AENSI Journals
Australian Journal of Basic and Applied Sciences
ISSN:1991-8178
Journal home page: www.ajbasweb.com

Permeation Properties of Lightweight Oil Palm Shell Concrete

Kim Hung Mo, Ubagaram Johnson Alengaram, Michael Yong Jing Liu, Mohd Zamin Jumaat

University of Malaya , Department of Civil Engineering, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO
Article history:
Received 15 April 2014
Received in revised form 22 May 2014
Accepted 25 October 2014
Available online 10 November 2014

Keywords:
oil palm shell; porosity; water absorption; blast furnace slag

ABSTRACT
Background: This paper presents the effect of 20-60% cement replacement by ground granulated blast furnace slag (GGBS) on the permeation properties of lightweight oil palm shell concrete (OPSC). **Results:** GGBS replacement level of 40% was found to be most effective in reducing the permeable pores in OPSC, exhibiting decrease in porosity and coefficient of water absorption by about 2% and 10%, respectively at the age of 28 days while reduction of 4% and 24% was observed after 90 days. **Conclusion:** All of the GGBS-based OPSC mixes achieved grade 30 concrete with 28-day compressive strength in the range of 36-43 MPa.

To Cite This Article: Kim Hung Mo, Ubagaram Johnson Alengaram, Michael Yong Jing Liu, Mohd Zamin Jumaat., Permeation Properties Of Lightweight Oil Palm Shell Concrete. ***Aust. J. Basic & Appl. Sci.,*** *8(19): 143-145, 2014*

INTRODUCTION

As Malaysia is of one the world's leading exporter of crude palm oil, the large production of palm oil generates huge amount of waste materials such as oil palm shell (OPS) which could lead to land and air pollution. Researchers found that the utilization of OPS in producing lightweight aggregate concrete (LWAC) has been effective, having achieved OPS concrete (OPSC) with compressive strength exceeding 40 MPa (Alengaram, U.J., 2013). In order to develop OPSC for other structural applications, such as water retaining structures and marine structures, a more comprehensive durability studies would be required. The OPS has smooth concave and convex surfaces, and combined with the presence of micro-pores on its surfaces (Alengaram, U.J., 2011), zone of weak interface bond between the OPS and cement matrix could exist. This could cause OPSC to be more vulnerable towards permeability of external agent and affects the durability of the concrete. The use of finer mineral admixture such as ground granulated blast furnace slag (GGBS) to partially replace cement is known to be beneficial in enhancing the packing density by acting as filler as well as undergoing pozzolanic reaction with calcium hydroxide (CH) to form calcium silicate hydrate (CSH). The improved microstructure of concrete could enhance the durability of concrete and protect steel reinforcement in reinforced concrete members. In this investigation, a preliminary study will be conducted on the permeation properties of OPSC as a platform for future durability research of OPSC. Different level of ordinary Portland cement (OPC) replacements by GGBS was studied to obtain the optimum amount of GGBS in OPSC with regard to the permeation properties.

Experimental Procedure:

Materials and mix proportion:

OPC and GGBS that were used had specific gravity and specific surface area of 3.10 and 352 m^2/kg, and 2.90 and 405 m^2/kg, respectively. The oxide composition of OPC and GGBS are listed in Table 1. Manufactured sand of size 300 µm-5 mm and pre-soaked OPS with size between 2.36-14 mm was used as fine and coarse aggregates, respectively. A PCE-based superplasticizer (SP) and potable water were also used in the mixing.

Four mixes used in this study had constant water to binder, sand to binder and aggregate to binder ratio of 0.33, 1.70 and 0.65, respectively. The binder content was fixed at 550 kg/m^3 and the variables studied were the percentages of OPC replacement with GGBS by mass, namely 20% (M2), 40% (M3) and 60% (M4). The mix without GGBS was used as control in this investigation (M1). SP was used at 1.0% by mass of binder in all mixes to ensure workability. All specimens were subjected to continuous moist curing until age of testing.

Corresponding Author: Kim Hung Mo, University of Malaya, Department of Civil Engineering, 50603, Kuala Lumpur, Malaysia.
Tel: +60172119378; E-mail: mokimhung@siswa.um.edu.my

Table 1: Oxide composition of OPC and GGBS.

	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	Na_2O	SO_3	K_2O	LOI
OPC	19.8	63.4	5.1	3.1	2.5	0.19	2.4	1.0	1.8
GGBS	33.8	43.9	13.4	0.52	5.4	0.2	0.1	0.31	1.0

Test method:

Compressive strength test was done at the age of 28-day on 100 mm cube in accordance with BS EN 12390-3: 2002. The porosity and coefficient of water absorption tests were done at the age of 28- and 90-days. In the porosity test, disc specimen with 100 mm ϕ and thickness of 50 mm were pre-conditioned by oven drying at temperature of 105˚C for 48 hours. The weight of the disc specimen was taken as W_1. Two saturation techniques were adopted; the vacuum saturation technique and cold water saturation technique as conducted by Safiuddin and Hearn (Safiuddin, M., N. Hearn, 2005). The saturated surface dry weight of the disc sample (W_2) were taken after immersion in water for 24-hr. The porosity (P) was determined from the Eq. 1 below where W_b is the buoyant weight of disc.

$$P(\%) = \frac{w_2 - w_1}{w_2 - w_b} \times 100\%. \quad (1)$$

The coefficient of water absorption was measured by the rate of uptake of water in 60 minutes as proposed by Ganesan et al. (2008). In this test, the cube specimen used was kept partially immersed in water up to a depth of 5 mm and the amount of water absorbed during the first 60 minutes was determined. Coefficient of water absorption was calculated using the Eq. 2 where K is the coefficient of water absorption (m^2/s), Q is volume of water absorbed (m^3), t is time taken in seconds and A is the surface area of concrete in contact with water (m^2).

$$K = \left(\frac{Q}{A}\right)^2 \times \left(\frac{1}{t}\right). \quad (2)$$

RESULT AND DISCUSSION

Compressive strength:

As shown in Table 2, all of the mixes had 28-day compressive strength in the range of 36-45 MPa, which satisfied the lower limit of 17 MPa for structural lightweight concrete in accordance with ACI-213R. The control mix M1 had higher compressive strength compared to mixes with GGBS (M2, M3 and M4). This could be attributed to the slower hydration of GGBS compared to OPC. Since hydration of GGBS requires CH, which is a by-product of OPC hydration, the higher amount of OPC replacement with GGBS could have caused lower amount of CH produced and consequently reduced the reactivity of GGBS. This is especially significant at 60% GGBS content where about 20% of reduction in compressive strength was noticed compared to the control concrete without GGBS. Shafigh et al. (2013) also reported that the reduction in 28-day compressive strength of OPSC is between 17% and 23% when about 50% and 70% GGBS were used as OPC replacement, respectively.

Table 2: Compressive strength and porosity of OPSC at 28-day.

Mix	28-day compressive strength (MPa)	Porosity (%)			
		Vacuum saturation		Cold water saturation	
		28-day	90-day	28-day	90-day
M1	45.2	14.0	14.0	12.1	12.1
M2	43.0	14.4	13.8	12.7	11.2
M3	39.7	13.8	13.5	12.5	10.6
M4	36.4	17.0	15.9	13.1	12.2

Porosity:

From Table 2, it was found that vacuum saturation revealed higher porosity values for all the OPSC mixes compared to cold water saturation. This was reasoned by Safiuddin and Hearn (2005) that vacuum saturation is capable of taking into account the air porosity. All of the porosity by vacuum saturation ranged from 13.8-17% and 13.5-15.9% at 28- and 90-day, respectively while porosity of OPSC by cold water saturation ranged from 12.1-13.1% and 10.6-12.0% at 28- and 90-day, respectively. There were only minimal differences in porosity at 28 days among mixes M1, M2 and M3, regardless of the saturation technique. A possible explanation to this was that up to 40% of GGBS, the GGBS had undergone significant hydration by 28 days and thus porosity values did not differ much. The mix M4, however, showed highest porosity for both saturation techniques at 28 days. This could be attributed to the slower hydration of the larger volume of GGBS in the mix, which could cause the formation of higher number and coarser water permeable pores. At 90 days, all GGBS mixes showed reduced porosity while the control concrete showed no reduction in porosity. This was attributed to the effect of GGBS, which could still undergo hydration process at later stages and hence enhance the microstructure of OPSC. Porosity of mix M3 was found to be lowest among the mixes and mix M4 remained as the mix with highest porosity after 90 days. The lowest porosity in mix M3 could be due to the continuous hydration of GGBS that reduced the pore sizes and number of pores of OPSC. Further, the ability of finer GGBS particle to penetrate the surface pores of OPS could improve the pore area between the OPS and cement matrix, thus reducing its porosity. Alengaram et al. (2011) also reasoned that the use of mineral admixture such as silica fume and fly ash could serve the mentioned purpose. Even though the porosity of M4 mix with 60% GGBS was reduced at 90 days, the mix still had the highest porosity. Although the GGBS particles had undergone continuous hydration, it was possible that a high number of un-hydrated GGBS particles were still present as a result of limited availability of CH.

Coefficient of water absorption:

Coefficient of water absorption is suggested as a measure of permeability of water [3]. The coefficient of water absorption for all mixes is presented in Table 3. Higher coefficient of water absorption implied higher water permeability of the concrete and vice versa. At 28- and 90-days, the coefficient of water absorption decreased in the following order: M4, M1, M2 and M3.

Table 3: Water absorption coefficient of OPSC at 28- and 90-day.

Mix	Coefficient of water absorption (× 10^{-10} m^2/s)	
	28-day	90-day
M1	0.640	0.613
M2	0.636	0.518
M3	0.576	0.467
M4	0.769	0.677

At 28 days, the control concrete had coefficient of water absorption of about 0.64 × 10^{-10} m^2/s and only slight difference was observed for the mix M2. The mix M3, however, experienced a decrease of about 10% while further replacement of up to 60% of GGBS led to increase of about 20% in coefficient of water absorption. This was consistent with the findings of porosity, which suggested that 40% GGBS replacement could be beneficial in refining the pore structure in OPSC after 28 days. On the other hand, higher replacement level of 60% was found to have increased the permeable pores in OPSC, resulting in highest coefficient of water absorption. After water cured for 90 days, coefficient of water absorption of 0.61, 0.52, 0.47 and 0.68 × 10^{-10} m^2/s were observed for mixes M1, M2, M3 and M4, respectively. All GGBS mixes experienced reduction in coefficient of water absorption in the range of 12-18% whereas the control concrete showed only 4% decrease. This could be attributed to the higher reactivity of GGBS at the later stages which improved the pore structure of OPSC.

Conclusion:

OPC replacement with 40% of GGBS in OPSC exhibited the lowest 28-day porosity and coefficient of water absorption of 13.8% and 0.576 × 10^{-10} m^2/s, respectively due to the improvement in pore structure by GGBS. The beneficial effect of GGBS in enhancement of OPSC pore structure over time was also observed through the reduction in the 90-day porosity and coefficient of water absorption while plain OPC had only minimal effect.

ACKNOWLEDGEMENT

This research work was funded by the University of Malaya under the grant RP018/2012B (Development of Geopolymer Concrete for Structural Application).

REFERENCES

Alengaram, U.J., B.A. Al Muhit, M.Z. Jumaat, 2013. Utilization of Oil Palm Kernel Shell as Lightweight Aggregate in Concrete – A Review, *Construction and Building Materials*, 38: 161-172.

Alengaram, U.J., H. Mahmud, M.Z. Jumaat, 2011. Enhancement and Prediction of Modulus of Elasticity of Palm Kernel Shell Concrete, *Materials & Design*, 32(4): 2143-2148.

Ganesan, K., K. Rajagopal, K. Thangavel, 2008. Rice husk ash blended cement: Assessment of Optimal Level of Replacement for Strength and Permeability Properties of Concrete, *Construction and Building Materials* 22(8): 1675-1683.

Safiuddin, M., N. Hearn, 2005. Comparison of ASTM Saturation Techniques for Measuring the Permeable Porosity of Concrete, *Cement and Concrete Research*, 35(5): 1008-1013.

Shafigh, P., M.Z. Jumaat, H.B. Mahmud, U.J. Alengaram, 2013. Oil Palm Shell Lightweight Concrete Containing High Volume Ground Granulated Blast Furnace Slag, *Construction and Building Materials,* 40: 231-238.