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BEHAVIOR OF LIGHTWEIGHT CONCRETE CONTAINING PALM OIL SHELL AS COARSE AGGREGATE

BITRUS, EMMANUEL ACHARA

A project report submitted in partial fulfillment of the
requirement for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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I declare that this project report entitled "*Behavior of lightweight concrete containing palm oil shell as coarse aggregate*" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my caring Brother, Mr. Philemon for moral and financial support all this years.

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ABSTRACT

The need to source for alternative and affordable building materials that can be afforded by ordinary people in developing countries and the need to utilize industrial waste in a more safer way, has attracted the attention of engineers and public to study the possibility of utilizing palm oil shell as one of the construction materials. This study investigates the behavior of palm oil shell as coarse aggregate in the production of lightweight concrete through experimental work. The behavior in compression, flexural, modified compression, ultrasonic pulse velocity, expansion, shrinkage; brick walls in compression are all studied. The concrete samples used in this study include 100x100x500 mm prism, 100x100x100 mm cube, 220x100x70 mm brick size, and a brick wall of 1000x450x70 mm. The results of the study show that palm oil shell concrete had an average compressive strength of 15 N/mm^2 and its flexural strength was in the range of 2.5-3.5 N/mm^2 at 28 day. For the expansion, POS concrete had 78 micro-strains at 7 day and there after had just 4 % increment at 28 day and 56 day while aerated concrete had higher value of about 48 % at 28 day and 56 day. The drying shrinkage of POS concrete at 7 day was about 55 micro-strains at 7 day and increment of about 30 % at 28 and 56 day. On application of compressive force on brick walls, POS concrete brick wall had first crack at 200 KN load and failed at 567 KN load. On the other hand, the aerated concrete had first crack at 100 KN load and failed at 178 KN load. The experimental results show that palm oil shell as aggregate in lightweight concrete production demonstrated satisfactory and better results compared with aerated concrete. It can be concluded that palm oil shell can be used as coarse aggregate for lightweight concrete.

ABSTRAK

Keperluan untuk mencari bahan binaan alternatif yang murah dan mampu digunakan oleh orang awam di negara membangun dan keperluan untuk menggunakan bahan buangan dalam keadaan yang lebih selamat telah menarik minat jurutera dan masyarakat untuk mengkaji kemungkinan penggunaan tempurung kelapa sawit dalam pembinaan. Projek ini dijalankan bagi mengkaji kelakunan konkrit ringan yang menggunakan tempurung kelapa sawit sebagai agregat kasar. Sifat kekuatan mampatan, lenturan, kekuatan mampatan ubahsuai, denyutan ultrasonik, pengembangan, pengecutan, dan kekuatan mampatan dinding menggunakan bata di kaji. Sampel konkrit yang digunakan prisma bersaiz 100x100x500 mm, kiub 100x100x100 mm, bata bersaiz 220x100x70 mm, dan dinding bata 1000x450x70 mm. Keputusan ujikaji menunjukkan kekuatan mampatan purata konkrit ringan tempurung kelapa sawit (KRTK) ialah 15 N/mm^2 dan kekuatan lenturan dalam lingkungan 2.5 – 3.5 N/mm^2 pada umur 28 hari. Bagi nilai pengembangan pula KRTK pada umur 7 hari ialah 78 mikrostrain dan meningkat 4% pada umur 28 dan 56 hari manakala konkrit berudara mempunyai nilai yang lebih tinggi sebanyak 48% pada umur 28 dan 56 hari. Pengecutan KRTK pada umur 7 hari adalah 55 mikrostrain dan meningkat 30% pada umur 28 dan 56 hari. Bagi dinding bata pula, dinding bata KRTK menunjukkan keretakan awal pada beban 200 kN dan gagal pada beban 567 kN. Bagi dinding bata konkrit berudara pula keretakan awal berlaku pada beban 100 kN dan gagal pada beban 178 kN. Keputusan ujikaji menunjukkan penggunaan tempurung kelapa sawit memberikan keputusan yang memuaskan dan lebih baik dari konkrit berudara. Kesimpulan yang boleh dibuat ialah tempurung kelapa sawit boleh digunakan dalam penghasilan konkrit ringan.

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A	-	Cross section Area
b	-	Beam width
d	-	Effective depth
f_c	-	Concrete strength
kg	-	Kilogram
LVDT		ongitudinal Variable Displacement Transducer
L	-	Total span length
m^3	-	Cubic meter
mm^2	-	Characteristic strength of links
MR	-	Modulus of Rupture
POS	-	Palm oil shell
P	-	Load
RH	-	Relative Humidity
UPV	-	Ultrasonic Pulse Velocity

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is composed of sand or stone, as aggregate, which are combined with cement paste to serve as binder and its strength development. Aggregates are produced in various sizes which are considered fine (sand) or coarse (crushed stone or gravel), the major constituents of concrete is the aggregate which makes it affordable as construction material. Lightweight concrete has been in use in construction industry for over 60 years ago in the western world (Europe), and has since then been on the international market for more than 20 years.

Palm oil shell as aggregate in concrete will further make construction more affordable where it suits, this could be traced to its availability in abundance in a place like Malaysia, where palm oil trees dominate their plantation. Shells obtained from industries responsible for extraction of oil from these palm nuts are used as fuel to generate power in these industries. Malaysia is among countries that are short of lightweight aggregates, therefore, if alternative is made available for these industries for power generation, then this shell can be effectively used as lightweight aggregate in areas where they can be used.

Structural lightweight aggregate concretes have been used in both reinforced and pre-stressed concretes. The use of lightweight aggregate concrete generally results in an overall saving of some percentage of the total cost of the equivalent normal weight concrete and also the reduction in density allows smaller structural members. Most of the lightweight aggregates used are factory-made expanded clay, shale and others. The concrete produced using these lightweight aggregates have a wide range of densities and strength. However, for structural use, concrete of grade 20 and above is preferred. In South East Asia the use of lightweight aggregate concrete is not common due to lack of understanding of the production technique for lightweight aggregate and insufficient information about the structural performance of lightweight aggregate concrete.

However, recently efforts have been made by researchers on the use of agricultural waste, palm oil shells as lightweight aggregate to produce structural lightweight aggregate concrete in Asia and Africa. Palm oil shell has stony endocarps that surround the kernel; the shells come in different shapes and sizes. They are light and naturally sized; they are ideal for substituting aggregates in lightweight concrete construction. Since palm oil shell are hard and stony, even though of organic origin, they will not contaminate or leach to produce toxic substances, once they are bound in concrete matrix. Normally, the shells are flaky and of irregular shape that depends on the breaking pattern of the nut. Palm oil shell is available in large quantities in palm oil producing countries in Asia and Africa. Malaysia alone produces nearly four million tons of palm oil shell annually and this is likely to increase as more production of palm oil is expected in the near future.

1.2 Problem statement

The increase in general building activity and civil engineering construction, particularly in the field of reinforced concrete and road building, and the consequent spectacular increase in the consumption of available reserve of materials for these activities has already led to some competitive and shortages of natural aggregates suitable for reinforced concrete construction in some areas or regions of the world. In some areas this shortage is caused by actual lack of suitable materials and could only be remedied by the importation of aggregates from other areas at an increased cost due to high transport charges.

It would seem natural then that industry in general, building and civil engineering industries in particular, should be increasingly forced to consider the possibility of utilizing the vast, un-sighting and idle accumulation of waste materials left behind by industrial activities. By using the agriculture waste namely the palm oil shell of the palm oil fruit, partially or totally replacing the stone aggregate in concrete, will solve problem in managing waste and utilizing the waste as raw material.

The increased cost of building which is attributed by cost of building materials, cost of labor, and the like, the use of lightweight aggregate from agriculture waste will have a direct financial benefit, capable of fairly close assessment, in lower steel consumption and reduced self weight, leading to savings in the design of the foundation and of the load bearing structure and to better anti seismic properties. There are other benefits which cannot be quantified easily; for example, a reduction in weight is followed by savings in transport and greater ease of operation on the site; there is less human fatigue and lead to faster speed of erection and hence to a reduction of funding costs, also a powerful way to put new buildings to useful and profitable employment as early as possible.

1.3 Aims of the study

The research is conducted to study the behavior of palm oil shell (POS) as coarse aggregate in the production of lightweight concrete. Their engineering properties are compared with aerated concrete. Based on these properties, their applications as brick wall is equally studied to assist certain application suitability in this regard. Other areas of application in civil engineering construction are suggested. POS which is solid waste in industries is disposed beneficially in this regard.

1.4 Research objectives

The objectives of this research are;

i) To study the properties of lightweight concrete containing palm oil shell as coarse aggregate.

ii) To compare the performance of palm oil shell concrete and aerated concrete.

iii) To study the behavior under compression of brick wall manufactured using palm oil shell brick and aerated concrete brick.

1.5 Scope of the research

This research involves studying the behavior of palm oil shell (POS) concrete, considered as lightweight concrete and compared with aerated concrete. The study covers their compressive strength, flexural strength, Ultra Pulse Velocity (UPV), modified compressive strength, expansion and shrinkage, and compressive force on brick walls of the two form of concrete in this work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Production of lightweight concrete is a technology aimed at reducing dead load on building structures to reduce the overall cost of building by saving on foundation. As the dead load to be imposed is reduced when lightweight concrete are used as partitions and decoration on facades, labor cost is reduced as few workers will be required to execute a task in lightweight construction compared to normal weight concrete construction. Using palm oil shell as aggregate in concrete will help further reduction in cost as the product is available in abundance in countries where they are produced and used mainly as fuel to generate energy in industries, Okafor, (1998). Palm oil shell as aggregate in lightweight concrete is a potential to take care of insufficient supply of aggregates for lightweight concrete production, which is seen as a threat to its wide range of application and acceptance as a dominant material in construction industries.

2.2 Production of lightweight concrete

According to Wainwrigh and Neville, (1978), and Okafor, (1998), the use of lightweight aggregate has been the successful method of production of lightweight concrete. The use of lightweight concrete has been embraced and is successfully implemented in construction industries for concrete production. Most lightweight aggregate occur naturally and usually of volcanic origin, while others are manufactured.

According to Okafor, (1988), Palm oil shell is of organic origin produced in appreciable quantities in countries where they are produced in the tropics. After the palm kernel has been processed, when the oil is extracted from the palm nut, the shell is obtained from the palm nut. After processing, the nut is usually kept for drying to ease cracking of the kernel. This is usually the practice in Nigeria and some other countries. In an organized setting, where palm oil mills are set-up, the nut is cracked into pieces by machines, the products of the process are palm kernel which is converted to variety of useful products and the shell is the by-product. In some of these countries where they are produced, usually, the palm oil shell is used as domestic fuel. Efforts in research has been tried in Nigeria to assess its suitability as a road base material, even though no reliable report has been tendered on its performance as a base material.

2.3 Reliability of usage of palm oil shell as lightweight aggregate in concrete production.

According to Kirkaldy, and Sutatanto, (1976), most countries that produce palm oil, palm oil shell is considered as waste, causing significant disposal problems. Malaysia is one of the recognized countries for the production of palm oil. Research has shown that in every one million tons of palm oil produced, about 0.8 million tons of palm oil shells are generated. As at 1993, the estimated oil production is 7.4 million tons, out of which about 6 million tons are generated as palm oil shell. Shamsuddin, and Williams, (1992), considered the possibility of using palm oil shell as fuel to boilers. This came up as the result of alarming rate of its generation of waste, and this stimulated lots of researches among which its possibility to be used as fuel to boilers. Basri, Mannan, and Zain, (1999), studied the possibility of improving the biodegradability of palm oil shell using poly vinyl alcohol, and this improved the strength characteristics of palm oil shell concrete. This indicates that the availability of palm oil shells as lightweight aggregate in concrete proves to be reliable once the POS is bound in the concrete matrix.

2.4 Description of palm oil shell

Palm oil shells are known to have hard and stony endocarps that surround the kernel and the shells are usually in different shapes and sizes. They are light and are naturally sized; they are appropriate for replacing aggregates in lightweight construction, since they are known to be hard and of organic origin, once used to produce concrete, they will hardly contaminate or leach to produce toxic substances, since they are bound in concrete matrix, CEB – FIP, (1977). This gives lightweight concrete made with palm oil shell an advantage over aerated concrete, since permeability is low and the chance for carbonation is reduced.

Okafor, (1988), described Palm oil shell to have irregular shape after cracking and therefore its shape cannot be defined. The shape takes pattern of cracking on the shell and usually composed of many shapes ranging from parabolic or semi-circular shapes, flaky shapes and other irregular shapes. After cracking the edges of the shells are rough and spiky and the overall shape becomes concave and convex with a fairly smooth surface. There is no fixed thickness for the shell, this depend on the species from which it is obtained, ranging from 1.5 mm to 4 mm and usually between 2 mm and 3 mm.

2.5 Properties of structural lightweight aggregates

The dry density of compacted concrete made with different lightweight aggregates varies from about 800 – 2100 kg/m^3 for cube strength ranging from 7 – 50 N/mm^2 CEB – FIP, (1977). Structural lightweight concrete is defined in most codes of practice and by RILEM in a more restricted way by limiting the density of lightweight concrete to between 1200 and 2000 kg/m^3.

Short, and Kinniburgh, (1978), made some classifications, for sand and gravel concrete, the measured dry density ranges from about 2200 kg/m^3 for 28-day cube strength of about 7 N/mm^2, to about 2300 kg/m^3 for cube strength of about 28 N/mm^2. For the same average 28-day cube strength, the dry density of compacted foamed slag concrete ranges from about 1700 – 1900 kg/m^3, when the mix contain only lightweight aggregate; when the fines consist of sand and lightweight materials in equal parts, then the corresponding densities vary between 1800 and 2000 kg/m^3. The density of concrete made with expanded clay and pulverized-fuel ash aggregate varies from about 1400 – 1600 kg/m^3, when made without sand from 1600 – 1800 kg/m^3 when the fines include sand, for the range of 28-day cube strengths.

2.6 Justification for use of lightweight concrete

Kinniburgh, (1984), from his research conducted and practical experience in the industry has shown that, with lightweight concrete, a faster building rate can be achieved compared to the more traditional materials, for this reason many builders today are ready to pay heavily more, for example, for lightweight concrete blocks than for burnt clay bricks, for the same area of walling. The haulage for building materials like clay bricks are limited not by volume but by weight. When suitable containers are design with larger volumes, it can haul a larger volume of lightweight concrete economically.

Kinniburgh, (1984), also, put forward that, property which is less obvious but considered important, is the ability of lightweight concrete to have a relatively low thermal conductivity; property which improves with decreasing density. In recent years, with the increasing cost and scarcity of energy sources, more attention has been given than formerly to the need for reducing fuel consumption while maintaining, and indeed improving, comfort condition of buildings. This point can be illustrated by the fact that a 125 mm thick solid wall of aerated concrete will give thermal insulation about four times greater than that of a 230 mm clay brick wall.

Short, and Kinniburgh, (1978), stated that, apart from the technical advantage in building, some lightweight concrete have the additional advantage of creating opportunity for the utilization of industrial wastes, such as clinker, pulverized-fuel ash and blast furnace slag. Outside agriculture, building is the largest single industry in most countries, and the only one able to absorb vast quantities of industrial waste of which million of tons are generated annually.