Supplement to Joint Sawing Practices And Effects on Durability

Appendix D – Implementation Activities

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16. Abstract

Joint deterioration has become a renewed concern for concrete pavements in Northern climates. Recently, a large number of relatively young pavements (less than 20 years) have experienced premature joint deterioration requiring disproportionately high amounts of maintenance. While specifications and testing help to identify d-cracking aggregates, optimize mixtures for low shrinkage and permeability, utilize advanced air testing techniques, and help determine potential deicer issues; the current joint deterioration problem spans many states and concrete mixtures and has the potential, if left unchecked, to seriously damage the reputation of concrete pavements as durable, low maintenance options.

This report supplement presents findings from the implementation study conducted during the 2019 paving season to document contractor joint sawing equipment and practices. A total of five construction projects were visited, documenting activities from the placement of concrete materials through the sawing of the transverse contraction joints.

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1.0 INTRODUCTION

This report supplement provides documentation of activities conducted to promote the implementation of findings from WHRP Project 0092-16-01 – Joint Sawing Practices and Effects on Durability. Implementation activities were completed prior to, and during the 2019 construction season in Wisconsin. Activities included podium presentations at major conferences in Wisconsin, development and distribution of a joint sawing questionnaire, face-to-face meetings with selected contractors in advance of the 2019 paving season, and site visits to selected projects to document activities from concrete placement to contraction joint sawing.

1.1 Conference Presentations

Podium presentations were made at the Wisconsin Transportation Builders Association Contractor-Engineer Conference, held on January 17-18 in Middleton, WI and at the Wisconsin Concrete Pavement Association's 2019 Annual Concrete Pavement Conference, held on February 14-15 in Oshkosh, WI. Each presentation provided an overview of Project 0092-16-01 activities and included discussions on key project findings and the forthcoming implementation activities. Each conference was attended by key transportation personnel, including WisDOT staff, contractor representatives, transportation engineering consultants and researchers. Copies of all presentation slides were made available on the association websites.

1.2 Joint Sawing Questionnaire

A joint sawing questionnaire, as shown in Figure 1.2.1, was developed and distributed to engineers and contractors to provide information on the joint sawing practices intended for use during the 2019 construction season. Contractors were encouraged to complete and return the questionnaire for each and every project being constructed on the state and national highway systems. As shown, the questionnaire requested information on the aggregate types being used within the concrete mixture as well as the types of sawing equipment and blades expected for use, which was intended to encourage consideration of selecting blades specific to the aggregates being used, which was one of the primary research findings from WHRP Project 0092-16-01.

Concrete Pavement Joint Sawing Questionnaire
Developed under WHRP Project 0092-16-01

Concrete Paving Contractor:		
Contact Name & Phone Number:		
State Project ID:		
Paving Location:		
Paving Length (mi):		
Expected Start Date:	Expected Finish Date:	
Slab Thickness (in):	Joint Spacing (ft):	
Coarse Aggregate Type(s):		
Fine Aggregate Type(s):		
Joint Sawing Contractor Name:		
Contact Name & Phone Number:		
Anticipated Saw Type: Conventional ☐ Early Entry ☐ Other (Specify)		
Sawing Equipment Brand/Model:		
Blade Brand/Model:		
Sawing Depth (in):	Expected Sawing Length (ft/blade):	
☐	Please check box to indicate you will ensure blades and shoes are changed together if early entry saws are being used.	

Please return by email or US Mail to: James Crovetti
4986 Arthur Rd.
Slinger, WI 53086
414-640-5329
cta-llc@charter.net

Figure 1.2.1 Project 0092-16-01 Joint Sawing Questionnaire

1.3 Field Project Selection

Candidate construction projects were selected in consultation with Mr. Kevin McMullen, President of the Wisconsin Concrete Pavement Association, to ensure adequate representation from the main concrete paving contractors based in Wisconsin. Consideration was also given to selecting projects that would be representative of mainline paving operations and that were using a range of coarse aggregates to include both the predominate southern limestones and the northern igneous gravels. Details of the selected projects and site visit observations are provided in Chapter 2.

1.4 Contractor Meetings

Face-to-face meetings were held between the Principal Investigator and contractor representatives from Zignego Construction, Chippewa Concrete Services, Vinton Construction, Trierweiler Construction and Michels Paving during the period of April 5 – 22, 2019. All meetings were conducted at the main offices of each of the selected contractors with the exception of Trierweiler Construction, where the meeting took place at the field office of the IH 39/90 project.

The primary purposes of each meeting were to reiterate the key findings from Project 0092-16-01, to discuss project scheduling for the construction projects selected for possible inclusion into the implementation workplan, to review the joint sawing questionnaire, and to answer any contractor questions. During each meeting, the Principal Investigator assured each contractor that site visits were for information purposes only, and that no collected data would be used for project acceptance and/or progress payment considerations. All contractors were welcoming and cooperative during the face-to-face meetings, providing assurances that the Principal Investigator would be granted unrestricted access on each project site.

2.0 OBSERVATIONS DURING PAVEMENT CONSTRUCTION

2.1 Introduction

Site visits were made to five construction sites during the 2019 paving season to document the joint sawing practices, including three rural divided highway projects and two urban multi-lane facilities. Project sites were selected in consultation with Mr. Kevin McMullen, President of the Wisconsin Concrete Pavement Association, to ensure adequate representation from the main paving concrete companies operating in Wisconsin. Selected projects included both limestone and the igneous gravels as the predominate coarse aggregate types.

Prior to the actual site visits, extensive communications between research personnel, contractors and WisDOT staff were undertaken to coordinate schedules and to ensure project objective were met. Contractors were informed that observations made, and data collected by the research staff were for informational purposes only and would not be used for project acceptance and/or progress payment considerations.

It is noted that all parties were very cooperative during communications, which greatly aided in successfully meeting project goals in a timely manner.

2.2 USH 151 – Iowa County – Zignego Company

Paving along USH 151 was completed by the Zignego Company as provided in the plans for State Project Number 1204-04-77. The mainline pavement details include a 9.5 inch doweled concrete pavement over a 6 inch dense graded aggregate base. Paving was completed using a Guntert & Zimmerman S850 slip form paver equipped with an automated dowel bar inserter.

The project site was visited on Monday, May 13 to observe paving and joint sawing operations. Paving on this date included placement of the mainline SB lanes, beginning at 9:35 AM at Station 177+67 and proceeding northeast to Station 203+86. A monitoring joint was randomly selected near 183+08, just north of the merge point with the USH 18 Ramp H. Paving near the monitoring joint was completed at 11:30 AM and the curing compound was applied at 12:55 PM. Joint sawing operations were completed at 7:01 PM.

A small bucket sample of concrete was obtained during paving at the monitoring joint and used to conduct a Super Air Meter (SAM) test and to cast a 6 inch cylinder for monitoring mix temperature and electrical resistivity with the Giatec Smartbox device. The SAM test was conducted for informational purposes only and was intended to provide comparative values for hardened air voids analyses to be conducted on the Giatec cylinder sample at Marquette University. Electrical resistivity measurements were collected for informational purposes and to provide data for possible use in selecting appropriate timing of the joint sawing operations.

During paving operations on May 13, visual observations of the last 15 transverse joints sawn in the concrete placed on the previous day of paving (May 10) indicated that none had activated, i.e., no indications of a crack extending down from the saw cut were noted. An extending caliper was used to measure the saw cut depth at one joint, with a value of 2.62 inches observed.

Figures 2.2.1 – 2.2.4 provide representative photos taken during the paving operations. Tables 2.2.1 and 2.2.2 provide environmental data obtained during paving and joint sawing operations. The SAM test conducted on grade by the author during paving provided a corrected air content of 5.9% and a SAM number of 0.15, which are in general agreement with the average values of 6.0% and 0.20, respectively, provided in the GeoTest Quality Control Plan. The hardened air voids analysis conducted by the author (ASTM C457, Procedure B) yielded a spacing factor of 0.0052 inches.

Figure 2.2.1: First Load of Concrete on USH 151

Figure 2.2.2: Dowel Bar Handling Prior to Insertion

Figure 2.2.3: Pavement Texturing and Curing Compound Equipment

Figure 2.2.4: Paving and Testing Operations at the Monitoring Joint

Table 2.2.1: USH 151 Environmental Data – May 13, 2019 (LocalConditions.com)

Time (CDT)	Temp F	RH (%)	Dew Point F	Barometer (inHG)	Wind Speed (mph)	Wind Direction
7:15 AM	44.6	87.1	41.0	29.93	3	wnw
7:55 AM	50.0	76.2	42.8	29.94	6	wnw
8:15 AM	50.0	81.6	44.6	29.94	5	nw
8:55 AM	55.4	66.9	44.6	29.94	8	nnw
9:15 AM	55.4	62.5	42.8	29.95	7	wnw
9:35 AM	59.0	54.9	42.8	29.95	7	nw
9:55 AM	59.0	54.9	42.8	29.94	5	nnw
10:15 AM	60.8	51.5	42.8	29.94	8	nnw
10:55 AM	62.6	45.1	41.0	29.95	6	nnw
11:15 AM	64.4	36.8	37.4	29.95	3	n
11:55 AM	64.4	34.3	35.6	29.94	3	w
12:15 PM	66.2	32.2	35.6	29.94	7	nnw
1:55 PM	68.0	28.1	33.8	29.93	4	wnw
2:15 PM	66.2	29.9	33.8	29.93	7	nne
2:55 PM	66.2	32.2	35.6	29.93	-	-
4:15 PM	69.8	26.5	33.8	29.92	-	-
5:15 PM	64.4	29.7	32.0	29.93	-	-
5:55 PM	68.0	26.2	32.0	29.93	-	-
6:15 PM	66.2	29.9	33.8	29.93	-	-
6:55 PM	62.6	31.6	32.0	29.93	-	-
7:15 PM	62.6	34.0	33.8	29.93	-	-
7:35 PM	60.8	36.2	33.8	29.94	-	-
7:55 PM	59.0	41.4	35.6	29.94	3	w

Table 2.2.2: USH 151 Environmental Data – May 13, 2019 (Portable Weather Station)

Time	Air F	Wind mph	Pressure inHg	RH %	Pavement F
9:00 AM	63.0	2.1	28.78	42.24	
9:30 AM	67.7	1.6	28.78	35.72	
10:00 AM	70.3	2.4	28.78	33.78	
10:30 AM	73.5	1.4	28.78	29.63	
11:00 AM	71.2	1.3	28.79	29.94	
11:30 AM	73.7	1.7	28.78	27.99	
12:00 PM	77.5	1.4	28.78	22.96	67.1*
12:30 PM	76.3	2.3	28.77	20.26	66.2
1:00 PM	67.6	4.3	28.77	30.05	66.2
1:30 PM	70.4	2.4	28.77	29.41	68
2:00 PM	78.2	1.6	28.77	19.34	68.9
2:30 PM	71.3	0.6	28.77	28.26	69.8
3:00 PM	69.4	1.1	28.76	27.75	70.7
3:30 PM	84.7	2.6	28.76	17.31	75.2
4:00 PM	68.8	0.7	28.76	28.32	73.4
4:30 PM	76.7	1.7	28.76	19.63	76.1
5:00 PM	75.5	2.9	28.76	21.73	80.6
5:30 PM	80.8	2.8	28.76	17.95	82.4
6:00 PM	69.4	3.0	28.76	27.00	83.3
6:30 PM	79.0	1.9	28.76	17.83	88.7
7:00 PM	73.7	0.7	28.76	22.49	91.4

*Pavement probe inserted into slab at mid-depth at 11:40AM

The sawing questionnaire returned by the Zignego Company indicated conventional Husqvarna FS 7000D and FS 6600D walk behind saws would be used with Esch JSWU-414 blades. Discussions with the sawing personnel indicated a Jaguar JSWU-414 blade was generally used on the FS 7000D saw while the FS 6600D saw used the Husqvarna 14140 1DP blade. It was further indicated that saw blades generally lasted 1.5 to 2 nights of sawing.

Coarse aggregates 1 & 2 were indicated as crushed limestone and the fine aggregate was listed as a washed sand. Mix design data supplied by Geotest, Inc. indicated the coarse aggregates were produced from the Swiggum Quarry and the fine aggregates were obtained from the Helana Pit. Mohs hardness values were not provided for the coarse aggregates. To provide an indication of the of the fine aggregate angularity (FAA), an uncompacted voids analysis (AASHTO T304) was conducted by the author using a sample of sand obtained at the batch plant during paving, which yielded an FAA of 40.9.

Joint sawing operations began at 6:18 PM with the Husqvarna saws operating with blade speeds of 2,400-2,500 RPM and reached the monitoring joint at 7:01 PM. Joint sawing operations generally proceeded with each saw cutting alternate transverse joints in a 2-step process. Step one included a single direction cut over approximately ¾ of the width of paving, with step 2 finishing the cut in the opposite direction for the remaining ¼ of the slab width. Complete sawing of each transverse joint was completed 90 seconds or less. After a number of transverse joints were finished, the FS 7000D saw shifted to cutting the longitudinal joint up to the point where transverse joints were completed. During longitudinal joint sawing, the FS 6600D saw continued cutting successive transverse joints in the 2-step process. Once the longitudinal saw cutting reached the transverse cutting, the saws again teamed up to continue cutting alternate transverse joints. This process generally repeated throughout the saw cutting operations, with relocations of the water truck as needed.

Figures 2.2.5 – 2.2.7 provide representative photos taken before and during the joint sawing operations. Figure 2.2.8 provides a plot of data obtained with the Giatec Smartbox for the period from paving to joint sawing. Using a Baseline reading of 19.4 Ohms, the "maturity" between paving and joint sawing, as represented by the shaded triangular region, is calculated as 4,425 Ohm-minutes. After sawing was completed in the vicinity of the monitoring joint, visual observations of the joint surfaces indicated that no spalling or breakout had occurred. Probe depths in the monitored joint indicated an average sawing depth of 3.22 inches.

Figure 2.2.5: Husqvarna FS 7000D Conventional Saw

Figure 2.2.6: Transverse Saw Cutting with the Husqvarna 6600D Conventional Saw

Figure 2.2.7: Transverse and Longitudinal Saw Cutting

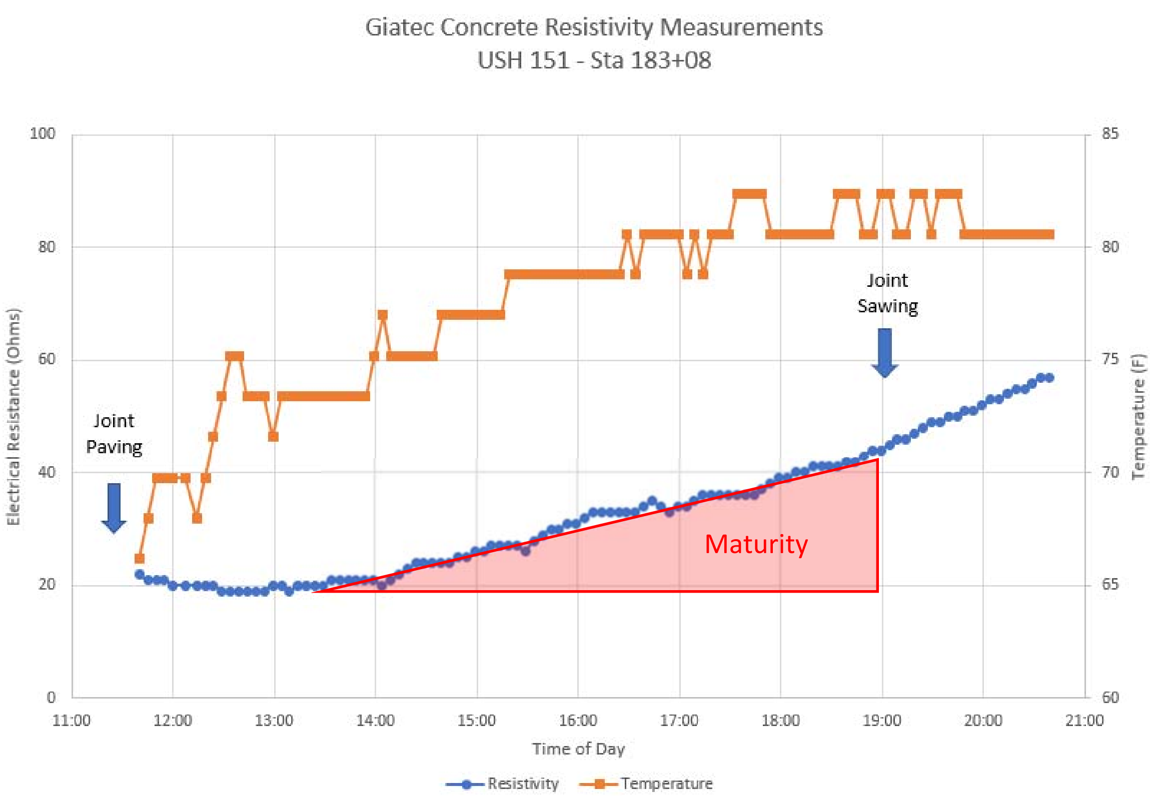

Figure 2.2.8: Giatec Smartbox Data from Concrete Cylinder

2.3 USH 61 – Grant County – Chippewa Concrete Services

Paving along USH 61 (Madison St) was completed by Chippewa Concrete Services as provided in the plans for State Project Number 1650-07-71. The mainline pavement details include a 8.5 inch doweled concrete pavement, a 6 inch dense graded aggregate base and a 12 inch select crush subgrade treatment underlain by a Type SR Geogrid. Hand-pour paving was completed using a vibrating screed and dowel bar baskets.

The project site was visited on Tuesday, May 14 to observe paving and joint sawing operations. Paving on this date included placement of the SB lanes of Madison St in downtown Lancaster between Maple St and Cherry St and various portions of Cherry Street between Monroe St and Jefferson St. Paving began on Madison at 8:15AM, beginning near Station 22+25 and proceeded north to Station 23+26. A monitoring joint was randomly selected near Station 22+96, opposite of the old Bank building. Paving near the monitoring joint was completed at 9:42 AM and the curing compound was applied at 11:55 AM. Joint sawing operations were initiated at 2:25 PM and completed at 4:46 PM.

A small bucket sample of concrete was obtained during paving at the monitoring joint and used to conduct a Super Air Meter (SAM) test and to cast a 6 inch cylinder for monitoring mix temperature and electrical resistivity with the Giatec Smartbox device. The SAM test was conducted for informational purposes only and was intended to provide comparative values for hardened air voids analyses to be conducted on the Giatec cylinder sample at Marquette University. Electrical resistivity measurements were collected for informational purposes and to provide data for possible use in selecting appropriate timing of the joint sawing operations.

Figures 2.3.1 – 2.3.4 provide representative photos taken during the paving operations. Table 2.3.1 provides environmental data obtained during paving and joint sawing operations. The portable weather station had a malfunction with the data storage disk which could not be recovered. The SAM test conducted on grade by the author during paving provided a corrected air content of 5.6% and a SAM number of 0.17. No comparative SAM numbers were available, but a QC value of 6.0% air is in general agreement with the SAM value obtained by the author. The hardened air voids analysis conducted by the author (ASTM C457, Procedure B) yielded a spacing factor of 0.0058 inches.

Figure 2.3.1: USH 61 (Madison St.) Paving Site Prior to First Load of Concrete

Figure 2.3.2: Concrete Placement Near Monitoring Location

Figure 2.3.3: Dowel Basket Placement and Vibrating Screed

Figure 2.3.4: Hand Spray Application of Curing Compound

Table 2.3.1: USH 61 Environmental Data – May 14, 2019 (LocalConditions.com)

Time (CDT)	Temp F	RH (%)	Dew Point F	Barometer (inHG)	Wind Speed (mph)	Wind Direction
7:15 AM	49.5	82.1	44.2	30.02	4	se
7:55 AM	51.6	80.6	45.9	30.02	3	sse
8:15 AM	54.7	75.1	46.9	30.03	-	-
8:55 AM	55.9	76.2	48.6	30.03	-	-
9:15 AM	59.0	56.4	43.5	30.03	5	s
9:55 AM	60.6	54.0	43.9	30.03	5	ssw
10:15 AM	62.1	52.8	44.6	30.03	6	sw
10:55 AM	63.9	49.9	44.8	30.03	7	s
11:15 AM	64.4	48.6	44.6	30.03	10	ssw
11:55 AM	66.4	42.4	42.8	30.03	13	ssw
12:15 PM	66.6	40.9	42.1	30.02	14	s
1:15 PM	66.6	41.5	42.4	30.00	14	s
1:55 PM	67.3	40.5	42.4	29.99	8	ssw
2:15 PM	67.3	42.5	43.7	29.99	11	ssw
2:55 PM	67.1	41.0	42.6	29.98	13	s
3:15 PM	67.3	41.3	43.0	29.98	11	sw
3:55 PM	68.2	44.4	45.7	29.97	15	ssw
4:15 PM	67.5	44.0	44.8	29.97	11	ssw
4:55 PM	67.1	44.6	44.8	29.97	12	sw
5:15 PM	66.2	46.3	45.0	29.97	13	s
5:55 PM	65.3	50.8	46.6	29.97	10	ssw
6:15 PM	63.5	53.7	46.4	29.97	9	ssw

The sawing questionnaire returned by Chippewa Concrete Services indicated an early entry Husqvarna Soff Cut walk behind saw would be used with an Orange 13.5 inch blade. Discussions with the sawing personnel indicated a Zenesis Green 14 inch saw blade is generally used and that shoe changes are made based on wear characteristics dependent on the type of sawing, i.e., long straight cuts versus radius cuts. It was further indicated that saw blades for long straight cuts could generally reach 3,000 – 3,500 feet of cutting while radius cuts could limit sawing to lengths of 1,800 – 2,000 feet per blade. Visual inspection of the sawing shoe indicated it was in generally good shape with at opening ranging in width from 0.211 to 0.24 inches.

Coarse aggregates 1 & 2 were indicated on the returned questionnaire as sandstone and the fine aggregate was listed as a pit sand. Mix design data supplied by American Engineering Testing indicated the coarse aggregates were produced from the Swiggum Quarry (1-1/2" CA) and the Schneider Quarry (3/4" CA) and fine aggregates were obtained from the Turner Pit. Mohs hardness values were not provided for the coarse aggregates. To provide an indication of the fine aggregate angularity (FAA), an uncompacted voids analysis (AASHTO T304) was conducted by the author using a sample of sand obtained at the batch plant during paving, which yielded an FAA of 40.8.

Joint sawing operations began at 2:25 PM with a Husqvarna Soff Cut Model 4200 Early Entry Green Concrete Saw equipped with the Zenisis Green 14 inch blade operating at 3,500–3,600 RPM. Transverse joint sawing was completed in a single directional pass, starting at the interface between the existing concrete slab placed on an earlier day and continuing to the outer edge of the newer slab. Transverse sawing reached the monitoring joint at 2:32 PM and was fully completed by 2:35, at which time sawing of the longitudinal joint commenced. As the longitudinal sawing crossed the first transverse joint, diagonal cracks were noted on both sides of the longitudinal joint at the approach side of the transverse joint. Longitudinal joints sawing was suspended for approximately 2 hours, giving time for additional curing of the transverse joints. Longitudinal sawing was re-started at 4:46 PM, with plastic inserts used to protect the transverse joints. Additionally, a used saw blade was placed over the transverse joint to protect the joint under the action of the blade guide wheel. No additional cracking or spalling was noted along the longitudinal or transverse joints.

Figures 2.3.5 – 2.3.7 provide representative photos taken before and during the joint sawing operations. Figure 2.3.8 provides a plot of data obtained with the Giatec Smartbox for the period from paving to joint sawing. Using a Baseline reading of 39 Ohms, the "maturity" between paving and joint sawing, as represented by the shaded triangular region, is calculated as 660 Ohm-minutes. After sawing was completed in the vicinity of the monitoring joint, visual observations of the joint surfaces indicated that no spalling or breakout had occurred other than that noted during longitudinal joint sawing. Probe depths in the monitored joint indicated an average sawing depth of 2.43 inches.

Figure 2.3.5: Husqvarna 4200 Soff Cut Early Entry Green Saw

Figure 2.3.6: Longitudinal Joint Saw Cutting

Figure 2.3.7: Finished Transverse Joint Saw Cut

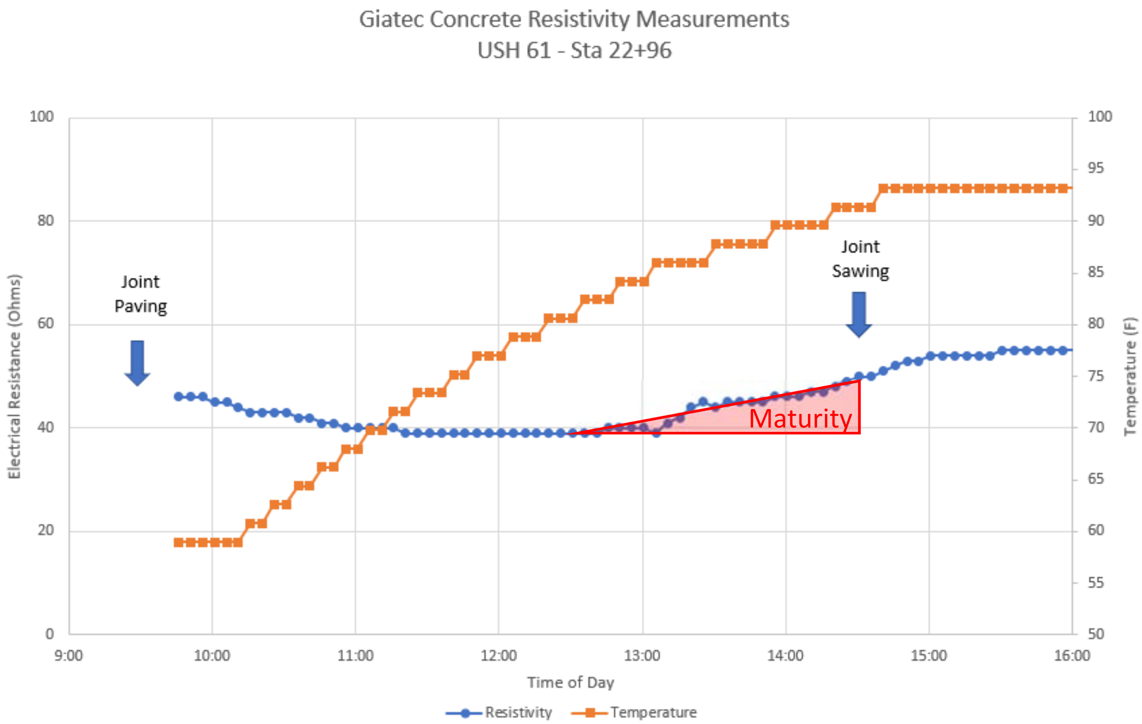

Figure 2.3.8: Giatec Smartbox Data from Concrete Cylinder

2.4 BUS 51 – Portage County – Vinton Construction

Paving along BUS 51 was completed by Vinton Construction as provided in the plans for State Project Number 6414-00-80. The mainline pavement details include a 9.0 inch doweled concrete pavement over a 6 inch dense graded aggregate base layer. Paving was completed with a Rexcon Town & Country Slip Form paver using dowel bar baskets.

The project site was visited on Tuesday, May 21 to observe paving and joint sawing operations. Paving on this date included placement of the NB lanes of BUS 51 in near downtown Whiting between Porter St and Willow St. Paving began at 7:00 AM, beginning near Station 228+25 and proceeded north to approximately Station 245+00. A monitoring joint was randomly selected near Station 233+75, opposite the US Army Corp of Engineers building. Paving near the monitoring joint was completed at 10:28 AM and the curing compound was applied at 11:55 AM. Joint sawing operations were initiated at 8:55 PM and completed near the monitoring joint at 10:15 PM.

A small bucket sample of concrete was obtained during paving at the monitoring joint and used to conduct a Super Air Meter (SAM) test and to cast a 6 inch cylinder for monitoring mix temperature and electrical resistivity with the Giatec Smartbox device. The SAM test was conducted for informational purposes only and was intended to provide comparative values for hardened air voids analyses to be conducted on the Giatec cylinder sample at Marquette University. Electrical resistivity measurements were collected for informational purposes and to provide data for possible use in selecting appropriate timing of the joint sawing operations.

Figures 2.4.1 – 2.4.4 provide representative photos taken during the paving operations. Tables 2.4.1 and 2.4.2 provide environmental data obtained during paving and joint sawing operations. The portable weather station had a malfunction with the data storage disk which precluded the use of data after 5:50 PM. The SAM test conducted on grade by the author during paving at 3:00 PM near Sta 241+75 provided a corrected air content of 7.5% and a SAM number of 0.08. These values compare reasonably well with contractor tests conducted earlier in the day at 9:25 AM near Sta 240+00, providing a corrected air content of 7.2% and a SAM number of 0.01. Mix design information provided by Gremmer & Associates indicated a SAM number of 0.18 The hardened air voids analysis conducted by the author (ASTM C457, Procedure B) yielded a spacing factor of 0.0061 inches.

Figure 2.4.1: Concrete Placement Near Monitoring Location

Figure 2.4.2: Concrete Placement Over Dowel Baskets

Figure 2.4.3: Pavement Texture Equipment

Figure 2.4.4: Application of Curing Compound

Table 2.4.1: BUS 51 Environmental Data – May 21, 2019 (LocalConditions.com)

Time (CDT)	Temp F	RH (%)	Dew Point F	Barometer (inHG)	Wind Speed (mph)	Wind Direction
6:15 AM	39.0	93.8	37.4	30.16	-	-
6:55 AM	41.9	88.8	38.8	30.18	-	-
7:55 AM	46.2	68.7	36.5	30.18	5	e
8:15 AM	46.9	66.4	36.3	30.17	8	e
8:55 AM	48.4	58.9	34.7	30.18	12	e
9:15 AM	49.3	57.4	34.9	30.18	9	ese
9:55 AM	51.1	53.3	34.7	30.19	13	e
10:15 AM	52.3	52.0	35.2	30.19	13	e
10:55 AM	53.4	48.9	34.7	30.18	15	ese
11:15 AM	54.1	48.0	34.9	30.18	18	e
11:55 AM	55.4	48.2	36.1	30.17	15	ese
12:15 PM	55.6	48.2	36.3	30.16	16	e
12:55 PM	55.6	45.9	35.1	30.15	14	ese
1:15 PM	56.7	44.1	35.1	30.14	17	e
1:35 PM	56.3	44.4	34.9	30.14	16	ese
1:55 PM	56.3	43.1	34.2	30.13	15	ese
2:15 PM	55.9	43.0	33.8	30.13	19	e
2:55 PM	55.4	44.2	34.0	30.12	15	e
3:15 PM	56.3	43.7	34.5	30.10	14	ese
4:15 PM	54.5	43.4	32.7	30.07	17	ese
4:55 PM	54.7	42.5	32.4	30.07	18	e
5:15 PM	54.5	43.8	32.9	30.06	17	e
5:35 PM	54.0	45.9	33.6	30.05	13	e
5:55 PM	53.6	48.6	34.7	30.03	13	e
6:15 PM	52.5	52.4	35.6	30.03	13	e
6:55 PM	52.2	52.7	35.4	30.01	15	e
7:15 PM	51.8	55.0	36.1	30.01	10	e
7:55 PM	51.1	59.3	37.4	30.00	13	e
8:15 PM	51.1	58.5	37.0	29.99	12	e
8:55 PM	51.3	56.1	36.1	29.97	16	e
9:15 PM	51.1	56.0	36.0	29.98	13	e
9:55 PM	51.3	54.1	35.2	29.96	13	e
10:15 PM	51.1	54.9	35.4	29.97	13	e
10:55 PM	50.7	57.2	36.1	29.93	15	e
11:15 PM	51.4	54.9	35.8	29.91	15	e

Table 2.4.2: BUS 51 Environmental Data – May 21, 2019 (Portable Weather Station)

Time	Air F	Wind mph	Pressure inHg	RH %	Pavement F
10:00 AM	61.5	4.2	29.08	43.5	66.2
10:30 AM	62.2	8.8	29.07	41.2	68.0
11:00 AM	63.9	5.8	29.07	37.6	69.8
11:30 AM	65.1	3.5	29.07	34.7	63.5*
12:00 PM	67.8	2.2	29.05	32.6	63.5
12:34 PM	65.1	0.6	29.05	36.8	63.5
1:00 PM	64.5	1.6	29.05	34.1	63.5
1:30 PM	64.4	5.8	29.03	35.8	63.5
2:00 PM	65.7	0.9	29.02	33.6	64.4
2:30 PM	66.3	7.8	29.02	33.3	64.4
3:00 PM	65.0	0.9	29.00	33.9	64.4
3:30 PM	63.8	7.5	28.99	34.7	65.3
5:30 PM	58.8	1.3	28.94	41.1	67.1
5:50 PM	57.7	4.5	28.92	43.6	68.0**

*Pavement probe inserted into slab at mid-depth at 11:05AM

**Data file corrupted after 6:00 PM

The sawing questionnaire returned by Vinton Construction indicated a Husqvarna FS 4800 conventional saw would be used with Husqvarna 14x155 blades. Discussions with the sawing personnel indicated the Husqvarna high performance green blades are operated at 2,100 RPM and generally provide around 50,000 inch-feet of cutting per blade.

Coarse and fine aggregates were indicated on the returned questionnaire as Wimmie Sand & Gravel. Mohs hardness values were not provided for the coarse aggregates. To provide an indication of the of the fine aggregate angularity (FAA), an uncompacted voids analysis (AASHTO T304) was conducted by the author using a sample of sand obtained at the batch plant during paving, which yielded an FAA of 40.6.

Joint sawing operations began at 8:55 PM with each Husqvarna FS 4800D saw working in tandem to cut each transverse joint, with one saw traveling in one direction and the other in the opposite direction. Transverse joint sawing continued for approximately 150 feet (10 joints), at which time sawing operations were suspended to allow time for blowing out the joints with compressed air for subsequent joint sealing operations. Transverse sawing reached the monitoring joint at 10:30 PM.

Figures 2.4.5 – 2.4.7 provide representative photos taken before and during the joint sawing operations. Figure 2.4.8 provides a plot of data obtained with the Giatec Smartbox for the period from paving to joint sawing. Using a Baseline reading of 35.8 Ohms, the "maturity" between paving and joint sawing, as represented by the shaded triangular region, is calculated as 12,963 Ohm-minutes. After sawing was completed in the vicinity of the monitoring joint, visual observations of the joint surfaces indicated that no spalling or breakout had occurred. Probe depths in the monitored joint indicated an average sawing depth of 2.88 inches.

Figure 2.4.5: Husqvarna HI PERF Green Blade

Figure 2.4.6: Transverse Joint Saw Cutting

Figure 2.4.7: Tandem Transverse Joint Saw Cutting

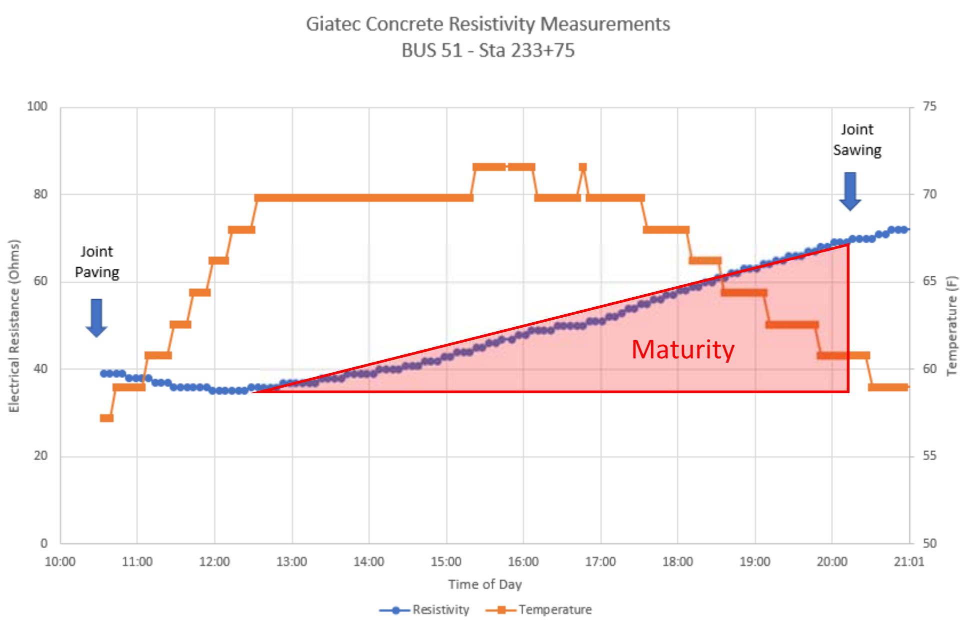

Figure 2.4.8: Giatec Smartbox Data from Concrete Cylinder

2.5 IH 39/90 – Dane County – Trierweiler Construction

Paving along IH 39/90 was completed by Trierweiler Construction as provided in the plans for State Project Number 1007-11-80. The mainline pavement details include a 12.0 inch doweled concrete pavement over a 6 inch dense graded aggregate base layer underlain by a 16 inch select crushed material layer. Paving was completed with a Gomaco GHP 2800 Slip Form paver equipped with an automated dowel bar inserter.

The project site was visited on Tuesday, July 16 to observe paving and joint sawing operations. Paving on this date included placement of the SB lanes of IH 39/90 just north of the intersection with CTH N. Paving began at 5:57 AM, beginning near Station 2352+75 and proceeded south to approximately Station 2323+00. A monitoring joint was randomly selected near Station 2350+50. Paving near the monitoring joint was completed at 7:00 AM and the curing compound was applied at 8:00 AM. Joint sawing operations were initiated at 3:55 PM and completed near the monitoring joint at 4:00 PM.

A small bucket sample of concrete was obtained during paving at the monitoring joint and used to conduct a Super Air Meter (SAM) test and to cast a 6 inch cylinder for monitoring mix temperature and electrical resistivity with the Giatec Smartbox device. The SAM test was conducted for informational purposes only and was intended to provide comparative values for hardened air voids analyses to be conducted on the Giatec cylinder sample at Marquette University. Electrical resistivity measurements were collected for informational purposes and to provide data for possible use in selecting appropriate timing of the joint sawing operations.

Figures 2.5.1 – 2.5.4 provide representative photos taken during the paving operations. Table 2.5.1 provides environmental data obtained during paving and joint sawing operations. The portable weather station had a malfunction with the data storage disk which precluded the use of this data. The SAM test conducted on grade by the author during paving near Sta 2350+50 provided a corrected air content of 7.7% and a SAM number of 0.12, which compare favorably with the reported QC values of 6.0% and 0.18, respectively. The hardened air voids analysis conducted by the author (ASTM C457, Procedure B) yielded a spacing factor of 0.0034 inches.

Figure 2.5.1: First Load Placement at 5:57 AM

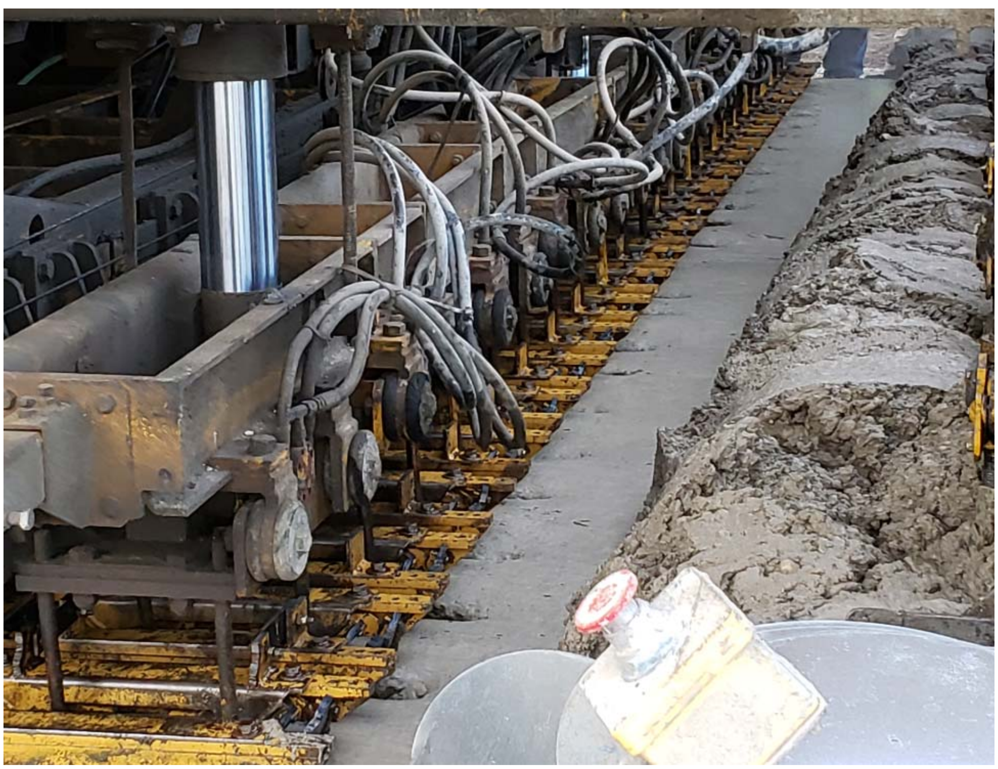

Figure 2.5.2: Automated Dowel Bar Inserter

Figure 2.5.3: Pavement Texture Equipment

Figure 2.5.4: Application of Curing Compound

Table 2.5.1: IH 39/90 Environmental Data – July 16, 2019 (LocalConditions.com)

Time (CDT)	Temp F	RH (%)	Dew Point F	Barometer (inHG)	Wind Speed (mph)	Wind Direction
5:00 AM	73.4	73.5	64.4	29.89	9	sw
5:45 AM	71.6	83.1	66.2	29.90	3	wsw
6:00 AM	71.6	83.1	66.2	29.90	6	wsw
6:45 AM	73.4	78.2	66.2	29.90	3	sw
7:00 AM	71.6	83.1	66.2	29.91	6	sw
7:15 AM	73.4	78.2	66.2	29.91	6	sw
7:45 AM	73.4	78.2	66.2	29.91	7	ssw
8:00 AM	73.4	78.2	66.2	29.92	5	sw
8:15 AM	73.4	78.2	66.2	29.92	4	sw
8:45 AM	73.4	78.2	66.2	29.93	6	ssw
9:00 AM	75.2	73.7	66.2	29.92	6	ssw
9:15 AM	75.2	73.7	66.2	29.93	6	sw
9:45 AM	75.2	73.7	66.2	29.92	3	ssw
10:00 AM	78.8	65.4	66.2	29.92	5	ssw
10:15 AM	78.8	65.4	66.2	29.93	5	ssw
10:45 AM	78.8	65.4	66.2	29.93	-	-
11:00 AM	80.6	65.6	68.0	29.93	5	w
11:15 AM	80.6	65.6	68.0	29.93	4	w
11:45 AM	80.6	65.6	68.0	29.92	7	wsw
12:00 PM	82.4	61.9	68.0	29.92	4	w
12:15 PM	82.4	61.9	68.0	29.91	3	ssw
1:00 PM	84.2	62.1	69.8	29.90	6	sw
1:15 PM	84.2	58.4	68.0	29.90	3	sw
1:45 PM	86.0	55.2	68.0	29.89	-	-
2:00 PM	84.2	58.4	68.0	29.88	-	-
2:45 PM	86.0	58.7	69.8	29.87	3	sse
3:00 PM	87.8	52.1	68.0	29.87	-	-
3:15 PM	87.8	52.1	68.0	29.86	3	ssw
3:45 PM	87.8	52.1	68.0	29.86	3	wnw
4:00 PM	87.8	52.1	68.0	29.86	5	w
4:15 PM	87.8	52.1	68.0	29.85	4	wnw
4:45 PM	89.6	49.2	68.0	29.85	-	-
5:00 PM	87.8	52.1	68.0	29.85	-	-
5:15 PM	87.8	52.1	68.0	29.85	-	-
5:45 PM	87.8	52.1	68.0	29.84	-	-
6:00 PM	89.6	49.2	68.0	29.84	-	-

The sawing questionnaire returned by Trierweiler Construction indicated a 70HP Husqvarna riding saw would be used with Husqvarna C922E and F1150 blades. Discussions with the sawing personnel indicated the Husqvarna professional blades are operated at 2,700 RPM and generally provide around 10,000-20,000 inch-feet of cutting per blade.

Coarse and fine aggregates were indicated on the returned questionnaire as dependent of the area of paving, with Mohs hardness values ranging from 5 – 8. Information provided on the verification report indicates the No. 1 Stone was provided by the Townline Pit, the No. 2 Stone by Prairie Avenue Concrete and the Fine Aggregate by the Hurd Pit. To provide an indication of the of the fine aggregate angularity (FAA), an uncompacted voids analysis (AASHTO T304) was conducted by the author using a sample of sand obtained at the batch plant during paving, which yielded an FAA of 41.7.

Transverse joint sawing operations began at 3:55 PM with two Husqvarna RS 4800D saws working independently to cut each transverse joint. The riding saws were equipped with front-mounted rubber plows which were used to push off excess slurry during the transverse sawing operations. The transverse joints were sawn in one direction over approximately 80% of the slab width, the riding saw was then reversed back to a point slightly offset of the sawing starting point, and the slurry was then push-plowed off the slab in the same direction as the cutting direction. The saw was then reversed and rotated to allow for sawing and slurry push-off over the remaining 20% of the slab width. Transverse joint sawing continued for approximately 18 joints, at which time sawing operations were suspended to allow time to finish cutting of the longitudinal joint from the previous day of paving. The longitudinal joint saw was a rig-guided, self-propelled Husqvarna RS 8500D. Transverse sawing reached the monitoring joint at 4:00 PM. It should be noted that prior to the start of joint sawing operations, the transverse joints from the previous day of paving were pressure washed and then sealed with a spray-applied Aquanil Plus 40 Penetrating Silane Sealer.

Figures 2.5.5 – 2.5.7 provide representative photos taken before and during the joint sawing operations. Figure 2.5.8 provides a plot of data obtained with the Giatec Smartbox for the period from paving to joint sawing. Using a Baseline reading of 44.8 Ohms, the “maturity” between paving and joint sawing, as represented by the shaded triangular region, is calculated as 4,235 Ohm-minutes. After sawing was completed in the vicinity of the monitoring joint, visual observations of the joint surfaces indicated that no spalling or breakout had occurred along the transverse joints during the actual saw cutting operation; however, there were some areas where the steering wheel had caused slight cracking as it crossed the sawn joint, as shown in Figure 2.5.9. Probe depths in the monitored joint indicated an average sawing depth of 4.08 inches. It is also noted that observations from a few of the transverse joints from the previous day of paving indicated some aggregate dislodgement along the joint and cracking in areas where the steering wheel of the riding saw has crossed the joint, as shown in Figures 2.5.10 and 2.5.11.

Figure 2.5.5: Transverse Joint Sawing with the Husqvarna RS 8500D

Figure 2.5.6: Slurry Push-Off with the Rubber Plow

Figure 2.5.7: Longitudinal Joint Saw Cutting with the Guided FS 8500D

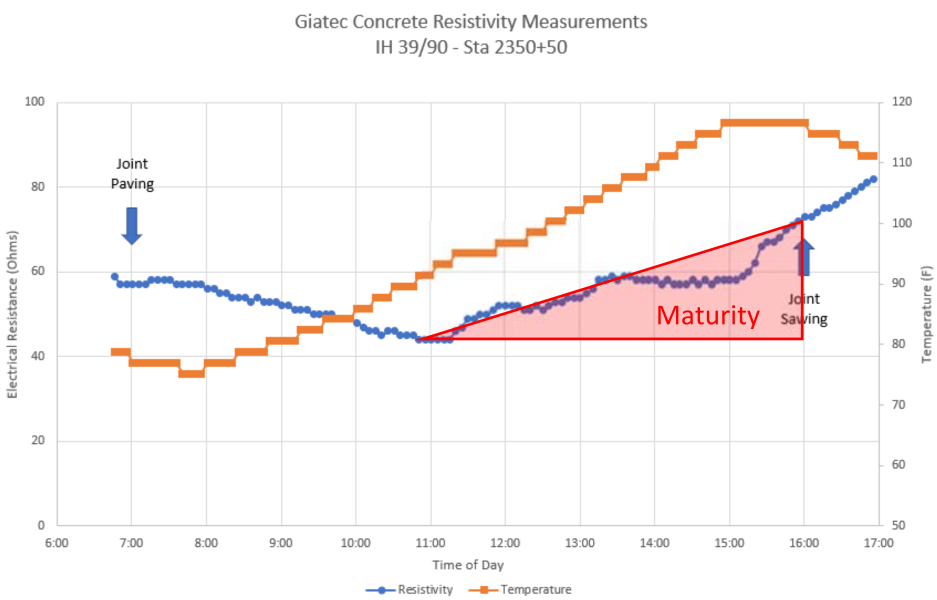

Figure 2.5.8: Giatec Smartbox Data from Concrete Cylinder

Figure 2.5.9: Joint Crack Due to Wheel Movement

Figure 2.5.10: Aggregate Dislodgement Noted on Sawing from Previous Day

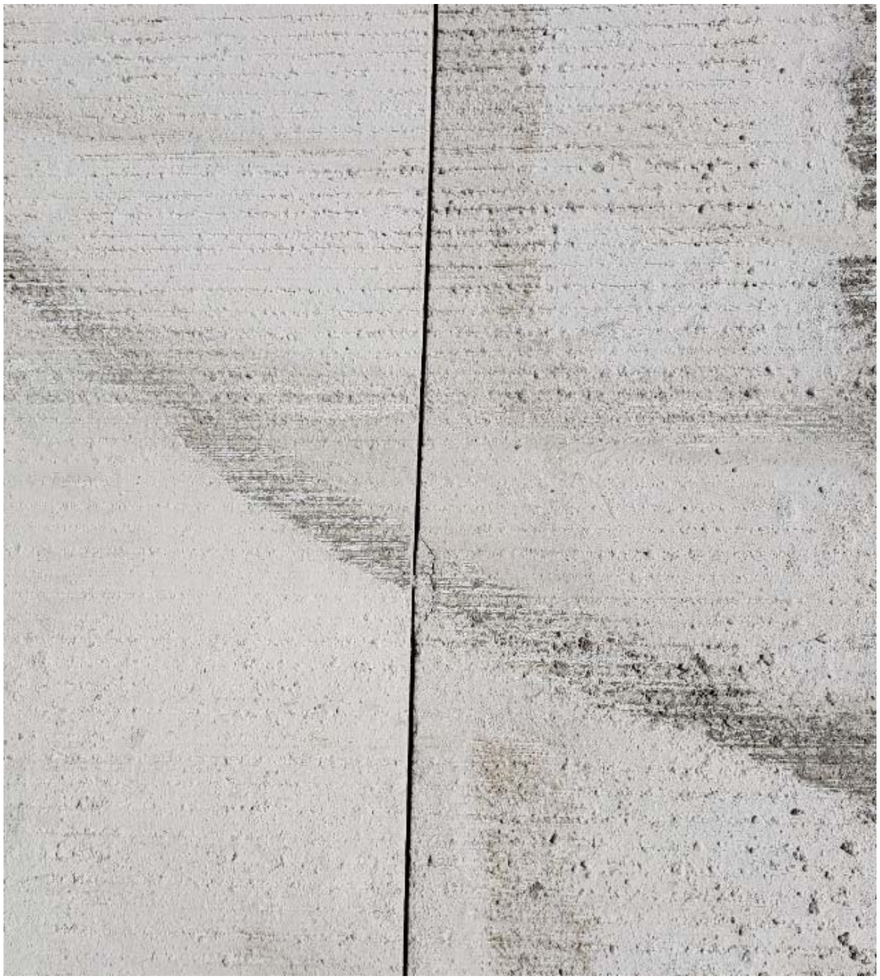

Figure 2.5.11: Transverse Joint Cracking Noted on Sawing from Previous Day

2.6 IH 41/94 – Racine County – Michels Paving

Paving along IH 41/94 was completed by Michels Paving as provided in the plans for State Project Number 1033-02-79. The mainline pavement details include a 12.0 inch special doweled concrete pavement over a 6 inch dense graded aggregate base layer underlain by a 16 inch select crushed material layer. Paving was completed with a Guntert & Zimmerman S850 Slip Form paver equipped stringless paving controls and an automated dowel bar inserter.

The project site was visited on Wednesday, July 17 to observe paving and joint sawing operations. Paving on this date included placement of the SB lanes of IH 41/94, starting at a point just north of Leetsbir Road and suspending around 1:15 PM due to heavy rains. Paving began at 6:00 AM, beginning at Station 798+87 and proceeded north to Station 816+61. A monitoring joint was randomly selected near Station 801+50. Paving near the monitoring joint was completed at 7:08 AM and the curing compound was applied at 8:35 AM. Joint sawing operations were initiated at 3:00 PM and completed near the monitoring joint at 4:35 PM.

A small bucket sample of concrete was obtained during paving at the monitoring joint and used to conduct a Super Air Meter (SAM) test and to cast a 6 inch cylinder for monitoring mix temperature and electrical resistivity with the Giatec Smartbox device. The SAM test was conducted for informational purposes only and was intended to provide comparative values for hardened air voids analyses to be conducted on the Giatec cylinder sample at Marquette University. Electrical resistivity measurements were collected for informational purposes and to provide data for possible use in selecting appropriate timing of the joint sawing operations.

Figures 2.6.1 – 2.6.4 provide representative photos taken during the paving operations. Tables 2.6.1 and 2.6.2 provide environmental data obtained during paving and joint sawing operations. The SAM test conducted on grade by the author during paving near Sta 801+50 provided a corrected air content of 4.7% and a SAM number of 0.10, which is a considerably lower air content than the reported QC value of 6.2%. The hardened air voids analysis conducted by the author (ASTM C457, Procedure B) yielded a spacing factor of 0.0062 inches.

Figure 2.6.1: Paver Ready for First Load at 5:20 AM

Figure 2.6.2: Stringless Paving Operations

Figure 2.6.3: Pavement Texture Equipment

Figure 2.6.4: Application of Curing Compound

Table 2.6.1: IH 41/94 Environmental Data – July 17, 2019 (LocalConditions.com)

Time (CDT)	Temp F	RH (%)	Dew Point F	Barometer (inHG)	Wind Speed (mph)	Wind Direction
5:00 AM	75.2	83.4	69.8	29.90	3	wnw
5:15 AM	75.2	83.4	69.8	29.90	3	wnw
5:45 AM	75.2	83.4	69.8	29.90	-	-
6:00 AM	75.2	83.4	69.8	29.90	3	wnw
6:15 AM	75.2	83.4	69.8	29.91	3	wnw
6:45 AM	75.2	83.4	69.8	29.91	-	-
7:00 AM	77.0	78.5	69.8	29.91	4	nnw
7:15 AM	77.0	78.5	69.8	29.92	5	nnw
7:45 AM	78.8	74.0	69.8	29.92	4	n
8:00 AM	78.8	74.0	69.8	29.93	5	n
8:15 AM	80.6	74.2	71.6	29.93	6	nne
8:45 AM	80.6	74.2	71.6	29.93	7	nne
9:00 AM	80.6	74.2	71.6	29.93	6	nne
9:15 AM	80.6	74.2	71.6	29.95	7	n
10:00 AM	78.8	78.7	71.6	29.95	6	nne
10:45 AM	80.6	74.2	71.6	29.96	8	e
11:00 AM	78.8	78.7	71.6	29.96	7	ese
11:45 AM	80.6	74.2	71.6	29.96	7	ese
12:00 PM	80.6	74.2	71.6	29.97	9	ese
12:15 PM	80.6	74.2	71.6	29.96	9	se
12:45 PM	80.6	74.2	71.6	29.96	7	se
1:00 PM	80.6	69.8	69.8	29.96	8	sse
1:15 PM	80.6	69.8	69.8	29.97	7	sse
1:45 PM	78.8	74.0	69.8	29.96	6	se
2:00 PM	78.8	74.0	69.8	29.95	7	ese
2:15 PM	78.8	74.0	69.8	29.96	5	se
2:45 PM	78.8	74.0	69.8	29.96	4	sse
3:00 PM	78.8	78.7	71.6	29.95	5	ssw
3:15 PM	80.6	69.8	69.8	29.94	5	s
3:45 PM	82.4	65.8	69.8	29.93	3	ese
4:00 PM	82.4	65.8	69.8	29.93	7	se
4:15 PM	82.4	65.8	69.8	29.93	7	sse
4:45 PM	82.4	58.2	66.2	29.93	7	se
5:00 PM	82.4	58.2	66.2	29.93	8	se

Table 2.2.2: IH 41/94 Environmental Data – May 13, 2019 (Portable Weather Station)

Time	Air F	Wind mph	Pressure inHg	RH %	Pavement F
6:00 AM	77.1	0.0	29.13	76.8	82.4
6:30 AM	77.4	0.6	29.13	75.8	83.3
7:00 AM	78.9	0.7	29.13	73.4	85.1
7:30 AM	85.2	1.3	29.14	59.9	89.6*
8:00 AM	82.6	1.3	29.15	64.5	89.6
8:30 AM	88.8	0.6	29.16	54.2	89.6
9:00 AM	93.1	1.1	29.16	49.2	89.6
9:30 AM	95.6	1.7	29.17	46.8	92.3
10:00 AM	93.8	4.0	29.17	52.5	90.5
10:30 AM	96.1	1.4	29.17	47.0	90.5
11:00 AM	93.4	0.6	29.18	49.6	92.3
11:30 AM	94.0	2.3	29.18	49.3	94.1
12:00 PM	90.0	2.9	29.18	54.7	95.0
12:30 PM	92.6	3.6	29.17	50.6	97.7
1:00 PM	88.8	1.9	29.18	59.1	95.0
1:30 PM	80.4	1.7	29.19	84.9	97.7
2:00 PM	83.5	2.1	29.17	81.4	99.5
2:30 PM	83.1	1.4	29.19	77.1	101.3
3:00 PM	86.2	0.8	29.18	69.5	102.2
3:30 PM	89.7	2.1	29.16	61.8	104.0
4:00 PM	92.3	0.7	29.16	54.4	104.9
4:30 PM	92.4	2.3	29.16	51.0	106.7

*Pavement probe inserted into slab at mid-depth at 7:20AM

The sawing questionnaire returned by Michels Paving indicated a Husqvarna RS 8500 riding saw would be used with Jaguar Diamond Disc 822 PZ blades. Discussions with the sawing personnel indicated the Husqvarna professional blades are operated at 2,800 RPM and generally provide around 35,000 inch-feet of cutting per blade.

Coarse aggregates were indicated on the returned questionnaire as Limestone from the Lannon Quarry. Fine aggregates were indicated as Sands from the Thelan Pit. No Mohs hardness values were provided. To provide an indication of the of the fine aggregate angularity (FAA), an uncompacted voids analysis (AASHTO T304) was conducted by the author using a sample of sand obtained at the batch plant during paving, which yielded an FAA of 41.8.

Transverse joint sawing operations began at 3:00 PM with the Husqvarna RS 4800D saw working independently to cut each transverse joint. Excess slurry on the slab surface was pushed off with a hand-held rubber plow once each transverse joint sawing operation was completed. Transverse joint sawing continued for approximately 7 joints, at which time sawing operations were suspended to allow time for additional curing. A Blade change to a new Jaguar 822 PZ was completed at 4:20 PM. Transverse sawing reached the monitoring joint at 4:35 PM.

Figures 2.6.5 – 2.6.7 provide representative photos taken before and during the joint sawing operations. Figure 2.6.8 provides a plot of data obtained with the Giatec Smartbox for the period from paving to joint sawing. Using a Baseline reading of 25 Ohms, the "maturity" between paving and joint sawing, as represented by the shaded triangular region, is calculated as 6,300 Ohm-minutes. After sawing was completed in the vicinity of the monitoring joint, visual observations of the joint surfaces indicated that no spalling or breakout had occurred along the transverse joints during the saw cutting operation. Probe depths in the monitored joint indicated an average sawing depth of 3.89 inches.

Figure 2.6.5: Transverse Joint Sawing with the Husqvarna RS 8500D

Figure 2.6.6: Transverse Joint Sawing with the Husqvarna RS 8500D

Figure 2.6.7: Slurry Push-Off with the Rubber Plow

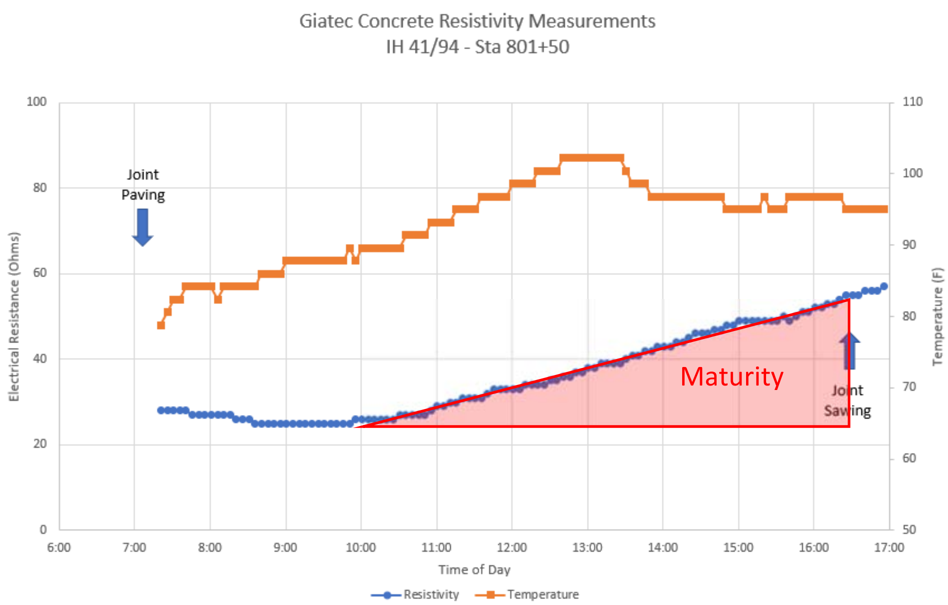

Figure 2.6.8: Giatec Smartbox Data from Concrete Cylinder

3.0 SUMMARY AND RECOMMENDATIONS

This report provides documentation of activities completed to advance the implementation of research findings and recommendations from WHRP Project 0092-16-01. The main recommendations from the 0092-16-01 study were:

- Saw blades should be matched with the predominant coarse aggregates used within the concrete mixture,
- Sawing equipment must be kept in good working order, with bearings and flanges properly maintained and shoe plates on early entry saws changed with each and every blade change,
- Sawing windows must be appropriately selected to minimize or eliminate damage to the faces of the sawn joints as well as the surface of the concrete along the sawn joint,
- Saw blade logs should be maintained to document usage and replacement intervals.

Site visits were made to five construction sites during the 2019 paving season to observe joint sawing practices and to collect supporting data related to the quality of the concrete and joint sawing practices. Measurements with the Super Air Meter and of hardened air voids indicated that all concrete being placed should provide acceptable durability. Contractors were using the sawing equipment and blades they had indicated on their returned questionnaires and were generally following best practices for joint sawing and using equipment types/models similar to those used on the test sites constructed under WHRP Project 0092-16-01. However, it is the opinion of the author that more can be done to ensure optimal performance of the sawn concrete joints. The following recommendations are provided for consideration:

- **Saw Blade Selection**: The selection of a saw blade for a specific paving job should be based on a number of considerations, including coarse and fine aggregate types, strength of the concrete mix and the inclusion of supplementary cementitious materials, the type and horsepower of the saw. It is recommended that aggregate data such as the Mohs hardness for coarse aggregates and the angularity of the fine aggregates, be provided to aid in the proper blade selection. In general, joint sawing is considered as "green cutting" in the industry, and with soft aggregates like limestones (Mohs ~ 3) a blade with a hard matrix should be used. For hard aggregates like granites (Mohs ~6), a blade with a soft matrix should be used. Guidelines for selected saw blades based on fine aggregate angularity (FAA) are not currently available. Within the Superpave guidelines for hot mix asphalt design, FAA values of 45 or greater represent angular particles that are considered necessary for highly trafficked pavements. Additional research is needed to adapt the FAA test results for saw blade selection.

- **Joint Sawing Plan:** The questionnaire that was developed for this project was the first step in improving communications and considerations for joint sawing equipment and methods. The project plans for a few of the projects included in the field visits included a general note indicating "The contractor shall provide a concrete joint detail 14 days prior to paving for approval by the engineer." Discussions with project inspectors during field visits indicated that these submitted joint details generally include only the layout of joints adjacent to appurtenant structures. It is recommended that the questionnaire developed for this study be transitioned into a specific DOT Form that must be submitted prior to construction, thereby providing a mechanism for review/acceptance of the joint sawing equipment and blades.
- **Joint Inspections**: Joint sawing is often completed during nighttime hours when only the sawing crew is present. This in itself does not constitute a problem, but inspection of the sawn joints during and after operations is recommended, including measurements of saw cut depth and joint surface cracking/spalling. A review of the daily diaries and inspector notes from the day of, and the day after field project visits, found no observations/measurement of the sawn joints. As the cost of joint sawing is considered incidental to the cost of the concrete pavement construction, there may be no specific remedies for anything other than replacing slabs with random cracking. Having joint sawing as a specific bid item, with potential pay reductions if the work is not completed properly, is recommended to provide a mechanism for better control.
- **Timing of Sawing**: The initiation of joint sawing operations remains a decision of the sawing personnel based on their experience. Observations of joint cracking during sawing during the field visits, including cracking of the transverse joint during longitudinal joint sawing with early entry equipment and cracking of the transverse joint during movements of the conventional riding saws, indicate that joint sawing operations may still be starting too soon. A data driven method is recommended to aid in the development of appropriate saw timing windows. Resistivity measurements, similar in concept to concrete maturity readings taken to predict concrete strength for opening to traffic, provide data related to the

initial setting of the concrete and can be monitored by the sawing crew on site to provide objective measures of concrete setting based on the specific site conditions after placement. A modified maturity method was presented using data obtained during the study. For the conventional sawing projects, maturity values ranging from 4,235 Ohm-minutes to 12,963 Ohm-minutes were calculated. The one project that showed minor joint cracking during equipment movements had the lowest maturity calculation of 4,235 Ohm-minutes, but this value was similar to the value of 4,425 Ohm-minutes calculated for another project without observed saw-induced cracking. Concrete resistivity measurements collected during the site visits show promise, but more research is needed to determine if this data can provide the resolution needed for accurately establishing times to initiate joint sawing operations.

- **Saw Blade Logs**: It is recommended that contractors be encouraged/required to provide saw blade logs to document the usage and blade life (inch-feet of cutting) for the various saw blade / concrete mixture combinations. The returned questionnaires indicated a significant range in saw blade life expectations, likely dependent on the particular combination of these factors as well as the expectations for the sawing crew's performance.