Two-Phase Model of Pavement Fracture

PROBLEM

Internal swelling associated with alkali-silica reaction (ASR) and frost damage from ice crystallizing in the pore space are two forms of pavement distress that occur even in the absence of external forces. This *eigenstress* (stress produced without external loading) can happen at various points in the pavement depending on factors such as the physical arrangement of aggregates within the concrete, the pore-size distribution, and moisture and temperature profiles. CSHub researchers are working to understand fracture at all levels, from the nano-scale up. Therefore, it is important to have a model that allows for the evaluation of cracks as they are forming in the concrete, before they reach the interface with the subgrade. This brief explains the development of a new two-phase representation, which incorporates the elastic material properties of the pavement and subgrade and offers a more realistic response and allows researchers to more accurately incorporate the *eigenstress*.

APPROACH

Previous CSHub models used springs to represent resistance in deforming pavement. In the new model, researchers recreate the stress field of the concrete-subgrade system being evaluated to offer a more realistic depiction. Cracks of varying partial depth are introduced to the pavement system (see inset in Fig. 1) and the parameters governing the behavior of fracture are observed. In the model, the height of the pavement *H*, the depth of crack penetration *l*, and the two sets of elastic constants (G_p, κ_p) and (G_s, κ_s) of the concrete and subgrade are considered. By using an analytic equation that relates the crack opening displacement to a load distribution along the surface of the crack, researchers are able to analyze non-uniform stress profiles. Hence, the risk of fracture due to *eigenstress* can be assessed in relation to the characteristics of the subgrade. An expected insight from this model is a better understanding of how the load profile in pavement may influence the depth and interval of crack formation.

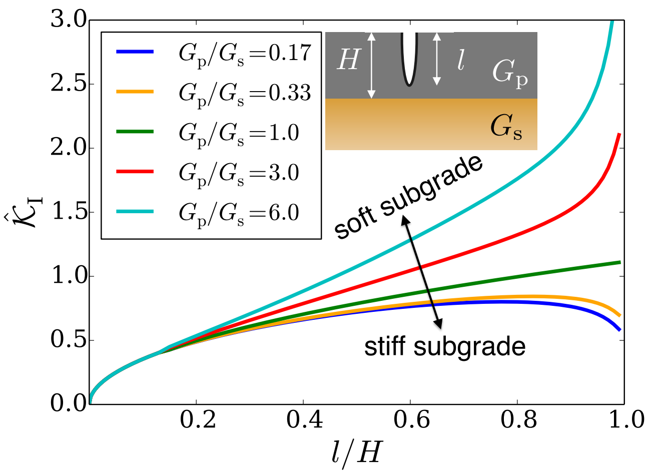

Fig. 1. Factor $\mathcal{K}_I$ as a function of the depth of crack advance. The curves represent different shear modulus ratios between pavement and subgrade.

FINDINGS

For this brief, results are presented for a fracture that is created by a force that is proportional to the stiffness of the pavement. Figure 1 plots the stress response near the crack tip for different shear modulus ratios against the crack depths. Results for stiff subgrades showed that the stress intensity factor initially increases and then decreases as the crack advances, with the subgrade resisting more of the stress near the crack tip as the crack gets larger. Conversely, soft subgrades resist less of the near-crack-tip stress, which dramatically increases the risk of advancing and perpetuating the fracture process Future studies will link the ASR expansion and freeze-thaw mechanisms to the imposed crack surface load and investigate the stress relief due to periodic arrangements of cracks.

IMPACT

This analysis presents the framework upon which microscopically derived *eigenstresses* can be incorporated into a fracture resistant design for pavement systems. As the behavior of C-S-H concrete in response to ASR and the freeze-thaw mechanisms in the pore space are revealed, the micro-phase information acts as input to the macroscopic fracture model. This model offers a more realistic response to resistance below the pavement in the material subgrade. It also gives a more accurate description of the stresses close to the crack tip.

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