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PROPERTIES OF TIRE CRUMB AND OIL PALM FRUIT FIBRE IN LIGHTWEIGHT MORTAR

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Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chair: Farah Nora Aznieta Binti Abd.Aziz, PhD
Faculty: Engineering

This research work was carried out to investigate the influence of oil palm fruit fibre (OPFF) in tire crumb incorporated mortar. It was necessitated due the increase in the quest for lightweight aggregate concrete which has been growing in recent years as a result of the benefit of reduced density of the self-weight of structural components derived from it. This has led the search for more suitable lightweight aggregate material that could be more suitable in terms of strength and durability. Attempt to use recycled waste tire as aggregate in concrete and mortar has been encouraging due to its low density when compared with natural mineral aggregates concrete. However, employing waste tire aggregates has always resulted in reduced strength properties such as compressive, flexural and tensile strengths. Most attempts made so far to recover the losses in strengths of waste tire concretes and mortars has been made by the use of chemicals, compounds or other additives to either pre-treat the waste tire aggregate surfaces or added to the matrix which may have a long time effect on the concrete material. These will increase cost of the mortar or concrete due to the cost of the chemical usage. Hence this research aims to use OPFF obtained as a by-product of the factory production of palm oil crude at 0.5%, 1% and 1.5% by mass of cement content and tire crumb aggregate content of 0%, 10%, 20%, 30%, and 40% by volume of aggregate. Two types of tire crumb aggregates are included; untreated and treated using cement paste. The properties such as workability, density, absorption, compressive, split tensile, flexural strengths, shrinkage and microstructure were investigated. The result showed that for untreated tire crumb mortars, addition of OPFF at 0.5% by weight of cement improved these properties but with 1% and 1.5% OPFF, most of these properties reduce when compared to the control samples. On the other hand, these properties showed excellent performance in treated tire crumb mortars with an addition of 0.5 % - 1.5% OPFF. In conclusion, the addition of OPFF in treated tire crumb (0-40%) mortars performed excellently at all fibre content (0.5-1.5%) and in untreated tire crumb of 0.5% OPFF content. Density of the mortar was also found to be decreased with increase in rubber and the addition of fibre did not affect the density significantly. However addition of OPFF showed significant effect on the durability such as water absorption of mixes regardless of the replacement percentages of tire crumb but affected by either treated or untreated tire crumb, with the treated tire crumb showed better results. Therefore, OPFF could be used in the development of

structural lightweight mortar; however, more investigations are required to ascertain the durability performance of these composite mortar materials.

Abstrak tesis yang dikemukakan kepada SenatUniversiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Sarjana Sains

SIFAT-SIFAT REMAH TAYAR DAN GENTIAN BUAH KELAPA SAWIT DI DALAM MORTAR RINGAN

Oleh

SANI MOHAMMED BIDA

Juli, 2014

Pengerusi: Farah Nora Aznieta Abdul Aziz, PHD
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Penyelidikan ini telah dijalankan untuk menyiasat pengaruh serat kelapa sawit (OPFF) dan sisa tayar hancur di dalam mortar.Penyelidikan ini diperlukan seiring dengan peningkatan usaha bagi mencari konkrit aggregat ringan di mana ianya telah berkembang sejak kebelakangan ini berikutan dengan pengurangan berat komponen-komponen struktur yang terhasil daripadanya.Hal ini telah membawa kepada pencarian bahan yang lebih sesuai sebagai aggregat ringan dan mempunyai lebih kesesuaian dari segi kekuatan dan ketahanlasakan.Percubaan untuk menggunakan sisa tayar dikitar semula sebagai aggregat di dalam konkrit dan mortar telah digalakkan berikutan ketumpatannya yang rendah berbanding dengan konkrit beraggregat mineral semulajadi.Walau bagaimana, penggunaan aggregat sisa tayar sentiasa mengakibatkan pengurangan ciri-ciri kekuatan seperti kekuatan mampatan, lenturan dan tegangan. Pelbagai percubaan telah dibuat bagi mengatasi kehilangan kekuatan konkrit dan mortar sisa tayar seperti penggunaan bahan kimia, kompaun dan bahan tambah, sama ada bagi pra-rawat permukaan aggregat sisa tayar atau menambah kepada matriks yang mungkin mempunyai kesan jangka panjang ke atas bahan konkrit. Ini mengakibatkan kenaikan kos disebabkan kos bahan kimia yang digunakan. Oleh yang demikian, penyelidikan ini cuba untuk menggunakan serat semulajadi, OPFF yang didapati sebagai bahan sisa daripada penghasilan minyak mentah kelapa sawit di kilang pada 0.5%, 1% dan 1.5% daripada berat kandungan simen dan juga sebagai kandungan aggregat halus sisa tayar daripada isipadu aggregat sebanyak 0%, 10%, 20%, 30% dan 40%. Dua jenis aggregat sisa tayar telah digunakan; aggregat sisa tayar tidak dirawat dan aggregat sisa tayar dirawat dengan menggunakan simen lebihan. Ciri-ciri mortar seperti kebolehkerjaan, ketumpatan, penyerapan, mampatan, tegangan pisah, kekuatan lenturan, pengecutan, dan telah disiasat. Hasilnya menunjukkan bahawa bagi mortar tayar sisa tidak dirawat, penambahan OPFF pada 0.5 % mengikut berat simen bertambah baik sifat-sifat ini tetapi dengan 1%, dan 1.5% OPFF kebanyakan sifat-sifat ini berkurangan apabila dibandingkan dengan sampel kawalan. Sebaliknya, sifat-sifat ini menunjukkan prestasi yang sangat baik bagi mortar tayar sisa yang dirawat dan tambahan 0.5% - 1.5% OPFF. Kesimpulannya, didapati penambahan OPFF dalam mortar dengan sisa tayar terawat (0-40%) menunjukan keupayaan yang sangat baik bagi kandungan OPFF 0.5-1.5% dan bagi sisa tayar tak terawat, kandunngan OPFF optimum adalah 0.5%. Ketumpatan semua campuran mortar ini menurun dengan peningkatan kandungan sisa tayar dan kandungan OPFF tidak memberikan kesan yang jelas. Walau bagaimanapun penambahan OPFF menunjukkan kesan yang signifikan ke atas ketahanan campuran tanpa mengira peratusan penggantian tayar

sisa tetapi terjejas oleh jenis sisa tayar, sama ada dirawat atau tidak dirawat, dengan sisa tayar dirawat menunjukkan keputusan yang lebih baik Oleh yang demikian, OPFF boleh digunakan dalam pembangunan mortar struktur baur ringan, walaubagaimanapun kajian lebih mendalam perlu dijalankan bagi mempastikan keupayaan kebolehtahanan bahan composit mortar ini.

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I certify that a Thesis Examination Committee has met on 11th July, 2014 to conduct the final examination of SANI MOHAMMED BIDA on his thesis entitled "PROPERTIES OF TIRE CRUMB AND OIL PALM FRUIT FIBRE IN LIGHTWEIGHT MORTAR" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the (Masters of Science).

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DECLARATION

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I hereby confirm that:

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This is to confirm that:

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AEA	Air entraining agent
CMA	Coarse mineral aggregate
CRA	Coarse rubber aggregate
DHEC	Department of Health and Environment Control
EPS	Expanded polystyrene beads
FCRA	Fine and coarse rubber aggregates
FMA	Fine mineral aggregate
FRA	Fine rubber aggregate
HDPE	High density polyethylene
LWAC	Lightweight aggregate concrete
LWC	Lightweight concrete
MCE	Methocel Cellulose Ethers
NWA	Normal weight aggregate
OPFF	Oil palm fruit fibre
OPKS	Palm oil kernel shells
PCC	Portland cement concrete
SBR	Styrene-butadiene rubber
SCC	Self consolidated concrete
SEM	Scanning electron microscopy
SF	Silica fume
SLWC	Structural lightweight concrete
SP	Superplasticizer
TALC	Tire-added latex concrete
TRA	Tire rubber ash
F0	Mortars samples containing neither fibre nor waste tire
F0CR10	Mortars samples containing 10% waste tire
F0CR20	Mortars samples containing 20% waste tire
F0CR10	Mortars samples containing 30% waste tire
F0CR10	Mortars samples containing 40% waste tire
F5	Mortars samples containing 0.5% without fibre
F5CR10	Mortars samples containing 0.5% fibre and 10% waste tire
F5CR20	Mortars samples containing 0.5% fibre and 20% waste tire
F5CR30	Mortars samples containing 0.5% fibre and 30% waste tire
F5CR40	Mortars samples containing 0.5% fibre and 40% waste tire
F10	Mortars samples containing 1.0% fibre
F10CR10	Mortars samples containing 1.0% fibre and 10% waste tire
F10CR20	Mortars samples containing 1.0% fibre and 20% waste tire
F10CR30	Mortars samples containing 1.0% fibre and 30% waste tire
F10CR40	Mortars samples containing 1.0% fibre and 40% waste tire
F15	Mortars samples containing 1.5% fibre
F10CR10	Mortars samples containing 1.5% fibre and 10% waste tire
F10CR20	Mortars samples containing 1.5% fibre and 20% waste tire
F10CR30	Mortars samples containing 1.5% fibre and 30% waste tire
F10CR40	Mortars samples containing 1.5% fibre and 40% waste tire

CHAPTER 1

INTRODUCTION

1.1 Background

The need to meet up with increasing economic and social challenges and the general increase in global population has led to the increasing number of vehicular traffic today. These vehicles use tires which expire within 3-4 years and are then disposed-off as waste tires. The accumulation of waste tires on dumping sites and in some countries all around continuously accumulate as it is non-bio-degradable and continuously occupied available landfills. The US Environmental Protection Agency estimated that about 3 billion waste tires were dumped in stock piles and a lot more are scattered all around in gullies, forest and empty lots in America with about 242 Million generated annually and about 77% of this yearly accumulation end up illegally dumped, landfilled and stockpiled (Li et al., 2004). In Malaysia alone, the number of vehicle waste tires generated annually amounted to about 8.2 million and about 60% of this material is being disposed-off indiscriminately without definite route (Thiruvangodan, 2006). In the UK, it is estimated that about 40 million waste tires is generated per year, that is, more than 100,000 tires per day have been ending up as waste and it is expected to grow further by 63% by the year 2021 due to the expected increase in road traffic (Kew et al., 2004).

Waste tires disposal raises serious health concern to the environment and municipal authorities since it contains large void which serves as a breading space for mosquitoes, mice and other insects (Li et al., 2004; Rangaraju & Gadkar, 2012; Mohammed, et al., 2012). It also posed a serious fire treat and pollution to the environment as it is highly inflammable and once ignited can continuously burn for as long as possible (Naik & Singh, 1991; Mavroulidou & Figueiredo, 2010) exposing environment to a number of harmful chemicals both in air and water. In 1993, United States Environmental Protection Agency reported that fire took hold of 7 million tire dump in Virginia and continuously burn for about 9 months causing serious environmental pollution (Garrick, 2001). In Wales, where the largest landfill in Britain for waste tires was situated, an intense fire broke out in the middle of the tire dump and continuously burn for 11 years (Mavroulidou & Figueiredo, 2010).

The growing challenges of managing disposal of waste tires have led to the ban of disposal of this material on landfills by many authorities. In 1998, 48 states in the United State of America had appropriated tire crumb laws, regulations in which 34 states provide market encouragements to control waste tires, 35 states banned waste tires landfilling in whole, and 8 states banned waste tire landfilling in whole or shredded. Only 6 states did not restrict waste tire disposal. The EU in 2003 issue directive (Council Directive 1999/31/EC) putting ban on land filling by waste tire in whole or shredded form (Mavroulidou & Figueiredo, 2010; Sgobba et al., 2010; Richardson et al., 2012). This has necessitated quest for alternative solution for the re-use of waste tires by many institutions and researchers. The state of South Carolina Department of Health and Environment Control (DHEC) initiated a Tire Fund to support research designed to encourage waste tire re-use most especially in

civil engineering applications as part of effort to reduce landfilling by waste tire (Pierce & Blackwell, 2003).
Different alternative methods have been exploited for the disposal of waste tires which include but not limited to: recycling for the production of other rubber materials; used as fuel for incineration and in kiln; ground rubber application in play grounds; used in asphalt rubber modified concrete and recently in civil engineering as composite material in the form of tire ash, tire crumb, and tire chips fine aggregate and coarse aggregates and in cement as additive (Li et al., 1998; Siddique & Naik, 2004; Rangaraju & Gadkar, 2012).

Waste tire material has been experimented in various forms as a composite material in concrete production. The incorporation of tire material in concrete always result in improved properties of concrete, although, with reduced compressive and some other strength properties. Therefore, various proportions of rubber, admixtures, mix ratios, water content and accelerators has been used to improve the strength and more research works are required to achieve excellent performance (Khaloo et al., 2008; Ganjian et al., 2009; Mohammed etal., 2012; Issa & Salem, 2013; Liu et al., 2013).

Oil palm fruit fibre is a natural fibre produced during the extraction process of palm oil crude from oil palm fruit bunch after boiling and removal of the palm kernel seeds from the fruit bunch. Okpala (1990) and Okafo (1988) described oil palm fibre as a waste product derived by removing oil from oil palm fruit. Oil palm tree is similar to coconut palm tree, hence shares many features with it and is scientifically refers to as Elaeisguineensis which is found mainly in East Africa (Pantazi and Ahmad, 2001; Ismail and Hashim, 2008). In the early years, oil palm tree was found in the East Africa most especially during the era of Pharaohs about 5000 years ago but recently, its cultivation in the South East Asia has become pronounced most especially in countries like Malaysia and Indonesia (Abdullah, 1984). Olanipekun et al. (2006) reveals that oil palm trees are found in large volume in Asia, America and Africa, most especially in Nigeria.

Malaysia and Indonesia are the world largest producers of oil palm crude, their production account for about 80% of the total palm oil of the world. Malaysia is the second largest producer of palm oil in the world producing about 18.5 million tons annually with about 3.87 million ha of land being used in the plantation of oil palm (Mundi.com). Malaysian Government has targeted an area expansion for higher yield of palm oil plantation by 2020 to cover about 4.6 million hectares (Ismail and Hashim, 2008). The increase in the production of oil palm by the day has serious impact on the environment which entails increase in the production of waste oil palm kernel shell and fibre material to be disposed-off.

In 2007, Malaysian Government lunched Ninth Malaysian Plan (RMK-9) and one of the main agenda is to begin to export this agricultural waste material. Therefore, there should be an effort to fully utilize the oil palm waste such as its leaves, trunks and fruit bunches significantly to the other industry (mundi.com). This would change the global perspective of seeing oil palm fruit fibre (OPFF) as waste material and garbage to economically viable resources and alternative solutions such as usage in construction industry would be a way out.

Natural fibres are mostly agricultural by-products regarded as wastes and are in most cases obtained at no cost from farm houses and factories. Some natural fibres available are Oil Palm Fruit fibre (OPFF), Oil palm Trunk fibre, Coconut fibre, Bamboo etc. OPFF is the most readily available of all these fibres which is the more reason why more research efforts should be carried out on it for greater benefits.

1.2 Problem Statement

The quest for lightweight concrete has been on the increase thus, leading to discovery of more lightweight aggregate materials such as waste tire crumb aggregate. These aggregates has shown good potentiality when use in concrete due to its low density which result in reduced self-weight.

Rossignolo & Agnesini (2004) also reported that the structural efficacy of LWAC is more imperative than considering only it strength. This is because; reduced density for the same strength level lowers the self-weight, foundation size and overall construction costs. However, significant losses are experience in mechanical properties such as compressive, flexural and split tensile strength when waste tire crumb is incorporated in concrete. Most efforts carried out so far to revamp the losses involved the use of chemicals and compounds to pre-treat the rubber aggregate or are used as an additive in the matrix which is expensive. Therefore, more researches are required to establish alternative ways of improving some of the mechanical properties aforementioned at reasonable cost.

Natural fibre such as palm oil fruit fibre is the most dominant waste material in Malaysia which is obtained as agricultural waste product and it utilization has not received any significant attention despite it numerous benefits. Study by Abdullahi et al. (2011) on fibre length, fibre pre-treatment and mix ratio has shown that significant improvement could be made in the physical, mechanical and thermal properties of concrete when fibre is employed in concrete. The concerns with the brittleness of concrete are alleviated to a large extent by reinforcing it with fibres of various materials and could be effective in arresting cracks at all levels which provides mechanism that reduces the effect of crack initiation by bridging and improving ductility (Banthia and Sappakittipakorn, 2007).

Based on advantages of waste tires in producing a lightweight mortar and concrete and its disadvantages in strength reduction, also, benefit of fibre in improving the properties of concrete was carried out in this work with the aim of producing a lightweight mortar using waste tire and oil palm fruit fibre. Success of this research may provide an alternative green material in the construction industry apart from reducing waste tire and agricultural waste material that are abundant.

1.3 Objectives

In order to achieve the aim of this research, the following objectives are outline:

1. To determine the effect of different tire crumb and oil palm fruit fibre content on the properties of mortar with a target compressive strength of 17 MPa.

2. To determine the workability, density, compressive, split tensile, flexural strengths, water absorption and the shrinkage behaviour of lightweight mortar using tire crumb and oil palm fruit fibre samples produced and compares its performance.

3. To examine the microstructure of the lightweight mortar produced from cement treated and untreated tire crumb and oil palm fruit fibre.

1.4 Scope and Limitation

This research is limited to laboratory investigation to determine the mechanical properties of the mortar samples produced by following the standard method of practices in civil engineering laboratory practice using tire crumb as partial replacement of aggregate and oil palm fruit fibre (OPFF) as addition by mass of the cement content. The properties determine include workability, density, water absorption, compressive, flexural, split tensile strengths, shrinkage and micro-structure. The fibre content of 0.5%, 1% and 1.5% by mass of cement and tire crumb content of 0, 10%, 20%, 30% and 40% by volume of aggregate are used in this work.

1.5 Layout of Thesis

This section presents the layout of thesis and the content of each chapter.

Chapter one presents the background to the need for the reuse of tire crumb in this research and also the aim and objective of the study. Problem statement, scope and limitation of the research work are also presented.

Chapter two presents the literature review on some aspects concerning lightweight aggregate concrete and various lightweight aggregate (LWA) materials used in various research works and detail researches conducted on lightweight concrete material using tire crumb.

Chapter three: present the research methodology employed in this experiments. The procedure employed, materials used, improvement technique used on the crumble tire, fibre and the method used in determining the properties of the samples produced during the experiment.

Chapter four describes in details result obtained from the experiments carried out on the material and the mechanical properties; compressive strength test, flexural test, split tensile, workability, and the micro-structure of the hardened mortar samples.

Chapter five presents the conclusions and recommendations based on the data obtained and the result of the analysis carried out for further investigation or action.

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