DEVELOPMENT OF SELF-COMPACTING LIGHTWEIGHT CONCRETE MADE OF PALM OIL CLINKER

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To my beloved family, lecturers and friends

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ABSTRACT

This report presents the findings on development of self-compacting lightweight concrete using lightweight aggregate. In this study, palm oil clinker (POC) is used to replace normal gravel as course aggregate in concrete. There are two types of mix design in this project which are the normal self – compacting concrete as the control mix and the POC mix with 100% POC replacement for course aggregate. Slump flow test is carried out at fresh state to measure the self – compactability of the concrete. At hardened state, compressive strength test is conducted using cubes for these two types of concrete mix at the age of 7 and 28 days. Splitting tensile and flexural strength test were also conducted using cylinders and prisms, on the age of 28 days, respectively and were also wet – cured. The result shows that by using POC as lightweight aggregate and superplasticizer as the admixture, lightweight self – compacting concrete with high workability and strength almost similar to normal self – compacting concrete can be produced. This study also includes a vertical load test on a 500 mm x 500 mm wall with thickness 125 mm for both types of mix design. Throughout the test, data such as load capacity, behavior of cracks and failure mode were observed. The test results showed that specimens with POC achieved almost similar performance in terms of ultimate load capacity with only 14.3% difference.

ABSTRAK

Laporan ini membentangkan penemuan terhadap pembangunan konkrit ringan pemadatan sendiri menggunakan agregat ringan. Dalam kajian ini, batu hangus kelapa sawit (BHKS) telah digunakan bagi menggantikan batu kerikil biasa sebagai agregat kasar di dalam konkrit. Terdapat dua jenis bancuhan konkrit dalam projek ini, iaitu konkrit pemadatan sendiri biasa sebagai bancuhan kawalan dan bancuhan daripada BHKS dengan menggunakan 100% BHKS bagi menggantikan agregat kasar. Ujian aliran runtuhan telah dijalankan pada keadaan basah bagi mengenalpasti kebolehpadatan sendiri konkrit. Pada keadaan keras pula, ujian kekuatan mampatan telah dijalankan dengan menggunakan kiub bagi kedua-dua jenis konkrit pada umur 7 dan 28 hari. Ujian kekuatan tegangan dan lenturan juga telah dilakukan dengan masing-masing menggunakan silinder dan prisma pada umur 28 hari dan juga telah diawet basah. Hasil kajian menunjukkan bahawa menggunakan BHKS sebagai agregat ringan dan superspasticizer sebagai bahan campuran, konkrit ringan pemadatan sendiri dengan kebolehkerjaan serta kekuatan tinggi boleh dihasilkan. Kajian ini turut melibatkan 500 mm x 500 mm dinding dengan ketebalan 125 mm di bawah beban menegak bagi kedua-due jenis bancuhan konkrit. Sepanjang ujian dijalankan, data-data seperti kapasiti beban, kelakuan retak dan mod kegagalan telah diperhatikan. Hasil ujian menunjukkan bahawa specimen dengan BHKS mencapai prestasi hampir sama dari segi kapasiti beban muktamad dengan hanya perbezaan 14.3%.

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LIST OF ABBREVIATIONS

ASTM	–	American Society for Testing and Materials
BS	–	British Standard
DOE	–	Department of Environment
LWSCC	–	Lightweight self – compacting concrete
LVDT	–	Linear Variable Differential Transformer
POC	–	Palm oil clinker
SCC	–	Self – compacting concrete

CHAPTER 1

INTRODUCTION

1.1 Background Study

Palm oil industry in Malaysia is one the leading industry contributing a lot for the nation's development. However, despite its generous contribution, the palm oil industry is producing too much waste disposal, which in the long run can definitely harm our environment. One of the main by-products of palm oil is clinker. Palm oil clinker (POC) is the by-product from burning of fibers and husks inside the boiler under very high temperature in order to generate the steam engine for oil extracting process. Substituting POC in the concrete mix as course aggregate will produce lightweight concrete due to its low density. According to the British Standard, BS 8110: Part 2: 1985, concrete having the densities of 2000 kg/m^3 or less are classified as lightweight concrete.

Globalization has improved the perspective of engineers and contractors toward new technologies related to concrete. Among many grabbing the attention is lightweight concrete. Lightweight concrete can be defined as the concrete with substantially lower unit weight than that made from gravel or crushed stone. The decrease in concrete weight reduces dead load on structure, thus making the

construction less expensive. This study focused on using POC as a replacement for course aggregate in the concrete mix. Ahmad *et. al.* (2009) stated that POC has the specific gravity of 2.17 compared to conventional aggregates which is 2.6.

A relatively new technology is the self-compacting concrete (SCC) which is regard as a high performance composite, that flow under its own weight over a long distance without segregation and without the use of vibrators. SCC produce several benefits including improved constructability, labour reduction, increase bond to reinforcing steel, accelerate project schedules and many more. The Akashi-Strait Bridge in Japan is one the concrete structural building that utilizes the use of SCC extensively.

SCC can have many benefits and will shorten the construction time. However, special attention should be focused on for instance formwork should be designed to withstand fluid concrete pressure that will be higher than regular concrete. Apart from that, production of SCC require more experience and care that the conventional concrete. According to Nascimento *et. al.* (2013), to be classified as SCC, the concrete should have three basic properties which are filling ability, possibility and segregation resistance.

Since the use of lightweight concrete in construction reduces the cost, a research is carried out to study the development of SCC using POC as the lightweight aggregate. This paper reports the result of experimental study on the replacement of POC as course aggregate in the lightweight self compacting concrete mixture with a small percentage use of superplasticizer as the admixture.

1.2 Problem Statement

The civil construction industry is responsible for a large consumption of natural resources. Crushed gravel from quarries, for instance, has been the most widely used material as course aggregate for concrete. The constant used of this material over a long period will cause progressive exhaustion which can potentially lead to a serious environmental impact.

An alternative to minimize the extraction of natural gravel, which proves to generate environmental problems in the long run, is the use of palm oil clinker (POC) from the waste of agricultural industry as a replacement for course aggregate. POC weighing less than conventional gravel can potentially be classified as lightweight material for production of lightweight concrete.

Self compacting concrete (SCC) which is a highly flow able concrete that spreads into the formworks without the need of mechanical vibration poses many advantages. By using POC as the course aggregate for the SCC, many benefits will be obtained such as lesser exploitation of natural resources and less waste disposal from the palm oil industry.

In terms of wall paneling, noise traveling across form one room to another seems to be the big issue for human comfort. Therefore, the mix design can be used for precast wall panel due to the advantage of lightweight concrete which is high in sound absorbance.

1.3 Objectives of Study

With regards to the problem statement mentioned, a research study involving laboratory experiment will be carried out with the following objectives:

i. To develop the mix design of self-compacting lightweight aggregate using both normal and POC aggregate.

ii. To study the mechanical properties of lightweight self – compacting concrete by using palm oil clinker as 100 % course aggregate replacement.

iii. To study the behavior of self-compacting lightweight precast wall panel with respect to load capacity, deflection, cracking pattern and failure modes.

1.4 Scope of Study

For this research, focuses were on the material properties of different concrete design mix using palm oil clinker (POC) as course aggregate replacement, becoming lightweight self compacting concrete (SCC). POC of size 10 mm was used as course aggregate replacement in this study. Important material properties such as compressive strength, tensile strength, and flexural strength were the main focus. In order to fully understand the development of lightweight self compacting concrete using POC, a series of test were conducted. The test conducted was at fresh state and hardened state.

The concrete mix involves normal self – compacting concrete as the control mix and the POC mix with 100% POC replacement for course aggregate. Slump test was conducted at fresh state to ensure the concrete mix meets the requirement of 150 mm slump for it to be considered as SCC. At hardened state, compressive strength test is conducted on the cubes of these two types of concrete mix at the age of 7 and 28 days. The test cubes are 100 mm x 100 mm x 100 mm size and wet – cured. Splitting tensile and flexural strength test were also conducted on the age of 28 days and were also wet – cured. The splitting tensile test consists of cylinders of size 150 mm x 300 mm, while flexural test involve prism of size 100 mm x 100 mm x 500 mm. The comparison both concrete mixes were to be observed throughout the experiment.

Apart from obtaining material properties, two smaller scale walls of size 500 mm x 500 mm with thickness 125 mm was constructed for the testing under vertical load. Both of the walls were wet – cured for 28 days before tested. The test involves two point vertical loads on top of the wall. Important results such as load capacity, deflection, cracking pattern and failure modes were noted.

1.5 Limitation of Study

Limitation of study is important to ensure the objectives of research are achieved without any excessive wastage of material, time and work done. In this research, two types of design mix were obtained namely normal weight self – compacting concrete and lightweight self- compacting concrete. The materials used include Ordinary Portland cement, sand, gravel, fly ash and superplasticizer. Palm oil clinker (POC) is used as full substitution to conventional gravel for the lightweight mix. The POC is obtained from a nearby palm oil plantation factory in Kulai. During the experiment, focuses were on the physical properties as well as strength

development of the concrete samples for performance study. Slump flow test was conducted to obtain physical properties of slump for each concrete mix. The performances of the concrete studied include compressive strength, tensile strength, and flexural strength. For these material properties, cylinders, cubes and prisms were casted and tested according to respective material property test. The dimensions of the moulds are according to the standard size requirement. Besides these tests, a structural element which is a 500 mm x 500 mm x 125 mm wall panel was casted and tested by applying vertical load only.

1.6 Significant of Study

The results of this study are expected to provide substantial information and highlighting the contribution of palm oil clinker (POC) as a material substitution for conventional gravel in order to produce lightweight self compacting concrete (LWSCC). Researches done by others have proven that using POC to develop LWSCC has improved or obtained similar material performance and eliminating any significant negative effects. Apart from that, using POC in LWSCC will reduce the amount of waste generated by the palm oil industry as well as decreasing the use of natural gravel in construction industry. Another potential contribution of this study is to provide an alternative in wall construction. Walls constructed form lightweight aggregate can contribute positively in the precast concrete industry. If POC is widely used to substitute natural gravel, more green or environmental friendly building projects can be developed.

REFERENCES

A.A Maghsoudi, S. Mohamadpour, M. Maghsoudi, 2010, *Mix Design and Mechanical Properties of Self Compacting Lightweight Concrete*, International Journal of Civil Engineering.

Bashar S. Mohamad, Khandaker M. Anwar Hossain, W.L. Foo and M. Abdullah, 2000, Rapid *Chloride Permeability Test on Lightweight Concrete Made with Oil Palm Clinker*, Journal of Engineering Research, Vol. 1, Issue 4, pp 1863 – 1870.

D.E Berner and H. Shi, 2000, *Application of High Performance Lightweight Concrete in Floating Barge Gate*, Ben C Gerwick, Inc, Oakland, California, United States.

F. Nascimento, L. Andreia, R.C. Cecche Lintz, M.R. Russo Seydell, 2013, *Production of Self- Compacting Concrete Using Rock Breaking Residues*, Trans Tech Publication, Switzerland, Vols 785-786 pp 157-162.

H. Rudolf and H. Michala, *Development of Lightweight Self-Compacting Concrete Using Liapor Lightweight Concrete*, Brno University of Technology.

Hipolito J. C. Sousa and Antonio P.O. Carvalho, (1998), *A New Sound Absorbing Lightweight Concrete Masonry Block*, University of Porto. Rua dos Bragas, Portugal.

Koh Heng Boon, Lee Yee Loon, David Yeah Eng Chuan, Roslli Noor Mohamed, *The Use of Palm Oil Clinker in Self-Compacting Lightweight Concrete*, Universiti Tun Hussein Onn Malaysia (UTHM).

K.S. Harmon, *Engineering Properties of Structural Lightweight Concrete*, Carolina State Company, Unites States.

M.A. Manan and K. Neglo, 2010, *Mix Design for Oil Palm Boiler Clinker (OPBC) Concrete,* Journal of Science and Technology, Vol. 30, No. 1, pp 111-118.

M. Peterson, 2008, *High-Performance and Self-Compacting Concrete in Housing Building*, Lund Institute of Technology, Lund University, Sweden.

Mohd Hilton Ahmad, Lee Yee Loon, Nurazuwa Mohd Noor, Suraya Hani Adnan, 2009, *Shrinkage of Malaysian Palm Oil Clinker Concrete,* Universiti Tun Hussein Onn Malaysia (UTHM).

N. Mustapure and H. Eramma, 2014, *Experimental Investigation on Cellular Lightweight Concrete Blocks for Varying Concrete of Density*, University BDT College of Engineering, Davangere India, International Journal of Advanced Technology in Engineering and Science, Vol.2, Issue No. 8. 2009,

P.O. Modani and V.M. Mohitkar, 2014, *Performance of Recycled Aggregates in Self Compacting Concrete*, the Indian Concrete Journal, Vol. 88, No. 10, pp 57-64.

Roslli Bin Noor Mohamed, 2001, *The Performance of Prestressed Lightweight Concrete Using Plam Oil Clinker*, Universiti Teknologi Malaysia.

Suhaizad Sulaiman, Y.L. Lee, H.B. Koh, Ting Leong Wu, 2004, *Water Permeability of Lightweight Aggregate Concrete*, Universiti Tun Hussein Onn Malaysia (UTHM), International Conference on Concrete Engineering and Technology.

Y.P. Sachdeva, S. Naval and M. Bansal, 2013, *Self Compacting Concrete Using Waste Material*, IOSR Journal of Engineering, Vol 3, Issue 2, pp 24-30.