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

1 INTRODUCTION

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 necessary\(^2\).

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\(^3\)\(^4\).

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

2.1 Rapid 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

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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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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.

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.

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.

Decompress the drilled hole with a vacuum pump with the three-way cock opened to a vacuum level of 20 kPa (150mmHg) which is lower than that of X1 of 21.3 kPa(160mmHg) when the three-way cock is closed.

Due to the inflow of air from the peripheral wall of the hole, the time T when the vacuum level decreased from X1 of 21.3kPa (160mmHg) to X2 of 25.3 kPa (190mmHg) is measured while X1=13.3 kPa and X2=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.

\[ Kd = \frac{(X_2 - X_1)}{T} \]  \hspace{1cm} (1)

Kd : Air permeation speed (kPa/s)
X1 : Vacuum level at the start of testing. (kPa)
X2 : 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. Table 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 kind B (SCB) and the Portland Fly-Ash Cement type B (FCB), unit water content were 202, 185, 178, 170 and 162kg/m³ 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 unsealed. The age of testing were 1, 3, 6month.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grade</th>
</tr>
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<tbody>
<tr>
<td>water cement ratio</td>
<td>30, 40, 60, 80%</td>
</tr>
<tr>
<td>Unit water content</td>
<td>202, 185, 178, 170, 162kg/m³</td>
</tr>
<tr>
<td>Air content</td>
<td>1.0, 2.0, 4.5, 6.0%</td>
</tr>
<tr>
<td>Age of drying</td>
<td>1, 3, 7, 28day</td>
</tr>
<tr>
<td>Test age</td>
<td>1, 3, 6month</td>
</tr>
</tbody>
</table>

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
prevent drying. After the specified drying age, the specimens were placed in a thermostatic chamber with a temperature of 20°C 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 × 150 mm 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

Figure 2(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.

Figure 2(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 Portland fly-ash cement type B was larger than that using ordinary Portland cement while the difference in the age of drying was large.

Figure 2(c) shows relationship between unit water content and air-permeability test result. The influence of the unit water content on the rapid air-permeation speed was small compared with other factors.

Figure 2(d) shows relationship between air content and air-permeability test result. The rapid air-permeation speed tended to increase as the air content increased.

Figure 2(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 increased until the age of drying 7 day while became small at the age of drying between 7 to 28 days.

Figure 2(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.

![Table 2: Mix proportion of concrete](image)
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.

REFERENCES

2) Architectural Institute of Japan “Test methods for Quality control and Maintenance of Reinforced Concrete Building” 2007.3