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THE ROLE OF CEMENT DUST IN BASALT-DE-ALUMINATED KAOLIN BRICKS

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ABSTRACT

Effect of gradual substitution of altered basalt by a few percent of cement dust (0, 5, 10, and wt.15%) on the ceramic properties of basalt-de-aluminated kaolin fired up to 1100ºC was studied. The results show that the samples containing 5 and 10 wt% cement dust give the higher suitable ceramic properties than the other samples. As the cement dust contents increases in the sample the apparent porosity enhances and the bulk density decreases at all temperature. Also, The XRD results reveal that the peaks of plagioclase and pyroxene of the altered basalt completely disappears in the sample containing cement dust and the intensity peaks of diopside sharply increase with cement dust content and firing temperature.

Keywords: altered basalt, cement dust, de-aluminated kaolin, apparent porosity, bulk density, compressive strength.

INTRODUCTION

A lot of research is currently being done on recycling and how to reuse the waste in the building industry [1]. In the brick-making industry, there has also been researched on how to reuse different wastes in order to manufacture better quality bricks [2-4].

A previous study evaluated basalt waste (In Egypt, basalt extrusions at Abu Zaabal near Cairo are being quarried) in the manufacturing of bricks [5]. The quality of the basalt was determined by means of chemical analysis, differential thermal analysis (DTA), TGA and X-ray diffraction techniques. The physico-mechanical properties of the fired sample were investigated. The results showed that good ceramic properties were produced at a firing temperature of 1050ºC.

On another study, investigation was carried out for making building bricks from Abu Zaabal altered basalt and de-aluminated kaolin waste. Samples were prepared and dried at 105ºC as well as fired at different temperature ranging from 900 to 1100ºC for 2 h soaking time, The result revealt that good quality bricks can be produced from 90-70 basalt at 10-30% de-aluminated kaolin at all firing temperatures [6].

Cement dust is a hazardous solid waste that is produced by the cement industry. It is produced in two forms either as kiln dust, which leaves the kiln with the flue gases or as by-pass dust which is associated with the part of the fine flue gases that are made to leave the kiln near its upper end in order to eliminate as much possible alkali salts which can negatively affected the properties of the clinker of cement [7].

Duschene and Readon [8], in their attempt to study the behavior of the cement dust, have stated that it consists of extremely fine particles mainly calcium, sodium and potassium salts. In the building bricks industry, on the other side, cement dust was incorporated, as a fluxing agent, with clay bricks [9, 10] and recently, as a partial replacement of feldspare in the manufacture of wall tiles [11]. In both cases, the maximum recommended percent addition did not exceed 10%.

The aim of this study is to evaluate the ceramic properties of basalt-de-aluminated kaolin bricks containing cement dust. The physico-mechanical properties as well as mineralogical composition for some selected samples were then compared to those of similar bricks without cement dust. The use of this additives in bricks could produce cost saving in raw materials for brick manufactures and serve as an efficient means of recycling a waste product.

EXPERIMENTAL WORK

Materials and methods

The waste materials used in this study were altered basalt (From Abu Zaabal quarries), de-aluminated kaolin (it was obtained from Egyption Shaabah Company and cement dust as a by-product of National Cement Company, Egypt. The chemical analysis of these waste materials was performed by XRF and is given in Table-1.

Table-1. Chemical oxide composition of starting materials, wt %.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	SO_3	LOI
Basalt	47.95	15.30	12.04	10.35	6.22	3.45	0.11	1.02
DAK	83.20	5.13	0.70	0.11	0.20	2.37	0.85	9.37
Cement dust	13.40	3.85	1.92	46.25	1.85	0.05	5.12	22.31

DAK de-aluminated kaolin

It is clear that altered basalt has CaO, MgO, total iron as Fe_2O_3, Al_2O_3 and SiO_2 with predominance of SiO_2. These are the main oxides forming the plagioclase and pyroxene minerals. The de-aluminated kaolin was mainly composed of SiO_2 and traces other oxides. Some authors have shown de-aluminated kaolin to have high quartz and amorphous silica levels along with amorphous Al_2O_3 [6]. On the other hand, cement dust was found to consist mainly of calcium hydroxide, calcium carbonate, calcium silicate, sodium chloride, potassium chloride and quartz [7].

Methods

Basalt waste material was ground using a 0.6 mm roller mill. The output was further ground on a fine roller mill to a fine powder of about 100 um. The specific surface area of the de-aluiminated kaolin was 90.5 m^2/g [14]. The cement dust was sieved through (150µm) sieve. The characterization of the altered basalt by means of DTA, TG, and XRD were done in the previous work [5]. The mix composition of different batches is shown in Table-2.

Table-2. Mix composition of different batches, wt %.

Mix no	Basalt	DAK	Cement dust
M_0	90	10	0
M_1	85	10	5
M_2	80	10	10
M_3	75	10	15

These mixes were formed into a compact mass in a 1-inch cylindrical mould with 5% water at a pressure of 150 g/cm^2. The samples were dried at a rate of 5ºC/min from room temperature to 105ºC. The dried samples were then fired at 800, 900, 1000 and 1100ºC for 0.5 h soaking time. The firing rate used was 10ºC/ min until the desired firing temperature was reached. The physico-mechanical properties of the fired samples were investigated. These properties included linear firing shrinkage, apparent porosity, bulk density and crushing strength. Some selected fired samples were investigated to their mineral composition by XRD techniques.

RESULTS AND DISCUSSIONS

Linear shrinkage

The linear shrinkage of fired samples is shown in Figure-1. The results show that the firing shrinkage was gradually increased with temperature up to 1100ºC. This can be explained by the sintering process, which increases with the firing temperature. During heating of the altered basalt in the samples to maturing temperature, some of its minerals continued to dehydrate up to 700 ºC, giving rise to a mixture of active amorphous SiO_2, Al_2O_3 [5]. Between 700 and 800ºC, notably at temperature exceeding 800ºC, impurities such as iron, titanium, alkalis and alkaline earth oxides act as fluxing agents for the total SiO_2 and Al_2O_3 in the fired body. The presence of these oxides tends to reduce the maturing temperature and decrease the melting point of the liquid phase. On the other side, the data indicates that the firing shrinkage for samples containing cement dust slightly enhances with cement dust content. This may be due to the expansion associated with decomposition of calcium carbonate and hydrated lime.

Apparent porosity

The apparent porosity of the samples fired up to 1100ºC was shown in Figure-2. It is clear that the apparent porosity of the fired samples was gradually enhanced up to 1000ºC, then rapidly decreased from 1000 to 1100ºC. This can be illustrated to the sintering process, which increases with the firing temperature. Also, by increasing the cement dust content from 0 to 15%, the porosity was increased. This attributed to the fact that the altered basalt contains a higher amount of fluxing oxides, which leads to give a higher liquid phase content with heating temperature up to 1100ºC.

Bulk density

The bulk density of the fired samples with and without cement dust was shown in Figure-3. The data shown that the bulk density of fired samples decreases with the increasing cement dust content at all firing temperatures. Also, the sample without cement dust has a higher value of bulk density than the other samples with firing temperatures. On the other side, when the basalt content increases in the sample, the mixes are rich in iron oxide, titania, magnesia, and fluxing oxides, namely, Na_2O, K_2O, Fe_2O_3, TiO_2 and MgO. The presence of these oxides tends to reduce the maturing temperature along with reducing the melting point of the liquid phase, which leads to increase the sintering properties with fired temperature and the bulk density was increased. It can be concluded that the samples containing cement dust have a lower bulk density with suitable apparent porosity than the control sample.

Compressive strength

The compressive strength of fired samples is illustrated in Figure-4. The results show that the compressive strength of the fired samples increases with increasing firing temperature up to 1100ºC; on the other hand, with the increasing cement dust in the sample, the compressive strength was slightly decreased. This may be due to increase the apparent porosity with cement dust content at all firing temperatures (Figure-2). Also, the control sample contains a higher amount of fluxing oxides which tends to increase the liquid phase content and reducing the melting point of the samples to give good mechanical properties with firing temperatures.

In the ternary phase diagrams (5) of alumina, silica and fluxing oxides, the temperatures of initial liquid phase formation due to each oxide are (in ºC): TiO_2 1478, Mg 1425, $FeO+Fe_2O_3$ 1210-1300, Na_2O 1050, K_2O 980.

The problem of melt development is concerned with the phase equilibrium in an eight component system. Therefore, the liquid phase is expected to form at a temperature lower than 980ºC, the lower of the above invariant points. So, with increasing of the firing temperature up to 1100ºC, the higher fluxing oxide contents lead to a reduction in the viscosity of the liquid phase and good vitrification parameters are expected.

It can be illustrated that the samples containing 5 and 10% cement dust give suitable mechanical properties for building bricks.

Phase composition of the fired samples

The XRD patterns of the fired samples without cement dust fired at 800, 1000, 1100ºC are shown in Figure-5. The results show that Labradorite and calcium orthosilicate are the main crystalline phases detected in the sample and intensity of their peaks increases with temperature. In addition, some XRD lines belong to diopside ($CaO.MgO.2SiO_2$) are shown especially at 1100 º C. This is mainly due to the fluxing effect of the high content of the impurity oxides, namely Fe_2O_3, CaO, MgO, Na_2O, and K_2O on firing of the samples up to 1100ºC. This leads to the formation and development of corresponding amounts liquid phase which solidifies after cooling into a glassy silicate phases which act as a bond for the crystalline phases.

The XRD patterns of the sample containing 15% cement dust and fired at 800, 1000, and 1100ºC are illustrated in Figure-6. The results show that the relative amounts of plagioclase and pyroxene phases of the basalt raw materials are reduces with firing. Also, with increasing firing temperature the labradorite and calcium orthosilicate phases decrease and the intensity of the diopside phase content is gradually enhanced. This is due to the fact that when calcite and dolomite breakdown into CaO and MgO, the CaO and MgO are incorporated into the structure of new mineral phases, principally in high temperature such as diopside ($CaO.MgO.2SiO_2$). It is evident that the development of diopside phase in samples containing cement dust is responsible for improvement the mechanical strength especially at higher temperature.

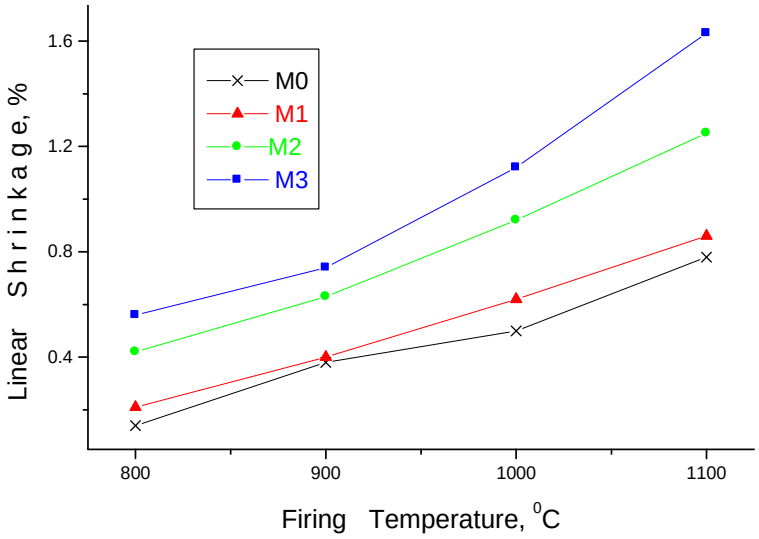

Figure-1. Firing shrinkage of fired samples with and without cement dust.

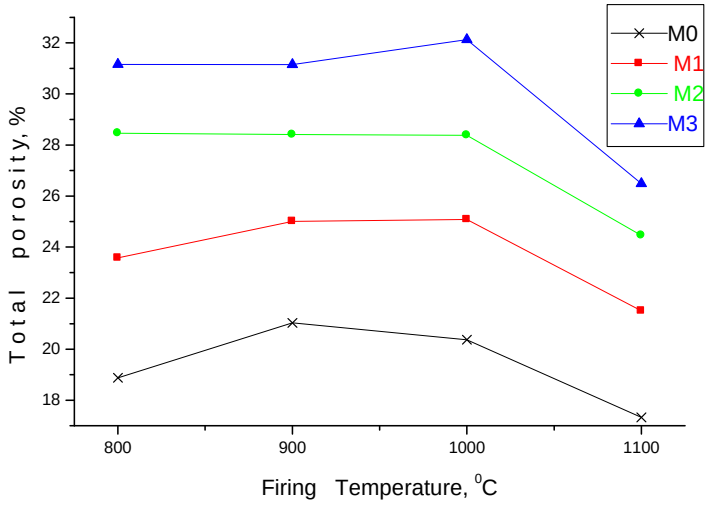

Figure-2. Apparent porosity of fired sample fired up to 1100ºC.

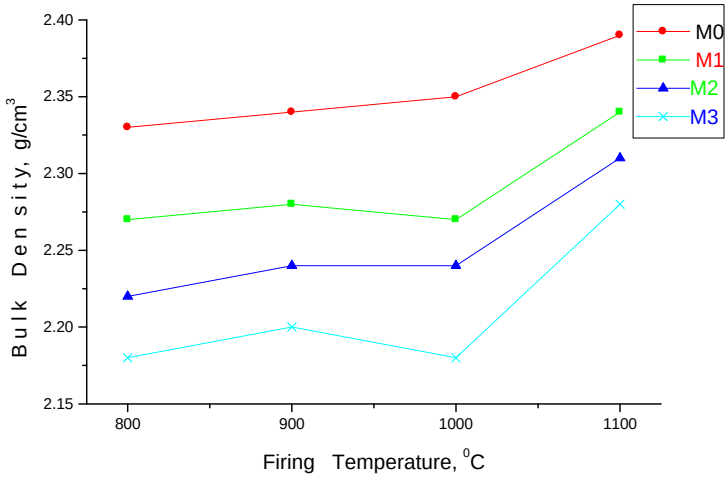

Figure-3. Bulk density of fired sample fired up to 1100ºC.

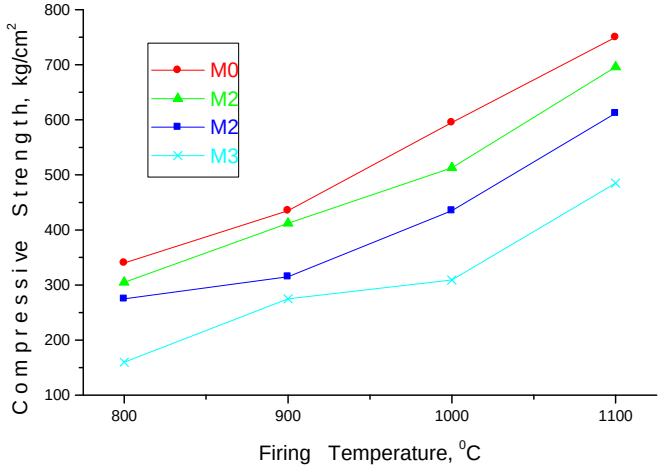

Figure-4. Compressive strength of samples with and without cement dust.

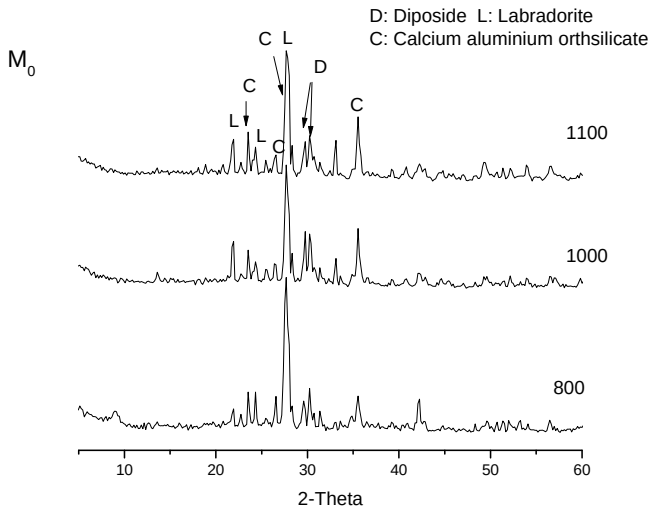

Figure-5. XRD patterns of samples without cement dust fired at 800, 1000, 1100ºC.

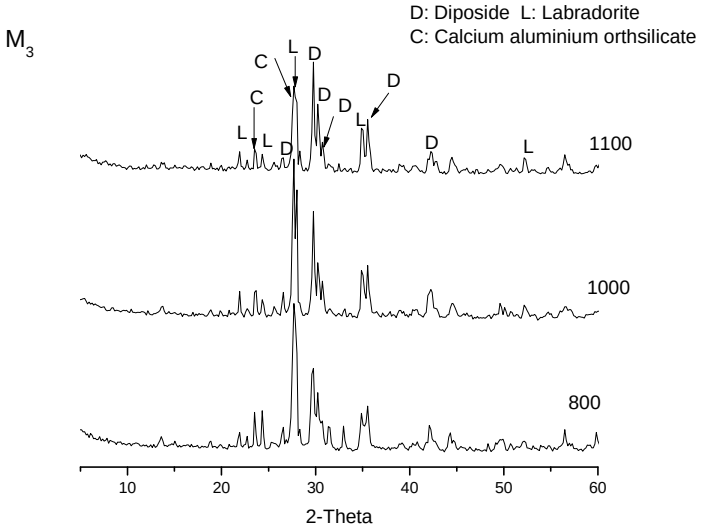

Figure-6. XRD patterns of samples containing cement dust fired at 800, 1000, 1100ºC.

CONCLUSIONS

The main results obtained from this investigation are summarized as follows:

- The addition of cement dust to basalt de-aluminated kaolin improves the apparent porosity and reduces bulk density of the samples.
- The results show that the samples containing 5 and 10 wt% cement dust give the higher suitable ceramic properties than the other samples.
- With increasing firing temperature of the samples containing cement dust the labradorite and calcium orthosilicate phases decrease and the intensity of the diopside phase content is gradually enhanced.

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