Study of Water Absorption Properties in Actual Structural Concrete Based on Pore structure

Nagoya Institute of Technology, Student Member, Macharia Peter Kuira
Nagoya Institute of Technology, BOUADOU Nda Yacoub
Nagoya Institute of Technology, Lai Lai Mon
Nagoya Institute of Technology, Member, Ryo Yoshida

In this study, concrete cores were taken from concrete of actual structures that were more than 40 years old, and moisture penetration tests were conducted as specified by the Japan Society of Civil Engineers and ASTM.
Concrete of real structures is subject to external influences such as drying and carbonation and therefore, unlike homogeneous concrete made in the laboratory, the pore structure of real structural concrete is affected by the environment from the surface to the interior.
Based on this pore structure, this study examines the effect of carbonation undergone by the real structure on the moisture penetration properties obtained from various tests.

Key Words: *water sorptivity, capillary, pore structure, permeability coefficient, porosity.*

1. Introduction

Concrete is prone to attack by ingress of aggressive agents from its surrounding environment and the ability to resist this intrusion is termed as durability. Durability of concrete has attracted a lot of attention from researchers for a long time in making efforts to retain its original form, quality and serviceability while opposing weathering action, abrasion, chemical attack, and any other process of deterioration[1]. The entry and movement of deteriorative agents into cementitious concrete is largely influenced by the pore system which acts as the transport mechanism that is mainly comprised of permeability, diffusion, and absorption[2]. Absorption is the ability to take in water or aqueous solution by capillary suction while permeability is the measure of flow of fluids under pressure into a material. Diffusion on the other hand is the movement of ions caused by concentration gradient.[3] The capillary pore volume, size and distribution network are critical in determining this transport mechanism.

Deterioration of concrete structures has resulted to increased costs of repair and maintenance. In Japan for instance, even though many civil concrete structures show satisfactory performance on their intended serviceability, there are still quite others that have deteriorated and need repair or strengthening in order to achieve their service life[4]

This study focuses on investigation of water movement properties of concrete from existing structures using JSCE-G 582-2018 and ASTM C1585-13 water absorptivity standard methods. The results are further analyzed in relation to carbonation depth, water permeability as well as the internal pore structure.

2. Materials

A total of 24, 150mmxø100mm concrete cores were drilled from Tokai-dori line railway track balustrade walls. Visual inspection was done to sort out cores with open voids, cracks, and other visible defects. The suitable cores were wrapped and stored in an open container under the room temperature for 100 days. Using 5ml Rilem Tubes, surface water absorption test was conducted on either surface of each core to determine the water absorption rate within the first 20 minutes so as to identify suitable grouping of the cores. After the surface water absorption test, the cores were dried in an oven at 80°C until the mass change in 24hrs was less than 0.1%.

3. Experimental Method

3.1 JSCE-G 582-2018 Test Standard

The following method was applied to determining moisture penetration rate coefficients of concrete subjected to water in short time. Drilled concrete cores were sealed with aluminium tape on the lateral sides and dried in a controlled chamber at a temperature of 40 ± 2°C and relative humidity of 30 ± 5% until 24- hour mass change was less than 0.1%. The specimens cooled to room temperature by natural heat loss for of 1 hour and then stored in a closed container for 24 hours. Tap water of 20° ± 2C temperature stored in a controlled environment of 20 ± 2°C temperature for 24 hours was used. The mass change after immersion was recorded at 1 min, 5 10, 20 30, 60 min and at every hour up to the 6th hour. The mass was again recorded at 24 hours and 48 hours after immersion. After 48 hours, moisture penetration depth was determined by spraying a color-differentiating water detector that conforms with NDIS 3423 specification. Five measurement points, (L1 – L5) ,were recorded for each half of the specimen and the distance from the sealed edge of the specimen was not less than 20 mm.

$$\mathrm{A} = \frac{\sum_{n=1}^{n}\left(\sqrt{t_i}-\overline{\sqrt{t}}\right)\cdot(L_i-\bar{L})}{\sum_{n=1}^{n}\left(\sqrt{t_i}-\overline{\sqrt{t}}\right)} \qquad \text{Constant B} = \bar{L} - A\cdot\overline{\sqrt{t_\iota}}$$

The second half of the split specimen was sprayed with phenolphthalein solution to determine carbonation depth by taking five measured lengths using a metal rule.

3.2 ASTM C1585-3 Test Standard

Disc concrete specimens of ø100 mm diameter with length of 50±3 mm were cut from the 150mm cores and vacuum saturated for 24 hrs. The internal and external disc concrete specimen for 9 drilled cores were used. The side surfaces were sealed with aluminium tape and later conditioned in an environmental chamber at a temperature of 50±2˚C and RH of 80 ± 3 % for 3 days. Each sample was then placed in a sealed container at 23 ± 2˚ C for 15 days. The sealed concrete specimens were later put in pan in which water was filled to the marked level. Mass change was measured and recorded at 1 min, 5 10, 20 30, 60 min and at every hour up to the 6th hour. The mass was again recorded at 24 hours, 48 hours and then 24 hours apart up to the eight days. The absorption was calculated using the formula,

$\boldsymbol{i} = \frac{\boldsymbol{m_t}}{\boldsymbol{a*d}}$ Where, **I** = the absorption, $\mathbf{m_t}$ = the change in specimen mass (g), at the time **t**, **a** = the exposed area of the specimen, in mm^2, and **d**=the density of the water in g/mm^3.

3.3 Water Permeability Test

After ASTM test method, the disc concrete cores used were soaked in saturated calcium hydroxide solution for 24 hours under room temperature. Using a water porosimeter, the water flow rate was recorded until a constant flow was attained for both the external and internal disc concrete cores and permeability coefficient (K_w) was calculated.

$K_w = \frac{l\gamma_w}{P_1 - P_2} \times \frac{Q}{A}$ where **l**= Core thickness, **γw**=unit volume of water, **Q**=amount of permeable water, **A**=cross section area of core, $\boldsymbol{P_1}$=pressure of the test, $\boldsymbol{P_2}$=atmospheric pressure.

3.4 Absorption Rate Test

Split cores after JSCE water absorption tests were sliced into 15mm deep pieces from the end surface which was in contact with water. The slices were then crushed to separate the mortar from the coarse aggregate. Mortar samples obtained were soaked in acetone for seven days and then vacuum dried for another seven days. After the drying stage, the dry mass of the samples was recorded before being immersed for 24 hours with mass change recording after 1min, 5, 10, 15, 30, 60mins. The mass was also recorded at interval of one hour up to six hours.

$wa = \left\{\frac{m_1 - m_2}{V}\right\} x100$ $\mathbf{w_a}$= Absorption rate (%)$\mathbf{m_1}$ = mass in air, $\mathbf{m_2}$ = absolute dry mass (g), **v** = volume of the specimen, in mm^2

4. Experimental results and discussion.

The moisture permeation coefficient for JSCE set of cores which was obtained from the permeation formula was contrasted to the slope of absorption curve in the ASTM set of cores. The internal set of cores had a strong correlation with an R2 value of 0.92 as shown in *Fig 2.*

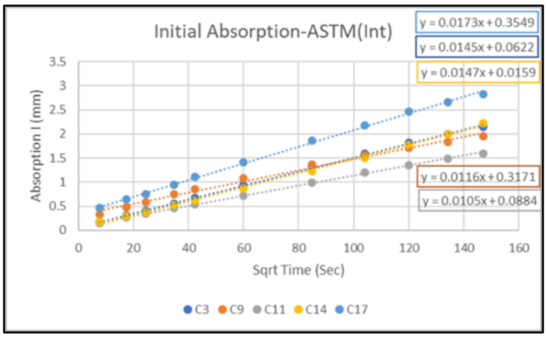

Fig. 1 ASTM Initial absorption curve.

From the slope of the curve in *Fig.1*, which is the absorption against square root of time in seconds, absorption coefficient can be deduced.

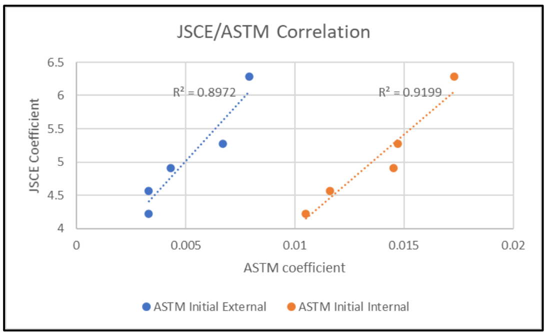

Fig. 2 Coefficient correlation (Initial Absorption)

The absorption coefficient for the internal set of cores was slightly above the coefficient of the external cores for the initial absorption.

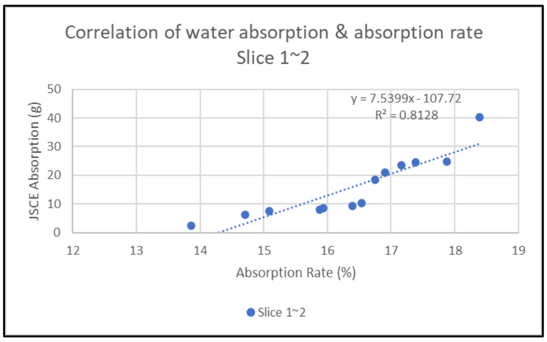

Fig. 3 JSCE absorption and absorption rate correlation

5. Conclusion.

The initial water absorption by the JSCE and ASTM set of cores was different which could be attributed to the different conditioning methods. However, the permeation coefficients had a close correlation especially with the internal set of cores. The absorption rate of mortar samples was different from the external surface to the interior of the concrete cores which was a possible indication of a heterogeneous pore structure. The permeability coefficient also showed a slight difference between the internal and external sections of the cores but there was no traceable relationship between the water absorption depth and carbonation depth.