CONCRETE PAVEMENT PRESERVATION

Performance of a Test Section with Various Test Cells of Unique Joint Sealant and Contractor-Established Joints

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Background

In 2003 the MnDOT concrete engineering unit maintained an approved product list that included a variety of joint sealants. Performance of some of the sealants was not very salutary. This necessitated an abrogation of the approved list of joint sealants, whereupon, many manufacturers were informed about a process which seemed feasible to use at that time for readmission into the list. This was the NTPEP program that was looking into the performance of joint sealants. In consequence an unbonded overlay project on US Highway 10 between Motley and Staples, Minnesota was chosen as a test site. The contractor was to provide typical unsealed joints while the various sealant manufacturers were to provide all their prescribed joints and seal them. The NTPEP program provided a protocol for evaluation of the joints and a scoring criterion primarily for the condition of the sealers.

The NTPEP monitoring was done for 7 years but at this stage the condition of the joints was reported as merely the performance of the joint sealers, evident in adhesion failure, cohesion failure or lack of these. Consequently at the eighth year MnDOT concrete research unit got involved in these test sections and the effect of these joint preparations and conditions were measured in terms of pavement ride quality and other deterministic variables.

During the NTPEP evalutation MnDOT coordinated traffic control activities, established all staging and installation areas, coordinated the installation activity for each of the supplier/installer teams, and conducted annual evaluations, material testing and data analysis.

PROJECT DETAILS

Eastbound US 10 – Unbonded PCC Overlay, 7” reinforced concrete, placed on 1.5” Permeable Asphalt Stabilized Stress Release Course 33’wide, HMA shoulders, 14’ driving lane, 13 passing lane. 15’ Contraction joint spacing. Concrete was poured on September 8, 2003.Widening Saw Cut -September 10, 2003. Detail B depth was modified to 1 ¼” to allow use of ½” backer rod for Hot-Pour Sealants. All hot-pour products use the same configuration. Widths were sawed to ½”. Minimal spalling was seen after sawing.

Detail "E” of the MnDOT concrete joint specification was used for the silicone sealants. Final saw cut was done to 3/8” x 1 ¼”. All products were installed with backer rod. Each joint was sandblasted and blown out beginning at 7:00 am on the day of sealing. Heat lancing is not standard procedure on concrete, but because of the rain experienced the day before the heat lance was used to dry out the joints. The test sections were assigned to various product manufacturers as shown in table 1 and table 2.

According to NTPEP guidelines, the host state scheduled installation dates and times with the sealant suppliers and coordinated scheduling and layout of test sections. A MnDOT inspector was assigned to each supplier.

Table 1: Test Section Location Allocation

2003 NTPEP Evaluation of Joint Sealers for PCC Pavements MnDOT In-Service Field Performance Evaluation				
Mn/DOT ID	**NTPEP Number**	**Company**	**Product Trade Name**	**Jt. Sealant Configuration**
Cell 1		Shafer	Unsealed	C1A-D
Cell 2		Shafer-Single Cut Hot Pour	Meadows 3723 HP	C1A-D Modified
Cell 3	JS(2003)-1	Deery American Corporation	DEERY 101 ELT	C2B-D Modified
Cell 4	JS(2003)-11	Crafco, Inc.	Roadsaver 522	C2B-D Modified
Cell 5		Shafer	Unsealed	C1A-D
Cell 6	JS(2003)-12	Crafco, Inc.	Superseal Low-Mod	C2B-D Modified
Cell 7	JS(2003)-16	McAsphalt, Inc.	BERAM 3060 LM	C2B-D Modified
Cell 8		DS Brown	Delastic E-686	C3D-D
Cell 9	JS(2003)-2	Dow Corning Corporation	Dow Corning® 888	C4E-D
Cell 10	JS(2003)-3	Dow Corning Corporation	Dow Corning® 890-SL	C4E-D
Cell 11	JS(2003)-4	May National Associates, Inc.	Bondaflex Sil 728 NS	C4E-D
Cell 12	JS(2003)-5	May National Associates, Inc.	Bondaflex Sil 728 SL	C4E-D
Cell 13	JS(2003)-6	May National Associates, Inc.	Bondaflex Sil 728 RCS	C4E-D
Cell 14	JS(2003)-7	Tremco, Inc.	Spectrum 800	C4E-D
Cell 15	JS(2003)-8	Tremco, Inc.	Spectrum 900 SL	C4E-D
Cell 16	JS(2003)-9	Pecora Corporation	301NS Silicone	C4E-D
Cell 17	JS(2003)-10	Pecora Corporation	300SL Silicone	C4E-D
Cell 18	JS(2003)-13	Crafco, Inc.	Roadsaver Silicone SL	C4E-D
Cell 19	JS(2003)-14	Crafco, Inc.	Roadsaver Silicone 902	C4E-D
Cell 20	JS(2003)-17	Watson Bowman Acme Corporation	WABO® Silicone Seal	C4E-D
Cell 21	JS(2003)-18	CSL Silicones, Inc.	CSL 341 Non-Slump	C4E-D
Cell 22	JS(2003)-19	CSL Silicones, Inc.	CSL 316 Self-Leveling	C4E-D
Cell 23		Shafer	Unsealed	C1A-D

The manufacturers created the joints to the specification best suited for the performance of their products. In consequence, a variety of joint types are indicated in the tables as prescribed by the manufacturers. As a preference the contractor cut unsealed joints to the MnDOT spec for unmodified C1AD based on the MnDOT standard (1)

http://www.dot.state.mn.us/materials/concretedocs/joint_sealing_guidelines.pdf

TABLE 2: Test Section Location

Joint Seal Test Cell Locations			
Cell	Begin Station	End Station	Length
1	1194+92.30	1196+27.11	134.81
2	1196+42.10	1197+75.44	133.34
3	1197+89.92	1199+23.57	133.65
4	1199+39.23	1200+74.76	135.53
5	1200+90.26	1202+24.36	134.10
6	1202+39.25	1203+75.02	135.77
7	1203+90.31	1205+25.01	134.70
8	1205+40.55	1206+77.49	136.94
9	1206+92.09	1208+27.68	135.59
10	1208+42.75	1209+77.61	134.86
11	1209+92.12	1211+25.33	133.21
12	1211+42.72	1212+76.78	134.06
13	1212+91.36	1214+28.01	136.65
14	1214+42.83	1215+76.81	133.98
15	1215+91.71	1217+26.92	135.21
16	1217+41.60	1218+76.62	135.02
17	1221+00.38	1222+36.62	136.24
18	1222+50.88	1223+86.10	135.22
19	1224+00.20	1225+35.49	135.29
20	1225+50.52	1226+84.56	134.04
21	1226+99.44	1228+34.63	135.19
22	1228+49.79	1229+85.57	135.78
23	1230+00.11	1231+34.82	134.71

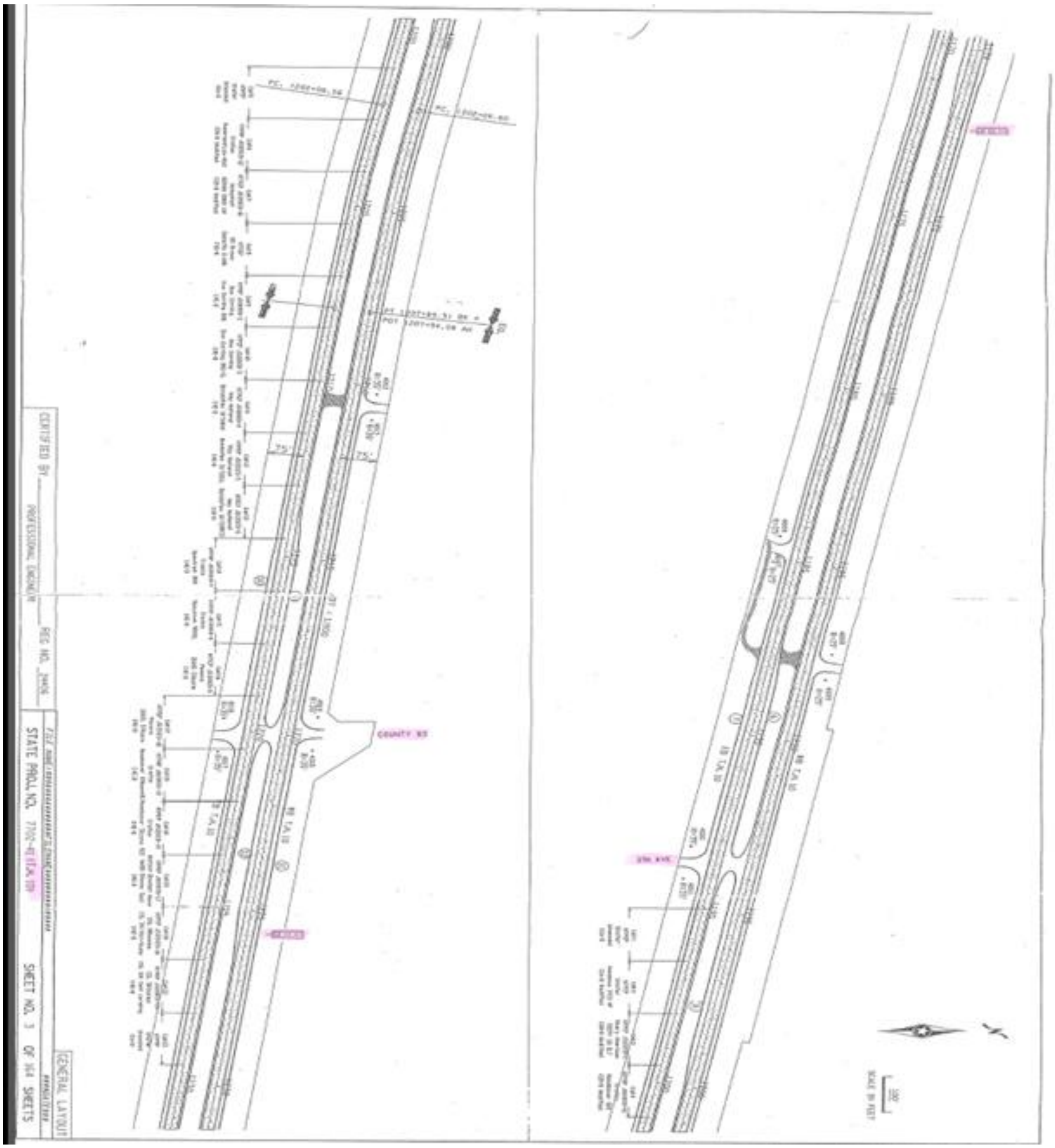

Figure 1: Construction layout showing test section limits.

Table 3: Test Section 2009 Measured Joint Widths

SECTION	Joint Widths x 10^3 (inch)		
	LWP	B/W WP	RWP
1-1	283	243	220
1-5	206	214	233
1-8	289	274	283
2-3	196	222	232
2-4	284	267	286
2-10	252	232	203
3-5	608	656	607
3-6	603	615	584
3-7	529	495	498
4-2	565	550	535
4-9	629	654	574
5-2	210	217	237
5-8	280	276	290
8-2	450	455	446
8-3	452	457	419
8-4	442	498	451
14-4	486	484	501
14-7	479	446	452
15-7	403	402	405
15-8	573	574	555
15-9	495	527	511
17-1	461	446	469
17-2	451	438	433
17-3	412	427	402
18-1	442	433	428
18-2	447	443	457
18-3	519	516	515
20-3	456	444	441
20-4	423	435	448
20-5	655	539	537
20-6	432	448	458
20-9	483	467	470
21-6		467	
21-8	415	416	420

EARLIER MONITORING CRITERIA

Earlier monitoring protocol was based on the NTPEP schedule and process for evaluating joint sealants. Before installation, GPS or Reference Point stationing of test sections were documented, each joint in the test section labeled and each joint photographed. Joints were labeled by test section and joint number. For example the first joint in the Test Section 4 was labeled 4-1. A pavement condition survey done according to SHRP criteria and a detailed sketch of the joints including the location of each sealant were done. The sketch included slope of the pavement, joint spacing, joint width and any special condition of the joints. The joint spacing for each test section was reported. Three joints were pinned with PK nails or pins on each side of the joints for each test section. These pins were used to monitor joint movement during the course of the evaluation. The annual average daily traffic and the closest weather data station was also reported. Manufacturers supplied performance characteristics such as the amount of joint movement the sealant is capable of withstanding or the sealant working range, the recommended joint preparation and sealant installation procedures, and when the area can be reopened to traffic. These conditions were applied if they did not conflict with the agency's construction practices. Assigned inspectors directed the suppliers and installers to their designated test sections from the staging area. The joint preparation and sealant installation techniques used during the installation were recorded. Any deviation from the manufacturer's recommendations was noted. Additionally, the manufacturer's representatives were allowed to provide comments on the joint preparation and sealant installation. If the manufacturer's representative did provide such comments, they were included with the installation report. Once product installation was completed the suppliers removed leftover material and trash from the test deck. Digital photographs were taken of each finished sealed joint. These initial photographs were used for comparison to the photos taken at evaluation intervals.

Field observations: Field evaluation observations were taken each year from the date of installation or at a time in which the sealant is in its greatest extension. The NTPEP evaluation lasted for three years. It was mandatory that no maintenance work be done on the test sections for those three years. Before any reading was taken, sand and debris was removed from the test deck using a gas operated leaf blower. The Individual Joint Field Evaluation Worksheets were used to track field observation over the course of the 3 year evaluation. It was helpful to use a different color of ink for documenting sealant performance for each yearly evaluation. The NTPEP JS/CS Photographic Reference Guide was used as a guide to rate sealant distresses.

Water Infiltration: Water infiltration was measured as the percentage of the overall joint length where water can bypass the sealant and enter the joint either through complete adhesion or cohesion failure. Adhesion and cohesion failures were determined through the SHRP Visual Inspection Method. All joints in the driving lane were inspected to determine the percent allowing water infiltration. Any visual cracks, splits or openings in the sealant or between the sealant and PCC were examined to determine the depth of the opening. Instruments such as a dull knife or a thin blade spatula were used in the evaluation. The percentages of joints that allow water infiltration were determined by the equation:

$$\%L = (Lf/ Ltot)* 100 \quad (1)$$

where:

%L = Percent length of the joint allowing water infiltration

Lf = Total length of the joint sealant field test section allowing the infiltration of water (inches)

Ltot = Total length of the joint sealant field test section (inches)

Each joint is then rated into a level of severity. The ratings were as follows:

1) No Water
2) Infiltration: %L = 0% < %L < 1%
3) Low Severity Water Infiltration: 1% < %L < 10%
4) Medium Severity Water Infiltration: 10% < %L < 30%
5) High Severity Water infiltration: %L > 30%

Debris or Stone Retention Severity Rating: No Debris Retention: No stones or debris were stuck to the top of the sealant or embedded on the Surface of the sealant/ PCC interface.

Low Severity: Occasional stones and/or debris were stuck to the top of the sealant, or debris embedded on the surface of the sealant/PCC interface.

Medium Severity: Stones or debris were stuck to the sealant and some debris is deeply embedded in the sealant or material embedded between the sealant and the joint face but not entering the joint below the sealant.

High Severity: A large amount of stones and debris were stuck to and deeply embedded in the sealant or filling the joint, or a considerable amount of debris is embedded between the sealant and the joint face and entering the joint below the sealant.

Seal Condition Number (SCN): The water infiltration and stone retention severity ratings were used to calculate a Sealant Condition Number.

"Sealant Condition Number" (SCN) was assigned to the sealant once a year for three years. Each distress type was rated as having no distress, low, medium, or high severity distress. The results of the two severity distress ratings were inserted into the following equation to provide the SCN.

$$SCN = 1(L) + 2(M) + 3(H) \qquad (2)$$

Where

SCN = Sealant Condition Number

L = the number of low severity sealant conditions

M = the number of medium severity sealant conditions

H = the number of high severity sealant conditions

If the sealant material has no defects, then the SCN is defined as 0, the best possible rating. A SCN of 6, the worst possible rating, is obtained when both the debris retention and water infiltration were rated as high severity.

Spalling: This is the length of any jointing, breaking, chipping or fraying of joint edges. The length and severity of spalling was measured along each joint. Spalled areas were not counted as adhesion failure.

Joint Movement: Longitudinal and transverse joint movements were measured by installing pins or nails on both sides of three transverse joints. A drill was used to make a pilot hole for the installation of the pins. Pins were place far enough away from the joints so as not to cause further deterioration in the pin installation process. At each evaluation, joint movement was measured as the distance between the pins measured by a caliper minus the spacing between the pins at installation. Vertical movements at the joints or ruts were measured by the Georgia Fault meter or a straightedge, wedge and caliper. Both joint movement measurements were an average of nine measurements per test section.

Joint Spacing: The average joint spacing along with the spacing standard deviation was reported. This information is acquired from the joint map done prior to installation of products.

Photo Log: Photographs of each joint for each test section per evaluation cycle was taken and included in the report.

Tracking: Tracking of sealant by traffic was measured as linear distance in inches that the sealant tracks from the sealed joint in the direction of traffic. The distance of tracking and photographs may be used to determine levels of severity. Annual Average Daily Traffic, Deicing Chemicals Used and Weather Data Annual average daily traffic in terms of total vehicle and commercial vehicles were reported. Tons of salt per lane mile, tons of salt/sand mixture per lane mile and gallons of salt brine per lane miles used were reported each year. Monthly daily high temperature, monthly daily low temperature, number of days per month below freezing and total monthly precipitation was reported from the nearest weather station. Additional information such as the pavement condition, environmental conditions, secondary cracking and traffic conditions will also be recorded.

Summary of NTPEP Evaluation: The original reports about this test section are contained in the following reports:

Current NTPEP Reports

http://www.ntpep.org/Pages/JSReports.aspx (2) and (3)

NTPEP Report 16001.2 - Two Year Report of Field and Laboratory Evaluations of Joint Sealant Materials for Portland Cement Concrete (2003 Minnesota Test Deck)

NTPEP Report 16001.3 - Three Year Report of Field and Laboratory Evaluations of Joint Sealant Materials for Portland Cement Concrete (2003 Minnesota Test Deck)

CURRENT EVALUATION

The Evaluation procedure is based more on the effect of the joints on pavement roughness and pavement condition. Table of measurements of joint width is shown in table 2. The following discusses the IRI in each of the test sections while ascertaining the degree to which the joints affect IRI. The pavement condition number is plotted against IRI in each sample to evaluate the effect and ascertain if the joint conditions explain the IRI.

Joint Performance History (Visual Observation)

A visual observation (Figures 2 to 6) of the joints revealed that most of the failures in the first few years of observation were true observations of the durability of the seals but not an indication of pavement performance. Some of the joints showed spalling at the 3rd year and others showed characteristic sliver spalling that are indicative of inadequacy of the timing of joint sawing. However it is interesting to note that the Dow Corning cell 10 showed evidence of material loss as early as the first year and the joint performance visibly grew worse with time. This material exhibited various failure characteristics that may have accentuated spalling and joint degradation but the degradation was early enough to be attributed to factors extraneous to the sealer. It was therefore inconclusive but there was a synergy of poor joint establishment and poor joint sealer.

Joint 4.3	Joint 4.3	Joint 4.3	Joint 4.3	Joint 4.3
Driving	Driving	Driving	Driving	Driving
Initial	1 Year	2 Years	3 Years	6 Years

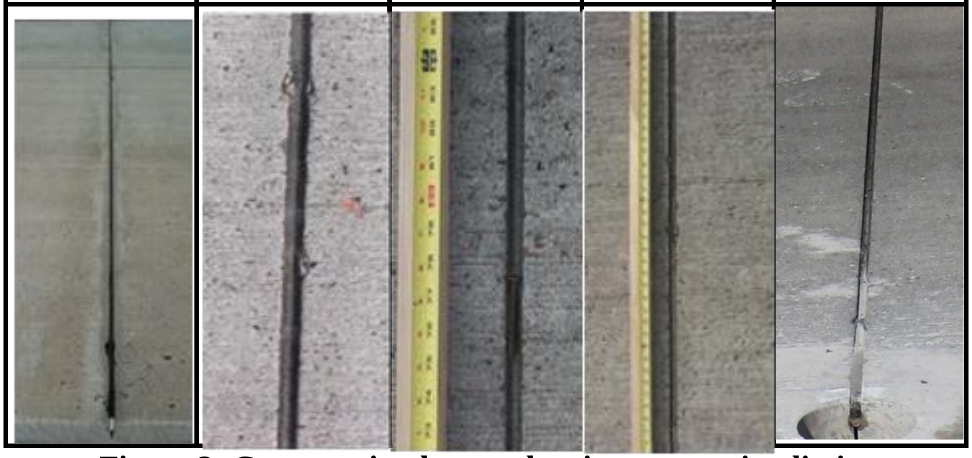

Figure 2: Construction layout showing test section limits

Joint 7.10	Joint 7.10	Joint 7.10	Joint 7.10	Joint 7.10
Driving	Driving	Driving	Driving	Driving
Initial	1 Year	2 Years	3 Years	6 Years

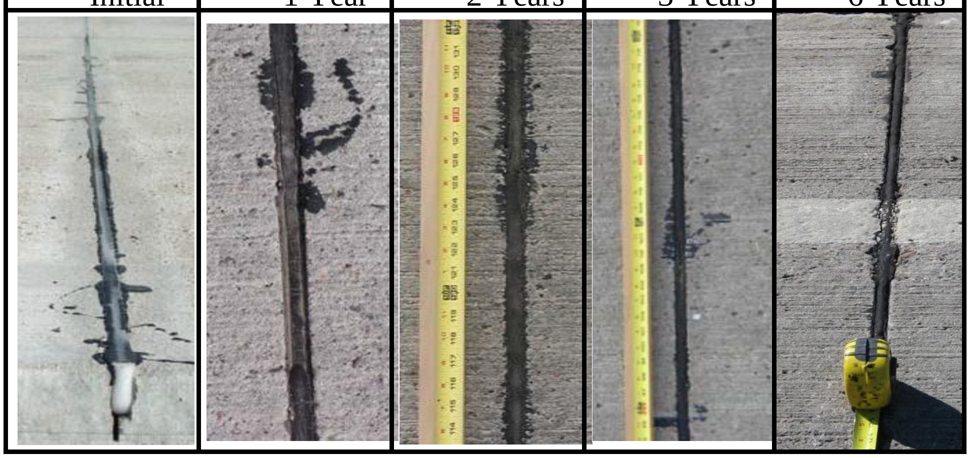

Figure 3: Construction layout showing test section limits

Joint 10.2	Joint 10.2	Joint 10.2	Joint 10.2	Joint 10.2
Driving	Driving	Driving	Driving	Driving
Initial	1 Year	2 Years	3 Years	6 Years

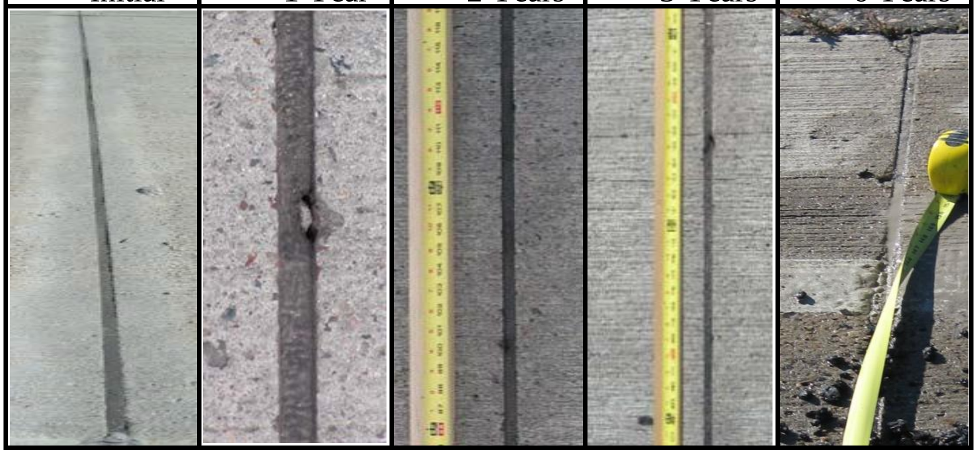

Figure 4: Construction layout showing test section limits

Joint 14. 7	Joint 14. 7	Joint 14. 7	Joint 14. 7	Joint 14. 7
Driving	Driving Lane	Driving Lane	Driving	Driving
Initial	1 Year ‘04	2 Years	3 Years	6 Years

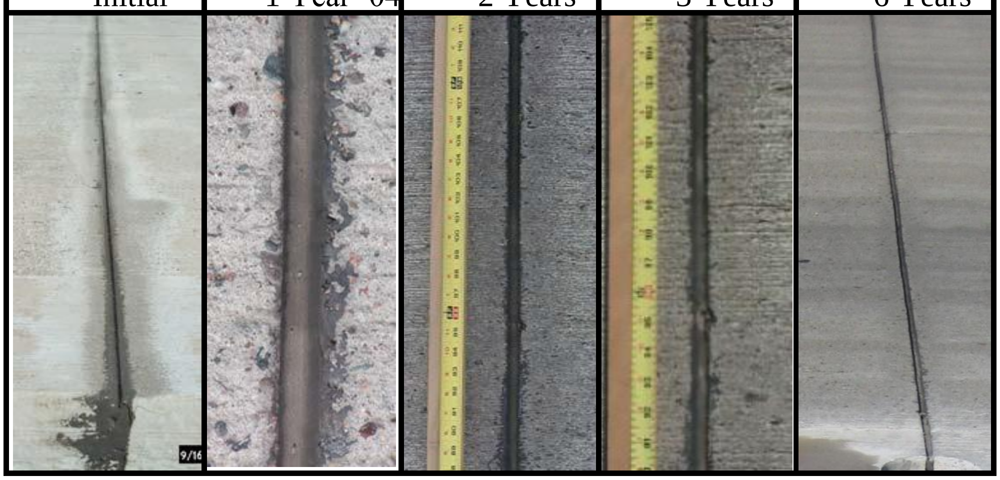

Figure 5: Construction layout showing test section limits

Joint 21.6	**Joint 21.6**	**Joint 21.6**	**Joint 21.6**	**Joint 21.6**
Driving	Driving Lane	Driving Lane	Driving	Driving
Initial	1 Year ‘04	2 Years	3 Years	6 Years
				

Figure 6: Construction layout showing test section limits

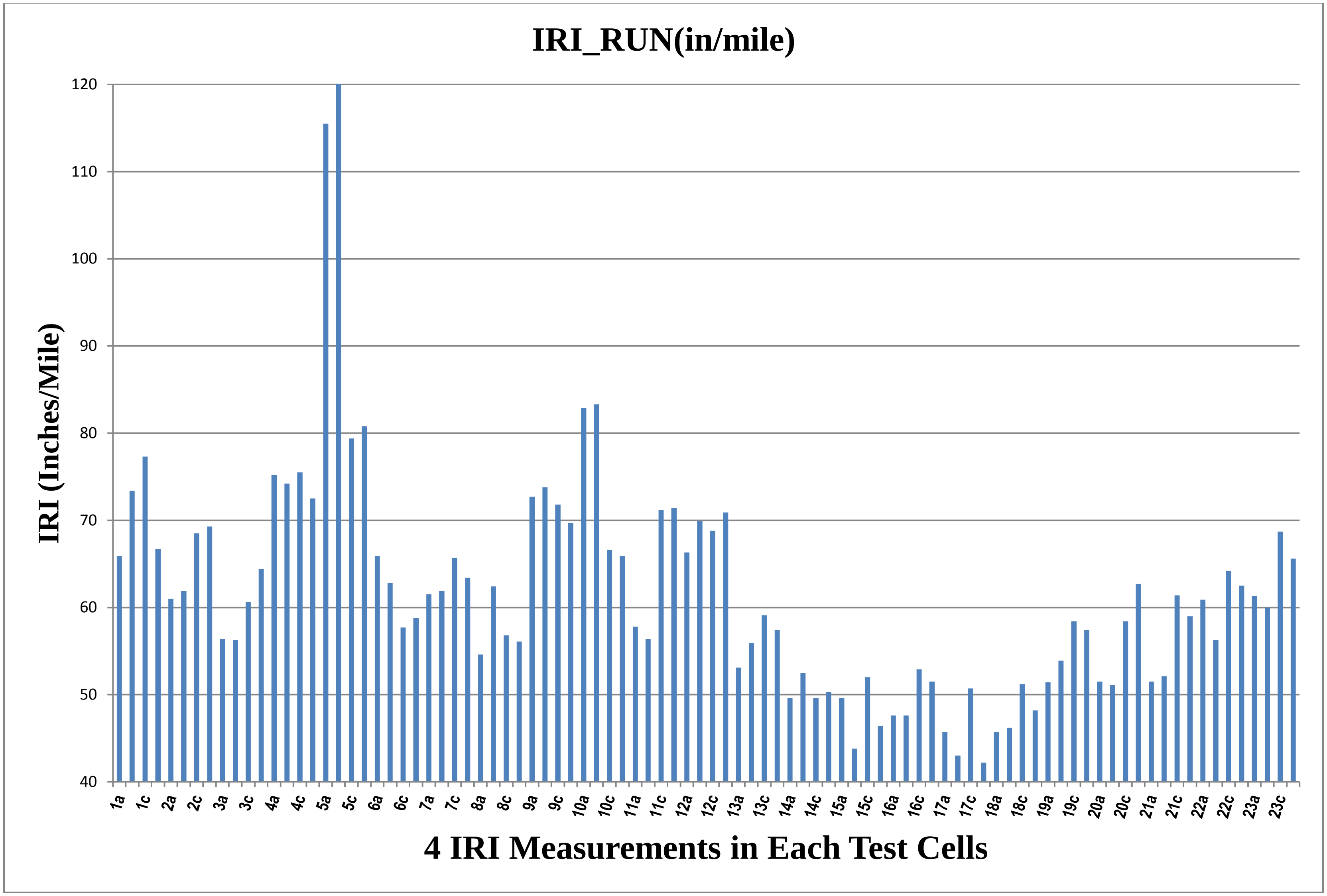

Figure 7: Light weight Profiler Runs on Test Sections

Pavement Smoothness Analysis

In 2009 ride measurements were conducted using the MnDOT Lightweight profiler to generate the international roughness index. Figure 10 shows a continuously measured IRI that was cropped in each test section. IRI ranged from 43 inches per mile to 120 inches per mile indicating the overall test section generally has a good ride quality for a 7 year old pavement. In individual test sections the joint conditions were reflected by the IRI. It was ascertained that of the sealed joints the Dow Corning Joints in cell 10 was the worst performing. It is evident from figure 7 that of the sealed joints the highest IRI of 83 inches per mile was recorded in cell 10 which was the test cell with the Dow Corning joint sealant. Additionally, the unsealed joints registered the highest overall IRI of 120 inches per mile and most of the others were between 63 and 83 inches per mile, which is good but generally higher that IRI measured in sealed joints. Some authors have attributed measurable effects of joints on IRI... Izevbekhai (4) shows that proportionate increases in faulting in all panels lead to corresponding increases in IRI. To further ascertain if joints are causative at least in part to the spiked IRI in cell 5, a power spectrum density analysis was conducted. The PSD showed spikes at a wavelength of 15ft, and harmonics at 7.5ft and 3.75ft, indicating that we cannot rule out joints (15 ft interval) as a major contributor to the IRI in that test section. Figure 8 shows that detail.

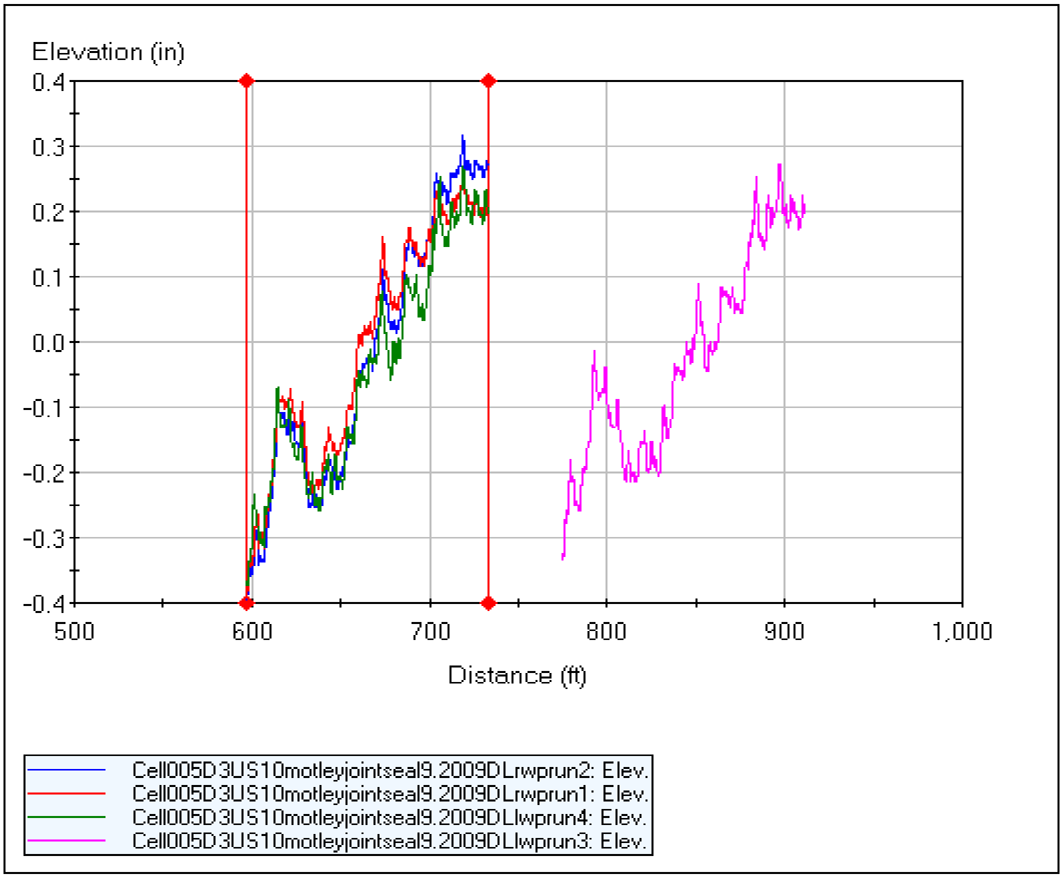

Figure 8: Cropped Cell 5 Profilogram

Table 3: IRI and RN Summary in Cell 5

Cell005D3US10motleyjointseal9.2009DLlwprun3		
Channel Title	**IRI (in/mi)**	**RN**
Elev.	115.5	3.30
Cell005D3US10motleyjointseal9.2009DLlwprun4		
Channel Title	**IRI (in/mi)**	**RN**
Elev.	121.6	3.28
Cell005D3US10motleyjointseal9.2009DLrwprun2		
Channel Title	**IRI (in/mi)**	**RN**
Elev.	80.8	3.66
Cell005D3US10motleyjointseal9.2009DLrwprun1		

Channel Title	IRI (in/mi)	RN
Elev.	79.4	3.67

Input	Value	Unit
PSD Calculation	Slope	
Use Point Reset	No	
Frequency Averaging	No	
Constant Frequency Interval	0.003048	cycle/ft
Pre-Processor Filter	None	

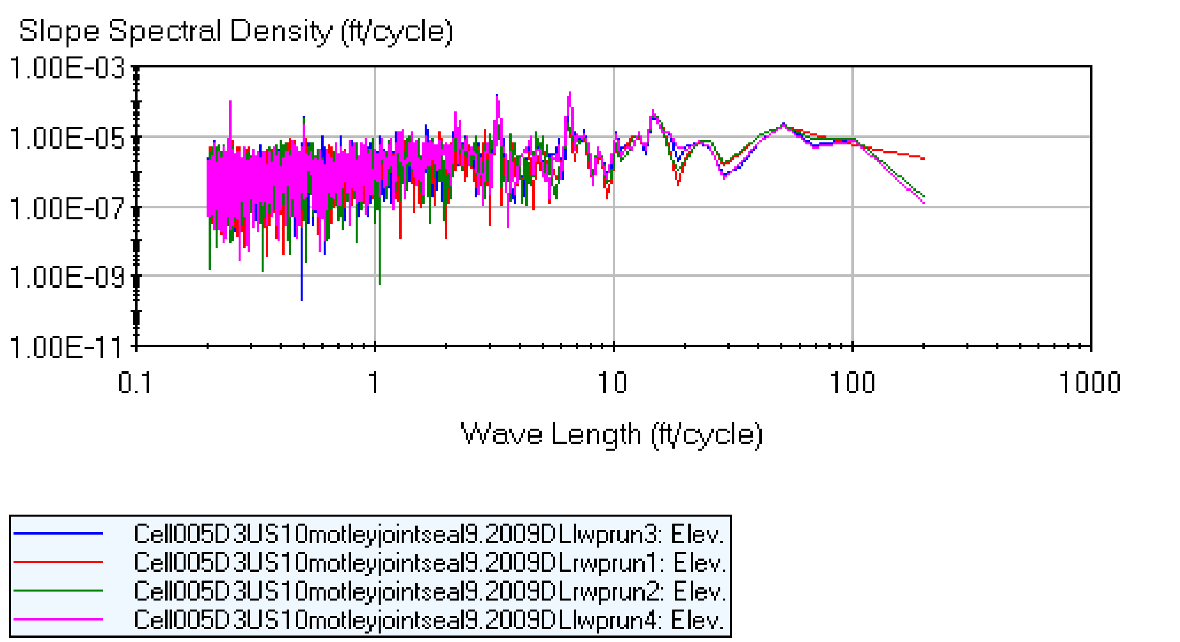

Figure 9: Analysis - Power Spectral Density in Cell 5

CONCLUSION

It is interesting to observe that within 7 years, the performance of the joints already affect the performance of the joints and consequently the performance of the sealants. At this point in the ongoing study there is strong evidence against the practice of leaving joints unsealed. The worst performances by far were observed in the unsealed joints.

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CAVEAT LECTOR

This report represents the opinion of the authors from research conducted by the authors and not the Minnesota Department of transportation or any agency/institution. It does not constitute a standard and does not purport to do so. Any appearance of similitude to a standard or representation thereto exists only in the imagination of the reader.

REFERENCES

1) Minnesota Department of Transportation (2005)   Standard for Joint Sealants URL http://www.dot.state.mn.us/materials/concretedocs/joint_sealing_guidelines.pdf Assessed 08-10-2012

2) NTPEP NTPEP Report 16001.2 - Two Year Report of Field and Laboratory Evaluations of Joint Sealant Materials for Portland Cement Concrete (2003 Minnesota Test Deck) URL http://www.ntpep.org/Pages/JSReports.aspx Assessed 08-12-2012.

3) NTPEP **NTPEP Report 16001.3** - Three Year Report of Field and Laboratory Evaluations of Joint Sealant Materials for Portland Cement Concrete (2003 Minnesota Test Deck) URL http://www.ntpep.org/Pages/JSReports.aspx Assessed 08-12-2012.

4) Izevbekhai, B.I. (2012) Tire Pavement Interaction Noise of Concrete Pavements. Thesis in Partial Fulfillment of Requirements for Doctor of Philosophy. University of Minnesota.