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Experimental investigation on fresh and hardened properties of high strength fibre reinforced concrete using GGBFS and micro silica.

Investigación experimental sobre las propiedades frescas y endurecidas del hormigón reforzado con fibras de alta resistencia utilizando GGBFS y microsílice.

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ABSTRACT

The use of High Strength Concrete (HSC) has increased now a day. The concrete is one of the most useful construction materials, but the major defects of concretes are brittle in nature, low workability and low tensile strength. Experimental study is carried out to assess fresh and hardened properties of high strength fibre reinforced concrete (HSFRC). In addition to normal materials, silica fume and GGBS are added to achieve higher strength and poly propylene fibres are added to improve its ductility. The content of silica fume and GGBS is 5% and 25% respectively by weight of cement. Water to cementitious material ratio is 0.31. Mixes with different percentages of poly propylene fibres such as 0.5%, 0.1%, and 1.5% by the weight of cementitious content are added. To improve the workability characteristics of the low water-binder ratio HSC mix, the Poly Carboxylate Ethylene-based chemical admixtures are used. The fresh properties were investigated in terms of slump and mechanical performances of the HSFRC over HSC are evaluated in terms of compressive, flexural, and split tensile strength.

Keywords: High Strength Fibre Reinforced Concrete, Poly Propylene Fibres, Workability, Retention time, Compressive Strength Split Tensile Strength, Flexural Strength

RESUMEN

El uso de Hormigón de Alta Resistencia (HSC) ha aumentado hoy en día. El hormigón es uno de los materiales de construcción más útiles, pero los principales defectos del hormigón son su naturaleza quebradiza, su baja trabajabilidad y su baja resistencia a la tracción. Se lleva a cabo un estudio experimental para evaluar las propiedades frescas y endurecidas del hormigón reforzado con fibra de alta resistencia (HSFRC). Además de los materiales normales, se añaden humo de sílice y GGBS para lograr una mayor resistencia y se añaden fibras de polipropileno para mejorar su ductilidad. El contenido de humo de sílice y GGBS es del 5% y 25% respectivamente en peso de cemento. La proporción de agua a material cementoso es de 0,31. Se agregan mezclas con diferentes porcentajes de fibras de polipropileno como 0,5%, 0,1% y 1,5% en peso de contenido cementoso. Para mejorar las características de trabajabilidad de la mezcla HSC con una proporción baja de agua y aglutinante, se utilizan aditivos químicos a base de policarboxilato de etileno. Las propiedades en fresco se investigaron en términos de asentamiento y el rendimiento mecánico del HSFRC sobre el HSC se evaluó en términos de resistencia a la compresión, flexión y tracción dividida.

Palabras clave: Hormigón reforzado con fibras de alta resistencia, fibras de polipropileno, trabajabilidad, tiempo de retención, resistencia a la compresión, resistencia a la tracción dividida, resistencia a la flexión

INTRODUCTION

The conventional fiber reinforced concrete (FRC) made by adding fibers in normal strength concrete only exhibits an increase in ductility compared with the plain matrix, whereas high strength fiber reinforced concrete (HSFRC) made by adding fibers in HSC exhibits substantial strain hardening type of response which leads to a large improvement in both strength and toughness compared with the plain matrix.Despite various improvements in the mechanical properties of hardened concrete, the use of low water cement ratio and fibers reduces the fluidity of the material, which can cause negative impact in the workability of the high strength fiber reinforced concrete. The low water cement ratio and addition of strength performance improvers may cause difficulties for fresh concrete mixing, handling, placing and consolidation.However the flaws in the fresh properties can be overcome by proper design and selection of high range water reducing admixture. The superplasticizer gives the concrete adequate workability at low water-cement ratios, leading to concrete with greater strength. The water-reducing retarder slows the hydration of the cement and allows workers more time to place the concrete.High strength Fiber Reinforced concrete (HSFRC) is widely used in construction. Its dense structure guarantees the augmentation of mechanical properties and durability. HSFRC also will provide more safety to the structures than the normal concrete due to its post-failure pseudo ductile behavior. This research project aims to develop concrete mixes with high compressive strength and evaluate their ability to provide high ductility and high tensile properties.

MATERIALS AND METHODS

A. Materials Used

The main component used in this study is OPC (53grade) with a specific gravity of 3.12, as specified by IS: 269–2015[1]. Fine aggregate, sand used was conforming to Zone II and Coarse aggregates sieve size is less than 12.5mm as the compliance of IS383:2016. Super plasticizer is Master glenium Ace 30 DG, GGBFS [2] with specific gravity of 2.89 and Micro Silica [2] with specific gravity of 2.2 conforming to IS 9103-1999, IS 16714-2018 and IS 15388-2003 respectively. In addition, Polypropylene fibers [1] are also used. The tests conducted includes preliminary tests on cement, fine aggregate and coarse aggregate and found these material properties confirms to the IS codes.

Fig 1: GGBFS

Fig 2: Micro Silica

B. Methodology

Initially, mix design of M70 grade concrete was performed with GGBFS 25% and Micro silica 5%. The mix proportions were determined according to IS 10262-2019. M70 concrete mixtures were prepared with variouspercentages of Polypropylene fibers such as 0%, 0.5%, 1% and 1.5%. These mixes are designated as HSC, HSFRC 1, HSFRC 2, and HSFRC 3, respectively. For each of these mixes, workability was assessed by slump flow test and mechanical properties such as compressive strength, flexural strength and split tensile strength was evaluated. From this the optimum mix is determined with respect to the mechanical properties and workability. The cube specimens of 150x150x150 mm size were subjected to compressive strength tests in accordance with the guidelines outlined in IS: 516 - 1959. For evaluating split tensile strength, concrete cylinders measuring 300mm in height and 150 mm in diameter were cast and tested in accordance with the guidelines provided in IS: 516-1999 (Reaffirmed 2004). For evaluating split tensile strength, concrete cylinders measuring 500 mm length, 100mm in height and 100 mm width were cast and tested in accordance with the guidelines provided in IS: 516-1999 (Reaffirmed 2004).

RESULTS AND DISCUSSIONS

On fresh concrete slump test was conducted and on hardened concrete, compressive strength test, flexural and split tensile strength tests were conducted. The details of the tests are discussed below.

A. Workability of Concrete

Workability of concrete is defined as the property of freshly mixed concrete which determines the ease and homogeneity, with which it can be mixed, placed, compacted and finished [4]. Some of the factors affecting workability are water cement ratio, method of mixing concrete, method of compaction, method of placing, environmental condition. The strength of concrete is inversely proportional to the workability. It is because when the water from the concrete dries up, it leaves behind voids during the setting of concrete. One of the methods used for determining workability is slump cone test. This method is suitable for concretes of high workability. Through trial mix it was found out that when 1% of superplasticizer was used to get the required workability and the slump values are shown in table 1.

Table 1: Workability values of M70 Concrete

Mix ID	HSC	HSFRC 1	HSFRC 2	HSFRC 3
% of Fibers	0 %	0.5 %	1 %	1.5 %
Slump Time	Initial	Initial	Initial	Initial
Slump Behaviour	Collapse	200 mm Slump	120 mm Slump	No Slump

Initially mix displayed collapse slump. Then the addition of each 0.5% of fibers decreased the workability. In 1.5% dosage, the concrete was no more workable.

B. Compressive Strength

Compressive strength test was carried out on the casted cubes. The compressive strength of concrete cubes was assessed by using compression testing machine according to IS 516:1959. The load at failure of each cube was noted. Three cubes were tested and their average value is reported. Table 2 shows the average compressive strength of various mixes.

Table 2: Compressive Strength Values

Mix ID	HSC	HSFRC 1	HSFRC 2	HSFRC 3
7 Days (N/mm^2)	62.92	62.8	63.37	62.06
28 Days (N/mm^2)	77.54	77.54	80.06	76.88

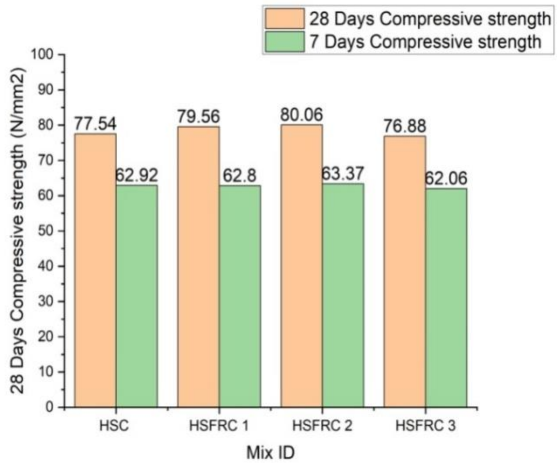

Fig. 3: Variation in compressive Strength Values

Fig 3 shows the compressive strength of the concrete after 28 days with different fiber dosages. It is observed that the compressive strength increased with increasing fiber dosage [5]. But the percentage increase in compressive strength with increasing fiber dosages is not appreciable beyond 1%. Space between aggregates and fibers is filled with air due to poor workability, which already starts to accumulate during the mixing process when the fibers percentage is more. So these voids might be the reason for not gaining appreciable increase in compressive strength.

A. Flexural Strength

The flexural strength of HSC was found using universal testing machine after 28 days of curing. Flexural strength test was conducted based on IS 516 1959 (Reaffirmed 2004).

Table 3: Flexural Strength Values

Mix ID	HSC	HSFRC 1	HSFRC 2	HSFRC 3
7 Days (N/mm^2)	8.25	9.50	10.50	11.75
28 Days (N/mm^2)	12.00	12.50	13.50	14.00

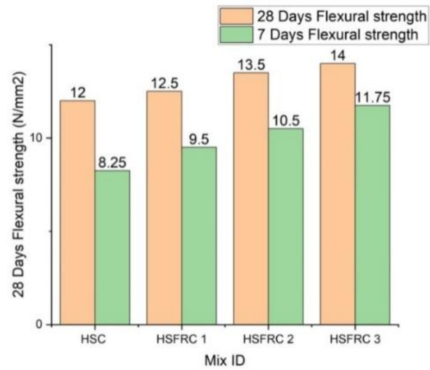

Fig. 4: Variation in Flexural Strength Values

The test results in Fig 4 clearly reflect that the addition of fiber dosage will increase the tensile strength [9]. The test results showed an increase from 12 to 14 MPa in concrete when fiber is added. The experiments showed that by adding fibers, the failure mode changed from brittle to ductile, thus indicating that fiber dosage has an enormous influence on the post-crack behavior of HSFRC. There was no brittle failure, because PP fibers under bending tensile load prevented the opening of a crack and finally prevented the sudden destruction of the concrete. Due to integrity of concrete matrix and interlocking effect of fibers will increase the flexural strength [10].

A. SplitTensileStrength

The tensile strength of concrete is one of the basicand important properties. Splitting tensile strength test on the concrete cylinder is a method to determine the tensile strength of concrete asper IS516:1999.The concrete develops cracks under when subjected to tensile forces [10]. Thus, it is important to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Table4 shows the split tensile strength of tested specimen.

Table 4: Split tensile Strength Values

Mix ID	HSC	HSFRC 1	HSFRC 1	HSFRC 1
7 Days (N/mm^2)	2.73	2.70	3.00	3.60
28 Days (N/mm^2)	4.23	4.53	4.93	5.15

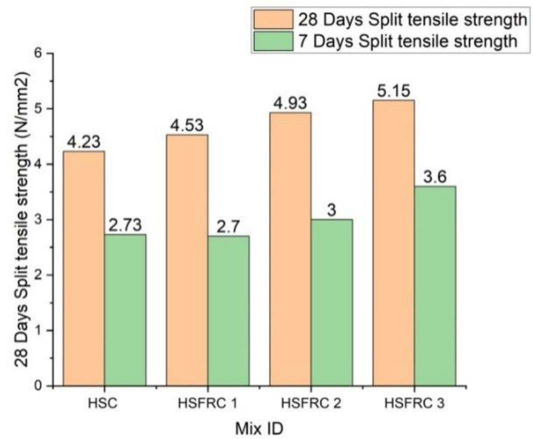

Fig. 5: Variation in Split Tensile Strength Values

Tensile strength is an important property of concrete since concrete structures are highly vulnerable to tensile cracking due to various loading conditions. Figure 5 shows the variation in split tensile strength of various mixes at 7 and 28 days.

The addition of fibers to the concrete mix has a major impact on the tensile strength of concrete [9]. The test results showed that strength increased in each stage of fiber addition ie, from 4 MPa (normal concrete) to 5.15 MPa (fiber dosage of 1.5%). The strength increased due to the interlocking effect of fibers in the concrete. It observed that the splitting tensile strength was increased 20% due to the addition of fibers at 1.5%.

By analysing the fresh and hardened properties of M70 grade high strength fibre reinforced concrete, the optimum was selected as 1% addition of fibreie, HSFRC2. The result of workability and compressive strength were led to this conclusion. It showing that beyond 1% of fibre addition will adversely affect the workability and compressive strength. The concrete is no more workable and there was a substantial reduction in compressive strength beyond 1% of fibre addition.

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