FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM WITH A LAYER OF ENGINEERED CEMENTITIOUS COMPOSITE IN THE TENSION ZONE

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Abstract: This study has been done to analyze the change in strength, ductility and crack control behavior of Reinforced concrete beam when it is strengthened with steel and basalt reinforcement and Engineered Cementitious Composite (ECC) layer at the bottom of the beam. In order to investigate the influence, different thickness of ECC layer is casted, 25mm, 35mm, and 45mm. In order to check all the behavior, the enhanced beams are compared to the regular Reinforced Cement Concrete (RCC) Beams with same dimension and rebar position. Specimens are tested in two-point bending and the crack patterns are seen. The experimental result shows that in steel rebar and ECC enhanced beams the cracks starts to appear on later stage as compared to regular RCC beams. In case of basalt rebar ECC enhanced beam there are very minor cracks develop at initial stage in concrete section, not in ECC section, on further loading cracks starts to develop in ECC layer, after removing the load the beam comes back to its original position, now both using ECC layer and basalt rebar in concrete beam increases the bond strength, overall load carrying capacity and first crack load can be concluded. To summarize, applying ECC layer can reduce the crack width and delays the initial cracking time and makes cracks uniformly distributed in beams.

Keywords – Basalt Fiber Reinforced Polymer (BFRP), Strain Hardening Cementitious Composite (SHCC), Engineered cementitious composite (ECC), Ductility, Anti-corrosion bars.

1. INTRODUCTION

Conventional RC structure is faced with problems such as the formation of wide cracks due to its brittleness, a variation of live loads over time as well as the impact of climate. According to published research works, strain hardening cement-based composite (SHCC) became known in 1990 for its extraordinary higher strain/ductility performance, as well as strength, when compared to traditional normal concrete (NC) and fiber reinforced concrete (FRC). However, a type of SHCC called SIFCON (Slurry Infiltrated Fiber Concrete) was first reported in the late 1980s. In direct tensile tests, up to the elastic region, the stress increases as the strain increases, and after the first crack, the fiber bridging capacity of the SHCC leads to increase in stress upon further increase in strain. This so-called strain hardening continues until localization occurs in a crack, which leads to the onset of strain softening. In compression, ECC has a similar strength as concrete while the strain at the ultimate strength is nearly twice that of conventional concrete. Previous studies have indicated that the compatible deformation between ECC and steel reinforcement can reduce interfacial bond stresses and eliminate bond splitting cracks and surface spalling. Flexural members reinforced with basalt fiber reinforced polymer (BFRP) reinforcement can hence exhibit significant increases in ductility, load carrying capacity, shear resistance, and damage tolerance if concrete is replaced by ECC material.

2. MATERIAL PROPERTIES

I - CEMENT

OPC-43 has been used for this study.

Table 1 Physical Properties of OPC-43

Characteristics	Test Result
Fineness	95%
Consistency	30%
Initial Setting Time	115 minute
Final Setting Time	225 minute

II. FINE AGGREGATE

Locally available aggregates passing through 4.75mm sieve and retained on .7mm sieve are used as fine aggregate .The test procedures area as per IS383:1970 is carried out to determine the properties of Fine Aggregate.

Table No. 2 Physical Properties of Fine Aggregate

Characteristics	Test Value
Grading Zone	Zone II
Fineness Modulus	3.11
Specific Gravity	2.69
Silt Content	2.48%

III. COARSE AGGREGATE

Locally available aggregate of 10 mm is used having specific gravity 2.7.

Table No. 3 Physical Properties of Coarse Aggregate

Characteristics	Observed value
Fineness modulus	3.488
Specific gravity	2.71
Water absorption	0.52%

IV. ADMIXTURE

Polycarboxlate Ether Superplasticizer is chemical admixture used to increase the workability of concrete. It reduces the water cement ratio without negatively affecting the workability. And superplasticizer also helps in reducing the cement content by reducing the water content. IS 9103:2007 is referred.

Table No. 4 Properties of Superplasticizer

Properties	
Specific Gravity	1.15
Chlorides	Nil
Nitrates	Nil
Sulphates	0.5%
Appearance	Straw Coloured liquid
Freezing point	+5 °C Material can be reconstituted by agitating at 30 °C.
Role in Concrete	Improves workability and flow properties of concrete.

V. PVA FIBER

PVA Fibbers (polyvinyl alcohol) are high-performance reinforcement fibres for concrete and mortar. PVA fibres are well-suited for a wide variety of applications because of their superior crack-fighting properties, high modulus of elasticity, excellent tensile and molecular bond strength, and high resistance to alkali, UV, chemicals, fatigue and abrasion. PVA fibres are unique in their ability to create a molecular bond with mortar and concrete that is 300% greater than other fibres.

Technical Parameter

Material	100% PVA
Fiber type	Bunchy monofilaments
Density	1.29
Formula	$(CH_2CHOH)n$
Titer	1.80-2.40 Dtex
Dry breaking tenacity	≥11.50 cN/dtex≥
Dry breaking elongation	4.0-9.0% (L/L)
Initial modulus	280 cN/dtex
Hot water resistance	2.0%≤
Oil agent content	0.2%≤
specification	12MM

Properties:

The main purpose of PVA fiber are cement mortar insulating mortar putty powder.

1. Improve the cracking resistance of mortar;
2. Improve the proof permeability of mortar;

3. Improve shock resistance seismic capacity.

VI. BASALT AND STEEL

Basalt rebar and HYSD steel rebar is used

Characteristics	Steel Rebar	Basalt Rebar
Dia. (mm)	6, 8	8
Max. Tensile strength (MPa)	550	1100
Elastic Modulus (GPa)	200	50
Min. Elongation at break (%)	>14	2.5

3. EXPERIMENTAL PROCEDURE

In this experimental study total 15 beams were casted of size (150x150x700) mm. In which

I. 3 – Reference beams of RCC with steel reinforcement.
II. 3 – RCC beams of 25 mm ECC layer with steel reinforcement.
III. 3 – RCC beams of 35 mm ECC layer with steel reinforcement.
IV. 3 – RCC beams of 45 mm ECC layer with steel reinforcement.
V. 3 – RCC beams of 40 mm ECC layer with basalt reinforcement.

CASTING OF ECC LAYER

The ECC used in the experiment consist of cement, sand passing through 2.36 mm sieve, PVA fiber, Superplasticizer and water. The detailed receipt shown in table below. The properties of PVA fiver are shown in table below. The mixing of ingredients should be done according to the design mix proportion. First, cement and sand is mixed in a mixer and then PVA fiber of 2% by wt. of cement is added in the mixer, then mixer is allowed to rotate for 4 minutes for uniform distribution of PVA fiber. Now, water is added in the mix in two parts, first half of water is poured directly in the mixer and remaining of the water is added with superplasticizer of 0.2% by wt. of cement and then poured in the mixer. Mixer is allowed to rotate for next 5 minutes. With prepared mixture, ECC layers of different thickness i.e. 25mm, 35mm, 45mm, Then the mold is place in vibration table to fix the ECC layer and hold the cage (steel & basalt rebar) at appropriate thickness and position. Now, the specimen with ECC layer and cage were allowed to set.

Mix proportion of ECC

Cement	Sand	Superplasticizer	PVA Fiber	w/c ratio
1	2	0.2% by wt. of cement	2% by wt. of cement	0.40

Strength of ECC Cubes, (70.60 x 70.60 x 70.60) mm

Age	Sample1	Sample2
Day 7	29.72	28.80
Day 28	45.27	43.87

CASTING OF CONCRETE LAYER

A Concrete mix of M25 grade was prepared according to mixed design and after that the prepared concrete was casted above the ECC layers and compacted with the help of vibration table. The details of design mix is given below

Compressive Strength of cubes

Days	Cube1	Cube2	Cube3	Mean
7 Days	23.3 N/mm^2	24 N/mm^2	22.9 N/mm^2	23.4 N/mm^2
28 Days	34 N/mm^2	32.2 N/mm^2	32 N/mm^2	32.73 N/mm^2

Mix proportion of concrete

Cement	w/c ratio	Fine aggregate	Coarse aggregate	superplasticizer
1	0.40	2.3	2.1	0.002

4. RESULTS

After testing all the specimens of different thickness of ECC layer on Flexural Testing Machine, it is found that there is no change in the initial cracks at given load with respect to reference specimen, for the ECC thickness of 25 mm. But for the specimen having ECC layer of thickness 35 mm and 45 mm the cracks starts to develop at later stage on increasing the load. In all the specimens of ECC the thickness of cracks get reduced and the pattern of cracking has changed. In basalt reinforced beam with ECC layer of 40mm the behavior of initial cracks and final cracks on given load are same as in reference beam but, after releasing the load the specimen the beam goes back to its original position, and on again loading the specimen it get reduced by 5% - 10% of its peak load.

SAMPLE	LOAD (INITIAL CRACKS STARTS)	PEAK LOAD (SAMPLE FAILED)
REFERENCE BEAM		
1	69.32	110.52
2	68.71	103.27
3	67.20	102.15
ECC LAYER OF 25mm THIKNESS IN STEEL REINFORCED BEAM		
1	61.42	112.73
2	62.36	112.67
3	63.01	102.17
ECC LAYER OF 35mm THICKNESS IN STEEL REINFORCED BEAM		
1	73.02	110.26
2	71.26	102.25
3	79.09	102.57
ECC LAYER OF 45mm THICKNESS IN STEEL REINFORCED BEAM		
1	83.20	109.05
2	81.82	104.30
3	93.02	112.67
ECC LAYER OF 40mm THICKNESS IN BASALT REINFORCED BEAM		
1	60.79	108.67
2	61.30	102.85
3	60.30	105.01

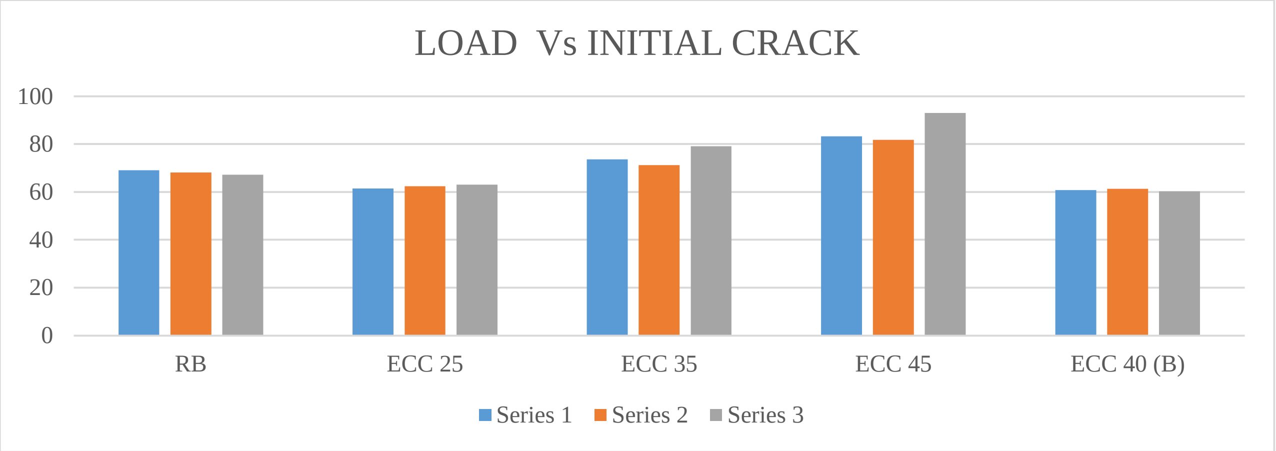
5. CONCLUSION

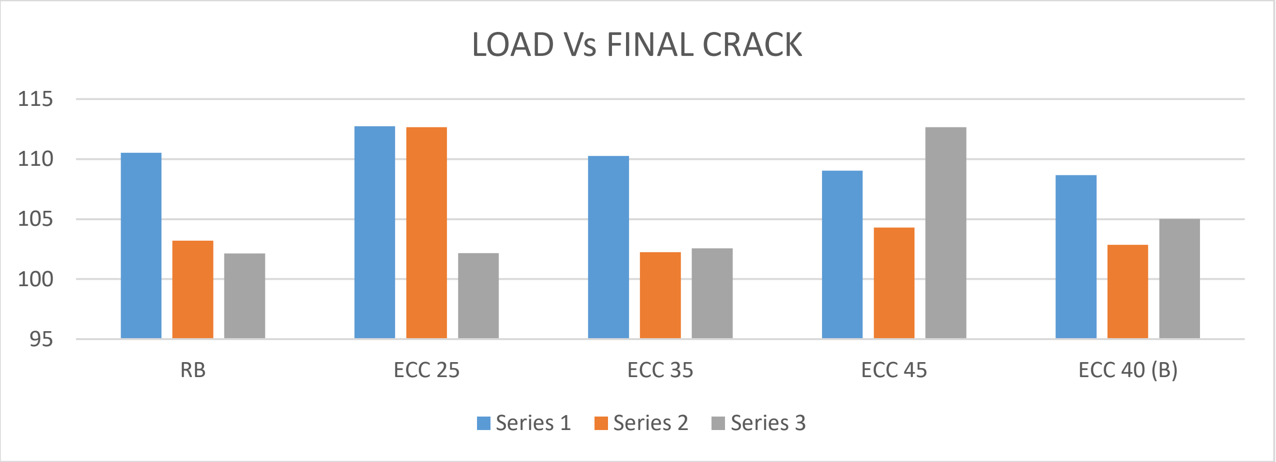
From the above results following conclusion can be drawn:

- The crack control behavior of ECC layer in RCC beams with steel and basalt re-bars and delay the initial crack time of the beam with respective loading. Initial crack developed firstly above the concrete layer and then propagates to ECC layer.
- Ductile failure is observed in beam when main reinforcement are embeded in ECC. Brittle failure are observed in beam when main reinforcement is not embaded in beam.
- ECC layer has high strain carrying capacity as compared to ordinary concrete that's why ECC delays the failure of ordinary concrete layer but minimal cracking of itself.
- ECC performs only when main longitudinal reinforcement embaded sufficiently within the ECC layer.
- On and above 35 mm of ECC layer in tension zone there is increase in the initial crack time with respect to applied load.
- There is uniformity in cracking pattern in ECC layers of all the beam.
- In basalt and ECC compositions:
    - The initial crack starts in concrete zone not in ECC layer which shows the bond strength between basalt and ECC is very strong.
    - After releasing the load on final cracking the specimen goes back to its original position which shows the elastic property of basalt and ECC.
    - If the braked specimen is further reloaded then its strength retains is 90% - 95% from previous loading which is very good and is useful in heavily earthquake prone areas, as the member regains its original shape and the cracks can be repaired by various retrofitting techniques.

6. FUTURE SCOPE

- ECC layer is used in pure tension zone to check its property for removing the extra reinforcement in the beam.
- Waste plastic materials which is made of PET (polyethylene terephthalate) can be used in place of PVC fiber for reducing environmental degradation.
- Basalt bar can be used in place of main reinforcement bar in tension zone with ECC layer can be used in long span beams for reducing the depth of beam.





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