POZZOLANIC AND STRENGTH PROPERTIES OF MORTAR CONTAINING CHEMICALLY PRE-TREATED COAL BOTTOM ASH

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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 Doctor of Philosophy.

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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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Thesis submitted in fulfillment of the requirements
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DEDICATION

DEDICATED

TO

MY MOTHER:
JAUYAH BINTI CHE OMAR
A strong and gentle soul who taught me to trust in ALLAH, believe in hard work and that so much could be done with little

MY FATHER:
EMBONG BIN ALI
For earning an honest living for us and for supporting and encouraging me to believe in myself

MY HUSBAND:
TENGKU AMIR SHAH BIN TENGKU ALIM SHAH
Thank you for always giving me support and love

&

MY DAUGHTER:
TENGKU AIRA RAISYA BINTI TENGKU AMIR SHAH

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ABSTRAK

Pada masa kini, penyelidikan intensif dalam pengeluaran bahan-bahan pozzolanic yang sangat reaktif dari sisa industri untuk menggantikan simen adalah penting. Tindakan ini dijangka meningkatkan kadar kitar semula sisa industri dan pada masa yang sama mengurangkan pengekstrakan sumber batu kapur yang tidak boleh diperbaharui. Ciri-ciri unik abu bawah arang batu sebagai salah satu pozzolan berasaskan perindustrian semakin kurang popular kerana reaktiviti rendah dan pelenturan logam berat akibat kaedah konvensional yang digunakan untuk pelupusan. Oleh itu, pendekatan alternatif telah dikaji untuk menggunakan abu bawah arang batu dengan selamat untuk menghapuskan risiko pelepasan bahan logam berat dan meningkatkan kualiti abu bawah arang batu sebagai bahan pozzolanic atau penganti simen. Pra-rawatan dengan larutan asid dengan pelbagai pembolehubah digunakan untuk mengurangkan bahan bendasing yang merosakkan kualiti abu. Ia melibatkan merendam abu bawah arang batu dalam kepekatan larutan asid yang berbeza untuk selang masa yang berlainan dan dibiarkan kering di dalam ketuhar pada suhu 105ºC semalaman. Parameter terbaik abu bawah arang batu selepas pra-rawatan kemudian menjalani proses-gelifikasi dengan pelbagai pemboleh ubah dengan mengunakan bahan berasaskan alkali dan direndam selama 2 jam. Abu-abu yang dihasilkan kemudian ditentukan komposisi oksida, analisis saiz zarah, ciri-ciri mineralogik dan struktur mikro menggunakan pendarfluor x-ray, pembelahan x-ray dan mikroskop elektron pengimbasan pelepasan medan. Kesan silika terlarut telah dinilai berdasarkan sifat-sifat ini. Pelbagai peringkat penggantian simen diuji (0-10%) dalam kajian ini. Prestasi mortar selepas dibancuh sebelum dan selepas mengeras diuji melalui kekuatan mampatan, keliangan, haba penghidratan, analisis Thermogravimetry dan mikrostruktur. Abu bawah arang batu yang dirawat dengan parameter optimum telah menunjukkan jumlah logam yang rendah. Jumlah logam yang dilepaskan berkorelasi dengan penambahan kandungan silika yang ketara berbanding dengan abu bawah arang batu yang belum dirawat. Transformasi abu bawah arang batu yang dirawat ke dalam bentuk cecair telah memberikan sumbangan positif kepada sifat pengikat mortar dalam sistem simen. Transformasi abu bawah arang batu yang dirawat ke dalam bentuk larut telah memberikan sumbangan positif kepada sifat pengikat mortar dalam sistem daripada spesimen mortar yang tidak dirawat dan dirawat. Dalam kajian ini, 5% pengantian simen dengan abu arang batu dalam bentuk larut telah menunjukkan prestasi kekuatan yang stabil dari awal pengujian kekuatan hingga akhir. Penambahbaikan struktur mikro selepas dimasukkan cecair silika dikesan dengan penambahan Calcium-Silicate-Hydrate (C-S-H) yang didapati di permukaan zarah simen. Mikrostruktur padat dan kuat yang rapat dapat dilihat antara satu sama lain dalam membentuk struktur yang berterusan. Reformasi mikrostruktur ini telah menguatkan ikatan dan mengisi liang-liang mikro matriks simen dan akhirnya meningkatkan prestasi kekuatan makro. Berdasarkan analisis statistik melalui koefisien korelasi pearson, ianya dapat dilihat pembolehubah seperti porosity, penambahan kandungan silika, luas permukaan, berat unit dan penyingkiran aluminium oksida yang lebih tinggi telah menunjukkan korelasi yang berpotensi penting dengan kekuatan mampatan mortar. Sementara itu, dalam kajian ini, jumlah oksida besi, kalsium oksida, dan magnesium oksida dianggap kurang penting untuk prestasi kekuatan mampatan mortar berasaskan CBA.

ABSTRACT

An intensive research to produce highly reactive pozzolan, particularly from industrial waste, to replace the role of cement in construction material is crucial. This action would increase the recycling rate of industrial waste and, concurrently, reduce the extraction of non-renewable resources of limestone. Unique characteristic of coal bottom ash as one of the industrial based pozzolan gained less popularity because of its low reactivity and heavy metal leaching due to conventional method used for disposal. Few researches are available in the use of coal bottom ash as an alternative pozzolan. Most of the literatures discussed the functionality of it as an aggregate. Therefore, an alternative approach was deliberated in this research to safely utilized coal bottom ash by eliminate risk of leaching and enhance the quality of bottom ash as pozzolanic purpose. Pre-treatment with acid solution at various parameters was used to reduce deleterious material and impurities from the coal ash. The process begun with soaking of ash in various concentration of acid solutions with different time interval and left dried in an oven at 105ºC overnight. Coal bottom ash after the pre-treatment with optimum parameter was then undergo solution-gelification process with various alkali based solution for 2 hours soaking durations. The ash obtained was then characterized by determining its chemical oxides composition, particle size analysis, mineralogical characteristics and microstructure using x-ray fluorescence, x-ray diffraction and field emission scanning electron microscope. The effect of soluble silica was evaluated based on these properties. Various level of replacement (0-10%) was used in this study. Fresh and hardened mortar performance was evaluated via compressive strength, porosity, heat of hydration, thermogravimetry and microstructure analysis. The treated ash obtained with optimum parameters has exhibited significantly lower amount of metals. The amounts of metals leached out correlates with the significant increment of silica content compared with raw ash. Transformation of treated CBA into soluble form has offered a positive contribution to the properties of mortar binder in cementitious system which was evidenced by strength activity index value than untreated and treated mortar specimen. In this study, 5% of soluble silica was found as the optimum cement replacement that shows significant strength increment from early and later age. Refinement of microstructure after soluble silica inclusion by secondary Calcium- Silicate- Hydrate (C-S-H) was found scattered on the surface of cement particles with compact and reticular microstructure closely interweaving with each other in forming continuous structure. This microstructure reformation have effectively strengthen the bonding and filled the micro pores of cement matrix and improved the macro strength performance. Statistical analysis using pearson correlation coefficients shows the potentially important correlation between the compressive strength performances and the independent variables of porosity, addition of silica content, surface area, unit weight and higher removal of aluminum oxide. From this study, coal bottom ash shows a positive prospect to be developed as an alternative pozzolan after pre-treatment process. It would also assist in the green disposal of this scheduled waste.

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LIST OF ABBREVIATIONS

AAC	Autoclaved Aerated Concrete
ANOVA	Analysis of Variance
BA	Bottom Ash
BET	Brunaeur Emmet Teller
BJH	Barett Joyner Halenda
BS	Boiler Slag
CA	Coal Ash
C-A-H	Calcium Aluminate Hydrate
CBA	Coal Bottom Ash
CFA	Coal Fly Ash
CCP	Coal Combustion Products
CCT	Clean Coal Technologies
CH	Calcium Hydroxide
C-S-H	Calcium-Silicate-Hydrate
EDS	Energy Dispersion Spectroscopy
EE	Extraction Efficiency
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EU	Europe
FA	Fly Ash
FESEM	Field Emission Scanning Electron Microscopy
FGD	Flue Gas Desulfurization
HCl	Hydrochloric Acid
HSD	Honestly Significance Difference
HTG	High Turbidity Gel
ICPMS	Inductive Coupled Plasma Mass Spectroscopy
ITZ	Interfacial Transition Zone
LOI	Loss on Ignition
LTG	Light Turbidity Gel
MIP	Mercury Intrusion Porosimetry
MSW	Municipal Solid Waste

MTG	Medium Turbidity Gel
NaOH	Sodium Hydroxide
OPC	Ordinary Portland Cement
RE	Renewable Energy
RHA	Rice Husk Ash
SAI	Strength Activity Index
SCBA	Sugarcane Bagasse Ash
SEM	Scanning Electron Microscope
SSA	Specific Surface Area
SYSTAT	Statistical Software
TGA	Thermogravimetry Analysis
UHPC	Ultra High Performance Concrete
USA	United States of America
WCA	World Cement Agency
XRD	X-ray Diffraction
XRF	X-ray Fluoresence

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