

DEVELOPMENT OF DAN KWIAN CLAY FOR USE IN CERAMIC TILE INDUSTRY

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Abstract

The serious problem for pottery villages in Thailand, especially Dan Kwian village, is the falling prices of products due to oversupply. The aim of this work is to develop the properties of Dan Kwian clay for use in the production of ceramic tiles for which there is a big market. Feldspar and quartz were used to improve the firing properties of Dan Kwian clay. The compositions of the mixture were designed by a tri-axial diagram. The samples were formed by uniaxial dry press, and were sintered at 1200°C for 1 h. The results show that by adding a small amount of feldspar, i.e. 10 mass%, the firing properties of Dan Kwian clay are significantly improved and are useable for ceramic tiles.

Keywords: Dan Kwian, Dan Kwian clay, ceramic tiles, Dan Kwian tiles, ceramic tile industry

Introduction

Dan Kwian is a famous pottery village in Thailand located in Chok Chai district, Nakhon Ratchasima province. Most products of Dan Kwian are unglazed earthenware, and are made from Dan Kwian clay. Dan Kwian clay is a kind of secondary clay, red in color, which has high plasticity and a high firing strength. Although Dan Kwian clay has useful properties for producing various kinds of ceramic products, most factories in Dan Kwian produce only pottery. Nowadays, the falling prices of such products are a serious problem for Dan Kwian. The causes are the intense market competition and oversupply of products.

Numerous researchers have tried to improve the prices of Dan Kwian products by developing

a new glaze, changing the fabrication process, and changing the fuel of Dan Kwian kilns (Srilomsak *et al.*, 2006; Rattanachan, 2007; Jongpleumpiti and Tangchaichit, 2011; Raksorn *et al.*, 2013; Srilomsak *et al.*, 2014). However, the problems of Dan Kwian have not been solved because the new knowhow totally changes the original process and is too complicated for the businesses in Dan Kwian. Moreover, all the research works still focused on the old product, i.e., pottery, the sales of which cannot be increased in because the market is not strong enough. Therefore, a simple production process and a larger distribution market are the solutions to sustainably solve the problem for Dan Kwian.

Ceramic tiles are products used in the

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construction and building industry, are required in large numbers, and have a wide market distribution. In addition, the processing of ceramic tiles is not complicated, can be done on a small or large scale, and can be produced by hand or with high technology machines.

The aim of this work is to develop ceramic wall and/or floor tiles from Dan Kwian clay. Feldspar and quartz are used to improve the firing properties of the Dan Kwian clay.

Materials and Methods

Dan Kwian clay from Dan Kwian was dried in an oven at 150°C for 24 h before being milled by disc mill and then was passed through a sieve number 120 mesh to obtain the powder of Dan Kwian clay. The other raw materials used in this work included feldspar powder and quartz powder (Sibelco Minerals (Thailand) Co. Ltd., Pathum Thani, Thailand). The particle size of the feldspar powder and quartz powders was 45 μm . All raw materials were dried at 150°C for 24 h before being packed into a brass cone mold. The packed powder was heated to 1200°C, at a heating rate of 5 K/min, and a soaking time of 1 hour; after that, the cone height had changed and

was measured to examine the fusion of the raw materials.

Dan Kwian clay powder, feldspar powder, and quartz powder were mixed in a porcelain mortar. The ratios of the mixture were designed by a tri-axial diagram as shown in Figure 1. The powder mix was uniaxially pressed into a rectangular shape under 15 MPa for 30 sec, then was sintered in the electric furnace at 1200°C, at a heating rate of 5 K/min, and a soaking time of 1 h. The sintered samples were cut into a size of 5 mm \times 5 mm \times 30 mm for testing the water absorption (Wa) and flexural strength (σ).

Water absorption of the fired samples was measured following the International Organization for Standardization (ISO) standard 10545-3 (ISO, 1995). The samples were immersed in water and held in a vacuum chamber of 100 kPa for 30 min to fill up the open pores with water. Flexural strength was measured by the three-loading method (Universal Testing Machine model 5565, Instron Corp., Norwood, MA, USA) according to ISO standard 10545-4 (ISO, 2004). Chemical compositions of the Dan Kwian clay were evaluated by X-ray fluorescence (XGT-5200 X-ray Analytical Microscope, Horiba Ltd., Kyoto, Japan).

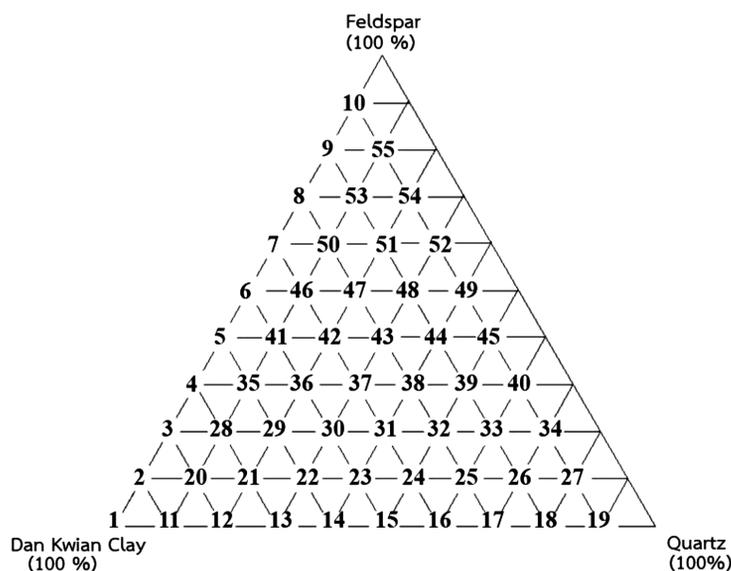


Figure 1. Tri-axial diagram used to design the mixture compositions

Results

The chemical compositions of Dan Kwian clay are shown in Table 1. Silica (SiO₂) is the main composition, i.e., 72.95 mass%. Table 2 shows the raw material fusion test. The cone heights of the feldspar and Dan Kwian clay collapsed 26% and 12%, respectively. The cone height of quartz does not change after firing.

Water absorption of the Dan Kwian clay after firing is 8.2%, and is reduced by adding feldspar, as illustrated in Figure 2. By adding feldspar 10 mass%, the water absorption of Dan Kwian clay is reduced to 6%, and it continuously declined with increasing the amount of feldspar. On the other hand, Figure 2 shows that quartz increases the water absorption of the Dan Kwian clay.

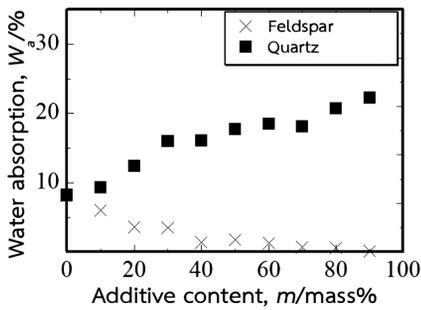


Figure 2. Water absorptions of the fired mixtures for different additive contents

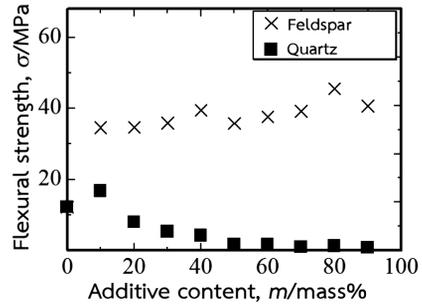


Figure 3. Flexural strengths of the fired mixtures for different additive contents

Table 1. Chemical compositions of Dan Kwian clay

Compounds	Content (wt%)
SiO ₂	72.95
Al ₂ O ₃	18.76
K ₂ O	1.02
CaO	0.38
MgO	1.19
TiO ₂	0.84
Fe ₂ O ₃	4.72
Other	0.14

Table 2 Raw material fusion test at 1200°C for 1 h

Raw materials	Cone height changed (%)
Dan Kwian clay	12
Feldspar	26
Quartz	0

The flexural strength of the Dan Kwian clay after firing is 12.2 MPa, and is significantly increased by adding feldspar, as shown in Figure 3. By adding feldspar 10 mass%, the flexural strength of the Dan Kwian clay is 34.5 MPa. On the other hand, quartz reduce the flexural strength of the Dan Kwian clay.

By using feldspar combined with quartz to improve the firing properties of Dan Kwian clay, the flexural strengths of the compositions

that are located close to the quartz area are lower than the flexural strengths of the compositions that are located close to the feldspar area, as illustrated in Figure 4. Likewise, the water absorptions of the compositions that are located close to the quartz area are higher than the water absorptions of the compositions that are located close to the feldspar area, as illustrated in Figure 5.

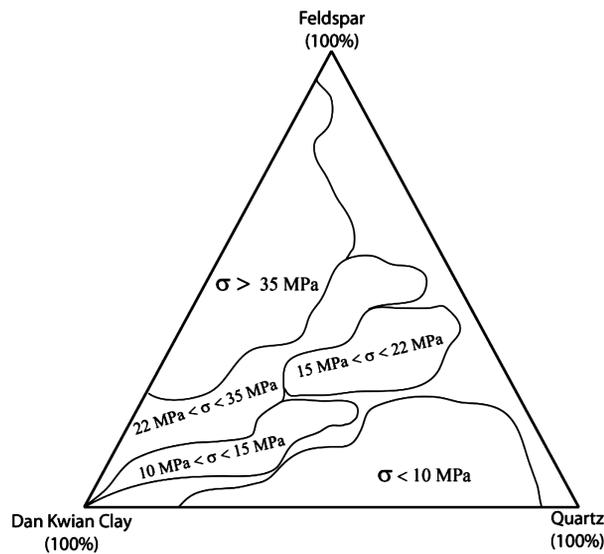


Figure 4. Flexural strength areas of the fired mixtures

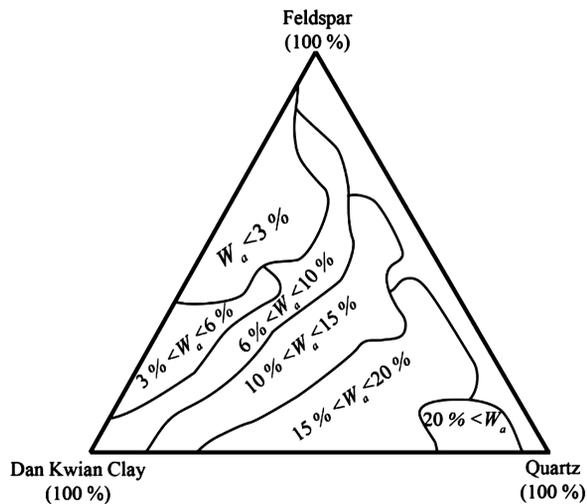


Figure 5. Water absorption areas of the fired mixtures

Discussion

Although, numerous properties are required for ceramic tiles, the most important properties are strength and water absorption. Table 3 shows the ISO standard for flexural strength and water absorption of ceramic wall tiles and floor tiles (ISO, 1998), and demonstrates that Dan Kwian clay cannot be used alone for producing ceramic tiles, because the flexural strength and water absorption of Dan Kwian clay does not correspond to the ISO standard. Feldspar is a flux material, is melted at the sintering temperature, and increases the liquid phase in the fired samples. The liquid phase fills up the pores in the samples during the firing process. Therefore, by adding feldspar, the flexural strength of Dan Kwian clay is significantly increased, while the water absorption of Dan Kwian clay is reduced. In contrast, quartz is a heat resistant material, and it increases the

sintering temperature. The unique property of Dan Kwian clay is that it has a high quartz (SiO_2) content. The evidence in this work agrees well with the result of the previous study by Rattanachan (2007). As a result, by adding a small amount of quartz, the firing strength of Dan Kwian clay is significantly reduced, while the water absorption of Dan Kwian clay is increased.

Figure 6 shows the areas of compositions that are suitable to be used for producing ceramic wall tiles or floor tiles, and there is feldspar in all of the compositions. By adding feldspar 10 mass%, the fired sample is useable for both ceramic wall and floor tiles. Ceramic wall tiles are not required to have the same high strength and low porosity as ceramic floor tiles. Consequently, the combination of quartz and feldspar can be used to modify Dan Kwian clay for making ceramic wall tiles. There are not any

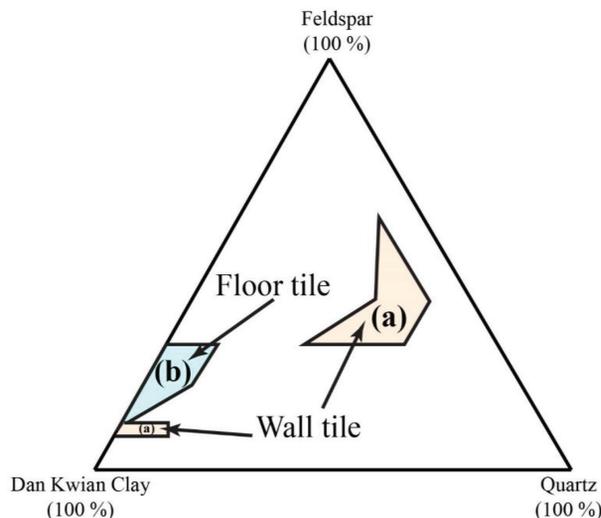


Figure 6. Areas of compositions which are useable for producing (a) wall tiles and (b) floor tiles

Table 3. International standard for ceramic wall tile and floor tile according to ISO 13006 (ISO, 1998)

Type of ceramic tiles	Properties	
	Flexural strength	Water absorption
Ceramic floor tile	> 22 MPa	3% - 6%
Ceramic wall tile	> 15 MPa	> 10%

compositions between quartz and Dan Kwian clay that can be used for producing ceramic floor and wall tiles.

Conclusions

The results in the present work show that Dan Kwian clay is a useful raw material for use in the ceramic tile industry. By adding a small amount of feldspar, i.e., 10 mass%, the firing properties of Dan Kwian clay are significantly improved and are functional for ceramic wall and floor tiles. Quartz increase water absorption, while reduce the firing strength of Dan Kwian clay. The mixture between quartz and Dan Kwian clay cannot be used for making both ceramic wall and floor tiles. If quartz is used as a raw material, feldspar is required in the compositions to modify the properties of Dan Kwian clay for the production of ceramic wall tiles.

The knowledge in this work opens an opportunity to utilize Dan Kwian clay for making a new product besides pottery, and introduces a new raw material source for the ceramic tile industry.

Acknowledgements

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