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Rapid Testing Method for Air-Permeability of Concrete in Structure Using Drilled Hole

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1 INRODUCTION

Construction of the long-lasting building has been requested in the approach for the sustainable recycling society. In JASS 5, it is recommended that reinforcement corrosion and serious deterioration of concrete structures should be avoided, and the working period of 100 to 200 years is expected. It is thus important to evaluate the quality of near-surface concrete that protects reinforcing bars[1].

The current quality control is performed by the process management and the evaluation of specimens. Thus the quality including the state of construction and environmental conditions cannot be evaluated. To evaluate the actual performance of concrete structures, method evaluating the quality and applicable to the concrete structure is neces-sary[2].

The tests evaluating the quality of concrete in structure include strength, density, basic physical properties, water and air permeability. As an Air-permeability test that can be applied to the concrete in structure, the author has modified the method of Figg that uses the drilled hole[3][4].

As a method applicable to concrete in structure, evaluation of the Air-permeability of cover concrete from the surface to the depth of about 5cm is pro-posed using the rapid air-permeability test[5]. The rapid air-permeation speed of the concrete with a different water-cement ratio, unit water content, type of cement, air content, the age of drying and test age was measured. Influences of the mix proportion and the various curing methods on the rapid air-permeation speed were examined.

2 RAPID TESTING METHOD FOR AIR PERMEABILITY OF CONCRETE IN STRUCTURE USING DRILLED HOLE

2.1Rapid testing method for air permeability of concrete in structure using drilled hole

Testing apparatus used for rapid air-permeability test is a vibration type electric drill, blade of drill, vacuum meter (digital manometer), vacuum pump, silicon stopper, injection needle and vinyl hose.

2.2 Correction and tuning of testing apparatus

The correction of testing apparatus is executed by measuring the standard specimen prior to the test. This is to confirm the presence of problems and the difference in the volume of decompression chamber. According to the result, the adjustment or repair of the testing apparatus and decompression chamber are needed by changing the hose length, if different from the reference value.

2.3 Operating procedure of rapid air permeability test

The operation of the rapid air permeability test is executed according to the following procedures of (1) -(6)

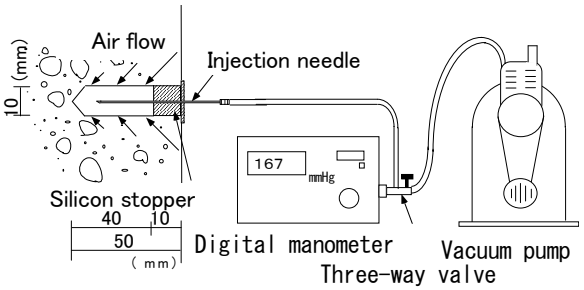

Fig.1 Rapid air-permeability test device

ドリル削孔を用いた構造体コンクリートの
簡易透気試験方法の提案

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(1)The rapid air-permeability test was performed using a drilled hole with a diameter of 10mm and a depth of 50mm drilled with a vibration drill and the apparatus is shown in Figure 1. At this time, the distance between the adjoining drilled hole centers is assumed to be 50mm or more.

(2)The drilled hole is sealed with a silicon cap with a diameter of 10mm and a depth of 10mm. The gap between the silicon cap and the concrete should be sealed with epoxy resin of fast-curing not to allow air leakage.

(3)After the solidification of epoxy resin, the injection needle is inserted in the center part of the silicon cap. To avoid filling of the hole of needle, a wire with a diameter approx. 0.44mm is inserted in the injection hole of a needle beforehand.

(4)The injection needle, a digital manometer, and a vacuum pump are connected with the vinyl pressure hose.

(5)Decompress the drilled hole with a vacuum pump with the three-way cock opened to a the vacuum level of 20 kPa (150mmHg) which is lower than that of X_1 of 21.3 kPa(160mmHg) when the three-way cock is closed.

(6)Due to the inflow of air from the peripheral wall of the hole, the time T when the vacuum level de-creased from X_1 of 21.3kPa (160mmHg) to X_2 of 25.3 kPa (190mmHg) is measured while X_1=13.3 kPa and X_2=33.3kPa are adopted when the interval was less than ten seconds. After repeating the measurements of (5) and (6) 4 times, rapid air permeation speed Kd can be calculated with the following equation.

Table 1: Parameter and grade of concrete

Parameter	Grade
water cement ratio	30, 40, 60, 80%
Classification of cement	Ordinary Portland cement, High-early strength Portland cement, Moderate-heat Portland cement, Portland blast-furnace slag cement kind B, Portland fly-ash cement kind B
Unit water content	202, 185, 178, 170, 162kg/m^3
Air content	1.0, 2.0, 4.5, 6.0%
Age of drying	1, 3, 7, 28day
Test age	1, 3, 6month

$$Kd=(X_2-X_1)/T \qquad (1)$$

Kd : Air permeation speed (kPa/s)
X_1 : Vacuum level at the start of testing. (kPa)
X_2 : Vacuum level at the end of testing.(kPa)
T : Testing time (s)

Measured values of the second and third testing were averaged excluding the result of the first test.

3 EXAMINATION OF PARAMETERS AFFECTING THE RAPID AIR-PERMEATION SPEED

3.1 Outline of Concrete

3.1.1 Parameter and grade of concrete

In this chapter, influences of the water cement ratio, type of cement, unit water content, air content, age of drying and the test age on the rapid air-permeation speed when applying the proposed method to concrete in structures were examined. Tale 1 shows parameter and grade of concrete. The concrete used in this experiment was proportioned with an ordinary Portland cement (OPC), the water-cement ratio of 60%, the unit water content of 185kg/m3, the targeted air content of 4.5% and the targeted slump of 18cm. When parameters varied, water-cement ratio were 30, 40, 60 and 80%, cement types were the ordinary Portland cement (OPC), the high-early strength Portland cement (HPC), the moderate-heat Portland cement (MPC), the blast-furnace slag cement type B (SCB) and the Portland Fly-Ash Cement type B (FCB), unit water content were 202, 185, 178, 170 and 162kg/m^2 and, targeted air content were 1.0, 2.0, 4.5 and 6.0%. As curing conditions, material ages that drying started were 1, 3, 7 and 28day, when the specimens were unmolded or unsealeded. The age of testing were 1, 3, 6month.

3.1.2 Materials, mix proportion and properties of concrete.

The mix proportion of the concrete is shown in Table 2.

3.1.3 Preparation, curing, and age of testing

The dimensions of the specimens are 150×150×200mm and the 150×150mm side was used for testing. Sides other than the test side were coated with an epoxy resin to

Table 2: Mix proportion of concrete

Parameter	Water cement ratio (%)	Classification of cement	Target air content (%)	Unit content (kg/m³)				Admixture (g/m³)		
				Water	Cement	Fine aggregate	Coarse aggregate	Ad1	Ad2	Ad3
Water cement ratio	30	OPC	4.5	185	617	577	943	—	6180	900
	40			185	463	658	990	1160	—	1100
	60			185	308	849	923	770	—	1500
	80			185	231	893	947	578	—	1300
Classification of cement	60	OPC	4.5	185	308	849	923	770	—	1167
		HPC		185	308	849	923	770	—	1750
		MPC		186	310	849	923	770	—	1575
		SCB		183	305	849	923	770	—	2500
		FCB		181	302	849	923	770	—	2667
Unit water content	60	OPC	4.5	202	336	823	884	840	—	2000
				185	308	849	923	770	—	1182
				178	297	787	1018	738	—	1773
				170	283	803	1035	708	—	1720
				162	270	817	1053	668	—	1636
Air content	60	OPC	1.0	192	319	880	956	—	—	—
			2.0	190	316	871	947	782	—	152
			4.5	185	308	849	923	770	—	1085
			6.0	181	302	832	905	758	—	1970

prevent drying. After the specified drying age, the specimens were placed in a thermostatic chamber with a temperature of 20℃ and the relative humidity of 60% till the ages of each specimen reaches three months. The test positions were four cross points obtained when dividing each 150× 150mm side into three parts.

3.1.4 Measurement of rapid air–permeation speed

The rapid air-permeation speed was measured with the proposed method "rapid testing method for air permeability of structural concrete using drilled hole". The measurement was performed at the material age of three months while it was 1, 3 and 6 months when the differences by material age were examined.

3.2 Results of the experiments

Figure2(a) shows relationship between water-cement ratio and air-permeability test results. The rapid air-permeation speed increased with an increase of the water-cement ratio. When the water-cement ratio exceeded 60%, this tendency was more remarkable. At the same water-cement ratio, the rapid air-permeation speed tended to increase with the age of drying.

Figure2(b) shows relationship between type of cement and air-permeability test results. The rapid air-permeation speed of the concrete using high-early strength Portland cement was smaller than that using ordinary Portland cement while the difference in the age of drying was small. The rapid air-permeation speed of the concrete using moderate-heat Portland cement, blast-furnace slag cement type B and Port-land fly-ash cement type B was larger than that using ordinary Portland cement while the difference in the age of drying was large.

Figure2(c) shows relationship between unit water con-tent and air-permeability test result. The influence of the unit water content on the rapid air-permeation speed was small compared with other factors.

Figure2(d) shows relationship between air content and air-permeability test result. The rapid air-permeation speed tended to increase as the air content increased.

Figure2(e) shows relationship between age of drying and air-permeability test result. When the drying age progressed, the rapid air-permeation speed became small in every water-cement ratios. The difference in rapid permeation speed by the age of drying in-creased until the age of drying 7 day while became small at the age of drying between 7 to 28 days.

Figure2(f) shows relationship between test age and air-permeability test result in concrete at the age of drying 1 day. When the material age progressed, the rapid air-permeation speed increased. The amount of increase in the rapid air-permeation speed at ages from 3 to 6 months became smaller than that at ages from 1 month to 3 months.

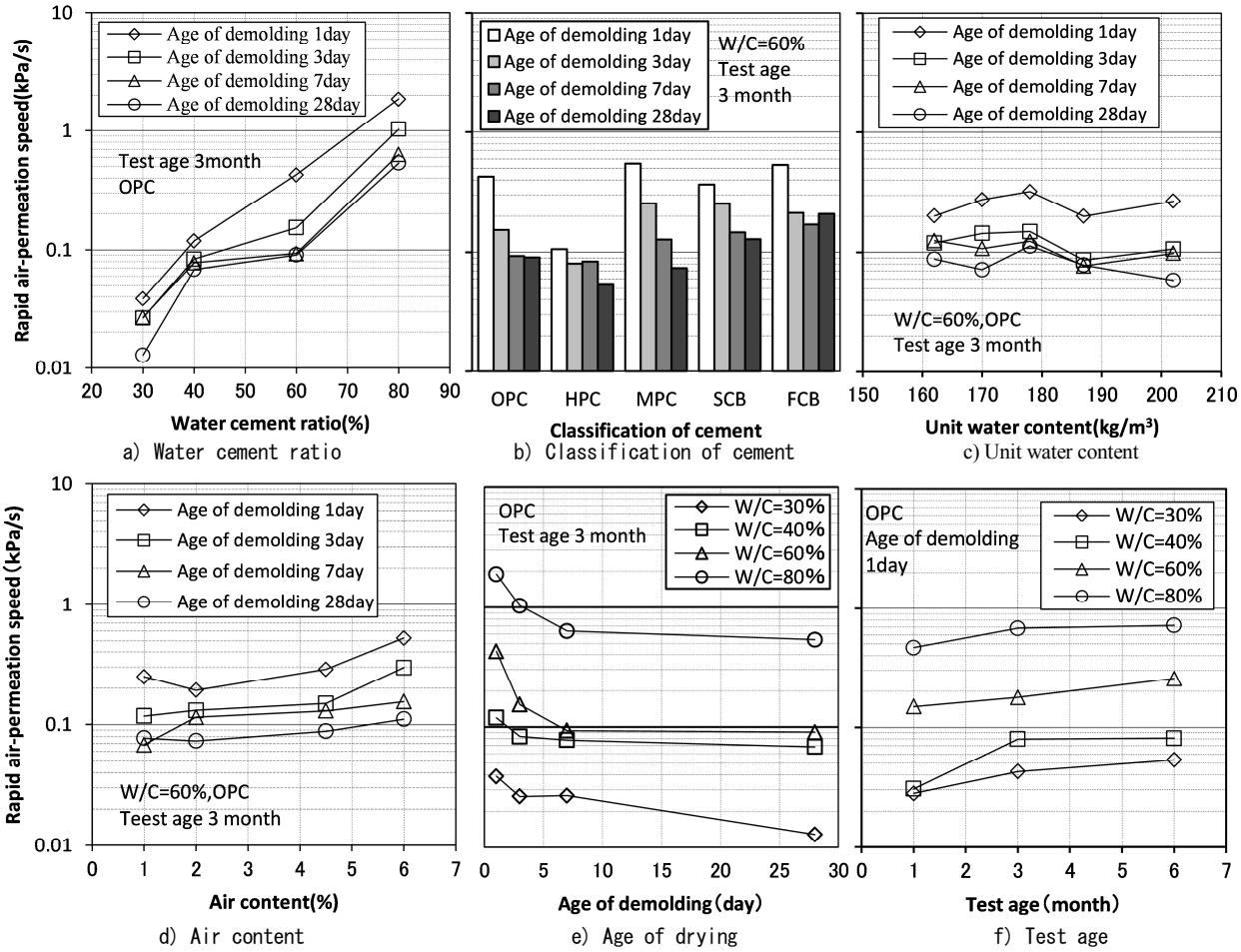

Fig. 2 Relationship between various characteristic and air-permeation speed

4 SUMMARY

The results obtained in this study are as follows.

- The rapid air-permeation speed was measured using drilled hole with a diameter of 10mm, the depth of 50mm, hose length of 1000mm and distance between the adjoining drilled hole centers of 50mm or more. The measurement was four times while measured values excluding the result of the first test was averaged. The test method "rapid testing method for air permeability of structural concrete using drilled hole" was proposed.
- Measurements of the proposed test method were examined with various parameters. As a result, rapid air-permeation speed increased, when water cement ratio increased, cement hydration delayed, air content increased, age of drying became earlier and test age was delayed. Among factors affecting the rapid air-permeation speed, water-cement ratio, the type of cement and the age of drying was notable while those of the unit water content, the air content and the test age were small.

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