THE MECHANICAL PROPER[illegible]S) LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING PALM OIL CLINKER AS PARTIAL SAND REPLACEMENT

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ABSTRACT

Oil palm shell (OPS) and palm oil clinker (POC) is a waste from palm industries which is excess from a process where electricity was generated in palm oil factories. The use of this POC material as partial sand replacement material in concrete will help lower the pollution to the environment. This thesis presents an experimental study on effect of POC content towards mechanical properties of OPS LWAC. Two types of mixes that has been used in this study that is plain OPS LWAC containing 100% natural river sand and another mix containing POC as partial sand replacement. POC used as partial sand replacement from ranges from 0% to 20%. All specimens were cast and subjected to water curing until the testing date. Specimens were tested for compressive strength and flexural strength up to 28 days. The highest compressive strength and flexural strength achieved reaching up to 34.4 MPa and 3.42 MPa respectively at age 28 days with 20% POC as partial sand replacement. Conclusively use of POC up to 20% increases the compressive strength and flexural strength of OPS lightweight aggregate concrete.

ABSTRAK

Tempurung kelapa sawit (OPS) dan batu klinker kelapa sawit (POC) ialah sisa buangan industri kelapa sawit hasil daripada pembakaran sisa buangan bagi menjana tenaga elektrik untuk kegunaan kilang kelapa sawit. Penggunaan bahan POC sebagai bahan separa pengganti pasir di dalam campuran konkrit boleh membantu mengurangkan pencemaran kepada alam sekitar. Kajian ini melaporkan kesan penggunaan POC sebagai bahan separa pengganti pasir terhadap sifat-sifat mekanikal konkrit aggregat dengan OPS. Terdapat dua jenis campuran konkrit digunakan iaitu konkrit OPS dgn menggunakan 100% pasir semulajadi dan konkrit OPS yg mengandungi batu klinker sebagai bahan pengganti separa. Peratusan batu klinker sebagai bahan pengganti separa untuk pasir adalah 0% kepada 20%. Semua specimen dihasilkan telah diawet menggunakan kaedah awetan air sehingga masa diuji tiba. Semua specimen diuji dari segi kekuatan mampatan dan kekuatan lenturan pada hari ke-7,14 dan 28. Bacaan tertinggi untuk kekuatan mampatan ialah 34.4 MPa dan kekuatan lenturan ialah 3.42 pada umur specimen yang ke-28 hari dengan 20% batu klinker sebagai bahan separa pengganti pasir. Kesimpulannya, penggunaan batu klinker sebagai bahan separa pengganti pasir sebayak 20% meningkatkan kekuatan mampatan dan kekuatan lenturan konkrit aggregat dengan OPS.

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LIST OF ABBREVIATIONS

POC	Palm Oil Clinker
OPS	Oil Palm Shell
LWAC	Lightweight Aggregate Concrete
ASTM	America Society Testing and Materials
BS	British Standard

LIST OF SYMBOLS

P	The maximum load failure
A	The cross-sectional area of cube
Fcf	Flexural strength
F	Maximum load
L	Distance between supporting rollers
d_1	The lateral dimensions of the specimens
d_2	The lateral dimensions of the specimens

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete is the mixture of cement, course aggregate, sand, water and admixture that used in construction. Nowadays, a lot of studies been done by researchers in order to improve the uses of concrete in construction. In majority of developed countries, due to the increasing cost of raw materials and the continuous reduction of natural resources, the use of waste materials is a potential alternative in the construction industry. Waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications (Mannan and Ganapaty, 2003). Thus, in Malaysia, where the waste materials generated is 16000 tons per day (Lau, 2004), we can take advantage from the problems regarding the waste materials such as pollution by using the waste materials as partial sand replacement and as aggregates in our construction industries. Waste materials are mostly generated by agricultural industries, industrial industries and domestic waste produced by communities. As for this research, the waste material that will be used is waste from agricultural industries, palm oil plantation industries.

In Malaysia, the rate of environment pollution is undoubtedly high and the waste material generated from the oil palm plantation is one of the main contributors of this. Along this wastes generated by oil palm plantation, there are by-product that end up at landfill known as oil palm shell (OPS) and palm oil clinker (POC). This waste can be used as partial sand replacement under certain process. Palm oil clinker is the by-product from burning of fibers and husks inside the boiler under high temperature to generate the steam engine for oil extraction (Ahmad *et al*, 2008). It also known, immense construction of buildings and other structures required huge amount of concrete. River sand which is one of the compulsory materials in concrete also struggle with reduction of natural resources due to continuous mining activities. Our environment will be negatively affected and not mentioning the future generation social life with all the troubles cause by the mismanagement of natural resources. Hence, sand mining activities must be controlled and manage properly.

Research conducted by Mannan and Kurian (2006) found that oil palm shell (OPS) can be used as aggregate for the production of lightweight concrete. OPS aggregate shows a lot of potential as lightweight aggregate for construction as the bulk density of OPS is much less than stone aggregate OPS concrete becomes a lightweight concrete with a density of about 1850 kg/m^3. Where the compressive strengths of OPS concrete range from 20 to 24 N/mm^2 for 28 days which satisfies the strength requirement of structural lightweight concrete. It is seen that integrating POC as partial sand replacement would reduce the amount of natural sand used.

1.2 PROBLEM STATEMENT

The oil palm shell (OPS) and Palm oil clinkers (POC) obtained from palm oil factories which are the excess product from a process where all the waste from oil palm plantation such as empty fruit bunches, fibers, and kernels burnt to generate electricity. It has been reported in 2007, there was approximately 3 million tons of waste product derived throughout the electricity generated process in Malaysia (Lau, 2004). The mass production of waste material will harm our environment if no proper treatment taken to reduce it. Using POC as material for sand replacement material in concrete is a great way to lessening the negative effect to the environment.

Sand mining activities which contribute to the depletion of natural resources also one of the concerns for selecting material for construction. The depletion of natural resources invites the increase of cost of material because construction material such as river sand depended on the natural resources. The uses of POC as partial sand replacement would help to preserve the environment by decreasing the mining activities and also reduce the high dependency of construction industry towards the natural resources of sand. The utilization of waste products from oil palm plantation will lessen the negative effect to the environment.

1.3 OBJECTIVES OF THE RESEARCH

The objectives of the study are as follow:

I. To determine the effect of crushed palm oil clinker (POC) as a partial sand replacement on compressive strength of OPS lightweight aggregate concrete.
II. To determine the effect of crushed palm oil clinker (POC) as a partial sand replacement on flexural strength of OPS lightweight aggregate concrete.

1.4 SCOPES OF RESEARCH

This research focuses on investigating the mechanical properties of OPS lightweight aggregate concrete containing crushed palm oil clinker (POC) as partial sand replacement. The mechanical properties that have been investigated are compressive strength and flexural strength. Oil palm shell used as lightweight aggregate for concrete.

In this research, two mixes have been used. First one was plain OPS concrete containing 100% river sand as control mix, and the other 4 mixes are OPS with POC as partial sand replacement. For compressive strength test, this case will involve 5 samples of mix concrete cast in cube moulds (100 x 100 x 100 mm^3) with the presence of POC proportion as partial sand replacement, 5%, 10%, 15%, and 20% respectively for each case. Then, as for flexural strength test, it will involves 5 samples of beam casted in 100 x 100 x 500 mm^3 size of mould with the same cases as compressive strength. After the cube samples have been water cured, the test on compressive strength and flexural strength of cube samples commence. The entire test on samples conducted on 7, 14, and 28 days. All the test or experiment conducted was done according to the existing standards.

1.5 SIGNIFICANCE OF RESEARCH

The main purpose of this research is to minimize the pollution on environment caused by the waste products from oil palm industry. Manipulating the POC and OPS will reduce the large amount of waste produces and a more environmental friendly can be produce. Moreover, the potential alternative material using the oil palm plantation waste as partial replacement material on concrete will reduce the high dependency on natural resources thus preserving the environment. Furthermore, this study offers the oil palm industries alternative method on the disposal of waste by manipulating it on construction work.

1.6 LAYOUT OF THESIS

Chapter 1 provides a brief introduction regarding the oil palm shell (OPS) lightweight aggregate concrete used and POC as the partial sand replacement in concrete. There's also information about the problem statement and objective of the research. The scopes and significance of study also present in this chapter.

Chapter 2 presents the literature review and a short brief about the issues investigated in this research. It focused on research done by previous student or researchers and lastly the conclusion of the literature review also included. Chapter 3 represents the methodology, materials and experimental work during research. The specific methods for each work elaborated here and the existing standard available were referred.

Chapters 4 discuss on the data findings during research investigation. All the result from test presented in form graph or picture. Lastly, chapter 5 gave the founding of the research and discussions are made on the accomplishment of research objectives. Recommendations for future study also provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lightweight concrete is made of lightweight aggregate which are consists of natural aggregate and manufactured aggregate. The requirements needed by aggregate to be classified as lightweight aggregate are given in ASTM C330 – 89 and BS 3797: 1990. Lightweight concrete had some characteristics that normal concrete doesn't. Some of the specialty is the difference in density where the density of lightweight concrete is lower than normal one. This research studies the potential of using waste materials instead of natural sources from sand mining. In this study, the use of palm oil clinkers as partial sand replacement in OPS LWAC was been researched.

2.2 Benefits of LWAC

The structural use of lightweight aggregate concrete has been successfully utilized worldwide with the rapid development of technology of concrete in the recent years (Rossignolo and Agnesini, 2004). There are some advantages possess by lightweight aggregate concrete which make it suitable for structural development such as the improvement of concrete durability, reduction in formwork and propping, and etc. which is helping the construction industry a lot. The reductions in dead loads of concrete also play the role in making savings in foundation and reinforcement of structural building because of its low in cost for construction.

Lightweight aggregates nowadays are can be found in a wide range of densities, strengths, and sizes. This makes it possible to design concrete with a very wide area of concrete construction, a concrete of very low density for insulation. A lot of research was done by researchers to improve LWAC uses in construction industries. This is because of the advantages founded mentioned above which is for example, LWAC low density reduces the dead load of concrete where giving more comfortable in handling it on site construction and some of LWAC provides insulating properties to concrete such as durability against acid attack . Along with this, it is easy to handle, and heavy duty tools are not required to operating the construction of LWAC.

2.3 Properties of LWAC

Lightweight aggregate concrete is a modern building material with advanced properties such as low density and thermal conductivity as stated before this. This type of concrete has higher porosity which was the reason for its limited strength and more deformable than normal-weight aggregates. The weakest component of most lightweight aggregate concrete is neither the cement matrix nor the interfacial transition zone, but the aggregates. Therefore the mechanical performances of lightweight aggregate concrete are controlled not only by the cement matrix quality but also by the aggregate volume in concrete and by the aggregates properties (Bumanis, *et al.*, 2013). The density of lightweight concrete varies based on the material used for the concrete. Normal lightweight concrete density is 1850 kg/m^3. Mouli and Khelafi (2008) stated on their research regarding the performance of lightweight aggregagte concrete using pozzolan material as partial cement replacement where the densities of the lightweight concrete for the specimen control is 1820 kg/m^3 and each proportions of pozzolan material replaced the cement content, the densities was different. Depending on the specified density, generally between 1500 and 2000 kg/m^3, it is possible to produce high strength lightweight aggregagte concrete with compressive strength varying from 40 to 90 MPa (Costa, *et al.*, 2012)

The workability of fresh concrete depends on the properties of materials used, the proportion of mixture and also the conditions of environment. The workability of concrete cause by low water content ratio can invite the honeycomb on concrete because it hard to be compacted. To achieve desired workability, water demand on the properties and number of fines aggregates in the concrete. High absorption ratio of water compared to normal sand also identified as a factor for palm oil clinkers to be used as partial replacement aggregate. The workability of the concrete was tested while the concrete still in fresh state, and slump test carried out using standard method according to BS EN: 12350-2:2000 9. Flexural strength is the ability of material to bend without obtaining any major deformities. A standard experiment called the three-point test can calculate an object's flexural strength. Flexural strength is the stress on the surface of the specimens which should be accompanied by the breaking of the specimen and the three-point test is designed for materials that break at relatively small deflection (Sulaiman *et al.,* 2008). In engineering construction, knowing a material's flexural strength is important in order to make sure that the material is strong enough to use in structures.

The compressive strength test was conducted on the cubes to study the strength development of OPS LWAC containing various proportion of POC as sand replacement at curing ages. According to Elices and Rocco (2008) there are some factors that interacting with the compressive strength of concrete namely as the water cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, where in this study it referred to the bond between OPS lightweight aggregate concrete and POC as partial sand replacement which are the shape, strength, and size of the aggregates itself. The7-day compressive strength for palm oil clinker varies from 24 N/mm^2 to 37 N/mm^2 and 28-days compressive strength ranging from 34 N/mm^2 to 42 N/mm^2. Besides all the properties of LWAC stated above, there are also other properties of LWAC that also need to be highlighted.

Water absorption also another important properties of LWAC. Water absorption is a measure of the capillary forces exerted by the pore structure causing fluids to be drawn in to the body of the material. The water absorption of concrete is a quantity that measures the unsaturated flow of fluids into the concrete (Lo *et al.*, 2006). Because of this water absorption the effective w/c ratio will decrease and inside the LWAC a "water tank" will be found. This water absorption makes it possible that hydration continues relatively long, namely when at later ages initially absorbed water is transported to the hydrating paste (EuRam, 2000).

2.4 Innovation in LWAC

Many researchers study the potential of lightweight aggregate concrete in order to gain more knowledge on the efficiency of this type of concrete. Mouli and Khelafi (2008) investigated the effect of using crushed pozzolan as lightweight aggregate (LWA) while using natural sand in all mixes to produce a lightweight aggregate concrete (LWAC). The improvement was spotted in split and flexural tensile strengths where proven very useful on service life of a structure by decreasing cracking due the reinforcement corrosion.

Kockal and Ozturan (2011) study the effects of aggregate properties such as strength, porosity, water absorption, bulk density and specific gravity on the strength and durability of lightweight fly ash aggregate concrete (LWAC).The effect on concrete mechanical properties and durability were explained in this research by using four properties of aggregates namely sintered lightweight fly ash aggregates, coldbonded lightweight fly ash aggregate and normalweight aggregate. Kockal and Ozturan research show the various kind of material that suitable for concrete production industry.

Bumanis *et al.* (2013) study the alkali-silica reactivity of foam glass granules in structure of lightweight concrete. In their research, lightweight aggregate concrete (LWAC) made with foam glass granules (FGG) are subjected to alkali silica reactions (ASR) between FGG and cement matrix. The aim of the study was to identify the effect of different cements on the ASR which occurs between FGG and binder. One of the methods suggested by those researchers on how to limit ASR is incorporation of active pozzolans in the LWAC mixture design. For this study, the used of OPS aggregate as coarse aggregate and palm oil clinker (POC) as partial sand replacement is another great innovation in concrete making industry where this kind of mixes have never been attempted before. By fully utilizing the waste from palm oil plantation, the amount of solid waste will reduce and pollution which always negatively affect our environment will also be reduce.

2.5 Palm Oil Clinker (POC)

2.5.1 Definition

Palm oil mill in Malaysia incinerate palm oil waste to produce steam needed for the milling process. The waste product of incineration is palm oil clinker (POC). Palm oil clinker (POC) is a waste by-product from the incineration process of oil palm shells and fibers. They are porous and lightweight in nature, which makes them suitable for use as a lightweight aggregate (Kanadasan and Razak, 2013). The melted ashes accumulates during the incineration process that sticks on the boiler walls and against steam tubes and solidifies to form masses called clinkers. In this study, palm oil clinker will be used as partial sand replacement in concrete mixture. It was chosen because for an alternative for sustaining green environment due to increasing of the sand mining activities which causing the depletion of natural sources.

2.5.2 Physical Properties

POC categorized as waste by-product from palm oil industry and has appearance of a porous stone with gray in color. The clinkers forms are usually flaky and irregular with rough and spiky broken edges (Robani and Chan, 2009).The particle size ranges from fine gravel to fine sand. Coal bottom ash particles have interlocking characteristics. Bottom ash is lighter and more brittle as compared to natural sand. The specific gravity of the bottom ash varies from 1.39 to 2.33 depending upon its chemical composition (Singh and Siddique, 2013). Table 2.1 shows the Physical properties of palm oil clinker.

Table 2.1: Physical properties of POC

Properties	Aggregate			
	Fine POC	**Coarse POC**	**Sand**	**Gravel**
Aggregate size (mm)	<5	5-14	<5	5-14
Specific gravity	2.15	1.73	2.66	2.63
Moisture content (%)	0.5±0.25	1±0.5	0.08	0.28
Water absorption (%)	10±5	3±2	0.39	0.58
Aggregate crushing value (%)	-	56.44	-	17.93
Aggregate crushing value (Ten percent fines)	-	16.99	-	-

Source: (Kanadasan and Razak, 2013)

2.5.3 Chemical Properties

The chemical properties of palm oil clinker (POC) consist of Silicca dioxide, Feric oxide, Potassium aluminium oxide, Calcium oxide, Magnesium oxide, Phosphorus pentoxide, Titanium dioxide and Natrium oxide. The chemical properties are as Table 2.2 below.

Table 2.2 Chemical Properties of POC

Element		**Concentration (%)**
Silicca dioxide	SiO_2	81.8
Feric oxide	Fe_2O_3	5.18
Potassium	K_2O	4.66
Aluminium oxide	Al_2O_3	3.5
Calcium oxide	CaO	2.3
Magnesium oxide	MgO	1.24
Phosphorus pentoxide	P_2O_5	0.76
Titanium dioxide	TiO_2	0.17
Natrium oxide	Na_2O	0.14

Source: (Robani and Chan, 2009)

2.5.4 Application of POC in Concrete Research

POC has been used widely in concrete production not only for as partial material replacement but also used as cement after undergoes certain process. This was proven by Puertas *et al.* (2008) where by using waste material namely clinker to produce cement material instead of using raw resources for manufacturing it. The study indicates that the waste material can be used to manufacture cement since the properties of the final product is close to the standard available for cement properties.

Moreover, Mohammed *et al.* (2011) also concludes their study on analytical and experimental studies on composite slabs utilizing palm oil clinker concrete. In their research, palm oil clinker (POC) aggregates was used to fully replace normal aggregates to produce structural lightweight concrete. The structural behavior and the shear-bond strength of the POC concrete composite slabs are satisfactory. This implies that POC can be adequately used in the construction of composite slabs.

There is also another study regarding the use of POC done by Kanadasan and Razak (2013) where their research was the mix design for self-compacting palm oil clinker concrete based on particle packing. In their study, is stated that self-compacting concrete (SCC) has progressively developed to become a concrete that is both efficient as well as providing a quality product without comprising its durability. Reduced labor needs, good surface finishing, extended workability and excellent hardened properties are some of the key elements of SCC. The POC aggregates, which are a waste material to be landfilled, perform satisfactorily as aggregate materials. With the escalating environmental pollution due to waste material from the agricultural industry, utilizing POC in concrete will benefit the construction industry. The sustainability of aggregate can be prolonged since the source of natural aggregates are depleting.

The performance and durability of POC concrete also research by Zakaria and Cabera (1996) by replacing the natural aggregates in the production of concrete. Their found that the produced concrete was on par with normal concrete in term of strength and durability of lightweight concrete. Moreover, some properties such as water absorption of LWAC also had proven better than normal one. Thus, utilizing waste material namely POC for concrete making is an adequate solution for regions where natural aggregates are scarce or demolition and or industrial wastes are abundant.

2.6 Oil Palm Shell (OPS)

Oil palm shell (OPS) also one of the waste product from palm oil industries. Similar to palm oil clinker (POC), the negative impact from the waste into the environment also one of the major concern nowadays. At present, Malaysia has produced more than half of the world's total output of palm oil (Mannan and Ganapathy, 2003) which means that the total waste produced also high in number. Therefore, utilization of OPS in concrete making can be another step to lower the high amount of waste pollution in Malaysia.

Shafigh and his fellow researchers (2010) study the used of OPS as a lightweight aggregate for production of high strength of lightweight concrete. In this research, their study the density, air content, workability, cube compressive strength and water absorption of the LWAC. Other than that, Mannan and Ganapaty (2001) also researched the long term strength of concrete with OPS as coarse aggregate. The investigation was up to 365 days on compressive strength of OPS concrete for different curing environment. The results from their study show that compressive strength of OPS concrete varies depending on curing regime and in their report, their recommend to use OPS concrete in structural LWAC. Wahab *et al.* (2012) study the mechanical properties of concrete added with fine palm oil clinker and their found out that for early 7 days of strength shows considerably increment about 19% for 5% fine POC inclusion and 23% for 10% fine POC inclusion compared to the control specimen. A researched also done by Kurama and Kaya (2008) regarding the usage of coal combustion bottom ash in concrete mixture where the strength of compressive and flexural strength of cured specimens shows an increment after addition of 15% of bottom ash. Therefore, in this study, OPS were used as coarse aggregate by integrating it together with POC as partial sand replacement.

2.7 Sand Mining

Concrete is one of the materials that largely used in construction widely around the world. Thus, the depletion of natural resources is can't be avoided anymore. River sand which is one of the compulsory materials for concrete making mainly produced from sand mining having a major problem which is the depletion of natural resources. Due to the high demand on natural sand for construction in developing countries such as Thailand and Malaysia, it's forcing the industries search for alternative material to be used in concrete making. Saifuddin (2007) claimed in his researched that it is required to identify alternative materials to lessen or replace the demand of natural sand. Due to nowadays worsen situation which might affect the price of natural resources, researchers started to study a lot of alternative to stop the problem.

Siddique and Aggarwal (2014) investigating bottom ash and waste foundry sand as partial replacement of fine aggregates. The study investigated the effect of waste foundry sand and bottom ash in equal quantities as partial replacement of fine aggregates in various percentages. Al-Tayeb and his fellow researchers (2013) study effect of partial sand replacement by using recycled fine crumb rubber on the load performance of hybrid rubberized-normal concrete under impact load. In this study, the effect of partial replacement of sand by recycled fine crumb rubber on the performance of hybrid concrete (double layer beam with rubberized top and normal bottom) under impact three point bending loading was investigated experimentally and numerically. Rubberized concrete mixes were prepared by partial substitution (10% and 20% replacements by volume) of sand by recycled fine crumb rubber of particle size. So far, no research has been conducted to investigate the potential of POC to be used as partial sand replacement in OPS lightweight aggregate concrete production. Figures below show the sand mining activities located in Selangor, Malaysia and the condition of the environment cause by sand mining activities. Figure 2.1 shows the sand mining site while Figure 2.2 and Figure 2.3 shows the polluted environment.