Enhancing Reinforced Cement Concrete (RCC) Performance Using Basalt and Polypropylene Fiber Reinforcement: A Comprehensive Review

Souvik Giri[1], Prof. Souvik Sharma[2], Prof. (Dr.) Biman Mukherjee[3]

[1,] M.Tech Student of Narula Institute of Technology, West Bengal, India
[2] Professor, Dept. of Civil Engineering, Narula Institute of Technology, West Bengal, India
[3]Professor & Former HOD, Dept. of Civil Engineering, Narula Institute of Technology, West Bengal, India,

---***---

Abstract - This review presents current research on reinforced cement concrete (RCC) systems that eliminate conventional steel reinforcement by using **basalt fibers and polypropylene fibers** as alternative reinforcement materials. Steel reinforcement is widely used but is prone to corrosion, increases project costs, and contributes to embodied carbon. Basalt and polypropylene fibers offer improved durability, corrosion resistance, and tensile strength while enhancing ductility and crack control in cementitious matrices. The review covers material characteristics, effects on mechanical and durability properties, fiber hybridization, practical considerations, and future research directions.

Key Words: Reinforced Cement Concrete (RCC), Basalt Fibers, Polypropylene Fibers, Alternative Reinforcement, Fiber Hybridization , Corrosion Resistance, Mechanical Properties, Durability, Crack Control, Embodied Carbon, Durability, Crack Control, Embodied Carbon

1.INTRODUCTION

Reinforced cement concrete uses embedded steel reinforcement to carry tensile stresses because conventional concrete is weak in tension. While effective, steel is **susceptible to corrosion**, requires significant maintenance, and contributes to construction cost and carbon footprint. Alternative reinforcement strategies using **synthetic and mineral fibers** have gained attention. Basalt fibers and polypropylene fibers are promising due to their high tensile strength, chemical resistance, low cost (for polypropylene), and enhanced durability performance.

2. Rationale for Steel Replacement

Steel reinforcement provides ductility and tensile capacity, but challenges include:

- Corrosion leading to durability deterioration
- High life-cycle costs (maintenance and repair)
- Carbon and energy cost of steel production

Fiber-reinforced concrete (FRC) aims to distribute tensile stresses through fiber bridging mechanisms, reducing dependence on conventional rebars.

3. Material Characteristics

3.1 Basalt Fibers

Basalt fibers are produced from melted basalt rock and possess:

- High tensile strength (~2.8–4.8 GPa)
- Good chemical and thermal resistance
- Non-corrosive nature
- Excellent bonding with cementitious matrix

3.2 Polypropylene Fibers

Polypropylene fibers are synthetic, thermoplastic micro-fibers with:

- Low density
- High impact resistance
- Good plastic shrinkage crack control
- Reduced permeability due to microcrack resistance
- Lower tensile strength compared to basalt, but effective in hybrid systems

4. Effect on Fresh Concrete Properties

Addition of fibers influences workability:

- **Basalt fibers** tend to reduce slump due to high surface area.
- **Polypropylene fibers** improve cohesion but also reduce workability if dosages are high.
- Use of **plasticizers** is often required to maintain workability.

5. Mechanical Performance

5.1 Compressive Strength

Inclusion of fibers generally **increases compressive strength**, though responses vary with fiber type and dosage.

5.2 Tensile and Flexural Strength

- Basalt fibers significantly improve tensile and flexural capacity due to high stiffness and bond strength.
- Polypropylene fibers improve tensile strain capacity and energy absorption but are limited in strength compared to basalt.
- **Hybridization** (combining basalt and polypropylene) often shows synergistic benefits.

5.3 Ductility and Toughness

Fiber reinforcement enhances post-cracking toughness and strain capacity due to fiber bridging effects across cracks.

6. Durability Performance

Fiber inclusion enhances:

- Crack resistance and reduced permeability
- Resistance to freeze–thaw cycles
- Improved impact resistance
- Reduced alkali-silica reaction propagation

Long-term durability is especially improved due to the **non-corrosive nature** of basalt and polypropylene fibers, making them superior to steel in aggressive environments.

7. Hybrid Fiber Systems

Combining basalt with polypropylene fibers can:

- Improve **both strength and toughness**
- Control micro- and macro-cracks simultaneously
- Enable tailored performance for specific applications

8. Practical Aspects and Implementation Challenges

8.1 Fiber Dispersion

Uniform dispersion is critical for performance. Clumping leads to weak zones.

8.2 Dosage Optimization

Excessive fiber content can reduce workability and negatively affect strength.

8.3 Standardization

Lack of design codes and guidelines prevents large-scale adoption. More testing and code development are required.

8.4 Cost Considerations

Basalt fiber cost is currently higher than steel and common fibers; however, lifecycle cost benefits may offset initial investment.

9. Future Research Directions

- Experimental studies on **full-scale structural elements** using basalt/polypropylene composites
- Optimization of hybrid fiber ratios
- Long-term durability studies in real environments
- Development of design methodologies and codes
- Life-cycle assessment (LCA) comparing steel-free systems with conventional RCC

3. CONCLUSIONS

Steel-free reinforced concrete using basalt and polypropylene fiber reinforcement shows promising potential as a sustainable and durable alternative to traditional steel reinforcement. These fibers enhance mechanical performance, ductility, and durability while addressing challenges related to corrosion and lifecycle maintenance. Continued research, standardization, and cost reduction will support broader implementation in the construction industry.

REFERENCES

1. ACI Committee 544, "State-of-the-Art Report on Fiber Reinforced Concrete," *American Concrete Institute*, 2019.
2. Brandt, A.M., "Fiber Reinforced Cement-based (FRC) Composites after Over 40 Years of Development in Building and Civil Engineering," **Composite Structures**, Vol. 86, pp. 3-9, 2008.
3. Bentur, A., and Mindess, S., "Fiber Reinforced Cementitious Composites," **CRC Press**, 2007.
4. Özbay, E., et al., "Mechanical Properties of Basalt Fiber Reinforced Concrete," **Construction and Building Materials**, Vol. 42, pp. 102-106, 2013.
5. Li, V.C., "On Engineered Cementitious Composites (ECC): A Review of Tensile Performance," **Cement and Concrete Composites**, Vol. 28, pp. 1-15, 2006.
6. Yoo, D.-Y., et al., "Flexural Behavior of Concrete Reinforced with Basalt Fiber," **Journal of Materials in Civil Engineering**, Vol. 29, No. 3, 2017.
7. Pantazopoulou, S.J., and Plati, C., "Response of Hybrid Fiber Concrete," **ACI Materials Journal**, Vol. 96, No. 4, pp. 373-381, 1999.