Ghana J. Sci. **47** (2007), 123-129

THE STUDY OF MFENSI CLAY IN THE ASHANTI REGION OF GHANA

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Abstract

Mfensi clay is one of the most useful clay types in the Ashanti Region. In view of its importance, a study has been carried out to determine its characteristics to serve as a guide for local pottery ventures and ceramics industries. Methods used for the study include X-ray fluorescent analysis (XRF), X-ray diffraction (XRD), firing test, plasticity index (Atterberg's method), particle size analysis, thermo-gravitational analysis (TGA), exothermic and differential thermal analysis (DTA), and endothermic analysis (EDA). The study revealed very invaluable information about the following characteristics of Mfensi clay: Chemical composition, Mineral assemblage, Shrinkage, Water absorption, Colour, Refractoriness, Plastic index, Particle size distribution, X-ray diffraction pattern, Combustion, decomposition and evaporation, and Phase transition, crystallization. Mfensi clay was reasonably plastic and when fired at 1100 °C, turned yellowish-brown. The clay is suitable for earthenware and stoneware, apart from bricks and tiles, owing to its high refractoriness.

Résumé

Nsiah, J. K.: *La céramique: Etude d'argile de Mfensi dans la région d'Ashanti du Ghana.* L'argile de Mfensi est l'une de type d'argile la plus utile dans la région d'ashanti. Vu son importance, une étude a été entreprise pour déterminer ses caractéristiques qui serviront d'indication générale pour les entreprises de la poterie locale et l'industrie céramique dans son ensemble. Les méthodes employées pour l'étude comprennent Analyse rayons X fluorescent (RXF), diffraction des rayons X (DRX), essai de cuisson, indice de plasticité (méthode d'Atterberg), analyse de la taille de particule, analyse thermogravitationnelle (ATG), analyse exothermique, analyse thermique différentielle (ATD) et analyse endothermique (AED). L'étude révélait d'information inestimable des caractéristiques suivantes d'argile de Mfensi: la composition chimique; assemblage minéral; le retrait; absorption d'eau; couleur; réfractérité; indice de nature plastique; distribution de taille de particule; dessin de diffraction des rayons X; la combustion, la décomposition, l'évaporation ; transition de phase, cristallisation. L'argile de Mfensi était de la nature plastique raisonnable et quand elle était cuite à 1100 °C, elle se changeait en brune jaunâtre. L'argile est approprié pour la poterie et les pots de grès à part les briques et les tuiles en raison de ses réfractérités élevées.

Introduction

Before any ceramic material like clay is used, either on its own or as a component part of a body, it is important that proper scientific analysis is carried out for understanding and acceptance.

It is worth noting that although Mfensi clay is very important to the pottery industry, no detailed scientific studies have been performed on it.

Since the establishment of the Kwame Nkrumah University of Science and Technology, Kumasi, the Ceramics, Sculpture, Design and Foundation sections, as well as the Department of Rural Art of the College of Art, have depended on this clay for teaching, research and the fabrication of ceramic products.

There is also a number of individuals who have established small-scale industries, producing pottery wares such as water coolers, grinding bowls, palm wine pots, etc., as well as bricks, at Mfensi. One of those people is the late Dr

Kyerematen, the founder of the Ghana National Cultural Centre, Kumasi, who built a cooler factory at Mfensi over 30 years ago (Nsiah, 1979). This study was carried out at the Basic Research Laboratory Analysis Center 1, 2, 3 of the Inax Corporation (a leading ceramic manufacturing company) in the cities of Nagoya and Tokoname, Japan in 1993/1994. The study was aimed at giving the much-needed scientific data required for teaching, research and production purposes, so as to understand the material much better.

Experimental

The term clay is applied both to materials having a particle size of less than 2µm (25,000 µm = 1inch) and to the family of minerals that have similar chemical compositions and common crystal structural (Foley, http://pubs.usgs.gov/info/clays, 2004). Stated more scientifically, it is a hydrous silicate of alumina, that is to say, a compound of alumina and silica chemically combined with water. A theoretical formula of this substance reads $Al_2O_3.2SiO_2.2H_2O$ (Chappell, 1979).

There are two types of clay, namely primary and secondary clays. Primary clays are also called residual clays. They are found in the same vicinity as the parent rock from which they decomposed. Primary clays are basically of one type, the kaolin. Kaolin is extremely refractory clay with a melting point of over 1260 ^{o}C. Secondary clays are those that have been moved from the site of the parent rock by the forces of water, wind, or glacial action (Chappell, 1979). Clay products include bricks, stoneware, pottery, tiles and glazes (Worral, 1986).

Terminology

The thermo gravimetric analysis (TGA) is carried out on the sample to determine their mass change during the firing process. The change in the mass of the sample is measured as a percentage of the weight of the body. Examples of chemical reactions that lead to mass change are combustion, decomposition and evaporation. The differential thermal analysis (DTA) is a chemical process that determines reactions that do not lead to mass changes in a sample. Examples are phase transition and crystallization. This analysis reveals the colour, refractoriness, water absorption capacity and shrinkage properties of ceramic materials (INAX Corporation, 1975).

Thermo mechanical analysis (TMA)

The analysis is a physical measurement process which is carried out to measure the volume or length change of the clay samples. This is done with equipment called the thermo dilatometer. The thermal analysis is very important in investigating the thermal behavior of the ceramic materials that are to be fired in kilns.

Chemical composition

The chemical composition of a clay sample is the main indicator of the properties of the sample. The constituent compounds and their respective influence on clay sample are as follows: (1) Al_2O_3 (Kaolinite) –this is responsible for the refractoriness and plasticity of a sample (Worral, 1986); (2) K_2O and Na_2O – the moisture expansion capacity and the vitreous temperature the sample exhibits; (3) Fe_2O_3 – this constituent determines the colour of the clay sample after firing.

Particle size analysis

This is the determination of the predominant size particles that form a particular clay sample. This analysis is necessary to control the bulk density of the pressed body or fired body. It also helps to determine the amount of grinding that each clay sample requires during processing.

The main procedures followed during the experiment are illustrated by Fig. 1. They consist of (1) Qualitative analysis of elements (XRF); (2) Quantitative analysis of contents (XRF); (3) Identification of various kinds of minerals (XRD); (4) Thermal analysis (TGA, DTA, TMA); (5) Particle size analysis; (6) Plasticity, and (7) Other analysis.

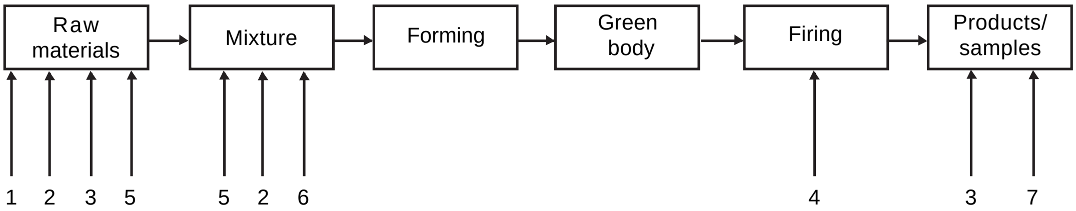

Fig. 1a. Overall experimental procedure

As shown above, the raw samples were taken through the qualitative analysis, quantitative analysis, identification and particle size analysis. After these tests, the samples were mixed with water to form a mixture, which was subjected to particle size analysis, quantitative analysis and plasticity tests. Therefore, the samples were formed and the green bodies fired to their respective temperatures. After firing, the thermal analysis (TGA, DTA and TMA) were carried out on all the samples to observe their thermal behaviour. Finally, the products were taken through identification and other relevant tests.

Fig. 1b below is the detailed experimental processes used.

The sample of clay were examined for their chemical composition using an X-ray fluorescent device. The X-ray fluorescent analysis was carried out as follows: 0.5 g of each sample was weighed and mixed with 5.0 g of glass powder and shaken to ensure a good mixture. The mixture was then heated to a temperature of 1000 ºC, at which it melted into a gelatinous form. Glass beads were made out of the gel and an amount of HCl was added. The resulting substance served as the specimen for the X-ray analysis. The specimen was put into an X-ray spectrometer, which indicated the various constituents of the clay samples.

In the X-ray diffraction test, the samples were first ground into powder. The ground samples were put in holders before setting the holders in the diffractometer. Characteristics XRD pattern obtained from the diffractometer for the samples were compared with standard XRD patterns to determine mineral composition of each sample.

Analytical instruments used for the experiment

X-ray fluorescence analyzer (XRF). This instrument served the purpose of revealing the concentrations of the element contained in each sample, by measuring the intensity of X-ray

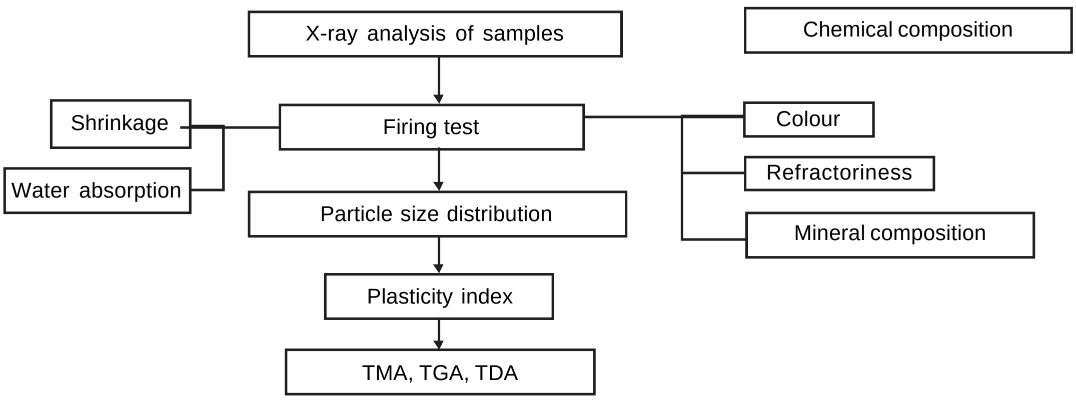

Fig. 1b. Detailed experimental processes

fluorescence of the samples. The intensity of X-ray fluorescence does not reveal elements in the sample.

X-ray diffractometer (XRD). This instrument analysed the crystals that make up the clay sample and draws their characteristic diffraction pattern. By reading these patterns, it is possible to determine the constituent minerals of the clay samples (Rhodes, 1969).

Particle size analyzer. This was used to determine the particulate nature of each clay sample. The instrument employs either the sedimentation method or the laser diffraction method.

Thermo gravimetric analyzer and differential thermal analyzer. These instruments were used to determine weight losses and the thermal behaviour of each sample.

Thermo-mechanical analyzer. This instrument measured the change in length of the sample when they were exposed to heat (temperature change).

Results and discussions

Mfensi clay has low temperature fluxes, summing up to only 6.6 per cent and refractoriness of 20.7 per cent. This means that the clay can withstand high temperatures. It is, thus, suitable for the production of some medium range refractory materials. It is, however, less plastic owing to its low plastic limit. Thus, Mfensi clay is more difficult to form and it can easily crack after forming. It, however, shrank remarkably, with a value of 11.0 per cent after firing. Its mineral assemblage was found to be quartz, kaolinite, microcline and muscovite. The low percentage of Fe_2O_3 gave rise to its yellowish brown/cream colour.

Clay particles of Mfensi clay have a median diameter of 2.3 µm, and the particle size distribution pattern is illustrated on the tri-axial diagram in Fig. 2 (Fraser, 1979). The characteristics spectra of Mfensi clay from X-ray fluorescence and diffraction, and the mineral assemblage are indicated on Fig. 3. The DTA curve (Fig. 4) shows that this clay experienced dehydration only at temperature of 502.4 °C. The phase transformation from α quartz to β quartz occurred at 571.2 °C, whereas crystallization occurred at 943.3 °C. The TGA curve (Fig. 4) showed a 9.6 per cent loss of weight as a result of the combustion of organic matter.

Conclusion

The low plasticity exhibited by the clay demands that extra care is exercised during its processing. Consequently, it is advisable to add some shamot (grog) or sand to prevent too much shrinkage and cracking of Mfensi clay products. Moreover, the clay experienced substantial mass change after firing, meaning that it contained appreciable

TABLE 1

Chemical composition of clay samples

Chemical constituent (CC)	*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*CaO*	*MgO*	*K_2O*	*Na_2O*	*TiO_2*	*Ig loss*	*Total*
Per cent of CC in Mfensi clay	63.7	20.7	3.4	0.2	0.4	1.4	0.2	1.0	8.1	99.1

TABLE 2

Plasticity test results (Atterberg's method)

	Plastic limit (W1)	*Liquid limit (W2)*	*Plastic index (W1-W2)*
Mfensi clay	57.3	23.7	33.6

TABLE 3

Firing test results

	Firing temperature (°C)	*Shrinkage (%)*	*Water absorption (%)*
Mfensi clay	1100	11.0	3.4

TABLE 4

Mineral assemblage of clay sample

Sample	*Mineral assemblage*
Mfensi clay	Quartz, Kaolinite, Microcline, Muscovite

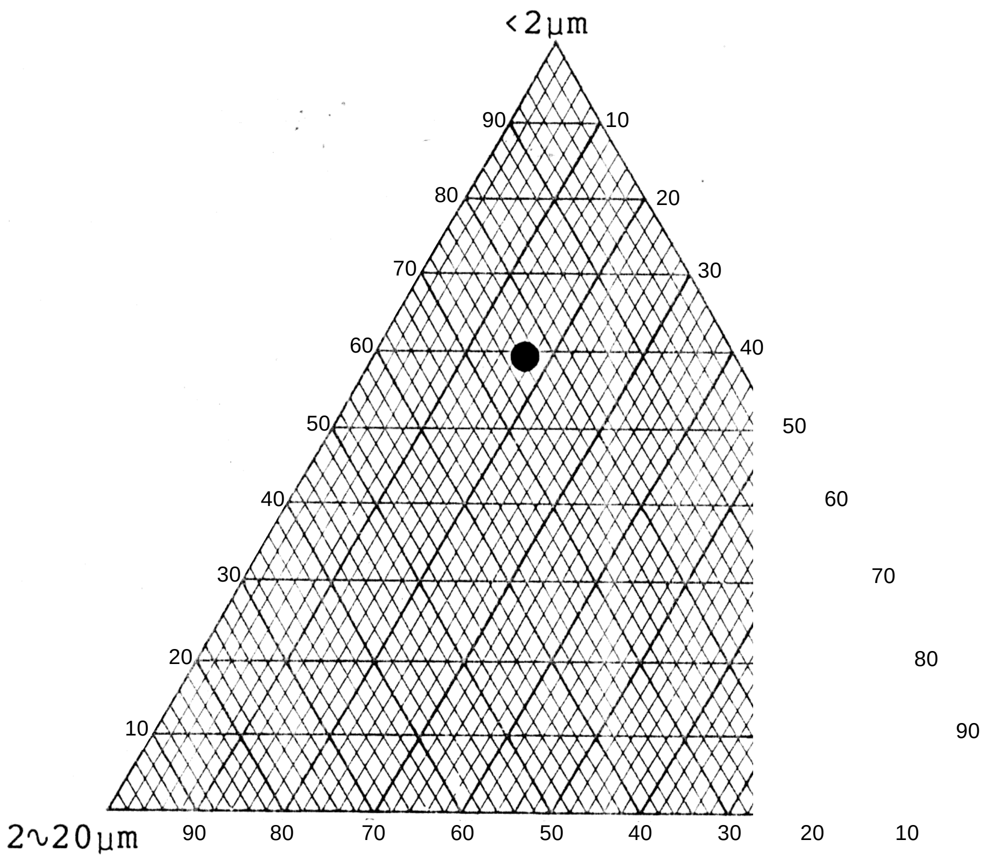

Fig. 2. Tri-axial representation of particle size distribution of Mfensi Clay

6) XRD pattern

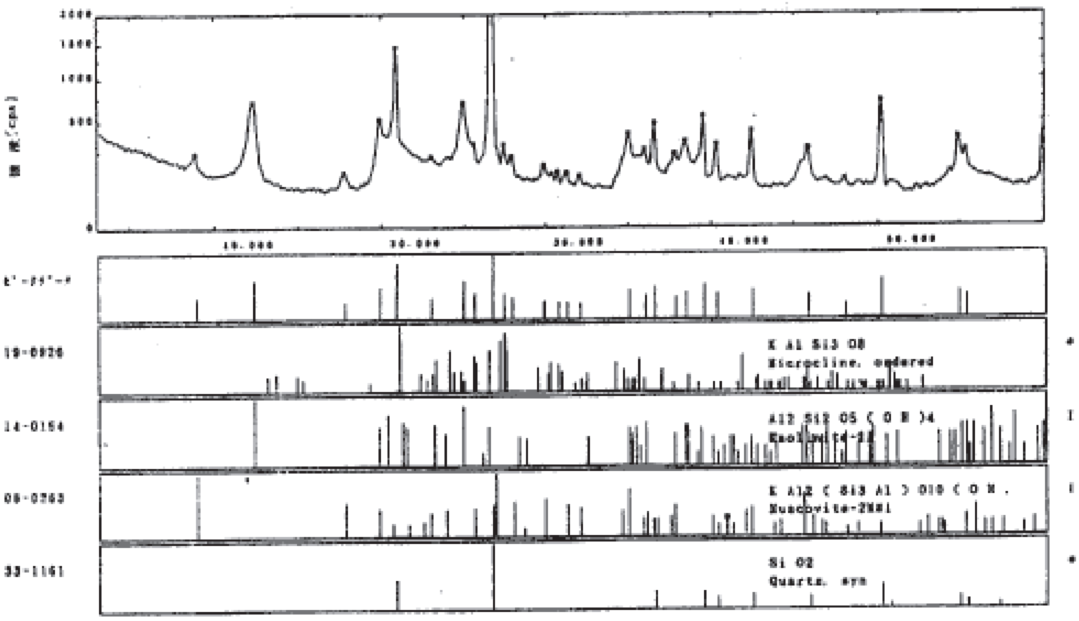

Fig. 3. X-ray diffraction spectrum for Mfensi clay

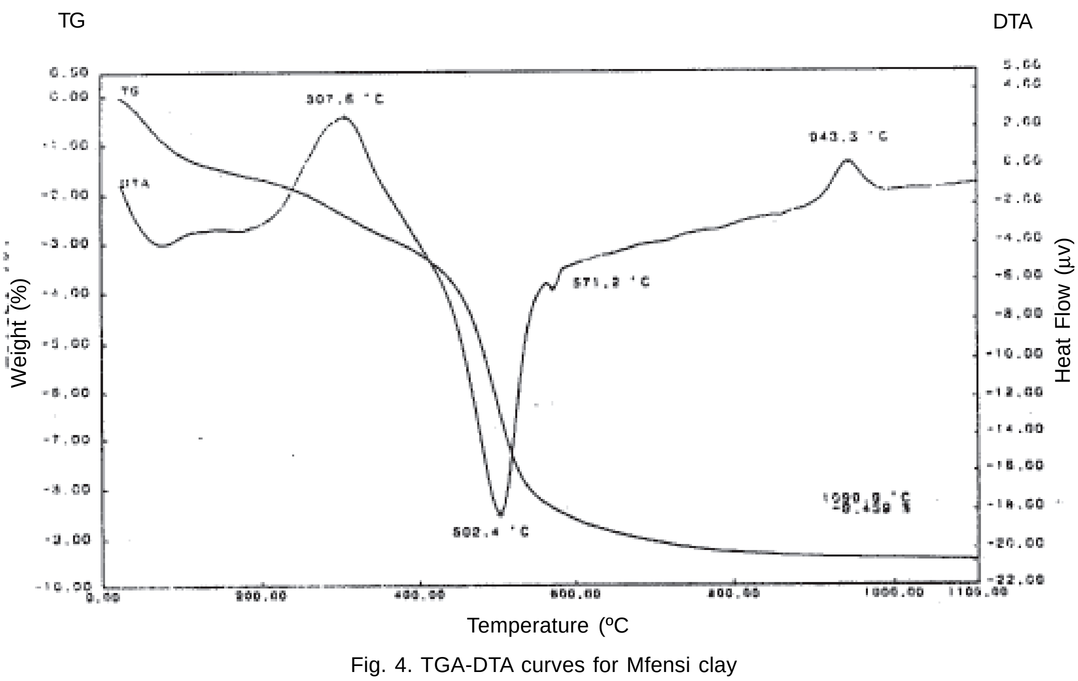

Fig. 4. TGA-DTA curves for Mfensi clay

amount of organic material, which also contributed to its low plasticity. Mfensi clay is, thus, suitable for earthenware and stoneware production, apart from bricks and tiles, owing to its high refractoriness. A mixture of Mfensi clay and any other clay, with a higher plasticity index, would result a material of varying properties useful for many ceramic products.

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Received 09 Jun 04; revised 20 Nov 07.