- Technical Paper -

EFFECT OF MOISTURE CONTENT ON SURFACE WATER ABSORPTION TEST AND AIR PERMEABILITY TEST

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ABSTRACT

The effects of moisture content on Surface Water Absorption Test (SWAT) and on Torrent air permeability test were investigated. Three mix proportions of concrete and three kinds of curing conditions were provided. Water absorption resistance p_{600} and air permeability kT showed almost constant values when moisture content was lower than a kind of threshold value . The threshold values in moisture content measured by two moisture meters were exhibited respectively both for water absorption and air permeability.

Keywords: SWAT, air permeability, moisture content, relative humidity (R.H.), covercrete quality

1. INTRODUCTION

Water absorption and gas permeability of covercrete are always one of the biggest concerns from the viewpoint of the durability of concrete structures. Water absorption and gas permeability of covercrete are affected not only by porosity of concrete, but also by several factors. Moisture content is one of them [1]. The change of moisture content caused by ambient wetting and drying has a considerable effect on absorption and permeability of covercrete.

There have been many methods to measure water absorption of covercrete. Surface Water Absorption Test (SWAT) device developed by the authors [2], [3] is used in this research. A non-destructive air permeability test developed by Torrent [4] is also used. It has been pointed out in previous studies that when surface moisture of covercrete measured by CMEX-II is over 5.5%, the results of air permeability become small which will cause overestimating of air permeability resistance [5]. However, the number of research works related to the effects of moisture content on water absorption and gas permeability is so much limited.

The objective of this present study is to investigate the effects of moisture content of covercrete on water absorption and air permeability. Concrete specimens with three kinds of mix proportions will be cured in different R.H. conditions, and the moisture content, resistances against water absorption and air permeability will be measured.

2. MEASURING DEVICES

2.1 SWAT

SWAT is a fully non-destructive test developed by Hayashi and HOSODA [2], [3]. It consists of a water cup with a graduated tube, as shown in Fig.1. From the measured absorption data, p_{600}, defined as the rate of water absorption at 10 minutes (600 seconds) after the start of measurement, is calculated in ml/m^2/s. The authors have proposed two threshold values for evaluating covercrete quality as shown in Table 1 [2], [3].The amount of absorbed water in 10 minutes can also be an index to evaluate the resistance against water absorption.

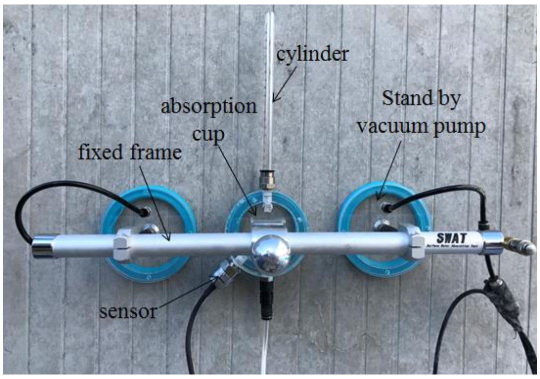

Fig.1 SWAT device

Table 1 Grading of covercrete quality by SWAT

Water absorption rate at 600 seconds	Quality		
	Good	Ordinary	Poor
p_{600}(ml/m^2/s)	0.25 or under	Over 0.25 and 0.5 or under	Over 0.5

2.2 Torrent permeability tester

Torrent permeability tester is used in this research, and kT, coefficient of permeability in m^2 units is obtained. Grading for evaluating covercrete quality shown in Table 2 has been proposed [4].

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Table 2 Classification of the quality of the “covercrete” based on the Coefficient of Air Permeability *kT*[4]

Quality	Excellent	Very good	Fair	Poor	Very Poor
Coefficient of Air permeability $kT(10^{-16}m^2)$	<0.01	0.01-0.1	0.1-1	1-10	>10

Table 3 Mix proportion of concretes

Max. aggregate (mm)	Slump (cm)	Air (%)	W/C (%)	s/a (%)	Mix compositions(kg/m^3)					
					W	C	Fine aggregate	Coarse aggregate	Admixture	
									[1]Ad	[2]AE
20	12	4.5	40	45	160	400	777	634	4.4	0.8
20	12	4.5	50	47	160	320	841	685	3.2	0.64
20	12	4.5	60	48.5	160	267	890	682	2.67	0.53

[1]Ad: Water reducing admixture, [2]AE: Air entraining agent

It is has also been proposed that Torrent results can be adopted when the surface moisture content measured by CMEX-II device is 5.5% or less [5].

2.3 Moisture meters

In this research, two kinds of moisture meters are used to measure moisture content of concrete at the surface of the specimens. One of them is CMEX-II, a capacitive sensing method. The other is HI-520-2, a radio frequency capacity method.

3. EXPERIMENTAL PROCEDURES

3.1 Materials and mix proportions

Ordinary Portland cement was used to make 27 rectangular specimens in total. Three kinds of mix proportion shown in Table 3 were provided. Coarse aggregate used for mixing had maximum diameter Ø20mm. Air content of the concrete was around 4±0.5%. The specimen can be seen in Fig.2.

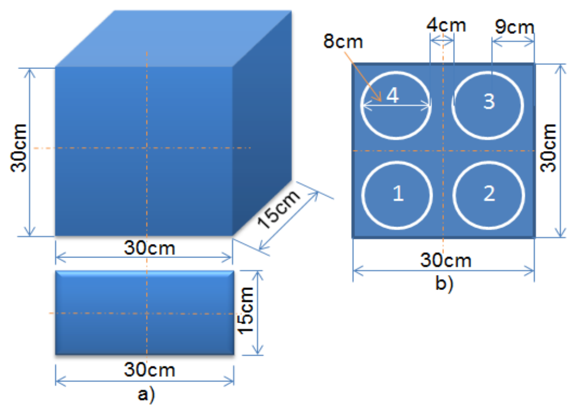

Fig.2 a) Specimen, b) Measurement locations

3.2 Curing conditions

Three kinds of curing conditions were provided for preparing the specimens in this research as follows. All the specimens were placed in the curing room. In the curing room, the temperature was set at $(20\pm1)^0$C and the R.H. was set at (60±2)%.

(1) Formwork was removed at one day after placing. After that, the specimens were exposed in the curing room.

(2) Formwork was removed at seven days after placing. After that, the specimens were exposed in the curing room.

(3) Formwork was removed at one day after placing. After that, the specimens were cured in water of $(20\pm1)^0$C for six days (the age of concrete was seven days). Then, the specimens were exposed in the curing room.

Three same specimens were made for three kinds of curing conditions explained above (nine specimens). Nine specimens were made for three kinds of mix proportion (totally 27 specimens).

3.3 Different environmental conditions for producing different moisture conditions of the specimens

At the age of over 60 days, testing of 27 specimens was started. The process of testing is as follows

Nine groups of specimens were provided (three mix proportions, three curing conditions). In each group, three same specimens were moved into three different environmental conditions for one or two days. The first specimen was kept in the curing room at $(20\pm1)^0$C and (60±2)% R.H. The second was moved to a room where R.H. was 80±2% and the temperature was $(20\pm1)^0$C. The last one was moved to a room where R.H. was 99.9% and the temperature was $(20\pm1)^0$C. The Experimental procedures can be seen in Fig.3.

3.4 Water absorption and air permeability test

SWAT and Torrent air permeability test were conducted for all specimens one or two days after they had been moved in three different environmental conditions. Some specimens were stored in those environmental conditions for two days so that moisture contents measured by moisture meters were sufficiently varied. SWAT and Torrent air permeability measurements were basically conducted at 4 points on both sides of the specimen as shown in Fig.2b.

Before conducting SWAT and Torrent test, moisture content was measured at the surface of each measuring points as explained above. Moisture content was measured by two moisture testers, CMEX-II and HI-520-2.

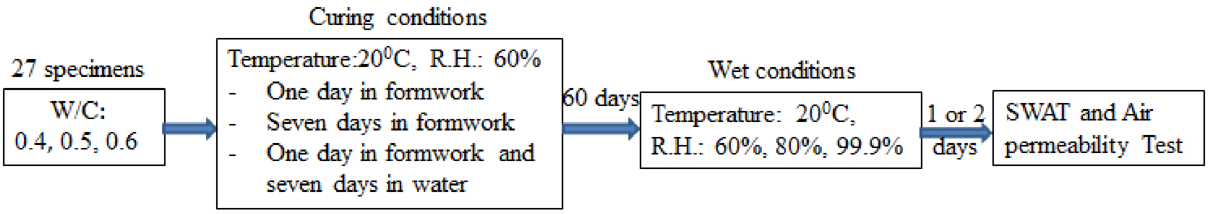

Fig.3 Experimental procedures

After measuring the moisture content, Torrent test was conducted. SWAT was implemented at the same measurement points at least 20 minutes after Torrent test. Waiting for 20 minutes is sufficient for inner pressure of concrete to come back to the original state before conducting Torrent test [6].

4. RESULTS AND DISCUSSIONS

After finishing curing of specimens for more than 60 days as preceding sections, the specimens were moved into humid rooms (R.H. 99.9%, 80%, and 60%) and measurements were started. At one day after the specimens were moved into the humid rooms, measurements were conducted at the one side of the specimen. At two days after the specimens were moved, measurements were conducted at the other side of the same specimen. Totally, measurements were conducted at 8 points in a specimen.

In this paper, due to the limitation of space, all the measured data cannot be explained. Among nine kinds of specimens (three W/C ratios, three curing conditions), six kinds of specimens were selected so that the effects of moisture content could be clearly explained. The measured results in those six kinds of specimens are exhibited in Figs.4-9.

4.1 General Trend

As can be seen in Figs.4-9, water absorption and air permeability showed smaller values (p_{600} and kT) in higher moisture content. It seems in each graph that p_{600} and kT showed almost constant values when moisture content is lower than a kind of threshold value. The moisture meter CMEX-II seems to show larger variation in measured moisture content than HI-520-2.

In this research, two moisture meters were used. The authors have not clarifed the characteristics or effective depths of these moisture meters (which depth in concrete is measured), and the environmental conditions for specimens are limited in this research, Therefore, the authors will not propose a kind of threshold value of surface moisture content for appropriate measurement of SWAT and Torrent air permeability.

4.2 Surface Water Absorption Test

When we see the results of SWAT in 6 kinds of specimens, p_{600} seems apparently smaller when the moisture content measured by CMEX-II is higher than around 6.0%.

On the other hand, when the moisture content was measured by HI-520-2, p_{600} showed apparently smaller values when the moisture content was higher than around 5.0%.

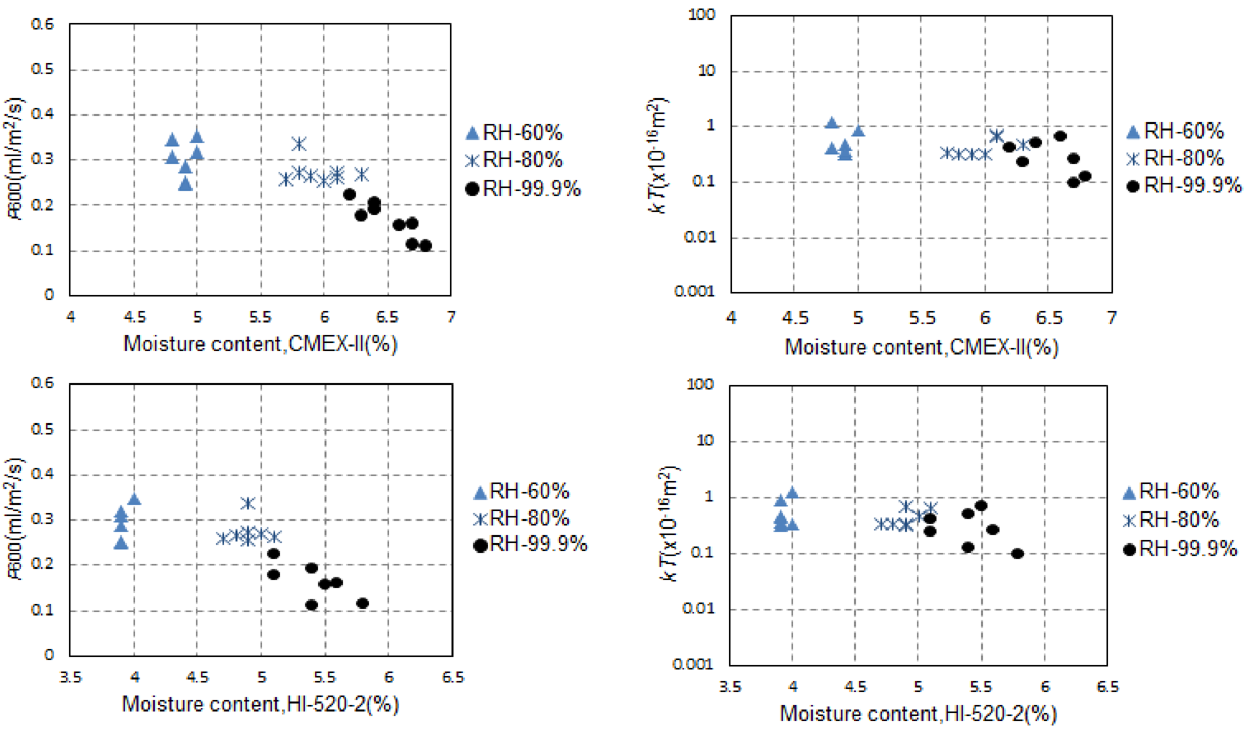

Fig.4 Water absorption and air permeability results (W/C= 40%, sealed for one day)

4.3 Torrent Air Permeability Test

From Figs.4-9, we can see that beyond around 6.0% in moisture content measured by CMEX-II, *kT* showed smaller values. At present, 5.5% in moisture content measured by CMEX-II is utilized as a threshold value to judge whether appropriate measurement can be done, however, this value seems conservative, so it can be increased according to further investigation.

When HI-520-2 was used, the threshold value of moisture content was around 5-5.5%.

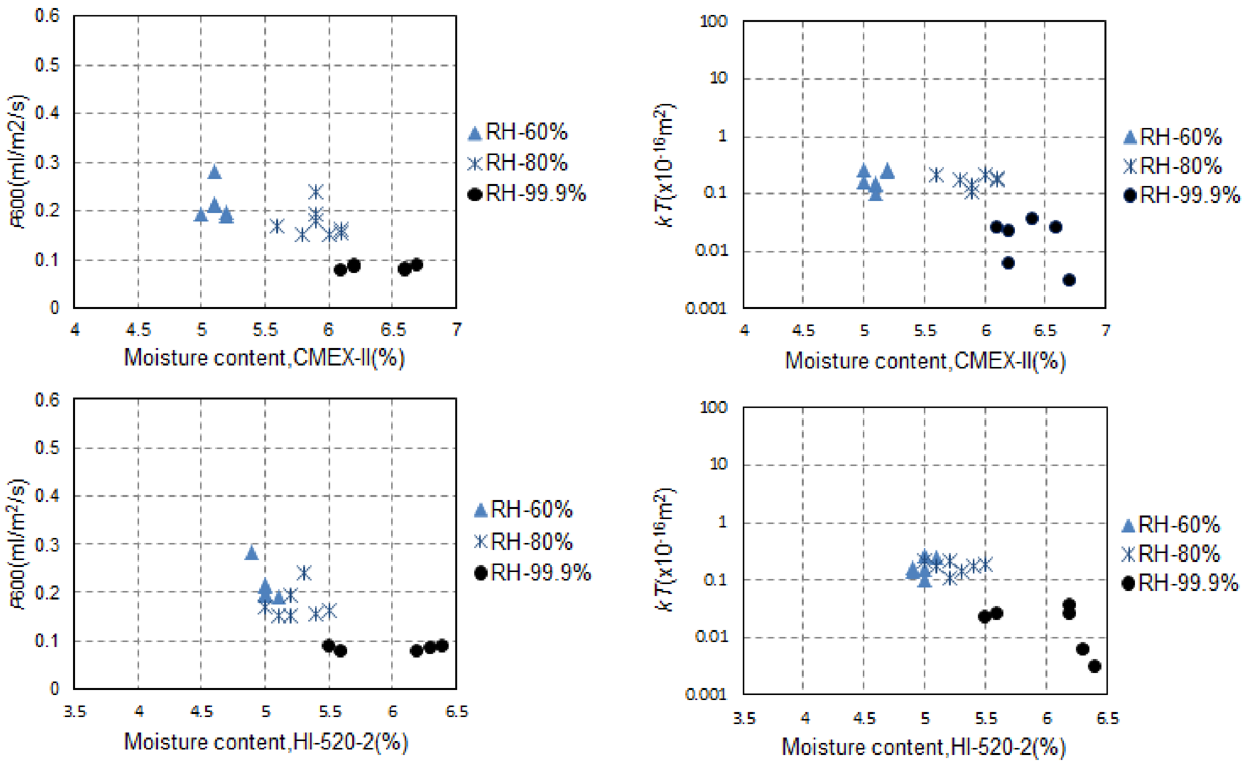

Fig.5 Water absorption and air permeability results (W/C=40%, sealed for one day and six days water curing)

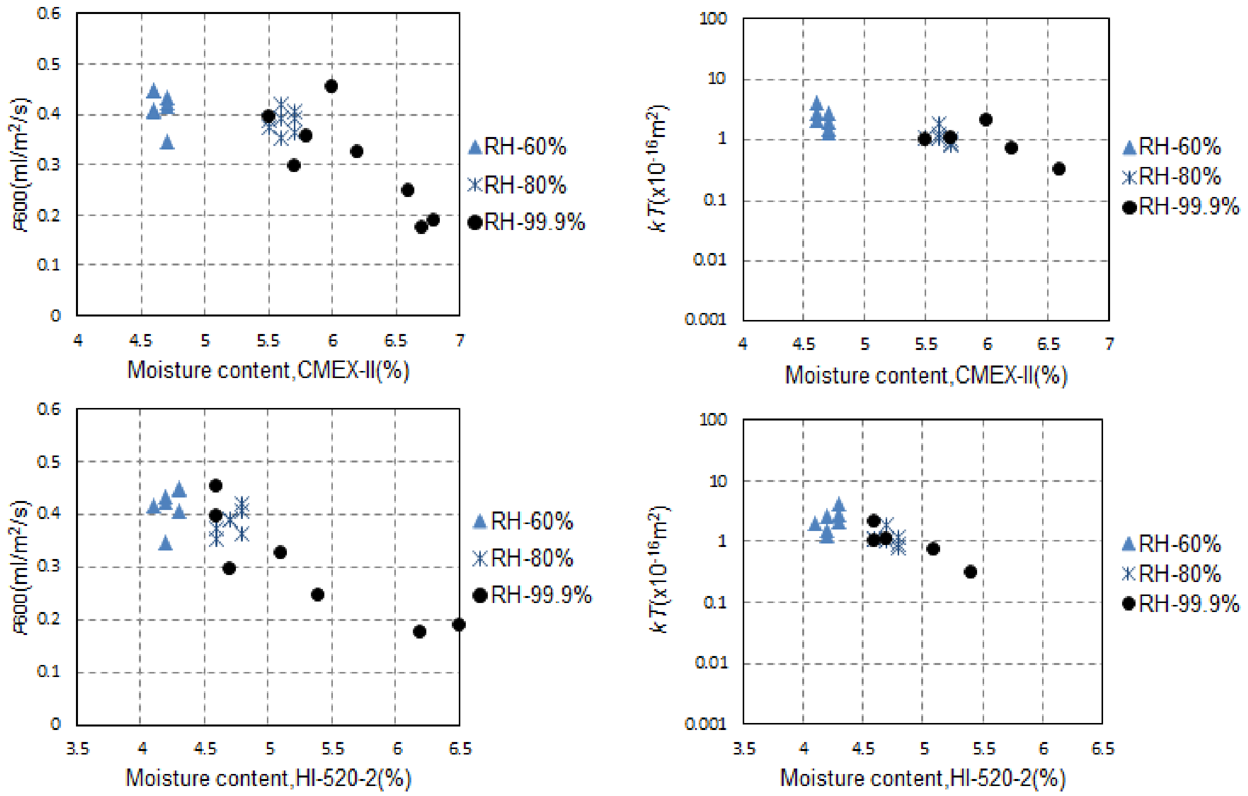

Fig.6 SWAT absorption and air permeability results (W/C=50%, sealed for one day)

4.4 Future Tasks

As can be seen in Fig.8, HI-520-2 showed smaller distribution than CMEX-II. The charactersitics of the moisutre meters should be deeply investigated.

In this research, dried specimens were stored in wet environment for one or two days. In reality, there can be many kinds of moisture distribution in covercrete. Further investigation is needed to establish measurement system considering the effect of moisture content.

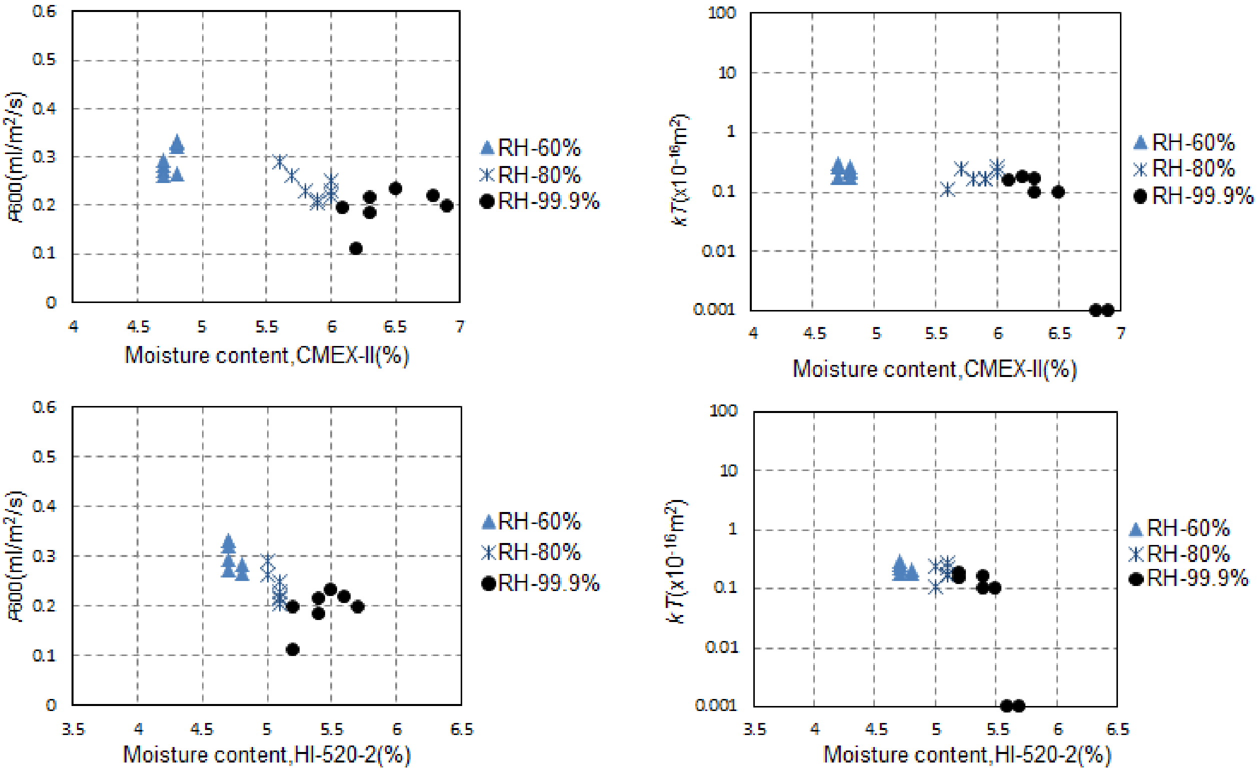

Fig.7 SWAT results and air permeability (W/C=50%, sealed for one day, and six day in water)

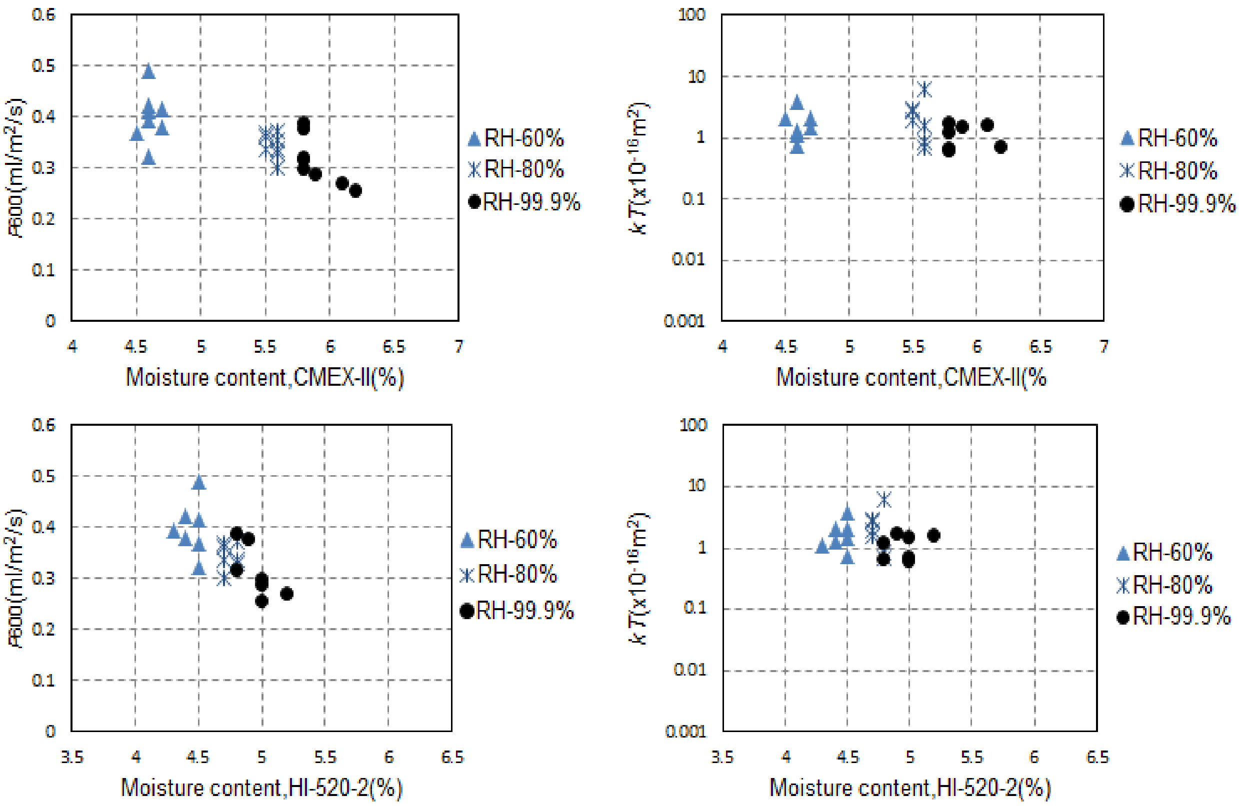

Fig.8 SWAT results and air permeability (W/C=60%, sealed for seven days)

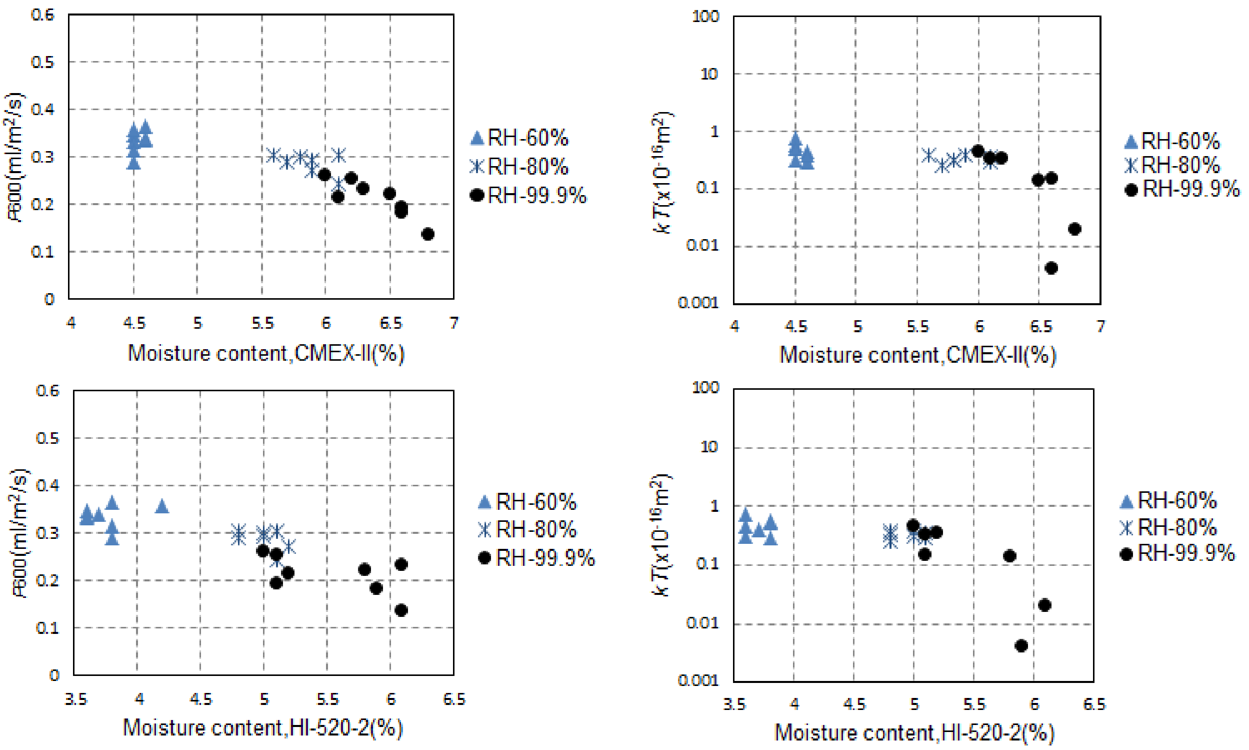

Fig.9 SWAT results (W/C =60%, sealed for one day and six days water curing)

5. CONCLUSIONS

In this research, three kinds of mix proportion and three kinds of curing conditions were provided for rectangular concrete specimens. Surface Water Absorption Test and Torrent air permeability test were conducted. The following conclusions were experimentally obtained.

(1) Water absorption resistance (p_{600}) was affected by moisture content of concrete. p_{600} was apparently smaller when the moisture content measured by CMEX-II was higher than around 6.0%. When the moisture content was measured by HI-520-2, p_{600} showed apparently smaller values when the moisture content was higher than around 5.0%.

(2) Air permeability (kT) was affected by moisture content of concrete. Beyond around 6.0% in moisture content measured by CMEX-II, kT showed smaller values. When HI-520-2 was used, the threshold value of moisture content was around 5-5.5%.

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