Addition of Residual Sludge in the Elaboration of Ceramic Matrices

Natalia Fuentes, José G. Ascencio and Samir A. Isenia

Universidad de La Guajira - Faculty of Engineering
Km 5 via Maicao, Riohacha - La Guajira, 728 27 29, Colombia

Copyright © 2018 Natalia Fuentes, José G. Ascencio and Samir A. Isenia. This article is distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

The study of the incorporation of residual sludge in the production of ceramics is one of the challenges of current research, as it constitutes an environmental and economically safe solution for treatment. The present investigation evaluated the physical and mechanical characteristics of the bricks with additions of residual sludge from wastewater treatment plants, for use as building materials, doing this at different times; material collection, selection and production of ceramics by addition percentages (5, 10, 15, 20 and 30%) and temperatures (TH, 800, 900, 1000 °C). It was determined a directly proportional behavior in the resistances in relation to the temperatures, on the contrary inversely proportional in the aggregate of sludge’s, being found the average resistance of 29.8 MPa and the lower average absorption of 15.53% for bricks cooked at temperatures of 1000 °C, witnessing the best results at this temperature. Finally, the ceramics with the addition of sludge from the wastewater treatment plants have higher resistance than the standards in all the tests carried out; indicating that adding them to the clay mixture increases the resistance property in the elaborated ceramics.

Keywords: muds, clays, ceramic material, resistance, absorption

1. Introduction

The rapid urbanization and industrialization worldwide is causing serious environmental problems, among which is the management, final disposal and use of high volumes of sludge generated in wastewater treatment plants worldwide; becoming one of the most significant challenges of today [1], [2]. The problems in
most countries lie in the high costs, the scarcity of landfills, the risks to the
environment and human health of the surrounding communities, among others.
[3], [4].

One of the major concerns of the construction sector in this type of research, is
that the use of sewage sludge reduces the quality of the brick, [5], [6], altering
some properties, such as resistance to compression, absorption, durability, thermal
and acoustic insulation [7], [8]. Perspective that has been changing with the
investigations of [3], [9], [10], that report the positive effects in the properties
such as less weight, low density, improvements in the mechanical properties with
specific addition percentages, low consumption of energy, among others.

Additionally, current trends in European countries seek through normative
processes, regulate the heat transfer coefficients of building materials, in order to
reduce the final energy consumption; support the trend towards the production of
thermal insulation bricks, [11], [12], and [13].

Starting from the principles of sustainable development, and supported by the
tendency to obtain materials with minimum energy consumption, the production
of bricks incorporating organic waste in the ceramic matrix makes the use of
sludge from wastewater treatment systems viable. They have shown it [7], [12],
[14], [15], [16], [17], in recent studies, the present investigation, proposed a
thermal analysis, to optimize the quality of the ceramic matrices, with additions of
residual sludge; achieving improvements in the physical, chemical and biological
properties of the bricks. The chemical behavior of the dehydroxylation reactions
of the sludge in the ceramic matrices that take place at 450-500 °C was evaluated
and the decomposition reactions of organic matter at 400-700 °C, until the
formation of the vitreous material [2], to have control over the diffusion
processes, which facilitate the transformation of these to carbon dioxide and the
crystallization of silica and other components, from 900 °C for the vitrification of
ceramic matrices, necessary to join the particles that give durability and resistance
to the product obtained, avoiding excessive thermal stresses in the temperature
deltas.

2. Materials and methods

To determine the exploitation of the use of residual muds as an addition of
replacement for the clay in the manufacture of ceramic matrices that meet the
quality standards required for the ceramic industry, it is convenient to highlight
three moments; . Collection of sludge and clays: Sludge samples come from the
by-product generated from a wastewater treatment plant, considering that the
production of this waste derives management problems and inadequate disposal,
generating environmental implications in the area due to its composition
chemistry in addition to the high volumes reached. The sludge was subjected to
controlled combustion at a temperature of 550 °C, in order to analyze results obtained
Addition of residual sludge in the elaboration of ceramic matrices

between ceramic matrices with the addition of dry muds - clay, ceramic matrices, calcined mudstones - clay and ceramic matrices of clay only. **i. Collection of sludge and clays:** Sludge samples come from the by-product generated from a wastewater treatment plant in the city of Valledupar - Colombia, considering that the production of this waste derives management problems and inadequate disposal, generating environmental implications in the area due to its chemical composition in addition to the high volumes reached. The sludge was subjected to controlled combustion at a temperature of 550 °C, in order to analyze results obtained between ceramic matrices with the addition of dry sludge – clay, ceramic matrices with addition of calcined sludge – clay and clay – only clay matrices.

On the other hand, the clays come from natural origin of banks of extraction of this mineral material, destined for the elaboration of ceramics free of impurities and polluting material. A crushing and sieving process was applied to the different samples to obtain particles of sizes not greater than 1.18 mm, therefore a workable and adherent mixture was guaranteed due to the granulometric distribution of the materials worked; **ii. Selection of percentages of additions and cooking temperatures:** 60 ceramic matrices were prepared with the addition of residual sludge in order to establish the best response to the tests of resistance to compression and absorption of submerged water, taking as reference the addition percentages (dry sludge and calcined sludge) and temperatures used in the firing of the ceramic matrices established by the analysis of different investigations among which are [3], [10], [18], in this way, percentages of (5, 10, 15, 20 and 30%) of residual sludge, were selected in this way, to be cooked at different temperatures, inside which the oven temperature is considered, reaching an internal temperature of the artisanal oven of 750 °C, in the same way temperatures of, (800, 900 and 1000 °C). In a similar way, 6 ceramic matrices were elaborated in the absence of residual sludge, taking them as a control reference for the comparison of the results compared to those containing residual sludge. The modular dimensions of (5x5x10 cm) and an average weight of 0.36 kg net weight were established. Finally the ceramic matrices were dried at an ambient temperature of 40 °C for 24 H; then the cooking process was carried out at 700 °C in order to eliminate traces of organic matter for 1 H, then increase the cooking at different temperatures 800, 900 and 1000 °C in a muffle.

Finally, **iii. Determination of the physical and mechanical characteristics of ceramic matrices:** The ceramic matrices were examined for their quality according to the ASTM [19], for the use of masonry ceramics, where a minimum individual resistance of 17.20 Mpa and a submerged individual absorption of 17% are fixed. For the test of mechanical resistance to compression and absorption of submerged water, they were tested in the ceramic matrices taking into account the sampling and testing procedures of the ceramic bricks as established in the ASTM [20].
**Results and discussion**

The characterization of the ceramic bricks in relation to the different firing temperatures were related to the average weight among the ceramics obtained, it showed higher values in the standard bricks (365.83 g), followed by the ceramics with additions of calcined sludge (360.32 g) and dry sludge (358.47 g), which may be due to the granulometric differences of the materials that influence the compaction of the mixtures. The values of linear contraction of the bricks are observed a tendency to increase in function of the temperature, excluding the coccids at temperatures of 1000 °C, which showed negative results, meaning that some of these had a linear increase in one of its dimensions.

The determination of the physical and mechanical properties of the ceramic bricks in relation to the resistance to compression with the temperature evaluated (Oven, 800 °C, 900 °C and 1000 °C), presented significant differences (K-W: 8,800; P<0,032; N: 120); where it is evident that the highest average values recorded were of 36.6; 39.7; 40.7 y 48.5 Mpa respectively. Finding that the highest resistance of the compression was 51.0 MPa for a temperature of 1000 °C of cooking, and the lowest compressive strength was 10.0 MPa where the firing process was handled the internal temperatures of artisanal ovens. The standard bricks (100% clay) presented a similar behavior; with resistances of 26.3; 22.2; 34.0 and 36.6 MPa for oven temperatures, 800; 900; and 1000 °C respectively. Evidencing the existence of a directly proportional relationship between temperature and resistance; consequently most ceramics cooked at different temperatures comply with the provisions of the ASTM [19].

**Table 1.** Resistance to compression (MPa), submerged absorption (%) of ceramic bricks with sewage sludge; for different temperatures (Oven, 800, 900 and 1000 °C).

<table>
<thead>
<tr>
<th>Cooking temperature (°C)</th>
<th>Resistance (Mpa)</th>
<th>Absorption Submerged (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH</td>
<td>22,6±3,06</td>
<td>17,23±0,18</td>
</tr>
<tr>
<td>800</td>
<td>26,2±2,94</td>
<td>17,34±0,14</td>
</tr>
<tr>
<td>900</td>
<td>29,8±3,74</td>
<td>17,01±0,35</td>
</tr>
<tr>
<td>1000</td>
<td>29,8±2,01</td>
<td>15,53±0,69</td>
</tr>
<tr>
<td>K-W</td>
<td>8,800</td>
<td>33,156</td>
</tr>
<tr>
<td>P</td>
<td>0,032</td>
<td>0,000</td>
</tr>
</tbody>
</table>

Submerged absorption and temperature showed an inversely proportional relationship, with significant differences (K-W: 33,156 P<0,000, N: 120); where it is evidence that the average values registered were (17.23; 17.34; 17.01 y 15.53%) for temperatures Oven; 800, 900 and 1000 °C respectively; in which, only comply with the ASTM [19], bricks made with temperatures of 1000 °C for use in masonry. It was also shown that the averages of the standard ceramics (16.01%) are below the maximum limits of submerged absorption, established by the ASTM [19], with an individual percentage of 17%.
The influence of temperature in the production of ceramic bricks by sludge – clay mixtures is directly proportional to the resistance to compression, as well as the results presented in the investigations of [10], [21], and [22]. The average values for those cooked at 1000 °C reached resistances up to 48.7 MPa, values similar to that reported by [21], who showed resistances of 50.26 MPa at a temperature of 1050 °C, and lower than that reported by [22], who showed resistance of 22.72 MPa at a temperature of 900 °C; these averages of resistance to compression were found in the maximum temperatures worked by the authors. This directly proportional relationship between resistance to compression and temperature is due to the high content of silica (SiO2) in the mixtures, which is a common component of brick-making floors; it changes to its crystalline form at temperatures above 573 °C. The formation of glass is necessary to join the particles and make the product strong and durable, begins at approximately 900 °C, as indicated [2]. The submerged absorptions presented an inversely proportional relationship with respect to temperature, being similar to those presented by [3], [10], who reported lower percentages of absorption at temperatures of 1050 °C and 1200 °C respectively, which were the highest temperatures worked by these authors. It can be said that there is a significant correlation between submerged absorption and temperature, similar with [21], which presented the same variations where, at a higher temperature, less water absorption, conversely, when working at a lower temperature, the greater the water absorption.

Figure 1. Resistances and submerged absorption of ceramic bricks with wastewater biosolids as a function of temperatures (800 °C, 900 °C, 1000 °C and furnace), A) Compressive strength. B) Submerged absorption.

Conclusions

The Compression resistances analyzed in the ceramic bricks show a directly proportional relationship, as the cooking temperature increases, the compression resistance of the ceramic matrices increases similarly, this is evidenced in worked temperatures of 1000 °C reaching a resistance of 51.0 Mpa, likewise for temperatures
worked in artisanal ovens (750 °C) the resistance to understanding reached 10 Mpa. It is noteworthy that the ceramics with the addition of sludge from the wastewater treatment plants, they have higher resistance than the standard bricks in all the tests carried out, indicating that adding them to the clay mixture for the production of ceramic bricks increases the property of resistance in them.

Water absorption tests on bricks cooked at (800, 900 °C) failed to comply with the ASTM [19], exceeding the limits allowed, on the other hand, they only managed to achieve a large part of the cooking at a temperature of 1000 °C, for the masonry.

References


Addition of residual sludge in the elaboration of ceramic matrices


Received: October 12, 2018; Published: November 26, 2018