

## **DEVELOPMENT OF ADDITIVES FOR ENERGY IMPROVEMENT IN PORCELAIN TILE FIRING**

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## 1. INTRODUCTION

Porcelain tile is a type of ceramic tile that requires higher firing temperatures (1180–1220°C) because it needs to exhibit practically zero apparent porosity. The mechanism that produces these low porosity values is sintering in the presence of liquid phase. The sintering rate and temperature range depend mainly on the quantity of liquid phase and its viscosity, parameters that in turn depend on the chemical and mineralogical composition of the material [1].

In this study a material has been developed that can be added to porcelain tile compositions to increase the sintering rate, thus reducing energy consumption and CO<sub>2</sub> emissions. Lithium oxide was selected as the base constituent of the additive, which is a vigorous flux that does not display the disadvantage of increasing the tendency to deform by pyroplasticity. In order to select the secondary ingredients of the additive, the chemical composition of the glassy phase that formed during porcelain tile firing (mainly SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Na<sub>2</sub>O) was determined and, by consulting the phase diagrams [2], the oxides were determined that, together with lithium oxide, formed eutectic points with the mixture corresponding to this glassy phase. The additives were obtained by mixing several raw materials that contained the selected oxides, and their influence on porcelain tile firing behaviour was evaluated.

## 2. EXPERIMENTAL

In order to conduct the study, a porcelain tile spray-dried powder was used to which the different formulated additives were added. The compositions were characterised on a laboratory scale by determining their pressing behaviour (compaction diagram) and firing behaviour (vitrification diagram and tendency to deform by pyroplasticity). After the laboratory-scale study, pilot trials were conducted with the best compositions, followed finally by several industrial trials.

## 3. RESULTS

The variation of the maximum densification temperature (T<sub>max</sub>, obtained from the vitrification diagrams) with the raw material percentage that contributed lithium oxide (base raw material) is plotted in Figure 1. A 5% content of this raw material (which provided a temperature reduction of 30°C) was selected to evaluate the effectiveness of the mixtures that contributed lithium oxide together with the oxides selected from the phase diagrams. The variation of bulk density at a temperature of 1130°C of the compositions with 5% additive as a function of the relative percentage of the complementary raw materials is presented in Figure 2. This figure clearly shows that the oxide that they contribute as well as its relative proportion with relation to the base raw material notably influenced the effective-

ness of the additive. Most of the mixtures provided a lower bulk density than the composition with 100% base raw material (100%MB), indicating decreased efficiency. However, some complementary raw materials displayed a similar or greater efficiency than the 100% base raw material.

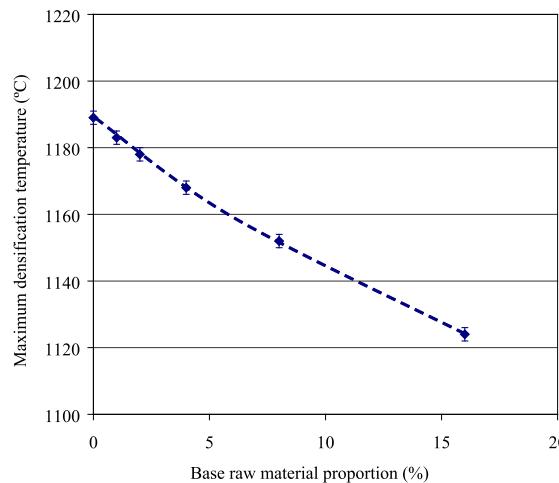


Figure 1. Maximum densification temperature as a function of the base raw material content

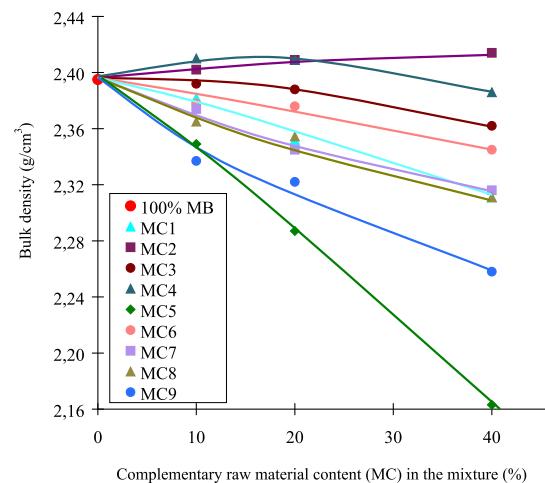


Figure 2. Bulk density at 1130°C of the compositions with 5% of the different studied mixtures as a function of the percentage of complementary raw material in the mixture

The characterisation of the most effective mixtures was completed by determining their vitrification diagrams and pyroplastic deformation. Starting with the mixture that provided the best results (high fusibility and pyroplasticity index lower than or equal to  $4 \text{ cm}^{-1} \times 10^5$ ), tertiary mixtures were formulated (base raw material and two complementary raw materials) using the information obtained in the phase diagrams.

The two tertiary mixtures with the best results were processed on a pilot scale. The results obtained, shown in Figure 3, indicate that it is possible to reduce the firing temperature by about 40°C on introducing the two mixtures in a 5% addition. With relation to the starting composition, no worsening in the rheological behaviour of the suspension or changes in the bulk density, linear shrinkage, or colour of the pieces were observed.

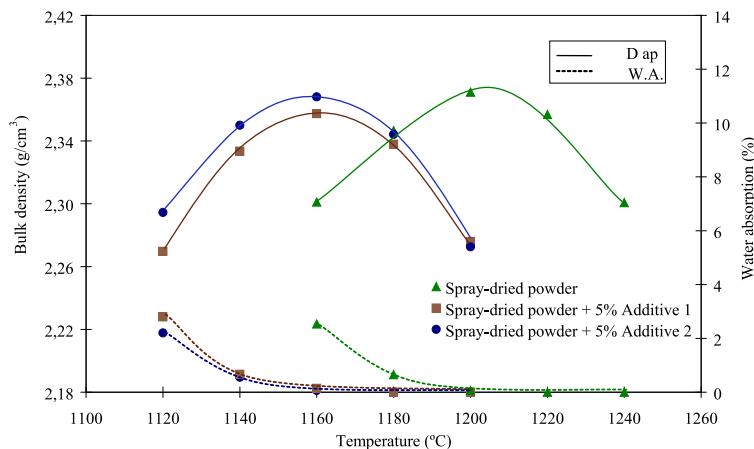


Figure 3. Vitrification diagrams of the spray-dried powders obtained in the pilot trials.

One of these additives was used in industrial-scale trials in a 2% addition. The results obtained confirmed the effectiveness of the additive in reducing the peak temperature as well as its zero influence on the rheology, bulk density, firing shrinkage, and colour of the body. In another of the trials performed, the usefulness of the additive was verified for obtaining tiles with glossy finishes without any defects and water absorption below 0,5% (the tiles being formed with lower bulk density). It should be noted that, in spite of the increased fusibility, the tiles with the additive, fired using the usual cycle, displayed no glaze defects or curvatures related to excessive pyroplastic deformation.

#### **4. CONCLUSIONS**

Fluxing additives were developed for porcelain tile composition. Their use allows:

- A considerable reduction in the peak firing temperature (about 40°C with an addition of 5%).
- Tiles to be obtained with glossy finishes, because frits with greater fusibility (and hence better stretching) can be used
- The duration of the firing cycle to be reduced.
- Energy consumption and CO<sub>2</sub> emissions to be reduced.

These additives do not modify the rheological behaviour of the composition or the bulk density, linear shrinkage, or colour of the tiles in the maximum densification state.

#### **ACKNOWLEDGEMENTS**

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