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## Chloride Resistance of Concrete Containing Rice Husk Ash by Rapid Migration Test

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### ABSTRACT

Sodium chloride is the most influencing factor that affects the durability of concrete. The main objective of this study is to investigate the influence of rice husk ash (RHA) having different percentages cement replacement on sodium chloride solution of concrete with wetting and drying cycles. Rapid migration test (RMT) was performed on concrete containing RHA. The relationships between all test results were experimentally investigated. In this study, RHA was used as a supplementary cementing material to replace an ordinary Portland cement type I by the percentage of 10%, 20%, 30%, and 40% by weight of cement. Water to binder ratio was kept constant at 0.49. Test results showed that chloride penetration depth of concrete containing RHA is lowest than that of OPC concrete. On the other hand, a positive correlation exists between the total charge passed, depth of penetration, time, and initial current.

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## INTRODUCTION

Previous studies have shown that the long-term performance of concrete can be improved through the incorporation of supplementary cementitious material. Ramadhansyah (2012) reported that chloride-induced corrosion resistance of concrete is significantly improved with the use of RHA. It is universally accepted that concrete incorporated with pozzolanic materials and exposed to aggressive solutions, like chloride and sulfate, exhibit a substantial increase in durability due to the reduced amount of larger pores. Cyclic wetting-drying causes continuous moisture movement through concrete pores. According to Hong (1998) cyclic wetting and drying can increase the concentrations of ions i.e. chlorides, by evaporation of water. The drying of the concrete also increases the oxygen as required for steel corrosion, as oxygen has a substantially lower diffusion coefficient in saturated concrete. In fact diffusion of oxygen through air can be as high as 10,000 times the diffusion of oxygen in water (Islam, M.M., 2010). From the literature review presented, it can be seen that the partial substitution of pozzolanic materials, helps improve the durability of concrete especially when exposed to chloride attack. However, the available information on the effect of sodium chloride solution on RHA-blended cement concrete is very limited, especially in the condition of wetting and drying cycles. For this reason, it is important to study the chloride resistance of concrete containing rice husk ash by rapid migration test under wetting and drying cycles.

### Experimental Procedure:

#### Cement and Aggregate:

OPC (Blue Lion Cement) Type I was used as the major binder material in the production of moderate-strength concrete (40MPa). The mean particle size of the OPC was 10.11  $\mu\text{m}$ , and its density was 3.12  $\text{g/cm}^3$ . The chemical composition of the OPC is in the standard range, with 70% CaO, 17.8% SiO<sub>2</sub>, 3.9% Al<sub>2</sub>O<sub>3</sub>, 3.2% Fe<sub>2</sub>O<sub>3</sub>, 1.5% MgO, and 3.6% SO<sub>3</sub>. Local natural sand derived from granite was used as the fine aggregate in the concrete mixtures. The 20 mm crushed granite stones were used as the coarse aggregate. The coarse and fine aggregates each had a specific gravity of 2.65 and water absorption of 0.48% and 0.86%, respectively. The specific gravity of an aggregate is considered to be a measure of strength or quality of materials.

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***Rice husk ash:***

Initially, the RHA was incinerated in a gas furnace at a heating rate of 10 °C/min until it reached 700 °C. It was then maintained at this temperature for 6 h. After the burning process was completed, the ash was left inside the furnace for cooling; it was removed the following day. The ash was then ground in the laboratory ball mill with porcelain balls. The main component of the RHA is SiO<sub>2</sub>. The combined total amount of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Fe<sub>2</sub>O<sub>3</sub> is 93.48%. The American Society for Testing and Materials (ASTM) method requires that the three main oxides make up no less than 70% of pozzolanic material; the RHA thus met this requirement.

***The Samples preparation and curing conditions:***

A laboratory study was undertaken to investigate the effects of reagent-grade sodium chloride on the OPC and RHA blended cement concrete. The solution of sodium chloride used in the investigation was 5% by weight of volume (Ramadhansyah, P.J., 2012). RHA replacement levels of 10%, 20%, 30%, and 40%, by weight of cement were used in this study and referred as RHA10, RHA20, RHA30, and RHA40. In the blended cement, the RHA material was thoroughly mixed with the ordinary Portland cement, and water was then added into the mixer. However, to maintain slump values, superplasticizer Glenium C380 was added into the mix. After mixture was ready, the concrete was cured in water maintained at room temperature for a minimum of 28 days to achieve strength of 40 MPa. After 28 days of curing under water, the specimens were transferred to sodium chloride solution with wetting and drying cycles.

***Rapid Migration Test (RMT):***

The rapid migration test was conducted using the RCPT instrument. The test procedure is described in NT Build 492-99 (NT Build, 1999). After the specimens were vacuumed in a vacuum desiccator, the 50 mm thick slices were placed between two acrylic cells. One cell was filled with 0.3N NaOH solution, whereas the other was filled with 10% NaCl solution. A direct current voltage of 30 V was applied across the two sides, and the initial current was measured. After completing the test, the specimen was split into two half. Then, 0.1M AgNO<sub>3</sub> solution was sprayed on the fresh concrete surface and the depth of chloride penetration was measured.

## RESULTS AND DISCUSSION

***Depth of chloride penetration:***

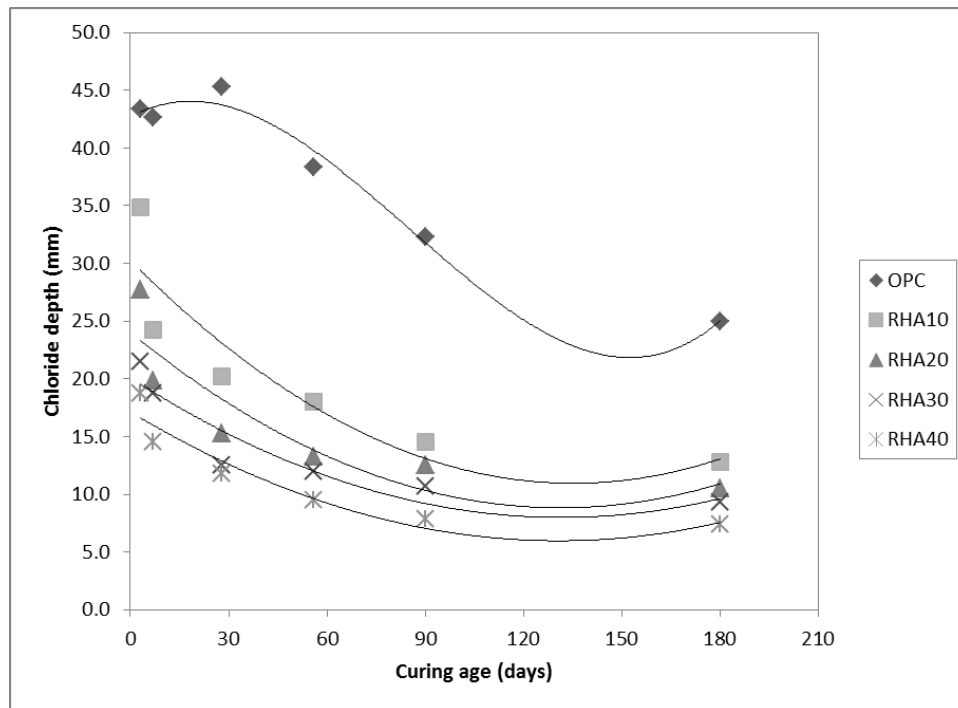
The results of RMT on OPC and RHA blended cement concrete exposed in sodium chloride solution by wetting-drying cycles for 3, 7, 28, 56, 90, and 180 days are illustrated in Figure 1, which clearly show that the chloride penetration depth of OPC concrete is higher than that of RHA blended cement concrete. This may be due to the intermittent wetting-drying exposure. During wetting, chloride solution penetrates a layer of concrete; during drying, the evaporation front moves inward and takes some of the chloride with it (Polder, R.B., 2002). In addition, the values of penetration depth decrease, as the level of replacement of the RHA increases. For example, compared with the penetration depth of the OPC concrete (penetration depth of 45.3 mm) at the early age (i.e., 28 days), incorporations of 10% and 20% of RHA reduce the penetration depth value to 20.3 and 15.3 mm, respectively. However, the chloride penetration depth values of RHA concrete are the lowest at 12.5 and 11.8 mm at 30% and 40% replacement levels, respectively. Furthermore, the general trend in Figure 1 shows that the values of depth of penetration decreased with exposure time.

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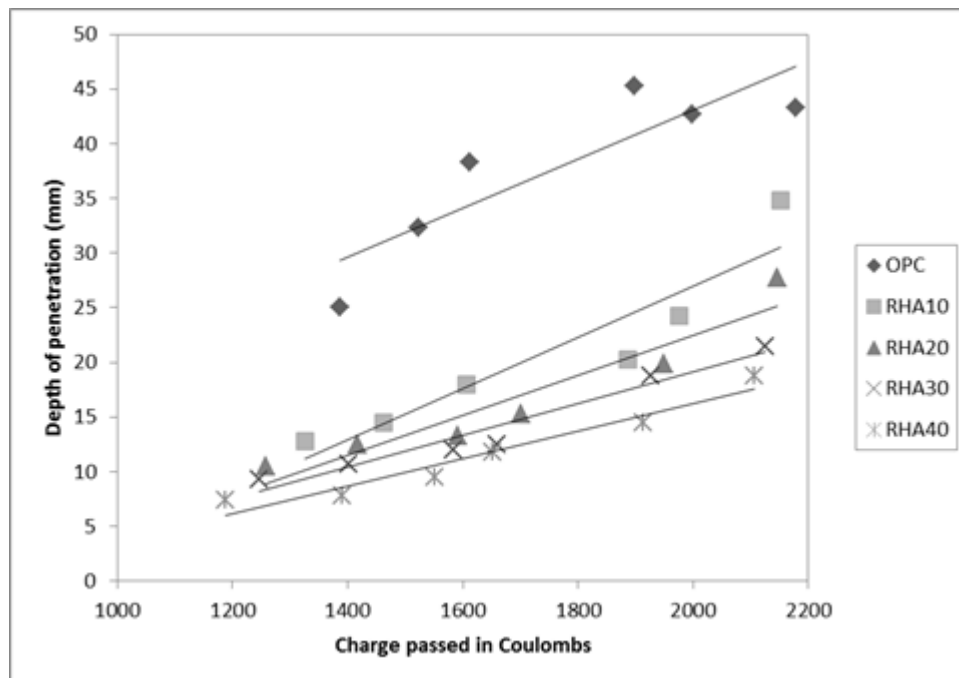
***Relationship between total charge passed and depth of chloride penetration:***

A positive relationship exists between the total charge passed and the depth of chloride penetration as shown in Figure 2. As the depth of penetration increases, the total charge passed also increases accordingly. For instance, at the age of 180 days, at 10% RHA replacement level, the depth of penetration was increased from 12.8 to 34.8 mm as the total charge passed increased from 1327 C to 2152 C, respectively. In addition, specimens with replacement of RHA exhibited low total charge passed, as indicated by lower depth of chloride penetration even though they were subjected to chloride solution with wetting and drying cycles. The result also

indicates that the resistance to chloride-ion migration in RHA blended cement concrete is higher than that in OPC concrete. It can be concluded that the use of RHA in blended cement reduced the chloride ions ingress, verified by charge passed, indicating that RHA may be utilized as effective mineral addition for designing durable concrete structures subjected to aggressive environments, such as sodium chloride.



**Fig. 1:** Depths of chloride penetration for OPC and RHA-concrete.

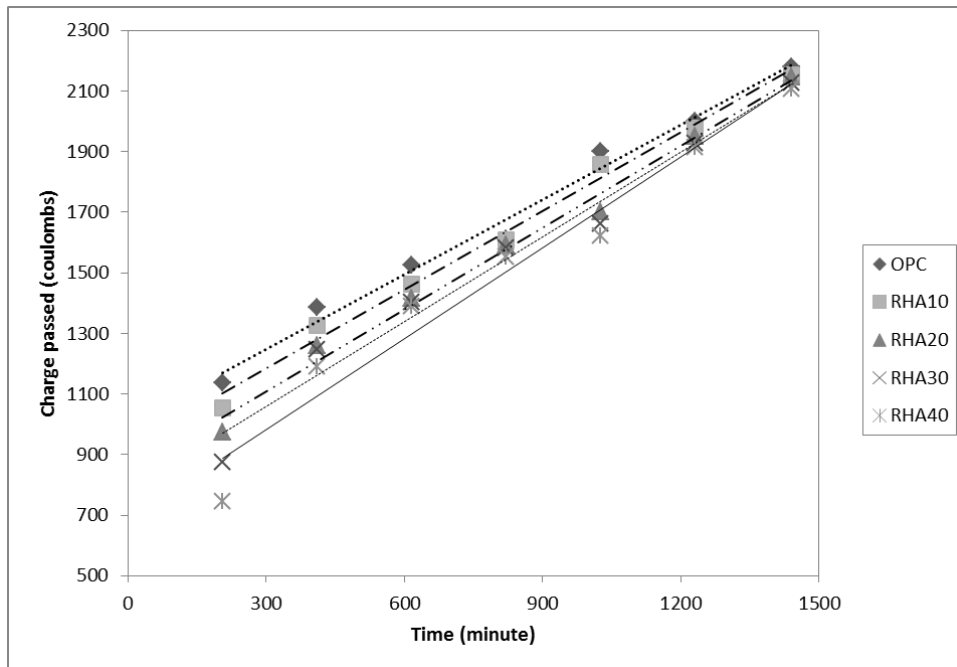


**Fig. 2:** Relationship between depth of penetration and total charge passed.

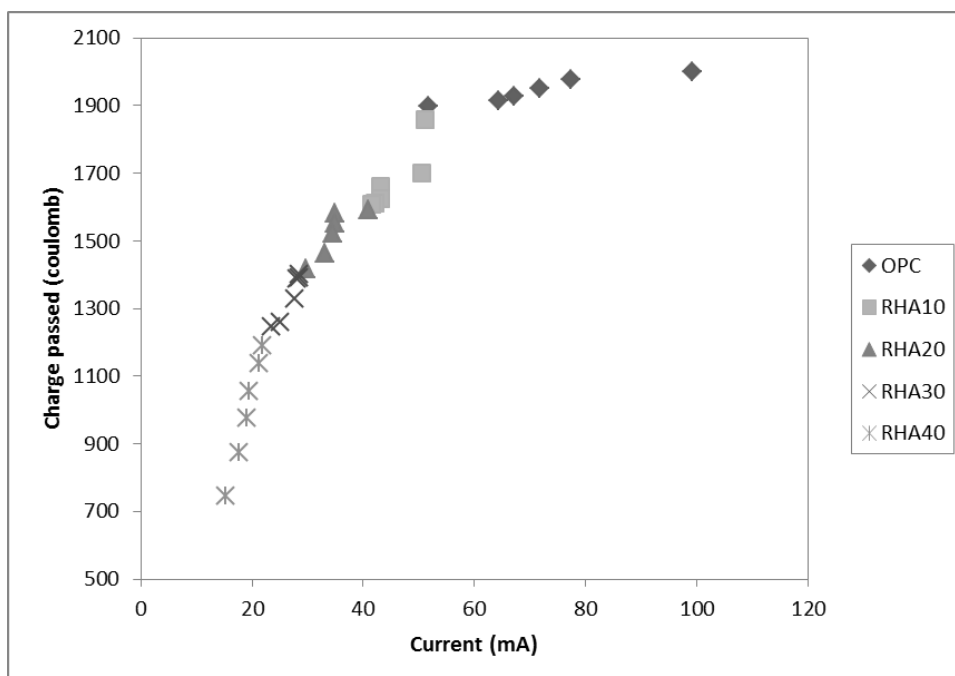
**Relationship between total charge passed, time and initial current:**

From Figure 3(a), the total charge passed increases as the time also increases accordingly. This results indicate that RHA blended cement concrete becomes more permeable than those of OPC concrete due to pozzolanic reaction. The pozzolanic reaction takes place when CH is released and produced more CSH gel, thus

the pores become filled and the resistance of the concrete to chloride attack is also increased probably due to the formation of more CSH gel. From the data in Figure 3(b), the total charge passed and corresponding initial current was in the range of about 1899–1999 C and 51.80–99.200 mA; 746–1857 C and 15.3–51.2 mA, respectively for OPC and RHA blended cement concrete. It clearly shown that RHA blended cement concrete is better quality compared to OPC concrete, as indicated by low charge passed. Furthermore, where the increment of the total charge passed after 6 hours is the result of an increment in initial current. It can be concluded that the RHA blended cement concrete had a much lower initial current and total coulombs than the OPC concrete.



**Fig. 3(a):** Relationship between total charge passed versus time.



**Fig. 3(b):** Relationship between total charge passed versus initial current.

**Conclusion:**

The results obtained in this study clearly indicate that the addition of RHA as cement replacement materials provides additional improvements in chloride penetration depth to sodium chloride solution via wetting and drying cycles. A high degree of replacement (30% or 40%) leads to low depth of penetration. Addition of RHA, because of the pozzolanic reaction, decreases the total charge passed of specimens, and hence increases the concrete durability. In general, an excellent correlation exists between the total charge passed, depth of penetration, time, and initial current.

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