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THERMODYNAMICS OF INTERACTING CONTINUA WITH SURFACES AND CREEP ANALYSIS OF CONCRETE STRUCTURES

Z.P. BAŽANT,

Department of Civil Engineering, The Technological Institute, Northwestern University, Evanston, Illinois, U.S.A.

Creep, shrinkage and delayed thermal dilatations of concrete are caused essentially by diffusion of water and other molecules along mono-and multimolecular layers confined between two hydrophylic solid surfaces of cement paste particles. The constitutive equation based on thermodynamics of such processes has been recently developed by the author. It represents a special type of equation of state for interacting continua.

The physical processes involved and the derivation of the constitutive equation at variable temperature and pore humidity are briefly reviewed and discussed, showing a simplified formulation sufficient for practical analysis. The constitutive equation is presented in the form of a system of first order differential equations with a broad spectrum of retardation times. The numerical stress analysis based on direct step forward finite difference approximation of these equations was found to be numerically unstable, except for unacceptably small magnitudes of the time step. However, if the constitutive equation is converted to a certain system of integro-differential equations for stress, strain and further hidden state variables, a numerical algorithm which is stable for arbitrarily increasing time steps can be formulated by introducing finite sum approximations for the integrals involved. Development of a computer program for a long thick-walled hollow concrete cylinder is then briefly described. This program is presently being used for evaluation of the material parameters by trial and error method from the test data. It can also be used for the analysis of stresses caused by creep and temperature effects in the walls of a prestressed concrete reactor vessel.

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DISCUSSION

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R. D. BROWNE, U. K.

How does your concept for representing the water state in concrete account for the creep of hardened cement paste when in a completely saturated state ?

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Z. P. BAŽANT, U. S. A.

I regret I have not devoted enough time to this point. Here, of course, there seems to be contradiction in the fact that macropores are saturated and cannot accommodate much water expelled from the micropores by creep. Actually, however, the pores are never fully saturated because of self-desiccation caused by hydration. In addition, one has to realize that, because of the smallness of creep strains in concrete, the amount of water to be transferred between the micro- and macropores as a result of creep is extremely small. Finally, part of the creep is also due to changes in the solid particles due to diffusion of solid adsorbent ions. In view of these three facts, I do not see any difficulty in assuming the volumetric creep in saturated concrete to be due to water migration.