Research Journal of Applied Sciences, Engineering and Technology 7(22): 4720-4722, 2014
DOI:10.19026/rjaset.7.857
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: January 07, 2014 Accepted: January 24, 2014 Published: June 10, 2014

Research Article

Corrosion Resistance of High Strength Concrete Containing Palm Oil Fuel Ash as Partial Cement Replacement

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Abstract: This experimental work investigates the influence of POFA as partial cement replacement towards corrosion resistance of high strength concrete. Plain high strength concrete (P0) with 100% ordinary Portland cement (control specimen) and POFA high strength concrete containing POFA as partial cement replacement material were used. At the first stage, mix with 20% POFA (P20) has been identified as the best performing mix after cubes (150×150×150 mm) containing various content of POFA as partial cement replacement were prepared, continuously water cured and subjected to compressive strength test at 28 days. At the second stage of study, control specimen (P0) and high strength concrete mix containing 20% POFA (P20) were prepared in form of cylinders with reinforcement bar buried in the middle for corrosion resistance test. Specimens were subjected to half cell potential technique following the procedures outlined in ASTM C876 (1994). Incorporation of POFA as partial cement replacement has contributed to densification of microstructure making the concrete denser thus exhibit higher resistance towards corrosion as compared to plain concrete.

Keywords: Corrosion resistance, durability, high strength concrete, palm oil fuel ash, partial cement replacement

INTRODUCTION

Production of Palm Oil Fuel Ash (POFA) a solid waste from palm oil industry in increasing amount (Hussin and Abdullah, 2010) and greenhouse gas emmisions resulting from the manufacturing of cement (Obla, 2009) which affect the environment has inspired many researchers to work on solving this problem. After POFA has been identified as pozzolanic material which is suitable to used in concrete production in 20th century, this waste material has been integrated as partial cement replacement to produce various types of concrete which consume lesser amount of cement, greener and more economic. Owing to larger amount of cement consumption of high strength concrete compared to plain concrete, this building material has been produced by incorporating POFA as partial cement replacement.

Properties of high strength concrete upon utilization of POFA as partial cement substitute when investigated in terms of mechanical properties (Sata *et al*., 2004), sulphate resistance (Hussin and Abdullah, 2009), acidic resistance (Mohamed *et al*., 2010), transport properties comprising porosity, gas permeability and water permeability (Megat Johari *et al*., 2012) has shown positive improvement as compared to plain concrete. However, the corrosion resistance of high strength concrete when POFA is integrated as partial cement replacement in the mix remain to be explored. Therefore, the present research discusses the corrosion resistance of high strength concrete specimens consisting POFA as partial cement replacement. Thus, this experimental work which investigates the effect of palm oil fuel ash as partial cement replacement towards corrosion resistance high strength concrete were conducted at laboratory of Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang.

MATERIALS AND METHODS

Locally produced Ordinary Portland Cement (OPC) was used as binder to produce all the specimens. The coarse aggregate used was granite aggregate with maximum size of 20 mm. Fine aggregate used is local river sand. Super plasticizer of type F high range water reducing admixture complying with (ASTM C494-05, 2005) was integrated during concrete mix preparation to improve workability and reduce the water cement ratio used. Tap water was used for concrete preparation as well as for curing purpose. Palm oil fuel ash were collected from the palm oil mill, in the state of Pahang, West Malaysia. The collected ash were sieved and grind to be fine enough fulfilling the requirement in ASTM C618-05 (2005) before used as partial cement replacement material.

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Table 1: Mix proportion of plain high strength concrete (P0) and POFA high strength concrete (P20)

Material (kg/m^3)	Plain high strength concrete	POFA high strength concrete
Cement	500	400
Palm oil fuel ash	0	100
Coarse aggregate	1195	1195
Sand	797	797
Water	90	90
Super plasticizer	1%	1%

At the first stage of the experimental work, plain high strength concrete mix having compressive strength around 60 MPa at 28 days were prepared using DOE method. The plain concrete that act as control specimen were produced using 100% cement as binder. Then, POFA high strength concrete mixes were produced by integrating 10, 20 and 30% POFA, respectively as partial cement replacement. All specimens were cast in form of cubes (150×150×150 mm) and demoulded after 24 h before subjected to water curing for 7 and 28 days. Then, compressive strength test was carried out in accordance to BSEN 12390-3 (2009) to determine the best performing POFA high strength concrete mix to be used in the next stage of study.

At the second stage of study, POFA high strength concrete mix produced through incorporation 20% POFA which exhibit the highest compressive strength of all and plain specimen were used to prepare specimen for corrosion resistance test. The mix proportion of both mixes are tabulated in Table 1. The corrosion resistance of specimens were investigated by conducting half cell potential technique by following the procedures outlined in ASTM C876 (1994). All the specimens were prepared in form of cylinders of 80 mm diameter and 160 mm height with reinforcement bar buried in the middle. The duration of this testing is 10 weeks (5 cycles). For each cycle consist of 2 weeks. The first week, the concrete cylinder is immersed in 5% on NaCl solutions. After one week duration is over, the reading of half-cell potential is taken at 6 different spot on the cylinder to get the average value of half-cell potential data. For the second week, the specimen is left at room condition to enhance the development of corrosion. This step is repeated until the fifth cycle is over.

RESULTS AND DISCUSSION

As can be observed in Fig. 1, utilization of POFA as partial cement replacement between 10 to 30% produces mixes exhibiting higher strength than control specimen. In POFA mixes, presence of POFA as pozzolanic material together with availability of Calcium Hydroxide and continuous moisture presence has enabled pozzolanic reaction to take place. This reaction consumes Calcium Hydroxide in concrete which is susceptible to aggressive environment and most importantly generates secondary C-S-H gel

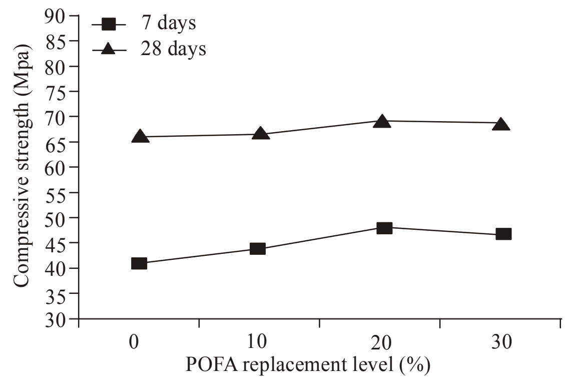

Fig. 1: Effect of POFA content towards compressive strength of high strength concrete at 7 and 28 days

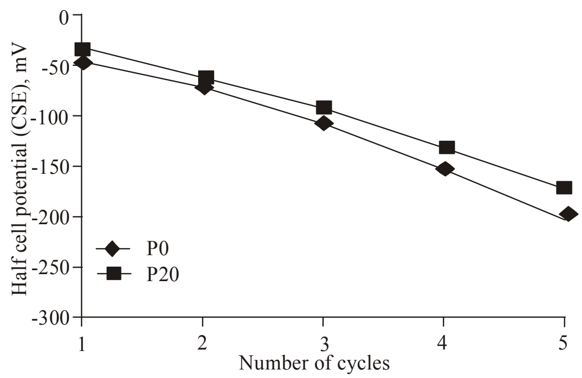

Fig. 2: Potential vs. number of cycles of exposure for plain concrete (P0) and POFA high strength concrete (P20) in 5% NaCl solution

making the blended cement high strength concrete having less voids than plain specimen. The formation of larger amount of secondary C-S-H gel that fills in the existing voids causes the concrete internal structure to be denser thus having higher capacity to sustain load. In this case, addition of 20% POFA as partial cement substitute has results in concrete having the most compact microstructure compared to other mixes which assist the particular mix to exhibit highest strength of all specimens. It is interesting to note that this finding is also in agreement with previous researchers (Hussin *et al*., 2009; Kroehong *et al*., 2011) who integrate 20% POFA as partial cement replacement material producing concrete exhibiting the highest compressive strength as compared to mixes with other replacement level. Conclusively, the next stage of the research has been continued by using specimen consisting 20% POFA as partial cement replacement that exhibit the highest strength and plain concrete produced using 100% OPC that used for comparison purpose.

The results on corrosion resistance for both plain concrete (P0) and POFA high strength concrete (P20) which obtained in form of half-cell potential values is shown in Fig. 2. By referring to ASTM 876 (1994), the potential value of P20 indicates that the probability for corrosion is very low for this blended cement high strength concrete. The half-cell potential value of concrete with POFA which is higher than plain concrete indicate the better resistance of the blended cement concrete towards corrosion. Incorporation of POFA increases the amount of calcium silicate hydrate gel contributing to concrete pore refinement and making the concrete dense. Furthermore, the filler effect of fine POFA that strengthen the transition zone between the paste and the aggregate also improves the concrete internal structure resulting to exhibit higher strength and durability as well. The densification of POFA high strength blended cement concrete microstructure makes this concrete more corrosion resistant in comparison to plain concrete. The function of microstructure densification through pozzolanic effect that contributes towards enhancement of strength and durability has been highlighted by Isaia *et al*. (2003).

CONCLUSION

Inclusion of POFA at 20% replacement level improved the corrosion resistance properties of steel in concrete. Utilization of POFA as partial cement replacement contributes produce denser structure of POFA high strength concrete in comparison to control specimen thus assisting this blended cement high strength concrete to be more durable towards corrosion.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support by Ministry of Higher Education of Malaysia and Universiti Malaysia Pahang.

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