The influence of air in mortar on the results of the RCM test

THE INFLUENCE OF AIR ON THE RESULTS OF THE RCM TEST

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Abstract

Chloride penetration into concrete structures reduces their service life. When chloride reaches the steel rebar, it may corrode which eventually leads to concrete deterioration. Hence, it is important to test concrete on chloride penetration resistance. Such testing often takes a long time, because of the slow process of chloride penetration. Therefore, using an accelerated test is an obvious choice. The RCM test is one of the most commonly used techniques to measure the chloride diffusion coefficient in concrete. One of the disadvantages of the RCM test is that it requires a saturated sample, while structures in practical conditions are mostly unsaturated. In this paper, the RCM test is performed for unsaturated mortar. Standard mortar samples with various air content of 0%, 2%, 4%, 6%, 8% and 10% are investigated. The air content in the sample is obtained by first water-saturating the sample under vacuum and than by placing the sample in a climate chamber with a relative humidity of 10% and a temperature of 50°C to induce drying, until the desired air content of the sample is reached. After the RCM test, the chloride penetration depth is measured with colorimetric and titration methods. The results show that the more air content in the samples is, the deeper chloride penetration in the samples will be.

Key Words: *RCM test, Mortar, Colorimetric method, Titration method, capillary suction*

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1. INTRODUCTION

Although, concrete is known as one of the most durable materials, damage of concrete structures could still occur. Chloride-induced corrosion of reinforcing steel is one of the problems of such structures. Therefore, a prediction of chloride ingress into concrete is of a great importance. Many short-term laboratory testing methods have been developed for examining chloride transport properties. The rapid chloride migration test (RCM), developed by Tang [1] and published as a guideline in NT Build 492 [2], is the most commonly used short-term test in practice. Many authors [3-7] preformed the test with saturated samples, while in practice the structures are mostly unsaturated. Therefore the purpose of this paper is to investigate unsaturated samples. This is executed by studying the influence of various air content, 0, 2, 4, 6, 8 and 10%, in the sample on the RCM test results. Furthermore, the chloride penetration into the samples is measured with two methods, colorimetric and titration. The outcome of methods is analyzed and compared.

2. SAMPLE PREPARATION

Cylindrical mortar samples with water cement ratio of 0.5 and cement type CEM I 42.5 N are examined in this paper. The samples are cured in water for one year. Six samples of 20 mm thickness and 100 mm in diameter are cut from the cylindrical samples. The samples are provided with various air percentages as shown in Table 1.

The desired air contents in the samples are obtained by first saturating the samples (vacuum saturation). This procedure starts by placing the samples in a desiccator. An air pressure of 4 kPa is applied on the samples for 3 h to remove the air from the specimen. After water is added to the samples in the desiccator, the pressure is maintained for another hour. The samples are then left in water for additional 20 h at atmospheric pressure. After the saturation process is completed, the samples are dried for a short period in a climate chamber with a relative humidity of 10% and temperature of 50° C.

Table 1: Samples with various air contents

Sample	Air content
1	0%
2	2%
3	4%
4	6%
5	8%
6	10%

Further, by using the Eqs (1) and (2) the air content (V_{air}) in each sample is calculated.

$$V_{air} = V_{sample} \cdot P_{air} \quad (1),$$

where V is the volume and P is the air content in the sample (%). The volume of the air equals the volume of water that leaves the void of the sample, and is given by,

$$V_{water} = \frac{M_{water}}{\rho_{water}} \quad (2),$$

where M is the mass and ρ the density. By measuring the total mass of the sample, the mass of the water released by the sample will also be determined and with this the volume of air in the samples is computed.

After achieving samples with desired air contents, the samples are sealed with plastic foil for one week. This is done to obtain an even distribution of the air in the samples.

3. RCM TEST

The Rapid Chloride Migration test (RCM test) is a test based on a forced ionic migration. This ionic migration is induced by an external electrical voltage applied across the mortar samples. Due to the potential difference between the electrodes, chloride ions will migrate from the catholyte solution, through the mortar sample, toward the anolyte solution. The set-up of the RCM test is shown in Fig. 1. The catholyte solution is 10% NaCl (100 g NaCl per 0.9 l water) and the anolyte solution is NaOH (12 g NaOH per 1 liter water). The samples are clamped tightly in non-conductive rubber sleeves and placed on an inclined support. This is done to let the gas bubbles, which will be generated on the cathode (below the sample), evacuate freely. The initial voltage of 30 V is applied to measure the initial current. Based on the value of the current, the duration of the RCM test and the value of the voltage applied during the test are determined, following the specifications given in the guideline NT Build 492 [2]. The current measured in this study resulted in a duration of six hours with a voltage of 10 Volt, taking in to account the thickness of the sample.

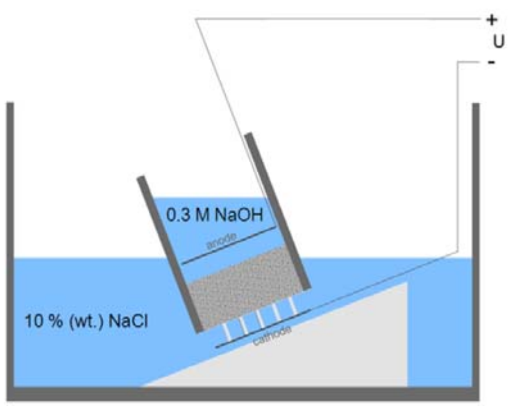

Fig. 1: RCM test set-up

After the RCM experiment, the chloride penetration depth in the samples is measured with two different techniques: colorimetric method and titration method. In order to measure the penetration with the colorimetric method, the samples are removed from the rubber sleeves and split in half by applying force. Then, the fractured surface is sprayed with a colorimetric indicator (0.1 M AgNO3). The colorimetric indicator visualizes the chloride penetration and makes it possible to measure the penetration depth. This is measured at seven positions in the sample, as shown in Fig. 2. An average of the seven measurements is calculated and assumed to represent the penetration depth for the whole sample. This procedure is repeated for all samples.

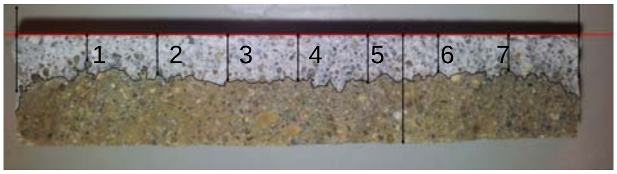

Fig. 2: Sample split in half for the colorimetric method

Titration is also used to measure chloride penetration in the samples. This procedure starts with grinding layers of 2 mm with Profile Grinder 110. The obtained powder is dried at 100°C to a constant mass and cooled down to room temperature. From each layer, 2 g of the collected powder is placed in a beaker. After adding 35 ml of distilled water and 2 ml nitric acid of 1M, the beaker is shaken manually for 1 min. The solution is brought to boil, cooled afterwards, and poured onto filter paper. The obtained solution is adjusted to 100 ml, and used for the determination of the concentration of chloride. The concentration is measured by Metrohm MET 702 automatic titration. A silver nitrate solution of 0.01 M is used as a titration solution.

4. RESULTS

Fig. 3 shows the chloride penetration depth in the samples with various air content measured by a colorimetric method. The results show that the chloride penetrated approximately 7 to 14 mm in the samples. The inaccuracies of chloride penetration are due to the inhomogeneity of mortar. The results also show that higher air content leads to deeper penetration of chloride.

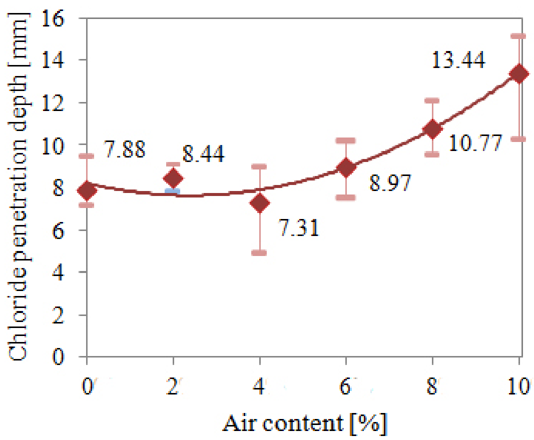

Fig. 3: Chloride penetration depth by colorimetric method

The results of chloride penetration with titration of the same samples tested previously using a colorimetric method are shown in Fig. 4. The results in this case show that the chloride penetrated approximately 8.5 to 14.5 mm in the samples. Also in this case, a higher air content in the sample results in a deeper penetration of chloride.

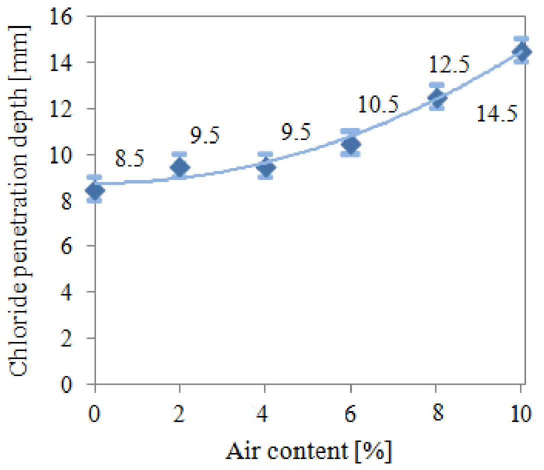

Fig. 4: Chloride penetration depth by titration

The comparison of colorimetric and titration methods is shown in Fig. 5. Both methods feature a similar trend. However, the chloride penetration depth measured by titration is approximately 10% higher. This is because measuring with the colorimetric method is limited to 0.2% of the total chloride concentration in mortar/concrete, while titration method can measure chloride concentrations below 0.1%.

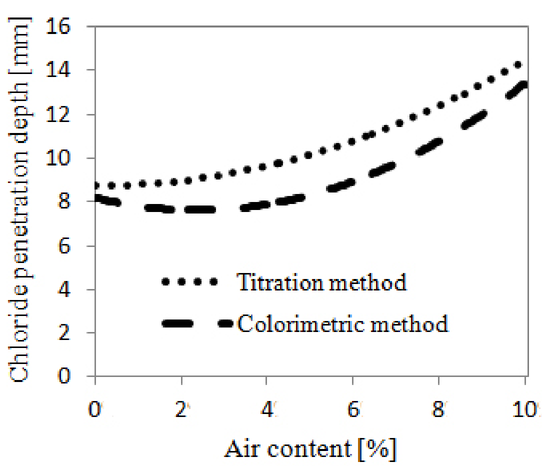

Fig. 5: Comparison between colorimetric and titration methods

CONCLUSIONS

In this paper samples with various air content are tested with RCM test to study the influence of air on the RCM test results. Six mortar samples with 0, 2, 4, 6, 8 en 10% air are examined. The chloride penetration depth in the samples is measured with colorimetric and titration methods after the RCM test. The results of both methods show similar results. However the titration method is more accurate, because the technique measures chloride concentration below 0.1%, while colorimetric method is limited to 0.2%. Moreover, from the results can be concluded that a higher air content in the sample results in a deeper chloride penetration. This can be explained by the capillary suction. If air is present in mortar/concrete sample in the RCM test, then capillary suction is an additional chloride transport mechanism besides the electrical migration. Because capillary suction is faster than migration, more chloride penetrates in the samples. Also, more air in the samples results in stronger capillary suction that leads to deeper chloride penetration.

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