JOINT SEALANT RESEARCH

Rigid Pavement Treatments & Repairs

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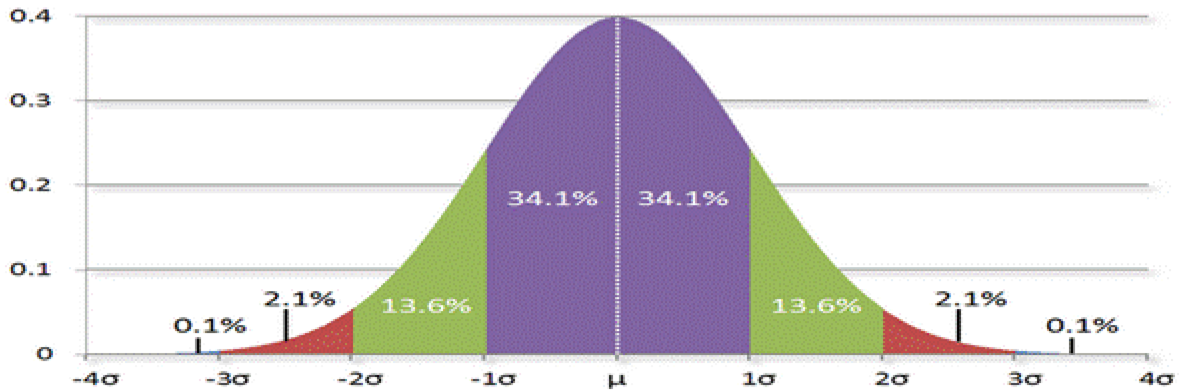
The Concern and the Risk



- Erode-able Base Material
- Heavy Traffic
- Moist Condition

Sealing Necessary

- Sufficient Drainage System
- Low Traffic
- Dry Climate

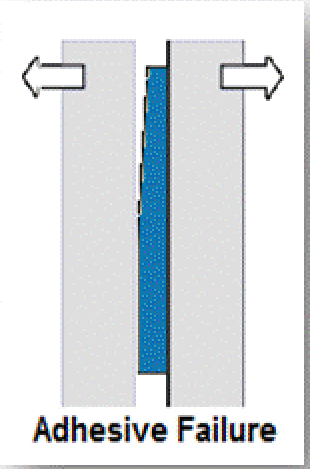
Sealing should be considered if budget is available

Failure Mechanism

- **Adhesive Failure ;**

  Debonding of the sealant and slabs

Top View (Field)



Section View

What causes it?

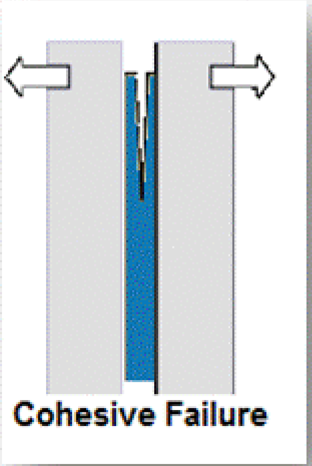
- Cycles of loading (Traffic, Temperature)
- Sealant fatigue
- Existence of dust and uncleanness
- Freeze-Thaw damages

Failure Mechanism

- **Cohesive Failure ;**

  Fatigue Failure of the Sealant material

Top View (Field)

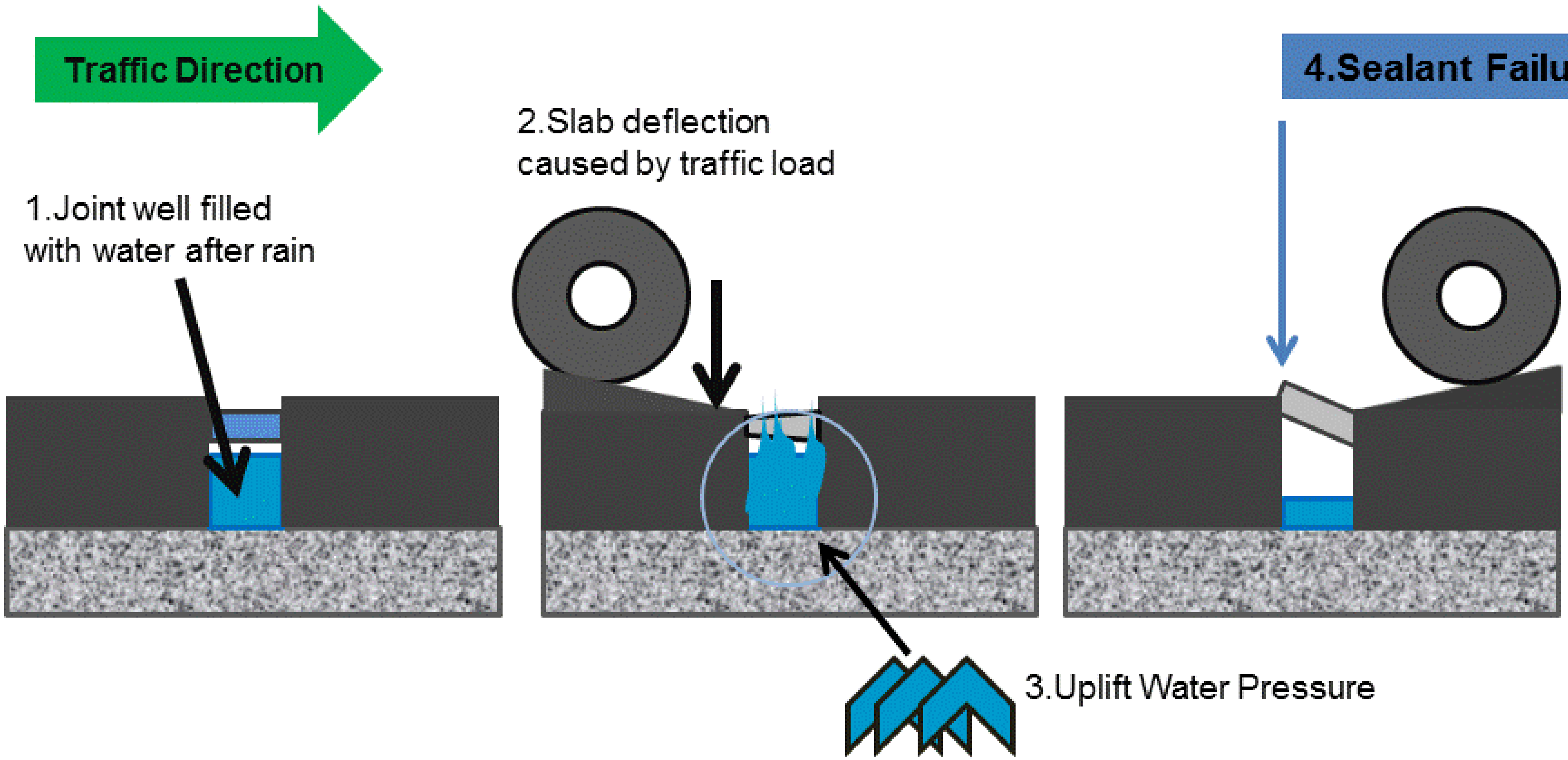


Section View

What causes it?

- Cycles of loading (Traffic, Temperature)
- Solar energy and sunrise
- Material stiffening (Loss of flexibility)
- Freeze-thaw damages after crack initiation

Effect of Water Hydro Pressure on Sealant Failure
<u>Upward</u>



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

Sealant Failure due to Hydraulic Pressure

- The sealant has been forced out;
- Hydro pressure from the water in the joint after heavy traffic is passing

Sealant Failure due to Hydraulic Pressure

Upward Failure

Unbroken Joints

Sealant Design

- Problems with Narrow Joints:
  - Improper Shape Factor
  - Excessive Stress when Curling –warping
  - Transverse Cracks in the middle of the slabs

Field Testing

- **Joint Sealant Type**
  - **Hot Pour** rubberized asphalt
  - **Silicone** self-leveling
  - preformed **Compression**

- **Joint Seal Condition** +
  - 25% debonded
  - 50% debonded
  - 75% debonded
  - Completely debonded

Movable Joint

opening after debonding

- **Joint Well Installation**
  - **Different dirtiness prior to sealing**
  - **Different moisture prior to sealing**

Flow Rate on Existing Unsealed Joint

Saw cut width: 1/8 inch

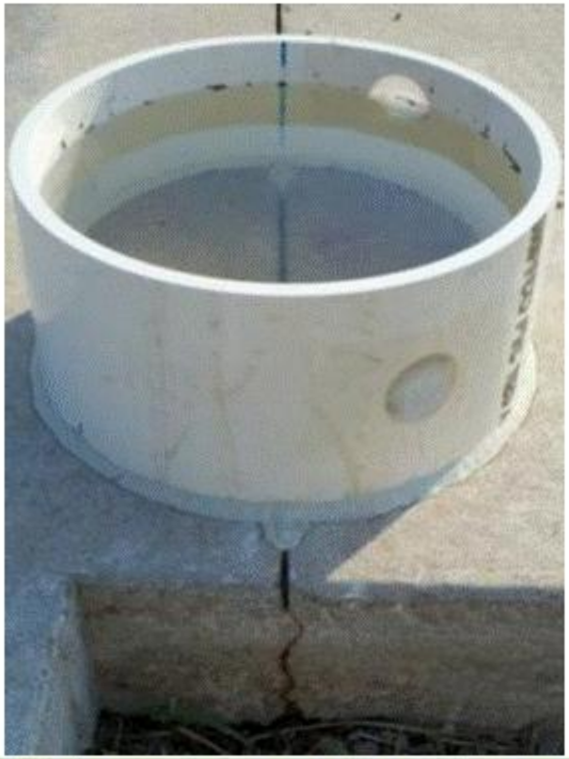
Crack widths: 0.04 inch

Flow Rate (0.18 psi water head pressure):

0.11 gal/hr/ft (dirty joint well)

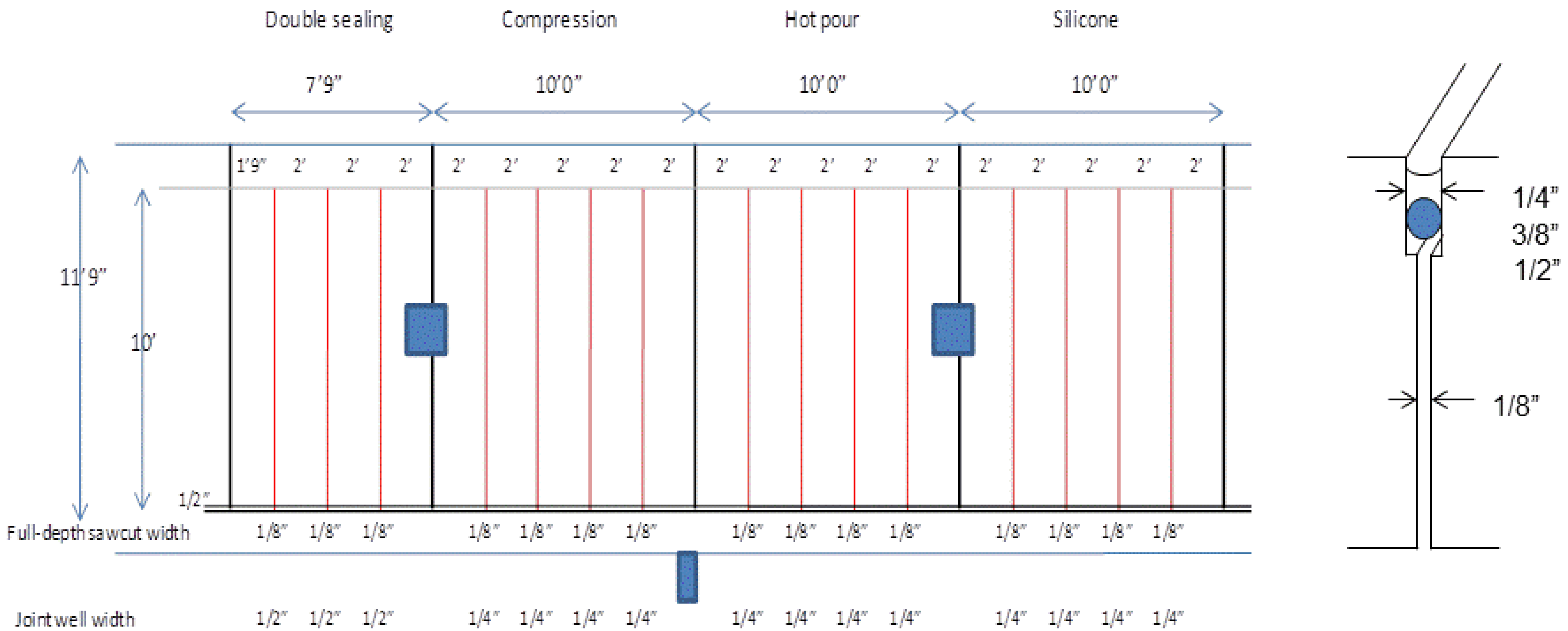
0.14 gal/hr/ft (cleaned joint well)

Cracks could NOT be cleaned perfectly



Test Site Preparation

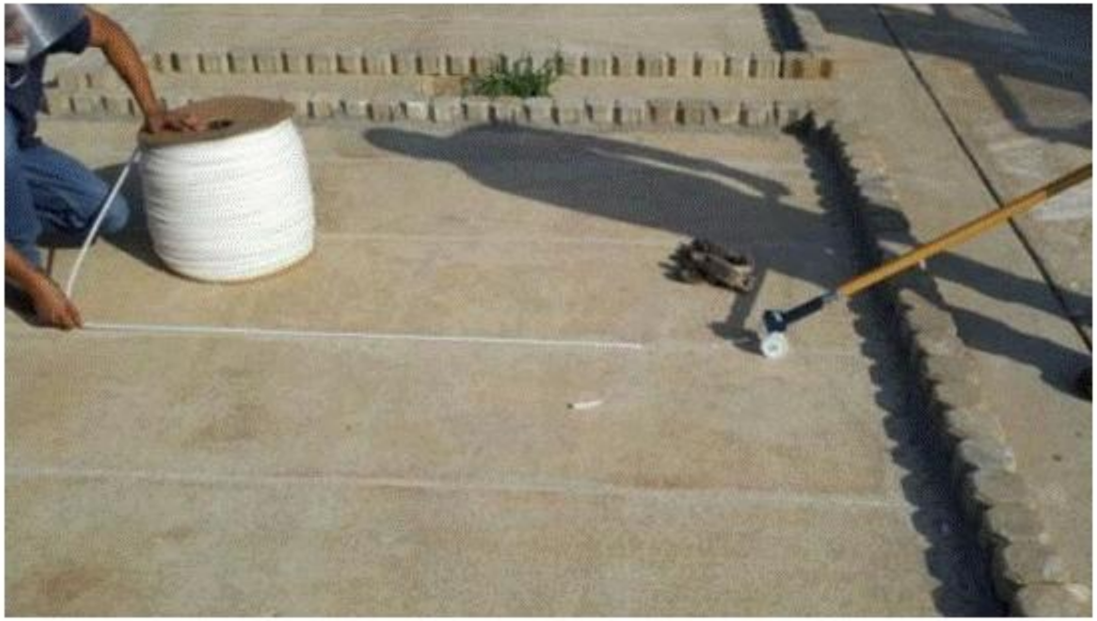
Sawcut Layout of Test Area



Sand and Air Blasting

Compression Seal Placement

Backer Rod Placing



Silicon and Hot-pour Seal Placement

Debonding Sealants

Silicon

Bonded

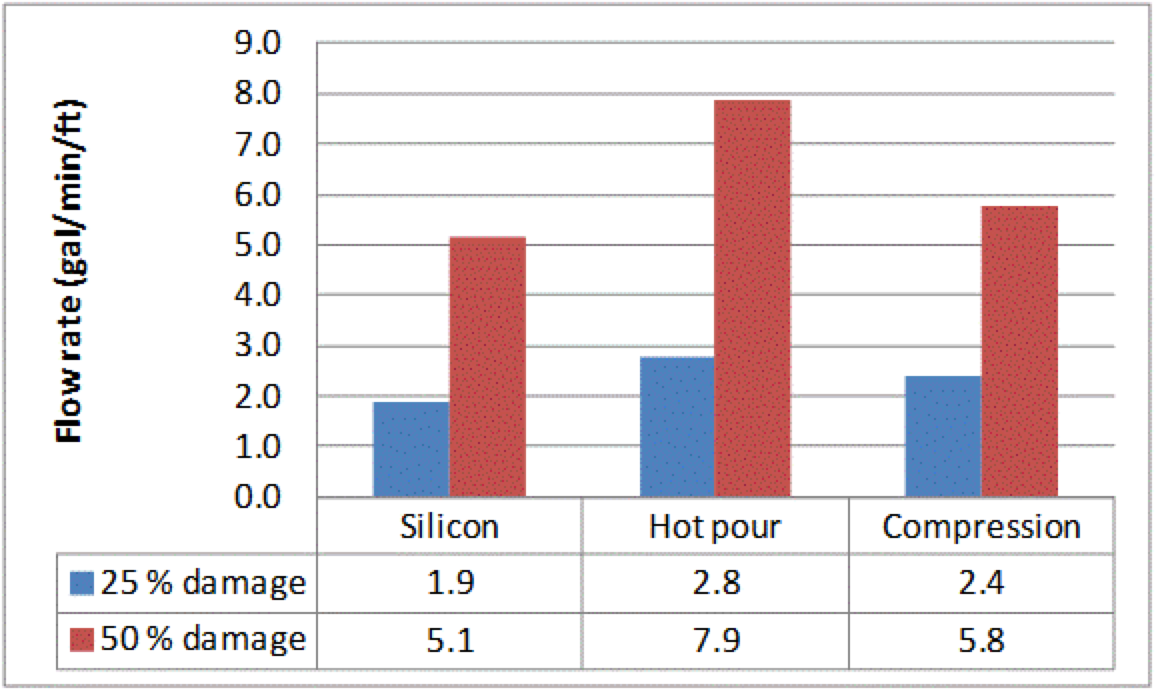
Debonded

Hot pour

Bonded

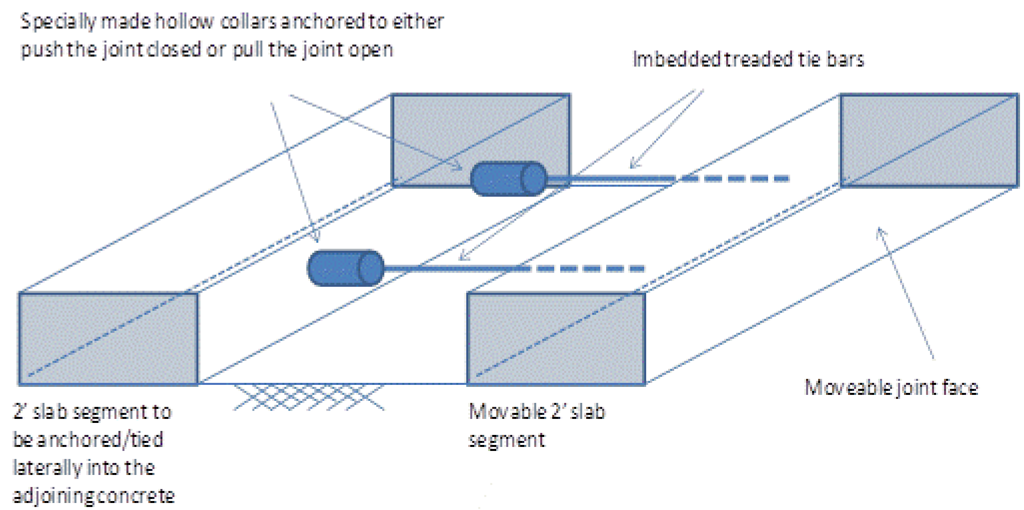
Debonded

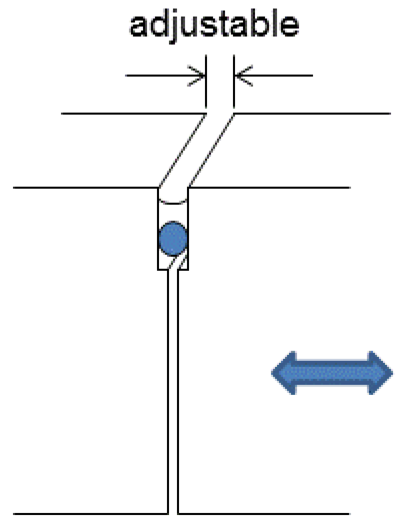
Flow Test Results of Sealed Joints

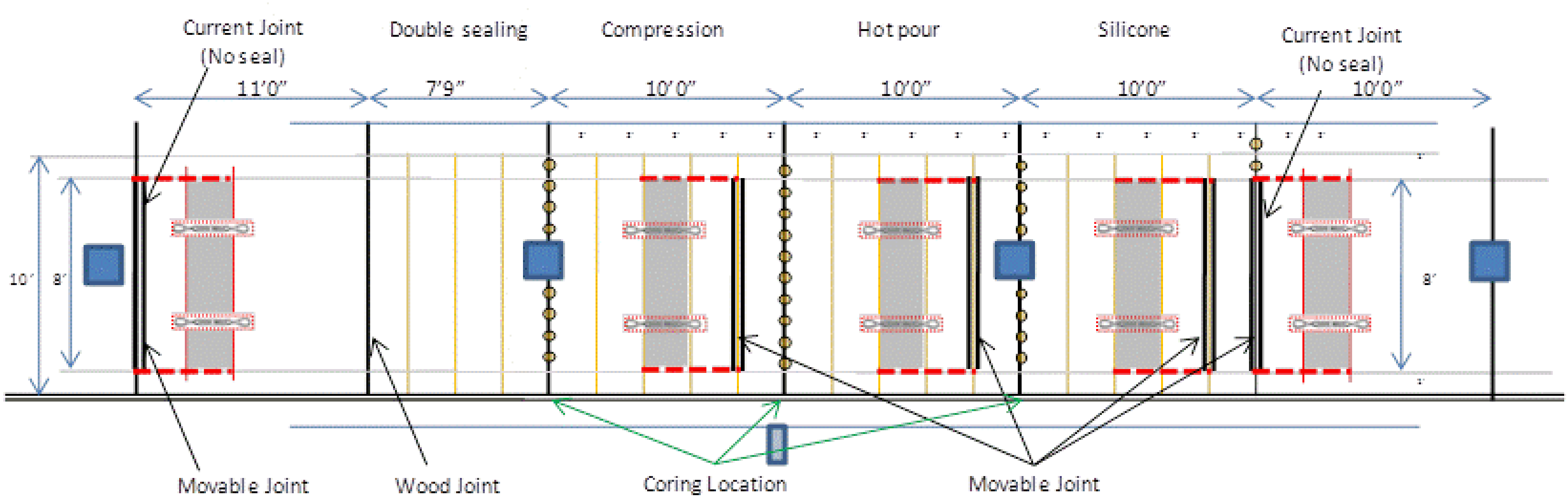


- Controlling the joint sealant damage precisely is very difficult
  - Hot pour sealant possibly damaged more than target value

Movable Joint System

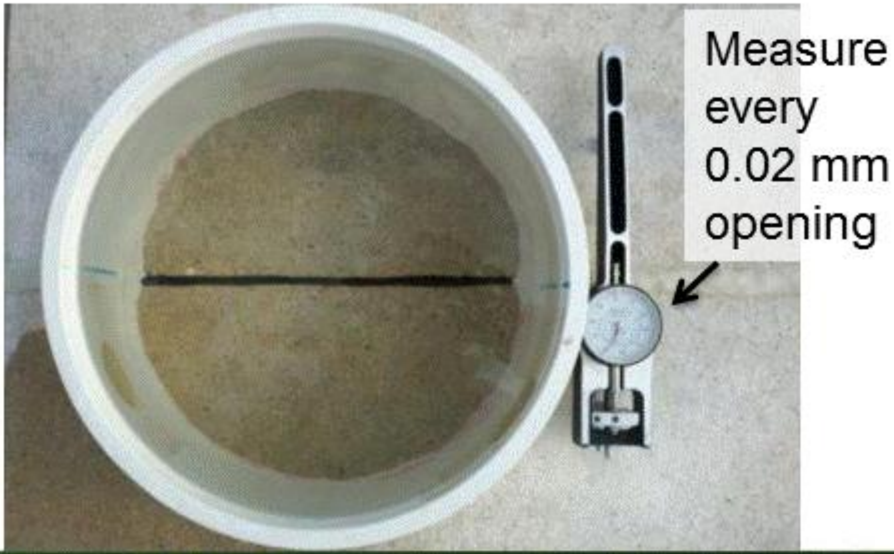






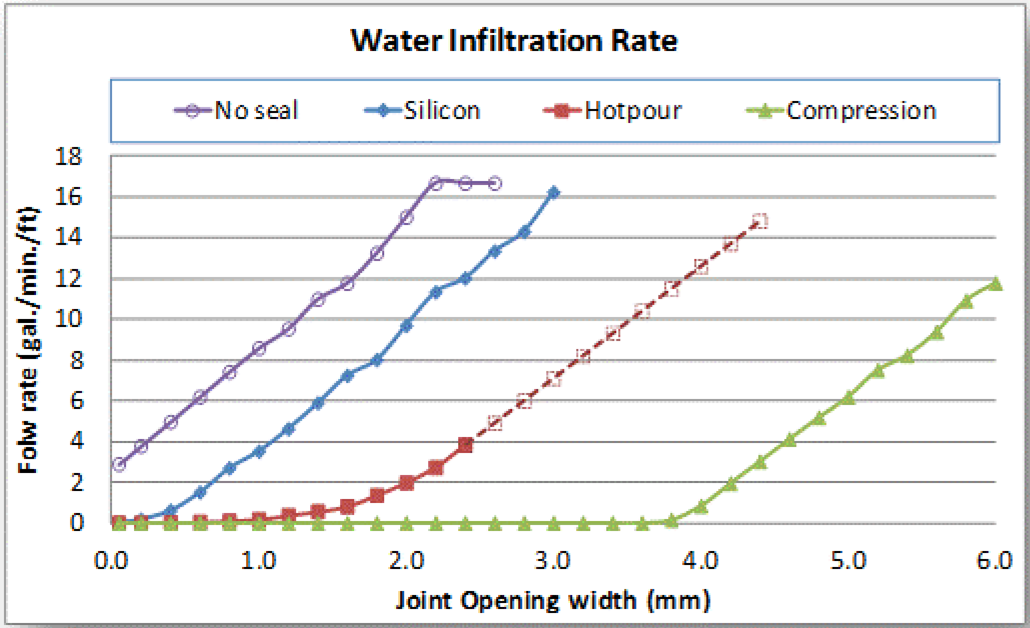
Installation of Movable Joint System

Movable Joint System



Flow Rate vs. Joint Opening

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



Flow Rate vs. Various Debonding Percentage - Silicon Sealant

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

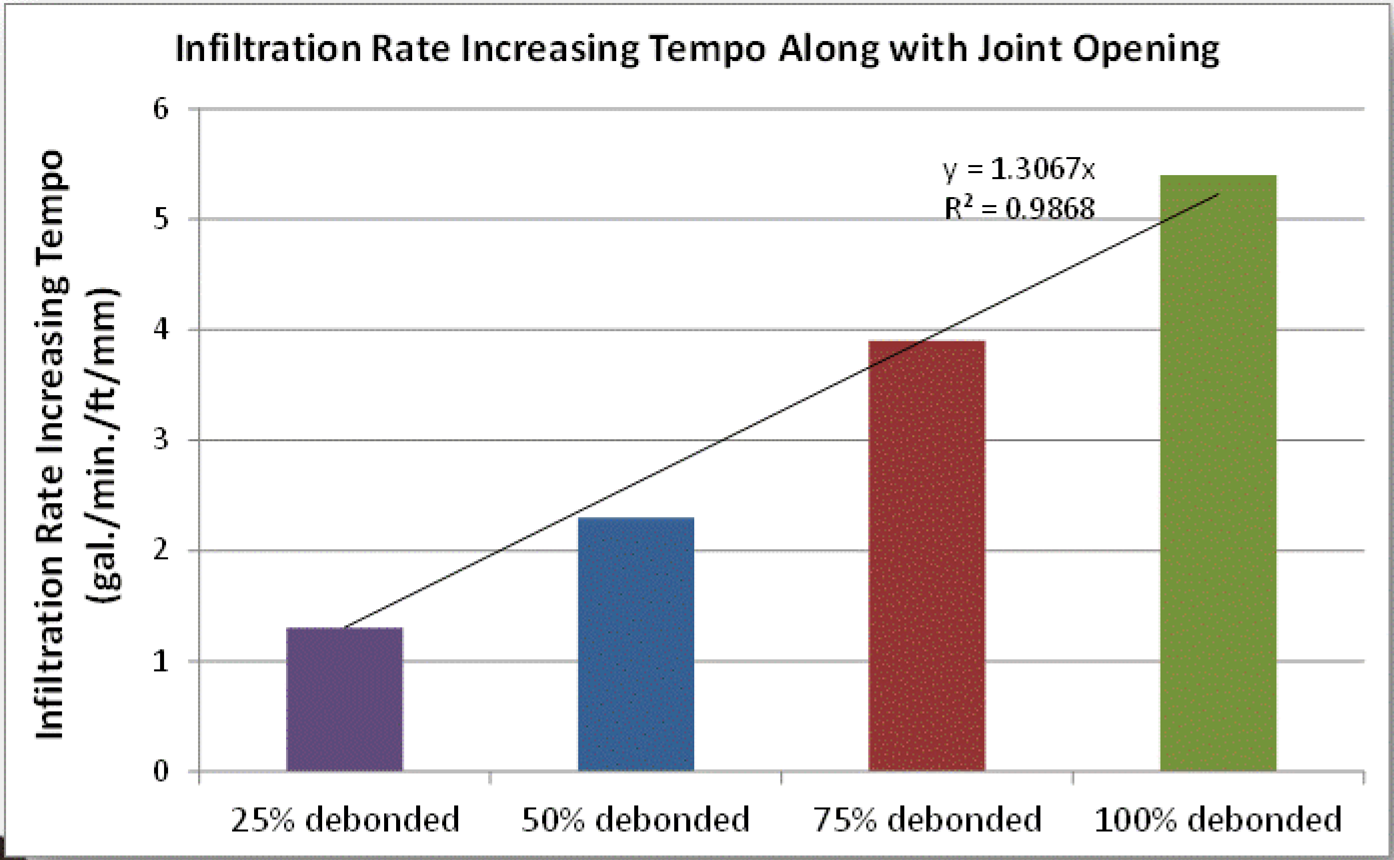
25% debonded

50% debonded

75% debonded

100% debonded

Infiltration Rate vs. Debonding - Silicon Sealant



Flow Rate vs. Debonding Percentage - Hot pour Sealant

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

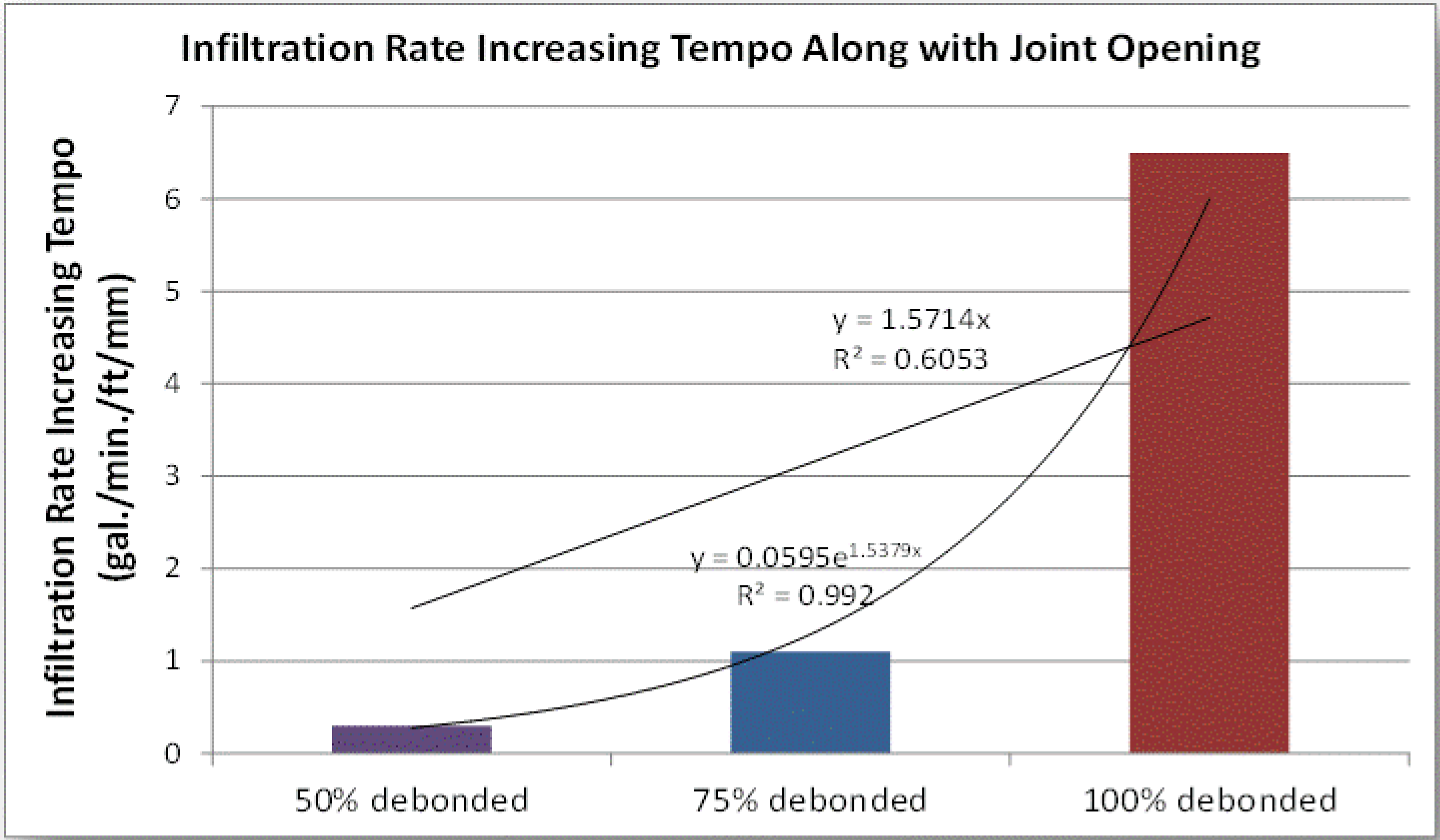
25% debonded

50% debonded

75% debonded

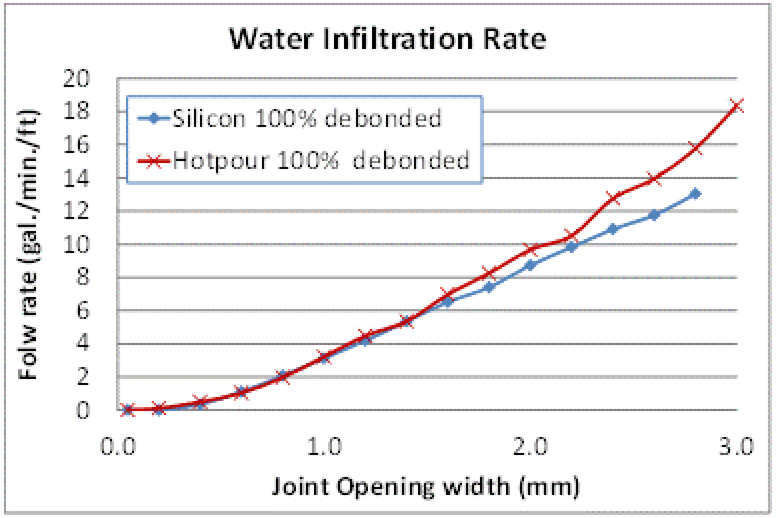
100% debonded

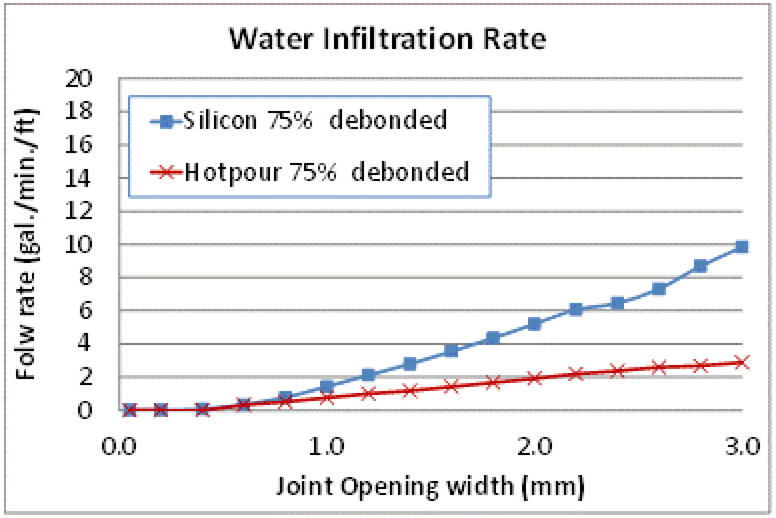
Infiltration Rate vs. Various Debonding – Hot pour Sealant

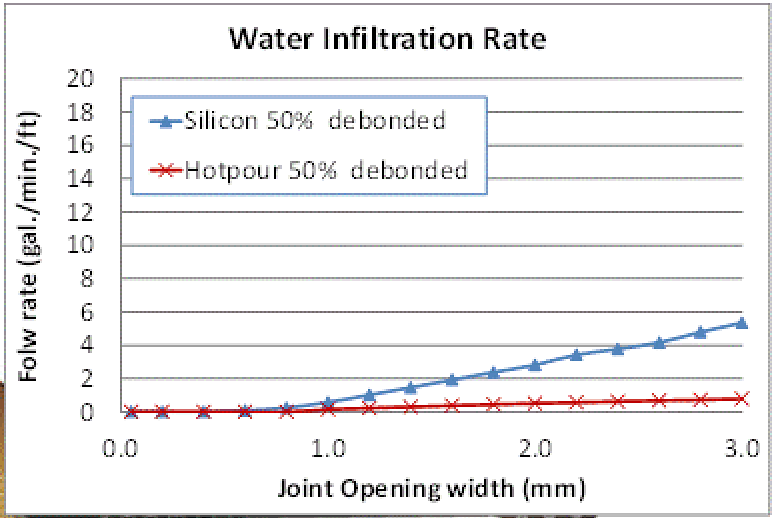


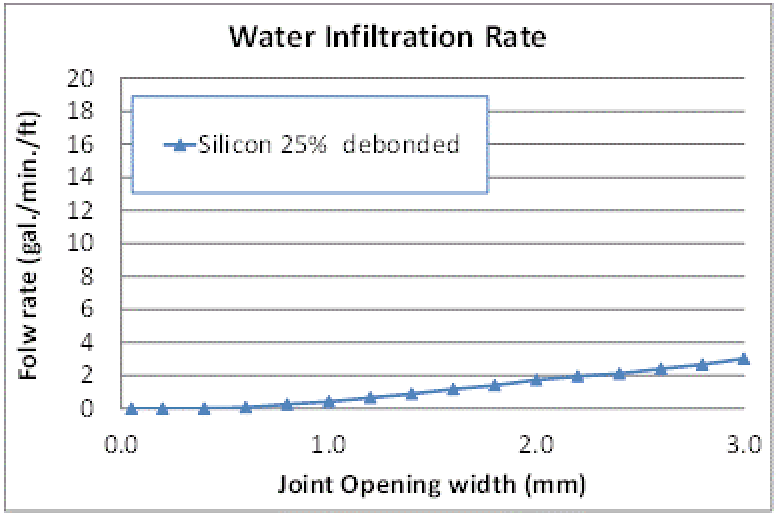
25% debonded hot pour sealant is failed to test (debonded more than plan during the test)

Silicon Sealant vs. Hot pour Sealant







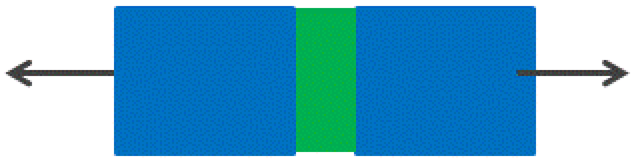


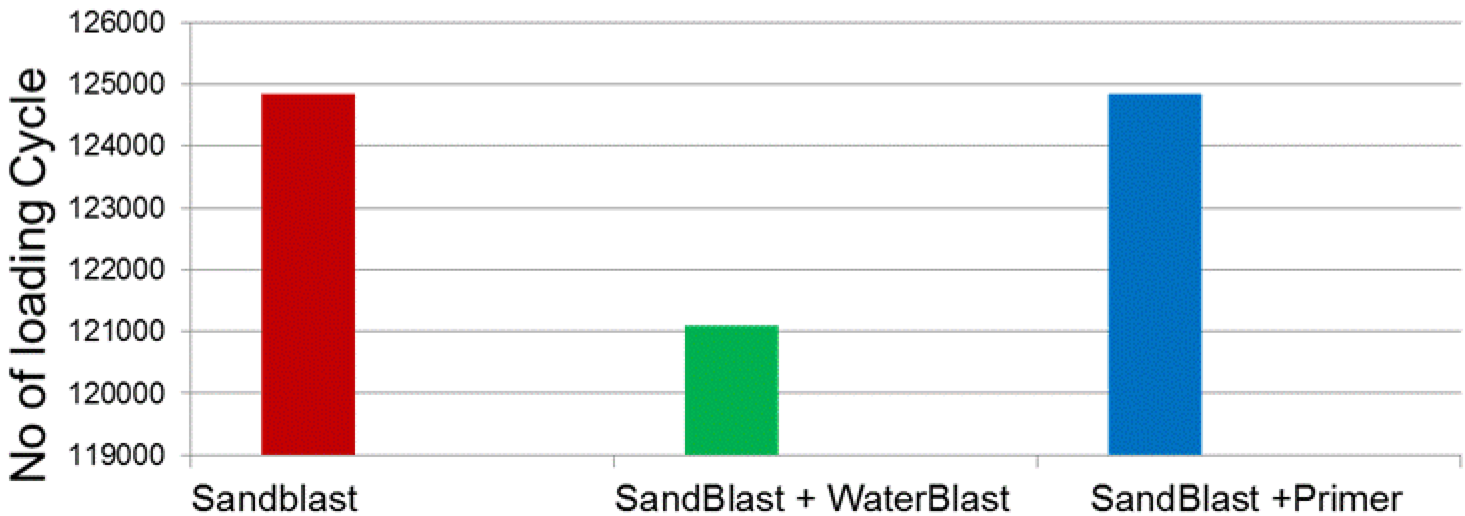
The Effect of Surface Preparation

Inputs :

Sealant Type: Two-Part Self Leveling Silicone

Aggregate Type: Limestone





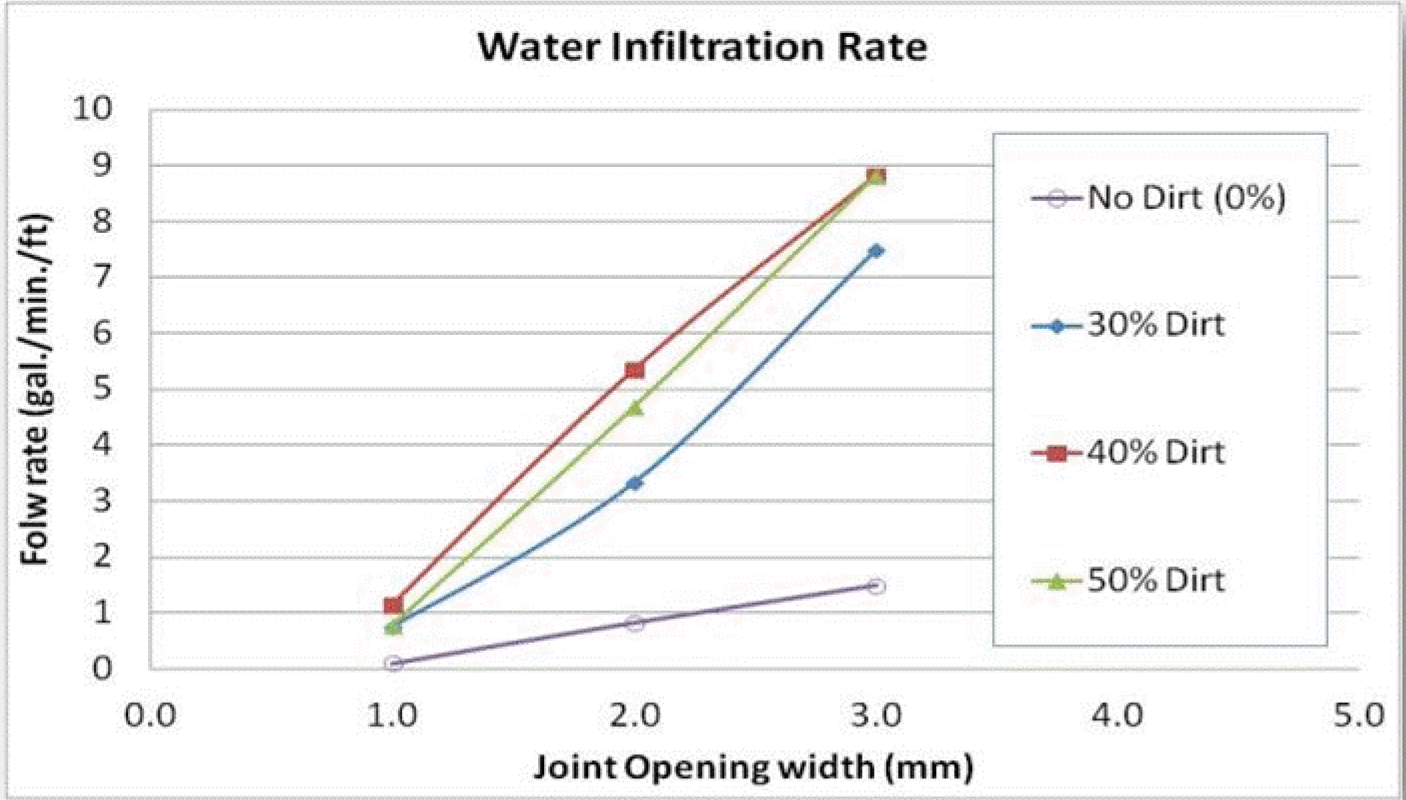
Changing the surface preparation method can increase the Number of cycle load

Flow Rate vs. Dirtiness level

- Four Different Dirtiness levels were applied by brushing slurries with different concentrations on the joint walls prior to sealing;

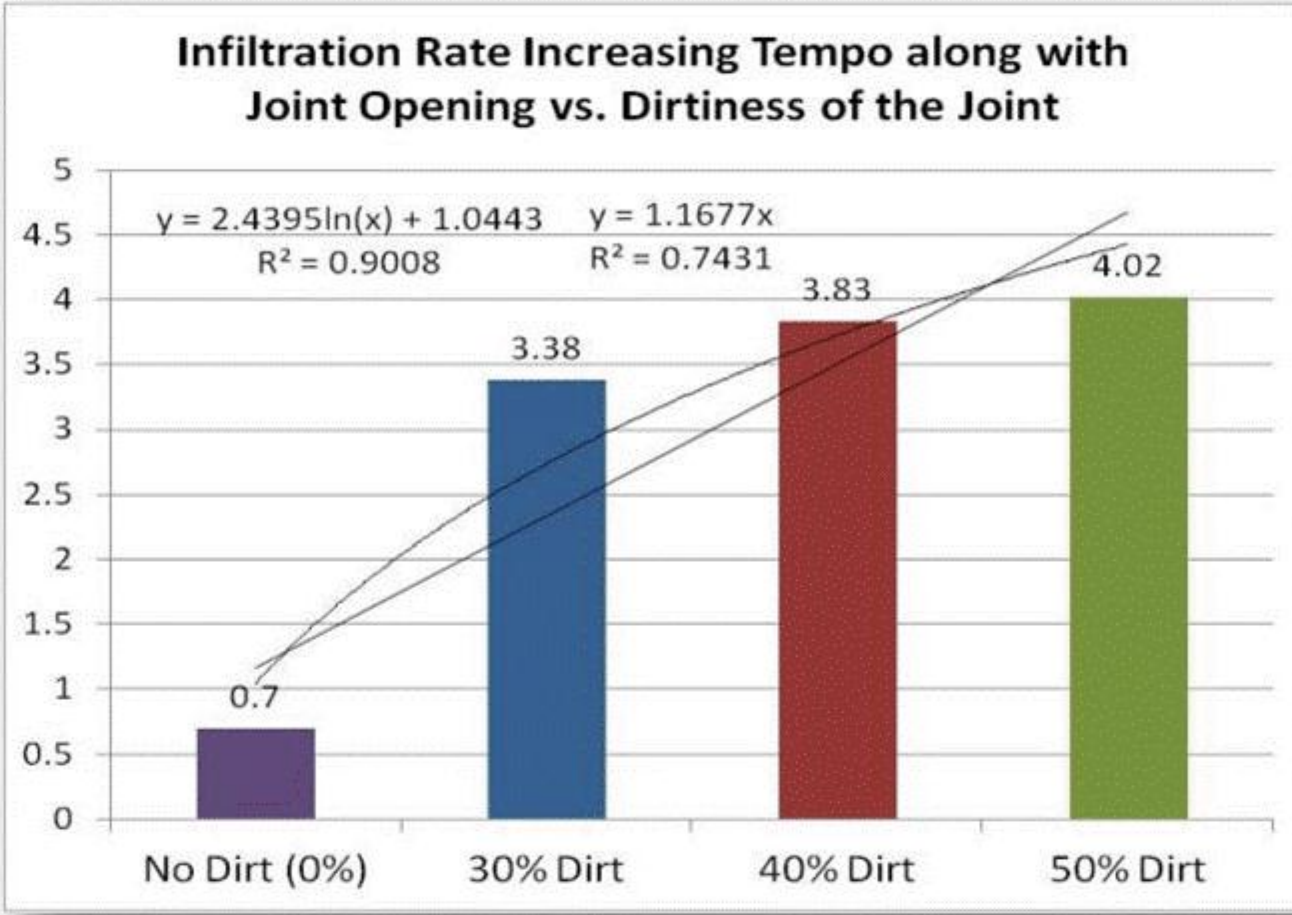
1. Clean Joints, No Dirt (0% Slurry)
2. Dusty Joints (30% Concentration of Slurry)
3. Dirty Joints (40% Concentration of Slurry)
4. Very Dirty Joints (50% Concentration of Slurry)

Flow Rate vs. Dirtiness level



With the maximum joint opening (3 mm) the very dirty joint allows 6 times more water into the joint compare to a clean joints

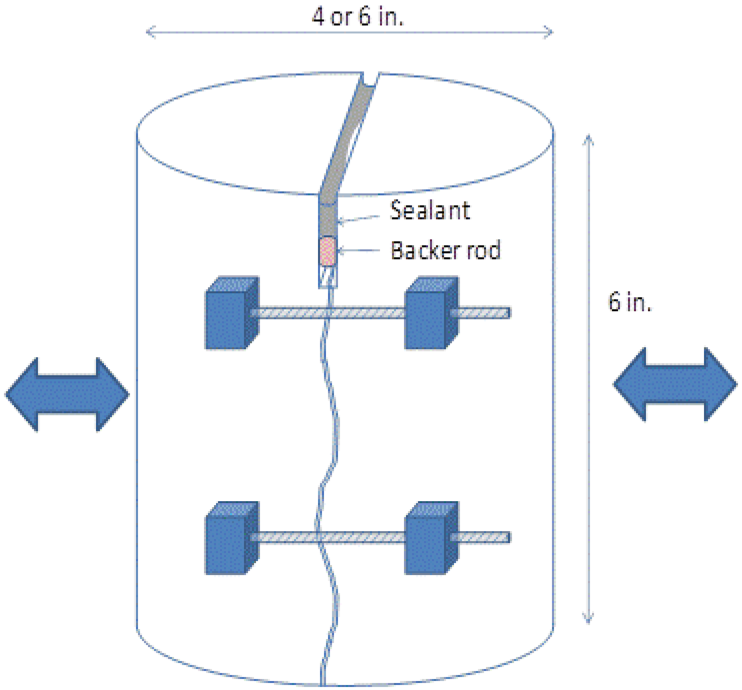
Flow Rate Increasing Rate with Joint Opening for Different Dirtiness Levels

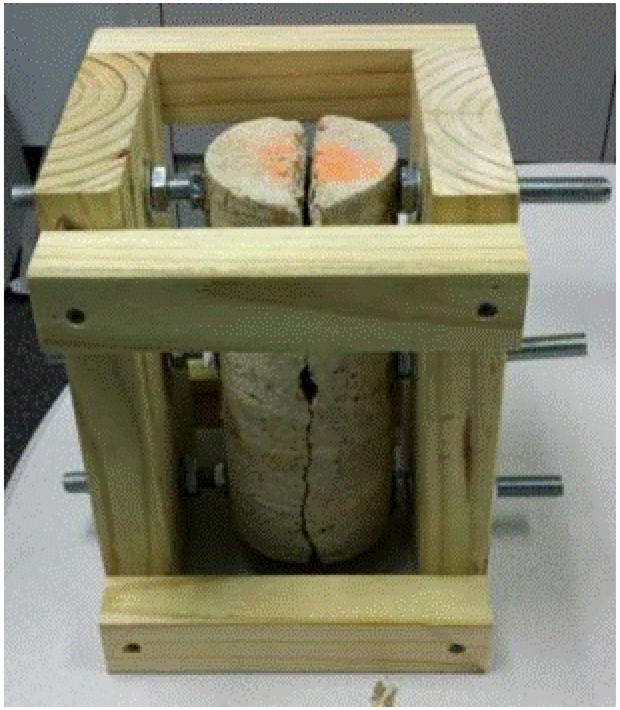


On Going Field Tests

- Bonding Quality vs. Moisture on Joint Well
  - Four different Moisture levels

Lab Test for Aging Effect



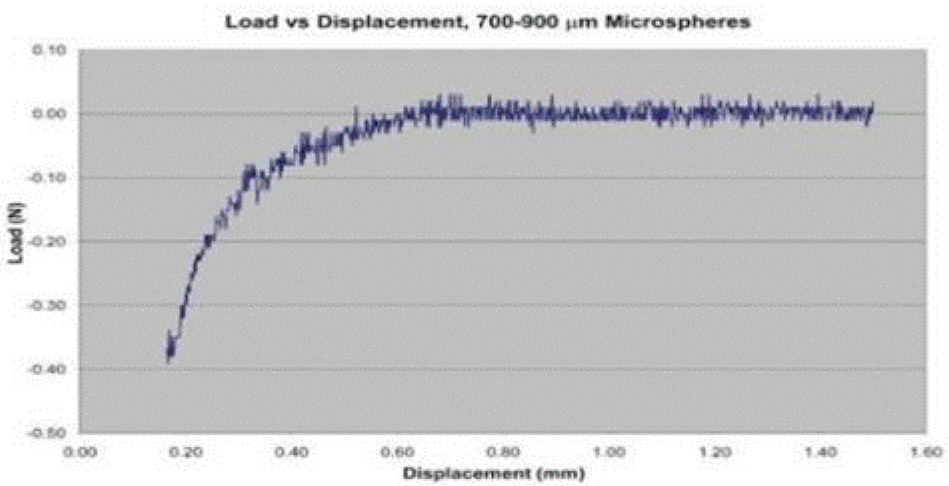


Electro Force Device

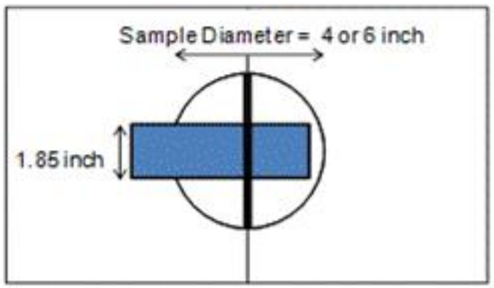
- Electro Force Device for aging test (Cycle of loading and unloading)

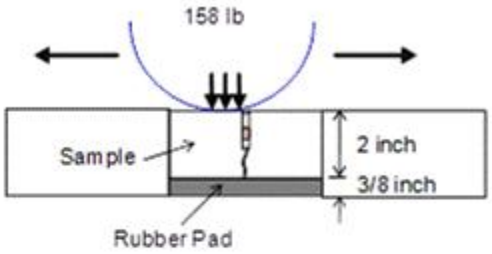
Evaluation of Sealant Longevity

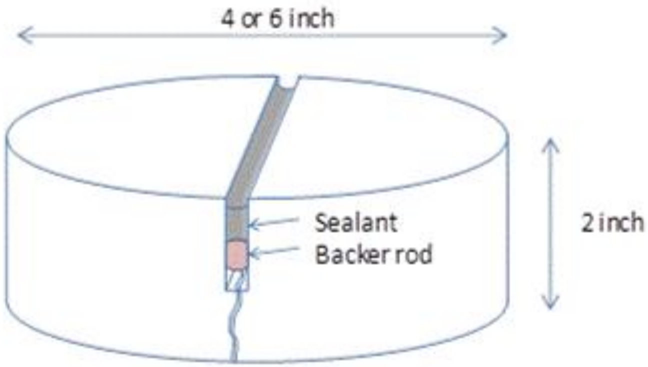
1. Aging the samples in "Environmental Room"
2. Adjust the Electro Force Device to the slab movement strain
3. Testing the aged and un-aged samples in the lab.
4. Testing the samples from the field (known traffic & climate)
5. Calibration of the lab data to the field

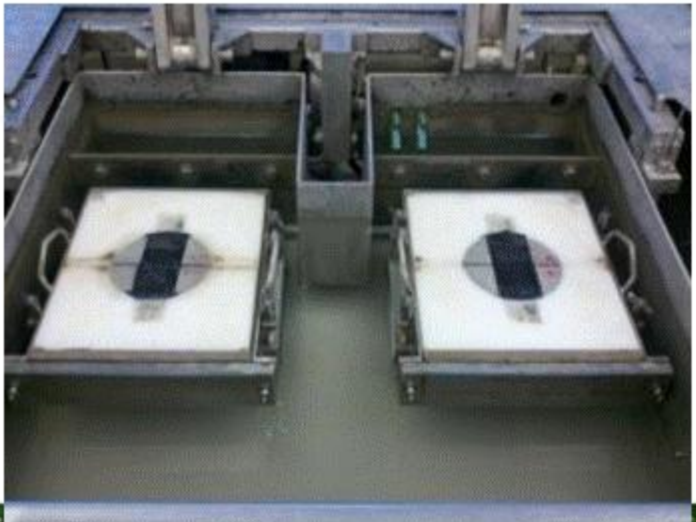


Lab Test for Sealant Bonding Failure









The Erosion Model

Theory

Lab Data

Field Data

Erosion Model

$$\frac{f_i}{f_0} = e^{-\left(\frac{\alpha}{N-\Delta}\right)^{\lambda}}$$

$$N = ESAL * p\ (\%)$$

- Climate (Rain)
- Climate (Aging)
- Drainage Sys
- Sealant Bond
- Sealant Installation
- Traffic
- Field and Lab Data

P is a probability function that contains three factors :

P1 : Probability of the **Rain** (# of wet days/ 365)

P2 : **Drainage** (1- Drainage Condition Score)

P3: **Sealant Quality**

$$P_3 = (Seal\ Bonding\ Condition) * (Sealant\ Installation)$$

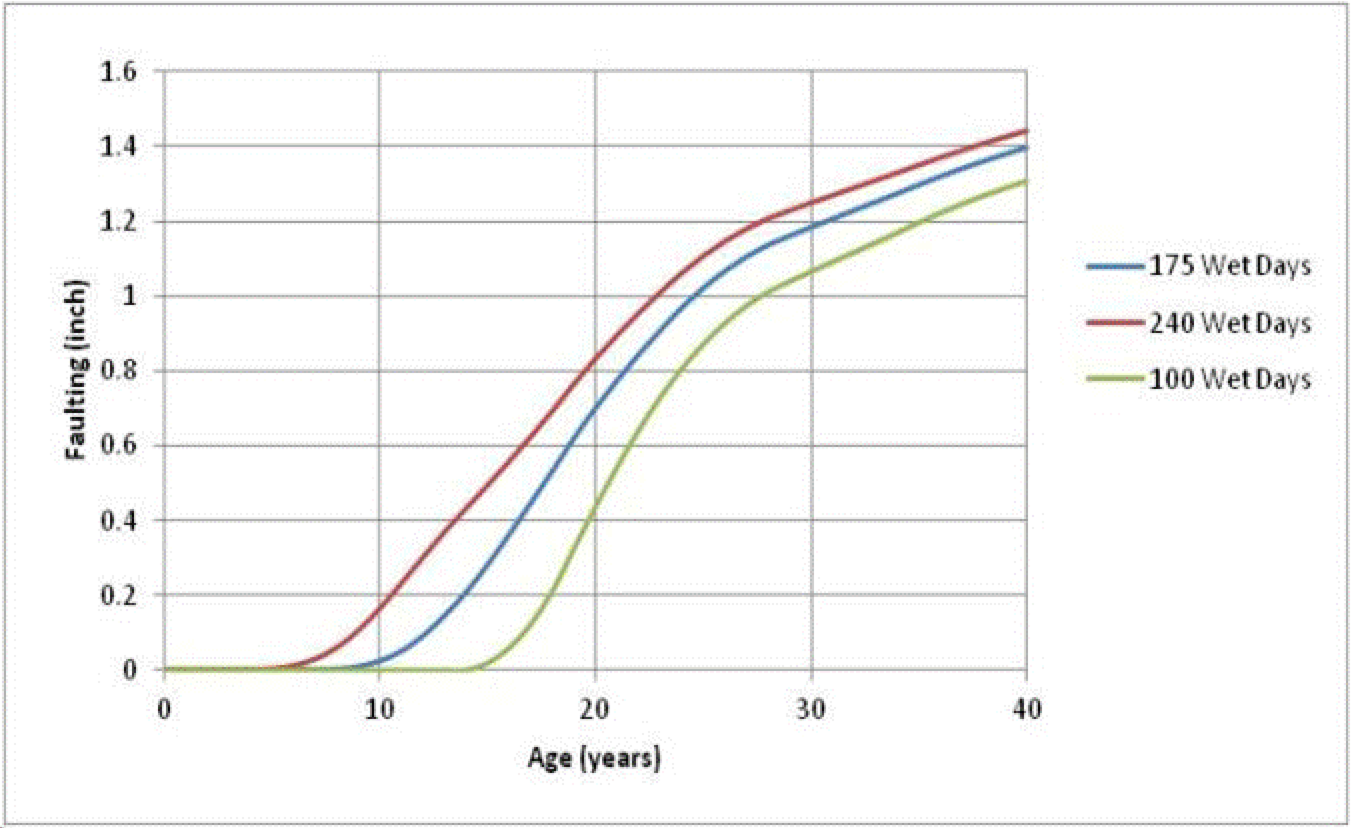
Sensitivity Analysis – Pavement Structure

The Pavement

Traffic (AADT) : 30'000
Slab Thickness:10 "
Joint Spacing :15"
LTE: No Dowel
AC Base layer,2"
CTS as subbase,5"

Sensitivity Analysis- Effect of Wet Days (P1)

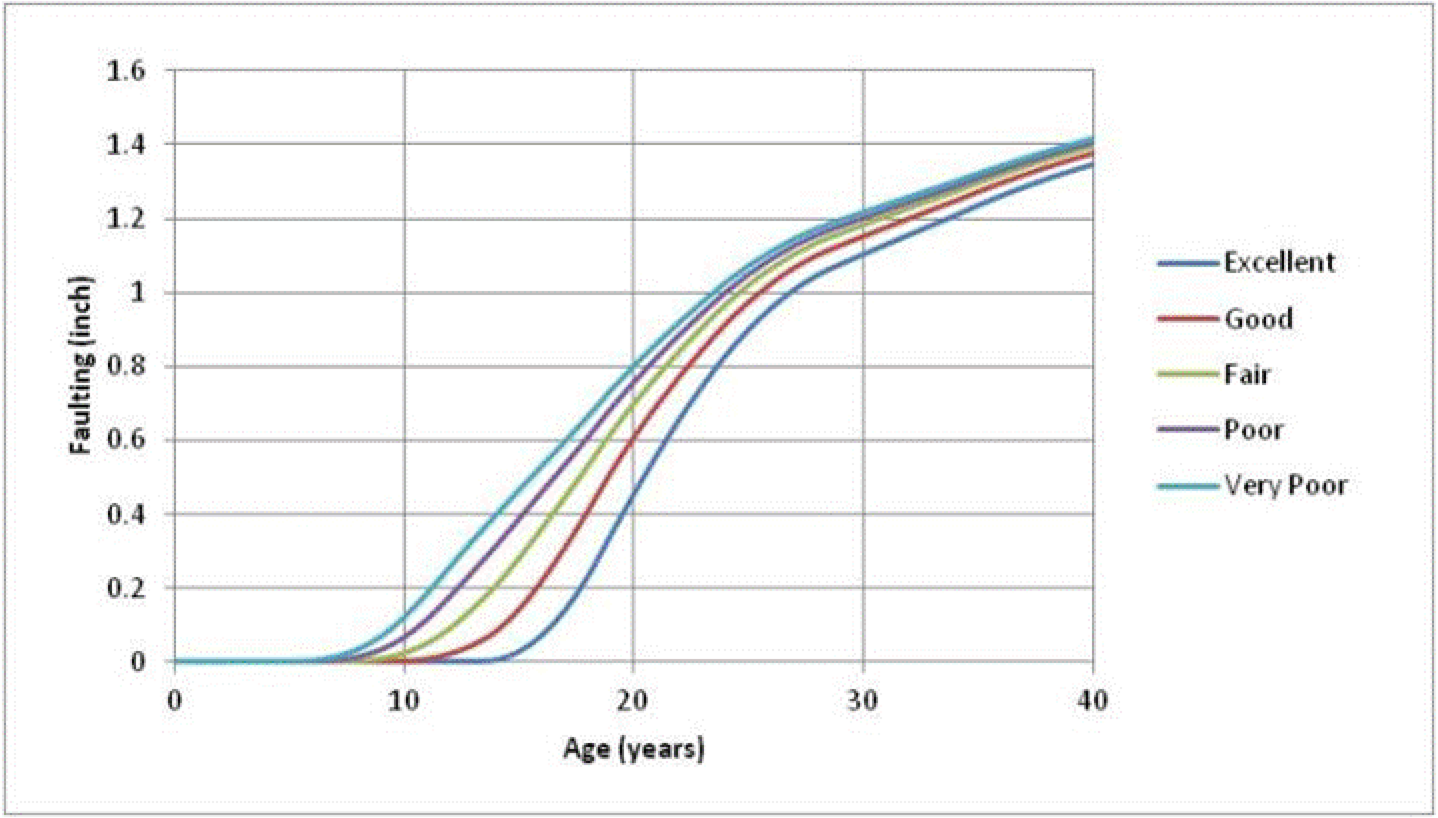
P1 : Probability of the **Rain** (# of wet days/ 365)



For all these seal type is silicon, Installation and drainage are moderate condition

Sensitivity Analysis- Effect of Drainage (P2)

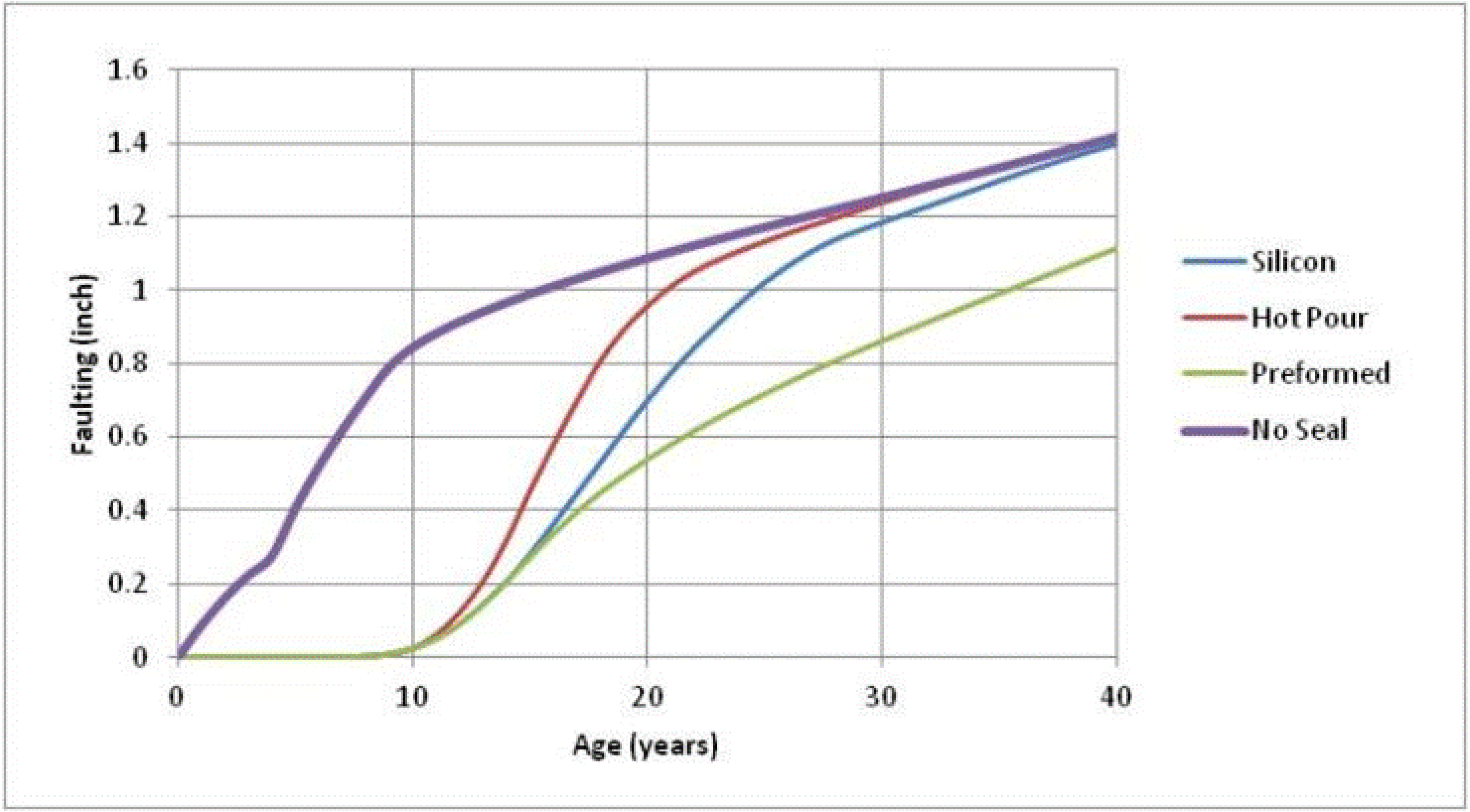
P2 : **Drainage**



For all these seal type is silicon, Installation is moderate condition, 175 wet days in a year

Sensitivity Analysis- Effect of Seal Type & Quality

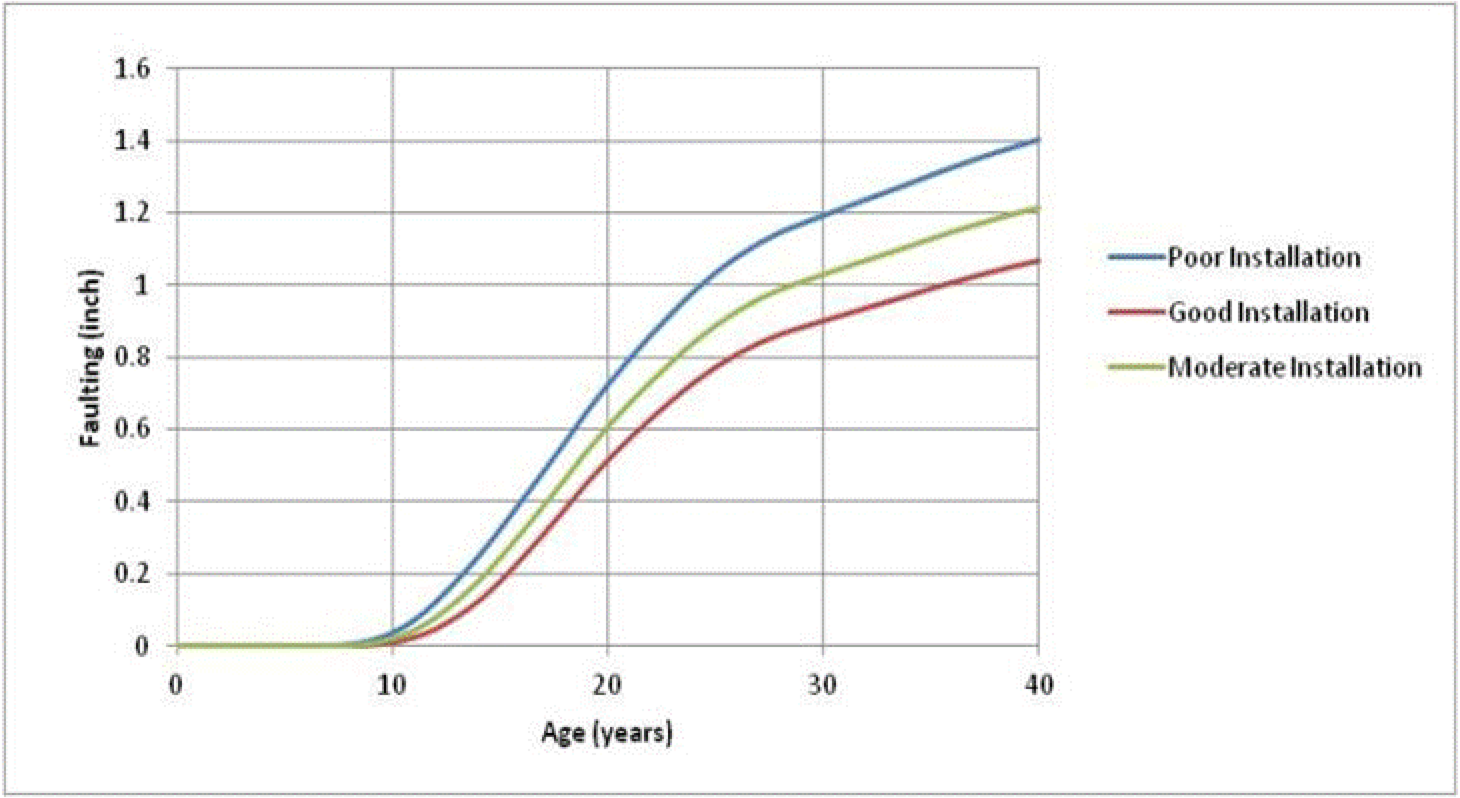
P3: **Sealant Quality**



For all these Installation and drainage are moderate condition, 175 wet days in a year

Sensitivity Analysis- Effect of Seal Installation

P3: *P4*: **Sealant Installation**



For all these drainage is moderate condition, 175 wet days in a year, silicon sealant

Thanks for your attention