© 2016 IJSRSET | Volume 2 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Development of Rigid Pavement by using ECC Material - A Review

Pratik H. Patel, Prof. Binal Patel, Prof. S. M. Damodariya
Civil Engineering Department, Parul Institute of Engineering & Technology, Vadodara, Gujarat, India

ABSTRACT

ECC is likely to the fiber reinforced concrete. ECC contains Cement, sand, coarse aggregate, fine aggregate, water, ECC fiber and some admixture like fly ash, silica fume etc. An ECC is highly crack resistant with the tensile strain capacity over the conventional concrete. In this research work used polypropylene fiber as an ECC material. Polypropylene fiber having many advantageous characteristics like high chemical and corrosion resistance, high tensile strength, excellent abrasion resistance, long life span etc. the bonding between cement and Polypropylene fiber stabilize the crack propagation in the concrete. Hence in this research work study the behavior of ECC using polypropylene fiber incorporating with Fly ash. In the prepared mix design o%, 1%, 2%, 3% of polypropylene fiber is used. Also 40% and 50% Fly ash is replaced with cement. The experimental study is to present the effect of addition of polypropylene fiber and replacement of Fly ash with cement on the behavior of concrete under compressive and tensile test.

Keywords: ECC (Engineering Cementitious Composite), Fly Ash, Polypropylene Fiber.

I. INTRODUCTION

In the last several decades, concrete with increasingly high compressive strength have been used for structural applications. However, most of these materials remain brittle. In some cases, the brittleness as measured by the brittleness number (Hillerborg, 1983) actually increases as the compressive strength goes up. This poses potential danger and limitations of high strength concrete in structural applications. In certain locations, such as where steel and concrete come into contact (e.g.steel anchors in concrete at column base) or in connections of steel/concrete hybrid structures, the high stress concentration created can lead to fracture failure of the concrete. In seismic elements, high ductility in the concrete can make a significant difference in the seismic response of the overall structure. These and other examples discussed below point to the need to develop cost effective high ductility cementitious materials suitable for structural applications. In the last several years, the University of Michigan has been investigating a composite material known as Engineered Cementitious Composites, or ECC for short. In many respects, this material has characteristics similar to medium to high strength concrete. However, the tensile strain capacity generally exceeds 1% with the most ductile composite in the 6-8% range. This article briefly reviews these emerging materials, and also reports on some ongoing developmental application studies.

In terms of material constituents, ECC utilizes similar ingredients as fiber reinforced concrete (FRC). It contains water, cement, sand, fiber, and some common chemical additives. Coarse aggregates are not used as they tend to adversely affect the unique ductile behavior of the composite. In general 2% or less by volume of discontinuous fiber is adequate, even though the composite is designed for structural applications. Because of the relatively small amount of fibers, and its chopped nature, the mixing process of ECC is similar to those employed in mixing normal concrete. A typical composition employs w/c ratio and sand/cement ratio of 0.5 or lower. Unlike some high performance FRC, ECC does not utilize large amounts of fiber. Also by deliberately limiting the amount of fibers, a number of proprietary studies have concluded economic feasibility of ECC in specific structural applications. Various fiber types can be used in ECC, but the detail composition must obey certain rules imposed by micromechanics considerations (Li, 1998; Kanda and Li, 1998). This means that the fiber, cementitious matrix, and theinterface (mechanical and geometric) properties must be of a correct combination in order to attain the unique behavior of ECCs. Thus ECC designs are guided by micromechanical principles. Most data so far has been collected on PVA-ECC (reinforced with PolyVinyl Alcohol fibers) and PE-ECC (reinforced with high modulus polyethylene fibers).

FRC or fiber reinforced high strength concrete, the first crack continues to open up as fibers are pulled out or ruptured and the stress-carrying capacity decreases. This post-peak tension softening deformation is typically represented by a softening stress-crack opening relationship. In ECC, first cracking is followed by a rising stress accompanied by increasing strain. This strain-hardening response gives way to the common FRC tension softening response only after several percent of straining has been attained, thus achieving a stress-strain curve with shape similar to that of a ductile metal. Closely associated with the strain-hardening behavior are the high fracture toughness of ECC, reaching around 30 kJ/m2, similar to those of aluminum alloys (Maalej et al, 1995). In addition, the material is extremely damage tolerant (Li, 1997), and remains ductile even in severe shear loading conditions (Li et al, 1994). To illustrate the ductility of ECC, Fig. 1 shows the deformed shape of a ECC plate subjected to flexural load. These behaviors appear to be scale invariant, confirmed by specimens with sizes ranging from cm to meters (maximum 1.5 m longest dimension) scale. The compressive strength of ECC varies from 30 to 70 MPa, depending on the matrix composition. Compressive strain capacity is approximately double those of FRC's (0.40.65%) (Li, 1998). A most common question asked of ECC is how it achieves its unique ductile properties, but uses ingredients similar to those for FRC or HPFRC, and at the same time contains such small amount (typically less than 2% by volume) of discontinuous fibers. The answer lies in the composite constituent tailoring. A fiber has several attributes - length, diameter, strength, elastic modulus, etc. Interface has chemical and frictional bonds, as well as other characteristics such as slip-hardening behavior. And a cementitious matrix has fracture toughness, elastic modulus and flaw size which can be controlled within a certain range. The tailoring process selects or otherwise modifies these "micromechanical" parameters so that their combination gives rise to the ECC composite with its attendant properties. Tailoring is guided by micromechanical analyses (Li and Leung, 1992; Li, 1993; Kanda and Li, 1998), which quantitatively accounts for the mechanical interactions between the fiber, matrix and interface when the composite is loaded. Note that unlike the even smaller amount of fibers used in shrinkage control in some FRCs, fibers in ECC are used to create composite properties suitable for structural applications.

Characteristics of polypropylene Fiber:

Polypropylene has the following advantages over conventional materials previously used.

- High chemical and corrosion resistance
- Light weight and rigid
- High tensile strength
- Excellent abrasion resistance
- Low moisture absorption
- Easily machined and cut
- Easy to maintain and clean
- Excellent thermal insulating properties
- Excellent dielectric properties
- Long life span

II. METHODS AND MATERIAL

A. Literature Review

Srinivasa. C. H. et.al [1] in their research paper present about different activities are taking place in all over the world in last one decade on behavior and development of ECC using polyvinyl alcohol fiber. Engineering cementitious content can be deigned based on micro mechanical model with strain capacity of 3 to 5% compared to 0.01% of conventional concrete. Less than 2 percent of fiber content provides extensive strain hardening properties of the ECC.

M.D. Lepech & G.A. Keoleian et.al [2] presented the study based on ductile behavior critical for sustainable enhancement. ECC is eliminating reflective cracking, a major cause of premature overlay failure, thereby increasing durability and reducing life-cycle maintenance. On the bases of experimental and theoretical study verify the green material and durable overlay design approaches. Significant sustainability improvement has been achieved with use of industrial waste and green raw material. Over 70% reduction in ECC constitution and 50% reduction in thickness is achieved without reducing its mechanical characteristics.

Shunzhi Qian et.al [3] in this paper, they introduce and demonstrate this novel concept via experimental study on the reflective cracking resistance of small-scale ECC overlaid concrete beam. The ECC specimens totally eliminate the reflective cracking mode by developing extensive micro-cracks under flexural fatigue loading, in addition to a much enhanced MOR compared to controlled concrete specimen. Based on FEM analysis of the overlay system and fatigue performance of the ECC beam, a simplified design chart for ECC overlay is presented for use in practice and LCALCC analysis. The proposed ductile overlay approach should greatly enhance the durability and sustainability of the future pavement overlay.

Nurdeen M. Altwair et.al [4] in this paper they report increase the rate of expansion due to alkali-silicate reaction. The negative effect of w/b ratio on ECC bars expansion was lower as POFA/C ratio increased.The durability performance of engineered cementitious composites (ECC) containing high volume of palm oil fuel ash (POFA) when subjected to accelerated alkaline environmental conditions.

S. Boughanem et.al [5] in these paper they studied a ductility level required to reduce the brittle failure. In this research we use the cement powder and admixture manufacture by two method and mechanical test is done on specimens. Stain hardening behavior and multiple cracking is observed in both tensile and flexural test. The aim of the present study is to contribute to the understanding of these issues in order to facilitate the implementation of these materials.

Chethan.v.r et.al [6] in this paper presents current scenario about various active research that are taking place around the world on study of behavior of Engineered Cementitious Composites (ECC) by incorporating Polyvinyl Alcohol (PVA) and other kinds fibers and by using various mineral ad-mixtures. Engineered Cementitious Composites is mainly designed based on paradigm of micro-mechanical interaction with exceptional strain capacity of about 3 to 5% compared to 0.01% of normal concrete. The volume fraction of the fiber used is also less than 2 percent and showing an extensive strain hardening behavior of the composites.

Ms. E. Ramya et.al [7] present the properties of ECC provides better properties in seismic resistance application. In this present work they investigate deflection and mechanical properties of ECC for different proportion of polypropylene fiber and compare with conventional concrete. Also find out the compressive strength and tensile strength of cube and cylinder.

Xiaoyan Huang et.al [8] in this paper reports the results of an initial attempt of using iron ore tailings (IOTs) to develop greener engineered cementitious composites (ECCs). ECC is a unique class of high-performance fiber-reinforced cementitious composites featuring high tensile ductility and durability. They replaced the cement with iron ore tailings (IOTs) to check the environmental sustainability of ECC. Mechanical property of ECC is check by the author.

B. Material Used

Ordinary Portland Cement

Ordinary Portland cement (often referred to as OPC) is the general type of cement in use around the world, because it is the basic key ingredient for making concrete, mortar, stucco and most of the grouts specially prepared for specific purpose. It is made by intergrinding of argillaceous and calcareous materials.

Physical properties of OPC

Fineness

Particle fineness of Portland cement affects rate of hydration, which affects the rate of strength gain. Smaller is the particle size, the greater is the surface area-to- volume ratio, means more area is available for the reaction of water-cement per unit volume.

Soundness

The ability of a hardened cement paste to retain its shape after setting is known as soundness. The cement samples containing excessive amounts of free lime are subjected to volume change. Soundness of cement is determined by using Le chartliars equipment.

Consistency

The ability of cement paste to flow is known as consistency. The cement paste consistency is determined by using Vicat apparatus when the plunger penetrates by 10±1 mm and the corresponding water-cement ratio is reported as the Std consistency of cement.

Setting Time:

Initial setting time is defined as the time that elapsed from the instant of adding water until the pastes behave as plastic material thus offering resistance against the penetration. Whereas final setting time referred to be the time that is required for the cement paste to reach a certain state of hardness to bear some load and is tested by using Vicat apparatus.

Specific gravity:

The particle density which is measured by excluding the air between particles of OPC is found to be in the range of 3.1 to 3.25. The density of cement is determined by density bottle apparatus and here kerosene is used.

Sand

Good river bank sand in absence of any earthy matter and organic matter. Particles are angular in shape passing 250 micron and retaining 150 micron standard sieve. Sample is washed in water to get free from silty and earthy and other organic content and dried over a period of 48 hours of sunlight.

Water

Water which fits for drinking purpose is considered for mixing the ingredients, and should be free from suspended impurities and foreign matters such as acids, alkalis. Water plays two key roles in a concrete mix. Firstly, it chemically reacts with constituents of cement to form paste where paste holds aggregates in suspension phase until paste hardens. Secondly, it act as lubricant in mixing of ingredients.

Fly Ash

In the coal powered power generating plants the exhaust gases which comes out after burning is treated with electrostatic precipitators and the fine particles that collected in it is known as flyash and the ash which doesn't comes out with the exhaust flue gases is termed bottom ash. Fly ash constitutes substantial amount of silicon dioxide (SiO_2) in the form of both amorphous and crystalline form and calcium oxide (CaO), both being effective ingredients in many coal-bearing rock strata.

Super plasticizer

This is used to improve the rheological properties of fresh concrete. Super plasticizers are the additives to fresh concrete which helps in dispersing constituents uniformly throughout the mix. This is achieved by their deflocculatiion action on cement particles by which water entrapped is released and is available for workability. Super plasticizer increases slump properties from 5cm to 20cm without addition of water and thereby reducing the water requirement by 15 to 20 percent. This results in improvement of vital properties like density, water tightness. Where sections are having closer reinforcements, the use of super-plasticizer increase workability and no compaction is required. The permeability of concrete is key property which contributes to durability, the use of superplasticizer increases workability maintaining low water to cement ratio. The permeability of cement paste reduces considerably with reduction in water to cement ratio. Thus super plasticizer can be used effectively to improve various properties of concrete and to avoid defects like honeycombing.

Fibers

The high performance fiber reinforced cementitious composite is characterized by the presence of fibers in a less quantity compared to FRC .Generally the fiber used in ECC is PVA ,One of the remarkable characteristics of this fiber is capable of strong bonding with cement matrix. The layer of $Ca(OH)_2$ called as Interfacial transition zone is formed round PVA fiber and is formed as white part, and in case of poly propylene, and glass it is not observed . It is known PVA makes complex cluster with the metal hydroxide of cement matrix. It is pursued that Ca^+ and OH^- two different ions in the cement slurry are attracted by PVA fibers and makes layer of $Ca(OH)_2$ around the fibers and hence the $Ca(OH)_2$ layer plays an important role for bonding strength between the fiber and the matrix. However there is an absence of some surface coating around the Poly propylene fibers and glass fibers which are possessing high tensile strength but they are not coated with any epoxy and they are susceptible for alkali environment of matrix this makes us to do an experimental study by selecting these fibers.

This paper present literature review on the performance of ECC material use for sustainable development of rigid overlay pavement. In this paper most of the literature shows the effect of ECC material in flexural and tensile test. Ordinary concrete is more costly then the ECC concrete. Also in the production of ordinary cement involves large amount of CO emission. When in the ECC concrete use pozzollanic material for replace the cement. So ECC is the greener concrete.

III. RESULTS AND DISCUSSION

Compressive and tensile strength review was taken on the basis of experimental study. A summary is given in graph. The FIG shows the replacement of fly ash with OPC. The larger total cementitious content and lower water cement ratio, higher structural properties have been observed. Use of polypropylene fiber has been shown to improve the properties of concrete.

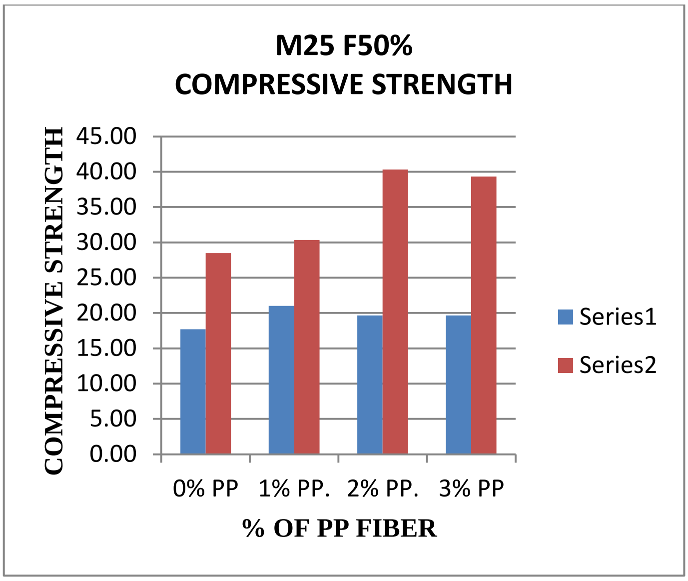

Figure 1. M25 FLY ASH(50%) Compressive strength

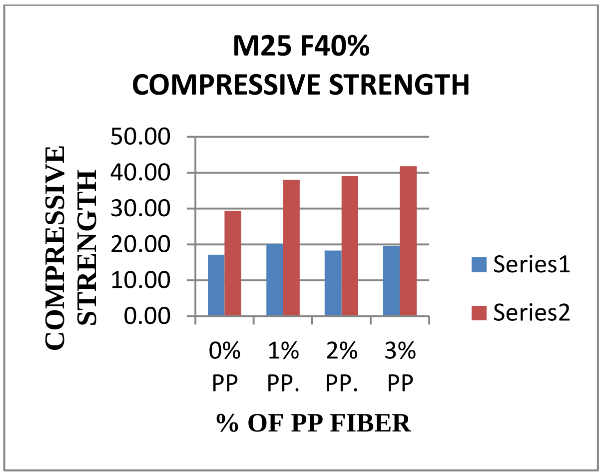

Figure 2. M25 FLY ASH(40%) Compressive strength

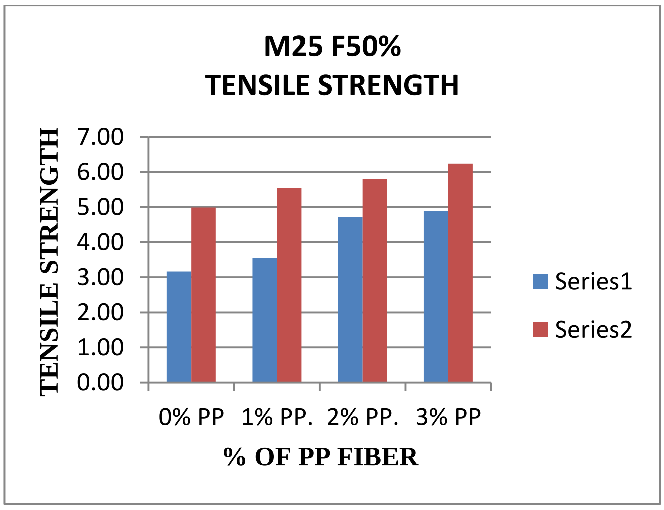

Figure 3. M25 FLY ASH(50%) Tensile strength

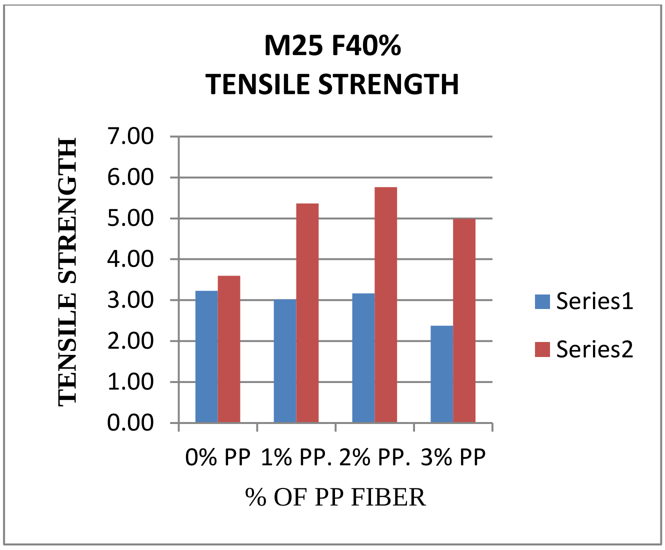

Figure 4. M25 FLY ASH(40%) Tensile strength

IV. REFERENCES

[1] Srinivasa. C. H, Dr. Venkatesh "A Literature Review on Engineered Cementitious Composites for Structural Applications", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278- 0181,Vol. 3 Issue12, December-2014

[2] M.D. Lepech & G.A. Keoleian, "Design of green engineered cementitious composites for pavement overlay applications", Life-Cycle Civil Engineering - Biondini & Frangopol (eds), 2008

[3] Shunzhi Qian, Victor C. Li, Han Zhang, Gregory A. Keoleian, "Durable and sustainable overlay with ECC", 9th International Conference on Concrete Pavements, San Francisco, California, August 17-21, 2008.

[4] Nurdeen M. Altwair, Abdelhamed Ganaw, "Effect of water-binder ratio and treated palm oil ash on alkali-silica reaction resistance of engineered cementitious composites (ecc)", International Journal of Technical Research and Applications, July-Aug 2014.

[5] S. Boughanem et al, "Engineered Cement Composites Properties For Civil Engineering Applications", 18th international conference on composite materials.

[6] Chethan.V.R, Dr.M.Ramegowda, Manohara.H.E "Engineered Cementitious Composites- A Review.",International Research Journal of Engineering and Technology (IRJET), Aug-2015.

[7] Ms. E. Ramya, Ms. S. Nalini, Mrs. S. Sivaranjini, Mr. R.M. Saravanakumar "Experimental Investigation of Polypropylene Fiber in Engineered Cementitious Composites", International Journal of Civil and Structural Engineering Research, October 2014 - March 2015.

[8] Xiaoyan Huang, Ravi Ranade, Victor C. Li, F.ASCE "Feasibility Study of Developing Green ECC Using Iron Ore Tailings Powder as Cement Replacement", journal of materials in civil engineering, JULY 2013.