Getting Familiar with the BCOA-ME Design Guide

Bonded Concrete Overlay of Asphalt Pavements Mechanistic-Empirical Design Guide (BCOA – ME)

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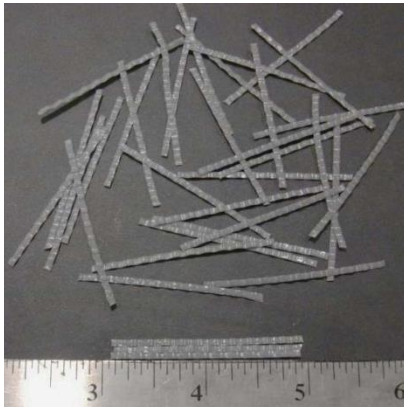
FHWA Pooled Fund Study TPF 5-165

EFFECT OF FIBER ON JOINT PERFORMANCE

Benefits of structural fibers



Current: Increase MOR

Advantage

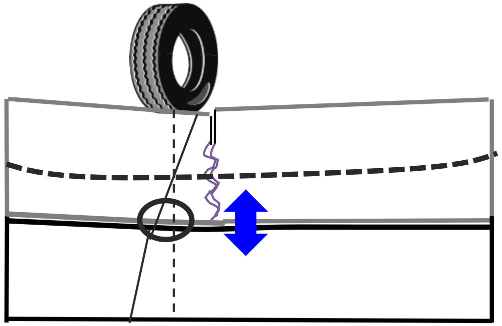
- Increase fracture toughness
- Decrease crack/joint width
- Potential increase in load transfer

Disadvantage

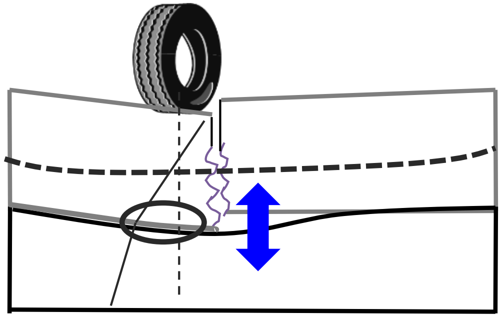
- Increase cost of PCC by approx. 20%

Influence on load transfer

1. Reduce load related stress on the loaded slab;
2. Reduce debonding tensile “stresses between the layers.



High LTE

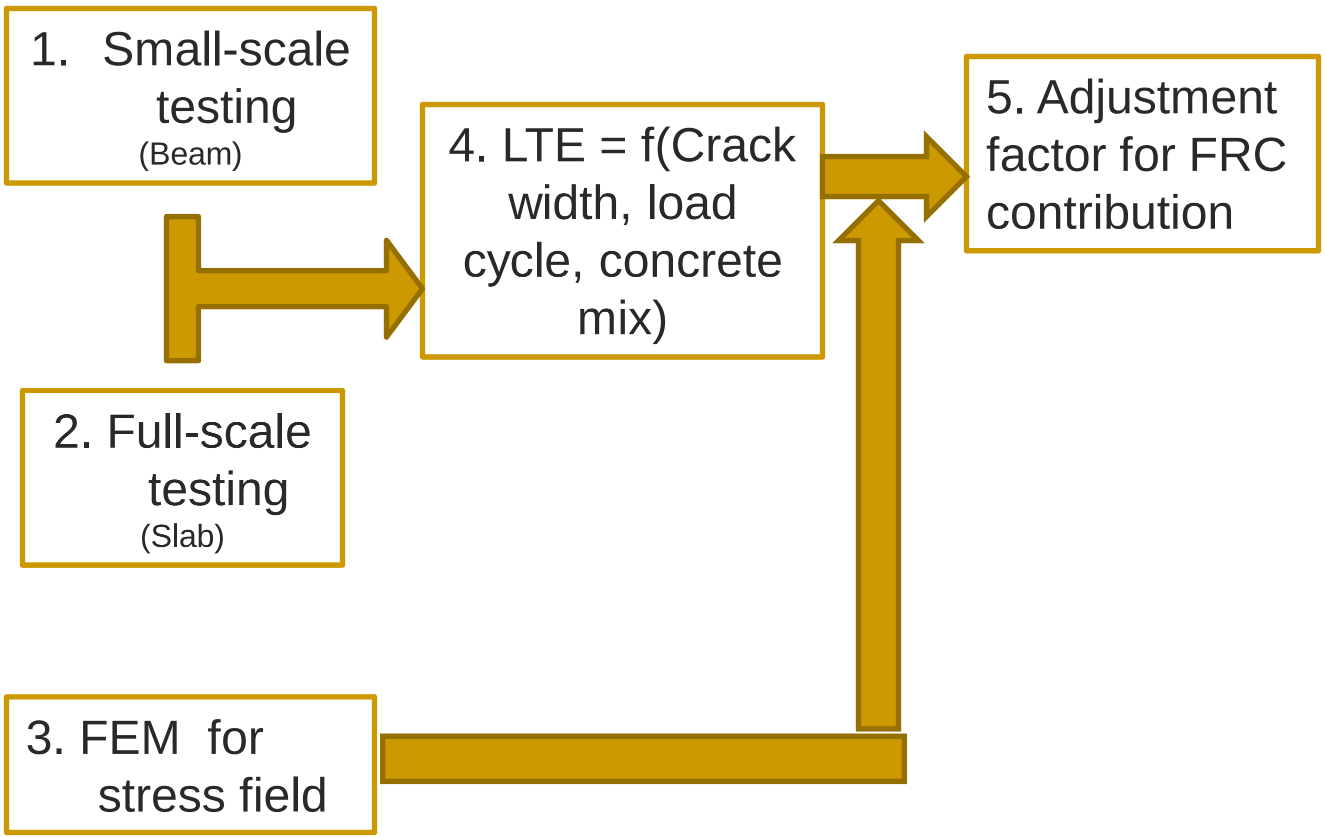


Low LTE

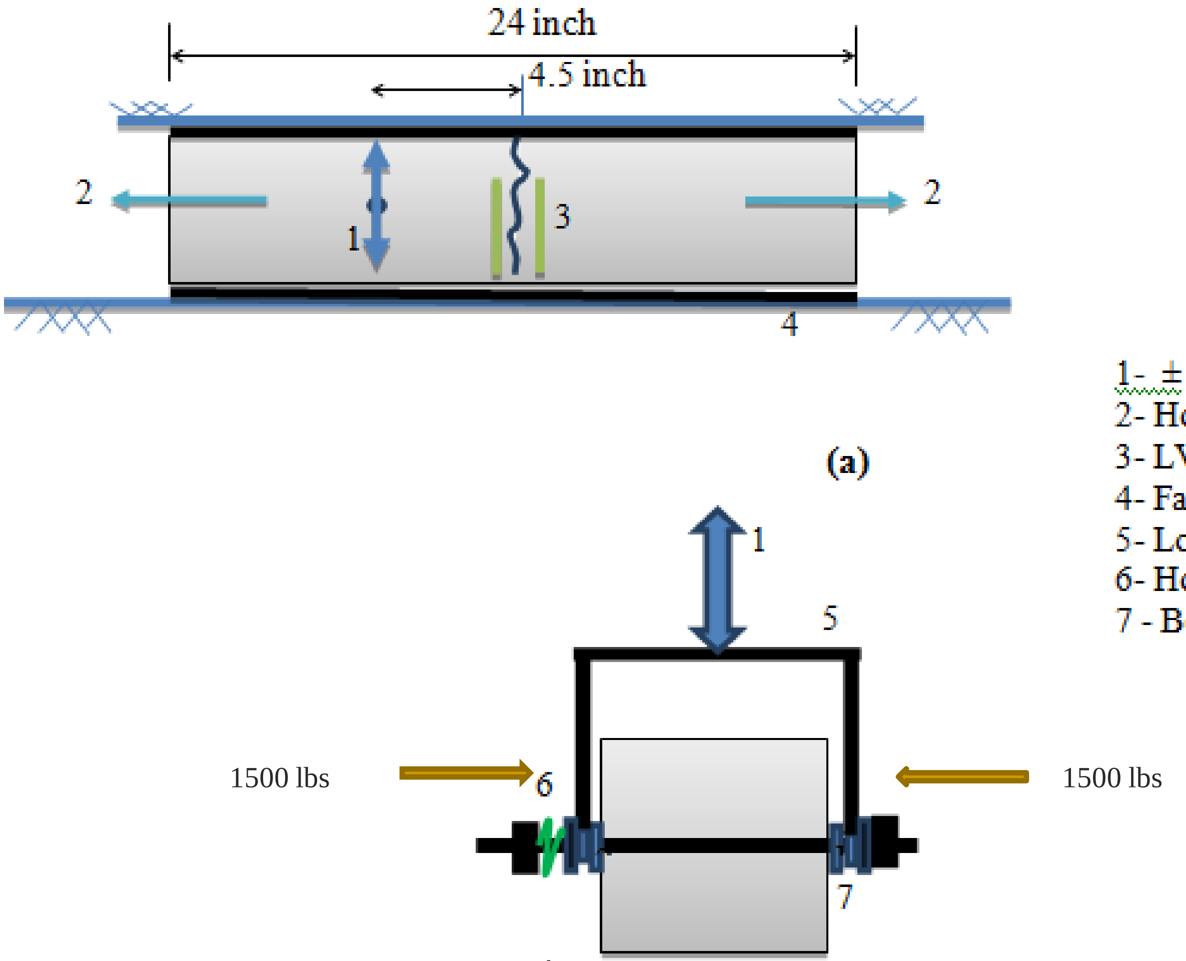
$$LTE = \frac{\Delta_U}{\Delta_L} \times 100 \text{ percent}$$

Δ_U and Δ_L = def. at unloaded and loaded slabs.

Strategy


1. Small-scale testing (Beam)
2. Full-scale testing (Slab)
3. FEM for stress field
4. LTE = f(Crack width, load cycle, concrete mix)
5. Adjustment factor for FRC contribution

1. Development of small-scale test

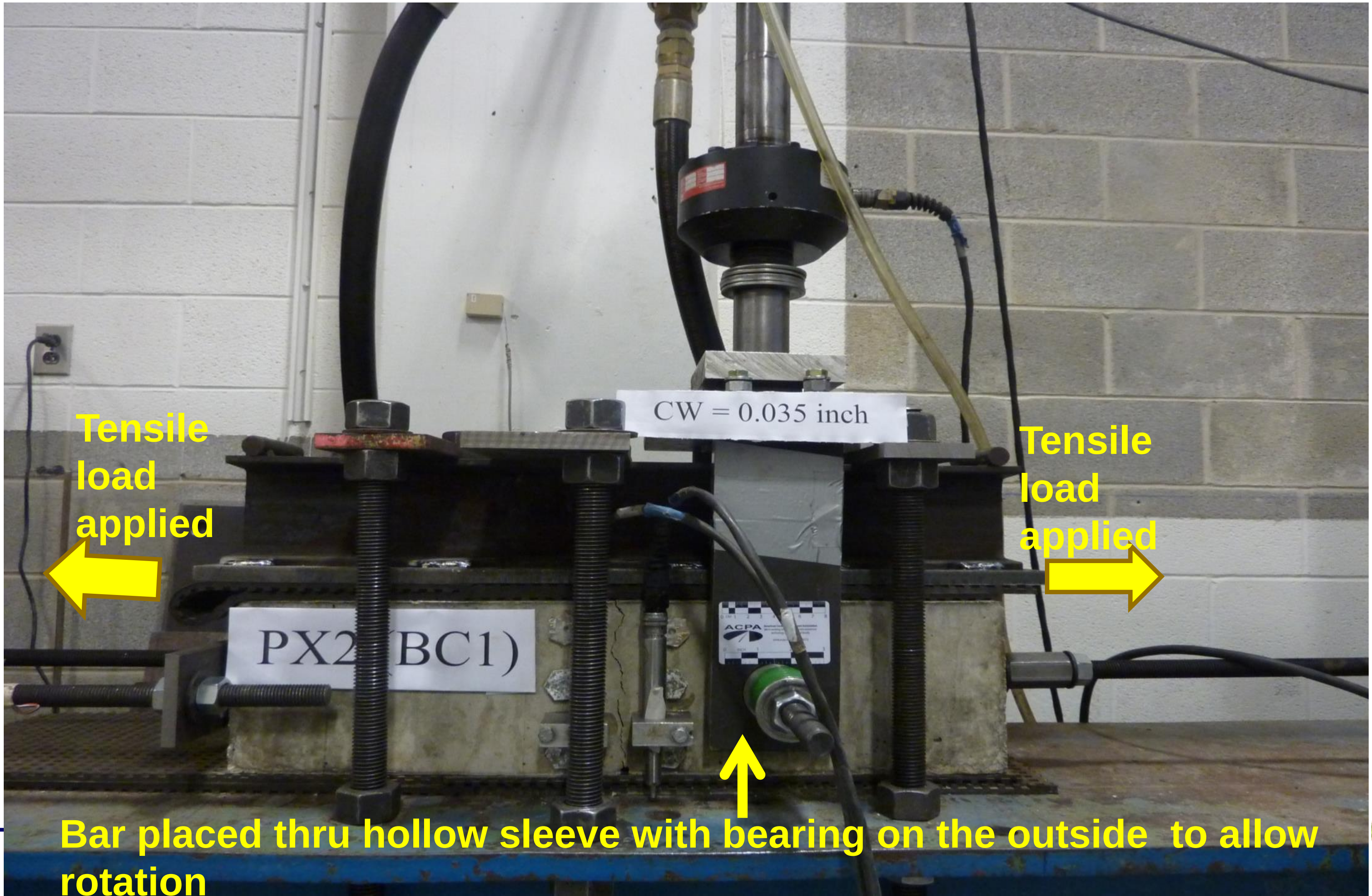


Not to scale

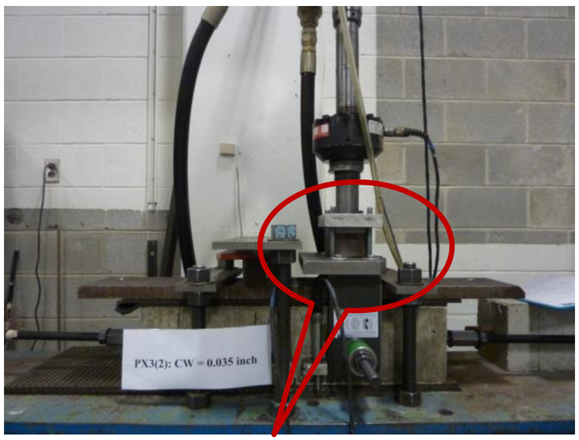
1- ± 1050 lbs load
2- Horizontal force
3- LVDTs
4- Fabcel, artificial foundation
5- Load plate
6- Horizontal load application spring
7 - Bearing

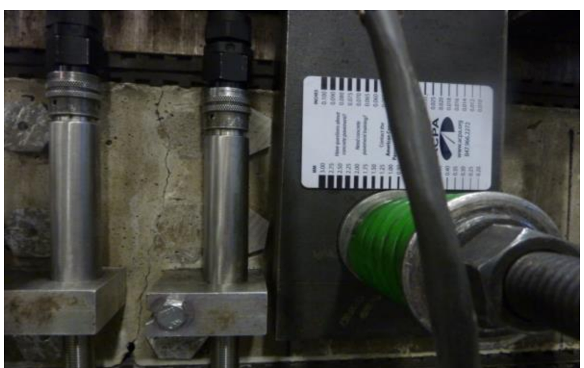
Load rate = 10 Hz

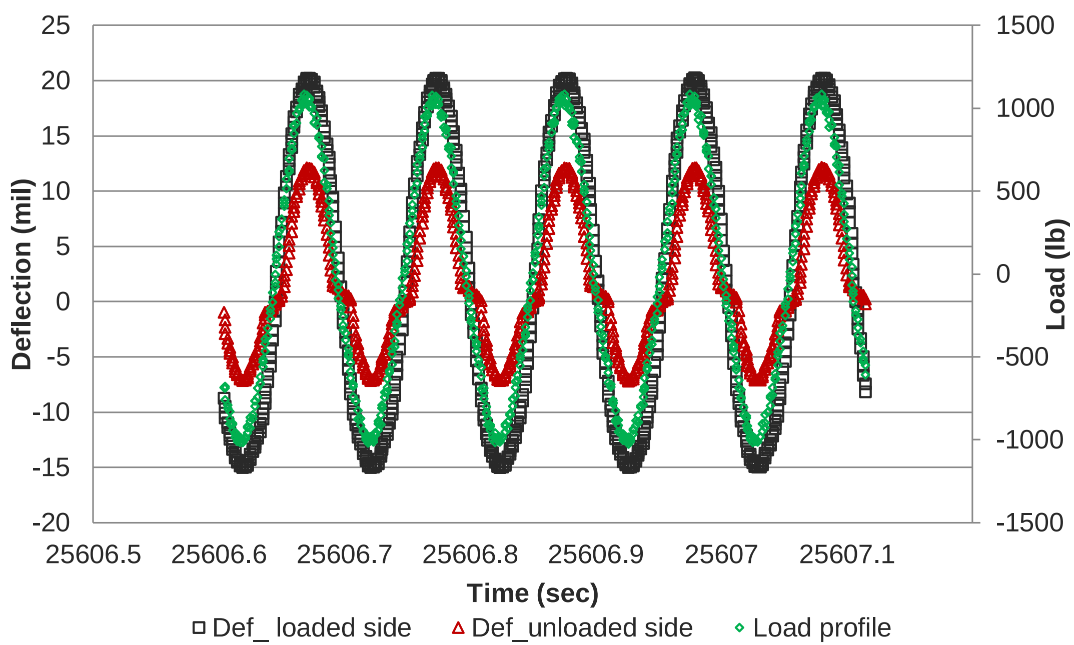
1. Small-scale LTE testing



1. Small-scale LTE testing







2. Large-scale testing

Fibers Considered

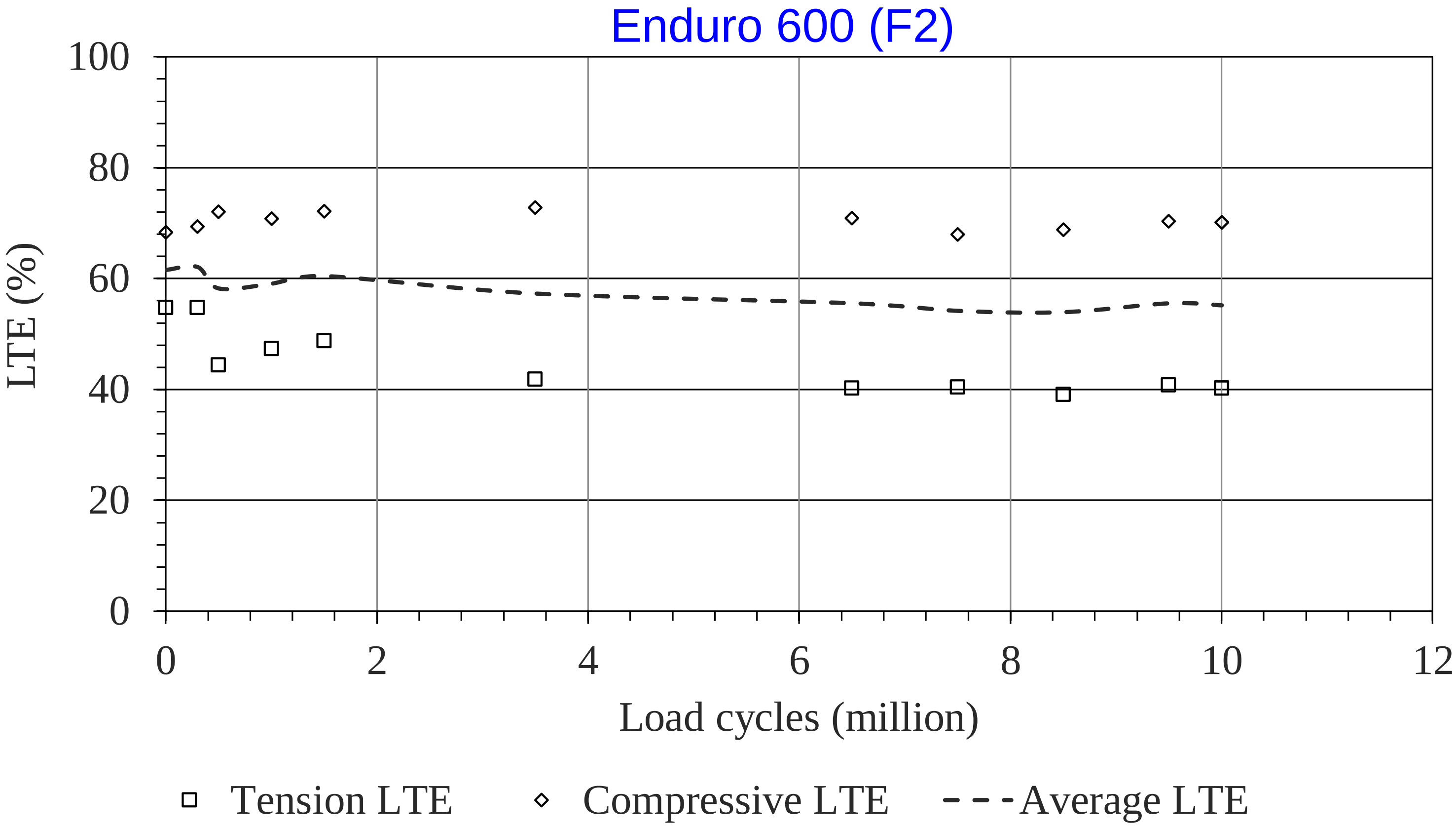
Synthetic Fiber	Brand	Length (inch)	Shape	Cross section (inch x inch)	Specific gravity	Aspect ratio	Quantity (lb/cy)
Straight	Strux: 90/40	1.57	Rectangular	0.05 x 0.004	0.92	90	5.25
Crimped	Enduro 600	1.75	Rectangular	0.05 x 0.03	0.91	40	6.2

Strux 90/40 (F1)

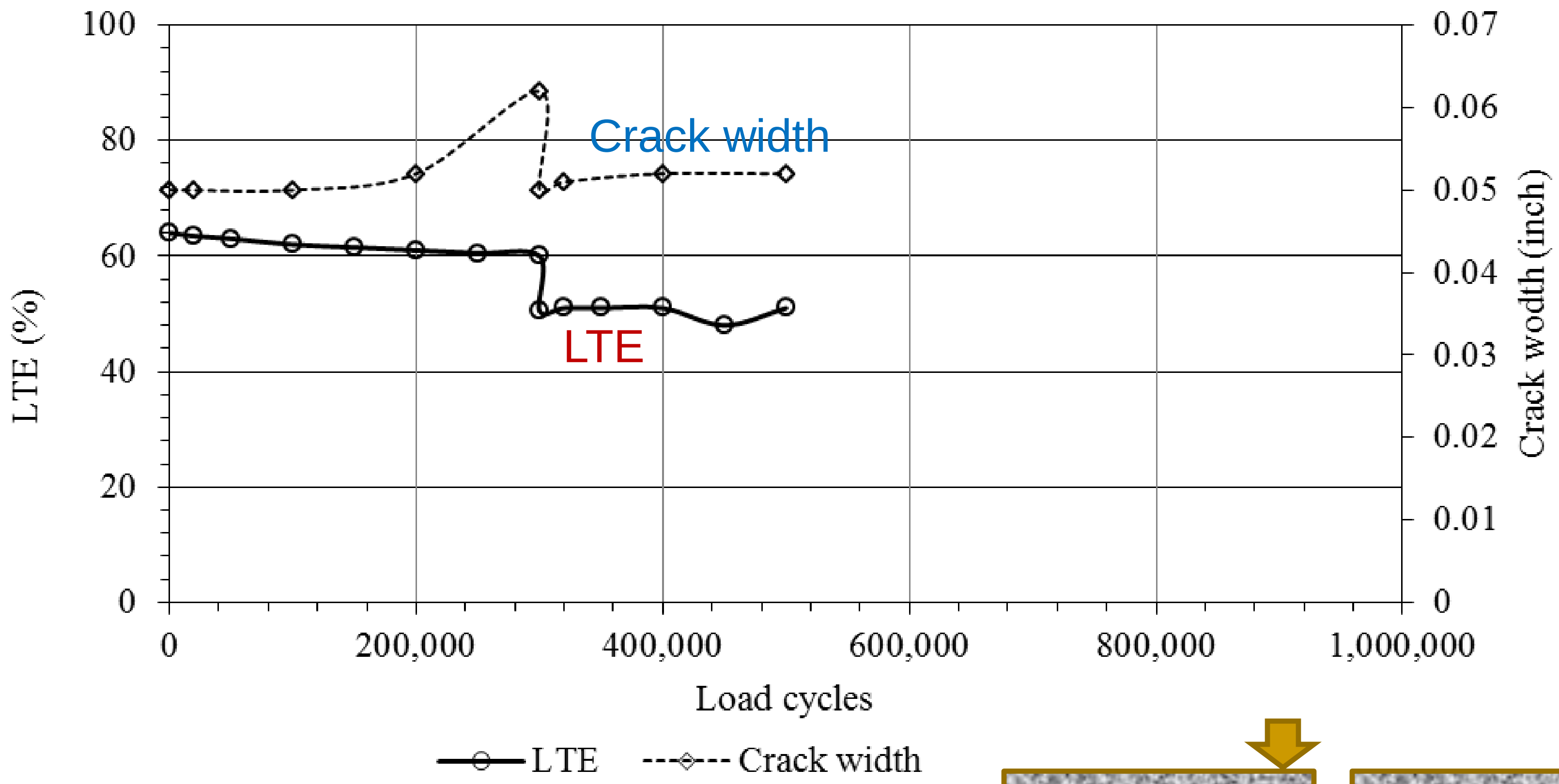
Target residual strength = 20%

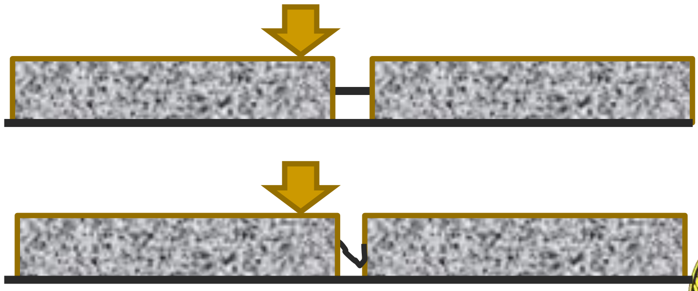
Enduro 600 (F2)

No Fatigue of Fiber

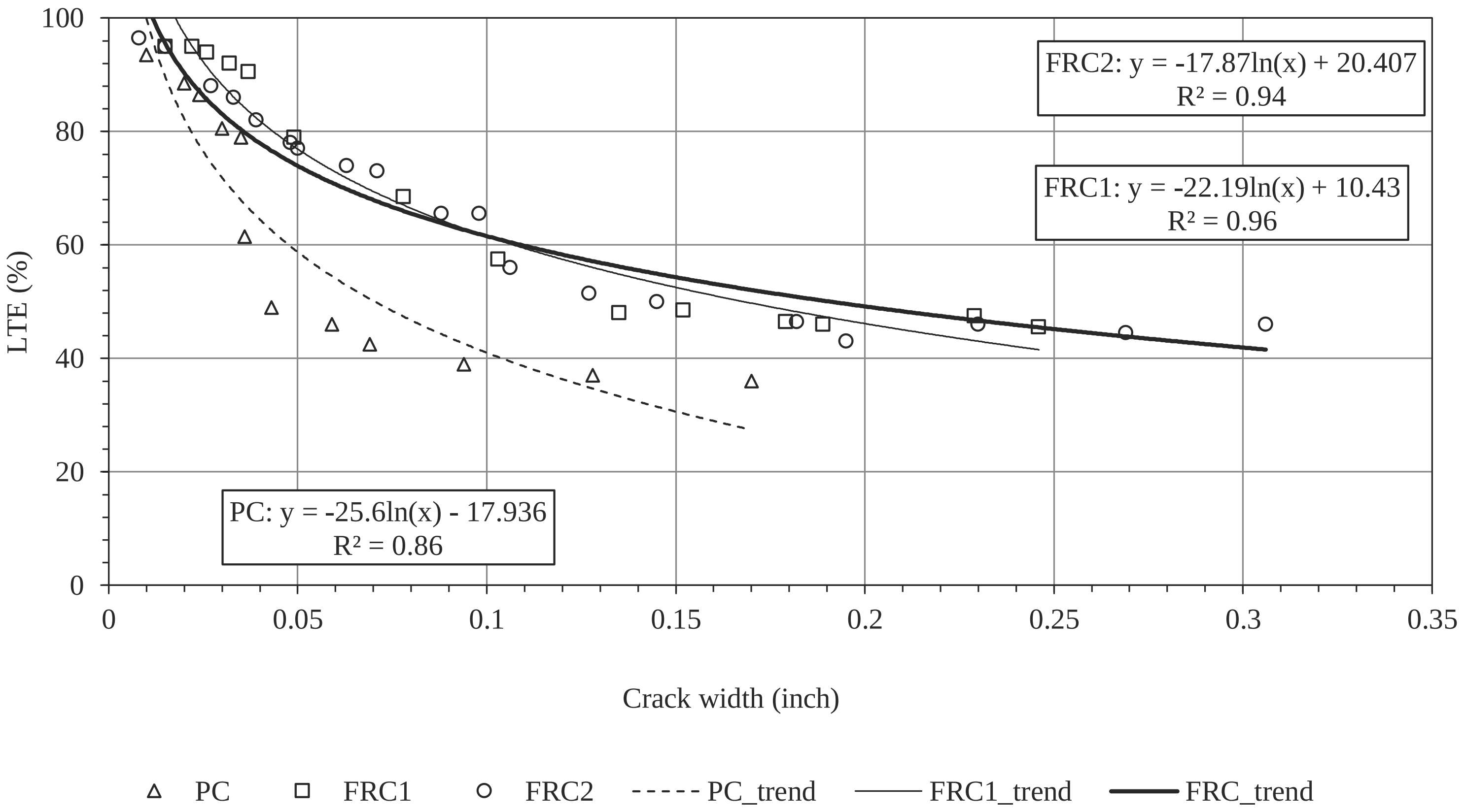


Effects of reduction in crack width

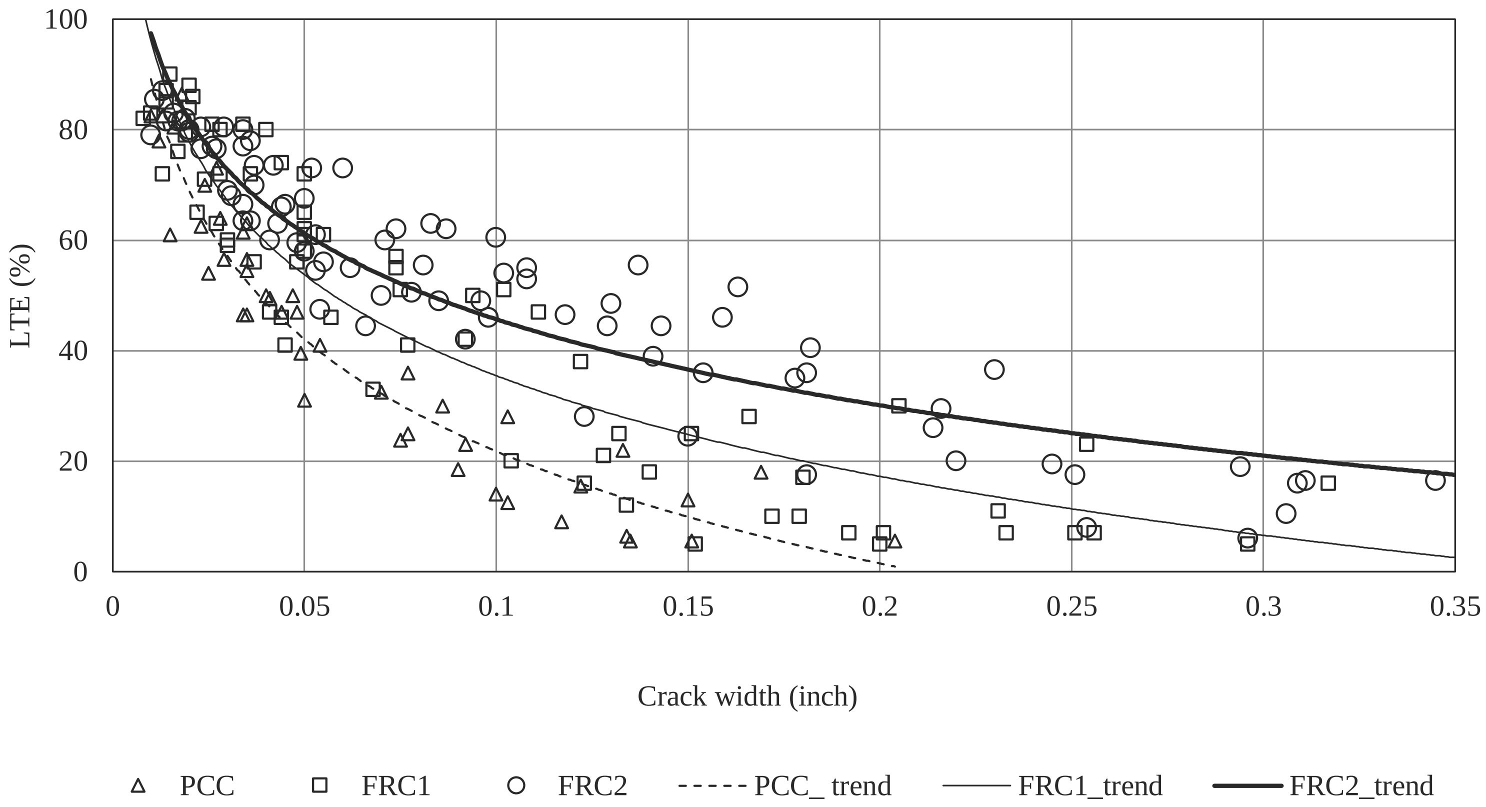




Slab performance



Beam performance



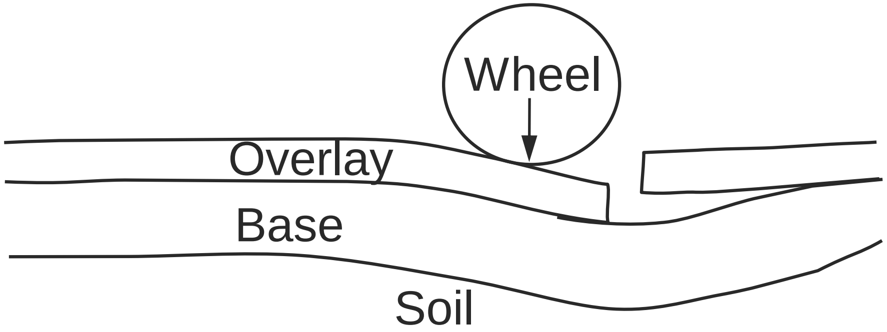
Comments

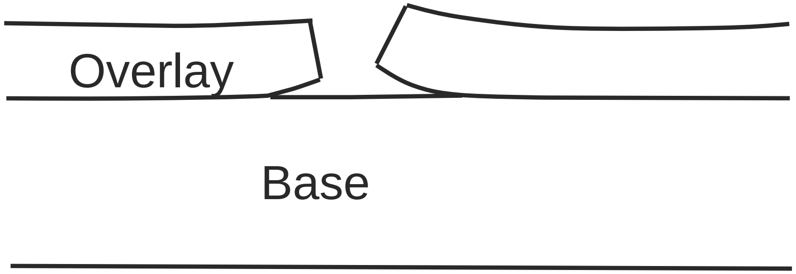
- Even though the shapes, sizes and aspect ratios of the two fibers were different, performances were similar.
- Residual strength fiber selection criteria could possibly indicate equivalent joint performance.
- Fibers increases LTE by 10%
- Fiber did not exhibit fatigue after 10 million load applications
- Effectiveness of fiber appears to decrease when crack width is less than max. crack opening experienced

DEBONDING MODEL

Interface Debonding

Debonding Force > Debonding Resistance





Tensile failure

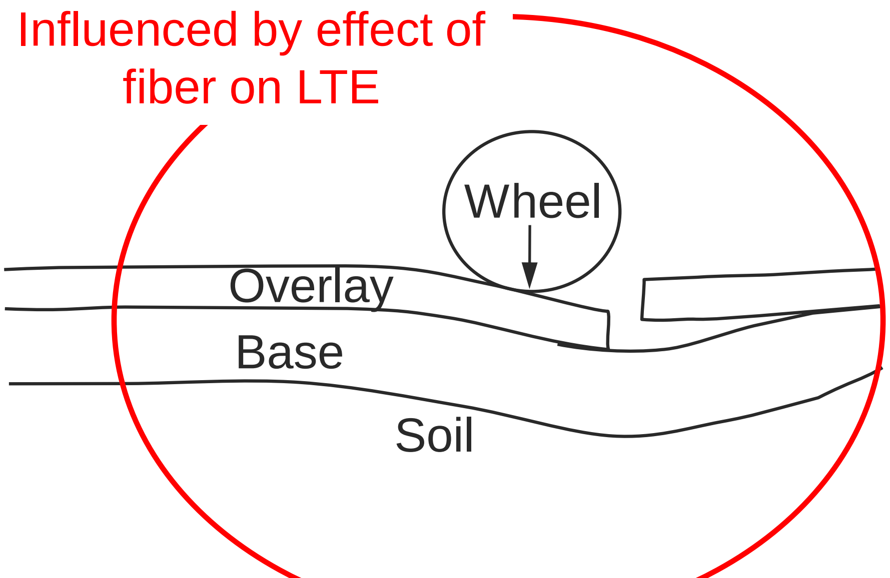
1. Wheel load
2. Curling/warping

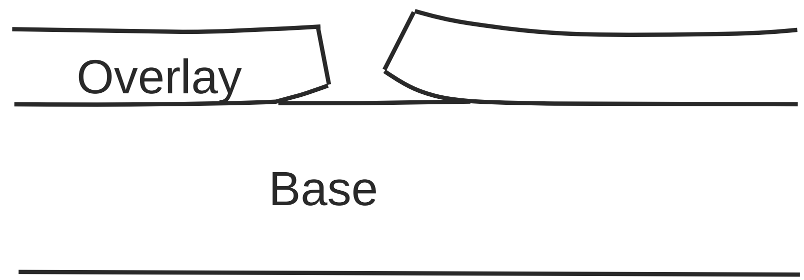
Shear failure

1. Wheel brake
2. Differential length change

Interface Debonding

Debonding Force > Debonding Resistance





Tensile failure

1. Wheel load
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Shear failure

1. Wheel brake
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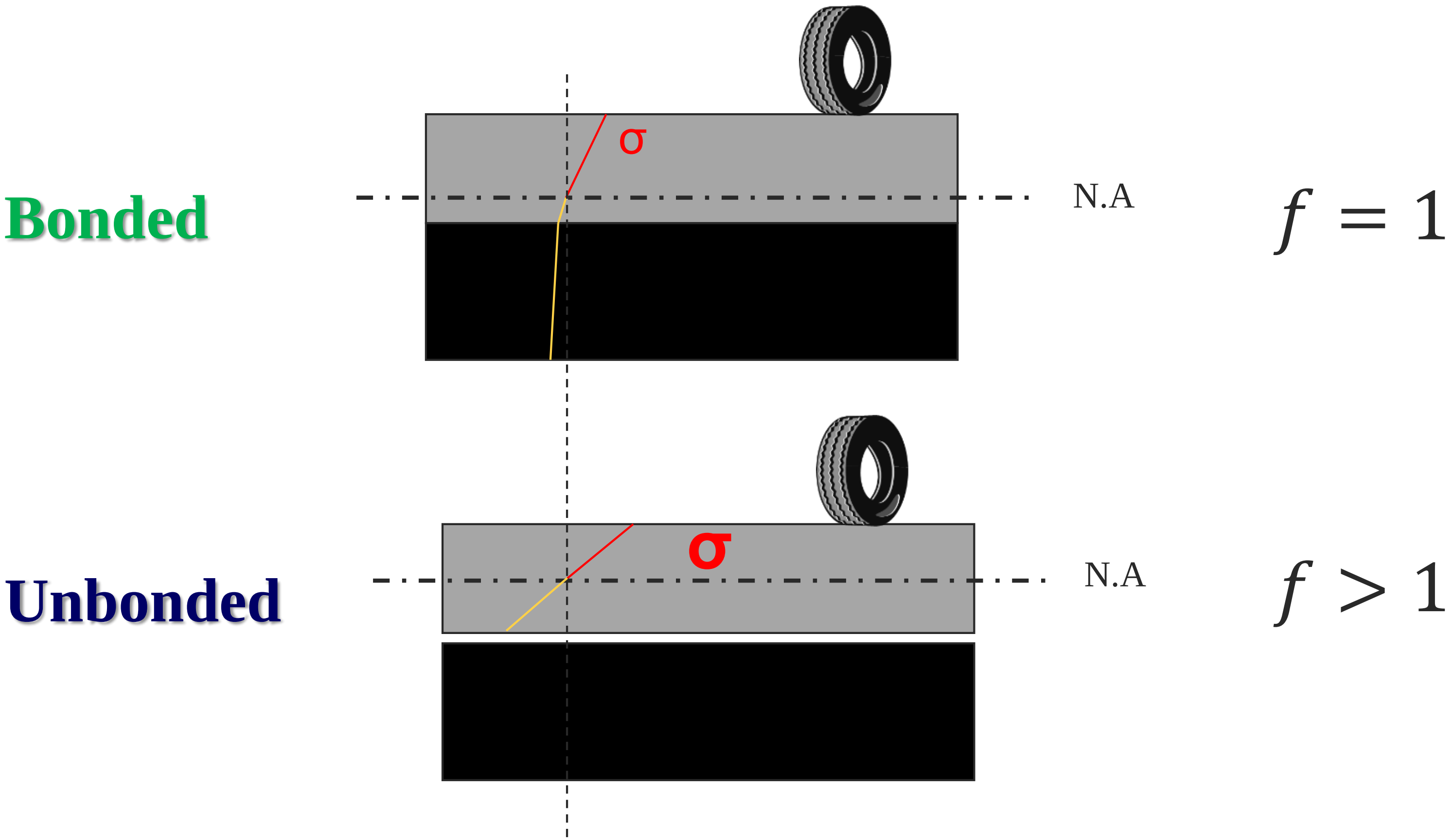
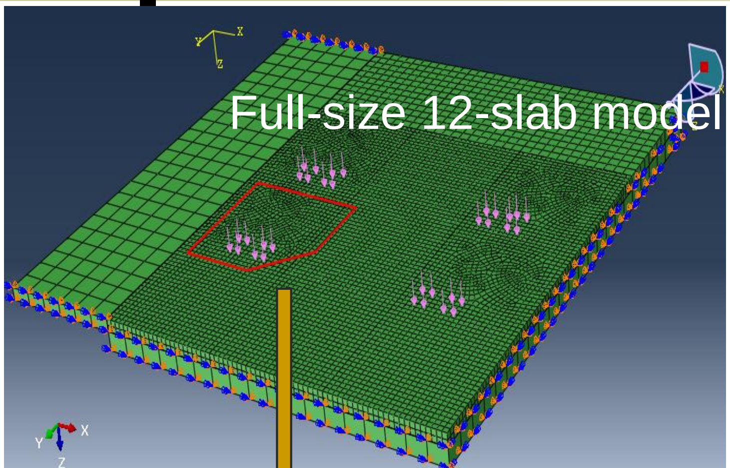
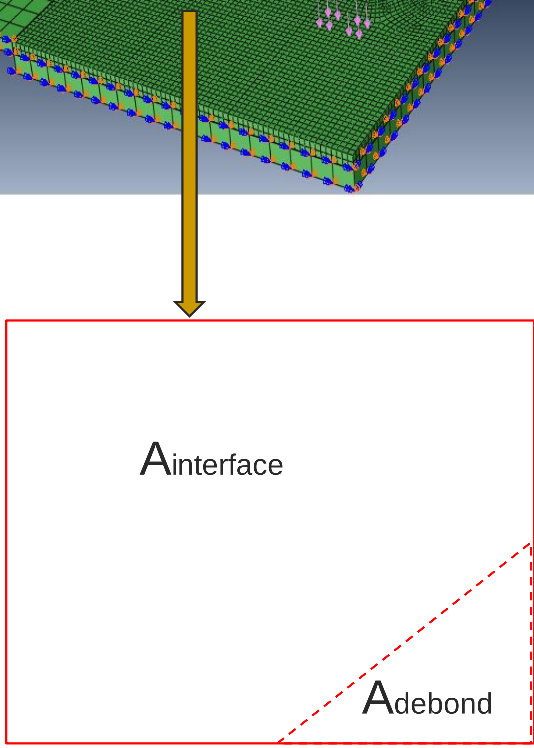
Interface bond

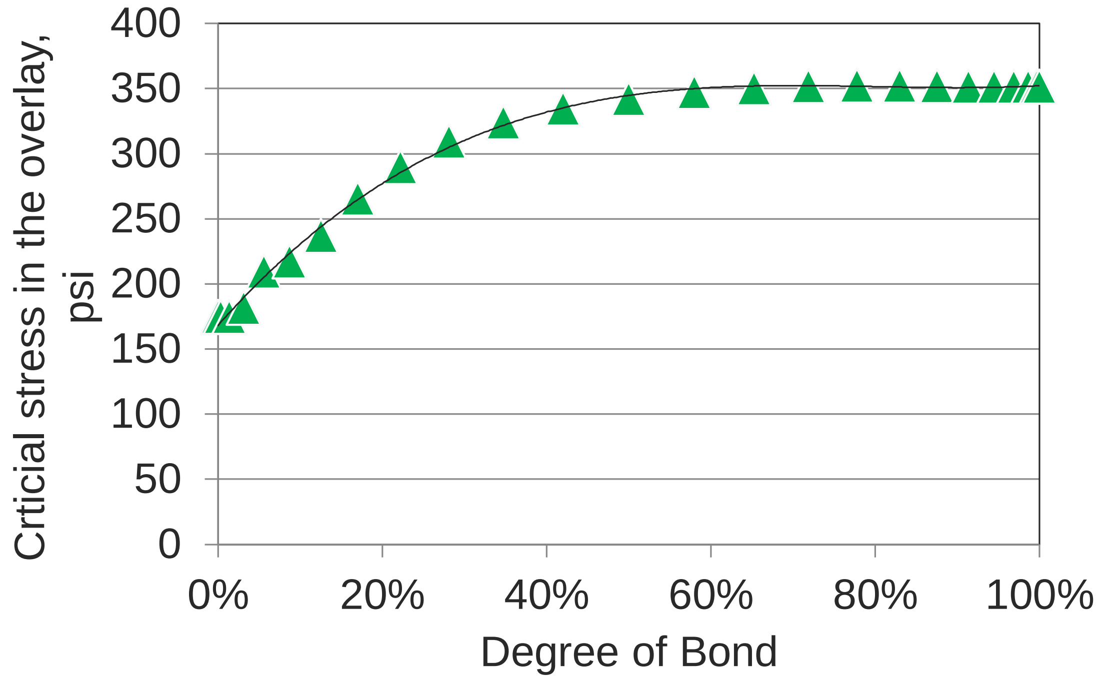
$$\sigma_{design} = f(degree\ of\ bond) \cdot \sigma_{bonded}$$



Effect of partial bonding







$$DB\% = \frac{A_{debond}}{A_{interface}}$$

Considerations in current design

	Degree of Bond (DB)
CDOT	Increase stress by 65%-59%[1]
NJDOT	Engineering judgment
PCA	Increase stress by 36%[2]
ICT	Same as PCA method

1. Based on Colorado data, 2. based on Missouri and Colorado Data

Proposed debonding model

Paris' law:

$$A_{debond} = c\left(\frac{\Delta G}{Gc}\right)^{m} \text{N}$$

$\Delta G\ = Energy\ release\ rate, a\ function\ of\ appled\ load$

$Gc{=}\ Critical\ energy\ release\ rate, a\ function\ of\ material\ testing$

$c, m{=}\ Coefficients\ from\ slab\ testing$

$N{=}\ Number\ of\ loads$

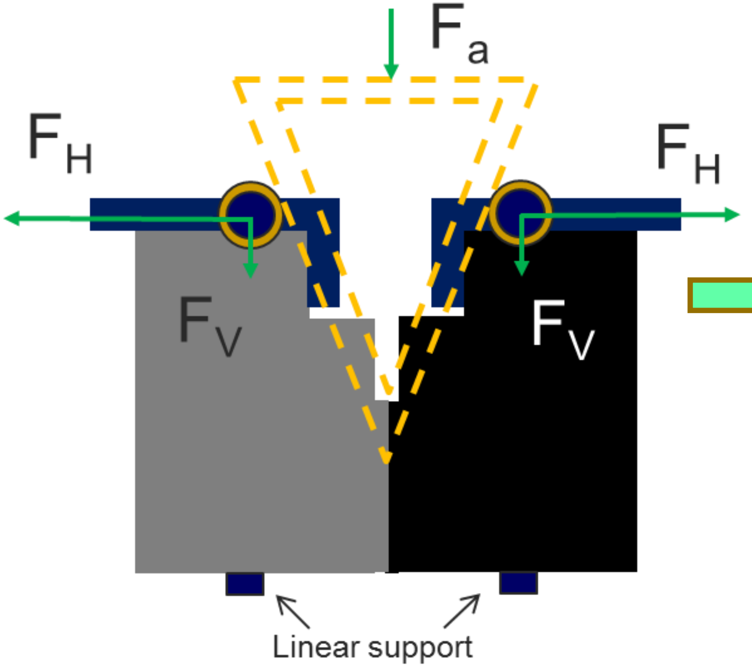
Material Characterization

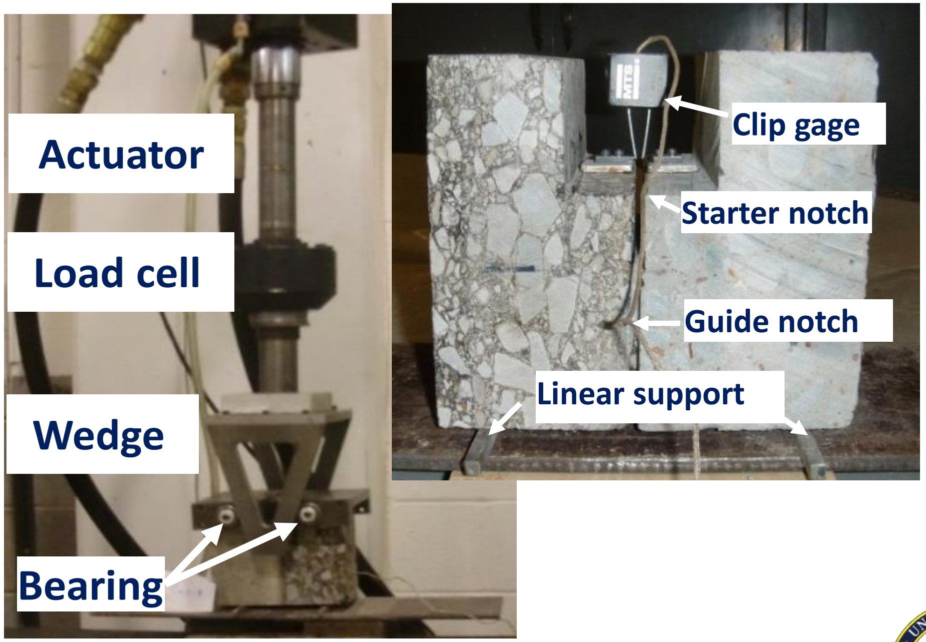
$$A_{debond} = c\left(\frac{\Delta G}{Gc}\right)^m N$$

$$logGc = B_0 + B_1 logR + B_2 loga_0$$

$R: Interface\ roughness$

$a_0: Initial\ flaw\ size$

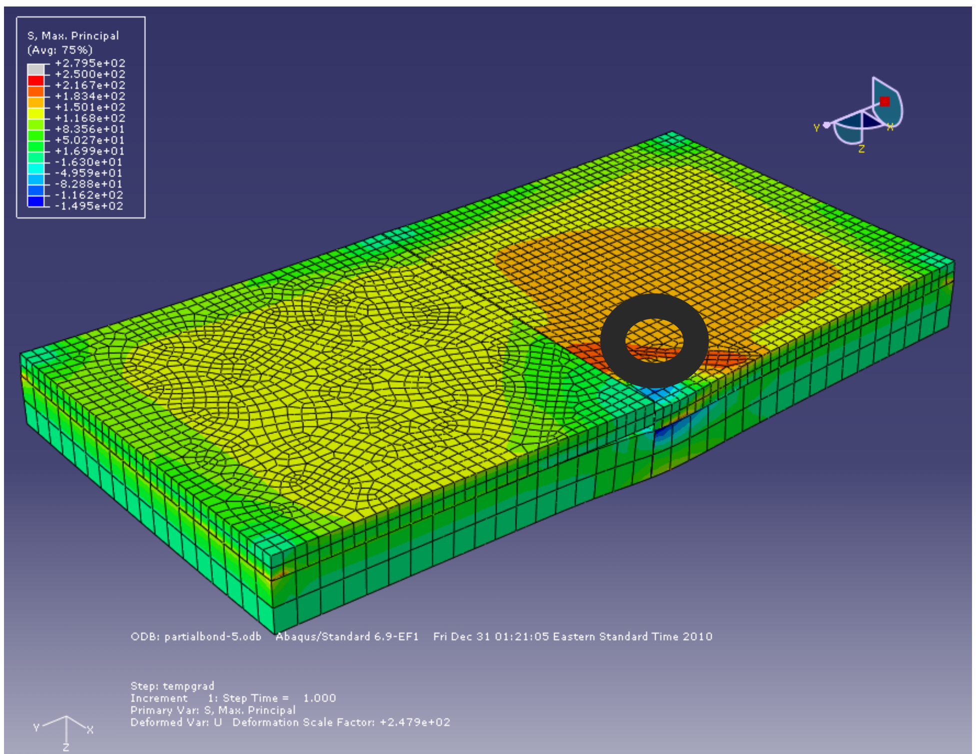




Calculation of debonding force

$$A_{debond} = c\left(\frac{\Delta G}{Gc}\right)^{m} \mathrm{N}$$

$$\Delta G = f(L, h_{pcc}, h_{HMA}, E_{HMA}, P, A_{debond})$$



L: *Slab size*

h_{pcc}: *Overlay thickness*

h_{HMA}: *Asphalt thickness*

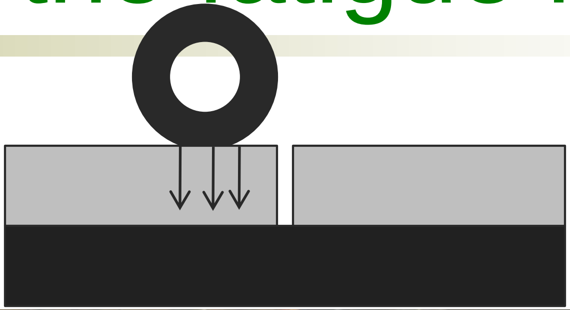
E_{HMA}: *Asphalt stiffness*

P: *load vector*

A_{debond}: *current debonding size*

Calibration of the fatigue law

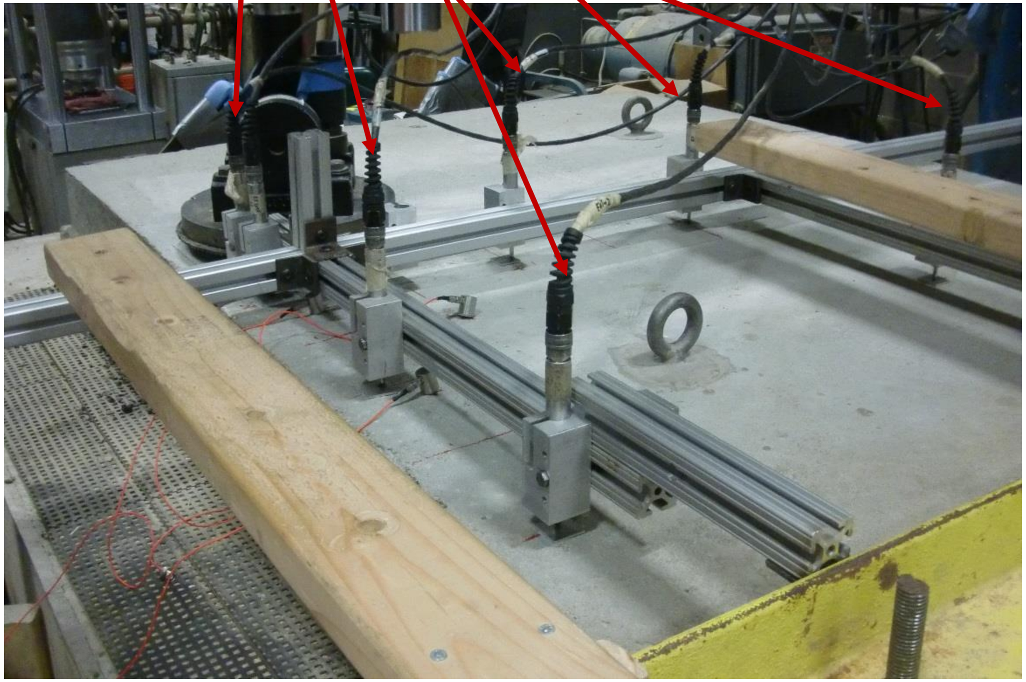
$$A_{debond} = c\left(\frac{\Delta G}{Gc}\right)^m \mathrm{N}$$



Methods to determine A_{debond} @ N

$$A_{debond} = c\left(\frac{\Delta G}{Gc}\right)^m N$$

1. Deflection method



Deflections measured during testing of slabs

Deflections from FE models w/ various DB%

Methods to determine A_{debond} @ N

$$A_{debond} = c\left(\frac{\Delta G}{Gc}\right)^{m} N$$

2. Impact echo method