Using Concrete Maturity Testing to Optimize Road Opening Timing

What Was the Need?
In concrete pavement construction, engineers must determine how long the concrete should be allowed to cure after placement before cutting joints, removing forms and opening a road to traffic. During hydration, the strength of concrete gradually increases as the cement in the mixture reacts with water. Letting concrete cure too long unnecessarily lengthens traffic delays, but opening a road early can damage it.

Current MnDOT specifications determine when to open a road to traffic by creating a 75-pound beam specimen to be tested for flexural strength—the stress at which a bending material fractures—after seven days. Because a given concrete mixture will cure more quickly in warmer conditions, contractors may make extra specimens for testing at earlier intervals. However, this process is labor-intensive, and engineers would like to have a more efficient way to determine whether a road is ready to open to traffic. One such technique predicts a concrete’s strength from its maturity, or the way its temperature changes over time. This works because the strength of concrete is correlated with its temperature history. However, the method requires developing a mathematical model, or “maturity curve,” for each mixture. While some curves have been developed for standard mixes, research was needed to develop curves for MnDOT mixes, which often have a lower water-to-cement ratio and include alternative cementitious materials such as fly ash.

What Was Our Goal?
MnDOT wanted to develop strength-maturity relationships for concrete mixtures that allow contractors, field personnel and materials engineers to estimate the in-place strength of concrete pavements with reduced sampling and testing. The focus was on mixes that have high supplementary cementitious materials content and low water-cement ratios.

What Did We Do?
To develop maturity curves, researchers conducted field tests over three construction seasons on 18 paving projects that used various concrete mixes. During construction, researchers placed sensors in concrete pavements to evaluate time-temperature relationships while curing. Then they took sample specimens that had cured for various lengths of time—from 12 hours to 28 days—and measured their flexural strength. Using these results, they developed curves showing how strength varied with maturity, measured as temperature multiplied by time. They also compared the ease of use and accuracy of various types of sensors.

Researchers then conducted laboratory testing to evaluate how changing the proportions of cementitious materials and their ratio to water would affect the maturity curves. The purpose of this sensitivity analysis was to determine how precise mixture ratios have to be for a given maturity curve to be accurate for that mixture. Researchers analyzed 2-inch mortar cubes made from 15 different mixes for their compressive strength and full-size beams made from select mixes for their flexural strength.
Researchers then evaluated different mathematical models and their ability to predict concrete strength from maturity. Finally, they developed a database of concrete mixes and their associated maturity curves, created a draft construction specification and produced a draft laboratory manual detailing the use of maturity curves for portland cement concrete pavement construction projects.

**What Did We Learn?**

Overall results showed that MnDOT can successfully use maturity to accurately predict the strength of portland cement concrete. The laboratory sensitivity analysis showed that it is necessary to carefully control batch proportions during construction, and that deviations from the approved mix design exceeding 5 percent by weight should require development of a different maturity curve.

Researchers recommend that MnDOT use an exponential mathematical model for maturity curves, based on its ability to fit early age strength data better than other tested models and because of its low level of error and other advantages. The maturity database developed by researchers can be used to establish the soundness of the maturity method for predicting concrete strength in the field. It includes mix characteristics and all test results from laboratory and field projects, and allows users to develop maturity curves using additional information from new mixes and maturity testing.

The specifications created for this project include recommendations for the three major functions of the maturity method: maturity curve development, usage during construction and curve validation.

**What’s Next?**

MnDOT will evaluate the draft specification created by this project for possible implementation. The use of maturity curves could allow contractors to avoid costly mistakes associated with early joint cutting and road openings, and to optimize mix selection based on performance requirements and anticipated ambient conditions.