POZZOLANIC PROPERTIES OF HYDROTHERMAL SILICA GEL EXTRACTED FROM SUGARCANE BAGASSE USING ECO-FRIENDLY APPROACH

by

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A Thesis

Submitted to the Postgraduate Studies Programme

as a Requirement for the Degree of

MASTER OF SCIENCE

CIVIL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR,

PERAK

MARCH 2016

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
ASR	Alkali Silica Reaction
BA	Bagasse Ash
BET	Brunauer–Emmett–Teller
BJH	Barrett-Joyner-Halenda
BSE	Backscattered Electron
CRM	Cement Replacement Material
C-S-H	Calcium- Silicate- Hydrate
CH	Calcium Hydrate
C_3A	Tricalcium Aluminate
C_3S	Dicalcium Silicate
EDX	Energy Dispersive X-ray
FESEM	Field Emission Scanning Electron Microscopy
FA	Fly Ash
GGBS	Ground Granulated Blast Furnace Slag
HCl	Hydrochloric Acid
LOI	Loss of Ignition
MK	Metakaolin
NMR	Nuclear Magnetic Resonance
NaOH	Sodium Hydroxide
OBA	Original Bagasse Ash
OPC	Ordinary Portland Cement
OSA	Oil Shale Ash
PAI	Pozzolanic Activity Index
POFA	Palm Oil Fuel Ash
PVP	Polyvinylpyrrolidone
RHA	Rice Husk Ash
SCBA	Sugarcane Bagasse Ash
SCM	Supplementary Cementitious Materials

SCSA	Sugarcane Straw Ash
SCWA	Sugarcane Waste Ash
SEM	Scanning Electron Microscopy
SF	Silica Fume
SS	Sodium Silicate
SSA	Specific Surface Area
TGA	Thermogravimertry Analysis
UNEP	United Nations Environment Programme
XRF	X-Ray Fluorescence
XRD	X-Ray Diffraction

ABSTRACT

In the production of sustainable concrete, it is quite essential to develop highly reactive silica rich materials to substitute cement. Sugarcane bagasse ash as one of the agricultural based pozzolan gained less popularity due to its relatively low amorphous silica content after incineration process (< 50% silica). Therefore, an alternative approach was studied in this research to extract high proportion of amorphous silica from sugarcane bagasse that fulfils the minimum requirement of pozzolanic standard. The process was divided into three stages, which were obtaining optimum pre-treatment variables, obtaining optimum burning variables, and substantiation of pozzolanic feature. Pre-treatment variables were done to remove all impurities and deleterious material from the ash. It involved soaking of bagasse in different concentration of hydrochloric acid solution (0.1M, 0.5M and 1.0M) for different interval of time (1,2 and 3 hours) after which it was dried in a dedicated solar drying chamber for 48 hours. The optimum combination of hydrochloric acid concentration and soaking time was identified based on atomic absorption spectroscopy and x-ray fluorescence. Bagasse treated with optimum parameter would then undergo burning process with various temperatures (600,700 and 800°C) and durations (1, 2 and 3 hours). The produced ash was characterized by determining its oxides composition, particle size analysis, specific surface area, pore volume, mineralogical characteristics and micro-structure using x-ray fluorescence, x-ray diffraction and field emission scanning electron microscope, respectively. 0.1M has emerged as the best concentrations with the extraction of silica could reach 83-89% with 1 hour soaking duration. 1 hour burning at 800°C concluded as the most feasible in producing amorphous state of ash. The ash obtained with optimum parameters was amorphous, chemically stable, and ultra-fine. The optimum ash was tested for its pozzolanic reactivity and indicated quite high pozzolanic reactivity index, which contributed to the significant improvement on the compressive strength properties of cementitious mortar of untreated, treated and silica gel at 2.5 and 5% replacement.

ABSTRAK

Dalam pengeluaran konkrit mampan, ia adalah penting untuk menghasilkan reaktif silika yang reaktif untuk menggantikan simen. Abu hampas tebu sebagai salah satu pozolan berasaskan pertanian mendapat kurang populariti disebabkan oleh kandungan silika amorfus yang agak rendah selepas proses pembakaran (<50% silika). Oleh itu, satu pendekatan alternatif dikaji untuk mengeluarkan bahagian yang tinggi silika amorfus daripada hampas tebu yang memenuhi keperluan minimum pozzolanic. Proses ini telah dibahagikan kepada tiga peringkat, pembolehubah pra-rawatan optimum, pembolehubah pembakaran optimum, dan ciri pozzolanic. pembolehubah pra-rawatan dilakukan untuk mengeluarkan semua kotoran dan bahan yang merosakkan dari abu. Ia melibatkan rendaman hampas tebu dalam kepekatan berbeza larutan asid hidroklorik (0.1m, 0.5m dan 1.0M) untuk tempoh masa yang berbeza (1,2 dan 3 jam) selepas itu ia telah dikeringkan dalam kebuk pengeringan solar selama 48 jam. Gabungan optimum asid hidroklorik dan masa rendaman telah dikenal pasti berdasarkan spektroskopi penyerapan atom dan x-ray pendarfluor. Hampas tebu dirawat dengan parameter optimum kemudian akan menjalani proses pembakaran dengan pelbagai suhu (600.700 dan 800°C) dan tempoh (1, 2 dan 3 jam). Abu yang dihasilkan dicirikan dengan menentukan oksida komposisi, analisis saiz zarah, kawasan permukaan tertentu, isi padu liang, ciri-ciri mineralogi dan mikro-struktur menggunakan x-ray pendarfluor, x-ray pembelauan dan bidang pelepasan imbasan mikroskop elektron. 0.1M telah muncul sebagai kepekatan yang terbaik dengan pengekstrakan silika boleh mencapai 83-89% dengan tempoh rendaman 1 jam. 1 jam membakar pada 800°C kesimpulan sebagai yang paling layak dalam menghasilkan keadaan amorfus abu. Abu optimum telah diuji untuk kereaktifan pozzolanic dan menunjukkan indeks kereaktifan pozzolanic agak tinggi , yang menyumbang kepada peningkatan yang besar ke atas sifat-sifat kekuatan mampatan mortar simen yang tidak dirawat , dirawat dan silika gel di penggantian 2.5 dan 5%.

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PUBLICATIONS

Journal Publications:

1. Rahimah Embong, Andri Kusbiantoro, Nasir Shafiq, Muhd Fadhil Nurruddin, *"Strength and Microstructural Properties of Fly Ash Based Geopolymer Concrete containing High-Calcium and Water-Absorptive Aggregate"*, Journal of Cleaner Production, vol. 112, pp. 816-822, 2016. (IF : 3.844)

2. *Rahimah Embong, Nasir Shafiq, Andri Kusbiantoro,Muhd Fadhil Nurruddin , "Effectiveness of Low-Concentration Acid and Solar Drying as Pre-Treatment Features for Producing Reactive Sugarcane Bagasse Ash"*, Journal of Cleaner Production, vol. 112, pp. 953-962, 2016. (IF : 3.844)

Conference Publications:

1. Rahimah Embong, Nasir Shafiq, Andri Kusbiantoro, *"Silica Extraction and Incineration Process of Sugarcane Bagasse Ash (SCBA) as Pozzolanic Materials: A Review"*, The Engineering Technology International Conference (ETIC 2015) University Malaysia Pahang, Bali, Indonesia, 10-11 August 2015 (Scopus Indexed Journals) (Paper Presented).

2. Rahimah Embong, Nasir Shafiq, Andri Kusbiantoro, *"Extraction of Silica Gel From Agricultural Waste For Pozzolanic Application: A Review"* , First International Conference on Science, Engineering, and Environment GEOMATE International Society, Kyoto, Japan, 19-21 November 2015, (Scopus Indexed Journals) (Paper presented).

3. Rahimah Embong, Nasir Shafiq, Andri Kusbiantoro, *"Refinement of Microstructure and Interfacial Transition Zone in Cementitious Framework Containing Chemically Pre-treated Sugarcane Bagasse Ash (SCBA)"* Sustainable Construction Materials & Technologies (SCMT4). University of Nevada,Las Vegas, USA, August 7-11, 2016 (Abstract Accepted)