Technological Behavior of Red Ceramics Incorporated with Brick Waste

Sergio N. MONTEIRO, Carlos Maurício F. VIEIRA, Eduardo. A. de CARVALHO
State University of the North Fluminense - UENF Advanced Materials Laboratory - LAMAV
Av. Alberto Lamego, 2000, Campos dos Goytacazes, RJ, 28013-602, Brazil
e-mail: sergio.neves@ig.com.br, vieira@uenf.br, eatem@uenf.br

ABSTRACT
In the present paper crushed fired brick waste, commonly known as grog, was used in mixtures with clayey body to make typical red ceramics for bricks. The effect of the grog addition up to 20 wt.% on the extrusion stage as well as on properties and microstructure of bricks fired at 700°C was evaluated. The results indicate that the extrusion of the unfired clayey body was not impaired by the grog addition. Additions above 5 wt.% decreased the mechanical strength of both, the dry body and the fired ceramic pieces. This can be associated with the increase in porosity during the firing stage owing to the grog behavior.

Keywords: Brick waste, clays, properties, red ceramics.

1 INTRODUCTION
The production of porous red clayey ceramic products such as bricks is a worldwide activity that generates, everyday, a huge amount of conventional materials for building construction. In fact, the commonly available clay in the form of easily collected soil in many countries and its low cost processing, make red ceramic one of the most extensively used material. However, in order to attend the temperature required for transformation of clay into red ceramics, wood or petroleum based fuels are burnt. This consumes natural resources and results in air pollution. Moreover, the brittle characteristic of the porous red ceramic makes it easy to break during processing and handling while in the industry. These broken pieces are considered as an industrial waste and, so far, with limited uses such as road capping.

A more attractive use for this waste is its recycling in the form of crushed powder, known as grog, to partial replace the clay in the ceramic processing. In previous work [1, 2] grog form bricks produced in Campos dos Goytacazes, Brazil, was investigated in terms of additions to ceramic bodies for roofing tile fabrication at 970°C.

In the present paper, the addition of the same type of grog in mixture with clayey body to make bricks at a temperature of 700°C was investigated. This temperature is traditionally obtained with firewood by the local industries. The objective of this work was then, to study the effect of recycling brick waste in the same industry.

2 MATERIALS AND METHODS
The materials used in this investigation were a kaolinitic clay usually employed for brick production and a grog from brick wastes. The grog, crushed to 20 mesh, was added in amounts of up to 20 wt.% into clayey bodies using a dry mixer. The characterization of the grog was performed by the following methods. The mineral constituents were obtained by X-ray diffraction in a model URD 65 Seifert diffractometer operating with Cu-Kα radiation. The chemical composition was obtained in a model PW 2400 Philips fluorescence spectrometer. The particle size distribution was obtained by sieving and sedimentation method [3]. The thermoanalysis was obtained in a model SDT 2960 TA instrument.

The properties of cylindrical samples pressed 31 mm in diameter and 11 mm in length with different amounts of grog were evaluated through the following procedures. The workability was measured by the Atterberg consistency limits [4, 5]. The dry density was measured by dimensional method dividing the dry weight for the apparent volume of the sample.

After firing samples at 700°C for 60 minutes and cooling them until room temperature inside furnace, the following tests were performed. The fired diametrical shrinkage was determined by the difference between the dry diameter of the sample and the diameter after firing, using a precision caliper. The
water absorption was determined by measuring the weight gain of the tested sample after soaking in boiling water for two hours. The mechanical strength was determined by diametrical compression in a model 5582 Instron machine.

The microstructure of the fracture surface was analyzed by scanning electron microscopy, SEM, in a model DSM 962 Zeiss microscope.

3 RESULTS AND DISCUSSION

Table 1 shows the chemical composition of the grog. The relatively high amount of Al₂O₃ and low content of alkaline oxides, which serve as fluxes, indicate that the grog came from a typical kaolinitic clay. Furthermore, the SiO₂/Al₂O₃ ratio of 2.21, above that of 1.18 associated with kaolinite, indicates an excess of SiO₂ in the form of free quartz.

Table 1: Chemical composition of the grog.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>55.98</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>25.36</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>9.57</td>
</tr>
<tr>
<td>TiO₂</td>
<td>1.32</td>
</tr>
<tr>
<td>K₂O</td>
<td>2.24</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.64</td>
</tr>
<tr>
<td>CaO</td>
<td>0.37</td>
</tr>
<tr>
<td>MgO</td>
<td>0.97</td>
</tr>
<tr>
<td>LoI</td>
<td>3.30</td>
</tr>
</tbody>
</table>

Figure 1 shows the XRD pattern of the grog. The major peaks are associated with quartz (Q) in agreement with the results in Table 1. Other peaks are related to kaolinite (K) and muscovite mica (M). The presence of kaolinite can be attributed to the low-firing temperature, 600°C, used for producing the brick that generated the grog. It should be remembered that above this temperature kaolinite transforms to metakaolinite, which is an amorphous material and, consequently, displays no XRD peaks [6].

![Figure 1: X-ray diffraction pattern of the grog.](image)

Figure 2 shows the particle size distribution of the grog with predominance of the range from 200 to 600 μm, corresponding to medium size sand, according to the International Society of Soil Science [7], the grog is actually composed of particles aggregated by solid state sintering mechanism [8].
Figure 2: Particle size distribution of the grog.

Figure 3 shows the thermoanalysis curves, DTA/TG, of the grog. Peak A is due to the loss of hygroscopic water. Peak B is due to the transformation of the remaining kaolinite into metakaolinite, in agreement with the XRD result in Figure 2. Peak C is due to the allotropic transformation of α-quartz into β-quartz. Finally, peak D is due to metakaolinite decomposition [6].

Figure 3: DTA/TG curves of the grog.

Figure 4 shows the diagram related to the extrusion prognostic using the Atterberg limits [9]. The incorporation of 20 wt.% of grog, B20G, decreases the plastic index of the grog-free industrial body, IB, but still maintains the clayey body within the limits for optimum extrusion. Higher amounts of grog, however, will displace the clayey body outside the optimum region.
Table 2 presents the values of dry density and diametral compression for the different unfired compositions. Additions of grog above 5 wt. %, slightly decrease the dry density owing, probably, to the excess of coarse particles revealed in Figure 2. The dry mechanical strength, given by diametral compression, suffers a significant decrease above 10 wt.% of grog addition. This can be attributed to its higher porosity and lower amount of hydrated aluminum silicates with particle size below 2μm.

Table 2: Dry properties of the compositions.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Dry bulk density (g/cm³)</th>
<th>Dry diametral compression (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB</td>
<td>1.97 ± 0.01</td>
<td>1.23 ± 0.11</td>
</tr>
<tr>
<td>B5G</td>
<td>1.97 ± 0.01</td>
<td>1.21 ± 0.03</td>
</tr>
<tr>
<td>B10G</td>
<td>1.92 ± 0.01</td>
<td>1.17 ± 0.04</td>
</tr>
<tr>
<td>B20G</td>
<td>1.92 ± 0.01</td>
<td>0.89 ± 0.04</td>
</tr>
</tbody>
</table>

Figure 5 shows, simultaneously, the graphs for the water absorption, diametral shrinkage and mechanical strength of 700°C fired specimens as a function of the percentage of grog addition. The mechanical strength first increases up to 5% of grog addition and then decreases for higher amounts of addition. Within the experimental error, the firing diametral shrinkage, in practice, does not change with grog addition. Consequently, the system composed of clay and grog that was originally fired at 600°C will only partially undergo the sintering reactions needed for red ceramic consolidation at 700°C.

Figure 5: Firing properties of the compositions.
Since the grog has a relatively coarse particles, Figure 4, that are more like those of medium sand, its addition to clay will act as an inert non-plastic material. This should result in porosity that will not consolidate at 700°C. It is important to mention that clayey ceramics fired at 700°C do not undergo effective consolidation. At this temperature, the liquid phase formation is still low and the solid state sintering occurs only among the clay mineral particles [8].

SEM micrographs of the fracture surface of the industrial ceramic body IB and the composition with 20% of grog addition, B20G, are shown, respectively, in Figs. 6 and 7. It can be observed that both bodies present a rough fractured surface with loose particles and interconnected pores. A fracture surface with an apparently lower amount of pores is observed, Figure 6, for the industrial ceramic body, IB, in comparison with that of the B20G composition shown in Figure 7. Therefore, the SEM analysis tends to confirm that the relatively coarse particles of the grog result in greater porosity for the incorporated ceramic product.

**Figure 6**: SEM photomicrographs of fractured region of the industrial ceramic body IB.

**Figure 7**: SEM photomicrographs of fractured region of the composition with 20 wt.% of grog addition B20G.

4 CONCLUSIONS

The addition of a grog from bricks produced with firewood as fuel to a clayey body that was then fired at 700°C led to the following results:

- Grog additions up to 20 wt.% did not impair the plasticity of the industrial clayey body and thus may be considered adequate for extrusion process.
• Grog additions above 5 wt.% were found to worsen the packing of the particles. However, the dry mechanical strength was only reduced for the 20 wt.% addition.
• According to all evaluated properties, the additions of grog may be performed up to 5 wt.% without impairing either the processing or the quality of the final ceramic. Additions of grog in higher amounts increase the porosity of the fired pieces, which is detrimental to the technological properties of the red ceramic bricks.
• The results showed that grog, a non-plastic type of waste, can be advantageous for the processing and quality of bricks fired at temperatures obtained using firewood as fuel.

5 ACKNOWLEDGMENT

The authors wish to thank the Brazilian federal agencies CNPq (Process 150444/2003-6) and CAPES for supporting this investigation as well as the Rio de Janeiro State agencies FAPERJ and FENORTE/TECNORTE for providing scientific initiation scholarships and technical grants.

6 REFERENCES


