University of Pittsburgh

PITT | IRISE

IRISE: Joint Design Optimization

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Panel Members

- Matt Blough, Pennsylvania Turnpike
- Chuck Niederriter, Golden Triangle
- Charles Buchanan, Pennsylvania Turnpike
- Lydia Peddicord, PennDOT
- Jason Molinero, Allegheny County
- Yathi Yatheepan, FHWA

Slab design philosophy

- **Slab thickness** => prevent fatigue cracking
- **Slab length (joint spacing)** => long as possible to decrease costs associated with construction/maintenance without developing mid-slab cracking or hindering the performance of the joint.

Slab design philosophy

- **Slab thickness** => prevent fatigue cracking (rarely occurs)
- **Slab length (joint spacing)** => long as possible to decrease costs associated with construction/maintenance without developing mid-slab cracking or **hindering the performance of the joint**.

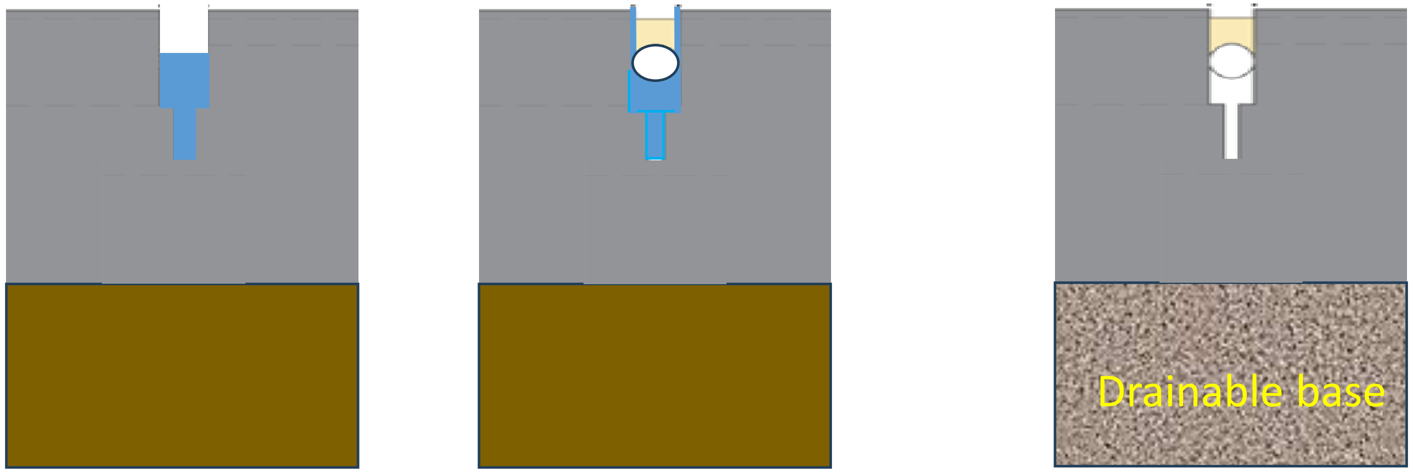
hindering the performance of the joint

Longer slab => larger joint opening

- Lower agg interlock load transfer
- More difficult to keep sealed

Joint performance – Concrete durability

- Durable concrete mixture – PEM
- Concrete < 85% saturated (Taylor et al. in 2012)
  - Avoid ponding in the joint
    - Well-sealed joint
    - Activated joints
    - Drainable base



Reduced potential for PCC distress

Increased potential for PCC distress

Joint performance - Design

- Effective load transfer

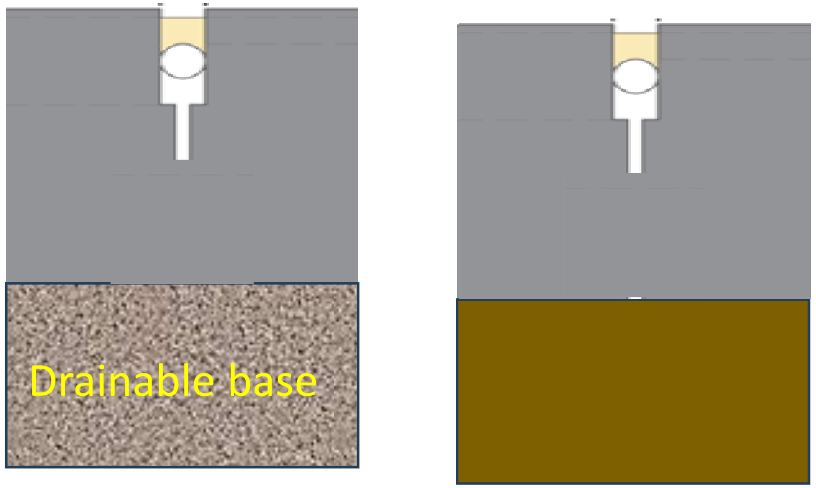
  (Faulting, corner breaks)
- Drainable base

  (Erosion, pumping)
- Joint sealing
  - prevent entry of deicing salts

    (Dowel corrosion – faulting, PCC durabiltiy)
  - prevent entry of water

    (Pumping, erosion, dowel corrosion, PCC durability)
  - prevent incompressibles (small pebbles and sand)

    (Spalling, blowups)

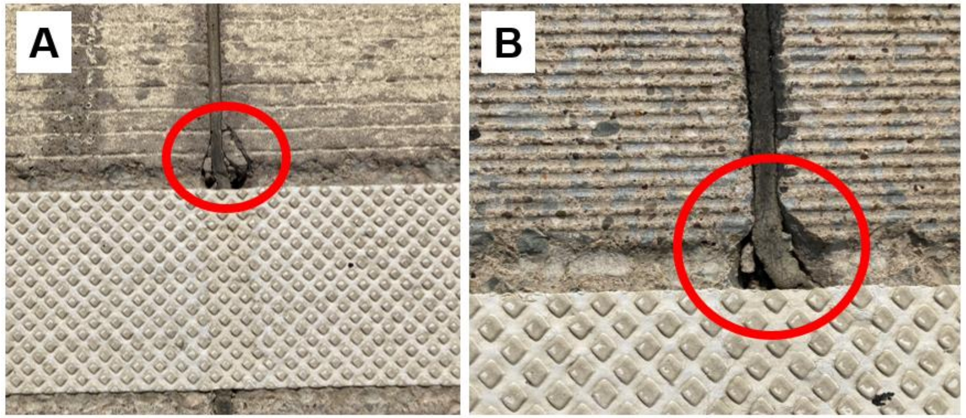


Reduced potential
for pumping & erosion

Task B: Field performance data

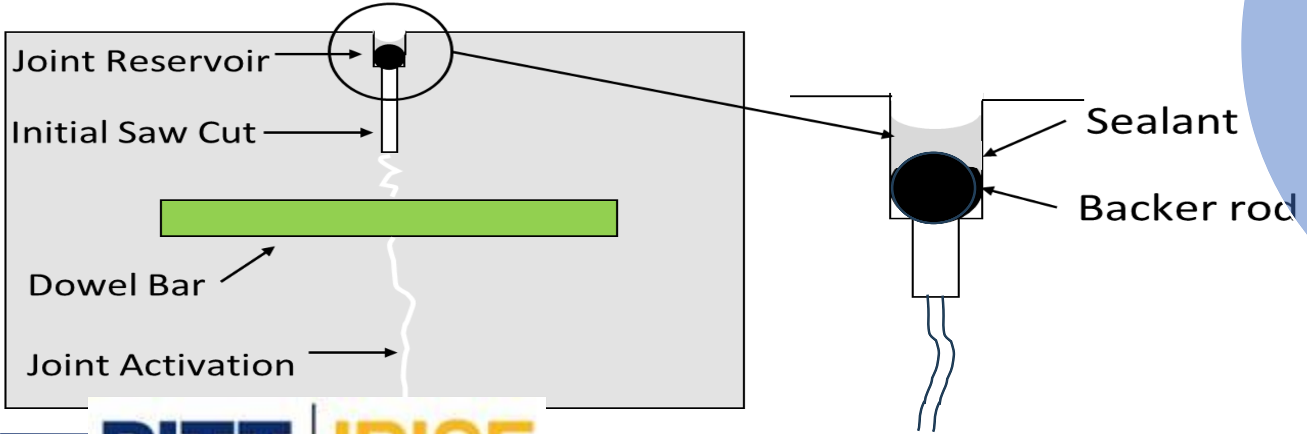
- **Blowups** – no performance data
- **Spalling**
  - 94% of PennDOT sections with fewer than 10 years in service display less than 10% joints spalled.
  - Of the 6% of sections with early spalling, most significant factors are construction year and joint sealant type (Type II vs IV).
  - 78% of Turnpike sections had 100% joints spalled but attributed to reflective tape installation and not sealant performance
- **Faulting**
  - Limited faulting in both PennDOT and Turnpike datasets threshold for observable faulting (0.25 in).

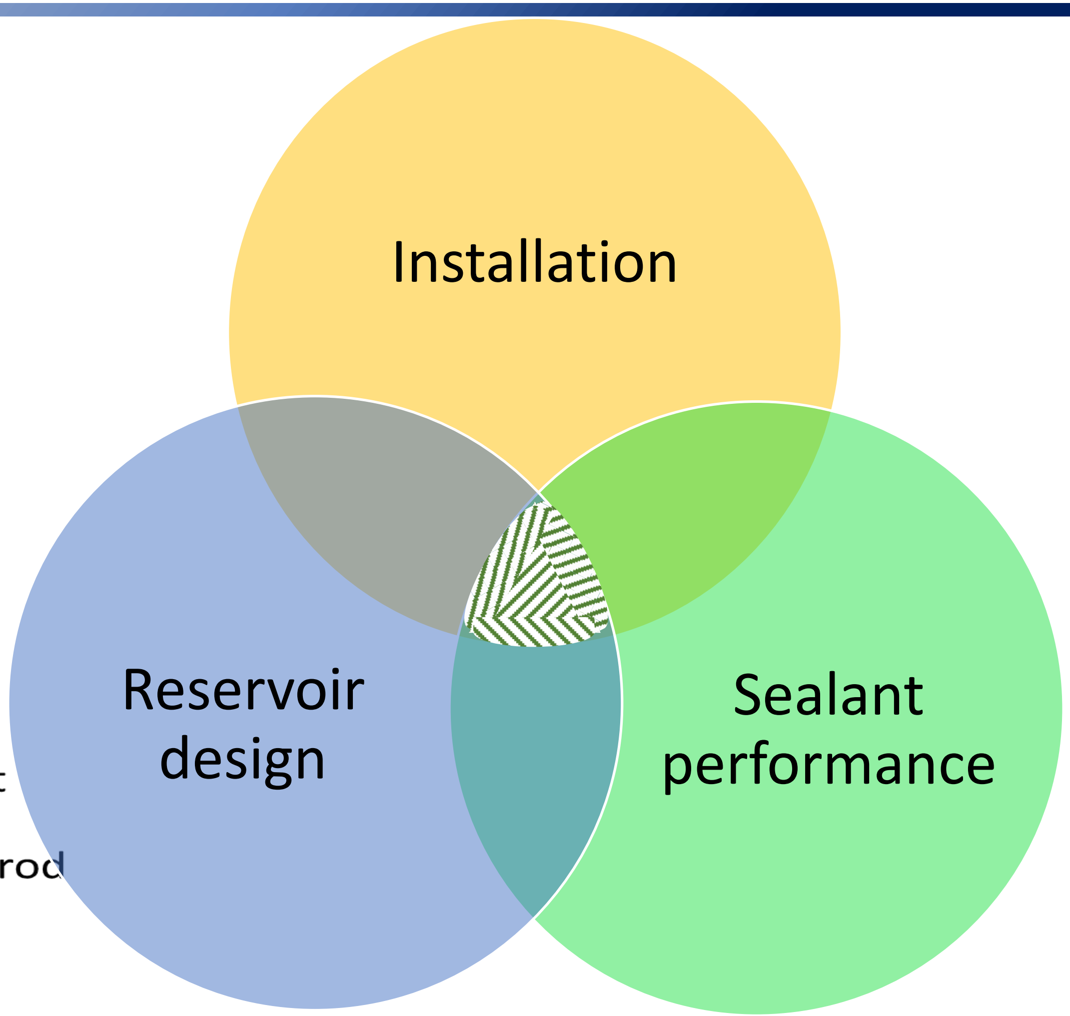
Thanks to Ed Skorpinski (PTC) and Lydia Peddicord (PennDOT)



Transverse Jt. sealant performance

Installation
Sealant performance
Reservoir design





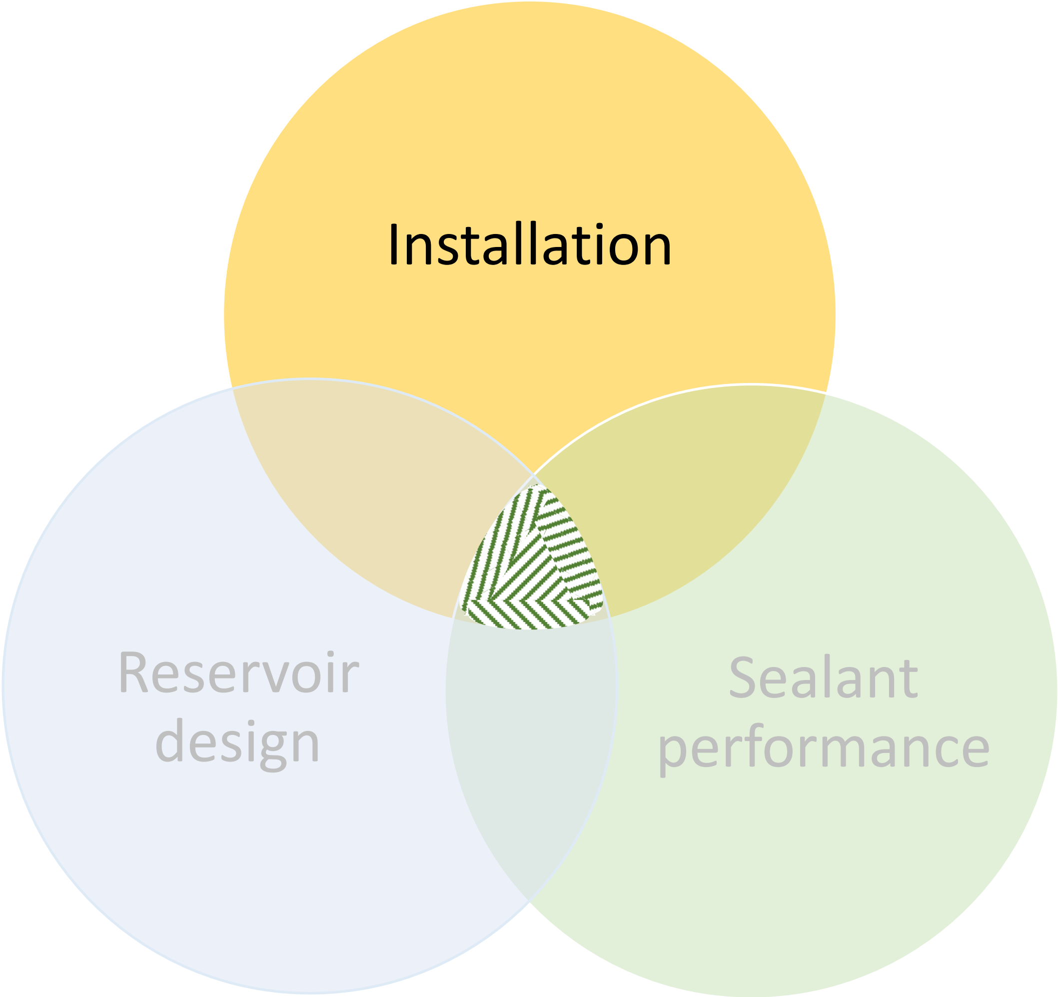
Transverse Jt. sealant performance

Installation

- Wipe test (is this sufficient?)
- Vacuum saw slurry ?

Sealant performance

Reservoir design



Reservoir design

Installation

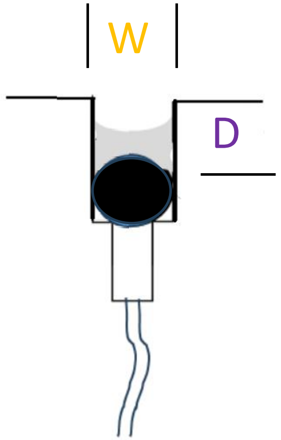
Sealant performance

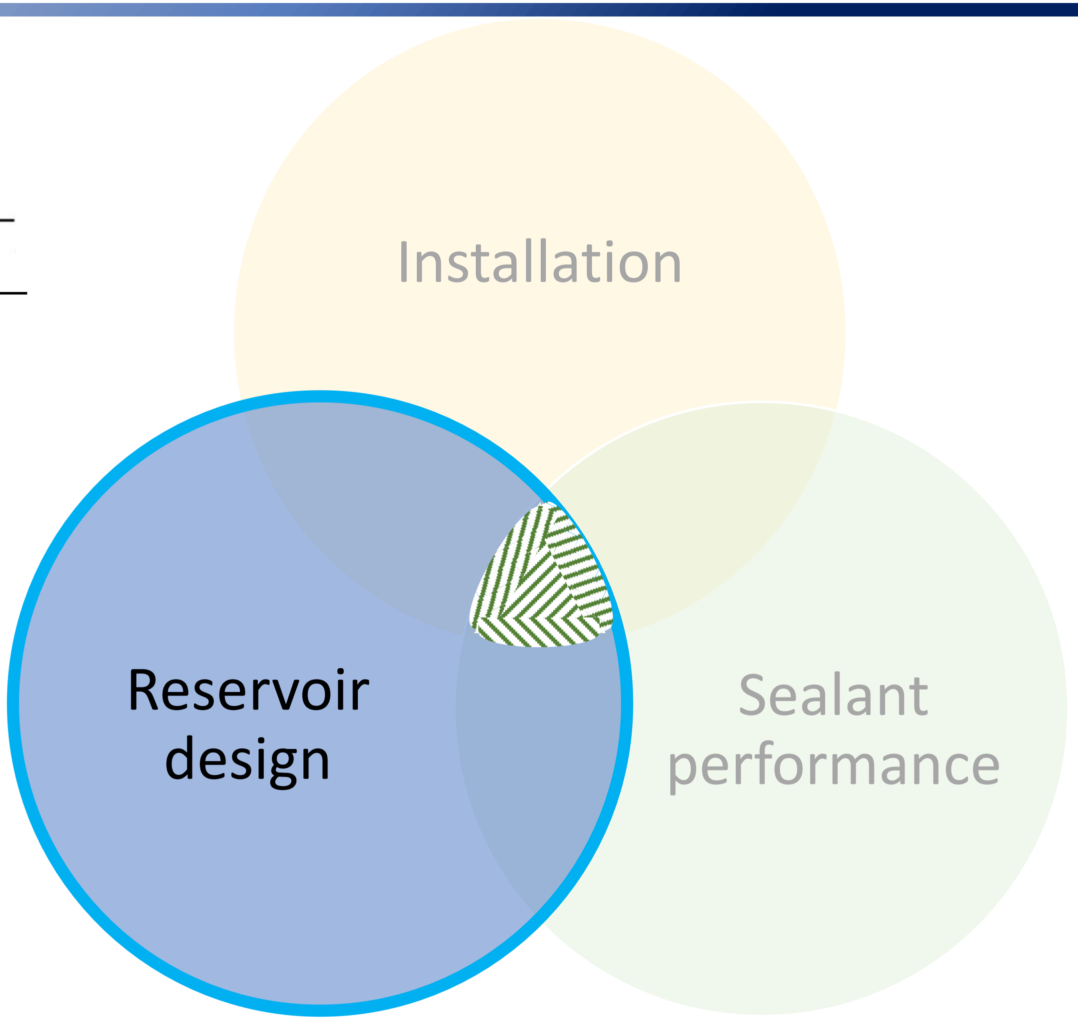
Reservoir design

- Single cut (fill)
- Reservoir

  AASHTO 93 Guide

  1. Allowable strain = ΔL/ W
  2. Shape factor = D/W





Task C: Transverse Jt. sealant performance

Installation

Sealant performance

Reservoir design

- Single cut (fill)
- Reservoir

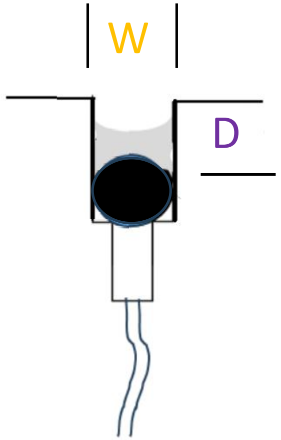
AASHTO 93 Guide

1. Allowable strain = ΔL/ W

   Cohessive failure

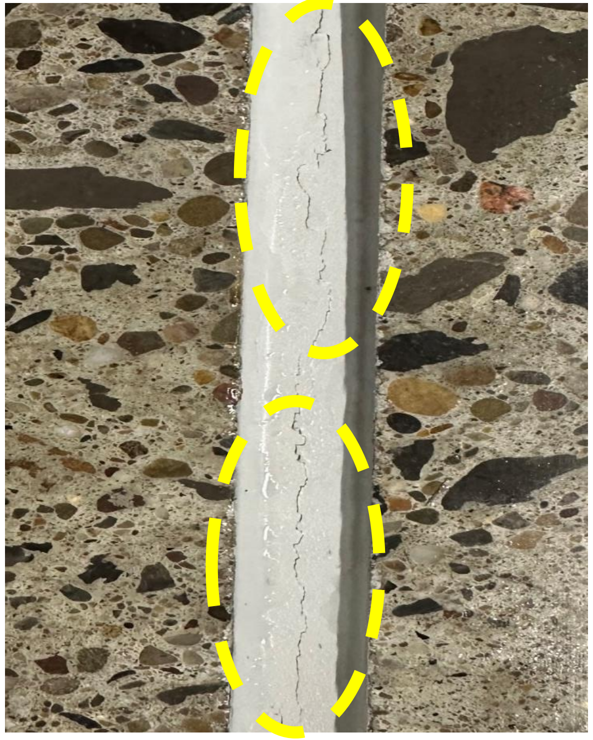
2. Shape factor = D/W

   Adhesive failure



Adhesive Failure

Cohesive Failure



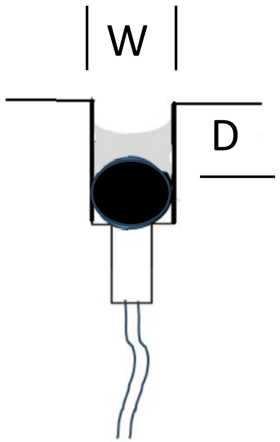
Task C: Transverse Jt. sealant performance

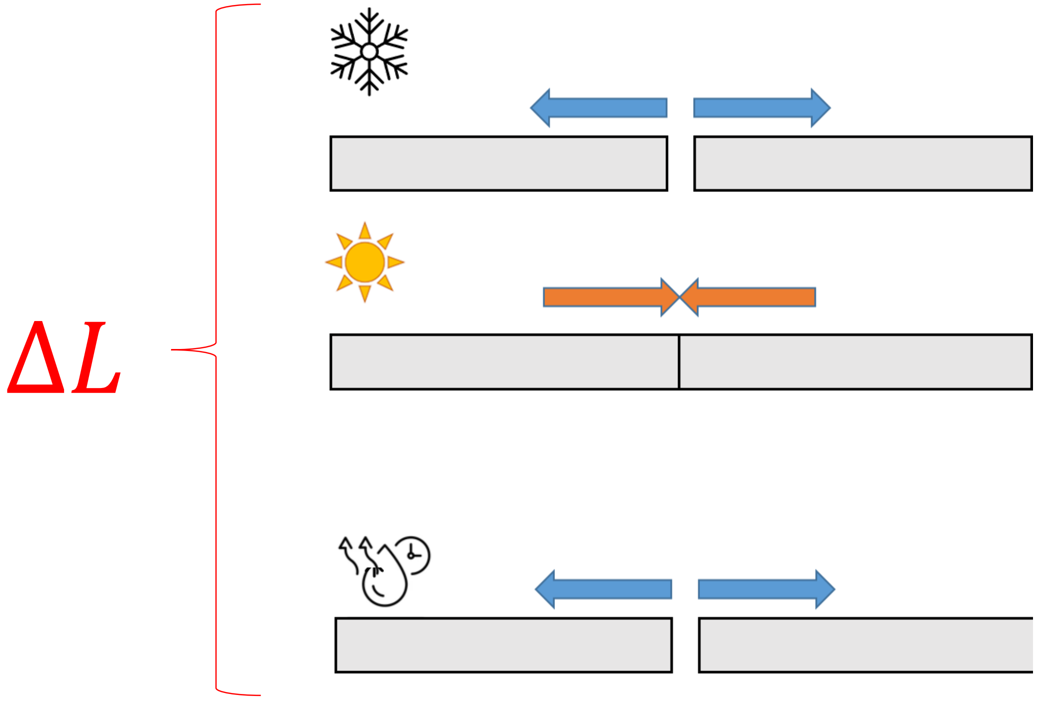
Installation

Sealant performance

Reservoir design

- AASHTO 93 Guide
  1. Allowable strain = ΔL/ W
  2. Shape factor = D/W





Allowable strain and Shape factor = f (sealant type)

Task C: Predicted reservoir design width

$$\Delta L_{design(Old)} = CL(\Delta T\alpha + \varepsilon_{DS})$$

$$\Delta L_{design(New)} = L(C_{Therm}\Delta T\alpha + C_{D.S.}\varepsilon_{DS})$$

Smart Pavement Data

Where,

- L = 15 ft
- C_{therm} = 1 (Field value)
- ΔT = 85°F - 20°F = 65°F
- α = 5.71/°F (Lab value)
- $C_{D.S.}$ = 0.20 (Field value)
- ε_{DS} = 630 με (Lab value)
- C = 0.65 (Old value)

Therefore,

- ΔL_{design} = 0.084 in
- ΔL_{design} = 0.114 in

Field measured joint widths

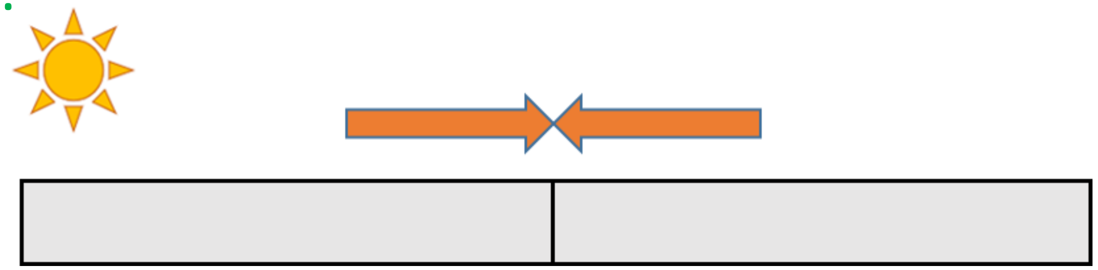
Project	Pavement Construction Year	Type of Sealant	Age of Pavement (Years)	Age of Sealant (Years)	Ave. Jt. Width (in)	Max. Jt. Width (in)	Min. Jt. Width (in)	Max. Jt. Opening (in)	Min. Jt. Opening (in)
A02N	2003	Type IV	18	2	0.50	0.63	0.43	0.25	0.06
A02S	2006	Type IV	15	2	0.42	0.51	0.35	0.14	-0.02
A05	2015	Type II	6	4	0.38	0.55	0.28	0.18	-0.10
A08A	2002	Type II	20	1	0.59	0.71	0.47	0.33	0.10
A10	2014	Silicone	8	8	0.54	0.59	0.43	0.21	0.06
A12A	2016	Type II	5	5	0.50	0.51	0.47	0.14	0.10
A12B	2018	Type IV	3	3	0.48	0.55	0.43	0.18	0.06

Theoretical ΔL @ 20F = 0.084 in

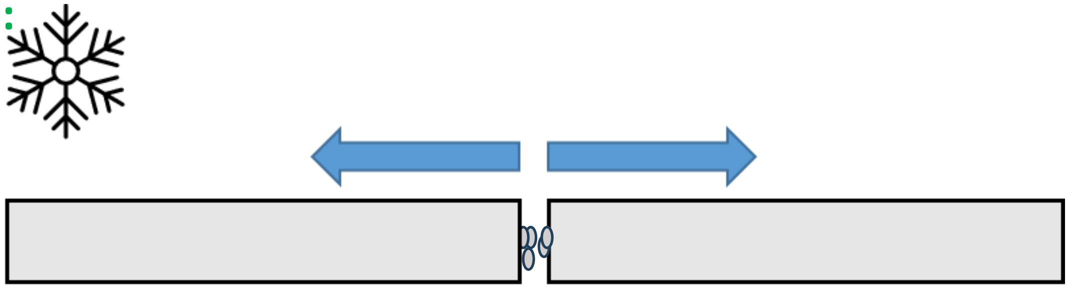
Thanks to Lydia Peddicord (PennDOT)

Sealant failure: joint widths can widen over time…

Step 1:

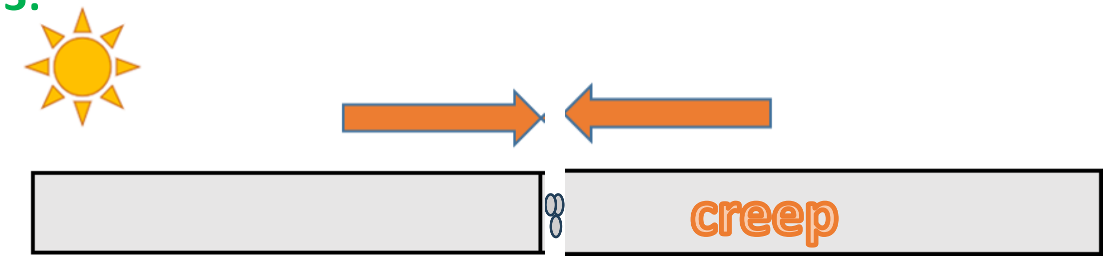


Step 2:



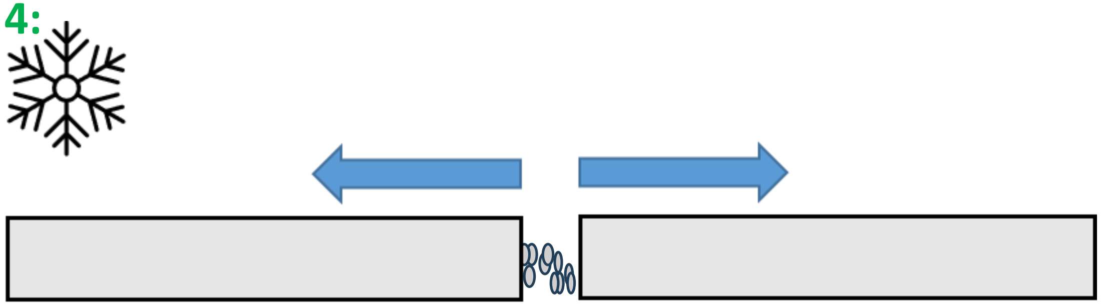
Incompressible enter the joint

Step 3:

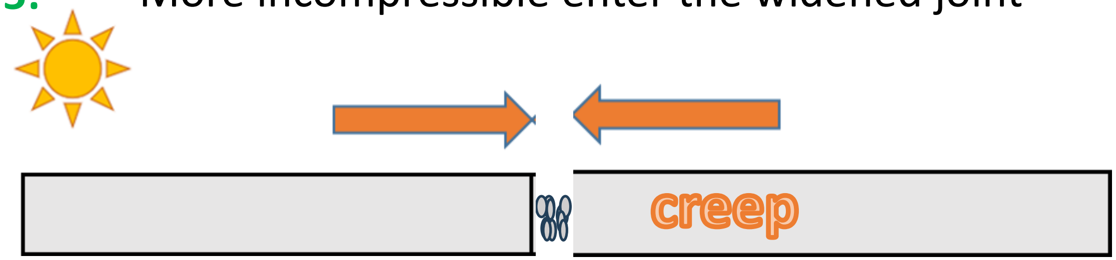


1. Incompressible restrict joint closure
2. Stress builds up
3. Stress relaxation through creep so joint width at zeros stress increases

Step 4:

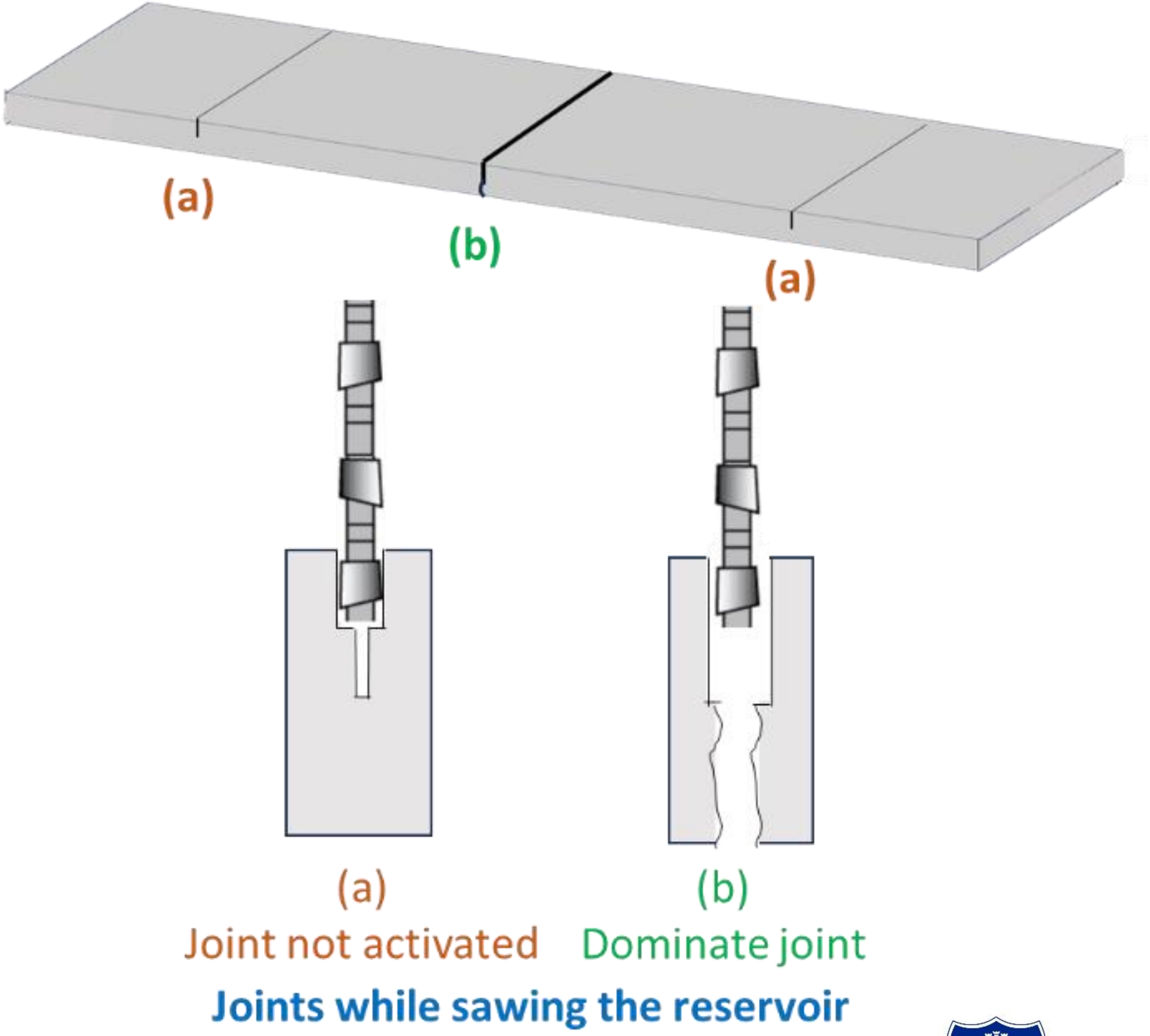


Step 5: More incompressible enter the widened joint

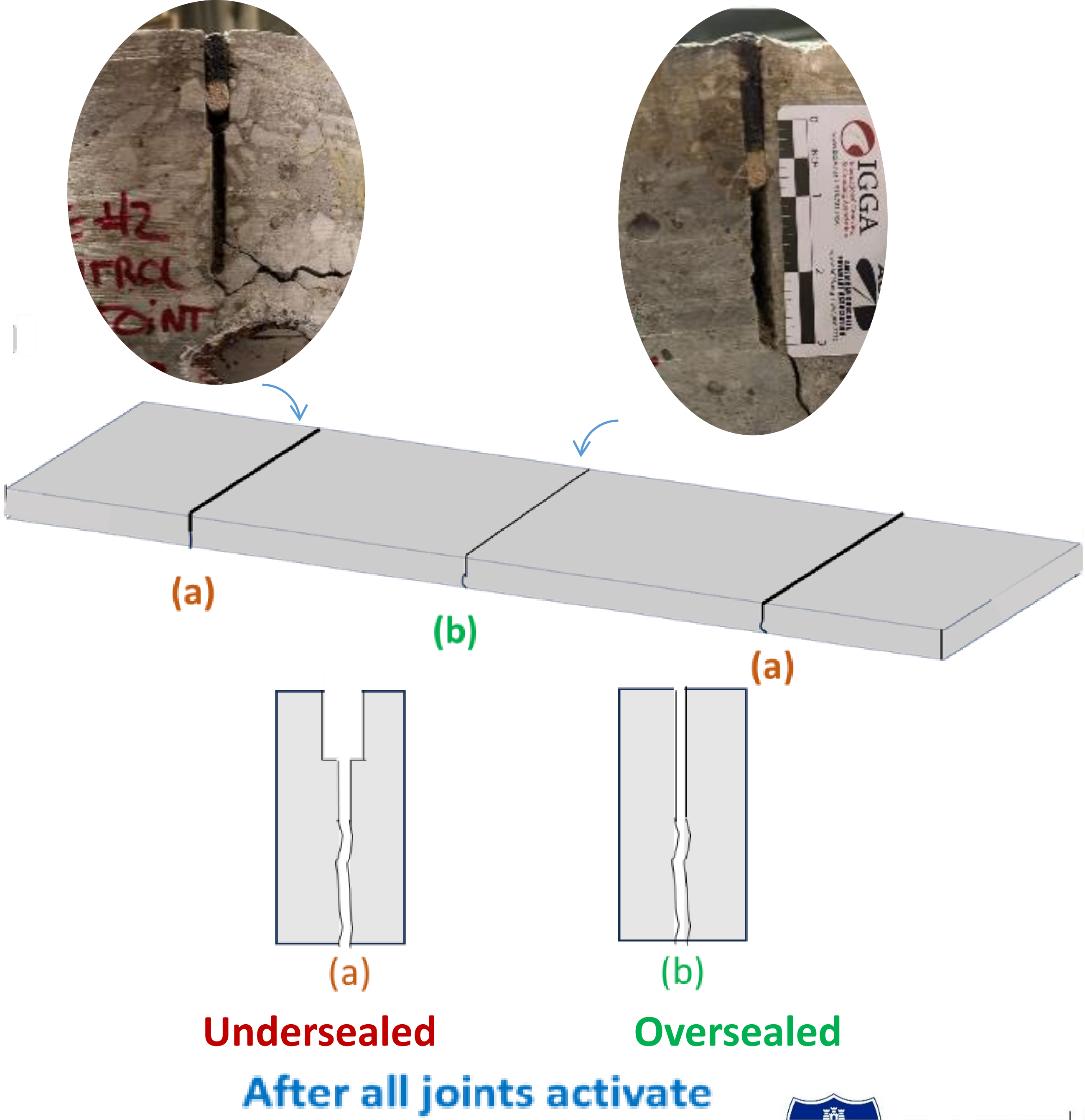


1. Incompressible restrict joint closure
2. Stress builds up
3. Stress relaxation through creep so joint width at zeros stress increases again

Sealant failure: dominant joints



Sealant failure: dominant joints



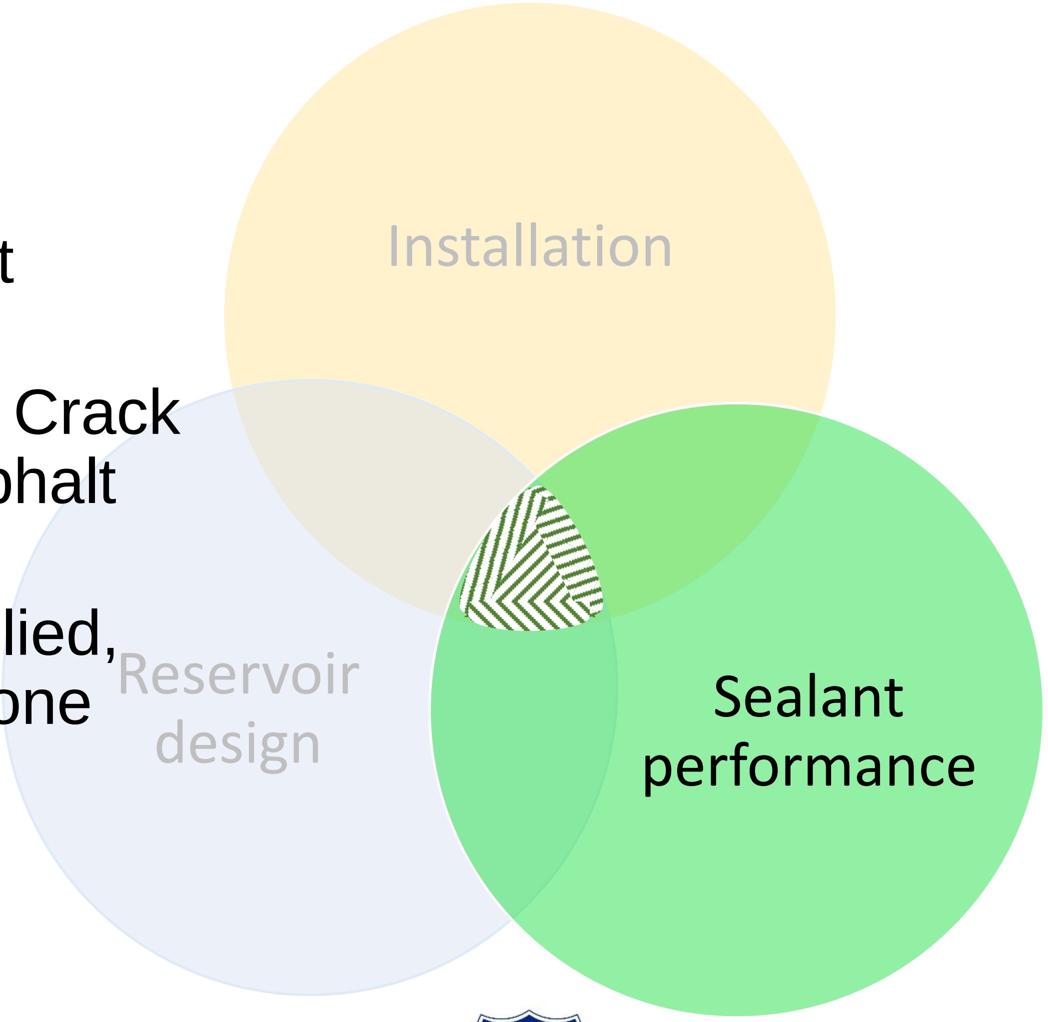
Transverse Jt. sealant performance

Installation

Sealant performance

- Silicone vs ~~Type II and~~ Type IV (Type IV still not performing as previous?)
  - ASTM D6690: Standard Spec. for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements
  - ASTM D5893: Standard Spec. for Cold-Applied, Single-Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements

Reservoir design



Sealant materials

Sealant meets material specs/performance requirements

- Adhesion/cohesion requirements in ASTM 5329
- Closed-cell backer rod
- **Fatigue exposure typically not considered**

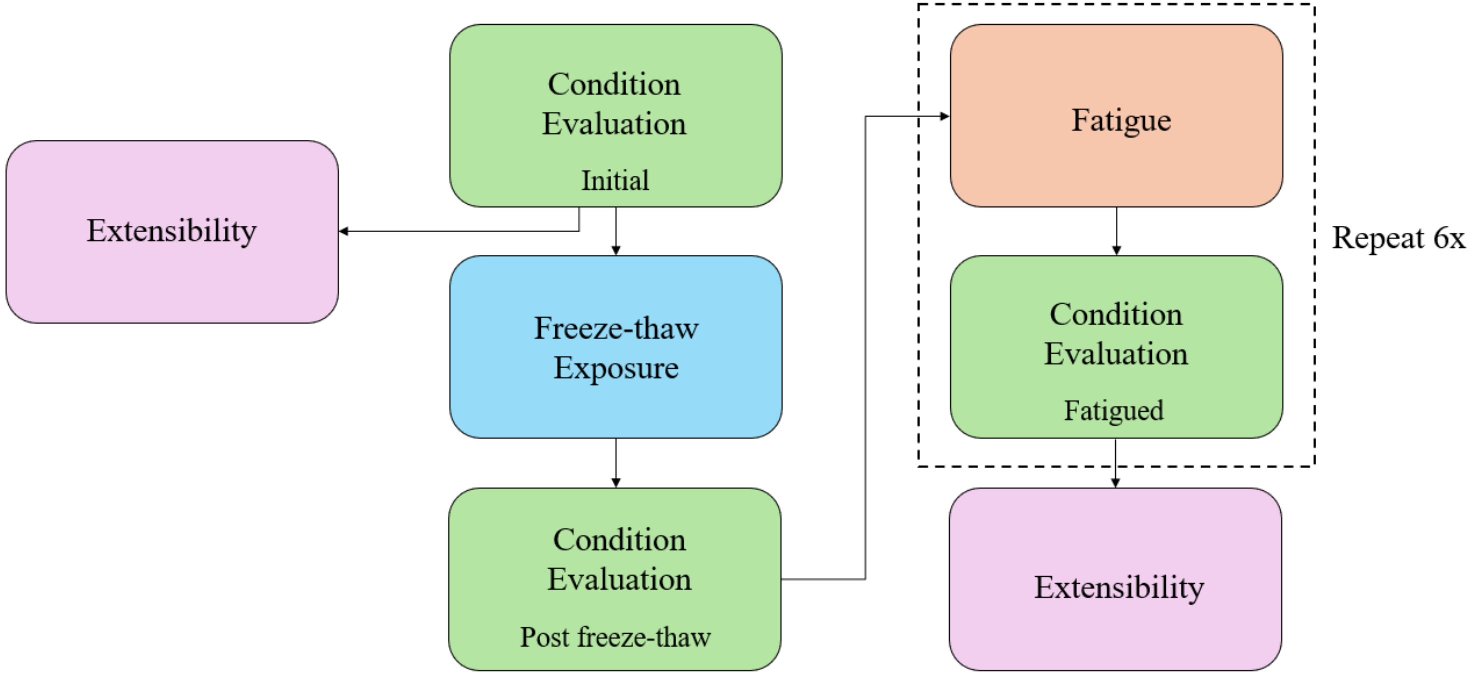
Characterize 42 yrs of simulated performance

Simulated field conditions:

- Exposure:
  - Freeze-thaw cycles
- Fatigue
  - Joint opening/closing (thermal loading)
  - Vertical (vehicle loading)

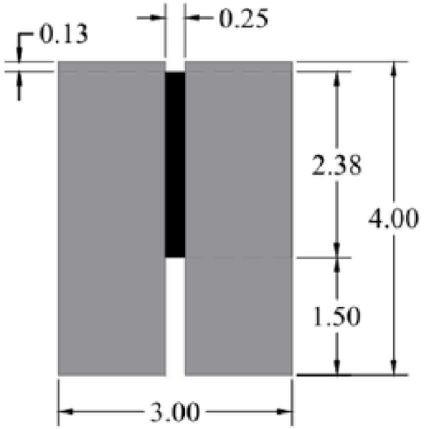
Condition assessment:

- Joint permeability
- Sealant stiffness

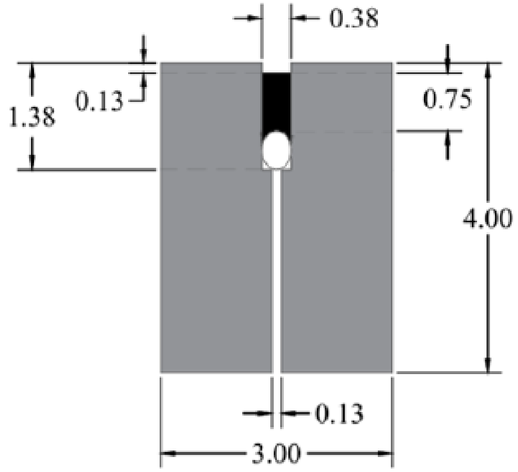


Joint designs and materials

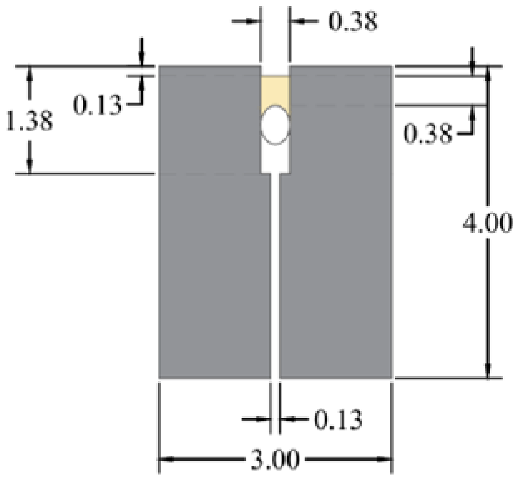
- Asphalt: P&T Products Dura-Fill 3405 LM (K)
- Silicone: Sikasil 728 Non-Sag Silicone Sealant
- Asphalt filled
  - ACPA recommendation
  - Sealant W:D = 1:9.5
- Asphalt reservoir
  - Detail D Pub 72M
  - Sealant W:D = 1:2
- Silicone reservoir
  - Joint Type P Pub 72M
  - Sealant W:D = 1:1



Asphalt filled



Asphalt reservoir

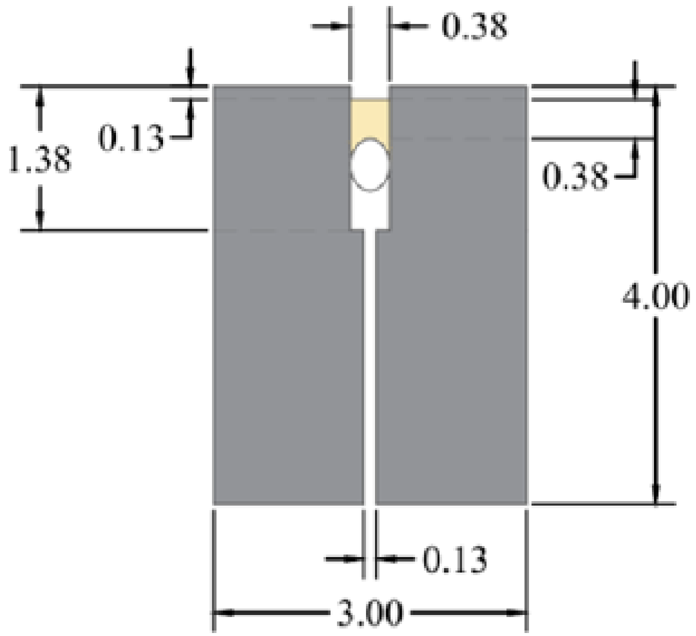


Silicone reservoir

Joint designs and materials

Pavement CamoSeal by Main Street Materials

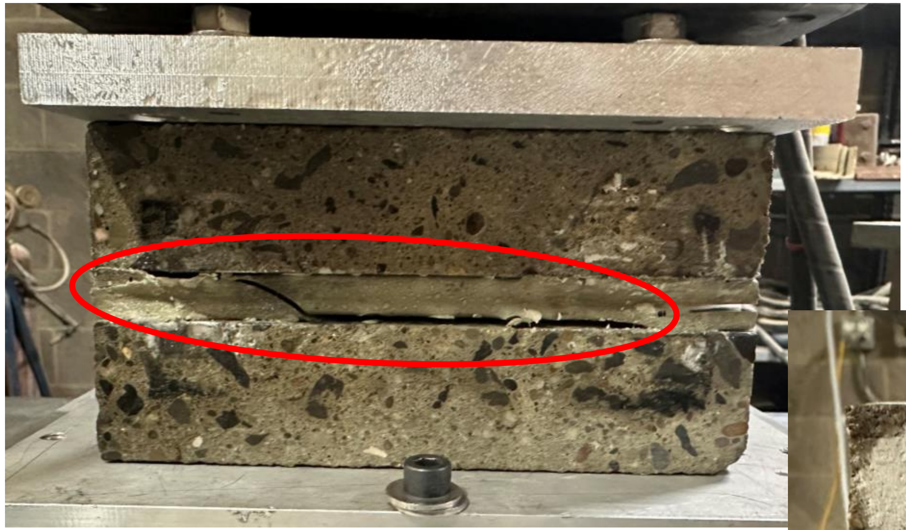
- Caltrans Approved (Recently)
- Joint Type P Pub. 72M
- Sealant W:D = 1:1



Joint designs and materials

Pavement CamoSeal by Main Street Materials

- Poor performance in preliminary testing
- Joint opening/closing: immediate adhesive & cohesive failure
- Vehicle loading: immediate cohesive failure



Manufacturer suggested different blend better suited for colder climates

Joint designs and materials

Pavement CamoSeal by Main Street Materials

- Poor performance in preli ng
- Joint opening/closing: i adhesive & cohesive f
- Vehicle loading: imme ohesive failure

Manufacturer suggest rent blend better suited for c climates

Specimen fabrication

- Cast 3-in x 4-in x 6-in concrete specimens
- Plane the surface
- Saw the reservoir
- Seal the joint
  - Asphalt sealed in field
  - Silicone sealed in lab

Specimens sealed in field

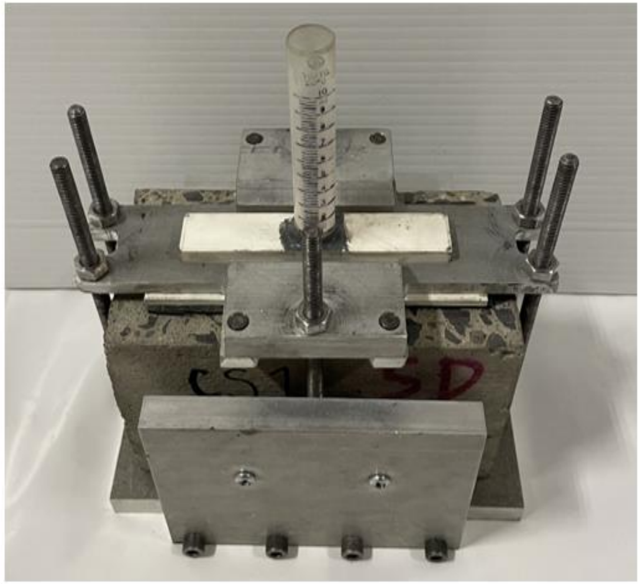
Asphalt reservoir

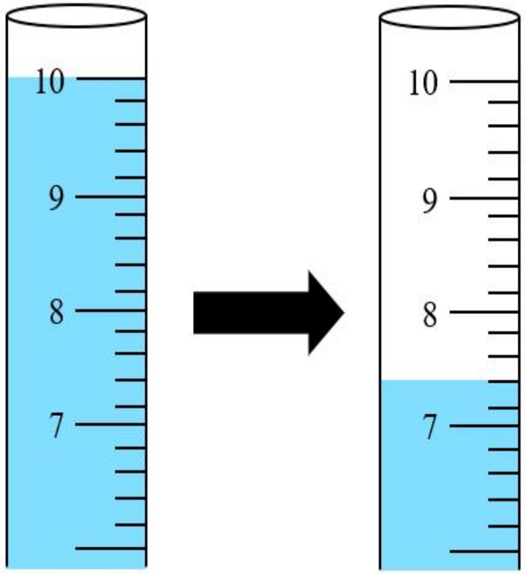
Asphalt filled

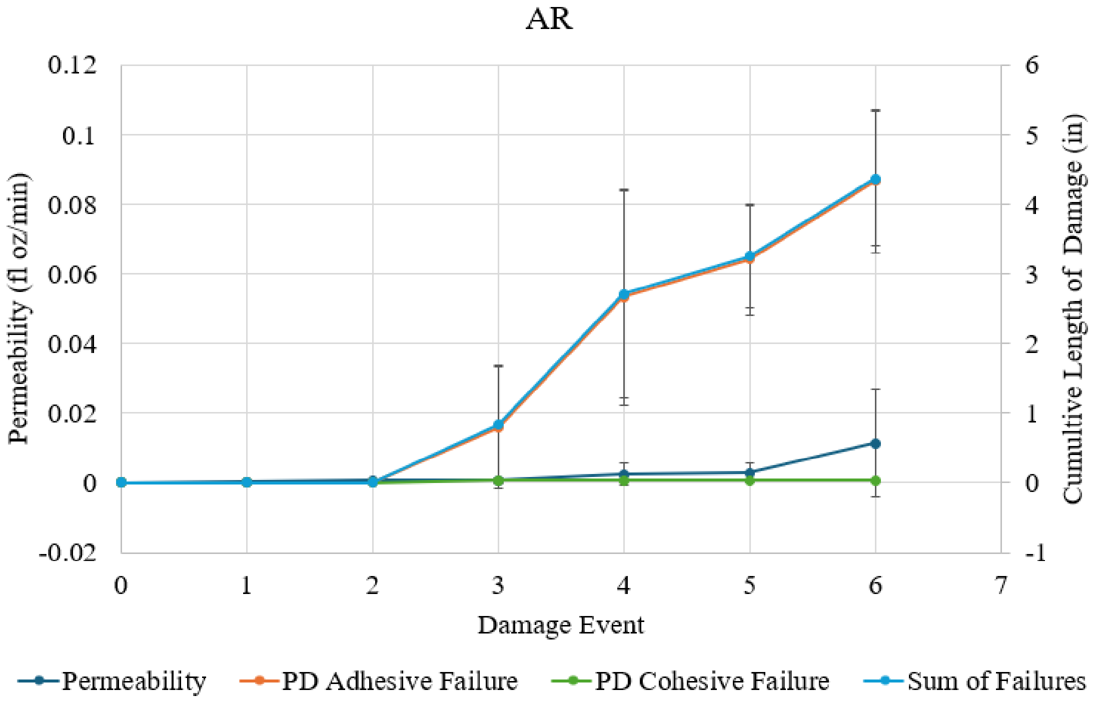
Silicone reservoir

Condition Evaluation: joint permeability

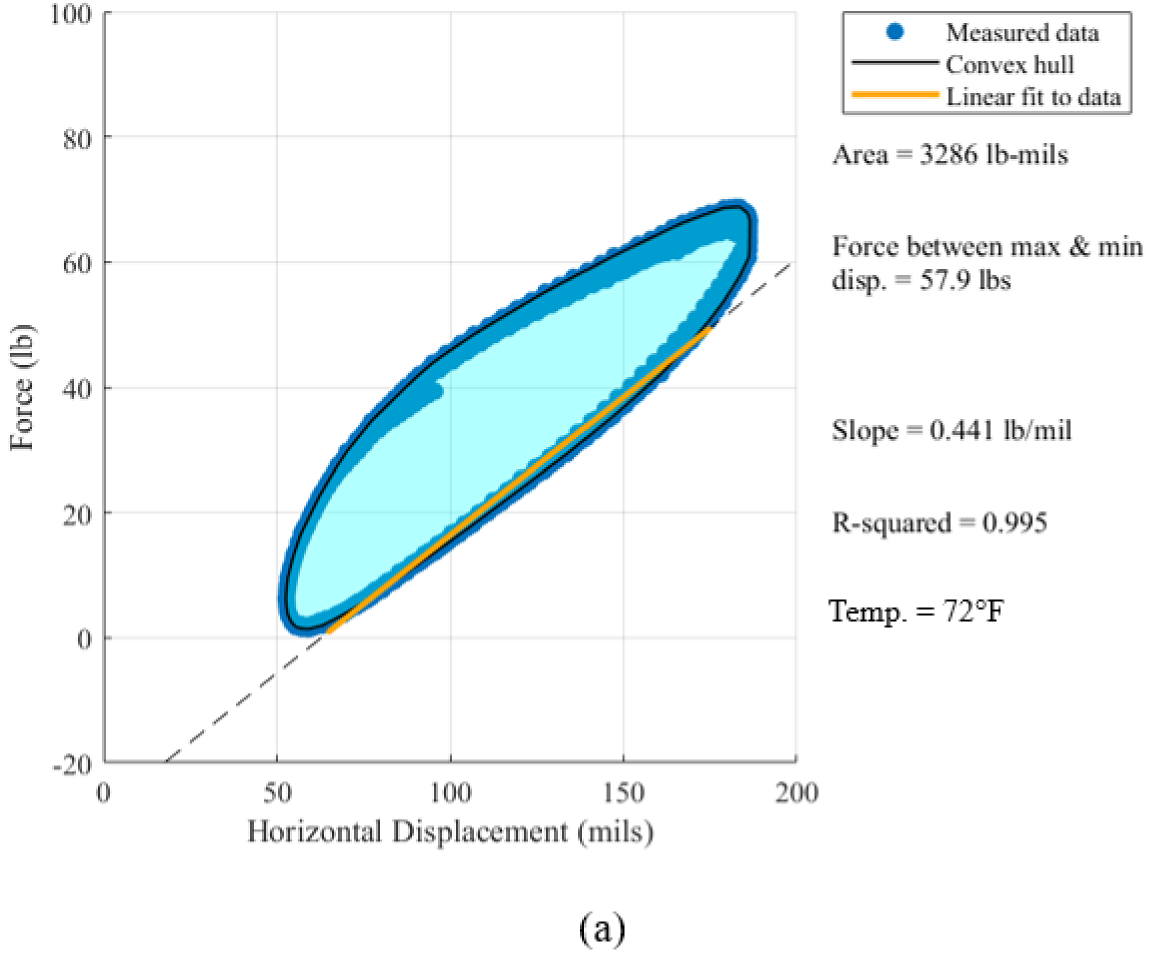
Permeability Apparatus



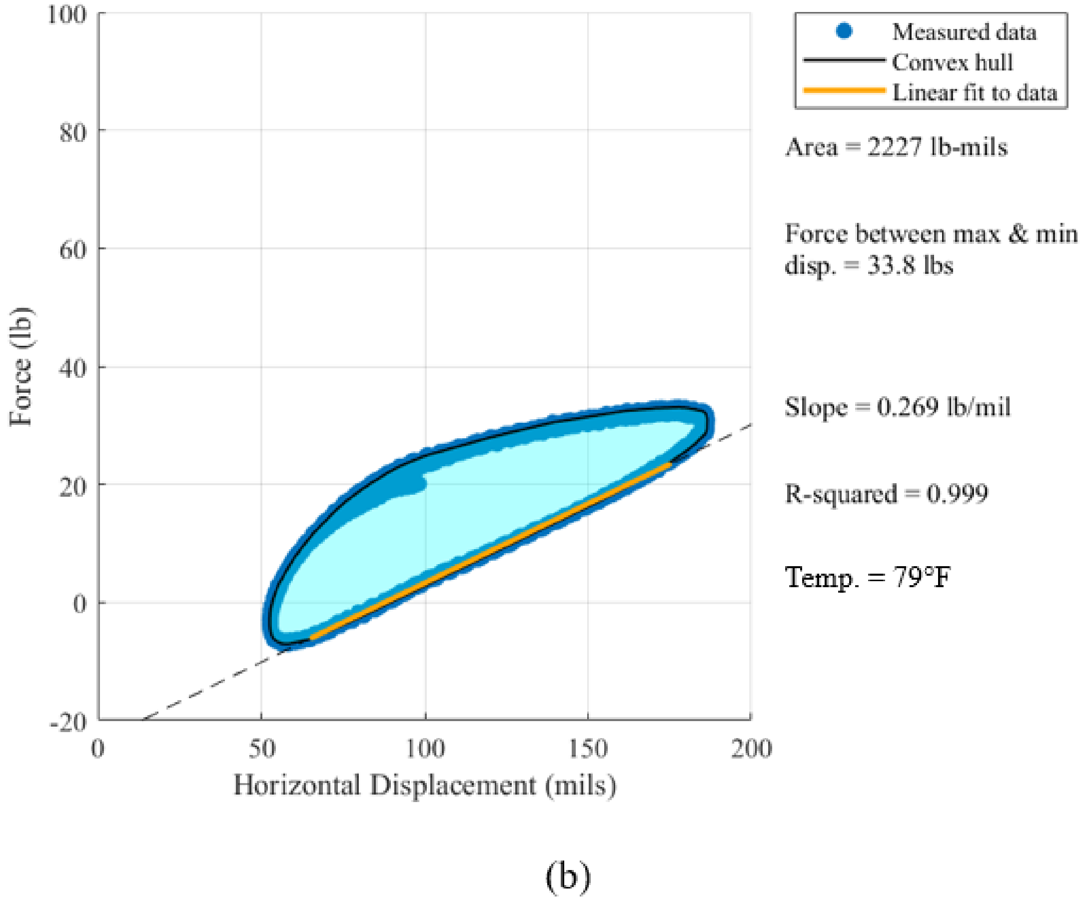




Findings: sealant stiffness



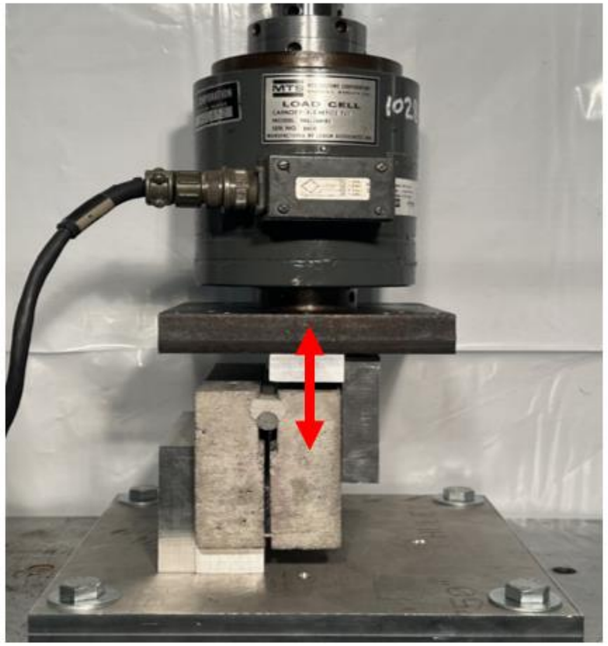
After 1st damage event



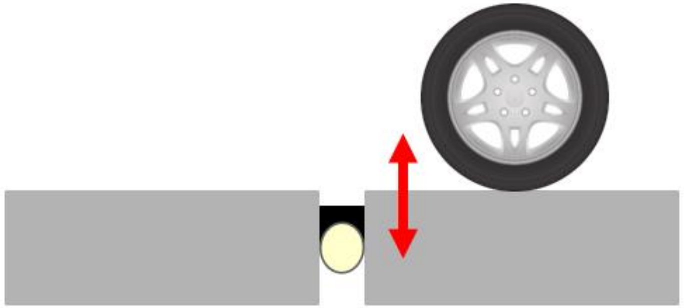
After 6th damage event

Fatigue – Vehicle loading

- Cycle +/- 10 mils
- 42 years (30,000 cycles @ 5 Hz)
- Haversine wave
- Test temp. = 20°F



Vehicle loads



Fatigue – Joint Opening/Closing

Initial protocol:

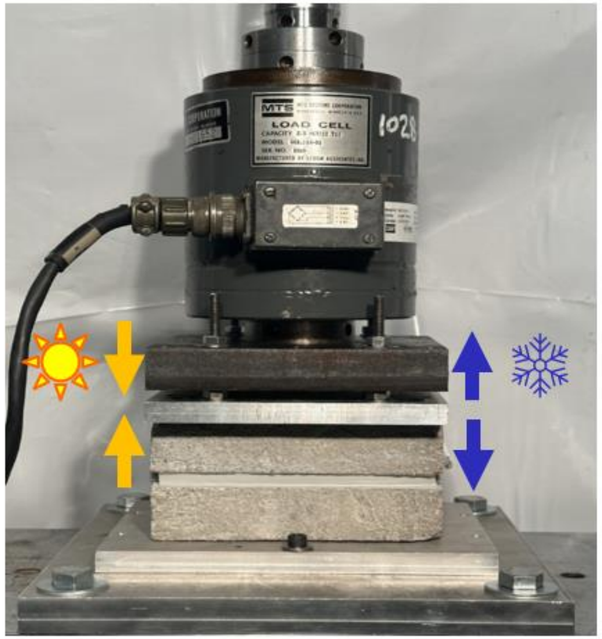
- Cycle between +53 and +78 mils (SR-22 TC data: ave. daily low -1 std dev ~ ave. daily high +1 std. dev.)
- 5,100 cycles (~42 yrs)

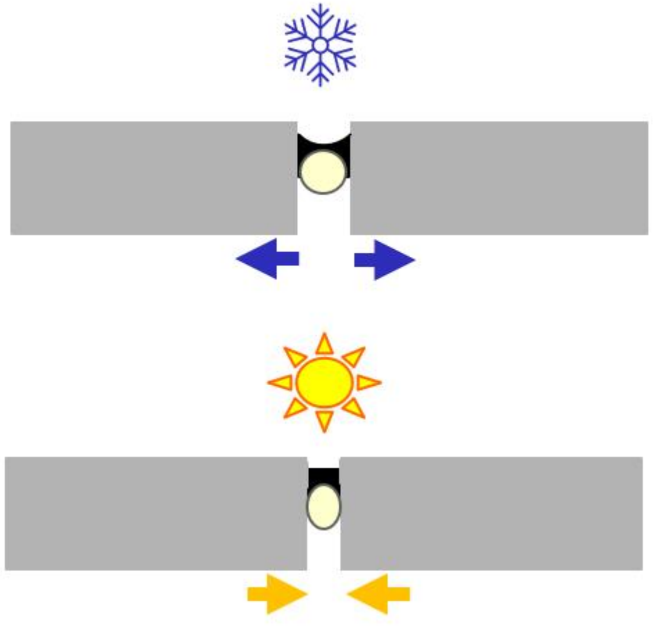
No damage accumulation under typical conditions

Revised protocol:

- Cycle between +53 and +186 mils (PennDOT joint sealant survey)

Joint opening Nov. – Feb. months





- Haversine wave @ 1 Hz
- Test temp. = 20°F

Findings

- Vehicle loading does not cause significant sealant damage
- Typ. jt. openings (0.04 to 0.07 in) sufficiently large to fail asphalt filled joint
  - Narrow joint width causing poor seal quality and greater cohesive stress
- Reduction in performance lower for silicone reservoir design than asphalt designs
  - Silicone material is stiffer but more pliable as compared to the asphalt material
- **Both asphalt reservoir and silicone reservoir should meet performance needs with proper installation**

Note: Loss in performance

from oxidation not considered

Acknowledgements

- IRISE Consortium members
- Edward Skorpinski (PA Turnpike Commission)
- James Young and Brandon Farrel (Gulisek)
- Lydia Peddicord (PennDOT)
- Tom Bryan (Bryan Concrete) and Justin Bryan (Neville Aggregates)
- Jack Parkhurst (University of Pittsburgh)

Acknowledgements

Thank you!

Questions?

PITT PAVEMENT ENGINEERING

Citations

American Concrete Pavement Association, "Concrete Pavement Joint Sealing/Filling," ACPA, 2018.

Tanyildizi, M. “Joints in rigid pavements,” Advanced Engineering Days, 2022.