS

Seismic retrofitting plays a vital role in enhancing the resilience, safety, and economic viability of structures, particularly in earthquake-prone regions. The literature underscores the importance of integrating financial incentives and market-based strategies to encourage property owners to invest in retrofitting measures. Research highlights the effectiveness of various retrofitting techniques, including energy dissipation devices, shear wall mechanisms, steel bracing, and fiber-reinforced polymer (FRP) jacketing, in strengthening deteriorated structures. Moreover, standardized guidelines and evaluation frameworks remain essential for ensuring uniform implementation and effectiveness of seismic strengthening practices.

While retrofitting presents a cost-effective alternative to demolition and reconstruction, its success depends on addressing inherent structural weaknesses and improving post-repair performance assessments. Case studies demonstrate that retrofitting can significantly enhance structural strength, longevity, and market value, making it a viable solution for seismic risk mitigation.

However, further research is needed to refine cost-effective solutions and establish comprehensive seismic resistance evaluation codes, particularly in regions lacking standardized procedures. The growing acceptance of innovative retrofitting technologies, including base isolation and advanced FRP applications, suggests a promising future for seismic resilience improvements in modern construction practices.

REFERENCES

[1] Agrawal, V., Garg, S., Nagar, R., & Chandwani, V. (2016). Seismic retrofitting of rc building with soft storey and floating columns. International Journal of Structural and Construction Engineering, 10(12), 1487–1495. https://www.researchgate.net/profile/Vinay-Chandwani/publication/310612049_Seismic_Retrofitting_of_RC_Buildings_with_Soft_Storey_and_Floating_Columns/links/5833cf2e08ae004f74c5b469/Seismic-Retrofitting-of-RC-Buildings-with-Soft-Storey-and-Floating-Columns.pdf

[2] Ando, S. (2012). Evaluation of the policies for seismic retrofit of buildings. Journal of Civil Engineering and Architecture, 6(4), 391. https://iris.unibas.it/bitstream/11563/38515/1/Issue%204%20of%202012%20of%20Journal%20of%20%20Civil%20Engineering%20and%20Architecture.pdf#page=5

[3] Bahmani, M., & Zahrai, S. M. (2023). Proposed Methodology and Comprehensive Design Process for Seismic Rehabilitation of Steel Structures with Supplemental Viscous Dampers. Civil Engineering Infrastructures Journal, 56(1), 79–103. https://ceij.ut.ac.ir/article_89016.html

[4] Chen, P.-C., Weng, Y.-T., Tsai, K.-C., & Chou, C.-C. (n.d.). Case Study on Seismic Retrofit Design and Performance Evaluation of A 34-Story Steel Building. Retrieved February 9, 2025, from https://www.aees.org.au/wp-content/uploads/2013/11/14-Chen-Pei-Ching.pdf

[5] Dasgupta, A. (2018). Retrofitting of concrete structure with fiber reinforced polymer. International Journal, 4(9), 42–49. https://www.academia.edu/download/57625599/IJIRSTV4I9021.pdf

[6] Di Trapani, F., Malavisi, M., Marano, G. C., Sberna, A. P., & Greco, R. (2020). Optimal seismic retrofitting of reinforced concrete buildings by steel-jacketing using a genetic algorithm-based framework. Engineering Structures, 219, 110864. https://www.sciencedirect.com/science/article/pii/S0141029619348746

[7] EGBELAKI, T., Wilkinson, S., & Nahkies, P. B. (2012). Impacts of the Property Market on Seismic Retrofit Decisions. 18th Annual Pacific-Rim Real Estate Society Conference, Adelaide, 15-18 January. https://www.researchgate.net/profile/Suzanne-Wilkinson-2/publication/260343414_Impacts_of_the_property_investment_market_on_seismic_retrofit_decisions/links/5463cefe0cf2837efdb34629/Impacts-of-the-property-investment-market-on-seismic-retrofit-decisions.pdf

[8] Hajjar, M., Izzuddin, B. A., Macorini, L., & Mabsout, M. (n.d.). Simplified modal analysis of multi-storey RC buildings for application in seismic retrofitting. Retrieved April 3, 2024, from https://repository.lboro.ac.uk/articles/conference_contribution/Simplified_modal_analysis_of_multi-storey_RC_buildings_for_application_in_seismic_retrofitting/12097623

[9] Lakshmanan, N. (2006). Seismic evaluation and retrofitting of buildings and structures. ISET Journal of Earthquake Technology, 43(1), 31–48. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=366b55ed09f9ae99739d02353cfb815f47607ddc

[10] Lazaris, A. (2019). Seismic evaluation and retrofitting of an existing building in Athens using pushover analysis. https://www.diva-portal.org/smash/record.jsf?pid=diva2:1352911

[11] Mangan, S. D. (2023). A Performance-Based Decision Support Workflow for Retrofitting Residential Buildings. Sustainability, 15(3), 2567. https://www.mdpi.com/2071-1050/15/3/2567

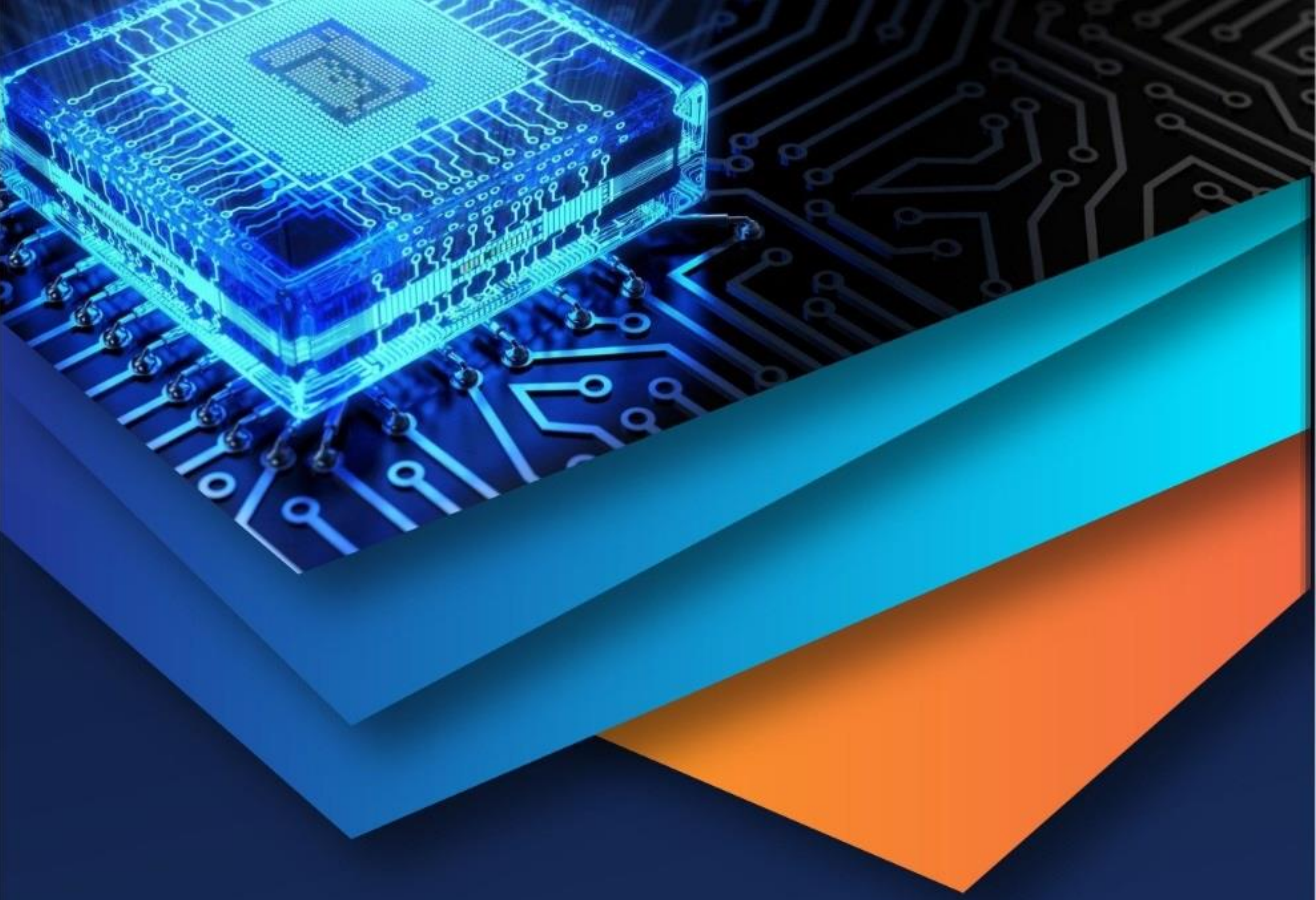
[12] Menna, C., Felicioni, L., Negro, P., Lupíšek, A., Romano, E., Prota, A., & Hájek, P. (2022). Review of methods for the combined assessment of seismic resilience and energy efficiency towards sustainable retrofitting of existing European buildings. Sustainable Cities and Society, 77, 103556. https://www.sciencedirect.com/science/article/pii/S2210670721008222

[13] Pandharipande, P. P., Badar, A. M., & Satone, S. R. (2022). “REVIEW PAPER ON SEISMIC RETROFITTING OF STRUCTURES. https://www.ijrar.org/papers/IJRAR22B1573.pdf

[14] Pardeshi, D. G., Bhoge, R. S., & Kolhe, S. R. (n.d.). Retrofitting of RCC Apartment Building–A Case Study. Retrieved February 9, 2025, from http://www.ijirse.com/wp-content/upload/2023/09/K7030.pdf

[15] Sarker, P., Begum, M., & Nasrin, S. (2011). Fiber reinforced polymers for structural retrofitting: A review. J. Civ. Eng, 39(1), 49–57. http://mail.jce-ieb.org/doc_file/3901004.pdf

[16] Skokandić, D., Vlašić, A., Kušter Marić, M., Srbić, M., & Mandić Ivanković, A. (2022). Seismic assessment and retrofitting of existing road bridges: State of the art review. Materials, 15(7), 2523. https://www.mdpi.com/1996-1944/15/7/2523



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY