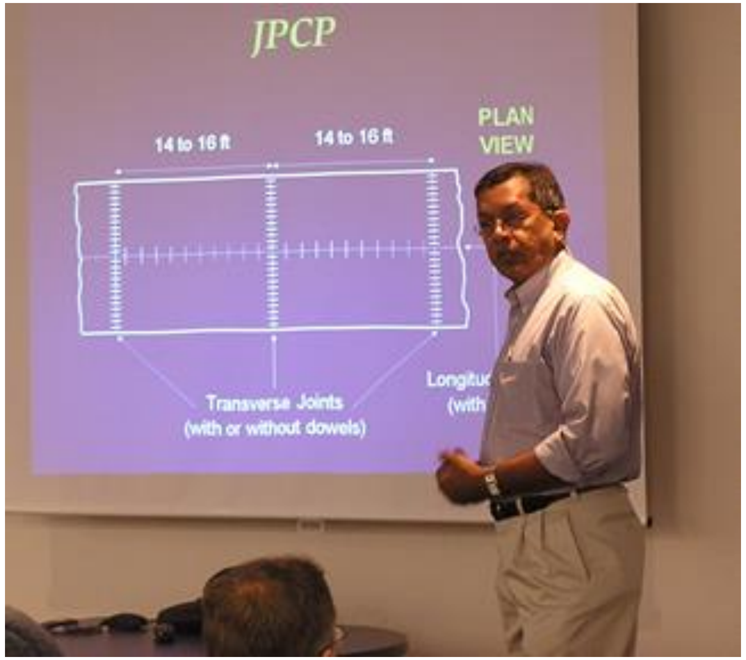
Designing Concrete Overlays

ACI Virtual Concrete Convention



Julie M. Vandenbossche, Ph. D., P. E.
William Kepler Whiteford Professor
University of Pittsburgh
-April 1, 2021-

Dr. Shiraz Tyabji

Field Observations

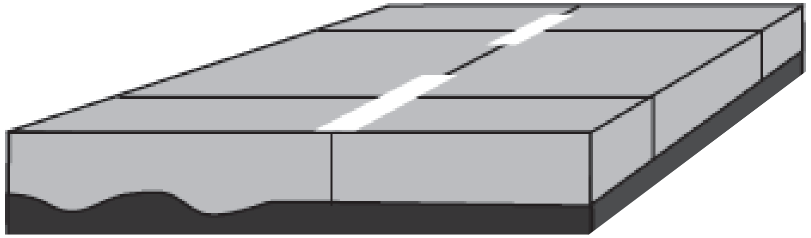
Dr. Shiraz Tyabji

Leadership and Service

International Info. Exchange

Evolution in overlay design

Whitetopping



https://intrans.iastate.edu/app/uploads/2018/09/overlay_construction_doc_dev_guide_w_cvr.pdf

First Whitetopping

- South 7th street in Terre Haute, Indiana - 1918
- Existing flexible pavement was overlaid with 3 - 4 in. of reinforced concrete

During 40's and 50's -

- Used to upgrade military & civil airports

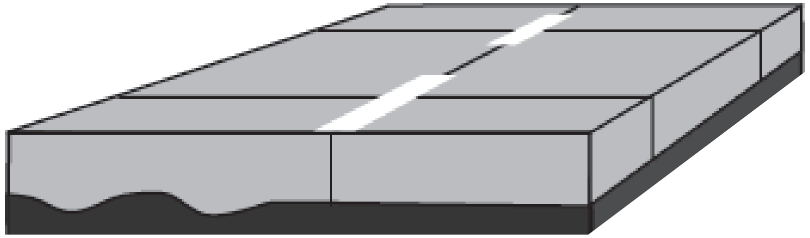
Highway use

- Started approx. 1960
- Types have included JPCP, JRCP, CRCP, FRC

-Jim Mack

Evolution in overlay design

Whitetopping



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AASHTOWare Pavement ME Design

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-Jim Mack

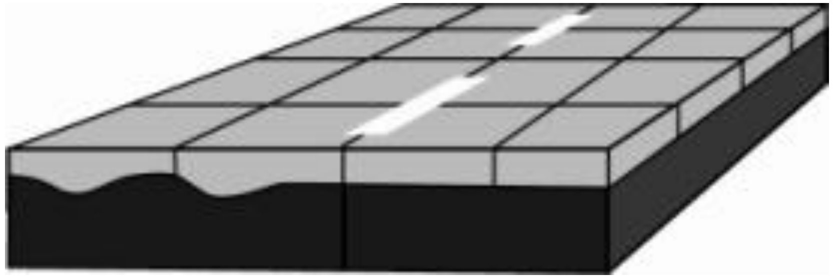
Design as a JPCP on HMA base.

Evolution in overlay design

Ultra-thin whitetopping (UTW)

Typ.2-4 in

UTW Calculator
Mack et al



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Thin whitetopping (TWT)
Typ. 4-6 in

Colorado Design Procedure
CTL (Wu Sheehan & Tyabji)

- Pavement instrumentation
- 3-D FE

Evolution in overlay design

Ultra-thin whitetopping (UTW)

Typ.2-4 in

UTW Calculator
Mack et al

BCOA ME
University of Pittsburgh

- Additional failure modes
- Climatic considerations
- Expanded 3-D FE models
- Performance data

Colorado Design Procedure
CTL (Wu Sheehan & Tyabji)

- Pavement instrumentation
- 3-D FE
- Trans. cracking

Thin whitetopping (TWT)

Typ. 4-6 in

Evolution in overlay design

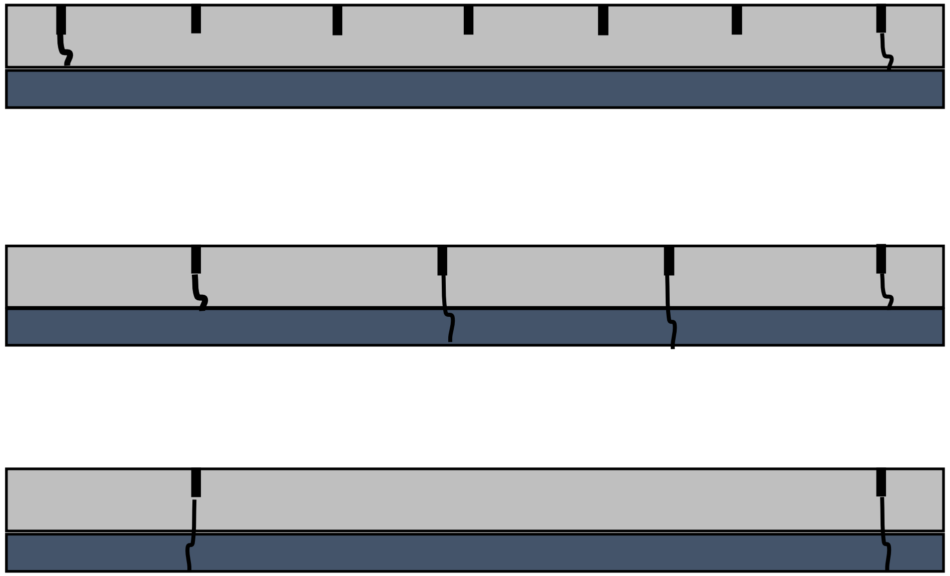
Panel Thickness	Panel size	Failure Mode	Design Procedure
≤ 6.5 in	Small slabs (≤ 4.5 ft)	1. Corner Breaks	1. BCOA - ME 2. ACPA
	Midsize slabs (4.5 to 8 ft)	1. Long. Cracks 2. Diagonal Cr	nt ME-SJPCP
	Larger slab (10	) (wheelpath) verse Cracks	1. BCOA - ME 2. Pavement ME-JPCP* 3. CoDOT
≥ 6.5 in	width	1. Transverse Cracks	Conventional design 1. AASHTO '93 2. Pavement ME 3. Etc....

Faulting not considered…yet

*Pavement ME does not design against longitudinal cracks for full lane width slabs

Incorporating a faulting model

Frequency and depth of joint activation ?



- Fiber
- Slab size
- PCC/asphalt thickness

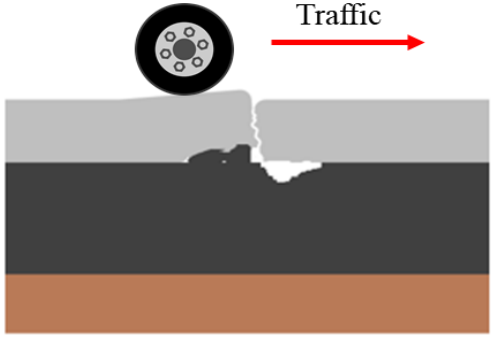
PennDOT and NRRA

Incorporating a faulting model

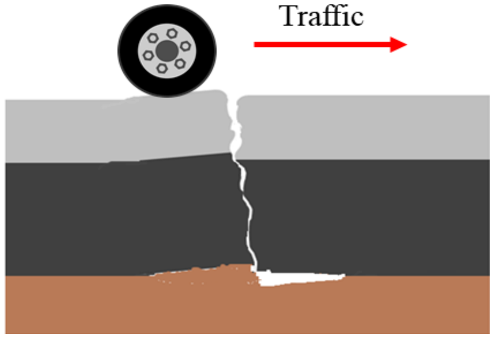
1. Flexural stiffness ratio (FSR)

$$Flexural\ stiffness = D_i = \frac{E_i h_i^3}{12(1-\mu_i^2)}$$

$$FSR = \frac{D_{PCC}}{D_{Asphalt}}$$



or



2. Panel size
   - < 4.5 ft
   - 4.5 ft - 8.5 ft
   - Full lane width

Criteria

Midsize slabs (4.5 ft - 8.5 ft)

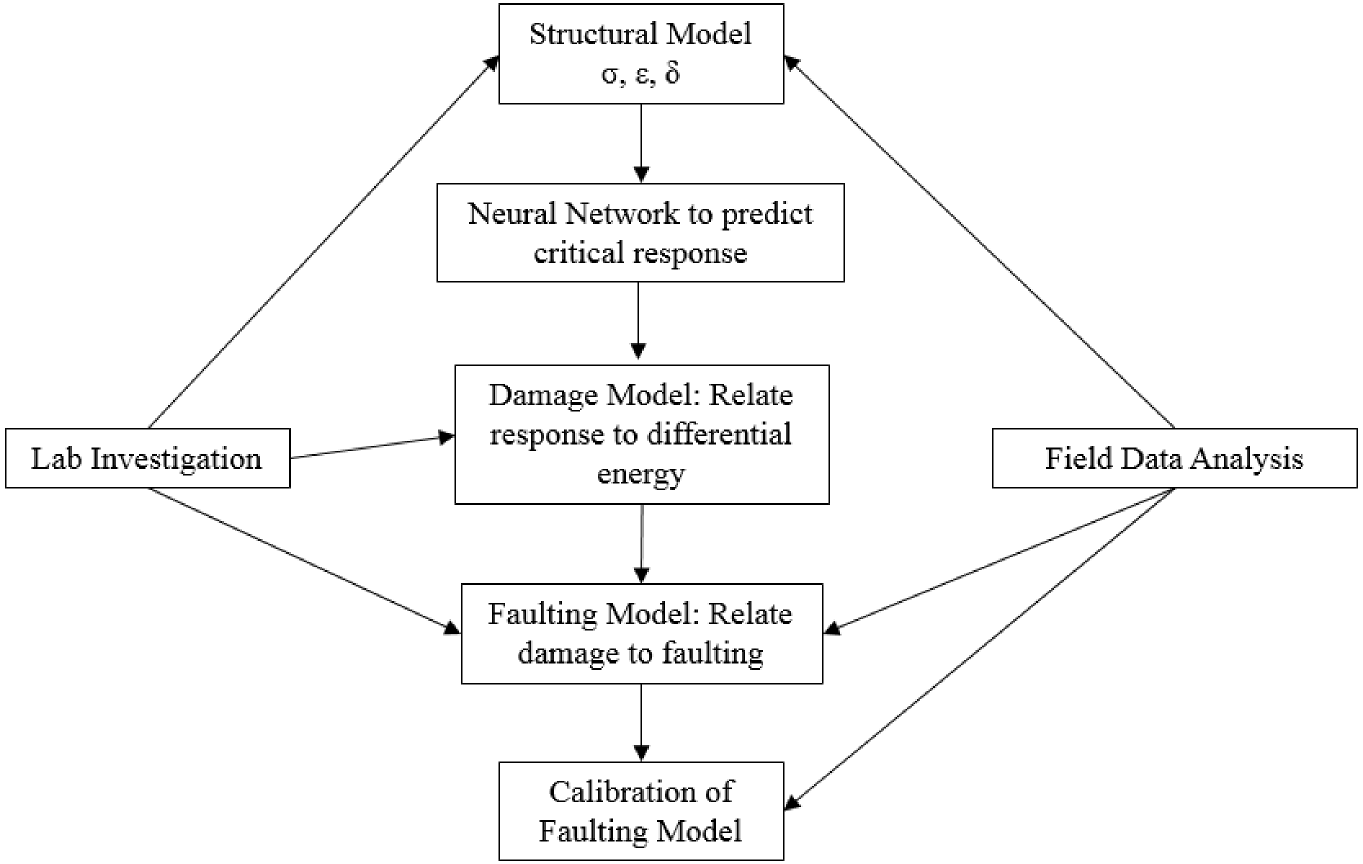
- FSR≤ 0.4: PCC only
- FSR> 0.4: Partial depth with every 6th joint full-depth

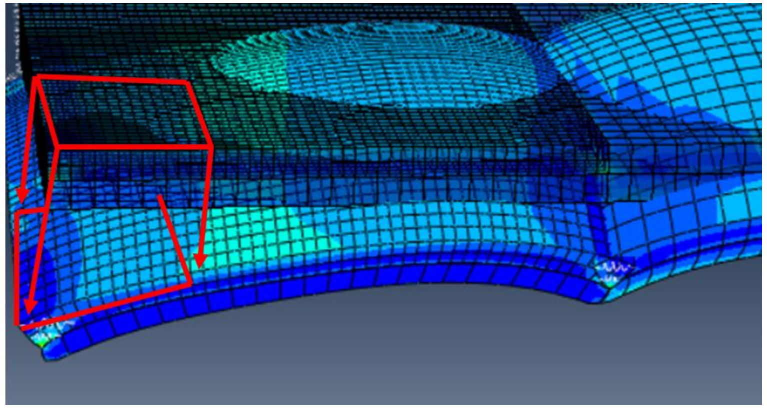
Full lane width:

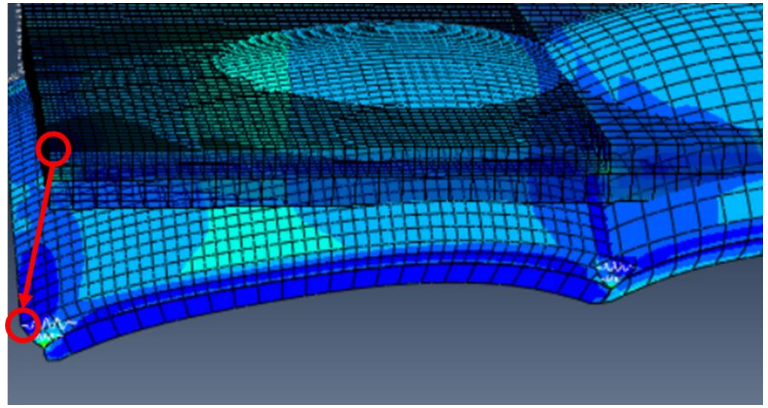
- Full-depth for every joint

DeSantis et al. 2016 (ICCP 2016)

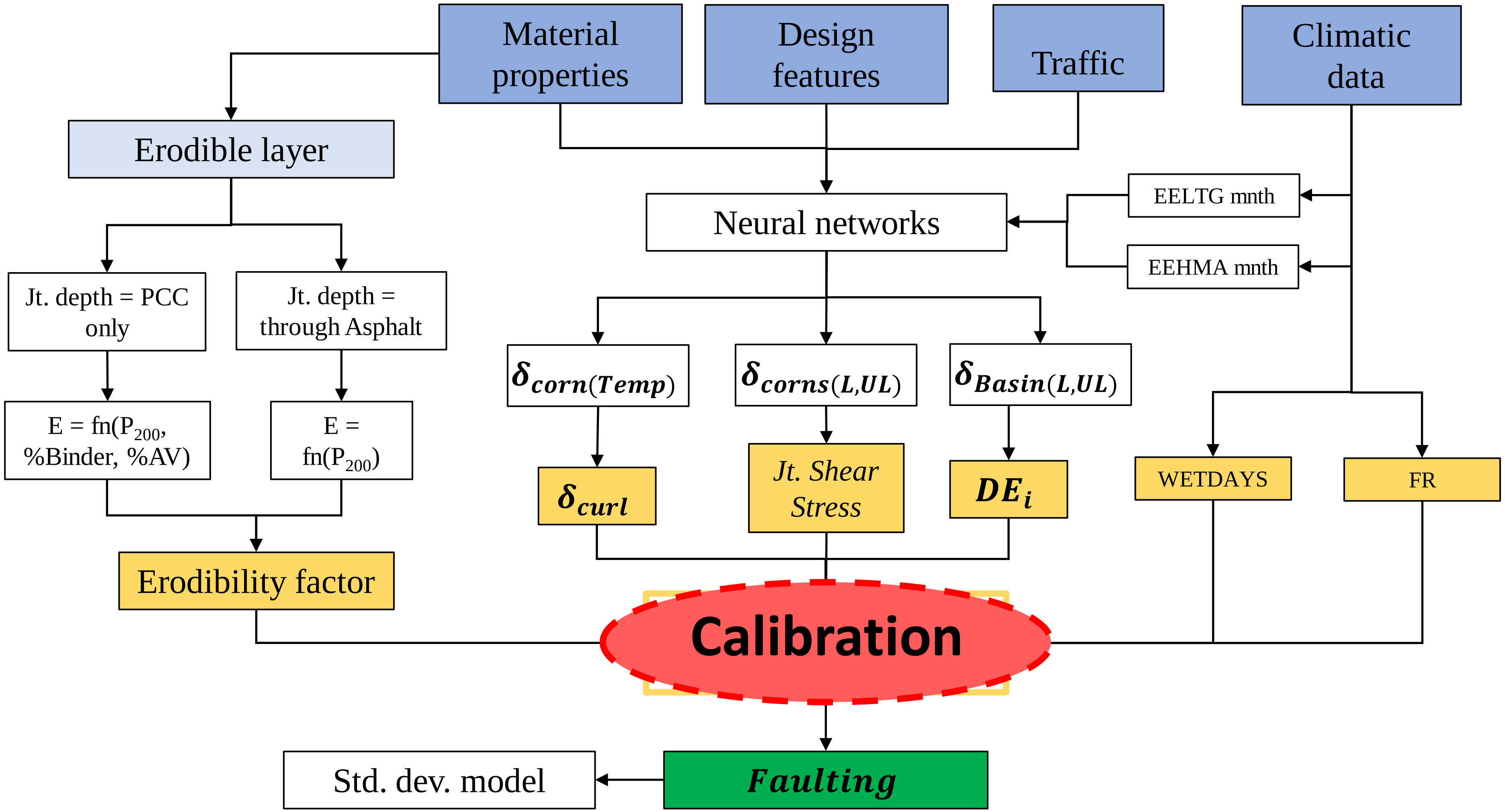
Incorporating a faulting model







Incorporating a faulting model



Incorporating a faulting model

$$\boldsymbol{F_i = F_{i-1} + C_7 * C_8 * DE_i * [C_5 * E]^{C_6}}$$

$$\boldsymbol{\Delta Fault_i = \left(C_3 + C_4 * FR^{0.25}\right) * (F_{i-1} - Fault_{i-1}) \quad * C_8 * DE_i}$$

$$\boldsymbol{Fault_i = Fault_{i-1} + \Delta Fault_i}$$

F_0 =initial maximum mean transverse joint faulting (in)
FR = base freezing index (% time that the top of the base is below freezing (<32°F))
δ_{curl} = max mean monthly PCC upward slab deflection due to curling
E = erosion potential of interlayer: f(% binder content, % air voids, P_{200} for partial depth)
P_{200} = Percent of interlayer aggregate passing No. 200 sieve
$WETDAYS$ = Average number of annual wet days (> 0.1 in of rainfall)
F_i =maximum mean transverse joint faulting for month i (in)
F_{i-1} = maximum mean transverse joint faulting for month i-1 (in)
DE_i = Differential energy density of accumulated during month i
$\Delta Fault_i$ = incremental monthly change in mean transverse joint faulting during month i (in)
$C_1 \ldots C_8$ = Calibration coefficients
$Fault_{i-1}$ = mean joint faulting at the beginning of month i (0 if i = 1)
$Fault_i$ = mean joint faulting at the end of month i (in)

Incorporating a faulting model

$$F_i = F_{i-1} + C_7 * C_8 * DE_i * [C_5 * E]^{C_6}$$

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Incorporating a faulting model

Full depth joint activation:

Erodibility index

Assigned integer value
based upon base type

1 – extremely erosion resistant

to

5 – very erodible

MEPDG Documentation Appendix JJ

Erodibility Class	Material Description and Testing
1	(a) Lean concrete with approximately 8 percent cement; or with long-term compressive strength > 2,500 psi (>2,000 psi at 28-days) and a granular subbase layer or a stabilized soil layer, or a geotextile fabric is placed between the treated base and subgrade, otherwise class 2. (b) Hot mixed asphalt concrete with 6 percent asphalt cement that passes appropriate stripping tests and aggregate tests and a granular subbase layer or a stabilized soil layer (otherwise class 2). (c) Permeable drainage layer (asphalt treated aggregate or cement treated aggregate and with an appropriate granular or geotextile separation layer placed between the treated permeable base and subgrade.
2	(a) Cement treated granular material with 5 percent cement manufactured in plant, or long-term compressive strength 2,000 to 2,500 psi (1,500 to 2,000 psi at 28-days) and a granular subbase layer or a stabilized soil layer, or a geotextile fabric is placed between the treated base and subgrade; otherwise class 3. (b) Asphalt treated granular material with 4 percent asphalt cement that passes appropriate stripping test and a granular subbase layer or a treated soil layer or a geotextile fabric is placed between the treated base and subgrade; otherwise class 3.
3	(a) Cement-treated granular material with 3.5 percent cement manufactured in plant, or with long-term compressive strength 1,000 to 2,000 psi (750 psi to 1,500 at 28-days). (b) Asphalt treated granular material with 3 percent asphalt cement that passes appropriate stripping test.
4	Unbound crushed granular material having dense gradation and high quality aggregates.
5	Untreated soils (PCC slab placed on prepared/compacted subgrade)

Incorporating a faulting model

Partial depth joint activation:

$$\alpha = \log(1 + a * P_{200} + b * \%AV - c * \%Binder)$$

$\alpha =$ Erodibility index

$P_{200} =$ Percent passing No. 200 sieve in interlayer

$\%AV =$ Percent air voids in asphalt interlayer

$\%Binder =$ Percent binder in asphalt interlayer

$a, b, c =$ Calibration coefficients (8.7346, 1.6989, 1.8323)

$$E = \begin{Bmatrix} (a * \alpha^2 - b * \alpha + c) & \textit{Undoweled Pavements} \\ (d * \alpha^2 - e * \alpha + f) & \textit{Doweled Pavements} \end{Bmatrix} \alpha > 1.16$$

$$E = \begin{Bmatrix} (h * \alpha) & \textit{Undoweled Pavements} \\ (i * \alpha) & \textit{Doweled Pavements} \end{Bmatrix} \alpha < 1.16$$

$a \ldots i =$ Calibration coefficents

Incorporating a faulting model

Full depth joint activation:

Not finalized

	Values for different models		
	BCOA		
Coefficient	FULL	PCC ONL[illegible]	[illegible]avement ME
CDOWEL	7*Diam.Dow.	0.7[illegible]	-
C1	1.2[illegible]	[illegible]	1.29
C2	[illegible]	[illegible]	1.1
C3	[illegible]	[illegible]01725	0.001725
C[illegible]	[illegible]	0.0008	0.0008
C5[illegible]	[illegible]-04	0.05	250
C6	4.215	2.4	0.4
C7	0.90	3.562	1.2
C8[2]	1/(5x10^5)	1/(5x10^5)	400

[1]Different Erosion model
[2]Previous model used C8 as dowel damage coefficient not used for calibration

Unbonded Concrete Overlays (UBOL)

Existing concrete pavement

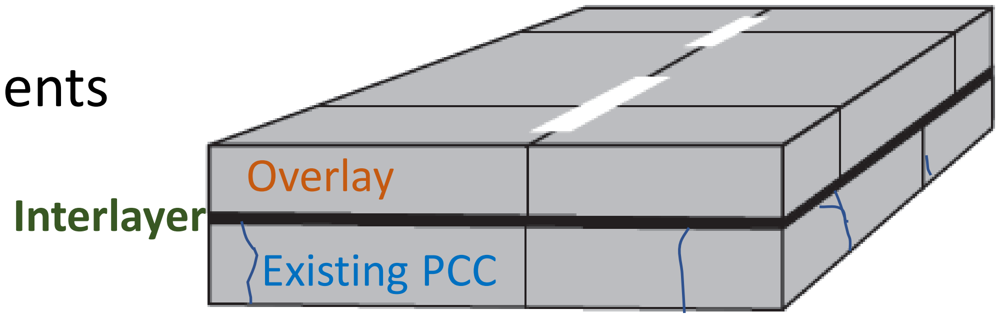
- Moderately to significantly deteriorated pavements
  - Few, if any, pre-overlay repairs required
- Stable and uniform support layer

Interlayer

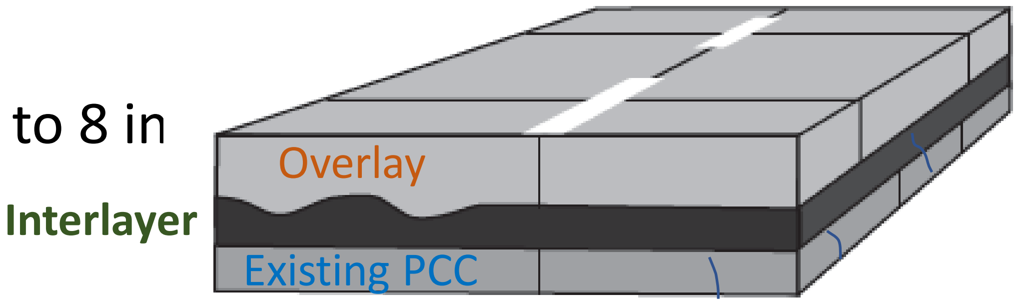
- HMA or nonwoven geotextile fabric

Overlay

- Thicker than bonded concrete overlays – typ. 6 to 8 in
- Durable surface
- Increased structural capacity



Existing concrete pavement



Composite pavement

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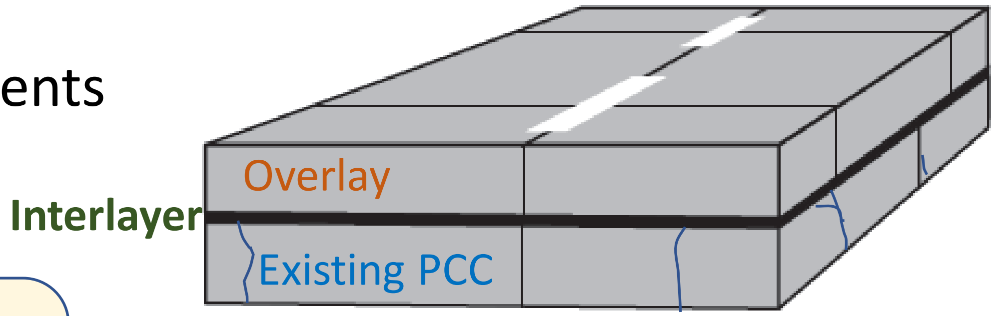

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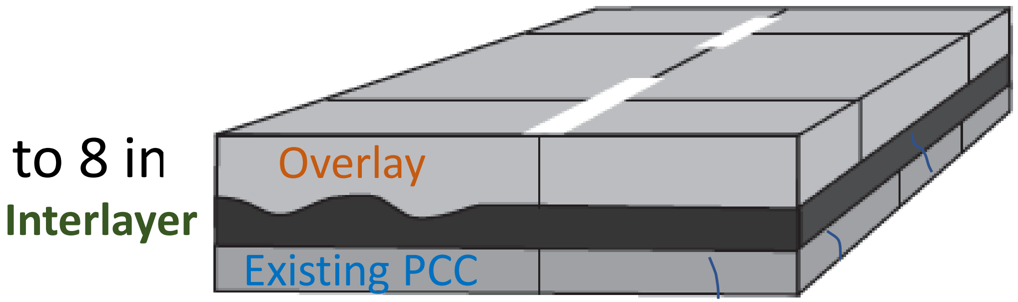


Composite pavement

Desirable interlayer characteristics

5 Steps to Success

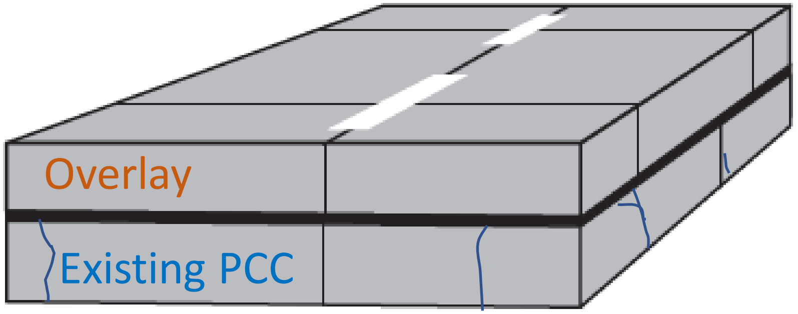
1. Balance permeability and strength
2. Erosion resistant mix (resistant to stripping)
3. Ensure proper compaction is achieved for AC interlayers
4. Keep moisture out of joints (seal/fill)
5. Provide a drainage path for water to exit pavement

Accounted for in Pitt UBOL Design Procedure

Best Practices

- Construction
- Maintenance
- Design

Overlay design



TPF(5)-169 - Development of an Improved Design Procedure for Unbonded Concrete Overlays:

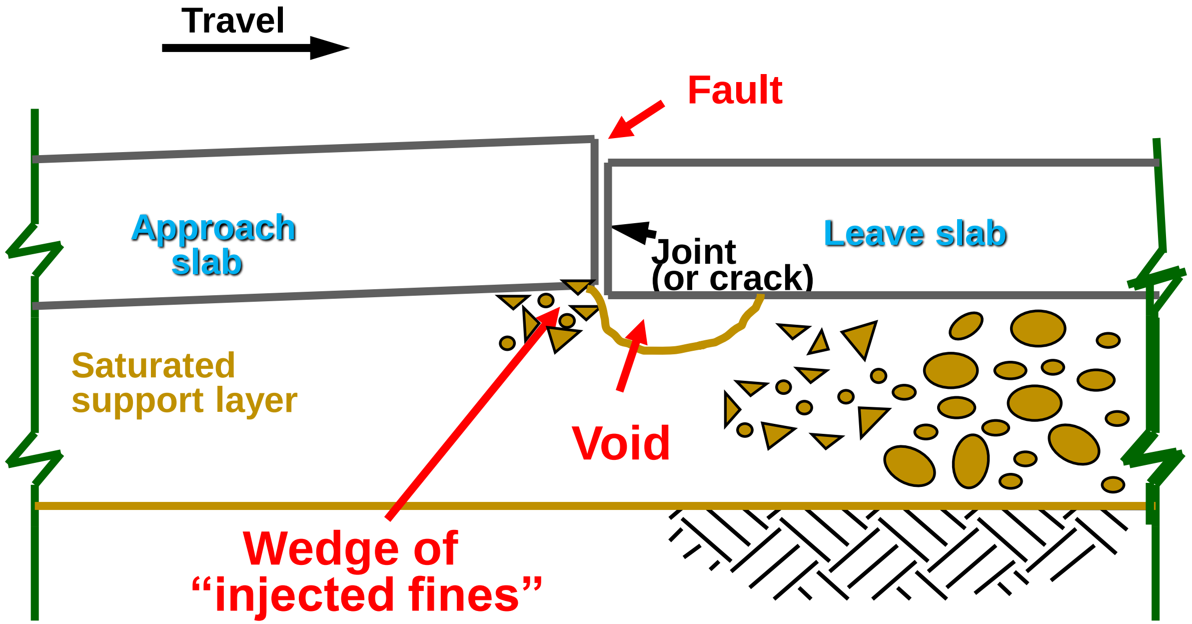
<u>Primary Goal:</u>
Incorporate Effect of Interlayer on Performance

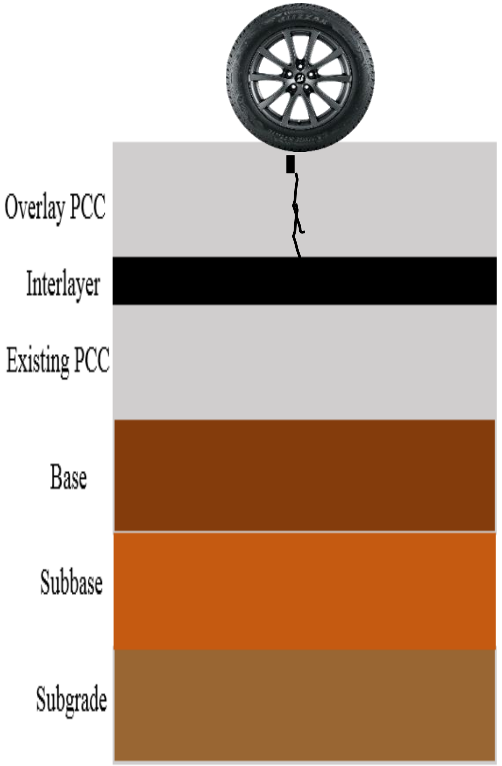
AASHTOWare Pavement ME Design

Do NOT consider effect of interlayer on performance

UBOL Design - Faulting

Pavement Interactive





UBOL Design

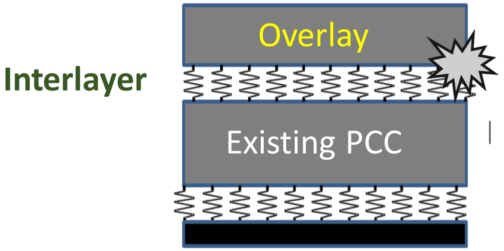
Failure type:

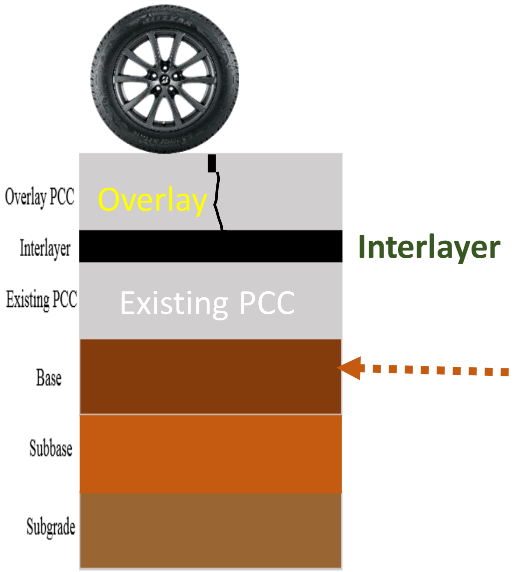
Cracking

- Transverse fatigue cracking : Pavement-ME & Pitt UBOL ME
- Corner/longitudinal cracking due to transverse joint interlayer damage: Pitt UBOL ME

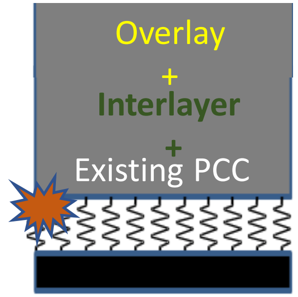
Faulting

Pitt UBOL ME – Source of fines: **Interlayer**

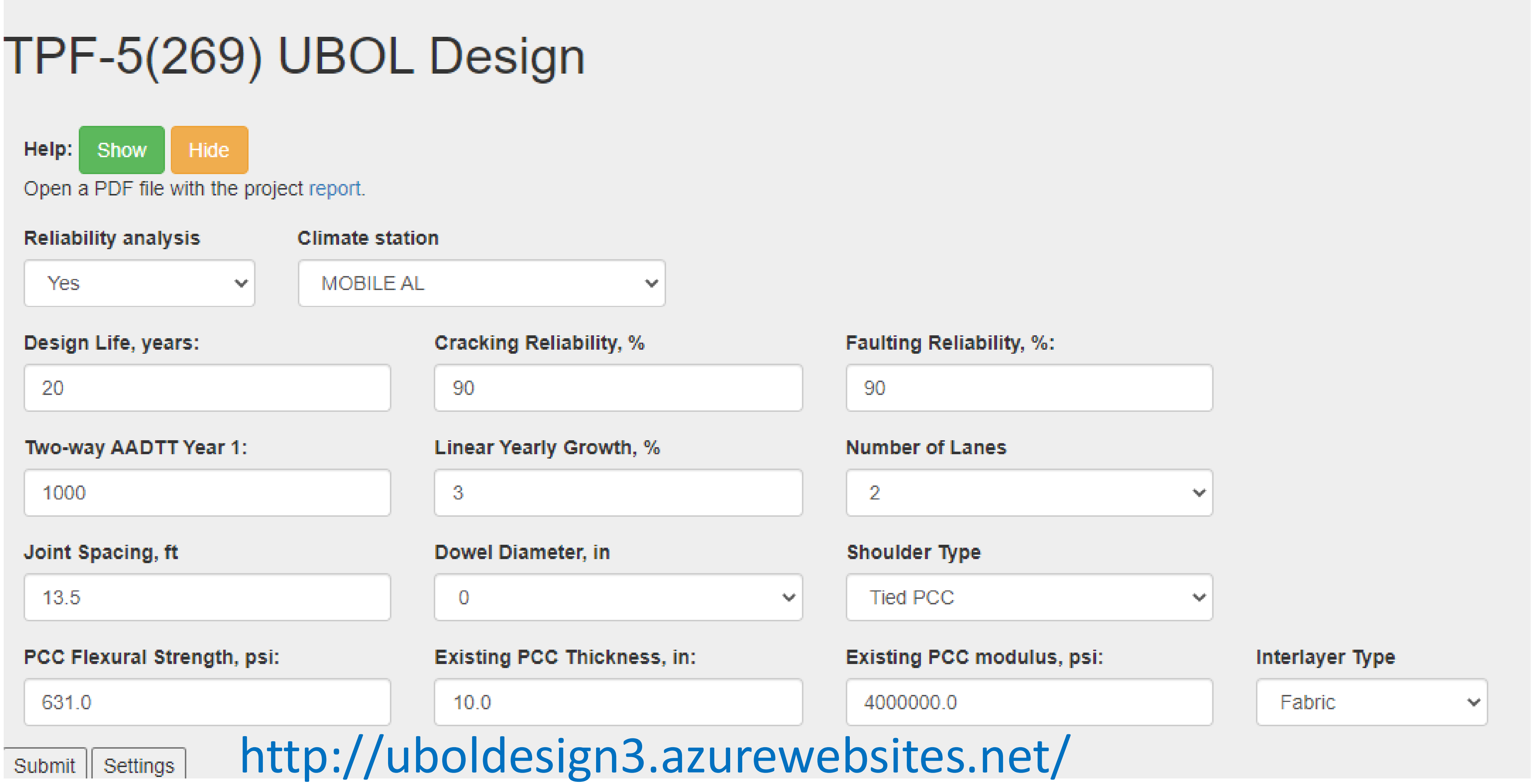




Pavement ME – Source of fines: **Base**

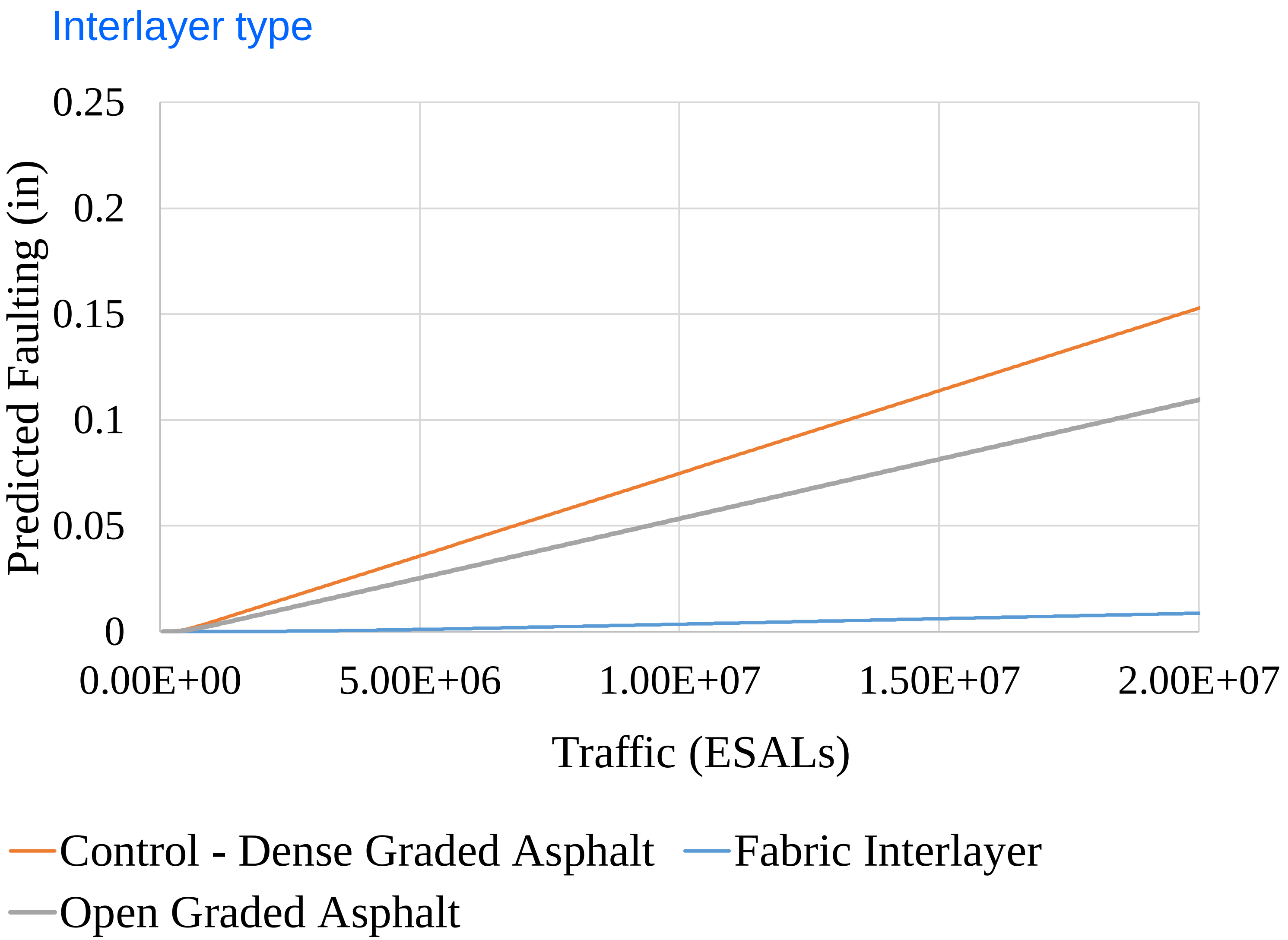


Pitt UBOL ME



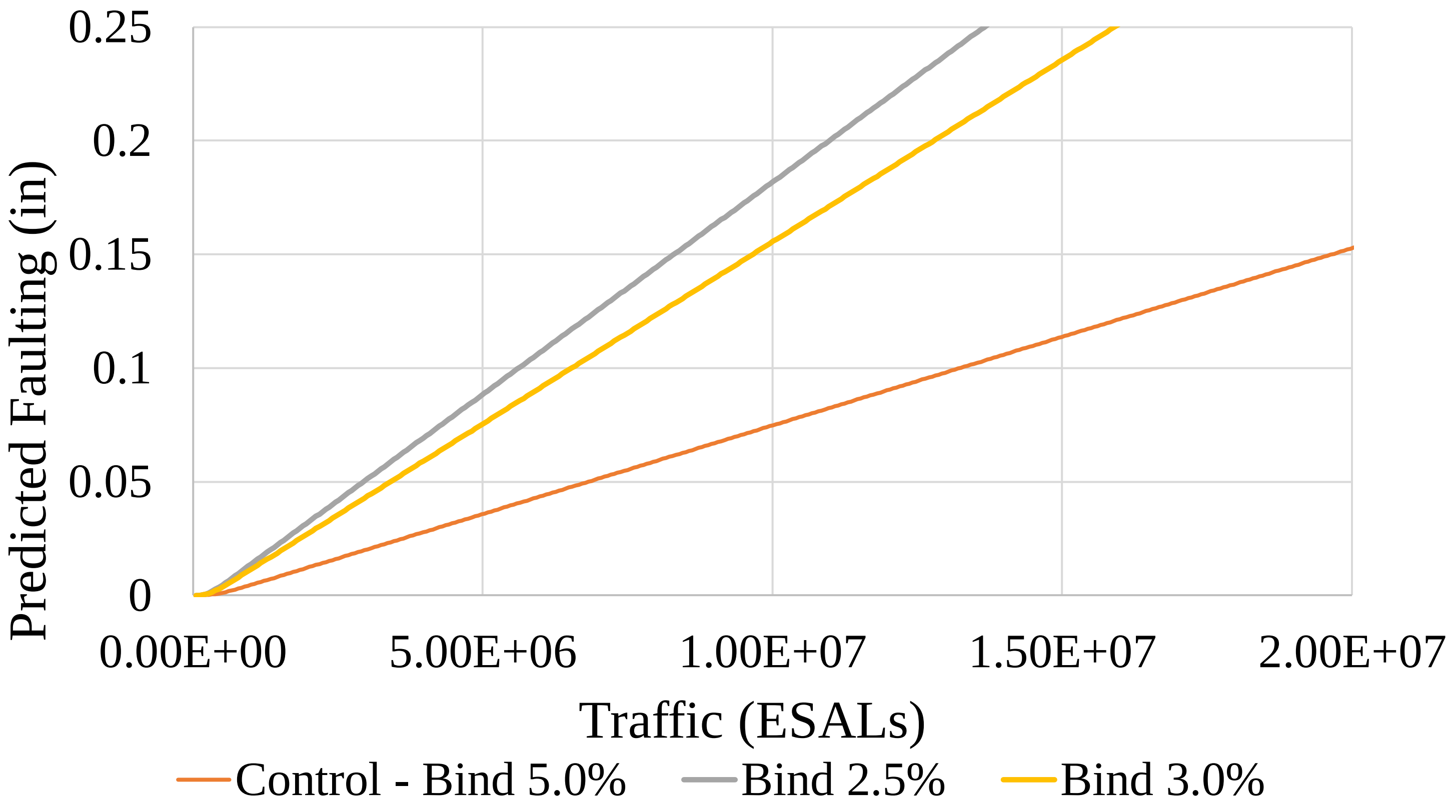
http://uboldesign3.azurewebsites.net/

Pitt UBOL – Interlayer type

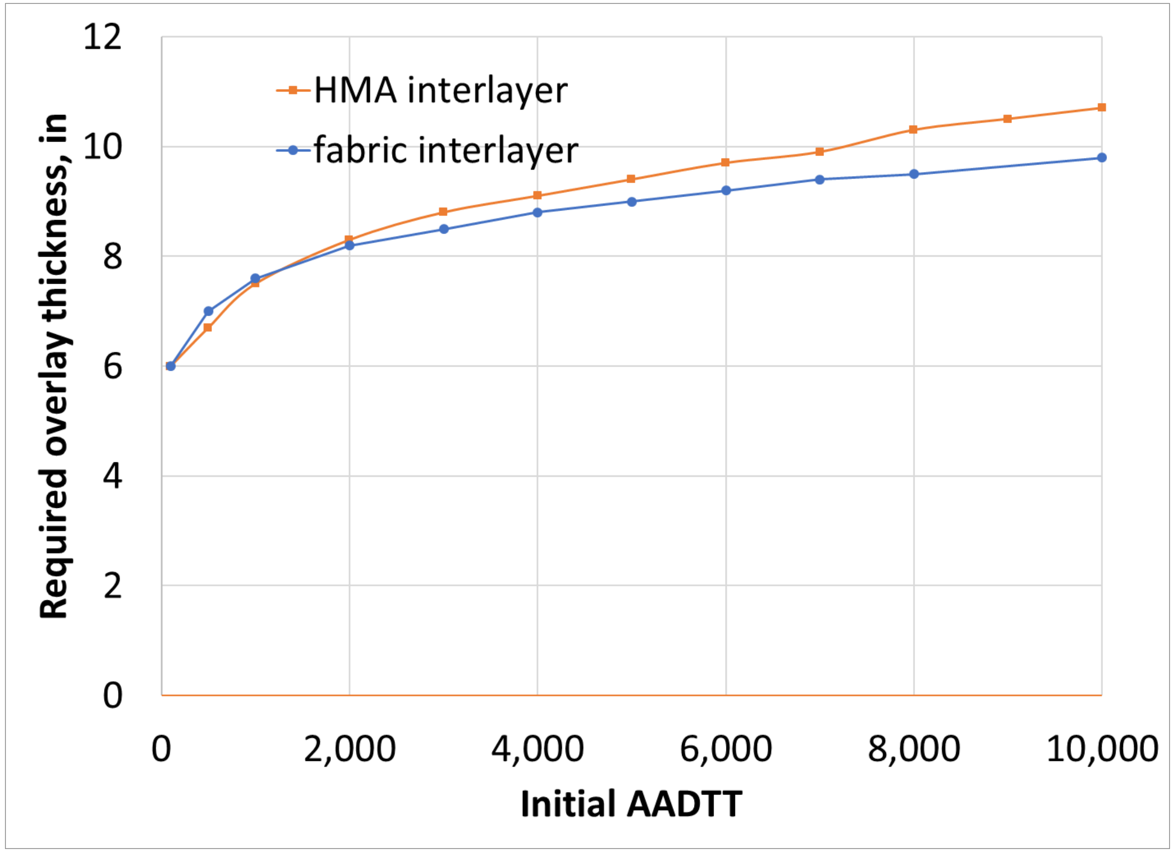


Pitt UBOL – Interlayer properties

Interlayer effective binder content



Pitt UBOL -Effect of Interlayer Type



Thank You

Any Questions?

Contact Info.

Julie Vandenbossche, P.E., Ph.D.:

jmv7@pitt.edu

https://engineering.pitt.edu/JulieVandenbossche

https://uboldesign3.azurewebsites.net