PHYSICAL AND CHEMICAL PROPERTIES OF POLYMER IMPREGNATED CONCRETE ON THE PREPARATION CONDITIONS

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Introduction

Polymers have been employed as concrete admixtures to improve durability of the concrete structures that have degraded due to exposure to weather and polluted environments. Based on the mode of their addition polymer cement concrete is classified as – Polymer Modified Cement Concrete or Mortars (PMC/PMM), Polymer Concrete or Mortars (PC/PM), Polymer Impregnated Concrete or Mortars (PIC/PIM) (1). The latter is one the oldest polymer cement composites and is prepared by impregnating the monomer into the concrete or mortar structures and then by polymerizing the monomer. PICs possess superior strength, chemical resistance and low water absorption compared to other polymer cement composites. Some of the applications where these composites find use are reactors, bridges, pipes, storage bunkers for chemicals and structures in marine environments (2,3).

Conventionally PICs are prepared by immersing the precast concrete structure in a mixture of a monomer and an initiator for a few hours at room temperature and polymerizing the monomer by thermal methods (4). This results in monomer loss during polymerization at high temperature thus affecting the properties of the PIC. In this work we describe a method to increase the monomer impregnation thereby reducing such losses. The monomer is introduced into the voids and pores of the precast concrete by subjecting the experimental setup to ultrasonic vibrations thereby enhancing the chances of monomer impregnation to a greater degree than the conventional procedure. The impregnated specimens are dried, vacuum packed to prevent monomer loss and subsequently polymerized using microwaves. When compared with composites prepared by conventional methods and ordinary precast concrete, it was observed that this procedure increased the degree of polymerization of the monomer in the concrete structures thereby improving both the mechanical and chemical resistant properties of the composite.

Experimental program

The precast cement mortar specimens used were first impregnated with methyl methacrylate and then polymerized using two different procedures. The mechanical and chemical resistant properties of these PICs after exposure to 5M sulphuric acid for different periods were evaluated and their microstructures analyzed.

Materials

Compressive strength was evaluated for precast cement mortars cubical specimens of dimensions 5cm X 5cm X 5cm weighing around 250g and flexural strength for specimens of dimensions 4cm X 4cm X 16cm weighing 530g approximately. Ordinary Portland cement and sand conforming to Korean standard KS L 5100 were used in the preparation of the specimens. The water to cement ratio was 0.48 while the cement, sand and water were mixed in the proportion 1:2.45:0.48.

Impregnation and Polymerization

The precast mortar specimens were dried in a hot air oven (Samwoo Science make) at 80° C for 12 hours. These were annealed to room temperature and weighed before impregnation. The monomer, Methyl methacrylate (MMA) was mixed with 1% by weight of 2, 2'-Azobisisobutyronitrile **(AIBN)** as initiator using a magnetic stirrer. The mortar samples were immersed into this mixture and impregnated by placing the setup in a water bath inside an ultrasound vibration system for 4.5 hours at room temperature. The samples were dried, weighed and vacuum packed in PET packets to prevent loss of monomer during polymerization.

The samples were thermally polymerized by two different procedures viz. using conventional methods and microwaves. In the conventional method the packed impregnated mortar samples were immersed in hot water at 80° C to achieve uniform heating for three hours. Polymerization of the specimens in the microwave reactor was done at a frequency of 2450MHz (400W) at 80°C for two hours. After polymerization the samples were removed from the PET packets, cooled to room temperature and weighed.

Performance

The mechanical properties evaluated for the PIC specimens were compressive and flexural strengths. The durability of these composites when exposed to various chemical environments was evaluated by calculating the weight loss.

Compressive strength is a basic property used to assess the performance of hardened concrete made for a particular application. It is calculated by dividing the maximum load applied when the cubical specimen fails by its cross sectional area resisting the load. In this work the cubical specimens of 5cm X 5cm X 5cm were employed and the evaluation of these properties was performed in accordance to KS L 5105 standards (5). The maximum load needed to break the conventional cement mortar and PIC samples was determined using a Servo UTM US-200.

In concrete, cracks can propagate very easily in tension and excessive cracking of concrete causes serviceability and durability problems. In this work, the flexural strengths of conventional cement mortar and PIC specimens of dimensions 4cm X 4cm X 16cm were evaluated according to ASTM C293 - 08. A Digital Flexure Tensile Tester HJ-1171 was employed to calculate the flexural strengths of the conventional cement mortar and the PIC specimens.

The decrease in durability of concrete structures due to increasing environmental pollution is a matter of great concern. Many admixtures including polymers are employed to increase this durability. In this work, two series of specimens viz. conventional cement mortar and PIC, were weighed and immersed in 5M sulphuric acid for different periods of exposure time – 3,5,7 and 14 days to assess the extent of damage caused due to the interaction of the samples with the external chemicals. The cumulative weight losses of the PIC specimens on exposure to the acid were compared to those obtained for ordinary Portland cement mortar samples.

Microstructural studies

The degree of polymerization and molecular weight distribution of the polymer plays a vital role in determining the properties of the polymer impregnated concrete (R). In this study the above parameters were calculated using Gel Permeation Chromatography (Model Waters) and refractive index detector. A few grams of the PIC prepared from conventional thermal as well as microwave methods were mixed with tetrahydrofuran (THF) so as to extract and dissolve the PMMA. The solution was then analyzed for calculation of the above.

Porosity and pore size distribution are inversely proportional to the compressive strength of conventional cement mortars since the effective area to resist the applied load on them decreases as the voids and pores increase. A Micromeritics make automated mercury Porosimeter 9520, was employed to determine the pore characteristics in both the conventional cement mortar and PIC specimens.

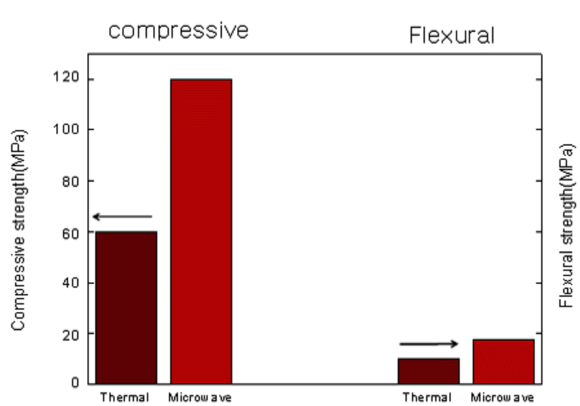
Investigations using scanning electron micrographs revealed porosity and micro cracks in the conventional cement mortars before and after impregnation and subsequent polymerization of the monomers. A Scanning electron microscope (Jeol Make JSM-6390 Model) was used to carry out these studies. Samples of 1-2 mg weight were subjected to gold sputtering to make them conducting.

Results and discussion

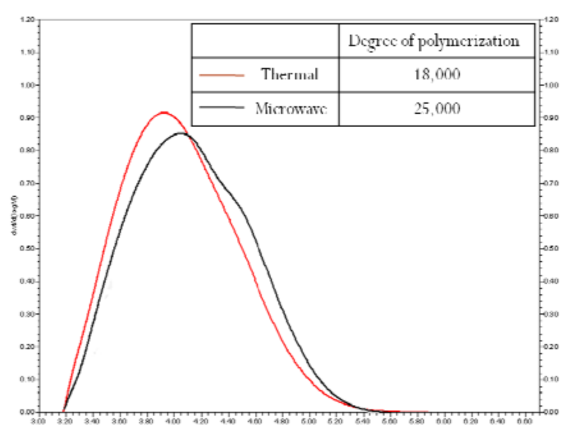
Effect of modes of polymerization on the strength of the polymer Impregnated mortar

In this work two procedures were employed to polymerize the monomer that has been impregnated into the cement mortar – the conventional thermal method and the current microwave method

As inferred in Fig.1 (a) the strength of composites prepared by microwaves was also found to be far superior to those prepared from conventional methods.



(a)



(b)

Fig.1 (a) Comparison of the strengths of PIC specimens prepared from thermal and microwave methods

(b) Degree of polymerization of monomer in thermal and microwave methods

The compressive and flexural strengths of the PICs prepared using microwave heating were found to be around two and three times that of the ones prepared using the conventional heating methods respectively. This could be attributed to the higher degree of polymerization of the monomers within the pores of the precast cement mortars as observed in Fig.1(b). It is seen that the degrees of polymerization of the monomer in the conventional and the microwave heating methods were estimated to be 18000 and 25000 respectively. When the monomer is converted to the polymer within the pores, it occupies only 80% of the original volume of the pores (2). It may therefore be inferred that the effective area to resist the applied load on the specimen is directly proportional to the degree of polymerization. It was also noted that the time taken for heating in the latter method was far less resulting in a substantial reduction of energy consumed.

Durability

Fig.2 and Table 1 depicts the chemical resistant properties of the PICs on exposure to 5M sulphuric acid were compared with those obtained for conventional cement mortar by calculating the weight losses for different periods of exposure time.

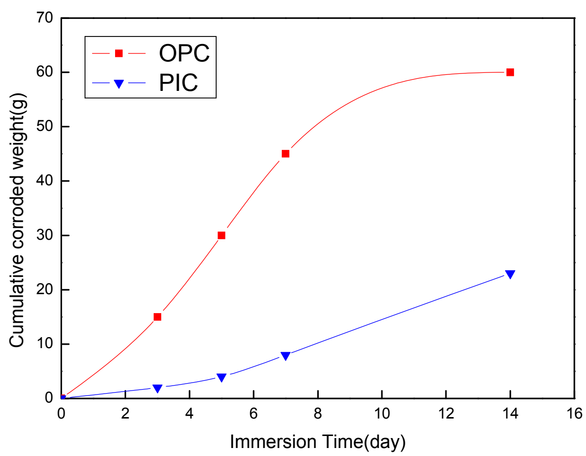


Fig.2 Effect of preparation conditions on chemical resistance (After dipping in 5M – sulphuric acid solution on dipping time, checking the corroded weight of the sample)

Immersion Time (day)	**Cumulative corroded weight(g) - OPC**	**Cumulative corroded weight(g) - PIC**
0	0	0
3	15	2
5	30	4
7	40	8
14	60	23

Table 1 Loss of weight of the samples when exposed to sulphuric acid

Investigations revealed that the cumulative corroded weight was greater for conventional cement mortars than PICs. The sulphuric acid underwent interactions with conventional OPC thereby dissolving a part of the set cement. This results in loss of weight and weakening of the material progressively by removal of the cementing constituents (8). The presence of the polymer in a PIC not only envelopes the cement mortar but also seals the voids formed during the cement hydration. This prevents cement-acid interactions that would otherwise result in loss of weight of the composite.

Microstructural studies

As part of the microstructural studies the porosity and morphology of the polymer cement matrix in the PIC was studied.

From Fig.3 the porosities of conventional cement mortars and the PICs were found to be 17.3% and 9.8% respectively.

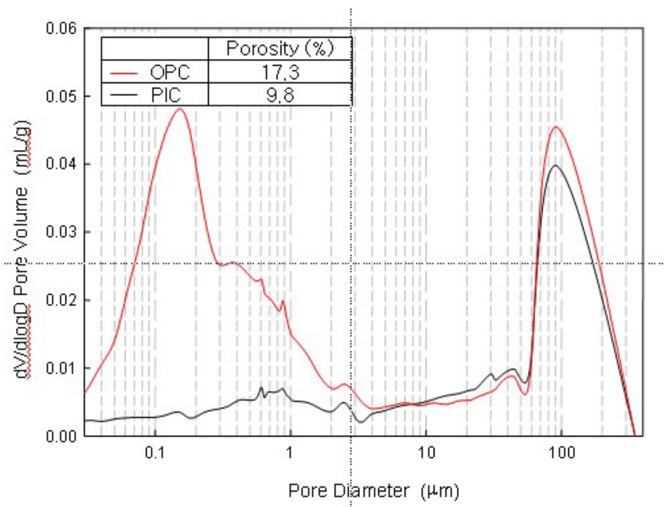
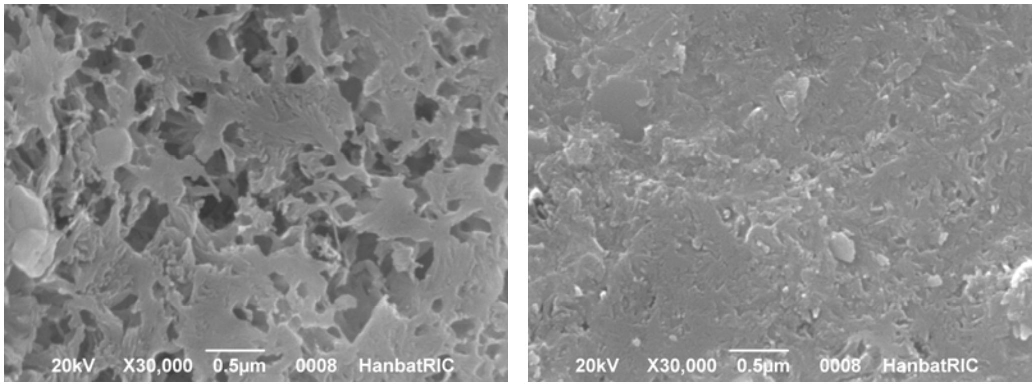


Fig.3 Comparison of the Pore diameter in OPC and PIC specimens

The decrease in porosity in the latter case could be attributed to the sealing of the voids and micro-cracks by the polymer in the precast cement mortar thereby increasing durability and strength of the cement structure as seen in the previous section.

Further, the morphological studies conducted using the scanning electron microscope (Fig.4 (a) and (b)) revealed the presence of large pores and voids in the conventional cement mortars that were not impregnated by the polymer.



(a) OPC (b) PIC

Fig.4 Scanning electron micrographs of (a) OPC and (b) PIC

The microstructure of PICs shows a more compact and uniform structure with smaller voids due to the presence of polymer in the cracks and voids.

Conclusions

From the above studies the following conclusions were inferred:

1. The degree of polymerization of monomer is greater in case of PIC specimen prepared by microwaves than ones prepared from conventional thermal methods.

2. The mechanical and chemical resistant properties of PIC composites are superior to the conventional cement mortar.

3. Porosity of the conventional cement mortar is greatly reduced when it is impregnated with polymers thereby increasing its durability when it is exposed to chemically polluted environments.

4. Polymers give a more compact structure to the cement matrix and seal the cracks in cement mortar matrix.

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