EFFECT OF BY-PASS CEMENT DUST ON THE PROPERTIES OF CLAY BRICKS

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The suitability of the mixture of by-pass cement dust as non plastic material and the clay for the production of bricks was tested. Three mixtures having the compositions 100/0, 90/10 and 80/20 (wt.%) clay - cement dust were investigated. Hand moulded briquettes were dried and fired for 2 hours at 600, 700, 900 and 1000 °C with firing rate 2.5 °C min^{-1}. The physical and mechanical properties of the dried and fired articles were measured. The results show that the substitution of 10 wt. % clay by cement dust increases the gas permeability of the fired bricks, which prevents bloating, and increases the crushing strength of bricks with firing temperature up to 1000 °C. The substitution of 20 wt.% cement dust brings the decrease in the crushing strength.

INTRODUCTION

Up to few years ago, production of cement in Egypt was mainly conducted by the wet process. The shift to the dry process increased three times the amount of accumulated dust. The utilization of cement dust, from the various sectors of industry, is a present day concern involving the problem of energy and pollution.

Cement kiln dust as a by product from the cement industry can be used in a number of different ways as soil stabilizer, sub-base roads, filler for bituminous paving and asphaltic materials, replacement of soda in green glass, blended cements ... etc. [1].

Sabrah et al. [2] studied the possibility of utilizing cement dust as a substitution for some clay in brick making. The ceramic and physical properties of the dried and fired articles were investigated. The addition of cement dust increases the lime content, which can change the physical and chemical properties of the produced articles. In 1986, this author also investigated the system clay /grog/ cement dust and studied the substitution of clay by cement dust in the mix 70 clay / 30 grog (wt.%). Grog was substituted by 10, 20 and 30 wt.% of the cement dust. The results indicated that the substitution of clay by cement dust decreases the bulk density and increases the porosity of the fired bodies. The substitution of 10 wt.% clay by cement dust improves the green crushing strength whereas the crushing strength of the bricks was decreased [3].

Blumen [4] carried out a search aiming to increase the speed of the reaction of silicate formation in the system $CaO.Al_2O_3.SiO_2$ by using common salt and thereby to prevent the destructive action of free lime in clay bodies, particularly in building brick. It was concluded that common salt as a mineraliser facilitates the reaction of CaO of the clay with the NaCl, favouring the formation of β-$2CaO.SiO_2$ and $3CaO.Al_2O_3$ at relatively low temperature near 1000 °C. The disadvantage of the salt are: the colour change, spotting in the fired goods and the elevated level of scumming. At lower firing temperatures, the addition of ordinary amount of salt may have low or no effect. The calcium compounds act as fluxes in clay at high temperatures. They react with alumina and silica to form low melting phases and thus reduce the vitrification temperature of the clay, as well as produce a mobile fluid of great corrosive power. When cooled, the liquid readily forms a glass also exhibits impermeability and resistance to fluid [5]. On further heating, the glass softens at low temperatures and may cause serious distortions of the body.

Tite and Maniatis [6] showed by SEM the internal morphologies developed when non-calcareous and calcareous clays were fired between 750 °C and 1200 °C. The $CaCO_3$ decreases the vitrification temperature, at which the clay begins to produce a more porous structure, to lower temperature of about 100 to 250 °C. Abdul-Maula and Odler [7] investigated the effect of minor oxides of raw mixes on the burnability. MgO, Na_2O, K_2O and SO_3 accelerated the reaction of free CaO below 1300 °C, but had a detrimental effect at higher temperature. Investigations were carried out on the suitability of by-pass cement dust as non plastic and fluxing material with clay for the production of clay bricks at lower firing temperature.

EXPERIMENTAL PART

Materials and methods of investigation

The materials used in this work were clay from Belbies area (Sharkia governorate), Egypt, and "By-pass cement dust" produced as a by-product of "Suez cement company" Egypt. These raw materials were subjected to chemical (table 1), mineralogical (X-ray diffractometer) and DTA analysis. The grain size distribution of clay and by-pass were determined by sieve analysis and sedimentation method as can be seen in table 2.

Table 1. Chemical analysis of the raw material (wt.%).

Oxides	Belbies Clay	By-pass cement dust
SiO_2	53.90	13.30
Al_2O_3	22.40	3.25
Fe_2O_3	6.41	1.89
TiO_2	1.67	n.d
CaO	1.70	45.75
MgO	1.69	1.80
Na_2O	1.61	1.87
K_2O	1.28	2.31
SO_3	0.59	4.11
Cl^-	0.20	2.77
L.O.I	8.34	22.31

Table 2. Grain size distribution of the investigated materials (wt.%).

Particle size μ.m (%)	Belbies Clay	By-pass cement dust
1000 - 500	0.00	0.00
500 - 250	0.90	0.80
250 - 125	1.60	2.91
125 - 63	6.80	16.07
63 - 31	7.00	54.47
31 - 8	18.80	9.42
8 - 2	18.80	8.09
<2	46.10	8.24

In order to study the physical and ceramic properties of the produced articles, the precrushed lumpy clay was ground using a fine laboratory mill. The ground materials were sieved through 0.5 mm sieve and mixed together on dry weight basis. Three mixtures having the composition 100/0, 90/10 and 80/20 clay-by-pass cement dust were investigated.

The clay as well as by-pass cement dust of each mix were mixed with water to produce a plastic body according to Pfefferkorn method. The amount of mixing water was added to the clay in a closed container and allowed to temper for 24 hours to prevent the evaporation of the moisture. The paste was hand formed in steel moulds having the width 2.54 cm and length 2.54 cm. The formed bricks were left to dry at room temperature for 48 hours and then over night at 110 °C, and fired in a muffle furnace for 2 hours at 600, 700, 800, 900, 1000 °C, with firing rate of 2.5 °C m^{-1}. The physico-mechanical properties of the dried and fired bricks such as crushing strength, bulk density, and water absorption of solid samples were measured.

RESULTS AND DISCUSSION

Constitution of the raw materials

The chemical analysis (table 1) indicates that the Belbies clay contains low amount of Al_2O_3 (22.40 wt.%) and considerable amount of Fe_2O_3 and other oxide impurities. The content of total fluxing oxides is higher than 15 wt.%. The low Al_2O_3 content and elevated level of oxide impurities are suggested to improve the suitability of the material from the manufacture of heavy-clay products [8].

The chemical analysis of by-pass cement dust reveals the enrichment of CaO, Na_2O, K_2O,SO_3 and Cl.

The XRD pattern of clay sample revealed the presence of major minerals such as montmorillonite, kaolinite and quartz, as well as trace minerals as illite, goethite and feldspar figure (1). The mineral composition of by-pass cement dust shows calcite as major mineral, in addition to trace minerals of sylvite (KCl), quartz and anhydrite.

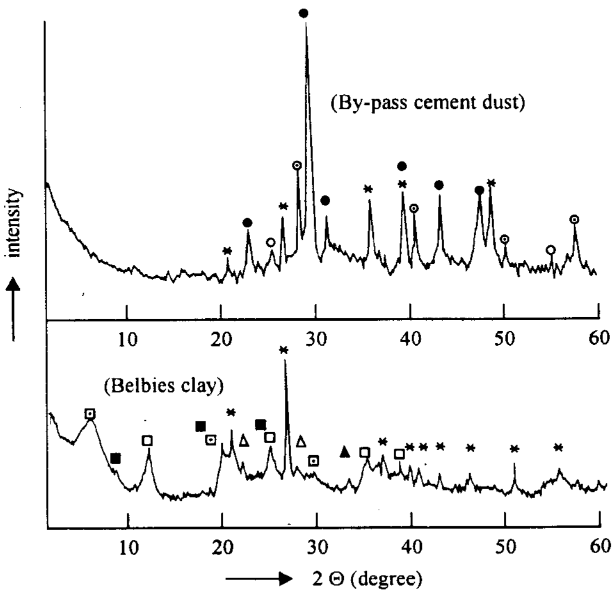

Figure 1. The X-ray diffraction spectrum of the by-pass cement dust and the clay.
● - calcite, O - calcium sulphate, Δ - feldspar, ▲ - goehnite, ■ - illite, □ - kaolinite, ⊡- montmorillonite, * - quartz, ⊙- sylvite

Figure 2 shows the differential thermal analysis (DTA) curves of the clay and by-pass cement dust. The clay sample thermogram shows three endothermic reactions with temperature peak at about 103, 275 and 530 °C. The first endothermic effect indicates the remo-

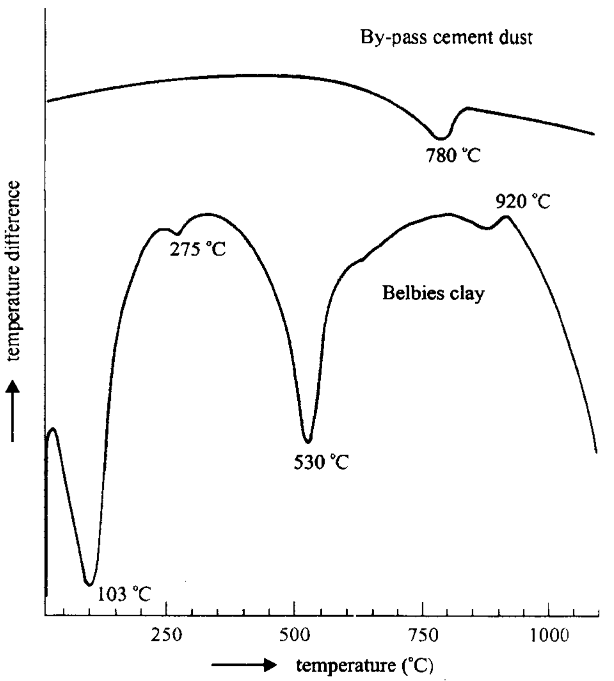

Figure 2. The DTA thermograms of the by-pass cement and the clay.

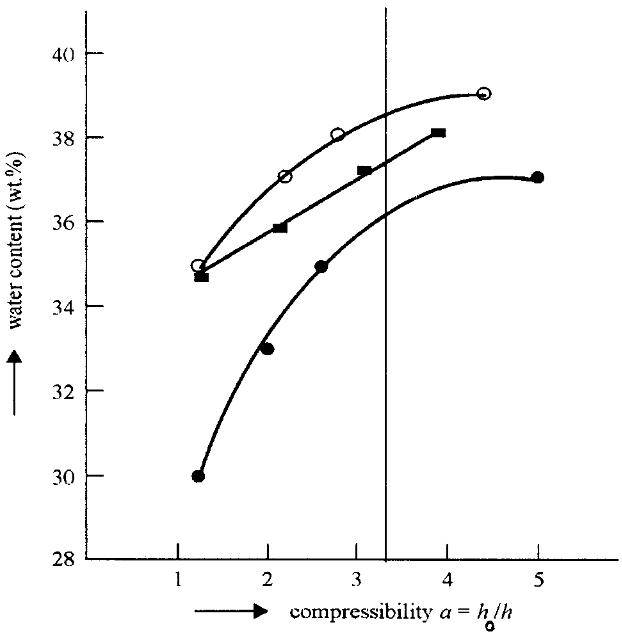

Figure 3. Plasticity curves for the clay/by-pass cement clay. ● - 100 Clay, ○ - 10 % Dust, ■ - 20 % Dust; h_0 – initial height of the test specimen, h – height of the specimen after compression.

val of the moisture and the interlayer water loss from kaolinite, montmorillonite and illite whereas the second peak at 275 °C is attributed to dehydration of goethite present in the clay. The third endothermal at 530 °C corresponds with the loss of structural OH ions. The S shaped endothermic / exothermic peak of montmorillonite at 850 - 920 °C shows the destruction of the original structure of the clay minerals and the formation of new phases such as aluminosilicates.

The DTA of by-pass cement dust exhibits an endothermic peak at 780 °C, corresponding with the dissociation of calcite.

Plasticity

The method of Pfefferkorn [9], based on deformation caused by action of a piston on cylinder of clay at different water contents, is adopted in the present work (figure 3). The water content corresponding to the deformation ratio 3.3 is considered as the water of plasticity. However, the addition of 20 wt.% of by-pass cement brings about a decrease in the plasticity coefficient (PC). Grimshow [10] illustrated that the presence of alkali ions in the clay improves the plasticity.

Drying properties

Figures 4 and 5 show the variation of the green crushing strength, linear shrinkage and loss in weight of solid bricks made from clay and by-pass cement dust. It is clear that the substitution of 10 wt.% clay by cement dust decreases the green crushing strength. The strength of dried samples decreases with decreasing content of the clay and the minimum crushing is obtained at 20 wt.% addition of dust. Kohl [11] measured dry crushing strength for different shale clays. He found the value 87.88 kg cm^{-2} for calcium clay and 99.12 kg cm^{-2} for sodium clay. The loss of water from the body results in an overall volume reduction usually referred to as shrinkage. This property is very important from an industrial point of view. It was observed that the increase in the cement dust decreases drying shrinkage. Therefore, mixture of 20 wt.% dust gives the minimum values of drying shrinkage as well as maximum loss in weight.

Firing properties

The physical properties of the clay/by-pass cement dust bricks fired at 600, 700, 800, 900, 1000 °C are given in figures 6-8. These figures show the relation between crushing strength, water absorption and bulk density as well as linear shrinkage and firing temperature. The crushing strength of only clay brick increases with temperature up to 800°C then decreases at 900 °C due to the bloating of the sample. The bloating occurs during the vitrification stage of firing and is attributable to the generation of gas within the clay mass. Two conditions are necessary for bloating, firstly to prevent the free escape of the gas via the pores and secondly to allow so-

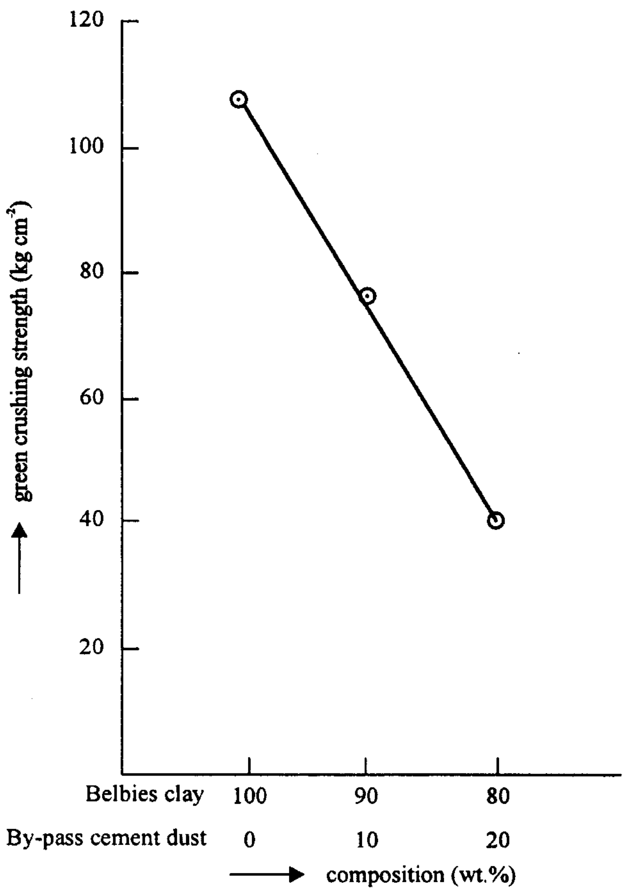

Figure 4. Green crushing strength of clay/by-pass cement dust mixtures.

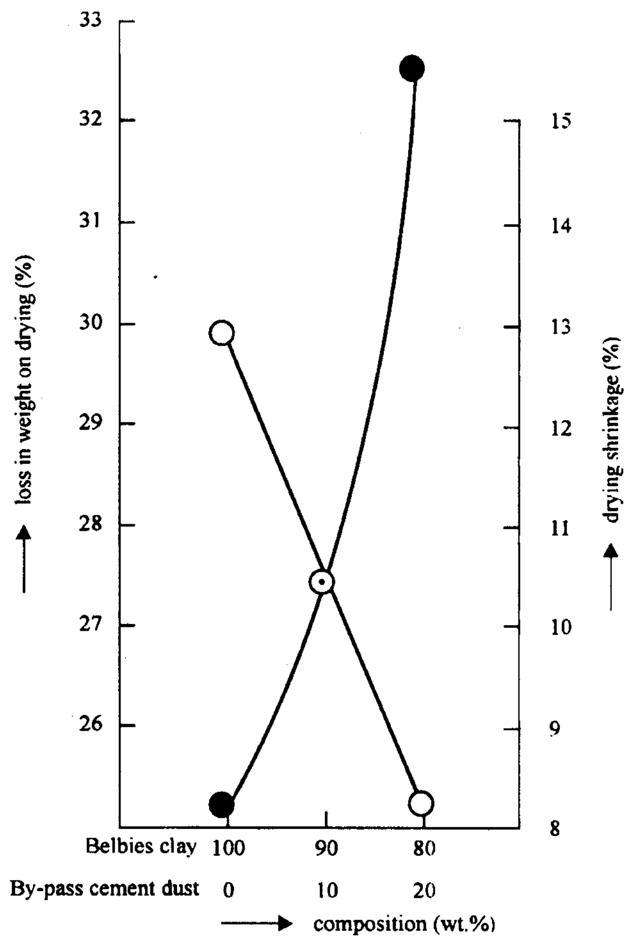

Figure 5. Drying shrinkage and loss in weight on drying of clay/by-pass cement dust mixtures.
○ - linear drying shrinkage, ● - loss in weight

me distortion of the shape by the pressure generated [12]. Workers in U.S.A. and UK [12] suggested that a suitable ultimate composition to yield a bloating aggregate would lie within the limits: 50-75 SiO_2, 15-30 Al_2O_3, 10-20 ($CaO+MgO+Fe_2O_3$ + K_2O+Na_2O), (wt.%).

The chemical analysis of Belbies clay on calcined basis brought the values: 59.44 SiO_2, 24.70 Al_2O_3 and 13.93 total fluxing oxides (wt.%), which exist within the limits of bloated clay [12].

The bulk density, water absorption for the clay brick could not be determined because it has no binding properties at 600 °C. Clews [12] found that when clay was heated to about 600 °C, it has been decomposed and is plastic no longer. A clay test piece fired in this way will not break down and recombine with water when immersed and its resistance to such attack increases as the firing temperature is increased.

On the other hand, rising of firing temperature from 700 to 1000°C leads to an increase in shrinkage, density and to a decrease in water absorption of the fired briquettes. These physical changes are related mainly to the action of vitrification.

The substitution of 10 % clay with by-pass cement dust prevents bloating in the clay sample and increases compressive strength of bricks with firing temperature. The chemical composition of this batch composition is 44.45 SiO_2, 18.25 Al_2O_3 and 15.46 total fluxing oxides (wt.%) being insufficient for bloating. In addition, an increase in bulk density and decrease of water absorption and shrinkage occurs with an increase of firing temperature.

At 20 wt.% of the cement dust, the apparent porosity is increased again leading to the decrease in the crushing strength, bulk density and shrinkage due to enhancement of the thermal decomposition of hydrated cement dust with removal of moisture and CO_2 during firing.

According to the above results, it can be concluded that dense building bricks of adequate physical properties could be produced from clay by substituting up to 10 wt.% cement dust and firing up to 800 °C. Therefore, The X-ray diffraction pattern of samples fired at 800 °C are shown in figure 9. The XRD of fired clay illustrates minor amounts of anorthite (CAS_2), hematite (Fe_2O_3) with quartz and illite as the major components. Sample containing 10 wt.% of the cement dust shows quartz, hematite, anorthite and minor amount of illite. At 20 wt. % of the dust, the illite is completely disappeared, with increased amount of anorthite and presence of gehlenite, anhydrite, wollastonite, hematite and quartz. On the other hand Belbies clay sample shows relatively higher illite and lower anorthite content. This is in agreement with the findings of Ghosh [13] on studying the phase changes occurring during firing clay-lime mixture. It was concluded that the clay minerals dissociate between 500 and 700 °C into the amorphous alumino-silicate mixture (metakaolin), whereas calcium carbonate decomposes into CaO between 600-800 °C. The CaO content decreases above 800 °C and disappears almost completely at 950 °C. This is due to the formation of the metastable phases: wollastonite ($CaO.SiO_2$), anorthite ($CaO.Al_2O_3.2SiO_2$) and gehlenite ($2CaO.Al_2O_3.SiO_2$).

CONCLUSION

By-pass cement dust can be used as non-plastic material in clay bricks. The addition of the dust prevents bloating, increases crushing strength and decreases the drying as well as firing shrinkage. The mixture containing 10 wt.% by-pass cement dust with clay fired at 800 °C for 2 hours is the optimum amount to produce clay bricks with adequate physico-mechanical properties.

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VYUŽÍVÁNÍ ÚLETU Z CEMENTÁŘSKÝCH PECÍ JAKO PŘÍDAVNÉ SUROVINY PŘI VÝROBĚ CIHEL

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Využívání odpadních vedlejších produktů z různých odvětví průmyslu je důležitým úkolem přítomné doby, úzce spjatým s problematikou úspory energie a ochrany životního prostředí. Spaliny z cementářských pecí mají vysoký obsah tuhých částic a jsou největším zdrojem znečištění atmosféry cementárnou. Problémy s likvidací tuhých odpadů vznikají v případě cementářského úletu, což je směs jemných podílů vsázky, částečně kalcinovaných jemných podílů vsázky, částečně kalcinovaných jemných podílů slínku a kondenzovaných těkavých látek.

Cílem této práce bylo ověřit využití cementářského úletu ve formě neplastické směsi s jílem jako suroviny pro výrobu cihel. Úlet byl přidáván do jílu v množství 10 a 20 hmot.%. Ručně zformovaná zkušební tělíska byla vypalována při teplotě až 1000 °C rychlostí ohřevu 2,5 °C min^{-1}. Na těchto vzorcích byly zjišťovány fyzikální vlastnosti, jako úbytek hmotnosti a smrštění sušením a výpalem, a mechanické vlastnosti, jako objemová hmotnost a pevnost v tlaku. Na cihlách vypálených při teplotě 800 °C byla provedena rentgenová difrakční analýza.
Výsledky ukázaly, že náhrada jílu 10 hmot.% zabraňoval expanzi při výpalu a zvyšovala pevnost v tlaku vypálených tělísek. Zvýšením přídavku úletu na 20 hmot.% se zvýšila propustnost vypáleného materiálu, a tím také pórovitost a nasákavost. V důsledku toho se snížila objemová hmotnost a pevnost v tlaku. Směs 90/10 jílu a úletu (hmot.%) prokázala zvýšení pevnosti v tlaku po výpalu při teplotách až do 1000 ° C. Po výpalu na 800 °C vykazoval jíl a také směs s obsahem 20 hmot.% úletu zvýšení pevnosti, avšak při vyšších teplotách výpalu pevnost klesala. Po výpalu na 1000 °C měla nejvyšší pevnost směs s 10 hmot.% úletu, následovaná samotným jílem. Nejnižší pevnost měla směs s 20 hmot.% úletu.

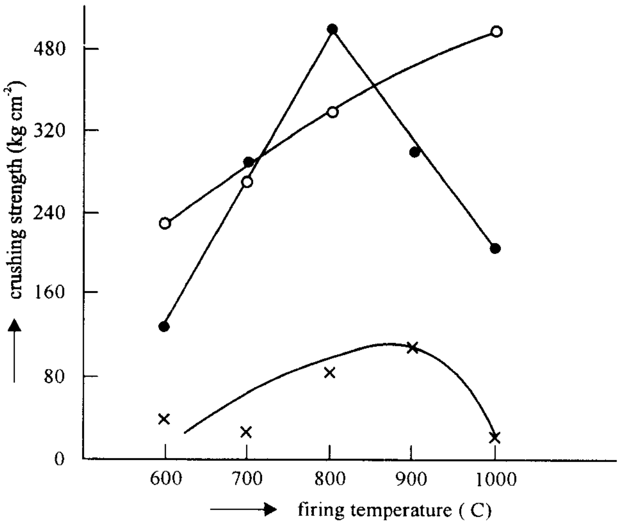

Figure 6. Crushing strength of bricks fired at 600, 700, 800, 900 and 1000 °C.
● - 100 wt.% clay, ○ - 10 wt.% of the cement dust, × - 20 wt.% of the cement dust

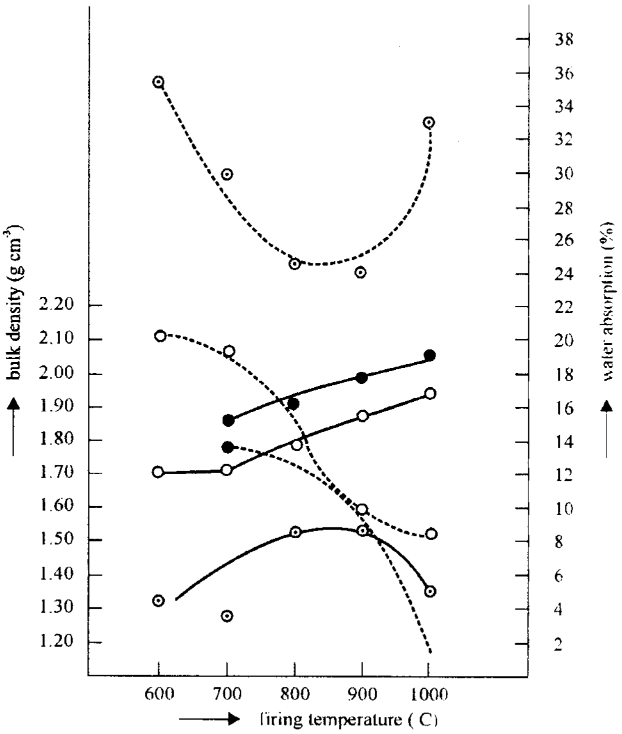

Figure 7. Bulk density (— — —) and water absorption (———) of bricks fired at 600, 700, 800, 900 and 1000 °C.
● - 100 wt.% clay, ○ - 10 wt.% of the cement dust, ⊙- 20 wt.% of the cement dust

the X-ray analysis of the clay containing 0, 10 and 20 wt.% cement dust fired at 800 °C for 2 hours showing the mineralogical composition of the fired bodies was made.

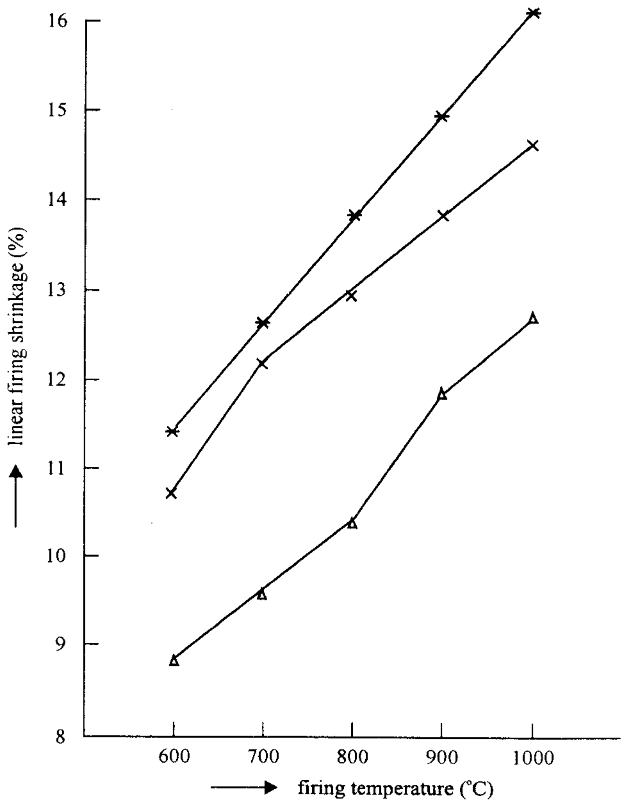

Figure 8. Firing shrinkage of clay/by pass cement dust mixes fired at different temperatures.
* - 100 wt.% clay, × - 10 wt.% of the cement dust, Δ - 20 wt.% of the cement dust.

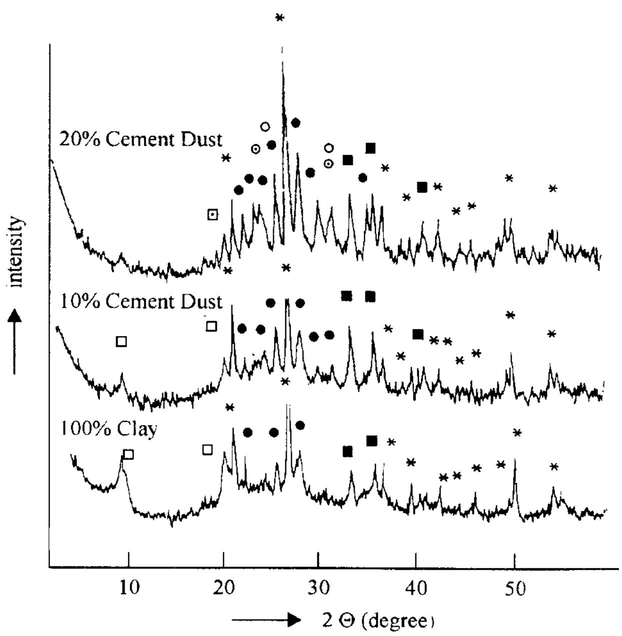

Figure 9. The X-ray diffraction spectrum of the clay/by-pass cement dust fired at 800 °C.
● - anorthite, ○ - calcium sulphate, ⊙- gehlenite, ■ - hematite, □ - illite, * - quartz, ⊡- wollastonite