PROPERTIES OF POLYMER-MODIFIED MORTARS

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Abstract: The using of epoxy resin as repair material in concrete is quite common. Previous research proof that epoxy resin in concrete can give strength and have high durability towards aggressive environment. Usually epoxy resin needs a hardener to make it hard when mix with concrete but in this research, the development of concrete by using epoxy resin without hardener is investigate. Epoxy resin without hardener or can be known as epoxy-modified mortar also can mix well with cement and harden the concrete. This is due to the present of hydroxide ion in cement hydrate that can react with epoxy resin and make it harden. This paper is present a strength properties of epoxy-modified mortar up to three months. In this research an epoxy resins (Diglycidyl Ether of Bisphenol A) without any hardener is used as polymeric admixture to prepare polymeric-cementitious materials and their strength properties are analysed. Epoxy-modified mortars are prepared with various polymer-cement ratios, subjected to initial wet/dry curing plus long term dry. The optimum mix proportion of epoxy resin content in concrete is determined. The result shows that, the optimum polymer to cement ratio is 10% with dry/wet curing and up to three month of strength development, the compressive strength continuously increased.

Keyword: epoxy resin, strength, strength development, epoxy-modified mortar

1.0 INTRODUCTION

Epoxy resins have been used for industrial applications for nearly 40 years. Epoxy resin has desirable properties such as high adhesion and chemical resistance, and has widely been used as adhesives and corrosion-resistant paints in the construction industry. Incorporation of the epoxy resin into cement mortar can be expected to impart its desirable properties to the mortar. Until now, in the preparation of conventional polymer-modified mortars using the epoxy resin, the use of any hardener has been considered indispensable for the hardening of the epoxy resin (Ohama et al. 1989). The authors have noticed the fact that epoxy resins can harden in the presence of alkalis (Butt et al. 1971; Kakiuchi 1985), and have successfully developed the polymer-modified mortars using epoxy resin without any hardener. As a result, the disadvantage of the two-component mixing of the epoxy resin and hardener has been overcome.

In this paper, polymer- modified mortars using epoxy resin without any hardener are prepared with various polymer-cement ratios, and tested for compressive strength and flexural strength. For comparison, the normal ordinary cement mortar are prepared and tested in the same manner. From the test results, the compressive and flexural strength of epoxy-modified mortars using epoxy resin without the hardener are discussed.

2.0 EXPERIMENTAL

2.1 Materials

2.1.1 Cement

Obtained from Holcim Cement Manufacturing Company of Malaysia conforming to ASTM C150 standard is used. The properties of the cement are given in Table 1. The important composition of OPC mortar is calcium because in order for OPC to perform the hydration process, the amount of calcium must be high and enough.

Table 1: Chemical composition of Ordinary Portland Cement

Constituent	Percentage by weight (%)
Silica, SiO_2	19.8
Alumina, Al_2O_3	5.6
Iron Oxide, Fe_2O_3	3.4
Calcium, CaO	62.7
Magnesia, MgO	1.2
Sodium, N_2O	0.02
Phosphorus, P_2O_5	0.1
Loss of Ignition, LOI	2.1
Lime saturated factor	1.0

2.1.2 Fine Aggregate

A fine aggregate used in this present study is commonly known as river sand. Local river sand available in Material and Structure Laboratory, Faculty of Civil Engineering with specific gravity of 2.62 and fineness modulus of 2.85 in saturated surface dry condition was used as shown in figure 1. The fine and coarse aggregates are dried first in an oven, and then wetted until saturated surface-dry condition is reached.

Figure 1: Fine aggregate in saturated surface dry condition

2.1.3 Epoxy Resin

Diglycidyl Ether of Bisphenol A Type of epoxy resin is used in the mix proportion as shown in figure 2. 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 epoxy-modified mortar.

Figure 2: epoxy resin

Table 2: Properties of epoxy resin

Epoxy equivalent	Molecular weight	Density (g/cm3, 20°C)	Viscosity (MPa・s, 20°C)	Flash point (°C)
184	380	1.16	38000	264

2.2 *Experimental Procedure*

2.2.1 *Preparation of Epoxy-Modified Mortar*

In order to prepare the mortar mixtures, a 20L capacity mechanical mixer with a rotating speed of 80rpm is used as shown in figure 3. For all mixtures, the sand was initially blended with the amount of water calculated to be necessary to bring the sand to saturated-surface-dry condition. This amount of water is mixed with sand for 1 min to obtain the saturated-surface-dry condition. Firstly, the sand and cement were mix together until achieved a homogeneous. After that, epoxy resin was added and mixed for 3 minutes before adding water.

According to JIS A 1171 (Test Methods for Polymer-Modified Mortar), hardener-free epoxy-modified mortars were mixed with a mass ratio of cement to fine aggregate 1:3, polymer-cement ratios (P/C) of 0, 5, 10, 15 and 20%, and a water-cement ratio of 48.0%. Their flows were in the range of 170±5. Cube specimens 70x70 mm for compressive strength test and beam specimens 40×40×160 mm for flexural test were moulded, and subjected to a curing for 28 days. Rhe mix proportion of the epoxy-modified mortar shown in Table 3.

Table 3: Mix Proportion

	kg/m^3		%		
Sand	Cement	Water	Polymer/cement ratio	Water/Cement Ratio	Sand: Cement ratio
1517	506	228	0		
1517	506	228	5		
1517	506	228	10	0.48	3:1
1517	506	228	15		
1517	506	228	20		

Figure 3: Fine aggregate in saturated surface dry condition

2.2.2 *Curing Condition*

Two curing condition was applied for epoxy-modified mortars/concrete 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.

2.2.3 *Compressive Strength*

The compressive strength test was conducted using compressive test machine at Civil Engineering Material and Structure and the method was specified in a lab manual. Cured specimens were tested for compressive tests according to BS1881-Part 116, 1982 'Compressive Strength of Concrete Cube'. An increasing of compressive load was applied to the specimen until failure occurred to obtain the maximum compressive load. The cube size was 70x70x70mm and the average three specimens were taken.

For the strength development test, the test conducted at the end of the test period. The strength test was important as it would indicate the performances of specimens after leave at certain period. The compressive strength was calculated based on the equation

$$\sigma_c = P/A$$

where
P = load (kN)
A = Area (mm^2)
σ_c = compressive strength (MPa)

3.0 RESULT AND DISCUSSION

3.1 *Effect of curing condition*

There are two types of curing condition for epoxy-modified mortar which is dry cured and dry wet cured. The reason for different type of curing is to see the effect curing to epoxy-modified mortar. The result for 28 days curing is shown in graph below.

Figure 4 represent the compressive strength of epoxy-modified mortar after 28 days curing. The result shows the compressive strength between two different types of curing condition. From the graph, dry wet cured give higher compressive strength compare to dry cured. This was happened for all percentage of epoxy resin in mortar. This is due to the characteristic of mortar that needs water in early stage. For dry wet cured, first the specimens were put in water. In this stage, the hydration processed of cement hydrate was occurring and give an early strength to mortar. For polymerization process, dry condition of curing is needed. As a result, dry wet cured specimens give higher compressive strength than dry cured specimens.

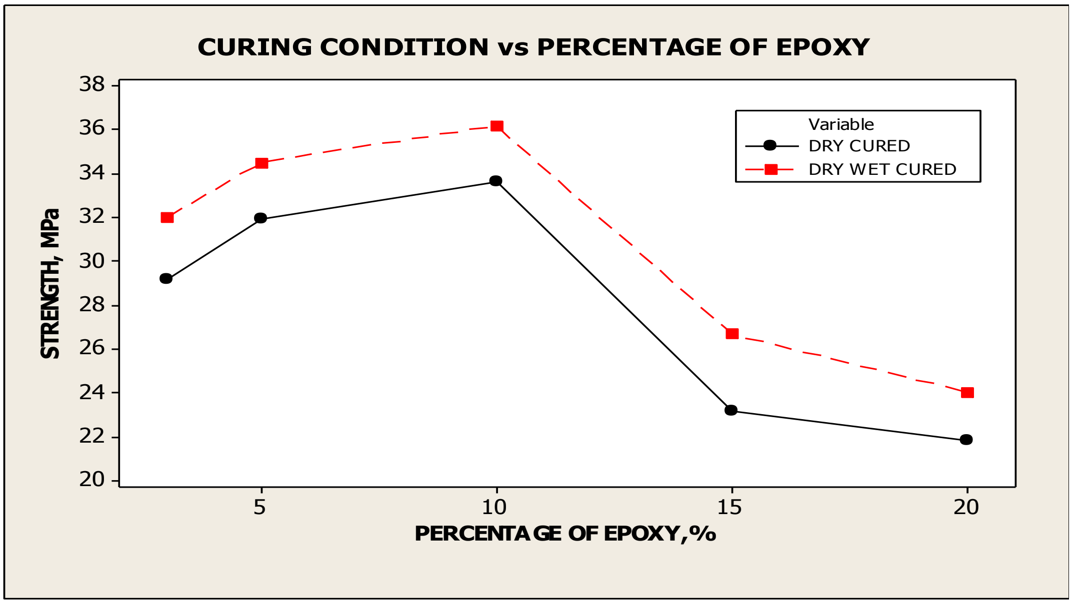

Figure 4: Curing condition vs. percentage of epoxy

3.2 Optimum Mix Proportion

The optimum mix proportion was obtained from compressive strength test. The graph below shows the compressive result for 28 days curing.

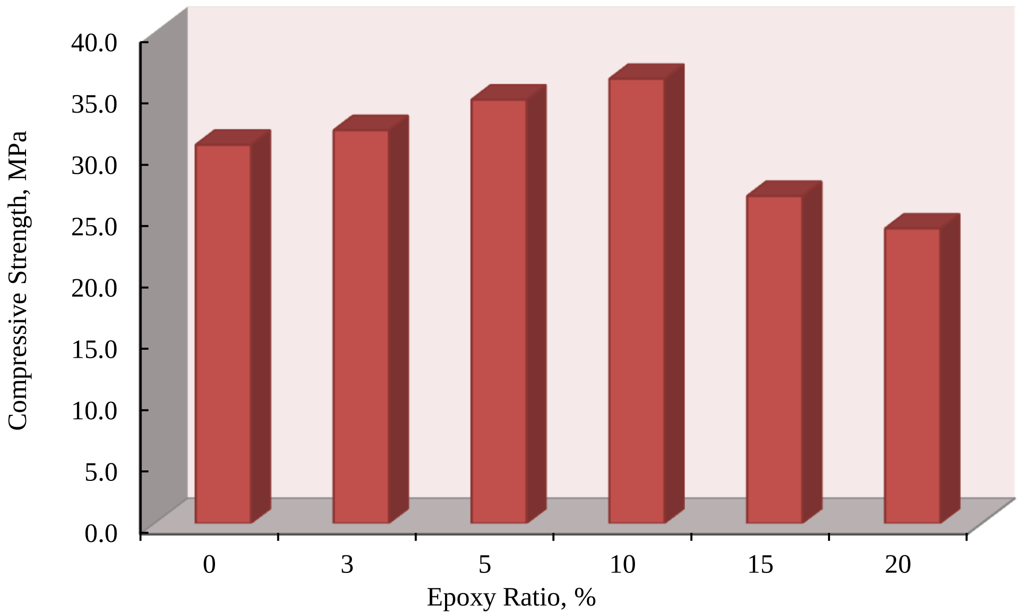

Figure 5: compressive strength with various epoxy ratios.

Figure 5 exhibits the different percentage of epoxy resin in mortar. In mixing process, various percentages of epoxy resin were added to see the effect in compressive strength. Normal mortars give 30MPa of for 28 days curing while 10% epoxy ratio gives 36MPa which is higher than other ratios. It is considerably higher than the strength of normal mortar. Epoxy-modified mortar without epoxy can give higher strength because due to the present of alkalis from hydration process in mortar.

The compressive strength was increased until 10% of epoxy ratios. After that, the additions of epoxy with percentage higher than 10% give lower compressive strength. The decreasing in compressive strength is due to the presence of considerable amount of epoxy resin which is not hardened in the epoxy-modified mortars. From the result obtain, 10% of epoxy ratio is consider as an optimum mix proportion because it gives higher compressive strength. The optimum mix proportion is as shown in table 4.

Table 4: Optimum Mix Proportion

	kg/m^3			%	
Sand	Cement	Water	Polymer/cement ratio	Water/Cement Ratio	Sand: Cement ratio
1517	506	228	10	0.48	3:1

3.3 Flexural test

The flexural test was conducted to see the material's ability to resist deformation under load. The result of epoxy-modified mortar is shown in figure below.

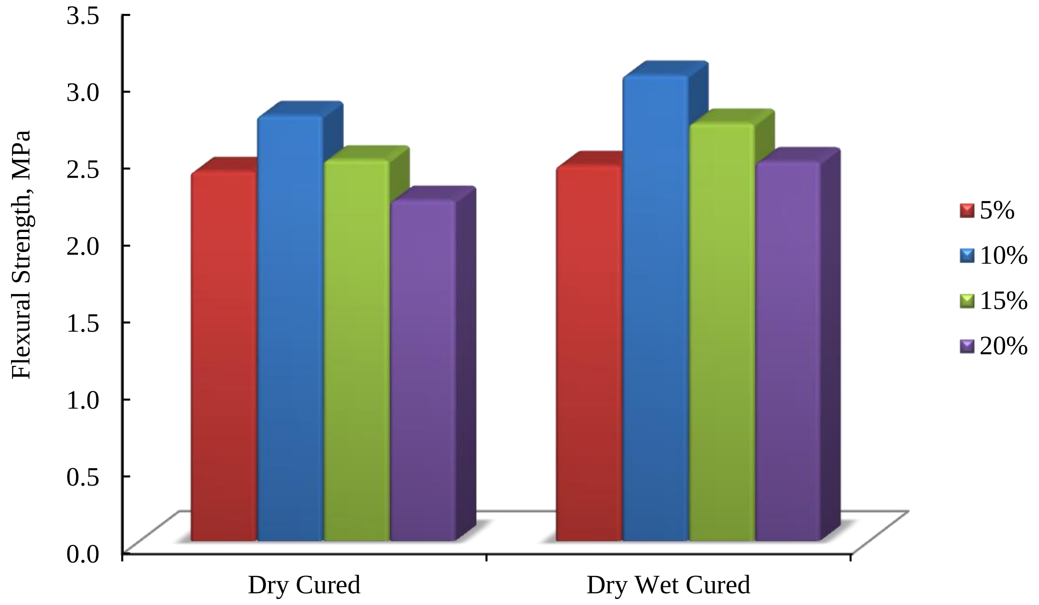

Figure 6: Flexural strength vs. type of curing condition.

Flexural strength of epoxy-modified mortar was present in figure 6. From the figure, 10% of epoxy ratio gives higher flexural strength for both curing condition. 5% of epoxy gives flexural strength of 2.5MPa for both curing while 10% epoxy ratios gives almost 3MPa. On the other hand, 15% and 20% gives lower flexural strength for both curing. 10% of epoxy-modified mortar gives higher flexural strength due to the epoxy resin in mortar react well with alkalis from cement hydrate which is produce more dense and durable mortar.

4.0 CONCLUSION

From the test results, the following conclusion can be summarized:

1. The compressive strength of epoxy-modified mortar without using hardener reach the optimum epoxy ratio of 10% with the strength is 36MPa in 28 days. The suitable curing condition is dry wet cured which is give a good condition for hydration and polymerization process to occur.
2. The flexural strength of 3MPa was achieved with the epoxy ratio of 10%, which is higher than others ratios.
3. From the above test results, it is concluded that, epoxy-modified mortar of 10% epoxy ratio could be recommended as optimum mix proportion and to improve the properties of cement mortar without using any hardener.

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