Characterizing the Impact of Curling and Warping on Ride Quality

By
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Acknowledgments

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• Iowa DOT, Iowa Highway Research Board, and FHWA
Curling and warping is a simple behavior affected by many variables.

Liang and Niu (1989)
Yu et al. (2004)
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Curling and warping is a simple behavior affected by many variables.

Liang and Niu (1989)
Yu et al. (2004)
Curling and warping affects pavement performance and structural integrity.

Chang et al. (2008)
Kosmatka (2003)
Curling and warping affects pavement performance and structural integrity.

Chang et al. (2008)
Kosmatka (2003)
The state of Iowa has one of the highest percentages of PCC pavements in the nation.
Curling and warping characterization can be done using different tools.
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Morning

Afternoon
Curling and warping characterization can be done using different tools.
Curling and warping characterization can be done using different tools.
Westergaard equations represent an idealized model of the reality!

\[ z = -z_0 \frac{2 \cos \lambda \cosh \lambda}{\sin 2 \lambda - \sinh 2 \lambda} \left[ (-\tan \lambda + \tanh \lambda) \cos \frac{x}{l\sqrt{2}} \cosh \frac{x}{l\sqrt{2}} + (\tan \lambda + \tanh \lambda) \sin \frac{x}{l\sqrt{2}} \sinh \frac{x}{l\sqrt{2}} \right] \]

Westergaard (1927)
Westergaard equations represent an idealized model of the reality!

Westergaard (1927)
The Mechanistic-Empirical mindset wins again!

\[ z = -z_0 \frac{2 \cos \lambda \cosh \lambda}{\sin 2 \lambda - \sinh 2 \lambda} \left( \frac{(-\tan \lambda + \tanh \lambda) \cos \frac{x}{\sqrt{2}} \cosh \frac{x}{\sqrt{2}} + (\tan \lambda + \tanh \lambda) \sin \frac{x}{\sqrt{2}} \sinh \frac{x}{\sqrt{2}}}{l \sqrt{2}} \right) \]

\[ PSG = \frac{\alpha \Delta T + \Delta \varepsilon_{sh}}{h} \]

\[ l = \frac{4 \sqrt{Eh^3}}{\sqrt{12(1 - \mu^2)k}} \]

Chang et al. (2008)
Iowa’s LTPP section was analyzed in-house following the 2GCI approach.
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IRI is not a linearly separable statistic.

IRI = 80.09 in./mi
IRI is the average value of the absolute suspension strokes of a quarter-car model simulations.
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IRI is a non-linear function of a linear filter.
Fourier transform decomposes a profile into sinusoidal waves.
Filters are products of multiplication in the frequency domain.
Profiles with curling and warping show unique signatures in the frequency domain.
The Pseudo-Gradient can be manipulated to predict the change in IRI.

\[ \delta \text{ PSG} = 8.12 \times 10^{-6} \, \varepsilon/\text{in} \]

IRI = 58.29 in/mile

\[ \delta \text{ PSG} (\varepsilon/\text{in}) \]

IRI (in/mile)
The impact of changing relative radius of stiffness can give estimates of the design impact.
References


