Identifying the extent of shrinkage-induced surface cracking from the time-dependent deflections of concrete beams exposed to symmetric and non-symmetric drying

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The service life of reinforced concrete structures is to a considerable extent determined by the durability of the concrete cover, which protects the steel reinforcement from corrosion. This cover is subject not only to mechanical loading but also to environmental actions causing non-negligible eigenstrains with different sources. Probably the most significant phenomenon is drying shrinkage, which is approximately proportional to the decrease in relative humidity. Moisture diffusion in concrete is extremely slow and highly nonlinear, which causes steep gradients in relative humidity distribution even without severe drying conditions. Due to the internal restraint by the cross section (which remains planar), such nonuniform field gives rise to self-equilibrated stresses which are partially relieved by creep of concrete but might attain tensile strength and cause cracking.

In 2019, an extensive experimental campaign on the time-dependent behavior of structural concrete exposed to drying conditions has been initiated at CTU in Prague [1]. All samples were prepared from an identical batch of concrete and cured for one month. The key component of the program was a set of simply supported beams of various sizes ($L = 1.75 - 3.0$ m, $h = 0.05 - 0.2$ m) and several sealing setups which influenced not only the drying rate, but also the degree of internal restraint and thereby the extent of damage. Although the experiment is located indoors, the measured mid-span deflections promptly respond to seasonal and surprisingly even daily variations in relative humidity. In contrast to conventional experiments on symmetric cylinders, the measured response in bending experiments with non-symmetric drying allows to distinguish the individual components of deformation more clearly and to assess the drying shrinkage-induced damage.

Bayesian inference allows for a robust, probabilistic, and well-posed formulation of parameter identification, even for combining limited data acquired from different experimental scenarios. The probabilistic formulation provides not only a single-point estimate of the material parameters but also an evaluation of the underlying uncertainty in the estimated values reflecting the experimental error (i.e., the uncertainty in the observed quantities) on one side and also the uncertain prior expert knowledge about the parameter feasible or more probable values. The main drawback of Bayesian inference arising from its high computational requirements due to repeated FE-based simulations will be mitigated by constructing the polynomial chaos-based surrogates for simulated response quantities. As an additional advantage, polynomial surrogates provide a fast and elegant way to evaluate the global variance-based sensitivity analysis, which allows us to analyze the effect of material parameters or their specific combinations on particular observed quantities.

In this contribution, such framework uses data from coupled hygro-mechanical low-fidelity finite element simulations in program OOFEM to identify the parameters of the constitutive models, in particular the modified Microprestress-solidification theory [2] with the damage extension and the model for moisture transport proposed by Kuenzel. Finally, the computed distribution of damage and its influence on stiffness in bending is experimentally verified.

References

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