PERFORMANCE OF FOAMED CONCRETE BY USING BY PRODUCT MATERIAL: PALM OIL CLINKER CRUSHED (POCC) AS SAND REPLACEMENT

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ABSTRACT

An experimental programmed on foamed concrete and palm oil clinker crushed (POCC) aggregates is presented. Foam concrete also known as aerated concrete because concrete that produced by using cement combined with fine sand and foam. Significant amount of wastes are generated from palm oil mills which constitutes nuisance to the environment. These wastes if used as aggregate in concrete will serve to sanitise the environment and creates cheaper,' renewable aggregates for construction purposes. (POCC) which is abundantly available has the potential as a replacement for sand in the production of foamed concrete. This study investigates the effect of replacement of palm oil clinker crushed towards the mechanical properties of foamed concrete. The aim of this research is to determine the compressive strength and elastic modulus of foamed concrete with density of 1600 kg/m^3 with various percentages of (POCC). The mix proportion ratio was used through this research is 2:1:1 consists of cement to sand to water. Four types of mix design were prepared with the constant w/c of 0.50 and POCC content of 0%, 5%, 10% and 15% by the total sand respectively. Air curing (natural environmental) was considered at age of 7, 28 and 60 days. The higher compressive strength achieved through the percentage of addition of POCC increased due to days. It is revealed that the compressive strength of foamed concrete increased significantly. When the percentage of POCC replaced with sand increase, the strength of samples was increased significantly. The modulus of elastic was increased constantly by increasing the percentage of POCC due to curing days. This study indicates that foamed concrete with POCC content can be utilized as lightweight concrete.

ABSTRAK

Eksprimen ini mengenai konkrit buih berongga dan klinker kelapa sawit. Kajian ini membincangkan kesan penggantian klinker hasil daripada pembakaran kelapa sawit. Semasa proses pembakaran, terdapat banyak lebihan sisa tersebut dibuang dan tidak digunapakai. Lanjutan daripada itu, ia akan menjadi keras dan membentuk klinker. Untuk mengatasi masalah ini, klinker kelapa sawit tersebut akan dijadikan sebagai pasir gentian. Matlamat kajian ini adalah untuk menguji kekuatan mampatan dan modulus elastik konkrit buih berongga yang terdiri daripada pelbagai peratus klinker kelapa sawit hancur (POCC) yang mempunyai densiti 1600 kg/m^3. Dalam penyelidikan ini, nisbah bahagian campuran yang telah digunakan ialah 2:1:1 yang mengandungi simen, pasir dan air. Empat jenis rekabentuk campuran disediakan dengan malar nisbah air kepada simen adalah 0.5 dan kandungan POCC terdiri daripada 0%, 5%, 10% dan 15% daripada berat sebenar pasir. Pengawetan udara (alam semulajadi) telah dijalankan pada tempoh 7, 28 dan 60 hari. Kekuatan mampatan mencapai tahap yang lebih tinggi melalui pertambahan peratusan POCC disebabkan pertambahan tempoh pengawetan. Keputusan juga menunjukkan bahawa kekuatan mampatan konkrit buih berongga meningkat secara seragam. Bagi ujian modulus elastic, kekuatan turut meningkat dengan peningkatan peratusan POCC. Kajian ini menunjukkan bahawa konkrit buih berongga dengan kandungan batu klinker kelapa sawit yang hancur dapat digunakan sebagai konkrit ringan.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
BS	-	British Standard
LWC	-	Light Weight Concrete
MOE	-	Modulus of Elastic
NWC	-	Normal Weight Concrete
OPC	-	Ordinary Portland Cement
POC	-	Palm Oil Clinker
POCC	-	Palm Oil Clinker Crushed
W/C	-	Water- Cement

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The term 'conventional concrete' denotes many things. Conventional concrete is known as a universal material. Conventional concrete is the most widely used man-made construction material in the world today. There are records of conventional concrete being used 5000 years ago, as well as in Roman times, in Mediaeval Europe and 18^{th} and 19^{th} century Britain and France. Bill et al., (2002) stated that conventional concrete also becomes a principal construction material in every country of the world since about 1900. Conventional concrete is one of the versatile construction materials, offering potentially unlimited opportunities for developing diverse forms of construction, as its ingredients, namely cement, sand, aggregates, and water, are available all over the globe. Besides that conventional concrete is also very excellent characteristics of requires substantially less maintenance then other material (Svetlana et al., 2006).

According to Svetlana et al., (2006) conventional concrete manufacturing process is quite complex and includes a number of steps, such as proportioning, batching, mixing, placing, compacting, finishing, and curing. Tony and Brian stated

that conventional concrete will be more durable, will be specified with greater consideration of the environmental and will attain significantly higher strengths. Therefore, concrete in its evolving form will continue to provide ever increasing challenges and opportunities for repair and redecoration, and will continue to be a dominant construction material. Conventional concrete has a high compressive strength while its tensile strength is low.

Foamed concrete is a versatile, low-density material, which comprises a cement-based mortar, or paste, as the base mix, with at least 20% by volume of foam. The material is being used in an ever-increasing number of fill, geotechnical and semi-structural applications (Jones et al., 2005). The fresh state properties of foam concrete are stability of foam concrete and consistency of the foam concrete, were very much affected by the water content in the base mix and the amount of foam added along with the other solid ingredients in the mix (Mat, 2008). Narayanan et al., (2000) defined that foam concrete was classifies to two types that are lightweight and aerating agent. Papayianni (1987) proved that foamed concrete also an environmentally acceptable, lightweight and requires less consumption of primary materials that are available locally. Besides that the amount of construction will be reduce by using foam concrete (Srinivasan, 2005).

Foam concrete is lightweight concrete in which air-void are entrapped in the mortar matrix by means of a suitable aerating agent. Foam concrete also known as aerated concrete because concrete that produced by using cement or lime mortar combined with fine sand and foam. In the last few years, there have been significant developments in the understanding of foamed concrete that have given confidence for engineers to broaden its use to more demanding situations. Furthermore, it's minimal consumption of primary aggregate resources (Jones et al., 2005). Furthermore, the addition of the pre-formed foam into a base mix lowers the density of the base materials whilst increases the yield, with the more foam added, the lighter the resultant material (Aldridge, 2000).

Foamed concrete densities more strong compared to conventional concrete that are ranging from 300 kg/m^3 to 1700 kg/m^3. The lower densities produce the lower strengths and at present even the densities at the upper limits do not produce strengths much above 15 N/mm^2. Again as per standard concretes the strength of foamed materials in the main can be attributed to the cement and water content for any given mix, unlike normal concretes. However the type of forming agent used will have a considerable bearing on the final strength along with, to a certain extent, the type of fine aggregate used. In modern times the use of recycled materials as foam concrete ingredients is gaining popularity because of increasingly rigid environmental legislation. Normally, in construction there will use sand as an ingredient for foam concrete.

Sand is a well-known building material and has occupied a very important place in construction work. In order to obtain a strong, durable and economical concrete mix, it is necessary understand the characteristic and behavior of ingredients. The comment materials are used to replace sand are clinker crushed, fly ash, limestone, natural pozzolanas, blast furnace slag, coal fly ash, etc (Eurocode2, 2003). Therefore, using palm oil clinker crushed (POCC) materials as partial replacement of sand can be a useful remedy (Aldridge, 2000).

POCC is more suitable material to replace sand to design foam concrete. This is because POCC more cheaply compared to other materials and also contains the same compounds with sand. Most of companies are using POCC as a placement material for sand to control the cost of project. POCC is produced from raw materials, such as limestone and clay, which are crushed, homogenized and fed into a rotary kiln. POCC consists mainly of calcium-oxide, silicium-oxide, aluminium-oxide and iron-oxide. POCC is hydraulically more active than slag. Dvorkin (2002) proved that clinker ash contains 63% to 66% of calcium-oxide, 22% to 24% of silicium oxide, 4% to 8% of aluminium-oxide and 2% to 4% of iron-oxide.

In this present study, four different various percentage of POCC with one mix proportion were tested. The basic approach of this study is to determine the compressive strength of foam concrete by the replacement of sand with POCC. On the other hand, the test also to estimate the mechanical properties of foamed concrete.

1.2 Objective of Study

The objectives of this study are:

i. To determine the effectiveness of oil palm waste clinker crushed and it's potential as partial replacement mixes in foam concrete.

ii. To determine the modulus of elastic of foam concrete replace with different percentage of oil palm waste clinker crushed as sand replacement.

1.3 Problem Statement

Nowadays, many problems were happened that indirectly warned the world about the hardness of conventional concrete in our future. There are many problems were happened in this world such as structural failure and cracking by weathering, the ecological system was unbalance by the blasting the rock to produce aggregates and the main industrial cities, building roof and wall corrosion by chemical reaction

that can weak the building structure. Reasonably, the conventional concrete is not suitable for future construction demand and not esthetically effective. To reduce this problem, most of the construction place is using foam concrete to replace conventional concrete. In additional, foam concrete also very light of weight and various usages compared to conventional concrete. If the strength of foam concrete increase whiles the cost of cement also increase. To condense this problem, construction company must use waste material such as clinker ash, fly ash, limestone, natural pozzolanas, blast furnace slag and coal fly ash as a replacement of cement. The most suitable waste material to cut down the cost of construction budget is clinker ash. Besides that clinker ash also have same contains with concrete that are calcium-oxide, silicium-oxide, aluminium-oxide and iron-oxide. It's clearly shows that clinker ash is more suitable waste material and same contains with concrete. In this study, more information will be achieved to provide a practical approach for the future development. To produce the foam concrete by using clinker ash as a replacement of cement, the same amount of work force, budget and duration for project using the conventional concrete which can produce the greater achievement.

1.4 Scope of Study

This study was determined the behaviors of the POCC as a replacement of sand to foam a foam concrete and also concentrated on mechanical properties namely compressive strength of foam concrete. In this research 128 samples of foam concrete will be formed which is 32 samples for every particular day. According to British Standard 1881, the cube sample's dimension is 150 mm × 150 mm × 150 mm while the cylinder sample's dimension is 150 mm × 300 mm. The mix design comprises of cement, water, palm oil clinker crushed (POCC), sand and foaming agent. The POCC was used as a replacement of sand in the forming of foamed concrete.

The serial of mix proportion comprises of cement to sand and palm oil clinker crushed to water is labeled as MJT1, MJT2, MJT3 and MJT4. There are four types various percentage of POCC were prepared that are 0%, 5%, 10% and 15%. Every series of percentage will use one type of mix proportion that is 2:1:1. Besides that the proportions mix of samples with water-cement ratio of 0.50 to be used respectively. The entire samples were cured in air (natural environmental) for 7 days, 28 days and 60 days for all mixes. The compressive strength test will be conducting after curing period. Table 1.1 shows the number of samples that were used.

Table 1.1: Number of Sample of Foamed Concrete due to Air Curing Condition

Label of Sample	Percentage of POCC (%)	Mix Proportion	Number of Samples / Days			
		Cement: Sand: Water	7	14	28	60
MJT1	0	2: 1: 1	8	8	8	8
MJT2	5	2: 1: 1	8	8	8	8
MJT3	10	2: 1: 1	8	8	8	8
MJT4	15	2: 1: 1	8	8	8	8

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Conventional concrete is the most widely used man-made construction material. Foamed concrete can be defined as a combination of extremely lightweight foamed material which is containing cement, water and foamed agent. It is obtained by mixing cement, water and aggregates in required proportions. The mixture when placed in forms and allowed to cure becomes hard like stone. The hardening is caused by chemical action between water and cement. It continues for a long time and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of larger particles like coarse aggregate are filled by the smaller particles like fine aggregates and the voids of fine aggregates are filled with cement. In a concrete mix the cement and water form a paste called cement water paste which in addition to filling the voids of fine aggregate acts as binder on hardening.

The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, on the proportions of mix, the method of compaction and other controls during placing, compaction and curing. The popularity of the concrete is due to the fact that from the common ingredients and make sure the ingredients is possible to tailor the properties of concrete to meet the demands of any particular situation. The advances in concrete technology have paved the way to make the best use of locally available materials by judicious mix proportioning and proper workmanship, so as to produce concrete satisfying performance requirements. Nowadays, there are many problems occurred in construction such as structural failure and cracking by weathering due to environmental effect.

Foamed concrete is a good alternative to prevent this problem in construction. Even though foamed concrete is a good alternatives, in the other side foamed concrete also faced the same problem with conventional concrete. Due to the problem faced by foamed concrete, 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).

2.2 Definition of 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). The foam agent serves as temporary wrapping material for the air bubbles until the cement mix develops its own final set and strength. According to British Standard

8110: Part 2 (1985), the foamed concrete density is begins in the range of 2000 kg/m^3 or less than conventional concrete. Furthermore, John (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.

2.3 History of 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 foamed concrete 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 conventional 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).

2.4 The Uses of Foamed Concrete

There are many uses of foamed concrete for construction as a light of weight compared to conventional concrete. Foamed concrete used in insulating water pipes and also heating the insulation on roofs. Besides that foamed concrete also was used for reinforced concrete and screed and thickening for general purposes especially when such screeds or thickening and weight to floors and other structural members. The foamed concrete was used to fixing bricks to receive nails from joinery, principally in domestic or domestic type construction. Furthermore, foamed concrete used to casting structural steel to protect the foamed concrete against fire and corrosion or as a covering for architectural purposes.

2.5 Advantages of Foamed Concrete

Foamed concrete have many advantages such as it can reduced dead load of wet concrete allows longer span to be poured un propped. Besides that foamed concrete also economies the design of supporting structure such as foundation and walls of lower floors, ecological compatibility, possesses high workability, good thermal and sound thermal properties. It's can save the time period to settle the project and also more easy to labor finish the project. Alex (2003) noted that foamed concrete can be produced right on the spot of construction and be casted according to necessary shapes by pumping straight to where it is required. Furthermore, foamed concrete also easy and fast production reduced the transportation costs and used a little cement.

2.6 Foamed Concrete Properties

In order to evaluate the relations between the physical properties and the structural properties of foamed concrete 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 foamed concrete mixture. The density is an important physical property that has to be investigated. According to Kearsley (1990), porosity, ash/cement ratio, and age are also variables, which will influence the structural characteristic of foamed concrete.

Strength, durability, impermeability and volume stability are the most important structural characteristics of concrete. Strength usually gives an overall view of the quality of concrete and also directly related to the structure of the cement paste (Neville, 1987). Therefore in the rest of the research, the compressive strength will be use as the structural property indicating the quality of foamed concrete.

2.6.1 Physical Properties of Foamed Concrete

Physical properties of foamed concrete are durability, thermal conductivity and water absorption and capillarity. In the present chapter were discussed detailed of physical properties of foamed concrete.

2.6.1.1 Durability of Foamed Concrete

Generally, the durability of foamed concrete is as good as conventional concrete. Amiri et al., (1994) stated that the foamed concrete incorporating lightweight aggregates has better chemical resistance compared to conventional concrete. Foamed concrete containing high-volume fly ash has significantly superior resistance to conventional concrete without fly ash in freezing and thawing tests.

Amiri et al., (1994) mentioned that foamed concrete performs equally well under cryogenic conditions such as for the storage of liquid gases due to its low penetrability. Foamed concrete also possess higher strain capacity which results in greater crack resistance. It is worth nothing that the stated properties are enhanced at low temperature.

2.6.1.2 Thermal Properties of Foamed Concrete

A material thermal insulation property is described as foamed concrete to resist the flow of heat and is given as k value. The "*u*" value can be determined by utilizing the information of structure and the "*u*" value is generally specified by architects and the value. A typical sand cement screed would have a *k* value of 1.8 w/mk which compares to 0.3 w/mk for a 1000 kg/m^3 density foamed concrete. The making of foamed concrete is six times more thermal efficient compared to conventional concrete. Obviously the conventional concrete have a much greater strength compared to foamed concrete, but used in the correct circumstances this would not create a problem (Aldridge, 2000).