PROPERTIES AND ENVIRONMENTAL IMPACT OF RECYCLING CIGARETTE BUTTS (CBs) IN FIRED CLAY BRICK

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ABSTRACT

Brick is one of the man-made building materials that have been used since the early human civilization. Due to the attractive appearance, strength and durability, it often used for construction, civil engineering works and landscape design. This study is focused on the effects of incorporating cigarette butts (CBs) into fired clay brick. The investigation includes characterization, optimum percentage of CBs incorporated, physical and mechanical properties, leachability and indoor air quality. Therefore, clay soil samples obtained from Hoe Guan Brick Sdn Bhd were used as control in this research while 2.5% and 5.0% by weight of CBs were incorporated into the clay bricks for subsequent experiments. Different heating rates were used during the firing processes which are 1^{o}C/min**,** 3^{o}C/min and 5^{o}C/min respectively. All samples were fired at 1050^{o}C. The results suggested that the heating rates of 1^{o}C/min with 2.5% CBs are adequate to achieve optimum properties. The results also indicated that the maximum compressive strength of fired clay brick was obtained with 2.5% CBs of fired clay brick at 1^{o}C/min heating rate compared to others. The density becomes lightweight by 16% to 21% compared to conventional bricks as the percentage of CBs increased. The thermal conductivity of the bricks also improved from 24.6% to 46.1% with the increasing of CBs. In addition, leachability results indicated that the leaching of heavy metals were below the United States Environmental Protection Agency (USEPA) and Environmental Protection Agency Victoria (EPAV) regulations. Finally, laboratory testing for Indoor Air Quality (IAQ) revealed that CB Brick complied with the Industry Code of Practice on Indoor Air Quality (ICOP-IAQ).

ABSTRAK

Bata adalah salah satu daripada bahan binaan buatan manusia yang telah digunakan sejak awal tamadun manusia. Oleh kerana penampilan yang menarik, kuat dan berketahanan, ia sering digunakan untuk pembinaan, kerja-kerja kejuruteraan awam dan reka bentuk landskap. Kajian ini memberi tumpuan kepada kesan menggabungkan puntung rokok (CBs) ke dalam batu bata tanah liat. Penyiasatan termasuklah pencirian, peratusan optimum kemasukan puntung rokok, ciri-ciri fizikal dan mekanikal, larut resapan dan kualiti udara dalaman. Oleh itu, sampel tanah liat diperolehi daripada Hoe Guan Bata Sdn Bhd telah digunakan sebagai kawalan dalam kajian ini manakala 2.5% dan 5.0% puntung rokok mengikut berat telah dimasukkan ke dalam bata tanah liat untuk eksperimen berikutnya. Kadar pemanasan yang berbeza telah digunakan semasa proses pembakaran iaitu 1°C/min, 3°C/min dan 5°C/min. Semua sampel telah dibakar pada 1050°C. Keputusan mencadangkan kadar pemanasan 1°C/min dengan 2.5% CBs adalah mencukupi untuk mencapai ciri-ciri yang optimum. Hasil menunjukkan bahawa kekuatan mampatan maksimum bata tanah liat dibakar telah diperolehi dengan 2.5% puntung rokok pada 1°C/min kadar pemanasan berbanding dengan yang lain. Ketumpatan menjadi ringan sebanyak 16% kepada 21% berbanding dengan bata konvensional apabila peratusan puntung rokok meningkat. Kekonduksian terma bata juga bertambah baik daripada 24.6% hingga 46.1% dengan peningkatan peratusan puntung rokok. Di samping itu, keputusan menunjukkan bahawa hasil larut lesap logam berat adalah mematuhi peraturan-peraturan United States Environmental Protection Agency (USEPA) dan Environmental Protection Agency Victoria (EPAV). Akhir sekali, ujian makmal untuk Kualiti Udara Dalaman (IAQ) mendedahkan bahawa bata puntung rokok mematuhi Industry Code of Practice on Indoor Air Quality (ICOP-IAQ).

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percent
≤	-	Less-than or Equal to
≥	-	Greater-than or Equal to
°C	-	Degree Celsius
°C/min	-	Degree Celsius per minute
µ	-	micro
µm	-	Micro meter
A	-	Area
AAS	-	Atomic Absorption Spectroscopy
Al	-	Aluminium
Al_2O_3	-	Aluminum oxide
As	-	Arsenic
Ba	-	Barium
BS	-	British Standard
C	-	Ceiling limit
CaO	-	Calcium oxide
CB Brick	-	Cigarette Butt Brick
CBA	-	Clay Brick Organization
CBs	-	Cigarette Butts
Cd	-	Cadmium
Ce	-	Cerium
CETP	-	Code on Envelope Thermal Performance
Cfu/m^3	-	Colony Forming Unit per Cubic Meter
cm^3	-	Cubic centimeter
CO	-	Carbon Monoxide
Co	-	Cobalt
CO_2	-	Carbon Dioxide
Cr	-	Chromium
Cs	-	Cesium
Cu	-	Copper
CuO	-	Copper(II) oxide
EN	-	European Standard
EPA	-	Environmental Protection Agency
EPAV	-	Environmental Protection Agency Victoria
ER	-	Empty Room
et al	-	And others
ETS	-	environment tobacco smoke
FDA	-	Food and Drug Administration
Fe	-	Ferum
Fe_2O_3	-	Ferric oxide

FEMA	-	Flavor and Extract Manufacturers Association
g	-	Gram
g/cm^3	-	Gram per cubic meter
Ga	-	Gallium
GAST	-	Global Adult Tobacco Survey
HCHO	-	Formaldehyde
IAQ	-	Indoor Air Quality
ICOP-IAQ	-	Industry Code of Practice on Indoor Air Quality
ISO	-	International Organization for Standardization
k	-	thermal conductivity
K_2O	-	Potassium oxide
K_a	-	Aspect Ratio Factor
kg/m^3	-	Kilogram per cubic meter
kN	-	Kilonewton
L	-	thickness
L/min	-	Liter per minute
La	-	Lanthanum
LL	-	Liquid Limit
LOI	-	Loss of Ignition
L_s	-	Actual Length – Dry Length
M_1	-	Dry Mass
m_1	-	Mass of wet brick
M_2	-	Wet Mass
m_2	-	Submerged mass of brick
mg/L	-	Milligram per litre
mg/m^3	-	Milligram per cubic meter
MgO	-	Magnesium oxide
mm	-	milimeter
Mn	-	Mangan
MnO	-	Manganese(II) oxide
m_o	-	Ambient mass
Mo	-	Molybderium
MOH	-	Ministry of Health Malaysia
Mpa	-	Megapascal
N/mm^2	-	Newton per millimeter square
NA	-	Not Available
Na_2O	-	Sodium oxide
Nb	-	Niobium
ND	-	Not Detectable
Ni	-	Nickel
O_3	-	Ozone
OMC	-	Optimum Moisture Content
P_2O_5	-	Phosphorus pentoxid
PAHs	-	polycyclic aromatic hydrocarbon
Pb	-	Lead
PI	-	Plasticity Index
PL	-	Plastic Limit
PM_{10}	-	Particulate Matter
ppm	-	part per million
PVA	-	polyvinyl acetate

Q	-	Heat flow
Rb	-	Rubidium
RECESS	-	Research Centre for Soft Soil
RH	-	Relative humidity
RMK10	-	Rancangan Malaysia ke10
S	-	Shrinkage
Sb	-	Antimony
Sc	-	Scandium
SEM	-	Scanning Electron Microscope
SiO_2	-	Silicon dioxide
Sn	-	Tin
SO_3	-	Sulphur trioxide
Sr	-	Strontium
SrO	-	Strontium oxide
TCLP	-	Toxicity Characteristic Leaching Procedure
TEL	-	Thermal Environmental Laboratory
Th	-	Thorium
Ti	-	Thallium
TiO_2	-	Titanium dioxide
TVOC	-	Total volatile organic compounds
twa	-	time-weighted average
U	-	Uranium
USEPA	-	Unites States Environmental Protection Agency
UTHM	-	Universiti Tun Hussein Onn Malaysia
UTM	-	Universal Testing Machine
V	-	Vanadium
VOCs	-	Volatile organic compound
W/mK	-	Watt per meter Kelvin
WHO	-	World Health Organization
WiSC	-	Walk in Stability Chamber
wt.	-	Weight
XRF	-	X-Ray Fluorescence
Y	-	Yttrium
Zn	-	Zinc
ZnO	-	Zinc oxide
Zr	-	Zirconium
ZrO_2	-	Zirconium dioxide
ΔT	-	temperature gradient
ρ	-	Density

CHAPTER I

INTRODUCTION

1.0 Introduction

Along with rapid economic development and growing in population, Malaysia is dealing with challenges of waste management. Various approaches developed, nevertheless the implementation of waste management still gets less attention by most management teams. Example of solid waste management problems is lack of disposal areas, ineffective disposal method and illegal disposal area by irresponsible parties. Malaysia has no alternative, except to handle waste disposal properly in order or have to deal with environmental risks. In fact, cigarette butts (CBs) are one of the most littered items in the world (Slaughter *et al*., 2011; Micevska *et al*., 2006; Warne, 2002).

In Malaysia, CBs is difficult to manage because it often combined with domestic waste and it is very challenging to separate CBs waste due to their small size but large in volume. This problem is getting complicated when the number of discarded CBs is growing. According to National Health and Morbidity Survey, approximately about 3 million out of 28 million people in Malaysia (21.5%) are hardcore smokers (Osman and Azlan, 2007). Meanwhile, a statistic by Ministry of Health Malaysia (2000) in "Modul Berhenti Merokok 2001" reported that teenagers dominate smoking habits every day. With this high statistic, there is a huge number of CBs need to be disposed (MOH, 2001). Moreover, the attitude of those smokers that disregard CBs as waste and have been discarded CBs directly to the environment will cause worst environmental pollution.

The impact of CBs littering is not only towards the environment, but it is also harmful to the marine life and aquatic life. The butts were found in the stomach of fish, birds, whales and other marine life that swallow this poisonous filter (Roe & David, 2007). Furthermore, the Environmental Protection Agency (EPA) states that the cigarette butts can take up to 15 years to degrade (Ha, 2007). There are about 4,200 chemical compounds classified as tobacco constituents, but 10,000 not have yet to be discovered (Rodgman & Perfetti, 2009).

Meanwhile, a rapid growth of the construction sector led to an increasing of the demand of construction materials in Malaysia. According to the National Housing Policy in Malaysia Tenth Plan (RMK10, 2014), has determined that the housing sector will be further enhanced to provide adequate housing and quality public services as well as full equipped. According to a report in the RMK10, the government has targeted the construction of 78,000 units of affordable housing to meet the needs of low-income nation in Malaysia. Therefore, following with a high demand housing sector and the rapid growth of construction projects, the demand for low cost raw materials for construction also rose up.

1.1 Problem Statement

Malaysia is currently facing with litter pollution; especially CBs that is toxic to the environment (Register, 2000). CBs may be littered directly to the environment or indirectly via runoff water or carried away from streets and sidewalks to storm drains (Novotny *et al*., 2009; Sawdey *et al*., 2011). This problem will increase as the attitudes of some people are not concerned about this matter. The government has allocated a variety of methods to reduce CBs waste, but it is still less effective even though the program of "Hari Tanpa Tembakau Sedunia Peringkat Kebangsaan 2013" has been launched (MOH, 2013). According to a survey of Global Adult Tobacco Survey (GAST) released by World Health Organization, there are more than 40% of Malaysia men smoke, or a total of 4.7 million adults smokers, meanwhile, almost no women (less than 1%) smoke in Malaysia (WHO, 2012).

CBs are also known as cigarette filters are designed to absorb vapors and to accumulate smoke components. CBs contain hazardous chemicals such as lead, cadmium and arsenic that are partially filtered out through the smoking process. CBs are forms of non-biodegradable litter and can take approximately 12 months to break down in fresh water and up to 5 years to break down in seawater. According to Kadir & Mohajerani (2010), it is difficult to recycle CBs because there is no easy mechanism or efficient and economical procedures to ensure the separation of chemical trap inside the CBs. Furthermore, the chemicals that leach out from CBs could give a serious impact to human and marine life.

From previous researchers, attempts have been made to incorporate many types of waste in the production of bricks, zinc smelting slag (Hu *et al*., 2014); sludge (Victoria, 2013; Arsenovic, 2012; Hegazy *et al*., 2012); waste tea (Demir, 2006); limestone dust, wood sawdust (Turgut & Algin, 2007); kraft pulp waste (Demir *et al*., 2005); hydraulic limes and hydrated calcium lime (Costigan *et al*., 2010). Incorporating such wastes into brick bodies always involves at least two environmental benefits; incorporating of wastes that are difficult to dispose and savings in clay raw materials (Abi, 2014; Victoria, 2013). Moreover, fibrous waste mostly improved the thermal properties as the waste could act as pore formers additives and producing lightweight brick.

Meanwhile, environmental concern on building materials become increased especially when it related with the demand for low cost raw materials for construction. Recently, researchers have been promoting alternative low cost raw materials for example to incorporate different types of waste into building material specifically on fired clay brick as it is one of the most demanding building materials, but little was known regarding their emissions and the effect on indoor air quality (IAQ). Not so many researchers are focusing on this issue except few researchers have investigated on IAQ by incorporating several wastes into fired clay brick (Hu *et al*., 2014; Victoria, 2013; Arsenovic *et al*., 2012; Chiang *et al*., 2009; Weng *et al*., 2003). Therefore, in this study, CBs waste was collected and incorporated in fired clay brick as an alternative disposal method to CBs and cater its pollution problems. Investigation on its advantages of the brick properties as well as its impact towards the environment either through leaching or emission also have been carried out. The choice to use CBs in fired clay brick is due to the several following factors; (a) bricks are made of clay, therefore they are homogenous and can blend with other substances (Ribeiro *et al*., 2004), (b) high temperature during firing process of fired clay brick will allows volatilization of dangerous components, thus changes the chemical characteristic of the materials and eliminates the toxic components through fixation process (Vieira *et al*., 2006; Weng *et al*. 2003).

1.2 Objective of the Study

The aim of this study was to investigate the impact by incorporating CBs in fired clay bricks. The objectives of the study were:

(i) to determine the characteristic of Cigarette Butts (CBs).
(ii) to identify the optimum percentage of incorporating CBs into fired clay brick.
(iii) to analyze the physical and mechanical properties by incorporating CBs into fired clay brick.
(iv) to evaluate the impact of CBs incorporation into fired clay brick towards leachability and indoor air quality (IAQ).

1.3 Scope of the Study

The scope of work of this research is to examine the possibility of CBs to be incorporated in fired clay bricks. Preliminary laboratory work such as soil classification test including liquid limit (LL), plastic limit (PL) and plasticity index (PI) were carried out according to the BS 1377:1990. The CBs was collected weekly around Parit Raja and Taman Universiti restaurant. Before proceed with brick manufacturing, clay soil sample and CBs were analyze with X-Ray Fluorescence Analysis (XRF), conducted at Analytical Laboratory, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM).

The sample preparation to manufacture fired clay brick was conducted at the Research Centre for Soft Soil (RECESS). Meanwhile, the physical and mechanical properties such as compressive strength, water absorption, firing shrinkage and dry density were carried at Structural Laboratory. To obtain the microscopic porosity image of manufactured brick, Scanning Electron Microscope (SEM) was conducted at Mechanical Laboratory, Faculty of Mechanical and Manufacturing Engineering, UTHM. Another test for leachability was conducted at Water and Wastewater Laboratory and Analytical Laboratory, Faculty of Civil and Environmental Engineering, UTHM. On the other hand, the IAQ was conducted at the Thermal Environmental Laboratory (TEL), Faculty of Mechanical and Manufacturing Engineering, UTHM.

In this study, different percentages of CBs (0%, 2.5% and 5.0%) were incorporated into fired clay brick. Different heating rates of brick firing were also conducted during firing stage with 1°C/min, 3°C/min and 5°C/min. The firing temperature was used up to 1050°C. The physical and mechanical properties were tested according to BS 3921:1985. Meanwhile, for the thermal properties, Hot Guarded Plate Method was used according to BS EN ISO 8990. The leachability test was conducted according to the Environmental Protection Agency (EPA) Method 1311, Toxicity Characteristic Leaching Procedure (TCLP). For the determination of IAQ; the laboratory building scale was operated in a small scale chamber and exposed to temperature and humidity follow Industry Code of Practice on Indoor Air Quality (ICOP-IAQ).

1.4 Significance of Study

The idea of recycling CBs started when most of the developed countries especially Australia, New Zealand and some in the United Kingdom do their yearly cleanup day and count every single littered item on the streets. For 7 years in a row, CBs has become the most littered item compared with others, although receptacles provided almost everywhere (Clean Up Day, 2012; Cigwaste, 2009).

By realizing that Malaysia has high smokers and very little receptacles provided to throw the CBs, the CBs must be recycled in an appropriate method. By incorporating CBs into fired clay brick could become an alternative disposal method for CBs as well as reduces CBs waste in landfill, waterways, streams and seawater (Sawdey *et al*., 2011; Slaughter, 2010). Furthermore, CBs is a toxic material that contains more than 4000 chemicals. This will be harmful to the environment when the littering of CBs dissolved in any sources of water.

Besides to overcome pollution problems, recycling CBs in fired clay brick could help to reduce raw material consumption during manufacturing of brick. This is because raw material needs to preserve for the future generation. Therefore, sustainability is one of the concepts that have been taking attention by several researchers to recycle those wastes into building material.

In this study, CB Brick could be a potential insulation material as CBs could act as pore-forming additives that will reduce the thermal conductivity of the manufactured CB Bricks due to its cellulose acetate fiber content. An adequate brick

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