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

What causes it?

- Cycles of loading (Traffic, Temperature)
- Sealant fatigue
- Existence of dust and **uncleaness**
- Freeze-Thaw damages
Cohesive Failure
Fatigue Failure of the Sealant material

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

Upward

1. Joint well filled with water after rain
2. Slab deflection caused by traffic load
3. Uplift Water Pressure
4. Sealant Failure

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

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

Movable Joint opening after debonding
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

- Silicon
- Hot pour
- Compression
- Double seal
Sawcut Layout of Test Area

Double sealing | Compression | Hot pour | Silicone

7'9" | 10'0" | 10'0" | 10'0"

11'9" | 10' | 1/2"

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"

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"
Sand and Air Blasting
Compression Seal Placement
Debonding Sealants

Silicon

Bonded

Debonded

Hot pour

Bonded

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

Specially made hollow collars anchored to either push the joint closed or pull the joint open.

2' slab segment to be anchored/tied laterally into the adjoining concrete.

Imbedded threaded tie bars.

Moveable joint face.

Current Joint (No seal) 11'0"
Double sealing 7'9"
Compression 10'0"
Hot pour 10'0"
Silicone 10'0"
Current Joint (No seal) 10'0"

Movable Joint
Wood Joint
Coring Location
Movable Joint
Installation of Movable Joint System
Movable Joint System

Measure every 0.02 mm opening
# Flow Rate vs. Joint Opening

<table>
<thead>
<tr>
<th>Joint opening width (inch)</th>
<th>Joint opening width (mm)</th>
<th>Flow rate (gallon/min./ft)</th>
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## Water Infiltration Rate

- **No seal**
- **Silicon**
- **Hotpour**
- **Compression**

![Graph showing water infiltration rate vs. joint opening width](image)
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

Infiltration Rate Increasing Tempo Along with Joint Opening

\[
\gamma = 1.3067x \\
R^2 = 0.9868
\]

Infiltration Rate Increasing Tempo (gal./min./ft./mm)

- 25% debonded
- 50% debonded
- 75% debonded
- 100% debonded
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

Infiltration Rate Increasing Tempo Along with Joint Opening

25% debonded hot pour sealant is failed to test
(Debonded more than plan during the test)
Silicon Sealant vs. Hot Pour Sealant

Water Infiltration Rate

- Silicon 100% debonded
- Hotpour 100% debonded

Water Infiltration Rate

- Silicon 75% debonded
- Hotpour 75% debonded

Water Infiltration Rate

- Silicon 50% debonded
- Hotpour 50% debonded

Water Infiltration Rate

- Silicon 25% debonded
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 compared to a clean joint.
Flow Rate Increasing Rate with Joint Opening for Different Dirtiness Levels

Infiltration Rate Increasing Tempo along with Joint Opening vs. Dirtiness of the Joint

\[ y = 2.4395\ln(x) + 1.0443 \quad R^2 = 0.9008 \]
\[ y = 1.1677x \quad R^2 = 0.7431 \]
On Going Field Tests

- Bonding Quality vs. Moisture on Joint Well
  - Four different Moisture levels
Lab Test for Aging Effect

4 or 6 in.

6 in.

Sealant
Backer rod

2012 NATIONAL PAVEMENT PRESERVATION CONFERENCE  ROAD TRIP: DRIVING THE MESSAGE FOR CHANGE
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

[Diagram showing a sample diameter of 4 or 6 inches, a sample size of 2 inches, and a rubber pad with a 2-inch thickness.]

[Images of a testing apparatus with samples and rubber pads.]
The Erosion Model

Theory

Lab Data

Field Data
Erosion Model

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

\[ N = ESAL \times p \ (\%) \]

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

\( P \) is a probability function that contains three factors:

- \( P_1 \): Probability of the Rain (\# of wet days/365)
- \( P_2 \): Drainage (1 - Drainage Condition Score)
- \( P_3 \): Sealant Quality

\[ P_3 = (Seal \ Bonding \ Condition) \times (Sealant \ Installation) \]
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

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