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FIBER REINFORCED CONCRETE

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Abstract - Fiber-reinforced concrete (FRC) has piqued interest in civil engineering in the few recent years because of its ability of improving weak tensile strength and shrinkage cracks of concrete. There are many possibilities in the research field for FRC. This paper reviews, summarizes and compares the current and past researches on FRC. Based on the main research achievements on FRC in recent years, this paper compiles and briefs the existing theoretical research FRC materials and related topics to facilitate the reference of researchers in the same field.

Introduction

1.1. GENERAL INTRODUCTION

In 1849, a French gardener named Joseph Monier invented the reinforced concrete.

Concrete is the most commonly used and is a versatile building material. The advantages of concrete are high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. Its requirement is at high stake nowadays. However, compared to other materials like polymers and metals, Concrete is much brittle and has a poor tensile strength. On the basis of fracture toughness value, steel is approximately 100 times more crack resistant than concrete. Concrete in service is prone to more corrosion, saturation, scaling, discoloration, and other effects.

The addition of fiber in the concrete matrix helps in gaining superior fracture strength, toughness, impact resistance, flexural strength, fatigue resistance - which is also the primary reason for adding fibers to the matrix. This paved the way for fiber reinforced concrete (FRC).

2. MATERIAL COMPOSITION AND PROPERTIES

FRC contains small fibrous materials that distribute uniformly and oriented randomly. FRC is a mixture of cement, concrete, and discontinuous, discrete and uniformly dispersed short fibers. FRC has top-notch thermo-mechanical properties over conventional concrete. The notable mechanical properties of FRC are high fracture toughness, flexural strength, high compressive and tensile strength, high first-crack strength, great impact resistance, and excellent energy absorption capacity with reduced internal pores.

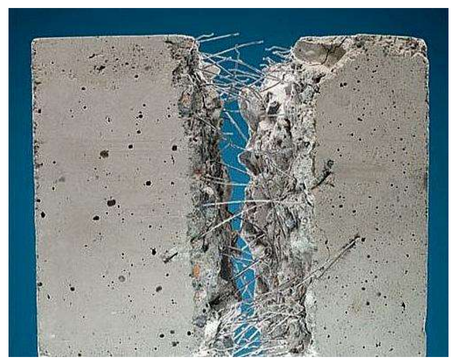

FIGURE – 1: FIBER REINFORCED CONCRETE

3. TYPES OF FRC

The kinds of fibers used are primarily classified as: steel, synthetic glass, and organic or natural fibers.

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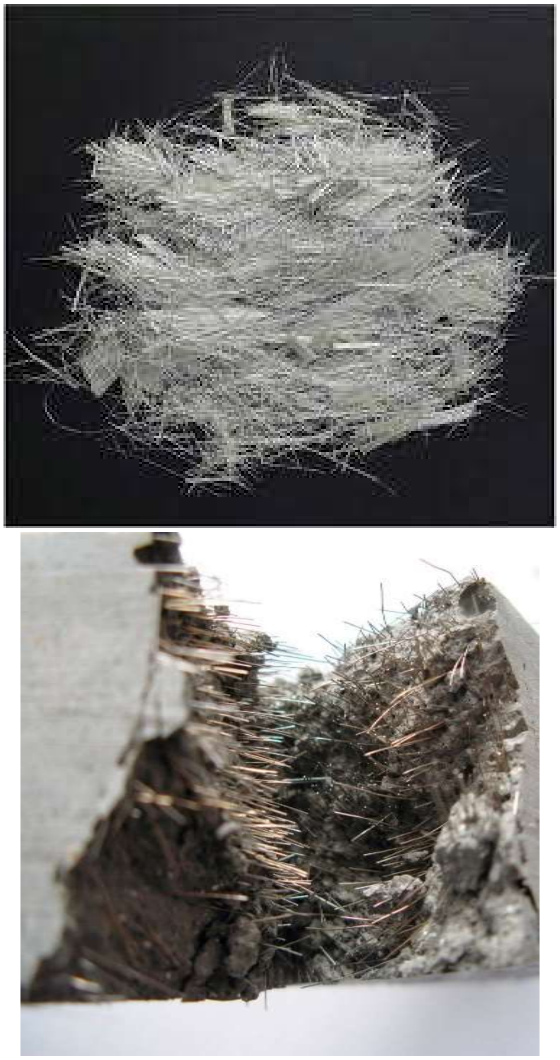

FIGURE – 2: STEEL, GLASS, AND NATURAL FIBERS IN REINFORCEMENT

3.1. Some common types of fibers are:

Cellulose Fibers – They are manufactured from processed wood pulp products. The control and reduction of plastic shrinkage cracking is attained with this.

Glass Fibers - GFRC is a primarily used material in architecture and panel structures made of cement.

Macro-Synthetic Fibers - These became known in the recent few decades as a suitable substitute to steel fibers with proper proportioning. Materials like polypropylene and other polymer blends that has similar physical characteristics are typically used as steel fibers. They vary from 3 to 20 lbs/yd (1.8 to 12 kg/m3).

Micro-Synthetic Fibers: These fibers are generally used for the protection and mitigation of plastic shrinkage cracking in concrete. Most are manufactured from polypropylene, polyethylene, polyester, nylon and other synthetic materials, such as carbon, aramid and acrylics. Micro-synthetic fibers are generally dosed at low volumes ranging from 0.03 to 0.2% by volume of concrete – 0.5 to 3.0 lbs/yd (0.3 to 0.9 kg/m3).

Natural Fibers: These fibers include naturally available materials such as coconut, jute, sugarcane, and sisal. They come in varying lengths, geometries and material characteristics.

Poly-Vinyl Alcohol (PVA) Fibers: These are synthetic-made fibers that can alter the flexural and compressive performance of concrete when used at higher volumes.

Specialty Fibers: Covering all the above fiber types, this classification generally relates to newly manufactured or specified materials that do not belong to these categories.

Steel Fibers: These fibers are generally used for providing concrete with enhanced toughness and post-crack load carrying capacity. They are usually made from carbon or stainless steel, typically loose or bundled, and then shaped into varying geometries such as crimped, and hooked-end 15. Steel fibers have maximum lengths ranging from 1.5” to 3” (30 to 80 mm) and can be dosed at 10 to 100 lbs/yd (6 to 67 kg/m3).

4. MIXING TECHNIQUES

There are two primary ways to mix fibers to the concrete matrix. They are: Dry-mix and wet-mix. The methods are chosen based on whether the fibers are mixed with the aggregates and cement before or after the raw materials are combined with water. These methods vary depending on the type of fiber used as synthetic and steel fibers having separate handling requirements.

4.1.DRY-MIX METHOD:
In this method, the fibers are added to the raw materials such as dry aggregates (sand and gravel) and cement before any water is introduced.

This method involves adding the coarse aggregates first, then the fibers and lastly, fine aggregate and cement. As the mixer starts, this layering prevents the clumping of fibers (bailing). After the addition of fibers, the dry materials are mixed for almost a minute to scatter the fibers before adding water.

This method is effective for various fibers and can be performed at a ready-mix plant or on-site.

4.2.WET-MIX METHOD:

In this method, the fibers are added to the raw materials after the concrete has already been wetted and mixed. This is common in adding fibers to a ready-mix truck on-site.

The raw materials are added first in the truck mixer and then the fibers are added gradually.

Then the mixer is let to run at a high speed for several minutes (approximately 5–7 minutes) to ensure proper dispersion. Water-reducing admixtures or superplasticizers are added to the mixture along with the fibers after adding ample amount of water without adding more water as fibers can decrease the workability or slump of the concrete.

5. ARCHITECTURAL AND STRUCTURAL APPLICATIONS

FRC has Improved durability, crack resistance, and aesthetic finishes which makes it famous among residential developers. Structural Elements: Foundations: FRC material gives a stronger and more crack resistant foundation in residential buildings. Walls: FRC is used in walls to improve their load bearing capacity and resistance to cracking and moisture. Roofs: FRC roofs offer excellent weather resistance for Indian climates from Rajasthan's heat to Kerala's rains. Its high load bearing capacity, reduced maintenance costs, and resistance to wear and tear makes it suitable for floors and slabs in commercial buildings as well.

5.1. ARCHITECTURAL EXAMPLES:

- Heydar Aliyev Cultural Center, Baku, Azerbaijan

Designed by Zaha Hadid, the fluid and sculptural form of this building is a prime example of FRC's architectural potential. Material use: Glass Fiber Reinforced Concrete (GFRC) panels were the primary material used for the façade. It was chosen as it has a high durability and ability to be moulded into complex, double-curved shapes with minimal joints.

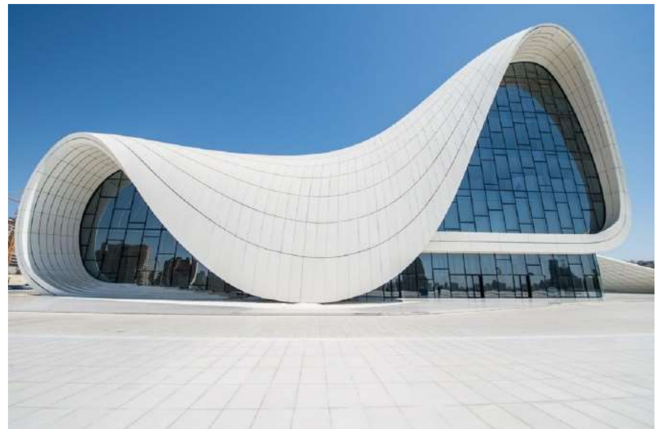

FIGURE – 3: HEYDER ALIYEV CULTURAL CENTER, AZERBAIJAN

- Cube House, Germany

The Cube House uses carbon fiber-reinforced concrete (CFRC) to form its key structural elements. Material use: CFRC is used in the precast elements as it allows the building to have distinctive and complex geometry.

FIGURE – 4: CUBE HOUSE, GERMAN

- Long Museum, Shanghai, China

This museum, designed by Atelier Deshaus, is built as a historical bridge and features dramatic, cantilevering concrete structures. Material use: FRC is used for its enhanced strength and flexural properties which makes it suitable for the bold cantilevered forms, which make up for the limitations of traditional concrete.

FIGURE – 5: LONG MUSEUM, CHINA

6. ENVIRONMENTAL ASPECTS

The most important advantages, on the basis of environment, of FRC is that it is able to reduce the need for conventional steel reinforcement. Production of steel is energy demanding and generates high level of greenhouse gas emissions. Adding reinforcement fibers (steel fibers) directly to the concrete mix can reduce the need for reinforcing fabric in some applications.

Giving Waste a Second Life: Recycled and Reused Fibers. Nowadays, reinforcement fiber are being made from reused materials. For example, decommissioned wind turbined plates post-consumer plastics, and even recycled steel.

7. INNOVATIONS

7.1. GRAPHENE FIBER REINFORCED CONCRETE (GNFRC) – A few tests prove that graphene improves the compressive strength of the concrete to the highest average value because of its synergistic effect and the combination of steel and polypropylene fibers.

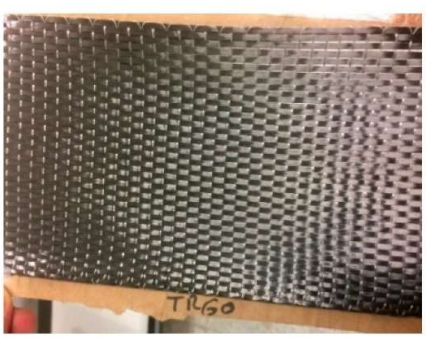

FIGURE – 6: GRAPHENE FIBER REINFORCEMENT

7.2. NANO CELLULOSE FIBERS (NCFs) – NCFs are another type of reinforcement materials that sparked an interest in recent years due to their high hydrogen capabilities. They carry cellulose properties like biodegradability, renewability, and sustainability.

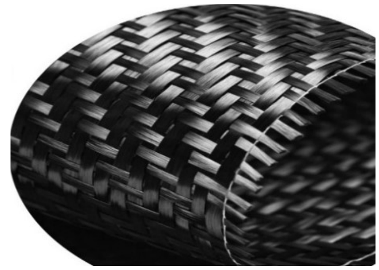

FIGURE – 7: NANO CELLULOSE FIBER REINFORCEMENT

CONCLUSION:

FRC, addition of fibers in concrete matrix, plays an important role in making the versatile material, concrete into a more flexible, economical, environment-friendly, and less brittle material with higher tensile strength. Usage of FRC makes a complex geometric structure withstand the loads for an extended period of time than the conventional concrete. Since the researches on FRC are yet to be continued, the material might become the next versatile and most commonly used mainly due to its characteristics.

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