Research Brief
Issue 8, 2015

An Analysis of Concrete Joint Sawing

PROBLEM

As concrete hardens and its mechanical properties evolve from liquid to stone, early-age shrinkage generates thermo- and chemo-mechanical internal stresses, also known as eigenstresses. These accumulated stresses can result in formation of random and uncontrolled cracks in portland cement concrete (PCC) pavements, especially when pavement is constrained either by neighboring sections or subgrade action. Pavement joints are cut to release some of the early-age eigenstresses and to avoid uncontrolled pavement cracking. An important question raised for pavements with typical joint spacing is: What is the latest time (or level of maturity) before which joints must be cut to avoid generation of random cracks?

APPROACH

We developed a model that relates the critical degree of hydration (the degree of hydration below which joints must be cut to avoid cracking) to pavement material and structural properties. The model is based on application of fracture criterion to an elastic beam resting on an elastic foundation. The energy release rate and stress intensity factor due to shrinkage-induced eigenstresses were obtained for both infinite- and finite-length pavements. To avoid fracture, according to linear elastic fracture mechanics (LEFM), the stress intensity factor must not exceed the fracture toughness of concrete. Using this criterion, as well as the elastic thermo-chemo-mechanical couplings of concrete at early ages, the LEFM quantities are expressed as functions of degree of hydration, thus establishing the link between the critical degree of hydration and different pavement properties.

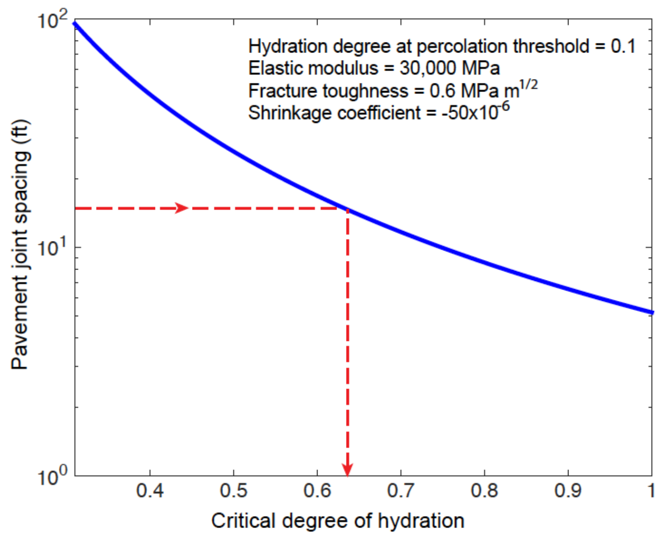

Figure 1. Pavement joint spacing versus the critical degree of hydration for typical values of concrete elastic modulus, fracture toughness and shrinkage coefficient

FINDINGS

We found that the stress intensity factor, and thus the risk of fracture, for an infinite pavement is always greater than that of a finite-length pavement. Hence, joint sawing (converting an infinite pavement to a finite-length pavement) if done at the right moment will avoid formation of additional unwanted and uncontrolled random cracks. From a material design perspective, the critical degree of hydration varies linearly with the ratio of fracture toughness to elastic modulus. It also scales linearly with the inverse of shrinkage coefficient. The mechanistic model provides a link between the critical degree of hydration and pavement joint spacing in terms of concrete material properties (see Figure 1). For instance, for a typical pavement section with joints that are 15 ft. apart and concrete with a typical degree of hydration of 0.1 at percolation threshold, the model predicts a critical hydration degree of 0.63. The findings thus far provide a relationship between pavement properties and the critical degree of hydration. Relating these results to the critical level of maturity requires information regarding the affinity of the chemical reaction, which is the subject of future research. Once this affinity is known, by adapting to the external temperature through hydration kinetics, the critical level of concrete maturity and thus the critical time of joint sawing can be determined.

IMPACT

To design longer-lasting pavements the risk of pavement fracture must be minimized. This model provides a means to estimate the critical hydration degree for cutting pavement joints to minimize this risk and enhance pavement performance. By relating the degree of hydration with concrete maturity, and monitoring it in the field, the critical time of saw cutting can be determined. In addition, the functional relationships developed herein, provide insight into the design of both pavement material and structure.

This research was carried out by 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. Authors: Dr. Arghavan Louhghalam in collaboration with Prof. Franz-Josef Ulm