



RESEARCH SERVICES

OFFICE OF POLICY ANALYSIS,
RESEARCH & INNOVATION

TECHNICAL SUMMARY

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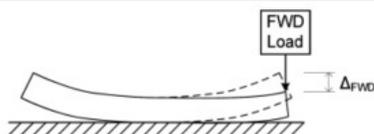
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PROJECT COST:

\$64,000



Curl leaves voids underneath the corners of concrete slabs, leading to greater FWD deflections.

Predicting Environmental Effects on Concrete Pavements

What Was the Need?

Environmental conditions, including daily and seasonal fluctuations in temperature and moisture, affect the longevity and performance of pavements. These fluctuations are greater near the pavement's surface, where it is exposed to the environment. The resulting temperature and moisture differences between the top and bottom of a concrete pavement slab, or gradients, lead to differing amounts of expansion or contraction and a consequent [curling or warping of the slab](#), either upward or downward.

Curling due to temperature gradients occurs during construction itself, leading to a certain amount of built-in curl that will be maintained by concrete slabs regardless of actual changing temperature gradients from the weather. Because curled slabs receive higher stresses in some areas than others when subjected to traffic loads, built-in curl can lead to premature cracking. Consequently, estimating built-in curl—which is quantified in degrees Fahrenheit as the equivalent temperature gradient needed to deform a flat slab to the same shape as a curled slab—is critical to using mechanistic empirical design to determine how a pavement's design will affect its performance life.

However, there is currently no method for accurately determining built-in curl, and the built-in curl value suggested by the [Mechanistic-Empirical Pavement Design Guide](#) does not take into account the effects of design, materials and construction practices.

What Was Our Goal?

The goal of this project was to determine how the material and geometrical properties of concrete slabs affect built-in curl to improve the accuracy of mechanistic-empirical pavement design.

What Did We Do?

Researchers began by creating a mathematical model to help determine how the shapes of concrete slabs change with their temperature gradients and:

- Geometrical properties, such as slab width, thickness, length and position within the pavement.
- Material properties, such as stiffness, unit weight and coefficient of thermal expansion (a measure of how concrete will expand or contract in response to temperature changes).

Researchers then determined how the resulting changes in the shapes of slabs could be expected to affect measurements of the deflections of slab corners in response to a large load, taken using a falling weight deflectometer. Deflections are greater at the corners of slabs when they curl upward than when they are flat since curling creates voids into which pavements can recess in response to loads.

Researchers used this model to estimate built-in curl for pavement test sections at the MnROAD pavement research facility by comparing predicted correlations between FWD corner deflections and temperature gradients to those measured in the field. For

Developing a method to accurately determine built-in curl is critical to using mechanistic empirical design to produce more cost-effective, durable pavements.

“Until we can accurately estimate built-in curl, we’re still far from truly optimizing our concrete pavement designs.”

—Tom Burnham
MnDOT Senior Road
Research Engineer

“This project helps us better understand the factors that affect permanent concrete pavement warping. This understanding can lead to greater reliability and longer pavement service life.”

—Jacob Hiller
Assistant Professor,
Michigan Technological
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Engineering

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To verify results for back-calculating curl from FWD measurements, researchers compared it to an alternative method involving backcalculation from surface profiling.

a given FWD deflection and slab composition, built-in curl is the difference between the temperature gradient predicted by the model—or total curl—and the temperature gradient measured in the field.

Finally, researchers evaluated an alternative method for predicting built-in curl using an automated laser profilometer to measure the shapes of slab surfaces, comparing field measurements to mathematical models that predict profiles for slabs of a similar composition and temperature gradient.

What Did We Learn?

Researchers created a spreadsheet-based program with a user-friendly interface for back-calculating the expected total curl of concrete slabs from the FWD measurements, temperature gradients, and material and geometrical properties. This program analyzes data using an artificial neural network, a sophisticated model that detects patterns in data sets. However, because of limitations in using FWD deflections to predict curl, this program can be used to calculate built-in curl only when total curl is more negative than -9 degrees F. Gradients of this size are rare in Minnesota, requiring measurement on a hot morning following a cold evening.

Results showed that all test cells had negative built-in temperature gradients. However, total curl was more negative than -9 degrees F in only two MnROAD cells, indicating that the artificial neural network model developed in this study generally could not be used to estimate built-in curl for Minnesota conditions. Further, none of the methods for analyzing profilometer data gave realistic results, and their values for built-in curl did not match those calculated using the artificial neural network.

What’s Next?

More research is needed to determine how well the model developed in this study predicts thermal gradients. MnROAD researchers will also continue to test pavement cells to build a database of information that will ultimately help pavement designers better determine values for built-in curl. Doing so will facilitate the design of more cost-effective and reliable pavements.

This Technical Summary pertains to Report 2011-16, “Field Evaluation of Built-in Curling Levels in Rigid Pavements,” published June 2011. The full report can be accessed at <http://www.lrb.org/PDF/201116.pdf>.