THE DURABILITY PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING COAL BOTTOM ASH

NURUL ATIKAH SHAFIKA BINTI JAMIL

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at University Malaysia Pahang or any other institution.

____

(Student's Signature)

Full Name : NURUL ATIKAH SHAFIKA BINTI JAMIL

ID Number : AA15101

Date : 31th May 2019

THE DURABILITY PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING COAL BOTTOM ASH

NURUL ATIKAH SHAFIKA BINTI JAMIL

Thesis submitted in partial fulfillment of the requirements
for the award of the
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

First and foremost, Alhamdulillah, all the praises and thanks be to Allah S.W.T. With His permission, I can finish up this thesis report on time. I would like to give a special thank you and give a high appreciation to my research supervisor, Dr. Khairunisa Binti Muthusamy. Without her assistance and dedicated involvement in every step throughout the process, this paper would have never been accomplished. I also want to thank you from the bottom of my heart for your support and understanding throughout the course of the study.

Furthermore, getting through my dissertation required more than academic support. I would like to give my sincere thanks to all my group lab members and staff members of the Civil Engineering and Earth Resources Department, UMP, who almost time helped me in many ways and made my work at UMP pleasant and unforgettable. I cannot begin to express my gratitude and appreciation for their friendship. They have been unwavering in their personal and professional support during the time I spent on my research.

Most importantly, none of this could have happened without my beloved family. To my parents, I am very grateful for their sacrifice, patience, and understanding that was inevitable to make this work possible. I cannot find the appropriate words that could interpret to describe my appreciation for their devotion, support, and faith in my ability to achieve my goals. I acknowledge my sincere indebtedness and gratitude to my parents for their loves, dreams, and sacrifices throughout my life. Special thanks should be given to my fellow members. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

ABSTRAK

Tempurung kelapa sawit (OPS) dan abu arang (CBA) ialah sisa buangan industri kelapa sawit dan sisa buangan industri arang hasil daripada pembakaran sisa buangan bagi menjana tenaga elektrik untuk kegunaan kilang kelapa sawit dan kilang arang. Penggunaan bahan abu arang (CBA) sebagai bahan separa pengganti pasir di dalam campuran konkrit, ia dapat membantu menggurangkan pencemaran kepada alam sekitar. Kajian ini membuat penyelidikan tentang kesan penggunaan CBA sebagai bahan separa pengganti pasir terhadap sifat-sifat ketahanan konkrit aggregat dengan OPS. Terdapat dua jenis campuran konkrit digunakan iaitu konkrit OPS dengan menggunakan 100% pasir semulajadi dan konkrit OPS yang mengandungi abu arang sebagai bahan pengganti separa. Peratusan abu arang sebagai bahan pengganti separa untuk pasir adalah 0%, 10%, 20% dan 30%. Semua specimen dihasilkan telah diawet menggunakan kaedah awetan udara sehingga masa diuji tiba. Semua specimen diuji dari segi kedayatahanan penyerapan air, ujian keliangan dan rintangan asid terhadap konkrit OPS. Konkrit OPS dengan 10% CBA sebagai bahan pengganti separa untuk pasir mempunyai bacaan peratusan yang paling rendah untuk penyerapan air iaitu 1.305%. Bacaan peratusan yang paling rendah untuk ujian keliangan ialah 5.88% dengan 10% CBA sebagai bahan pengganti separa untuk pasir. Untuk rintangan asid, penurunan berat pada konkrit yang terendah ialah 3.376% dengan 10% CBA sebagai bahan pengganti separa untuk pasir. Konklusinya, penggunaan abu arang dengan jumlah yang sesuai sebagai bahan pengganti separa untuk pasir mempunyai kedayatahanan yang tinggi dari segi penyerapan air, keliangan dan rintangan asid konkrit OPS.

ABSTRACT

Oil palm shell (OPS) and coal bottom ash (CBA) is an industrial waste product. This waste material generated electricity from the burning of this waste for the purpose of their mill. The usage of CBA as partial sand replacement in the mixture of concrete can helped to reduce pollution to the environment. This research was to investigate the effect of usage CBA as partial sand replacement on durability properties of the OPS concrete. There were two types of the concrete mixture used which is OPS concrete with 100% river sand and OPS concrete containing CBA as partial sand replacement. Percentages of CBA as partial sand replacement for sand were 0%, 10%, 20%, and 30%. All the specimens undergo curing which was air curing until the time for testing. All specimens were being tested in terms of water absorption, porosity and acid resistance. OPS concrete with 10% of CBA as partial sand replacement had a lowest percentage of water absorption which is 1.305%. For porosity, OPS concrete with 10% of CBA as partial sand replacement had a lowest percentage which is 5.88%. And for acid resistance, OPS concrete with 10% of CBA as partial sand replacement had a lowest percentage which is 3.376%. Conclusion, the usage of suitable amount of CBA as partial sand replacement increase the durability of OPS concrete in terms of water absorption, porosity and acid resistance.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

g	gram
h	hour
P	Porosity

LIST OF ABBREVIATIONS

AA	Alternative Aggregate
ASR	Alkali-Silica Reaction
ASTM	American Society for Testing and Materials
BS	British Standard
CBA	Coal Bottom Ash
CO2	Carbon Dioxide
FA	Fly Ash
FGG	Foam Glass Granule
FKASA	Faculty of Civil Engineering and Earth Resources
GHG	Greenhouse Gas
LWA	Lightweight Aggregate
LWAC	Lightweight Aggregate Concrete
MPOB	Malaysian Palm Oil Board
M-SAND	Manufactured Sand
OPS	Oil Palm Shell
POC	Palm Oil Clinker
SCM	Supplementary Cementitious Materials

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Green concrete as concrete produced by utilizing alternative or recycled waste materials in order to reduce energy consumption, environmental impact and natural resource consumption (Jin & Chen, 2013). The production of green concrete by using waste material in the construction industry reduced the greenhouse gas emission and limited landfill space. Furthermore, green concrete had numerous advantages such as improvement in concrete properties, low carbon footprint, conservation of natural resources and etc. This waste material can be either used in supplementary cementitious materials (SCM) or alternative aggregate (AA) in green concrete and it can be classified into 3 categories which were agricultural, industrial and municipal wastes. For this research, we used the oil palm shell (OPS) from agricultural waste and coal bottom ash (CBA) from industrial wastes.

The waste material generated from oil palm plantation is the main contributor which led to increasing the rate of environment pollution. Along with this waste material generated by oil palm plantation, there was a by-product that ends up at landfill which known as Oil Palm Shells (OPS) and Coal Bottom Ash (CBA). Production of Coal Bottom Ash (CBA) was about 8.5 million tons of coal ash as waste which included of Bottom Ash and Fly Ash. This waste can be used as a partial sand replacement under a certain process. Coal Bottom Ash is the by-product formed in coal-fired electricity power stations (coal combustion). This usage can minimize energy consumption during the production of cement, lower carbon dioxide (CO_2) emissions and finally reduced the waste effectively.

According to Mineral and Geoscience Department Malaysia, it is reported that the production of granite aggregate was about 100 million tons in 2014 which increased by 30% since the year 2007. This could lead to environmental degradation where the deforestation of green hills took place to obtain limestones to produce cement and coarse aggregate which in result the destruction of flora and fauna occurred. With the transformation of a green hill to barren land, it will cause soil erosion which also affected the quality of water and also aquatic life in the water. Furthermore, from deforestation, it can cause greenhouse gas emission which is the main contributor to global climate change.

1.2 PROBLEM STATEMENT

In Malaysia, there were 2 largest non-renewable energy resources which were oil and gas where the oil also came from oil palm industry, from this situation, in results which can cause plenty of waste product produced. The annual production of waste oil palm shell (OPS) was over 4 million tons which can cause the usage of landfill areas increasing. From this also, it can cause pollution and health problems for the environment. Production of coal also produced waste abundantly, which can lead to pollution and health problems to the people and the environment. Production of granite is from limestone where it reduced the green hill, in the result this product can cause the destruction of flora and fauna and lastly can be caused the global warming due to the reduction of green hills and trees. With the replacement of oil palm shell as coarse aggregate, it reduced the production of granite. The quarrying of natural sand will result in environmental issues such as lowering ground water level, destruction of natural habitats, soil erosion, etc. The usage of natural sand where the results will have limited supply, source location and the presence of impurities. In order to fulfill the increased in demand of more consistent supply, controlled quality, and environmental friendly sand, it showed that the usage of manufactured sand was better than natural sand plus it was less costly compared to the natural sand.

Researchers have attempted to utilize recycled sand from construction waste (Ledesma et al.,2015). Manufactured sand was readily available and its quality controlled process would enable it to be used as a replacement for conventional sand. Recent researches showed that the use of M-sand as a complete replacement of natural sand was possible without any significant detrimental effect on the compressive strength of concrete (Nanthagopalan and Santhanam, 2011).

1.3 OBJECTIVES OF THE RESEARCH

The objectives of the study are as follow:

i) To study the effect of coal bottom ash (CBA) as a partial sand replacement on water absorption of OPS lightweight aggregate concrete.

ii) To study the effect of coal bottom ash (CBA) as a partial sand replacement on porosity of OPS lightweight aggregate concrete.

iii) To study the effect of coal bottom ash (CBA) as a partial sand replacement on acid resistance of OPS lightweight aggregate concrete.

1.4 SCOPE OF THE RESEARCH

This research focused on investigating the durability properties of OPS lightweight aggregate concrete containing coal bottom ash (CBA) as partial sand replacement. The durability properties that have been investigated were water absorption, acid resistance, and porosity. The acid resistance test was conducted by measuring the weight loss of cube immersed on sulfuric solution. An oil palm shell was used as a coarse lightweight aggregate for concrete and in the condition of saturated surface dry. In this research, we used 100x100x100 mm^3 of cube specimens for these three types of tests which were water absorption, acid resistance, and porosity. Percentage of CBA used for partial replacement of sand was 0%, 10%, 20% and 30%.

1.5 SIGNIFICANCE OF RESEARCH

The main purpose of this research was to minimize the pollution on the environment caused by the waste products from the oil palm industry and the coal industry. Manipulating the CBA and OPS reduced a large amount of waste produced and more environmental friendly can be produced. Moreover, the potential alternative material using the oil palm plantation and the coal combustion waste as partial replacement material on concrete will reduce the high dependency on natural resources thus preserving the environment. Furthermore, this study offered the oil palm industries

REFERENCES

Abdul Wahab E.S., Omar R., Che Osmi F.S., Muhamad Khairussaleh N.A., Abdullah A., (n.d.). 2012. Preliminary study on Mechanical properties of concrete added with fine palm oil.

Al-Tayeb M., Abu Bakar B., Ismail H., Md Akil H., 2013. Effect of the partial replacement of sand by recycled fine crumb rubber on the performance of hybrid rubberized-normal concrete under impact load: experiment and simulation. *Journal of the Cleaner Production,* Volume 46, pp. 284-289.

Alengaram U.J., Al Muhit B.A., Jumaat M.Z., 2013. Utilization of oil palm kernel shell as lightweight aggregate in concrete. *Construction and Building Materials,* Volume 38, pp. 161-172.

Andrande L.B., Rocha J.C., Cheriaf M., 2007. Evaluation of concrete incorporating bottom ash as a natural aggregates replacement. *Waste management.* Volume 27, pp. 1190-1199.

Aslam M., Shafigh P., Jumaat M.Z., Lachemi M., 2016. Benefits of using blended waste coarse lightweight aggregates in structural lightweight aggregate concrete. *Journal of Cleaner Production,* Volume 119, pp. 108-117.

Bai Y., Darcy F., Basheer P.A.M., 2005. Strength and drying shrinkage properties of concrete containing furnace of bottom ash as fine aggregate. *Construction and Building Materials,* Volume 19, pp. 691-697.

Bilir T., 2012. Effect of non-ground slag and bottom ash as fine aggregate on concrete permeability properties. *Construction and Building Materials,* Volume 26, pp. 730-734.

Bumanis G., Bajare D., Locs J., Korjakins A., 2013. Alkali-silica reactivity of foam glass granules in the structural of lightweight concrete. *Construction and Building Materials,* Volume 47, pp. 274-281.

Costa H., Julio E., Lourenco J., 2012. A new approach for shrinkage prediction of high strength lightweight aggregate concrete. *Construction and Building Materials,* Volume 35, pp. 84-91.

Dash M.K., Patro S.K., Rath A.K., 2016. Sustainable use of industrial waste as partial replacement of fine aggregate for preparation of concrete. *International Journal of Sustainable Built Environment,* Volume 5, pp. 484-516.

Euram B. 2000. Mechanical properties of lightweight aggregate concrete. European Union.

Fanjul A.F., Abril A.J.T., Brotons F.B., 2018. A new methodology for determining water absorption of lightweight. *Construction and Building Materials,* Volume 165, pp. 596-607.

Islam M.M.U., Mo K.H., Alengaram U.J., Jumaat M.Z., 2016. Durability properties of sustainable concrete containing high volume palm oil waste materials. *Journal of Cleaner Production,* Volume 137, pp. 167-177.

Jayaranjan M.L.D., Van Hullebusch E.D., Annachhatre A.P., 2014. Reuse option for coal-fired power plant bottom ash and fly ash. *Reviews in Environmental Science and Biotechnology,* Volume 13, pp. 467-486.

Jin R., Chen Q., 2013. An investigation of the current status of "green" concrete in the construction industry. *49th ASC Annual International Conference Proceedings (2013).* Google Scholar.

Jumaat M.Z., Alengaram U.J., Mo K.H., 2015. Experimental investigation on the properties of the lightweight concrete containing waste oil palm shell aggregate. *Procedia Engineering,* Volume 125, pp. 587-593.

Khankaje E., Salim M.R., Mirza J., Hussin M.W., Rafieizonooz M., 2016. Properties of sustainable lightweight previous concrete containing oil palm kernel shell as coarse aggregate. *Construction and Building Materials,* Volume 126, pp. 1054-1065.

Kim H.K., 2015. Utilization of sieved and ground coal bottom ash powders as a course binder in a high-strength mortar to improved workability. *Journal of Construction and Building Materials,* Volume 91, pp. 57-64.

Kim H.K., Lee H.K., 2011. Use of power plant bottom ash as fine and coarse aggregates in high-strength concrete. *Construction and Building Materials,* Volume 25, pp. 1115-1122.

Kim H.K., Jang J.G., Choi Y.C., Lee H.K., 2014. Improved chloride resistance of high-strength concrete amended with coal bottom ash for internal curing. *Construction and Building Materials,* Volume 71, pp. 334-343.

Kim H.M., Alengaram U.J., Jumaat M.Z., 2016. Assessing some durability properties of sustainable lightweight oil palm shell concrete incorporating slag and manufactured sand. *Journal of Cleaner Production,* Volume 112, pp. 763-770.

Kockal N.U., Ozturan T., 2011. The durability of lightweight concretes with lightweight fly ash aggregates. *Constructions and Building Materials,* Volume 25, pp. 1430-1438.

Kurama H., Kaya M., 2008. Usage of coal combustion bottom ash in the concrete mixture. *Construction and Building materials,* Volume 22, pp. 1922-1928.

Ledesma E.F., Jimenez J.R., Ayuso J., Fernandez J.M., de Brito J., 2015. Maximum feasible use of recycled sand from construction and demolition waste for eco- mortar production - Part-I: ceramic masonry waste. *Journal of Cleaner Production,* Volume 87, pp. 692-706.

Ledesma E.F., Cartuxo F., de Brito J., Evangelista L., Jimenez J.R., 2015. Rheological behavior of concrete made with fine recycled concrete aggregates- Influence of the superplasticizer. *Construction and Building Materials,* Volume 89, pp. 36-47.

Liew K.M., Sojobi A.O., Zhang L.W., 2017. Green concrete: Prospect and challenges. *Construction and Building Materials,* Volume 156, pp. 1063-1095.

Lo T.Y., Cui H.Z., Nadeem A., Li Z.G., 2006. The effects of air content on the permeability of lightweight concrete. *Cement and Concrete Research,* Volume 36, pp. 1874-1878.

Lo W.C., 2006. Decoupling of the coupled poroelastic equations for quasistatic flow in deformable porous media containing two immiscible fluids. *Advances in Water Resources,* Volume 29, pp. 1893-1900.

Mannan M.A., Ganapathy C., 2001. Long term strength of concrete with oil palm shell as coarse aggregate. *Cement and Concrete Research,* Volume 31, pp. 1319-1321.

Mannan M.A., Ganapathy C., 2002. Engineering properties of concrete with oil palm shell as coarse aggregate. *Construction and Building Materials,* Volume 16, pp. 29-34.

Mannan M.A., Kurian V.J., Teo D.C.L., 2006. Structural concrete using Oil Palm Shell (OPS) as Lightweight Aggregate. *Turkish Journal of Engineering and Environmental Sciences,* Volume 30, pp. 251-257.

Mannan M.A., Ganapathy C., Kurian V.J., Teo D.C.L., 2007. Lightweight concrete made from oil palm shell (OPS): structural bond and durability properties. *Building and Materials,* Volume 42, pp. 2614-2621.

Mo K.H., Alengaram U.J., Jumaat M.Z., Yap S.P., 2015. Feasibility study of high volume slag as cement replacement for sustainable structural lightweight oil palm shell concrete. *Journal of Cleaner Production,* Volume 91, pp. 297-304.

Mohammed S.A., Karim M.R., 2017. Review: application of coal bottom ash as aggregate replacement in highway embankment, acoustic absorbing wall and asphalt mixtures. *IOP Conference Series: Materials Science and Engineering,* Volume 210

Mouli M., Khelafi H. 2008. Performance characteristic lightweight aggregate concrete containing natural pozzolan. *Building and Environment,* Volume 43, pp. 31-36.

Nanthagopalan P., Santhanam M., 2011. Fresh and hardened properties of self-compacting concrete produced with manufactured sand. *Cement and Concrete Composites,* Volume 33, pp. 353-358.

Neville A.M., 2011. Properties of concrete, 5th Edition, Pearson Education Limited.

Pasetto M., Baldo N., 2016. Recycling of waste aggregate in cement bound mixtures for road pavement bases and sub-bases. *Construction and Building Materials,* Volume 108, pp. 112-118.

Ramme B.W., Tharaniyil M.P., 2013. We energies coal combustion products utilization handbooks. 3rd edition. We Energies, U.S.A. Google scholar.

Sabil K.M., Aziz M.A., Lal B., Uemura Y., 2013. Effect of torrefaction on the physiochemical properties of oil palm empty fruit brunches, mesocarp, and kernel shell. *Biomass Bioenergy,* Volume 56, pp. 351-360.

Saifuddin M., Raman S., Zain M., 2007. Utilization of quarry waste fine aggregates in the concrete mixture. *Journal of applied sciences research,* Volume 3(3), pp. 202-208.

Sairanen M., Rinne M., 2019. Dust emission from crushing of hard rock aggregates. *Atmospheric Pollution Research,* Volume 10, pp. 656-664.

Shafigh P., Jumaat M.Z., Mahmud H., 2010. Mix design and mechanical properties of oil palm shell lightweight aggregate concrete: A review. *International Journal of the Physical Sciences,* Volume 5(14), pp. 2127-2134.

Shafigh P., Mahmud H., Jumaat M.Z., 2012. Oil palm shell lightweight concrete as a ductile material. *Materials and Design,* Volume 36, pp. 650-654.

Shafigh P., Jumaat M.Z., Mahmud H., Abd Hamid N.A., 2012. Lightweight concrete made from crushed oil palm shell: Tensile strength and effect of initial curing on compressive strength. *Construction and Building Materials,* Volume 27, pp. 252-258.

Shafigh P., Alengaram U.J., Mahmud H., Jumaat M.Z., 2013. Engineering properties of the oil palm shell lightweight concrete containing fly ash. *Materials and Design,* Volume 49, pp. 613-621.

Shafigh P., Mahmud H., Akashah F.W., Soofinajafi M., 2016. Mechanical properties of high strength concrete containing Coal Bottom Ash and Oil Palm Boiler Clinker as fine aggregate. *The 4th International Building Control Conference 2016 (IBCC 2016),* Volume 66, pp. 1-8.

Siddique R., 2013. Compressive strength, water absorption, sorptivity, abrasion resistance and permeability of self-compacting concrete containing coal bottom ash. *Construction and Building Materials*, Volume 47, pp. 1444-1450.

Siddique, R., 2014. Utilization of industry by-products in concrete. *Journal of Procedia Engineering,* Volume 95, pp. 335-347.

Siddique R., Aggarwal Y., 2014. Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates. *Construction and Building Materials,* Volume 54, pp. 210-223.

Siddique R., Singh G., Singh M., 2018. Recycled option for metallurgical by-product (spent Foundry sand) in green concrete for sustainable construction. *Journal of Cleaner Production*, Volume 172, pp. 1111-1120.

Singh M., Siddique R., 2013. Effect of coal bottom ash as partial replacement of sand on properties of concrete. *Resources, Conservation and Recycling,* Volume 72, pp. 20-32.

Singh M., Siddique R., 2014. Compressive strength, drying shrinkage, and chemical resistance of concrete incorporating coal bottom ash as a partial or total replacement of sand. *Construction and Building Materials,* Volume 68, pp. 39-48.

Singh M., Siddique R., 2014. Strength properties and microstructural properties of concrete containing coal bottom ash as partial replacement of fine aggregate. *Construction and Building Materials,* Volume 50, pp. 246-256.

Singh M., Siddique R., 2015. Properties of concrete containing a high volume of coal bottom ash as fine aggregate. *Journal of Cleaner Production*, Volume 91, pp. 269-278.

Singh M., Arya S., 2018. Influence of coal bottom ash as a fine aggregate replacement on various properties of concrete: A review. *Journal of Resources, Conservation, and Recycling,* Volume 138, pp. 257-271.

Teo D.C.L., Mannan M.A., Alexander J., Ganapathy C., 2006. Quality improvement of oil palm shell (OPS) as coarse aggregate in lightweight concrete. *Building and Environment,* Volume 41, pp. 1239-1242.

Yuksel I., Bilir T., Ozkan O., 2007. The durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate. *Building and Environment*, Volume 42, pp. 2651-2659.

Yuksel I., Ozkan O., Muratoglu O., 2007. Strength properties of concrete incorporating coal bottom ash and granulated blast furnace slag. *Waste management,* Volume 27, pp. 161-167.

Yuksel I., Siddique R., ozkan O., 2011. Influence of high temperature on the properties of concrete made with industrial by-products as fine aggregate replacement. *Construction and Building Materials,* Volume 25, pp. 967-972.