Multiscale Structural Analysis of a Displacement-Monitored Experiment on a Segmented Tunnel Ring

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ABSTRACT

A real-scale test on a displacement-monitored segmented tunnel ring [1] is analyzed. The diameter of the ring amounts to 6.2 m, its thickness to 35 cm, and its axial length to 1.2 m. The ring consists of six precast reinforced concrete segments, resulting in six segment-to-segment interfaces. During testing, the structure was subjected to radial point loads resulting from 24 equally distributed hydraulic jacks. They simulated the anisotropic earth-pressure. A displacement monitoring system was used to measure interfacial discontinuities (relative displacement jumps in the radial and the circumferential direction as well as relative rotation angles) and convergences (both in the vertical and the horizontal direction). As for modeling, the stiffness and the fracture energy of nanoscopic calcium-silicate-hydrates – known from molecular dynamics simulations, documented in the open literature – are upscaled to the material level of concrete, using the research results documented in [2]. The homogenized properties are implemented into a micro-fracture-mechanics model for tensile softening of concrete [2]. The semi-analytical structural analysis of the tunnel ring is based on so-called "transfer relations", representing analytical solutions of the first-order circular arch theory [3]. Both the *prescribed* point loads *and* the *measured* interfacial discontinuities enter the structural analysis as input. The assessment of the predictive capabilities of the simulation approach is based on the comparison of model-predicted and measured convergences. A very satisfactory agreement is obtained. This proves the usefulness of the proposed concept. The presented multiscale structural analysis provides valuable insight into the structural behavior of the tested tunnel ring. It is shown that small initial imperfections regarding the assemblage of the ring result in a pronounced unsymmetric structural behavior, even under symmetric external loading.

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