Impact Factor (SJIF):3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444
Volume 3, Issue 6, June-2016

Parametric Study on Flexural Strength of Hybrid ECC

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Abstract — Bendable Concrete also known as Engineered Cementitious Composites abbreviated as ECC is class of ultra-ductile fiber reinforced cementitious composites, characterized by high ductility and tight crack width control. ECC is capable to exhibit considerably enhanced bendability because of its high capacity to store strain energy. It is reinforced with micromechanically designed polymer fibers which gives it higher flexibility. The aim of this study is to investigate the hardened property (i.e. Flexural Test) of ECC by addition of both PVA and Steel fibers in different proportion. In this study, four different combinations of PVA and Steel fiber used to find out the better combination for getting the higher elastic properties. The result of Flexural strength of various ECC mix with different percentage of fibers are compare with Conventional Concrete design according to Indian Standard. All beams were tested under four-point loading test at different age in U.T.M.

Keywords- Bendable concrete, ECC-Engineered Cementitious Composites, Deflection, Compressive Strength, Flexural Strength

I. INTRODUCTION

The Bendable concrete is defined as Engineered Cementitious composites known as ECC. Generally Conventional concretes does not possess bendability and have strain capacity of 0.1 percent of a load they can carry in compression which making it highly rigid and brittle. This unbendability of a normal concrete is a reason of failure below strain and had been the pushing factor for the evaluation of bendable concrete. ECC exhibits damage tolerance and excellent ductile properties, which are multiple cracking properties and strain-hardening with strain capacity of 1.5% to 7% in tension.

"Engineered Cementitious Composite is an easily mixed mortar based cementitious composite are reinforced with specially chosen short fibres, generally polymer fibres. ECC is a highly ductile and strain-hardening cementitious composite. This material sponsor a percent of maximum tensile strain attributed to a synergistic effect of high-performance polymer fibre and mortar matrix. When ECC is applied to seismic components and repair constructions, unprecedented high performance structural members can be expected.

Figure 1: Response of ECC under Flexural Loading
Sources: www.buildingindustry.org/bundles/image

It prevents the fiber from rupturing which would lead to large cracking. Thus an ECC deforms much more than a normal concrete but without fracturing. Figure 1 represents the behavior of ECC under flexural loading and it can be seen that the beam can deform well without direct failure. Different ingredients of ECC are work together for sharing the applied load. ECC has proved to be 50 times more flexible than traditional concrete, and 40 times lighter, which could even influence design choices in skyscrapers. Additionally, the excellent energy absorbing properties of ECC make it especially suitable for critical elements in seismic zones.

II. EXPERIMENTAL PROGRAM

A. Materials and Mix Proportions:

In this study, the ingredients used in the production of ECC mixtures include 53 grade Ordinary Portland cement (OPC) as in table 1 and fly ash (FA) fulfilling requirement according to IS 3812 {Part-I} with Specific Gravity of Fly ash measured using pycnometer as 2.12 and Fineness modulus (Retained on 45 Micron sieve) was 9%, sand with fineness modulus of 2.718 mm respectively, water, polyvinyl alcohol (PVA) fibers, Steel fibers and a Polycarboxylate-based high range water reducer (HRWR). The physical properties and chemical compositions of OPC, FA, are listed in Table 1 and 2. The PVA fibers produced in China from ANHUI Elite Industrial Co., Ltd are 6 mm in length with the length–diameter ratio of 200 and elongation of 7.5%. The tensile strength and density of PVA fiber are 1300 MPa and 1300 kg/m3, respectively.

TABLE-1
PHYSICAL PROPERTIES OF CEMENT

Test	Value
Standard Consistency	27%
Initial Setting time	140 min
Final Setting time	200 min
Soundness	1.5 mm

TABLE-2
MIX PROPORTION OF ECC

MATERIAL	FIBERS			
	0.5% PVA + 1.5% STEEL	1% PVA + 1.5% STEEL	0.5% PVA + 2% STEEL	1% PVA + 2% STEEL
CEMENT	558	558	558	558
FLY ASH	670	670	670	670
SAND	493	493	493	493
WATER	292	292	292	292
SP	9.824	9.824	9.824	9.824
All quantities in kg/m^3 & % are in the ratio of (cement + fly ash).				

TABLE-3
MIX PROPORTION OF CC

CEMENT	WATER	F.A	C.A		SP*
			20MM	10MM	
404.13	197.16	658.09	720.09	480.06	0.013
* is the unit in kg w.r.t to % of cement content					

The ECC mix proportions with different proportion of fibers are shown in Table 2 in this study. Table 3 indicates the mix design of CC. The ECC mixtures are prepared in a standard mortar mixer at a constant amount of binder material (1228 kg/m3) and constant W/B of 0.24.

B. Specimen Preparation and Measurement

Solid ingredients, including cement, mineral admixtures and sand are first mixed for 60 s. Water and HRWR are then added into the dry mixture and mixed for 1 min. PVA and Steel fibers are slowly added into the mortar matrix and mixed until all fibers evenly distributed. Additionally, slight adjustment in the amount of HRWR is performed to achieve consistent rheological properties for better fiber distribution and workability. The mixtures are then cast into moulds and demoulded after 24 h. After being demoulded, ECC specimens are cured in curing room where the temperature is 24 ± 2 °C for 7 and 28 days respectively.

Prismatic specimens measuring 500 mm * 100 mm * 50 mm are used to conduct four-point bending test for each mix. Flexural test is carried out for each mix at the age of 7 days and 28 days respectively.

Figure: 2 Setup for Flexural Strength

III. RESULT AND ANALYSIS

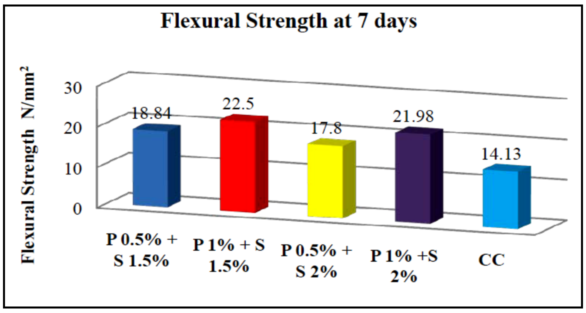

Figure: 3

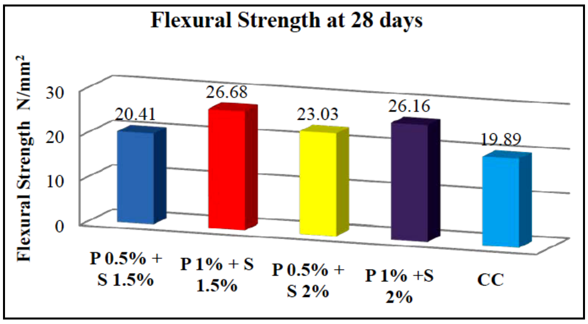

Figure: 4

By adding Steel & PVA fibers to ECC mixtures, its flexural strength increases compare To Conventional Concrete almost about 50%.

The flexural strength of (P 1% + S 1.5%) is higher than other hybrid ECC. The flexural strength of hybrid ECC is more as compared to the conventional concrete and also addition of fibres increase the flexural strength by almost about 40-50 percent than conventional concrete.

Figure: 5 Failure Pattern Observed In Beam

For (P 0.5% + S 1.5%) and (P 0.5% + S 2%), there is about 15% increase in flexural strength as we increase the steel fiber with the 0.5% of PVA. There is about 20-30% of increment in flexural strength at the age of 28 days for all ECC mix. The combination of 1% of PVA and 1.5% of Steel fiber in ECC mix gives best results.

Figure: 6 Failure Pattern Observed In Beam

IV. CONCLUSIONS

- The Flexural strength for the ECC mixes with 1% PVA and 1.5% Steel gives best results and should be economical due to less percentage of PVA fibers.
- Increasing the percentage of PVA fibers leads to increased deflection capacity of specimen so as to increase its flexural strength.
- Flexural strength and deflection is inversely related with the cross section area of the specimen.
- There is a 75% of increase in flexural strength capacity of specimen as we increase the PVA fiber from 0.5% to 1%.
- ECC enhanced with Hybrid fibers shows an average increment of 40 % in the flexural strength.

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