Compressive Strength of Oil Palm Shell Lightweight Aggregate Concrete Containing Clinker as Sand Replacement

[1]Muhammad Nazrin Akmal Ahmad Zawawi, Khairunisa Muthusamy,
Faculty of Civil Engineering and Earth Resources
Universiti Malaysia Pahang
Lebuhraya Tun Razak, 26300 Gambang, Pahang
[1]nazrinakmal89@gmail.com

Nasly Mohd Ali
CCA Systems Sdn Bhd.
118, Jalan Intan, Gombak Setia
Batu 6, Jalan Gombak, 53100 Kuala Lumpur

Abstract—Annually, huge quantity of solid wastes namely oil palm shell and clinker from Malaysian palm oil mills were disposed as waste at dumping site. Continuous dumping of waste which has been increases over the years causes more land to be used for waste disposal and also cause pollution to the environment. Realizing that utilization of these waste material in concrete production would reduce amount of waste disposed, efforts has been taken to integrate both oil palm shell and clinker as mixing ingredient to produce palm oil waste lightweight aggregate concrete. The present research was conducted to investigate the effect of palm oil clinker as sand replacement towards workability, density and compressive strength of oil palm shell lightweight aggregate concrete. All the specimens were prepared in form of cubes and water cured until the testing age. The compressive strength test was carried out at 7 and 28 days. The result shows that inclusion of suitable amount of palm oil clinker as sand replacement would be able to produce a more environmental friendly oil palm shell lightweight aggregate concrete suitable for structural application. Incorporation of palm oil clinker as mixing ingredient would reduce the amount of clinker disposed as waste and also control the use of natural river sand mined from the river bed thus ensuring ecological balance as well as cleaner environment for future generation.

Keywords—Oil palm shell lightweight aggregate concrete; clinker; sand replacement; density; compressive strength

1. INTRODUCTION

Palm oil clinker and oil palm shell are two types of solid waste generated from Malaysian palm oil industry. Since Malaysia is one of the world largest palm oil producers, quantity of wastes generated are also in huge amount. According to [1], the palm oil industry is also a major contributor to the pollution problem in this country with an estimated 2.6 million tonnes of solid waste produced annually. Every year approximately 6.89 million tonnes of oil palm shell (OPS) were produced [2]. Another waste material which appears like porous rock known as palm oil clinker is also thrown as waste. It is generated abundantly and has small commercial value in the country [1]. Looking at the long term effort, continuous dumping of these materials would create more need for landfills and environmental problems unless it is used in production of any material. Success in integrating these waste as raw material for production of other product would lead towards lesser amount of palm oil waste disposed, saving of landfills and also reduction in the cost spent by palm oil industry for waste management. At the same time, the growing construction industry causes increase in concrete production which in turn creates larger demand for natural sand supply over the years. Mining activity at the river is one of the methods to obtain natural sand supply. However, excessive river sand mining demand would create negative impact to the river environment in terms of destruction of habitat of flora and fauna as well as water quality. The issue of natural sand mining and its negatives impact to environment has been well elaborated by [3] and [4]. In relation to this issue, introducing other material to function as sand replacement partially or fully is one of the ways to reduce quantity of sand mined from the river. Concern towards cleaner and sustainable environment has led many researchers [5, 6, 7, 8, 9] to investigate the potential use of various types of waste materials as fine aggregate replacement in concrete production. With the aim to reduce problems posed by both construction and palm oil industry, the present research investigates the possibility of integrating palm oil clinker as sand replacement in lightweight concrete production. The paper discusses the effect of palm oil clinker content as fine aggregate towards workability and strength performance of oil palm shell lightweight concrete.

2. EXPERIMENTAL PROCEDURE

A. Materials

Ordinary Portland cement (OPC), sand, oil palm shell, palm oil clinker, water, water reducing admixture are among the materials used in concrete preparation. Ordinary Portland cement (OPC) for a single source was used throughout the experimental work. Supplied tap water was used for concrete mixing and curing. Water reducing admixture was used to achieve the targeted workability of concrete mix with reduced water content. Both oil palm shell (OPS) and palm oil clinker (POC) were supplied by nearby palm oil mill. Figure 1 and 2 illustrates the appearance of oil palm shell and palm oil clinker at the mill. Both materials were packed in the gunny and brought to the laboratory for further cleaning and processing. At the laboratory, palm oil clinker was crushed to be fine enough suitable to be used as fine aggregate replacement as shown in Figure 4.

Figure 1: Dumping site of palm oil wastes

Figure 2: Oil palm shell

Figure 3: Raw palm oil clinker from the palm oil mill

Figure 4: Crushed palm oil clinker

B. Mix Proportioning and Testing Procedure

Three types of mixes oil palm shell lightweight aggregate containing different content of palm oil clinker as sand replacement have been used in this experimental work. Three types of testing that are workability, compressive strength and dry density were investigated. The amount of cement, oil palm shell, water reducing admixture and water used were kept constant for all mixes. Only the amount of clinker used is varied. Detail of the mixes used is tabulated in Table 1. All the specimens were prepared in form of cubes and demoulded after 24 hours. Then, all the specimens were left immersed in tap water until the testing age. The compressive strength test is conducted on the specimen following the procedure in [10] at 7 and 28 days using 100 x 100 x 100 mm standard cubes specimen. The workability of high strength palm oil clinker lightweight aggregate concrete was indicated using slump flowability following the procedures in [11].

3. RESULTS

As can be observed in Table 1, amount of palm oil clinker integrated as sand replacement in oil palm shell lightweight aggregate concrete influence the workability of mix. The slump produces by M1 is categorized as shear slump with 90 mm slump. On the other hand, the slump of M2 and M3 that contains clinker more than M1 is classified as true slump. Inclusion of larger amount of clinker which is porous reduces concrete workability making the mix becomes stiffer and more difficult to work with. Clinker tends to absorbs water during mixing process thus complicate the mixing process. This resulted in too little water remains for mixing process which then prevented the concrete mix to achieve the desired workability. This findings is in line with [12], indicates that the absorption capacity of lightweight aggregate concrete is high due to the porous nature of aggregate used.

As for strength performance, results in Figure 5 shows that the compressive strength of OPS lightweight aggregate concrete is affected by quantity of POC used in the mix. On overall, all mixes exhibit continuous strength development with curing age. Continuous water curing promotes undisturbed hydration process leading to generation of larger amount of C-S-H gel in the concrete internal structure. As a result, the concrete is denser and possess ability to sustain larger load. The significant role of water presence during curing has been highlighted by [13] who stated that continuously water supply able to enhance the strength of concrete. Based on the study conducted in 1986 by [14], the curing method has a big influence towards strength development in concrete matrix through C-S-H gel production. The test result revealed that the compressive strength of concrete increases when more POC is used. Integration of higher amount of POC makes the concrete denser leading to the increment in compressive strength of concrete.

Looking at the density aspect, the concrete becomes heavier along with the increment of palm oil clinker content used. Use of high content of clinker causes the concrete to possess density more than 1850 kg/m^3 and heavier which is not suitable to applied as structural lightweight concrete. Use of clinker less than 670 kg/m^3 reduces the concrete weight enabling it to be classified as lightweight concrete. This is because [15] defines the allowable lightweight concrete density is between 300 to 1850 kg/m^3. Thus, M2 and M3 density exceeded the available density standard thus cannot be categorized as lightweight concrete. Only M1 can be classified as lightweight concrete with the density value of 1845 kg/m^3 which is less than 1850 kg/m^3 (practical range of densities for lightweight concrete) and approximately 25% lighter than normal concrete. Adding clinker as fine aggregate beyond 670 kg/m^3 would result in concrete with higher dry density (more than 1850 kg/m^3) thus cannot be considered as lightweight aggregate concrete. Since the minimum requirement for lightweight concrete to be used for structural application is 17 MPa [15], OPS lightweight aggregate concrete containing palm oil clinker of 670 kg/m^3 can be used for structural application as the compressive strength exceeded this minimum requirement.

Table 1: Mix Proportion of the control mix (kg/m^3)

Material	M1	M2	M3
Cement	500	500	500
Oil Palm Shell	360	360	360
Palm Oil Clinker	670	770	870
Water	250	250	250

Table 2: Slump test result

Mixes	Slump (mm)	Category
M1	90	Shear slump
M2	0	True slump
M3	0	True Slump

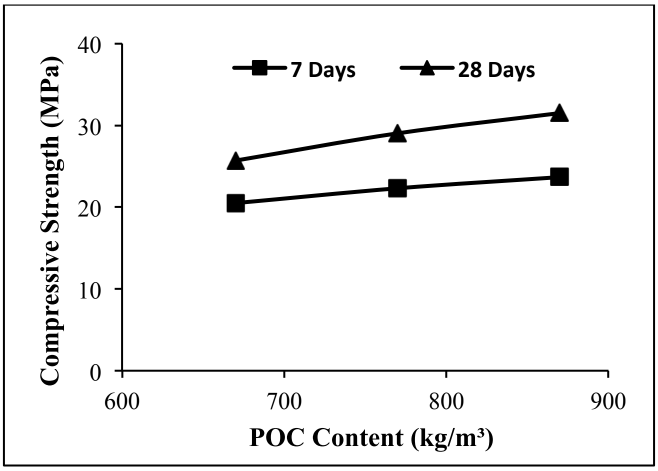

Figure 5: Compressive strength of lightweight concrete containing various percentage of POC

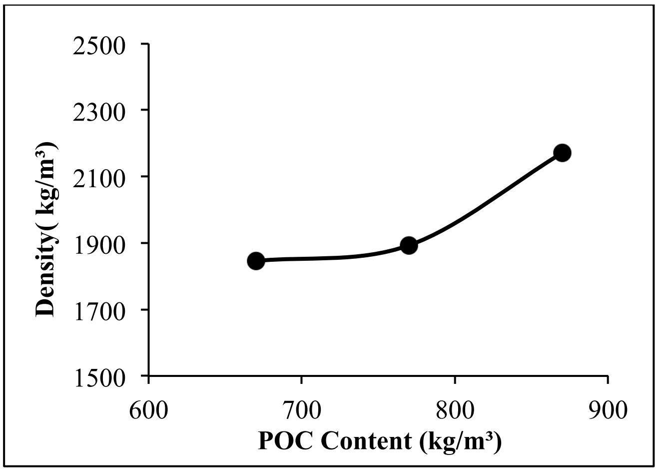

Figure 6: Density of lightweight concrete containing various percentage of POC

4. CONCLUSION

Inclusion of palm oil clinker influence both density and compressive strength of oil palm shell lightweight aggregate concrete. Only suitable content of palm oil clinker used able to produce concrete with the density less than 1850 kg/m^3 allowing it to be classified as lightweight concrete. Integration of palm oil clinker as natural sand replacement in concrete production would be able to decrease amount of palm oil industry waste disposed, reduce the dependency of river sand supply and most importantly contribute towards healthier environment.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the management team of the nearby palm mill for providing the waste materials to be used for this research purpose. The financial provided by Universiti Malaysia Pahang through RDU140371 is also acknowledged.

REFERENCES

[1] F. Abutaha, H. Abdul Razak, and J. Kanadasan, “Effect of palm oil clinker on fresh and hardened properties of concrete” Construction and Building Materials, vol. 112, pp. 416-423, 2016.

[2] H. L. H. Chong, P. S. Chia, Ahmad, M. N. Ahmad, “The adsorption of heavy metal by Bornean oil palm shell and its potential application as constructed wetland media,” Bioresource Technology, vol. 130, pp. 181–186, 2013.

[3] N. Manap and N. Voulvoulis, “Environmental management for dredging sediments,” Journal of Environmental Management, vol. 147, pp. 338–348, 2015.

[4] M. A. Asyraf, M. J. Maah, I. Yusoff, A. Wajid and K. Mahmud, “Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia,” Scientific Research and Essays, vol. 6, pp. 1216 –1231, 2011.

[5] A. Sales, and S. A. Lima, “Use of Brazillian sugarcane bagasse ash in concrete as sand replacement,” Waste Management, vol. 30, pp. 1114–1122. 2010.

[6] M. Singh, and R. Siddique. “Effect of coal bottom ash as partial replacement of sand onproperties of concrete Resources,” Conservation and Recycling, vol. 72, pp. 20-32, 2013.

[7] G. G. Prabhu, H. H. Jung and Y. K. Yun, “Effects of foundry sand as a fine aggregate in concrete production,” Construction and Building Materials, vol. 70, pp. 514–521, 2014.

[8] F. Mat Yahaya, K. Muthusamy and M. W. Hussin, “Long term investigation of sulphate resistance of aerated concrete containing palm oil fuel ash,” ARPN Journal of Engineering and Applied Sciences, vol. 11, pp. 2406–2411, 2015.

[9] K. Muthusamy, N. N. A. Tukimat, N. N. Sarbini and N. A. Zamri, “Exploratory study on the use of crushed cockle shell as partial sand replacement in concrete,” International Journal of Research in Engineering and Science, vol. 4, pp. 67–71, 2016.

[10] BSEN12390 – 3, “Testing hardened concrete : Compressive strength of test specimens.,” British standard Institution, London, 2009.

[11] British Standard, “Testing Fresh Concrete. Slump test,” London, BS EN 12350-2, 2000.

[12] N. Bozkurt and S. Yazicioglu, “Strength capillary water absorption of lightweight concrete under different curing conditions,” Indian Journal of Engineering and Materials Sciences. Vol. 17, pp. 145–151, 2010.

[13] A. M. Neville, Properties of Concrete. London: Pearson Education Limited, 1995.

[14] S. Popovics, “Effect of curing method and final moisture condition on compressive strength of concrete”. ACI Materials Journal. Vol 83, pp. 650–657, 1986.

[15] A. M. Neville, Properties of concrete. 4th ed. London: Pearson Education Limited, 2005.