STUDY ON MECHANICAL AND THERMAL BEHAVIOR OF THE LIGHTWEIGHT AGGREGATE GEOPOLYMER CONCRETE (LWAGC) USING FLY ASH

By

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بسم الله الرحمن الرحيم

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LIST OF ABBREVIATIONS

OPC	Ordinary Portland Cement
LWC	Lightweight Concrete
LWA	Lightweight Aggregate
LWAGC	Lightweight Aggregate Geopolymer Concrete
LWAC	Lightweight Aggregate Concrete
GHS	Green House Gasses
FA	Fly Ash
GGBS	ground granulated blast-furnace slag
AA	Alkali-Activated
MK	Metakaolinite
NWC	Normal Weight Concrete
LECA	Lightweight Expanded Clay Aggregate
ACI	American Concrete Institute
HWC	Heavy Weight Concrete
ASTM	American Standard of Testing Materials
LOI	Loss On Ignition
ACAA	American Coal Ash Association
SMA	Stone Mastic Asphalts
XRD	X-ray Diffraction
Class F	Low-calcium Fly ash
Class C	High-calcium Fly ash
RT	Room Temperature
SEM	Scanning Electron Microscopy
TGA	Thermogravimetric Analysis
AFLA	Alkali-activated FA Artificial LWA
EPS	Expanded Polystyrene Beads
OD	Oven- Dry
BFS	Blast Furnace Slag
HPA	High Performance Ash
RHBA	Rice Husk-Bark Ash

POC	Palm Oil Clinker
XRF	X-ray Fluorescence
SSD	Saturation Surface Dry
FM	Fineness Modulus
AD	Air-Dry Condition
BS	British Standard
UTM	Universal Testing Machine
EN	European Standard
EDS	Energy Dispersive Spectrometry
BSE	Backscattered Electron
DTG	Thermogravimetric Analysis
DTA	Differential Thermal Analysis
IMR	Individual Mass Retained
CPR	Cumulative Percent Retained
CPP	Calculated Percent Passing
ITZ	Interface Transition Zone
CTE	Coefficient of Thermal Expansion
PS	Poly-sialate
PSS	Poly-sialate siloxo
PSDS	Poly-sialate-disiloxo

LIST OF SYMBOLS

Si	Silicon
Fe	Iron
Ti	Titanium
Al	Aluminum
O	Oxygen
Na	Sodium
K	Potassium
Ca	Calcium
Mg	Magnesium
M^+	Alkali Ion
CO_2	Carbon Dioxide
CaO	Calcium Oxide
H_2O	Water
Na_2O	Sodium Oxide
Al_2O_3	Aluminum Oxide
SiO_2	Silicon Dioxide
Fe_2O_3	Iron Oxide
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
%	Weight Percent
m	Meter
M	Molar
MPa	Mega Pascal
θ	Theta
cP	Centipoise
g	Gram
°C	Degree Celsius
mm	Millimeter
KN	Kilo Newton

kV	Kilo Volt
Å	Angstrom
Mam	Milliampere
μm	Micrometer
kg/m^3	Kilogram Per Cubic Meter
Psi	Pascal
Ib	Pound
ft	Foot
yd	Yard
W_s	SSD Weight
W_d	OD Weight
W_i	Immersed Weight
Wssw	Weight of Saturated Specimen in Water
ε	Thermal Strain
α	Coefficient of Thermal Expansion
Δl	Length Change
$l_\circ$	Initial Length of the Specimens
ΔT	Temperature Difference
Q	Quartz
M	Mullite
H	Hematite
$Ca(OH)_2$	Calcium Hydroxide
C-S-H	Calcium Silicate Hydrate
Ma	Magnetite
W	Wollatonite
A	Aegirine
C	Calcium Iron Silicate
He	Hercynite

T	Tridymite
#	Sodium Silicate
N	Nepheline
S	Sodium Aluminum Silicate
f_c	Residual Compressive Strength
t	Exposure Temperature
$f'c$	Compressive Strength

Kajian Kelakuan Mekanikal dan Terma Konkrit Geopolimer Agregat Ringan (LWAGC) Menggunakan Abu Terbang

ABSTRAK

Geopolimer adalah sebahagian daripada sains polimer, kimia dan teknologi yang membentuk salah satu bidang utama sains bahan dalam menghasilkan bahan baru hijau yang boleh dijadikan alternatif bahan simen kepada Portland simen biasa (OPC) kerana sifatnya yang mesra alam. Kajian tentang struktur konkrit agregat ringan telah ditemui di dalam kajian sedia ada. Tesis ini membentangkan prosedur proses sintesis daripada konkrit geopolimer agregat Ringan (LWAGC) berdasarkan American Concrete Institute (ACI) Piawaian Jawatankuasa 211(ACI 211,2). LWAGC telah disediakan dengan menggunakan pengaktif alkali daripada Abu Terbang (FA) yang mengandungi natrium silikat (Na_2SiO_3) dan larutan natrium hidroksida (NaOH). Pengikat geopolimer ini telah digunakan untuk mengikat campuran agregat semulajadi dan agregat ringan tanah liat berkembang (LECA). Ciri-ciri fizikal, mekanikal , mikrostruktur dan terma yang dihasilkan LWAGC sebelum dan selepas terdedah kepada suhu tinggi diantara 100 - 800 °C telah dikaji dengan terperinci melalui kajian ini. Keputusan fizikal dan mekanikal LWAGC yang tidak terdedah kepada suhu pemanasan 100° C hingga 800 °C menunjukkan ia menepati Piawaian ACI 211,2 untuk mereka bentuk LWAGC struktur berasaskan teknologi pengeopolimeran. Campuran LWAGC yang segar telah mencatatkan nilai penurunan iaitu 95 mm , manakala LWAGC keras memiliki kekuatan mampatan sebanyak 18.86 MPa dengan isipadu 1438.70 kg/m^3, pada hari ke 28. Ini membenarkan ia diklasifikasikan sebagai LWAGC struktur yang boleh digunakan sebagai bahan binaan. LWAGC yang tidak terdedah juga menunjukkan kekuatan mampatan meningkat secara berterusan apabila penuaan dibuat sehingga 1 tahun. Kajian nisbah optimum Activator/FA digunakan diantara 0.3-0.7 menunjukkan bahawa nisbah Activator/FA yang dicadangkan oleh Piawaian ACI 211,2 iaitu 0.59 adalah kandungan pengaktif paling optimum. Ini adalah kerana ia menyediakan kebolehkerjaan yang dikehendaki dan mempunyai kekuatan mampatan yang paling tinggi berbanding dengan nisbah ujian lain. Keputusan mekanikal, fizikal dan mikrostruktur menunjukkan agregat (pasir/pasir + LWA) meningkatkan ketahanan api mortar geopolimer FA dan LWAGC. Kekuatan LWAGC meningkat selepas terdedah kepada suhu diantara 100 °C sehingga 300° C. Bahan-bahan ini adalah sangat sesuai untuk aplikasi pada suhu sehingga 300 °C.

Study on Mechanical and Thermal Behavior of the Lightweight Aggregate Geopolymer Concrete (LWAGC) Using Fly Ash

ABSTRACT

Geopolymers are part of polymer science, chemistry and technology that forms one of the major areas of materials science as well as in producing of new green materials that can alternative cementitious material to ordinary Portland cement (OPC) due to their brilliant environmentally-friendly benefits. Structural lightweight aggregate concrete LWAC has been found in the available literature. This thesis presents the synthesis process procedures of a structural lightweight aggregate geopolymer concrete (LWAGC) system based on the American Concrete Institute (ACI) committee 211-standard (ACI 211.2). The LWAGC was prepared by alkali activation of a Fly Ash (FA) consist of sodium silicate (Na_2SiO_3) and sodium hydroxide solution (NaOH). The geopolymer paste binder was used to bind a mixture of natural aggregates and lightweight expanded clay aggregate (LECA). The physical, mechanical, microstructural and thermal properties of the prepared LWAGC before and after being exposed to elevated temperatures ranged of 100-800 °C were extensively investigated through this work. The physical and mechanical results of the unexposed LWAGC to heating temperatures of 100 °C to 800 °C showed that it comply the ACI 211.2 standard for designing a structural LWAGC based on the geopolymerization technology. The fresh LWAGC mixture was recorded a slump value of 95 mm, while the hardened LWAGC possessed a compressive strength and volume of 18.86 MPa and 1438.70 kg/m^3, respectively at 28 days. These classify it as a structural LWAGC which can be used as a construction material. The unexposed LWAGCs were also showed a continuous strength gaining versus aging times up to 1 year. The optimizing of Activator/FA mass ratio used in the LWAGC preparation has been also investigated at a range of 0.3-0.7, which revealed that the Activator/FA mass ratio proposed by the ACI 211.2 standard of 0. 59 was the optimum activator content as it provide the desired workability and the highest compressive strength than other tested ratios. The microstructural and physical analysis showed that, the thermal properties of LWAGC improved significantly after been exposed to elevated temperature of 400 °C, 600 °C and 800 °C. The mechanical, physical and microstructural results showed the aggregates (sand/sand + LWA) significantly improved the fire resistance of FA geopolymer mortar and LWAGC. The strength of the LWAGC increased after exposed to 100 °C to 300 °C. These materials are excellent for the applications up to 300 °C.