PORCELAIN TILE MANUFACTURE IN COLOMBIA: A STRATEGY FOR THE DOMESTIC CERAMIC MARKET

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ABSTRACT

This study has allowed Colombian clays from local mines to be assessed. The clays were mineralogically characterised by X-ray diffraction and chemically characterised by X-ray fluorescence. They were also subjected to DTA-TG thermal analysis, dilatometric analysis, in addition to microstructural analysis by scanning electron microscopy (SEM), particle size distribution analysis by laser diffraction, and measurement of the chromatic coordinates by the CIE-Lab system.

The physical-ceramic properties were similarly evaluated after subjecting the raw materials to firing temperatures between 1090°C and 1220°C, determining the linear shrinkage, porosity (water absorption), mechanical strength, plasticity, and pyroplastic deformation.

Based on these results an evaluation and estimation were made of the usability of these materials in the manufacture of ceramic floor and wall tiles by developing body formulations with stoneware, semi-stoneware, earthenware (porosa), and porcelain tile characteristics. Compositions were thus obtained that reached an appropriate water absorption for the intended use, in a range of temperatures from 1045ºC to 1220ºC, with a 60-min firing cycle.

1. INTRODUCTION

In the last 5 years the Colombian market has undergone radical changes in regard to the variables involved in decision-taking for refurbishment and construction. Homes have become an extension of the owner's personality, and the widespread trend is to devote more time and money in purchasing decisions concerning articles for the home.

Refurbishment cycles have dropped from 7 to 4 years; the low interest rates and facilities for obtaining mortgages have spurred on the home building sector in Colombia, with decoration specifications that satisfy the new needs of Colombian consumers, who are increasingly better informed in their purchasing decisions.

Within the context of these changes, porcelain tile has positioned itself among consumers as a hot product in the domestic market, with technical and decorative qualities far beyond those of traditional ceramics. In the Colombian market, porcelain tile has become a product of the future with greater added value, which in many cases can far exceed the price of traditional ceramics.

In Colombia there are four floor and wall tile manufacturers of porosa and stoneware tile, which supply most of the country and manufacture about 54 million m^2/year. However, domestic market needs are not fully met and in addition, following global trends, 20% of sales currently come from imported products. On a general level, from a strategic viewpoint, porcelain tile is a fast-growing market segment on the domestic level, with good export potential to neighbouring countries and to countries in the Caribbean, Central America, as well as to the United States.

In view of the above, the main objective of this study was to develop porcelain tile formulations using Colombian national raw materials. The national raw materials were, therefore, first characterised by physico-chemical analysis using X-ray fluorescence, X-ray diffraction, and scanning electron microscopy, mainly in order later to be able to develop porcelain tile body formulations that would allow innovative tile products to be obtained with high technical performance features, such as abrasion resistance, low porosity, high mechanical strength, impermeability, and resistance to chemical attack and frost.

These formulations were prepared for testing by means of the corresponding vitrification diagrams (% linear shrinkage; % water absorption versus temperature). Using selected formulations, it was further sought to optimise the process in order to scale up to industrial level with a view to offering this product on the domestic and international market, thus enabling part of the porcelain tile imports into Colombia to be reduced.

2. EXPERIMENTAL DEVELOPMENT

Samples of Colombian raw materials were obtained from different geological formations in different areas of Colombia (Antioquia, Caldas, Boyacá, Santander, and Tolima), including raw materials from mines of the Eurocerámica company, and exploration and commercial materials. All analyses were performed in Spain (Laboratories of the Central Scientific Instruments Service of Jaume I University, Castellón, and the company Tierra Atomizada, S.A., Alcora) and in Colombia (National University of Colombia, Medellín, and the company Eurocerámica, S.A.)

2.1. Mineralogical characterisation

The composition of the crystalline phases in the powders of the starting materials, as well as in the fired products, was determined by X-ray diffraction (XRD) using a Panalytical X'pert PRO MPD diffractometer of the National University of Colombia, Medellín, with a Cu anode and voltage of 40 kV with an intensity of 40 mA. The diffractograms were obtained in a 2θ range from 5 to 80º.

2.2. Chemical characterisation

Chemical analysis was carried out at Jaime I University of Spain and at the company Tierra Atomizada, S.A., on powders of the starting materials by X-ray fluorescence (XRF). Loss on ignition was determined by subjecting the clays to 900ºC for 1 hour.

2.3. Physical-ceramic characterisation

The individual raw materials and the proposed formulations were characterised by determining their rheological behaviour, plasticity, after-pressing expansion, water absorption, dry shrinkage, fired shrinkage, and particle size distribution (PSD). Vitrification curves were also constructed. The characterisation was performed at Eurocerámica, and at Jaime I University, as well as with the support of CIMEX of the National University of Colombia, Medellín, and the company Tierra Atomizada, S.A.

2.4. Thermal analysis

The physical and/or chemical changes produced during firing and the transformations that could alter the chemical composition were identified. This was performed by differential thermal analysis (DTA), thermogravimetric analysis (TGA), and dilatometric analysis. Differential thermal analysis (DTA) was performed at the National University of Colombia, Medellín; differential thermal analysis (DTA) and thermogravimetric analysis (TGA) was jointly carried out at Jaume I University, Castellón; and dilatometric analysis was conducted at the company Eurocerámica, Medellín.

3. RESULTS

The characterisation results of the selected raw materials are set out below. Samples were studied from the following Formations: Amagá Formation, La Soledad–Amalfi Formation, Abejorral Formation, Cumbre–Santander Formation, and Arcabuco–Boyacá Formation. Mineralogical characterisation, thermal analysis, and physical-ceramic characterisation were performed on all samples.

3.1. Clay from the Amagá Formation:

This was found to be a montmorillonitic clay with high quartz content, which displayed endothermic peaks at 126ºC and 298ºC owing to the elimination of adsorbed water (physical water).

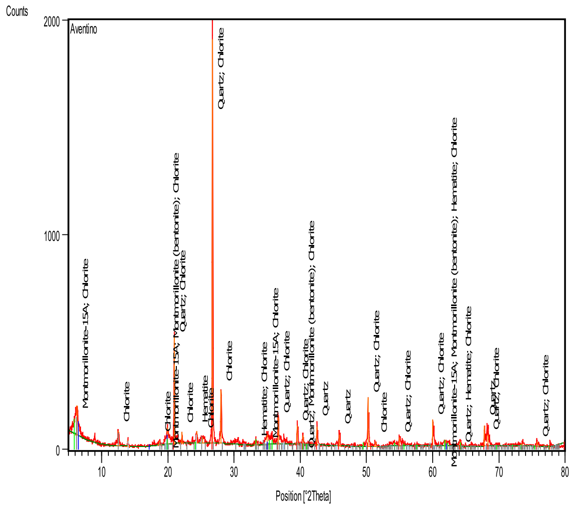

Figure 1. Diffractogram Amagá Formation

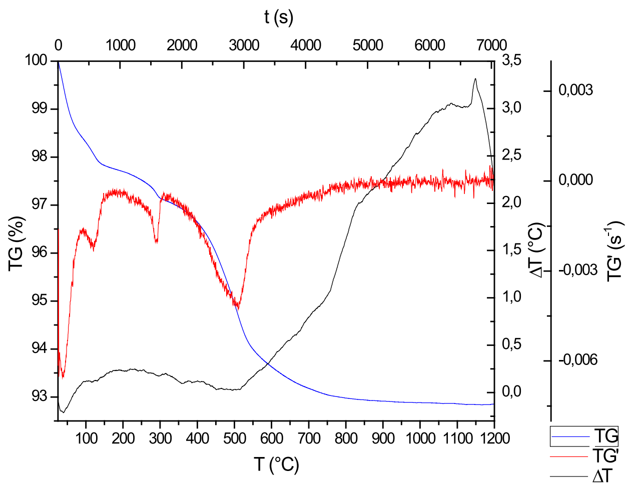

Figure 2. DTA – TG – DTG curves Amagá Formation

3.1.1. Physical-ceramic characterisation

This was a plastic material (22,65%) with a fired mechanical strength close to 300 kg/cm^2, yielding good bulk density (2,04 g/cm^3) with a pressing pressure of 250 kg/cm^2

It exhibited a minimum water absorption at 1165ºC with an unstable linear shrinkage of 5,5%, after which it displayed strong expansion owing to occluded gases in the sample.

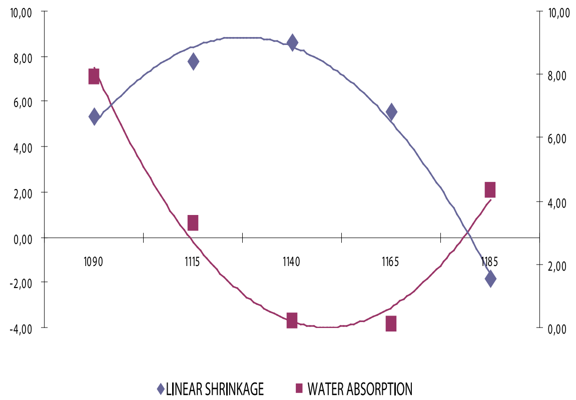

Figure 3. Vitrification curve Amagá Formation

3.2. La Soledad–Amalfi Formation

According to the X-ray diffraction analyses, this was a composition made up of Illite and Quartz.

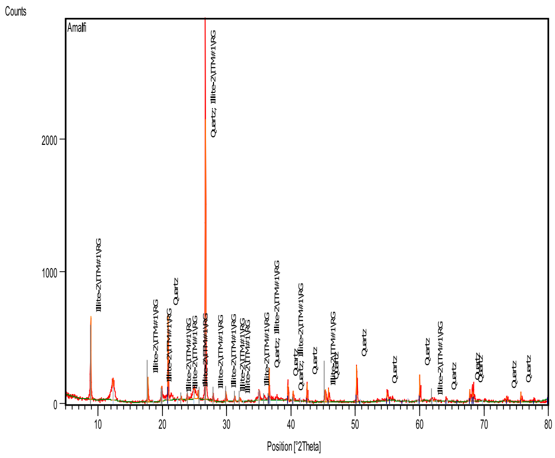

Figure 4. Diffractogram La Soledad–Amalfi

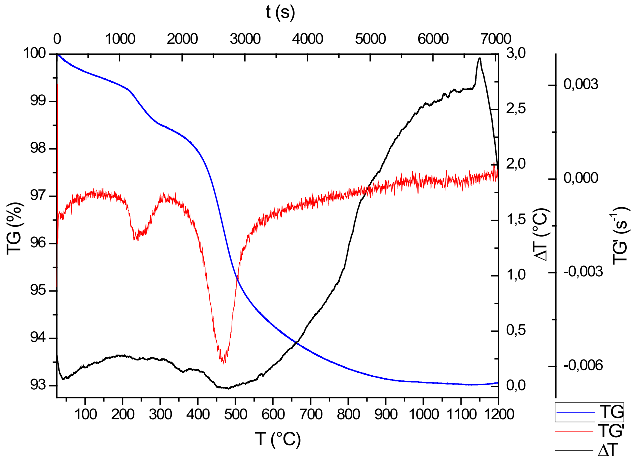

Figure 5. DTA – TG – DTG curves La Soledad-Amalfi

3.2.1. Physical-ceramic characterisation

Owing to the characteristic composition of this material, vitrification did not occur in the range of temperatures up to 1200ºC, at which it still displayed a water absorption of 7,5%. Despite being a readily formable plastic clay (23% PI), it was so refractory that it did not allow fired mechanical strength values above 75 kg/ cm^2 to be obtained.

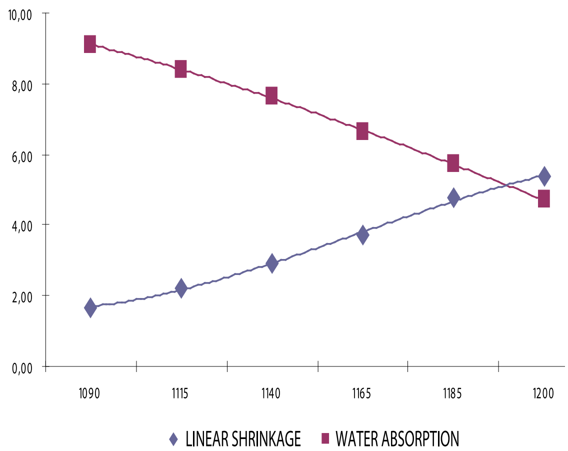

Figure 6. Vitrification curve La Soledad-Amalfi

With regard to its chemical composition, it had a SiO_2/Al_2O_3 ratio of 55,8/23,8 with a Potassium content of 2,64%, while that of the other constituents was very low.

3.3. Abejorral Formation

This material was found to have a composition mainly made up of Quartz and Illite.

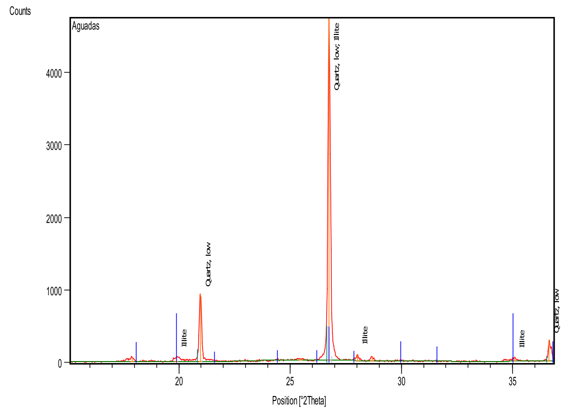

Figure 7. Diffractogram Abejorral – Caldas

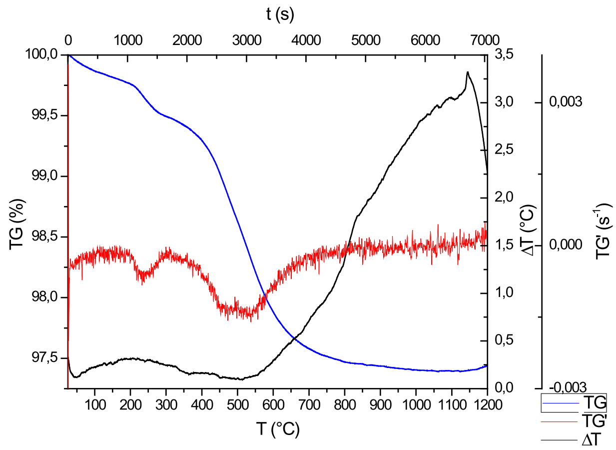

Figure 8. DTA – TG – DTG curves Abejorral – Caldas

3.3.1. Physical-ceramic characterisation

Owing to its high quartz content, this material displayed a refractory behaviour and exhibited low linear shrinkage with high apparent porosity in the range of temperatures of the vitrification curve. It provided thermal stability in a wide range of temperatures.

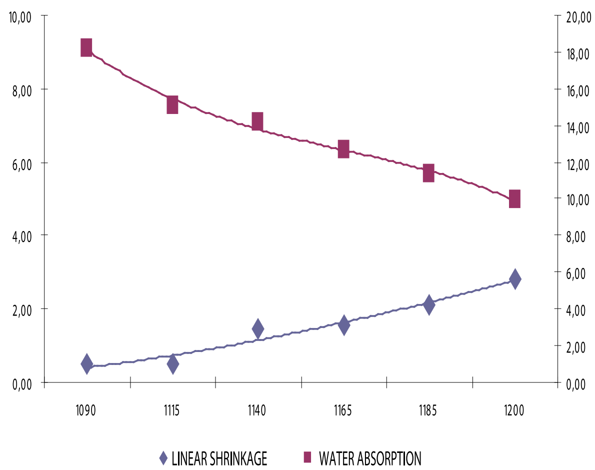

Figure 9. Vitrification curve Abejorral – Caldas

It displayed low mechanical strength, 56 kg/cm^2, and low bulk density, 1.8 g/cm^3.

3.4. Cumbre-Santander Formation

This was an Illitic clay, with a presence of Kaolinite and Quartz.

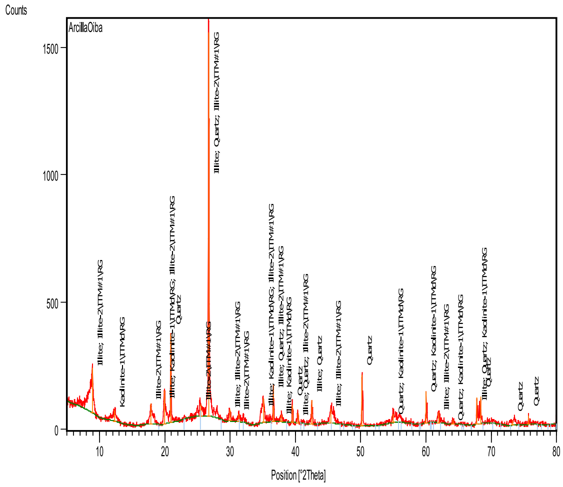

Figure 10. Diffractogram Cumbre–Santander

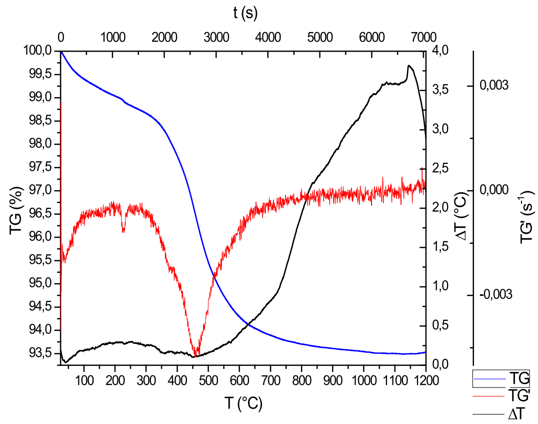

Figure 11. DTA – TG – DTG curves Cumbre–Santander

3.4.1. Physical-ceramic characterisation

This clay reached minimum water absorption at 1165ºC with a linear shrinkage of almost 10%. The slope of the linear absorption curve was pronounced between 1090ºC and 1115ºC, indicating that the material was quite active in this range of temperatures: vitrification started at 1115ºC, and after 1185°C the material underwent a slight expansion. Linear shrinkage was stable throughout the evaluated range of temperatures.

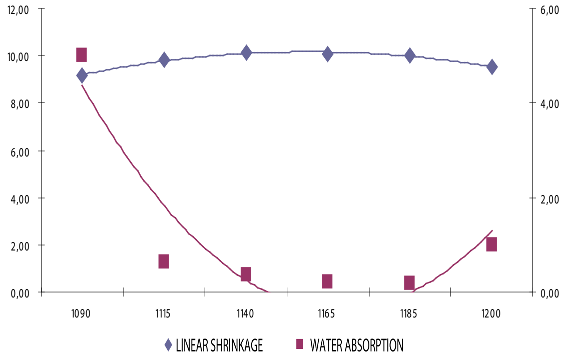

Figure 12. Vitrification curve Cumbre–Santander

3.5. Arcabuco – Boyacá

Mineralogically this material displayed characteristic peaks of Illite and Quartz.

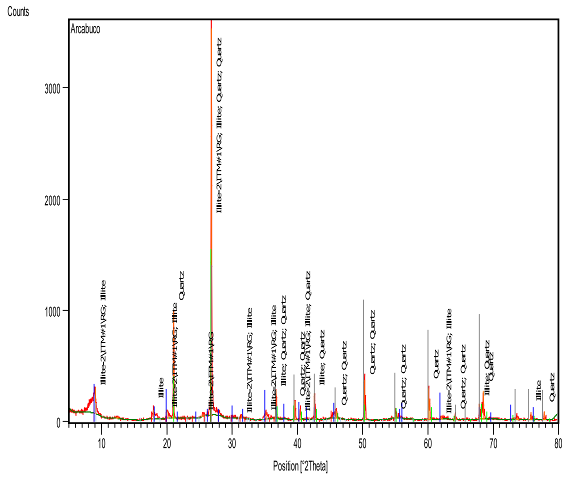

Figure 13. Diffractogram Arcabuco material

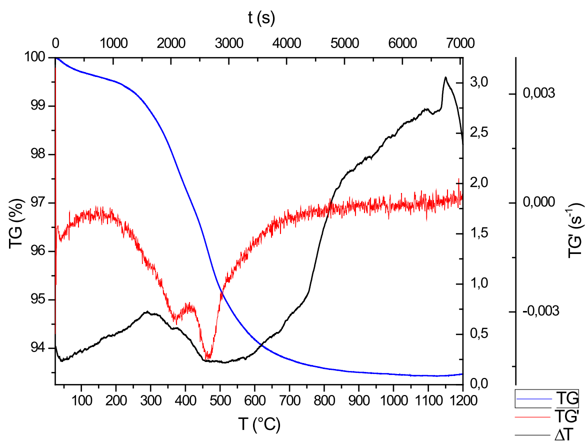

Figure 14. DTA – TG – DTG curves Los Pozos Arcabuco material

3.5.1. Physical-ceramic characterisation

This was a white-coloured material that did not undergo significant changes in the range of temperatures of the vitrification curve; the behaviour was linear for both the linear shrinkage and the water absorption curves. At 1200ºC, values of about 6% linear shrinkage and 5% water absorption were obtained.

The material displayed good plasticity (22,71% PI) and a good compaction range (2,03–2,08 g/cm^3) at low pressure and moisture content.

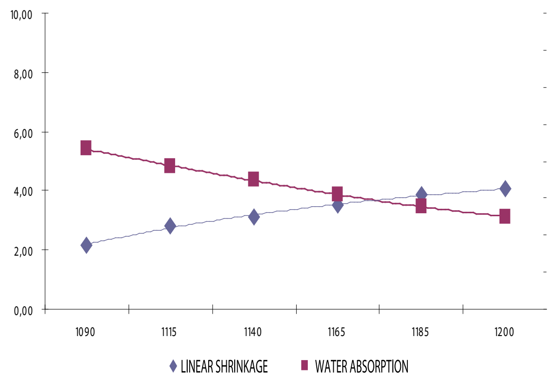

Figure 15. Vitrification curve Arcabuco material

With regard to its chemical composition, this material had a SiO_2/Al_2O_3 ratio of 58,62%/25,32%, and contained Potassium (2,97%) and Sodium (1,46%).

4. CONCLUSIONS

The characterisation of Colombian raw materials enabled porcelain tile body formulations to be developed for producing tiles with high abrasion resistance, low porosity, high mechanical characteristics, impermeability, and resistance to chemical attack and frost.

This project allowed the necessary technical and economic conditions to be developed to produce white-firing ceramic tile bodies, with porcelain tile technical characteristics, from Colombian raw materials.

Local raw materials were selected from Colombian national mines and the chemical, mineralogical, and physical-ceramic characteristics of all these materials were determined.

Using the selected raw materials, body compositions of porous single-fired wall tile (monoporosa), stoneware tile, and porcelain tile were formulated and the relevant physical-ceramic and thermal analyses were performed in order to define, at laboratory level, the optimum working conditions in each of their milling, spray-drying, pressing, glazing, and firing processes.

This project has laid the groundwork for industrial scale-up in order to be able to manufacture porcelain tile with Colombian raw materials. This will allow porcelain tile to be offered on the domestic and international market and, thus, part of the porcelain tile imports into Colombia to be reduced.

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