EFFECT OF SAND ADDITION ON THE PROPERTIES OF CLAY BODY FOR TRAGUAN POTTERY

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Received: April 10, 2017; Revised: September 10, 2017; Accepted: September 14, 2017

Abstract

This research shows the effect of the addition of sand on the properties of the clay body for Traguan pottery. The sand content was mixed with Traguan pottery clay in the ratios of 5-30 wt%. The green samples were fired at 800, 1,000, and 1,200°C for 30 min. It was found that the addition of quartz of 5 wt% affected the improvement of the bending strength of the fired ceramics because of the stable sand structure. However, large sand particles resulted in the deterioration of the densification with an addition higher than 5 wt% and caused a lower bending strength. Therefore, the optimum bending strength (24.8 MPa) of fired clay was obtained with the addition of sand of less than 5 wt%.

Keywords: Sand, clay body, pottery, property, ceramic

Introduction

Traguan pottery is one of the secondary occupations that can make an income for the Ban Traguan community in Srirattana district, Sisaket province in Thailand. The main products are non-glazed ceramics such as pots, vases, and lamps. Although the clay can be formed into different shapes due to the behavior of its plasticity property, high shrinkage of the clay leads to deformation in the ceramics after the drying and firing processes. This effect is due to the fine particles and the fluxing agent phase in the clay that causes a lower melting point. This problem can be improved by the addition of sand into the mixture because the stability of sand can reduce the shrinkage process (Alonso-Santurde *et al.*, 2012, 2011). In the traditional Traguan process, Traguan clay is loaded into the extruding chamber, while sand is added to the mix in an irregular amount. This has the effect of generating large cracks after firing at 800°C, leading to an increase in the manufacturer's costs. Therefore, the objective of this research is aimed at studying the optimum sand addition in the preparation of the clay mixture. Both the clay and sand in the different ratios were mixed before the extrusion process and the fired biscuit-coloured ceramics were studied for their physical and mechanical properties.

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Materials and Methods

The clay for pottery from Ban Traguan, Srirattana district in Sisaket province in Thailand was used in this research. Traguan clay and sand were sieved through a No. 40 mesh sieve (425 µm). Chemical analysis of the clay was carried out prior to its characterization by the X-ray fluorescence technique with a Mesa-500w X-Ray Fluorescence Analyzer (Horiba Ltd., Kyoto, Japan). The mineralogical composition was identified by the X-ray diffraction (XRD) technique with an X'Pert PRO MPD (PANalytical B.V., Almelo, Netherlands) in a 2θ range of 5-70° with a step size of 0.0084°. Additions of 5, 10, 15, 20, 25, and 30 wt% of sand to the clay body were made to the mixture. The plasticity of the clay mixtures in all the compositions was formed into cylinder shapes by hand extrusion with a diameter of 10 mm. The length of the cylinder samples was about 6 cm so that they could be bent for consideration of crack defects. Rectangular test specimens, with a length of 100 mm, width of 20 mm, and thickness of 10 mm, were prepared by pressing in a plaster mold with approximately 22-32 wt% of water. The specimens were dried at 110°C until a constant weight was achieved. These specimens were then fired in an electric laboratory furnace at 800, 1000 and 1200°C, with 30 min at the soaking temperatures. The heating/cooling rate was 3°C/min. Water absorption and the bulk density of the fired samples were measured following ASTM C 373-88 (ASTM, 2002). The 3 point bending strength was determined using a 5566 Universal Testing Machine, (Instron, Norwood, MA, USA).

Results and Discussions

Characteristics of Clay Powders

The particle size of the Traguan clay (7.040 µm) was smaller than the size of the sand particles (383.54 µm). This implied that large sand particles would improve the shrinkage of the clay after the forming and firing processes (Grimshaw, 1971; Kingery *et al*., 1991). The chemical compositions of the Traguan clay and sand are shown in Table 1.

The sand composition has high SiO_2 of 98.924%. The clay's composition indicates mainly SiO_2 and Al_2O_3 which corresponds to the presence of XRD patterns of kaolinite and quartz, as shown in Figure 1. The high content of Fe_2O_3 (6.148%) and TiO_2 (1.319%) had the effect of the dark brown color that is characteristic in Traguan pottery. The shade of the biscuit-coloured ceramic depends not only on the Fe_2O_3 content but also on the firing conditions (Rahaman, 1995; Singer and Singer, 1963). The XRD pattern of Traguan clay is shown in Figure 1. It was found that the structure was indicated mainly as quartz mineral, while the peak patterns of kaolinite were slightly observed. It is well known that kaolinite is distinguished by its 1:1 layer structure (Deer *et al*., 1992; Murray, 2007; Ryan, 1978).

Plasticity of Clay

Different amounts of sand were mixed into the Traguan clay with the weight ratio of 5-30% (Table 2). Water was then added into the composition for the improvement of the plasticity. However, the addition of the water content was different depending on the sand composition. The large particles and non-plasticity behavior of the sand led to the lower water content.

Figure 2 shows the plasticity test of the mixtures. Cracks were observed with the increasing sand composition. The clays mixed with 0-10%wt of sand had a smooth surface. Although cracking was slightly generated in the clays mixed with 15-25%wt of sand, the clays could be formed by the throwing method. In contrast, deformation of the shape of the pottery appeared in the clay mixed with 30%wt of sand. This result corresponded to the non-plasticity of the sand's properties (Grimshaw, 1971; Ryan, 1978).

Physical Properties

The clay mixed with different sand contents was fired at 800-1200°C and resulted

Table 1. Chemical composition of the raw materials (wt%)

Material	Oxide composition (%wt)								
	SiO_2	Al_2O_3	K_2O	Na_2O	MgO	CaO	Fe_2O_3	TiO_2	ZrO_2
Sand	98.324	0.053	-	-	-	-	1.207	0.413	-
Clay	70.801	20.499	1.107	-	-	0.081	6.148	1.319	0.045

Table 2. The mixed clay with different sand additions

Formula	Clay: Sand	wt% of water
1	100:0	31.93
2	95:5	28.91
3	90:10	28.27
4	85:15	26.59
5	80:20	25.51
6	75:25	25.23
7	70:30	22.76

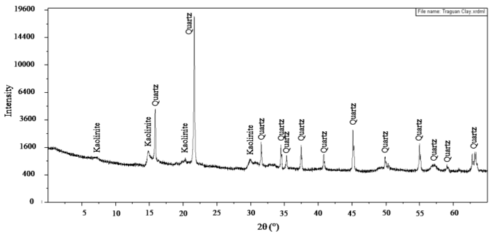

Figure 1. X-ray diffraction of Traguan pottery clay

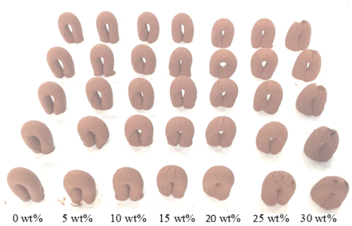

Figure 2. The plasticity of the clay mixture

in the linear shrinkage values shown in Figure 3. The shrinkage values of the clay mixtures tended to decrease with a higher sand content in the range of firing temperatures between 800-1200°C. As regards the firing temperature, the linear shrinkage values were significantly increased due to the volatility of the steam in the clay structure.

The water absorption values of the clay mixtures are shown in Figure 4. At 800°C and 1000°C, all the clay mixtures had similar shrinkage values because of the lower vitrification points of clay and sand. This was related to the bulk density results of the fired samples at 800°C and 1000°C (Figure5) in which it was seen that the bulk density was slightly decreased. However, both the water absorption and bulk density were obviously changed after being fired at 1200°C. It was found that the water absorption increased, while the bulk density decreased with the increasing sand content. This was explained by the vitrification of the sand particles being slower when compared with the clay material (Shackelford and Doremus, 2008). Therefore, lower densification was observed for the clay mixture that had a higher sand content.

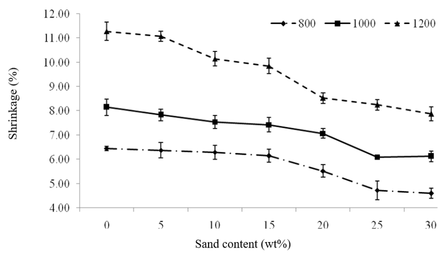

Figure 3. Linear firing shrinkage of the clay mixtures at the different firing temperatures

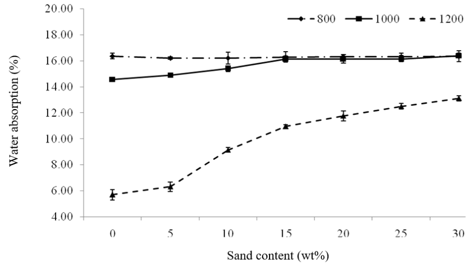

Figure 4. Water absorption of the clay mixtures at the different firing temperaturesclay

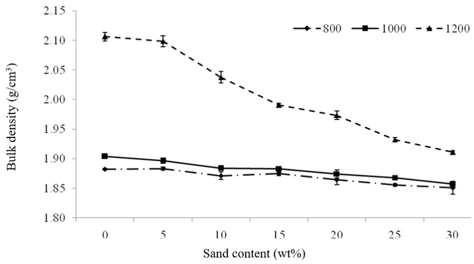

Figure 5. Bulk density of the clay mixtures at the different firing temperatures clay

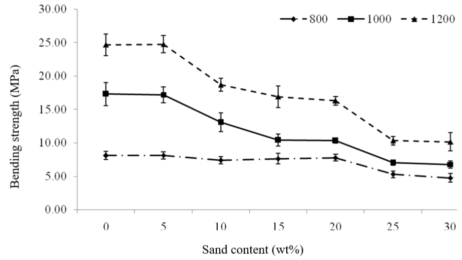

Figure 6. Bending strength of the clay mixtures at the different firing temperatures

Additionally, the vitrification of the sand was still affected by the low densification for the clay mixtures with high sand contents.

As regards the bending strength, the fired samples at 800, 900, and 1000°C are shown in Figure 6. The clay mixed with 5%wt of sand addition had almost no effect on the bending strength of the fired samples. However, the bending strength distinctly deteriorated after the addition of sand at more than 5 wt%. This effect was clearly correlated to the low densification of the clay mixtures.

It is known that the strength depends on the densification of the samples because porous defects are an essential variable for deterioration of the strength values (Ece and Nakagawa, 2002; Alonso-Santurde *et al*., 2011). With regard to the effect of the firing temperature, the bending strength was improved with the increasing temperature due to the higher densification behavior.

Conclusions

The difference in the sand content in Traguan clay was responsible for its physical and mechanical properties. The clay mixed with 5 wt% sand could be slightly affected in relation to the densification and strength after being fired at 1,200°C. However, the bending strength obviously decreased with the increasing sand content of more than 5 wt% due to lower densification. The optimum sand addition was achieved for the clay mixed with less than 5 wt%.

Acknowledgments

The author would like to thank the National Research Council of Thailand and Sisaket Rajabhat University for the financial support of this work.

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