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Comparison Based Analysis on Plain & Fibre Reinforced Concrete

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ABSTRACT

This investigation is done to analyse the properties of fibre reinforced composite concrete of natural fibres and rounded steel fibres in a comparative based study for both standard concrete(SC) as well as fibre reinforced(FRC) concrete of high strength. In both SC and FRC, as the fibre amount is increased there is appreciable decrement in the workability as the fibre content is raised. Studies have been done on both type of FRC i.e. Normal Strength Concrete (NSC) and High Strength Concrete(HSC).In NSC, the compressive strength test has shown that the strength reduces in comparison to that of plain standard concrete for both types of fibres. In HSC, the compressive strength was found to be decreased as compared to plain concrete for coconut coir fibre and also decreases for increasing fibre volume dosage rate while it increases for steel fibre for increasing fibre dosage rate. It is also seen that upto a certain extent, increase in fibre content increases the compressive strength up to a certain extent(approximately 35% increment observed) then with further increasing fibre content, the compressive strength starts decreasing. This research has shown that addition of coconut coir fibres in both type of concrete does increase the ductility, toughness as well as impact resistance of concrete, whereas it is observed that there is a significant decrement in the workability of fresh concrete due to these fibres. The reduction in workability can however be overcome by using different admixtures such as plasticizers and super plasticizers which helps in releasing water from the gel pores of the cement particles.

INTRODUCTION

Concrete is a construction material composed of cement as well as other cementations materials such as fly ash and slag content, aggregate (generally a coarse aggregate such as gravel, limestone, or granite, plus a fine aggregate such as river sand), water, and chemical admixtures. Apart from its excellent properties, concrete shows a rather low performance when subjected to tensile stress. Another rather recent development is steel fibre reinforced concrete (SFRC). The concept of using fibres as reinforcement is not new. Fibres have been used as reinforcement since ancient times. The initial application of fibres in concrete incorporated the usage of asbestos in the fibre reinforced concrete which was very easily available in many countries and was also a cheap and promising fibre in relation to the strength it provides to the FRC. But later it was found that there were many toxic effects of asbestos on human being and the environment of asbestos constructed materials leads to development of lung cancer in human beings. Hence it is now an outdated material to be used as a fibre. Many other types of fibres are now developed which imparts greater strength (tensile, impact, compressive) to the FRC.

Effect of fibres in concrete

Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete.

The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fibre is higher than that of the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material.

LITERATURE REVIEW

Fibre Reinforced Concrete

Since ancient times, fibres have been used to reinforce brittle materials. Straw was used to reinforce sun baked bricked bricks, and horse hair was used to reinforce masonry mortar and plaster. In modern times, a wide range of engineering materials including ceramics, plastic, cement and gypsum products incorporate fibres to enhance the composite properties. The composite properties include flexural strength, compressive strength, crack control, durability, and shrinkage and fire resistance.

Fibre reinforced concrete is an enhanced crack resistant and relatively ductile concrete, produced by using different types of fibres like polyester, polypropylene, glass and steel etc. that minimizes the problems of plastic shrinkage cracks of the concrete and sustainability improves its static and dynamic properties like the Flexural impact and Tensile strength. The newly developed FRC named as Engineered Cementations Composite (ECC) is 500 times more resistant to cracking and 40 percent lighter than traditional concrete. ECC can sustain strain-hardening up to several percent strain, resulting in a material ductility of at least two orders of magnitude higher when compared to normal concrete or standard fibre reinforced concrete. ECC also has unique cracking behaviour. When loaded to beyond the elastic range, ECC maintains crack width to below 100 µm, even when deformed to several percent tensile strains.

Recent studies performed on a high-performance fibre-reinforced concrete in a bridge deck found that adding fibres provided residual strength and controlled cracking. By adding steel fibres while mixing the concrete, a so-called homogeneous reinforcement is created. This does not notably increase the mechanical properties before failure, but governs the post failure behaviour. Thus, plain concrete, which is a quasi-brittle material, is turned to the pseudo ductile steel fibre reinforced concrete.

Table 1: Typical Properties of Different Types of Fibres

Type of fibre	**Tensile strength(x 10^3MPa)**	**Young's modulus(x 10^5MPa)**	**Ultimate elongation(percent)**	**Specific gravity**
Asbestos	0.56-0.98	0.84-1.40	0.60	3.20
Carbon	2.10-2.80	2.81-4.22	0.5-1.00	2.00
Cotton	0.42-0.70	0.049	3.00-10.00	1.50
Glass	1.05-3.87	0.70	1.50-3.50	2.50
Nylon	0.77-0.84	0.04	16.00-20.00	1.10
Steel	0.28-4.22	2.03	0.50-3.50	7.86

Fibre Reinforced Versus Unreinforced Concrete

Unreinforced concrete has a low tensile strength and low strain capacity at fracture. These shortcomings are overcome by addition of reinforcing bars or prestressing steel. Reinforcing steel is continuous and is located in the structure to enhance performance. Fibres are discontinuous and are generally distributed randomly throughout the concrete matrix.

Because of the flexibility in methods of fabrication, fibre reinforced concrete can be an economic and useful construction material. For example, thin (13 to 20mm) precast glass fibre reinforced concrete is used in cladding panels. In slabs, tunnelling and excavation support applications, steel and synthetic fibre reinforced concrete and shotcrete have been used.

Types of Fibres

There are numerous fibre types available for commercial and experimental use. The basic fibre categories are:-

Steel fibre
Glass fibre
Synthetic fibre
Natural fibre
Asbestos fibre
Carbon fibre

These fibres further include their sub type fibres for ex. Polyester, Amarid, Acrylic, Polypropylene, coconut coir, Bamboo, Jute, Stainless Steel, Sisal, Polyethylene fibres etc.

Properties of Freshly Mixed SFRC

The properties of SFRC in its freshly mixed state are influenced by the aspect ratio of the fibre, fibre geometry, its volume fraction, the matrix proportions, and the fibre-matrix interfacial bond characteristics. For conventionally placed SFRC applications, adequate workability should be insured to allow placement, consolidation, and finishing with a minimum of effort, while providing uniform fibre distribution and minimum segregation and bleeding. For a given mixture, the degree of consolidation influences the strength and other hardened material properties, as it does for plain concrete. In the typical ranges of volume fractions used for cast in-place SFRC (0.25 to 1.5 volume per cent), the addition of steel fibres may reduce the measured slump of the composite as compared to a non-fibrous mixture in the range of 1 to 4 in. (25 to 102 mm).

The tendency of a SFRC mixture to produce balling of fibres in the freshly mixed state has been found to be a function of the maximum size and the overall gradation of the aggregate used in the mixture, the aspect ratio of the fibres, the volume fraction, the fibre shape, and the method of introducing the fibres into the mixture. The larger the maximum size aggregate and aspect ratio, the less volume fraction of fibres can be added without the tendency to ball.

Properties of Hardened SFRC Composite

In compression, the ultimate compressive strength of concrete by the presence of fibres, increases ranging from 0 to 15 per cent for up to 1.5 per cent by volume of fibres.

In direct tension, the improvement in strength is significant. The strength increases from 30 to 40 per cent for addition of fibre up to 1.5 per cent by volume in mortar or concrete.

Static friction, skid, and rolling resistance of SFRC and identical plain concrete cast into laboratory-size slab samples were compared in a simulated skid test. The SFRC had 3/8 in. (9.5 mm) maximum size aggregates. Test results showed that the coefficient of static friction for dry concrete surfaces, with no wear, erosion, or deterioration of the surface, was independent of the steel fibre content. After simulated abrasion and erosion of the surface, the steel fibre reinforced surfaces had up to 15 per cent higher skid and rolling resistance than did plain concrete under dry, wet, and frozen surface conditions. The laboratory tests have been performed on cracked fibre concrete sample in saturated chloride environment. It is observed that if the crack is less than 0.1mm, no corrosion takes place. Whereas if the crack is more than 0.1mm the corrosion takes place through cracks. To reduce the potential for corrosion at cracks alloyed carbon steel fibres, stainless steel fibres, or galvanised carbon steel fibres are used.

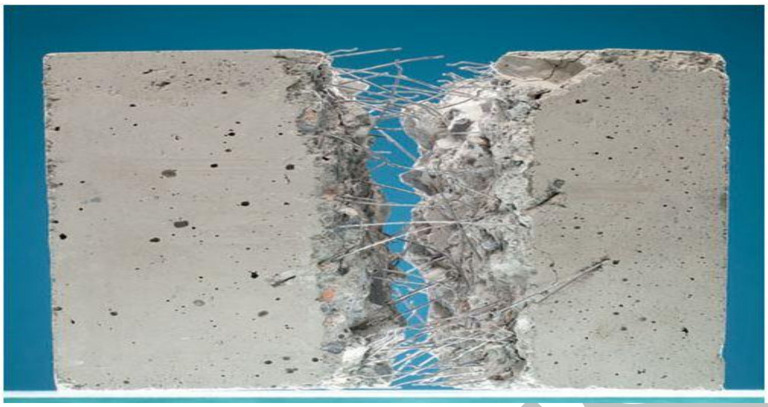

Figure 1. SFRC Sample

APPLICATIONS

Cast in place applications

- Repairs and new constructions on major dams and hydraulic structures to provide resistance to erosion and cavitation.
- Repair and rehabilitation of marine structures like piles and caissons.
- Used in highway paving.
- Application of steel fibres along with roller compacted concrete (RCC) mix improves the material properties.

Precast application

- SFRC is used in Europe to precast complete automobile garages for single family residences.
- It is used to replace traditional reinforcement in tilt up panels up to 24 feet high.

DISCUSSIONS-

I.COMPARISON OF SC AND FRSC FOR COMPRESSIVE STRENGTH

The compressive strength of SC (standard concrete) and FRSC (fibre reinforced standard concrete) specimens exposed to different elevated temperature is expressed as percentage of 28 days compressive strength of SC (standard concrete) at room temperature. The variation of compressive strength with temperature has been plotted as shown in Fig-1

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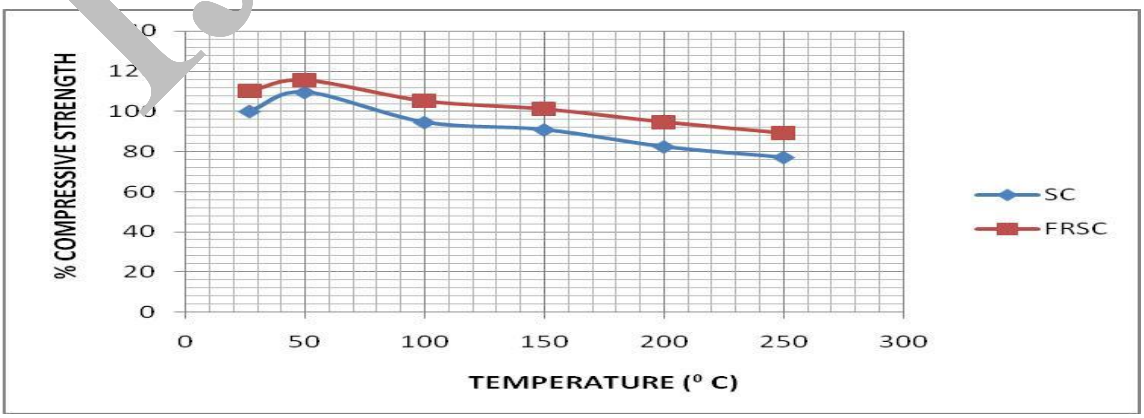

Fig. 1 Comparison of variation compressive strength with temperature for SC and FRSC

From Fig 1, it can be observed that FRSC exhibits more compressive strength than the SC at the all temperatures. As the temperature is increased FRSC maintained low decrement profile than SC resulting in more percentage compressive strengths after 100^0C. The difference between compressive strength of FRSC and SC varies in the range is 6-10 percentage.

II. COMPARISON OF SC AND FRSC FOR SPLIT TENSILE STRENGTH

The split tensile strength of SC (standard concrete) and FRSC (fibre reinforced standard concrete) specimens exposed to different elevated temperature is expressed as percentage of 28 days compressive strength of SC (standard concrete) at room temperature. The variation of compressive strength with temperature has been plotted as shown in Fig-2.

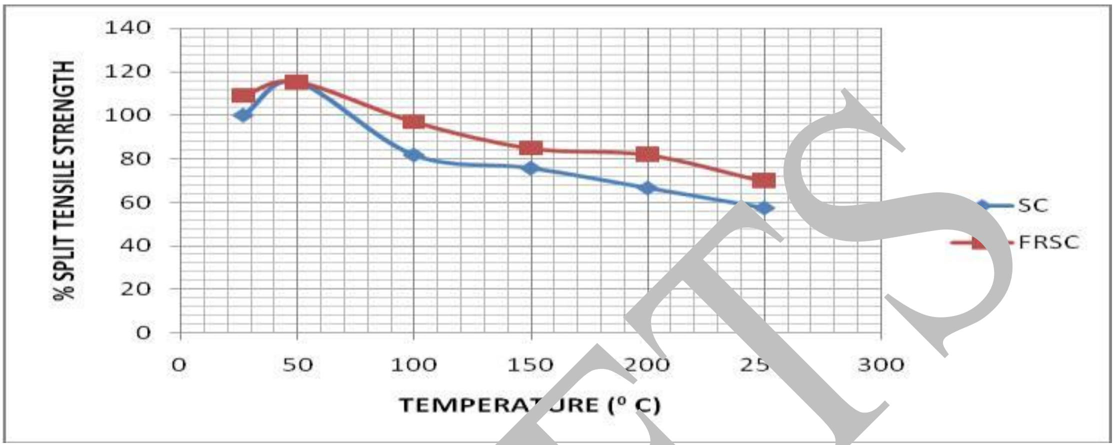

Fig. 2 Comparison of variation split tensile strength with temperature for SC and SFRC

From Fig 2, it can be observed that FRSC exhibits more split tensile strength than the SC at the all temperatures. As the temperature is increased FRSC maintained low decrement profile than SC resulting in more percentage split tensile strengths after 100^0C. The difference between split tensile strength of FRSC and SC varies in the range is 0-12 percentage.

III.COMPARISON OF SC AND FRSC FOR FLEXURAL STRENGTH

The flexural strength of SC (standard concrete) and FRSC (fibre reinforced standard concrete) specimens exposed to different elevated temperature is expressed as percentage of 28 days compressive strength of SC (standard concrete) at room temperature. The variation of compressive strength with temperature has been plotted as shown in Fig-3.

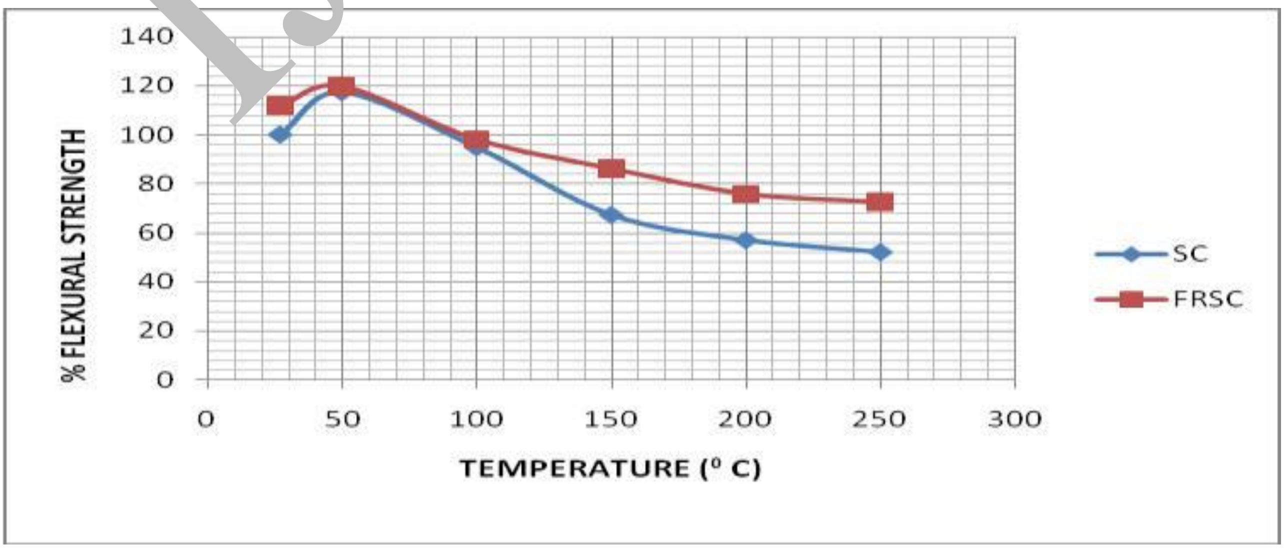

Fig. 3 Comparison of variation flexural strength with temperature for SC and FRSC

From Fig 3, it can be observed that FRSC exhibits more flexural strength than the SC at the all temperatures. As the temperature is increased FRSC maintained low decrement profile than SC resulting in more percentage flexural strengths after 100^0C. The difference between flexural strength of FRSC and SC varies in the range is 0-20 percentage.

CONCLUSION

- Comparison studies were conducted out on Normal Plain Concrete and Fibre Reinforced Concrete.
- Compressive Strength of M20 Grade Steel FRC at 28 days is found to be 19.2% higher than that of Normal Plain Concrete.
- It is found that addition of fibers' upto a limit increases strength and after that it leads to reduction in strength.
- Addition of Steel Fibres results in increase of Compressive, Flexural, Tensile and Impact Strength of Concrete considerably.
- Compressive Strength of Polypropylene FRC is found to be nearly equal to Normal Plain Concrete.
- Addition of Polypropylene Fibres results only in increase of Impact Strength of concrete.
- Flexural Strength of Steel FRC increased considerably as compared to Plain Normal Concrete.
- Flexural Strength of both type of Concrete came out to be 15% of the Compressive Strength of Concrete.
- On the whole it has been concluded that for heavily loaded structures subjected to higher stresses Fibre Reinforced Concrete should be used for Construction.

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