PERFORMANCE OF LIGHTWEIGHT FOAMED CONCRETE USING PALM OIL CLINKER (CRU [illegible] REPLACEMENT

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ABSTRACT

Palm oil industry is one of the most important Argo industries in Malaysia. Anually, large amounts of solid waste of palm oil residue are not utilized as a functional wastage and affect the environmental problems. Through public concerns and research effort, the agro waste by-product materials have potential to be utilized as construction material to replace conventional sand. In this study, the effectiveness of agro waste clinker by-product namely palm oil clinker crushed (POCC) was developed as an alternative material to replace the sand. In this present study, the effect of using different percentage of POCC to lightweight foamed concrete (LWC) due to compressive strength and elastic modulus were investigate. Four series of mix formulation LWC were prepared comprise of 0%, 5%, 10% and 15% as sand replacement from the total weight of sand. All the LWC specimens were cured in air curing for different curing ages namely 7, 28 and 60 days. The result revealed that by replacing the sand with POCC to LWC were significantly effect the compressive strength. The compressive strength also improved due to increasing the curing days. On the other hand, the modulus of elastic was improved significantly by increasing the percentage of POCC due to different curing days. It is noted that the optimum mix design to produce LWC-POCC was obtained by using 10% of POCC as sand replacement.

ABSTRAK

Industri minyak sawit adalah salah satu industri pertanian paling penting di Malaysia. Setiap tahun, sejumlah besar sisa pepejal kelapa sawit tidak digunakan sebagai bahan pembaziran yang boleh digunapakai dan akan mempengaruhi masalah alam sekitar. Melalui keprihatinan orang awam dan juga usaha kajian, pembuangan sisa pertanian ini mempunyai potensi untuk dimanfaatkan sebagai bahan dalam pembinaan untuk menggantikan pasir konvensional. Dalam kajian ini, keberkesanan klinker sisa pepejal pertanian yang dinamakan klinker kelapa sawit hancur (POCC) dibangunkan sebagai bahan alternatif untuk menggantikan pasir. Dalam kajian ini, pengaruh penggunaan peratusan POCC yang berbeza untuk konkrit ringan berongga (LWC) diuji terhadap ujian kekuatan mampatan dan modulus keanjalan disiasat. Empat siri formulasi campuran LWC disediakan terdiri dari 0%, 5%, 10% dan 15% sebagai pengganti pasir dari berat keseluruhan pasir. Semua sampel LWC diawetkan di udara pada usia berbeza iaitu 7, 28 dan 60 hari. Keputusan kajian menunjukkan bahawa dengan menggantikan pasir dengan POCC untuk LWC secara signifikasinya mempengaruhi kekuatan mampatan. Kekuatan mampatan juga meningkat kerana peningkatan hari pengawetan yang berbeza. Disamping itu, didapati modulus keanjalan meningkat secara signifikan dengan meningkatkan peratusan POCC dan berbezaan hari pengawetan. Didapati campuran optimum untuk menghasilkan LWC-POCC diperolehi dengan menggunakan 10% dari POCC sebagai pengganti pasir.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for testing and Materials
BS	-	British Standard
LWC	-	Lightweight Concrete
MOE	-	Modulus of Elasticity
FKASA	-	Fakulti Kejuruteraan Awam dan Sumber Alam
OPC	-	Ordinary Portland Cement
POC	-	Palm Oil Clinker
POCC	-	Palm Oil Clinker Crushed
W/C	-	Water-Cement

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Generally, conventional concrete is produced in the density ranges of 2200 kg/m^3 to 2600 kg/m^3. Last decade has seen great strides in the realm of concrete density and fantastic compressive strengths. The strength concrete is seriously affected by the degree of it compaction, consistence of the mix of that concrete can be transported, placed and finished sufficiently easily and without segregation (Neville, 1993).

Since the government of Malaysia had a vision and mission about the green buildings construction where it is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. The reason why government of Malaysia concern about the green building because it is designed to save energy and resources, recycle materials and minimize the emission of toxic substances throughout its life cycle. SMART tunnel is the one of the mega project was build according to Industry Building System (IBS).

Even though conventional concrete is a remarkable building material, it has disadvantages such as not flexible or heat insulating enough to be used independently for building structure components and extremely heavy limiting for use as building structure components. In addition to the lack of flexibility and lightweight weakness of insulating properties, conventional concrete is further not adequate for use as building element.

Since the conventional concrete has problems and disadvantages, there are an alternative to improve the existing conventional concrete due to the density. The development of lightweight foamed concrete (LWC) were introduced. According to the BS 8110: Part 2: 1985 it was defined that LWC begin in the density range of less than conventional concrete which is 2000 kg/m^3or less. Decreasing the weight and density produces significant changes which improves many properties of concrete, both in placement and applications.

LWC can be defined as a combination of extremely lightweight foamed materials containing cement, water and foam agent. It can be produced at the construction site similarly to ordinary concrete. The difference between conventional concrete and LWC is it does not use coarse aggregate, but pre-formed foam. Aldridge (2005) revealed that foamed concrete is a type of concrete having an air content of more than 25% which distinguished it from highly air entertained materials. LWC has many advantages such as it could posses excellent in workability, good thermal, does not decompose and it is durable as rock. In addition, Narayanan and Ramamurthy (2000) noted that the most benefits of LWC are reducing the dead weight of structure which economizes the design of supporting structure. However LWC has disadvantages in terms of the lower density ranges LWC does not develop the compressive strength of plain concrete.

As an alternative to solve the problems, a various research were developed to increase the compressive and performance of LWC. One of the researches was introduced are replacing of sandby using product by waste material. This method is the most suitable because it does not create any pollution. From the by product by waste material that not being use or recycled it is better to reuse it as a replacement in construction materials.

In this study, introduce a product by waste material from palm oil plantation namely palm oil clinker crushed (POCC) in the mixing of LWC as a sand replacement. This material is chosen because in Malaysia it is stated that the total of waste is more than 30 millions tone per annum which generate more than 8 millions tone of empty fruit bunch (Fauziah, 2005).

This study is important to determine the performance of LWC by adding various percentages of POCC as sand replacement by weight of sand and determine compressive strength of it and determine the effect of using different percentages of LWC as sand replacement to lightweight foamed concrete.

1.2 Objectives of Study

The objectives of this study are:

i. To determine the compressive strength of lightweight foamed concrete with different percentage of palm oil clinker crushed (LWC-POCC) as sand replacement.

ii. To determine the modulus of elasticity of lightweight foamed concrete with different percentage of palm oil clinker crushed (LWC-POCC) as sand replacement.

iii. To determine the effect of using different percentage of POCC as sand replacement to LWC.

1.3 Problem Statement

Nowadays world has been witnesses a lot of revolution in the using of LWC for the construction industry. Many researches had done to find any materials that can be used to replace the raw material in LWC. Basically, the main ingredients of LWC are cement, foam agent, fine aggregates (sand) and water.

Sand was the key ingredient in LWC provision because it demand in rising construction field, in the course of time it will decline and might be due one time later it will completely been used. Besides that, activity sand mining could also cause ecological system in disturbed rivers and mountains.

As such to overcome this, a study reduce sand use in LWC should be conducted. Through this problem, one solution suggested is the use of palm oil plantation wastage namely POCC as replacement with a portion by total weight of sand. Study the optimum percentage composition of POCC can replace sand would be made for overcome this problem.

1.4 Scope of Study

In this study, the lightweight foamed concrete (LWC) were produced to investigation the compressive strength and modulus of elasticity using different percentage of palm oil clinker crushed (POCC) as sand replacement. The percentages of POCC as sand replacement by total weight of sand are 0%, 5%, 10% and 15%. POCC were mixed with cement, fine aggregate, foam agent and water. The design of density for LWC must be obtained is 1400 kg/m^3 with mix proportion ratio 2:1:1 comprises of cement to sand to water ratio 0.5. Otherwise, the LWC without sand replacement were design as a control mix.

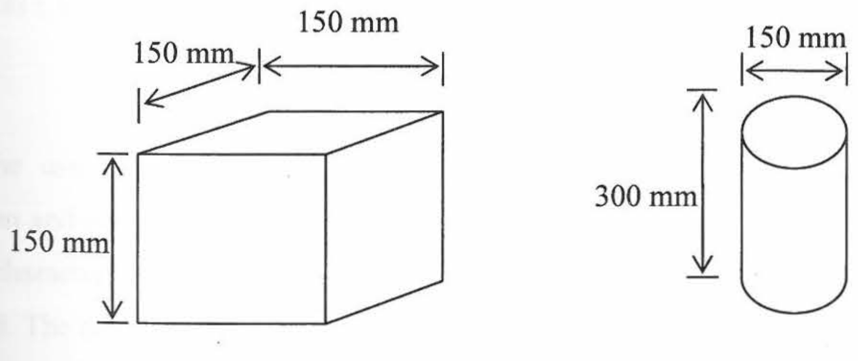
There were 36 cubes LWC were prepared to be test on compressive strength and 36 cylinders are prepared to be test on modulus of elasticity. Minimum three samples were prepare for each parameter and the sample must accordance to BS: 1881: Part 108: 1983 for 0%, 5%, 10% and 15%. All the specimens were tested after expose to air curing at 7, 28, 60 days. The number of sample prepared as shown in Tables 1.1 and 1.2. In addition, the dimension for cubes and cylinder is 150 mm x 150 mm x 150 mm and 150 mm x 300 mm respectively as shown in Figure 1.1. After the specimens matured at the followed curing days, the compressive test and modulus of elasticity was conduct in the FKASA Laboratory. The method of testing is according to the BS: 1881: Part 116: 1983.

Table 1.1 Numbers of LWC-POCC Specimens due to Compressive Strength

Mix Design	Mix proportion	Percentage of POCC (%)	Numbers of sample (cubes)		
	Cement: sand: water		7 days	28 days	60 days
1400 kg/m^3	2 : 1 :1	(Control)	3	3	3
		5	3	3	3
		10	3	3	3
		15	3	3	3

Table 1.2 Numbers of LWC-POCC Specimens due to Modulus of Elasticity

Mix Design	Mix proportion	Percentage of POCC (%)	Numbers of sample (cylinder)		
	Cement: sand: water		7 days	28 days	60 days
1400 kg/m^3	2 : 1 :1	(Control)	3	3	3
		5	3	3	3
		10	3	3	3
		15	3	3	3



a) Cube specimen

b) Cylinder Specimen

Figure 1.1: Dimension of Standard Specimens

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lightweight foamed concrete (LWC) is a class of aerated concrete. Aerated concrete can be classified according to the methods and agents used to introduce air in the concrete. Aerated concrete can be produced by introducing air entraining agent, gas forming chemicals and foaming agents. Concrete which is aerated using foaming agent is known as LWC. Foaming agents can be synthetic based or protein based.

The used of LWC offer many benefits and advantageous particularly fast completion and easy application compared to other materials such as steel and timber. LWC is characterized by its low compressive strength and high insulation against heat and sound. The compressive strength and other functional properties of LWC are greatly influenced by the amount of air content introduced by foaming agents.

The application of LWC in civil engineering works is very broad as it can be used in almost every parts of building from the superstructure right down to the substructure, including wall panels and roofing. Any conventional panels or masonry units used for load and non-load bearing walls using normal concrete can be replaced directly by LWC panels and units. Very low density LWC can be used as thermal and sound insulation panels, filtering media and floating blocks for fishery purposes.

This is due to the major problem that exists on usage of conventional concrete are extremely heavy limiting for use as building structure components. Many researchers try to produce new materials that are lower density but in the same time could posses the same strength of the existing conventional concrete. The production of this material could be ease to construction especially for Industry Building System (IBS) requirements since it would be a great advantage to pre-cast systems (Shaari, 2004). Thus the production of lightweight foamed concrete reinforced with palm oil clinker crushed (LWC-POCC) is one of the alternative way to improve the existing conventional concrete. Reinforcing the LWC-POCC may be used to help resist compressive forces and improve dynamic properties.

On the other hands, LWC offers many benefits including reducing the dead weight of a structure which economizes the design of supporting structures including the foundation and walls of lower floors. Alex (2000) suggested that with appropriate mixed design, a range of LWC with densities ranging from 300 kg/m^3 to 1600 kg/m^3 can be produced. Besides that strength of LWC is mainly dependent on the amount of sand while density is dependent on the amount of foam introduced (Hamidah et al, 2003). Other parameters that affecting the strength of LWC are sand cement ratios, water – cement ratios, curing regimes, types of sand and particle distribution of sand.

Basically, a foamed concrete that has lower density, the amount of sand that could be incorporated is also limited due to the problems related to mix segregation and stability. The amount of sand in foamed concrete requires compressive optimization to ensure production of a sufficiently strong mix for the intended purposes without sacrificing both the economics of the production and the practically in the mixing and placing of such concrete (Hamidah et al., 2003).

Significantly, LWC is a good alternative to prevent this problem in construction. Even though LWC is a good alternative, in the other side LWC also faces some problems like conventional concrete that is insufficient water can cause lack of cohesion between particles, thus loss in strength of LWC. Likewise too much water can cause cement to run off aggregates to form laitance layers, subsequently weakens in strength (Kamsiah et al., 2007).

Due to the problem faced by LWC, the best solution is using palm oil clinker crushed (POCC). The density of conventional concrete is produces in the ranges of 2200 kg/m^3 to 2600 kg/m^3.Conventional concrete have many problems due to the density (Gambhir, 1986). In this present chapter, the reviews of LWC were presented.

2.2 Lightweight Foamed Concrete

Generally, lightweight foam concrete (LWC) can be defined as a combination of extremely lightweight foam concrete materials containing cement, water and foam agent. It can be produced at the construction site similarly to ordinary concrete.

LWC can be produced by adding a pre-foamed agent to cement base mortar. Foamed concrete is one type of lightweight concrete that has an air content of more than 25%. The air will be introduced into a mortar or concrete mix using two principles method.

Furthermore, the first stage is preformed foam from a foam generator can be mix with other constituent in a higher- shear mixer. Decreasing the weight and density produces a significant change which improves many properties of foam concrete, both in placement and application (Alexander, 1977). The definition, history, properties and applications and development of LWC were discussed in this present section.

2.2.1 Definition of Lightweight Foamed Concrete

Aldridge (2005) stated that in basic form concrete is a blend of sand, cement and water (the base mix) and pre-formed foam, which in itself is a mixture of foaming agent, water and air. The foam concrete partially combination of a cement-based mortar mixed with at least 20 % by volume air (Jones et al. 1993). Furthermore, John August (1997) noted that the very lightest density mixes which is 300 kg/m^3 to 900 kg/m^3 are often made using foam in the absence aggregates. According to BS 8110: Part 2 (1985), the foamed concrete density is begins in the range of 2000 kg/m^3 or less than conventional concrete.

2.2.2 Historical of Lightweight Foamed Concrete

Foamed Concrete was first developed in Stockholm, Sweden in the early 1900's. The original material was known as "gas concrete" to be used in producing heat-insulated building materials. The gas concrete is now known as cellular concrete, foamed concrete, aerated concrete and autoclaved cellular concrete. Generally, the properties of foam concrete can be indicated by doing laboratory testing.

The Expanded Clay and Slate Institute proved that most of the bridges appeared to be in good condition. According to Diona et al., (1994), it was found that in Japan LWC had been used since 1964 as a railway station platform. Even though some cracks were reported, but these posed no structure problems. A second structure comprising both LWC and normal concrete which had been in sea water for 13 years was examined for salt penetration. In the late 1980's and 1990's, the foamed concrete was carried out in Netherland for the research development (Van, 1991).

2.2.3 Advantages of Lightweight Foamed Concrete

Lightweight foamed concrete (LWC) physical properties are determined by various mix designs of cements, palm oil clinker crushed, fines aggregates and volumes of entrained foam. Generally LWC has many advantages compared to conventional concrete such as light, doesn't settle, excellent load spreading and requires no compaction. However, the biggest advantages is the fact that it can be produced right on the spot of construction and be casted according to necessary shapes by pumping straight to where it is required (Alex, 2000). In addition, the LWC also offers the advantages such as thermal insulation and high durability.

2.2.4 Weight Reduction

Lightweight foamed concrete (LWC) density ranges from 250 kg/m^3 to 1800 kg/m^3, as compared to 2400 kg/m^3 for conventional concrete. Therefore, the weight of structure built of foam concrete would undoubtedly be reduced significantly thus, requiring less structure steel reinforcement and smaller foundations (Alex, 2000).

2.2.5 Thermal Insulation

Thermal insulation of concrete is important since it could determine the strength to thermal for the concrete itself. A thermal insulation property is described as its ability to resist flow of heat and is given as *k* value. Lightweight foamed concrete (LWC) with a density of 1200 kg/m^3, for instance, can produce a monolithic wall five times thinner, requires ten times less raw material (by weight) and possesses five time more superior thermal insulation property compared to that of conventional concrete. The amplitude–ratio and phase-displacement of a thick 150 mm thick of wall with a density of 1100 kg/m^3 causes the outside temperature of a building to take between 10-12 hours to reach the inside. Such a duration, which is much longer than that of conventional concrete wall, results in a more energy-efficient enclosure. A study by Aldridge (2005) stated that a typical sand cement screed would have a *k* value of 1.8 W/mk which compares to 0.3 W/mk for 1000 kg/m^3 density foam concrete, making the LWC six times more thermally efficient.

2.2.6 High Durability

Generally, the durability of lightweight foamed concrete (LWC) is as good as normal concrete. Studies by Amiri et al., (1994) showed that LWC incorporating lightweight aggregate has better chemical resistance compared to that of normal concrete. It is shown that LWC containing air pores of diameter ranging of from 30 μm to 50 μm have shown better resistance to freeze-thaw than that of normal concrete.

In addition, Amiri et al., (1944) indicated that LWC performs equally well under cryogenic conditions such as for the storage of liquid gases due to its low penetrability. Lightweight aggregate concrete also posses higher strain capacity which results in greater crack resistance. It is worth nothing that the stated properties are enhanced at low temperatures.

2.3 Lightweight Foamed Concrete Properties

In order to evaluate the relations between the physical properties and the structural properties of lightweight foamed concrete (LWC) these properties have to be identified. Kearsley, (1999) stated that a target casting density is determined and dry density of the mixture is the most important factor affecting the properties of the mixture when undertaking the design of a LWC mixture. The density is an important physical property that has to be investigated. According to Kearsley (1990) noted that porosity, ash / cement ratio, and age are also variables, which will influence the structural characteristic of LWC.