IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

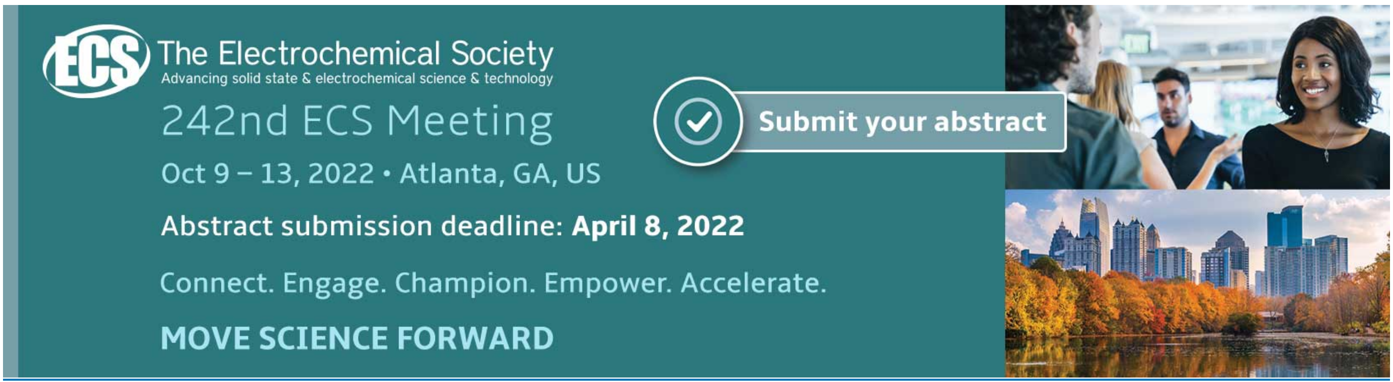
Study on Fired Clay Bricks by Replacing Clay with Palm Oil Waste: Effects on Physical and Mechanical Properties

To cite this article: A A Kadir *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **209** 012037

View the article online for updates and enhancements.

You may also like

- Thermal Insulation Enhancement of Metakaolin-Based Geopolymer Concrete Using Waste Clay Brick
Mahmood F. Ahmed, Wasan I. Khalil and Qias J. Frayyeh
- Reuse of pulverized fired clay brick wastes as cement substitute in mortar for sustainable construction
Oluwarotimi Olofinnade, Anthony Ede, Julius Ndambuki et al.
- A Review on Use of Crushed Brick Powder as a Supplementary Cementitious Material
Mani Mohan, Aditya Apurva, Nishant Kumar et al.



This content was downloaded from IP address 103.86.131.118 on 07/03/2022 at 02:37

Study on Fired Clay Bricks by Replacing Clay with Palm Oil Waste: Effects on Physical and Mechanical Properties

A A Kadir[1,2], N A Sarani[1], M M A B Abdullah[3,2], M C Perju[2,4] and A V Sandu[2,4]
[1]Department of Water and Environmental Engineering, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
[2] Center of Excellence Geopolymer and Green Technology (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
[3]Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
[4]Faculty of Materials Science and Engineering, Gheorghe Asachi Technical University of Iasi, Romania

E-mail: aeslina@uthm.edu.my[1], nramira1987@gmail.com[2]

Abstract. Palm oil is one of the major agricultural industries in Malaysia. Due to the poor management system, the discarded palm oil waste has always been linked to the environment issues. During processing of palm oil, a considerable amount of solid waste by-products in the form of fibres, shells, empty fruit bunches and fly ashes are produce rapidly. Therefore, this study was conducted to incorporate 1%, 5% and 10% of palm oil waste into fired clay brick. Samples of brick were fired at 1050°C temperature with heating rates of 1°C/min. Manufactured bricks were tested with physical and mechanical properties including firing shrinkage, dry density, water absorption and compressive strength. The results demonstrated that the replacement of 1% up to 5% of palm oil waste had improved several properties, although, a decrease of performance in certain aspects has also been observed. As a result, palm oil waste can be utilized in an environmentally safe way into fired clay brick thus providing adequate properties of fired clay brick.

1. Introduction

Oil palm plantation is one of the successful stories of agricultural industry in Malaysia. From a modest beginning in the early 1920s, the palm-oil industry developed rapidly where Malaysia is the second largest palm oil production after Indonesia [1]. From figure 1, production of crude palm oil has recorded a marginal decrease until December 2016 with 15% to 17.3 million tonnes compared to 19.9 million tonnes in year 2015 [2]. The decrease was due to lingering effects of the El Nino, rejection of additional palm oil levy in France and low stockpiles [3]. However, it is projected to increase in year 2017 since world palm oil production increase by 5.65 million tonnes or 9.6% compared to last year with 64.5 million tonnes [1]. This is due to higher fresh fruit bunch processed from newly matured area especially in Sabah and Sarawak and also a better management of the organization.

Meanwhile, oil planted area in Malaysia as the year of 2015 has reached 5.64 million hectares with increasing of 4.6% compared to previous year. According to Figure 2, Sabah is still the largest planted area with 27.4%, followed by Sarawak with 25.5%. Peninsular Malaysia accounted with 47% of total planted area [4].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

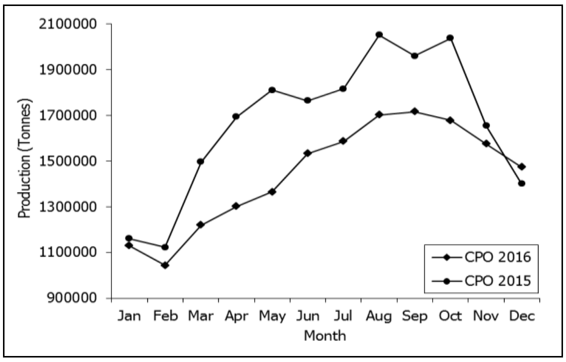


Figure 1. Monthly production of crude palm oil for the year of 2016 [2].

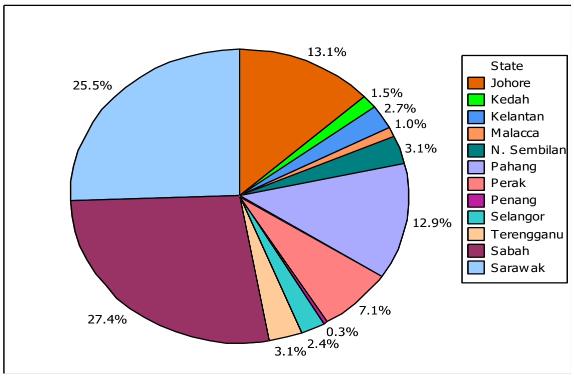


Figure 2. Oil planted area by state as at December 2015 [4].

The nation's pollution dilemma caused by the oil palm sector is increased by an annual crop of 4 million tons of solid waste [5]. A large area is required for the disposal of these palm oil waste materials. According to [6], one of the problems associated with the production of palm oil is large quantities of processed residues that have no economic value and it only disposed of by illegal and uncontrolled open burning which is discouraged by Department of Environment Malaysia.

Table 1. Waste generated during palm oil process [8].

Wastes	Quantity of waste generated
Empty fruit bunch	22%
Palm fibre	13.5%
Palm kernel shell	5.5%
Palm oil mill effluent	67%

In the processing of crude palm oil and palm kernel from fresh fruit bunch, the palm-oil industry produces substantial amount of biomass wastes in the form of fibres, shells and empty bunches which is higher in fibre content [7]. From the extraction of fresh fruit bunch, palm oil consists only 10% of the total biomass and the rest 90% are discarded as waste [8]. Currently, shell and fibre are used extensively as fuel for the production of steam in the palm-oil mills as a means of waste disposal and energy recovery. Table 1 shows the waste generated during palm oil processing. Palm oil fiber (PF) is natural fiber extracted from palm oil vascular bundle the empty fruit bunch (EFB) through the retting process Palm fiber is stable and non-hazardous biodegradable material which can use or processed for various purposes such as ceramic, soil stabilization, compaction, brick manufacturing and mattress erosion control. Palm kernel shell is hard to decompose and has been reused as mulch. According to [9], approximately 5 tons of palm kernel shell is obtained from 66 tons of fresh fruit bunches. Palm kernel shell has high grade solid, low ash and low sulphur content.

Meanwhile, empty fruit bunch is the by-product from crude palm oil mill which having low economic value before more application being developed. Currently, the major application of empty fruit bunch has extracted the fibre for others industry. By realizing empty fruit bunch has potential as energy sources, it has been used in clay brick to save energy during firing stage [6], [10].

Another concern is palm oil fuel ash (POFA). POFA is the ash produced from the husk fibres and shells during palm oil burning. Currently, shells and fibre wastes are utilized widely as fuel for the production of steam in palm oil mills. However, about 5% of ash weight is engendered after combustion process. This ash is amassed from the boiler and directly dumped onto open fields close to the mill. Hence, disposal of this waste becomes equipollent compulsory.

Agreeing by [11], 998 million tonnes of agricultural waste is produced every year and in Malaysia itself, 1.2 million tonnes of agricultural waste is disposed of in landfills annually. Waste material from agricultural activities would cause environmental pollution and this waste must be managed properly to eliminate the effect towards the environment. Other than that, health implication of poor waste management can be very damaging to the people.

1.1. Incorporation Waste into Fired Clay Bricks

Reduction of dumped waste and towards environment sustainability can be ensured by appropriate consumption or recycling of these materials. Incrementing world population and life demand are persistently raising the price of crude materials and reducing the natural resources. Along with this line, researches have been concentrated to utilise waste materials as a potential alternative in the construction industry.

Brick is the man-made building materials that have been used since the early human civilisation. Bricks are broadly used for construction, civil engineering work and landscape design since it has an attractive appearance, strength and durability, fire and weather resistance, thermal and sound insulation. The quality of brick usually depends on the composition of raw materials, production method, firing method and firing temperature [12]. Because of the versatility of clay, when it mixed with water, clay mineral give a plastic mass that can be formed by pressure and fired in a furnace [13]. This firing process transforms the clay into a building component in high performance of properties.

Fired clay brick can describe as common, facing or engineering brick. Common brick has no visual finish and ordinarily used for general building work particularly when brickwork is to be rendered, plastered or unseen in the finished work. It is also widely used as interior wall surface or exterior walls that are below the ground level. Facing brick are manufactured to give an attractive finish. It was intended to be used in both structural and non-structural masonry, where appearance required. The colour which may be uniform or multi coloured resulted from the mixes of clay used and the firing condition. Facing brick is available in a wide range of colours, textures, smooth, light or sandy. It often applies to the top or the surface of the wall for ecstatic factor. Engineering bricks usually are dense, strong, used to support heavy loads, and also where the effects of impact damage, water absorption or chemical attack that needs to be minimised. Moreover, they are further subdivided into facing and common according to their properties.

2. Materials and method

2.1. Materials

Clay soil was supplied by a brick manufacturer located at Yong Peng, Johor. Upon delivery, clay soil was oven dried at 105°C for 24 hours. Dried clay soil was crushed and ground to yield homogenous size pass through a 500 μm sieve.

Meanwhile, palm oil waste was collected from palm oil mill plantation at Kluang, Johor. Palm oil wastes used in this study consists of palm kernel shell (PKS), palm oil fuel ash (POFA), palm fibre (PF) and empty fruit bunch (EFB). Palm oil wastes also were oven dried to keep constant mixing water content during brick manufacturing. The samples of PKS, PF and EFB need to be crushed and ground pass through 4.75 mm and retained at 2.36 mm nominal sieve. Meanwhile, POFA was sieved to remove the leftover of nutshells and fibres which are not completely burned during burning process in boiler. Figure 3 to figure 6 shows different type of palm oil waste used in this study. The chemical composition of clay soil and palm oil waste were analysed using X-Ray Fluorescence (XRF).

Figure 3. Palm oil fuel ash.

Figure 4. Palm kernel shell.

Figure 5. Palm fibre.

Figure 6. Empty fruit bunch.

2.2. Methods

The geotechnical properties of clay soil and palm oil waste such as soil classification and specific gravity test were determined according to British Standard [12]. Soil classification is necessary to analysed because it define or classify type of soil or predict soil performance when combining with waste. This test covers the determination of plastic limit, liquid limit and plasticity index. Meanwhile, specific gravity test was performed using small pyknometer method. Distilled water was used as a standard for density bottle fluid. However, samples contain salts such as palm oil waste, kerosene was used as fluid. Before conducting a trial mix of control brick and clay-POW brick, necessary amount of water need to determine in order to achieve adequate plasticity of the mixture. Adequate water can minimize absence of cracking during drying and firing process. Optimum moisture content can be performed by Standard Proctor Test according to British Standard [13].

2.3. Brick manufacturing

The trial mix was prepared to determine suitable percentage of palm oil waste content for brick manufacturing. The ratio of palm oil waste was calculated based on specific gravity of the samples. The sample was started by mixing clay soil and clay-waste sample with predetermined water. The mixture was then pressed into mould for the following size; 215 mm x 102.5 mm x 65 mm with pressure of 3000 psi. The wet brick sample was kept for 24 hours at room temperature followed by oven dried at 105°C for another 24 hours. The dried bricks finally were fired in a furnace at 1050°C with heating rates of 1°C/min. Control brick with zero waste also was prepared for control purpose.

IOP Conf. Series: Materials Science and Engineering **209** (2017) 012037 doi:10.1088/1757-899X/209/1/012037

The manufactured bricks were designed as control brick (CB) for brick without waste, palm kernel shell brick (PKSB), palm oil fuel ash brick (POFAB), palm fibre brick (PFB) and empty fruit bunch brick (EFBB). The manufactured clay bricks then went through a series of test including physical and mechanical properties such as firing shrinkage, dry density, water absorption [14] and compressive strength [15].

3. Results and discussion

3.1. Characterization of raw materials

The clay soil presents a typical composition and mainly consists of Silica (SiO_2), Alumina (Al_2O_3) and Ferric Oxide (Fe_2O_3) with 55.7%, 24.4% and 4.46% respectively. Minor contents in clay soil consist of Sodium Oxide (Na_2O) and Calcium Oxide (CaO) with 0.3% and 0.25% respectively. Palm Oil Fuel Ash (POFA) was found high in Silica (SiO_2), Ferric Oxide and Calcium Oxide (CaO) content with 32.7%, 13.36% and 11.1% respectively. This significant amount of Silica in POFA is greatly contributing to the pozzolanic reaction thus increased the binding between clay soil particles [16], [17]. Meanwhile, chemical compositions in Palm Kernel Shell (PKS) were high in Ferric Oxide (Fe_2O_3), (SiO_2) and Calcium Oxide (CaO) with 34.37%, 22.58% and 14.3% respectively. Chemical composition test also found that Silica (SiO_2), Ferric Oxide (Fe_2O_3), Calcium Oxide (CaO) and Sulphur Trioxide (TiO_2) are the major element present in both Palm Fibre (PF) and Empty Fruit Bunch (EFB). The concentrations are 22.58%, 10.13%, 15.00% and 7.38% for PF and 25.4%, 15.84%, 13.33% and 7.56% for EFB. It can be concluded that major chemical composition of palm oil wastes are extremely similar to clay soil and high silica in raw materials is beneficial to increase strength of bricks [18].

Table 2. Chemical composition of raw materials.

Oxides	Clay soil	PKS	POFA	PF	EFB
SiO_2	55.7	22.58	32.7	26.9	25.4
Al_2O_3	24.4	9.08	3.32	9.8	8.27
Na_2O	0.3	0.37	NA	NA	0.31
K_2O	2.24	2.14	15.9	8.46	7.41
Fe_2O_3	4.46	34.37	13.36	10.13	15.84
CaO	0.25	14.3	11.1	15.0	13.33
MgO	1.2	1.88	2.34	3.19	4.25
P_2O_5	NA	1.65	NA	6.07	0.87
TiO_2	0.94	0.79	NA	1.28	1.59
MnO	0.94	0.16	NA	0.19	0.51
SO_3	NA	1.56	3.65	7.38	7.56
CuO	NA	NA	NA	0.2	0.15
Cr_2O_3	NA	0.2	NA	0.15	0.4
ZnO	NA	0.3	NA	NA	NA

3.2. Properties of manufactured brick

3.2.1. Firing shrinkage. The addition of palm oil waste into fired clay brick has changed the shrinkage of the clay bricks where total shrinkage was increased with increasing of palm oil waste. The results in figure 7 have shown that the addition of 10% of palm oil waste might result in various pore sizes after firing thus increased the shrinkage values of bricks. By comparing different types of palm oil waste, the presence of EFB demonstrates highest shrinkage compared to PKS, POFA and PF into the mixture. It was found that cellulose fibre in EFB absorbed the water the within the existing particles and became the leading cause of the increased need for water thus resulted in the increased firing shrinkage of brick. This data obtained was in good agreement with the results reported by [19],

IOP Conf. Series: Materials Science and Engineering **209** (2017) 012037 doi:10.1088/1757-899X/209/1/012037

controlling shrinkage during firing process could minimize deforming of sample due to excessive shrinkage.

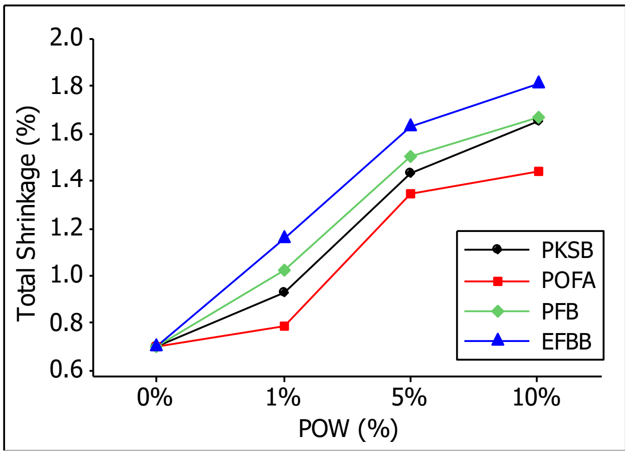


Figure 7. Firing shrinkage of POW brick.

3.2.2. Dry density. The result in figure 8 shows that the density of palm oil waste brick was inversely proportional to the percentages of palm oil waste added in the mixture. As a result, there was a linear decreased in dry density.

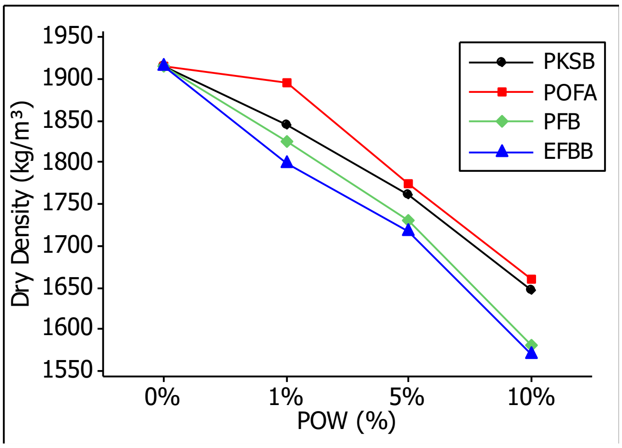


Figure 8. Dry density of POW brick.

It was found that the dry density was decreased with an increasing amount of palm oil waste ranging from 1% to 10%. In the meantime, different types of palm oil waste show different pattern of dry density where EFBB is lighter compared to other palm oil waste brick (with addition 1% to 10% of EFB). This is because of the characteristic of EFB and PF itself which is high in organic matter, could be eliminated during sintering process. This is similar to [20] that weight loss could be due to elimination of the organic matter from the clay and residue using combustion and to the removal of water content from clay mineral due to dehydroxylation reactions in the clay. Meanwhile, POFAB is likely high compared to others palm oil waste brick due to the fineness of the POFA particles which is eventually filling the voids between clay particles.

3.2.3. Water absorption. Figure 9 shows a correlation between the increasing percentages of palm oil waste which tend to increased water absorption. Increasing the percentages of POWs from 1% to 10% into fired clay brick resulted in an increment of water absorption. The same pattern of water absorption for different types of palm oil waste is quite similar with the result in firing shrinkage where POFAB absorb low water during 5 hours boiling test compared to PKSB, PFB and EFBB. Meanwhile, it can be seen in the case of incorporation 5% and 10% of PF and EFB, there are narrow differences in the water absorption; however both bricks still absorb high water content. This may happen because the elimination of the organic matter from the brick bodies during sintering process created numerous pores inside the brick.

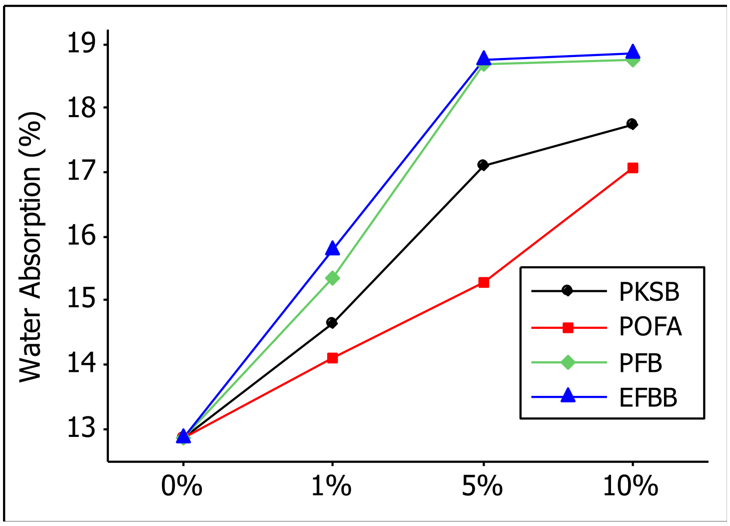


Figure 9. Water absorption of POW brick.

3.2.4. Compressive strength. Figure 10 shows that brick with higher percentage of waste obtained lower strength. It is expected that PFB and EFBB contain high organic matter thus leave pores inside brick during sintering process. By comparing different of POWs, waste contains lower organic content such as POFA achieved higher compressive strength compared to waste with high organic content.

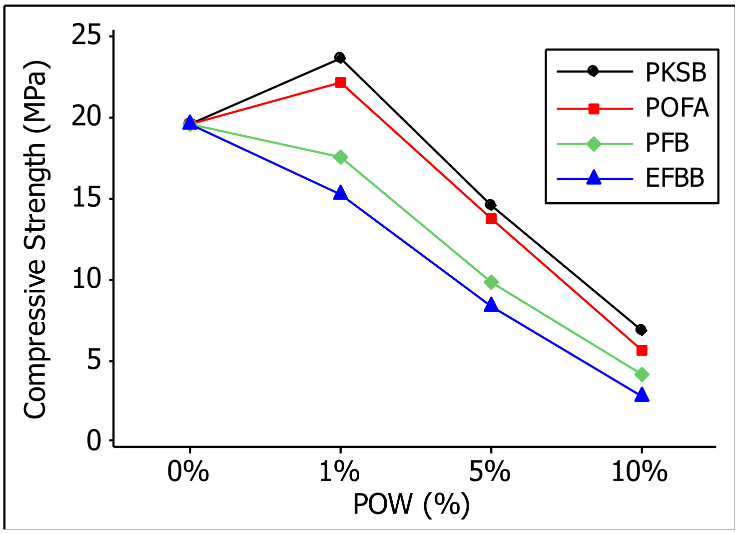


Figure 10. Compressive strength of POW brick.

This might be due to a significant amount of silica in POFA is believed to contribute towards the pozzolanic reaction during hydration thus improving binder with clay soil.

4. Conclusion

The brick in this study was manufactured from clay and potential palm oil waste (PKS, POFA, PF and EFB) by controlling the optimum ratio/percentages of waste into fired clay brick. Initial examination on the brick appearance found that there are minimum defects such as minor crack and no bloating were observed after firing. Regarding physical and mechanical properties, incorporation of palm oil waste to the clay body increases the required water content for maintained the plasticity of the mixture. Shrinkage of the brick is firmly increased to the expected stabilization effect of cellulose-fibre which is mostly due to very high water content. The study has found that all the manufactured POWs brick were under allowable limit of shrinkage and size variation of the brick samples were virtually uniformed. The results indicated that is possible to incorporate 1% up to 10% of palm oil waste into fired clay brick, which fulfills several limit standards and possesses mechanical properties similar to those of control brick. However, incorporation of 20% and 30% of palm oil waste has found to be failed due to major disintegration effect during sintering stage. It is noteworthy that 20% palm oil waste content and above has a significant effect on the poor structure which leads to black coring effect and causing poor surface texture of brick. However, this could be improved by increasing mixing times or prolongs firing time in the next stage.

The recycling of these agricultural wastes may present clear advantages from economical and technological aspect which are the reduction of costs related to use of alternative raw materials, reduction of consume of virgin raw materials, the obtainment of porous bricks with insulating ability when organic waste is used and the obtainment of bricks with excellent mechanical properties of using palm oil waste.

References

[1] World Palm Oil Production, https://www.worldpalmoilproduction.com/default.asp
[2] Malaysian Palm Oil Board, http://bepi.mpob.gov.my/index.php/en/statistics/production/168-production-2016/746
[3] Kong S, http://www.theborneopost.com/2016/11/14/sarawaks-palm-oil-sector-sees-decline-as-el-nino-effect-lingers/
[4] Malaysian Palm Oil Board, http://bepi.mpob.gov.my/images/area/2015/Area_summary.pdf
[5] Ismail M, Ismail M A, Lau S K, Muhammad B and Majid Z 2010 *Concr. Res. Lett.* **1** 60-66
[6] Abdullah N and Sulaiman F 2013 *Biomass Now - Sustainable Growth and Use* (Malaysia, InTech)
[7] Awalludin M F, Sulaiman O, Hashim R and Nadhari W N A W 2015 *Renew. Sustain. Energy Rev.* **50** 1469-84
[8] Mahlia T M, Abdulmuin M, Alamsyah T M and Mukhlishien 2011 *Energy Convers. Manag.* **42** 2109-18
[9] Embrandiri A, Singh R P, Ibrahim H M and Ramli A A 2012 *Environmentalist* **32** 111-117
[10] Yuhazri M Y, Sihombing H, Yahaya, Said S H, Nirmal M R U, Lau S and Tom P P 2009 *Glob. Eng. Technol. Rev.* **2** 26-32
[11] Agamuthu P 2013 *Waste Manag. Res.* **31** 1-2
[12] BS 1377-1 1990 *British Standard (BS). Methods of Test for Soils for Civil Engineering Purposes - Part 1: General Requirements and Sample Preparation*
[13] BS 1377-4 1990 *Methods of Test for Soils for civil engineering purposes - Part 4: Compaction-Related Tests*
[14] BS EN 772-21 2011 *Methods of test for Masonry Units Part 21 : Determination of Water Absorption of Clay and Calcium Silicate Masonry Units by Cold Water Absorption*
[15] BS EN 772-1 2011 *Methods of Test for Masonry Units Part 1 : Determination of Compressive Strength*
[16] Pourakbar S, Asadi A, Huat B B K and Fasihnikoutalab M H 2015 *Transp. Geotech.* **3** 24-35

[17] Oyeleke R B, Yusof M B, Salim M R and Ahmad K 2011 *Int. J. of Renewable Energy Resources* **1** 1-8
[18] Hegazy B E E, Fouad H A and Hassanain A M 2011 *J. Am. Sci* 569-576
[19] Baccour H, Medhioub M, Jamaoussi F and Mhiri T 2009 *J. Mater. Process. Technol.* **209** 2812-17
[20] Eliche-Quesada D, Martínez-Martínez S, Pérez-Villarejo L, Iglesias-Godino F J, Martínez-García C and Corpas-Iglesias F A 2012 *Fuel Process. Technol.* **103** 166-173

Acknowledgment
The authors gratefully acknowledge the Center for Graduate Studies UTHM for research support.