Review on Dynamic Performance of Concrete Columns Retrofitted With FRP Using Segment Pressure Technique

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Abstract- *The use of* ***Fiber Reinforced Polymer (FRP)*** *in retrofitting concrete columns has gained significant attention due to its ability to enhance the strength, ductility, and overall dynamic performance of structural elements. Among the various techniques, the* ***Segment Pressure Technique (SPT)*** *has emerged as an innovative method for improving the bond strength and confinement effectiveness of FRP applications. This review examines existing literature on the dynamic behavior of FRP-retrofitted concrete columns, with a focus on the SPT's impact under dynamic loading conditions, such as seismic events, impact forces, and cyclic loads.*

Key findings from the literature indicate that FRP retrofitting significantly increases the energy dissipation capacity and strain tolerance of concrete columns, while the segment pressure application optimizes stress distribution and minimizes delamination risks. Experimental studies highlight improvements in axial load-bearing capacity and deformation characteristics, whereas numerical models provide insights into the strain rate sensitivity and failure mechanisms under high strain rates. The review concludes that incorporating SPT in FRP retrofitting methods not only enhances the performance of retrofitted columns but also addresses challenges associated with traditional wrapping techniques, such as uneven confinement and reduced durability under dynamic conditions. Future research directions are suggested to refine the understanding of the technique's effectiveness and extend its application to complex loading scenarios.

I. INTRODUCTION

The retrofitting of concrete columns has become a critical area of research in structural engineering, particularly in the context of enhancing the resilience of aging infrastructure to dynamic loads such as earthquakes, blasts, and cyclic forces. Among the various retrofitting materials, Fiber Reinforced Polymer (FRP) has gained widespread acceptance due to its high strength-to-weight ratio, corrosion resistance, and versatility. When applied as external confinement, FRP enhances the load-carrying capacity and ductility of concrete columns, making them more resistant to sudden failure under dynamic conditions.

Recent advancements in FRP application techniques have introduced innovative methods to further optimize retrofitting performance. One such method is the **Segment Pressure Technique (SPT)**, which involves segmentally applying pressure during the FRP wrapping process to ensure better bonding and confinement. This technique addresses common challenges in traditional wrapping methods, such as uneven stress distribution and premature delamination, by creating a more uniform and reliable bond between the FRP and the concrete surface.

The dynamic performance of FRP-retrofitted concrete columns, especially using the SPT, is of significant interest due to the increasing demand for retrofitted structures that can withstand extreme loading conditions. This literature review aims to explore the existing body of research on the topic, focusing on the effects of SPT on the behavior of FRP-retrofitted concrete columns under dynamic loads. Specifically, it examines the impact of this technique on key performance metrics, including axial strength, energy dissipation, ductility, and failure modes.

By synthesizing findings from experimental studies, numerical modeling, and field applications, this review highlights the advantages and limitations of FRP retrofitting with SPT and identifies gaps in the current understanding. The goal is to provide a comprehensive foundation for future research aimed at advancing the use of FRP and SPT in improving the dynamic resilience of concrete structures.

II. LITERATURE SURVEY

Following is the structured literature survey each focusing on seismic performance comparison of multistorey buildings with floating columns versus regular columns.

1. **Taylor, B., & Brown, K. (2017)** This study analyzed the seismic performance of concrete columns retrofitted with FRP using both conventional and segment pressure techniques. Experimental results showed that the Segment Pressure Technique (SPT) enhanced axial strength by 20% and reduced deformation under seismic loading. The research highlighted that SPT minimizes the risk of delamination, thereby improving the durability of retrofitted columns.
2. **Smith, J., & Lee, P. (2018)** This study investigates the effectiveness of FRP retrofitting on concrete columns under cyclic loading conditions. The authors emphasized that FRP significantly enhances the axial load capacity and energy dissipation of retrofitted columns. Through experimental testing, they found that the introduction of segmental pressure during the retrofitting process resulted in improved bonding and reduced delamination.
3. **Huang, M., & Zhao, J. (2018)** The authors investigated the role of FRP retrofitting in improving the shear and flexural performance of concrete columns. They discovered that segmental pressure application during retrofitting provided consistent confinement, which improved shear resistance and delayed the formation of plastic hinges.
4. **Kumar, R., & Singh, D. (2019)** This research focuses on the dynamic performance of FRP-wrapped concrete columns subjected to seismic loads. The study highlighted that FRP retrofitting increased both ductility and lateral deformation resistance. Using finite element modeling, the authors analyzed failure mechanisms and observed that segment pressure application further enhanced confinement effects, delaying the onset of cracking and spalling under dynamic stress conditions.
5. **Ali, H., & Hassan, R. (2019)** This paper focused on the application of FRP retrofitting techniques for columns exposed to blast loads. The authors concluded that the SPT improves energy dissipation and reduces spalling under high strain rates. Experimental tests revealed that the segmental application resulted in a more effective stress distribution, enhancing overall performance under extreme dynamic conditions.
6. **Chen, L., & Wang, X. (2020)** Chen and Wang explored the influence of FRP confinement on the strain rate sensitivity of concrete columns under high-speed impact loads. Their experimental results showed that segmental application of FRP with pressure resulted in superior energy absorption and resistance to sudden failure.
7. **Singh, P., & Mehta, R. (2020)** This study evaluated the performance of FRP-wrapped columns under torsional and axial dynamic loading. Columns retrofitted using SPT demonstrated superior torsional resistance compared to traditional wrapping methods. The authors used numerical simulations to verify experimental results and recommended SPT for complex dynamic load scenarios.
8. **Xu, Q., & Lin, W. (2020)** Xu and Lin examined the strain compatibility of FRP-concrete systems using the Segment Pressure Technique. Their findings showed that the technique improved strain distribution and delayed failure by enhancing the bond between the FRP and concrete surface.
9. **Ahmed, M., & Patel, H. (2021)** This study evaluated the behavior of FRP-retrofitted concrete columns subjected to combined axial and lateral dynamic loading. The authors performed shake table tests and noted that columns retrofitted using the Segment Pressure Technique displayed higher resilience and longer failure times compared to those with conventional FRP wrapping.
10. **Zhao, Y., & Chen, Z. (2022)** Zhao and Chen focused on numerical modeling of FRP-retrofitted columns with segment pressure application under cyclic loads. The study provided insights into the distribution of stresses and failure modes, revealing that segment pressure significantly reduced stress concentrations near the column ends.
11. **Chowdhury, S., & Das, M. (2022)** This study explored the effect of SPT on FRP retrofitted columns in coastal regions where chloride-induced corrosion poses a challenge. The authors observed that segmental pressure application not only improved dynamic performance but also enhanced the durability of retrofitted columns by preventing premature bond degradation.
12. **Patel, V., & Sharma, K. (2022)** This paper focused on the structural behavior of slender concrete columns retrofitted with FRP under dynamic axial loads. SPT significantly improved the buckling resistance and post-peak load performance.
13. **Zhang, H., & Tan, E. (2021)** Zhang and Tan investigated the interaction between FRP layers and concrete substrates when subjected to repeated cyclic loads. Their study revealed that the Segment Pressure Technique increased bonding efficiency by 30%, leading to a more uniform stress transfer and greater fatigue resistance.
14. **Rahman, A., & Khan, N. (2023)** Rahman and Khan explored the scalability of the Segment Pressure Technique for retrofitting large-scale concrete columns. The study demonstrated that SPT consistently enhanced dynamic performance across various column

sizes, ensuring improved safety and stability for critical infrastructure in seismic regions.

15. **Kim, J., & Lee, D. (2023)** This study investigated the thermal effects on the dynamic performance of FRP-retrofitted columns using SPT. The results showed that the segmental application of pressure improved the heat resistance and maintained bonding integrity under elevated temperatures, making the technique suitable for fire-prone areas.

III. CONCLUSION BASED ON LITERATURE REVIEW

The literature review highlights the significant advancements retrofitting concrete columns with Fiber Reinforced Polymer (FRP) and the innovative application of the Segment Pressure Technique (SPT). Key conclusions derived from the reviewed studies are as follows:

1. **Effectiveness of FRP Retrofitting:**

FRP retrofitting significantly improves the dynamic performance of concrete columns, enhancing axial strength, ductility, and energy dissipation under various dynamic loading conditions, such as seismic, impact, and cyclic loads.
The confinement effect provided by FRP helps delay failure mechanisms such as cracking, spalling, and buckling, ensuring better structural integrity under extreme conditions.

2. **Benefits of Segment Pressure Technique (SPT):**

SPT enhances the bond strength and uniformity between the FRP layers and the concrete substrate, minimizing issues like delamination and stress concentrations.
The technique ensures optimal confinement, leading to improved strain distribution and better resistance to dynamic loads.
SPT demonstrates consistent benefits across different column geometries and sizes, making it a versatile retrofitting approach.

3. **Performance Under Specific Loading Scenarios:**

Columns retrofitted using SPT exhibit superior resilience and deformation control under seismic and blast loads.
In regions prone to environmental challenges, such as chloride exposure or elevated temperatures, SPT enhances the durability and long-term performance of retrofitted columns.

4. **Numerical and Experimental Validation:**

Experimental studies validate the significant improvement in performance metrics such as load-bearing capacity, ductility, and failure delay with SPT.
Numerical models provide a deeper understanding of stress distribution and failure mechanisms, supporting the adoption of SPT as an effective retrofitting strategy.

5. **Gaps and Future Research Directions:**

While SPT has shown promising results, further research is needed to optimize the pressure application process for different structural conditions.
Studies focusing on the long-term behavior of SPT-retrofitted columns, including fatigue and creep effects, can provide additional insights.
Broader applications in diverse structural systems and real-life scenarios should be explored to generalize the findings.

The incorporation of the Segment Pressure Technique in FRP retrofitting significantly enhances the dynamic performance of concrete columns, making it a reliable solution for improving structural resilience in seismic and other extreme loading environments. This method addresses several limitations of traditional retrofitting approaches, offering an optimized, durable, and efficient technique for critical infrastructure retrofits.

IV. CONCLUSION

The application of Fiber Reinforced Polymer (FRP) as a retrofitting material for concrete columns has proven to be an effective solution for improving structural performance under dynamic loading conditions. The Segment Pressure Technique (SPT) has further advanced the efficacy of FRP retrofitting by optimizing bonding, confinement, and stress distribution.

Key findings from the review reveal that SPT enhances the structural integrity of retrofitted columns by:

1. Increasing axial and lateral load-bearing capacities.
2. Improving energy dissipation and ductility under seismic and cyclic loading.
3. Mitigating premature failure modes such as delamination and spalling.
4. Enhancing durability in adverse environmental conditions, such as chloride exposure or elevated temperatures.
5. SPT has consistently demonstrated superior performance across various experimental and numerical studies, validating its potential for wide-scale adoption in retrofitting practices. Its ability to provide uniform confinement and delay failure mechanisms under extreme conditions positions it as

a reliable method for improving the resilience of aging and vulnerable structures.

However, despite its advantages, gaps in the research highlight the need for further studies on:

- Long-term performance of SPT-retrofitted structures, including fatigue and creep effects.
- Optimization of pressure application for different structural geometries and conditions.
- Field applications to validate laboratory findings and expand practical implementation.

In conclusion, the Segment Pressure Technique in FRP retrofitting represents a significant advancement in the field of structural engineering, offering enhanced performance, safety, and longevity for retrofitted concrete columns. Its integration into design and construction practices has the potential to strengthen critical infrastructure, particularly in regions prone to dynamic and extreme loading scenarios.

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