University of Pittsburgh

Unbonded Concrete Overlays of Existing Concrete Pavements (UBOLs): Task 3 Structural Model Development

TAP Meeting
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Task 2: Consolidation

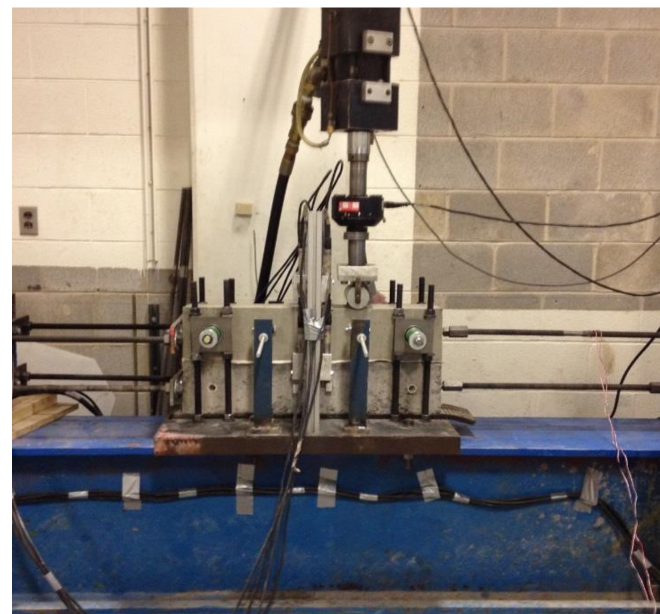
Permanent deformation in HMA

Increasing permanent deformation

- MI open graded
- MI dense graded
- MN dense graded
- MN open graded

Fabric not influenced

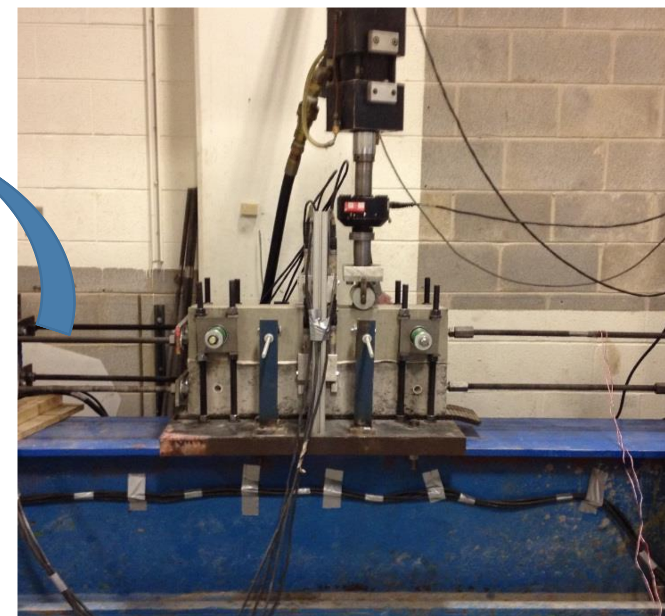
Longitudinal outer wheel path crack in LTPP section



Task 2: Fatigue

Fatigue in interlayer

- MN open graded
- None exhibited in other interlayers

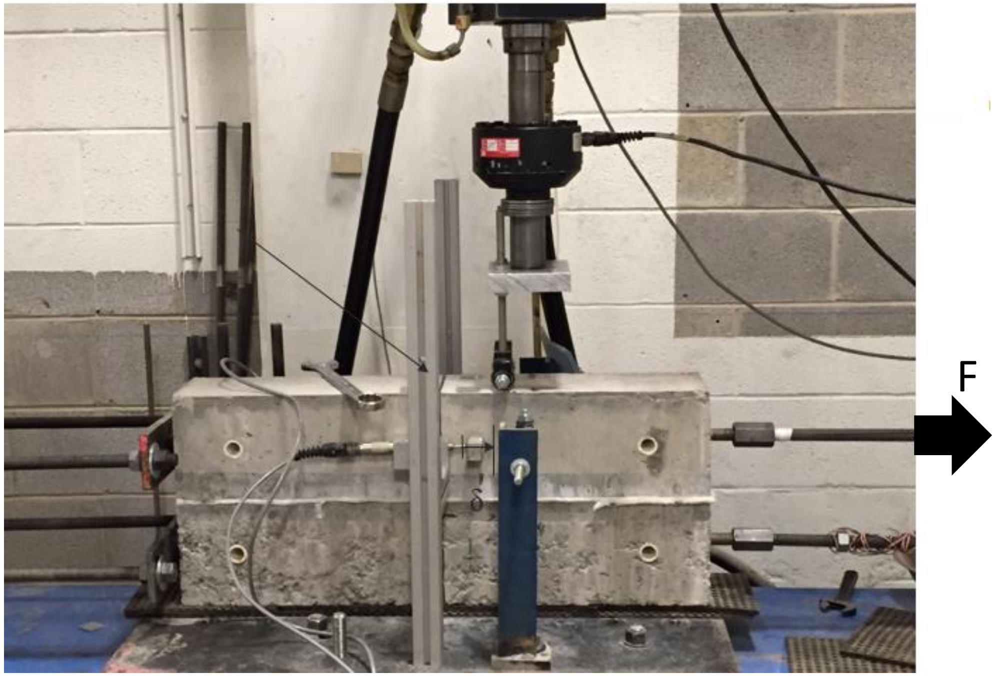


Task 2: Friction

Frictional restraint

Decreasing frictional restraint

- MI open graded
- MI dense graded
- MN dense graded
- MN open graded
- 10 oz fabric glued
- 10 oz fabric pinned
- 15 oz fabric glued
- 15 oz fabric pinned



Task 2: Friction

Too much vs too little

- All joints not working (large effective panel size)
- Result: Jt deterioration and/or fatigue cracking

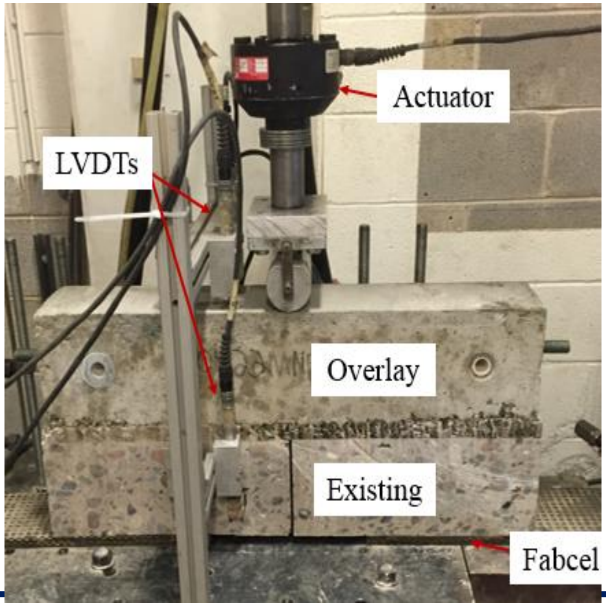
Not deployed (Approx. 0.25-in wide)

Deployed (Approx. 0.5-in wide)

SR 50 UBOL in Bridgeville, PA

Task 2: Reflective cracking

- Reflective cracking not generated when fully supported
- Fabric tends to increase resistance to reflective cracking when compared to HMA
- MI open graded appears to perform better than other HMA interlayers
  - Greater resistance to reflective cracking and less permanent deformation



Task 2: Direct tension

- Examine curling warping stresses
- Measure vertical deformations within interlayer and interface strength

Decreasing resistance to vertical uplift

MI dense graded
MN dense graded
MI open graded
MN open graded
10 oz fabric
15 oz fabric

Joint performance

- Erosion
- Consolidation
- Fatigue
- Faulting

Interlayer erosion

Contributing Factors

- Moisture
- Traffic
- Asphalt susceptibility
- Drainage

US-23 in MI

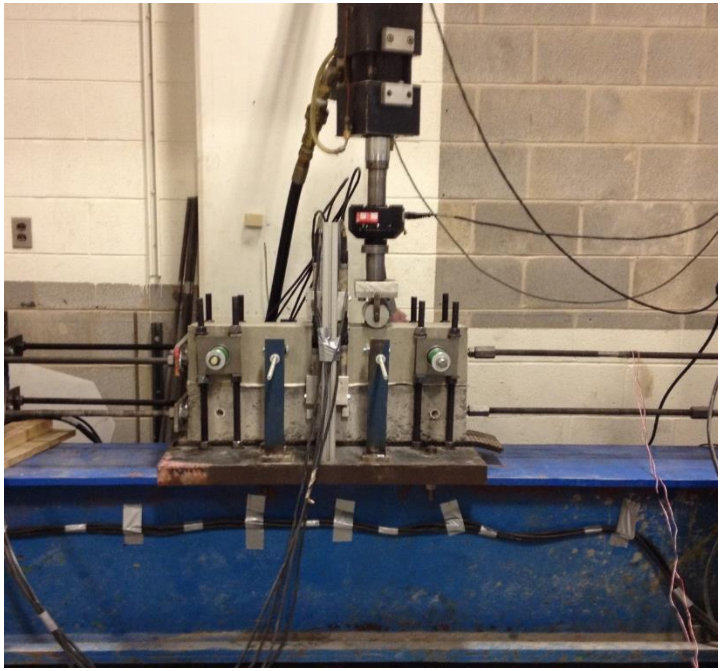
Photo courtesy of Andy Bennett

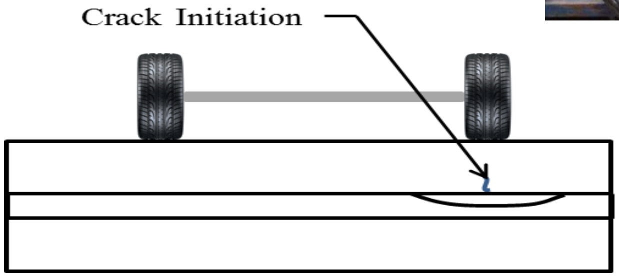
Interlayer erosion

- Erodibility factor
  - Interlayer drainability
  - Binder content
  - Film thickness
  - Permeability
  - Binder and aggregate type
- Predicted erosion depth
  - Critical response from FEM rapid solution
  - Erodibility factor

Consolidation

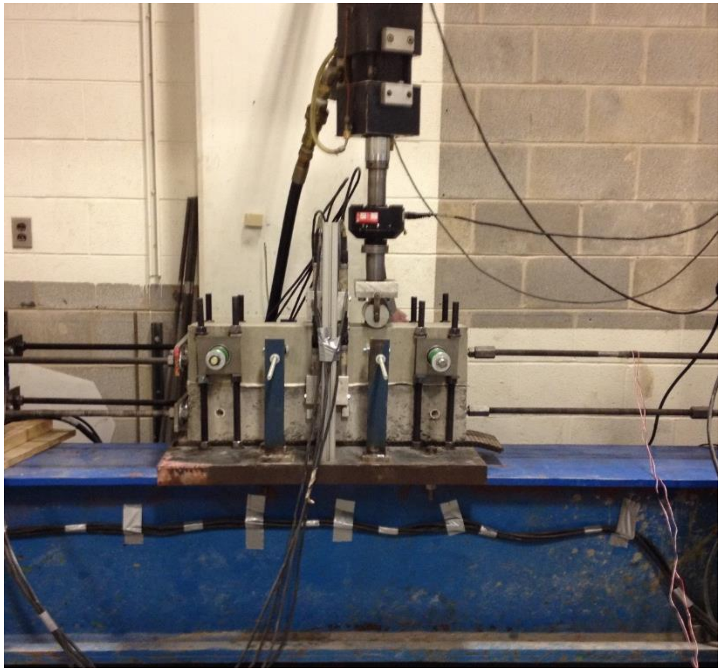
- Void created in interlayer
- Observed in lab testing
- Contributing factors
    - Traffic
    - Asphalt compressive strength
    - Vertical interlayer strain
    - LTE and Mag. of deflection





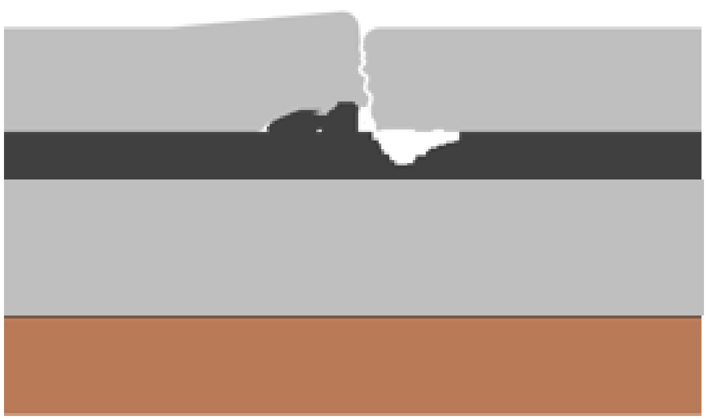
Interlayer fatigue

- Observed in lab testing
- Contributing factors
  - Traffic
  - Asphalt compressive strength
  - Vertical interlayer strain
  - LTE and mag. of deflection

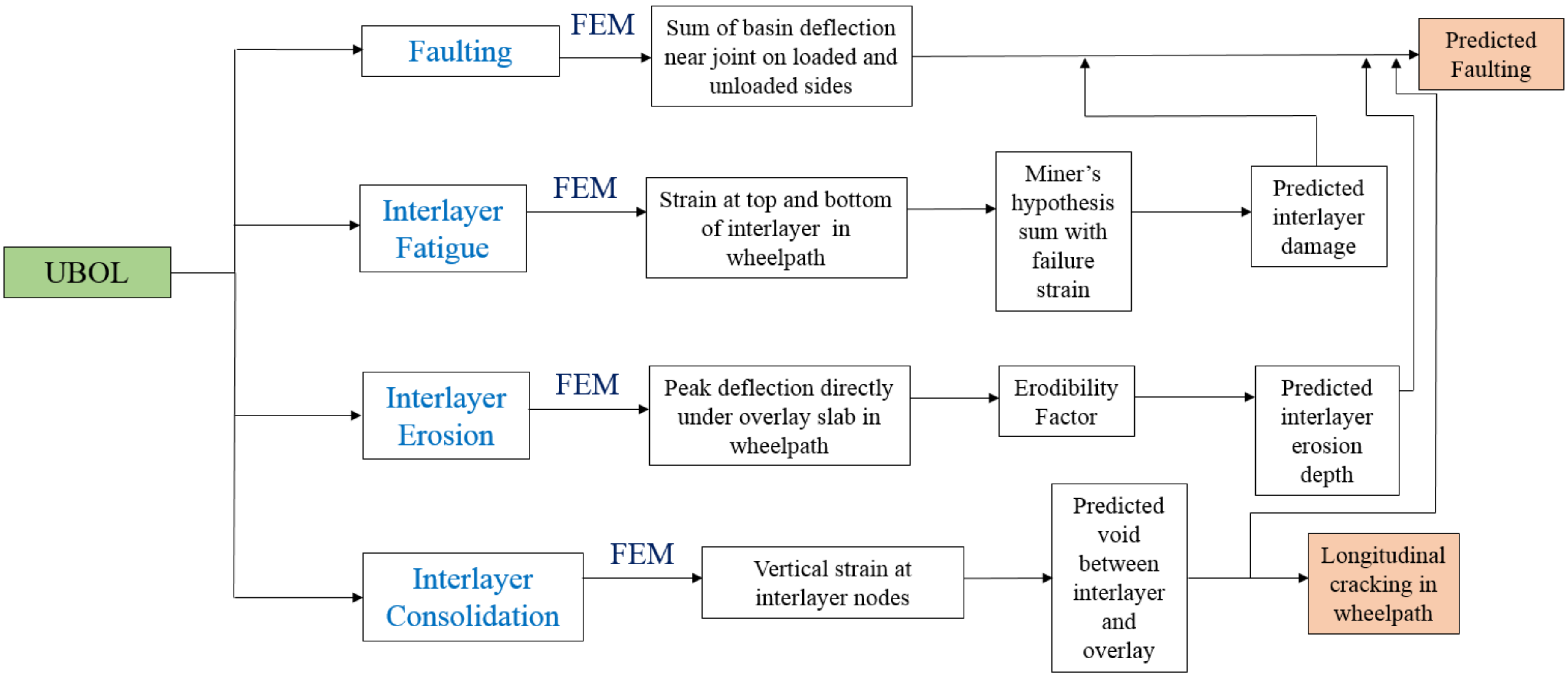


Faulting

- Occurs in HMA interlayer (not fabric)
- Affected by
  - Fatigue
  - Erosion
  - Consolidation



Faulting prediction framework

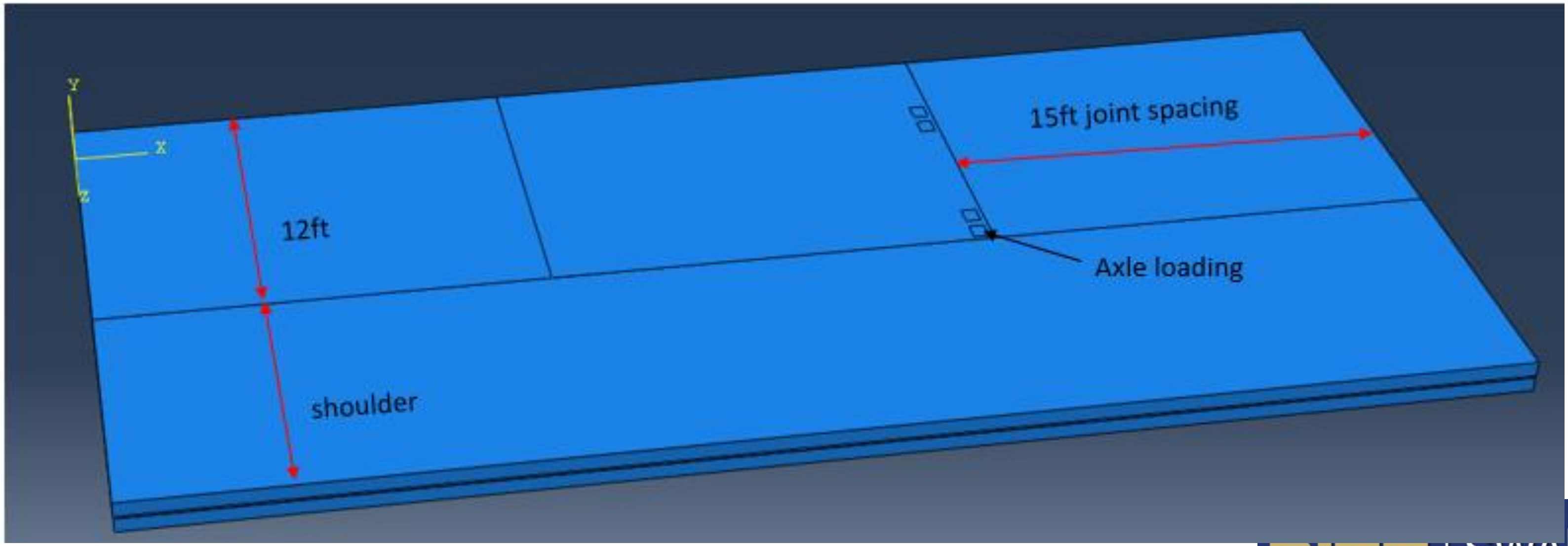


Neural Network development

- FEM results to develop rapid solutions
- NN trained to predict critical responses

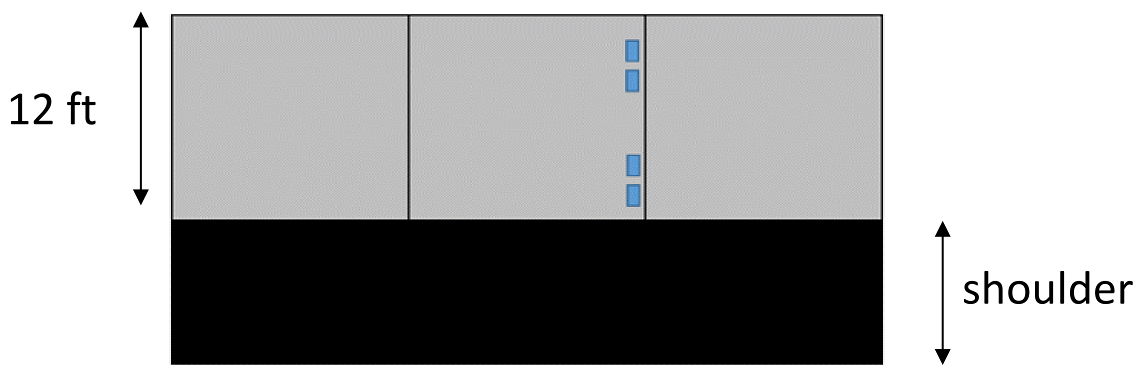
Joint faulting response

- 3D ABAQUS Model
- Model:
  - 3 overlay slabs
  - Shoulder
  - Asphalt Interlayer (no fabric)
  - Existing PCC

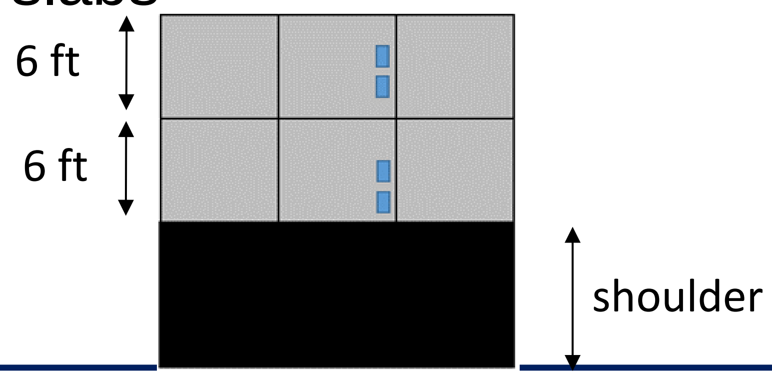


Slab sizes

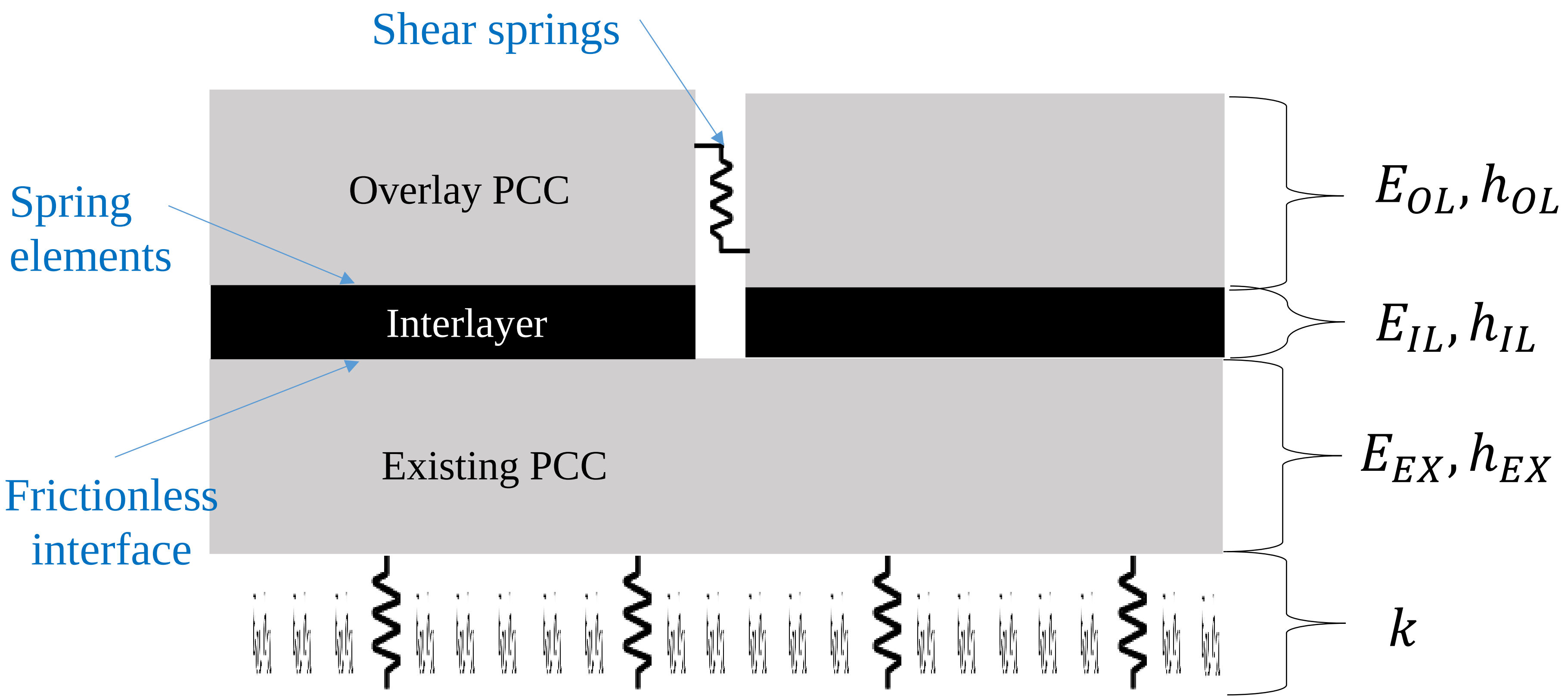
- 3 overlay slabs
- 12 ft lane (jt. spacing = 10, 15, 20 ft)



- 6 ft x 6 ft slabs

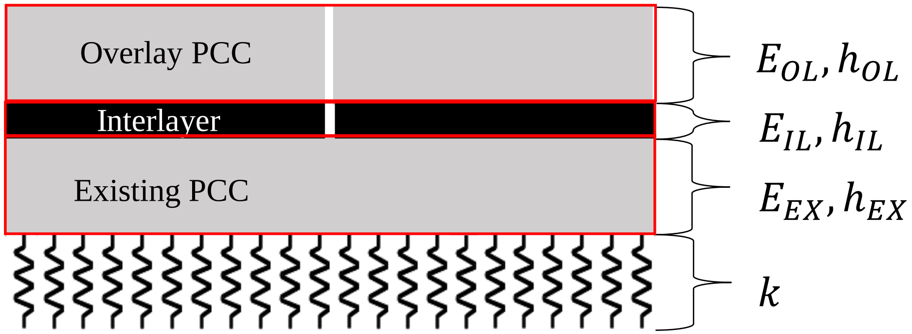


Modeling properties



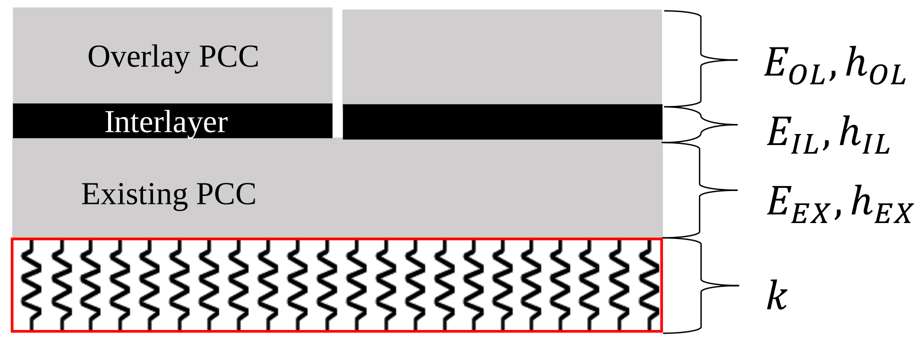
PCC and asphalt layers

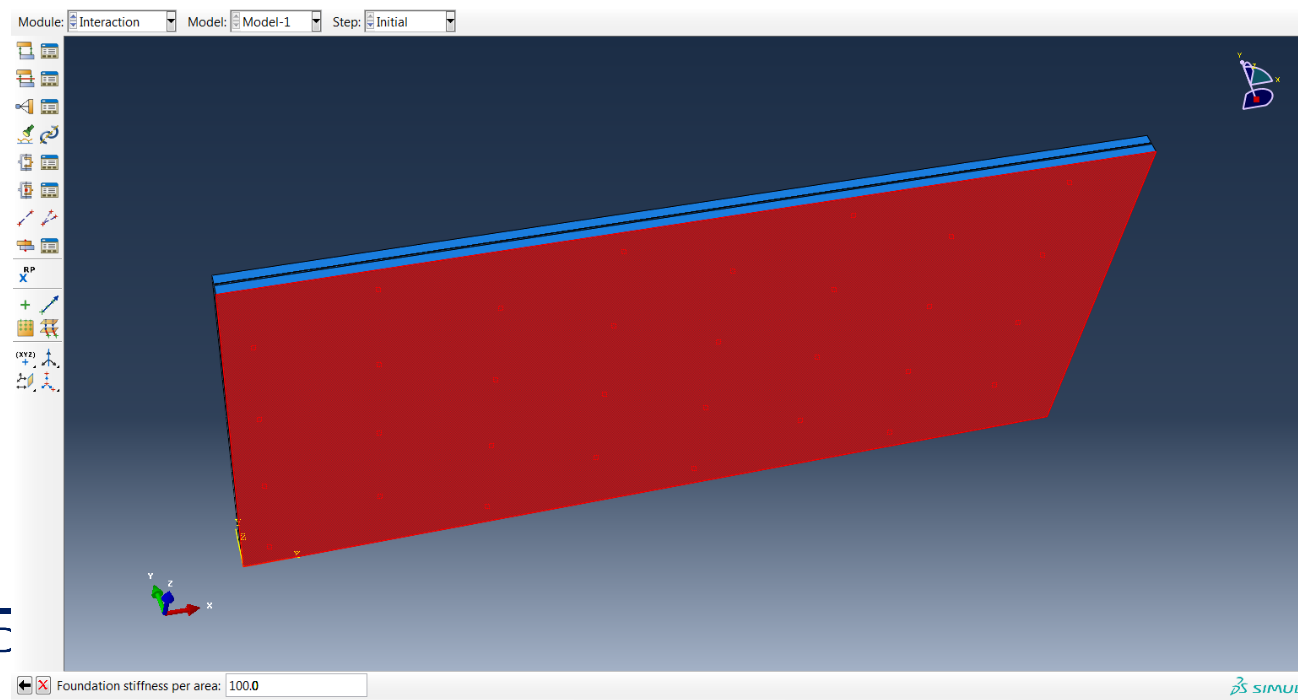
- Elastic solids
  - E
  - μ_{pcc} = 0.18, μ_{hma} = 0.35
- Isotropic linear expansion
  - α_{pcc}, α_{hma}
- 20 node brick elements
  (C3D20 quadratic element)



Foundation support

- Winkler foundation





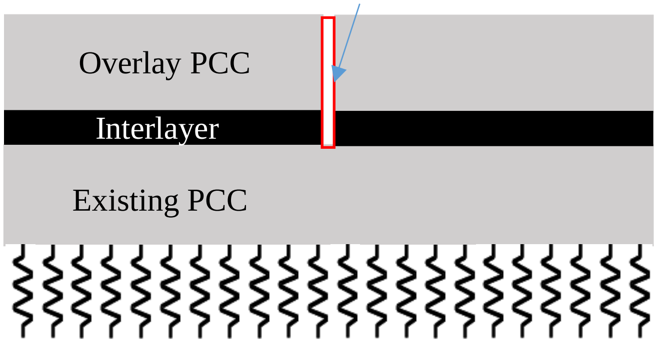
Transverse joints

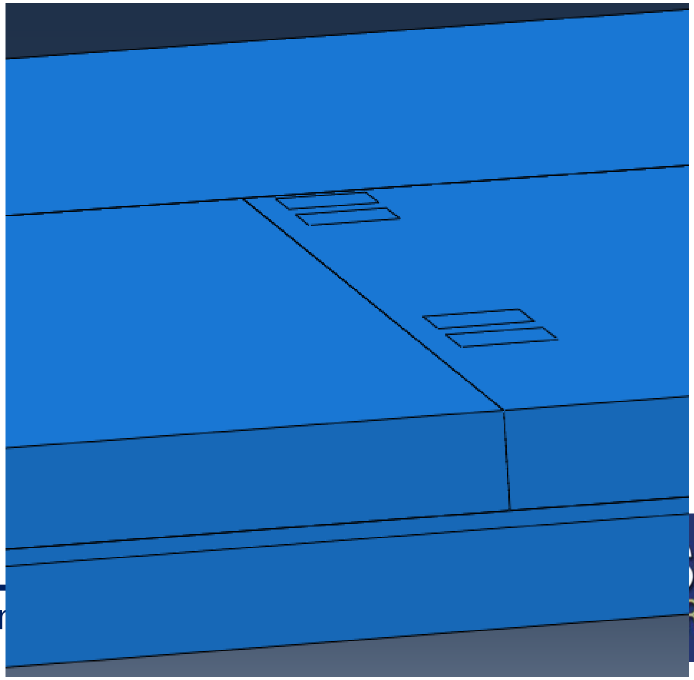
- Joint through overlay and asphalt

- Load transfer in PCC only
  - Shear springs at overlay nodes
  - No load transfer through interlayer
  - Only dof in vertical direction
  - Simulate aggregate interlock and doweled joints

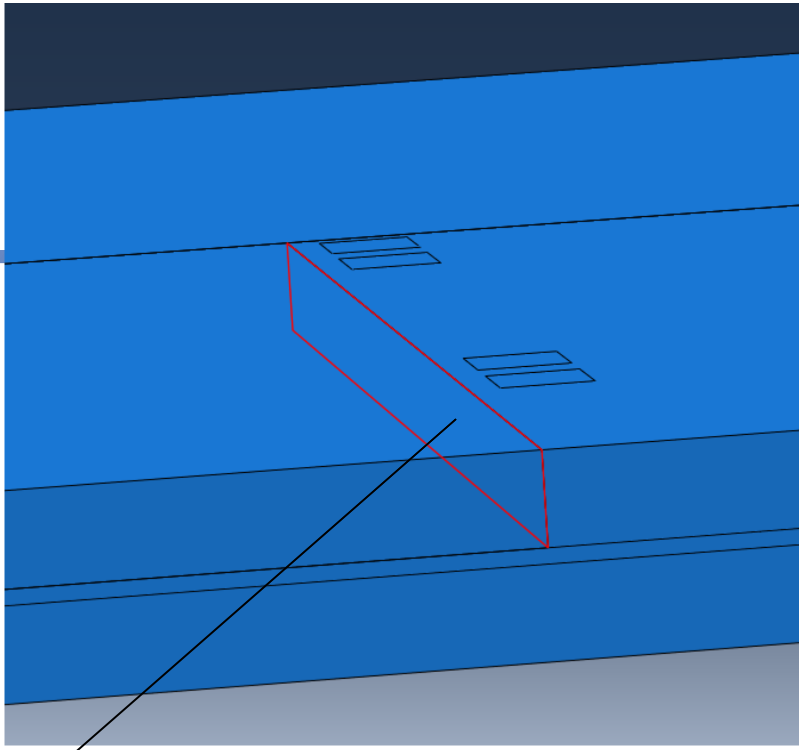
- Hard contact between joint surfaces - simulate compression effects

Shear spring for overlay load transfer

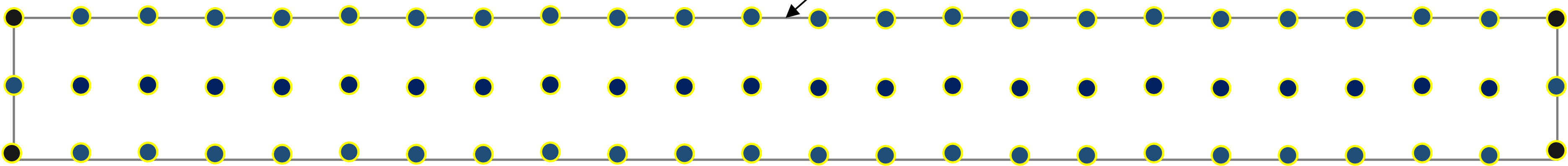




Transverse joints



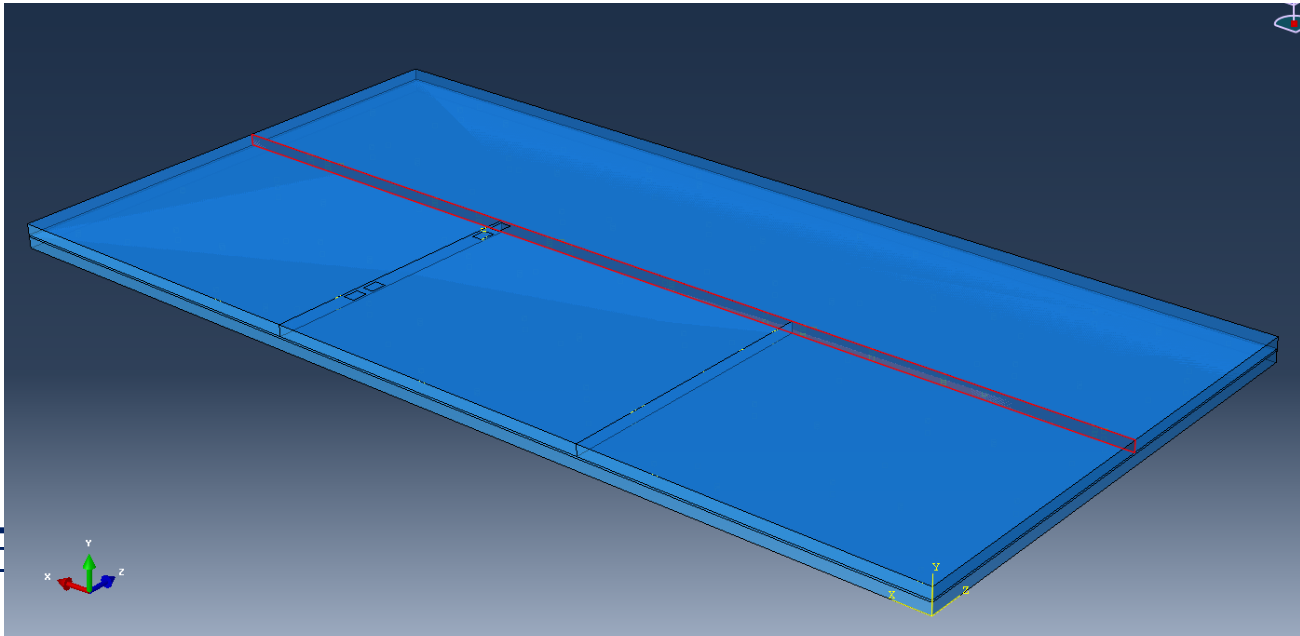
- 3 spring stiffnesses
  - Corner nodes - K
  - Edge nodes - 2K
  - Interior nodes - 4K



Longitudinal joints

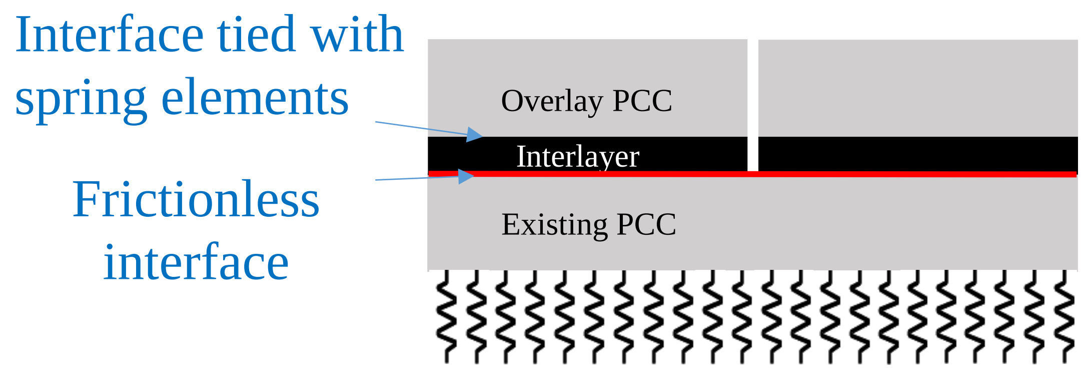
- Lane-shoulder joint
  - Asphalt shoulder – LTE = 0%
  - Tied PCC shoulder – LTE ~ 90%

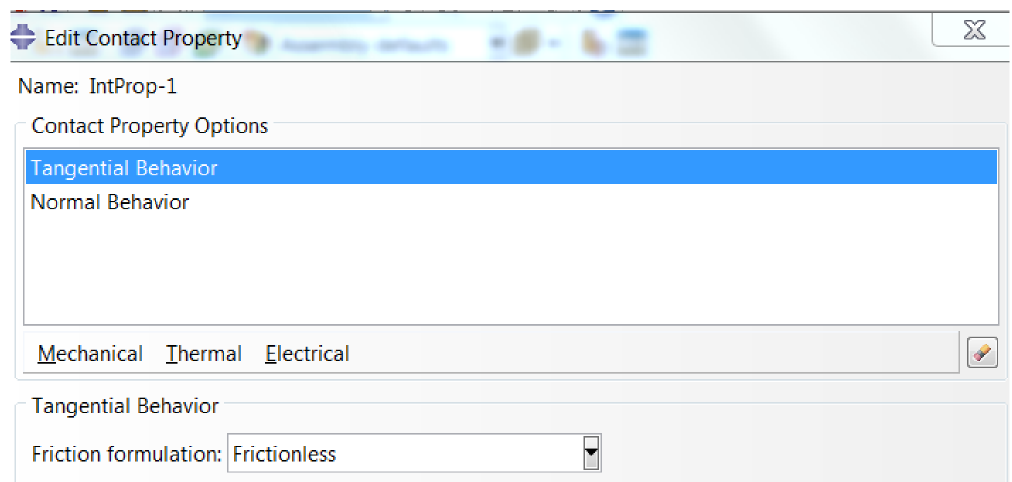
- 6 ft x 6 ft longitudinal joint
  - Longitudinal LTE = Transverse LTE (undoweled jt)
  - Longitudinal LTE < Transverse LTE (doweled jt)



Interface bond: existing-interlayer

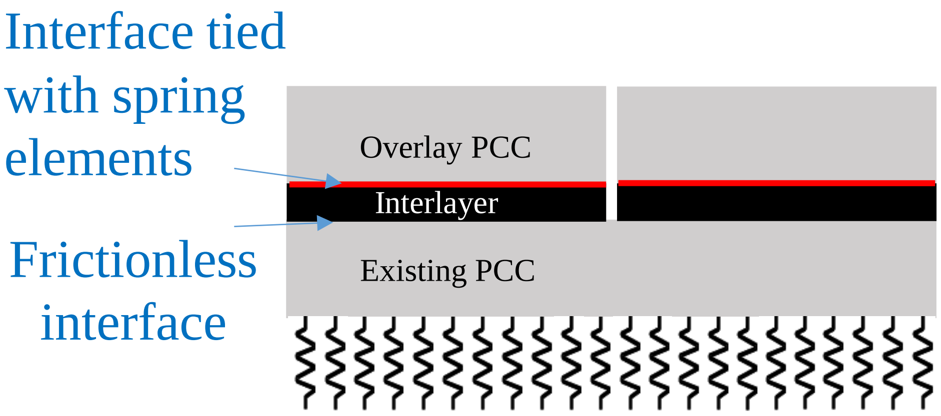
- Interaction between top of existing and interlayer:
  - Treated as frictionless
  - Full slip between two surfaces





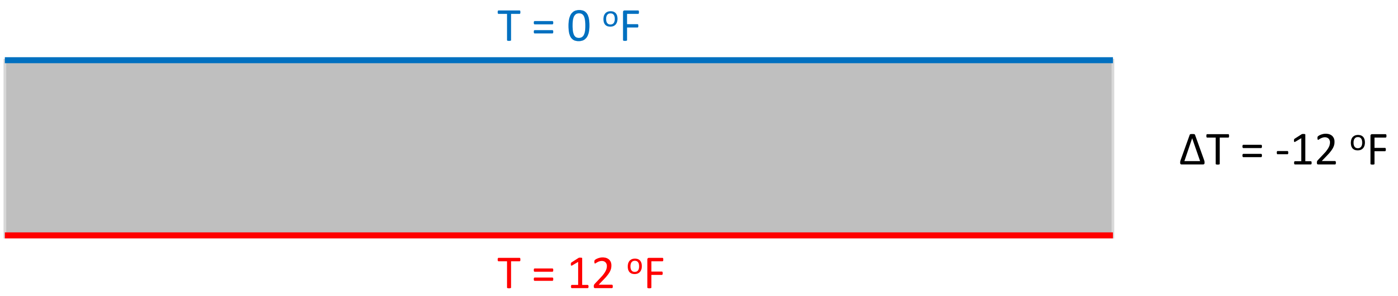
Interface bond: overlay-interlayer

- Interaction between overlay and interlayer:
  - Treated as fully bonded
  - Achieved with stiff springs connecting nodes of parts
  - Response can be modified to achieve debonding and to introduce gap between overlay and interlayer



Thermal loads

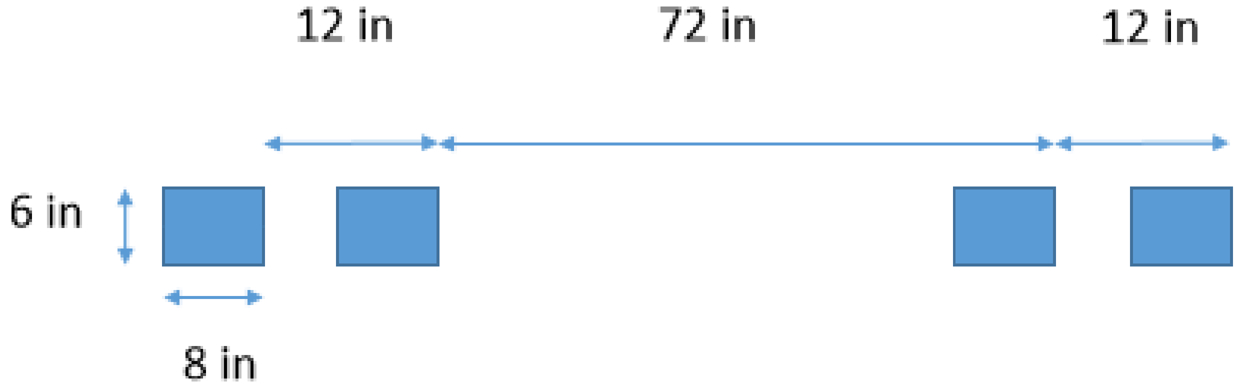
- Uniform distributed temperature loads
  - Predefined field on top/bottom PCC surfaces
  - 3 temperature differences considered
    - -12, 0, 24 °F



- Equivalent strain will be used to convert nonlinear temperature differences

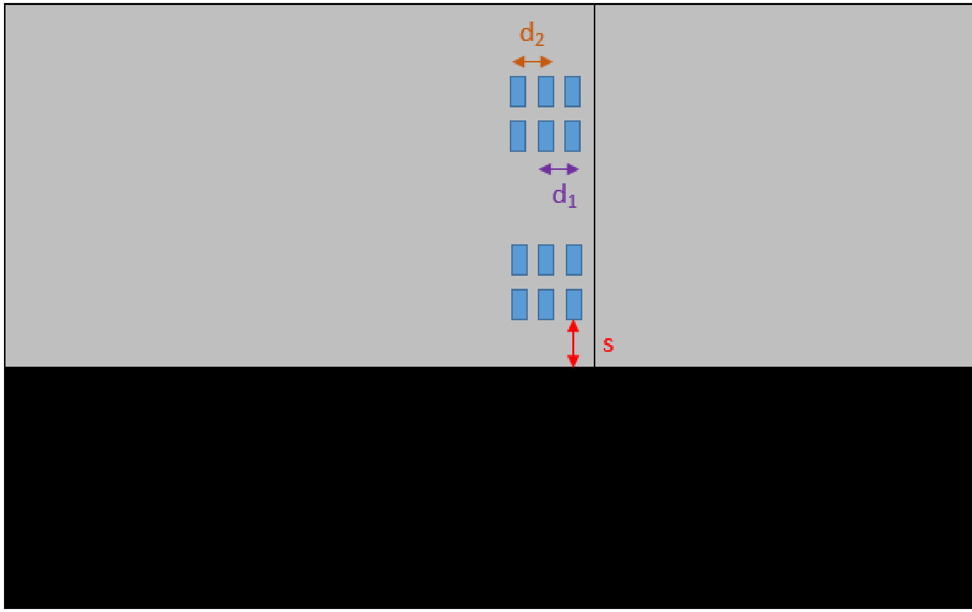
Axle configuration

- Tire footprint of 6 in x 8 in
- Single, tandem, and tridem
- Wheel wander



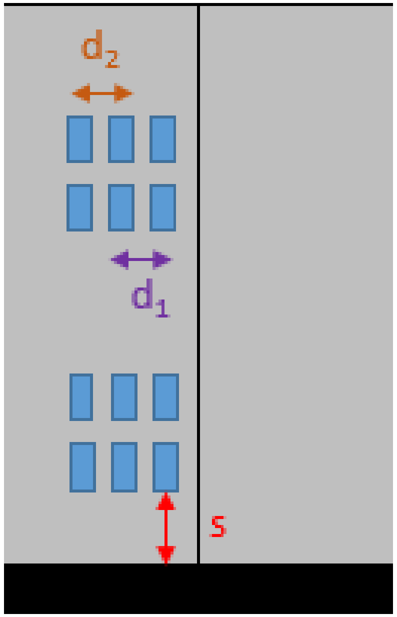
Axle type and wheel wander

- s = wheel wander
  - 0, 2, 6, 12, 36 in
- d_1 = tandem axle spacing
  - 0, 40 in
- d_2 = tridem axle spacing
  - 0, 40 in



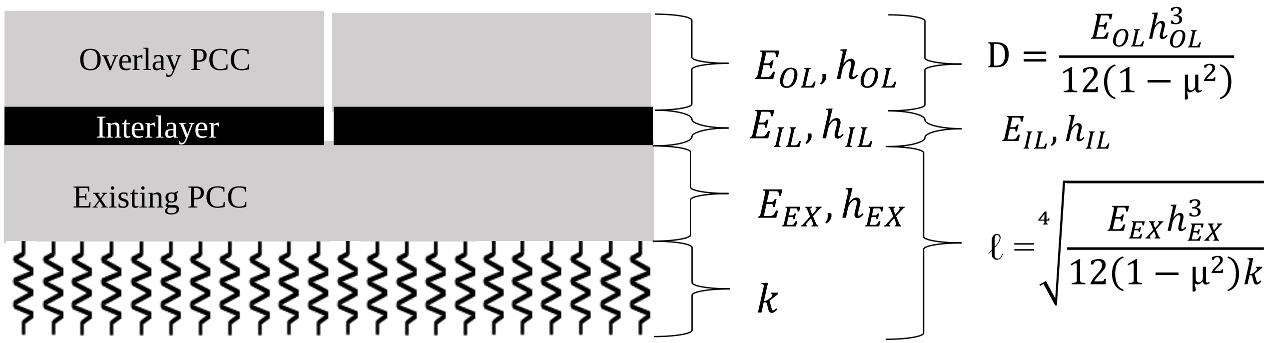
Load magnitude

- Single axles
  - 0 – 45,000 lbs (15,000 lb increment)
- Tandem axles
  - 0 – 90,000 lbs (30,000 lb increment)
- Tridem axles
  - 0 – 120,000 lbs (40,000 lb increment)



- Gravity load
  - Uniform pressure on surface
  - Equal to weight of structure

Reduction of parameters



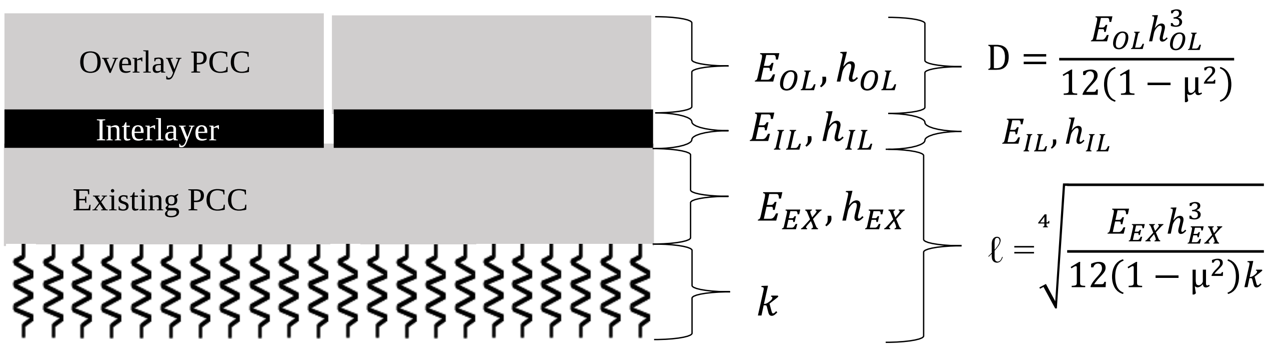
- Overlay represented w/ flexural stiffness, D

$$\mathrm{D} = \frac{E_{OL} h_{OL}^3}{12(1-\mu^2)}$$

- Existing PCC & foundation represented w/ radius of relative stiffness, ℓ

$$\ell = \sqrt[4]{\frac{E_{EX} h_{EX}^3}{12(1-\mu^2)k}}$$

Reduction of parameters

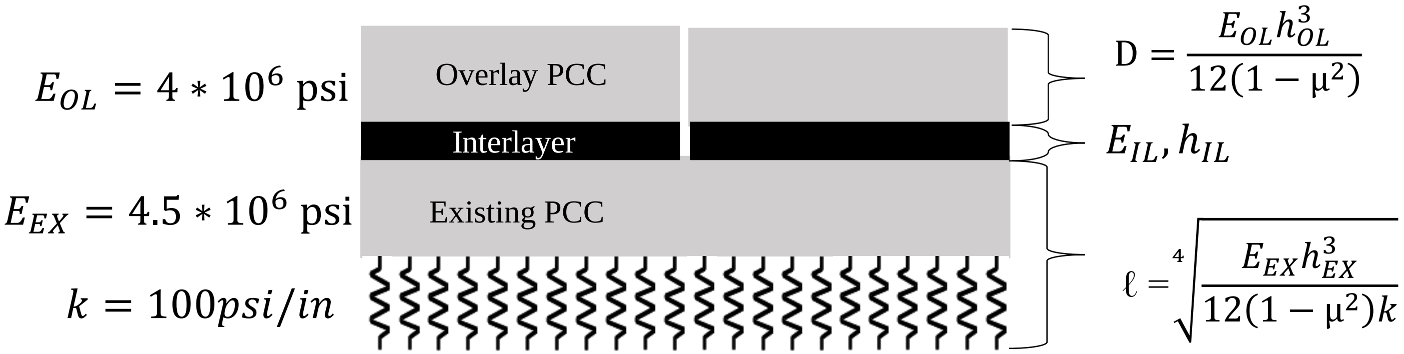


- PCC E and k-value kept constant
- Change h of PCC layers to change D_{OL} and ℓ

Range of parameters

Parameter	Range				
Existing slab and foundation, l (in)	20	35	50	65	80
PCC Poisson's ratio	0.18				
Overlay Flexural Stiffness, D (#-in)	2.00E+07	2.40E+08	4.60E+08	6.80E+07	9.00E+08
Overlay PCC jt spacing (ft)	6	10	15	20	
Overlay PCC CTE (in/in/°F)	3.80E-06	5.50E-06			
Overlay Temp Difference (°F)	-12	0	24		
Interlayer Thickness (in)	2				
Interlayer Stiffness (psi)	100000	400000	700000	1000000	
Interlayer Poisson's ratio	0.35				
Interlayer CTE (in/in/°F)	6E-06				
Lane shoulder LTE (%)	Tied PCC	Asphalt			
Wheel wander (in)	0	2	6	12	36
Single axle (lb)	0-45,000 (15 kip increment)			Fractional	
Tandem axle (lb)	0-90,000 (30 kip increment)			Factorial	
Tridem axle (lb)	0-120,000 (40 kip increment)				

Range of parameters



- D and ℓ ranges result in wide range of slab thicknesses considered:
  - $h_{OL} = 3.9 - 13.8$ in
  - $h_{EX} = 3.5 - 22$ in

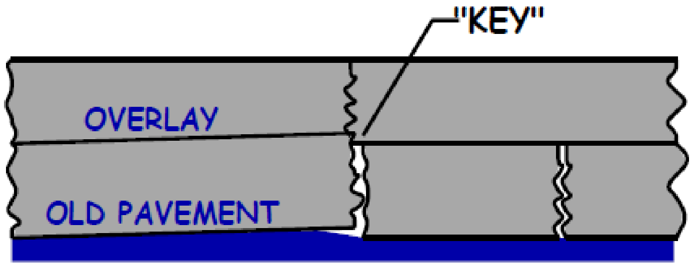
Thank You

Any Questions?

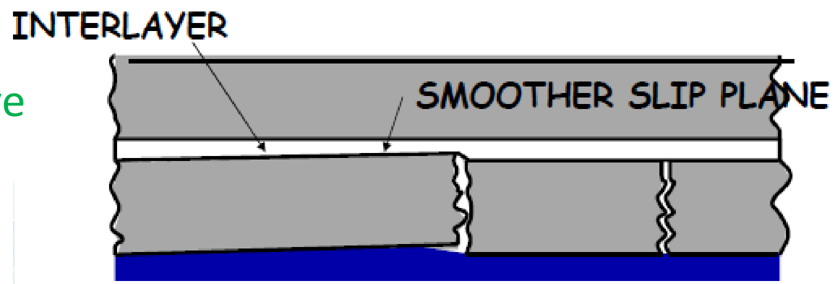
Keying in overlay

- How much faulting can be in existing pavement before nonwoven fabric no longer prevents keying?
  - Function of fabric thickness

Reflective Cracking



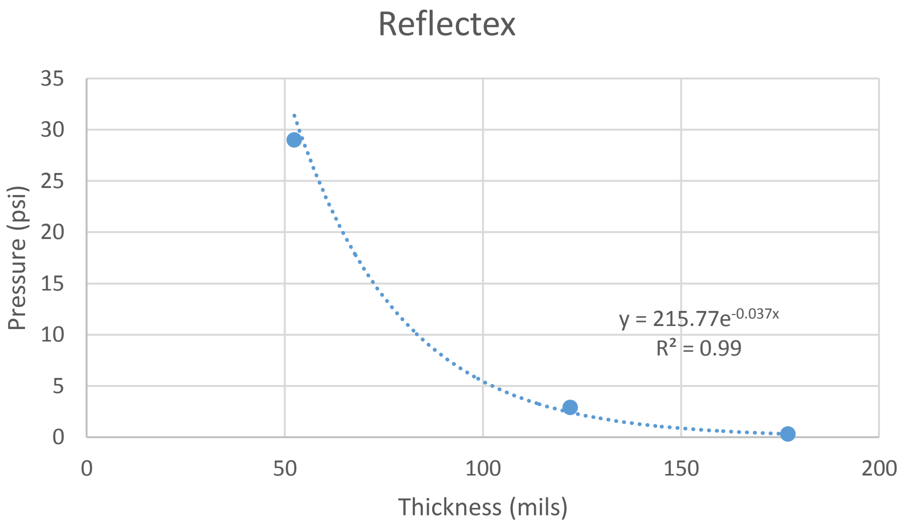
No reflective Cracking



Photos courtesy of John Donahue of MoDOT

Reflectex fabric thickness

- ASTM D5199 – relate pressure to overlay thickness



Overlay Thickness (in)	Thickness (mils)
0.28	177
2.8	122
28	52.4

- Thickness due to self-weight of 6 in overlay ~ 96 mils