University of Pittsburgh

PITT | IRISE

Prediction of Dowel Corrosion and Effect on Performance of Concrete Pavements - IMPLEMENTATION

IRISE Annual Meeting

May 22nd, 2025

Julie M. Vandenbossche, PhD, PE

Charles Donnelly

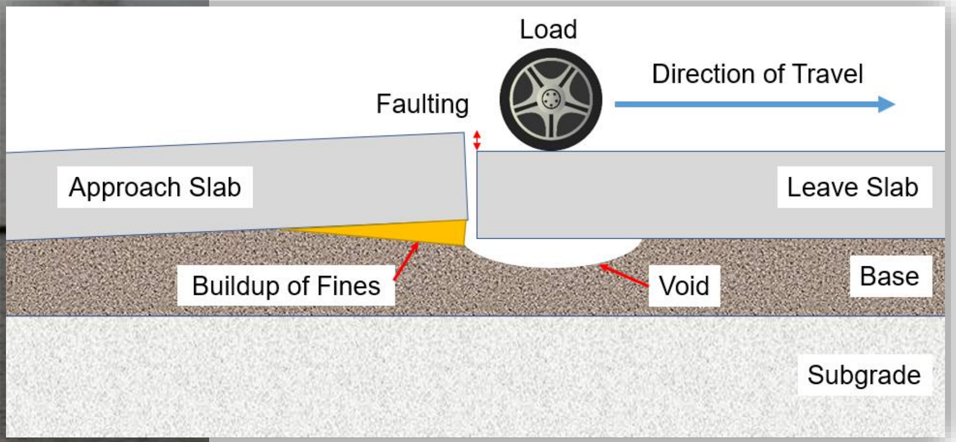
Gabriela Salach

Megan Darnell

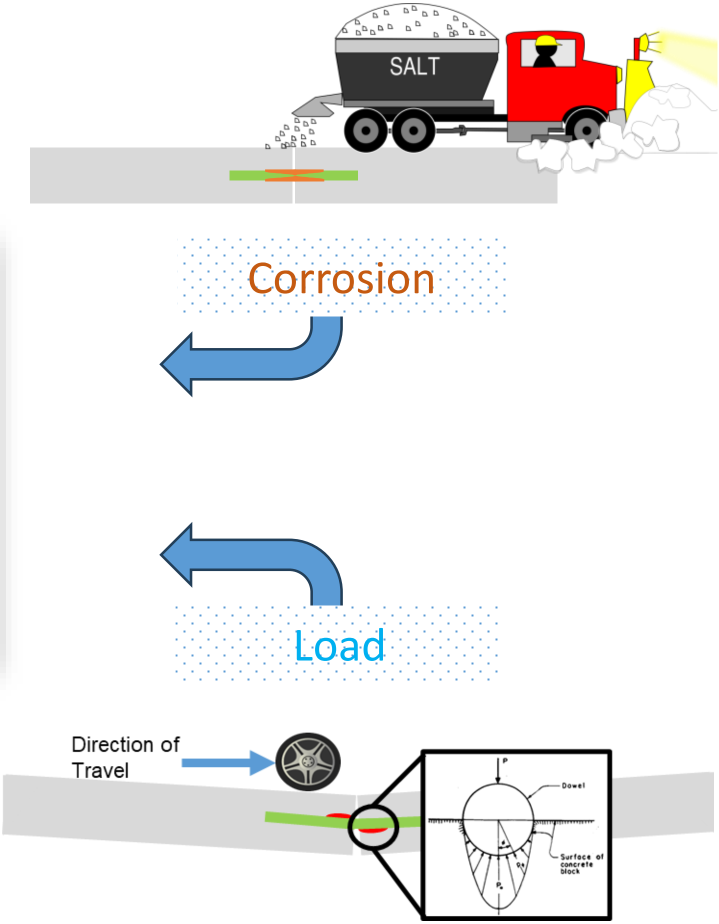
Alessandro Fascetti, PhD

Faulting

Difference in elevation between the approach and leave slabs



Source: pavementinteractive.org



Marcus, Henri." ACI Journal Proceedings. Vol. 48. No. 10. 1951.

Objectives

Account for the following in faulting prediction models

1. Load damage (Decouple doweled and undoweled jts in calibration)
2. Non-standard dowel designs
3. Corrosion

Load damage

Nonstandard dowels

Corrosion

Implementable products

1. Guidance on long-life dowel selection (corrosion)
2. Use of dowel equivalence for non-standard dowel designs (load damage)
3. Corrosion and dowel damage faulting prediction model

Dowel load damage model

Nonstandard dowels

Dowel corrosion model

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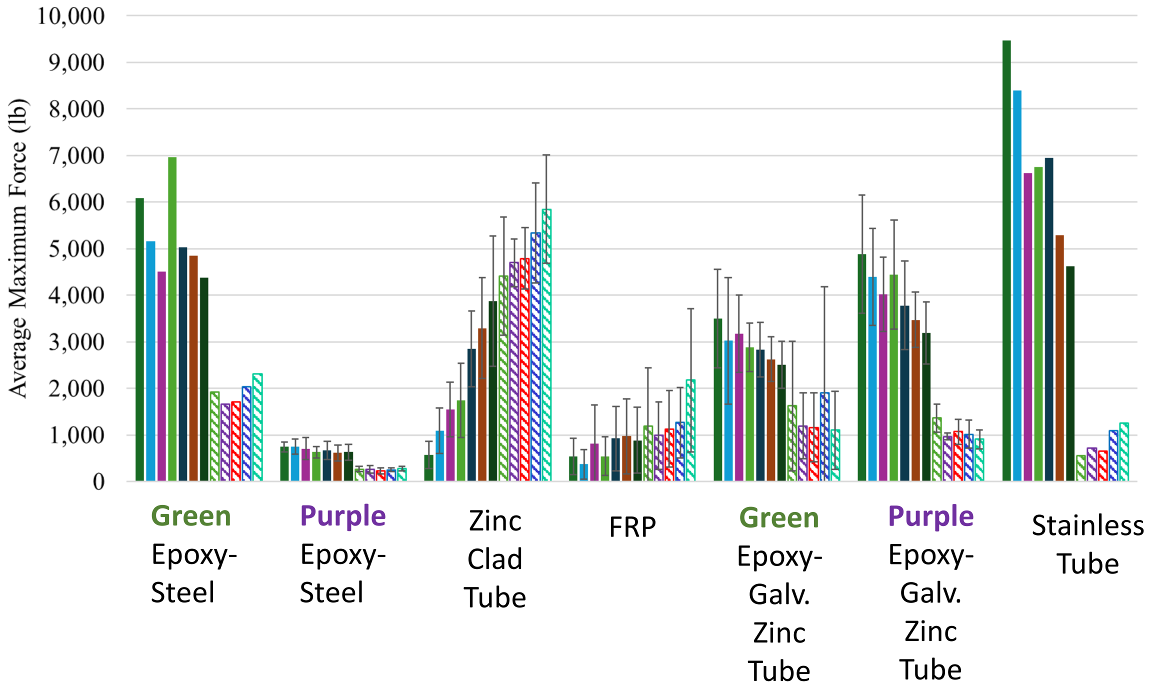
Load damage

Nonstandard dowels

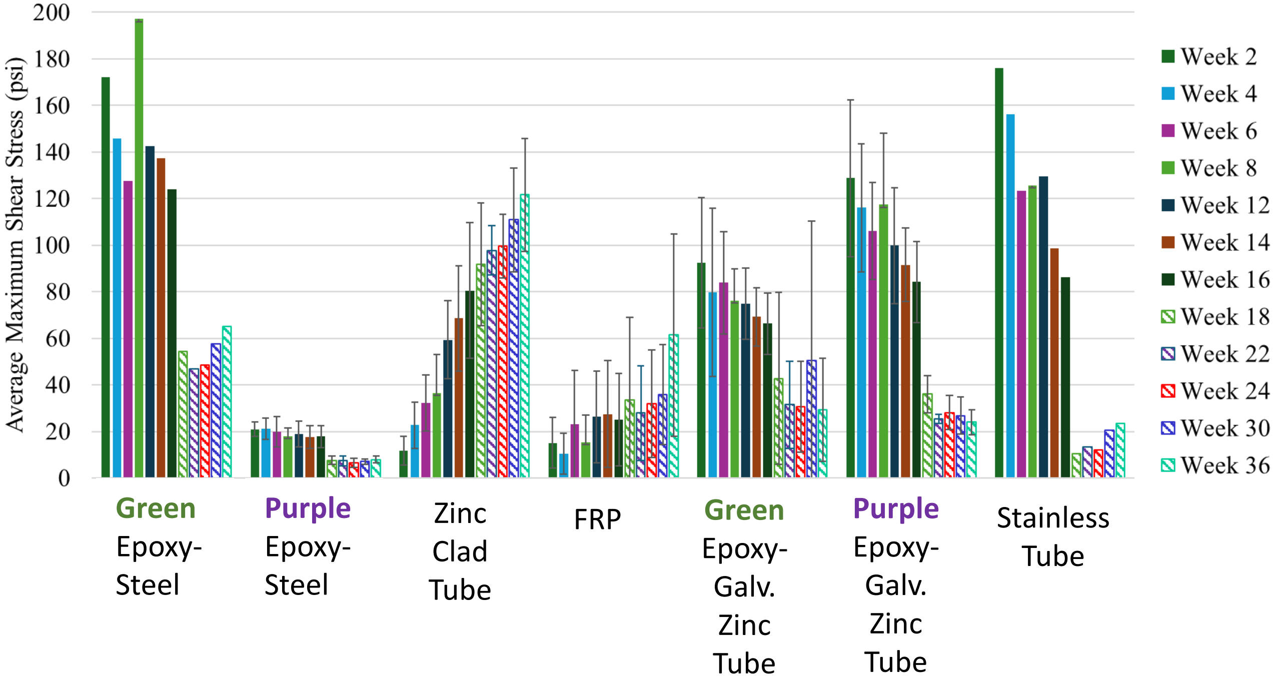
Dowel corrosion

Simulated joint opening/closing



Average maximum force for joint opening/closing

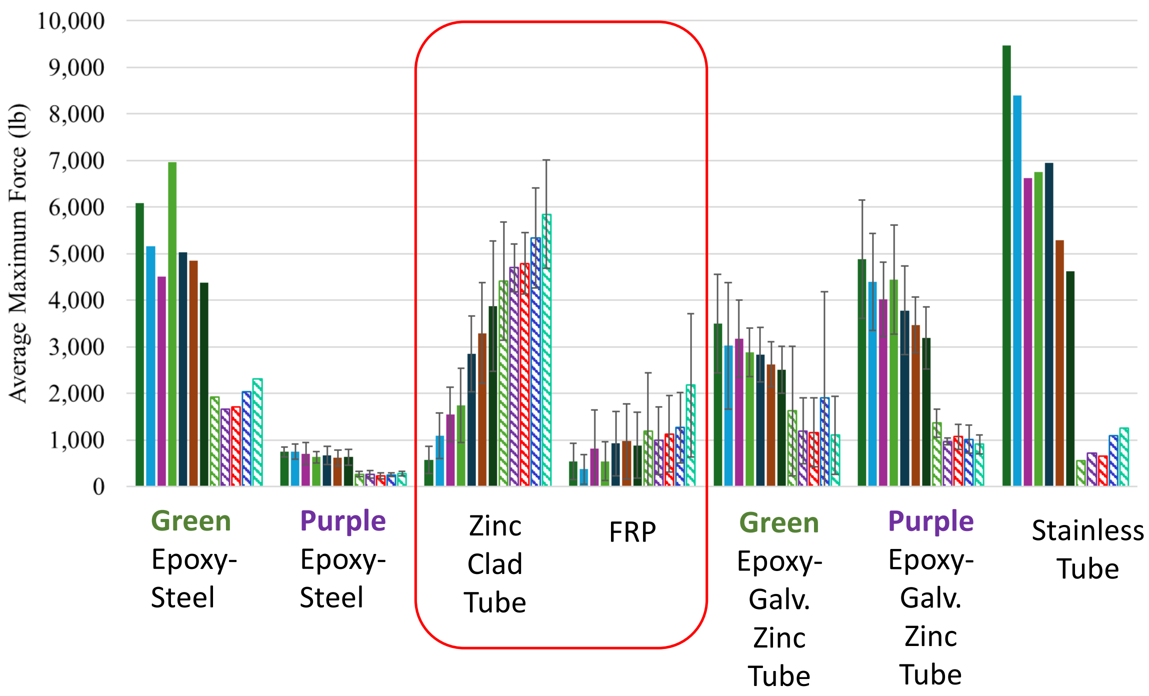
Dowel diameter and coating



Average maximum shear stress for joint opening/closing

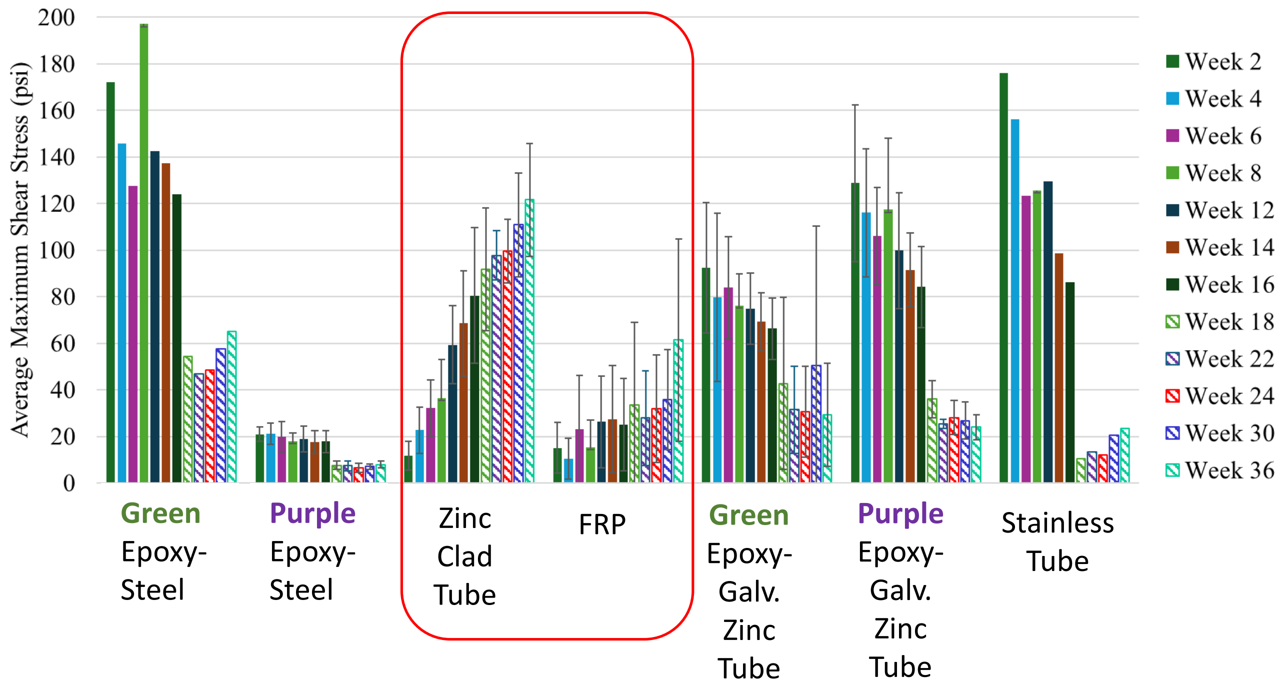
Coating

Simulated joint opening/closing: FRP? & Zinc clad



Average maximum force for joint opening/closing

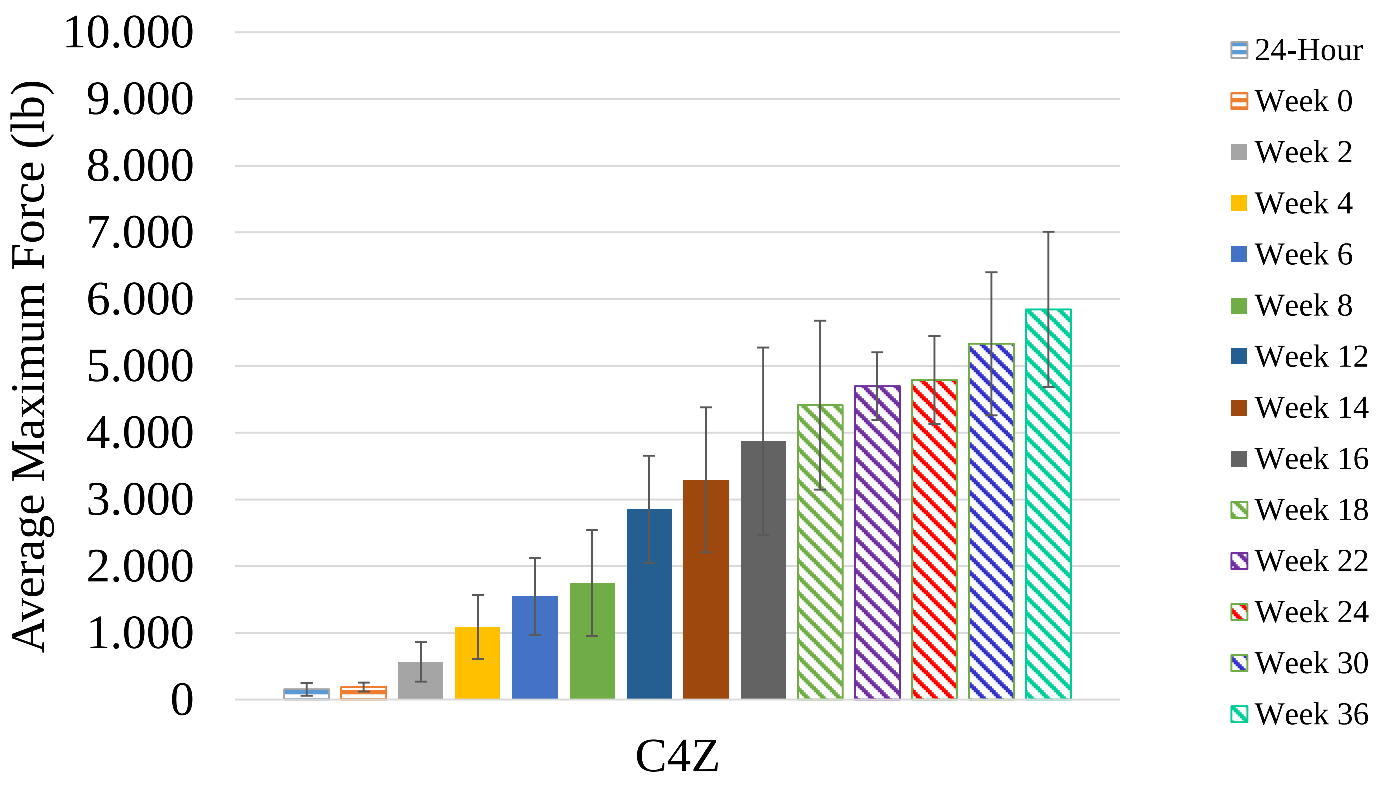
Dowel diameter and coating



Average maximum shear stress for joint opening/closing

Coating

Simulated joint opening/closing



Zinc-clad dowel (C4Z)

Zinc clad vs zinc galvanized

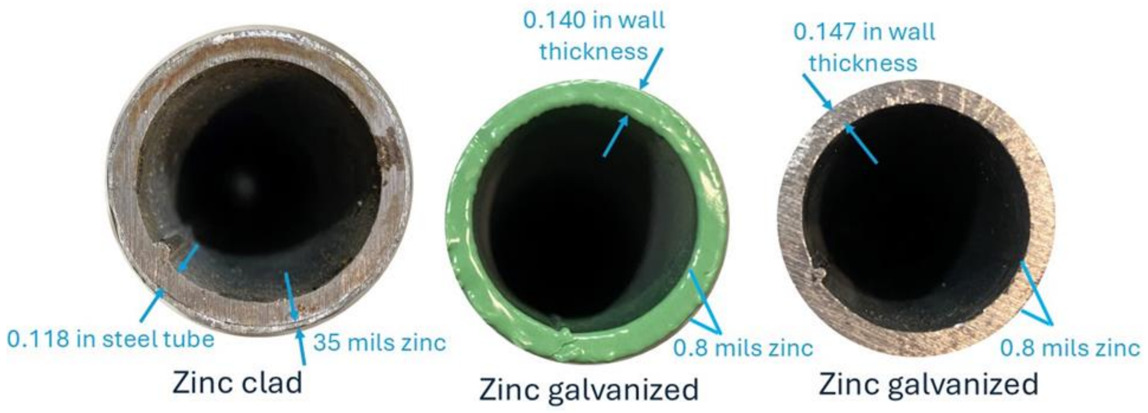
Degradation Process: depassivation -> galvanized layer is dissolved -> surrounding zinc is depleted -> corrosion of the steel.

Zinc galvanized

- Dowel protected by epoxy coating then thin zinc galvanized layer

Zinc clad

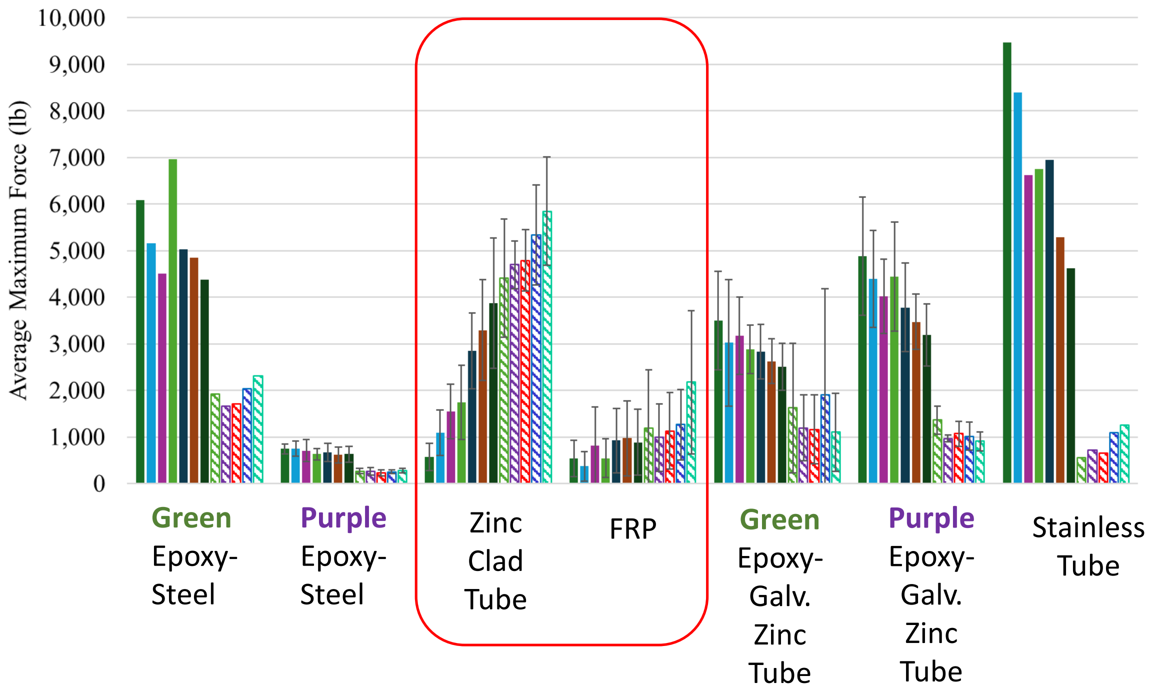
- More pure zinc to react (35 mils vs 0.8 mils) = more zinc oxide produced
- Corrosion resistant but increased potential for spalling and joint lock-up



Results worth implementing? .. If so, steps needed?

Results:

- Zinc Clad?.... FRP?



Implementable products

1. Guidance on long-life dowel selection (corrosion)
2. Use of dowel equivalence for non-standard dowel designs (load damage)
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Load damage

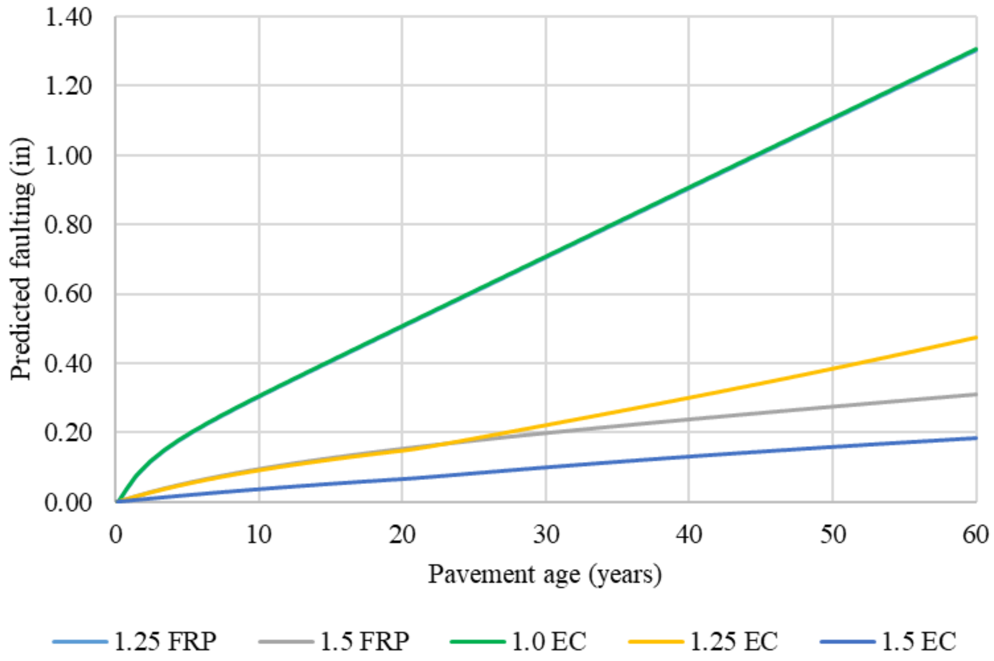
Nonstandard dowels

Corrosion

Results worth implementing? .. If so, steps needed?

Nonstandard dowels

$$d_{eq} = \frac{30}{DowelSpace} \sqrt[7]{\frac{d_o^3 * E_{dowel} * [(d_o)^4 - (d_i)^4]}{E_{steel}}}$$



Implementable products

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Load damage

Nonstandard dowels

Corrosion damage

Steel vs galvanized dowels

Corrosion rates (in^2/wk):

Purple vs Green steel:

C2G** approx. = **C2P

Purple vs Green galvanized:

C2G is **2.5x** faster than **G1P**

Steel vs galvanized

Green: **C2G & C2P** is **3x** faster than **G1G**

Purple: **C2G & C2P** is **7x** faster than **G1P**

- Galvanized layer reduces probability of corrosion development with double barrier system

Galvanized (G1P) Carbon steel (C2P)

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Purple vs green epoxy

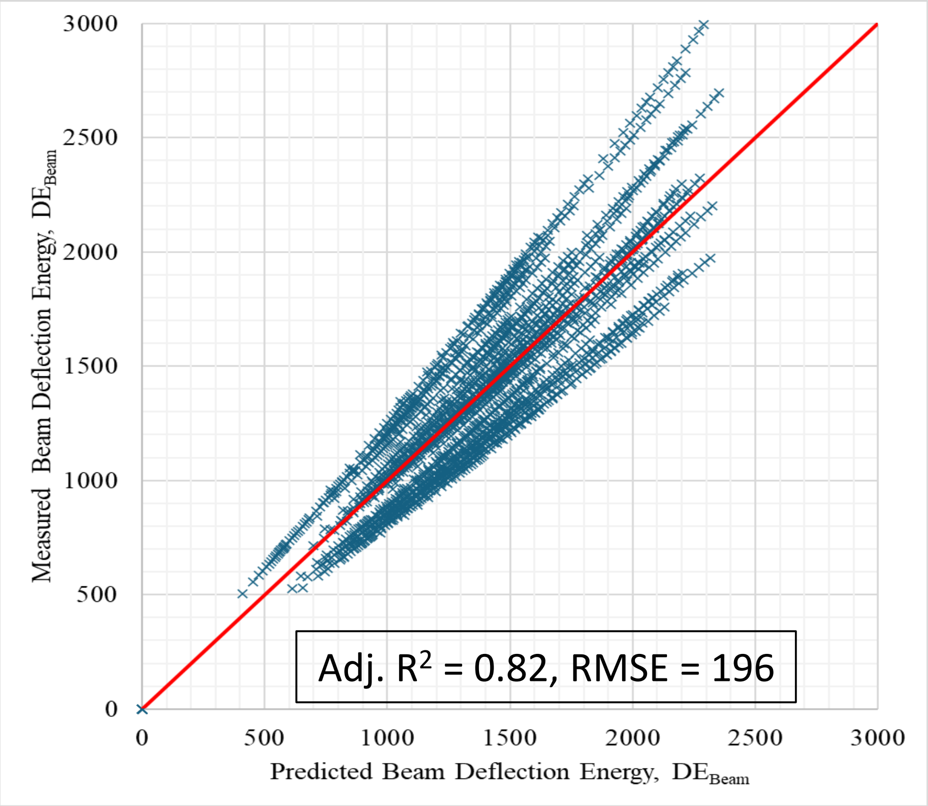
- Pliable green epoxy coating tended to **bunch up and peel** during the joint opening/closing simulation
- Area of corrosion on the **G1G** dowels is **2.4x** greater than **G1P** dowels

C2G3

Load damage

$$DE_{Beam} = \alpha_1 * \log(x+1) + \alpha_2 * \log(x+1) * \frac{\log(Load)}{\beta} + \alpha_3 * \frac{\log(x+1)}{\beta}$$

x = number of load cycles,
$Load$ = applied load (lb),
$\beta = \sqrt[4]{\frac{K*d}{4*E_{dowel}*I}}$,
$K = \frac{E_{PCC}}{h_{PCC}}$ = modulus of dowel-concrete reaction (psi)
E_{PCC} = concrete elastic modulus (psi),
h_{PCC} = PCC thickness (in)
d = dowel diameter (in),
E_{Dowel}= dowel elastic modulus (psi),
I = moment of inertia (in^4),
C_8 = calibration coefficient
α_1 = 592.8, α_2 = 353.3, α_3 = -1256.5,



Corrosion and load damage model

$$DOWDAM = \begin{cases} C_{Corr} * \sum [\, \alpha_1 * log(x_i + 1) + \alpha_2 * log(x_i + 1) * \frac{log(Load_i)}{\beta} + \alpha_3 * \frac{log(x_i + 1)}{\beta}] & if\ Load_i \geq 900 \\ C_{Corr} * \sum \frac{Load_i}{900} * [\, \alpha_1 * log(x_i + 1) + \alpha_2 * log(x_i + 1) * \frac{log(900)}{\beta} + \alpha_3 * \frac{log(x_i + 1)}{\beta}] & if\ Load_i < 900 \end{cases}$$

x = number of load cycles,
Load = applied load (lb),
Beta = $\sqrt[4]{\frac{K*d}{4*E_{dowel}*I}}$,
$K = \frac{E_{PCC}}{h_{PCC}}$ = modulus of dowel-concrete reaction (psi)
E_{PCC} = concrete elastic modulus (psi),
h_{PCC} = PCC thickness (in)
d = dowel diameter (in),
E_{Dowel}= dowel elastic modulus (psi),
I = moment of inertia (in^4),
α_1 = 592.8, α_2 = 353.3, α_3 = -1256.6,
C_8 = calibration coefficient,
t = pavement age (months),
C_{EXP} = exposure rating,
$C_{Coating}$ = coating rating, and
jw = joint width (in)

$$C_{Corr} = C_8 * t^{C_{EXP} * C_{Coating}}$$

Freezing index (°F day)	C_{EXP}
< 100	0
100 - 400	0.15
400 - 600	0.2
600 - 1000	0.25
> 1000	0.25

$$C_{Coating} = \alpha * (\pi * d) * jw$$

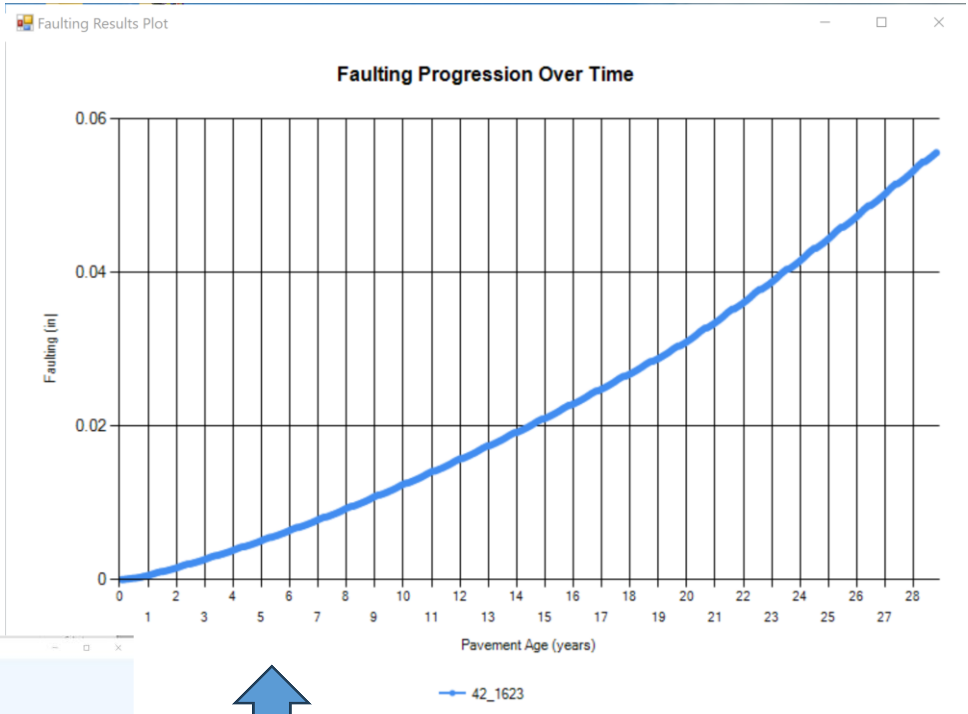
Dowel coating and material type	α
Epoxy-coated steel	0.15 (20 yrs;1x))
Green galvanized	0.075 (40 yrs; 3x)
Purple galvanized	0.01 (50 yrs; 7x)
Non-corrodible bars (FRP & stainless steel)	0 (never)

Results worth implementing? .. If so, steps needed?

Nonstandard dowels

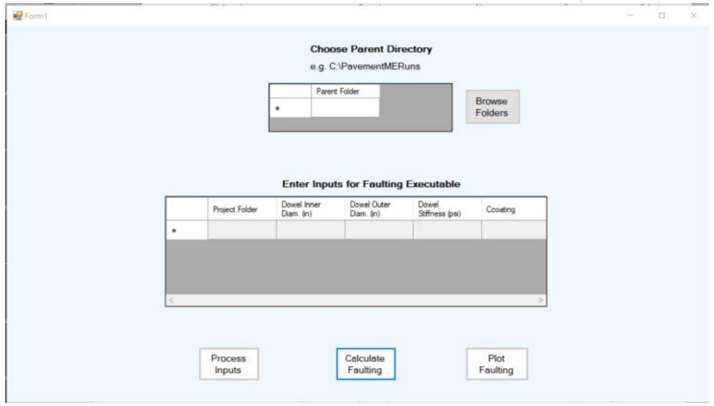
Load damage

Corrosion damage



AASHTOWare Pavement ME Design

Output Files



Acknowledgements

CAWP
Constructors Association of Western Pennsylvania

CDR | MAGUIRE ENGINEERING

FRANK BRYAN CONCRETE FACTORY

NEVILLE AGGREGATES

GOLDEN TRIANGLE CONSTRUCTION®
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Thank you!

Questions?