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Fresh Properties of Natural Sustainable ECC Mortar without Fibers

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ABSTRACT

Sustainable material design incorporates microstructures that interwove with analysis of the life cycle, with focus on parameters such as social, economic and environment. The new initiative has been made in the developments of engineered cementitious composites with distinct features of extreme ductility which was adjudged to be better in some features than fibre reinforced concrete (FRC). But the demerit of Engineered Cementitious Composites (ECC) about the lack of design based load bearing capacity for the structural members of building components. Rather, its mostly for infrastructural applications whereby it majorly fit comfortably for repairs and retrofitting of dilapidating existing structures. In this research work, some preliminary experimental work was done with the use of natural sand instead of fine sand with the cement substitution of natural pozzollanic material, metakaolin, modified with nanosilica and epoxy without any fiber. The fresh properties show some features that are better than the features of the base design M45 ECC.

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INTRODUCTION

Concrete is one of the most extensively used materials in the construction industry all over the word. It is claimed that two billion tons were used each year in the whole world,[1] . Major Concrete applications mostly offer considerable strength at lower cost. Supplementary cementitious materials (SCMs) are identified as finely ground solid materials that are mostly used in cement supplements in a concrete mix to achieve one aim or target. The mixture of these cementitious materials brings about a chemical reaction with hydrating cement and result in a modified paste chemical microstructure. Likewise, their friendly environmental impact and ability to improve concrete workability, mechanical properties and durability made them to be a good material for construction applications. Metakaolin is a type of SCM fall within ASTM C 618, Class N pozzolan specifications. The uniqueness of Metakaolin lies on the fact that it is not the by-product of any industrial process nor it is entirely natural. It is manufactured from a naturally occurring mineral under a close monitored for cementing applications. Metakaolin production differs from other type of SMC, it is normally produced under careful and controlled environmental condition to refine its color, remove inert impurities and as well tailor the particle sizes,[2, 3]. As a result of this process of production, a very high degree of purity and more pozzolanic reactivity tenacity are attained.

i.Research Significance:

Metakaolin possess pozzolanic reactivity which significantly modifies the microstructure of concrete and enhance the overall mechanical and durability performance[4, 5]. Hence because of its particle size, Metakaolin probably require a lesser HRWRA than other cementitious material like silica fume to achieve the same measurement of slump flow[3]. The importance of this research is to study the effects of metakaolin in a composite material.

Experimental Programme:

The experimental study was designed purposely to assess the early age properties of natural Engineer cementitious mortar containing metakaolin, nanosilica and epoxy. A total number of 120 samples of 50 x 50 x 50mm cubes samples and 40 x 40 x 160mm mortar prisms were used for compressive strength and flexural

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strengths tests. All variables in the specimens remain fixed except for the various cementitious cement replacement materials used and the hybridization of the three cement replacement. The structural properties considered at early ages include compressive strength, flexural strength, density, and slump.

MATERIALS AND METHODS

Materials:

i.Binder and fine aggregate:

Type 1 Ordinary Portland cement, supplied locally was used in the mix and metakaolin produced in the laboratory under a control condition was used and the physical properties are shown in table 1.

Table 1: The physical properties of Metakaolin produced in the laboratory in % weight.

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
53.03	0.93	35.63	1.81	0.02	0.57	0.04	0.04	1.88	0.06

Nanosilica material was used to achieve two aims in this experiment, first is to increase the silica content of the fine sand used since silica sand was not used. Secondly, it’s to serve as a cement substitutes. The Nanosilica was supplied by Sigma-Aldrich with specific gravity of 1.289 and pH at $25^{O}C$ of 9.1. The particle size was 20.0 – 24.0 nm according to the supplier specification. Fine sand supplied locally in Penang, Malaysia was used instead of silica sand as used in the originally invented ECC M45 which is generally accepted as a base standard. HRWA superplasticer was used in all the mix at 0.5% weight of the binder.

ii.Mixing Proportion:

A polycarboxylic ether based high range water reduction agent was used at 0.5% of the binder weight with portable water and the mix proportion includes binder: sand: water ratio of 0.8:1.0:0.3. The cement content was replaced at 10% for metakaolin, 1.5% for Nanosilica and 1.5% of Epoxy. Meanwhile, Portland cement was the only binder used in the control specimen.

iii. Mortar mixing and fresh properties tests:

The mixing process of all specimens was carried out using a portable laboratory mechanical mixer whereby all materials were mixed together, with sand first, then cement and other additives with water, mixed together until a homogenous mixture was formed. The ASTM flow test procedure was performed on the fresh mixes with the use of a flow table as prescribed in ASTM Standard 230 and also testing procedure in ASTM Standard C109.

The wet uniformed mix was then cast into different sizes of moulds according to all tests and ages to be considered. In this case water curing regime was used. The cast samples were kept in the mould for 24hours before de-moulded and transfer to the curing water tank. The mix was cast using moulds size 40 x 40 x 160mm prism and 50 x 50 x 50mm cubes. Samples for three ages were prepared, 7, 28 and 56 days. All the samples remain in the curing location till the test date.

RESULTS AND DISCUSSION

i.Bulk density:

The bulk density of all the samples is as shown in the table 4 below.

Mix Designation	Bulk Density(kg/m^3)
C	2230
MN	2220
ME	2225
MNE	2234

C= control, MN=metakaolin + nanosilica, ME= metakaolin+ Epozy, MNE= metakaolin +nanosilica + epozy(hybridized).

ii.Early age Compressive strengths:

The results of the compressive strength of the various samples were as shown in Fig.1. The compressive strength of hybridized sample was higher than others at 56 day age. This was closely followed by the control samples. The difference in strength is 9%, while the percentage difference is 22% of samples with metakaolin and epoxy. At 28days the hybridized samples has 11% higher strength than the control samples while samples with metakaolin has 56MPa, about a 19 % difference in strength. This suggested that the combination of Nanosilica and epoxy with metakaolin at 10% weight of cement can produce a better concrete than the control samples.

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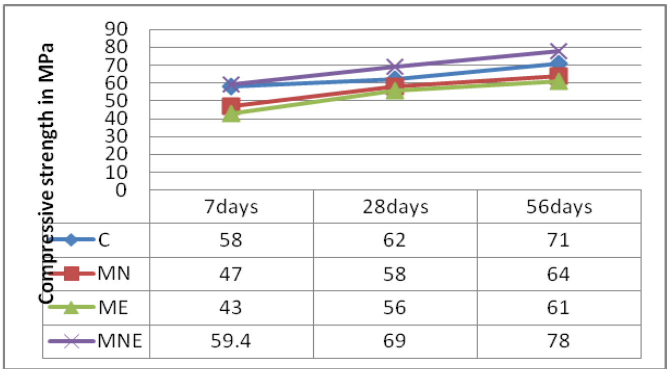

Fig. 1: Shows the Compressive strength of samples at different ages in MPa.

iii.Early ages Flexural strength:

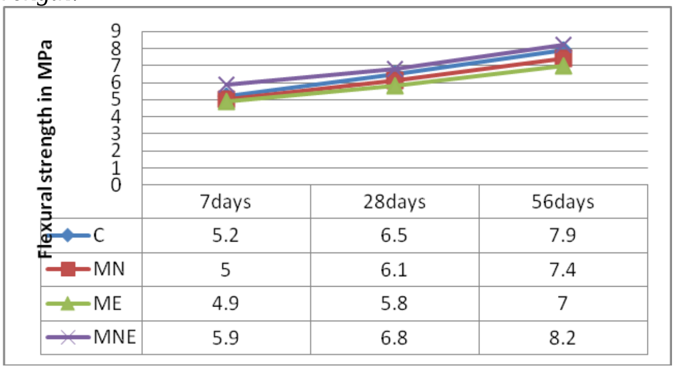

Fig. 2: Shows the Flexural Strength of samples at different ages in MPa.

At 7 days, hybridized samples have the highest flexural strength of 5.9MPa, this is higher than the samples that contain Metakaolin and Epoxy which has 4.9MPa. It is the lowest of all the samples. At ages 28 and 56, both control samples and hybridized samples has 6.5MPa and 6.8MPa, 7.9MPa and 8.2MPa respectively.

Conclusion and recommendation:

From this study, it can be concluded that, metakaolin in the presence of nanosilica, epoxy can produce a better cementitious concrete higher than the standard based ECC M45 at ages 28 and 56. On the othe hand nanosilica can as well influence the strength of concrete made of metakaolin.

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