Advances in Environmental Biology, 9(5) April 2015, Pages: 81-83

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Improving the Matrix Strength of Green Engineered Cementitious Composites

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ARTICLE INFO

Article history:
Received 12 October 2014
Received in revised form 26 December 2014
Accepted 1 January 2015
Available online 17 February 2015

Keywords:
Engineered cementitious composites, Mechanical properties, Drying Shrinkage, Metakaolin.

ABSTRACT

The advent of engineered cementitious composites (ECC), as a sustainable high performance cementitious material is a plus to cement and concrete industry most importantly the infrastructure sectors. But Fly ash, a supplementary cementitious material which made up the necessary ingredients has a deficiency of lower matrix strength when apply in high quantity and most importantly at the early age. This paper aimed at the production of green ECC with strong matrix strength, focusing on early age strength. A series of laboratory investigations were carried out to study both the drying shrinkage and mechanical properties of ECC made with metakaolin. The laboratory experimental result reveals that ECC with metakaolin still achieves high mechanical properties at 56days. When this was compared to ECC that contain only fly ash, the experimental ECC that contain Metakaolin increases in compressive strength.

To Cite This Article: Alonge O. Richard and Mahyuddin Ramli., Improving the Matrix Strength of Green Engineered Cementitious Composites. ***Adv. Environ. Biol., 9(5),*** *81-83, 2015*

INTRODUCTION

Fiber reinforced concrete material has undergone some series of phases. Since 1980's there has been an increase in interest in creating a fibre reinforced concrete material with tensile ductility. ECC is a family of materials with a feature of tensile strength and ductilities that can be adjusted depending on the demands of a particular structure. It as well represents a family of materials with different functionalities in complementing to other common known features of high tensile ductility and fine multiple crackings.

The name Engineered Cementitious Composites was initiated and adopted by the inventor Prof. Li to stress the Micromechanics basics behind the design of this material. Meanwhile Micromechanics serves as a strong tool to direct design of materials for certain targeted composites properties, also, it enables a fruitful linkages between materials engineering and structural performance design. [1]

According to literatures, ECC had been produced locally using various local materials in various countries such as Japan [2], Europe[3] and South Africa[4] hence this research study using local source materials from Malaysia to design a green ECC that has characterised early age strength and mechanical properties better than M45 ECC standard.

Experimental Programme:

i. Materials and Mix proportions:

The ingredient used for the production of ECC mortar includes ordinary Portland cement (PC), metakaolin and natural sand, instead of micro silica sand, water, Coconut and Oil palm fruit bunch fibres and a polycarboxylate-based high range water reducer (HRWR). The physical properties and chemical compositions of PC and Metakaolin are listed in Table 1.

The dimension of local oil palm fruit bunch fibre and coconut fibre used are between 6mm to 12mm in length and 40 µm to 50 µm in diameter.

ii. Mixtures:

ECC mixtures are mixed in a standard portable laboratory mixer. All solid ingredients including PC, MK and fine aggregates are firstly mixed together for the first 2min, then water and HRWR are added into the dry

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mixture and mixed for another 2min.The fibers are slowly added to the concrete and later demoulded after 24hrs. The specimens are cured in water till the date of test. The mix proportion is shown in table 2.

Table 1: Shows the physical and chemical composition of Cement and Metakaolin.

Chemical composition	PC	MK	Physical Properties	PC	MK
SiO_2	21.26	52.5	Loss on ignition	1.61	1.32
Al_2O_3	4.79	44.5	Density kg/m3	318	139
Fe_2O_3	3.14	0.9			
CaO	64.10	0.04			
MgO	2.35	0.57			
NaO	0.02	0.04			
SO_3	2.63				
TiO_2		0.93			
K_2O		1.88			

Table 2: Shows the Mix proportion of the ECC SAMPLES.

Sample	Cement/sand	W/C ratio	Metakaolin	Coconut Fiber	Oil Palm Fruit bunch fiber.
ECC-0	1: 0.8	0.3	0%	2%	2%
ECC-5	1: 0.8	0.3	5%	2%	2%
ECC-10	1: 0.8	0.3	10%	2%	2%

iii. Specimen preparation and measurement:

The ECC mixtures were cast using moulds size 100mm x 100mm x 500mm prism and 100mm x 100mm x 100mm cubes and prepared for compressive strength, drying shrinkage and flexural strength tests. The Flexural test was done using four point loading machine, the span length of the flexural loading is 300mm.

Compressive strength test was carried out at the age of 7, 28 and 56 days. Nine prisms are prepared for each mixture of different ages. The same goes for the shrinkage. After removing from the moulds, ECC specimens for drying shrinkage are stored at room temperature of 25±2^{O}C and relative humidity of 50±5%. The dry shrinkage for each mixture was measured up to 90days of age. The length measurement started immediately after the demoulding of the specimen and this is considered as the initial length while calculating the drying shrinkage. The change in length of the samples is measured daily for a period of 7days and then weekly for a period of 90days. All tests were carried out in accordance with the respective America standard of test methods.

RESULTS AND DISCUSSION

i. Flexural strength:

The flexural test as shown in Fig. 1 reveals that the ECC-5-C made of coconut fibre with 5% metakaolin replacement on binder weight has the highest flexural strength at 56 days,it has 6.93MPa and this is about 9% higher than the close which ECC-0-C which has 6.31MPa. At 28days, ECC-O-OF has the highest Flexural strength of 5.87MPa while that of ECC-10-OF has the lowest of 4.79MPa. This result is above that of ECC M45 which is the base standard of all ECC products and it may be as a result of the metakaolin efficiency to strengthen the matrix of ECC better than fly ash.

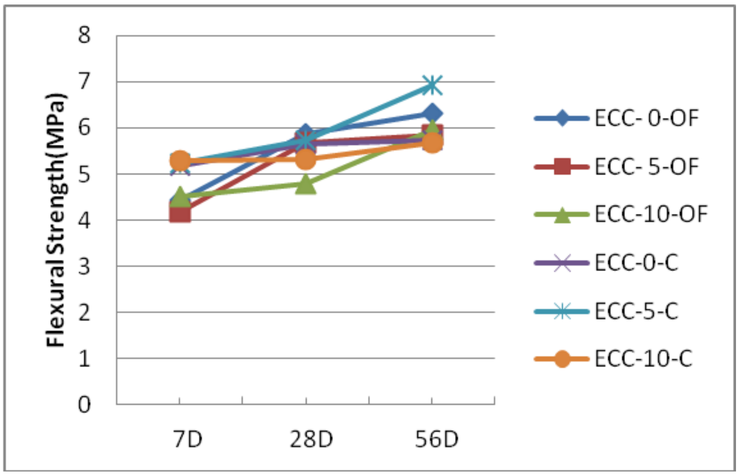

Fig. 1: Shows the flexural test result of the samples.

ii.Compressive Strength:

The result reveals that ECC-5-C possess the highest compressive strength of 79.29MPa and with 3% higher than that of ECC-O-OF. It shows that the presence of metakaolin and coconut fibre strengthen the matrix of the ECC. The lowest strength is recorded by ECC-5-OF at 56days. At 28days ECC-5-C recorded the highest strength also and closely followed by ECC-5-OF. This is as shown in Fig.

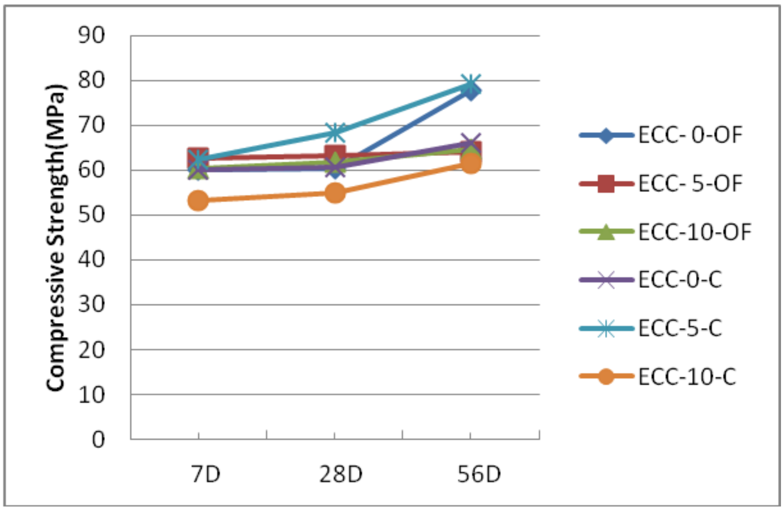

Fig. 2: Shows the Compressive strength of the samples.

iii. Dry Shrinkage:

The dry shrinkage of the samples revealed that the drying shrinkage of ECC specimens is much higher than that of normal structural concrete and this may be as a result of lack of coarse aggregates in the mixtures of ECC. The drying shrinkage of ECC with mixture of metakaolin increases at the early ages most importantly at the early 5days out of the 7days. The conclusion is that the incorporation of metakaolin and local fibres can increases drying shrinkage of ECC mixtures. All the samples have less than 200x 10^{-6} at the first 7days and ranges between 200-400 x 10^{-6} at 28days while at 56 days, it was between the ranges from 600-700 x 10^{-6} and till 90days, the ranges was 800-1100 x 10^{-6}.

Meanwhile, the dry shrinkage increases slightly for all samples with increasing metakaolin contents which indicate that the higher the metakaolin content, the higher the shrinkage with ages.

Conclusion:

A new set of localized ECC was produced in this study. The incorporation of metakaolin and local fibres into ECC matrix increases the strength of the ECC most importantly at the early ages. This permits the early field work application in some circumstances that warrant early settings. Dry shrinkage of all samples is a little higher than normal concrete and this is due to the absence of coarse aggregates in the mixtures.

ACKNOWLEDGEMENT

The authors acknowledge the input of Universiti Sains Malaysia as the research project was funded under the USM Research scheme RU-PRGS No-1001/PPBGN/84611 year 2013.

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