USE OF THE OPTICAL FLEXIMETER TO EVALUATE THE TENDENCY OF CERAMIC TILES AND TILE BODIES TO DEFORM DURING FIRING

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1. INTRODUCTION

The lack of planarity that ceramic tiles can display at the kiln exit often stems from differences in thermal expansion between the materials that make up the tile (body, engobe, and glaze) [1]. On other occasions, lack of planarity is due to an excessive tendency of the body to deform as a result of pyroplasticity (mainly in vitrified products) [2]. In this study an optical fleximeter [3] was used to determine the variation of tile body curvature during the firing cycle owing to pyroplasticity, as well as the effect that different engobes had on the tendency to curve.

2. EXPERIMENTAL

In this study, industrial red-firing stoneware tile bodies and porcelain tile bodies, without and with engobe, were used. Prismatic test pieces about 8.5 cm long, 7 mm wide, and 7 mm thick were cut from these samples, and the evolution of curvature during firing was determined with an optical fleximeter. The expansion–shrinkage curves of the tile bodies and of test pieces formed from some of the engobes were obtained by dilatometry.

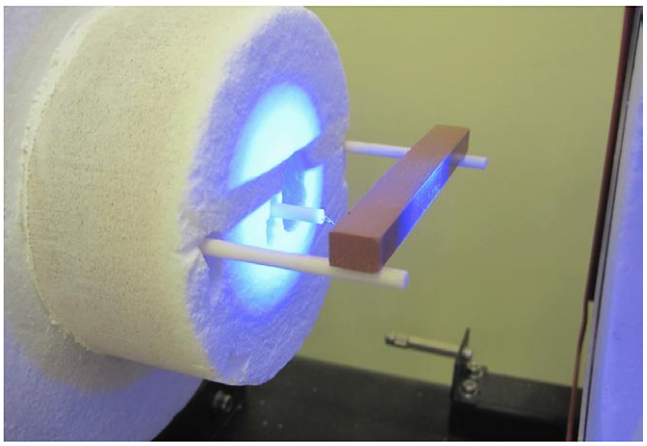

Figure 1. Detail of the optical fleximeter.

3. RESULTS

As Figure 2 shows, the sag or strain deflection depends markedly on the thickness of the piece. In this study it was therefore decided to use an index that was independent of the dimensions of the piece. By analogy with the pyroplasticity index (PI), a deformation index (DI) was defined as the opposite to the IP, according to the following expression:

$$DI = -PI = -\frac{4 \cdot e^2 \cdot s}{3 \cdot L^4}$$

where:

e : thickness of the piece

s : strain deflection

L : distance between supports

The negative values of the deformation index thus correspond to concave curvatures and the positive values to convex curvatures. It was observed that, in the case of tile bodies without engobe, the only curvature observed was the curvature associated with pyroplastic deformation (Figure 3). As a result of the increase in the quantity of glassy phase and the reduction in viscosity of this phase when temperature rose, the deformation index increased with peak firing temperature [2].

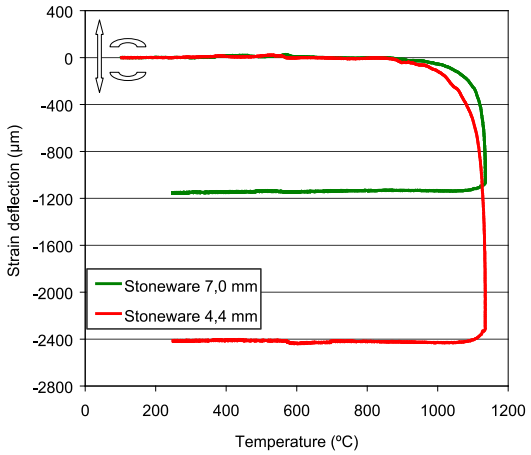

Figure 2. Variation of sag during the firing cycle.

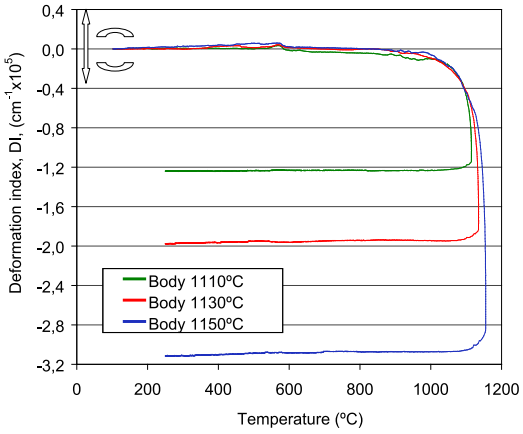

Figure 3. Variation of the DI during the firing cycle of a stoneware tile body.

The deformation curves of a stoneware tile body with different engobes and of the same body without engobe are plotted in Figure 4. It shows that the engobes significantly modified the tendency of the body to curve above 1000ºC, this phenomenon being particularly pronounced in the case of engobe 1 and of scarce magnitude in engobe 5. This matched industrial practice, since the tiles produced with engobe 1 displayed planarity defects that decreased in magnitude until they disappeared with engobe 5. In order to establish whether this behaviour was due to some type of interaction between the engobe layer and the body, the study was repeated with a porcelain tile body and the same trend was found.

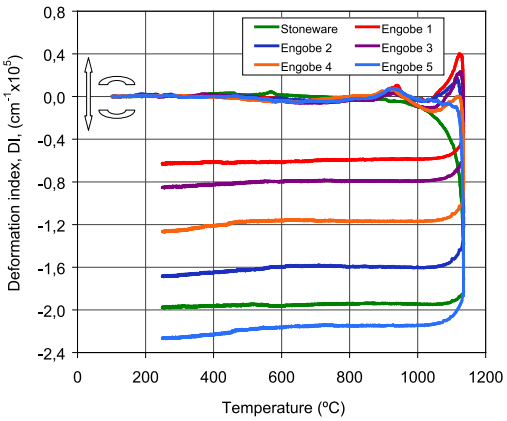

Figure 4. Variation of the DI during the firing cycle (stoneware tile body with different engobes).

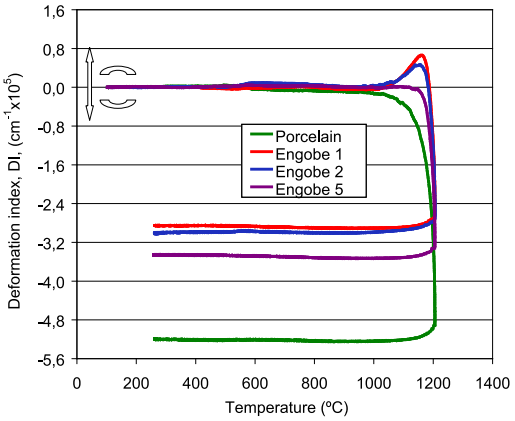

Figure 5. Variation of the DI during the firing cycle (porcelain tile body with different engobes).

As engobes do not exhibit such a high degree of fusibility as glazes, it was thought that the differences in shrinkage between the body and the engobe might lead to the changes in curvature above 1000ºC. The expansion-shrinkage curves of the stoneware tile body and of the engobes with extreme behaviours (1 and 5) were therefore determined (Figure 6). Engobe 1 began to shrink at lower temperatures than the body and, from about 1000ºC, it exhibited a stabilisation of the shrinkage, which coincided with the onset of shrinkage and deformation by pyroplasticity of the body. In contrast, engobe 5 exhibited a variation of shrinkage with temperature that was more similar to that of the body. The comparison of the values of the slopes of these curves with the values of the deformation index satisfactorily explains the different curvature of the pieces above 1000ºC (Figure 7), since the lower shrinkage rate of the engobes with respect to that of the body produced a convex curvature. This phenomenon was more pronounced in engobe 1 owing to its greater difference in shrinkage rate with respect to that of the body. The reason that in the range 900–1000ºC no changes of curvature of the engobed bodies were observed with respect to that of the body without engobe was that, in this range of temperatures, the proportion of glassy phase in the body was low, displaying low deformation by pyroplasticity. The high stiffness of the body in this range led the differences in shrinkage of the engobes with respect to that of the body to translate into an increase in stresses and not into changes in curvature.

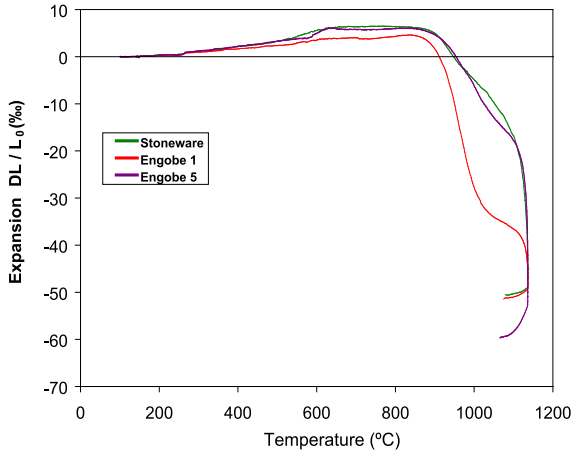

Figure 6. Expansion-shrinkage curve of the stoneware tile body and engobes 1 and 5.

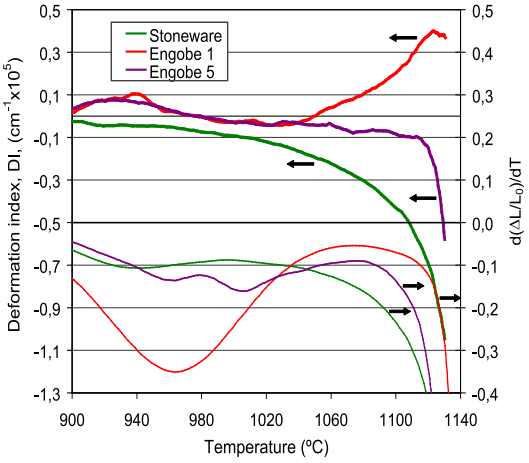

Figure 7. Variation of the deformation index and slope of the expansion-shrinkage curves.

4. CONCLUSIONS

The determination of the deformation curves of tile bodies without and with engobe by means of the optical fleximeter is very useful when it comes to solving problems of lack of planarity in ceramic tiles. This study shows that differences in shrinkage of the engobes with respect to that of the tile body can cause curvatures in the preheating stage.

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