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Effects of organic residues on physical and mechanical properties of fired clay brick

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Abstract

The clay composite and production of fired clay bricks are essential for the sustainability of clay bricks. The aim of this study was to investigate the physical and mechanical properties of fired clay bricks due to effects of organic residues. Sawdust and coffee ground were used as organic residues added into raw brick clay at variation of firing temperatures. Organic residues were conducted with different concentrations of 0, 2.5, 5.0, 7.5 and 10% by weight. The brick clay specimens were fired in gas kiln furnace at 900, 1000 and 1100 ^{o}C. Results revealed that the rising of organic residues obtained the increasing of the open porosity but the bulk density and compressive strength were decreased. The organic residues showed a potential of additives into raw brick clay used in the manufacturing of lightweight fired clay bricks.

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Keywords: fired clay bricks; porosity; compressive strength; residues

1. Introduction

Bricks are wildly used as construction materials in many countries around the world. Clay bricks, the household products made from the local clay in a rural area since ancient time. There are still several historic buildings and ruins left in certain ancient cities displaying different states of deterioration [1]. Properties of bricks are affected as a result of physical, chemical and mineralogical alteration. Compressive strength and water absorption are two major physical properties of brick that are good predictors of brick's ability to resist cracking of face [2]. The additives, mixed in the clay bricks are burning out during the firing process producing extra energy, and decreasing the total energy need of the industrial furnace [3]. Lightweight bricks were usually manufactured by adding combustible additives as a forming size and firing temperature [4]. Most frequent used pore formers in clay brick manufacturing can be classified into two groups: organic and inorganic pore generator. For organic generators, they are sawdust, coal, coke, papermaking sludge, grass and rice husk, and inorganic ones are polystyrene prelate and dolomite or calcite [5]. The porous character of light bricks will increase the

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quality of structures in terms of heat and noise isolation, thereby reducing heating costs in turn affecting environment positively [6]. In this study, an organic residue (sawdust and coffee ground) is used as a pore forming agent for several reasons. Sawdust is a waste from the primary woodworking industry. Sawmills have yields between 50% and 55%; only about half of the volume of wood consumed is transformed into products. Proper use of by-products is thus very important. Sawdust is used primarily in thermal processes (biomass), due to its high content of organic matter, and to a lesser extent for livestock and agriculture. Little work has attempted, however, to develop the use of these wastes in the production of building materials [7]. The main chemical components of sawdust are carbon 60.8%, hydrogen 5.19%, oxygen 33.83% and nitrogen 0.90%. Dry wood is primarily composed of cellulose, lignin, hemicelluloses and minor amounts (5-10%) of extraneous materials [8, 9]. Coffee grounds represent a residue widely generated by the service sector. At present, they are neither recycled nor used as fertilizer in agriculture or for compost production. The main compounds in coffee grounds are K_2O (23.87%), P_2O_5 (23.66%), MgO (22.93%), CaO (13.37%) and Na_2O (8.42%). The other compounds are SiO_2, Al_2O_3, Fe_2O_3, MnO, TiO_2 and SO_3 [10]. The main objective of this study was to investigate the feasibility of the aforementioned types of organic residues on the properties of fired building bricks.

2. Materials and Methods

In order to measure the physical and mechanical properties and feasibility of using organic residues material for brick production, the materials and methods are explained in this section.

2.1 Properties of brick raw material

The clay used in this study was taken from one of the local brick plants in the Maha Sarakham province, Thailand. Chemical analysis of the brick clay was carried out prior to characterization by X-ray fluorescence technique (Horiba Mesa-500 w). The chemical composition of clay is given in Table 1. The mineralogical composition of raw brick clay were achieved using an X-ray diffractometer technique (XRD: X' Pert PRO MPD, Philips, Netherland). The major crystalline phases found in clay were quartz, muscovite, kaolinite, feldspar and hematite. The average particle size distribution of clay was analyzed by diffraction (Mastersizer 2000+Hydro2000 MU, Melvern Instrument Ltd, UK), as shown in Fig 1. Sawdust waste was supplied by sawmill. The coffee ground waste was supplied by the local coffee shop. These wastes were dried for 24 hrs, at 110 ^{o}C to remove moisture.

2.2 Preparation of test specimens

In order to determine the extent of the pore-forming effects of the two residues (sawdust and coffee ground), several different amounts of residues (0%, 2.5%, 5.0%, 7.5% and 10%) were chosen. Each batch of specimens was mixed in a porcelain ball mill in order to ensure homogenous mixing. Then, each was mixed with 25-30% of water to enhance plastic condition of mixture in order to obtain the desired shape when it was formed with brick hand molding into soft-mud rectangular clay brick whose internal dimension was 5.0 cm x 9.5 cm x 3.0 cm. The clay brick specimens were air dried at room temperature for 24 hrs, and then over dried at 110 ± 5 ^{o}C for another 24 hrs to remove water content. Then, each group of green specimens was fired at three different temperatures: 900, 1000 and 1100 ^{o}C with one hour soaking time in gas kiln furnace. The specimens were naturally cooled down to room temperature in the furnace.

2.3 Testing method for the physical and mechanical properties of fired clay bricks

Shrinkage was determined by directly measuring the length of a specimen before and after firing at 900-1100 °C. The linear drying shrinkage and total linear shrinkage of the specimens as a percentage of plastic length, were determined following ASTM standard C326-82.

Physical and mechanical properties such as compressive strength, water absorption, bulk density and apparent porosity of specimens were assessed in accordance with the standard of American society for testing and materials (ASTM) C 773-88 and C 373-88.

Table 1. Chemical composition of the clay (% wt.)

SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	TiO_2	Mn_2O_3	LOI*	Total
59.94	20.84	4.90	0.20	2.20	0.84	1.60	9.30	99.82

*LOI (loss on ignition)

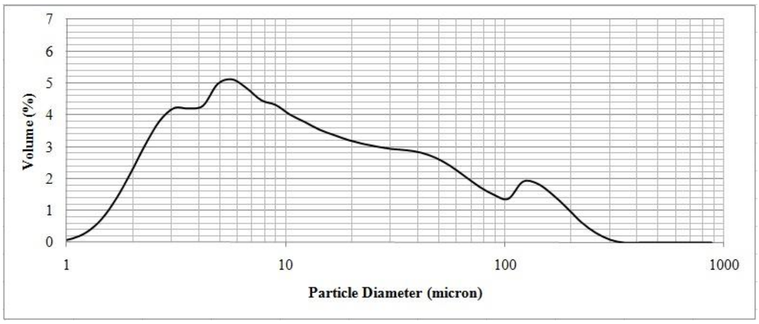

Fig. 1. The average particle size distribution of clay

3. Results and Discussion

The bricks in this research were manufactured from clay and either organic residues (sawdust and coffee ground), residue by controlling the optimum sintering temperatures and residue ratio. The results of the properties of five batches of fired clay bricks are summarized in (Table 2-4). The physical and mechanical properties investigated and reported are firing shrinkage, water absorption, bulk density, apparent porosity, apparent density and compressive strength.

3.1 Characterisation of the fired clay bricks

The linear shrinkage of the bricks is a significant parameter, since large contractions may lead to tension and even to broken pieces [10]. In general, shrinkage used in shaping clay bricks occurs due to the leaving of water from clay body. In other words, when water between clay particles leaves particles come closer and shrinkage occurs [5]. Normally, a good quality of bricks exhibits shrinkage below 8% [11]. In this study, clay bricks were fired at the temperatures rangging between 900 and 1100 °C. The results indicated that shrinkage occurred in the fired clay bricks was in the range of 3.45 – 6.05% (sawdust) and 3.34 – 6.12% (coffee ground). Table. 2 indicated the percentage of shrinkage rises with an increasing in the amounts of organic residues addition.

Table 2. The percentage of shrinkage of fired clay bricks with the variation of organic residues content at an increasing in firing temperatures

Organic residues content (%)	Sawdust			Coffee ground		
	900 °C	1000 °C	1100 °C	900 °C	1000 °C	1100 °C
0	3.45	4.10	4.71	3.34	3.88	4.03
2.5	3.18	4.32	4.94	4.01	4.27	4.33
5.0	4.27	5.11	5.27	4.73	4.87	4.95
7.5	4.83	5.70	5.53	5.07	5.21	5.30
10	5.24	5.96	6.05	5.26	5.47	6.12

The bulk density, water absorption, apparent porosity and apparent density as a function of residues content and firing temperatures in the 900 - 1100 °C, temperature range is shown in Table 3. All of the properties measured showed changes depending on the sintering temperature and the type and content of the organic wastes. The density of clay bricks depends on several factors which are specific gravity of the raw material used, method of manufacturing and degree of burning [5]. As the density of a clay brick decreases, its strength also decreases, but its water absorption increases. In this study, the bulk density of fired clay bricks was inversely proportion to the quantity of wastes added in the mixture. The bulk density of specimens decreased with an increasing in the amounts of wastes ranging from 2.5 to 10%. The bulk density of specimens increased with an increasing in firing temperature. As a result, they bulk density in the ranges of (1.27 g/cm^3) to (1.57 g/cm^3) of sawdust while the, coffee ground was 1.33 to 1.57 g/cm^3 fired at 900 – 1100 ^{o}C (Table 3). The bulk density is related to durability and water absorption of bricks.

The water absorption is a key factor affecting the durability of bricks and is an indirect measure of open porosity [10]. When water infiltrates bricks, it decreases the durability of bricks. Thus, the internal structure of bricks must be dense enough to void the intrusion of water. To increase density and decrease water absorption of bricks, the firing temperature must be raised [12]. In this study, the amount of wastes additive in clay bricks fired at lower temperature (900 ^{o}C) increased the water absorption rate in a linear manner. On the contrary, when clay bricks with higher amounts of wastes additive were fired at a high temperature (1100 ^{o}C), the water absorption of fired clay bricks decreased. According to Table 3, the water absorption of fired clay bricks fired at the temperatures between 900 and 1100 °C was 18.46 - 32.17% sawdust and 16.76 – 29.84% coffee ground.

Water absorption was directly proportional to the apparent porosity. Therefore, similar trends were observed in water absorption and apparent porosity. The study yields that fired clay bricks showed various apparent porosity depending on the amount of wastes addition. Results show the highest porosity was 45.33% with 10% of sawdust addition, and the lowest porosity was 31.36% with 2.5% sawdust addition. Results revealed that the rising of organic residues obtained the increasing of the open porosity but the bulk density and compressive strength were decreased. The using of coffee ground addition indicated the highest porosity at 40.13% and the lowest porosity at 27.63%. The porosity in fired clay bricks observed in this study was occurred when wastes additive was burnt out during firing process. Conclusively, the apparent density varied depending on the amount of wastes addition in clay body and firing temperatures. Table 3 shows the physical properties of fired clay bricks with the variation of organic residues content at an increasing in firing temperatures. Results reveal that the apparent density of clay bricks were 1.77 to 2.45 g/cm^3 when used sawdust and coffee ground as the additives. The increasing in firing temperatures was also increased the apparent density of clay bricks. However, when the percentages of wastes content were decreased, the apparent densities were also decreased.

Table 3. The physical properties of fired clay bricks with the variation of organic residues content at an increasing in firing temperatures

Organic residues content (%)						
Properties	Temperature (°C)	0%	2.5%	5.0%	7.5%	10%
Water absorption (%) Sawdust	900	21.20	24.13	23.36	29.42	32.17
	1000	19.17	21.11	24.42	27.33	29.96
	1100	17.20	18.46	21.43	25.14	27.66
Coffee ground	900	19.16	22.40	25.00	27.36	29.84
	1000	17.33	19.21	21.15	24.64	28.80
	1100	15.44	16.76	19.31	22.01	25.43
Apparent porosity (%) Sawdust	900	32.27	35.41	39.24	41.01	45.33
	1000	31.87	33.74	37.18	39.89	42.20
	1100	29.76	31.36	35.40	37.76	40.27
Coffee ground	900	29.16	33.42	34.40	37.61	40.13
	1000	27.26	28.81	31.92	34.16	36.86
	1100	25.38	27.63	29.44	31.43	33.18
Bulk density (g/cm^3) Sawdust	900	1.53	1.47	1.38	1.30	1.27
	1000	1.61	1.53	1.47	1.35	1.30
	1100	1.66	1.57	1.53	1.48	1.37
Coffee ground	900	1.50	1.46	1.41	1.37	1.33
	1000	1.58	1.51	1.47	1.40	1.38
	1100	1.62	1.57	1.50	1.46	1.43
Apparent density (g/cm^3) Sawdust	900	2.31	2.16	1.97	1.85	1.77
	1000	2.50	2.47	2.31	2.26	2.19
	1100	2.67	2.54	2.44	2.38	2.26
Coffee ground	900	2.43	2.37	2.28	2.15	2.07
	1000	2.52	2.44	2.36	2.30	2.27
	1100	2.64	2.57	2.48	2.37	2.41

Compressive strength is a mechanical property used in clay brick specifications. It has assumed great importance for two reasons. Firstly, with a higher compressive strength, other properties such as flexure, resistance to abrasion, etc., are also improved. Secondly, while other properties are relatively difficult to evaluate, the compressive strength is easy to determine [13]. The compressive strength of ceramic materials is the most important engineering-quality index for building materials [10]. According to the TISI-77 standard, the compressive strength of bricks must be 3.5 MPa [14]. In this study the result indicated that the strength of clay bricks greatly depended on the amount of wastes additive and the firing temperature. The results of compressive strength (Table. 4) indicated that compressive strength of fired clay bricks increased with increasing in firing temperature. An increasing in compressive strength was due to a decreasing in porosity and an increasing in bulk density with an increasing temperature. Table 4 shows the compressive strength of fired clay bricks with the variation of wastes content at an increasing in firing temperatures. The range of compressive strength of 8.77-18.27 MPa was observed when used sawdust as the additive. The using of coffee ground as the additive obtained the range of compressive strength of 8.86-15.16 MPa.

Table 4. The compressive strength (MPa) of fired clay bricks with the variation of organic residues content at an increasing in firing temperatures

Organic residues content (%)	Sawdust			Coffee ground		
	900 ^oC	1000 ^oC	1100 ^oC	900 ^oC	1000 ^oC	1100 ^oC
0	14.36	16.40	18.27	12.74	14.83	15.16
2.5	13.16	14.64	16.48	11.86	13.21	14.70
5.0	10.35	12.16	13.36	10.48	11.36	12.84
7.5	9.85	10.48	11.57	9.74	10.22	11.16
10	8.77	10.11	10.81	8.86	9.67	10.42

*Thai Industrial Standards Institute (TISI-77) Compressive strength is 3.5 MPa

4. Conclusion

The organic residues i.e. sawdust and coffee ground were showed a potential of additives into raw clay bricks in this study. The addition of organic residues is mainly designed to produce lightweight and more porous fired clay bricks. Firing clay bricks specimens between 900 and 1100 ^oC and increasing the content of the organic residues addition lead to increases in the shrinkage and water absorption. In addition, the rising of organic residues content in clay bricks was increased the apparent porosity. It was found that the apparent porosity was occurred when organic residues was burnt out during firing process. However, the compressive strength obtained in this study was 18.27 MPa that higher than the required strength of the TISI-77 which required 3.5 MPa. Generally as the porosity amount increases, the strength properties decrease in the traditional ceramic system. Conclusively, the results revealed that organic residues could be regarded as a potential addition to raw materials used in the manufacturing of lightweight fired clay bricks.

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References

[1] Phonphuak N. Effects of additives on physical and thermal insulation properties of construction brick. Ph.D. Thesis, Thesis, Chiang Mai University 2011.

[2] Karaman S, Ersahin S, Gunal H. Firing temperature and firing time influence on mechanical and physical properties of clay bricks. *J Sci Ind Res* 2006;**65**:153-159.

[3] Viktor B, László AG. Improvement of insulation properties of conventional brick products. *J Mater Sci For* 2008;**589**:1-6.

[4] Kung YC, Ping HC, Ching RU, Kuang LC, Chris C. Lightweight bricks manufactured from water treatment sludge and rice husks. *J Hazard Mater* 2009;**171**:76-82.

[5] Karaman S, Gunal H, Ersahin, S. Quantitative analysis of pumice effect on some physical and mechanical properties of clay bricks. *J Appl Sci* 2008;**8**:1340-1345.

[6] Yüksel A, Mehmet AY, M Sadrettin Z, Ahmet AK. Using phosphogypsume and boron concentrator wastes in light brick production. *Const Build Mater* 2007;**21**:52-56.

[7] D Eliche Q, F.A. Corpas L, L Pérez V, F.J. Iglesias G. Recycling of sawdust, spent earth from oil filtration, compost and marble residues for brick manufacturing. *Const Build Mater* 2012;**34**:275-284.

[8] Demir I. Effect of organic residues addition on the technological properties of clay bricks. *Waste Manag* 2008;**28**:622-627.

[9] Horisawa S, Sunagawa M, Tamai Y, Matsuoka Y, Tohru Miura T, Terazawa M. Biodegradation of nonlignocellulosic substances II: physical and chemical properties of sawdust before and after use as artificial soil. *J Wood Sci* 1999;**45**:492-497.

[10] D Eliche Q, C martíez G, M.L. Martínez C, M.T. Cotes P, L Pérez V, N Cruz P, F.A. Corpas I. The use of different forms of waste in the manufacture of ceramic bricks. *J Appl Sci* 2011;**52**:270-276.

[11] Weng CH, Lin DF, Chiang PC. Utilization of sludge as brick materials. *Adv Environ Res* 2003;**7**:679-685.
[12] Phonphuak N, Thiansem S. Using charcoal to increase properties and durability of fired test briquettes. *Const Build Mater* 2012;**29**:612-618.
[13] Okunade EA. The effect of wood ash and sawdust admixtures on the engineering properties of a burnt laterite-clay brick. *J Appli Sci* 2008;**8**:1042-1048.
[14] TISI 77, Standards specification for building brick (Solid masonry unit made from clay or shale) *Thai Industrial Standards Institute*, 1988, p. 3.