Investigate The Engineering Properties of Epoxy-Modified Mortars As Self-Healing Materials

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***Abstract*— The aim of this study as mentioned above is to investigate the properties of Mortars to develop a self-healing polymeric-cementitious material using polymeric admixture, epoxy resin (Diglycidyl Ether of Bisphenol A Type). This study investigates the engineering properties of epoxy-modified mortars as self-healing materials. In this research an epoxy resin (diglycidyl ether of bisphenol A) without any hardener is used as polymeric admixture to prepare polymeric-cementitious materials and their self-healing function is evaluated. Epoxy-modified mortars are prepared with various polymer-cement ratios, subjected to initial wet/dry curing plus long term dry curing and tested for strength properties. The fundamental properties such as workability, influence of curing, strength development and water absorption are investigated. The results show that 10% of polymer - cement and wet dry curing was optimum to modify the strength properties of mortar.**

Keywords— Polymer-cement ratio, epoxy resin; Strength development

I. INTRODUCTION

Concrete has been an artificial rock related to natural rocks used for construction worldwide since two centuries [1]. This material has transformed the physical appearance in rural areas because it is strong, durable besides it is virtually cheap. The principal components of the concrete include cement, water and the aggregate is tailored to its characteristic variety of the final product [2]. Therefore, the structural designer must establish previous properties that are vital for a specific application that will help to choose the composition of the concrete [3]. This is just to ensure standards for the mixtures. Concrete possess naturally high compressive strength, but unfortunately possess low tensile strength [4]. Conversely, the application of material reinforcements is good for tensile forces.so, in this paper, we offer effective liquid polymer in mechanical properties of mortars [5].

II. MATERIALS

A. *Ordinary Portland cement (OPC)*

Obtained from Holcim Cement Manufacturing Company of Malaysia conforming to ASTM C150 standard is used.

B. *Epoxy Resin*

Diglycidyl Ether of Bisphenol A Type of epoxy resin is used in the mix proportion. Epoxy resin is store in room temperature to avoid a damage to epoxy resin. A 5% to 20% of epoxy resin is added into the mix proportion in order to determine an optimum mix proportion for self-healing mortar using epoxy resin.

C. *Fine Aggregate*

The fine aggregate used is river sand as provide in Structure and Materials Laboratory, UTM with specific gravity of 2.62 and fines modulus of 2.85 in saturated surface dry condition.

III. MIX PROPORTION

A total of three series of mixtures are prepared in the laboratory trials. Series control mortar mixtures are prepared as control specimens. The control mixtures are made of ordinary Portland cement, fine aggregates and water. The water to binder ratio for all mixtures is set at 0.48. The polymer to binder ratio are varies from 5% until 20% of addition.

The mixing process of epoxy resin self-healing mortar is same as ordinary Portland cement process. In order to achieve the specific design strength, a strict quality control is required while preparing for material and mixing it. All specimens are made with fine aggregate to cement ratio by mass of 3:1. The fine aggregate is in a saturated surface dry condition. There is various design of polymer to cement ratios are varies which were 0, 5%, 10%, 15% and 20%. The ration are varies in order to achieve optimum mix proportion. The water to cement ratio used were 0.48.

TABLE I. MIX PROPORTIONS OF SELF-HEALING MORTARS

kg/m³			%		
Cement	Water	Sand	P/C	W/C	Sand: Cement ratio
506	228	1517	0	0.48	3:1
			5		
			10		
			15		
			20		

IV. SPECIMEN PREPARATION

In order to prepare the mortar mixtures, a 20 L capacity mechanical mixer with a rotating speed of 80rpm is used. For all mixtures, the fine aggregates used were in saturated-surface-dry condition. First, the fine aggregates and cement were mix together until the mixture properly mixed. After that epoxy resin was added and mix for about 2 minutes. Water was added as a last stage of mixing and mixed for another 2 minutes. Flow test were conducted to see the fresh properties of epoxy resin mortars. All mixtures will be mixed according to ASTM standards. Cubic specimens of size 70 x 70 x 70 mm for compressive strength test and the beam size 40 x 40 x 160 mm for flexural test are prepared.

V. Curing Conditions

There are two curing condition were applied for epoxy resin mortars which are dry-wet cured and dry cured. For dry-wet cured, the specimens were put under wet gunny for 2-d and after that 5-d in water. After 5-d, the specimens were taken out and put in room temperature for 21-d. For dry cured, the specimens were put under wet gunny for 2-d and after that leave at room temperature for another 26-d.

VI. Results and Discussion

A. *Flexural Test*

Flexural test was conducted in beam size of 40 x 40 x 160 mm. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. Flexural test conducted based on Flexural - ASTM C348 – 08, 'Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars'.

$$\sigma = 3FL/2bd2$$

Where:

F = load (force) at the fracture point (N)

L = length of the support span (mm)

b = width (mm)

d = thickness (mm)

Fig. 1. Flexural test.

For analysis of flexural strength with various polymer/cement ratio (5%, 10%, 15% and 20%) selected for flexural test, 32 beam specimens with the size of 40 x 40 x 160 mm were tested for flexural strength. The specimens were tested at 28 days after curing with two type of curing dry curing and dry wet curing. In these test, sample under a load in a three-point bending until failure occurs. In this part will be compared the results with control samples OPC.

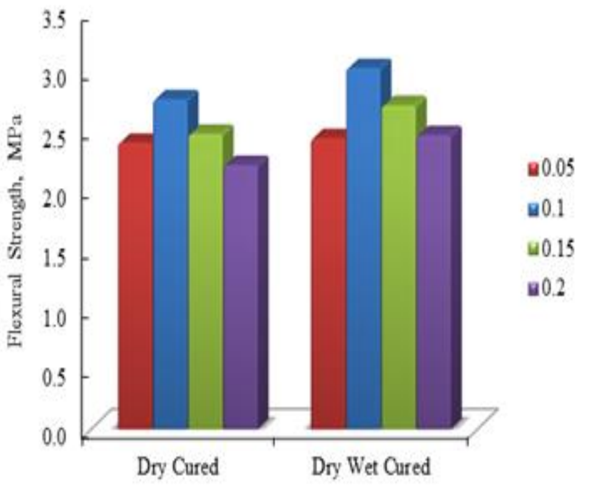

Fig. 2. Bar chart comparing Flexural strength with various P/C ratios.

From figure 2 the results show the 10% polymer-cement it is the optimum percentage, but when compare the results with control OPC the flexure strength reduce with added polymer in mix.

B. *Water Absorption*

Test was carried out according to ASTM C 140 – 07a "Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units". The specimens were casted in 70x70x70 mm mould.

After the specimens matured, it was immerse in water at a temperature of 26.7°C for 24 hours. The specimens were suspended and completely submerged in water to measure the weight. Subsequent to saturation, all specimens was dried in a ventilated oven at 100 to 115 °C for not less than 24 hours and until two successive weighing at intervals of 2 hours show an increment of loss not greater than 0.2% of weight of the specimen.

$$\text{Water absorption (\%)} = [(Ws – Wd)/Wd] \times 100$$

Where:

Ws = saturated weight of specimen, kg

Wd = oven-dry weight of specimen, kg

Fig. 3. Water Absorption Test.

Water absorption for mortar is important in order to get the rate of water absorb by the mortar. The rate of water absorb for mortar indicate the stability of the mortar. Mortar who have high water absorption may not be good in quality to be use since the mortar will tends to absorb much water during construction works. Water absorption test was conducted according to the ASTM C140 - 07 at 28 days by using the specimens and average value was taken to calculate the water absorption. Comparison of water absorption between controls samples OPC and different P/C%.

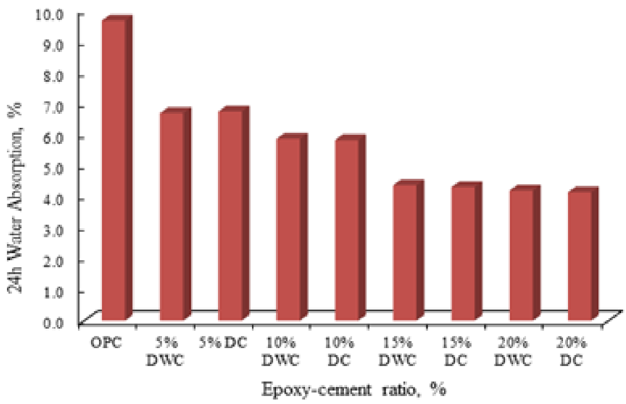

Fig. 4. Bar chart comparing Water absorption with various P/C ratios.

From figure 4 the results had shown that increasing ratio of polymer-cement (5%, 10%, 15% and 20%) in the mortar that will cause decrease in the ratio of water absorption(6.72, 5.8, 4.29, 4.12) respectively with dry curing and (6.67, 5.84, 4.35, 4.18) respectively with wet dry curing and compare the results with control OPC (9.85Mpa).

C. Tensile Strength Test

Cylindrical test is required to determine the indirect tensile strength of concrete. Cylindrical test is based on ASTMD 3039. For tensile strength test is calculated using the formula:

$$Ft=2P/\pi DL$$

Where:

P = maximum load apply to sample (KN)

D = diameter of the cylinder (mm)

L = the length of the cylinder (mm)

Fig. 5. Tensile strength test.

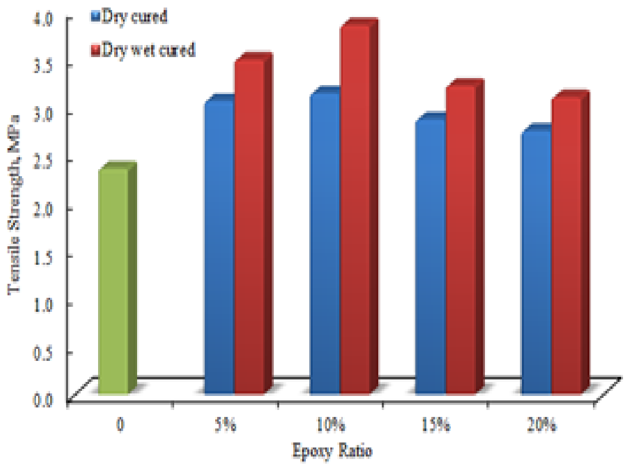

Fig. 6. Tensile Strength Test.

From figure 6 the results had shown that ratios of polymer-cement (5%, 10%, 15% and 20%) in the mortar that will cause given the results of tensile strength (Mpa) (3.11, 3.27, 2.92 and 2.83) respectively with dry curing, (3.52, 3.98, 3.18 and 4.18) respectively with wet dry curing, the optimum result with 10% polymer – cement ratio it is given the maximum tensile strength, the polymer increased tensile strength when compare with control OPC (2.4 Mpa).

VII. Conclusions

The research investigated Mechanical properties of mortars with used polymer, the results of this study prove the water Absorption decreases as the polymer-cement percentage increase, the optimum polymer to cement ratio is 10% to improve the tensile strength, the flexure strength reduce wit used polymer. It is expected that study will help to develop the strength properties of mortars.

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REFERENCES

[1] Dry, Carolyn. "Procedures developed for self-repair of polymer matrix composite materials." Composite Structures 35, no. 3 (1996): 263-269.

[2] Yang, Jinglei, Michael W. Keller, Jeffery S. Moore, Scott R. White, and Nancy R. Sottos. "Microencapsulation of isocyanates for self-healing polymers." Macromolecules 41, no. 24 (2008): 9650-9655.

[3] Jones, A. S., et al. "Life extension of self-healing polymers with rapidly growing fatigue cracks." Journal of the Royal Society Interface 4.13 (2007): 395-403.

[4] Wiktor, Virginie, and Henk M. Jonkers. "Quantification of crack-healing in novel bacteria-based self-healing concrete." Cement and Concrete Composites 33, no. 7 (2011): 763-770.

[5] Burattini, Stefano, Barnaby W. Greenland, David Chappell, Howard M. Colquhoun, and Wayne Hayes. "Healable polymeric materials: a tutorial review." Chemical Society Reviews 39, no. 6 (2010): 1973-1985.