Minimizing Thermal Cracks in Concrete Pavements

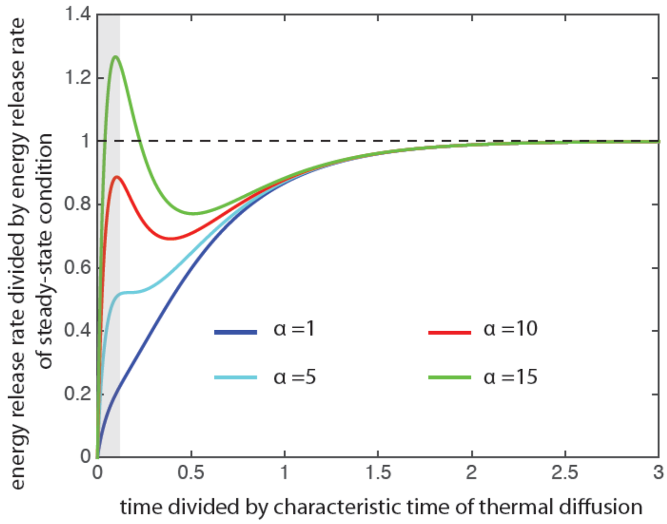
Research Brief: Volume 6, 2016

PROBLEM

Pavements subjected to sufficient stress are susceptible to fracture that can significantly reduce their durability. Thermo-mechanical eigenstresses (self-generated stresses due to thermal cycles within concrete pavements) are known to result in axial forces (expansion and contraction) and moments (bending and flexing) that can lead to fracture. This brief examines the risk of fracture of concrete pavements due to thermal cycles. CSHub researchers model the risk of fracture due to temperature changes and propose a method for estimating the risk of thermal cracking in transient-state conditions (when pavement is still undergoing a change in temperature) and steady-state conditions.

APPROACH

Researchers observe the thermal gradient after a pavement is subjected to an external temperature change. After some time, the variations disappear and the pavement arrives at a constant steady-state temperature over the pavement thickness. Researchers then solve the thermal diffusion equation (which measures the rate of heat transfer) for a pavement subjected to a change in temperature at the surface. Assuming little or no heat exchange with subgrade, the temperature profile over the pavement thickness is estimated and the distribution of eigenstresses is evaluated. Eigenstresses (modeled as a beam on elastic foundation) were integrated to obtain the energy release rate (a measure of the energy dissipated per unit of surface area of the fracture) and the corresponding stress intensity factor (a measure of the stress state at a crack tip related to the rate of crack growth; this is used to establish failure criteria due to fracture).



The risk of cracking was calculated over time following a temperature change. The process is time-dependent because heat takes time to diffuse. Each line (α) represents a pavement with a different thermal diffusion coefficient (a measure of how effectively the pavement is able to conduct heat). The temperature profile is expected to eventually be the same for all systems (represented by the dashed line), but intermediate values differ due to the difference in heat transfer.

FINDINGS

Researchers note that when the pavement is in a transient state both axial forces and moments are observed, however a constant temperature in the steady-state condition only induces axial forces. Researchers also observed that the allowable temperature change under steady-state conditions scales with pavement thickness and joint spacing, and (as shown in the figure) that the energy release rate due to the change in thermal gradient can be higher than its corresponding value in a steady-state condition. This means that fracture is most likely to occur before the pavement reaches the steady-state condition. Designs typically only consider the steady-state condition. This research suggests that incorporating information on the risk-of-fracture during the transient period can allow engineers to develop pavements that are less prone to cracking.

WHY DOES THIS RESEARCH MATTER?

- The design of durable pavements requires a means to minimize the risk of pavement fracture.
- The model proposed in this brief identifies the important structural and material parameters affecting pavement fracture resistance due to thermal cycles for both transient and steady state thermal conditions.
- The model can be used to investigate the risk of fracture due to eigenstresses generated through other types of distress mechanisms such as Alkali-Silica Reactions (ASR) and Freeze-Thaw.

CSHub@MIT with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub@MIT is solely responsible for content. This research was carried out by Dr. Arghavan Louhghalam with collaboration with Prof. Franz-Josef Ulm. Thomas Petersen assisted in the development of this brief.