IMPACT OF COPPER COATED MACRO STEEL FIBRES ON HARDENED PROPERTIES OF SCC WITH PPC

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Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

A study has been made to appraise the performance of Portland Pozzolanic blended Cement (PPC) with limited replacement of hypo-sludge and steel fibers. In this investigation, the self-compacting concrete (SCC) was achieved by EFNARC guidelines. To achieve fluidity, new generation superplasticizers based on polycarboxylic ethers were used. The hypo-sludge is used as cement replacement material in concrete to limit the CO_2 emissions from cement industries. Limited replacements of sludge are 2, 4, 6, 8, 10, and 12% by cement weight. To determine the optimum dosage of hypo-sludge in self-compacting concrete, based on strength at 28 days. The maximum compressive strength obtained at 2 percent sludge in PPC considered as optimal dosage of hypo-sludge in self-compacting concrete mix (HYSCC). To this HYSCC mix, two different diameters of copper-coated macro steel fibres with various percentages 0.6, 0.8, 1.0 & 1.2 were added and different strength parameters like compressive, splitting, and flexural strength was calculated for all fibre reinforced self-compacting concrete (FRSCC1 to FRSCC8). FRSCC1 to FRSCC4 represents the 0.2 mm diameter 13 mm cut length and FRSCC5 to FRSCC8 represents 0.3 mm diameter and 12 mm cut length. 150 mm cube for a compression test, 300×150 mm cylinder for splitting test, and 500×100×100 mm prism for tensile strength test specimens were cast. All test samples are cured at 7, 28, and 56 days before testing. The strength parameters achieved with fibre reinforced self-compacting concrete (FRSCC1 to FRSCC8) are compared with the conventional self-compacting concrete SCC0 and optimum hypo-sludge self-compacting concrete HYSCC and conclusions were made.

Keywords: Blended cement, Hypo-sludge, Copper coated steel fibers, Compressive strength, Splitting strength, tensile strength.

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DOI: 10.31838/ecb/2023.12.1.100

1. Introduction

Self-compacting Concrete (SCC) also known as high workability concrete, self–consolidating concrete, or self-leveling concrete, recognizing the lack of uniformity and complete compaction of concrete by vibration, due to lack of skilled labour, the university of Tokyo, Japan developed SCC that does not require full compaction. The SCC has become popular for prefabricated products and ready mixed concrete in the year 2000. This concrete is known as fibre reinforced concrete. Ultratech PPC, Suraksha, and Jaypee cement (PPC) are some of the brand names of PPC in India.

Literature Review

Lava Kumar et al (2017) A study on the hardened properties of SCC with cement was replaced by hypo sludge, and different percentages of polypropylene fibres are added. The hypo sludge is replaced in Ordinary Portland Cement at 2, 4, 6, 8, and 10%. They conclude 4% replacement of cement by hypo sludge is optimum SCC4. For this optimum percentage of hypo sludge self-compacting concrete mix (SCC4), 0.2, 0.3, 0.4, and 0.5% Recrons 3s fibres were added and they conclude the maximum compressive and flexural strength occurred at 0.3% polypropylene fibre and maximum splitting strength obtained at 0.4% polypropylene fibre reinforced self-compacting mix.

Sasikala et al (2017) In her study strength characteristics of SCC with slag cement was replaced by hypo sludge, and different percentages of polyester fibres in 6 and 12 mm cut lengths are added. In this study, 4 % hypo sludge is replaced with slag cement as the optimum percentage. Recron 3s polyester fibres 0.2, 0.3, 0.4, and 0.5% by cement weight added to the optimum dosage of hypo sludge. The compression, splitting, and tensile strength was found at 7, 28, and 56 days. The maximum compressive strength showed at 0.3% and maximum splitting and flexural strength showed at 0.4% polyester fibres in both cut lengths.

Dharani et al (2015) In her study 10, 20, and 30 % of hypo sludge (HS) were replaced in cement, and 30, 40, and 50% of copper slag (CS) was replaced in the sand and studied hardened characteristic for total six concrete mixes. The study showed higher values of compression and tensile strength at 10 % and splitting strength at 20 % of HS concrete mix. In CS concrete mixes, the higher value of compression at 50 %, higher value of splitting at 40%, and higher value of tensile strength at 30% at 28 days of curing.

Details of Experimental Investigation

A. Ingredients used

In the present work, PPC cement was used for developing SCC conforming to (IS:1489-1994) which had a specific gravity 3.12. Sand is used as fine aggregate. The specific gravity and fineness modulus of sand was 2.64. Coarse aggregate of size 12.5 mm and its specific gravity and fineness modulus were 2.67 and 2.54 respectively. Hypo sludge is a solid waste from paper industries. Two different diameters and cut lengths (0.2 mm & 13 mm and 0.3 mm & 12 mm) of copper-coated steel fibres were used in this work. The Physical properties of cement are given in Table1. A polycarboxylate ether super-plasticizer and VMA were used. In general, fresh water is used for mixing the constituents of concrete.

Table 1 Tests on cement

Sr. No.	Property	PPC result	Permissible limits
1	Normal Consistency	30%	25-35%
2	Initial Setting Time	41 min	30 min
3	Final Setting Time	485 min	600 min
4	Specific Gravity	3.02	3.10

B. Mixture proportioning of SCC

A longer was initially made to obtain the constituents of SCC mix following the general guidelines given by EFNARC 2005, making use of mix quantities of the different ingredients obtained by no. of trails mixes were prepared and checked for their compatibility. Table 2 gives the mix proportions details. In this work, mix proportion obtained from EFNARC regulations was used.

Table 2 Final mix proportions of SCC

Cement (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	W/C Ratio	SP %
495	977	793.22	0.35	0.6

C. Acceptance criteria

The flowability of SCC mixes was studied by conducting tests such as slump flow, J-Ring test, U-box, L-box, and V– Funnel test. The mix obtained after several trials were taken as the reference mix for studying the rheological and strength properties. The quantity of the superplasticizers was adjusted every time to ensure smooth flow ability. Table3. The slump flow test was shown in Fig C

Table 3 Workability test results

Method	Unit	Experimental data	Acceptable values as per EFNARC	
			Minimum	Maximum
Slump flow by Abrams cone	mm	630	550	650
T_{50} time	sec	3.45	2	5
V-Funnel	sec	11	8	12
L-Box	h_2/h_1	0.85	0.8	1.0

D. Test program

Cube Compressive strength of size 150 mm and cylindrical splitting strength of size 150×300 mm were tested on 2000 kN and 500 kN capacity of compression testing machine respectively at 7, 28, and 56 days curing. Flexural test carried out on concrete prisms 100×100×500 mm using a Universal testing machine capacity of 1000 kN at 7, 28, and 56 days. The test specimens of cube, cylinder and prism are shown in Figures.

Fig. D1 Fig. D2 Fig. D3

Fig.C

2. Result and Discussion

A. Test results of SCC0, HYSCC, and FRSCC

In this work different percentages of hypo-sludge replacement by weight of Portland pozzolanic cement in SCC. Conventional Self-compacting concrete is designated as SCC0. SCC with hypo sludge designated as HYSCC and with 2, 4, 6, 8, 10, and 12 % paper sludge in SCC designated as HYSCC2, HYSCC4, HYSCC6, HYSCC8, HYSCC10, and HYSCC12 respectively. Influence of different percentages of hypo-sludge in compression strength of self-compacting concrete at 7 and 28 days as shown in Table 4. The maximum compressive strength was obtained at 2 per cent hypo-sludge with partial replacement in cement was treated as optimum hypo-sludge self-compacting concrete mix (HYSCC). Tests on hardened concrete such as compression, splitting, and tensile strengths have been evaluated for SCC0, HYSCC, and fiber-reinforced self-compacting concrete mixes FRSCC1 to FRSCC8. The different percentages of 0.6, 0.8, 1.0, and 1.2 of 0.2 mm diameter copper coated steel fibres were incorporated into the optimum hypo-sludge mix are designated as FRSCC1, FRSCC2, FRSCC3, and FRSCC4 respectively and the same percentages of 0.3 mm diameter and 12 mm cut length copper coated steel fibres are designated as FRSCC5, FRSCC6, FRSCC7, and FRSCC8. Fiber-reinforced self-compacting concrete mixes FRSCC1 to FRSCC8 have different diameters, cut lengths, percentages of copper-coated steel fibres and different strength properties evaluated at different ages in Table 5.

Table 4 Test results of Self-compacting concrete with different percentages of hypo-sludge

S.No	Mix designation	Hypo-sludge Percentage	Compressive strength MPa	
			7 Days	28 Days
	SCC0	0	36.58	49.42
1	HYSCC2	2	40.93	51.72
2	HYSCC4	4	38.15	49.86
3	HYSCC 6	6	37.40	49.33
4	HYSCC8	8	36.89	48.42
5	HYSCC10	10	36.00	47.07
6	HYSCC12	12	32.90	44.07

Table 5 Test results of copper-coated steel fibre reinforced self-compacting concrete (FRSCC) in Portland Pozzolanic Cement (PPC)

Mix details	Diameter mm	Length mm	Fibres %	Compressive Strength N/mm^2			Split Tensile Strength N/mm^2			Flexural Strength N/mm^2		
				7 Days	28 Days	56 Days	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days
SCC0	-	-	-	36.58	49.42	54.22	2.63	3.35	3.78	3.31	4.22	5.24
HYSCC	-	-	-	40.96	51.72	57.33	2.89	3.45	3.95	3.80	4.45	5.48
FRSCC1	0.2	13	0.6	35.56	45.48	52.22	2.87	3.38	3.85	3.74	4.32	5.13
FRSCC 2	0.2	13	0.8	36.00	46.63	53.34	2.98	3.58	4.00	3.89	4.46	5.25
FRSCC 3	0.2	13	1.0	37.40	48.41	54.93	3.12	3.64	4.22	3.96	4.52	5.46
FRSCC 4	0.2	13	1.2	37.78	49.78	57.78	3.14	3.74	4.35	4.09	4.89	5.80
FRSCC 5	0.3	12	0.6	32.85	41.59	49.19	2.24	3.05	3.65	3.65	4.65	5.55
FRSCC 6	0.3	12	0.8	34.89	43.63	50.66	2.60	3.48	4.05	3.71	4.73	5.76
FRSCC 7	0.3	12	1.0	35.33	45.93	51.81	2.93	3.75	4.36	3.98	5.15	6.04
FRSCC 8	0.3	12	1.2	36.63	46.37	52.45	3.18	3.98	4.55	4.25	5.28	6.28

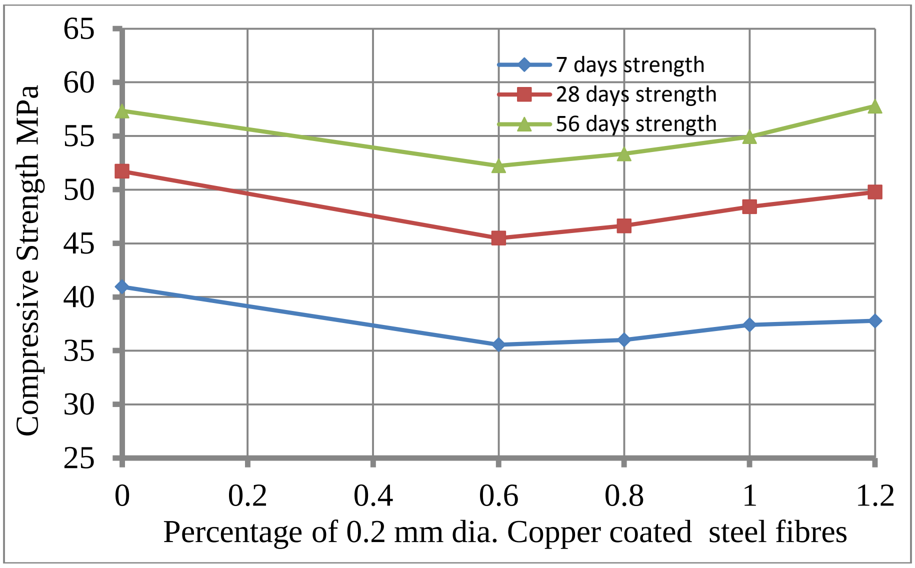

Fig 1 Compressive strengths of 0.2 mm dia Macro steel FRSCC

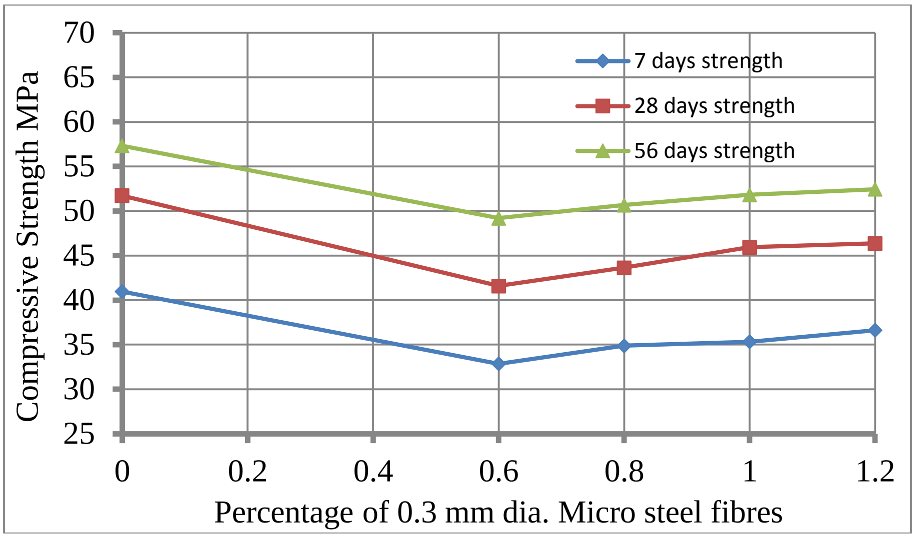

Fig 2 Compressive strengths of 0.3 mm dia Macro steel FRSCC

B. Compressive strength

All fibre reinforced self-compacting concrete showed lesser compressive strength than optimum hypo sludge self-compacting concrete (HYSCC) at all ages in both diameters of copper coated steel fibres. The strength of all FRSCC1 to FRSCC8 showed increasing order, as the increase in age of curing. The maximum strengths of FRSCC4 were 49.78, and 57.78 MPa obtained at 28 and 56 days curing respectively with all other FRSCC mixes. It was 0.963, 1.008 times optimum hypo sludge self-compacting concrete mix (HYSCC) at 28 and 56 days respectively. In 0.2 mm diameter fibre reinforced concrete mixes showed a gradual increase in strength as the percentage of fibre increases at all ages as shown in Fig1. Similarly, the fibres having 0.3 mm diameter showed the same trend as shown in Fig2. All FRSCC mixes showed ductile failure as the percentage of steel fibres increased. It is observed 0.2 mm diameter steel fibres showed higher strength than 0.3 mm diameter fibres. From Table5 the concrete strength containing 0.3 mm diameter steel fibre was 0.914, 0.942 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 0.6 per cent steel fibres. The strength of concrete containing 0.3 mm diameter fibres was 0.936, 0.950 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 0.8 per cent steel fibres. The strength of concrete containing 0.3 mm diameter steel fibre was 0.949, 0.944 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 1.0 per cent steel fibres. The strength of concrete containing 0.3 mm diameter steel fibre was 0.932, 0.908 times the concrete strength having 0.2 mm diameter fibres at 28 and 56 days respectively in 1.2 per cent steel fibres.

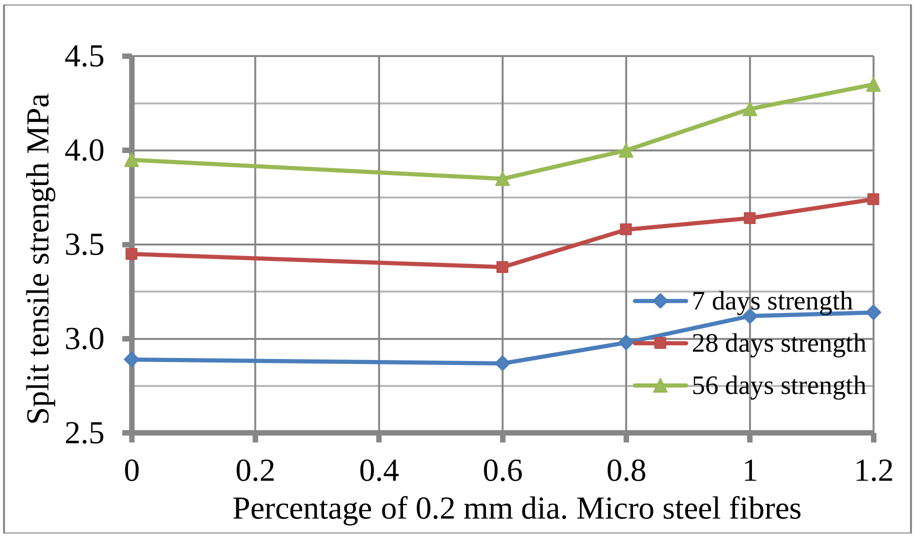

Fig 3 Split tensile strengths of 0.2 mm ø Macro steel FRSCC

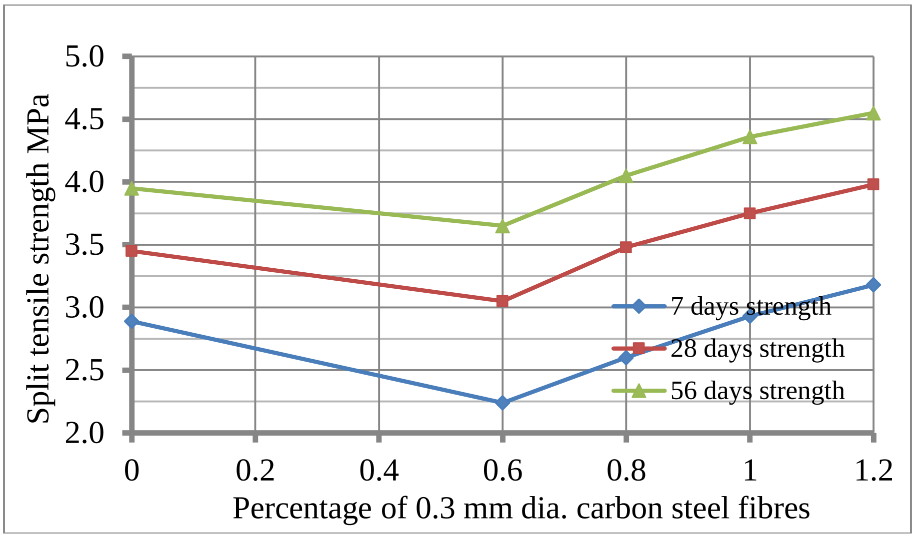

Fig 4 Split tensile strengths of 0.3 mm ø Macro steel FRSCC

C. Split-tensile strength

The splitting strength of all FRSCC1 to FRSCC8 showed increasing order as days of water curing increased. The maximum splitting strengths of FRSCC8 were 3.98, and 4.55 MPa obtained in 28 and 56 days of curing respectively. It was 1.154 and1.152 times HYSCC at 28 and 56 days respectively. All fibre reinforced self-compacting concrete showed a linear increase in strength as the percentage of fibre increases in both diameter fibres at all ages as shown in Fig 3 and 4. From Table5 the splitting strength of concrete has 0.3 mm diameter steel fibre were 0.902, 0.948 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 0.6 per cent fibres. The concrete strength containing 0.3 mm diameter steel fibre was 0.972, 1.013 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 0.8 per cent fibres. The splitting strength of concrete containing 0.3 mm diameter steel fibre was 1.030, 1.033 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 1.0 per cent fibres. The indirect tensile strength of concrete containing 0.3 mm diameter steel fibre was 1.064, 1.046 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 1.2 per cent steel fibres.

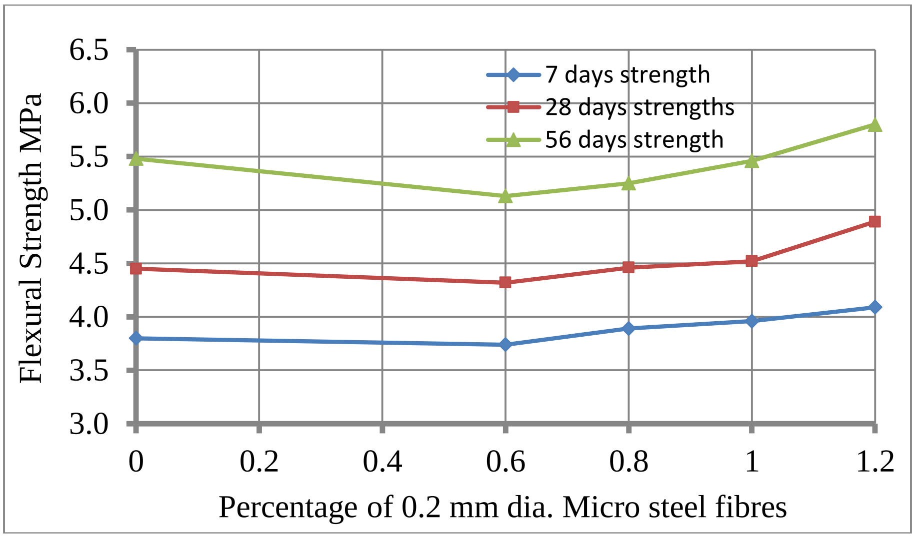

Fig 5 Flexural strengths of 0.2 mm ø Macro steel FRSCC

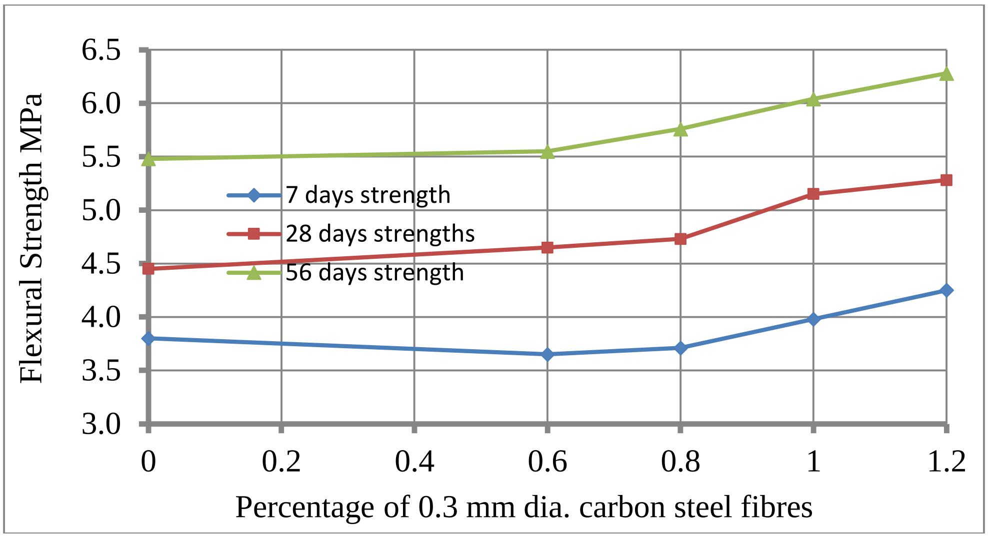

Fig 6 Flexural strengths of 0.3 mm ø Macro steel FRSCC

D. Flexural strength

The maximum flexural strength was 5.28, 6.28 MPa obtained at 1.2 per cent copper coated fibres having 0.3 mm diameter (FRSCC8) at 28 and 56 days curing respectively. It was 1.186, and 1.146 times optimum hypo sludge HYSCC at 28 and 56 days respectively. All fibre reinforced self-compacting concrete showed a gradual increase in flexural strength as percentage of steel fibre increases in both diameter fibres at all ages as shown in Fig 5 and 6. From Table5 the flexural strength of concrete containing 0.3 mm diameter steel fibre was 1.076, and 1.081 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 0.6 per cent steel fibres. The flexural strength of concrete containing 0.3 mm diameter steel fibre was 1.060, and 1.097 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 0.8 per cent steel fibres. The flexural strength of concrete containing 0.3 mm diameter steel fibre was 1.139, and 1.106 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 1.0 per cent steel fibres. The flexural strength of concrete containing 0.3 mm diameter steel fibre was 1.079, and 1.083 times the concrete having 0.2 mm diameter fibres at 28 and 56 days respectively in 1.2 per cent steel fibres.

Recommendations:

The recommendations arrived from the investigation.

- The optimum dosage of hypo-sludge is 2.0 % in the Portland pozzolanic cement.
- As the percentage of copper-coated steel fibres increases compression gradually increases in FRSCC in two steel fibres and increases ductile failure.
- The maximum compressive strength was obtained at 1.2 per cent of 0.2 mm Ø macro steel fibres in all ages.
- The maximum splitting and tensile strength was obtained at 1.2 per cent of 0.3 mm Ø copper-coated steel fibres of all ages.
- It is observed that 0.2 mm diameter copper coated steel fibre showed higher compressive strength over 0.3 mm diameter copper coated steel fibres.

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