Study the Bond strength of engineered cementitious composites with reinforcement

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Abstract- **In modern construction infrastructure development is highly improved. The engineered cementitious composites (ECC) are high ductile and flexural property are used to improve the load carrying capacity of the concrete. Polyvinyl alcohol (PVA) fiber can be used as a better convenient material for ECC and more quantity of PVA can be produced yearly around 650,000 tons per year. It can be used in cement-based composite materials as many ways. For achieving balanced composite performance, the design procedure of PVA is more requirable for structural applications and practical design consideration. PVA gives a positive results in terms of micro structure behavior the formation of Ca(OH)2 were found to be reduced which contributes to better adhesion between the paste and the aggregates. A ductile fiber-reinforced cementitious composite (DFRCCs) investigates the effects of freeze-thaw cycles, and water-to-binder ratio as well as reinforcing fiber combination on flexural properties and cracking procedure of DFRCC prismatic specimens. The DFRCC determined from the results of durability test such as Dynamic Modulus of elasticity, Toughness Index, Mass loss.**

Index Terms- **Cement based composites; PVA fiber; ECC.**

I. INTRODUCTION

Concrete is weak in tension but it is strong in compression. The process of shrinkage and thermal expansion to induced the cracks in concrete surface. It occur the tensile stress; it may leads to the propagation of internal cracks and exposes the surface of the concrete. The formation of cracks in RC structures under both mechanical service load and climatic load because of the concretes are half-brittle with low tensile strain capacity. For example freezing and thawing in cold weather and shrinkage cracks these are affected for the RC structures. Many of the hydraulic structures are designed for the period of 50 to 100 years depending upon the particular utilization (1). Generally the poor implementation of concrete materials gets deteriorated before their lifetime (2). To improve the durability of hydraulic structure will be the world wide engineering challenge and the maintenance cost is comparatively low. The formation of concrete cracks are caused due to the improper durability of hydraulic structures are the most common causes in field condition (3, 4). The cracked concrete is a quick deterioration of easy entries for aggressive ions (for example sulphate, chloride ions) which can easily enter into the structure (5). The effective cracks of the corrosion process are neglected when the cracks are relatively small. Controlled crack width can be easily achieving suitable durability performance of concrete in hydraulic structures. Still the crack width control is considered as an important challenge for conventional concrete. The crack initiation and propagation in the concrete is an effective movement for careful selection and ratio of material, controlled temperature during the construction (6-8). ECC is a group of high performance fiber reinforced cementitious composites characterizing high tensile ductility and narrow crack width. Under the tensile load, ECC exposes a pseudo strain-hardening behavior by progressing several micro-cracks. ECC reaches 3-5% of the tensile strain capacity will be 300-500 times more than the normal concrete (9-11). The test results intimate the ductility of ECC specimens are losses after 300 freeze-thaw cycles both in water and Na2SO4 solution. Moreover, the durability of ECC under hot and moist environment (12), natural environment (13) and alkaline environment (14) were also proceed empirically more than conventional concrete.

What is ECC and advantages

In modern construction infrastructure development is highly improved. The engineered cementitious composites (ECC) are high ductile and flexural property are used to improve the load carrying capacity of the concrete. Engineered cementitious composite (ECC), is a new type of high performance fiber reinforced cementitious composites with high ductility. Engineered cementitious composites (ECC) with extreme tensile ductility, on the order of several hundred times that of normal concrete or fiber reinforced concrete (FRC). The components of engineered cementitious composites is same to that of fiber reinforced concrete like cement, sand, water, fiber and a few chemical additives. The mixing of engineered cementitious composites is similar to that the normal concrete. The engineered cementitious composites are economical by the reduction in the utilization of fiber even if maintaining the strength and ductility. If the fiber reinforced concrete, the crack develops with the rupture of the fibers due to which the stress bearing capability is decreased. Moreover, the engineered cementitious composites have high fracture toughness. The engineered cementitious composites do not add more amount of fiber not like the fiber reinforced concrete. The basic difference between the engineered cementitiuos composites and fiber reinforced concrete is that after cracking the engineered cementitious composite strain hardened at that time the fiber reinforced concrete does not exhibit such a behavior. ECC is depending upon the matrix composition and the compressive strength varies from 30 to 70MPa. The performance of ECC specimens incorporating hybrid PVA- SMA fiber reinforcement under tensile and impact loading was evaluated by conducting direct uniaxial tensile and drop weight impact tests the tensile capacity of ECC composites was improved due to SMA fiber addition. ECC specimens incorporating 2% PVA and 1% SMA fibers achieved highest tensile capacity at the same testing age. The impact resistance of mono and hybrid-fiber ECC specimens was found to be 30 to 700 times higher than that of the plain fibreless ECC control specimens (15).

Current apllication of ECC

Now a day, an investment constriction for public infrastructure has accumulated in many industrial countries. Life cycle costing (LCC) is an appropriate management for long-term and sustainable investment. In this journal is the evaluation of high-performance materials (HPM) using LCC to reduce that investment constriction. Investment in public infrastructure is an important policy area for most developed and developing countries. In particular, repair and maintenance costs dominate the public discussion. The engineered cementitious composites are used in shear elements that are subjected to a cyclic loading, in the mechanical elements of the beam and column combination and for general structural repairs. These composites are commonly used in structures that have high energy absorption, including dampers, steel element joints and for hybrid steel connections. Including the structural applications, these composites are used as a shielding layer for increasing the corrosive resistance of structures. Other potential applications of engineered cementitious composites include underground structures, highway pavements and bridge decks.

Why this study

Current situation of ECC is widely used in many countries. So the bond behavior between the ECC and steel bar is most important property. That’s why the bond strength using the pull-out test is studied in this paper.

II RESEARCH SIGNIFICANCE

pull out test on ECC

There are two specimens are used in the pull out test. The single bar embedded vertically along the central axis in each specimen. The bar shall project down for a distance of about 10mm from the bottom of the cube and shall project top face of the bar necessary distance to provide sufficient length of bar to extend the support of the testing machine. The 100mm cube and 12mm rod is adopted for referred as IS: 2770 (part 1) – 1967. The length of the rod is 540mm. A steel box of size 110x110x130mm and the thickness of mould is 10mm is used in pull out test. One side of the box is opened because of the pull out specimens are easily fixed it and removed. The top face of the box is centrally cut it and the size of 20mm so the rod is easily fixed the test setup and removed. The 16mm diameter of the rod is vertically along the center of the box. The length of the supporting rod is based on the total length of the testing machine (UTM). The pull out test is used to calculate the bond strength between the steel rod and ECC specimen with varies percentage of fiber combinations. The rod is pulled out after the failure of ECC specimen.

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

III MIX PROPORTION

The mix proportions for pull-out test is combination of 3 fibers (PVA, PP and Glass fibers) are added in varies percentages

Mix	Cement	Fly Ash	Fine Aggregate	Water-Binder Ratio	SP (%)	Fiber Volume Fraction (%)		
						PVA	PP	GF
Mix 1	1	0.3	1	0.35	1	2	-	-
Mix 2	1	0.3	1	0.35	1	1.35	0.65	-
Mix 3	1	0.3	1	0.35	1	1	1	-
Mix 4	1	0.3	1	0.35	1	0.65	1.35	-
Mix 5	1	0.3	1	0.35	1	1.35	-	0.65
Mix 6	1	0.3	1	0.35	1	1	-	1
Mix 7	1	0.3	1	0.35	1	0.65		1.35
Mix 8	1	0.3	1	0.35	1	-	-	2

TABLE I Mix Proportion For Pull-Out test

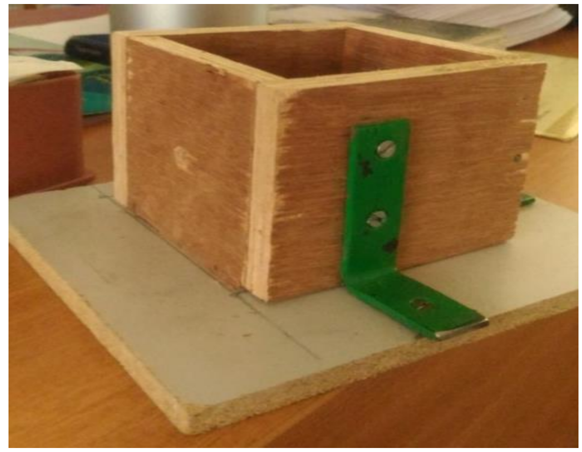
IV EXPERIMENTAL METHODS

Pull-out test

Using IS: 2770 (part 1) – 1967 this code book covers the method for the comparison of the bond resistance of different types of reinforcing bars with concrete by means of a pull-out test as shown in table 2

Table 2 Specification for pull-out test using IS: 2770 (part1):1967

Diameter of the Bars in mm	Size of the cube in mm
Up to and including 12	100
Over 12 up to and including 25mm	150
Over 25 mm	225



“Fig. 1” Pull-out test mould and their specifications

Size of the mould = 100X100X100mm

Diameter of the rod = 12mm

Thickness of the mould = 10mm

The pull-out casting mould is easy to casting the specimens and the dimensions of the mould are accurately and easily to removing the mould under demoulding. The pull-out casting mould as shown in fig 1

“Fig. 2” Mould used to hold the specimen

Table 3 specification for pull-out testing mould

Specification of mould	Size of mould in mm
Length	110
Breadth	110
Height	130
Thickness	12
Free space inside the mould	20
Supporting rod height	325
Diameter of supporting rod	12

The pull-out specimen is fixing for open of the mould. The free space inside the specimen is 20mm and holds the pull rod is top side of the UTM to adjust the UTM machine. The bottom side of the UTM is adjusting and holds the supporting rod. When the load is applying the UTM to pull. The specimens attain the yielding stress the crack will be developed on either side of the specimen and the specimen is attaining the ultimate stress the bond between the rod and the mortar is loose.

V RESULTS AND DISCUSSION

A. Testing methods

Mortar specimens were exited from the curing environment within the specified time and after cleaning with water from the surface was dried after 2 hours. Specimens are measured after brushing and cleaning of the surface. And, the bond strength testing of concrete and steel rebar was performed by 16 mm diameter, according to Rilem tensile standard on concrete samples.

Bond strength test of concrete and steel rebar pulling out rebar stop happens at two different moments

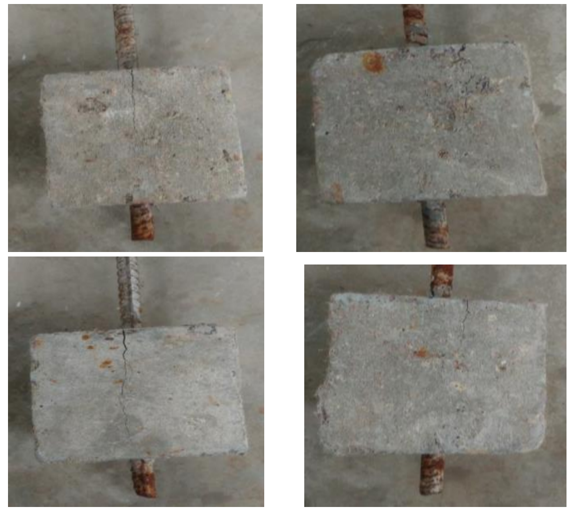
- Pulling out rebar without breaking concrete piece and
- Pulling out rebar with breaking concrete piece.

B. Test procedure

The test specimen shall be mounted in a suitable testing machine in such a manner that the bar is pulled axially from the cube. The end of the bar at which the pull is applied shall be that which projects from the top face of the cube as cast.

Bond strength between the mortar cubes added different fibers with different composition and reinforcing bar

"Fig. 3" Pull-out test set-up

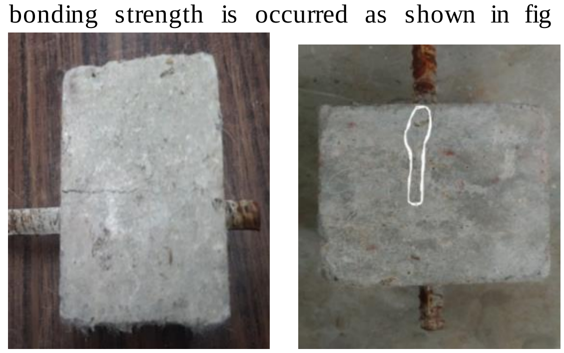


"Fig. 4 The crack development on four faces in ECC specimen

The either side of the crack propegation is straightly occurred over the specimenas shown in fig 4. This specimens are high compressive strength and more bonding to the reinforcement so the ECC specimens are compared with convensional concrete high strength and ductility.

"Fig. 5 Pull-out test failure and crack development in ECC specimen

The crack development is started with the bonding for the specimen and the crack development is prolonging on four face of the specimen. The radial cracks are occurred. These specimens are attaining the yielding strength the bond will be released. These specimens are compared with above specimen less bonding strength is occurred as shown in fig 5.



"Fig. 6 The crack development on four faces in ECC specimen

The propagation on the two sides is highly occurred and the other two side of the crack development is very low because these specimens are less bond strength compared to the above specimens as shown in fig 6.

C. Calculation of bond stress using IS: 2770 (part 1):1967

For the purpose of this test, the average bond stress shall be the value obtained for each specimen, by dividing the applied load at the slip specified, by the surface area of the embedded length of the bar; and then taking the average value for the group of each type of bar in the test series.

The formula for a bond strength of the ECC specimen
= bond strength / contact area
= bond strength/ (пxϕxL)
Where, п - constant
ϕ – Diameter of the rod
L – Length of the rod in contact area of the specimen

Table 4 Ultimate stress of the specimen

s.no	Mix (%)	Ultimate Strength(KN)	Ultimate stress(N/mm^2)
1	PP 2%	24.58	9.78
2	PVA 2%	21.85	8.69
3	PP 1.35%+PVA 0.65%	22.9	9.11
4	PP 1%+PVA 1%	23.1	9.19
5	PP0.65%+PVA 1.35%	23.5	9.35
6	PVA1.35%+Glass fiber0.65%	24.32	9.65
7	PVA0.65%+ Glass fiber1.35%	22.55	9.23
8	PVA1%+Glass fiber1%	24..75	9.56
9	Glass fiber2%	25.36	9.68

The yield and ultimate stresses pull-out specimens are calculated the stresses are compared to the design bond stresses in limit state method for a conventional concrete using IS: 456(2000). These specimens are M40 grade of concrete and if the conventional concrete design bond stress is 1.9N/mm^2. The design bond strength of the pull-out specimens are above 9 times more than that of design bond strength of conventional concrete. The ECC specimens are to achieve the high strength and ductile behavior.

VI CONCLUSION

The conclusions drawn from the bond strength results are dealt in this paper.

- The ECC materials are to achieve the high bonding to the reinforcement is studied in this paper
- These specimens are M40 grade of concrete and if the conventional concrete design bond stress is 1.9N/mm^2
- The design bond strength of the pull-out specimens are above 9 times more than that of design bond strength of conventional concrete
- The PP2% of ECC specimen is high bond strength between the ECC and reinforcement when compared to the other specimens
- The combination of PVA and PP specimens are more bond strength compared to the PVA 2% of ECC specimen
- The combination of PP and PVA specimens are the bond strength value is slightly varied from the 2% PP specimen

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