FHWA/LTPP Monitoring Program

Evaluation of Pavement Performance

Forensic Study for Specific Pavement Study (SPS) Sections 390106 (SPS-1) and 390902 (SPS-9)
U.S. RT. 23 Southbound, Delaware County, Ohio

Report No. FHWA-TS-09-39-01

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m_3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

LONG TERM PAVMENT PERFORMANCE
FORENSIC EVALUATION AND PERFORMANCE
COMPARISONS OF LTPP SECTIONS 390106 AND 390902
U.S. RT. 23, DELAWARE, OHIO

Table of Contents

List of Figures

List of Tables

LONG TERM PAVMENT PERFORMANCE
FORENSIC EVALUATION AND PERFORMANCE
COMPARISONS OF LTPP SECTIONS 390106 AND 390902
U.S. RT. 23, DELAWARE, OHIO

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Executive Summary

A forensic study was conducted in July 2008 on the southbound lanes of U.S. 23 in Delaware County, OH to evaluate the pavement performance and what may have contributed to the differences in performance of these rural arterial pavement sections with the same traffic and environmental conditions.

Based on meetings and a preliminary site review, sections 390106 (SPS-1) and 390902 (SPS-9) were selected. The primary differences between the sections are the thickness of AC, drainage method, and characteristics of the of the asphalt mixes. Section 390106 has a total AC layer thickness of 371mm whereas 390902 has a total of 503mm. Section 390106 doe not have any drainage whereas 390902 has a PATB layer, a non-woven geotextile fabric layer and 100mm drain piping. Both sections use a conventional AC-20 hot mix for the asphalt treated base layers but the 390902 section used the Superpave PG 58-28 binder for the AC surface and binder lifts.

This report primarily used information from the LTPP database including environmental, traffic, construction, materials and monitoring data throughout the life time of the pavement (construction through to forensic investigation).

MEPDG performance characteristics were predicted for the two pavement types. The predicted performance indicated that both sections would meet the 90% Reliability criteria for a 20-year design term with the exception of rutting in the AC layers.

Significant distresses on section 390106 covered the complete surface area and may be associated with an issue with the construction paver slot conveyors (that resulted in discontinuities and segregation of material during the laydown process). The ride quality for this section is approaching a level that would be considered in need of improvement. The distress on section 390902 is minimal and the majority of cracking has occurred recently. The ride quality for this section is that of a new pavement.

Core examination from both sections indicated that all cracking was top down with a great amount of stripping. Deterioration at the interface of the surface and AC binder lifts were visible on the cores from section 390106. The ATB from both sections had visible voids and there was some observed bonding issues between paving layers 2 and 3 of the ATB for section 390902. The interface of the AC bound layers with the aggregate base show minimal, if any, signs of stripping. The surface of 390106, which was starting to ravel, had some loose aggregate when probed with a sharp edge, whereas the surface for 390902 was firm and intact.

The analysis of the FWD data for section 390106 indicated that the deflections at the time of the forensic study were near double of what they were after construction. Similarly, the resilient moduli backcalculated from the FWD data shows a sharp decrease in strength over time. The deflections and backcalculated resilient moduli representative of the

subgrade show minimal change indicating that the structural failure is primarily in the bound layers. The analysis of the FWD data for 390902 shows minimal change over time in deflections and backcalculated resilient moduli.

The analysis of the materials data did not reveal any results that would significantly affect the performance of these pavements. The PG grading for the Superpave mix used for the surface and AC binder lift has performed much better than that of the Hveem mix design using the AC-20 binder. The paver issue in 390106 did not appear to be an issue for the Superpave mixes, although the intermittent longitudinal crack at the inner edge of the outer wheelpath could be related to this issue. Another common problem with AC mixes has been related to the additive polyphosphoric acid used as an anti-stripping agent. An incorrect rate of input can have a reverse effect resulting in premature raveling and stripping. Based on the surface condition and the stripping noted in the interface of the surface and AC binder lifts for 390106, this is also a possibility for the breakdown of the surface on this section. There was no information on any admixes being added to the Superpave mix which may have contained 'pure' binder.

After 12.5 years of service, the requirement for these two sections is quite different. Section 390106 is in need of rehabilitative action to restore the surface condition and structural strength of the section. Section 390902 could have extended life with some minor maintenance such as crack sealing.

LONG TERM PAVMENT PERFORMANCE
FORENSIC EVALUATION AND PERFORMANCE
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U.S. RT. 23, DELAWARE, OHIO

Long Term Pavement Performance
Forensic Evaluation
Test Sections 390106 and 390902, Delaware County, Ohio

1.0 Introduction

The Ohio Department of Transportation, in conjunction with the Federal Highway Administration, constructed a comprehensive test road to evaluate pavement performance in an area of uniform topography, soil and climate. A total of 40 pavement test sections were constructed, of which 34 were instrumented for the purpose of monitoring the seasonal and dynamic response of the pavement. The instrumentation installation, data collection, reduction and analysis was a co-operative effort of the Ohio Department of Transportation, Federal Highway Administration and six universities – University of Akron, Case Western Reserve University, University of Cincinnati, Ohio University, Ohio State University, and the University of Toledo with Ohio University serving as the coordinating agency. The performance of the sections as constructed has been well documented with some of the sections exhibiting failure within weeks of being constructed and opened to traffic. A number of reports have been produced documenting the failures and performance of the sections that can be obtained from the Ohio Department of Transportation website at http://.dot.state.oh.us/research/pavements.htm. The FHWA-LTPP program was provided funding through the Focus Area Leadership and Coordination (FALCON) process toward forensic studies on pavement sections exhibiting failure due to construction, traffic and/or environmental circumstances or that is exhibiting unique performance characteristics. Two sections were selected from the Ohio Specific Pavement Study (SPS) project; section 390106 was selected from the SPS-1 study of ‘Structural Factors for Flexible Pavements’ and section 390902 from the SPS-9 study on ‘Asphalt Field Verification of Superpave Mixes’. The selected sections are located on the southbound driving lane of U.S. 23, approximately 40-km north of Columbus and 3.25-km south of Waldo in Delaware County, Ohio as shown in Figure 1. This four-lane section of U.S. 23 is classified as a rural arterial.

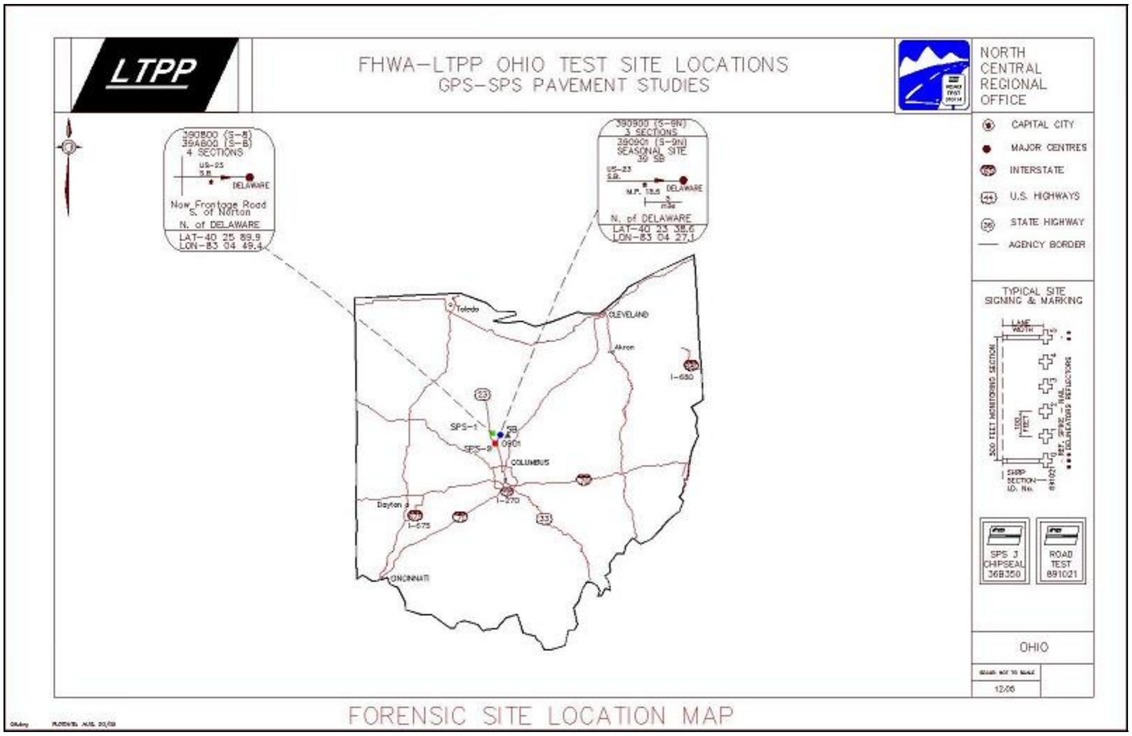

Figure 1: Site Location Map

The construction for this project started in 1994 with subgrade preparation, drainage and grading with the base and surface construction from August through October of 1995. The newly constructed LTPP pavement sections were opened to traffic in November 1995. The SPS-1 and SPS-9 Asphalt Concrete Cement (ACC) experiment test sections were constructed in the southbound lanes with SPS-2 Portland Cement Concrete (PCC) pavement sections in the northbound lanes. An SPS-8 'Study of Environmental Effects in the Absence of Heavy Traffic (PCC and ACC)' was also constructed on an extended portion of the southbound service road. The performance on the SPS sections has been variable for which a lot depended on structural thickness and material types, material handling and/or construction practice, traffic and drainage. The two sections evaluated as part of this forensic investigation have performed up to expectation although the SPS-9 project has exceeded expectation as there has been minimal deformation or cracking on this section. All sections on the southbound lanes have received the same traffic loading, as the mainline is shut down during periods of construction, testing or maintenance, with the traffic diverted to service roads. This investigation is to examine the factors that may have contributed to the differences in performance between SPS-1 section 390106 and SPS-9 section 390902 which were constructed during the same time frame, utilizing the same contractors, exposed to the same environmental conditions and having the same traffic loadings.

LONG TERM PAVMENT PERFORMANCE
FORENSIC EVALUATION AND PERFORMANCE
COMPARISONS OF LTPP SECTIONS 390106 AND 390902
U.S. RT. 23, DELAWARE, OHIO

Records available for sections 390106 and 390902 include construction, material sampling and laboratory analysis (done at time of construction), Ground Penetrating Radar (GPR), core samples, Falling Weight Deflectometer (FWD), Distress surveys (Manual and Photo), longitudinal and transverse profile, traffic from a continuous monitoring weigh-in-motion (WIM), and environmental data from an 'at site' weather station. As part of the forensic investigation, 100mm core samples were extracted in areas exhibiting 'no distress' and 'various levels of distress', with 150mm core samples in the mid-lane and outer wheelpath at FWD, DCP, split-spoon and moisture sample test locations. The 150mm cores were transferred to the state agency laboratory for testing to characterize material properties and effects of wear and aging. As laboratory analysis of aggregate and subgrade materials was not part of the SPS-9 study, material samples were collected and forwarded to Braun/Intertec for analysis and reporting. Cutting of trenches across the width of the pavement was not deemed practical for this project, based on funding limitations and a preliminary review that indicated the failures exhibited on the surface were mainly associated with cracking.

This report documents the available historical information, forensic data collection and sampling, core sample examination, laboratory analysis and results, condition assessments, structural evaluation, findings and conclusions. The information provided far exceeds the needs of a forensic investigation involving pavement performance and failure mechanisms, as the report contains much of the information that is available from the LTPP database for these sections.

2.0 Preparation and Planning

2.1 Planning Meeting and Preliminary Site Review

The forensic study planning meeting took place at the Wilderness Trail Conference Room, District 6, 400 E William Street, Delaware, OH on June 4, 2008. This meeting was arranged to provide information on the selection process for the forensic sites, provide an overview of the historical information available for the potential sections, and discuss the roles and responsibilities of the parties involved. Following the meeting, Roger Green escorted the Regional Support Contractor (RSC) attendees to the SPS project location on U.S. RT 23. The review of the SPS project indicated sections 390106 and 390902 were the best candidates for the forensic study, due to the location and types and variation of distress. SPS-1 section 390159, which was extensively distressed, was also considered, if time and resources permitted during time of testing and sampling. Follow-up instructions and arrangements with ODOT and FHWA-LTPP were conducted over the next few weeks prior to the field visit scheduled for July 15-17, 2008. Figures A-1 and A-2, Appendix A provide the minutes of the meeting and the roles and responsibilities respectively.

2.2 Site Investigation Group

The site investigation and forensic study of Section 390106 and 390902 was a cooperative effort between Ohio Department of Transportation Office of Materials Management, Research and Development Section, Federal Highway Administration (FHWA) Long Term Pavement Performance (LTPP) Division, and Stantec Consulting Inc., FHWA-LTPP North Central Regional Support Contractor (NCRSC). The personnel shown in Table 1 participated at the site inspection, materials sampling, data collection, observations and material handling:

Table 1: Site Investigation Group

Name	Agency	Task/Job Title
Roger Green	OH DOT / Research	LTPP Coordinator
Jack Springer	FHWA-LTPP	Contract Office Technical Representative (COTR)
Kirk Beach	ODOT / Central Office	Geotechnical Engineering
Adam Au	ODOT / Central Office	Transportation Engineering
Jerry Carey	ODOT / Test Boring	Drilling/Sampling
Randy Sabo	ODOT / Test Boring	Drilling / Sampling
Kelly Mc Leish	ODOT / Test Boring	Drilling / Sampling
Brandt Henderson	Stantec Consulting Inc.	Field Operations/Supervisor
Gabe Cimini	Stantec Consulting Inc.	Data/ Data Base Manager
Alfred Lip	Stantec Consulting Inc.	Data Collection/Engineer
Jesse Dickes	Stantec Consulting Inc.	Data Collection/Engineer

2.3 Site Assessment and Work Plan

The U.S. RT. 23 SPS project is scheduled for rehabilitation in 2011. As a number of the LTPP sections within the SPS-1 project limits have already been removed from service due to rehabilitation, it was decided that coring and sampling within the 152.4-meter section would not be an issue, as the benefits would out weigh those of extending the monitoring on these sections. In conjunction with the manual distress survey, a review of the areas with cracks and no cracks would be conducted for the purpose of selecting those locations for 100mm core samples. The core samples would be used to determine the extent of damage to the asphalt surface layers, including location, width and depth of cracking, areas of visible voids, aggregate deterioration, binder adhesion or lack thereof and sufficiency of bonding between layers. At the completion of the FWD survey (conducted every 7.62-meters); core locations would be selected, based on a review of the deflection results, from both the midlane and outer wheelpath. In the selected location two 150mm cores, 450mm apart, would be drilled to the bottom of the pavement surface, reducing the water to a trickle for the last 50mm of drilling so as not to contaminate the base material with excess moisture. The 150mm cores would be retained for measurements and laboratory testing. Dynamic Cone Penetration (DCP) testing is scheduled for the core hole at the FWD location with the split spoon and moisture sampling done in the nearby core hole 450mm upstream.

For SPS-9 section 390902, the aggregate and subgrade material would be collected, weighed and bagged for transfer to the Braun/Intertec laboratory. In addition to the Dipstick® transverse profile survey, rod and level measurements are planned to determine pavement, shoulder and grade cross-fall. Longitudinal profiles are to be collected with the ICC MDR4083 inertial profiler prior to the lane closures and sampling. Numerous photos were scheduled to document the data collection operation and site conditions. On completion of sampling, the 100-mm cores would be retained by the NCRSC and the 150mm cores delivered to the ODOT laboratory for testing and analysis.

3.0 Environment and Traffic Loading

The LTPP IMS database provides the following environmental data summarized in Table 2 as the annual average values:

Table 2: Environmental Data

Description	Annual Average
Freezing Index (C-Days)	362.8
Precipitation (mm)	1024
July High Air Temperature (°C)	33.5
January Low Air Temperature (°C)	-18.9
Days Above 32°C	11.2
Days Below 0°C	114.9
Wet Days	166.1
No. of Freeze/Thaw Cycles	83.1
Annual Frost Depth (m)	0.66

The statistics in Table 2 are based on 13 years of climatic data. Figures B-1 to B-8, Appendix B provides plots summarizing the historical annual and monthly Humidity, Precipitation, Solar Radiation and Temperature.

Figure B-9, Appendix B illustrates the annual water table elevations from the piezometer installed at section 390901. Water table data was collected at this location from May 1998 through October 2003. A fairly significant seasonal and annual variation in the depth of the water table is noticeable with the water table being as high as 1.4m and as low as 4.2m from the pavement surface. The depth to water at the time of the forensic study was 2.25m. With such a high and variable water table the surface and base need to be sufficiently elevated from the subgrade and/or provided with good drainage. For this study section 390106 did not include an in-place drainage or permeable layer, whereas 390902 had a 100-mm Permeable Asphalt Treated Base (PATB) with edge drains and outlets.

A weigh-in-motion (WIM) system was installed in southbound lanes of U.S. 23, centrally located among the SPS sections, to weigh and classify all individual single and tandem wheel loads. The WIM scale (in each lane) consists of two weigh plates placed in the pavement so as to cover the entire 3.66-meter lane width. The WIM equipment was manufactured by Mettler-Toledo, Inc, Westerville, OH. The WIM scales were calibrated by MACTEC, the FHWA-LTPP traffic pool fund study contractor, in 2004 (failed) and 2005 (passed). The WIM scale has been in operation since November 1997 with a number of down periods, but is currently working and providing data for processing and uploads to the LTPP traffic database.

The traffic information available from the LTPP database provided the following traffic information for the monitoring lane based on 2 years of estimated and 10 years of monitoring data.

- Annual Average Daily Traffic (AADT) of 11,118 vehicles/day
- Annual Average Daily Truck Volume of 1782.
- Annualized traffic loading 628 KESALs (Class 9)
- Annual growth rate of 0.6%

As previously mentioned the mainline roadway was closed during periods of reconstruction, maintenance or testing with minor exceptions, as the traffic is diverted to the U.S. 23 service roads. Based on the traffic estimates and WIM data collected there was 8,107 KESALs (Class 9) in the SPS lane from the opening in November 1995 until the time of the forensic in July 2008.

4.0 Section 390106

4.1 Design and Life Expectancy

Using the design procedure from the 2004 Mechanistic Empirical Pavement Design Guide (MEPDG) the following would be the predicted levels of cracking, rutting and cumulative heavy traffic at 90% reliability for 12.5 years.

- Longitudinal Cracking – 0 meters for 152.4-meter section
- Transverse Cracking – 0.54 meters for 152.4-meter section
- Alligator Cracking – 0% top down
- Alligator Cracking – 0.11% bottom up (1.52% at Reliability)
- Rut Depth – 9.91mm at Reliability (3.77mm AC, .29mm Base, 3.54mm Subgrade, Total 7.59mm)
- Thermal Cracking – 0.55 meters for 152.4-meter section (3.06 meters at Reliability)
- IRI – 1.58 m/km (2.16 m/km at Reliability)
- The cumulative heavy loads are 7,068,890.

The 20-year analysis for this section indicated this section would meet the reliability criteria for the full design term with the exception of permanent deformation (rutting) in the AC layers. Figure C-1, Appendix C provides the summary of the input variables for the MEPDG analysis for data extracted from the LTPP database.

4.2 Pavement Structure

The Design and As-Built thickness are provided in Table 2. The as-built layer thicknesses are well within the thickness tolerance for a pavement construction project.

Table 3: Pavement Structure - 390106

Layer	Layer No.	Design Thickness (mm)	As-Built Thickness (mm)	Description
Surface Layer	5	51	43	Dense-Graded, Hot-Laid AC (Hot-Mixed, Hot-Laid Asphalt Concrete, Dense-Graded)
AC Layer Below Surface (Binder Course)	4	127	127	
Treated Base Layer	3	203	201	Dense-Graded, Hot-Laid AC (Dense-Graded, Hot-Laid, Central Plant Mix)
Aggregate Base Layer	2	102	97	Processed Granular Base Materials (Crushed Stone)
Subgrade	1	-	-	Low Plasticity Clays and Silty-Clays (AASHTO Classification A 6-7)

4.3 Construction

U.S. 23 mainline was constructed in an area that was previously occupied by residential housing. During the construction process the houses were removed and the land cleared in preparation for the roadway construction. As part of the subgrade preparation the low spots (located where the building basements were removed) were filled with local material. The subgrade preparation was started on October 1, 1994. The information provided by ODOT was that the local material imported to bring the subgrade to grade was initially removed as part of the residential construction. In the spring of 1995, it was determined that some of the embankment was unsuitable. The embankment in these locations was removed and new fill was placed. Information from the LTPP database indicated a cut and fill was necessary to level the grade in the area of section 390106 in preparation for base construction. Fill material was placed from 0-24 meters, with cut from 24-37 meters and fill for the remainder of the 152.4 meter section. A 22.1 ton sheep-foot compactor was used to compact the subgrade in 300mm thick lifts. The subgrade was completed on July 31, 1995. The placement of the unbound aggregate base material was started on August 1, 1995 and completed on October 16, 1995. A CMI trimming machine was used to level the base to grade with a 16.5 ton single drum vibratory roller used to compact the base.

The southbound portion of U.S. 23 containing the SPS-1 section 390106 was constructed as follows:

- The driving lanes are 3.66 meter wide lanes with the outside lane being monitored.
- The outside monitoring lane was constructed with a hot mix asphalt surface over an asphalt treated base, with an aggregate underlying base layer over compacted subgrade.
- The inside shoulder is 1.22 meters wide with a 200mm base and 178mm hot mix asphalt surface.
- The outside shoulder (adjacent to the monitored lane) is 3.05 meters wide with a 200mm base and 178mm hot mix asphalt surface.
- There was no drain layer or subsurface drainage installed.
- The longitudinal surface joint was 3.66 meters from the outside shoulder lane edge joint or centered between the two southbound lanes.

The asphalt paving was contracted to SE Johnson, Sidney, OH. The placement of the asphalt bound layers took place in the fall between October 17 and October 26, 1995. The asphalt was processed at Stonco’s Drum Mix Plant. AC-20 asphalt cement, provided by Amoco, Toledo, Ohio, was used for all of the asphalt mixes. The hot mix asphalt was transported a distance of 40km with haul times averaging 35 minutes to the placement location. All asphalt layers were placed with a Blaw Knox PF 200B paver at a width of 3.8 meters. Table 3 provides the information on the paving and compaction of the hot mix asphalt layers.

Table 4: Plant Mixed Asphalt Bound Layers - Paving and Compaction

Layer	Lift No.	Placement Dates	Placement Thickness (mm)	Average Plant Mix Temp. (ºC)	Min/Max Placement Temp. (ºC)	Breakdown Roller (Metric Tonnes)	Breakdown Coverage	Finish Roller (Metric Tonnes)	Finish Coverage	Mean Air Temp. (ºC)	Compacted Thickness (mm)	Curing period (days)
ATB	1	17-10-95	76.2	135	120-132	Steel Drum Vibratory (7.2)	11	Steel wheel Tandem (6.2)	9	8.3	63.5	0
	2	17-10-95	76.2	135	120-132	Steel Drum Vibratory (7.2)	11	Steel wheel Tandem (6.2)	9	15.6	63.5	0
	3	17-10-95	95.3	135	120-132	Steel Drum Vibratory (7.2)	11	Steel wheel Tandem (6.2)	9	12.8	76.2	1
AC Binder	1	18-10-95	95.3	155	130-135	Pneumatic-Tired (689 kPa)	11	Steel wheel Tandem (6.2)	9	-	76.2	1
	2	19-10-95	71.2	155	130-135	Pneumatic-Tired (689 kPa)	11	Steel wheel Tandem (6.2)	9	-	58.4	7
AC Surface	1	25 to 26 Oct-95	55.9	155	132-135	Steel Drum Vibratory (7.2)	11	Steel wheel Tandem (6.2)	11	7.2	45.7	-

Note: Breakdown roller completed the intermediate compaction

4.4 Ground Penetrating Radar

Ground Penetrating Radar (GPR) data was collected on April 27, 2003 to document the variability in thickness of the asphalt surface, ATB and aggregate pavement layers for the U.S. 23 SPS-1 project. Figures D-1 and D-2, Appendix D provide the results of the GPR survey for the midlane and outer wheel path of section 390106, respectively. Based on the construction information this section should have had in the neighborhood of a 180mm binder/surface course over 200mm of ATB on a 100mm of aggregate base. The results of the GPR study show for the most part that the surface/binder layer was slightly less than the 180mm determined from construction and coring records and was more uniform in the outer wheelpath than the midlane. The ATB for the midlane was more variable than the outer wheelpath with the thickness averaging slightly less than 200mm whereas the outer wheelpath averaged slightly more. The aggregate base was equal to or greater than 100mm with the wheelpath being more uniform than the midlane. GPR is an excellent method of determining variability within a pavement structure with some tolerance limitations when determining actual thickness. The GPR data for this section would indicate that the construction platform is relatively uniform with some outliers but well within construction tolerances.

4.5 Forensic Material Sampling and Observation

The profile, MDS and FWD surveys were completed on July 15, 2008 prior to selecting the locations for coring, DCP and split-spoon sampling. The locations for the surface material, DCP and split-spoon sampling, was based on a review of the FWD data to select representative areas of pavement response. The deflection results indicated the pavement response was relatively uniform over the section length with 3 locations for sampling selected based on minor variations in deflection readings. The 150mm cores that would be used for laboratory analysis and provide access for DCP and split-spoon sampling were located in the midlane and outer wheelpath at stations 0+00, 2+25 (68.5m) and 4+50 (137.2m). The DCP location was at the spot of the FWD test with the split spoon sampling offset by 450mm in the southbound direction. The cores from the DCP location were selected for the laboratory analysis with the second set of cores retained as backup in the event additional materials were needed. The locations for the 100mm cores were based on an examination of the surface to select representative areas with cracks or no visible surface cracks that would provide core samples that could be examined to determine the extent of damage. Figure E-3, Appendix E, provides a general photo of section 390106 that depicts the types of distresses evident over the length of section. The primary distresses were slight to moderate alligator cracking that was in the wheelpaths and propagating from the longitudinal and partial transverse cracks. Longitudinal cracks were evident at the centerline and edge of the lane, where it abuts the shoulder. The surface is weathered with many of the cracks showing signs of raveling as shown in Figure E-4, Appendix E. A unique set of longitudinal cracking was evident at midlane and approximately a meter either side of the midlane near the edge of the wheelpath. In discussion with Roger Green, and review of the reports from the ODOT forensic studies[(1)], it was previously determined that this cracking was a result of a paver issue. Very similar observations were made during a Colorado top-down crack study [(2)(3)]. Of twenty-five longitudinal crack sites in Colorado, 72% were top-down cracking and 67% of the top-down cracking was associated with visual segregation at the bottom of the surface layer. A relatively large portion of coarse aggregates is distributed in the bottom half of the surface layer. The Colorado study further identified the source of the segregation. Certain models of pavers caused the early longitudinal cracking at the pavement locations corresponding to the edges of the slat conveyors and the center point of the paver. This explains the straight line longitudinal cracks shown in Figure E-3, Appendix E. A photo of the AC placement is provided in Figure E-1, Appendix E. A photo taken a year after construction shows signs of the longitudinal lines that eventually opened in to longitudinal cracks is shown in E-2, Appendix E.

Figure 2 shows the layout of sampling and test locations for the thirty-six 100mm cores that would be used to examine the asphalt layers and associated cracking, and the twelve 150mm cores that would be retrieved for laboratory samples, and to provide access for DCP and split-spoon testing.

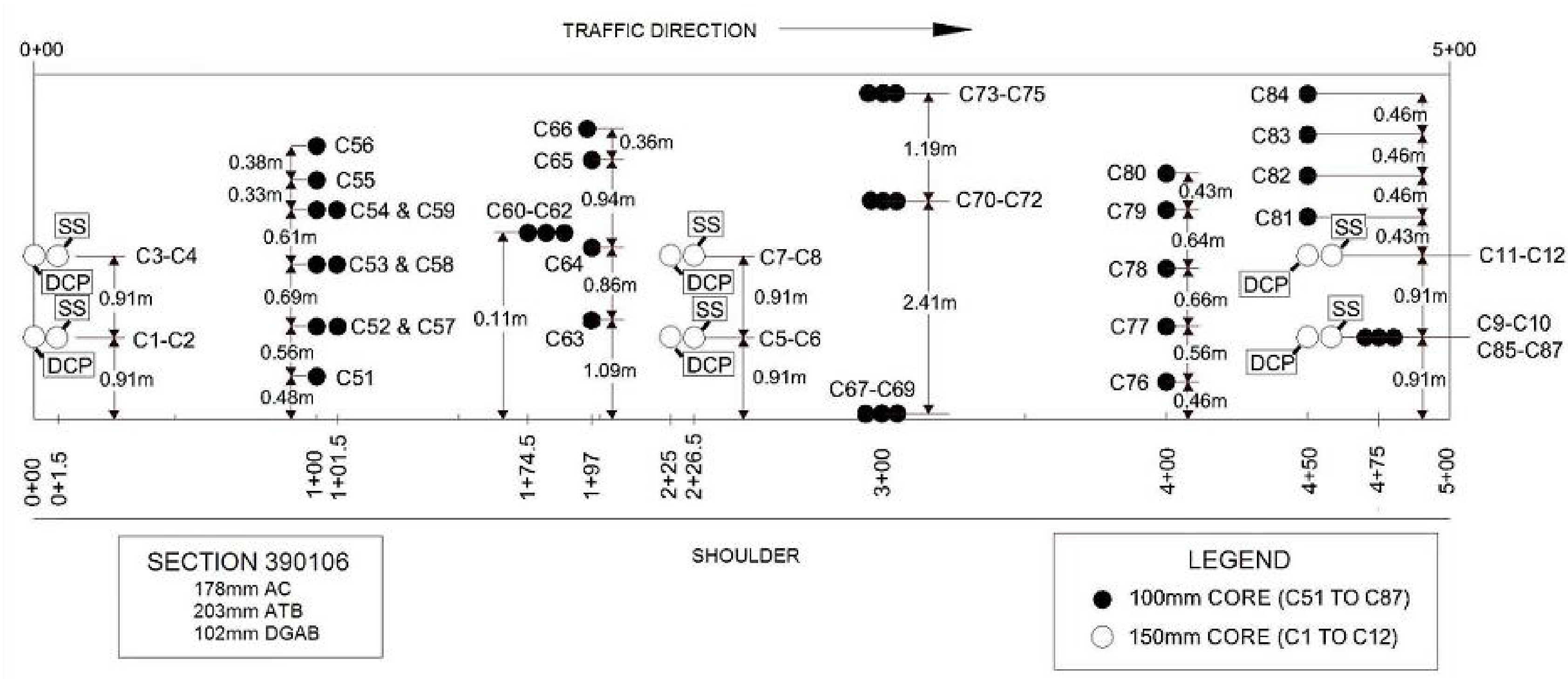

Figure 2: Layout of Sampling and Test Locations

4.5.1 Cores and Core Examination

ODOT Materials and Testing did the core sampling and transfer of the 150mm cores to the laboratory. The core unit was setup for the 100mm cores whereas the drill rig was used to take the 150mm cores at the location for the DCP and split-spoon sampling. A photo of the core unit and drill rig is provided in Figure F-1, Append F. The 150mm cores were removed from the core hole at the completion of drilling and set aside to air dry. When dry, the interface of the surface, binder layers and ATB was determined and marked. The markings were measured in 4 locations on the circumference of the core and averaged. The core was then labeled for identification and examined to determine the location and type of distress with cracks noted as being top down or bottom up and to what depth. These cores were then sealed and packed for transfer to the ODOT laboratory for testing. Example photos that depict the measurement and labeling are provided in Figure F-2 (Station 0+00), F-4 (Station 2+25) and F-6 (Station 4+50) of Appendix F. The photos in Figure F-2 to F-7 also provide examples of the top down cracking, stripping of the surface and intermediate layers and bond separation between the paving layers. The details of the measurements and examination of the cores are provided in Table 5.

The 100mm cores were removed, dried and labeled, packaged and set aside for transfer to the NCRSC facility for measurement and examination. A minimum of 3 cores were taken in the location of a specific distress. Not all cores were taken to full depth, as it was determined that the distress was mainly in the surface/binder layers with the ATB intact, showing minimal voids and stripping at the aggregate base interface. Figure F-8, Appendix F provides a photo showing the core locations and Figure F-9, Appendix F provides a photo showing the core samples taken from cracks at centerline, edge of inner wheelpath and the edge of pavement. The detailed measurements and core examination results for sample numbers C67 through C75, which are represented in the photos, are provided in Table 5. The full depth cores were taken at the cracks on the edge of the pavement; the cores from the edge of wheelpath and centerline were partial cores taken to the depth of the interface between binder and ATB. As is evident from these cores the cracking was primarily in the surface and top layer of the AC binder course, with a significant amount of stripping/deterioration at the bottom of the surface course and the top lift of the binder course. The segregation of the AC at time of paving, which has been documented as being a particular issue with certain pavers, could have contributed to the deterioration and stripping evident in the surface and binder course.

Based on the examination of the cores, roughly 50% of the cores had visible void areas primarily in the ATB layer. Although the surface was substantially raveled, only 3% of the cores had aggregate particles loose enough to be separated. Lack of bond between layers or separation due to raveling and/or cracking was documented for greater than 50% of the cores. All cracks identified were top down with the majority to a depth of 46mm and ranging from a minimum of 2.5mm to a maximum of 145mm.

Table 5: Summary of Core Measurement and Examination

6" Core Sample #	Station	PE Offset (m)	Layer	Measurements (mm) 1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top /Bottom
C1	0+00	0.914	5	45.7				45.7	45.7	45.7	369.6	DCP	Y	N	N	Y	45.7	T
			4	119.4	121.9	119.4	121.9	119.4	121.9	120.7								
			3	203.2	203.2	203.2	203.2	203.2	203.2	203.2								
C3	0+00	1.83	5	43.2				43.2	43.2	43.2	94.0	DCP	Y	N	N	N		
			4	50.8				50.8	50.8	50.8								
			3															
C5	2+25	0.914	5	43.2				43.2	43.2	43.2	369.6	DCP	Y	N	N	CND		
			4	127.0	127.0	127.0	127.0	127.0	127.0	127.0								
			3	198.1	198.1	200.7	200.7	198.1	200.7	199.4								
C7	2+25	1.83	5	43.2				43.2	43.2	43.2	375.3	DCP	Y	N	N	CND		
			4	129.5	129.5	129.5	129.5	129.5	129.5	129.5								
			3	203.2	200.7	203.2	203.2	200.7	203.2	202.6								
C9	4+50	0.914	5	45.7	43.2	43.2		43.2	45.7	44.0	44.0	DCP	Y	N	N	CND		
			4															
			3															
C11	4+50	1.83	5	45.7	45.7	45.7	43.2	43.2	45.7	45.1	369.6	DCP	Y	N	Y	N		
			4	127.0	127.0	127.0	127.0	127.0	127.0	127.0								
			3	198.1	198.1	195.6	198.1	195.6	198.1	197.5								
C2	0+01.5	0.914	5	45.7	45.7	45.7	45.7	45.7	45.7	45.7	367.7	Split Spoon	Y	N	N	N		
			4	121.9	121.9	121.9	121.9	121.9	121.9	121.9								
			3	200.7	200.7	198.1	200.7	198.1	200.7	200.0								
C4	0+01.5	1.83	5	43.2	45.7	43.2	45.7	43.2	45.7	44.5	363.9	Split Spoon	Y	N	Y	Y	45.7	T
			4	121.9	121.9	124.5	124.5	121.9	124.5	123.2								
			3	195.6	195.6	195.6	198.1	195.6	198.1	196.2								
C6	2+26.5	0.914	5	43.2				43.2	43.2	43.2	372.7	Split Spoon	N	N	N	CND		
			4	127.0	124.5	127.0	127.0	124.5	127.0	126.4								
			3	203.2	203.2	203.2	203.2	203.2	203.2	203.2								

Table 4 (Continued): Summary of Core Measurement and Examination

6" Core				Measurements (mm)														
Sample #	Station	PE Offset (m)	Layer	1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top /Bottom
C8	2+26.5	1.83	5	45.7				45.7	45.7	45.7	378.5	Split Spoon	Y	N	N	CND		
			4	129.5	129.5	129.5	129.5	129.5	129.5	129.5								
			3	203.2	203.2	203.2	203.2	203.2	203.2	203.2								
C10	4+51.5	0.914	5	43.2				43.2	43.2	43.2	43.2	Split Spoon	Y	N	N	CND		
			4															
			3															
C12	4+51.5	1.83	5	43.2	45.7	45.7	45.7	43.2	45.7	45.1	367.7	Split Spoon	Y	N	Y	N		
			4	124.5	124.5	124.5	124.5	124.5	124.5	124.5								
			3	200.7	198.1	195.6	198.1	195.6	200.7	198.1								
4" Core																		
C51	1+00	0.483	5	45.7	45.7	45.7	45.7	45.7	45.7	45.7	397.2	fatigue	Y	N	N	N		
			4	133.4	137.2	133.4	133.4	133.4	137.2	134.3								
			3	215.9	221.0	215.9	215.9	215.9	221.0	217.2								
C52	1+00	1.041	5	45.7	44.5	44.5		44.5	45.7	44.9	379.2	fatigue	N	N	Split	Y	17.8	T
			4	133.4	132.1	129.5	129.5	129.5	133.4	131.1								
			3	203.2	203.2	198.1	208.3	198.1	208.3	203.2								
C54	1+00	2.337	5	44.5	43.2			43.2	44.5	43.8	329.6	fatigue	Y	N	N	Y	43.2	T
			4	120.7	120.7	114.3	120.7	114.3	120.7	119.1								
			3	165.1	165.1	171.5	165.1	165.1	171.5	166.7								
C56	1+00	3.048	5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	389.6	fatigue	N	N	Y	Y	5.1	T
			4	134.6	134.6	133.4	134.6	133.4	134.6	134.3								
			3	209.6	209.6	213.4	210.8	209.6	213.4	210.8								
C57	1+01.5	1.041	5	44.5	44.5			44.5	44.5	44.5	101.0	fatigue	N	N	N	CND	45.7	T
			4	57.2	57.2	55.9	55.9	55.9	57.2	56.5								
			3															
C59	1+01.5	2.337	5	44.5	45.7			44.5	45.7	45.1	261.0	fatigue	N	N	N	Y	45.7	T
			4	120.7				120.7	120.7	120.7								
			3	95.3				95.3	95.3	95.3								

Table 4 (Continued): Summary of Core Measurement and Examination

4" Core	Station	PE Offset (m)	Layer	Measurements (mm)				Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top /Bottom
Sample #				1	2	3	4											
C76	4+00	0.457	5	40.6	40.6			40.6	40.6	40.6	167.6	fatigue	Y	N	Split	Y	CND	CND
			4	124.5	127.0	129.5	127.0	124.5	129.5	127.0								
			3															
C77	4+00	1.016	5	40.6	40.6	40.6	40.6	40.6	40.6	40.6	375.0	fatigue	Y	N	Y	Y	2.5	T
			4	127.0	129.5	127.0	127.0	127.0	129.5	127.6								
			3	209.6	205.7	208.3	203.2	203.2	209.6	206.7								
C79	4+00	2.311	5	43.2	43.2	43.2	43.2	43.2	43.2	43.2	373.4	fatigue	Y	N	Split	Y	43.2	T
			4	127.0	120.7	120.7	121.9	120.7	127.0	122.6								
			3	203.2	209.6	209.6	208.3	203.2	209.6	207.6								
C70	2+97	2.438	5	45.7				45.7	45.7	45.7	104.1	outside edge of fatigue	N	N	N	Y	104.1	T
			4	61.0	55.9	61.0	55.9	55.9	61.0	58.4								
			3															
C71	3+00	2.438	5	45.7				45.7	45.7	45.7	103.5	outside edge of fatigue	N	N	N	Y	45.7	T
			4	58.4	58.4	57.2	57.2	57.2	58.4	57.8								
			3															
C72	3+03	2.438	5	45.7				45.7	45.7	45.7	103.8	outside edge of fatigue	N	N	N	Y	45.7	T
			4	57.2	58.4	58.4	58.4	57.2	58.4	58.1								
			3															
C60	1+74.5	2.083	5	43.2	44.5	43.2	43.2	43.2	44.5	43.5	99.7	mid-lane longitudinal cracking	CND	N	Split	Y	43.2	T
			4	55.9	55.9	55.9	57.2	55.9	57.2	56.2								
			3															
C61	1+76	2.083	5	44.5	43.2			43.2	44.5	43.8	100.0	mid-lane longitudinal cracking	N	N	Split	Y	43.2	T
			4	55.9	57.2	55.9	55.9	55.9	57.2	56.2								
			3															
C62	1+77.5	2.083	5	44.5	40.6	40.6		40.6	44.5	41.9	319.1	mid-lane longitudinal cracking	Y	N	Split	Y	43.2	T
			4	127.0	133.4	127.0	121.9	121.9	133.4	127.3								
			3	147.3	152.4	152.4	147.3	147.3	152.4	149.9								

Table 4 (Continued): Summary of Core Measurement and Examination

4" Core Sample #	Station	PE Offset (m)	Layer	Measurements (mm) 1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top /Bottom
C78	4+00	1.676	5	40.6	40.6	40.6		40.6	40.6	40.6	241.9	mid-lane longitudinal cracking	Y	N	Split	Y	40.6	T
			4	120.7	119.4			119.4	120.7	120.0								
			3	81.3	81.3			81.3	81.3	81.3								
C67	2+97	0.025	5	45.7	45.7	43.2	45.7	43.2	45.7	45.1	388.3	edge longitudinal cracking	Y	N	Y	Y	27.9	T
			4	134.6	133.4	134.6	132.1	132.1	134.6	133.7								
			3	209.6	209.6	203.2	215.9	203.2	215.9	209.6								
C68	3+00	0.025	5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	325.1	edge longitudinal cracking	N	N	Y	Y	91.4	T
			4	129.5	127.0	133.4	133.4	127.0	133.4	130.8								
			3	152.4	147.3	152.4	147.3	147.3	152.4	149.9								
C69	3+03	0.025	5	44.5	43.2	43.2	43.2	43.2	44.5	43.5	380.7	edge longitudinal cracking	N	N	Y	Y	43.2	T
			4	133.4	133.4	129.5	129.5	129.5	133.4	131.4								
			3	205.7	203.2	205.7	208.3	203.2	208.3	205.7								
C73	2+97	3.632	5	43.2	44.5	45.7	44.5	43.2	45.7	44.5	167.0	center-line longitudinal cracking	Y	Y	N	Y	96.5	T
			4	124.5	120.7			120.7	124.5	122.6								
			3															
C74	3+00	3.632	5	44.5	45.7	45.7	44.5	44.5	45.7	45.1	174.6	center-line longitudinal cracking	Y	N	N	Y	96.5	T
			4	127.0	132.1			127.0	132.1	129.5								
			3															
C75	3+03	3.632	5	45.7	45.7	44.5	44.5	44.5	45.7	45.1	161.9	center-line longitudinal cracking	Y	N	N	Y	88.9	T
			4	114.3	114.3	119.4	119.4	114.3	119.4	116.8								
			3															
C85	4+73.5	0.914	5	44.5				44.5	44.5	44.5	44.5	longitudinal cracking in WP	CND	CND	CND	CND	CND	CND
			4															
			3															
C86	4+75	0.914	5	44.5	44.5			44.5	44.5	44.5	44.5	longitudinal cracking in WP	CND	CND	N	Y	CND	T
			4															
			3															

Table 4 (Continued): Summary of Core Measurement and Examination

4" Core Sample #	Station	PE Offset (m)	Layer	Measurements (mm) 1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top /Bottom
C87	4+76.5	0.914	5								242.6	longitudinal cracking in WP	N	N	N	CND	CND	CND
			4	116.8	116.8	114.3	116.8	114.3	116.8	116.2								
			3	127.0	127.0	127.0	124.5	124.5	127.0	126.4								
C63	1+97	1.092	5	43.2				43.2	43.2	43.2	99.1	transverse cracking	CND	N	Split	Y	CND	T
			4	55.9	55.9			55.9	55.9	55.9								
			3															
C64	1+97	1.956	5	44.5	44.5	43.2	44.5	43.2	44.5	44.1	374.7	transverse cracking	N	N	Y	Y	96.5	T
			4	133.4	133.4	133.4	133.4	133.4	133.4	133.4								
			3	196.9	203.2	185.4	203.2	185.4	203.2	197.2								
C65	1+97	2.896	5	43.2	44.5	44.5	43.2	43.2	44.5	43.8	386.7	transverse cracking	N	N	Split	Y	43.2	T
			4	127.0				127.0	127.0	127.0								
			3	215.9	215.9			215.9	215.9	215.9								
C66	1+95.5	3.251	5	44.5	43.2	44.5	44.5	43.2	44.5	44.1	372.7	transverse cracking	N	N	Y	Y	2.5	T
			4	129.5	127.0	127.0	129.5	127.0	129.5	128.3								
			3	190.5	203.2	198.1	209.6	190.5	209.6	200.3								
C81	4+50	2.261	5	45.7	45.7			45.7	45.7	45.7	371.7	transverse cracking	N	N	Split	Y	25.4	T
			4	121.9	121.9			121.9	121.9	121.9								
			3	203.2	203.2	205.7		203.2	205.7	204.0								
C82	4+50	2.718	5	43.2	43.2	43.2	43.2	43.2	43.2	43.2	301.0	transverse cracking	N	N	Split	Y	43.2	T
			4	121.9	121.9	121.9	127.0	121.9	127.0	123.2								
			3	134.6				134.6	134.6	134.6								
C83	4+50	3.175	5	44.5	44.5	44.5	43.2	43.2	44.5	44.1	368.0	transverse cracking	Y	N	Y	Y	121.9/ 144.8	T
			4	124.5	129.5	127.0	127.0	124.5	129.5	127.0								
			3	190.5	195.6	200.7	200.7	190.5	200.7	196.9								
C84	4+50	3.632	5	50.8	45.7	45.7	45.7	45.7	50.8	47.0	96.5	transverse cracking	N	Y	Split	Y	96.5	T
			4	45.7	50.8	50.8	50.8	45.7	50.8	49.5								
			3															

Table 4 (Continued): Summary of Core Measurement and Examination

4" Core Sample #	Station	PE Offset (m)	Layer	Measurements (mm) 1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top /Bottom
C53	1+00	1.727	5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	370.5	Longitudinal crack	Y	N	N	Y	45.7	T
			4	120.7	121.9	121.9	127.0	120.7	127.0	122.9								
			3	203.2				203.2	203.2	203.2								
C58	1+01.5	1.727	5	45.7	45.7	45.7	45.7	45.7	45.7	45.7	103.2	Longitudinal crack	N	N	N	Y	45.7	T
			4	57.2	57.2	57.2	58.4	57.2	58.4	57.5								
			3															
C55	1+00	2.667	5	45.7	45.7	45.7	45.7	45.7	45.7	45.7	383.9	no distress	N	N	Y	N		
			4	127.0	133.4	127.0	133.4	127.0	133.4	130.2								
			3	209.6	203.2	209.6	209.6	203.2	209.6	208.0								
C80	4+00	2.743	5	40.6	43.2	43.2	44.5	40.6	44.5	42.9	248.6	no distress	N	N	Y	N		
			4	121.9	124.5	124.5	121.9	121.9	124.5	123.2								
			3	82.6	82.6	82.6	82.6	82.6	82.6	82.6								

Notes: Measurements 1-4 are starting with traffic direction going clockwise.

Shading indicates measurement not available.

CND – Cannot Determine

4.5.2 Split-Spoon and DCP Results

Split spoon sampling has been in use in North America since the early days of construction as a measure of soil resistance to penetration. The Standard Penetration Test (SPT), which records the number of blows for a specific distance (i.e. count number/150mm), can be used to determine the shear strength and bearing capacity of soils to that of excellent or very poor. The advantage of split-spoon sampling over the FWD and DCP is that a relatively undisturbed sample of the soil is retrieved as part of the penetration of the sampling probe into the soil materials. The retrieved soil samples can be used to determine layer thickness, moisture content, perform Atterberg Limit tests and classification of the soils; all very useful when evaluating the strength characteristics of the soil. Aside from familiarity with the process and results, this is probably one of the main reasons this test method is still popular with highway agencies, even though quicker and more consistent results can be obtained from FWD or DCP tests. Table 6 provides the results of the split-spoon sampling for the three midlane and outer wheelpath locations sampled. The results indicate the aggregate base and subgrade materials are poor supporting layers. The values from the base material can be considered rather questionable as the base was damp from the core activity, along with the core spin off causing the top 25-50mm of material to loosen. Figures G-1 to G-3, Appendix G are photos showing the split-spoon sampling, split spoon sample material, and packaging and labeling of sample material for moisture determination, respectively. The split-spoon field data sheets are provided in Appendix I.

Table 6: Summary of Split Spoon Sampling Results (16, 17-Jul-08)

Location	Station	Offset	Lane	Description	Moisture Content	Depth (m)		Blows/150mm						
	(ft)	*(m)*			*(%)*	*From*	*To*	*N-count*						
C2	0+01.5	0.91	OWP	~100mm granular base		0	1.067	2	2	3	6	8	7	10
				fine-grained silty clay w/ traces of shale	20.5									
C4		1.83	ML	~100mm granular base		0	1.067	2	2	2	7	7	7	11
				fine-grained silty clay w/ traces of shale	20.0									
C6	2+26.5	0.91	OWP	~100mm granular base		0	1.067	5	5	8	9	8	6	9
				fine-grained silty clay w/ traces of shale	15.8									
C8		1.83	ML	~100mm granular base		0	1.067	2	5	6	7	10	8	9
				fine-grained silty clay w/ traces of shale	17.3									
C10	4+51.5	0.91	OWP	~100mm granular base	9.0	0	1.067	4	4	5	4	7	8	9
				fine-grained silty clay w/ traces of shale	18.1									
C12		1.83	ML	~100mm granular base		0	0.914	4	4	3	4	8	8	
				fine-grained silty clay w/ traces of shale	20.5									

The Dynamic Cone Penetrometer (DCP) has become more popular in recent years amongst highway agencies for determining the strength of pavement soils, particularly during construction, and to a lesser degree for rehabilitation evaluations. The DCP is very versatile in that it is easily transported, requires minimal skill to operate and the results can be obtained with very little effort. The Dynamic Cone Penetration Index (DCPI) has been correlated to CBR, unconfined compressive strength, resilient modulus and shear strength. The weakness for the DCP is that the penetration is highly dependent on the moisture content and there is no sample recovered for visual inspection or to determine moisture content.

Table 7 provides the results from the DCP tests performed at the three locations selected from FWD tests in the midlane and outer wheelpath. The field moisture values were taken from the soil samples retrieved as part of the split-spoon sampling. As previously mentioned the base material was disturbed, therefore moisture samples were only available for the outer wheelpath at station 4+50 (137.2m). Although the field moistures were slightly above optimum, there were no adjustments to the DCP results; similarly there were no seasonal adjustment factors applied to the FWD results. A photo of the operators performing the DCP test is provided in Figure G-4, Appendix G. The field data sheets are provided in Appendix H.

Table 7: Summary of DCP Test Results (16-Jul-08)

Location	Station *(ft)*	Offset *(m)*	Lane	Layer	Layer Type	Field Moisture *(%)*	DCPI *(mm/blow)*	DCP CBR	DCP Moduli *(MPa)*	FWD CBR	FWD Moduli *(MPa)*
C1	0+00	0.91	OWP	4 & 5	AC						6726.4
				2	Base		13	17	107.4		
				1	Subgrade	20.5	29	8	65.6	9	74.6
C3		1.83	ML	4 & 5	AC						4366.2
				2	Base		11	19	114.3		
				1	Subgrade	20	25	12	81.3	10	86.3
C5	2+25	0.91	OWP	4 & 5	AC						7535.7
				2	Base		9	27	142.9		
				1	Subgrade	15.8	18	14	93	10	83.3
C7		1.83	ML	4 & 5	AC						5093.1
				2	Base		11	20	119.6		
				1	Subgrade	17.3	17	13	89	10	79.2
C9	4+50	0.91	OWP	4 & 5	AC						4695.6
				2	Base	9	8	39	179.7		
				1	Subgrade	18.1	22	12	81.7	9	70.8
C11		1.83	ML	4 & 5	AC						5958.1
				2	Base		7	33	150		
				1	Subgrade	20.5	25	10	74.4	8	69.9

CBR=(MR/1200)

4.5.3 Material Properties and Laboratory Test Results

Laboratory tests were conducted on the subgrade, aggregate base material, and asphalt bound layers from material samples obtained during the processing and placement of the various pavement layers as part of the construction and testing done at the SPS-1 project in 1995. The results of the sampling and laboratory analysis that could be obtained from the LTPP database have been summarized and included in this report. As part of the forensic investigation, core samples were collected from the midlane and outer wheelpath and forwarded to the Ohio DOT test laboratory where the following tests were conducted:

- Binder extraction (% air voids, % binder, flexural creep stiffness-aged and indirect tension failure stress)
- Bulk and maximum specific gravity
- Resilient Modulus (Indirect Tension tests at 25 °C)

These tests were conducted to determine the effects of aging on the hot mix asphalt and if any of these properties were factors in the deterioration of the bound pavement layers. The material properties for the unbound layers (base and subgrade) are provided in Table 8. The crushed stone base was placed directly on the subgrade to a depth of 150mm. The density tests taken at time of construction indicate the material was compacted within the 95% tolerance of the standard proctor test. The subgrade was classified as a fine-grained silty clay that was proof rolled, leveled and graded prior to the placement of the surface layers. Again, this material was well compacted with the density results exceeding the requirements. The results of the nuclear density tests taken during the time of construction are provided in Table 9. The pavement structure has shown no signs of settlement or fatigue in the bottom layers of the asphalt bound layers, which would indicate no issues were evident with the support structure, especially with this location having a relatively high and variable water table with no external drains or drain layer. The pavement layer thickness and aggregate properties are provided in Table 10. The ATB consists of 67% gravel with a maximum stone size of 38.1mm, the AC binder and surface layers had equal amounts of gravel and sand with a maximum stone size of 25.4 and 19.1 millimeters respectively. The core samples taken from this section indicated that the locations of cracks and associated stripping at the layer interfaces, many of which were the result of the paver placement segregation issue, were all associated with the layers having the higher percentage of sand and smaller maximum stone size.

The specifications for the AC-20 asphalt binder sourced from Amoco, Toledo, Ohio are provided along with the results from the laboratory tests conducted on the AC materials from the SPS-1 project in Table 11. The same binder type and source was used for all bound layers. There appears to be a fairly significant difference in the viscosity properties provided by the vendor and those determined from laboratory analysis of the plant mix sampled materials. The penetration and AC content fall within the design specifications for the plant mix used for this project based on ODOT material specifications. The various AC properties for the materials sampled and tested shortly after construction and from the core samples taken as part of the forensic study are provided in Table 12. The information available indicated the air voids post construction ranged from 5.9% to 7.7% for the ATB and 9.9% to 13% for the AC binder and surface layers. The range of air voids from the forensic test results were 4.8% to 14.1% for the ATB with 9.8% to 12.5% for the AC binder and surface layer. These results would indicate a much higher variability for the ATB with minimal or no change to the AC binder and surface course over time. A comparison of the Bulk Specific Gravity (BSG) post construction and from the forensic tests shows a higher variability for the ATB for the recent test results and minimal difference between the timeframes for the AC binder and surface layers. The percentage of water absorption for the three layers ranged from 1% to 6% on the samples tested post construction to 0% on the samples derived from the forensic cores. The Maximum Specific Gravity (MSG) is very similar with the results from the recent tests being slightly higher. The results indicate the MSG values for the ATB were similar to the BSG test results in that they were highly variable.

Table 13 provides the results of the Resilient Moduli and binder property tests performed at the completion of construction and as part of the forensic study. The information as requested for the forensic laboratory testing, as was determined after a review of the LTPP database, would not provide direct comparative results to that of the data available in the LTPP database. In this instance similar tests may not have been performed as they may not have been requested or the equipment to perform the testing may not have been available. The modulus values are provided in different formats but would indicate a fairly large change has occurred in the intermediate AC binder layer. The results of the flexural creep stiffness test also indicate a fairly large difference in properties between the AC binder layer and that of the ATB or surface layer.

Table 8: Material Properties - Unbound Layers

Description	Granular Base	Subgrade
Borehole Location	BA 301-302	B2
Material (Code)	Crushed Stone (303)	Fine-Grained Silty Clay (131)
Resilient Modulus (MPa)	271.1	135.7
Lab Max. Dry Density (kg/m3)	2179	1874
Lab Opt. Moisture Content (%)	8.0	13.0
In-situ Wet Density (kg/m3)	2249	2223
In-situ Dry Density (kg/m3)	2140	2039
In-situ Moisture Content (%)	5.1	9
Liquid Limit		28
Plastic Limit		16
Plasticity Index	NP	12
% Gravel	68	8
% Sand	21	20
% Passing #200	8.5	70.6
Max Stone Size (mm)	38.1	19.1
Specific Gravity	2.757	2.759

Table 9: Nuclear Density Testing at Time of Construction

Date	Station	Offset (m)	Layer	Layer Type	In-situ Dry Density (kg/m^3)	In-situ Moisture (%)
31-Jul-95	1+75	1.83	1	Subgrade	1953	11.2
	2+50				2001	9.5
	4+00				1975	9.4
	5+50				2039	9.0
16-Oct-95	1+00				1982	5.4
	1+00		2	Granular Base	1982	5.4
	2+50				2069	5.5
	4+00				2211	4.6
18-Oct-95	1+00		3	ATB	2215	
	2+50				2175	
	4+00				2136	
20-Oct-95	1+00		4	AC - Binder	2115	
	2+50				2089	
	4+00				2144	
13-Nov-95	1+00		5	AC - Surface	2101	
	2+50				2145	
	4+00				2172	

Note: AC bound layer density was reported as dry density

Table 10: Aggregate Material Properties - Bound Layers

Description	AC - Surface	AC - Binder	ATB
Material (Code)	Hot Mixed, Hot Laid AC, Dense Graded (1)	Hot Mixed, Hot Laid AC, Dense Graded (1)	HMAC (319)
Layer #	5	4	3
% Gravel	47	46	67
% Sand	47.3	47.9	25.7
% Passing #200	5.7	6.1	7.3
Max Stone Size (mm)	19.1	25.4	38.1
BSG of Coarse Agg.	2.500	2.530	2.500
Absorption (%)	1.8	2.1	2.7
BSG of Fine Agg.	2.51	2.54	2.53
Absorption (%)	2.4	2.5	1.7

Table 11: Binder Properties - Bound Layers

Layer Type	Layer #	AC Content (%)	Average Specific Gravity	Kinematic Viscosity @ 60°C ($g*cm^{-1}*s^{-1}$)	Absolute Viscosity @ 135°C (mm^2/s)	Penetration of AC @ 25°C (.1mm)	Original AC material at 25 ºC (cm)
Amoco Specifications	3,4 & 5	-	1.031	2043	392	-	105
ATB	3	5.2	1.042	4998	527	24	-
AC - Binder	4	6.4	1.041	4438	530	39	-
AC - Surface	5	6.7	1.04	6232	572	35	-

Table 12: Post Construction and Forensic AC Properties

Sampling Date	Layer #	Layer Type	Air Voids (%)			BSG			Water Abs. (%)			MSG		
			Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
20-Nov-95	3	ATB	7.7	5.9	6.8	2.224	2.267	2.245	1.0	3.0	1.8	2.410	2.410	2.410
	4	AC - Binder	13.0	10.7	11.7	2.139	2.194	2.170	1.0	3.0	1.8	2.458	2.458	2.458
	5	AC - Surface	10.8	9.9	10.4	2.189	2.212	2.200	2.0	6.0	3.5	2.455	2.455	2.455
23-Jun-06	3	ATB				2.255	2.308	2.290	1.0	2.0	1.7			
15-Jul-08	3	ATB	4.8	14.1	8.7	2.239	2.807	2.439	0.0	0.0	0.0	2.444	2.474	2.462
	4	AC - Binder	10.4	12.5	11.3	2.174	2.230	2.208	0.0	0.0	0.0	2.484	2.494	2.488
	5	AC - Surface	9.8	11.0	10.4	2.198	2.234	2.217	0.0	0.0	0.0	2.471	2.480	2.476

Table 13: Layer Moduli and Asphalt Binder Properties

Sampling Date	Layer #	Complex Modulus G* (kPa)	Phase Angle d (°)	Stiffness			M_R @ 25°C (MPa)	Poisson @ 25°C (v)	Indirect Tensile Strength (MPa)			Indirect Tensile Poisson (v)
				Min	Max	Avg			Min	Max	Avg	
20-Nov-95	3						2510	0.32				
	4						3570	0.36	0.43	0.97	0.68	0.42
	5								0.81	0.9	0.86	0.31
23-Jun-06	3						4400	0.17	0.82	1.24	1.04	0.18
15-Jul-08	3	4850	49.2	101.0	298.0	191.0						
	4	8730	45.3	160.0	425.0	282.8						
	5	5350	49.1	104.0	309.0	198.0						

4.6 Collection and Reporting of Monitoring Data

As part of the forensic testing at this LTPP SPS-1 site, Falling Weight Deflectometer (FWD), Manual Distress Survey (MDS), Transverse and Longitudinal Profiles and Elevation data were collected. This data has been added to the LTPP Information Management System (IMS) database. The pavement performance monitoring data has been analyzed and historical trends are reported as part of this document. Post construction FWD testing was performed in October of 1995 and material sampling began the following month in November. Profile and MDS data was collected on this section in August, 1996 and November, 1996 respectively. The following provides the results of the analysis and reports on the trends in the data from the initial data collected as part of the LTPP program to the last set of data collected as part of the forensic study.

4.6.1 Deflection Data Analysis Results

The FWD data was collected with the FHWA-LTPP FWD following the guidelines and protocols established for collecting FWD data for the LTPP program. A total of nineteen drops (3 seating, 4 at 26kN, 4 at 40kN, 4 at 54kN and 4 at 72kN) are taken at each test point. A photo showing the FWD in operation is provided in Figure E-9, Appendix E.

The average normalized temperature corrected deflections for the 40-kN equivalent loading for all the stations for both midlane and outer wheel path were plotted with time. The surface deflection trends, as reported from the sensor located under the load plate, are provided for all stations in Figure J-1, Appendix J. Similarly, the results representing the subgrade deflection trends, as reported from the sensor located 1.524 meters from the load plate, are provided for all stations in Figures J-2, Appendix J. The deflection trend, as presented in the Figure J-1 show a continual increase in deflection indicating the pavement is losing strength as time progresses. The deflection trend as provided in Figure J-2 indicate that the subgrade deflections have been very stable with time as only a slight change is evident. The backcalculated resilient moduli from the historical FWD deflection data is provided in Figure J-5, Appendix J. The pavement moduli, as observed over time, show a steady decrease in strength. The distressed surface layers, as evident from the core review, would indicate that some decrease in pavement strength should be evident on this section. The historical trend in subgrade resilient moduli is provided in Figure J-6, Appendix J. The results would indicate a slight weakening of the subgrade support but for the most part a minimal change over time. There was minimal difference observed between the midlane and outer wheelpath; this again is somewhat consistent with the distress observed on the surface which were located over the complete surface area rather than being primarily associated with the wheelpaths.

The layer analysis, for the FWD deflection data collected on July 15, 2009, is provided in Table 14 with the statistical comparison provided in Table 15. These results, with a few exceptions, show the support layers to be relatively uniform over the length of the section. The moduli values for the aggregate base material is lower than expected; this could be the result of filtration of fines from the subgrade which was not separated by a filter layer and/or difficulties in backcalculating moduli from thin pavement layers.

Table 14: Summary of FWD Layer Analysis (15-Jul-08)

Lane	Chainage	AC (MPa)	ATB (MPa)	Granular Base (MPa)	Subgrade (MPa)
ML	0+00	4366.25	561.58	47.45	86.25
OWP		6726.44	366.34	24.08	74.61
ML	0+25	5082.40	584.60	40.86	85.18
OWP		5490.97	532.88	38.52	93.60
ML	0+50	4745.88	932.48	37.56	76.27
OWP		6166.56	717.01	45.03	79.72
ML	0+75	6103.47	737.26	42.58	60.78
OWP		6963.19	735.42	27.86	65.21
ML	0+99	5697.15	658.83	30.96	61.99
OWP	1+00	6976.28	657.44	29.64	70.27
ML	1+25	5604.66	1056.02	70.68	74.62
OWP		8703.10	1067.46	42.58	77.08
ML	1+50	5093.14	916.34	47.56	76.27
OWP		8683.36	755.23	52.96	84.99
ML	1+75	5952.27	825.40	43.90	76.10
OWP		6778.97	1153.02	52.32	89.93
ML	2+00	5284.39	845.39	42.90	74.28
OWP		5867.87	917.02	55.38	87.17
ML	2+25	5093.14	1114.38	56.68	79.24
OWP		7535.73	1237.21	50.98	83.30
ML	2+50	4841.12	1369.90	101.88	79.42
OWP		8290.60	1536.91	64.59	83.70
ML	2+75	4678.73	1479.57	69.01	66.07
OWP		9022.81	907.22	38.52	74.45
ML	3+00	5231.55	770.17	42.90	76.44
OWP		10040.34	560.47	33.54	86.43
ML	3+25	5096.33	1064.19	55.59	88.20
OWP		5074.82	1529.90	50.34	96.28
ML	3+50	6454.66	871.35	45.31	89.93
OWP		6851.73	1253.70	55.59	102.08
ML	3+75	4861.64	758.96	47.69	98.75
OWP		5942.00	1083.99	52.99	115.26
ML	4+00	5886.26	1145.86	36.57	84.09
OWP	3+99	7996.58	887.39	46.50	102.57
ML	4+25	5607.99	1234.81	54.54	77.63
OWP		7908.80	1118.97	58.29	78.86
ML	4+50	5958.15	616.53	36.33	69.94
OWP		4695.63	774.18	37.54	70.83
ML	4+75	6648.23	603.48	32.50	75.91
OWP		5754.70	661.74	34.75	85.50
ML	5+00	6165.12	944.42	42.58	72.47
OWP		11027.89	769.36	47.09	78.86

Table 15: Statistical Summary of FWD Layer Analysis

Layer	Lane	Min (MPa)	Max (MPa)	Avg (MPa)	Std. Dev. (MPa)
AC	ML	4366.3	6648.2	5450.1	623.2
	OWP	4695.6	11027.9	7261.8	1638.8
ATB	ML	561.6	1479.6	909.1	259.0
	OWP	366.3	1536.9	915.4	314.3
Aggregate Base	ML	31.0	101.9	48.9	16.0
	OWP	24.1	64.6	44.7	10.9
Subgrade	ML	60.8	98.8	77.6	9.1
	OWP	65.2	115.3	84.8	12.1

4.6.2 Manual Distress Data Analysis Results

The historical trend for the four distress types (longitudinal wheelpath and non wheelpath, block and fatigue cracks) evident on the pavement surface of site 390106, are provided in Figures K-1 and K-2 of Appendix K. The results are from both photo interpretation of the PASCO film and the Manual Distress surveys conducted from 1996 to the final distress survey on July 15, 2008. The survey results indicate some distress was evident on the surface starting in 1996 but became much more predominant in 2001 and steadily increased up to the final survey in 2008. The distress surveys did not show a continuous trend for any particular distress type as the distresses were primarily associated with the deterioration of the longitudinal lines representing the edge of the slot conveyor and the center point of the paver. These longitudinal lines, which became predominantly longitudinal cracks, over time joined to form block cracking and eventually became alligator cracking, based on the LTPP MDS rating guidelines. An explanation for the unusual trends for the surface distress is provided below:

- Between the 2002 and 2004 MDS, longitudinal wheel path cracking was classified as alligator cracking
- Between the 2004 and 2006 MDS, longitudinal non-wheel path cracking was classified as block cracking
- Between the 2006 and 2008 MDS, block cracking reduced due to an increase in alligator cracking
- Between the 2006 and 2008 MDS, new longitudinal non-wheel path cracking was identified near the pavement edge and centerline

Photos that show the pavement condition in late 1997 and at the time of the MDS taken in conjunction with the forensic data collection are provided in Figures E-2 to E-4, Appendix E.

4.6.3 Longitudinal Profile Data Analysis Results

Figure 3 provides the historical IRI data for section 390106. A review of the Historical IRI shows that the pavement roughness steadily increased up until 2000 and then remained fairly constant with a slight increase in 2008. The surface distresses on this section are mainly in the slight to moderate category with minimal distortion on a section with practically no longitudinal grade. Based on these results the ride quality can be considered acceptable with no near term intervention required.

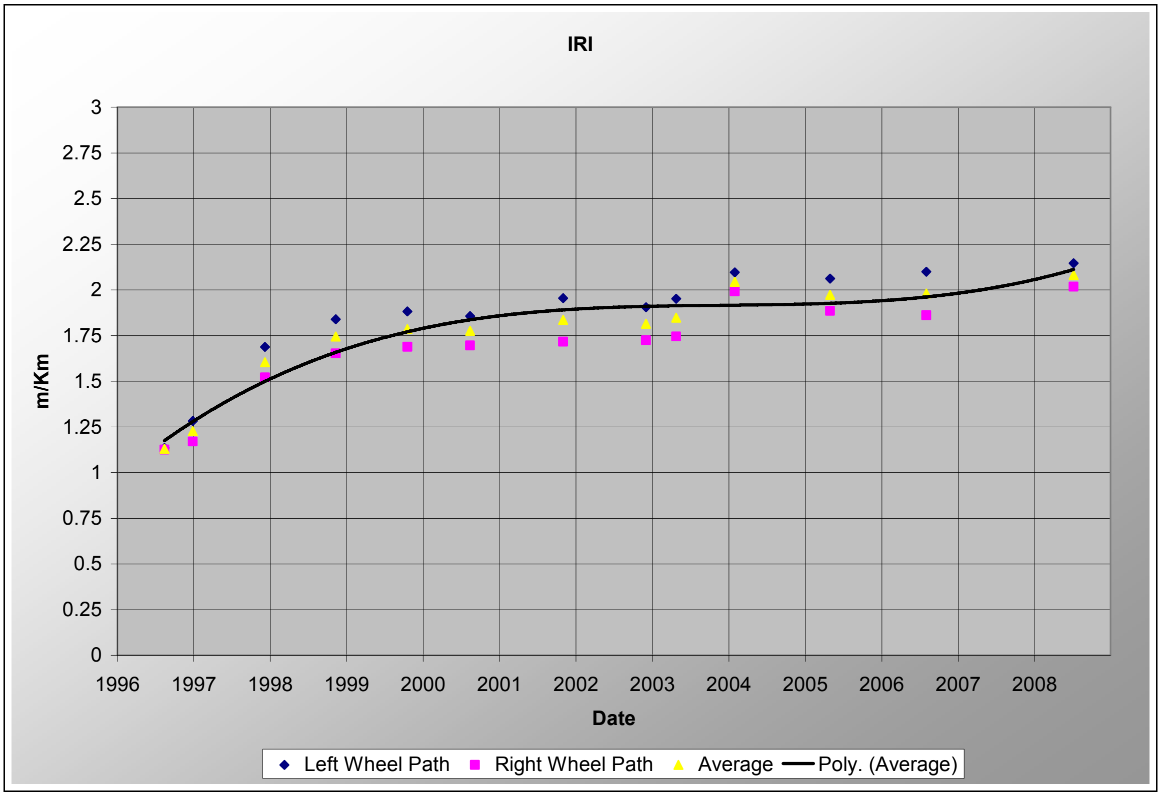

Figure 3: Historical Trend in IRI

4.6.4 Transverse Profile Data Analysis Results

The historical trends in rut depth from the Dipstick® transverse profiles are provided in Table 16. The average results are also provided in graphical format in Figure 4. These results indicate a very slight progression in rut depth over time with the right rut in most cases being slightly deeper than the left. The average rut depth for the survey on July 15, 2008 was 6.5mm in the right wheelpath and 4.5mm in the left wheelpath, which is not significantly more than the results as recorded from the 1996 survey. The results of the transverse profile survey would indicate that rutting was not an issue for this section.

Table 16: Summary of the Historical Trend in Rut Depth

Survey Date	Left Depth (Wire Ref)			Right Depth (Wire Ref)			Max Mean (Wire Ref) Left or Right
	Mean	Min	Max	Mean	Min	Max	
5-Nov-96	1.7	0.6	2.9	1.8	0.8	2.5	1.8
19-Dec-97	1.6	0.7	2.4	1.6	0.9	2.4	1.6
11-Sep-99	2.3	1.2	3.3	2.3	1.2	4.3	2.3
12-Apr-01	2.8	1.8	3.6	2.5	0.5	4.4	2.8
27-Aug-02	2.3	1.4	3.5	2.9	1.7	4.1	2.9
8-Oct-04	4.0	2.2	5.8	4.7	2.8	7.1	4.7
20-Jun-06	4.6	3.5	6.8	7.3	5.3	9.4	7.3
15-Jul-08	4.5	2.7	5.7	6.5	4.2	8.5	6.5

*All Rut values are in mm

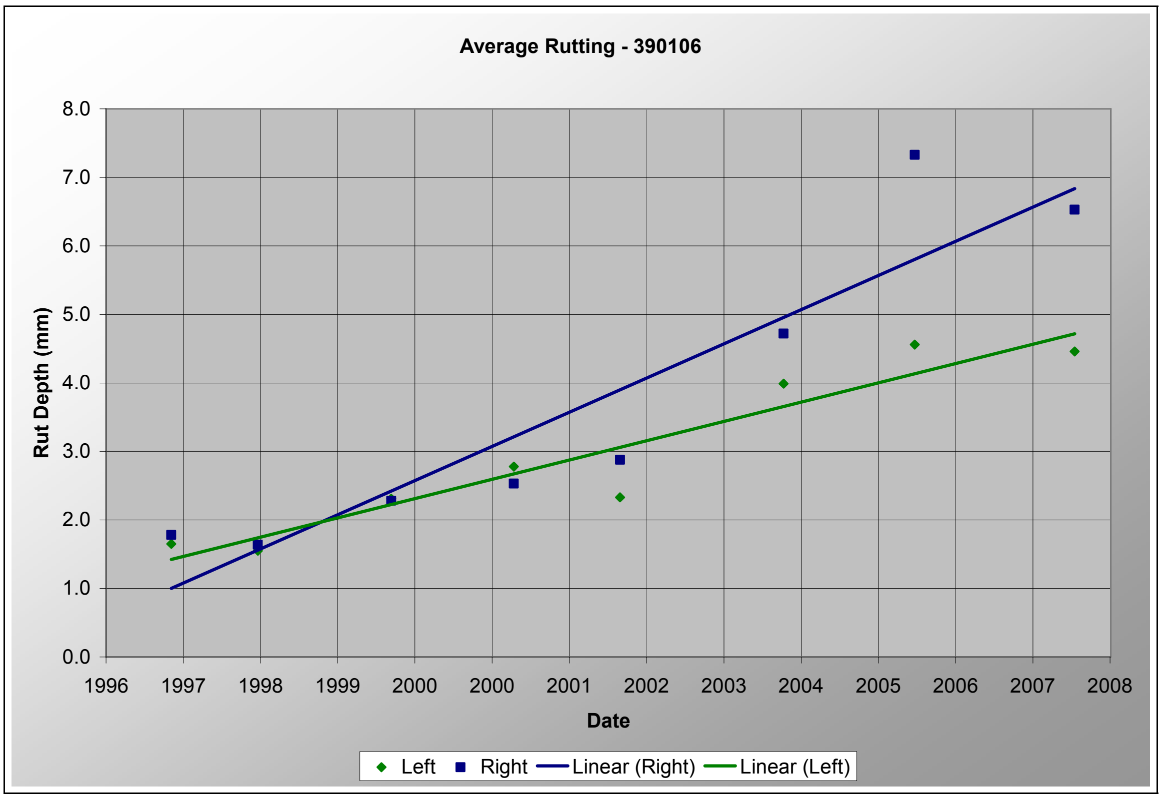

Figure 4: Graphical Presentation of Rut Depth

4.6.5 Elevation Data Analysis Results

A Six-Point set of levels were taken at 15.24m intervals over the 152.4m length of the section at centerline, right wheelpath, midlane, left wheelpath, pavement edge and 2m from edge on the paved shoulder. The results of the elevation survey are provided in Figure 5. The results show a slight deviation in elevation at the wheelpath location with a

1.5% slope for the pavement and a 3.7% slope from edge to 2m on the paved shoulder. These results would indicate sufficient slope for water runoff from the pavement surface. These results are consistent with those observed during the site review and as evident in the photo provided in Figure E-10, Appendix E.

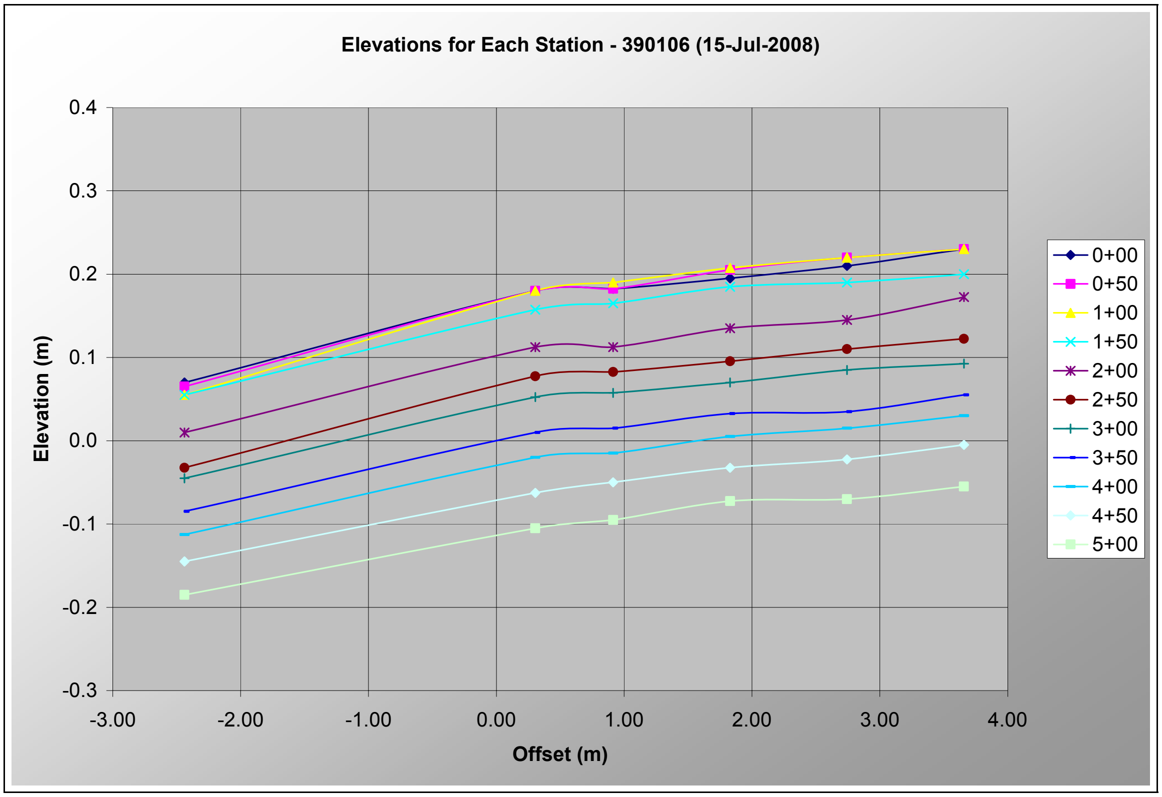

Figure 5: Results of Elevation Survey

4.7 Pavement System Performance

Based on the historical traffic data and inputs to the MEPDG, which were primarily extracted from the LTPP database, there should have been minimal cracking, rutting and ride deterioration observed on this section over the 12.5 years that this section was in service. The distresses recorded as part of the distress surveys show substantially more cracking than projected; there was in excess of 275 linear meters of longitudinal cracks with fatigue and block cracking covering an area in excess of 325 m^2, based on the MDS survey conducted at the time of the forensic investigation. The rutting depth of 7mm is slightly less than the 9mm projected and the IRI at 2.2 m/km is roughly the same as projected. The pavement response, based on the FWD deflections doubled over the time with a significant reduction in the overall pavement moduli as presented in Figure J-5, Appendix J.

An examination of the cores taken at the time of the forensic survey indicated the pavement failure was mainly in the surface and AC binder lifts. The ATB layer was intact and for the most part sound with minimal, if any, stripping at the interface to the aggregate base. The laboratory analysis of the different bound layers indicated the biggest change was in the AC binder layer with the ATB layers being somewhat more variable at the time of the forensics when compared with the tests that were performed post construction. The mix design properties, processing and placement of the various AC layers did not show any areas of concern. The layer thickness, aggregate properties, bituminous content, air voids, penetration etc. were all within the specifications provided by ODOT.

Based on the results, observations and information provided, the primary reason for the failures, in regard to the distresses on the pavement surface, was related to the failure of the paver to properly maintain the blend characteristics of the asphalt and place an even layer profile over the width of the section. This issue seemed more predominant for the surface/binder layers. Information provided, but not contained within the records indicated that the stripping observed may not have been fully related to the segregation of materials at laydown, but may have resulted from the quantity of polyphosphoric acid that was blended into the mix as an anti-stripping additive. If this admix is in the range of 0.5% it has a tendency to reduce stripping, but if blended at a high ratio (1-2%) it has the reverse effect and actually promotes stripping.

A rehabilitation strategy for this section should include milling at least 60mm to remove the disintegrating surface to a depth that would provide a sound base to apply and overlay that would restore the structural integrity of the pavement. Based on the information collected, this section would not require any geometric or drainage improvements, as there does not appear to be any issue with the performance of the aggregate and subgrade materials or rideability for this section.

5.0 Section 390902

5.1 Design and Life Expectancy

Using the design procedure from the 2004 Mechanistic Empirical Pavement Design Guide (MEPDG) the following would be the predicted levels of cracking, rutting and cumulative heavy traffic at 90% reliability for 12.5 years.

- Longitudinal Cracking – 0 meters for 152.4-meter section
- Transverse Cracking – 0 meters for 152.4-meter section
- Alligator Cracking – 0% top down
- Alligator Cracking – 0.01% bottom up (1.46% at Reliability)
- Rut Depth – 9.68mm at Reliability (4.37mm AC, 0.29mm Base, 2.65mm Subgrade, Total 7.32mm)
- Thermal Cracking – 0 meters for 152.4-meter section (2.40 meters at Reliability)
- IRI – 1.21 m/km (1.64 m/km at Reliability)
- The cumulative heavy loads are 7,082,170.

The 20-year analysis for this section indicated this section would meet the reliability criteria for the full design term with the exception of permanent deformation (rutting) in the AC layers. With this exception the structural design for this section would far exceed a 20-year lifespan.

Figure C-2, Appendix C provides the summary of the input variables for the MEPDG analysis for data extracted from the LTPP database.

5.2 Pavement Structure

The Design and As-Built thickness are provided in Table 17. The as-built layer thickness is well within the thickness tolerance for a typical pavement construction project.

Table 17: Pavement Structure - 390902

Layer	Layer No.	Design Thickness (mm)	As-Built Thickness (mm)	Description
Original Surface Layer	6	51	46	Dense-Graded, Hot-Laid AC (Hot-Mixed, Hot-Laid Asphalt Concrete, Dense-Graded)
AC Layer Below Surface (Binder Course)	5	51	58	
Asphalt Treated Base (ATB) Layer	4	305	305	Dense-Graded, Hot-Laid AC (Dense-Graded, Hot-Laid, Central Plant Mix)
Permeable Asphalt Treated Base (PATB) Layer	3	102	94	Open-Graded, Hot-Laid AC (Open-Graded, Hot-Laid, Central Plant Mix)
Subbase Layer	2	152	152	Processed Granular Base Materials (Crushed Stone)
Subgrade	1	-	-	Clayey Soils (Silty Clay)

5.3 Construction

As previously mentioned, excavation along with the importation of local fill material was necessary to prepare the area for the construction of the mainline portion of US 23. The subgrade preparation was started on September 11, 1994 and completed on July 31, 1995. A 22.1 ton sheep-foot compactor was used to compact the subgrade in 300mm thick lifts. The placement of the unbound aggregate base material was started on August 3, 1995 and completed on August 20, 1995. A CMI trimming machine was used to level the base to grade with a 16.5 ton single drum vibratory roller used to proof roll the subgrade and compact the 152mm thick base.

The southbound portion of U.S. 23 containing the SPS-9 section 390902 was constructed as follows:

- The driving lanes are 3.66 meter wide lanes with the outside lane being monitored.
- The outside monitoring lane was constructed with a hot mix asphalt surface (AC) on an asphalt treated base (ATB) over a permeable asphalt treated base (PATB) with a non-woven geotextile filter fabric layer placed between the ATB and PATB. The PATB was place on a 150mm crushed stone subbase layer over compacted subgrade.
- The inside shoulder is 1.22 meters wide with a 305mm crushed stone base and 100mm hot mix asphalt surface.
- The outside shoulder (adjacent to the monitored lane) is 3.05 meters wide with a 305mm crushed stone base and 100mm hot mix asphalt surface.

- Based on the information provided, a continuous drain, comprising of a drainage blanket with longitudinal drains of 100mm inside diameter pipe, was placed at the shoulder edge of the pavement.
- The longitudinal surface joint was 3.66 meters from the outside shoulder lane edge joint or centered between the two southbound lanes.

The permeable asphalt treated base was placed on August 24, 1995. The paving of the ATB was completed on October 4, 1995; a geotextile was placed over the PATB during the paving of the ATB. The binder courses were placed between October 6-7, 1995 with the surface course placed between October 8-9, 1995. The asphalt was processed at Stonco's Drum Mix Plant. The hot mix asphalt was transported a distance of 40km with haul times averaging 35 minutes to the placement location. All asphalt layers were placed with a Blaw Knox PF 200B paver at a width of 3.8 meters. Table 18 provides the information on the paving and compaction of the hot mix asphalt layers.

Table 18: Plant Mixed Asphalt Bound Layers - Paving and Compaction

Layer	Lift No.	Placement Dates	Placement Thickness (mm)	Average Plant Mix Temp. (ºC)	Min/Max Placement Temp. (ºC)	Breakdown Roller (Metric Tonnes)	Breakdown Coverage	Finish Roller (Metric Tonnes)	Finish Coverage	Mean Air Temp. (ºC)	Compacted Thickness (mm)	Mean Density (kg/m³)	Density Standard Deviation (kg/m³	Min. Density (kg/m³)	Max. Density (kg/m³)	No. of Samples	Curing period (days)
PATB	1	24-Aug-95	142	-	-/-	6.4	7	6.4	7	22	102	-	-	-	-	-	4
Geotextile Fabric	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ATB	1	4-Oct-95	94	132	-/-	7.3	11	6.4	9	-	76	2187	40	2127	2244	12	31
	2	4-Oct-95	94			7.3	11	6.4	9	-	76						1
	3	4-Oct-95	94			7.3	11	6.4	9	-	76						5
	4	4-Oct-95	94			7.3	11	6.4	9	19	76						3
AC Binder	1	7-Oct-95	71	146	-/-	7.3	15	6.4	11	16	58	2319	85	2201	2467	12	2
AC Surface	1	9-Oct-95	56	150	-/-	7.3	13	6.4	11	19	46	2305	29	2263	2344	12	-

Note: Breakdown roller completed the intermediate compaction
Note: Density – Troxler Model 3440 SN23964 Backscatter Measurements at Count Rate 2825

5.4 Forensic Material Sampling and Observation

The profile, MDS and FWD surveys were completed on July 15, 2008 prior to selecting the locations for coring, DCP and split-spoon sampling. The locations for the sampling of surface material, DCP and split-spoon sampling, was based on a review of the FWD data to select a representative area of pavement response. The deflection results indicated the pavement response was relatively uniform over the section length. The 150mm cores, that would be used for laboratory analysis and provide access for DCP and split-spoon sampling, were located in the middle of the section, at the midlane and outer wheelpath of station 2+50 (76.2-meters). The DCP location was at the spot of the FWD test with the split spoon sampling offset by 450mm in the southbound direction. The cores from the DCP location were selected for the laboratory analysis with the second set of cores retained as backup in the event additional materials were needed. The locations for the 100mm cores were based on an examination of the surface to select representative areas with cracks or no visible surface cracks that would provide core samples that could be examined to determine the extent of damage or lack thereof.

Figure 6 shows a plan view of the locations for the four 150mm cores that would be retrieved for laboratory testing, provide access for DCP tests, split-spoon sampling and auguring to collect aggregate and subgrade samples for laboratory analysis. Also located on the plan view are the thirteen 100mm cores that would be used to examine the asphalt layers and associated cracking. Example photos that depict the types of distress are provided in Figures E-5 (intermittent longitudinal crack at the inside edge of the inner wheelpath), E-6 (transverse crack extending from edge to centerline), E-7 (very slight intermittent alligator cracking branching from a longitudinal crack in the wheelpath) and E-8 (centerline paving joint) of Appendix E.

LONG TERM PAVMENT PERFORMANCE
FORENSIC EVALUATION AND PERFORMANCE
COMPARISONS OF LTPP SECTIONS 390106 AND 390902
U.S. RT. 23, DELAWARE, OHIO

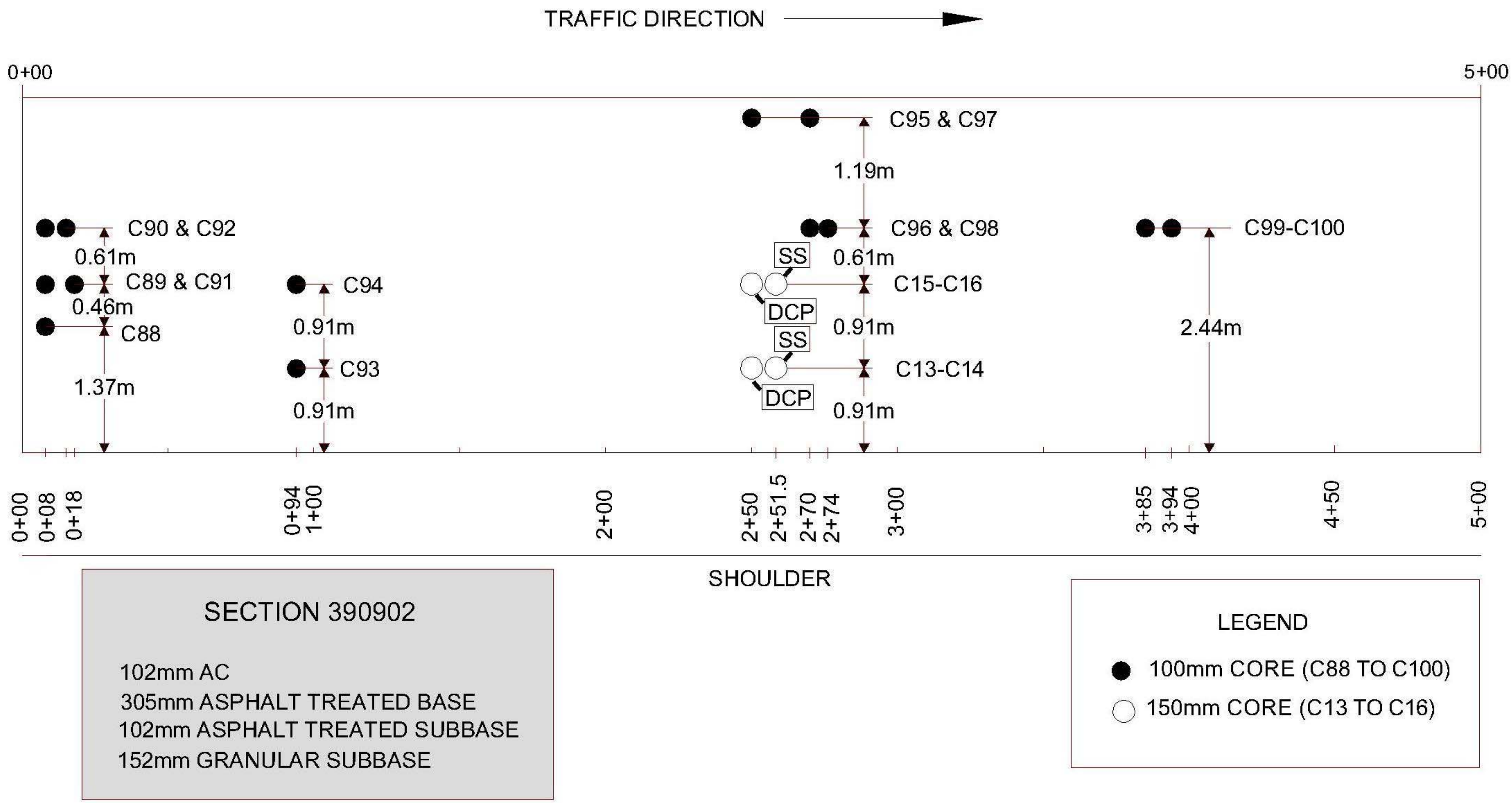

Figure 6: Layout of Sampling and Test Locations

5.4.1 Cores and Core Examination

The core sampling, handling, measurement and marking followed the same procedure as for section 390106. The details of the measurements and examination of the cores are provided in Table 19. Figure F-10, Appendix F provides a photo of the location and layout for the cores in the midlane and outer wheelpath at station 2+50. Figure F-11, Appendix F provides a photo showing the measurement and marking of the core along with a bond separation between layers 2 and 3 of the ATB. Figure F-12, Appendix F shows the cracks and voids evident in layers 2 and 3 of the 4 paving layers of ATB. Figure F-13, Appendix F shows the non woven geotextile fabric that was placed between the PATB and ATB. Figure F-14 provides a photo of the core hole with voids evident in the ATB. The 100mm cores taken at the longitudinal cracks indicated that the top down crack was evident through the surface and AC binder layers with stripping evident at the base of the surface layer and the AC binder layer. The photo in Figure F-15, Appendix F shows the longitudinal crack and associated deterioration of the bottom of the surface layer and the binder layer. The 100mm cores taken at the two of three transverse cracks indicated the top down cracks at these locations only went part way through the surface layer with all layers being intact. The core taken in the wheelpath at the location of the slightly longitudinal cracking were in the range of 100mm or greater. The core taken at the centerline paving joint showed no cracking, separation or bond issue.

Table 19: Summary of Core Measurement and Examination

6" Core	Station	PE Offset (m)	Layer	Measurements (mm)				Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top/ Bottom
Sample #				1	2	3	4											
C13	2+50	0.914	6	45.7	45.7	45.7	45.7	45.7	45.7	45.7	511.2	DCP	Y	N	Y	N	-	-
			5	58.4	58.4	58.4	58.4	58.4	58.4	58.4								
			4	304.8	304.8	302.3	302.3	302.3	304.8	303.5								
			3	104.1	104.1	101.6	104.1	101.6	104.1	103.5								
C15	2+50	1.83	6	45.7	48.3	48.3	48.3	45.7	48.3	47.6	529.6	DCP	Y	N	Y	N	-	-
			5	53.3	50.8	53.3	55.9	50.8	55.9	53.3								
			4	317.5	320	317.5	315	315	320	317.5								
			3	111.8	109.2	114.3	109.2	109.2	114.3	111.1								
C14	2+51.5	0.914	6	45.7	45.7	45.7	45.7	45.7	45.7	45.7	508.6	Split Spoon	Y	N	Y	N	-	-
			5	55.9	58.4	58.4	58.4	55.9	58.4	57.8								
			4	304.8	304.8	304.8	302.3	302.3	304.8	304.2								
			3	96.5	101.6	104.1	101.6	96.5	104.1	101								
C16	2+51.5	1.83	6	48.3	48.3	48.3	50.8	48.3	50.8	48.9	528.3	Split Spoon	Y	N	Y	N	-	-
			5	71.1	68.6	68.6	68.6	68.6	71.1	69.2								
			4	304.8	307.3	304.8	304.8	304.8	307.3	305.4								
			3	104.1	101.6	106.7	106.7	101.6	106.7	104.8								
4" Core																		
C88	0+08	1.37	6	45.7	44.5	45.7	44.5	44.5	45.7	45.1	509.9	transverse cracking	Y	N	Y	N		
			5	50.8	50.8	53.3	50.8	50.8	53.3	51.4								
			4	312.4	315	317.5	315	312.4	317.5	315								
			3	99.1	96.5	99.1	99.1	96.5	99.1	98.4								
C89	0+08	1.83	6	45.7	45.7	45.7	45.7	45.7	45.7	45.7	411.8	transverse cracking	N	N	Y	Y	2.5	T
			5	53.3	53.3	55.9	55.9	53.3	55.9	54.6								
			4	309.9	311.2	312.4	312.4	309.9	312.4	311.5								
			3															

Table 18 (Continued): Summary of Core Measurement and Examination

4" Core Sample #	Station	PE Offset (m)	Layer	Measurements (mm) 1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top/ Bottom
C93	0+94	0.914	6	43.2	44.5	43.2	43.2	43.2	44.5	43.5	502.6	transverse cracking	Y	N	Y	Y	2.5	T
			5	53.3	55.9	55.9	55.9	53.3	55.9	55.2								
			4	299.7	304.8	304.8	302.3	299.7	304.8	302.9								
			3	99.1	106.7	99.1	99.1	99.1	106.7	101								
C94	0+94	1.83	6	48.3	48.3	48.3	48.3	48.3	48.3	48.3	506.1	transverse cracking	Y	N	Y	Y	5.1	T
			5	55.9	55.9	58.4	55.9	55.9	58.4	56.5								
			4	304.8	304.8	299.7	309.9	299.7	309.9	304.8								
			3	96.5	96.5	96.5	96.5	96.5	96.5	96.5								
C90	0+08	2.44	6	45.7	45.7	44.5	45.7	44.5	45.7	45.4	415.6	longitudinal cracking	Y	N	Split	Y	99.1	T
			5	50.8	55.9	50.8	53.3	50.8	55.9	52.7								
			4	317.5	317.5	317.5		317.5	317.5	317.5								
			3															
C97	2+70	2.44	6	45.7	45.7	43.2	45.7	43.2	45.7	45.1	499.7	left WP	Y	N	Y	N		
			5	53.3	53.3	50.8	55.9	50.8	55.9	53.3								
			4	317.5	317.5	325.1	325.1	317.5	325.1	321.3								
			3	81.3	76.2	86.4	76.2	76.2	86.4	80								
C92	0+15	2.44	6	45.7	45.7	45.7	45.7	45.7	45.7	45.7	510.9	25mm from longitudinal cracking	Y	N	Y	N		
			5	58.4	58.4	63.5	57.2	57.2	63.5	59.4								
			4	309.9	304.8	297.2	309.9	297.2	309.9	305.4								
			3	99.1	101.6	101.6	99.1	99.1	101.6	100.3								
C98	2+74	2.44	6	45.7	45.7	45.7	45.7	45.7	45.7	45.7	509.3	longitudinal cracking	N	Y	Y	Y	12.7	T
			5	71.1	58.4	55.9	63.5	55.9	71.1	62.2								
			4	297.2	299.7	297.2	289.6	289.6	299.7	295.9								
			3	106.7	104.1	104.1	106.7	104.1	106.7	105.4								
C100	3+94	2.44	6	43.2	43.2	43.2	45.7	43.2	45.7	43.8	483.9	25mm from longitudinal cracking	Y	N	Y	N		
			5	58.4	58.4	58.4	55.9	55.9	58.4	57.8								
			4	299.7	299.7	299.7	299.7	299.7	299.7	299.7								
			3	82.6				82.6	82.6	82.6								

Table 18 (Continued): Summary of Core Measurement and Examination

4" Core Sample #	Station	PE Offset (m)	Layer	Measurements (mm) 1	2	3	4	Min.	Max.	Average	Total	Surface Distress	Void present	Rough Surface	Layer intact	Crack present	Avg. Crack depth (mm)	Crack at Top/ Bottom
C96	2+70	2.44	6	45.7	45.7	45.7	43.2	43.2	45.7	45.1	502.9	longitudinal cracking in WP	Y	Y	Y	N		
			5	53.3	53.3	50.8	53.3	50.8	53.3	52.7								
			4	299.7	299.7	299.7	299.7	299.7	299.7	299.7								
			3	106.7	106.7	101.6	106.7	101.6	106.7	105.4								
C99	3+85	2.44	6	44.5	44.5	44.5	44.5	44.5	44.5	44.5	521.3	longitudinal cracking in WP	Y	Y	Split	Y	109.2	T
			5	69.9	66	63.5	66	63.5	69.9	66.4								
			4	299.7	302.3	304.8	304.8	299.7	304.8	302.9								
			3	108	108	108	106.7	106.7	108	107.6								
C95	2+50	3.63	6	48.3	48.3	45.7	48.3	45.7	48.3	47.6	510.5	center-line longitudinal Joint	Y	N	Y	N		
			5	50.8	53.3	53.3	50.8	50.8	53.3	52.1								
			4	309.9	304.8	304.8	309.9	304.8	309.9	307.3								
			3	99.1	106.7	101.6	106.7	99.1	106.7	103.5								
C91	0+18	2.44	6	45.7	45.7	45.7	45.7	45.7	45.7	45.7	515	Longitudinal cracking in WP	Y	N	Split	Y	259.1	T
			5	55.9	58.4	58.4	58.4	55.9	58.4	57.8								
			4	307.3	304.8	317.5	304.8	304.8	317.5	308.6								
			3	104.1	101.6	101.6	104.1	101.6	104.1	102.9								

Notes: Measurements 1-4 are starting with traffic direction going clockwise.

Shading indicates measurement not available.

5.4.2 Split Spoon Sampling

Table 20 provides the results of the split-spoon sampling for the midlane and outer wheelpath locations sampled. The results indicate the aggregate base and subgrade materials are poor supporting layers. The values from the base material can be considered rather questionable as the base was damp from the core activity, along with the core spin off causing the top 25-50mm of material to loosen. The split-spoon field data sheets are provided in Appendix I.

Table 20: Summary of Split Spoon Sampling Results (16-Jul-08)

Location	Station *(ft)*	Offset *(m)*	Lane	Description	Moisture Content *(%)*	Depth (m)		Blows/150mm					
						From	*To*	*N-count*					
C14	2+51.5	0.91	OWP	~150mm granular base	9.0	0	0.914	9	7	8	10	8	10
				fine-grained silty clay w/ traces of shale	14.0								
C16		1.83	ML	~150mm granular base	8.0	0	0.914	8	5	7	8	6	6
				fine-grained silty clay w/ traces of shale	16.0								

5.4.3 DCP Testing

Table 21 provides the results from the DCP tests performed at the FWD test points in the midlane and outer wheelpath. The field moisture values were taken from the soil samples retrieved as part of the split-spoon sampling. Although the field moistures were slightly above optimum there were no adjustments to the DCP results; similarly there were no seasonal adjustment factors applied to the FWD results. The field data sheets are provided in Appendix H.

Table 21: Summary of DCP Test Results (17-Jul-08)

Location	Station *(ft)*	Offset *(m)*	Lane	Layer	Layer Type	Field Moisture *(%)*	DCPI *(mm/blow)*	DCP CBR	DCP Moduli *(MPa)*	FWD CBR	FWD Moduli *(MPa)*
C13	2+50	0.91	OWP	5 & 6	AC						15069.1
				2	Subbase	9	7	44	190.9	20	166.5
				1	Subgrade	14	10	25	137.1	13	103.1
BA15	2+50	1.83	ML	5 & 6	AC						10531.5
				2	Subbase	8	7	41	186.1	20	162.1
				1	Subgrade	16	13	17	108.2	13	104.5

5.4.4 Material Properties and Laboratory Test Results

The LTPP SPS-9 'Superpave' program was a study to evaluate the field performance of asphalt materials that were developed and based on the binder specifications and properties of premium mixes. Limited information was available from the LTPP database on the properties of the base, subbase and subgrade materials as the study was to evaluate and compare the performance of the AC bound materials. As part of the forensic study samples of the aggregate base and subgrade were extracted from the access created at the core holes at station 2+50 and forwarded to LTPP laboratory contractor (Braun/Intertec) for testing and analysis. The crushed aggregate base was removed by hand with a 120mm flight auger used to bring up the subgrade material to a depth of 2-meters. Table 22 summarizes the material properties for the aggregate subbase and subgrade collected at Station 2+50 as part of the forensic study conducted on July 17, 2008. Figures A-3 and A-4, Appendix A provides the list of material tests to be completed by Braun/Intertec.

Laboratory tests were conducted on the asphalt bound layers from material samples obtained during the processing and placement of the various pavement layers as part of the forensic testing. The results of the sampling and laboratory analysis available from the LTPP database have been summarized and included in this report. As part of the forensic investigation, core samples were collected from the midlane and outer wheelpath at station 2+50 and forwarded to the Ohio DOT test laboratory were the following tests were conducted.

- Binder extraction (% air voids, % binder, flexural creep stiffness-aged and indirect tension failure stress)
- Bulk and maximum specific gravity
- Resilient Modulus (Indirect Tension tests at 25 ºC)

These tests were conducted to determine the effects of aging on the hot mix asphalt and if any of these properties were factors in the performance of the bound pavement layers.

The pavement structure has shown limited distress with no signs of settlement and only minimal fatigue in the asphalt bound layers, which would indicate no issues were evident with the support structure. This section also had a PATB and drainage system installed which from a visual examination were still functional. As previously noted, the relatively high and variable water table in this area did not appear to have any affect on the pavement performance.

The crushed stone base was placed on the subgrade to a depth of 150mm. The density tests taken at time of construction indicate the compacted material was 90% of proctor based on the material tested as part of the forensic study. The field examination of the aggregate material found some separation of coarse and fine material during the loosening and hand removal. The subgrade was a fine-grained silty clay with traces of shale. This material was well compacted with the density results exceeding the requirements. The results of the nuclear density tests taken during the time of construction are provided in Table 23. The pavement structure has shown no signs of settlement or fatigue in the bottom layers of the asphalt bound materials. Some minor filtration of fines into the base material was noted but not considered an issue. The high and variable water table did not appear to be an issue with this pavement structure as it was constructed with a PATB layer along with a fabric drain layer and drain pipes, with no observed issues. The pavement layer thickness and aggregate properties are provided in Table 24. The high void PATB was 94% coarse aggregate with a maximum stone size of 25.4mm. The ATB was 42.5% coarse aggregate with a maximum stone size of 19mm. Information regarding the aggregate properties for the surface and AC binder layers at time of construction were limited as there were issues with some of the computations and samples were disposed of before additional tests could be accomplished.

The specifications for the AC-20 asphalt binder sourced from Amoco, Toledo, Ohio are the same as provided in Table 11. The summary of the asphalt properties are provided in Table 25. The Superpave binder was a PG 58-22. The various specification and laboratory results in Table 25 have a number of fields for which information was not available at the time of reporting.

The various AC properties for the materials sampled and tested shortly after construction and from the core samples taken as part of the forensic study are provided in Table 26. The information available indicated the air voids post construction ranged from 9.5 to 15% for the ATB, much higher than the design specification for this mix. The test results for the AC binder show a slight increase in the air voids with the average post construction being 7.6% and the forensic test results 9.5%. The surface course shows a decrease in air void content from 6.9% to 5.3%. These results would indicate a much higher variability for the ATB with minimal change for the AC binder and surface course over time. A comparison of the Bulk Specific Gravity (BSG) post construction and from the forensic tests shows a higher variability for the ATB for the recent test results with minimal difference between the timeframes for the AC binder and surface layers. The percentage of water absorption for the three layers ranged was very low with 0% on the samples derived from the forensic cores. The Maximum Specific Gravity (MSG) is very similar for those tests taken at the time of construction and the more recent tests taken as part of the forensic study.

Table 27 provides the results of the Resilient Moduli and binder property tests performed at the completion of construction and as part of the forensic study. The information as requested for the forensic laboratory testing, as was determined after a review of the LTPP database, would not provide direct comparative results to that of the data available in the LTPP database. In this instance, similar tests may not have been performed as they may not have been requested or the equipment to perform the testing may not have been available. The results from the forensic study would indicate that the AC binder layer strength and stiffness are somewhat less than that of the ATB or surface layers.

Table 22: Material Properties - Unbound Layers

Description	Subbase	Subgrade	Subgrade
Material (Code)	Crushed Stone (303)	Silty Clay (131)	Silty Clay (131)
Resilient Modulus (MPa)	125.1	135.8	127.1
Specific Gravity	2.783	2.738	2.745
Lab Max. Dry Density (kg/m^3)	2231	1928	1890
Lab Opt. Moisture Content (%)	8	12	14
Avg. In-situ Wet Density (kg/m^3)	2101	2168	2168
Avg. In-situ Dry Density (kg/m^3)	2020	1958	1958
Avg. In-situ Moisture Content (%)	4	10.7	10.7
Liquid Limit	16	35	36
Plastic Limit	17	15	16
Plasticity Index	NP	20	20
% Gravel	58	3	2
%Sand	31	24.4	20.9
Max Stone Size (mm)	25.4	12.7	9.5
% Passing #200	11	72.6	77.1

Table 23: Nuclear Density Testing at Time of Construction

Date	Station	Offset (m)	Layer Type	Layer	In-situ Dry Dens. (kg/m^3)	In-situ Moisture (%)
25-Jul-95	1+00	1.22	Subgrade	1	1871	11.5
	2+50				2012	10.0
	4+00				1992	10.6
28-Jul-95	5+50	1.83			1958	10.8
19-Aug-95	1+00		Gran. Subbase	2	2017	3.6
	2+50				2042	4.0
	4+00				2016	4.4
	5+50				2004	4.1
6-Oct-95	1+00		ATB	4	2145	
	2+50				2225	
	4+00				2188	
8-Oct-95	1+00		AC - Binder	5	2426	
	2+50				2223	
	4+00				2314	
15-Nov-95	1+00		AC - Surface	6	2095	
	2+50				2306	
	4+00				2270	

Note: AC bound layer density was reported as dry density

Table 24: Summary of Aggregate Material Properties - Bound Layers

Description	AC - Binder	ATB	PATB
Material (Code)	Hot Mixed, Hot Laid AC, Dense Graded (1)	Asphalt Treated Mixture (321)	Open Graded, Hot Laid, Central Plant Mix (325)
Layer #	5	4	3
% Gravel		42.5	94
% Sand		52.8	2.8
% Passing #200		4.8	3.2
Max Stone Size (mm)		19.1	25.4
BSG of Coarse Agg.	2.490	2.490	
Absorption (%)	2.8	2.8	
BSG of Fine Agg.	2.52	2.5	
Absorption (%)	2.4	2.2	

Note: Not all laboratory data available due to calculation errors – samples disposed of before corrections could be possible

Table 25: Summary of Asphalt Properties - Bound Layers

Description	AC - Surface			AC - Binder			Asphalt Treated Base		
Layer Number	6			5			4		
Material (Code)	Hot Mixed, Hot Laid AC, Dense Graded (1)			Hot Mixed, Hot Laid AC, Dense Graded (1)			Asphalt Treated Mixture (321)		
Placement Thickness (mm)	56			71			4 lifts of 94 (376)		
Compacted Thickness (mm)	46			58			304		
Asphalt Cements							Amoco AC-20		
High Temp. Perf. Grade (PG) Binder	58			58					
Low Temp. Perf. Grade (PG) Binder	28			28					
Bulk Specific Gravity	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***
	2.301	2.378	2.344	2.256	2.523	2.324			
Absorption (%)	0			2.35					
Maximum Specific Gravity	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***
	2.531	2.541	2.536	2.416	2.545	2.506	2.441	2.537	2.5
Design AC Content (%)		5.4							
Effective AC content (%)		4.1							
Design Air Voids (%)		4							
AC Content (%)				***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***
				5.5	6.7	6.21	5.2	6.1	5.5
M_R @ 25°C (MPa)	***Min***	***Max***	***Avg***						
	2440	5440	3391						
Poisson @ 25°C, v	***Min***	***Max***	***Avg***						
	0.23	0.55	0.39						
BSG of Coarse Aggregate				2.49					
Absorption of Coarse Aggregate (%)				2.8					
BSG of Fine Aggregate				2.52					
Absorption of Fine Aggregate (%)				2.4					
Penetration @ 77°F (0.1 mm)	59						33		
Penetration @ 115°F (0.1 mm)	233						223		
Penetration Index	2.4						0.1		
Specific Gravity	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***			
	1.027	1.027	1.027	1.028	1.041	1.028			
Kin. Visc. Calib. Constant (centistokes/s)				2.9					
Kin. Visc. Efflux Time (sec)				174.4					
Kin. Visc. @ 275°F (centistokes)	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***			
	229	229	229	229	507	285			
Abs. Visc. Calib. Factor (poise/sec)				63					
Abs. Visc. Flow Time (sec)				73.5					
Abs. Visc. Vacuum Pressure (in of Hg)				11.8					
Abs. Viscosity @ 140°F (poise)	***Min***	***Max***	***Avg***	***Min***	***Max***	***Avg***			
	928	928	928	928	4630	1668			
Indirect Tensile Strength (MPa)	***Min***	***Max***	***Avg***						
	0.52	1.26	0.858						
Indirect Tensile Calculated Poisson, v	***Min***	***Max***	***Avg***						
	0.29	0.75	0.48						
				99	100	99.8	100	100	100

Table 26: Post Construction and Forensic AC Properties

Sampling Date	Layer Type	Layer	Air Voids %			BSG			WATER ABS.	MSG		
			Min	Max	Avg	Min	Max	Avg	*(%)*	Min	Max	Avg
6-Dec-95	ATB	4								2.441	2.537	2.500
	AC - Binder	5	7	8.5	7.6	2.256	2.523	2.324	2.35	2.416	2.545	2.506
	AC -Surface	6	6.9	6.9	6.9	2.301	2.378	2.344	0	2.531	2.541	2.536
15-Jul-08	ATB	4	9.5	15.0	12.2	2.230	2.808	2.640	0	2.441	2.469	2.457
	AC - Binder	5	9.1	10.0	9.5	2.283	2.310	2.299	0	2.536	2.545	2.540
	AC -Surface	6	5.2	5.3	5.3	2.398	2.411	2.405	0	2.531	2.542	2.538

Table 27: Layer Moduli and Asphalt Binder Properties

Sampling Date	Layer Type	Layer	Complex Modulus *G* (kPa)*	Phase Angle *d (°)*	Stiffness *(MPa)*			M_R @ 25°C *(MPa)*			Poisson @ 25°C *(v)*			Indirect Tensile Strength *(MPa)*			Indirect Tensile Poisson *(v)*		
					Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	*Min*	*Max*	*Avg*	*Min*	*Max*	*Avg*
6-Dec-95	ATB	4																	
	AC - Binder	5																	
	AC - Surface	6						2440	5440	3391	0.23	0.55	0.39	0.52	1.26	0.858	0.29	0.75	0.48
15-Jul-08	ATB	4	9420	44.0	156.0	403.0	271.0												
	AC - Binder	5	5600	43.4	93.4	261.0	170.7												
	AC - Surface	6	7850	38.8	116.0	298.0	200.8												

5.5 Collection and Reporting of Monitoring Data

As part of the forensic testing at this LTPP SPS-1 site, Falling Weight Deflectometer (FWD), Manual Distress Survey (MDS), Transverse and Longitudinal Profiles and Elevation data were collected. This data has been added to the LTPP Information Management System (IMS) database. The pavement performance monitoring data has been analyzed and historical trends are reported as part of this document. Post construction FWD testing was performed in October of 1995 and material sampling began the following month in November. Profile and MDS data was collected on this section in August, 1996 and November, 1996 respectively. The following provides the results of the analysis and reports on the trends in the data from the initial data collected as part of the LTPP program to the last set of data collected as part of the forensic study.

5.5.1 Deflection Data Analysis Results

The average normalized temperature corrected deflections for the 40-KN equivalent loading for all the stations for both midlane and outer wheel path were plotted over time. The surface deflection trends, as reported from the sensor located under the load plate, are provided for all stations in Figure J-3, Appendix J. Similarly, the results representing the subgrade deflection trends, as reported from the sensor located 1.524 meters from the load plate, are provided for all stations in Figures J-4, Appendix J. The deflection trends indicate that the surface and subgrade deflections have been very stable with time as only a slight change is evident. The backcalculated resilient moduli for the pavement structure calculated from the historical FWD deflection data is provided in Figure J-7, Appendix J. The pavement moduli, as observed over time, indicates that minimal change is structural strength has occurred. The historical trend in subgrade resilient moduli is provided in Figure J-8, Appendix J. The results would indicate there has been minimal change to the subgrade support over time. The layer analysis, for the FWD deflection data collected on July 15, 2009, is provided in Table 28 with the statistical comparison provided in Table 29. These results, with a few exceptions, show the support layers to be relatively uniform over the length of the section in the wheelpath with the midlane showing a fair amount of variability. The moduli values for the aggregate base material is lower than expected; this could be the result of filtration of fines from the subgrade which was not separated by a filter layer and/or difficulties in backcalculating moduli from thin pavement layers.

Table 28: Summary of FWD Layer Analysis (15-Jul-08)

Lane	Chainage	AC (MPa)	ATB (MPa)	Subbase (MPa)	Subgrade (MPa)
ML	0+00	6202.71	5365.52	299.04	86.13
OWP		13552.30	6534.18	182.50	187.77
ML	0+50	17794.94	4469.45	189.53	188.20
OWP		19989.41	5397.97	184.77	195.53
ML	1+00	13990.76	5164.59	173.45	142.40
OWP		18582.38	6654.64	161.91	154.86
ML	1+50	12999.86	4812.96	132.51	125.78
OWP		13609.85	6068.53	160.50	121.89
ML	2+00	14384.22	4858.82	135.80	120.67
OWP		15834.47	5862.28	117.51	113.53
ML	2+50	10531.50	5666.52	162.05	104.54
OWP		15069.12	6929.37	166.50	103.14
ML	3+00	17634.31	3956.10	139.44	124.21
OWP		15889.61	5011.78	127.34	122.48
ML	3+50	13956.48	4720.28	206.36	167.67
OWP		15326.40	6304.05	172.95	167.60
ML	4+00	10711.30	5096.04	170.21	163.51
OWP		10490.64	6620.76	231.80	161.62
ML	4+50	11852.87	5624.50	179.57	163.51
OWP		12636.18	8194.31	226.49	155.73
ML	5+01	12058.99	5956.77	185.36	142.40
OWP	5+00	13936.43	6749.72	165.28	143.98

Table 29: Statistical Summary of FWD Layer Analysis

Layer	Lane	Min (MPa)	Max (MPa)	Avg (MPa)	Std. Dev. (MPa)
AC	ML	6202.7	17794.9	12919.8	3285.5
	OWP	10490.6	19989.4	14992.4	2653.4
ATB	ML	3956.1	5956.8	5062.9	581.4
	OWP	5011.8	8194.3	6393.4	842.2
Subbase	ML	132.5	299.0	179.4	46.1
	OWP	117.5	231.8	172.5	34.8
Subgrade	ML	86.1	188.2	139.0	30.3
	OWP	103.1	195.5	148.0	30.1

"Subgrade" column has been corrected using a factor of 0.33 in order to match field moduli

5.5.2 Manual Distress Data Analysis Results

The historical trend for the three distress types (fatigue cracks in wheel path, longitudinal cracking, and transverse cracks) evident on the pavement surface are provided in Figures K-3, K-4 and K-5 of Appendix K, respectively. The results are from both photo interpretation of the PASCO film and the Manual Distress surveys conducted from 1996 to the final distress survey on July 15, 2008. The survey results indicate that some signs of distress in the wheelpath became evident in 2001. The distress surveys between 2001 and 2004 classified the longitudinal wheelpath cracking as alligator cracking. The intermittent longitudinal crack on the edge of the inner wheelpath started in 2001 as a few meters in length and it wasn't until 2008 that its length increased to 18-meters. There were no transverse cracks identified until the survey conducted in 2008 at which time three moderate cracks were recorded. The visual observation indicated only minimal fracture of the cracks with no associated raveling or cracking. The Photos provided in Figures E-5 through E-7, Appendix E show the types of cracking and general pavement condition.

5.5.3 Longitudinal Profile Data Analysis Results

Figure 7 provides the historical IRI data for section 390902. A review of the Historical IRI shows no change in roughness over time for this flat and smooth pavement. Based on these results the ride quality can be considered excellent.

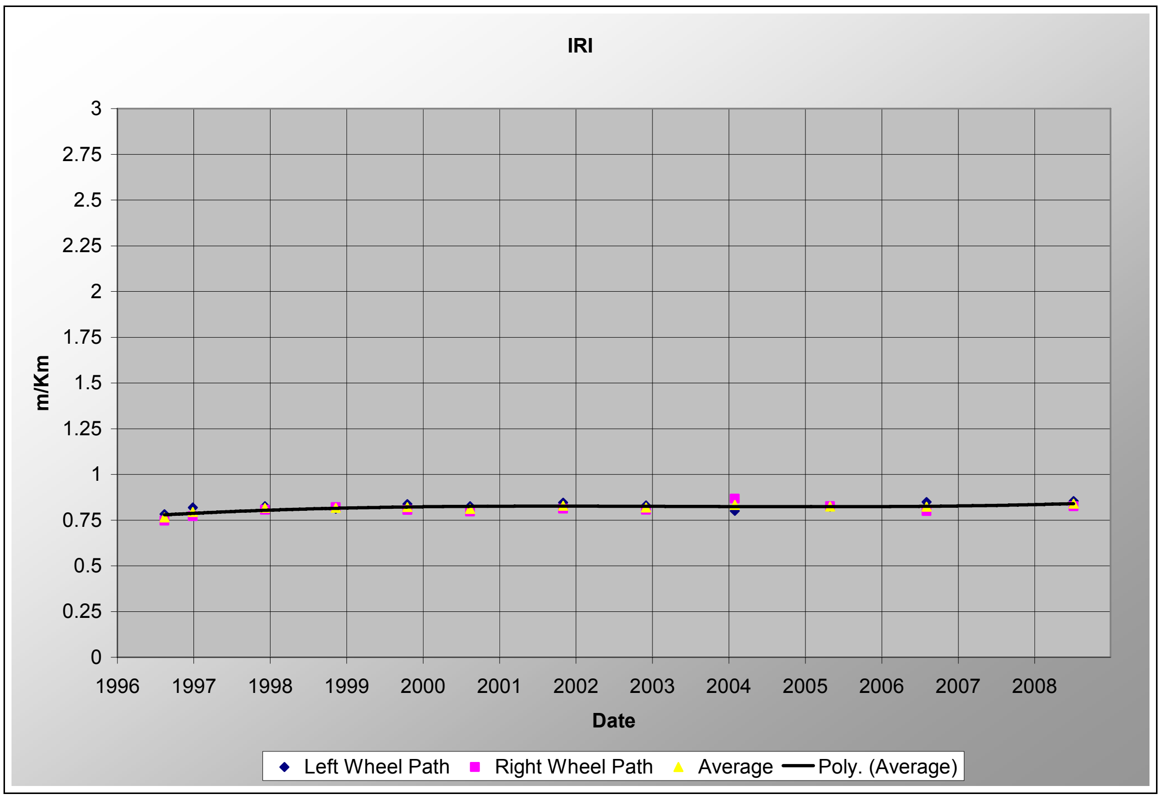

Figure 7: Historical Trend in IRI

5.5.4 Transverse Profile Data Analysis Results

The historical trends in rut depth from the Dipstick® transverse profiles are provided in Table 30. The average results are also provided in graphical format in Figure 8. These results indicate a very slight change in rut depth over time with the right rut in most cases being slightly deeper than the left. The average rut depth for the survey on July 15, 2008 was 1.4mm in the left wheelpath and 2.8mm in the right wheelpath with a maximum rut depth of 4.3mm. The results of the transverse profile survey indicate that rutting is not an issue for this section**.**

Table 30: Summary of the Historical Trend in Rut Depth

Survey Date	Left Depth (Wire Ref)			Right Depth (Wire Ref)			Max Mean (Wire Ref) Left or Right
	Mean	Min	Max	Mean	Min	Max	
6-Nov-96	0.6	0.1	1.6	1.1	0.4	2.0	1.1
12-Sep-99	0.8	0.2	1.6	1.9	1.2	3.4	1.9
12-Apr-01	1.0	0.3	1.9	2.0	1.3	3.0	2.0
29-Sep-04	1.1	0.3	2.0	2.3	1.7	3.2	2.3
15-Jul-08	1.4	0.8	2.3	2.8	1.7	4.3	2.8

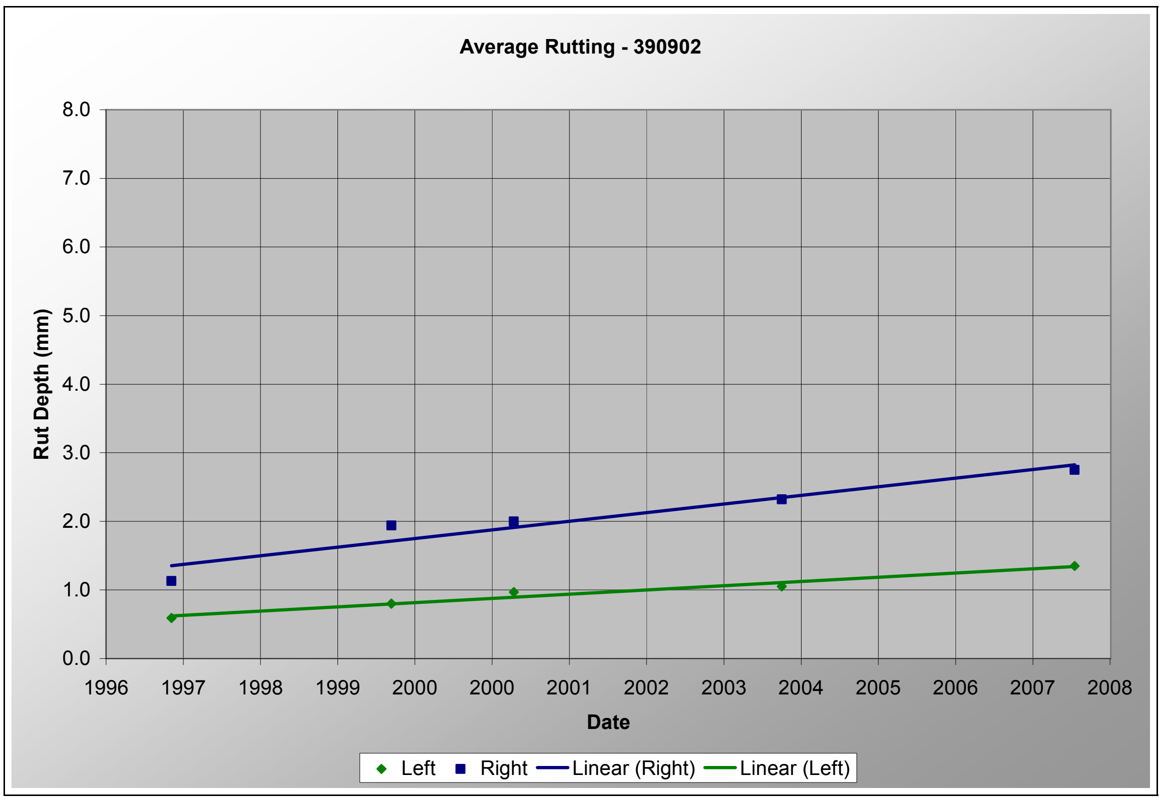

Figure 8: Graphical Presentation of Rut Depth

5.5.5 Elevation Data Analysis Results

A Six-Point set of levels were taken at 15.24m intervals over the 152.4m length of the section at centerline, right wheelpath, midlane, left wheelpath, pavement edge and 2m from edge on the paved shoulder. The results of the elevation survey are provided in

Figure 9. The results show a slight deviation in elevation at the wheelpath location with a 1.2% slope for the pavement and 3.2% slope from edge to 2m on the paved shoulder. These results would indicate sufficient slope for water runoff from the pavement surface. These results are consistent with those observed during the site review and as evident in the photo provided in Figure E-11, Appendix E.

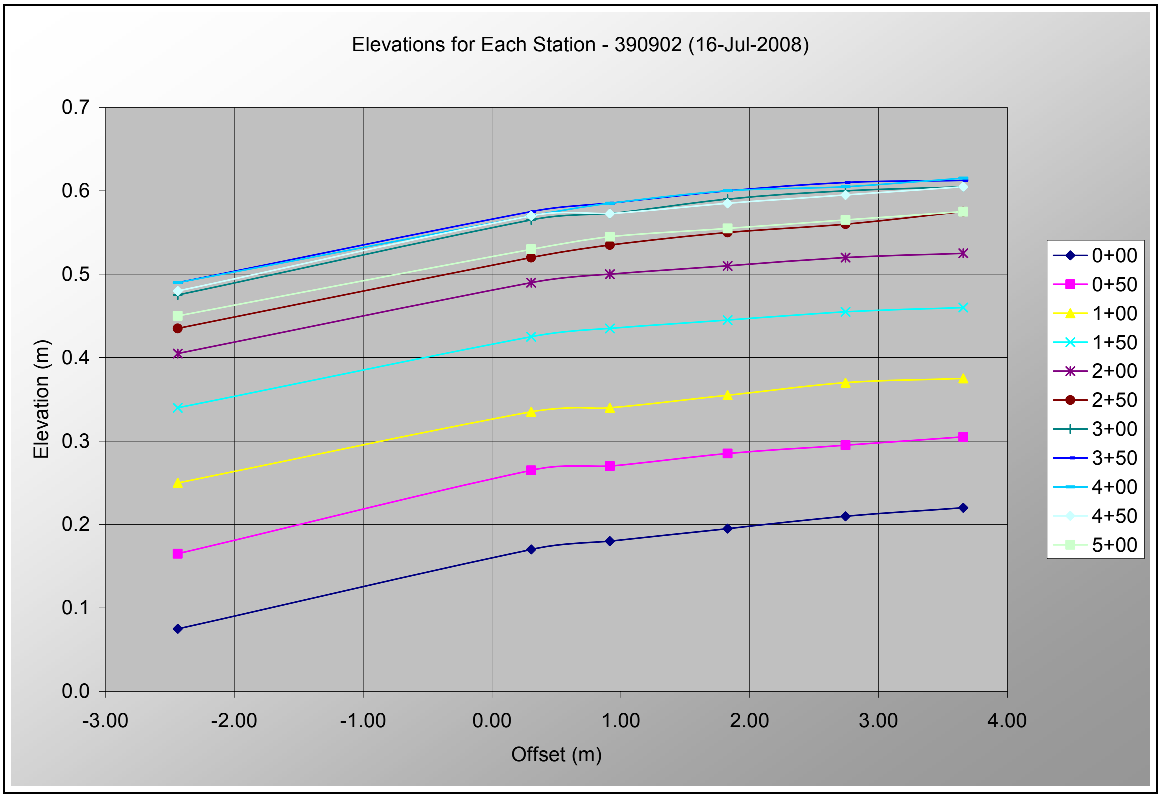

Figure 9: Results of Elevation Survey

5.6 Pavement Systems Performance

Based on the historical traffic data and inputs to the MEPDG, which were primarily extracted from the LTPP database, there should have been minimal cracking, rutting and ride deterioration observed on this section over the 12.5 years that this section was in service. The structural adequacy of this section should also have shown minimal change as the design of this section far exceeds the 20-year traffic projections for this section. The distress recorded as part of the distress surveys shows more cracking than projected; there was 18 linear meters of intermittent longitudinal cracking observed on the inner edge of the inner wheelpath for which a small portion had associated cracking and three transverse cracks starting from the edge of pavement progressing towards the centerline. Practically no rutting has occurred on this section based on the historical Dipstick® surveys. The ride quality for this section has been exceptional as it has maintained an IRI index that is virtually the same as when constructed. The pavement response, based on the FWD deflections, has shown minimal change with time and is more than structurally adequate for the traffic projections.

An examination of the cores taken at the time of the forensic survey indicated the main problem was with the intermittent longitudinal crack on the inner edge of the inner wheelpath. The longitudinal cracks were top down with some stripping of the surface and binder layer and a depth extending in to the ATB. The transverse cracking was only visible in the surface layer and did not have any associated deterioration. There were no signs of cracking of the centerline longitudinal joint; core samples taken from this area indicated no issues at the interface joint between the driving and passing lane. The examination of the cores also indicated the ATB, although primarily intact, did show some signs of distress at the interface of the second and third lifts. The laboratory analysis of the different bound layers indicated the biggest change was in the AC binder layer with the ATB layers being somewhat more variable at the time of the forensics when compared with the tests that were preformed post construction. The mix design properties, processing and placement of the various AC layers did not show any areas of concern. The layer thickness, aggregate properties, bituminous content, air voids, penetration etc. were all within the specifications provided by ODOT.

Based on the information available, it is difficult to determine the cause for the intermittent longitudinal crack that appears on the inner edge of the inner wheelpath. It is felt that this may have been an issue related to the failure of the paver to properly maintain the blend characteristics of the asphalt although there were no other signs that this could have been the problem. The transverse cracking observed on the surface of this section was very shallow unlike that of the longitudinal cracking indicating there is probably not a relationship between the two crack types. These cracks have only shown up recently to any proportion; as they progress it may become more evident as to the possible cause.

Based on the observations and evaluation this section does not require any immediate remedial activities but is a good candidate for preventative maintenance strategies to seal the observed longitudinal and transverse cracks.

6.0 Summary Discussion

1. A forensic study was conducted on a sections selected from the SPS-1 and SPS-9 projects on the southbound lanes of U.S. 23 in Delaware County, OH to evaluate the pavement performance and what may have contributed to the differences in performance of these rural arterial pavement sections with the same traffic and environmental conditions.
2. The primary differences between the SPS-1 390106 section and the SPS-9 390902 section is the thickness of the AC, drainage method, and characteristics of the of the asphalt mixes. Section 390106 has a AC layer thickness of 371mm that includes surface, binder and ATB layers whereas 390902 has a AC layer thickness of 503mm with surface, binder, ATB and PATB. Section 390106 relies on the slope of the pavement structure and a coarse aggregate base for drainage whereas 390902 has the additional benefit of the PATB and a non-woven geotextile fabric layer with 100mm drain piping to channel the water from the pavement. Both sections use a conventional AC-20 hot mix for the asphalt treated base layers but the 390902 section used the Superpave PG 58-28 binder for the AC surface and binder lifts. The AC aggregate, mineral fillers and admixes for this project followed ODOT specifications for surface, binder and asphalt treated bases.
3. The information from the LTPP database was used to populate the MEPDG inputs and determine the predicted performance characteristics for the two pavement types. The predicted performance indicated that both sections would meet the 90% Reliability criteria for a 20-year design term with the exception of rutting in the AC layers.
4. The distresses on section 390106 were longitudinal, alligator and block cracking with raveling covering the complete surface area. Four distinct longitudinal lines, spaced at 0.61m and starting 0.91 meters from the edge of pavement towards the centerline, appear on the pavement surface. Based on information acquired as part of the investigation, these lines (which formed longitudinal cracks) were associated with an issue with the paver slot conveyors that resulted in discontinuities and segregation of material during the laydown process. There was also cracking of the edge and centerline pavement joints. The ride quality for this section is approaching a level that would be considered in need of improvement. The distress on section 390902 included an intermittent longitudinal crack at the inner edge of the inner wheelpath with a very small portion having associated cracking and three transverse cracks from edge of pavement toward centerline. There were no observed edge or centerline joint cracks. The majority of cracking evident on 390902 has occurred recently as documented from the historical MDS surveys. The ride quality for this section, which has been shown little change since construction, is that of a new pavement. Based on surface condition section 390106 is in need of some form of rehabilitative activity whereas 390902 is only showing needs for some preventative maintenance activities.

5. The examination of cores taken from both sections indicated that all cracking was top down with a greater amount of stripping and deterioration at the interface of the surface and AC binder lifts visible on the cores from section 390106. The ATB from both sections had visible voids and there was some observed bonding issues between paving layers 2 and 3 of the ATB for section 390902. The interface of the AC bound layers with the aggregate base show minimal, if any, signs of stripping. The surface of 390106, which was starting to ravel, had some loose aggregate when probed with a sharp edge, whereas the surface for 390902 was firm and intact.
6. The analysis of the FWD data for section 390106 indicated that the deflections at the time of the forensic study were near double of what they were after construction. Similarly the resilient moduli backcalculated from the FWD data shows a sharp decrease in strength over time. The deflections and backcalculated resilient moduli representative of the subgrade show minimal change indicating that the structural failure is primarily in the bound layers. The analysis of the FWD data for 390902 shows minimal change over time in deflections and backcalculated resilient moduli. The structure for 390902 is over design for the predicted traffic and therefore should have a structural life greater than the 20 years.
7. Why the difference for performance of these two similar sections having the same traffic and environment? The analysis of the materials data did not reveal any results that would significantly affect the performance of these pavements. The PG grading for the Superpave mix used for the surface and AC binder lift has performed much better than that of the Hveem mix design using the AC-20 binder. The paver issue related to the placement with the Blaw Knox paver (creating longitudinal separations and segregation at the edges of the slot conveyors and the center point of the paver) did not appear to be an issue for the Superpave mixes, although the intermittent longitudinal crack at the inner edge of the outer wheelpath could be related to this issue. A common problem with AC mixes in the area of IL, IN and OH has been related to the additive polyphosphoric acid used as an anti-stripping agent. Input in a range of 0.5% this ingredient results in very good performance but if the rate of input is greater than 1% it can have a reverse effect resulting in premature raveling and stripping. Based on the surface condition and the stripping noted in the interface of the surface and AC binder lifts for 390106 this is also a possibility for the breakdown of the surface on this section. There was no information on any admixes being added to the Superpave mix which may have contained ‘pure’ binder.
8. After 12.5 years of service the requirement for these two sections is quite different. Section 390106 is in need of rehabilitative action to restore the surface condition and structural strength of the section. Section 390902 could have extended life with some minor maintenance such as crack sealing.

References

1. Shad M. Sargand et al, "Evaluation of Pavement Performance on Delaware 23 Interim Report-Forensic Study for Sections 390103, 390108, 390109, 390110 of Ohio SHRP U.S. 23 Test Pavement, January 2006
2. Stroup-Gardiner, M., "Influence of Segregation on Pavement Performance" AAPT vol. 69, 2000, pp 424-454.
3. Donna Harmelink, Tim Aschenbrener, "Extent of Top-Down Cracking in Colorado", Rpt CDOT-DTD-R-200-7, 2003.

Appendices

Appendix A - Meeting Minutes, Roles and Responsibilities

To: Meeting Attendees

From: Basel Abukhater

Date: **June 17, 2008**

Reference: **Notes of June 4/08 LTPP Meeting at OH DOT**
FILE: 1-745-52257 Phase 143

OH DOT LTPP Meeting: June 4/08 at the Wilderness Trail Conference Room, District 6, 400 E William Street, Delaware OH, from 10:00am.

Attendees:

- Roger Green, ODOT Pavement Engineer, 614-995-5993, Roger.Green@dot.state.oh.us
- Bill Edwards, Ohio University, 740-397-2837, Edwards@ecr.net
- Duane Soisson, ODOT District 6 MOT, 740-833-8162, Duane.Soisson@dot.state.oh.us
- Roger Ryder, FHWA Ohio Division, 614-280-6849, Roger.Ryder@fhwa.dot.gov
- Robert Lloyd, ODOT Delaware County, 740-833-8104, Robert.Lloyd@dot.state.oh.us
- Robert Taylor, ODOT District 6 Planning, 740-833-8354, Robert.Taylor@dot.state.oh.us
- Brandt Henderson, LTPP-Stantec Field Operations, 716-632-0804, brandtworks@bellnet.ca
- Gabe Cimini, LTPP-Stantec Data Base, 716-632-0804, Gabe.Cimini@Stantec.com
- Basel Abukhater, LTPP-Stantec Materials & Traffic, 716-632-0804, Basel.Abukhater@Stantec.com

The objective of the meeting was to discuss with the agency the details of the LTPP plan for conducting forensic investigation at one of the SPS-1 sections on the southbound lanes of US-23 in Delaware County. We need to "DETERMINE POSSIBLE CAUSES FOR FAILURES WITHIN THE TEST SECTION"

The LTPP North Central Regional Office (NCRO) Team handouts included the following items:

- Roles and Responsibilities
- Information Summary SPS Fact Sheets for the SPS-1 section
- OH DOT LTPP Forensic Investigation Tasks, Internal Document, Updated 6/3/08

The meeting began with introductions while Basel Abukhater distributed the handouts for the meeting. Brandt Henderson explained the background of the forensic program and how input from ODOT was part of the forensic plan.

The forensic plan is carried out over two days. The first day is for the monitored data collection. Deflection, Manual Distress, Transverse Elevations, Profiles, Video, Photos, and Drainage Assessment will be done during the first day and thus Traffic control will be the only item needed from ODOT.

The second day will be for the destructive testing. Coring, Split Spoon, Dynamic Cone Penetrometer (DCP), moisture sampling, and patching of holes will be done during the second day.

Section 390106 has been chosen as the section to test. Roger Green asked if deflection testing would be done on all sections, but because of the limited forensic funds, concentrating on one site would be the best option. If another site is desirable then we could alter the plan and perform measurements on more than one site. The issue of overtime was discussed and ODOT said overtime would not be an issue, so extended days would be acceptable. The entire SPS project will be overlaid in 2011.

Coring of the distressed locations would have to be done to investigate the cause. Coring would be done near the center line of the lane, at the mid lane, and at the edge of pavement, to view the consistency across the width of the pavement. Brandt asked if ODOT had dry cut coring capabilities and the response was that ODOT could not do dry cut coring. Brandt explained the process of doing a wet cut to a certain point and then cleaning out the water and punching through to simulate a dry cut. ODOT was familiar with that technique and agreed to let Brandt work with the coring crew to obtain this wet/dry cut core. Six inch cores will be required for the DCP locations.

Roger Green was concerned about the centerline coring interfering with the moving traffic but Brandt explained that the centerline coring was only for investigation and could be done so that it did not interfere with the moving traffic. Centerline coring will not be done if safety is a concern, as safety always comes first. With the four foot shoulder present on this site, Robert felt that it could be done.

Bill Edwards from Ohio University asked about the seasonal site and Basel responded that the seasonal sites are at the SPS-2 and SPS-9 experiments and we would not be investigating these sites. Roger mentioned that additional wells for water table height determination were present on the project and Brandt asked Roger to send a copy of the historical data from the wells (Roger provided this data on 6/5/08).

Brandt asked if ODOT could collect GPR data at this location and Roger responded that ODOT does not have a GPR unit to perform this task. Gabe added that GPR was collected by LTPP at this site in the past and we will use this information in the final report.

Brandt explained that a report will be produced documenting what was done. This report will be given to ODOT to review and edit as well as add more information. Roger added that the notes from the 1995 construction supervised by Braun/SME may still be available. He will check with Lisa from ODOT, who was also present during the construction, to see if she still has the notes that may help in answering some of the forensic investigation questions.

Gabe talked about the FactSheets handout explaining what is available in the LTPP database from this site. Roger noticed that there is a limited amount of Friction data available, which ODOT has and could supply for entry to the LTPP database. Gabe responded that Friction data was a requirement and later became optional, but if we receive it from ODOT then we can load it to the database.

Bill Edwards asked if we were going to test the permeability of the aggregate. Brandt felt it would be great if the University could do this test but our responsibility is limited to coring and handing over the samples to the University or ODOT to do the testing. Also, if this type of testing was desired than a bigger hole would have to be made to obtain these samples. All material obtained form the Spilt Spoon operation will be taken back with the North Central Regional Contractor for moisture analysis. The blow count will be recorded during the Split Spoon sampling and given to Brandt.

Basel asked ODOT to make sure that the utility clearance/permit is available before the forensic investigation starts. Roger will take care of this task.

At the end of the meeting Roger mentioned that site 390160 may have been overlaid recently. A visit to the site after the meeting by Roger, Brandt, Gabe, and Basel, confirmed that the site has not been overlaid yet. We discussed possibly looking at more than one section based on the information that ODOT will be providing the lane closure for the complete SPS-1 project to collect FWD data. We have 3 situations at the SPS-1 and SPS-9 projects; a state experiment section which has failed completely and the selected section which is showing deterioration, both at the SPS-1 site, and section 02 at the SPS-9 site which is showing minimal deterioration.

If any corrections are required please inform the author as soon as possible.

THANK YOU

Basel Abukhater

Basel Abukhater,
LTPP NORTHERN REGIONS – Traffic and Materials Manager

Copies:
Attendees
Jack Springer FHWA-LTPP
Frank Meyer LTPP-NCRO Project Manager
File Copy

Figure A-1 Meeting Minutes

Federal Highway Administration (FHWA) – Long Term Pavement Performance (LTPP) Forensic Investigation

AGENCY: OHIO **MEETING DATE: JUNE 4, 2008**

Roles and Responsibilities

There are a number of groups involved with the work done under this effort. The primary groups involved with this work include:

- FHWA-LTPP
- Highway Agency – Personnel for Materials Input, Traffic Control and Sampling
- Regional Support Contractor (RSC)
- Technical Support Services Contractor (TSSC)

	AGENCY			RSC
√	Traffic Control		√	Falling Weight Deflectometer (FWD) & Automated Temperature Data Logger (ATDL)
√	Core Unit with 4 ¼" OD barrel		√	Manual Distress Survey (MDS)
	Dry Core Unit with 6" OD barrel (DCP & Split Spoon locations)		√	Transverse Profiles
√	Boring Unit with Split Spoon		√	Longitudinal Profiles
?	Nuclear Gauge		√	Dynamic Cone Penetrometer (DCP)
√	Lab Work – Aging, Voids, Density		√	Video
√	Patching		√	Photos
√	Transport of Cores to Agency Lab		√	Water Table
	Ground Penetrating Radar (GPR)			Inspect Drainage System (no drainage, outlets off)
?	INO Unit, Rut Measurements		√	Five to Nine Point Elevations
√	Permit / Clearance		√	Mark Core Locations
			√	Wrap & Label Cores with Documentation
			√	Visual Examination & Thickness of Cores (Stripping – Photos)
			√	Lab Work - Moisture

Please check items approved

Agency Optional - Trenching

Figure A-2, Roles and Responsibilities

LONG TERM PAVMENT PERFORMANCE
FORENSIC EVALUATION AND PERFORMANCE
COMPARISONS OF LTPP SECTIONS 390106 AND 390902
U.S. RT. 23, DELAWARE, OHIO

SHRP ID:	
LOCATION STATION AND OFFSET:	
LOCATION NO:	
SAMPLE NO:	
DATE:	
FIELD SET:	

LAB TEST:	**SURFACE LAYER**	**BINDER LAYER**	**BASE LAYER**
	Check box when test is completed		
Bulk Specific Gravity - LTPP Protocol AC02/P02, Form T02 - AASHTO T166-88 (attached)			
Maximum Specific Gravity - LTPP Protocol AC03/P03, Form T03 - AASHTO T209-90 (attached)			
Dynamic Shear Rheometer - LTPP Protocol AE07/P27, Form T27 (attached)			
Bending Beam Rheometer - LTPP Protocol AE08/P28, Form T28 (attached)			
Direct Tension - LTPP Protocol AE09/P29, Form T29 (attached)			
Volumetric Analysis - AASHTO PP19 (attached)			

Figure A-3: Asphalt Material Tests to be Completed by Braun/Intertec

PROJECT LEVEL TESTS Forensic Investigation SPS-9 PROJECT 390900, Section 390902, US-23 SOUTHBOUND, DELAWARE, OH Sample Location: BA15 - Station 2+50, 6' Offset from PE					
		Layer Code	**A**	**A**	**B**
		Layer Number	**1** **Lower Subgrade Layer**	**1** **Upper Subgrade Layer**	**2** **Base Sample**
		Layer Type	**SS-131**	**SS-131**	**GB-303 DGAB**
		Sample Number	**BS16**	**BS15**	**BG15**
		Sample Size	**1 bag total 30 lbs**	**1 bag total 30 lbs**	**1 bag total 30 lbs**
SHRP Test	**SHRP Protocol**	**Laboratory Test Name**	**UNBOUND GRANULAR SUBGRADE & BASE**		
SS01	P51	Sieve Analysis	1	1	
SS02	P42	Sieve & Hydrometer	1	1	
SS03	P43	Atterberg Limits	1	1	
SS07	P46	Resilient Modulus	1	1	
SS13	P71	Specific Gravity	1	1	
UG01	P41	Particle Size Analysis			1
UG02	P41	Sieve Analysis			1
UG04	P43	Atterberg Limits			1
UG07	P46	Resilient Modulus			1
UG13	P71	Specific Gravity			1

Figure A-4: Granular Material Tests to be Completed by Braun/Intertec

Appendix B - Historical Environmental Data

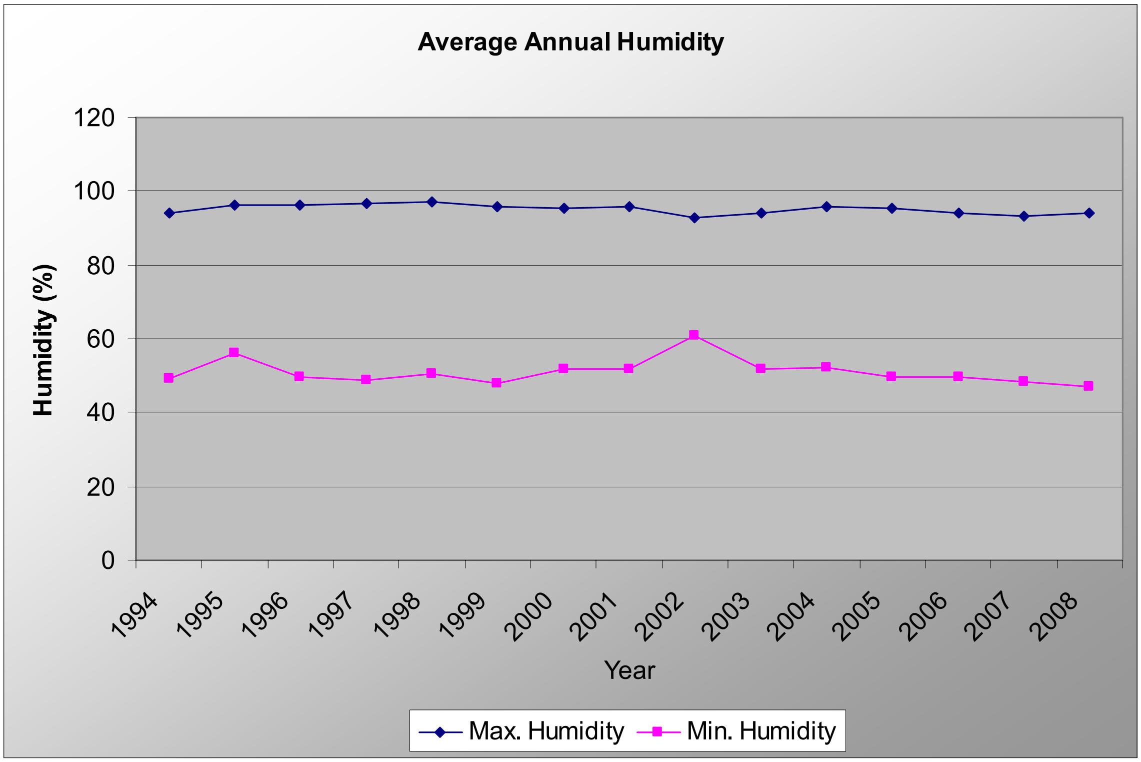

Figure B-1: Average Annual Humidity

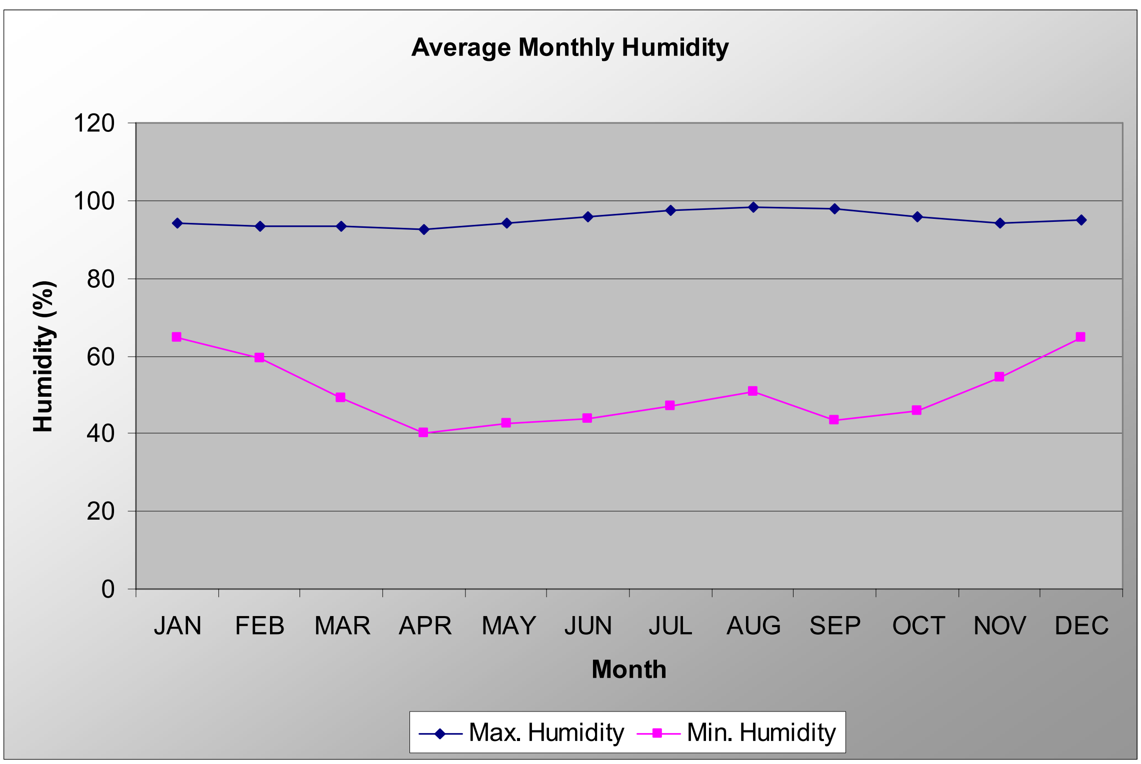

Figure B-2: Average Monthly Humidity

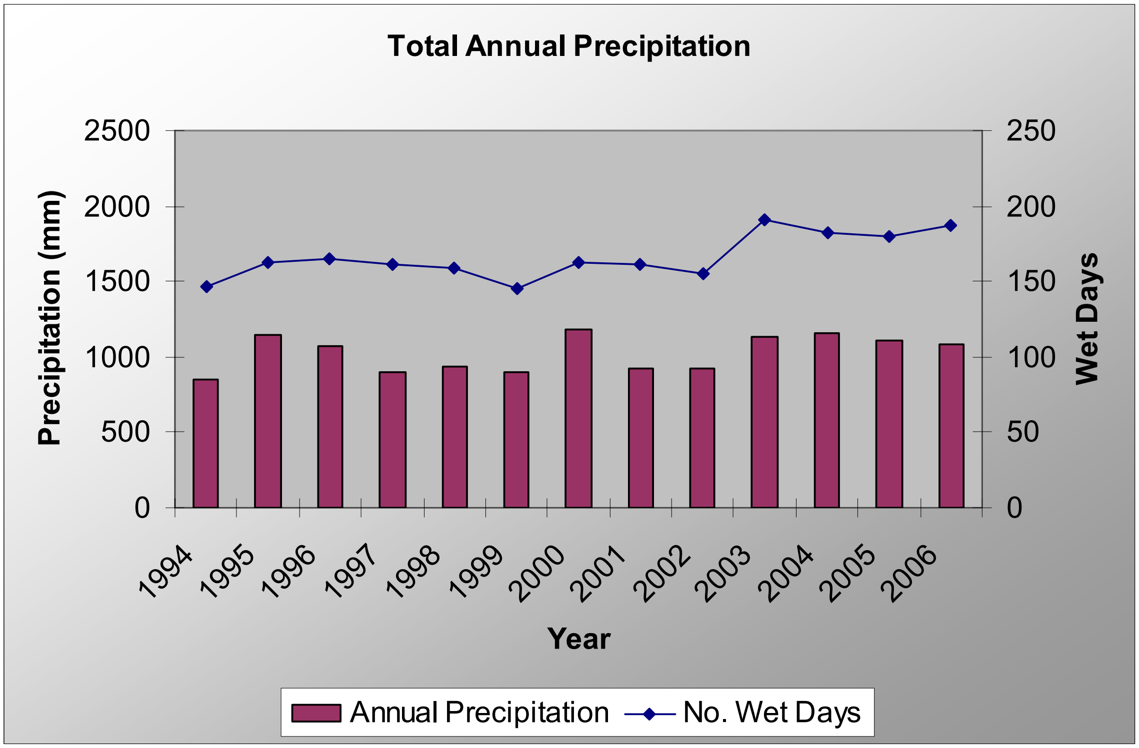

Figure B-3: Total Annual Precipitation

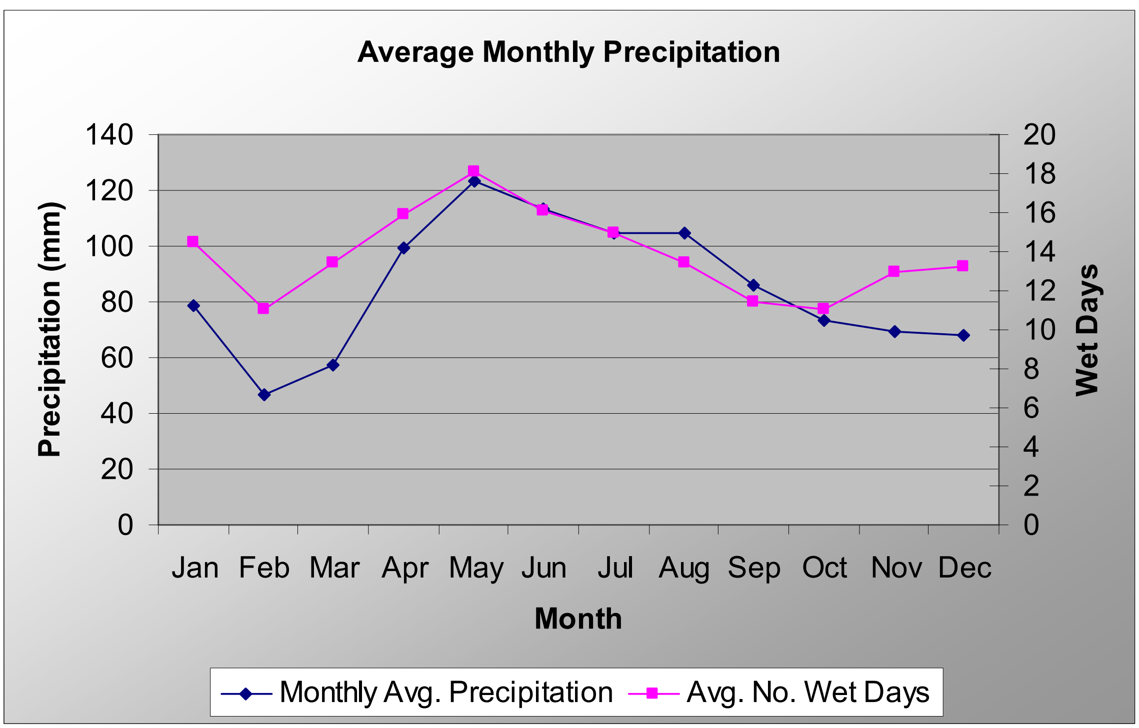

Figure B-4: Average Monthly Precipitation

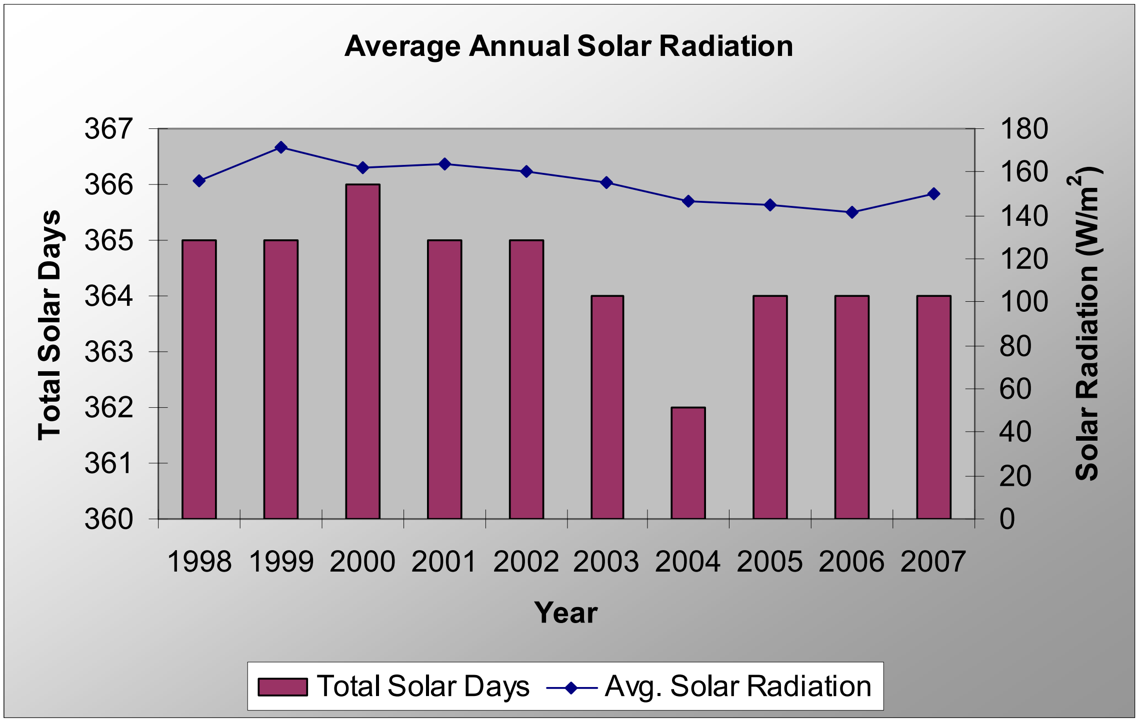

Figure B-5: Average Annual Solar Radiation

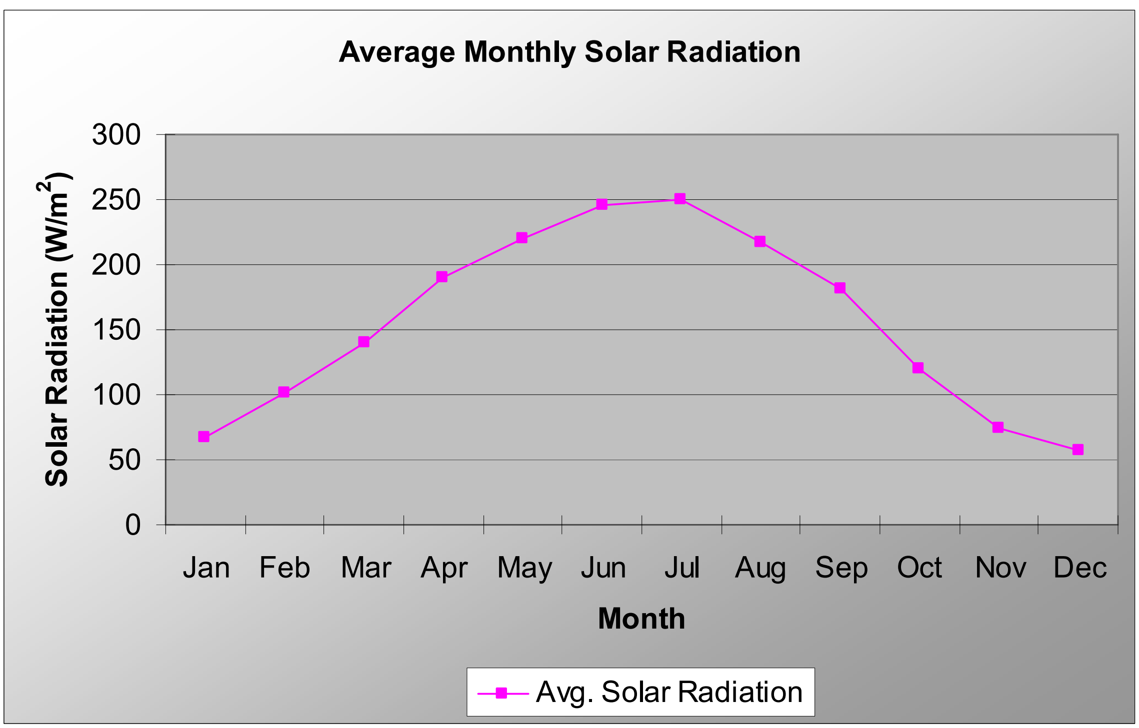

Figure B-6: Average Monthly Solar Radiation

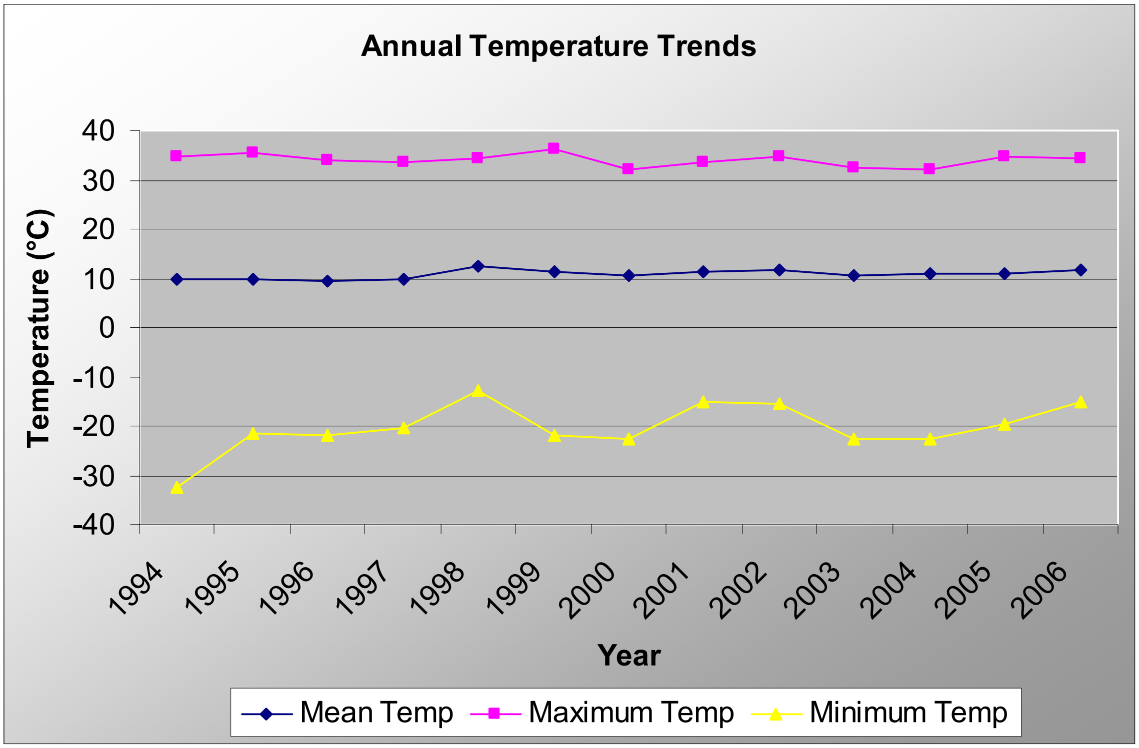

Figure B-7: Annual Temperature Trends

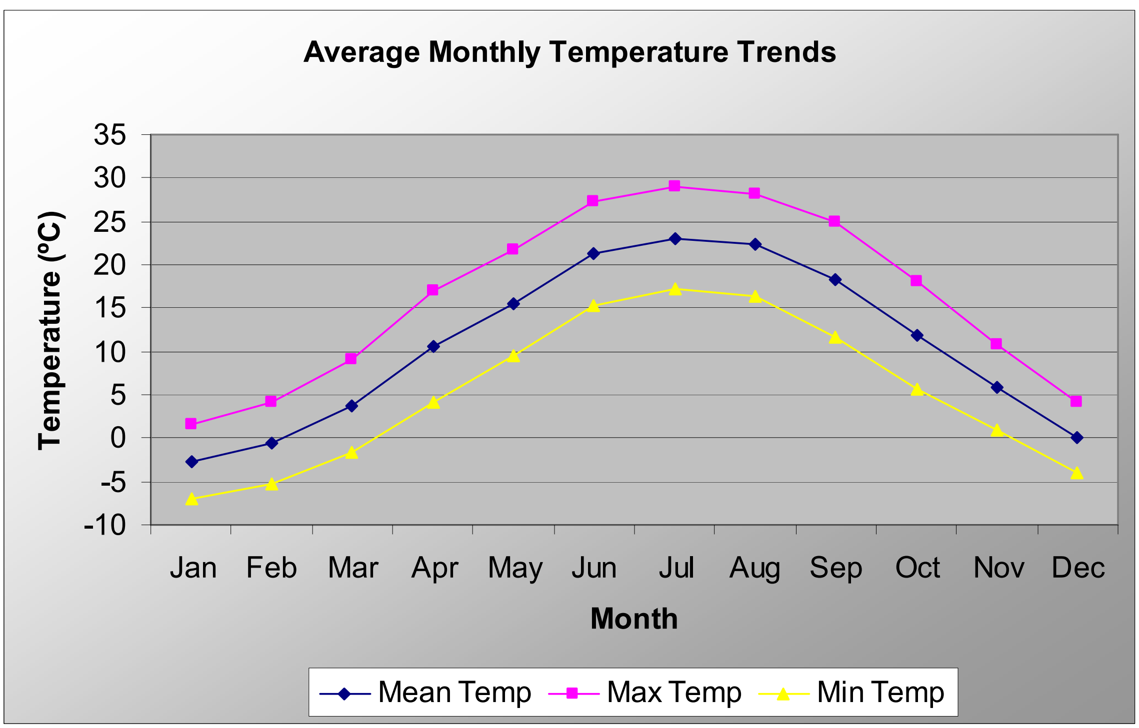

Figure B-8: Average Monthly Temperature Trends

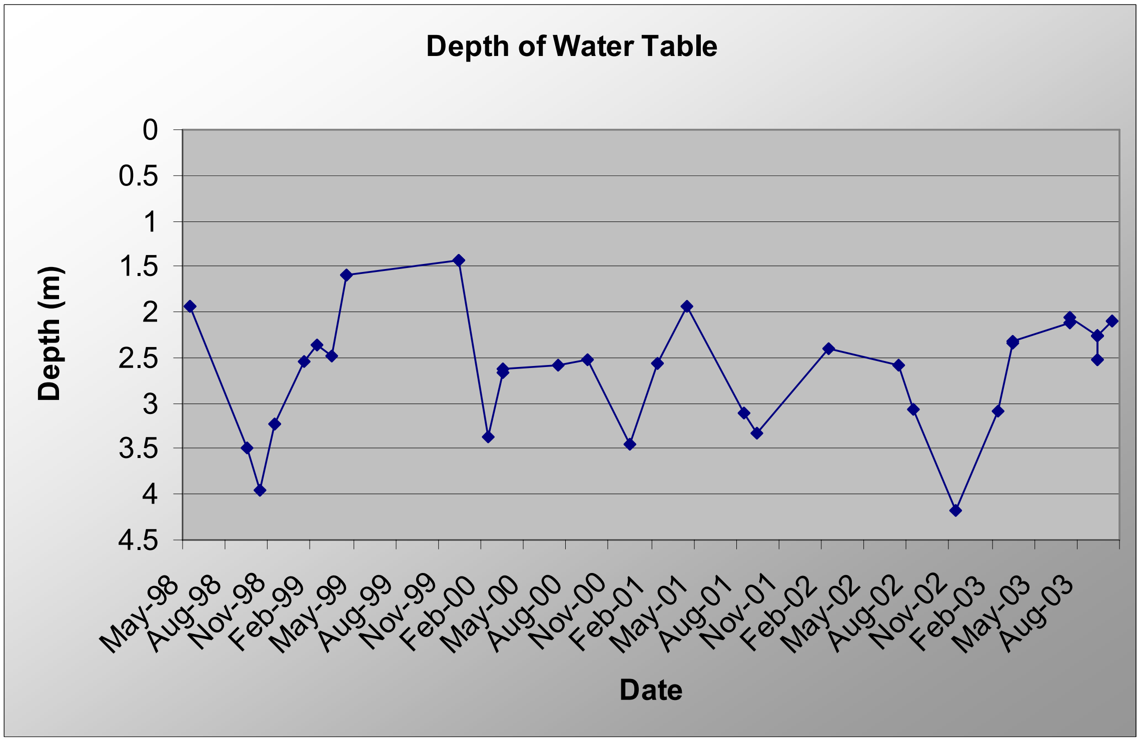

Figure B-9: Annual Water Table Trend From Section 390901

Appendix C - MEPDG Input Summary

Project: OH-390106.dgp

General Information

Design Life	20 years
Base/Subgrade construction:	August, 1995
Pavement construction:	September, 1995
Traffic open:	November, 1995
Type of design	Flexible

Description:

Analysis Parameters

Performance Criteria

	Limit	Reliability
Initial IRI (in/mi)	71.63	
Terminal IRI (in/mi)	172	90
AC Surface Down Cracking (Long. Cracking) (ft/mile):	2000	90
AC Bottom Up Cracking (Alligator Cracking) (%):	25	90
AC Thermal Fracture (Transverse Cracking) (ft/mi):	1000	90
Chemically Stabilized Layer (Fatigue Fracture)	25	90
Permanent Deformation (AC Only) (in):	0.25	90
Permanent Deformation (Total Pavement) (in):	0.75	90
Reflective cracking (%):	100	

Location:	Delaware, Ohio	
Project ID:		39
Section ID:		390106
Date:	8/17/2009	
Station/milepost format:	Miles: 0.000	
Station/milepost begin:		20.9
Station/milepost end:		19
Traffic direction:	South bound	

Default Input Level

Default input level	Level 3, Default and historical agency values.

Traffic

Initial two-way AADTT:	3444
Number of lanes in design direction:	2
Percent of trucks in design direction (%):	50
Percent of trucks in design lane (%):	87.1
Operational speed (mph):	55

Traffic -- Volume Adjustment Factors

Monthly Adjustment Factors (Level 1, Site Specific - MAF)

	Vehicle Class									
Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1.06	0.76	0.82	0.68	0.66	0.91	0.92	0.97	0.82	1.07
February	1.21	0.83	0.94	0.76	0.74	1.06	1.10	1.06	1.07	1.06
March	1.31	0.85	0.95	0.80	0.84	1.14	1.10	1.12	1.15	1.07
April	1.11	1.04	1.07	1.26	1.01	1.05	1.12	1.07	0.99	1.06
May	1.28	1.08	0.98	1.15	1.18	1.03	1.17	2.26	1.01	1.12
June	0.92	1.11	1.22	1.21	1.27	1.02	1.08	0.85	1.03	1.30
July	0.82	1.07	0.99	1.23	1.36	0.93	0.94	0.81	0.88	0.78
August	0.91	1.16	1.09	1.16	1.31	1.02	1.01	0.81	1.00	0.93
September	0.83	1.04	1.02	1.07	1.11	0.90	0.83	0.75	1.04	0.79
October	0.96	1.08	1.12	1.16	0.96	1.03	1.04	0.85	1.09	1.02
November	0.89	0.97	1.00	0.86	0.77	0.98	0.89	0.70	1.01	0.81
December	0.80	0.93	0.79	0.62	0.66	0.95	0.84	0.74	0.92	0.98

Vehicle Class Distribution
(Level 1, Site Specific Distribution)

AADTT distribution by vehicle class

Class 4	4.5%
Class 5	8.8%
Class 6	3.4%
Class 7	0.5%
Class 8	7.4%
Class 9	70.7%
Class 10	1.5%
Class 11	1.8%
Class 12	0.3%
Class 13	1.1%

Hourly truck traffic distribution
by period beginning:

Midnight	2.1%	Noon	6.2%
1:00 am	1.8%	1:00 pm	6.3%
2:00 am	1.9%	2:00 pm	6.2%
3:00 am	2.1%	3:00 pm	5.8%
4:00 am	2.6%	4:00 pm	5.5%
5:00 am	3.3%	5:00 pm	4.9%
6:00 am	4.0%	6:00 pm	4.4%
7:00 am	4.9%	7:00 pm	3.8%
8:00 am	5.5%	8:00 pm	3.3%
9:00 am	5.5%	9:00 pm	2.9%
10:00 am	5.9%	10:00 pm	2.6%
11:00 am	6.1%	11:00 pm	2.4%

Traffic Growth Factor

Vehicle Class	Growth Rate	Growth Function
Class 4	0.6%	Linear
Class 5	0.6%	Linear
Class 6	0.6%	Linear
Class 7	0.6%	Linear
Class 8	0.6%	Linear
Class 9	0.6%	Linear
Class 10	0.6%	Linear
Class 11	0.6%	Linear
Class 12	0.6%	Linear
Class 13	0.6%	Linear

Traffic -- Axle Load Distribution Factors

Level 1: Site Specific

Traffic -- General Traffic Inputs

Mean wheel location (inches from the lane marking):	18
Traffic wander standard deviation (in):	10
Design lane width (ft):	12.14

Number of Axles per Truck

Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.72	0.29	0.00	0.00
Class 5	2.00	0.01	0.00	0.00
Class 6	1.09	0.95	0.00	0.00
Class 7	1.61	0.31	0.37	0.29
Class 8	2.55	0.49	0.00	0.00
Class 9	1.22	1.89	0.00	0.00
Class 10	1.28	1.14	0.65	0.10
Class 11	4.90	0.04	0.01	0.00
Class 12	3.95	1.02	0.00	0.00
Class 13	2.53	1.06	0.13	0.49

Axle Configuration

Average axle width (edge-to-edge) outside dimensions,ft):	8.5
Dual tire spacing (in):	12

Axle Configuration

Tire Pressure (psi) :	120

Average Axle Spacing

Tandem axle(psi):	51.6
Tridem axle(psi):	49.2
Quad axle(psi):	49.2

Climate

icm file:	C:\Documents and Settings\colmedo\My Documents\MEPDG\OH\390106.icm
Latitude (degrees.minutes)	40.4
Longitude (degrees.minutes)	-83.07
Elevation (ft)	950
Depth of water table (ft)	8.23

Structure--Design Features

HMA E* Predictive Model:	NCHRP 1-37A viscosity based model.
HMA Rutting Model coefficients:	NCHRP 1-37A coefficients
Endurance Limit (microstrain):	None (0 microstrain)

Structure--Layers

Layer 1 -- Asphalt concrete

Material type:	Asphalt concrete
Layer thickness (in):	1.8

General Properties

General

Reference temperature (F°):	70

Volumetric Properties as Built

Effective binder content (%):	11
Air voids (%):	8.5
Total unit weight (pcf):	148

Poisson's ratio:	0.31 (user entered)

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve:	0
Cumulative % Retained 3/8 inch sieve:	12
Cumulative % Retained #4 sieve:	32.5
% Passing #200 sieve:	4.45

Asphalt Binder

Option:	Conventional viscosity grade
Viscosity Grade	AC 20
A	10.7709 (correlated)
VTS:	-3.6017 (correlated)

Thermal Cracking Properties

Average Tensile Strength at 14ºF:	388.07
Mixture VMA (%)	19.5
Aggregate coeff. thermal contraction (in./in.)	0.000005
Mix coeff. thermal contraction (in./in./ºF):	0.000013

Load Time (sec)	Low Temp. -4ºF (1/psi)	Mid. Temp. 14ºF (1/psi)	High Temp. 32ºF (1/psi)
1	2.7E-07	4.79E-07	6.87E-07
2	2.98E-07	5.61E-07	8.79E-07
5	3.39E-07	6.89E-07	1.22E-06
10	3.73E-07	8.06E-07	1.56E-06
20	4.11E-07	9.42E-07	1.99E-06
50	4.67E-07	1.16E-06	2.76E-06
100	5.14E-07	1.35E-06	3.53E-06

Layer 2 -- Asphalt concrete

Material type:	Asphalt concrete
Layer thickness (in):	5

General Properties

General

Reference temperature (F°):	77

Volumetric Properties as Built

Effective binder content (%):	11
Air voids (%):	8.5
Total unit weight (pcf):	148
Poisson's ratio:	0.29 (user entered)

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve:	0
Cumulative % Retained 3/8 inch sieve:	12
Cumulative % Retained #4 sieve:	32.5
% Passing #200 sieve:	4.45

Asphalt Binder

Option:	Conventional viscosity grade
Viscosity Grade	AC 20
A	10.7709 (correlated)
VTS:	-3.6017 (correlated)

Layer 3 -- Asphalt permeable base

Material type:	Asphalt permeable base
Layer thickness (in):	7.9

General Properties

General

Reference temperature (F°):	77

Volumetric Properties as Built

Effective binder content (%):	11
Air voids (%):	8.5
Total unit weight (pcf):	148

Poisson's ratio: 0.16 (user entered)

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve:	0
Cumulative % Retained 3/8 inch sieve:	23
Cumulative % Retained #4 sieve:	42.5
% Passing #200 sieve:	4.75

Asphalt Binder

Option:	Conventional viscosity grade
Viscosity Grade	AC 20
A	10.7709 (correlated)
VTS:	-3.6017 (correlated)

Layer 4 -- Crushed stone

Unbound Material:	Crushed stone
Thickness(in):	3.8

Strength Properties

Input Level:	Level 3
Analysis Type:	ICM inputs (ICM Calculated Modulus)
Poisson's ratio:	0.35
Coefficient of lateral pressure,Ko:	0.5
Modulus (input) (psi):	30000

ICM Inputs

Gradation and Plasticity Index

Plasticity Index, PI:	1
Liquid Limit (LL)	6
Compacted Layer	No
Passing #200 sieve (%):	8.7
Passing #40	20
Passing #4 sieve (%):	44.7
D10(mm)	0.1035
D20(mm)	0.425
D30(mm)	1.306
D60(mm)	10.82
D90(mm)	46.19

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8"	57.2
1/2"	63.1
3/4"	72.7
1"	78.8
1 1/2"	85.8
2"	91.6
2 1/2"	
3"	
3 1/2"	97.6
4"	97.6

Calculated/Derived Parameters

Maximum dry unit weight (pcf): 127.2 (derived)
Specific gravity of solids, Gs: 2.76 (user input)
Saturated hydraulic conductivity (ft/hr): 0.05054 (derived)
Optimum gravimetric water content (%): 7.4 (derived)
Calculated degree of saturation (%): 57.4 (calculated)

Soil water characteristic curve parameters: Default values

Parameters	Value
a	7.2555
b	1.3328
c	0.82422
Hr.	117.4

Layer 5 -- A-6

Unbound Material:	A-6
Thickness(in):	Semi-infinite

Strength Properties

Input Level:	Level 3
Analysis Type:	ICM inputs (ICM Calculated Modulus)
Poisson's ratio:	0.35
Coefficient of lateral pressure,Ko:	0.5
Modulus (input) (psi):	19682

ICM Inputs

<u>Gradation and Plasticity Index</u>

Plasticity Index, PI:	12
Liquid Limit (LL)	28
Compacted Layer	Yes
Passing #200 sieve (%):	70.6
Passing #40	84
Passing #4 sieve (%):	96
D10(mm)	0.0002554
D20(mm)	0.0006523
D30(mm)	0.001666
D60(mm)	0.02776
D90(mm)	1.358

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	70.6
#100	
#80	77
#60	
#50	
#40	84
#30	
#20	
#16	
#10	92
#8	
#4	96
3/8"	98
1/2"	99
3/4"	100
1"	100
1 1/2"	100
2"	100
2 1/2"	
3"	100
3 1/2"	
4"	

<u>Calculated/Derived Parameters</u>

Maximum dry unit weight (pcf):	110.4 (derived)
Specific gravity of solids, Gs:	2.76 (user input)
Saturated hydraulic conductivity (ft/hr):	2.013e-005 (derived)
Optimum gravimetric water content (%):	16.2 (derived)
Calculated degree of saturation (%):	79.8 (calculated)

Soil water characteristic curve parameters: Default values

Parameters	Value
a	102.6
b	0.7195
c	0.25424
Hr.	500

Distress Model Calibration Settings - Flexible

AC Fatigue	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	0.007566
k2	3.9492
k3	1.281
AC Rutting	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
	-
k1	3.35412
k2	1.5606
k3	0.4791
Standard Deviation Total Rutting (RUT):	0.24*POWER(RUT,0.8026)+0.001
Thermal Fracture	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	1.5
Std. Dev. (THERMAL):	0.1468 * THERMAL + 65.027
CSM Fatigue	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	1
k2	1
Subgrade Rutting	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
Granular:	
k1	2.03
Fine-grain:	
k1	1.35
AC Cracking	
AC Top Down Cracking	
C1 (top)	7
C2 (top)	3.5
C3 (top)	0
C4 (top)	1000
Standard Deviation (TOP)	200 + 2300/(1+exp(1.072-2.1654*log(TOP+0.0001)))

AC Bottom Up Cracking

C1 (bottom)	1
C2 (bottom)	1
C3 (bottom)	0
C4 (bottom)	6000
Standard Deviation (TOP)	1.13+13/(1+exp(7.57-15.5*log(BOTTOM+0.0001)))

CSM Cracking

C1 (CSM)	1
C2 (CSM)	1
C3 (CSM)	0
C4 (CSM)	1000
Standard Deviation (CSM)	CTB*1

IRI

IRI HMA Pavements New

C1(HMA)	40
C2(HMA)	0.4
C3(HMA)	0.008
C4(HMA)	0.015

IRI HMA/PCC Pavements

C1(HMA/PCC)	40.8
C2(HMA/PCC)	0.575
C3(HMA/PCC)	0.0014
C4(HMA/PCC)	0.00825

Figure C-1, 390106 MEPDG Input Summary

Project: OH-390902.dgp

General Information

Design Life	20 years
Base/Subgrade construction:	August, 1995
Pavement construction:	September, 1995
Traffic open:	January, 1996
Type of design	Flexible

Description:

Analysis Parameters

Performance Criteria

	Limit	Reliability
Initial IRI (in/mi)	48.48	
Terminal IRI (in/mi)	172	90
AC Surface Down Cracking (Long. Cracking) (ft/mile):	2000	90
AC Bottom Up Cracking (Alligator Cracking) (%):	25	90
AC Thermal Fracture (Transverse Cracking) (ft/mi):	1000	90
Chemically Stabilized Layer (Fatigue Fracture)	25	90
Permanent Deformation (AC Only) (in):	0.25	90
Permanent Deformation (Total Pavement) (in):	0.75	90
Reflective cracking (%):	100	

Location:	Delaware, Ohio	
Project ID:		39
Section ID:		390902
Date:	8/17/2009	
Station/milepost format:	Miles: 0.000	
Station/milepost begin:		18.5
Station/milepost end:		17.7
Traffic direction:	South bound	

Default Input Level

Default input level	Level 3, Default and historical agency values.

Traffic

Initial two-way AADTT:	3444
Number of lanes in design direction:	2
Percent of trucks in design direction (%):	50
Percent of trucks in design lane (%):	87.1
Operational speed (mph):	55

Traffic -- Volume Adjustment Factors

Monthly Adjustment Factors (Level 1, Site Specific - MAF)

	Vehicle Class									
Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1.06	0.76	0.82	0.68	0.66	0.91	0.92	0.97	0.82	1.07
February	1.21	0.83	0.94	0.76	0.74	1.06	1.10	1.06	1.07	1.06
March	1.31	0.85	0.95	0.80	0.84	1.14	1.10	1.12	1.15	1.07
April	1.11	1.04	1.07	1.26	1.01	1.05	1.12	1.07	0.99	1.06
May	1.28	1.08	0.98	1.15	1.18	1.03	1.17	2.26	1.01	1.12
June	0.92	1.11	1.22	1.21	1.27	1.02	1.08	0.85	1.03	1.30
July	0.82	1.07	0.99	1.23	1.36	0.93	0.94	0.81	0.88	0.78
August	0.91	1.16	1.09	1.16	1.31	1.02	1.01	0.81	1.00	0.93
September	0.83	1.04	1.02	1.07	1.11	0.90	0.83	0.75	1.04	0.79
October	0.96	1.08	1.12	1.16	0.96	1.03	1.04	0.85	1.09	1.02
November	0.89	0.97	1.00	0.86	0.77	0.98	0.89	0.70	1.01	0.81
December	0.80	0.93	0.79	0.62	0.66	0.95	0.84	0.74	0.92	0.98

Vehicle Class Distribution

(Level 1, Site Specific Distribution)

AADTT distribution by vehicle class

Class 4	4.5%
Class 5	8.8%
Class 6	3.4%
Class 7	0.5%
Class 8	7.4%
Class 9	70.7%
Class 10	1.5%
Class 11	1.8%
Class 12	0.3%
Class 13	1.1%

Hourly truck traffic distribution

by period beginning:

Midnight	2.1%	Noon	6.2%
1:00 am	1.8%	1:00 pm	6.3%
2:00 am	1.9%	2:00 pm	6.2%
3:00 am	2.1%	3:00 pm	5.8%
4:00 am	2.6%	4:00 pm	5.5%
5:00 am	3.3%	5:00 pm	4.9%
6:00 am	4.0%	6:00 pm	4.4%
7:00 am	4.9%	7:00 pm	3.8%
8:00 am	5.5%	8:00 pm	3.3%
9:00 am	5.5%	9:00 pm	2.9%
10:00 am	5.9%	10:00 pm	2.6%
11:00 am	6.1%	11:00 pm	2.4%

Traffic Growth Factor

Vehicle Class	Growth Rate	Growth Function
Class 4	0.6%	Linear
Class 5	0.6%	Linear
Class 6	0.6%	Linear
Class 7	0.6%	Linear
Class 8	0.6%	Linear
Class 9	0.6%	Linear
Class 10	0.6%	Linear
Class 11	0.6%	Linear
Class 12	0.6%	Linear
Class 13	0.6%	Linear

Traffic -- Axle Load Distribution Factors

Level 1: Site Specific

Traffic -- General Traffic Inputs

Mean wheel location (inches from the lane marking):	18
Traffic wander standard deviation (in):	10
Design lane width (ft):	12.14

Number of Axles per Truck

Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.72	0.29	0.00	0.00
Class 5	2.00	0.01	0.00	0.00
Class 6	1.09	0.95	0.00	0.00
Class 7	1.61	0.31	0.37	0.29
Class 8	2.55	0.49	0.00	0.00
Class 9	1.22	1.89	0.00	0.00
Class 10	1.28	1.14	0.65	0.10
Class 11	4.90	0.04	0.01	0.00
Class 12	3.95	1.02	0.00	0.00
Class 13	2.53	1.06	0.13	0.49

Axle Configuration

Average axle width (edge-to-edge) outside dimensions,ft):	8.5
Dual tire spacing (in):	12

Axle Configuration

Tire Pressure (psi) :	120

Average Axle Spacing

Tandem axle(psi):	51.6
Tridem axle(psi):	49.2
Quad axle(psi):	49.2

Climate

icm file: C:\DG2002\Projects\OH-390902\390902.icm

Latitude (degrees.minutes)	40.39416
Longitude (degrees.minutes)	-83.0742
Elevation (ft)	955
Depth of water table (ft)	8.23

Structure--Design Features

HMA E* Predictive Model:	NCHRP 1-37A viscosity based model.
HMA Rutting Model coefficients:	NCHRP 1-37A coefficients
Endurance Limit (microstrain):	None (0 microstrain)

Structure--Layers

Layer 1 -- Asphalt concrete

Material type:	Asphalt concrete
Layer thickness (in):	1.8

General Properties

General

Reference temperature (F°): 77

Volumetric Properties as Built

Effective binder content (%):	11
Air voids (%):	4
Total unit weight (pcf):	148

Poisson's ratio: 0.35 (user entered)

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve:	0
Cumulative % Retained 3/8 inch sieve:	12
Cumulative % Retained #4 sieve:	32.5
% Passing #200 sieve:	4.45

Asphalt Binder

Option:	Superpave binder grading
A	11.0100 (correlated)
VTS:	-3.7010 (correlated)

High temp. °C	Low temperature, °C						
	-10	-16	-22	-28	-34	-40	-46
46							
52							
58							
64							
70							
76							
82							

Thermal Cracking Properties

Average Tensile Strength at 14ºF:	425.93
Mixture VMA (%)	15
Aggregate coeff. thermal contraction (in./in.)	0.000005
Mix coeff. thermal contraction (in./in./ºF):	0.000013

Load Time (sec)	Low Temp. -4ºF (1/psi)	Mid. Temp. 14ºF (1/psi)	High Temp. 32ºF (1/psi)
1	2.57E-07	3.58E-07	4.53E-07
2	2.84E-07	4.22E-07	5.97E-07
5	3.24E-07	5.24E-07	8.6E-07
10	3.58E-07	6.17E-07	1.13E-06
20	3.96E-07	7.28E-07	1.49E-06
50	4.51E-07	9.04E-07	2.15E-06
100	4.99E-07	1.07E-06	2.84E-06

Layer 2 -- Asphalt concrete

Material type: Asphalt concrete
Layer thickness (in): 2.3

General Properties

General
Reference temperature (F°): 77

Volumetric Properties as Built
Effective binder content (%): 11
Air voids (%): 8.5
Total unit weight (pcf): 148

Poisson's ratio: 0.35 (user entered)

Thermal Properties
Thermal conductivity asphalt (BTU/hr-ft-F°): 0.67
Heat capacity asphalt (BTU/lb-F°): 0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve: 0
Cumulative % Retained 3/8 inch sieve: 12
Cumulative % Retained #4 sieve: 32.5
% Passing #200 sieve: 4.45

Asphalt Binder

Option: Superpave binder grading
A 11.0100 (correlated)
VTS: -3.7010 (correlated)

High temp. °C	Low temperature, °C						
	-10	-16	-22	-28	-34	-40	-46
46							
52							
58							
64							
70							
76							
82							

Layer 3 -- Asphalt concrete

Material type:	Asphalt concrete
Layer thickness (in):	12

General Properties

General

Reference temperature (F°):	70

Volumetric Properties as Built

Effective binder content (%):	11
Air voids (%):	8.5
Total unit weight (pcf):	148

Poisson's ratio:	0.23 (user entered)

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve:	0
Cumulative % Retained 3/8 inch sieve:	23
Cumulative % Retained #4 sieve:	42.5
% Passing #200 sieve:	4.75

Asphalt Binder

Option:	Conventional viscosity grade
Viscosity Grade	AC 20
A	10.7709 (correlated)
VTS:	-3.6017 (correlated)

Layer 4 -- Asphalt concrete

Material type:	Asphalt concrete
Layer thickness (in):	3.7

General Properties

General

Reference temperature (F°):	70

Volumetric Properties as Built

Effective binder content (%):	11
Air voids (%):	8.5
Total unit weight (pcf):	148
Poisson's ratio:	0.35 (user entered)

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23

Asphalt Mix

Cumulative % Retained 3/4 inch sieve:	17
Cumulative % Retained 3/8 inch sieve:	87
Cumulative % Retained #4 sieve:	94
% Passing #200 sieve:	3.2

Asphalt Binder

Option:	Conventional viscosity grade
Viscosity Grade	AC 20
A	10.7709 (correlated)
VTS:	-3.6017 (correlated)

Layer 5 -- Crushed stone

Unbound Material:	Crushed stone
Thickness(in):	6

Strength Properties

Input Level:	Level 3
Analysis Type:	ICM inputs (ICM Calculated Modulus)
Poisson's ratio:	0.35
Coefficient of lateral pressure,Ko:	0.5
Modulus (input) (psi):	30000

ICM Inputs

Gradation and Plasticity Index

Plasticity Index, PI:	1
Liquid Limit (LL)	6
Compacted Layer	No
Passing #200 sieve (%):	8.7
Passing #40	20
Passing #4 sieve (%):	44.7
D10(mm)	0.1035
D20(mm)	0.425
D30(mm)	1.306
D60(mm)	10.82
D90(mm)	46.19

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8"	57.2
1/2"	63.1
3/4"	72.7
1"	78.8
1 1/2"	85.8
2"	91.6
2 1/2"	
3"	
3 1/2"	97.6
4"	97.6

Calculated/Derived Parameters

Maximum dry unit weight (pcf):	127.2 (derived)
Specific gravity of solids, Gs:	2.76 (user input)
Saturated hydraulic conductivity (ft/hr):	0.05054 (derived)
Optimum gravimetric water content (%):	7.4 (derived)
Calculated degree of saturation (%):	57.4 (calculated)

Soil water characteristic curve parameters: Default values

Parameters	Value
a	7.2555
b	1.3328
c	0.82422
Hr.	117.4

Layer 6 -- A-6

Unbound Material:	A-6
Thickness(in):	Semi-infinite

Strength Properties

Input Level:	Level 3
Analysis Type:	ICM inputs (ICM Calculated Modulus)
Poisson's ratio:	0.35
Coefficient of lateral pressure,Ko:	0.5
Modulus (input) (psi):	19682

ICM Inputs

<u>Gradation and Plasticity Index</u>

Plasticity Index, PI:	12
Liquid Limit (LL)	28
Compacted Layer	Yes
Passing #200 sieve (%):	70.6
Passing #40	84
Passing #4 sieve (%):	96
D10(mm)	0.000255
D20(mm)	0.000652
D30(mm)	0.001666
D60(mm)	0.02776
D90(mm)	1.358

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	70.6
#100	
#80	77
#60	
#50	
#40	84
#30	
#20	
#16	
#10	92
#8	
#4	96
3/8"	98
1/2"	99
3/4"	100
1"	100
1 1/2"	100
2"	100
2 1/2"	
3"	100
3 1/2"	
4"	

Calculated/Derived Parameters

Maximum dry unit weight (pcf):	110.4 (derived)
Specific gravity of solids, Gs:	2.76 (user input)
Saturated hydraulic conductivity (ft/hr):	2.013e-005 (derived)
Optimum gravimetric water content (%):	16.2 (derived)
Calculated degree of saturation (%):	79.8 (calculated)
Soil water characteristic curve parameters:	Default values

Parameters	Value
a	102.6
b	0.7195
c	0.25424
Hr.	500

Distress Model Calibration Settings - Flexible

AC Fatigue	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	0.007566
k2	3.9492
k3	1.281

Distress Model Calibration Settings - Flexible

AC Fatigue	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	0.007566
k2	3.9492
k3	1.281

AC Rutting	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	-3.35412
k2	1.5606
k3	0.4791
Standard Deviation Total Rutting (RUT):	0.24*POWER(RUT,0.8026)+0.001

Thermal Fracture	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	1.5
Std. Dev. (THERMAL):	0.1468 * THERMAL + 65.027

CSM Fatigue	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
k1	1
k2	1

Subgrade Rutting	Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
Granular:	
k1	2.03
Fine-grain:	
k1	1.35

AC Cracking

AC Top Down Cracking

C1 (top)	7
C2 (top)	3.5
C3 (top)	0
C4 (top)	1000
Standard Deviation (TOP)	200 + 2300/(1+exp(1.072-2.1654*log(TOP+0.0001)))

AC Bottom Up Cracking

C1 (bottom)	1
C2 (bottom)	1
C3 (bottom)	0
C4 (bottom)	6000
Standard Deviation (TOP)	1.13+13/(1+exp(7.57-15.5*log(BOTTOM+0.0001)))

CSM Cracking

C1 (CSM)	1
C2 (CSM)	1
C3 (CSM)	0
C4 (CSM)	1000
Standard Deviation (CSM)	CTB*1

IRI

IRI HMA Pavements New

C1(HMA)	40
C2(HMA)	0.4
C3(HMA)	0.008
C4(HMA)	0.015

IRI HMA/PCC Pavements

C1(HMA/PCC)	40.8
C2(HMA/PCC)	0.575
C3(HMA/PCC)	0.0014
C4(HMA/PCC)	0.00825

Figure C-2, 390902 MEPDG Input Summary

Appendix D - Ground Penetrating Radar Layer Profiles

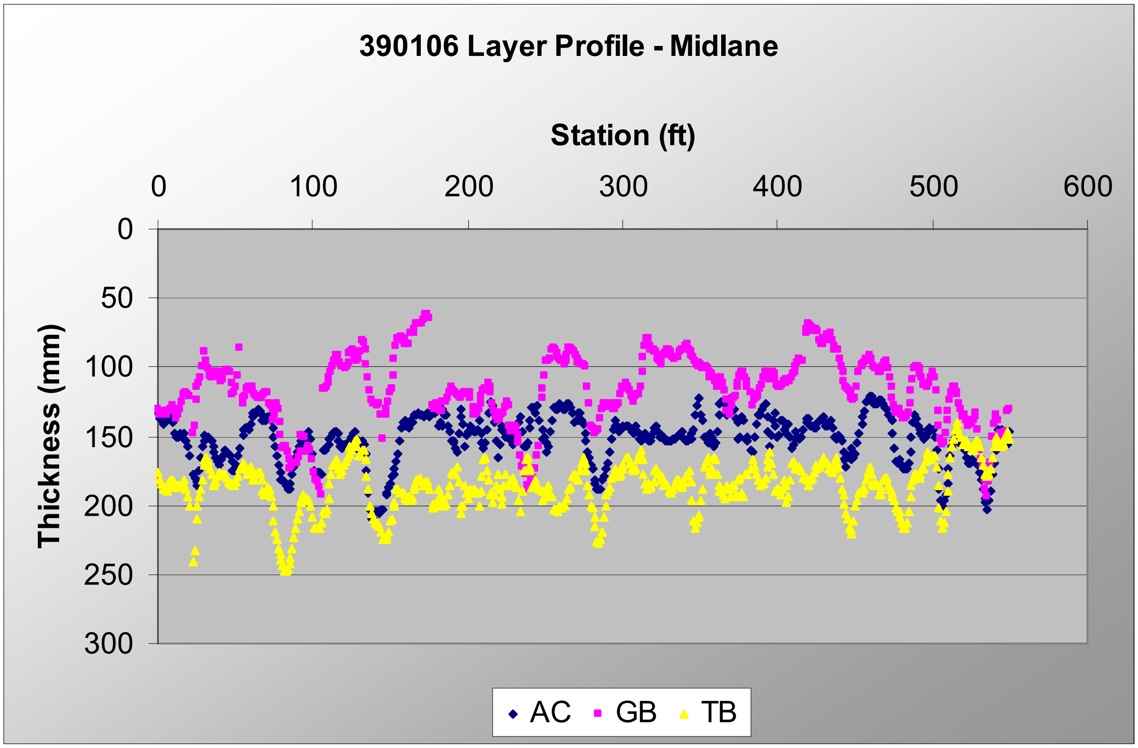

Figure D-1: Midlane GPR Layer Profiles

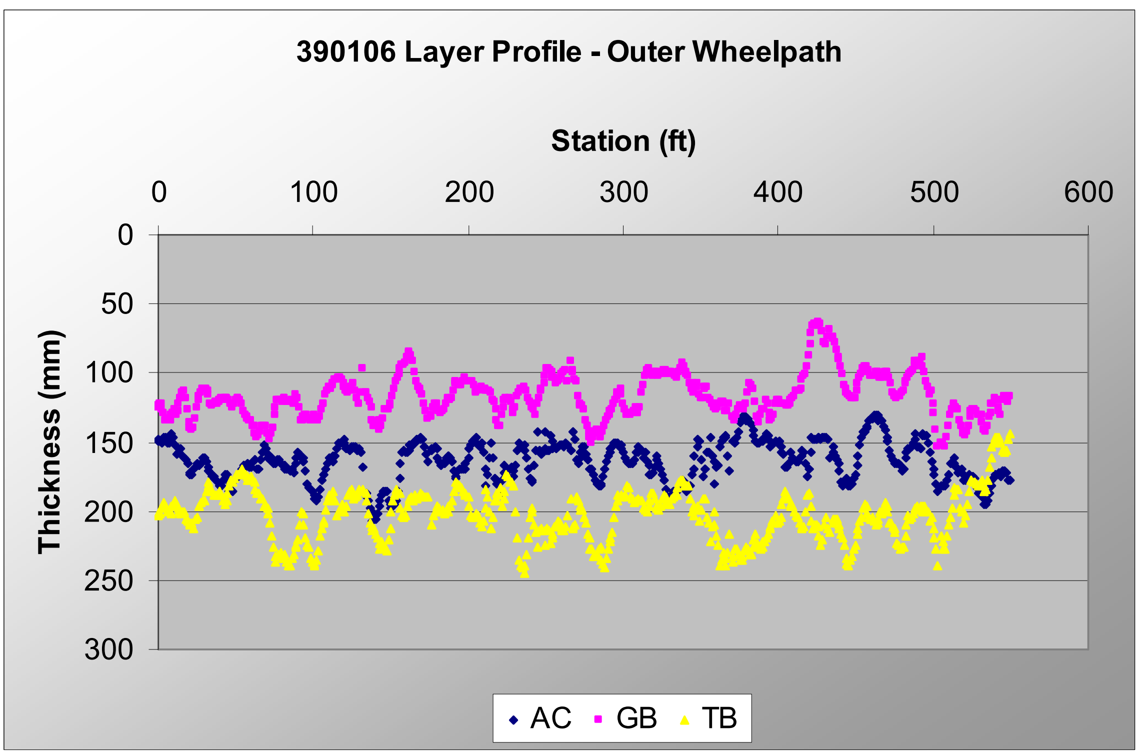

Figure D-2: Outer Wheelpath Layer Profiles

Appendix E - Site Photos

Figure E-1: Paving with the Blaw Knox PF-200B Paver

Figure E-2: Photo Showing Initial Formation of Longitudinal Cracks (390106)

Figure E-3: Photo Depicting Types of Surface Distresses (390106)

Figure E-4: Photo Showing Ravelling of Longitudinal Cracks (390106)

Figure E-5: Photo of Intermittent Longitudinal Crack Edge of Inner Wheelpath (390902)

Figure E-6: Photo of Transverse Crack (390902)

Figure E-7: Photo Showing Alligator Cracks in Inner Wheelpath (390902)

Figure E-8: Photo of Centerline Joint (390902)

Figure E-9: Photo of FWD Testing in Outer Wheelpath

Figure E-10: Photo of Elevation Survey and Pavement Grade for 390106

Figure E-11: Photo of Elevation Survey and Pavement Grade for 390902

Appendix F - Coring and Core Photos

Figure F-1: ODOT coring - 100mm and 150mm Cores

Figure F-2: Station 0+00 Cores - Outer Wheelpath and Midlane (390106)

Figure F-3: Station 0+01.5 Cores - Outer Wheelpath and Midlane (390106)

Figure F-4: Station 2+25 Cores - Outer Wheelpath and Midlane (390106)

Figure F-5: Station 2+26.5 Cores - Outer Wheelpath and Midlane (390106)

Figure F-6: Station 4+50 Cores - Outer Wheelpath and Midlane (390106)

Figure F-7: Station 4+51.5 Cores - Outer Wheelpath and Midlane (390106)

Figure F-8: Core locations at Station 3+00 (390106)

Figure F-9: 100mm Core Samples from Centerline, Midlane and Edge (390106)

Figure F-10: Location of Cores at Station 2+50 (390902)

Figure F-11: Core shows bond separation between layer 2/3 of ATB

Figure F-12: Core showing layer separation and voids

Figure F-13: Core showing geo-fabric between ATB and PATB

Figure F-14: Photo of core hole showing voids in ATB

Figure F-15: Cores with longitudinal crack and stripping at interface to base and surface

Appendix G - Drilling and Sampling Photos

Figure G-1: Split-Spoon Sampling

Figure G-2: Split-Spoon Sample Material

Figure G-3: Packaging and Labeling of Sample Material for Moisture Determination

Figure G-4: Performing the DCP test

Appendix H - DCP Sampling Sheets

********************************** SPS LABORATORY TESTING DATA SHEET *******************************

SHEET # ____ OF ____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO — **STATE CODE:** 39
STATE: OH — **SHRP ID:** 0106
OPERATOR: BH/JCD — **FIELD SET NO.:** 3
TEST DATE: 16 - Jul - 20 08 — **LOC NO.:** C1

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 0 + 00' — DEPTH OF ZERO POINT BELOW SURFACE: 371 mm
LATERAL LOCATION (Distance from outside lane marker): 0.91 m

Initial Scale Reading at zero blows 173 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	30	30	10	1	10	20	n/a
2	3	74	44	15	1	15	14	n/a
3	3	209	135	45	1	45	4.1	21.2
4	1	252	43	43	1	43	4.3	21.2
5	1	291	39	39	1	39	4.8	21.2
6	1	324	33	33	1	33	6	21.2
7	1	357	33	33	1	33	6	21.2
8	1	389	32	32	1	32	6	21.2
9	1	434	45	45	1	45	4.1	21.2
10	1	479	45	45	1	45	4.1	21.2
11	1	502	23	23	1	23	9	20.1
12	1	520	18	18	1	18	11	20.1
13	1	537	17	17	1	17	12	20.1
14	3	577	40	13	1	13	16	20.1
15	3	631	54	18	1	18	11	20.1
16	3	681	50	17	1	17	12	20.1
17	2	714	33	17	1	17	12	20.1
18								
19		**END**						
20								
21								
22								
23								
24								
25								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE
(B) NOTE End at 887 - can not read scale

CERTIFIED — VERIFIED AND APPROVED: Brandt Henderson — DATE: 5-Sep-2008 (dd-mmm-yyyy)

AFFILIATION: ____ — *AFFILIATION:* LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 1 of 9

********************************** SPS LABORATORY TESTING DATA SHEET *******************************

SHEET # ____ OF ____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO — **STATE CODE:** 39
STATE: OH — **SHRP ID:** **0106**
OPERATOR: BH/JCD — **FIELD SET NO.:** 3
TEST DATE: 16 - Jul - 20 08 — **LOC NO.:** **C3**

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 0 + 00' DEPTH OF ZERO POINT BELOW SURFACE: 363 mm
LATERAL LOCATION (Distance from outside lane marker): 1.83 m

Initial Scale Reading at zero blows 180 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	34	34	11	1	11	20	n/a
2	3	64	30	10	1	10	20	n/a
3	3	102	38	13	1	13	16	n/a
4	1	164	62	62	1	62	2.9	19.7
5	1	213	49	49	1	49	3.7	19.7
6	1	265	52	52	1	52	3.5	19.7
7	1	323	58	58	1	58	3.1	19.7
8	1	364	41	41	1	41	4.6	19.7
9	1	392	28	28	1	28	7	19.7
10	1	415	23	23	1	23	9	19.7
11	1	443	28	28	1	28	7	19.7
12	1	470	27	27	1	27	7	20.1
13	1	487	17	17	1	17	12	20.1
14	1	505	18	18	1	18	11	20.1
15	2	537	32	16	1	16	13	20.1
16	2	564	27	14	1	14	15	20.1
17	2	592	28	14	1	14	15	20.1
18	2	614	22	11	1	11	20	20.1
19	2	640	26	13	1	13	16	20.1
20	2	665	25	13	1	13	16	20.1
21	2	688	23	12	1	12	18	20.1
22	2	707	19	10	1	10	20	20.1
23	2	730	23	12	1	12	18	20.1
24	2	750	20	10	1	10	20	20.1
25		**END**						

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE
(B) NOTE

CERTIFIED — VERIFIED AND APPROVED — DATE

Brandt Henderson — 5-Sep-2008
dd-mmm-yyyy

AFFILIATION: — *AFFILIATION:* LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 2 of 9

********************************** SPS LABORATORY TESTING DATA SHEET *******************************

SHEET # ____ OF ____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO
STATE: OH
OPERATOR: BH/JCD
TEST DATE: 16 - Jul - 20 08

STATE CODE: 39
SHRP ID: 0106
FIELD SET NO.: 3
LOC NO.: C5

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 2 + 25'
DEPTH OF ZERO POINT BELOW SURFACE: 371 mm
LATERAL LOCATION (Distance from outside lane marker): 0.91 m

Initial Scale Reading at zero blows 168 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	27	27	9	1	9	25	n/a
2	3	49	22	7	1	7	35	n/a
3	3	79	30	10	1	10	20	n/a
4	3	126	47	16	1	16	13	9.4
5	2	158	32	16	1	16	13	9.4
6	2	187	29	15	1	15	14	15.8
7	2	213	26	13	1	13	16	15.8
8	2	238	25	13	1	13	16	15.8
9	2	260	22	11	1	11	20	15.8
10	2	280	20	10	1	10	20	15.8
11	2	302	22	11	1	11	20	15.8
12	3	337	35	12	1	12	18	15.8
13	3	372	35	12	1	12	18	15.8
14	3	410	38	13	1	13	16	15.8
15	3	453	43	14	1	14	15	15.8
16	3	520	67	22	1	22	9	15.8
17	3	582	62	21	1	21	10	18.3
18	2	619	37	19	1	19	11	18.3
19	2	654	35	18	1	18	11	18.3
20	2	723	69	35	1	35	5	18.3
21	1	775	52	52	1	52	3.5	18.3
22		**END**						
23								
24								
25								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS
(A) CODE ____ ____ ____ ____ ____ ____ ____ ____
(B) NOTE ________________

CERTIFIED ________________ VERIFIED AND APPROVED Brandt Henderson DATE 5-Sep-2008 dd-mmm-yyyy

AFFILIATION: ________ *AFFILIATION:* LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 3 of 9

******************************** SPS LABORATORY TESTING DATA SHEET ******************************

SHEET # ______ OF ______

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO — **STATE CODE:** 39
STATE: OH — **SHRP ID:** 0106
OPERATOR: BH/JCD — **FIELD SET NO.:** 3
TEST DATE: 16 - Jul - 20 08 — **LOC NO.:** C7

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 2 + 25' — DEPTH OF ZERO POINT BELOW SURFACE: 376 mm
LATERAL LOCATION (Distance from outside lane marker): 1.83 m

Initial Scale Reading at zero blows 177 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	33	33	11	1	11	20	n/a
2	3	65	32	11	1	11	20	n/a
3	3	139	74	25	1	25	8	17.4
4	3	180	41	14	1	14	15	17.4
5	3	224	44	15	1	15	14	17.4
6	3	263	39	13	1	13	16	17.4
7	3	298	35	12	1	12	18	17.4
8	3	333	35	12	1	12	18	17.4
9	3	371	38	13	1	13	16	17.4
10	3	413	42	14	1	14	15	17.4
11	3	467	54	18	1	18	11	17.4
12	3	538	71	24	1	24	8	17.4
13	3	603	65	22	1	22	9	17.9
14	3	658	55	18	1	18	11	17.9
15	3	710	52	17	1	17	12	17.9
16	3	788	78	26	1	26	8	17.9
17		END						
18								
19								
20								
21								
22								
23								
24								
25								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE ______ ______ ______ ______ ______ ______ ______ ______
(B) NOTE ________________________

CERTIFIED ____________________

VERIFIED AND APPROVED: Brandt Henderson

DATE: 5-Sep-2008 (dd-mmm-yyyy)

AFFILIATION: ____________

AFFILIATION: LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 4 of 9

********************************** SPS LABORATORY TESTING DATA SHEET *********************************

SHEET # _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO — **STATE CODE:** 39
STATE: OH — **SHRP ID:** **0106**
OPERATOR: BH/JCD — **FIELD SET NO.:** 3
TEST DATE: 16 - Jul - 20 08 — **LOC NO.:** **C9**

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 4 + 50' — DEPTH OF ZERO POINT BELOW SURFACE: 370 mm
LATERAL LOCATION (Distance from outside lane marker): 0.91 m

Initial Scale Reading at zero blows 171 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	11	11	4	1	4	60	9.4
2	3	28	17	6	1	6	40	9.4
3	3	48	20	7	1	7	35	9.4
4	3	77	29	10	1	10	20	9.4
5	3	117	40	13	1	13	16	15.1
6	3	171	54	18	1	18	11	15.1
7	3	214	43	14	1	14	15	15.1
8	3	266	52	17	1	17	12	15.1
9	3	316	50	17	1	17	12	15.1
10	3	369	53	18	1	18	11	15.1
11	3	464	95	32	1	32	6	15.1
12	2	531	67	34	1	34	6	15.1
13	2	596	65	33	1	33	6	22.6
14	2	652	56	28	1	28	7	22.6
15	2	704	52	26	1	26	8	22.6
16	2	744	40	20	1	20	10	22.6
17	2	759	15	8	1	8	30	22.6
18		END						
19								
20								
21								
22								
23								
24								
25								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE
(B) NOTE

CERTIFIED — VERIFIED AND APPROVED: Brandt Henderson — DATE: 5-Sep-2008 (dd-mmm-yyyy)

AFFILIATION: _______ — *AFFILIATION:* LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 5 of 9

********************************** SPS LABORATORY TESTING DATA SHEET ********************************

SHEET # ____ OF ____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO — **STATE CODE:** 39
STATE: OH — **SHRP ID:** 0106
OPERATOR: BH/JCD — **FIELD SET NO.:** 3
TEST DATE: 16 - Jul - 20 08 — **LOC NO.:** C11

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 4 + 50' — DEPTH OF ZERO POINT BELOW SURFACE: 371 mm
LATERAL LOCATION (Distance from outside lane marker): 1.83 m

Initial Scale Reading at zero blows 172 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	24	24	8	1	8	30	n/a
2	3	43	19	6	1	6	40	n/a
3	3	68	25	8	1	8	30	n/a
4	3	106	38	13	1	13	16	n/a
5	3	179	73	24	1	24	8	17.3
6	2	238	59	30	1	30	6	17.3
7	2	295	57	29	1	29	7	17.3
8	2	332	37	19	1	19	11	17.3
9	2	368	36	18	1	18	11	17.3
10	2	408	40	20	1	20	10	17.3
11	2	459	51	26	1	26	8	17.3
12	2	574	115	58	1	58	3.1	17.3
13	1	615	41	41	1	41	4.6	23.8
14	1	645	30	30	1	30	6	23.8
15	1	668	23	23	1	23	9	23.8
16	1	692	24	24	1	24	8	23.8
17	1	711	19	19	1	19	11	23.8
18	1	735	24	24	1	24	8	23.8
19	1	742	7	7	1	7	35	23.8
20	1	755	13	13	1	13	16	23.8
21		**END**						
22								
23								
24								
25								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE ____ ____ ____ ____ ____ ____ ____ ____
(B) NOTE ________________

CERTIFIED ________________ — VERIFIED AND APPROVED: Brandt Henderson — DATE: 5-Sep-2008 (dd-mmm-yyyy)

AFFILIATION: ________________ — *AFFILIATION:* LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 6 of 9

********************************** SPS LABORATORY TESTING DATA SHEET *******************************

SHEET # _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO
STATE: OH
OPERATOR: BH / GC
TEST DATE: 17 - Jul - 20 08

STATE CODE: 39
SHRP ID: 0902
FIELD SET NO.: 2
LOC NO.: C13

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 2 + 50'
DEPTH OF ZERO POINT BELOW SURFACE: 511 mm
LATERAL LOCATION (Distance from outside lane marker): 0.91 m

Initial Scale Reading at zero blows 165 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	0	0	0	#DIV/0!	1	#DIV/0!		
2	3	25	25	8	1	8	30	8.5
3	3	32	7	2	1	2	100	8.5
4	5	50	18	4	1	4	60	8.5
5	5	72	22	4	1	4	60	8.5
6	5	95	23	5	1	5	50	8.5
7	5	120	25	5	1	5	50	8.5
8	3	155	35	12	1	12	18	8.5
9	3	195	40	13	1	13	16	13.5
10	3	215	20	7	1	7	35	13.5
11	3	245	30	10	1	10	20	13.5
12	3	260	15	5	1	5	50	13.5
13	3	295	35	12	1	12	18	13.5
14	3	330	35	12	1	12	18	13.5
15	3	358	28	9	1	9	25	13.5
16	3	385	27	9	1	9	25	13.5
17	3	406	21	7	1	7	35	13.5
18	3	435	29	10	1	10	20	13.5
19	3	465	30	10	1	10	20	13.5
20	3	495	30	10	1	10	20	13.5
21	3	527	32	11	1	11	20	13.5
22	3	571	44	15	1	15	14	13.5
23	3	590	19	6	1	6	40	13.5
24		END						
25								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE _____ _____ _____ _____ _____ _____ _____ _____
(B) NOTE ____

CERTIFIED ________________
VERIFIED AND APPROVED Brandt Henderson
DATE 5-Sep-2008 dd-mmm-yyyy

AFFILIATION: ____________
AFFILIATION: LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 7 of 9

********************************** SPS LABORATORY TESTING DATA SHEET ********************************

SHEET # ______ OF ______

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION: NCRO | **STATE CODE:** 39
STATE: OH | **SHRP ID:** 0902
OPERATOR: BH / GC | **FIELD SET NO.:** 2
TEST DATE: 17 - Jul - 20 08 | **LOC NO.:** C15

HAMMER WEIGHT: [X] 8-Kg [ ] 4.6-Kg
LOCATION STATION: 2 + 50' DEPTH OF ZERO POINT BELOW SURFACE: 531 mm
LATERAL LOCATION (Distance from outside lane marker): 1.83 m

Initial Scale Reading at zero blows 165 mm

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
1	3	17	17	6	1	6	40	7.5
2	3	35	18	6	1	6	40	7.5
3	3	45	10	3	1	3	80	7.5
4	3	58	13	4	1	4	60	7.5
5	3	72	14	5	1	5	50	7.5
6	3	90	18	6	1	6	40	7.5
7	3	105	15	5	1	5	50	7.5
8	3	125	20	7	1	7	35	7.5
9	3	165	40	13	1	13	16	14.8
10	3	200	35	12	1	12	18	14.8
11	3	225	25	8	1	8	30	14.8
12	3	245	20	7	1	7	35	14.8
13	3	265	20	7	1	7	35	14.8
14	3	295	30	10	1	10	20	14.8
15	3	331	36	12	1	12	18	14.8
16	3	366	35	12	1	12	18	14.8
17	3	400	34	11	1	11	20	14.8
18	3	435	35	12	1	12	18	14.8
19	3	477	42	14	1	14	15	14.8
20	3	515	38	13	1	13	16	14.8
21	2	555	40	20	1	20	10	14.8
22	1	580	25	25	1	25	8	14.8
23	1	597	17	17	1	17	12	14.8
24	1	610	13	13	1	13	16	14.8
25	1	625	15	15	1	15	14	14.8

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS
(A) CODE
(B) NOTE

CERTIFIED | VERIFIED AND APPROVED | DATE
Brandt Henderson | 5-Sep-2008
dd-mmm-yyyy

AFFILIATION: ________ *AFFILIATION:* LTPP-NCRO

Form T72, June 2006

DCP Sampling - Page 8 of 9

********************************** SPS LABORATORY TESTING DATA SHEET ********************************

SHEET # ______ OF ______

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72
Continuation
BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION:	NCRO	STATE CODE:	OH
STATE:	OH	SHRP ID:	0902
OPERATOR:	BH / JCD	FIELD SET NO.:	2
TEST DATE:	17 - Jul - 20 08	LOC NO.:	C15

III- SUMMARY OF RESULTS

Read No	Number of blows	Scale Reading (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
26	2	645	20	10	1	10	20	19.7
27	2	665	20	10	1	10	20	19.7
28	2	690	25	13	1	13	16	19.7
29	2	710	20	10	1	10	20	19.7
30		**END**						
31								
32								
33								
34								
35								
36								
37								
38								
39								
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41								
42								
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55								

Note: If additional rows are needed, please use continuation data sheet.

IV - COMMENTS

(A) CODE ______ ______ ______ ______ ______ ______ ______ ______

(B) NOTE ____________________

CERTIFIED	VERIFIED AND APPROVED	DATE
	Brandt Henderson	5-Sep-2008
		dd-mmm-yyyy
AFFILIATION:	*AFFILIATION:* LTPP - NCRO	

Form T72 Continuation, June 2006

DCP Sampling - Page 9 of 9

Appendix I - Split Spoon Sampling Sheets

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

SHRP REGION NC
STATE OHIO
STATE CODE 39
SHRP ASSIGNED ID 0106

LTPP EXPERIMENT SPS-1 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — FIELD SET NO. 3

LOG OF BORE HOLE (A-Type)

DCG SHEET: 03
DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 1 OF 8
BORING DATE 07-15-08 LOCATION: STATION 0+01.5 BORE HOLE NUMBER: C2
BORE HOLE SIZE: 6 (inch Diam.) OFFSET 3 feet from °/s

Scale (Inches)	Strata Changed (Inches)	Sample Number (1)	# Blows (2) 6"	6"	6"	Ref? Y/N (3)	DLR (Inches) (4)	IOP (5)	Material Description	Material Code
	1.8"	—	—	—	—	—	—	—	AC-SURFACE	1
	6.6"	—	—	—	—	—	—	—	AC-BINDER	1
10.0	14.5"	—	—	—	—	—	—	—	ASPHALT TREATED BASE	319
20.0	18.5"	—	2	—	—	N	—	—	CRUSHED GRAVEL	303
30.0										
40.0	56.5"	—	2	3	6	N	—	—	SILTY CLAY W/ TRACES OF SHALE	131
50.0										
60.0										
70.0										
80.0										
90.0										
100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS:

CERTIFIED
Crew Chief, Contractor
Affiliation:

VERIFIED AND APPROVED
Brandt Henderson
SHRP Representative
Affiliation: LTPP-NCRO

MONTH-DAY-YEAR
JUL-15-19 2008
Date

Form S02A/April 1990

Split Spoon Sampling - Page 1 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

STATE CODE 39
SHRP REGION NC
STATE OHIO
SHRP ASSIGNED ID 0106

LTPP EXPERIMENT SPS-1 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — FIELD SET NO. 3

LOG OF BORE HOLE (A-Type)

DCG SHEET: 03

DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 2 OF 8
BORING DATE 07-15-08 LOCATION: STATION 0+01.5 BORE HOLE NUMBER: C4
BORE HOLE SIZE: 6 (inch Diam.) OFFSET 6 feet from °/s

Scale (Inches)	Strata Changed (Inches)	Sample Number (1)	# Blows (2) 6"	6"	6"	Ref? Y/N (3)	DLR (Inches) (4)	IOP (5)	Material Description	Material Code
	1.8"	—	—	—	—	—	—	—	AC-SURFACE	1
	6.7"	—	—	—	—	—	—	—	AC-BINDER	1
10.0	14.4"	—	—	—	—	—	—	—	ASPHALT TREATED BASE	319
20.0	13.4"	—	2	—	—	N	—	—	CRUSHED GRAVEL	303
30.0 40.0 50.0	56.4"	—	2	2	7	N	—	—	SILTY CLAY W/ TRACES OF SHALE	131
60.0 70.0 80.0 90.0 100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS: ______

CERTIFIED ______
Crew Chief, Contractor
Affiliation: ______

VERIFIED AND APPROVED
Brandt Henderson
SHRP Representative
Affiliation: LTPP-NCRO

MONTH-DAY-YEAR
JUL-15-2008
Date

Form S02A/April 1990

Split Spoon Sampling - Page 2 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

SHRP REGION NC
STATE OHIO
STATE CODE 39
SHRP ASSIGNED ID 0106

LTPP EXPERIMENT SPS-1 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section_____ (b) After Section_____ *FIELD SET NO.* 3
LOG OF BORE HOLE (A-Type) *DCG SHEET: 03*
DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 3 OF 8
BORING DATE 07-15-08 *LOCATION: STATION* 2+26.5 *BORE HOLE NUMBER:* C6
BORE HOLE SIZE: 6 (inch Diam.) *OFFSET* 3 *feet from °/s*

Scale (Inches)	*Strata Changed (Inches)*	*Sample Number* (1)	*# Blows* (2) 6"	6"	6"	*Ref? Y/N* (3)	*DLR (Inches)* (4)	*IOP* (5)	*Material Description*	*Material Code*
	1.7"	–	–	–	–	–	–	–	AC-SURFACE	1
	6.7"	–	–	–	–	–	–	–	AC-BINDER	1
10.0	14.7"	–	–	–	–	–	–	–	ASPHALT TREATED BASE	319
20.0	20.7"	–	5	–	–	N	–	–	CRUSHED GRAVEL	303
30.0		–	5	8	9	N	–	–	SILTY CLAY	131
40.0	56.7"									
50.0										
60.0										
70.0										
80.0										
90.0										
100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS:
CERTIFIED VERIFIED AND APPROVED MONTH-DAY-YEAR
Brandt Henderson JUL-15-2008

Crew Chief, Contractor SHRP Representative Date
Affiliation: Affiliation: LTPP-NCRO

Form S02A/April 1990

Split Spoon Sampling - Page 3 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

STATE CODE 39
SHRP REGION NC
STATE OHIO
SHRP ASSIGNED ID 0106

LTPP EXPERIMENT SPS-1 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — FIELD SET NO. 3

LOG OF BORE HOLE (A-Type)

DCG SHEET: 03
DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 4 OF 8
BORING DATE 07-15-08 LOCATION: STATION 2+26.5 BORE HOLE NUMBER: C8
BORE HOLE SIZE: 6 (inch Diam.) OFFSET 6 feet from °/s

Scale (Inches)	Strata Changed (Inches)	Sample Number (1)	# Blows (2) 6"	6"	6"	Ref? Y/N (3)	DLR (Inches) (4)	IOP (5)	Material Description	Material Code
	1.8"	—	—	—	—	—	—	—	AC-SURFACE	1
	6.9"	—	—	—	—	—	—	—	AC-BINDER	1
10.0	14.9"	—	—	—	—	—	—	—	ASPHALT TREATED BASE	319
20.0	18.9"	—	2	—	—	N	—	—	CRUSHED GRAVEL	303
30.0	56.9"	—	5	6	7	N	—	—	SILTY CLAY	131
40.0										
50.0										
60.0										
70.0										
80.0										
90.0										
100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS: ____

CERTIFIED ____
Crew Chief, Contractor
Affiliation: ____

VERIFIED AND APPROVED
Brandt Henderson
SHRP Representative
Affiliation: LTPP-NCRO

MONTH-DAY-YEAR
JUL-15-2008
Date

Form S02A/April 1990

Split Spoon Sampling - Page 4 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

STATE CODE 39
SHRP REGION NC
STATE OHIO
SHRP ASSIGNED ID 0106

LTPP EXPERIMENT SPS-1 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — FIELD SET NO. 3

LOG OF BORE HOLE (A-Type) DCG SHEET: 03

DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 5 OF 8
BORING DATE 07-15-08 LOCATION: STATION 4+51.5 BORE HOLE NUMBER: C10
BORE HOLE SIZE: 6 (inch Diam.) OFFSET 3 feet from °/s

Scale (Inches)	Strata Changed (Inches)	Sample Number (1)	# Blows (2) 6"	6"	6"	Ref? Y/N (3)	DLR (Inches) (4)	IOP (5)	Material Description	Material Code
	1.7"	–	–	–	–	–	–	–	AC-SURFACE	1
	6.7"	–	–	–	–	–	–	–	AC-BINDER	1
10.0	14.5"	–	–	–	–	–	–	–	ASPHALT TREATED BASE	319
20.0	17.5"	–	4	–	–	N	–	–	CRUSHED GRAVEL	303
30.0									SILTY CLAY	131
40.0	55.5"	–	4	5	4	N	–	–		
50.0										
60.0										
70.0										
80.0										
90.0										
100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS: ____

CERTIFIED ____
Crew Chief, Contractor
Affiliation: ____

VERIFIED AND APPROVED
Brandt Henderson
SHRP Representative
Affiliation: LTPP-NCRO

MONTH-DAY-YEAR
JUL-15-~~19~~2008
Date

Form S02A/April 1990

Split Spoon Sampling - Page 5 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

STATE CODE 39
SHRP REGION NC
STATE OHIO
SHRP ASSIGNED ID 0106

LTPP EXPERIMENT SPS-1 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — *FIELD SET NO.* 3
LOG OF BORE HOLE (A-Type) *DCG SHEET: 03*
DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 6 OF 8
BORING DATE 07-15-08 *LOCATION: STATION* 4+51.5 *BORE HOLE NUMBER:* C12
BORE HOLE SIZE: 6 (inch Diam.) *OFFSET* 6 *feet from °/s*

Scale (Inches)	*Strata Changed (Inches)*	*Sample Number* (1)	*# Blows* (2) 6"	6"	6"	*Ref? Y/N* (3)	*DLR (Inches)* (4)	*IOP* (5)	*Material Description*	*Material Code*
	1.8"	—	—	—	—	—	—	—	AC-SURFACE	1
	6.7"	—	—	—	—	—	—	—	AC-BINDER	1
10.0	14.5"	—	—	—	—	—	—	—	ASPHALT TREATED BASE	319
	18.5"	—	4	—	—	N	—	—	CRUSHED GRAVEL	303
20.0										
30.0	50.5"	—	4	3	4	N	—	—	SILTY CLAY	131
40.0										
50.0										
60.0										
70.0										
80.0										
90.0										
100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS:
CERTIFIED VERIFIED AND APPROVED MONTH-DAY-YEAR
Brandt Henderson JUL-15-~~19~~2008
Crew Chief, Contractor SHRP Representative Date
Affiliation: Affiliation: LTPP-NCRO

Form S02A/April 1990

Split Spoon Sampling - Page 6 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

STATE CODE 39
SHRP REGION NC
STATE OHIO
SHRP ASSIGNED ID 0902

LTPP EXPERIMENT SPS-9 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — FIELD SET NO. 3
LOG OF BORE HOLE (A-Type) DCG SHEET: 03
DRILLER ODOT EQUIPMENT USED CME-140 SHEET NUMBER 8 OF 8
BORING DATE 07-16-08 LOCATION: STATION 2+51.5 BORE HOLE NUMBER: C16
BORE HOLE SIZE: 6 (inch Diam.) OFFSET 6 feet from °/s

Scale (Inches)	Strata Changed (Inches)	Sample Number (1)	# Blows (2) 6"	6"	6"	Ref? Y/N (3)	DLR (Inches) (4)	IOP (5)	Material Description	Material Code
	1.9"	—	—	—	—	—	—	—	AC-SURFACE	1
	4.6"	—	—	—	—	—	—	—	AC-BINDER	1
10.0	16.6"	—	—	—	—	—	—	—	ASPHALT TREATED BASE	321
20.0	20.7"	—	—	—	—	—	—	—	ASPHALT TREATED SUBBASE	325
	26.7"	—	4	—	—	N	—	—	CRUSHED STONE	303
30.0 40.0 50.0	56.7"	—	4	3	4	N	—	—	GREY BROWN SILTY CLAY W/ TRACES OF SHALE	131
60.0 70.0 80.0 90.0 100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. ***Refused*** - If the splitspoon is refused, place a Y in the ***REFUSAL*** column and complete ***Driving Length To Refusal*** column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. ***Driving Length To Refusal*** - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. ***Inches Of Penetration*** - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS: ____

CERTIFIED ____
Crew Chief, Contractor
Affiliation: ____

VERIFIED AND APPROVED
Brandt Henderson
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MONTH-DAY-YEAR
JUL-16-~~19~~2008
Date

Form S02A/April 1990

Split Spoon Sampling - Page 7 of 8

SHRP-LTPP
FIELD MATERIAL SAMPLING
AND FIELD TESTING

STATE CODE 39
SHRP REGION NC
STATE OHIO
SHRP ASSIGNED ID 0902

LTPP EXPERIMENT SPS-9 ROUTE/HIGHWAY US-23 Lane 1 Direction SB
SAMPLE/TEST: (a) Before Section — (b) After Section — *FIELD SET NO.* 3
LOG OF BORE HOLE (A-Type) *DCG SHEET: 03*
DRILLER ODOT EQUIPMENT USED CME 140 SHEET NUMBER 7 OF 8
BORING DATE 07-16-08 *LOCATION: STATION* 2+51.5 *BORE HOLE NUMBER:* C14
BORE HOLE SIZE: 6 (inch Diam.) *OFFSET* 3 feet from °/s

Scale (Inches)	*Strata Changed (Inches)*	*Sample Number* (1)	*# Blows* (2) 6"	6"	6"	*Ref? Y/N* (3)	*DLR (Inches)* (4)	*IOP* (5)	*Material Description*	*Material Code*
	1.8"	—	—	—	—	—	—	—	AC-SURFACE	1
	4.1"	—	—	—	—	—	—	—	AC-BINDER	1
10.0	16.1"	—	—	—	—	—	—	—	ASPHALT TREATED BASE	321
20.0	20.1"	—	—	—	—	—	—	—	PATB	325
	26.1"	—				N	—	—	CRUSHED STONE	303
30.0		—				N	—	-	GREY BROWN SILTY CLAY W/ TRACES OF SHALE	131
40.0	56.1"									
50.0										
60.0										
70.0										
80.0										
90.0										
100.0										

1. Record sample numbers for splitspoon/thin-walled tube samples taken from the subgrade.
2. For splitspoon samples, record the number of blows for the first, second and third 6 inches of penetration.
3. *Refused* - If the splitspoon is refused, place a Y in the *REFUSAL* column and complete *Driving Length To Refusal* column. Refusal is defined as less than 1 inch of penetration with 100 blows.
4. *Driving Length To Refusal* - Record penetration to refusal of splitspoon from the top of the pavement surface.
5. *Inches Of Penetration* - Record from start of splitspoon sampling procedure if 100 blows is reached before one foot of penetration. If penetration exceeds 12 inches before 100 blows is reached, enter middle 6 inches plus depth of penetration into the last 6 inches when 100 blows was reached (not including seating drive); record to nearest tenth of an inch.

GENERAL REMARKS: ________

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Crew Chief, Contractor
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VERIFIED AND APPROVED
Brandt Henderson
SHRP Representative
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MONTH-DAY-YEAR
JUL-16-~~19~~2008
Date

Form S02A/April 1990

Split Spoon Sampling - Page 8 of 8

Appendix J - FWD Historical Plots

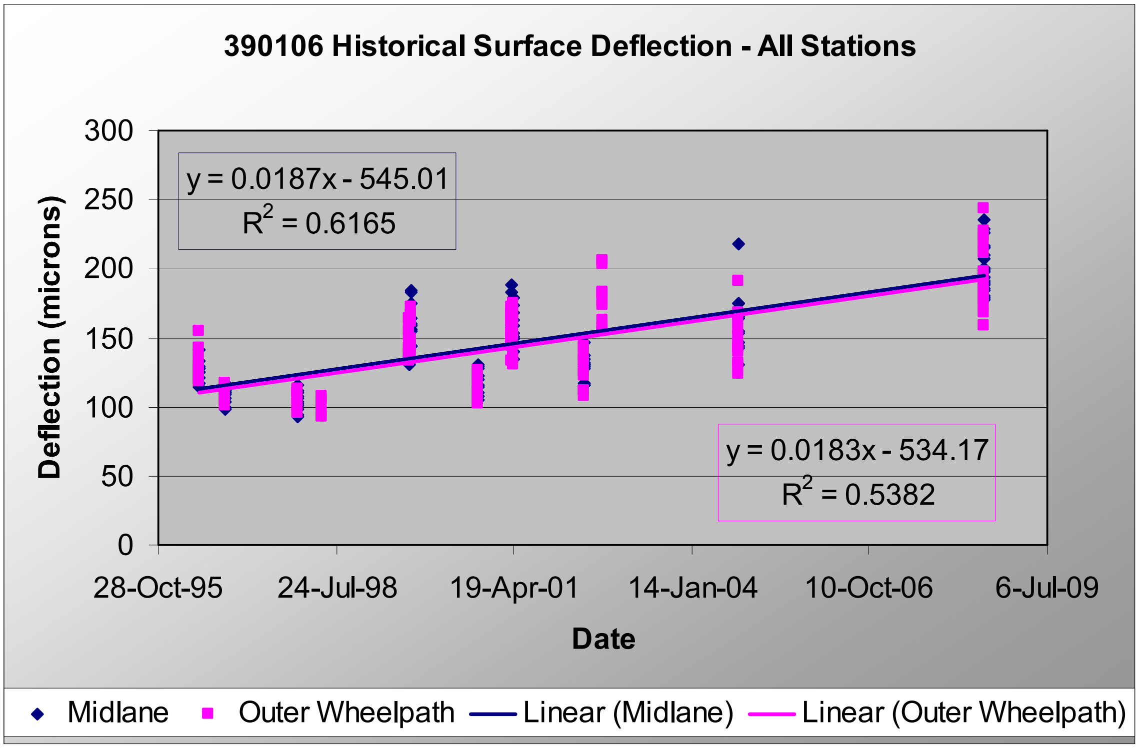

Figure J-1: Historical Trend Surface Deflections (390106)

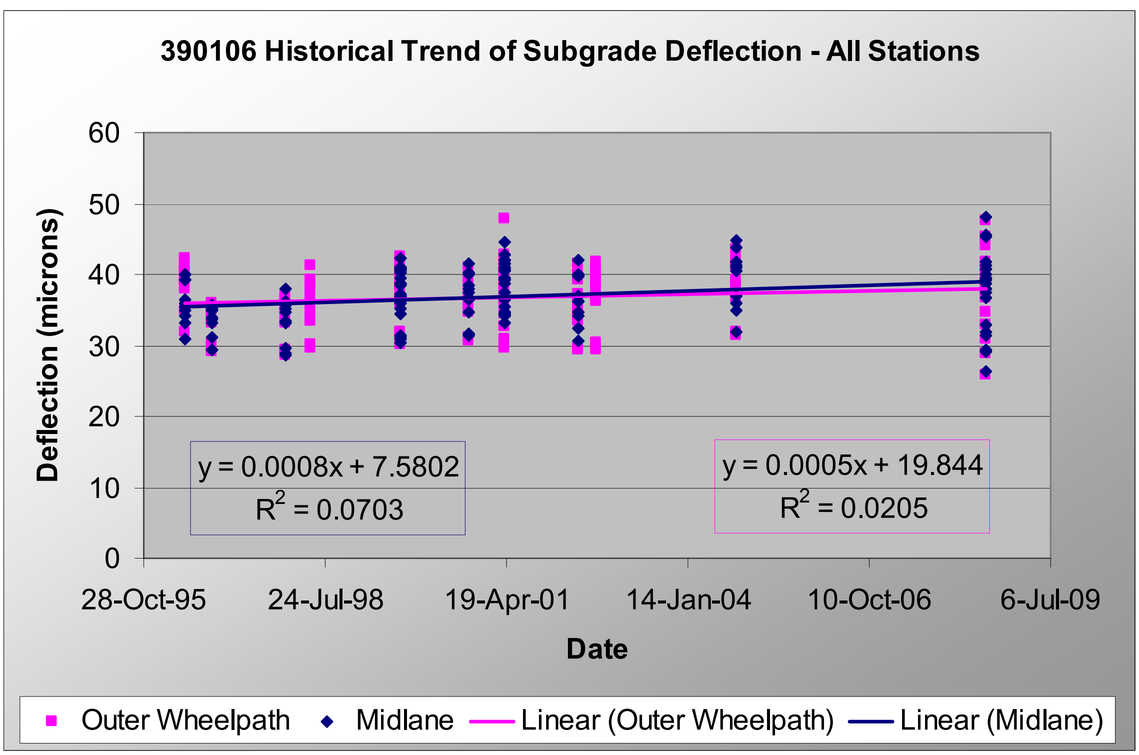

Figure J-2: Historical Trend of Subgrade Deflections (390106)

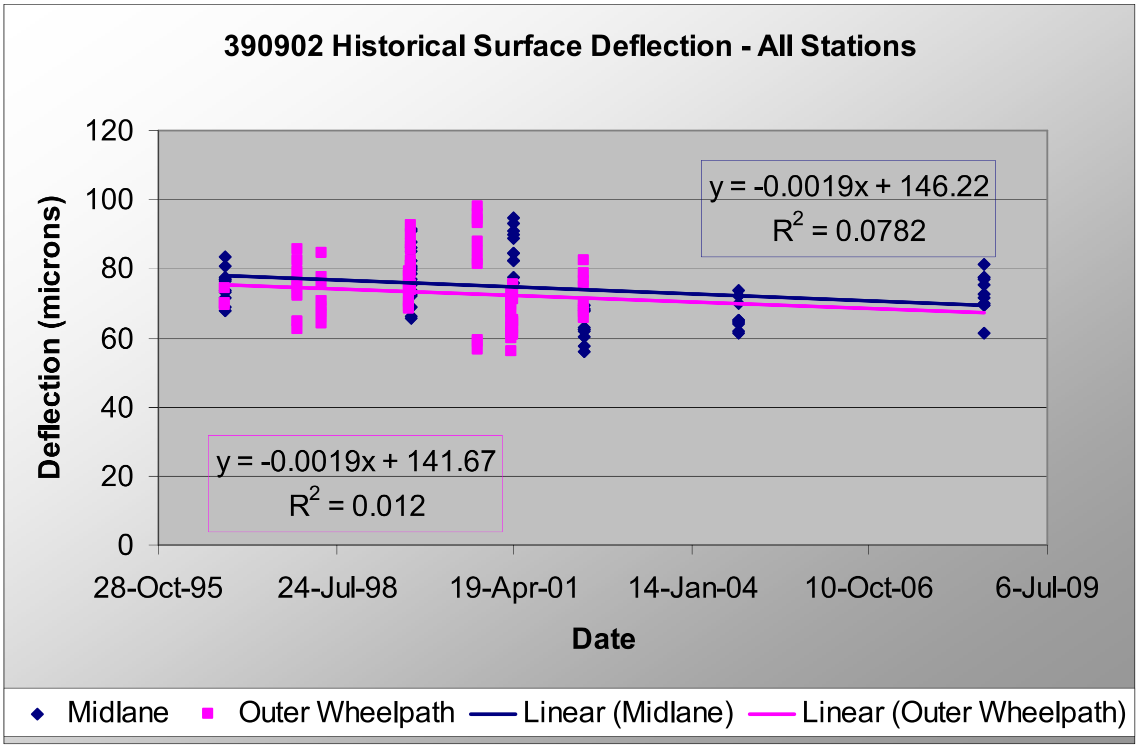

Figure J-3: Historical Trend of Surface Deflections (390902)

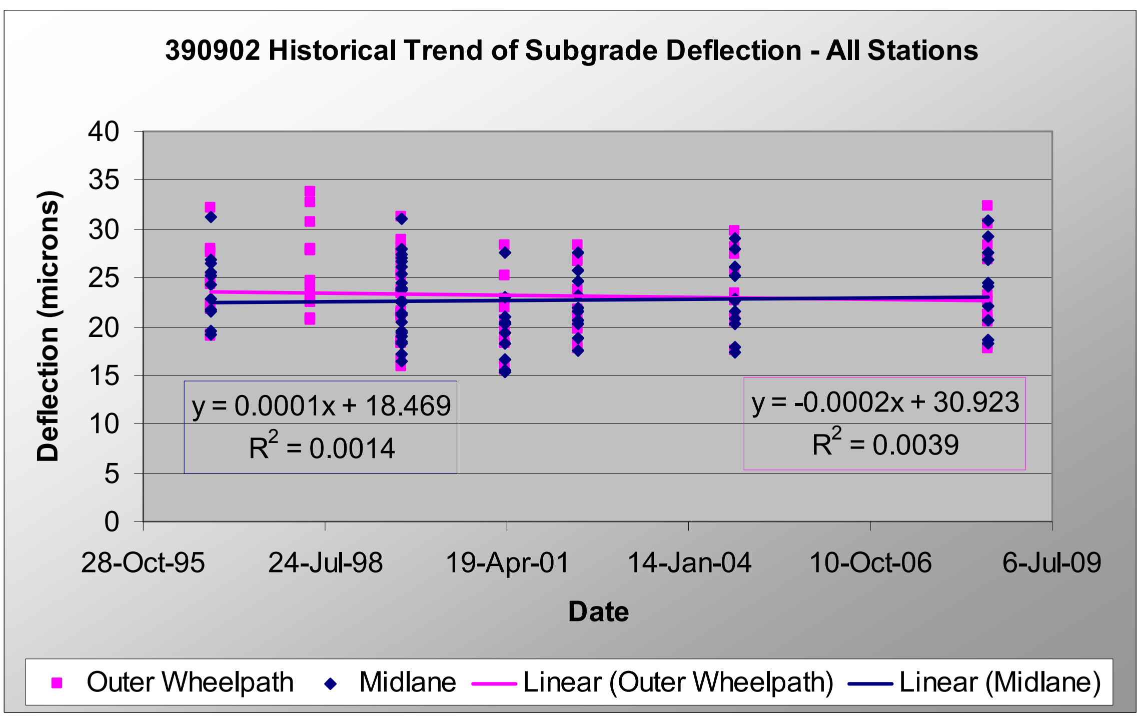

Figure J-4: Historical Trend of Subgrade Deflections (390902)

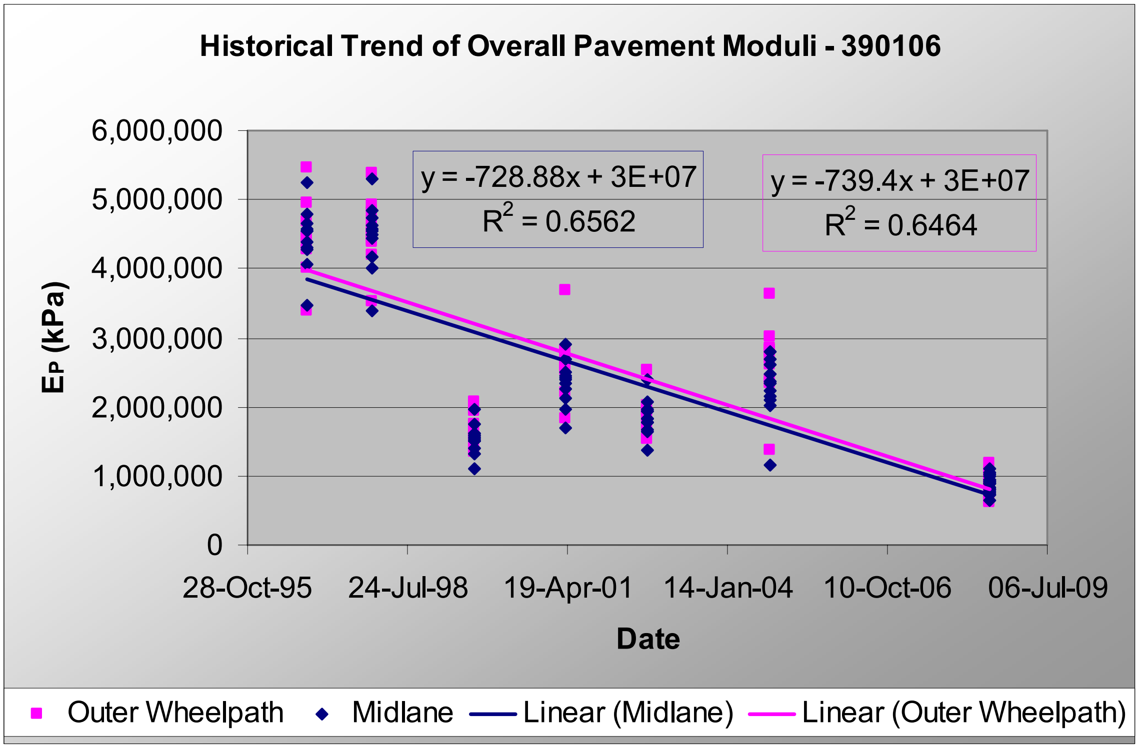

Figure J-5: Historical Trend of Pavement Resilient Moduli (390106)

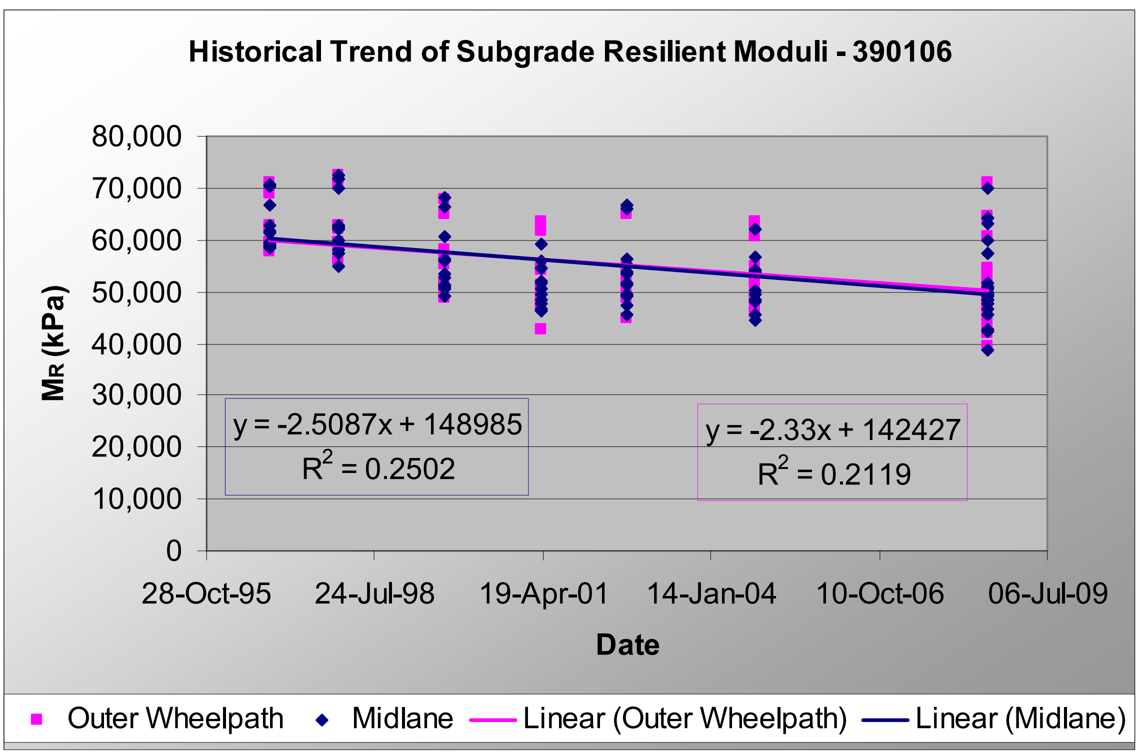

Figure J-6: Historical Trend of Subgrade Resilient Moduli (390106)

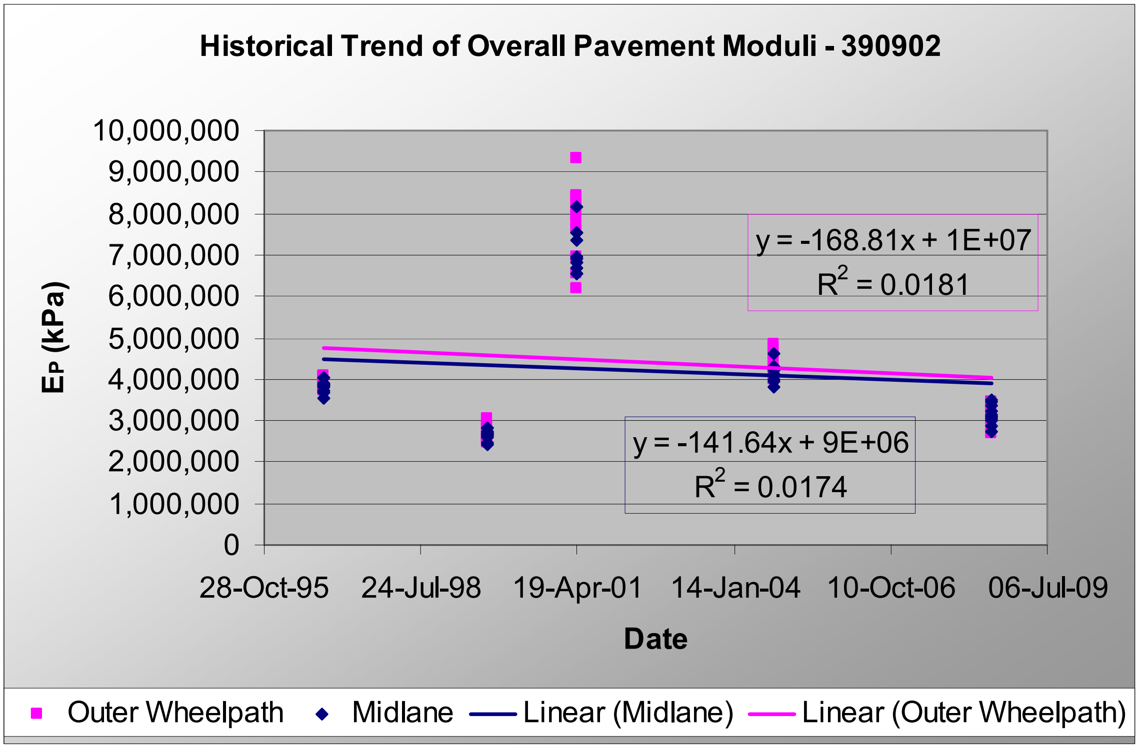

Figure J-7: Historical Trend of Pavement Resilient Moduli (390902)

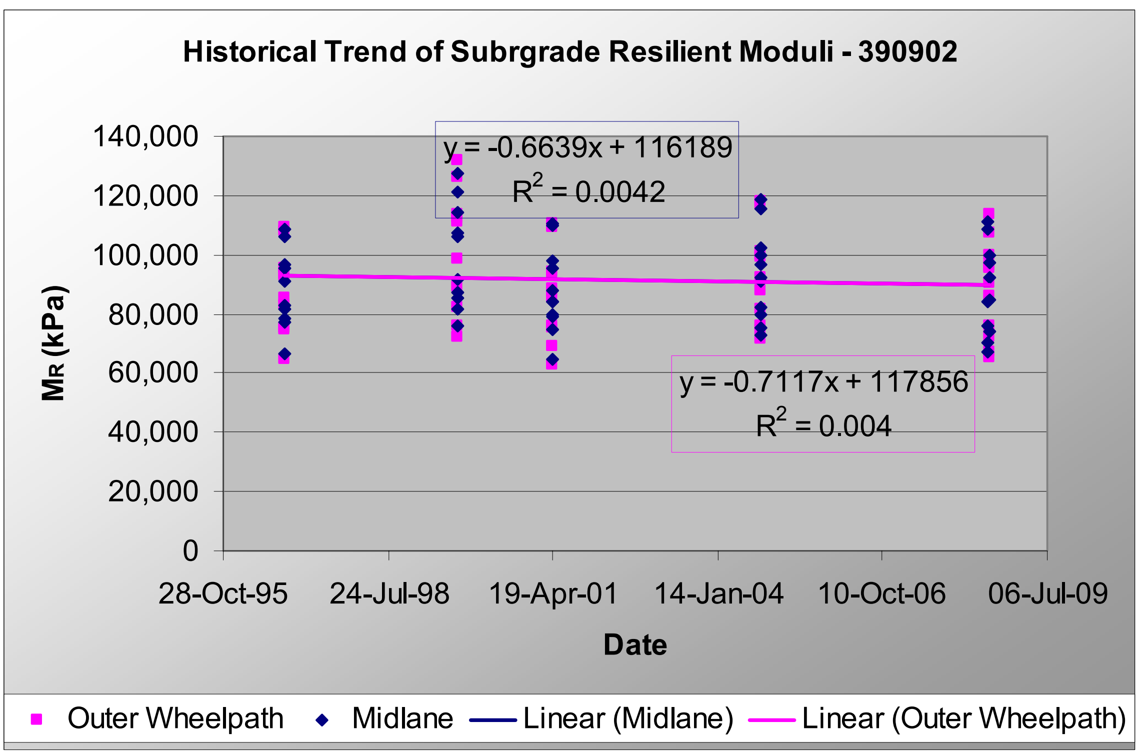

Figure J-8: Historical Trend of Subgrade Resilient Moduli (390902)

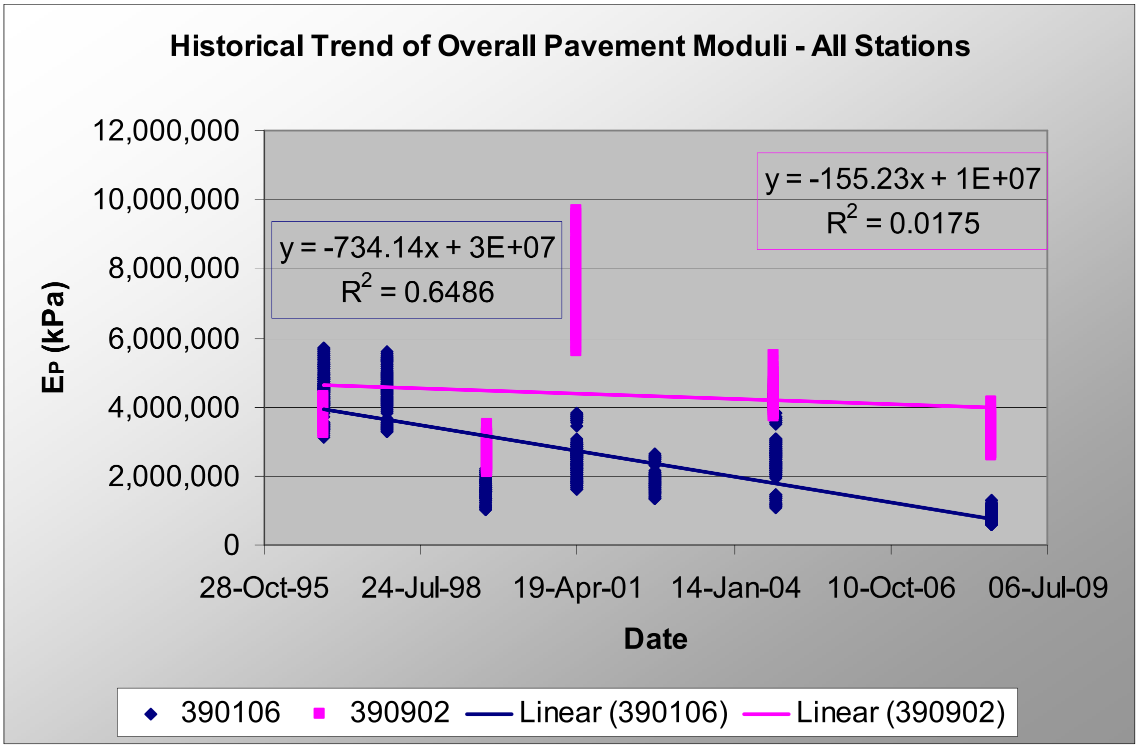

Figure J-9: Comparing Historical Trends in Overall Pavement Resilient Moduli

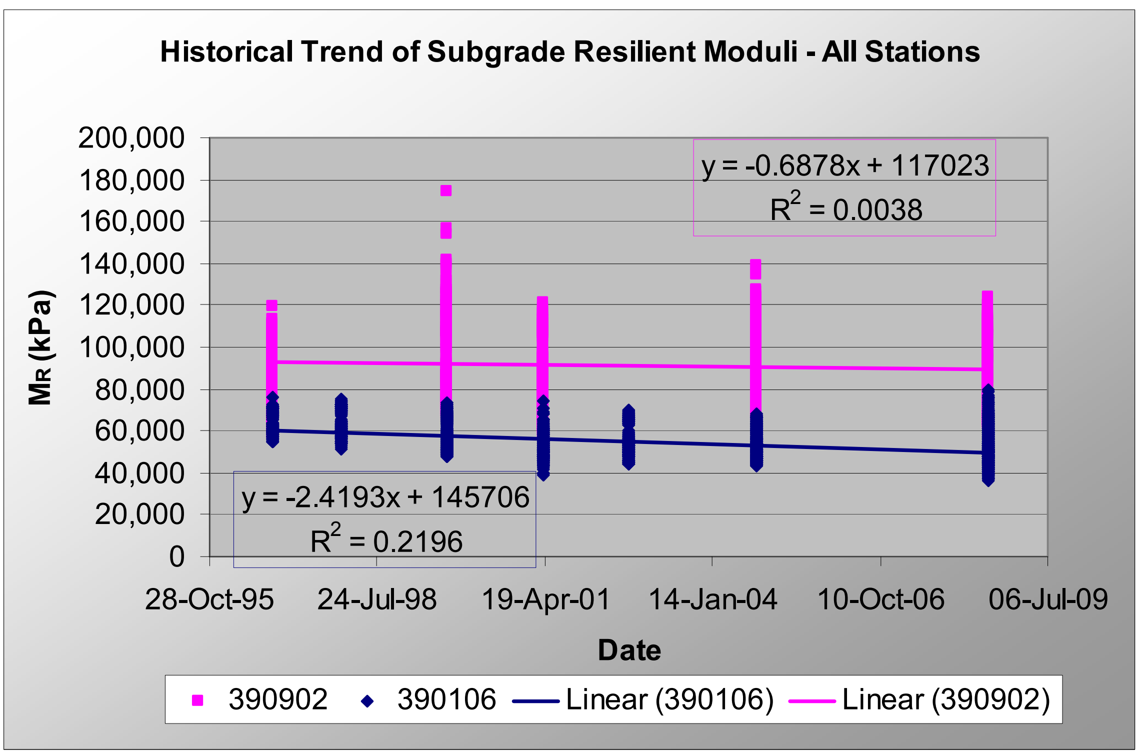

Figure J-10: Comparing Trends in Subgrade Resilient Moduli

Appendix K - Manual Distress Historical Plots

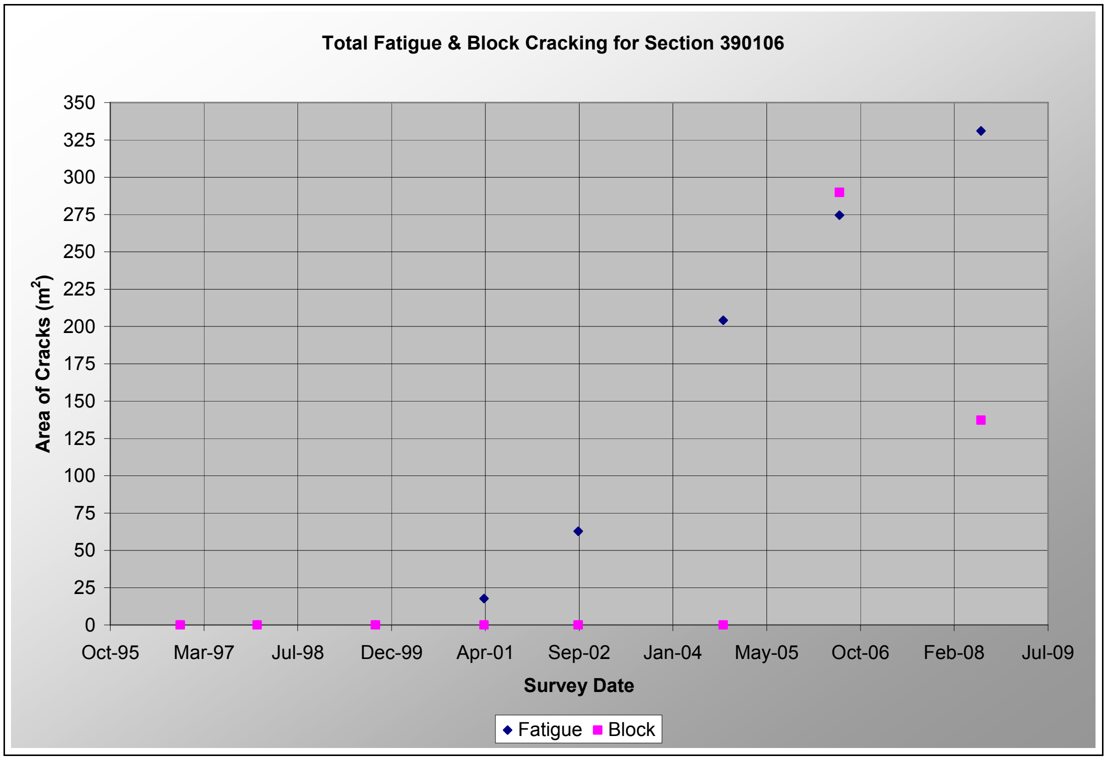

Figure K-1: Historical Trend in Fatigue and Block Cracking (390106)

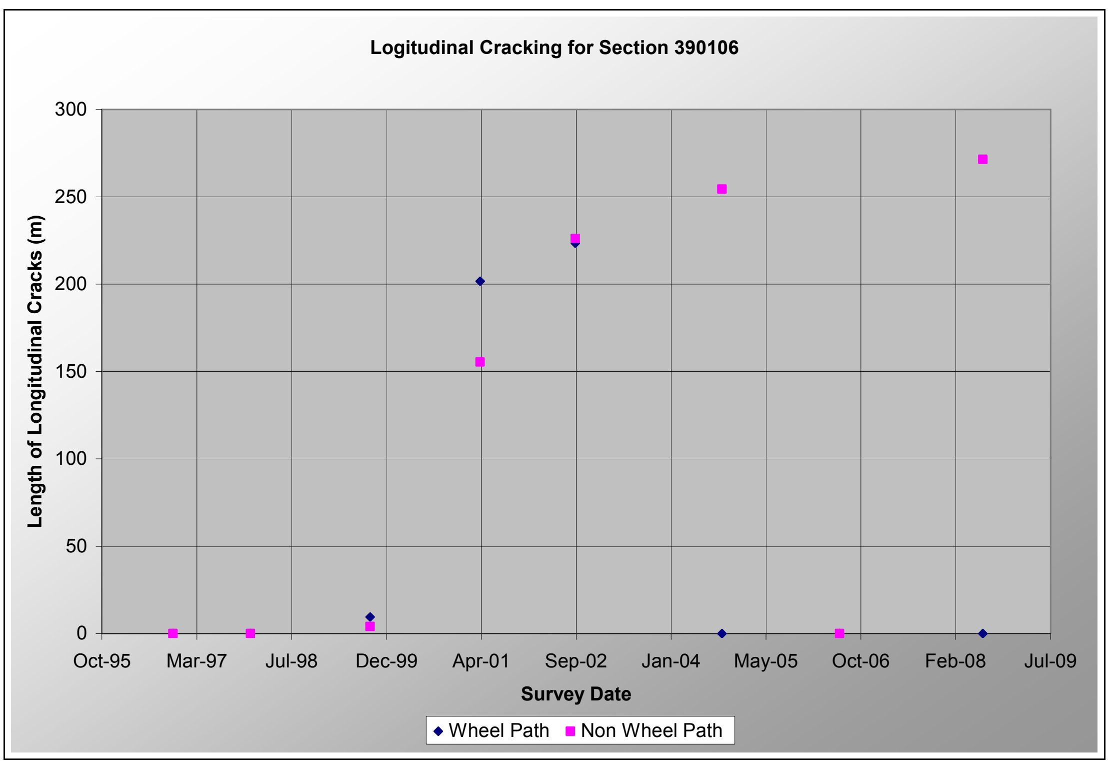

Figure K-2: Historical Trend in Longitudinal Cracking (390106)

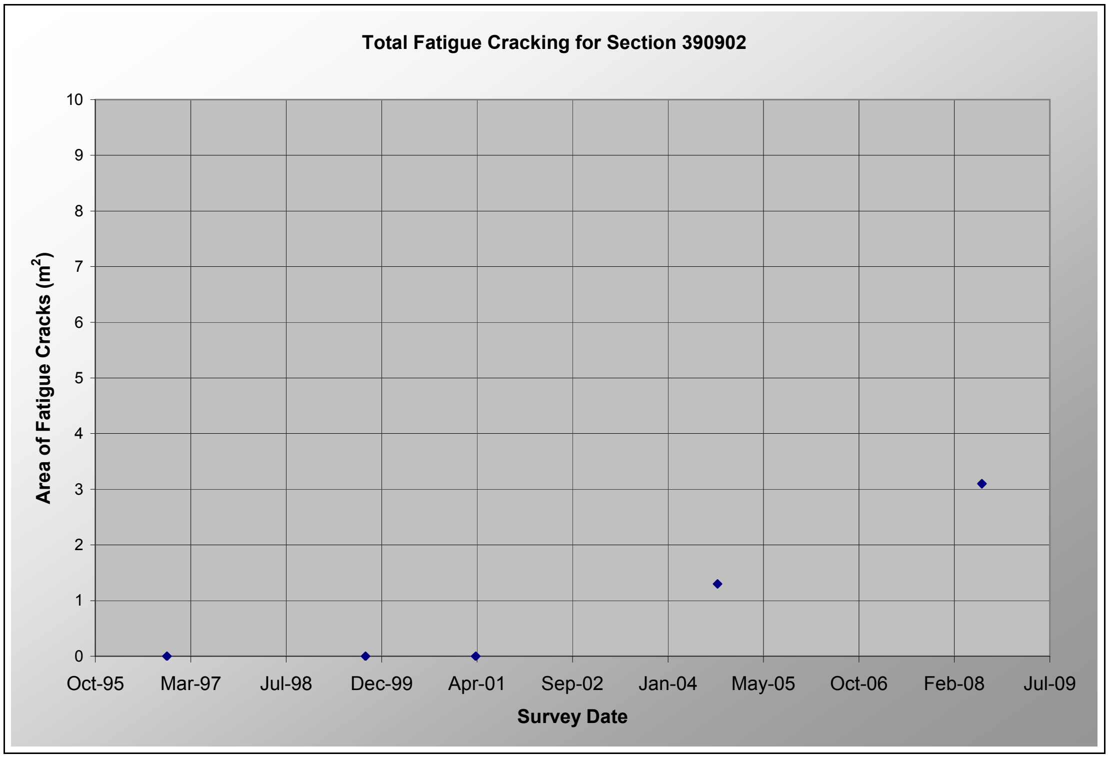

Figure K-3: Historical Trend in Fatigue Cracking (390902)

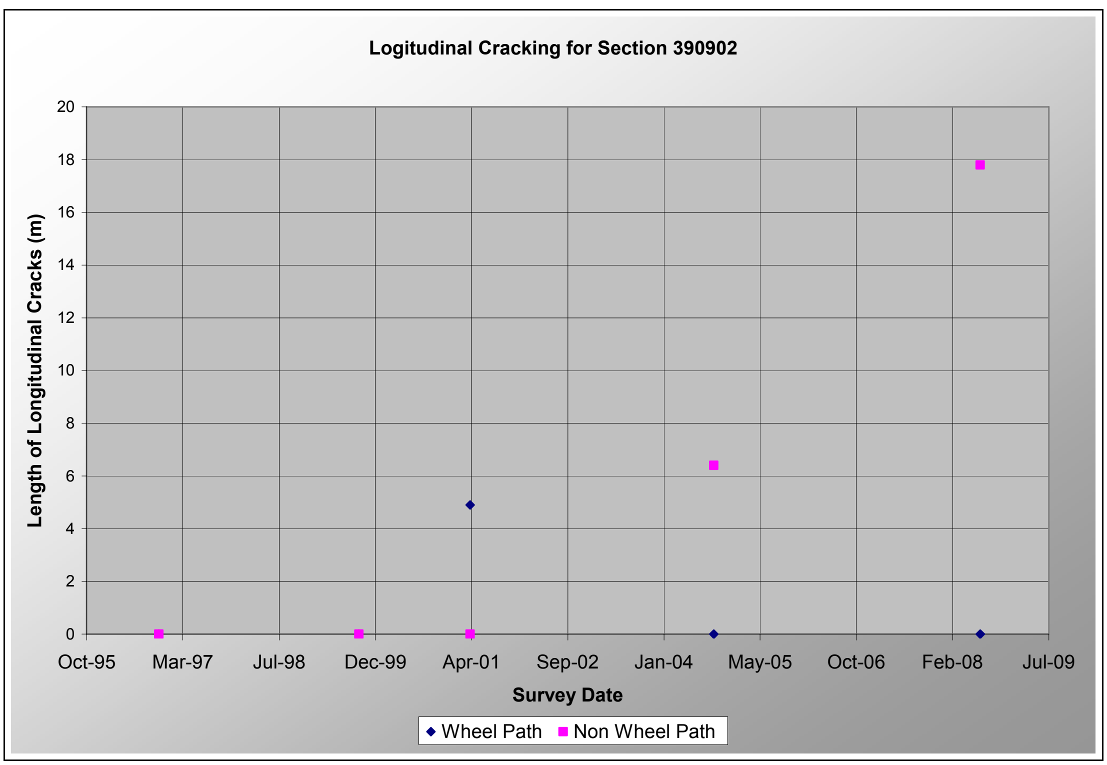

Figure K-4: Historical Trend in Longitudinal Cracking (390902)

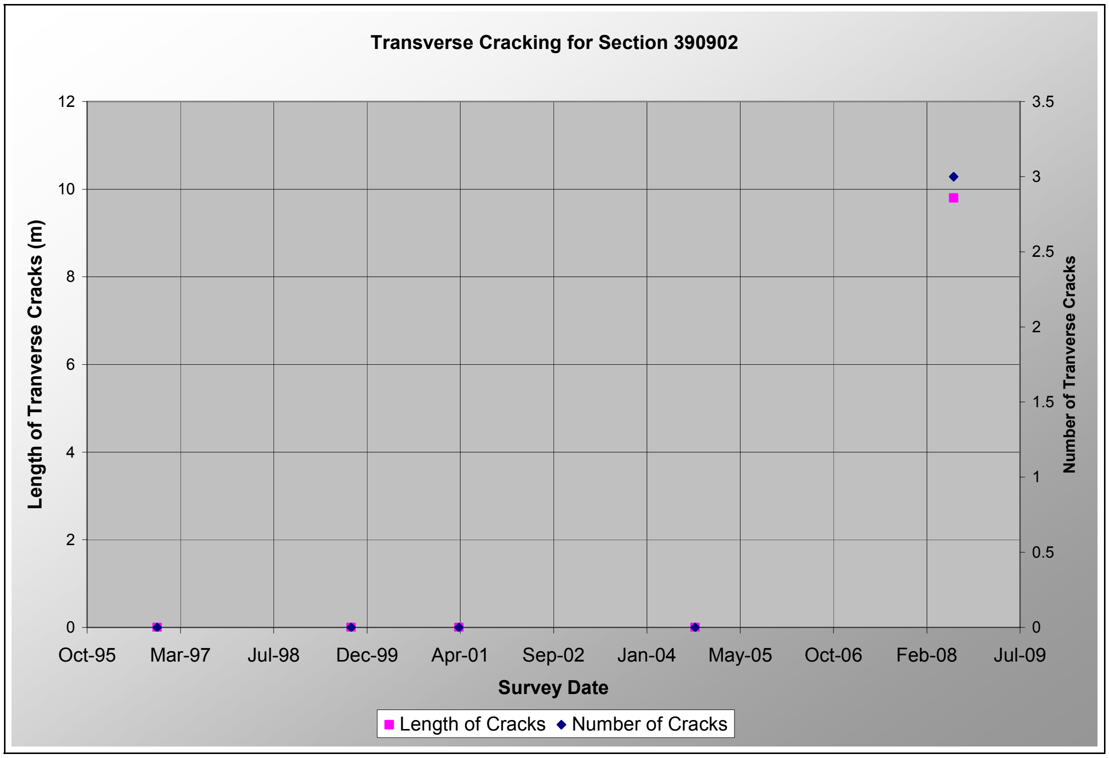

Figure K-5: Historical Trend in Transverse Cracking (390902)