The 2018 Structures Congress (Structures18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Crack healing characteristics of centrifugal concrete pipe by Water permeability test

HaeSik Woo[1)], SungWon Yoo[2)], *Young Cheol Choi[3)] and SangHwa Jung[4)]

[1), 2), 3)] Department of Civil and Environmental Engineering, Gachon University, 1342 Seongnamdaero, Sujeong-gu, Seongnam-si, Gyeonggi-do, 13120, Korea
[4)] Construction Technology Research Center, Korea Conformity Laboratories, 199, Gasan digital 1-ro, Geumcheon-gu, Seoul, 08503, Korea
[3)] zerofe@gachon.ac.kr

ABSTRACT

Recently, many researches have been carried out to increase the service life of reinforced concrete structures, which are expensive to repair or hard to repair, by self-healing cracks and the like. Crack self-healing technology of concrete is important not only in material aspect but also in evaluation method. The water permeability test is the most widely used method to evaluate the self-healing performance of concrete. In this study, the correlation between initial crack width and permeability was investigated. The test results were analyzed with respect to the change of the crack width with time.

1. INTRODUCTION

Generally, cracks occur in reinforced concrete structures due to shrinkage, hydration heat, and external load. Cracks in reinforced concrete structures act as channels for harmful ions such as chlorine and sulfate. Penetration of harmful ions into the concrete causes deterioration such as corrosion of steel bars. As a result, the durability life of the structure is reduced (Ji et al., 2016). Therefore, the repair of the cracks occurring in the concrete structure increases the service life of the structure. Recently, due to the deterioration of many concrete structures, the cost of maintenance has increased, and the interest in self-healing technology that heals the cracks in the concrete structures has been increased (Huang et al., 2016).
In order to evaluate the quantitative self-healing performance of concrete, many researchers have used the water permeability test. The water permeability test is a relatively simple method to measure the flow rate through the crack space under constant hydraulic conditions. However, the water permeability test greatly varies the

---

[1)] Graduate
[2)] Professor
[3)] Associate Professor
[4)] Chief research engineer

amount of flow measured by the crack width. Also, it is quite difficult to experimentally generate a constant crack width for the same specimen. For this reason, it is difficult to objectively compare the self-healing performance of the combination of material variables.

In this paper, the self-healing mix proportions of centrifugal concrete are derived by blast-furnace slag powder, mineral admixture for high strength, crystalline admixture. The concrete specimens were manufactured by using centrifugal molding process. A water permeability test was performed to evaluate the self-healing performance. Crack closing test was also carried out through an optical microscope. For the quantitative comparison of the experimental results, the correlation between crack width and permeability was derived. Using the results, the water permeability test results were converted into the change of the crack width over time and the self-healing performance was analyzed.

2. EXPERIMENT METHOD

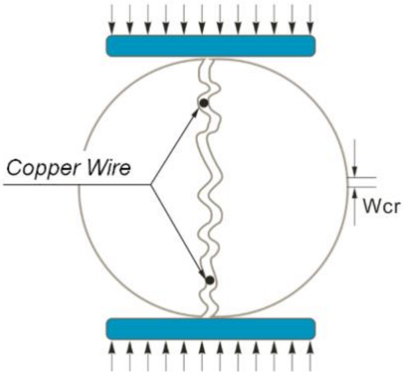
Table 1 shows the mix proportions of centrifugal molded concrete. To evaluate the crack self-healing performance of concrete, 30% replacement of blast furnace slag powder and crystalline admixture composed of anhydrite and Na_2SO_4 were used. In addition, PC600 was used to improve the strength of all variables, and a chemical admixture was applied at a binder weight ratio of about 0.8% to improve workability.

ID	W/B (%)	Unit weight [kg]						
		Water	OPC	GGBS	PC600	CA	S	G
Plain	49	2.9	5.9	-	-	-	13.5	22.1
S30	20	1.7	3.4	2.5	2.5	-	13.5	22.1
S30A5NS3	30	2.3	3.4	2.5	1.8	0.67	13.5	22.1

Table. 1 Mix proportions of centrifugal molded concrete

In case of adding blast furnace slag powder and self-healing mixture, the centrifugal molding process should be modified and the rotation speed (RPM) and rotation time (min) were important variables. In this study, optimum condition was derived based on the surface finishing condition of the centrifugal molded specimen.

The test specimens were cut to 100 mm in diameter and 40 mm in height, and water permeability test was performed. The water permeability test was carried out under constant pressure based on the method presented in Rilem TC 221. As shown in Fig. 1, cracks were induced by splitting tensile test. The specimen was completely separated into two pieces, and about 200 ㎛ copper wire was inserted into the crack surface to maintain the crack width. In order to prevent the change of the crack width during the test, the specimen was placed in a rubber ring, fixed with a steel clamp, and then subjected to a permeability test. The crack widths of specimen were measured by using optical microscope. The surface crack widths of the specimens were measured at 5 locations along the cracks and the average values were used.



(a) induced crack

(b) water permeability test device

Fig. 1 Parameters of centrifugal molding conditions

3. EXPERIMENT RESULTS

3.1 Correlation between initial crack width and permeability

In order to investigate the correlation between the initial crack width and the flow rate, the experimental results were used to compare the flow rate, specimen size, head difference, and flow time. The water permeability test results of centrifugal molded concrete and M. Roig-Flores et al., 2016 were compared. Based on the experimental results, the relationship between the initial crack width and the amount of permeability is shown in a graph (Fig. 2). The permeability used in the graph was modified by the permeability coefficient as shown in Equation (1).

$$k_e = \frac{Ql}{l_c ht} \tag{1}$$

Fig. 2 shows the initial surface crack width and the modified permeability coefficient according to the experimental results. As shown in Fig. 2, the initial crack width of the centrifugal molded concrete is 0.05 ~ 0.30 mm, and the flow rate is in the range of 0 ~ 0.024 mL/mm/min. In addition, M. Roig Flores et al., 2016 confirmed that the initial crack width was in the range of 0.05-0.55 mm and the permeability was in the range of 0-0.12 mL/mm/min. When the flow rate is relatively large even though the crack width is small, the apparent crack width is small, but the crack width in the specimen inside is large and the flow rate is large.

3.2 Change in permeability over time.

Fig. 3 shows the results of the water permeability test of the centrifugal molded concrete specimens. The measured permeability was expressed by the amount of permeability and the time through equation (1). The graphs for the combination of Plain formulation and S30 showed similar tendency to decrease in permeability and similar to the permeability at 0.004 mL/mm/sec at 28 days after curing. In the case of S30A5NS3, it was confirmed that the amount of water decreased sharply at 2 days of healing time, and the amount of water was close to 0 at 14 days of healing time.

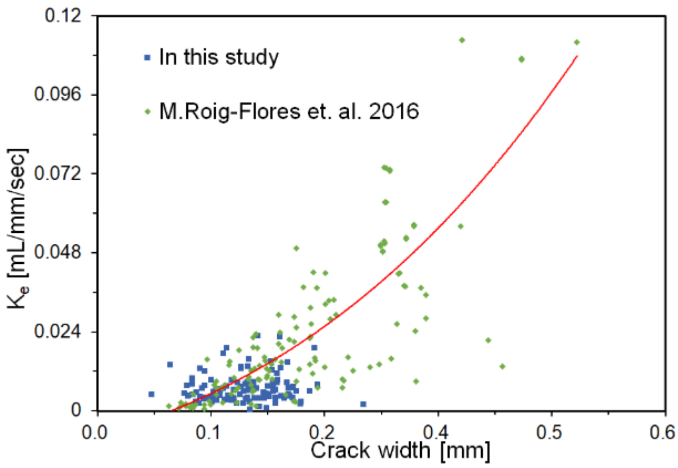
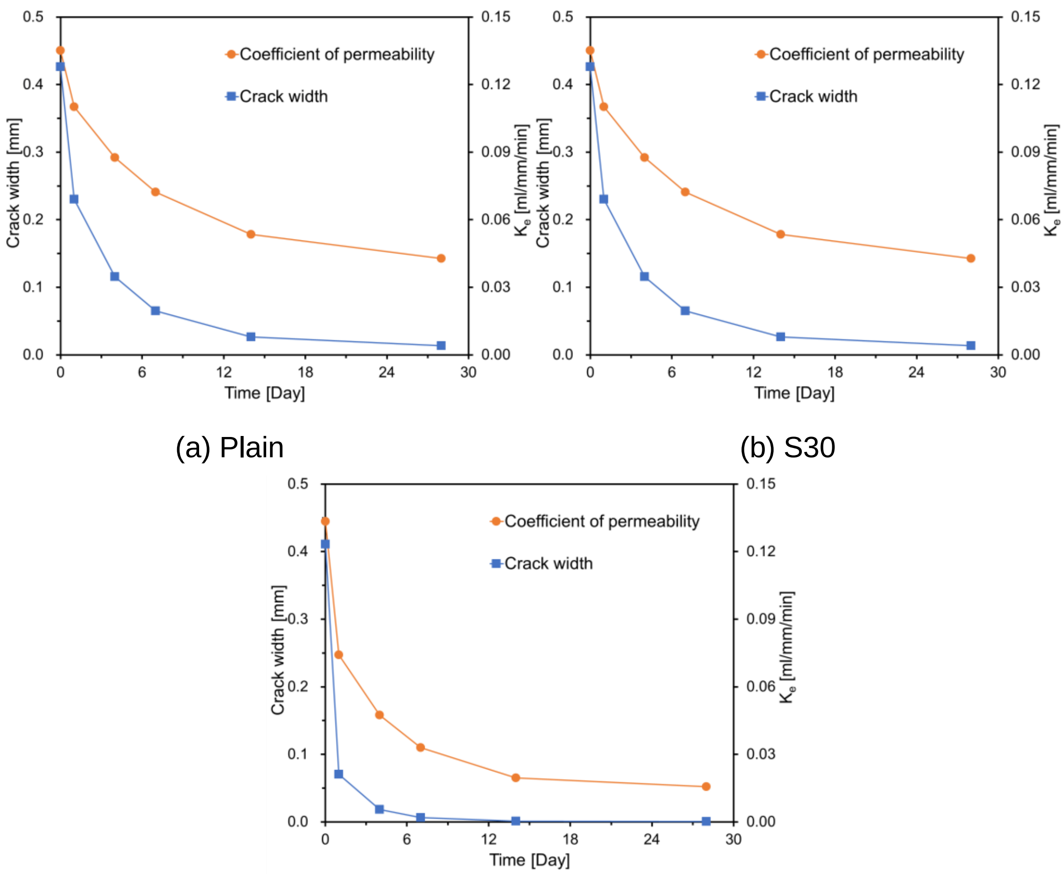


Fig. 2 Initial Crack width-K_e result



(a) Plain

(b) S30

(c) S30A5NS3

Fig. 3 Time-K_e results (Plain, S30, S30A5NS3)

4. CONCLUSIONS

In this paper, the crack self-healing performance of centrifugal molded concrete was evaluated by water permeability test. The experimental results are shown as the crack width over time. The results of this study are summarized as follows.

(1) When the permeability is larger than the initial crack width, it appears that the difference between the apparent crack width and the crack width in the specimen is large. In the evaluation of self-healing by the water permeability test, it is considered that the index other than the surface crack width of the specimen is necessary.

(2) In the case of Plain and S30, the water permeability test showed a similar trend, and the water flow decreased by 96% and 90% at 28 days of healing time.

(3) In the case of S30A5NS3, the amount of water decreased sharply in about 2 days, and on 14th day, the amount of water was 0, indicating that the crack was completely healed.

ACKNOWLEGEMENT

This research was financially supported by the Korean Ministry of Environment as “Public Technology Program Based on Environmental Policy” (2016000700003).

REFERENCES

Y. Ji, Y. Hu, L. Zhang and Z. Bao. (2016), “Laboratory studies on influence of transverse cracking on chloride induced corrosion rate in concrete,” Cem. Concr. Compos, 69, 28-37.

M. Otieno, H. Beushausen, M. Alexander. (2016), “Chloride-induced corrosion of steel in cracked concrete,” Cem. Concr. Res, 79, 373-385.

H. Huang, G. Ye, C. Qian, E. (2016), “Schlangen, Self-healing in cementitious materials: Materials, methods and service conditions,” Mater. Des, 92, 499-511.

Y. Abdel-Jawad, F. Dehn. (2005), “Self-healing of self-compacting concrete,” In: SCC2005 conference, Orlando, Florida, USA, 1023–1029.

Z. Zhang, S. Qian, H. Ma. (2014), “Investigating mechanical properties and self-healing behavior of micro-cracked ECC with different volume of fly ash,” Constr. Build. Mater, 52, 17-23.

T. Kishi, T.H. Ahn, A. Hosoda, S. Suzuki, H. Takaoka. (2007), “Self-healing behaviour by cementitious recrystallization of cracked concrete in corporating expansive agent,” Proceedings of the First International Conference on Self-Healing Materials, 18–20.

K. V. Tittelboom, E. Gruyaer, H. Rahier, N. D. Belie. (2013), “Influence of mix composition on the extent of autogenous crack healing by continued hydration or calcium carbonate formation,” Constr. Build. Mater, 37, 349-359.

S. Granger, A. Loukili, G. Pijaudier-Cabot, G. Chanvillard. (2007), “Experimental characterization of the self-healing of cracks in an ultra high performance cementitious material: Mechanical tests and acoustic emission analysis," Cem. Concr. Res, 37, 519–527.