PROPERTIES OF HIGH STRENGTH PALM OIL CLINKER LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING PALM OIL FUEL ASH AS PARTIAL CEMENT REPLACEMENT WITH INCLUSION OF 1% SIKA VISCO-CRETE®-2199

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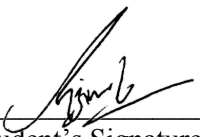

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ABSTRAK

Di Malaysia, banyak sisa kilang minyak kelapa sawit seperti batu baur ringan kelapa sawit (POC) dan abu terbang kelapa sawit (POFA) terus dijana atas permintaan minyak sawit yang tinggi. Kedua-dua jenis sisa ini pada kebiasaanya dibuang di tapak pelupusan berdekatan dan menyebabkan pencemaran alam sekitar. Penggunaan abu terbang kelapa diperhatikan masih belum diterokai dalam pembuatan konkrit berkekuatan tinggi batu baur ringan batu kelapa sawit. Oleh itu, penggunaan kedua-dua jenis bahan buangan kelapa sawit ini dalam pembuatan konkrit berkekuatan tinggi akan dapat mengurangkan sebahagian besar jumlah sisa pepejal yang dibuang di tapak pelupusan. Selain itu, penggunaan POC sebagai batu baur kasar dalam konkrit berkekuatan tinggi dapat membantu dalam usaha mengekalkan sumber semula jadi seperti granit dan batu kapur bagi generasi akan datang. Justeru, penyelidikan ini dijalankan bagi mengkaji prestasi konkrit berkekuatan tinggi batu baur ringan batu kelapa sawit yang mengandungi abu terbang sawit sebagai pengganti simen separa dengan 1% SIKA Visco-Crete®-2199 dari segi sifat mekanikal, ketahanlasakan dan ketahanan terhadap suhu tinggi. Campuran percubaan telah dijalankan untuk memilih campuran konkrit berkekuatan tinggi terbaik dengan mengambil kira ketumpatan, kebolehkerjaan dan kekuatan konkrit berkekuatan tinggi. Setelah campuran terbaik ditentukan, lima jenis campuran konkrit berkekuatan tinggi POC Gred 60 disediakan yang terdiri daripada 0%, 10%, 20%, 30% dan 40% POFA sebagai pengganti separa simen dengan 1% SIKA Visco-Crete®-2199. Dalam kajian ini, konkrit berkekuatan tinggi POC dengan 100% simen dan 1% SIKA Visco-Crete®-2199 bertindak sebagai spesimen kawalan dan 3500 spesimen yang terdiri daripada kiub, prisma dan silinder disediakan dan diuji sepanjang kajian ini. Pada peringkat pertama penyelidikan ini, kesan kandungan POFA sebagai pengganti simen separa terhadap kekuatan mampatan konkrit berkekuatan tinggi POC dengan 1% SIKA Visco-Crete®-2199 telah dikaji. Kemudian, kesan kaedah pengawetan terhadap sifat mekanikal, ketahanlasakan dan ketahanan terhadap suhu tinggi disiasat. Empat jenis kaedah pengawetan iaitu pengawetan air, pengawetan udara, pengawetan awal air dan pengawetan plastik digunakan untuk menilai sifat mekanikal konkrit berkekuatan tinggi POC yang mengandungi POFA sebagai pengganti separa simen serta 1% SIKA Visco-Crete®-2199 dari segi kekuatan mampatan, kekuatan lenturan, kekuatan regangan dan kekuatan anjalan. Keempat-empat kaedah pengawetan ini juga digunakan untuk menentukan kesannya terhadap sifat ketahanlasakan iaitu serangan asid, rintangan sulfat, pengkarbonan dan penyerapan air. Selain itu, ujian ketahanan api dijalankan dan disejukkan dengan kaedah dibiarkan terdedah di udara persekitaran. Hasilnya, penggantian 10% POFA menunjukkan prestasi yang lebih baik daripada penggantian POFA yang lain apabila diawet menggunakan semua jenis pengawetan. Penemuan ini juga menunjukkan bahawa pengawetan air adalah kaedah pengawetan terbaik apabila diuji menggunakan ujian mekanikal dan ketahanlasakan. Sebaliknya, pengawetan udara adalah tidak sesuai kerana ia merencatkan tindakbalas kimia yang diperlukan bagi penghasilan kalsium silikat hidrat justeru menyebabkan pencapaian kekuatan yang rendah. Pengawetan air menggalakkan proses penghidratan serta reaksi pozzolana disamping meningkatkan struktur dalaman konkrit berkekuatan tinggi POC yang mengandungi POFA dan 1% SIKA Visco-Crete®-2199 justeru menyebabkan kadar penyerapan yang lebih rendah berbanding dengan spesimen yang diawet menggunakan kaedah lain. Konkrit berkekuatan tinggi yang mengandungi 10% POFA menunjukkan ketahanan yang lebih tinggi terhadap suhu tinggi.

ABSTRACT

In Malaysia, the abundance of palm oil wastes namely palm oil clinker (POC) and palm oil fuel ash (POFA) continuously increasing due to high palm oil demand. These two types of waste are usually dumped at the nearby landfill which causes environmental problems. It is observed that the utilization of palm oil fuel ash in palm oil clinker lightweight aggregate concrete has yet to be explored. Thus, it is seen that the use of these two types of palm oil waste materials in high strength concrete production would reduce some of the total amount of waste disposed at landfill. Furthermore, POC used as coarse aggregate in high strength concrete would preserve natural resources such as granite and limestone for future generation. Thus, this research was conducted to investigate the mechanical, durability and elevated temperature performances of high strength palm oil clinker lightweight aggregate concrete containing palm oil fuel ash as partial cement replacement with 1% SIKA Visco-Crete®-2199. Trial mixes were conducted to select the best high strength concrete mix by taking into account the density, workability and strength. After the best mixes was determined, five types of POC mixes of Grade 60 were prepared consisting of 0%, 10%, 20%, 30% and 40% POFA as partial cement replacement with 1% SIKA Visco-Crete®-2199. In this research, high strength POC lightweight aggregate concrete with 100% OPC and incorporation of 1% SIKA Visco-Crete®-2199 (OPC LWAC) act as control specimen and 3500 specimens comprising of cubes, prisms and cylinders were prepared and tested throughout this experimental study. At the first stage, the effect of POFA content as partial cement replacement towards compressive strength of high strength POC lightweight aggregate concrete with 1% SIKA Visco-Crete®-2199 were investigated. Then, the effect of curing methods towards mechanical, durability and elevated temperature were investigated. Four types of curing methods namely water curing, air curing, initial water curing and plastic curing were used to examine the mechanical properties of POC LWAC containing POFA as partial cement replacement with 1% SIKA Visco-Crete®-2199 in terms of compressive strength, flexural strength, splitting tensile strength and modulus of elasticity. These four curing regimes were also used to determine their affect towards durability aspects namely acid attack, sulphate resistance, carbonation and water absorption. Apart from that, elevated temperature test was conducted and the specimens were cooled using air cooling. From the results, they show that 10% POFA replacement resulted in better performance than other POFA replacements when subjected to all types of curing. The findings also show that water curing is the best curing method for mechanical and durability testing. On the other hand, air curing is not suitable as it disturbs the reactions needed for production of calcium silicate hydrate gel causing lower amount of the gel and strength. Water curing promotes better hydration process and pozzolanic reaction that improves the internal structure of POC LWAC containing POFA with 1% SIKA Visco-Crete®-2199 causing it to exhibit lower absorption rate as compared to other curing. High strength concrete specimens containing 10% POFA also exhibit better resistance upon subjected to elevated temperature.

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LIST OF SYMBOLS

A_c	Cross sectional area of the specimen
Al_2O_3	Aluminium oxide
C	Carbon
$CaCl_2$	Calcium chloride
$CaCO_3$	Calcium carbonate
CaO	Calcium oxide
$Ca(OH)_2$	Calcium hydroxide
CO_2	Carbon dioxide
C-S-H	Calcium silicate hydrate
C_3A	Tricalcium aluminate
C_3S	Tricalcium silicate
d	Diameter
d_1	The lateral dimensions of the cross sections
d_2	The lateral dimensions of the cross sections
E_c	Modulus of elasticity in compression
f_c	Compressive strength
f_{ca}	Average compressive strength of cubes immersed in acid solutions
f_{cf}	Flexural strength
f_{cw}	Average strength of concrete cubes cured in water
f_e	average compressive strength of concrete cubes cured in Na_2SO_4
F_{cf}	The breaking load
f_c	Compressive strength
f_{cw}	Average strength of concrete cubes cured in water
Fe_2O_3	Ferric oxide
GPa	Gigapascal
h	Hour
HCl	Hydrochloric acid
H_2SO_4	Sodium sulphate
kg	Kilogram

kg/m^3	Kilogram per cubic metre
kN/s	Kilo nodes per second
K_2O	Pottasium oxide
l	Length
MgO	Magnesium oxide
Mi	Initial weight before exposure to sulfuric acid
mins	Minutes
MLt	Cumulative weight reduction
mm	Milimetre
mm^2	Square milimeters
MnO	Manganese oxide
MPa	Megapascal
M_o	Mass of oven-dried specimen in air, g
M_d	Mass of surface-dry specimen in air after immersion and boiling, g
M_a	Apparent mass of specimen in water after immersion and boiling, g
Mt	Weight at time
m_1	Mass of specimens before immersion
m_2	Mass of specimens after immersion
m_1	Mass of specimens before heated
m_2	Mass of specimens after heated
m^2/g	Square meters per gram
m^2/kg	Square meters per kilogram
N	Newton
N/mm^2	Newton/square millimetre
Na_2O	Sodium oxide
Na_2SO_4	Sodium sulphate
P	Maximum load applied to the specimen
pH	Potential of hydrogen
P_2O_5	Phosphorus pentoxide
R_c	Compressive strength reduction
RM	Ringgit Malaysia

SiO_2	Silicon dioxide
SO_3	Sulphur trioxide
Sp	Superplasticizer
T	Splitting tensile strength
t	Time
TiO_2	Titanium oxide
w/c	Water-cement ratio
σ_a	Upper loading stress
σ_b	Basic stress
ϵ_a	Mean strain under the upper loading stress
ϵ_b	Mean strain under the basic stress
σ_m	Average compressive strength of concrete cubes cured in water
σ_s	Average compressive strength of concrete cubes cured in Na_2SO_4
°C	Degree Celcius
µm	Micrometre
π	pi
Ø	Diameter
%	Percent
&	And

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ACV	Aggregate crushing value
AIV	Aggregate impact value
ASTM	American Society for Testing and Materials
BET	Brunauer-Emmett-Teller
BS	British Standard
BS EN	British Standard European Norm
CPO	Crude palm oil
DOI	Digital Object Identifier
EFB	Empty fruit bunches
FELDA	Federal Land Development Authority
GDP	Gross domestic product
HSLWC	High strength lightweight concrete
HSLWAC	High strength lightweight aggregate concrete
i.e.	id est
ITZ	Interfacial transition zone
LOI	Loss of ignition
LWA	Lightweight aggregate
LWAC	Lightweight aggregate concrete
LWC	Lightweight concrete
MS EN	Malaysian Standard European Norm
OPC	Ordinary Portland cement
OPS	Oil palm shell
OPT	Oil palm trunks
PFA	Pulverized fuel ash
POC	Palm oil clinker
POFA	Palm oil fuel ash
POME	Palm oil mill effluent
SEM	Scanning Electron Microscope
SF	Silica fume
SSD	Saturated surface dry

XRD	X-ray diffraction
XRF	X-ray fluorescence
YTL	Yeoh Tiong Lay

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