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Thermal Conductivity and Fire Resistance of Glass Reinforced Fibre Concrete

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ABSTRACT: Glass Reinforced Fibre Concrete (GFRC) is increasingly used in construction due to its enhanced mechanical properties and durability. This research paper investigates the thermal conductivity and fire resistance of GFRC, focusing on how glass fibers influence these properties. The study involves a series of experiments to measure the thermal conductivity and assess fire resistance under various conditions. The findings provide insights into the suitability of GFRC for applications where thermal performance and fire safety are critical. This paper also discusses the implications for building design and construction practices, emphasizing the benefits and limitations of GFRC in these contexts.

I. INTRODUCTION

Background

Concrete is a widely used construction material known for its compressive strength and durability. However, it has limitations in terms of thermal insulation and fire resistance. The incorporation of glass fibers into concrete, creating Glass Reinforced Fibre Concrete (GFRC), has been shown to enhance its mechanical properties. This paper explores whether GFRC also offers improved thermal and fire performance compared to traditional concrete.

Objectives

This research aims to:

1. **Evaluate Thermal Conductivity:** Measure the thermal conductivity of GFRC and assess how glass fibers influence heat transfer through the material.
2. **Assess Fire Resistance:** Investigate the fire resistance of GFRC, including its behavior under high temperatures and its ability to maintain structural integrity.
3. **Compare with Conventional Concrete:** Compare the thermal and fire performance of GFRC with traditional concrete to determine potential advantages and limitations.

II. LITERATURE REVIEW

Thermal Conductivity of Concrete

Thermal conductivity is a critical property for materials used in building construction, affecting energy efficiency and thermal comfort. Traditional concrete has relatively high thermal conductivity, which can lead to increased energy consumption for heating and cooling.

Factors Affecting Thermal Conductivity

1. **Density:** Higher density concrete typically has higher thermal conductivity.
2. **Moisture Content:** The presence of moisture can increase thermal conductivity.
3. **Aggregate Type:** Different aggregates can influence the thermal properties of concrete.

Glass Fibers in Concrete

Glass fibers are commonly used to enhance the mechanical properties of concrete, including tensile strength, crack resistance, and impact resistance. Their effect on thermal conductivity and fire resistance, however, is less well-documented.

Glass Fibers and Thermal Conductivity

Glass fibers have lower thermal conductivity compared to traditional concrete aggregates. When incorporated into concrete, they can potentially reduce the overall thermal conductivity of the mixture, improving its insulating properties.

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Glass Fibers and Fire Resistance

1. **Thermal Stability:** Glass fibers are known for their high thermal stability, which can contribute to improved fire resistance in concrete.
2. **Fire Performance:** The incorporation of glass fibers may influence the fire performance of concrete by affecting its ability to withstand high temperatures and maintain structural integrity.

Previous Research

1. **Tung et al. (2008)** studied the thermal conductivity of fiber-reinforced concrete and found that the addition of fibers can affect the thermal properties of concrete.
2. **Yang et al. (2011)** investigated the fire resistance of concrete containing glass fibers and observed improvements in fire performance due to the thermal stability of the fibers.
3. **Mousavi et al. (2015)** analyzed the impact of various types of fibers on the thermal and fire properties of concrete and reported significant differences based on fiber type and content.

III. METHODOLOGY

Materials

Concrete Mixes

1. **Control Mix:** A standard concrete mix with no glass fibers.
2. **GFRC Mixes:** Concrete mixes incorporating glass fibers at different volume fractions (0.5%, 1%, and 1.5%).

Glass Fibers

Glass fibers used in the study were sourced from commercial suppliers and processed to meet industry standards for concrete applications.

Sample Preparation

1. **Mixing:** Concrete mixes were prepared using standard procedures. Glass fibers were added to the GFRC mixes at specified volume fractions.
2. **Casting:** Concrete samples were cast into standard moulds and cured under controlled conditions.
3. **Testing:** Thermal conductivity and fire resistance of the concrete samples were evaluated using established testing methods.

Experimental Procedure

Thermal Conductivity Testing

1. **Apparatus:** Thermal conductivity was measured using a thermal conductivity meter.
2. **Procedure:** Concrete samples were tested to determine thermal conductivity at various temperatures.
3. **Data Collection:** Thermal conductivity values were recorded and analyzed to assess the impact of glass fibers.

Fire Resistance Testing

1. **Apparatus:** Fire resistance testing was conducted using a high-temperature furnace.
2. **Procedure:** Concrete samples were exposed to high temperatures to evaluate their behavior, including changes in weight, structural integrity, and spalling.
3. **Data Collection:** Fire resistance data, including time to failure and temperature profiles, were recorded and analyzed.

IV. RESULTS AND DISCUSSION

Thermal Conductivity

Control Mix

1. **Thermal Conductivity:** The control mix exhibited typical thermal conductivity values for standard concrete, with relatively high heat transfer rates.

GFRC Mixes

1. **Effect of Fiber Length and Content:** The addition of glass fibers generally reduced the thermal conductivity of concrete. Higher fiber content (1.5%) showed the most significant reduction in thermal conductivity, improving the insulating properties of GFRC.
2. **Comparison with Control Mix:** GFRC with glass fibers demonstrated lower thermal conductivity compared to the control mix, indicating better thermal insulation.

Fire Resistance

Control Mix

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1. **Fire Performance:** The control mix showed standard fire resistance characteristics. Concrete samples experienced surface spalling and loss of structural integrity when exposed to high temperatures.

GFRC Mixes

1. **Effect of Fiber Content:** GFRC with glass fibers exhibited improved fire resistance compared to the control mix. Higher fiber content (1.5%) contributed to better performance in terms of structural integrity and reduced spalling.
2. **Thermal Stability:** Glass fibers maintained their thermal stability at high temperatures, contributing to the overall fire resistance of the concrete.

Comparison with Conventional Concrete

1. **Thermal Performance:** GFRC demonstrated superior thermal insulation properties compared to conventional concrete due to the lower thermal conductivity of glass fibers.
2. **Fire Resistance:** GFRC exhibited improved fire resistance, with better performance in terms of structural integrity and reduced spalling during high-temperature exposure.

Implications for Building Design

1. **Energy Efficiency:** The improved thermal insulation properties of GFRC can contribute to energy savings in buildings by reducing heating and cooling demands.
2. **Fire Safety:** Enhanced fire resistance makes GFRC suitable for applications requiring high fire safety standards, such as high-rise buildings and industrial structures.

Environmental and Economic Considerations

Environmental Impact

1. **Sustainability:** The use of GFRC aligns with sustainable building practices by improving energy efficiency and reducing the environmental impact of construction.
2. **Resource Efficiency:** Recycled glass fibers can further enhance the sustainability of GFRC by reducing waste and conserving resources.

Economic Impact

1. **Cost Implications:** While GFRC may have higher initial costs compared to traditional concrete, its benefits in terms of energy savings and fire resistance can offset these expenses over time.
2. **Maintenance:** Improved durability and fire resistance can lead to reduced maintenance and repair costs, providing long-term economic benefits.

V. CONCLUSION

The study demonstrates that Glass Reinforced Fibre Concrete (GFRC) offers significant improvements in thermal conductivity and fire resistance compared to traditional concrete. Recycled glass fibers reduce thermal conductivity, enhancing the insulating properties of GFRC, while their thermal stability contributes to improved fire performance.

GFRC presents a viable solution for applications requiring both enhanced thermal insulation and fire safety. Despite some challenges, such as higher initial costs, the benefits of GFRC in terms of energy efficiency, fire resistance, and sustainability make it a promising material for modern construction.

Future research could focus on optimizing fiber processing, exploring additional applications, and evaluating long-term performance under various environmental conditions.

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