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ENGINEERING PROPERTIES OF POLYMER MORTAR

by

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ABSTRACT

The understanding of environmental influenced on the properties of polymer mortar composites is still far from complete. This preliminary investigation is to provide some informative data to this unsettle topic. When cured in hot humid environment, it has been observed that the specified compressive strength is obtained as early as 1 day age but the modulus of elasticity is significantly less than the specified values. The flexural strength of polymer mortar composites has been expressed as a function of compressive strength. However, the compressive strength of polymer mortar composites cannot be used as a measure of the modulus of elasticity.

INTRODUCTION

As the design principles of both reinforced and prestressed concrete were refined, more elegant and complex structures were built with subsequent enhanced aesthetics. Unfortunately, this also led to serviceability problems with some of these structures. Blame is often attributed to the quality of the concrete and its inability to resist aggressive environmental attack. As a result, there have been a revival of interest in the understanding of normal concrete of high quality and also the development of new materials including polymer mortar and concrete composites.

The polymer behaviour is well recognised that these materials are influenced by the environmental conditions during the curing phase and in service, which may range from subzero to refractory temperatures and from a very dry to full saturation. While normal concrete is slightly affected by these conditions, the polymer materials are significantly affected and may be completely inhibited [1]. Nevertheless polymer mortar and concrete composites may be formulated to provide a very wide range of properties including from brittle to ductile, impermeable to porous and skid resistant to water shedding.

The polymer materials used in the repair works in the construction industry are generally epoxy resins. They are commonly used which can be categorised as cosmetic repair or structural repair [2]. Epoxy resins are produced by combining modified or unmodified resins with a variety of curing agents which are often referred to as hardeners. The selection of these resins and hardeners are greatly depend on the requirements of the final applications. Some important considerations in the selection include product viscosity, adequate pot life, good chemical and water resistance, impermeable to water and oil, high strength and good adhesion. Often no single product will meet all of the desired requirements and the manufacturers are constantly forced to prioritised the requirements to make intelligent choice.

Malaysia is a hot humid climate country which encounters heavy rainfall with an average amount mean relative humidity of about 85% on the lowlands. Its temperature is uniform throughout the year with annual average temperatures varies within ± 1.66 of 26.27°C [3]. Nevertheless it's monthly highest maximum and monthly lowest minimum temperatures ranging from 35°C to 20°C respectively.

The present investigation is therefore aimed to evaluate the mechanical properties of three types of polymer mortar composites which were cured in a hot humid condition until the age for testing. The evaluation was made by measuring the compressive strength, flexural strength and modulus of elasticity at different curing period. Statistical expressions are also presented in an attempt to estimate the long term engineering properties.

EXPERIMENTAL PROGRAMME

Materials and Specimen Preparation

Three types of epoxy resin mortars, which are commercially available in the Malaysian market, were used in this investigation. These materials were supplied in a prepacked container which consist of the liquid resin, hardener and the filler if required. Mixing was carried out following the proportion and procedure specified by the manufacturer. Specimens were cured in an ambient laboratory condition of 27°C and 80% rh. Table 1 shows the mechanical properties of all the three types of polymer mortar composites specified by the manufacturer which were determined at 20°C. It also includes the code of identification of the polymer mortar composites.

Compressive Strength

The compressive strength test was carried out using 40 mm cubes in accordance with BS 6319: Part 2 [4]. A 3000 kN Tonipact machine was used in all tests at a loading rate of 1.2 kN/s. Three specimens were tested at each curing age of 0.75, 3, 7, 14 and 21 days.

Flexural Strength

The flexural strength test was conducted with a central point loading system using specimens of 25 x 25 x 100 mm prisms in accordance with BS 6319: Part 3 [4]. Three specimens were used in determining the flexural strength at each curing age of 0.75, 3, 7, 14 and 21 days.

Table 1: Engineering properties and code of identification of polymer mortar composites

Engineering Properties	ELS	EPM	EPP
Compressive strength (MPa)	50.00	70.00	80.00
Flexural strength (MPa)	21.00	30.00	65.00
Modulus of elasticity (GPa)	15.00	16.00	10.00

Modulus of Elasticity

The modulus of elasticity was measured using 40 x 40 x 160 mm prisms in accordance with BS 6319: Part 6 [4]. Measurements were made at 3, 7, 14 and 21 days.

PRESENTATION OF RESULTS AND DISCUSSION

The results of properties investigated in this work are shown in Figure 1, Figure 2 and Figure 3. Each data point used to obtain the empirical expression is the average of three measurements. The curves shown in these Figures were obtained statistically using the least square method. They were intended to show the engineering properties trends of different types of polymer mortar composites cured in hot humid environment.

Compressive strength

Compressive strength is an important strucutural parameter used for compliance in most codes and standards, in designing concrete structures. Frequently, this compressive strength is also used as an indication of the development of other properties such as modulus of rupture and modulus of elasticity. These relationships are also presented and discussed in this paper.

Figure 1 shows the development of compressive strength of all the three types of polymer mortars investigated. In comparison with the specified strength (Table 1), all the three types of polymer mortar composites attain the specified strength, which was determined at 20°C, as early as 1 day age. This observation indicates that the rate of strength development of polymer mortar composites is higher when cured in hot humid environment. In addition, these materials are specified to achieve their full cure from 2 to 7 days depending on temperature. It can also be seen that compressive strength of polymer mortar composites is governed by the curing length and type of polymer used.

The ELS polymer mortar composite shows a small increase in strength from 1 day to 21 day age, while EPM and EPP polymer mortar composites show a substantial increase in strength of 47% and 30% respectively.

Flexural strength
Figure 2 presents the flexural strength of all the three types of polymer mortar composites investigated. Regardless of the polymer type, the flexural strength development trends are similar in all the three types of polymer mortar composites. Nevertheless the flexural strength value for EPP polymer mortar is 20% lower than that of the specified value which was determined at 20°C. However, the flexural strength values for ELS and EPM polymer mortars are 43% and 82% higher respectively. These results confirm the established fact that flexural strength of polymer mortar composites is governed by the type of polymer and the curing condition.

Modulus of elasticity
The modulus of elasticity of all the three types of polymer mortar composites determined at various curing ages are shown in Figure 3. The increase in the modulus of elasticity for EPM and EPP polymer mortar composites shows a similar trend. However, the modulus of elasticity of ELS polymer mortar composite shows a higher rate of increase. The results also indicate that the modulus of elasticity at 7 day age of all the three types of polymer mortar composites are 50 - 60% lower than those specified values which were determined at 20°C. This reveals the fact that modulus of elasticity of polymer mortar composites depends on the exposure condition. Similar observation has also been reported for hardened concrete in hot humid climate [3].

STATISTICAL EXPRESSIONS FOR ENGINEERING PROPERTIES

In practice, statistical expressions are useful in estimating the long term engineering properties. In this investigation, the compressive strength and flexural strength of polymer mortar composites are expressed as follows:

Compressive strength

$$f_{cu} = a\, Ln\,(t) + b$$

Flexural strength

$$f_{bt} = c\, Ln\,(t) + d$$

where

f_{cu}	=	Compressive strength (MPa)
f_{bt}	=	Flexural strength (MPa)
a,b,c,d	=	Empirical constants

Table 2 : Values of constants and coefficient of determination for engineering properties

Engineering properties	Mix type	Empirical constants				R^2
		a	b	c	d	
Compressive strength	ELS	2.7088	54.827	-	-	0.9599
	EPM	9.9545	80.176	-	-	0.9715
	EPP	7.1946	87.255	-	-	0.7508
Flexural strength	ELS	-	-	3.0291	28.207	0.6932
	EPM	-	-	2.5863	51.574	0.8707
	EPP	-	-	3.1872	45.860	0.9948

Table 2 gives the values of constants a, b, c and d together with the coefficient of determination (R^2). The high values of R^2 indicate that engineering properties of polymer mortar composites can be expressed as a function of natural logarithm of curing period. This natural logarithm function has also been used to express the engineering properties of polymer modified concrete composites [5]. It can be seen that these constants are influenced by the type of polymer mortar composites. These observations agree with the well-established fact that properties of polymer mortar and concrete composites are dependent on the polymer type, of which can be formulated for a wide range of specific applications.

RELATION BETWEEN FLEXURAL STRENGTH, MODULUS OF ELASTICITY AND COMPRESSIVE STRENGTH

Figure 4 and Figure 5 show the relationships between flexural strength and modulus of elasticity with compressive strength respectively. Regardless of the type of polymer mortar composite, it can be seen that in hot humid environment, a linear relationship between flexural strength and compressive strength is established which can be expressed as $f_{bt} = 0.55 f_{cu}$. (Figure 4). This tends to suggest that these polymer mortar composite materials are practically suitable to be used as repair material in either beam or column repair works. Although improve in flexural strength is beneficial in designing a concrete structure, this consideration still needs to be examined further when making the selection for repair material.

Unlike the concrete, of which the modulus of elasticity can be expressed as a function of compressive strength [6], the scatter points in Figure 5 indicate that the compressive strength cannot be used as a measure of modulus of elasticity of polymer mortar composites. The results show that some polymer mortar composites with high compressive strength deform more than some of the lower strength polymer mortar composites.

This fact is very significant to engineers when selecting the appropriate repair material. For example, if these materials are used in column repair work and the load is applied parallel to the bond line of repair, this load will be transferred to the higher modulus material, i.e. concrete, which may cause failure [7].

CONCLUSIONS

This investigation has examined the influence of curing condition on the engineering properties of polymer mortar composites. By examining the effects on commercially available products, it is possible to highlight the importance of considering more than a single parameter in the selection of repair materials. The understanding that high compressive strength material, such as concrete, exhibits high modulus of elasticity is no more applicable to polymer mortar composite when tested in hot humid environment. In optimizing the use of polymer mortar composite as repair material, it has to be designed not only for its final application but also for its service environmental condition.

ACKNOWLEDGEMENTS

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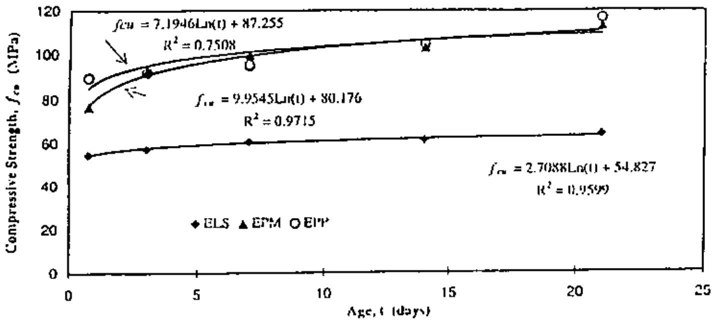

Figure 1 Compressive strength development of polymer mortars

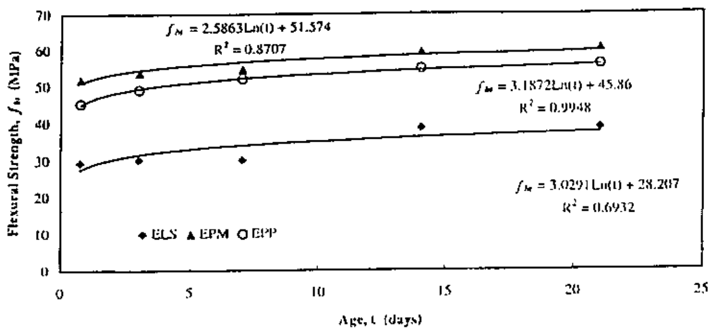

Figure 2 Flexural strength development of polymer mortars

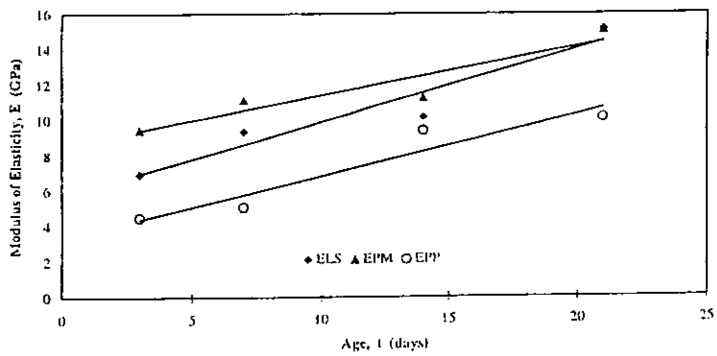

Figure 3 Modulus of elasticity of polymer mortars at various curing ages

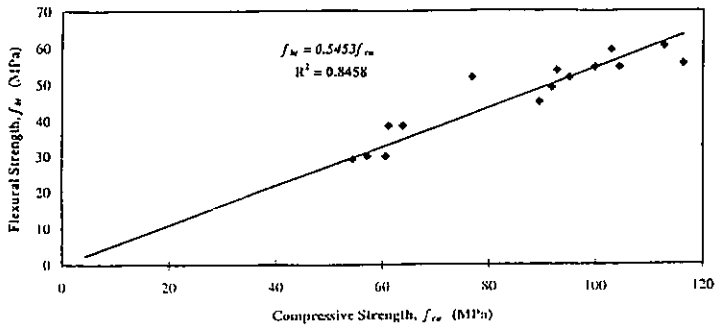

Figure 4 Relation between flexural strength and compressive strength of polymer mortars

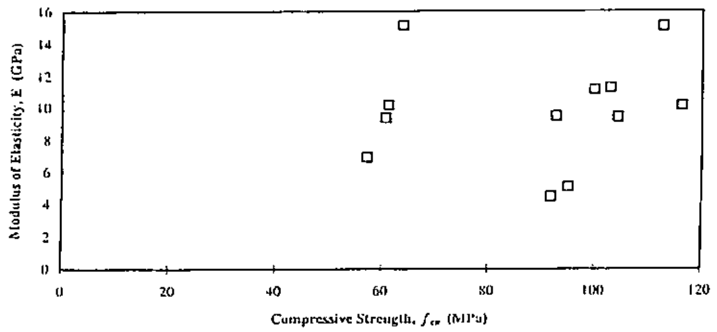

Figure 5 Relation between modulus of elasticity and compressive strength of polymer mortars