Thermochimica Acta, 51 (1981) 315–323
Elsevier Scientific Publishing Company, Amsterdam—Printed in The Netherlands

THERMAL STUDIES OF BASALT AND CLAY FOR THE MANUFACTURE OF BUILDING BRICKS

B.A. SABRAH, N. BURHAM
Faculty of Education, Cairo University, Fayoum (Egypt)

H. El-DIDAMONY
Faculty of Science, Zagazig University, Zagazig (Egypt)

(Received 20 May 1981)

ABSTRACT

Abou-Zaabal basalt and Fayoum clay were investigated in order to replace the Nile silt which until now has been used for the manufacture of building bricks. The quantity of silt diminished after the construction of the Aswan High Dam in Egypt. Thermochemical studies were carried out on these materials to show their mineralogical construction. A mixture of basalt powder and clay (75%:25% by weight) was prepared as bricks to show the suitability of basalt as a substitute for clay.

The results showed that the semi-altered basalt consists of some clay minerals as well as the minerals of fresh basalt. The resultant products increase with decrease in grain size of the basalt. The basalt:clay (75:25) mix can be used for the manufacture of building bricks.

INTRODUCTION

The amount of Nile silt required for the manufacture of brick in Egypt became less after the construction of the Aswan High Dam in Egypt. Accordingly, research projects are now being carried out in order to discover substitutes for this raw material. Ibrahim and Gad [1,2] have used shaley deposits and clay for making common brick. The clays are, in general, highly plastic materials of kaolinitic fire-clay type, with varying proportions of three-layer minerals in different stages of decomposition. The efficient use and processing of these clays is only possible by adding the required amount of plasticity reducing agents. Basalt powder can be one of these materials. Basalt is a volcanic, holocrystalline fine-grained rock. It is the most abundant of extrusive rocks, occurring chiefly as flows and also as a pyroclastic material. Basalt is the main constituent of oceanic islands and also the common component of continental masses. Plagioclase feldspars (labradorite) and pyroxenes (augite) are the major minerals, with ilmenite, magnetite, olivine and other accessory minerals [3].

Basalt is found in some localities on the borders of the Nile Delta as basaltic extrusions in the form of sheets. The uppermost layer of the basaltic extrusions is known as weathered basalt, which is an intermediate stage of alteration of the fresh basalt into clay. Grim [4] and Searle and Grimshaw [5] concluded that clays derived from basic igneous rocks such as basalt are usually rich in montmorillonite. Accordingly, it was thought that brick could be obtained by using basalt powder. In order to obtain the paste of basaltic powder of good plasticity, it was decided to mix it with some clay [6].

Therefore, the variation in weight and expansion or shrinkage of such minerals due to the effect of heat seemed to be a matter of interest to the technology of firing. The mineralogical composition of materials used in the ceramic industry can be determined by derivatograms. Thermochemical studies were carried out on Abou-Zaabal basalt and Fayoum clay to show the mineralogical constitution of each. The mixture, consisting of 75% basalt and 25% clay, was made as bricks to show the suitability of these raw materials for brick manufacture.

EXPERIMENTAL

The materials used in this work are basalt powder (Abou-Zaabal), and clay (Fayoum), Egypt. The chemical analysis is given in Table 1. The pre-crushed lumpy basalt was ground, using a roller mill, to a granulation of 0–3 mm. The output was further ground on a laboratory fine roller mill (gap setting 0.8 mm) and sieved through a 1 mm sieve. Lumps of clay were ground in the same manner.

The mineral constitution of the raw materials can be identified using an X-ray diffractometer (Cu$K\alpha$ radiation and a scan speed of $2\theta = 2°\mathrm{C\ min^{-1}}$), and a DTA analyzer at 10°C $\mathrm{min^{-1}}$. The thermal behaviour and weight loss of the clay, basalt < 1 mm, fine basalt < 20 μm, medium 20–40 μm and coarse basalt from 40 μm up to 1 mm were determined. The reversible thermal expansion or shrinkage of the clay and also the mix (75% basalt : 25% clay) were measured from room temperature up to 1050°C on heating and cooling.

As a second step a mix was prepared from basalt and clay with the above percentages. The clay was mixed with all the necessary moisture and allowed to stand in a desiccator for about 16 h. The amount of basalt powder under 1 mm was then added and homogenized in a laboratory screen feeder. The mix was also allowed to stand for about 16 h. Extrusion was then performed using a two-stage de-airing extruder operated under vacuum. It was relatively easy to extrude this mass into solid and perforated briquettes with 45% perforation and two cores. The samples were then marked with shrinkage marks and weighed in order to determine the linear shrinkage and also the loss in weight upon drying and firing. The briquettes were dried to constant weight at 105°C before firing in an electric furnace at 950°C and soaked for 4 h. Physical properties such as cold crushing strength, apparent porosity and bulk density were measured [7,8].

TABLE I

Chemical analysis of Fayoum clay and Abou-Zaabal basalt

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O+Na_2O	Loss on ignition	Total
Clay	52.90	14.40	12.67	2.60	1.05	0.30	3.08	12.85	99.85
Basalt	49.40	15.26	15.00	9.05	4.74	1.02	1.10	4.90	100.47

RESULTS AND DISCUSSIONS

Labradorite was found to be the main constituent of the basalt sample (semi-altered), as shown in Fig. 1. Augite, ilmenite and magnetite, as well as alteration products were also identified. These alteration products are represented mainly by a montmorillonite–illite mixed layer. The X-ray diffraction pattern of the clay sample also showed that this clay consists of kaolinite, illite, montmorillonite, quartz and a montmorrillonite–illite mixed layer.

Differential thermal analysis of the basalt, fine, medium, and coarse fractions, and also the clay are shown in Fig. 2. Ramachandran [9] indicated the characteristic endothermic and exothermic effects of different clay minerals. The results show endothermic effects with peak temperatures in the range 25–220°C. This may be related to the removal of the moisture and to the interlayer water loss from kaolinite, montmorillonite and illite. The endothermic reaction peaks at about 220 and 310°C in the basalt samples may be due to the loss of water present in the colloidal constituents and to dehydration of some iron hydroxide.

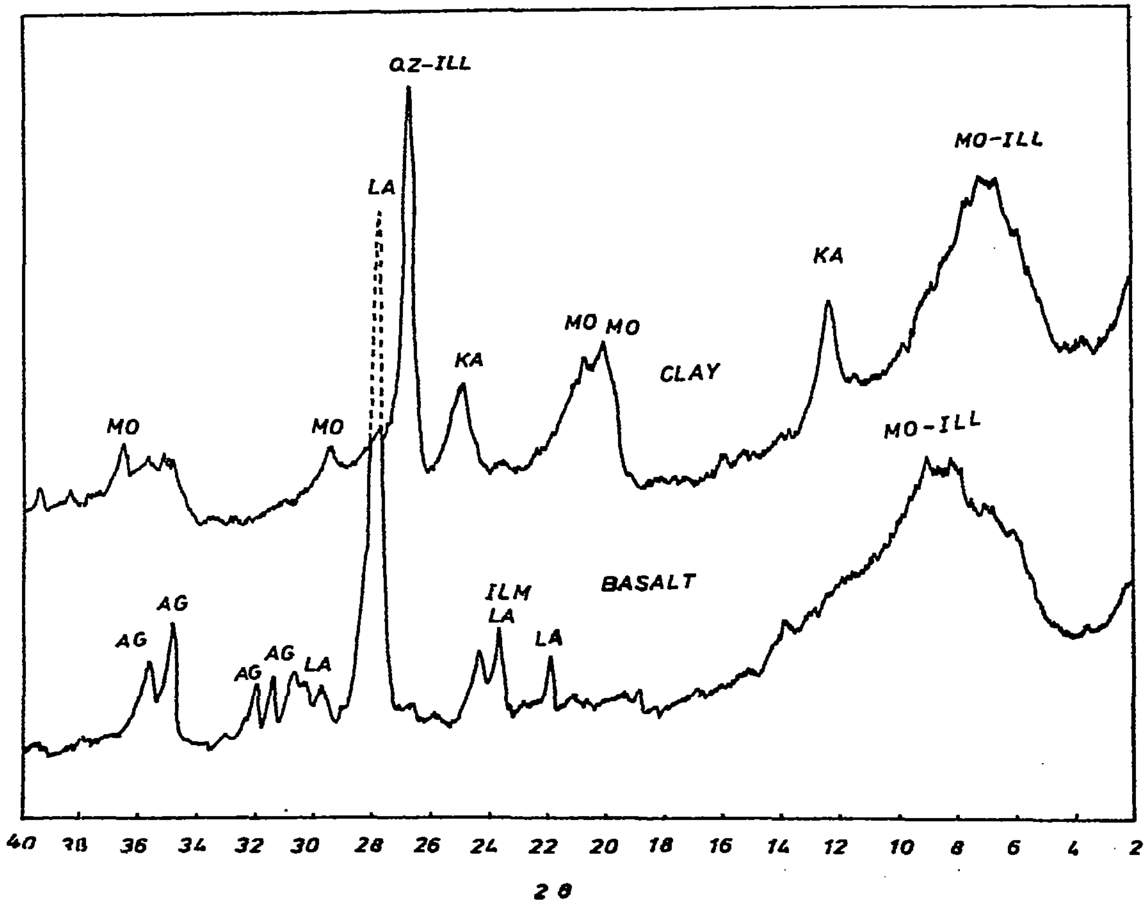

Fig. 1. X-Ray diffraction pattern of Fayoum clay and Abou-Zaabal basalt. Mo = Montmorillonite: Ill = illite; Ka = kaolin; Qz = quartz; La = labradorite; AG = augite and Ilm = ilmenite.

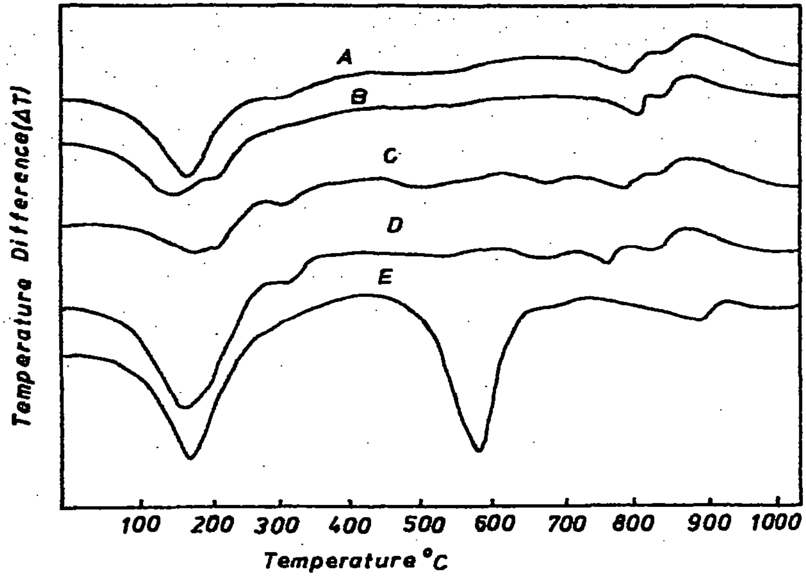

Fig. 2. Differential thermograms of A, normal basalt < 1 mm; B, coarse basalt; C, medium basalt; D, fine basalt; and E, clay.

Many of the clay minerals show an endothermic peak in the range 500–840°C associated with loss of structural OH ions. The endothermic effects at about 520 and 685°C are due to the loss of OH ions from the illite, montmorillonite and kaolinite present in the basalt samples. The intense endothermic peak at 580°C in the clay sample may be due to the hydroxylation of kaolinite. The weak endothermic effects with peak temperatures at 770–790°C and 840°C may be attributed to the dehydroxylation of montmorillonite.

Some of the clay minerals undergo an endothermic reaction in the region 800–950°C which is often followed by an exothermic reaction, and is attributed to recrystallization. The S-shaped endothermic/exothermic peak of montmorillonite appears at 850–900°C. This is due to the destruction of the original structure of the clay minerals and formation of new phases such as silicates. The endothermic effect at 700–900°C may also be attributed to the calcination of the dolomitic limestone.

The results indicate that the fine basalt is markedly illitic-montmorillonitic in character. This partly applies to the medium sized fraction. The amount of clay minerals increases with decrease in grain size of the altered basalt. From the results of X-ray diffractometry and DTA it is clear that the clay sample is composed of kaolinitic fire-clay and a proportion of montmorillonitic–illitic mixed layer. Free quartz was also identified.

The thermal gravimetric analysis of clay and basalt samples is shown in Fig. 3. The total weight losses in the case of clay, basalt < 1 mm, fine, medium and coarse basalt ranges are 12.90, 4.90, 3.30, 5.90 and 8.10%, respectively. The low-temperature region (25–250°C) has the variations 4.05, 2.50, 1.30, 1.70 and 3.30% for all samples, respectively. The loss in weight in this region is mainly due to humidity and interlayer water losses from kaolinite, montmorillonite and illite [10]. TG curves of

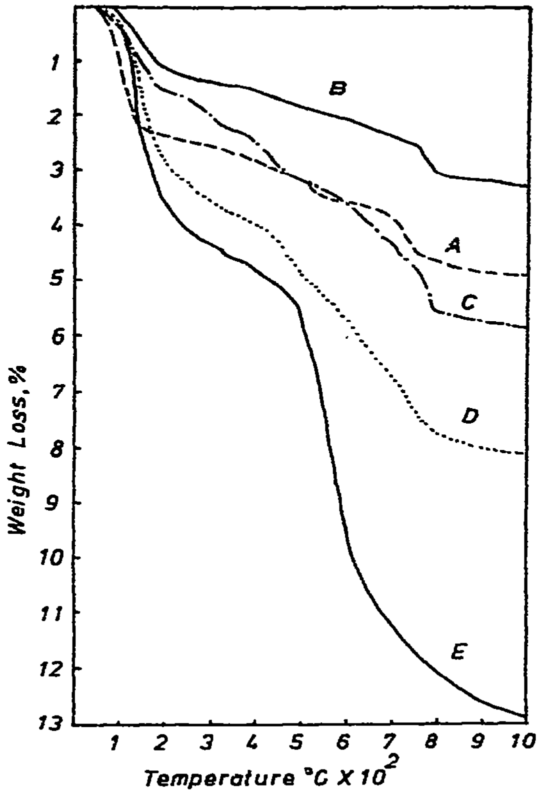

Fig. 3. Thermal gravimetry of A, basalt < 1 mm; B, coarse basalt; C, medium basalt; D, fine basalt; and E, clay.

the above-mentioned samples indicate that the loss in weight in this region takes place in one stage in some samples. This is attributed to the presence of some colloidal constituents. The loss in weight of medium basalt represented by the DTA curves at about 300°C is due to the hydroxylation of small amounts of iron hydrate. This indicates that the iron hydroxide in basalt is found in the medium fraction. Weight losses of 5.50, 0.50, 0.35, 0.75 and 1.35% were detected in the temperature range 500–640°C on the TG curves of clay, normal basalt, coarse, medium and fine basalt samples, respectively. This loss can be attributed to the hydroxylation of clay minerals such as kaolinite, montmorillonite, and illite. The presence of these minerals was confirmed by the strong endothermic reaction peaks on the DTA curves of the samples.

TG curves of the basalt samples indicate that basalt does not contain any carbonate matter. The loss in weight of the clay sample in the temperature range 640–1000°C may be due to the decomposition of small amounts of associated carbonates. On the other hand, the TG curves of the basalt samples show a weight loss in the temperature range up to 840°C, which is also attributed to montmorillonite dehydration.

From the TG curves of the basalt samples, it is indicated that basalt is composed of a percentage of montmorillonite–illite mixed layers in addition to the clay

TABLE 2

Physical and mechanical properties of the mix (75% basalt:25% clay) fired at 950°C for 4 h soaking time

Type of bricks	Dried linear shrinkage (%)	Fired linear shrinkage (%)	Dried wt. loss (%)	Fired wt. loss (%)	Green crush strength (kg cm^{-2})	Fired crush strength (kg cm^{-2})	Bulk density (g cm^{-3})	Apparent porosity (%)	Water absorp. (%)
Solid	8.125	1.630	21.400	3.930	31	124	2.005	30.62	15.28
Perf.	8.075	1.585	20.586	4.090	13	72	2.010	30.31	15.10

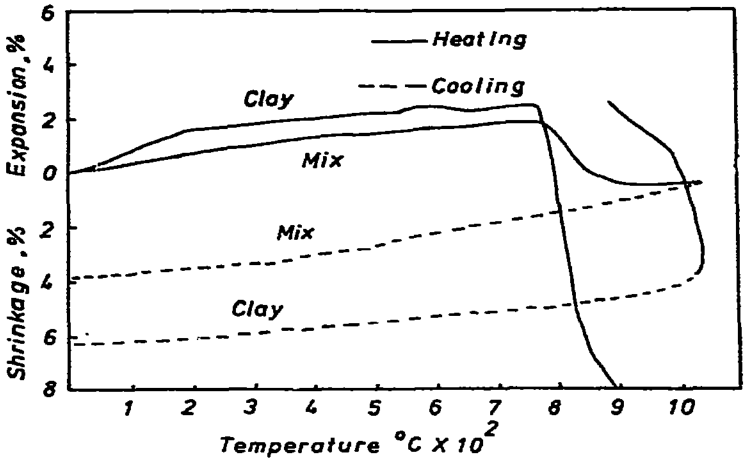

Fig. 4. Reversible linear expansion of clay and mix (75% basalt:25% clay) fired between 25 and 1050°C, heating and cooling.

minerals. By dividing the loss in weight in the range 500–640°C of basalt samples by weight loss of clay, it is concluded that the percentages of clay minerals for normal basalt, coarse, medium and fine basalt are 9.09, 5.45, 13.64 and 25.54%, respectively.

Figure 4 shows the thermal expansion and shrinkage of the clay and the mix (75 basalt:25 clay) on firing and cooling from 25 to 1050°C. The results show that the addition of basalt to clay improves the thermal behaviour of the clay, i.e., decreases the expansion on firing and also increases the reversible expansion on cooling. Clay expands slowly up to 760°C, then contracts sharply up to 1050°C. The magnitude of thermal expansion from room temperature to 760°C reaches 2.50%. On prolonged firing up to 1050°C, it shrinks markedly by about 16.50%. On cooling the reversible expansion occurs by about 2.50%.

In the case of the mix (75 basalt:25 clay), it expands up to 780°C and then contracts up to 1050°C. The magnitude of expansion and contraction ranges are 1.75 and 2.20%, respectively. It contracts sharply on firing from 785 to 875°C and then slowly to 1050°C. On cooling it expands by 3.30%. It is clear that the thermal behaviour of clay is improved by the addition of basalt, i.e. it exhibits reversible expansion on heating and cooling. Therefore basalt can be used as a substitute for clay and also as a plasticity and expansion–shrinkage reducing agent of the clay.

The physical properties of the prepared briquettes, solid and perforated, fired at 950°C for 4 h soaking time are shown in Table 2. It is clear that the perforation of the briquettes improves the physical properties of the fired samples. The briquettes produced were of satisfactory quality and the results obtained are in the range of International Standards [7,8].

CONCLUSIONS

From the above findings the following conclusions may be drawn. Abou-Zaabal basalt consists of labradorite as the main constituent, with augite, ilmenite and also alteration products of montmorillonite–illite mixed layers. Fayoum clay has kaolinite, montmorillonite, illite and also a montmorillonite–illite mixed layer with some quartz. Fine basalt is more altered than the medium and the coarse fractions. The clay minerals in the above samples have the contents 5.45, 13.64 and 24.54%, respectively. The basalt can be used as a substitute for clay, as a plasticity, expansion–shrinkage reducing agent.

REFERENCES

1 D.M. Ibrahim and G. Gad, Sprechsaal, 107 (1974) 547.
2 D.M. Ibrahim and G. Gad, J. Chem. U.A.R., 21 (1978) 297.
3 G.H. Beal and H.L. Ritter, Am. Ceram. Soc., Bull., 55 (1976) 579.
4 R.E. Grim, Applied Clay Mineralogy, McGraw Hill, New York, 1962, p. 43.
5 A.B. Searle and R.W. Grimshaw, The Chemistry and Physics of Clay and Other Ceramic Materials, Ernst Benn Ltd., London, 1959, p. 41.
6 M.R.H. Ramez and B.A. Sabrah, J. Chem. U.A.R., 14 (1971) 507.
7 ASTM Standards, Am. Soc. Test. Mater., C20-46 (1958) 374.
8 ASTM Standards, Am. Soc. Test. Mater., C133-55 (1966) 74.
9 V.L. Ramachandran, Application of Differential Thermal Analysis in Cement Chemistry, Chemical Publishing Co. Inc., New York, 1969.
10 R.E. Grim, Clay Mineralogy, McGraw Hill, New York, 2nd edn., 1968.