B-1-1 Evaluation of silicate-based surface impregnation by using micro cracking concrete specimen

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ABSTRACT: The main components of silicate-based surface impregnation react with calcium hydroxide, which is formed during the process of cement hydration, and form a C-S-H gel in the concrete. There are several types of silicate-based surface impregnation available. The main component used in commercialized penetrants is lithium silicate, sodium silicate, potassium silicate or their mixture. It is well known that sodium silicate can react with calcium hydroxide well among these components. When it is rubbed into the crack of concrete, the crack can be occupied by C-S-H gel formed by the reaction of sodium silicate and calcium hydroxide of cement hydration and then, water leakage is stopped. However, there is no method to estimate the effect of silicate-based surface impregnation on stopping water through concrete cracking. The new test method to judge the effect of silicate-based surface impregnation on stopping water is proposed in this paper. The method to prepare the concrete specimen with micro-crack is also shown in this paper. The width of micro-crack can be controlled by the diameter of pipe where concrete is cast. The concrete specimen can be used with micro-crack depending on the purpose of investigation.

KEY-WORDS: Micro-cracking concrete specimen, crack width, water leakage, carbonation

INTRODUCTION

Cracking induces the deterioration of concrete member. Air, moisture or chloride easily penetrate crack and get rods rust [1] [2]. In ordinary, the crack whose width is less than 0.2 mm is regarded as harmless. However, the osmotic pressure makes salt water easily moved into the inside of concrete through the crack. Furthermore, when the concrete structure must not leak, crack is fatal defect even if it is a plain concrete. There is no crack harmless to concrete structures. It is important to examine the effect of permeability of both water and air for the design of high durability concrete structures.

The method to prepare the concrete specimen with micro-crack is shown in this paper. By using the concrete specimen with micro-crack, it is shown that the silicate-based surface impregnation [3] whose main ingredient is sodium silicate prevents cracks from carbonating concrete and from leaking water.

EXPERIMENT OUTLINE

The method to induce micro-crack in concrete specimen

The outline to make the concrete specimen with micro-crack is shown in Fig. 1. In this experiment, ready mixed concrete whose nominal strength 24N/mm^2, whose slump is 8 cm, whose maximum size of aggregate is 20 mm is used. This concrete is cast in PVC (polyvinyl chloride) pipe as shown in Fig. 1 (1). Three types of PVS pipe standardized in JIS (Japan Industrial Standard) K 6741 is used: VU75 (inner diameter: 83 mm, thickness: 2.7 mm), VU100 (inner diameter: 107 mm, thickness: 3.1 mm) and VU150 (inner diameter: 154 mm, thickness: 5.1 mm). The concrete cast in PVC pipe was cured in water for two weeks without removing from PVC pipe. After curing, concrete specimen was cut to a height 5 cm with PVC pipe. The specimen was put in transverse and applied load according to the splitting tensile strength test method (see Fig. 1(3). After crack is checked by visual observation, loading was removed. The specimen with cracking is shown in Fig. 1(4).

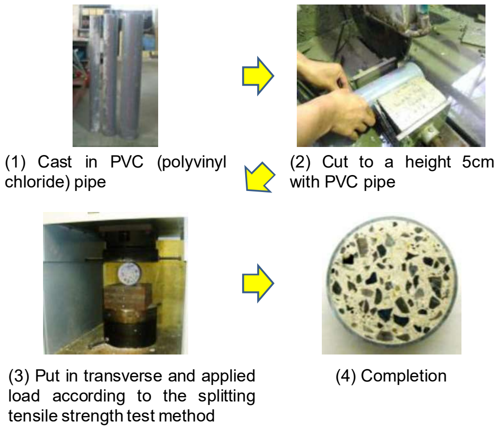

Fig.1. The method to induce micro-crack in concrete specimen

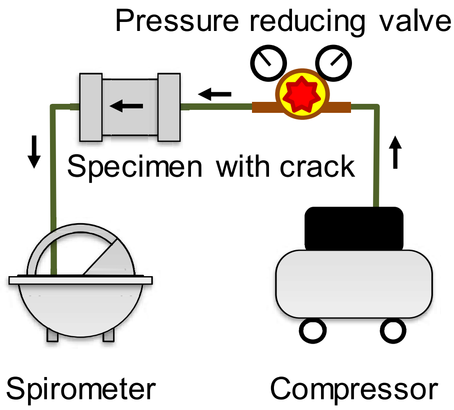

Fig.2. The outline of devise for air permeability test

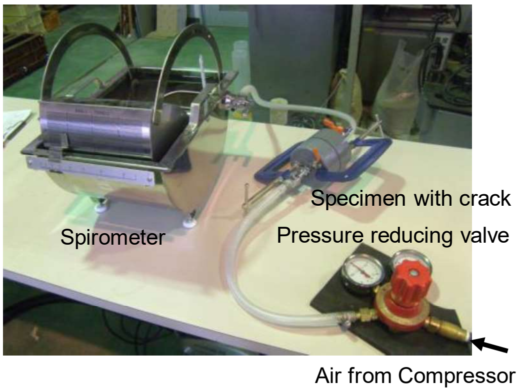

Photo1. The devise for air permeability test

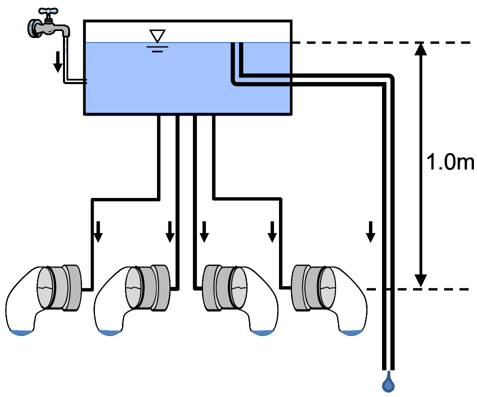

Fig.3. The outline of devise for water permeability test

Measuring of crack width

Microscope whose minimum division is 0.01mm was used for measuring of crack width. Crack width was measured at five points of each side of specimen. Nominal crack width is an average crack width of measured crackings.

Air permeability test

The outline of devise for air permeability test is shown in Fig. 2. The concrete specimen with crack whose diameter was 83mm was used for this test. The air pressure was controlled to 0.05Mpa by pressure reducing valve. The amount of air through the cracking of concrete was measured by spirometer. The amount of air per a second was calculated by the time when the amount of air reached 1,000mL. The picture of devise for air permeability test is shown in Photo 1.

Water permeability test

The outline of devise for water permeability test is shown in Fig. 3. The concrete specimen with crack whose diameter was 83mm was used for this test. The water pressure of 1 atmosphere was applied to specimen. The water through the cracking of concrete saved up in plastic bag. The amount of water per an hour was obtained by test. The picture of devise for water permeability test is shown in Photo 2.

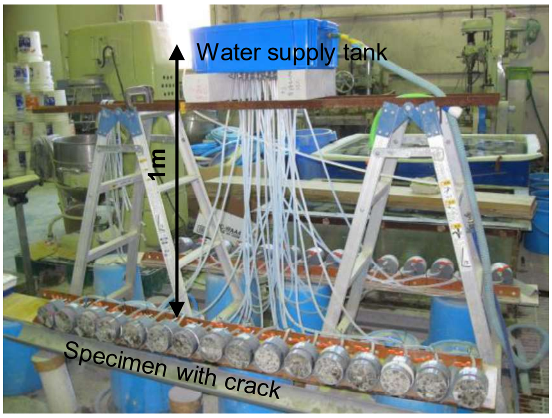

Photo2. The devise for water permeability test

Observation of internal cracking of concrete specimen

The outline of method to observe the internal cracking of concrete specimen is shown in Fig. 4. Fluorescent paint with adhesive agent was press-fit in the cracking by air pump. After solidification of adhesive, specimen was sawed by diamond cutter according to Fig. 4. Black light irradiated the concrete section and luminous cracking was observed.

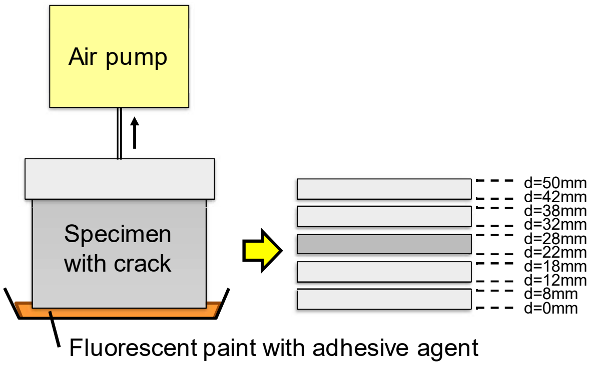

Fig.4.The outline of method to observe the internal cracking of concrete specimen.

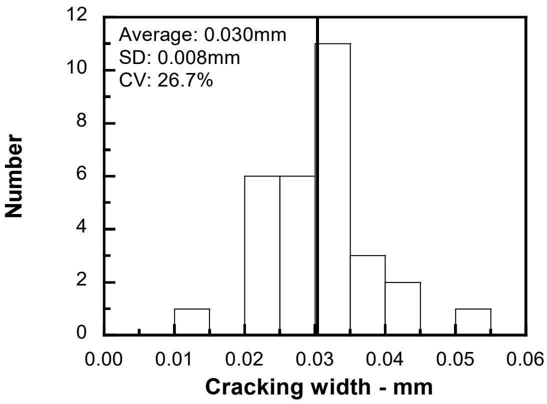

Fig. 5. The distribution of cracking width of concrete specimen whose diameter is 83mm.

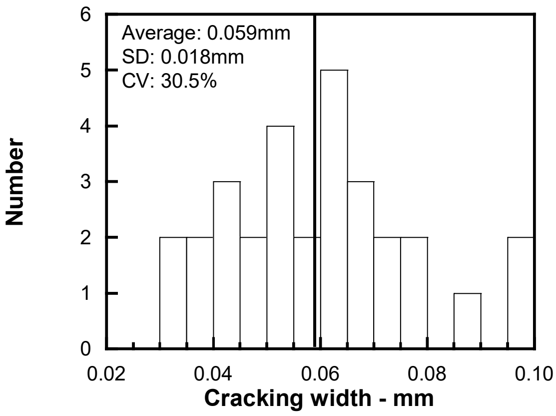

Fig. 6. The distribution of cracking width of concrete specimen whose diameter is 107mm.

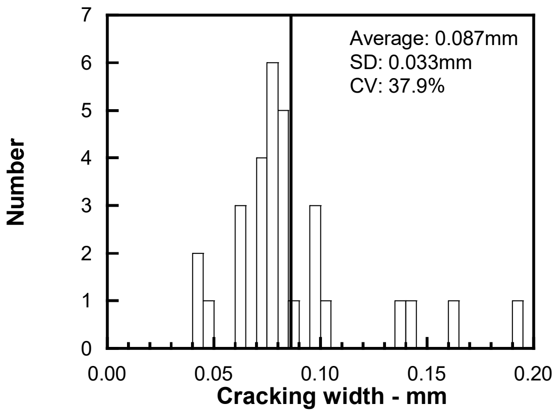

Fig.7. The distribution of cracking width of concrete specimen whose diameter is 154mm.

CONCRETE SPECIMEN WITH CRACKING

Distribution of crack width of the specimen

Fig. 5 shows distribution of cracking width of concrete specimen whose diameter is 83mm. The number of specimens is 30. The average of crack width is 0.030mm and coefficient of variation is 26.7%. Fig. 6 and Fig. 7

shows the distribution of crack with whose diameter is 107mm and 154mm, respectively. The average of crack width of concrete specimen whose diameter is 107mm and 154mm is 0.059mm and 0.087mm, respectively. Coefficient of variation of crack width of concrete specimen whose diameter is 107mm and 154mm is 30.5% and 37.9%, respectively. The average and coefficient of variation of crack become bigger with the diameter of concrete specimen.

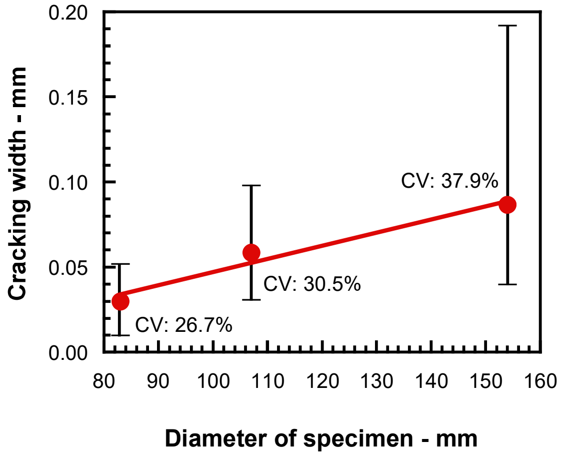

Fig.8. The relationship between crack width and diameter of concrete specimen

Fig. 8 shows the relationship between crack width and diameter of concrete specimen. The filled circles show the average of crack width of 30 specimens. The vertical lines in the Fig. mean the range of the biggest crack and the smallest crack. The applied load, the speed of removing load and so on seem to affect the crack width. However, crack width can be controlled by the diameter of specimen. That is, the concrete specimen with crack whose expected width can be made by selecting the PVC pipe.

Air permeability and water permeability of cracked specimen

Fig. 9 shows the relationship between air permeability and crack width measured visually. The air permeability is measured by the concrete specimen with crack whose diameter is 83mm. The number of specimen is 100. As clear from this Fig., the larger the specimen, the more the air permeability measured by the equipment shown in Fig. 2.

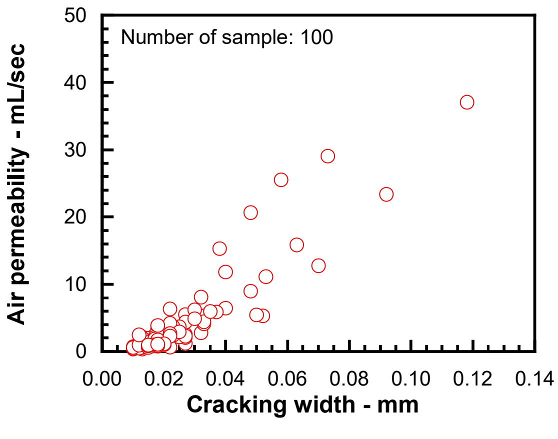

Fig.9. The relationship between air permeability and cracking width.

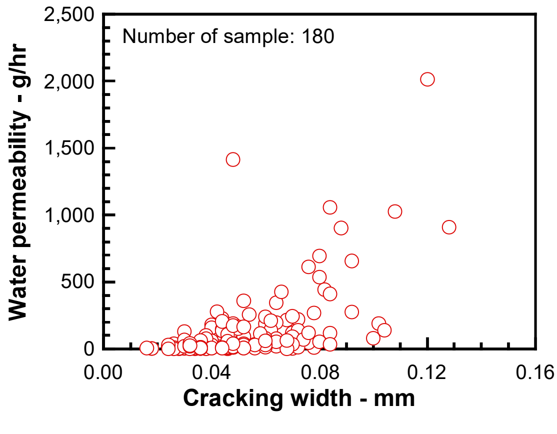

Fig.10. The relationship between water permeability and cracking width.

Fig. 10 shows the relationship between water permeability and crack width measured visually. The water permeability is measured by the concrete specimen with crack whose diameter is 83mm. The number of specimen is also 100. As for this relation, the linear relation is not clear. That is, the effect of crack width on water permeability is not big.

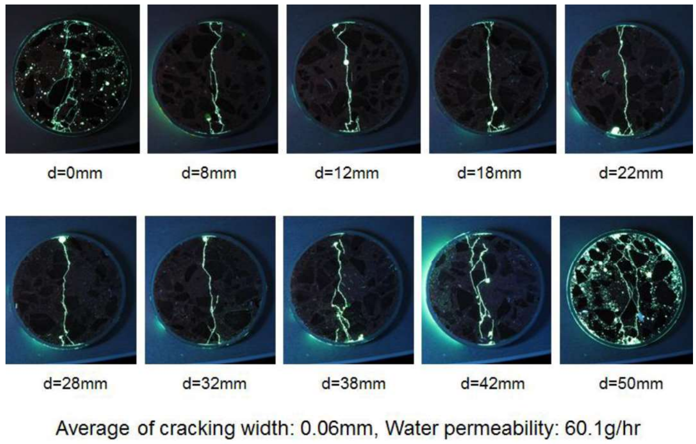

Photo 3. The cross section of concrete in which water can flow through at 60.1g/hr.

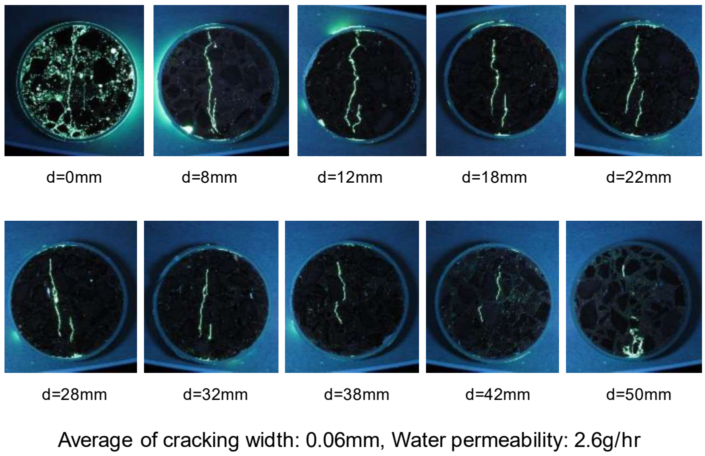

Photo 4. The cross section of concrete in which water can flow through at 2.6g/hr.

Photo 3 and Photo 4 show the cross section of concrete in which water can flow through at 60.1g/hr and 2.6g/hr, respectively. The average crack width of both specimen is almost 0.06mm. d in these Fig. is the distance from the surface of the specimen. In every cross section shown in Photo 3, crack appears from one end to another. That is, crack penetrates, perfectly. On the other hand, some cross section shown in Photo 4, crack appear partially.

In the specimen with much water permeability, there are fully penetrated crack as shown in Photo 3. Whereas, the specimen with low water permeability, there are partially penetrated crack as shown in Photo 4. In other words, when the crack width on the surface and water permeability is the same, the condition of inner cracks is judged to be almost the same.

Thesis for the specimen with crack treated with the surface impregnation

Fig. 11 shows the effect of type of surface impregnation on shutting the water leakage. The crack width used in this test is 0.10±0.01mm. Water permeability at the start of test is 65±50mmg/hr. When the cracked specimen is treated with silicate-based surface impregnation, water is shut faster than that treated with nothing. When the cracked specimen is treated with silane surface impregnation, water is shut slower than that treated with nothing.
Photo 5 shows comparison of carbonation measured on the two types of concrete specimen with cracking. One specimen is treated on the surface with nothing. Another specimen is treated on the surface with silicate-based surface impregnation. Crack width on both specimen is 0.10±0.01mm. The sprayed phenolphthalein liquid is sprayed on the cross section. The outline of carbonation accelerated test is as follow: temperature is 30.0±1.0°C, relative humidity is 60±5%, concentration of carbon dioxide is 5.0±0.2%, the period of test is two weeks.

The carbonated area of specimen shown in Photo 5 (a) is much wider than that shown in Photo 5 (b). Especially, carbonation yields along the crack on specimen treated with nothing. On the other hand, the specimen with cracking is protected by silicate-based surface impregnation, well. As shown in Fig. 11 and Photo 5, it is obvious that the effect of impregnation ban be judged by the specimen proposed us.

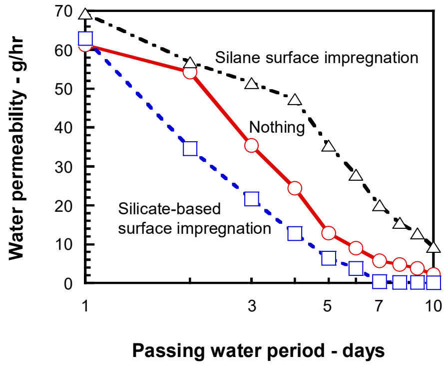

Fig.11. The example of water permeability test

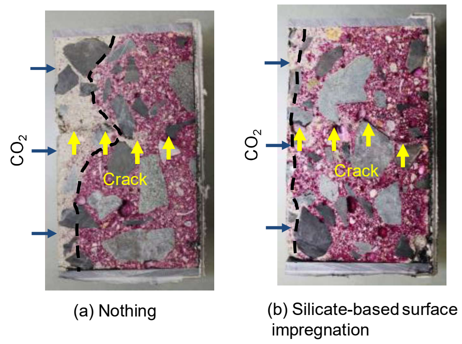

Photo 5. The example of carbonation test

Making way to concrete specimen with cracking out of existing structures

Fig.12 shows the making way to concrete specimen with cracking out of existing structures. Concrete core is hollowed out of existing structure by core drill whose inner diameter is 75mm (see Fig. 12 (1)). The concrete core is put in VU75 (inner diameter: 83mm, thickness: 2.7mm) standardized in JIS K 6741 whose one end is closed (see Fig. 12 (2)). The gap between PVC pipe and concrete core is filled with epoxy resin of low viscosity type (see Fig. 12 (3)). Hardened epoxy resin, concrete core in PVC pipe is cut to a height 5cm with PVC pipe (see Fig. 12(4)). The center part of specimen is used for test (see Fig. 12(5)). The specimen was put in transverse and applied load according to the splitting tensile strength test method (see Fig. 12(6). After crack is checked by visual observation, loading is removed. Fig. 12(7) is the specimen with cracking by using concrete core out of exiting specimen. This specimen can be used for water permeability test shown in Fig. 3 enough well.

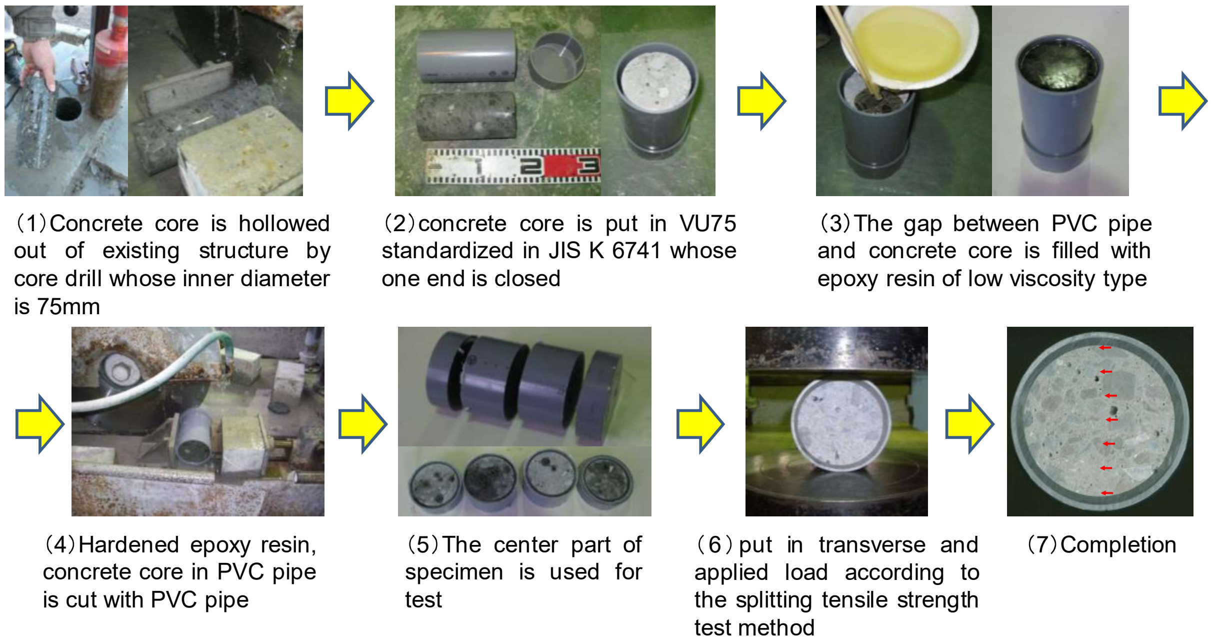

Fig.12. The making way to concrete specimen with cracking out of existing structures

CONCLUSIONS

1. By using PVC pipe, concrete specimen with cracking can be made. Crack width can be controlled by diameter and width of PVC pipe.

2. Air permeability is increased with the width of cracking of concrete.

3. Water permeability is independent of the width of cracking of concrete measured visually. It is affected by the condition of inner cracks.

4. The concrete specimen with cracking can be also made from concrete core out of existing structure.

5. When the concrete specimen with cracking is used, the effect of impregnation on carbonation water permeability and so on can be judged.

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