Journal of Applied Sciences

ISSN 1812-5654

science alert

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Journal of Applied Sciences 7 (24): 4023-4027, 2007
ISSN 1812-5654

Influence of Prepackaged Polymer-Modified Mortar as a Modifier on Strength of Concrete

Abdullah Saand, Mohammad Ismail and Salihuddin Radin Sumadi
Department of Structures and Materials, Faculty of Civil Engineering,
Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor Bahru, Malaysia

Abstract: This study introduce a new trend of utilising Prepackaged Polymer-Modified Mortar (PPMM) as a modifier to ordinary concrete for producing Polymer-Modified Concrete (PMC). The experimental study articulates the strength development of proposed polymer-modified concrete. A range of quantities of PPMM, as 5 to 50%, were mixed with ordinary concrete of 30 N mm^{-2} characteristic strength to produce polymer-modified concrete and to evaluate for compressive strength, tensile strength, density and workability. The material behaviour in terms of compressive strength and tensile strength, together with density and slump was investigated by casting and testing cubes of 100 mm size, cylinders 100 mm dia and 200 mm height. This Preliminary study shows that compressive strength and tensile strength is improved significantly by inclusion of various quantities as percentages of PPMM to ordinary concrete and curing regime as specified by JIS. PPMM dosages of 5 to 20% resulted considerably higher compressive and tensile strength than that of ordinary concrete, on the other hand further increase in percentage of PPMM gave less strengths. Results demonstrated more prominent percentage increase in tensile strength than compressive strength of produced polymer-modified concrete. Polymer-modified concrete mixes with all percentage dosages of PPMM were found cohesive and workable.

Key words: Polymer-modified concrete, prepackaged polymer-modified mortar, compressive strength, tensile strength, PPMM as a modifier

INTRODUCTION

Mostly, the polymer-modified concrete and polymer-modified mortars are made by mixing the polymer-based admixtures. The combination of concrete and polymers or polymer-based materials can exploit the useful properties of the both. The use of polymers as modifier for mortars and concretes, to improve the strength, durability and workability, is well known.

On the word of Ohama (1995), polymer-modified or polymer cement mortar and polymer cement concrete are materials made by partially replacing the cement hydrate binders of conventional cement mortar or concrete with polymer. A number of thermoplastic or thermosetting polymers, in various forms, are used in modifying mortar and concrete, like; liquid resin, latexes, redispersible polymer powders and water-soluble homo-polymers or copolymers (Ohama, 1998, 2007; Fowler, 1999). Generally, polymers in the form of liquid or powders are mixed in fresh cement mortar and concrete, during mixing process. However, at the jobsite, problems are some times faced in preparing mixes because of complex mix calculations, resulting batch to batch variation in the properties. The advent of powdered emulsions (powdered cement modifiers) with improved qualities made possible the production of PPMM and settled down that tedious job and uncertainties in the mixes, in case of mortar.

The ready-mixed products as polymer-modified mortars have being launched in various countries. Prepackaged Polymer-Modified Mortars (PPMM) are highly helpful in improving the handling procedures and to avoid mixing errors (Afridi *et al*., 2001). Only water has to be added in the dry blends on the construction site prior to application (Hackel *et al*., 1987; Afridi *et al*., 2003).

Nonetheless, still similar problem exists for polymer-modified concrete production, to undertake such complexity, possible usage of those strictly controlled manufactured products; PPMM as a modifier can get rid of that and has not been studied, yet.

In Pakistan, M/s. DadaBhoy Construction Technologies (Pvt.) Ltd have indigenously developed a range of Hi-Bond, Prepackaged Polymer Modified Mortars (PPMM) and slurries since 1997. In Japan, Polymer-Modified Mortar (PMM) is most widely used for finishing

Corresponding Author: Abdullah Saand, Postgraduate Studies Office, Faculty of Civil Engineering, Universiti Teknologi Malaysia, UTM 81310 Skudai, Johor, Malaysia Tel: +60127257891 Fax: +6075566157

and repair works, but Polymer-Modified Concrete (PMC) is seldom employed because of poor cost-performance balance (Ohama, 1997). However, PMC is widely used for bridge deck overlays and patching work in the United States (Fowler, 1990). The primary limitation and one of impediments to the use of PMC is its cost (Fowler, 1999; Kardon, 1997). The Polymer-Modified Concrete (PMC) can possibly be developed as cost- befitting and effective concrete repair material as well, by utilising PPMM, as a modifier. The usage of prepackaged polymer-modified mortars as modifier is not documented; no any research data is available on use of PPMM as modifier to ordinary concrete; except few successful case-histories (Afridi *et al*., 2006) of repair and renovation and recent initiated research by author. The pre-damaged beams repaired with Polymer-Modified Mortar (PMM) prepared by using PPMM as modifier; shows significantly improved flexural behaviour, as damaged to reinstate, for operational use (Saand *et al*., 2006).

Such current case-histories and research results encouraged to investigate performance behaviour of the possible and prospective combinations of Prepackaged Polymer-Modified Mortar (PPMM) and ordinary concrete, to develop reliable matrix as Polymer-Modified Concrete (PMC).

MATERIALS AND METHODS

Materials used: Ordinary Portland Cement (OPC) of Seladang brand from Tenggara Cement Manufacturing Sdn. Bhd. complied with the Type I Portland Cement as in ASTM C150: 1992 and BS 12: 1991 which is same as Malaysian Standard MS 522: part I: 2003.

Prepackaged Polymer-Modified Mortar (PPMM); a commercial prepackaged formulation developed in Pakistan named as, Hi-Bond (Universal), Prepackaged Polymer-Modified Mortar. Hi-Bond (Universal); PPMM consists of cement-sand mixture, an organic film-forming re-dispersible polymer powder and other related ingredients in appropriate ratios.

The fine aggregate and coarse aggregate used were crushed granite type, complied with the requirement of ASTM C778-91. The sand, 55% passing the 600 μm sieve, was sieved; to remove foreign and rubbish material and to get size less than 4.75 and 2.36 mm, for use in ordinary and polymer-modified concrete mixes, respectively. The nominal size 10 mm, coarse aggregates were washed, to remove the dust, debris or any other rubbish material and air dried, before use.

Tap water; suitable for drinking; was used to manufacture concrete mixes.

Table 1: Proportioning of Ordinary Concrete

Ordinary cement	426.00 (kg m^{-3})
Fina aggregates	722.00 (kg m^{-3})
Coarse aggregates	997.00 (kg m^{-3})
Water	230.00 (kg m^{-3})
W/C ratio	0.54
Siump	30-60.00 (mm)

Concrete mix design and trials: The characteristic compressive strength of ordinary concrete (reference concrete) used in this study was taken as 30 N mm^{-2} at 28 days. To get correct proportion of constituent materials, the concrete mix design was done on the basis of DoE's Design of Normal Concrete Mixes', BRE, 1997, as shown in Table 1. To satisfy the mix design for ordinary concrete of characteristic strength 30 N mm^{-2}, trial mixing was done, as per ASTM C 192- 02 and the testing as per ASTM C109.

Preparation of Polymer-Modified Concrete (PMC) samples: Polymer-modified concrete specimens were fabricated by addition and subtraction of PPMM into ordinary concrete mix. Whatever percentage of PPMM was added, same percentage of hydraulic cement and fine sand was reduced as per their manufacturing percent content in Prepackaged Polymer-Modified Mortar (PPMM).

The samples of polymer modified concrete were produced with basic mix proportion as: Ordinary Concrete (OC) : PPMM (%) : w/b ratio. Altogether, 27 cubes (100 mm size) and 27 cylinders (100, 200 mm height) were prepared to study material behaviour in terms of compressive strength, tensile strength, density and workability, as per specifications of JIS A 1171: 2000 and ASTM C192.

Various percentage dosages of PPMM (5, 10, 15, 20, 25, 30, 40 and 50%) as modifier were introduced to ordinary concrete. For ordinary concrete, as per mix design, 0.54 w/c ratio was used. For polymer-modified concrete, optimum w/b ratio 0.45 was opted, based on evaluation of different w/b ratios in terms of workability and strength development. The curing of PMC specimen was done as per Japanese Industrial Standard (JIS); 2 days moist plus 5 days water (pond curing) plus 21 days dry curing at room temperature.

Testing: Considering the relative importance of compressive strength and tensile strength, in some application for restoration of deteriorated concrete in compression and/or in tension zones, these properties were investigated. The testing for compressive strength, tensile strength, density and workability was carried out on modified and unmodified concrete samples. Cube-crushing tests for compressive strength and cylinder-

Table 2: Effect of PPMM dosages to compressive strength, density and slump of PMC

Polymer-modified concrete mix: Ordinary concrete	Percentage DHPMM	W/B	Ultimate load (KN)	Average ultimate load (KN)	Compressive strength* ($N\ mm^{-2}$)	Weight (kg)	Density ($kg\ m^{-3}$) at testing	Slump (mm)	Age (days)
	0	0.54	280	326.97	32.70	2.392	2413	50	
			331			2.441			
			370			2.405			
	5		530	504.77	50.48	2.418	2412	8	
			459			2.398			
			525			2.420			
	10		502	498.62	49.86	2.364	2379	10	
			496			2.393			
			498			2.380			
	15		422	421.67	42.17	2.350	2349	15	
			415			2.347			
			428			2.349			
Grade 30	20	0.45	442	402.29	40.23	2.364	2343	20	28
			380			2.325			
			385			2.340			
	25		327	331.00	33.10	2.334	2326	22	
			335			2.319			
			331			2.324			
	30		308	294.33	29.43	2.247	2267	26	
			285			2.365			
			290			2.189			
	40		282	283.39	28.34	2.160	2156	30	
			290			2.153			
			278			2.156			
	50		272	270.70	27.07	2.158	2150	34	
			265			2.155			
			275			2.136			

Table 3: Effect of PPMM dosages to tensile strength, density and slump of PMC

Polymer-modified concrete: Ordinary concrete	Percentage of PMM	W/C ratio	Ultimate load (KN)	Average ultimate load (KN)	Tensile strength ($N\ nm^{-2}$)	Weight (kg)	Density ($kg\ m^{-3}$) at testing	Slump (mm)	Age (days)
	0	0.54	108.70	108.70	3.46	2.392	2413	50	
			110.70			2.441			
			106.70			2.405			
	5		142.85	142.85	4.55	2.418	2412	8	
			140.10			2.398			
			145.60			2.420			
	10		146.05	146.05	4.65	2.364	2379	10	
			151.10			2.393			
			141.00			2.380			
	15		139.60	139.60	4.45	2.350	2349	15	
			135.70			2.347			
			143.50			2.349			
Grade 30	20	0.45	112.10	113.50	3.61	2.364	2343	20	28
			113.50			2.325			
			114.90			2.340			
	25		100.65	100.65	3.21	2.334	2326	24	
			99.60			2.319			
			101.70			2.324			
	30		99.60	97.37	3.10	2.247	2267	30	
			97.60			2.365			
			94.90			2.189			
	40		87.20	86.60	2.76	2.160	2156	30	
			86.10			2.153			
			86.50			2.156			
	50		77.59	74.74	2.38	2.158	2150	32	
			71.89			2.155			
			74.74			2.136			

splitting tests for indirect tensile strength on 28 days were conducted as per JIS A 1171: 2000 and ASTM C109, using DARTEC universal testing machine, with loading rate 3 and 2 KN sec^{-1}, respectively. The slump of each individual batch and density at testing age of each specimen were carried out and recorded. The details of all test results are precisely incorporated in Table 2 and 3.

RESULTS AND DISCUSSION

It is obvious from the experimental data composed in Table 2, that the compressive strength of modified concrete mixes is improved by using PPMM as a modifier to ordinary concrete. Polymer-Modified Concrete (PMC) produced with PPMM dosages of 5 to 25% to Ordinary Concrete (OC) mixes, resulted increased strength than that of ordinary concrete. However, further increase in percent dosages of PPMM to ordinary concrete shows less strength than the characteristic and trial mix strength of ordinary concrete.

It is apparent from the experimental data gathered in Table 3 that the tensile strength of modified concrete mixes is enhanced by the use of PPMM as a modifier to ordinary concrete. Polymer-modified concrete produced with 5 to 20% dosages of PPMM to ordinary concrete, resulted increased strength than the characteristic strength of ordinary concrete. The content of PPMM more than 20% in polymer-modified concrete mixes gave less strength than the strength of ordinary concrete.

In polymer-modified mortar and concretes, aggregates are bound by a co-matrix formed by hydrated cement phase and polymer phase interpenetration, improving bond between matrix and aggregates and resulting superior properties to conventional concrete. The tendency of strength increase and decrease of ordinary concrete modified with various percent dosages of PPMM correlates the research outcomes made by many researchers. The decrease of strength with more than 20% PPMM content is obvious because of the decrease in density on further increase of PPMM percent, a shown in Table 2 and 3.

During each batch of the casting, testing for slump was interesting to note, that all the samples shows notable cohesiveness. Even with slump value range of 8 to 50 mm, behaviour was as true slump, no any single test shown shear or collapse slump. The strength development trend of mixes with various percent dosages of PPMM, water-binder ratio and slump relation is illustrated in Fig. 1 and 2.

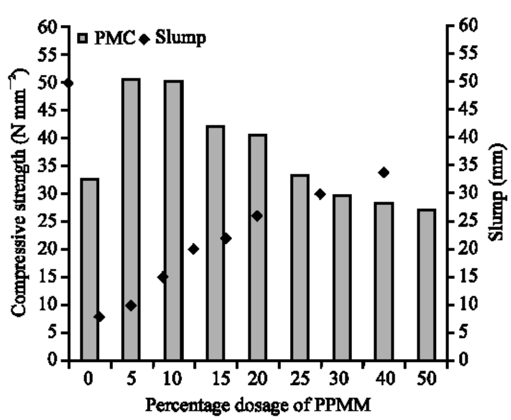

Fig. 1: Compressive strength percentage PPMM and slump illustration

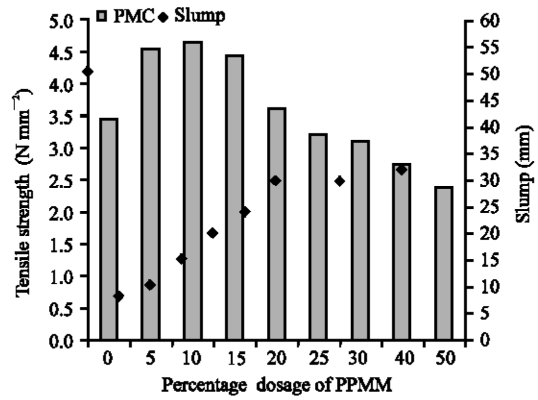

Fig. 2: Tensile strength, percentage PPMM and slump illustration

CONCLUSION

On the basis of resulted presented here it can be concluded that the compressive and tensile strength of produced PMC composites is improved considerably and mixtures found cohesive and workable. From the present study it is obvious that the utilisation of Prepackaged PPMM as modifier for development of polymer-modified concrete will confidently work, resulting more effective and cost benefiting repair and strengthening for restoration of deteriorated structures.

The optimum polymer-modified concrete composites matrix will only be formulated and recommended on the basis of further outcomes of the on-going in-depth evaluation of PMC mixes in-terms of other important properties as repair material criterion.

ACKNOWLEDGMENTS

The study presented here is a part of author's on-going doctoral research. The Prepackaged PPMM for this research was provided by DadaBhoy Construction Technologies (Pvt.) Ltd., Karachi, Pakistan. The facilities for carrying out this research were provided by Structures and Materials Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Skudai, Johor Bahru, Malaysia. Authors owe the support of Dr. M.U.K. Afridi on the conduct of this research.

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