DEVELOPMENT OF RED WALL TILE COMPOSITION BY DRY GRINDING PROCESS WITH EXPERIMENTAL DESIGN METHOD

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ABSTRACT

In this study, an attempt was made in order to develop a red wall tile body with the dry process. In order to achieve this, experiments were designed as $2^4 3^1$ multi-level factorial design, individual effects of the main five factors (temperature, clay 1, clay 2, clay 3 and feldspar) and their interactions were determined. 24 formulations were prepared with territorial clays and feldspar (Turkey). The samples were ground at laboratory hammer mill and unidirectional dry pressed in a die with rectangular cavity (50 mm x 100 mm) .The samples were fired at 1100ºC and 1135ºC using a fast firing cycle in a laboratory roller kiln. The samples were characterized before and after firing by using XRD, EDX and SEM. The physical properties (linear shrinkage, flexural strength and water absorption) were measured. Results were analyzed by MINITAB 14 statistical software program. The preliminary experimental results showed that it was possible to obtain a dry ground red wall tile body with the properties in accordance with ISO-EN 10545.

1. INTRODUCTION

Ceramic tiles are commonly produced from a mixture of raw materials containing clay, flux, and refractory filler. Each raw material within the body formulation contributes differently to the final properties. A broad range of products varying in dimensions, strength, apparent porosity, surface texture, decorative coatings and overall quality are produced by the tiles industry[1].

The wall tiles are characterized by high porosity, low expansion by moisture adsorption, and high dimensional stability. These properties are acquired through the formation of certain crystalline phases during the firing stage, such as calcium silicates and aluminosilicates (gehlenite, anorthite, wollastonite), as a result of the reaction between decomposition products of the clays and calcium oxide, introduced normally as calcite[2].

Most of the energy is consumed in the grinding operations for ceramic industry. Dry milling of ceramic raw materials offers advantages in comparison with the wet milling process. The dry grinding process is an energy saving process. The dry process strongly diminishes the thermal consumption because the spray dryers are not used at this process[3-4]. Regarding energy saving, the dry process strongly diminishes the thermal consumption. A small amount of thermal energy is used in the mills to avoid make dirty the rollers by agglomerations formed by condensation of moisture from the raw materials[5]. And also with dry grinding; no need of processing additives, and reduced maintenance and environmental impact[6].

2. EXPERIMENTAL METHODS AND MATERIALS

Red wall tile recipes prepared according to the mixed-level factorial design. $2^4 3^1$ mixed-level factorial design with three replications was utilized in the experiments. Clay 1 has 3 (65-70-75) and clay 2 (10-20) clay 3 (0-5), Na-Feldspar (20-25) and temperature (1100 - 1135ºC) have 2 levels. According to X-ray spectra of raw materials, clay 1, clay 2 and clay 3 mainly contain quartz, illite, kaolinite and calcite, Na-feldspar contain albite and quartz.

3. RESULTS AND DISCUSSION

From the ANOVA table for flexural strength, effective main factors are clay 1, clay 2, and temperature. The effective interactions are clay 1*Na-feldspar, clay 1*clay 2, clay 1*clay 3, Na-feldspar*clay 2, clay 2*clay3 and clay 1*clay 2*clay 3* Na-feldspar. Firing temperature with 66.9 % is the most significant main factor for flexural strength. With the rising of firing temperature, the response increases. In the Figure 2, there is a peak point for clay 1 at medium value; the maximum flexural strength is obtained at this point. One of the effective interaction is clay 2*clay 3. Clay 2 is sensitive for response at clay 3 high level when it decreases the strength increase. Clay 3 is proportional to the flexural strength; when clay 3 increases strength improves. At the Na-feldspar*clay 2 interaction; when the clay 2 is at low level and the Na-feldspar is at high level, much higher strength value is obtained. So, Na-feldspar value is determined as high level (Figure 1). For maximum flexural strength; formulation is, clay 1 is medium level, clay 2 is at low level, clay 3 is at high level and Na-feldspar is at low level. It is known that porosity decreases mechanical strength by effectively reducing the materials cross sectional area. Pores can concentrate stress and reduce the flexural stress necessary to the rupture. The best criterion to indicate the reduction of porosity is bulk density.

Generally, the higher the bulk density the higher the modulus of rupture (MOR). MOR is the most widely used method to characterize the mechanical behaviour of traditional ceramic bodies due to its simplicity and is calculated by the three- and four-points methodologies[7-8]. According the ISO-EN 10545, when thickness of the wall tile is lower than 7.5 mm, MOR values must be higher than 15 N/mm^2 and experimental for unglazed tiles results show that the MOR values are lower than 15 N/mm^2. For double firing process when the tile fired with glaze (glost firing) the flexural strength rise about 4-5 N/mm^2. So that, the flexural strength values at 1135ºC will be appropriate for ISO-EN 10545.

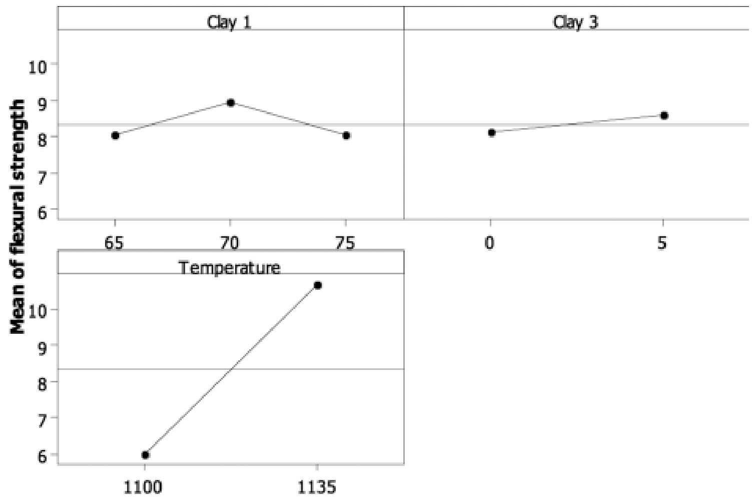

Figure 1. Main effects plots for mean flexural strength value.

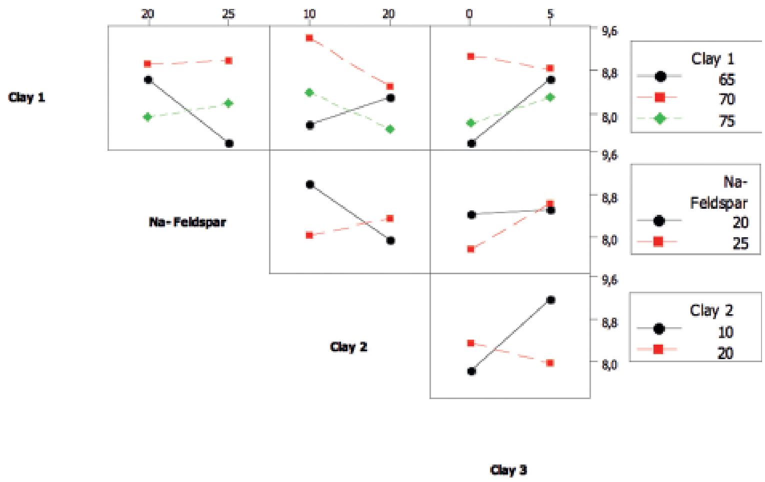

Figure 2. Two factor interaction for mean flexural strength value.

4. CONCLUSIONS

Red wall tiles had been produced from dry ground local clays which contain high amount of illite. The red wall tiles meet ISO-EN 10545 standard requirements. High flexural strength value was obtained at 1135ºC; using clay 1 is at medium level, clay 2 is at low level, clay 3 is at high level and Na-feldspar is at low level. Because the production was realized without using a spray dryer, CO_2 emission and energy consumption were decreased.

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