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THE UTILIZATION OF COFFEE WASTE INTO FIRED CLAY BRICK

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ABSTRACT

The rapid growth of coffee industry is accompanied by a staggering increase in the amount of agriculture waste produced. In coffee producing countries, coffee wastes constitute a source of severe contamination and a serious environmental problem. In this study, the investigation on the possibility to utilize the coffee waste (CW) incorporated into the fired clay brick was carried out. The main purpose of this study is to determine the physical, mechanical properties and leach ability test of bricks incorporated with different percentages of CW. In this methodology, control brick (CB) and three different percentages of coffee waste brick (CWB) (1%, 3% and 5%) were manufactured and fired at 1050 °C. Physical and mechanical properties including shrinkage, density and compressive strength were reported and discussed. Additionally, leaching of heavy metals from manufactured clay brick was tested by using Toxicity Characteristics Leaching Procedure (TCLP). The results reported that with the incorporation of CW, the shrinkage increased linearly but still comply with minimum standard below 8% and good quality of brick was manufactured. Meanwhile, the results showed that density value decreased up to 30% from the normal brick with increased percentages of CW. The decreased compressive strength value of all the manufactured brick is still complies with minimum standard. On the other hand, heavy metals concentration leach out from different percentages of coffee waste brick is not exceeding the limit of 5 mg/L allowed by United States Environmental Protection Agency (USEPA). As a conclusion, the incorporation of CW into fired clay brick gives some advantages to the brick properties and also provides alternative solution on disposing the CW. In addition, the CW could also be a potential of low cost waste additive for the production of a brick.

Keywords: coffee waste, fired clay brick, physical and mechanical properties, TCLP, heavy metals.

INTRODUCTION

The increase in the number of agricultural industries in Malaysia supports economic growth positively but it affects the environment negatively by generating large amounts of agriculture wastes. As a result, agriculture wastes are generated in large quantities throughout the world. Globally, 998 million tons of agricultural waste are produced in a year and in Malaysia, 1.2 million tons of agricultural waste is disposed into landfills annually (Agamuthu and Fauziah, 2009).

On the top of that, in coffee producing countries, coffee wastes constitute a source of severe contamination and a serious environmental problem. For this reason, since the middle of the last century, efforts have been made to develop methods for its utilization as a raw material for the production of feeds, beverages, vinegar, biogas, caffeine, pectin, pectin enzymes, protein, and compost (Franca and Oliveira, 2009).The use of processed CW has been the subject of numerous studies which, in general, lead to the conclusion that coffee by-products and wastes can be used in a variety of ways.

Many research studies have been conducted for the replacement, reusing and recycling of CWbut there is lack attention has been diverted to utilizing in manufacturing bricks. Nevertheless, from previous research, many types of waste material have been successfully utilized in manufacturing bricks, for example, cigarette butts (Kadir and Mohajerani, 2015; Kadir et al. 2015), mosaic sludge (Rahim et al., 2015), sawdust (Banhidi and Gomze, 2008) fly ash (Lin, 2006) and palm oil waste (Kadir et al., 2013).The utilization of these waste will reduce environmental impacts and their disposal.

Therefore, in this study, the utilization of CW as a raw material in manufacturing fired clay bricks was conducted. The main aim of this investigation is to determine the physical and mechanical properties of CWbricks. Thus, leachabilityCW also will be investigated by using TCLP method.

MATERIALS AND METHOD

Preparation of raw materials

Clay soil (CS) and CW are raw materials that were used in this study. The CS and CW was obtained from Hap Seng Company at Sedenak, Johor. Then, CS and CW was collected and stored properly at laboratory before being used. The raw materials were oven-dried for 24 hours at 105 °C. After drying finished, the raw materials was sieved before brick manufacturing to ensure the particle size of were uniform with no impurities.

Preparation of raw materials

In this study, four types of brick were manufactured which are control brick (CB) and coffee waste brick (CWB) with size 225m x 110mm x 65mm. Different percentages of CW (1%, 3% and 5%) were added into fired clay brick. All the brick samples were fired at 1050 °C with heating rates 1°C/min.

The manufactured clay bricks then underwent a series of test including physical, mechanical properties and leachability test. The physical and mechanical properties of the fired bricks were determined by conducted a several testing such as shrinkage, density and compressive strength. These testing were according to BS

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3921:1985(BS 3921, 1985). Meanwhile, the test of Toxicity Characteristic Leaching Procedure (TCLP) was conducted using USEPA Method 1311 (USEPA, 1992).

RESULTS AND DISCUSSION

The Characteristic Clay Soil (CS) and Coffee Waste (CW)

Table-1 recorded the concentration of elements content between CS and CW. From the results, both of CS and CW indicate higher level of Iron Oxide (Fe_2O_3) with 55600 ppm and 9000 ppm respectively. In the meantime, other elements which are Chromium (Cr), Manganese (MnO), Copper (Cu), Barium (Ba), Nickel (Ni) and Lead (Pb) are also high in CW samples with 457 ppm, 400 ppm, 181 ppm, 100 ppm, 59 ppm and 18 ppm respectively. Meanwhile, CS are low in Cr (34 ppm), followed by Cu (13 ppm) and Ni (9 ppm). Otherwise, Zinc (Zn) and Arsenic (As) are high in CS with 161 ppm and 21 ppm respectively. Based on the XRF result, most of the heavy metals are higher in CW compared to CS. Therefore, the CW could not be disposed of directly to the landfill. Heavy metals accumulation in the CW will give a bad impact towards the environment.

Table-1. Elements of CS and CW.

Elements	Formula	Concentration (ppm)	
		CS	CW
Scandium	Sc	21	4
Vanadium	V	74	32
Chromium	Cr	34	457
Manganese	MnO	-	400
Iron oxide	Fe_2O_3	55600	9000
Cobalt	Co	8	5
Nickel	Ni	9	59
Copper	Cu	13	181
Zinc	Zn	161	36
Gallium	Ga	24	3
Arsenic	As	21	1
Rubidium	Rb	118	8
Strontium	Sr	39	29
Yttrium	Y	38	5
Zirconium	Zr	336	45
Niobium	Nb	13	4
Molybdenum	Mo	-	1
Tin	Sn	2	1
Cesium	Cs	12	4
Barium	Ba	318	100
Lanthanum	La	70	-
Cerium	Ce	70	14
Lead	Pb	17	18
Thorium	Th	21	8
Uranium	U	6	1

Meanwhile, the results in Table 2 shows that the majority of the chemical composition are higher in CS compared to CW. Silicon Dioxide (SiO_2) and Aluminum Oxide (Al_2O_3) in CS have the highest percentages of chemical composition with 65.77% and 23.73% respectively. Meanwhile, Barium Oxide (BaO) obtained the lowest percentages with 0.27%. In terms of CW, highest percentages of chemical composition are Iron Oxide (Fe_2O_3) and Calcium Oxide (CaO) with 4.58% and 3.75%. Besides, Molybdenum Trioxide (MoO_3) represents the lowest percentages with 0.17%. Although the chemical composition is different, due to clay soil flexibility, various types of waste materials and origins are successfully incorporated inside clay brick and the properties obtained are still within the limits set by the required standards (Viruthagiri et al., 2014).

Table-2. Chemical composition of CS and CW.

Composition	Formula	Concentration (%)	
		CS	CW
Iron Oxide	Fe_2O_3	1.19	4.58
Calcium Oxide	CaO	1.14	3.75
Magnesium Oxide	MgO	0.92	-
Zirconium Dioxide	ZrO_2	0.83	-
Silicon Dioxide	SiO_2	65.77	3.27
Aluminum Oxide	Al_2O_3	23.73	1.84
Sodium Oxide	Na_2O	2.99	-
Potassium Oxide	K_2O	1.98	1.71
Sulfur Trioxide	SO_3	-	0.99
Chlorine	Cl	-	0.78
Phosphorus Pentoxide	P_2O_5	0.40	0.25
Titanium Dioxide	TiO_2	0.39	0.22
Copper(II) Oxide	CuO	-	0.21
Molybdenum Trioxide	MoO_3	-	0.17
Barium Oxide	BaO	0.27	-

Physical and mechanical properties

Shrinkage, density, and compressive strength were the testing parameters conducted in this study.

Shrinkage

As shown in Figure-1, shrinkage increased linearly with the increasing of CW incorporation. The highest shrinkagewere demonstrated by CWB5 (3.12%) followed by CWB3 (2.98%) and CWB1 (2.24%). The lowest shrinkagewas obtained with CB (2.19%). Based on the result, it was observed that the water content influenced the shrinkage occur on the brick samples. Usually, a good quality of brick exhibit shrinkage below 8% (BIA, 2004). Figure-1 showed the amount of shrinkage for each mixing which is below 8%, then a good quality of bricks was manufactured.

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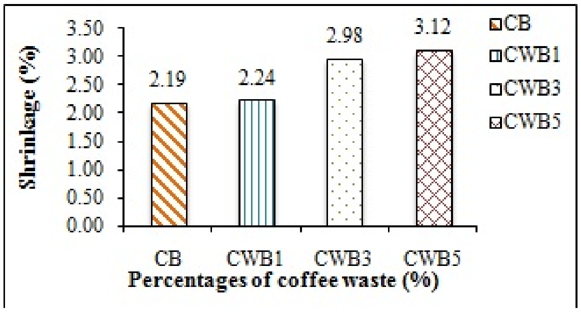

Figure-1. Comparison of shrinkage with different percentages of CW.

Density

Figure-2 shows the density values for different percentages of CWB. Based on the results, it was recorded that the CB had the highest density value with 1930.13 kg/m^3 and followed by CWB1 (1873.36kg/m^3). Then, the value of density for CWB3 is 1748.42 kg/m^3. Meanwhile, CWB5 obtained the lowest density value with 1673.15 kg/m^3. According to Figure-2, it can be concluded that, the increase in the amount of waste influence the density of bricks. As the bricks become more porous it will result to lightweight brick.

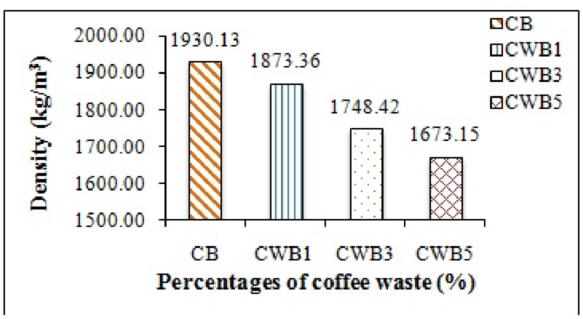

Figure-2. Comparison of density with different percentages of CW.

Compressive Strength

Figure-3 shows that the results of compressive strength decrease steadily with the increase of CW percentages. The highest compressive strength was obtained by CB with the strength of 21.75 N/mm^2. Compressive strength for CWB1 is 18.91 N/mm^2, followed by CWB3 with 12.59 N/mm^2. Meanwhile, the lowest compressive strength is determined by CWB5 with the strength value of 10.24 N/mm^2. Therefore, the increase percentages of CW will decrease the strength of bricks. According to BS 3921:1985, the bricks could not be categorized as an engineering bricks because the strength do not achieve 50 to 70 N/mm^2. However, the strength is still complied with aminimum standard of compressive strength (less than 5 N/mm^2). Nevertheless, strength is only suitable to be used for non-load bearing purposes.

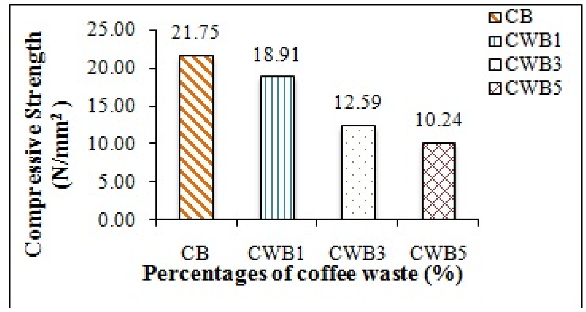

Figure-3. Comparison of compressive strength between different percentages of CW.

Leachability of heavy metals in coffee waste brick

Figure-4 shows the results of heavy metals concentration in leachate from CB and CWB incorporated into fired clay bricks. The CB resulted in high concentration of heavy metals which are Co (0.561), Zn (4.260) and Ba (4.680). Nevertheless, CWB1 and CWB3 brick had a good quality when the concentrations of heavy metals are quietlow as brick manufactured. As shown, the concentration of heavy metals in each brick is not exceeding the limit of 5 mg/L allowed by USEPA.

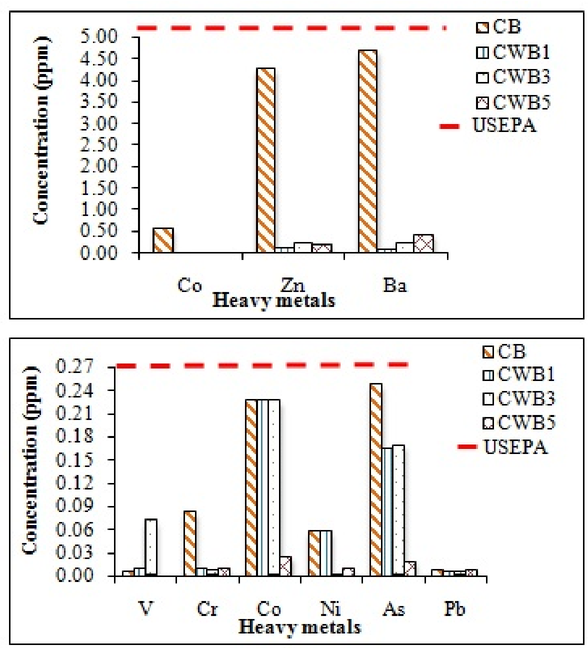

Figure-4. Concentration of heavy metals with different percentages of CW.

From Figure-5, it shows that concentration of the heavy metals between Fe and Mn with differentpercentages of CW. The trends indicated that the increasing of CW percentages will increase the heavy metals leach from CWB. CWB5 for brick had a higher concentration of Fe and Mn with 5.917 mg/L and 4.443 mg/L respectively. Although Fe and Mn concentration limits are not stated in

USEPA (1992), both the metals leaching concentrations are still low in all specimens.

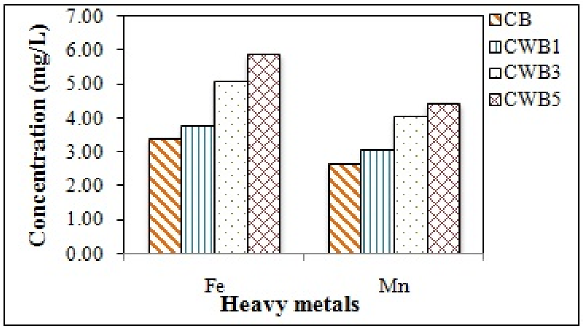

Figure-5. Concentration of heavy metals with different percentages of CW.

CONCLUSIONS

In coffee producing countries, coffee wastes constitute a source of severe contamination and a serious environmental problem. Manufacturing bricks is one of the solutions to reduce the disposal problem and environmental issue. Regarding to the advantages of properties, the utilization of CW waste into fired clay brick could act as low-cost pore formers to produce lightweight brick. In the meantime, some of the properties decreased by incorporating the waste but it still producing adequate fired clay brick that comply with the standard and suitable for non-load bearing purposes. The consideration of leachability of heavy metals in CWB also not affected when the concentration of heavy metals in each brick is not exceeding the limit allowed by USEPA. Nevertheless, the incorporation of CW into fired clay brick gives some advantages to the brick properties and also provides an alternative solution on disposing of the CW. In addition, the CW could also be a potential of low-cost waste additive for the production of brick.

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