Use of Liquid Polymer to Prevent Moisture Loss during Curing and to Improve Watertightness at the Hardening Stage

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Abstract

In this study, the application of liquid polymer to form an internal barrier to prevent the loss of moisture in concrete during curing and to improve the watertightness at the hardening stage was investigated. In normal practice, a barrier or seal type cure is achieved by applying external plastic sheets or spraying curing foam around the surface of a concrete structure. In some cases, this process may be difficult to perform properly, for example, concrete structures with large surface areas or with complicated shapes. Hence, liquid polymer (acrylic based) is introduced. However, the process is different from the external one. Instead of using an external barrier sheet wrapping, an internal barrier is formed using the formation of the polymer film around the outer surface. Results indicated that the polymer was able to be used as an internal barrier successfully to prevent moisture loss in concrete. With a sufficient amount of water inside the concrete, the internal barrier created by the polymer film was able to prevent moisture evaporation and allowed concrete strength to develop regularly on its own without adding additional water. In addition, at the later stage, the efficiency of the polymer film or network, once fully formed throughout the concrete, was also found to improve the ability of the concrete to prevent the penetration of water. Results from the penetration tests indicated that the watertightness of polymer concrete was by far superior to that of plain concrete.

Key words: Liquid Polymer, Watertightness, Seal Type Curing, Internal Barrier, Polymer Concrete

1. Introduction

1.1 Early Stage

Portland cement is the most commonly used construction material in the world. It is also known by the name of hydraulic cement, which is the reflection of the hardening process that involves the reaction between water and cement particles (hydration reaction). To produce good concrete, it is important to keep the hydration reaction continuing until all the major reactions are completed without disruption. This can be obtained by the process called 'curing'. The aim of curing is to maintain the level of humidity inside concrete at over 80% during the first 28 days.

Under normal conditions, there are two types of curing: 1) moist and 2) seal or barrier curing. The concept of moist curing is to continue supplying additional moisture to the concrete during the hydration process which can be performed by ponding, spraying or sprinkling. As for the seal or barrier type, the idea is to prevent the loss of moisture from the concrete by means of using an external barrier such as plastic sheets, paper or membranes.

In practice, the moist cure is the most commonly used in general conditions. However, due to the difficulty in maintaining a high level of humidity for a long period of time, the sealed type was introduced. Cautiously, when choosing the sealed curing, engineers have to make sure that there is plenty of water available inside the concrete to finish all major hydration without causing self-desiccation. This can simply be judged by looking at the value of the w/c ratio. Theoretically, a w/c ratio of over 0.40 is believed to provide sufficient water to keep the hydration process going without supplying any additional water. Therefore, it is recommended to use sealed curing when the w/c ratio of concrete is higher than 0.40. Seal type curing has been used and accepted widely because of its ability to reduce labor costs and time.

In this study, liquid polymer (acrylic based) is introduced and used as an internal sub-surface barrier for the sealed type curing. However, the process is different from the conventional one. Instead of using an external barrier sheet wrap around the outer surface of the structural members, the barrier obtained in this study is formed internally using the formation of the polymer film around the outer surface. The process starts by mixing fresh concrete with liquid polymer. Then, after demoulding and allowing the surface of the specimen to get in touch with the air and dry, the polymer film is formed around the surface of the specimen. At early age, it is expected that the polymer film, if formed properly around the surface, will act as a barrier to prevent the loss of moisture. This, allows the hydration process to continue without disruption.

1.2 Hardening Stage

However, because the process of hardening, which involves the hydration reaction between water and cement particles, never is perfect, there will always be unhydrated cement particles and unused water. This unused water, once dried out, will turn into pores (mostly capillary pores) in various sizes. These pores are connected either to each others directly or through the gel pores. The existance of a high volume of pores puts concrete at risk of being penetrated by water, gas, or other chemical substances which could be harmful to concrete and slowly, leads to the deterioration of structures.

Often, the deterioration process starts with the occurrence of a surface crack (due to poor tensile strength, shrinkage, etc.) and then is followed at by the migration of the gases or liquids into the inner-concrete (through the surface-cracks and the pores). Some unknown gases or chemical substances can react with concrete and cause the loss of integrity and properties. Examples of such reactions include the carbonation reaction between carbon dioxide gas and calcium hydroxide (cause the leaching of bicarbonate) which makes concrete surfaces become porous, decay and permeable, or the chloride induced – corrosion in rebar which is caused by the loss of protective film around the rebar due to the decrease of pH .

In order to reduce the risk of concrete being attacked by harmful substances, the permeability resistance of concrete must be improved. There are several ways to improve the permeability of concrete by means of either reducing the total volume of pores, or reducing the volume of larger sized pores (permeable pores).

In addition to the use of polymer as an internal barrier at the early stage of curing, at a later stage, once the polymer film or network is fully formed inside the concrete, it is also expected to fill up a number of pores inside the concrete and, hence, improves the watertightness and increases the water penetration resistance significantly.

2. Experimental Procedure

Materials used in this study consist of cement Portland Type I, river sand, coarse aggregate (MSA. 25mm), water and polymers. In the case of polymer, two types of polymers were used: Acrylic (AC) and Styrene Acrylic Copolymer (SAC). The properties of both polymers are given in Table 1.

The mix proportion of all concrete was set at 1:0.43:2.4:3.0 (Cement : Water : Coarse : Fine), which provided an average compressive strength of about 40.76 MPa. However, in the case of the polymer modified concrete (PMC), the polymers were added into fresh concrete during the mixing at 15% by cement weight. The polymer came in a liquid form with different percentage of water content (Table 1); therefore, the amount of water for each mix was adjusted (reduced) to compensate for extra water.

Table 1 Property of Polymers

Property	Type of Polymer Modifier	
	Acrylic (AC)	Styrene-Acrylic (SAC)
Appearance	Whitish	White
Solids Cont., %	55	50
pH	4.0-7.0	7.0-8.0
Viscosity, cps	< 1000	1000-4000
Part. Size, mm	0.0001-0.0003	0.0001-0.0002
Tg, °C	5	16
MFFT, °C	10-14	25

Note: MFFT-Minimum Film Forming Temperature

The concrete was mixed using a pan type mixer, placed in cubic-150x150x150 mm oiled metal moulds in three layers and each layer was roughly compacted with steel rod before being covered with polyethylene sheets. After 24 hours, the specimens were demolded and subjected to different conditions of curing. Depending on the concrete type, the plain concrete specimens were subjected to a moist curing of 28 days, while the polymer concrete specimens were subjected to an air curing of 28 days. The casting and curing schedule is given in Table 2.

Table 2 Casting and Curing Schedule

Designation	Concrete type	Curing Condition	No. of Spec
OPC	Plain	Moist 28 days	8
AC	AC-Polymer Conc.	Air 28 days	8
SAC	SAC-Polymer Conc.	Air 28 days	8

Three tests were carried out: 1) Compression test 2) Water penetration test (DIN 1048) and 3) Microstructure observation using an SEM. Test 1 and 2 were carried out at the Department of Civil Engineering, King Mongkut's Institute of Technology-North Bangkok, while Test 3 was carried out at Chulalongkorn University.

3. Results and Discussion

3.1 Compressive Strength

The compressive strength and response obtained from each concrete are given in Fig. 1. The compressive strength of the plain concrete was found to be around 29 MPa, while those mixed with polymer were found in between 27.5 to 30.8 MPa depending on the type of the polymer.

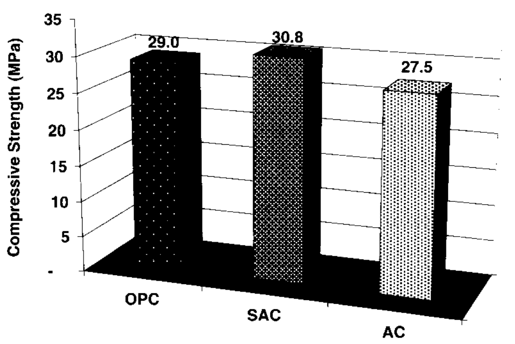
In the case of plain concrete, under the water curing condition, the hydration process was able to continue without any disruption because there was a substantial amount of water throughout 28 days. This resulted in concrete having a normal rate of strength development and gaining the final strength as expected.

However, in the case of polymer concrete, the major key ingredient for curing 'water' had been taken out from the curing process. This left the water inside, which was assumed to be sufficient for all major hydration reactions to complete, without adding any more water. The role of the polymer was to get hardening first at the surface (once in contact with air) to prevent moisture loss and to allow the hydration process inside to continue on its own (Fig. 2).

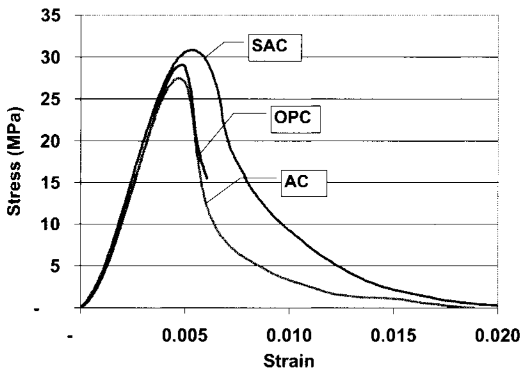
The process described above seemed to work well with the polymer concrete as seen by the comparative values of the compressive strength obtained from both plain and polymer concrete. The polymer had successfully proved to act as an internal barrier to prevent moisture loss during the curing, providing that there was sufficient water inside the concrete to carry out the hydration process on its own.

3.2 Water Penetration Resistance

Results from the test are given in Fig. 3. In all cases, the penetration resistance of both PMCs was found to be higher than that of OPC. The average depth of penetration of OPC was found to be around 38 mm, while the average of AC and SAC was around 21 mm and 17 mm, respectively. It was believed that the polymer, once properly formed, was able to fill-up pores inside the concrete and seal-up water from penetrating through (Fig. 4).



(a)



(b)

Fig. 1 (a) Compressive Strength and (b) Compressive Response

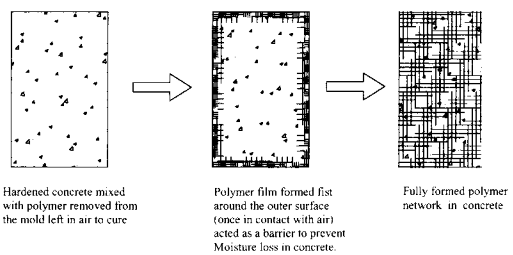


Fig.2 Schematic Illustration of the Formation of Polymer Film around the Specimen Surface

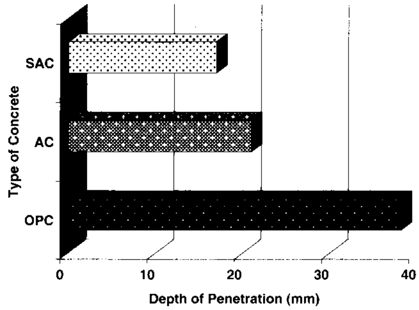


Fig. 3 Average Depth of Water Penetration

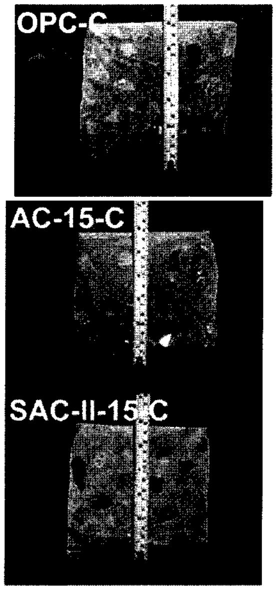


Fig. 4 Cut Specimen

3.3 Microstructure Observation

In order to investigate the internal structure of both plain concrete and PMC, the cracked surfaces taken from the tested specimens were observed using a scanning electron microscope (Fig. 5-7). At a zooming ratio of x700, the microstructure of OPC was found to be quite porous; the crack surface was filled with pores of various sizes (Fig. 5). In contrast, the pictures from the PMC showed a denser crack surface with less number of pores than that of OPC (Fig. 6). The formation of the polymer film was also observed as seen in Fig. 7.

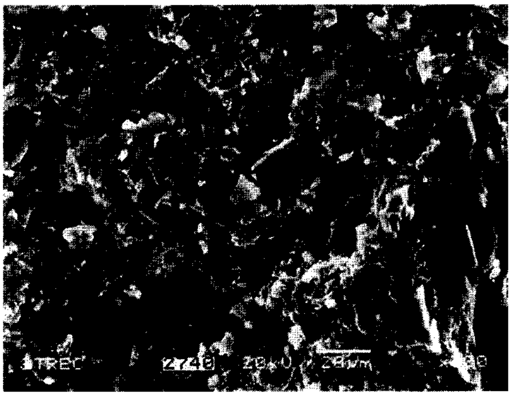


Fig. 5 Microstructure of OPC

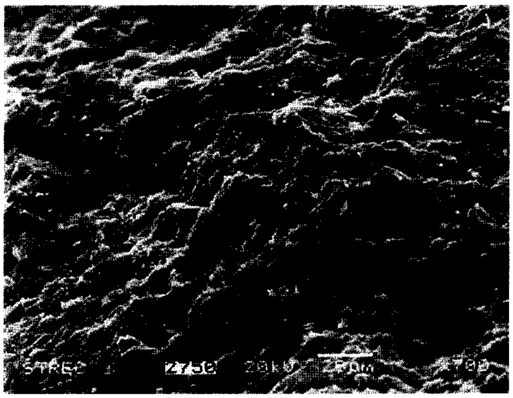


Fig. 6 Microstructure of PMC

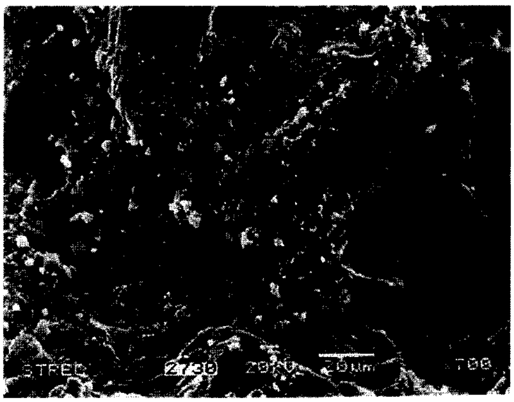


Fig. 7 Formation of Polymer Film

4. Conclusion

4.1 Polymers were successfully used as an internal barrier to prevent moisture loss in concrete. Providing that there was sufficient water inside the concrete to process its own hydration reaction, the internal barrier created by a polymer film was able to prevent moisture evaporation and allowed concrete strength to develop regularly without adding additional water during the first 28 days. The strength of 15% polymer concrete (without water cure) was found to be as high as that of plain concrete (cured regularly under water)

4.2 The resistance to water penetration of concrete can be improved significantly by simply adding liquid polymer into concrete during the mixing process. With proper curing conditions, a polymer film and network formed inside the concrete structure and pores. This decreased the depth of water penetration by half.

4.3 Pictures obtained from the SEM also showed PMC with denser and less pores microstructure as compared to OPC.

5. Acknowledgement

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6. References

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