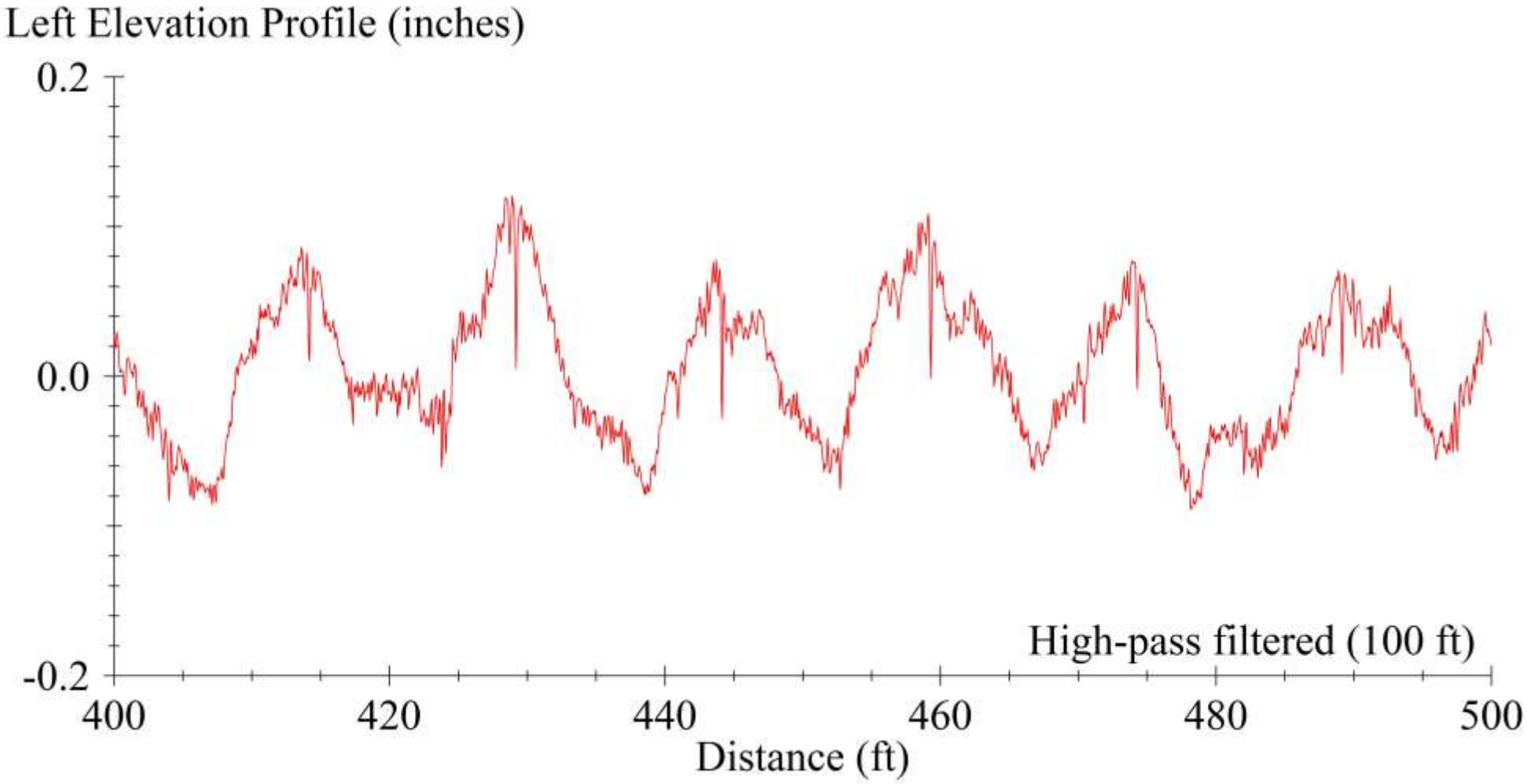
Investigation of Profile-Based Curl and Warp Analysis Using LTPP Profile Data

By
Steven M. Karamihas
University of Michigan Transportation Research Institute
With Kevin Senn and Timin Punnackal, NCE
And Larry Wiser, FHWA

RPUG Road Profile Users' Group

AZ Section 040213, Upward Curl



Source: FHWA

PE 2019

RPUG Road Profile Users' Group

Advancement of Curl and Warp…..

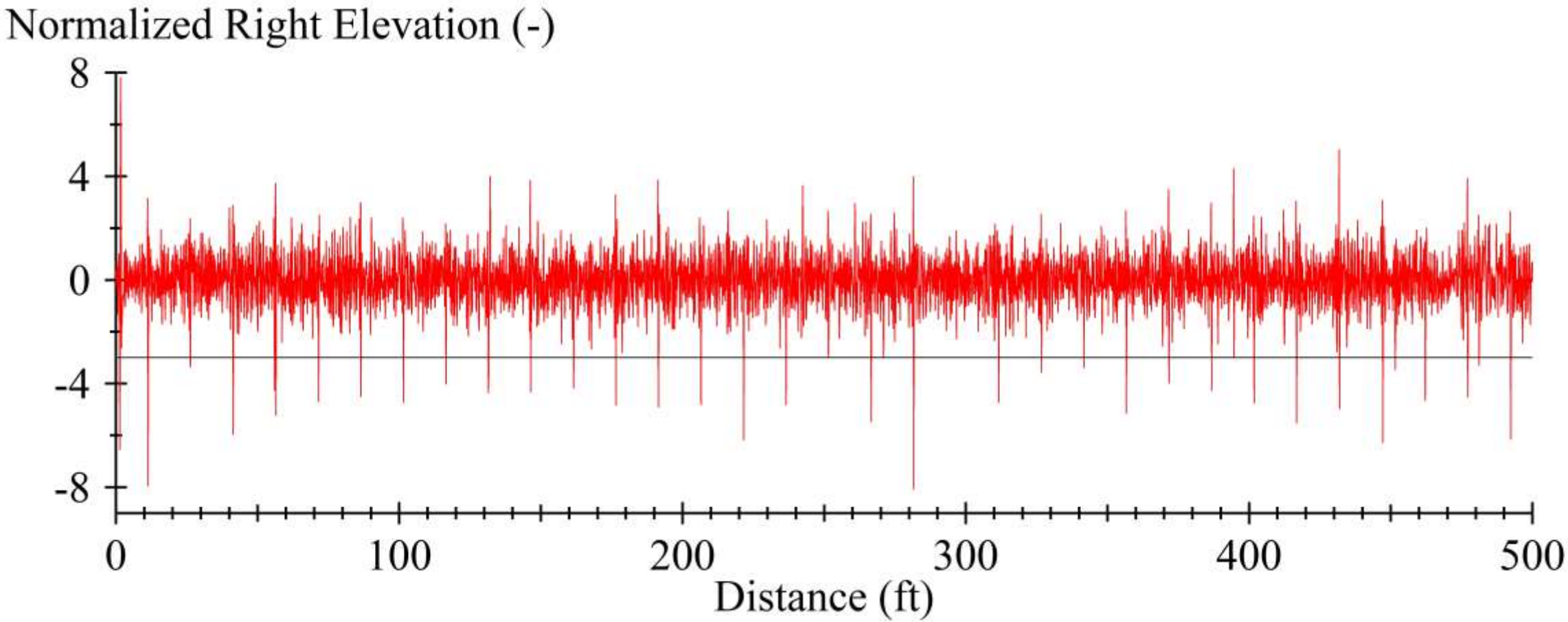
- Estimate the level of curl and warp of JPCC using profile.
- Relate curl and warp to roughness.
- Refine an existing method.
- Apply the method to a broader set of sections.

“What would the roughness be without curl and warp?”

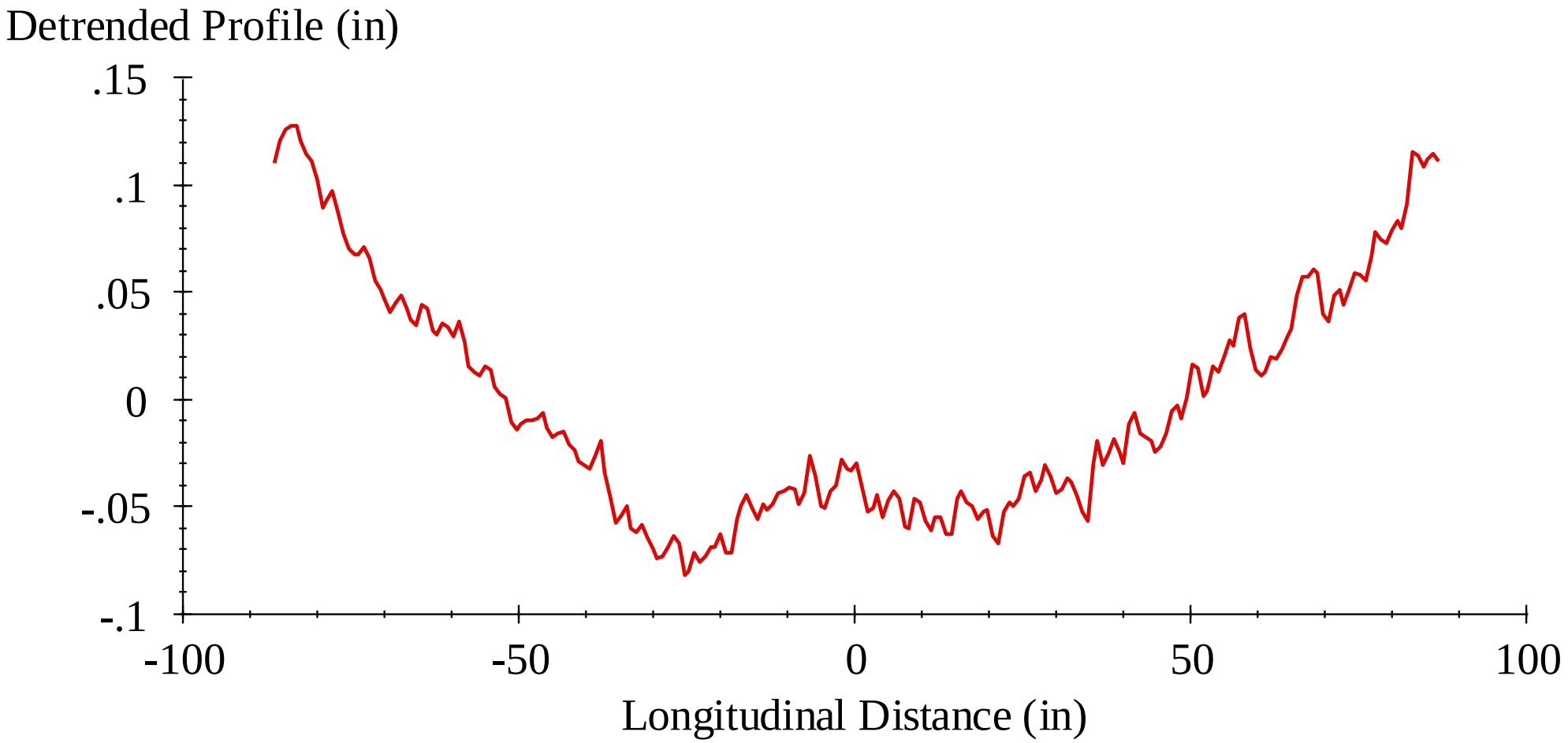
Core Method (Chang, Rasmussen, et al.)

- Locate the joints.
- Isolate slab profiles.
- Fit slab profiles to an assumed function (Westergaard).
- Cast the result in terms of strain gradient.
- Aggregate over a test section.

Joint Finding



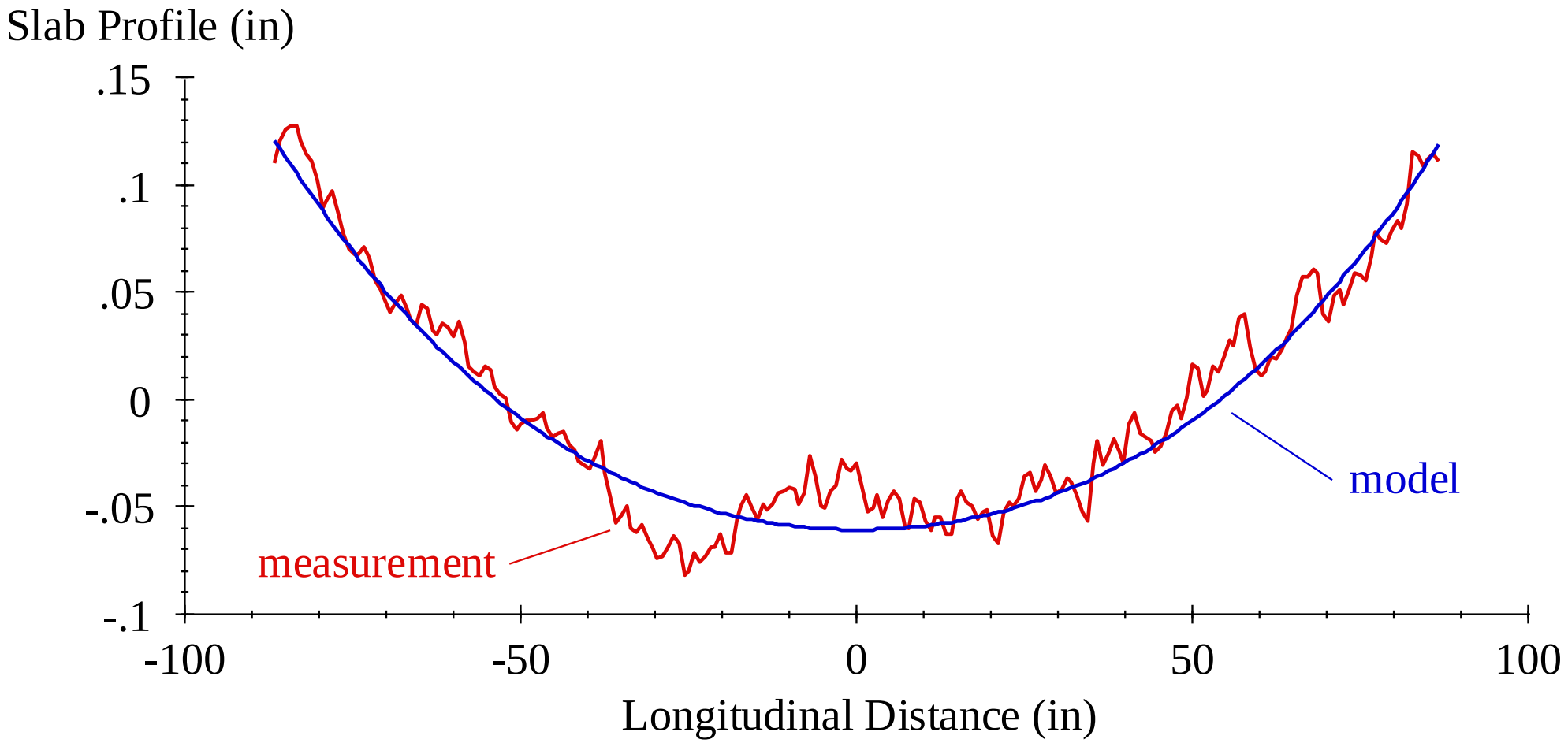
Isolated Slab Profile



Source: FHWA-HRT-12-068

RPUG Road Profile Users' Group

Fitted Slab Profile



Source: FHWA-HRT-12-068

RPUG Road Profile Users' Group

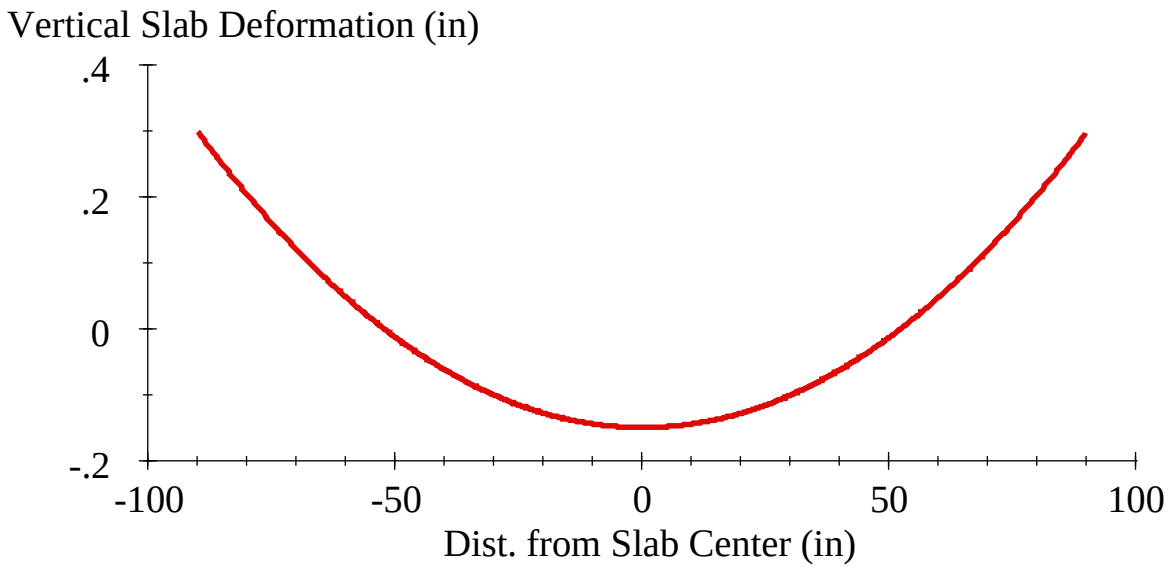
Westergaard Model

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

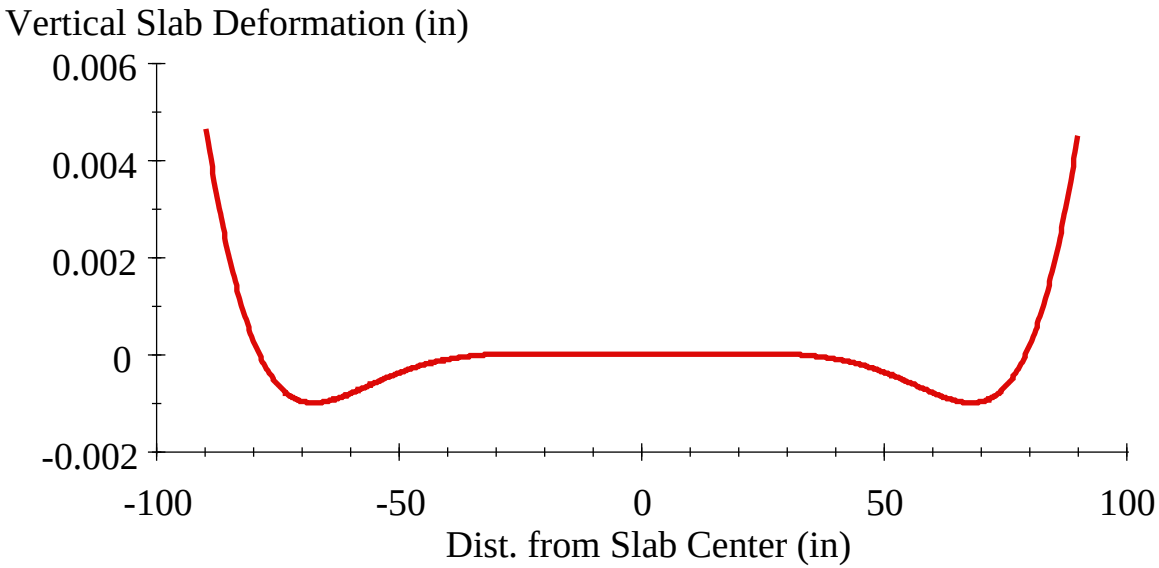
$$\lambda = \frac{b}{l\sqrt{8}} \qquad l = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}} \qquad z_0 = \frac{-(1+\mu)(\alpha\Delta T + \Delta\varepsilon_{sh})}{h}l^2$$

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

Idealized Slab Shapes



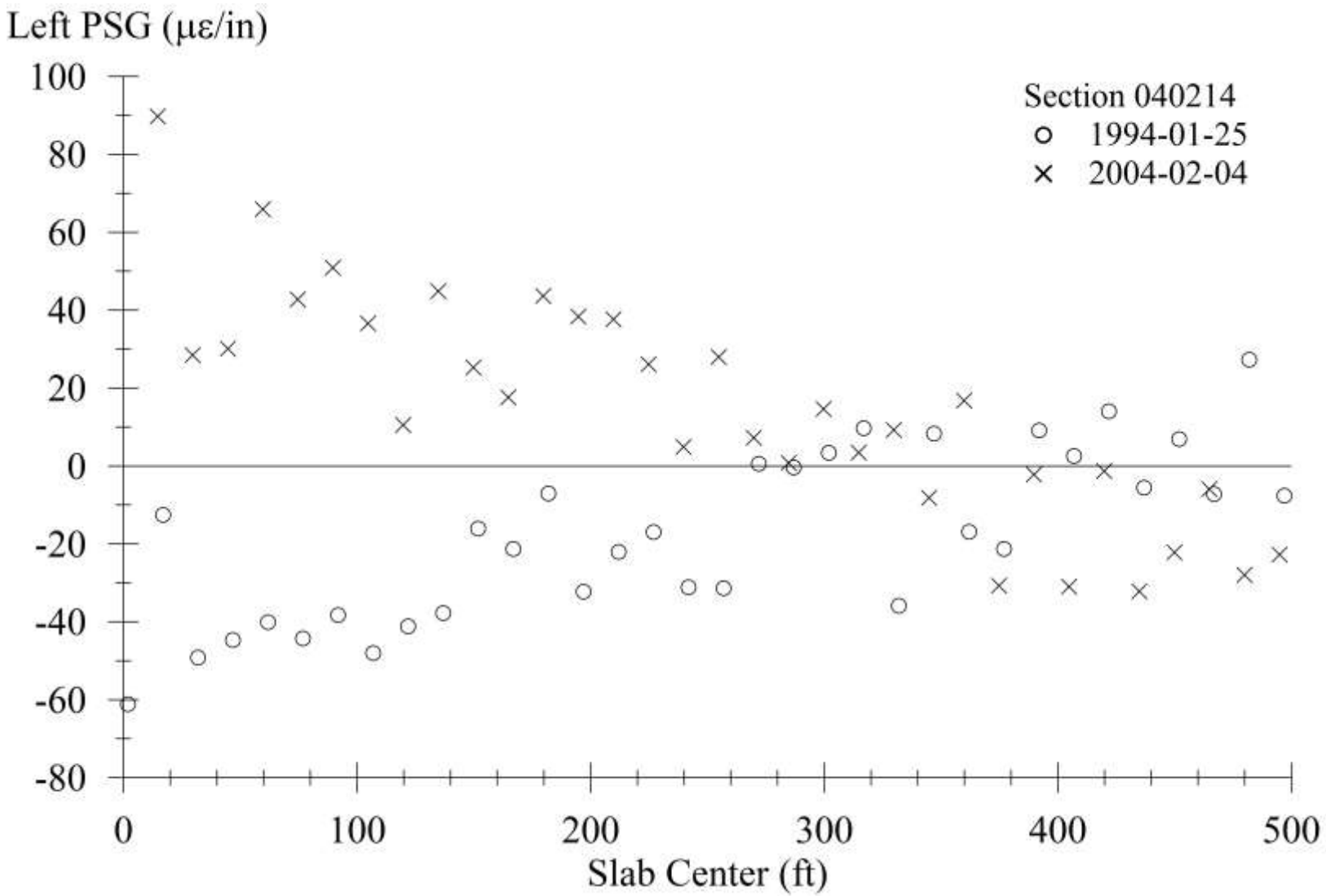
RRS (l) = 10 inches
PSG = -40 με/inch



RRS (l) = 80 inches
PSG = -40 με/inch

Source: Rasmussen

Structural Evaluation, Spatial Trends

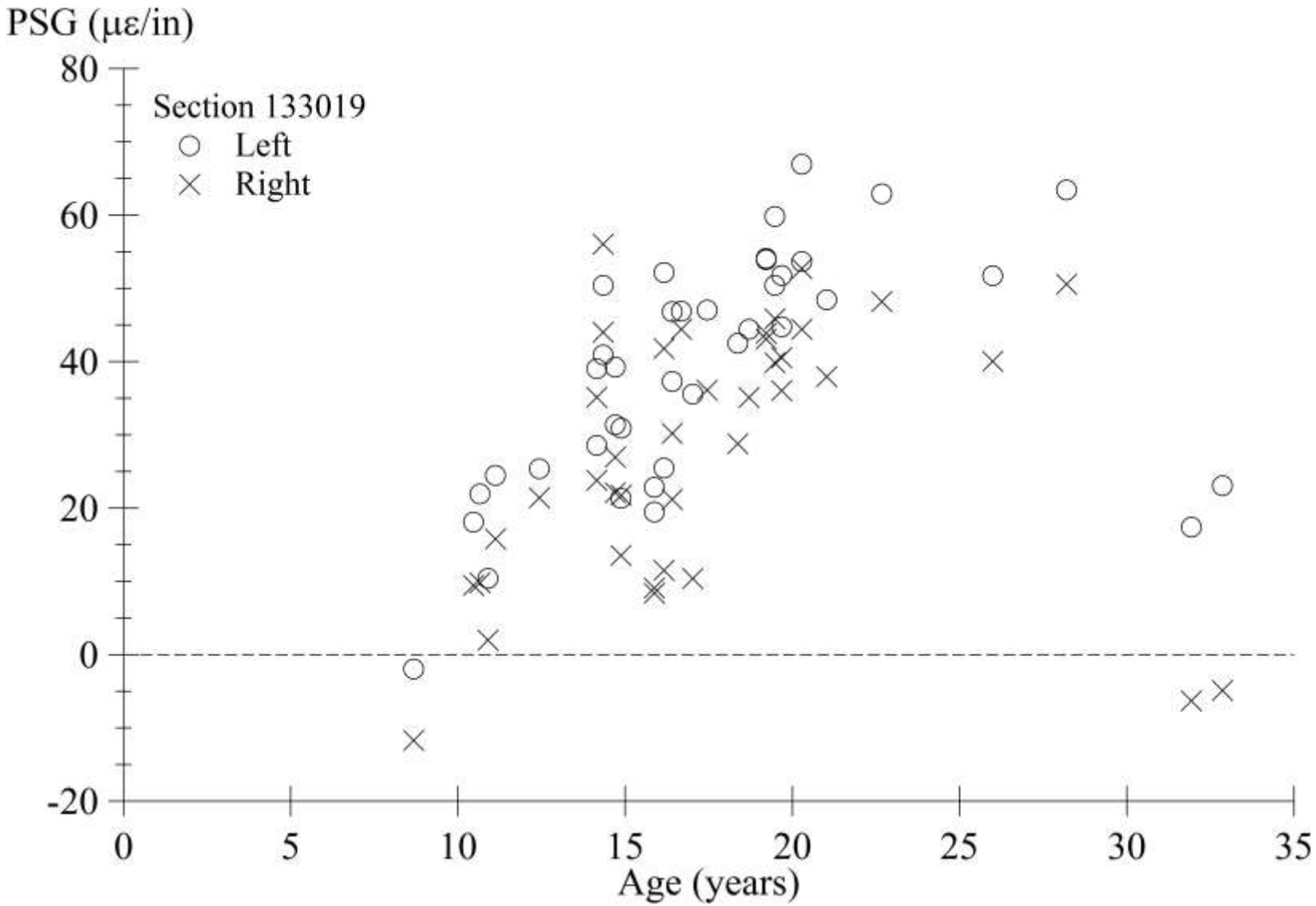


Downward Curl

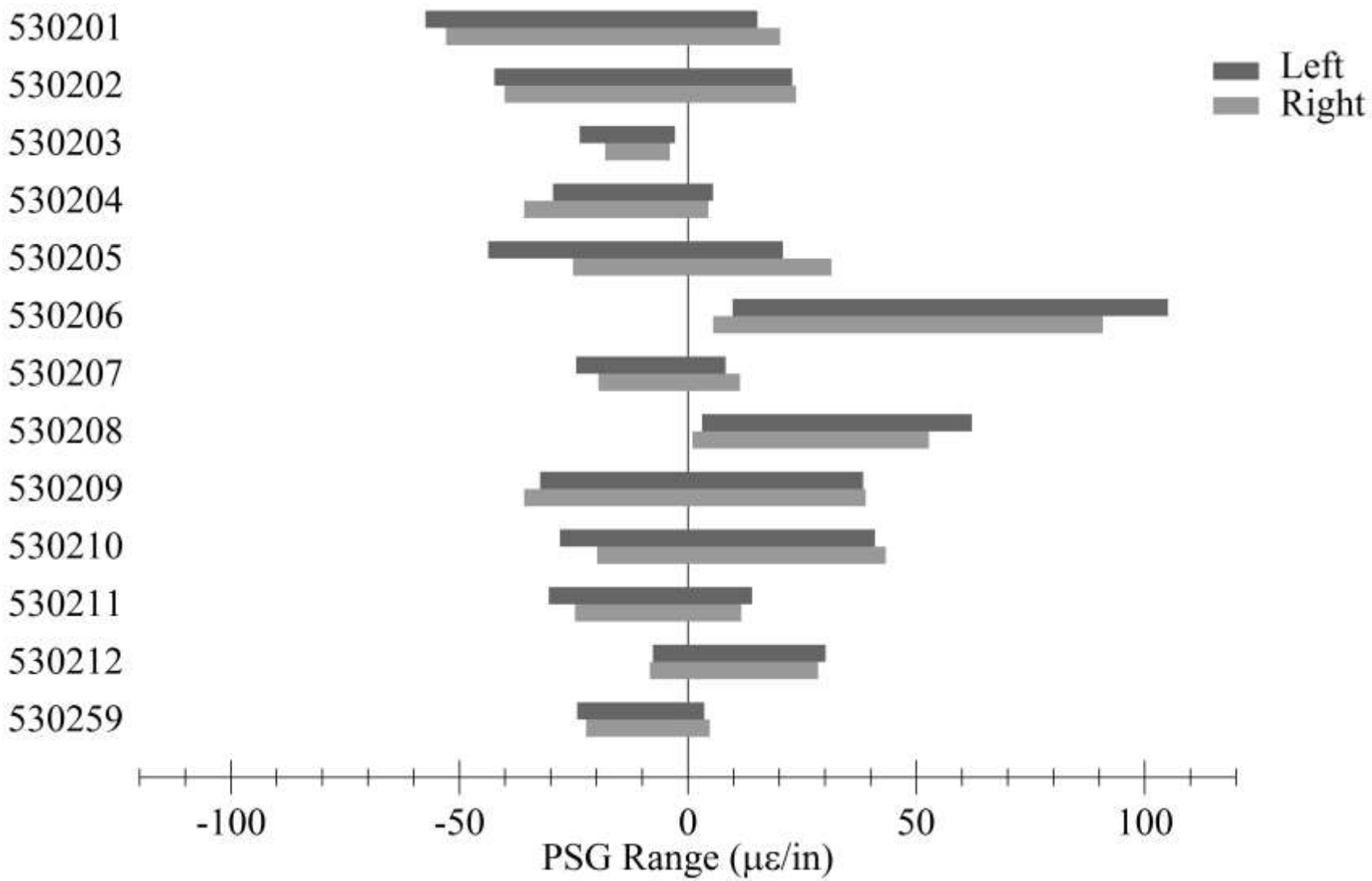
Upward Curl

RPUG Road Profile Users' Group

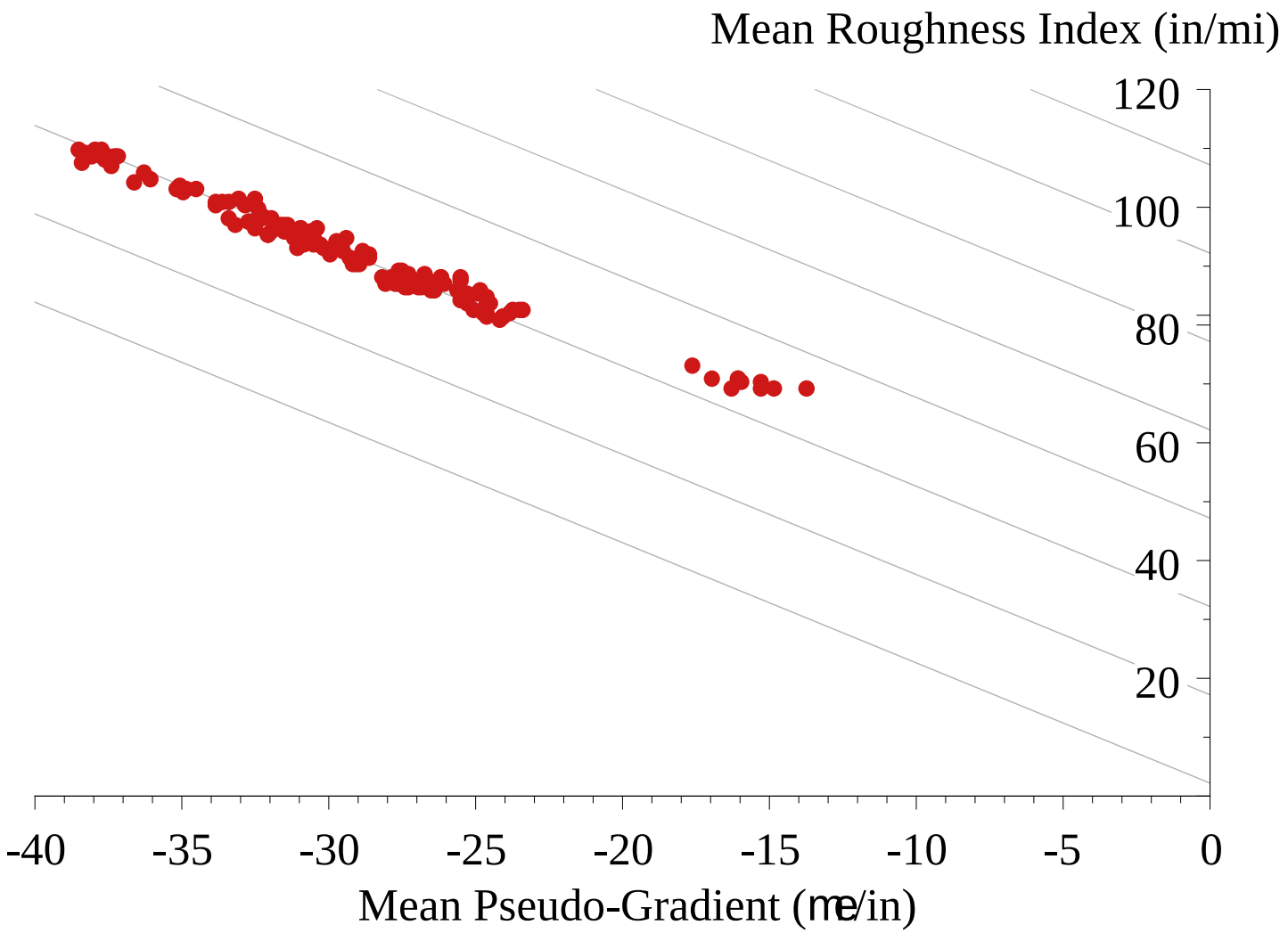
Structural Evaluation, Trends Over Time



Structural Evaluation, by Test Section



IRI Versus PSG, Hypothesis

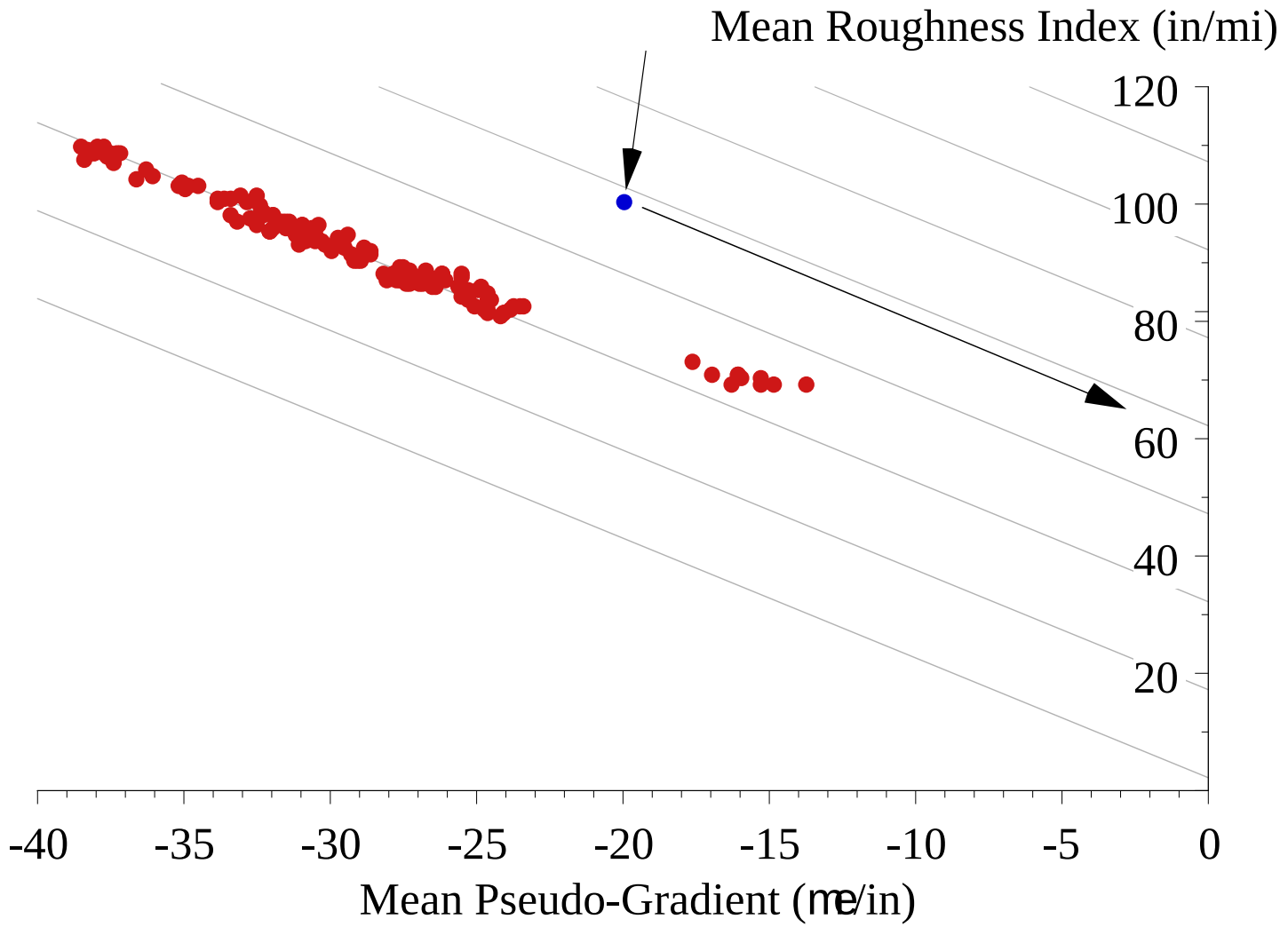


TRB 2008, Session 573

PE 2019

RPUG Road Profile Users' Group

IRI Versus PSG, Hypothesis

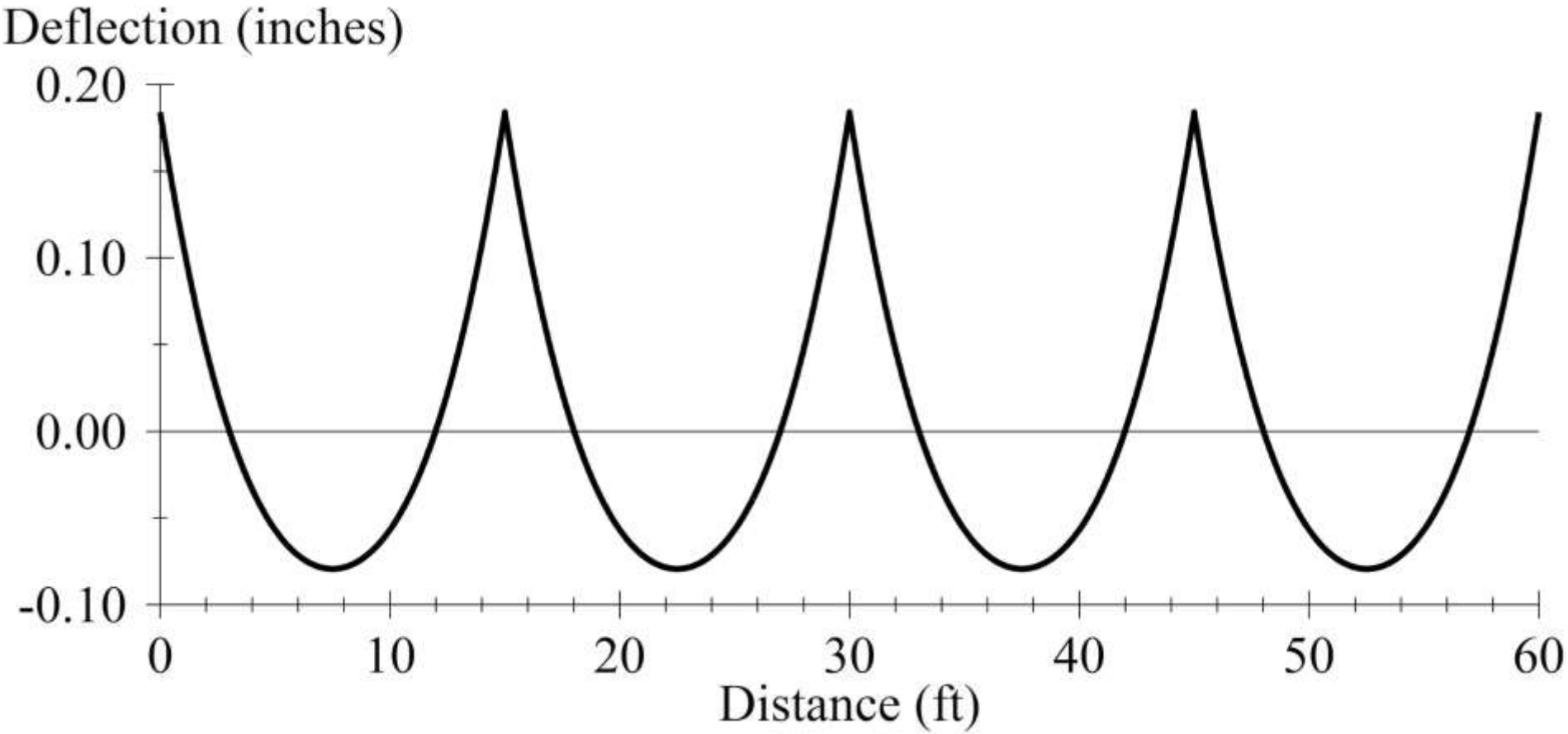


TRB 2008, Session 573

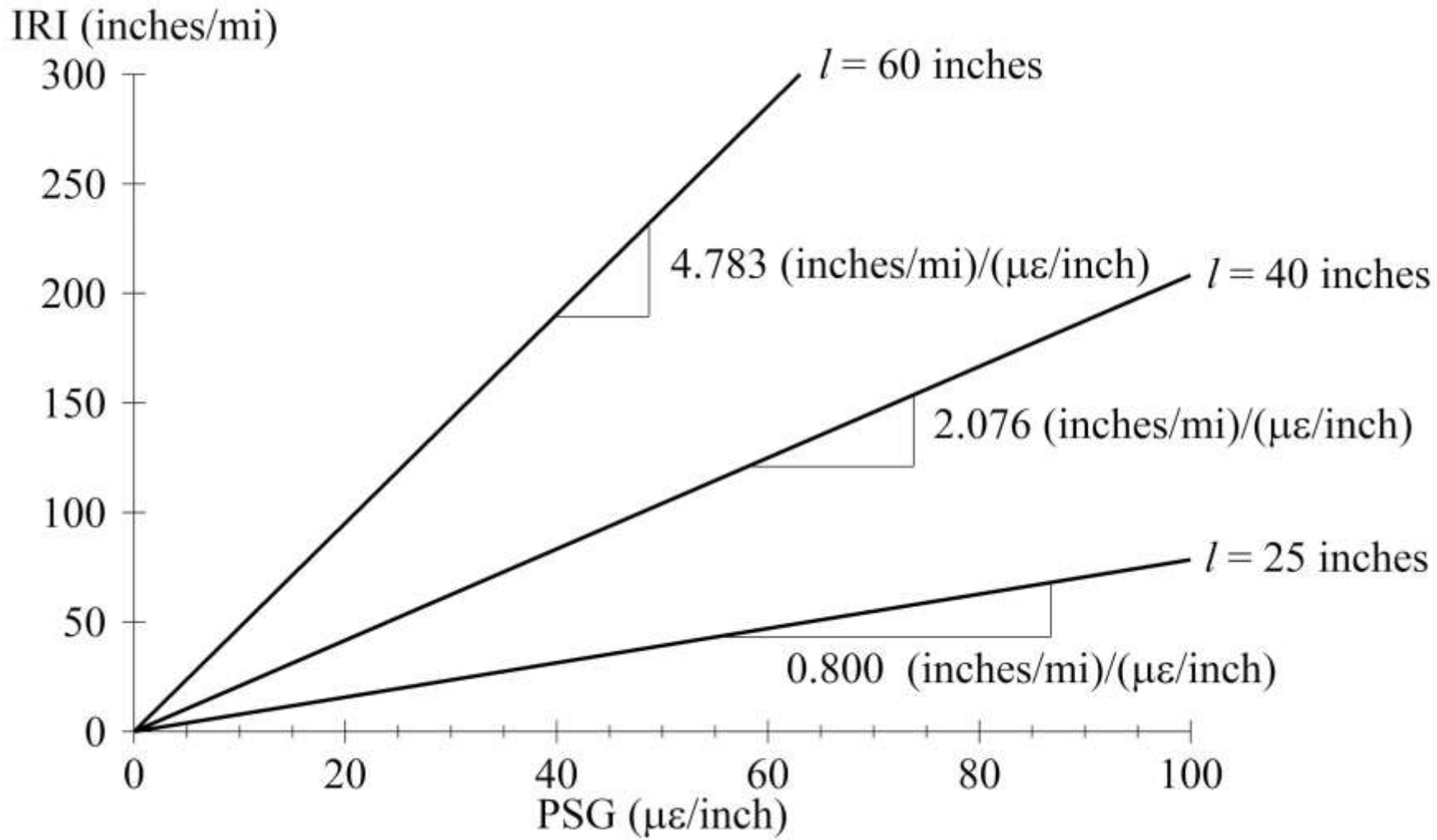
PE 2019

RPUG Road Profile Users' Group

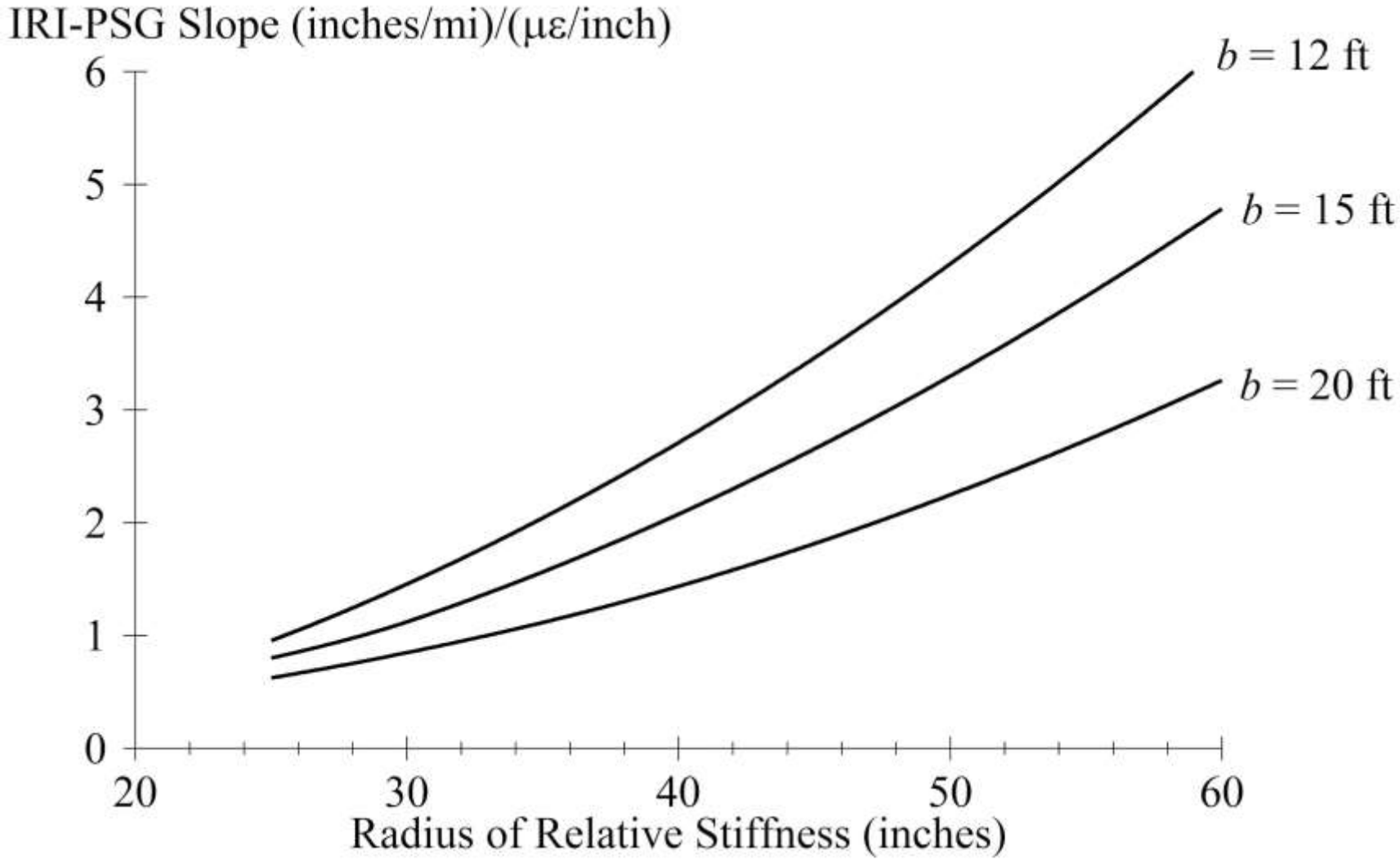
Idealized Profile (l = 40 inches)



IRI versus PSG



IRI/PSG Slope

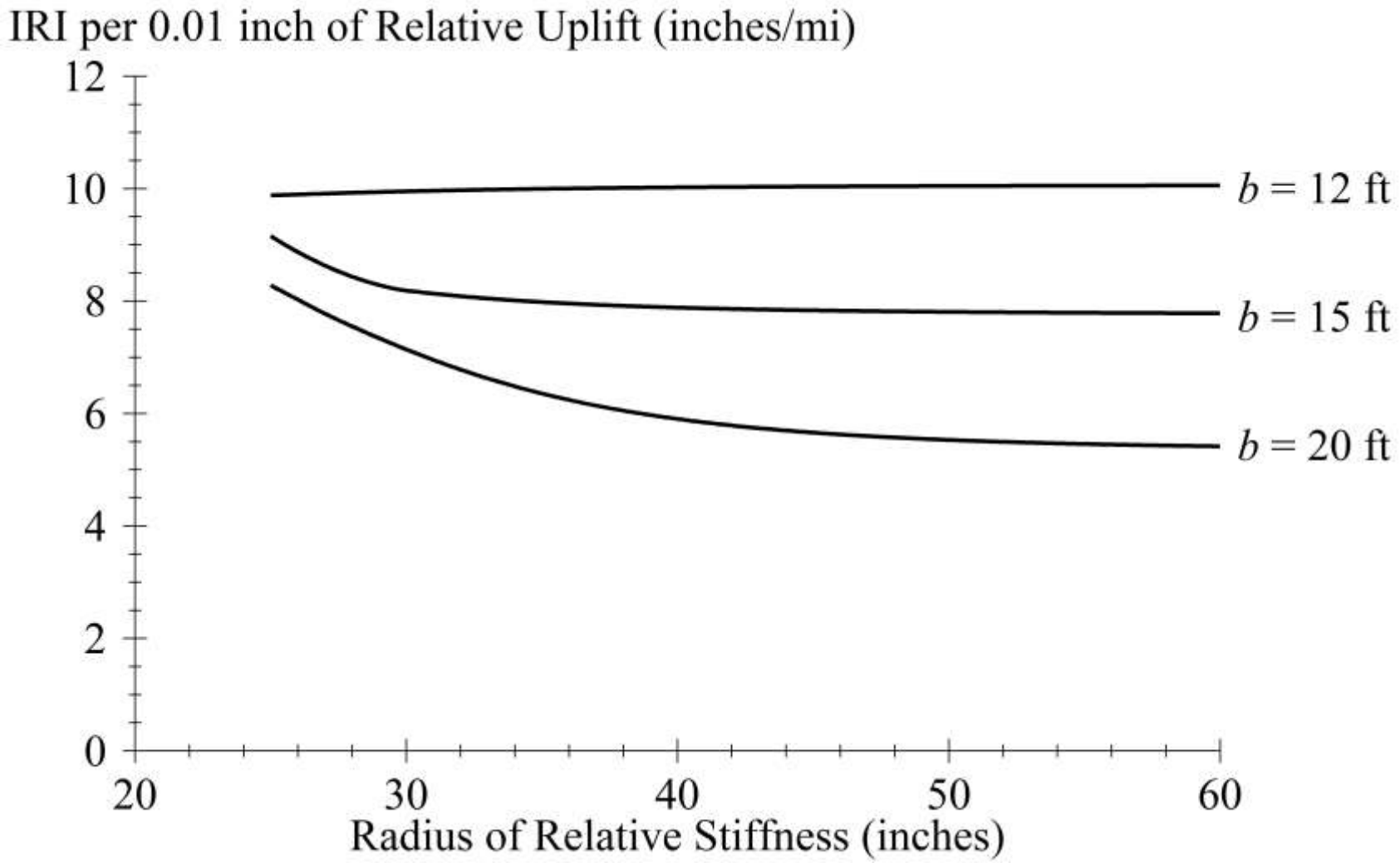


Uplift and PSG

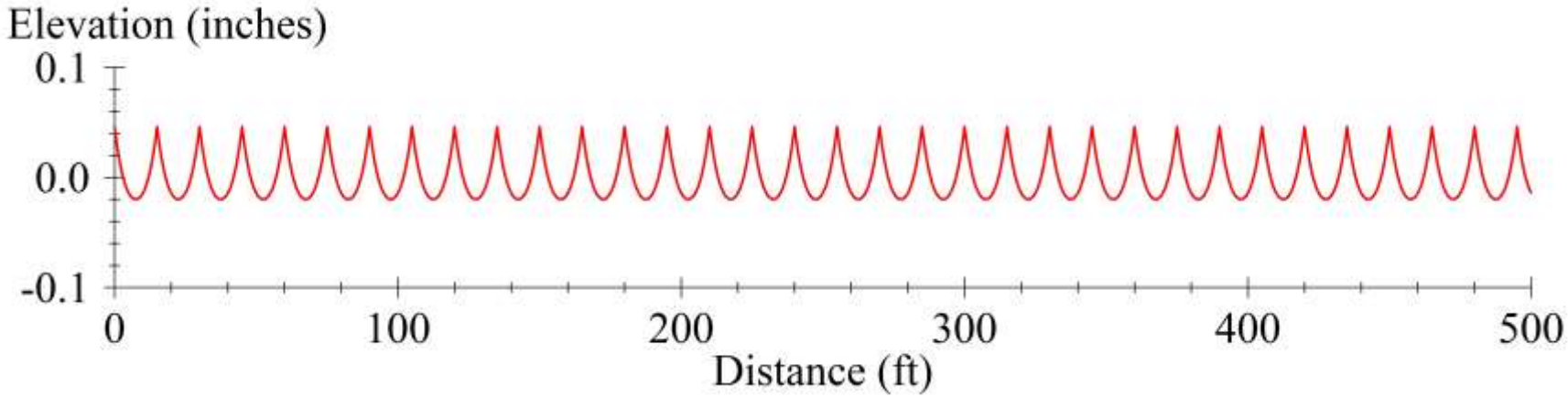
$$z(x) = z_0 f(x,l,b) = -PSG(1+\mu)l^2 f(x,l,b)$$

$$\Delta z = z(b/2) - z(0) = -PSG(1+\mu)l^2 \left(1 - \frac{s_\lambda ch_\lambda - c_\lambda sh_\lambda}{s_\lambda c_\lambda - sh_\lambda ch_\lambda} \right)$$

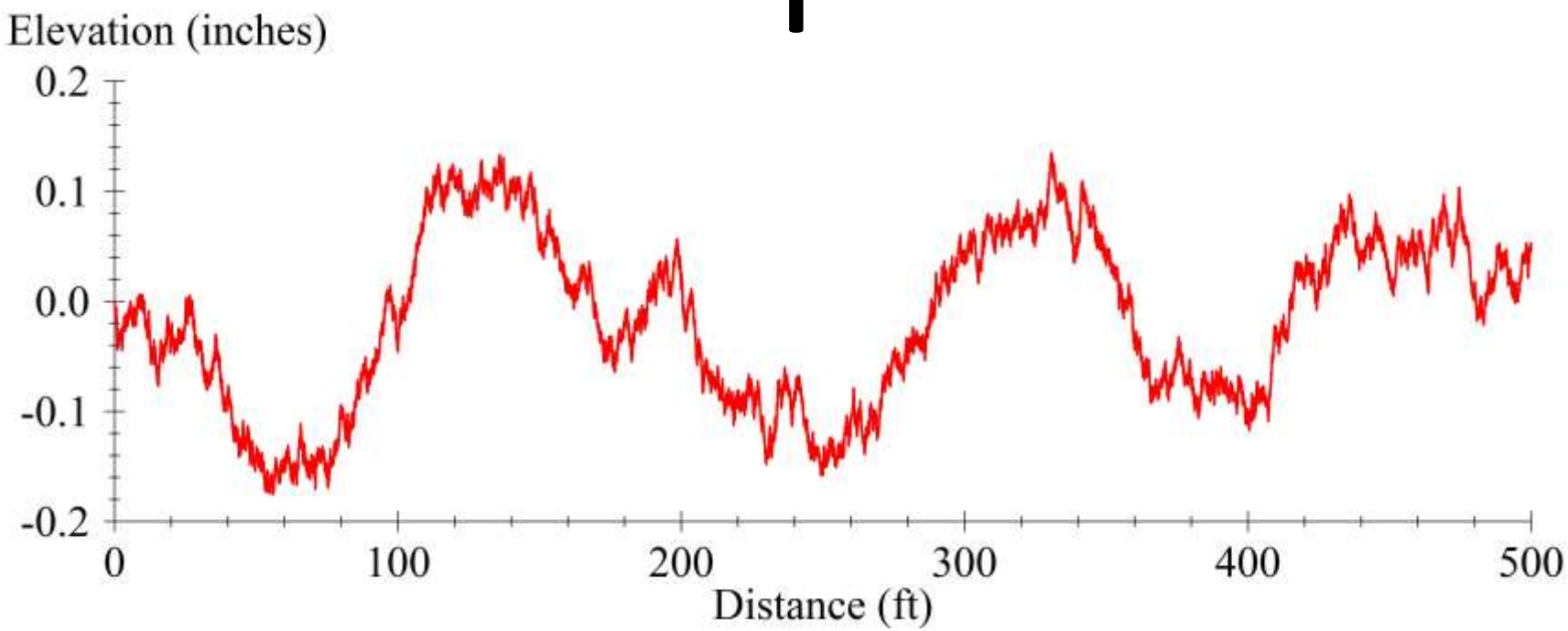
IRI Versus Uplift



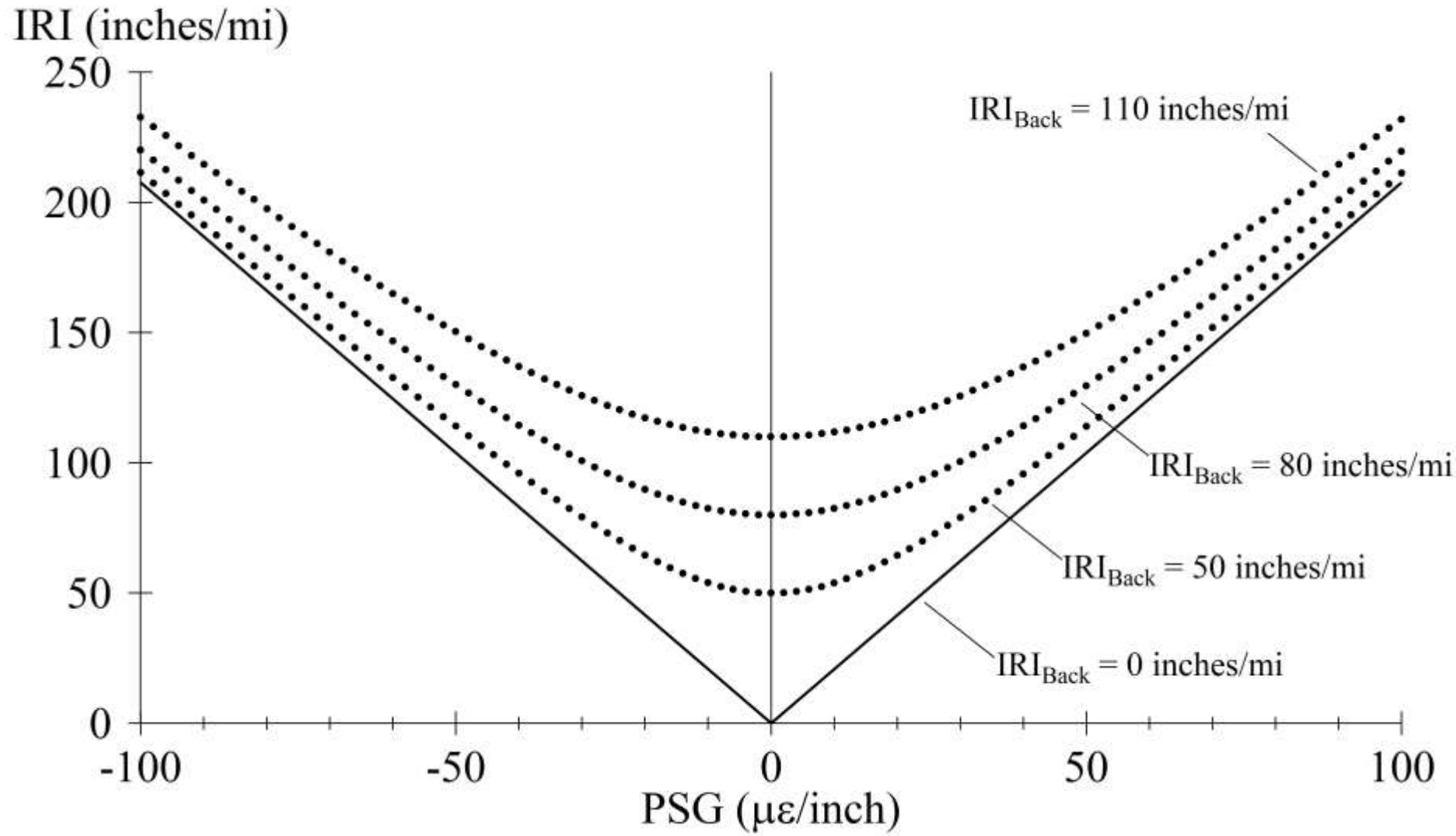
Idealized Curl and Background Roughness



+



Idealized Curl and Background Roughness



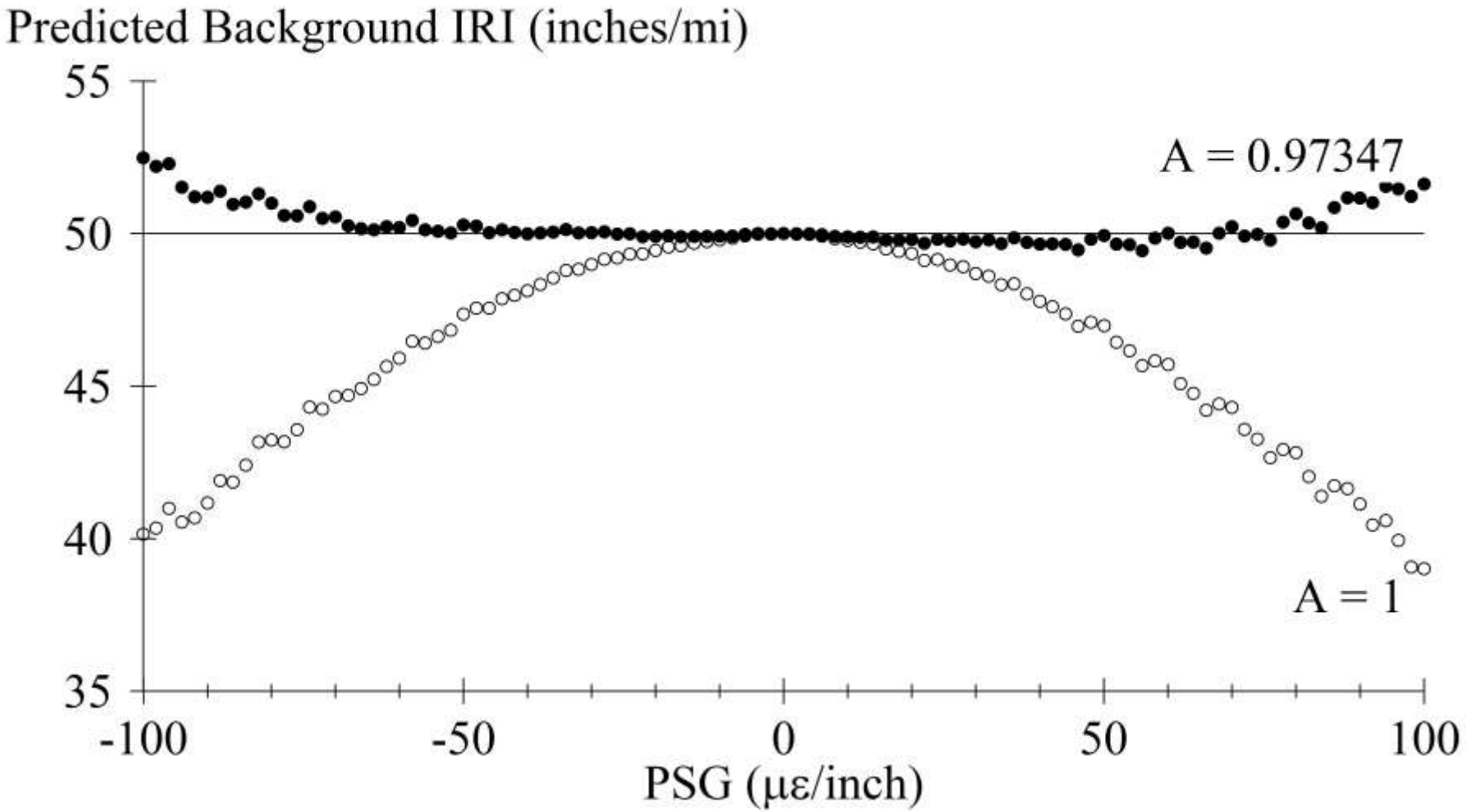
Idealized Curl and Background Roughness

$$IRI_{Comb} = \sqrt{IRI_{Curl}^2 + IRI_{Back}^2}$$

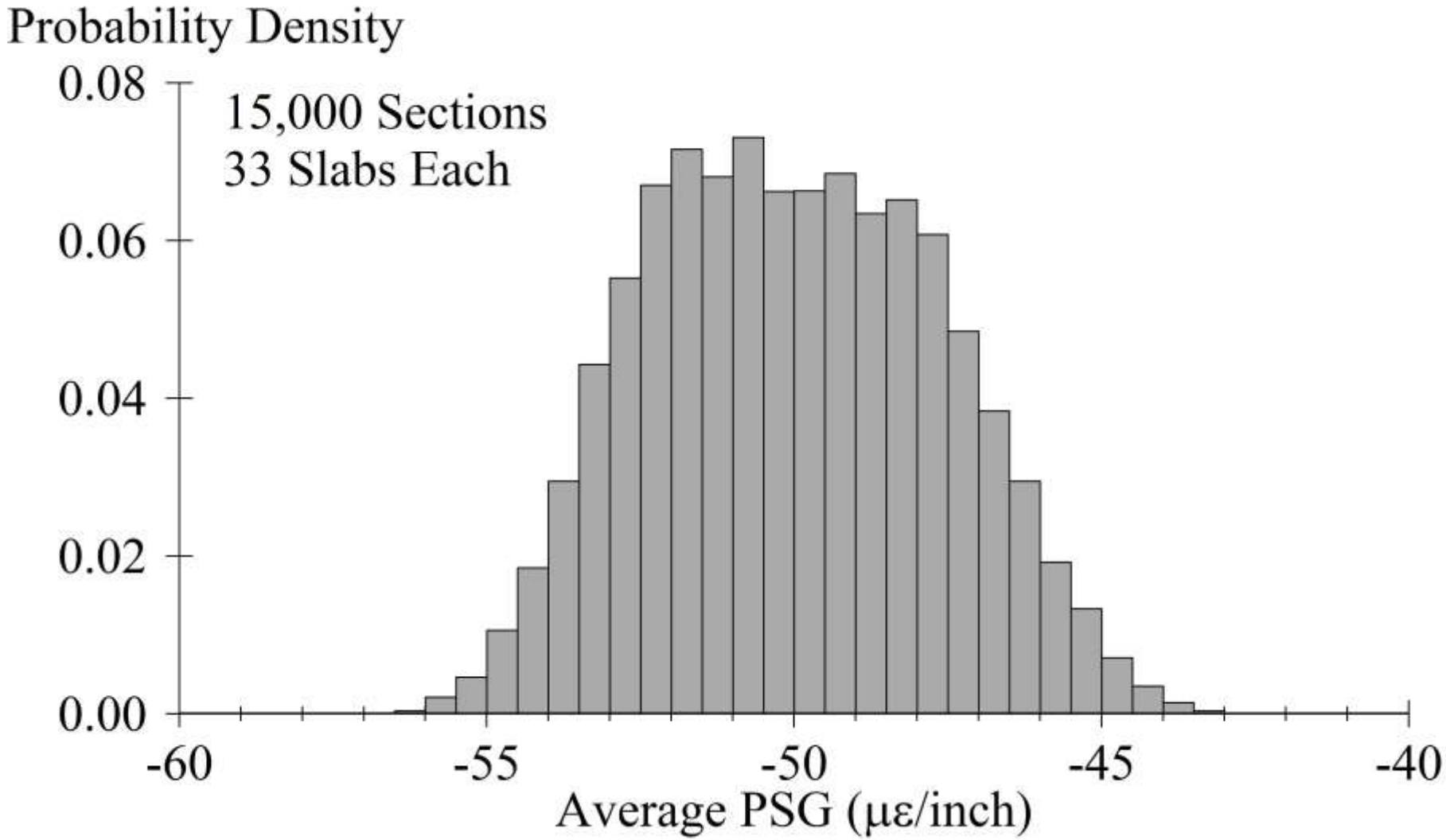
$$IRI_{Comb} = \sqrt{\left(PSG\frac{dIRI}{dPSG}\right)^2 + IRI_{Back}^2}$$

Background Roughness

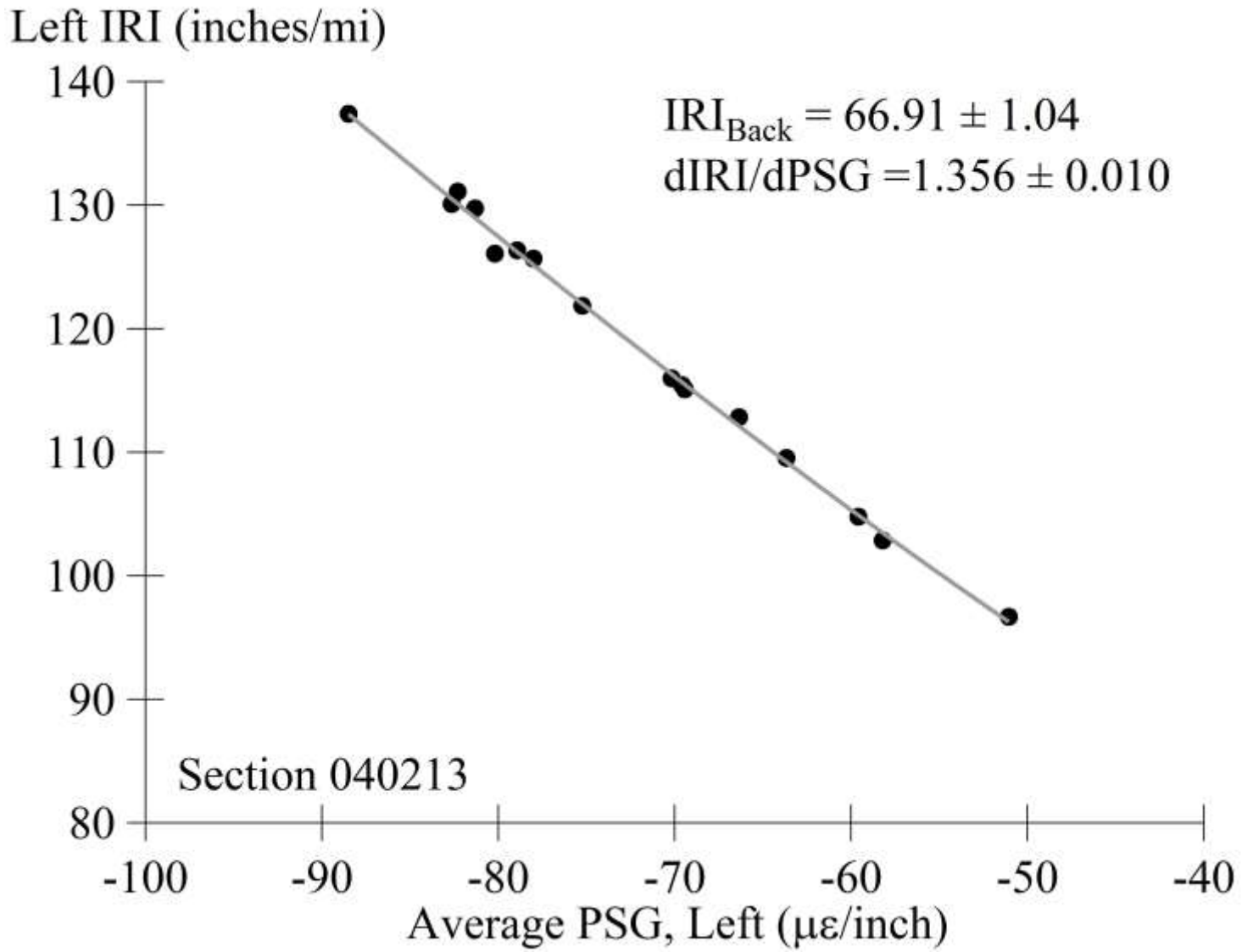
$$IRI_{Back} = \sqrt{IRI_{Comb}^2 - A\left(PSG\frac{dIRI}{dPSG}\right)^2}$$



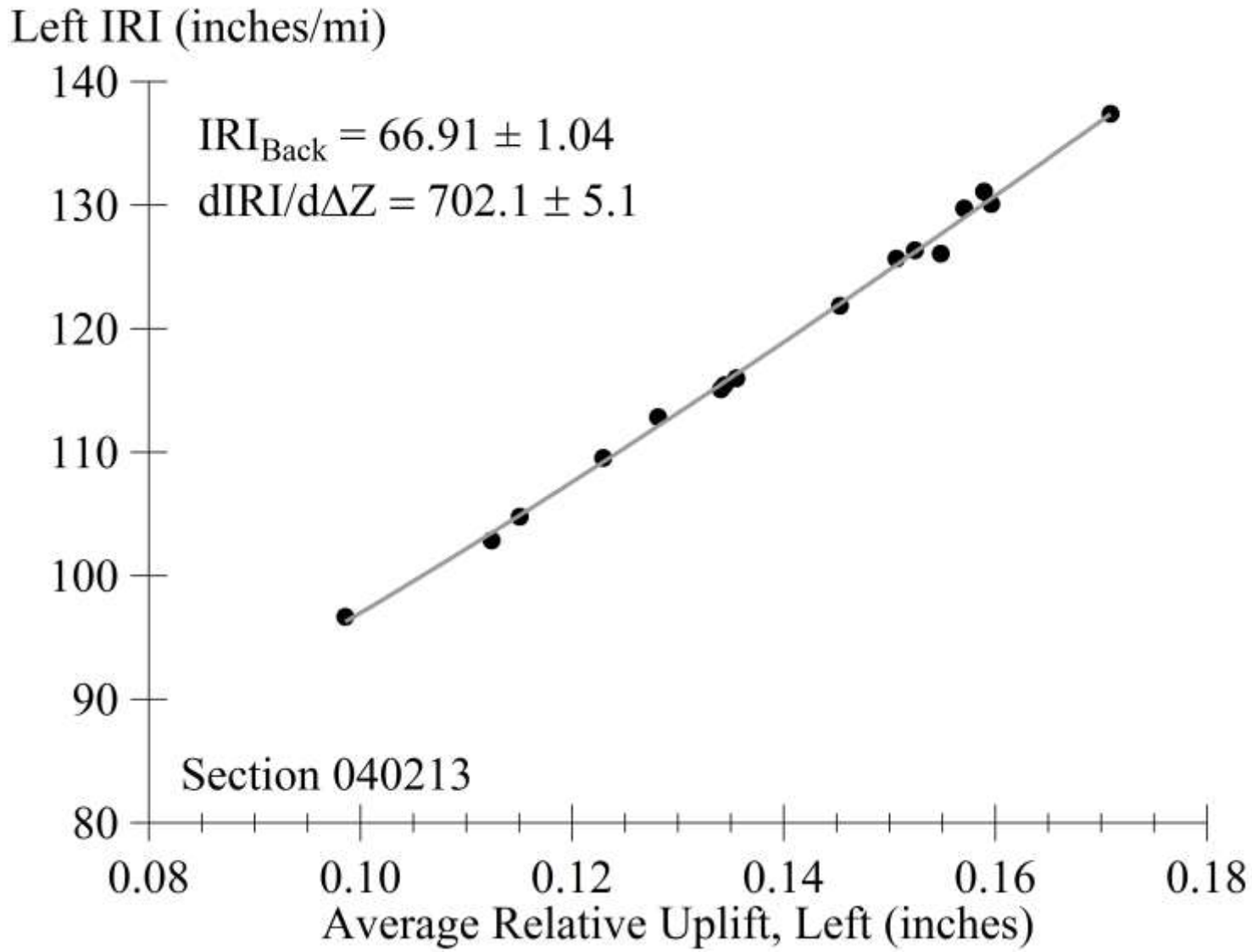
Section-Wide PSG Average



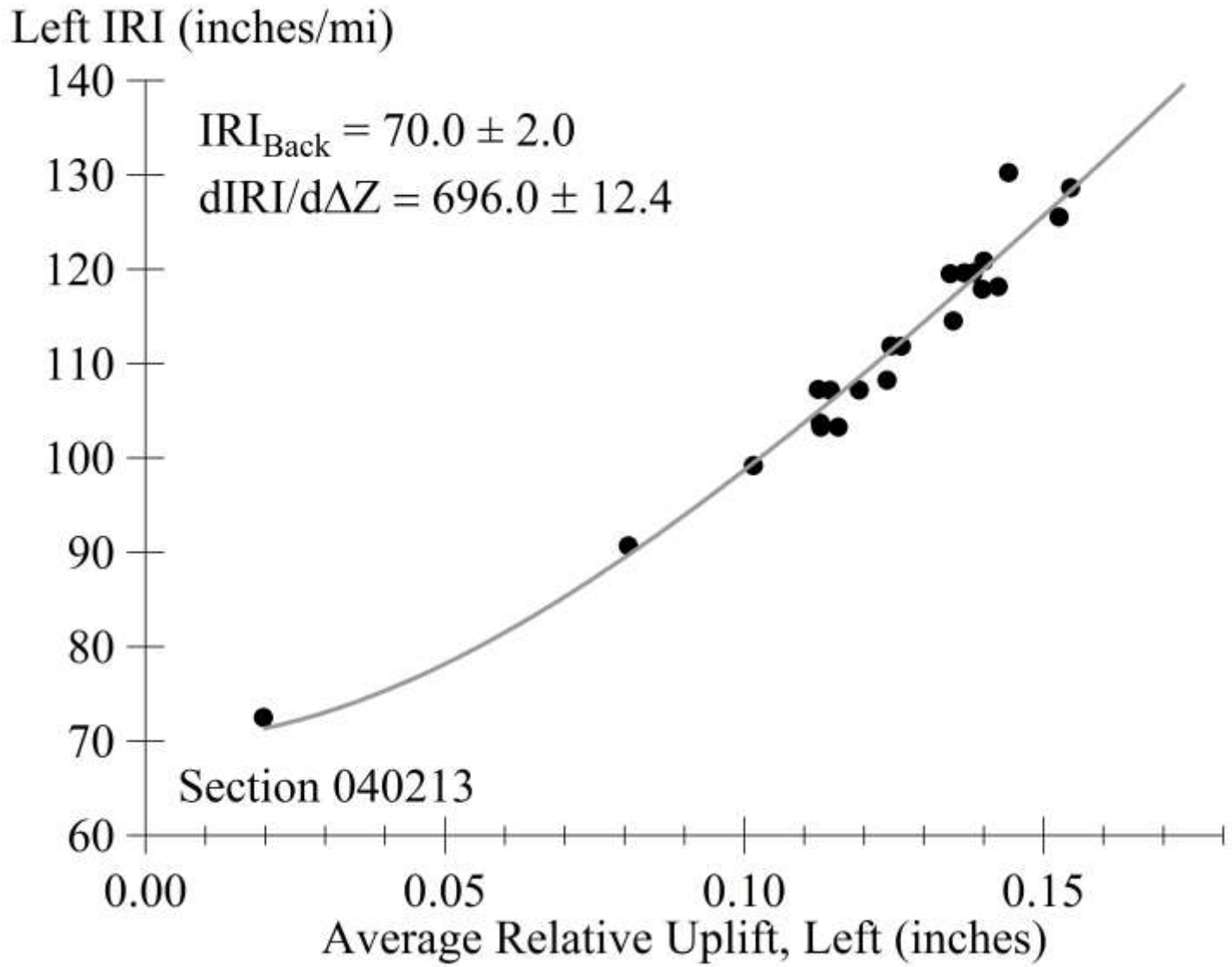
IRI versus PSG, FHWA Data



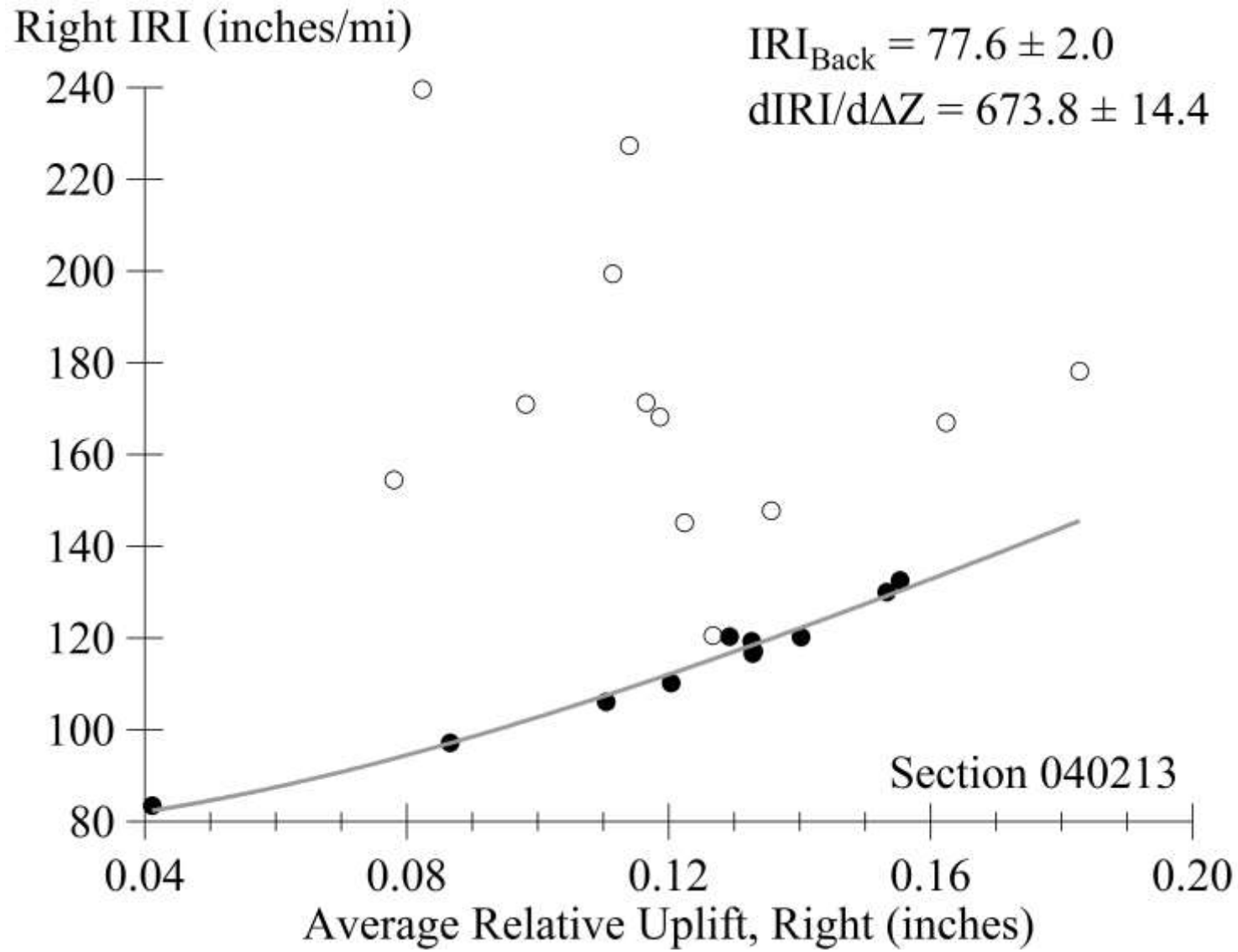
IRI versus Uplift, FHWA Data



IRI versus Uplift, LTPP Data



IRI versus Uplift, LTPP Data



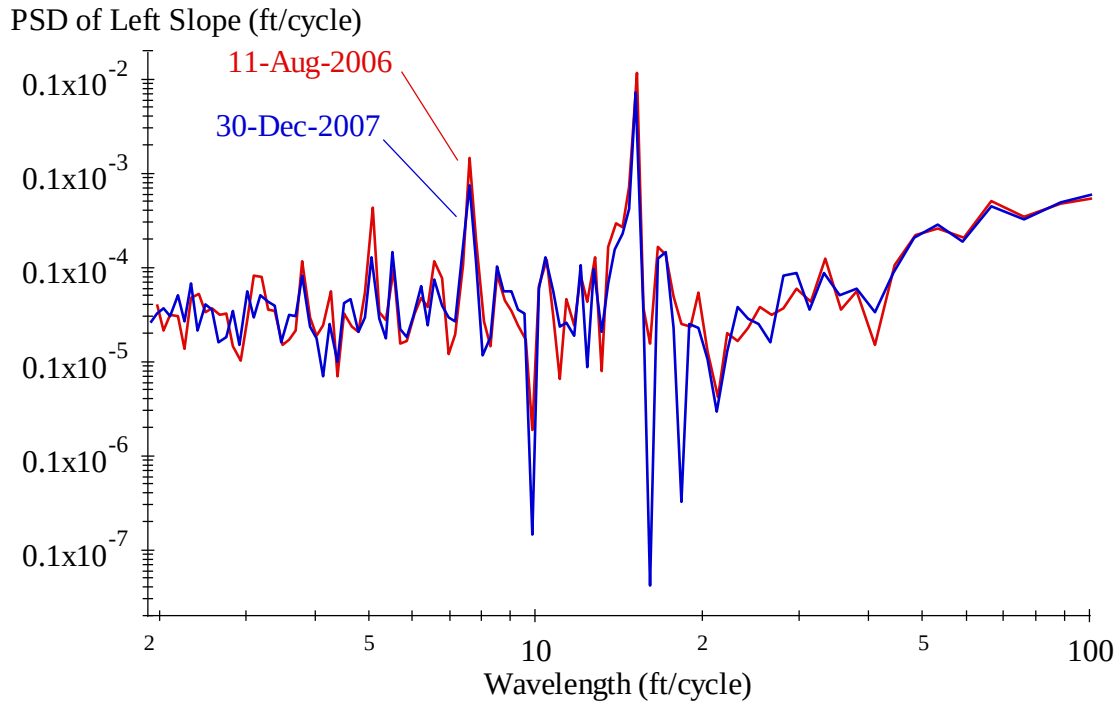
RPUG Road Profile Users' Group

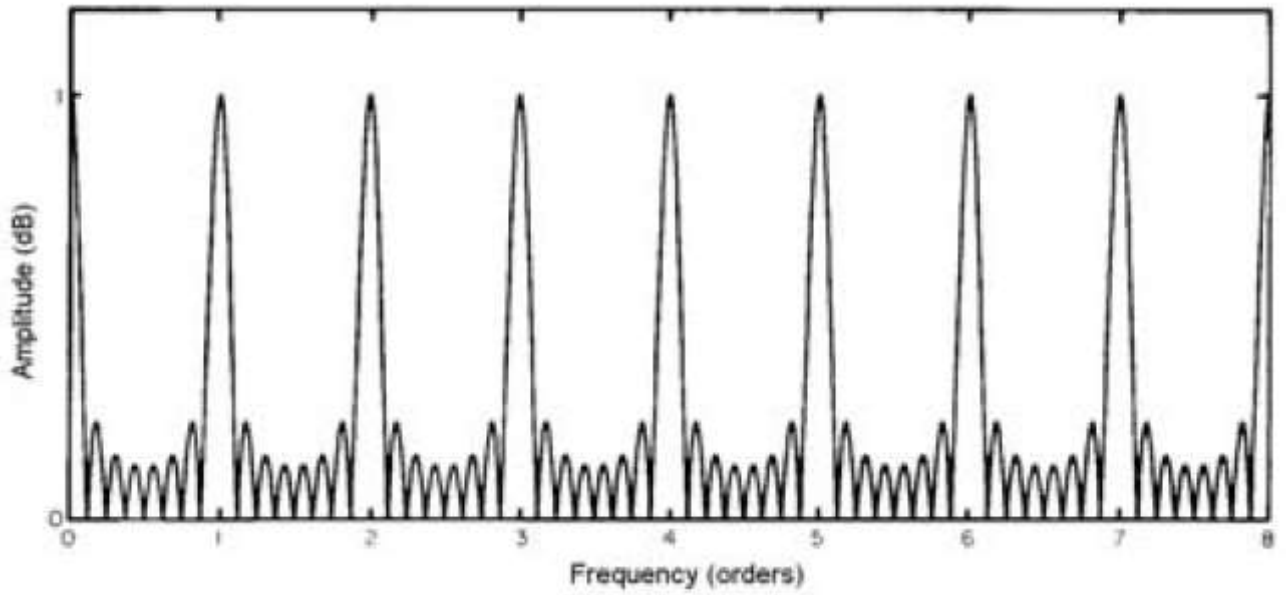
Assessment

- The fitted values relating IRI to uplift were not systematically related to the theory.
- This could be caused by:
  - The structural model.
  - The “sum of squares” model.
  - The low number of slabs per section.
  - Some other thing I haven’t noticed.

Possible Next Steps...

- Notice something new.
- Difference profiles.
- Spectral methods.
- Specialized filters.
- “Advanced” methods.





The Report……

is in the editing phase.

Thank you!!!!