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Development of Economical Polymer-modified Concrete for Repair of Concrete Structures in Pakistan

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Abstract

Being well recognized in repair, rehabilitation and maintenance of concrete structures, polymer modified concretes are new high-performance materials. The present study was focused on the availability and use of polymer-modified concrete under local conditions in Pakistan. Various polymer compositions with subsidiary chemicals were prepared in the laboratory, and their feasibility in the repair of structures was experimentally verified. The results demonstrated that the tensile strength of the polymer-modified concrete, made with altered PVA emulsion, was three times more than the ordinary concrete. Polymer-modified concrete with altered PVA emulsion showed excellent bonding with old concrete. Furthermore, the above combination was highly cost efficient when compared to the use of PVA emulsion.

Key Words: Polymer modified concretes; Polymer-modified concrete with altered PVA emulsion; Tensile strength; Bonding; Repair of concrete structures

1. Introduction

Polymer modified concretes are a relatively high-performance materials that has been developed since the early 1960s [1-2]. Differences between the properties of individual polymers and polymer modified concretes have been investigated by several researchers [3]. Polymer-modified concrete consists of well-graded aggregates bonded together by a strong resin binder (or plastic glue) instead of the water and cement alone typically used in cement-based materials. Polymer-modified concretes are very strong, anticipated to be durable, and cures very rapidly, which is an important consideration in many civil engineering applications [4].

Polymer-modified concrete is being used in many structural and construction applications [5]. It can be used successfully as a thin overlay (6-24 mm thick) for repairing spalled or damaged structural components like building, bridges and hydraulic structures, precast components and industrial floor application [6-8]. Therefore, their availability and application in local construction is worth to explore.

In Pakistan, there is a need to understand and use these high performing polymers for repair and rehabilitation. These polymers to be used for polymer-modified concrete are available in the local market. However, there is a need on the part of concrete technologists to use them efficiently for the improvement in the properties of polymer modified concrete. Table 1 shows different polymers used in concrete in the world and Table 2 shows the cost of a few selected polymers in Pakistan to be used for the modification.

Table 1: Polymers used for the modification of concrete in the world

Sr.No	Name of polymer	Abbreviation
1.	Ethyl vinyl acetate Emulsion	EVA
2.	Polyvinyl acetate Emulsion	PVA
3.	Methyl meta crylate Emulsion	MMA
4.	Styrene butadiene rubber	SBR

Table 2: Cost of polymers used for modification of concrete in Pakistan

Sr. No	Name of polymer	Abbreviation	Cost in Rs
1	Ethyl vinyl acetate Emulsion	EVA	3500/liter
2	Polyvinyl acetate Emulsion	PVA	40 to 90/kg
3	Styrene butadiene rubber	SBR	100/kg

High cost of polymers may limit the use of these materials in repairs and rehabilitation of concrete structure for practical applications. However, their use with other subsidiary chemicals could reduce their cost. This cost reduction may, therefore, help to promote the use of polymer in concrete. Hence, cheaper polymers may be made for this purpose. Thus, the present study was conducted with the objective to investigate the feasibility of using locally available principal polymers with subsidiary chemicals.

2. Materials and Methods

Polymer-modified concrete was prepared in the lab using principal polymer PVA with the addition of two subsidiary chemicals i.e. (1) Acrylic glue (AG) and (2) Carboxymethyl Cellulose (CMC). Hereafter, these polymer-modified concretes would be referred as PVA-AG modified concrete and PVA-CMC modified concrete. Chemical composition of the polymer-modified concrete was varied with a change in the proportion of PVA, AG and CMC. This was done to achieve the best combination of PVA and subsidiary chemicals, which when mixed with concrete could be used in repair and maintenance of concrete structures.

Tensile strength and compressive strength of the concrete was investigated using Mohr and Federhoff AG and Fressia Maeros machines, respectively. Tensile strength of the polymer-modified concrete was analyzed by performing modulus of rupture test using prism of dimensions 4 inch x 4 inch x 20 inch. Cube test on samples of size 4 inch x 4 inch x 4 inch was performed to find out the compressive strength of concrete. Mix proportions for the control portland cement concrete mix against which performance of polymer-modified concrete will be compared, have been given in Table 3.

Table 3: Properties of the control concrete used in the present study

Sr.No	Property	Units
1	Concrete mix proportion	1:1.5:3
2	Size of aggregate	Passing BS sieve ½
3	W/c ratio	0.5
4	Water curing	7-days

The research work was divided into two portions: (1) The effect on the tensile and compressive strengths of ordinary concrete was studied by adding polymer and subsidiary chemicals in varying proportions and (2) existing concrete piece was repaired with polymer modified concrete and effect on the tensile strength of the repaired sample was evaluated.

3. Results and Discussion

3.1 *Tensile and compressive strength of polymer-modified concrete*

Tensile and compressive strengths of ordinary concrete and polymer modified concrete using varying proportions of PVA emulsion and subsidiary chemicals have been shown in Figure 1.

It can be observed from Figure 1 that the polymer alteration resulted in an increase in the flexural tensile and compressive strength of the ordinary concrete. Mechanical properties such as tensile strength and compressive strength seemed to have a linear relationship. The results showed that the composition of chemicals played an important role in polymer performance from strength point of view. Highest tensile strength i.e., 1,200 Psi with corresponding highest compressive strength 12,400 Psi was achieved in polymer-modified concrete with the ratio of 4:4:1 by weight of PVA, AG and CMC, respectively. It was about 3 times more than the ordinary concrete. Increase in the tensile strength of the concrete enhances its suitability to be sued for the repair of old concrete structures. Current allowable flexural tension stresses are relatively low in comparison to allowable

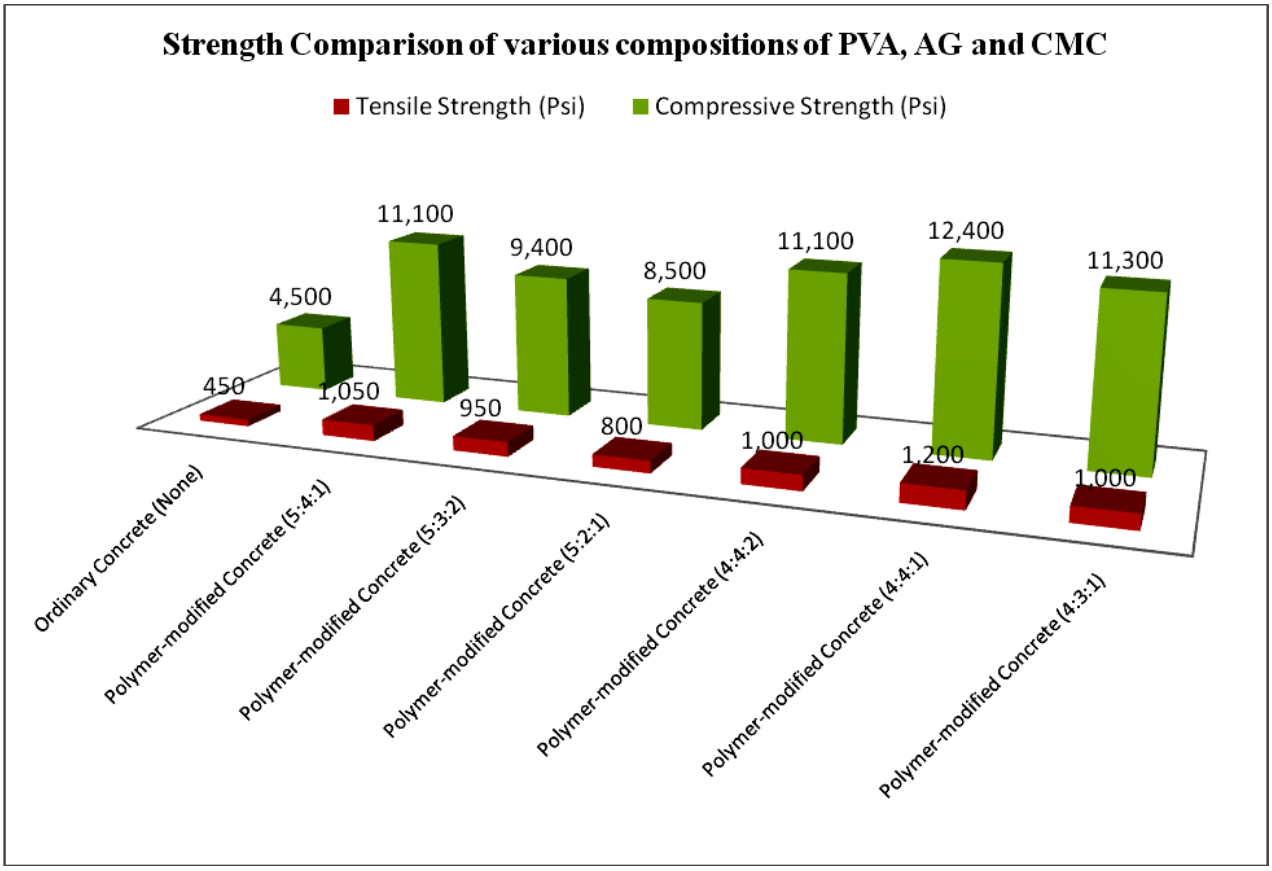

Figure 1: ` Strength comparison between different types of polymer modified concretes

compressive stresses in ordinary concrete [9]. Although non reinforced ordinary concrete can properly and successfully be used in a variety of structural applications. Its use, however, is often limited in practice by the low limits on flexural tension strength. A three times improvement in the tensile strength of ordinary concrete by the said PVA-AG-CMC addition would increase its scope in many structures.

3.2 *Tensile strength of repaired concrete using polymer-modified concrete*

In order to study the effect on the tensile strength of ordinary concrete when repaired using polymer-modified concrete, a concrete sample around 2 years old was used. The size of the original concrete samples was 4 inch x 4 inch x 20 inch. A piece of 4 inch x 4 inch x 4 inch was cut from the middle of the original sample and the gap was filled with polymer-modified concrete. Repaired samples were tested for their tensile strength after curing. For curing, samples was immersed in water for 7 days and then taken out and wrapped by wet jute bags for a period of further 7 days. The tensile strength of samples repaired with polymer-modified concrete, ordinary concrete and unbroken non-repaired samples are exhibited in Table 4.

It was noted that five out of five specimens of polymer-modified concrete showed excellent bonding with old concrete. It can be seen in Table 4 that tensile strength of sample repaired with ordinary concrete was just 50psi. Whereas, those of the samples repaired with polymer-modified concrete, the highest strength of 550 psi was obtained with ratio 4:4:1 by weight of PVA, AG and CMC, respectively. It was even higher than non-broken un-repaired sample, which was 500 psi. Thus the results suggested the feasibility to apply

Table 4:

Table 4: Tensile strength comparison between various types of concrete in repair of concrete structures

Sr No.	Specimen type	Proportion of PVA, AG and CMC	Tensile Strength (Psi)
1	Repaired with Ordinary concrete	None	50
2	Repaired with polymer-modified concrete	5:4:1	500
3	Repaired with polymer-modified concrete	5:3:2	400
4	Repaired with polymer-modified concrete	5:2:1	350
5	Repaired with polymer-modified concrete	4:4:2	450
6	Repaired with polymer-modified concrete	4:4:1	550
7	Repaired with polymer-modified concrete	4:3:1	450
8	Non broken, non repaired, concrete sample	None	500

polymer-modified concrete for repair purposes. Especially, it can be used in the repair and rehabilitation of monuments in Pakistan which are of esteemed historic nature. In Lahore, it can be applied to secure many historic structures, which can attract several tourists in the country.

Technical data like color, mix ratio, dosage, pH, storage, packaging, application, usage, and precaution for polymer-modified concrete of ratio (PVA emulsion, AG and CMC) 4:4:1, showing best results, has been shown in Table 5.

Table 5: Technical data of polymer-modified concrete with ratio 4:4:1 by weight of PVA, AG and CMC

Sr. No.	Speci-fications	Description
1	Color	White milk like when shook properly.
2	Mix ratio	4:4:1 of PVA, Acrylic glue and CMC by weight in solvent water.
3	Dosage	50 ml of liquid is required to make a volume of concrete = 320 in^3.
4	pH	pH of the sample was 8.
5	Storage	Should store in dry conditions away from sunlight.
6	Packaging	Chemical composition & proportion is with the user and can be made according to use.
7	Application	The surface to be repaired should be cleaned properly. Loose aggregate should be removed. Concrete should be applied in layers and should be properly compacted.
8	Usage	For structural repair of deteriorated concrete and mortar. The polymer can be used on exterior and interior, horizontal and vertical over head surfaces.
9	Precaution	The liquid polymer should be thoroughly mixed with concrete and concrete should be cured for 7 days. Blanket curing is preferable.

3.3 *Cost of lab manufactured polymer-modified used in present study*

Various ingredients with their cost to produce 1 Kg of polymer have been listed in Table 6. It can be seen in Table 6, that the total cost to produce 1 Kg of polymer combination of ratio 4:4:1 came to be Rs 10/Kg whereas the cost of cheapest polymer available in the market varies from Rs 40 to 100/Kg. Thus substantial cost saving can be achieved by using the said polymer combinations developed during the present research studies.

Table 6: Cost analysis to make 1kg of altered polymer with a ratio of 4:4:1 by weight of PVA, AG and CMC

Chemicals used	**Cost/kg (Rs.)**	**Quantity for making 1kg of altered polymer (gm)**	**Cost to make 1kg of altered polymer (Rs)**
PVA	50	40	2.0
AG	40	40	1.6
CMC	120	10	1.4
Water	N.A.	910	N.A.
Other utilities[1]	N.A.	N.A.	5.0

[1]Labour charges, equipments etc

4. Conclusions

Following conclusion can be drawn from the present study.

The strength of polymer-modified concrete is greatly influenced by the mixing ratio of ingredients. A ratio of 4:4:1 by weight of PVA, AG and CMC showed excellent results in bearing flexural tension stresses of 1200 psi which was three times more than the ordinary concrete.

The tensile strength of ordinary concrete repaired with the above ratio of polymer-modified concrete was 550 psi, which was even more than the tensile strength of un repaired un-broken sample. It also showed excellent bonding with old concrete.

Cost of altered polymer for best ratio of 4:4:1 was only Rs 10/Kg, which was 4 to 10 times less than cost of ordinary polymer available in the market. Thus technical and economic feasibility of using modified polymer concrete for the repair of concrete structures under local conditions was established.

5. References

[1] American Concrete Institute (ACI); Guide for the Use of Polymers in Concrete" ACI 548.1R-97, Detroit, (1997)

[2] Y. Ohama, K. Demura and M. Komiyama (1979). Proc. 22nd Japan Congress on Materials Research. The Society of Materials Science, Japan, 360-363

[3] Latex modified concretes and mortars. National Cooperative Highway Research Program. Synthesis of Highway Practice No. 179, National Cooperative Highway Research Program, Washington, D.C, (1992).

[4] A. P. Craft and K. S. Rebeiz; (2002). Journal of Energy Engineering, 128, 24-27

[5] Jo, Byung-Wan, Park, Seung-Kook, Kim, Cheol-Hwan. (2009). ACI Structural Journal, (2006) http://www.highbeam.com/doc/1P3-1268540071.html

[6] S. K. Rebeiz, D. W. Fowler and D. R. Paul; (1993). Journal of Materials in Civil Engineering. 5, 273-278

[7] C. Vipulanandan and E. Paul; (1993). Journal of Materials in Civil Engineering. 5, 62-82

[8] C. Vipulanandan and S. Mebarkia; (1995). Journal of Engineering Mechanics, 121, 1359-1365.

[9] Building Code Requirements for Masonry Structures; ACI 530-95/ASCE, 5-95/TMS 402-95, American Concrete Institute, Detroit; American Society of civil Engineers, New Yor; and the Masonry Society, Boulder, Colo. (1995).