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Research Article

Sintering and Technological Properties of Dry Pressed Ceramic Body Containing Kastamonu Mud and Clay

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Abstract

Kastamonu is a city built on the valley of Karacomak River in Turkey. There is a mud which is used inside of the kiln for repairing kiln bricks. In this study, Kastamonu mud (KM) and clay were used in the ceramic recipe as raw materials to produce dry pressed ceramic bodies. Firstly, chemical compositions of used raw materials were determined by using XRF analysis. Ceramic mixture containing Kastamonu mud and clay was prepared. It was mixed for 3 hours. Prepared mixture was dried and granulised by using sieve. Afterthen Kastamonu mud containing 20 wt% and 30 wt% clay were shaped by dry pressing method using metal mold with 45 MPa pressing pressure. The samples were then sintered at 1050, 1100 and 1150 sintering temperatures. Green and sintered density, firing shrinkage and water absorption of samples were determined. Sintered density of the samples were measured by Archimed method. It was concluded that this material with the addition of clay can be used as a new ceramic raw material due to its suitable technological properties at 1150°C sintering temperature. Some coloured glaze recipes were applied on to the Kastamonu mud (KM) containing 20 wt% clay body sintered at 1150°C. Especially, this dry pressed body is suitable for industrial forms with its artistic glazes. Sintering and technological properties such as density, water absorption, firing shrinkage of each body were measured. Scanning electron microscopy (SEM) studies were carried out to analyse the microstructure and to see ceramic body-glaze interactions. The best firing shrinkage, water absorption and density values were obtained with KM 20 samples sintered at 1150°C as 12.9%, 5.2% and 2,57 g/cm^3, respectively.

Key Words: Ceramic, Kastamonu Mud, Technological Properties, Sintering, Dry Pressing.

1. Introduction

Different shaping method can be used for different kinds of mud or clay in producing ceramic. Dry pressing is a common way to shape ceramic parts (Donzel et.all, 2018). It is one of the most popular shaping processes, includes a relatively simple technology while allowing high production rates . In uniaxial compaction, the stress is applied by a punch in a mould whose side walls can not move. This process allows the fabrication of rather complicated shapes (Bortzmeyer, 2012).

Clays and most of the ceramic mud include alumina, silica, small quantities other minerals. Red mud contains alumina, silica, magnesia, iron oxide and some other minerals (Atkin, 2005).

Demirkol (Demirkol, 2017) studied forming of ceramics by dry pressing method and characterization of it. She used a Kınık (Pazaryeri-Bilecik) red mud. Red mud granules were dry pressed at 45 MPa pressing pressure in her study. Green samples were sintered at between 900-1000°C.

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Villarejo et. all (Villarejo, 2012) studied the production of new materials based on clay and red mud derived from the aluminium industry. Their aim was to produce ceramic materials by adding the red mud into a ceramic matrix and neutralizing this mud in the matrix itself.

Babisk et.all. (Babisk, 2014) studied properties of clay ceramic incorporated with red mud. They used dry pressing method for shaping and sintered the samples at 750, 950 and 1050°C.

Demirkol et. all (Demirkol, 2016) found a new ceramic raw material. It is a Kastamonu mud (KM) which is used inside of the kiln for repairing kiln bricks. In their study, Kastamonu mud was used alone and in the ceramic recipes as a raw material to produce slip casted ceramic. They used 40 vol. % solid content slip for all cast samples. Kastamonu mud alone and containing 20 wt.% and 30 wt. % clay were shaped by slip casting method using plaster mold. Prepared samples were then sintered at 1050, 1100 and 1150 °C sintering temperatures. According to their results of study, KM is not suitable for making ceramic on its own due to cracking after heat treatment. But when it is formed with clay it is a good ceramic material for artistic applications. KM containing 20 wt% clay sintered at 1150 °C showed the best water absorption, density and firing shrinkage as 7,3 %, 2,45 g/cm^3 and 11,1%, respectively. This raw material can be considered as cheap sources of alumina and silica.

This paper presents sintering and technological properties of dry pressed ceramic body containing Kastamonu mud which is a new ceramic raw material and clay. The effects of clay addition to KM for industrial applications and some glaze studies were examined. Optimum clay amount and sintering temperature were determined with best technological properties.

2. Materials and Methods

Kastamonu mud (KM) ceramic raw material found by Demirkol et.all. (Demirkol, 2016) was used in this study as a main raw material to produce dry pressed ceramic bodies. Its chemical analysis was performed by XRF at Kocaeli University. Table 1 shows the chemical analysis of KM. As seen in Table 1 it includes Si, Al, K, Na, Mg, Fe as a main elements of mud. Fe_2O_3 gives the mud color which is between red and yellow.

Table 2 exhibits the chemical analysis of used clay. The clay was obtained from Eczacibasi Esan Company. It composed of mainly SiO_2 and Al_2O_3. Plasticity of Kastamonu mud is very low. This clay improves the plasticity of it. In this case, the dry pressed green samples extrude from the metal mold at unbroken form.

Table 1: *Chemical Analysis of Kastamonu Mud*

Element	% wt	Element	% wt	Element	% wt
O	49,10	Si	28,10	K	1,28
Na	1,29	P	0,05	Ca	0,65
Mg	2,18	S	0,13	Ti	0,02
Al	9,99	Cl	0,05	Fe	7,15

Table 2: *Chemical Analysis of Used Clay*

Element	% wt	Element	% wt	Element	%wt
SiO_2	60,46	K_2O	2,56	NiO	0,01
Al_2O_3	33,15	CaO	0,50	Rb_2O	0,02
P_2O_5	0,10	TiO_2	1,67	SrO	0,07
SO_3	0,17	Fe_2O_3	1,27	ZrO_2	0,02

A water-based slurry was prepared by mixing the Kastamonu mud, clay and polyvinyl alcohol (PVA) as binder. It was mixed for 3 hours. The aqueous suspension containing 60 wt.% KM, clay mixture and 0.5 wt.% binder was spray dried. Afterthen Kastamonu mud containing 20 wt% and 30 wt% clay were shaped by dry pressing method using metal mold with 45 MPa pressing pressure, separately. Metal mold with 75x7x4 mm dimensions was used to produce rectangular flexural strength samples. Pellets were prepared with 3 mm diameters to measure density, water absorption and firing shrinkage. Then all samples sintered at 1050, 1100 and 1150 °C sintering temperatures.

Sintered density of samples were measured by using Archimed method.

3. Results and Discussion

In this study, technological properties of dry pressed KM20 and KM30 ceramic bodies were examined. Table 3 shows the (a) firing shrinkage (b) water absorption (c) density of KM20 and KM30 sintered at different sintering temperatures. Firing shrinkage increased with increasing sintering temperature and it decreased with increasing clay addition in Kastamonu mud due to lower density of clay. KM20 ceramic body at 1150°C sintering temperature showed the highest shrinkage value as 12.9%.

During uniform drying where the rate of surface evaporation is equal to the transport rate of water through the sample walls, shrinkage occurs. During solid state sintering, particles having a contact surface are fused by diffusional effects, decreasing further the amount of closed porosity causing further shrinkage (Erkmen, 2016).

Table 3: *(a) Firing Shrinkage (%) (b) Water Absorption (%) (c) Density (g/cm ^{3}) KM20 and KM30 Sintered at Different Sintering Temperatures.*

(a)

Sintering Temperature (°C)	KM20 (%)	KM30 (%)
1050	9,8	7,2
1100	10,6	8,9
1150	12,9	10,9

(b)

Sintering Temperature (°C)	KM20 (%)	KM30 (%)
1050	9,6	10,8
1100	7,0	8,3
1150	5,2	7,1

(c)

Sintering Temperature (°C)	KM20 (g/cm^3)	KM30 (g/cm^3)
1050	2,28	2,13
1100	2,48	2,30
1150	2,57	2,42

Water absorption values of samples decreased with increasing sintering temperature and it increased with increasing additive clay as expected. Also, porosity level decreased with increasing sintering temperature,. The lowest water absorption value was obtained as 5,2 vol. %. with KM20 sintered at 1150°C.

Density values of KM20 and KM30 increased with increasing sintering temperature and it decreased with increasing clay addition. The best density value was obtained as 2,57 g/cm^3 with KM20 ceramic body sintered at 1150°C.

(a)

(b)

Figure 1: *Glazed Form of KM20 samples (a) containing black copper oxide (b) containing iron oxide.*

As a result increasing sintering temperature porosity level and consequently water absorption decreased similar to Demirkol et. all's (Demirkol, 2016) study. In their study, they produced slip casted KM20 and KM30 as a new ceramic material. They obtained the best values of firing shrinkage, water absorption and density as 11.1%, 7.3% and 2.45 g/cm^3 with slip casted KM20 ceramic sintered at 1150°C.

It is concluded that to produce Kastamonu mud ceramic containing 20 wt.% clay sintered at 1150°C by dry pressing method is given more good technological results than to produce it by slip casting method.

Glazed form of KM20 samples were produced. Two glaze recipes from literature (Tacyildiz, 2018) were prepared and applied onto the KM20 bodies sintered at 1150°C. Figure 1a is including black copper oxide and Figure 1b is including iron oxide as a color transmitter. Harmony of KM20 ceramic body and glaze is good. This KM20 ceramic mud is a good candidate for industrial and artistic applications.

Thanks to this study, it is aimed to mention the city of Kastamonu with ceramics.

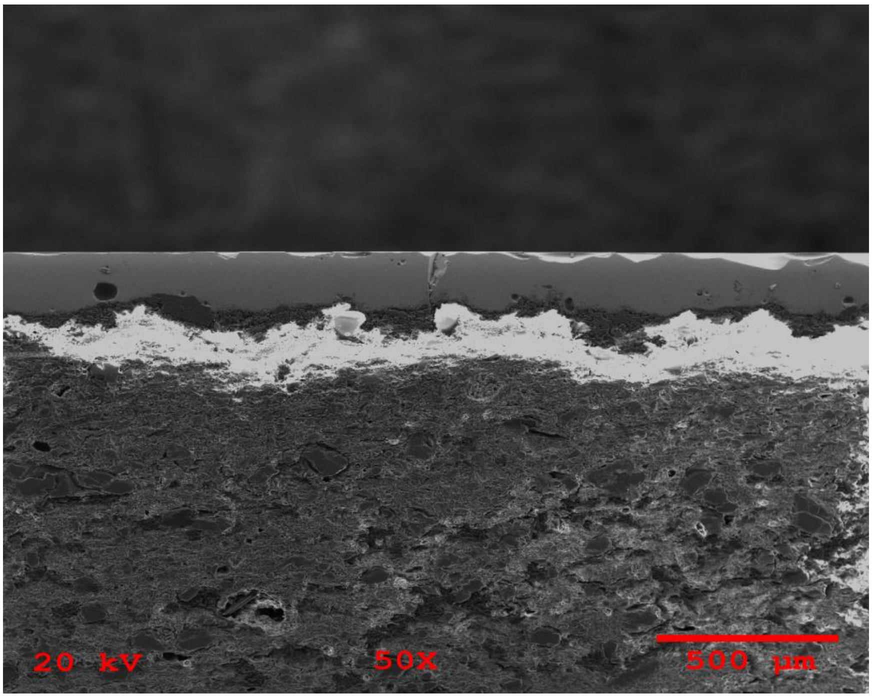

Figure 2: *SEM photography of glazed KM20 ceramic sintered at 1150°C.*

Figure 2 shows the SEM photography of glazed KM20 ceramic sintered at 1150°C. Glaze and ceramic body interaction is good and there isn't any crack at the glaze surface.

4. Conclusions

In this study, sintering and technological properties of dry pressed ceramic body containing Kastamonu mud and clay were investigated. The following conclusions were obtained.

Kastamonu mud (KM) containing 20 wt.% clay sintered at 1150°C showed better technological properties than Kastamonu mud (KM) containing 30wt.% clay sintered at 1150°C.

Firing shrinkage increased with increasing sintering temperature in two ceramic bodies. The highest shrinkage value was obtained as 12.9% with KM20 ceramic body sintered at 1150°C.

Water absorption values of Kastamonu mud ceramics containing different amount of clay decreased with increasing sintering temperature and it increased with increasing clay amount. The lowest water absorption value was obtained as 5,2 vol.% with KM20 sintered at 1150°C.

The best density value was obtained as 2,57 g/cm^3 with KM20 ceramic body sintered at 1150°C.

According to literature dry pressed KM20 and KM30 ceramic bodies sintered at 1150°C showed higher technological properties than slip casted KM20 and KM30 ceramic bodies sintered at 1150°C.

Dry pressed KM20 ceramic body sintered at 1150°C is suitable for artistic glazes. Harmony and interaction between ceramic body and glaze is very good.

Dry pressed KM20 ceramic bodies sintered at 1050, 1100 and 1150°C are suitable for artistic application and artistic glazes.

Dry pressed KM20 ceramic body sintered at 1150°C is suitable for especially industrial applications.

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