FOAMING OF CLAY SUSPENSIONS. INFLUENCE OF RHEOLOGY ON FOAM MICROSTRUCTURE AND MECHANICAL PROPERTIES

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1. INTRODUCTION

Ceramic foams are materials with a large surface area, high permeability, low density, low specific heat, and high thermal insulation. Cell size, cell morphology, and the degree of interconnection between cells are also important factors that influence potential applications of these materials.

The techniques used for obtaining them can be divided into three large groups: replication techniques, techniques for incorporating organic or inorganic fugitive phases, and foaming techniques by the introduction of a gaseous phase. In this last group, a distinction is made between gas generation in melts and the incorporation of a gaseous phase in suspensions.

This study addresses the feasibility of obtaining ceramic foams using this last technique [1], which consists of introducing air into the suspension directly through vigorous agitation, so that the gas bubbles that are initially introduced as foam-generating nuclei grow and form polyhedral cells.

2. EXPERIMENTAL

Red-firing clay (IC), of the type commonly used in ceramic tile manufacturing, was used in this study. This clay contains a mixture of clay minerals with an illitic-kaolinitic structure, and an abundant quantity of quartz. The influence of suspension solids content (40-60%), foamer content (0.75-3%), and stabiliser content (0.1-0.6%) on suspension rheology was studied, together with resulting foam bulk density, microstructure, and compressive strength.

The foam used was an anionic surfactant in an aqueous solution, which acts by reducing water surface tension. The stabiliser used belongs to the long-chain polysaccharide family.

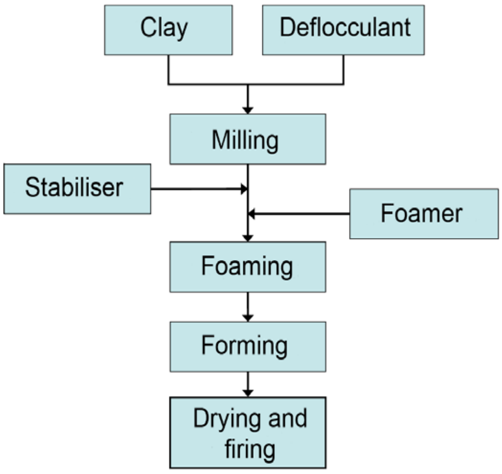

Figure 1. Flow chart of ceramic foam preparation by the incorporation of gaseous phase through vigorous stirring.

Figure 1 presents a diagram of the experimental procedure followed. The foaming of the suspensions was carried out using a concentric crown stirrer. The foams obtained were introduced into prism-shaped polyvinyl acetate moulds, in which they were dried. They were fired in an electric laboratory kiln at a maximum temperature of 1000 ºC for 60 minutes. The heating rate was 5ºC/minute and cooling was by natural convection.

3. RESULTS

The degree of foaming of a suspension depends on its surface tension and viscosity [2]. The foaming agent reduces surface tension, while the stabiliser increases suspension viscosity, which delays lamella draining.

The flow curve of suspensions with the stabiliser was used to calculate suspension viscosity at rest (η_0), using the Carreau model [3]. Figure 2 shows the extent to which suspension viscosity reduces foam porosity at the different studied foamer contents [4]. On the other hand, at the same viscosity, the increased foamer content increases foam porosity until a foamer content of 1.5% is reached, beyond which no differences are detected [5]. The figure also shows that the foamer is more efficient at low viscosity levels, a situation that encourages bubble formation.

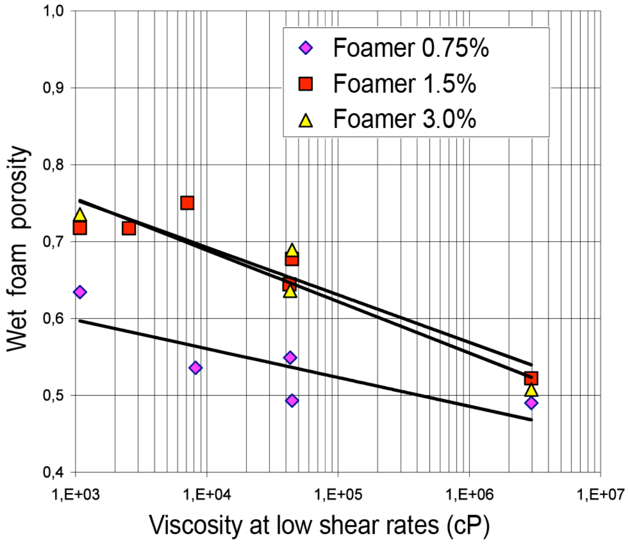

Figure 2. Porosity behaviour of wet foam as a function of viscosity at low shear rates and foamer content.

The compressive strength of the fired foam is plotted versus its bulk density in figure 3. The results were fitted using equation 1, proposed by Gibson & Ashby [6], where C_2 is a coefficient equivalent to the product $\sigma_S \cdot c_1 \cdot (1/\rho_s)^n$ of the equation:

$$\sigma = C_2 \rho^n$$

Equation 1.

Figure 3 shows the results using the stabiliser content (figure 3a) and the solids content (figure 3b) as parameters. It is observed that at the same bulk density, decreasing the stabiliser content and increasing the solids content give rise to foams with greater mechanical strength. This effect is due to the influence of both parameters on foam microstructure. Thus, figure 4 displays micrographs of foams with a very similar bulk density (ρ = 0.41-0.49 g/cm^3) obtained under different conditions. The progression through series a, b, and c shows that pore size increases and that the pores are more interconnected as a result of the smaller amount of material in the pore walls. This microstructural change decreases foam compressive strength, an aspect observed in foams of other materials [6].

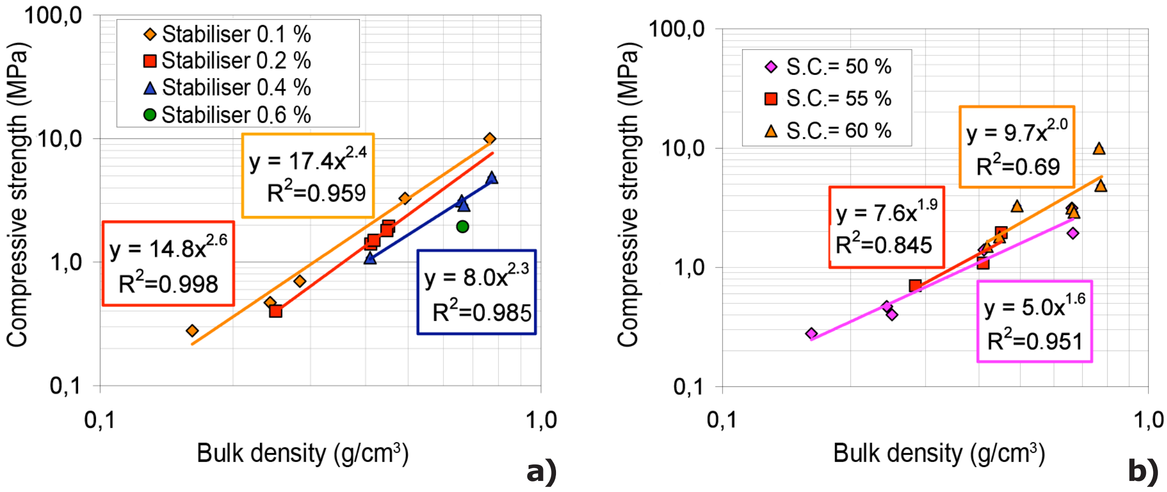

Figure 3. Relationship between compressive strength and bulk density of fired foams at different stabiliser and solids contents. (S.C.).

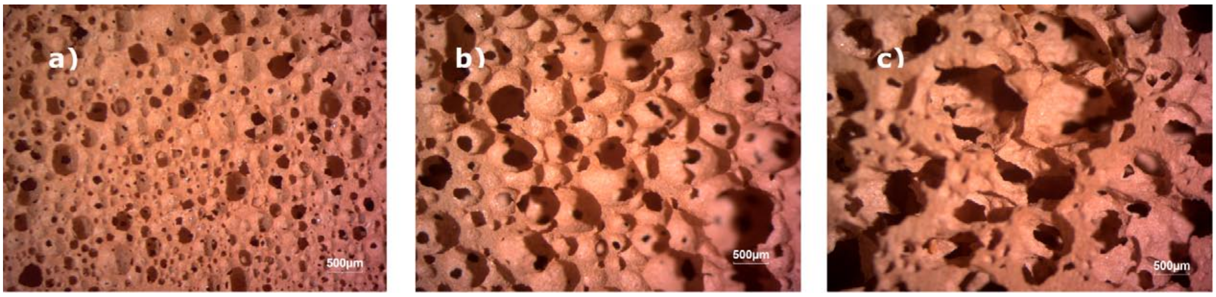

Figure 4. Micrographs of foams with similar bulk density obtained under different conditions.

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