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### PROPERTIES OF POLYMER-MODIFIED MORTARS

Introduction In modern concrete construction and repair works the role of polymers is increasing day by day. Polymers are either incorporated in a cement–aggregate mix or used as a single binder. The composites made by using polymer along with cement and aggregates are called polymer-modified mortars (PMM) or polymer-modified concrete (PMC), while composites made with polymer and aggregates are called polymer mortar (PM) or polymer concrete (PC). Since polymers are costly the former type of application is preferred over the latter in most of the situations. The incorporation of polymers greatly improves strength, adhesion, resilience, impermeability, chemical resistance and durability properties of mortars and concrete [1–3]. These properties make PMM a suitable material for making various structural and non-structural pre-cast products, repair of structural members, waterproofing, anticorrosive and decorative finishes, overlay of pavements, bridges and industrial floors [1,4]. A number of thermoplastic or thermosetting polymers are used in modifying mortars and concrete. These are used in various forms like: liquid resins, latexes, redispersible powders and water-soluble

homopolymers or copolymers [5]. The choice of the polymer depends upon the intended use, and requirement of performances like strength, durability and chemical resistance. Moreover, the polymer systems can also be modified by use of additives like surfactants, stabilisers, antifoaming agents and colouring pigments [1].

Polymer latexes are dispersion of polymer particles of size 0.05–5.00  $\mu\text{m}$  in water [5]. For making PMM, most of the researchers use latexes of a single or combinations of polymers like polyvinyl acetate, copolymers of vinyl acetate–ethylene, styrene–butadiene, styrene–acrylic, and acrylic [1,5,6]. Latex can also be made by using epoxy resin, which comes under the non re-emulsifiable category. The non re-emulsifiable latexes are expected to have greater resistant to chemical, alkaline and humid environment.

Epoxy emulsion was prepared by emulsifying epoxy resin, based on diglycidyl ether of bisphenol-A, and amino-amide based hardener in water by using a non-ionic surfactant. Additives like defoaming, wetting and anticatering agents, and fillers were also used. For both, epoxy emulsion and acrylic emulsion, similar dosages of additives were used. The prepared epoxy emulsion had density of 1.00–1.05  $\text{g}/\text{cm}^3$ , epoxide equivalent value of 200–300 g eq and total solids of  $60 \pm 2\%$ ; while acrylic emulsion had density of 1.05–1.10  $\text{g}/\text{cm}^3$  and total solids  $38 \pm 2\%$ .

Ordinary Portland cement, grade 43, and quartz sand No. 10 were used for making the PMM test specimens. Properties of the cement and sieve analysis of the sand used in this study are reported in Tables 1 and 2, respectively. To study the effect of polymer–cement ratio on various properties specimens were prepared by varying the polymer–cement ratio from 0% to 30% by mass of cement. A cement–sand ratio of 1:3 by mass was kept constant for all the specimens. For all the mixes the water–cement ratio (w/c) was adjusted to maintain a constant flow between 110 and 120 mm.

Five specimens of 40 mm · 40 mm · 160 mm size were prepared for three-point flexure test. After flexural test the specimens were cut from the ends, i.e., from the uncracked portion of the specimens to obtain cubes of size 40 mm · 40 mm · 40 mm for determining compressive strength and water absorption. For carbonation and chloride ion penetration tests three prisms of 40 mm · 40 mm · 80 mm size for each test were moulded. After moulding, the specimens were allowed to cure in the mould for first 24 h. During this period the moulds were covered with wet cloth and polyethylene sheet. The specimens were then kept in the laboratory conditions,  $20 \pm 2$  °C and  $50 \pm 5\%$  relative humidity (RH) for the next 27 d. It is known that the water curing degrades the mechanical strength of polymer modified cementitious mortars [2,7]. Hence, water curing was eliminated for PMM specimens, while one set of control specimens, i.e., specimens without polymer was water cured and another was air cured. Water absorption, flexural and compressive strength tests were carried out according to JIS A 1171–2000 and JIS A 6203–2000 [8,9].

Table 1 - Properties of cement used

Property	Value
Density ( $\text{g}/\text{cm}^3$ )	3.08
Specific surface area ( $\text{cm}^2/\text{g}$ )	2540
Chemical analysi (%) Silica, $\text{SiO}_2$	21.40
Lime, CaO	62.25
Alumina, $\text{Al}_2\text{O}_3$	8.95
Iron Oxide, $\text{Fe}_2\text{O}_3$	2.80
Magnesia, MgO	1.46
Loss on ignition	1.52

Table 2 Sieve analysis of quartz sand

I.S. sieve size	Mass retained (%)	Cumulative mass retained (%)
4.75 mm	–	–

2.36 mm	–	–
1.18 mm	–	–
600 lm	40	40
300 lm	30	70
150 lm	30	100

In the carbonation test, the finished and bottom surfaces and two ends of the cured mortar samples were coated with epoxy resin based paint. The specimens were then placed in a test chamber for 14 d at a CO<sub>2</sub> gas concentration of 5%, temperature 30 °C and 60% RH. The carbonated samples were then split into two pieces by using a splitting-tensile device. Immediately after splitting a 2% alcoholic solution of phenolphthalein was sprayed on the newly exposed inner surfaces of the specimens. The depth of each cross-section without colour change was measured as carbonation depth. For the chloride-ion penetration test, the cured samples were immersed in a 2.5% sodium chloride solution at 25 °C for 7 d. The samples were split after the test and the split cross-sections were sprayed with 0.1% sodium fluorescein and 0.1 N silver nitrate solution. The depth of the rim of each cross-section changed to white was measured as chloride ion penetration depth.

The effect of polymer addition on water–cement ratio required to maintain the desired flow (110–120 mm) is shown in Fig. 1. The required quantity of water decreases with the addition of both polymers. However, the decrease is relatively more in case of acrylic emulsion. A reduction in water requirement was expected not only due to the presence of surfactants in the polymers but also due to the lower surface tension of polymer molecules, which facilitates better flow of the mix at the same water content.

Fig. 1. Effect of polymer addition on water–cement ratio required to maintain flow

The results of polymer addition on compressive strength of the mortar at 28 and 90 d are shown, respectively. The compressive strength of unmodified water cured mortar specimen is 39.5 MPa at 28 d and 45.0 MPa at 90 d curing. It can be seen that both 28 and 90 d compressive strengths of the mortar increase with polymer–cement ratio. However, the compressive strength of PMM is less than that of water cured control specimens when the polymer–cement ratio is less than 20%. Nevertheless, the 90 d compressive strength is higher than water cured specimens when the polymer–cement ratio is more than 20% for both the polymer systems. While comparing the 28 and 90 d strength of PMM and water cured control specimens it appears that in water cured specimens most of the hydration is completed within 28 d; whereas in PMM the process of hydration/polymerisation continues till around 90 d. However, this period may vary depending upon various parameters such as type of polymer, additives and their dosages. Nevertheless, the slow rate of strength gain of PMM is not expected to affect the performance, because the strength development can continue without any external aid. The results also show that at the same polymer–cement ratio the epoxy emulsion modified mortars have better compressive strength than acrylic modified mortars.

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