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THERMOVISCOPLASTIC ANALYSIS OF ROLLER COMPACTED CONCRETE

M. H. F. Barros*, R. A. F. Martins† and C. C. Ferreira*

* Departamento de Engenharia Civil
Faculdade de Ciências e Tecnologia, Universidade de Coimbra
Polo II, Pinhal de Marrocos, Coimbra
e-mail: {hbarros,carla}@dec.uc.pt web: http://www.dec.uc.pt

† Departamento de Engenharia Mecânica
Faculdade de Engenharia da Universidade do Porto, R. Dr. Roberto Frias, Porto
e-mail: {rfmarti}@fe.up.pt web: http://www.fe.up.pt

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Summary. *In this work is developed the software for the thermo-mechanical analysis of large concrete placements with special emphasis on RCC dams. In these dams the construction schedule has high influence in long-term concrete temperature and in stress fields, whose variations can produce important thermal cracking. This paper describes a methodology for predicting the thermal and stress state of a RCC dam using a two dimensional model. This analysis involves the following parts: the thermal analysis of concrete structures considering heat generation in the structure and temperature evolution in the ambient; the mechanical analysis by non linear models using an elasto-visco-plastic model and taking into account the rheology of the concrete from very young to old ages. Numerical analysis are performed with the ICOLD [1] proposed data and the results are compared with other solutions*

1 INTRODUCTION

It is a well known fact that large concrete placements pose special problems in what concerns to the high temperatures generated in the concrete due to the hydration heat of the cement paste. If not controlled, these temperatures can result in fractures and damage for the structure. As a matter of fact the thermal stresses produced can be higher than those experienced by the structures during its lifetime.

In this paper is described a methodology to predict the thermal state of a dam based on a 2D analysis, which correspond to consider that most of the hydration heat developed during construction will migrate through the RCC on the plane normal to the axis of the dam. The main results of the thermal analysis carried out are presented and discussed. The results presented refer to a dam defined by ICOLD [1], where the construction procedures and schedule, characteristics of the materials, initial and limit conditions are the indicated. The results obtained in thermal analysis with the present model are compared to the values measured and calibration results[1].

In addition to the thermal analysis the stress field is computed using the elasto-visco-plastic model.

2 FORMULATION OF THE THERMAL PROBLEM

The heat transfer in a body is ruled by the Fourier equation, stating that the heat velocity through a surface, with components (v_x, v_y , v_z), is proportional to the temperature gradient T in the normal direction, that is in the x direction

$$v_x = \left(\frac{\partial Q}{\partial t}\right)_x \frac{1}{A} = -k_x \frac{\partial T}{\partial x} \tag{1}$$

where k_x, is the heat conductivity in the axial direction x, in cal/(cm s ºC) or W/(m ºC). A similar result is obtained for the other directions (where k_y and k_z are used).

In the transient behaviour T is also time dependent, that is T(x,y,z,t), and some of the heat is used in raising the temperature of the body. In this problem the heat capacity c is the amount of heat needed to increase in 1ºC the unit mass of the body. The heat balance in the time interval, with ρ being the mass density, where $h^2 = k/\rho c$ is the difusibility and q a heat generation rate, producing q calories by unit of time and volume, is given by

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{1}{h^2}\frac{\partial T}{\partial t} + \frac{q}{k} \tag{2}$$

The temperature function T(x,y,z,t), satisfies Fourier equation in the domain, at every time step. In the initial moment t_0 the condition concerning the initial body temperature termed T_0^*, must be satisfied. The boundary conditions can be either a prescribed temperature T_A^*, or Dirichlet condition in S_1 or a flow condition, or Cauchy condition, in the remaining boundary S_2, as described in [2].

3 STRESS ANALYSIS MODEL

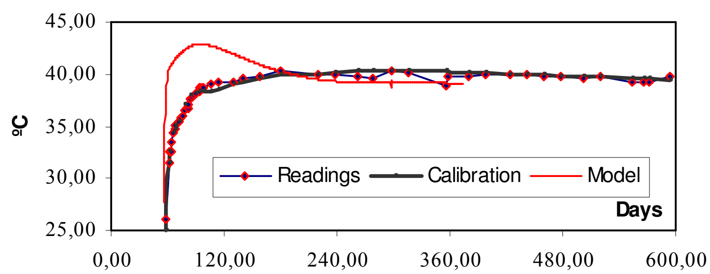
The nonlinear behaviour is approximated by the elastoviscoplastic model described in Owen et al. [3]. The viscoplastic strain rate $\dot{\varepsilon}^{vp}$ is defined by the following flow rule

$$\dot{\varepsilon}^{vp} = \gamma \frac{F - \left(\sigma_y + H^{\prime} \bar{\varepsilon}^{vp}\right)}{\sigma_y} \tag{3}$$

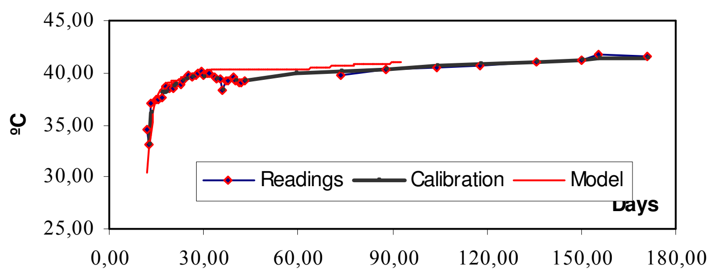
Where σ_y is the yield stress, F the yield criterion, γ the fluidity parameter, H' the hardening parameter and $\bar{\varepsilon}^{vp}$ is the accumulated viscoplastic strain.

4 THERMAL ANALYSIS RESULTS

A RCC dam designated by Tha Dan dam [1], is considered in the present analysis. The characteristics, such as, geometry, materials, boundary and initial conditions, are given in reference [1]. Figures 1a) and 1b) represent the temperature variation during the time at central point located at the elevations 35.00 and 50.70, respectively.



Figures 1a) Temperature variation during the time at central point located at the elevation 35.00.



Figures 1b) Temperature variation during the time at central point located at the elevation 50.70.

Figures 2 represents the temperature distribution at day 219 (Fig 2a) and 310 (Fig 2b).

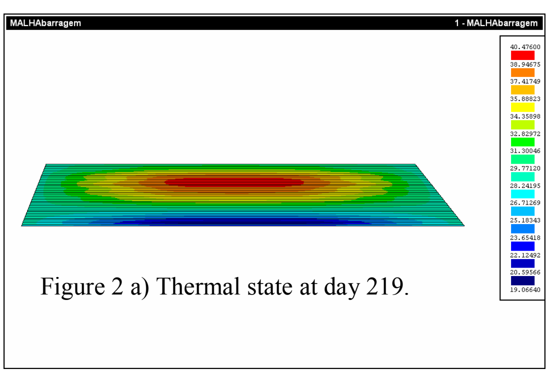


Figure 2 a) Thermal state at day 219.

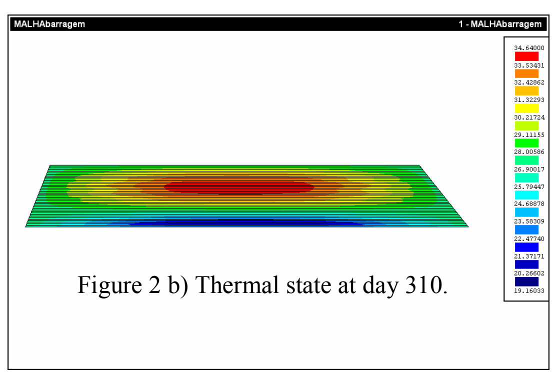


Figure 2 b) Thermal state at day 310.

5 STRESS ANALYSIS RESULTS

The parameters of the model in the stress analysis are: E=29,43GPa, σ_y=0.98 KPa, γ=0.5x10-9, H'=22563MPa, F is the Von Mises criterion. For the thermal analysis the properties are given in [1]. In Figure 3, the thermal state is represented at the day corresponding to the maximum principal stress in elastic analysis (Fig. 4) and non-linear present model (Fig.5,MPa).

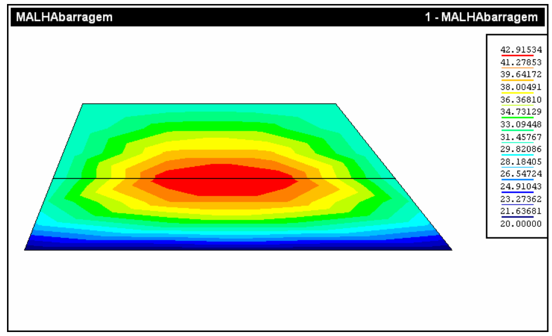


Figure 3. Thermal state at day 377.

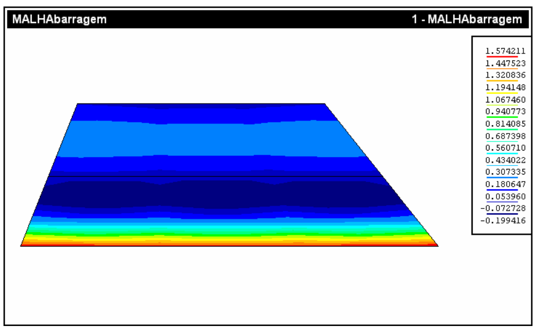


Figure 4. Maximum principal elastic stress at day 377.

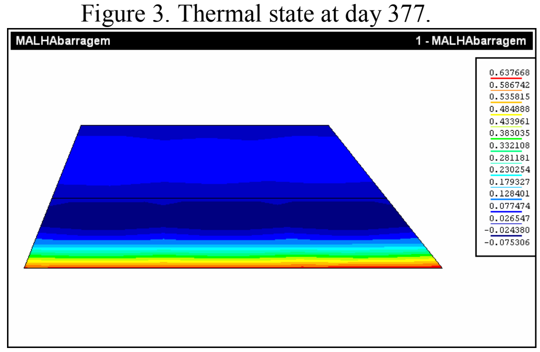


Figure 5. Maximum principal nonlinear stress at day 377.

6. CONCLUSIONS

In this work are presented models for the nonlinear analysis of concrete under variable thermal state. The finite element method is applied in the calculation of the temperature in a RCC dam with heat generation due to hydration of concrete. The nonlinear behaviour of concrete is considered by the use of the elastoviscoplastic model that approximates the creep of concrete in young ages.

7. ACKNOWNLEDGEMENTS

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