Chloride Attack Resistance of Concrete with Rice Hull Ash

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Abstract: Concrete is a durable material, it can, however, deteriorate faster when reinforcing bars and other embedded content in it corrode. Corrosion of reinforcing bars occurs when chemicals like chloride penetrate the concrete matrix. This paper examines the effect of adding various amounts of RHA (0%, 11%, 18%, 25% RHA/OPC) to concrete compressive strength and chloride penetration resistance. Results showed that while the amount of RHA in the concrete matrix increases, the percent penetration decreases, however, the compressive strength of concrete was reduced by more than half. The result is contrary to most researches specifically along compressive strength. The poor strength performance may be attributed to the quality of RHA used in the study.

Keywords: RHA, corrosion resistance, concrete admixture, organic, silica

1. Introduction

Concrete is one of the most widely used and oldest manufactured construction material with the earliest recorded use date back to 6500BC (Pepin, 2017; Chemistry World, 2008). Portland cement is the primary constituent material in concrete production, demand for this material will reach 4.7 billion tons by 2022 (Rowland, 2017). The need is because concrete has low-carbon-footprint and remarkably good building material (Chemistry World, 2008; Coppenholle, 2017). Structures built using concrete are durable and capable of withstanding different environmental condition (Quraishi et al., 2016). One weakness of concrete is when chlorides, carbon dioxide, moisture, etc. penetrate the matrix which may corrode reinforcement bars or rebars (ibid). As rebars corrode, the rust created requires additional space in the concrete which eventually cause it to crack, delamination and spalling (PCA, nd). This weakness, however, can be managed in many ways such as making concrete more resistant to chloride attack. Corrosion protection can be made through good design and construction practices, sufficient concrete cover of rebars, low permeability concrete, corrosion inhibitors and others (Smith & Virmani, 2000). One such material to reduce permeability is the use of RHA or the rice hull ash (Huang, et al., 2017; Talsania et al., 2015, Singh & Kaushik, 2014). Research findings also suggests that RHA improves other parameters of concrete including compressive strength (Siddika et al., 2018; Singh et al., 2016; Talsania et al., 2015, Singh & Kaushik, 2014; Kartini et al., 2010) it even was used to improve soil strength (Orale, 2008)

Rice husk is an agricultural waste which accounts for 20% of the rice produced (Glushankova, et al., 2018). The ash produced from burning rice hull contains about 85 to 95% percent of amorphous silica

(Zareei et al., 2017). In the study of Ayub et al. (2014), a silica admixture that is amorphous, glassy, or reactive is a requirement to attain good results.

2. Objectives

The objective of this research was to determine the chloride attack of rice husk ash (RHA) enhanced concrete and assess the compressive strength performance of the concrete.

3. Methodology

3.1 Research Design.

The study used an experimental research design. The study has two phases: first, investigation of the effects of various RHA replacements to the compressive strength of the mortar specimen and; second, determination of the impact of various RHA replacements to the corrosion of the reinforcing bars. A total of 24 samples were prepared for a compression test. Chloride penetration was observed after the compression test.

3.2 Materials Sourcing and Preparation

The cement used was an ordinary Portland cement (APO brand), and fine aggregates were purchased locally. Rice hull was collected from local farms in Samar which was processed into RHA at Soils and Materials Testing Laboratory of Samar State University. Chloride solution was locally formulated using a (sea)salt concentrate.

The RHA was burned using a blow torch (approximately with temperature from 800-1000°C) for 2 hours after which it was subjected to vigorous shaking using US sieve No. 200. Mortar design is following ASTM C192. Compression and Chloride Penetration Test used a cylindrical mortar, with 2 inches diameter by 4 inches height. Fine aggregates used were graded according to ASTM D422 (100% passing sieve No 4 and 10% passing sieve No. 200).

3.3 Mix Design Proportion

Table 1 shows four design mixtures by weight of materials (RHA, fine aggregate and cement used) used in this study.

Table 1. Mix Design

	Mixture	M1	M2	M3	M4
RHA/Cement		0.00	0.11	0.18	0.25
% by Weight	RHA	0.00	2.50	3.75	5.00
	Fine Aggregates	75.00	75.00	75.00	75.00
	Cement	25.00	22.50	21.25	20.00
Total (%)		100.00	100.00	100.00	100.00

3.4 Test Specimen Preparation

The sample was prepared to conform to ASTM C470 requirements. The cement and RHA were mixed manually and were combined with sand. A total of 24 specimens (Figure 1) were cast into the PVC cylindrical molds and cured for 7, 14 days in accordance with ASTM C192.

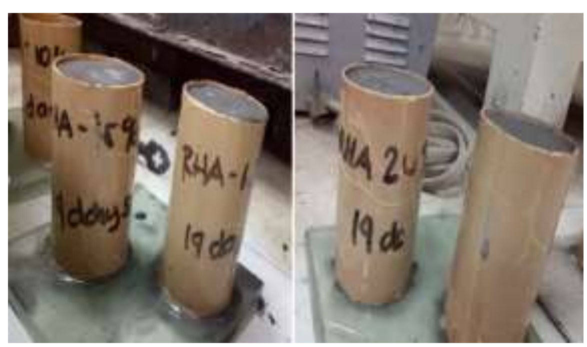

Figure 1. Sample Specimen (50ø x 100mm)

3.4 Testing Facilities and Procedure

The compressive strength of each mixture was determined by subjecting all the mortar specimens to compression using akN Universal Testing Machine. These specimens were tested for every combination in a manner that the load was applied gradually without shock and continued until the sample fails following ASTM C 39 standards.

The concrete samples were cured for 7 and 14 days and placed under a pressure container (Figure 2) with adding 1.24 liters of water as 2/3 to the height of the cylinder having 3% NaCl concentrate. A pressure of about 80 Psi was applied for 30 minutes. Afterward, the specimens were split into half using to determine chloride solution penetration. Penetration level measurement was done by applying 0.05M Silver Nitrate ($AgNO_3$) solution onto the sample; a colorimetric method for analysis of chloride penetration in Concrete. Four points on each longitudinal side were measured for a total of eight-point depth measurement for each specimen.

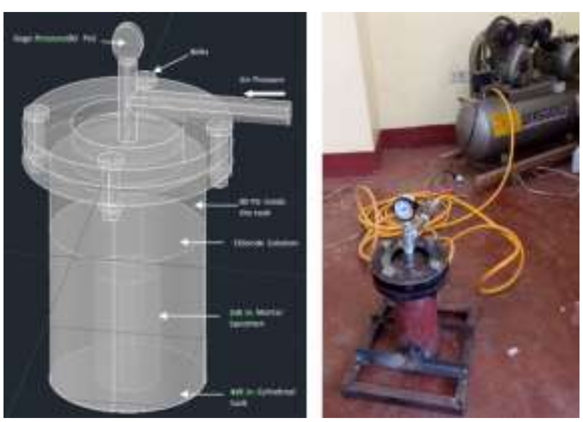

Figure 2. SSU Solution Penetration Apparatus

Figure 3. Penetration Visualization

4. Results and Discussion

The addition of RHA in a concrete matrix improves some of its parameters including compressive strength. The effects, however, are sensitive, the optimal mixture needs to be discovered to maximize potentials of RHA enhanced concrete.

4.1 Failure Mode

The table shows the type of failure the samples have exhibited. A common type of failure of normal concrete is a cone, cone-and-split, and cone and share (Hamad, 2017; ASTM 2003; Concrete Construction, 1999). Cone failure results when friction on the platens of the testing machine restrains lateral expansion of the mortar as the vertical compressive force was applied. This limitation confined the mortar near the platens and resulted in two relatively undamaged cones, and the cylinder expanded more laterally and exhibited a splitting failure similar to columnar mode.

Shear type of failure is associated with samples with a high-sand mixture. A columnar kind of failure is more on an issue on an improper testing share (Concrete Construction, 1999). Other literature says it's a common failure for high strength specimen made of mortar or neat cement paste, but not common to ordinary concrete (Neville, 1995) like samples in this study. This means that the recorded compressive strength of the sample with this type of failure is likely higher.

Table 1. Failure Mode

Cement/ RHA	Failure Mode	
	7 days curing	14 days curing
0.00	Columnar*	Cone & Split
0.11	Cone & Split	Shear
0.18	Shear	Cone
0.25	Shear	Shear

**attributed to the testing problem.*

4.2 Compressive Strength of Samples

The compressive strength of mortar without RHA is higher for both 7 and 14 days curing. This means that as a percent of RHA increases, concrete strength also decreases. The optimal cement to RHA ratio for better compressive strength is approximately between 10 to 20% after which a decrease of strength is observed (Zareei et al., 2017; Hossain, et al., 2011; Dabai et al., 2009; Ismael & Waliuddin,1996; OBILADE, 2014). Other studies however reported; differently, some has no changes while other has improved the compressive strength of concrete with RHA (Rajput et al., 2013; Ephraim et al., 2012; Malhotra & Mehta, 2004; Khalaf & Yousif, 1984). The strength of concrete with and without RHA was also observed in the study of Kumar (2012). The early strength of concrete with RHA was lesser, and it increases with age (ibid). In this study, the numbers are different which may be associated with the quality of RHA used as components are affected by the method used in the production of RHA.

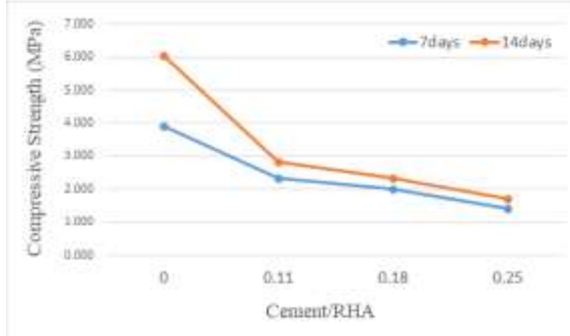

Figure 4. Compressive Strength of Specimen

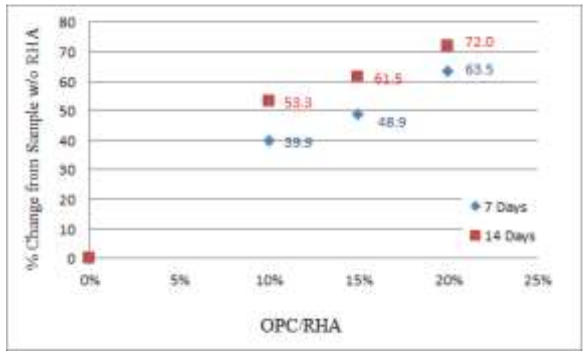

Figure 5. Percent Difference in Compressive Strength

A reduction of an average of 46.6% was observed for samples with 10% RHA contrary to other research reports where 10 to 20% RHA replacement for OPC did improve concrete strength. The reduction increased further to an average of 55.2% and 67.7% for samples with 15 and 20% RHA replacement of OPC. This results may be attributed to the quality of RHA used in which properties were not tested (to control quality) in this study.

4.3 Chloride Penetration Test

Reinforced concrete structures are stable until its reinforcing bars starts to deteriorate. However, when the concrete matrix covering the reinforcement bars is penetrated with chlorides, carbon dioxide

(CO_2), moisture and others will corrode (Quraishi et al., 2017).

The sample with no RHA had the highest average value for the depth of penetrating chloride. It means that incorporation of RHA lessened the diffusion of chloride ion inside the concrete and prevented it from reaching the reinforcing steel. This is attributed to the additional cement gel (C-S-H) produced by rice ash. The gel helped in minimizing the voids and blocked capillary inside the concrete making it less permeable to chloride and another chemical attack.

Shown in Figure 7 is the percent change in chloride penetration versus the RHA content. It shows that a 10% replacement of OPC reduced the penetration from 7.125mm for pure mortar cylinder to 5.125 mm or about 28.1% for samples cured for 14 days and tested at 14 days. This reduction was further increased as RHA percentage increased. At 20% replacement of OPC, a decrease of about 70.2% was observed. This is almost the same as the study of Zareei et al., (2017), where a 78% reduction in chloride penetration was noted. A 40% RHA replacement was seen as the optimal mix that results in lesser chloride penetration (Jayanti et al., 2016).

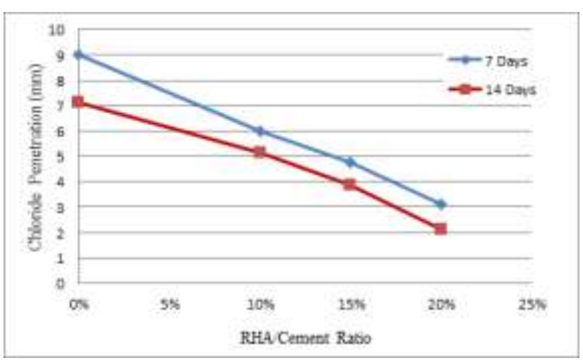

Figure 6. Chloride Penetration

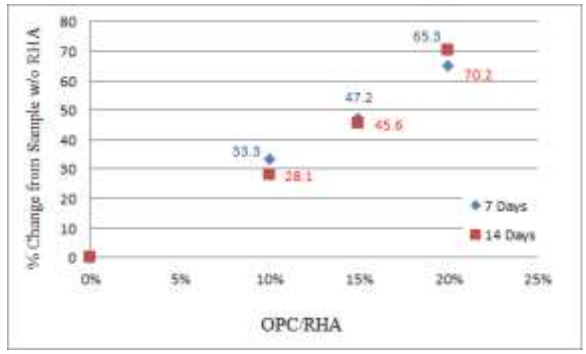

Figure 5. Percent Difference of Chloride Penetration

A reduction of an average of 30.7% was observed for samples with 10% RHA contrary to other research reports where 10 to 20% RHA replacement for OPC did improve concrete strength. The reduction increased further to an average of 46.4% and 67.8% for samples with 15 and 20% RHA replacement of OPC. This results may be attributed to the quality of RHA used in the test. Different burning and feeding methods results into different characteristics (e.g., color, sizes, chemical composition) and performance when used as a replacement of OPC in concrete (Jaya et al., 2013; Rozainee et al., 2010; Habeeb, GA. & Mahmud, HB., 2010).

4.3 Chloride Penetration and Compressive Strength

Salt like NaCl do not damage concrete, but the effects of salt can such as corrosion impact to embedded rebars and its behaviour during freezing and thawing process. Concrete produced using water with dissolved salt has better compressive strength (Tiwari et al., 2014; Wegian, 2010; Taylor & Kuwairi, 1978; Griffin & Henry, 1964) but in the study of Mbadike and Elinwa (2011) is the opposite. Sodium chloride (NaCl) solution in concrete has accelerating effects on concrete compressive strength but is not sustained (Wegian, 2010).

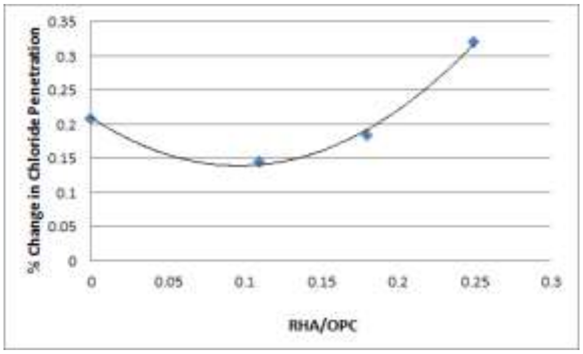

Figure 6. Chloride Penetration

As the concrete with RHA ages, chloride penetration improves. An average of 21.4% reduction was observed between the 7-day and 14-day penetration data. This suggests that rebars are more protected in concrete with RHA.

5. Conclusion and Recommendation

The compressive strength of concrete with RHA reduces significantly as the amount of the admixture increases. This result can be attributed to the quality of RHA used. On the other hand, concrete with a higher replacement ratio of OPC by RHA has produced better resistance to chloride penetration. As concrete with RHA ages, chloride penetration also decreases.

The resistance to permeability depending on the quality of RHA may be explored. The effect of RHA (assumed to be of different quality as compared to literature with positive RHA impact on strength) with varying quality needs examination.

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