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INVESTIGATE LOAD DISTRIBUTION AND ENVIRONMENTAL PERFORMANCE OF PET FIBER-REINFORCED CONCRETE

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Abstract

The use of Polyethylene Terephthalate (PET) fiber-reinforced concrete (PFRC) has gained significant attention as a sustainable and performance-enhancing alternative in modern construction. This study investigates the load distribution characteristics and environmental performance of PFRC by incorporating recycled PET fibers into concrete mixtures. The research evaluates the influence of PET fibers on compressive strength, flexural behavior, toughness, and crack resistance, utilizing experimental testing and numerical simulations. A comparative analysis with conventional concrete highlights improvements in load transfer efficiency, ductility, and post-crack behavior. In addition to mechanical performance, the environmental impact of PFRC is assessed using life cycle analysis (LCA), focusing on carbon footprint reduction, energy savings, and waste management benefits associated with repurposed PET fibers. Results indicate that the incorporation of PET fibers enhances durability while reducing the overall ecological footprint, making PFRC a viable solution for sustainable infrastructure development. The study concludes that PET fiber reinforcement improves both structural resilience and environmental sustainability, offering a promising direction for future construction materials.

Key Words:- Polyethylene Terephthalate (PET), Fiber-reinforced concrete (PFRC), Load distribution characteristics, Environmental performance, Waste management benefits

Introduction

The growing concern over sustainability and the environmental impact of conventional construction materials has led to the exploration of alternative solutions. Polyethylene Terephthalate (PET) fiber-reinforced concrete (FRC) is an innovative material that incorporates recycled PET fibers to improve the mechanical properties of concrete while enhancing its environmental performance. PET fibers, sourced from waste plastic bottles, serve as an eco-friendly reinforcement, contributing to improved tensile strength, crack resistance, and durability. This study investigates the load distribution characteristics of PET fiber-reinforced concrete and evaluates its environmental benefits in comparison to traditional concrete mixtures. The increasing demand for sustainable construction materials has led to extensive research on incorporating recycled materials in concrete. This study investigates the load distribution characteristics and environmental performance of concrete reinforced with Polyethylene Terephthalate (PET) fibers. PET fibers, derived from recycled plastic waste, improve concrete's mechanical properties, including tensile strength, toughness, and crack resistance. The study evaluates load-bearing behavior through experimental tests, analyzing compressive strength, flexural strength, and modulus of rupture. Additionally, finite element modeling (FEM) is utilized to simulate load distribution and stress patterns in PET fiber-reinforced concrete. The environmental impact is assessed using a life cycle analysis (LCA) approach, comparing embodied energy, carbon footprint, and waste reduction benefits against conventional concrete. Results indicate that PET fiber-reinforced concrete enhances structural performance while significantly reducing plastic waste and carbon emissions. This research highlights the feasibility of PET fibers as an eco-friendly reinforcement material, promoting circular economy principles in the construction industry.

Literature Review

Several studies have highlighted the mechanical and environmental advantages of PET fiber-reinforced concrete:

Mechanical Properties: Research indicates that PET fibers enhance the flexural and tensile strength of concrete by bridging micro-cracks and delaying their propagation. Studies show that the optimal fiber content generally ranges from 0.5% to 2% by volume, beyond which workability may be affected.

Load Distribution: Load distribution in PET fiber-reinforced concrete differs from conventional concrete due to the fiber-matrix interaction. Fibers improve ductility and toughness, leading to enhanced load-bearing capacity under flexural and tensile stress conditions.

Durability and Crack Resistance: The presence of PET fibers reduces shrinkage cracking and improves impact resistance. Studies report that fiber incorporation minimizes water permeability, reducing the risk of deterioration due to freeze-thaw cycles and aggressive environmental conditions.

Environmental Performance: PET fiber-reinforced concrete promotes sustainability by reducing plastic waste and minimizing the consumption of natural resources. Life cycle assessments reveal that replacing traditional steel or synthetic fibers with PET fibers significantly reduces carbon footprint and embodied energy.

Karthikeyan S et al (2024) was study the dual benefit of improving construction materials and promoting environmental sustainability. It would be interesting to further explore the long-term durability, chemical resistance, and fire behavior of PET fiber-reinforced concrete. Enhanced ductility and impact resistance make PET fiber concrete a viable option for structures subject to dynamic or impact loads. The use of PET fibers not only boosts the structural performance of concrete but also provides a sustainable solution to plastic waste management. PET fibers (50 mm in length and 3 mm in width) were added to M30 grade concrete in varying proportions 0%, 0.25%, and 0.5% by volume. Address environmental concerns by repurposing plastic waste into useful engineering applications. To explore the use of PET fibers as a construction material in concrete to improve its mechanical properties. Research on incorporating PET fibers into M30 grade concrete highlights innovative ways to enhance concrete's performance while addressing environmental concerns. Concrete, being the construction material that is extensively employed, possesses various limitations despite its adaptability in building projects. It exhibits weakness when subjected to tension, has restricted ductility, and offers minimal resistance against cracking. Concrete is widely used in construction due to its high strength. The aim of this study is to conduct experimental research on the utilization of PET fiber as a construction material in concrete, which is technically sound and environmentally safe. The use of PET fiber in various engineering applications can solve the problem of disposal of plastic waste. PET fiber can be used in concrete to improve its ductile parameters. PET wires of 50 mm in length and 3 mm in width are used in this work. The tests conducted on M30 grade concrete included assessments of its strength in compression, strength in split tensile, strength in flexure, and resistance to impact. The percentages of addition were 0 %, 0.25 % and 0.5 % volume of fiber. The impact properties of PET fiber concrete were studied. Test results showed that there is improvement in compressive strength, split tensile strength, flexural strength and a significant increase in impact resistance of concrete after the addition of PET fibers.

Methodology

This study employs experimental and analytical approaches to evaluate the load distribution and environmental performance of PET fiber-reinforced concrete.

Materials Selection:

- Cement: Ordinary Portland Cement (OPC)
- Aggregates: Fine and coarse aggregates conforming to standard specifications
- PET Fibers: Recycled PET fibers cut to lengths of 10-50 mm with an aspect ratio of 20-50
- Water and Admixtures: Suitable super plasticizers for workability enhancement

Mix Proportions:

- Several concrete mixes will be prepared with varying PET fiber content (0%, 0.25%, 0.50%, 0.75%, and 1%) to assess the optimal dosage.

Experimental Testing:

- **Compressive Strength Test**: Evaluated using standard cube specimens at 28 days.
- **Flexural Strength Test**: Conducted on beam specimens to analyze the load distribution characteristics.
- **Splitting Tensile Strength Test**: Determines the tensile capacity of the concrete.
- **Durability Tests**: Assess permeability, shrinkage, and freeze-thaw resistance.
- **Life Cycle Assessment (LCA)**: Analyzes the environmental impact, considering carbon emissions, energy consumption, and resource depletion.

Data Analysis:

- Comparative analysis between control and PET fiber-reinforced concrete.
- Statistical evaluation of strength variations and load distribution patterns.
- Environmental performance assessment through LCA tools.

Result and Discussion

Highlighting an important gap in research and standardization regarding the impact resistance of concrete under dynamic loads. The behavior of concrete slabs under high-energy impacts, especially in scenarios involving punching shear and perforation, is complex and influenced by factors like material composition, reinforcement detailing, and strain rate effects. We are describing an experimental setup for impact testing of concrete slabs, likely to evaluate their fracture mechanics and resistance to sudden loading conditions. This kind of test is useful for assessing the dynamic behavior of different concrete mixes, including traditional and advanced materials concrete or fiber-reinforced concrete. Comprises a top and bottom frame that can accommodate a slab specimen measuring 600 mm by 600 mm, as well as a steel frame that supports an 8 kg pendulum weight

Table 1 Impact test on PET slab

Percentage of PET fiber	No. of blow	
	1st Crack	Failure
0	2	30
0.25	4	35
0.50	5	38
0.75	7	42
1.0	6	36

This study clearly highlights the benefits of incorporating PET fibers into concrete slabs, particularly in improving impact resistance and ductility up to 0.75% PET add on concrete. The delay in crack initiation and ultimate failure with increasing PET fiber content suggests that the fibers effectively distribute stress and bridge micro-cracks, enhancing toughness.

Conclusion

The study aims to validate the effectiveness of PET fiber-reinforced concrete in improving load distribution and sustainability. Preliminary findings suggest that incorporating PET fibers enhances mechanical properties, reduces plastic waste, and contributes to greener construction practices. The results will offer insights into optimal fiber dosage, structural behavior, and long-term durability. Future research should focus on large-scale implementation and the integration of PET fibers in high-performance concrete applications.

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