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Investigation of Flexural Behavior of Engineered Cementitious Composites

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Abstract **- Traditional concrete is brittle, rigid and less durable. The search for the new material in construction industry results in the development of new class of Fiber Reinforced Concrete (FRC), known as Engineered Cementitious Composites (ECC). They impart ductility and durability to the structure. In concrete structural cracks develop even before loading, particularly due to drying shrinkage or other causes of volume changes. When loaded, the micro cracks propagate and open up, and owing to the effect of stress concentration, additional cracks form in places of minor defects. The development of micro cracks is the main cause of inelastic deformation in concrete. This paper deals with flexural behavior of ECC.**

Keywords: **- Poly Vinyl Alcohol (PVA fiber), Engineering Cementitious Composities, Flyash**

I. INTRODUCTION

Concrete is the most extensively used material in civil engineering construction so that considerable attention is taken for improving the properties of concrete with respect to strength and durability. India's total installed capacity of cement stood at 320 million tons per annum (mtpa). Carbon concentration in cement spans from approximately 5% in cement structures to 8% in the case of roads in cement. The cement industry produces about 5% of global man-made CO_2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. The amount of CO_2 emitted by the cement industry is nearly 900 kg of CO_2 for every 1000 kg of cement produced. Use of industry waste like fly ash to partly replace cementing material in concrete system addresses the sustainability issues and its adoption will enable the concrete construction industry to become more sustainable. Transition zone, represents the interfacial region between the particles of coarse aggregate and the hardened cement paste. Transition zone is generally a plane of weakness and therefore has far greater influence on the behavior of concrete. Transition Zone can be avoided by eliminating coarse aggregate. Engineered Cementitious Composites is an easily moulded mortar-based composite reinforced with short random fibers, usually polymer fibers. ECC has a strain capacity in the range of 3–7%, compared to 0.1% for ordinary Portland cement. The large strain is contributed by sequential development of multiple cracks, instead of continuous increase of crack opening. The high fracture toughness and controlled crack width make ECC improve serviceability and durability of infrastructures. Engineered cementitious composite is composed of cement, sand, fly ash, water, small amount of admixtures and an optimal amount of fibers. In the mix coarse aggregates are deliberately not used because property of ECC Concrete is formation of micro cracks with large deflection. Coarse aggregates increases crack width which is contradictory to the property of ECC Concrete. In ECC transition zone is eliminated. ECC is ductile in nature. Under flexure, normal concrete fractures in a brittle manner. In contrast, very high curvature can be achieved for ECC at increasingly higher loads, much like a ductile metal plate yielding. Extensive inelastic deformation in ECC is achieved via multiple micro- cracks

II. MATERIALS USED

Cement: Ordinary Portland Cement, 53Grade conforming toIS12269–1987.
Fine Aggregate: Locally available river sand conforming to grading zone II ofIS383–1970.
Water: Potable water as per IS: 456-2000.
Fibres: PVA fiber has suitable characteristics as reinforcing materials for cementitious composites.
Flyash: Flyash class F obtained from Mettur Thermal Power Plant which confines asperIS3812-2000.
Superplasticizer: Glenium was used as chemical admixture to enhance the workability of the concrete.

III. MIX DESIGN

The mix design for ECC Concrete is basically based on Micromechanics design basis. Micromechanics are a branch of mechanics applied at the material constituent level that captures the mechanical interactions among the fiber, mortar matrix, and fiber–matrix interface. Typically, fibers are of the order of millimeters in length and tens of microns in diameter, and they may have a surface coating on the nanometer scale. Matrix heterogeneities in ECC, including defects, sand particles, cement grains, and mineral admixture particles, have size ranges from nano to millimeter scale. However the micromechanics based mix design requires pull test to be carried on the PVA fibers, which is not possible in the laboratory. Hence the ideal mix proportion given in the literature of ECC-ECC Concrete was used as the guidelines to determine the proportion of various constituents in the concrete.

TABLE I MIX PROPRTION

Mix	Cement (kg/m^3)	F.A	Flyash	W/C	SP	PVA-Fibre
CM	1	0.8	1.2	0.56	0.018	-
ECC	1	0.8	1.2	0.56	0.018	0.034

IV. EXPERIMENTAL INVESTIGATION

A. Workability Studies

Slump Test: Slump test is used to determine the workability of fresh concrete. The test is simple and cheap. It is suitable to use in the laboratory and also at site. Although the test is simple, but the testing has to be done carefully.It also mentioned that a slump less than 25mm will indicate a very stiff concrete and a slump that more than 125mm will indicates a very runny concrete.

B. Tests on Hardened Concrete

Flexural Behaviour of Ecc Beam: Beam is a structural member which is acted upon by a system of external loads at right angle to the axis. Bending implies deformation of the member produced by loads perpendicular to its axis as well as force couples acting in a plane passing through the axis of the member. When a beam is loaded it is bent and subjected to bending moments. The bending equation is based upon the theory of pure bending and the assumptions taken thereupon, which require that the beam should be subjected to constant bending moments unaccompanied by shearing forces.

The value of modulus of rupture depends on the dimensions of the beam and the manner of loading. The system of loading used in finding the flexural tension are central point loading and third point loading. In the central point loading, the maximum fibre stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two point, the critical crack may appear at any section, not strong enough to resists the stress within the middle third, where the bending moment is maximum. It can be expected that the two point loading will yield a lower value of modulus of rupture than the central point loading.

Details Of Beams: The main reinforcement consists of 2 numbers of 10mm dia bars at bottom and 2 numbers of 8mm dia at top with a clear cover of 25mm. The shear reinforcement includes stirrups of 8mm dia bars at 100mm c/c spacing.

Specimen Details: All beams were cast in wooden moulds to maintain the dimension of the beam specimens as100 mm X 200mm X 2000 mm. They were simply supported over an effective span of 1700 mm and clear cover of beam was 20 mm. Two legged vertical stirrups of 8 mm diameter at a distance of 100 mm centre to centre were provided as shear reinforcement.

Details and Designation of Beams: The details and designation of beam specimens are given in table 2.The letter CB refers to the control beam without PVA fibre and the letter ECCB refers to the ECC beam with PVA fibre.

TABLE II DETAILS AND DESIGNATION OF BEAM

Mix	Designation of the beam	No of test specimen	Size in mm
M0	CB	1	100X200X2000
M1	ECCB	1	100X200X2000

Casting and Curing of Beam Specimens: Clean and wide surface is used to preparation of concrete. Reinforcement should be clearly done through the design detailing diagram. Well oil coated plywood’s were used for moulding the concrete, because the absorbing of water is lower than other seasoned wood. Compaction of beam was done properly through the beam. Then ply wood is removed and the beams were left for curing for 28 days.

Testing Procedure for Beam Specimens: A typical two point loading experimental set up is used. The crack patterns were also recorded at every load increment. All beams were tested up to failure. The beams to be tested are placed in a loading frame of capacity 1000 kN. The end condition of the beam is to be kept as simply supported. The beam is to be divided into number of grids before placing in the loading frame for the observation of crack pattern. The load cell is to be placed in the loading jack at the centre of the beam from which load imparted to the beam can be observed. Deflections were measured under the loading point and at the mid span using Linear Variable Differential Transducer (LVDT).

Crack Patterns: As expected, flexure cracks initiated in the pure bending zone. As the load increased, existing cracks propagated and new cracks developed along the span. In the case of beams with larger tensile reinforcement ratio some of the flexural cracks in the shear span turned into inclined cracks due to the effect of shear force. The width and the spacing of cracks varied along the span. The beams initially by yielding of the tensile steel followed by the crushing of concrete in the compression face. The cracks at the mid-span opened widely near failure. Near peak load, the beams deflected significantly, thus indicating that the tensile steel must have yielded at failure. The final failure of the beams occurred when the concrete in the compression zone crushed, accompanied by buckling of the compressive steel bars. The failure mode was typical of that of an under-reinforced concrete beam.

Fig.1 Crack pattern

V. RESULTS AND DISCUSSIONS

A. Workability Studies

TABLE III SLUMP CONE TEST

Sl. No.	Mix Proportions	Slump Value mm
1	CM	55
2	ECC	53

Workability of ECC mix is found to be slightly less than control mix because of addition of PVA fibers

B. Strength Studies

TABLE IV FLEXURAL STRENGTH TEST

Sl. No.	Load kN	Deflection mm	
		CM	ECC
1	0	0	0
2	10	0.07	1.33
3	20	2.12	2.08
4	30	4.26	2.15
5	40	6.42	2.94
6	50	8.94	3.82
7	60	11.96	4.7
8	70	15.97	8.62
9	80	20.1	11.73
10	90	20.1	15.49
11	100	24.21	19.56
12	110	31.96	23.9
13	120	35.89	32.37
14	130	38	33.5

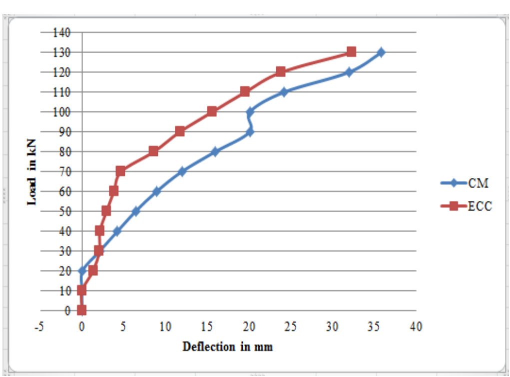

Fig. 2 Load Vs deflection

TABLE V INITIAL CRACK

Sl. No.	Mix Proportions	Initial Crack, kN
1	CM	25
2	ECC	40

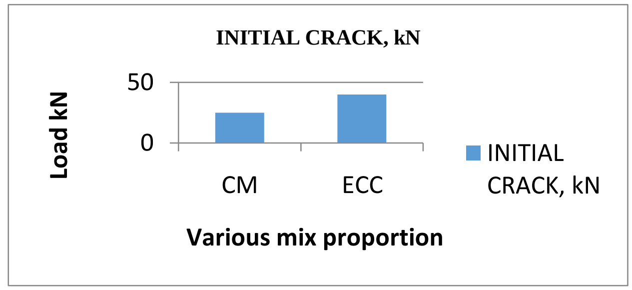

Fig. 3 Initial crack

ECC mix cracks at higher load comparing with control mix because of the fibers and also there is no transition zone which is the strength limiting zone.

TABLE VI ULTIMATE LOAD

Sl. No.	Mix Proportions	Ultimate Load, kN
1	CM	145
2	ECC	160

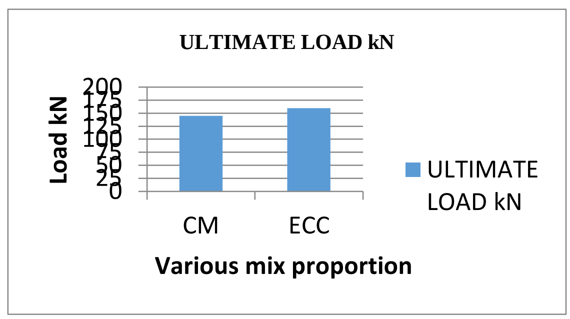

Fig. 4 Ultimate Load

Ultimate load carrying capacity of ECC mix is higher than Control mix.

VI. CONCLUSION

Based on the experiment the following conclusion is drawn within the limitation of test results.

1. The mix design of ECC is based on micromechanics study. In this project the ideal mix is generated from the literatures.
2. The flexural strength of ECC can withstand about 10% more load than the nominal mix.
3. In flexural test results, the Beam can withstand high load and a large deformation without succumbing to the brittle fracture typical of normal concrete, even without the use of steel reinforcement.

4. The Beam is able to withstand high load and a large deformation without succumbing to the brittle fracture, even without the use of steel reinforcement.
5. The cracks width in the ECC is found to be very small when compared with the control mix.

VII. SCOPE FOR FUTURE WORK

The following are the some of the points recommended for further investigations.

1. Although by decreasing water/cementitious material ratio, ECC Concrete can achieve high strength concrete. But the workability will be very low. Therefore it is recommended that the casting should be done with the help of pan mixer so that workability can be improved.
2. More investigations and studies required to find out shear resistance of concrete so that the application of concrete in earthquake resistant structures can be tested.
3. More laboratory work to be done to find out the corrosion resistance capacity of concrete. Therefore it is recommended that the testing can be done by casting ECC Concrete beams with steel reinforcing bars.

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