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Capacity Evaluation of Penetration-Reinforcing Agent

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1. Introduction

The capacity and applicability of the organic-inorganic synthesized penetration-reinforcing agent that was developed with the purpose of preventing aging and improving durability in concrete structures as their number of years in service increased were proven through experimental methods.

The developed organic-inorganic penetration-reinforcing agent creates the effect of increasing compressive strength as well as produces higher durability against the aging factors of the environment.

2. Capacity Evaluation

This section aims to discuss the penetrating ability, concrete strengthening effect, and ability of restraining aging of the surface penetration-reinforcing.

2.1 Penetration Depth

As concrete strengthening and preventing aging by filling the capillary pores can be manifested with respect to the penetrated depth, the evaluation of the penetrated depth can be the basic factor for evaluating the capacity of the penetration-reinforcing agent. Φ100 x 100mm specimens of the water-cement ratios 35%, 40%, 50%, and 60% were produced, and those were cured during 120 days under the conditions of relative humidity 50% and temperature 20℃±3℃. After curing, the upper surface of specimens was applied with penetration-reinforcing agent and the penetrated depth was measured 14 days after the application. The penetrated depth measured from the surface to the depth that displayed the ability to sprinkle water after splitting the specimen in half according to the KS F4930[1]. Compressive strength of specimen and the penetrated depth of each amount of application according to the w/c changes are shown in Figure 1. and Figure 2..

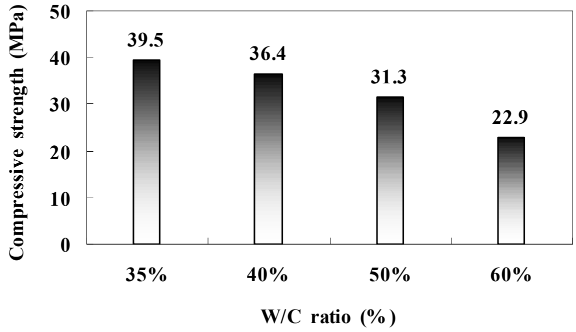

Figure 1. Compressive strength of specimen by w/c ratio

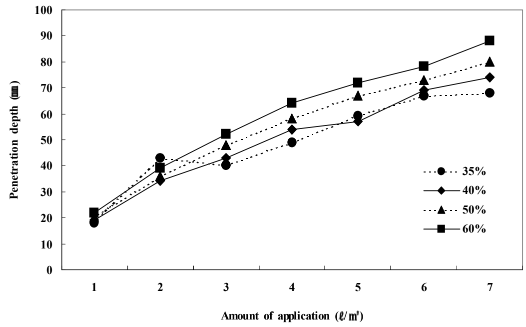

Figure 2. Penetrated depth by w/c ratio and amount of application

The results of penetrated depth measurements show that at 2ℓ/㎡, the penetrating depth is more than 30mm from a low strength of w/c 60% to a high strength of 35%.

2.2 Microstructure Characteristics

The results of the SEM analysis showed that, for the specimens with no application, many pores existed among the hydrates as shown in Figure 3., and out of these, pores formed by hydration were in the range of 10nm~100um, and capillary pores, in the range of 3nm~2um. Here, the observed hydrates were ettringite, calcium silicate hydrate, and calcium hydroxide.

In the cases of specimens applied with the penetration-reinforcing agent, not only were compact microstructure formed through the O-Si-O bonds as shown in Figure 4., but also the deterioration of durability could be prevented due to the existence of micro pores that give air permeability.

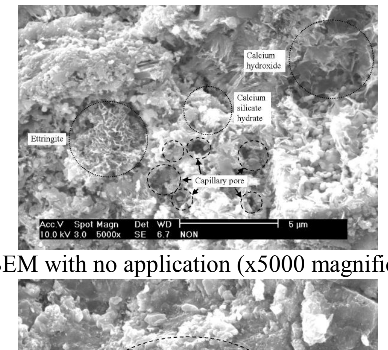

Figure 3. SEM with no application (x5000 magnifications)

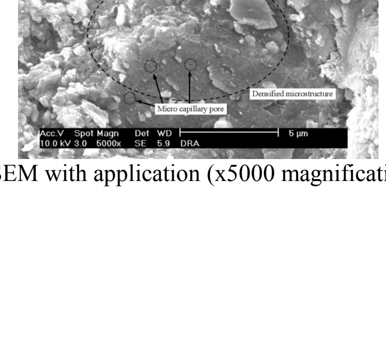

Figure 4. SEM with application (x5000 magnifications)

2.3 Concrete Strengthening Effect

For evaluating the concrete strengthening effect from the penetration-reinforcing agent, specimens of Φ100 x 200mm of mixture were produced, and those were cured during 28 days under the conditions of relative humidity 50% and temperature 20℃±3℃. After curing, the penetration-reinforcing agent was applied and the compressive strength was measured 14 days after the application.

The results of the measurements showed concrete strengthening effect of 11.4% (3MPa), with the compressive strength of the concrete with no application 26.4MPa and the compressive strength of the concrete with application 29.4Mpa.

In order to evaluate the concrete damage restoration capacity by the penetration-reinforcing agent after being damaged, after carrying out a freezing and thawing up to 150 cycles under a temperature condition of -18℃~+4.5℃, the penetration-reinforcing agent was applied. After 7 and 28 days of application, compressive strength, coefficient of permeability, and porosity were measured. The results of the measurements showed that the compressive strength increased by 1.46 times with the application, 28 days after the application. These signify that capacity of concrete was restored when the penetration-reinforcing agent was applied on concrete with destroyed internal microstructures and lowered strength due to the freezing and thawing.

For the coefficient of permeability, after 28 days of application, it decreased by 45% with the application, which was consistent with the results of increase in compressive strength.

2.4 Restraining Aging and Restoring Capacity

The capacity of recovery from salt-water damage, carbonation, freezing and thawing, and compound aging was evaluated.

The restraining capacity test on salt water damage was carried out by measuring the amount of aqueous chloride solution contained by depth. After penetration-reinforcing agent was applied on the bottom of a Φ100 x 100mm specimen, and its side was coated with epoxy in order to derive the chloride penetration in one direction and deposited in a NaCl 3.6% aqueous solution for 28 days. The results of evaluation showed that the chloride concentration by depth decreased when the penetration-reinforcing agent was applied and the capacity in restraining damage from salt water was 97% in contrast to the one without application.

The restoring capacity test on salt water damage was carried out with mortar of W/C 54%, using NaCl solutions of 0.01, 0.03, 0.1, and 0.2% as mixing water by measuring the amount of chloride that was fixated due to the penetration-reinforcing agent from extracted samples of each depth. The results show that the chloride fixation effect by the penetration-reinforcing agent was 70~72%.

The restraining capacity test on carbonation was carried out by measuring the colored depth with phenolphthalein by coating the side with epoxy to derive the penetration of carbon dioxide in one direction. After applying the penetration-reinforcing agent on the Φ 100 x 100mm specimen and exposing the specimen for 91 days in a carbonation accelerating test apparatus, in a condition of carbon dioxide concentration 10%, temperature 30±3℃, and relative humidity 60±5%. The results showed that the progression speed of carbonation decreased when the penetration-reinforcing agent was applied and its capacity for restraining carbonation was 96% in comparison to the one without application.

The restraining capacity test on freezing and thawing was carried out by freezing with air and thawing with water in a condition of –18~+4.5℃ after applying the penetration-reinforcing agent on the 100x100x400mm specimens. The results showed that the relative dynamic elastic modulus was in a fine condition at 90% level at 300 cycles when the penetration-reinforcing agent was applied, but the relative dynamic elastic modulus dropped to under 60% at 150 cycles when the agent was not applied. This outcome was the result of restraining the penetration of external moisture, that of a waterproof layer forming simultaneously as the microstructure of concrete densified by the penetration-reinforcing agent decreased the internal moisture that was capable of being frozen.

The evaluation test on the capacity in restraining compound aging that considered both freezing-thawing and salt water damage was carried out, and measuring the mass of scaled off particles after 50 cycles. The evaluation results show that when the penetration-reinforcing agent was not applied, as the number of cycles increased, the mass of scaled off particles had a tendency to increase due to the complex reaction of freezing-thawing and salt water damage than when the agent was applied. Specifically, the mass of application was only 26% of mass of no application at the 50cycle point. The surface peeling grade of ASTM C672 was Grade 3 where the thick aggregate was exposed for without application, and Grade 0 where there was almost no surface peeling for with application.

3. Conclusion

The penetration-reinforcing agent used in this paper improved the shortcomings of existing surface protecting materials composed of organic and inorganic materials aimed waterproof capacity.

It is judged to be capable of being applied for the improvement of durability of concrete structures in use as well as prevention of aging of new structures, based on its high penetrating capacity.

REFERENCES

[1] Korea Standards Association, Penetrating water repellency of liquid type for concrete surface application, Korea Standards Association KS F 4930 (2002)