Impact of Joint Sealing Effectiveness on Concrete Pavement Performance

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International Grooving and Grinding Association

Why Concrete Pavement Preservation

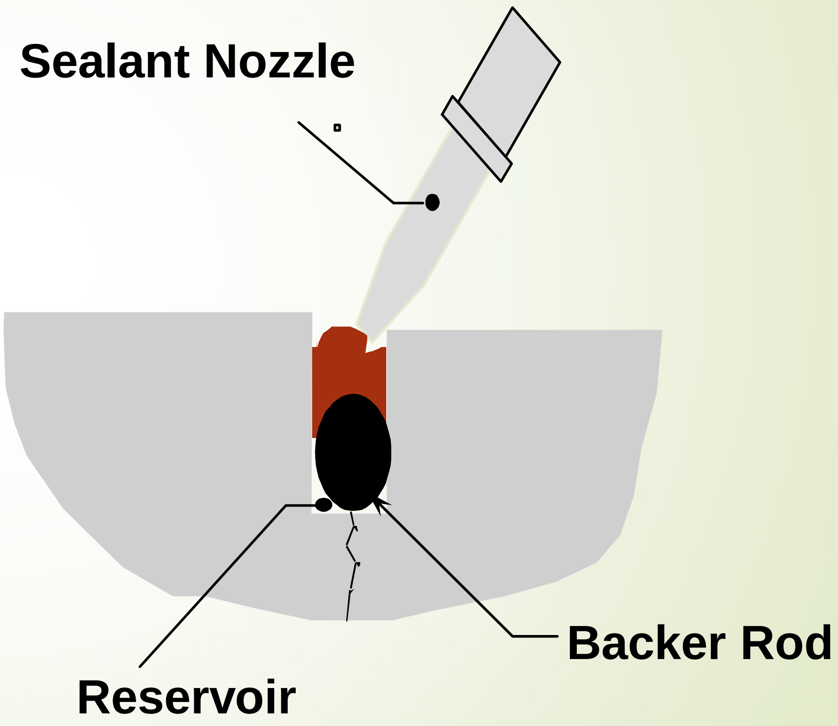
Bellefontaine, Ohio 1925

Presentation Outline

- Why do we seal?
- Field Performance Issues
- Sealant Life and When to Reseal
- Design of Joint Sealant Installation
- Sealant Selection and Installation
- Can We Seal Joints?
- How Does Sealing Impact Pavement Performance

Reasons for Joint Resealing

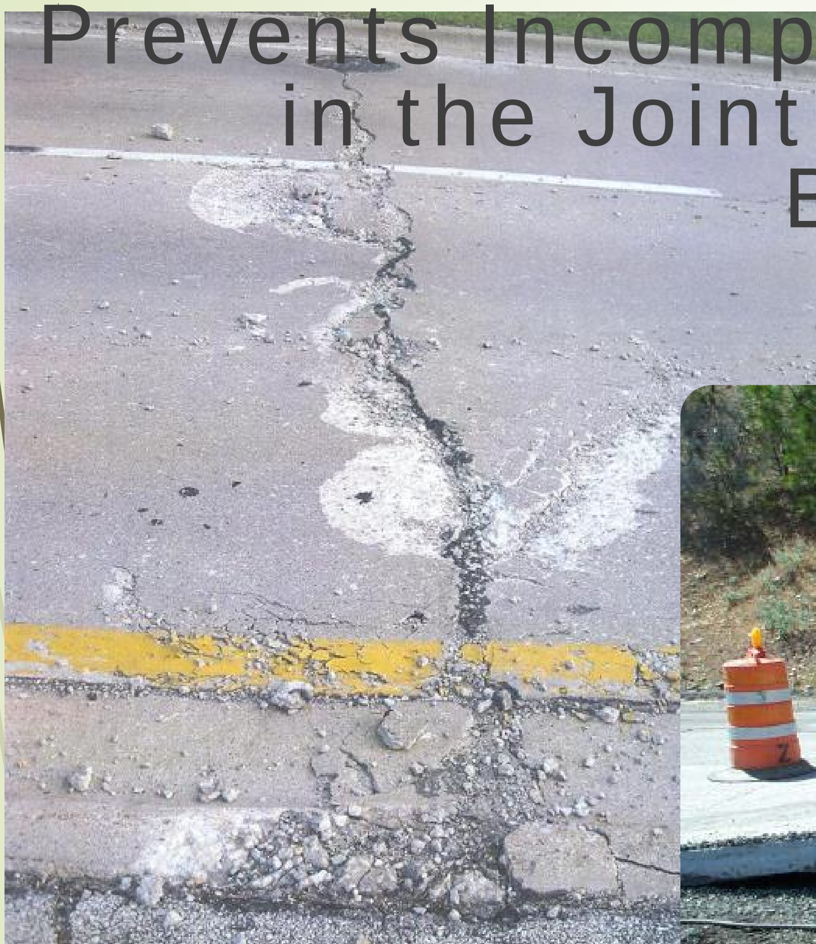
- Minimizes water & incompressibles into pavement system
- Reduces subgrade softening, pumping and erosion of fines and spalling
- Prevents Joint Associated Distress?
- Reduces Noise (Joint Slap)



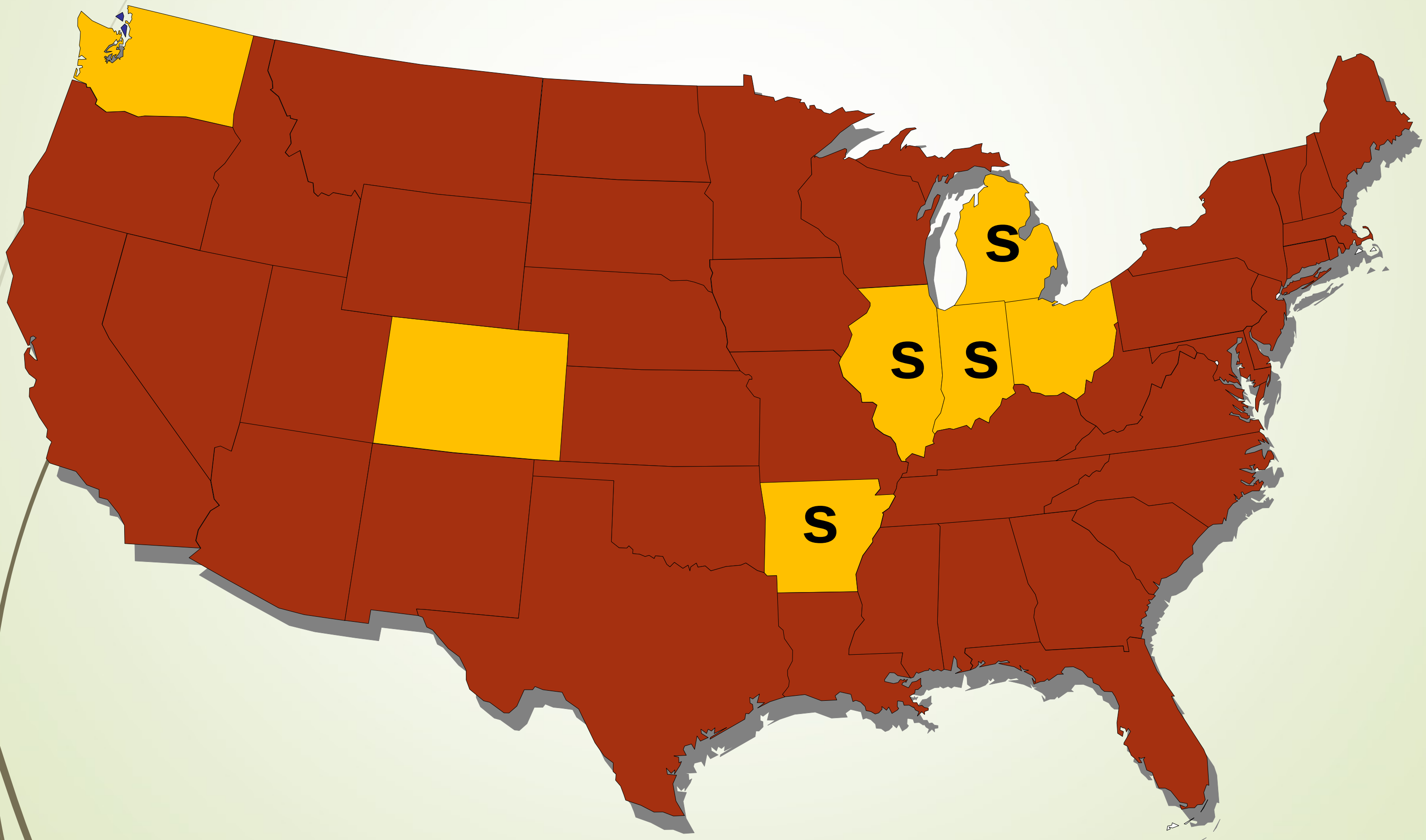
Field Performance?

Why Seal Joints and Cracks

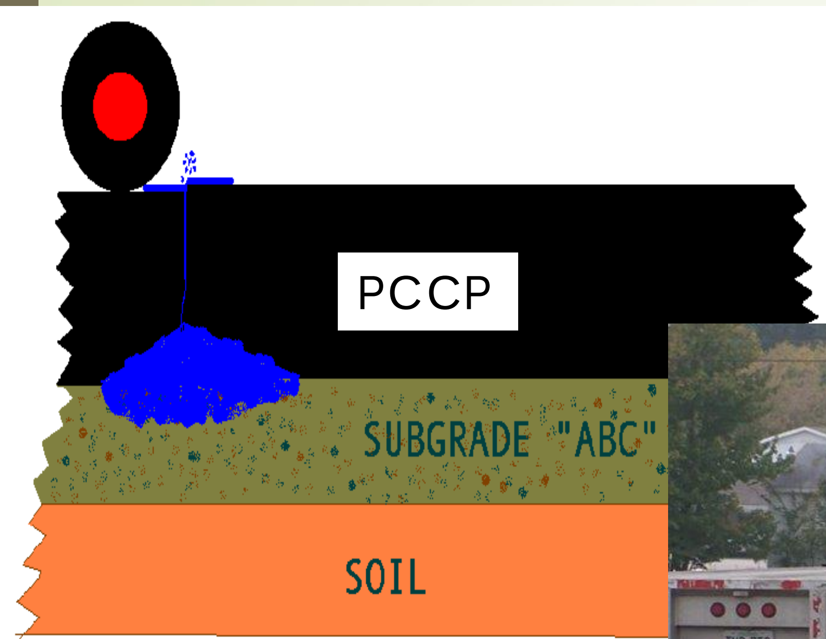
Prevents Incompressible from Lodging in the Joint — Slab Growth and Blow Ups



States With Examples and Studies



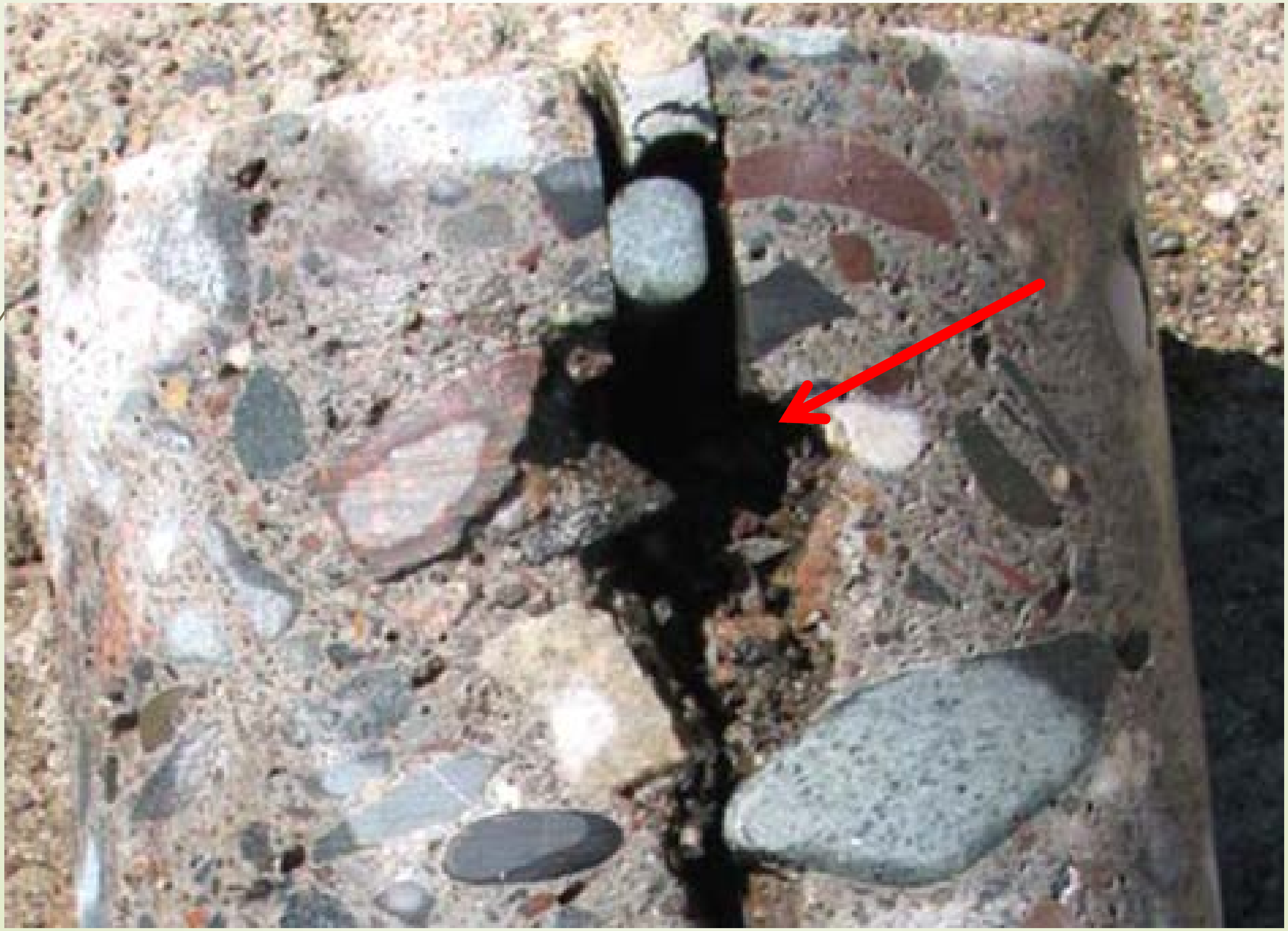
Why Seal Joints and Cracks



Prevents Water from Entering the Subgrade:

- -Prevents subgrade erosion
- -Voids beneath the slab

Water Damage to Pavements



The Top Doesn't Always Tell the Story

Joint Associated Distress

When to Reseal & Sealant Longevity

- Adhesive Failures
- Cohesive Failures
- % Damaged or Missing

When the Sealant is No Longer Serving its Intended Function

Reseal or Original Seal?

Defining Sealant Life

LTPP Pavement Maintenance Materials: SHRP Joint Reseal Experiment, Final Report

PUBLICATION NO. FHWA-RD-99-142 SEPTEMBER 1999

Crafco 221 = 5.4 – 9.8 yrs
Crafco 231 = 6.4 – 9.5 yrs
Dow 888 SL = 12.8 yrs
Dow 888 = 13.9

232% to 348% Increase for Silicone

U.S. Department of Transportation
Federal Highway Administration

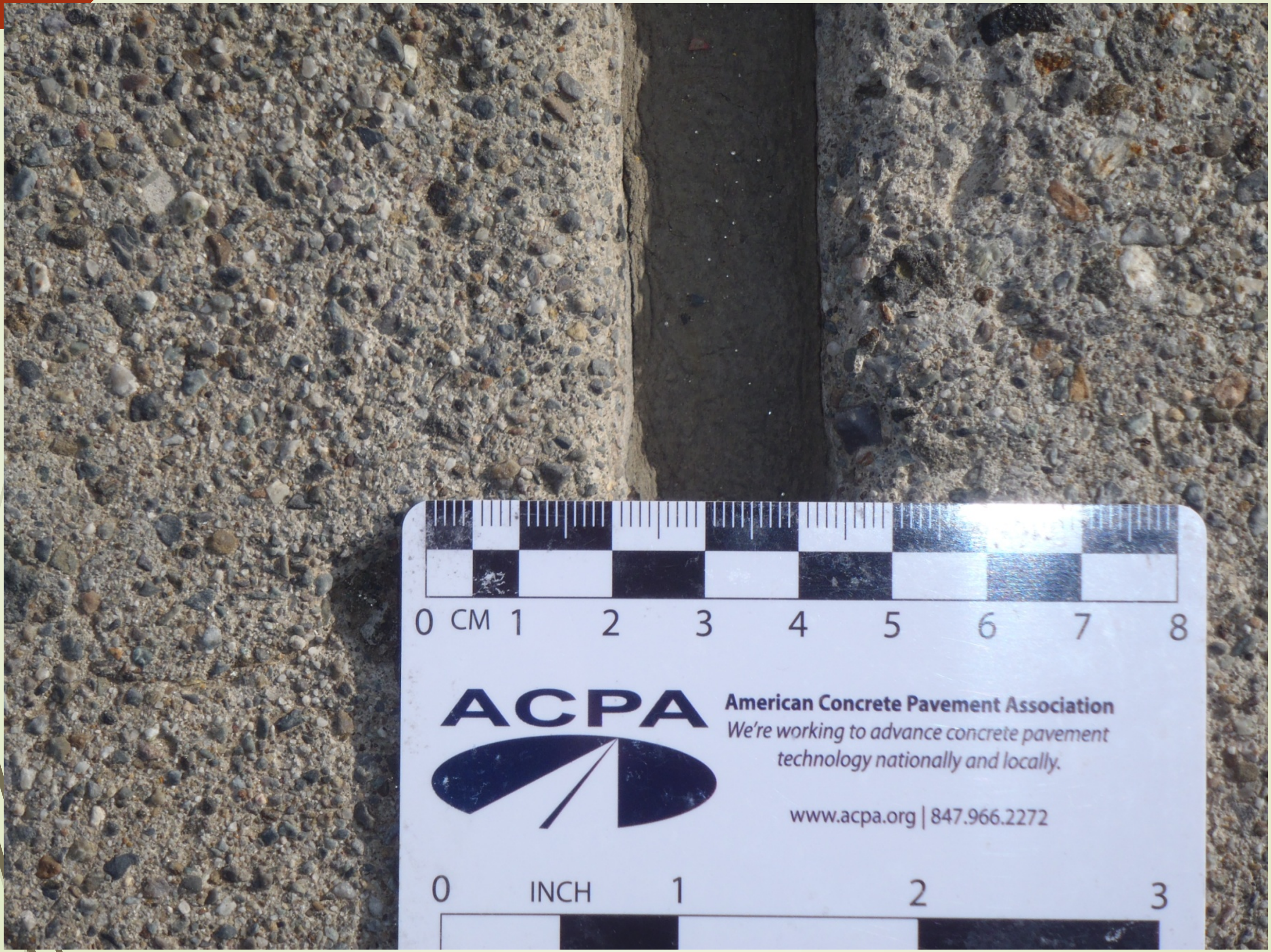
Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

LTPP

Sealant Material	Configuration	Time at Which 75% Effectiveness Level Was Reached, months *					
		Arizona	Colorado	Iowa	Kentucky	South Carolina	Average
Koch 9005	1	116	66	94	156	63	99
	2	112	66	91	191	90	110
	3			148	182	49	126
	4	105	61				83
Crafco RS 231	1	52	80	76	86	92	77
	2	135	69	118	108	138	114
	3			103	155	80	113
	4	83	72				78
Meadows Sof-Seal	1		34	40	39	55	42
	2		40	51	64	46	50
	3			57	161	31	83
	4		43				43
Koch 9030	1		31	50	60	41	46
	2		32	63	50	58	51
	3			59	143	15	72
	4		37				37
Meadows Hi-Spec	1	43					43
	2	94					94
	4	76					76
Crafco RS 221	1	65					65
	2	105					105
	4	117					117
Dow 888	1	198	145	130	186	178	167
Dow 888-SL	1	183	110	125	164	186	154
Mobay 960-SL	1	194	93	65	115	168	127
Mobay 960	1			143			143
Crafco 903-SL	1	194					194
Koch 9050	1		19		136		78
Dow 888 w/ primer	1			151			151
Dow 888-SL w/ primer	1			143			143
Koch 9005 w/ primer	1				173		173

* Times greater than 82 months are extrapolated to a maximum of 200 months.

20 Year Old Sealant In Airfield



Same Airfield - One Year Old Sealant Installation

Same 20 Year Old Airfield Sealant Installation

Design of Sealant Installation

Design of Sealant Installation

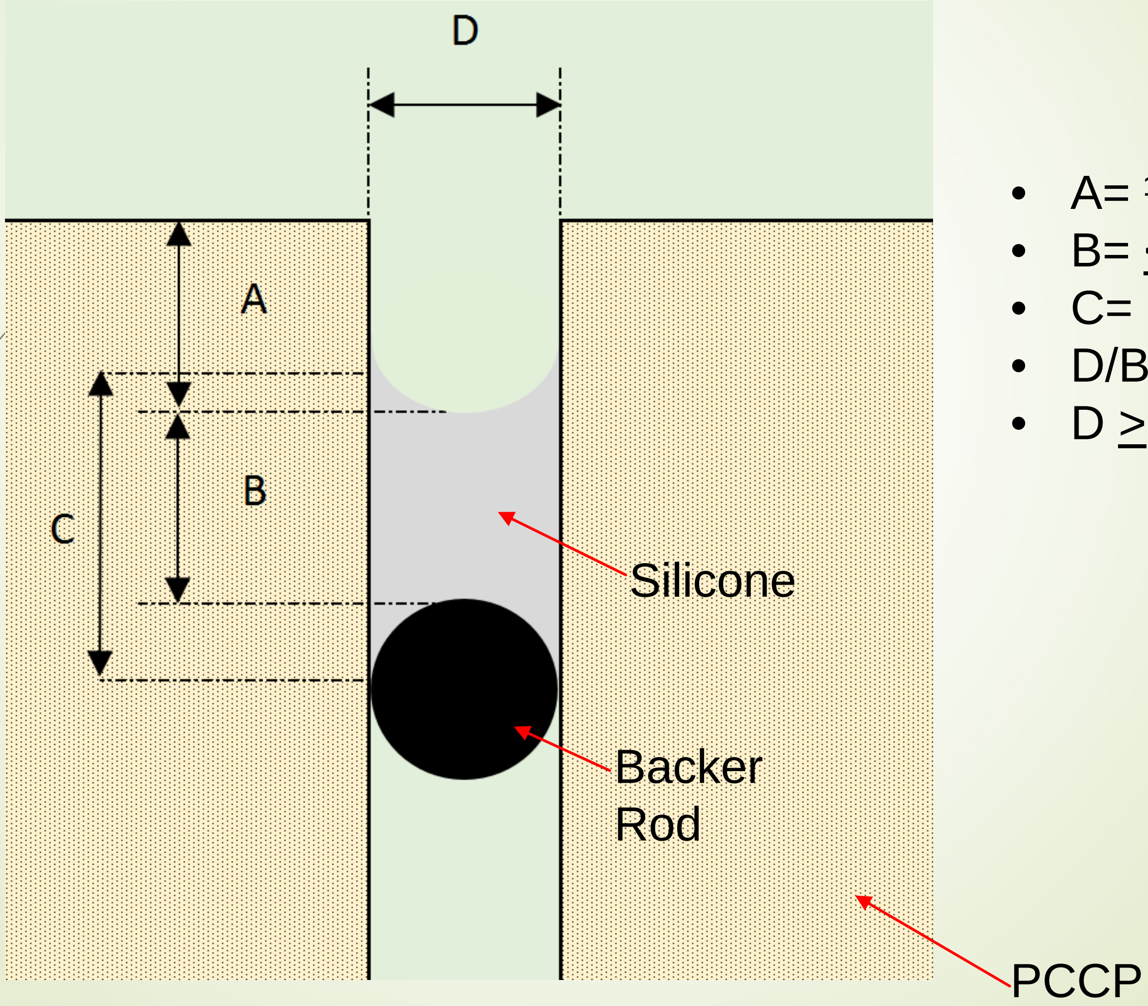
Sealant Performance Depends On:

- Design Factors (See ACPA App Website)
  - Anticipated Movement
  - Construction Schedule and Installation Conditions
  - Required Performance Period
  - Noise Considerations
- Sealant Selection---Proper Design and Specification for Application
- Joint Preparation---<u>Clean</u>, <u>Dry</u>, and <u>Bondable</u>
- Sealant installation
  - Silicone & Compression Seal Should be Recessed
  - Hot Pour Should be Flush Filled
  - Backer Rods Appropriate for Sealant Type
  - Primer?

Allowable Joint Opening Movements (Compression/Extension)

- **Hot Pour Sealants: 25% Extension**
- **Silicone Sealants: 50% Compression to 100% Extension**
- **Compression Seals: 15% min Compression to 50% Extension**

Guidelines for Joint Design



- A= ¼” to 3/8”
- B= $\leq$ 3/8”
- C= Min of ¼”
- D/B $\geq$ 2
- D $\geq$ ¼”

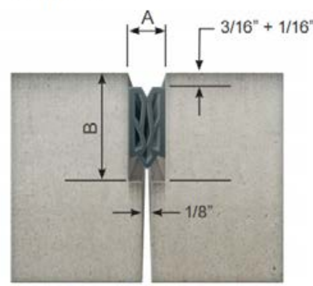
Manufacturer Design Tables Silicone and Compression Seal

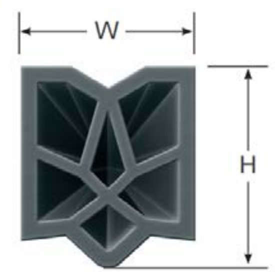
*Joint Width	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"	1 1/8"	1 1/4"	1 3/8"	1 1/2"
Minimum Sealant Recess	1/4"	1/4"	5/16"	5/16"	3/8"	3/8"	3/8"	1/2"	1/2"	1/2"	1/2"
Backer Rod Diameter [1]	3/8"	1/2"	5/8"	3/4"							
Sealant Bead Thickness	1/4"	1/4"	1/4"	5/16'							
Minimum Joint Saw/Reservoir Depth	1 1/8"	1 1/4"	1 1/2"	1 3/4							
Minimum Backer Rod Depth	1/2"	1/2"	5/8"	11/16							
Estimated Usage Non-Sag	245	149	112	70							
Estimated Usage Self-leveling(ft./gal)	273	172	130	82							

Meeting Specifications

Delastic® Preformed Pavement Seals meet ASTM standard specifications. They are also recognized by the FHWA, U.S. Army Corps of Engineers, the U.S. Air Force, the FAA, consulting engineers and other agencies as an effective, long-lasting concrete pavement joint seal solution.

Delastic® Preformed Pavement Seals have been successfully used on high performance concrete pavements throughout the U.S. Many of these installations have protected pavements located in extreme hot and cold climates in excess of 20 years.





Typical joint design for the "E" and "V" series pavement seals

Airports, including military bases all over the world rely on Delastic® Preformed Pavement Seals.

40-year-old Preformed Compression Seal at DFW Airport.

Delastic® Preformed Pavement Seal Characteristics

Delastic® Seal Catalog No.	Seal Characteristics			Joint Design Criteria			Typical Installed Width (A)**
	Nominal Width (W)	Nominal Height (H)	Max. Movement [1]	Narrowest Opening [2]	Widest Opening [3]	Minimum Depth (B)	
E-437	**0.437** (11.11)	**0.937** (23.81)	**0.153** (3.88)	**0.219** (5.56)	**0.372** (9.45)	**1.000** (25.40)	**0.250** (6.35)
E-562	**0.562** (14.29)	**0.625** (15.88)	**0.188** (4.78)	**0.290** (7.37)	**0.478** (12.14)	**1.063** (27.00)	**0.3125** (7.94)
E-686	**0.687** (17.46)	**0.687** (17.46)	**0.259** (6.59)	**0.325** (8.26)	**0.584** (14.84)	**1.188** (30.18)	**0.375** (9.53)
E-816	**0.812** (20.64)	**0.830** (21.08)	**0.313** (7.95)	**0.378** (9.59)	**0.691** (17.54)	**1.438** (36.53)	**0.500** (12.70)
E-1006	**1.000** (25.40)	**1.000** (25.40)	**0.450** (11.43)	**0.400** (10.16)	**0.850** (21.59)	**1.625** (41.28)	**0.500-0.5625** (12.70-14.29)
E-1256	**1.250** (31.75)	**1.000** (25.40)	**0.563** (14.30)	**0.500** (12.69)	**1.063** (26.99)	**1.875** (47.63)	**0.750** (19.05)
V-1625	**1.625** (41.28)	**1.125** (28.58)	**0.631** (16.03)	**0.750** (19.05)	**1.381** (35.08)	**2.250** (57.15)	**0.875** (22.23)
E-2000	**2.000** (50.80)	**1.500** (38.10)	**0.950** (24.13)	**0.750** (19.05)	**1.700** (43.18)	**2.500** (63.50)	**1.125** (28.58)
E-2500	**2.500** (63.50)	**2.500** (63.50)	**1.125** (28.58)	**1.000** (25.40)	**2.125** (53.98)	**3.375** (85.73)	**1.375** (34.93)
E-3000	**3.000** (76.20)	**2.500** (63.50)	**1.550** (39.37)	**1.000** (25.40)	**2.550** (64.77)	**4.000** (101.60)	**1.750** (44.45)

***Above:** First number shown in bold represents inches, metric dimensions (mm) are shown in parentheses. Notes:*Thickness of the seal wall and internal web are not drawn to scale. 1 Maximum movement which seal will accommodate in joint with correct design. 2 A narrower opening will place excessive stress on the seal and may cause premature failure. 3 A wider opening may not provide sufficient compressive force to hold the seal in place.** To be used as reference only. Installed width may vary by project.*

ACPA Joint Movement Estimator

ACPA

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/// JOINT AND SEALANT MOVEMENT ESTIMATOR ///

LOCATION DETAILS

State: Arizona

Location: Phoenix

CONCRETE MATERIAL DETAILS

Cement Type: Type I/II

Cementitious Materials Content (lb/yd^3): 600.0

Coefficient of Thermal Expansion ($10^{-6}/^{o}F$): 5.00

CONCRETE PAVEMENT STRUCTURE DETAILS

Concrete Pavement Thickness (in.): 10.00

Transverse Joint Spacing (ft): 15.00

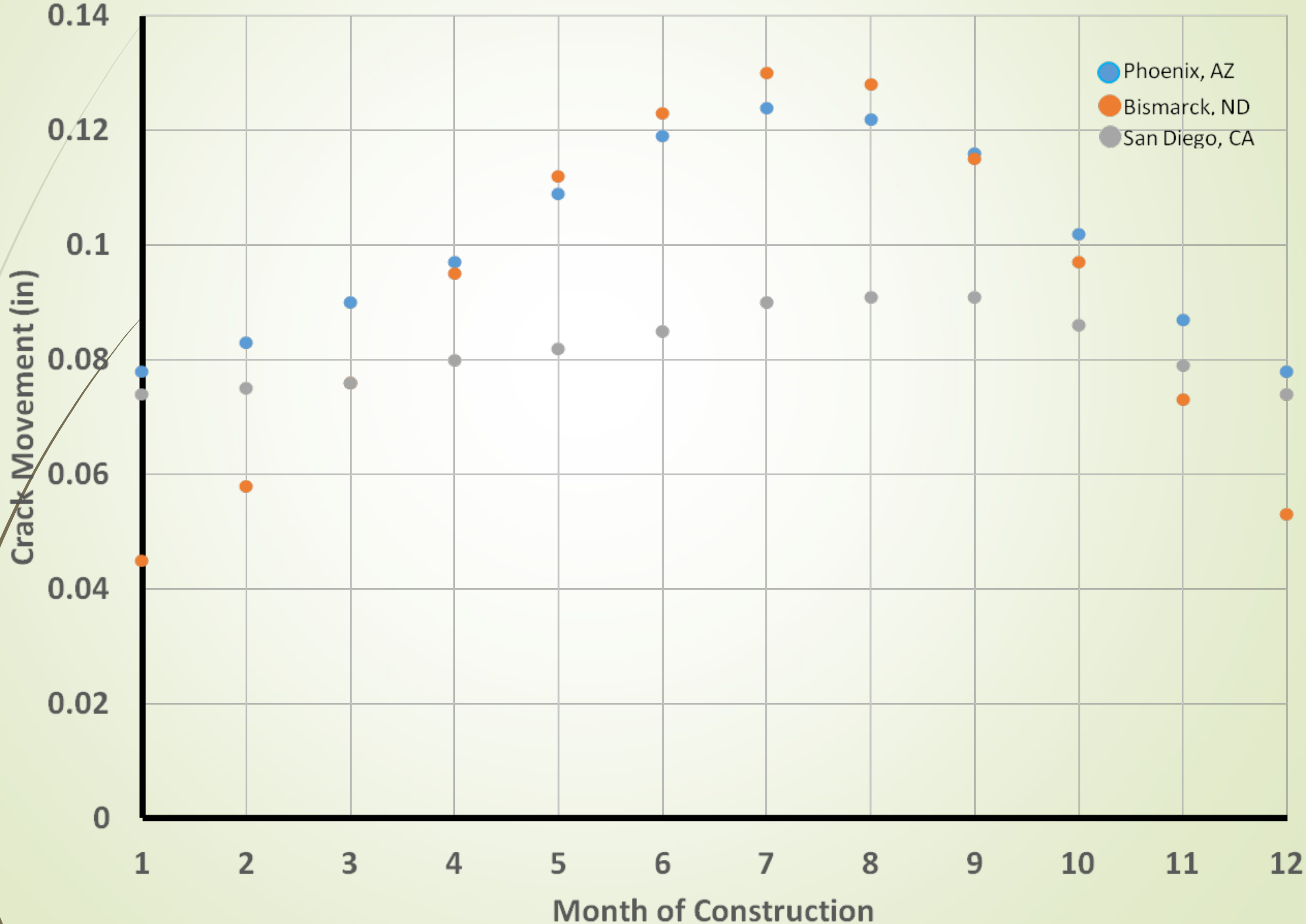
CONSTRUCTION DETAILS

Month of Construction: June

Curing Procedure: Curing Compound

Calculate | Save Inputs

Crack Opening Width based on Time of Year of Placement



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Joint Slap Adds 5 dBA to Overall Pavement Noise at 70 MPH

Description

For passenger cars, 70% to 90% of the traffic generated noise is produced by the tire-pavement interaction. Thus, additional traffic generated noise due to such vehicles is well characterized through evaluation of just the tire-pavement interaction. In the U.S., this is accomplished with the use of On-Board Sound Intensity (OBSI; see image on the right in the header) per AASHTO TP-76.

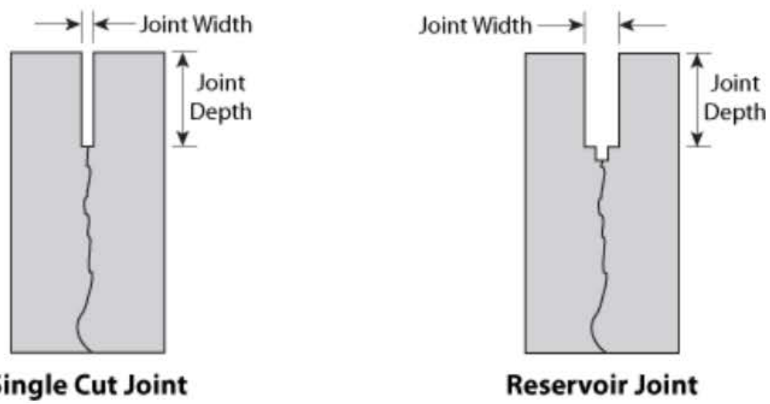
As a vehicle travels over joints in a jointed concrete pavement, there is a joint slap noise that contributes to the overall tire-pavement noise. When evaluating pavements using OBSI techniques, it is generally only convenient to determine the overall pavement noise levels. These levels are a function of both the joint slap effect and the pavement texture effect.

This tool, based on the work of Dr. Paul Donavan[1], was developed to allow designers to estimate the impact of various joint geometries and condition on the overall tire-pavement noise level and to provide guidance to maintenance efforts in terms of the noise benefit attainable through sealing joints

Concrete Pavement Details

Joint Spacing (ft): 15

Joints Sealed: ○ Yes ◉ No



Joint Width (in.): 0.625

Joint Depth (in.): 1.5

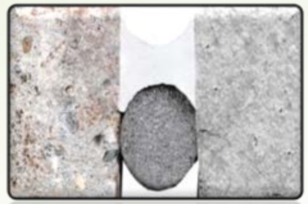
Traffic and Pavement Texture Details

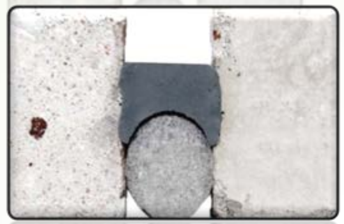
Vehicle Speed (mph): 70

Sealant Material Selection

Sealant Types

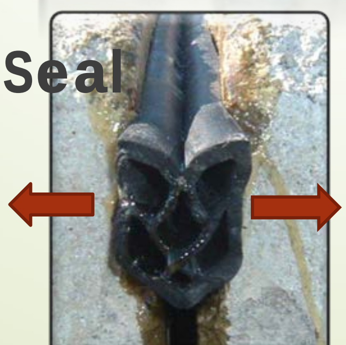
- **Silicone**
  - Non Sag
  - Self Leveling
  - Rapid Cure





- **Hot Pour**
  - Standard Modulus
  - Low Modulus

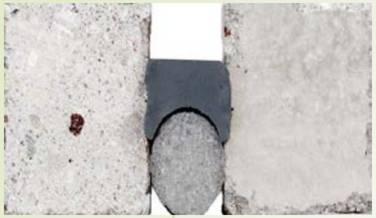
- **Compression Seal**



NON-SAG SILICONE

- Light Gray
- Horizontal or Vertical Application
- Low Modulus
- Requires Tooling
- Rehab or New Pavements
- Seals Small Spalled areas in Joint Walls
- Tack Free in 25 to 90 mins.
- Full Cure through in 14 days

SELF-LEVELING SILICONE



- Dark Grey
- Horizontal Application Only
- Ultra Low Modulus
- Neat Seal-No Tooling
- Rehab or New Pavements
- Tack Free in 3 hours max
- Full Cure through in 21 days
- 6% maximum grade
- AC/PC Joints ???

Asphalt Hot Pour Joint/crack Sealants

- ASTM D-6690:

  Type I - ASTM D1190

  Type II - ASTM D 3405

  Type III – Low Modulus

  Type IV - Fed Spec SS-S-1401C

  FAA P 605-ASTM D-6690

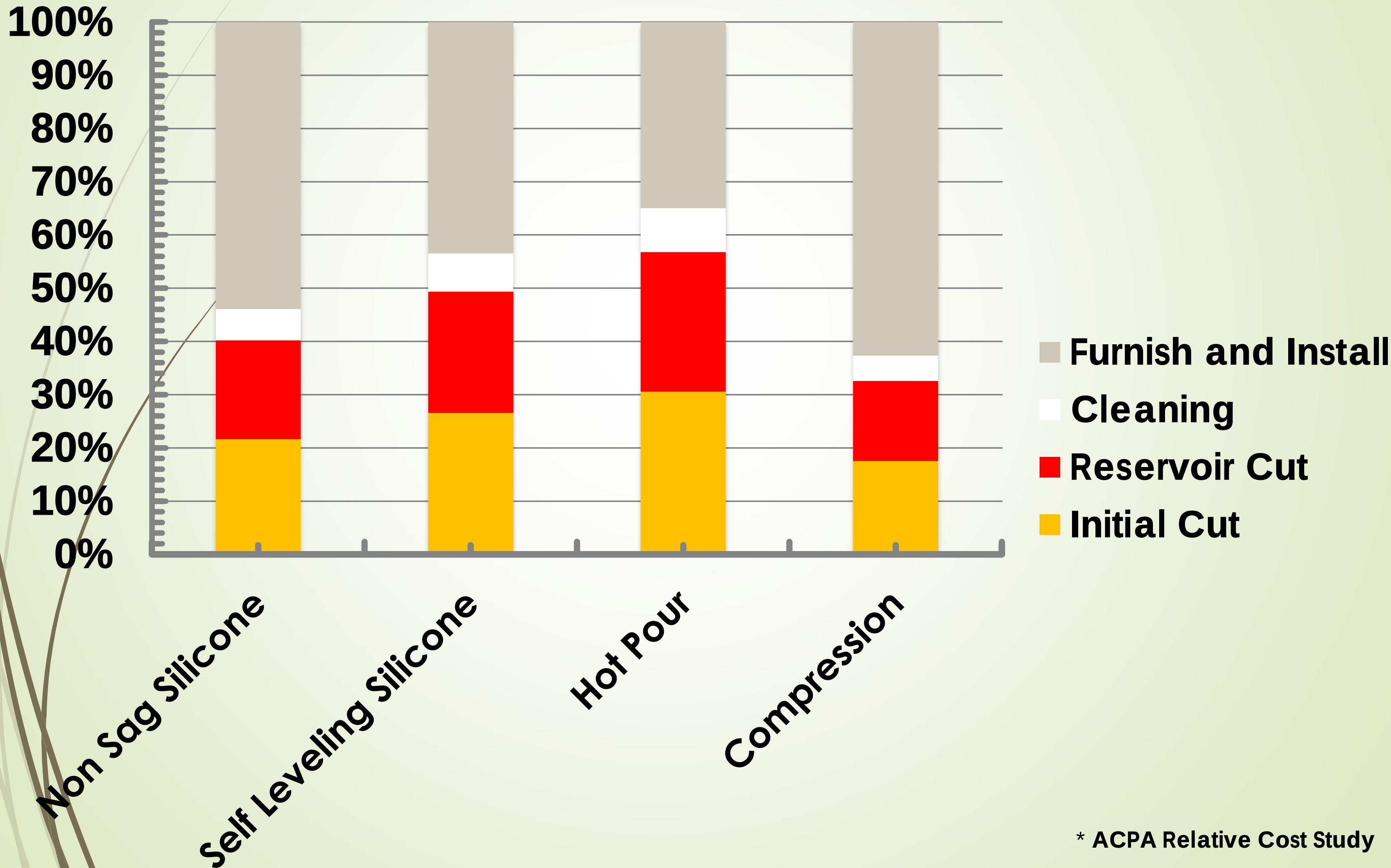
  State Specifications

Compression Seal

- Extruded from compounds of neoprene (polychloroprene) which meet or exceed current ASTM standard specifications
- Uses adhesive/lubricant for installation
- Requires proper installation equipment

Cleaning Joints

Percent of Total Cost For Each Operation of Sealing a Joint*



* ACPA Relative Cost Study

Clean Isn't an Option

- Finger Test

Power Washing After Green Sawing

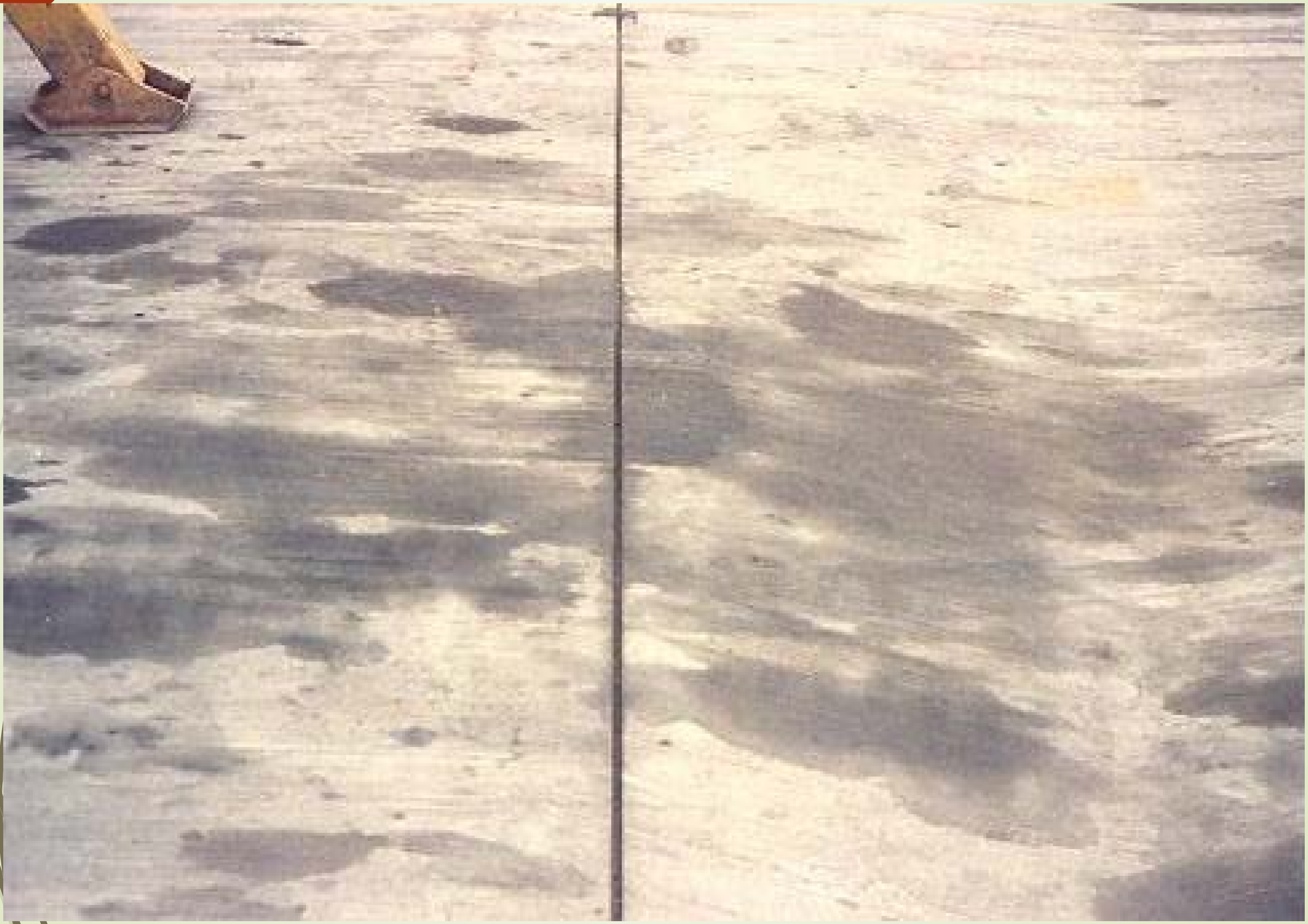
Intersecting Joints After Power Washing

Media Blasting

Media Blasting

Keeping Joints Cleaned and Protected After You've Cleaned Them.....

Do You Know Where Your Oil is?

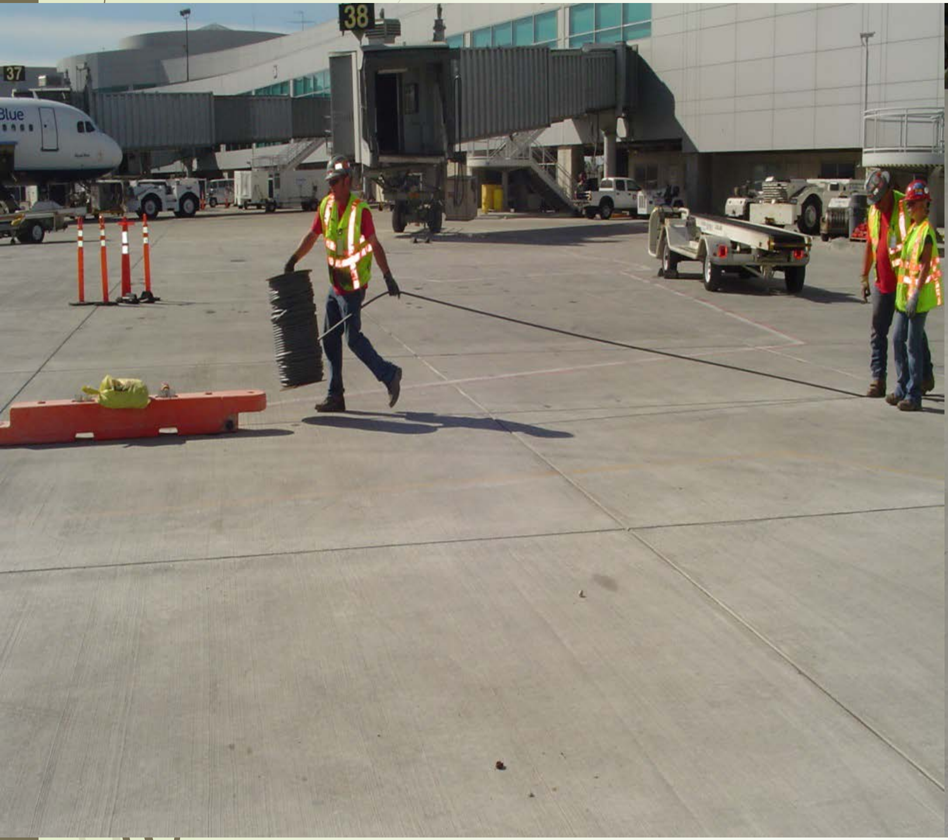


Keep the Joints Clean During Construction

Early Traffic Damage

Installing Sealant Sytems

Inserting and Rolling Backer Rod



BACKER ROD

- 25% Larger than Joint
- Cold Rod/Hot Rod
- Closed Cell Backer Rod
- Do Not Puncture Backer Rod-bubbling
- Do Not Stretch Backer Rod

Inserting and Rolling Backer Rod

Installing Backer Rod

Hot Pour Joint Sealant Configuration

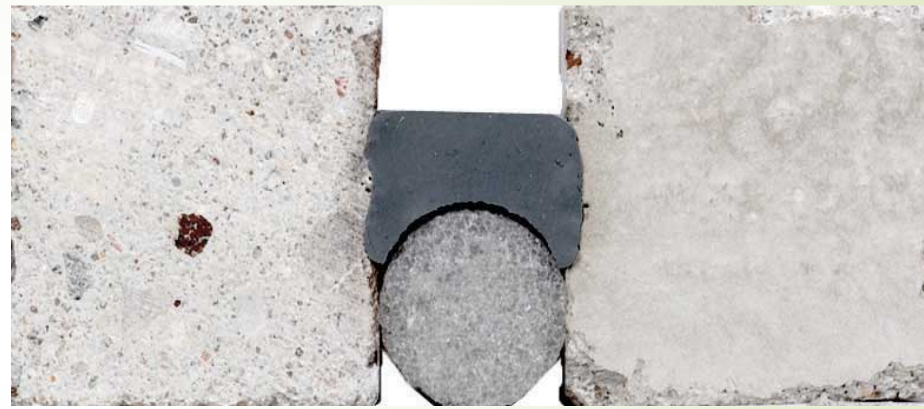
40° F Minimum Pavement Temperatures

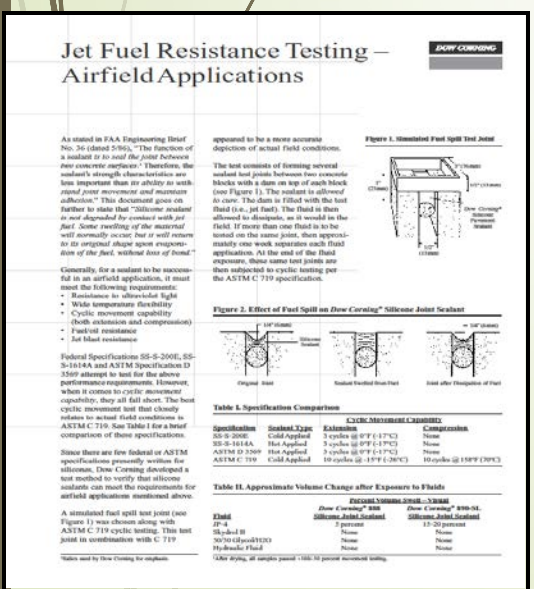
Flush Fill, Recessed or Over-band - - ->

Flush Filled **Recessed** **Flush Filled**

Installing Hot Pour Sealants

Silicone Joint Sealant Configuration





Jet Fuel Resistance Testing – Airfield Applications

As stated in FAA Engineering Brief No. 36 (dated 5/86), "The function of a sealant *is to seal the joint between two concrete surfaces*.[1] Therefore, the sealant's strength characteristics are less important than *its ability to withstand joint movement and maintain adhesion*." This document goes on further to state that "*Silicone sealant is not degraded by contact with jet fuel. Some swelling of the material will normally occur, but it will return to its original shape upon evaporation of the fuel, without loss of bond.*"

Generally, for a sealant to be successful in an airfield application, it must meet the following requirements:

- Resistance to ultraviolet light
- Wide temperature flexibility
- Cyclic movement capability (both extension and compression)
- Fuel/oil resistance
- Jet blast resistance

Federal Specifications SS-S-200E, SS-S-1614A and ASTM Specification D 3569 attempt to test for the above performance requirements. However, when it comes to *cyclic movement capability*, they all fall short. The best cyclic movement test that closely relates to actual field conditions is ASTM C 719. See Table I for a brief comparison of these specifications.

Since there are few federal or ASTM specifications presently written for silicones, Dow Corning developed a test method to verify that silicone sealants can meet the requirements for airfield applications mentioned above.

A simulated fuel spill test joint (see Figure 1) was chosen along with ASTM C 719 cyclic testing. This test joint in combination with C 719 appeared to be a more accurate depiction of actual field conditions.

The test consists of forming several sealant test joints between two concrete blocks with a dam on top of each block (see Figure 1). The sealant is *allowed to cure*. The dam is filled with the test fluid (i.e., jet fuel). The fluid is then allowed to dissipate, as it would in the field. If more than one fluid is to be tested on the same joint, then approximately one week separates each fluid application. At the end of the fluid exposure, these same test joints are then subjected to cyclic testing per the ASTM C 719 specification.

[1]Italics used by Dow Corning for emphasis.

Figure 1. Simulated Fuel Spill Test Joint

Figure 2. Effect of Fuel Spill on *Dow Corning*® Silicone Joint Sealant

Table I. Specification Comparison

Specification	Sealant Type	Cyclic Movement Capability: Extension	Compression
SS-S-200E	Cold Applied	3 cycles @ 0°F (-17°C)	None
SS-S-1614A	Hot Applied	3 cycles @ 0°F (-17°C)	None
ASTM D 3569	Hot Applied	3 cycles @ 0°F (-17°C)	None
ASTM C 719	Cold Applied	10 cycles @ -15°F (-26°C)	10 cycles @ 158°F (70°C)

Table II. Approximate Volume Change after Exposure to Fluids

Fluid	Percent Volume Swell – Visual: *Dow Corning*® 888 Silicone Joint Sealant	*Dow Corning*® 890-SL Silicone Joint Sealant
JP-4	5 percent	15-20 percent
Skydrol II	None	None
50/50 Glycol/H2O	None	None
Hydraulic Fluid	None	None

[1]After drying, all samples passed +100/-50 percent movement testing.

1. Recess min 1/8”- 1/2” Below Surface
2. 2 to 1 Ratio
3. Tooling Required

Silicone Sealing Application

40° F Minimum Pavement Temperatures
1/8” Minimum Recess
Requires Tooling

Silicone Sealant Installed at Joint Intersection

Silicone Adhesion Test

1. Make a knife cut horizontally across the silicone

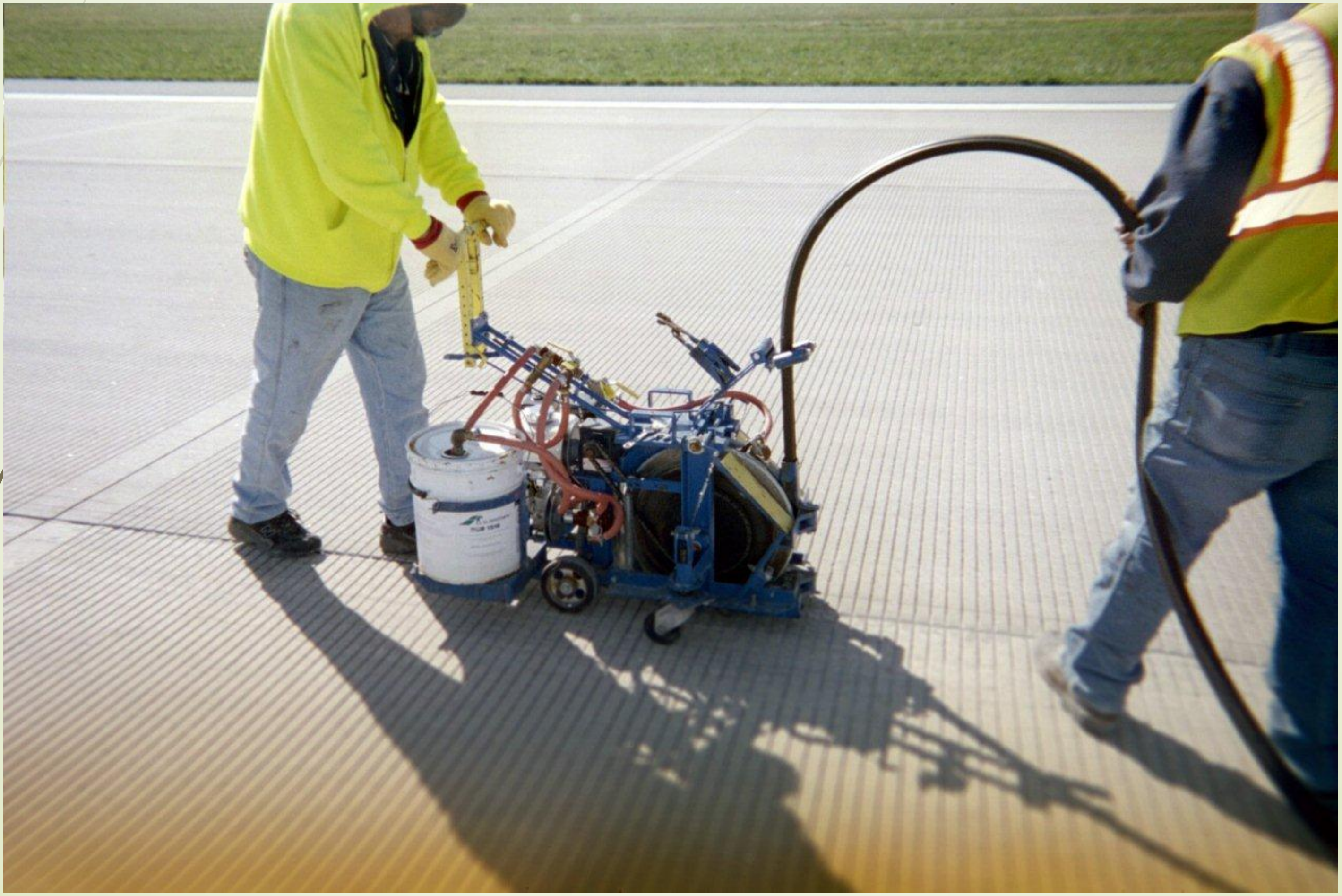
2. Make a vertical cut approximately 3 inches long on each side of the joint

3. Hold the piece of silicone firmly and slowly pull at a 90° angle. If adhesion is proper, the silicone will not pull out of the joint, but will eventually tear cohesively

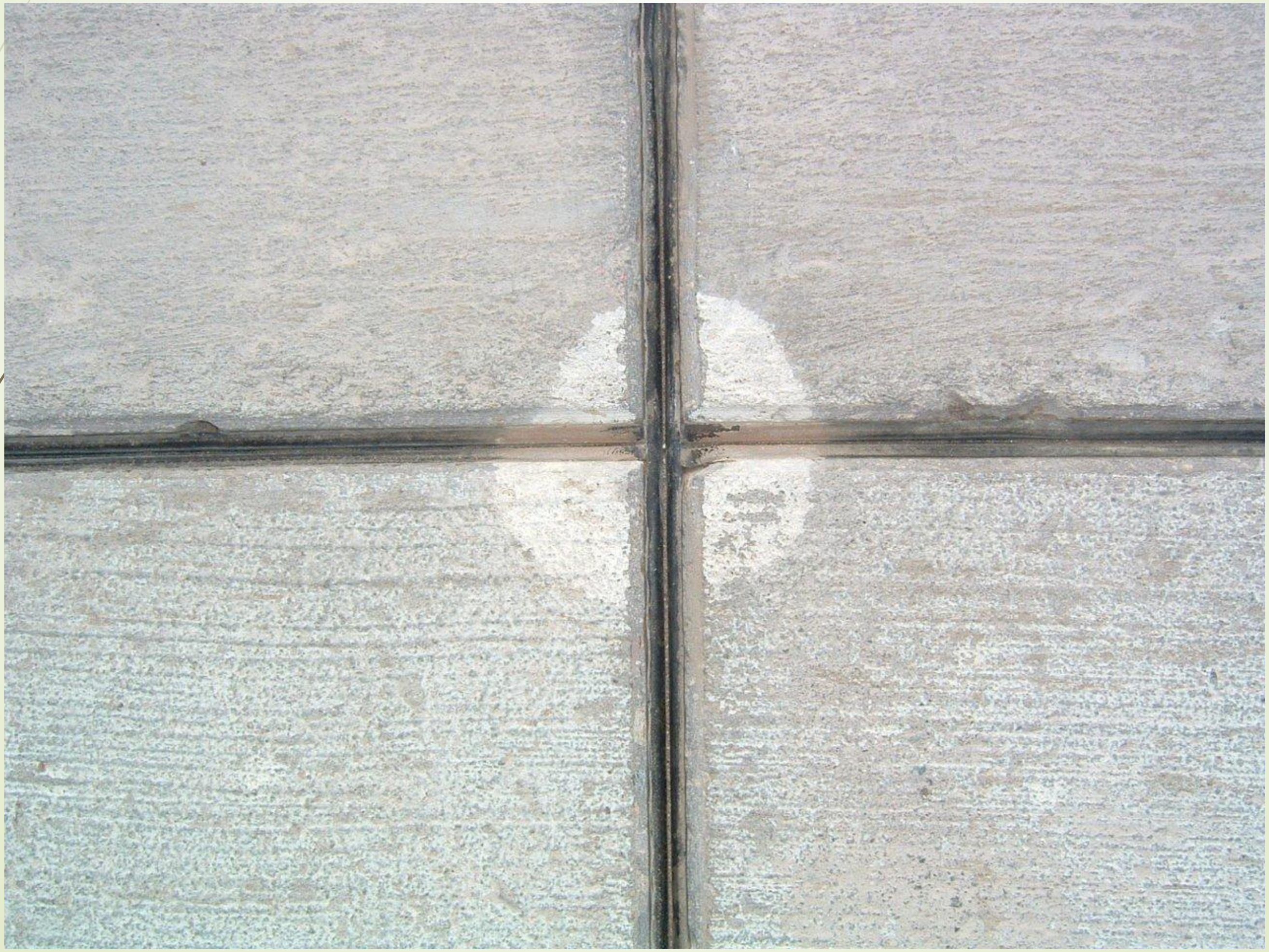
Compression Seal Installation

- Lubricant-Adhesive shall meet ASTM D2835
- Installation Above 32 F
- Install Sealant in Longitudinal Joint First
- Cut Longitudinal Joint in Center of Each Transverse Joint
- Install Transverse Joint Continuously Across
- Sealant Stretch Should be Less than 4 %
- Recess Sealant 3/16”

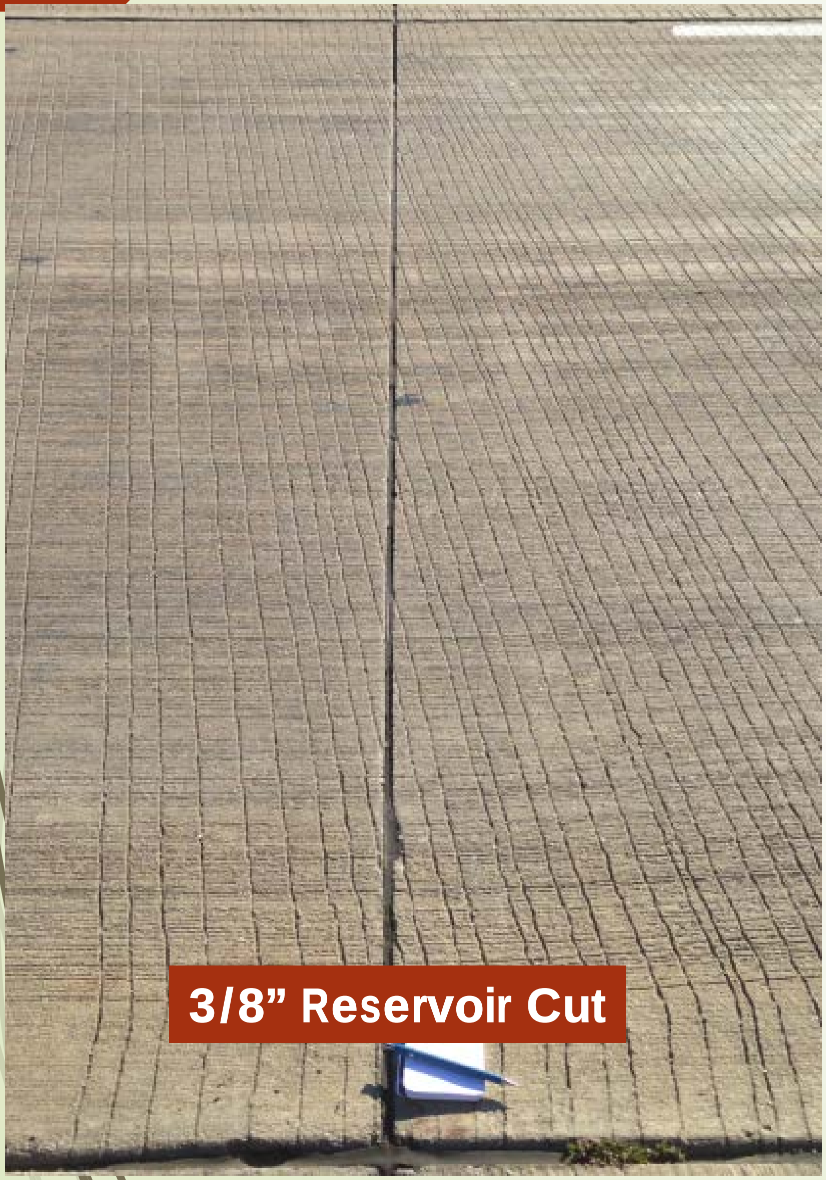
Properly Installing Compression Seal

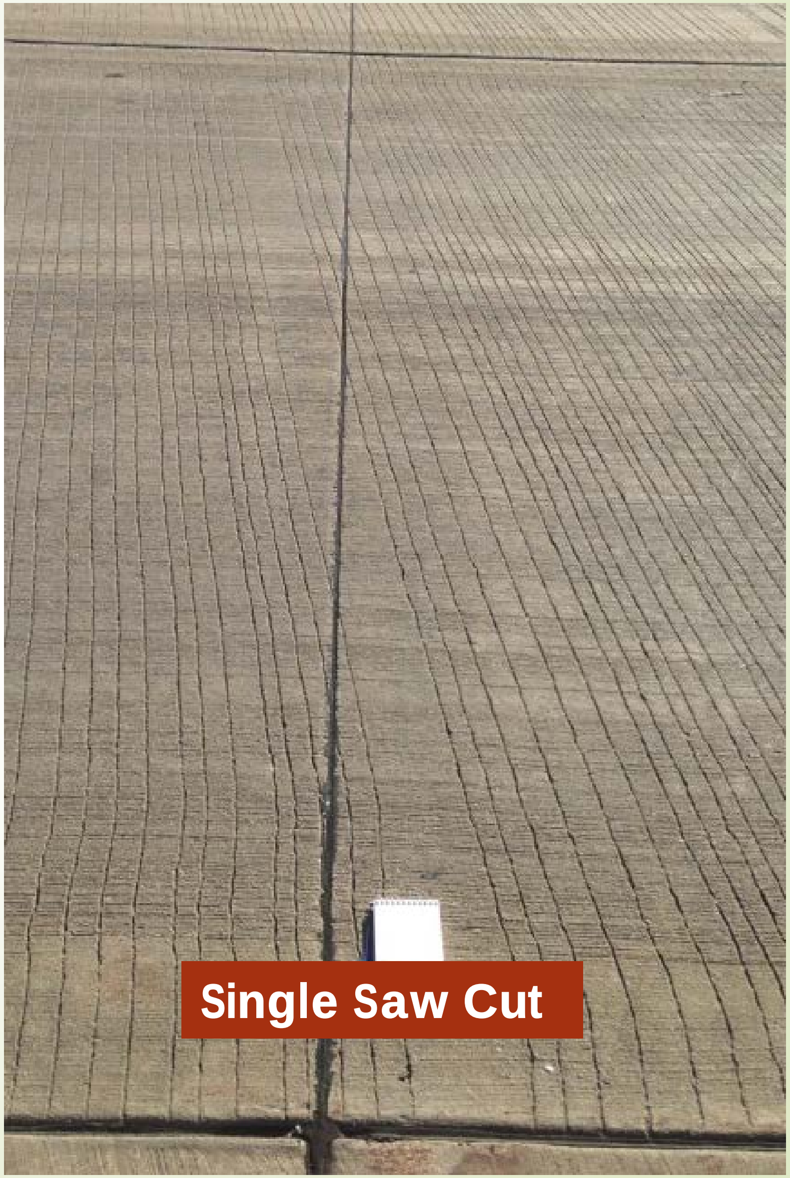


Compression Seal at Joint Intersection



Hot Pour Sealants





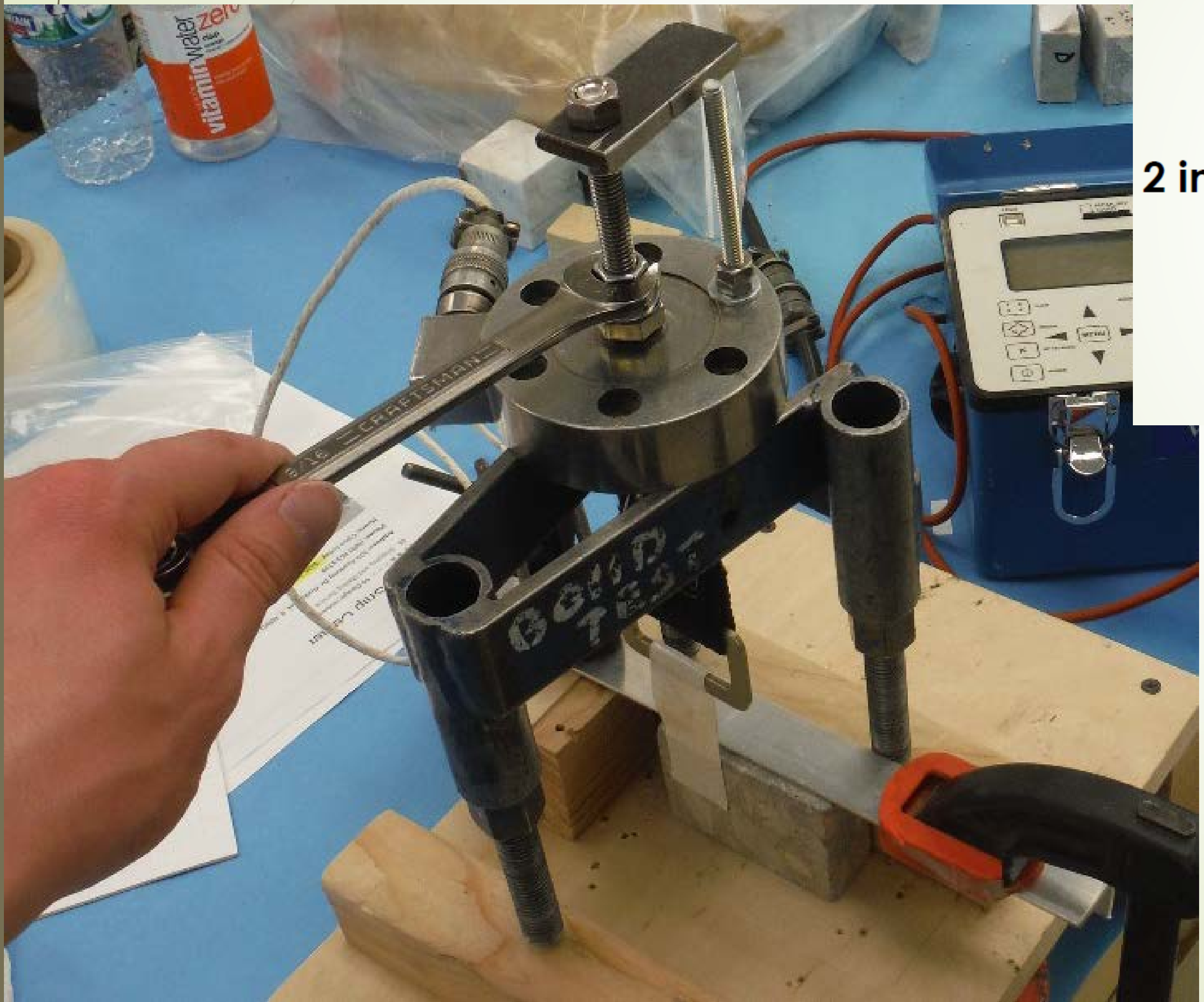
Single Saw Cut Sealant Extrusion

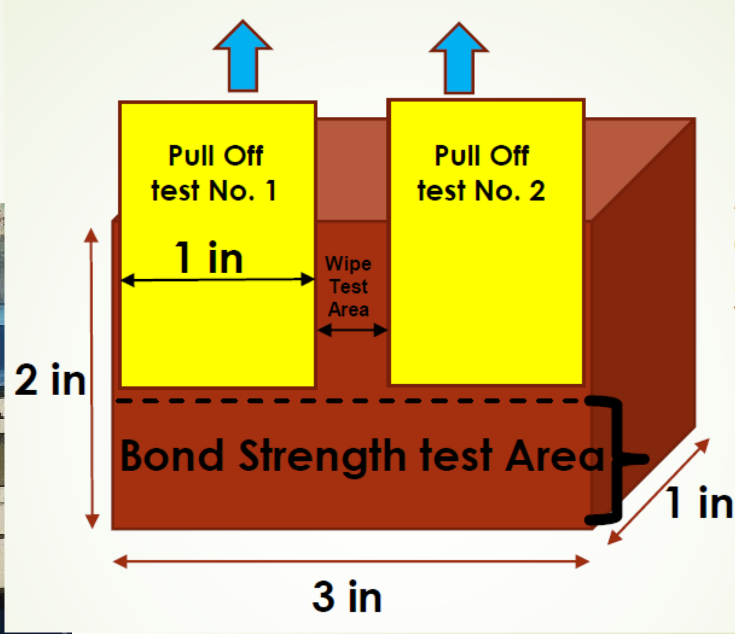
Can We Seal a Joint?

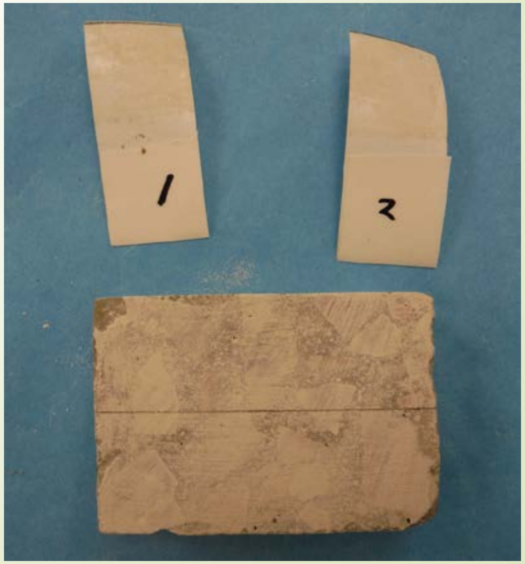
20 Years Old

1 Year Old

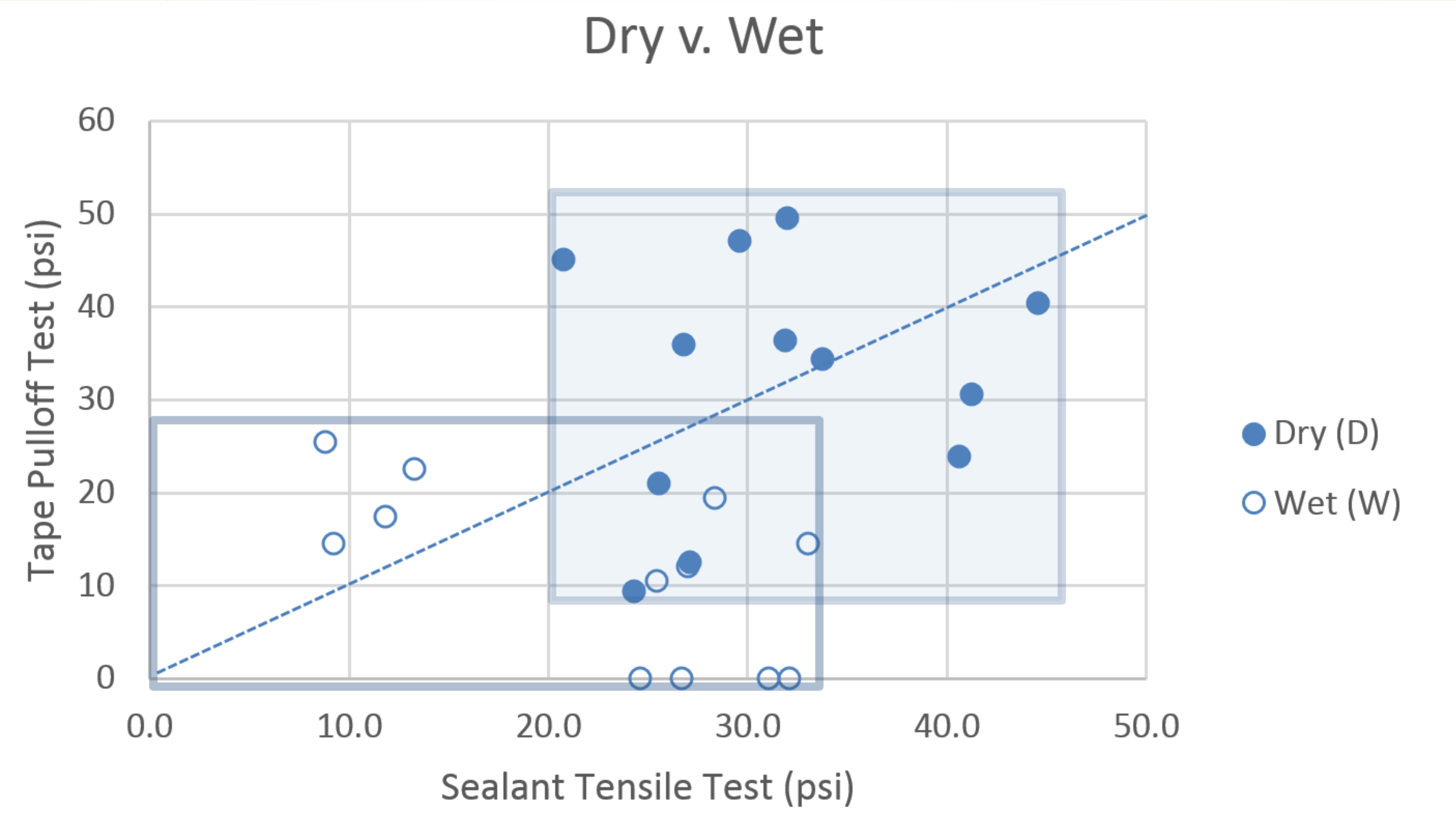
WJE Pull Off Test







Comparison of Tape Pull off Test to Tensile Bond Test



Is Sealant Cost Effective?

FHWA Sealant Effectiveness Study

CONCRETE PAVEMENT
CPTP
TECHNOLOGY PROGRAM

TechBrief

The Concrete Pavement Technology Program (CPTP) is an integrated, national effort to improve the long-term performance and cost-effectiveness of concrete pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, CPTP's primary goals are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation. The program was designed to produce user-friendly software, procedures, methods, guidelines, and other tools for use in materials selection, mixture proportioning, and the design, construction, and rehabilitation of concrete pavements.

www.fhwa.dot.gov/pavement/concrete

U.S. Department of Transportation
Federal Highway Administration

Performance of Sealed and Unsealed Concrete Pavement Joints

This TechBrief presents the results of a nationwide study of the effects of transverse joint sealing on performance of jointed plain concrete pavement (JPCP). This study was conducted to assess whether JPCP designs with unsealed transverse joints performed differently from JPCP designs with sealed transverse joints. Distress and deflection data were collected from 117 test sections at 26 experimental joint sealing projects located in 11 states. Performance of the pavement test sections with unsealed joints was compared with the performance of pavement test sections with one or more types of sealed joints.

BACKGROUND

The sealing of tran[illegible]rse contraction jo[illegible]s in JPCP has been standard practice throughout mu[illegible] of the United Stat[illegible] for many years. Its widespread use is due to t[illegible] commo[illegible] belief that sealin[illegible] joints improves concrete pavement performance [illegible] two w[illegible] by reduci[illegible] water infiltration into the pavement structure, there[illegible] reducing [illegible]rence of moisture-related distresses such [illegible]ing and [illegible]ng, and by preventing the infiltration of incompress[illegible] (i.e., s[illegible] stones) into the joints, thereby reducing the likelih[illegible] of pressure-rela[illegible] joint distresses such as joint spalling and blowups.

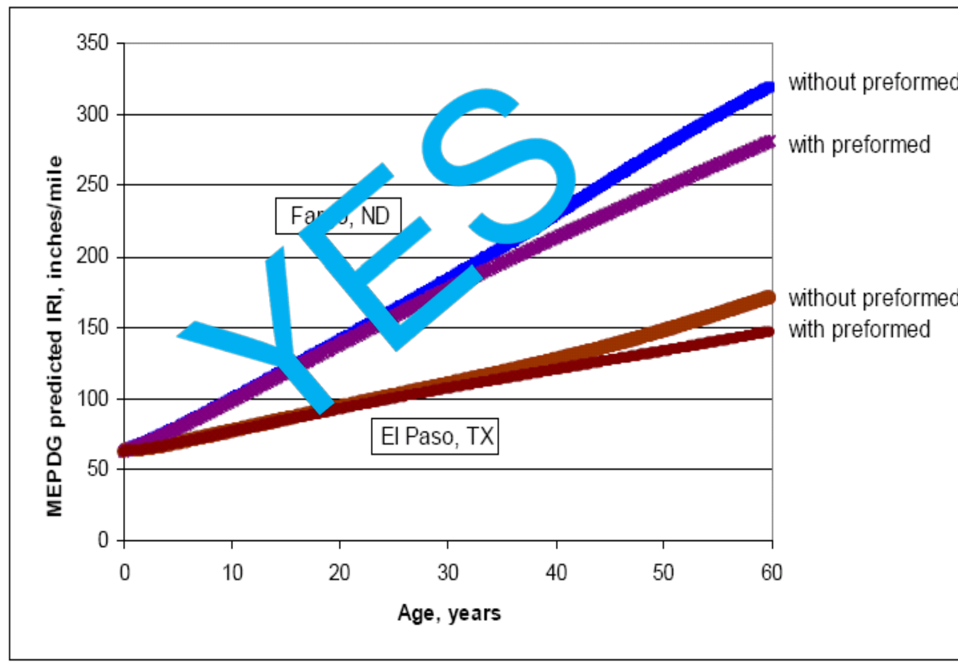
Tra[illegible]rse joints in jointed concrete pavement (JCP) are typically created by mak[illegible] an initial saw cut to force controlled cracking, followed by a second, wide[illegible] saw cut to produce a reservoir for the joint sealant material. This traditional approach of sawing and sealing transverse contraction joints is estimated to account for between 2 and 7 percent of the initial construction cost of a JCP. Moreover, these sealed transverse joints require resealing one or more times over the service life of the pavement, leading to additional costs in terms of labor, materials, operations, and lane closures.

Recently, several State departments of transportation (DOTs) have been questioning conventional transverse joint sawing and sealing practices. These agencies contend that the benefits derived from sealing do not offset the costs associated with the placement and continued upkeep of the sealant over the life of the pavement. As a result, they have been experimenting with different sawing and sealing alternatives, for example:

- Narrow unsealed joints, consisting of single saw cuts that are left unsealed.
- Narrow filled joints, consisting of single saw cuts that are filled with sealant that adheres to the sides and bottom of the saw cut.
- Narrow sealed joints, consisting of single saw cuts that contain a narrow backer rod and sealant material.

NO

AASHTO New Design Guide



Is Sealant Cost Effective

The Second
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP 2 REPORT S2-R26-RR-2

Guidelines for the Preservation
of High-Traffic-Volume Roadways

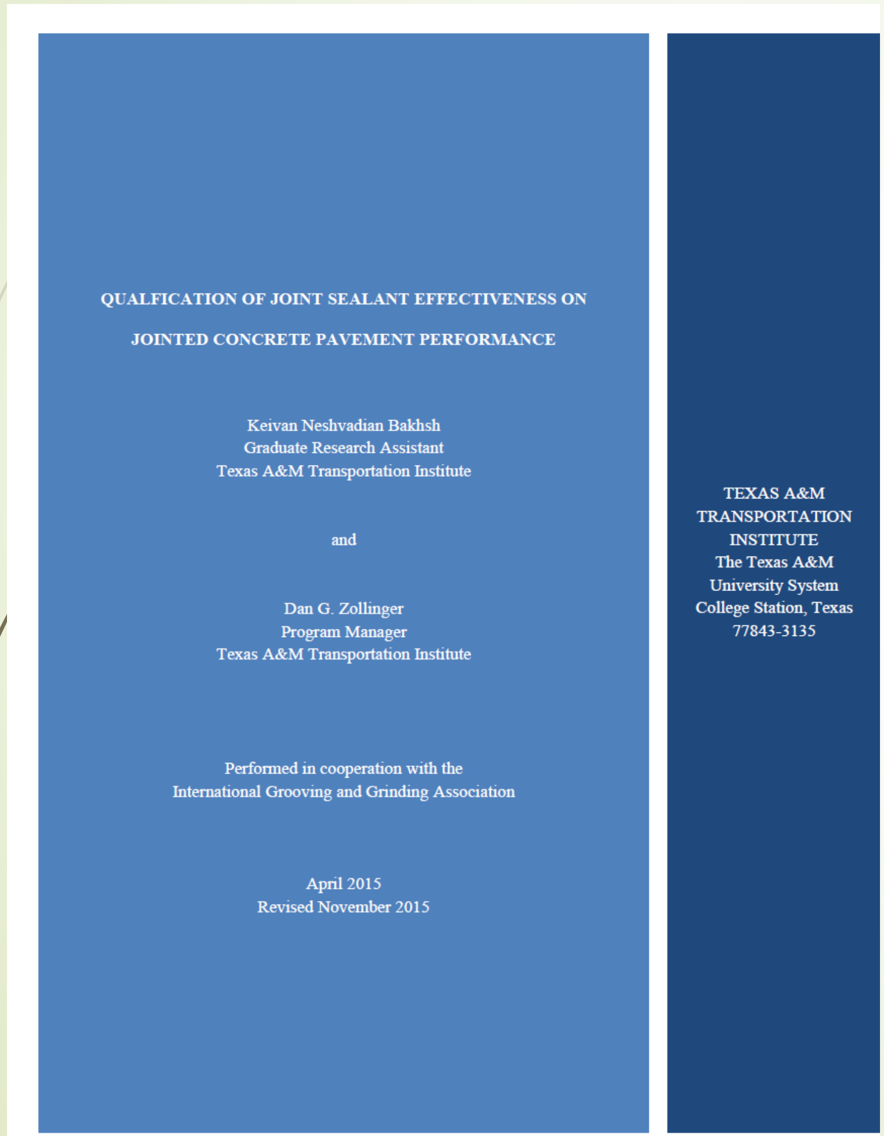
D. Peshkin, K. L. Smith, A. Wolters, and J. Krstulovich
Applied Pavement Technology, Inc.
Urbana, Illinois

J. Moulthrop and C. Alvarado
Fugro Consultants, Inc.
Austin, Texas

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2011
www.TRB.org

Treatment	Expected Performance	
	Treatment Life (yr)	Pavement Life Extension (yr)
Concrete joint resealing	2–8	5–6
Concrete crack sealing	4–7	NA
Diamond grinding	8–15	NA
Diamond grooving	10–15	NA
Partial-depth concrete patching	5–15	NA
Full-depth concrete patching	5–15	NA
Dowel bar retrofitting	10–15	NA
Ultra-thin bonded wearing course	6–10	NA
Thin HMA overlay	6–10	NA

Effectiveness---
Newest Research Findings



QUALFICATION OF JOINT SEALANT EFFECTIVENESS ON

JOINTED CONCRETE PAVEMENT PERFORMANCE

Keivan Neshvadian Bakhsh
Graduate Research Assistant
Texas A&M Transportation Institute

and

Dan G. Zollinger
Program Manager
Texas A&M Transportation Institute

Performed in cooperation with the
International Grooving and Grinding Association

April 2015
Revised November 2015

TEXAS A&M
TRANSPORTATION
INSTITUTE
The Texas A&M
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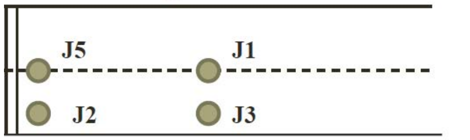
College Station, Texas
77843-3135

A key outcome of this project is advancement of a mechanistic tool for analysis of specific combinations of traffic, climate, base materials, and sealant condition on subbase erosion and pavement performance

TTI Work

9 FWD Testing.



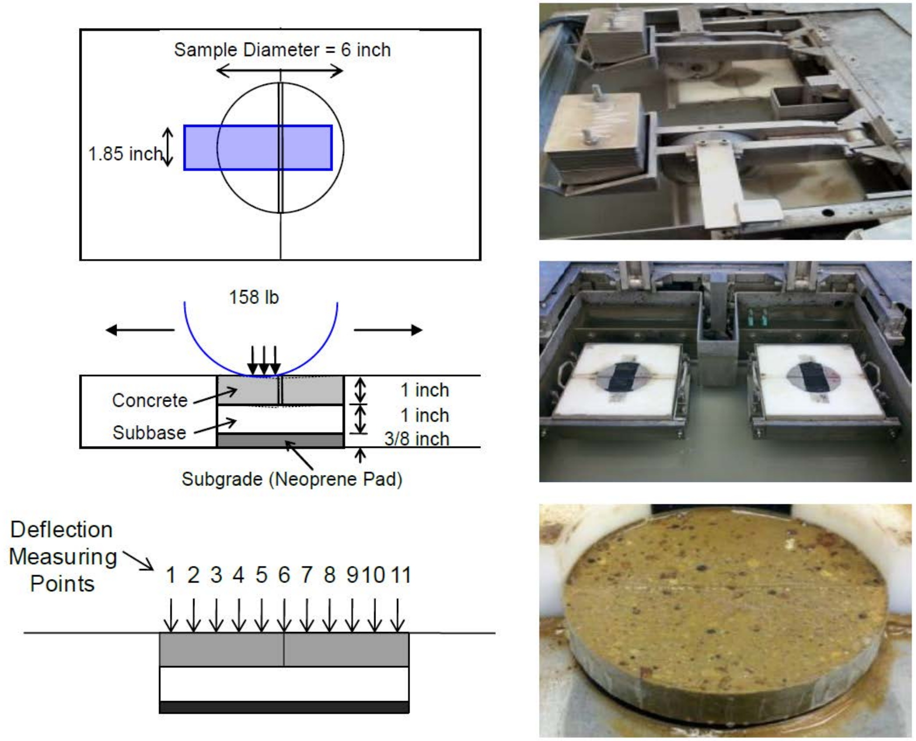
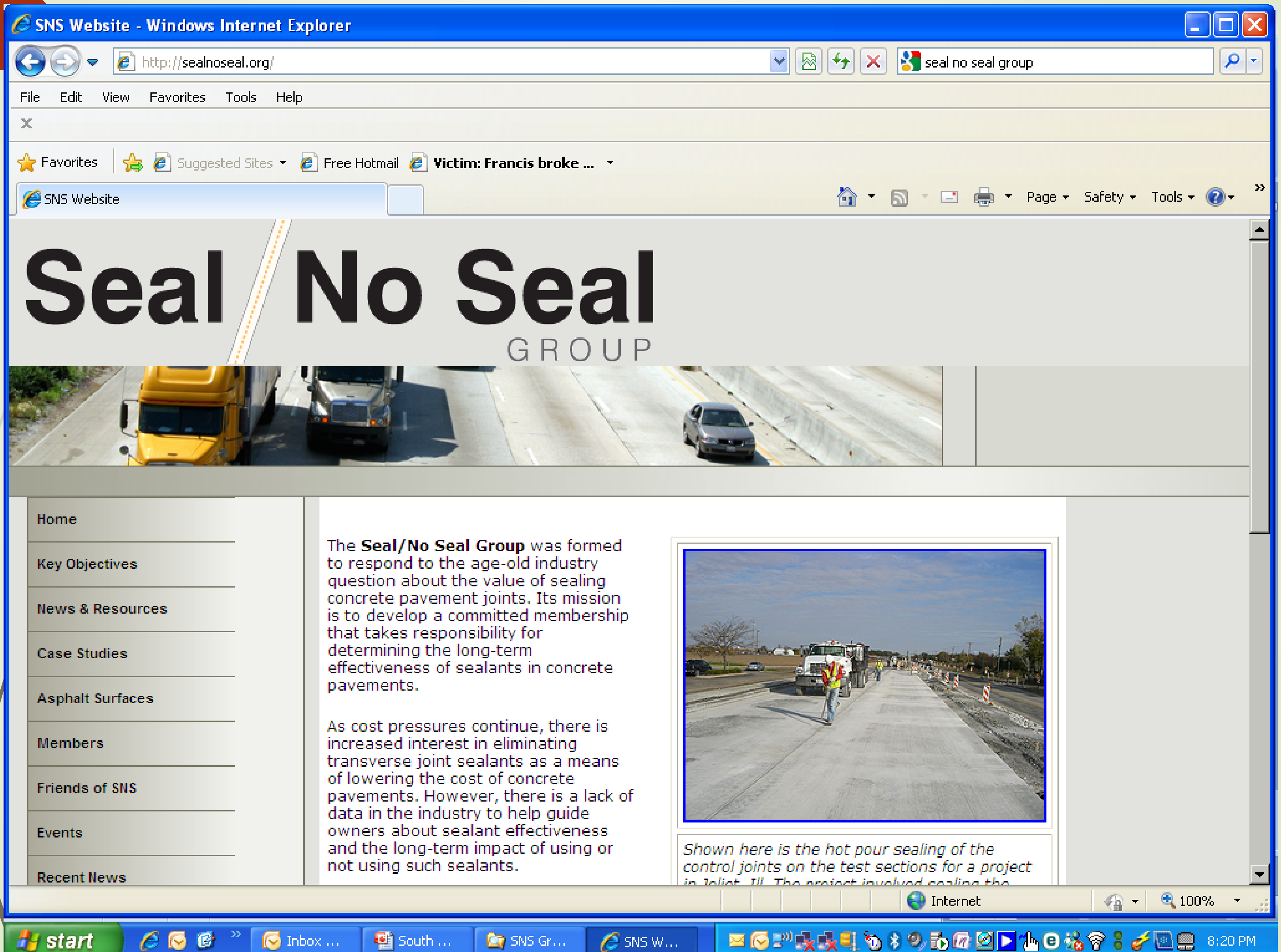


Figure D.1 Erosion Test Using Hamburg Wheel-Tracking Device.

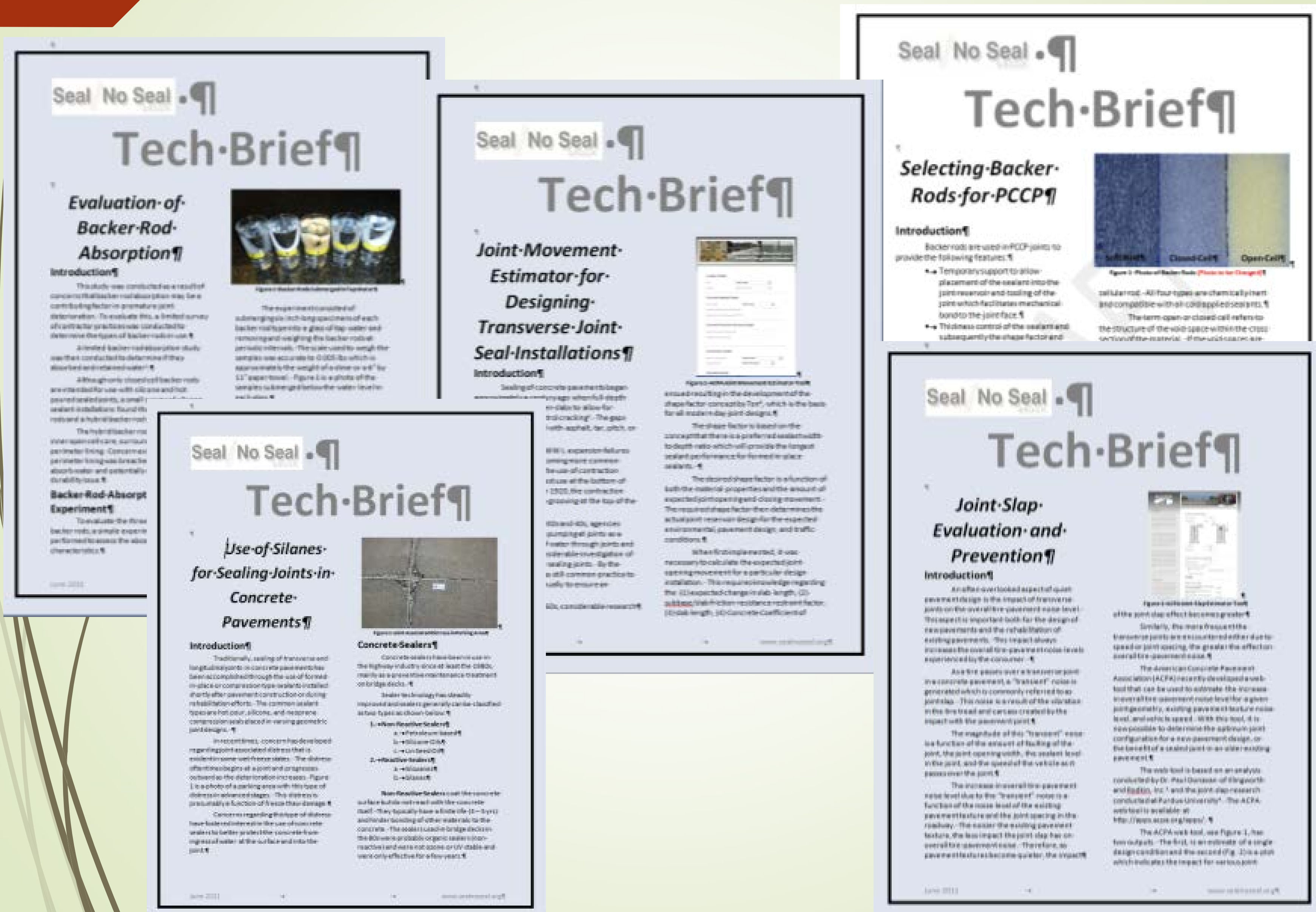
Summary

- Design Joint Sealant System for the Expected Joint Movements
- Select a Joint Sealant Material and Backer Rod Appropriate for the Intended Purpose
- Ensure Proper Cleaning and Preparation– Clean, Dry and Bondable
- Inspect the Work and Verify its Acceptability

Sealnoseal.org



Tech Briefs


Seal No Seal
Tech Brief
Evaluation of Backer Rod Absorption
Introduction
Backer Rod Absorption Experiment

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Tech Brief
Joint Movement Estimator for Designing Transverse Joint Seal Installations
Introduction

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Tech Brief
Use of Silanes for Sealing Joints in Concrete Pavements
Introduction
Concrete Sealers

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Selecting Backer Rods for PCCP
Introduction

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Tech Brief
Joint Slap Evaluation and Prevention
Introduction

Questions

Seal/No Seal GROUP

IGGA International Grooving & Grinding Association

Your Pavement Preservation Resource since 1972

Place Sealant That Only Covers Joint

Seal Joint Without Cleaning

Overband Hot Pour Sealant

What Not to Do