A regularized damage model for structural analyses of concrete dams in the presence of ASR

M. Colombo[†,*], C. Comi[†]

[†] Department of Civil and Environmental Engineering (DICA)
Politecnico di Milano
Piazza Leonardo da Vinci, 32, 20133 Milan, Italy
e-mail: martina.colombo@polimi.it, claudia.comi@polimi.it – Web page: http://www.dica.polimi.it

ABSTRACT

Concrete is one of the most used materials in civil engineering, but its durability can be reduced by several chemical phenomena, among them the alkali-silica reaction (ASR) plays a fundamental role. During ASR amorphous silica of aggregates reacts with the high alkaline solution in concrete micro pores to form a hydrous alkali-calcium-silica gel, which expands in the presence of moisture and causes increase of displacements and cracks formation in concrete structures. A key dissipative phenomenon related to ASR is certainly micro-cracking, which results in non-symmetric, progressive degradation of mechanical properties (strength and stiffness). In [1] a phenomenological two-phase isotropic damage model for the evaluation of the effects of ASR in existing concrete dams was proposed. This model takes into account the simultaneous influence of both humidity and temperature through two uncoupled diffusion analyses: the heat diffusion analysis and the moisture diffusion analysis. The solution of these two analyses are considered as input for a consequent mechanical analysis, used to define the response due to ASR.

The model in [1] is local, with fracture energy pseudo-regularization, hence, as damage develops, the boundary value problem may become ill-posed and mesh-dependent results are obtained in numerical analyses. Such difficulties can be solved implementing a real regularization technique, as proposed in the literature ([2]-[4]). In all regularized models the introduction of a material characteristic length fixes the width of the zone in which damage localizes, thus preventing strain localisation into a line with consequent zero energy dissipation. In this work a nonlocal formulation of the bi-phase chemo-mechanical model [1] is proposed for the description of ASR-induced degradation. Nonlocality has been introduced replacing strain invariants by their nonlocal counterpart, obtained by weighted average over a spatial neighbourhood of each point. This approach has been validated using 2D simple examples (samples with inhomogeneous materials), then it has been applied to a real case of existing concrete gravity dam (Fontana dam). In this dam damage develops close to the external skin (which is the most subject to the saturation degree variation) and localizes in a crack starting from the inspection gallery (geometric inhomogeneity). When using the local damage model, the pattern of the damaged zones depends on mesh size, while the non-local formulation allows to obtain mesh-independent results.

REFERENCES

[1] Comi C., Kirchmayr B., Pignatelli R., “Two-phase damage modeling of concrete affected by alkali–silica reaction under variable temperature and humidity conditions”, *International Journal of Solids and Structures*, Vol. **49**, pp. 3367–3380, 2012

[2] Comi C., “A non-local model with tension and compression damage mechanisms”, *European Journal of Mechanics – A/Solids*, Vol. **20**, pp. 1–22, 2001

[3] Pijaudier-Cabot G., Bažant Z.P., “Non-local damage theory”, *Journal of Engineering Mechanics ASCE*, Vol. **113**, pp. 1512–1533, 1987

[4] Peerlings R.H.J., de Borst R., Brekelmans W.A.M., de Vree J.H.P., “Gradient-enhanced damage for quasi-brittle materials”, *International Journal for Numerical Methods in Engineering*, Vol. **39**, pp. 3391–3403, 1996