STUDY FOR EFFECT OF SURFACE IMPREGNANT APPLYING FOR DETERIORATED CONCRETE

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ABSTRACT

It is necessary to prevent deterioration of concrete structures for extending the service life. The surface impregnant method is one of the methods for improving the durability of concrete structures. Many studies of impregnated materials with newly constructions have been conducted and studies on application to existing structures for maintenance and management have not been done sufficiently.
In this study, we studied 2cases. (1) The impregnated material was applied after curing. (2) The specimen was allowed to stand in a deteriorated environment for 6, 13, 17weeks, and then impregnated material was applied. Three types of impregnating materials were used silane-based impregnate for forming a water-repellent layer, lithium silicate based impregnating material which solidifies weak part, and sodium silicate based impregnate which forms insoluble crystals inside the pores and densifies the surface layer. For comparison with these three types of impregnating materials, mortar was also used as a general coating method. Test methods are accelerated carbonation test and salt water immersion test were performed. To make it an existing structure, accelerated carbonation test and salt water immersion test were carried out for 2weeks in advance.
As a result, both newly constructions and existing structures, it was found that the sodium silicate based impregnate was effective for accelerated carbonation and the silane based impregnate was effective for cholride ion penetration.
Keywords: Surface impregnant; Concrete; Durability; Maintenance

1. INTRODUCTION

To extend the life of reinforced concrete structures, it is necessary to prevent the deterioration of durability. Surface protection method is one of methods to prevent deterioration of durability of reinforced concrete structures. This can be divided into a surface coating method and a surface impregnant method. In the surface coating method, the covering material covers the concrete surface, thereby blocking penetration of deterioration factors. However, the covering material is damaged by external shock, ultraviolet rays or the like, so that the deteriorating factor permeates from the damaged portion and the effect of the surface coating method cannot be exhibited. Also, the surface impregnant method has two merits. The first is that construction can be done at low cost without detracting from the appearance of concrete. Secondly, it penetrates into the inside of the concrete, reforms the surface layer of the concrete and makes the water repellent, so the influence by the external environment becomes small. Various impregnating materials have been developed and studied so far. Many tests have been conducted to confirm the effect of the impregnating agent when it is used at the age of young aged of concrete considering its use for a newly constructed structure. However, there are not so many cases of investigations assuming the use of impregnants for existing structures. For example, it is a use for a structure whose deterioration has already advanced. In this time, we compare with the case where various impregnating materials (silane type, silicate type) are applied to concrete that has been deteriorated beforehand and applied to concrete not undergoing degradation action. And we will show the result of experimentally verifying the effect.

2. EXPERIMENT OUTLINE

2.1 Type of Impregnator Used and Overview of Specimen

Three types of impregnating materials were prepared for this study, referring to the concrete library published by Japan Society of Civil Engineers. The first is a silane-based impregnant (solventless solvent of alkylalkoxy-silane) that forms a water-repellent layer. The second is a lithium silicate-based impregnating material that solidifies fragile parts. The third type is a sodium silicate impregnating material (reaction type) which produces insoluble crystals inside the pores and densifies the surface layer. For comparison with these three types, cement paste (W/C=40%, ordinary portland cement) was also used as the inorganic coating method. A specimen of 10 * 10 * 10 cm was made of concrete with water cement ratio of 60% using ordinary portland cement. The next day, remove the mold. After that, it was exposed in a laboratory for 6days, it was cured in the air. After the curing was completed, epoxy resin was applied to the side of the specimen to open two faces. Incidentally, one of the two open surfaces was coated with an impregnant of the manufacturer's standard usage amount, and the other surface was treated as an uncoated surface, and the depth of deterioration was compared. The process after applying the epoxy resin was divided into three stages of (1) pre-deterioration (2) application of impregnant (3) post-deterioration, and carbonation acceleration test and salt water immersion test were conducted in steps (1) and (3). Then, as shown in **Figure 1.**, a specimen simulating a newly constructed structure and a test specimen simulating an existing structure were prepared and tested.

2.2 Accelerated Carbonation Test

The carbonation promotion test was carried out in an environment with a temperature of 20℃, a humidity of 60% and a CO_2 concentration of 5% with reference to JIS A 1153.

Measurement of the carbonation depth was in conformity with JIS A 1152. Phenolphthalein solution was sprayed. Calculated by measuring 6points at 15mm intervals with the discolored area as the average carbonation depth.

2.3 Salt Immersion Test

In the salt water immersion test, specimens immersed in salt water with a salinity concentration of 3% and a temperature of 20°C. After the age, these specimens were split. Thereafter, an aqueous

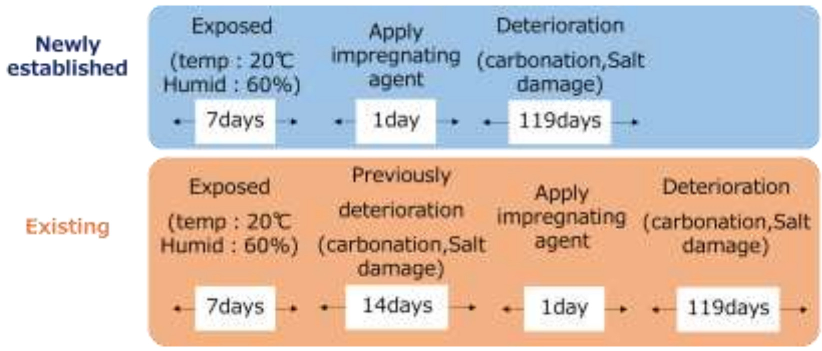

Figure 1. Process of test and curing, degradation environment

solution of silver nitrate was sprayed on the split face. The white colored part is defined as the depth of penetration into the salt, and the penetration depth is the same as in "2.2 Accelerated carbonation test". The age of the test material was the same for the degradation action period, and the carbonation and salt damage were newly established at 6weeks, 13weeks, 17weeks, and the existing was at 8weeks and 19weeks.

3. EXPERIMENT RESULTS

3.1 Application Effect of Surface Impregnated Material to New Construction

This test simulated a new construction. Impregnant materials and coating materials were applied to the specimens immediately after completion of curing. The test results of the specimens exposed to degraded environment are shown in **Figure 2.** (carbonation) and **Figure 3.** (salt damage). Both carbonation and salt damage showed at 17weeks of age. Carbonation showed that there was no significant progress in carbonation after 6weeks in any of the imbibed materials even if the material age had passed.

On the other hand, in paste coating, the carbonation depth is the smallest at 6weeks of age. Also, after 6weeks, the carbonation depth tended to increase. This means that it takes time to neutralize

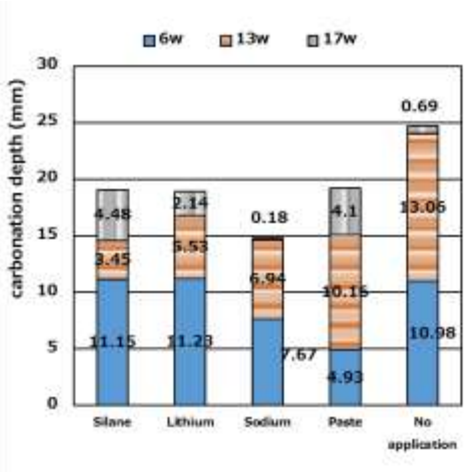

Figure 2. Newly established and corbonation promotion test results

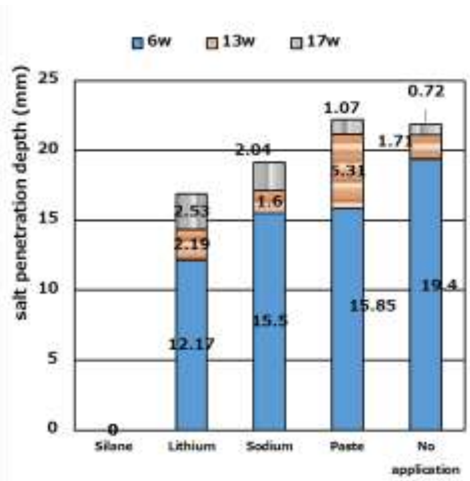

Figure 3. Newly established Salt water immersion test result

the coated part in paste coating, but after that, there is no carbonation inhibiting effect. Also, in the impregnating materials used in this study, the sodium silicate type showed the most carbonation suppressing effect. Next, in the case of salt damage, the penetration depth of the salt decreased ascompared with that without application with an impregnating material excluding the paste coating. In particular, the silane type impregnated material showed the highest suppressing effect. This may be because salt water did not penetrate due to the influence of the water repellent layer. The inhibition effect was also seen for lithium and sodium systems compared to without coating, and the paste coating was almost the same value as without application at the age of 17weeks.

3.2 Effect of Application of Surface Impregnated Material to Existing

Apply the impregnant material to the specimen that has been pre-deterioratated (10, 17mm) for 2weeks in an accelerated carbonation environment. After that, the test results of the carbonation depth advanced again by exposure to the accelerated carbonation environment are shown in **Figure 4.** With paste coating, progress of deterioration could not be confirmed until 9weeks from the end of pre-degradation. However, paying attention to the deterioration rate from 9weeks to 20weeks, degradation progresses by 11 to 14mm with no paste coating and no application. In addition, carbonation inhibiting effect in paste coating was not observed. The carbonation progression of the specimen coated with the impregnated material was about 4 to 6mm, which resulted in suppression of the rate of progress of deterioration. Among them, the sodium system showed the highest inhibition rate. It is thought that this is due to impregnant and modification of the sodium system up to the uncarbonate region. In the silane type and lithium type, the carbonation depth tended to increase after coating.

Next, **Figure 5.** shows the pre-deterioration by saltwater dipping for 2weeks. After that, the results of salt penetration depth which is immersed again in salt are shown. As a result of applying the impregnating material and the covering material after pre-deterioration, the penetration depth of the salt tended to increase with the lithium type and the paste coating as the deterioration period became longer as in the case without coating. On the other hand, in the case of silane type and sodium type, deterioration progress little from pre-deterioration is not seen. And, it showed a great suppressive effect. Therefore, it is considered that using a silane system forming a water repellent layer and a sodium system having a high reforming effect can be expected to have an effect on salt penetration when pre-degraded.

3.3 Study on Performance Evaluation of Impregnated Material

Tables 1. and Tables 2. show the rate of deterioration suppression by impregnant material and coating material application at 17weeks of age with carbonation and salt damage, respectively. The new construction is the depth of deterioration without coating, and the existing setting is the inhibition rate against the deterioration depth advanced by the post-degradation test without application. The silane type has the highest suppression rate against salt damage and the inhibition rate is low against carbonation. In addition, the new establishment has a higher inhibition rate in salt damage and carbonation compared to existing facilities. It is thought that this is because the internal state of the concrete affected the formation of the water repellent layer. Usually, a silane-based impregnated material is applied and the split surface is immersed in water, whereby the formed water-repellent layer can be visually confirmed. However, the water repellent layer could not be confirmed in the specimen which had been degraded in advance and simulated the existing one. After taking out the specimen from the salt water, it was dried for 1 day in an environment of 20℃. RH 60%. However, compared to the dry state of the surface layer, it is thought that water remained inside. In the lithium system, the deterioration suppression rate 1 was lower as compared with other impregnated materials. Since the lithium type solidifies by drying, it is necessary to keep the concrete in a dry state in order to develop the modifying effect. In the performance evaluation for salt damage in this research, we think that it was not always effective because it is always wet condition. In addition, it is necessary for study on carbonation suppression and spallation resistance to be combined with other construction

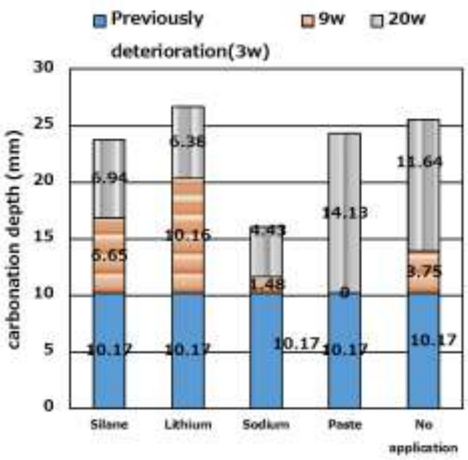

Figure 4. Existing Experimental results of accelerated cabonation test

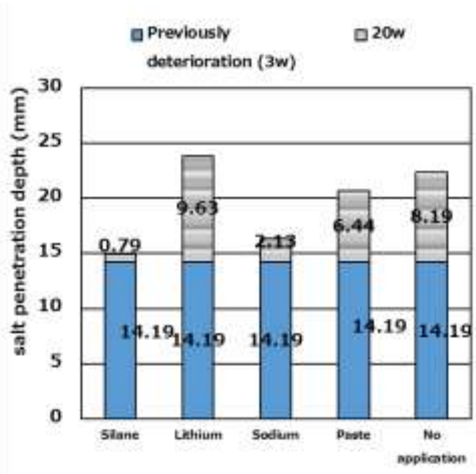

Figure 5. Existing Salt immersion test results

Table 1. Evaluation of impregnant performance against carbonation

	Silane	Lithium	Sodium	Paste	No application
Newly established	19.08	18.91	14.79	19.19	23.56
Suppression rate□	19%	20%	37%	19%	-
Existing	11.19	13.62	4.87	11.64	12.64
Suppression rate□	12%	-7%	62%	8%	-

Table 2. Evaluation of impregnant performance against salt damage

	Silane	Lithium	Sodium	Paste	No application
Newly established	0.00	16.89	19.14	22.23	23
Suppression rate□	100%	27%	17%	3%	-
Existing	0.65	7.93	1.75	5.3	6.74
Suppression rate□	90%	-18%	74%	21%	-

methods, etc., as stipulated by Japan Society of Civil Engineering [2]. In this research as well, it was low for carbonation. The sodium system showed great effect on both carbonation and newly established and existing. The sodium based impregnating material reacts with calcium hydroxide in the concrete to form C-S-H gel and has the function of densifying the voids. Originally, concrete has a large amount of calcium hydroxide, but when carbonation occurs, calcium hydroxide disappears. Therefore, it is considered that suppression by the sodium system is difficult in the existing specimen for carbonation. However, it showed a high suppression rate as a result.This is because the sodium based impregnating material penetrated even to the undeveloped region further behind the carbonation region where calcium hydroxide is deficient.

As a result, it seems that the effect of suppressing carbonation was demonstrated by reforming the uncarbonate zone. In addition, since the sodium type penetrates into the interior using water as a medium, it is necessary to keep it in a wet state immediately after coating. For this reason, existing test specimens with salt damage inside which moisture is present are considered to have impregnated the impregnant deeper and reformed to the deep part. The performance evaluation of carbonation and salt damage of each impregnating material and covering material is summarized in **Table 3.** based on the experimental results obtained by this study. It was confirmed that suitable impregnating materials differ depending on newly established, existing and degrading factors working from this.

Table 3. Performance evaluation of impregnated materials and coating materials

Silane	Water repellent layer can be formed both in newly established and exising.	Sodium	In the existing, the back of the neutralized area was reformed.
Lithium	There is not much suppressing effect on existing facilities.	Paste	Both the newly established and existing facilities fix degration factors and temporarily stop degradation progression.

4. CONCLUSION

The results obtained in this research are shown below.

(1) Regardless of newly established or existing, it was found that the effect of impregnating materials of sodium type in carbonation and silane type of salt damage is large.

(2) Silane type and lithium type showed great inhibitory effect by newly establishing. With the new construction and the existing construction, the sodium type and the paste coating were able to demonstrate the same suppressive effect.

(3) For applications to existing structures, it is thought that consideration is necessary for concrete with moisture inside even when the surface layer is dry. In the future, it is necessary to apply the impregnant material application method under such conditions and the method to judge the penetration depth of the impregnant material.

5. REFERENCES

Japan Society of Civil Engineers "Concrete Library 119 Surface Protection Method Design and Construction Guidelines" (2005)

Civil Engineering Society "Concrete Library 137 Design and Construction Guideline for Silicate Surface Impregnant Method (Draft)" 2012