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Ceramic properties of a Turkish clay in the Aydın region

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The aim of this study is to determine the ceramic properties of Karacasu clay (KC) fired at various temperatures. For this purpose, the clay sample was first characterized by chemical analysis, X-ray diffraction (XRD), DTA/TG analysis and plasticity measurements. The mineralogical composition of KC was dominated by illite/mica, kaolinite, smectite, quartz and hematite. DTA/TG analyses showed comparable behaviour to those of illitic clays. The data obtained from plasticity tests indicated that KC was very high plastic clay. To evaluate firing behaviors, pressed clay samples were fired separately at temperatures between 850 and 1200 °C. Fired specimens were evaluated by water absorption, linear shrinkage, bulk density, bending strength, X-ray diffraction (XRD) and scanning electron microscopy (SEM). The results showed that there became a significant densification at temperatures especially above 1000 °C. Based on the technological characteristics, KC could be used in the manufacture of structural ceramics.

Key words: Karacasu clay, Characterization, Firing behavior, Ceramic properties.

Introduction

Clays have been used in many industrial applications for a very long time. One of the main industrial usage of clays is production of ceramics. Applications of the clay minerals depend on their compositions, structures and physical properties. The physical and chemical properties of the clay minerals change with firing temperature and determine its use as an industrial ceramic raw material [1-5].

In the Aegean region of Turkey there are extensive red firing clay deposits. These clays are currently being used for traditional pottery and brick production. In the region of Karacasu, red firing plastic clays are used for the production of pottery. Karacasu has been a center for ceramic production for ages. Nowadays, it still preserves its traditional ways and originality with respect to both form and type of products and production technology [6].

Karacasu clay (KC) is a primary material for the local ceramic manufacturers. Although very limited studies on the quality and potential use of KC have been reported in the literature [6-7], influence of firing temperature on ceramic properties of KC has not been studied.

In this study, ceramic properties of KC were investigated in terms of physical, chemical, mineralogical, and thermal properties and also their ceramic behaviours. These data are very crucial for evaluating their potential suitability as raw materials in various ceramic applications.

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Materials and Methods

In this research, the clay sample was obtained from a deposit located in Karacasu (Aydın). This deposit is representative and currently used for ceramic production.

The clay was characterized by chemical analysis, X-ray diffraction (XRD), DTA/TG analysis and plasticity measurements. The chemical composition of clay samples was analyzed by Atomic Absorbtion Spectroscopy (GBC). The phases present in the samples were identified by X-ray diffraction (XRD) using a Rigaku Model diffractometer with monochromotic CuKα radiation. Thermal analyses of the samples were done by using a Shimadzu DTG-60 H model DTA/TG. The plasticity was measured by the Atterberg limits: plastic limit, liquid limit and plastic index, according to the norms (ASTM, D 4318-10).

In order to enlighten the ceramic properties the technological properties on a laboratory scale, pellet clay samples were used. To produce pellet samples, clay sample was dried and ground. The ground agglomerates were then humidified up to 6 wt.% water. The humid powders were pressed under 150 kg/cm^2 pressure to obtain 100 × 50 × 8 mm prismatic samples. The shaped samples were dried at 110 °C for 24 h and fired at 850-1200 °C using a laboratory kiln (Nabertherm LH 15/14). Fired samples were used to characterize the firing properties of the material. The physical properties were determined according to the standards suggested by ISO 10545-3 and ISO 10545-4. Phase changes with increasing temperature were investigated by X-ray diffraction. The microstructures of the fired samples were analyzed by a scanning electron microscope; SEM (JEOL-JSM 6060).

Results and Discussion

Characteristics of the clay

Table 1 lists the chemical compositions in terms of oxide contents, as well as loss of ignition for KC. This clay consists of mainly SiO_2 and Al_2O_3 which correspond to about 78% because of the presence of clay minerals and quartz. Also, as typical Aegean clay [9], KC consists of significant amount of iron oxide which gives the reddish color after firing [10]. The K_2O content in clay raw material is due to the existence of illite content. Fig. 1 shows the result of XRD analysis of whole rock KC sample. The following mineralogical phases were identified: illite/mica, kaolinite, smectite, quartz and hematite.

One of the main parameters of the usage of the clay in ceramic manufacturing is plasticity. Plasticity of KC sample was evaluated by determining the consistency limits (Table 2). According to the plasticity index value which is a measure of the plasticity of clay, KC can be considered as very high plastic clay. The minimum percentage of moisture to obtain necessary plasticity is defined by plastic limit parameter that is very important for technological processes in terms of drying [11]. High plastic limit value of KC indicates the difficulty for the drying process.

DTA/TG measurements indicate that KC exhibits similar patterns to those of illitic clays (Fig. 2). An endothermic reaction occurs at a temperature of about 100 °C due to the loss of water. At this temperature the weight loss of the sample was 1.76%. Depending on dehydroxylation, another endothermic peak appears at a temperature of about 500 °C. The weight loss associated with this reaction was 2.27%. Above this temperature there is no significant change observed in the DTA plot. The total weight loss was 5.91%.

Table 1. Chemical analysis results of KC.

Oxides (wt.%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	LOI
KC	60.34	17.31	6.64	0.57	0.42	0.49	1.38	1.00	9.78

Table 2. Plasticity parameters of KC clay given by consistency limits.

Consistency limits	Plastic limit (wt.%)	Liquid limit (wt.%)	Plasticity index (wt.%)
KC	28.9	69.8	40.9

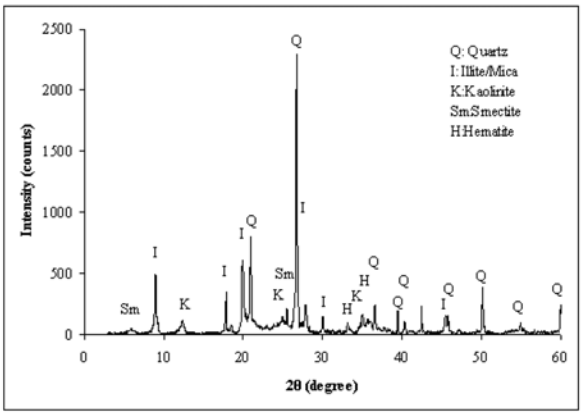

Fig. 1. XRD pattern of the whole rock from KC.

Firing properties

Fig. 3 shows the diffraction patterns of the clay samples after firing for 30 minutes between 850 °C and 1200 °C. During heating decomposition and phase transformation processes take place [1, 8]. At 850 °C, the peak of kaolinite is not seen due to the transformation of kaolinite into metakaolinite. Quartz, hematite and illite peaks are still seen. At 1000 °C it can be seen that the peaks of illite have disappeared and above 1000 °C, cristobalite and mullite phases begin to develop.

In Fig. 4, water absorption and bulk density values of the clay samples fired at different temperatures are shown. As temperatures increases, there becomes a liquid phase formation that reduces the volume of the open pores by penetrating them. The volume of the open pores affects the water absorption values. The water absorption is closely related to densification [1]. The densification behavior of the clay samples is influenced by the flux content (K_2O and Fe_2O_3). Although

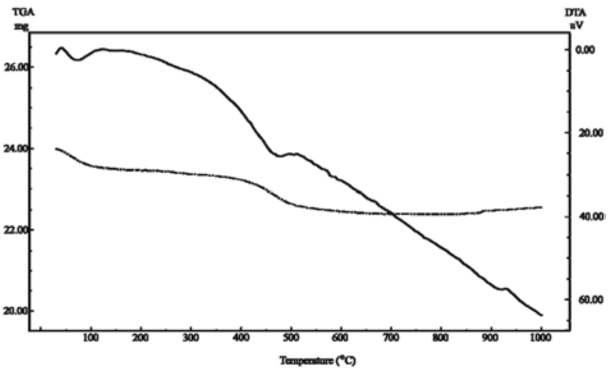

Fig. 2. DTA/TG curves of the clay sample.

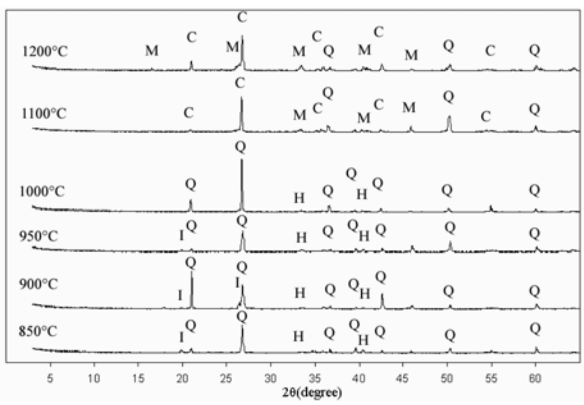

Fig. 3. XRD patterns for KC samples fired at different temperatures (Q: Quartz, I: Illite, H: Hematite, M: Mullite, C: Cristobalite).

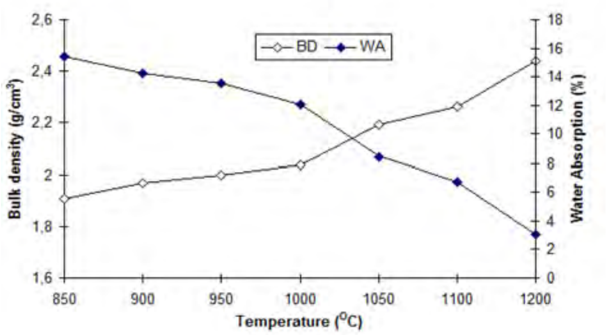

Fig. 4. Bulk density and the water absorption values of KC samples fired at different temperatures.

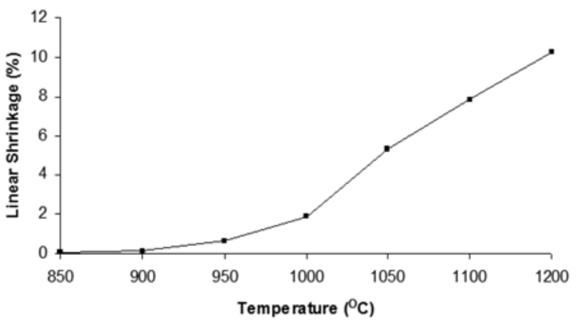

Fig. 5. Linear shrinkage values of the KC samples as a function of firing temperature.

KC has low amount alkaline fluxes (Table 1), it is reasonable to think that the high amount of iron oxide plays a key role on densification. This promotes the formation of glassy phase [10]. As a result, the water absorption values tended to decrease and bulk density values tended to increase with increasing temperature and the greatest tendency was found above 1000 °C. The bulk density values vary between 1.91% and 2.44% while water absorption values are between 15.41% and 3.04%.

The linear shrinkage values behave differently below and above 1000 °C (Fig. 5). This behavior is firmly correlated with the densification behavior discussed above. The bending strength values of KC samples fired at elevated temperatures are given in Fig. 6. It was observed that bending strength values increase with temperature as a result of sintering. The bending strength increases from 2.87 MPa to 22.43 MPa as the clay samples become denser.

Fig. 7 shows the examination of microstructures of the KC samples fired at various temperatures. Between 850 and 950 °C, sample surfaces have microscopic pores and voids. It is reasonable to think that microstructural features remain unchanged up to 950 °C and clay minerals can be seen at their laminar morphology. Above 950 °C one can see the decrease in the porosity and the change of structure due to the beginning of vitrification. At 1100 °C the porosity on the sample

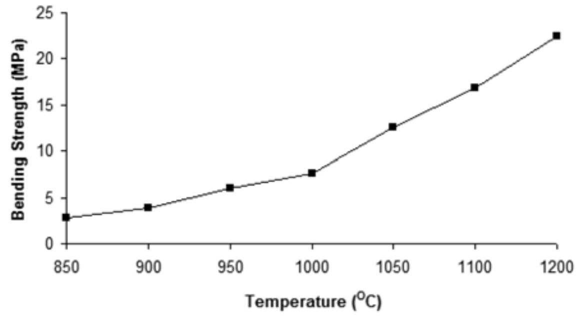

Fig. 6. Bending strength values of KC samples fired at different temperatures.

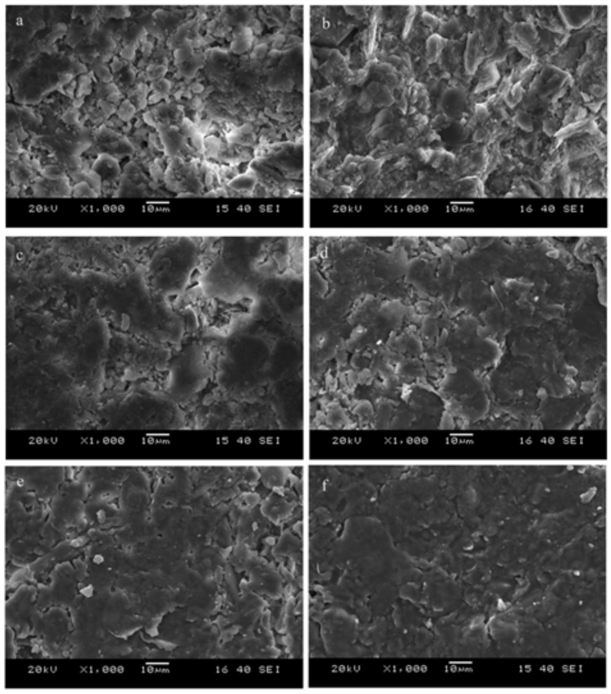

Fig. 7. SEM micrographs of the clay samples fired at: (a) 850 °C, (b) 900 °C, (c) 950 °C, (d) 1000 °C, (e) 1100 °C and (f) 1200 °C.

surface becomes lesser due to the increase of the liquid phase. At 1200 °C the structure is dense.

Conclusions

In this study, the characteristics and the effect of the firing temperature on ceramic properties of Karacasu (Aydın) clay (KC) were investigated. From the results obtained, the following conclusions can be drawn:

The predominant oxides in KC are SiO_2, Al_2O_3 and Fe_2O_3. Illite/mica, kaolinite, smectite, quartz and hematite are found as the main phases. The plasticity index indicated that KC is very high plastic clay that enables KC to form a plastic body. On the other hand, KC has a high plastic limit value that can lead some drying problems.

The firing behaviors of KC were evaluated by water absorption, linear shrinkage, bulk density, bending strength, X-ray diffraction (XRD) and scanning electron microscopy (SEM). The changes in the physical properties were slight up to 950 °C. Especially above 1000icant increase inthe bulk density and linear shrinkage was observed whereas water absorption values decreased. During firing phase trans-formation occurred and ultimate phases obtained were cristobalite, mullite and quartz. SEM micrographs, taken at increasing firing temperatures, show the reduction of porosity and the progression of enhanced densification with increasing temperature.

In view of these evaluations, this raw material is suitable for porous structural ceramics, such as brick, besides pottery production.

References

1. H. Baccour, M. Medhioub, F. Jamoussi, T. Mhiri, J. Mater. Process. Tech. 209 (2009) 2812-2817.
2. B.K. Ngun, H. Mohamad, S.K.Sulaiman, K. Okada, Z.A. Ahmad, Appl. Clay Sci. 53 (2011) 33-41.
3. H. H. Murray, Clay Miner. 34 (1999) 39-49.
4. P. Pıaly, C. Nkoumbou, F. Vıllıé Ras, A. Razafıtıa namaharavo, O. Barres, M. Pelletıer, G. Ollıvıer, I. Bıhannıc, D. Njopwouo, J. Yvon & J-. P. Bonnet, Clay Miner. 43 (2008) 415-435.
5. M.I. Carretero, M. Dondi, B. Fabbri , M. Raimondo, Appl. Clay Sci. 20 (2002) 301-306.
6. S. Çizer, in Second International Ceramics Congress. Vol.1. Traditional Ceramics (1994) Istanbul 482-489.
7. Z. Yayla, in International Conference-Clays, clay minerals and layered materials-CMLM2009 (2009) Moscow, Russia.
8. M. Medhioub, H. Baccour, F. Jamoussi and T. Mhiri, J. Ceram. Process. Res. 11 (2010) 209-214.
9. İ. Özkan, M. Çolak, R.E. Oyman, Appl. Clay Sci. 49 (2010) 420-425.
10. F.A.C. Milheiro, M.N. Freire, A.G.P. Silva, J.N.F. Holanda, Ceram. Int. 31 (2005) 757-763.
11. S.N. Monteiro, C.M.F. Vieira, Appl. Clay Sci. 27 (2004) 229-234.
12. ASTM, D 4318-10, Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils. (2010).
13. ISO 10545-3, Ceramic Tiles-Part3: Determination of Water Absorption, Apparent Porosity, Apparent Relative Density and Bulk Density (2000).
14. ISO 10545-4, Ceramic Tiles-Part4: Determination of Modulus of Rupture and Breaking Strength (2000).