PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING FLY ASH AS PARTIAL SAND REPLACEMENT

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING FLY ASH AS PARTIAL SAND REPLACEMENT

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LIST OF SYMBOLS

kg/m^3	Kilogram per cubic metre
mm	Millimetre
MPa	Megapascal
%	Percent
&	And
µm	Micrometer
°C	Degree Celcius
f_c	Compressive Strength
P	Maximum load applied to the specimen
N	Newton
A_c	Cross-sectional area of the specimen
mm^2	Square millimetre
s	Second
f_{cf}	Breaking load
Ø	Diameter
N/mm^2	Newton per square millimetre
σ_a	Upper loading stress
σ_b	Basic stress
ϵ_a	Mean strain under the upper loading stress
ϵ_b	Mean strain under basic stress
σ_m	Average compressive strength of concrete cured in water
σ_s	Average compressive strength of concrete cured in Na_2SO_4
E_c	Elasticity in compression
m_1	Mass of specimens before immersion
m_2	Mass of specimens after immersion
±	Plus-minus
T	Splitting tensile strength
d	Diameter
l	Length
kg	Kilogram
W/mK	Watts per meter-Kelvin

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
Al	Aluminium
Al_2O_3	Aluminium oxide
ASTM	American Society for Testing and Materials
BET	Brunauer, Emmett and Teller
BS	British Standard
BS EN	British Standard European Norm
Ca	Calcium
$CaCO_3$	Calcium carbonate
CaO	Calcium oxide
$Ca(OH)_2$	Calcium hydroxide
CIDB	Construction Industry Development Board
CO_2	Carbon dioxide
C-S-H	Calcium silicate hydrate
CSR	Compressive strength reduction
CuO	Copper
C_3A	Tricalcium aluminate
DDIs	Domestic direct investments
EE	Energy efficiency
EFP	Empty fruit bunch
FA	Fly ash
FDIs	Foreign direct investments
Fe	Iron
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
FESEM	Field Emission Scanning Electron Microscope
Fe_2O_3	Iron oxide
FM	Fineness modulus
GBI	Green Building Index
GDP	Gross domestic product
GTFS	Green Technology Financing Scheme

H_2O	Water
IOI	Industrial Oxygen Incorporated
K	Potassium
KeTTHA	Kementerian Tenaga Teknologi Hijau Dan Air
K_2O	Potassium oxide
LOI	Loss of ignition
LWA	Lightweight aggregate
LWAC	Lightweight aggregate concrete
LWC	Lightweight concrete
MgO	Magnesium oxide
MnO	Manganese
MPOB	Malaysian Palm Oil Board
MS	Malaysian Standard
Na	Sodium
NRMCA	National Ready Mix Concrete Association
OPC	Ordinary Portland Cement
OPS	Oil palm shell
PAIP	Pengurusan Air Pahang Berhad
PKC	Palm kernel cake
POC	Palm oil clinker
POFA	Palm oil fuel ash
POME	Palm oil mill effluent
PV	Solar photovoltaic
RE	Renewable energy
RILEM	International Union of Laboratories and Experts in Construction Materials, Systems, and Structures
RM	Ringgit Malaysia
Sdn Bhd	Sendirian Berhad
SEM	Scanning Electron Microscopy
Si	Silicon
SiO_2	Silicon dioxide
SMEs	Small and medium enterprises
SMIs	Small- and medium-sized industries

SO_3	Sulphur trioxide
SP	Superplasticizer
SSD	Saturated surface dry
Ti	Titanium
UK	United Kingdom
UNEP	United Nations Environment Programme
w/c	Water to cement ratio

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ABSTRAK

Industri minyak kelapa sawit yang berkembang telah meningkatkan bahan buangan kelapa sawit yang dikenali sebagai tempurung kelapa sawit (OPS) dan lebih daripada 4 juta tan dibuang di tapak pelupusan setiap tahun. Pada masa yang sama, kira-kira 350 juta tan abu terbang (FA) yang merupakan bahan buangan loji arang batu dihasilkan setiap tahun. Disebabkan pengeluaran sisa yang besar, ia memberi kesan yang buruk kepada persekitaran. Pada masa yang sama, kemajuan industri pembinaan telah meningkatan aktiviti perlombongan pasir sungai. Perlombongan yang tidak terkawal menimbulkan kesan buruk terhadap alam sekitar seperti pendalaman sungai dan hakisan tebing sungai. Keperluan bahan pembinaan dan isu masalah alam sekitar yang semakin meningkat disebabkan bahan buangan industri minyak sawit telah mencetuskan penyelidikan ke arah menghasilkan teknologi baru hijau seperti konkrit ringan. Kajian sebelum ini pernah mengintegrasikan OPS bersama abu terbang kelapa sawit (POFA) serta abu terbang (FA) sebagai bahan gentian separa simen. Walaubagaimanapun, penggantian abu terbang (FA) sebagai pengganti pasir dalam penghasilan konkrit agregat ringan tempurung kelapa sawit (OPS LWAC) separa masih belum dikaji. Justeru, penyelidikan ini memberi tumpuan kepada penggunaan FA sebagai bahan pengganti pasir sungai dalam penghasilan OPS LWAC. Abu terbang (FA) digunakan sebagai pengganti pasir separa dalam pengeluaran konkrit agregat ringan (LWAC) bagi mengurangkan penggunaan pasir dalam pembinaan, mengurangkan pencemaran dan jumlah sisa yang dilupuskan. Sementara itu, penggunaan OPS dalam konkrit agregat ringan (LWAC) sebagai pengganti agregat kasar akan membantu mengekalkan sumber semula jadi seperti granit dan batu kapur. OPS LWAC dengan 100% pasir sungai digunakan sebagai spesimen kawalan. Kemudian, satu siri campuran OPS LWAC yang dicampur dengan FA dengan peratusan seperti 10%, 20%, 30% dan 40% telah disediakan. OPS pula digunakan sebagai agregat kasar yang menggantikan 100% batu granit. Campuran terbaik telah dipilih dan digunakan untuk menyiasat sifat mekanik dan ketahanlasakan OPS LWAC. Kesan pengawetan iaitu pengawetan air, udara dan pengawetan air awal terhadap sifat mekanik OPS LWAC yang mengandungi FA turut dikaji. Selain itu, ujian lain yang dijalankan ialah rintangan sulfat, penyerapan air dan karbonasi. Semua spesimen diuji sehingga 9 bulan. OPS LWAC yang mengandungi 10% FA menunjukkan prestasi terbaik antara semua peratusan dari segi mekanikal dan ketahanlasakan. Penggunaan abu terbang (FA) yang sesuai meningkatkan jumlah C-S-H yang terhasil daripada proses penghidratan dan pozzolanik dan mengisi kekosongan struktur dalaman konkrit menjadikannya padat dan kuat. Penggantian 40% FA memberi kesan terburuk kepada OPS LWAC dari segi sifat mekanikal dan ketahanan. Penemuan menunjukkan bahawa pengawetan air adalah kaedah pengawetan yang terbaik untuk memastikan prestasi yang lebih baik terhadap kekuatan mampatan, lenturan, keanjalan dan kekuatan tegangan OPS LWAC yang mengandungi FA diikuti dengan pengawetan air awal dan pengawetan udara. Juga, OPS LWAC dengan 10% FA mempamerkan ketahanan yang lebih tinggi berbanding spesimen kawalan serta lain-lain campuran apabila diserang sullfat. OPS LWAC dengan 10% FA mempunyai prestasi rintangan yang lebih baik dalam sulfat kerana tindak balas pozzolanik yang mengurangkan kuantiti kalsium hidroksida yang mudah diserang oleh persekitaran yang agresif. Tiada karbonasi dikesan pada spesimen yang diawet menggunakan air serta pengawetan air awal kecuali specimen yang diawet dalam udara persekitaran. Pengawetan air menggalakkan proses penghidratan dan reaksi pozzolanik yang meningkatkan struktur dalaman OPS LWAC dengan FA menyebabkan ia mempamerkan kadar penyerapan yang lebih rendah berbanding kaedah pengawetan yang lain.

ABSTRACT

The steady growth of the palm oil industry has led to the generation of the palm oil mill by-product known as oil palm shell (OPS) amounting more than 4 million tonnes annually which are dumped in the landfill. At the same time, the annual world production of fly ash (FA) which is a by-product of coal-fired electric power plants is approximately 350 million tonnes. Due to large production, these waste are also dumped that in turn, significantly affects the surrounding environment. On the other hand, the growing construction industry has led towards the increase in river sand mining activities. However, unregulated mining by the authorities may pose adverse impact towards the environment as it lowers the stream bottom, which in turn may lead to bank erosion. The growing demand for construction material and environmental issues created from the by-products of palm oil industry as well as coal industry have initiated research towards producing a new lightweight concrete. OPS has been previously utilized with POFA and FA as partial cement replacement. However, it is non-trivial to mention that study on the integration of fly ash (FA) as sand replacement in OPS LWAC has yet been reported. Thus, this research focuses on investigating the properties of Oil Palm Shell Lightweight Aggregate Concrete (OPS LWAC) containing various percentage of FA as partial sand replacement. Fly Ash (FA) is utilized as partial sand replacement in the production of Lightweight Aggregate Concrete (LWAC) in order to reduce sand usage in construction, reduce pollutions as well as the amount of waste disposed. Meanwhile, the use of OPS in lightweight aggregate concrete (LWAC) as a coarse aggregate replacement will help to preserve natural resources such as granite and limestone. The plain OPS LWAC content with 100% sand was used as a control mix. Then, a series of OPS LWAC mixes with FA of various percentages such as 10%, 20%, 30% and 40% were prepared. The OPS was utilized as coarse aggregate with 100% replacement throughout the research. The best mix acquired from the trial mixes were used to investigate the mechanical and durability properties of OPS LWAC. The effect of curing namely water curing, air curing and initial water curing regimes on mechanical properties aspect of OPS LWAC containing FA has been determined. Furthermore, other durability properties tests have been carried out namely sulphate resistance test, water absorption and carbonation. All specimens were tested until 9 months. OPS LWAC containing 10% FA performs the best amongst all percentages in terms of mechanical and durability properties. The inclusion of a suitable amount of fly ash produces larger amount of C-S-H gel from both hydration and pozzolanic reaction which fills in the void of concrete internal structure making the concrete denser and stronger. It was demonstrated that 40% of FA replacement provided the worse effect to the OPS LWAC in term of mechanical and durability properties. The findings show that water curing is the best curing method to ensure better performance on compressive strength, flexural strength, modulus of elasticity and splitting tensile strength of OPS LWAC containing FA followed by initial water curing and air curing. Also, OPS LWAC with 10% FA exhibit higher durability compared to control specimens and others mixes when subjected to sulphate attack. OPS LWAC with 10% FA has better performance in sulphate solutions since the pozzolanic reactions reduce the quantity of calcium hydroxide which is vulnerable towards aggressive environment. No carbonation rate was detected for specimens subjected to water curing and initial water curing except for air curing. Water curing promotes better hydration process and pozzolanic reaction that improves the internal structure of OPS LWAC containing FA causing it to exhibit lower absorption value compared to other curing methods.

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