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Advancements in Retrofitting Masonry Structures: A Review on Fiber Reinforced Polymer (FRP) Applications

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Abstract
Retrofitting masonry structures to enhance their structural resilience and seismic resistance is a growing concern in civil engineering. Fiber Reinforced Polymer (FRP) systems have emerged as a promising solution due to their superior mechanical properties, lightweight nature, and adaptability. This review paper synthesizes the latest advancements in FRP applications for masonry retrofitting, emphasizing the research gaps identified in experimental studies. The effectiveness of Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP), and Basalt Fiber Reinforced Polymer (BFRP) in tensile, compressive, and seismic performance is critically analyzed. While previous research demonstrates substantial performance improvements, issues such as debonding, anisotropic behavior, and long-term durability remain unresolved. This review underscores the necessity for optimizing installation techniques, hybrid FRP systems, and sustainable material alternatives to enhance the efficiency and applicability of FRP retrofitting in masonry structures.

Keywords: Masonry Retrofitting, Fiber Reinforced Polymer, Structural Strengthening, Seismic Resistance, Sustainability

Introduction

Masonry structures, characterized by their historical significance and widespread use, often fail to meet modern safety standards due to environmental degradation and seismic vulnerability. Retrofitting techniques have become essential to enhance their structural performance. Among various strengthening methods, Fiber Reinforced Polymer (FRP) systems have gained significant attention due to their high tensile strength, corrosion resistance, and ease of application. This paper reviews existing studies on FRP-based retrofitting, identifying key challenges such as material behavior, environmental impact, and cost-effectiveness.

Research Gap Despite the extensive use of FRP systems in structural retrofitting, several research gaps persist:

- **Debonding Issues:** Inadequate adhesion between FRP layers and masonry surfaces leads to premature failure.
- **Anisotropic Material Behavior:** Variations in fiber orientation impact load distribution and overall structural integrity.
- **Environmental Concerns:** The production of synthetic FRP materials contributes to high energy consumption and carbon emissions.
- **Economic Constraints:** The high initial cost of FRP systems limits their widespread adoption. This review highlights the need for optimized FRP applications, improved material formulations, and hybrid reinforcement strategies to bridge these gaps.

Methodology

The review follows a systematic approach by analyzing peer-reviewed journals, experimental studies, and case reports on FRP-based masonry retrofitting. The methodology includes:

1. **Literature Compilation:** Research articles, conference papers, and field studies published in the last two decades were reviewed.
2. **Comparative Analysis:** Performance metrics such as tensile strength, compressive strength, and seismic resistance were compared across different FRP types.
3. **Sustainability Assessment:** Environmental impact studies were considered to evaluate the ecological footprint of FRP materials.
4. **Economic Feasibility:** Cost-benefit analyses of FRP systems were examined to determine their practicality.

FRP Types and Their Applications

- **Carbon Fiber Reinforced Polymer (CFRP):** Provides the highest tensile strength but is expensive.
- **Glass Fiber Reinforced Polymer (GFRP):** Offers a balance between performance and cost.
- **Basalt Fiber Reinforced Polymer (BFRP):** Exhibits superior environmental sustainability with moderate strength properties.

Mechanical Performance of FRP-Retrofitted Masonry

- Tensile and compressive strength improvements observed in experimental studies.
- Enhancement in seismic resistance, energy dissipation, and ductility.

Challenges and Limitations

- Material degradation over time.
- Complexity in installation and quality control.
- Need for hybrid solutions integrating multiple fiber types.

Sustainability and Economic Viability

- Life-cycle assessment of FRP materials.
- Cost-performance analysis of various FRP types.
- Future directions for bio-based and recycled FRP systems.

Conclusion

FRP systems have proven to be highly effective in enhancing the structural integrity of masonry buildings, particularly in seismic-prone regions. However, challenges related to debonding, anisotropic behavior, and sustainability must be addressed. Future research should focus on hybrid FRP solutions, smart monitoring systems, and the development of eco-friendly alternatives to synthetic polymers. By addressing these gaps, FRP technology can be further refined to achieve long-term efficiency and widespread adoption in structural retrofitting.

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