

Combined Experimental and Numerical Study of Heat and Mass Transfer in Thick-Walled Concrete Vessels

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ABSTRACT

In order to be able to simulate spatial temperature and moisture distributions in concrete as function of time it is necessary to determine first of all a series of transport coefficients. Heat diffusion coefficients have been determined as function of humidity content and temperature. The diffusion equation has been solved numerically and the experimentally determined parameters have been used. Measurements of the time dependant spatial temperature distributions have been carried out on a thick-walled hollow concrete cylinder with an inner heated liner. The numerical predictions are compared with the experimental results.

1 INTRODUCTION

In some reactor types the zone of the thick-walled concrete cylinder which is close to the steel liner may be heated under service conditions up to 120° C. Under these conditions hydrothermal reactions will occur and heat and moisture diffusion will take place for a long period, most probably for the whole life cycle of the structure.

For this reason it is essential to be able to predict the heat and moisture distribution as function of space and time in a realistic way. In a recent contribution an experimental set-up to measure these distributions on a model has been described (K. Zängle et al 1989). In the meantime different test series have been carried out with this model. Some of the results will be presented here.

2 DETERMINATION OF TRANSPORT COEFFICIENTS

Thermal and hygral transport coefficients have been determined experimentally. On a special reactor concrete made with basalt the thermal conductivity has been measured as function of moisture content and temperature. Results are shown in Figs. 1 and 2. These data will be used in the numerical prediction of the thermal distribution in the heated model.

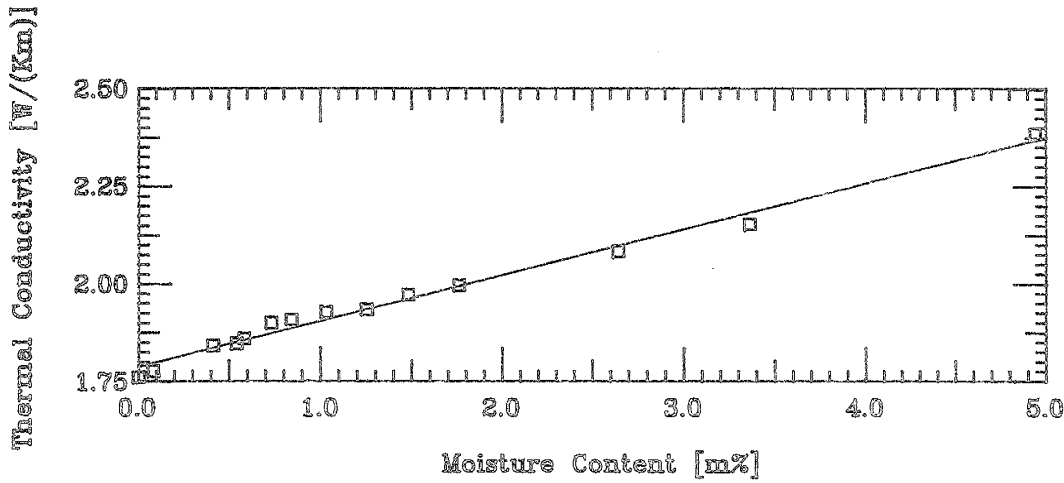


Fig.1: Measured thermal conductivity as function of moisture content at room temperature.

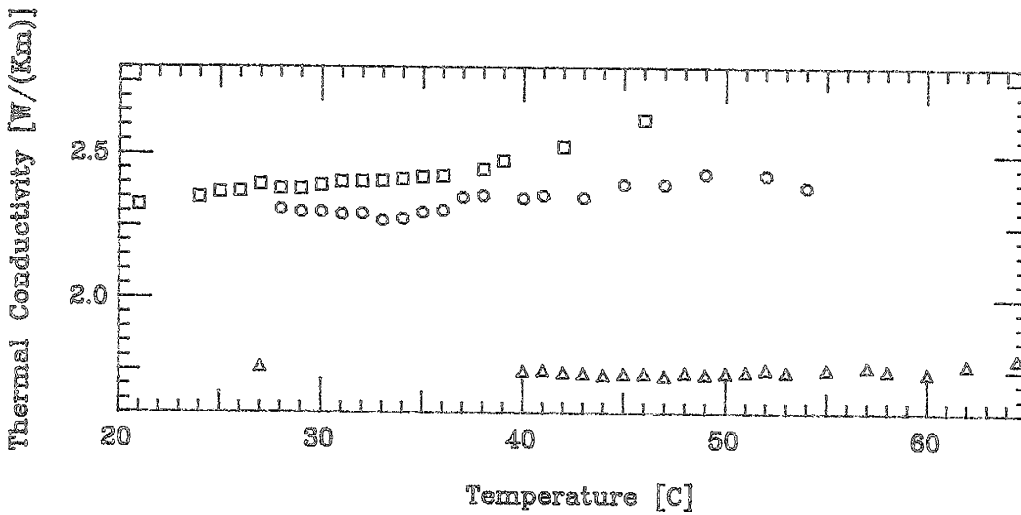


Fig.2: Measured thermal conductivity as function of temperature in:
 □ ○ : moisture-saturated condition
 △ : dried condition.

3 DETERMINATION OF THE TEMPERATURE DISTRIBUTION IN A THICK-WALLED CYLINDER

The model of a prestressed concrete vessel is schematically shown in Figs. 3 and 4. The position of the different measuring points is indicated. During a first heating period the liner was heated up to a constant temperature of 70° C. The temperature evolution as measured with thermocouples at points 1 to 7 is shown in Fig. 5A with dashed lines. The distance of the seven measuring points from the liner is indicated in Fig. 3. The numerical prediction is shown with solid lines. Similar results

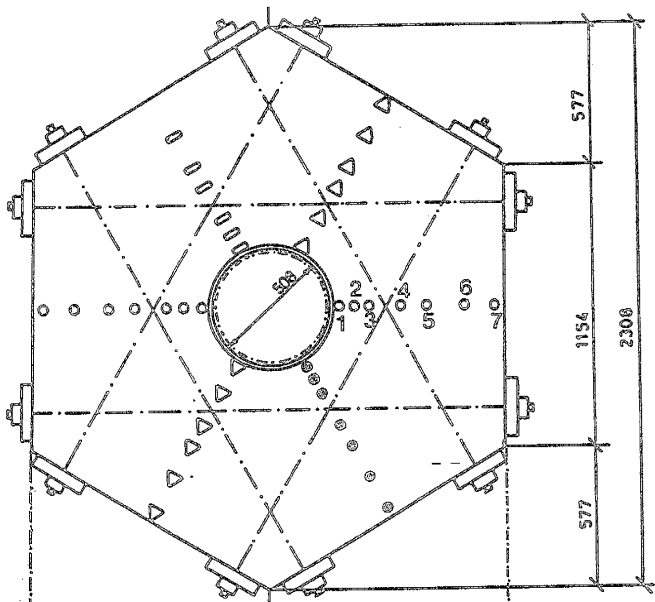


Fig. 3:

Model vessel (Plan-view)

- △ Lambda- gauge
- Thermocouple
- Pressure- gauge
- ⊙ Moisture-electrode

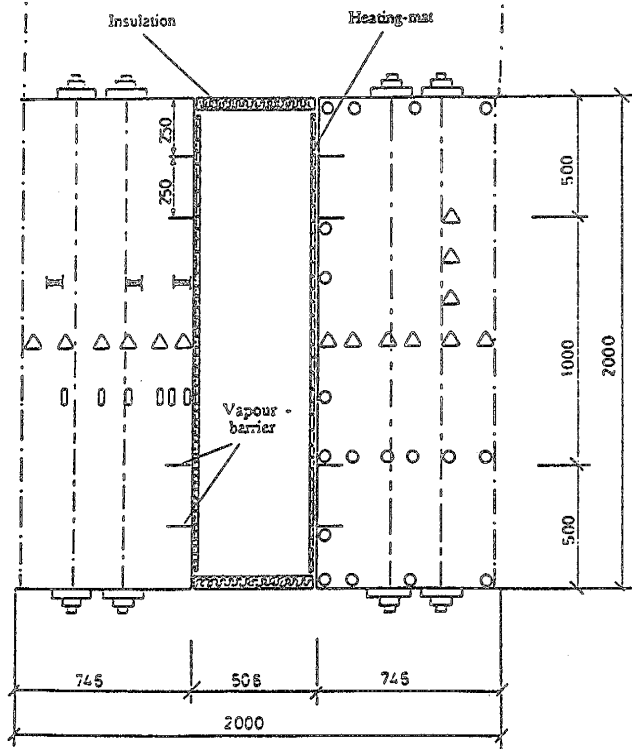


Fig. 4:

Model vessel (sectional view)

- △ Lambda- gauge
- Thermocouple
- Pressure- gauge
- ┃ Strain- gauge

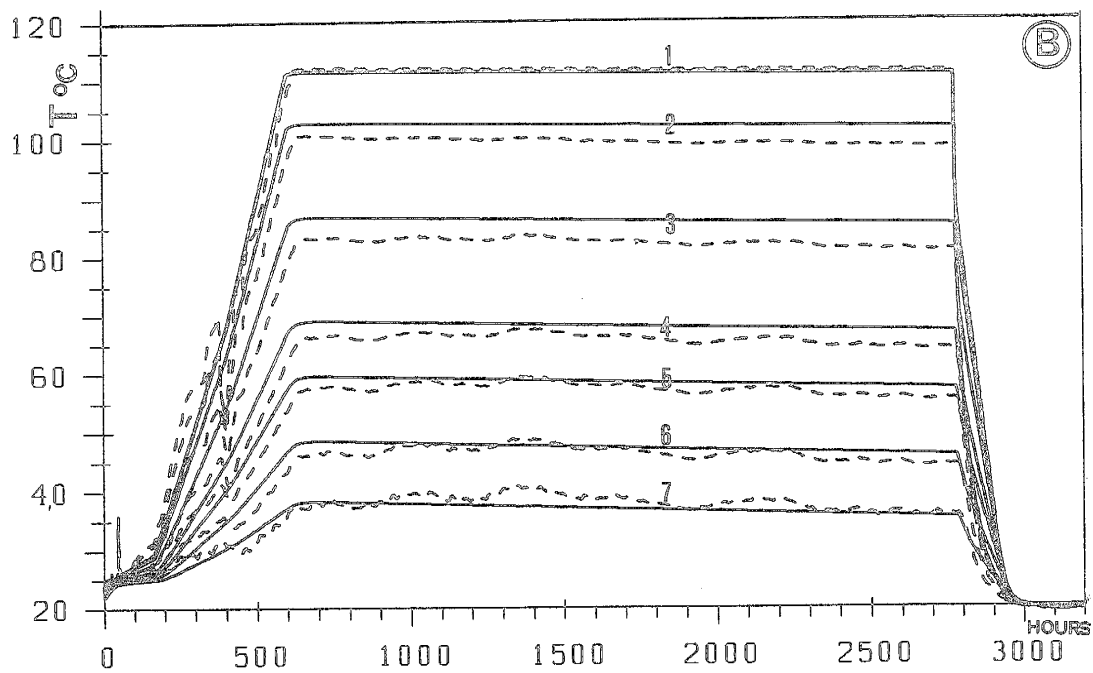
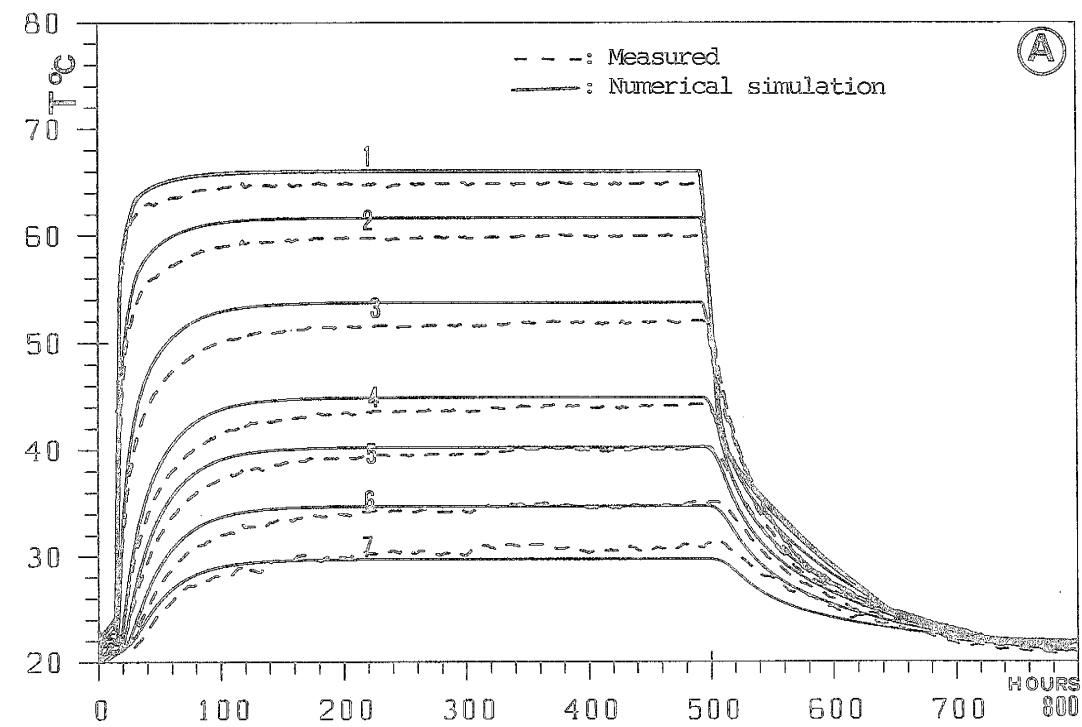


Fig.5: Temperature evolution at different distances from the liner (see Fig.1 for the positions of thermocouples). In case A, the liner was heated to a temperature of 70°C , in case B the temperature of the liner was 120°C .

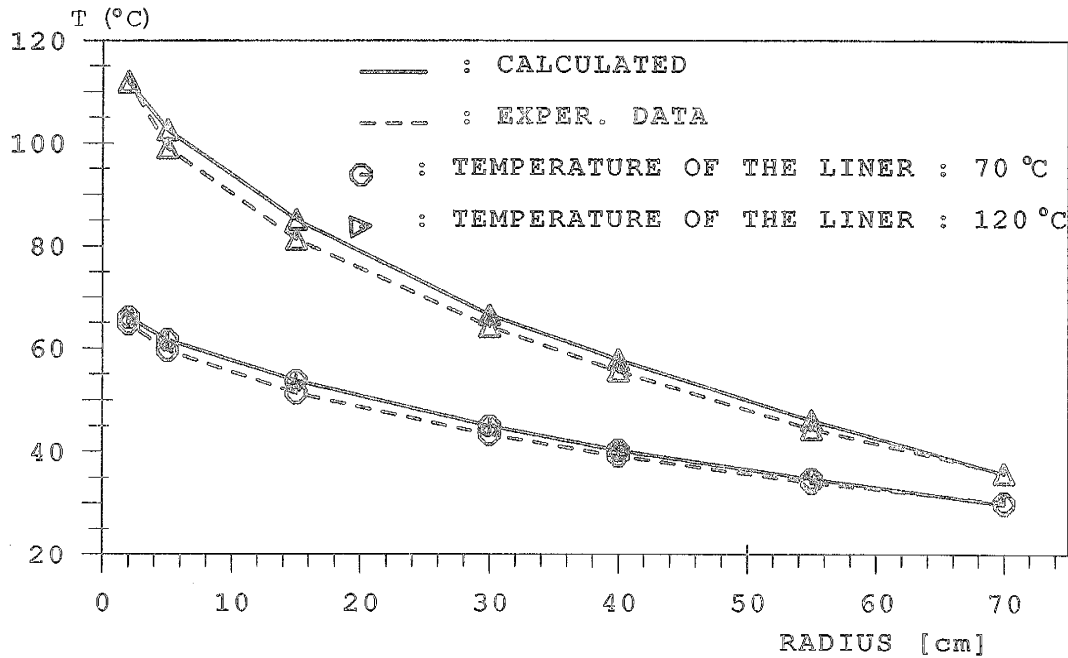


Fig.6: Spatial temperature distributions at steady state.

of a subsequent heating period during which the liner was kept at a constant temperature of 120° C are shown in Fig. 5B. In Fig. 6 the spatial temperature distributions after the steady state had been reached are shown for both heating periods.

4 CONCLUSIONS

- Thermal conductivity of concrete depends both on moisture content and temperature.
- In using measured transport coefficients it is possible to predict the heating and cooling of a thick-walled cylinder.
- The temperature distribution at steady state conditions can be numerically predicted.
- In a similar way moisture transport coefficients can be measured and moisture distribution can be predicted (X.Wittmann et al 1989)

ACKNOWLEDGEMENT

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