Introduction to Engineered Cementitious Composites (ECC)

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Abstract— This paper deals with various works carried out in the field of Engineered Cementitious Composites (ECC). ECC exhibits various properties like ductility, strain-hardening behavior, controlled crack propagation etc. This article reviews the major works on experimental researches carried out to find the best mix, studies carried to find the compression, flexural and tensile characteristics of ECC. The results of each study are highlighted and also the benefits of such study are discussed.

Keywords: Engineered cementitious composites (ECC), Polyvinyl Alcohol Fiber (PVA), Supplementary Cementitious Materials (SCMs), Fly Ash (FA), Blast Furnace Slag (SL), Alccofine, Three-Point-Bending Test, Single Fiber Pullout Test

I. INTRODUCTION

Engineered cementitious composites (ECC) are a ductile material without coarse aggregate to increase tensile properties. The use of cement is more in ECC when comparing with the normal concrete. Nowadays cement is replaced by silica fume, fly ash , slag etc..ECC is also used for repair and retrofit works. ECC exhibits high deformation capacity when comparing with normal concrete. Crack propagation is controlled and increases the early strength of structures. Sometimes, ECC is provided at the tension zone of concrete structures and hence it results in rebar corrosion. For making the use of ECC economical, locally available materials are used. ECC consists of cement, sand, fiber and chemical additives. Most of the works in ECC is carried out by using Polyvinyl Alcohol fiber (PVA) and some using polyethylene (PE) and polypropylene (pp) fibers. Compressive strength of ECC varies from 20MPa to 90MPa. ECC shows flexural property reflecting its tensile ductility. A flexural strength of 10-15 MPa is achieved. Using polycarboxylate ether based super plasticizers helps in reduction of water to binder ratio.

II. LITERATURE REVIEW

A. Ductile Engineered Cementitious Composite Elements for Seismic Structural Application

Hiroshi Fukuyama et.al in the paper entitled “Ductile Engineered Cementitious Composite Elements for Seismic Structural Application” investigates the upgrading effects on structural performance of ECC reinforced elements. . The ECC employed in this research is Polyvinyl Alcohol (PVA) fiber reinforced mortar. A tension-compression reversed cyclic test of ECC material and a structural test with six beam elements were conducted. New structural elements with ECC are expected to reduce the seismic response and damage of structures. ECC is known for its ductile behavior and damage tolerance and thus resulted in applying to seismic resistant structural elements. In this work a tension-compression reversed cyclic test with cylindrical specimen was conducted to observe the uniaxial mechanical properties of PVA-ECC. The results showed that PVA-ECC with 1.5 % of fiber volume fraction exhibits strain-hardening with strain capacity of around 1.5 % in tension. For studying the potential of ECC in structural performance of elements, a cyclic loading test of six beam elements was conducted. The test results indicate that the brittle failures as shear failure and bond splitting failure observed in the RC Beams can be prevented by using PVA-ECC in place of the concrete.

B. Development of Ecoefficient Engineered Cementitious Composites Using Supplementary Cementitious Materials as a Binder and Bottom Ash Aggregate as Fine Aggregate

Jin Wook Bang et.al in the paper entitled “Development of Ecoefficient Engineered Cementitious Composites Using Supplementary Cementitious Materials as a Binder and Bottom Ash Aggregate as Fine Aggregate” studies develops ecoefficient engineered cementitious composites (ECC) using supplementary cementitious materials (SCMs), including fly ash (FA) and blast furnace slag (SL) as a binder material. The cement content of the ECC mixtures was replaced by FA and SL with a replacement rate of 25%. In addition, the fine aggregate of the ECC was replaced by bottom ash aggregate (BA) with a substitution rate of 10%, 20%, and 30%. The influences of ecofriendly aggregates on fresh concrete properties and on mechanical properties were experimentally investigated. The test results revealed that the substitution of SCMs has an advantageous effect on fresh concrete’s properties; however, the increased water absorption and the irregular shape of the BA can potentially affect the fresh concrete’s properties. The substitution of FA and SL in ECC led to an increase in frictional bond at the interface between PVA fibers and matrix, improved the fiber dispersion, and showed a tensile strain capacity ranging from 3.3% to 3.5%. It is suggested that the combination of SCMs (12.5% FA and 12.5% SL) and the BA aggregate with the substitution rate of 10% can be effectively used in ECC preparation.

C. Utilization of Local Ingredients for the Production of High-Early-Strength Engineered Cementitious Composites

Hanwen Deng in the paper entitled “Utilization of Local Ingredients for the Production of High-Early-Strength Engineered Cementitious Composites” studies the locally available ingredients for the production of ECC. In this study, it utilizes all the local ingredients available in Chinese market including matrix materials and all fibers to produce high-early-strength ECC (HES-ECC). The matrix properties and fiber/matrix interfacial micromechanics properties were obtained from three-point-bending test and single fiber pullout test. Mechanical properties of HES-ECC were achieved by direct tensile test. Experimental results show that HES-ECC was successfully developed by using all Chinese materials. When using the domestic PVA fiber at 2%, the strength requirement can be achieved but only a low ductility. When using the domestic PE fiber at 0.8%, the strength and deformation requirement both can be obtained.

HES-ECC developed in this study exhibited compressive strength of more than 25 MPa within 6 hours, and an ultimate tensile strength of 5-6 MPa and tensile strain capacity of 3-4% after 60 days. Moreover, the cost of using domestic fiber can be largely reduced compared with using imported fiber, up to 70%; it is beneficial to the promotion of these high-early-strength ECCs in the Chinese market. Engineering cementitious composites (ECCs) is a class representative of the new generation of high-performance fiber-reinforced cement-based composites (HPFRCC) with medium fiber content. *e unique properties of tremendous ductility and tight multiple crack behavior indicate that ECC can be used as an effective retrofit material.

D. Experimental Study on Strength of Engineered Cementitious Composite Prepared By Using Alccofine and Fly Ash

Parul Khaped et.al I the paper entitled "Experimental Study on Strength of Engineered Cementitious Composite Prepared by Using Alccofine and Fly Ash" studies the effect of partial replaced of fly ash And Alccofine with cement with 10%, 15%, 20%, 25% and the volume fraction of the fiber used is also less than 2 percent. This paper highlights the effects of polyvinyl alcohol (PVA) on the toughness, compressive and flexural strength of engineered cementitious composite cubes and beam. Compressive test and flexural tests were carried out to PVA fiber reinforced engineered cementitious composites (ECC) with different mix proportions. The results showed that if Alccofine is replaced by 20% with 0.4% PVA fibers the compressive strength is increased when compared to normal concrete. The addition of PVA Fibers improved compressive strength and durability marginally while the flexural strength is improved largely. It is found that the Optimum result for flexural strength gain with 0.4% PVA fiber with 20% replacement of Alccofine.

E. Engineered Cementitious Composites (ECC) – Material, Structural, and Durability Performance

Victor Li in the paper entitled "Engineered Cementitious Composites (ECC) – Material, Structural, and Durability Performance" comments about the various aspects of ECC in terms of material, structural and durability performance and checks its relevance. The most unique property of ECC is the high tensile ductility and also the metal-like behavior. The low fiber content makes ECC easily adaptable to construction project execution in the field or to precast plant structural element production. ECC is used in on-site self-consolidating casting, and spraying, as well as off-site precasting and extrusion. ECC helps in better utilization of steel reinforcements in reinforced ECC members. ECC enhances structural performance and reduce corrosion of steel reinforcement resulting in increased durability.

III. Conclusion

More research works are to be carried out to effectively incorporate ECC in construction industry. More focus should be given to seismic design of structures using ECC material. More supplementary materials are to investigated if it can effectively replace cement which is the major constituent of ECC. Since cement production results in emission of large amounts of carbon dioxide into the atmosphere, a major contributor for green house effect and global warming, it is inevitable either to search for another material or partly replace it by an alternate material. ECC is an evolution from fiber reinforced cement. The basic knowledge of ECC should be easily available to public. Mix design codes and practices should be developed for proper guidance. More studies should be conducted on each constituents of concrete.

References

[1] Hiroshi Fukuyama, Yukihiro Sato, Victor C Li, Yasuhiro Matsuzaki and Hirozo Mihashi, "Ductile Engineered Cementitious Composite Elements For Seismic Structural Application," 12WCEE, 2000, 1672.

[2] JinWook, Bang,G. ,Ganesh Prabhu, Yong Il Jang,and Yun Yong Kim, "Development of Ecoefficient Engineered Cementitious Composites Using Supplementary Cementitious Materials asa Binder and Bottom Ash Aggregate as Fine Aggregate, Hindawi Publishing Corporation , International Journal of Polymer Science ,Volume 2015, Article ID 681051, 12 pages http://dx.doi.org/10.1155/2015/681051

[3] Hanwen Deng, " Utilization of Local Ingredients for the Production of High-Early-Strength Engineered Cementitious Composites", Hindawi Advances in Materials Science and Engineering, Volume 2018, Article ID 8159869, 15 pages. https://doi.org/10.1155/2018/8159869

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

[5] Victor Li, "Engineered Cementitious Composites (ECC) – Material, Structural, and Durability Performance", August 30, 2007, ResearchGate https://www.researchgate.net/publication/268273534

