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Utilisation of IGCC slag and clay steriles in soft mud bricks (by pressing) for use in building bricks manufacturing.

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Abstract

The subject of this study is the application to the construction of soft mud bricks (also known as pressed bricks), both green and heat-treated bodies, built from raw materials from Santa Cruz de Mudela, Ciudad Real, and IGCC slag from the power central of Puertollano (Ciudad Real, Spain). For this purpose, industrial level tests have been performed: the production of these kind of bricks from mixes of waste from ores of construction clays and to significant fraction of different ratios and clay granulometries mixed with IGCC slag. The results of this experimentation suggests that not only can IGCC slag be applied to a ceramic process, but also its use gives several advantages, as water and energy savings, as well as improvements on the final properties of products.

1. Introduction

IGCC slag is an inorganic vitreous product which is produced as a result of the combustion process of electric power central stations by the combined cycle IGCC. Therefore, in Europe is implanted and in operation two of this type of power plant, one of them being the Central Thermal IGCC of ELCOGAS, S.A, in Puertollano (Ciudad Real, Spain) the only one in Spain (ELCOGAS ; Mendez, 1996). This central produces electrical energy through a thoroughly different innovative technology to that of conventional power thermal stations, which consists of the combustion of a coal and coke mixture of oil to generate a synthetic gas. This gas is burnt after; in what is designated a combined cycle, producing electrical energy (Sendin ; CECA). In the process two types of solid residues are generated: fly ashes and slags represent 85% of the total of residues. Since the IGCC industrial process as well as the departure fuel are different from those of the conventional thermal power stations, the ashes as well as the IGCC slag have some physical properties, different chemistry from those of the ashes and conventional slags. Thus, since the IGCC slag is a novel residual material that up until now only has been investigated by the Applied Mineralogy Laboratory of the University of Castilla- La Mancha (UCLM), the only one which has accomplished in the last years a physical characterization and mineralogy of such slags in order to investigate its possible fields of application. As was deduced from these studies, the IGCC slag is a material not pollutant it can be considered as a by-product since its susceptible utilization as a secondary raw material in various industrial activities, even though its currently being marketed as a potential material demand with similar properties (Acosta *et al*., 2001 ; Acosta *et al*., 2002).

It is the first time that IGCC slag has been added to ceramic processing; no previous references in scientific and technological literature have been found regarding previous investigations of this type, or that they might have been manufactured pressed products or extruded with this slag addition. However, there are antecedents of fly ashes of conventional central thermal power stations used in the ceramic material production of bricks and even in the glass and glass-ceramics manufacture (Barbieri *et al*., 1997; Barbieri *et al*., 2000;Romero *et al*., 2000 ; Romero and Rincón, 2000).

On the other hand, in Santa Cruz de Mudela (in the same province as the IGCC power plant) clays production exists that is exploited for extruded products and waste mineral steriles. From these clay deposits, which are withdrawn from main production due to their high content in silica sand, makes them not adapted for extrusion. These mine steriles do not have application at present and their accumulation to the edge of deposits generates an important environmental problem. However, since they have a large clay fraction susceptible to be used for pressed bricks manufacture since this product does not demand as much plasticity as the extruded bricks.

The objective of these investigations is the utilization of the sterile deposits jointly to the IGCC slag through their recycling in the manufacture of soft body bricks. From an environmental point of view, the obtained material would cost less in its manufacture since it would take advantage of waste by-products. In fact, a company in Santa Cruz de Mudela, RÚSTICOS- LA MANCHA S.L., already manufactures a new type of body brick taking advantage of these by-products.

2. Material and methods

The bodies to manufacture the soft mud brick have been formulated as of the cover material of clay deposits from Santa Cruz de Mudela (Ciudad Real) and the IGCC slag from the Power Thermal Plant of ELCOGAS S.A.

The slag IGCC is a black color glass, with vitreous sheen, concoidal fracture and surface that presents a variable porosity. It is not considered a plastic material and its density is of 2.56 g/cm^3. Its chemical composition is basically located in the $CaO–Al_2O_3–SiO_2$ composition system (Table 1). The slag is submitted to a grinding process, in the same power thermal plant, with the one which is obtained a grain from type sand, susceptible to being separated into different fractions and when it is necessary submitted to subsequent grindings (Acosta et al., 2001). With respect, the viscosity–temperature behavior is a “short glass” as has been proven by heating hot stage optical microscopy (HSM), and this glassy waste devitrificates at 850 °C giving rise to crystallization of haematite, anorthite and cristobalite (Acosta et al., 2002). The mine clay sterile deposits show a bulk fraction size sand in the one which prevail quartz grains mainly and carbonates, and a fine minerals fraction of the clay between those which appear illite, kaolinite and in smaller proportion smectite (Fig. 1).

Table 1. Major elements determined by XRF in IGCC slag simple

Oxide	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	TiO_2	P_2O_5	SO_3	LOI[a]
%	56.93	18.77	4.38	0.05	0.97	11.44	1.70	0.33	0.47	0.04	1.81	2.64

[a] LOI, loss of ignition.

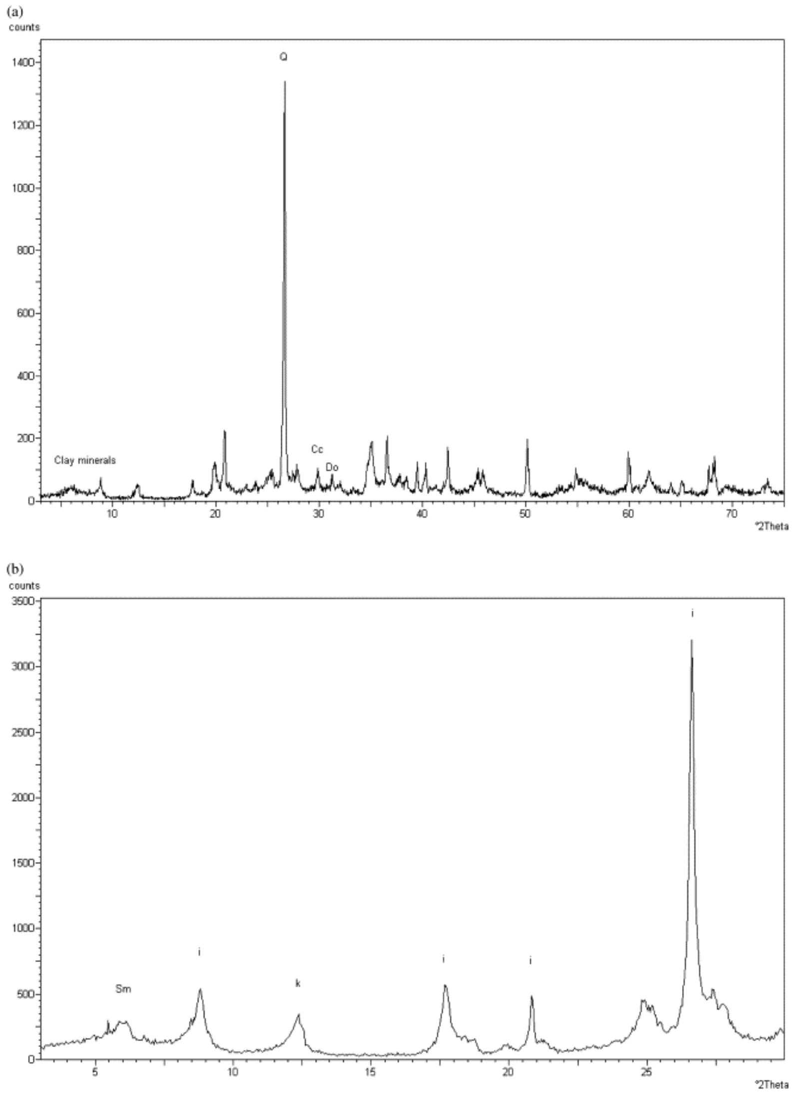

Fig. 1. DRX of clay sterile. (a) Powder sample (b) oriented aggregated of clay fraction sample.

Table 2 shows its chemical composition. Because it is not a very plastic material—therefore would not be adapted by itself to be used in the extrusion process—however, it can be pressed easily as is demonstrated in this investigation, since the pressed product does not require high plasticity limits. Concerning the density this is of 2.76 g/cm^3.

Table 2. Major elements determined by XRF in clay sterile simple

Oxide	SiO_2	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	TiO_2	LOI[a]
%	55.87	19.59	2.42	8.03	2.95	1.52	0.091	0.69	0.08	1.01	8.61

[a] LOI, loss of ignition.

Table 3 shows the composition of bodies elaborated, where the ratio sand/clay is 60/40, as well as the quantity of water added and the grain size. The drying temperature is 65° C and the firing temperature is 930 °C

Table 3. Composition of the bodies elaborated with quantity of water added. The size grain of IGCC slag in E50B is smaller than 620 μm

Mixture	Clay Sterile (%)	IGCC slag (%)	Water added (%)
P	100	–	22
E30	70	30	20
4,00E+50	50	50	16.70
E50B	50	50	16.33

3. Results and discussion

It has been proved that bodies elaborated with slag are better molded by pressing than those in which slag has not been used in the body composition. Thus, the quantity of water added for molding is reduced while the slag content in the body is increased. This means a water saving in the process, involving additionally an energetic saving in the drying operation. The final materials have been tested according to the usual Standards for brick manufacturing (Facincani, 1992).

The slag addition supposes a loss by dried smaller and also smaller contractions in the process of dried, such and as were expecting due to the decrease of the clayed fraction. For so much, there is a clear degreasing effect of the slag in the molding of these materials.

The physical and technological properties of the final fired bricks are shown in the Table 4. It can be seen how the slag addition affects the properties of the heat-treated product. The mixtures with slag have a smaller loss of weight by firing and a smaller contraction depending of how much more slag is contained in the mixture and smaller sized grains. What is same occurs with the water absorption values: they are smaller in the mixtures that contain slag. All the mixtures present some lower water suction values to the limits demanded by the UNE Standards.

Table 4. Behavior of the fired product

Mixture	LOI (%)	Cc (%)	Absorption (%)	Water suction (g/cm^2 min)
P	7.08	6.16	15.17	0.09
E30	5.49	6.64	11.81	0.10
E50	3.73	4.42	10.43	0.11
E50B	3.58	4. 00	10.57	0.13

LOI, loss of weight after firing; Cc, contraction after firing; P, standard; E30, 30% of slag; E50, 50% of slag with grain size <4 mm; E50,: 50% of slag with grain of 620 µm.

Once the body is heated, the major phase that appears is the quartz. The mineralogical composition (Fig. 2) of both samples is similar except the additional presence of plagioclase (as anorthite crystallization) which appears in the mixtures formulated with IGCC slag. This plagioclase proceeds from the devitrification of the slag during the thermal treatment of the ceramic process (Acosta et al., 2002). Thus, amorphous/vitreous slag addition not only helps the sintering process, but also the formation of a transitional glassy phase which devitrifies lately after sintering improving the mechanical properties of this type of bricks.

In the frost resistance test (UNE 67028), all the bricks surpassed 25 cycles from −15 °C to ambient temperature following the cycling demanded by the Standard, they also supported 50 cycles without presenting alteration. With respect to the compression mechanical testing all bricks surpassed the value of 45 MPa, being not possible to differentiate the compression resistance among the compositions here investigated.

With respect to sound showed by bricks to be beaten is more acute when the slag content increases. The fired samples depict an aspect and typical color of construction red bricks as can be seen in Fig. 3. The slag raises the color tone due to the formation of hematite as a consequence of the devitrification of the glassy phase. In the mixtures, which contain slag with grain type sand, the grains from the surface of bricks offer a range for production of different brick products.

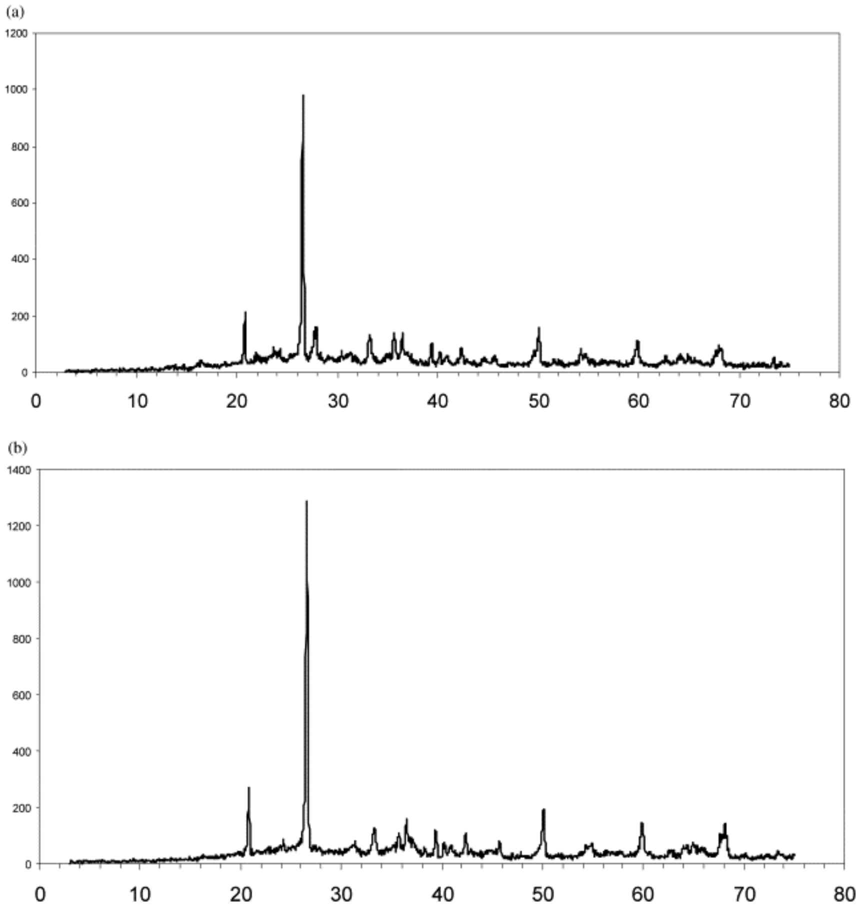

Fig. 2. DRX of final bricks. (a) E30 (b) P.

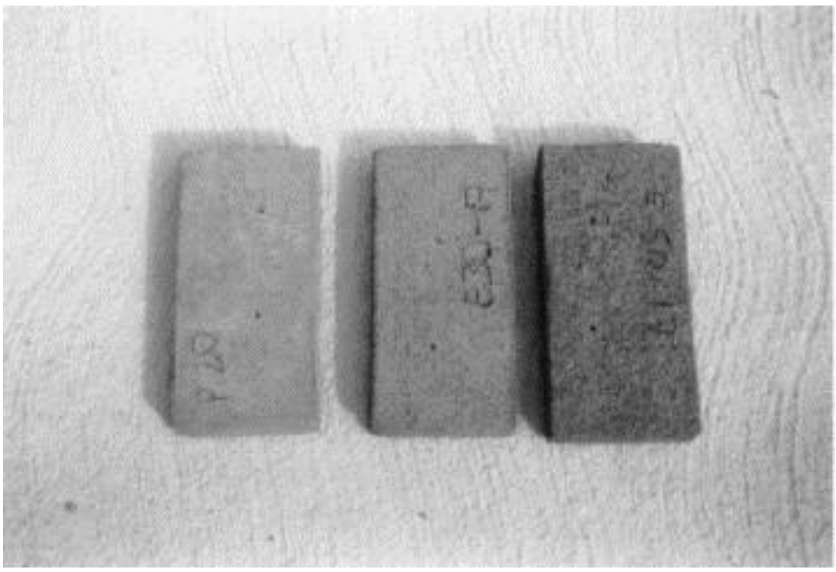

Fig. 3. Aspect fired bricks, from the left to right: standard brick, brick with 30% slag and brick with 50% slag.

4. Conclusion

According to the UNE Standard 67019 the bricks manufactured with IGCC slags can be classified as manual, massive, rugged and face-view. The results obtained in this investigation have been very satisfactory for the objectives set out. Since demonstrating the idea of taking advantage of the clay deposit sterile and the IGCC slag not only it is viable but provides many benefits. During the drying process and firing a considerable reduction in water loss and contraction is observed, directly proportional to the quantity of slag added. The decrease of losses by drying in the process of dried is translated in an energetic saving upon must dry less water, in addition to have less possibilities of breaking of samples. The decrease of the retraction is a very important factor since greater contractions can destabilize the samples causing ruptures of the same in the interior of the oven. In the finished product, the slag improves some properties demanded by the procedures that they are: the water absorption and the resistance to the frost conditions. Furthermore, the ceramics with slag present a most vitreous sound. With respect to color, another quality of the piece, the slag modifies it giving rise to a more reddish tone, so that is possible to obtain material with different color ranges playing with the proportions and grain size of slag added. With the utilization of these wastes high ecological construction products can be manufactured due to the consequent saving in raw material (not opening of new mineral deposits) with an economic saving in production costs (water, energy) which give rise to some excellent properties according to European standards.

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