

Behavior of steel fibre reinforced ternary blended concrete under flexure



Engineering

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ABSTRACT

During static flexural strength test conducted on simply supported beams under third point loading, settings are made to collect load deflection data. This data collected for all the beams is used for the calculation of flexural toughness. Toughness is calculated by determining the area under load deflection curve using NCS software. In this paper, an attempt is made to study the properties of steel fibre reinforced concrete with ternary blends. The mix design was carried out for M30 grade concrete as per IS: 10262-2009 which yielded a proportion of 1:1.86: 2.41 with a w/c ratio of 0.45. Before mixing, 30% of cement was replaced by (FA + SF) or (FA+GGBFS) or (FA+MK) according to the proportions such as (0+0), (30+0), (25+5), (20+10), (15+15), (10+20), (5+25) and (0+30) respectively. So in this paper the performance of the flexural toughness for various steel fibre reinforced ternary blended concrete are found. Also the toughness factor was found for normal mix (without steel fibres with 0% cement replacement). It was found that the toughness of reference mix (mix containing 1% steel fibre and 0% cement replacement) was increased by 56% for 28 day curing and 35% for 90 day curing. This suggests that the ductility of blended concrete is more compared to the reference concrete as the increase is more by 70% in all the ternary blended mixes. This is due to the maximum pozzolanic effect after 90 days, since the pozzolanic reactions are slow.

INTRODUCTION

Beside many advantages of concrete, it has deficiencies like low tensile strength, prone to cracking, low post cracking capacity, brittleness, low ductility, not capable to accommodate large deformations and low impact strength. These deficiencies lead concrete to be brittle material with low tensile strength and limited ductility. The contribution of conventional steel reinforcement in RCC structural elements to take care of tensile stresses is limited only in its own plane. Fibres influence the mechanical properties of concrete or mortar in all modes of failure, especially those that induce fatigue and tensile stress. The strengthening mechanism of fibers involves transfer of stress from matrix to the fiber by inter facial shear or by interlock between the fibers and the matrix. Addition of steel fibers in concrete mix significantly improves the cracking behavior and ultimate strength of deep beams. Addition of steel fibers in concrete results in an increase of beam stiffness. In addition to increase in flexural strength, a considerable increase in toughness is also imparted by the fibers. The fiber reinforced concrete is also gaining more importance these days especially in the earthquake resistant structures, where ductility plays an important role.

While static flexural strength test was conducted on simply supported beams under third point loading, settings were made to collect load deflection data in tabular as well as graphical form. In general load and deflection increases almost proportionately up to the first crack. Toughness is calculated by determining the area under load deflection curve using NCS software. The area beneath this load/deflection graph is a measure of the energy required to achieve a certain deflection and is a measure of the ductility that a fibre reinforced composite possesses. The JSCE-SF4 was used to calculate the toughness factor which is described below.

Flexural toughness factor = $T_b \times L$

$\delta t_b \cdot b \times h$

T_b = area up to $L/150$

δt_b = deflection at $L/150$

L = Length of the specimen

b = Width of the specimen

h = Depth of the specimen

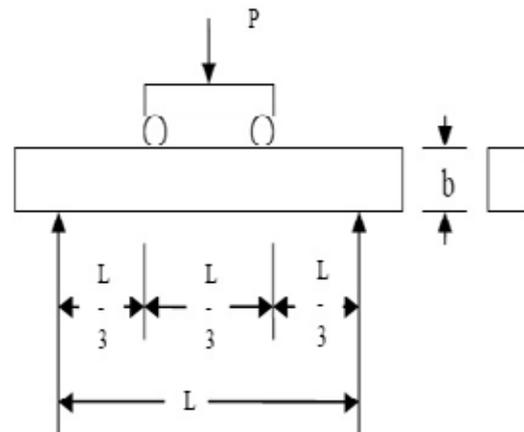


Figure 1 Flexural strength test Experimental program

The mix design was carried out for M30 grade concrete as per IS: 10262-2009 which yielded a proportion of 1:1.86: 2.41 with a w/c ratio of 0.45. The dosage of super plasticizer

used was 0.78% (by weight of cement). The cement, sand and coarse aggregates were weighed according to the proportion of 1:1.86: 2.41 and dry mixed. Before mixing, 30% of cement was replaced by (FA + SF) or (FA+GGBFS) or (FA+MK) according to the proportions such as (0+0), (30+0), (25+5), (20+10), (15+15), (10+20), (5+25) and (0+30) respectively. For assessing the flexural toughness standard specimen of beam of size 100 x 100 x 500 mm were cast. The specimens were finished smooth and kept under wet gunny bags for 24 hours after which they were cured for 28 days and 90 days. A dial gauge was provided below the beam as shown in the figure to measure the deflection.

Materials

The cement used was normal portland 53 Grade OPC cement, the composition of which is given in table 1. The sand used was from Bodeli from orsang river with zone 2. The sieve analysis result are given in table 2. The kapachi used is black trap from Sevalia, Timba. It was found the aggregate used in the study were confirming to the specification laid down in IS 383- 1970. Specific gravity, water absorption and gradation of sand (FM) test were carried out as per IS 2386 (part I and Part III) – 1963. Physical test for specific gravity, water absorption, gradation, impact, crushing value were carried out for coarse aggregate as per IS -2386 (I, II & IV) 1963 and are so as in table 3.

Experimental results

Toughness index test results for ternary blended SFRC

Following tables gives the toughness values and its percentage increase or decrease with reference mix for different ternary blended steel fibre reinforced concrete for 28 days and 90 days curing. The flexural toughness value of normal concrete without steel fibre is found to be 1.66 and 2.00 for 28 days and 90 days respectively.

The variation of toughness value is shown in Fig. 6.14 and 6.15

Table 1 Flexural toughness value results for 28 days

Percentage replacement of cement by ternary blend	Ternary blended FRC with FA + SF		Ternary blended FRC with FA + GGBS		Ternary blended FRC with FA + MK	
	Toughness value	% increase or decrease of toughness wrt reference mix	Toughness value	% increase or decrease of toughness wrt reference mix	Toughness value	% increase or decrease of toughness wrt reference mix
(0+0) (Ref. mix)	2.59	-	2.59	-	2.59	-
(30+0)	2.9	12	2.9	12	2.9	12
(25+5)	3.49	35	3.44	33	3.44	33
(20+10)	3.53	36	3.62	40	3.83	48
(15+15)	3.85	49	3.92	51	4.06	57
(10+20)	3.99	54	4.05	56	4.05	56
(5+25)	3.62	40	3.41	32	3.41	32
(0+30)	3.44	33	3.2	24	3.2	24



Figure 2 Variation of 28 days toughness value
Table 2. Flexural toughness value test results for 90 days

Percentage replacement of cement by ternary blend	Ternary blended FRC with FA + SF		Ternary blended FRC with FA + GGBS		Ternary blended FRC with FA + MK	
	Toughness value	% increase or decrease of toughness wrt reference mix	Toughness value	% increase or decrease of toughness wrt reference mix	Toughness value	% increase or decrease of toughness wrt reference mix
(0+0)	2.71		2.71		2.71	
(30+0)	3.16	17	3.16	17	3.16	17
(25+5)	3.6	33	3.59	32	3.53	30
(20+10)	4.26	57	3.89	44	4.21	55
(15+15)	4.48	65	4.06	50	4.71	74
(10+20)	4.8	77	4.78	76	4.2	55
(5+25)	4.31	59	3.27	21	3.87	43
(0+30)	4.03	49	3.94	45	3.54	31

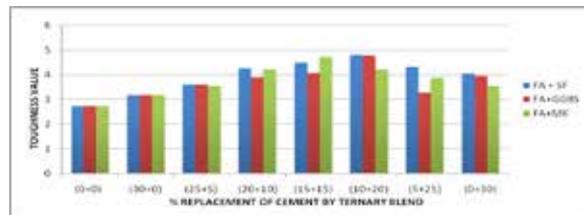


Figure 3. Variation of 90 days toughness value
Observation and discussion

1. It is observed that the flexural toughness of ternary blended steel fibre reinforced concrete shows higher flexural toughness at (10+20) replacement with (FA+SF) combination. There after the flexural toughness shows a decreasing trend. This observation is true for 28 days and 90 days strength, where percentage increase in flexural toughness is found to be 54% and 77% respectively with respect to reference mix.

This may be attributed to the fact that at a replacement level of (10+20) with (FA+SF) combination, most of the pores in the concrete matrix gets filled up there by rendering a dense microstructure. Also it may be due to the fact that at a replacement level of (10+20) with (FA+SF) combination the higher pozzolanic reaction takes place which can induce the later age flexural toughness. The pozzolanic reaction forms secondary hydrated products or C-S-H gel which is responsible for the additional flexural toughness. Thus the synergistic effect of (FA+SF) plays an important role.

Thus it can be concluded that the flexural toughness of ternary blended steel fibre reinforced concrete shows higher flexural toughness at a replacement level of (10+20) with (FA+SF) combination.

2. It is observed that the flexural toughness of ternary blended steel fibre reinforced concrete shows higher flexural toughness at (10+20) replacement with (FA+GGBFS) combination. There after the flexural toughness shows a decreasing trend. This observation is true for 28 days and 90 days strength, where percentage increase in flexural toughness is found to be 56% and 76% respectively with reference to reference mix.

This may be attributed to the fact that at a replacement level of (10+20) with (FA+GGBFS) combination, most of the pores in the concrete matrix gets filled up there by rendering a dense microstructure. Also it may be due to the fact that at a replacement level of (10+20) with (FA+GGBFS) combination the higher pozzolanic reaction takes place which can induce the later age flexural toughness. The pozzolanic reaction forms secondary hydrated products or C-S-H gel which is responsible for the additional flexural toughness. Thus the synergistic effect of (FA+GGBFS) plays an important role.

Thus it can be concluded that the flexural toughness of ternary blended steel fibre reinforced concrete shows higher flexural toughness at a replacement level of (10+20) with (FA+GGBFS) combination.

3. It is observed that the flexural toughness of ternary blended steel fibre reinforced concrete shows higher flexural toughness at (15+15) replacement with (FA+MK) combination. There after the flexural toughness shows a decreasing trend. This observation is true for 28 days and 90 days strength, where percentage increase in flexural toughness is found to be 57% and 74% respectively with reference to reference mix.

This may be attributed to the fact that at a replacement level of (15+15) with (FA+MK) combination, most of the pores in the concrete matrix gets filled up there by rendering a dense micro-structure. Also it may be due to the fact that at a replacement level of (15+15) with (FA+MK) combination the higher pozzolanic reaction takes place which can induce the later age flexural toughness. The pozzolanic reaction forms secondary hydrated products or C-S-H gel which is responsible for the additional

flexural toughness. Thus the synergistic effect of (FA+MK) plays an important role.

Thus it can be concluded that the flexural toughness of ternary blended steel fibre reinforced concrete shows higher flexural toughness at a replacement level of (15+15) with (FA+MK) combination.

Conclusion

1. Flexural toughness strength of ternary blended steel fibre reinforced concrete shows higher flexural toughness strength at a replacement level of (10+20) with (FA+SF) combination.

2. Flexural toughness strength of ternary blended steel fibre reinforced concrete shows higher flexural toughness strength at a replacement level of (10+20) with (FA+GGBFS) combination.

3. Flexural toughness strength of ternary blended steel fibre reinforced concrete shows higher flexural toughness strength at a replacement level of (15+15) with (FA+MK) combination.

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