FLEXURAL BEHAVIOUR OF FIBER REINFORCED CONCRETE USING PVA-ECC

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Abstract : Polyvinyl alcohol (PVA) fiber is considered as one of the most suitable polymeric fibers to be used as the reinforcement of engineered cementitious composites (ECC), though the unique microstructure characteristics of PVA fiber add challenge to the material design. In this paper, an investigation was planned to study the compressive and flexural behavior of this concrete using different percentage of fibers. The test results indicate that 15% increment in the compressive strength was observed with addition of fiber in the order of 1.2%. Flexure test conducted for specimen with fiber content 1.6% and 1.8% has shown Central deflection of 29.5 mm for the maximum bending stress of 11.52 MPa. The control mix (for specimen without fiber) has shown almost negligible deflection for the maximum bending stress of 1.92 MPa before undergoing failure, which merely indicates that using PVA –ECC mix, brittle nature of concrete can be partially converted to ductile nature.

Index Terms **- ECC, PVA , Fibers ,Flexural Strength, Compressive Strength**

I. Introduction

Engineered Cementitious Composites (ECC) is a unique representative of the new generation of high performance fibre reinforced cementitious composites, featuring high ductility and medium fiber content. Material engineering of ECC is constructed on the paradigm of the relationships between material microstructures, processing, material properties, and performance, where micromechanics is highlighted as the unifying link between composite mechanical performance and material microstructure properties [1]. The established micromechanics models guide the tailoring of composite constituents including fibre, matrix and interface for overall performance, and elevate the material design from trialand-error empirical testing to systematic holistic "engineered" combination of individual constituents. The microstructure to composite performance linkage can be further extended to the structural performance level and integrate the material design into performance based design concept for structures [2]. In that sense, ECC embodies a material design approach in addition to being an advanced material and provides an additional degree of freedom in structural performance. Polyvinyl alcohol (PVA) fiber emerged during a search of low cost high performance fibers for ECC. The hydrophilic nature of PVA fiber imposed great challenge in the composite design, as the fibers are apt to rupture instead of being pulled out because of the tendency for the fiber to bond strongly to cementitious matrix. Careful engineering in fibre geometry, fibre/matrix interface and matrix properties is of vital importance to achieve high ductility in PVA-ECC. To guide the tailoring process, micromechanical models accounting for the uniqueness of PVA-fibre were developed.

The objective of this paper is to provide a performance summary of an exemplary PVAECC.As large scale applications of ECC are emerging, the data collected here may serve as reference for structural engineers. To limit the paper length, the composite modelling and design considerations will be only briefly described.

II. MATERIALS

Cement used for the work is Ordinary Portland cement. Numerous organic compounds used for adhering, or fastening materials, are called cements, but these are classified as adhesives, and the term cement alone means a construction material. Blast furnace slag may also be used in some cements and the cement is called Portland slag cement (PSC). The color of the cement is due chiefly to iron oxide. In the absence of impurities, the color would be white, but neither the color nor the specific gravity is a test of quality. Ordinary Portland cement (OPC) – 53 grade was used. The fine aggregate used was the sand obtained from river bed, which is clear from all sorts of organic impurities was used in this experimental program. The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.68. The grading zone of fine aggregate was zone III as per Indian Standard.

The flyash used was low calcium ASTM class F obtained from local suppliers, and locally available Melamine Formaldehyde Sulphonate based Super plasticizer, namely Conplast SP 430 was used. The PVA fiber used in the study had a diameter of 39 μm, a length of 12 mm, and overall Young's modulus of 25.8 MPa.

The mix design used for the study is comprising of ASTM Type I Portland cement and fly ash were used. Large aggregates were excluded in ECC mix design, and only fine sand was incorporated. The silica sand used here had a maximum grain size of 250 μm and an average size of 110 μm. The design details are shown in the Table 2.1 indicates the mix used for PVA-ECC which is based on literature. Table 2.2 shows a separate mix design which is done for the M25 grade concrete and for which compression test was carried out for different percentage of fiber.

Table 2.1: Mix proportions of PVA-ECC (in kg/m^3) for Flexure Test

Cement	Sand	Class F Fly ash	Water	Super plasticizer	PVA Fiber
583 Kg	467 Kg	700 Kg	298 Kg	19 Kg	26 Kg

Table 2.1: Mix proportions for compression test (in kg/m^3)

AGGREGATES				CEMENT	Water	Admixture	Fibers (1.2%)
R-sand	C-Sand	10mm	20mm				
225	526	564	564	330	158	2.64	26

III. METHODLOGY

The two tests were conducted for different Mix proportion. Compressive strength test was conducted on 150 mm cube size samples using M25 grade ready mix concrete for different percentage of Polyvinyl alcohol fiber. 2 point load flexural strength test was conducted on the beam specimen of size 304.8mm x76.2mm x 25 mm based on Mix design given in the literature of flexure test using PVA ECC also flexure test was conducted for different percentage of Polyvinyl alcohol fiber. The design details are respectively shown in Table 2.2 and Table 2.1. The 7days and 28 days compressive strength test was conducted with and without fiber. The flexural result is given by F = M/S., where, F= Bending Stress, M = Bending Moment in KNm, S = Section modulus = I/Y in mm^3, I = moment of inertia in mm^4 (bd^3/12),and Y = Depth of neutral axis in mm (d/2). Figure 1 shows the PVA –ECC specimen before and after the test.

Fig 1 PVA –ECC specimen before testing (zero deflection) and after testing (At 0.8KN load, 28mm deflection)

IV. RESULTS AND DISCUSSIONS

The test results for compressive strength, indicate that the maximum compressive strength of 20.5 MPa was obtained at an end of 7 days of curing. The 28 day strength was about 34 MPa. The maximum strength was obtained for the fibre content of 1.2 %. The test results are indicated in a bar chart shown in figure 2 for 7days and figure 3 for 28 days of curing.

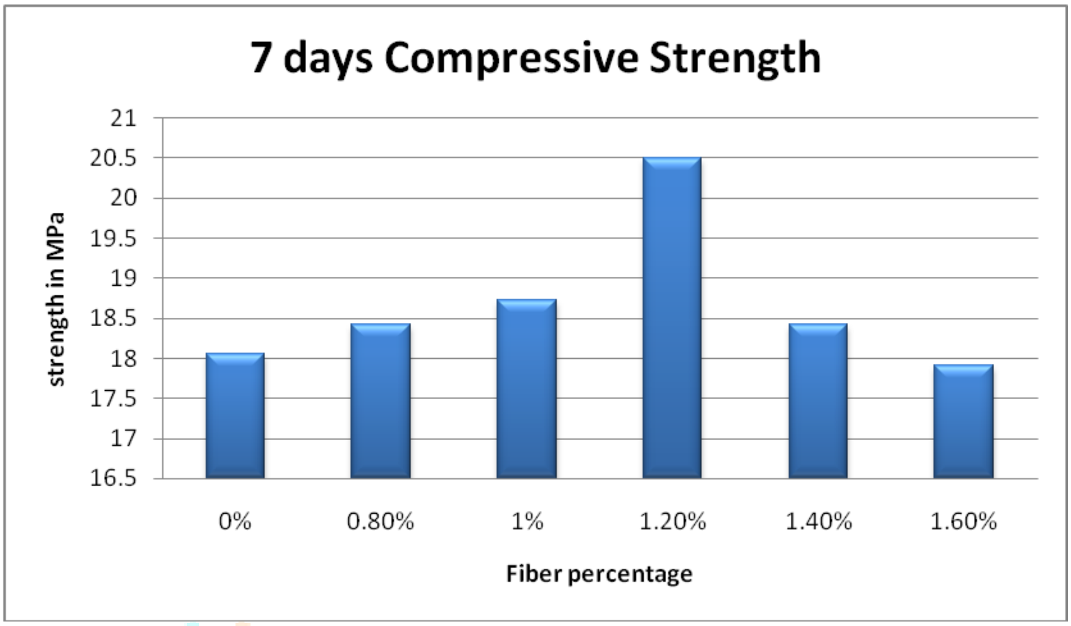

Fig 2 Variation of Compressive Strength with fibre content (7days)

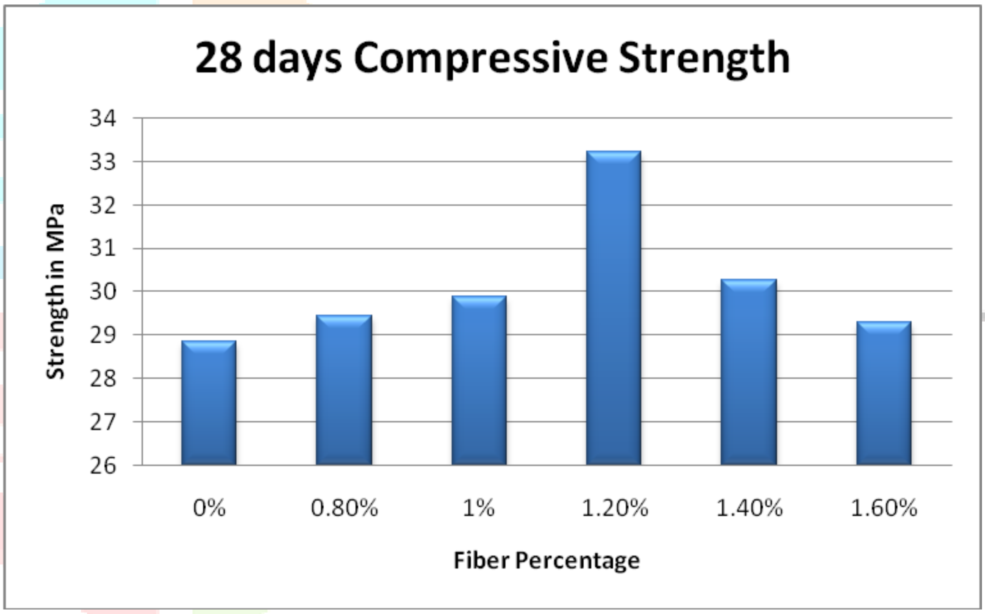

Fig 3 Variation of Compressive Strength with fibre content (28 days)

The test results for flexure indicate that the the control mix without fiber shows a sudden failure without any mark able deflection. The results are indicated in figure 4. As the percentage of fiber increases the load handling capacity of the concrete also increases in bending. Flexure test results for 1.2% fiber indicates that no visible cracks are appeared up to 0.5KN loading. The sample data sheet of results is shown in Table 4.1. The variation of Bending Strength with deflection is shown in Figure 5.

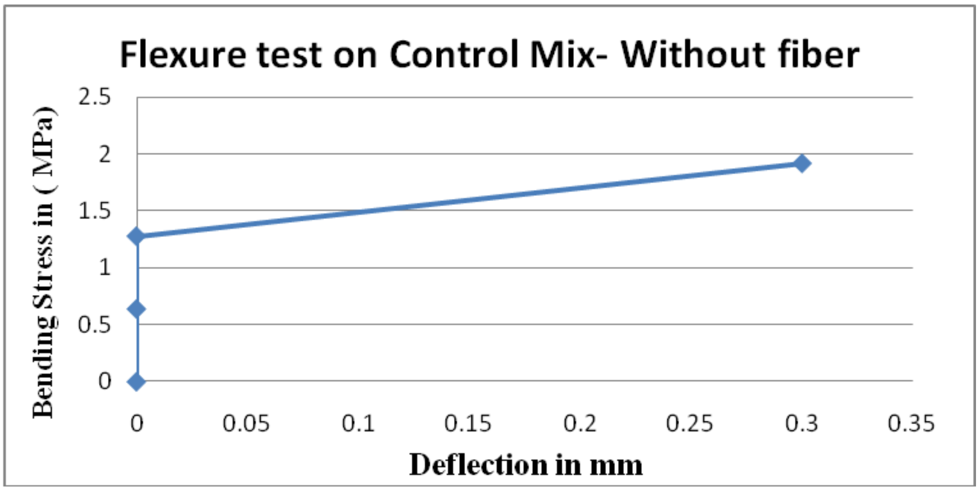

Fig 4 Variation of Bending Strength with Deflection for control mix (28 days)

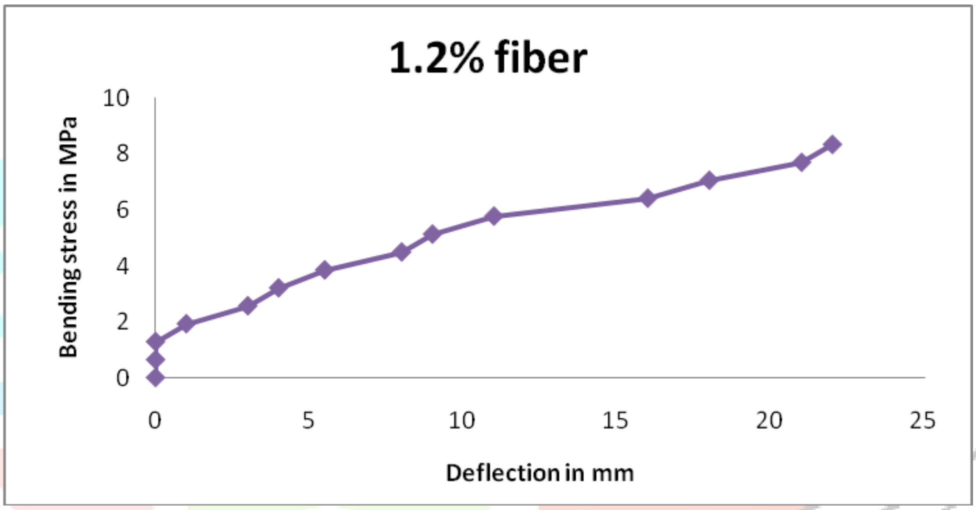

Fig 5 Variation of Bending Strength with Deflection for 1.2% fiber (28 days)

Table 4.1: Typical data sheet of results for Flexure test (for 1.2% fiber)

Flexure test for 1.2% fiber									
SL no	Load in KN	Centre Deflection in mm	Bending test span						
			Length = a=L/3	Width in mm	Depth in mm	M=W*a (KN-mm)	S=bd^2/6 in mm^3	F=M/S in MPa
1	0	0	102	76.5	25	0	7968.75	0
2	0.05	0	102	76.5	25	5.1	7968.75	0.64
3	0.1	0	102	76.5	25	10.2	7968.75	1.28
4	0.15	1	102	76.5	25	15.3	7968.75	1.92
5	0.2	3	102	76.5	25	20.4	7968.75	2.56
6	0.25	4	102	76.5	25	25.5	7968.75	3.2
7	0.3	5.5	102	76.5	25	30.6	7968.75	3.84
8	0.35	8	102	76.5	25	35.7	7968.75	4.48
9	0.4	9	102	76.5	25	40.8	7968.75	5.12

10	0.45	11	102	76.5	25	45.9	7968.75	5.76
11	0.5	16	102	76.5	25	51	7968.75	6.4
12	0.55	18	102	76.5	25	56.1	7968.75	7.04
13	0.6	21	102	76.5	25	61.2	7968.75	7.68
14	0.65	22	102	76.5	25	66.3	7968.75	8.32

Similar test results were developed for varied % of fibers up to 2.2% and the behavior is studied. For 1.4% fiber mix, No visible crack are appeared till 0.6KN loading; for 1.6% no visible crack are appeared till 0.6KN loading; for 1.8%, specimen takes 0.9KN load and deflection 29.5mm before failure crack. For 2.0% fiber Specimen takes more load 1.0K N but comparatively deflection was reduced to 21mm. The 2.2% fiber mix concrete sample specimen takes more load 1.0KN but comparatively deflection was still less i.e. 19mm.

All the test results indicates that the inclusion of fiber in the normal concrete lead to an increase in the ductile property to a good measurable extent. Thus making concrete good in tension also. Figure 6 indicates the Variation of Bending Strength with Deflection for 2.2% fiber at the end of 28 days.

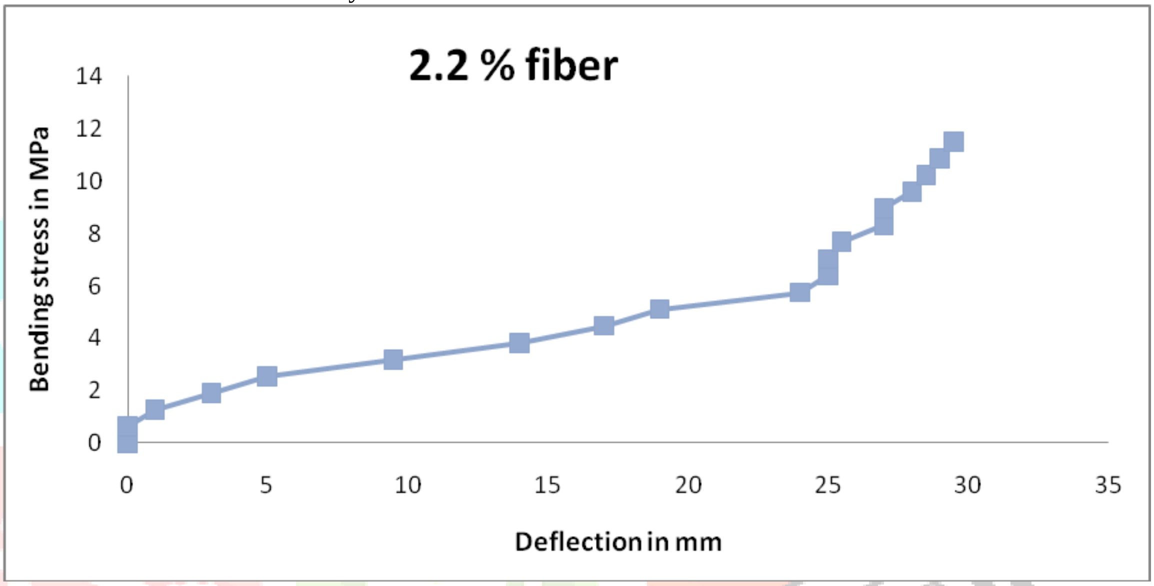

Fig 6 Variation of Bending Strength with Deflection for 2.2% fiber (28 days)

Table 4.2 indicate the collective results of the flexural test for varied percentage of fibers. The table indicates that as the percentage of fibers increases the maximum bending stress before failure also increases upto certain value, and there after it remains almost constant. But the deflection value increases up to a optimum value and there after starts decreasing. Figure 7 indicates the variation of bending stress with the addition of fibers.

Table 4.2: Typical data sheet of results for Flexure test (for 1.2% fiber)

Sl no	**Description**	**Max load taken in KN**	**Max deflection in mm**	**Max Bending stress in N/mm2**	**Remarks**
1	Without fiber	0.15	0.03	1.92	Sudden Failure without deflection
2	1.2% fiber	0.65	22	8.32	No visible cracks appeared up to 0.5kN load
3	1.4% fiber	0.8	29	10.24	No visible cracks appeared up to 0.6kN load
4	1.6% fiber	0.9	29.5	11.52	No visible cracks appeared up to 0.6kN load

5	1.8% fiber	0.9	29.5	11.52	Specimen takes more load (0.6KN) as well as deflection(29.5mm)
6	2.0 % fiber	1	21	12.8	Specimen takes more load (1.0KN) but deflection is less(29.5mm)
7	2.2% fiber	1	19	12.8	Specimen takes more load (1.0KN) but deflection is less(29.5mm)

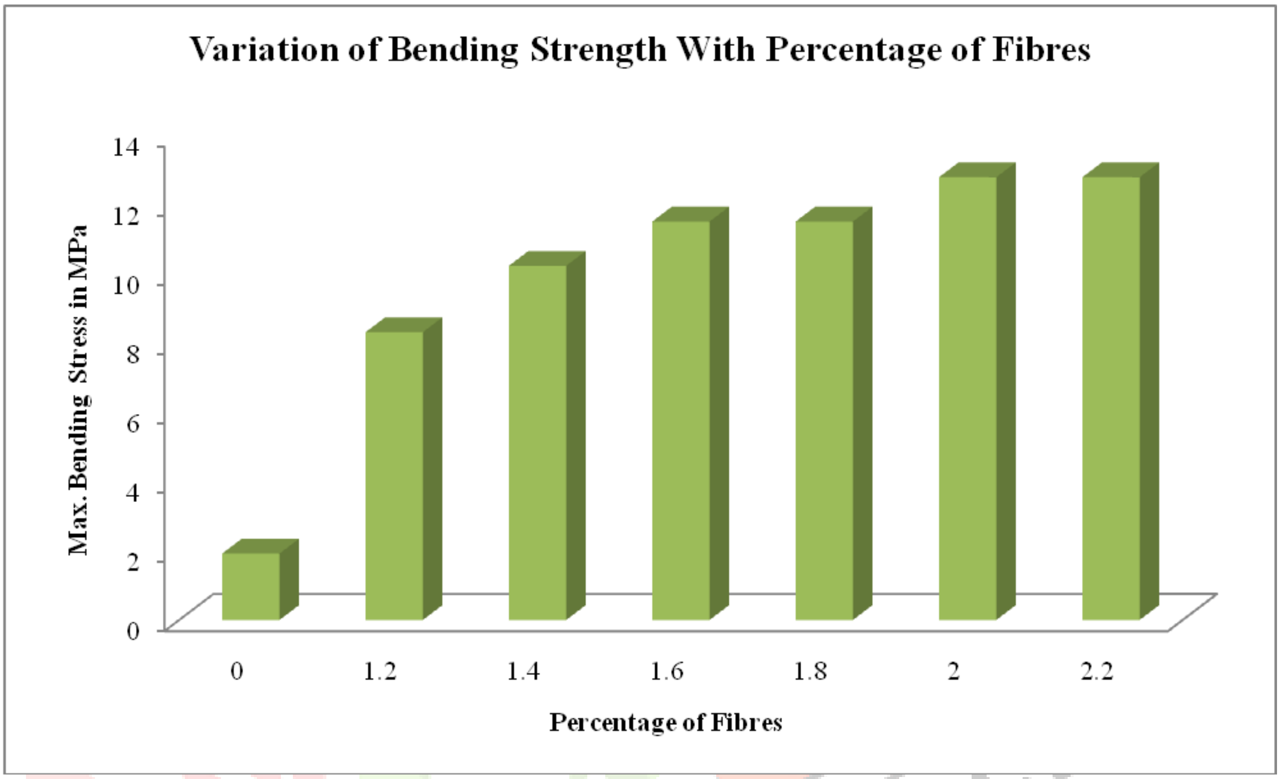

Fig 7 Variation of Maximum Bending Stress With Percentage of Fibres (28 days)

V. CONCLUSION

The effect of addition of PVA fiber to concrete mix has been investigated by testing the concrete specimen with different fiber percentage .Compression test was conducted for M25 grade mix proportion and Flexure test was conducted for PVA-ECC mix Proportion. From the test results it can be concluded that the maximum compressive strength of 33.23 MPa can be obtained for the fiber content of 1.2%, which was 15% better than the compressive strength results of control mix without fibers. Flexure test conducted for specimen indicates that as the percentage of fibers increases the maximum bending stress before failure also increases upto certain value, and there after it remains almost constant. The flexure test with fiber content 1.6% and 1.8% has shown Central deflection of 29.5 mm for 0.9 KN maximum load and the maximum bending stress was observed 11.52 MPa. For the control mix (for specimen without fiber) has shown only 0.03 mm deflection for corresponding maximum load of 0.15 KN and maximum bending stress of 1.92 MPa. This indicates that using PVA –ECC mix, brittle nature of concrete can be converted to ductile nature.

VI. Acknowledgment

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