Numerical Homogenization in Viscoelastic Analysis

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KEYWORDS: *Numerical Homogenization, Finite Element Method, Viscoelasticity, Asphalt Concrete.*

The leading role of heterogeneous materials used in civil engineering requires dedicated numerical methods for detailed analysis of their behavior. The Finite Element Method (FEM) is used in our research as the general tool for numerical analysis. Due to the heterogeneity of the analyzed domain and the physical nonlinearity (observed mainly within the matrix phase), the straightforward approach is rather ineffective. In our ongoing research, the numerical homogenization is developed. As the test material, asphalt concrete is considered.

A number of homogenization methods based on the Representative Volume Element (RVE) can be found in the literature [1-3]. For the purposes of this research, the numerical homogenization approach presented in [4] is adopted. Based on the high-quality image and its further processing, the asphalt concrete specimen with the underlying microstructure is reconstructed. In this research, the analysis is limited to the 2D case with two phases distinguished, i.e. the aggregate and the mastic. The reconstructed microstructure is accounted for at the RVE level and the effective tensors of material parameters are subsequently evaluated. The main idea of the proposed approach is to avoid time consuming evaluation of the tangent matrices resulting from the transient problem. Instead, the inelastic strain evolution contributes to the load vector. As a result, the effective stiffness matrices of macroscale elements remain the same for the whole time-stepping algorithm. Moreover, the nonlinear strain evolution needs to be analyzed, accounting for the microstructure solely at the RVE level. The averaged inelastic strain is transferred to the corresponding Gauss point.

The obtained numerical results confirm the applicability of the proposed approach. One can observe a substantial reduction of the number of degrees of freedom compared to the straightforward analysis carried out using the overkill mesh. On the other hand, the additional modeling error introduced by the homogenization is kept at the acceptable level of several percent (measured in L2 norm).

The proposed framework can be further generalized to the 3D case with the microstructure reconstructed using e.g. the X-ray computed tomography. Also, a number of nonlinear material models can be easily incorporated at the RVE level to increase the applicability of the developed approach.

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