ASSESSMENT OF THE CERAMIC TILE INNER TEMPERATURE PROFILE IN FIRING

J.E. Enrique; V. Cantavella; E. Monfort; G. Mallol

Instituto de Tecnología Cerámica
Asociación de Investigación de las Industrias Cerámicas
Universitat Jaume I. Castellón. Spain.

1. INTRODUCTION

During the firing of ceramic tile all kinds of reactions can arise (clay mineral dehydroxylation, oxidation of organic matter, carbonate breakdown, etc.). It is also in firing tile that the greatest firing shrinkage, decrease in porosity and water absorption occurs in the case of products with low water absorption.

All these phenomena depend on temperature; however, exactly how this magnitude varies with temperature often remains undetermined, for various reasons:

- On many occasions, the experiments performed with a view to determining given materials properties (such as linear shrinkage or water absorption) are run on test specimens that undergo standard heat treatment. On ending the experiment, the measured property depends on the whole heat-treatment cycle used, and a direct relationship cannot be established between the property and a specific temperature.
- The variation of temperature as a function of time gives rise to temperature gradients within the tile, during heating as well as during cooling.
- It is common practice to use kiln temperature as the actual tile temperature. Ambient temperature may be orientational, but it is at times quite different from tile surface temperature and may be even further removed from the actual temperature inside the tile.

It is moreover known that thermal gradients are directly responsible for the appearance of certain phenomena such as differential shrinkage in ceramic materials, which entails dimensional defects and curvatures and cause microstructural heterogeneities generally.

2. HEAT TRANSMISSION MODEL

In order to assess temperature distribution within tile, a simple model has been used, which makes a series of simplifying assumptions:

- Heat transmission basically takes place in two dimensions: in the direction of the thickness of the material, and in the direction marked by tile advance inside the kiln.
- Energy exchange as a result of the variation in enthalpy associated with chemical reactions is not taken into account.

- Thermal conductivity remains unaffected by microstructural, compositional or temperature changes.

The fact that tile surface temperature varies with time makes it impossible to obtain an analytical solution to the problem, which is why a numerical technique was adopted to solve it (finite element method).

Temperature at the bottom of the tile was determined using a sensing roller, while temperature at the top was calculated by assuming that the temperature difference (ambient-tile surface) would be alike at both the top and bottom of the tile.

3. RESULTS OF THE SIMULATION AND DISCUSSION

Using a standard heat-treatment cycle (Fig. 1), the evolution of the temperature profiles was determined as a function of time inside an 8 mm-thick tile.

Fig. 2 shows a plot of:

- The difference between top and bottom tile temperatures (ΔT).
- The difference (average between top and bottom surface temperature)-(tile centre temperature) ($\Delta^2 T$). This parameter provides an indication of the extent to which the temperature profile deviates from linearity and is related to the internal stresses that arise in the tile.

It can be observed during heating, that the arising temperature differences between the inner part and the surface of the tile are highly significant, but that the difference between the top and bottom surface is even more important (Fig. 3). ΔT is greater than $\Delta^2 T$ because one side is being heated more than the other.

During firing, both ΔT and $\Delta^2 T$ are virtually brought back to zero, whereas in cooling (Fig. 4), ΔT is smaller than $\Delta^2 T$: both sides of the tile cool much faster than the centre, and the arising inner stresses can be quite important.

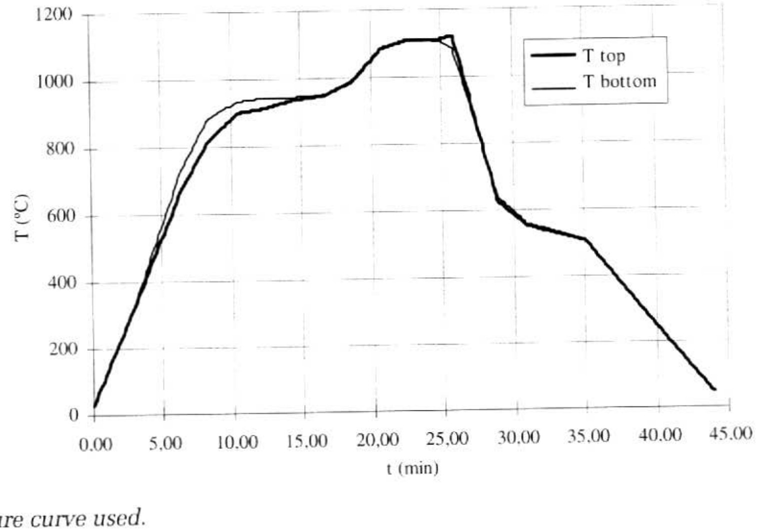

Figure 1. *Temperature curve used.*

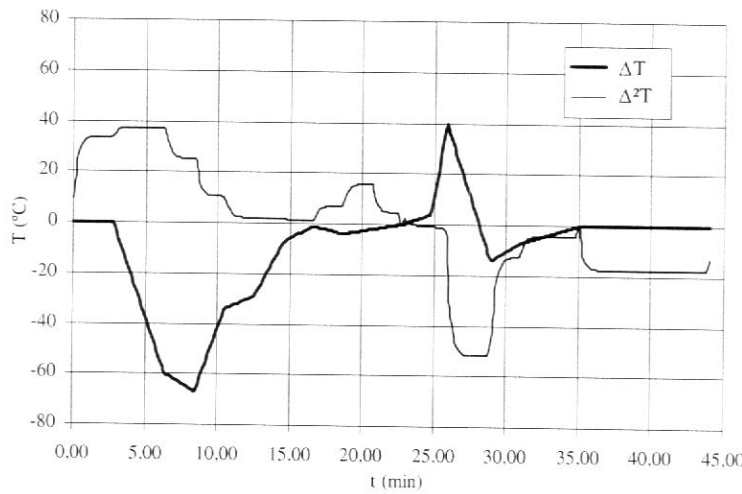

Figure 2. *Tile inner temperature difference.*

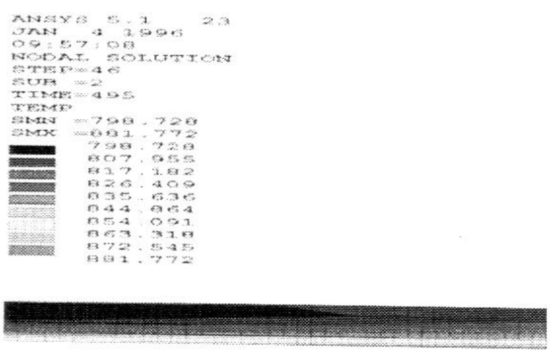

Figure 3. *Temperature profile in heating.*

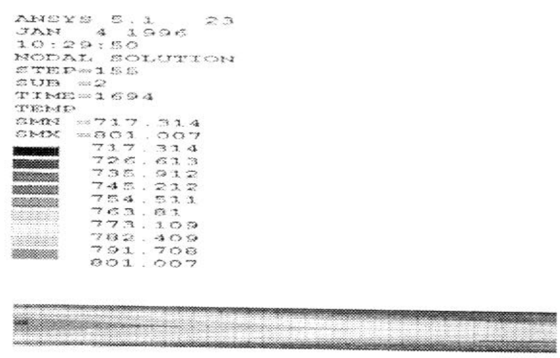

Figure 4. *Temperature profile in cooling..*

4. REFERENCES

(1) COSTA, E. Ingeniería Química, vol. 4, Transmisión de calor. Madrid: Alhambra, 1983-1988.

(2) JAKOB, M. Heat Transfer. New York: John Wiley, 1949-1957.

(3) EDWARDS, T. Relationship between Finite Element Analysis and Firing Brick. Am. Ceram. Soc. Bull., 72 (9), 41-43, 93, 1993

Corrigendum

On page 92, in Fig. 10, **Temperature (°C)** should read Dwell **Time (min.)**