Response of RC columns with transient creep in a natural fire environment

A. Sadaoui† and Khennane*

†University of Tizi-Ouzou
Faculté du Génie de la Construction, Algeria
e-mail: a_sadaoui@yahoo.com

*University of New South Wales
Australian Defence Force Academy, Canberra, Australia
e-mail: a.khennane@adfa.edu.au

ABSTRACT

The response of a reinforced concrete (RC) structure in a real fire environment is relatively complex comparatively to that at ambient temperatures. The structural elements are subject to a combination of thermo-mechanical actions that arise from restrained thermal elongations, degradation of the mechanical properties of the constituents, and transient creep in concrete. Transient creep, also usually referred to as transitional thermal creep or load induced creep, is unique to concrete and develops only during first time heating of the concrete under compressive stresses.

The aim of this study is to investigate the effect of transient creep phenomenon on the structural response of RC column elements subjected to natural or parametric fires using a macroscopic finite element model developed by the authors. The model, capable of analysing the response of RC columns from pre-fire stages to collapse in fire environment, is specially developed for the analysis of RC structures under severe thermo-mechanical loads, which accounts for transient creep explicitly as an additional component of the total strain of the concrete or implicitly through the use of the materials' properties recommended by Eurocode 2.

The developed computer model contains two modules: a heat transfer module and a structural module. The heat transfer module assumes that under realistic fire conditions, and if only the temperature field is required, the heat transfer problem can be solved in an uncoupled way. The model requires the knowledge of the initial moisture content as it accounts for the latent heat due to the evaporation of water by introducing a water vapour fraction, which is a function of temperature. The generated temperatures in each point are used as input to the structural analysis model, which includes the computation of the transitional thermal creep force in the structural element. Gaussian and Simpson rules are used respectively to integrate the stiffness matrices and internal forces along the longitudinal and transverse directions.

The formulation is based on a co-rotational approach and makes use of a tangential operator derived by integrating the stress-strain rates of concrete and steel reinforcement at elevated temperatures. It includes geometrical non linear effects resulting from large displacements and small strains theory, degradation of the elastic and inelastic material properties with temperature. The strain rate is broken into its constitutive parts: elastic, plastic, transitional thermal creep and thermal expansion rates.

Through the obtained results, it is shown that the transient creep phenomenon significantly influence the fire response of RC columns. It is shown that conventional failure criteria based on crushing of the concrete and yielding of steel may not be conservative under certain fire scenarios. It was also found that the conventional method based on standard fire exposure may not be conservative if the resulting fire has a decay phase similar to the severe fire scenario used in this work.

REFERENCES

[1] Sadaoui A., Illouli S. & Khennane A., Effect of restraints on the response of RC columns in a parametric fire, FraMCoS-8, 8th International Conference on Fracture Mechanics of Concrete and Concrete Structures', 10-14 mars 2013, Toledo, Spain.
[2] Sadaoui A., Khennane A. 2012, Effect of transient creep on the behaviour of reinforced concrete beams in a fire, *ACI Materials Journal*, Vol. 109, No 6, November-december 2012.
[3] A. Sadaoui, A. Khennane and S. Kaci, *Behaviour of reinforced concrete frames in a fire environment including transitional thermal creep*, Australian Journal of Structural Engineering, AJSE, V7, N°3, 2007, ISSN: 1328-7982.
[4] EN 1992-1-2, Eurocode 2: Design of concrete structures- Part 1-2: general rules- Structural fire design. Prénorme Européenne, Nov. 1995.