SEAL NO SEAL

Performed in cooperation with the
Seal No Seal Group

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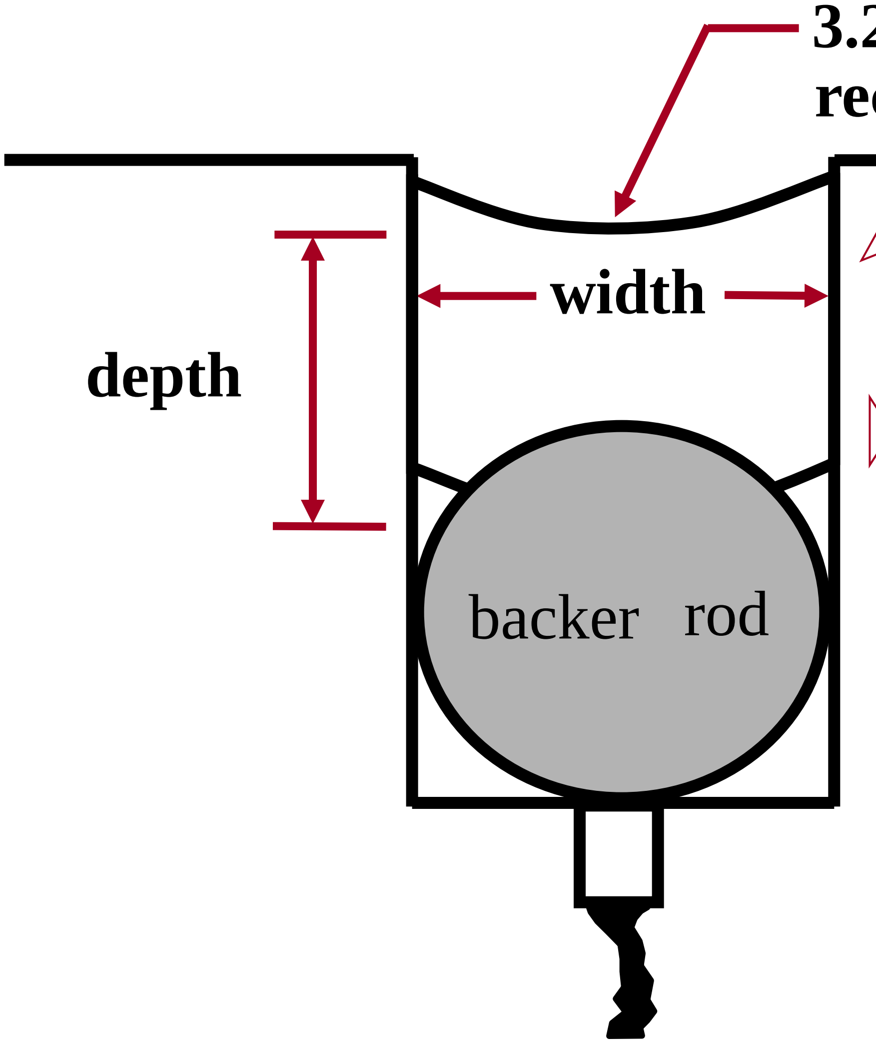
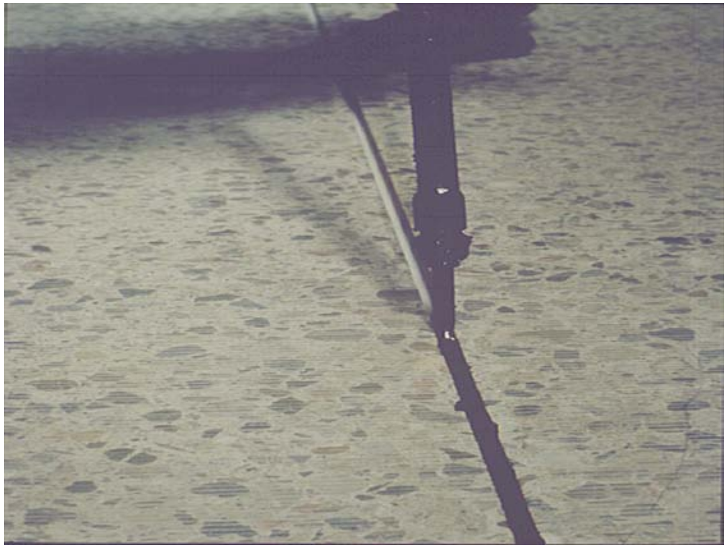
Outline

- Background
- Seal/No Seal, Risk Perspective
- Sealant Failure Modes
- Evaluation of Sealant Longevity
- Field Tests
- Ongoing Field/Lab Tests
- Test Results

Joint Design



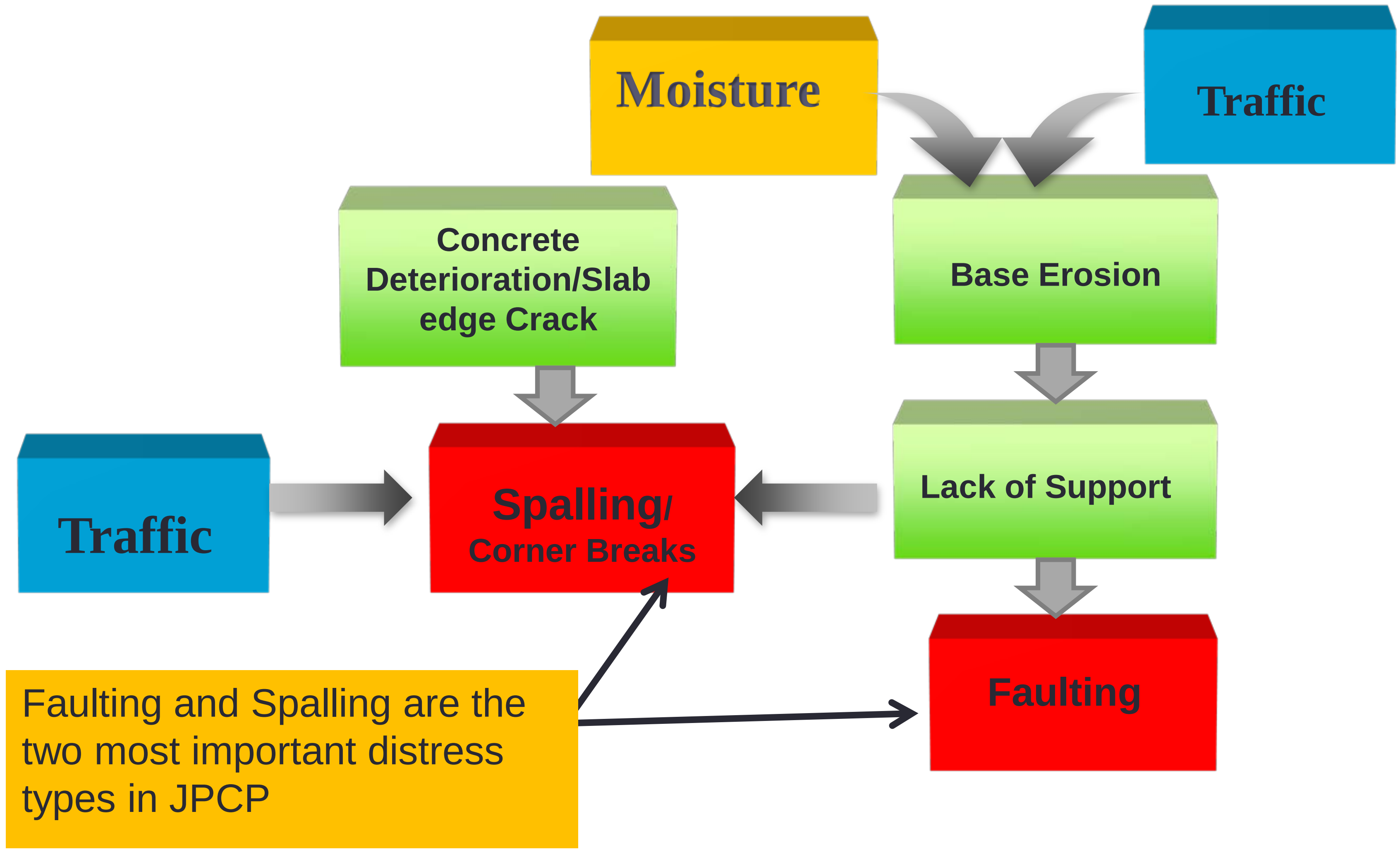


The Concern

- Joint seals are not working well enough
- Not keeping the joint free of moisture
- Field observations have noted the presence of water
- LTPP faulting data : strong correlation to annual rainfall

An average service life less than 10 years

Joint Sealant Damage and Moisture Related Distress



1995 NCHRP Survey (State Highway Agencies)

- **9 states :Seal the joint (**No concern about subsurface drainage)
- **30 States: Seal the joint** (Plus using a permeable layer, subsurface drainage system or both)
- **10 States: Do not rely on the Sealants (**But use of a drainage layer, other subsurface drainage, or both)
- **Only 1 State (Wisconsin)** reported that it had dispensed with joint sealing entirely.

The results of a nationwide survey (Hand et al.2000)

Do you seal/reseal joints in new concrete pavements?

- 72% of the responding states reported that they **do seal**
- 66% of them also reseal joints; 14% **do not reseal**
- The 3 states that reported that they do not were **Alaska, Hawaii, and Wisconsin**

The results of a recent nationwide survey (Hand et al.2000)

DOT Research on Seal-No Seal

- **Only 17%** reported that the decision is made by research
- **Only 20%** of the responding DOT's reported that they had studied the effect of sealing on pavement performance;

Seal - No Seal

- Should be an engineering risk-based decision
  - Cost
  - Benefit
- Probability of failure should be defined relative to the key factors

- Key factors
    - Annual rainfall
    - Seasonal temperature changes
    - Traffic levels
    - Subbase type, strength, thickness, and stiffness
    - Joint stiffness

The Risk

- Present sealing practices are not 100% perfect and durable

- Costs associated with sealing
    a. Material
    b. Labor
    c. Construction
    d. Repair
    e. Traffic and Lane closure

- Annual saving of **$6,000,000** by no-seal policy in Wisconsin (Shober, 1997)

  This amount is for around 15 years ago and for the particular network size

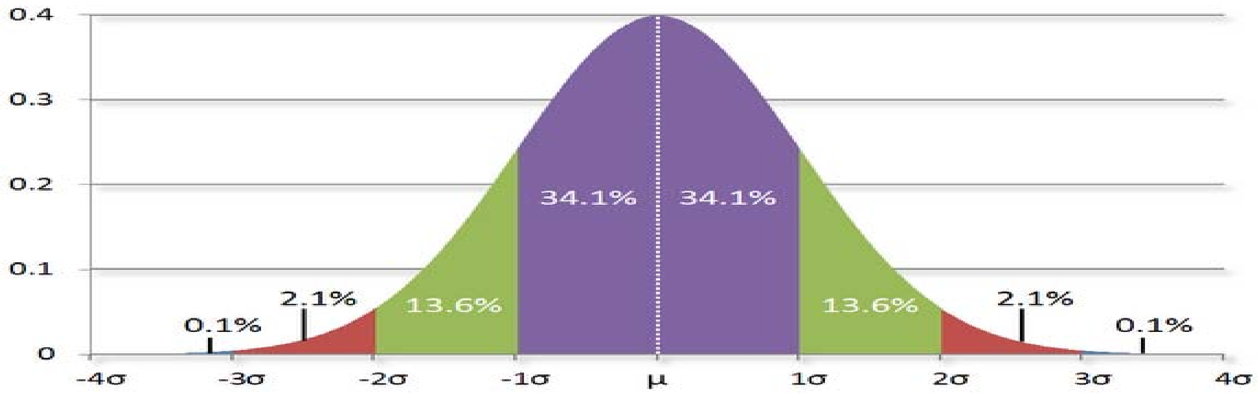
The Risk

- Risks of No-Seal

  No Seal → Base Erosion → Significant Cost

- Joint sealing should impact the potential for **Erosion**
- Can lead to **Faulting** and **Spalling**
  - **More reasonable to prevent than to repair!!**
- Subbase repair is costly (Full Depth Repair)

The Risk



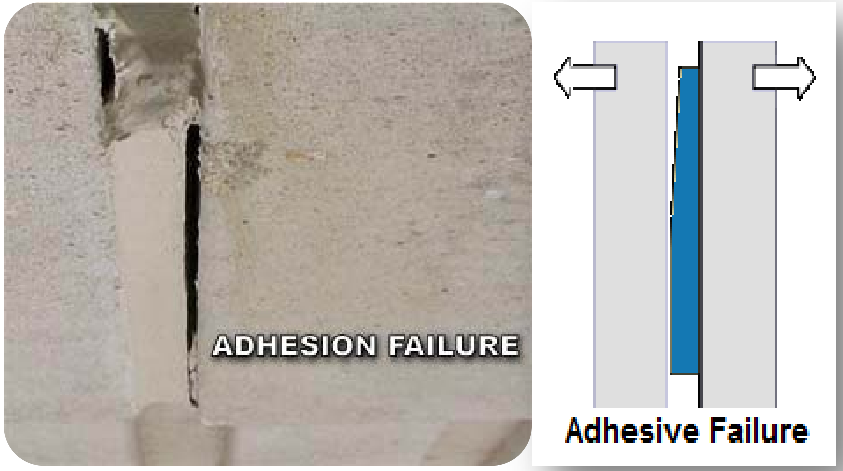
- Example of No-Seal Preference:
  If the pavement has sufficient drainage, low traffic , dry climate

- Example of Seal
  Erodible base material, heavy traffic, moist condition

Failure Mechanism

- **Adhesive Failure** ;

  Debonding of the sealant from the well side wall (cleanliness?)



- **Cohesive Failure** ;

  Tensile failure within the sealant material

  (Aging)

Other Possible Failure Modes

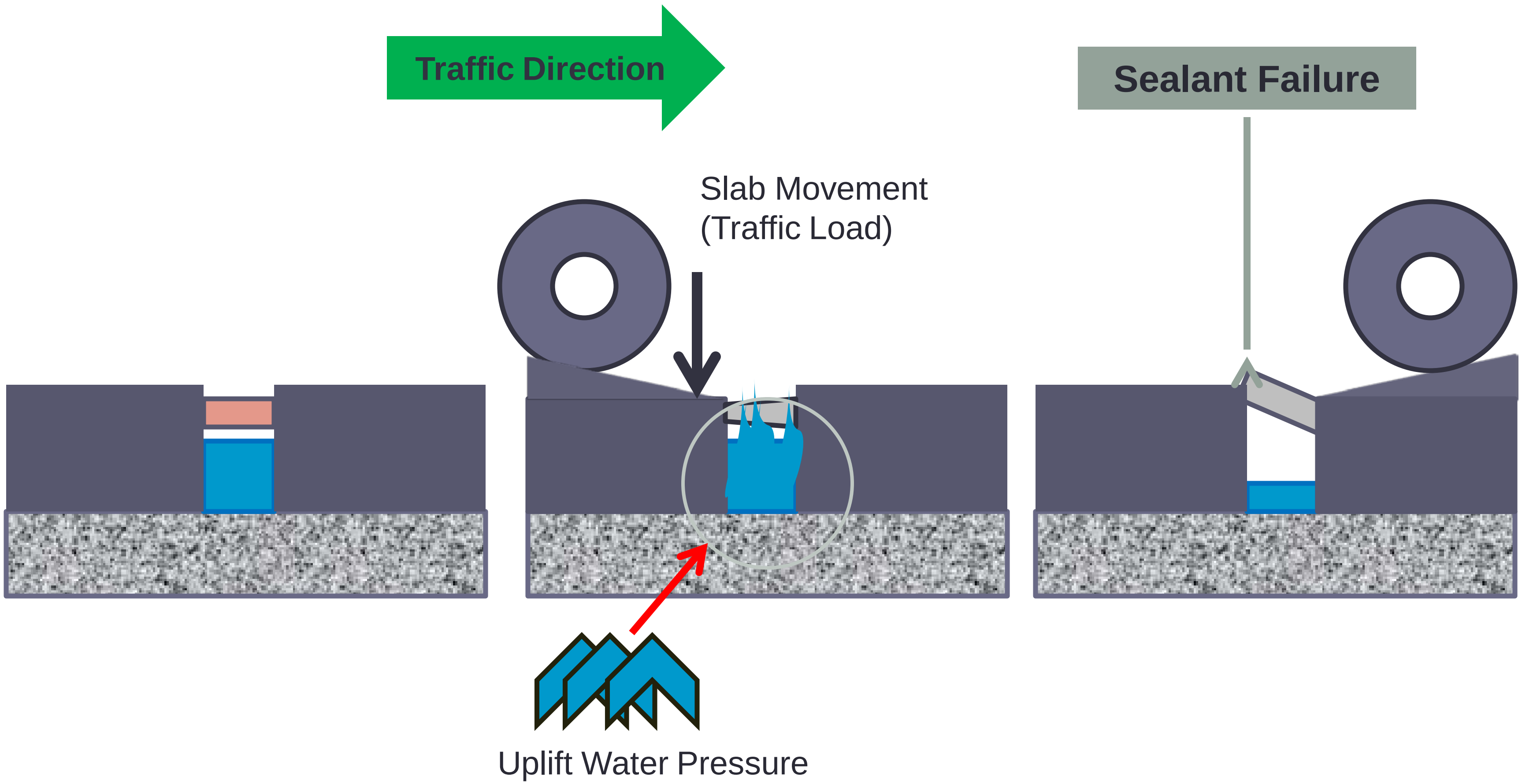
- **Hydraulic pressure from tires (at the Surface)**

  The water trapped on the joint push the seal down when heavy traffic passes

- **Hydraulic pressure due to pumping (Bottom-Up)**

  The water trapped in the well pumps up when the heavy traffic passes

Effect of Water Hydro Pressure on Sealant Failure



Surface Water → Traffic Passing → **Upward** pressure on sealant

Sealant Failure due to Hydraulic Pressure

Sealant Failure due to Hydraulic Pressure

Freeze-thaw Damage

- **Weathering** **(Moisture, Sun & Solar diffusion Energy)**
- **Loading Cycle** **(Temperature Changes, Traffic)**

Major Factors

- Permeability of the joint
- Widened joints/cracks
- Installation (Surface cleanness, Existence of Moist when installing, etc)

Other Factors

The Effect of Surface Preparation (Zollinger & Gurjer Model)

- Bonding test in tension on sealants

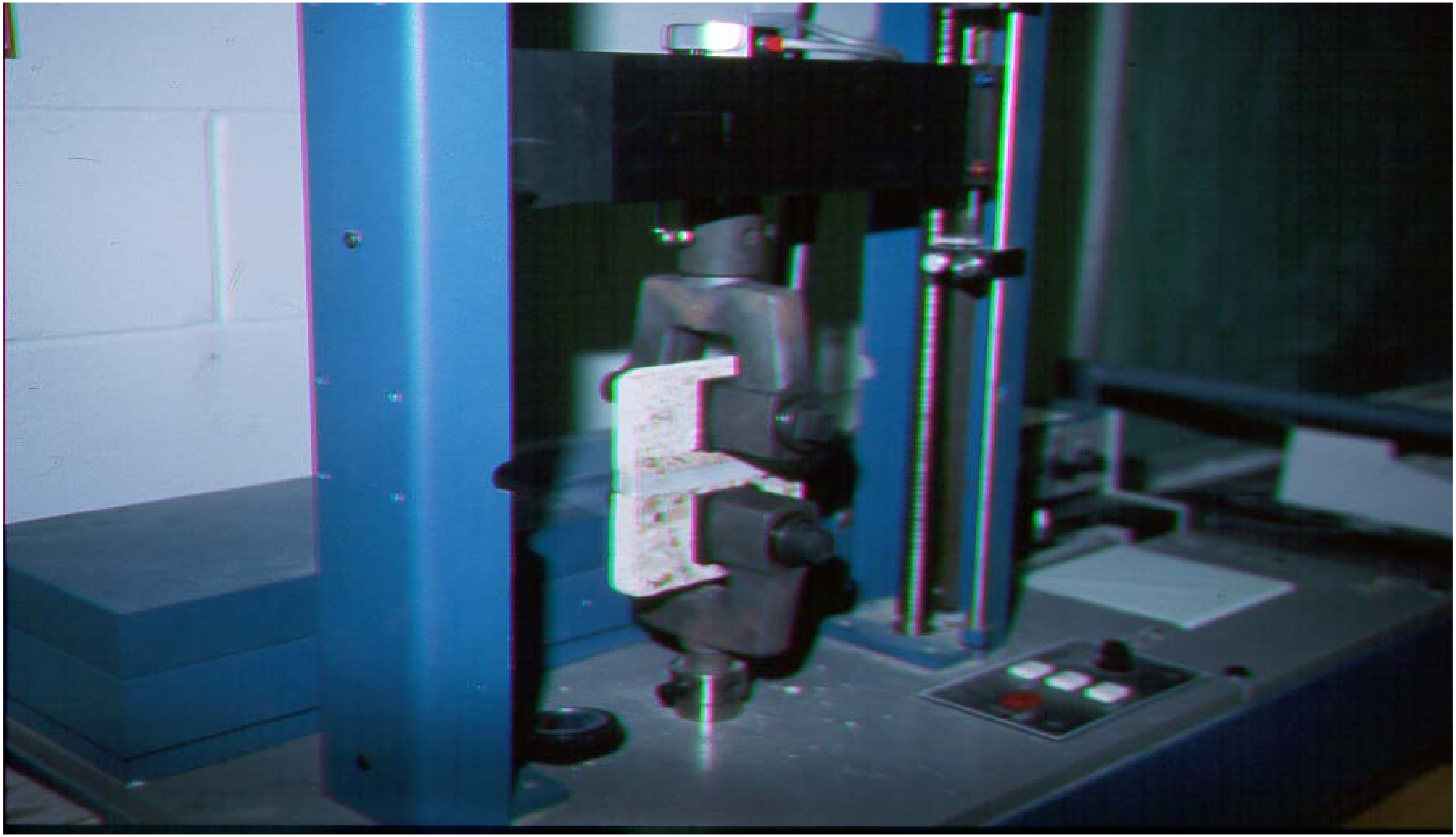
- Three different surface preparations :
  - Sand Blasted Surface
  - Water Blast+ Sand Blast
  - Sand Blast + Primer

Coefficients for surface preparation

$$\boxed{N_b = f_1 \frac{S_b}{E} \varepsilon_s^{\,f_2} \varepsilon_L^{\,f_3}} \Rightarrow \boxed{N_{lab} = a_m . N_b} \Rightarrow \boxed{N_{fc} = \lambda \times (-Ln\,(c_b))^{(1/k)}}$$

Bond Test Specimen

Bond Fatigue Testing

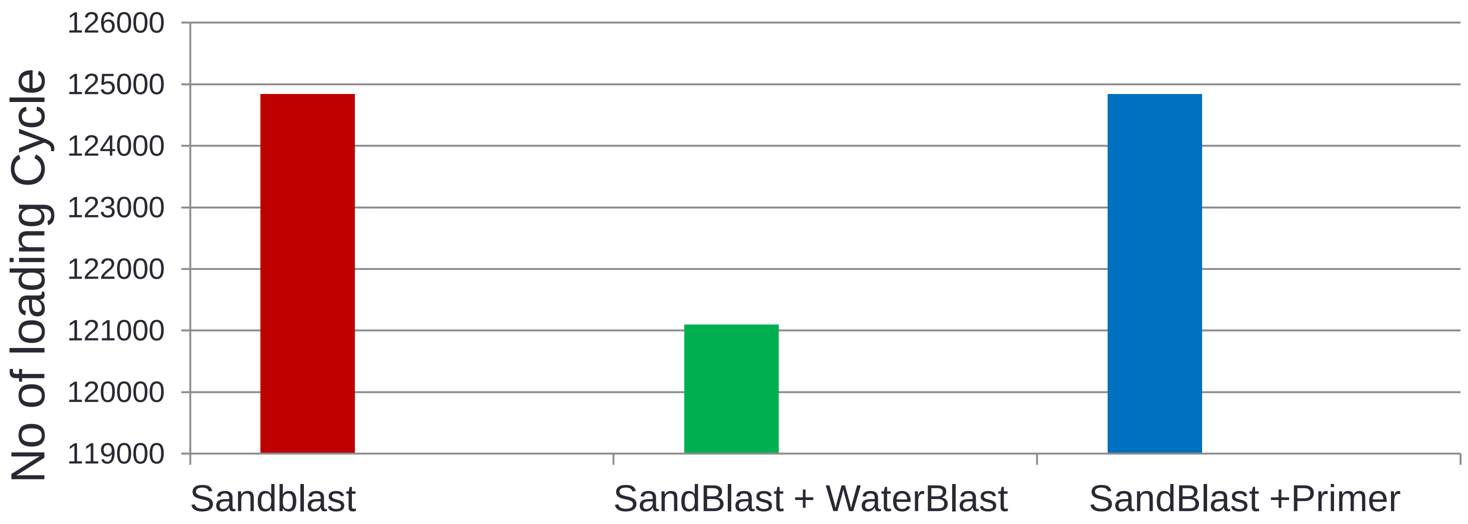


The Effect of Surface Preparation

Inputs :

Sealant Type: Two-Part Self Leveling Silicone

Aggregate Type: Limestone



Changing the surface preparation method can only increase the Number of cycle load by 3%

Sealant Design

- Problems with sealing narrow joints:
  - Shape factor and stress limits
  - Correct joint spacing
  - Unbroken transverse joints

Field and Laboratory Flow Testing

- **Joint Sealant Type**
  - **hot pour** rubberized asphalt
  - **silicone** self-leveling
  - preformed **compression**

- **Joint Seal Condition**
  - 25% deboned
  - 50% deboned
  - 75% deboned
  - Completely deboned

+

Movable Joint

opening after debonding

- **Joint Well Configuration**
  - **1/4 inch** wide by 1-¼ inch deep
  - **3/8 inch** wide by 1-¼ inch deep
  - **1/2 inch** wide by 1-¼ inch deep

Test Site Preparation

Sawcut Layout of Test Area

Double sealing — 7'9"
Compression — 10'0"
Hot pour — 10'0"
Silicone — 10'0"

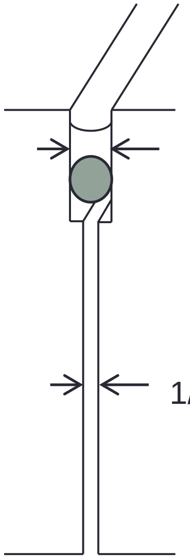
1'9" 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2' 2'

11'9"

10'

1/2"

Full-depth sawcut width	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
Joint well width	1/2"	1/2"	1/2"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"



Flow Rate on Existing Unsealed Joints

Saw cut width: 1/8 inch

Crack widths: 0.04 inch

Flow Rate (0.18 psi water head pressure):

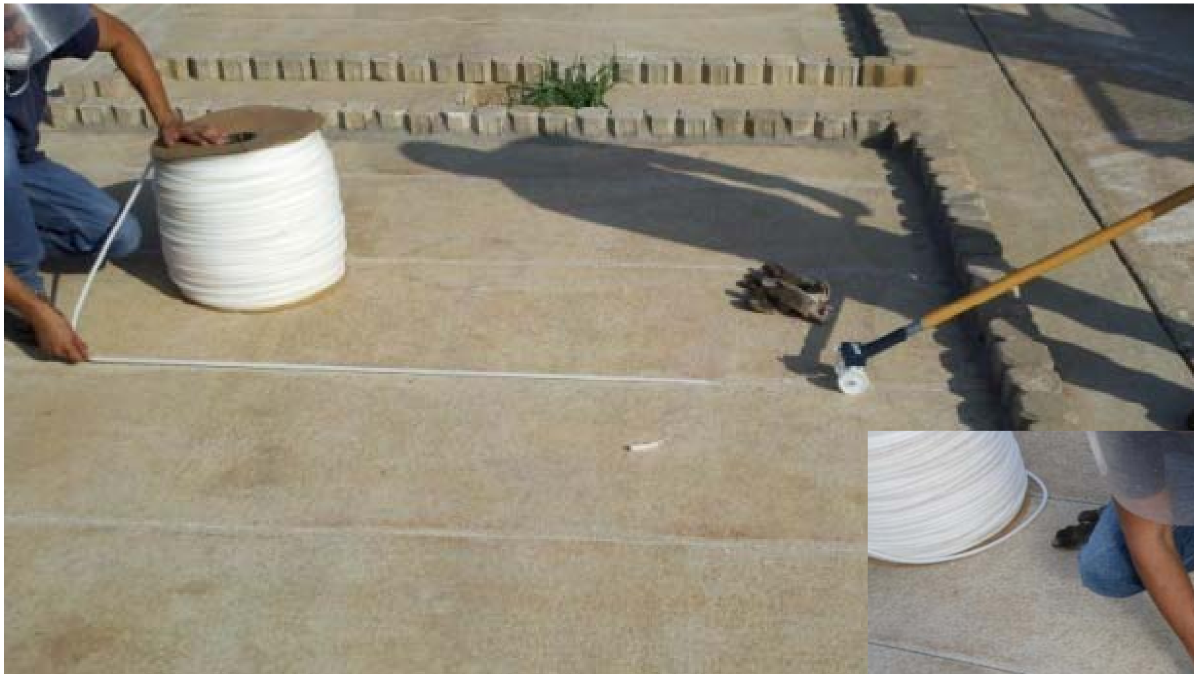
0.11 gal/hr/ft (dirty joint well)

0.14 gal/hr/ft (cleaned joint well)

Cracks could NOT be cleaned perfectly

Sand and Air Blasting

Backer Rod Placing

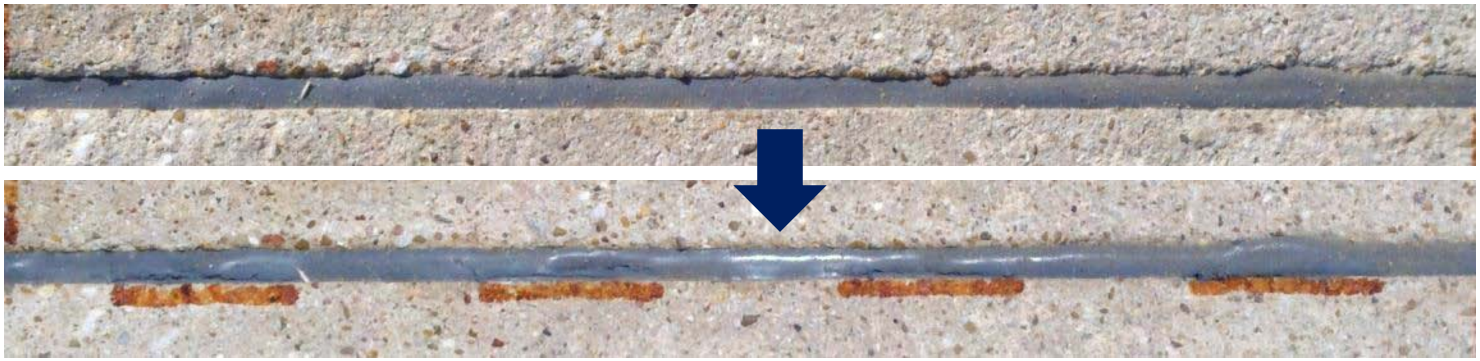


Silicon and Hot-pour Seal Placement

Compression Seal Placement

Debonding Sealants

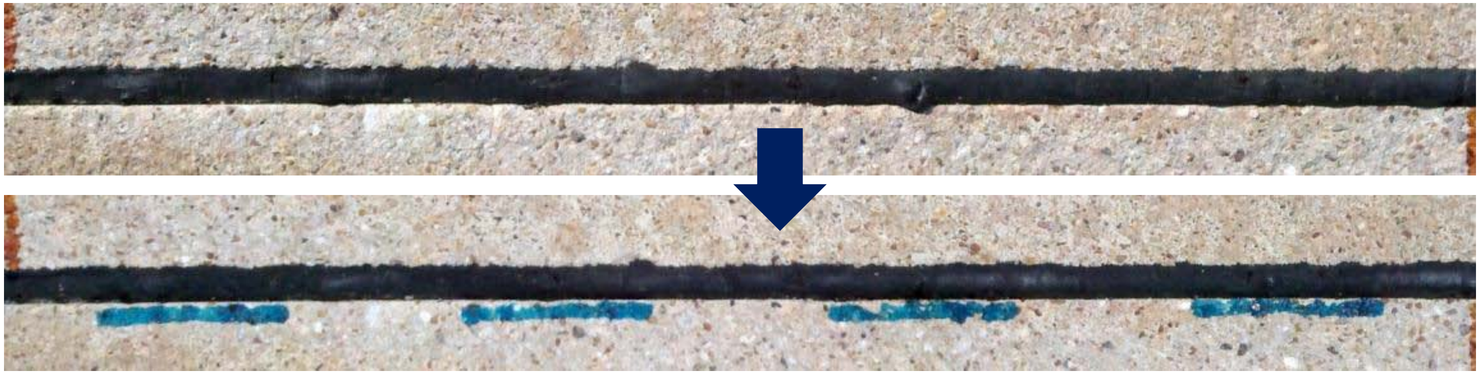
Silicon



Bonded

Debonded

Hot pour



Bonded

Debonded

After debonding, tight contact allows no infiltration

25% Damaged Sealing Conditions

Silicon

Hot-pour

Compression

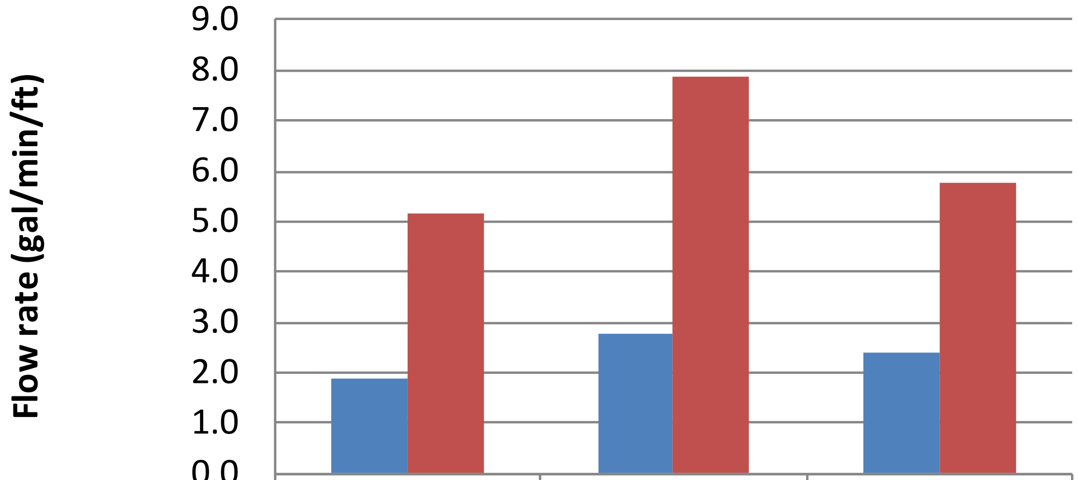
50% Damaged Sealing Conditions

Silicon

Hot-pour

Compression

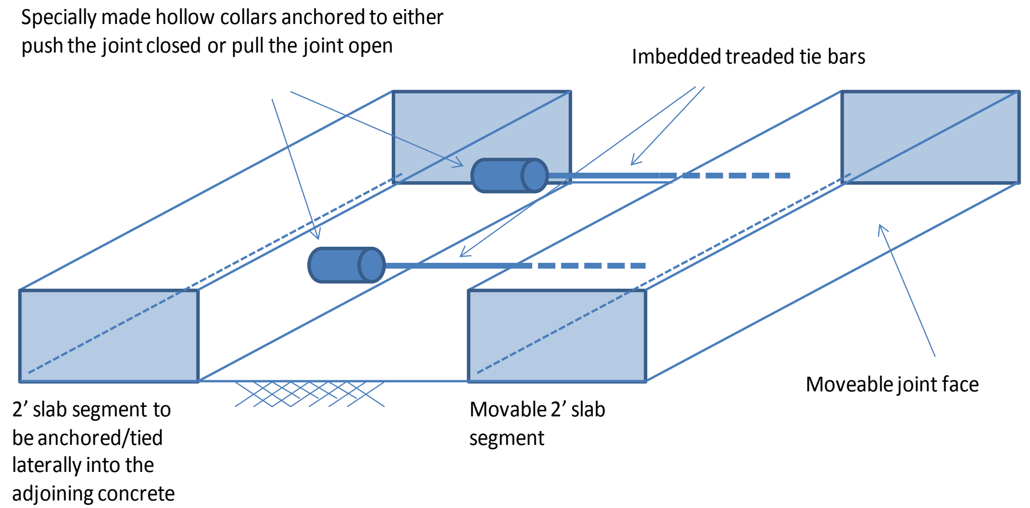
Flow Test Results of Sealed Joints

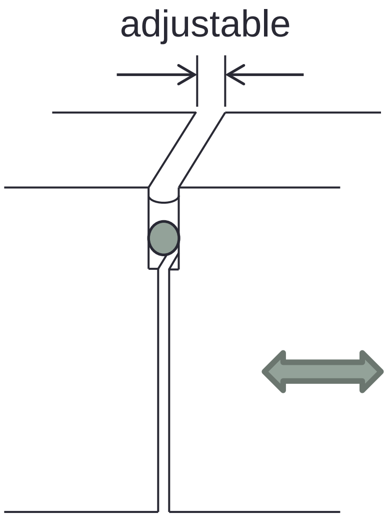


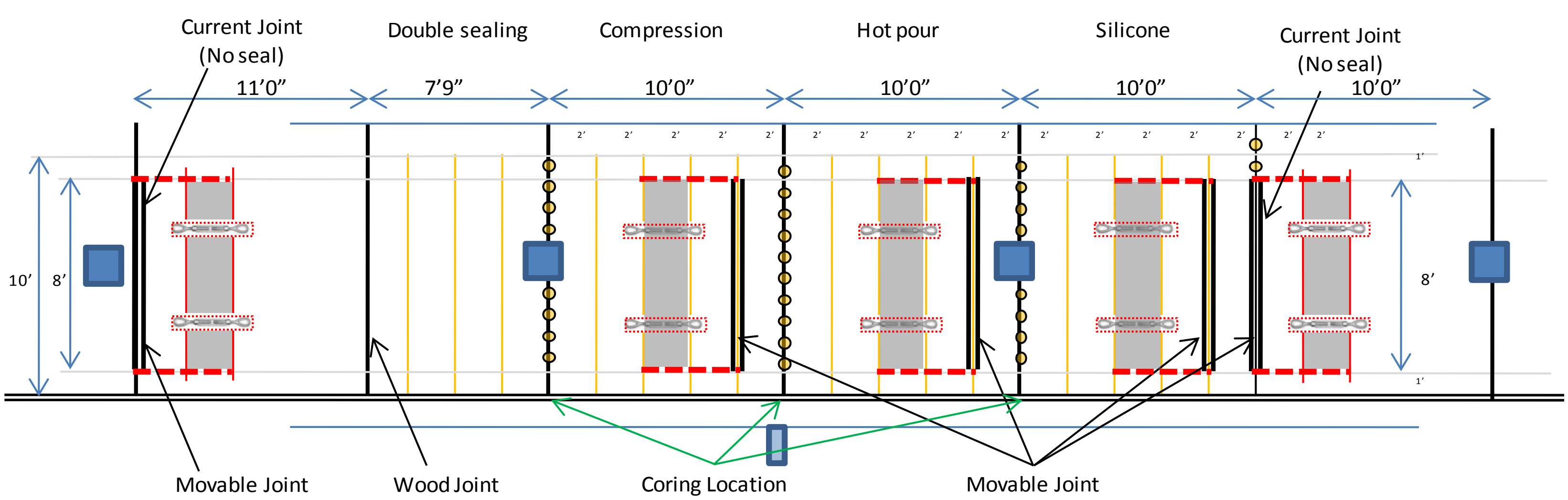
	Silicon	Hot pour	Compression
25 % damage	1.9	2.8	2.4
50 % damage	5.1	7.9	5.8

- Controlling the joint sealant damage precisely is very difficult
    - Hot pour sealant possibly damaged more than target value

Movable Joint System

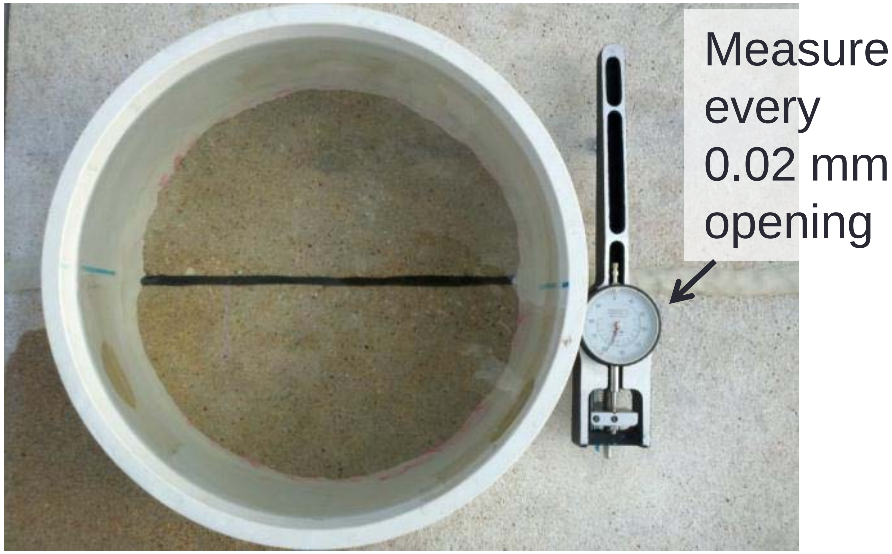






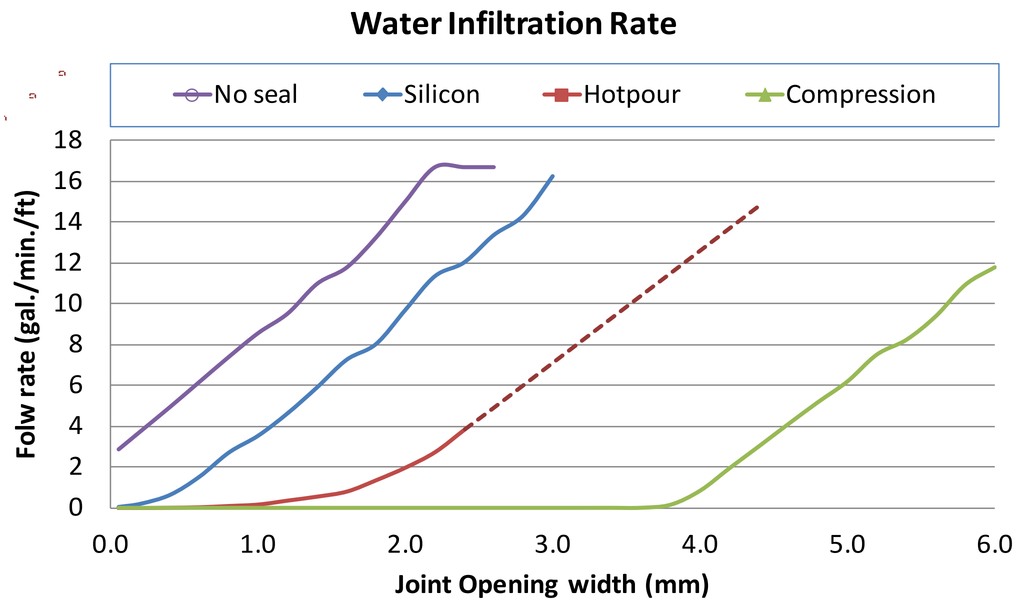
Installation of Movable Joint System

Movable Joint System



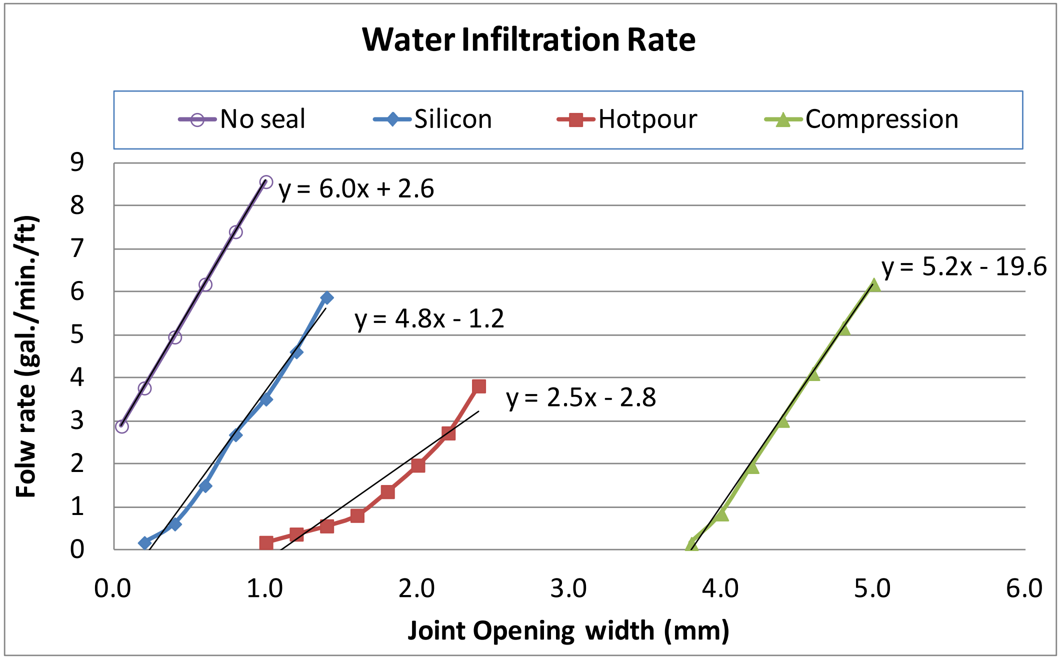
Flow Rate vs. Joint Opening (1/4”)

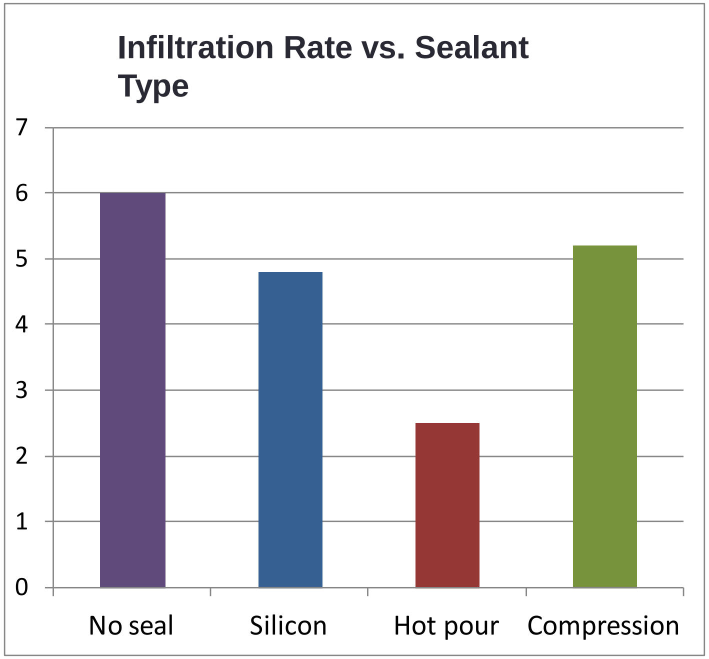
Joint opening width (inch)	Joint opening width (mm)	Flow rate (gallon/min./ft)			
		No seal	Silicon	Hotpour	Compression
0.002	0.05	2.9	0.020	0.001	0
0.008	0.2	3.8	**0.18**	0.01	0
0.016	0.4	5.0	0.6	0.03	0
0.024	0.6	6.2	1.5	0.05	0
0.031	0.8	7.4	2.7	0.1	0
0.039	1.0	8.6	3.5	**0.18**	0
0.047	1.2	9.5	4.6	0.4	0
0.055	1.4	11.0	5.9	0.6	0
0.063	1.6	11.8	7.2	0.8	0
0.071	1.8	13.2	8.0	1.4	0
0.079	2.0	15.0	9.7	2.0	0
0.087	2.2	16.7	11.3	2.7	0
0.094	2.4	16.7	12.0	3.8	0
0.102	2.6	16.7	13.3		0
0.110	2.8		14.3		0
0.118	3.0		16.2		**0.000**
0.126	3.2				0.001
0.134	3.4				0.002
0.142	3.6				0.005
0.150	3.8				**0.16**
0.157	4.0				0.8
0.165	4.2				1.9
0.173	4.4				3.0
0.181	4.6				4.1
0.189	4.8				5.2
0.197	5.0				6.2
0.205	5.2				7.5
0.213	5.4				8.2
0.220	5.6				9.4
0.228	5.8				10.9
0.236	6.0				11.8



- **Install sealants during summer (90 °F)**
- **100% debonded**
- **Initial crack width of unsealed joint = 0.06 in. (1.5 mm)**
- **Crack of unsealed joint was cleaned perfectly**

Increasing Infiltration Rate vs. Sealant Types





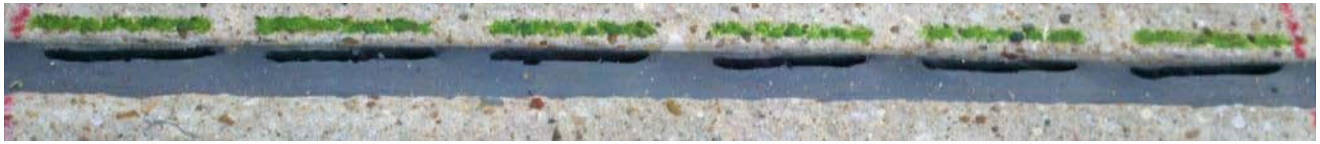
Hot pour sealant allowed lower rates of infiltration than other sealants when the opening of sealant is less than 1 mm

Flow Rate vs. Various Debonding Percentage - Silicon Sealant

3/8 inch Joint - Silicon sealant - installed during winter (50 °F)

25% debonded

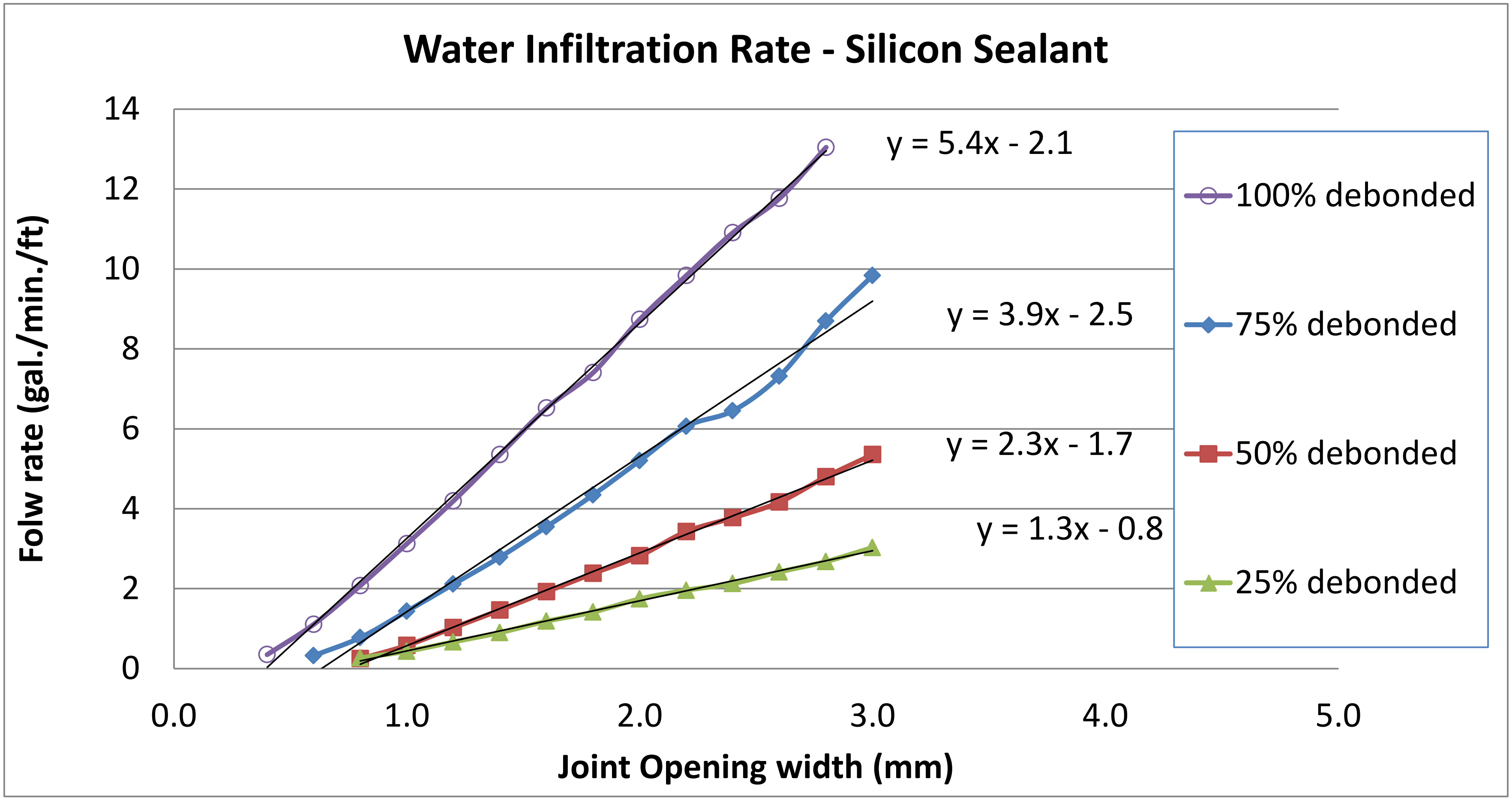
50% debonded



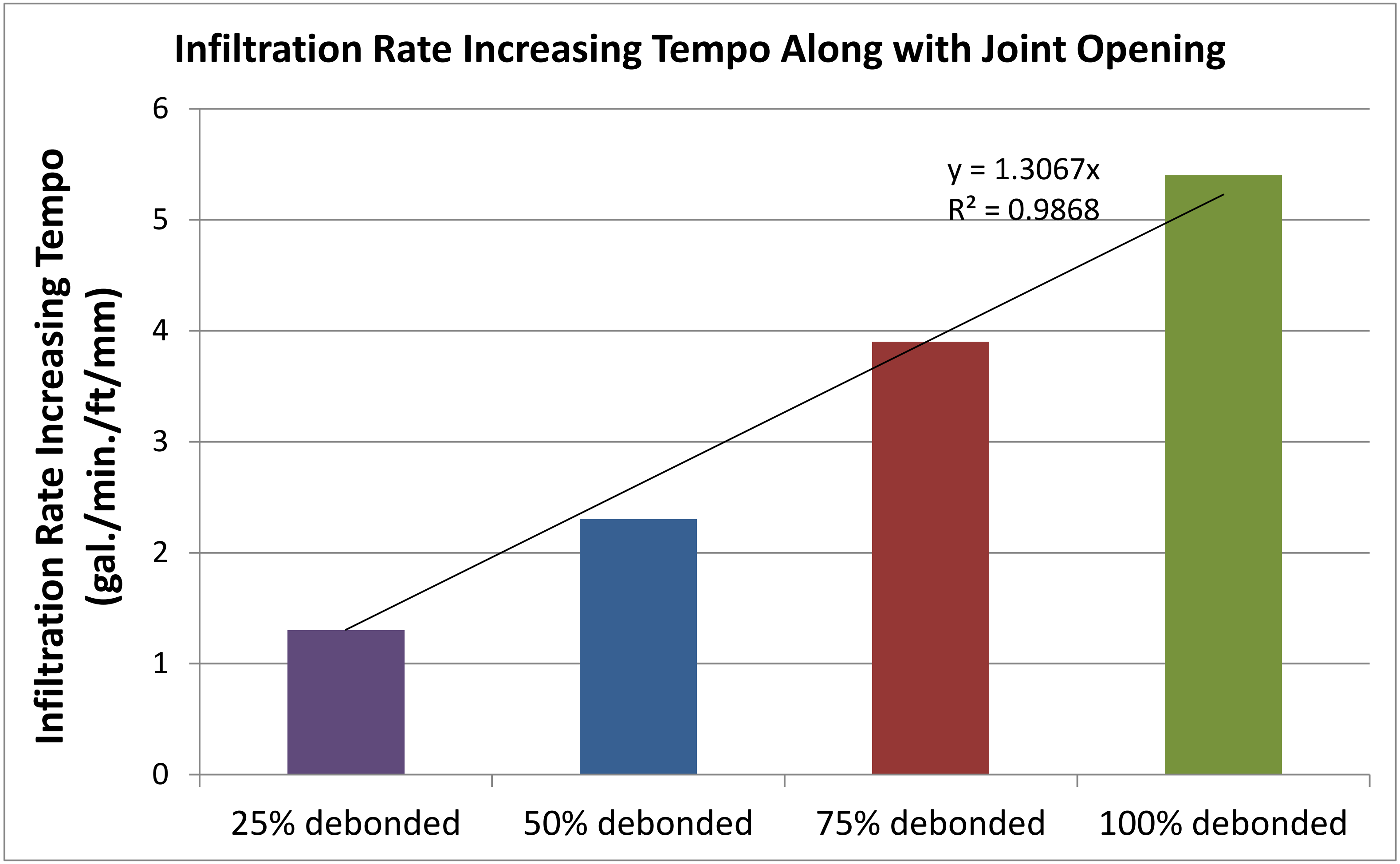
75% debonded

100% debonded

Flow Rate vs. Various Debonding Percentage - Silicon Sealant



Increasing Tempos of Infiltration Rate vs. Various Debonding - Silicon Sealant



Flow Rate vs. Various Debonding Percentage - Hot pour Sealant

3/8 inch Joint – Hot pour sealant - installed during winter (50 °F)

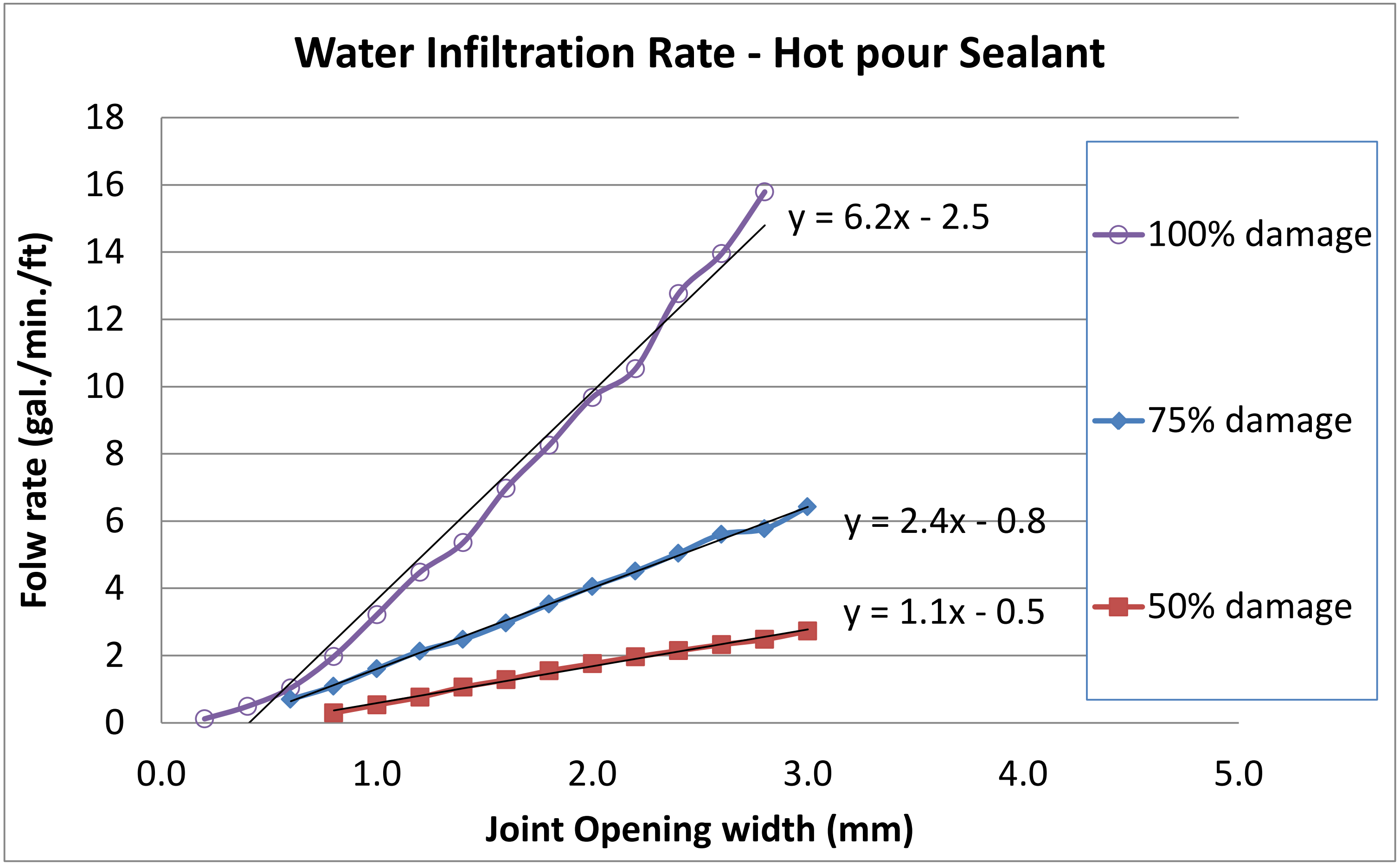
25% debonded

50% debonded

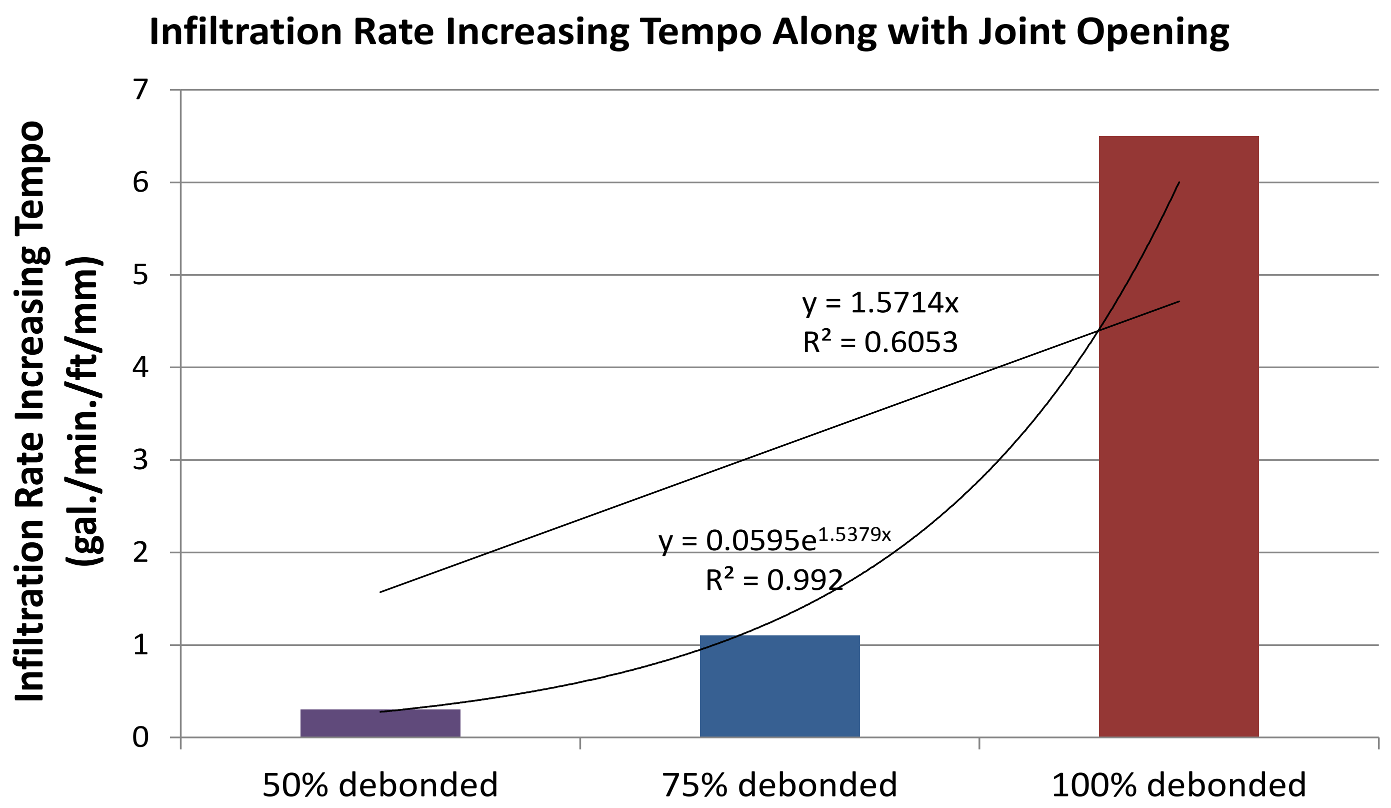
75% debonded

100% debonded

Flow Rate vs. Various Debonding Percentage - Hot pour Sealant

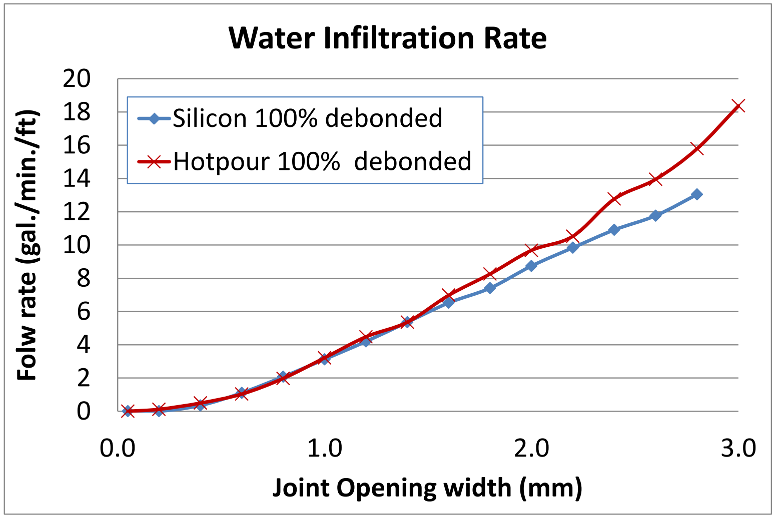


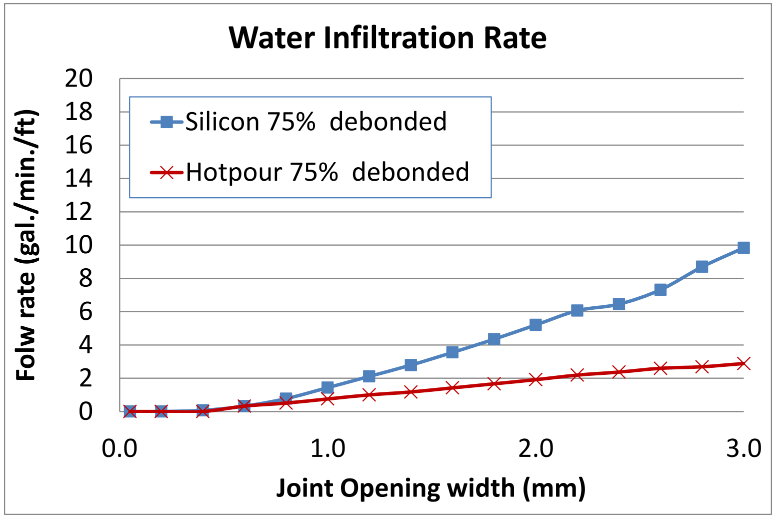
Increasing Tempos of Infiltration Rate vs. Various Debonding – Hot pour Sealant

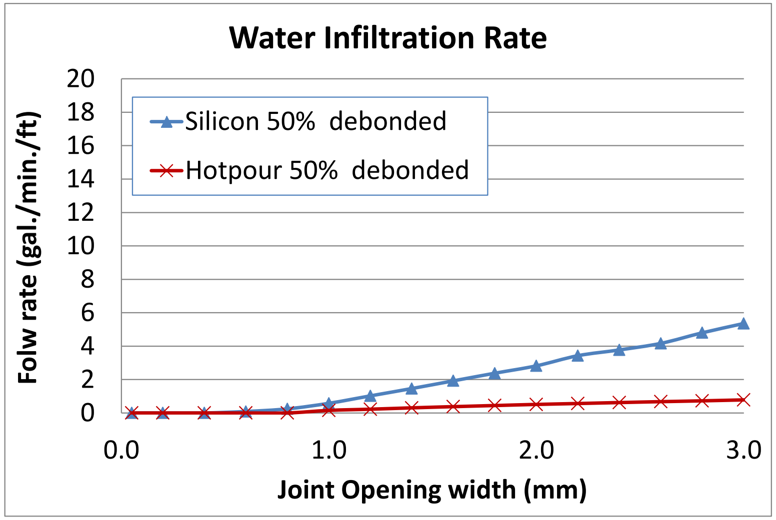


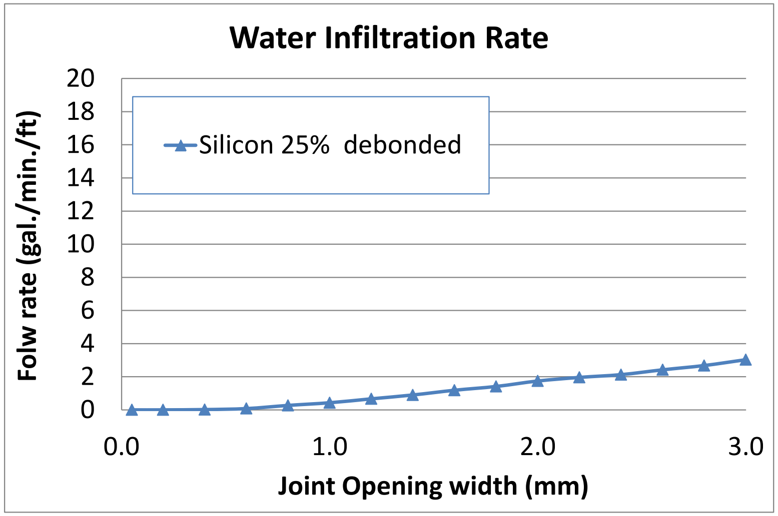
25% debonded hot pour sealant is failed to test (debonded more than plan during the test)

Silicon Sealant vs. Hot pour Sealant





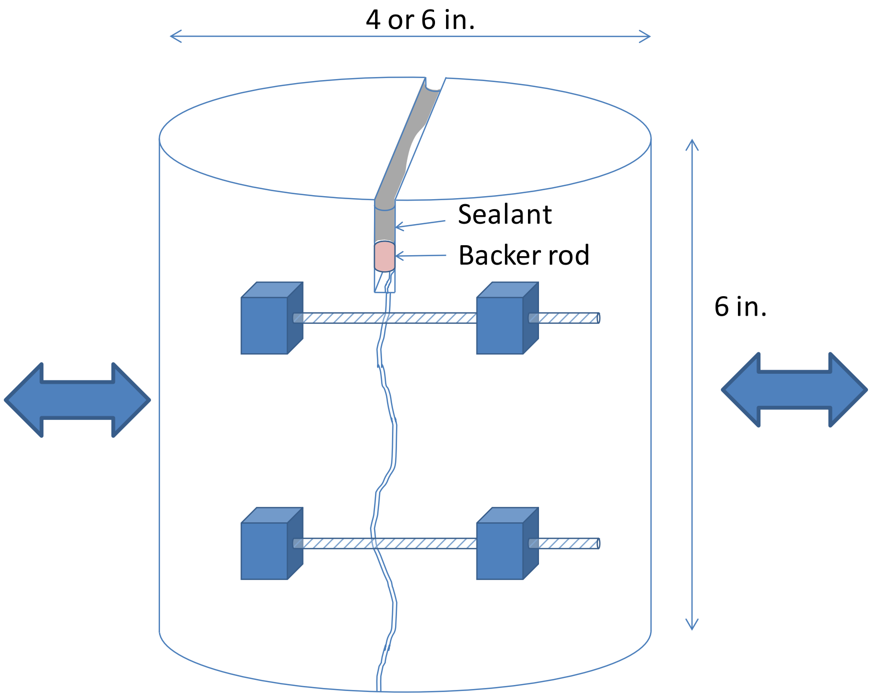


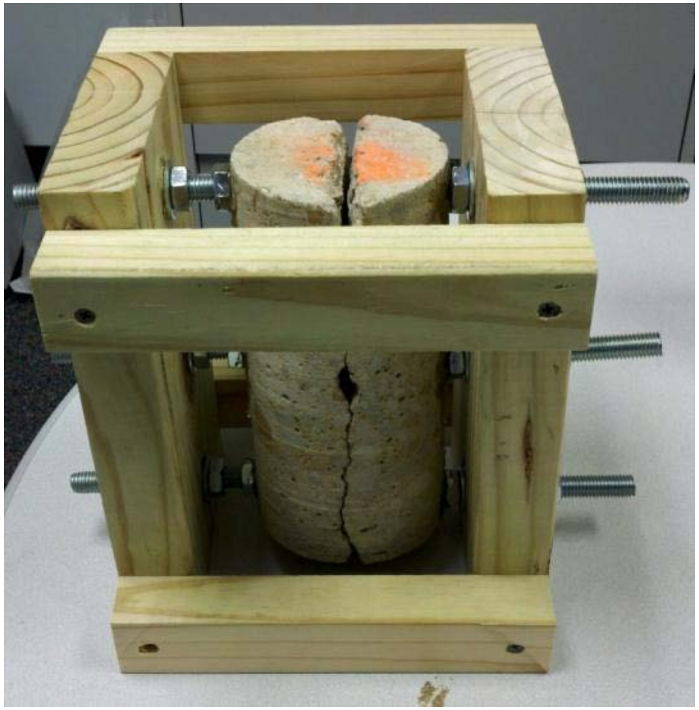


On Going Field Tests

- Flow Rate vs. Different Joint Well Width
  - 3/8 inch joint well
  - 1/2 inch joint well
- Bonding Quality vs. Joint Well Dirtiness
  - Four different dirtiness levels
- Bonding Quality vs. Moisture on Joint Well
  - Four different Moisture levels

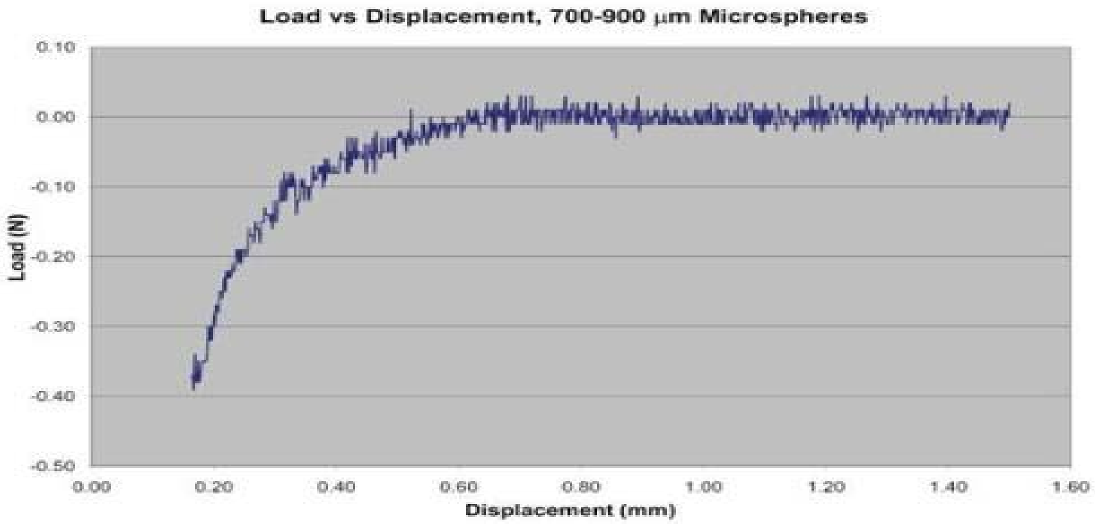
Lab Test for Joint Permeability





Evaluation of Sealant Longevity

1. Aging the samples in “Environmental Room”
2. Adjust the Electro Force Device to the slab movement strain
3. Testing the aged and un-aged samples in the lab.
4. Testing the samples from the field (known traffic & climate)
5. Calibration of the lab data to the field



Electro Force Device

- Electro Force Device for aging test

  (Cycle of loading and unloading)

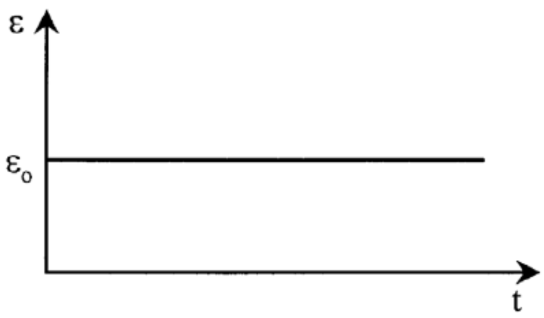
Electro Force Device

Advantages:

- Quick setting and results
- Working with smaller samples
- Ability to load both on tension and compression
- Adjustable to different load frequency
- Constant strain and constant stress tests

Relaxation Test

Relaxation Test



$$\sigma = \sigma_0 e^{-t/\tau}$$

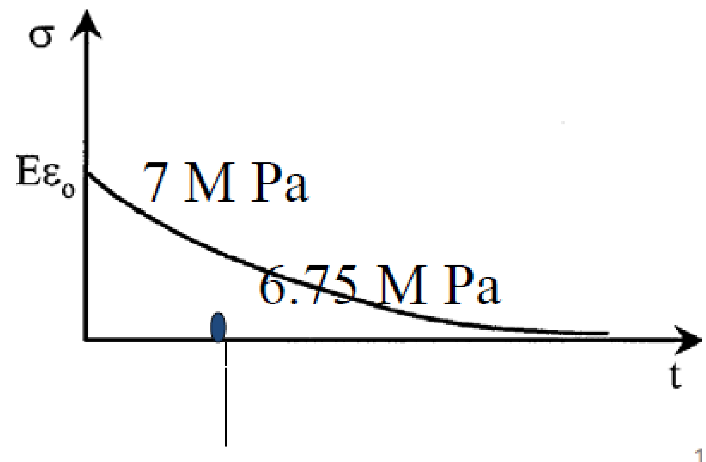
$$\sigma = \sigma_0 e^{-t/\tau}$$

$$6.75 = 7e^{-6/\tau}$$

$$-\frac{6}{\tau} = \ln\left(\frac{6.75}{7}\right) = -0.036; \tau = 165\,weeks$$

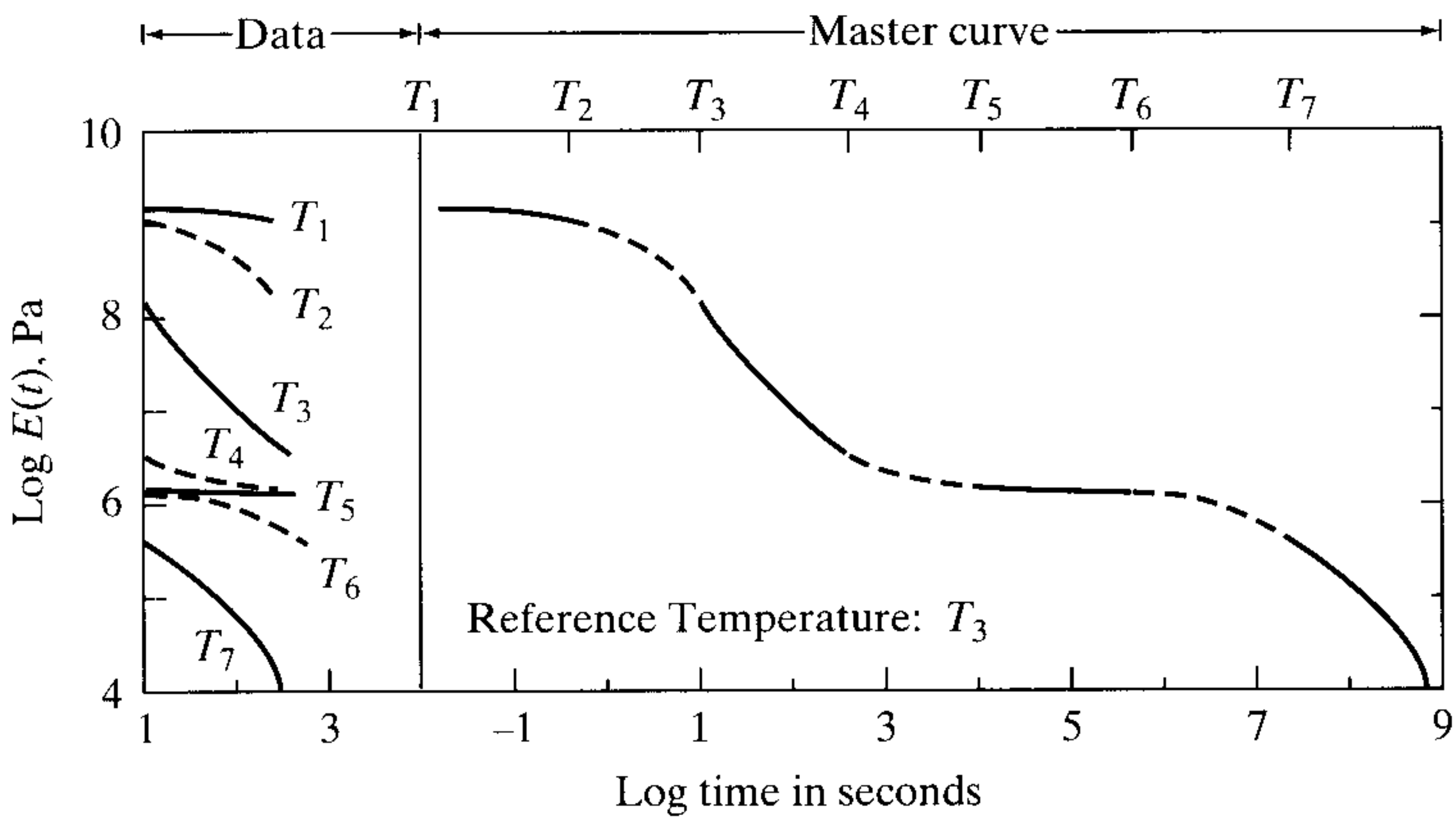
$$10 = \sigma_0 e^{-52/165} = 0.730\sigma_0$$

$$\sigma_0 = \frac{10}{0.73} = 13.7\,MPa$$



Creep in Polymers / Asphalt

- creep modulus / relaxation modulus
  - master reference curve - define properties for long & short times of loading not practical or feasible in laboratory testing

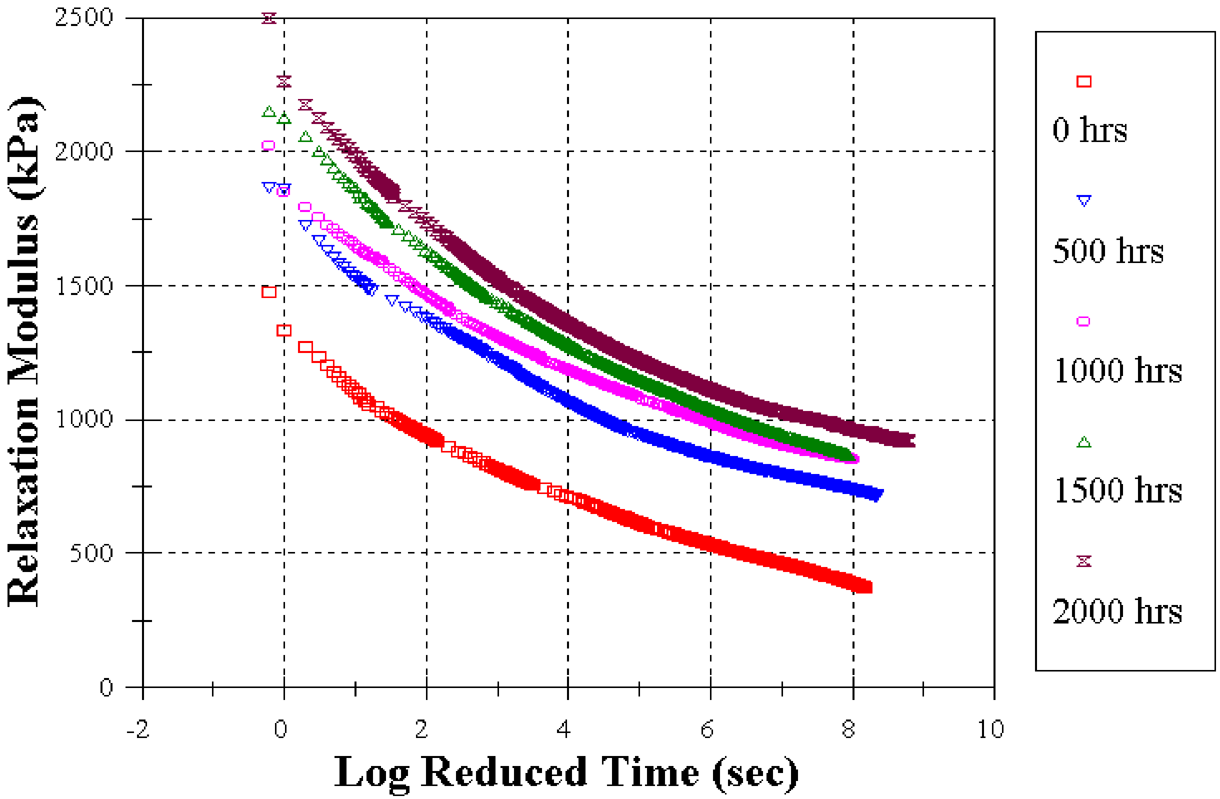


Weathering Device

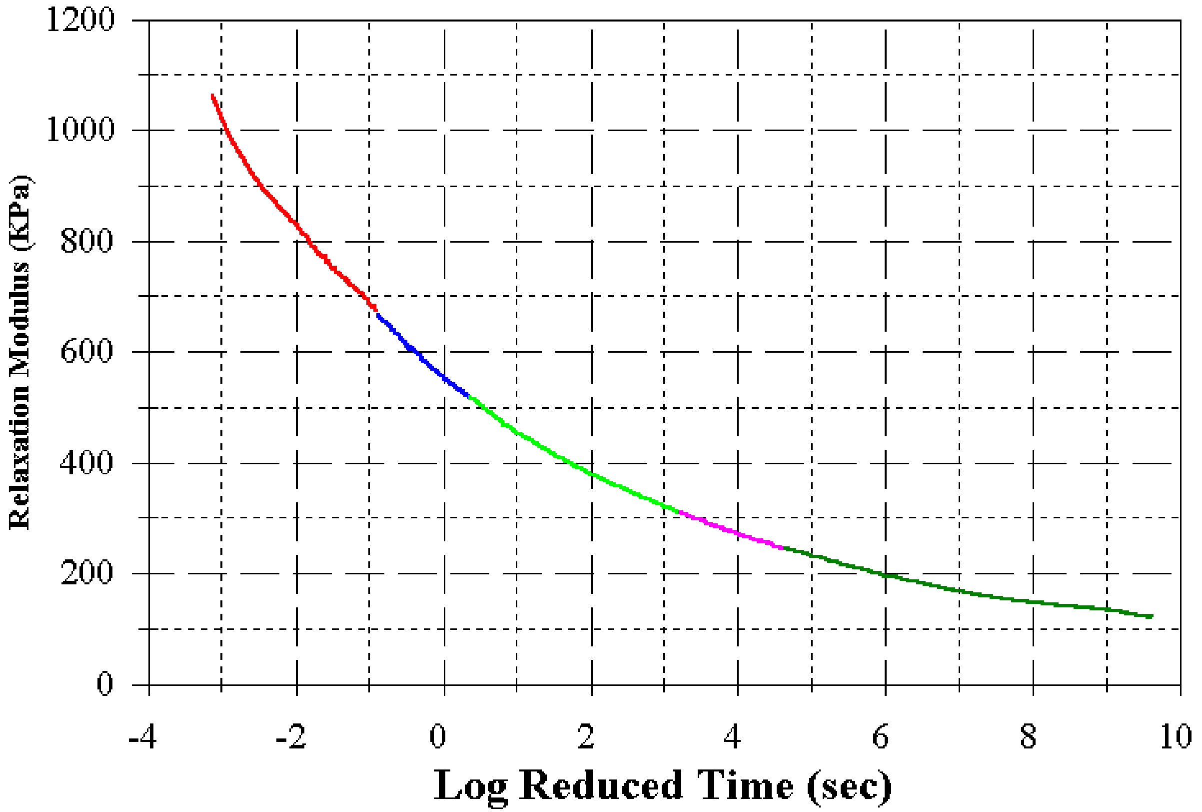
Weathering and Aging of Specimens

Relaxation Testing of Aged Specimen

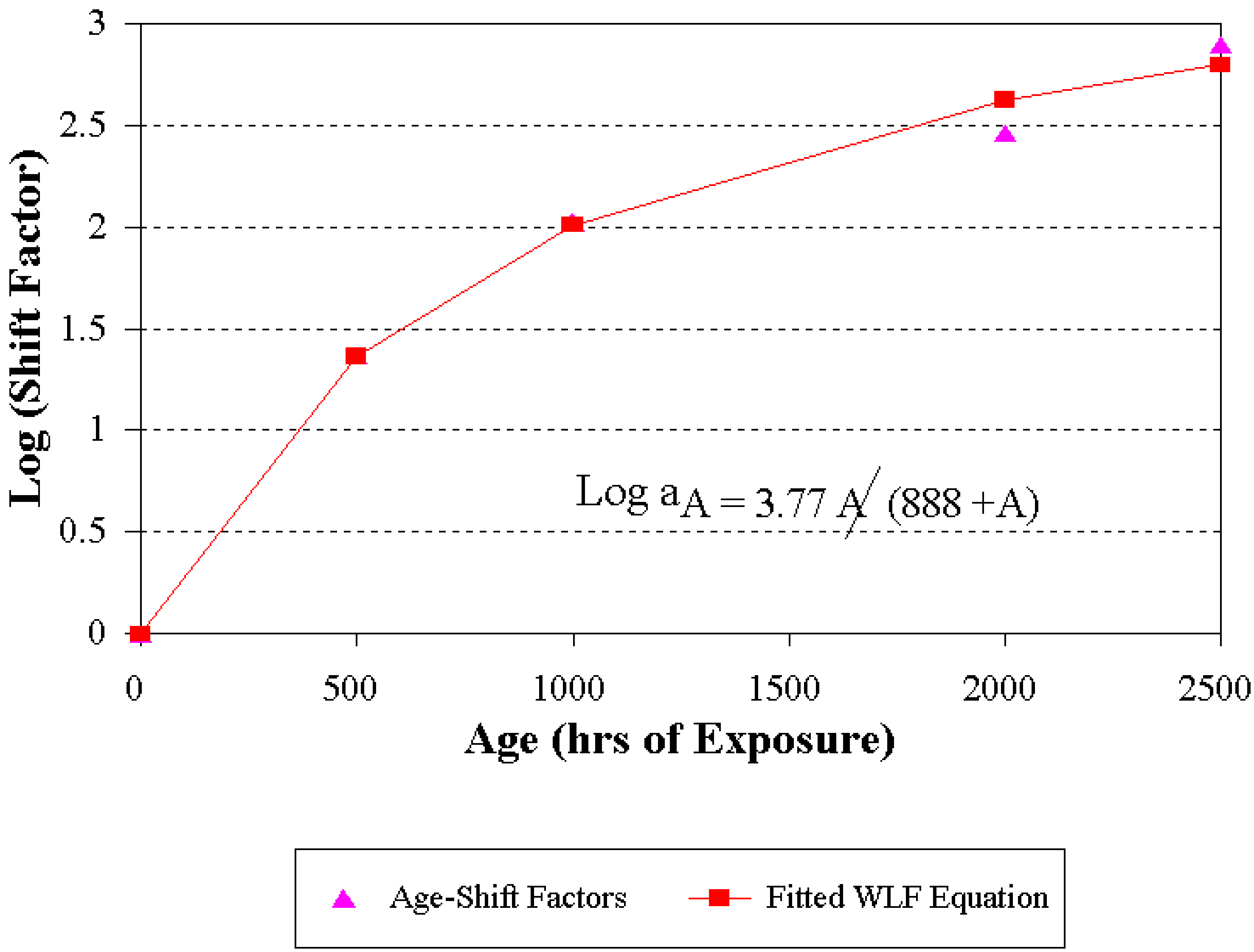
Relaxation Aging Curves: Percol



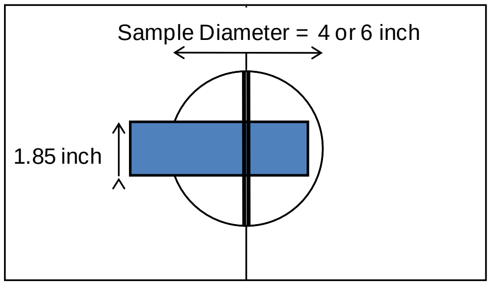
Master Relaxation Aging Curve: D888

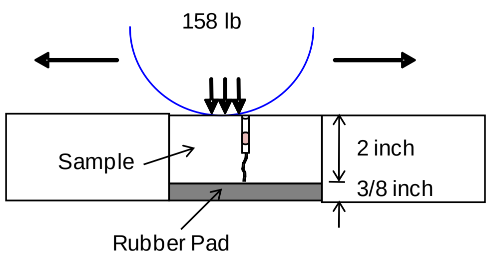


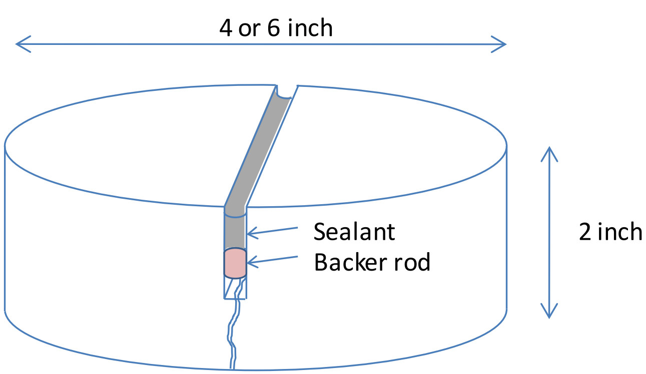
Age Shift Factor: D888

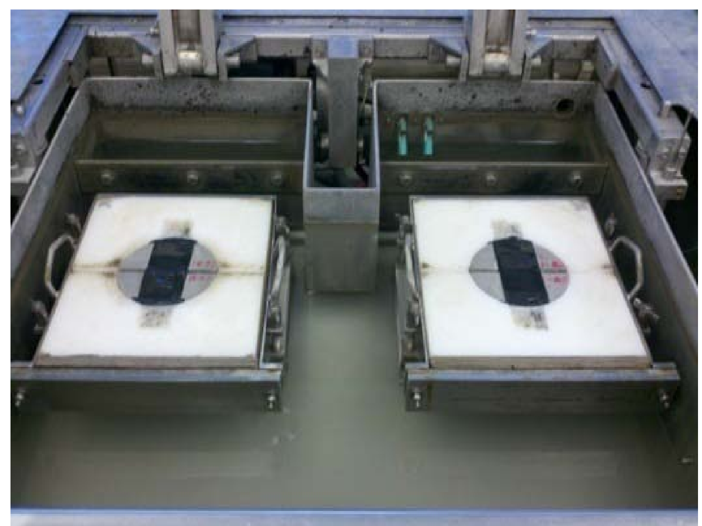


Lab Test for Sealant Bonding Failure









Thanks for your attention

Questions?