Water Absorption Properties of Concrete Using Surface Penetrants Influenced by Various Freezing and Thawing Conditions

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Introduction

In order to prevent frost damage of concrete structures, surface penetrants having water absorption suppressing effect are applied to the concrete surface. As representatives of surface penetrants, silane type with the impregnated area gel hydrophobized and water absorption can be suppressed, and silicate type with surface get densified by filling the interspaces and cracks in the concrete with the C-S-H gel are widely used. While these surface penetrants are reported to be effective against frost damage, there are reports that the surface penetrants have large variation in the water absorption suppressing effect, even water absorption accelerated under the freezing and thawing conditions. There are also reports that the surface deterioration were more serious in the concrete coated with silane penetrants under freezing-thawing conditions, the influence of surface penetrants on frost damage of concrete is unclear.

In freezing and thawing conditions, if the water freezes first, it assumes that water can be pushed into the unfrozen concrete by freezing pressure and pushing force raised by frozen water. If the concrete freezes first, it assumes that the water can be attracted to frozen concrete by freezing pressure and drawing force raised by frozen concrete. It depends on the freezing direction, and the water absorbing properties in these cases are thought to be different.

In this study, in order to clarify the influence of the surface penetrants on water absorption properties and deterioration of concrete under different freezing-thawing conditions, a bottom surfaced water absorption test and freezing-thawing test were carried out in which the freezing direction was changed by using heat insulation material to simulate different freezing and thawing conditions, the water absorption properties of concrete were investigated.

According to the results, the silane-based penetrants whose water absorption was suppressed in the water absorption test got higher water absorption rates than that of the no coating ones under the condition of upper heat insulation, the water absorption rate got accelerated.

Keywords: concrete, surface penetrants, freezing-thawing, water content, water absorption rate, water movement

Outline of Experiment

The experimental plan is shown in Table 1. Concrete test specimens using three types of surface penetrants and one without coating were used. In series II, sensor was used in two type of concrete to measure the change of water content in each layer by electrode method during freezing and thawing conditions.

Figure 1 shows the experiment flow. After 11 days of bottom surface water absorption test as shown in Fig.2c), the water content of specimens got stable, then bottom surface freezing-thawing test using three kinds of heat insulation methods as shown in Figure 2 was carried out.

The bottom surface water absorption freezing-thawing test was one in which freezing and thawing was performed under condition of absorbing water from the bottom surface. Here, degreasing cotton and water were placed in stainless steel containers (240×160×30 mm), the specimens were immersed in water on the wet degreasing cotton and kept the water level about 5mm above the bottom surface.

The bottom surface water absorption freezing-thawing test was conducted in a program temperature control tank. The ambient temperature setting of the program temperature control tank was based on keeping the central ministry between the specimens and degreasing cotton of the specimens in no insulation at the level of -20°C • 2.5h, 20°C • 2.5h, and all the specimens in the three conditions of heat insulation were tested in the same environment. 5h/cycle was conducted by about 100 cycles. After completion of the tests, the specimens were dried at 105 °C, and the absolute dry weight was measured.

In series II, in order to exclude the impact of temperature on specific resistance, the resistance was measured by keeping the measurement temperatures in each layer at about 25-28 °C. Table 2 shows the mixture proportion of concrete specimens, and Table 3 shows the outline of surface penetrants. Figure 3 shows specimens (100×100×40 mm) overview, the penetrants were coated on the water absorption surface (bottom surface) and four side surfaces, the opposite surface (upper surface) was kept exposed state (no treatment). Non was the specimens that keeps exposed condition (no treatment) on all sides.

Table 1. Experimental plan

<table>
<thead>
<tr>
<th>Concrete types</th>
<th>Specimen types</th>
<th>Condition of bottom surface freezing-thawing test</th>
<th>Experiment contents</th>
<th>Measurement items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series I</td>
<td></td>
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</tr>
<tr>
<td>w/c=60%</td>
<td>Silane type</td>
<td>Upper insulation</td>
<td>A : bottom surface water absorption test (11 days) (20°C • 60%R.H.)</td>
<td>- Water absorption test : Mass, moisture meter, mass water content (specific resistance by electrode method)</td>
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<tr>
<td></td>
<td>×2</td>
<td>Bottom insulation No insulation</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Silicate type×1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No coating</td>
<td>Upper insulation</td>
<td>B : bottom surface freezing-thawing test (100 cycles) (-20°C•2.5h, 20°C•2.5h)</td>
<td>- Freezing-thawing test : Mass, moisture meter, contact angle visual appearance observation ultrasonic wave propagation velocity mass water content (specific resistance by electrode method).</td>
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<tr>
<td></td>
<td>×1</td>
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<tr>
<td>Series II</td>
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<tr>
<td>w/c=35%</td>
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<tr>
<td>w/c=55%</td>
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- Water absorption test : Mass, moisture meter, mass water content (specific resistance by electrode method)
- Freezing-thawing test : Mass, moisture meter, contact angle visual appearance observation ultrasonic wave propagation velocity mass water content (specific resistance by electrode method).
Results and Discussion

• Temperature change on upper and bottom surfaces

Figure 4 shows the temperature change of the upper and bottom surfaces of the specimens in the freezing-thawing test. In the upper insulation, the water froze first, the freezing of the concrete was delayed about 10 minutes, it assumes that water can be pushed into the unfrozen specimens. In the bottom insulation, the concrete froze first, and the freezing of the water was delayed about 30 minutes, it assumes that water can be drawn into the frozen specimens. Also, in no insulation, the freezing of the water was delayed by about 10 minutes.

The freezing periods of the upper and bottom surfaces in three heat insulation methods kept 2.5h~3h, and the thawing periods kept 2h~2.5h. In upper insulation, the minimum freezing temperature of upper and bottom temperature were about -10℃. In bottom insulation, while the minimum freezing temperature of upper surface was about -10℃, the minimum bottom face was only -2℃. In no insulation, the minimum freezing temperature of upper and bottom surface were about -15℃, the minimum freezing temperature was lower than the other conditions.

• Water absorption properties of water absorption test and freezing-thawing test (series I)

The curves of the water absorption and freezing-thawing test are shown in Figure 5. As a characteristic of these water absorption curves, the water absorption rates are calculated.
as shown in Figure 6. Water absorption rates are obtained in four periods: (1) initial water absorption, (2) the water absorption get stable, (3) water absorption at the start of freezing-thawing test and (4) water absorption from the 5th cycle of freezing-thawing test to the time of deterioration. These water absorption rates of each period are shown in Figure 7. The following tendencies are recognized from Figure 5 and Figure 7.

(1) At the beginning of the water absorption test, compared with the no coating specimens, it is obviously that the water absorptions were suppressed in the specimens coated with surface penetrants. Especially, water absorption was largely suppressed in silane-based penetrants. Although the water absorption suppressing effect of Rd was recognized, the water content was somewhat lower than Non.

(2) After 11days of water absorption test, the water absorption were almost stable, the water content of Cn, Mr still remained low.

(3) When the freezing-thawing test started, the water content of silane-based Cn and Mr showed a tendency of increasing along with the freezing-thawing cycles, however, the water absorption rates and water content still remained lower than Non in any heat insulation methods. At the beginning of freezing-thawing test, Rd showed higher water absorption rate than Non in any heat insulation methods, as a result, the water content got higher than Non.

(4) As for the water absorption curve from the 5th cycle of freezing-thawing test to the time of deterioration (as the deterioration was not found in bottom insulation, the rates were calculated from 5th cycle to the end of freezing-thawing test), the increasing of water contents of Cn and Mr in upper insulation were remarkable. In the upper and bottom insulation the water absorption rates of Cn and Mr exceed the values of Non, and it can be said that the water absorptions of Cn and Mr under these conditions were promoted, on the other hand, in no insulation, the water absorption rates of Cn and Mr still remained lower than Non.

As for Rd, the water absorption rate and water content still kept higher than Non after freezing-thawing test started in any heat insulation methods.

• Moisture meter measurement result (series I)

Figure 8 shows the water content (moisture meter measurement value) of the water absorption surface (bottom surface) and the upper surface of the specimens in the freezing-thawing test. Before the start of freezing-thawing test, the water content of the bottom surface and the upper surface in Cn and Mr were lower than Non. In the case of Rd, the water content of the bottom surface was equivalent to Non, some of the values on the upper surface were small, which seemed that the water absorption was suppressed. After freezing-thawing test started, the water content of the upper surface which remained low in Rd rose sharply, it was considered that the water absorption was promoted in freezing-thawing test.

In Cn and Mr, the water content showed a tendency to rise after freezing-thawing test started, and this tendency was remarkable especially in upper insulation. It seemed that in upper insulation the water pushing force at the time of freezing was greater than the force which can hold the contact angle of surfaces with silane penetrants, so the water content rose when freezing. In addition, some of the rising trends of the water content are larger on the upper surface, and it is conceivable that water is pushed into the upper part at a state where the water content of the impregnation layer is low.

• Specific Resistance (series II)

Figure 9 shows the specific resistance of each layer in each concrete specimen under upper heat insulation condition during water absorption test and freezing-thawing test. From the figures, the change of water content in bottom surface (first layer), interlayer (second layer) and upper surface (third layer) can be obtained.

For W/C=35% concrete, in silane types Cn and Mr, the specific resistance of each layer almost kept the same decreasing trends, the bottom surface still kept relatively high specific resistance and the interlayer still kept lowest specific resistance in concrete during the freezing-thawing test. It seems that water has moved into the concrete and transferred to the upper part through water repellent layer (impregnation layer- bottom surface). In silicate type Rd and Non, the specific resistance of the bottom surface decreased dramatically, along with which the specific resistance of the interlayer and upper surface got dramatically decreased after the specific resistance of bottom surface got stable, finally the specific resistance of each layer reached the same level after several freezing-thawing cycles. It seems that as the water absorption progresses, the bottom surface absorbs water to near saturation state, then the water transfer to the interlayer and upper surface, finally the water content of each layer of concrete reaches a stable saturation state.

For W/C=55% concrete, the situation is almost the same as the case of 35% water cement ratio.
Conclusions

(1) During freezing-thawing process, for those using silane penetrants, the surface deterioration was suppressed compared with the no coating ones in any heat insulation methods, the effect against frost damage could be found. For those using silicate penetrants, the surface deterioration was almost the same with the no coating ones in any heat insulation methods, the effect of frost damage suppression could not be seen.

(2) For the specimens using silicate penetrants, although the water absorption suppressing effect could be found in the water absorption test, in freezing-thawing test, the water content suddenly increased, it became water absorption promoted.

(3) In no insulation, the water absorption rates of the silane penetrants were suppressed compared with the no coating ones in the freezing-thawing test, but in the upper insulation, the water absorptions rates exceeded that of the no coating ones, the water absorption became accelerated.

(4) In bottom insulation, no deterioration and significant change in water absorption could be found, for the minimum freezing temperature of bottom temperature was only -2°C.

(5) In silane penetrants, water may be pushed into the upper part of the concrete at a state where the water content of the impregnation layer is low in freezing-thawing test. In silicate penetrants and no coating ones, as the water absorption test and freezing-thawing test progresses, the bottom surface absorbs water to saturation state, then the water transfer to the interlayer and upper surface, finally the interlayer and upper surface successively reach the saturation state.

References


