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Study of engineered cementitious composite concrete and its various Characteristics and applications

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Abstract : 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 behaviour of the composites.

Keywords- ECC, fibers, mineral ad-mixtures.

Introduction : Conventional concretes are almost un-bendable and have a strain capacity of only 0.1 percent making them highly brittle and rigid. This lack of bendability is a major cause of failure under strain and has been a pushing factor in the development of an elegant material namely, Engineered Cementitious Composites abbreviated as ECC. This material is capable to exhibit considerably enhanced flexibility. An ECC has a strain capacity of more than 3 percent and thus acts more like a ductile metal rather than like a brittle glass. A bendable concrete is composed of all the ingredients of a traditional concrete minus coarse aggregates or crushed stones and is reinforced with micromechanically designed polymer fibers. Plain concrete possesses a very low tensile strength, low ductility and little resistance to cracking. Internal micro-cracks are inherently present in the concrete (due to drying shrinkage) and its poor tensile strength is due to the propagation of these cracks (under loading), eventually leading to brittle failure of the concrete. Thus an ECC deforms much more than a normal concrete but without fracturing.

INGREDIENTS OF ECC CONCRETE

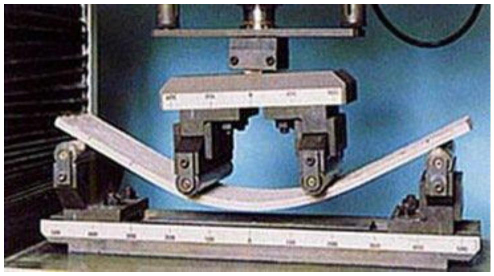
The material ingredients of engineered cementitious composite are similar to that of fiber reinforced concrete, including cement, sand, water, fiber, and a few chemical additives. Unlike the fiber reinforced concrete, the engineered cementitious composites do not include large volume of fiber. The mixing procedure of engineered cementitious composites is similar to that employed for the normal concrete. The engineeredcementitious composites are economical by a reduction in the usage of fiber while maintaining the desired characteristics of strength and ductility.

1. 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.
2. 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.

3. 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.
4. Flyash : 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.
5. 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
6. 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.

Engineered Cementitious Composite Mix Proportions				
Cement	**Fine Silica Sand**	**Water**	**Superplasticizer**	**PVA Fibre (Fraction Volume %)**
1	**0.363**	**0.25**	**0.02**	**1.5**

EXPERIMENTAL INVESTIGATIONS ON ECC : The development of ECC is based on the micromechanics of fiber bridging and matrix crack extension. The theoretical foundation was first described by Li [Li, 1993]. As a result of the micromechanics analysis, it was shown that pseudo strain-hardening under tensile loading can be accomplished with short randomly oriented fiber reinforcement of a cementitious matrix, at moderate dosage no more than 2% by volume. Typically, fibers are of the order of millimeters in length and tens of microns in diameter, and they may have a surface coating on the nanometer scale. Matrix heterogeneities in ECC, including defects, sand particles, cement grains, and mineral admixture particles, have size ranges from nano to millimimeter scale. However the micromechanics based mix design requires pull test to be carried on the PVA fibers, which is not possible in the laboratory. Hence the ideal mix proportion given in the literature of ECC-ECC Concrete was used as the guidelines to determine the proportion of various constituents in the concrete.



The tensile ductility of ECC governs the flexural behaviour of the composite. When exposed to bending, multiple sub-parallel micro cracks form within the tension zone of the composite thus enabling the existence of larger deflections and curvature by means of deflection hardening. Deflection hardening is a property that is difficult to achieve with standard FRC. As the depth of the FRC element increases, deflection hardening becomes more difficult to achieve under bending due to tension-softening. However, the elements geometry does not affect ECC's ability to attain deflection hardening Typically the flexural strength and first crack strength for ECC's ranges between 10-30 MPa and 3-7 MPa, respectively

6. Impact Energy Absorption Characteristic

The high energy absorption characteristic of an ECC is referred to as the materials flexural toughness whereby it is the composites ability to resist breaking apart. This property is determined from the calculated area under the load-deflection curve when exposed to a 4-point bending test (Noushini et al. n.d.). An increase in fibre fraction volume, up to 2%, has shown to have a major impact on the composites flexural toughness (Atahan et al. 2013). The flexural toughness increases as the fibre fraction volume increases. (Atahan et al. 2013) demonstrated that energy absorption was also affected by w/c ratio. For a constant PVA fibre fraction volume, a higher w/cm results in higher energy absorbed by the composite. The lower the w/c ratio exhibited by a mixture, the higher the interfacial bond created between the matrix and the fibres. This results in fibre rupture which in turn dampens the energy absorption capacity of the composite.

Conclusion : According to previous studies on FRC, it can be found that fibre reinforcement is an effective way of improving the strength, ductility, and toughness of brittle materials. To achieve the best FRC function, fibres are supposed to have a relatively higher modulus of elasticity, higher tensile strength (at least 200% - 300%) and significantly higher elongation in tension compared to that of plain concrete and also in addition, having proper bond characteristics with cement matrix (Naaman et al. 2001). Engineered Cementitious Concrete's ductility and toughness can be improved with the use of PVA fibre. It can be used as reinforcement due to its high tensile strength and good adhesion to the cement matrix.

PVA-ECC exhibits similar compressive characteristics to that of normal and high strength concrete. ECC's demonstrate compressive strengths in the range of 20 - 95 MPa. In addition, a continual reduction in compressive strength is witnessed with the successive increase in fibre content

Application : ECC has proved to be 500 times more flexible than traditional concrete, and 40 times lighter, which could even influence design choices in skyscrapers. Additionally, the excellent energy absorbing properties of ECC make it especially suitable for critical elements in seismic zones. Engineered cementitious composites are being used in shear elements that are subjected to a cyclic loading, in the mechanical elements of the beam and column combination, and for general structural repairs. These composites are commonly being used in structures that have a high energy absorption, including dampers, steel element joints and for hybrid steel connections. In addition to the structural applications, these composites are being used as a shielding layer for increasing the corrosive resistance of structures. Other potential targets of engineered cementitious composites include underground structures, highway pavements, and bridge decks.

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