Research and Development Journal
Volume 27 Issue 2 April-June 2016

Received 4 May 2016 Accepted 22 July 2016

FIRED-CLAY BRICKS PRODUCED FROM HIGH COAL-BIOMASS ASH CONTENTS

The Engineering Institute of Thailand under H.M. The King's Patronage

The Engineering Institute of Thailand under H.M. The King's Patronage

FIRED-CLAY BRICKS PRODUCED FROM HIGH COAL-BIOMASS ASH CONTENTS

Natt Makul[1] and Gritsada Sua-iam[2]

[1]Assistance Professor, Department of Building Technology, Faculty of Industrial Technology,
Phranakhon Rajabhat University, 9 Changwattana Road, Bangkhen Bangkok, 10220, Thailand, shinomomo7@gmail.com

[2] Lecturer, Division of Civil Engineering, Faculty of Engineering, Bangkokthonburi University,
16/10 Leabklongtaweewatana Road, Taweewatana Bangkok,10170 Thailand, cm_gritsada@hotmail.com

ABTRACT

Under the concept of green building in Thailand, clay brick is possible to use to prevent heat, moisture, and sound from permeating a building from the outside. The objective of this research was to modify ordinary clay brick, which is currently produced in small plants of across the country, and to investigate its characteristics in term of formability and physical properties. Coal biomass ash was used as a replacement for clay at 25, 50 and 75% by weight. These are appropriate mix proportions based on the specifications in the Thailand Industry Standard (TIS), inasmuch as bricks can be made and burned at temperature 600, 900 and 1100ºC with little damage to their formation. Furthermore, the burning conditions and processes were modified based on phase change concept of composite materials. The microstructure and required standard of the modified clay brick were experimentally investigated. The test results showed that coal biomass ash has great potential as a replacement for clay because the properties of fired-clay bricks were improved by using coal biomass ash.

KEYWORDS: Fired-clay bricks, High weight ratio, Formability, Coal-biomass ash.

1. Introduction

Based on a simple manufacturing process and the use of cheap and abundant raw materials (clay, sand and water), clay bricks are one of the most used building materials [1]. Brick is an extremely old building material, known to have been used in the Mesopotamia region since the third millennium BC. The term “brick” encompasses a wide number of products obtained by mixing clay, preparing and moulding it, before slow drying and finally firing in an oven [2]. However, with the recent development of more reliable materials, bricks come across technical limits because of their weight and limited thermal resistance [1]. Over the past decade, building brick development has moved toward reducing brick weight and increasing its thermal insulation ability. The number of inner pores in building bricks is a critical factor in constructing modern green buildings [3]. Energy can be saved in buildings by using materials that have a high resistance to heat [4-6]; and thus it is necessary to improve on existing bricks in order to create options that are more resistant to fire and have the ability to bear more weight. To date, based on the criteria of high heat resistance and high bearing ability, standard bricks have been the most suitable material. However, to meet the needs of contemporary construction an additional criterion comes into play: construction materials must be relatively light [7]. However, producing fired-clay bricks consumes lots of clay, which is a matter of some concern, as the country’s farming is based on land with high clay content. To save cultivated land, reduction in the use of clay in fired-clay bricks production should be addressed [8].

The recycling of by-products and wastes is an increasingly major problem for the future of humanity. One of the major byproducts is coal fly ash, which is produced in significant amounts in the world [9]. More than 800 tons per day of combined coal biomass ash may be produced by a typical plant in Thailand. The ash must be properly stored to prevent spreading and subsequent air and environmental problems in the communities surrounding the plants. Currently, the ash is warehoused, leading to excessive storage costs [10]. On the other hand, coal biomass ash, which is solid waste produced by thermal power stations, has not been utilized effectively. In particular, the large amount of coal biomass ash in a wet state occupies a lot of land and pollutes the environment, and it is difficult to use in cement and concrete because of its low quality and high water content. However, it is possible to use coal biomass ash as a raw material to replace clay in fired-clay bricks. There are some advantages using fly ash as raw material of bricks. For example firing energy can be saved because of the amounts of carbon contained in fly ash [8,9].

2. Materials and methods

2.1 Materials

Clayey soil obtained from the Ayutthaya province, Thailand, was used in this study. In addition, coal-biomass ash (CBA) from a thermal power plant that uses coal and biomass from Prachinburi province, Thailand, as a main fuel was also used throughout. The chemical composition of the soil is given in Table 1.

Table 1 Chemical composition of clay and biomass (%wt.).

Materials	SiO_2	Al_2O_3	C_aO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	TiO_2	LOI
Clay	72.26	12.53	0.52	5.75	1.91	0.58	0.05	0.50	0.09	0.74	5.14
CBA	47.39	20.51	9.05	6.71	1.50	1.35	0.08	0.63	0.32	0.97	8.63

The content of SiO_2 in coal biomass ash (47.39 %wt.) is lower than that in clay (72.26 %wt.), but the content of Al_2O_3 in coal biomass ash (20.51 %wt.) is much higher than that in clay (12.53 %wt.). Scanning electron micrographs images (SEM) of (a) Clay and (b) Coal biomass ash as shown in Figure 1.

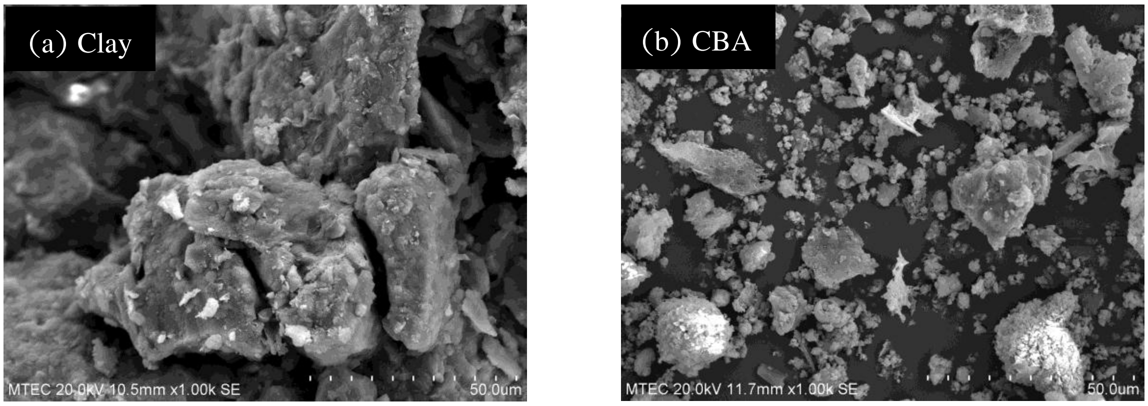

Figure 1 Scanning electron micrographs images (×1000) of (a) Clay and (b) CBA.

2.2 Unfired bricks making

For the brick mixtures, clayey soil was ground using a mechanical grinding machine. The particle size distribution of each of these mixtures was compared to the CBA particles as presented in Figure 2. The mix proportions of the bricks with and those without CBA are summarized in Table 2.

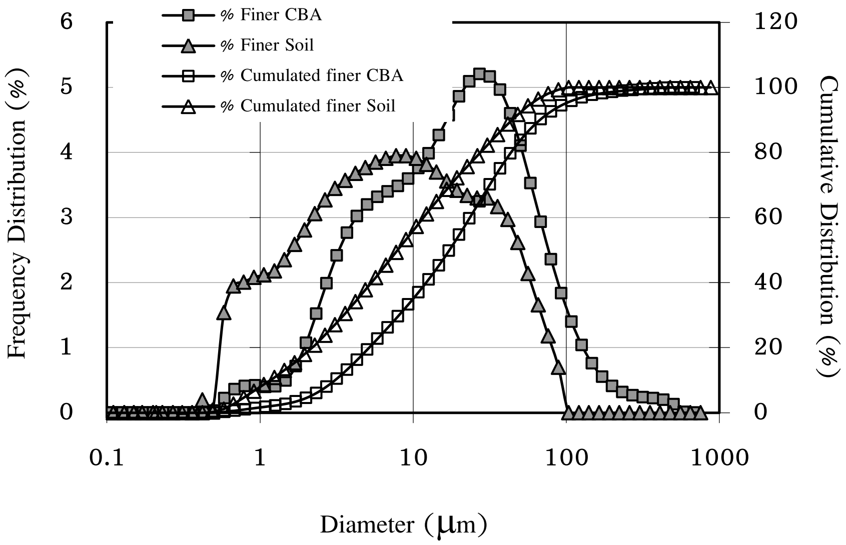

Figure 2 Particle-size distributions of clayey soil and CBA particles.

Table 2 Details of Brick mixtures.

Brick type	Materials (%wt.)	
	Clay	CBA
FB0	100	0
FB25	75	25
FB50	50	50
FB75	25	75

2.3 Heating program and testing procedures

The control brick samples (FB0) and the bricks containing the coal biomass ash as a replacement for clay at 0, 25, 50, and 75%, respectively, were used to form what looked like typical bricks, as presented in Figure 3. They were then dried at 110^0C for 4 hours and heated in electrical furnace as shown in Figure 4 to temperatures held constant at 600^0C for the 25% biomass ash brick, 900^0C for the 50% CBA brick, and 1100^0C for the 50% biomass ash brick for 3 h with a heating rate of 10^0C/minute as shown in Figure 5.

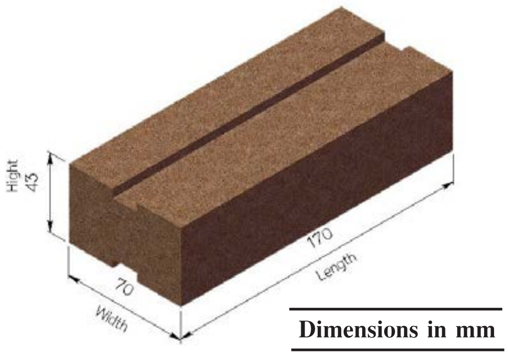

Figure 3 Typical brick specimen

Figure 4 Electrical furnace

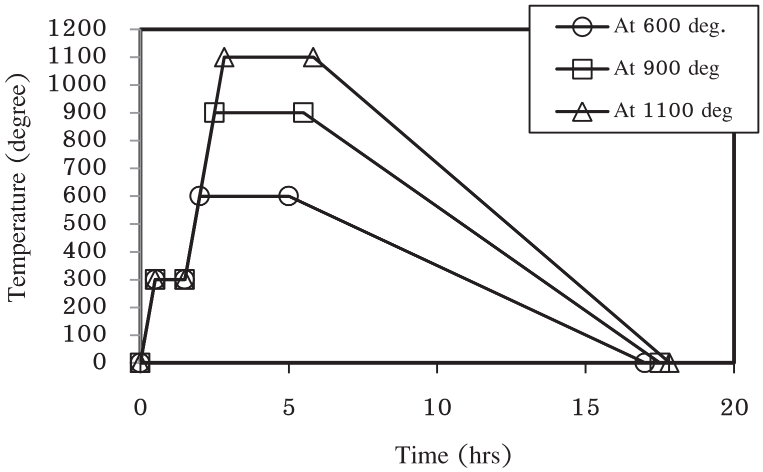

Figure 5 Heating program of bricks.

After burning, each brick sample was measured to determine the extent of its weight loss, and the weight loss was reported in percentage terms. Additionally, a microstructural characteristic was used to determine the microstructure and morphology of the samples in order to establish the optimization proportion.

3. Results and discussion

3.1. Water requirement

The required quantity of water (depending on the brick type) was added to obtain the desired humidity and plasticity that are necessary to avoid defects onto the structure during the process [1]. The water requirement satisfies the formability of all the bricks containing CBA. Figure 6 indicates that the water requirement increases as the amount of CBA increases relative to the amount of clay. When the proportion of CBA in bricks is 75% by weight the water requirement of mixtures increases to 60%, 37% and 12% of 0%, 25% and 50%weight of fly ash. The results indicate that the bricks with high weight ratio of coal biomass ash (till 75%wt) could be casted. The water requirement value increased with the proportion of fly ashes due to the plasticity of the mix decreased with the increment of the proportion of fly ashes [9]. Indeed, the water will preferentially be retained by the biomass and less by the clay particles [1].

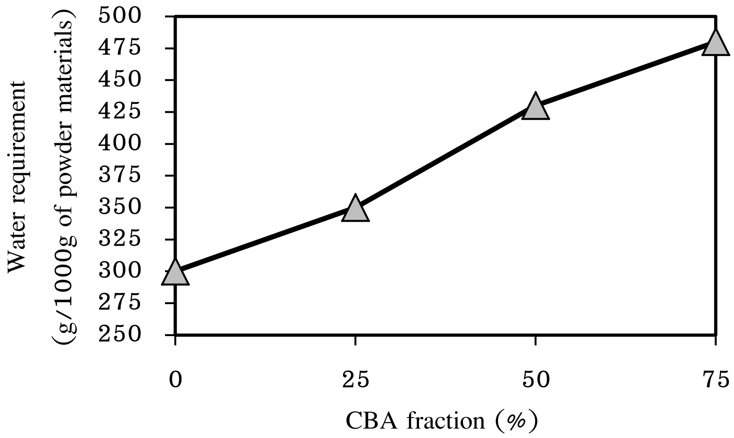

Figure 6 Water requirements of bricks.

3.2. Dimension and weight loss after fired

The dimensions and weight of the bricks after burning are described in Table 3. In terms of dimensions, which represents the change in dimensions of the material before and after drying, is a critical property. Indeed, a large contraction of the sample could create tension and breakage [1]. From the result, some of the bricks increased in size. However, as CBA replaced a greater percentage of the clay, the CBA bricks did not show any clear trend in regard to dimension loss. This may have been because CBA particles can resist the whole internal structure of brick better than clay when water molecules are induced outwards after the brick has shrunk. The shrinkage of samples as a result of sintering. CBA mixtures sintered at 1100 ^{0}C had shrinkage of approximately 10%. Shrinkage increased with sintering temperature [3]. When firing temperature was above 1000 ^{0}C, a little amount of high temperature liquids produced because of some low melting point materials bored in clay and fly ash. The liquid enhances the connecting between particles of clay and fly ash and is favorable for the melting of phases and reacting of components each other. Till 1100 ^{0}C, partial vitrescence was observed in bricks with large shrinkage and deformation [8].

The burning induced less weight loss in the CBA-bricks than in the control bricks. Weight decreased with increasing the temperature and coal biomass ash addition. They also have higher open porosity values [3]. Indeed, during the manufacturing process especially drying and firing steps, biomass particles breakdown leaving pores in the clay matrix, which results in an increase of the bulk porosity. Because of this increase of porosity is also related to a decrease of the bulk density of the material, as air is lighter than clay [1]. When coal biomass ash was added, the brick density was significantly lower, because of the lower density of the additive compared to that of bricks [2]. Fired bricks with a high replacing ratio of fly ash was lighter than fired clay bricks, that is favorable for the building [8].

Table 3 Weight and dimension loss after fired

Fired-clay brick	Fired temp. [ºC]	Dimension loss (%) Width	Length	Height	Weight loss (%)
FB0	600	5.57	4.22	5.83	8.58
	900	4.90	3.85	4.26	24.29
	1100	3.21	3.01	7.52	25.48
FB25	600	0.91	0.32	1.04	8.56
	900	3.60	2.76	3.26	24.88
	1100	5.13	5.27	6.84	26.36
FB50	600	1.28	0.58	0.93	13.74
	900	2.34	1.95	2.26	33.73
	1100	13.84	8.25	12.33	33.95
FB75	600	0.15	0.13	10.65	7.96
	900	2.23	1.82	2.81	10.84
	1100	9.92	7.04	11.33	37.53

3.3. Microstructural characteristics

With increased heating temperature, the plate shape is the main composition at 600^{0}C and 900^{0}C, whereas a temperature of 1100^{0}C contributes to sinter, resulting in a plate-shaped structure that gives way to a more agglomerated shape. In addition, at 1100^{0}C, bigger pores are generated due to the high level of vapor (moisture at high pressure). This is due to the total or partial melting of clayey particles associated with the escape of trapped gases in the matrix of the samples [2]. In comparing the control bricks and the CBA bricks, we found that at 600^{0}C and at 900^{0}C, the structure did not differ significantly in terms of shape, whereas at 1100^{0}C, Figure 7(a-f) shows thermally induced cracks resulting from the thermal conductivities among the CBA, the clay particles, and the water molecules. In addition, the fly ash particles however do not melt even at temperatures as high as 1000 ^{0}C [2].

The CBA fractions in the clay brick samples after heating at 900^{0}C are given in Figure 7(e). We found that increasing the temperature to 75 %wt. induced a plate-shaped microstate. Some parts of the bricks consisted of CBA particles with a roundish shape. Moreover, the CBA particles in particular showed a spalling off of the outer shell at high temperatures coupled with a more porous inner shell due to the inward absorption of water and subsequently being subjected to heat. As a result, the CBA particles were rapidly pushed out such that the brick as a whole became more porous.

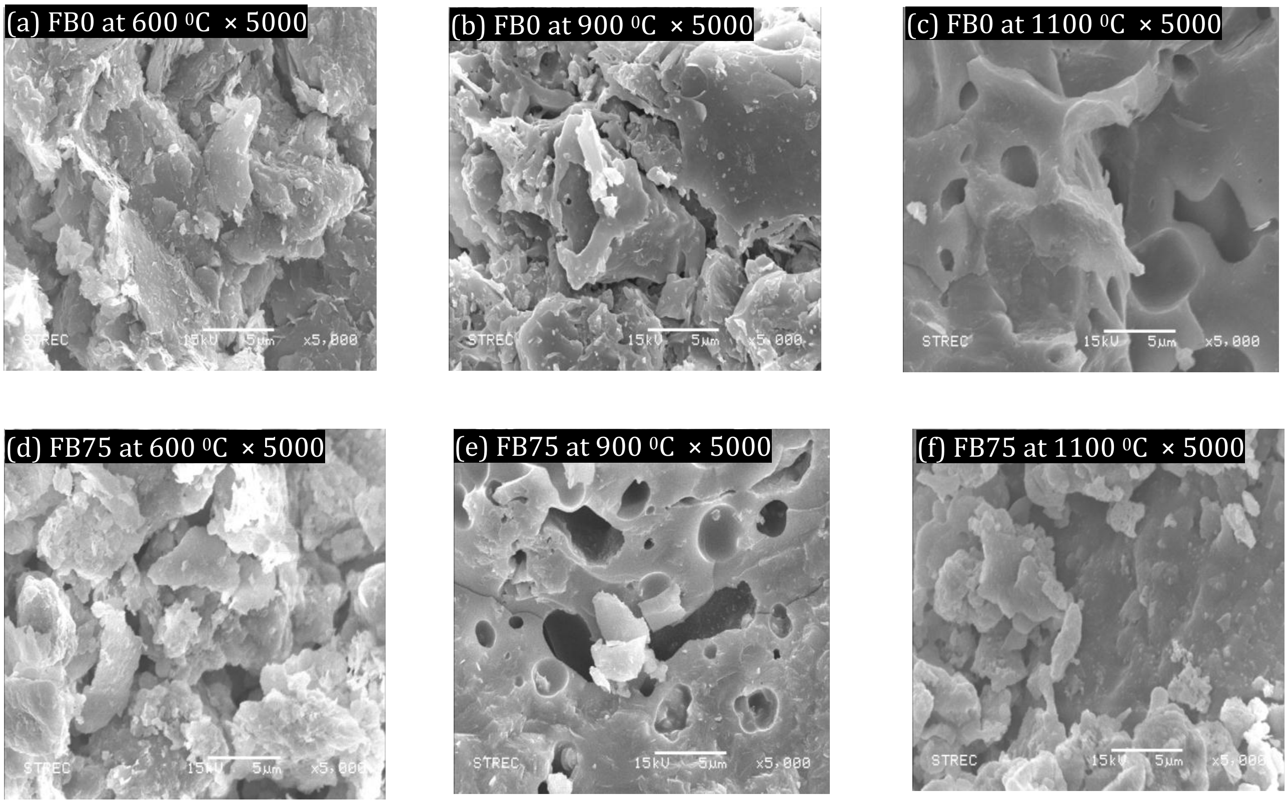

Figure 7 Micrographs of bricks mixed with CBA and without CBA at different heating temperatures.

4. Conclusions

From the experimental results, it can be stated that:

(a) Based on the formation condition, as the amount of CBA increases so the bricks require more water for formability.

(b) The bricks made with CBA were smaller though they showed less weight loss after burning than the control bricks did.

(c) At heating temperatures of 600^{0}C and 900^{0}C, the morphology of the CBA-bricks and the control bricks did differ significantly, and at a 1100^{0}C all the bricks generated an agglomerated shape.

References

[1] Bories, C., Aouba, L., Vedrenne, E., Vilarem, G., (2015). Fired clay bricks using agricultural biomass wastes: Study and characterization. *Construction and Building Materials*. 91, pp. 158-163.

[2] Cultrone, G., Sebastián, E., (2009). Fly ash addition in clayey materials to improve the quality of solid bricks. *Construction and Building Materials*. 23, pp. 1178-1184.

[3] Chiang, K.Y., Chou, P.H., Hua, C.R., Chien, K.L. and Cheeseman, C. (2005). Lightweight bricks manufactured from water treatment sludge and rice husks. *Journal of Hazardous Materials*. 171, pp. 76-82.

[4] Zhihong, Z. (1997). Energy efficiency and environmental pollution of brickmaking in China. *Energy*. 22, pp. 33-42.

[5] González, I., Galán, E., Miras, A. and Vázquez, M.A. (2011). CO_2 emissions derived from raw materials used in brickfactories. Applications to Andalusia (Southern Spain). *Applied Clay Science*. 52, pp. 193-198.

[6] Edmond, G. and Ijaz, H. (2003). Transition from traditional brick manufacturing to more sustainable practices. *Energy for Sustainable Development*. 7, pp. 66-76.

[7] Topçu, İ.B. and IŞikdağ, B. (2007). Manufacture of high heat conductivity resistant clay bricks containing perlite. *Building and environment*. 42, pp. 3540-3546.

[8] Xu, L., Guo, W., Wang, T. and Yang, N. (2005). Study on fired bricks with replacing clay by fly ash in high volume ratio. *Construction and Building Materials*. 19, pp. 243-247.

[9] Leiva, C., Arenas, C., Alonso-fariñas, B., Vilches, L.F., Peceño, B., Rodriguez-galán, M., Baena, F., (2016). Characteristicsof fired bricks with co-combustion fly ashes. *Journal of Building Engineering*. 5, pp. 114-118.

[10] Jidrada, P., Sua-iam, G., Chatveera, B., Makul, N., (2016). Recycling of combined coal-biomass ash from electric power plant waste as a cementitious material: characteristics and improvement . Journal of Material Cycles and Waste Management. 18(3), pp.527-540.