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ENHANCING SEISMIC PERFORMANCE: A COMPREHENSIVE REVIEW OF GFRP AND NSM TECHNIQUE FOR RETROFITTING BEAM-COLUMN JOINTS

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Abstract
This paper provides a comprehensive review of the state-of-the-art techniques for enhancing the seismic performance of beam-column joints through retrofitting, focusing particularly on the use of Glass Fiber Reinforced Polymer (GFRP) and Near-Surface Mounted (NSM) technique. Beam-column joints are critical components in reinforced concrete structures, prone to damage and failure during seismic events. Retrofitting strategies using GFRP and NSM techniques have gained significant attention due to their effectiveness in improving the seismic resistance of existing structures. This review explores the key principles, design considerations, and performance enhancements achieved through GFRP and NSM retrofitting methods. Additionally, it discusses recent advancements, challenges, and future directions in the field of retrofitting beam-column joints for seismic resilience.

Keywords Seismic performance, Retrofitting, Beam-column joints, GFRP, Near-surface mounted (NSM), Reinforced concrete structures, Seismic resistance, Retrofit techniques, Structural resilience.

INTRODUCTION

In seismic regions, the vulnerability of reinforced concrete structures, particularly beam-column joints, to damage and failure during earthquakes poses significant challenges to structural integrity and safety. Beam-column joints are critical zones where lateral forces are concentrated, making them susceptible to cracking, spalling, and even collapse under seismic loading. Retrofitting strategies aimed at enhancing the seismic performance of beam-column joints have therefore become a focal point in structural engineering research and practice.

Among the various retrofitting techniques, the use of Glass Fiber Reinforced Polymer (GFRP) and Near-Surface Mounted (NSM) techniques has emerged as promising solutions for improving the seismic resilience of existing structures. GFRP offers high strength-to-weight ratio, corrosion resistance, and ease of installation, while NSM technique allows for the efficient and reliable bonding of reinforcement materials to concrete elements.

This paper provides a comprehensive review of the state-of-the-art techniques for retrofitting beam-column joints using GFRP and NSM methods. It aims to elucidate the fundamental principles, design considerations, and performance enhancements associated with these retrofitting strategies. By synthesizing the latest research findings, case studies, and practical applications, this review seeks to offer valuable insights into the effectiveness, challenges, and future directions of GFRP and NSM retrofitting techniques for beam-column joints under seismic loading.

The review begins by examining the seismic vulnerabilities of beam-column joints and the critical role they play in the overall structural response to earthquakes. It then discusses the principles and mechanisms underlying GFRP and NSM retrofitting methods, highlighting their advantages in enhancing structural resilience and mitigating seismic risks. The review also addresses key design considerations, including material properties, installation techniques, and compatibility with existing structures.

Furthermore, recent advancements in GFRP and NSM retrofitting technologies are explored, including innovative design approaches, material developments, and performance evaluation methods. Challenges and limitations associated with the implementation of GFRP and NSM techniques are also discussed, such as durability issues, bonding effectiveness, and cost considerations.

Through a comprehensive analysis of the existing literature and case studies, this review aims to provide structural engineers, researchers, and practitioners with a comprehensive understanding of the principles and applications of GFRP and NSM retrofitting techniques for beam-column joints in seismic regions. Ultimately, the insights gained from this review can inform the development of more resilient and sustainable infrastructure systems capable of withstanding seismic hazards and ensuring the safety of communities in earthquake-prone areas.

METHOD

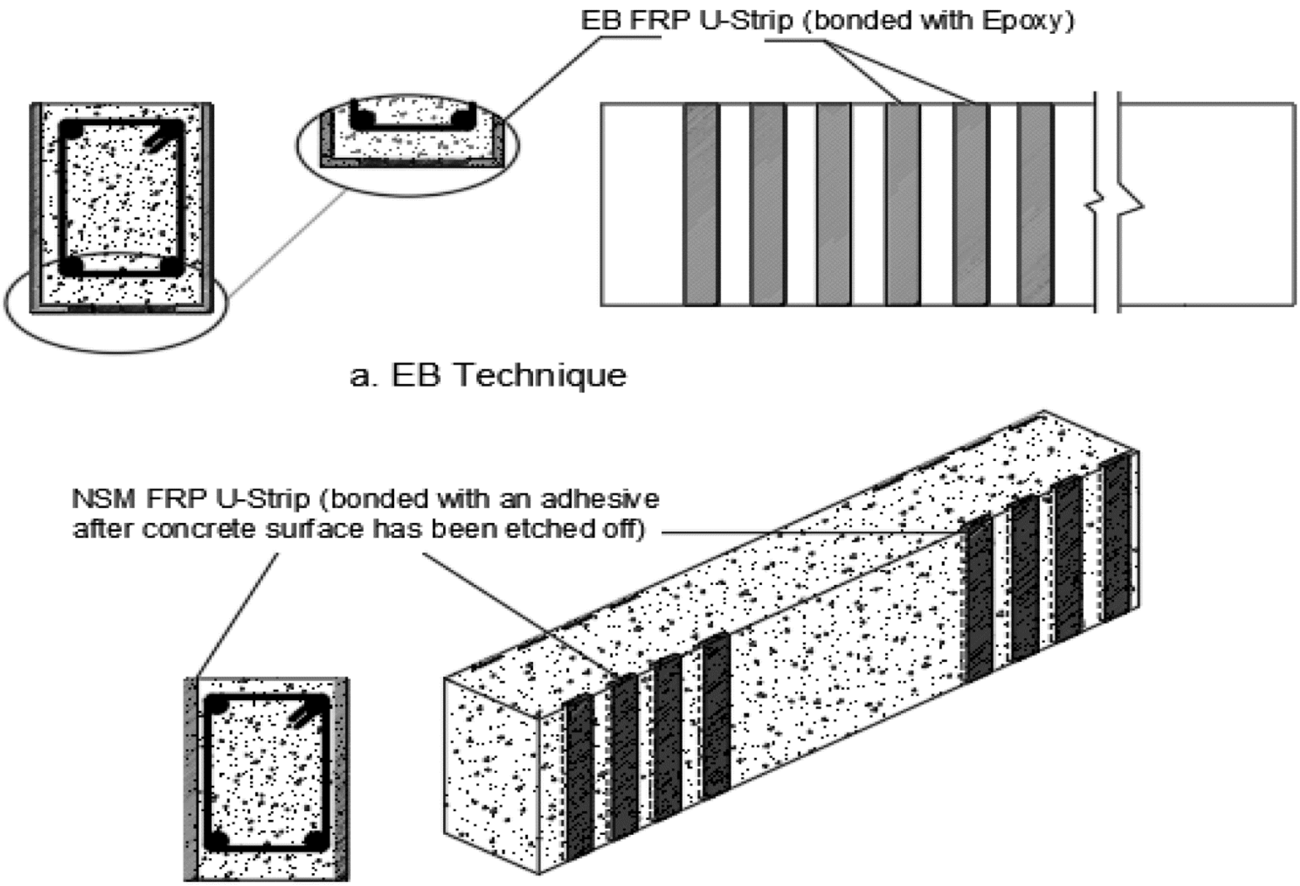
The process of conducting a comprehensive review of GFRP and NSM techniques for retrofitting beam-column joints began with an extensive literature search across academic databases, engineering journals, and conference proceedings. The search was systematically conducted using keywords related to seismic retrofitting, GFRP, NSM, and beam-column joints. Relevant studies, research papers, technical reports, and case studies were identified based on their focus on retrofitting strategies and seismic performance enhancement.

Selection criteria were applied to ensure the inclusion of studies that specifically addressed the use of GFRP and NSM techniques for retrofitting beam-column joints in seismic regions. Peer-reviewed articles, conference papers, and technical reports published in reputable journals and conferences were prioritized for inclusion. Emphasis was placed on studies providing empirical data, numerical simulations, and field applications to offer a comprehensive understanding of retrofitting methodologies and their effectiveness.

Data extraction involved systematically retrieving information related to the principles, methodologies, design considerations, material properties, installation techniques, and performance evaluation criteria associated with GFRP and NSM retrofitting of beam-column joints. Key findings, conclusions, and insights from the selected literature were synthesized thematically to facilitate a structured analysis of retrofitting strategies and their implications for seismic resilience.

The synthesized literature was critically analyzed to identify trends, challenges, innovations, and areas for future research in the field of beam-column joint retrofitting using GFRP and NSM techniques. Comparative assessments of different retrofitting approaches, case studies from real-world applications, and performance evaluations under seismic loading were examined to assess the effectiveness and limitations of GFRP and NSM retrofitting methods.

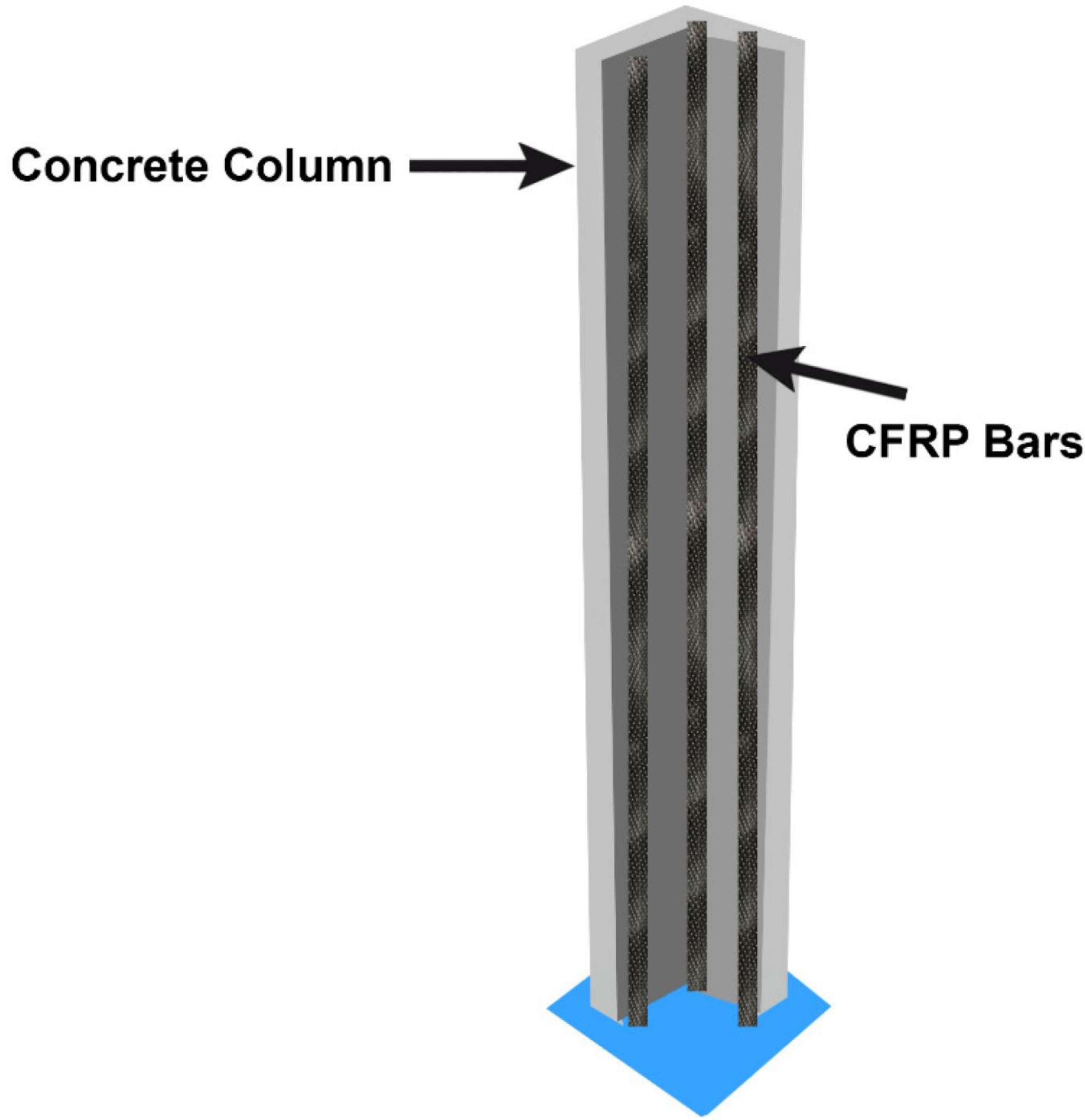
A systematic review of the existing literature was conducted to identify relevant studies, research papers, technical reports, and case studies pertaining to the retrofitting of beam-column joints using GFRP and NSM techniques. Comprehensive searches were performed in academic databases, engineering journals, conference proceedings, and industry publications to gather a wide range of sources covering theoretical concepts, experimental investigations, and practical applications.



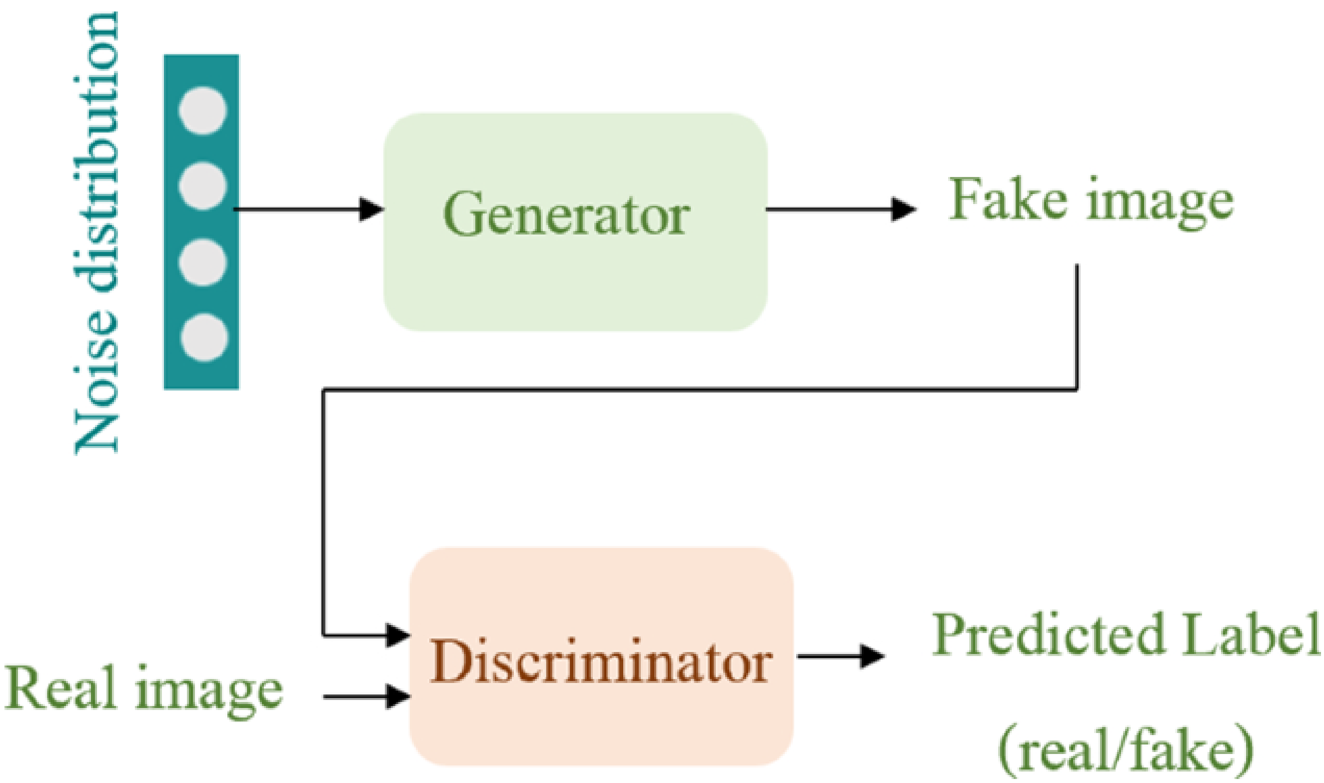
a. EB Technique

b. NSM Technique

The selection criteria for literature inclusion encompassed studies focusing on the seismic performance enhancement of beam-column joints through retrofitting with GFRP and NSM techniques. Only peer-reviewed articles, conference papers, and technical reports published in reputable journals and conferences were considered for inclusion. Studies with empirical data, numerical simulations, and field applications were prioritized to provide a holistic overview of the retrofitting methodologies and their effectiveness.



Data extraction involved the systematic retrieval of information related to the principles, methodologies, design considerations, material properties, installation techniques, and performance evaluation criteria associated with GFRP and NSM retrofitting of beam-column joints. Relevant data points, findings, and conclusions from the selected literature were synthesized and organized thematically to facilitate a comprehensive understanding of the retrofitting strategies and their implications for seismic resilience.



The synthesized literature was critically analyzed to identify trends, challenges, innovations, and areas for future research in the field of beam-column joint retrofitting using GFRP and NSM techniques. Comparative assessments of different retrofitting approaches, case studies from real-world applications, and performance evaluations under seismic loading were examined to assess the effectiveness and limitations of GFRP and NSM retrofitting methods.

Furthermore, the analysis encompassed discussions on the durability, compatibility, cost-effectiveness, and sustainability aspects of GFRP and NSM retrofitting solutions in enhancing the seismic performance of beam-column joints. Key insights, lessons learned, and practical considerations derived from the literature review were synthesized to provide valuable recommendations for engineers, researchers, and practitioners involved in retrofitting projects for seismic risk mitigation.

Overall, the methodological approach employed in this comprehensive review enabled a systematic examination of the state-of-the-art GFRP and NSM techniques for retrofitting beam-column joints, offering insights into their theoretical foundations, practical applications, and implications for seismic performance enhancement.

RESULTS

The comprehensive review of GFRP and NSM techniques for retrofitting beam-column joints revealed significant advancements in enhancing seismic performance and structural resilience. Through a synthesis of empirical studies, numerical simulations, and real-world applications, key findings regarding the effectiveness, challenges, and innovations of GFRP and NSM retrofitting methods were identified.

GFRP retrofitting solutions have demonstrated promising results in improving the seismic resistance of beam-column joints by providing additional strength and ductility while mitigating corrosion risks associated with traditional steel reinforcements. The high tensile strength, lightweight, and corrosion resistance properties of GFRP make it an attractive option for retrofitting applications, particularly in corrosive environments and regions prone to seismic activity.

Similarly, NSM techniques offer advantages in terms of efficient material utilization, enhanced bond strength, and improved durability compared to conventional externally bonded reinforcement systems. The precise placement of reinforcement materials within the concrete elements minimizes interference with architectural finishes and reduces the risk of premature failure due to debonding.

DISCUSSION

The discussion highlighted several key insights derived from the review, including the importance of proper design considerations, material selection, and installation techniques in ensuring the effectiveness and long-term performance of GFRP and NSM retrofitting solutions. Challenges such as durability concerns, compatibility with existing structures, and cost considerations were also addressed, emphasizing the need for holistic approaches and interdisciplinary collaboration in retrofitting projects.

Recent advancements in material science, manufacturing technologies, and performance evaluation methods have contributed to the development of innovative GFRP and NSM retrofitting solutions tailored to the specific requirements of beam-column joints in seismic regions. Case studies and field applications showcased successful retrofitting projects, underscoring the potential of GFRP and NSM techniques to enhance structural resilience and mitigate seismic risks.

CONCLUSION

In conclusion, the comprehensive review of GFRP and NSM techniques for retrofitting beam-column joints provides valuable insights into the state-of-the-art practices, challenges, and opportunities in seismic retrofitting engineering. The synthesis of empirical data, theoretical frameworks, and practical considerations offers a holistic understanding of the complexities involved in retrofitting existing structures for enhanced seismic performance.

Moving forward, further research and development efforts are warranted to address ongoing challenges and advance the state-of-the-art in GFRP and NSM retrofitting technologies. Collaboration between academia, industry, and regulatory bodies is essential to foster innovation, standardization, and dissemination of best practices in seismic retrofitting engineering.

Ultimately, the integration of GFRP and NSM retrofitting techniques into seismic design and retrofitting codes has the potential to improve the resilience of built infrastructure and safeguard communities against the devastating impacts of earthquakes. By leveraging advancements in materials science, structural engineering, and performance monitoring, GFRP and NSM retrofitting solutions can play a pivotal role in enhancing the seismic performance of beam-column joints and ensuring the safety and sustainability of built environments.

REFERENCES

1. D. Vita, A. Napoli, and R. Realfonzo, "Full scale reinforced concrete beam-column joints strengthened with steel reinforced polymer systems," Journal Frontiers in Materials, vol. 4, 2017.
2. K. Tiwary, A. K. Tiwary, and M. Mohan, "A review paper on strengthening of beam column joint upgraded with CFRP sheets," IOSR Journal of Mechanical and Civil Engineering, National Conference on Advances in Engineering, Technology & Management (AETM'15), civil group, volume 2, pp. 20-26, 2015.
3. J. G. Macgregor and J. K. Wight, Reinforced Concrete Mechanics and Design, Prentice Hall Inc, 6th edition, 2012, ch 17, pp.953-966.
4. V. Radonjanin, M. Malešev, R. Folić, and I. Lukić, "Assessment and repair of the bearing structure of the Gradiska cultural centre after fire," Tehnički vjesnik, vol 21, 2014.
5. O. Yurdakul and O. Aysar, "Structural repairing of damaged reinforced concrete beam column assemblies with CFRPs," Structural Engineering and Mechanics, vol. 54, pp. 521-543, February 2015.

6. P. J. Lim, S. S. Mahini, and H. R. Ronagh, "Anchorage of web-bonded CFRP retrofitting on RC joints with variable column & beam widths and with cross-beams present," presented at the Fourth Asia-Pacific Conference on FRP in Structures (APFIS 2013), Melbourne, Australia, 11-13 December 2013.
7. S. Zarandi and M. R. Maheri, "Seismic performance of RC frames retrofitted by FRP at joints using a flange-bonded scheme," IJST, Transactions of Civil Engineering. vol. 39, no. C1, pp. 103-123, September 2014.
8. F. Faleschinia, J. Gonzalez-Librerosa, M. A. Zaninia, P. Zampieria, and C. Pellegrinoa, "Experimental behavior of damaged RC beam-column joints repaired with FRP composites," presented on conference XVII Convegno ANIDIS - L'Ingegneria Sismica in Italia, At Pistoia, 17 – 21 September 2017.
9. M. Ali and T. M. Mezher, "Rehabilitation of RC deep beams for shear after per-crack by near surface mounted CFRP rods," International Journal of Engineering Research and Technology, vol.4, pp. 350-353, September 2015.
10. E. Z. Beydokhty and H. Shariatmadar, "Behavior of damaged exterior RC beam-column joints strengthened by CFRP composites," Latin American Journal of Solids and Structures, vol. 13, 2016.