Effect of mix proportions and construction conditions on permeability properties of surface and internal concrete

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ABSTRACT

Reinforced concrete is exposed to environmental conditions which may lead to corrosion of reinforcing steel due to carbonation or salt damage. Durability against these factors is determined by the permeability properties of the concrete. It is generally believed that permeability properties are constant for both surface and internal concrete, but in reality the permeability may vary due to water-cement ratio, cement type, and curing conditions, so it is necessary to understand the effect of these variables on the permeability properties of surface and internal concrete. In this research, a new method for evaluating permeability properties by vacuum pump was developed. This method determines the permeability property based on concrete absorption area and change of weight. The results clarify the effect of the research variables on the permeability property. It was found that curing significantly affects the permeability of surface concrete, and the internal permeability increases as the water-cement ratio increases. For Portland blast furnace slag cement, the importance of curing period for improving the concrete permeability was clarified. Utilizing this examination method may allow for estimation of concrete mix proportions and construction conditions.

Keywords: permeability property, cement type, water-cement ratio, curing period

1. INTRODUCTION

In recent years durability of concrete structures has become more important for reducing life cycle cost. Generally, the diffusion coefficient, an indicator of durability and permeability of concrete, is considered constant in a concrete structure. However, it is believed that the diffusion coefficient at the surface is different than that inside concrete because surface and internal concrete properties differ depending on the water-cement ratio, bleeding property and drying conditions due to curing period. To improve durability against carbonation and salt damage, the influence of these durability factors should be understood.

There are some suggestions for concrete durability evaluation tests; however, those methods are not able to understand the difference between surface and internal conditions. Therefore, a method for easily evaluating the durability on both the concrete surface and interior is necessary. This research aims at the establishment of a permeability evaluation method for the concrete structure and tries to understand the influence of the factors mentioned above. The process of this research is as follows. From the first test, the influence of curing period on water-cement ratio on concrete permeability property was examined. Next, the influence of permeability property considering the difference between concrete surface and interior was evaluated. Finally, using these results the permeability of concrete exposed at a construction site was measured.

2. EXPERIMENTAL OUTLINE

2.1 Permeability test for uniform specimens (Step 1)

Table 1 shows the concrete mix proportions for the permeability test on uniform concrete. To understand curing period suitable for kind of cement, Portland cement and Blast-furnace slag cement which have many shares in the country were used. Materials for mixing were prepared and stored at 20℃ for 24 hours before casting. The test pieces were 100×100×50 mm beams. Figure 1 shows the curing method and period, and the total curing period was 28 days. The period of sealed curing was decided according to the Japan Standard Specifications for Concrete Structures (JSCE, 2007).

Table 1: Mix proportions (air permeability and Slump test)

cement	W/C	s/a	Amount of unit(kg/m^3)								SL	Air
	(%)	(%)	W	C	BFS	S	G	AE water reducing agent	AE	SP	(cm)	(%)
OPC	55	47	172	313	0	855	982	C*0.25%	C*0.02%		12.0	4.2
	45	45	172	382	0	792	987	C*0.25%	C*0.02%		14.5	3.9
	30	42	172	573	0	672	946			C*0.9%	21.5	5.8
BB	55	47	172	156	156	850	976	C*0.25%	C*0.02%		17.5	4.0
	45	45	172	191	191	786	979	C*0.25%	C*0.02%		18.5	4.3
	30	42	172	287	287	663	933			C*0.9%	64×62	4.6

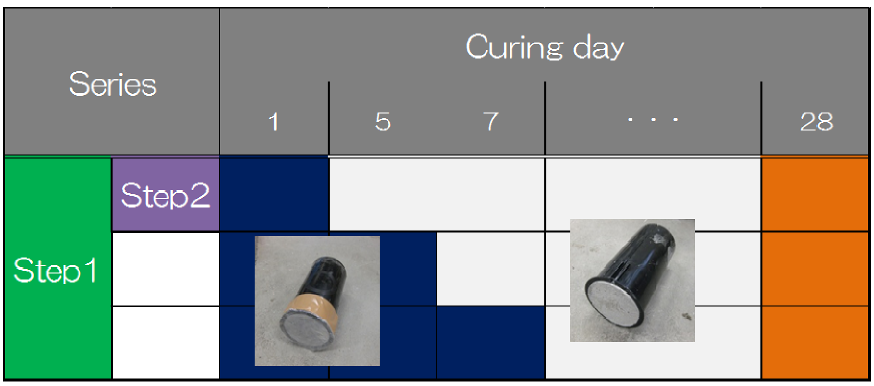

Figure 1: Relationship between curing method and curing period

2.2 Influence of depth in the permeability test (Step 2)

Concrete mix proportions are same as given in Table 1, and the specimens were cylinders ϕ 100 × 200mm. The specimen forms were removed after curing (Figure 1) to understand the relationship between permeability property and depth from surface of concrete. Tests were conducted 28 days after casting.

2.3 Method of permeability test

Figure 2 shows the method for the developed permeability test. After curing, specimens were dried in oven for one day and specimen sides were sealed by aluminum tape to protect from water penetration under vacuum conditions. These specimens were set in a container, and water was poured to half the specimen's height. Specimen containers were placed in a desiccator and vacuum conditions were applied by vacuum pump, which draws water up through the specimens. These specimens were then split in compression and the permeability was evaluated as the ratio of area which absorbed water. In Step 1, the permeability property was calculated as the ratio of water absorption area per all cross sections. In Step 2, it was calculated as the ratio of water absorption area per unit area in which all cross sections were divided into 1-cm segments.

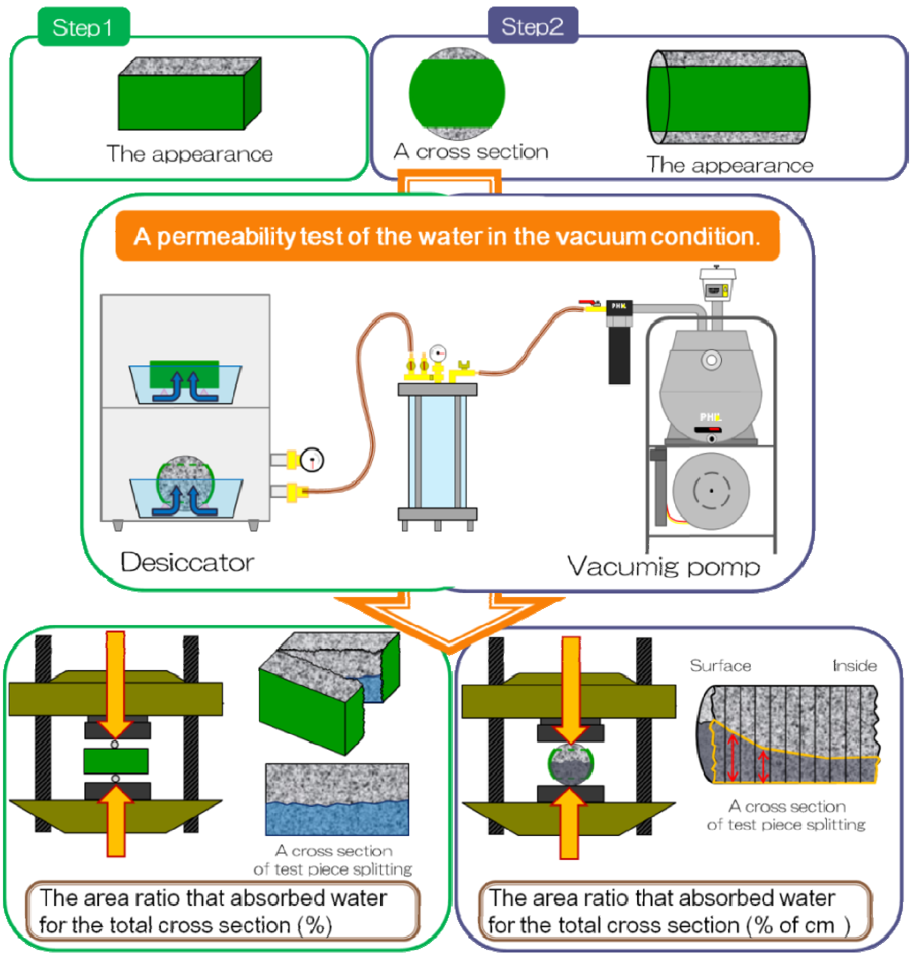

Figure 2: Method of permeability test

3. RESULTS AND DISCUSSION

3.1 Permeability test results for Step 1

Figures 3 and 4 show the results from the new permeability test. For both cement types, permeability property tends to decrease as water-cement ratio increases. In case of high water-cement ratio, the water which is not necessary for hydration increases, so the permeability property was greatly affected by outside condition of concrete. In the blast-furnace slag cement, the permeability property was higher than cement when the curing period was one day. However, permeability properties of both cement types showed a similar result when the curing period was seven days. It is believed that the pore structure changed due to the hydration velocity of the blast-furnace slag cement, which is slower than the Portland cement. These result showed that curing period is important to improve permeability property of surface concrete.

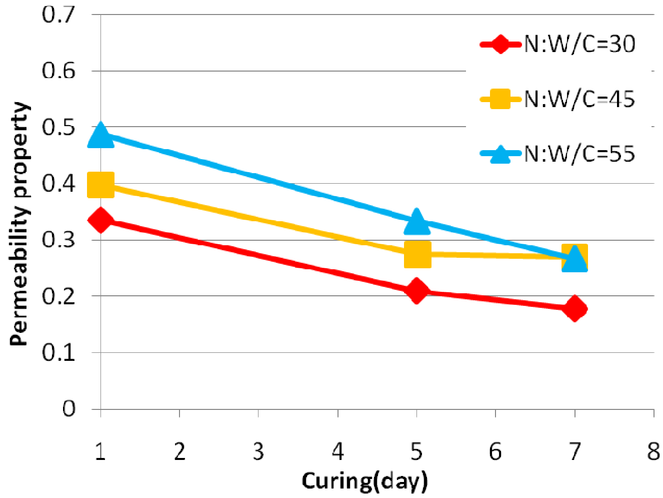

Figure 3: Relationship between permeability property and curing period (Portland cement : N)

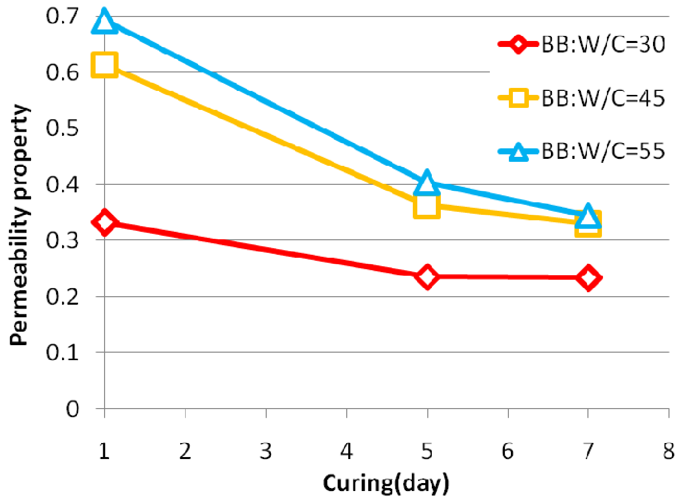

Figure 4: Relationship between permeability property and curing period (Blast-furnace slag cement : BB)

3.2 Permeability test results for Step 2

Figures 5 and 6 show the results of the permeability test for Step 2. Similar to the previous results, permeability property of both cement types tends to decrease as water-cement ratio increases. In addition, the permeability property of both ends of these specimens showed a tendency to become higher by drying from surface. The inflexion point at which the permeability property stopped changing is regarded as the curing influence area; this area (the shaded areas in the figures) for both cement types was about five centimeters. The difference in permeability in the flat area was regarded as the influence of the water-cement ratio because it is not affected by the external conditions. In both figures, the permeability property at both ends (the shaded areas in the figures) was different. It is believed that this difference is due to the difference between casting direction and water transportation direction.

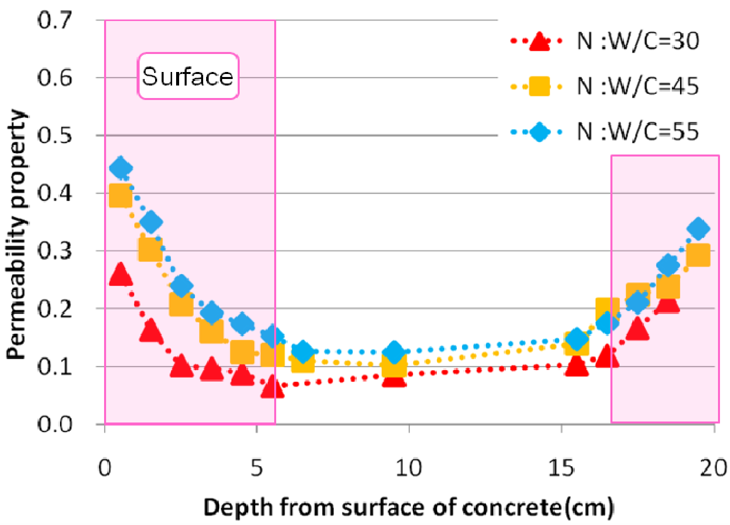

Figure 5: Relationship between permeability property and depth from surface of concrete (Portland cement : N)

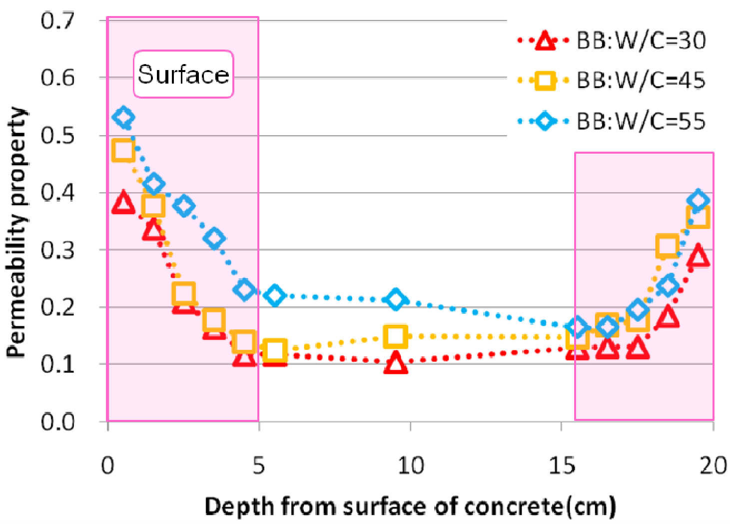

Figure 6: Relationship between permeability property and depth from surface of concrete (Blast-furnace slag cement : BB)

4. Application of the permeability test to on-site concrete

The results of Steps 1 and 2 were arranged in Figures 7 and 8 to examine the relationship between permeability property and the water-cement ratio, and the permeability of concrete exposed at a construction site was evaluated using these figures. The concrete information known before examination is as follows. The specimen was cast in ϕ 100×200 mm framework in a tunnel as shown in Figure 9. The upper end of the specimen was exposed on-site where it was located 30 meters from the tunnel entrance, and it was examined 30 days after casting. The specimen cement was blast-furnace slag cement. However, information such as the water-cement ratio and curing period was unknown, so these were predicted using the permeability test. Figure 10 shows the result of permeability test and an estimate of the water-cement ratio and curing period.

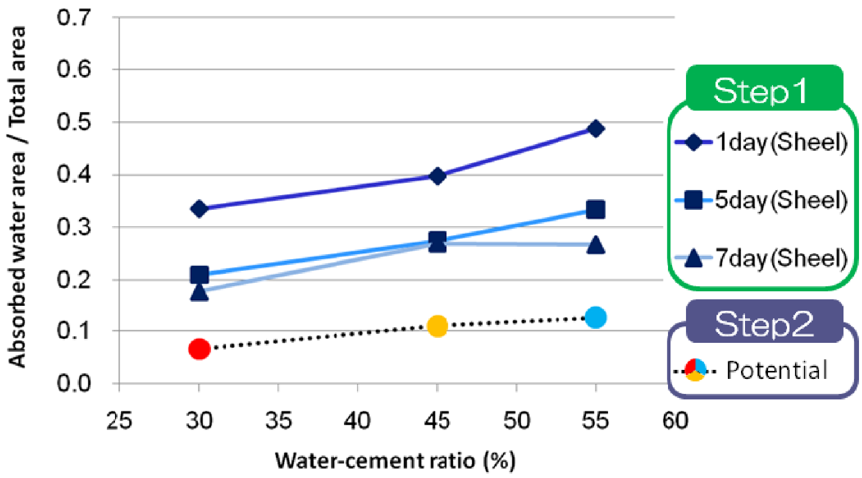

Figure 7: Relationship between permeability property and water-cement ratio (Portland cement : N)

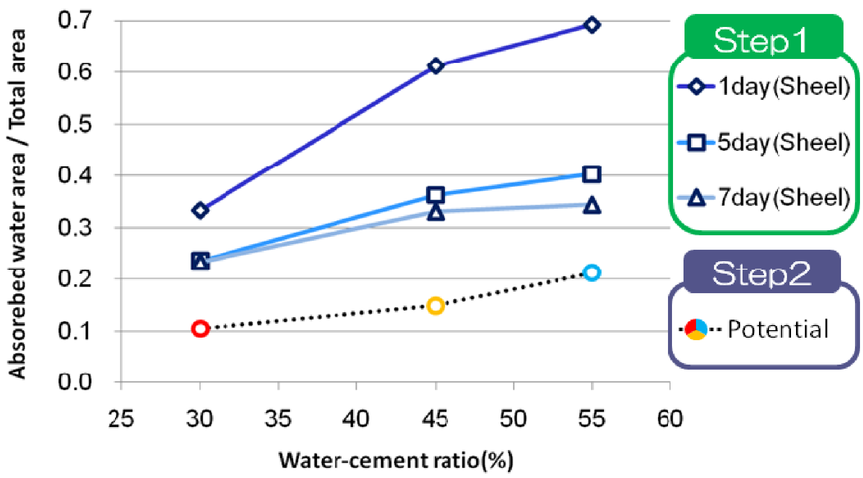

Figure 8: Relationship between permeability property and curing period (Blast-furnace slag cement : BB)

Firstly, the permeability property of internal concrete was compared with a test result of the potential (Step 2) and the water-cement ratio was estimated to be about 53% by the intersection point. Next, the permeability property of surface concrete was compared with the test result of Step 1, and the curing period was estimated to be between one and five days. After finishing the permeability test, the actual concrete information was received from the contractor. The water-cement ratio was 52.5% and curing period was two days, which demonstrates that this result showed that the permeability test can estimate these factors.

Figure 9: Tunnel where the specimen was cast

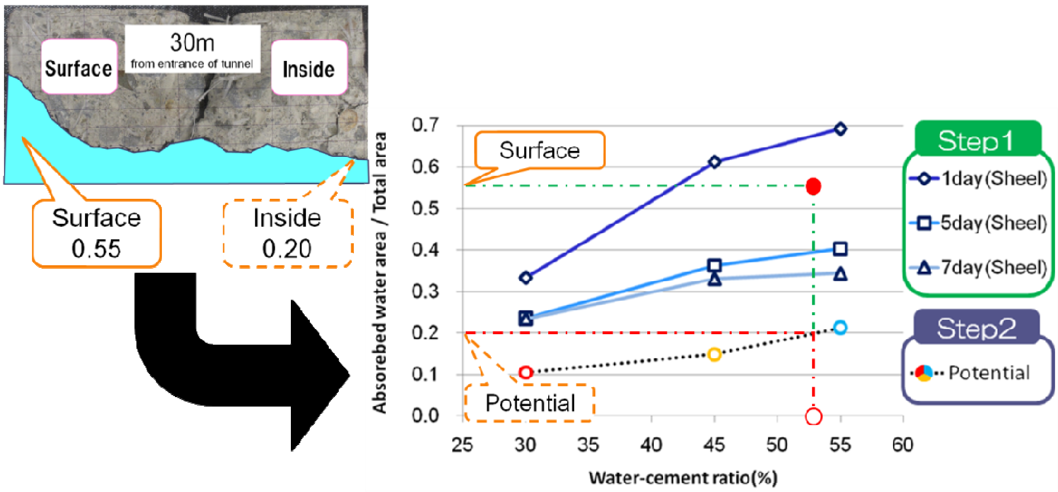

Figure 10: Result of permeability test and estimation method for water-cement ratio and curing period

5. CONCLUSION

This research aimed to establish a method for evaluating the permeability property of concrete structures, and also tried to understand the influence of durability factors. The conclusions of this study are as follows.

1. It was confirmed that the water-cement ratio and curing period had an influence on permeability property of surface and internal concrete.
2. It was clarified that the permeability property was greatly influenced by curing period. In this research, the original concrete properties could be estimated and the permeability property could be evaluated using the results from Steps

1 and 2, which examined the influence of curing time and difference between surface and internal properties. However, this estimation was only verified with one on-site specimen at this time.
3. In the future, it will be necessary to examine other types of cement and curing methods, and to increase the number of specimen in order to improve the precision of the method.

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