International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 2, Issue 2, pp: (40-46), Month: October 2014 - March 2015, Available at: www.researchpublish.com

Experimental Investigation of Polypropylene Fiber in Engineered Cementitious Composites

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Abstract: **An Engineered Cementitious composite is an ultra ductile cementitious composite which is highly crack resistant, with a tensile strain capacity over that of normal concrete. Engineered Cementitious Composites is similar to Fiber Reinforced Concrete. FRC contains water, cement, fine and coarse aggregate, fiber, and some common chemical additives. But only difference between FRC and ECC is, in ECC coarse aggregates are not used as they tend to adversely affect the unique ductile behavior of the composite. Polypropylene fibers have advantageous characteristics, the weak bond with the cement matrix as a result of their smooth surface and chemical inertness remains a large limitation. It has been demonstrated that the fiber-matrix bond strongly affects the ability of fibers to stabilize crack propagation in the matrix. As the bond between fiber and matrix is mainly mechanical, it seems that incorporating silica fume into fiber reinforced cement composites provides a better bond with the matrix through pore refinement and better distribution of the hydration products. Hence, in this project an effort was made to study the effect of PP fibers on the mechanical properties of mortars incorporating silica fume. Six fiber volume fractions 0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5% were considered. The experimental study is to present the behaviour of prism with optimum percent of fibers under two point loading.**

Keywords: **Engineered Cementitious Composites, polypropylene fiber, cement paste, silica fume, and properties of concrete.**

1. INTRODUCTION

Concrete is widely used in civil engineering construction. Though concrete is convenient and inexpensive to be made, in brittle behaviour upon tensile loading is one of its adverse properties that lead to the development of fiber reinforced cementitious composites. The brittle behaviour of concrete is due to fast growing of a single crack that leads to the uncontrollable failure in section. In order to improve the behaviour of concrete, fiber reinforced concrete is made by adding discrete short fibers into the concrete matrix. This is called Engineered Cementitious Composites. Here fibers act as bridges across the crack to delay their propagation.

Engineered cementitious composites (ECC, also known as “ECC Concrete”), developed in the last decade, may contribute to safer, more durable, and sustainable concrete infra-structure that is cost-effective and constructed with conventional construction equipment. With two percent by volume of short fibers, ECC has been prepared in ready-mix plants and transported to construction sites using conventional ready-mix trucks. The moderately low fiber content has also made shotcreting ECC viable.

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 with widths limited below 60micron (about half the diameter of human hair).Use of high ductility concrete in seismic zones is recommended due to its high seismic response. Thus, it was envisaged that the development of cementitious materials with high ductility would be valuable for structural applications.

2. SCOPE AND BACKROUND

Engineered Cementitious Composite (ECC), also called bendable concrete, is an easily molded mortar-based composite reinforced with specially selected short random fibers, usually polymer fibers. Unlike regular concrete, ECC has a strain capacity in the range of 3–7%, compared to 0.1 % for ordinary Portland cement (OPC). ECC therefore acts more like a ductile metal than a brittle glass (as does OPC), leading to a wide variety of applications. ECC looks similar to ordinary Portland cement-based concrete, except that it does not include coarse aggregate and can deform (or bend) under strain. ECC has been widely used in a variety of civil engineering applications; the properties of ECC (high damage tolerance, high energy absorption, and ability to deform under shear) give it superior properties in seismic resistance applications.

3. OBJECTIVE

The objective of the present investigations is to investigate the mechanical and deflection characteristics of ECC for various proportions of polypropylene fiber and comparing the results of cement mortar. The investigation is aimed at finding out the Compressive strength, Tensile strength of cube and cylinder and Load Vs deflection from beam.

4. MATERIAL USED

4.1 Cement

Pozzolanic cement (PPC) is used for control mortar. It is made by intergrinding of ordinary Portland cement clinker and pozzolana. The pozzolana is essentially a silicious material containing clay upto 80%. In the manufacture of pozzolana cement, about 30% of pozzolana material is added to the ordinary port land cement clinkers. It is widely used for hydraulic structures such as dams and wires etc.

4.2 fine aggregate

The fine aggregate (sand) used was clean dry river sand. Locally available free of debris and nearly riverbed sand is used as fine aggregate. The sand was sieved to remove all pebbles. Among various characteristics, the most important one is it is grading coarse sand may be preferred as fine sand increases the water demand of concrete and very fine sand may not be essential in as it usually has larger content of thin particles in the form of cement. The sand particles should also pack to give minimum void ratio, higher voids content leads to requirement of more mixing water.

4.3 Polypropylene fiber

Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. The function of the polypropylene fiber mixed into concrete is not to replace the steel but to avoid the creation of micro cracks in the concrete. Polypropylene fibers are used in concrete to obtain a much better, more stable surface and more resistant piece of concrete. It reduces the danger of micro cracks dramatically. This increase the lifetime of the structure. Polypropylene fibers in concrete, in diameter range of 22 to 35 micron by 19mm long, reduce the flow of water through the concrete matrix by preventing the transmission of water through the normal modes of ingress, e.g. capillaries, pore structure, cover concrete, etc.

Fig.1. Polypropylene fiber

4.4 Water

Water fit for drinking is generally considered fit for making concrete. Water should be free from acids, oils, alkalis, vegetables or other organic Impurities. Soft waters also produce weaker concrete. Water has two functions in a concrete mix. Firstly, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a vehicle or lubricant in the mixture of fine aggregates and cement.

4.5 Silica fume

Silica fume, also known as **microsilica**, is an amorphus (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions. With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

Fig.2. Silica Fume

5. MIX PROPORTION FOR ECC

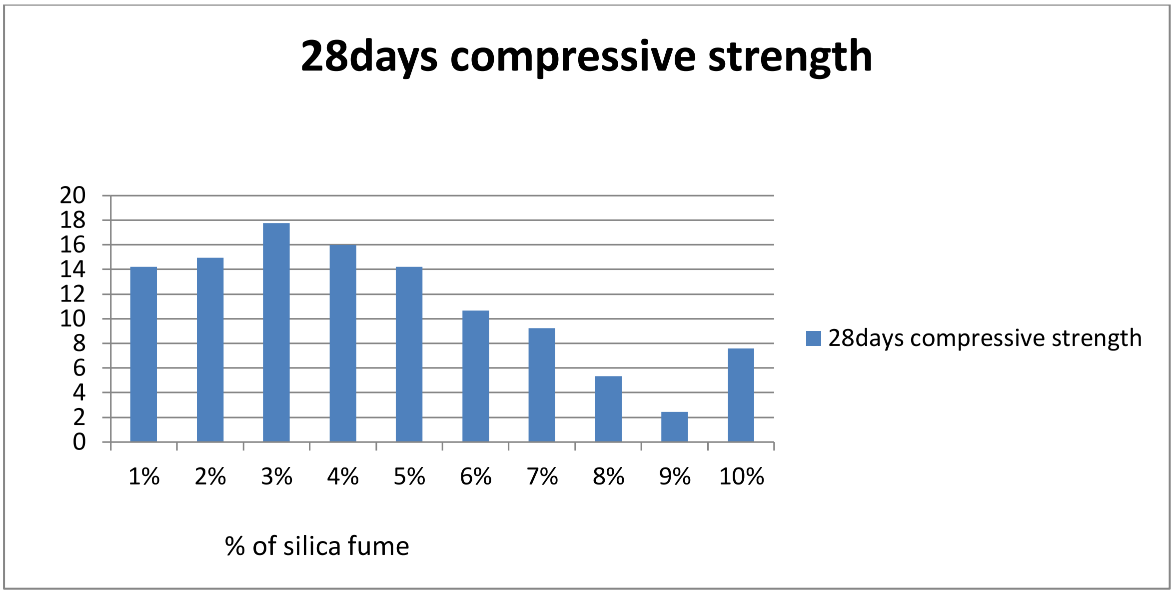
ECC is a mortar based composite and typically has around 2 to 3 times more cementitious material than conventional concrete. The modified mix contains a cementitious content much higher than common concrete pavements. Another identifying property of Polypropylene-ECC is an extremely large fraction of pozzolanic material.

Table 1. Mix Proportion

Cement	Sand	w/c ratio
1	3	0.45

5.1 Optimum level of silica fume

The percentage of silica fume used for general concrete work (0-10%) was taken. The moulds (75x75x75mm) were casted and tested under 28 days compressive strength. Finally the optimum level of silica fume from the graph is 3%.



Graph 1. Compressive Strength

5.2 Detail mix proportion

ECC is a mortar based composite and typically has around 2 to 3 times more cementitious material than conventional concrete. The modified mix contains a cementitious content much higher than common concrete pavements. Another identifying property of Polypropylene-ECC is an extremely large fraction of pozzolanic material.

Table 2. Mix proportion

Mix	Cement	Sand	w/c ratio	Fiber in volume %	Silica fume
Ordinary mortar	1	3	0.45	-	-
				0.1	
	1	3	0.45	0.2	
ECC1				0.3	-
				0.4	
				0.5	
				0.1	
	1	3	0.45	0.2	
ECC2				0.3	3 % of cement content
				0.4	
				0.5	

5.3 Preparation of ECC

The performance of the ECC Concrete was influenced by the mixing. This means that a proper & good practice of mixing can lead to better performance & quality of the ECC Concrete. A proper mix of concrete is encouraged to the strength of concrete & better bonding of cement with the PVA fibers. Once the concrete mix design was finalized, the mixing was carried out. The mixing of ECC Concrete was carried out by using hand mixing. The procedure of hand mixing was as follows:-

Add sand, cement, 3% silica fume & 45% water &super plasticizer. Once the homogenous mixture is formed, add the PP fibers slowly. Mix all the constituents till the fibers are homogenously mixed in the matrix.

5.4 Placing, Compaction & Casting Of Concrete Specimens

Before placing of concrete, the concrete mould must be oiled for the ease of concrete specimens stripping. The oil used is a mixture of diesel & kerosene. Special care was taken during the oiling of the moulds, so that there are no concrete stains left on the moulds. Once the workability test of ECC Concrete was done, the fresh concrete must be placed into the concrete moulds for hardened properties tests. During the placing of fresh concrete into the moulds, tamping was done using Tamping rod in order to reduce the honeycombing. After placing the concrete into the moulds, vibrations were done using a table vibrator. The vibration of concrete allows full compaction of the fresh concrete to release any entrained air voids contained in the concrete. If the concrete were not compacted to a proper manner, the maximum strength of the concrete cannot be achieved. After vibration operation, the leveling of concrete was done on the surface of the concrete. Leveling is the initial operation carried out after the concrete has been placed &compacted. After the leveling of the fresh concrete was done, the concrete in the mould was left overnight to allow the fresh concrete to set.

Fig. 3. Compaction of mortar

5.4. Curing Of Concrete Specimen

After leaving the fresh concrete in the moulds to set overnight, the concrete specimens in the moulds were stripping. The identification of concrete specimens was done. After 24 hours, all the concrete specimens were placed into the curing tank with a controlled temperature of 25 0C in further for 28 days for the hardened properties test of concrete. Curing is an important process to prevent the concrete specimens from losing of moisture while it is gaining its required strength. Lack of curing will lead to improper gain in the strength. After 28 days of curing, the concrete specimens were removed from the curing tank to conduct hardened properties test of ECC Concrete.

Fig. 4. Curing of test specimen

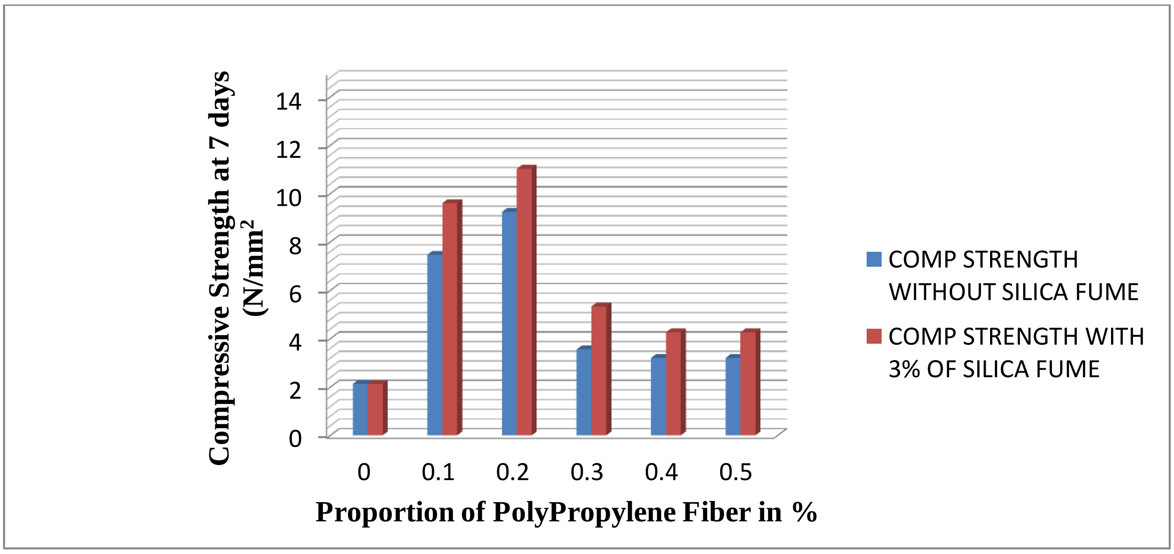
6. TESTING OF ECC

6.1 Determination of Compressive Strength on ECC

Compression test is the most common test used to test the hardened concrete specimens because the testing is easy to make. The specimens used in compression test were the cube of 75x75x75mm. Apparatus and test Procedure of compression test the apparatus and equipment's used in compression test were according to IS: 509-1959 and is shown in figure testing machine: Aimin compression testing machine.The procedure is as below: The testing for the specimens should be carried out as soon as possible after taking out from the curing rank i.e. Saturated Surface Dry condition (SSD).The specimen need to get measurement before testing. The length and height of specimen is measured and recorded. Clean the uncapped surface of the specimen and place specimen in the testing machine .The axis of specimen is aligned with the centre of thrust of the seated plate. Plate is lowered until the uniform bearing is obtained. The force is applied and increased continuously at a rate equivalent to 20 MPa compressive stresses per minute until the specimen failed. Record the maximum force from the testing machine.

Fig. 5. Compression testing machine

6.2 Compressive Strength of ECC with & without silica fume



Graph 2. Proportion of poly propylene fiber in %

From this graph it was noted that the optimum level of compressive strength of mortar increases with increase in percentage of fiber upto 0.2% compared to ordinary cement mortar and Decreases with further increase in percentage of fiber.

7. CONCLUSION

From the experimental investigation it was noted that,

- In addition of fiber with silica fume to cement mortar at lower volume fraction (0.2%), the strength of mortar achieves 2% higher than normal cement mortar.
- Formation of crack is arrested by using polypropylene fiber.

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