Evaluation on Durability Improvement for Concrete Power Plant Facility Using Surface Penetration Supplement

Ki-Beom Kim, Jang-Hwa Lee, Jong-Suk Lee, and Do-Gyeum Kim

***Abstract*—The key factors which needs to be placed under consideration when preparing a contingency plan for aging degradation of concrete structures are that unlike steel, concrete is not as tightly bonded at the molecule level and is a porous material with many pore spaces making it vulnerable to salt damage, neutralization and other key factors to penetrate the surface and degrades the durability of the structure. Thus, the concept of a retrofitting and protection method for the concrete structure to improve its durability is to prevent degradation factors penetrating the concrete surface.**

***Index Terms*—Aging Factor, concrete absorption rate, concrete power plant facility, surface penetration supplement.**

I. Introduction

Most power plant structures- including the nuclear reactors- are constructed mainly out of concrete and are exposed to harsh environmental conditions as they are constructed near the sea. The establishment of an effective management method to prevent and counter aging degradation is very important in the perspective of life cycle management due to the characteristics of structures where complete replacement of problem sources is not possible.

When establishing a plan for aging degradation of concrete structures, the key focus should be on the fact that the molecule of concrete is not as tight as steel and is a porous material with many pore spaces making it vulnerable to salt damage, neutralization and other key factors to penetrate the surface and degrades the durability of the structure [1], [2]. Thus, this study aims to create a new application system geared toward the usage of new material base surface penetration supplements and the characteristics of power plants to protect the concrete structure from degradation factors and recover the capability of the structure.

Currently studies are being conducted both domestically (Republic of Korea) and internationally to develop a surface barrier to protect the concrete surface and the structure itself and a few products have been developed and are currently being used. These products, however, still contains many problems such as the limits of penetration, short lifespan, lacking the ability to improve the structure and more which needs to be addressed [3], [4]. In the case of the domestic market, all of the products used are unproven foreign products which are not living up to the standards in terms of quality when actually applied in the field. Thus, considering the importance and the growing needs of extending the life span and durability of concrete power generation facilities as well as major industrial structures, this field of study is at a point where research and development must be conducted at a national level.

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II. Experiment Study

A. Test Specimens

Test specimens manufactured in accordance to the following chart. Ready mixed concrete were used to create the specimens and concrete strength 24MPa and 35MPa has been used for the assessment [5].

The aggregate were to be smaller than 15mm, target slump at 10cm, and target air volume at 4.5±1.5%.

TABLE I: Mixing Ratio of Concrete

Strength of design	W/C (%)	S/a (%)	Unit Content(kg/m^3)			
			Water	Cement	Sand	Gravel
f_c=24MPa	48	46	178	370	771	891
f_c=35MPa	42	46	169	401	754	891

B. Absorption Rate Test

The specimen used for the absorption rate assessment was a 100×100mm test piece applied with the synthetic material. One side of the test piece was coated with epoxy and was air dried curing. The weight of the specimen was recorded for 7 days on a 24 hour interval. [6]

$$A = \frac{W_2 - W_1}{W_1} \times 100 \tag{1}$$

where A is absorption ratio, W_1 is specimen weight before absorption, W_2 is specimen weight after absorption.

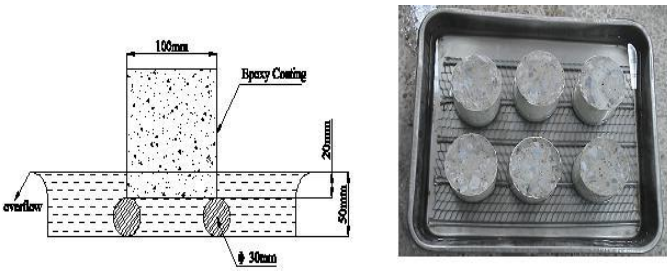

Fig. 1. Absorption Test.

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The specimen was taken out and dried of all surface liquid and measured to the 100th place and the results are as Fig. 1. The comparative absorption rate was measured as well.

C. Water Permeability Resistance

The specimen used for the water permeability assessment was a 200×200×100mm rectangle concrete test piece which was coated with the synthetic material and undergone the process of air drying curing for 3 days. Permeability measurement was conducted by using a German company's product GWT-4000kit. This device allows the measurement of water permeability without destroying the test piece.[7] As depicted in Fig. 2, water is inserted in the water filling cup up till the valve and then the surface of the concrete is sprayed in normal pressure followed by penetrating the concrete surface for 5 minutes with water a 1 Bar to test permeability.[8] The coefficient is calculated as the following. Also, a comparison has been made between the applied and non-applied concrete test piece.

$$C_{cp} = \frac{q}{P/L}[mm^2/\sec \cdot BAR] \tag{2}$$

where C_{cp} is water permeability coefficient, q is velocity of flow (mm/sec), P is atomospheric pressure (P= 1 bar), L is thickness of gasket(15mm).

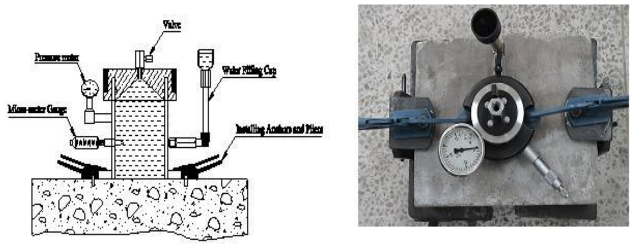

Fig. 2. Water Permeability Resistance

D. Air Permeability Resistance

The specimen used for the air permeability assessment was a 200×200×100mm rectangle concrete test piece which was coated with the synthetic material and undergone the process of air drying curing for 3 days. Permeability measurement was conducted by using a product from German company P's Permeability Tester, This device allows the measurement of water permeability without destroying the test piece.[9][10] As depicted in <Pic 3.23> air permeability is measured by measuring the changes of pressure within an air-tight container for 720 seconds which draws air out of the concrete.

The measured air permeability coefficient (K) can be calculated by the model theory proposed by Torrent. Also, the air permeability has been compared between the applied and non-applied test piece.

$$K = 4\left(\frac{V_c(dP_{1/dt})^2}{A(P_A^2 - P_I^2)}\right) \cdot \frac{\mu P_a}{\varepsilon} \int_{t_0}^{t} [1 - (\frac{P_I}{P_a})^2] dt \tag{3}$$

where K is Air permeability coefficient(Vc(m^2), dPI/dt is differential part of time t(Nm^{-2}s^{-1}), μ is air kinematic viscosity, Vc is inside volume of chamber(m^3), ε is porosity of concrete(m^{-3}), A is Area of contact with inside chamber(m^2), PI is pressure of inside chamber, P_a is atomosphere pressure(Nm^{-2})

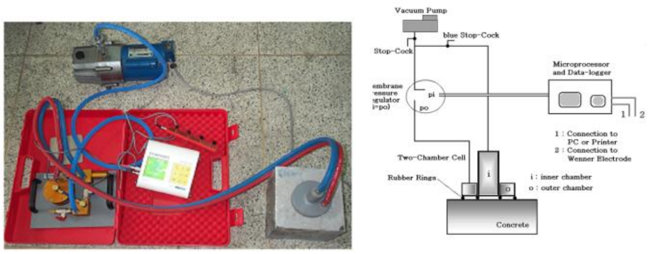

Fig. 3. Air Permeability Resistance

III. Result

A. Absorption Rate Test

Fig. 4 depicts the effects the synthetic material has on absorption rate. Regardless of the hardness of the basic test piece, test piece with the synthetic material showed greater effects in lowering the absorption rate andAcTe-1, AcTe-2 and AcU$_{cf}$ displayed the greatest results. As like the compression strength test, AcTe-1 and AcU$_{cf}$ prevents absorption by coating the surface of the concrete. AcTe-2 fills any gaps and strengthens the bond of the concrete structure to lower absorption.

TABLE II: Absorption Analysis of Synthetic Material(F_C=24MPa)

	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcU$_{cf}$	TeaU$_{cf}$
Absorption (%)	0.96	0.05	0.17	0.62	0.65	0.2	0.68
Ratio	1	0.05	0.18	0.64	0.68	0.21	0.71

TABLE III: Absorption Analysis of Synthetic Material(F_C=35MPa)

	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcU$_{cf}$	TeaU$_{cf}$
Absorption (%)	0.82	0.04	0.14	0.52	0.55	0.17	0.59
Ratio	1	0.05	0.17	0.63	0.67	0.21	0.72

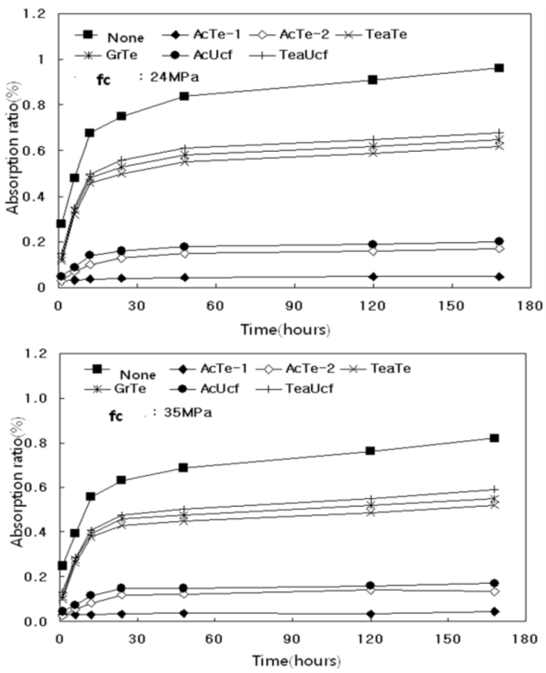

Fig. 4. Absorption ratio result

Table IV and Fig. 5 are the results of testing the water absorption level for each different synthetic material after conduct 168hours of concrete absorption rate assessment. As a result base test pieces showed a absorption depth of 37~56mm while test pieces with AcTe-1, AcTe-2 and AcU_{cf} applied showed significantly lower values.

TABLE IV: ABSORPTION DEPTH RESULT(MM)

	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcU_{cf}	$TeaU_{cf}$
f_{ck}=24MPa	56	2	3	15	25	5	23
f_{ck}=35MPa	37	2	3	9	18	4	18

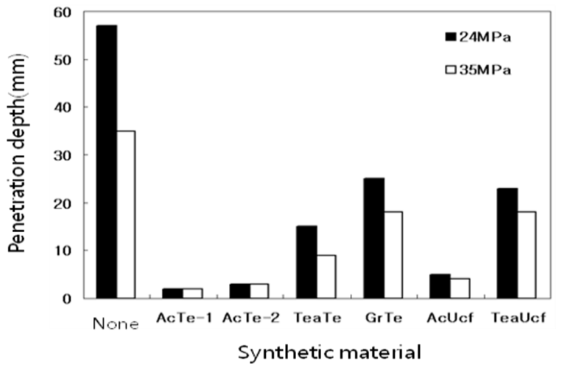

Fig. 5. Penetration depth

B. Water Permeability Resistance

Fig. 6 depicts the effects the synthetic material has on permeability coefficient. Regardless of the hardness of the basic test piece, test piece with the synthetic material showed a much lower permeability coefficient, and AcTe-1, AcTe-2 and AcU_{cf} showed greater effects in decreasing the permeability coefficient. As like the previous tests, AcTe-1 and AcU_{cf} prevents the penetration of moisture by coating the surface of the concrete. AcTe-2 fills any gaps and strengthens the bond of the concrete structure to lower permeability coefficient.

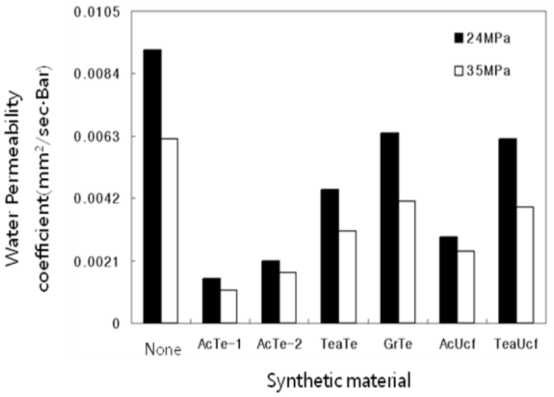

Fig. 6. Water Permeability Coefficient

TABLE V: WATER PERMEABILITY COEFFICIENT OF SYNTHETIC MATERIAL(F_C=24MPA)

Water Permeability	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcU_{cf}	$TeaU_{cf}$
Coefficient	0.0092	0.0015	0.0021	0.0045	0.0064	0.0029	0.0062
Ratio	1	0.16	0.22	0.49	0.69	0.32	0.67

TABLE VI: WATER PERMEABILITY COEFFICIENT OF SYNTHETIC MATERIAL(F_C=35MPA)

Water Permeability	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcUcf	TeaUcf
Coefficient	0.0062	0.0011	0.0017	0.0031	0.0041	0.0024	0.0039
Ratio	1	0.18	0.27	0.50	0.66	0.38	0.63

C. Air Permeability Resistance

Fig. 7 depicts the effects the synthetic material has on air permeability coefficient. Regardless of the hardness of the basic test piece, the test piece with the synthetic material showed a much lower air permeability coefficient and AcTe-1, AcTe-2 and AcU_{cf} showed greater effects in decreasing the permeability coefficient. As like the previous tests, AcTe-1 and AcU_{cf} prevents the penetration of moisture by coating the surface of the concrete. AcTe-2 fills any gaps and strengthens the bond of the concrete structure to lower permeability coefficient.

TABLE VII: AIR PERMEABILITY COEFFICIENT OF SYNTHETIC MATERIAL(F_C=24MPA)

Air Permeability	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcUcf	TeaUcf
Coefficient ($\times10^{-16}$ mm^2)	2.45	0.25	0.37	1.25	1.92	0.61	1.88
Ratio	1	0.10	0.15	0.51	0.78	0.25	0.77

TABLEVIII: AIR PERMEABILITY COEFFICIENT OF SYNTHETIC MATERIAL(F_C=35MPA)

Air Permeability	None	AcTe-1	AcTe-2	TeaTe	GrTe	AcUcf	TeaUcf
Coefficient ($\times10^{-16}$ mm^2)	1.76	0.19	0.28	0.98	1.54	0.49	1.59
Ratio	1	0.11	0.16	0.56	0.88	0.28	0.90

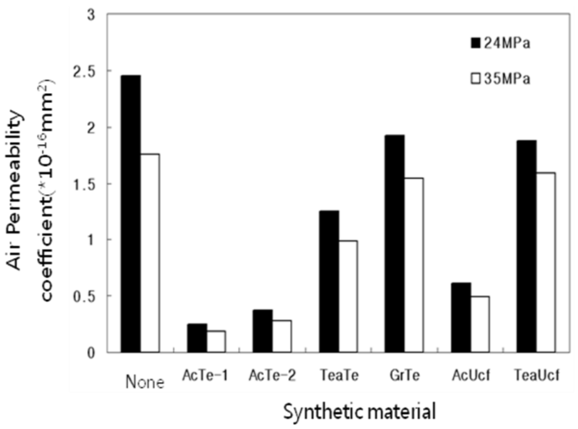

Fig. 7. Air Permeability Coefficient

IV. CONCLUSIONS

Structure absorbability, water permeability, air permeability has been measured to assess concrete adaptability

1) The assessment can conclude that synthetic material AcTe-2 is most viable for the development of the penetration reinforcing agent
2) In the case of AcTe-2, under circumstance where the pressure strength is low more pores occur within the concrete. By applying the synthetic material these pores are filled and ultimately lowering the permeability coefficient
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