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Experimental Investigation of Flexural Performance of Sandwiched Engineered Cementitious Composite Concrete Slab and Analysis using ANSYS Software

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ABSTRACT

Engineered cementitious composite (ECC) is an ultra-ductile cement based material reinforced with fibers. It is also called as Bendable concrete. ECC has many capabilities due to its superior properties characterized by high ductility, low permeability and high tensile strength. In this paper, the conventional concrete and engineered cementitious composite concrete are prepared of M30 grade incorporated with polypropylene fiber and sandwiched using steel mesh and the results are being compared and studied. The flexural behaviour of a sandwiched engineered cementitious composite (ECC) is studied and compared with that observed in a conventional concrete. Results of the sandwiched ECC concrete slab test indicate that brittle failures as shear failure and bond splitting failure observed in the conventional concrete slab can be prevented by using PP-ECC in place of the concrete. As a result, the sandwiched PP-ECC concrete slab indicate excellent ductile manner.

Keywords: Engineered cementitious composite, Bendable concrete, Poly Propylene Fiber, and Sandwiched ECC.

1 Introduction

Engineered cementitious composite (ECC) is a material prepared based on a cement mortar matrix with short random fibers with a volume fraction of up to 2.0%. It belongs to the family of Ultra High Toughness Cementitious Composite (UHTCC) which displays outstanding mechanical properties in strain hardening, tensile strength, and ultimate strain capability. The type, geometry, volume fraction, and other strength characteristics of the fibers used in the mix decide the mechanical behaviours of ECC. ECC mixes are usually developed with polyvinyl alcohol (PVA) fibers, steel fibers (SF), PolyPropylene (PP), and PolyEthylene (PE) fibers. The purpose of incorporating fibers is to improve the strain hardening nature, tensile strength, and energy absorption of the concrete, which facilitates damage reduction in the concrete structure subjected to dynamic and impact effects.

ECC obtains a better advantage in recent applications with excellent mechanical and multiple fine cracking behaviour. Its performances in bridge decks, dampers, repair material for dams,



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irrigation channels, viaducts, and retaining walls are notable ones. ECC improves fatigue resistance and energy absorption; suppresses vibration control; resists against severe environmental exposures, and, furthermore, is maintenance free.

The ECC introduced in the RCC which underwent flexural loading produces thinner cracks at the tensile face. The finer cracks decrease the crack-induced stress concentration in the beam, thereby resulting in effective stress distribution in the bottom layer of the beam. Day by day application of ECC in construction is massive for a variety of infrastructure facilities. In the future, the scope of using ECC may augment various construction sectors.

The hybridisation in the ECC with low modulus PVA fibers, PP fibers, and high modulus glass fibers exhibit notable improvement in the mechanical properties of the ECC mix.

2 Materials and Methods

This part briefly explains the methodology adopted in this experimental work. It also includes material collection, testing of materials, casting of conventional test specimen, testing of conventional specimen, casting of ECC test specimen, testing of ECC specimen, analysis using ANSYS software, Result analysis and conclusion. The materials that are used for the preparation of ECC concrete and conventional concrete are cement, fine aggregate, coarse aggregate, water, silica fume, polypropylene fiber and steel mesh.

3 Proposed Work Explanation

The performance of the ECC Concrete was influenced by the mixing. A proper mix of concrete is encouraged to the strength of concrete & better bonding of cement with the PP fibers. Add sand, cement, 3% silica fume & water. Once the homogenous mixture is formed, add the PP fibers slowly. Mix all the constituents till the fibers are homogeneously mixed in the matrix.

Table 1: Design mix of ECC Concrete

MIX	CEMENT	M SAND	W/C RATIO	FIBER	SILICA FUME
ECC	1	3	0.45	0.4	3% of cement
				1.2	
				2.0	

The construction ECC slabs took place in two stages. In the first stage, concrete was poured into the formwork at the designated place 125 mm. Then the steel mesh was placed. The steel mesh was placed in it for bonding. After 8 hours, ECC was poured at the remaining space of 125mm, in the second stage of construction. Similarly, ECC slab were cast in two stages for different percentage of fibre content.



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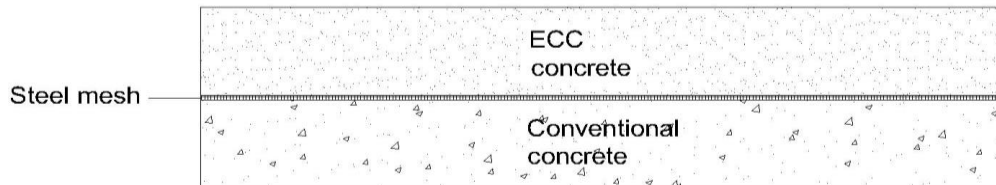


Figure 1: Sandwiched ECC concrete slab diagram

4 Results and Discussion

The uniaxial tensile and Two-point bending tests were conducted to evaluate the properties of ECC. The 700mm×450mm×250mm specimen was used for both tests. The universal testing machine was used for loading. The test conducted on conventional concrete are Compression test and Split tensile test. ANSYS software is used for analysis of slab by finite element method (FEM)

4.1 Compression Strength Test on Conventional Concrete

Table 2: Compressive strength of cubes at 7 days.

Sl.no	Specimen	Ultimate load (KN)	Ultimate compressive strength (N/mm ²)
1	Cube 1	438	20.5

Table 3: Compressive strength of cubes at 14 days.

Sl.no	Specimen	Ultimate load (KN)	Ultimate compressive strength (N/mm ²)
1	Cube 2	605	29.8

Table 4: Compressive strength of cubes at 28 days.

Sl.no	Specimen	Ultimate load (KN)	Ultimate compressive strength (N/mm ²)
1	Cube 3	648	32.1

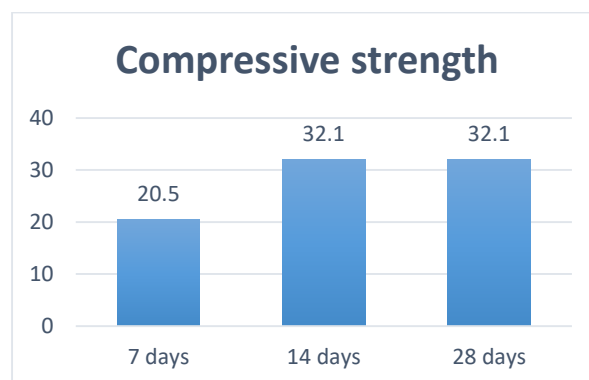


Figure 2: Graphical representation of compressive strength



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4.2 Split Tensile Test on Conventional Concrete

Table 5: Split tensile strength of cylinder at 7 days

Sl.no	Specimen	Ultimate load (KN)	Ultimate tensile strength (N/mm ²)
1	Cylinder 1	110	1.57

Table 6: Split tensile strength of cylinder at 14 days

Sl.no	Specimen	Ultimate load (KN)	Ultimate tensile strength (N/mm ²)
1	Cylinder 2	150	2.13

Table 7: Split tensile strength of cylinder at 28 days

Sl.no	Specimen	Ultimate load (KN)	Ultimate tensile strength (N/mm ²)
1	Cylinder 3	200	2.83

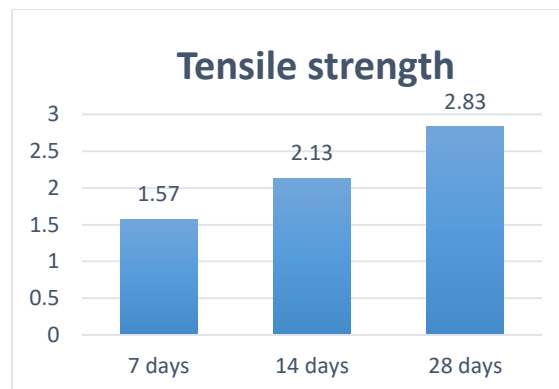


Figure 3: Graphical representation of tensile strength

4.3 Compression Strength Test on Sandwiched ECC Slab

Table 8: Compressive strength of ECC.

Sl No	Mix	Compressive strength		
		7 days	14 days	28 days
1	ECC (Fiber-0.4%)	19.7	27.2	31.4
2	ECC (Fiber- 1.2%)	20.1	27.7	32.1
3	ECC (Fiber- 2.0%)	20.6	28.3	32.9



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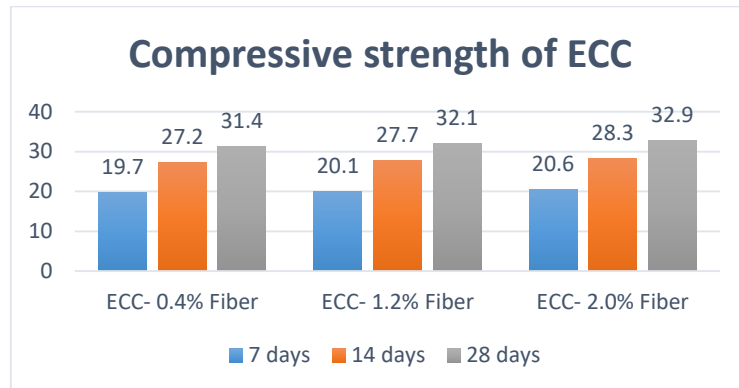


Figure 4: Graphical representation of compressive strength

4.4 Flexural Strength Test of ECC

Table 9: Flexural strength of ECC.

Sl No	Mix	Flexural strength		
		7 days	14 days	28 days
1	ECC (Fiber- 0.4%)	2.91	3.27	3.67
2	ECC (Fiber- 1.2%)	3.14	3.42	3.91
3	ECC (Fiber- 2.0%)	3.54	3.67	4.2

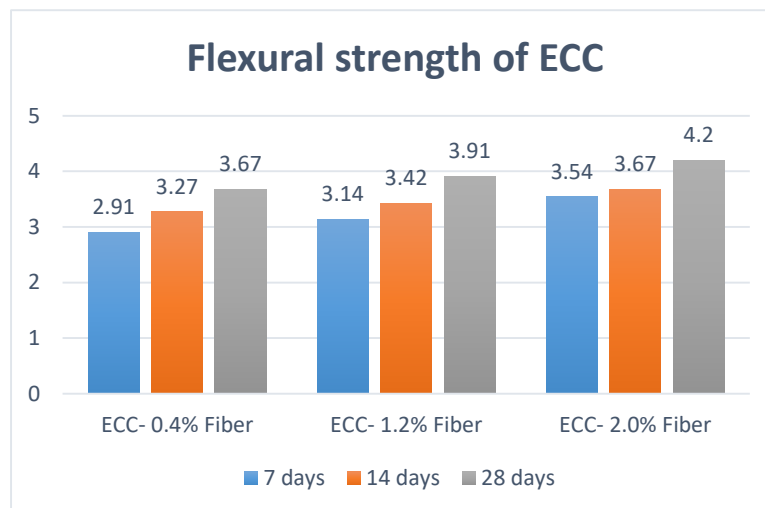


Figure 5: Graphical representation of flexural strength

4.5 Analysis of Slab Using ANSYS Software

Table 10: Analysis of slab

Sl No	Reactions	Results
1	Total Deformation	$3.4467 \times 10^{-5} \text{ m}$



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2	Equivalent Von-misses Stress	$1.0287 \times 10^5 \text{ Pa}$
3	Equivalent Von-misses Stress	$3.4467 \times 10^{-6} \text{ m/m}$

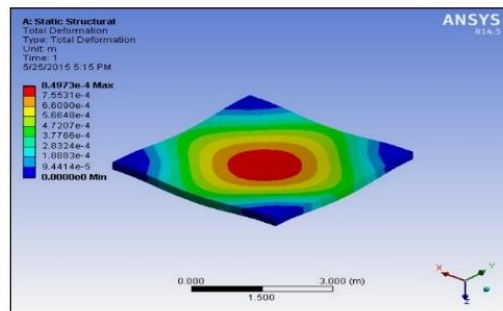


Figure 6: Analysis using ANSYS Software

5 Conclusions

Ordinary Portland cement, though costly and energy intensive is the most widely used ingredient in the production of concrete mixes. This work suggests the need for developing a new class of ECCs which has the strain hardening property but which can be processed with conventional equipment. The result is a moderately low fibre volume fraction (<2%) composite which shows extensive strain-hardening, with strain capacity of about 3 to 5% compared to 0.01% of normal concrete. According to test results, the slab is withstanding high load and a large deformation without succumbing to the brittle fracture typical of normal concrete. The significant properties of ECC Concrete are ductility, durability, compressive strength, and self-consolidation. When long term cost and environmental impacts are accounted for, as suggested by the life cycle cost/impact analyses for the ECC bridge deck, the advantages offered by ECC over conventional concrete become even more compelling.

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