Indian J.Sci.Res. 17(2): 200 - 205, 2018

ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

A REVIEW OF ENGINEERED CEMENTITIOUS COMPOSITE

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Abstract–Concrete is the most extensively used construction material which has high compressive strength. But one major weakness of concrete is the brittle facture behavior in tension, with low tensile strength and ductility due to this many deterioration problems occurred in the structures. Therefore we are analyzing the previous research and choose a best solution to avoid those deterioration problems and structural failures. We are referred previous studies of Bendable Concrete and analyzing their strength compared to normal concrete. Bendable Concrete is also known as Engineered Cementitious Composite without coarse aggregate. This project deals with the study of research to analyzing strain value of the member made of bendable concrete.ECC is class of ultra-ductile fiber reinforced cementitious composites. A bendable concrete is reinforced with micromechanically designed polymer fibres. Engineered cementitious composite made with the combination of PVA fiber and Fly Ash as admixtures. Literature survey of fresh and mechanical properties of different ECC mixtures are evaluated by incorporating supplementary cementitious material it has been thoroughly done. The study of literature suggested the use of PVA fiber and Fly Ash for Engineered Cementitious Composite.

***Keywords* -** PVA fibers, compressive strength, flexural strength, deflection.

I. Introduction

Concrete is the most extensively used construction material which has high compressive strength. Concrete is understood to consist of a graded range of stone aggregate particles bound together by a hardened cement paste. One major weakness of concrete is the brittle facture behavior in tension, with low tensile strength and ductility. This brittleness has been recognized as a bottleneck hindering structural performances in safety, durability and sustainability. The lack of structural ductility is due to brittle nature of concrete in tension which may lead to structural integrity. Many infrastructure deterioration problems and failures can be traced back to the cracking and brittle nature of concrete.

In order to overcome the brittle fracture of concrete and to obtain strength and ductility, in this project an attempt has been made to investigate the strength and ductile behaviour of Bendable composite. The strength and ductile behaviour has been demonstrated using high volume fraction of Fly Ash and high tenacity Polyvinyl Alcohol fibres composites of Bendable Composite. High volume fraction of Fly Ash tends to reduce Polyvinyl Alcohol fiber interfacebond and toughness to attain high tensile strain capacity.

Bendable Composite is also called Engineered Cementitious Composites is ductile in nature. Bendable composite, an easily moulded mortar-based composite reinforced with short random fibres, usually polymer fibers. Bendable Composite is developed based on micromechanics and fracture mechanics theory to feature large tensile ductility. Bendable Composite has a strain capacity in the range of 3–7%, compared to 0.1% for ordinary portland cement. The large strain is contributed by sequential development of multiple cracks, instead of continuous increase of crack opening. The high fracture toughness and controlled crack width make bendable composite improve serviceability and durability of infrastructures.

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 microstructure to composite performance linkage can be further extended to the structural performance level and integrate the material design into performance based design concept for structures. The micromechanics-based model suggests very different engineering strategies for different types of fiber systems.

ECC has a variety of unique properties, including tensile properties superior to other fiber-reinforced composites, the use of only a small volume fraction of fibers (~ 2%), tight crack width. These properties are due largely to the interaction between the fibers and cementing matrix, which can be custom-tailored through micromechanics design. Essentially, the fibers create many micro cracks with a very specific width, rather than a few very large cracks (as in conventional concrete.) This micro cracking behavior leads to superior corrosion resistance (the cracks are so small and numerous) as well as to self-

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healing. In the presence of water (during a rainstorm, for instance) un reacted cement particles recently exposed due to cracking hydrate and form a number of products that expand and fill in the crack. It is the tightly controlled crack widths seen in ECC that ensure all cracks thoroughly heal when exposed to the natural environment.

Bendable Composite has been successfully applied to dam repair, bridge deck overlays, coupling beams in high rise buildings and other structural elements and systems. The properties of ECC (high damage tolerance, high energy absorption, and ability to deform under shear) give it superior properties in seismic resistance applications when compared to normal concrete.

This Research needs for India has immeasurably vast infrastructure needs and it is high time to rethink how to develop and use construction materials, concrete products, design and construction technology to meet the needs and challenges of the 21^{st} century.

New technologies involving fly ash and fibers in concrete need to be urgently explored. To adopt a holistic design approach to materials and structures, it demands a clear understanding of how these materials behave in real structures exposed to real exposure conditions.

The ultimate goal of research in bendable composite is to improve the safety, durability, ductility and sustainability of infrastructure systems through innovative materials solution.In this review objective to study the ductile behaviourof Bendable Composite whereas normal concrete is brittle in nature, To determine the shear resistance of Bendable Composite so that the application of concrete in earthquake resistant structures can be identified, To determine the tensile strain capacity of Bendable Composite using strain indicator compared to 0.01% of normal concrete.

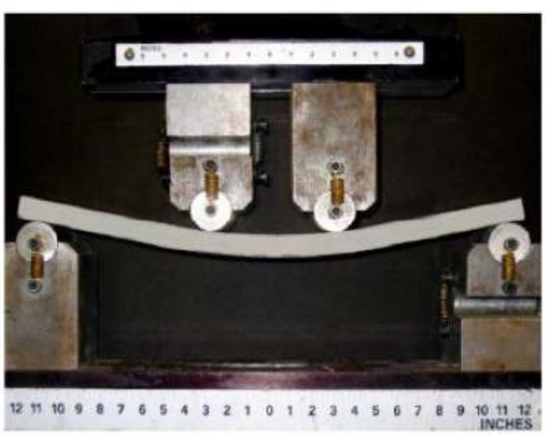

Fig.1 Engineered Cementitious Composite

II. Overview of Literature

Victor(2017) has investigated on CFRP-ECC Hybrid For Strengthening of The Concrete Structures, this paper proposed the strengthening of concrete structures using FRP composite and CFRP-ECC hybrid system for strengthening of the concrete structures. In this paper, ECC was developed with a tensile strain capacity of 3%, matrix ingredients of ECC include Type I ordinary Portland cement, Class F fly ash, fine aggregate (F-75 silica sand), water and water reducer (ADVA-190). The compression strength of the concrete was tested using a concrete 8 cylinder of 75 mm in diameter, The 28-day compressive strength was 40.5 MPa. concrete block was prepared the size of 12.5 mm X 12.5 mm X 25 mm, GFRB lengths were selected as 25 mm, 50 mm, 75 mm, 100 mm, 135 mm and 170 mm. The pull-out tests were conducted on a MTS 810, loading speed of 0.5 mm/min. The total length of the beam was 1524 mm with a span length of 1372 mm . The longitudinal steel rebar was 12.7 mm (0.5 in) in diameter and the stirrup was 6.4 mm (0.25 in) in diameter.

The four-point bending tests were conducted, loading capacity of 500 kN, the average compressive strength was 50.9 MPa., without PVA fiber compressive strength was 52.6 MPa. The tensile strain capacity of ECC in the current paper was tested as 2.8% (average).

The results up to 420 days of exposure to Na2SO4 and Na2SO4 + NaCl solutions. Further studies with longer exposure time are needed for better understanding of the longterm performance of ECC under those environments.

A. Behaviour of PVA Fiber Reinforced Cementitious Composite

Dhawaleand Joshi (2013) have investigated ECC for structural application, this paper suggests the need for developing a new class of FRC which has the strain hardening property but which can be processed which conventional equipment. Results shows extensive strain hardening, with strain capacity of about 3 to 5% compared to 0.01% of normal concrete. The beam is withstanding high load and large deformation without succumbing to the brittle fracture typical of normal concrete.

Victor C.Li and Shuxin Wang (2007) have investigated ECC with high-volume Fly Ash, this paper proposed high volume coal combustion by products including Fly ash and bottom ash were incorporated into ECC mixtures with intention of improving their sustainability performance. Increase of fly ash content also leads to lowering of matrix toughness. That proper mixture designing process can achieve high material performance even when using low quality waste products as cement substitutions.

Atahan et al.(2013) have proposed behavior of PVA fiber Reinforced Cementitious Composite under static and impact flexural effects to improving flexural and tensile behavior of comparatively thinner cement based elements.PVA volume fraction increases, the compressive strength increases. Depending on the matrix strength properties can be improved. The effect of matrix strength is more significant on absorption of impact energy than specific fracture energy, which is determined under static loads.

Haskett et al.(2007) have studied about Deflection of CFRB and PVA fiber Reinforced Concrete Beams paper proposed to PVA fiber increase the shear stress capacity of the sand coated bar low levels of slip, increase fiber content reduce the magnitude of maximum shear stress that could be transferred between the bar and concrete. The deflection model developed was able to predict the gradual reduction in strength post peak load. And also predict the ultimate flexural capacity of the beams.

Victor et al.(2001) have investigated Measuring and Modifying Interface Properties of PVA Fibers in ECC Matrix to single fiber pillout test was used in this study to measure the bond properties of PVA fibers, chemical bond in PVA/mortar is strong with G_d values in the range of 4 to 5 J/m^2. It does not lead to the fiber rupture. This study also indicates that it is important to incorporate slip depend frictional bond properties as long as full fiber debonding can be independently verified, this would desirable to develope PVA-ECC composite with improved ductility.

Saito et al.(2005) have investigated Properties of PVA Fiber as Reinforcing Materials For Cementitious Composites, this paper to study based on micromechanics design of ECC, results shows that PVA fibers has many advantages in properties as reinforcing materials for cementitious composite over other fibers. New type of PVA fiber HPFRCC has been developed and has started to use widely.

Mo Li and Victor C. Li (2013) have investigated about Rheology, fiber dispersion, and robust properties of Engineered Cementitious Composites, the study investigates the correlation between the rheological parameters of ECC mortar before adding PVA fibers, dispersion of PVA fibers, and ECC composite tensile properties. Strong correlation between the ECC mortar plastic viscosity, fiber dispersion and composite tensile properties. The study demonstrated that for ECC achieve robust tensile strain hardening behavior with designed tensile ductility, micromechanical material design should be combined with controlled material during process.

Lachemi et al. (2012) have proposed influence of Polyvinyl Alcohal, steel, and Hybrid Fibers on fresh and Rheological properties of self Consolidating Concrete, this paper proposed the maximum dosage of PVA is limited to increase 0.125% compared with 0.3% of metallic fiber. Results shows fresh rheological properties of FRSCC mixtures developed, PVA and metallic fibers and well as their combinations. A maximum slump flow reduction of approximately 45% was observed with PVA fibers compared with 19% of metallic fibers. The maximum dosage of 0.125% compared with 0.3% of metallic fibers study achieve FRSCC mixture increases workability and strain.

Tosun et al.(2017) have proposed Utilization and Selection of Proper Fly Ash In Cost Effective Green Htpp-Ecc Design. this study special types of environmentally friendly SHCCs known as High Tenacity Polypropylene-Engineered Cementitious Composites (HTPP-ECC) have been prepared by using two distinct type of fly ashes (FA) (Class C and Class F). results clearly showed that the physical and chemical properties of fly ash, directly affected the performance of composites both in fresh and hardened state.

B. Review Based Behavior and Characteristics of Other than PVA Fibers Using in ECC

Rathod J.D and Patodi S.C (2009) have studied about Effect of Cement: Sand Ratio and Fiber Orientation on Tensile Characteristics of ECC, this paper proposed to direct and indirect tensile test to characterize Engineered Cementitious Composite performance by varying cement is suggested for use in ECC as this matrix indicates all the desirable properties required for unique strain hardening behavior. Workability and tensile performance of the ECC deteriorates as cement sand decreases.

Jang et al. (1996) have studied about Influence of Rapid Freeze-Thaw Cycling on the Mechanical properties of Sustainable Strain –hardening Cement Composite (2SHCC), to investigated on silica sand, fly ash polyethylene terephthalate (PET) fibers, respectively the cement, PVA fibers and silica were replaced 10% and 25% PET fibers, for various curing ages and cycle number of freezing and thawing, the average , the average strength of cylinder is 35.4 to 46.3 MPa. The SHCC material provides equivalent resistance to deterioration in the rapid freezing and thawing environment compared to conventional SHCCs with raw components.

Mishra et al.(1996) have investigated tensile Behavior of Cement-Based Composite with Random Discontinuous Steel Fibers, this paper proposed properties of cement composite containing random discontinuous steel fibers are reported. Results shows high aspect ratio and bond strength, enhanced tensile strain capacity can occur in steel fiber reinforced cement based composites at a responsibility low fiber volume fraction. Interface bond strength=1.08MPa suggest that the short fiber with an aspect ratio of 40 could not possibly have achieved critical conditions for strain hardening. The opposite side of the specimen, as a result of rotational rigidity of the specimen grip. Mode of failure in these composites which are at the borderline between quasi brittleness and quasi ductility.

Yaman et al.(2013) have studied about Effect of Presoaked Expanded and Mechanical properties of Engineered cementitious Composites, suggested to investigation of the use of expanded perlite aggregate as saturated lightweight aggregates (LWA) with respect to mechanical and dimensional stability properties of engineered cementitious composite, replacement has a negative effect on compressive strength. This can be collective result of large aggregates size and low strength of LWA with respect to siliceous sand. Drying shrinkage of the ECC specimen that incorporates presoaked LWA was slightly greater than the control specimens.

Yang et al.(2017) have investigated about Experimental investigation on shear strength of engineered cementitious composites, This paper describes o the presence of fibres in the matrix. Instead of severe crushing and spalling in conventional concrete, a major shear crack was observed near the shear plane of ECC specimens, leading to a sudden drop of the shear force were made between experimental results and design values calculated according to ACI code. Results shows when the ratio of stirrups was relatively low. Instead of severe crushing and spalling of conventional concrete, only a major crack was formed at the shear plane of ECC-GGBS and ECC-FA.

Fischer et al.(2016) This paper describes an experimental investigation of the shear behavior of beams consisting of steel Reinforced Engineered Cementitious Composites, This study investigates and quantifies the effect of ECC's strain hardening and multiple cracking behavior on the shear capacity of beams loaded in shear. results to determined Fiber bridging of shear crack, thus increasing the shear capacity, Traditional shear reinforcement is activated at smaller individual crack deformations, Crack deformations are limited by fiber bridging mechanism and by activating traditional shear reinforcement at smaller crack deformations.

Jishen Qiu and En-Hua Yang (2017) This paper proposed fatigue deterioration of engineered cementitious composite (ECC), a unique high-performance fiber-reinforced concrete featuring high ductility, The flexural fatigue model incorporating the fatigue-dependent fiber-bridging constitutive model developed in this study could be used to predict the flexural stress-fatigue life of ECC and the resulting S-N curve agreed well with experimental results, s, flexural fatigue tests were conducted to ECC prisms on the macro-scale and single fiber fatigue pullout and embedded single fiber fatigue tests were conducted to unveil the sources of fatigue-dependency of ECC on the micro-scale. based analytical model to reveal the influences of fatigue dependency on the fiber-bridging and fatigue crack propagation in ECC.

Zhigang Zhang and Qian Zhang (2017) have studied about Self-healing ability of Engineered Cementitious Composites (ECC) under different exposure environments, e the self-healing process of ECC, 60 C hot water and Ca(OH)2 solution can be used to condition the specimen. In this paper, the influence of the above-mentioned environmental conditions on the self-healing behavior of ECC was experimentally investigated, The self-healing ability of ECC decays over time as demonstrated in the compressive test, fly ash reaction degree test, non-evaporable water content test and direct water flow test. However, the long term self-healing behavior can be effective enhanced by 60 C hot water and Ca(OH)2 solution immersion.

Qian Zhang et al.(2017) have investigated on Durability study on engineered cementitious composites (ECC) under sulfate and chloride environment paper investigated the feasibility of applying ductile engineered cementitious composites (ECC) as an alternative to conventional concrete in hydraulic structures to improve their durability performance. Specifically, the durability of ECC under sulfate and combined sulfate-chloride conditions were studied, Long-term exposure to aggressive (sulfate and sulfate chloride) solutions leads to increase of compressive strength, tensile strength and a reduction of tensile strain capacity of ECC. It retains multiple cracking and strain-hardening behavior with desirable high tensile ductility above 2% after 200 days of environmental exposure.

Jinlong et al. (2017) have studied about Flexural behavior of basalt FRP reinforced ECC and concrete beams, . In this paper, the flexural behavior of ECC and concrete beams reinforced with basalt FRP bars were numerically investigated with the software of ATENA/GID solver. E the ultimate tensile stress has little effect on the ultimate deflection of BFRP reinforced ECC beams. The increase of longitudinal reinforcement ratio can change the failure mode of ECC beams.

C. Based on Applications of ECC

Victor C. Li and Michael D. Lepech (2009) have studied about Applications of ECC for Bridge Deck Link Slabs, in this paper unique ultra high tensile ductility and tight cracks width of self consolidating ECC is explored in this applications to improve bridge deck constructability, durability and sustainability. ECC shoes unique behavior of pseudo strain hardening under tensile loads. The ECC slabs can be an effective replacement of conventional expansion joints resulting in significantly reduced bridge deck maintenance needs.

Dong et al.(2016) have investigated on application of ECC condensation research in T-junction, the research illustrated the relationship between condensation and heat transmission in T-junction. The condensation depends on the structure, thermal, momentum. Simple model based on Nusselt number and thermal parameters can be useful in the analysis of LOCA accident when in SBLOCA or the condition of full fill steam in cold leg. The correlation model is able to predict condensation in Tjunction within a reasonable range of uncertainly of the scenarios.

Leung et al.(2017) have investigated about Matrix design for waterproof Engineered Cementitious Composites (ECCs) To design a suitable ECC matrix for waterproofing applications, waterproofing admixture (WPA) was added to improve the wetting property and reduce the sorptivity, and shrinkage-reducing admixture (SRA) together with calcium sulfoaluminate cement (SAC) were introduced to control the drying shrinkagereplacing a small percentage of ordinary Portland cement (OPC) by calcium sulfoaluminate cement (SAC), a matrix with pleasurable waterproof ability and reduced drying shrinkage was developed.

III. Conclusion

This study was conducted to Compared with the standard mixing sequence, by mixing sequence increase the tensile strain capacity and ultimate tensile strength of ECC.The water to cementitious material (w/c) ratio 0.22-0.27gives the best result High volume fly-ash ECC maintained its characteristics of multiple-cracking, strain hardening and tight crack width control in extreme temperature condition. Compressive strength is directly related to the Flexural strength and inversely related to deflection but if the compressive strength is kept in limited ranges, the desirable value of related parameters can be obtained. Compressive strength decreases with the increase in the cementitious material i.e. fly ash, silica fume etc.

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