

# An Experimental Study on Organic Hybrid Admixture with Properties of Early onset Self-healing

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## ABSTRACT

Alternative for crack repairing is an integral part for concrete structure because crack formation causes effect on shortening the durability life by deteriorated durability of structure. Researches on self-healing of crack as a measure for crack repairing have been conducted continuously from long time ago until today. Recently, many studies have been conducted to confirm and interpret simple self-healing phenomenon, and moreover, to define the mechanism and to develop and apply more improved self-healing technology based on the findings.

Self-healing phenomenon is of healing cracks in structure as remanent unhydrated cement materials in structure form calcium carbonate, a hydration product, through hydration reaction by inflowing moisture through cracks. The self-healing function needs to be maintained to get manifested continuously, but shortening the self-healing revelation time through promotion of early self-healing reaction is also important.

This study was intended for early onset of self-healing function by promoting control of calcium ionic elution and fiber-shape crystal formation that are essential in self-healing generation by using organic hybrid admixture to improve early self-healing function. It was identified that phosphate system admixture type of organic admixture improved 15% of calcium concentration of permeability water, and is possible to improve early self-healing function by checking fiber-shape healing products.

## 1. INTRODUCTION

In the construction field, it has been largely advanced in the size or type of the building structure through the development of building materials, and it has been improved through the development of technology and research on the concrete which occupies a large part in building structures, but it is in a situation in which various problems appearing in various parts. One of these problems is cracks occurring in the concrete structure. It can be a factor to cause a serious structural problem if cracks occurring in concrete structures are neglected. Not only the external damage, but also in the case of iron bar in concrete structures exposed to water through the cracked part, the corrosion of iron bar can happen by oxidation. And due to the expansion of iron bar, the damage of concrete structures and deterioration in physical function can appear [1]. For the alternative for this, self-healing which restores the cracked part in concrete by itself is receiving attention. And a number of researches on self-healing concrete are in

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progress. It began to be known in earnest, starting from an international conference for self-healing materials which held in Netherlands In 2007, and with the development of inorganic self-healing materials using expansive admixture and the development of application technology of self-healing concrete which applied this at the head, the research has been actively in progress [2]. Inorganic self-healing materials heals cracks generating calcium carbonate by permeability of water and by reaction with calcium ions elution[3,4] This self-healing capability of inorganic concrete secured a level of crack width of self-healing with in 0.3mm, self-healing time within 28 days, and the improvement of self-healing capabilities is needed.

Accordingly, this study conducted the research on the promotion of the calcium ion elution through the substituting application of organic material to mortar which mixed the inorganic self-healing materials to improve the self-healing performance of previous inorganic self-healing materials, and it evaluated the characteristics of mortar according to the organic material and self-healing capabilities of cracked parts.

## 2. Experimental Procedure

### 2.1 Experimental design and mortar test

In this study, applying exchange of 8% for the organic self-healing admixture in mortar contrasting to the binder was set as the plain, and the experiment for the condition of applying exchange of 5%, 15% and 30%, contrasting to the inorganic self-healing admixture according to types of an inorganic self-healing admixture was conducted. And for the characteristics of tasks for each condition, analysis on setting time, flow, compressive strength, self-healing property and the fine structure of self-healing products was conducted. Experimental formulations for applying exchange of self-healing admixture are seen in table 1 below.

Table 1. mortar used self-healing admixture

Items	OP CC (%)	B:S	W/ C (%)	Organic self-healing admixture(B)	Organic-inorganic hybrid self-healing admixture		characteristics
					organic(B)	inorganic(A)	
plain	92	1:1.5	52	-	-	8(8%)	Self-healing shape SEM EDS Setting time flow compressive strength(1,3,7,,2 8days) self-healing performance
A	92			microcrystallize	B(%):A(%) =0.4:7.6 (5% replace), 1.2:6.8 (15% replace), 2.4:5.6 (30% replace)		
B				Acrylic			
C				Phosphate base			
D				Fatty acid alcohol			
E				Alkali phosphate			
F				Crustacea sludge			

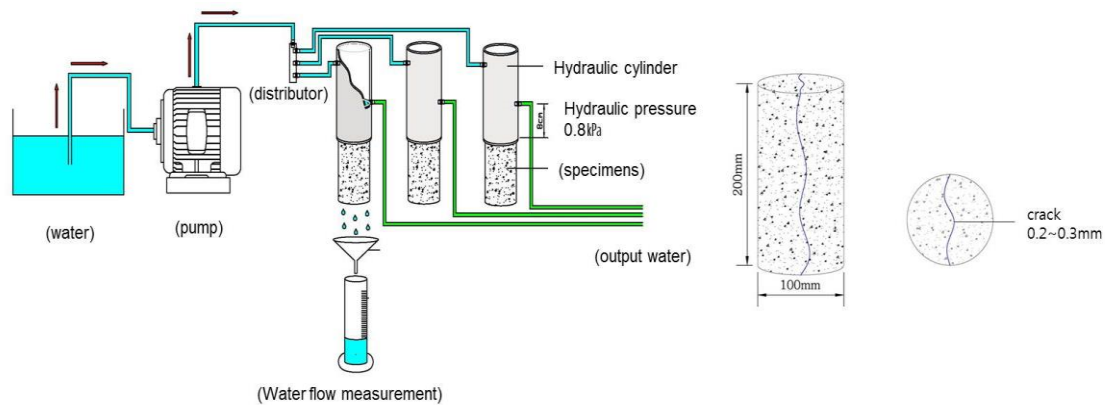


Fig. 1 Self-healing performance test

The experiment was conducted by composition of the mortar above, and the characteristics of fresh concrete was measured on the basis of KS F 2594, and the compressive strength according to aging day was measured based on KS F 2405, while conducting water curing ( $20 \pm 2$  °C) until the aging day after producing specimens. And water-flow test was conducted according to water-flow test method (Fig 1), and self-healing performance test through measurement of water permeability change. Also, changes in the calcium content among healing products according to applying exchange of organic self-healing material, through analysis on changes in elusion concentration of calcium ion and self-healing product through water-flow test, for the specimen which was molded mixing organic material suitable for hybrid self-healing admixture

### 3. Results and Discussion

#### 3.1 Setting time and flow

For setting properties and fluidity according to applying exchange 5~30% of organic self-healing material, A~F, A, B and F materials had the part which had the properties of setting time similar to the plain that mixed and applied only inorganic self-healing material, and in case of applying exchange of 30%, the setting time appeared to increase by more than 50 minutes. And in case of C material, shorter setting time than the plain could be confirmed for all, when applying exchange. In case of material A, B and F, the reactivity is low and the moisture absorption property is high, so the setting time of mortar appears to increase due to the gradual discharge of absorbed moisture. And material C was found to release heat due to the curing reaction of binder, and the setting time appears to be shortened due to this. As for the flow, initial flow was found to be possible to secure when mixing the material B, C and D, and the material A, E was shown to be greatly reduced in the initial flow due to the moisture absorption properties. After all, the material B, D found to be at the most appropriate level for the work characteristic for unconsolidated mortar when rate changes of substituting application was excluded.

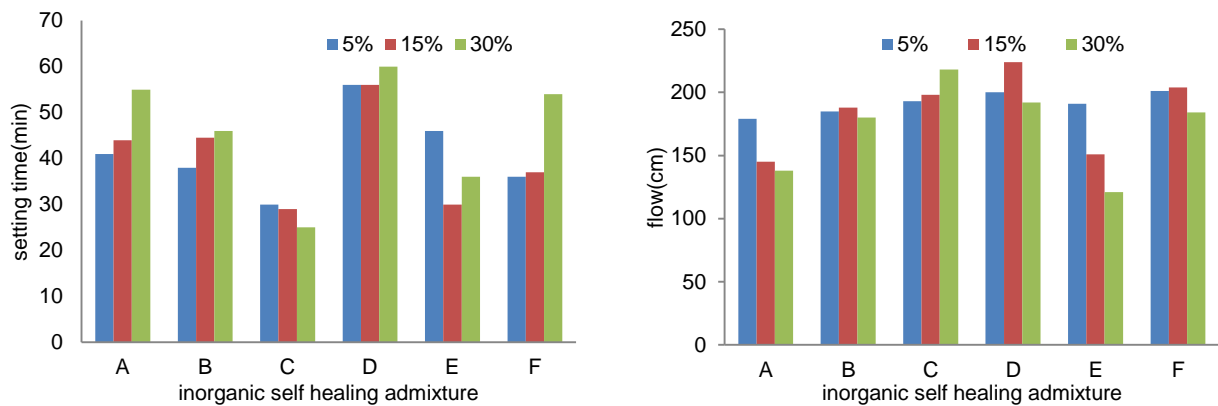
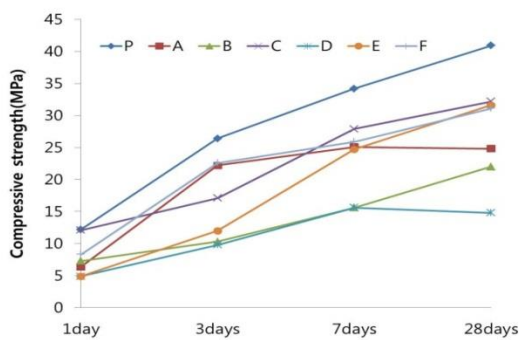


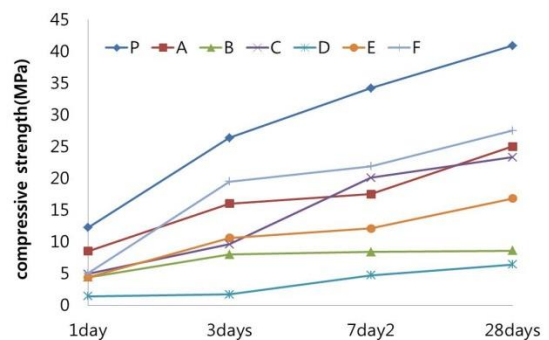
Fig. 2 workability with inorganic self-healing admixture type and replacement ratio

### 3.2 Compressive strength

Properties for compressive strength of mortar, according to applying exchange rate changes of the organic self-healing admixture, the material A~F was compared and evaluated according to the aging day(Fig 3). In case of applying 5% of applying exchange rate, there wasn't any big difference with the plain in the performance of compressive strength, so the result of the experiment was not recorded separately, and only the result of property evaluation for 15, 30% of applying exchange rate was illustrated. As in the result of the evaluation, as the applying exchange rate increased, the compressive strength decreased, and the strength decrease appeared to be more significant in the material B, D and E. Thus, the content amount according to the applying exchange of the weight is high because of characteristic of the material B of low importance, and strength decrease is found to be great for each applying exchange rate because reactivity is low. And for the material D, the fact that dispersion characteristic in water is low seems to be the cause in the nature of the characteristic of fat-forming element. The material E is determined to be the influence of decrease of



(15% organic self-healing admixture)



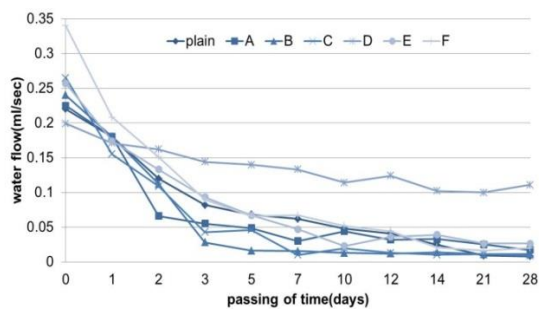
(30% organic self-healing admixture)

Fig. 3 Compressive strength according to organic self-healing admixture type and replacement ratio

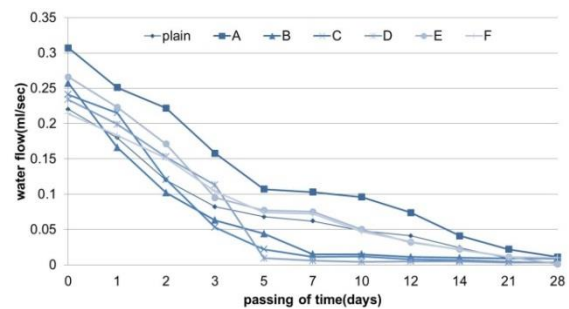
appearance of physical characteristics for cement binder because it was neutralized in the reaction process due to the phosphate composite. Relatively, as seen in the materials A, C which are low in the decrease of compressive strength, it seems to be advantageous in maintaining the physical performance according to applying material.

### 3.3 Self-healing characteristics

The change in self-healing performance for each aging day was compared and evaluated with the plain which applied only the inorganic self-healing admixture through the flow test after water curing the specimen produced according to types and change in mixing amount of inorganic self-healing material for 28 days, and after the optional micro fracture control process. As a result, when applying exchange of 15%, and in the norm of 28 days of water-flow process, the decreasing tendency similar to the result except for the material D was conformed, but cases of B and C showed the more excellent water permeability reducing properties than the plain in 12days after the water-flow. In case of applying 30% of exchange, the materials B,C,D showed more excellent properties than applying 15% of exchange as for the water permeability decreasing properties, and it appeared to be decreased greatly in water-flow amount at about 10~12 days after water-flow process.



(15% organic self-healing admixture)



(30% organic self-healing admixture)

Fig. 4 Flow rate according to organic self-healing admixture type and replacement ratio

### 3.4 Self-healing products analysis

In the experiment for the chance of water-flow amount according to the process of water-flow above, the analysis on the products of healing cracks was conducted for the specimen with high water permeability decreasing properties after water-flow process, and the result is shown in Fig 5 below. Self-healing product was found in the organic self-healing material B, C, E, F as following, but self-healing products couldn't be found in specimens of applying the material A,F. This is shown as the phenomenon of declining hydration reaction of unhydrated cement particle due to mixing of organic healing. And the healing product of the material B,C was confirmed to be in a shape of fiber, and as a result of the EDS analysis, host crystal of the material C was conformed to have the needle-like crystalline as seen in the photo. After all, in the case of producing the self-healing, precious inorganic material was cured by the crystalline material of calcium carbonate, but reducing effect of water-flow amount appeared larger

due to the connection between healing products by enabling the formation of healing products in fiber form through mixing the material, C.

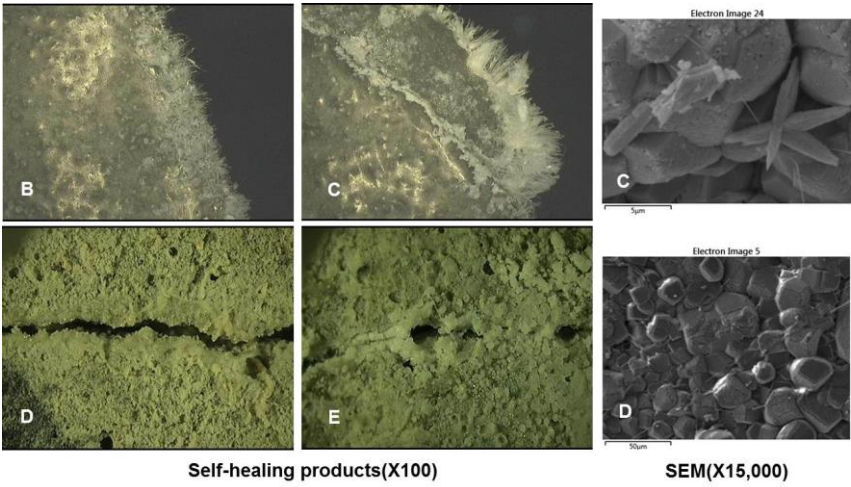


Fig. 5 Self-healing shape according to organic self-healing admixtures

EDS analysis was performed on the specimen which self-healing performance was expressed according to water-flow process, and the result is as follows (Fig. 6). In the case of the plain applying only conventional inorganic self-healing admixture, the content of calcium was conformed as 48.91% among healing products, and in the case of products according to applying organic material below, the calcium content was found to be 38.08% for the material B, 58.6% for the material C and 36.1% for the material F. Eventually, applying 15% of exchange of the material C among inorganic self-healing admixture was found to be effective for the improvement of calcium ionic property which is the major influence component of self-healing products through the analysis of healing products and calcium content was confirmed to be increased by 19.8% comparing to the plain.

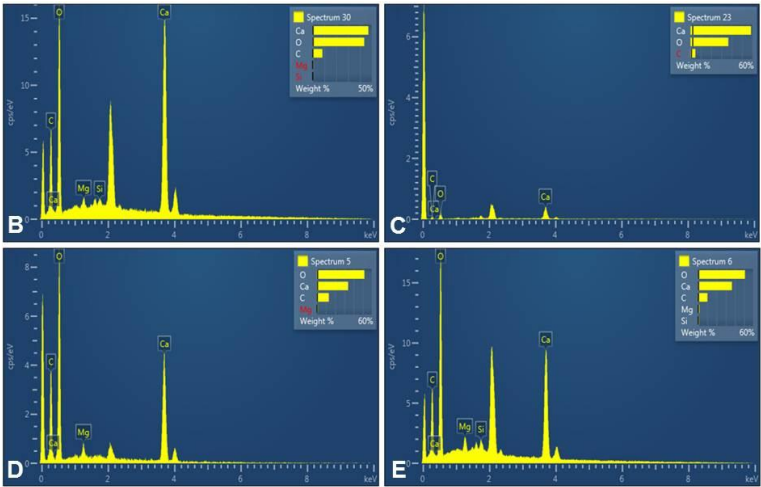


Fig. 6 EDS with Self-healing products according to organic self-healing admixtures



### 3.5 Calcium ion leaching characteristics

This experiment is to confirm the possibility of the improvement of self-healing property according to types of organic self-healing admixture and changes in applying exchange rate, and as the result of analyzing physical performance, work performance and self-healing performance, the condition of applying 15% of exchange for the material C was considered to be most appropriate. And for evaluating the possible part for reducing the self-healing time, the effect of the organic self-healing material C was confirmed by measuring the change in calcium ion concentration in flowing water according to the days after the water-flowing process as in Fig. 7. As a result, the calcium ion content in flowing water appeared to increase up to about 100h after water-flowing, and it appeared not to increase significantly repeated increases and decreases of the concentration after that. It is shown as the tendency of dramatically decreasing in water permeability up to the point of 5~7 days, similar to the previous decreasing tendency of water permeability.

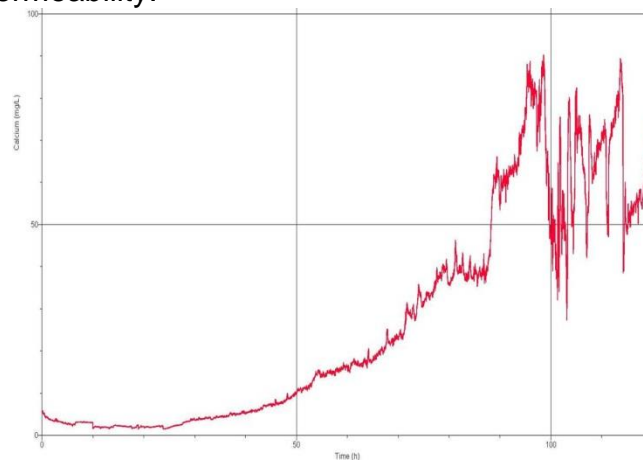


Fig. 7 calcium ion elution of specimen add on organic self-healing admixture

### 3. CONCLUSIONS

The result for evaluating the physical property and self-healing property of mortar according to types of organic self-healing comparing to inorganic self-healing admixture and changes in applying rate of exchange is as follows. As a result of comparing by the plain of applying 8% of previous inorganic self-healing admixture, appearance of self-healing performance was found to be possible within 10 days after applying 15% of exchange for organic self-healing admixture of phosphate system comparing to inorganic material. And as the result of analyzing the fine structure and the content, promoting the formation of self-healing products is confirmed to be possible due to the improvement of elution property of calcium. In addition, when forming the self-healing product, curing shape in a fiber form could be confirmed different from the inorganic material. And this becomes the chain type between products while creating healing, and self-healing property is considered to be excellent. But when mixing and applying organic material, it appeared to have lower property than the plain as for the compression strength and solidification time. After all, for the improvement of the physical performance and working performance, the additional research for

optimization of material through improving the property of the organic material is considered to be needed

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### **REFERENCES**

1. Dong-Cheol Park.(2013), "Water Permeability Resistance of Self-healing Concrete Incorporating Cementitious Expensive Materials", Korea Concrete Institute, v.25 n.2 2 1229-5515, 315-316.
2. Toshiharu Kishi, Tae-Ho Ahn, (20120), "Development of self-healing concrete and function of concrete cover", Self-Healing Concrete Technology international seminar, 18-29.
3. STAR 221-SHC (2013), "Self-Healing Phenomena in Cement-Based Materials", ISBN 978-007-6623-5
4. Bond, I. (ed),(2011) Proceedings 3<sup>rd</sup> International Conference on Self-Healing Materials, Bath, UK, 27-29 June 2011