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Study on durability properties of engineered CEMENTITIOUS composites

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ABSTRACT

Conventional concrete is almost unbendable and are highly brittle and rigid. There were number of experiments have been done to improve the bending properties of concrete. Bendable concrete is also called engineered cementitious composites abbreviated as ECC. This concrete does not contain any coarse aggregate which is replaced by fibers. This study is made on improving the properties of ECC by addition of polypropylene. The main objective of this project is to compare the durability properties of different proportioned ECC. ECC is a field-ready ductile concrete it has the potential to significantly contribute with enhancing infrastructure safety, durability. Polypropylene fibers and glass fibers are added to various proportions (0.5 %, 1%, 1.5% and 2% by weight of cement) and the durability properties are compared. Engineered cementitious composite to be improve the safety, durability, and sustainability of the structures and elements.

Keywords: Engineered Cementitious Composites, Polypropylene fibers, Glass fibers, Durability properties.

INTRODUCTION

Concrete is the most extensively used in the construction material and it has high compressive strength. Concrete is understood to consisting of a grade range of stone aggregate particles bound by the hardened cement paste. One major weakness of a concrete is the brittle fracture behavior in tension and with low tensile strength and ductility. The lack of structural ductility is due to brittle in nature of concrete in tension which may lead to the structural integrity. The performance-based design concept allows for the greater flexibility, e.g., in dimensioning and reinforcement detailing by structural engineers. Therefore, high performance of civil engineering materials with added sum admixture beyond their basic properties are highly desirable.

In this project, in order to study the durability properties of ECC, the transition zone which has exists between the cement paste and fine aggregate was removed by replacing the coarse aggregates completely with Polypropylene (PP) fiber and glass fiber and their structural performances were studied separately and used in this project.

LITERATURE REVIEW

1. **Hezhi Liu et.al.** (2016), Investigated the feasibility of applying ductile engineered cementitious composites (ECC) as an alternative to conventional concrete in hydraulic structures to improve their durability performance. In compressive and tensile behavior of ECC after long duration when exposure to Na2SO4 and Na2SO4 + NaCl solutions. In addition to micromechanics-based study on ECC can be quantitatively to characterize the influence of

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sulphate-chloride and sulphate solutions on the micromechanical parameters and it's including the matrix fracture toughness and matrix interfacial bond to each materials to providing insights into the underlyed mechanisms of the composite level behavior of ECC on under those environments.

2. **Sathishkumar. P et.al.,** (2016), The various trial mixes are cast and the mix design is finalized. Polyvinyl alcohol fibers, Polyethylene fibers, Polyester fibers and Polypropylene fibers are added in various proportions (0.5 %, 1%, 1.5% and 2% by weight of cement) and the strengths are compared. Cubes, Cylinders and beams are cast and the Compressive, split tensile and Flexural Strengths are to be compared.
3. **Yu Zhu, Zhaocai Zhang et.al.,** (2014), The ductility of ECC can be obviously improved by introducing high volume fly ash and slag replacing the cement, respectively. However, this compressive strength in ECC with slag and fly ash can be reduce 40% and 14%, respectively. In this system of binder materials with replacement 70% of cement, the combination of slag and fly ash can keep not only the excellent ductility on ECC, but also enough stronger matrix strength. Meanwhile, the combination of fly ash and silica fume increase the compressive strength, but weaken the toughness of ECC.
4. **Khin T. Soe et.al.,** (2013), Studied the durability properties of a new hybrid fiber-reinforced engineered cementitious composite (ECC) material reinforced with 1.75% polyvinyl alcohol (PVA) fiber and 0.58% steel (SE) fiber (M2) and 1.5% polyvinyl alcohol (PVA) fiber and 0.5% steel (SE) fiber (M1). They concluded that, M2 mix exhibits improved compressive strength, Young's modulus, ultimate flexural strength, flexural strain, tensile strength at first crack and ultimate tensile strength than the mix (M1).

ENGINEERED CEMENTITIOUS COMPOSITES

Engineered Cementitious Composite (ECC) is also called as Strain Hardening Cement-based Composites or more popularly known as the bendable concrete. It is an easily molded mortar-based composite reinforced with specially selected random fibers, usually the polymer fibers. Unlike regular concrete, ECC has been strain capacity in the range of 3–7%, compared to 0.01% for the ordinary portland cement (OPC) paste, mortar or concrete. ECC therefore acts more like a ductile metal like material rather than a brittle glass like material, leading to be wide variety of applications [1].

ECC is a fiber reinforced cement based composite material systematically engineered can be achieve to high ductility under tensile and shear loading. Maximum ductility should excess to 3% under uniaxial tensile loading can be attained with only 2% of fiber content by volume. This moderate amount of short discontinuous fibers allows the flexibility in construction execution, including self-compaction, self-consolidation casting and shot-creting. Recent research indicates that ECC holds promise in enhancing to safety, durability, and sustainability of any infrastructure [2].

OBJECTIVES AND APPLICATIONS OF ECC

Objectives

The major scope of the project can be develop to strength and durability with the mineral admixtures and chemical admixtures replaced to the aggregate and adding admixtures to apply into the buildings. The main scope of the project is given below.

- To investigate the durability properties of Engineered Cementitious Concrete.
- To investigate the corrosion resistance of cracked and uncracked Engineered Cementitious Concrete
- To develop the Engineered cementitious mix design [3-9].

Applications

- In this ECC concrete roads, bridges are no need for joints such as expansion joints, contraction joints in ECC it can be change its shape.

- ECC can be used to overlays the cracked concrete surface and it is applicable for joint less bridges, earthquake resistant structure.
- In this concrete is around 500 times more resistant to cracking than conventional concrete.
- The fiber slide within the concrete when bending occurs, providing with it is enough to prevent breakage and gives more durable to the concrete [10].

MATERIAL PROPERTIES

In this project the different types of fibers and admixture are used in this project.

Polypropylene Fiber

Polypropylene (PP) is also known as polypropene. It is one of the thermoplastic polymer used in a wide variety of applications. It can be produced via chain-growth polymerization from the monomer propylene. Polypropylene belongs to the group of polyolefin. It has similar properties to polyethylene, but it is slightly harder and more heat resistant. It is a mechanically rugged material in white and has a high chemical resistance. Polypropylene is widely used to produce commodity plastic and it is also used in packaging and labeling. In 2013, for polypropylene the global market was about 55 million tonnes.

Glass Fiber

Glass fiber (GF) consists of numerous extremely fine glass fibers. Glass fiber has low mechanical properties when compared to other fibers such as polymers and carbon fiber. Though not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Therefore, glass fibers are used as a reinforcing agent for many polymer products to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". They are also used in concrete to form glass fiber-reinforced concrete [11, 12].

Fly Ash (Class - F)

Class F fly ash is designated in originates from bituminous coals and anthracite. It can be consists mainly of alumina, silica and higher LOI than Class C fly ash. In this Class F fly ash is also lower calcium content than Class C fly ash and replacing with used in portland cement (pc), Class F fly ash can be used to portland cement replacing from 20-30% of the mass of cementitious material. The burning of harder, older bituminous coal and anthracite typically produces in Class F fly ash. This fly ash is a pozzolanic in nature, and contains less than 10% of lime (CaO) content. The alumina and glassy silica of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, with the presence of water in order to react and produce cementitious compounds [13].

Superplasticizer

Superplasticizers is also known as high range water reducers, and chemical admixtures used where well-dispersed particle suspension is needed. These polymers are used in dispersants to avoid particle segregation and to improve to their characteristics is suspensions such as the concrete applications. Their addition to concrete or mortar it allows the reduction of the water to cement ratio and do not affecting the workability of the mixture, and enables the production of concrete. This effected in improves the performance of the hardening fresh paste. The strength of concrete increases when the water cement ratio is decreases. In this superplasticizers are various chemical proportion and different types of superplasticizers are available but in this project using Conplast SP430 [14].

MIX PROPORTION OF ECC

Mix Proportions based on ECC Thesis. Micromechanics are a branch of mechanics applied at the material constituent level that captures the mechanical interactions among the fiber, mortar matrix, and fiber-matrix interface.

The fibers are the order of millimeters in length and tens of microns in the diameter, and they can have a surface coating on the nanometer scale. Matrix heterogeneities in the ECC, it including defects, sand particles, cement grains, and mineral admixture particles, etc. from Nano to millimeter scale. And the mix proportion is given below.

Table.1. Mix proportion of ECC (Polypropylene Fibers)

Mix	Cement	Fine Aggregate	W/C Ratio	Fly Ash	PP Fiber
M1	1	1.56	0.35	0.30	1%
M2	1	1.56	0.35	0.30	1.5%
M3	1	1.56	0.35	0.30	2%
M4	1	1.56	0.35	0.30	2.5%

Table.2. Mix proportion of ECC (Glass Fibers)

Mix	Cement	Fine Aggregate	W/C Ratio	Fly Ash	Glass Fiber
M1	1	1.56	0.35	0.30	1%
M2	1	1.56	0.35	0.30	1.5%
M3	1	1.56	0.35	0.30	2%
M4	1	1.56	0.35	0.30	2.5%

RESULTS AND DISCUSSION

The results were obtained from various tests conducted on laboratory. The various strength test results were categorized and variations were shown by using charts. It helps in identifying the differences in results. High volume of fly ash concrete is one of the green concrete concept to alternatives indirectly reducing into CO_2 emission and energy consumption related to the production of cement. This chapter describes the results of durability tests on three concrete grades each with a different fly ash replacement levels namely 0%, 50%, 55% at the age of 28 days [15].

Sulphate Attack Test

The concrete due to penetration of the sulphate in solution, in groundwater or sand for example, into the concrete from outside. This is the more common type and typically occurs where the water can be containing to dissolve sulphate penetrates the concrete.

Fig.1. Cube after test

Table.3. Sulphate attack test result comparison

S. NO	ECC	CONVENTIONAL CONCRETE
1	Sulphate attack is zero	Conventional concrete is affected by sulphate

Acid Attack Test

Sulphuric acid is more damaging to the concrete as it is combines an acid attack.it is the acid attack in concrete. An acid attack is diagnosed primarily by two main features: Absence of calcium hydroxide in to the cement paste. Surface dissolution of the cement paste exposing aggregates.

Fig.2. Cubes after test

Table.4. Acid attack test result comparison

S. NO	ECC	CONVENTIONAL CONCRETE
1	Acid does not affect ECC	Conventional concrete is affected by acid

Rapid Chloride Permeability Test (RCPT)

Rapid Chloride Permeability Test Equipment (RCPT) has multi-port testing apparatus and it is designed to test concrete samples in 100mm diameter with 50mm thickness. The Concrete ion permeability test for civil engineering departments and research centers. All the easy connections and ready to use chloride ion permeability test instrument for concrete.

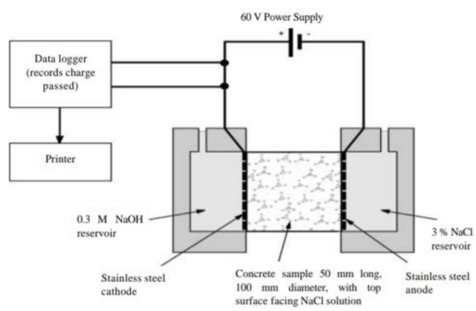

Fig.3. RCPT apparatus

Table.5. Rapid Chloride Permeability Test result comparison

S. No	Charge passed	Chloride Ion Penetrability	ECC	Conventional concrete
1	> 4000	High	_	_
2	2000 – 4000	Moderate	_	3700
3	1000 – 2000	Low	_	_
4	100 – 1000	Very low	960	_
5	< 100	Negligible	_	_

Carbonation Test

The percentage of CO_2 is present in the air it is vary from place to place. In case the rural areas, the concentration of CO_2 in air can be about 0.03% by volume, and the urban areas it may vary from 0.3% to 1.0%. This CO_2, in presence of moisture changes into dilute carbonic acid and also attacks the concrete and reduces alkalinity of concrete and building life time.

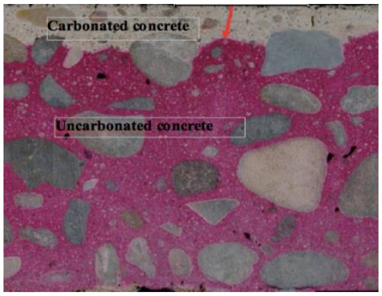

Fig.4. Cube after test

Table.6. Carbonation test result comparison

S. NO	ECC	CONVENTIONAL CONCRETE
1	Presents of carbonation is here	Presents of carbonation is here

Water Permeability Test

Permeability is defined as the property of governs the rate of flow of a fluid into the porous solid. Durability of concrete is ability to resist the weathering action, chemical attack, etc. and all types of deterioration. If the concrete is impermeable than corrosive agents cannot penetrate and attack concrete. Concrete has small pores like the diameter varies from 0.01 to 10 micron in cement pastes while it may be between 1 mm to 10mm when cement paste is laid over the aggregate.

Fig.5. Water permeability test apparatus

CONCLUSION

In this phase of project, engineered cementitious composite is made by replacing course aggregate with polypropylene fiber and glass fiber. The test was made to check their strength and durability of ECC. Thus course aggregate replaced in concrete helps in reduction of dead load as well as cost increased in course aggregate. The main objective of this study is to replace the course aggregate with both fibers in different proportions and to compare their durability properties in further.

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