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Performance of RHA Cement Concrete under Marine Environment via Wetting and Drying Cyclic by Rapid Migration Test

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Abstract: In this research, the performance of concrete containing rice husk ash (RHA) under marine environment through wetting and drying cycles was investigated. Five levels of cement replacement (0%, 10%, 20%, 30% and 40% by weight) were used. The total cementitious content used was 420 kg/m^3. A water/binder ratio of 0.49 was used to produce concrete having a target compressive strength of 40MPa at the age of 28 days. The performance of blended cement concrete under marine environment was evaluated using rapid migration test (RMT). The results clearly showed that RHA can be satisfactorily used as a cement replacement material in order to reduce the chloride penetration depth and hence increases the durability of concrete. Generally, the chloride penetration depth of concrete containing higher RHA replacement is decreased as the RHA replacement increases, resulting in concrete with higher resistance to seawater attack.

Keywords: Rice husk ash (RHA), marine, drying, wetting, rapid migration

1. Introduction

Over the years, there has been an increase in the use of industrial, agricultural, and thermoelectric plant residues in the production of concrete [1]. Different materials with pozzolanic properties such as fly ash (FA), condensed silica fume, blast-furnace slag, and rice husk ash (RHA) have played an important part in concrete production [2]. The addition of pozzolan decreases the formed CH by the pozzolanic reaction to produce more C-S-H gel that can improve the strength and durability of concrete [3]. The durability of concrete under an aggressive environment has drawn the attention of engineers and scientists for over a century.

According to Hekal et al. [4] and Zacarias [5], concrete structures exposed to severe conditions can be affected by three factors: (i) environmental conditions, such as freezing and thawing, wetting and drying, and temperature; (ii) chemical attack, i.e., type of salt, concentration, and presence of more than one kind of aggressive ions; and (iii) factors related to concrete properties, such as type of Portland cement (PC), water to binder ratio, etc. However, the most severe deterioration generally occurs in the wetting and drying cycle [6-8]. Several researchers have studied the performance of concrete with rice husk ash (RHA). However, a few studies have discussed the effects on RHA-blended cement on seawater attack with drying-wetting cycles, especially in terms of chloride penetration depth (RMT). In this study, the influences of different replacement levels of RHA-blended cement concrete under marine environment with wetting and drying cycles were investigated.

2. Materials and Mix Proportions

2.1 Cement

The ordinary Portland cement (Blue Lion Cement) was used as the major binder material in the production of moderate-strength concrete (40MPa). The chemical composition of OPC is in the standard range, with 70%, 17%, 3.9%, 3.2%, 1.50% and 3.60% of CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO and SO_3, respectively.

2.2 Aggregate

In this investigation, the coarse aggregate was crushed blue granite stone with size of 5 to 14 mm. The fine aggregate used was natural river sand passing by 4.75 mm sieve. The specific gravities of coarse and fine aggregates are approximately 2.665 and 2.715, respectively.

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2.3 Rice Husk Ash

The rice husk was incinerated in a gas furnace at a heating rate of 10°C/min until it reached 700°C and maintained at this temperature for 6 hours. After the completing burning process, the ash was left inside the furnace for cooling and removed it in the following day. The ash will then be taken into grinding process and it was performed by the laboratory ball mill with porcelain balls. The main component of RHA is SiO_2. The combined total amounts of SiO_2, Al_2O_3 and Fe_2O_3 are 93.48%. American Society for Testing and Materials C618-12 requires that pozzolanic material must contain a minimum of 70% of total amount of the three main oxides. This indicated that RHA have met the requirement of ASTM [9] to be categorized as pozzolanic materials.

3. Test Procedure

3.1 Concrete mix design and curing conditions

A laboratory study was undertaken to investigate the effects of reagent-grade NaCl on the OPC and RHA-blended cement concrete. The control mix was prepared using OPC. RHA replacement levels of 10%, 20%, 30%, and 40%, by weight of cement were used in this study. Constant water to binder ratio (w/b) of 0.49 was used throughout the investigation. 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 was added into the mix. After mixture was ready, the concrete were cured in water maintained at room temperature for a minimum of 28 days to achieve strength of 40MPa. After 28 days of curing under water, the specimens were transferred to sodium chloride solution with wetting and drying.

3.2 Rapid migration test

The rapid chloride penetration depth was conducted using the RCPT instrument. The test procedure is described in NT Build 492 [10]. 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. The current measurement at the beginning of the test indicates the test duration necessary to achieve a penetration depth approximately equal to half of the specimen length [11]. After completing the test, the specimen was split into two half. Then, 0.1M $AgNO_3$ solution was sprayed on the fresh concrete surface and the depth of chloride penetration was measured. When a silver nitrate ($AgNO_3$) solution is sprayed on the specimens, a chemical reaction occurs. According to NT Build 492-99, a chemical reaction becomes evident in white and brownish regions with well-distinguished boundaries [12]. The white region is caused by the precipitation of AgCl (silver-produced silver chloride). The brownish region is assumed to correspond to the "no chloride zone." The depth of the white front provides an idea of how far chloride has penetrated into the concrete [13].

4. Results and Discussion

4.1 Depth of chloride penetration

The chloride penetration depth, which was determined by spraying with 0.1N silver nitrate ($AgNO_3$) indicator for concrete subjected to seawater with drying-wetting cycles according to ASTM C1202 [14], were presented in Fig. 1. Concrete of better quality (with replacement using RHA) showed lower depth of chloride penetration even when exposed to seawater attack. In general, the penetration depth decreases as the amount of replacement RHA increases compared with the OPC concrete. For instance, at an earlier age (i.e. 28 days), the penetration depth of the control concrete was 49.50 mm. However, incorporations of 10% to 40% RHA reducing the depth of chloride penetration value in the range of 16.80 to 11.30 mm.

On the other hand, increasing RHA level from 10% to 40% had the effect of decreasing the depths of chloride penetration with age of exposure. It was observed that adding a pozzolan with high replacement levels in concrete, such as RHA, can significantly reduce penetration depth and better resistance to chloride ingress into concrete. Regardless of the replacement levels, for instance at the age of 56 days, when the value of RHA changed from 10% to 40%, the depth of chloride penetration decreased from 15.3 to about 9.7 mm. This implied that RHA hydrated slowly and resulting in depths of chloride penetration were decreased with the increase of RHA content. Generally, it can be concluded that RHA showed the best performance in resisting the penetration depth of concrete due to its finer particle size and enhanced pozzolanic activity compared to ordinary Portland cement.

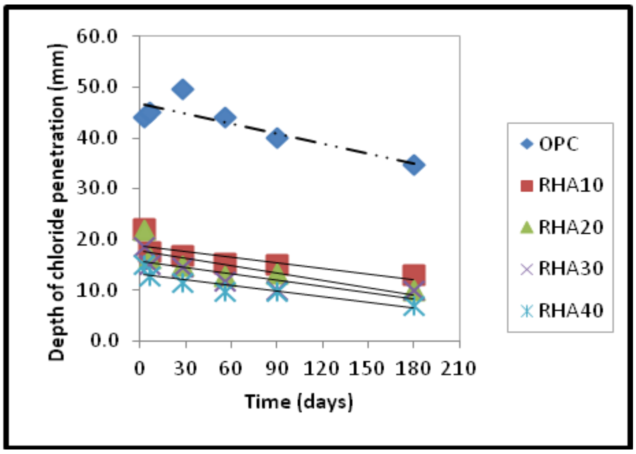

Fig. 1 Depths of chloride penetration of specimens under seawater attack with wetting-drying cyclic

4.2 Relationship between total charge passed and depth of chloride penetration

Fig. 2 presents a graphical illustration of the relationship between total charge passed and depth of penetration measured by RMT for OPC and RHA concrete subjected to seawater with drying-wetting cycles at ages 3, 7, 28, 56, 90, and 180 days. Generally, the depth of chloride penetration of OPC and RHA blended cement concrete increases with an increase in total charge passed. For instance, at 40% replacement RHA, the amount of increment is from about 9.7 mm to 15 mm as the total charge passed increases approximately 3557 C to 5489 C. Further, the depth of chloride penetration and the charge passed of OPC and RHA blended cement concrete have shown excellent correlation, with correlation coefficient R^2 exceeding 0.82 as shown in Table 1. A regression coefficient, R^2, of more than 0.80 indicates excellent correlation between the parameters. The data in Table 1 also demonstrated the other parameters of the relationship, such as 'c' and 'm' value. Generally, the 'c' and 'm' value for OPC concrete was higher than that of RHA blended cement concrete. It could be seen that an increase in 'c' and 'm' value leads to a greater total charge passed and depth of chloride penetration. The results also indicate that increasing RHA replacement in blended cement concrete also increased significantly their resistance against seawater attack, which is explained by lower 'c' and 'm' values.

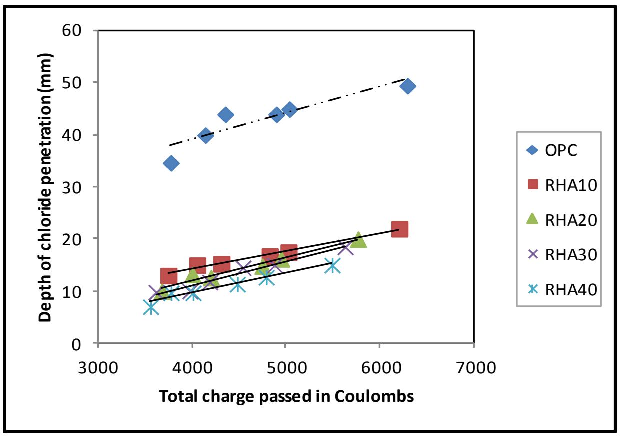

Fig. 2 Relationship between total charge passed and depth of chloride penetration.

4.3 Relationship between total charge passed and current

Previously, Feldman et al. [15] have found a good linear correlation between the total charge passed and the initial current of specimens. In order to determine these correlations, the relationship between total charge passed and current of OPC and RHA blended cement concrete were identified in this study. These are presented in Fig. 3, which shows that the total charge passed is proportional to the current. It was also observed that the total charge passed of specimens increased with increasing current. Generally, the total charge passed obtained from RMT is linearly related to the time and current. The results also showed that the slopes of all specimens were not significantly different. However, specimens with higher percentage of RHA exhibited lower total charge passed. It could be seen that an increase in the amount of RHA replacement, resulted in a decrease in the current. For OPC concrete, the initial current was high and then the current decreased considerably with increasing age. For RHA blended cement concrete, the initial current was low over the period of the testing, particularly those tested at later ages.

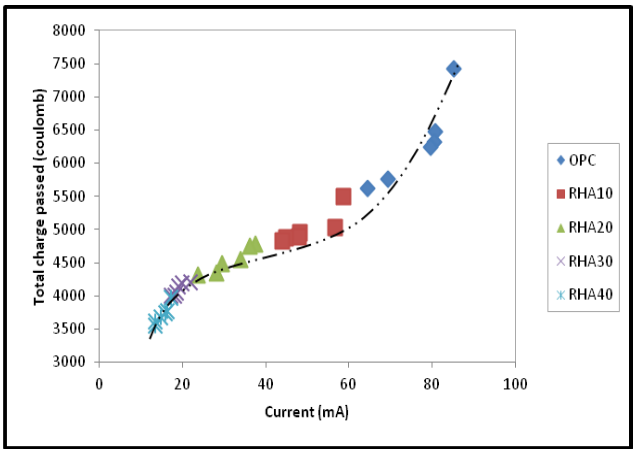

Fig. 3 Relationship between total charges passed and initial current for OPC and RHA blended cement concrete.

Table 1 Correlation between total charge passed and depth of chloride penetration.

Mixture type	Independent variable, x	Dependent variable, y	Constant		R^2
			c	m	
OPC	Total charge passed	Depth of chloride penetration	18.52	0.005	0.82
RHA10			0.265	0.003	0.98
RHA20			5.821	0.004	0.96
RHA30			7.407	0.004	0.96
RHA40			5.490	0.003	0.95

4.4 Relationship between initial current and time

In order to analyze the relationship between time and initial current, a logarithmic time versus logarithmic initial current measured by rapid migration test was calculated. The results are illustrated in Fig. 4. Clearly, the curves exhibited a two-stage development, indicating that these relationships were represented by two distinguishable slopes. . It showed that the coefficient of all specimens for primary and secondary slopes increased with age. For instance, the primary slope of 10% replacement RHA cement concrete had an increase in "*primary slope*" value from -0.194 to -0.003 with increasing curing age from 3 to 180 days. The longest curing age had higher "*primary*" values for slope, indicating that the decrease in current and resulted reduced total charge passed. On the other hand, the coefficient of "*secondary slope*" value was decreased when RHA replacement increased. Concrete containing RHA as replacement cement has lower "*secondary slope*" value than the OPC concrete. Furthermore, the increased incorporation of RHA in blended cement concrete resulted in the reduction of the total charge passed as indicated by the lowest initial current.

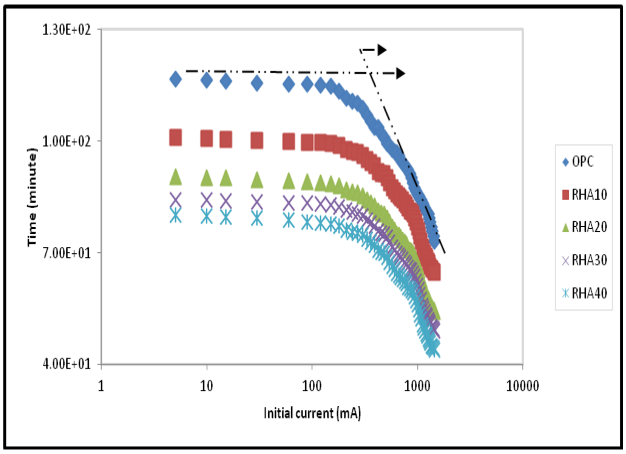

Fig. 4 Graphical determinations of primary and secondary slopes for OPC and RHA blended cement concrete.

5. Conclusions

The results obtained in this study clearly indicate that the addition of RHA as cement replacement materials provides additional improvements in depths of chloride penetration and resistance to seawater through drying-wetting cycles. Addition of RHA, because of the pozzolanic reaction, reduces the depth of chloride penetration and total charge passed of specimens, and hence increases the concrete durability. Thus, RHA may be utilized as effective mineral addition for designing durable concrete structures under seawater environment. Moreover, the relationship between chloride penetration depth and total charge passed of specimens have shown excellent correlation, with R^2 exceeding 0.82, indicating that excellent correlation between the parameters.

References

[1] Bharatkumar, B.H., Raghuprasad, B.K., Narayanan, R., Ramachandramurthy, D.S., and Gopalakrishnan S. Effect of fly ash and slag on the fracture characteristics of high performance concrete. *Materials and Structure*, Volume 38, (2005), pp. 63-72.

[2] Giaccio, G., de Sensale, G.R., and Zerbino R. Failure mechanism of normal and high strength concrete with rice-husk ash. *Cement and Concrete Composites*, Volume 29, (2007), pp. 566-574.

[3] Aziz, M.A.E., Aleem, S.A.E., Heikal, M., and Didamony, H.E. Hydration and durability of sulphate-resisting and slag cement blends in Caron's Lake water. *Cement and Concrete Research*, Volume 35, (2005), pp. 1592-1600.

[4] Hekal, E.E., Kisharb, E., and Mostafab, H. Magnesium sulfate attack on hardened blended cement pastes under different circumstances. *Cement and Concrete Research*, Volume 32, (2002), pp. 1421-1427.

[5] Zacarias, P.S. Alternative cements for durable concrete in offshore environments. *Offshore Mediterranean Conference and Exhibition in Ravenna*, Rome, Italy, (2007).

[6] Kaushik, S.K., and Islam, S. Suitability of sea water for mixing structural concrete exposed to a marine environment. *Cement and Concrete Composites*, Volume 17, (1995), pp.177-185.

[7] Memon, A.H., Radin, S.S., Zain, M.F.M., and Trottier, J.F. Effects of mineral and chemical admixtures on high-strength concrete in seawater. *Cement and Concrete Research*, Volume (32), (2002), pp. 373-377.

[8] Zuquan, J., Wei, S., Yunsheng, Z., Jinyang, J., and Jianzhong, L. Interaction between sulfate and chloride solution attack of concretes with and without fly ash. *Cement and Concrete Research*, Volume 37, (2007), pp. 1223-1232.

[9] ASTM C 618-12. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. *American Society for Testing and Materials*, West Conshohocken, PA 19428-2959, United States.

[10] NT Build 492. Nordtest method, chloride migration coefficient from non-steady-state migration experiments. *Nordic Council of Ministers*, Copenhagen, Denmark, (1999).

[11] Leng, F., Feng, N., and Liu, X. An experimental study on the properties of resistance to diffusion of chloride ions of fly ash and blast furnace slag concrete. *Cement and Concrete Research*, Volume 30, (2000), pp. 989- 992.

[12] Medeiros, M.H.F., Hoppe Filho, J., and Helene, P. Influence of the slice position on chloride migration tests for concrete in marine conditions. *Marine* Structures, Volume 22, (2009), pp.128-141.

[13] Meck, E., and Sirivivatnanon, V. Field indicator of chloride penetration depth. *Cement and Concrete Research*, Volume 33, (2003), pp. 1113-1117.

[14] ASTM C1202-10. Standard test method for electrical indication of concrete's ability to resist chloride ion penetration. *American Society for Testing and Materials*, West Conshohocken, PA 19428-2959, United States.

[15] Feldman, R.F., Prudencio, J.L.R., and Chan, G. Rapid chloride permeability test on blended cement and other concretes: correlations between charge, initial current and conductivity. *Construction and Building Materials*, Volume 13, (1999), pp. 149-154.