A STUDY ON THE USE OF OIL PALM SHELL IN LIGHTWEIGHT CONCRETE

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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ABSTRACT

An investigation into the potential use of waste oil palm shells (OPS) as coarse aggregate in concrete construction has been carried out. A suitable mix design of OPS concrete has been established. The long-term performance of OPS and control concretes with fly ash as partial cement replacement has been studied. All samples are tested under four curing conditions. The engineering properties of hardened concrete samples are determined using compressive strength tests, flexural strength tests, splitting tensile tests, modulus of elasticity tests and drying shrinkage tests. A non-destructive test, i. e. ultrasonic pulse velocity test also is performed. To ascertain concrete durability, the initial surface absorption tests, strength tests at high temperatures and performance test in $MgSO_4$ solution have been conducted. The most satisfactory performance in engineering properties for both types of concrete are observed in full water curing condition. Fly ash as partial cement replacement in OPS concrete is found to decrease the strengths compared with OPS concrete without fly ash. This investigation has concluded that there is a strong possibility for the utilisation of OPS as coarse aggregate in lightweight concrete construction. It can satisfy concerns for technical feasibility along with environmental and economic considerations. In future, the prospect for resource recovery of this waste material can be explored further. OPS, commonly regarded as an agricultural waste, could be accepted as a natural resource since OPS concrete has been proven to possess engineering characteristics comparable to conventional lightweight aggregate.

ABSTRAK

Satu Penyisatan ke atas potensi kelompang minyak sawit (oil palm shell atau OPS) sebagai batu-baur kasar dalam pembinaan konkrit telah dijalankan. Penyiasatan ini telah menghasilkan rekabentuk OPS yang boleh dipraktikkan. Prestasi jangka panjang OPS dan konkrit kawalan yang menggunakan abu terbang sebagai simen gantian telah dikaji. Semua sampel telah diuji di bawah empat keadaan. Sifat-sifat kejuruteraan sampel konkrit terkeras telah ditentukan dari ujian mampatan, ujian lenturan, ujian tegangan pemishah, ujian kekenyalan dan ujian kecutan kering. Ujian tanpa musnah iaitu halaju denyutan ultrabunyi juga telah dijalankan. Untuk menguji ketahanan konkrit ujian serapan permukaan awalan, ujian kekuatan pada suhu tinggi dan ujian prestasi dalam larutan magnesium sulfat juga telah dijalankan. Prestasi yang memuskan dari segi ciri-ciri kejuruteraan untuk kedua-dua jenis konkrit telah diperolehi dalam keadaan awet air penuh. Abu terbang yang digunakan sebagai gantian simen dalam konkrit OPS telah mengurangkan kekuatannya berbanding dengan konkrit tanpa abu terbang. Penyiastan ini mendapati OPS mempunyai potensi yang besar untuk digunakan sebagai batu-baur kasar dalam pembinaan konkrit ringan. Justeru itu OPS yang selama ini dianggap sebagai bahan buangan dalam industri kelapa sawit boleh dimajukan sebagai bahan komponen dalam campuran konkrit kerana mempunyai ciri-ciri kejuruteraan yang setara dengan batu-baur ringan lazim.

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LIST OF SYMBOLS AND ABBREVIATIONS

^{0}C	degree Celsius
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standard
C.F	Compaction Factor
$Ca(OH)_2$	Calcium Hydroxide
$CaCl_2$, CaCl	Calcium Chloride
CaO	Calcium Oxide
Cl^{-1}	Chloride
Comp. St.	Compressive Strength
C-S-H	Calcium Silicate Hydrate
d	day
E	Modulus of Elasticity
FA	Fly Ash
ISA	Initial Surface Absorption
$MgSO_4$	Magnesium Sulphate
$ml/m^2/sec$	mili litre/square meter/second
M-S-H	Magnesium Silicate Hydrate
OPC	Ordinary Portland Cement
OPS	Oil Palm Shell
ppm	parts per million
ssd	Saturated Surface Dry
UPV	Ultrasonic Pulse Velocity
w/c	water/cement ratio
$w/m^{0}C$	Watt/meter degree Celsius
W-1	Partial water - 1 curing
W-2	Plastic curing
W-3	Partial water - 2 curing
W-4	Full water curing

CHAPTER I

INTRODUCTION

1.1 GENERAL

In many developed countries, due to the increasing cost of raw materials and the continuous depletion of natural resources, the use of waste materials which are by-products from industries has great potential in the construction industry. Waste materials, when properly processed, have shown to be effective as construction materials and can readily meet design specifications.

Both natural and artificial aggregates are used in the construction industry. Furnace clinker and sintered pulverised fuel ash aggregates, used in lightweight concrete are well known, but these artificial aggregates are limited in supply.

The utilisation of agricultural waste in the construction industry has been studied for many years with limited commercial benefit. Utilisation of agricultural wastes in insulating board, hardboard, particle-board, block and tile productions have shown beneficial effects. The approach must be focused on a full use of local resources and proper adaptation of the wastes from the industrial and agricultural sectors.

In developing countries where abundant agricultural and industrial wastes are discharged, these wastes can be used as potential materials or replacement materials in the construction industry (Abang Ali 1982; Okafor 1991, 1988). This will have the double advantage of reduction in the cost of construction materials and also as a means of disposal of waste. With sufficient research on the development of these materials, the use of such materials becomes increasingly popular, economic and worthy.

The recycling or utilisation of solid wastes generated from most agro-based industries and manufacturing industries is very rewarding. The anxiety about enormous waste production, resource preservation, and material cost has focused attention for the reuse of solid wastes. Material recovery from the conversion of agricultural wastes and industrial wastes into useful materials has not only environmental gains, but may also preserve natural resources (Nontananandh 1990). It is thus appropriate that research on the effective utilisation of various types of solid waste has gained greater attention in the past few decades.

1.1.1 Use of Agricultural Wastes in Concrete Production

Concrete using agricultural waste abundant in an agro-based country such as Malaysia, presents an interesting alternative to the use of conventional concrete materials.

The application of agricultural waste in concrete has engineering potential and economic advantage. Each type of agricultural waste has physical and chemical properties which are suitable, in proper application, in concrete. In low-cost structures solid agricultural waste as coarse aggregate, together with cement matrix, can meet design specifications (Salam 1982). Agricultural wastes can also be used in non-load bearing concrete where compressive strength is not important. Agricultural fibres can be used in concrete to produce particle-boards, roofing-sheets, and partition-panels. Rice husk ash and palm-oil-fuel-ash as cement replacement materials have been investigated. From the previous investigations, three broad categories using agricultural waste in concrete can be classified as shown in Table 1.1 (Abdul Awal et al. 1997; Okafor et al. 1996; Badaruddin 1993; Abang Ali 1982).

TABLE 1.1 Classification of agricultural waste as construction material

No.	Type of application	Type of Agricultural Waste
1	As aggregates for concrete production	Oil palm shell (OPS)/ clinker Coconut shell, Rice husk and Saw dust
2	In fibre-reinforced concrete: as aggregates for particle board, roofing sheet, and partition panel production	Oil palm fibre, Coconut husk Rice straw and Sugarcane bagasse
3	As cement replacement material in concrete	Rice husk ash and Palm-oil-fuel ash

1.1.2 Generation of Waste in Oil Palm Industry

Palm oil is an economically important crop in several humid and tropical countries. Malaysia is one such zone of warm humid climate (Spence et al. 1983). At present, Malaysia has produced more than half of the world's total output of palm oil (PORIM 1998). Oil palm waste is in the form of leaves, fronds and old trunks from the palm plantations. The palm mill waste includes empty fruit bunches, shells, pericarp and effluent. The actual quantity of waste generated from oil palm trees is shown in Table 1.2 (Polprasert 1989; Mohd Noor et al. 1990). Limited efforts had been carried out in the past to gain economical benefits from these wastes as construction material in concrete.

The total area planted with oil palm in Malaysia covers about 2.6 million hectares (PORIM 1998), with capability of Oil Palm Shell (OPS) production of over 3.13 million tones annually (Polprasert 1989; Mohd Noor et al. 1990). The vast availability of this discarded OPS resource is as yet, unutilised commercially. Concrete with oil palm shell as coarse aggregate can be used for the construction of low-cost houses, farm structures, tennis courts, pavements and paving drains. Thus it is necessary to identify the potential use of this shell for value added products in concrete.

TABLE 1.2 Quantitative generation of oil palm waste

<table>
<tr><td colspan="3">Based on a hectare of planted oil palm tree</td></tr>
<tr><td colspan="2">Felled palm trunk once in 30 years:
Dry wt (kg/hec) = 74.48</td><td>Palm fronds:
At felling, Dry wt (kg/hec) = 14.47</td></tr>
<tr><td colspan="3">Fresh fruit bunches (FFB): Annual production (ton/hec) = 20.08</td></tr>
<tr><td>Empty fruit bunches :
22.0% FFB (ton/hec)
= 4.42</td><td>Fibre:
13.5% FFB (ton/hec)
= 2.71</td><td>Shell:
6.0 % FFB (ton/hec)
= 1.20</td></tr>
<tr><td colspan="3">Effluent</td></tr>
<tr><td>Sterilise condensate:
12.0% FFB (ton/hec)=2.46</td><td>Centrifugal sludge:
50% FFB (ton/hec)=10</td><td>Hydrocyclone washing:
5.0% FFB (ton/hec)=1.10</td></tr>
</table>

1.2 WASTE UTILISATION FEASIBILITY

The use of solid waste in the construction industry has received increasing attention as one of the promising solutions to the solid-waste problem. The use of solid waste as an ingredient in concrete is not a new idea. Millions of tons of agricultural and industrial waste such as fly ash, blast furnace slag, palm-oil-fuel-ash, rice husk, and silica fume have been used in concrete (Swamy 1997; Chatveera et al. 1997).

The current trend in environmental control and waste disposal is focused towards effective utilisation of agricultural and industrial wastes by applying more legal and moral restrictions on waste disposal. As a result, attention has been paid to the utilisation of certain types of agricultural and industrial waste as construction materials. Since civil engineering projects are of large-scale and need a great deal of material, the major technical characteristics of waste materials must be primarily understood before incorporation and use (Nontananandh 1990).

The feasibility of waste utilisation depends on many factors, including the cost/benefit analysis etc. (economic, social and environmental cost). The economic gain is mainly due to the cost of waste, which is usually either less than that of the natural material or much less than the cost of production of a new material. Environmental benefits are that natural resources and energy can be conserved and that the quantum of discharged waste into the environment is reduced. Optimum economic benefit will be achieved when wastes produced meet the following criteria (Nontananandh 1990):

1. low unit cost but high quality which saves on total construction cost,
2. can be used without extensive cost incurred from additional processing,
3. available in large quantity, easy to handle and store, and
4. can be used with no degradability of the resultant material's properties or the environment.

Thus, there is a need for research into the utilisation of waste from agriculture and industry for developing new construction materials.