International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 341-347, 2017

Mechanical Properties of Engineered Cementitious Composites

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Abstract : This reserach is aims to develope the new engineered cementitious composites with hybridation of steel short random fiber against polyvinyl alcohol fiber and polypropylene fiber. In this study, eight different mixes were investigated in which mixes with 2.0% of volume fraction of polyvinyl alcohol fiber and polypropylene fiber with 2.0% of volume fraction is kept as reference mixes. Steel fiber is placed in the above two mixes by 0.65%, 1.0% and 1.35% of volume fraction as a replacement of polyvinyl alcohol fiber and polypropylene fiber. Compressive, direct tensile tensile and three point flexural tests were conducted on the developed ECC mixes. Hybridation with steel fibers had a notable achievement on the direct tensile strength and flexural strength. From the results it is observed that mixes M4 and M8 performed better than the all other mixes.

1.0 Introduction:

Engineered cementitious composite (ECC) is a cement mortar based material material with short random fiber distributed with volume fraction of maximum of 2.0%. Generally this belongs to the family of ultra high touughness cement based composites with unique mechanical properties of tensile strength and strain hardening with ultimate strain behaviour. ECC is developed with polyvinyl alcohol fiber, polypropylene fiber and polyethylene fiber[1]. These fibers belong to the low modulus fiber category, which exhibit excellent strain hardening nature with resonable tensile strength. Usually the addition of fiber in to cement matrix/concrete is to improve the tensile strength, energy absorption, stiffness and damage reduction in the structure[2].

In recent years the application of ECC is accelerated for infrastructure development. There is a demand to improve the properties of ECC for wide range of application in construction industries. But ECC exhibits low tensile strength which can be overcame by improving the Tensile strength using fiberhybridation with combination of low modulus and high modulus fiber. In this study, an attempt is made to add high modulus steel fiber in the low modulus polyvinyl alcohol fiber and polypropylene fiber and thereby the mechanical properties were obsereved[3,4].

2.0 Materials and Experimental methods:

2.1 Materials and Casting

Ordinary Portland cement of 53 gradewith specific 3.16 and class F fly ash collected from mettur thermal power station were used in this study. Low modulus Poly vinyl alcohol, polypropylene and high modulus steel fibers were reinforced in ECC[5,6]. Various physical and mechanical properties of fibers are shown in table.1. Conplast SP430 from fosroc industries was used as super plasticizer to increase the workability of ECC mix[7,8]. Steel moulds are used for casting; mixer machine was used for mixing the cement, fly ash sand, fibers, super plasticizer and water. Initially powdered ingredients were added and allowed to mix for 5 minutes, and then super plasticizer was mixed with water and added in the mixer for another 5 minutes. These progresses shortly ended after adding the fibers in the cement matrix for 3 minutes and permitted the mix to distribute the fibers evenly spread over the mix. After that mixes were placed in the respective steel moulds, mixes having self consolidation capacity so no need for external vibration. Mixes were demoulded after 24 hours and placed into the water under room temperature[9,10]. Figure 1 (a) shows the specimen under casting and 1 (b) shows the casted specimen.

Table. 1 Physical and mechanical properties of fibre

Fibre	Diameter [µm]	Length [mm]	l/d ratio	Nominal tensile strength [MPa]
Polyvinyl alcohol	39	12	308	1600
Polypropylene	37	10	270	400
Steel	300	12	40	2000


(a) **(b)**

Figure.1 specimen under casting and the casted specimen.

2.2 Mix Proportions

Table.2 shows the mix proportion used in this investigation. Eight mixes were studied in this investigation, ECC with Polyvinyl alcohol fiber and Polypropylene fiber with volume fraction of 2.0 % [6]. Steel fiber was hybrided with the above to mixes in three different volume fraction of 0.65%,1.0% and 1.35%. Mono fiber reinforced composites was kept as reference mix.

2.3 Test Methods

2.3.1 Mini Slump cone test

Mini slump cone is a small size truncated cone type mould with 57 mm height 19 mm inner diamter in upper portion and 38.1 mm inner diameter on bottom side of the cone (Bahurudeen, et al., 2014). Figure.2 shows the typical mini slump apparatus, it was placed on the glass plate and filled with the ECC mortar paste up to top layer. After filling, the slump cone was lifted slowly and the paste was allowed to spread on the glass plate, where spreaded diameter is taken in to account.

Table 2. Mix design of ECC

Mix ID	Cement	Fly ash	Sand	Water/Binder ratio	Super Plasticizer [%]	Polyvinyl alcohol Volume [%]	Polypro-pylene Volume [%]	Steel Volume [%]
M1	1	0.43	0.7	0.35	1.1	2.0	--	--
M2	1	0.43	0.7	0.35	1.0	1.35	--	0.65
M3	1	0.43	0.7	0.35	1.0	1.0	--	1.0
M4	1	0.43	0.7	0.35	0.9	0.65	--	1.35
M5	1	0.43	0.7	0.35	1.1	--	2.0	--
M6	1	0.43	0.7	0.35	1.0	--	1.35	0.65
M7	1	0.43	0.7	0.35	1.0	--	1.0	1.0
M8	1	0.43	0.7	0.35	0.9	--	0.65	1.35

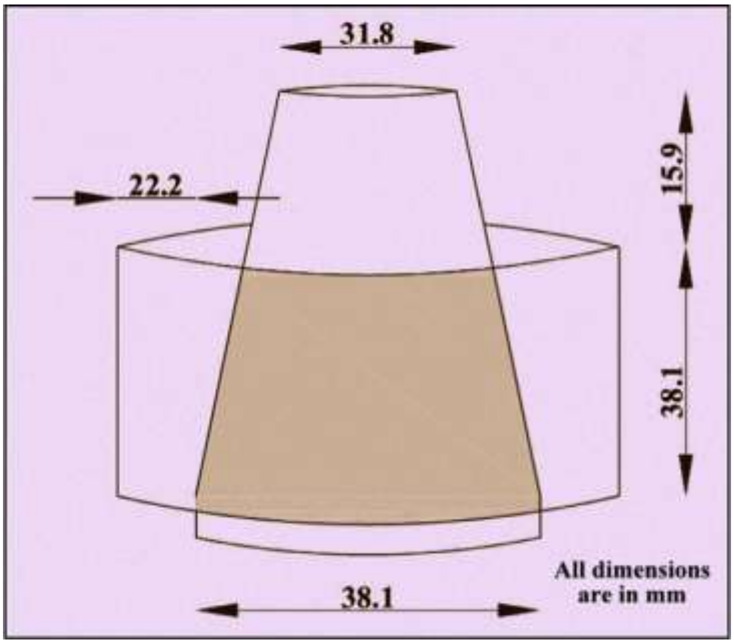

Figure.2 Mini Slump apparatus (Bahurudeen, et al., 2014)

2.3.2 Compressive Strength

This test was conducted as per IS 4031-6, 70.7 x 70.7 x 70.7 mm cube specimen were used to determine the compressive strength of the different mixes after 28 days curing. For each mix three specimen were tested and average value taken in to account.

2.3.3 Direct Tensile Strength

Dog bone specimen is used to determine the direct tensile test, figure.3 shows the Specimen detail and direct tensile test setup. Cross section 30 x 30 mm used in the mid portion and end portion extended to 60 x 30 mm. It designed such way that the failure occur at centre of the cross section. After 28 days curing three specimens were tested for determining the Direct Tensile Strength.

2.3.4 Flexural Strength

For determining the flexural strength of ECC mixes, prism size of 60 x 25 x 300 mm xwas used under three point bending test after 28 days curing as per ASTM C78-15.

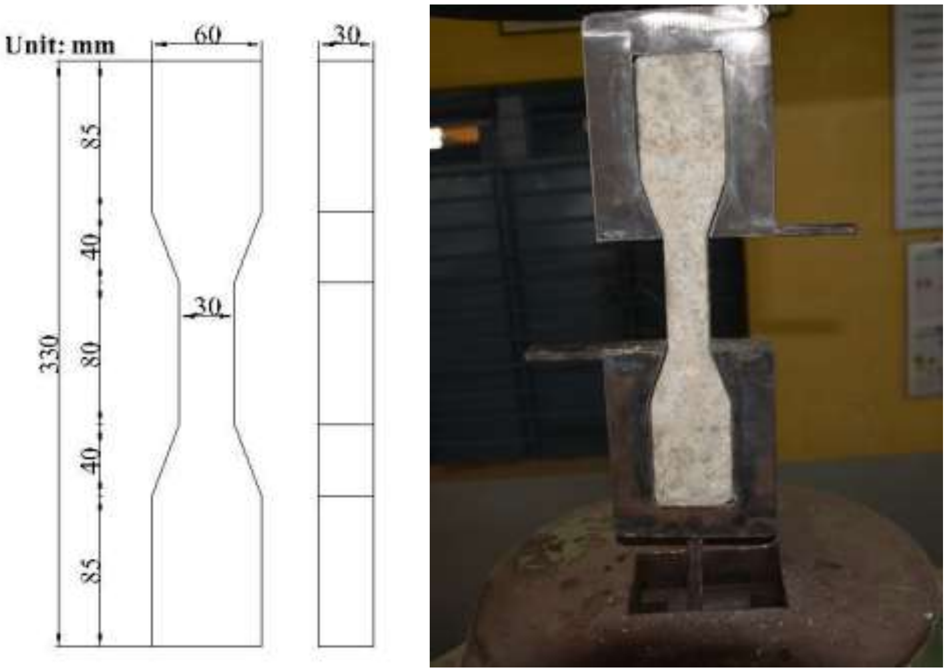

Figure.3 Dog bone specimen detail and test setup

3.0 Results and Discussion

3.1 Mini Slump Cone

Mini slump is used to identify the flowability of ECC mix, since it is a self consolidate composites. Table 3 shows the mini slump value of different mixes used in this study. Polyvinyl alcohol fiber and Polypropylene fiber was having reasonable water absorption capability, so that the slump flow in the ECC mix with the prescence of these fiber is low when compare to ECC mix hybridation with steel fibers. Figure.4 shows the Mini slump flow of ECC mix M1.

3.2 Compressive strength

ECC mixes were tested under CTM after 28 days curing to determine the compressive strength of composites. Figure. 5 shows the compressive strength of various ECC mixes. From the figure it is clearly seen that the there is no impact in compressive strenth by replacing the steel fiber against the polyvinyl alcohol and polypropylene fiber. Mix M1, M2, M3, M4, M5, M6, M7, M8 produce the compressive strength of 51, 51.5, 51.9, 52.6, 47.8, 49.3, 51.4 and 52.2 Mpa respectively.

Table 3. Mini slump value

Mix ID	Spread of Mini Slump Flow (mm)
M1	128
M2	131
M3	134
M4	136
M5	124
M6	127
M7	131
M8	133

Figure.4 Mini slump flow of ECC mix M1

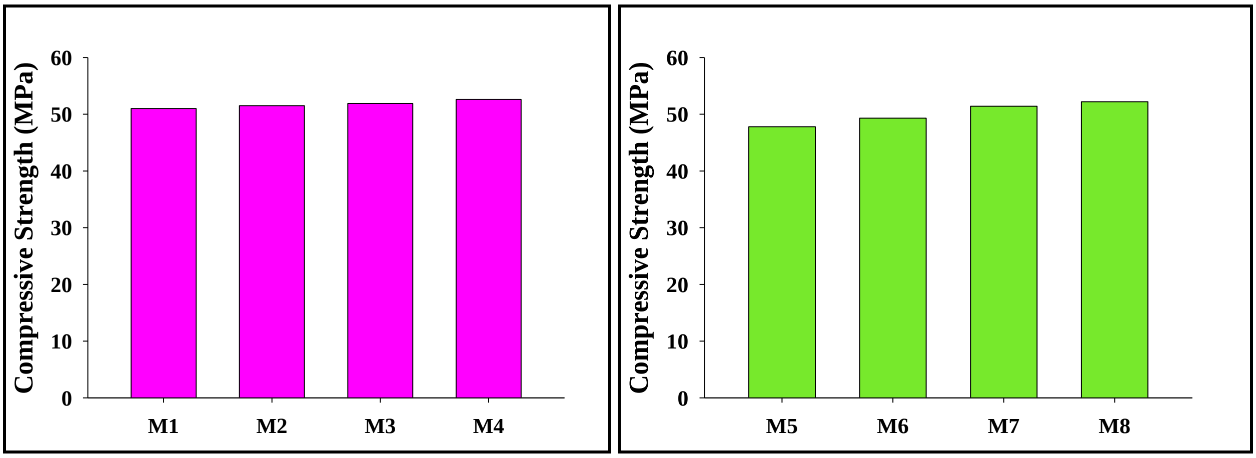

Figure.5 Compressive Strength of Various ECC Mixes

3.3 Direct tensile Strength

Scope of this work is to improve the mechanical performance of ECC, more than ever tensile and flexural performance of composites. Presence of steel fiber improves the tensile strength of ECC reasonably, Mix M1 exhibits the tensile strength of 5.53 MPa, Mixes M2, M3 and M4 exhibit 23.15%, 37.97% and 60.76% respectively higher than the reference mix M1. Similarly in the case of M5 mix with polypropylene fiber exhibit the tensile strength of 4.55 MPa, Mix M6, M7 and M8 exhibit 30.5%, 40.9% and 58.9% respectively higher than the reference mix M5. Figure.6 shows the tensile strength of various ECC specimens and figure.7 shows the typical failure pattern of dog bone specimens under direct tensile load.

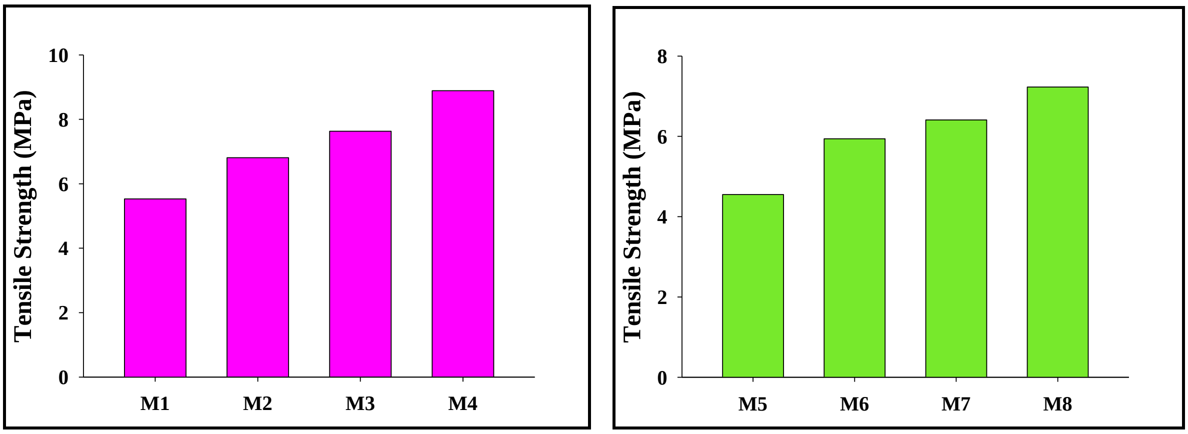

Figure.6 Tensile Strength of Various ECC Mixes

Figure.7 Typical failure of ECC under direct tensile load

3.4 Flexural Strength

Typical three point load test was used to find the flexural strength of 60 x 25 x 300 mm prism, where hybridation process turned out reasonable results in the flexural performance of ECC mixes. In the case of steel replacement against polyvinyl alcohol fiber mix M5 perform better than the all other mix, which exhibits 14.35 Mpa as a flexural strength which is 1.135, 1.09 and 1.04 times greater than the M1, M2 and M3 mixes respectively. In case ofhybridation with polypropylene fiber, mix M8 exhibits 12.13 Mpa which is 1.16, 1.12 and 1.065 times greater than the mixes M5, M6 and M7 respectively.

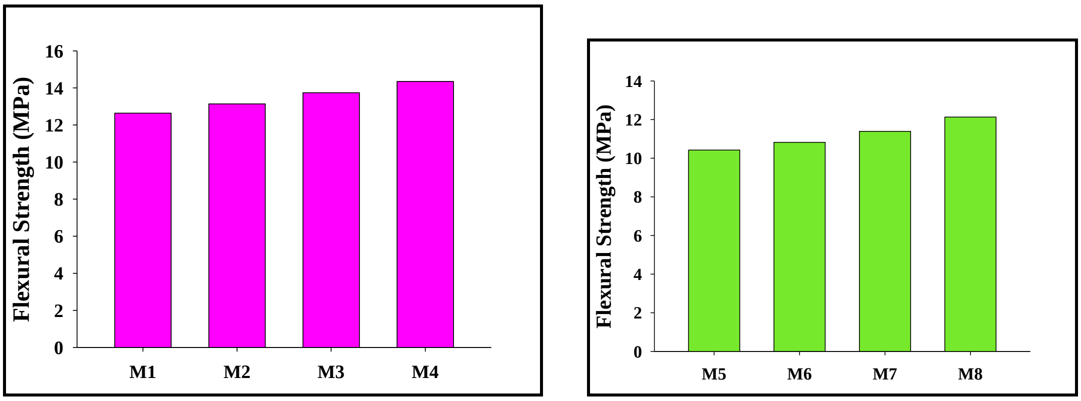

Figure.8 Flexural Strength of Various ECC Mixes

4.0 Conclusion

Based on the results obtained, the following conclusions were arrived in this research.

- Hybridation of steel fiber with the ECC mixes improves the workability parameters
- Presences of steel fiber in polyvinyl alcohol and polypropylene fibers does not affect the compressive strength of ECC mixes
- Results of direct tensile strength tests demonstrated that the presence of steel fiber in polyvinyl alcohol and polypropylene fibers mixes increases the tensile strength up to 60.00% than the reference mixes.
- Flexural preformance of hybridation mixes exhibited 16.00% more than the reference mixes.

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