Characterizing the Impact of Curling and Warping on Ride Quality

By

Ahmad Alhasan

Acknowledgments

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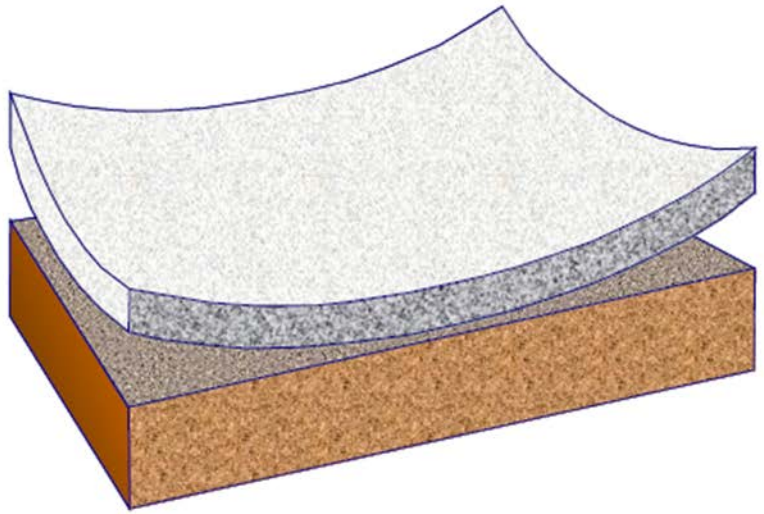
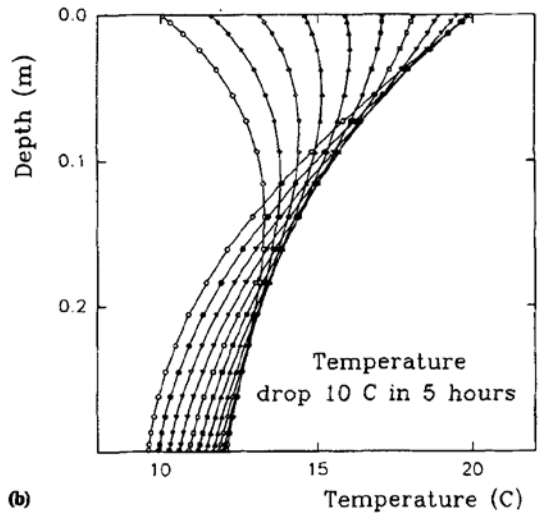
  - Shuo Yang, Halil Ceylan, Sunghwan Kim, and Yang Zhang.
- Iowa DOT, Iowa Highway Research Board, and FHWA

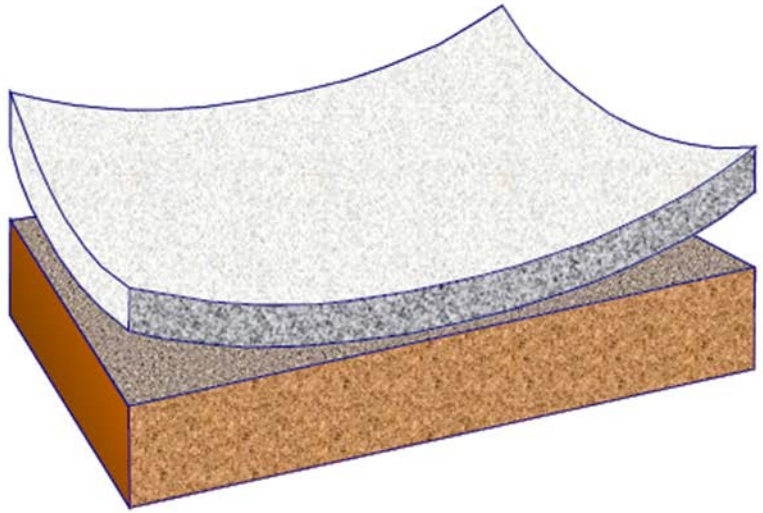
Curling and warping is a simple behavior affected by many variables.



Liang and Niu (1989)
Yu et al. (2004)

Curling and warping is a simple behavior affected by many variables.





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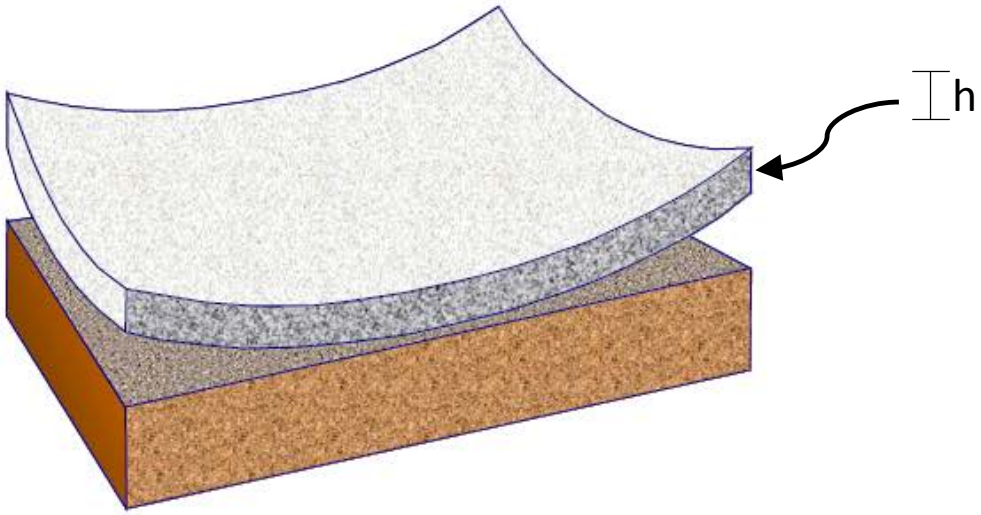

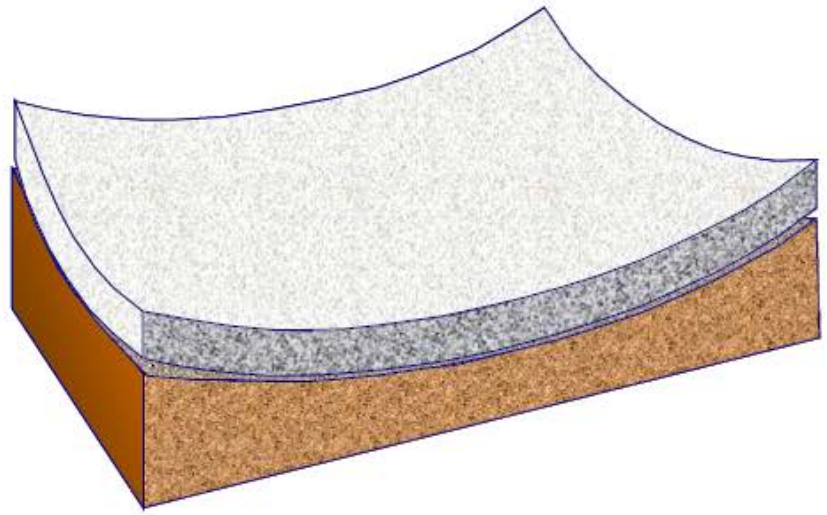

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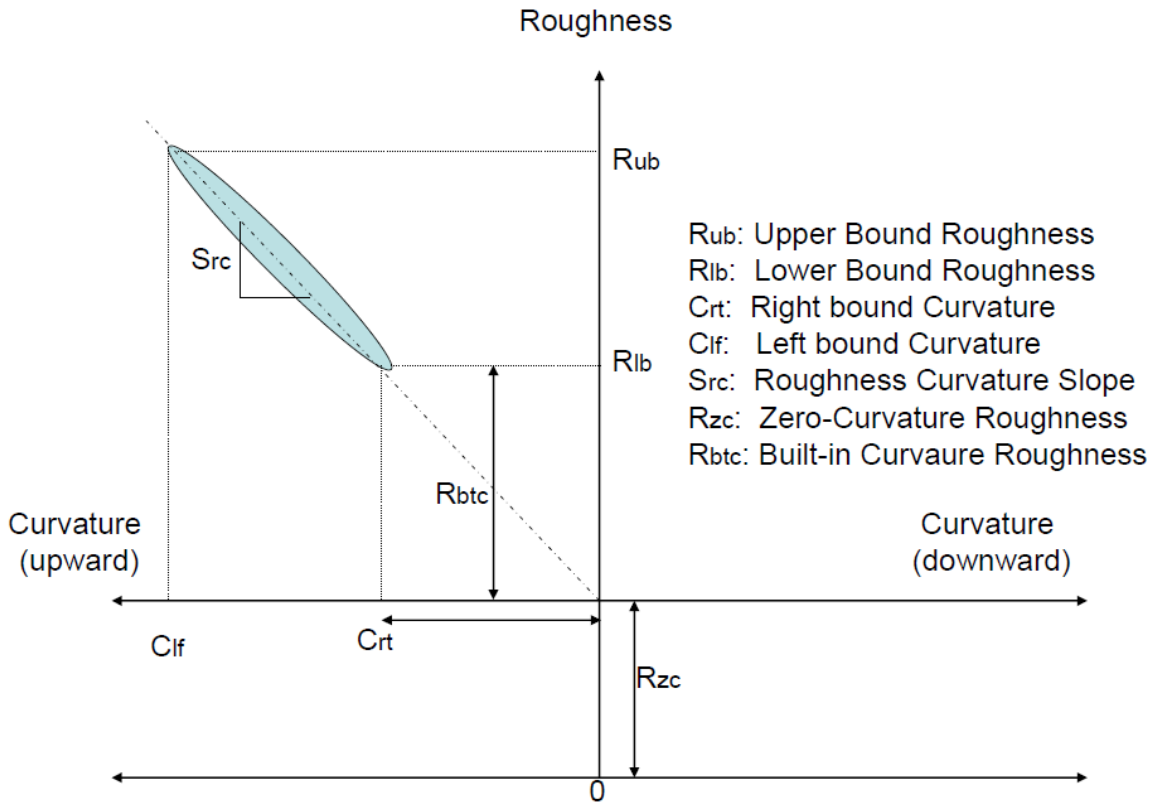
Curling and warping affects pavement performance and structural integrity.



Chang et al. (2008)
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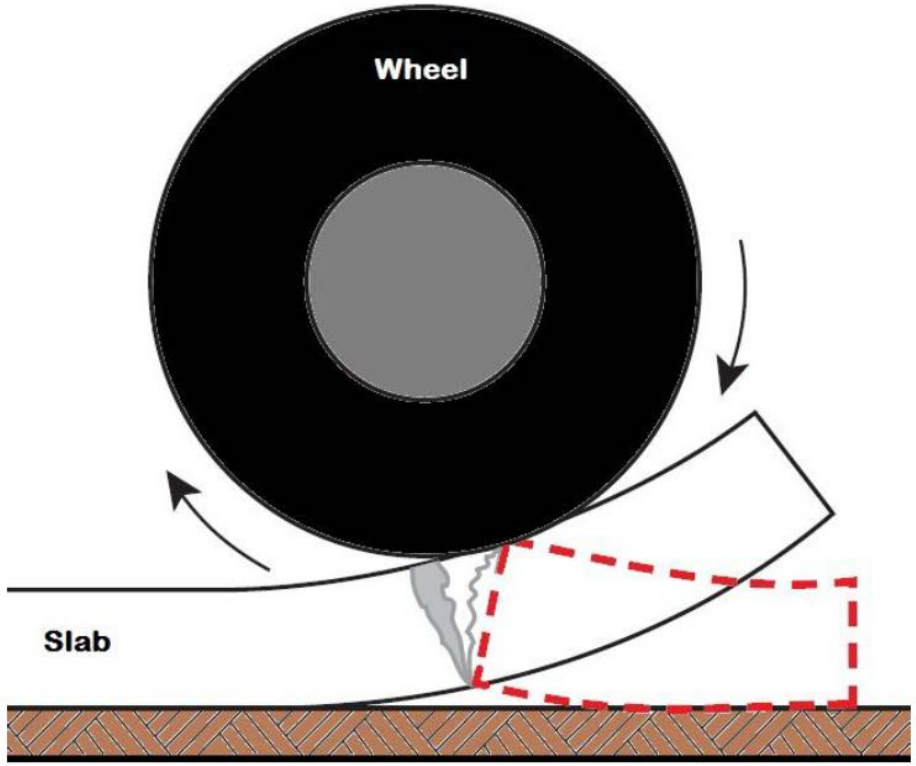

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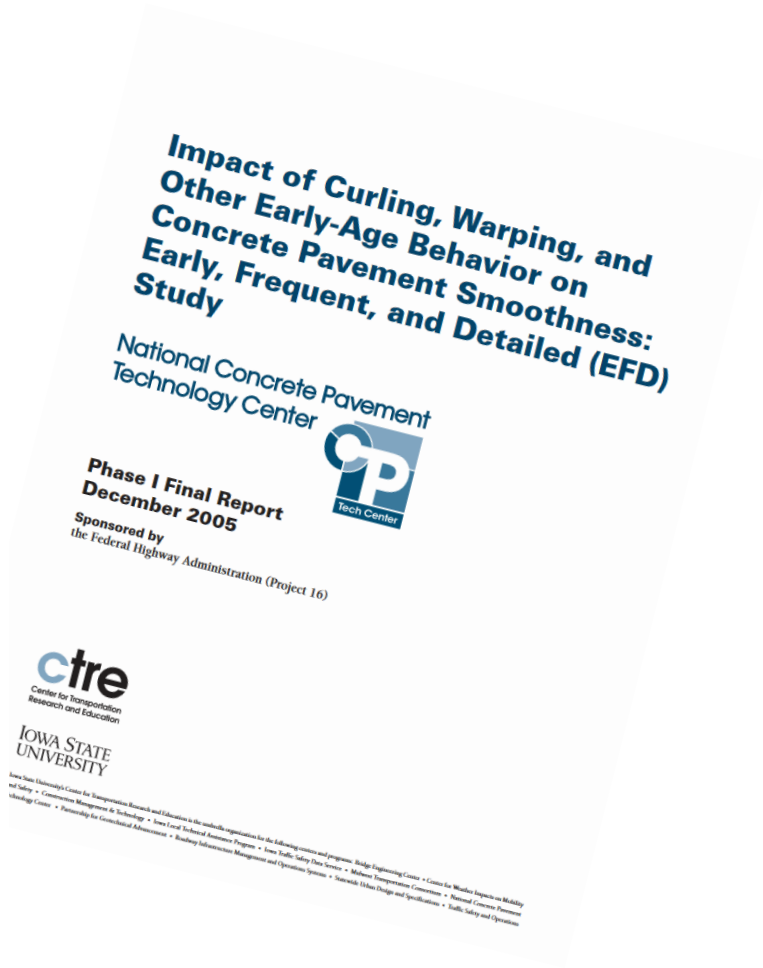
The state of Iowa has one of the highest percentages of PCC pavements in the nation.



Curling and warping characterization can be done using different tools.

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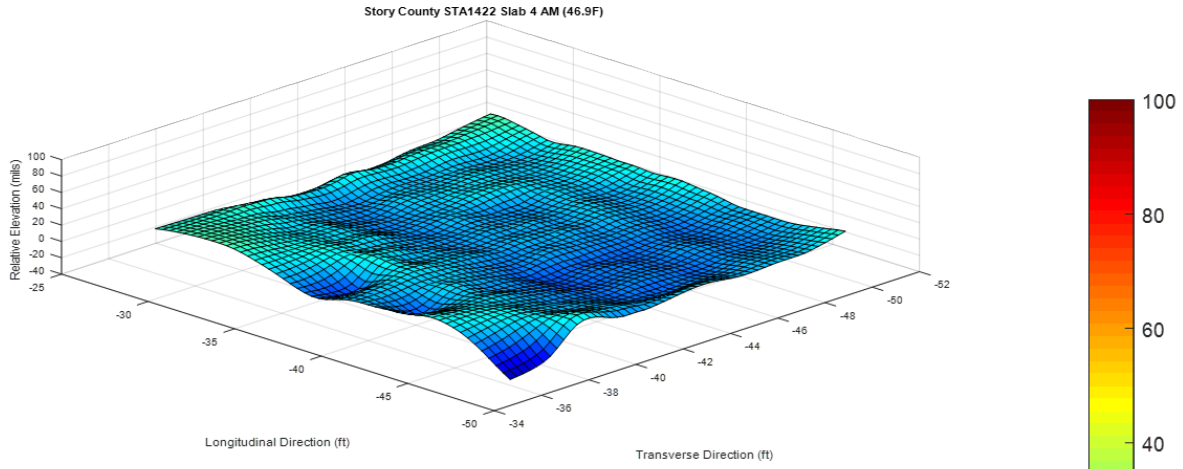
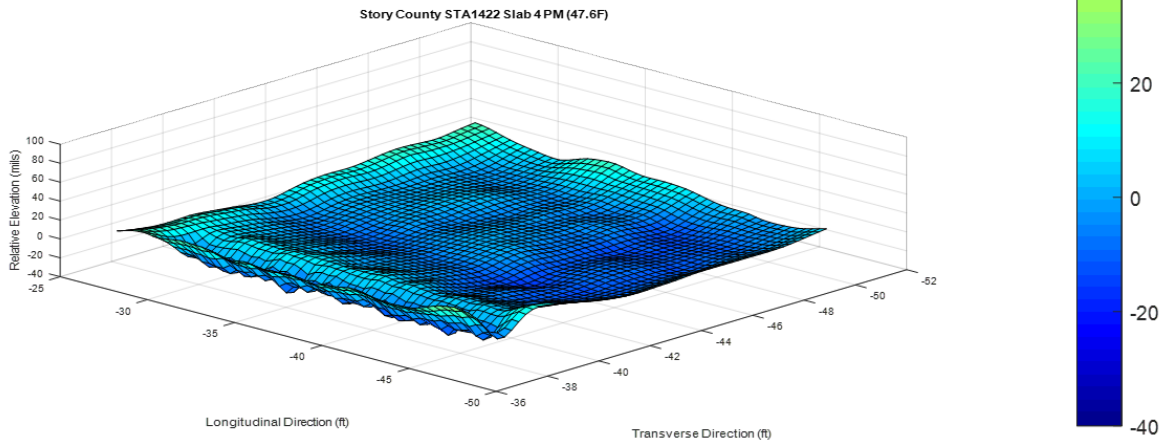
Morning



Afternoon



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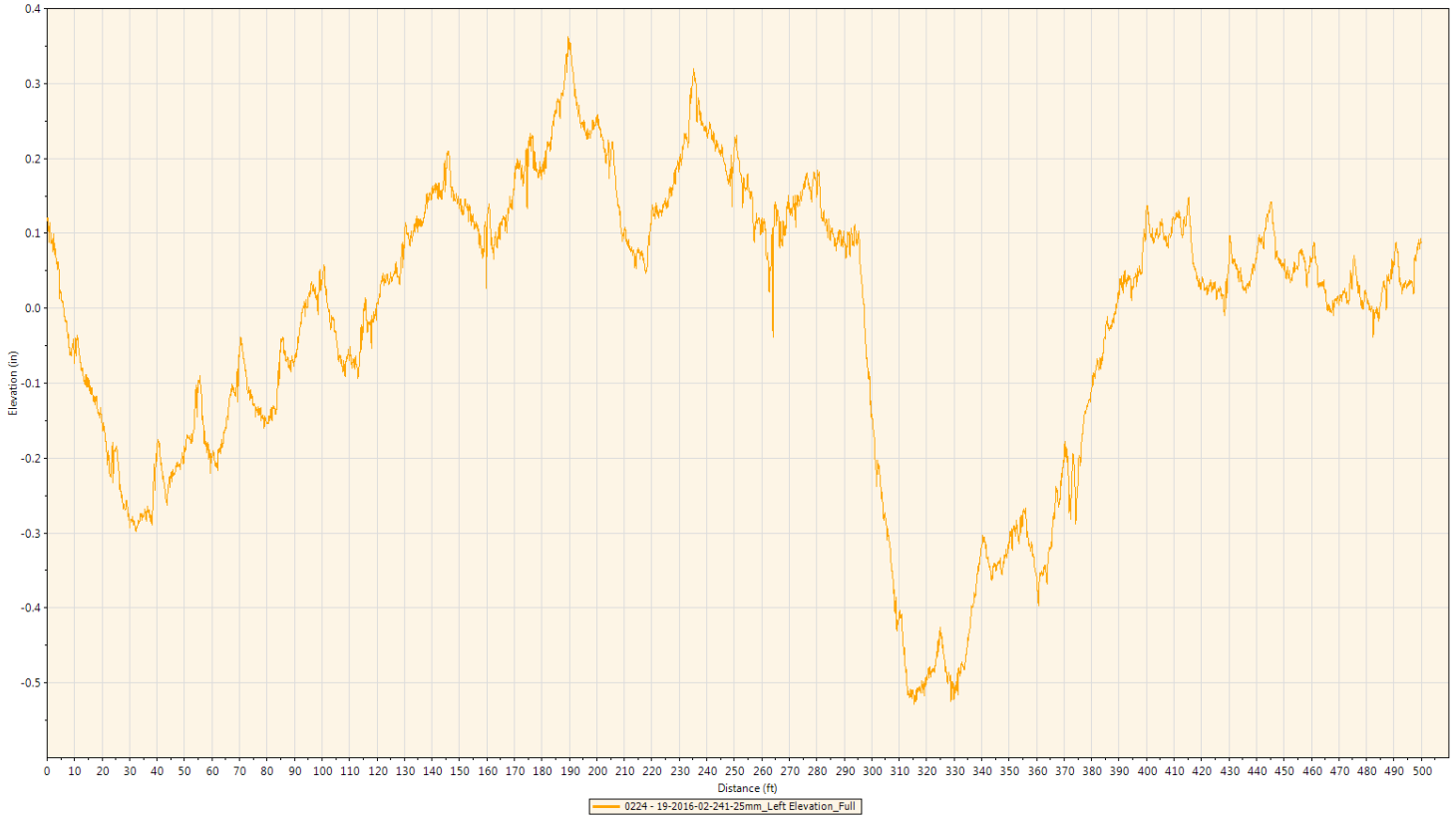

Westergaard equations represent an idealized model of the reality!

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

Westergaard (1927)

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The Mechanistic-Empirical mindset wins again!

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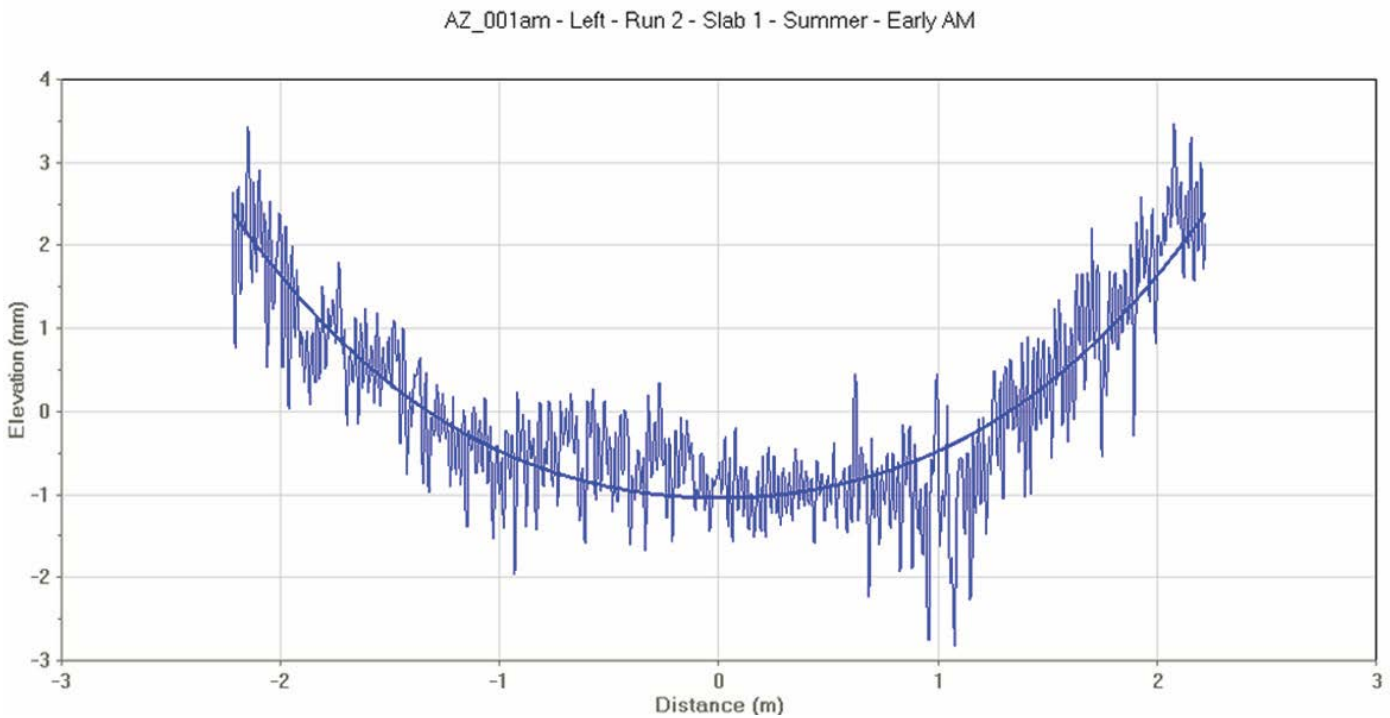
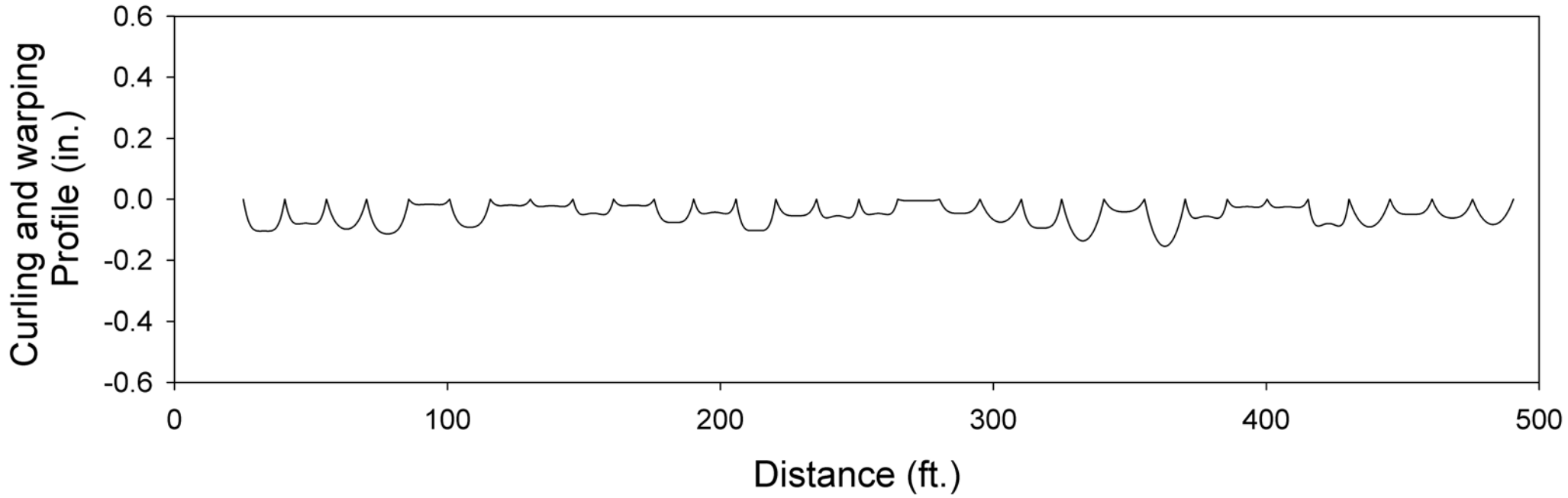
$$PSG = \frac{\alpha\Delta T + \Delta\varepsilon_{sh}}{h}$$

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



Chang et al. (2008)

Iowa's LTPP section was analyzed in-house following the 2GCI approach.



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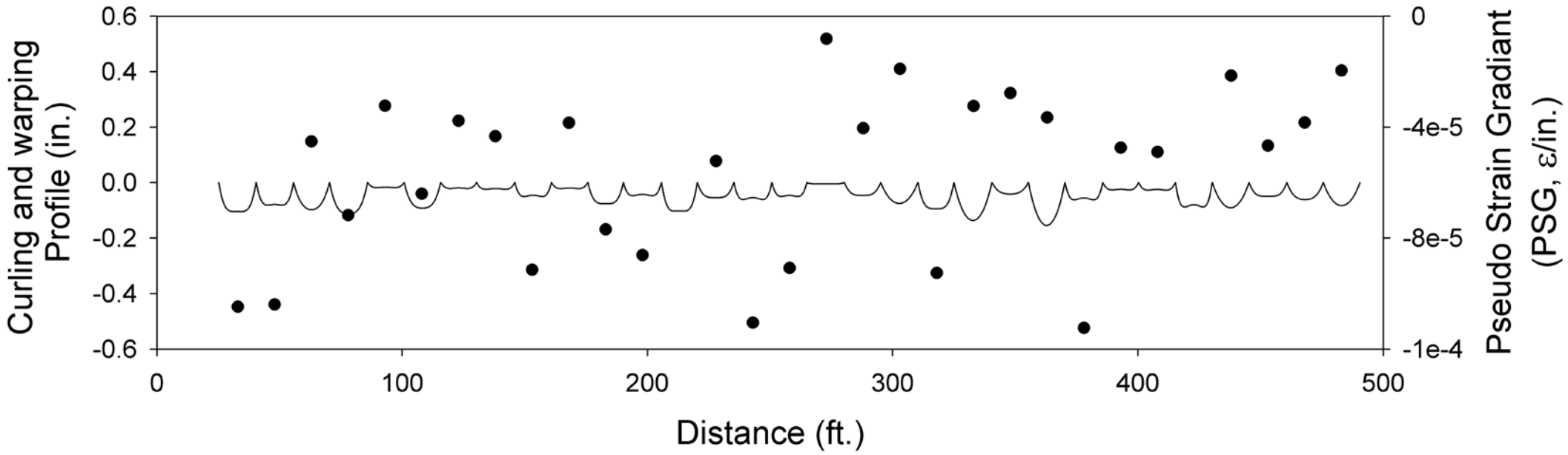
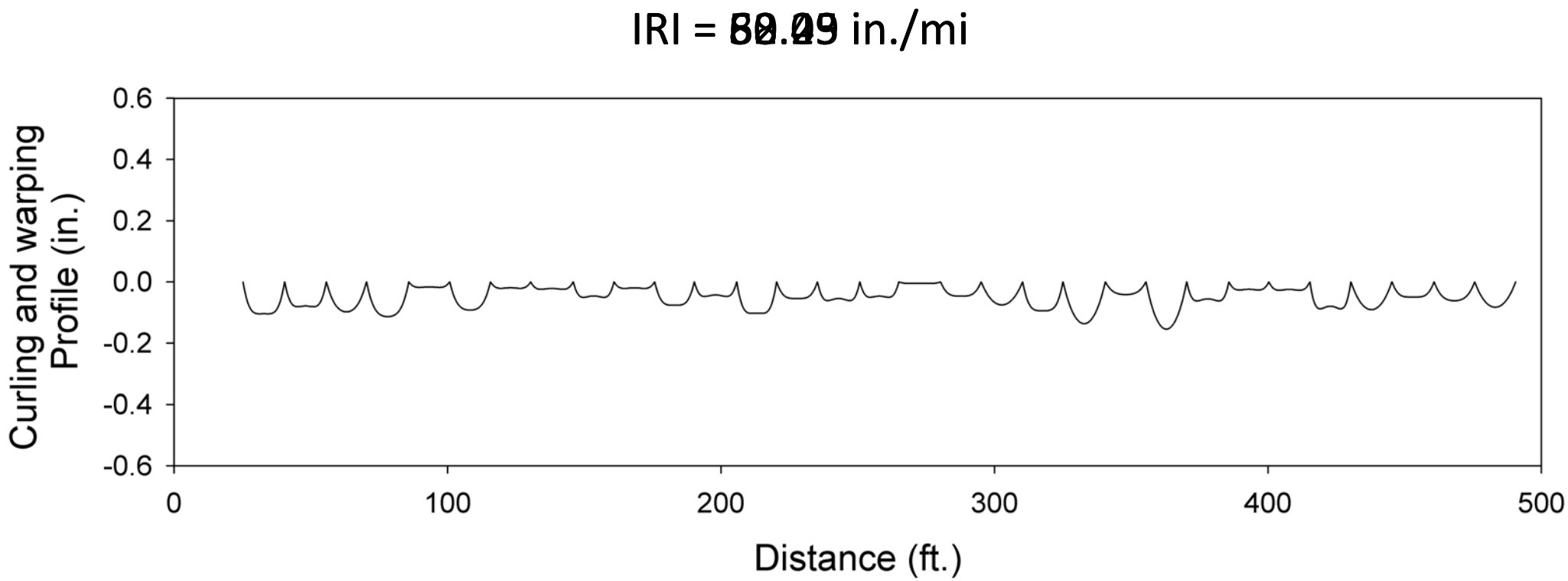
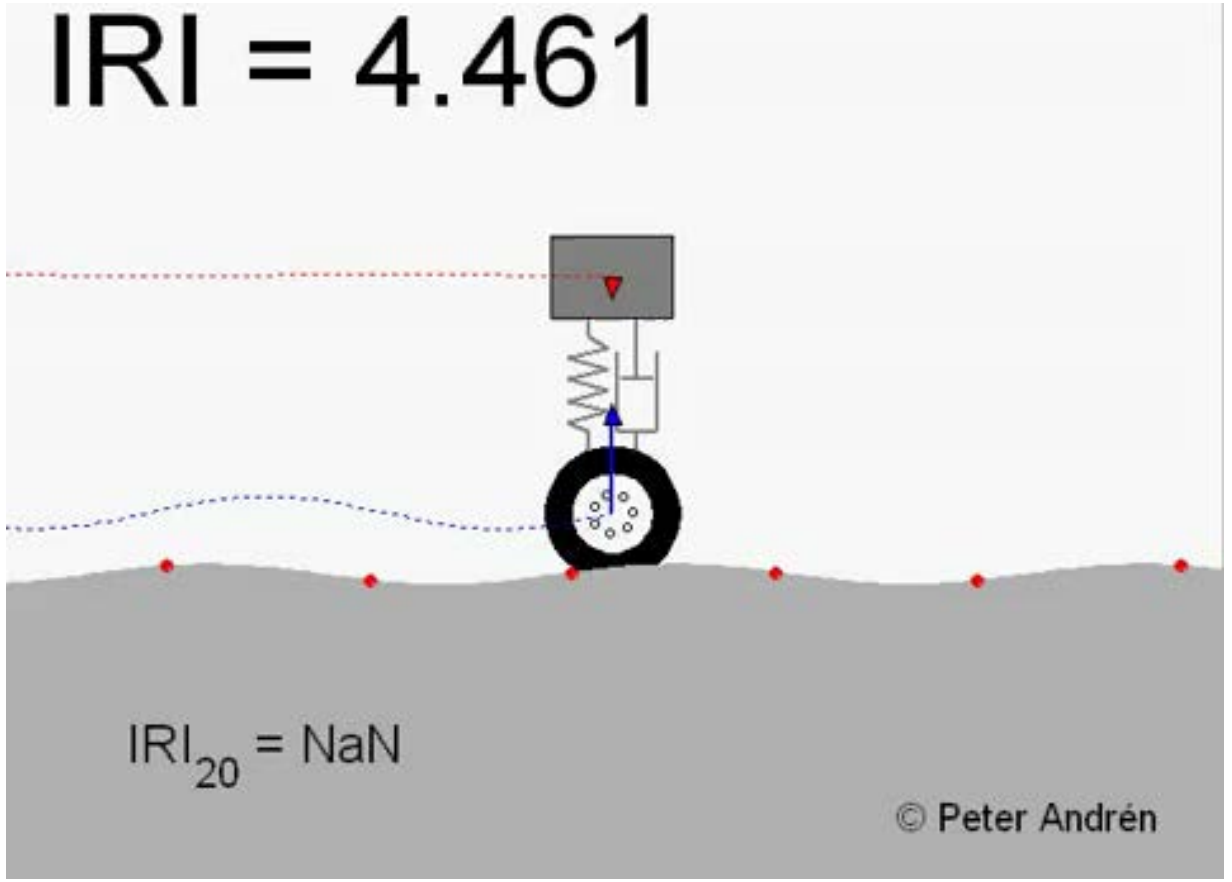


IRI is not a linearly separable statistic.



IRI is the average value of the absolute suspension strokes of a quarter-car model simulations.



ASTM E1926-08 (2015)

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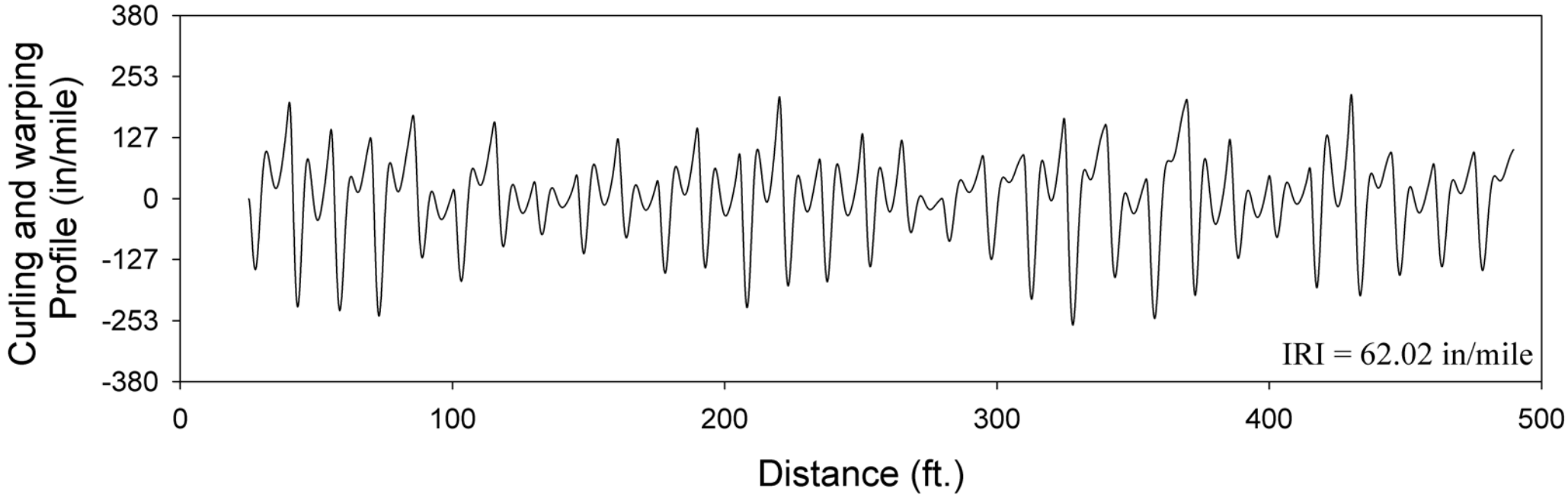
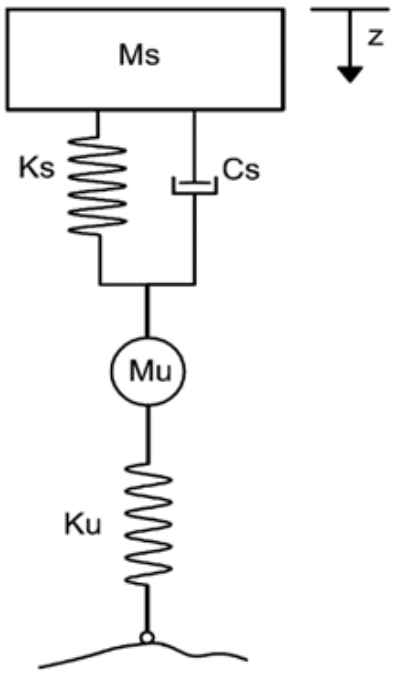
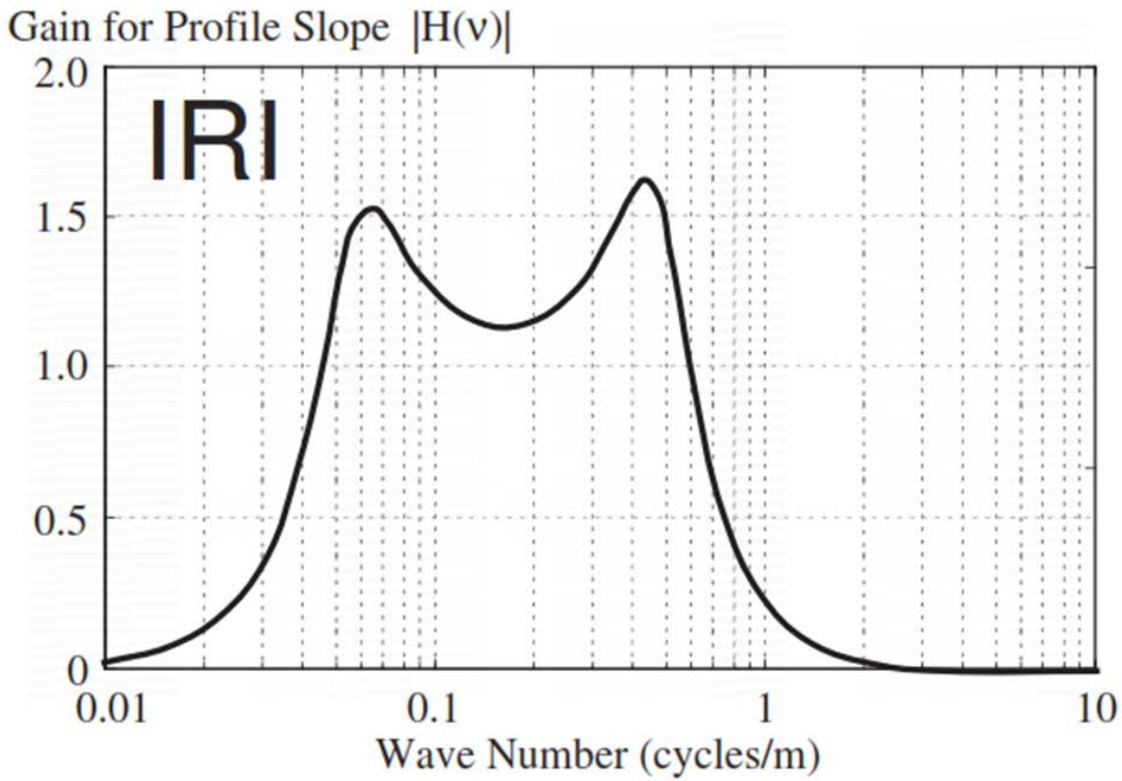


IRI is a non-linear function of a linear filter.

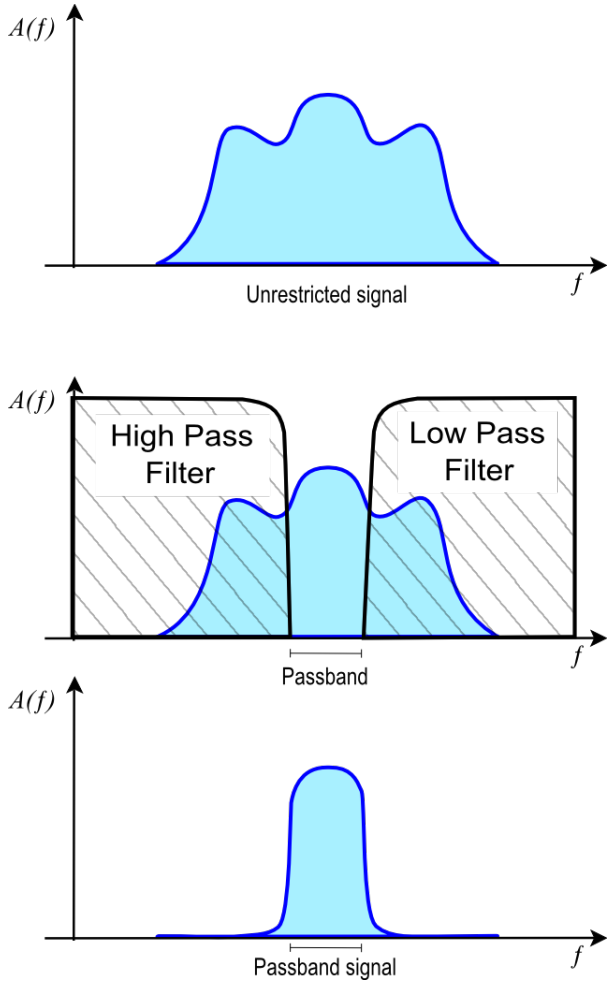




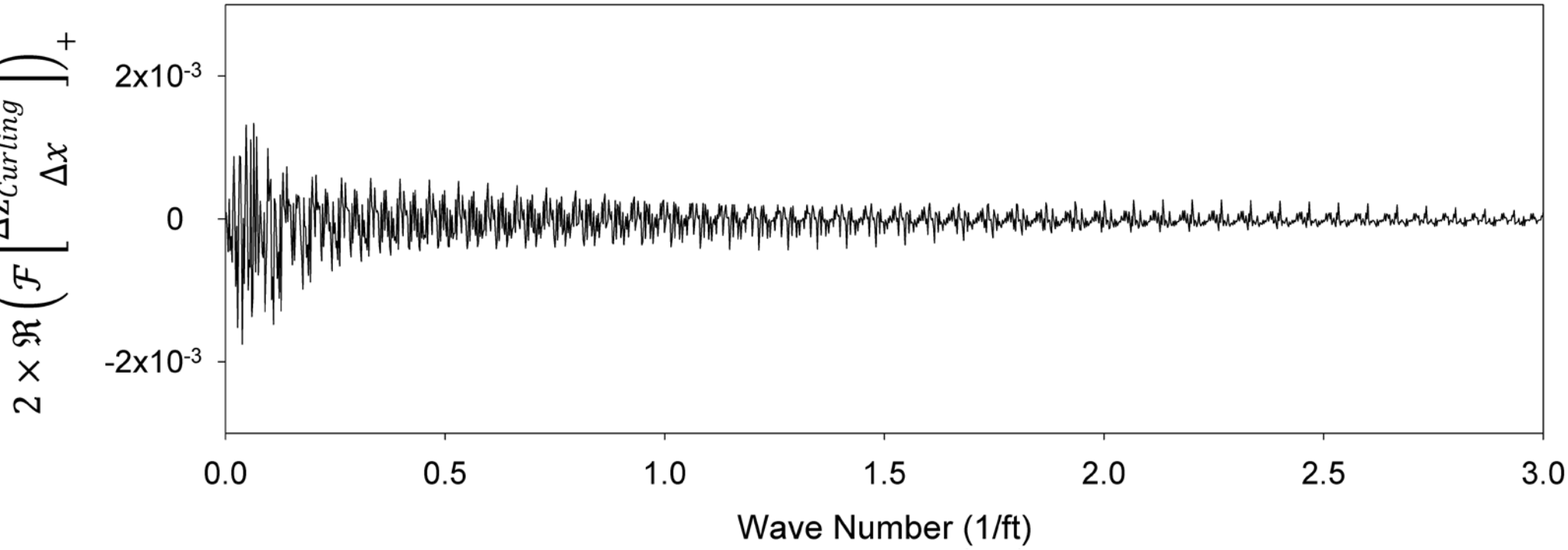
Fourier transform decomposes a profile into sinusoidal waves.

Wikipedia 2015

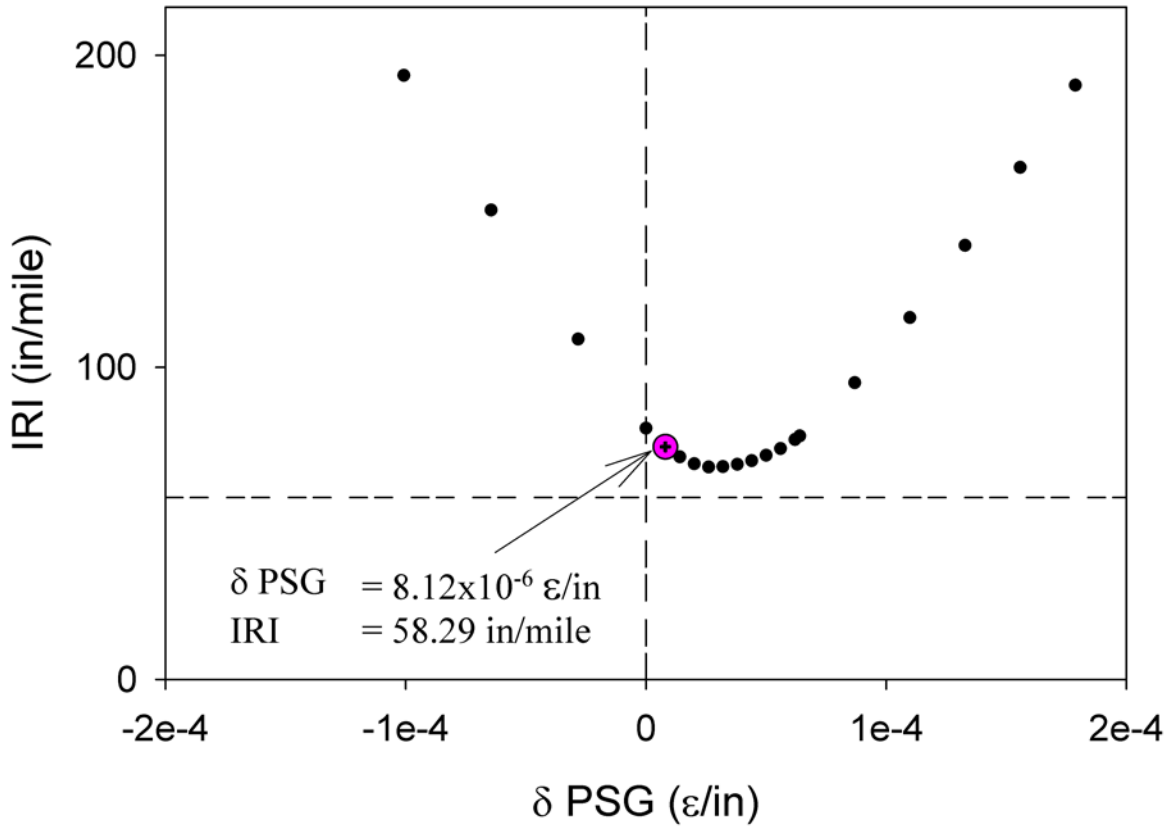
Filters are products of multiplication in the frequency domain.



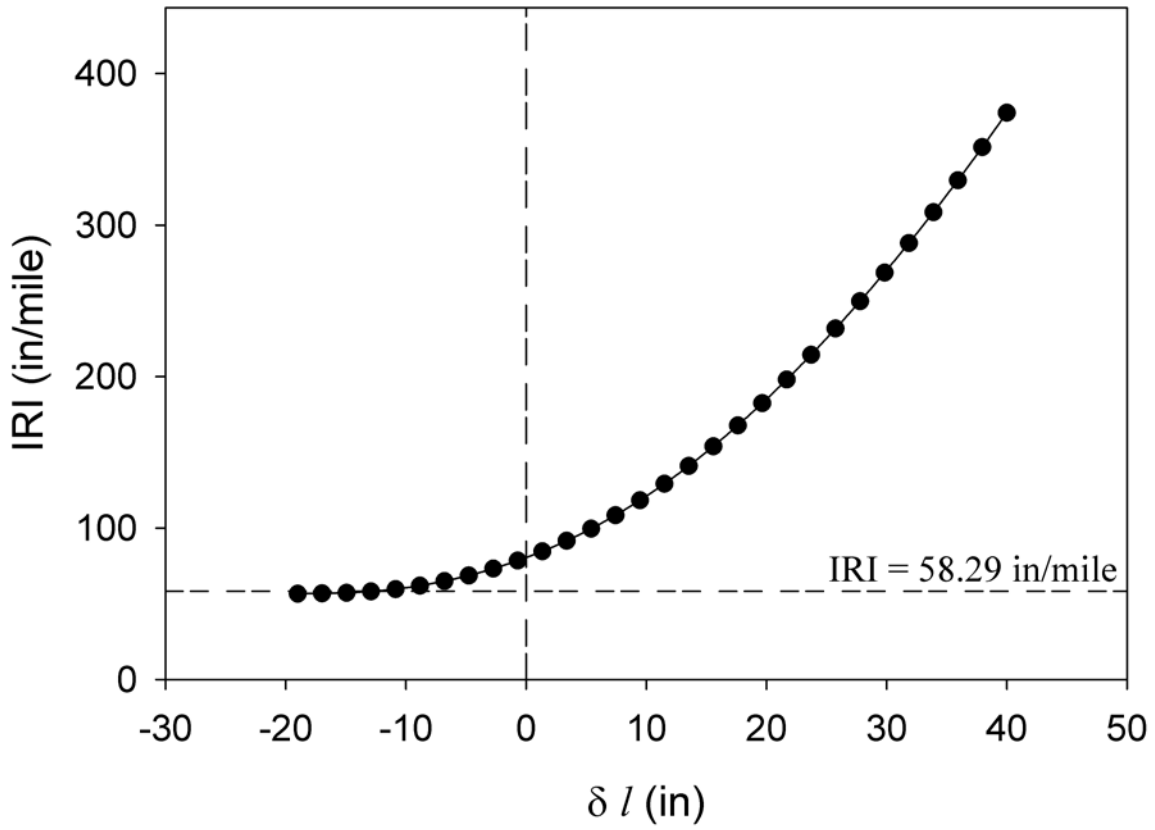
Profiles with curling and warping show unique signatures in the frequency domain.



The Pseudo-Gradient can be manipulated to predict the change in IRI.



The impact of changing relative radius of stiffness can give estimates of the design impact.



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