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Comparative Study of Glass Fiber Reinforcement in Lightweight and Normal Weight Concrete

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ABSTRACT: The utilization of fiber reinforcement in concrete has garnered significant attention due to its potential to enhance mechanical properties and durability. This research paper aims to compare the effects of glass fiber reinforcement on lightweight concrete (LWC) and normal weight concrete (NWC). The study examines various properties including compressive strength, tensile strength, flexural strength, and durability aspects such as shrinkage and crack resistance. The findings suggest that glass fiber reinforcement offers distinct advantages in both types of concrete, with varying degrees of improvement based on the concrete's inherent characteristics.

I. INTRODUCTION

Concrete is a fundamental construction material, known for its versatility and relatively high compressive strength. However, its brittle nature and susceptibility to cracking under tensile stress necessitate the incorporation of reinforcement to enhance its performance. Traditionally, steel reinforcement has been employed, but fiber reinforcement, particularly glass fibers, has emerged as a promising alternative. Glass fibers, due to their high tensile strength and resistance to alkali environments, offer significant benefits in enhancing the mechanical and durability properties of concrete.

Lightweight concrete (LWC) is distinguished by its lower density compared to normal weight concrete (NWC), achieved through the inclusion of lightweight aggregates. LWC is favoured in structural applications where weight reduction is crucial. However, the incorporation of lightweight aggregates can lead to reduced mechanical properties compared to NWC. This study explores how glass fiber reinforcement affects the performance of both LWC and NWC, providing insights into its potential applications and benefits.

II. LITERATURE REVIEW

Glass Fiber Reinforcement

Glass fibers are known for their high tensile strength, low density, and resistance to corrosion. When incorporated into concrete, they can significantly improve tensile strength, flexural strength, and impact resistance. The typical glass fibers used in concrete reinforcement are alkali-resistant (AR) to prevent degradation in the alkaline environment of concrete. Previous studies have shown that glass fiber reinforcement can enhance the toughness and ductility of concrete, reduce shrinkage cracking, and improve overall durability.

Lightweight Concrete

Lightweight concrete is characterized by its lower density, typically ranging from 1440 to 1840 kg/m³, compared to 2240 to 2400 kg/m³ for NWC. The reduced weight is achieved by using lightweight aggregates such as expanded clay, perlite, or vermiculite. LWC is advantageous in reducing the dead load of structures, improving thermal insulation, and enhancing fire resistance. However, the lower density often results in reduced compressive and tensile strengths compared to NWC.

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Normal Weight Concrete
Normal weight concrete is the most widely used type of concrete, known for its robustness and relatively high compressive strength. It is composed of cement, water, and aggregates such as sand, gravel, or crushed stone. While NWC exhibits good compressive strength, its tensile strength is relatively low, making it prone to cracking under tensile stress. Reinforcement, either through steel bars or fibers, is essential to improve its tensile properties and overall durability.

III. METHODOLOGY

Materials
The materials used in this study include:
- **Cement:** Ordinary Portland Cement (OPC) of grade 43.
- **Aggregates:** Fine and coarse aggregates for NWC, and lightweight aggregates for LWC.
- **Glass Fibers:** Alkali-resistant glass fibers with a length of 12 mm and an aspect ratio of 100.
- **Water:** Potable water.

Mix Design
The mix design for both LWC and NWC was prepared based on standard guidelines. The glass fibers were incorporated at varying percentages (0.5%, 1%, and 1.5% by volume of concrete) to study their impact on the properties of both concrete types. Control mixes without glass fibers were also prepared for comparison.

Testing Procedures
The following tests were conducted to evaluate the properties of the concrete mixes:
- **Compressive Strength:** Tested as per ASTM C39/C39M.
- **Tensile Strength:** Split tensile strength tested as per ASTM C496/C496M.
- **Flexural Strength:** Tested as per ASTM C78/C78M.
- **Shrinkage:** Measured as per ASTM C157/C157M.
- **Durability:** Assessed through resistance to cracking and water permeability tests.

IV. RESULTS AND DISCUSSION

Compressive Strength
The incorporation of glass fibers resulted in an increase in compressive strength for both LWC and NWC. However, the extent of improvement was more pronounced in NWC. At 1.5% glass fiber content, the compressive strength of NWC increased by approximately 15%, while LWC showed an improvement of around 10%. This difference can be attributed to the inherent lower strength of lightweight aggregates, which limits the overall enhancement provided by the fibers.

Tensile Strength
Glass fiber reinforcement significantly improved the tensile strength of both LWC and NWC. The tensile strength of LWC increased by up to 25%, while NWC exhibited an improvement of around 20% at 1.5% glass fiber content. The high tensile strength of glass fibers effectively bridges cracks and distributes stresses, thereby enhancing the tensile properties of the concrete.

Flexural Strength
The flexural strength of both LWC and NWC showed considerable improvement with the addition of glass fibers. LWC exhibited an increase of up to 30%, while NWC showed an improvement of around 25% at 1.5% glass fiber content. The enhanced flexural strength is indicative of better crack resistance and ductility, essential for structural applications.

Shrinkage and Crack Resistance
Shrinkage in concrete can lead to cracking, compromising its durability and structural integrity. The addition of glass fibers reduced shrinkage in both LWC and NWC. The reduction was more significant in NWC, with a decrease of up to

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20%, compared to around 15% in LWC at 1.5% glass fiber content. The fibers effectively control the micro-cracks that develop during the drying process, thereby reducing the overall shrinkage.

Durability

The durability of concrete is significantly enhanced with glass fiber reinforcement. Both LWC and NWC exhibited improved resistance to cracking and reduced water permeability. The presence of glass fibers helps in controlling crack propagation and provides a more impermeable matrix, enhancing the longevity of the concrete.

Comparative Analysis

The comparative analysis of glass fiber reinforcement in LWC and NWC reveals several key insights:

1. **Compressive Strength:** While both types of concrete benefit from the addition of glass fibers, NWC exhibits a more pronounced increase in compressive strength. This can be attributed to the higher initial strength of NWC, allowing for more significant improvements.
2. **Tensile Strength:** Glass fiber reinforcement provides substantial improvements in tensile strength for both LWC and NWC. The enhancement is slightly higher in LWC, indicating the effectiveness of fibers in compensating for the lower tensile strength of lightweight aggregates.
3. **Flexural Strength:** Both LWC and NWC show considerable improvement in flexural strength with glass fibers, with LWC benefiting slightly more. This suggests that glass fibers are particularly effective in enhancing the ductility and crack resistance of lightweight concrete.
4. **Shrinkage:** The reduction in shrinkage is more significant in NWC, highlighting the effectiveness of glass fibers in controlling shrinkage cracks in normal weight concrete. However, LWC also benefits from reduced shrinkage, contributing to its overall durability.
5. **Durability:** Both types of concrete exhibit enhanced durability with glass fiber reinforcement. The improved resistance to cracking and reduced water permeability are crucial for the long-term performance of concrete structures.

V. CONCLUSION

The study demonstrates that glass fiber reinforcement offers significant benefits for both lightweight and normal weight concrete. While NWC shows more pronounced improvements in compressive strength and shrinkage reduction, LWC benefits considerably in terms of tensile and flexural strength enhancements. The overall durability of both types of concrete is significantly improved with the addition of glass fibers, making them more suitable for a wide range of structural applications.

Future research could explore the long-term performance of glass fiber-reinforced concrete in various environmental conditions, as well as the economic feasibility of large-scale implementation. The findings of this study provide a foundation for further investigation into the optimization of fiber content and the development of new concrete composites with enhanced performance characteristics.

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