LIFE FOUNDRYTILE:RECOVERY OF SANDS AND FOUNDRY RESIDUES IN THE PRODUCTION OF CERAMIC TILES

M.F.Quereda Vázquez[(1)], C. Moreda Beltrán[(1)], C. Segarra Ferrando[(1)], F. Clarens Blanco[(2)], M. Mesas Suárez[(2)]

[(1)] Instituto de Tecnología Cerámica (ITC). Asociación de Investigación de las Industrias Cerámicas (AICE).

Universitat Jaume I. Castellón. Spain.

[(2)] Fundació CTM Centre Tecnològic, Plaça de la Ciència 2, 08243 Manresa, Spain

1. ABSTRACT

The iron foundry sector generates a high number of sands and foundry residues, more than 330,000 tons per year, throughout Spain. Although there are different valid recovery methods, the situation in reality is that more than 50% of these by-products are currently deposited in landfills.

Taking into account the production of ceramic tiles in Spain, if these by-products are introduced as a 5% substitution for clays and sands, full recovery could be achieved. At the European level, taking into account the generation of by-products and the production of tiles, 75% could be recovered.

Therefore, this study aims to demonstrate the technical, economic and environmental viability of the recovery of a fraction of iron foundry residues and sands for the production of ceramic tiles.

In this project, 22 samples of by-products have been characterized. The Fe_2O_3 and organic carbon content present in byproducts are the most critical aspects for recovery as raw materials for the production of ceramic tiles. To improve the recovery ratio, different pre-treatments have been carried out, obtaining satisfactory results using magnetic separation and thermal treatments.

In the next stage of the project, compositions representative of those used for the industrial manufacture of porcelain stoneware tiles, glazed tile red stoneware and red and white tile have been prepared and characterized.

2. INTRODUCTION

The iron foundry sector generates a high number of sands and foundry residues, more than 330,000 tons per year, throughout Spain. Depending on the moulding process used by the foundries, sands may be subdivided into green moulding sands and chemical moulding sands. Green moulding sands (in which bentonites are used as binders) is the most common in foundries; Green moulding sands are generated in the largest number in the sector. In chemical moulding sands, binders are organic (furanic and phenolic) and inorganic (silicate ester) compounds. The fine fraction of green moulding and chemical moulding sands originates mainly from aspirations present throughout the moulding process. Although there are different valid recovery methods, the situation in reality is that more than 50% of these by-products are currently deposited in landfills. Table 1 shows the quantities generated and the percentages recovered for each type.

Typology of byproducts	Generation (T/year)	% Recovered	% Dump
Green molding sands (AV)	223,689	45.8	54.2
Fine fraction of green molding sands (FV)	53,484	84.2	15.8
Fine fraction of chemical molding sands (AQ)	60,716	63.2	36.8
Fine fraction of chemical molding sands (FQ)	12,384	18.6	81.4

Table 1.*Generation and recovery percentages in Spain* ***for 2016.***

These by-products have silica as the main component, thus, they could partially replace sands and clays used in ceramic tile medium [1]. According to the economic activity of both sectors, in the case of Spain, with a degree of substitution of 5%, the production of tiles could absorb all by-products, both sand and residues, achieving 75% recovery at the European level.

Thus, this study, co-financed by the LIFE FoundryTile project [2], aims to demonstrate the technical, economic and environmental viability of the recovery of the fine fraction of iron foundry residues and sands for the production of ceramic tile, contributing to the implementation of the European Waste Framework Directive (Directive 2008/98/EC) and the objectives and goals of the Roadmap towards a Resource Efficient Europe.

3. MAIN RESULTS OBTAINED IN THE PROJECT

The project has characterized 22 samples of sand and residues from both green and chemical molding processes. Characterization consisted of the determination of chemical composition, mineralogical, particle size, thermal analysis, etc.

The results obtained from the characterization show that organic carbon (Corg) present in by-products as well as the Fe_2O_3 content (in the case of white tiles) are the most critical aspects for recovery as raw materials for the production of ceramic tiles. The organic carbon present in smelting by-products (mostly in fine fractions) comes, in the case of green molding processes, from the coal used as raw material in the process, and from chemical ligands such as phenolic and furan resins, for chemical molding processes.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	ppc	Corg
AV	89.0-95.0	2.5-3.0	0.7-0.8	0.3-0.5	0.4-0.6	0.4-0.5	0.1-0.3	1.7-5.1	0.8-3.0
FV	65.5-72.0	6.5-8.5	2.0-2.1	1.4-1.7	1.1-2.0	0.9-1.5	0.3-1.2	14-18	10-14
AQ	33.0-95.0	0.4-13.5	0.4-4.5	0.0-2.5	<0.1-17.5	0.2-1.0	0.1-1.0	0.4-4.1	0.1-2.5
FQ	24.5-94.0	0.9-20.5	0.4-5.5	0.1-3.5	<0.1-21.5	0.1-9.0	0.3-2.3	0.4-54	0.1-40

Table 2.*Chemical composition and organic carbon content of the different types of samples (%)*

To improve recovery ratios, different pre-treatments have been carried out, obtaining satisfactory results using magnetic separation (to reduce iron) and thermal treatments (to reduce organic compounds). In effect, calcining by-products at temperatures around 600° C eliminates practically all organic compounds. Figure 1 shows the tendency to form black cores in a porcelain stoneware composition (STD), from the composition obtained by adding 5% of the green molding residues (FV) and from the same composition but with the residue heat treated at 600ºC. These results confirm the validity of thermal treatments for the elimination of organic compounds.

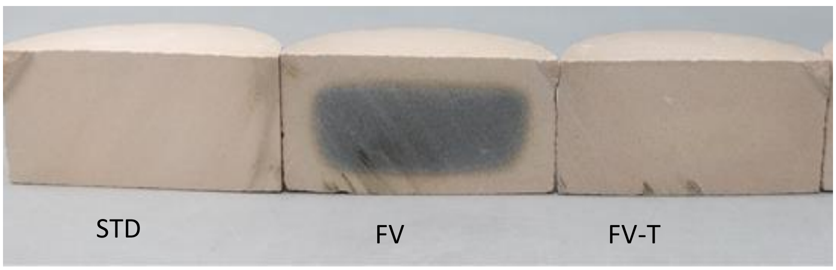

Figure 1. *Tendency to form black cores in a porcelain stoneware composition and by adding 5% treated and untreated byproducts (FV).*

In the next stage of the project, compositions representative of those used for the industrial manufacture of porcelain stoneware tiles, glazed tile red stoneware and red and white tile have been prepared and characterized. Two recovery options have been studied: recovery as much as possible of the chemical molding byproducts (that deposited in landfills in greater proportion) and recovery of all chemical molding residues next to the green molding sands as well as part of the green molding residues.

Recovery percentages have been established based on the criterion of not increasing the content of organic matter of compositions to inadmissible limits and in the case of the white compositions, the additional criterion of keeping the iron content within the margins of tolerance. Thus, in the case of mixtures not treated thermally, up to 3% byproducts could be introduced, this percentage may be increased up to 6% if a significant part of the byproduct is heat treated. These compositions have been prepared and initially characterized on a laboratory scale and subsequently on a pilot scale. By way of example, the following figure shows the gresification diagrams of the dried powders obtained at the pilot scale with red stoneware compositions. At present, the characterization of the compositions prepared at a pilot scale is being completed, the results obtained to date being satisfactory in terms of behaviour in terms of pressing and firing as well as the properties of the products (mechanical resistance, moisture expansion in tile compositions, fired colour for white compositions, thermal expansion, etc.). On the contrary, in spite of having taken into account the organic carbon contents of the byproducts, their decomposition must be more complicated than that of the organic matter present in the clays, observing a tendency to form larger black cores in the compositions with byproducts with respect to the initial compositions. For this reason, the formulation of new compositions is planned, reducing the proportion of byproducts that contain a greater quantity of organic compounds and the addition of organic matter oxidizing compounds.

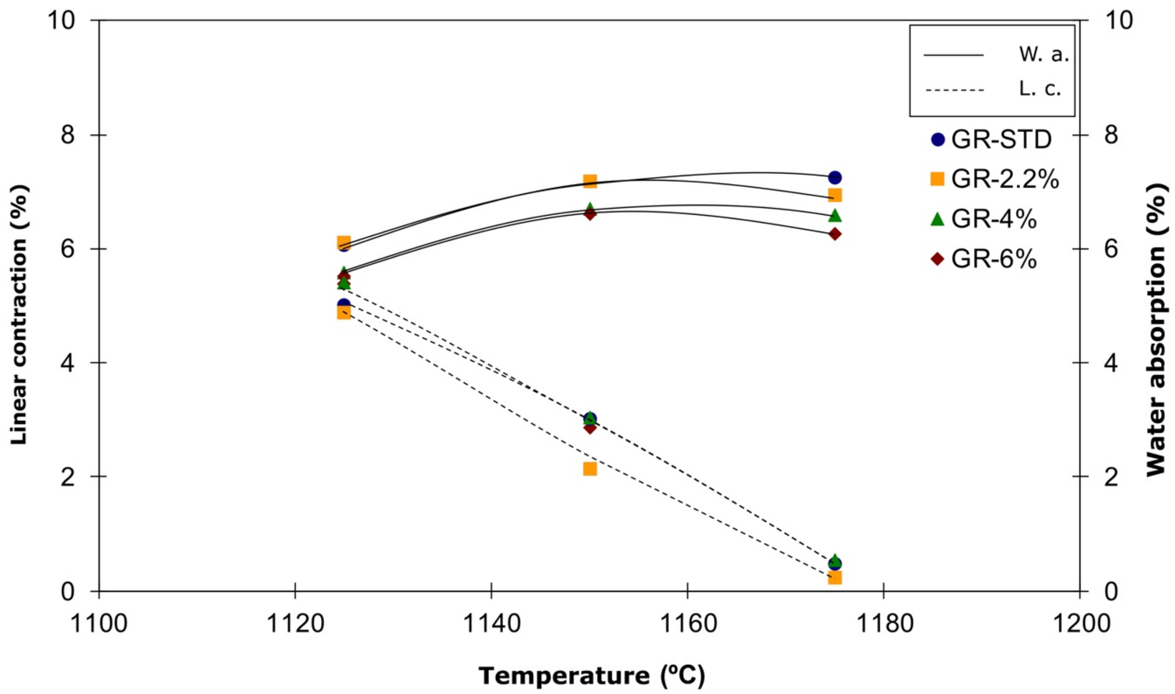

Figure 2. *Gresification diagrams of dried powders from red stoneware obtained at pilot scale.*

In the following phases of the project, industrial tests are planned, analysing the emission of compounds during firing while carrying out leachate tests on the products obtained.

According to the principles of the European Commission, new products must be environmentally friendly. For this purpose, the environmental suitability of the new solution will be evaluated through application of the Life Cycle Analysis methodology (LCA) and Chemical Risk Assessment (CRA) for all stages, from production to end of useful life. This LCA, together with a Life-Cycle Cost Analysis (LCCA) will focus especially on aspects related to the impact of transport, determining a maximum radius in which the application is favourable. It will also be necessary to evaluate and determine the optimal point between an increased percentage of recovery due to pre-treatments and increased costs, taking into account the evolution of both sectors as well as legal requirements.

4. ACKNOWLEDGEMENTS

LIFE FOUNDRYTILE (LIFE14 ENV/ES/000252) is a project co-financed by the European Union within the LIFE Environment and Resource Efficiency Programme. Likewise, the authors would like to thank the 17 companies that have provided data and samples along with project partners: Asociación de Fundidores del País Vasco y Navarra (AFV), Asociación Española de Fabricantes de Azulejos y Pavimentos Cerámicos (ASCER) and Grupo Euroatomizado.

5. REFERENCES

[1] SÁNCHEZ, E.; GARCÍA, J.; SANZ, V.; OCHANDIO, E. Criterios de selección de materias primas para la fabricación de pavimentos y revestimientos cerámicos.In:Qualicer:I World Congress on Ceramic Tile Quality.Conferences.[S.l.: s.n., 1990]. pp. 103-122.

[2] www.foundrytile.eu/es/.